

# TÜV RHEINLAND IMMISSIONSSCHUTZ UND ENERGIESYSTEME GMBH

Akkreditiertes Prüfinstitut



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>

**TÜV-Report: 936/21205926/A2**  
Cologne, 22.06.2007

[www.umwelt-tuv.de](http://www.umwelt-tuv.de)



[luft@de.tuv.com](mailto:luft@de.tuv.com)

**TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of  
DIN EN ISO/IEC 17025**

For the following field of work:

- Determination of emissions and immissions of air pollutants and odorants;
- Verification of the correct installation and the function as well as the calibration of continuous operating emission measuring systems including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and immissions as well as for electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 04-12-2010. DAR-Registration number: DAP-PL-3856.99.

The publication of extracts is subject to approval by  
**TÜV Rheinland Immissionsschutz und Energiesysteme GmbH**  
D - 51105 Köln, Am Grauen Stein, Tel: 0221 806-2756, Fax: 0221 806-1349



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>

<b>Tested measuring system:</b>	M200E
<b>Manufacturer of the instrument:</b>	Teledyne Advanced Pollution Instrumentation 9480 Carroll Park Drive San Diego, CA 92121 USA  EAS Envimet Analytical Systems Ges.m.b.h. Industriestrasse B 16 2345 Brunn/Gebirge Austria
<b>Time period of testing:</b>	September 2006 to June 2007
<b>Date of report:</b>	22.06.2007
<b>Number of report:</b>	936/21205926/A2
<b>Scope of report:</b>	In total 436 pages Manual from page 80 with 356 pages



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

## Table of content

1.	SUMMARY AND PROPOSAL FOR DECLARATION OF SUITABILITY .....	7
1.1	Summary .....	7
1.2	Proposal for declaration of suitability.....	8
2.	TERMS OF REFERENCE .....	9
2.1	Kind of testing .....	9
2.2	Objektive.....	9
3.	DESCRIPTION OF THE MEASURED SYSTEM.....	10
3.1	Measuring principle.....	10
3.2	Functionality of the measuring system .....	10
4.	TEST PROGRAMM .....	16
4.1	Test program according VDI 4202 .....	17
4.2	Test program according EN 14211 .....	17
5.	REFERENCE METHOD .....	18
5.1	Component: NO <sub>2</sub> .....	18
5.2	Component: NO.....	18
6.	TYP APPROVAL REGARDING VDI 4202 BL.1 .....	19
7.	TEST REQUIREMENTS ACCORDING EN 14211 .....	20
7.1	8.4 Determination of the performance characteristics during the laboratory test .....	20
7.1	8.4.3 Response time .....	23
7.1	8.4.4 Short-term drift.....	28
7.1	8.4.5 Repeatability standard deviation .....	31
7.1	8.4.6 „Lack of fit“ (residual from the linear regression function) .....	33
7.1	8.4.7 Sensitivity coefficient to sample gas pressure .....	39

7.1	8.4.8 Sensitivity coefficient to sample gas temperature .....	41
7.1	8.4.9 Sensitivity coefficient to the surrounding temperature .....	43
7.1	8.4.10 Sensitivity coefficient to electrical voltage.....	47
7.1	8.4.11 Interferences.....	49
7.1	8.4.12 Average test.....	52
7.1	8.4.13 Difference sample/calibration port.....	55
7.1	8.4.14 Converter efficiency .....	57
7.1	8.5 Determination of the performance characteristics during the field test.....	59
7.1	8.5.4 Long-term drift .....	61
7.1	8.5.5 Reproducibility under field conditiones .....	65
7.1	8.5.7 period of availability of the analyzer .....	68
	Appendix A (normative) Calculation residence times for a maximum allowable NO <sub>2</sub> increase in the sampling line [ISO 13964].....	70
	Appendix G (normative) Type approval after DIN EN 14211 .....	72
7.	RECOMMENDATIONS FOR THE USE IN PRACTICE .....	78
8	LITERATURE.....	79
9	APPENDIX.....	79

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 1. Summary and proposal for declaration of suitability

### 1.1 Summary

On behalf of Teledyne Advanced Pollution Instrumentation TÜV Rheinland Immissionsschutz und Energiesysteme GmbH has performed the suitability test of the measuring system M200E for the components NO, NO<sub>2</sub> und NO<sub>x</sub>.

The suitability test was carried out in compliance with the following guidelines and requirements:

- VDI 4202 Part 1: Minimum requirements for suitability tests of automated air quality measuring systems – point related measurement methods of gaseous and particulate pollutants, June 2002
- VDI 4203 Part 3: Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants, August 2004
- EN 14211 Ambient air quality – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, June 2005

The measuring system M200E operates using the chemiluminescence method.

The investigations have been carried out in the laboratory and during a field test, lasting three months.

The tested measuring ranges are:

Component		Measuring range		
Nitrogen dioxide	NO <sub>2</sub>	400	µg/m <sup>3</sup>	VDI 4202 Bl. 1
Nitrogen dioxide	NO <sub>2</sub>	500	µg/m <sup>3</sup>	EN 14211
Nitrogen monoxide	NO	1200	µg/m <sup>3</sup>	EN 14211

The minimum requirements have been fulfilled in the suitability test.

Therefore the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH proposes the publication as a suitability-tested measuring system for continuous monitoring of NO, NO<sub>2</sub>, and NO<sub>x</sub> in the ambient air.

## 1.2 Proposal for declaration of suitability

Due to the positive achieved results, the following recommendation for declaration of suitability as suitability-tested measuring system is given:

- 1.2.1 Measurement task** : Measuring system for determination of the NO, NO<sub>2</sub> and NO<sub>x</sub>-concentration in the ambient air
- 1.2.2 Name of device** : M200E
- 1.2.3 Measured components** : NO, NO<sub>2</sub> and NO<sub>x</sub>
- 1.2.4 Manufacturer** : Teledyne Advanced Pollution Instrumentation  
9480 Carroll Park Drive  
San Diego, CA 92121  
USA

EAS Envimet Analytical Systems Ges.m.b.h.  
Industriestrasse B 16  
2345 Brunn/Gebirge  
Austria

- 1.2.5 Suitability** : For continuous ambient air measurement of NO, NO<sub>2</sub> und NO<sub>x</sub>
- 1.2.6 Measuring ranges in the suitability test** : Nitrogen dioxide 0 to 400 µg/m<sup>3</sup>  
Nitrogen dioxide 0 to 500 µg/m<sup>3</sup>  
Nitrogen monoxide 0 to 1200 µg/m<sup>3</sup>
- 1.2.7 Software version** : Revision G.2
- 1.2.8 Restrictions** : -
- 1.2.9 Remarks** : -
- 1.2.10 Test house** : TÜV Rheinland Immissionsschutz und Energiesysteme GmbH,  
Köln  
TÜV Rheinland Group  
Responsible investigator: Dipl.-Ing. Martin Schneider
- 1.2.11 Test report** : 936/21205926/A2 from 22.06.2007



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 2. Terms of reference

### 2.1 Kind of testing

On behalf of the company Teledyne API, TÜV Rheinland Immissionsschutz und Energiesysteme GmbH performed a complete suitability test for the measuring system M200E. The test was performed as a complete suitability test regarding the minimum requirements.

### 2.2 Objektive

The objective of the test was to show, that the measuring system fulfils the german minimum requirements and the requirements of the EN 14211. Therefore the measuring system was tested in the following measuring ranges:

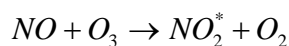
Table 1: *Tested measuring ranges*

Component		Measuring range		
Nitrogen dioxide	NO <sub>2</sub>	400	µg/m <sup>3</sup>	VDI 4202 Bl. 1
Nitrogen dioxide	NO <sub>2</sub>	500	µg/m <sup>3</sup>	EN 14211
Nitrogen monoxide	NO	1200	µg/m <sup>3</sup>	EN 14211

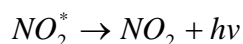
### 3. Description of the measured system

#### 3.1 Measuring principle

The principle of the M200E's measurement method is the detection of chemiluminescence, which occurs when nitrogen oxide (NO) reacts with ozone (O<sub>3</sub>). This reaction is a two-step process. In the first step, one molecule of NO and one molecule of O<sub>3</sub> collide and chemically react to produce one molecule of oxygen (O<sub>2</sub>) and one molecule of nitrogen dioxide (NO<sub>2</sub>). Some of the NO<sub>2</sub> retains a certain amount of excess energy from the collision and, hence, remains in an excited state, which means that one of the electrons of the NO<sub>2</sub> molecule resides in a higher energy state than is normal.



Thermodynamics requires that systems seek the lowest stable energy state, hence, the NO<sub>2</sub> molecule quickly returns to its ground state in a subsequent step, releasing the excess energy in form of a quantum of light (hν).



All things being constant, the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. More NO produces more light, which can be measured with a light-sensitive sensor in the near-infrared spectrum.

#### 3.2 Functionality of the measuring system

The M200E Nitrogen Oxides Analyzer is a microprocessor controlled instrument that determines the concentration of nitric oxide (NO), total nitrogen oxides (NO<sub>x</sub>, the sum of NO and NO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) in a sample gas drawn through the instrument. It requires that sample and calibration gases are supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O<sub>3</sub>), initiating a chemical reaction that gives off light (chemiluminescence). The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas. A catalytic-reactive converter converts any NO<sub>2</sub> in the sample gas to NO, which is then – including the NO in the sample gas – is then reported as NO<sub>x</sub>. NO<sub>2</sub> is calculated as the difference between NO<sub>x</sub> and NO.

The only gas that is truly measured in the M200E is NO. Any NO<sub>2</sub> contained in the gas is not detected in the above process since NO<sub>2</sub> does not react with O<sub>3</sub> to undergo chemiluminescence. In order to measure the concentration of NO or NO<sub>x</sub> (which is defined here as the sum of NO and NO<sub>2</sub> in the sample gas), the M200E periodically switches the sample gas stream through a converter cartridge filled with molybdenum chips heated to a temperature of 315° C. The heated molybdenum reacts with NO<sub>2</sub> in the sample gas and produces a variety of molybdenum oxides and NO. Once the NO<sub>2</sub> in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

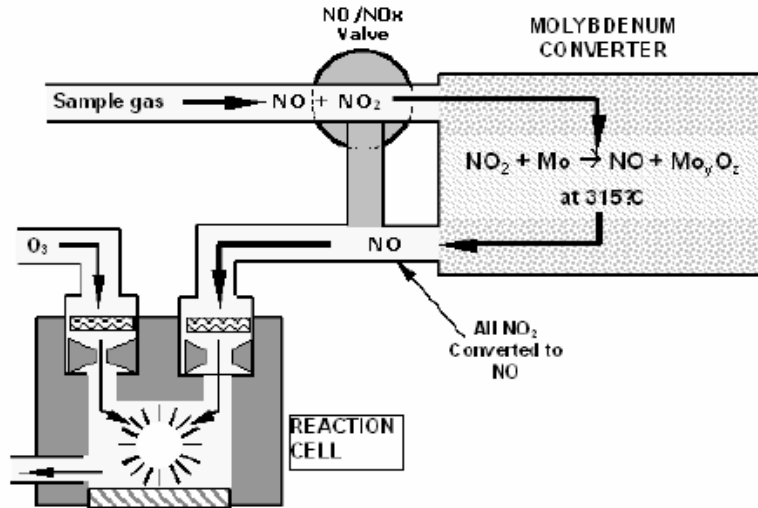


Figure 1: NO<sub>2</sub> Conversion Principle

By converting the NO<sub>2</sub> in the sample gas into NO, the analyzer can measure the total NO<sub>x</sub> (NO+NO<sub>2</sub>) content of the sample gas. By switching the NO<sub>2</sub> converter in and out of the sample gas stream every 6 - 10 seconds, the M200E analyzer is able to quasi-continuously measure both the NO and the total NO<sub>x</sub> content. The NO<sub>2</sub> concentration, finally, is not measured but calculated by simply subtracting the known NO content of the sample gas from the known NO<sub>x</sub> content.

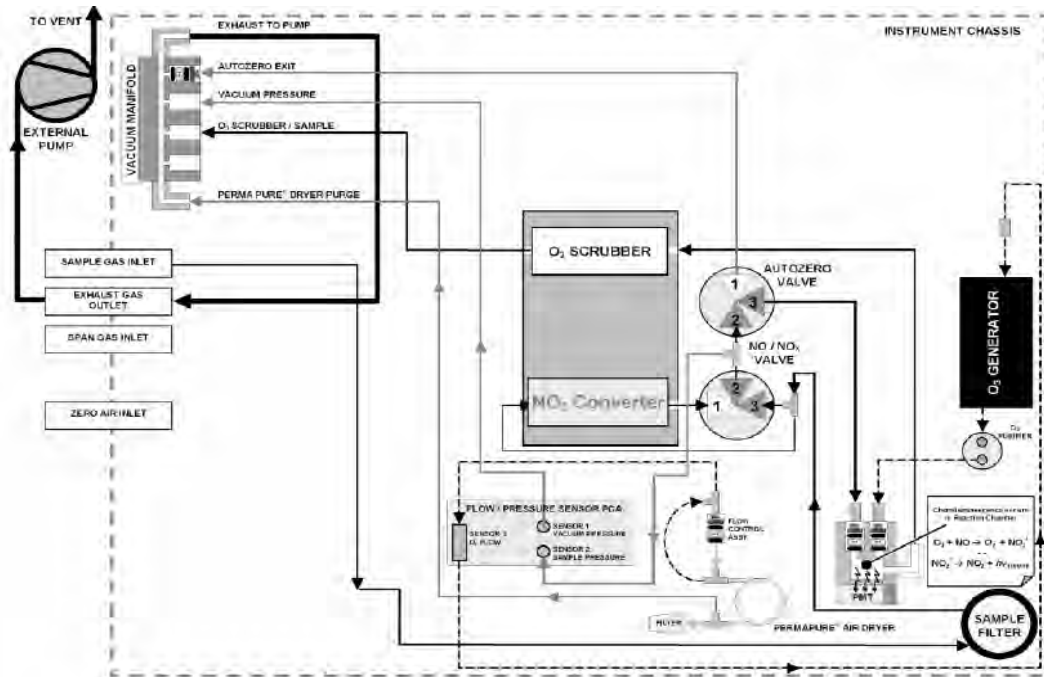


Figure 2: Pneumatisches Diagramm des M200E (Nullluft / Spangaseingang optional)

Components of the analyser

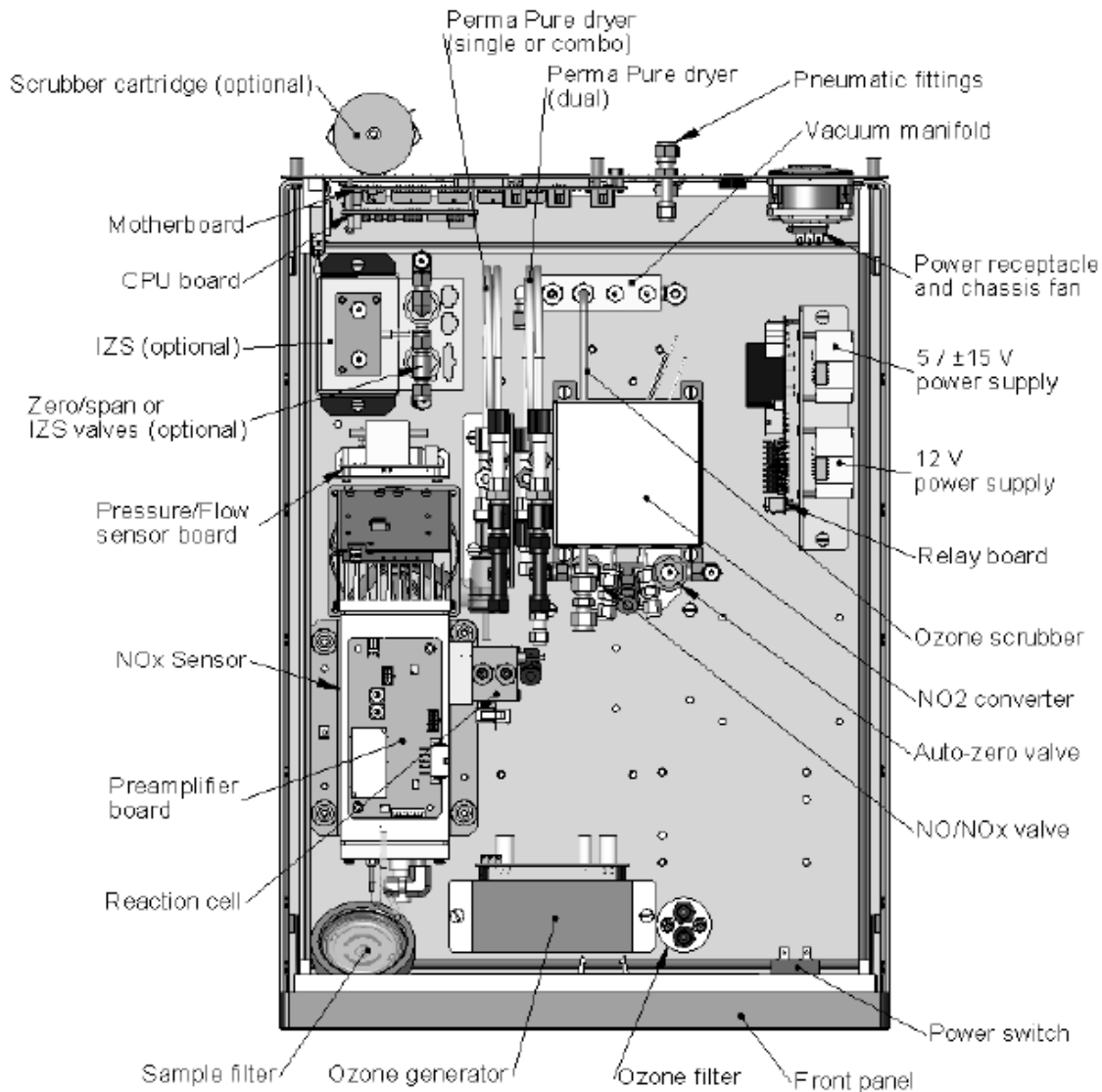


Abbildung 3: Aufbau des M200E

The Photo Multiplier Tube

The M200E uses a photo-multiplier tube (PMT) to detect the amount of light created by the NO and O<sub>3</sub> reaction in the reaction cell. A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiply through a sequence of such acceleration steps (dynodes) until a useable current signal is generated. This current increases or decreases with the amount of detected light.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### Optical Filter

The optical filter that lies between the reaction cell and the PMT (Figure 10-2). This filter is a high pass filter that is only transparent to wavelengths of light above 645 nm. In conjunction with the response characteristics of the PMT, this filter creates a very narrow window of wavelengths of light to which the M200E will respond.

### Pump and Exhaust Manifold

The gas flow for the M200E is created by an external pump that is pneumatically connected through a tube to the analyzer's exhaust port located on the rear panel. This pump creates a vacuum. Gas flow is created by keeping the analyzer's sample gas inlet near ambient pressure.

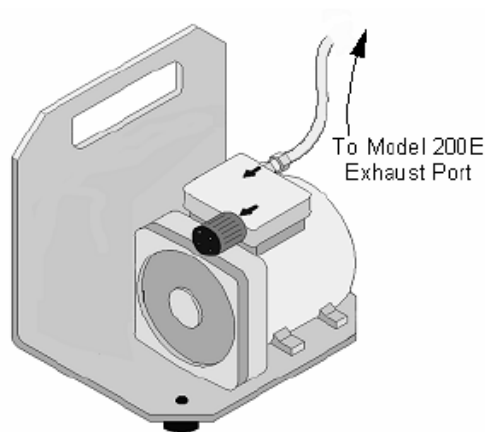


Figure 4: External pump

### Sample Particulate Filter

To remove particles in the sample gas, the analyzer is equipped with a PTFE membrane filter of 47 mm diameter with a 1 µm pore size.

### O<sub>3</sub> Generator

The ozone needed for the reaction of the NO is created inside of the analyser because of its instability and toxicity.

The M200E uses a corona discharge (CD) tube for creating its O<sub>3</sub>. Corona discharge generation is capable of producing high concentrations of ozone efficiently and with low excess heat. The M200E utilizes a dual-dielectric design. This method utilizes a glass tube with hollow walls. The outermost and innermost surfaces are coated with electrically conductive material. The air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O<sub>3</sub>. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O<sub>2</sub> molecules in the air stream splitting them into elemental oxygen. Some of these oxygen atoms recombine with O<sub>2</sub> to O<sub>3</sub>.

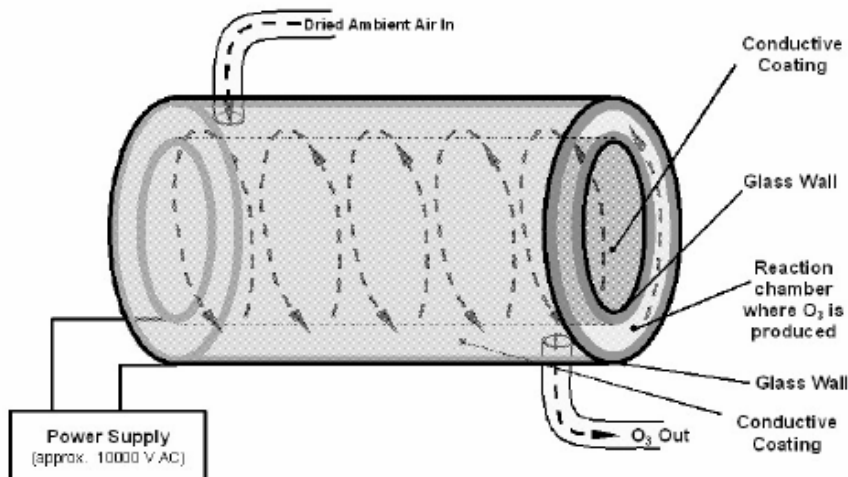


Figure 5: Ozone Generator Principle

#### Perma Pure® Dryer

The air supplied to the O<sub>3</sub> generation system needs to be as dry as possible. Normal room air contains a certain amount of water vapor, which greatly diminishes the yield of ozone produced by the zone generator. Also, water can react with other chemicals inside the O<sub>3</sub> Generator to produce chemicals that damage the optical filter located in the reaction cell such as ammonium sulfate or highly corrosive nitric acid.

To accomplish this task the M200E uses a Perma Pure® single tube permeation dryer. The dryer consists of a single tube of Nafion®, a co-polymer similar to Teflon® that absorbs water very well but not other chemicals. The Nafion® tube is mounted within an outer, flexible plastic tube. As gas flows through the inner Nafion® tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporates into the dry, purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.

This process is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds. The first step in this process is a chemical reaction between the molecules of the Nafion® material and water; other chemical components of the gases to be dried are usually unaffected. The chemical reaction is based on hydrogen bonds between the water molecule and the Nafion material. Other small polar gases that are capable of hydrogen bonds can be absorbed this way, too, such as ammonia (NH<sub>3</sub>) and some low molecular amines. The gases of interest, NO and NO<sub>2</sub>, do not get absorbed and pass the dryer unaltered.

To provide a dry purge gas for the outer side of the Nafion tube, the M200E returns some of the dried air from the inner tube to the outer tube (Figure 10-8). When the analyzer is first started, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low at first but improves as this cycle reduces the moisture in the sample gas and settles at a minimum humidity.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

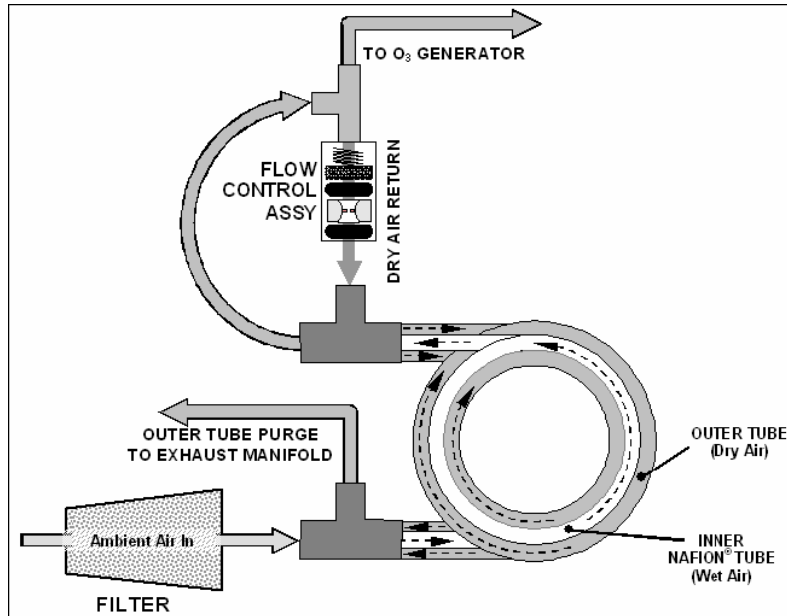


Figure 6: M200E Perma Pure® Dryer

### Ozone Scrubber

Even though ozone is unstable and typically reacts to form O<sub>2</sub>, the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream of the M200E by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O<sub>3</sub>, a special catalytic ozone scrubber is used to remove all of the O<sub>3</sub> exiting the reaction cell. Besides its efficient destruction of O<sub>3</sub>, this catalyst does not produce any toxic or hazardous gases as it only converts ozone to oxygen and it also does not pose an explosion hazard like charcoal scrubbers.

The O<sub>3</sub> scrubber is located inside the NO<sub>2</sub> converter housing next to the NO<sub>2</sub> converter in order to utilize residual heat given off by the converter heater. Even though the catalyst is 100% efficient at scrubbing ozone at room temperature, heating it significantly reduces the necessary residence time (the amount of time the gas must be in contact with the catalyst) for 100% efficiency and full efficiency can be maintained at higher gas flow rates. As this is a true catalytic converter, there are no maintenance requirements as would be required for charcoal-based scrubbers.

#### 4. Test programm

The lab and the field test has been carried out with two identical nitrogen oxide analyzers of the type M200E with the following serial numbers

Device 1: No. 1253

Device 2: No. 1257

The field test took place from the 13.02.2007 to th 14.05.2007. The analyzers have been installed during the field test in an air conditioned container. During the tests the analyzers were configured with the following electronic measuring ranges.

Component		Measurement range	
Nitrogen monoxide	NO	0 - 1000	ppb
Nitrogen dioxide	NO <sub>2</sub>	0 - 300	ppb

The evaluation based on the in table 1 mentioned certification ranges.



Figure 7: Picture of the analyzers in the measuring container



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

#### **4.1 Test program according VDI 4202, see results in chapter 6**

According to the requirements of the guideline VDI 4202 part 1 the following laboratory test program was established:

- Inspection of the general analyzer functions
- Determination of the device characteristic with test gases,
- Determination of the cross sensitivities against accompanying substances in the ambient air
- Test of the stability of the zero and span point in the allowed ambient temperature range,
- Determination of the influence of changes in the mains voltage to the measuring signal,
- Determination of the detection limit,
- Determination of the response time,
- Determination of the total uncertainty,
- Determination of the converter efficiency

According to the requirements of the guideline VDI 4202 part 1 the following field test program was established:

- Inspection of the general analyzer functions
- Functional check of the analyzer at the beginning and at the end of the field test,
- Determination of the detection limit,
- Determination of the maintenance interval,
- Reproducibility standard deviation,
- Long term drift at zero and span,
- Period of unattended operation,
- Availability of the analyzer,
- Determination of the total uncertainty.

#### **4.2 Test program according EN 14211, see results in chapter 7**

According to the requirements of the guideline EN 14211 the following laboratory test program was established:

- Inspection of the general analyzer functions
- Determination of the repeatability at zero and span
- Lack of fit
- Sensitivity coefficient of sample gas pressure
- Sensitivity coefficient of sample gas temperature
- Sensitivity coefficient of surrounding temperature
- Sensitivity coefficient of electrical voltage
- Interferents at zero and span
- Averaging effect
- Short term drift at zero and span
- Response time
- Converter efficiency
- Difference between sample/calibration port
- Determination of the total uncertainty

According to the requirements of the guideline EN 14211 the following field test program was established:

- Functional check of the analyzer at the beginning and at the end of the field test,
- Determination of the maintenance interval,
- Reproducibility standard deviation,
- Long term drift at zero and span,
- Period of unattended operation,
- Availability of the analyzer,
- Determination of the total uncertainty.

## 5. Reference method

### 5.1 Component: NO<sub>2</sub>

The NO<sub>2</sub> test gas has been produced by means of an permeation oven of the company MCZ during the tests in the laboratory and the field. For the validation of the produced NO<sub>2</sub> concentration and for the determination of the permeation rate of the used permeation tube the weight difference of the tube is checked weekly. During this times the permeation tube was stored under defined climatic circumstances

These gravimetric determination of the permeation rate has been done continuously during the complete suitability test. From the regular gravimetric checks there is an uncertainty of  $\pm 1 \%$  of the test gas resulting.

In addition different measurements with the Saltzman-method after VDI 2453 part 1 have been done at different concentration levels. Each adjusted concentration of the permeation system has been compared with the measured concentration of the analysers and the Saltzman method.

### 5.2 Component: NO

For the NO test gas offerings a gas out of a cylinder with the cylinder number 10517 from the manufacturer Praxair has been used. The uncertainty of the test gas was  $\pm 2 \%$ . The concentration of the test gas has been determined by the reference method after VDI 2456.

The different concentrations have been diluted by means of mass flow controllers by use of synthetic air as dilution gas.

#### Assembly in the lab and field

The set-up of the testing arrangement in the laboratory was matched to the requirements of the specific tests and was duplicated in a simplified manner in the field test site (see Figure 8).



Figure 8: Test gas application by permeation system and computer for controlling

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

## **6. Typ approval regarding VDI 4202 BI.1**

This chapter contains the test results regarding the German guideline VDI 4202 BI. 1. The test results fulfill the criteria's of the guideline. The evaluation is only of interest for the approval in Germany. Therefore a translation of this chapter has been omitted. The test results can be seen in the German version of this test report.

## **7 Test requirements according EN 14211**

### **7.1 8.4 Determination of the performance characteristics during the laboratory test**

A designated body shall perform the determination of the performance characteristics in the laboratory as apart of the type approval test. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this document. The test shall be performed on at least 2 analyzers in the laboratory test.

#### **8.4.2 Test conditions**

##### **8.4.2.1 General**

Before operating the analyzer, the operating instructions of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable products necessary.

The analyzer should be allowed to warm up during the time specified by the manufacturer before undertaking any tests. If the warm-up time is not specified, a minimum of 4 hours is recommended.

When applying test gases to the analyzer, the test gas system shall be operated sufficiently long before starting the tests in order to stabilize the concentrations applied to the analyzer.

Most analyzer systems are able to give an output signal as a moving average over an adjustable period of time and some systems automatically change this integration time as a function of the frequency of the fluctuations in concentration of the detected pollutant. These options are typically used in order to smooth output data. It needs to be demonstrated that the set value for the averaging time or the use of an active filter will not influence the result of the averaging test and response time set.

During laboratory and field tests for the type approval the settings of the monitor shall be as the manufacturer requires. All settings shall be noted down in the test report.

##### **8.4.2.2 Parameters**

For the determination of the various performance characteristics, test traceable to national standards shall be used, unless otherwise stated in this document.

##### **8.4.2.3 Test gases**

For the determination of the various performance characteristics, test gases ((synthetic) air containing a certain concentration) traceable to national standards shall be used, unless otherwise stated in this document. The uncertainties in zero and span gases used for the laboratory and field tests shall be proven to be insignificant.

### **7.2 Evaluation**

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of DIN EN ISO/IEC 17025.

The Laboratory test has been performed regarding the required quality standard of EN 14211 with two analyzers of type M200E.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

Page 21 of 436

Table 2: Relevant performance characteristics and criteria of EN 14211

No.	Performance characteristic	Symbol	Clause	Performance criterion
1	Repeatability standard deviation at zero	$S_{r,z}$	8.4.5	$\leq 1,0 \text{ nmol/mol}$
2	Repeatability standard deviation at concentration $c_t$ (at a level of the 8-hour mean limit value)	$S_{r,ct}$	8.4.5	$\leq 3,0 \text{ nmol/mol}$
3	"Lack of fit" (residual from the linear regression function)		8.4.6	
3a	Largest residual from the linear regression function at concentrations higher than zero	$X_l$		$\leq 4 \%$ of the measured value
3b	Residual at zero	$X_{l,z}$		$\leq 5,0 \text{ nmol/mol}$
4	Sensitivity coefficient of sample gas pressure	$b_{gp}$	8.4.7	$\leq 8,0 \text{ nmol/mol/kPa}$
5	Sensitivity coefficient of sample gas temperature	$b_{gt}$	8.4.8	$\leq 3,0 \text{ nmol/mol/K}$
6	Sensitivity coefficient of surrounding temperature	$b_{st}$	8.4.9	$\leq 3,0 \text{ nmol/mol/K}$
7	Sensitivity coefficient of electrical voltage	$b_v$	8.4.10	$\leq 0,3 \text{ nmol/mol/V}$
8	Interference at zero at concentration $c_t$ (at a level of the 8-hour mean limit value)		8.4.11	
8a	H <sub>2</sub> O with concentration 19mmol/mol	$X_{H_2O,z.ct}$		H <sub>2</sub> O $\leq 5,0 \text{ nmol/mol}$
8b	CO <sub>2</sub> with concentration 500 $\mu\text{mol/mol}$	$X_{CO_2,z.ct}$		CO <sub>2</sub> $\leq 5,0 \text{ nmol/mol}$
8c	O <sub>3</sub> with concentration 200 nmol/mol	$X_{O_3,z.ct}$		O <sub>3</sub> $\leq 2,0 \text{ nmol/mol}$
8d	NH <sub>3</sub> with concentration 200 nmol/mol	$X_{NH_3,z.ct}$		NH <sub>3</sub> $\leq 5,0 \text{ nmol/mol}$
9	Average effect	$X_{av}$	8.4.12	$\leq 7,0 \%$ of the measured value
10	Reproducibility standard deviation under field conditions	$S_{r,f}$	8.5.5	$\leq 5,0 \%$ of the average of a three month period
11	Long-term drift at zero	$D_{l,z}$	8.5.4	$\leq 5,0 \text{ nmol/mol}$
12	Long-term drift at span level	$D_{l,s}$	8.5.4	$\leq 5,0 \%$ of maximum of certification range
13	Short-term drift at zero	$D_{s,z}$	8.4.4	$\leq 2,0 \text{ nmol/mol}$ over 12 h
14	Short-term drift at span	$D_{s,s}$	8.4.4	$\leq 6,0 \text{ nmol/mol}$ over 12 h
15	Response time (rise)	$t_r$	8.4.3	$\leq 180 \text{ s}$
16	Response time (fall)	$t_f$	8.4.3	$\leq 180 \text{ s}$
17	Difference between rise and fall time	$t_d$	8.4.3	$\leq 10 \%$ relative difference, or 10 s, whatever is greater
18	Difference between sample/calibration port	$D_{sc}$	8.4.13	$\leq 1 \%$
19	Period of unattended operation		8.5.6	3 month or longer
20	Availability of the analyzer	$A_a$	8.5.7	$> 90 \%$
21	Converter efficiency	$E_{conv}$	8.5.6	$\geq 98\%$
22	Increase of the NO <sub>2</sub> concentration	$\Delta C_{TR}$		$\leq 4,0 \text{ nmol/mol}$

### **7.3 Findings**

A summary of the evaluation is mentioned at Table 33 on page 74 and 75.

Minimum requirement fulfilled? yes

### **7.4 Presentation of results**

Here not necessary.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.4.3 Response time

*Response time (rise) and Response time (fall) ≤ 180 s. The difference between rise- and fall time ≤ 10 % relative difference, or 10 s, whatever is the greatest.*

## 7.2 General requirements

The response time of the analyzer shall be determined at the nominal sample flow rate specified by the manufacturer.

The sample flow rate shall be kept constant within the requirements as given in 8.4.2 (± 1 %) during the test.

The determination of the response time shall be carried out by applying to the analyzer a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range and vice versa (see Figure 9).

The change from zero gas to span gas needs to be made almost instantly with the use of a suitable valve. The valve outlet shall be mounted direct to the inlet of the analyzer, and both zero gas and span gas shall have the same "oversupply" which is vented with the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyzer system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start (t = 0) of the (rise) lag time according to Figure 8. When the reading of 98 % of the applied concentration has been reached, the span gas can be changed to zero again, and this event is the start (t = 0) of the (fall) lag time. When the reading of 2 % of the applied concentration has been reached the whole cycle as shown in Figure 9 is complete.

The time between the beginning and the achievement of 90 % of the stable display has been determined. The total cycle must be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) have been calculated.

The relative difference in response times shall be calculated according to:

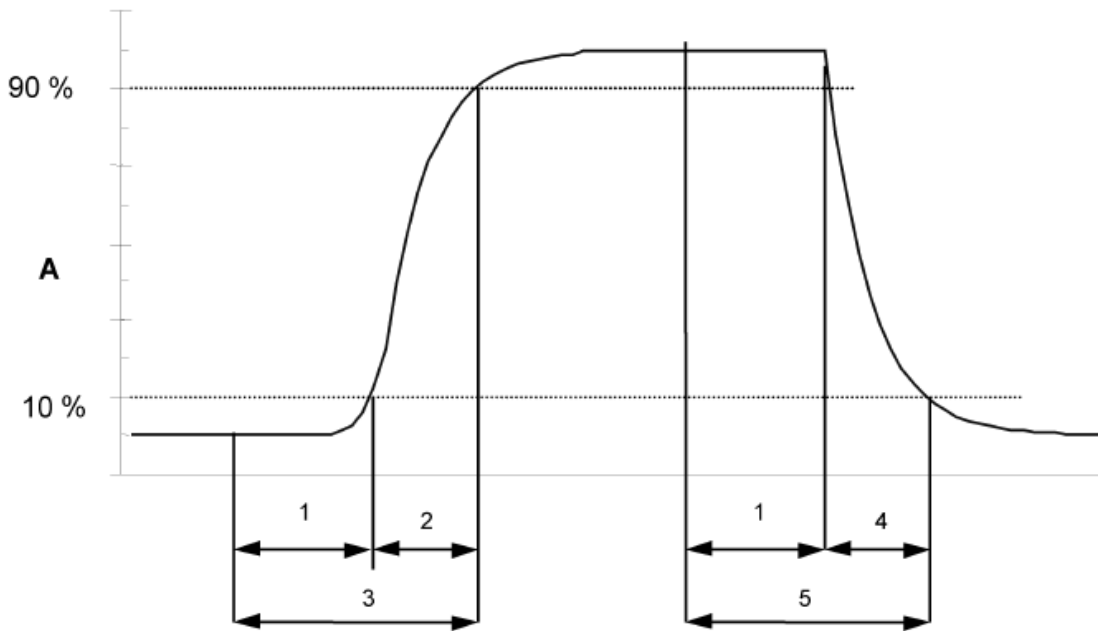
$$t_d = \left| \frac{t_r - t_f}{t_r} \right| \times 100\%$$

Where  $t_d$  is the relative difference between response time (rise) and response time (fall) (%)

$t_r$  is the average response time (rise) (average of 4 measurements) (s)

$t_f$  is the average response time (fall) (average of 4 measurements) (s)

$t_r$ ,  $t_f$  and  $t_d$  shall comply with the performance criterion.



**Key**

- A Analyser response
- 1 Lag time
- 2 Rise time
- 3 Response time (rise)
- 4 Fall time
- 5 Response time (fall)

Figure 9: Diagram illustrating the response time

**7.3 Performance of test**

The test has been enforced regarding the specifications of EN 14211. The data recording has been done with a data logger VDM Memograph of Endress und Hauser with a averaging time of 1s.

The response time has to be determined according to the EN 14211 for the components NO and NO<sub>2</sub>.



## 7.4 Evaluation

Table 3: Response times of the two analyzers for the component NO

Start Value [ppb]	Target Wert 90% [ppb]		Time Device 1253 [s]	Time Device 1257 [s]	Requirement DIN EN 14211 [s]	Requirement fulfilled?
0	675	$t_r$	44	47	180	yes
750	75	$t_f$	48	50	180	yes
<b>Difference</b>			<b>4</b>	<b>3</b>		
0	675	$t_r$	45	49	180	yes
750	75	$t_f$	43	45	180	yes
<b>Difference</b>			<b>2</b>	<b>4</b>		
0	675	$t_r$	47	45	180	yes
750	75	$t_f$	46	47	180	yes
<b>Difference</b>			<b>1</b>	<b>2</b>		
0	675	$t_r$	45	47	180	yes
750	75	$t_f$	47	46	180	yes
<b>Difference</b>			<b>2</b>	<b>1</b>		

For device 1 (1253) a maximum  $t_r$  of 47 s, a maximum  $t_f$  of 48 s and a  $t_d$  of 1,7 % has been calculated.  
For device 2 (1257) a maximum  $t_r$  of 49 s, a maximum  $t_f$  of 50 s and a  $t_d$  of 0,0 % has been calculated.

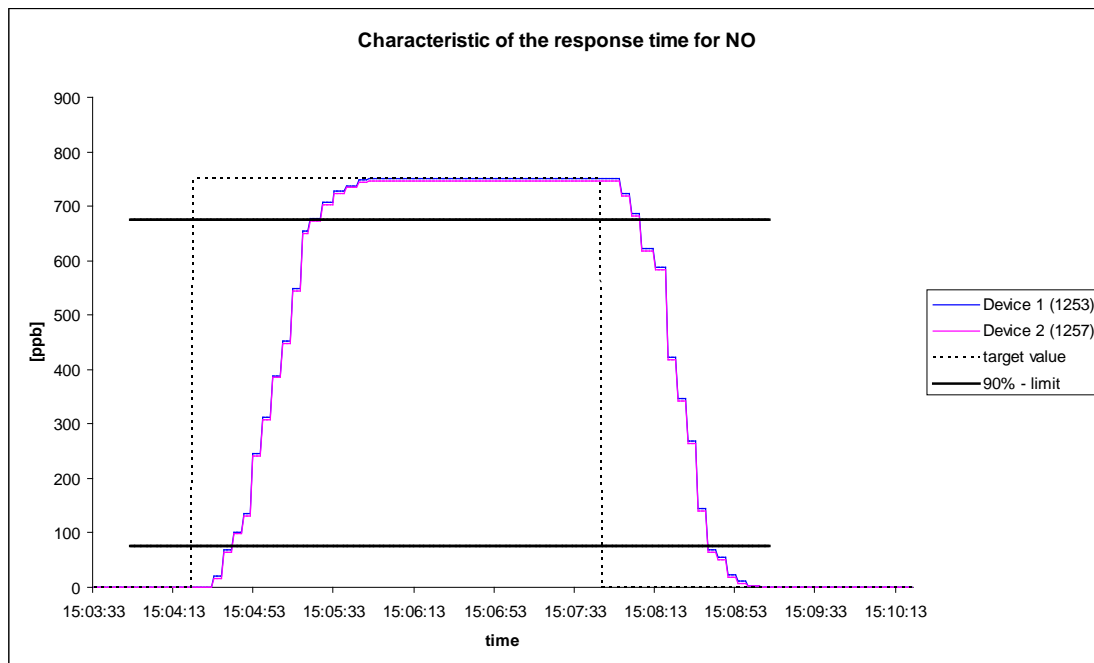


Figure 10: Characteristics of the response time for the component NO

Table 4: Response times of the two analyzers for the component NO<sub>2</sub>

Start Value [ppb]	Target Wert 90% [ppb]		Time Device 1253 [s]	Time Device 1257 [s]	Requirement DIN EN 14211 [s]	Requirement fulfilled?
0	180	t <sub>r</sub>	58	60	180	yes
200	20	t <sub>f</sub>	56	63	180	yes
<b>Difference</b>			<b>2</b>	<b>3</b>		
0	180	t <sub>r</sub>	59	61	180	yes
200	20	t <sub>f</sub>	61	58	180	yes
<b>Difference</b>			<b>2</b>	<b>3</b>		
0	180	t <sub>r</sub>	63	59	180	yes
200	20	t <sub>f</sub>	58	57	180	yes
<b>Difference</b>			<b>5</b>	<b>2</b>		
0	180	t <sub>r</sub>	61	63	180	yes
200	20	t <sub>f</sub>	64	60	180	yes
<b>Difference</b>			<b>3</b>	<b>3</b>		

For device 1 (1253) a maximum t<sub>r</sub> of 63 s, a maximum t<sub>f</sub> of 64 s and a t<sub>d</sub> of 0,8 % has been calculated..

For device 2 (1257) a maximum t<sub>r</sub> of 63 s, a maximum t<sub>f</sub> of 63 s and a t<sub>d</sub> of 2,0 % has been calculated.

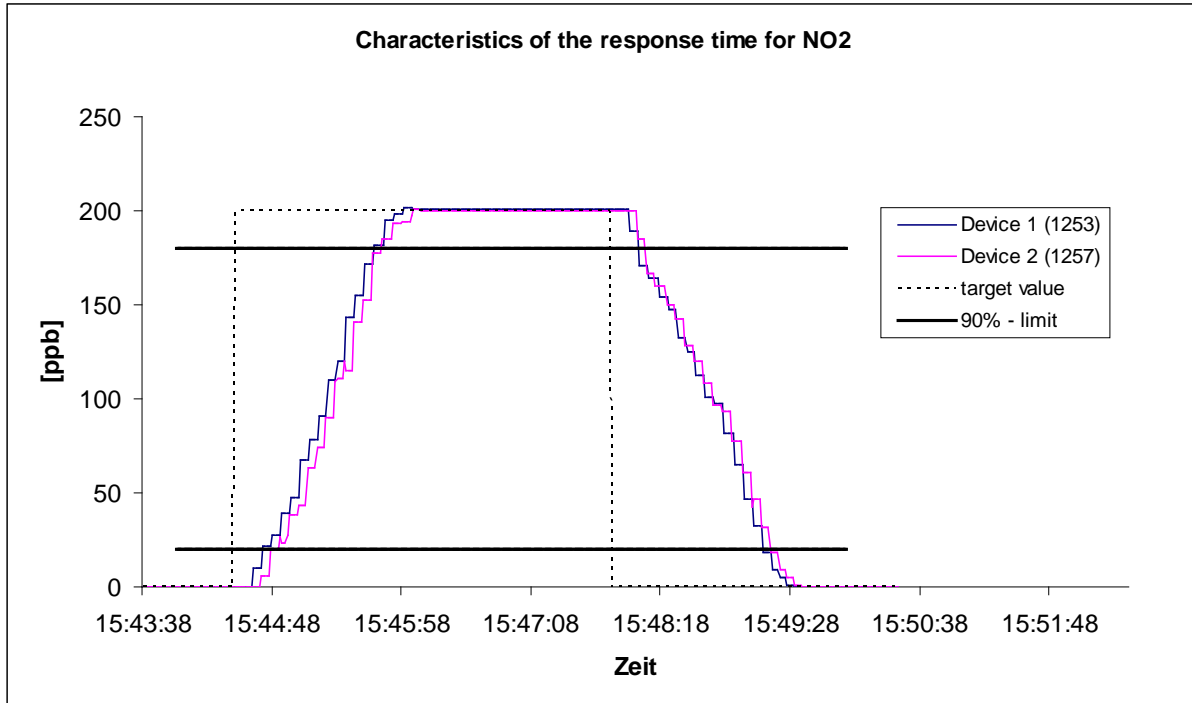


Figure 11: Characteristics of the response time for the component NO<sub>2</sub>

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

### **7.5 Assessment**

The determined response time is clearly below the allowed response time of 180 s. The relative difference between rise time and fall time fulfills the requirement of EN 14211.

Minimum requirement fulfilled? yes

### **7.6 Presentation of test results**

Here not necessary.

## 7.1 8.4.4 Short-term drift

*Short-term drift at zero ≤ 2,0 nmol/mol/12h (equal to 2 ppb/12h)*

*Short-term drift at span ≤ 6,0 nmol/mol/12h (equal to 6 ppb/12h)*

## 7.2 General requirements

After the required stabilization period, the analyzer shall be adjusted at zero and span level (around 70 % to 80 % of the maximum of the certification range). Wait the time equivalent to one independent reading and then record 20 individual measurements first at zero and then at span concentration. From these 20 measurements the average is calculated for zero and span level.

The analyzer shall be kept running under the laboratory conditions whilst analyzing ambient air. After a period of 12-hours zero and span gas is fed to the analyzer. Wait the time equivalent to one independent reading and then record 20 individual measurements first at zero and then at span concentration. The averages for zero and span level shall be calculated.

The short-term drift at zero and span level shall be calculated as follows:

$$D_{S,Z} = (C_{Z,2} - C_{Z,1})$$

Where:

$D_{S,Z}$  is the 12-hour drift at zero (nmol/mol);

$C_{Z,1}$  is the average of the zero gas measurements at the beginning of the drift period (just after calibration) (nmol/mol);

$C_{Z,2}$  is the average of the zero gas measurements at the end of the drift period (12h) (nmol/mol).

$D_{S,Z}$  shall comply with the performance criterion.

$$D_{S,S} = (C_{S,2} - C_{S,1}) - D_{S,Z}$$

Where:

$D_{S,S}$  is the 12-hour drift at span (nmol/mol);

$C_{S,1}$  is the average of the span gas measurements at the beginning of the drift period (just after calibration) (12h) (nmol/mol);

$C_{S,2}$  is the average of the span gas measurements at the end of the drift period (12h) (nmol/mol).

$D_{S,S}$  shall comply with the performance criterion.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211.

### 7.4 Evaluation

Table 5: Results of the short-term drift

	Device 1 (1253)	Device 2 (1257)
	[ppb]	[ppb]
$C_{z,1}$	0,5	-0,3
$C_{z,2}$	-0,2	-0,7
$D_{s,z}$	<b>-0,7</b>	<b>-0,4</b>
Requirement	2 ppb	2 ppb
fulfilled ?	<b>yes</b>	<b>yes</b>
$C_{s,1}$	724,8	725,3
$C_{s,2}$	723,4	723,5
$D_{s,s}$	<b>-0,7</b>	<b>-1,4</b>
Requirement	6 ppb	6 ppb
fulfilled ?	<b>yes</b>	<b>yes</b>

### 7.5 Assessment

The following short-term drift at zero ( $D_{s,z}$ ) has been determined:

Unit 1 (1253): -0,7 ppb/12 h

Unit 2 (1257): -0,4 ppb/12 h

The following short-term drift at span ( $D_{s,s}$ ) has been determined:

Unit 1 (1253): -0,7 ppb/12 h

Unit 2 (1257): -1,4 ppb/12 h

The short-term drift requirements of EN 14211 have been fulfilled.

Minimum requirement fulfilled? **yes**

### 7.6 Documentation

The measured values are stated in Table 6 and Table 7.

**Table 6:** Measured values of short-term drift regarding EN 14211, device 1 (1253)

Initial Value (18.01.2007)				Value after 12 h (18.01.2007)			
Zero Point		Span Point		Zero Point		Span Point	
[Time]	[ppb]	[Time]	[ppb]	[Time]	[ppb]	[Time]	[ppb]
07:25	1,0	8:13	722,0	19:30	-1,0	20:18	723,0
07:27	1,0	8:15	723,0	19:32	-1,0	20:20	724,0
07:29	1,0	8:17	723,0	19:34	-1,0	20:22	724,0
07:31	1,0	8:19	723,0	19:36	-1,0	20:24	723,0
07:33	0,0	8:21	723,0	19:38	0,0	20:26	723,0
07:35	0,0	8:23	724,0	19:40	0,0	20:28	723,0
07:37	0,0	8:25	725,0	19:42	0,0	20:30	722,0
07:39	0,0	8:27	725,0	19:44	0,0	20:32	722,0
07:41	0,0	8:29	726,0	19:46	0,0	20:34	724,0
07:43	0,0	8:31	725,0	19:48	0,0	20:36	723,0
07:45	1,0	8:33	726,0	19:50	0,0	20:38	723,0
07:47	0,0	8:35	726,0	19:52	0,0	20:40	723,0
07:49	2,0	8:37	726,0	19:54	0,0	20:42	723,0
07:51	1,0	8:39	726,0	19:56	0,0	20:44	724,0
07:53	0,0	8:41	725,0	19:58	0,0	20:46	724,0
07:55	1,0	8:43	726,0	20:00	0,0	20:48	724,0
07:57	1,0	8:45	725,0	20:02	0,0	20:50	724,0
07:59	0,0	8:47	726,0	20:04	0,0	20:52	724,0
08:01	0,0	8:49	726,0	20:06	0,0	20:54	724,0
08:03	0,0	8:51	725,0	20:08	0,0	20:56	724,0
<b>Average</b>	<b>0,5</b>	<b>Average</b>	<b>724,8</b>	<b>Average</b>	<b>-0,2</b>	<b>Average</b>	<b>723,4</b>

**Table 7:** Measured values of short-term drift regarding EN 14211, device 2 (1257)

Initial Value (18.01.2007)				Value after 12 h (18.01.2007)			
Zero Point		Span Point		Zero Point		Span Point	
[Time]	[ppb]	[Time]	[ppb]	[Time]	[ppb]	[Time]	[ppb]
07:25	-1,0	8:13	726,0	19:30	0,0	20:18	724,0
07:27	0,0	8:15	725,0	19:32	-1,0	20:20	724,0
07:29	0,0	8:17	725,0	19:34	-1,0	20:22	723,0
07:31	0,0	8:19	726,0	19:36	-1,0	20:24	723,0
07:33	-1,0	8:21	726,0	19:38	0,0	20:26	723,0
07:35	0,0	8:23	726,0	19:40	0,0	20:28	722,0
07:37	0,0	8:25	725,0	19:42	0,0	20:30	723,0
07:39	0,0	8:27	726,0	19:44	0,0	20:32	723,0
07:41	0,0	8:29	726,0	19:46	0,0	20:34	723,0
07:43	0,0	8:31	726,0	19:48	0,0	20:36	724,0
07:45	0,0	8:33	726,0	19:50	0,0	20:38	725,0
07:47	0,0	8:35	725,0	19:52	0,0	20:40	724,0
07:49	0,0	8:37	724,0	19:54	-1,0	20:42	724,0
07:51	0,0	8:39	725,0	19:56	-1,0	20:44	724,0
07:53	0,0	8:41	725,0	19:58	-1,0	20:46	724,0
07:55	0,0	8:43	724,0	20:00	-1,0	20:48	724,0
07:57	-1,0	8:45	725,0	20:02	-1,0	20:50	724,0
07:59	-1,0	8:47	725,0	20:04	-1,0	20:52	723,0
08:01	-1,0	8:49	725,0	20:06	-2,0	20:54	723,0
08:03	-1,0	8:51	725,0	20:08	-2,0	20:56	723,0
<b>Average</b>	<b>-0,3</b>	<b>Average</b>	<b>725,3</b>	<b>Average</b>	<b>-0,7</b>	<b>Average</b>	<b>723,5</b>

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.4.5 Repeatability standard deviation

*Repeatability standard deviation at zero ≤ 1,0 nmol/mol (equal to 1,0 ppb)*

*Repeatability standard deviation at span ≤ 3,0 nmol/mol (equal to 3,0 ppb)*

## 7.2 General requirements

After waiting the time equivalent of one independent reading 20 individual measurements both at zero concentration and at a test concentration ( $c_t$ ) similar to the hourly limit value shall be performed. From these measurements the repeatability standard deviation ( $s_r$ ) at zero concentration and at concentration  $c_t$  shall be calculated according to:

$$s_r = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

Where:

$s_r$  is the repeatability standard deviation (nmol/mol);

$x_i$  is the  $i$ 'th measurement (nmol/mol);

$\bar{x}$  is the average of the 20 measurements (nmol/mol);

$n$  is the number of measurements,  $n = 20$ .

The repeatability standard deviation shall be calculated separately for both series of measurements (zero gas and concentration  $c_t$ ).

$s_r$  shall comply with the performance criterion, both at zero and at the test concentration  $c_t$  (hourly limit value).

## 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211.

## 7.4 Evaluation

A summary of the determined test results according to EN 14211 is stated in Table 8.

Table 8: Repeatability standard deviation according to EN 14211

Measurement		Device 1 (1253)		Device 2 (1257)	
		NP	RP	NP	RP
		ppb	ppb	ppb	ppb
Number	n	20	20	20	20
Average	x	0,45	525	2,05	530
<b>Standard deviation</b>	<b>sr</b>	<b>0,94</b>	<b>1,05</b>	<b>0,83</b>	<b>1,23</b>
<b>Requirement of EN 14211</b>	<b>ppb</b>	<b>1</b>	<b>3</b>	<b>1</b>	<b>3</b>
<b>Requirement fulfilled?</b>		<b>yes</b>	<b>yes</b>	<b>yes</b>	<b>yes</b>

## 7.5 Assessment

Both M200E analyzers fulfill the minimum requirements at zero and span point.

Minimum requirements fulfilled? yes

## 7.6 Presentation of test results

The single measured values of the test are stated in Table 9.

Table 9: Measured values of repeatability standard deviation regarding EN 14211

Date	Time	Zero Point		Date	Time	Spanpoint	
		Device 1253	Device 1257			Device 1253	Device 1257
		[ppb]	[ppb]			[ppb]	[ppb]
29.09.2006	08:05 - 08:15	-1,0	3,0	29.09.2006	08:15 - 08:25	523	530
29.09.2006	08:25 - 08:35	0,0	3,0	29.09.2006	08:35 - 08:45	526	532
29.09.2006	08:45 - 08:55	-1,0	3,0	29.09.2006	08:55 - 09:05	524	532
29.09.2006	09:05 - 09:15	-1,0	3,0	29.09.2006	09:15 - 09:25	524	528
29.09.2006	09:25 - 09:35	-1,0	2,0	29.09.2006	09:35 - 09:45	526	529
29.09.2006	09:45 - 09:55	0,0	3,0	29.09.2006	09:55 - 10:05	527	529
29.09.2006	10:05 - 10:15	0,0	3,0	29.09.2006	10:15 - 10:25	526	530
29.09.2006	10:25 - 10:35	0,0	3,0	29.09.2006	10:35 - 10:45	526	532
29.09.2006	10:45 - 10:55	0,0	2,0	29.09.2006	10:55 - 11:05	525	529
29.09.2006	11:05 - 11:15	1,0	2,0	29.09.2006	11:15 - 11:25	527	528
29.09.2006	11:25 - 11:35	1,0	2,0	29.09.2006	11:35 - 11:45	525	528
29.09.2006	11:45 - 11:55	1,0	2,0	29.09.2006	11:55 - 12:05	525	529
29.09.2006	12:05 - 12:15	1,0	1,0	29.09.2006	12:15 - 12:25	525	530
29.09.2006	12:25 - 12:35	1,0	1,0	29.09.2006	12:35 - 12:45	525	530
29.09.2006	12:45 - 12:55	1,0	2,0	29.09.2006	12:55 - 13:05	525	530
29.09.2006	13:05 - 13:15	1,0	1,0	29.09.2006	13:15 - 13:25	525	530
29.09.2006	13:25 - 13:35	1,0	1,0	29.09.2006	13:35 - 13:45	525	530
29.09.2006	13:45 - 13:55	1,0	1,0	29.09.2006	13:55 - 14:05	526	531
29.09.2006	14:05 - 14:15	2,0	2,0	29.09.2006	14:15 - 14:25	526	530
29.09.2006	14:25 - 14:35	2,0	1,0	29.09.2006	14:35 - 14:45	527	530
Number		<b>20</b>	<b>20</b>	Number		<b>20</b>	<b>20</b>
Average		<b>0,45</b>	<b>2,05</b>	Average		<b>525</b>	<b>530</b>
Standard deviation		<b>0,94</b>	<b>0,83</b>	Standard deviation		<b>1,05</b>	<b>1,23</b>



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

#### 7.1 8.4.6 „Lack of fit“ (residual from the linear regression function)

*„lack of fit“ (residual from the linear regression function) 5 nmol/mol (equal to 5 ppb) at zero and ≤ 4 % from the measured value at concentrations higher than zero.*

#### 7.2 General requirements

The lack of fit of the analyzer shall be tested over the range between 0 % to 95 % of the maximum of the certification range using at least six concentrations (including the zero point). The analyzer shall be adjusted at a concentration of about 90 % of the maximum of the certification range. At each concentration (including zero) at least five individual readings shall be performed.

The concentrations shall be applied in the following sequence: 80 %, 40 %, 0 %, 60 %, 20 % and 95%. After each change in concentration at least four response times shall be taken into account before the next measurement is performed.

Calculation of the linear regression function and residuals shall be performed according to

Annex B (DIN EN 14211). All the (relative) residuals from the linear regression function shall fulfill the criteria.

The largest value of the relative residuals is reported as  $X_i$  and shall be taken into account in demonstrating compliance with type approval requirement 1. The value of the relative residual value at the level of the 1-hour emission limit value shall be taken in the calculation of type approval requirement 2 and 4.

Establishment of the regression line:

A linear regression function in the form of  $Y_i = A + B + X_i$  is made through calculation of the function

$$Y_i = a + B(X_i - X_z)$$

For the regression all measuring points (including zero) are taken into account. The total number of measuring points ( $n$ ) is equal to the number of concentration levels (at least six including zero) times the number of repetitions (at least five) at a particular concentration level.

The coefficient  $a$  is obtained from:

$$a = \sum Y_i / n$$

Where:

- $a$  is the average value of the  $Y$  – values;
- $Y_i$  is the individual  $Y$  – value;
- $N$  is the number of calibration points.

The coefficient  $B$  is obtained by:

$$B = \left( \sum Y_i (X_i - X_z) \right) / \sum (X_i - X_z)^2$$

Where:

- $X_z$  is the average of the  $X$  - values  $\left( = \sum (X_i / n) \right)$ ;
- $X_i$  is the individual  $X$  – value.

The function  $Y_i = a + B (X_i - X_z)$  is converted to  $Y_i = A + B * X_i$  through the calculation of A:

$$A = a - B * X_z$$

The residuals of the averages of each calibration point (including the zero point) are calculated as follows:

The average of each calibration point (including the zero point) at one and the same concentration  $c$  is calculated according to:

$$(Y_a)_c = \sum (Y_i)_c / m$$

Where:

$(Y_a)_c$  is the average Y – value at concentration level  $c$ ;

$(Y_i)_c$  is the individual Y – value at concentration level  $c$ ;

$M$  is the number of repetitions and one and the same concentration level  $c$ .

The residual of each average ( $d_c$ ) at each concentration level  $c$  is calculated according to:

$$d_c = (Y_a)_c - (A + B \times c)$$

Each residual to a value relative to its own concentration level  $c$  is expressed as::

$$(d_r)_c = \frac{d_c}{c} \times 100\%$$

### 7.3 Performance of test

The test has been enforced regarding the specifications of the DIN EN 14211.

### 7.4 Evaluation

The following linear regressions were found:

In Figure 12 and Figure 13 are the results of the group averages for the component NO in the graphs to see.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

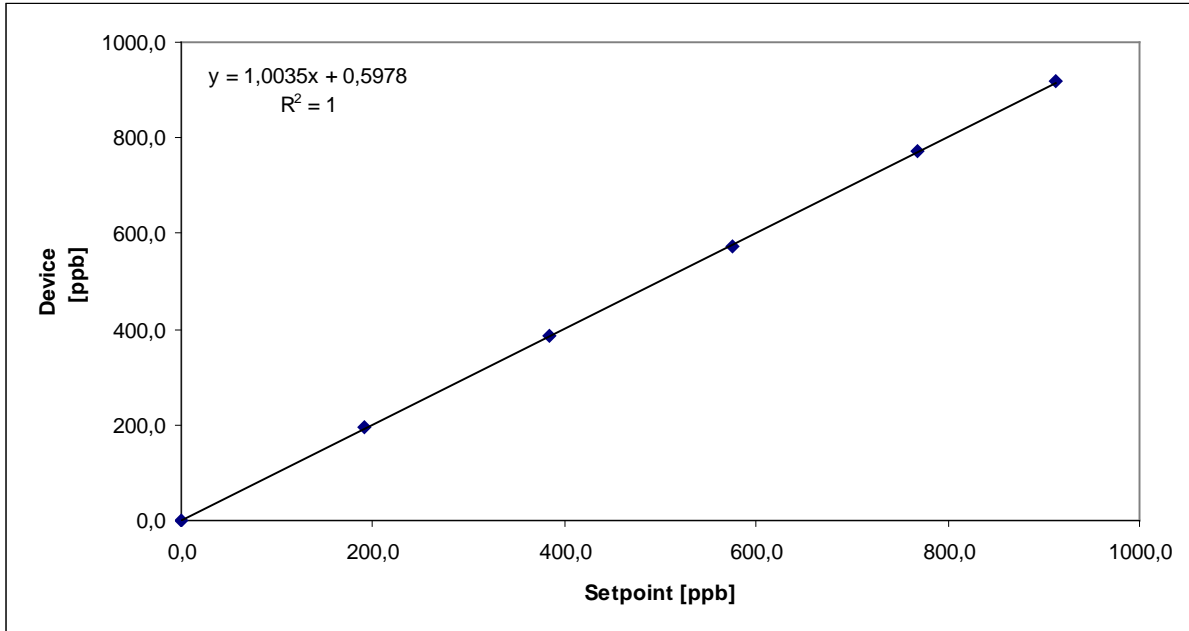


Figure 12: Analytical function from the group averages for unit 1, component NO

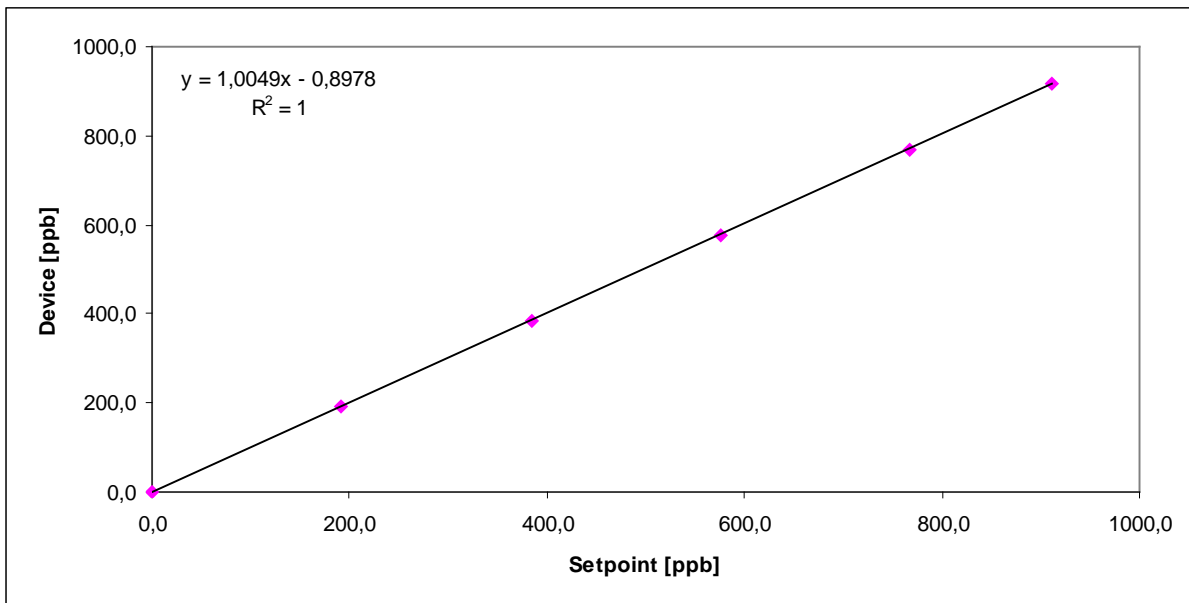


Figure 13: Analytical function from the group averages for unit 2, component NO

Device 1 (1253):  $Y = 1,0035x + 0,5978$

Device 2 (1257):  $Y = 1,0049x + 0,8978$

The following deviations have been determined:

Table 10: Deviations from the desired values, device 1 (1253)

Test Gas Setpoint	Measured Value*	Deviance**	Permitted Deviance	Deviance
[ppb]	[ppb]	[ppb]	EN 14211 [ppb]	(in % of measured value)
0,0	1,6	1,6	5,0	----
192,0	193,2	1,2	7,7	0,6
384,0	386,4	2,4	15,4	0,6
576,0	575,0	-1,0	23,0	-0,2
768,0	772,2	4,2	30,7	0,5
912,0	917,2	5,2	36,5	0,6

\* Average of 5 individual measurements

\*\* Measured value minus Setpoint

Table 11: Deviations from the desired values, device 2 (1257)

Test Gas Setpoint	Measured Value*	Deviance**	Permitted Deviance	Deviance
[ppb]	[ppb]	[ppb]	EN 14211 [ppb]	(in % of measured value)
0,0	-0,8	-0,8	5,0	----
192,0	192,2	0,2	7,7	0,1
384,0	385,8	1,8	15,4	0,5
576,0	576,4	0,4	23,0	0,1
768,0	770,2	2,2	30,7	0,3
912,0	916,8	4,8	36,5	0,5

\* Average of 5 individual measurements

\*\* Measured value minus Setpoint

## 7.5 Assessment

For device 1 (1253) a deviation from the linear regression line of 1,6 ppb at zero and maximum 0,6 % of measured value at a concentrations higher than zero could be determined.

For device 2 (1257) a deviation from the linear regression line of -0,8 ppb at zero and maximum 0,5 % of measured value at a concentrations higher than zero could be determined.

The determined results fulfill the requirements of EN 14211.

Minimum requirement fulfilled? yes

## 7.6 Presentation of the test results

The single measured values are stated in Table 12 and Table 13.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO2 and NOx ,  
Report-No.: 936/21205926/A2

Table 12: Measured values „lack of fit“ test, device 1 (1253)

Cycle	Date	Time	Measured Value [ppb]	Setpoint [ppb]	Deviation [ppb]
1	13.09.2006	10:35 - 10:45	1,0	0,0	1,0
1	13.09.2006	10:55 - 11:05	194,0	192,0	2,0
1	13.09.2006	10:25 - 10:35	387,0	384,0	3,0
1	13.09.2006	10:45 - 10:55	573,0	576,0	-3,0
1	13.09.2006	10:15 - 10:25	774,0	768,0	6,0
1	13.09.2006	11:05 - 11:15	915,0	912,0	3,0
2	13.09.2006	11:35 - 11:45	1,0	0,0	1,0
2	13.09.2006	11:55 - 12:05	190,0	192,0	-2,0
2	13.09.2006	11:25 - 11:35	386,0	384,0	2,0
2	13.09.2006	11:45 - 11:55	579,0	576,0	3,0
2	13.09.2006	11:15 - 11:25	769,0	768,0	1,0
2	13.09.2006	12:05 - 12:15	917,0	912,0	5,0
3	13.09.2006	12:35 - 12:45	2,0	0,0	2,0
3	13.09.2006	12:55 - 13:05	195,0	192,0	3,0
3	13.09.2006	12:25 - 12:35	383,0	384,0	-1,0
3	13.09.2006	12:45 - 12:55	576,0	576,0	0,0
3	13.09.2006	12:15 - 12:25	775,0	768,0	7,0
3	13.09.2006	13:05 - 13:15	919,0	912,0	7,0
4	13.09.2006	13:35 - 13:45	2,0	0,0	2,0
4	13.09.2006	13:55 - 14:05	193,0	192,0	1,0
4	13.09.2006	13:25 - 13:35	391,0	384,0	7,0
4	13.09.2006	13:45 - 13:55	576,0	576,0	0,0
4	13.09.2006	13:15 - 13:25	770,0	768,0	2,0
4	13.09.2006	14:05 - 14:15	919,0	912,0	7,0
5	13.09.2006	14:45 - 14:55	2,0	0,0	2,0
5	13.09.2006	15:05 - 15:15	194,0	192,0	2,0
5	13.09.2006	14:35 - 14:45	385,0	384,0	1,0
5	13.09.2006	14:55 - 15:05	571,0	576,0	-5,0
5	13.09.2006	14:25 - 14:35	773,0	768,0	5,0
5	13.09.2006	15:15 - 15:25	916,0	912,0	4,0

Table 13: Measured values „lack of fit“ test, device 2 (1257)

Cycle	Date	Time	Measured Value [ppb]	Setpoint [ppb]	Deviation [ppb]
1	13.09.2006	10:35 - 10:45	0,0	0,0	0,0
1	13.09.2006	10:55 - 11:05	197,0	192,0	5,0
1	13.09.2006	10:25 - 10:35	388,0	384,0	4,0
1	13.09.2006	10:45 - 10:55	580,0	576,0	4,0
1	13.09.2006	10:15 - 10:25	770,0	768,0	2,0
1	13.09.2006	11:05 - 11:15	916,0	912,0	4,0
2	13.09.2006	11:35 - 11:45	-2,0	0,0	-2,0
2	13.09.2006	11:55 - 12:05	189,0	192,0	-3,0
2	13.09.2006	11:25 - 11:35	384,0	384,0	0,0
2	13.09.2006	11:45 - 11:55	577,0	576,0	1,0
2	13.09.2006	11:15 - 11:25	771,0	768,0	3,0
2	13.09.2006	12:05 - 12:15	912,0	912,0	0,0
3	13.09.2006	12:35 - 12:45	-1,0	0,0	-1,0
3	13.09.2006	12:55 - 13:05	193,0	192,0	1,0
3	13.09.2006	12:25 - 12:35	381,0	384,0	-3,0
3	13.09.2006	12:45 - 12:55	579,0	576,0	3,0
3	13.09.2006	12:15 - 12:25	775,0	768,0	7,0
3	13.09.2006	13:05 - 13:15	917,0	912,0	5,0
4	13.09.2006	13:35 - 13:45	0,0	0,0	0,0
4	13.09.2006	13:55 - 14:05	190,0	192,0	-2,0
4	13.09.2006	13:25 - 13:35	390,0	384,0	6,0
4	13.09.2006	13:45 - 13:55	578,0	576,0	2,0
4	13.09.2006	13:15 - 13:25	764,0	768,0	-4,0
4	13.09.2006	14:05 - 14:15	920,0	912,0	8,0
5	13.09.2006	14:45 - 14:55	-1,0	0,0	-1,0
5	13.09.2006	15:05 - 15:15	192,0	192,0	0,0
5	13.09.2006	14:35 - 14:45	386,0	384,0	2,0
5	13.09.2006	14:55 - 15:05	568,0	576,0	-8,0
5	13.09.2006	14:25 - 14:35	771,0	768,0	3,0
5	13.09.2006	15:15 - 15:25	919,0	912,0	7,0

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.1 8.4.7 Sensitivity coefficient to sample gas pressure

*The sensitivity coefficient to sample gas pressure have to constitute  $\leq 8,0$  nmol/mol/kPa (equal to 8,0 ppb).*

### 7.2 General requirement

Measurements are taken at a concentration of about 70 % to 80 % of the maximum of the certification range at an absolute pressure of 80 kPa  $\pm$  0,2 kPa and at an absolute pressure of 110 kPa  $\pm$  0,2 kPa. At each pressure after waiting the time equivalent to one independent reading three individual measurements are recorded. From these 3 measurements the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

The sample gas pressure influence is calculated by:

$$b_{sp} = \left| \frac{(C_{P1} - C_{P2})}{(P_2 - P_1)} \right|$$

Where:

$b_{sp}$  is the sample gas pressure influence (nmol/mol/kPa);

$C_{P1}$  is the average concentration of the measurements at sampling gas pressure  $P_1$  (nmol/mol);

$C_{P2}$  is the average concentration of the measurements at sampling gas pressure  $P_2$  (nmol/mol);

$P_1$  is the sampling gas pressure  $P_1$  (kPa);

$P_2$  is the sampling gas pressure  $P_2$  (kPa).

$b_{sp}$  shall comply with the performance criterion.

### 7.3 Performance of test

The M200E analyzer determines the concentration of NO, NO<sub>2</sub> and NO<sub>x</sub> in a sample gas drawn through the instrument. It is equipped with a pump and sucks the requires sample gas in (approx. 0,5 l/min). These pump has to work against the ambient pressure. This means that the ambient pressure on sample inlet and behind the pump is equal. The obsessive induce of a over- or under pressure in these system could destroy the analyzer. It is required that test gas is given without pressure and abundant through the analyzer. The abounding gas drained off by a T-valve.

During the 3-month field test the ambient pressure conditions changed between 982 mbar and 1031 mbar. During the investigations no influence on ambient air pressure changes could be determined.

By running the analyzer with 5 sample gas filters at the same time it was tested how the analyzer reacts to a blocked sample gas filter no influence could be determined.

#### 7.4 Evaluation

Due to the assembling of the analyzer the sensitivity coefficient to sample gas pressure could not be determined repeatable without the risk of a demolition of the analyzer. During the field test no influence of the ambient air pressure in the range of 982 mbar and 1031 mbar could be determined.

The lowest ambient pressure during the field test has been measured on March 01 with 982 mbar (98,2 kPa). At the daily test gas giving (according to VDI 4202) a value of 61,3 µg/m<sup>3</sup> (equal to 32,1 ppb NO<sub>2</sub>) for device 1 (1253) and 61,9 µg/m<sup>3</sup> (equal to 32,4 ppb NO<sub>2</sub>) for device 2 (1257) has been measured.

The highest ambient pressure during the field test has been measured on March 12 with 1031 mbar (103,1 kPa). At the daily test gas giving (according to VDI 4202) a value of 59,9 µg/m<sup>3</sup> (equal to 31,4 ppb NO<sub>2</sub>) for device 1 (1253) and 61,3 µg/m<sup>3</sup> (equal to 32,1 ppb NO<sub>2</sub>) for device 2 (1257) has been measured.

Hence the following coefficient to sample gas pressure  $b_{gp}$  have been determined:

$$b_{gp} \text{ Device 1253} = 0,14 \text{ ppb/kPa}$$

$$b_{gp} \text{ Device 1257} = 0,06 \text{ ppb/kPa}$$

#### 7.5 Assessment

The sensitivity coefficient to sample gas pressure is lower than the allowed value of in maximum 3 ppb/kPa. The measured values of 0,14 ppb/kPa for device 1 (1253) and 0,06 ppb/kPa for device 2 (1257) are used for the calculation of the total uncertainty.

Minimum requirement fulfilled? yes

#### 7.6 Presentation of test results

Here not applicable.



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.1 8.4.8 Sensitivity coefficient to sample gas temperature

*The sensitivity coefficient to sample gas temperature have to constitute  $\leq 3,0$  nmol/mol/K (equal to 3,0 ppp/K).*

### 7.2 General requirement

For the determination of the dependence of the sample gas temperature measurements shall be performed at sample gas temperatures of  $T_1 = 0$  °C and  $T_2 = 30$ °C. The temperature dependence shall be determined at a concentration of about 70 % to 80 % of the maximum of the certification range. Wait the time equivalent to one independent and record 3 individual measurements at each temperature.

The sample gas temperature, measured at the inlet of the analyzer, shall be held constant for at least 30 min.

The influence of sample gas temperature is calculated from:

$$b_{gt} = \frac{(C_{T2} - C_{T1})}{(T_2 - T_1)}$$

Where:

$b_{gt}$  is the sample gas temperature influence (nmol/mol/°C);

$C_{T1}$  is the average concentration of the measurements at sample gas temperature  $T_1$  (°C);

$C_{T2}$  is the average concentration of the measurements at sample gas temperature  $T_2$  (°C);

$T_1$  is the sample gas temperature  $T_1$  (°C);

$T_2$  is the sample gas temperature  $T_2$  (°C).

$b_{gt}$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211.

The test gas system has been positioned inside of a climate chamber. The test gas was offered through an 20 m long conditioned sample gas line to the analyzers, which were positioned directly in front of the climate chamber. The test was done with 0 °C and with 30 °C.

#### 7.4 Evaluation

The following coefficient to sample gas temperature has been determined:

$$b_{gt} \text{ Device 1253} = 0,04 \text{ ppb/K}$$

$$b_{gt} \text{ Device 1257} = 0,03 \text{ ppb/K}$$

#### 7.5 Assessment

The sensitivity coefficient of the sample gas temperature  $b_{gt}$  is with 0,04 ppb/K for device 1253 and 0,03 ppb/K for device 1257 smaller than the required value of 3 ppb/K.

Minimum requirement fulfilled? yes

#### 7.6 Presentation of test results

The measured values are to see in Table 14.

Table 14: Measured values of determination of the sensitivity coefficient of sample gas temperature

Date	Time	Span Point		
		Temperature	Device 1 (1253)	Device 2 (1257)
		[°C]	[ppb]	[ppb]
07.02.2007	08:15 - 08:20	0	702,0	704,0
07.02.2007	08:20 - 08:25	0	706,0	704,0
07.02.2007	08:25 - 08:30	0	704,0	702,0
	<b>Average</b>	<b>C<sub>T1</sub></b>	<b>704,0</b>	<b>703,3</b>
07.02.2007	13:20 - 13:25	30	705,0	704,0
07.02.2007	13:25 - 13:30	30	708,0	704,0
07.02.2007	13:30 - 13:35	30	703,0	705,0
	<b>Average</b>	<b>C<sub>T2</sub></b>	<b>705,3</b>	<b>704,3</b>

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature

*Sensitivity coefficient to the surrounding temperature has to constitute  $\leq 3,0$  nmol/mol/K (equal to 3,0 ppb/K)*

## 7.2 General requirement

The influence of the surrounding temperature shall be determined at the following temperatures (within the specifications of the manufacturer:

- 1) at the minimum temperature  $T_{\min} = 273$  K;
- 2) at the laboratory temperature  $T_1 = 293$  K;
- 3) at the maximum temperature  $T_{\max} = 303$  K;

For this tests a climate chamber is necessary.

The influence shall be determined at a concentration around 70 % to 80 % of the maximum of the certification range. At each temperature setting after waiting the time equivalent to one independent reading three individual measurements at zero and at span shall be recorded.

The measurements shall be performed in the following sequence of the temperature settings:

$T_1, T_{\min}, T_1$  und  $T_1, T_{\max}, T_1$

At the first temperature ( $T_{\text{lab}}$ ) the analyzer shall be adjusted at zero and at span level (70 % to 80 % of the maximum of the certification range). Then three individual measurements are recorded after waiting the time equivalent to one independent reading at  $T_1$ , at  $T_{\min}$  and again at  $T_{\text{lab}}$ . This procedure shall be repeated at the temperature sequence of  $T_{\text{lab}}, T_{\max}$ , and at  $T_{\text{lab}}$ .

In order to exclude any possible drift due to factors other than temperature, the measurements at  $T_{\text{lab}}$  are averaged, which is taken into account in the following formula for calculation of the surrounding air temperature dependence:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T - T_1} \right|$$

Where:

- $b_{st}$  is the surrounding air temperature dependence at zero or span and at  $T_{\min}$  or  $T_{\max}$  ( $\mu\text{mol/mol}/^\circ\text{C}$ );
- $x_T$  is the average of the measurements at  $T_{\min}$  or  $T_{\max}$  (ppb);
- $x_1$  is the first average of the measurements at  $T_{\text{lab}}$  just after calibration (ppb);
- $x_2$  is the second of the measurements at  $T_{\text{lab}}$  just before calibration (ppb);
- $T_1$  is the surrounding air temperature at the laboratory (K);
- $T$  is the surrounding air temperature  $T_{\min}$  or  $T_{\max}$  (K).

For reporting the surrounding air temperature dependence the highest value is taken of the two calculations of the temperature dependence at  $T_{\min}$  and  $T_{\max}$ .

$b_{st}$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211.

### 7.4 Evaluation

The following sensitivity coefficients to the surrounding temperature have been determined:

Table 15: Sensitivity coefficient at zero for device 1253

	T [°C]	Mittelwert Gerät 1253 [ppb]	ermitteltes $b_{st}$ [ppb/K]	erlaubtes $b_{st}$ [ppb/K]	Kriterium erfüllt? DIN EN 14211
$T_1$	20	0,33	0,01	3	ja
$T_{\min}$	0	0,67			
$T_1$	20	0,67			
$T_1$	20	0,67	0,05	3	ja
$T_{\max}$	30	1,00			
$T_1$	20	0,33			

Table 16: Sensitivity coefficient at zero for device 1257

	T [°C]	Mittelwert Gerät 1257 [ppb]	ermitteltes $b_{st}$ [ppb/K]	erlaubtes $b_{st}$ [ppb/K]	Kriterium erfüllt? DIN EN 14211
$T_1$	20	0,33	0,03	3	ja
$T_{\min}$	0	-0,33			
$T_1$	20	0,33			
$T_1$	20	0,33	0,08	3	ja
$T_{\max}$	30	1,33			
$T_1$	20	0,67			

The sensitivity coefficients at zero are stated in Table 15 and Table 16. The results fulfill the performance criteria of EN 14211.

Table 17: Sensitivity coefficient at span for device 1253

	T [°C]	Mittelwert Gerät 1253 [ppb]	ermitteltes $b_{st}$ [ppb/K]	erlaubtes $b_{st}$ [ppb/K]	Kriterium erfüllt? DIN EN 14211
$T_1$	20	702,3	0,16	3	ja
$T_{min}$	0	698,7			
$T_1$	20	701,3			
$T_1$	20	701,3	0,52	3	ja
$T_{max}$	30	707,3			
$T_1$	20	703,0			

Table 18: Sensitivity coefficient at span for device 1257

	T [°C]	Mittelwert Gerät 1257 [ppb]	ermitteltes $b_{st}$ [ppb/K]	erlaubtes $b_{st}$ [ppb/K]	Kriterium erfüllt? DIN EN 14211
$T_1$	20	702,3	0,18	3	ja
$T_{min}$	0	699,0			
$T_1$	20	702,7			
$T_1$	20	702,7	0,03	3	ja
$T_{max}$	30	705,0			
$T_1$	20	703,0			

The sensitivity coefficients at span are stated in Table 17 and Table 18. The results fulfill the performance criteria of EN 14211.

## 7.5 Assessment

The sensitivity coefficient of the surrounding temperature  $b_{st}$  does not exceed the performance criteria of maximum 3,0 ppb/K. The largest coefficients  $b_{st}$  in each case, 0,52 ppb/K for device 1 (1253) and 0,18 ppb/K for device 2 (11257), have been taken for the calculation of the total uncertainty.

Minimum requirement fulfilled ? yes

## 7.6 Presentation of test results

The measured values are stated in Table 19.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

Table 19: Measured values of determination of the sensitivity coefficient of surrounding temperature

Date	Zero Point				Span Point			
	Time	Temperature [°C]	Device 1 (1253) [ppb]	Device 2 (1257) [ppb]	Time	Temperature [°C]	Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
02.02.2007	09:45 - 09:50	20	0,00	0,00	09:50 - 09:55	20	700,0	701,0
02.02.2007	09:55 - 10:00	20	1,00	1,00	10:00 - 10:05	20	702,0	702,0
02.02.2007	10:05 - 10:10	20	0,00	0,00	10:10 - 10:15	20	705,0	704,0
	<b>Average</b>		<b>0,33</b>	<b>0,33</b>	<b>Average</b>		<b>702,3</b>	<b>702,3</b>
05.02.2007	08:05 - 08:10	0	1,00	0,00	08:10 - 08:15	0	699,0	701,0
05.02.2007	08:15 - 08:20	0	1,00	0,00	08:20 - 08:25	0	700,0	698,0
05.02.2007	08:25 - 08:30	0	0,00	-1,00	08:30 - 08:35	0	697,0	698,0
	<b>Average</b>		<b>0,67</b>	<b>-0,33</b>	<b>Average</b>		<b>698,7</b>	<b>699,0</b>
05.02.2007	12:40 - 12:45	20	1,00	0,00	12:45 - 12:50	20	702,0	704,0
05.02.2007	12:50 - 12:55	20	0,00	0,00	12:55 - 13:00	20	702,0	701,0
05.02.2007	13:00 - 13:05	20	1,00	1,00	13:05 - 13:10	20	700,0	703,0
	<b>Average</b>		<b>0,67</b>	<b>0,33</b>	<b>Average</b>		<b>701,3</b>	<b>702,7</b>
05.02.2007	17:30 - 17:35	30	1,00	1,00	17:35 - 17:40	30	706,0	705,0
05.02.2007	17:40 - 17:45	30	1,00	2,00	17:45 - 17:50	30	708,0	704,0
05.02.2007	17:50 - 17:55	30	1,00	1,00	17:55 - 18:00	30	708,0	706,0
	<b>Average</b>		<b>1,00</b>	<b>1,33</b>	<b>Average</b>		<b>707,3</b>	<b>705,0</b>
06.02.2007	08:00 - 08:05	20	0,00	1,00	08:05 - 08:10	20	703,0	702,0
06.02.2007	08:10 - 08:15	20	0,00	1,00	08:15 - 08:20	20	702,0	703,0
06.02.2007	08:20 - 08:25	20	1,00	0,00	08:25 - 08:30	20	704,0	704,0
	<b>Average</b>		<b>0,33</b>	<b>0,67</b>	<b>Average</b>		<b>703,0</b>	<b>703,0</b>

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.1 8.4.10 Sensitivity coefficient to electrical voltage

*Sensitivity coefficient to the electrical voltage  $\leq 0,30 \text{ nmol/mol/V}$  (equal to  $0,30 \text{ ppb/V}$ )*

### 7.2 General requirement

The sensitivity coefficient of electrical voltage shall be determined at both ends of the specified voltage range,  $V_{\min}$  and  $V_{\max}$  at zero concentration and at a concentration around 70 % to 80 % of the maximum of the certification range. After waiting the time equivalent to one independent reading three individual measurements at each voltage and concentration level shall be recorded.

The voltage dependence is calculated according to the EN 14211 as follows:

$$b_v = \frac{(C_{V2} - C_{V1})}{(V_2 - V_1)}$$

Where:

$b_v$  is the voltage influence ( $\mu\text{mol/mol/V}$ );

$C_{V1}$  is the average concentration reading of the measurements at voltage  $V_1$  (nmol/mol);

$C_{V2}$  is the average concentration reading of the measurements at voltage  $V_2$  (nmol/mol);

$V_1$  is the minimum voltage  $V_{\min}$  (V) specified by the manufacturer;

$V_2$  is the maximum voltage  $V_{\max}$  (V) specified by the manufacturer.

For an analyzer operating on direct current the type approval test of voltage variation shall be carried out over the range of  $\pm 10 \%$  of the nominal voltage.

$b_v$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211. For the test a transformer was switched between the power supply and the analyzers. For the test zero and span gas was offered at the different voltages to the analysers.

### 7.4 Evaluation

The following sensitivity coefficients to electrical voltage have been determined:

$b_v$  Device 1253 NP: 0,01 (ppb/V)

$b_v$  Device 1253 RP: 0,00 (ppb/V)

$b_v$  Device 1257 NP: 0,01 (ppb/V)

$b_v$  Device 1257 RP: 0,03 (ppb/V)

## 7.5 Assessment

The sensitivity coefficient to electrical voltage  $b_v$  does not exceed the performance criteria of maximum 0,30 ppb/V according to EN 14211. The largest coefficients  $b_v$  in each case 0,01 ppb/V for device 1 (1253) and 0,03 ppb/V for device 2 (1257) have been taken for the calculation of the total uncertainty.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values of determination of the sensibility coefficient to electrical voltage are stated in Table 20 and Table 21.

Table 20: Measured values of determination of the sensitivity coefficient to electrical voltage at zero

Date	Time	Device 1 (1253)	Device 2 (1257)
		[ppb]	[ppb]
<b>Zero Gas with 210 V</b>			
10.01.2007	15:05 - 15:15	0,0	0,0
10.01.2007	15:25 - 15:35	0,0	1,0
10.01.2007	15:45 - 15:55	-1,0	1,0
<b>Average</b>		<b>-0,3</b>	<b>0,7</b>
<b>Zero Gas with 245 V</b>			
10.01.2007	16:15 - 16:25	0,0	1,0
10.01.2007	16:35 - 16:45	0,0	1,0
10.01.2007	16:55 - 17:05	0,0	1,0
<b>Average</b>		<b>0,0</b>	<b>1,0</b>

Table 21: Measured values of determination of the sensitivity coefficient to electrical voltage at span

Date	Time	Device 1 (1253)	Device 2 (1257)
		[ppb]	[ppb]
<b>Span Gas with 210 V</b>			
10.01.2007	15:15 - 15:25	680,0	681,0
10.01.2007	15:35 - 15:45	682,0	682,0
10.01.2007	15:55 - 16:05	682,0	681,0
<b>Average</b>		<b>681,3</b>	<b>681,3</b>
<b>Span Gas with 245 V</b>			
10.01.2007	16:25 - 16:35	683,0	683,0
10.01.2007	16:45 - 16:55	681,0	682,0
10.01.2007	17:05 - 17:15	680,0	682,0
<b>Average</b>		<b>681,3</b>	<b>682,3</b>



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.4.11 Interferences

*Interferences at zero and the concentration  $c_t$  (at the level of the 1-hour limit value). The allowed deviation is at  $\leq 5$  nmol/mol (equal to 5 ppb) for the component H<sub>2</sub>O, CO<sub>2</sub> and NH<sub>3</sub>, and  $\leq 2,0$  nmol/mol (equal tot 2 ppb) for the component ozone.*

## 7.2 General requirement

The analyzer response to certain interferents, which are expected to be present in ambient air, shall be tested. The interferents can give a positive or negative response. The test shall be performed at zero and at a test concentration ( $c_t$ ) similar to the 1-hour limit value.

The concentration of the mixtures of the test gases with the interferent shall have an uncertainty of less than 5 % and shall be traceable to national standards. The interferents to be tested and their respective concentrations are given in Table 22. The influence of each interferent shall be determined separately. A correction of the concentration of the measurand shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyzer at zero and span level the analyzer shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration as given in Table 22. With this mixture one independent measurement followed by two individual measurements shall be carried out. This procedure shall be repeated with a mixture of the measurand at concentration  $c_t$  and the interferent to be investigated. The influence quantity at zero and concentration  $c_t$  are calculated from:

$$X_{\text{int},z} = x_z$$

$$X_{\text{int},c_t} = x_{c_t} - c_t$$

Where:

$X_{\text{int},z}$  is the influence quantity of the interferent at zero (nmol/mol);

$x_z$  is the average of the measurements at zero (nmol/mol);

$X_{\text{int},c_t}$  is the influence quantity of the interferent at concentration  $c_t$  (nmol/mol);

$x_{c_t}$  is the average of the measurements at concentration  $c_t$  (nmol/mol);

$c_t$  is the concentration of the applied gas at the level of the 1-hour limit value ( $\mu\text{mol/mol}$ ).

The influence quantity of the interferences shall comply with the performance criteria, both at zero and at concentration  $c_t$ .

## 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211. The analyzers have been adjusted at zero and the concentration  $c_t$  (500 ppb). Afterward zero and span gas mixtures including the different interference gases have been given through the analyzers. The interfering components and concentrations are stated in Table 22 have been used.

Table 22: Interfering components regarding EN 14211

Interferences	Concentration
CO <sub>2</sub>	500 µmol/mol
H <sub>2</sub> O	19 mmol/mol
NH <sub>3</sub>	200 nmol/mol
O <sub>3</sub>	200 nmol/mol

## 7.4 Evaluation

The following responses to interfering components have been determined.

Table 23: Influence of the tested interfering components ( $c_t = 500$  ppb)

		Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
<b>H<sub>2</sub>O</b>	$X_z$	3,3	1,3
	$X_{int,z}$	<b>3,3</b>	<b>1,3</b>
	$X_{ct}$	496,7	496,3
	$X_{int,ct}$	<b>-3,3</b>	<b>-3,7</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>CO<sub>2</sub></b>	$X_z$	0,3	0,7
	$X_{int,z}$	<b>0,3</b>	<b>0,7</b>
	$X_{ct}$	500,7	501,3
	$X_{int,ct}$	<b>0,7</b>	<b>1,3</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>O<sub>3</sub></b>	$X_z$	-0,3	0,2
	$X_{int,z}$	<b>-0,3</b>	<b>0,2</b>
	$X_{ct}$	498,3	498,3
	$X_{int,ct}$	<b>-1,7</b>	<b>-1,7</b>
Maximum allowed deviance		2	2
fulfilled?		<b>yes</b>	<b>yes</b>
<b>NH<sub>3</sub></b>	$X_z$	0,7	0,0
	$X_{int,z}$	<b>0,7</b>	<b>0,0</b>
	$X_{ct}$	500,7	501,7
	$X_{int,ct}$	<b>0,7</b>	<b>1,7</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>

$c_t = 500$  ppb

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.5 Assessment

The responses to the interfering components H<sub>2</sub>O, CO<sub>2</sub>, O<sub>3</sub> and NH<sub>3</sub> do not exceed the performance criteria of EN 14211.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values are stated in Table 24.

Table 24: Measured values of the interference test

Date	Time	Device 1 (1253) [ppb]	Device 2 (1257) [ppb]	Date	Time	Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
<b>Zero Gas + H<sub>2</sub>O (19 mmol/mol)</b>				<b>Zero Gas + CO<sub>2</sub> (500 µmol/mol)</b>			
17.01.2007	08:35 - 08:45	3,0	1,0	17.01.2007	09:40 - 09:50	0,0	1,0
17.01.2007	08:55 - 08:05	4,0	2,0	17.01.2007	10:00 - 10:10	1,0	1,0
17.01.2007	09:15 - 09:25	3,0	1,0	17.01.2007	10:20 - 10:30	0,0	0,0
<b>Average</b>		<b>3,3</b>	<b>1,3</b>	<b>Average</b>		<b>0,3</b>	<b>0,7</b>
<b>Span Gas + H<sub>2</sub>O (19 mmol/mol)</b>				<b>Span Gas + CO<sub>2</sub> (500 µmol/mol)</b>			
17.01.2007	08:45 - 08:55	496,0	496,0	17.01.2007	09:50 - 10:00	501,0	503,0
17.01.2007	09:05 - 09:15	497,0	497,0	17.01.2007	10:10 - 10:20	500,0	500,0
17.01.2007	09:25 - 09:35	497,0	496,0	17.01.2007	10:30 - 10:40	501,0	501,0
<b>Average</b>		<b>496,7</b>	<b>496,3</b>	<b>Average</b>		<b>500,7</b>	<b>501,3</b>
<b>Zero Gas + O<sub>3</sub> (200 nmol/mol)</b>				<b>Zero Gas + NH<sub>3</sub> (200 nmol/mol)</b>			
17.01.2007	11:00 - 11:10	0,0	-0,6	17.01.2007	12:40 - 12:50	1,0	0,0
17.01.2007	11:20 - 11:30	0,0	0,0	17.01.2007	13:00 - 13:10	0,0	0,0
17.01.2007	11:40 - 11:50	-1,0	1,1	17.01.2007	13:20 - 13:30	1,0	0,0
<b>Average</b>		<b>-0,3</b>	<b>0,2</b>	<b>Average</b>		<b>0,7</b>	<b>0,0</b>
<b>Span Gas + O<sub>3</sub> (200 nmol/mol)</b>				<b>Span Gas + NH<sub>3</sub> (200 nmol/mol)</b>			
17.01.2007	11:10 - 11:20	499,0	500,0	17.01.2007	12:50 - 13:00	502,0	501,0
17.01.2007	11:30 - 11:40	498,0	498,0	17.01.2007	13:10 - 13:20	500,0	502,0
17.01.2007	11:50 - 12:00	498,0	497,0	17.01.2007	13:30 - 13:40	500,0	502,0
<b>Average</b>		<b>498,3</b>	<b>498,3</b>	<b>Average</b>		<b>500,7</b>	<b>501,7</b>

## 7.1 8.4.12 Average test

*The average effect has to constitute  $\leq 7\%$  of the measured value.*

## 7.2 General requirement

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyzer. In general the output of an analyzer is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging the following concentrations are applied to the

analyzer and readings are taken at each concentration:

- a constant concentration of NO<sub>2</sub> at a concentration  $\alpha_{1,NO_2}$  which is about twice the hourly limit value
- a stepwise varied concentration of NO between zero and 600 nmol/mol (concentration  $\alpha_{1,NO}$ ).

The time period ( $t_c$ ) of the constant NO concentration shall be at least equal to a period necessary to obtain four independent readings (which equals to at least sixteen response times). The time period ( $t_v$ ) of the varying NO concentration shall be at least equal to a period to obtain four independent readings. The time period ( $t_{NO}$ ) for the NO concentration shall be 45 s followed by a period ( $t_{zero}$ ) of 45 s of zero concentration.

Further:

$\alpha$  is the test concentration (nmol/mol);

$t_v$  is a whole number of  $t_{NO}$  and  $t_{zero}$  pairs, and contains a minimum of 3 such pairs.

The change from  $t_{NO}$  to  $t_{zero}$  shall be within 0,5 s. The change from  $t_c$  to  $t_v$  shall be within one response time of the analyzer under test.

The averaging effect ( $X_{av}$ ) is calculated according to:

$$X_{av} = \frac{C_{const}^{av} - 2C_{var}^{av}}{C_{const}^{av}} * 100$$

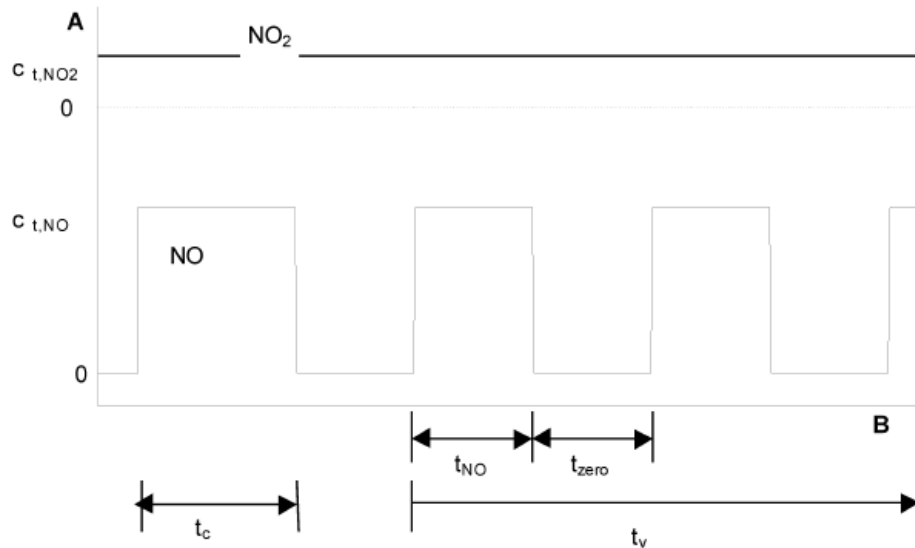
Where:

$X_{av}$  is the averaging effect (%);

$C_{const}^{av}$  is the average of the at least four independent measurements during the constant concentration period ( $t_c$ ) (nmol/mol);

$C_{var}^{av}$  is the average of the at least four independent measurements during the variable concentration period ( $t_v$ ) (nmol/mol).

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2



**Key**

- A Concentration (nmol/mol)
- B Time

Figure 14: Concentration variations for the averaging effect test ( $t_{NO} = t_{zero} = 45 \text{ s.}$ )

**7.3 Performance of test**

The test has been enforced regarding the specifications of EN 14211. At first a constant NO concentration has been applied to the analyzers and an average value was calculated. After this a varied concentration of NO between zero and the concentration  $c_t$  has been applied to the analyzer. With the help of a 3-way valve the concentration was changed every 45 s. During the time of varying concentrations an average value has been calculated.

**7.4 Evaluation**

In The following average has been calculated:

Constant average		variable average	
Device 1 (1253)	721,3 ppb	Device 1 (1253)	357,7 ppb
Device 2 (1257)	726,2 ppb	Device 2 (1257)	359,4 ppb

The outcome of this are the following averaging effects:

Device 1 (1253): 0,8 %

Device 2 (1257): 1,0 %

## 7.5 Findings

The performance criteria of EN 14211 have been fulfilled.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values are given in Table 25.

Table 25: Measured values of averaging test

Measurement (const)	Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
Measurement 1	721,0	725,8
Measurement 2	721,1	726,4
Measurement 3	721,4	726,2
Measurement 4	721,5	726,3
<b>Average C (const)</b>	<b>721,3</b>	<b>726,2</b>
<b>Measurement (var)</b>		
conz. t <sub>zero</sub>	345,4	351,2
conz. t <sub>NO</sub>	364,8	366,5
conz. t <sub>zero</sub>	348,6	346,4
conz. t <sub>NO</sub>	365,9	371,6
conz. t <sub>zero</sub>	351,8	352,3
conz. t <sub>NO</sub>	369,7	371,4
conz. t <sub>zero</sub>	351,2	350,7
conz. t <sub>NO</sub>	364,2	365,4
<b>Average C (var)</b>	<b>357,7</b>	<b>359,4</b>
<b>Averaging effect X<sub>av</sub> [%]</b>		
permitted averaging effect	7%	7%
Status	fulfilled	fulfilled

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.1 8.4.13 Difference sample/calibration port

*Difference between sample/calibration port has to constitute  $\leq 1,0$  %*

### 7.2 General requirement

If the analyzer has different ports for feeding sample gas and calibration gas the difference in response of the analyzer to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyzer with a test gas with a concentration of 70 % to 80 % of the maximum of the certification range through the sample port. The test shall consist of one independent followed by two individual measurements. After a period of at least 4 response times the test shall be repeated using the calibration port. The difference shall be calculated according to:

$$D_{SC} = \frac{x_s - x_c}{c_t} \times 100$$

Where:

$D_{SC}$  is the difference sample/calibration port (%);

$x_s$  is the average of the measured concentrations using the sample port (nmol/mol);

$x_c$  is the average of the measured concentrations using the calibration port (nmol/mol);

$c_t$  is the concentration of the test gas (nmol/mol).

$D_{SC}$  shall comply with the performance criterion.

### 7.3 Performance of test

The analyzers were not equipped with different sample/calibration ports. Just one sample inlet was available.

### 7.4 Evaluation

Here not applicable. For the calculation of total uncertainty the factor  $D_{SC} = 0$  has been taken.

### 7.5 Findings

Here not applicable

Minimum requirement fulfilled? Not applicable

## 7.6 Presentation of test results

As shown in Figure 15 no different gas inlets were available on the tested devices.

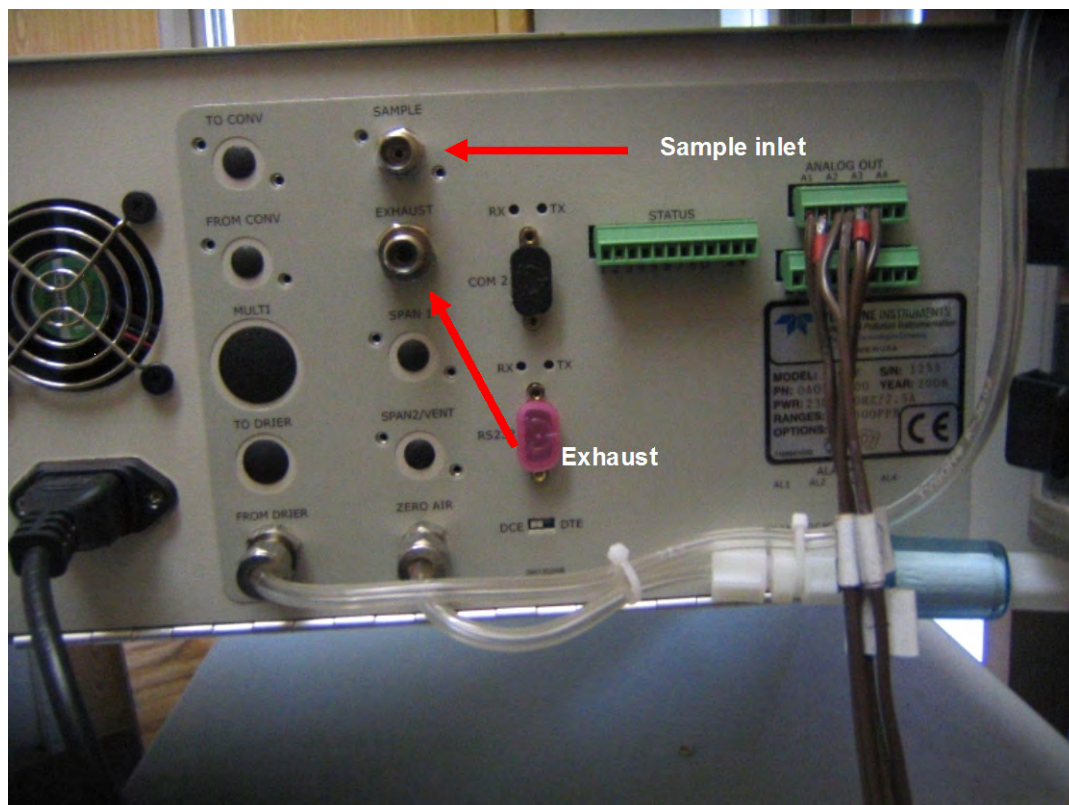


Figure 15: Backside of M200E analyzer



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.4.14 Converter efficiency

*Converter efficiency* ≥ 98 %

## 7.2 General requirement

The converter efficiency is determined by measurements with calculated amounts of NO<sub>2</sub>. This can be achieved by means of gas-phase titration of NO to NO<sub>2</sub> with ozone.

The test shall be performed at two concentration levels: at about 50 % and about 95 % of the maximum of the certification range of NO<sub>2</sub>.

The NO<sub>x</sub> analyzer shall be calibrated on the NO and NO<sub>x</sub> channel with a NO concentration around 70 % to 80 % of the maximum of the certification range of NO. Both channels shall be set to read the same value and the values shall be recorded.

A known concentration of about 50 % of the maximum of the certification range of NO shall be supplied to the analyzer until a stable output signal is achieved. This stabilization period shall be at least four times the response time of the analyzer. Four individual measurements are taken at the NO and NO<sub>x</sub> channel. The NO will then be reacted with O<sub>3</sub> to produce the required concentration of NO<sub>2</sub>. This mixture with a constant NO<sub>x</sub> concentration shall be supplied to the analyzer until a stable output signal is achieved. This stabilization period shall be at least four times the response time of the analyzer, the NO residue after the gas phase titration reaction shall be 10 % to 20 % of the original NO concentration. Four individual measurements are then taken at the NO and the NO<sub>x</sub> channel. The O<sub>3</sub> supply shall be switched off and the analyzer supplied with only NO until a stable output signal is achieved. This stabilization period shall be at least four times the response time of the analyzer. Then the average of the four individual measurements at the NO and NO<sub>x</sub> channel is checked to see whether it is equal within 1 % of the original values.

The converter efficiency is calculated from:

$$E_{conv} = \left( 1 - \frac{(NO_x)_i - (NO_x)_f}{(NO)_i - (NO)_f} \right) \times 100\%$$

Where:

$E_{conv}$  is the converter efficiency in %

$(NO_x)_i$  is the average of the four individual measurements at the NO<sub>x</sub> channel at the initial NO<sub>x</sub> concentration

$(NO_x)_f$  is the average of the four individual measurements at the NO<sub>x</sub> channel at the resulting NO<sub>x</sub> concentration after applying O<sub>3</sub>.

$(NO)_i$  is the average of the four individual measurements at the NO channel at the initial NO concentration

$(NO)_f$  is the average of the four individual measurements at the NO channel at the resulting NO concentrations after applying O<sub>3</sub>.

The lowest value of the two converter efficiencies shall be reported.

### 7.3 Performance of testing

The test has been enforced regarding the specifications of EN 14211.

### 7.4 Evaluation

The following converter efficiencies have been determined.

Table 26: Converter efficiency at a concentration of approx. 95 % of maximum of certification range of von NO<sub>2</sub> (range NO<sub>2</sub> = 0 – 261 ppb)

Device	channel	NO Gas	NO Gas	NO Gas	Converter
		Beginning	plus Ozon	End	
1253		[ppb]	[ppb]	[ppb]	[%]
	NO	887	625	889	<b>98,5</b>
	NO <sub>2</sub>	2	260	2	
	NO <sub>x</sub>	890	886	892	
Device	channel	NO Gas	NO Gas	NO Gas	Converter
		Beginning	plus Ozon	End	
1257		[ppb]	[ppb]	[ppb]	[%]
	NO	881	611	879	<b>98,5</b>
	NO <sub>2</sub>	2	266	3	
	NO <sub>x</sub>	883	879	882	

Table 27: Converter efficiency at a concentration of approx. 50 % of maximum of certification range of von NO<sub>2</sub> (range NO<sub>2</sub> = 0 – 261 ppb)

Device	channel	NO Gas	NO Gas	NO Gas	Converter
		Beginning	plus Ozon	End	
1253		[ppb]	[ppb]	[ppb]	[%]
	NO	879	777	882	<b>98,0</b>
	NO <sub>2</sub>	1	101	2	
	NO <sub>x</sub>	880	878	884	
Device	channel	NO Gas	NO Gas	NO Gas	Converter
		Beginning	plus Ozon	End	
1257		[ppb]	[ppb]	[ppb]	[%]
	NO	878	767	881	<b>98,2</b>
	NO <sub>2</sub>	1	106	2	
	NO <sub>x</sub>	878	876	882	

### 7.5 Findings

The converter efficiency fulfills at both concentration levels the requirement  $\geq 98\%$ . The smallest converter efficiencies in both case have been taken for the evaluation of total uncertainty.

Device 1 (1253): 98,0 %

Device 2 (1257): 98,2 %

Minimum requirement fulfilled? yes

### 7.6 Presentation of test results

Here not required.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.5 Determination of the performance characteristics during the field test

### 8.5.1 Overview

The determination of the performance characteristics in the field as a part of the type approval test shall be performed by a designated body. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this document.

In the field test during a period of three months 2 analyzers are tested for availability (period of unattended operation), reproducibility in the field and long-term drift. The analyzers are run in parallel at one and the same sampling point at a selected monitoring station with specific ambient air conditions. Operational requirements are given for the correct determination of the long-term drift and the reproducibility under field conditions.

### 8.5.2 Selection of a monitoring station for the field test

The selection of a monitoring station is based on the following criteria:

Location:

- periurban or rural station

Monitoring station facilities:

- sufficient capacity of the sampling manifold;
- enough room to place two analyzers with calibration gases and/or calibration facilities;
- surrounding temperature control for analyzers, climate controlled at 20°C ± 4°C with temperature registration;
- stable electrical voltage.

Other items that could be considered:

- presence of telemetry/telephone facilities for remote surveillance of the functioning of the equipment;
- accessibility.

## 7.2 General requirements

### 8.5.3 Operational requirements

After installation of the analyzers at the monitoring station the proper functioning of the analyzers shall be tested. This comprises (among other things) the proper connections to the sampling manifold, sample gas flows, correct temperatures of e.g. reaction chambers, response to zero and span gases, actual converter efficiency, data transmission and other items, which shall be judged necessary by the designated body.

After verification of the proper functioning, the analyzers shall be adjusted at zero and calibrated at a value of about 80 % of the maximum of the certification range.

During the three-month period, the maintenance requirements by the manufacturer of the analyzer shall be followed.

Measurements with zero and span gases shall be performed every two weeks. The concentration  $c_t$  of the span gas shall be around 90 % of the maximum of the certification range. One independent followed by 4 individual measurements shall be performed both at zero and at concentration  $c_t$ . The measurement results shall be recorded.

To exclude the effect of contamination of the filter when determining the drift of the analyzer the zero and span gases shall be fed to the analyzer without passing through the filter.

To avoid the possibility that the filter loading affects the results of the intercomparison of the two analyzers and to ensure that the filter loading will not compromise the quality of the air pollution data collected, the filter shall be changed just before each bi-weekly calibration. Filters, which had been preconditioned in the laboratory using NO gas mixtures, shall be used.

During the three-month period, no zero and span adjustments shall be made to the analyzer, as this will influence the determination of the long-term drift. The measurement data from the analyzer shall only be corrected in a mathematical way assuming a linear drift since the last zero and span check.

If an auto rescaling function or self-correction function is included and considered "normal operational condition", it shall be enabled during the field tests. The magnitude of any self correction shall be available to the test laboratory. The magnitude of the auto zero and the auto span drift corrections over the period of unattended operation (long-term drift) both have the same restrictions as laid down in the performance characteristics.

### **7.3 Performance of test**

Here not required.

### **7.4 Evaluation**

Here not required.

### **7.5 Findings**

The general specifications could be fulfilled.

Minimum requirements fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## 7.1 8.5.4 Long-term drift

*Long-term drift at zero  $\leq 5,0$  nmol/mol (equal to 5 ppb)*

*Long-term drift at span  $\leq 5$  % of maximum of certification range (equal to 48,0 ppb at a range from 0 to 960 ppb)*

## 7.2 General requirement

After each bi-weekly calibration the drift of the analyzers under test shall be calculated at zero and at span following the procedures as given underneath. If the drift compared to the initial calibration exceeds one of the performance criteria for drift at zero or span level, the "period of unattended operation" equals the number of weeks till the observation of the infringement, minus two weeks. For further (uncertainty) calculations the values for "long term drift" are the values for zero and span drift over the period of unattended operation.

At the beginning of the drift period five individual measurements are recorded (after waiting the time equivalent to one independent measurement just after the calibration) at zero and at span level.

The long-term drift is calculated as follows:

$$D_{L,Z} = (C_{Z,2} - C_{Z,1})$$

Where:

$D_{L,Z}$  is the drift at zero (nmol/mol);

$C_{Z,1}$  is the average concentration of the measurements at zero at the beginning of the drift period (just after the initial calibration) (nmol/mol);

$C_{Z,2}$  is the average concentration of the measurements at zero at the end of the drift period (nmol/mol) .

$D_{L,Z}$  shall comply with the performance criteria.

$$D_{L,S} = \frac{(C_{S,2} - C_{S,1}) - D_{L,Z}}{C_{S,1}} \times 100$$

Where:

$D_{L,S}$  is the drift at span concentration  $c_t$  (nmol/mol);

$C_{S,1}$  is the average concentration of the measurements at span level at the beginning of the drift period (just after the initial calibration) (nmol/mol);

$C_{S,2}$  is the average concentration of the measurements at span level at the end of the drift period (nmol/mol).

$D_{L,S}$  shall comply with the performance criteria.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14211. During the field test, test gas was given through the analyzers every 2 weeks. For the determination of long term drift the values of every biweekly measurements have been used. Table 28 and Table 29 show the results of the bi-weekly measurements.

### 7.4 Evaluation

Table 28: Results of the long term drift at zero

		Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
C <sub>Z,1</sub>	13.02.2007	0,10	0,04
C <sub>Z,2</sub>	23.02.2007	0	-0,2
<b>D<sub>L,Z</sub></b>	<b>23.02.2007</b>	<b>-0,10</b>	<b>-0,24</b>
C <sub>Z,2</sub>	09.03.2007	0,1	-0,8
<b>D<sub>L,Z</sub></b>	<b>09.03.2007</b>	<b>0,00</b>	<b>-0,84</b>
C <sub>Z,2</sub>	23.03.2007	-0,2	-0,7
<b>D<sub>L,Z</sub></b>	<b>23.03.2007</b>	<b>-0,30</b>	<b>-0,74</b>
C <sub>Z,2</sub>	05.04.2007	-0,2	-0,8
<b>D<sub>L,Z</sub></b>	<b>05.04.2007</b>	<b>-0,30</b>	<b>-0,84</b>
C <sub>Z,2</sub>	19.04.2007	0,5	-0,4
<b>D<sub>L,Z</sub></b>	<b>19.04.2007</b>	<b>0,40</b>	<b>-0,44</b>
C <sub>Z,2</sub>	04.05.2007	0,4	-0,5
<b>D<sub>L,Z</sub></b>	<b>04.05.2007</b>	<b>0,30</b>	<b>-0,54</b>
C <sub>Z,2</sub>	14.05.2007	0,2	-0,7
<b>D<sub>L,Z</sub></b>	<b>14.05.2007</b>	<b>0,10</b>	<b>-0,74</b>

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

Page 63 of 436

Table 29: Results of the long term drift at span

		Device 1 (1253) [ppb]	Device 2 (1257) [ppb]
C <sub>Z,1</sub>	13.02.2007	760,38	762,18
C <sub>Z,2</sub>	23.02.2007	762,5	762,9
D <sub>L,Z</sub>	<b>23.02.2007</b>	<b>0,28%</b>	<b>0,09%</b>
C <sub>Z,2</sub>	09.03.2007	765,6	763,5
D <sub>L,Z</sub>	<b>09.03.2007</b>	<b>0,69%</b>	<b>0,17%</b>
C <sub>Z,2</sub>	23.03.2007	767,6	761,3
D <sub>L,Z</sub>	<b>23.03.2007</b>	<b>0,95%</b>	<b>-0,12%</b>
C <sub>Z,2</sub>	05.04.2007	766,4	759,7
D <sub>L,Z</sub>	<b>05.04.2007</b>	<b>0,79%</b>	<b>-0,33%</b>
C <sub>Z,2</sub>	19.04.2007	768,6	758,7
D <sub>L,Z</sub>	<b>19.04.2007</b>	<b>1,08%</b>	<b>-0,46%</b>
C <sub>Z,2</sub>	04.05.2007	768,1	757,6
D <sub>L,Z</sub>	<b>04.05.2007</b>	<b>1,02%</b>	<b>-0,60%</b>
C <sub>Z,2</sub>	14.05.2007	765,9	754,2
D <sub>L,Z</sub>	<b>14.05.2007</b>	<b>0,73%</b>	<b>-1,05%</b>

## 7.5 Findings

For device 1 (1253) a maximum long term drift of 0,40 ppb at zero and maximum 1,03 % at span could be determined.

For device 2 (1257) a maximum long term drift of -0,84 ppb at zero and maximum -0,95 % at span could be determined.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values of the long term drift are stated in Table 30.

Table 30: Measured values of the determination of the long term drift

Date	Time	Device 1 (1253)	Device 2 (1257)	Time	Device 1 (1253)	Device 2 (1257)
	Zero Point			Span Point		
	[hh:mm]	[ppb]	[ppb]	[hh:mm]	[ppb]	[ppb]
13.02.2007	13:05	0	0	13:24	760,5	762,5
13.02.2007	13:07	0,1	0	13:26	760,7	762,2
13.02.2007	13:09	0,1	0	13:28	760,5	762,2
13.02.2007	13:11	0,1	0,1	13:30	760,2	762,0
13.02.2007	13:13	0,2	0,1	13:32	760,0	762,0
<b>Average</b>		<b>0,10</b>	<b>0,04</b>		<b>760,4</b>	<b>762,2</b>
23.02.2007	13:20	0	-0,2	13:50	762,5	762,9
09.03.2007	13:45	0,1	-0,8	14:15	765,6	763,5
23.03.2007	13:45	-0,2	-0,7	14:15	767,6	761,3
05.04.2007	13:25	-0,2	-0,8	13:55	766,4	759,7
19.04.2007	13:45	0,5	-0,4	14:15	768,6	758,7
04.05.2007	13:25	0,4	-0,5	13:55	768,1	757,6
14.05.2007	12:20	0,2	-0,7	12:50	765,9	754,2



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

### 7.1 8.5.5 Reproducibility under field conditions

*Reproducibility standard deviation under field conditions should be 5 % of the average over a three month period.*

### 7.2 General requirement

The reproducibility standard deviation under field conditions is calculated from the measured hourly averaged data during the three months period.

The difference  $d_f$  for each  $i$ -th parallel measurement is calculated from::

$$d_{f,i} = (x_{1,f})_i - (x_{2,f})_i$$

Where:

$d_{f,i}$  is the  $i^{\text{th}}$  difference in a parallel measurement (nmol/mol);

$(x_{1,f})_i$  is the  $i$ th measurement result of analyzer 1 (nmol/mol);

$(x_{2,f})_i$  is the  $i$ th measurement result of analyzer 2 at the same time as the measurement of analyzer 1 (nmol/mol)

The reproducibility (under field conditions) standard deviation ( $s_{r,f}$ ) is calculated according to:

$$s_{r,f} = \frac{\left( \sqrt{\frac{\sum_{i=1}^n d_{f,i}^2}{2n}} \right)}{av} \times 100$$

Where:

$s_{r,f}$  is the reproducibility standard deviation under field conditions (%);

$n$  is the number of parallel measurements;

$av$  is the average value during the field test (nmol/mol);

The reproducibility standard deviation under field conditions,  $s_r$ , shall comply with the performance criterion.

### 7.3 Performance of test

The standard deviation during field test has been determined from the hourly averaged values during field test period.

## 7.4 Evaluation

Table 31: Determination of standard deviation during field test

Standard deviation during field test			
Number of parallel measurements	n	=	2171
Average value during the field test	av	=	21,02 ppb
Standard deviation of parallel measurements	sd	=	0,374
<b>Reproducibility standard deviation (%)</b>	<b>S<sub>r,f</sub></b>	=	<b>1,77 %</b>

The standard deviation during field test is with 1,77 % of the three month average within the allowed limits.

## 7.5 Findings

The performance criteria of EN 14211 have been fulfilled.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

Here not required.

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

### **7.1 8.5.6 Period of unattended operation**

*The period of unattended operation shall be not less than 2 weeks.*

### **7.2 General requirement**

The period of unattended operation is the time period within which the drift is within the performance criterion for long-term drift. If the manufacturer specifies a shorter period for maintenance, than this will be taken as the period of unattended operation. If one of the analyzers malfunctions during the field test, than the field test shall be restarted to show whether the malfunction was coincidental or bad design.

### **7.3 Performance of testing**

The performance criteria's of long term drift (chapter 8.5.4) have been fulfilled during the three month field test. But he sample filters behind the gas inlet have been changed monthly.

### **7.4 Evaluation**

A maintenance interval of 4 weeks was determined because of the data of the long term drift investigation (Table 28 and Table 29) and the monthly maintenance work.

### **7.5 Findings**

The determined maintenance interval is at least 4 weeks.

Minimum requirement fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

## 7.1 8.5.7 period of availability of the analyzer

*Period of availability of the analyzer > 90 %.*

### 7.2 General requirement

The correct operation of the analyzers shall be checked at least every 14 days. It is recommended to perform this check every day during the first 14 days. These checks consists of plausibility checks on the measured values, as well as when available status signals and other relevant parameters. Time, duration and nature of any malfunctioning shall be logged.

The total time period with useable measuring data is the period during the field test during which valid measuring data of the ambient air concentrations are obtained. In this time period the time needed for calibrations, conditioning of sample lines and filters and maintenance shall not be included.

The availability of the analyzer is calculated as:

$$A_a = \frac{t_u}{t_t} * 100$$

Where:

$A_a$  is the availability of the analyzer;

$t_u$  is the total time period with validated measuring data;

$t_t$  is the time period of the field test minus the time for calibration, conditioning and maintenance.

$t_u$  and  $t_t$  shall be expressed in the same units.

The availability of each analyzer shall comply the performance criterion in.

### 7.3 Performance of testing

The total operating time is calculated from the start and final time of field test. The other periods of time are taken from the documentation of the test.

### 7.4 Evaluation

The periods of time for the determination of the availability for both analyzers are stated in Table 32.

Table 32: Availability of M200E

			Device 1 (1253)	Device 2 (1257)
Total running time	$t_t$	h	2171	2171
Calibration/maintenance	--	h	31	31
Operating time	$t_u$	h	2140	2140
Availability	$A_a$	%	98,6 %	98,6 %

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

The calibrating times result from the daily test gas tasks for the determination of the drift behavior and the maintenance interval. There have been no device caused outage times during the field test. The maintenance time results from the time needed for the replacement of the Teflon filter.

### **7.5 Findings**

The Availability is with 98,6 % higher than the required 90 %.

Minimum requirement fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

## Appendix A (normative) Calculation residence times for a maximum allowable NO<sub>2</sub> increase in the sampling line [ISO 13964]

The increase of the sampled nitrogen dioxide (NO<sub>2</sub>) is due the effect of the reaction of ambient ozone (O<sub>3</sub>) with nitric oxide in the sampling line.

The allowed increase of the NO<sub>2</sub> after EN 14211 is maximum 4 nmol/mol.

### 7.2 Equipment

The increase of the sampled nitrogen dioxide (NO<sub>2</sub>) is due to the effect of the reaction of ambient ozone (O<sub>3</sub>) with nitric oxide (NO) in the sampling line.

By means of the following formulas the influence of the residence time on the increase of NO<sub>2</sub> in the sampling line can be determined:

*Equation 1: Calculation of the increase of the NO<sub>2</sub> in the sampling*

$$[O_3]_0 = \frac{b \times [O_3]_t}{[O_3]_t - [NO]_t \times e^{(b \times k \times t)}}$$

with:

[O<sub>3</sub>]<sub>0</sub> is the ozone concentration at the sampling inlet

[O<sub>3</sub>]<sub>t</sub> is the ozone concentration after t seconds of residence time in the sampling line

[NO]<sub>t</sub> is the nitric oxide concentration after t seconds of residence time in the sampling line

b is the concentration difference between [O<sub>3</sub>]<sub>t</sub> and [NO]<sub>t</sub> with b ≠ 0

$$b = [O_3]_t - [NO]_t$$

k is the constant for the reaction of O<sub>3</sub> with NO

$$k = 4,43 \times 10^{-4} \text{ nmol/mol}^{-1} \text{ s}^{-1} \text{ bei } 298 \text{ K}$$

t is the residence time in seconds

The increase of NO<sub>2</sub> from the reaction of ozone and nitric oxide is calculated from the loss of ozone:

$$NO_2 = [O_3]_0 - [O_3]_t$$

By assuming certain concentrations for [O<sub>3</sub>]<sub>t</sub> and [NO]<sub>t</sub> and a certain residence time the increase of NO<sub>2</sub> can be calculated and compared to the NO<sub>2</sub> level already present.

### 7.3 Testing

The NO<sub>2</sub>-increase in the sample gas line was calculated with the following values:

[O<sub>3</sub>]<sub>t</sub> = 30 nmol/mol (the average ozone concentration during the field test period)

[NO]<sub>t</sub> = 15 nmol/mol (the average NO concentration during the field test period)

t = 1,75 s (is calculated out of the diameter of the sample gas line (6 mm), The length of the sample gas line (2 m) and the sample gas flow (2 l/min).

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

#### **7.4 Evaluation**

With the values from the tests a ozone concentration at the sample inlet [O<sub>3</sub>]<sub>0</sub> of 30,35 nmol/mol is resulting. The increase of the NO<sub>2</sub> concentration is 0,35 nmol/mol.

#### **7.5 Assessment**

The measuring system fulfils the requirements of the EN 14211. The calculated NO<sub>2</sub> increase is 0,35 nmol/mol and is much lower than the required increase of 4 nmol/mol.

Minimum requirement fulfilled? yes

#### **7.6 Documentation**

Here not essential.

## **Appendix G (normative) Type approval after DIN EN 14211**

*The type approval of the analyzer consists of the following steps:*

- 1) The value of each individual performance characteristic tested in the laboratory shall fulfill the criterion stated in table 1 (see 8.2 in DIN EN 14211).*
- 2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests fulfils the criterion as stated in the Council Directive 99/30/EC. This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in annex G of the DIN EN 14211.*
- 3) The value of each of the individual performance characteristics tested in the field shall fulfill the criterion stated in table 1 (see 8.2 of the DIN EN 14211).*
- 4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests fulfils the criterion as stated in the Council Directive 99/30/EC. This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in annex G of the DIN EN 14211.*

### **7.2 General requirements**

Calculation according to annex G of the DIN EN 14211.

### **7.3 Performance of the test**

At the end of the testing all elementary uncertainties have been calculated from of the test data.

### **7.4 Evaluation**

- to 1) The value of each single tested performance characteristic in the lab fulfils the criterion of the DIN EN 14211.
- to 2) The expanded uncertainty, calculated of the specific performance characteristics obtained in the laboratory tests, fulfils the performance criterion.
- to 3) The value of each single tested performance characteristic in the field fulfils the criterion of the DIN EN 14211.
- to 4) The expanded uncertainty, calculated of the specific performance characteristics obtained in the laboratory and the field tests, fulfils the performance criterion.



Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

## **7.5 Assessment**

The performance criteria of EN 14211 have been fulfilled.

Minimum requirement fulfilled? yes

## **7.6 Presentation of test results**

The results to the points 1 and 3 are to see in Table 33.

The results to the point 2 are to see in Table 34 and Table 36.

The results to the point 4 are to see in Table 35 and Table 37.

Table 33: Summary of test results

Performance characteristic	Performance criterion	Test result	Fulfilled	Page
8.4.5 Repeatability standard deviation at zero	$\leq 1,0$ nmol/mol	S <sub>r</sub> Device 1253: 0,94 ppb S <sub>r</sub> Device 1257: 0,83 ppb	yes	31
8.4.5 Repeatability standard deviation at concentration ct	$\leq 3,0$ nmol/mol	S <sub>r</sub> Device 1253: 1,05 ppb S <sub>r</sub> Device 1257: 1,23 ppb	yes	31
8.4.6 „lack of fit“ (residual from the linear regression function)	Largest residual from the linear regression function $\leq 4$ % of the measured value Residual at zero $\leq 5,0$ nmol/mol	X <sub>i,z</sub> Device 1253: NP 1,6 ppb X <sub>i</sub> Device 1253: RP 0,6 % X <sub>i,z</sub> Device 1257: NP -0,8 ppb X <sub>i</sub> Device 1257: RP 0,5 %	yes	33
8.4.7 Sensitivity coefficient of sample gas pressure	$\leq 8,0$ nmol/mol/kPa	b <sub>gp</sub> Device 1253: 0,14 ppb/kPa b <sub>gp</sub> Device 1257: 0,06 ppb/kPa	yes	39
8.4.8 Sensitivity coefficient of sample gas temperature	$\leq 3,0$ nmol/mol/K	b <sub>gt</sub> Device 1253: 0,04 ppb/K b <sub>gt</sub> Device 1257: 0,03 ppb/K	yes	41
8.4.9 Sensitivity coefficient of surrounding temperature	$\leq 3,0$ nmol/mol/K	b <sub>st</sub> Device 1253: 0,52 ppb/K b <sub>st</sub> Device 1257: 0,18 ppb/K	yes	43
8.4.10 Sensitivity coefficient of electrical voltage	$\leq 0,3$ nmol/mol/V	b <sub>v</sub> Device 1253: RP 0,01 ppb/V b <sub>v</sub> Device 1257: RP 0,03 ppb/V	yes	47
8.4.11 Interferents at zero and concentration ct	H <sub>2</sub> O $\leq 5,0$ nmol/mol CO <sub>2</sub> $\leq 5,0$ nmol/mol O <sub>3</sub> $\leq 2,0$ nmol/mol NH <sub>3</sub> $\leq 5,0$ nmol/mol	H <sub>2</sub> O Device 1253: NP 3,3 ppb / RP -3,3 ppb Device 1257: NP 1,3 ppb / RP -3,7 ppb CO <sub>2</sub> Device 1253: NP 0,3 ppb / RP 0,7 ppb Device 1257: NP 0,7 ppb / RP 1,3 ppb O <sub>3</sub> Device 1253: NP -0,3 ppb / RP 0,2 ppb Device 1257: NP -1,7 ppb / RP -1,7 ppb NH <sub>3</sub> Device 1253: NP 0,7 ppb / RP 0,0 ppb Device 1257: NP 0,7 ppb / RP 1,7 ppb	yes	49

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

Page 75 of 436

Performance characteristic	Performance criterion	Test result	Fulfilled	Page
8.4.12 Averaging effect	≤ 7,0 % of the measured value	X <sub>av</sub> Device 1253: 0,8 % X <sub>av</sub> Device 1257: 1,0 %	yes	52
8.4.13 Difference between sample/calibration port	≤ 1,0 %	D <sub>SC</sub> Device 1253: ---- D <sub>SC</sub> Device 1257: ----	Not applicable	55
8.4.3 Response time (rise)	≤ 180 s	t <sub>r</sub> Device 1253: max. 47 s (NO) t <sub>r</sub> Device 1257: max. 49 s (NO) t <sub>r</sub> Device 1253: max. 63 s (NO <sub>2</sub> ) t <sub>r</sub> Device 1257: max. 63 s (NO <sub>2</sub> )	yes	23
8.4.3 Response time (fall)	≤ 180 s	t <sub>f</sub> Device 1253: max. 48 s (NO) t <sub>f</sub> Device 1257: max. 50 s (NO) t <sub>f</sub> Device 1253: max. 64s (NO <sub>2</sub> ) t <sub>f</sub> Device 1257: max. 63 s (NO <sub>2</sub> )	yes	23
8.4.3 Difference between rise and fall time	≤ 10 % relative difference or 10 s whatever is the greatest	t <sub>d</sub> Device 1253: 1,7 % or 4 s (NO) t <sub>d</sub> Device 1257: 0,0 % or 4 s (NO) t <sub>d</sub> Device 1253: 0,8 % or 5 s (NO <sub>2</sub> ) t <sub>d</sub> Device 1257: 2,0 % or 3 s (NO <sub>2</sub> )	yes	23
8.4.14 Converter efficiency	≥ 98%	E <sub>conv</sub> Device 1253: 98,0 % E <sub>conv</sub> Device 1257: 98,2 %	yes	57
8.5.6 Period of unattended operation	3 month or less if manufacturer indicates a shorter period, but not less than 2 weeks	Device 1253: 4 weeks Device 1257: 4 weeks	yes	67
8.5.7 Availability of the analyzer	> 90 %	A <sub>a</sub> Device 1253: 98,6 % A <sub>a</sub> Device 1257: 98,6 %	yes	68
8.5.5 Reproducibility standard deviation under field conditions	≤ 5,0 % of the average of a three month period	S <sub>r,f</sub> Device 1253: 1,77 % S <sub>r,f</sub> Device 1257: 1,77 %	yes	65
8.5.4 Long-term drift at zero	≤ 5,0 nmol/mol	D <sub>l,z</sub> Device 1253: 0,4 ppb D <sub>l,z</sub> Device 1257: -0,84 ppb	yes	61
8.5.4 Long-term drift at span level	≤ 5,0 % of the average of a three month period	D <sub>l,s</sub> Device 1253: max. 1,03 % D <sub>l,s</sub> Device 1257: max. -0,95 %	yes	61
8.4.4 Short-term drift at zero	≤ 2,0 nmol/mol over 12 h	D <sub>s,z</sub> Device 1253: -0,7 ppb D <sub>s,z</sub> Device 1257: -0,4 ppb	yes	28
8.4.4 Short-term drift at span level	≤ 6,0 nmol/mol over 12 h	D <sub>s,s</sub> Device 1253: -0,7 ppb D <sub>s,s</sub> Device 1257: -1,4 ppb	yes	28

**Table 34: Expanded uncertainty obtained in the laboratory test for device 1253**

Instrument:		Teledyne		Serial No:		SN 1 (1253)		
Component:		NO		1h-limit value:		505 nmol/mol		
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty		
1	Repeatability at zero	≤ 1,0 nmol/mol	0,940	u <sub>r,z</sub>	0,11	0,0117		
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,050	u <sub>r,v</sub>	0,12	0,0135		
3	"lack of fit"	≤ 4,0%	0,600	u <sub>lv</sub>	1,75	3,0603		
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,140	u <sub>gp</sub>	1,29	1,6656		
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,040	u <sub>gt</sub>	0,50	0,2470		
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	0,520	u <sub>st</sub>	6,50	42,2196		
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,010	u <sub>v</sub>	0,17	0,0294		
8a	H <sub>2</sub> O with concentration 21 mmol/mol	≤ 5,0 nmol/mol	-3,787	u <sub>H<sub>2</sub>O</sub>	2,56	6,5357		
8b	CO <sub>2</sub> with concentration 500 µmol/mol	≤ 5,0 nmol/mol	0,704	u <sub>int,pos</sub>	0,99	0,9793		
8c	O <sub>3</sub> with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-1,714	or				
8d	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,700	u <sub>int,neg</sub>				
9	Averaging effect	≤ 7,0%	0,800	u <sub>av</sub>	2,33	5,4405		
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>pac</sub>	0,00	0,0000		
21	Converter efficiency	≥ 98	98,000	u <sub>EC</sub>	5,83	34,0033		
22	Increase of NO <sub>2</sub> concentration due to residence time	≤ 4,0 nmol/mol	0,350	u <sub>cr</sub>	1,02	1,0414		
23	Uncertainty calibration gas	≤ 3,0%	2,000	ucg	5,05	25,5025		
				combined standard uncertainty		u <sub>c</sub>	10,9898	nmol/mol
				expanded uncertainty		U <sub>c</sub>	21,9795	nmol/mol
				expanded uncertainty actual		U <sub>c,rel</sub>	4,35	%
				expanded uncertainty required		U <sub>req,rel</sub>	15	%

**Table 35: Expanded uncertainty obtained in the laboratory and field test for device 1253**

Instrument:		Teledyne		Serial No:		SN 1 (1253)		
Component:		NO		1h-limit value:		505 nmol/mol		
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty		
1	Repeatability at zero	≤ 1,0 nmol/mol	0,940	u <sub>r,z</sub>	0,11	0,0117		
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,050	u <sub>r,v</sub>	not respected because: u <sub>r,v</sub> = 0,11 < u <sub>r,f</sub>	-		
3	"lack of fit"	≤ 4,00%	0,600	u <sub>lv</sub>	1,75	3,0603		
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,140	u <sub>gp</sub>	1,29	1,6656		
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,040	u <sub>gt</sub>	0,50	0,2470		
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	0,520	u <sub>st</sub>	6,50	42,2196		
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,010	u <sub>v</sub>	0,17	0,0294		
8a	H <sub>2</sub> O with concentration 21 mmol/mol	≤ 5,0 nmol/mol	-3,787	u <sub>H<sub>2</sub>O</sub>	2,56	6,5357		
8b	CO <sub>2</sub> with concentration 500 µmol/mol	≤ 5,0 nmol/mol	0,704	u <sub>int,pos</sub>	0,99	0,9793		
8c	O <sub>3</sub> with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-1,714	or				
8d	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,700	u <sub>int,neg</sub>				
9	Averaging effect	≤ 7,00%	0,800	u <sub>av</sub>	2,33	5,4405		
10	Reproducibility under field conditions	≤ 5,0% of the average of 3 Mon.	1,770	u <sub>r,f</sub>	1,85	3,4278		
11	Long term drift at zero level	≤ 5,0 nmol/mol	0,400	u <sub>d,l,z</sub>	0,23	0,0533		
12	Long term drift at span level	≤ 5,0% of max. of certification range	1,030	u <sub>d,l,v</sub>	3,00	9,0185		
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>pac</sub>	0,00	0,0000		
21	Converter efficiency	≥ 98	98,000	u <sub>EC</sub>	5,83	34,0033		
22	Increase of NO <sub>2</sub> concentration due to residence time	≤ 4,0 nmol/mol	0,350	u <sub>cr</sub>	1,02	1,0414		
23	Uncertainty calibration gas	≤ 3,0%	2,000	ucg	5,05	25,5025		
				combined standard uncertainty		u <sub>c</sub>	11,6908	nmol/mol
				expanded uncertainty		U <sub>c</sub>	23,3816	nmol/mol
				expanded uncertainty actual		U <sub>c,rel</sub>	4,63	%
				expanded uncertainty required		U <sub>req,rel</sub>	15	%

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

Table 36: Expanded uncertainty obtained in the laboratory test for device 1257

Instrument:		Teledyne		Serial No:		SN 2 (1257)	
Component:		NO		1h-limit value:		505 nmol/mol	
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,830	u <sub>r,z</sub>	0,10	0,0095	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,230	u <sub>r,v</sub>	0,14	0,0189	
3	"lack of fit"	≤ 4,0%	0,500	u <sub>lv</sub>	1,46	2,1252	
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,060	u <sub>sp</sub>	0,55	0,3003	
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,030	u <sub>st</sub>	0,37	0,1393	
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	0,180	u <sub>st</sub>	2,25	5,0589	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,030	u <sub>v</sub>	0,51	0,2647	
8a	H2O with concentration 21 nmol/mol	≤ 5,0 nmol/mol	-4,219	u <sub>H2O</sub>	2,85	8,1119	
8b	CO2 with concentration 500 µmol/mol	≤ 5,0 nmol/mol	1,306	u <sub>int,pos</sub> or u <sub>int,neg</sub>	1,75	3,0462	
8c	O3 with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-1,719				
8d	NH3 with concentration 200 nmol/mol	≤ 5,0 nmol/mol	1,717				
9	Averaging effect	≤ 7,0%	1,000	u <sub>av</sub>	2,92	8,5008	
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>disc</sub>	0,00	0,0000	
21	Converter efficiency	≥ 98	98,200	u <sub>ec</sub>	5,25	27,5427	
22	Increase of NO <sub>2</sub> concentration due to residence time	≤ 4,0 nmol/mol	0,350	u <sub>tr</sub>	1,02	1,0414	
23	Uncertainty calibration gas	≤ 3,0%	2,000	0	5,05	25,5025	
combined standard uncertainty				u <sub>c</sub>		9,0383	nmol/mol
expanded uncertainty				U <sub>c</sub>		18,0766	nmol/mol
expanded uncertainty actual				U <sub>c,rel</sub>		3,58	%
expanded uncertainty required				U <sub>req,rel</sub>		15	%

Table 37: Expanded uncertainty obtained in the laboratory and field test for device 1257

Instrument:		Teledyne		Serial No:		SN 2 (1257)	
Component:		NO		1h-limit value:		505 nmol/mol	
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,830	u <sub>r,z</sub>	0,10	0,0095	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,230	u <sub>r,v</sub>	not respected because, u <sub>r,v</sub> = 0,13 < u <sub>r,f</sub>	-	
3	"lack of fit"	≤ 4,0%	0,500	u <sub>lv</sub>	1,46	2,1252	
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,060	u <sub>sp</sub>	0,55	0,3003	
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,030	u <sub>st</sub>	0,37	0,1393	
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	0,180	u <sub>st</sub>	2,25	5,0589	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,030	u <sub>v</sub>	0,51	0,2647	
8a	H2O with concentration 21 nmol/mol	≤ 5,0 nmol/mol	-4,219	u <sub>H2O</sub>	2,85	8,1119	
8b	CO2 with concentration 500 µmol/mol	≤ 5,0 nmol/mol	1,306	u <sub>int,pos</sub> or u <sub>int,neg</sub>	1,75	3,0462	
8c	O3 with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-1,719				
8d	NH3 with concentration 200 nmol/mol	≤ 5,0 nmol/mol	1,717				
9	Averaging effect	≤ 7,00%	1,000	u <sub>av</sub>	2,92	8,5008	
10	Reproducibility under field conditions	≤ 5,0% of the average of 3 Mon.	1,770	u <sub>f</sub>	1,85	3,4278	
11	Long term drift at zero level	≤ 5,0 nmol/mol	-0,840	u <sub>l,z</sub>	-0,48	0,2352	
12	Long term drift at span level	≤ 5,0% of max. of certification range	-0,950	u <sub>l,v</sub>	-2,77	7,6720	
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>disc</sub>	0,00	0,0000	
21	Converter efficiency	≥ 98	98,200	u <sub>ec</sub>	5,25	27,5427	
22	Increase of NO <sub>2</sub> concentration due to residence time	≤ 4,0 nmol/mol	0,350	u <sub>tr</sub>	1,02	1,0414	
23	Uncertainty calibration gas	≤ 3,0%	2,000	0	5,05	25,5025	
combined standard uncertainty				u <sub>c</sub>		9,8191	nmol/mol
expanded uncertainty				U <sub>c</sub>		19,6383	nmol/mol
expanded uncertainty actual				U <sub>c,rel</sub>		3,89	%
expanded uncertainty required				U <sub>req,rel</sub>		15	%

## 7. Recommendations for the use in practice

### 7.1 Work in the maintenance interval

In addition to the usual calibrating work it is important to frequently check the state of the inlet contained Teflon filters in front of the analyzer. The duration of the replacement interval of the filters which are to prevent the pollution of the devices through the sucked ambient air depends on the dust load at the location of installation. The alternating interval is committed to one month.

By the way, the statements of the manufacturer are to be considered.

Department of Environmental protection



---

Dipl.-Ing. Martin Schneider



---

Dipl.-Ing. Karsten Pletscher

Cologne, 22.06.2007  
936/21205926/A2

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> ,  
Report-No.: 936/21205926/A2

## 8 Literature

- VDI 4202 Blatt 1: Mindestanforderungen an automatische Immissionsmeseinrichtungen bei der Eignungsprüfung; Punktmessverfahren für gas- und partikelförmige Luftverunreinigungen, vom Juni 2002
- VDI 4203 Blatt 3: Prüfpläne für automatische Messeinrichtungen; Prüfprozeduren für Messeinrichtungen zur punktförmigen Messung von - und partikelförmigen Immissionen, vom August 2004
- DIN EN 14211 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Stickstoffdioxid und Stickstoffmonoxid mit Chemolumineszenz, Juni 2005
- VDI 2453 Blatt 2: 2002-10 Messen gasförmiger Immissionen; Messen der Stickstoffmonoxid- und Stickstoffdioxidkonzentration; Kalibrierung von NO/NO<sub>x</sub> Chemolumineszenz-Messgeräten mit Hilfe der Gasphasentitration. Berlin: Beuth Verlag
- VDI 2453 Blatt 1: 1990-10 Messen gasförmiger Immissionen; Messen der Stickstoffdioxidkonzentration; Manuelles photometrisches Basisverfahren (Saltzman). Berlin: Beuth Verlag
- Richtlinie 96/62/EG des Rates vom 27. September 1996 über die Beurteilung und die Kontrolle der Luftqualität ABl. L 296, S. 55
- Richtlinie 1999/30/EG des Rates vom 22. April 1999 über Grenzwerte für Schwefeldioxid, Stickstoffdioxid und Stickstoffoxide, Partikel und Blei in der Luft, ABl. L 163, S. 41

## 9 Appendix

Appendix 1: Manual

**TÜV RHEINLAND  
ENERGIE UND UMWELT GMBH**



# Addendum

Addendum II to the type approval report of the measuring system M200E (respective T200) for NO, NO<sub>2</sub> and NO<sub>x</sub> from Teledyne Advanced Pollution Instrumentation to the TÜV test report 936/21205926/A from 22.06.2007

Test report No.: 936/21221556/B  
Cologne, March 16, 2013



[luft@de.tuv.com](mailto:luft@de.tuv.com)

**The department of Environmental Protection of TÜV Rheinland Energie und Umwelt GmbH**  
is accredited for the following work areas:

- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Combustion chamber measurements;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of stack height and air quality projections for hazardous and odour substances;
- Determination of noise and vibration emissions and pollution, determination of sound power levels and execution of sound measurements at wind energy plants

**according to EN ISO/IEC 17025.**

The accreditation is valid up to 22-01-2018. DAkkS-register number: D-PL-11120-02-00.

Reproduction of extracts from this test report is subject to written consent.

**TÜV Rheinland Energie und Umwelt GmbH**  
**D-51105 Cologne, Am Grauen Stein, Tel: +49 221 806-5200, Fax: +49 221 806-1349**



**Blank page**

## Abstract

The following Addendum II contains an assessment of the measuring system Teledyne API M200E (respectively T200) for the component nitrogen oxide in terms of compliance with the requirements of the European standard EN 14211 in the version of 2012.

The measuring system Teledyne API M200E (respectively T200) were type-approved and announced as follows:

- M200E for NO, NO<sub>2</sub> and NO<sub>x</sub> with announcement of the Federal Environment Agency on 23<sup>rd</sup> of September 2007 (BANz. page 7925, chapter II number 2.1)

The announcement of the new design of the T-series was performed by notification:

- M200E respectively T200 for NO, NO<sub>2</sub> und NO<sub>x</sub> with announcement of the Federal Environment Agency on 10<sup>th</sup> of January 2011 (BANz. page 294, chapter IV notification 21 und 22), statement on 29<sup>th</sup> of September 2010

The measuring system M200E respectively T200 for NO, NO<sub>2</sub> and NO<sub>x</sub> from Teledyne Advanced Pollution Instrumentation meets also the requirements of DIN EN 14211 (version June 2005). Furthermore the manufacturing and quality management of the measuring system M200E and T200 for NO, NO<sub>2</sub> und NO<sub>x</sub> fulfill the requirements of EN 15267. The related announcement was performed by notification:

- M200E and T200 for NO, NO<sub>2</sub> und NO<sub>x</sub> with announcement of the Federal Environmental Agency on 12th of February 2013 (BANz. AT 05th of March 2013 B10, chapter V notification 4), statement on 11th of October 2012

Meanwhile the European standard EN 14211 was revised and re-released in the new version in November 2012. As part of the revision minimum performance criteria for type approval test have been revised.

The compliance with the requirements of the European standard EN 14211 (version November 2012) for the measuring systems Teledyne API M200E (respectively T200) for the component nitrogen oxide should be analyzed and documented within the following Addendum II. After its publication this Addendum II is an integral part of the TÜV Rheinland test report with the number 936/21205926/A as well as part of the addendum to the report with the reporting number 936/21219874/B and will also be available in the Internet under [www.qal1.de](http://www.qal1.de).

**Blank page**

## Table of content

1.	Overview of the results of the tests of the measuring system M200E (respectively T200) according to standard EN 14211 (version November 2012) .....	7
2.	Statement to test point “interferents at zero and at concentration $c_t$ ” .....	9
3.	Statement to test point “Difference between rise time and fall time” .....	10
4.	Statement to test point “Residence time in the analyzer” .....	11
5.	Update of the total uncertainty calculation according to Annex E of standard DIN EN 14211 (version November 2012) .....	12

**Blank page**

## 1. Overview of the results of the tests of the measuring system M200E (respectively T200) according to standard EN 14211 (version November 2012)

The following table gives an overview of the performance characteristics, performance criteria and test results according to standard DIN EN 14211 (November 2012) (based on test report 936/21205926/A from 22nd of June 2007 + Addendum to report with the report number 936/21219874/B of 11th of October 2012). In addition the changes between the requirements of the version from 2005 and the current version of 2012 will be pointed out. In the following chapters an explicit statement to these points can be found. Also the uncertainty calculation was updated to the status of the current standard version of 2012.

Performance characteristic	Performance criterion	Test result	complies	Compliance documented in
8.4.5 Repeatability standard deviation at zero	$\leq 1.0 \text{ nmol/mol}$	S <sub>r,z</sub> device 1253: 0.94 ppb S <sub>r,z</sub> device 1257: 0.83 ppb	yes	936/2120592 6/A from 22. July 2007
8.4.5 Repeatability standard deviation at concentration ct	$\leq 3.0 \text{ nmol/mol}$	S <sub>r,ct</sub> device 1253: 1.05 ppb S <sub>r,ct</sub> device 1257: 1.23 ppb	yes	936/2120592 6/A from 22. July 2007
8.4.6 Lack of fit (residual from the linear regression function)	Largest residual from the linear regression function at concentrations higher than zero $\leq 4 \%$ of the measured value Residual at zero $\leq 5.0 \text{ nmol/mol}$	r <sub>z</sub> device 1253: NP 0.50 ppb r <sub>max</sub> device 1253: RP -0.6 % r <sub>z</sub> device 1257: NP -0.39 ppb r <sub>max</sub> device 1257: RP 0.2 %	yes	936/2121873 4/B from 11. October 2012
8.4.7 Sensitivity coefficient of sample gas pressure	$\leq 8.0 \text{ nmol/mol/kPa}$	b <sub>gp</sub> device 1253: 0.14 ppb/kPa b <sub>gp</sub> device 1257: 0.06 ppb/kPa	yes	936/2121873 4/B from 11. Ocktober 2012
8.4.8 Sensitivity coefficient of sample gas temperature	$\leq 3.0 \text{ nmol/mol/K}$	b <sub>gt</sub> device 1253: 0.04 ppb/K b <sub>gt</sub> device 1257: 0.03 ppb/K	yes	936/2120592 6/A from 22. July 2007
8.4.9 Sensitivity coefficient of surrounding temperature	$\leq 3.0 \text{ nmol/mol/K}$	b <sub>st</sub> device 1253: 0.52 ppb/K b <sub>st</sub> device 1257: 0.18 ppb/K	yes	936/2120592 6/A from 22. July 2007
8.4.10 Sensitivity coefficient of electrical voltage	$\leq 0.3 \text{ nmol/mol/V}$	b <sub>v</sub> device 1253: RP 0.01 ppb/V b <sub>v</sub> device 1257: RP 0.03 ppb/V	yes	936/2120592 6/A from 22. July 2007
8.4.11 Interferents at zero and at concentration ct	H <sub>2</sub> O $\leq 5.0 \text{ nmol/mol}$ CO <sub>2</sub> $\leq 5.0 \text{ nmol/mol}$ NH <sub>3</sub> $\leq 5.0 \text{ nmol/mol}$	H <sub>2</sub> O device 1253: NP 3.3 ppb / RP -3.3 ppb device 1257: NP 1.3 ppb / RP -3.7 ppb CO <sub>2</sub> device 1253: NP 0.3 ppb / RP 0.7 ppb device 1257: NP 0.7 ppb / RP 1.3 ppb NH <sub>3</sub> device 1253: NP 0.7 ppb / RP 0.0 ppb device 1257: NP 0.7 ppb / RP 1.7 ppb	yes	Yes. refer to point 2

Performance characteristic	Performance criterion	Test result	complies	Compliance documented in
8.4.12 Averaging effect	≤ 7.0 % of value	E <sub>av</sub> device 1253: 0.8 % E <sub>av</sub> device 1257: 1.0 %	yes	936/21218734 /B from 11. Oktober 2012
8.4.13 Difference sample/calibration port	≤ 1.0 %	ΔX <sub>SC</sub> device 1253: ---- ΔX <sub>SC</sub> device 1257: ----	Not applicable	936/21205926 /A from 22. July 2007
8.4.3 Response time (rise)	≤ 180 s	t <sub>r</sub> device 1253: max. 47 s (NO) t <sub>r</sub> device 1257: max. 49 s (NO) t <sub>r</sub> device 1253: max. 63 s (NO <sub>2</sub> ) t <sub>r</sub> device 1257: max. 63 s (NO <sub>2</sub> )	yes	936/21205926 /A from 22. July 2007
8.4.3 Response time (fall)	≤ 180 s	t <sub>f</sub> device 1253: max. 48 s (NO) t <sub>f</sub> device 1257: max. 50 s (NO) t <sub>f</sub> device 1253: max. 64s (NO <sub>2</sub> ) t <sub>f</sub> device 1257: max. 63 s (NO <sub>2</sub> )	yes	936/21205926 /A from 22. July 2007
8.4.3 Difference rise time and fall time	≤ 10 s	t <sub>d</sub> device 1253: 4 s (NO) t <sub>d</sub> device 1257: 4 s (NO) t <sub>d</sub> device 1253: 5 s (NO <sub>2</sub> ) t <sub>d</sub> device 1257: 3 s (NO <sub>2</sub> )	yes	yes. refer to point 3
8.4.14 Converter efficiency	≥ 98%	E <sub>c</sub> device 1253: 98.0 % E <sub>c</sub> device 1257: 98.2 %	yes	936/21205926 /A from 22. July 2007
8.5.6 Period of unattended operation	3.0 months or less if manufacturer indicates a shorter period. but not less than 2 weeks	device 1253: 4 weeks device 1257: 4 weeks	yes	936/21205926 /A from 22. July 2007
8.5.7 Availability of the analyser	> 90 %	A <sub>a</sub> device 1253: 98.6 % A <sub>a</sub> device 1257: 98.6 %	yes	936/21205926 /A from 22. July 2007
8.5.5 Repeatability standard deviation under field conditions	≤ 5.0 % of the average of a three month period	S <sub>r,t</sub> device 1253: 1.77 % S <sub>r,t</sub> device 1257: 1.77 %	yes	936/21205926 /A from 22. July 2007
8.5.4 Long-term drift at zero	≤ 5.0 nmol/mol	D <sub>i,z</sub> device 1253: 0.4 ppb D <sub>i,z</sub> device 1257: -0.84 ppb	yes	936/21205926 /A from 22. July 2007
8.5.4 Long-term drift at span level	≤ 5.0 % of the average of a three month period	D <sub>i,s</sub> device 1253: max. 1.03 % D <sub>i,s</sub> device 1257: max. -0.95 %	yes	936/21205926 /A from 22. July 2007
8.5.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	D <sub>s,z</sub> device 1253: -0.7 ppb D <sub>s,z</sub> device 1257: -0.4 ppb	yes	936/21205926 /A from 22. July 2007
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	D <sub>s,s</sub> device 1253: -0.7 ppb D <sub>s,s</sub> device 1257: -1.4 ppb	yes	936/21205926 /A from 22. July 2007
8.4.15 Residence time in the analyzer	≤ 3.0 s	ca. 2.5 s	yes	Yes, refer to point 4

## 2. Statement to test point “interferents at zero and at concentration $c_t$ ”

[No. 8.4.11 of DIN EN 14211, test report 936/21205926/A from page 107]

As part of the revision of the standard DIN EN 14211 for the minimum performance criteria of the test point “interferents at zero and at concentration  $c_t$ ” the interferent component ozone has been deleted without replacement in the standard version of 2012.

Within the type approval test the influences of the interferent components H<sub>2</sub>O, CO<sub>2</sub> and NH<sub>3</sub> were determined below the permissible deviations.

Therefore the minimum requirements of the standard DIN EN 14211 in the version of 2012 are also fulfilled.



### **3. Statement to test point “Difference between rise time and fall time“**

[No. 8.4.3 of DIN EN 14211, test report 936/21205926/A from page 81]

As part of the revision of the standard DIN EN 14211 the minimum performance criteria of the test point “difference between rise time and fall time“ has been changed from  $\leq 10$  % relative difference or 10 s, depending on which value is the greater (version 2005), to the requirement of  $\leq 10$  s (version 2012).

The differences between rise and fall time determined within the type approval test are 4 s (device 1253) and 4 s (device 1257) for NO and 5 s (device 1253) and 3 s (device 1257) for NO<sub>2</sub>.

Therefore the minimum requirements of the standard DIN EN 14211 in the version of 2012 are also fulfilled.

#### 4. Statement to test point “Residence time in the analyzer“

[No. 8.4.15 of DIN EN 14211]

As part of the revision of the standard DIN EN 14211 the test point „Increase of NO<sub>2</sub>-concentration due to residence time in the analyzer“ (version 2005) was replaced by the new point „Residence time in the analyzer“ (version 2012).

The residence time in the measurement device is determined by calculation from the sample flow and the volume of the sample gas line and other relevant components (including the housing for the particulate filter) in the measuring device.

The following values were used for the measuring system M200E / T200:

1. sample flow: 0.5 l/min
2. volume within the system (up to measuring cell) 0.021 l

Based on these information's the residence time in the measuring system is calculated as about 2.5 s.

Therefore the minimum requirements of the standard DIN EN 14211 in the version of 2012 are also fulfilled.

## 5. Update of the total uncertainty calculation according to Annex E of standard DIN EN 14211 (version November 2012)

[Annex E of DIN EN 14211, Addendum to test report 936/21219874/B from page 14]

The calculation of the total uncertainty was updated based on the new version of the standard DIN EN 14211, Annex E.

The performance criteria of DIN EN 14211 (version 2012) were completely fulfilled.

**Table 1: Combined uncertainty of results during the laboratory test of device 1 (SN 1253)**

Measuring device: Teledyne API M200E/T200		Serial-No.: SN 1 (1253)				
Measured component: NO <sub>2</sub>		1h-limit value: 104.6 nmol/mol				
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty	Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.940	$u_{r,z}$	0.22	0.0466
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1.050	$u_{r,th}$	0.05	0.0023
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	-0.600	$u_{l,th}$	-0.36	0.1313
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0.140	$u_{sp}$	1.29	1.6656
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.040	$u_{st}$	0.10	0.0106
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.520	$u_{st}$	1.35	1.8113
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.010	$u_v$	0.04	0.0013
8a	Interferent H <sub>2</sub> O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	3.300	$u_{H_2O}$	1.43	2.0510
		≤ 10 nmol/mol (Span)	-3.300			
8b	Interferent CO <sub>2</sub> with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	$u_{int,pos}$	0.63	0.3915
		≤ 5.0 nmol/mol (Span)	0.700			
8c	Interferent NH <sub>3</sub> mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.700	$u_{int,neg}$	0.63	0.3915
		≤ 5.0 nmol/mol (Span)	0.700			
9	Averaging effect	≤ 7.0% of measured value	0.800	$u_{av}$	0.48	0.2334
18	Difference sample/calibration port	≤ 1%	0.000	$u_{asc}$	0.00	0.0000
21	Converter efficiency	≥ 98	98.00	$u_{ec}$	2.09	4.3765
23	Uncertainty of test gas	≤ 3%	2.000	$u_{cg}$	1.05	1.0941
Combined standard uncertainty				$u_c$	3.4445	nmol/mol
Expanded uncertainty				U	6.8890	nmol/mol
Relative expanded uncertainty				W	6.59	%
Maximum allowed expanded uncertainty				$W_{req}$	15	%

**Table 2: Combined uncertainty of results during the laboratory and field test of device 1 (SN 1253)**

Measuring device:		Teledyne API M200E/T200		Serial-No.:		SN 1 (1253)	
Measured component:		NO <sub>2</sub>		1h-limit value:		104.6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.940	u <sub>r,z</sub>	0.22	0.0466	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1.050	u <sub>r,h</sub>	not considered, as √2·u <sub>r,h</sub> = 0.06 < u <sub>r,f</sub>		-
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	-0.600	u <sub>l,h</sub>	-0.36	0.1313	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0.140	u <sub>sp</sub>	1.29	1.6656	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.040	u <sub>gt</sub>	0.10	0.0106	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.520	u <sub>st</sub>	1.35	1.8113	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.010	u <sub>v</sub>	0.04	0.0013	
8a	Interferent H <sub>2</sub> O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	3.300	u <sub>12O</sub>	1.43	2.0510	
		≤ 10 nmol/mol (Span)	-3.300				
8b	Interferent CO <sub>2</sub> with 500 μmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	u <sub>int,pos</sub>	0.63	0.3915	
		≤ 5.0 nmol/mol (Span)	0.700				
8c	Interferent NH <sub>3</sub> mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.700	u <sub>int,neg</sub>			
		≤ 5.0 nmol/mol (Span)	0.700				
9	Averaging effect	≤ 7.0% of measured value	0.800	u <sub>av</sub>	0.48	0.2334	
10	Reproducibility standard deviation under field conditions	≤ 5.0% of average over 3 months	1.770	u <sub>r,t</sub>	1.85	3.4278	
11	Long term drift at zero level	≤ 5.0 nmol/mol	0.400	u <sub>d,l,z</sub>	0.23	0.0533	
12	Long term drift at span level	≤ 5.0% of max. of certification range	1.030	u <sub>d,l,h</sub>	0.62	0.3869	
18	Difference sample/calibration port	≤ 1%	0.000	u <sub>ssc</sub>	0.00	0.0000	
21	Converter efficiency	≥ 98	98.000	u <sub>EC</sub>	2.09	4.3765	
23	Uncertainty of test gas	≤ 3%	2.000	u <sub>cg</sub>	1.05	1.0941	
Combined standard uncertainty				u <sub>c</sub>		3.9658	nmol/mol
Expanded uncertainty				U		7.9317	nmol/mol
Relative expanded uncertainty				W		7.58	%
Maximum allowed expanded uncertainty				W <sub>req</sub>		15	%

**Table 3: Combined uncertainty of results during the laboratory test of device 2 (SN 1257)**

Measuring device:		Teledyne API M200E/T200		Serial-No.:		SN 2 (1257)	
Measured component:		NO <sub>2</sub>		1h-limit value:		104.6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.830	u <sub>r,z</sub>	0.19	0.0379	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1.230	u <sub>r,1h</sub>	0.06	0.0032	
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	-0.200	u <sub>l,1h</sub>	-0.12	0.0146	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0.060	u <sub>sp</sub>	0.55	0.3003	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.030	u <sub>st</sub>	0.08	0.0060	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.180	u <sub>st</sub>	0.47	0.2170	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.030	u <sub>v</sub>	0.11	0.0114	
8a	Interferent H <sub>2</sub> O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	0.000	u <sub>H2O</sub>	0.19	0.0359	
		≤ 10 nmol/mol (Span)	0.000				
8b	Interferent CO <sub>2</sub> with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	0.700	u <sub>int,pos</sub>	0.68	0.4650	
		≤ 5.0 nmol/mol (Span)	1.300				
8c	Interferent NH <sub>3</sub> mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.000	u <sub>int,neg</sub>	0.68	0.4650	
		≤ 5.0 nmol/mol (Span)	1.700				
9	Averaging effect	≤ 7.0% of measured value	1.000	u <sub>av</sub>	0.60	0.3647	
18	Difference sample/calibration port	≤ 1%	0.000	u <sub>1sc</sub>	0.00	0.0000	
21	Converter efficiency	≥ 98	98.20	u <sub>EC</sub>	1.88	3.5449	
23	Uncertainty of test gas	≤ 3%	2.000	u <sub>CG</sub>	1.05	1.0941	
Combined standard uncertainty				u <sub>c</sub>	2.4771	nmol/mol	
Expanded uncertainty				U	4.9543	nmol/mol	
Relative expanded uncertainty				W	4.74	%	
Maximum allowed expanded uncertainty				W <sub>req</sub>	15	%	

**Table 4: Combined uncertainty of results during the laboratory and field test of device 2 (SN 1257)**

Measuring device:		Teledyne API M200E/T200		Serial-No.:		SN 2 (1257)	
Measured component:		NO <sub>2</sub>		1h-limit value:		104.6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.830	u <sub>r,z</sub>	0.19	0.0379	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1.230	u <sub>r,h</sub>	not considered, as √2·u <sub>r,h</sub> = 0.08 < u <sub>r,f</sub>	-	
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	-0.200	u <sub>l,h</sub>	-0.12	0.0146	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0.060	u <sub>sp</sub>	0.55	0.3003	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.030	u <sub>gt</sub>	0.08	0.0060	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0.180	u <sub>st</sub>	0.47	0.2170	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.030	u <sub>v</sub>	0.11	0.0114	
8a	Interferent H <sub>2</sub> O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	1.300	u <sub>12O</sub>	0.19	0.0359	
		≤ 10 nmol/mol (Span)	-3.700				
8b	Interferent CO <sub>2</sub> with 500 μmol/mol	≤ 5.0 nmol/mol (Zero)	0.700	u <sub>int,pos</sub> or u <sub>int,neg</sub>	0.68	0.4650	
		≤ 5.0 nmol/mol (Span)	1.300				
		≤ 5.0 nmol/mol (Zero)	0.000				
8c	Interferent NH <sub>3</sub> mit 200 nmol/mol	≤ 5.0 nmol/mol (Span)	1.700				
9	Averaging effect	≤ 7.0% of measured value	1.000	u <sub>av</sub>	0.60	0.3647	
10	Reproducibility standard deviation under field conditions	≤ 5.0% of average over 3 months	1.770	u <sub>r,t</sub>	1.85	3.4278	
11	Long term drift at zero level	≤ 5.0 nmol/mol	-0.840	u <sub>d,l,z</sub>	-0.48	0.2352	
12	Long term drift at span level	≤ 5.0% of max. of certification range	-0.950	u <sub>d,l,h</sub>	-0.57	0.3291	
18	Difference sample/calibration port	≤ 1%	0.000	u <sub>ssc</sub>	0.00	0.0000	
21	Converter efficiency	≥ 98	98.200	u <sub>EC</sub>	1.88	3.5449	
23	Uncertainty of test gas	≤ 3%	2.000	u <sub>cg</sub>	1.05	1.0941	
Combined standard uncertainty				u <sub>c</sub>		3.1815	nmol/mol
Expanded uncertainty				U		6.3630	nmol/mol
Relative expanded uncertainty				W		6.08	%
Maximum allowed expanded uncertainty				W <sub>req</sub>		15	%

Translation of the report on the suitability test of the ambient air measuring system M200E of the company Teledyne Advanced Pollution Instrumentation for the measurement of NO, NO<sub>2</sub> and NO<sub>x</sub>,  
Report-No.: 936/21205926/A2

## **Appendix 1**

### **Manual**

# Operation Manual

## *Model T200*

### *NO/NO<sub>2</sub>/NO<sub>x</sub> Analyzer*

Also supports operation of: when used in conjunction with:

**Model T200U Analyzer** T200U addendum, PN 06861

**Model T200U-NO<sub>y</sub> Analyzer** T200U addendum, PN 06861 and  
T200U-NO<sub>y</sub> addendum, PN 07303

**T200UP Photolytic Analyzer** T200UP addendum, PN 07450

**Model T201 Analyzer** T201 addendum, PN 07271

**Model T265 Analyzer** T265 addendum, PN 07337

© TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)  
9480 CARROLL PARK DRIVE  
SAN DIEGO, CA 92121-5201  
USA

Toll-free Phone: 800-324-5190

Phone: 858-657-9800

Fax: 858-657-9816

Email: [api-sales@teledyne.com](mailto:api-sales@teledyne.com)

Website: <http://www.teledyne-api.com/>





**NOTICE OF COPYRIGHT**

© 2010-2015 Teledyne Advanced Pollution Instrumentation. All rights reserved.

**TRADEMARKS**

All trademarks, registered trademarks, brand names or product names appearing in this document are the property of their respective owners and are used herein for identification purposes only.

This page intentionally left blank.

# SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol, and are placed throughout this manual and inside the instrument. The symbols with messages are defined as follows:



**WARNING:** Electrical Shock Hazard



**HAZARD:** Strong oxidizer



**GENERAL WARNING/CAUTION:** Read the accompanying message for specific information.



**CAUTION:** Hot Surface Warning



**Do Not Touch:** Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.



**Technician Symbol:** All operations marked with this symbol are to be performed by qualified maintenance personnel only.



**Electrical Ground:** This symbol inside the instrument marks the central safety grounding point for the instrument.

## CAUTION GENERAL SAFETY HAZARD



The T200 Analyzer should only be used for the purpose and in the manner described in this manual. If you use the T200 in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

**NEVER** use any gas analyzer to sample combustible gas(es).

### Note

Technical Assistance regarding the use and maintenance of any Teledyne API product can be obtained by contacting Teledyne API's Technical Support Department:  
Phone: 800-324-5190  
Email: [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)  
or by accessing the service options on our website at <http://www.teledyne-api.com>.

# CONSIGNES DE SÉCURITÉ

Des consignes de sécurité importantes sont fournies tout au long du présent manuel dans le but d'éviter des blessures corporelles ou d'endommager les instruments. Veuillez lire attentivement ces consignes. Chaque consigne de sécurité est représentée par un pictogramme d'alerte de sécurité; ces pictogrammes se retrouvent dans ce manuel et à l'intérieur des instruments. Les symboles correspondent aux consignes suivantes :



**AVERTISSEMENT** : Risque de choc électrique



**DANGER** : Oxydant puissant



**AVERTISSEMENT GÉNÉRAL / MISE EN GARDE** : Lire la consigne complémentaire pour des renseignements spécifiques



**MISE EN GARDE** : Surface chaude



**Ne pas toucher** : Toucher à certaines parties de l'instrument sans protection ou sans les outils appropriés pourrait entraîner des dommages aux pièces ou à l'instrument.



**Pictogramme « technicien »** : Toutes les opérations portant ce symbole doivent être effectuées uniquement par du personnel de maintenance qualifié.



**Mise à la terre** : Ce symbole à l'intérieur de l'instrument détermine le point central de la mise à la terre sécuritaire de l'instrument.



## MISE EN GARDE

**Cet instrument doit être utilisé aux fins décrites et de la manière décrite dans ce manuel. Si vous utilisez cet instrument d'une autre manière que celle pour laquelle il a été prévu, l'instrument pourrait se comporter de façon imprévisible et entraîner des conséquences dangereuses.**

**NE JAMAIS utiliser un analyseur de gaz pour échantillonner des gaz combustibles!**

# WARRANTY

## WARRANTY POLICY (02024 G)

Teledyne Advanced Pollution Instrumentation (TAPI), a business unit of Teledyne Instruments, Inc., provides that:

Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available.

## COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting are to be performed by the customer.

## NON-TAPI MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

## PRODUCT RETURN

All units or components returned to Teledyne API should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

The complete Terms and Conditions of Sale can be reviewed at [http://www.teledyne-api.com/terms\\_and\\_conditions.asp](http://www.teledyne-api.com/terms_and_conditions.asp)



### CAUTION – Avoid Warranty Invalidation

Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to the manual, Fundamentals of ESD, PN 04786, in its "Packing Components for Return to Teledyne API's Customer Service" section. The manual can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section; RMA procedures are under Help Center > Return Authorization.

This page intentionally left blank.

## CONVENTIONS USED IN THIS MANUAL

In addition to the safety symbols as presented in the *Important Safety Information* page, this manual provides *special notices* related to the safety and effective use of the analyzer and other pertinent information.

**Special Notices** appear as follows:

### ATTENTION

---

**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

**This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.**

---

### IMPORTANT

---

**IMPACT ON READINGS OR DATA**

**Could either affect accuracy of instrument readings or cause loss of data.**

---

### Note

---

**Pertinent information associated with the proper care, operation or maintenance of the analyzer or its parts.**

---

## REVISION HISTORY

This section provides information regarding changes to this manual.

### T200 User Manual, PN 06858

Date	Rev	DCN	Change Summary
2015 August 4	E	7057	Technical and administrative updates
2013 February 01	D	6646	Correct CE values; misc updates
2012 February 13	C	6213	Technical and Administrative Updates
2011, March 11	B	6018	Administrative Updates
2010	A	5847	Initial Release



# TABLE OF CONTENTS

Safety Messages .....	iii
Warranty .....	v
Conventions Used In this Manual .....	vii
Revision History .....	vii
<b>1. INTRODUCTION .....</b>	<b>15</b>
1.1. Features .....	15
1.2. Support Documentation .....	16
1.3. Options .....	16
<b>2. SPECIFICATIONS, APPROVALS, &amp; COMPLIANCE .....</b>	<b>19</b>
2.1. Specifications .....	19
2.2. EPA Reference Designation .....	20
2.3. Approvals and Certifications .....	21
2.3.1. Safety .....	21
2.3.2. EMC .....	21
2.3.3. Other Type Certifications .....	22
<b>3. GETTING STARTED .....</b>	<b>23</b>
3.1. Unpacking the T200 Analyzer .....	23
3.1.1. Ventilation Clearance .....	24
3.2. Instrument Layout .....	25
3.2.1. Front Panel .....	25
3.2.2. Rear Panel .....	29
3.2.3. Internal Chassis Layout .....	31
3.3. Connections and Setup .....	33
3.3.1. Electrical Connections .....	33
3.3.2. Pneumatic Connections .....	47
3.4. Startup, Functional Checks, and Initial Calibration .....	64
3.4.1. Start Up .....	64
3.4.2. Warning Messages .....	64
3.4.3. Functional Checks .....	67
3.4.4. Initial Calibration .....	68
3.4.4.1. Interferents .....	68
<b>4. OVERVIEW OF OPERATING MODES .....</b>	<b>73</b>
4.1. Sample Mode .....	74
4.1.1. Test Functions .....	74
4.1.2. Warning Messages .....	77
4.2. Calibration Mode .....	78
4.3. Setup Mode .....	79
4.3.1. Password Security .....	79
4.3.2. Primary Setup Menu .....	79
4.3.3. Secondary Setup Menu (SETUP →MORE) .....	80
<b>5. SETUP MODE MENUS .....</b>	<b>81</b>
5.1. SETUP → CFG: Configuration Information .....	81
5.2. SETUP →ACAL: Automatic Calibration Option .....	82
5.3. SETUP →DAS: Internal Data Acquisition System .....	82
5.4. SETUP →RNGE: Analog Output Reporting Range Configuration .....	82
5.4.1. T200 Physical Ranges .....	82
5.4.2. T200 Analog Output Reporting Ranges .....	82
5.4.3. SETUP → RNGE → MODE .....	84
5.5. SETUP → PASS: Password Protection .....	93
5.6. SETUP → CLK: Setting the Internal Time-of-Day Clock .....	96
5.6.1. Setting the Time of Day .....	96
5.6.2. Adjusting the Internal Clock's Speed .....	97
5.7. SETUP → COMM: Communications Ports .....	98
5.7.1. ID (Machine Identification) .....	98

5.7.2. INET (Ethernet) .....	99
5.7.3. COM1[COM2] (Mode, Baud Rate and Test Port) .....	99
5.8. SETUP → VARS: Variables Setup and Definition .....	99
5.9. SETUP → Diag: Diagnostics Functions .....	102
5.9.1. Signal I/O .....	104
5.9.2. Analog Output (DIAG AOUT) .....	105
5.9.3. Analog I/O Configuration (DIAG AIO) .....	105
5.9.4. Test Chan Output (Selecting a Test Channel Function for Output A4) .....	120
5.9.5. Optic Test .....	122
5.9.6. Electrical Test .....	122
5.9.7. Ozone Gen Override .....	122
5.9.8. Flow Calibration .....	122
<b>6. COMMUNICATIONS SETUP AND OPERATION .....</b>	<b>123</b>
6.1. Date Terminal / Communication Equipment (DTE DCE) .....	123
6.2. Communication Modes, Baud Rate and Port Testing .....	123
6.2.1. Communication Modes .....	124
6.2.2. Com Port Baud Rate .....	126
6.2.3. Com Port Testing .....	126
6.3. RS-232 .....	128
6.4. RS-485 (Option) .....	128
6.5. Ethernet .....	129
6.5.1. Configuring Ethernet Communication Manually (Static IP Address) .....	129
6.5.2. Configuring Ethernet Communication Using Dynamic Host Configuration Protocol (DHCP) .....	131
6.6. USB Port for Remote Access .....	134
6.7. Communications Protocols .....	136
6.7.1. MODBUS .....	136
6.7.2. Hessen .....	138
<b>7. DATA ACQUISITION SYSTEM (DAS) AND APICOM .....</b>	<b>147</b>
7.1. DAS Structure .....	148
7.1.1. DAS Channels .....	148
7.1.2. Viewing DAS Data and Settings .....	153
7.1.3. Editing DAS Data Channels .....	154
7.2. Remote DAS Configuration .....	166
7.2.1. DAS Configuration via APICOM .....	166
7.2.2. DAS Configuration via Terminal Emulation Programs .....	168
<b>8. REMOTE OPERATION .....</b>	<b>169</b>
8.1. Computer Mode .....	169
8.1.1. Remote Control via APICOM .....	169
8.2. Interactive Mode .....	170
8.2.1. Remote Control via a Terminal Emulation Program .....	170
8.3. Remote Access by Modem .....	172
8.4. Password Security for Serial Remote Communications .....	175
<b>9. CALIBRATION PROCEDURES .....</b>	<b>177</b>
9.1. Before Calibration .....	178
9.1.1. Required Equipment, Supplies, and Expendables .....	178
9.1.2. Calibration Gases .....	179
9.1.3. Data Recording Devices .....	181
9.1.4. NO <sub>2</sub> Conversion Efficiency (CE) .....	181
9.2. Manual Calibration Checks and Calibration of the T200 Analyzer in its Base Configuration .....	181
9.2.1. Setup for Basic Calibration Checks and Calibration .....	182
9.2.2. Performing a Basic Manual Calibration Check .....	183
9.2.3. Performing a Basic Manual Calibration .....	184
9.3. Manual Calibration with the Internal Span Gas Generator .....	186
9.3.1. Performing “Precision” Manual Calibration when Internal Span Gas (IZS) Generator Option is Present .....	186
9.3.2. Setup for Calibration with the Internal Span Gas Generator .....	187
9.3.3. CAL On NO <sub>2</sub> Feature .....	187

9.3.4. Performing a Manual Calibration Check with the Internal Span Gas Generator .....	189
9.3.5. Performing a Manual Calibration with the Internal Span Gas Generator .....	190
9.4. Manual Calibration and Cal Checks with the Valve Options Installed .....	193
9.4.1. Setup for Calibration Using Valve Options .....	193
9.4.2. Manual Calibration Checks with Valve Options Installed .....	194
9.4.3. Manual Calibration Using Valve Options .....	195
9.5. Automatic Zero/Span Cal/Check (AutoCal) .....	197
9.5.1. SETUP → ACAL: Programming and AUTO CAL Sequence .....	200
9.6. Calibration Quality Analysis .....	203
9.7. Gas Flow Calibration .....	204
<b>10. EPA PROTOCOL CALIBRATION .....</b>	<b>205</b>
<b>11. INSTRUMENT MAINTENANCE .....</b>	<b>207</b>
11.1. Maintenance Schedule .....	207
11.2. Predictive Diagnostics .....	209
11.3. Maintenance Procedures .....	210
11.3.1. Replacing the Sample Particulate Filter .....	210
11.3.2. Changing the O <sub>3</sub> Dryer Particulate Filter .....	211
11.3.3. Changing the Ozone Cleanser Chemical .....	212
11.3.4. Maintaining the External Sample Pump (Pump Pack) .....	214
11.3.5. Changing the Pump DFU Filter .....	215
11.3.6. Changing the Internal Span Gas Generator Permeation Tube .....	216
11.3.7. Changing the External Zero Air Scrubber (OPT 86C) .....	216
11.3.8. Changing the NO <sub>2</sub> Converter .....	219
11.3.9. Cleaning the Reaction Cell .....	221
11.3.10. Replacing Critical Flow Orifices .....	223
11.3.11. Checking for Light Leaks .....	224
11.3.12. Checking for Pneumatic Leaks .....	225
<b>12. TROUBLESHOOTING &amp; SERVICE .....</b>	<b>227</b>
12.1. General Troubleshooting .....	228
12.1.1. Fault Diagnosis with WARNING Messages .....	228
12.1.2. Fault Diagnosis With Test Functions .....	232
12.1.3. DIAG → SIGNAL I/O: Using the Diagnostic Signal I/O Function .....	233
12.2. Using the Analog Output Test Channel .....	235
12.3. Using the Internal Electronic Status LEDs .....	236
12.3.1. CPU Status Indicator .....	236
12.3.2. Relay PCA Status LEDs .....	236
12.4. Gas Flow Problems .....	238
12.4.1. Zero or Low Flow Problems .....	238
12.5. Calibration Problems .....	242
12.5.1. Negative Concentrations .....	242
12.5.2. No Response .....	243
12.5.3. Unstable Zero and Span .....	243
12.5.4. Inability to Span - No SPAN Button (CALS) .....	244
12.5.5. Inability to Zero - No ZERO Button (CALZ) .....	244
12.5.6. Non-Linear Response .....	244
12.5.7. Discrepancy Between Analog Output and Display .....	245
12.5.8. Discrepancy Between NO and NO <sub>x</sub> slopes .....	246
12.6. Other Performance Problems .....	246
12.6.1. Excessive Noise .....	246
12.6.2. Slow Response .....	246
12.6.3. Auto Zero Warnings .....	247
12.7. Subsystem Checkout .....	248
12.7.1. AC Main Power .....	248
12.7.2. DC Power Supply .....	249
12.7.3. I <sup>2</sup> C Bus .....	250
12.7.4. LCD/Display Module .....	250
12.7.5. Relay PCA .....	250
12.7.6. Motherboard .....	251

12.7.7. Pressure / Flow Sensor Assembly .....	255
12.7.8. CPU.....	256
12.7.9. RS-232 Communications .....	256
12.7.10. NO <sub>2</sub> → NO Converter .....	257
12.7.11. Determining CE by Simplified GPT Calibration .....	262
12.7.12. Photomultiplier Tube (PMT) Sensor Module.....	265
12.7.13. PMT Preamplifier Board.....	267
12.7.14. PMT Temperature Control PCA.....	268
12.7.15. O <sub>3</sub> Generator .....	269
12.7.16. Internal Span Gas Generator and Valve Options .....	270
12.7.17. Temperature Sensor .....	271
12.8. Service Procedures .....	272
12.8.1. Disk-On-Module Replacement Procedure .....	272
12.8.2. O <sub>3</sub> Generator Replacement .....	273
12.8.3. Sample and Ozone Dryer Replacement .....	273
12.8.4. PMT Sensor Hardware Calibration .....	274
12.8.5. Replacing the PMT, HVPS or TEC .....	276
12.8.6. Removing / Replacing the Relay PCA from the Instrument.....	279
12.9. Frequently Asked Questions .....	280
12.10. Technical Assistance .....	282
<b>13. PRINCIPLES OF OPERATION.....</b>	<b>283</b>
13.1. Measurement Principle .....	283
13.1.1. Chemiluminescence Creation in the T200 Reaction Cell .....	283
13.1.2. Chemiluminescence Detection in the T200 Reaction Cell.....	285
13.1.3. NO <sub>x</sub> and NO <sub>2</sub> Determination .....	286
13.1.4. Auto Zero .....	287
13.1.5. Measurement Interferences.....	288
13.2. Pneumatic Operation .....	291
13.2.1. Sample Gas Flow.....	291
13.2.2. Flow Rate Control - Critical Flow Orifices .....	293
13.2.3. Ozone Gas Generation and Air Flow.....	296
13.2.4. Pneumatic Sensors.....	300
13.3. Electronic Operation.....	302
13.3.1. Overview .....	302
13.3.2. CPU.....	304
13.3.3. Motherboard.....	305
13.3.4. Relay PCA .....	310
13.4. Sensor Module .....	316
13.5. Photo Multiplier Tube (PMT) .....	316
13.5.1. PMT Preamplifier .....	317
13.5.2. PMT Cooling System .....	319
13.6. Pneumatic Sensor Board .....	320
13.7. Power Supply/Circuit Breaker .....	321
13.7.1. AC Power Configuration .....	322
13.8. Front Panel Touchscreen/Display Interface.....	327
13.8.1. LVDS Transmitter Board.....	328
13.8.2. Front Panel Touchscreen/Display Interface PCA .....	328
13.9. Software Operation .....	328
13.9.1. Adaptive Filter .....	329
13.9.2. Temperature/Pressure Compensation (TPC).....	329
13.9.3. Calibration - Slope and Offset.....	330
Glossary .....	331
Index.....	335

**APPENDIX A - VERSION SPECIFIC SOFTWARE DOCUMENTATION****APPENDIX B - SPARE PARTS****APPENDIX C - REPAIR QUESTIONNAIRE****APPENDIX D - ELECTRONIC SCHEMATICS**

## FIGURES

Figure 3-1:	Front Panel Layout.....	25
Figure 3-2:	Display Screen and Touch Control .....	26
Figure 3-3:	Display/Touch Control Screen Mapped to Menu Charts .....	28
Figure 3-4:	Rear Panel Layout – Base Unit .....	29
Figure 3-5:	Internal Layout – Top View with IZS Option .....	31
Figure 3-6:	Internal Layout - Top View Showing Other Options .....	32
Figure 3-7:	Analog In Connector .....	34
Figure 3-8:	Analog Output Connector .....	35
Figure 3-9:	Current Loop Option Installed on the Motherboard .....	36
Figure 3-10:	Status Output Connector .....	37
Figure 3-11:	Energizing the T200 Control Inputs .....	38
Figure 3-12:	Concentration Alarm Relay .....	39
Figure 3-13:	Rear Panel Connector Pin-Outs for RS-232 Mode.....	42
Figure 3-14:	Default Pin Assignments for CPU COM Port Connector (RS-232) .....	43
Figure 3-15:	Jumper and Cables for Multidrop Mode.....	45
Figure 3-16:	RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram .....	46
Figure 3-17:	Gas Line Connections from Calibrator – Basic T200 Configuration .....	50
Figure 3-18:	Gas Line Connections from Bottled Span Gas – Basic T200 Configuration .....	51
Figure 3-19:	Pneumatics, Basic Configuration .....	53
Figure 3-20:	Rear Panel Layout with Z/S Valve Options (OPT 50A) .....	54
Figure 3-21:	Gas Line Connections for T200 with Z/S Valves Option (OPT 50A) .....	54
Figure 3-22:	Pneumatics with Zero/Span Valves OPT 50A .....	56
Figure 3-23:	Rear Panel Layout with Ambient Zero/Pressurized Span Valves OPT 50B.....	57
Figure 3-24:	Gas Line Connection w/Ambient Zero/Pressurized Span Valves (OPT 50B) .....	58
Figure 3-25:	Pneumatics with Ambient Zero/Pressurized Span Valves (OPT 50B) .....	59
Figure 3-26:	Rear Panel Layout with Internal Span Source (IZS) OPT 50G .....	61
Figure 3-27:	Pneumatics with the Internal Span Gas Generator (OPT 50G).....	62
Figure 3-28:	Pneumatics for Sample Conditioner OPT 86A .....	63
Figure 4-1:	Front Panel Display.....	73
Figure 4-2:	Viewing T200 Test Functions .....	75
Figure 5-1:	Analog Output Connector Pin Out .....	83
Figure 5-2:	SETUP – COM Menu.....	98
Figure 5-3:	COMM– Machine ID .....	99
Figure 5-4:	Accessing the DIAG Submenus .....	103
Figure 5-5:	Accessing the Analog I/O Configuration Submenus.....	106
Figure 5-6:	Setup for Checking / Calibrating DCV Analog Output Signal Levels.....	111
Figure 5-7:	Setup for Checking / Calibration Current Output Signal Levels Using an Ammeter.....	113
Figure 5-8:	Alternative Setup Using 250Ω Resistor for Checking Current Output Signal Levels .....	115
Figure 6-1:	COM – Communication Modes Setup .....	125
Figure 6-2:	COM – COM Port Baud Rate .....	126
Figure 6-3:	COM – COM1 Test Port.....	127
Figure 6-4:	COM - LAN /Internet Manual Configuration.....	130
Figure 6-5:	COM – LAN / Internet Automatic Configuration (DHCP) .....	132
Figure 6-6:	COM – Change Hostname.....	133
Figure 7-1:	Default DAS Channels Setup .....	152
Figure 7-2:	APICOM Remote Control Program Interface.....	166
Figure 7-3:	Sample APICOM User Interface for Configuring the DAS.....	167
Figure 7-4:	DAS Configuration Through a Terminal Emulation Program.....	168
Figure 8-1:	Remote Access by Modem .....	173
Figure 9-1:	Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ a Gas Dilution Calibrator.....	182
Figure 9-2:	Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ Bottled Gas .....	182
Figure 9-3:	Pneumatic Connections for T200 Precision Calibration when IZS Generator Present .....	186
Figure 9-4:	Pneumatic Connections for Manual Calibration/Checks with the Internal Span Gas Generator.....	186
Figure 11-1	Replacing the Particulate Filter .....	210

Figure 11-2:	Particle Filter on O <sub>3</sub> Supply Air Dryer.....	211
Figure 11-3:	Ozone Cleanser Assembly .....	212
Figure 11-4:	Zero Air Scrubber Assembly .....	218
Figure 11-5:	NO <sub>2</sub> Converter Assembly .....	220
Figure 11-6:	Reaction Cell Assembly .....	221
Figure 11-7:	Critical Flow Orifice Assembly .....	223
Figure 12-1:	Example of Signal I/O Function .....	234
Figure 12-2:	CPU Status Indicator .....	236
Figure 12-3:	Relay PCA Status LEDS Used for Troubleshooting .....	237
Figure 12-4:	Location of DC Power Test Points on Relay PCA .....	249
Figure 12-5:	Typical Set Up of Status Output Test .....	253
Figure 12-6:	Pressure / Flow Sensor Assembly .....	255
Figure 12-7:	Setup for determining NO <sub>2</sub> → NO Efficiency – T200 Base Configuration .....	259
Figure 12-8:	Pre-Amplifier Board Layout.....	275
Figure 12-9:	T200 Sensor Assembly.....	277
Figure 12-10:	Relay PCA with AC Relay Retainer In Place .....	279
Figure 12-11:	Relay PCA Mounting Screw Locations .....	279
Figure 13-1:	Reaction Cell with PMT Tube and Optical Filter .....	285
Figure 13-2:	T200 Sensitivity Spectrum .....	286
Figure 13-3:	NO <sub>2</sub> → NO Conversion .....	286
Figure 13-4:	Pneumatic Flow During the Auto Zero Cycle.....	288
Figure 13-5:	Vacuum Manifold, Standard Configuration .....	292
Figure 13-6:	Flow Control Assembly & Critical Flow Orifice.....	293
Figure 13-7:	Location of Flow Control Assemblies & Critical Flow Orifices .....	295
Figure 13-8:	Ozone Generator Principle .....	297
Figure 13-9:	Semi-Permeable Membrane Drying Process .....	297
Figure 13-10:	T200 Sample Dryer .....	298
Figure 13-11:	T200 Electronic Block Diagram .....	302
Figure 13-12:	CPU Board .....	304
Figure 13-13:	Relay PCA Layout (P/N 045230100) .....	310
Figure 13-14:	Relay PCA P/N 045230100 with AC Relay Retainer in Place .....	311
Figure 13-15:	Status LED Locations – Relay PCA.....	312
Figure 13-16:	Heater Control Loop Block Diagram.....	314
Figure 13-17:	Thermocouple Configuration Jumper (JP5) Pin-Outs.....	316
Figure 13-18:	Basic PMT Design .....	317
Figure 13-19:	PMT Preamplifier Block Diagram .....	318
Figure 13-20:	Typical Thermo-Electric Cooler .....	319
Figure 13-21:	PMT Cooling System Block Diagram.....	320
Figure 13-22:	Power Distribution Block Diagram .....	322
Figure 13-23:	Location of AC power Configuration Jumpers .....	323
Figure 13-24:	Pump AC Power Jumpers (JP7).....	324
Figure 13-25:	Typical Set Up of AC Heater Jumper Set (JP2).....	325
Figure 13-26:	Typical Jumper Set (JP2) Set Up of Heaters.....	326
Figure 13-27:	Front Panel and Display Interface Block Diagram .....	327
Figure 13-28:	Basic Software Operation .....	328

## TABLES

Table 1-1:	Analyzer Options.....	16
Table 2-2:	T200 Software Settings for EPA Reference .....	20
Table 3-1:	Ventilation Clearance.....	24
Table 3-5:	Analog Output Pin Assignments .....	35
Table 3-6:	Status Output Pin Assignments .....	37
Table 3-7:	Control Input Pin Assignments .....	38
Table 3-8:	Zero/Span Valves Operating States OPT 50A .....	56

Table 3-9:	Valve Operating States OPT 50B installed.....	60
Table 3-10:	Internal Span Gas Generator Valve Operating States OPT 50G .....	63
Table 3-11:	Possible Warning Messages at Start-Up .....	66
Table 4-1:	Analyzer Operating Modes .....	74
Table 4-2:	Test Functions Defined .....	75
Table 4-3:	Warning Messages Defined.....	77
Table 4-4:	Primary Setup Mode Features and Functions .....	79
Table 4-5:	Secondary Setup Mode Features and Functions .....	80
Table 5-1:	IND Mode Analog Output Assignments .....	86
Table 5-2:	Password Levels.....	93
Table 5-3:	Variable Names (VARS) .....	100
Table 5-4:	Diagnostic Mode (DIAG) Functions .....	102
Table 5-5:	DIAG - Analog I/O Functions .....	105
Table 5-6:	Analog Output Voltage Range Min/Max .....	107
Table 5-7:	Voltage Tolerances for the TEST CHANNEL Calibration.....	111
Table 5-8:	Current Loop Output Check.....	115
Table 5-9:	Test Channels Functions available on the T200's Analog Output.....	120
Table 6-1:	COM Port Communication Modes .....	124
Table 6-2:	Ethernet Status Indicators.....	129
Table 6-4:	RS-232 Communication Parameters for Hessen Protocol .....	138
Table 6-5:	Teledyne API's Hessen Protocol Response Modes .....	141
Table 6-6:	Default Hessen Status Flag Assignments .....	145
Table 7-1:	Front Panel LED Status Indicators for DAS.....	147
Table 7-2:	DAS Data Channel Properties .....	149
Table 7-3:	DAS Data Parameter Functions .....	157
Table 8-1:	Terminal Mode Software Commands .....	170
Table 8-2:	Teledyne API's Serial I/O Command Types .....	171
Table 9-1:	IZS Option Valve States with CAL_ON_NO <sub>2</sub> Turned ON.....	187
Table 9-2:	AUTOCAL Modes .....	197
Table 9-3:	AutoCal Attribute Setup Parameters.....	198
Table 9-4:	Example AutoCal Sequence.....	199
Table 9-5:	Calibration Data Quality Evaluation .....	203
Table 11-1:	T200 Maintenance Schedule .....	208
Table 11-2:	Predictive Uses for Test Functions .....	209
Table 12-1:	Front Panel Warning Messages .....	230
Table 12-2:	Test Functions - Indicated Failures.....	232
Table 12-3:	Test Channel Outputs as Diagnostic Tools .....	235
Table 12-4:	Relay PCA Watchdog LED Failure Indications.....	236
Table 12-5:	Relay PCA Status LED Failure Indications.....	237
Table 12-6:	DC Power Test Point and Wiring Color Codes .....	249
Table 12-7:	DC Power Supply Acceptable Levels .....	250
Table 12-8:	Relay PCA Control Devices .....	250
Table 12-9:	Analog Output Test Function - Nominal Values Voltage Outputs .....	251
Table 12-10:	Status Outputs Check.....	253
Table 12-11:	T200 Control Input Pin Assignments and Corresponding Signal I/O Functions.....	254
Table 13-1:	List of Interferents .....	290
Table 13-2:	T200 Valve Cycle Phases.....	293
Table 13-3:	T200 Gas Flow Rates .....	295
Table 13-4:	Relay PCA Status LED's.....	312
Table 13-5:	Thermocouple Configuration Jumper (JP5) Pin-Outs.....	315
Table 13-6:	AC Power Configuration for Internal Pumps (JP7) .....	324
Table 13-7:	Power Configuration for Standard AC Heaters (JP2) .....	325
Table 13-8:	Power Configuration for Optional Heaters (JP6) .....	326

# 1. INTRODUCTION

Teledyne API's Model T200 (also referred to as T200) NO/NO<sub>2</sub>/NO<sub>x</sub> Analyzer uses chemiluminescence detection (see Principles of Operation, Section 13, this manual), coupled with state-of-the-art microprocessor technology to provide the sensitivity, stability and ease of use needed for ambient or dilution CEM monitoring requirements of nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>) and total nitrogen oxides (NO<sub>x</sub>). Along with providing high accuracy and dependability, the T200 tracks operational parameters and issues warnings if they fall outside diagnostic limits, as well as stores easily retrievable data..

## 1.1. FEATURES

Some of the other exceptional features of your T200 Nitrogen Oxides Analyzer are:

- Ranges, 0-50 ppb to 0-20 ppm, user selectable
- Independent ranges and auto ranging
- Large, vivid, and durable graphics display with touch screen interface
- Microprocessor controlled for versatility
- Multi-tasking software to allow viewing test variables while operating
- Continuous self checking with alarms
- Permeation dryer on ozone generator
- Bi-directional RS-232, optional USB and RS-485, and 10/100Base-T Ethernet ports for remote operation
- Front panel USB ports for peripheral devices and firmware upgrades
- Digital status outputs to provide instrument operating condition
- Adaptive signal filtering to optimize response time
- Temperature and pressure compensation
- Converter efficiency correction software
- Catalytic ozone destruct
- Comprehensive internal data logging with programmable averaging periods
- Ability to log virtually any operating parameter
- 8 analog inputs (optional)
- Internal zero and span check (optional)



## 1.2. SUPPORT DOCUMENTATION

Download additional manuals from Teledyne API's website at <http://www.teledyne-api.com/manuals/>, to support the operation of the instrument:

- APICOM Software Manual, part number 07463
- DAS Manual, part number 02837
- Fundamentals of ESD (Electro-Static Discharge), part number 04786


## 1.3. OPTIONS

The options available for your analyzer are presented in Table 1-1. To order these options or to learn more about them, please contact the Sales Department of Teledyne Advanced Pollution Instrumentation at:

TOLL-FREE: 800-324-5190  
 PHONE: +1 858-657-9800  
 FAX: +1 858-657-9816  
 EMAIL: [apisales@teledyne.com](mailto:apisales@teledyne.com)  
 WEBSITE: <http://www.teledyne-api.com/>

**Table 1-1. Analyzer Options**

Option	Option Number	Description/Notes	Reference
<b>Pumps</b>		<b>Pumps meet all typical AC power supply standards while exhibiting same pneumatic performance.</b>	
	11A	Ship without pump	(TAPI Sales)
	11B	Pumpless Pump Pack	(TAPI Sales)
	12A	Internal Pump 115V @ 60 Hz	(TAPI Sales)
	12B	Internal Pump 220V @ 60 Hz	(TAPI Sales)
	12C	Internal Pump 220V @ 50 Hz	(TAPI Sales)
<b>Rack Mount Kits</b>		<b>Options for mounting the analyzer in standard 19" racks</b>	
	20A	Rack mount brackets with 26 in. (660 mm) chassis slides	(TAPI Sales)
	20B	Rack mount brackets with 24 in. (610 mm) chassis slides	(TAPI Sales)
	21	Rack mount brackets only (compatible with carrying strap, Option 29)	(TAPI Sales)
	23	Rack mount for external pump pack (no slides)	(TAPI Sales)

Option	Option Number	Description/Notes	Reference
<b>Carrying Strap/Handle</b>		<b>Side-mounted strap for hand-carrying analyzer</b>	
	29	Extends from “flat” position to accommodate hand for carrying. Recesses to 9mm (3/8”) dimension for storage. Can be used with rack mount brackets, Option 21. Cannot be used with rack mount slides.	(TAPI Sales)
	<b>CAUTION – GENERAL SAFETY HAZARD</b>		
	<b>THE T200 ANALYZER WEIGHS ABOUT 18 KG (40 POUNDS).</b>		
<b>TO AVOID PERSONAL INJURY WE RECOMMEND THAT TWO PERSONS LIFT AND CARRY THE ANALYZER. DISCONNECT ALL CABLES AND TUBING FROM THE ANALYZER BEFORE MOVING IT.</b>			
<b>Analog Input and USB port</b>		Used for connecting external voltage signals from other instrumentation (such as meteorological instruments).	
	64B	Also can be used for logging these signals in the analyzer’s internal DAS	Sections 3.3.1.2, and 7
<b>Current Loop Analog Outputs</b>		<b>Adds isolated, voltage-to-current conversion circuitry to the analyzer’s analog outputs.</b>	
	41	Can be configured for any output range between 0 and 20 mA. May be ordered separately for any of the analog outputs. Can be installed at the factory or retrofitted in the field.	Sections 3.3.1.4 and 5.9.3.7
<b>Parts Kits</b>		<b>Spare parts and expendables</b>	
	42A	<b>Expendables Kit</b> includes a recommended set of expendables for one year of operation of this instrument including replacement sample particulate filters.	Appendix B
	43	<b>Expendables Kit with IZS</b> includes the items needed to refurbish the zero air scrubber.	Appendix B
	45	<b>Spare Parts Kit</b> includes spares parts for one unit.	Appendix B
<b>Calibration Valves</b>		<b>Used to control the flow of calibration gases generated from external sources, rather than manually switching the rear panel pneumatic connections.</b>	
	50A	<b>AMBIENT ZERO AND AMBIENT SPAN VALVES</b> Zero Air and Span Gas input supplied at ambient pressure. Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	Section 3.3.2.3
	50B	<b>AMBIENT ZERO AND PRESSURIZED SPAN VALVES</b> Span Gas input from external, pressurized source; Span Gas flow rate maintained at 1 ATM by critical flow orifice & vented through Vent port. Shutoff valve stops flow of Span Gas when in sample mode to preserve pressurized gas source. Zero Air created via 2-stage scrubber & dry filter unit (DFU). Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	Section 3.3.2.4
	50G	<b>ZERO SCRUBBER AND INTERNAL SPAN SOURCE (IZS)</b> Span Gas generated from internal NO <sub>2</sub> permeation tube Zero Air created by 2-stage scrubber & DFU. Gases controlled by 2 internal valves: Sample/Cal & Zero/Span.	Sections 3.3.2.5 and 3.3.2.6
<b>NO<sub>2</sub> Permeation Tubes</b>		<b>Replacement tubes; identical size/shape; different permeation rates.</b>	
		Permeation Rate (± 25%)	Approximate NO <sub>2</sub> Concentration @ 50°C
	52B	421 ng/min	300ppb – 500 ppb ± 25%
	52G	842 ng/min	0600 – 1000 ppb ± 25%
		Each tube comes with a calibration certificate, traceable to a NIST standard, specifying its actual effusion rate of that tube to within ± 5% @ 0.56 liters per	
			Section 3.3.2.5

Option	Option Number	Description/Notes	Reference	
minute, calibration performed at a tube temperature of 50°C.				
<b>Communication Cables</b>		<b>For remote serial, network and Internet communication with the analyzer.</b>		
		Type	Description	
	60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with DB-25 serial connectors.	Section 3.3.1.8
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.	Section 3.3.1.8
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.	Section 3.3.1.8
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.	Section 3.3.1.8
<b>USB Port</b>		<b>For remote connection</b>		
	64A	For connection to personal computer. (Separate option only when Option 64B, <i>Analog Input and USB Com Port</i> not elected).	Sections 3.3.1.8 and 6.6	
<b>Concentration Alarm Relays</b>		<b>Issues warning when gas concentration exceeds limits set by user.</b>		
	61	Four (4) “dry contact” relays on the rear panel of the instrument. This relay option is different from and in addition to the “Contact Closures” that come standard on all TAPI instruments.	Section 3.3.1.7	
<b>RS-232 Multidrop</b>		<b>Enables communications between host computer and up to eight analyzers.</b>		
	62	Multidrop card seated on the analyzer’s CPU card. Each instrument in the multidrop network requires this card and a communications cable (Option 60B).	Section 3.3.1.8	
<b>Other Gas Options</b>		<b>Second gas sensor and gas conditioners</b>		
	65A	Oxygen (O <sub>2</sub> ) Sensor	Figure 3-6	
	86A	Ammonia removal sample conditioner (required for EN Certification)	3.3.2.6, 3.4.4.1	
	86C	External zero air scrubber	Sections 3.3.2.6, 9.1.2.1, 11.3.7, and 11.3.7.1, Table 11-1	
<b>Special Features</b>		<b>Built in features, software activated</b>		
	N/A	<b>Maintenance Mode Switch</b> , located inside the instrument, places the analyzer in maintenance mode where it can continue sampling, yet ignore calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop or Hessen protocol networks. Call Customer Service for activation.	(TAPI Tech Support)	
	N/A	<b>Second Language Switch</b> activates an alternate set of display messages in a language other than the instrument’s default language. Call Customer Service for a specially programmed Disk on Module containing the second language.	(TAPI Tech Support)	
	N/A	<b>Dilution Ratio Option</b> allows the user to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Call Customer Service for activation.	Section 5.4.3.5	

## 2. SPECIFICATIONS, APPROVALS, & COMPLIANCE

This section presents specifications for the T200, Agency approvals, EPA designation, and CE mark and safety compliance.

### 2.1. SPECIFICATIONS

Table 2-1 presents the instrument's parameters and the specifications that each meets.

**Table 2-1: T200 Basic Unit Specifications**

Parameter	Specification	
Min/Max Range (Physical Analog Output)	Min: 0-50 ppb Full Scale Max: 0-20,000 ppb Full Scale (selectable, independent NO, NO <sub>2</sub> , NO <sub>x</sub> ranges and auto ranges supported)	
Measurement Units	ppb, ppm, µg/m <sup>3</sup> , mg/m <sup>3</sup> (selectable)	
Zero Noise <sup>1</sup>	< 0.2 ppb (RMS)	
Span Noise <sup>1</sup>	< 0.5% of reading (RMS) above 50 ppb or 0.2 ppb, whichever is greater	
Lower Detectable Limit <sup>2</sup>	0.4 ppb	
Zero Drift	< 0.5 ppb (at constant temperature and voltage) /24 hours	
Span Drift	< 0.5% of Full Scale (at constant temperature and voltage) /24 hours	
Lag Time <sup>1</sup>	20 seconds	
Rise/Fall Time <sup>1</sup>	<60 seconds to 95%	
Linearity	1% of full scale / 24 hours	
Precision	0.5% of reading above 50 ppb	
Sample Flow Rate	500 cm <sup>3</sup> /min ± 10%	
AC Power	Rating	Typical Power Consumption
	110-120 V~ 60 Hz 3.0 A	100 W
	220-240 V~ 50/60 Hz 3.0 A	110 W
Power, Ext Pump	100 V~, 50/60 Hz 3.25 A 115 V~, 60 Hz 3.0 A 220-240 V~, 50/60 Hz 2.5 A	
Analog Output Ranges	10V, 5V, 1V, 0.1V (selectable) All Ranges with 5% Under/Over Range	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage	
Recorder Offset	± 10%	

Parameter	Specification
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital status outputs (7 defined, 1 spare) 6 opto-isolated digital control inputs (4 defined, 2 spar) 4 analog outputs
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs
Dimensions H x W x D	7" x 17" x 23.5" (178mm x 432 mm x 597 mm)
Weight	Analyzer: 40 lbs (18 kg) External Pump Pack: 15 lbs (7 kg)
Operating Temperature Range	5 - 40 °C (with EPA equivalency)
Humidity Range	0-95% RH non-condensing
Environmental Conditions	Installation Category (Over voltage Category) II Pollution Degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m
<sup>1</sup> As defined by the US EPA. <sup>2</sup> Defined as twice the zero noise level by the US EPA.	

## 2.2. EPA REFERENCE DESIGNATION

Teledyne API’s T200 nitrogen oxides analyzer is designated as an automated reference method (Number RFNA-1194-099) for NO<sub>2</sub> measurement, as defined in 40 CFR Part 53, when operated under the following conditions:

- Range: Any full-scale range between 0-0.05 and 0-1.0 ppm (parts per million).
- Ambient temperature range of 5 to 40°C.
- With PTFE filter element or a Kynar® DFU installed in the internal filter assembly.
- Equipped with ozone supply air filter
- Gas flow supplied by an external vacuum pump capable of ≤10 in-Hg-A at 2 standard liters per minute (slpm).
- Software Settings, see Table 2-2:

**Table 2-2: T200 Software Settings for EPA Reference**

Parameter	Setting
Dynamic Zero	OFF or ON
Dynamic Span	OFF
CAL-on-NO <sub>2</sub>	OFF
Dilution Factor	1.0 or OFF
Temp/Pres compensation	ON
AutoCal	ON or OFF
Independent range	ON or OFF
Auto range	ON or OFF

Under the designation, the T200 analyzer may be operated with or without the following:

- Rack mount with or without slides option
- Rack mount for external pump option
- 4-20mA isolated analog outputs option
- Status outputs
- Control input
- Analog input option
- Ethernet output
- RS-232 output
- RS-485 output
- Zero/Span Valves option
- Nafion-type sample gas conditioner option
- Internal Zero/Span (IZS) option

## **2.3. APPROVALS AND CERTIFICATIONS**

The Teledyne API Model T200 analyzer was tested and certified for Safety and Electromagnetic Compatibility (EMC). This section presents the compliance statements for those requirements and directives.

### **2.3.1. SAFETY**

IEC 61010-1:2001, Safety requirements for electrical equipment for measurement, control, and laboratory use.

**CE:** 2006/95/EC, Low-Voltage Directive

### **2.3.2. EMC**

EN 61326-1 (IEC 61326-1), Class A Emissions/Industrial Immunity

EN 55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

**CE:** 2004/108/EC, Electromagnetic Compatibility Directive

### 2.3.3. OTHER TYPE CERTIFICATIONS

MCERTS: Sira MC 050068/05

EN 14211 – Ambient Air Measurement for NO<sub>2</sub>

EN 15267 – Air Quality – Ambient Air Automated Measuring Systems

For additional certifications, please contact Technical Support:

**Toll-free Phone:** 800-324-5190

**Phone:** 858-657-9800

**Fax:** 858-657-9816

**Email:** [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

## 3. GETTING STARTED

This section addresses the procedures for unpacking the instrument and inspecting for damage, presents clearance specifications for proper ventilation, introduces the instrument layout, then presents the procedures for getting started: making electrical and pneumatic connections, and conducting an initial function and calibration check.

### 3.1. UNPACKING THE T200 ANALYZER



**CAUTION**  
**GENERAL SAFETY HAZARD**

To avoid personal injury, always use two persons to lift and carry the T200.

**ATTENTION**

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use Electro-Static Discharge (ESD) protection when working with electronic assemblies will void the instrument warranty. Refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.

-----



**CAUTION!**

Do not operate this instrument until you've removed dust plugs from SAMPLE and EXHAUST ports on the rear panel.

**Note**

-----  
Teledyne API recommends that you store shipping containers/materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty section in this manual and shipping procedures on our Website at <http://www.teledyne-api.com> under Customer Support > Return Authorization.  
-----



Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.

Included with your analyzer is a printed record of the final performance characterization performed on your instrument at the factory. This record, titled Final Test and Validation Data Sheet (P/N 04490) is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

With no power to the unit, carefully removed the top cover of the analyzer and check for internal shipping damage by carrying out the following steps:

1. Carefully remove the top cover of the analyzer and check for internal shipping damage.
  - a. Remove the setscrew located in the top, center of the Front panel.
  - b. Slide the cover backwards until it clears the analyzer's front bezel.
  - c. Lift the cover straight up.
2. Inspect the interior of the instrument to ensure all circuit boards and other components are in good shape and properly seated.
3. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and properly seated.
4. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the analyzer.



#### WARNING – ELECTRICAL SHOCK HAZARD

**Never disconnect PCAs, wiring harnesses or electronic subassemblies while under power.**

### 3.1.1. VENTILATION CLEARANCE

Whether the analyzer is set up on a bench or installed into an instrument rack, be sure to leave sufficient ventilation clearance.

**Table 3-1: Ventilation Clearance**

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	<b>10 cm / 4 in</b>
Sides of the instrument	<b>2.5 cm / 1 in</b>
Above and below the instrument	<b>2.5 cm / 1 in</b>

See Section 1.3 of this manual for various rack mount kit options are available for this analyzer. Refer to for more information.

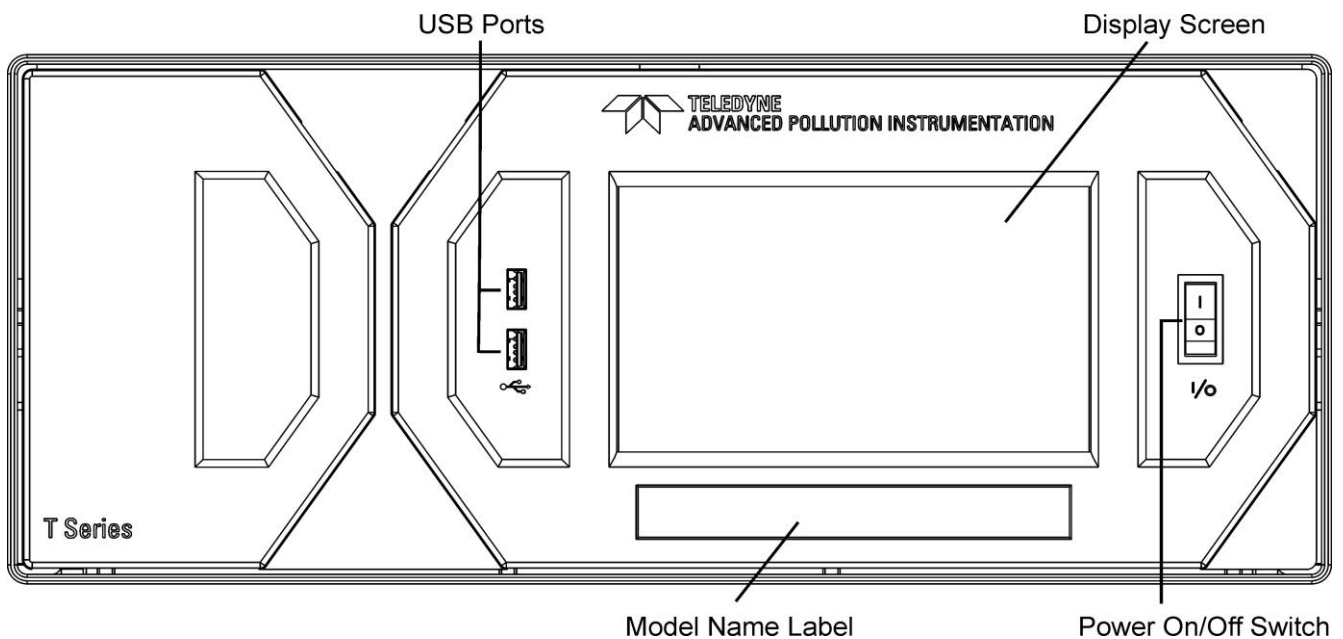
## 3.2. INSTRUMENT LAYOUT

Instrument layout shows front and rear panels and internal chassis.

### 3.2.1. FRONT PANEL

Figure 3-1 shows the analyzer's front panel layout, followed by a close-up of the display screen in Figure 3-2, which is described in Table 3-2. The two USB ports on the front panel are provided for the connection of peripheral devices:

- plug-in mouse (not included) to be used as an alternative to the touchscreen interface
- thumb drive (not included) to download updates to instruction software (contact TAPI Technical Support for information).



**Figure 3-1: Front Panel Layout**



**Figure 3-2: Display Screen and Touch Control**

The front panel interface shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above. The LEDs on the display screen indicate the Sample, Calibration and Fault states; also on the screen is the gas concentration field (Conc), which displays real-time readouts for the primary gases, NO, NO<sub>2</sub>, and NO<sub>x</sub>, and for the secondary gas if installed. The display screen also shows what mode the analyzer is currently in (Mode field), as well as messages and data (Param field). Along the bottom of the screen is a row of touch control buttons; only those that are currently applicable will have a label. Table 3-2 provides detailed information for each component of the screen.

## ATTENTION

### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not use hard-surfaced instruments such as pens to touch the control buttons.

**Table 3-2: Display Screen and Touch Control Description**

Field	Description/Function			
Status	LEDs indicating the states of Sample, Calibration and Fault, as follows:			
	Name	Color	State	Definition
	SAMPLE	Green	Off On Blinking	Unit is not operating in sample mode, DAS is disabled. Sample Mode active; Front Panel Display being updated; DAS data being stored. Unit is operating in sample mode, front panel display being updated, DAS hold-off mode is ON, DAS disabled
	CAL	Yellow	Off On Blinking	Auto Cal disabled Auto Cal enabled Unit is in calibration mode
	FAULT	Red	Off Blinking	No warnings exist Warnings exist
Conc	Displays the actual concentration of the sample gas currently being measured by the analyzer in the currently selected units of measure.			
Mode	Displays the name of the analyzer's current operating mode			
Param	Displays a variety of informational messages such as warning messages, operational data, test function values and response messages during interactive tasks.			
Control Buttons	Displays dynamic, context sensitive labels on each button, which is blank when inactive until applicable.			

Figure 3-3 shows how the front panel display is mapped to the menu charts illustrated in this manual. The **Mode**, **Param** (parameters), and **Conc** (gas concentration) fields in the display screen are represented across the top row of each menu chart. The eight touch **control buttons** along the bottom of the display screen are represented in the bottom row of each menu chart.

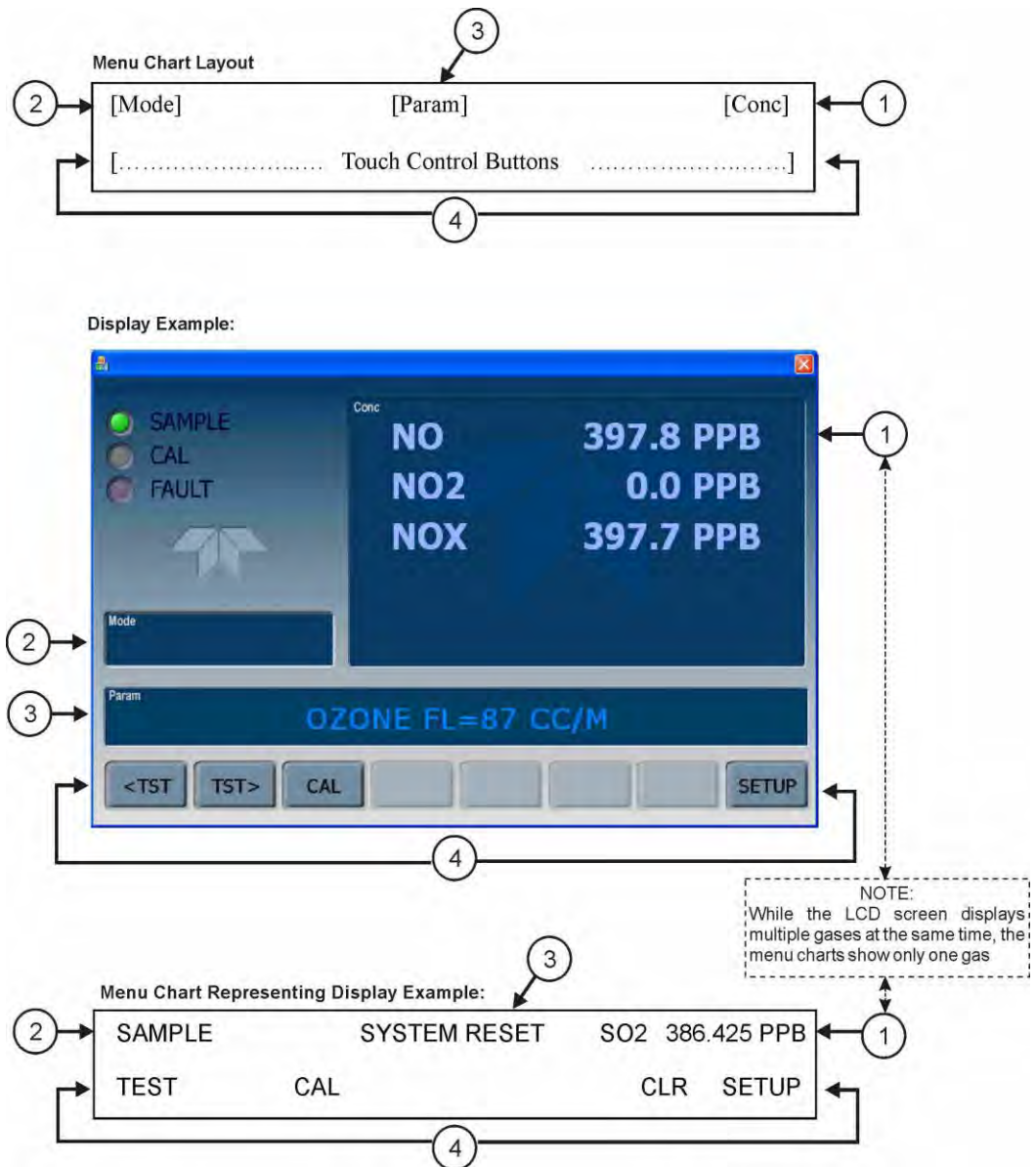


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

**Note**

The menu charts in this manual contain condensed representations of the analyzer’s display during the various operations being described. These menu charts are not intended to be exact visual representations of the actual display.

### 3.2.2. REAR PANEL

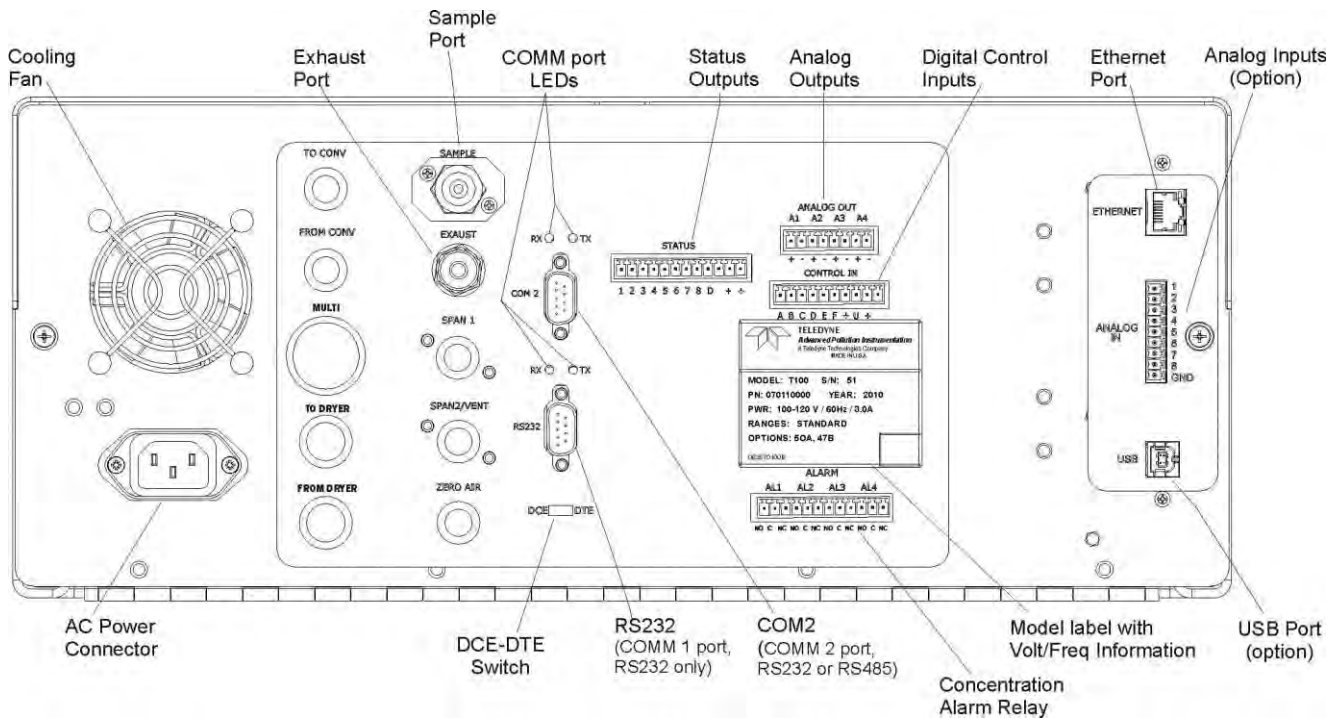



Figure 3-4: Rear Panel Layout – Base Unit

Table 3-3 provides a description of each component on the rear panel.

Table 3-3: Rear Panel Description

Component	Function
<b>cooling fan</b>	Pulls ambient air into chassis through side vents and exhausts through rear.
 <b>AC power connector</b>	Connector for three-prong cord to apply AC power to the analyzer. <b>CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label</b>
<b>Model/specs label</b>	Identifies the analyzer model number and provides power specs
<b>TO CONV</b>	(not used)
<b>FROM CONV</b>	(not used)
<b>MULTI</b>	(not used)
<b>TO DRYER</b>	(not used)
<b>FROM DRYER</b>	Outlet for internal sample gas dryer; connect to external zero air scrubber (for IZS options only).
<b>SAMPLE</b>	Connect a gas line from the source of sample gas here. Calibration gases can also enter here on units without zero/span/shutoff valve options installed.
<b>EXHAUST</b>	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument. The line must be ¼" tubing or greater.
<b>SPAN 1</b>	On units with zero/span/shutoff valves option installed, connect a gas line to the source of calibrated span gas here.
<b>SPAN2/VENT</b>	On units with pressurized span valve option, used for venting.
<b>ZERO AIR</b>	Internal Zero Air: On units with zero/span/shutoff valves option installed but no internal zero air scrubber attach a gas line to the source of zero air here.
<b>RX TX</b>	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
<b>COM 2</b>	Serial communications port for RS-232 or RS-485.
<b>RS-232</b>	Serial communications port for RS-232 only.
<b>DCE DTE</b>	Switch to select either data terminal equipment or data communication equipment during RS-232 communication.
<b>STATUS</b>	For outputs to devices such as Programmable Logic Controllers (PLCs).
<b>ANALOG OUT</b>	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
<b>CONTROL IN</b>	For remotely activating the zero and span calibration modes.
<b>ALARM</b>	Option for concentration alarms and system warnings.
<b>ETHERNET</b>	Connector for network or Internet remote communication, using Ethernet cable
<b>ANALOG IN</b>	Option for external voltage signals from other instrumentation and for logging these signals
<b>USB</b>	Connector for direct connection to laptop computer, using USB cable.
<b>Model Label</b>	Includes voltage and frequency specifications

### 3.2.3. INTERNAL CHASSIS LAYOUT

Figure 3-5 and Figure 3-6 show internal chassis configurations with different options.

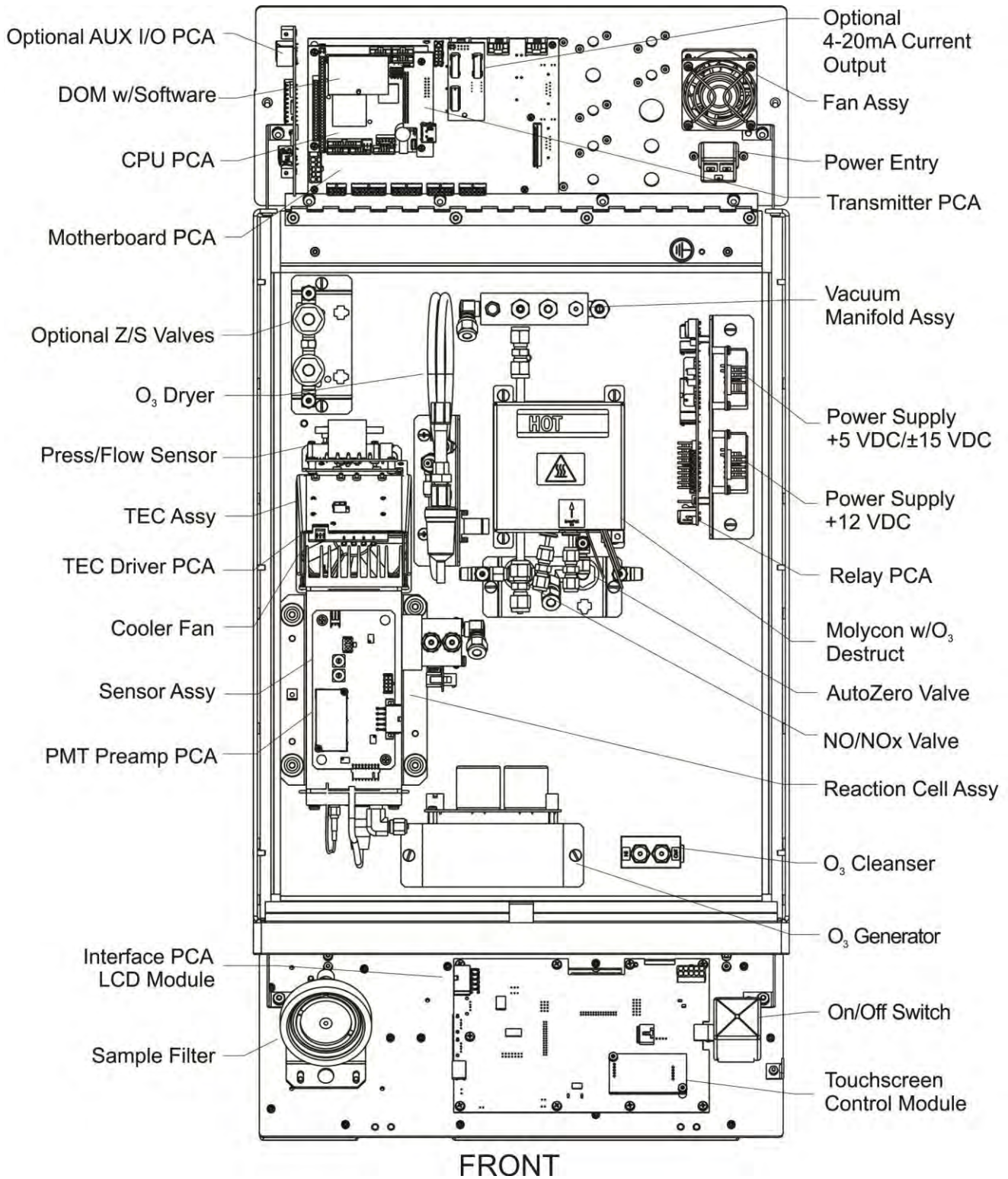


Figure 3-5: Internal Layout – Top View with IZS Option



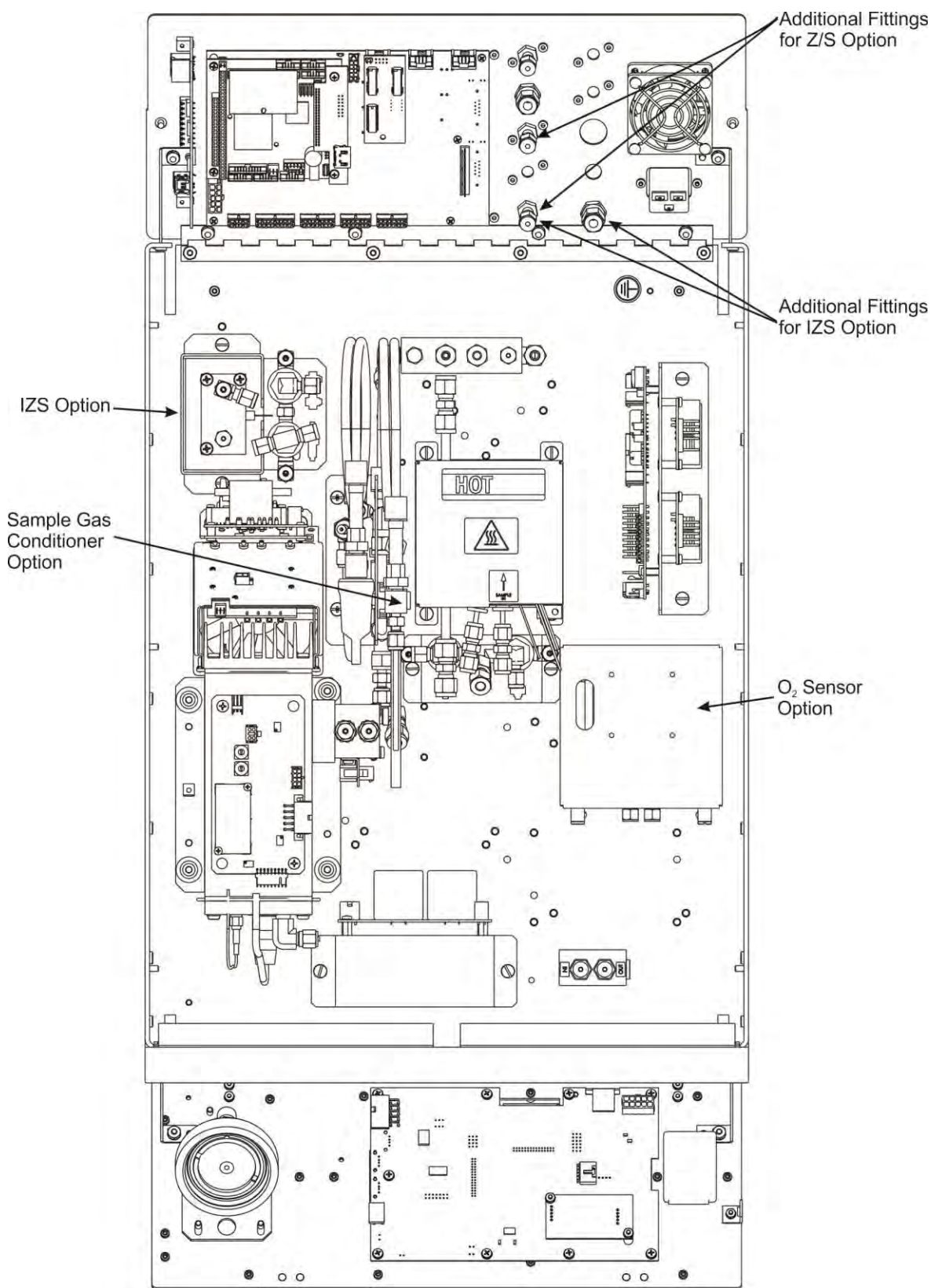


Figure 3-6: Internal Layout - Top View Showing Other Options

## 3.3. CONNECTIONS AND SETUP

This section presents the electrical (Section 3.3.1) and pneumatic (Section 3.3.2) connections for setup and preparing the instrument for operation.

### 3.3.1. ELECTRICAL CONNECTIONS

#### Note

To maintain compliance with EMC standards, cable length must be no greater than 3 meters for all I/O connections, which include Analog In, Analog Out, Status Out, Control In, Ethernet/LAN, USB, RS-232, and RS-485.

#### 3.3.1.1. CONNECTING POWER

Attach the power cord to the analyzer and plug it into a power outlet capable of carrying at least 10 A current at your AC voltage and that it is equipped with a functioning earth ground.



#### **WARNING** **ELECTRICAL SHOCK HAZARD**

**High Voltages are present inside the analyzers case.**  
**Power connection must have functioning ground connection.**  
**Do not defeat the ground wire on power plug.**  
**Turn off analyzer power before disconnecting or connecting electrical subassemblies.**  
**Do not operate with cover off.**



#### **CAUTION** **GENERAL SAFETY HAZARD**

**To avoid damage to your analyzer, ensure that the AC power voltage matches the voltage indicated on the analyzer's model/specs label (Figure 3-4) before plugging the T200 into line power.**

### 3.3.1.2. CONNECTING ANALOG INPUTS (OPTION)

The Analog In connector is used for connecting external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal DAS. The input voltage range for each analog input is 0-10 VDC and input impedance is nominally 20k $\Omega$  in parallel with 0.1 $\mu$ F.

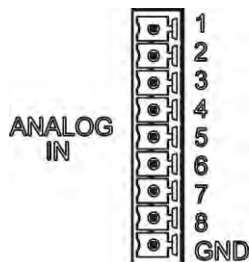


Figure 3-7: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 3-4.

Table 3-4: Analog Input Pin Assignments

PIN	DESCRIPTION	DAS PARAMETER <sup>1</sup>
1	Analog input # 1	AIN 1
2	Analog input # 2	AIN 2
3	Analog input # 3	AIN 3
4	Analog input # 4	AIN 4
5	Analog input # 5	AIN 5
6	Analog input # 6	AIN 6
7	Analog input # 7	AIN 7
8	Analog input # 8	AIN 8
GND	Analog input Ground	N/A

<sup>1</sup> See Section 7 for details on setting up the DAS.

### 3.3.1.3. CONNECTING ANALOG OUTPUTS

The rear panel Analog Output channels **A1**, **A2** and **A3** are assigned to the NO<sub>x</sub>, NO and NO<sub>2</sub> concentration signals of the analyzer with a default output voltage setting of 0 to 5 VDC and a reporting range of 0 to 500 ppb.

**A4** is assigned a user-selected diagnostic test function (see Section 5.9.4), also with a 0 to 5 VDC default analog output voltage setting. An optional Current Loop output is available for **A1**, **A2** and **A3** only.

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the rear panel of the analyzer. Pin-outs for the analog output connector are:

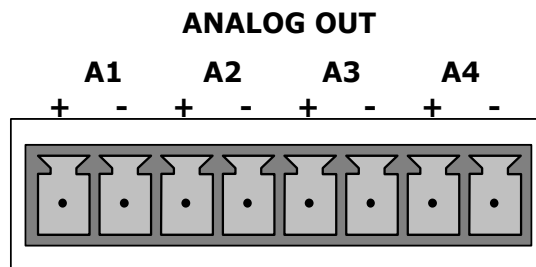


Figure 3-8: Analog Output Connector

Table 3-5: Analog Output Pin Assignments

PIN	ANALOG OUTPUT	SIGNAL	STANDARD VOLTAGE OUTPUT	CURRENT LOOP OPTION
1	<b>A1</b>	<b>NO<sub>x</sub> Concentration</b>	V Out	I Out +
2			Ground	I Out -
3	<b>A2</b>	<b>NO Concentration</b>	V Out	I Out +
4			Ground	I Out -
3	<b>A3</b>	<b>NO<sub>2</sub> Concentration</b>	V Out	I Out +
4			Ground	I Out -
7	<b>A4<sup>1</sup></b>	<b>TEST CHANNEL</b>	V Out	Not Available
8			Ground	Not Available

To change the settings for the analog output channels, see Section 5.9.2.

### 3.3.1.4. CURRENT LOOP ANALOG OUTPUTS (OPTION 41) SETUP

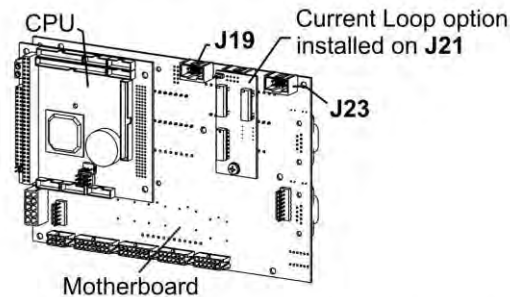
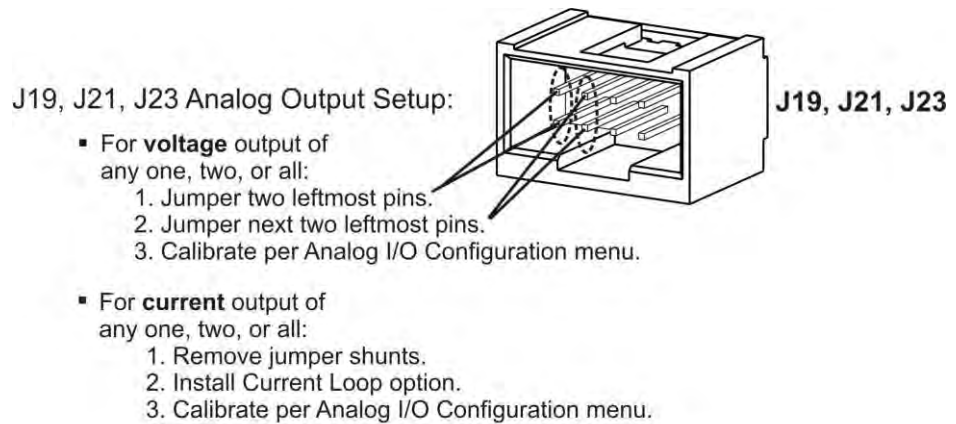
If your analyzer had this option installed at the factory, there are no further connections to be made. Otherwise, it can be installed as a retrofit for each of the analog outputs. This option converts the DC voltage analog output to a current signal with 0-20 mA output current, which can be scaled to any set of limits within that 0-20 mA range. However, most current loop applications call for either 2-20 mA or 4-20 mA range. All current loop outputs have a +5% over-range. Ranges with the lower limit set to more than 1 mA (e.g., 2-20 or 4-20 mA) also have a -5% under-range.

Figure 3-9 provides installation instructions and illustrates a sample configuration of one current output combined with two voltage outputs. Next are instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs. To calibrate or adjust these outputs see Section 5.9.3.7.

#### CAUTION – AVOID INVALIDATING WARRANTY



Service or handling of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.



Example setup: install jumper shunts for voltage output on J19 and J23; remove jumper shunts and install Current Loop option for current output on J21.

**Figure 3-9: Current Loop Option Installed on the Motherboard**

### CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

To convert an output configured for current loop operation to the standard 0 to 5 VDC output operation:

1. Turn off power to the analyzer.
2. If a recording device was connected to the output being modified, disconnect it.
3. Remove the top cover.
  - Remove the set screw located in the top, center of the rear panel.
  - Remove the screws fastening the top cover to the unit (one per side).
  - Slide the cover back and lift the cover straight up.
4. Remove the screw holding the current loop option to the motherboard.
5. Disconnect the current loop option PCA from the appropriate connector on the motherboard (see Figure 3-9).
6. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left most pins and the second shunt on the two adjacent pins (see Figure 3-9).
7. Reattach the top case to the analyzer.

The analyzer is now ready to have a voltage-sensing recording device attached to that output.

Calibrate the analog output as described in Section 5.9.3.2.

### 3.3.1.5. CONNECTING THE STATUS OUTPUTS

The status outputs report analyzer conditions via optically isolated NPN transistors that sink up to 50 mA of DC current. These outputs can be used to interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (PLCs). Each status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at pin D (see Figure 3-10).

#### ATTENTION

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.

The status outputs are through a 12-pin connector on the analyzer's rear panel labeled STATUS (Figure 3-4). Pin-outs for this connector are:

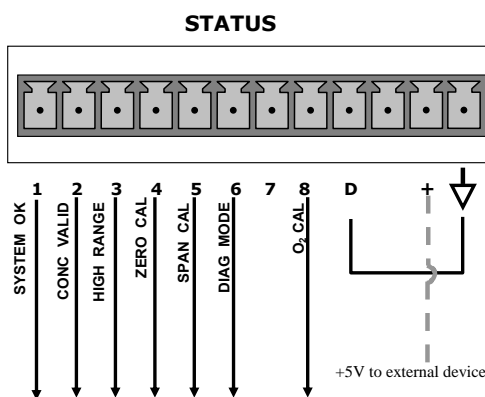


Figure 3-10: Status Output Connector

Table 3-6: Status Output Pin Assignments

OUTPUT #	STATUS DEFINITION	CONDITION
1	<b>SYSTEM OK</b>	On if no faults are present.
2	<b>CONC VALID</b>	On if O <sub>3</sub> concentration measurement is valid. If the O <sub>3</sub> concentration measurement is invalid, this bit is OFF.
3	<b>HIGH RANGE</b>	On if unit is in high range of DUAL or AUTO Range Modes.
4	<b>ZERO CAL</b>	On whenever the instrument is in <b>CALZ</b> mode.
5	<b>SPAN CAL</b>	On whenever the instrument is in <b>CALS</b> mode.
6	<b>DIAG MODE</b>	On whenever the instrument is in DIAGNOSTIC mode.
7-8	<b>SPARE</b>	
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
	<b>SPARE</b>	
+	DC Power	+ 5 VDC, 300 mA source maximum
↓	Digital Ground	The ground level from the analyzer's internal DC power supplies. This connection should be used as the ground return when +5VDC power is used.

### 3.3.1.6. CONNECTING THE CONTROL INPUTS

Three digital control inputs, through the rear panel CONTROL IN connector, can be used to remotely activate the zero and span calibration modes (see Section 9.1.2.4).

Energize the Control Inputs either by the internal +5V available from the pin labeled “+” (more convenient), or by a separate external 5 VDC power supply (ensures that these inputs are truly isolated). Refer to Figure 3-11.

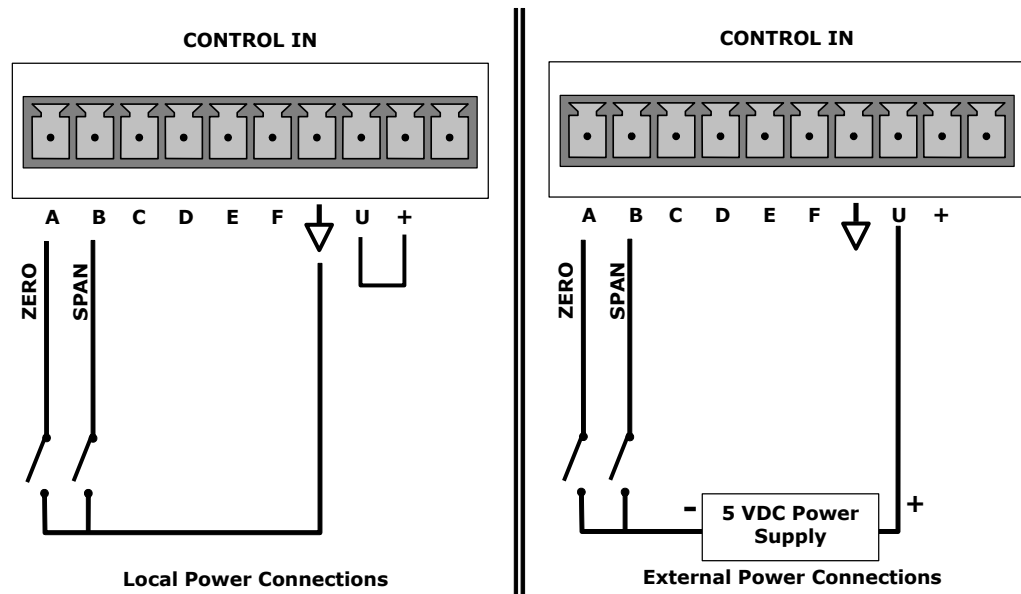


Figure 3-11: Energizing the T200 Control Inputs

Table 3-7: Control Input Pin Assignments

Input #	Status Definition	ON Condition
A	<b>REMOTE ZERO CAL</b>	The Analyzer is placed in Zero Calibration mode. The mode field of the display will read <b>ZERO CAL R.</b>
B	<b>REMOTE SPAN CAL</b>	The Analyzer is placed in Lo Span Calibration mode. The mode field of the display will read <b>SPAN CAL R.</b>
C, D, E & F	Spare	
⏚	Digital Ground	The ground level from the analyzer's internal DC Power Supplies (same as chassis ground).
U	External Power input	Input pin for +5 VDC required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the “U” pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

### 3.3.1.7. CONCENTRATION ALARM RELAY (OPTION 61)

The concentration relay option provides four (4) “dry contact” relays on the rear panel (Figure 3-12), each with 3 pins: Common (C), Normally Open (NO), and Normally Closed (NC).

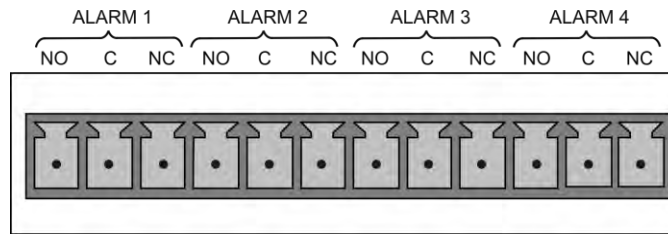


Figure 3-12: Concentration Alarm Relay

Alarm 1	“System OK 2”
Alarm 2	“Conc 1”
Alarm 3	“Conc 2”
Alarm 4	“Range Bit”

#### —ALARM 1” RELAY

Alarm 1 which is “System OK 2” (system OK 1, is the status bit) is in the energized state when the instrument is “OK” & there are no warnings. If there is a warning active or if the instrument is put into the “DIAG” mode, Alarm 1 will change states. This alarm has “reverse logic” meaning that a meter across the Common & Normally Closed pins on the connector will show that it is OPEN when the instrument is OK. This is so that if the instrument should turn off or lose power, it will change states and can be recorded with a data logger or other recording device.

#### —ALARM 2” RELAY & —ALARM 3” RELAY

The “Alarm 2 Relay” is associated with the “Concentration Alarm 1” set point in the software, and the “Alarm 3 Relay” on the rear panel is associated with the “Concentration Alarm 2” set point in the software.

Alarm 2 Relay	NO Alarm 1 = xxx PPM
Alarm 3 Relay	NO <sub>2</sub> Alarm 2 = xxx PPM
Alarm 2 Relay	NO <sub>x</sub> Alarm 1 = xxx PPM
Alarm 3 Relay	NO <sub>x</sub> Alarm 2 = xxx PPM

The Alarm 2 Relay will be turned on any time the concentration set-point is exceeded and will return to its normal state when the concentration value returns below the concentration set-point.

Although the relay on the rear panel is a NON-Latching alarm that resets when the concentration returns below the alarm set point, the warning on the front panel display will remain latched until it is cleared. Clear the front panel warning on by either touching the CLR menu button or going through the serial port.

In instruments that sample more than one gas type, there could be more than one gas type triggering the Concentration 1 Alarm (“Alarm 2” Relay). For example, the T200 instrument can monitor both NO & NO<sub>2</sub> gas. The software for this instrument allows configuring the alarms with 2 alarm levels for each gas.

NO Alarm 1 = 20 PPM  
NO Alarm 2 = 100 PPM



NO<sub>2</sub> Alarm 1 = 20 PPM  
NO<sub>2</sub> Alarm 2 = 100 PPM

In this example, NO Alarm 1 & NO<sub>2</sub> Alarm 1 will both be associated with the “Alarm 2” relay on the rear panel, allowing multiple alarm levels for individual gases.

A more likely configuration for this would be to put one gas on the “Alarm 1” relay and the other gas on the “Alarm 2” relay.

NO Alarm 1 = 20 PPM  
NO Alarm 2 = Disabled  
NO<sub>2</sub> Alarm 1 = Disabled  
NO<sub>2</sub> Alarm 2 = 100 PPM

#### **—“ALARM 4” RELAY**

This relay is connected to the “range bit”. If the instrument is configured for “Auto Range” and the instrument goes up into the high range, it will turn this relay on.

### **3.3.1.8. CONNECTING THE COMMUNICATIONS INTERFACES**

The analyzer has connectors for remote communications interfaces: **Ethernet**, **USB**, **RS-232**, **RS-232 Multidrop** and **RS-485** (each described here). In addition to using the appropriate cables, each type of communication method must be configured using the SETUP>COM menu (see Sections 5.7 and 6).

#### **ETHERNET CONNECTION**

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer’s rear panel Ethernet interface connector to an Ethernet port. Although the analyzer is shipped with DHCP enabled by default (Section 6.5.2), it should be manually assigned a static IP address.

**Configuration:** (manual, i.e., static) Section 6.5.1

## USB (OPTION) CONNECTION

The USB option is for direct communication between the analyzer and a PC; connect a USB cable between the analyzer and a computer USB port. Baud rates must match: check the baud rate on either the computer or the instrument and change the other to match (see Section 6.2.2). This USB connection can only be used when the **COM2** port is not in use except for RS-232 Multidrop communication.

**Configuration:** Section 6.6

### Note

---

**If this option is installed, the rear panel COM2 port cannot be used for anything other than Multidrop communication.**

---

## RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A, Section 1.3), as applicable, from the analyzer's RS-232 port to the device. Adjust the DCE-DTE switch (Figure 3-4) to select DTE or DCE as appropriate (Section 6.1).

**Configuration:** Section 6.3 and Section 6.7.2 (for Hessen protocol)

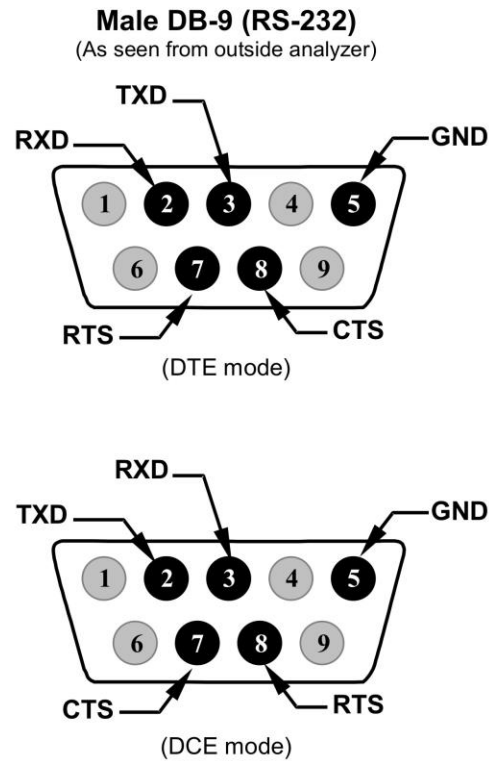
### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

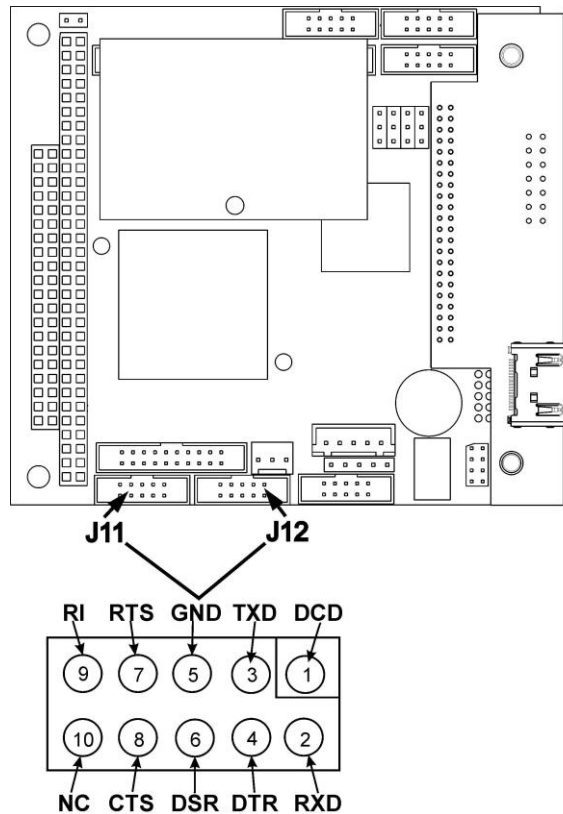
**Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 3-13) before using.**

---



**Figure 3-13 Rear Panel Connector Pin-Outs for RS-232 Mode**

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 3-14).



**Figure 3-14: Default Pin Assignments for CPU COM Port Connector (RS-232).**

Teledyne API offers two mating cables, one of which should be applicable for your use.

- P/N WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of the serial ports of most personal computers.
- P/N WR000024, a DB-9 female to DB-25 male cable. Allows connection to the most common styles of modems (e.g. Hayes-compatible) and code activated switches.

Both cables are configured with straight-through wiring and should require no additional adapters.

#### Note

**Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments before using.**

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the analyzer and a computer or modem, both the red and green LEDs should be on.

- If the lights are not lit, locate the small switch on the rear panel to switch it between DTE and DCE modes.
- If both LEDs are still not illuminated, ensure that the cable properly constructed.

Received from the factory, the analyzer is set up to emulate an RS-232 DCE device.

**RS-232 (COM1):** RS-232 (fixed) DB-9 male connector

- **Baud rate:** 115200 bits per second (baud)
- **Data Bits:** 8 data bits with 1 stop bit
- **Parity:** None

**COM2:** RS-232 (configurable to RS 485), DB-9 female connector

- Baud rate: 19200 bits per second (baud)
- Data Bits: 8 data bits with 1 stop bit
- Parity: None

### RS-232 MULTIDROP (OPTION 62) CONNECTION

When the RS-232 Multidrop option is installed, connection adjustments and configuration through the menu system are required. This section provides instructions for the internal connection adjustments, then for external connections, and ends with instructions for menu-driven configuration.

#### Note

Because the RS-232 Multidrop option uses both the RS232 and COM2 DB9 connectors on the analyzer's rear panel to connect the chain of instruments, COM2 port is no longer available for separate RS-232 or RS-485 operation.

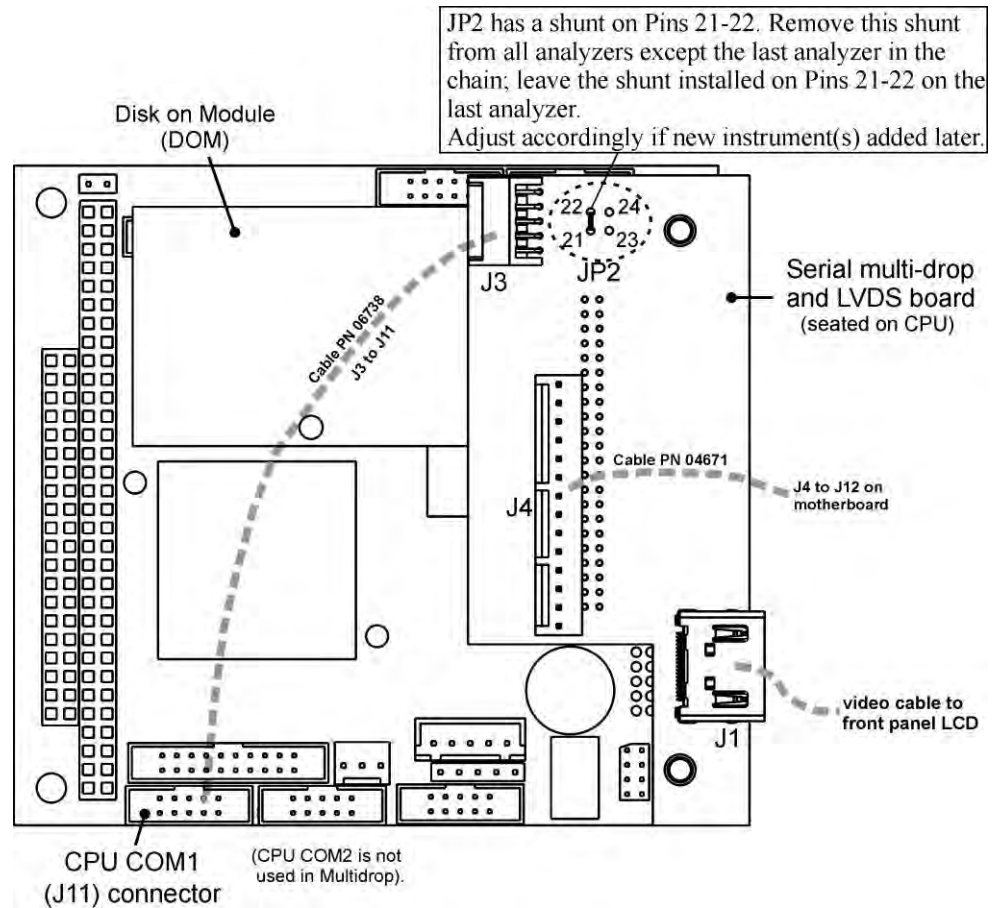
#### ATTENTION

##### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.

In each instrument with the Multidrop option there is a shunt jumpering two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 3-15. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

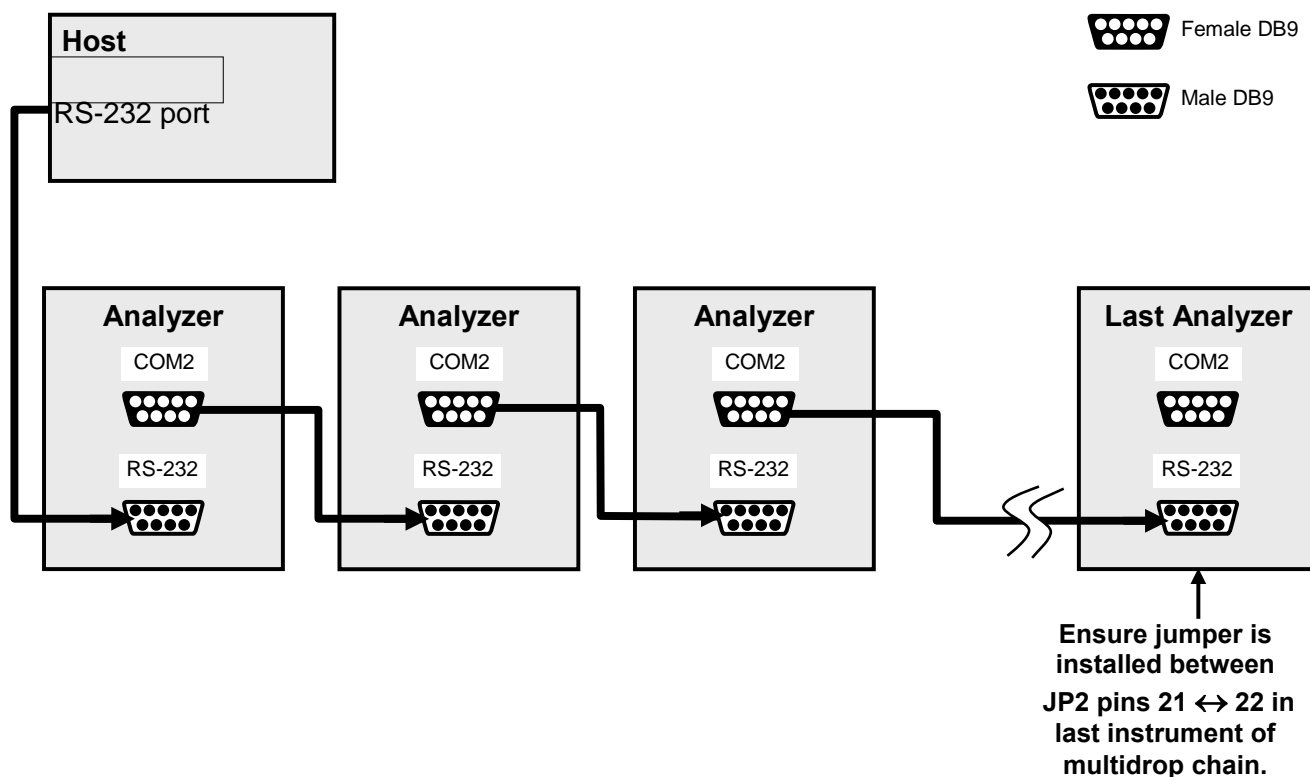
1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the Multidrop/LVDS PCA, which is seated on the CPU.
2. On the Multidrop/LVDS PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).
3. Check that the following cable connections are made in *all* instruments (again refer to Figure 3-15):
  - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector (Note that the CPU's COM2 connector is not used in Multidrop)
  - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
  - J1 on the Multidrop/LVDS PCS to the front panel LCD



**Figure 3-15: Jumper and Cables for Multidrop Mode**

(Note: If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 ↔ 22 of JP2 on the Multidrop/LVDS PCA in the instrument that was previously the last instrument in the chain.)

4. Close the instrument.
5. Referring to Figure 3-16 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.
6. On the rear panel of each analyzer, adjust the DCE DTE switch so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables internally wired specifically for RS-232 communication; see Table 1-1, "Communication Cables" and Section 3.3.1.8: Connecting the Communications Interfaces, "RS-232 Connection").



**Figure 3-16: RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram**

7. BEFORE communicating from the host, power on the instruments and check that the user-selectable Machine ID code is unique for each (Section 5.7.1).
  - a. In the SETUP Mode menu go to SETUP>MORE>COMM>ID. The default ID is typically the model number or "0".
  - b. to change the identification number, press the button below the digit to be changed.
  - c. Press/select ENTER to accept the new ID for that instrument.
8. Next, in the SETUP>MORE>COMM>COM1 menu (do not use the COM2 menu for multidrop), edit the COM1 MODE parameter as follows: press/select EDIT and set only QUIET MODE, COMPUTER MODE, and MULTIDROP MODE to ON. Do not change any other settings.
9. Press/select ENTER to accept the changed settings, and ensure that COM1 MODE now shows 35.
10. Press/select SET> to go to the COM1 BAUD RATE menu and ensure it reads the same for all instruments (edit as needed so that all instruments are set at the same baud rate).

**Note**

The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see step 7 above).

**Note**

Teledyne API recommends setting up the first link, between the Host and the first analyzer, and testing it before setting up the rest of the chain.

### RS-485 (OPTION) CONNECTION

As delivered from the factory, COM2 is configured for RS-232 communications. This port can be reconfigured for operation as a non-isolated, half-duplex RS-485 port. Using COM2 for RS-485 communication will disable the USB port. To reconfigure this port for RS-485 communication, please contact the factory.

### 3.3.2. PNEUMATIC CONNECTIONS

This section provides pneumatic connection information and important information about the gases required for accurate calibration (Section 3.3.2.1); it also illustrates the analyzer's pneumatic layouts in basic configuration and with options.

Before making the pneumatic connections, carefully note the following cautionary and additional messages:



#### CAUTION – GENERAL SAFETY HAZARD

Do not vent calibration gas or sample gas into enclosed areas.



#### CAUTION – GENERAL SAFETY HAZARD

In units with a permeation tube option installed, vacuum pump must be connected and powered on to maintain constant gas flow through the analyzer at all times. Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.

Remove the permeation tube when taking the analyzer out of operation and store in sealed container (use the original container that the tube was shipped in).

(See Figure 3-6 for location and Section 11.3.6 for instructions on how to remove the perm tube when the unit is not in operation).

#### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

Sample and calibration gases should only come into contact with PTFE tubing.

---



**ATTENTION****-----  
COULD DAMAGE INSTRUMENT AND VOID WARRANTY****Venting Pressurized Gas:**

In applications where any gas (span gas, zero air supply, sample gas) is received from a pressurized manifold, a vent must be provided to equalize the gas with ambient atmospheric pressure before it enters the analyzer to ensure that the gases input do not exceed the maximum inlet pressure of the analyzer, as well as to prevent back diffusion and pressure effects. These vents should be:

- at least 0.2m long
- no more than 2m long
- vented outside the shelter or immediate area surrounding the instrument

**Dust Plugs:**

Remove dust plugs from rear panel exhaust and supply line fittings before powering on/operating instrument. These plugs should be kept for reuse in the event of future storage or shipping to prevent debris from entering the pneumatics.

-----

**IMPORTANT****Leak Check:**

Run a leak check once the appropriate pneumatic connections have been made; check all pneumatic fittings for leaks using the procedures defined in Section 11.3.12.1.

-----

**3.3.2.1. ABOUT ZERO AIR AND CALIBRATION (SPAN) GAS**

Zero air and span gas are required for accurate calibration.

**Note**

-----  
Zero air and span gases must be supplied at twice the instrument's specified gas flow rate. Therefore, the T200 zero and span gases should be supplied to their respective inlets in excess of 1000 cc3/min (500 cc3/min x 2).  
-----

**ZERO AIR**

Zero air, or zero calibration gas, is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer.

For the T200 this means zero air should be devoid of NO, NO<sub>2</sub>, CO<sub>2</sub>, NH<sub>3</sub>, and H<sub>2</sub>O vapor.

**Note**

-----  
Moderate amounts of NH<sub>3</sub> and H<sub>2</sub>O can be removed from the sample gas stream by installing the optional sample gas dryer/scrubber (see Section 3.3.2.6).  
-----

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen (N<sub>2</sub>) could be used as a zero gas for applications where NO<sub>x</sub> is measured in nitrogen.
- If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

- For analyzers without the external zero air scrubber, a zero air generator, such as those offered by Teledyne API, can be used. Please visit the company website for more information.

### **CALIBRATION (SPAN) GAS**

Calibration gas is specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired reporting range. To measure NO<sub>x</sub> with the T200, it is recommended that the span gas have an NO concentration equal to 80% of the measurement range for your application.

#### **EXAMPLE:**

- If the application is to measure NO<sub>x</sub> in ambient air between 0 ppm and 500 ppb, an appropriate span gas would be 400 ppb.
- If the application is to measure NO<sub>x</sub> in ambient air between 0 ppm and 1000 ppb, an appropriate span gas would be 800 ppb.

Even though NO gas in nitrogen could be used as a span gas, the matrix of the balance gas is different and may cause interference problems or yield incorrect calibrations.

- The same applies to gases that contain high concentrations of other compounds (for example, CO<sub>2</sub> or H<sub>2</sub>O).
- The span gas should match all concentrations of all gases of the measured medium as closely as possible.

Cylinders of calibrated NO<sub>x</sub> and NO gas traceable to NIST standards specifications (also referred to as EPA protocol calibration gases or Standard Reference Materials) are commercially available.

### **SPAN GAS FOR MULTIPOINT CALIBRATION**

Some applications, such as EPA monitoring, require a multipoint calibration where span gases of different concentrations are needed. We recommend using an NO gas of higher concentration combined with a gas dilution calibrator such as a Teledyne API 700-Series Model. This type of calibrator mixes a high concentration gas with zero air to accurately produce span gas of the desired concentration. Linearity profiles can be automated with this model and run unattended overnight.

If a dynamic dilution system is used to dilute high concentration gas standards to low, ambient concentrations, ensure that the NO concentration of the reference gas matches the dilution range of the calibrator.

Choose the NO gas concentration so that the dynamic dilution system operates in its mid-range and not at the extremes of its dilution capabilities.

#### **EXAMPLE:**

- A dilution calibrator with 10-10000 dilution ratio will not be able to accurately dilute a 5000 ppm NO gas to a final concentration of 500 ppb, as this would operate at the very extreme dilution setting.
- A 100 ppm NO gas in nitrogen is much more suitable to calibrate the T200 analyzer (dilution ratio of 222, in the mid-range of the system's capabilities).

3.3.2.2. BASIC CONNECTIONS FROM CALIBRATOR, WITHOUT AND WITH SPAN GAS

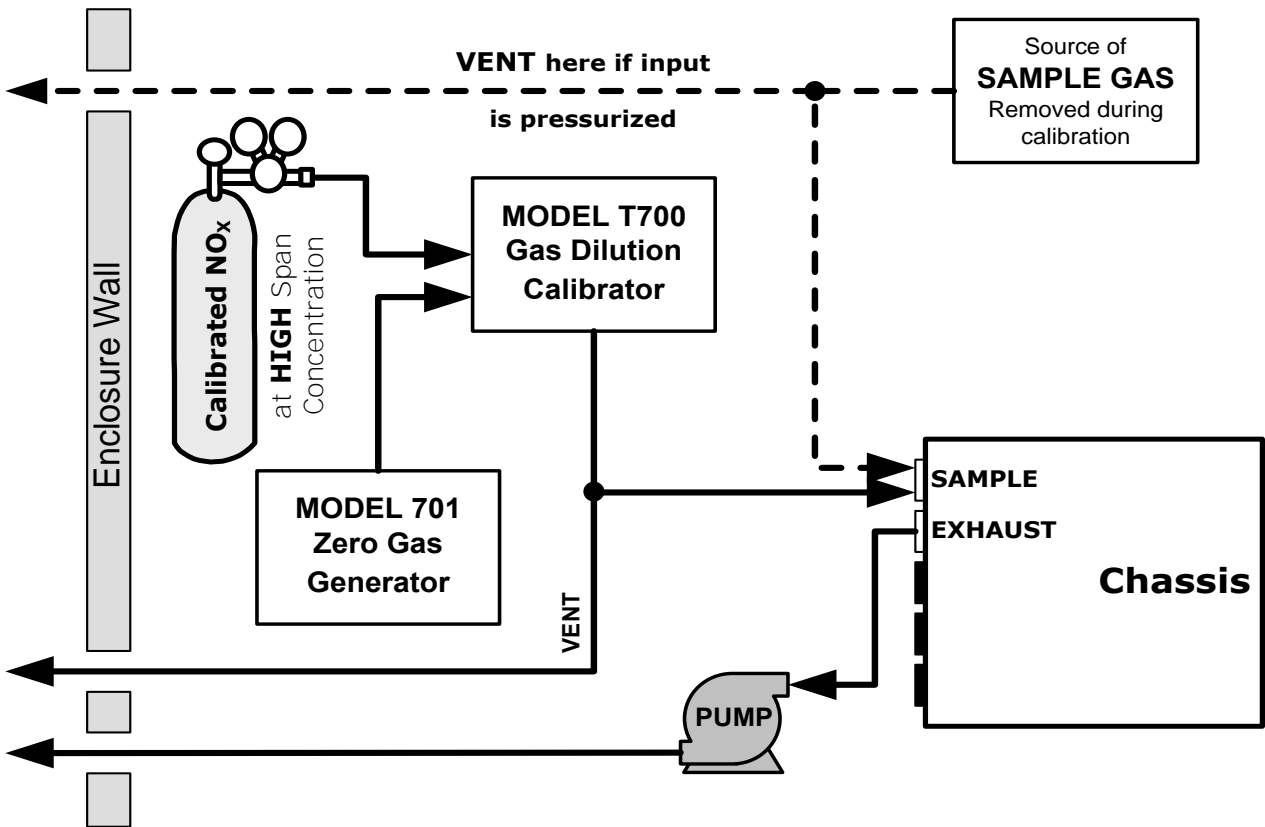


Figure 3-17: Gas Line Connections from Calibrator – Basic T200 Configuration

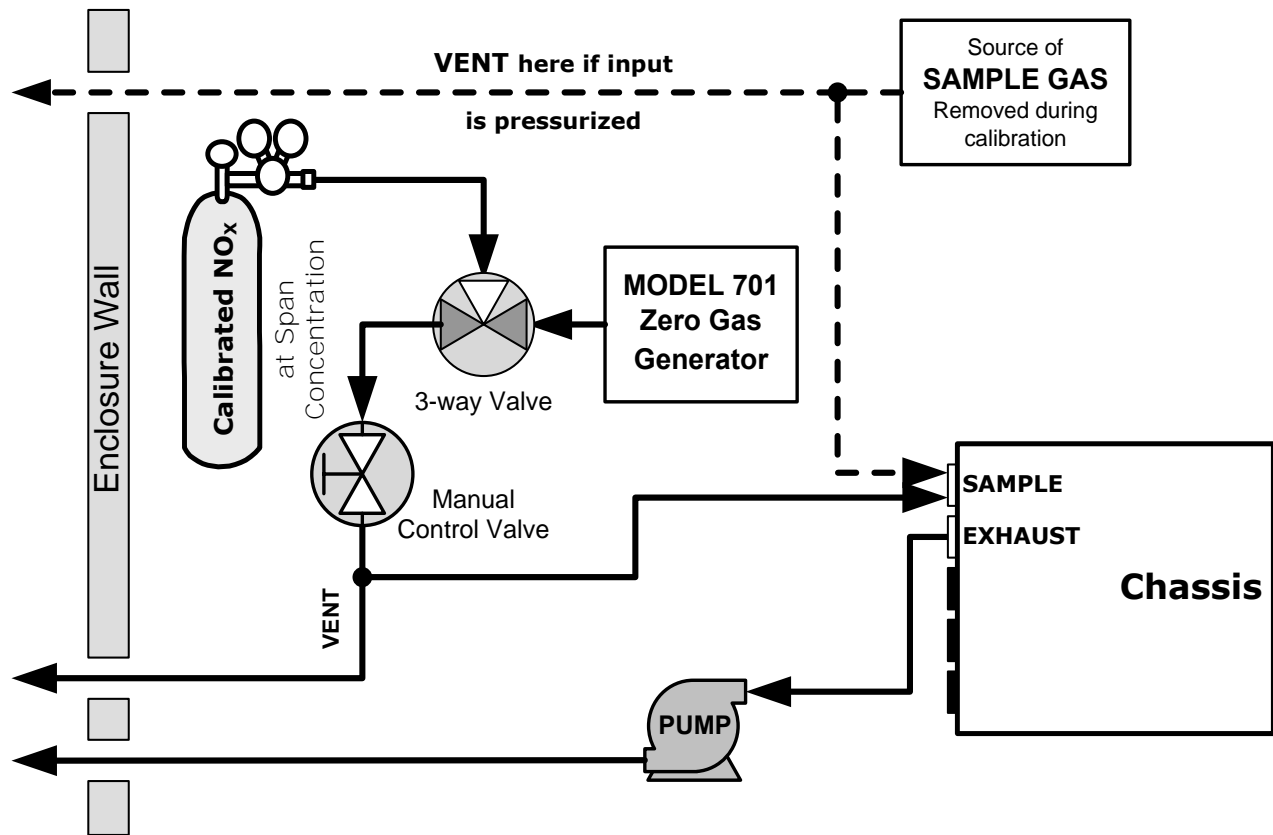


Figure 3-18: Gas Line Connections from Bottled Span Gas – Basic T200 Configuration

For the T200 basic configuration, attach the following pneumatic lines:

#### SAMPLE GAS SOURCE

Connect a sample gas line to the SAMPLE inlet; ensure that

- PTFE tubing is used; minimum OD ¼"
- sample gas pressure equals ambient atmospheric pressure (1.0 psig)
- In applications where the sample gas is received from a pressurized manifold and the analyzer is not equipped with one of the T200's pressurized span options, a vent must be placed on the sample gas line. This vent line must be:
  - no more than 10 meters long
  - vented outside the shelter or immediate area surrounding the instrument

#### CALIBRATION GAS SOURCES

- **CAL GAS & ZERO AIR SOURCES:** The source of calibration gas is also attached to the **SAMPLE** inlet, but only when a calibration operation is actually being performed.
  - Use PTFE tubing; minimum OD ¼".

## VENTING

To prevent back diffusion and pressure effects, both the span gas and zero air supply lines should be:

- vented outside the enclosure
- minimum OD ¼"
- not less than 2 meters in length
- not greater than 10 meters in length

## EXHAUST OUTLET

Attach an exhaust line to the EXHAUST outlet fitting. The exhaust line should be:

- of PTFE tubing; minimum OD ¼"
- maximum of 10 meters long
- vented outside the T200 analyzer's enclosure

### Note

-----  
**Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Sections 11.3.12 (or 11.3.12.2 for detailed check if leak suspected).**  
-----

## PNEUMATIC LAYOUT FOR BASIC CONFIGURATION

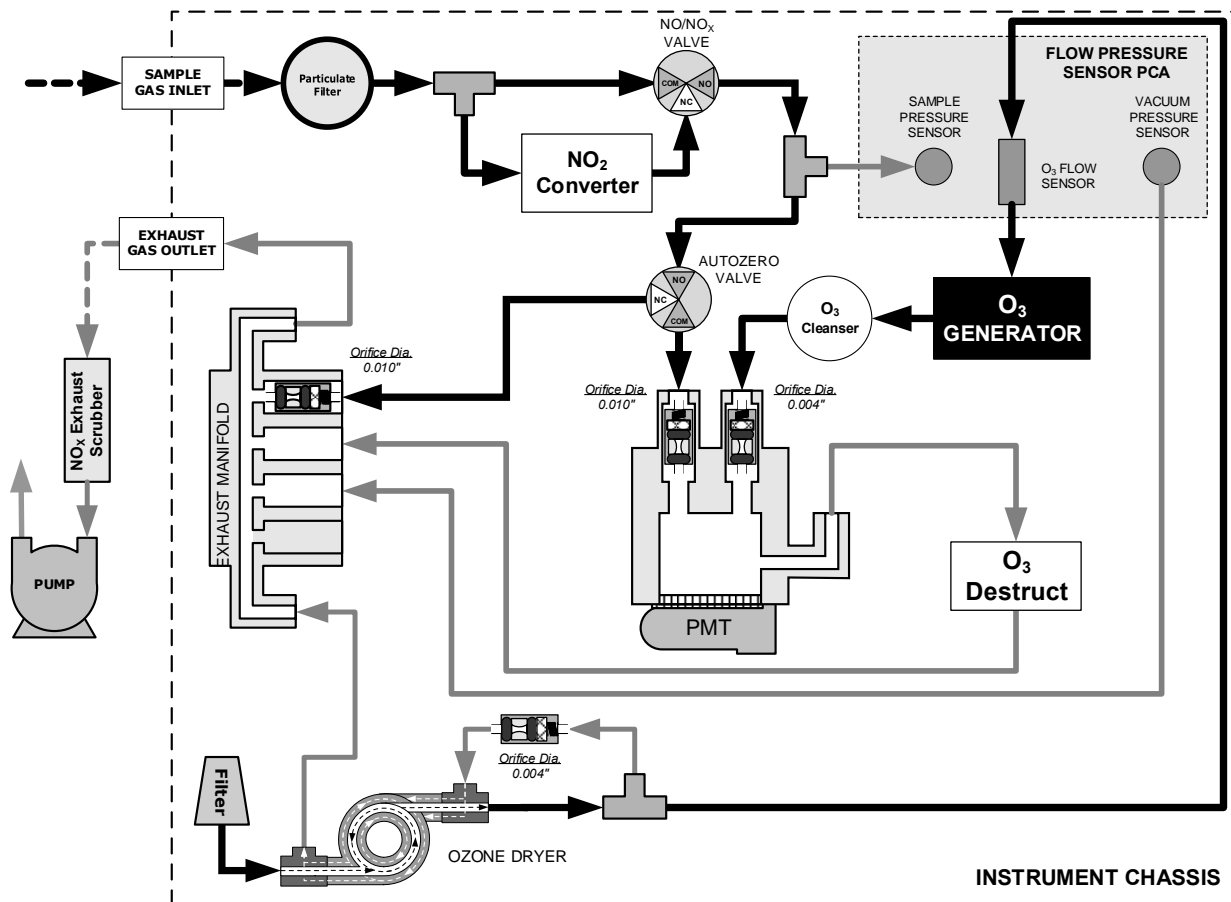


Figure 3-19: Pneumatics, Basic Configuration

## 3.3.2.3. CONNECTIONS W/AMBIENT ZERO/AMBIENT SPAN (Z/S) VALVES (OPT 50A)

This valve package includes:

- two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor
- two additional gas inlet ports (**ZERO AIR** and **SPAN1**)

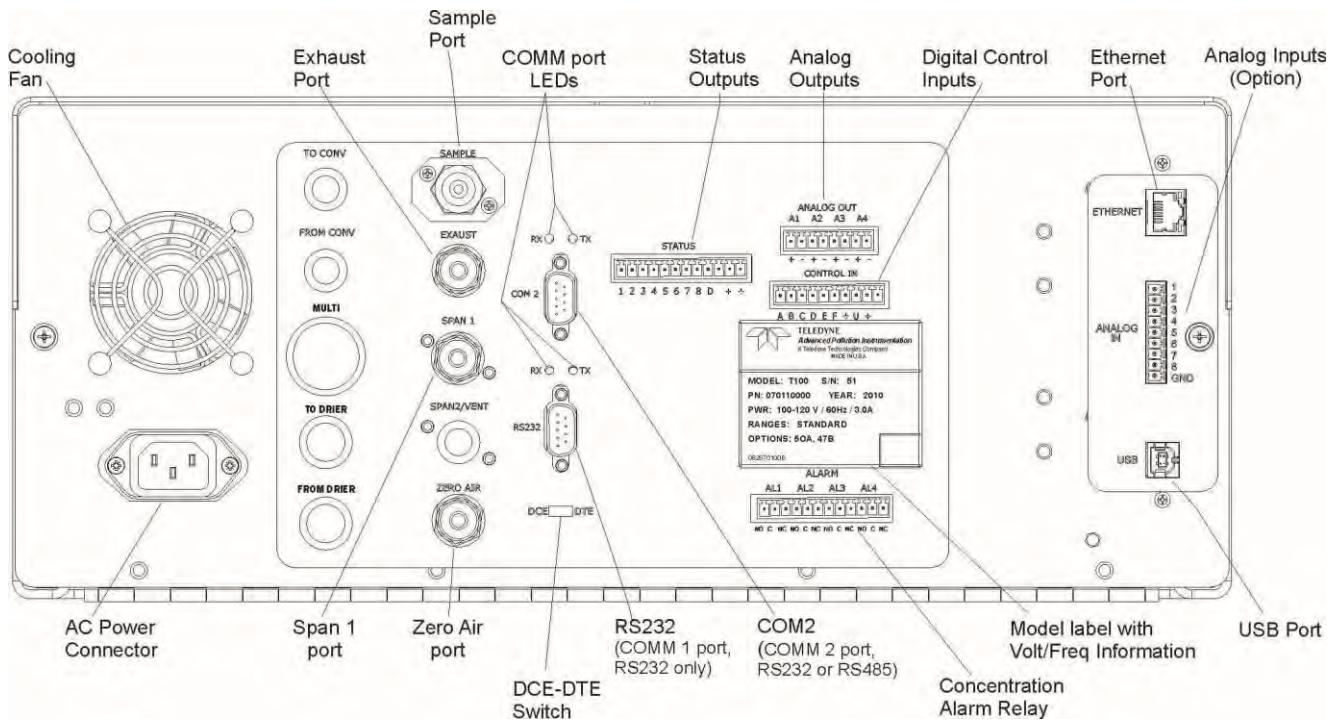


Figure 3-20: Rear Panel Layout with Z/S Valve Options (OPT 50A)

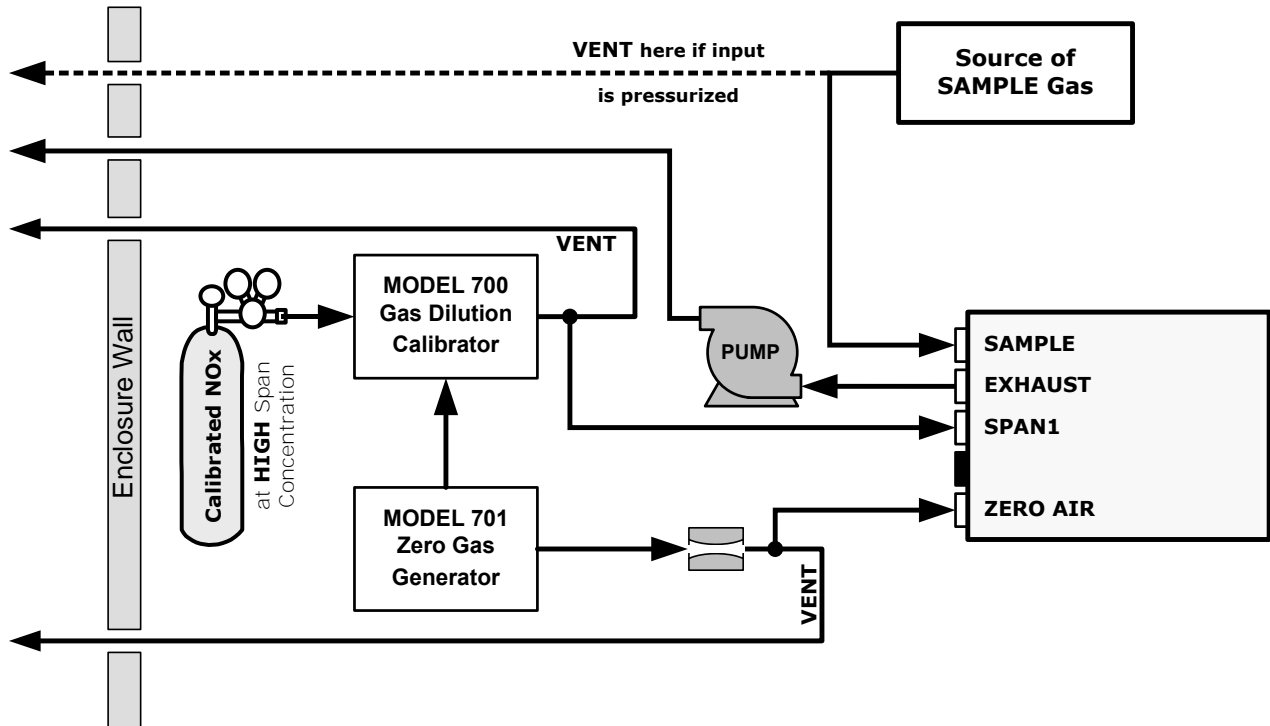


Figure 3-21: Gas Line Connections for T200 with Z/S Valves Option (OPT 50A)

**SAMPLE GAS SOURCE**

Attach a sample inlet line to the SAMPLE inlet fitting.

- Use PTFE tubing; minimum O.D 1/4".

- Sample Gas pressure must equal ambient atmospheric pressure (no greater than 1.0 psig).
- In applications where the sample gas is received from a pressurized manifold, a vent must be placed on the sample gas line. This vent line must be no more than 10 meters long.

### CALIBRATION GAS SOURCES

**SPAN GAS** Attach a gas line from the source of calibration gas (e.g. a Teledyne API's T700 Dynamic Dilution Calibrator) to the **SPAN1** inlet (see Figure 3-20). Use PTFE tubing; minimum O.D ¼".

**ZERO AIR** Zero air is supplied by the zero air generator such as a Teledyne API's M701. Attach a gas line from the source of zero air to the **ZERO AIR** inlet.

### VENTING

To prevent back diffusion and pressure effects, both the span gas and zero air supply lines should be:

- vented outside the enclosure
- not less than 2 meters in length
- not greater than 10 meters in length

### EXHAUST OUTLET

Attach an exhaust line to the **EXHAUST OUTLET** fitting. The exhaust line should be:

- ¼" PTFE tubing
- maximum 10 meters long
- vented outside the T200 analyzer's enclosure

### Note

---

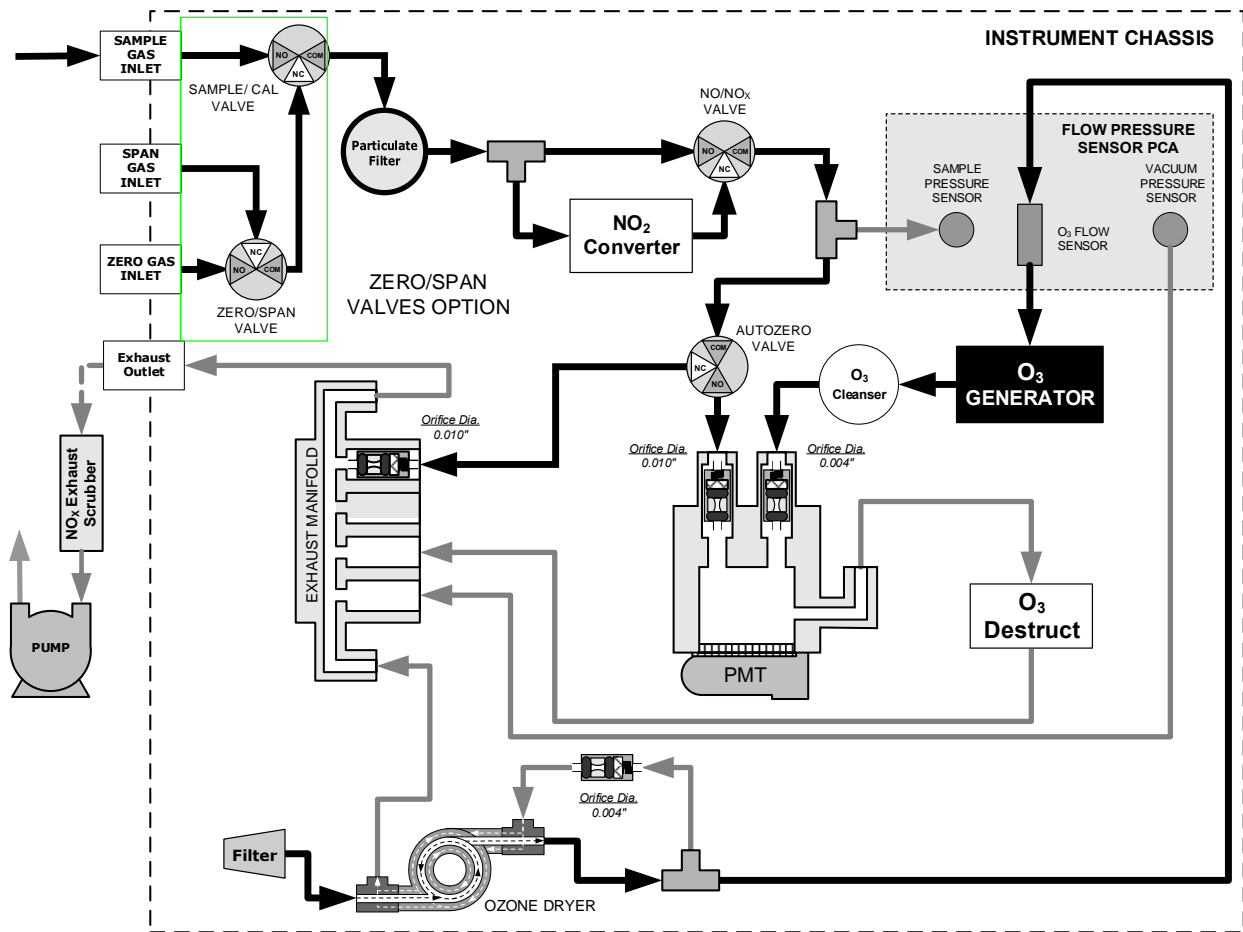
**Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Section 11.3.12.**

**For instructions on calibrating a T200 with this option installed, see Sections 9.2.3.2 and 9.4.**

---



**PNEUMATIC LAYOUT FOR AMBIENT ZERO/AMBIENT SPAN VALVES (OPT 50A)**



**Figure 3-22: Pneumatics with Zero/Span Valves OPT 50A**

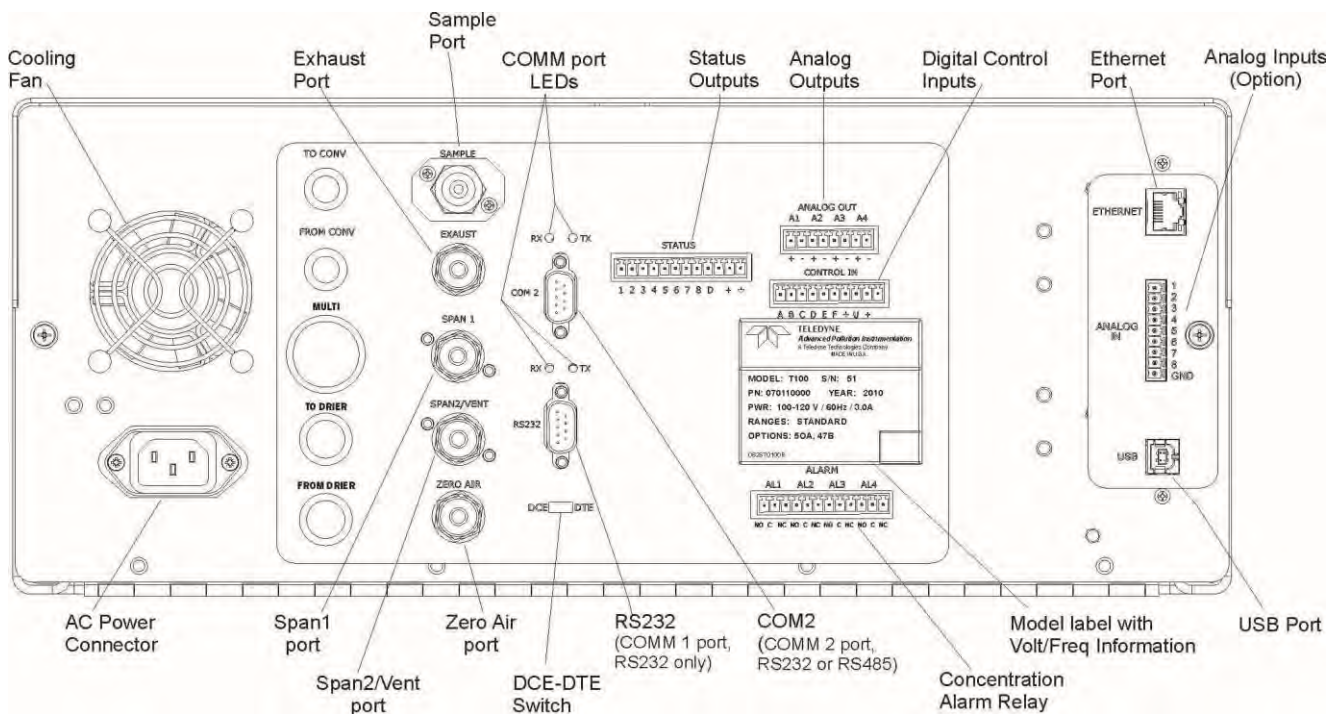
**Table 3-8: Zero/Span Valves Operating States OPT 50A**

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	NO → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to SPAN inlet	NC → COM

### 3.3.2.4. CONNECTIONS W/AMBIENT ZERO/PRESSURIZED SPAN VALVES (OPT 50B)

This calibration valve package is appropriate for applications where Span Gas is being supplied from a pressurized source such as bottled NIST SRM gases. This option includes:

- a critical flow orifice and vent to maintain the span Gas supply at 1 ATM
- a shutoff valve to preserve the span gas source when it is not in use
- two solenoid valves for the user to switch either zero, span or sample gas to the instrument's sensor
- three additional gas inlet ports (**ZERO AIR, SPAN** and **VENT**)



**Figure 3-23: Rear Panel Layout with Ambient Zero/Pressurized Span Valves OPT 50B**

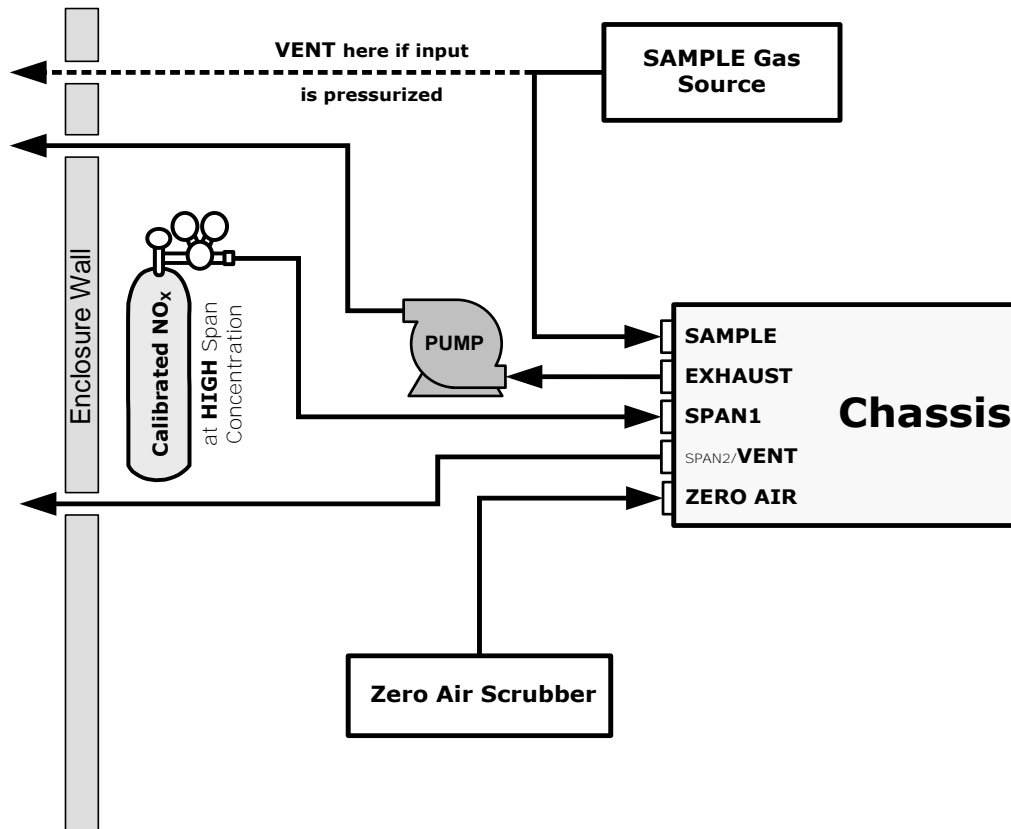


Figure 3-24: Gas Line Connection w/Ambient Zero/Pressurized Span Valves (OPT 50B)

### SAMPLE GAS SOURCE

Attach a sample inlet line to the SAMPLE inlet fitting.

- Use PTFE tubing; minimum O.D ¼”.
- Sample Gas pressure must equal ambient atmospheric pressure (29.92 in-Hg).
- In applications where the sample gas is received from a pressurized manifold, a vent must be placed on the sample gas line. This vent line must be:
  - no more than 10 meters long
  - vented outside the shelter or immediate area surrounding the instrument

### CALIBRATION GAS SOURCES

**SPAN GAS** Attach a gas line from the pressurized source of calibration gas (e.g. a bottle of NISTSRM gas) to the SPAN1 inlet. Use PTFE tubing, minimum O.D ¼”.

**ZERO AIR** (the dual-stage zero Air Scrubber makes zero air)

### VENTING

Attach a line to the SPAN2/VENT outlet. It should be:

- ¼” PTFE tubing
- vented outside the enclosure
- not less than 2 meters in length
- not greater than 10 meters in length

### EXHAUST OUTLET

Attach an exhaust line to the EXHAUST outlet fitting. The exhaust line should be:

- ¼" PTFE tubing
- a maximum of 10 meters long
- vented outside the T200 analyzer's enclosure

### PNEUMATIC LAYOUT FOR AMBIENT ZERO/PRESSURIZED SPAN (OPT 50B)

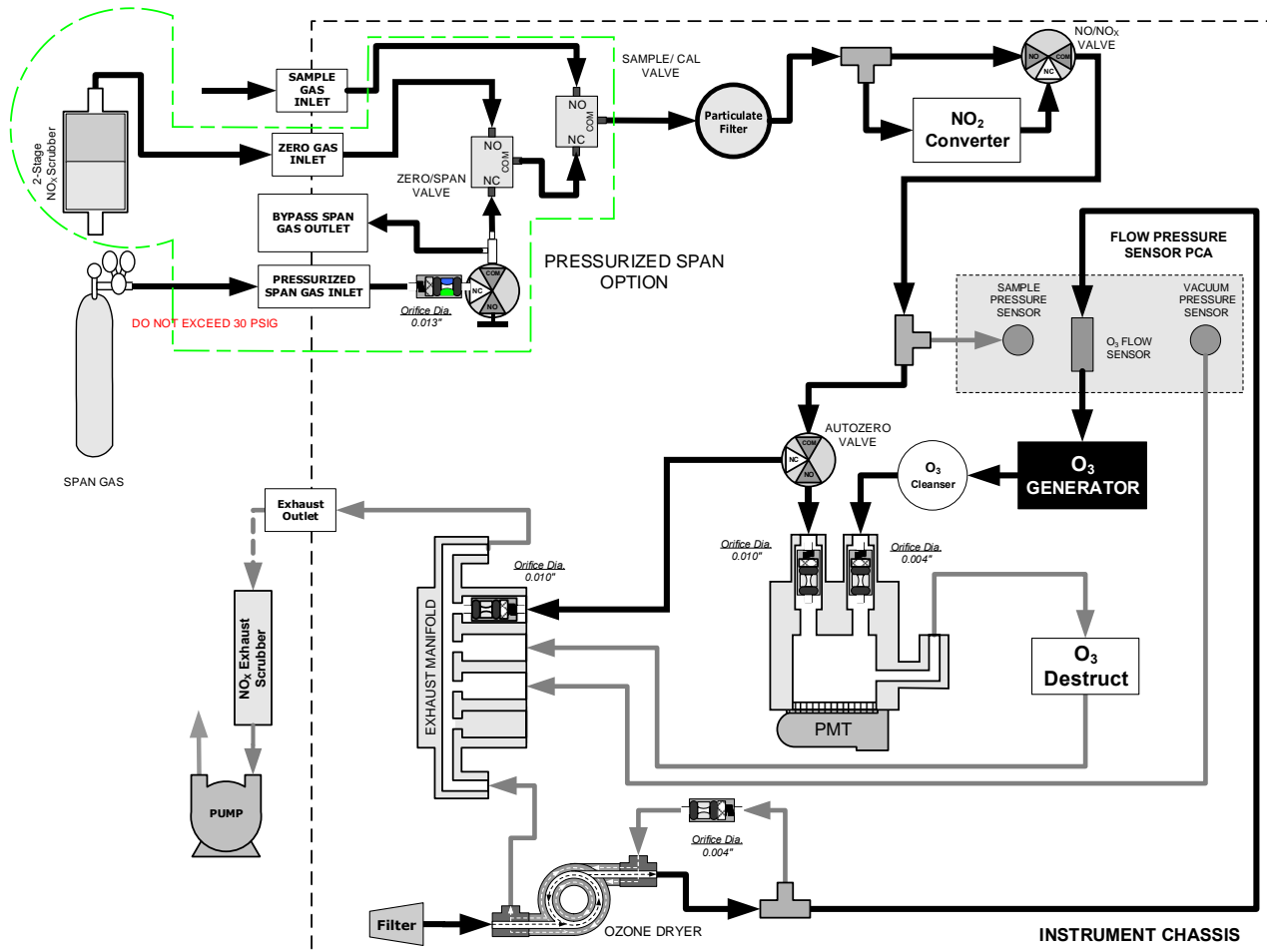


Figure 3-25: Pneumatics with Ambient Zero/Pressurized Span Valves (OPT 50B)

Table 3-9: Valve Operating States OPT 50B installed

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	NO → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
	Span Shutoff	Closed	
	Zero Air Shutoff	Closed	
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
	Span Shutoff	OPEN	
	Zero Air Shutoff <sup>1</sup>	Closed	
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to SPAN inlet	NC → COM
	Span Shutoff	Closed	
	Zero Air Shutoff	OPEN	

### 3.3.2.5. ZERO SCRUBBER AND INTERNAL SPAN SOURCE (IZS) (OPT 50G)

The internal NO<sub>2</sub> span gas generator and calibration valve option is intended for applications where there is a need for frequent automated calibration checks without access to an external source of span gas.

This valve package includes:

- a 2-stage external scrubber for producing zero air
  - 50% Purafil Chemisorbant<sup>®</sup> (for conversion of NO → NO<sub>2</sub>)
  - 50% charcoal (for removal of the NO<sub>2</sub>)
- a heated enclosure for a NO<sub>2</sub> permeation tube
  - This option package DOES NOT contain an actual permeation tube. See Table 1-1 for information on specifying the correct permeation tube for each application.
- a special desorber that removes all HNO<sub>3</sub> from the calibration gas stream
- one additional gas inlet port (**ZERO AIR**)
- one additional gas outlet port (**FROM DRYER**)
- two internal valves for switching between the sample gas inlet and the output of the zero/span subsystem

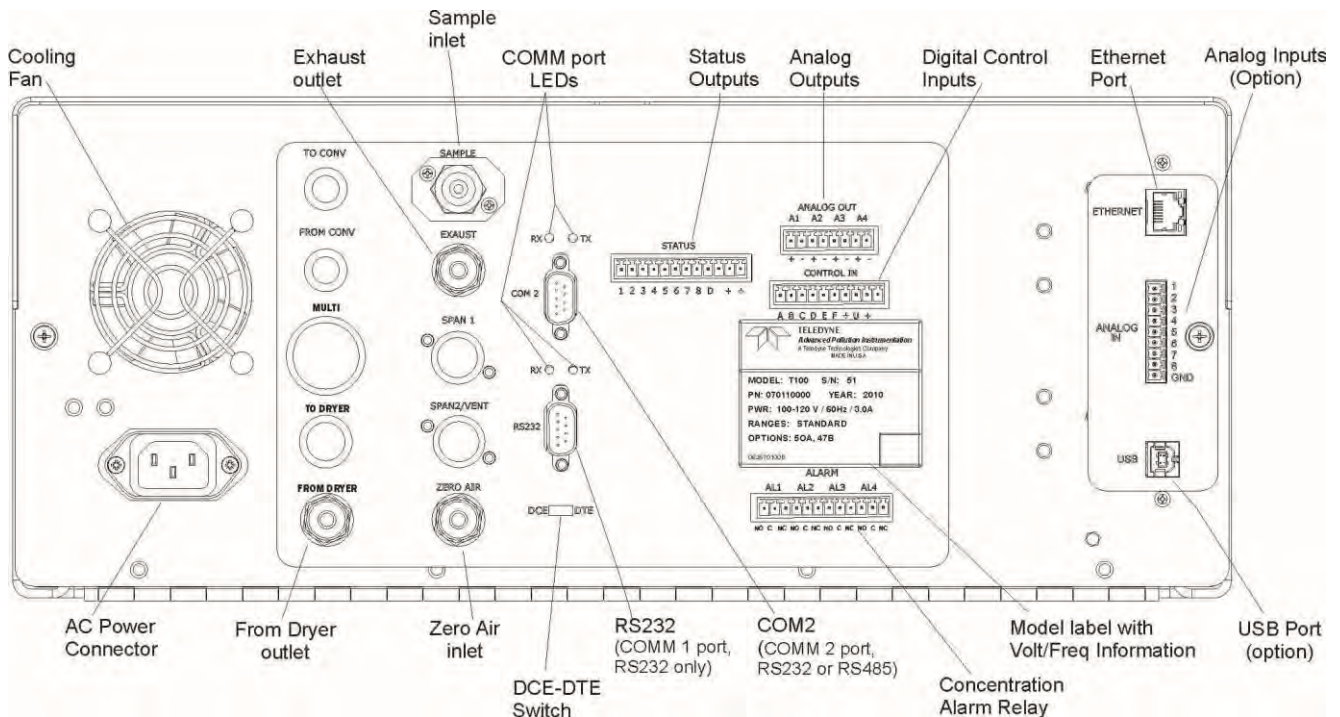


Figure 3-26: Rear Panel Layout with Internal Span Source (IZS) OPT 50G

### INTERNAL SPAN GAS GENERATION

The primary component of the internal span option is a permeation tube containing liquid NO<sub>2</sub>. As zero air is passed over a permeable membrane on the end of the tube, molecules of NO<sub>2</sub> slowly pass through the membrane mixing with the zero air.

The resulting concentration of the NO<sub>2</sub> span gas is determined by three factors:

- size of the membrane (the larger the area of the membrane, the more permeation occurs)
- temperature of the NO<sub>2</sub> (increasing the temperature of the permeation tube increases the pressure inside the tube, thereby increasing the rate of permeation)
- flow rate of the zero air (if the previous two variables are constant, the permeation rate of the NO<sub>2</sub> into the zero air stream will be constant; therefore, a lower flow rate of zero air produces higher concentrations of NO<sub>2</sub>)

In the Model T200 the permeation tube enclosure is heated to a constant 50° C (10° above the maximum operating temperature of the instrument) in order to keep the permeation rate constant. A thermistor measures the actual temperature and reports it to the CPU for control feedback.

The flow rate of zero air across the permeation tube is maintained at 50 ± 10 cm<sup>3</sup>/min by a critical flow orifice located in the analyzer's exhaust manifold.

## NITRIC ACID AND THE CHEMISTRY OF NO<sub>2</sub> PERMEATION TUBES

H<sub>2</sub>O reacts with NO<sub>2</sub> to form HNO<sub>3</sub> (nitric acid). The T200 mitigates this reaction by passing the air supply for the span gas generator through a special dryer; however, the permeable membrane of the NO<sub>2</sub> tube will still allow H<sub>2</sub>O from the ambient environment to slowly collect in the tube at increasingly higher concentrations. Over time this results in the presence of HNO<sub>3</sub> in the permeation tube which is exuded into the T200's pneumatics along with NO<sub>2</sub>.

HNO<sub>3</sub> is a liquid at room temperature, so once the HNO<sub>3</sub> is released by the permeation tube, it condenses and collects along the T200's wetted surfaces. While liquid HNO<sub>3</sub> does not directly affect the quality of NO<sub>x</sub> measurements of the T200, it does give off small amounts of gaseous HNO<sub>3</sub> which is converted into NO by the T200's NO<sub>x</sub> → NO converter, resulting in an artificially high NO<sub>2</sub> concentration by 8% to 12%. This is particularly bothersome when the T200 is attempting to measure a zero point, such as during calibration, since the NO<sub>2</sub> concentration will only reach a true zero point once the majority of the HNO<sub>3</sub> coating the wetted surfaces has reverted to NO<sub>2</sub> and this can take a very long time.

To resolve this, the T200 includes a special HNO<sub>3</sub> desorber, which eliminates any HNO<sub>3</sub> given off by the permeation tube before it can be converted into NO by the analyzer's converter.

## PNEUMATIC LAYOUT FOR ZERO SCRUBBER AND IZS (OPT 50G)

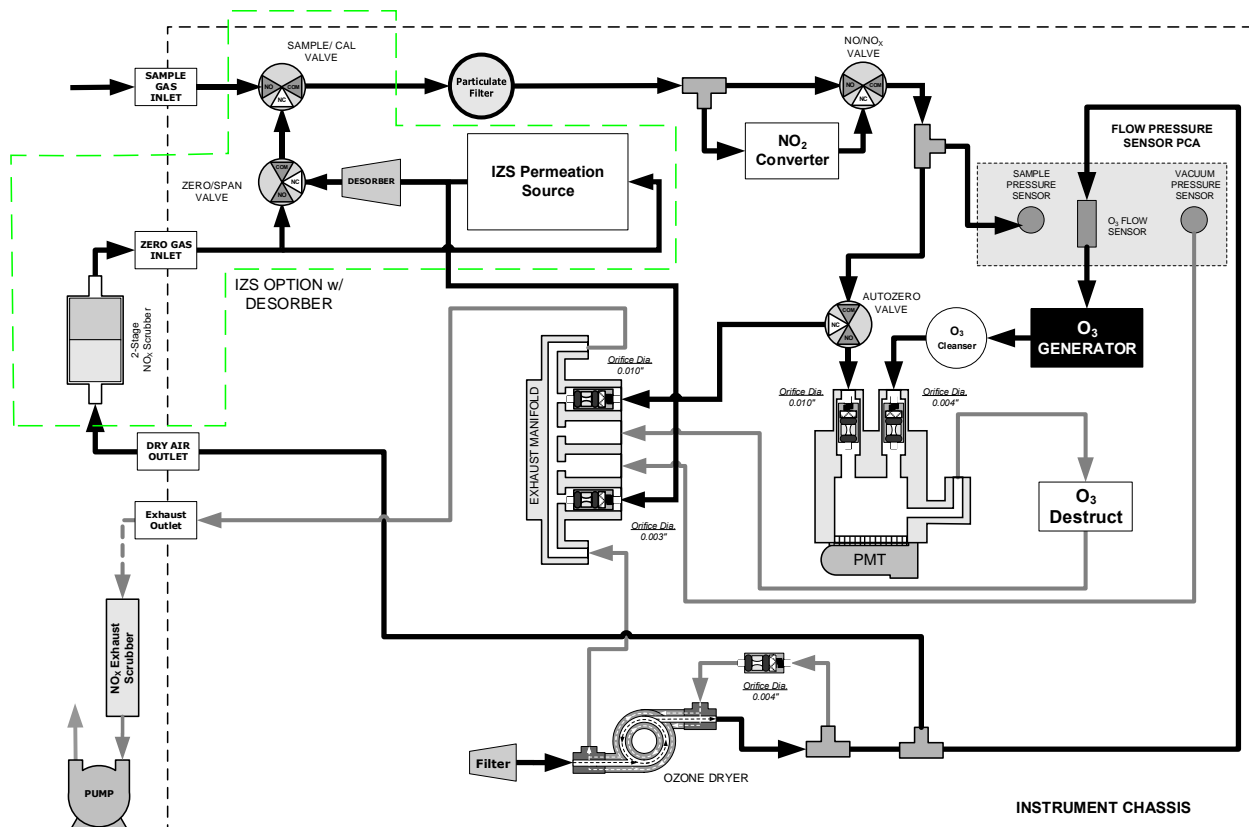


Figure 3-27: Pneumatics with the Internal Span Gas Generator (OPT 50G)

Table 3-10: Internal Span Gas Generator Valve Operating States OPT 50G

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	NO → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to SPAN inlet	NC → COM

3.3.2.6. GAS CONDITIONER OPTIONS

AMMONIA REMOVAL SAMPLE CONDITIONER (OPT 86A)

The T200 includes a permeation gas exchange tube to remove H<sub>2</sub>O from the ozone generator supply gas stream to a dew point of about -20° C (~600 ppm H<sub>2</sub>O) and effectively remove concentrations of ammonia (NH<sub>3</sub>) up to about 1 ppm.

An additional sample conditioner can be added to the T200’s sample gas stream.

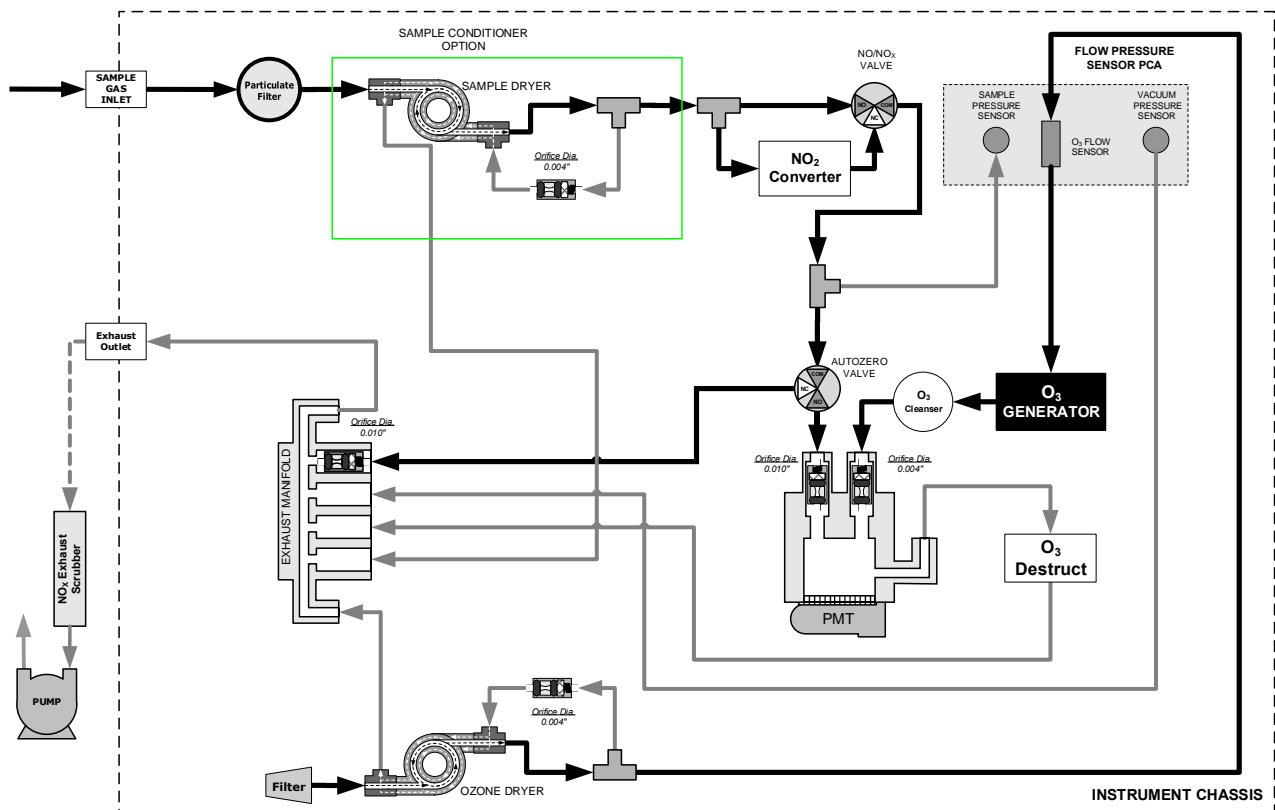


Figure 3-28: Pneumatics for Sample Conditioner OPT 86A



## 3.4. STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION



### CAUTION!

If the presence of ozone is detected at any time, power down the instrument and contact Teledyne API Technical Support as soon as possible:  
800-324-5190 or email: [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

We recommend that you read Section 13 to become familiar with the T200 principles of operation. For information on navigating the analyzer's software menus, see Appendix A.

### 3.4.1. START UP

After making the electrical and pneumatic connections, run an initial functional check. Turn on the instrument. The pump and exhaust fan should start immediately. The display will show a splash screen and other information during the initialization process while the CPU loads the operating system, the firmware, and the configuration data.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring the gas. However, there is an approximately one hour warm-up period before reliable gas measurements can be taken. During the warm-up period, the front panel display may show messages in the parameters (Param) field.

### 3.4.2. WARNING MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the analyzer's warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 30 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 12.1.

To view and clear warning messages, press:

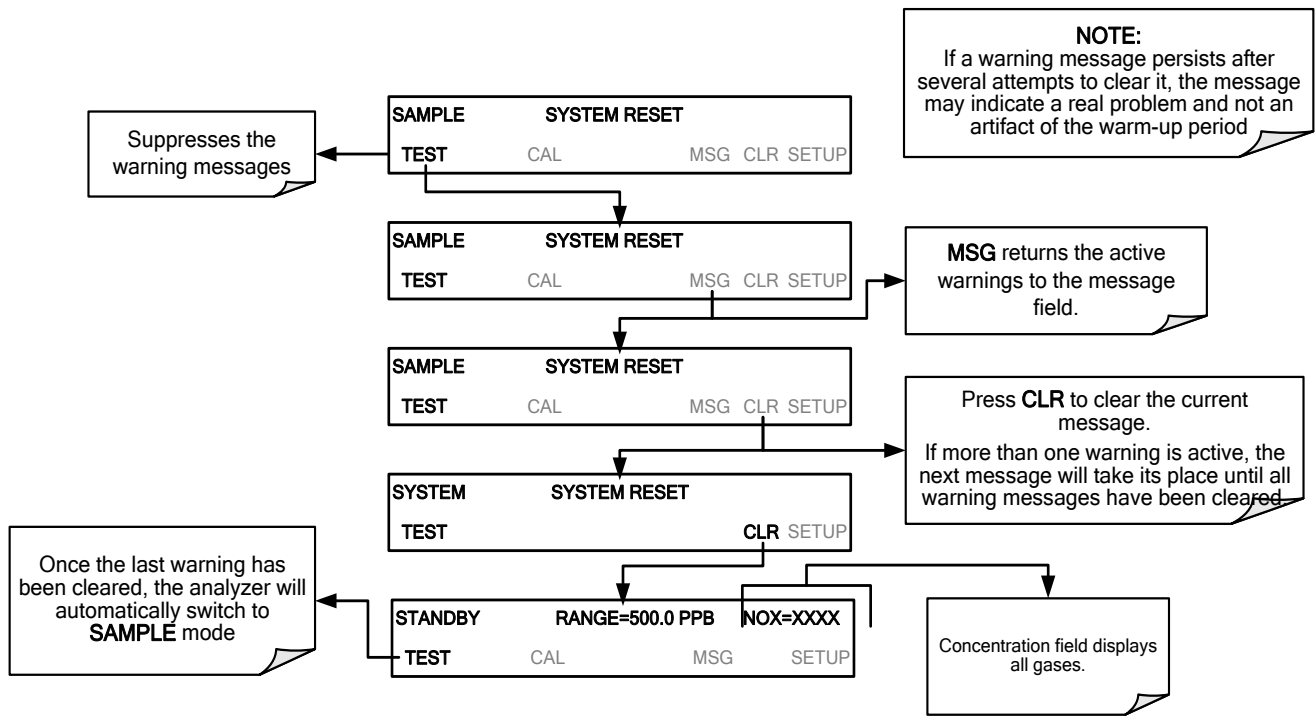


Table 3-11 lists brief descriptions of the warning messages that may occur during start up.

Table 3-11: Possible Warning Messages at Start-Up

MESSAGE	MEANING
SYSTEM RESET <sup>1</sup>	The computer has rebooted.
ANALOG CAL WARNING	The A/D or at least one D/A channel have not been calibrated.
BOX TEMP WARNING	The temperature inside the T200 chassis is outside the specified limits.
CANNOT DYN SPAN <sup>2</sup>	Contact closure span calibration failed while <i>DYN_SPAN</i> was set to <i>ON</i> .
CANNOT DYN ZERO <sup>3</sup>	Contact closure zero calibration failed while <i>DYN_ZERO</i> was set to <i>ON</i> .
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
DATA INITIALIZED	DAS data storage was erased before the last power up occurred.
OZONE FLOW WARNING	Ozone gas flow is too high or too low for accurate NO <sub>x</sub> , NO and NO <sub>2</sub> readings.
OZONE GEN OFF <sup>4</sup>	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on. Upon power up the Ozone generator will remain off for 30 minutes. This allows the ozone dryer to reach its working dew point.
RCELL PRESS WARN	Reaction cell pressure is too high or too low for accurate NO <sub>x</sub> , NO and NO <sub>2</sub> readings.
RCELL TEMP WARNING	Reaction cell temperature is too high or too low for accurate NO <sub>x</sub> , NO and NO <sub>2</sub> readings.
IZS TEMP WARNING <sup>5</sup>	IZS temperature is too high or too low for efficient O <sub>3</sub> production.
CONV TEMP WARNING	NO <sub>2</sub> to NO Converter temperature too high or too low to efficiently convert NO <sub>2</sub> to NO.
PMT TEMP WARNING	PMT temperature outside of warning limits.
AZERO WARN [XXXX] MV	AutoZero reading too high. The value shown in message indicates auto-zero reading at time warning was displayed.
HVPS WARNING	High voltage power supply output is too high or too low for proper operation of the PMT.
REAR BOARD NOT DET	CPU unable to communicate with motherboard..
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
<sup>1</sup> Clears 45 minutes after power up. <sup>2</sup> Clears the next time successful zero calibration is performed. <sup>3</sup> Clears the next time successful span calibration is performed. <sup>4</sup> Clears 30 minutes after power up. <sup>5</sup> Only Appears if the IZS option is installed.	

### 3.4.3. FUNCTIONAL CHECKS

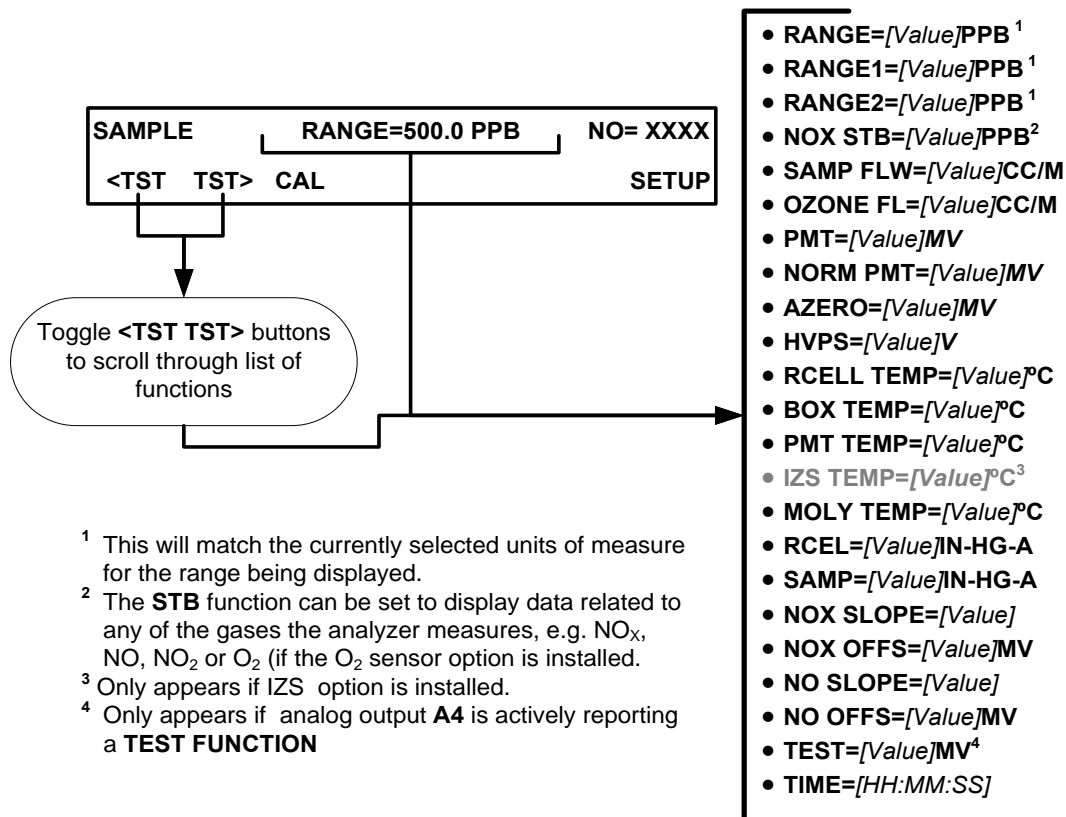
After the analyzer's components have warmed up for at least 60 minutes, verify that the software properly supports any hardware options that are installed.

For information on navigating through the analyzer's software menus, see the menu trees illustrated in Appendix A.1.

Check to ensure that the analyzer is functioning within allowable operating parameters.

- Appendix C includes a list of test functions viewable from the analyzer's front panel as well as their expected values.
- These functions are also useful tools for diagnosing problems with your analyzer.
- The enclosed Final Test and Validation Data sheet (P/N 04409) lists these values before the instrument left the factory.

To view the current values of these parameters press the following button sequence on the analyzer's front panel. Remember until the unit has completed its warm up these parameters may not have stabilized.



### 3.4.4. INITIAL CALIBRATION

To perform the following calibration you must have sources for zero air and calibration (span) gas available for input into the inlet/outlet fittings on the back of the analyzer (see Section 3.3.2.1).

**Note**

-----  
**A start-up period of 4-5 hours is recommended prior to performing a calibration on the analyzer.**  
-----

The method for performing an initial calibration for the T200 differs slightly depending on the whether or not any of the available internal zero air or valve options are installed.

- See Section 3.4.4.2 for instructions for initial calibration of the T200 analyzers in their base configuration.
- See Section 9.3 for instructions for initial calibration of T200 analyzers with an optional Internal Span Gas Generator (OPT 51A).
- See Section 9.4 for information regarding setup and calibration of T200 analyzers with Z/S Valve options.
- If you are using the T200 analyzer for EPA monitoring, refer to Section 10 for references and use only the EPA calibration method.

#### 3.4.4.1. Interferents for NO<sub>x</sub>, NO and NO<sub>2</sub> Measurements

The chemiluminescence method for detecting NO<sub>x</sub> is subject to interference from a number of sources including water vapor (H<sub>2</sub>O), ammonia (NH<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) but the T200 has been designed to reject most of these interferences.

- Ammonia is the most common interferent, which is converted to NO in the analyzer's NO<sub>2</sub> converter and creates a NO<sub>x</sub> signal artifact.
  - If the T200 is installed in an environment with high ammonia, steps should be taken to remove the interferent from the sample gas before it enters the reaction cell.
  - Teledyne API offers a sample gas conditioning option to remove ammonia and water vapor (Section 3.3.2.6).
- Carbon dioxide (CO<sub>2</sub>) diminishes the NO<sub>x</sub> signal when present in high concentrations.
  - If the analyzer is used in an application with excess CO<sub>2</sub>, contact Teledyne API's Technical Support Department (see Section 12.10) for possible solutions.
- Excess water vapor can be removed with one of the dryer options described in Section 3.3.2.6. In ambient air applications, SO<sub>2</sub> interference is usually negligible.

For more detailed information regarding interferents for NO<sub>x</sub>, NO and NO<sub>2</sub> measurement, see Section 13.1.5.

### 3.4.4.2. INITIAL CALIBRATION PROCEDURE FOR T200 ANALYZERS WITHOUT OPTIONS

The following procedure assumes that:

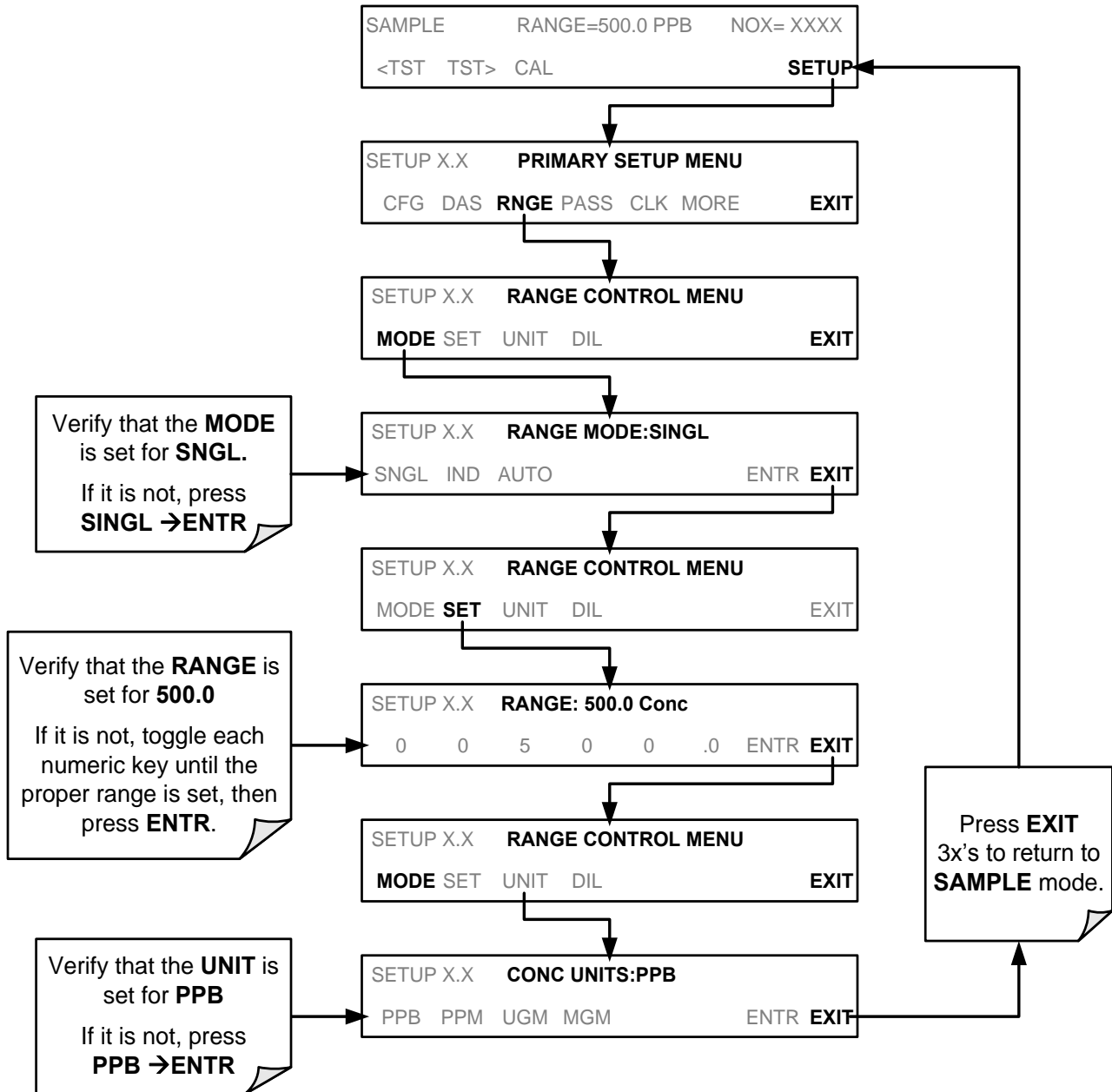
- The instrument DOES NOT have any of the available calibration valve or gas inlet options installed;
- Cal gas will be supplied through the SAMPLE gas inlet on the back of the analyzer and;
- The pneumatic setup matches that described in Section 3.3.2.

#### VERIFYING THE REPORTING RANGE SETTINGS

Although you can use any range setting, we recommend that you perform this initial checkout using following reporting range settings:

- Unit of Measure: PPB
- Reporting Range: 500 ppb
- Mode Setting: SNGL

While these are the default settings for the T200 analyzer, it is recommended that you verify them before starting the calibration procedure, by pressing the following menu button sequence:



**VERIFYING THE EXPECTED NO<sub>x</sub> AND NO SPAN GAS CONCENTRATION**

**IMPORTANT**

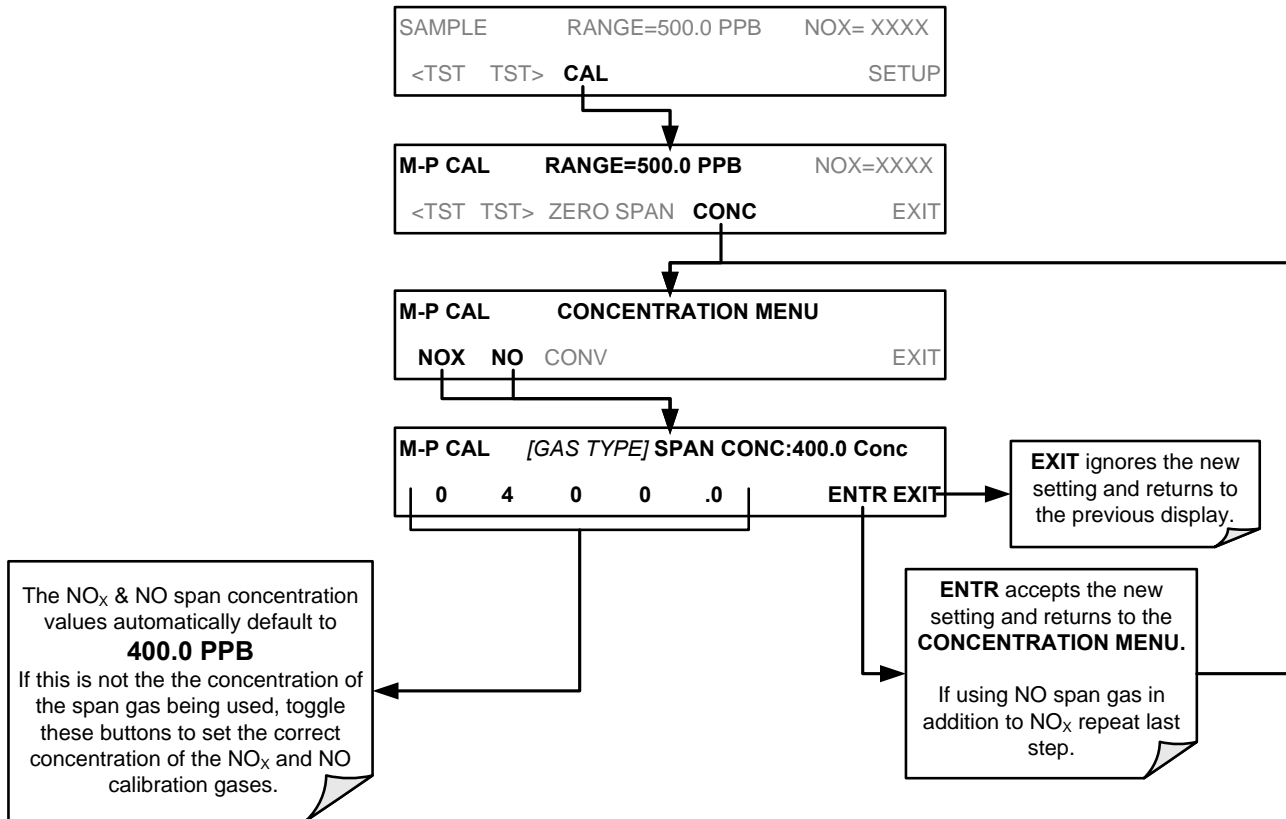
**IMPACT ON READINGS OR DATA**

Verify the **PRECISE** Concentration Value of the **SPAN** gases independently.

If you supply **NO** gas to the analyzer, the values for expected **NO** and **NO<sub>x</sub>** **MUST** be identical.

The **NO<sub>x</sub>** and **NO** span concentration values automatically defaults to **400.0 PPB** and it is recommended that calibration gases of that concentration be used for the initial calibration of the unit.

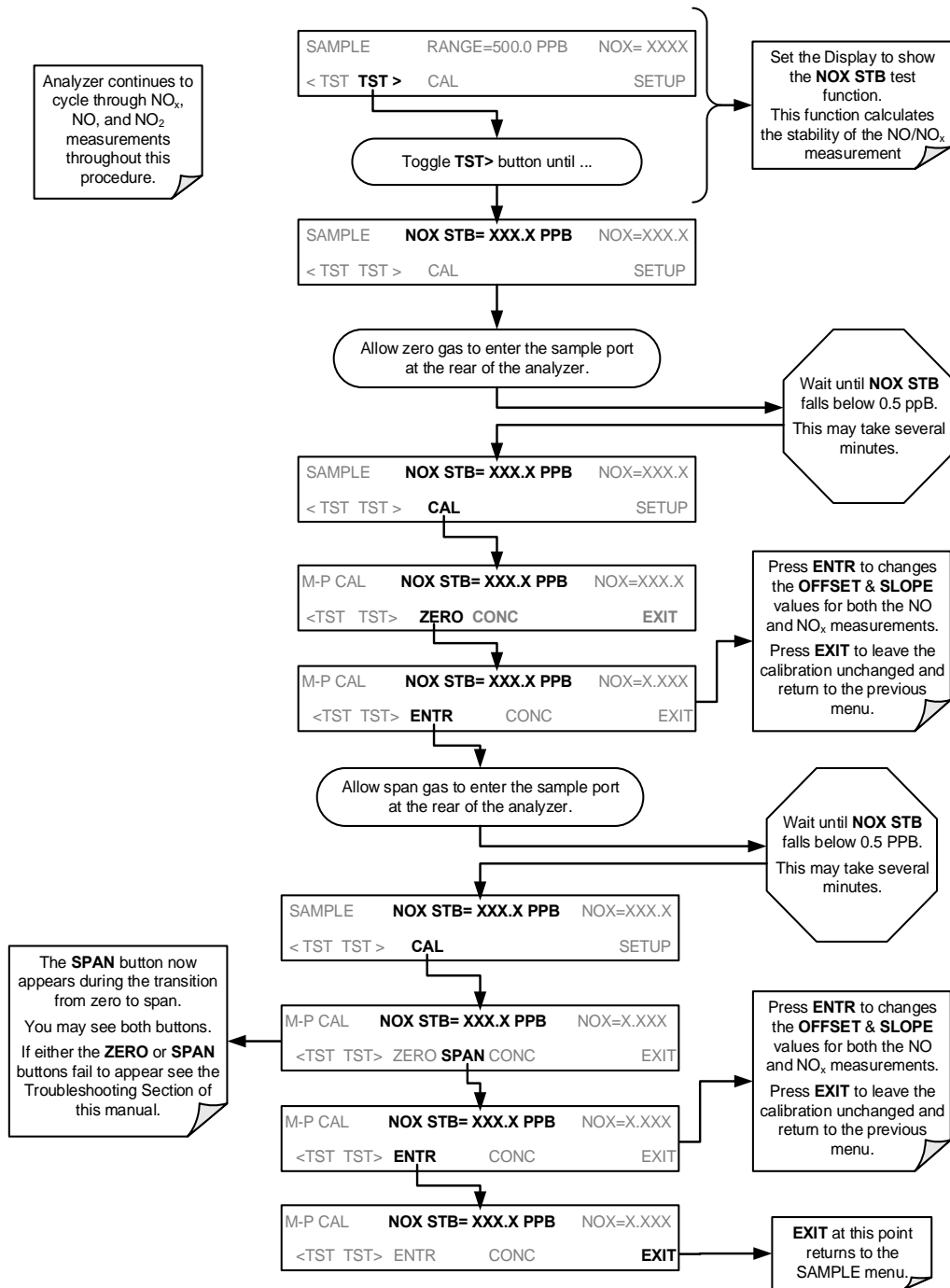
To verify that the analyzer span setting is set for **400 PPB**, press:



**INITIAL ZERO/SPAN CALIBRATION PROCEDURE**

To perform an initial calibration, press:





The T200 Analyzer is now ready for operation.

**Note**

Once you have completed the above set-up procedures, please fill out the Quality Questionnaire that was shipped with your unit and return it to Teledyne API. This information is vital to our efforts in continuously improving our service and our products. **THANK YOU.**

## 4. OVERVIEW OF OPERATING MODES

To assist in navigating the analyzer's software, a series of menu trees is available for reference in Appendix A of this manual.

### Note

Some control buttons on the touch screen do not appear if they are not applicable to the menu that you're in, the task that you are performing, the command you are attempting to send, or to incorrect settings input by the user. For example, the ENTR button may disappear if you input a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00. Once you adjust the setting to an allowable value, the ENTR button will reappear.

Of the several operating modes, **SAMPLE** mode is most common. In this mode, a continuous read-out of the NO<sub>x</sub> concentrations can be viewed on the front panel and can be output as an analog voltage from rear panel terminals.

**SETUP** is the next most common mode; it is used to configure the various sub systems, such as the Data Acquisition System (DAS), the reporting ranges, or the serial (RS-232 / RS-485 / Ethernet) communication channels. **SETUP** is also used for diagnostic tests during troubleshooting.



Figure 4-1: Front Panel Display

The mode field of the front panel display indicates to the user which operating mode the unit is currently running.

In addition to **SAMPLE** and **SETUP**, other modes the analyzer can be operated in are described in Table 7-1 below.

**Table 4-1: Analyzer Operating Modes**

MODE	EXPLANATION
<b>DIAG</b>	One of the analyzer's diagnostic modes is active.
<b>LO CAL A</b>	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer's AUTOCAL feature
<b>LO CAL R</b>	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
<b>M-P CAL</b>	This is the basic calibration mode of the instrument and is activated by pressing the CAL button.
<b>SAMPLE</b>	Sampling normally, flashing text indicates adaptive filter is on.
<b>SAMPLE A</b>	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
<b>SETUP X.#<sup>2</sup></b>	SETUP mode is being used to configure the analyzer. The gas measurement will continue during setup.
<b>SPAN CAL A<sup>1</sup></b>	Unit is performing SPAN calibration initiated automatically by the analyzer's AUTOCAL feature
<b>SPAN CAL M<sup>1</sup></b>	Unit is performing SPAN calibration initiated manually by the user.
<b>SPAN CAL R<sup>1</sup></b>	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
<b>ZERO CAL A<sup>1</sup></b>	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature
<b>ZERO CAL M<sup>1</sup></b>	Unit is performing ZERO calibration procedure initiated manually by the user.
<b>ZERO CAL R<sup>1</sup></b>	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.
<sup>1</sup> Only Appears on units with Z/S valve or IZS options.	
<sup>2</sup> The revision of the analyzer firmware is displayed following the word SETUP, e.g., SETUP G.3.	

## 4.1. SAMPLE MODE

This is the analyzer's standard operating mode where the instrument calculates NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations and displays their values in the **CONC** field of the display panel..

The **PARAM** field displays any warning messages and test functions, which provide information about the operational status of the analyzer.

### 4.1.1. TEST FUNCTIONS

**TEST** functions are displayed on the front panel whenever the analyzer is at the **MAIN MENU**, to provide information about the various parameters related to the analyzer's operation and its measurement of gas concentrations. This information is particularly useful when troubleshooting a performance problem with the T200 (see Section 13). See **Error! Reference source not found.** and Table 4-2 for the available **TEST** functions and their descriptions.

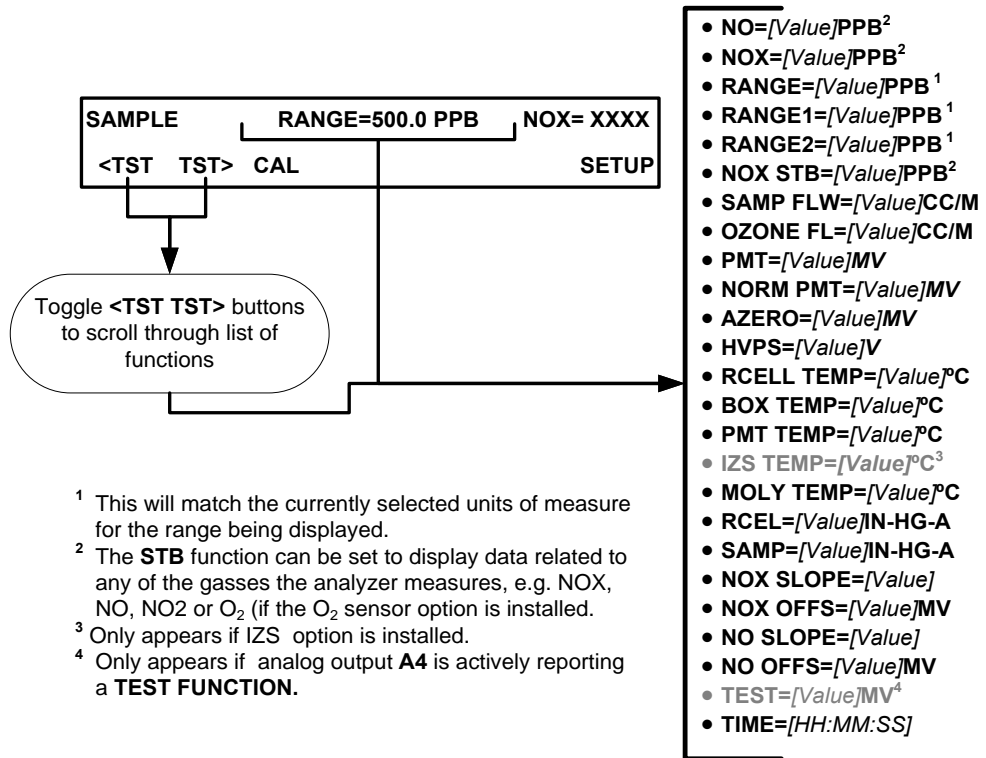


Figure 4-2: Viewing T200 Test Functions

Table 4-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
RANGE	RANGE	PPB, PPM, UGM & MGM	The Full Scale limit at which the reporting range of the analyzer's ANALOG OUTPUTS is currently set. <b>THIS IS NOT</b> the Physical Range of the instrument. See Section 5.4.1 for more information.
RANGE1 RANGE2			If <b>AUTO</b> Range mode has been selected, two <b>RANGE</b> functions will appear, one for each range: <ul style="list-style-type: none"> <li>• <b>RANGE1</b>: The range setting for all analog outputs.</li> <li>• <b>RANGE2</b>: The <b>HIGH</b> range setting for all analog outputs.</li> </ul>
RANGE1 RANGE2 RANGE3			If the <b>IND</b> Range mode has been selected, three <b>RANGE</b> functions will appear, one for each range: <ul style="list-style-type: none"> <li>• <b>RANGE1</b>: NO<sub>x</sub> concentration output un <b>A1</b>.</li> <li>• <b>RANGE2</b>: NO concentration output un <b>A2</b>.</li> <li>• <b>RANGE2</b>: NO<sub>2</sub> concentration output un <b>A3</b>.</li> </ul>
NOX STB	STABILITY	PPB	The standard deviation of concentration readings of the selected gas. <ul style="list-style-type: none"> <li>• Data points are recorded every ten seconds. The calculation uses the last 25 data points.</li> </ul>
SAMP FLW	SAMPFLOW	CC/M	Gas flow rate of the sample gas into the reaction cell.
OZONE FL	OZONEFLOW	CC/M	Gas flow rate of O <sub>3</sub> gas into the reaction cell.
PMT	PMT	MV	The raw signal output of the PMT.
NORM PMT	NORMPMT	MV	The signal output of the PMT after is has been normalized for temperature, pressure, auto-zero offset, but not range.
AZERO	AUTOZERO	MV	The PMT signal with zero NO <sub>x</sub> , which is usually slightly different from 0 V. This offset is subtracted from the PMT signal and adjusts for variations in the zero signal.

DISPLAY	PARAMETER	UNITS	DESCRIPTION
HVPS	HVPS	V	The output power level of the high voltage power supply.
RCELL TEMP	RCELLTEMP	C	The temperature of the gas inside the reaction cell temperature.
BOX TEMP	BOXTEMP	C	The temperature inside the analyzer chassis.
PMT TEMP	PMTTEMP	C	The temperature of the PMT .
IZS TEMP <sup>1</sup>	IZSTEMP	C	The temperature of the internal span gas generator's permeation tube.
MOLY TEMP	CONVTEMP	C	The temperature of the analyzer's NO <sub>2</sub> → NO converter.
RCEL	RCELLPRESS	IN-HG-A	The current pressure of the sample gas in the reaction cell as measured at the vacuum manifold.
SAMP	SAMPPRESS	IN-HG-A	The current pressure of the sample gas as it enters the reaction cell, measured between the NO/NO <sub>x</sub> and Auto-Zero valves.
NOX SLOPE	NOXSLOPE		The slope calculated during the most recent NO <sub>x</sub> zero/span calibration.
NOX OFFS	NOXOFFSET	MV	The offset calculated during the most recent NO <sub>x</sub> zero/span calibration.
NO SLOPE	NOSLOPE		The slope calculated during the most recent NO zero/span calibration.
NO OFFS	NOOFFSET	MV	The offset calculated during the most recent NO zero/span calibration.
TEST	TESTCHAN	MV	Displays the signal level of the Test Function that is currently being produced by the Analog Output Channel <b>A4</b> .
TIME	CLOCKTIME	HH:MM:SS	The current time. This is used to create a time stamp on DAS readings, and by the AutoCal feature to trigger calibration events.

<sup>1</sup>Only appears if Internal Span Gas Generator option is installed.

**IMPORTANT****IMPACT ON READINGS OR DATA**

A value of –XXXX” displayed for any of the TEST functions indicates an out-of-range reading or the analyzer’s inability to calculate it. All pressure measurements are represented in terms of absolute pressure. Absolute, atmospheric pressure is 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 300 m gain in altitude. A variety of factors such as air conditioning and passing storms can cause changes in the absolute atmospheric pressure.

## 4.1.2. WARNING MESSAGES

Warning Messages, listed in Table 4-3, are displayed on the analyzer's front panel when failures occur.

**Table 4-3: Warning Messages Defined**

MESSAGE	MEANING
<b>ANALOG CAL WARNING</b>	The A/D or at least one D/A channel has not been calibrated.
<b>AZERO WARN</b>	Auto-zero reading above set limit. Value shown in message indicates auto-zero reading at time warning was displayed.
<b>BOX TEMP WARNING</b>	The temperature inside the T200 chassis is outside the specified limits.
<b>CANNOT DYN SPAN</b>	Contact closure span calibration failed while <i>DYN_SPAN</i> was set to <i>ON</i> .
<b>CANNOT DYN ZERO</b>	Contact closure zero calibration failed while <i>DYN_ZERO</i> was set to <i>ON</i> .
<b>CONFIG INITIALIZED</b>	Configuration storage was reset to factory configuration or erased.
<b>CONV TEMP WARNING</b>	NO <sub>2</sub> → NO converter temperature outside of warning limits.
<b>DATA INITIALIZED</b>	DAS data storage was erased before the last power up occurred.
<b>HVPS WARNING</b>	High voltage power supply output outside of warning limits.
<b>IZS TEMP WARNING</b> <sup>1</sup>	IZS temperature outside of warning limits specified by <i>IZS_SET</i> variable.
<b>OZONE FLOW WARNING</b>	Ozone flow outside of warning limits.
<b>OZONE GEN OFF</b>	Ozone generator is off. This warning message clears itself when the ozone generator is turned on.
<b>PMT TEMP WARNING</b>	PMT temperature outside of warning limits.
<b>RCELL PRESS WARN</b>	Reaction cell pressure outside of warning limits.
<b>RCELL TEMP WARNING</b>	Reaction cell temperature outside of warning limits.
<b>REAR BOARD NOT DET</b>	Motherboard was not detected during power up.
<b>RELAY BOARD WARN</b>	CPU is unable to communicate with the relay PCA.
<b>SAMPLE FLOW WARN</b>	The flow rate of the sample gas is outside the specified limits.
<b>SYSTEM RESET</b>	The computer has rebooted.

<sup>1</sup> Only Appears if the Internal Span Gas Generator option is installed.

## 4.2. CALIBRATION MODE

The CAL button switches the analyzer into calibration mode. In conjunction with introducing zero or span gases of known concentrations into the analyzer, the user can adjust and recalculate the slope (gain) and offset of the measurement range. CAL mode is also used to check the current calibration status of the instrument.

If the instrument includes one of the available zero/span valve options, the SAMPLE mode display will also include CALZ and CALS buttons. Pressing either of these buttons also puts the instrument into calibration mode.

- The **CALZ** button is used to initiate a calibration of the analyzer's zero point using internally generated zero air.
- The **CALS** button is used to calibrate the span point of the analyzer's current reporting range using span gas.

### Note

---

**It is recommended that this span calibration be performed at 80% of full scale of the analyzer's currently selected reporting range.**

#### EXAMPLES:

**If the reporting range is set for 0 to 500 ppb, an appropriate span point would be 400 ppb.**

**If the of the reporting range is set for 0 to 1000 ppb, an appropriate span point would be 800 ppb.**

---

Due to their critical importance and complexity, calibration operations are described in detail in other sections of the manual:

- Section 9 details setting up and performing standard calibration operations or checks.
- Section 10 provides references for guidance in setting up and performing EPA protocol calibrations.

For information on using the automatic calibrations feature (**ACAL**) in conjunction with the one of the calibration valve options, see Sections 9.4.3 and 9.5.

### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

**To avoid inadvertent adjustments to critical settings, activate calibration security by enabling password protection in the SETUP – PASS menu (Section 5.5).**

---

## 4.3. SETUP MODE

Use SETUP Mode to configure the analyzer's hardware and software features, perform diagnostic procedures, gather information on the instrument's performance and configure or access data from the internal data acquisition system (DAS). For a visual representation of the software menu trees, refer to Appendix A.

SETUP Mode is divided between Primary and Secondary Setup menus and can be protected through password security.

### 4.3.1. PASSWORD SECURITY

Protect SETUP Mode with a security password through the SETUP>PASS menu (Section 5.5) to prevent unauthorized or inadvertent configuration adjustments.

### 4.3.2. PRIMARY SETUP MENU

The areas accessed and configured under the primary SETUP Mode menu are shown in Table 4-4.

**Table 4-4: Primary Setup Mode Features and Functions**

MODE OR FEATURE	CONTROL BUTTON LABEL	DESCRIPTION	MANUAL SECTION
Analyzer Configuration	<b>CFG</b>	Lists button hardware and software configuration information.	5.1
<i>Auto Cal Feature</i>	<b>ACAL</b>	<i>Used to set up and operate the AutoCal feature.</i> <ul style="list-style-type: none"> <li>• Only appears if the analyzer has one of the calibration valve options installed.</li> </ul>	5.2, 9.5
Internal Data Acquisition (DAS)	<b>DAS</b>	Used to set up the DAS system and view recorded data.	7
Analog Output Reporting Range Configuration	<b>RNGE</b>	Used to configure the output signals generated by the instruments analog outputs.	5.4
Calibration Password Security	<b>PASS</b>	Turns the calibration password feature ON/OFF.	5.5
Internal Clock Configuration	<b>CLK</b>	Used to set or adjust the instrument's internal clock.	5.6
Secondary <b>SETUP</b> Mode (Advanced <b>SETUP</b> features)	<b>MORE</b>	This button accesses the instruments secondary setup menu.	See Table 4-5



### 4.3.3. SECONDARY SETUP MENU (SETUP → MORE)

The areas accessed and configured under the secondary SETUP Mode menu are shown in Table 4-5.

**Table 4-5: Secondary Setup Mode Features and Functions**

MODE OR FEATURE	CONTROL BUTTON LABEL	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	<b>COMM</b>	Used to set up and operate the analyzer's various external I/O channels including RS-232; RS-485, modem communication and/or Ethernet access.	8
System Status Variables	<b>VARS</b>	Used to view various variables related to the instruments current operational status. <ul style="list-style-type: none"> <li>• Changes made to any variable are not acknowledged and recorded in the instrument's memory until the <b>ENTR</b> button is pressed.</li> <li>• Pressing the <b>EXIT</b> button ignores the new setting.</li> <li>• If the <b>EXIT</b> button is pressed before the <b>ENTR</b> button, the analyzer will beep alerting the user that the newly entered value has been lost.</li> </ul>	5.8
System Diagnostic Features and Analog Output Configuration	<b>DIAG</b>	Used to access a variety of functions that are used to configure, test or diagnose problems with a variety of the analyzer's basic systems. Most notably, the menus used to configure the output signals generated by the instruments' analog outputs are located here.	5.9, 5.9.2

#### IMPORTANT

##### IMPACT ON READINGS OR DATA

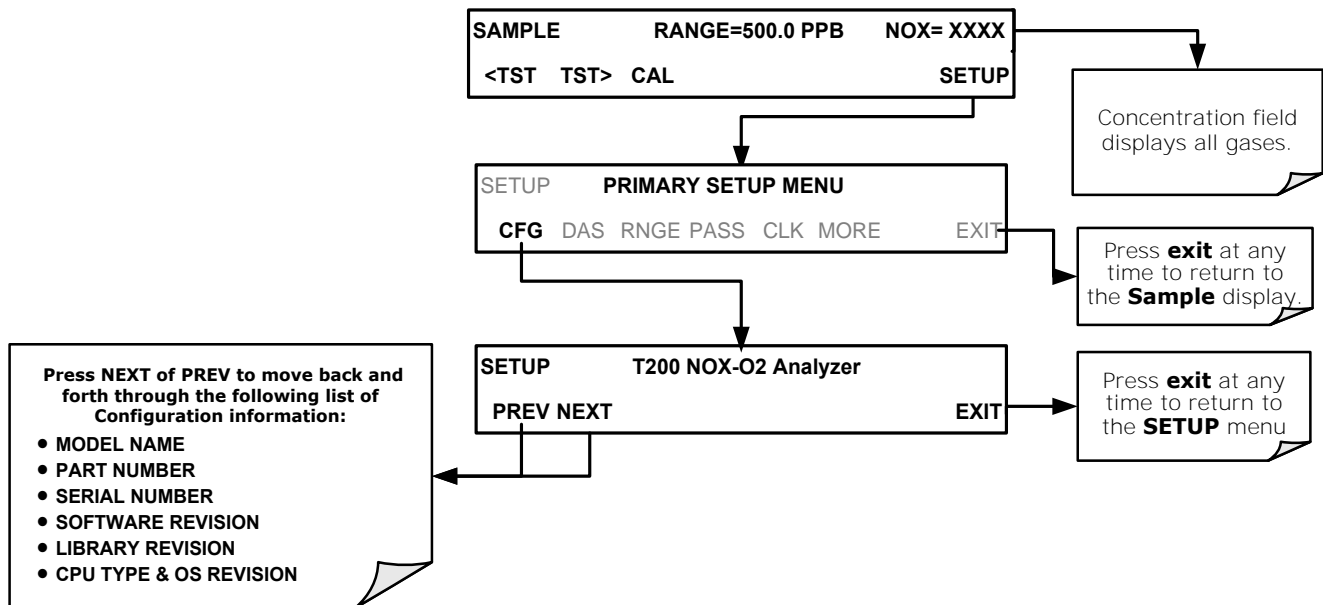
Any changes made to a variable during the SETUP procedures are not acknowledged by the instrument until the ENTR button is pressed. If the EXIT button is pressed before the ENTR button, the analyzer will make an audible signal before exiting the menu, alerting the user that the newly entered value had not been accepted.

## 5. SETUP MODE MENUS

Use SETUP Mode to set instrument parameters for performing configuration, calibration, reporting and diagnostics operations according to user needs.

### 5.1. SETUP → CFG: CONFIGURATION INFORMATION

Pressing the CFG button displays the instrument configuration information, which lists the analyzer model, serial number, firmware revision, software library revision, CPU type and other information. Use CFG to identify the software and hardware when contacting Technical Support. Special instrument or software features or installed options may also be listed here.



## 5.2. SETUP →ACAL: AUTOMATIC CALIBRATION OPTION

The menu button for this option appears only when the instrument has the zero span and/or IZS options. Section 9.5 provides details.

## 5.3. SETUP →DAS: INTERNAL DATA ACQUISITION SYSTEM

Use the SETUP>DAS menu to capture and record data. Section 7 provides configuration and operation details.

## 5.4. SETUP →RNGE: ANALOG OUTPUT REPORTING RANGE CONFIGURATION

Use the SETUP>RNGE menu to configure output reporting ranges, including scaled reporting ranges to handle data resolution challenges. This section describes configuration for Single, Dual, and Auto Range modes.

### 5.4.1. T200 PHYSICAL RANGES

The T200 measures NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations from 2 to 20,000 ppb.

Electronically the T200 analyzer converts the 0-5 volt analog signal output by the PMT to a digital signal with 4096 counts of resolution. Since its measurement range is 0 ppb to 20,000 ppb, this only allows about 3 ppb per count. While this might be acceptable for high concentration measurements made in parts per million units (ppm), it is not good enough for lower level NO<sub>x</sub> measurements. To overcome this limitation the T200 is designed with two physical measurement ranges:

- **LOW** range to measure concentration from 0 ppb to 2,000 ppb with a resolution of 0.27 ppb per count
- **HIGH** range to measure the full 20,000 ppb range of the analyzer

The analyzer's CPU chooses the appropriate range based on how the user sets up the reporting ranges for the instrument's analog outputs: when an analog range is selected with a lower limit between 0 and 2000 ppb, the analyzer will utilize its low physical range. When an analog range is in use that has a reporting range with an upper limit set between 2001 and 20,000 ppb, the instrument will operate in its high physical range.

Once both ranges have been using the same span gas values, the analyzer's front panel will accurately report concentrations between 0 and 20,000 ppb, seamlessly switching between the low and high physical ranges regardless of the selected analog reporting range.

### 5.4.2. T200 ANALOG OUTPUT REPORTING RANGES

For applications using chart recorders or other analog recording devices, the T200's 20,000 ppb physical range can cause resolution problems. For example, in an application where the expected concentrations of NO, NO<sub>2</sub> and NO<sub>x</sub> are typically less than 500 ppb, the full scale of expected values is only 2.5% of the instrument's 20,000 ppb physical range. The corresponding output signal would then only be recorded across 2.5% of the range of the recording device.

The T200 solves this problem by allowing the user to select a reporting range for the analog outputs that only includes that portion of the physical range that covers the specific application. This increases the reliability and accuracy of the analyzer by avoiding additional gain-amplification circuitry.

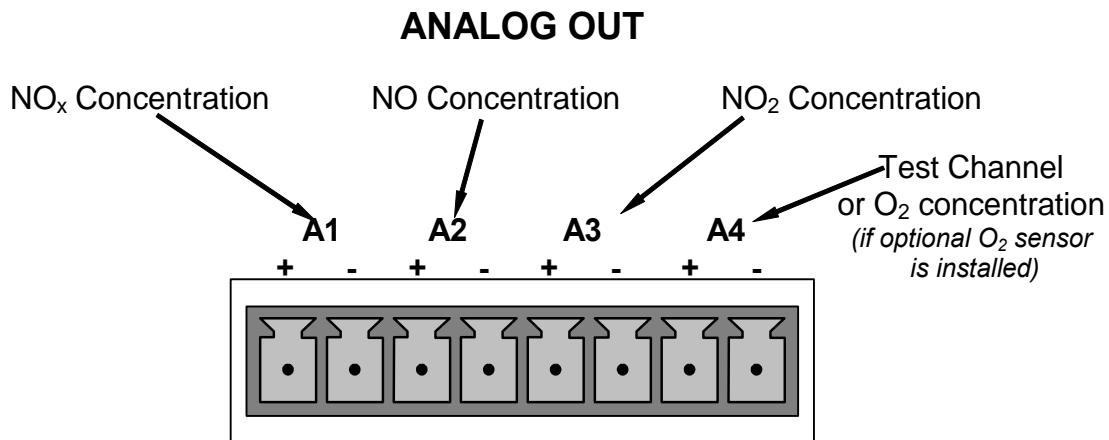
**Note**

Only the reporting range of the analog outputs is scaled.

Both the DAS values stored in the CPU's memory and the concentration values reported on the front panel are unaffected by the settings chosen for the reporting range(s) of the instrument.

#### 5.4.2.1. ANALOG OUTPUT RANGES FOR NO<sub>x</sub>, NO AND NO<sub>2</sub> CONCENTRATION

The analyzer has three active analog output signals related to NO<sub>x</sub>, NO and NO<sub>2</sub> concentration, accessible through a connector on the rear panel.



**Figure 5-1: Analog Output Connector Pin Out**

The **A1**, **A2** and **A3** channels output a signal proportional to the NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations of the sample gas, respectively. The T200 can be set so that these outputs operate in one of three modes: single range mode, independent range mode, or automatic range mode (Section 5.4.3).

Additionally, the signal levels of **A1**, **A2** and **A3** outputs can be:

- Configured full scale outputs of: 0 - 0.1 VDC; 0 – 1 VDC; 0 – 5 VDC or; 0 – 10 VDC
- Equipped with optional 0-20 mADC current loop drivers (see Section 3.3.1.4 ) and configured for any current output within that range analog output (e.g. 0-20 mA, 2-20 mA, 4-20 mA, etc.)

Together these two sets of parameters allow the user a great deal of flexibility in how the instrument reports NO<sub>x</sub> , NO and NO<sub>2</sub> concentration to external devices. For example, using the **IND** mode the following configuration could be created:

**A1** OUTPUT: NO<sub>x</sub> Output Signal = 4 – 20 mA representing 0-1000 ppb concentration values

**A2 OUTPUT:** NO Output Signal = 0 – 10 VDC representing 0-500 ppb concentration values.

**A3 OUTPUT:** NO<sub>2</sub> Output Signal = 0 – 5 VDC representing 0-500 ppb concentration values.

The user may also add a signal offset independently to each output (see Section 5.9.3.9) to match the electronic input requirements of the recorder or data logger to which the output is connected.

**IMPORTANT****IMPACT ON READINGS OR DATA**

The instrument does not remember upper range limits settings associated with the individual modes. Changes made to the range limits (e.g. 400 ppb → 600 ppb) when in one particular mode will alter the range limit settings for the other modes.

When switching between reporting range modes, ALWAYS check and reset the upper range limits for the new mode selection..

**5.4.2.2. ANALOG OUTPUT REPORTING RANGE DEFAULT SETTINGS**

The default setting for these the reporting ranges of the analog output channels **A1**, **A2** and **A3** are:

- SNGL mode
- 0 to 500.0 ppb
- 0 to 5 VDC

**5.4.3. SETUP → RNGE → MODE**

Single range mode (SNGL) reports all three of the NO<sub>x</sub> gas concentrations using the same reporting range span (see Section 5.4.3.1).

Independent range mode (IND) allows the NO<sub>x</sub>, NO and NO<sub>2</sub> analog outputs to be set with different reporting range spans (see Section 5.4.3.2).

Automatic range mode (AUTO) allows the analyzer to automatically switch the reporting range between two user upper span limits (designated LOW and HIGH) based on the actual concentrations being measured for each (see Section 5.4.3.3). These are not the same as the analyzer's low and high physical ranges (Section 5.4.1).

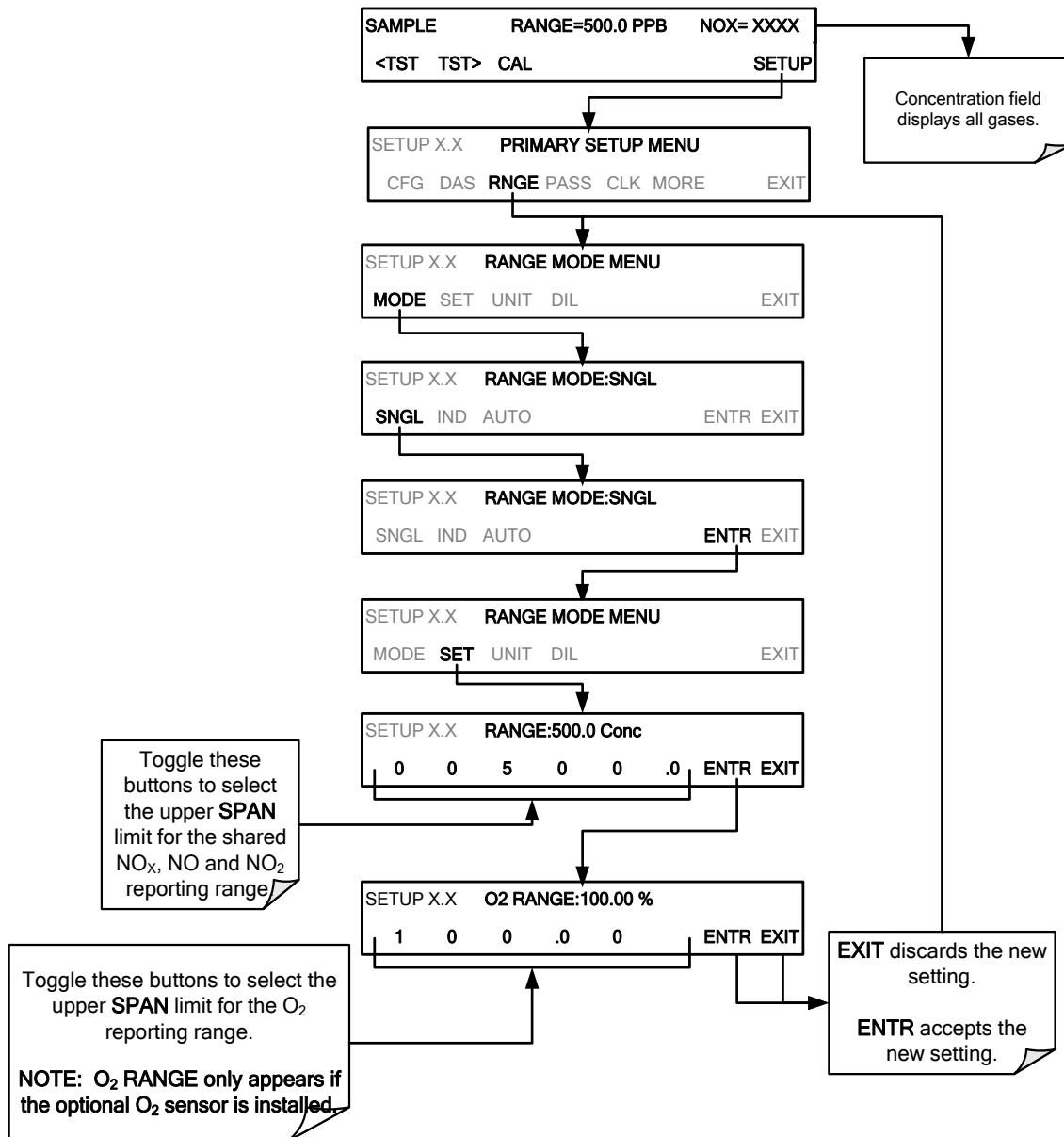
**5.4.3.1. SETUP → RNGE → MODE → SNGL: CONFIGURING THE T200 ANALYZER FOR SINGLE RANGE MODE****Note**

**Single Range is the default reporting range mode for the analyzer.**

When the single range mode is selected (SNGL), all analog NO<sub>x</sub>, NO and NO<sub>2</sub> concentration outputs (**A1**, **A2** and **A3**) are slaved together and set to the same reporting range limits (e.g. 500.0 ppb). This reporting range can be set to any value between 100 ppb and 20,000 ppb.

Although all three NO<sub>x</sub> outputs share the same concentration reporting range, the electronic signal ranges of the analog outputs may still be configured for different values (e.g. 0-5 VDC, 0-10 VDC, etc; see Section 5.9.3.1).

To select **SNGL** range mode and to set the upper limit of the range, press:



### 5.4.3.2. SETUP → RNGE → MODE → IND: CONFIGURING THE T200 ANALYZER FOR INDEPENDENT RANGE MODE

The independent range mode (**IND**) assigns the three NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations to individual analog output channels. In **IND** range mode the **RANGE** test function displayed on the front panel will then be replaced by three separate functions:

**Table 5-1: IND Mode Analog Output Assignments**

TEST FUNCTION	CONCENTRATION REPORTED	ANALOG OUTPUT CHANNEL
<b>RANGE1</b>	NO <sub>x</sub>	A1
<b>RANGE2</b>	NO	A2
<b>RANGE3</b>	NO <sub>2</sub>	A3

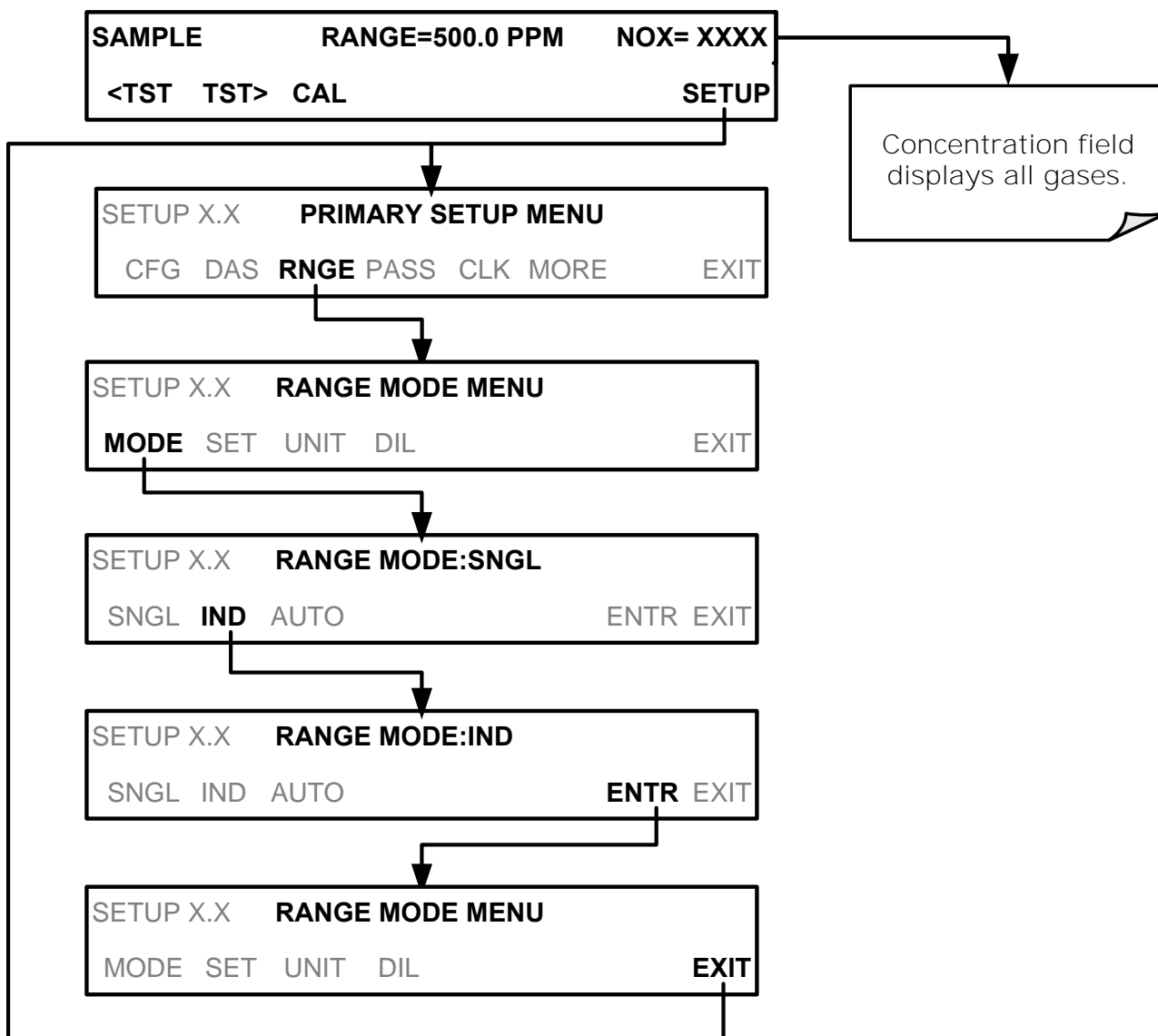
Each can be configured with a different reporting range upper limit and analog signal span:

EXAMPLE:

- NO<sub>x</sub> Concentration – **RANGE1** Set for 0-800 ppb & output **A1** set for 0-10 VDC
- NO Concentration – **RANGE2** Set for 0-200 ppb & output **A2** set for 0-5 VDC
- NO<sub>2</sub> Concentration – **RANGE3** Set for 0-400 ppb & output **A3** set for 0-5 VDC

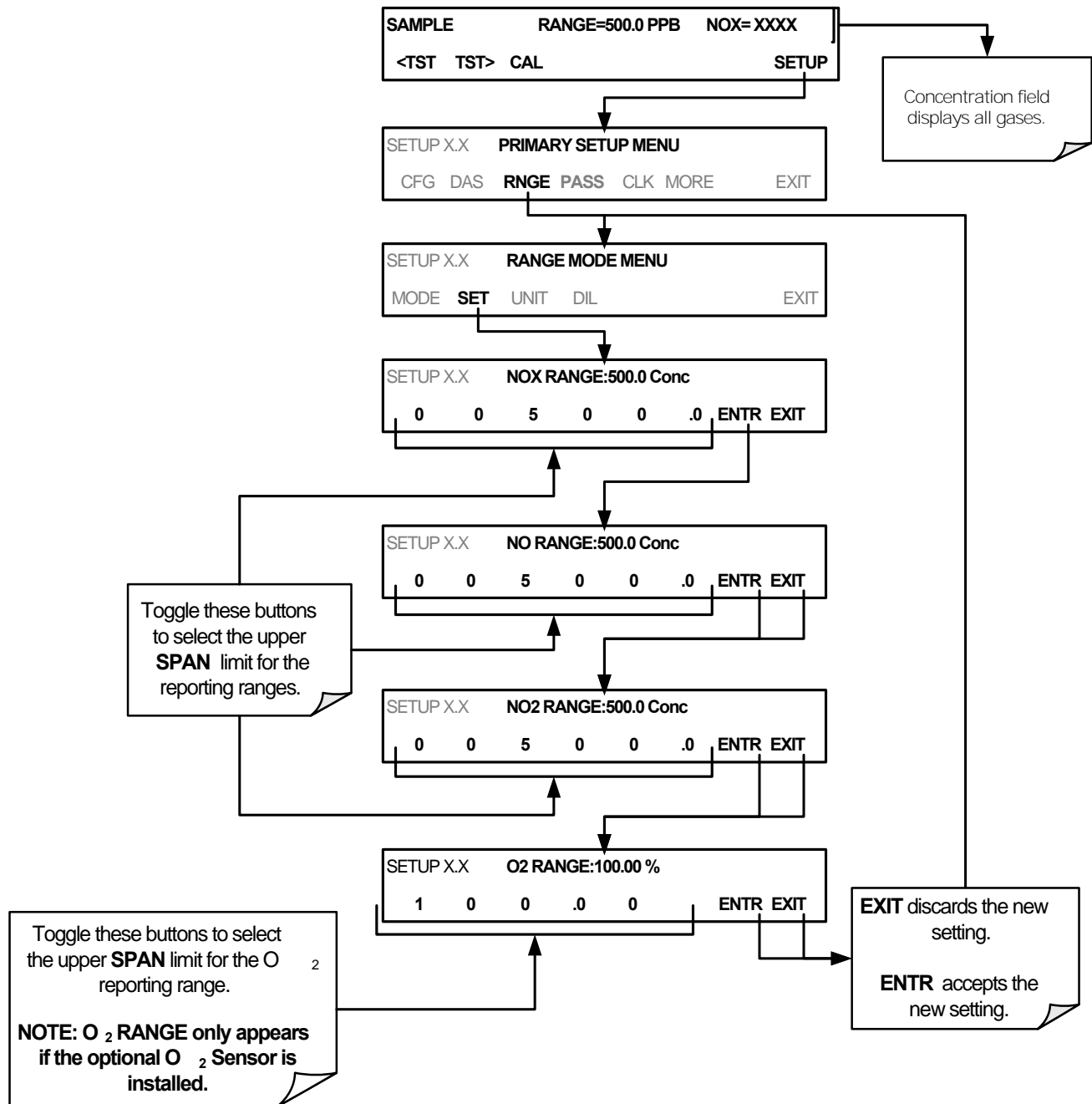
Setting analog range limits to different values does not affect the instrument's calibration.

To select the **IND** range mode, press the following buttons:





To set the upper range limit for each independent reporting range, press:



### 5.4.3.3. SETUP → RNGE → MODE → AUTO: CONFIGURING THE T200 ANALYZER FOR AUTO RANGE MODE

In AUTO range mode, the analyzer automatically switches the reporting range between two user-defined ranges (LOW and HIGH). The same low and high span settings are applied equally to NO, NO<sub>2</sub> and NO<sub>x</sub> readings.

- The unit will switch from **LOW** range to **HIGH** range when either the NO, or NO<sub>x</sub> concentration exceeds 98% of the low range span.
- The unit will return from **HIGH** range back to **LOW** range once both the NO and NO<sub>x</sub> concentrations fall below 75% of the low range span.

#### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

The **LOW & HIGH** ranges referred to here are **NOT** the same as the low & high physical ranges referred to in Section 5.4.1.

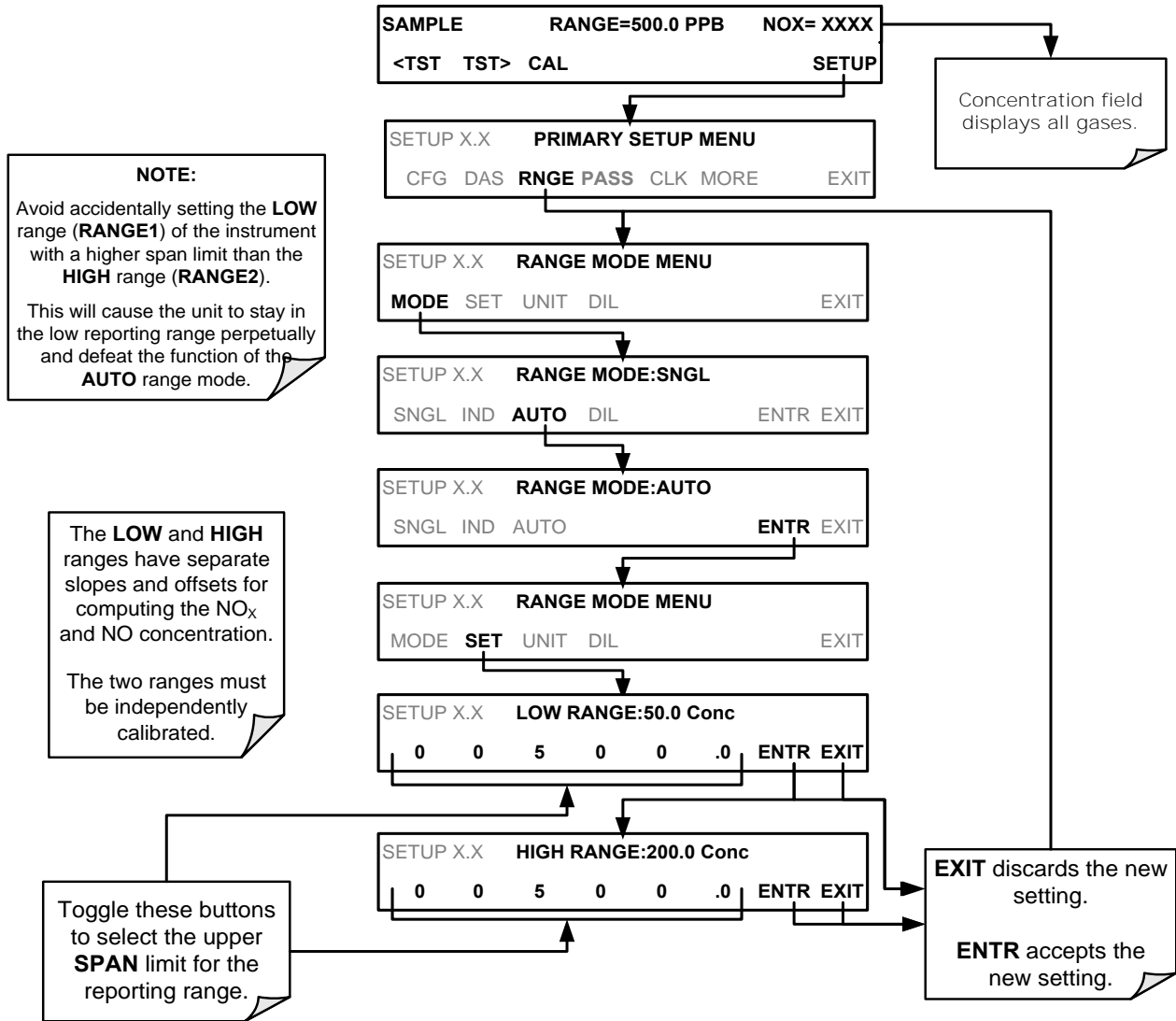
---

Also the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

- RANGE1: The LOW range setting for all analog outputs
- RANGE2: The HIGH range setting for all analog outputs

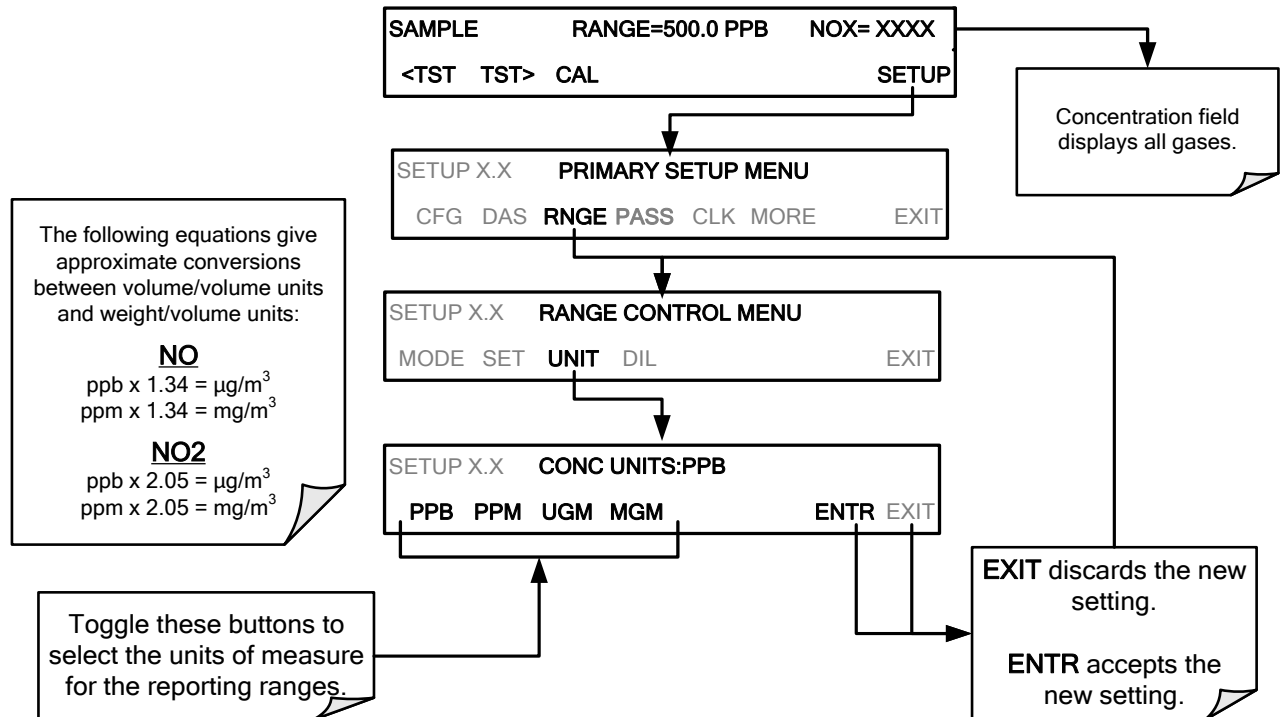
The **LOW/HIGH** range status is also reported through the external, digital status bits (Section 3.3.1.4).

To set individual ranges press the following menu sequence:



#### 5.4.3.4. SETUP → RNGE → UNIT: SETTING THE REPORTING RANGE UNITS OF MEASURE

The T200 can display and report concentrations in ppb, ppm, ug/m<sup>3</sup>, mg/m<sup>3</sup> units. Changing units affects all of the COM port values, and all of the display values for all reporting ranges. To change the units of measure press:



#### IMPORTANT

##### IMPACT ON READINGS OR DATA

Concentrations displayed in mg/m<sup>3</sup> and ug/m<sup>3</sup> use 0°C @ 760 mmHg for Standard Temperature and Pressure (STP).

Consult your local regulations for the STP used by your agency. (Example: US EPA uses 25°C as the reference temperature).

Once the Units of Measurement have been changed from volumetric (ppb or ppm) to mass units (ug/m<sup>3</sup> or mg/m<sup>3</sup>) the analyzer **MUST** be recalibrated, as the –expected span values” previously in effect will no longer be valid.

Simply entering new expected span values without running the entire calibration routine is not sufficient. This will also counteract any discrepancies between STP definitions.

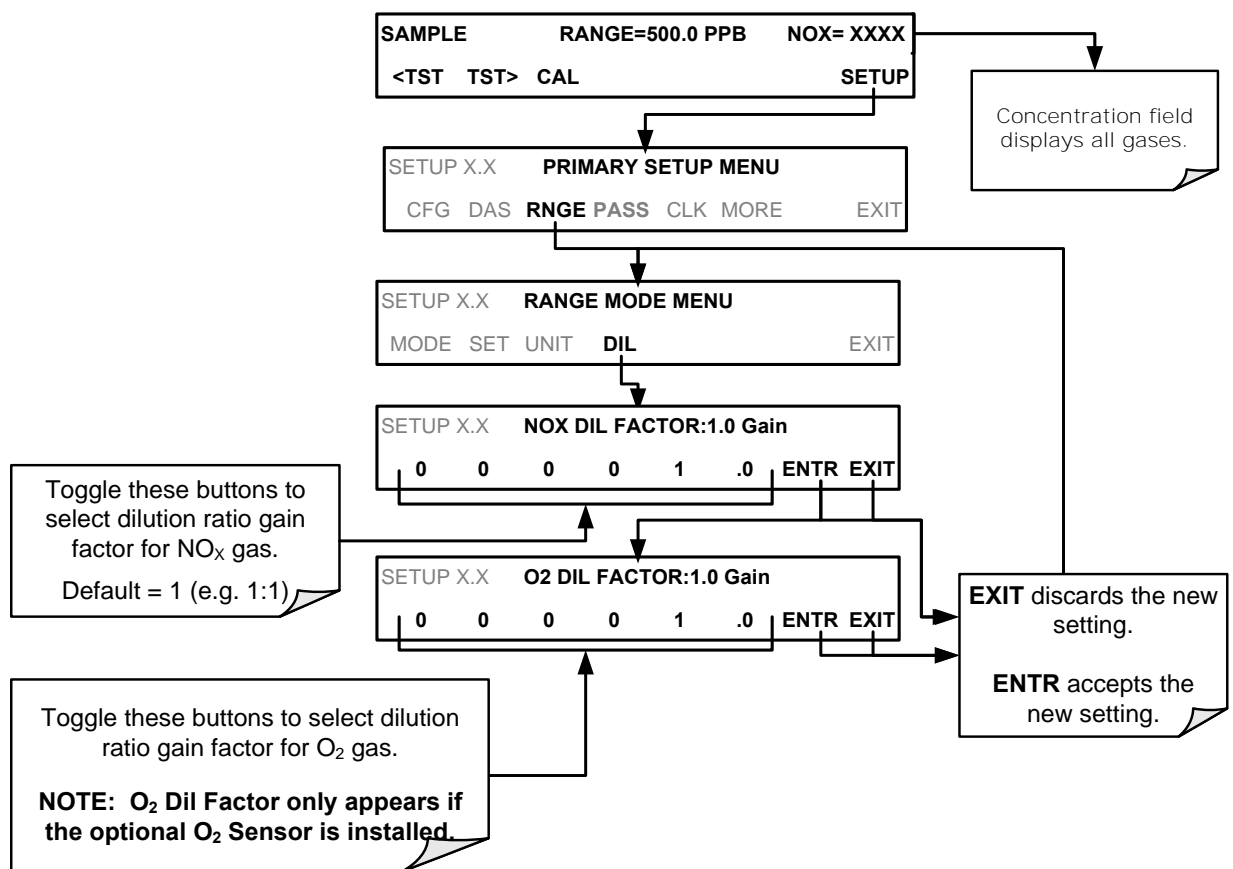
#### 5.4.3.5. SETUP → RNGE → DIL: USING THE OPTIONAL DILUTION RATIO FEATURE

The dilution ratio feature is a software utility option designed for applications where the sample gas is diluted before being analyzed by the T200. Typically this occurs in continuous emission monitoring (CEM) applications where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Once the degree of dilution is known, this feature allows the user to add

an appropriate scaling factor to the analyzer's NO, NO<sub>2</sub> and NO<sub>x</sub> concentration calculations so that the measurement range and concentration values shown on the instrument's front panel display and reported via the instrument's various outputs reflect the undiluted values.

Using the Dilution Ratio option is a 4-step process:

1. Select the appropriate units of measure (see Section 5.4.3.4).
2. Select the reporting range mode and set the reporting range upper limit (see Section 5.4.2).
  - Ensure that the upper span limit entered for the reporting range is the maximum expected concentration of the **UNDILUTED** gas.
3. Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):



4. Calibrate the analyzer.
  - Ensure that the calibration span gas is either supplied through the same dilution system as the sample gas or has an appropriately lower actual concentration.

**EXAMPLE:** If the reporting range limit is set for 100 ppm and the dilution ratio of the sample gas is 20 gain, either:

- a span gas with the concentration of 100 ppm can be used if the span gas passes through the same dilution steps as the sample gas, or;
- a 5 ppm span gas must be used if the span gas **IS NOT** routed through the dilution system.

## 5.5. SETUP → PASS: PASSWORD PROTECTION

The T200 provides password protection against accidental or unauthorized adjustments to the calibration and setup functions. When the passwords have been enabled in the **PASS** menu, the system prompts the user for a password anytime a password-protected function is selected. This allows normal operation of the instrument, but requires the password (101) to access the menus under **SETUP**. When **PASSWORD** is disabled (**PASS>OFF**), any operator can enter the Primary Setup (**SETUP**) and Secondary Setup (**SETUP>MORE**) menus, although, a password (default 818) is still required to enter the **VAR**s or **DIAG** menus in the Secondary Setup menu.

To enable password protection:

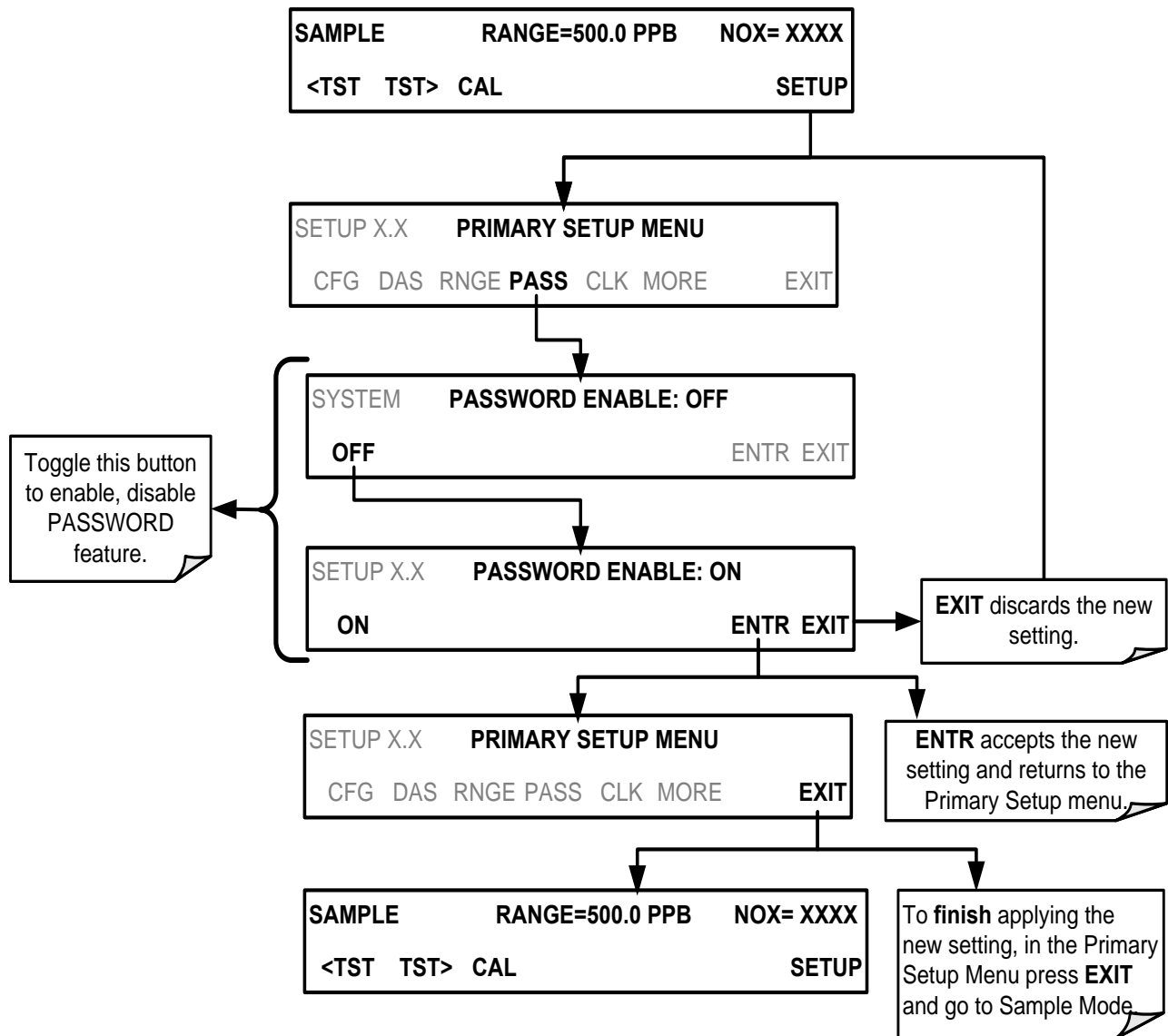
1. Press **SETUP>PASS**.
2. Press **OFF** (display shows **PASSWORD ENABLE:ON** and the **OFF** button becomes the **ON** button).
3. Press **ENTR** to accept the new setting (pressing **EXIT** in this submenu ignores the change and sends an audible signal indicating that the new setting did not take effect), and returns to the Primary Setup Menu.
4. **EXIT** the Primary Setup Menu to finish making the change effective.

There are three levels of password protection, which correspond to operator, maintenance and configuration functions. Each level allows access to all of the functions in the previous level.

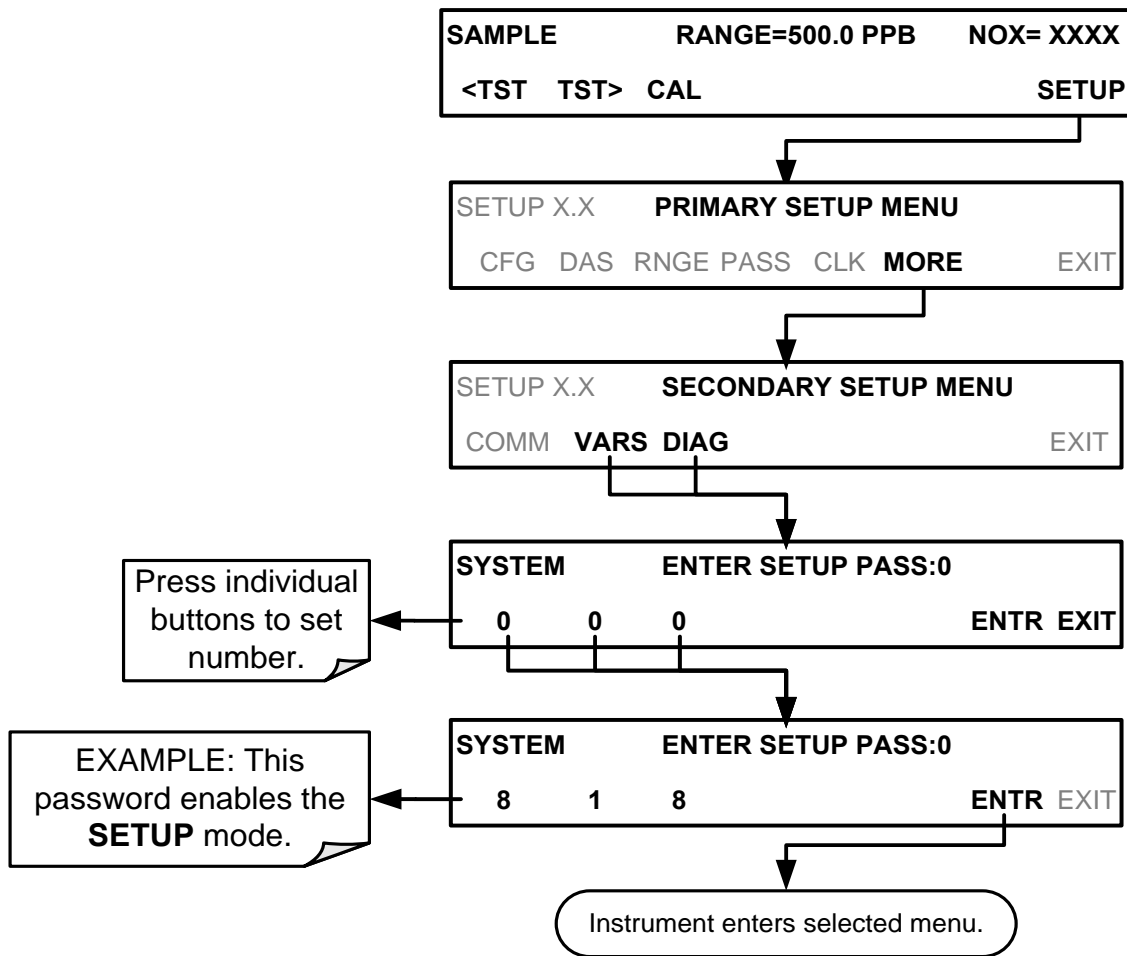
**Table 5-2: Password Levels**

<b>PASSWORD</b>	<b>LEVEL</b>	<b>MENU ACCESS ALLOWED</b>
Null (000)	Operation	All functions of the <b>MAIN</b> menu: <b>TEST, GEN</b> , initiate <b>SEQ, MSG, CLR</b>
101	Configuration/Maintenance	Access to Primary Setup and Secondary <b>SETUP</b> Menus when <b>PASSWORD</b> is enabled.
818	Configuration/Maintenance	Access to Secondary <b>SETUP</b> Submenus <b>VAR</b> s and <b>DIAG</b> whether <b>PASSWORD</b> is enabled or disabled.

To enable passwords, press:



Example: If all passwords are enabled, the following touchscreen control sequence would be required to enter the **VARs** or **DIAG** submenus:



**Note**

The instrument still prompts for a password when entering the VARS and DIAG menus, even if passwords are disabled, but it displays the default password (818) upon entering these menus. In this case, the user only has to press ENTR to access the password-protected menus.

In order to disable the PASSWORD feature after it has been turned ON, go to the SETUP menu, input the password, and press ENTR. In the Primary Setup Menu press PASS; then press ON to turn PASSWORD ENABLE back to OFF, and press ENTR to accept and apply the change (no need to press EXIT from the Primary Setup Menu this time).



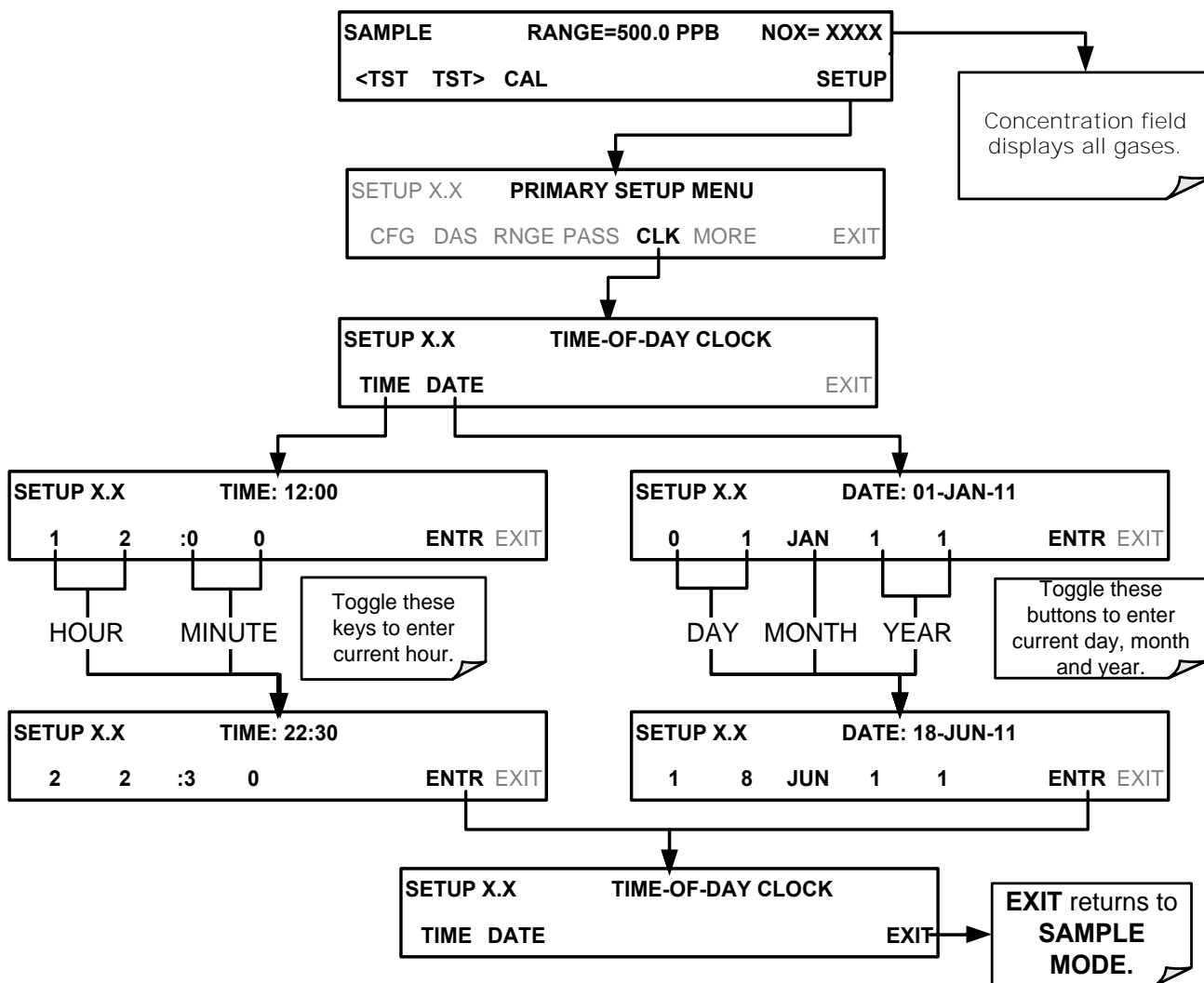
## 5.6. SETUP → CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK

The T200 has an internal clock for setting the time and day and adjusting its speed to compensate for faster or slower CPU clocks. Press SETUP>CLK to access the clock.

### 5.6.1. SETTING THE TIME OF DAY

The time-of-day feature of the internal clock supports the **DURATION** step of the automatic calibration (**ACAL**) sequence feature, has a built-in clock for the AutoCal timer, for the time TEST function, and for time stamps on COM port messages and on DAS data entries.

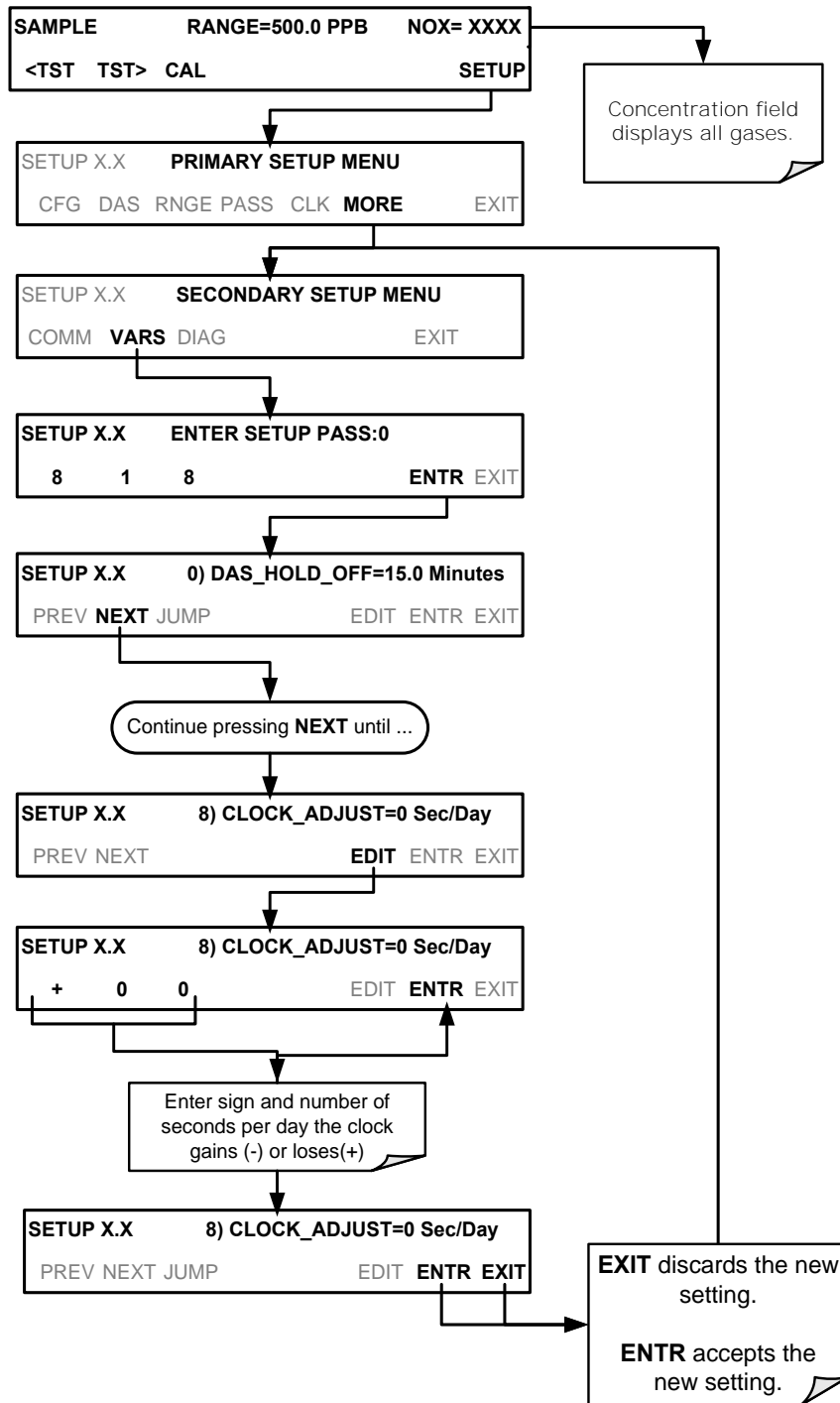
To set the clock's time and date, press:



### 5.6.2. ADJUSTING THE INTERNAL CLOCK'S SPEED

In order to compensate for CPU clocks that run fast or slow, adjust a variable called **CLOCK\_ADJ** to speed up or slow down the clock by a fixed amount every day.

The **CLOCK\_ADJ** variable is accessed via the **VARs** submenu: To change the value of this variable, press:



## 5.7. SETUP → COMM: COMMUNICATIONS PORTS

This section introduces the communications setup menu; Section 6 provides the setup instructions and operation information. Press SETUP>ENTR>MORE>COM to arrive at the communications menu.

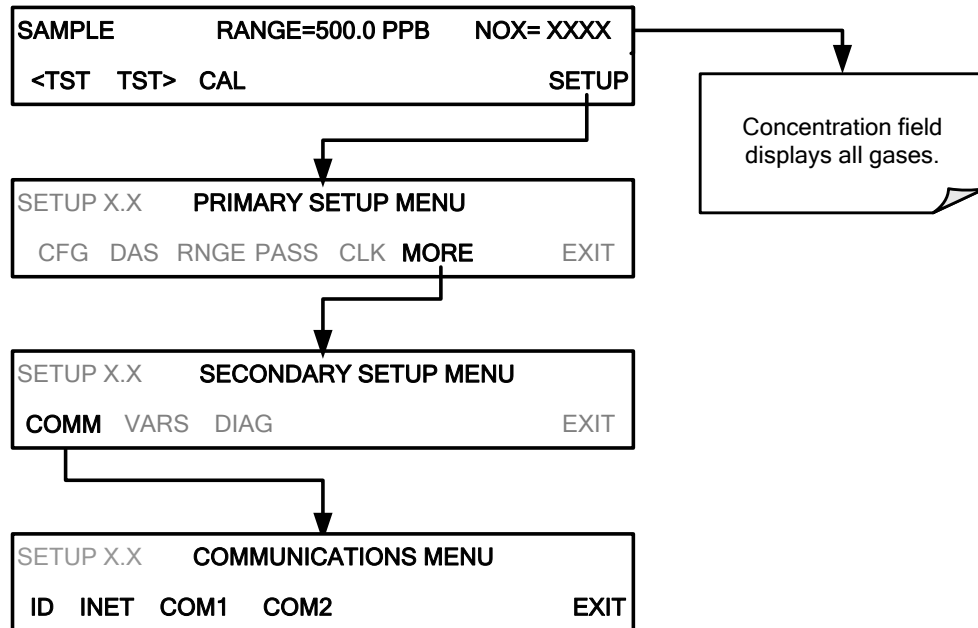


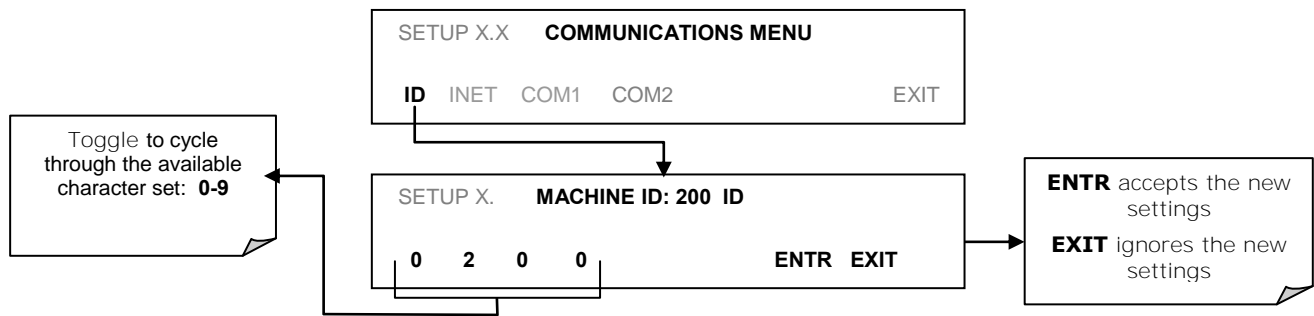
Figure 5-2. SETUP – COM Menu

### 5.7.1. ID (MACHINE IDENTIFICATION)

In the SETUP>MORE>COM menu press ID to display and/or change the Machine ID, which must be changed to a unique identifier (number) when more than one instrument of the same model is used:

- in an RS-232 multidrop configuration (Sections 3.3.1.8)
- on the same Ethernet LAN (Section 6.5)
- when applying MODBUS protocol (Section 6.7.1)
- when applying Hessen protocol (Section 6.7.2)

The default ID is typically the same as the model number, e.g., **0200** for the Model T200; it may also be **0**. Press any button(s) in the MACHINE ID menu (Figure 5-3) until the Machine ID in the Parameter field displays the desired identifier.



**Figure 5-3. COMM– Machine ID**

The ID can be any unique 4-digit number and can also be used to identify analyzers in other ways (e.g. location numbers, company asset number, etc.)

### 5.7.2. INET (ETHERNET)

Use `SETUP>COMM>INET` to configure Ethernet communications, whether manually or via DHCP. Please see Section 6.5.2 for configuration details.

### 5.7.3. COM1[COM2] (MODE, BAUDE RATE AND TEST PORT)

Use the `SETUP>COMM>COM1[COM2]` menus to:

- configure communication modes (Section 6.2.1)
- view/set the baud rate (Section 6.2.2)
- test the connections of the com ports (Section 6.2.3)

Configuring COM1 or COM2 requires setting the DCE DTE switch on the rear panel. Section 6.1 provides DCE DTE information.

## 5.8. SETUP → VARS: VARIABLES SETUP AND DEFINITION

Through the `SETUP>MORE>VARS` menu there are several user-adjustable software variables that define certain operational parameters. Usually, these variables are automatically set by the instrument's firmware, but can be manually re-defined using the `VARS` menu.

Table 5-3 lists all variables that are available within the 818 password protected level. See Appendix A2 for the T200 variables that are accessible through the remote interface.

Table 5-3: Variable Names (VARS)

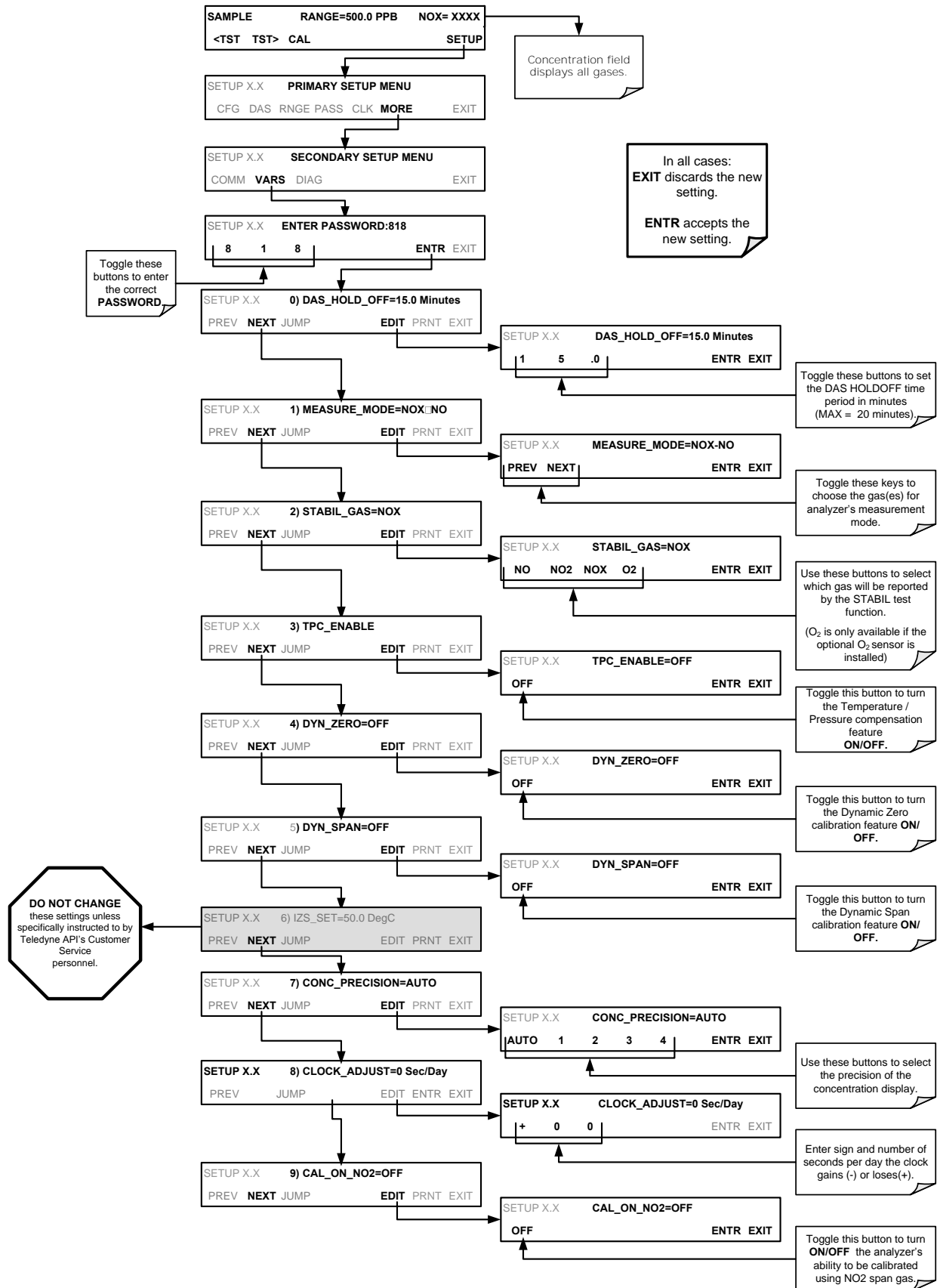
NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	VARS DEFAULT VALUES
0	DAS_HOLD_OFF	Changes the Internal Data Acquisition System (DAS) <b>HOLDOFF</b> timer: No data is stored in the DAS channels during situations when the software considers the data to be questionable such as during warm up of just after the instrument returns from one of its calibration mode to <b>SAMPLE</b> Mode.	May be set for intervals between 0.5 – 20 min	15 min.
1	MEASURE_MODE	Selects the gas measurement mode in which the instrument is to operate. NO <sub>x</sub> only, NO only or NO <sub>x</sub> and NO simultaneously.	NO; NO <sub>x</sub> ; NO <sub>x</sub> -NO	NO <sub>x</sub> -NO
2	STABIL_GAS	Selects which gas measurement is displayed when the <b>STABIL</b> test function is selected	NO; NO <sub>x</sub> ; NO <sub>2</sub> ;	NO <sub>x</sub>
3	TPC_ENABLE	Enables or disables the Temperature and Pressure Compensation (TPC) feature (Section 13.9.2).	ON/OFF	ON
4	DYN_ZERO <sup>1</sup>	Dynamic zero automatically adjusts offset and slope of the NO and NO <sub>x</sub> response when performing a zero point calibration during an AutoCal (see Section 9.5).	ON/OFF	OFF
5	DYN_SPAN <sup>1</sup>	Dynamic span automatically adjusts the offsets and slopes of the NO and NO <sub>x</sub> response when performing a span point calibration during an AutoCal (see Section 9.5).	ON/OFF	OFF
6	IZS_SET	Sets the internal span gas generator's permeation tube oven temperature. Changing this temperature will impact the NO <sub>2</sub> permeation rate (Section 3.3.2.5).	30°C - 70°C	51°C
7	CONC_PRECISION	Sets the number of significant digits to the right of the decimal point display of concentration and stability values.	AUTO, 1, 2, 3, 4	AUTO
8	CLOCK_ADJ	Adjusts the speed of the analyzer's clock. Choose + sign if the clock is too slow; choose - sign if the clock is too fast.	-60 to +60 s/day	0 sec
9	CAL_ON_NO <sub>2</sub>	Allows turning ON and OFF the ability to span the analyzer with NO <sub>2</sub> , in which case the instrument acts as if NO and NO <sub>x</sub> are spanned, even though it is supplied with NO <sub>2</sub> . The NO <sub>2</sub> concentration is then zero by default.	ON/OFF	OFF
10	SERVICE_CLEAR	Resets the service timer. Pressing OFF turns the setting to ON. ENTR resets the timer to 0 and returns the setting to OFF.	ON/OFF	OFF
11	TIME_SINCE_SVC	Displays number of hours since last service (since SERVICE_CLEAR was reset).	0-500000	0 Hrs
12	SVC_INTERVAL	Sets the number of hours between service reminders.	0-100000	0 Hrs

<sup>1</sup> Use of the DYN\_ZERO and DYN\_SPAN features are not allowed for applications requiring EPA reference.

## Note

There is a 2-sec latency period between when a VARS value is changed and the new value is stored into the analyzer's memory. DO NOT turn the analyzer off during this period or the new setting will be lost.

To access and navigate the VARS menu, use the following button sequence:



## 5.9. SETUP → DIAG: DIAGNOSTICS FUNCTIONS

A series of diagnostic tools is grouped together under the **SETUP→MORE→DIAG** menu. The parameters are dependent on firmware revision (see Appendix A). These tools can be used for troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and troubleshooting sections of this manual.

The various operating modes available under the **DIAG** menu are:

Table 5-4: Diagnostic Mode (DIAG) Functions

DIAG SUBMENU	SUBMENU FUNCTION	Front Panel Mode Indicator	MANUAL SECTION
<b>SIGNAL I/O</b>	Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled <b>ON</b> and <b>OFF</b> .	<b>DIAG I/O</b>	12.1.3
<b>ANALOG OUTPUT</b>	When entered, the analyzer performs an analog output step test. This can be used to calibrate a chart recorder or to test the analog output accuracy.	<b>DIAG AOUT</b>	12.7.6.1
<b>ANALOG I/O CONFIGURATION</b>	The signal levels of the instruments analog outputs may be calibrated (either individually or as a group). Various electronic parameters such as signal span, and offset are available for viewing and configuration.	<b>DIAG AIO</b>	5.9.2
<b>TEST CHAN OUTPUT</b>	Selects one of the available test channel signals to output over the <b>A4</b> analog output channel.	<b>DIAG TCHN</b>	5.9.4
<b>OPTIC TEST</b>	When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT ( <b>Error! Reference source not found.</b> ). This diagnostic tests the response of the PMT without having to supply span gas.	<b>DIAG OPTIC</b>	12.7.12.1
<b>ELECTRICAL TEST</b>	When activated, the analyzer performs an electrical test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	<b>DIAG ELEC</b>	12.7.12.2
<b>OZONE GEN OVERRIDE</b> <sup>1</sup>	Allows the user to manually turn the O <sub>3</sub> generator on or off. During initial power up TMR (timer) is displayed while the Ozone brick remains off for the first 30 minutes.	<b>DIAG OZONE</b>	12.7.15.1
<b>FLOW CALIBRATION</b> <sup>1</sup>	This function is used to calibrate the gas flow output signals of sample gas and ozone supply.	<b>DIAG FCAL</b>	9.7

<sup>1</sup> These settings are retained after exiting DIAG mode.

To access the various **DIAG** submenus, press the following buttons:

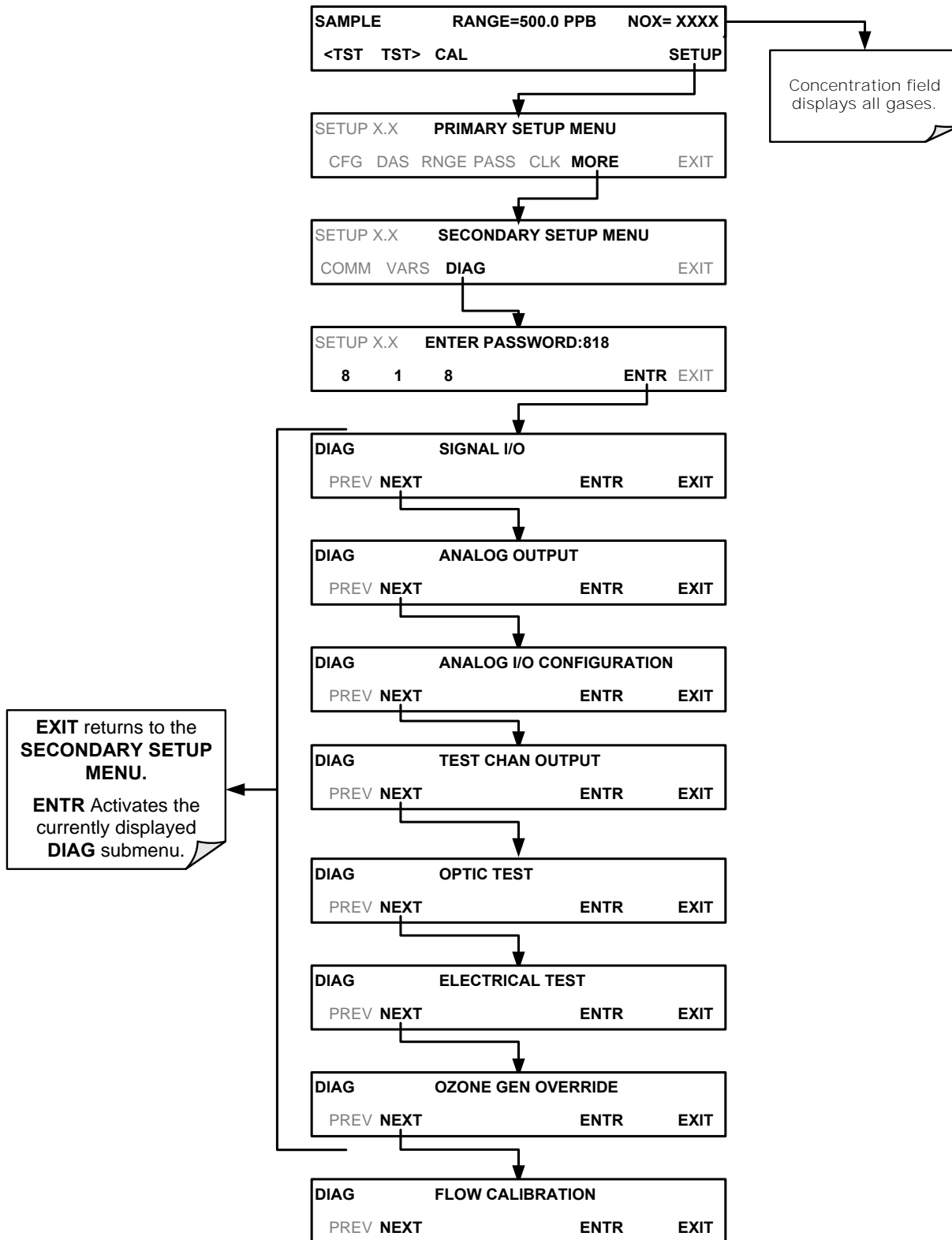


Figure 5-4: Accessing the DIAG Submenus



## 5.9.1. SIGNAL I/O

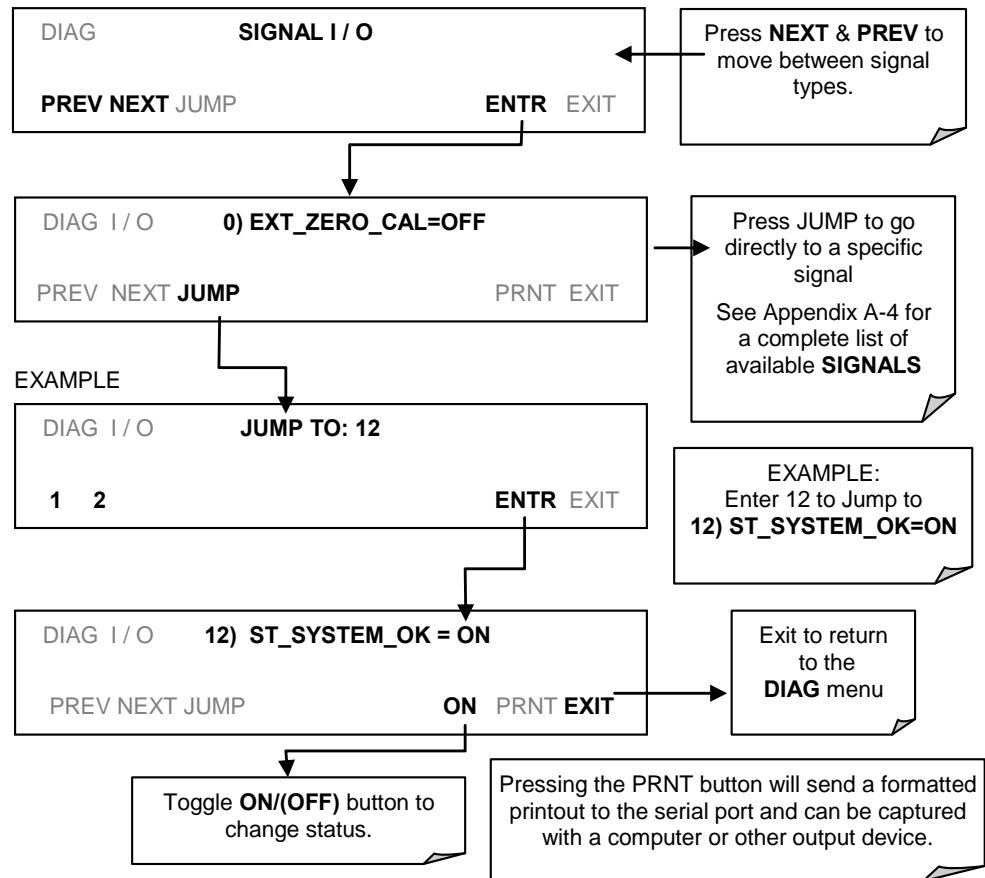
Use the signal I/O diagnostic mode to review and change the digital and analog input/output functions of the analyzer. Refer to Appendix A for a list of the parameters available for review under this menu.

### IMPORTANT

#### IMPACT ON READINGS OR DATA

Any changes of signal I/O settings will remain in effect only until the signal I/O menu is exited. Exceptions are the Ozone Generator Override and the Flow Sensor calibration, which remain as entered when exiting.

Access the signal I/O test mode from the DIAG Menu (Figure 5-4), then press:



## 5.9.2. ANALOG OUTPUT (DIAG AOUT)

Use Analog Output to verify functionality and accuracy of the analog outputs. The test forces all analog output channels to produce signals ranging from 0% to 100% of the full scale range in 20% increments. This test is useful to verify the operation of the data logging/recording devices attached to the analyzer.

Section 12.7.6.1 presents instructions for use in troubleshooting and service.

## 5.9.3. ANALOG I/O CONFIGURATION (DIAG AIO)

The T200 analyzer comes equipped with four analog outputs. The first three outputs (**A1**, **A2**, & **A3**) carry analog signals that represent the currently measured concentration of NO<sub>x</sub>, NO and NO<sub>2</sub> (see Section 5.4.2.1). The fourth output (**A4**) outputs a signal that can be set to represent the current value of one of several test functions (see Table 5-9).

The following table lists the analog I/O functions that are available in the T200 analyzer.

**Table 5-5: DIAG - Analog I/O Functions**

SUB MENU	FUNCTION	MANUAL SECTION
<b>AOUT CALIBRATED</b>	Initiates a calibration of the <b>A1</b> , <b>A2</b> , <b>A3</b> and <b>A4</b> analog output channels that determines the slope and offset inherent in the circuitry of each output. These values are stored and applied to the output signals by the CPU automatically.	5.9.3.1
<b>CONC_OUT_1</b>	Sets the basic electronic configuration of the <b>A1</b> output (NO <sub>x</sub> Concentration). There are four options: <ul style="list-style-type: none"> <li>• <b>RANGE<sup>1</sup></b>: Selects the signal type (voltage or current loop) and level of the output</li> <li>• <b>REC OFS</b>: Allows them input of a DC offset to let the user manually adjust the output level</li> <li>• <b>AUTO CAL</b>: Enables / Disables the <b>AOUT CALIBRATION</b> Feature</li> <li>• <b>CALIBRATED</b>: Performs the same calibration as <b>AOUT CALIBRATED</b>, but on this one channel only.</li> </ul>	5.9.2
<b>CONC_OUT_2</b>	• Same as for CONC_OUT_1 but for analog channel <b>A2</b> (NO Concentration)	
<b>CONC_OUT_3</b>	• Same as for CONC_OUT_1 but for analog channel <b>A3</b> (NO <sub>2</sub> Concentration)	
<b>TEST OUTPUT</b>	• Same as for CONC_OUT_1 but for analog channel <b>A4</b> (TEST CHANNEL)	5.9.4
<b>AIN CALIBRATED</b>	Initiates a calibration of the A-to-D Converter circuit located on the Motherboard.	5.9.3.10
<b>XIN1</b> . . . <b>XIN8</b>	For each of 8 external analog inputs channels, shows the gain, offset, engineering units, and whether the channel is to show up as a Test function.	5.9.3.11

To access the ANALOG I/O CONFIGURATION sub menu, press:

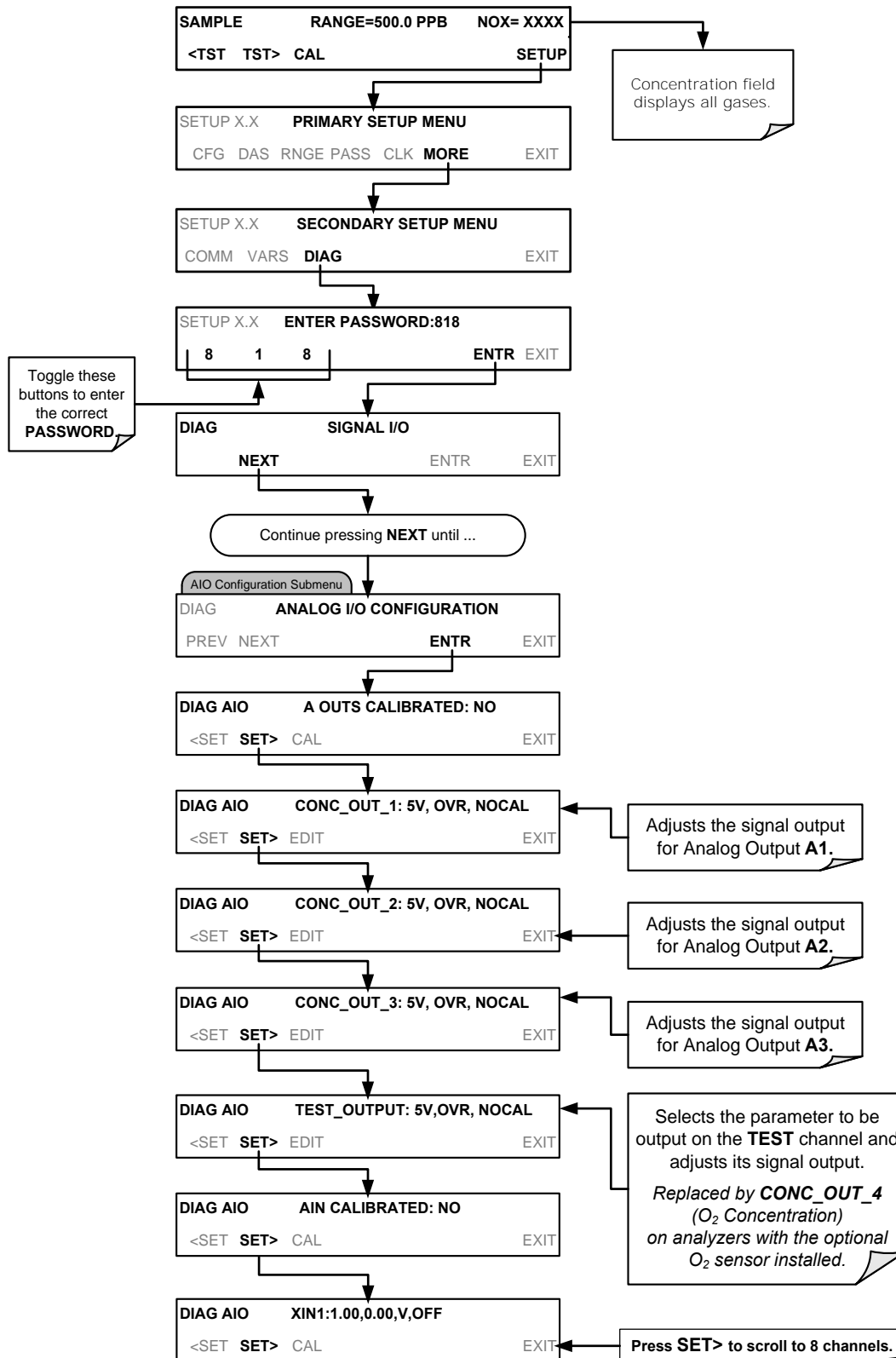


Figure 5-5: Accessing the Analog I/O Configuration Submenus

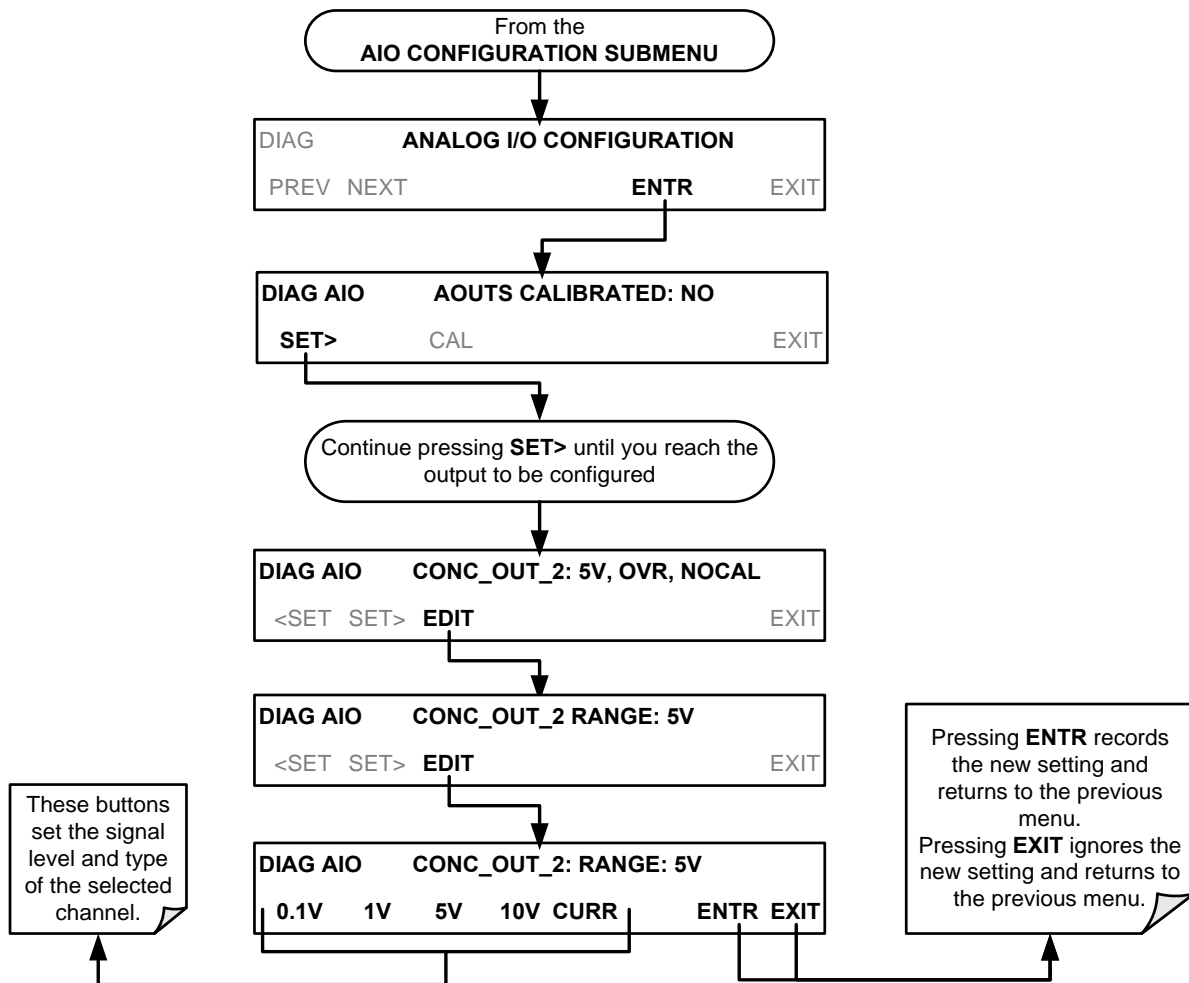
### 5.9.3.1. ANALOG OUTPUT VOLTAGE / CURRENT RANGE SELECTION

In its standard configuration the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 5-6). Each range is usable from -5% to +5% of the rated span.

Table 5-6: Analog Output Voltage Range Min/Max

RANGE NAME	RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
0.1V	0-100 mVDC	-5 mVDC	105 mVDC
1V	0-1 VDC	-0.05 VDC	1.05 VDC
5V	0-5 VDC	-0.25 VDC	5.25 VDC
10V	0-10 VDC	-0.5 VDC	10.5 VDC
The default offset for all VDC ranges is 0-5 VDC.			
CURR	0-20 mA	0 mA	20 mA
While these are the physical limits of the current loop modules, typical applications use 2-20 mA or 4-20 mA for the lower and upper limits. Please specify desired range when ordering this option. The default offset for all current ranges is 0 mA.			

To change the output type and range, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



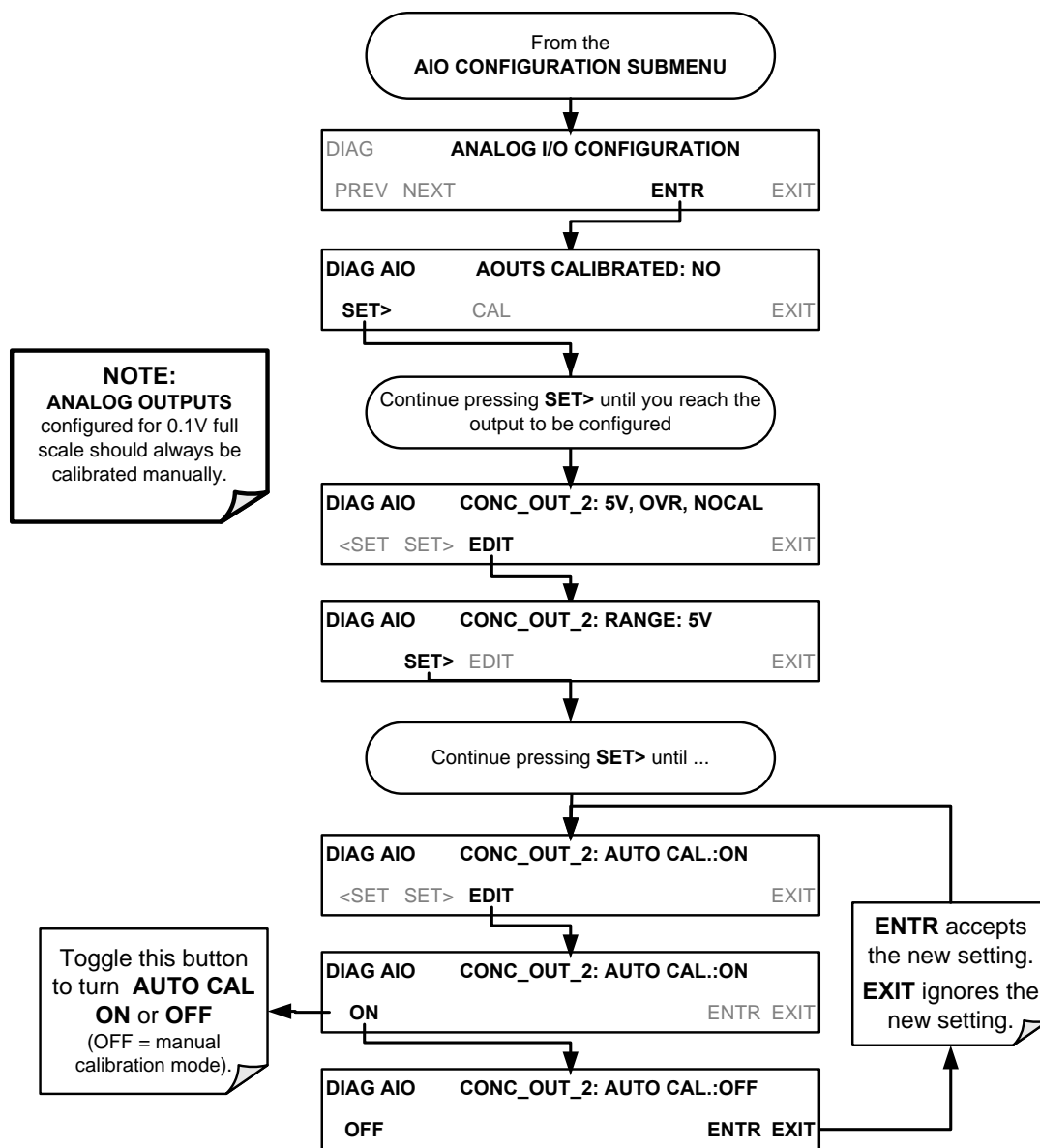
### 5.9.3.2. CALIBRATION OF THE ANALOG OUTPUTS

In its default mode, the instrument is configured for automatic calibration of all channels, which is useful for clearing any analog calibration warnings associated with channels that will not be used or connected to any input or recording device, e.g., data logger.

Manual calibration should be used for the 0.1V range or in cases where the outputs must be closely matched to the characteristics of the recording device. The AUTOCAL feature must be disabled first for manual calibration.

### 5.9.3.3. ENABLING OR DISABLING THE AUTOCAL FOR AN INDIVIDUAL ANALOG OUTPUT

To enable or disable the **AutoCal** feature for an individual analog output, elect the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



5.9.3.4. AUTOMATIC GROUP CALIBRATION OF THE ANALOG OUTPUTS

**IMPORTANT**

IMPACT ON READINGS OR DATA

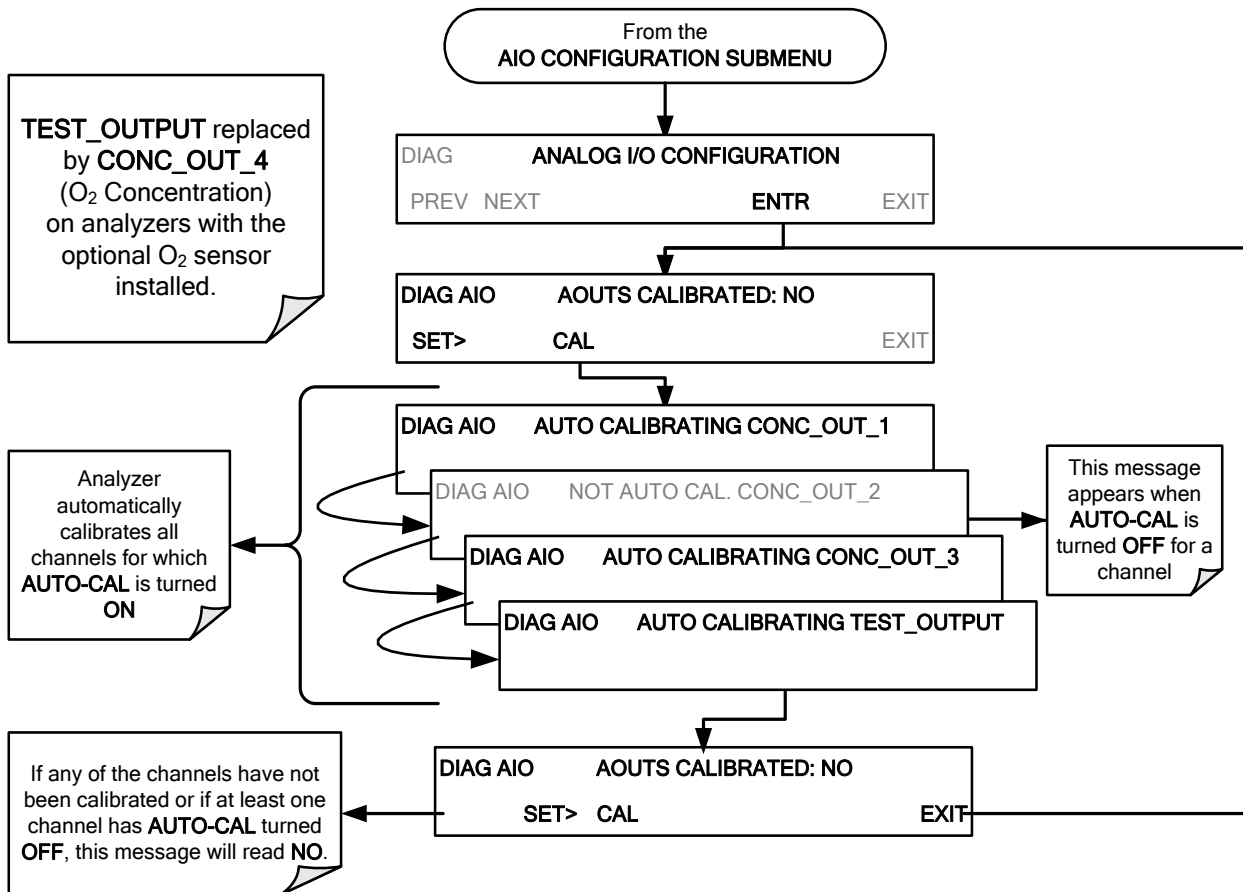
Manual calibration should be used for any analog output set for a 0.1V output range or in cases where the outputs must be closely matched to the characteristics of the recording device. (See Sections 5.9.3.2, 5.9.3.3, and 5.9.3.6).

**IMPORTANT**

IMPACT ON READINGS OR DATA

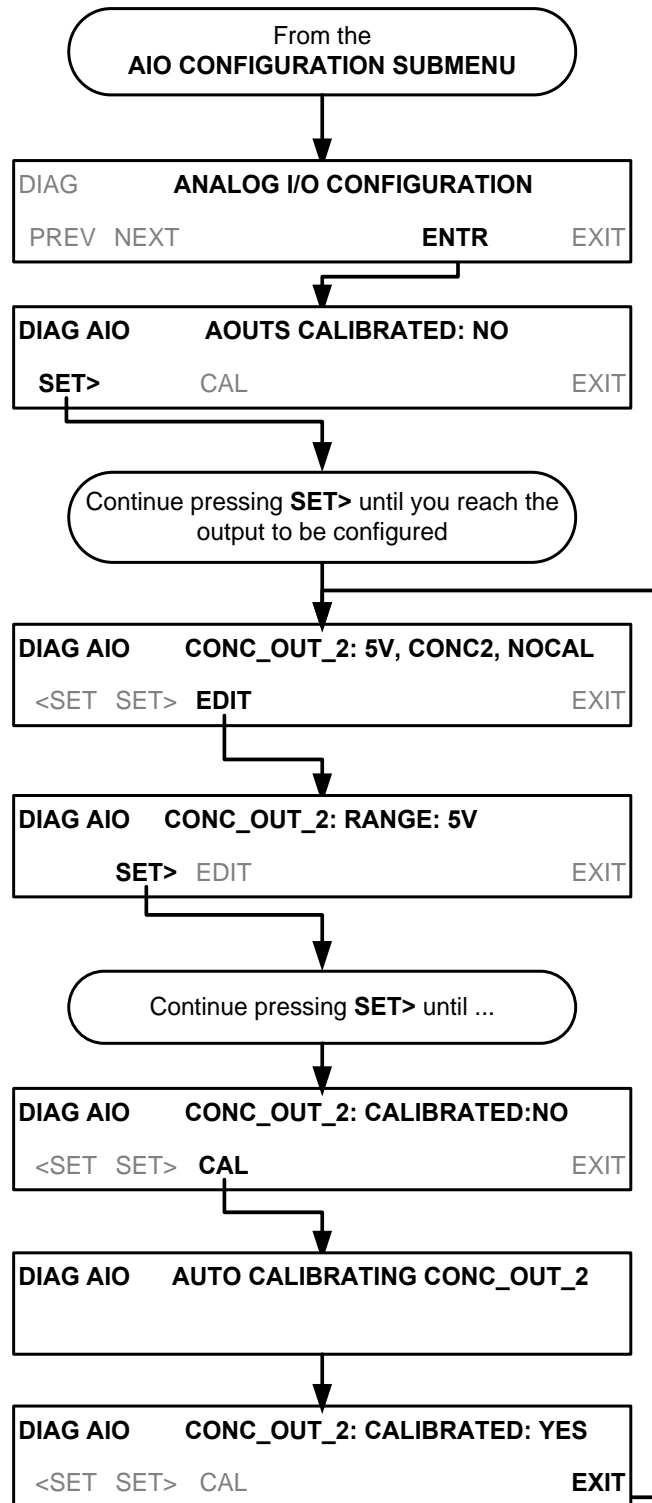
Before performing this procedure, ensure that the AUTO CAL for each analog output is enabled. (See Section 5.9.3.3).

To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



### 5.9.3.5. AUTOMATIC INDIVIDUAL CALIBRATION OF THE ANALOG OUTPUTS

Use the **AUTO CAL** feature to initiate an automatic calibration for an individual analog output; access the **ANALOG I/O CONFIGURATION** submenu (SETUP>MORE>DIAG>PASSWORD>NEXT . . . or see Figure 5-5) then press:



### 5.9.3.6. MANUAL CALIBRATION OF THE ANALOG OUTPUTS CONFIGURED FOR VOLTAGE RANGES

For highest accuracy, the voltages of the analog outputs can be manually calibrated.

#### Note

The menu for manually adjusting the analog output signal level will only appear if the AUTO-CAL feature is turned off for the channel being adjusted. (See Section 5.9.3.3).

Calibration is performed with a voltmeter connected across the output terminals and by changing the actual output signal level using the front panel buttons in 100, 10 or 1 count increments. See Figure 3-8 for pin assignments and diagram of the analog output connector.

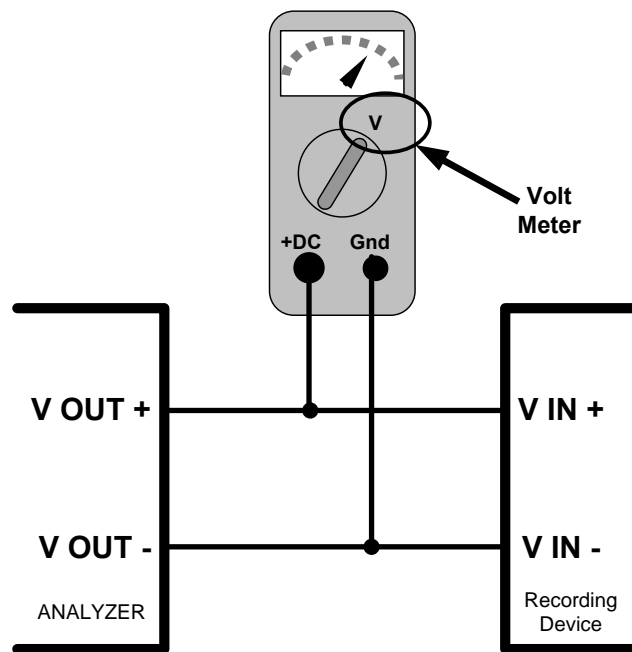


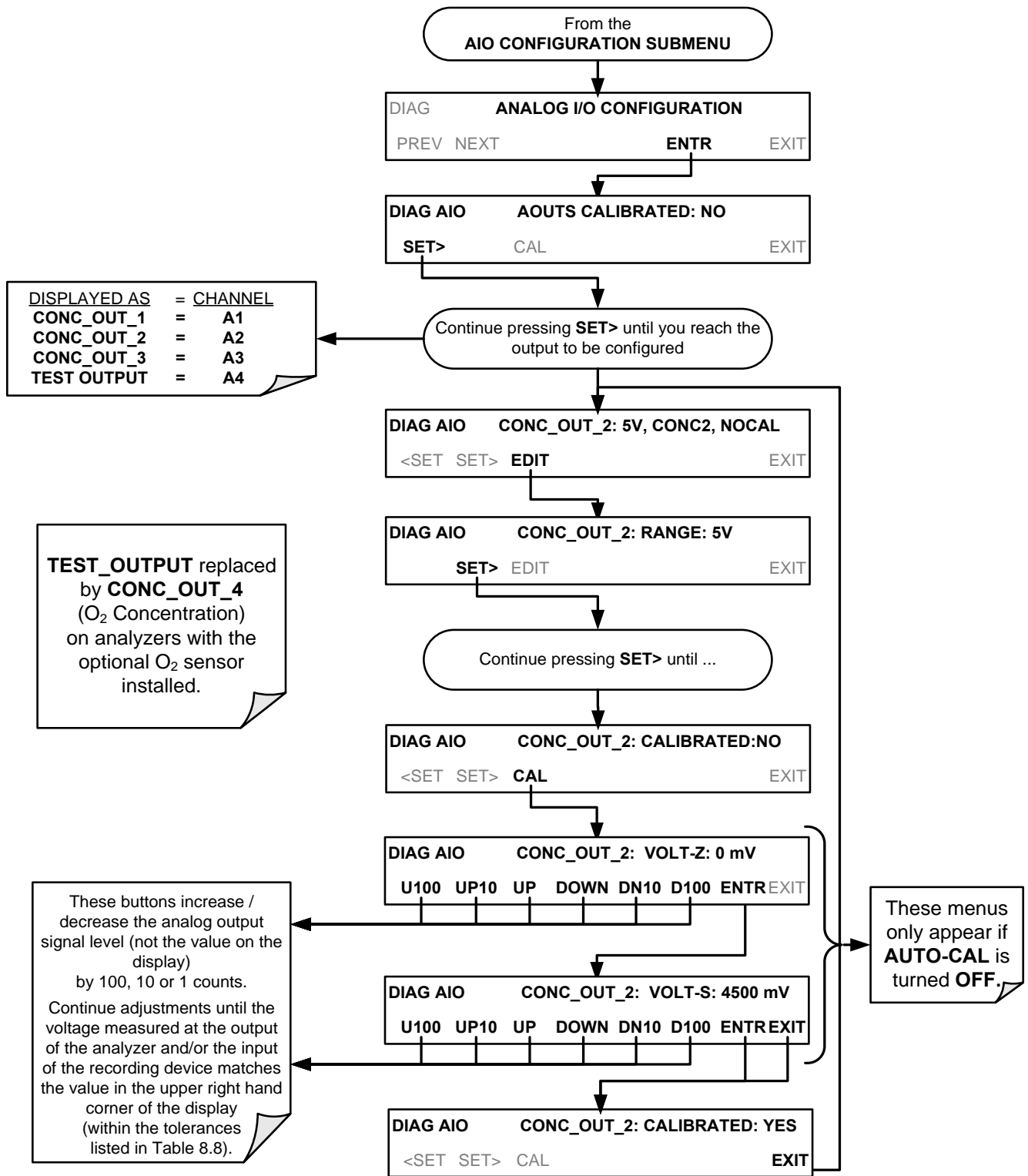
Figure 5-6: Setup for Checking / Calibrating DCV Analog Output Signal Levels

Table 5-7: Voltage Tolerances for the TEST CHANNEL Calibration

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE	MINIMUM ADJUSTMENT (1 count)
0.1 VDC	±0.0005V	90 mV	±0.001V	0.02 mV
1 VDC	±0.001V	900 mV	±0.001V	0.24 mV
5 VDC	±0.002V	4500 mV	±0.003V	1.22 mV
10 VDC	±0.004V	4500 mV	±0.006V	2.44 mV



To adjust the signal levels of an analog output channel manually, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



### 5.9.3.7. MANUAL ADJUSTMENT OF CURRENT LOOP OUTPUT SPAN AND OFFSET

A current loop option may be purchased for the **A1**, **A2** and **A3** Analog outputs of the analyzer. This option places circuitry in series with the output of the D-to-A converter on the motherboard that changes the normal DC voltage output to a 0-20 milliamp signal (See Section 3.3.1.4).

- The outputs can be ordered scaled to any set of limits within that 0-20 mA range, however most current loop applications call for either 0-20 mA or 4-20 mA range spans.
- All current loop outputs have a +5% over range. Ranges whose lower limit is set above 1 mA also have a –5% under range.

To switch an analog output from voltage to current loop, follow the instructions in Section 5.9.3.1 (select **CURR** from the list of options on the “Output Range” menu).

Adjusting the signal zero and span levels of the current loop output is done by raising or lowering the voltage output of the D-to-A converter circuitry on the analyzer’s motherboard. This raises or lowers the signal level produced by the current loop option circuitry.

The software allows this adjustment to be made in 100, 10 or 1 count increments. Since the exact amount by which the current signal is changed per D-to-A count varies from output-to-output and instrument-to-instrument, you will need to measure the change in the signal levels with a separate, current meter placed in series with the output circuit. See Figure 3-8 for pin assignments and diagram of the analog output connector.

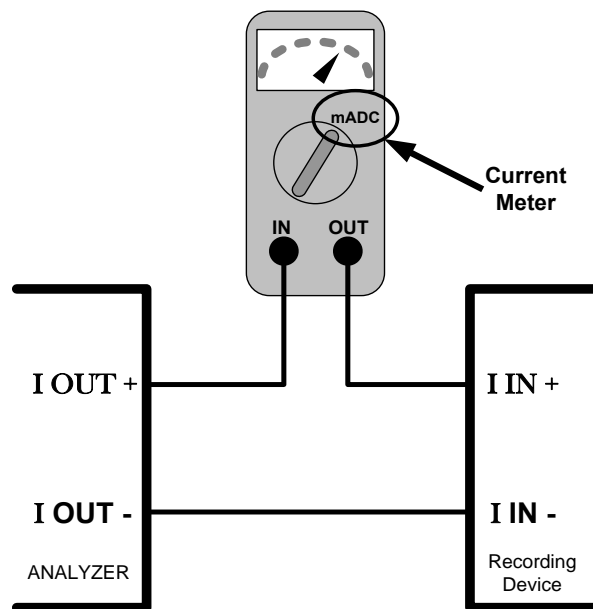


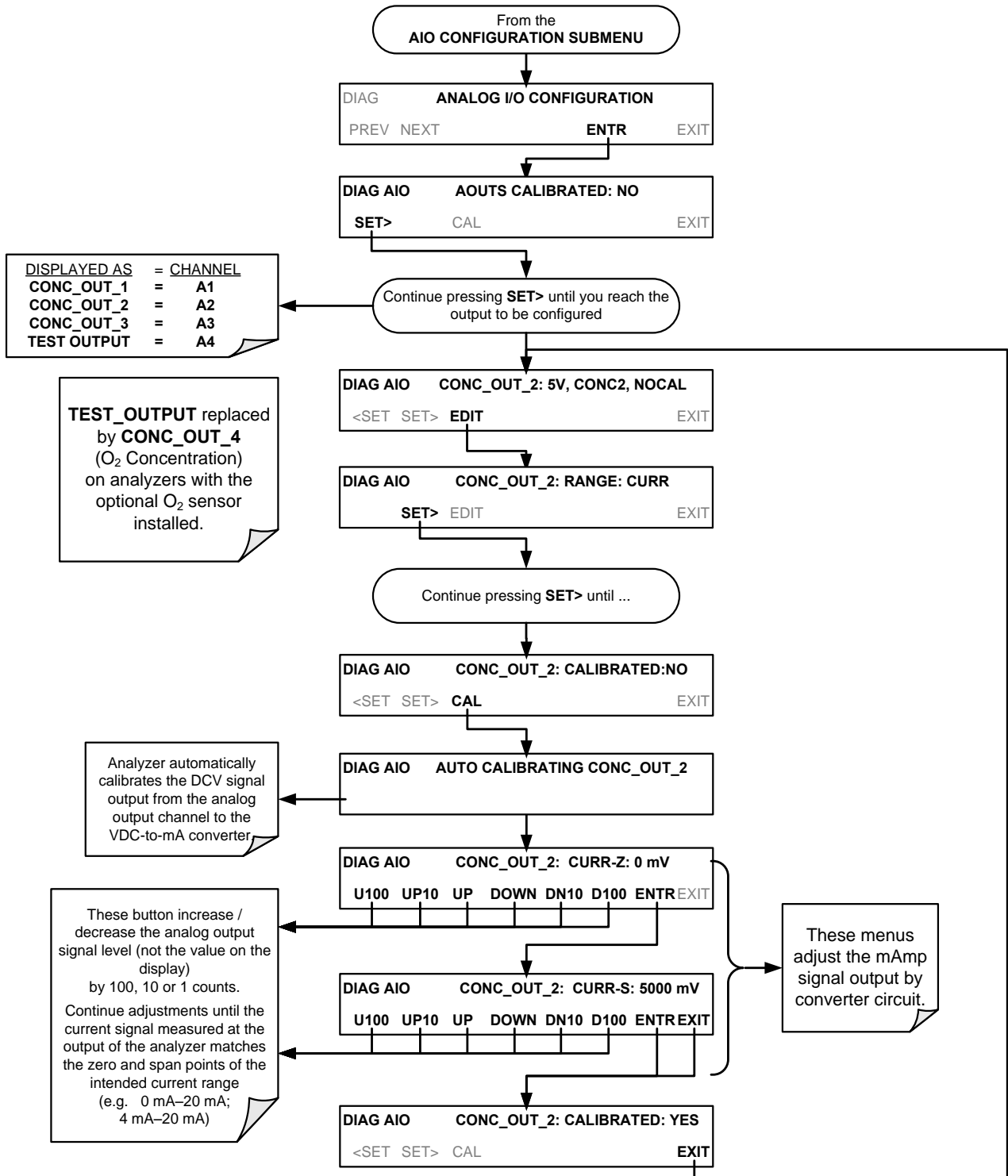
Figure 5-7: Setup for Checking / Calibration Current Output Signal Levels Using an Ammeter



#### CAUTION – GENERAL SAFETY HAZARD

Do not exceed 60 V peak voltage between current loop outputs and instrument ground.

To adjust the zero and span signal levels of the current outputs, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



An alternate method for measuring the output of the Current Loop converter is to connect a 250 ohm ±1% resistor across the current loop output in lieu of the current meter (see Figure 3-8 for pin assignments and diagram of the analog output connector). This allows the use of a voltmeter connected across the resistor to measure converter output as VDC or mVDC.

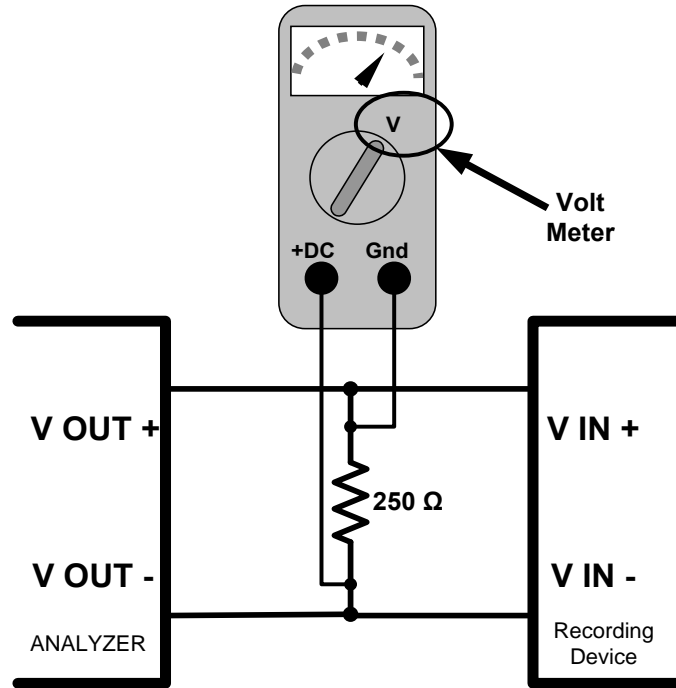


Figure 5-8: Alternative Setup Using 250Ω Resistor for Checking Current Output Signal Levels

In this case, follow the procedure above but adjust the output for the following values:

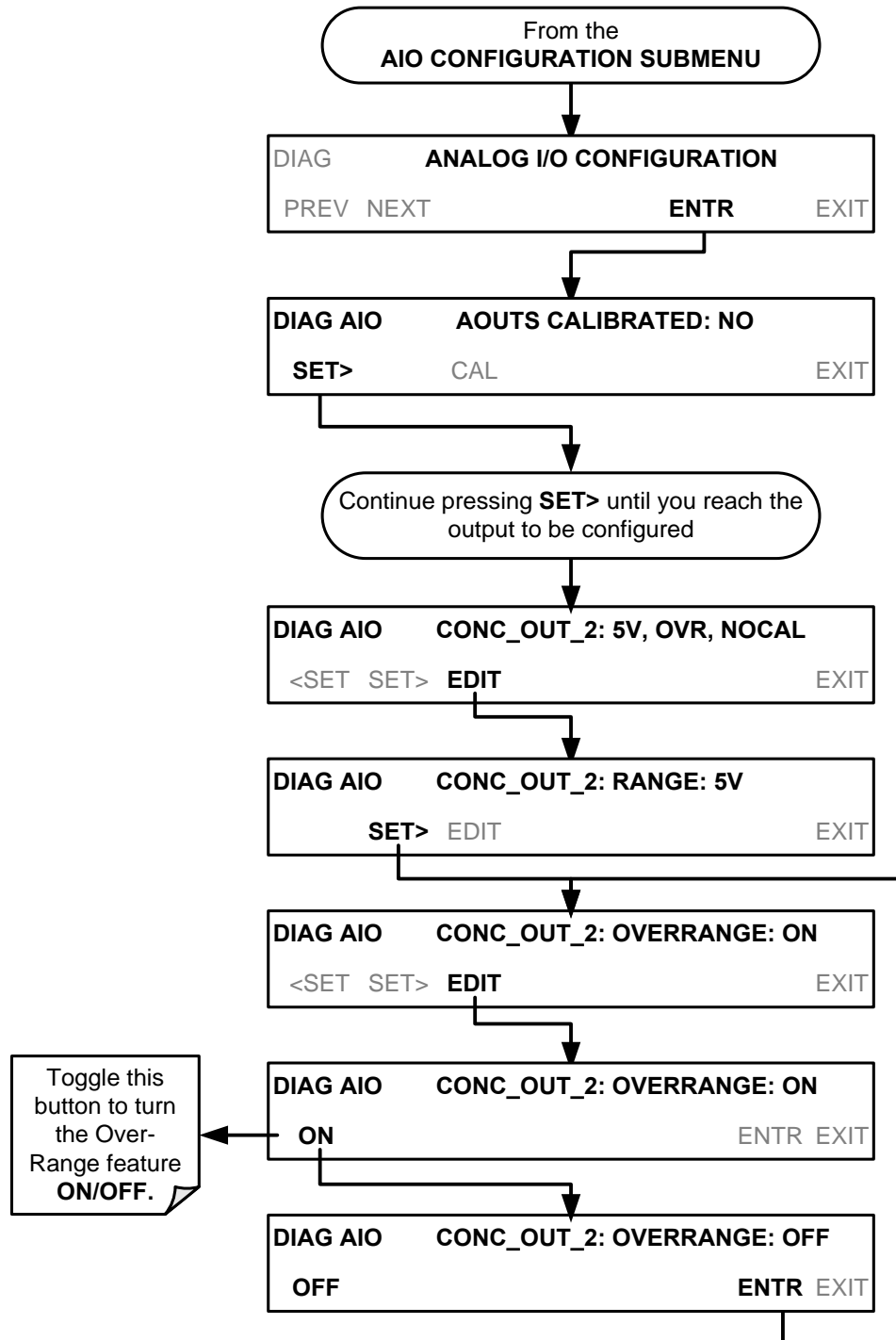
Table 5-8: Current Loop Output Check

% FS	Voltage across Resistor for 2-20 mA	Voltage across Resistor for 4-20 mA
0	500 mVDC	1000 mVDC
100	5000 mVDC	5000 mVDC

### 5.9.3.8. TURNING AN ANALOG OUTPUT OVER-RANGE FEATURE ON/OFF

In its default configuration, a  $\pm 5\%$  over-range is available on each of the T200's analog outputs. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

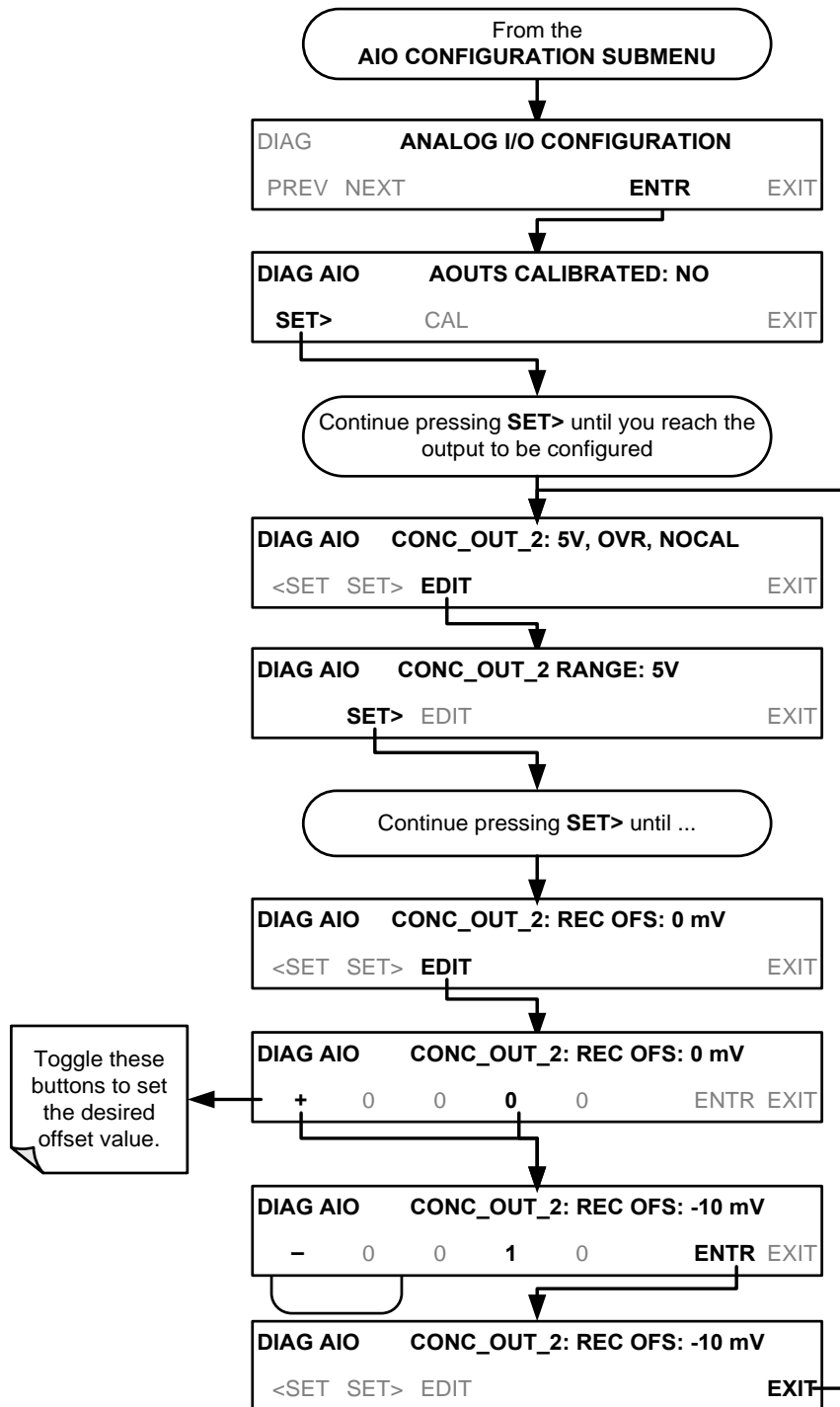
To turn the over-range feature on or off, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



### 5.9.3.9. ADDING A RECORDER OFFSET TO AN ANALOG OUTPUT

Some analog signal recorders require that the zero signal be significantly different from the baseline of the recorder in order to record slightly negative readings from noise around the zero point. This can be achieved in the T200 by defining a zero offset, a small voltage (e.g., 10% of span).

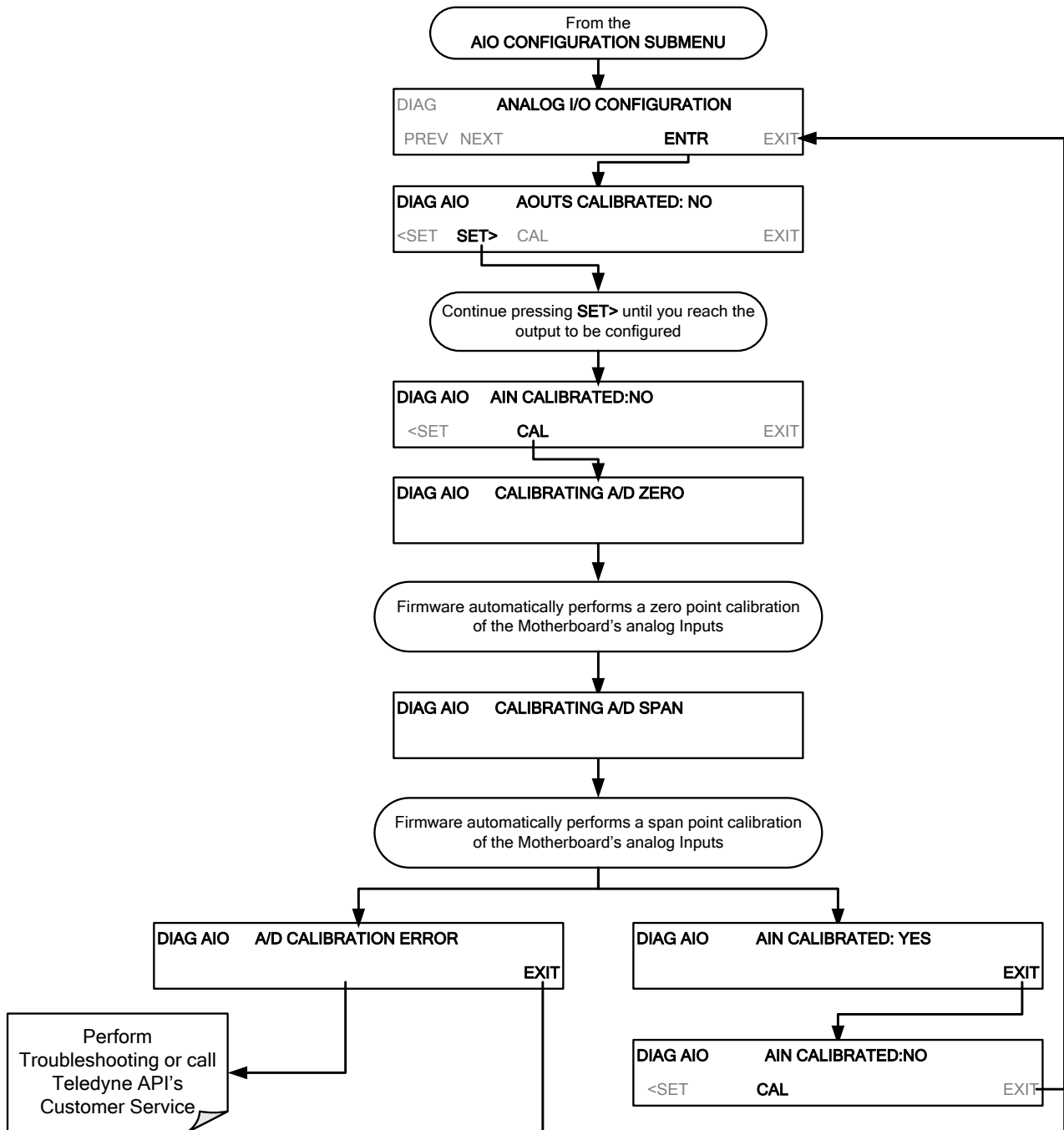
To add a zero offset to a specific analog output channel, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



### 5.9.3.10. AIN CALIBRATION

This is the submenu to conduct a calibration of the T200 analyzer’s analog inputs. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies.

To perform an analog input calibration, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 5-5) then press:



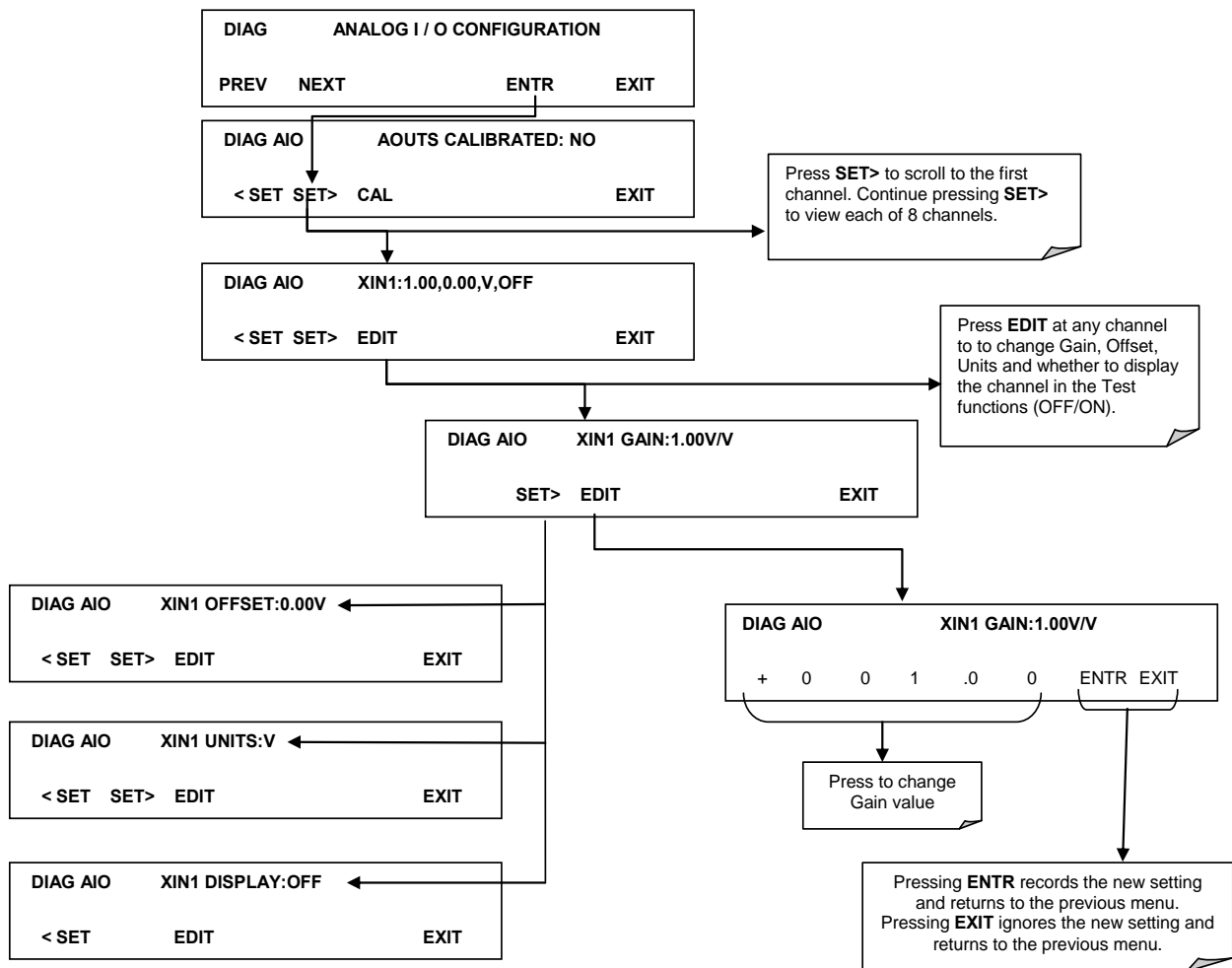
### 5.9.3.11. EXTERNAL ANALOG INPUTS (XIN1...XIN8) OPTION CONFIGURATION

To configure the analyzer’s optional external analog inputs, define for each channel:

- gain (number of units represented by 1 volt)
- offset (volts)
- engineering units to be represented in volts (each press of the touchscreen button scrolls the list of alphanumeric characters from A-Z and 0-9)
- whether to display the channel in the Test functions

These parameters can also be captured in the internal Data Acquisition System (DAS); refer to Appendix A for Analog-In DAS parameters.

To adjust settings for the Analog Inputs option parameters press:





### 5.9.4. TEST CHAN OUTPUT (SELECTING A TEST CHANNEL FUNCTION FOR OUTPUT A4)

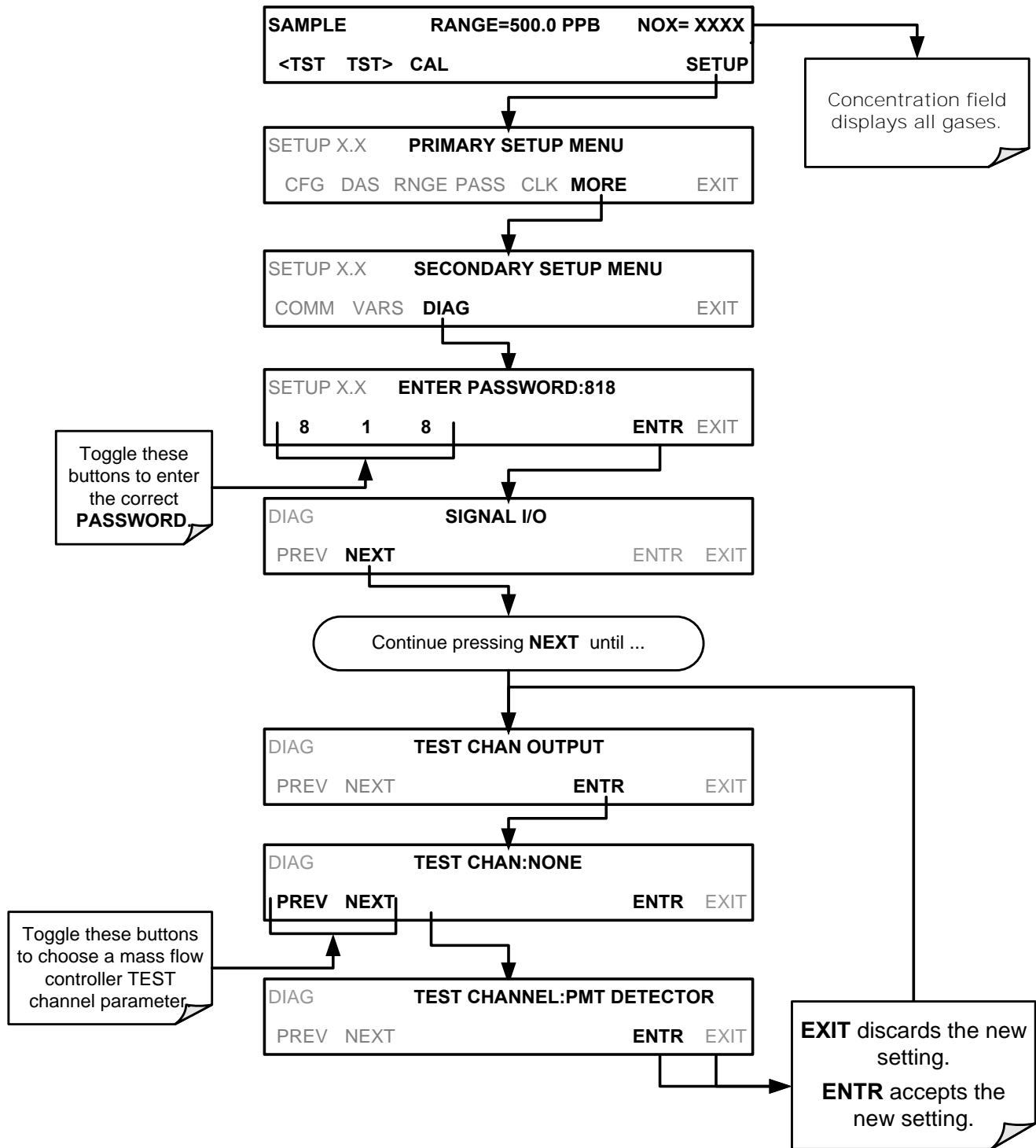
The test functions available to be reported are listed in Table 5-9:

Table 5-9: Test Channels Functions available on the T200's Analog Output

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE
NONE	<i>TEST CHANNEL IS TURNED OFF</i>		
PMT DETECTOR	The output of the PMT detector converted to a 0 to 5 VDC scale.	0 mV	5000 mV <sup>1</sup>
OZONE FLOW	The flow rate of O <sub>3</sub> through the analyzer as measured by the O <sub>3</sub> flow sensor.	0 cm <sup>3</sup> /min	1000 cm <sup>3</sup> /min
SAMPLE FLOW	The calculated flow rate for sample gas through the analyzer.	0 cm <sup>3</sup> /min	1000 cm <sup>3</sup> /min
SAMPLE PRESSURE	The pressure of the sample gas measured upstream of the Auto Zero Valve.	0 Hg-In-A	40 "Hg-In-A
RCELL PRESSURE	The pressure of gas inside the reaction cell of the sensor module.	0 Hg-In-A	40 Hg-In-A
RCELL TEMP	The temperature of gas inside the reaction cell of the sensor module.	0 °C	70 °C
MANIFOLD TEMP	Not used in the Model T200.		
IZS TEMP	The temperature of the permeation tube oven of the optional internal span gas generator.	0 °C	70 °C
CONV TEMP	The temperature NO <sub>2</sub> → NO converter.	0 °C	500 °C
PMT TEMP	The temperature inside PMT.	0 °C	50 °C
BOX TEMP	The temperature inside the T200's chassis.	0 °C	70 °C
HVPS VOLTAGE	Represents the output voltage of the PMT's high voltage power supply.	0 mV	5000 mV <sup>1</sup>

Once a function is selected, the instrument not only begins to output a signal on the analog output, but also adds **TEST** to the list of test functions viewable via the front panel display.

To activate the TEST Channel and select a function, press:



### 5.9.5. OPTIC TEST

The OPTIC TEST function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT. The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board. To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air. The optic test should produce a PMT signal of about  $2000 \pm 1000$  mV.

Section 12.7.12.1 presents instructions for use in troubleshooting and service.

#### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

**This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.**

---

### 5.9.6. ELECTRICAL TEST

The ELECTRICAL TEST function creates a current, which substitutes the PMT signal, and feeds it into the preamplifier board. This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard. It does not test the PMT itself. The electrical test should produce a PMT signal of about  $2000 \pm 1000$  mV.

Section 12.7.12.2 presents instructions for use in troubleshooting and service.

### 5.9.7. OZONE GEN OVERRIDE

This feature is used to manually turn the ozone generator off and on. Read Section 13.2.3 to understand the ozone generator, and refer to Section 12.7.15.1 for instructions on using the override feature in troubleshooting and service.

### 5.9.8. FLOW CALIBRATION

This function is used to calibrate the gas flow output signals of sample gas and ozone supply. Section 9.7 presents instructions for flow calibration. Used to adjust the gas flow calculations made by the CPU based on pressure and flow sensor readings.

## 6. COMMUNICATIONS SETUP AND OPERATION

This instrument's rear panel connections include an Ethernet port, a USB port (option) and two serial communications ports labeled **RS232**, which is the COM1 port, and **COM2** (refer to Figure 3-4). These ports give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal. Connection instructions were provided in Section 3.3.1.8.

This section provides pertinent information regarding communication equipment, describes the instrument's communications modes, presents configuration instructions for the communications ports, and provides instructions for their use, including communications protocol. Data acquisition is presented in Section 7.

### 6.1. DATE TERMINAL / COMMUNICATION EQUIPMENT (DTE DCE)

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic terminals always fall into the DTE category whereas modems are always considered DCE devices. The difference between the two is the pin assignment of the Data Receive and Data Transmit functions.

- DTE devices receive data on pin 2 and transmit data on pin 3.
- DCE devices receive data on pin 3 and transmit data on pin 2.

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel labeled **DCE DTE** (Figure 3-4) allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

### 6.2. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

Use the **SETUP>MORE>COM** menu to configure COM1 (labeled **RS232** on instrument rear panel) and/or COM2 (labeled **COM2** on instrument rear panel) for communication modes, baud rate and/or port testing for correct connection. If using a USB option communication connection, setup requires configuring the COM2 baud rate (Section 6.2.2).

## 6.2.1. COMMUNICATION MODES

Each of the analyzer's serial ports can be configured to operate in a number of different modes, listed in Table 6-1. As modes are selected, the analyzer sums the mode ID numbers and displays this combined number on the front panel display. For example, if quiet mode (01), computer mode (02) and Multi-Drop-Enabled mode (32) are selected, the analyzer would display a combined **MODE ID** of 35.

**Table 6-1: COM Port Communication Modes**

MODE <sup>1</sup>	ID	DESCRIPTION
QUIET	1	Quiet mode suppresses any feedback from the analyzer (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is still available but a command must be issued to receive them.
COMPUTER	2	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer operated control program.
HESSEN PROTOCOL	16	The Hessen communications protocol is used in some European countries. TAPI P/N 02252 contains more information on this protocol.
E, 8, 1	8192	When turned on this mode switches the COM port settings from No parity; 8 data bits; 1 stop bit to Even parity; 8 data bits; 1 stop bit.
E, 7, 1	2048	When turned on this mode switches the COM port settings from No parity; 8 data bits; 1 stop bit to Even parity; 7 data bits; 1 stop bit.
RS-485	1024	Configures the <b>COM2</b> Port for RS-485 communication. RS-485 mode has precedence over multidrop mode if both are enabled. Also, configuring for RS-485 disables the rear panel USB port.
SECURITY	4	When enabled, the serial port requires a password before it will respond (see Section 5.5). The only command that is active is the help screen (? CR).
MULTIDROP PROTOCOL	32	Multidrop protocol allows a multi-instrument configuration on a single communications channel. Multidrop requires the use of instrument IDs.
ENABLE MODEM	64	Enables to send a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING <sup>2</sup>	128	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF HANDSHAKE <sup>2</sup>	256	Disables XON/XOFF data flow control also known as software handshaking.
HARDWARE HANDSHAKE	8	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO <sup>2</sup>	512	Disables the <b>HARDWARE FIFO</b> (First In – First Out). When FIFO is enabled, it improves data transfer rate for that COM port.
COMMAND PROMPT	4096	Enables a command prompt when in terminal mode.
<sup>1</sup> Modes are listed in the order in which they appear in the <b>SETUP → MORE → COM → COM[1 OR 2] → MODE</b> menu <sup>2</sup> The default setting for this feature is <b>ON</b> . Do not disable unless so instructed by Teledyne API's Customer Service personnel.		

Communication Modes for each COM port must be configured independently. To turn on or off the communication modes for either COM1 or COM2, access the SETUP>MORE.[COM1 OR COM2] menu, and at the COM1 [2] Mode menu press EDIT.

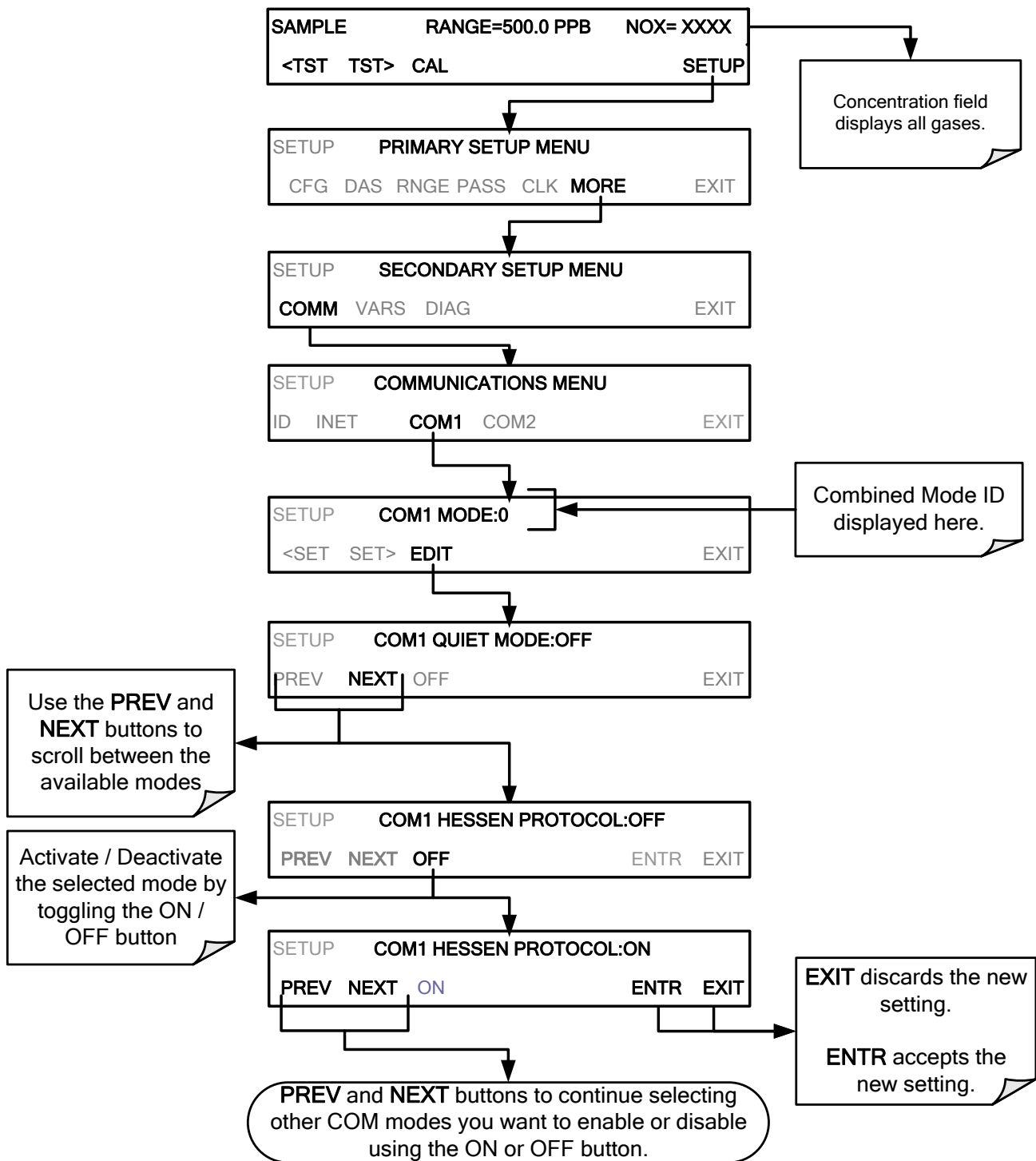


Figure 6-1. COM – Communication Modes Setup

### 6.2.2. COM PORT BAUD RATE

To select the baud rate of either COM Port, go to SETUP>MORE>COM and select either COM1 or COM2 as follows (use COM2 to view/match your personal computer baud rate when using the USB port, Section 6.6):

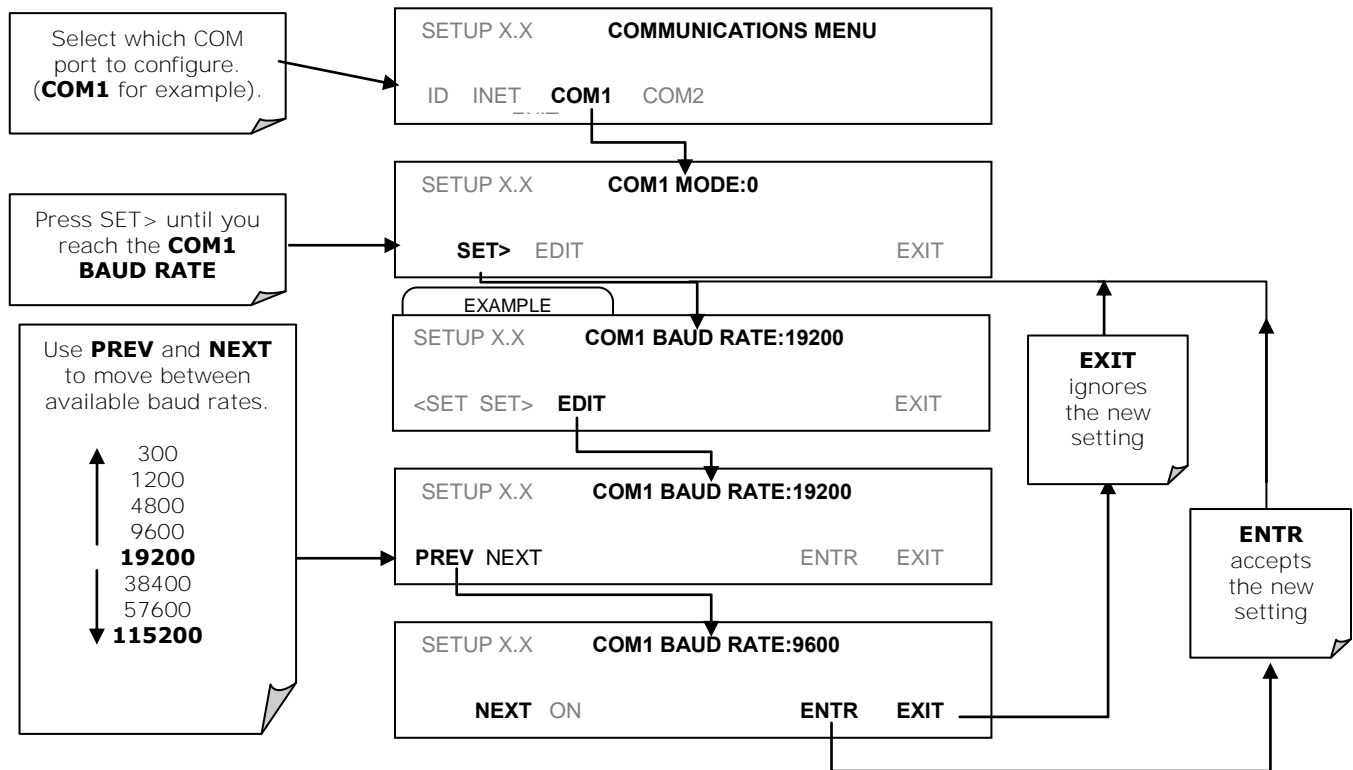


Figure 6-2. COM – COM Port Baud Rate

### 6.2.3. COM PORT TESTING

The serial ports can be tested for correct connection and output in the COM menu. This test sends a string of 256 ‘w’ characters to the selected COM port. While the test is running, the red LED on the rear panel of the analyzer should flicker.

To initiate the test press the following button sequence:

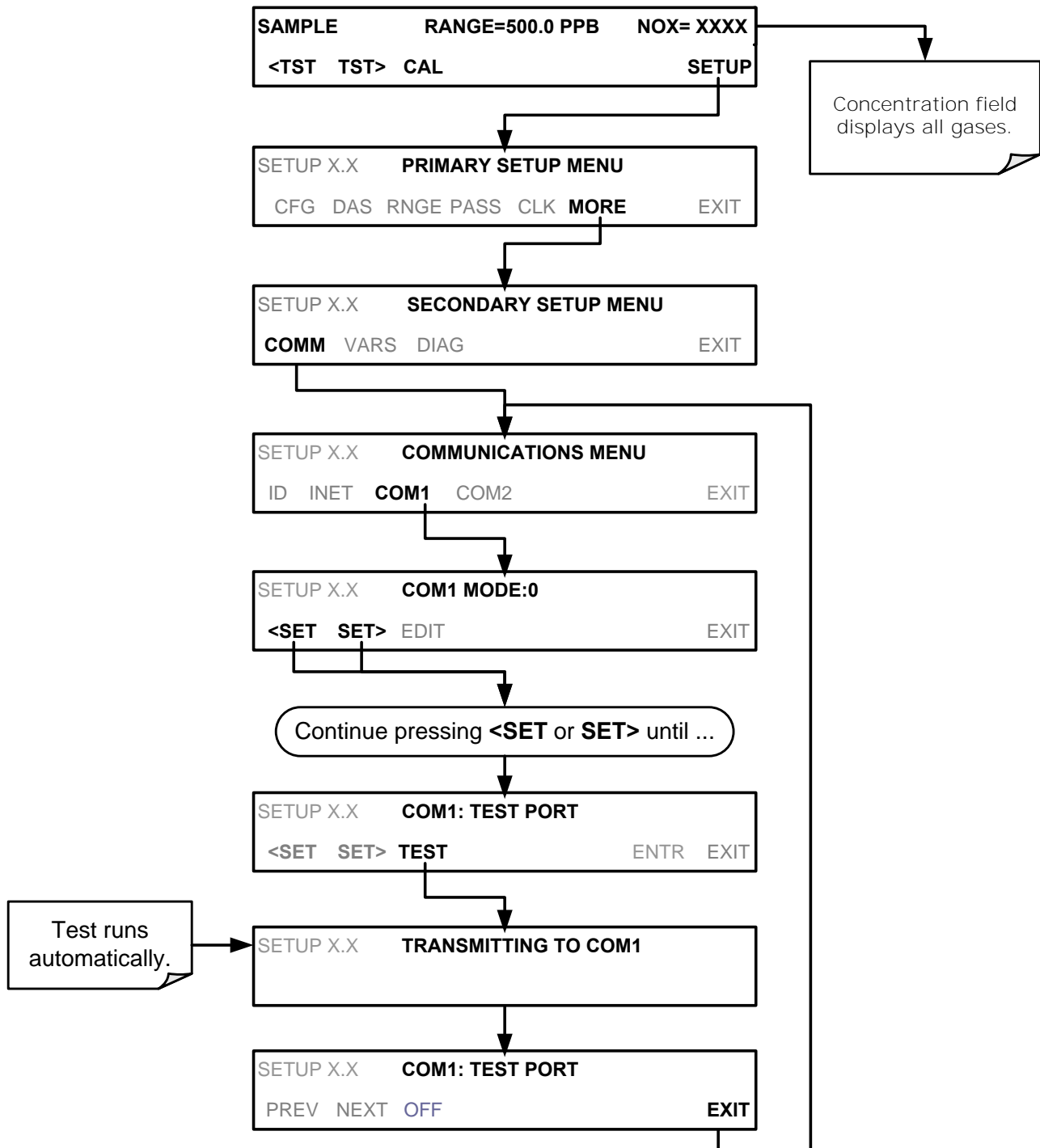


Figure 6-3. COM – COM1 Test Port



## 6.3. RS-232

The RS232 and COM2 communications (COMM) ports operate on the RS-232 protocol (default configuration). Possible configurations for these two COM ports are summarized as follows:

- **RS232** port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section 3.3.1.8.
- **COM2** port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

Note that when the rear panel **COM2** port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, **COM2** port cannot be used except for multidrop).

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne API Sales for more information on CAS systems.

To configure the analyzer's communication ports, use the SETUP>MORE>COM menu. Refer to Section 5.7 for initial setup, and to Section 6.2 for additional configuration information.

## 6.4. RS-485 (OPTION)

The COM2 port of the instrument's rear panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Customer Service. If this option was elected at the time of purchase, the rear panel was preconfigured at the factory.

## 6.5. ETHERNET

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using APICOM, terminal emulators or other programs.

The Ethernet connector has two LEDs that are on the connector itself, indicating its current operating status.

**Table 6-2: Ethernet Status Indicators**

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity)	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server (Section 6.5.2). This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used. Section 6.5.1 below details how to configure the instrument with a static IP address.

### 6.5.1. CONFIGURING ETHERNET COMMUNICATION MANUALLY (STATIC IP ADDRESS)

To configure Ethernet communication manually:

1. Connect a cable from the analyzer's Ethernet port to a Local Area Network (LAN) or Internet port.
2. From the analyzer's front panel touchscreen, access the Communications Menu (SETUP>MORE>COMM, see Figure 5-2).
3. Enter the INET menu shown in Figure 6-4, turning DHCP mode to OFF and editing the Instrument and Gateway IP addresses and Subnet Mask to the desired settings (default settings shown in Table 6-3).

Alternatively, from the computer, enter the same information through an application such as HyperTerminal.

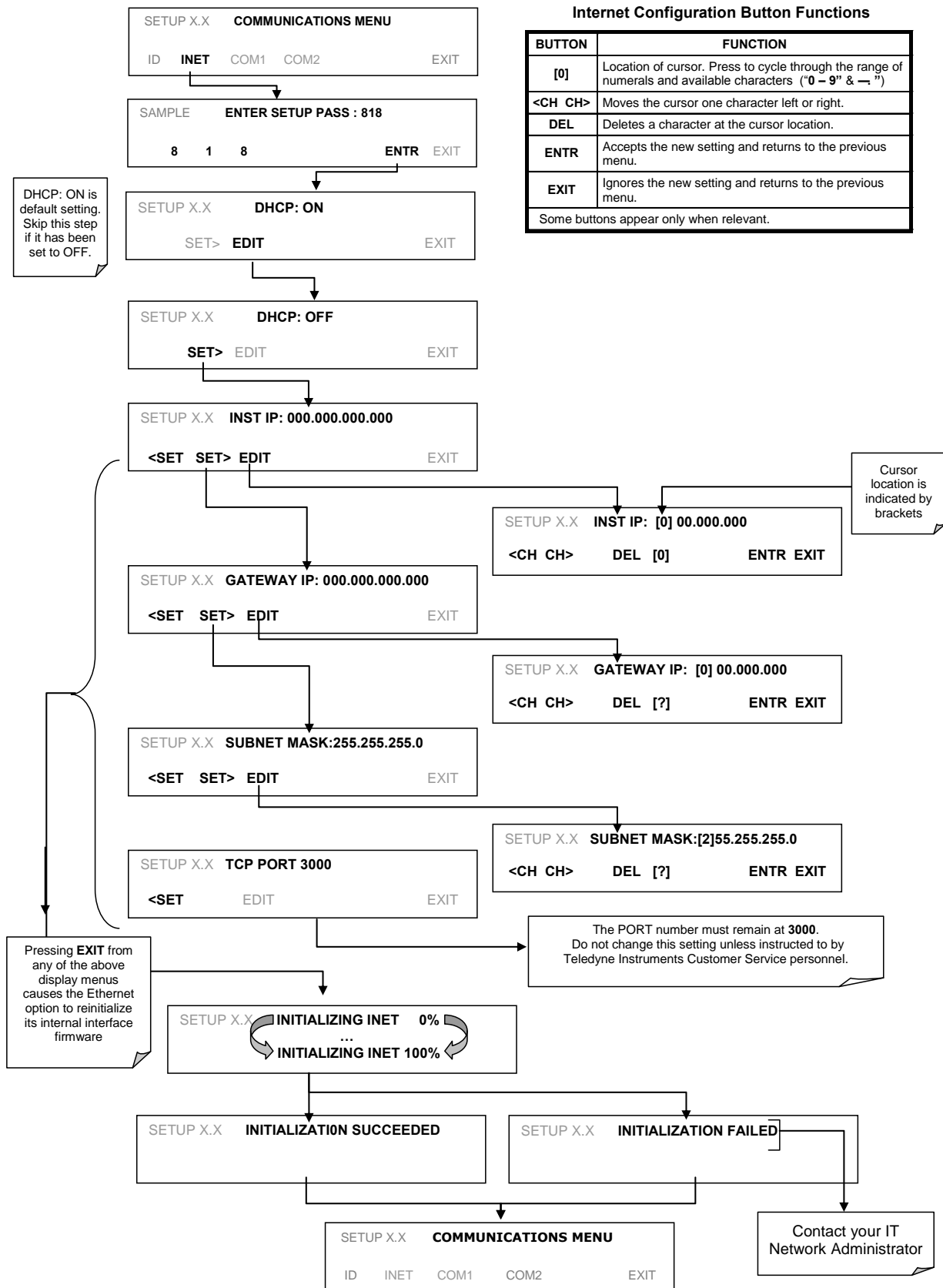


Figure 6-4. COM - LAN /Internet Manual Configuration

Table 6-3. LAN/Ethernet Default Configuration Properties

PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP	ON	This displays whether the DHCP is turned ON or OFF. Press EDIT and toggle ON for automatic configuration after first consulting network administrator.
INSTRUMENT IP ADDRESS		This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the analyzer itself.
GATEWAY IP ADDRESS	0.0.0.0	Can only be edited when DHCP is set to OFF. A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	0.0.0.0	Can only be edited when DHCP is set to OFF. Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
TCP PORT <sup>1</sup>	3000	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
HOST NAME	[initially blank]	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. To assign or change, see Section 6.5.2.1.
<sup>1</sup> Do not change the setting for this property unless instructed to by Teledyne API's Customer Service personnel.		

## 6.5.2. CONFIGURING ETHERNET COMMUNICATION USING DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP)

The default Ethernet setting is DHCP.

1. Consult with your network administrator to affirm that your network server is running DHCP.
2. Access the Communications Menu (SETUP>MORE>COMM, see Figure 5-2).
3. Enter the INET menu and follow the setup sequence as shown in Figure 6-5.

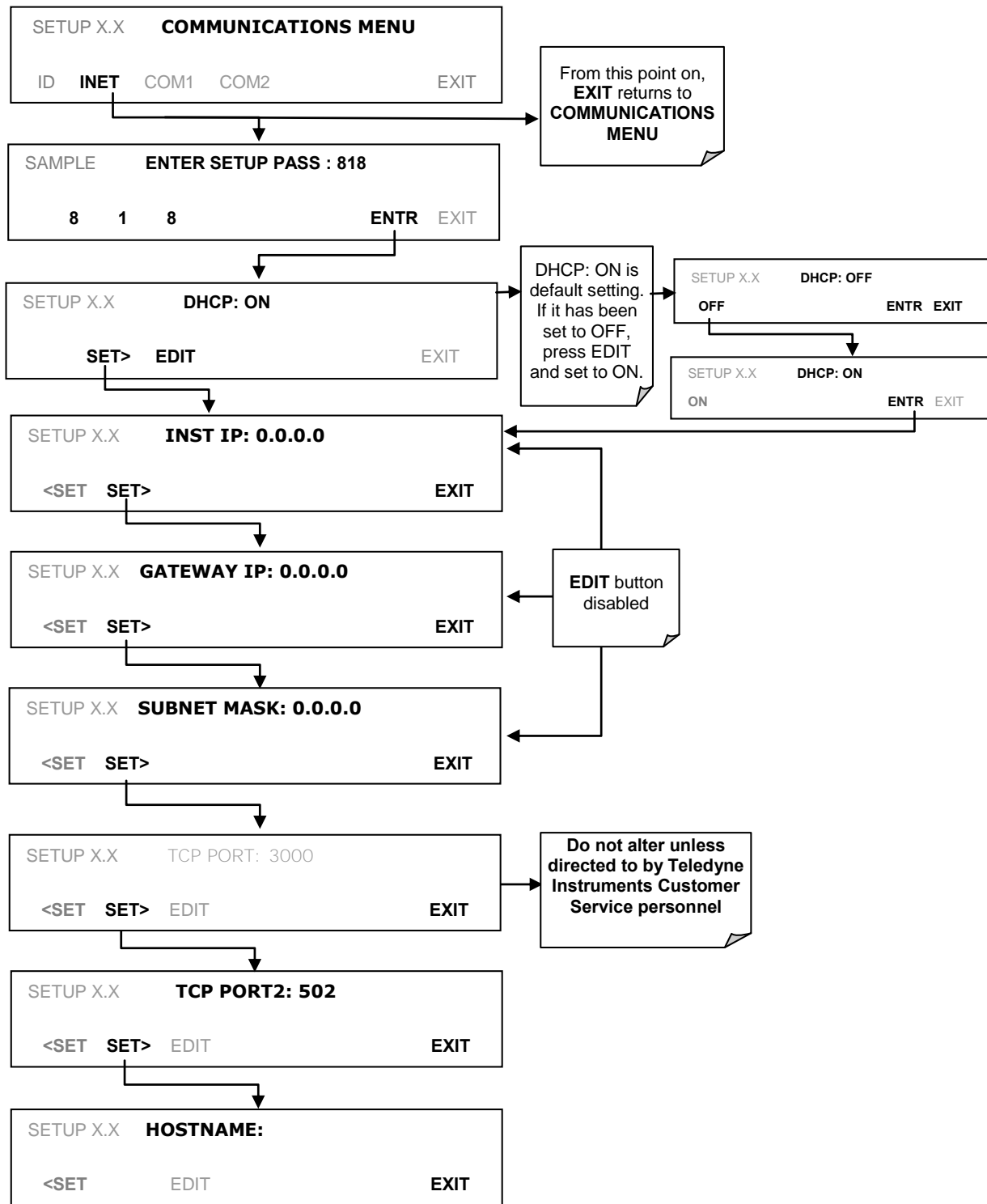


Figure 6-5. COM – LAN / Internet Automatic Configuration (DHCP)

**Note**

If the gateway IP, instrument IP and the subnet mask are all zeroes (i.e., –0.0.0.0”), the DHCP was not successful in which case you may have to configure the analyzer’s Ethernet properties manually. See your network administrator.

### 6.5.2.1. CHANGING THE ANALYZER'S HOSTNAME

The **HOSTNAME** is the name by which the analyzer appears on your network. The initial default Hostname is blank. To assign or change this name (particularly if you have more than one T200 analyzer on your network, where each must have a different Hostname), enter the **SETUP>COMM>INET** menu and scroll to the **HOSTNAME** menu as in Figure 6-5; make the changes as shown in Figure 6-6:

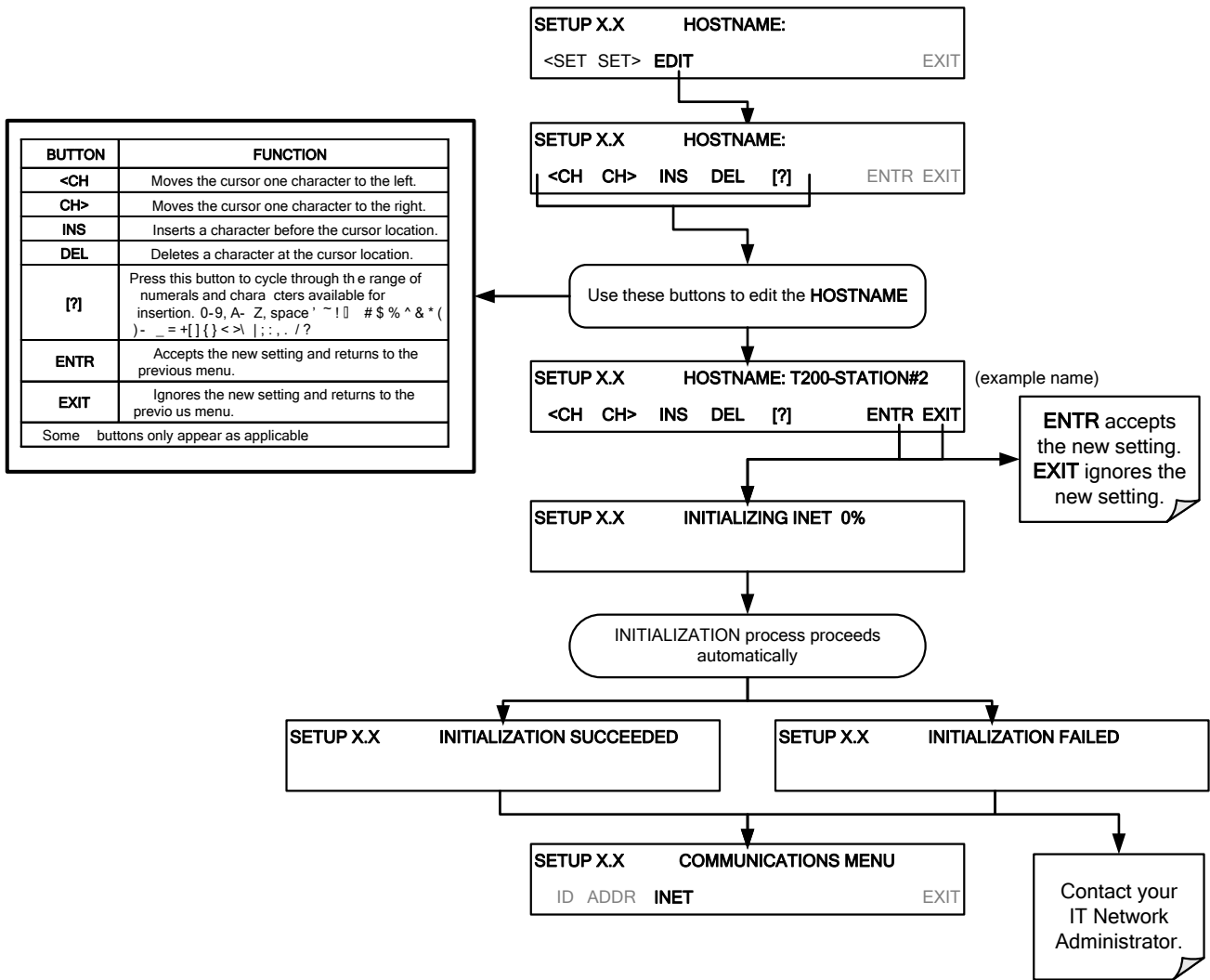


Figure 6-6. COM – Change Hostname

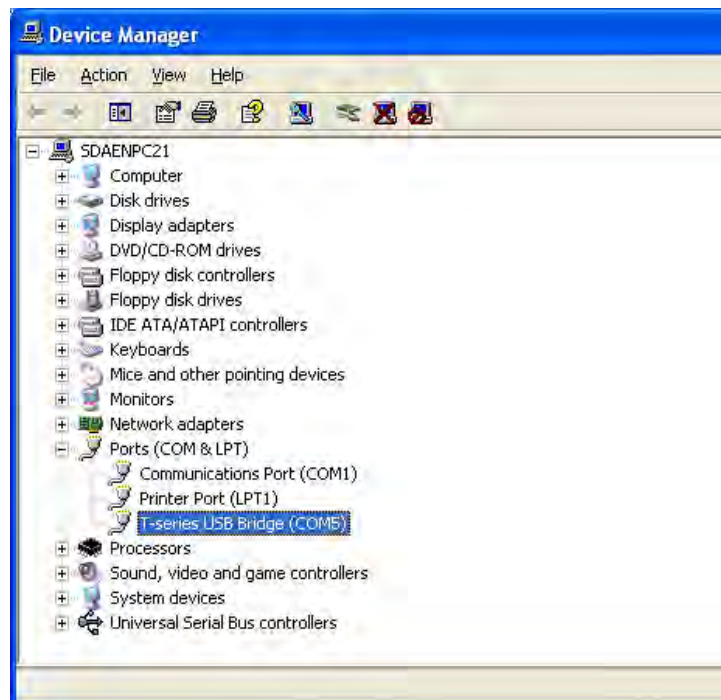
## 6.6. USB PORT FOR REMOTE ACCESS

The analyzer can be operated through a personal computer by downloading the TAPI USB driver and directly connecting their respective USB ports.

1. Install the Teledyne T-Series USB driver on your computer, downloadable from the Teledyne API website under Help Center>Software Downloads ([www.teledyne-api.com/software](http://www.teledyne-api.com/software)).
2. Run the installer file: “TAPIVCPInstaller.exe”



3. Connect the USB cable between the USB ports on your personal computer and your analyzer. The USB cable should be a Type A – Type B cable, commonly used as a USB printer cable.
4. Determine the Windows XP Com Port number that was automatically assigned to the USB connection. (Start → Control Panel → System → Hardware → Device Manager). This is the com port that should be set in the communications software, such as APIcom or Hyperterminal.



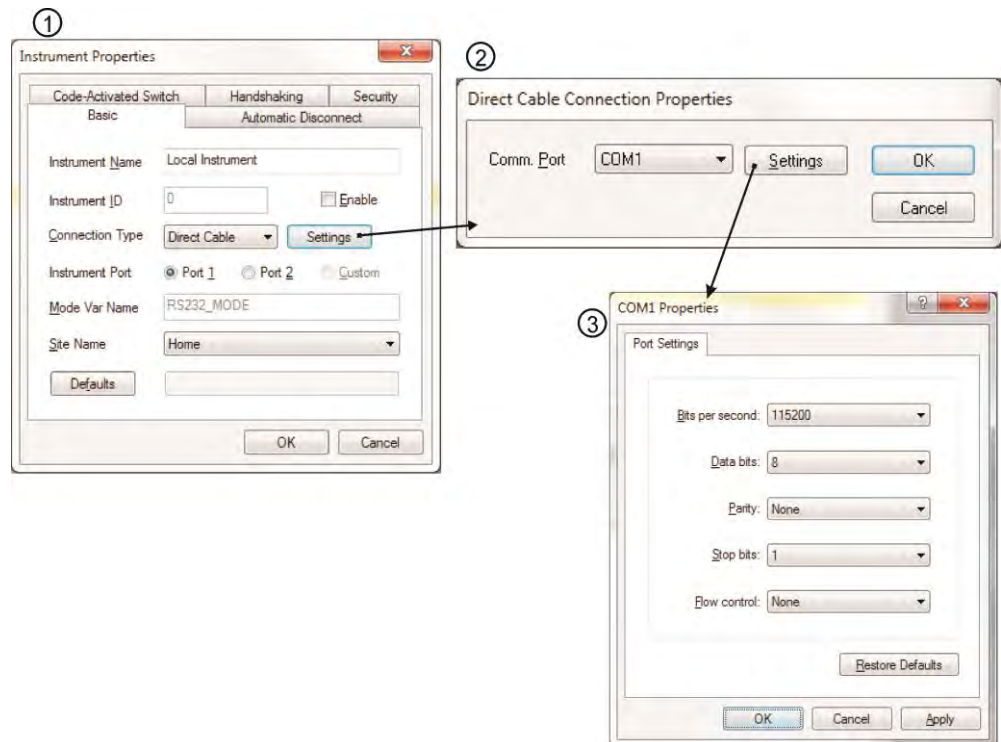
Refer to the Quick Start (*Direct Cable Connection*) section of the Teledyne APIcom Manual, PN 07463.

5. In the instrument's SETUP>MORE>COMM>COM2 menu, make the following settings:

Baud Rate: 115200  
 COM2 Mode Settings:

Quiet Mode	ON
Computer Mode	ON
MODBUS RTU	OFF
MODBUS ASCII	OFF
E,8,1 MODE	OFF
E,7,1 MODE	OFF
RS-485 MODE	OFF
SECURITY MODE	OFF
MULTIDROP MODE	OFF
ENABLE MODEM	OFF
ERROR CHECKING	ON
XON/XOFF HANDSHAKE	OFF
HARDWARE HANDSHAKE	OFF
HARDWARE FIFO	ON
COMMAND PROMPT	OFF

6. Next, configure your communications software, such as APIcom. Use the COM port determined in Step 4 and the baud rate set in Step 5. The figures below show how these parameters would be configured in the Instrument Properties window in APIcom when configuring a new instrument. See the APIcom manual (PN 07463) for more details.



#### Note

- **USB configuration requires that the baud rates of the instrument and the PC match; check the PC baud rate and change if needed.**
- **Using the USB port disallows use of the rear panel COM2 port except for multidrop communication.**



## 6.7. COMMUNICATIONS PROTOCOLS

Two communications protocols available with the analyzer are MODBUS and Hessen. MODBUS setup instructions are provided here (Section 6.7.1) and registers are provided in Appendix A. Hessen setup and operation instructions are provided in Section 6.7.2.

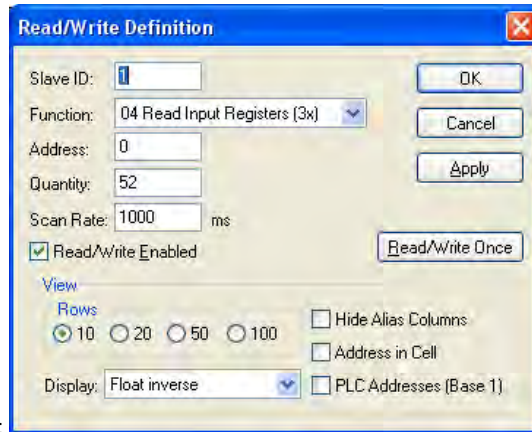
### 6.7.1. MODBUS

The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to [www.modbus.org](http://www.modbus.org) for MODBUS communication protocols.

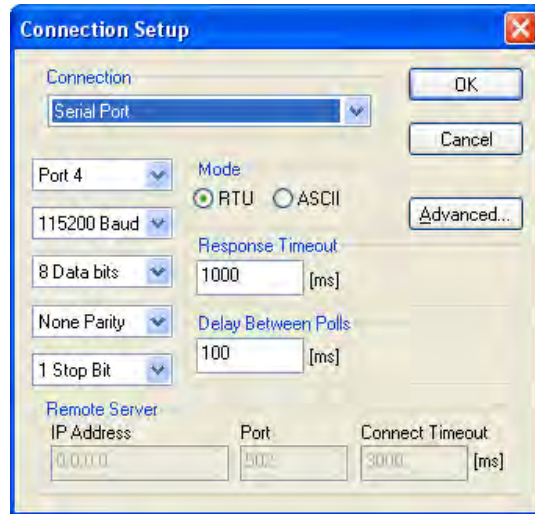
Minimum Requirements

- Instrument firmware with MODBUS capabilities installed.
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see [www.modbustools.com](http://www.modbustools.com))
- Personal computer
- Communications cable (Ethernet or USB or RS232)
- Possibly a null modem adapter or cable

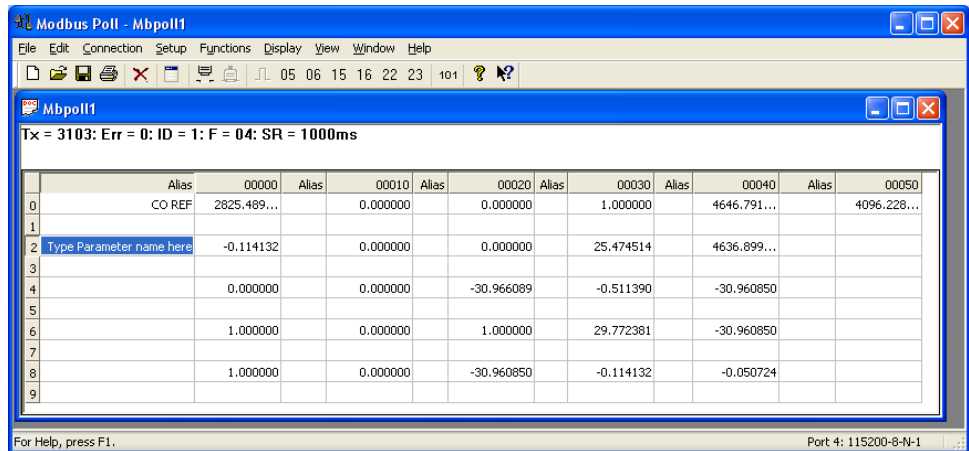
Actions	
Set Com Mode parameters  Comm          Slave ID	Ethernet: Using the front panel menu, go to SETUP – MORE – COM – INET; scroll through the INET submenu until you reach TCP PORT 2 (the standard setting is 502), then continue to TCP PORT 2 MODBUS TCP/IP; press EDIT and toggle the menu button to change the setting to ON, then press ENTR. (Change Machine ID if needed: see “Slave ID”).  USB/RS232: Using the front panel menu, go to SETUP – MORE – COM – COM2 – EDIT; scroll through the COM2 EDIT submenu until the display shows COM2 MODBUS RTU: OFF (press OFF to change the setting to ON. Scroll NEXT to COM2 MODBUS ASCII and ensure it is set to OFF. Press ENTR to keep the new settings. (If RTU is not available with your communications equipment, set the COM2 MODBUS ASCII setting to ON and ensure that COM2 MODBUS RTU is set to OFF. Press ENTR to keep the new settings).  If your analyzer is connected to a network with at least one other analyzer of the same model, a unique Slave ID must be assigned to each. Using the front panel menu, go to SETUP – MORE – COM – ID. The MACHINE ID default is the same as the model number. Toggle the menu buttons to change the ID.
Reboot analyzer	For the settings to take effect, power off the analyzer, wait 5 seconds, and power it on again.
Make appropriate cable connections	Connect your analyzer either: <ul style="list-style-type: none"> <li>• via its Ethernet or USB port to a PC (this may require a USB-to-RS232 adapter for your PC; if so, also install the software driver from the CD supplied with the adapter, and reboot the computer if required), or</li> <li>• via its COM2 port to a null modem (this may require a null modem adapter or cable).</li> </ul>
Specify MODBUS software settings (examples used here are for MODBUS Poll software)	1. Click Setup / [Read / Write Definition] /. <ol style="list-style-type: none"> <li>a. In the Read/Write Definition window (see example that follows) select a <b>Function</b> (what you wish to read from the analyzer).</li> <li>b. Input <b>Quantity</b> (based on your firmware’s register map).</li> <li>c. In the View section of the Read/Write Definition window select a <b>Display</b> (typically Float Inverse).</li> <li>d. Click <b>OK</b>.</li> </ol> 2. Next, click Connection/Connect. <ol style="list-style-type: none"> <li>a. In the Connection Setup window (see example that follows), select the options based on your computer.</li> <li>b. Press <b>OK</b>.</li> </ol>
Read the Modbus Poll Register	Use the Register Map to find the test parameter names for the values displayed (see example that follows If desired, assign an alias for each.



Example Read/Write Definition window:



Example Connection Setup window:



Example MODBUS Poll window:

## 6.7.2. HESSEN

The Hessen protocol is a multidrop protocol, in which several remote instruments are connected via a common communications channel to a host computer. The remote instruments are regarded as slaves of the host computer. The remote instruments are unaware that they are connected to a multidrop bus and never initiate Hessen protocol messages. They only respond to commands from the host computer and only when they receive a command containing their own unique ID number.

The Hessen protocol is designed to accomplish two things: to obtain the status of remote instruments, including the concentrations of all the gases measured; and to place remote instruments into zero or span calibration or measure mode. Teledyne API's implementation supports both of these principal features.

The Hessen protocol is not well defined; therefore, while Teledyne-API's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

### 6.7.2.1. HESSEN COM PORT CONFIGURATION

Hessen protocol requires the communication parameters of the T200's COM ports to be set differently than the standard configuration as shown in the table below.

**Table 6-4: RS-232 Communication Parameters for Hessen Protocol**

PARAMETER	STANDARD	HESSEN
Baud Rate	300 – 19200	1200
Data Bits	8	7
Stop Bits	1	2
Parity	None	Even
Duplex	Full	Half

To change the baud rate of the T200's COM ports, See Section 6.2.2.

To change the remaining COM port parameters listed in the table above, see Section 6.2.1, Table 6-1.

#### Note

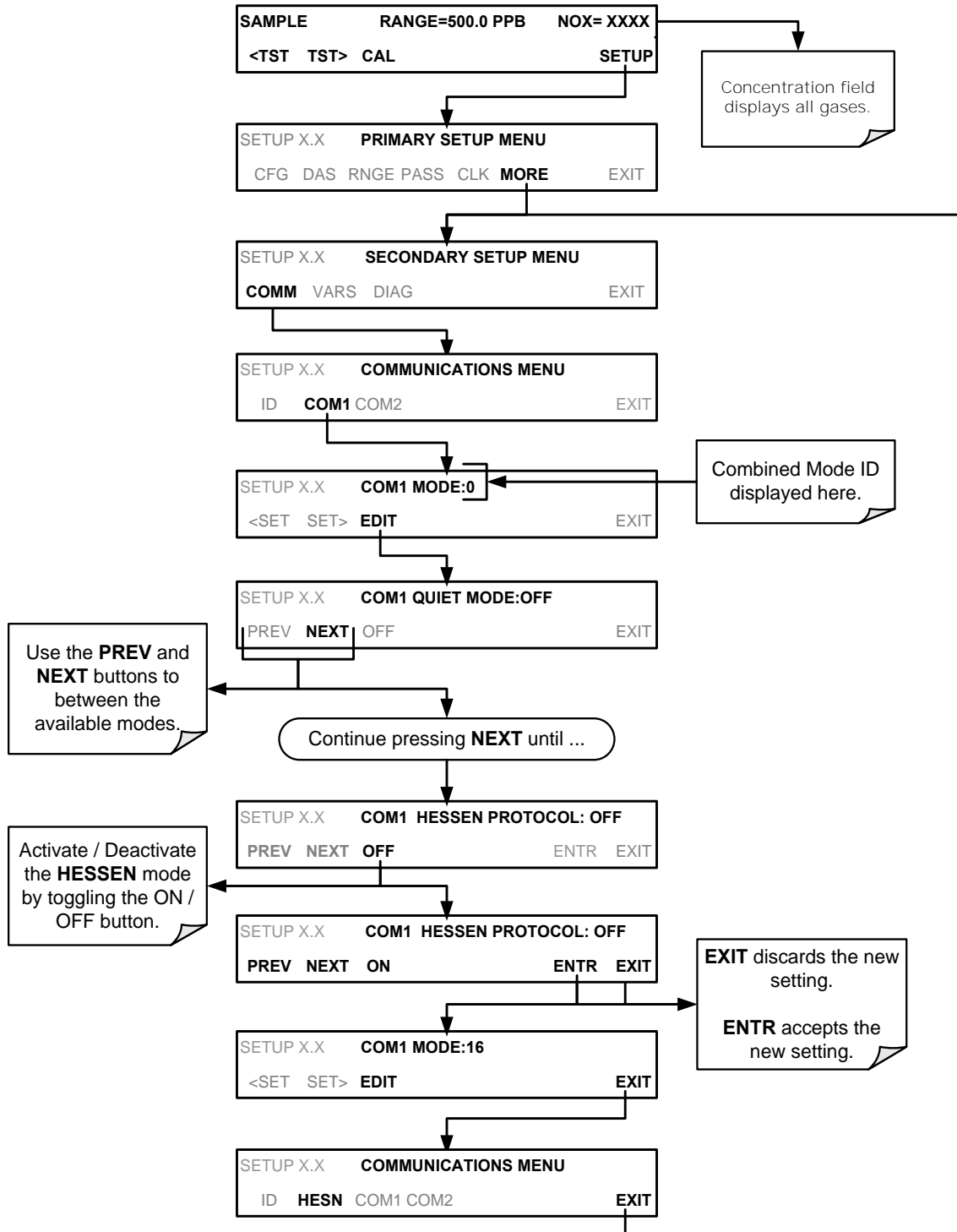
-----  
**Ensure that the communication parameters of the host computer are also properly set.**

**Also, the instrument software has a 200 ms latency period before it responds to commands issued by the host computer. This latency should present no problems, but you should be aware of it and not issue commands to the instrument too frequently.**  
 -----

### 6.7.2.2. ACTIVATING HESSEN PROTOCOL

Once the COM port has been properly configured, the next step in configuring the T200 in order to operate over a Hessen protocol network is to activate the Hessen mode for COM ports and configure the communication parameters for the port(s) appropriately.

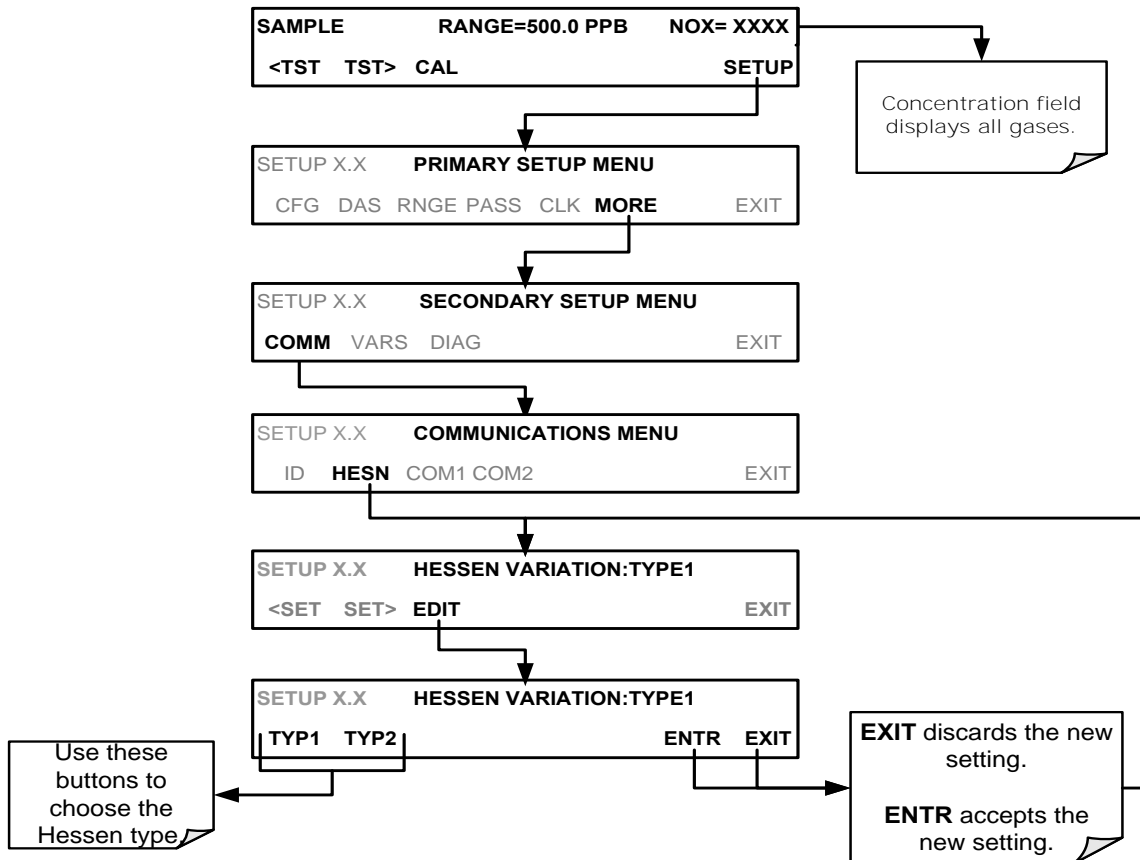
To activate the Hessen Protocol, press:



### 6.7.2.3. SELECTING A HESSEN PROTOCOL TYPE

Currently there are two versions of Hessen Protocol in use. The original implementation, referred to as **TYPE 1**, and a more recently released version, **TYPE 2** that has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between **TYPE 1** and **TYPE 2** download the *Manual Addendum for Hessen Protocol* from the Teledyne API's web site: <http://www.teledyne-api.com/manuals/>.

To select a Hessen Protocol Type press:



**Note**

- While Hessen Protocol Mode can be activated independently for COM1 and COM2, the TYPE selection affects both Ports.

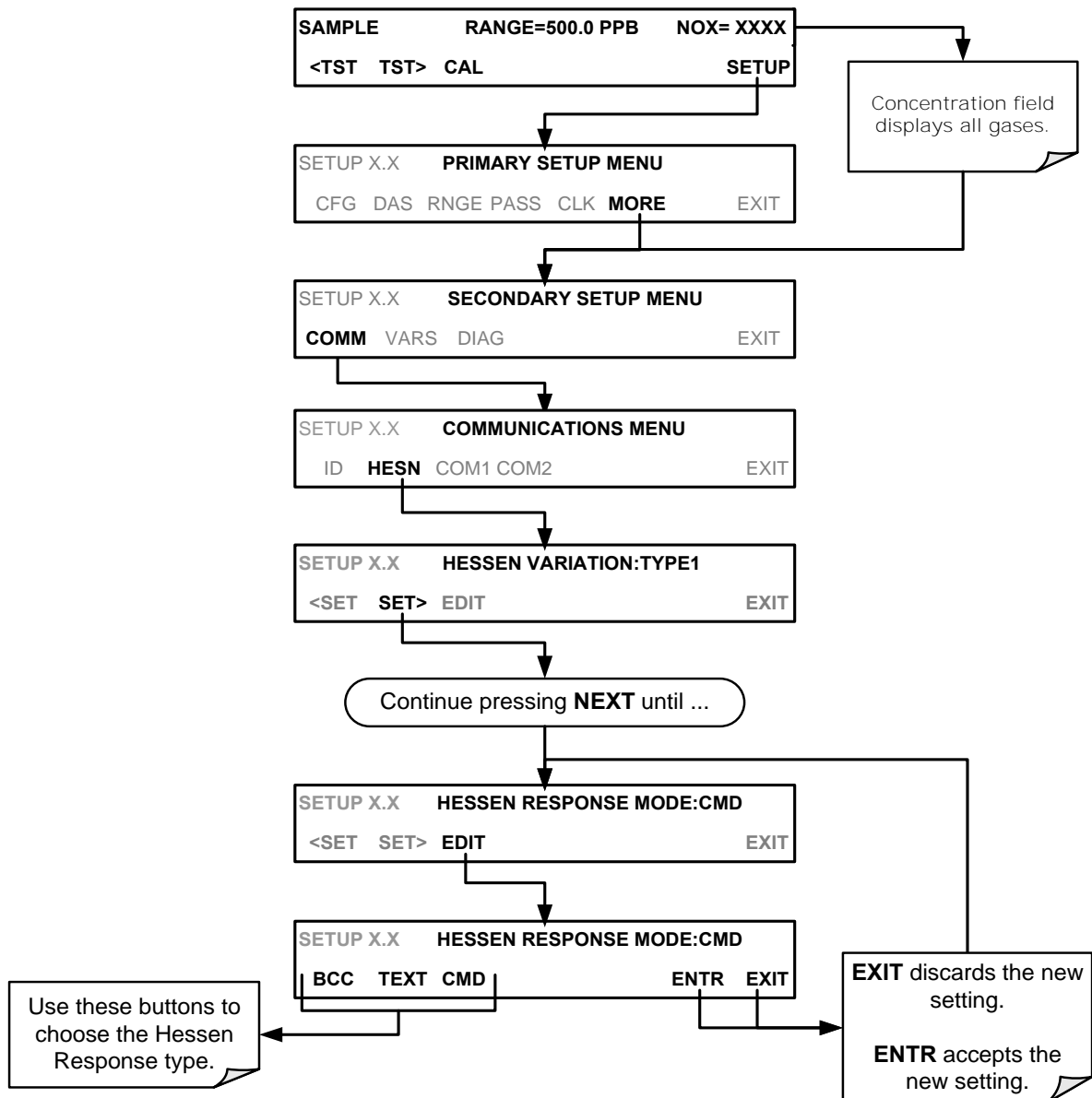
### 6.7.2.4. SETTING THE HESSEN PROTOCOL RESPONSE MODE

The Teledyne API's implementation of Hessen Protocol allows the user to choose one of several different modes of response for the analyzer.

**Table 6-5: Teledyne API's Hessen Protocol Response Modes**

MODE ID	MODE DESCRIPTION
<b>CMD</b>	This is the Default Setting. Responses from the instrument are encoded as the traditional command format. Style and format of responses depend on exact coding of the initiating command.
<b>BCC</b>	Responses from the instrument are always delimited with <STX> (at the beginning of the response, <ETX> (at the end of the response followed by a 2 digit Block Check Code (checksum), regardless of the command encoding.
<b>TEXT</b>	Responses from the instrument are always delimited with <CR> at the beginning and the end of the string, regardless of the command encoding.

To Select a Hessen response mode, press:



### 6.7.2.5. HESSEN PROTOCOL GAS LIST ENTRY FORMAT AND DEFINITIONS

The T200 analyzer keeps a list of available gas types. Each entry in this list is of the following format.

**[GAS TYPE],[RANGE],[GAS ID],[REPORTED]**

WHERE:

**GAS TYPE** The type of gas to be reported (e.g. NO<sub>x</sub>, NO and NO<sub>2</sub> etc.).

**RANGE** The concentration range for this entry in the gas list. This feature permits the user to select which concentration range will be used for this gas list entry. The T200 analyzer has two ranges: **RANGE1** or LOW & **RANGE2** or HIGH (see Section 5.4).

- 0 - The HESSEN protocol to use whatever range is currently active.
- 1 - The HESSEN protocol will always use RANGE1 for this gas list entry
- 2 - The HESSEN protocol will always use RANGE2 for this gas list entry
- 3 - Not applicable to the T200 analyzer.

**GAS ID** An identification number assigned to a specific gas. The T200 analyzer is a multiple gas instrument that measures NO<sub>x</sub>, NO and NO<sub>2</sub>. Their ID numbers are as follows:

NO<sub>x</sub> 211  
NO 212  
NO<sub>2</sub> 213

**REPORT** States whether this list entry is to be reported or not reported when ever this gas type or instrument is polled by the HESSEN network. If the list entry is not to be reported this field will be blank. It's default gas list consists of only reads:

**NOX, 0, 211, REPORTED**  
**NO, 0, 212, REPORTED**  
**NO2, 0, 213, REPORTED**

These default settings cause the instrument to report the concentration value of the currently active range. If you wish to have just concentration value stored for a specific range, this list entry should be edited or additional entries should be added to the list.

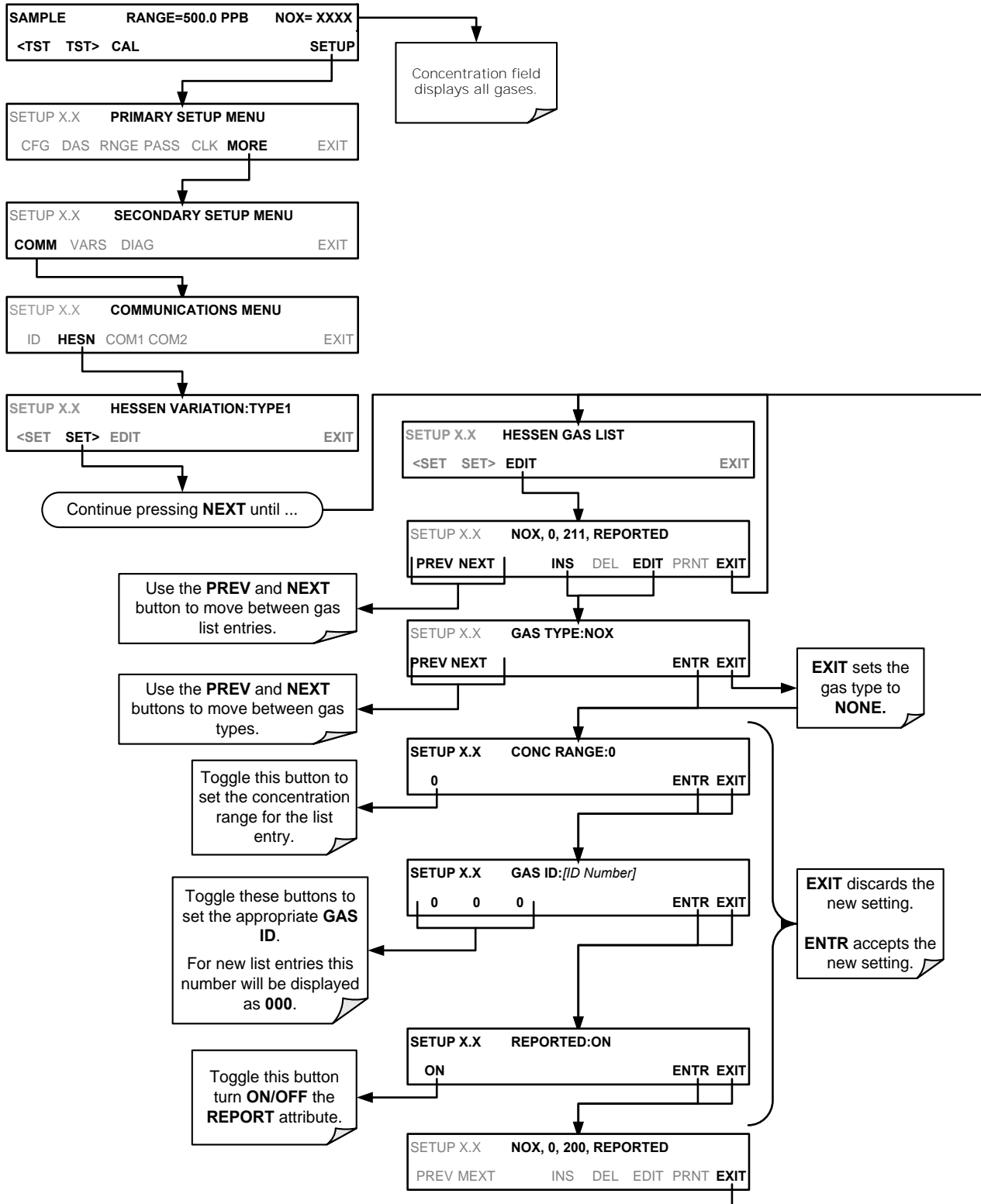
EXAMPLE: Changing the above NO<sub>x</sub> gas list entry to read:

**NOX, 2, 211, REPORTED**

Would only record the last NO<sub>x</sub> reading that occurred while **RANGE2** (HIGH) range was active.

### EDITING OR ADDING HESSEN GAS LIST ENTRIES

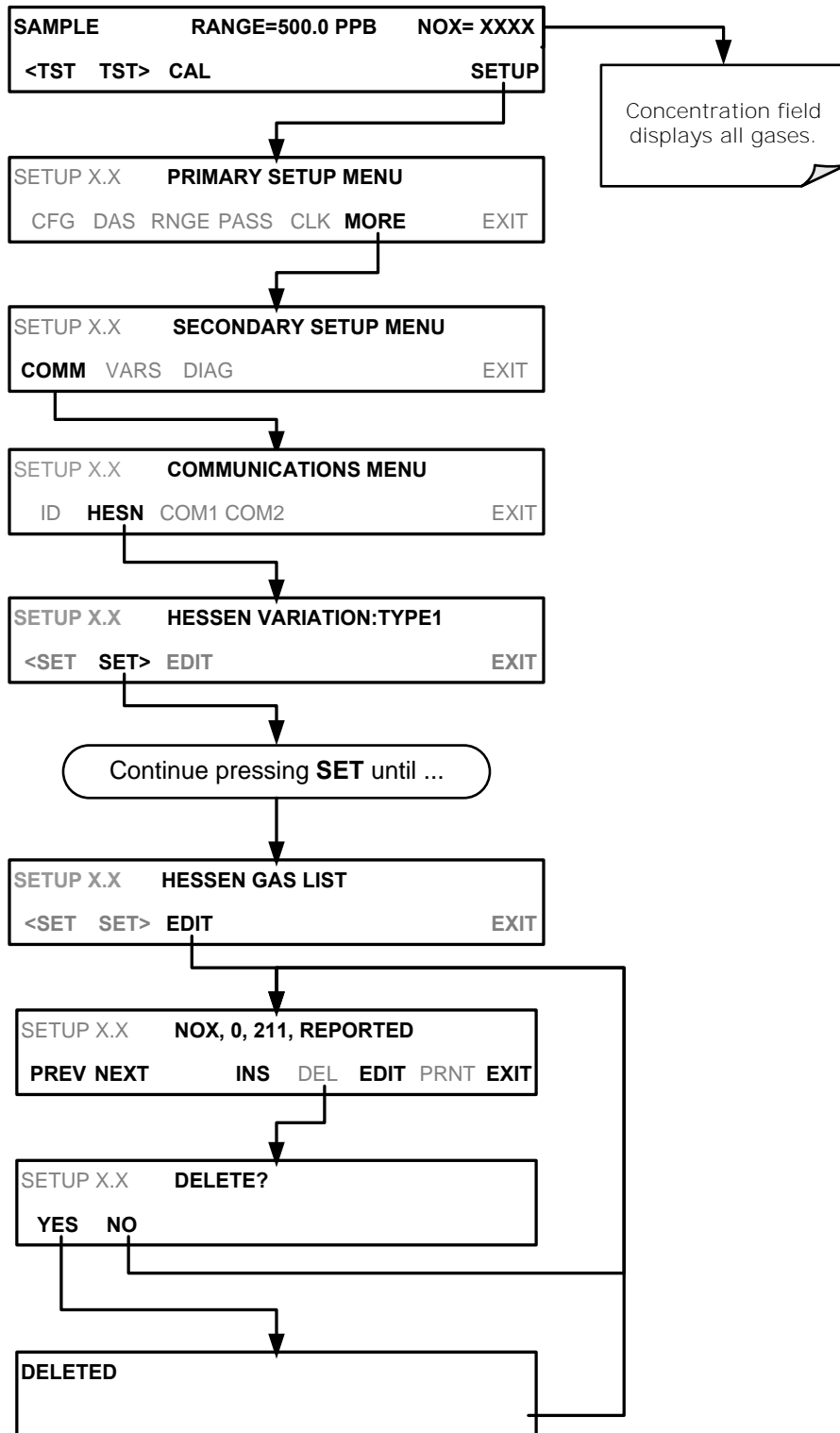
To add or edit an entry to the Hessen Gas List, press:





### DELETING HESSEN GAS LIST ENTRIES

To delete an entry from the Hessen Gas list, press:



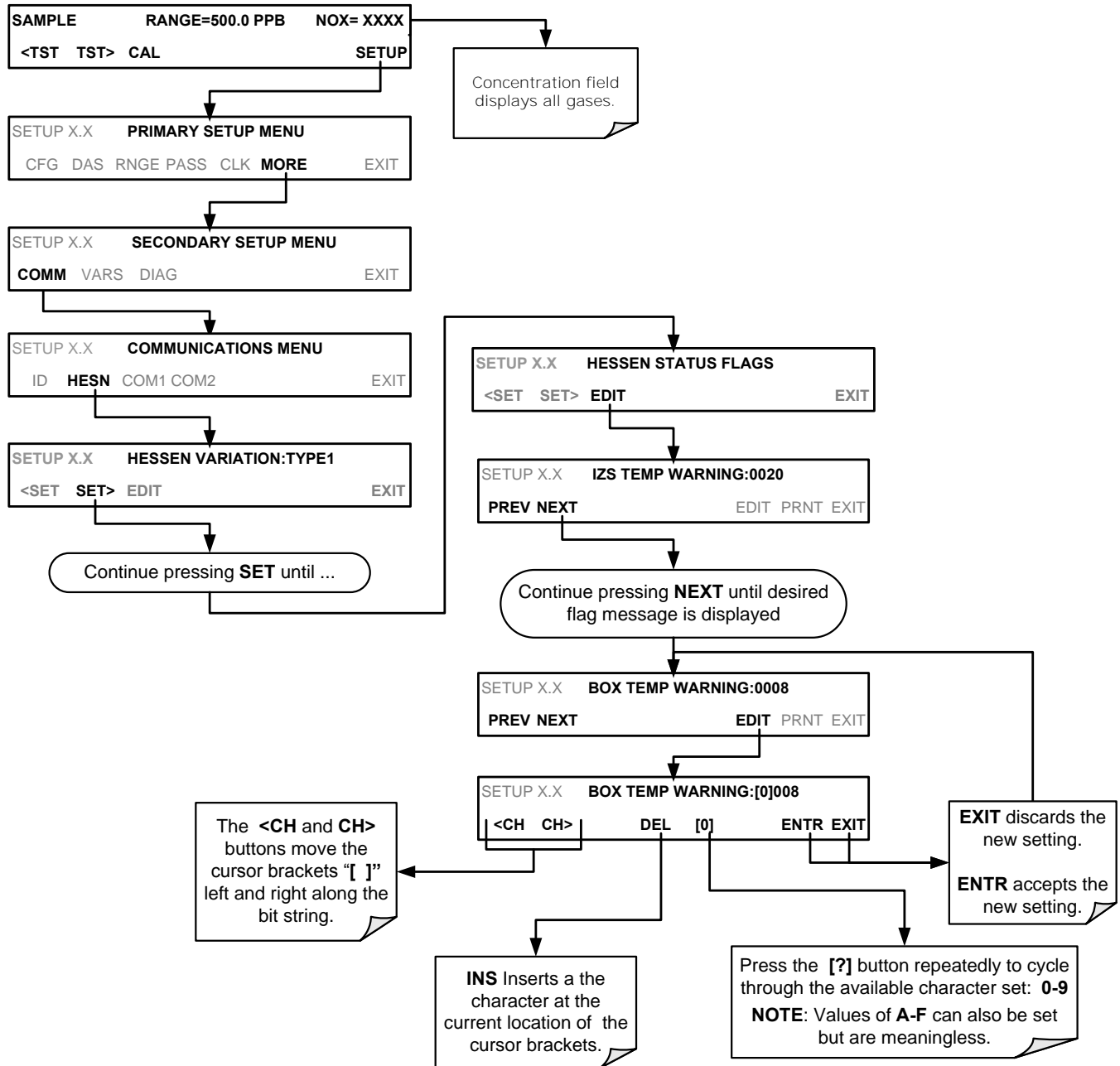
### 6.7.2.6. SETTING HESSEN PROTOCOL STATUS FLAGS

Teledyne API's implementation of Hessen protocols includes a set of status bits that the instrument includes in responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag. The default settings for these bit/flags are:

**Table 6-6: Default Hessen Status Flag Assignments**

STATUS FLAG NAME <sup>3</sup>	DEFAULT BIT ASSIGNMENT
<b>WARNING FLAGS</b>	
SAMPLE FLOW WARNING	0001
OZONE FLOW WARNING	0002
RCEL PRESS WARN	0004
BOX TEMP WARNING	0008
RCELL TEMP WARNING	0010
IZS TEMP WARNING <sup>1</sup>	0020
PMT TEMP WARN	0040
CONV TEMP WARNING	0080
INVALID CONC	8000
<b>OPERATIONAL FLAGS</b>	
In <b>MANUAL</b> Calibration Mode	0200
In <b>ZERO</b> Calibration Mode	0400
In <b>SPAN</b> Calibration Mode	0800
In <b>WARMUP</b> Mode	1000
<b>UNITS OF MEASURE FLAGS</b>	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
SPARE/UNUSED BITS	0100
<b>UNASSIGNED FLAGS (0000)</b>	
MANIFOLD TEMPERATURE <sup>2</sup>	HVPS WARNING
OZONE GEN OFF	FRONT PANEL WARN
SYSTEM RESET	ANALOG CAL WARNING
RELAY BOARD WARNING	CANNOT DYN ZERO
REAR BOARD NOT DETECTED	CANNOT DYN SPAN
AUTOZERO WARNING	Instrument is in MP CAL mode
<sup>1</sup> Only applicable if the optional internal span gas generator is installed. <sup>2</sup> Only applicable if the T200 is equipped with an oxygenator option. <sup>3</sup> It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit.  Be careful not to assign conflicting flags to the same bit as each status bit will be triggered if any of the assigned flags is active.	

To assign or reset the status flag bit assignments, press:



### 6.7.2.7. INSTRUMENT ID

Each instrument on a Hessen Protocol network must have a unique identifier (ID number). Refer to Section 5.7.1 for information and to customize the ID of each.

## 7. DATA ACQUISITION SYSTEM (DAS) AND APICOM

The T200 analyzer contains a flexible and powerful, internal data acquisition system (DAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The DAS feature of the T200 can store a large number of data points, which can, depending on individual configurations, cover days, weeks or months of valuable measurements. The data records are stored in non-volatile memory and are retained even when the instrument is powered off. Data are stored in plain text format for easy retrieval and use in common data analysis programs (such as electronic spreadsheets).

The DAS is designed to be flexible, users have full control over the type, length and reporting time of the data. The DAS permits users to access stored data through the instrument's front panel or remotely through its communication ports.

The principal use of the DAS is logging data for trend analysis and predictive diagnostics, which can assist in identifying possible problems before they affect the functionality of the analyzer. The secondary use is for data analysis, documentation and archival in electronic format.

To support the DAS functionality, Teledyne API offers APICOM, a program that provides a visual interface for remote or local setup, configuration and data retrieval of the DAS. Using APICOM, data can even be retrieved automatically to a remote computer for further processing. The APICOM manual, included with the program, contains a more detailed description of the DAS structure and configuration and is briefly described in this document.

The T200 is configured with a basic DAS configuration already enabled. The data channels included in this basic structure may be used as is or temporarily disabled for later or occasional use.

The green **SAMPLE LED** on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the DAS status:

**Table 7-1: Front Panel LED Status Indicators for DAS**

LED STATE	DAS Status
OFF	System is in calibration mode. Data logging can be enabled or disabled for this mode. Calibration data are typically stored at the end of calibration periods, concentration data are typically not sampled, diagnostic data should be collected.
BLINKING	Instrument is in hold-off mode, a short period after the system exits calibrations. DAS channels can be enabled or disabled for this period. Concentration data are typically disabled whereas diagnostic should be collected.
ON	Sampling normally.

**IMPORTANT****IMPACT ON READINGS OR DATA**

DAS operation is suspended whenever its configuration is edited using the analyzer's front panel and therefore data may be lost. To prevent such data loss, it is recommended to use the APICOM graphical user interface for DAS changes (Section 7.2.1).

Please be aware that all stored data will be erased if the analyzer's disk-on-module or CPU board is replaced or if the configuration data stored there is reset.

**Note**

The DAS can be disabled only by disabling or deleting its individual data channels.

## 7.1. DAS STRUCTURE

The DAS is designed around the feature of a “record”. A record is a single data point. The type of data captured in a record are defined by two properties:

- **PARAMETER** type that defines the kind of data to be stored (e.g. the average of O<sub>3</sub> concentrations measured with three digits of precision). See Section 7.1.3.3.
- A **TRIGGER** event that defines when the record is made (e.g. timer; every time a calibration is performed, etc.). See Section 7.1.3.2.

The specific **PARAMETERS** and **TRIGGER** events that describe an individual record are defined in a construct called a **DATA CHANNEL** (see Section 7.1.3). Each data channel relates one or more parameters with a specific trigger event and various other operational characteristics related to the records being made (e.g. the channels name, number or records to be made, time period between records, whether or not the record is exported via the analyzer's RS-232 port, etc.).

### 7.1.1. DAS CHANNELS

The key to the flexibility of the DAS is its ability to store a large number of combinations of triggering events and data parameters in the form of data channels. Users may create up to 20 data channels and each channel can contain one or more parameters. For each channel, the following are selected:

- one triggering event
- up to 50 data parameters, which can be the shared between channels
- several other properties that define the structure of the channel and allow the user to make operational decisions regarding the channel

**Table 7-2: DAS Data Channel Properties**

PROPERTY	DESCRIPTION	DEFAULT SETTING	SETTING RANGE
<b>NAME</b>	The name of the data channel.	<b>–NONE”</b>	Up to 6 letters or digits <sup>1</sup> .
<b>TRIGGERING EVENT</b>	The event that triggers the data channel to measure and store the datum.	<b>ATIMER</b>	Any available event (see Appendix A-5).
<b>NUMBER AND LIST OF PARAMETERS</b>	A user-configurable list of data types to be recorded in any given channel.	<b>1</b> (PMTDET)	Any available parameter (see Appendix A-5).
<b>REPORT PERIOD</b>	The amount of time between each channel data point.	<b>000:01:00</b> (1 hour)	000:00:01 to 366:23:59 (Days:Hours:Minutes)
<b>NUMBER OF RECORDS</b>	The number of reports that will be stored in the data file. Once the limit is exceeded, the oldest data is over-written.	<b>100</b>	Limited by available storage space, which depends on DAS configuration.
<b>RS-232 REPORT</b>	Enables the analyzer to automatically report channel values to the RS-232 ports.	<b>OFF</b>	OFF or ON
<b>CHANNEL ENABLED</b>	Enables or disables the channel. Allows a channel to be temporarily turned off without deleting it.	<b>ON</b>	OFF or ON
<b>CAL HOLD OFF</b>	Disables sampling of data parameters while instrument is in calibration mode <sup>2</sup> .	<b>OFF</b>	OFF or ON
<sup>1</sup> More with APICOM, but only the first six are displayed on the front panel). <sup>2</sup> When enabled records are not recorded until the DAS_HOLD OFF period is passed after calibration mode. DAS_HOLD OFF SET in the <b>VARs</b> menu (see Section 5.8).			

### 7.1.1.1. DEFAULT DAS CHANNELS

A set of default Data Channels has been included in the analyzer's software for logging NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations as well as certain predictive diagnostic data. For the software revision being shipped with the T200 at the time of this writing, these default channels are:

**CONC:** Samples NO<sub>x</sub> concentration at one minute intervals and stores an average every hour with a time and date stamp. Readings during calibration and calibration hold off are not included in the data.

- By default, the last 800 hourly averages are stored.

**CALDAT:** Logs new slope and offset of NO<sub>x</sub> and NO measurements every time a zero or span calibration is performed and the result changes the value of the slope (triggering event: **SLPCHG**). The NO<sub>x</sub> stability (to evaluate if the calibration value was stable) as well as the converter efficiency (for trend reference) are also stored.

- This data channel will store data from the last 200 calibrations and can be used to document analyzer calibration and is useful for detect trends in slope and offset (instrument response) when performing predictive diagnostics as part of a regular maintenance schedule (See Section 11.1).
- The CALDAT channel collects data based on events (e.g. a calibration operation) rather than a timed interval and therefore does not represent any specific length of time. As with all data channels, a date and time stamp is recorded for every logged data point.

**CALCHECK:** This channel logs concentrations and the stability each time a zero or span check (not calibration) is finished (triggered by exiting any calibration menu).

- The data of this channel enable the user to track the quality of zero and span responses over time and assist in evaluating the quality of zero and span gases and the analyzer's noise specifications.
- The **STABIL** parameter documents if the analyzer response was stable at the point of the calibration check reading. The last 200 data points are retained.

**DIAG:** Daily averages of temperature zones, flow and pressure data as well as some other diagnostic parameters (**HVPS**, **AZERO**).

- This data is useful for predictive diagnostics and maintenance of the T200.
- The last 1100 daily averages are stored to cover more than four years of analyzer performance.

**HIRES:** Records one-minute, instantaneous data of all active parameters in the T200. Short-term trends as well as signal noise levels can be detected and documented.

- Readings during calibration and the calibration hold off period are included in the averages.
- The last 1500 data points are stored, which covers a little more than one day of continuous data acquisition.

These default data channels can be used as they are, or they can be customized from the front panel to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels.

Appendix A lists the firmware-specific DAS configuration in plain-text format. This text file can either be loaded into APICOM and then modified and uploaded to the instrument or can be copied and pasted into a terminal program to be sent to the analyzer.

**IMPORTANT**

-----  
**IMPACT ON READINGS OR DATA**

**Sending a DAS configuration to the analyzer through its COM ports will replace the existing configuration and will delete all stored data. Back up any existing data and the DAS configuration before uploading new settings.**  
-----



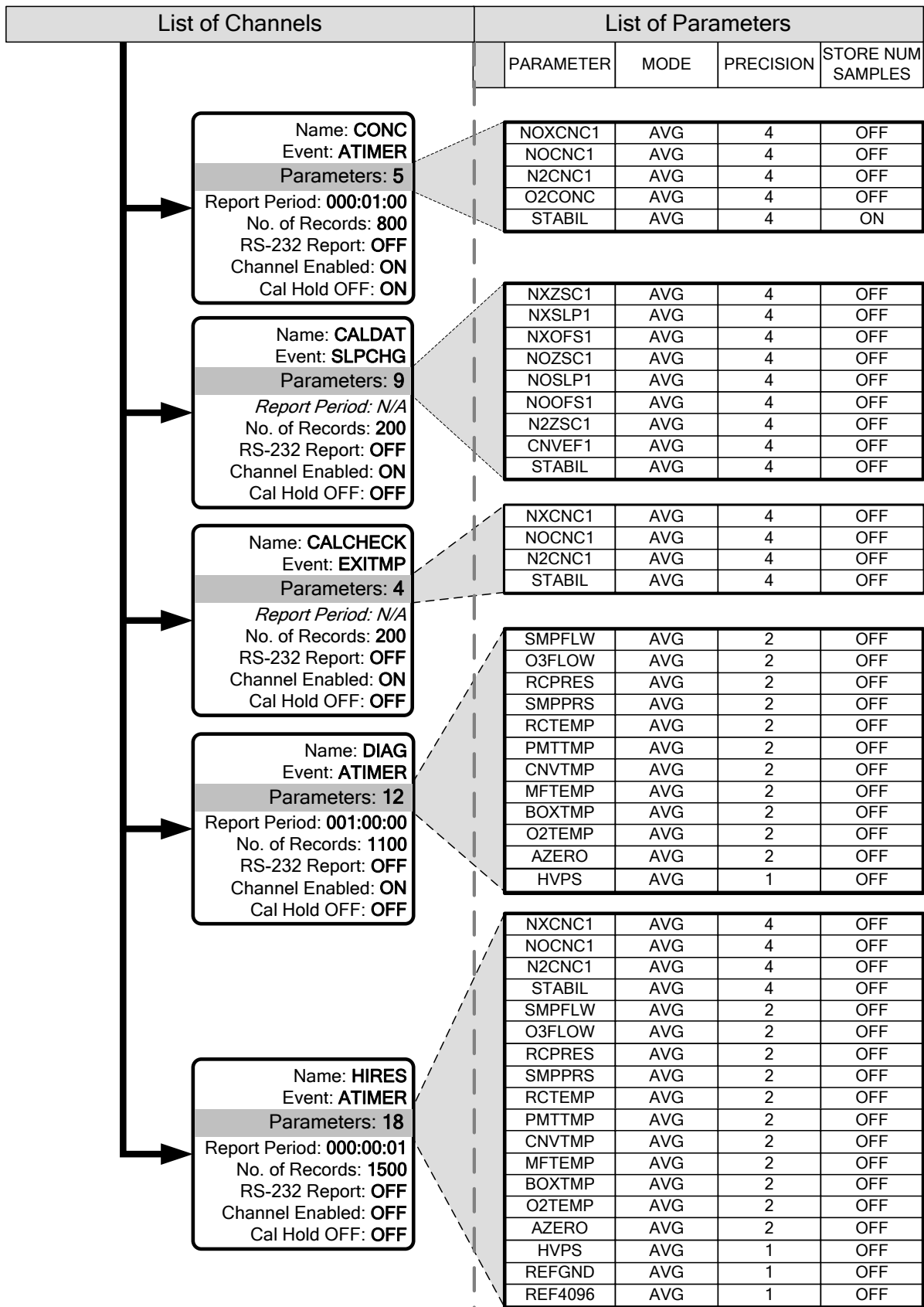


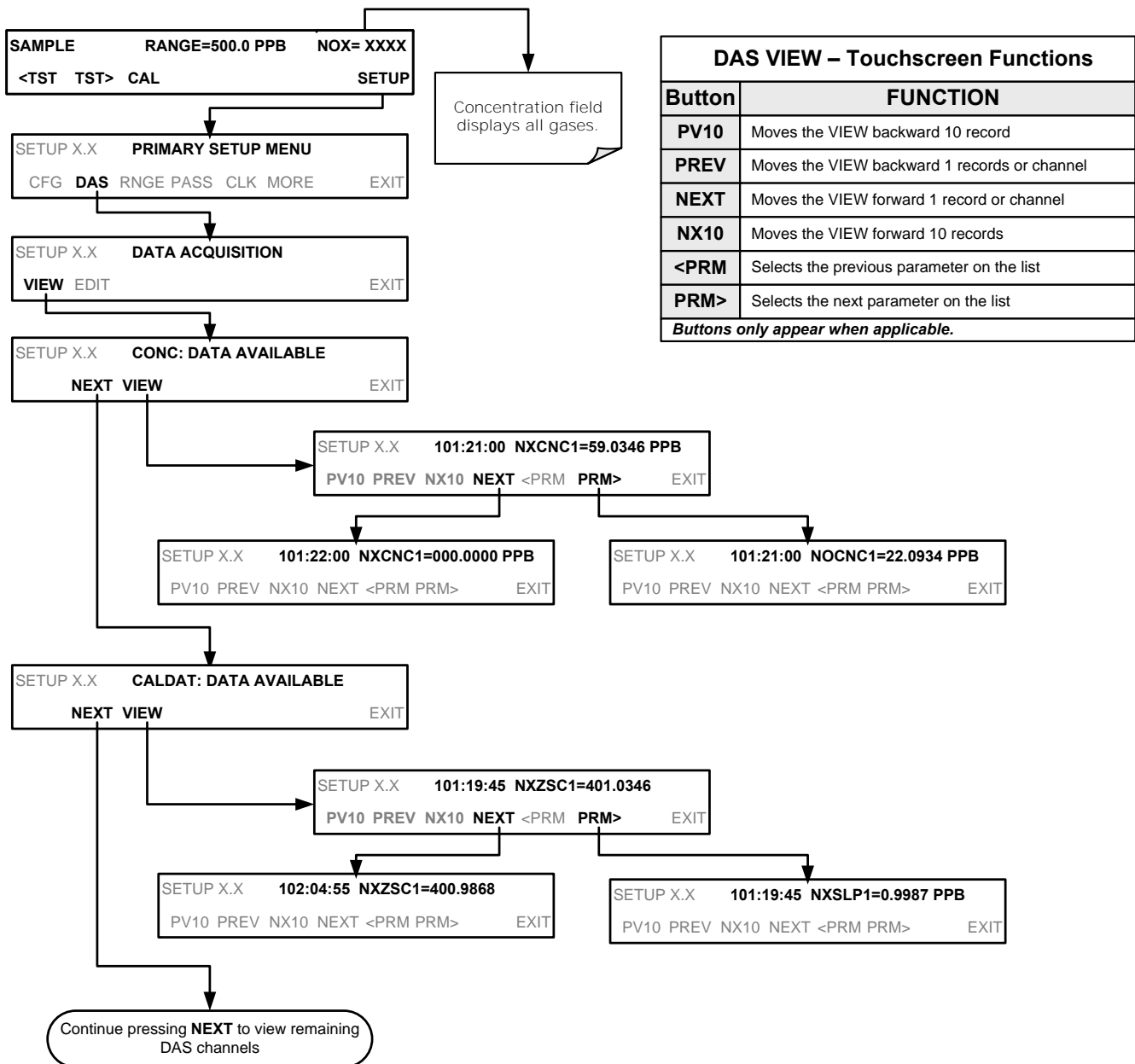
Figure 7-1: Default DAS Channels Setup

### 7.1.1.2. DAS CONFIGURATION LIMITS

The number of DAS objects is limited by the instrument’s finite storage capacity. For information regarding the maximum number of channels, parameters, and records and how to calculate the file size for each data channel, refer to the DAS manual downloadable from the TAPI website at <http://www.teledyne-api.com/manuals/> under Special Manuals.

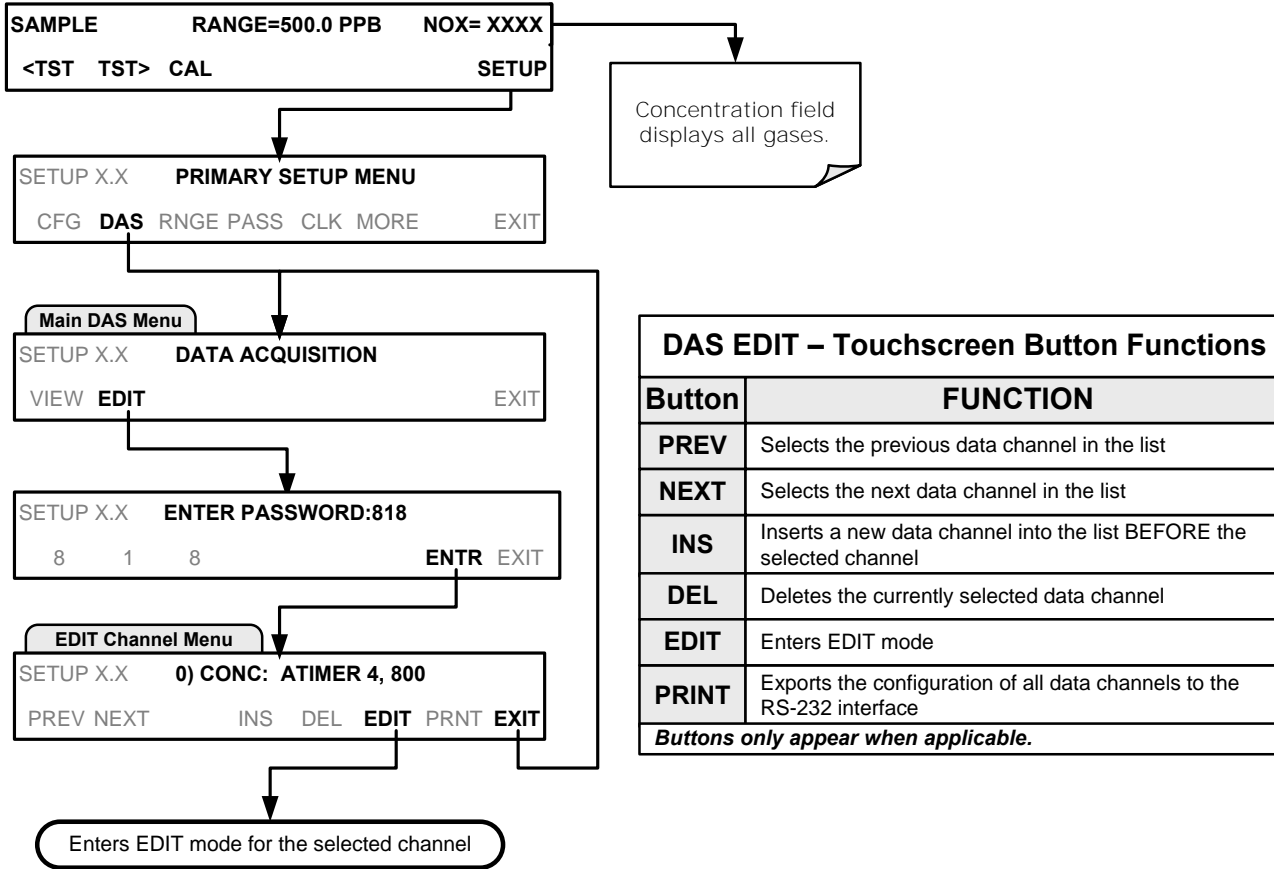
### 7.1.2. VIEWING DAS DATA AND SETTINGS

DAS data and settings can be viewed on the front panel through the following menu sequence.



### 7.1.3. EDITING DAS DATA CHANNELS

DAS configuration is most conveniently done through the APICOM remote control program. The following list of button strokes shows how to edit using the front panel.



When editing the data channels, the top line of the display indicates some of the configuration parameters.

For example, the display line:

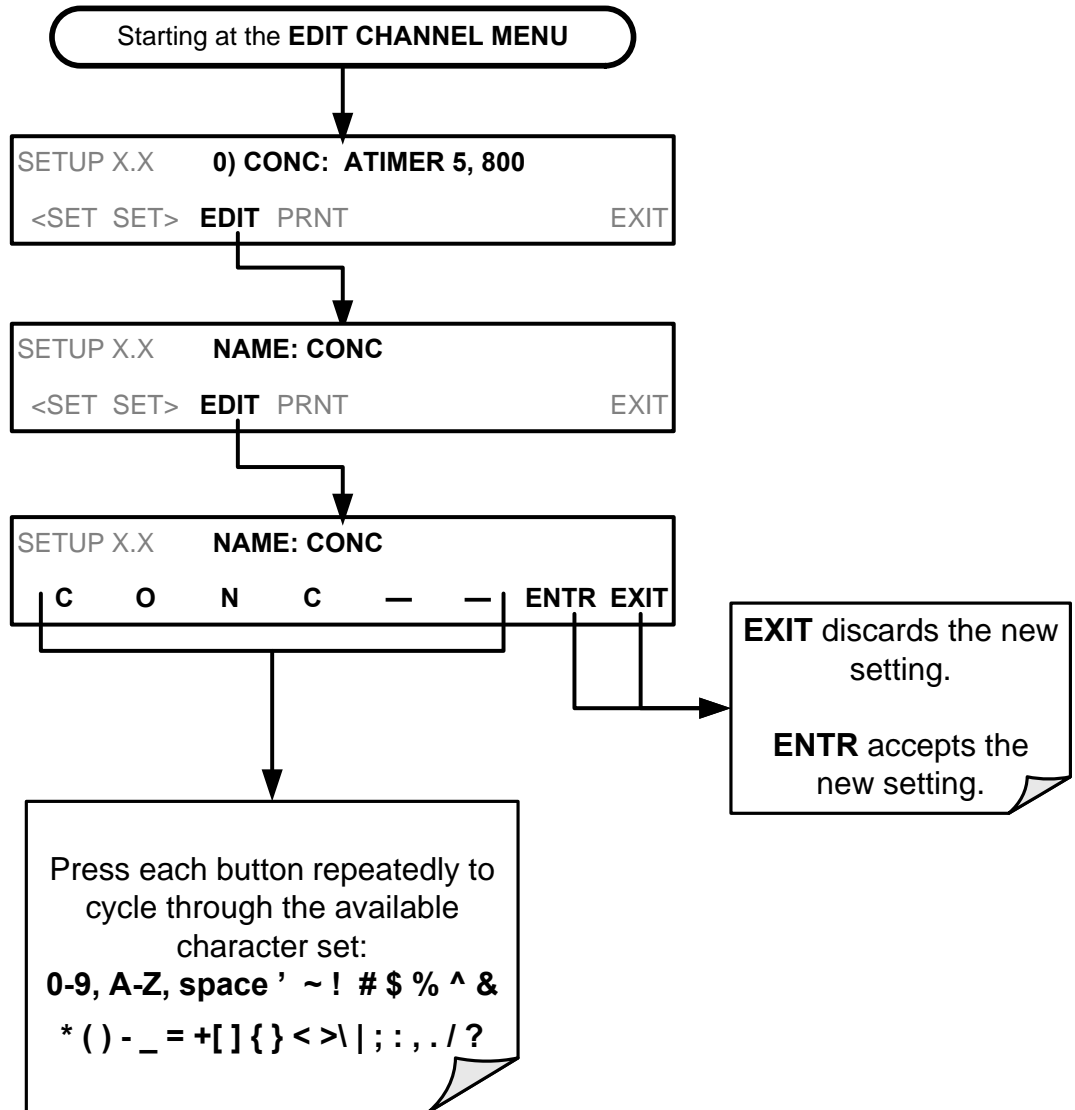
**0) NXCNC1: ATIMER, 5, 800**

Translates to the following configuration:

**Channel No.:** 0  
**NAME:** NXCNC1  
**TRIGGER EVENT:** ATIMER  
**PARAMETERS:** Five parameters are included in this channel  
**EVENT:** This channel is set up to store 800 records.

### 7.1.3.1. EDITING DAS DATA CHANNEL NAMES

To edit the name of a DAS data channel, follow the instruction shown in Section 7.1.3 then press:

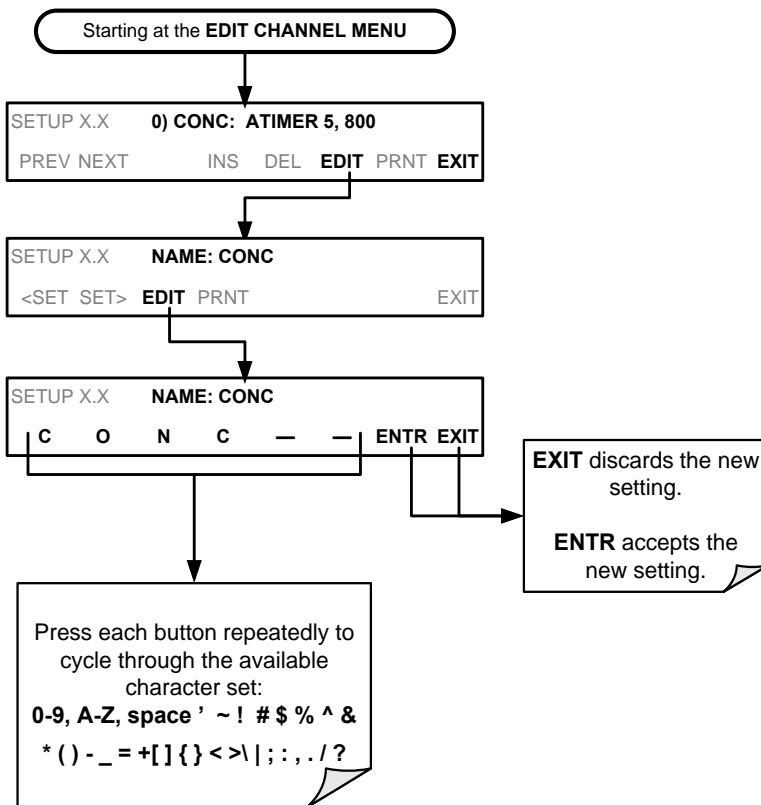


### 7.1.3.2. EDITING DAS TRIGGERING EVENTS

Triggering events define when and how the DAS records a measurement of any given data channel. Triggering events are firmware-specific and a complete list of Triggers for this model analyzer can be found in Appendix A-5. The most commonly used triggering events are:

- **ATIMER:** Sampling at regular intervals specified by an automatic timer. Most trending information is usually stored at such regular intervals, which can be instantaneous or averaged.
- **EXITZR, EXITSP, and SLPCHG** (exit zero, exit span, slope change): Sampling at the end of (irregularly occurring) calibrations or when the response slope changes. These triggering events create instantaneous data points, e.g., for the new slope and offset (concentration response) values at the end of a calibration. Zero and slope values are valuable to monitor response drift and to document when the instrument was calibrated.
- **WARNINGS:** Some data may be useful when stored if one of several warning messages appears such as **WTEMPW** (GFC wheel temperature warning). This is helpful for troubleshooting by monitoring when a particular warning occurred.

To edit the list of data parameters associated with a specific data channel, follow the instruction shown in Section 7.1.3 then press:



**Note**

**A full list of DAS Trigger Events can be found in Appendix A-5 of this manual.**

### 7.1.3.3. EDITING DAS PARAMETERS

Data parameters are types of data that may be measured and stored by the DAS. For each Teledyne API's analyzer model, the list of available data parameters is different, fully defined and not customizable. Appendix A-5 lists firmware specific data parameters for the T200. DAS parameters include data such as NO<sub>x</sub>, NO and NO<sub>2</sub> concentration measurements, temperatures of the various heaters placed around the analyzer, pressures and flows of the pneumatic subsystem and other diagnostic measurements as well as calibration data such as stability, slope and offset.

Most data parameters have associated measurement units, such as mV, ppb, cm<sup>3</sup>/min, etc., although some parameters have no units (e.g. **SLOPE**). With the exception of concentration readings, none of these units of measure can be changed. To change the units of measure for concentration readings, see Section 5.4.3.4.

**Note**

**DAS does not keep track of the units (i.e. PPM or PPB) of each concentration value. Therefore, DAS data files may contain concentration data recorded in more than one type of unit if the units of measure were changed during data acquisition**

Each data parameter has user-configurable functions that define how the data are recorded which are listed in Table 7-3:

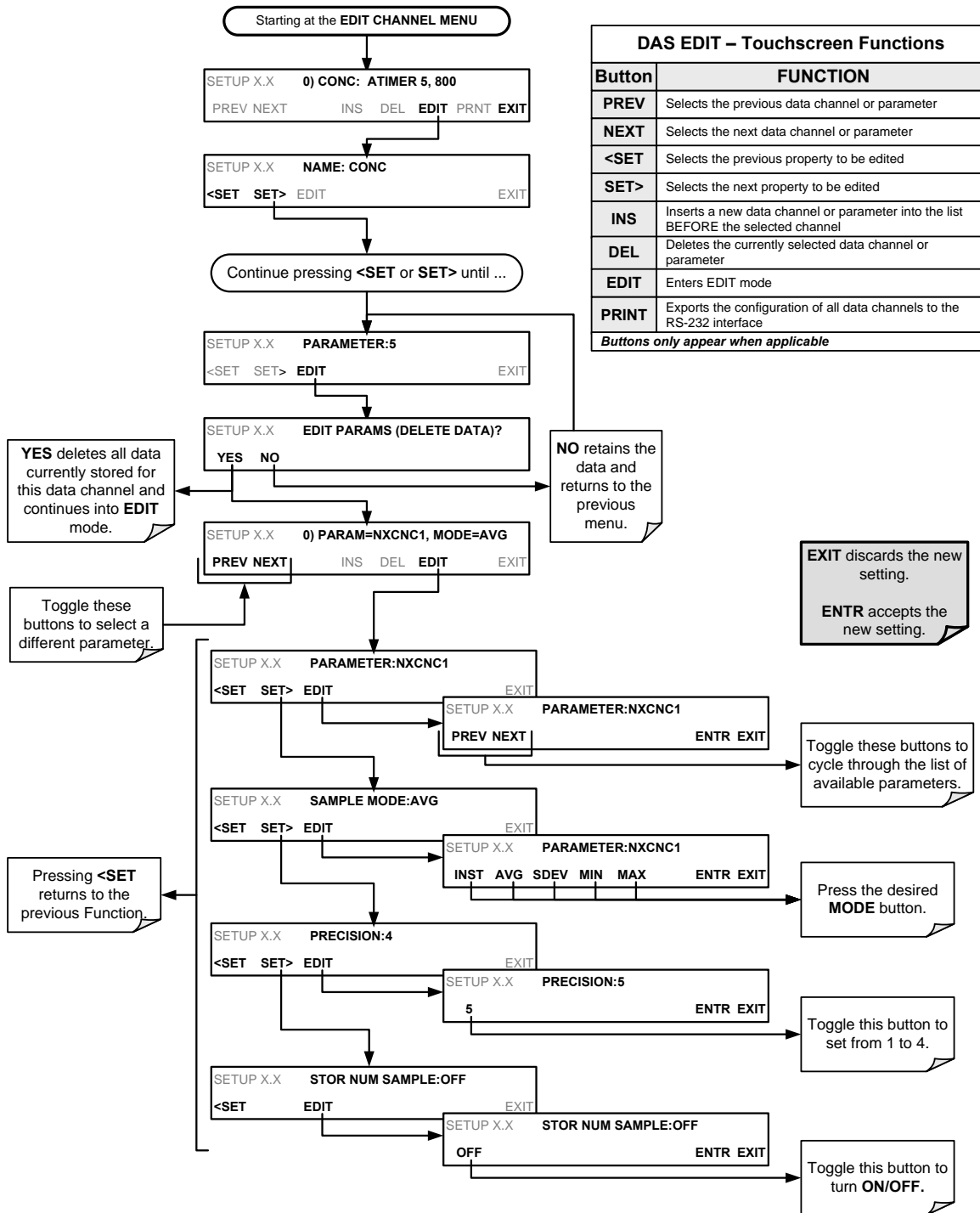
**Table 7-3: DAS Data Parameter Functions**

FUNCTION	EFFECT
PARAMETER	Instrument specific parameter name.
SAMPLE MODE	<b>INST:</b> Records instantaneous reading. <b>AVG:</b> Records average reading during reporting interval. <b>SDEV:</b> Records the standard deviation of the data points recorded during the reporting interval. <b>MIN:</b> Records minimum (instantaneous) reading during reporting interval. <b>MAX:</b> Records maximum (instantaneous) reading during reporting interval.
PRECISION	<b>0 to 4:</b> Sets the number of digits to the right decimal point for each record. Example: Setting 4; <b>-399.9865 PPB</b> Setting 0; <b>-400 PPB</b>
STORE NUM. SAMPLES	<b>OFF:</b> Stores only the average (default). <b>ON:</b> Stores the average and the number of samples in used to compute the value of the parameter. This property is only useful when the AVG sample mode is used. Note that the number of samples is the same for all parameters in one channel and needs to be specified only for one of the parameters in that channel.

Users can specify up to 50 parameters per data channel (the T200 provides about 40 parameters). However, the number of parameters and channels is ultimately limited by available memory.

Data channels can be edited individually from the front panel without affecting other data channels. However, when editing a data channel, such as during adding, deleting or editing parameters, all data for that particular channel will be lost, because the DAS can store only data of one format (number of parameter columns etc.) for any given channel. In addition, a DAS configuration can only be uploaded remotely as an entire set of channels. Hence, remote update of the DAS will always delete all current channels and stored data.

To modify, add or delete a parameter, follow the instruction shown in Section 7.1.3 then press:



**Note**

When the STORE NUM SAMPLES feature is turned on, the instrument will store the number of measurements that were used to compute the AVG, SDEV, MIN or MAX value but not the actual measurements themselves.

#### 7.1.3.4. EDITING SAMPLE PERIOD AND REPORT PERIOD

The DAS defines two principal time periods by which sample readings are taken and permanently recorded:

- **SAMPLE PERIOD:** Determines how often DAS temporarily records a sample reading of the parameter in volatile memory. **SAMPLE PERIOD** is only used when the DAS parameter's sample mode is set for AVG, SDEV, MIN or MAX.
- The **SAMPLE PERIOD** is set to one minute by default and generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol.
- **REPORT PERIOD:** Sets how often the sample readings stored in volatile memory are processed, (e.g. average, minimum or maximum are calculated) and the results stored permanently in the instruments Disk-on-Module (DOM) as well as transmitted via the analyzer's communication ports. The Report Period may be set from the front panel. If the INST sample mode is selected the instrument stores and reports an instantaneous reading of the selected parameter at the end of the chosen report period.

#### Note

---

In AVG, SDEV, MIN or MAX sample modes (see Section 7.1.3.3), the settings for the Sample Period and the Report Period determine the number of data points used each time the parameters are calculated, stored and reported to the COM ports.

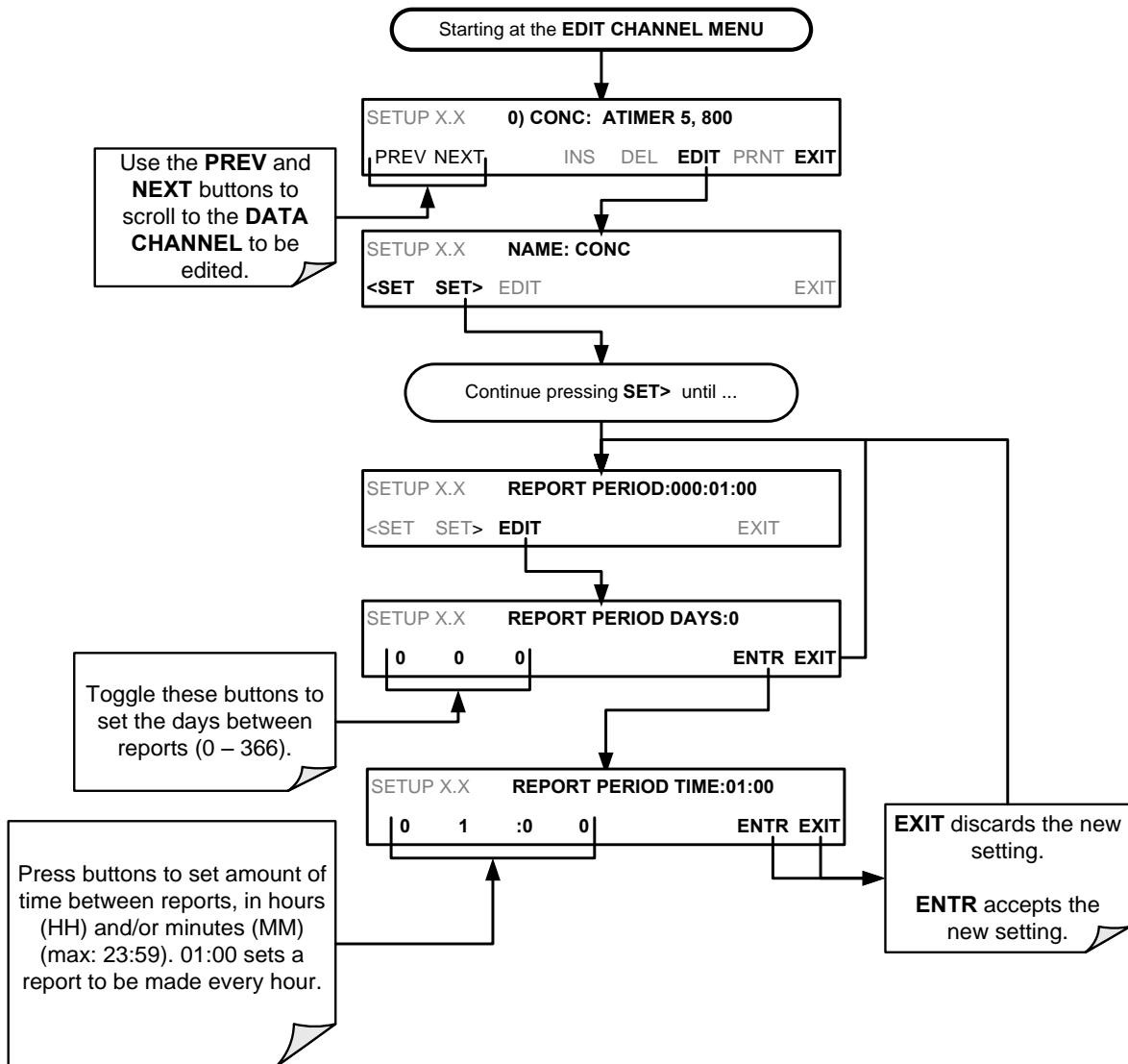
The actual sample readings are not stored past the end of the chosen report period.

When the STORE NUM SAMPLES feature is turned on, the instrument will store the number of measurements that were used to compute the AVG, SDEV, MIN or MAX value but not the actual measurements themselves.

---



To define the **REPORT PERIOD**, follow the instruction shown in Section 7.1.3 then press:



The **SAMPLE PERIOD** and **REPORT PERIOD** intervals are synchronized to the beginning and end of the appropriate interval of the instruments internal clock.

- If **SAMPLE PERIOD** is set for one minute the first reading would occur at the beginning of the next full minute according to the instrument's internal clock.
- If the **REPORT PERIOD** is set for of one hour, the first report activity would occur at the beginning of the next full hour according to the instrument's internal clock.

**EXAMPLE:**

Given the above settings, if DAS parameters are activated at 7:57:35 the first sample would occur at 7:58 and the first report would be calculated at 8:00 consisting of data points for 7:58. 7:59 and 8:00.

During the next hour (from 8:01 to 9:00), the instrument will take a sample reading every minute and include 60 sample readings.

### **7.1.3.5. REPORT PERIODS IN PROGRESS WHEN INSTRUMENT IS POWERED OFF**

If the instrument is powered off in the middle of a **REPORT PERIOD**, the samples accumulated during that period are lost. Once the instrument is turned back on, the DAS restarts taking samples and temporarily stores them in volatile memory as part of the **REPORT PERIOD** currently active at the time of restart. At the end of this **REPORT PERIOD**, only the sample readings taken since the instrument was turned back on will be included in any **AVG**, **SDEV**, **MIN** or **MAX** calculation.

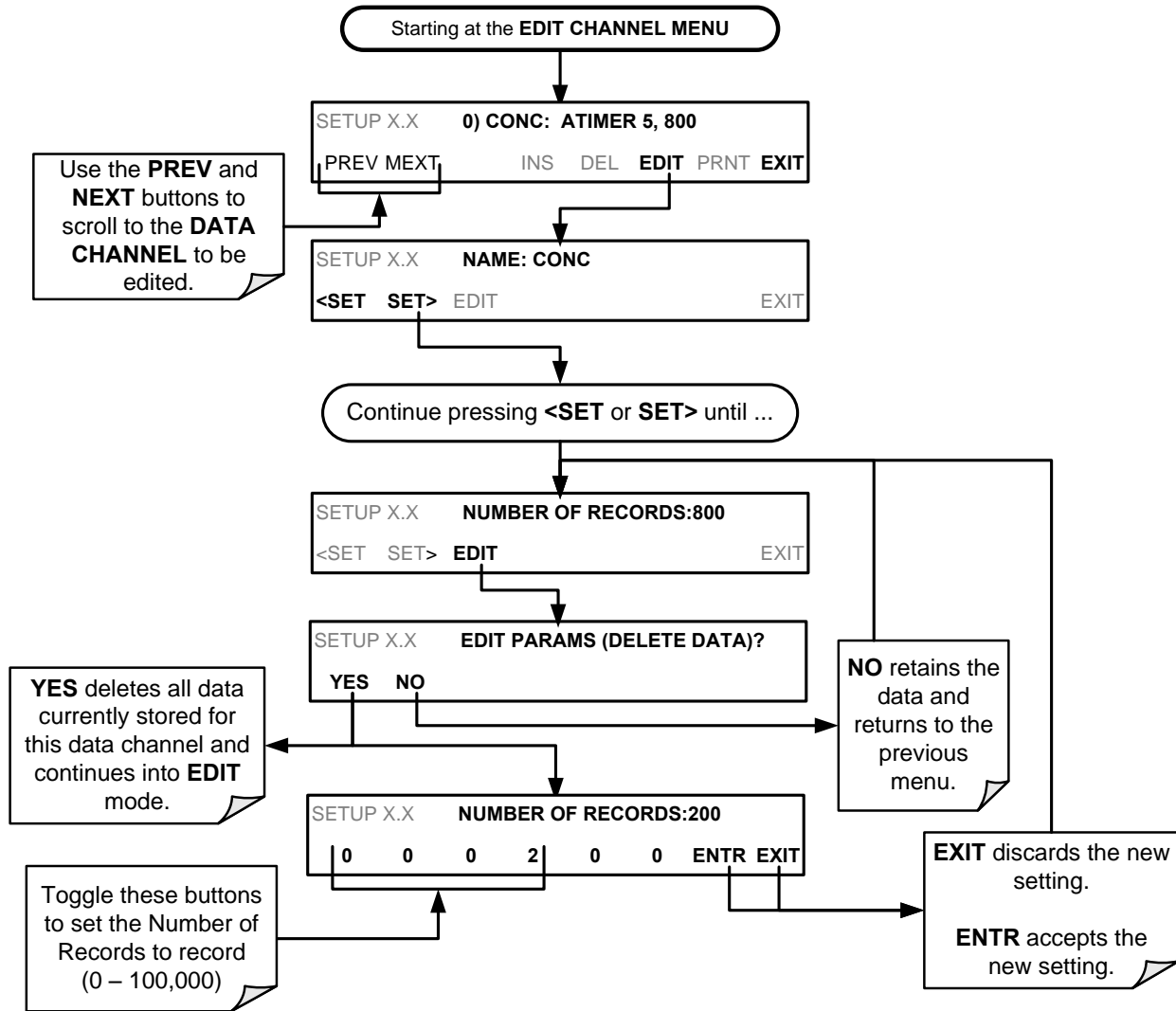
The **STORE NUM SAMPLES** feature will also report the number of sample readings taken since the instrument was restarted.

### **7.1.3.6. EDITING THE NUMBER OF RECORDS**

The number of data records in the DAS is limited by its configuration (one megabyte of space on the DOM). However, the actual number of records is also limited by the total number of parameters and channels and other settings in the DAS configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

The DAS will check the amount of available data space and prevent the user from specifying too many records at any given point. If, for example, the DAS memory space can accommodate 375 more data records, the **ENTR** button will disappear when trying to specify more than that number of records. This check for memory space may also make an upload of a DAS configuration with APICOM or a terminal program fail, if the combined number of records would be exceeded. In this case, it is suggested to either try to determine what the maximum number of records available is using the front panel interface or use trial-and-error in designing the DAS script or calculate the number of records using the DAS or APICOM manuals.

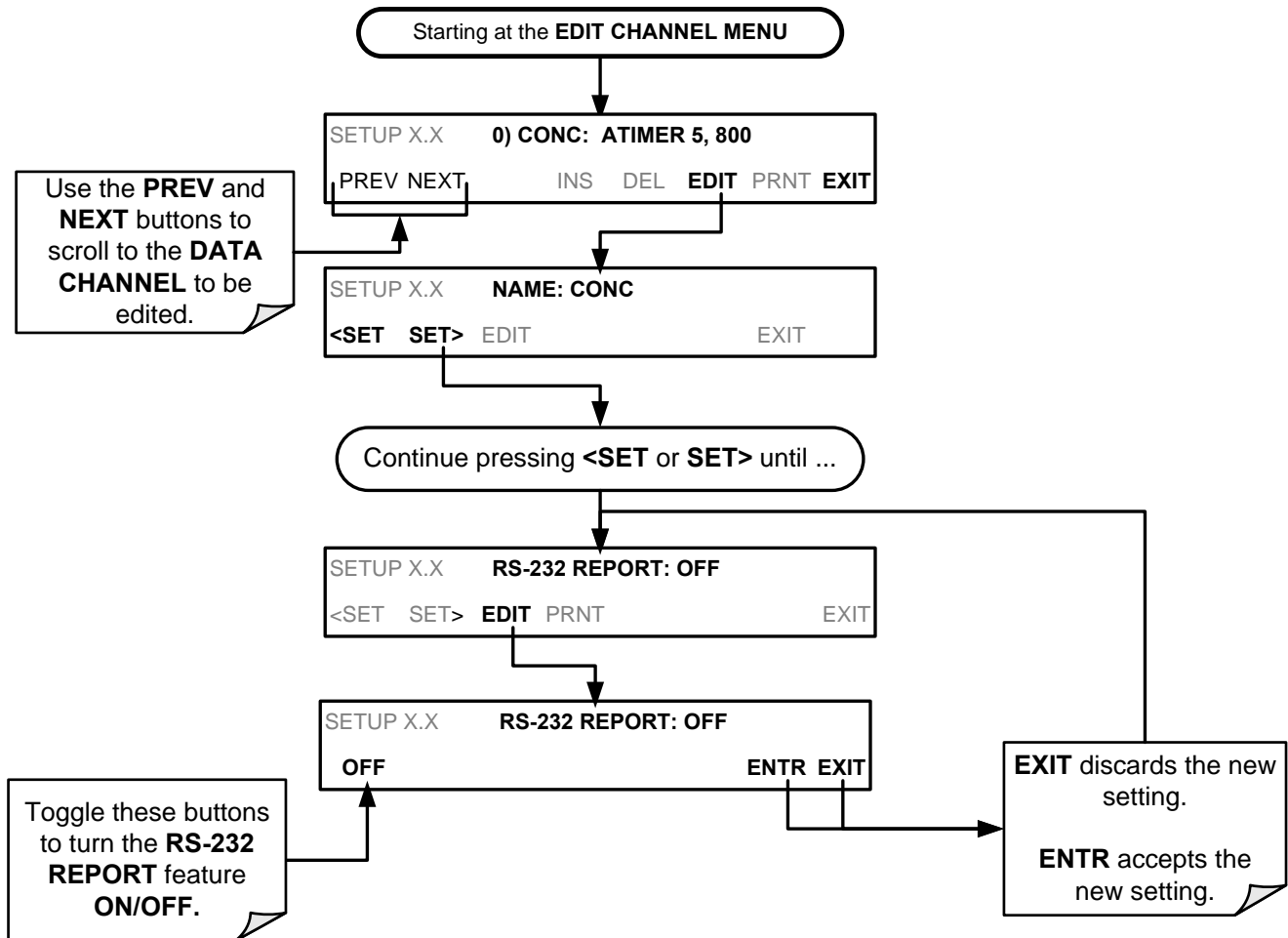
To set the **NUMBER OF RECORDS**, follow the instruction shown in Section 7.1.3 then press:



### 7.1.3.7. RS-232 REPORT FUNCTION

The DAS can automatically report data to the communications ports, where they can be captured with a terminal emulation program or simply viewed by the user using the APICOM software.

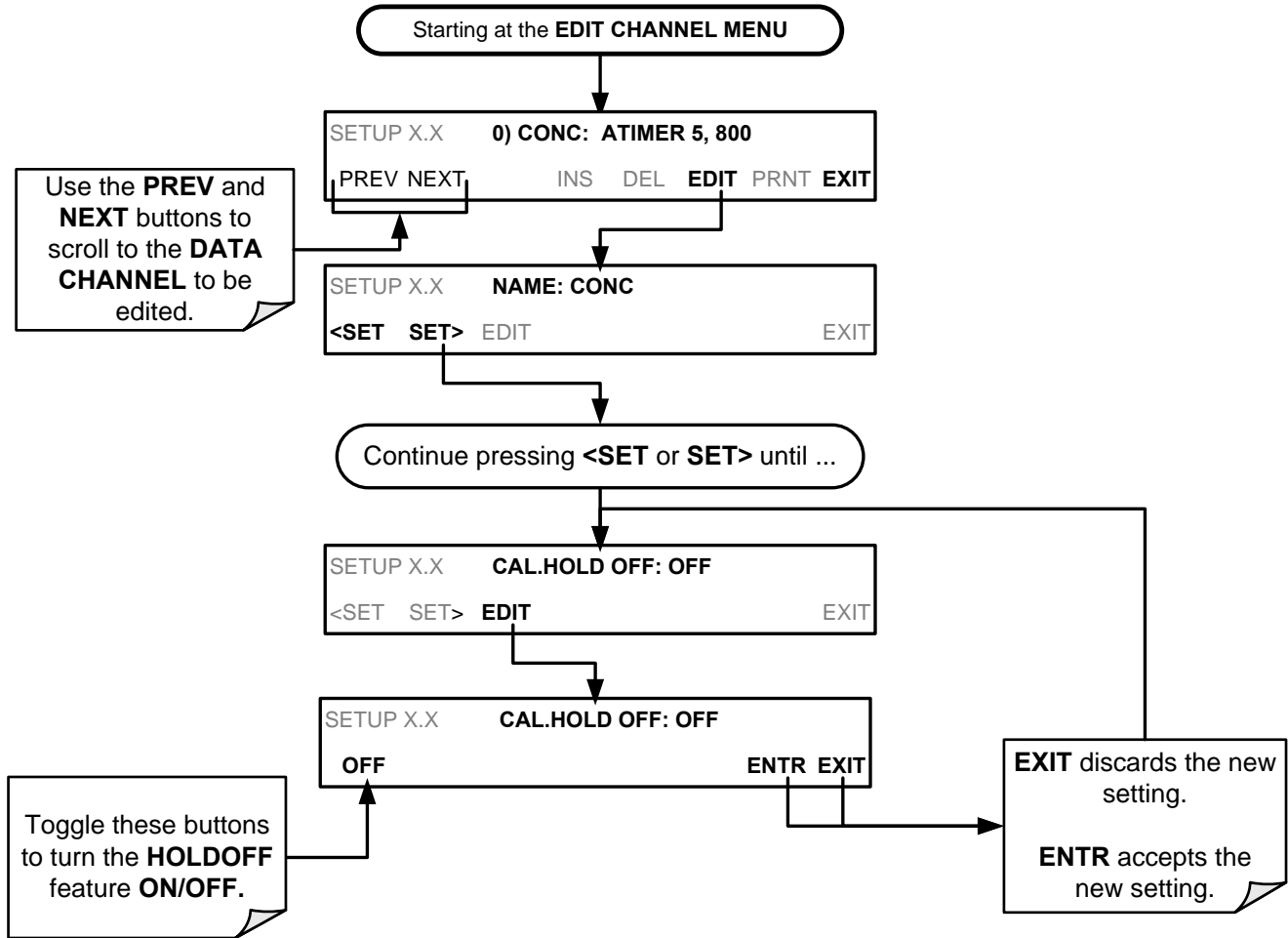
To enable automatic COM port reporting, follow the instruction shown in Section 7.1.3 then press:



### 7.1.3.8. HOLDOFF FEATURE

The DAS **HOLDOFF** feature prevents data collection during calibration operations.

To enable or disable the **HOLDOFF**, follow the instruction shown in Section 7.1.3 then press:



**HOLDOFF** also prevents DAS measurements from being made at certain times when the quality of the analyzer’s sample measurements may be suspect (e.g. while the instrument is warming up). In this case, the length of time that the **HOLDOFF** feature is active is determined by the value of the internal variable (**VAR**), **DAS\_HOLD**.

To set the length of the **DAS\_HOLD** period, go to the **SETUP>MORE>VAR** menu and at the **DAS\_HOLD** parameter (see Table 5-3), press the Edit button.

### 7.1.3.9. THE COMPACT REPORT FEATURE

When enabled, this option avoids unnecessary line breaks on all RS-232 reports. Instead of reporting each parameter in one channel on a separate line, up to five parameters are reported in one line.

The **COMPACT DATA REPORT** generally cannot be accessed from the standard DAS front panel menu, but is available via the instrument's communication ports by using APICOM or the analyzer's standard serial data protocol.

### 7.1.3.10. THE STARTING DATE FEATURE

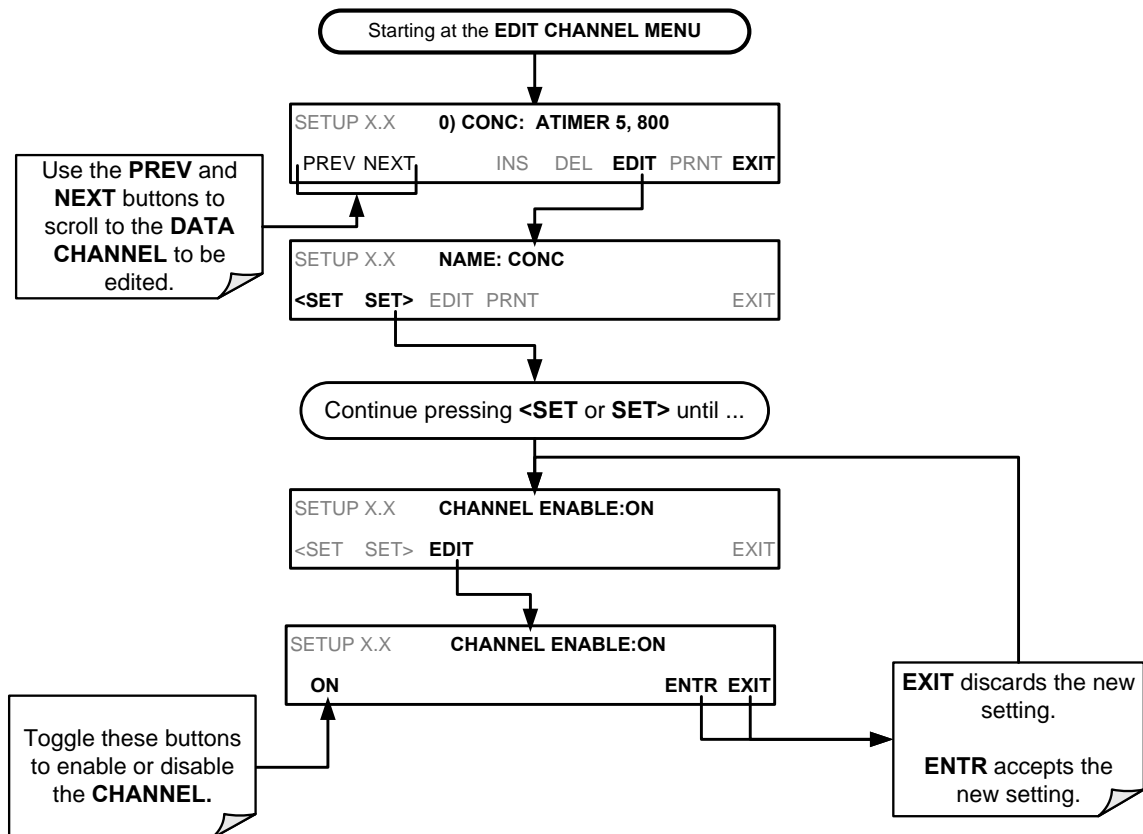
This option allows the user to specify a starting date for any given channel when the user wants to start data acquisition only after a certain time and date. If the **STARTING DATE** is in the past (the default condition), the DAS ignores this setting and begins recording data as defined by the **REPORT PERIOD** setting.

The **STARTING DATE** generally cannot be accessed from the standard DAS front panel menu, but is available via the instrument's communication ports by using APICOM or the analyzer's standard serial data protocol.

### 7.1.3.11. DISABLING/ENABLING DATA CHANNELS

Data channels can be temporarily disabled, which can reduce the read/write wear on the Disk-on-Module (DOM).

To disable a data channel, go to the DAS>EDIT menu as shown in Section 7.1.3 then continue as follows:



## 7.2. REMOTE DAS CONFIGURATION

The DAS can be configured and operated remotely via either the APICOM interface or a terminal emulation program. Once a DAS configuration is edited (which can be done offline and without interrupting DAS data collection), it is conveniently uploaded to the instrument and can be stored on a computer for later review, alteration or documentation and archival.

### 7.2.1. DAS CONFIGURATION VIA APICOM

Table 7-2 shows examples of APICOM's main interface, which emulates the look and functionality of the instrument's actual front panel. Figure 7-3 shows an example of APICOM being used to remotely configure the DAS feature.

The APICOM user manual (Teledyne API's P/N 039450000) is included in the APICOM installation file, which can be downloaded at <http://www.teledyne-api.com/software/apicom/>.

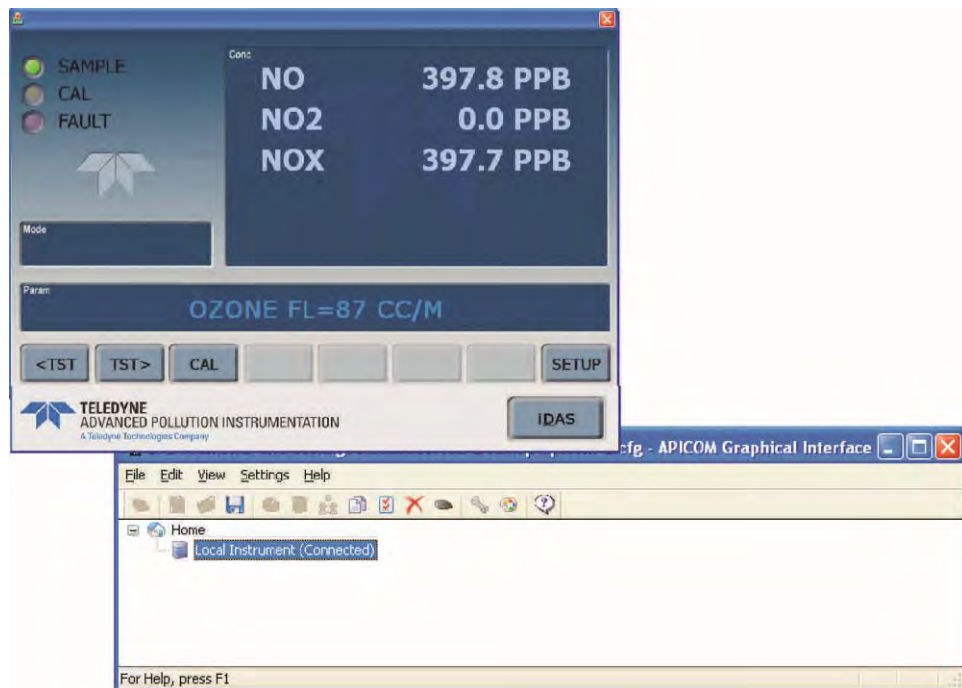


Figure 7-2: APICOM Remote Control Program Interface

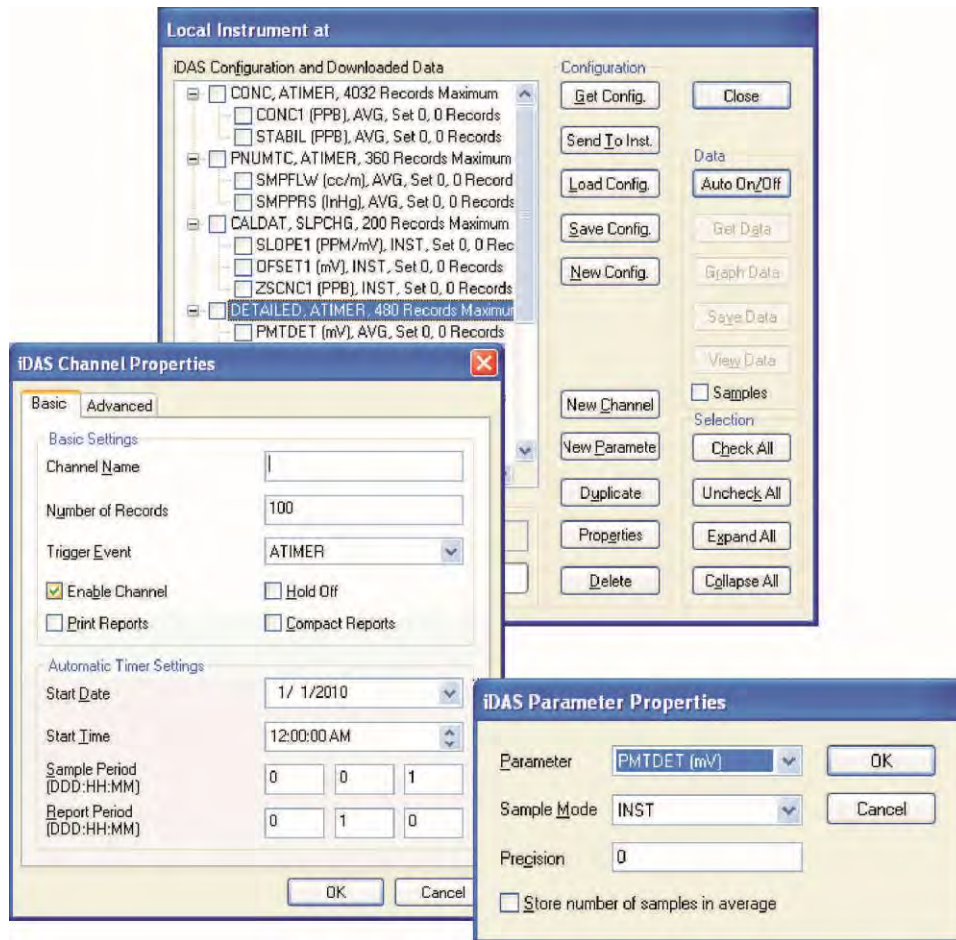


Figure 7-3: Sample APICOM User Interface for Configuring the DAS



## 7.2.2. DAS CONFIGURATION VIA TERMINAL EMULATION PROGRAMS

Although Teledyne API recommends the use of APICOM, the DAS can also be accessed and configured through a terminal emulation program such as HyperTerminal (see Figure 7-4 for example). It is best to start by downloading the default DAS configuration, getting familiar with its command structure and syntax conventions, and then altering a copy of the original file offline before uploading the new configuration.

```

SETUP PROPERTIES FOR ENGDAT:
NAME: ENGDAT
EVENT: ATIMER
REPORT PERIOD: 000:00:02
NUMBER OF RECORDS: 2000
RS-232 REPORT: ON
CHANNEL ENABLED: ON
CAL. HOLD OFF: OFF
PARAMETERS: 14
PARAMETER=RCTEMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=CNVTMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=PMTTMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=BOXTMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=O3FLOW, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=SMPFLW, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=SMPPRS, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=RCPRES, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=AZERO, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=HVPS, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=PMTDET, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=RF4096, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=REF-GND, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
  
```

Figure 7-4: DAS Configuration Through a Terminal Emulation Program

See Section 8.2.1 for configuration commands and their strict syntax. Commands can be pasted in from of an existing text file, which was first edited offline and then uploaded through a specific transfer procedure.

### IMPORTANT

#### IMPACT ON READINGS OR DATA

Whereas the editing, adding and deleting of DAS channels and parameters of one channel through the front-panel control buttons can be done without affecting the other channels, uploading a DAS configuration script to the analyzer through its communication ports will erase all data, parameters and channels by replacing them with the new DAS configuration. Backup of data and the original DAS configuration is advised before attempting any DAS changes.

## 8. REMOTE OPERATION

This section provides information needed when using external digital and serial I/O for remote operation. It assumes that the electrical connections have been made as described in Section 3.3.1.

The T200 can be remotely configured, calibrated or queried for stored data through the serial ports, via either **Computer mode** (using a personal computer) or **Interactive mode** (using a terminal emulation program).

### 8.1. COMPUTER MODE

Computer Mode is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM.

#### 8.1.1. REMOTE CONTROL VIA APICOM

APICOM is an easy-to-use, yet powerful interface program that allows the user to access and control any of Teledyne API's' main line of ambient and stack-gas instruments from a remote connection through direct cable, modem or Ethernet. Running APICOM, a user can:

- Establish a link from a remote location to the T200 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed manually on the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Retrieve, view, edit, save and upload DAS configurations (Section 7.2.1).
- Check on system parameters for troubleshooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and troubleshooting. Refer to the APICOM manual available for download from <http://www.teledyne-api.com/software/apicom/>.

## 8.2. INTERACTIVE MODE

Interactive mode is used with a terminal emulation programs or a “dumb” computer terminal.

### 8.2.1. REMOTE CONTROL VIA A TERMINAL EMULATION PROGRAM

Start a terminal emulation programs such as HyperTerminal. All configuration commands must be created following a strict syntax or be pasted in from a text file, which was edited offline and then uploaded through a specific transfer procedure. The commands that are used to operate the analyzer in this mode are listed in Table 8-1 and in Appendix A.

#### 8.2.1.1. HELP COMMANDS IN INTERACTIVE MODE

Table 8-1: Terminal Mode Software Commands

COMMAND	Function
<b>Control-T</b>	Switches the analyzer to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
<b>Control-C</b>	Switches the analyzer to computer mode (no echo, no edit).
<b>CR (carriage return)</b>	A carriage return is required after each command line is typed into the terminal/computer. The command will not be sent to the analyzer to be executed until this is done. On personal computers, this is achieved by pressing the ENTER button.
<b>BS (backspace)</b>	Erases one character to the left of the cursor location.
<b>ESC (escape)</b>	Erases the entire command line.
<b>?[ID] CR</b>	This command prints a complete list of available commands along with the definitions of their functionality to the display device of the terminal or computer being used. The ID number of the analyzer is only necessary if multiple analyzers are on the same communications line, such as the multi-drop setup.
<b>Control-C</b>	Pauses the listing of commands.
<b>Control-P</b>	Restarts the listing of commands.

#### 8.2.1.2. COMMAND SYNTAX

Commands are not case-sensitive and all arguments within one command (i.e. ID numbers, key words, data values, etc.) must be separated with a space character.

All Commands follow the syntax:

X [ID] COMMAND <CR>

Where:

**X** is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 8-2 and Appendix A-6.

**[ID]** is the machine identification number (Section 5.7.1). Example: the Command “? 200” followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 200.

**COMMAND** is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press ? <CR> or refer to Appendix A-6 for a list of available command designators

**<CR>** is a carriage return. All commands must be terminated by a carriage return (usually achieved by pressing the ENTER button on a computer).

**Table 8-2: Teledyne API's Serial I/O Command Types**

COMMAND	COMMAND TYPE
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

### 8.2.1.3. DATA TYPES

Data types consist of integers, hexadecimal integers, floating-point numbers, Boolean expressions and text strings.

**Integer** data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, +1, -12, 123 are all valid integers.

**Hexadecimal integer** data are used for the same purposes as integers. They consist of the two characters "0x," followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the 'C' programming language convention. No plus or minus sign is permitted. For example, 0x1, 0x12, 0x1234abcd are all valid hexadecimal integers.

**Floating-point numbers** are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point and zero or more digits. (At least one digit must appear before or after the decimal point.) Scientific notation is not permitted. For example, +1.0, 1234.5678, -0.1, 1 are all valid floating-point numbers.

**Boolean expressions** are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the key words ON and OFF.

**Text strings** are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark, followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, "a", "1", "123abc", and "()[]<>" are all valid text strings. It is not possible to include a quotation mark character within a text string.

Some commands allow you to access variables, messages, and other items. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

#### 8.2.1.4. STATUS REPORTING

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (Section 6.2.1, Table 6-1).

Status reports include warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the possible messages, and this for information on controlling the instrument through the RS-232 interface.

#### 8.2.1.5. GENERAL MESSAGE FORMAT

All messages from the instrument (including those in response to a command line request) are in the format:

X DDD:HH:MM [Id] MESSAGE<CRLF>

Where:

X is a command type designator, a single character indicating the message type, as shown in the Table 8-2.

DDD:HH:MM is the time stamp, the date and time when the message was issued. It consists of the Day-of-year (DDD) as a number from 1 to 366, the hour of the day (HH) as a number from 00 to 23, and the minute (MM) as a number from 00 to 59.

[ID] is the analyzer ID, a number with 1 to 4 digits.

MESSAGE is the message content that may contain warning messages, test measurements, variable values, etc.

<CRLF> is a carriage return / line feed pair, which terminates the message.

The uniform nature of the output messages makes it easy for a host computer to parse them into an easy structure. Keep in mind that the front panel display does not give any information on the time a message was issued, hence it is useful to log such messages for troubleshooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

### 8.3. REMOTE ACCESS BY MODEM

The T200 can be connected to a modem for remote access. This requires a cable between the analyzer's COM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

Once the cable has been connected, check to ensure that:

- The DTE-DCE is in the DCE position.
- The T200 COM port is set for a baud rate that is compatible with the modem,
- The Modem is designed to operate with an 8-bit word length with one stop bit.
- The **MODEM ENABLE** communication mode is turned **ON** (Mode 64, see Section 6.2.1).

Once this is completed, the appropriate setup command line for your modem can be entered into the analyzer. The default setting for this feature is:

**AT Y0 D0 H0 I0 S0=0**

This string can be altered to match your modem’s initialization and can be up to 100 characters long.

To change this setting press:

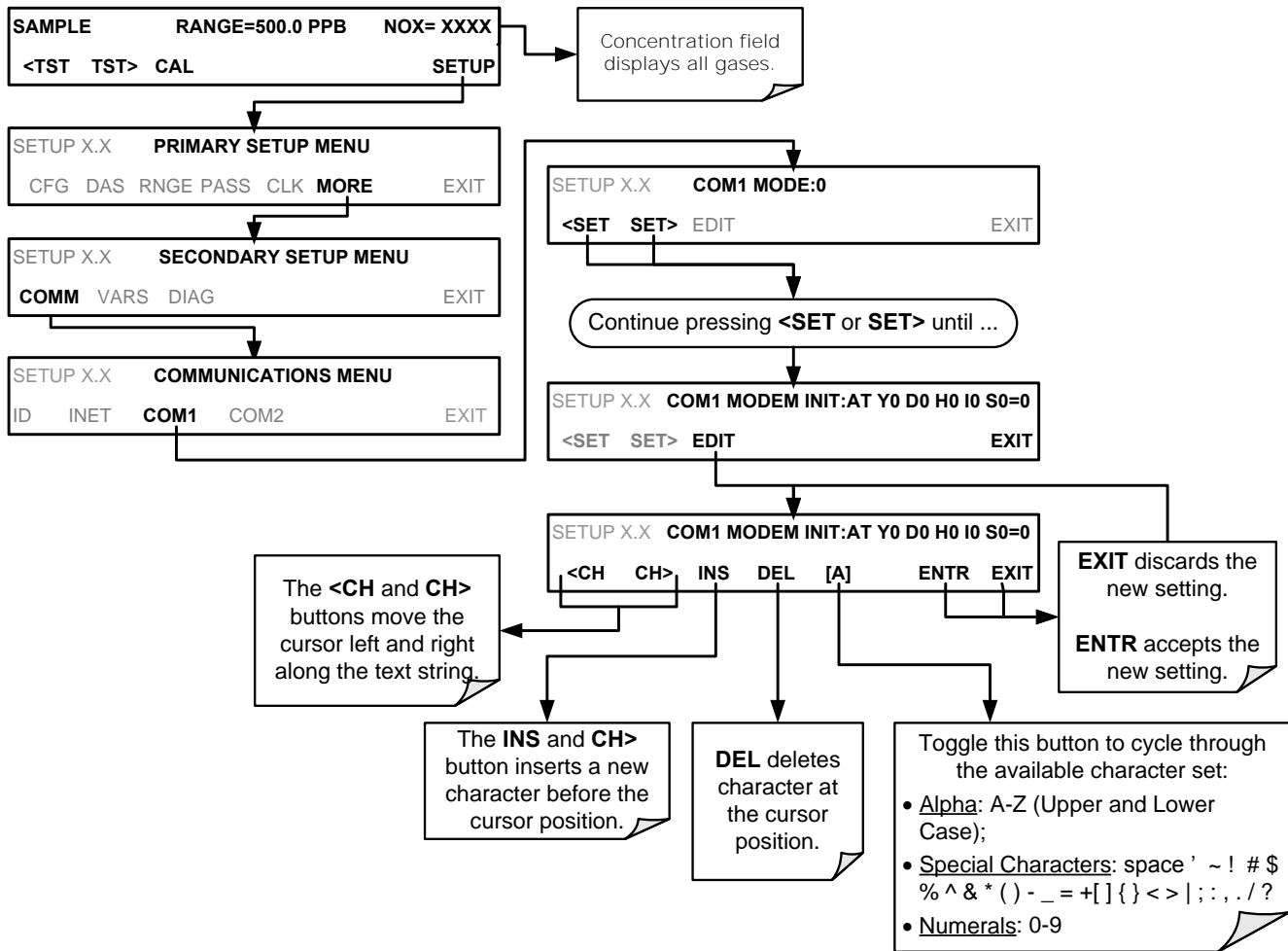
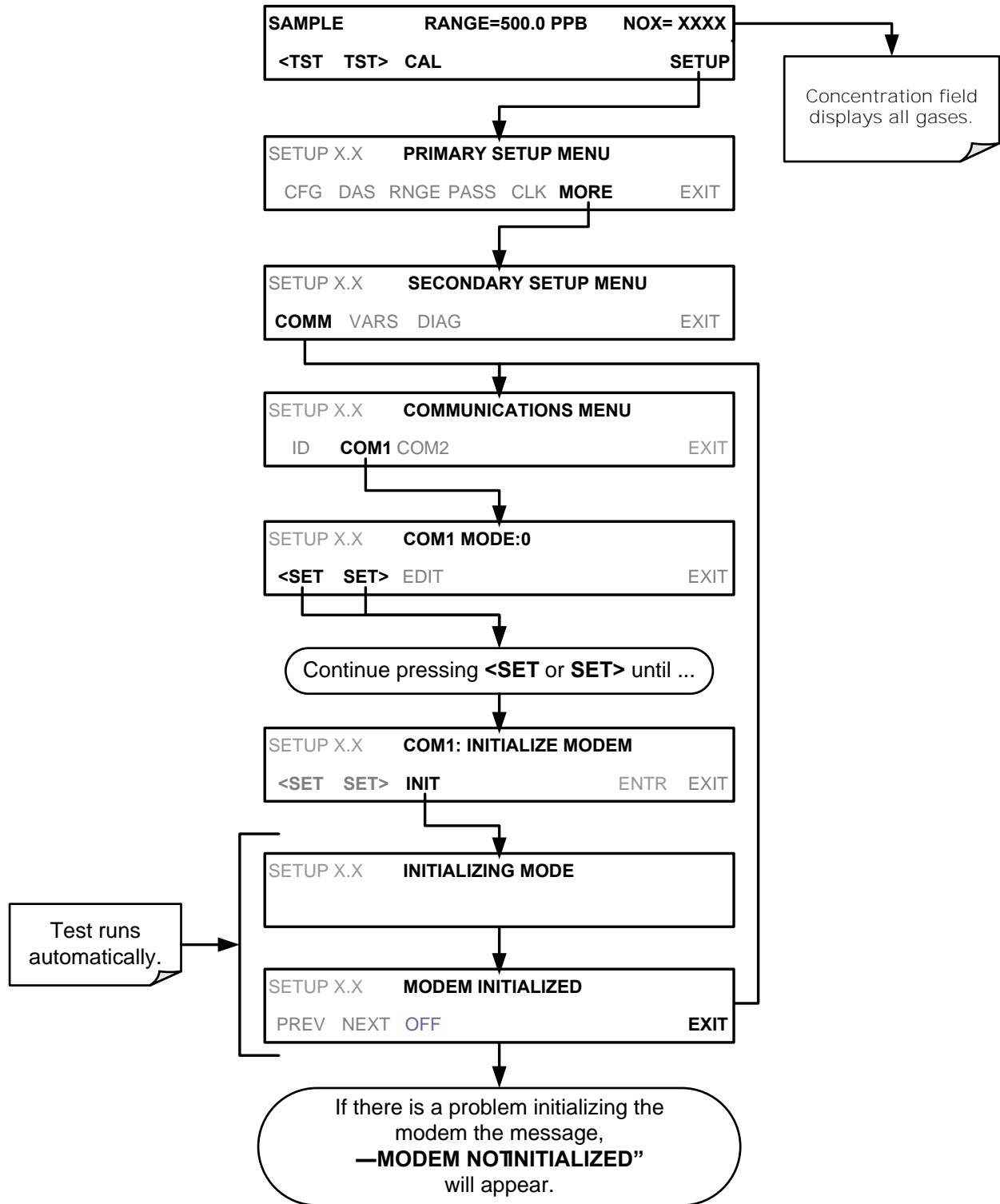


Figure 8-1: Remote Access by Modem

To initialize the modem press:



## 8.4. PASSWORD SECURITY FOR SERIAL REMOTE COMMUNICATIONS

In order to provide security for remote access of the T200, a LOGON feature can be enabled to require a password before the instrument will accept commands. This is done by turning on the **SECURITY MODE** (refer to Section 5.5). Once the **SECURITY MODE** is enabled, the following items apply.

- A password is required before the port will respond or pass on commands.
- If the port is inactive for one hour, it will automatically logoff, which can also be achieved with the LOGOFF command.
- Three unsuccessful attempts to log on with an incorrect password will cause subsequent logins to be disabled for 1 hour, even if the correct password is used.
- If not logged on, the only active command is the '?' request for the help screen.
- The following messages will be returned at logon:
  - LOGON SUCCESSFUL - Correct password given
  - LOGON FAILED - Password not given or incorrect
  - LOGOFF SUCCESSFUL - Connection terminated successfully

To log on to the T200 analyzer with **SECURITY MODE** feature enabled, type:

```
LOGON 940331
```

940331 is the default password. To change the default password, use the variable RS-232\_PASS issued as follows:

```
V RS-232_PASS=NNNNNN
```

Where N is any numeral between 0 and 9.



This page intentionally left blank.

# 9. CALIBRATION PROCEDURES

This section contains information for calibrating the T200 as well as other supporting information. For information on EPA protocol calibration, please refer to Section 10. This section is organized as follows:

## SECTION 9.1 – Before Calibration

This section contains general information you should know before about calibrating the analyzer.

## SECTION 9.2 – Manual Calibration Checks and Calibration of the T200 Analyzer in its Base Configuration

This section describes:

- The procedure for checking the calibrating of the T200 and calibrating the instrument with no zero/span valves installed or if installed, not operating. It requires that zero air and span gas be installed through the Sample port.
- Instructions for selecting the reporting range to be calibrated when the T200 analyzer is set to operate in either the IND or AUTO reporting range modes.

## SECTION 9.3 – Manual Calibration with the Internal Span Gas Generator

This section describes:

- The procedure for manually checking the calibration of the instrument with optional internal span gas generator installed.
- The procedure for manually calibrating the instrument using the optional internal span gas generator.

## SECTION 9.4 – Manual Calibration and Cal Checks with the Valve Options Installed

This section describes:

- The procedure for manually checking the calibration of the instrument with optional zero/span valves option installed.
- The procedure for manually calibrating the instrument with zero/span valves and operating.
- Instructions on activating the zero/span valves via the control in contact closures of the analyzers external digital I/O.

## SECTION 9.5 – Automatic Zero/Span Cal/Check (AutoCal)

This section describes:

- The procedure for using the AutoCal feature of the analyzer to check or calibrate the instrument.
- The AutoCal feature requires that either the zero/span valve option or the internal span gas generator option be installed and operating.

### SECTION 9.6 – Calibration Quality Analysis

This section describes how to judge the effectiveness of a recently performed calibration.

### SECTION 9.7 – Gas Flow Calibration

This section describes how to adjust the gas flow calculations made by the CPU based on pressure and flow sensor readings.

#### Note

Throughout this Section are various diagrams showing pneumatic connections between the T200 and various other pieces of equipment such as calibrators and zero air sources.

These diagrams are only intended to be schematic representations of these connections and do not reflect actual physical locations of equipment and fitting location or orientation.

Contact your regional EPA or other appropriate governing agency for more detailed recommendations.

## 9.1. BEFORE CALIBRATION

The calibration procedures in this section assume that the range mode, analog range and units of measure have already been selected for the analyzer. If this has not been done, please do so before continuing (see Section 5.4.3 for instructions).

#### Note

If any problems occur while performing the following calibration procedures, refer to Section 12.1 for troubleshooting tips.

### 9.1.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the T200 requires:

- Zero-air source.
- Span gas source.
- Gas lines - all gas line materials should be stainless steel or Teflon-type (PTFE or FEP).
  - High-concentration NO gas transported over long distances may require stainless steel to avoid oxidation of NO due to the possibility of O<sub>2</sub> diffusing into the tubing.
- A recording device such as a strip-chart recorder and/or data logger (optional).
- For electronic documentation, the internal data acquisition system (DAS) can be used.

## 9.1.2. CALIBRATION GASES

### 9.1.2.1. ZERO AIR

Zero air or zero calibration gas is defined as a gas that is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer.

For the T200, this means zero air should be devoid of NO, NO<sub>2</sub>, CO<sub>2</sub>, NH<sub>3</sub> or H<sub>2</sub>O vapor.

#### Note

**Moderate amounts of NH<sub>3</sub> and H<sub>2</sub>O can be removed from the sample gas stream by installing the optional sample gas dryer/scrubber (see Section 3.3.2.6).**

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen (N<sub>2</sub>) could be used as a zero gas for applications where NO<sub>x</sub> is measured in nitrogen.
- If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

For analyzers without the external zero air scrubber, a zero air generator such as the Teledyne API's Model 701 can be used. Please visit the company website for more information.

If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen could be used as a zero gas for applications where NO<sub>x</sub> is measured in nitrogen.

### 9.1.2.2. SPAN GAS

Span calibration gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired reporting range. To measure NO<sub>x</sub> with the T200, it is recommended that you use a span gas with an NO concentration equal to 80% of the measurement range for your application

#### EXAMPLE:

- If the application is to measure NO<sub>x</sub> in ambient air between 0 ppm and 500 ppb, an appropriate span gas would be 400 ppb.
- If the application is to measure NO<sub>x</sub> in ambient air between 0 ppm and 1000 ppb, an appropriate span gas would be 800 ppb.

We strongly recommend that span calibration be carried out with NO span gas. Alternatively it is possible to use NO<sub>2</sub> gas in a gas phase titration (GPT) calibration system.

Even though NO gas mixed into in nitrogen gas (N<sub>2</sub>) could be used as a span gas, the matrix of the balance gas is different and may cause interference problems or yield incorrect calibrations.

- The same applies to gases that contain high concentrations of other compounds (for example, CO<sub>2</sub> or H<sub>2</sub>O).

**Note**

**The span gas should match all concentrations of all gases of the measured medium as closely as possible.**

Cylinders of calibrated NO<sub>x</sub> and NO gas traceable to NIST-standards specifications (also referred to as EPA protocol calibration gases or Standard Reference Materials) are commercially available..

**9.1.2.3. SPAN GAS FOR MULTIPOINT CALIBRATION**

Some applications, such as EPA monitoring, require a multipoint calibration where span gases of different concentrations are needed. We recommend using an NO gas of higher concentration combined with a gas dilution calibrator such as a Teledyne API's Model T700. For more information see Section 3.3.2.1 and Section 10.

**9.1.2.4. NO<sub>2</sub> PERMEATION TUBES**

Teledyne API offers an optional internal span gas generator that utilizes an NO<sub>2</sub> permeation tube as a span gas source. The accuracy of these devices is only about ±5%.

Whereas this may be sufficient for quick, daily calibration checks, we recommend using certified NO gases for accurate calibration.

**CAUTION!**

**Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.**

**In units with a permeation tube option installed, either the tube must be removed and stored in sealed container (use original container that tube was shipped in) during periods of non-operation, or vacuum pump must be connected and powered on to maintain constant gas flow through the analyzer at all times.**

(See Figure 3-6 for location and Section 11.3.6 for instructions on how to remove the perm tube when the unit is not in operation).



### 9.1.3. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the serial or analog outputs of the T200.

- If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter.
- Data recording devices should be capable of bi-polar operation so that negative readings can be recorded.

For electronic data recording, the T200 provides an internal data acquisition system (DAS), which is described in detail in Section 7.

APICOM, a remote control program, is also provided as a convenient and powerful tool for data handling, download, storage, quick check and plotting (see Sections 7.2.1, and the APICOM software manual downloadable from:

<http://www.teledyne-api.com/manuals>

### 9.1.4. NO<sub>2</sub> CONVERSION EFFICIENCY (CE)

In order for the NO<sub>2</sub> converter to function properly, oxygen must be present in the sample stream. In addition, to ensure accurate operation of the T200, it is important to check the NO<sub>2</sub> conversion efficiency (CE) periodically and to update this value as necessary.

- See Section 12.7.10 for instructions on checking or calculating the current NO<sub>2</sub> → NO converter efficiency using T200's onboard firmware.
- See Section 12.7.11 for instructions on checking or calculating the current NO<sub>2</sub> → NO converter efficiency using a simplified Gas Phase Titration Method.

## 9.2. MANUAL CALIBRATION CHECKS AND CALIBRATION OF THE T200 ANALYZER IN ITS BASE CONFIGURATION

### IMPORTANT

### IMPACT ON READINGS OR DATA

#### ZERO/SPAN CALIBRATION CHECKS VS. ZERO/SPAN CALIBRATION

Pressing the ENTR button during the following procedure resets the stored values for OFFSET and SLOPE and alters the instrument's Calibration.

This should **ONLY BE DONE** during an actual calibration of the T200.

**NEVER** press the ENTR button if you are only *checking* calibration.

### 9.2.1. SETUP FOR BASIC CALIBRATION CHECKS AND CALIBRATION

Connect the sources of zero air and span gas as shown below in one of the following ways:

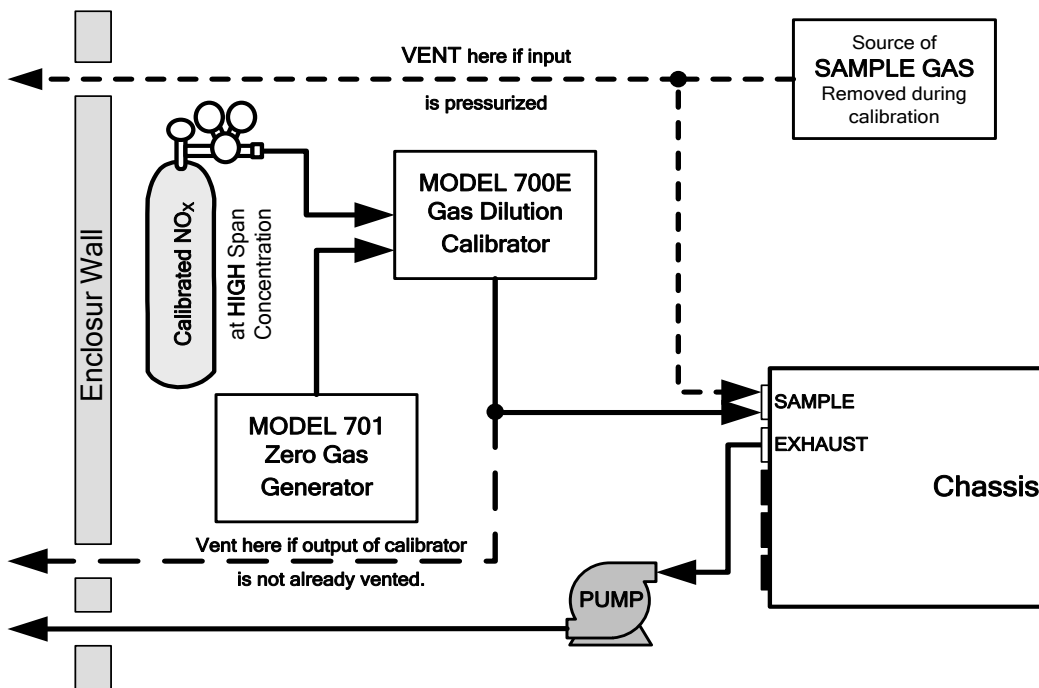


Figure 9-1: Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ a Gas Dilution Calibrator

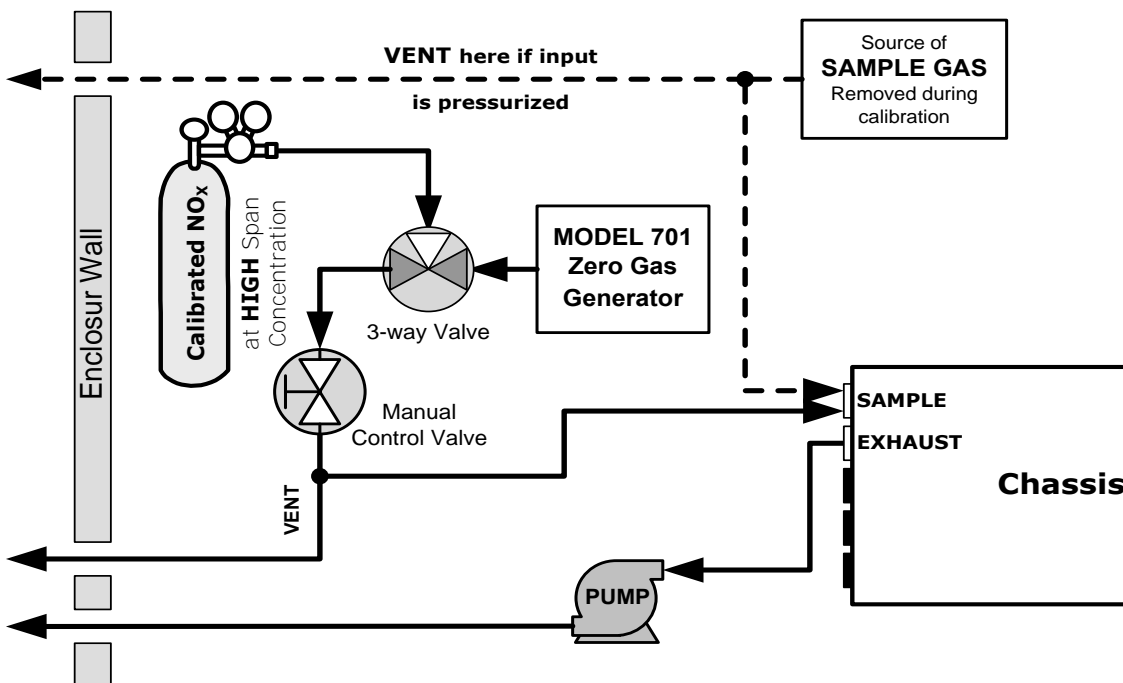
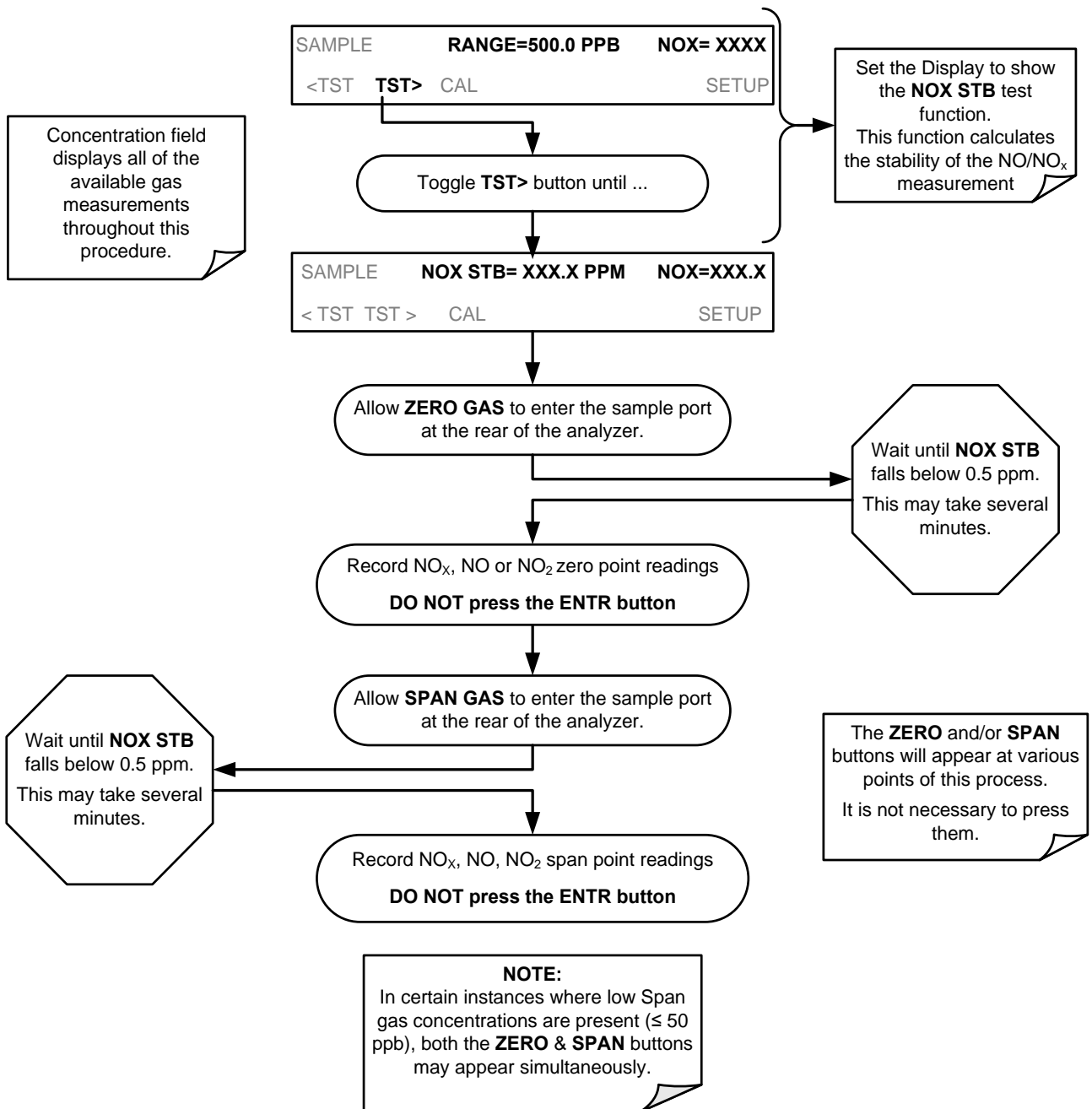


Figure 9-2: Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ Bottled Gas

### 9.2.2. PERFORMING A BASIC MANUAL CALIBRATION CHECK



**Note**

If the **ZERO** or **SPAN** buttons are not displayed, the measurement made is outside the allowable range for a reliable calibration.

See Section 12 for troubleshooting tips.



### 9.2.3. PERFORMING A BASIC MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the T200.

If the analyzer’s reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges **MUST** be calibrated separately.

#### 9.2.3.1. SETTING THE EXPECTED SPAN GAS CONCENTRATION

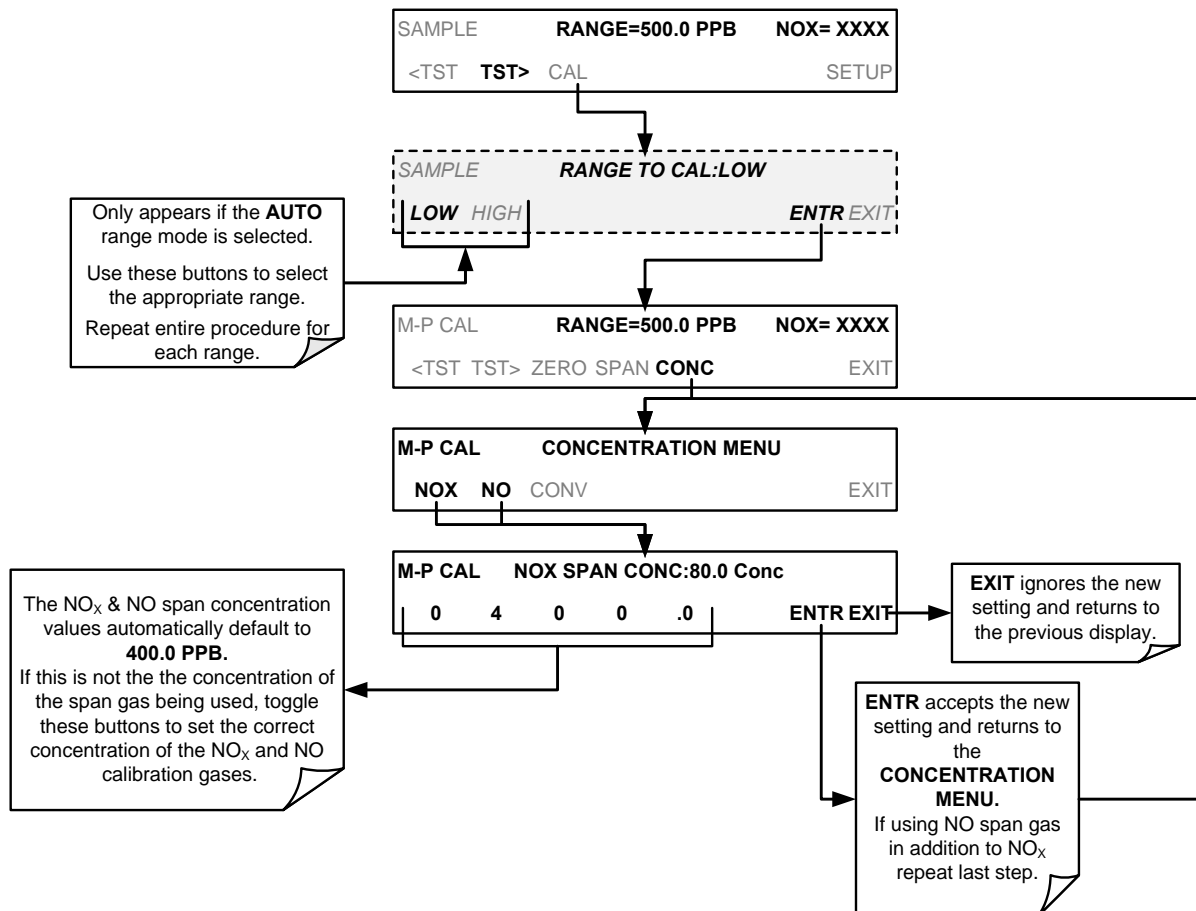
**Note**

The expected concentrations for both NO<sub>x</sub> and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.

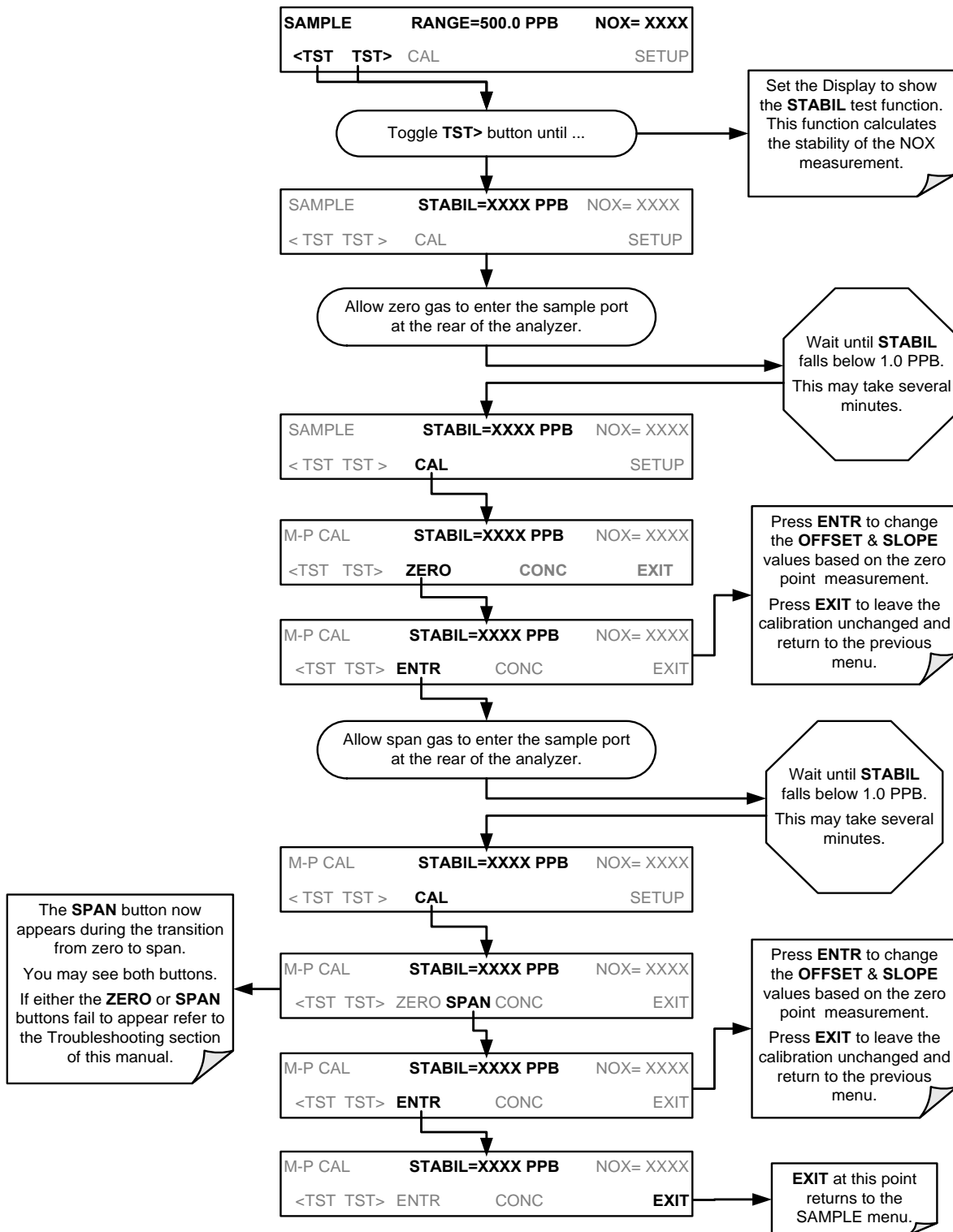
When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO<sub>2</sub> and vice versa).

The NO and NO<sub>x</sub> span gas concentrations should be 80% of range of concentration values likely to be encountered in your application. The default factory reporting range setting is 500 ppb and the default span gas concentration is 40.0 ppb.

To set the span gas concentration, press:



9.2.3.2. ZERO/SPAN POINT CALIBRATION PROCEDURE



Note

If the **ZERO** or **SPAN** buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration. See Section 12 for troubleshooting tips.

### 9.3. MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

The internal span gas generator’s NO<sub>2</sub> permeation tube has a limited accuracy of about ±5%.

#### 9.3.1. PERFORMING “PRECISION” MANUAL CALIBRATION WHEN INTERNAL SPAN GAS (IZS) GENERATOR OPTION IS PRESENT

It is necessary to perform a precision calibration using more accurate zero and span gas standards prior to IZS span calibration or cal check.

To perform a precision calibration of the T200, connect external sources of zero air and calibrated span gas (Section 9.1.2) and temporarily disconnect the sample gas source as shown below; then follow the procedures described in Section 9.2.3.

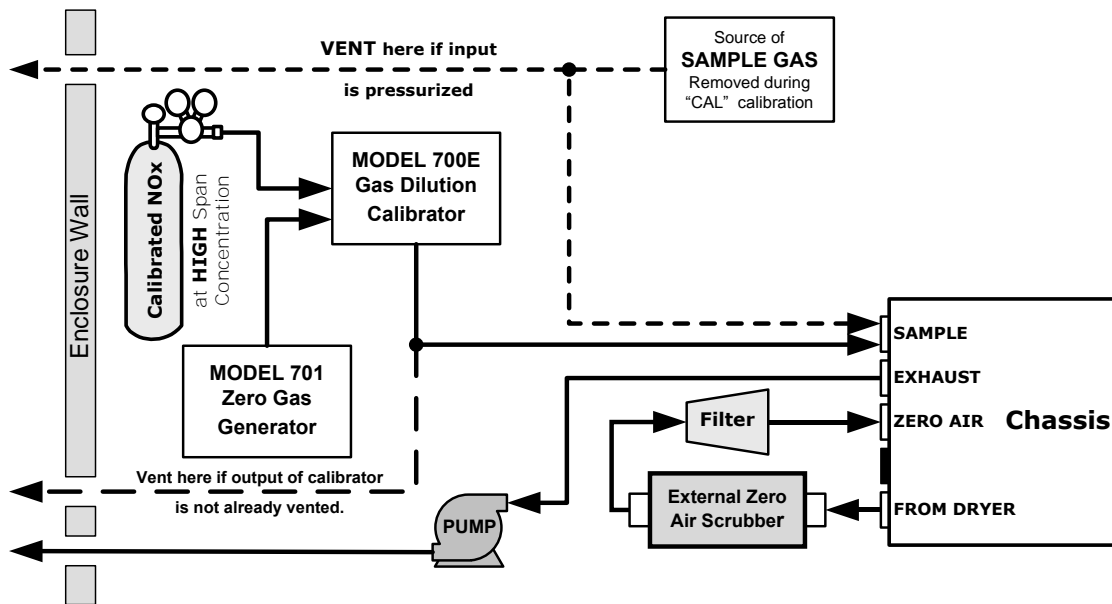


Figure 9-3: Pneumatic Connections for T200 Precision Calibration when IZS Generator Present

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

**DO NOT USE THE CALZ or CALS buttons even though they will be visible, as this will cause the instrument to use the internal zero air and span gas. Instead, press the CAL button. This will cause the analyzer to use the external calibration gas sources.**

### 9.3.2. SETUP FOR CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

Connect the sources of zero air and span gas as shown in Figure 9-4.

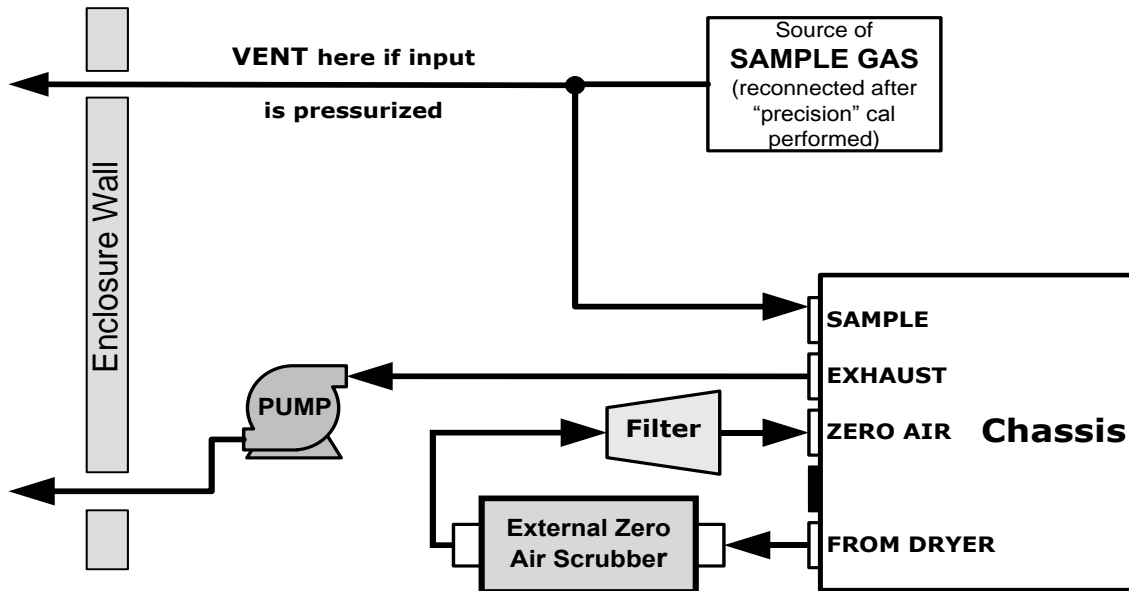


Figure 9-4: Pneumatic Connections for Manual Calibration/Checks with the Internal Span Gas Generator

### 9.3.3. CAL ON NO<sub>2</sub> FEATURE

When using the IZS option to calibrate the T200, the analyzer's **CAL\_ON\_NO<sub>2</sub>** feature must be turned on. This feature enables a continuous zero gas flow across the IZS permeation tube and through the NO<sub>2</sub> converter. It also programs the analyzer to use the NO output from the NO<sub>2</sub> converter to calibrate the span value of both NO and NO<sub>x</sub>.

#### Note

**This feature should only be enabled when a span calibration or calibration check is performed.**

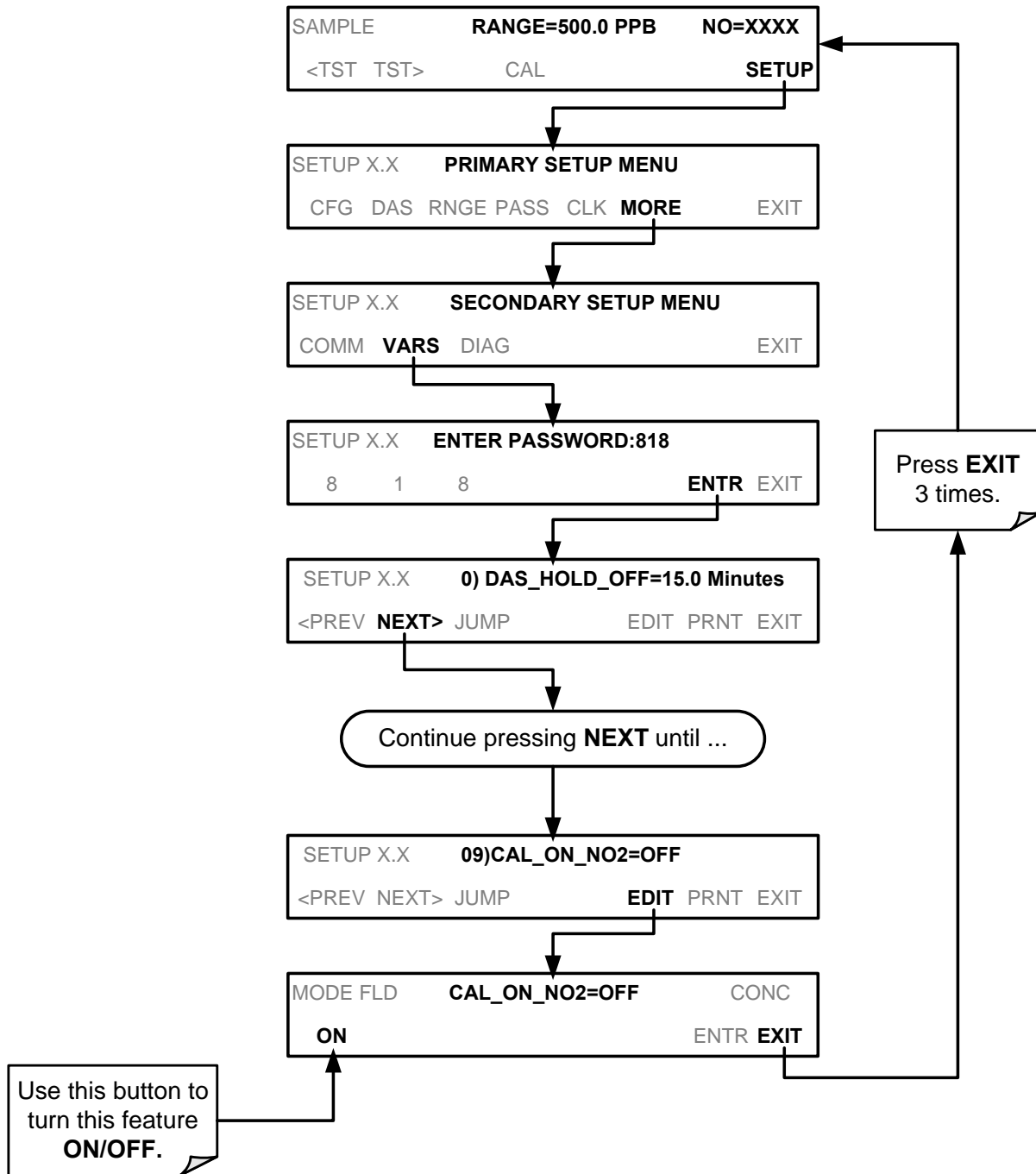
While **CAL\_ON\_NO<sub>2</sub>** is enabled, the NO<sub>2</sub> concentration will always be reported as zero. This is because the gas is continuously routed through the NO<sub>2</sub> converter and the analyzer's firmware simulates calibration with NO gas.

Table 9-1: IZS Option Valve States with **CAL\_ON\_NO<sub>2</sub>** Turned ON

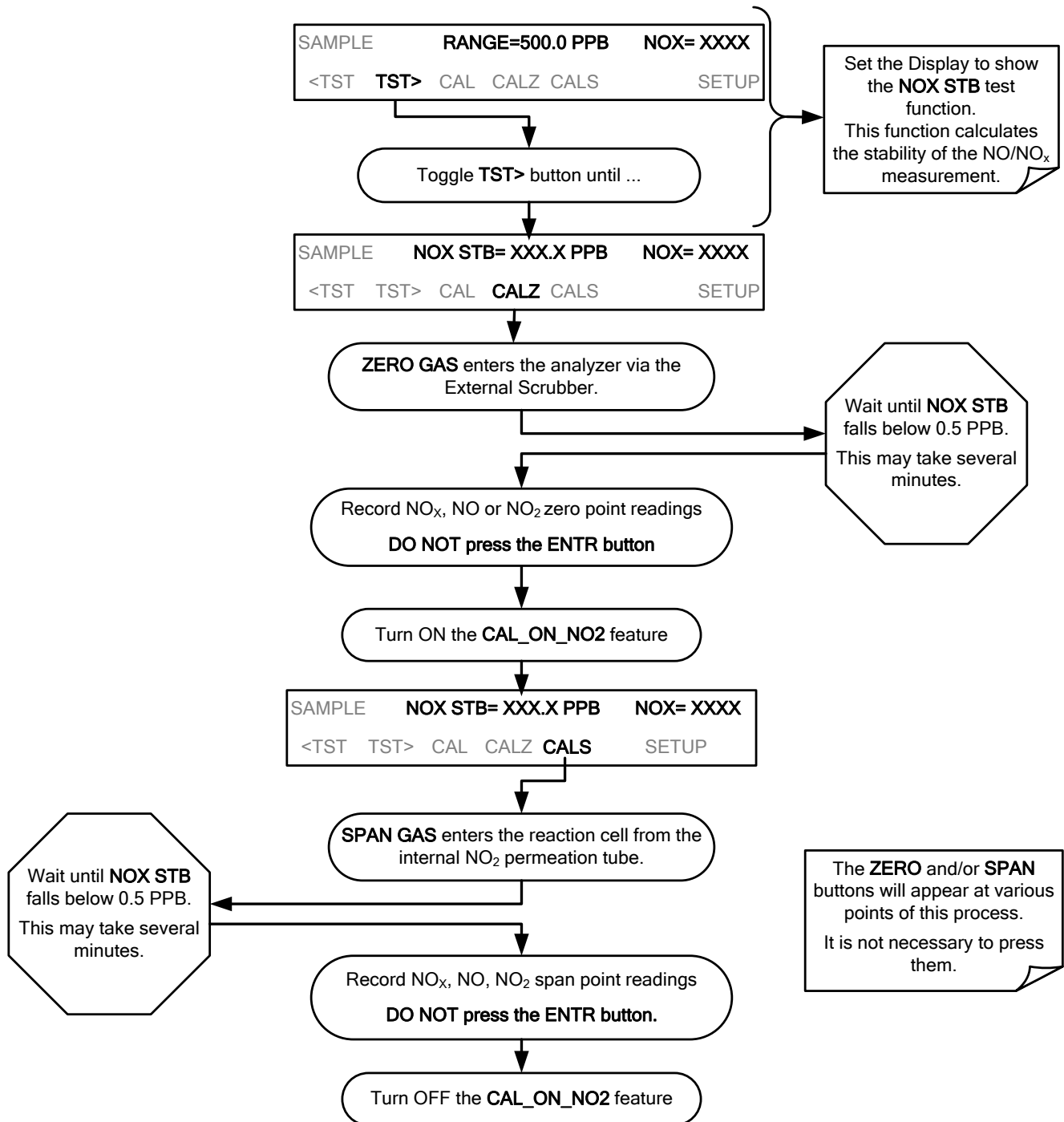
Valve	Condition	Valve Port Connections
Sample/Cal	Open to zero/span valve	1 → 2
Zero/Span	Open to SPAN GAS inlet	1 → 2
NO/NO <sub>x</sub> Valve	Open to NO <sub>2</sub> converter	1 → 2
Auto Zero Valve	Cycles normally	N/A

Since the instrument sees the same concentration of NO during both NO and NO<sub>x</sub> cycles, it reports an NO<sub>2</sub> concentration of zero.

TO turn the CAL\_ON\_NO<sub>2</sub> feature ON/OFF, press:



### 9.3.4. PERFORMING A MANUAL CALIBRATION CHECK WITH THE INTERNAL SPAN GAS GENERATOR



**Note**

If the **ZERO** or **SPAN** buttons are not displayed, the measurement made is out of the allowable range for a reliable calibration. See Section 12 for troubleshooting tips.

### 9.3.5. PERFORMING A MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

If the analyzer's reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges *MUST be calibrated separately*.

#### 9.3.5.1. SETTING THE EXPECTED SPAN GAS CONCENTRATION

**Note**

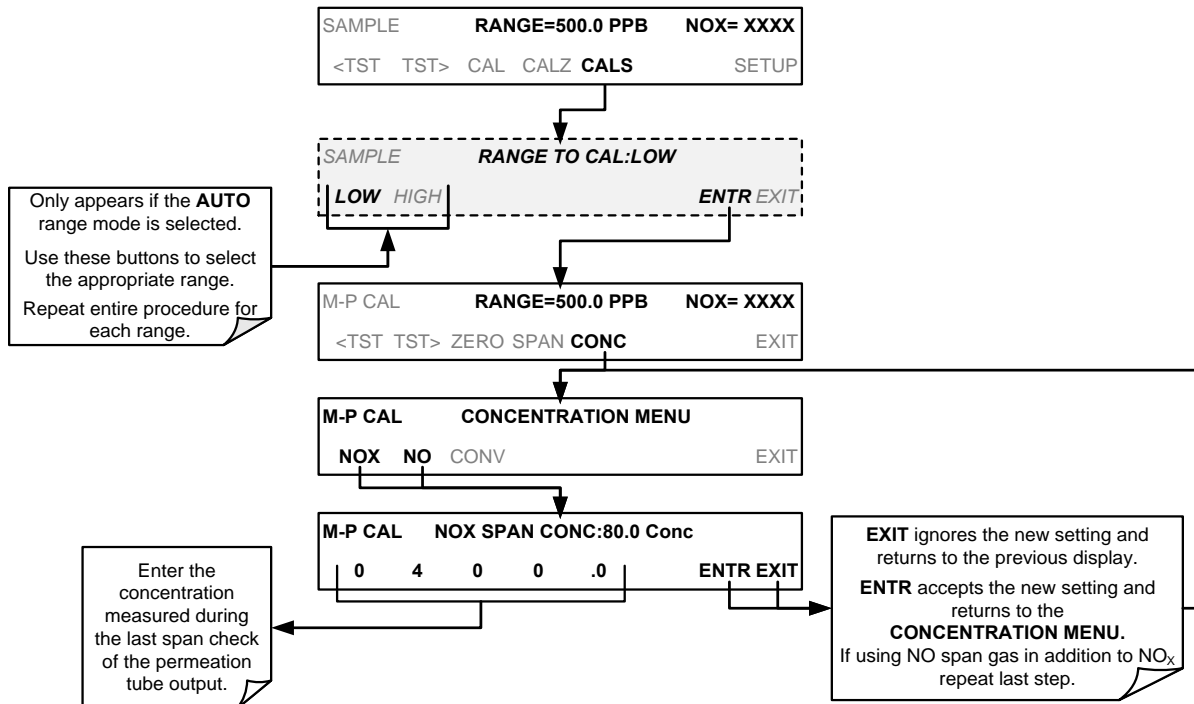
-----  
**The expected concentrations for both NO<sub>x</sub> and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.**

**When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO<sub>2</sub> and vice versa).**  
-----

When calibrating the instrument using the internal permeation tube as a span gas source, it is necessary to know, as close as possible, the concentration value of the gas being outputted by the tube. To determine this value:

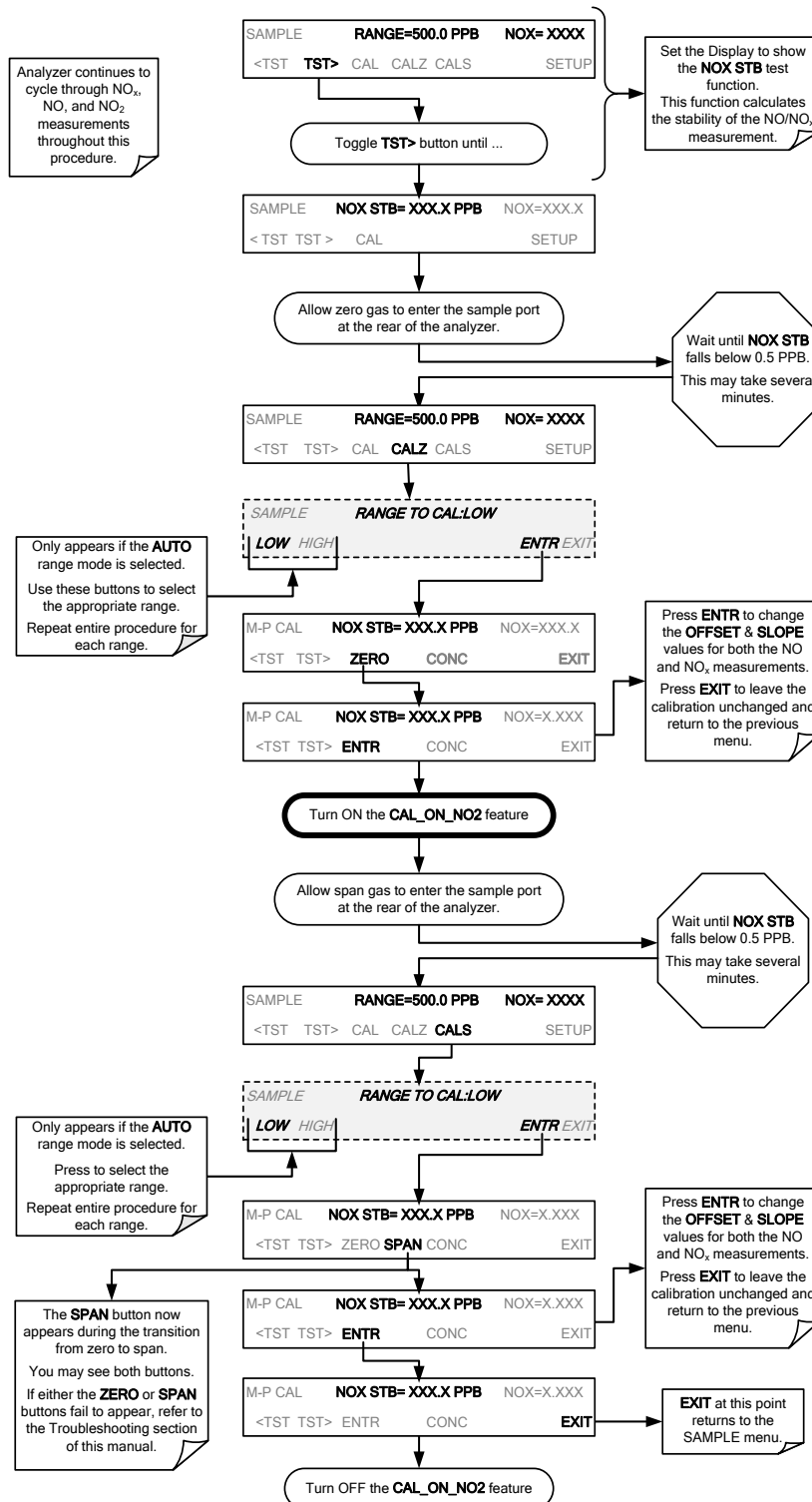
1. Perform a precision calibration of the instrument as describes in Section 9.3.1.
2. Perform a calibration check as described in Section 9.3.4.
  - Record the value displayed for NO/NO<sub>x</sub> during the span check portion of the procedure.
  - This will be the concentration value used in subsequent calibrations using the internal span gas source.
  - It is a good idea to measure the permeation tube output once every 4 to 6 months.
3. Ensure that the reporting range span point is set for a value at least 10% higher than the measured value of the permeation tube output

To set the span gas concentration, press:





### 9.3.5.2. ZERO/SPAN POINT CALIBRATION PROCEDURE WITH INTERNAL SPAN GAS GENERATOR



**Note**

If the **ZERO** or **SPAN** buttons are not displayed, the measurement made during during this procedure is out of the range allowed for a reliable calibration. See Section 12 for troubleshooting tips.

## 9.4. MANUAL CALIBRATION AND CAL CHECKS WITH THE VALVE OPTIONS INSTALLED

There are a variety of valve options available on the T200 for handling calibration gases (see Section 1.3 for descriptions of each).

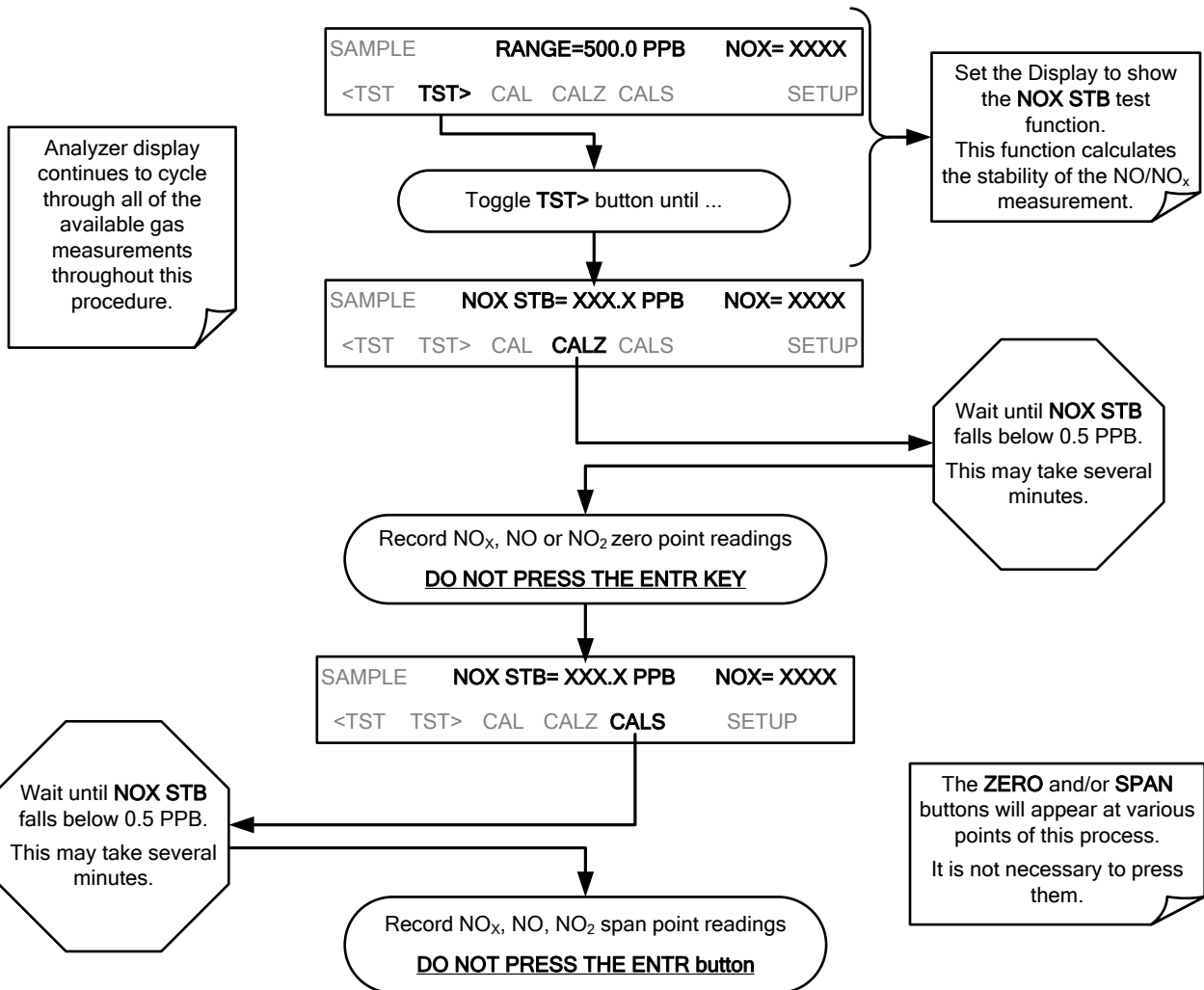
Generally performing calibration checks and zero/span point calibrations on analyzers with these options installed is similar to the methods discussed in the previous sections. The primary differences are:

- On instruments with Z/S valve options, zero air and span gas is supplied to the analyzer through other gas inlets besides the sample gas inlet.
- The zero and span calibration operations are initiated directly and independently with dedicated buttons (**CALZ & CALS**).

### 9.4.1. SETUP FOR CALIBRATION USING VALVE OPTIONS

Each of the various calibration valve options requires a different pneumatic setup that is dependent on the exact nature and number of valves present. Refer to the following diagrams for information on each of these valve sets.

### 9.4.2. MANUAL CALIBRATION CHECKS WITH VALVE OPTIONS INSTALLED



### 9.4.3. MANUAL CALIBRATION USING VALVE OPTIONS

The following section describes the basic method for manually calibrating the T200 NO<sub>x</sub> analyzer.

If the analyzer's reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges **MUST** be calibrated separately.

#### 9.4.3.1. SETTING THE EXPECTED SPAN GAS CONCENTRATION

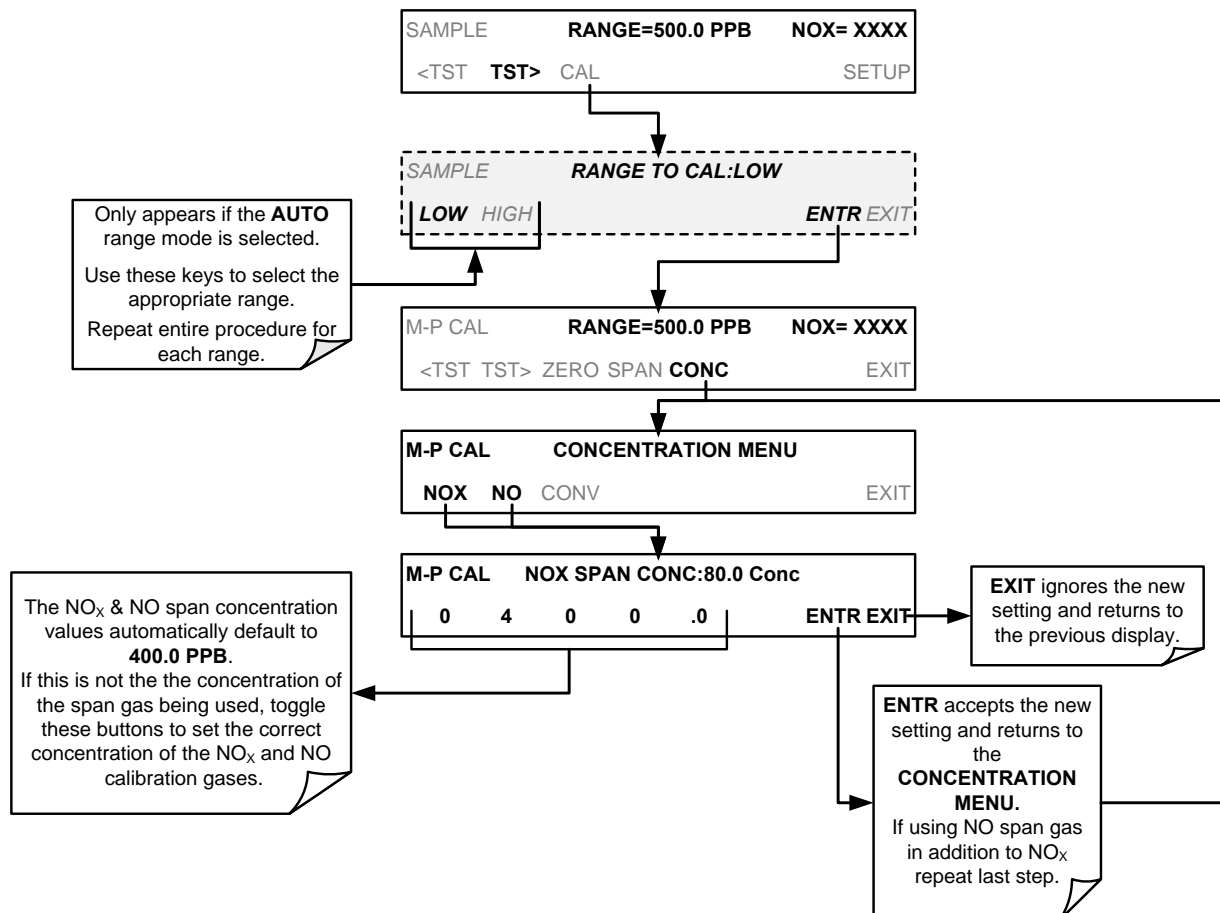
**Note**

The expected concentrations for both NO<sub>x</sub> and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.

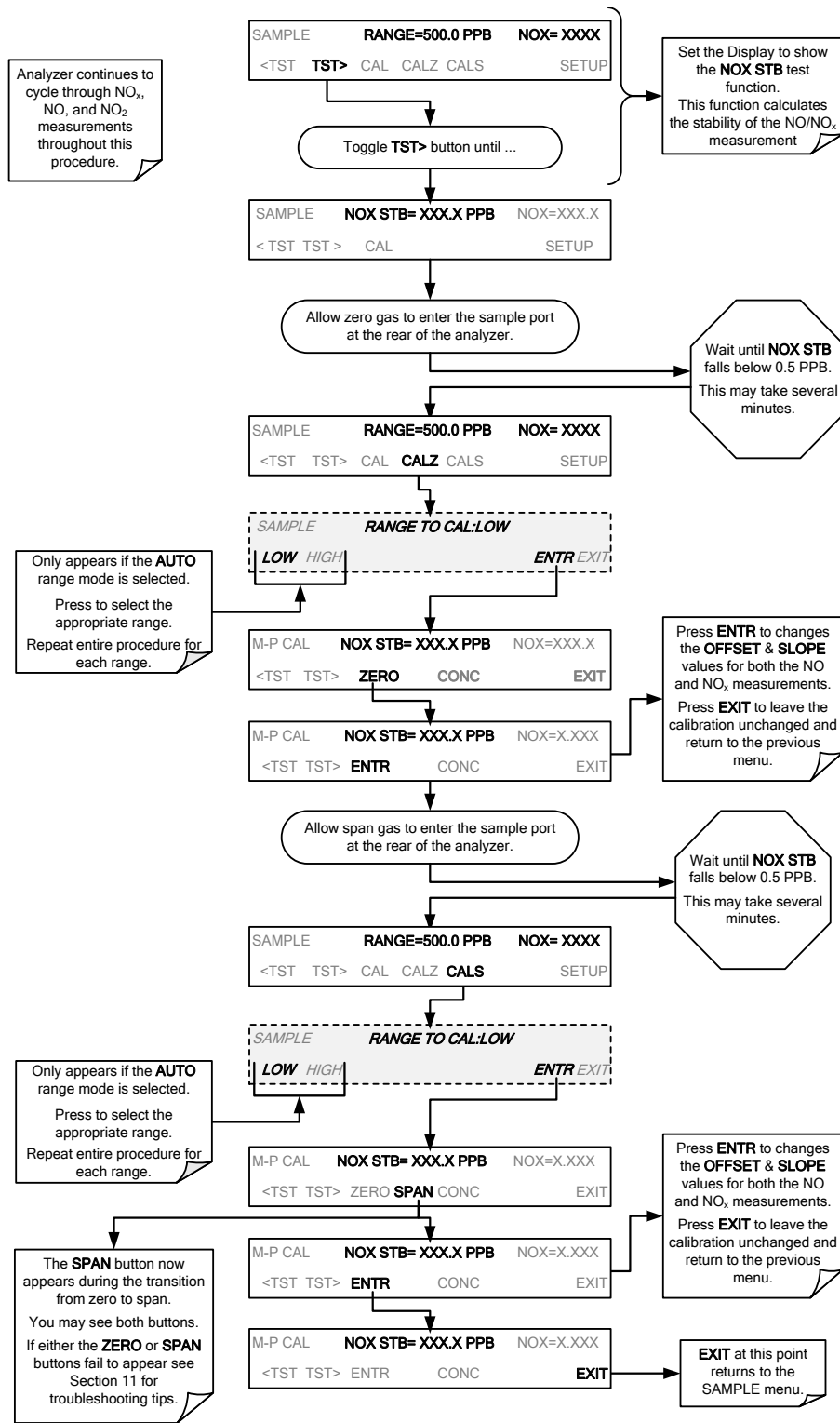
When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO<sub>2</sub> and vice versa).

The NO and NO<sub>x</sub> span gas concentrations should be 80% of range of concentration values likely to be encountered in your application. The default factory reporting range setting is 500 ppb and the default span gas concentration is 400.0 ppb.

To set the span gas concentration, press:



9.4.3.2. ZERO/SPAN POINT CALIBRATION PROCEDURE



Note

If the ZERO or SPAN buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration. See Section 12 for troubleshooting tips.

### 9.4.3.3. USE OF ZERO/SPAN VALVE WITH REMOTE CONTACT CLOSURE

Contact closures for controlling calibration and calibration checks are located on the rear panel **CONTROL IN** connector. Instructions for setup and use of these contacts are found in Section 3.3.1.6.

When the contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and the internal zero/span valves will be automatically switched to the appropriate configuration.

- The remote calibration contact closures may be activated in any order.
- It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading.
- The instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are being used in conjunction with the analyzer's AutoCal (see Section 9.5) feature and the AutoCal attribute "**CALIBRATE**" is enabled, the T200 will not re-calibrate the analyzer UNTIL when the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to **SAMPLE** mode.

If the AutoCal attribute "**CALIBRATE**" is disabled, the instrument will return to **SAMPLE** mode, leaving the instrument's internal calibration variables unchanged.

## 9.5. AUTOMATIC ZERO/SPAN CAL/CHECK (AUTOCAL)

The AutoCal system allows unattended periodic operation of the **ZERO/SPAN** valve options by using the T200's internal time of day clock. AutoCal operates by executing **SEQUENCES** programmed by the user to initiate the various calibration modes of the analyzer and open and close valves appropriately. It is possible to program and run up to three separate sequences (**SEQ1**, **SEQ2** and **SEQ3**). Each sequence can operate in one of three modes, or be disabled.

**Table 9-2: AUTOCAL Modes**

<b>MODE NAME</b>	<b>ACTION</b>
<b>DISABLED</b>	Disables the Sequence.
<b>ZERO</b>	Causes the Sequence to perform a Zero calibration/check.
<b>ZERO-SPAN</b>	Causes the Sequence to perform a Zero point calibration/check followed by a Span point calibration/check.
<b>SPAN</b>	Causes the Sequence to perform a Span concentration calibration/check only.

For each mode, there are seven parameters that control operational details of the SEQUENCE. They are:

**Table 9-3: AutoCal Attribute Setup Parameters**

ATTRIBUTE	ACTION
TIMER ENABLED	Turns on the Sequence timer.
STARTING DATE	Sequence will operate after Starting Date.
STARTING TIME	Time of day sequence will run.
DELTA DAYS	Number of days to skip between each Sequence execution. <ul style="list-style-type: none"> <li>If set to 7, for example, the AutoCal feature will be enabled once every week on the same day.</li> </ul>
DELTA TIME	Number of hours later each “Delta Days” Sequence is to be run. <ul style="list-style-type: none"> <li>If set to 0, the sequence will start at the same time each day. <b>Delta Time</b> is added to <b>Delta Days</b> for the total time between cycles.</li> <li>This parameter prevents the analyzer from being calibrated at the same daytime of each calibration day and prevents a lack of data for one particular daytime on the days of calibration</li> </ul>
DURATION	Number of minutes the sequence operates. <ul style="list-style-type: none"> <li>This parameter needs to be set such that there is enough time for the concentration signal to stabilize.</li> <li>The STB parameter shows if the analyzer response is stable at the end of the calibration.</li> <li>This parameter is logged with calibration values in the DAS.</li> </ul>
CALIBRATE	Enable to do a calibration – Disable to do a cal check only. <ul style="list-style-type: none"> <li>For analyzers with internal span gas generators installed and functioning, when used in US EPA applications, this setting must be set to OFF.</li> </ul>
RANGE TO CAL	LOW calibrates the low range, HIGH calibrates the high range. Applies only to auto and remote range modes; this property is not available in single and independent range modes.

## IMPORTANT

### IMPACT ON READINGS OR DATA

For US EPA controlled/related applications:

For analyzers used in US EPA controlled applications that have internal span gas generators option installed, the CALIBRATE attribute must always be set to OFF

Calibration of instruments used in US EPA related applications should only be performed using external sources of zero air and span gas with an accuracy traceable to EPA or NIST standards and supplied through the analyzer’s sample port.

The following example sets sequence #2 to do a zero-span calibration every other day starting at 1:00 AM on September 4, 2011, lasting 15 minutes, without calibration. This will start ½ hour later each iteration.

**Table 9-4: Example AutoCal Sequence**

<b>MODE AND ATTRIBUTE</b>	<b>VALUE</b>	<b>COMMENT</b>
<b>SEQUENCE</b>	<b>2</b>	Define Sequence #2
<b>MODE</b>	<b>ZERO-SPAN</b>	Select Zero and Span Mode
<b>TIMER ENABLE</b>	<b>ON</b>	Enable the timer
<b>STARTING DATE</b>	<b>Sept. 4, 2011</b>	Start after Sept 4, 2011
<b>STARTING TIME</b>	<b>1:00 AM</b>	First Span starts at 1:00AM
<b>DELTA DAYS</b>	<b>2</b>	Do Sequence #2 every other day
<b>DELTA TIME</b>	<b>00:30</b>	Do Sequence #2 ½ hr later each day
<b>DURATION</b>	<b>15.0</b>	Operate Span valve for 15 min
<b>CALIBRATE</b>	<b>OFF</b>	Calibrate at end of Sequence

## IMPORTANT

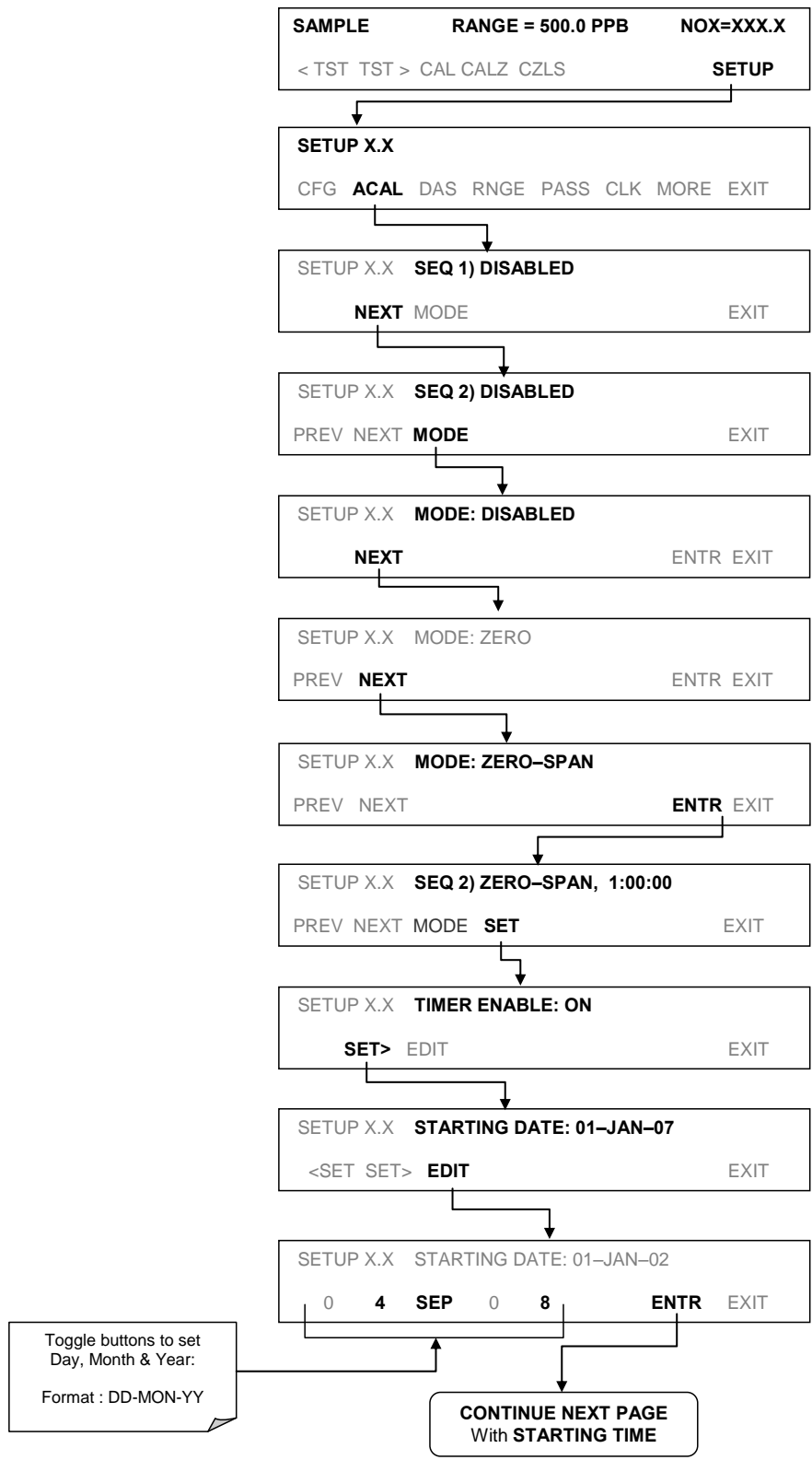
### IMPACT ON READINGS OR DATA

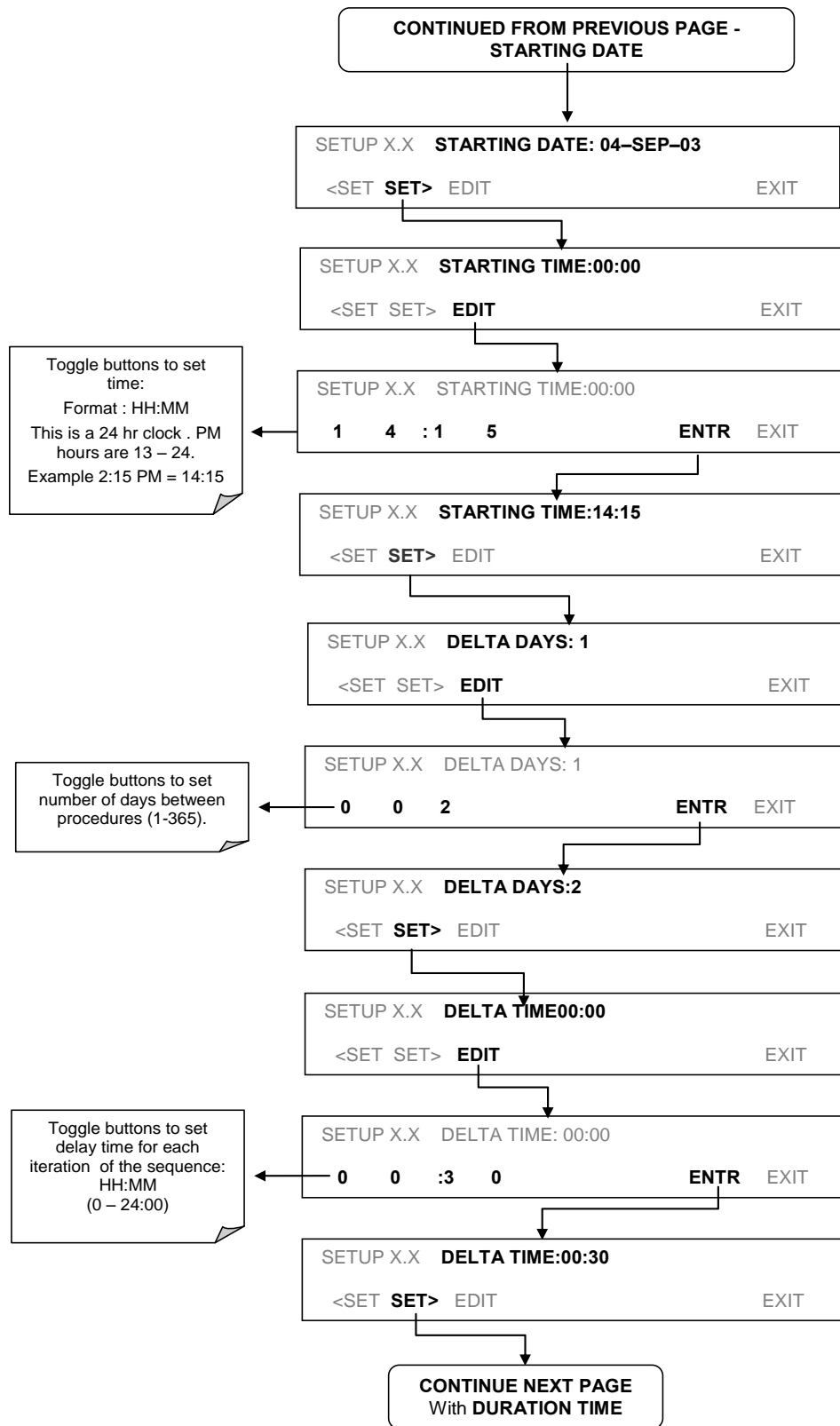
- The programmed STARTING\_TIME must be a minimum of 5 minutes later than the real time clock for setting real time clock (See Section 5.6).
- Avoid setting two or more sequences at the same time of the day.
- Any new sequence that is initiated whether from a timer, the COM ports or the contact closure inputs will override any sequence that is in progress.
- The CALIBRATE attribute must always be set to OFF on analyzers with IZS Options installed and functioning.
- Calibrations should ONLY be performed using external sources of Zero Air and Span Gas whose accuracy is traceable to EPA standards.

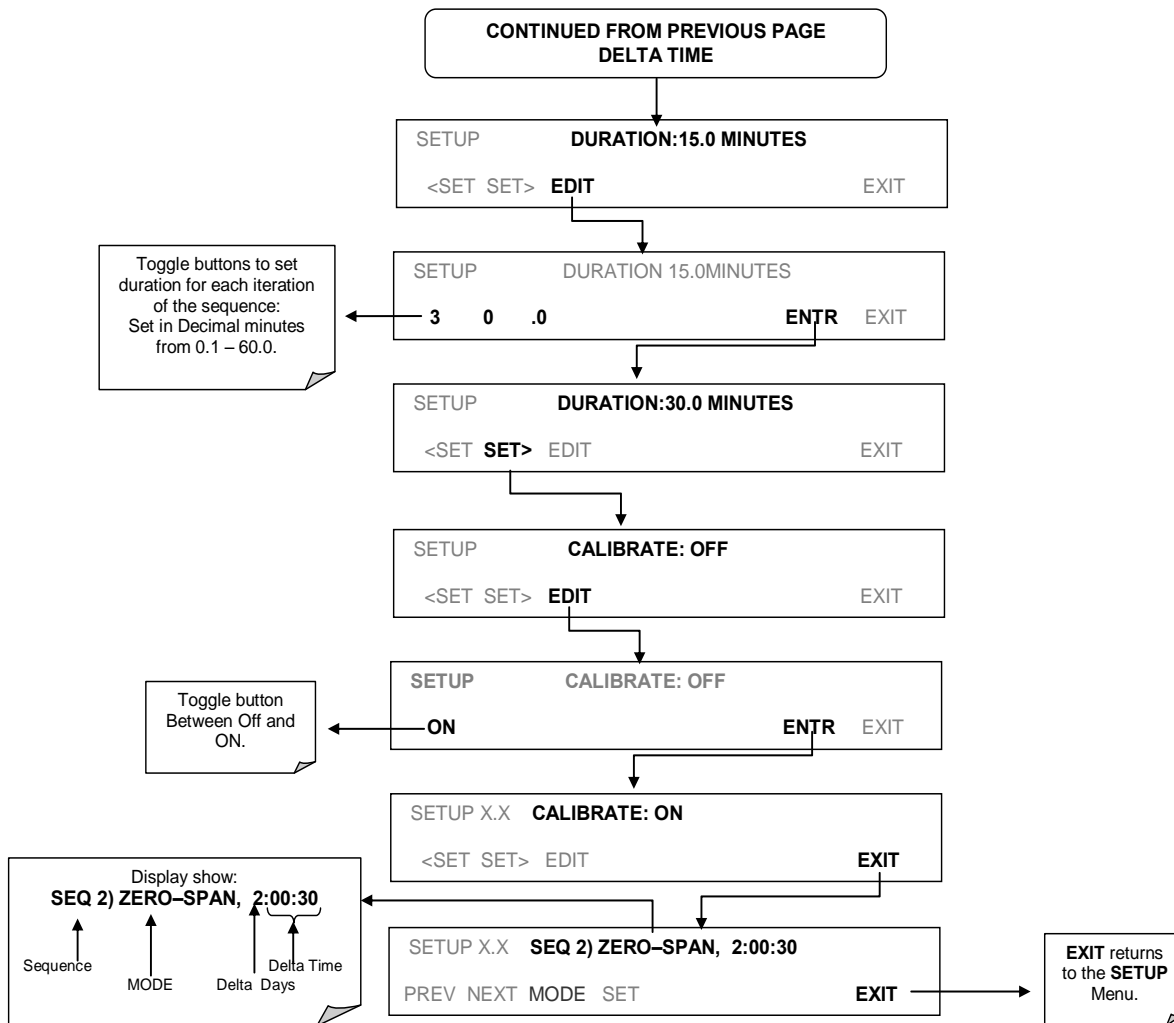


### 9.5.1. SETUP → ACAL: PROGRAMMING AND AUTO CAL SEQUENCE

To program the example sequence shown in Table 9-4, press:







**Note** If at any time an unallowable entry is selected (Example: Delta Days > 367) the ENTR button will disappear from the display.

## 9.6. CALIBRATION QUALITY ANALYSIS

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer, separately for NO and NO<sub>x</sub>. The values for these terms, both individually and relative to each other, indicate the quality of the calibration.

To perform this quality evaluation, you will need to record the values of the following test functions (see Section 4.1.1), all of which are automatically stored in the DAS channel CALDAT for data analysis, documentation and archival.

**NO OFFS**

**NO SLOPE**

**NOX OFFS**

**NOX SLOPE**

Ensure that these parameters are within the limits listed in Table 9-5 and frequently compare them to those values on the *Final Test and Validation Data Sheet (P/N 04490)* that came attached to your manual, which should not be significantly different. If they are, refer to the troubleshooting Section 12.

**Table 9-5: Calibration Data Quality Evaluation**

Function	Minimum Value	Optimum Value	Maximum Value
NOX SLOPE	-0.700	1.000	1.300
NO SLOPE	-0.700	1.000	1.300
NOX OFFS	-20.0 mV	0.0 mV	150.0 mV
NO OFFS	-20.0 mV	0.0 mV	150.0 mV

The default DAS configuration records all calibration values in channel CALDAT as well as all calibration check (zero and span) values in its internal memory.

- Up to 200 data points are stored for up 4 years of data (on weekly calibration checks) and a lifetime history of monthly calibrations.
- Review these data to see if the zero and span responses change over time.
- These channels also store the STB figure (standard deviation of NO<sub>x</sub> concentration) to evaluate if the analyzer response has properly leveled off during the calibration procedure.
- Finally, the CALDAT channel also stores the converter efficiency for review and documentation.

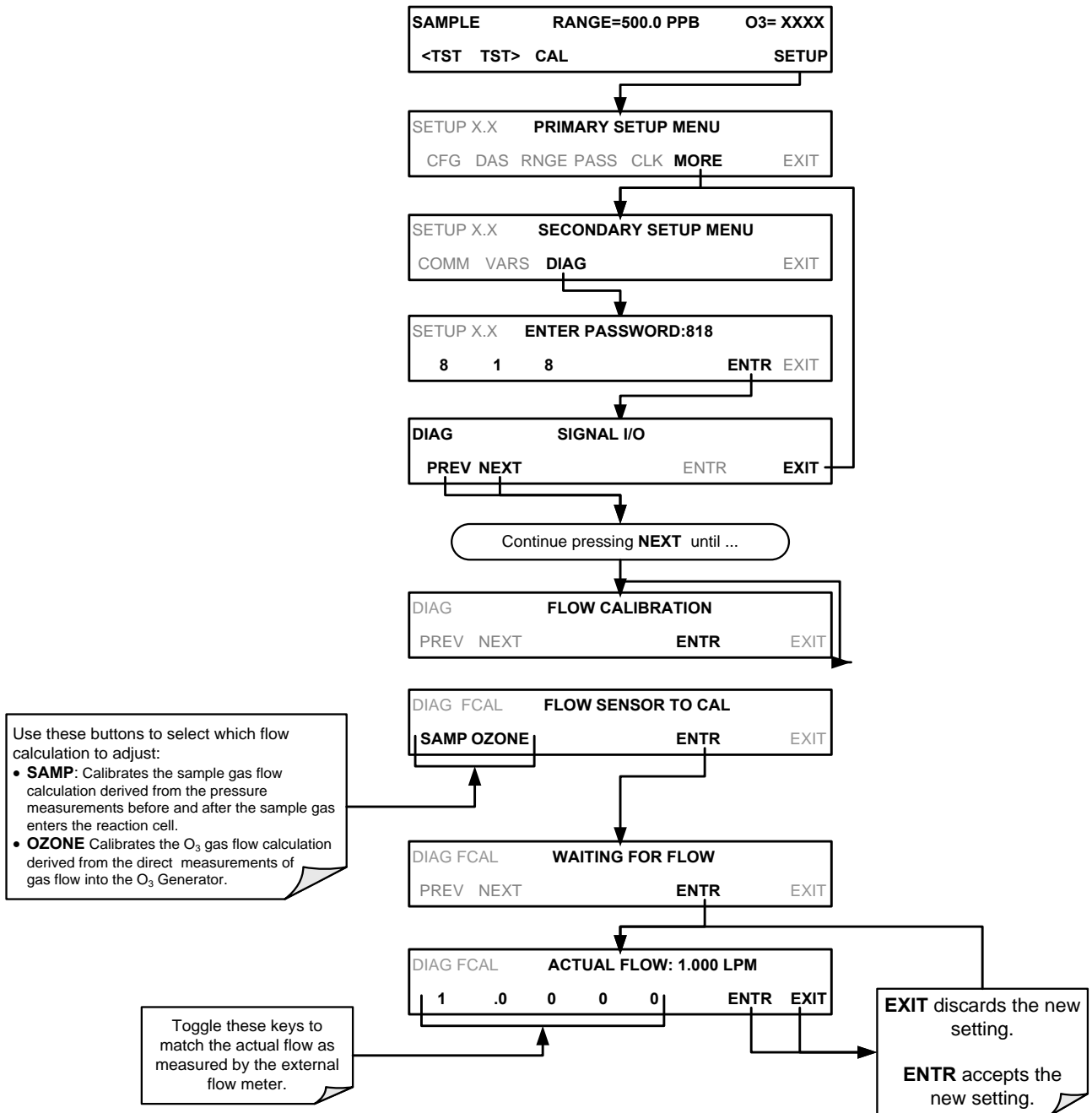
## 9.7. GAS FLOW CALIBRATION

Rate of sample gas and O<sub>3</sub> flow through the T200 is a key part of the NO<sub>x</sub>, NO and NO<sub>2</sub> concentration calculations. The **FLOW CALIBRATION** submenu located under the DIAG menu allows the calibration/ adjustment of these calculations.

**Note**

**A separate flow meter is required for this procedure.**

To calibrate the flow of gas calculations made by the CPU, press.



..

## 10. EPA PROTOCOL CALIBRATION

For U.S. EPA compliance always calibrate this instrument prior to use, adhering to the EPA designation conditions for operating this instrument (Section 2.2). Pay strict attention to the built-in warning features, periodic inspection, regular zero/span checks, regular test parameter evaluation for predictive diagnostics and data analysis, and routine maintenance. Any instrument(s) supplying the zero air and span calibration gasses used must themselves be calibrated and that calibration must be traceable to an EPA/NIST primary standard.

Comply with Code of Federal Regulations, Title 40 (downloadable from the U.S. Government Publishing Office at <http://www.gpo.gov/fdsys/>) and with Quality Assurance Guidance documents (available on the EPA website, <http://www.epa.gov/ttn/amtic/qalist.html>). Give special attention to specific regulations regarding the use and operation of ambient NO<sub>x</sub> analyzers (chemiluminescence).

This page intentionally left blank

# 11. INSTRUMENT MAINTENANCE

Follow the maintenance schedule set forth in Section 11.1. In general, the exterior can be wiped down with a lightly damp cloth.

## ATTENTION

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**  
**Avoid spraying anything directly onto any part of the analyzer.**  
-----

Service and troubleshooting are covered in Section Troubleshooting & Service.

## 11.1. MAINTENANCE SCHEDULE

Table 11-1 shows a typical maintenance schedule for the T200. Please note that in certain environments (i.e. dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.



### WARNING – ELECTRICAL SHOCK HAZARD

**DISCONNECT POWER BEFORE PERFORMING ANY OF THE FOLLOWING OPERATIONS THAT REQUIRE ENTRY INTO THE INTERIOR OF THE ANALYZER.**



### CAUTION – QUALIFIED PERSONNEL

**These maintenance procedures must be performed by qualified technicians only.**

## IMPORTANT

### IMPACT ON READINGS OR DATA

A span and zero calibration check (see CAL CHECK REQ'D Column of Table 11-1, T200 Maintenance Schedule) must be performed following some of the maintenance procedures listed herein. To perform a CHECK of the instrument's Zero or Span Calibration, refer to Section 9.3.

**DO NOT** press the ENTR button at the end of each operation. Pressing the ENTR button resets the stored values for OFFSET and SLOPE and alters the instrument's Calibration.

Alternatively, use the Auto Cal feature described in Section 9.5 with the CALIBRATE attribute set to OFF.



Table 11-1: T200 Maintenance Schedule

ITEM	ACTION	FREQ	CAL CHECK REQ'D	DATE PERFORMED												
TEST functions	Review and evaluate	Weekly	No													
Particulate filter	Change particle filter	Weekly (if in stack system: As Needed)	No													
Zero/span check	Evaluate offset and slope	Weekly	No													
Zero/span calibration	Zero and span calibration	Every 3 months	Yes													
External zero air scrubber option	Exchange chemical	Every 3 months	No													
External dryer option	Replace chemical	When indicator color changes	No													
Ozone cleanser	Change chemical	Annually	Yes													
Reaction cell window ("optical filter" in Figure 11-6)	Clean	Annually or as necessary	Yes													
DFU filters	Change particle filter	Annually	No													
Pneumatic sub-system	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	Yes if a leak is repaired													
Reaction cell O-rings & sintered filters	Replace	Annually	Yes													
PMT Sensor Hardware Calibration	Low-level hardware calibration	On PMT/ preamp changes or if slope is outside of 1.0±0.3	Yes													
Pump	Rebuild head	when RCEL pressure exceeds 10 in-Hg-A (at sea level)	Yes													
Inline Exhaust Scrubber	Replace	Annually	No													
NO <sub>2</sub> converter	Replace converter	Every 3 years or if conversion efficiency drops below 96%	Yes													
Desiccant bags	Replace	Any time PMT housing is opened for maintenance	n/a													

## 11.2. PREDICTIVE DIAGNOSTICS

Predictive diagnostic functions, including failure warnings and alarms built into the analyzer's firmware, aid in determining whether and when repairs are necessary.

The Test Functions can also be used to predict failures by looking at how their values change over time, compared to the values recorded on the printed record of the *Final Test and Validation Data Sheet*, P/N 04490. The internal data acquisition system (DAS) is a convenient way to record and track these changes. Use APICOM (Section 8.1.1) to download and review this data from a remote location.

The following table, checked weekly, can be used as a basis for taking action as these values change with time.

**Table 11-2: Predictive Uses for Test Functions**

FUNCTION	EXPECTED	ACTUAL	INTERPRETATION & ACTION
<b>RCEL</b> (pressure)	Constant to within ± 0.5 in-Hg-A	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Pump performance is degrading. Rebuild pump when pressure is above 10 in-Hg-A.
<b>SAMP</b> (pressure)	Constant within atmospheric changes	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Flow path is clogging up. Replace orifice filters.
		Slowly decreasing	Developing leak in pneumatic system to vacuum (developing valve failure). Check for leaks.
<b>OZONE FL</b>	Constant to within ± 15	Slowly decreasing	Flow path is clogging up. Replace orifice filters.
<b>AZERO</b>	Constant within ±20 of check-out value	Significantly increasing	Developing AZERO valve failure. Replace valve.
			PMT cooler failure. Check cooler, circuit, and power supplies.
			Developing light leak.
			O <sub>3</sub> air filter cartridge is exhausted. Change chemical.
<b>NO<sub>2</sub></b> (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Replace converter components.
<b>NO<sub>2</sub></b> <b>with IZS Option</b> <b>installed</b> (Concentration)	Constant response from day to day	Decreasing over time	Change in instrument response. Low level (hardware) calibrate the sensor. Degradation of IZS permeation tube. Change permeation tube.
		Heavily fluctuating from day to day	Ambient changes in moisture are affecting the performance. Add a dryer to the zero air inlet.
<b>NO</b> (Concentration)	Constant for constant concentration	Decreasing over time	Drift of instrument response; clean RCEL window. Check for flow leaks or irregularities.

## 11.3. MAINTENANCE PROCEDURES

Perform the following procedures as standard maintenance per Table 11-1.

### 11.3.1. REPLACING THE SAMPLE PARTICULATE FILTER

Inspect the particulate filter often for signs of plugging or contamination. Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the o-ring with your bare hands: use gloves or PTFE coated tweezers or similar handling to avoid contamination of the sample filter assembly.

To change the filter:

1. Turn OFF the analyzer to prevent drawing debris into the instrument.
2. Open the T200's hinged front panel and unscrew the retaining ring on the filter assembly.

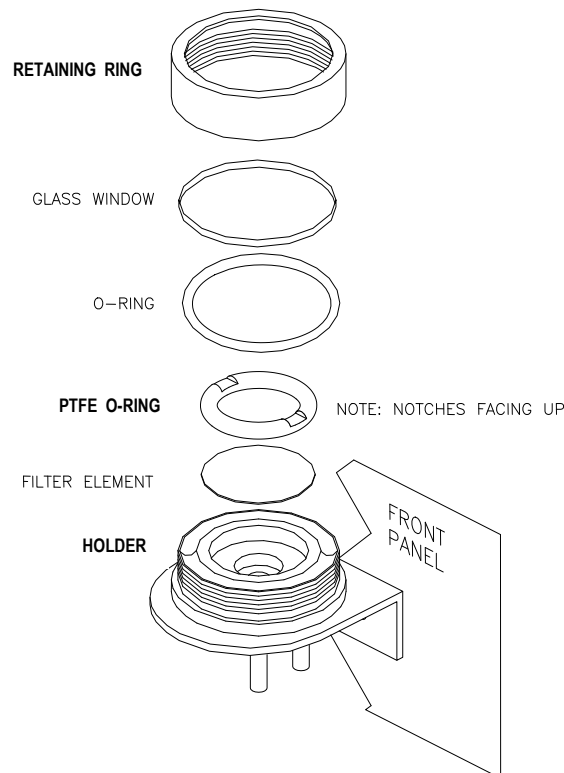


Figure 11-1 Replacing the Particulate Filter

3. Carefully remove the retaining ring, PTFE o-ring, glass window and filter element.
4. Replace the filter, being careful that the element is fully seated and centered in the bottom of the holder.
5. Reinstall the PTFE o-ring with the notches up; the glass window, then screw on the retaining ring and hand tighten. Inspect the seal between the edge of filter and the o-ring to assure a proper seal.
6. Restart the Analyzer.

### 11.3.2. CHANGING THE O<sub>3</sub> DRYER PARTICULATE FILTER

The air for the O<sub>3</sub> generator passes through a dryer equipped with a small particulate filter at its inlet, which prevents dust from entering the ozone dryer and degrading the dryer's performance over time. Change the filter according to the service interval in Table 11-1 as follows:

1. Before starting the procedure, check and record the average **RCEL** pressure and the **OZONE FLOW** values.
2. Turn off the analyzer, unplug the power cord and remove the cover.
3. Unscrew the nut around the port of the filter using two 5/8" wrenches.

#### ATTENTION

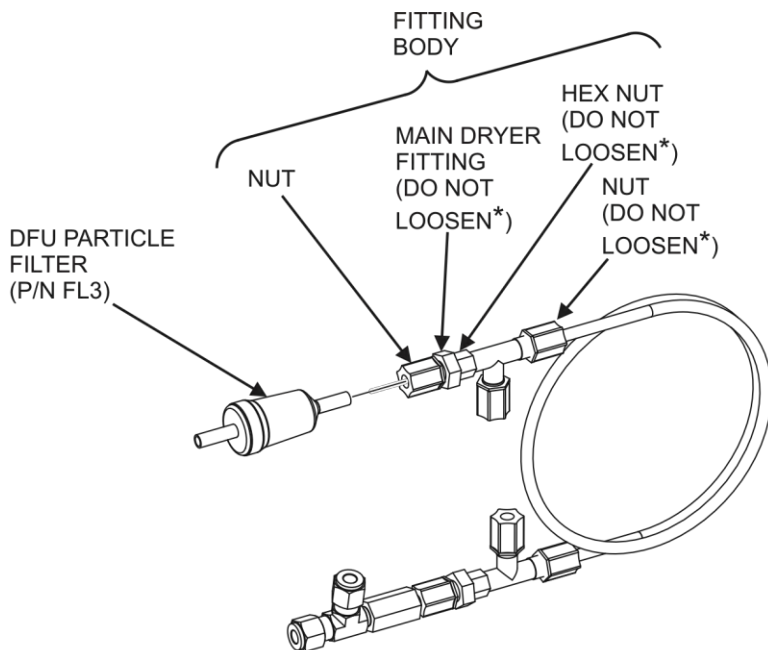
#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Ensure to use proper wrenches.

Hold the main dryer fitting with a 5/8" wrench to ensure that it does not turn against the dryer.

Performing this procedure improperly or with incorrect tools creates a risk of causing a significant leak.

4. Take off the old filter element and replace it with a suitable equivalent (Teledyne API P/N FL-3).



\* DO NOT LOOSEN THESE FITTINGS. HOWEVER, IF IT BECOMES NECESSARY TO RE-TIGHTEN THESE FITTINGS, ENSURE THAT THEY ARE TIGHTENED OVER THE PLASTIC INSERT AND THE O-RING OF THE INNER TUBING. TIGHTEN BY HAND AS MUCH AS POSSIBLE, AND THEN TIGHTEN 1/2 TURN WITH A WRENCH.

P/N 04543A

**Figure 11-2: Particle Filter on O<sub>3</sub> Supply Air Dryer**

5. Hold the main dryer fitting steady with a 5/8" wrench and tighten the nut with your hands.
  - If necessary use a second wrench but do not over-tighten the nut.
6. Replace the cover, plug in the power cord and restart the analyzer.

7. Check the O<sub>3</sub> flow rate; it should be around 80 cm<sup>3</sup>/min ± 15.
8. Check the RCEL pressure.
  - It should be the same value as before.
9. Refer to Section 11.3.12 to leak check after installing the new DFU particle filter.

### 11.3.3. CHANGING THE OZONE CLEANSER CHEMICAL

The ozone (O<sub>3</sub>) cleanser is located next to the O<sub>3</sub> generator (see Figure 3-5) and cleans the O<sub>3</sub> stream from solid and liquid contaminants that are created inside the O<sub>3</sub> generator. The content of the ozone cleanser needs periodical exchange according to Table 11-1. A rebuild kit is available from the factory (see Appendix B of this manual lists the part numbers).

To change the ozone cleanser chemical, follow these steps:

1. Turn off power to the analyzer and pump. Remove the analyzer cover and locate the O<sub>3</sub> filter in the front of the analyzer next to the O<sub>3</sub> generator.
2. Use a 7/16" wrench to remove both pieces of 1/8" male nut with tubing from the NPT fittings.

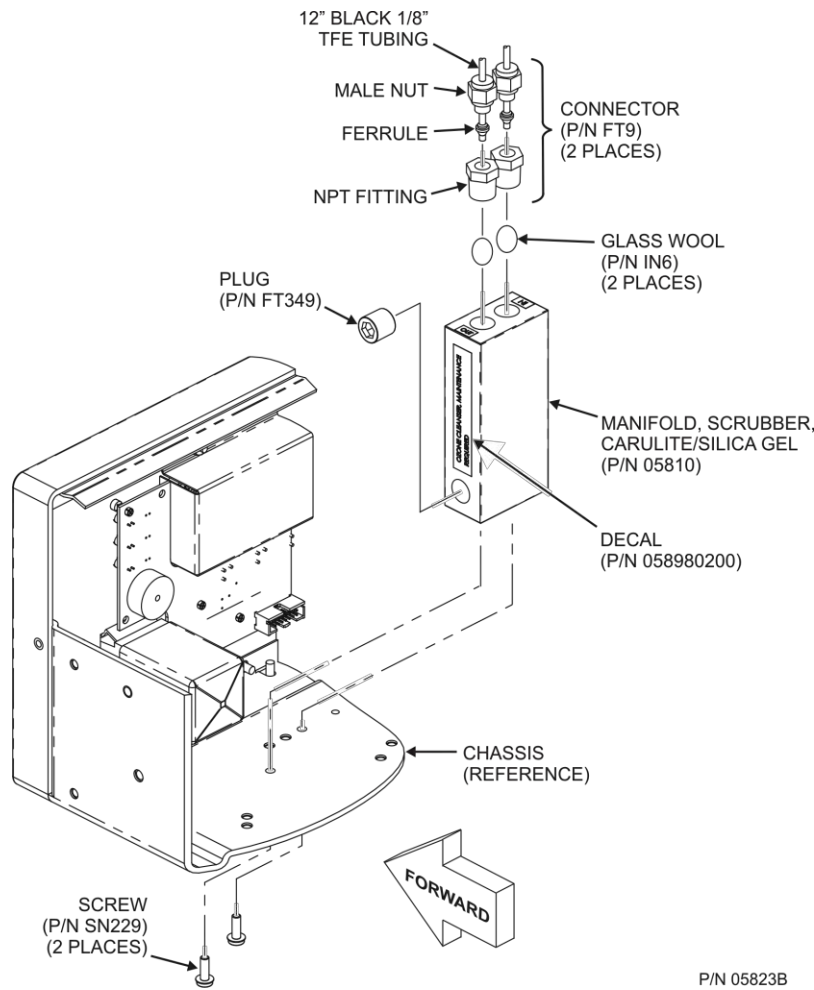


Figure 11-3: Ozone Cleanser Assembly

3. Remove the integrated screws with a Phillips screw driver and remove the scrubber manifold from the chassis.
4. Using a 9/16" wrench, remove both fittings from the cartridge.
5. Discard the glass wool.
6. Pour the contents of the scrubber manifold onto a sheet of white paper. If necessary, remove the plug to ensure that all the contents are poured out.
  - Notice any discoloration of the contents, which is usually white and slightly transparent.
  - The amount of discolored chemical (usually with yellow tint) may give you an indication of the lifetime of the chemical in your application.

The maintenance cycle of this item is dependent on ambient moisture, sub-micron particle load and other factors and may differ from that shown in Table 11-1.

7. Discard the used silica gel desiccant without touching it. It may contain nitric acid, which is a corrosive and highly irritating substance.



### CAUTION – GENERAL SAFETY HAZARD

**Immediately wash your hands after contact with the silica gel desiccant.**

8. Using a small powder funnel, fill the cartridge with about 10 g new silica gel desiccant (Teledyne API P/N CH43) so that it is level on both legs of the cartridge.
  - Slight vibration is required to settle the chemical into the cartridge and achieve tightest packing, which increases performance and lifetime of the filter.
  - Ensure that the level of the chemical does not protrude farther than the first two threads of the NPT fitting.

## IMPORTANT

### IMPACT ON READINGS OR DATA

**Use only genuine, pre-conditioned Teledyne API's refill kits for this procedure. Teledyne API's refill kits have been properly conditioned to prevent a significant increase of the T200's Auto Zero value which can cause large negative offsets, which may take 2-3 weeks to disappear.**

**Do not leave this material uncovered for more than a few seconds, as it will absorb contaminants from ambient air. Always store unused, well-covered refill material in a cool dry place.**

9. Seal the silica gel desiccant with 1 cm<sup>3</sup> of glass wool on each well.
  - Ensure that the plug is large enough and compressed into the cartridge so that the chemical is securely held in place.
10. Add new Teflon tape (P/N HN000036) to the NPT fittings.
11. Screw the NPT fittings back into the scrubber manifold.
12. Screw the cartridge back onto the chassis; orientation is not important.
13. Evaluate the ferrules on the tubing.
  - If the ferrules are too old, we recommend replacing them with new ferrules.
14. Reconnect the tubing using 7/16" and 9/16" wrenches.

- Do not over-tighten the fittings.
15. If the service interval for this item has been exceeded, it may also be necessary to clean the reaction cell as described in Section 11.3.9.
  16. Leak check the system using the pressurized approach described in Section 11.3.12.2.
    - If necessary, tighten the fittings some more but do not over-tighten.
  17. Restart the analyzer and pump and continue operation.
  18. Recalibrate the analyzer after one hour (Section 9).
    - If Auto Zero is high or is changing/not constant, you may have to wait a day until the silica gel is conditioned before recalibrating the instrument.

## 11.3.4. MAINTAINING THE EXTERNAL SAMPLE PUMP (PUMP PACK)

### 11.3.4.1. REBUILDING THE PUMP

The sample pump head periodically wears out and must be replaced when the **RCEL** pressure exceeds 10 in-Hg-A (at sea level, adjust this value accordingly for elevated locations).

- A pump rebuild kit is available from the factory. Refer to the label on the pump for the part number. Instructions and diagrams are included in the kit.
- A flow and leak check after rebuilding the sample pump is recommended.
- A span check and re-calibration after this procedure is necessary as the response of the analyzer changes with the **RCEL** pressure.

### 11.3.4.2. REPLACING THE SCRUBBER



#### CAUTION!

**Do NOT attempt to change the contents of the inline exhaust scrubber cartridge; change the entire cartridge.**

1. Through the SETUP>MORE>DIAG menu turn OFF the OZONE GEN OVERRIDE. Wait 10 minutes to allow pump to pull room air through scrubber before proceeding to step 2.
2. Disconnect exhaust line from analyzer.
3. Turn off (unplug) analyzer sample pump.
4. Disconnect tubing from (NO<sub>x</sub> or charcoal) scrubber cartridge.
5. Remove scrubber from system.
6. Dispose of according to local laws.
7. Install new scrubber into system.
8. Reconnect tubing to scrubber and analyzer.
9. Turn on pump.
10. Through the SETUP menu (per Step 1 above) turn ON the OZONE GEN OVERRIDE.

### 11.3.5. CHANGING THE PUMP DFU FILTER

The exhaust air from the analyzer passes through a small particle filter (Dry Filter Unit (DFU - filter), P/N FL3) before entering the pump. It should be replaced when:

- It becomes visibly dirty or;
- The pressure differential between the test functions **SAMP** and **RCEL** increases significantly.

#### 11.3.5.1. PROCEDURE FOR REPLACING FILTERS ON EXTERNAL PUMPS

1. Power down the analyzer and pump.
2. For internally mounted filters, skip the next two steps.
3. Remove the analyzer exhaust tube from the dust filter.
4. Remove the particle filter from the pump by pushing the white plastic ring into the fitting and pulling the filter out of the fitting.
  - If necessary, use needle-nose pliers to pry the filter out of the fittings.
5. Push a new filter into the pump fitting and ensure that the arrow on the filter points towards the pump.
6. Push the exhaust tubing onto the filter. Skip the next two steps.
7. For internally mounted filters at the inside rear panel, remove the chassis and locate the filter between the vacuum manifold and the exhaust port fitting.
8. Disconnect the clear tubing from the filter body and change the filter with the arrow pointing against the gas flow. To remove the hose clamps, slide the two clamp ends in opposite directions with a needle-nose pliers until the clamp comes apart. Reconnect the tubing by using the same or new clamps and pushing tightening them until a good seal is achieved.
9. Restart the pump and clear any error warnings from the front panel display.
10. After about 5 minutes, check the RCEL pressure reading and ensure that it is similar to its value before changing the filter but less than 10 in-Hg-A.

#### 11.3.5.2. PROCEDURE FOR REPLACING FILTERS ON INTERNAL PUMPS

1. Power down the analyzer and pump.
2. Remove the chassis top and locate the filter between the vacuum manifold and the exhaust port fitting.
3. Disconnect the clear tubing from the filter body and change the filter with the arrow pointing against the gas flow.
4. To remove the hose clamps, slide the two clamp ends in opposite directions with a needle-nose pliers until the clamp comes apart.
5. Reconnect the tubing by using the same or new clamps and pushing tightening them until a good seal is achieved.
6. Restart the pump and clear any error warnings from the front panel display.
7. After about 5 minutes, check the **RCEL** pressure reading and ensure that it is similar to its value before changing the filter (but less than 10 in-Hg-A).



### 11.3.6. CHANGING THE INTERNAL SPAN GAS GENERATOR PERMEATION TUBE

1. Turn off the analyzer, unplug the power cord and remove the cover.
2. Locate the permeation tube (see Figure 3-5) oven in the rear left of the analyzer.
3. Remove the top layer of insulation if necessary.
4. Unscrew the black aluminum cover of the oven (3 screws) using a medium Phillips-head screw driver.
  - Leave the fittings and tubing connected to the cover.
5. Remove the old permeation tube and replace it with the new tube.
  - Ensure that the tube is placed into the larger of two holes and that the open permeation end of the tube (plastic) is facing up.
6. Re-attach the cover with three screws.
  - Ensure that the three screws are tightened evenly.
7. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.
8. Carry out a span check to see if the new permeation device works properly (see Section 9.3.4).
9. The permeation rate may need several days to stabilize.

#### ATTENTION

---

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

**Do not leave instrument turned off for more than 8 hours without removing the permeation tube. Do not ship the instrument without removing the permeation tube. The tube continues to emit NO<sub>2</sub>, even at room temperature and will contaminate the entire instrument.**

---

### 11.3.7. CHANGING THE EXTERNAL ZERO AIR SCRUBBER (OPT 86C)

The external zero air scrubber that is included with several of the T200's optional calibration valve packages contains two chemicals:

- Pink Purafil<sup>®</sup> (P/N CH 9) that converts NO in the ambient air to NO<sub>2</sub>, and;
- Black, charcoal (P/N CH 1) that absorbs the NO<sub>2</sub> thereby creating zero air.

These chemicals need to be replaced periodically (see Table 11-1) or as needed.



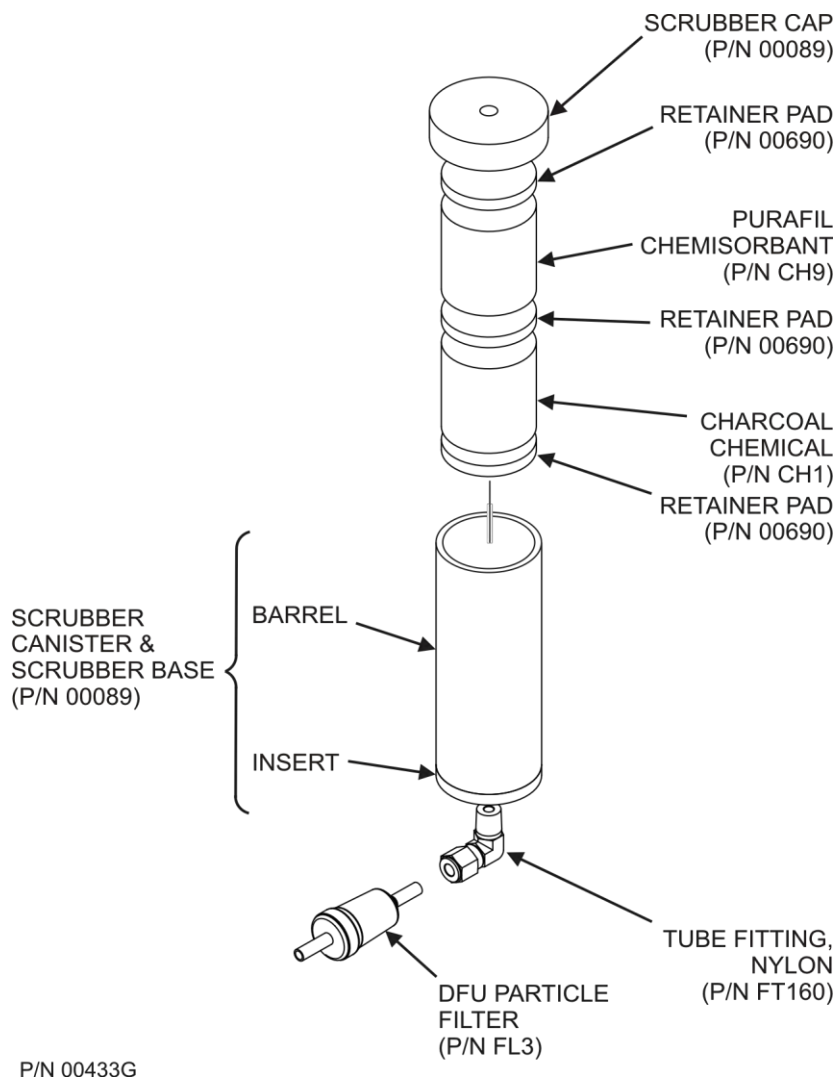
#### CAUTION!

**The following procedures apply only to the External Zero Air Scrubber and NOT to the inline exhaust scrubber cartridge that is part of the pump pack assembly.**

**IMPORTANT****IMPACT ON READINGS OR DATA**

**This procedure can be carried out while the instrument is running, however ensure that the analyzer is not in ZERO calibration mode.**

1. Locate the scrubber on the outside rear panel; Figure 11-4 shows the exploded assembly.
2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the DFU particle filter using 9/16" and 1/2" wrenches.
3. Remove the DFU particle filter from the cartridge using 9/16" wrenches.
4. Unscrew the top of the scrubber canister and discard the Purafil<sup>®</sup> and charcoal contents.
  - Ensure to abide to local laws about discarding these chemicals.
  - The rebuild kit (listed in Appendix B) comes with a Material and Safety Data Sheet, which contains more information on these chemicals.
5. It is not necessary to remove the insert from the barrel, but if removed, perform the following procedure:
  - Coat the threads of the insert with epoxy (Teledyne API P/N CH32).
  - Hand tighten insert to barrel.
6. It is not necessary to remove the nylon tube fitting from the insert, but if removed, apply Teflon tape (Teledyne API P/N HW36) to the threads of the nylon tube fitting before installing on the insert.
7. Refill the scrubber with charcoal at the bottom and the Purafil<sup>®</sup> chemical at the top.
  - Use three, white retainer pads to separate the chemicals as shown Figure 11-4
8. Replace the screw-top cap and tighten the cap; hand-tighten only.
9. If necessary, replace the filter with a new unit and discard the old. See Section 11.3.7.1.
  - The bottom retainer pad should catch most of the dust, the filter should not be visibly dirty (on the inside).
10. Replace the scrubber assembly into its clips on the rear panel.
11. Reconnect the plastic tubing to the fitting of the DFU particle filter.
12. Adjust the scrubber cartridge such that it does not protrude above or below the analyzer in case the instrument is mounted in a rack.
  - If necessary, squeeze the clips for a tighter grip on the cartridge.



**Figure 11-4: Zero Air Scrubber Assembly**

### 11.3.7.1. CHANGING THE EXTERNAL SCRUBBER'S DFU FILTER

There is also a DFU filter on the inlet of the external zero air scrubber that is included in several of the optional calibration valve packages.

To change this filter:

1. Disconnect the tube and fitting from one end and remove the filter from the scrubber canister.
2. Insert a new filter and reattach the tubing.
3. Ensure that the small arrow embedded on the filter points in flow direction, i.e., to analyzer.

### 11.3.8. CHANGING THE NO<sub>2</sub> CONVERTER

The NO<sub>2</sub> converter is located in the center of the instrument, Figure 3-5 for the location, and Figure 11-5 for the assembly.

The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple is to be reused.



#### CAUTION!

**Wear gloves prior to changing the NO<sub>2</sub> Converter to ensure that the fiberglass insulation does not come into contact with your skin.**

1. Turn off the analyzer power.
2. Remove the instrument cover and allow the converter to cool.
3. Remove the converter assembly cover as well as the Moly insulation (top layer and corner cut out layers) until the Moly converter assembly can be seen.

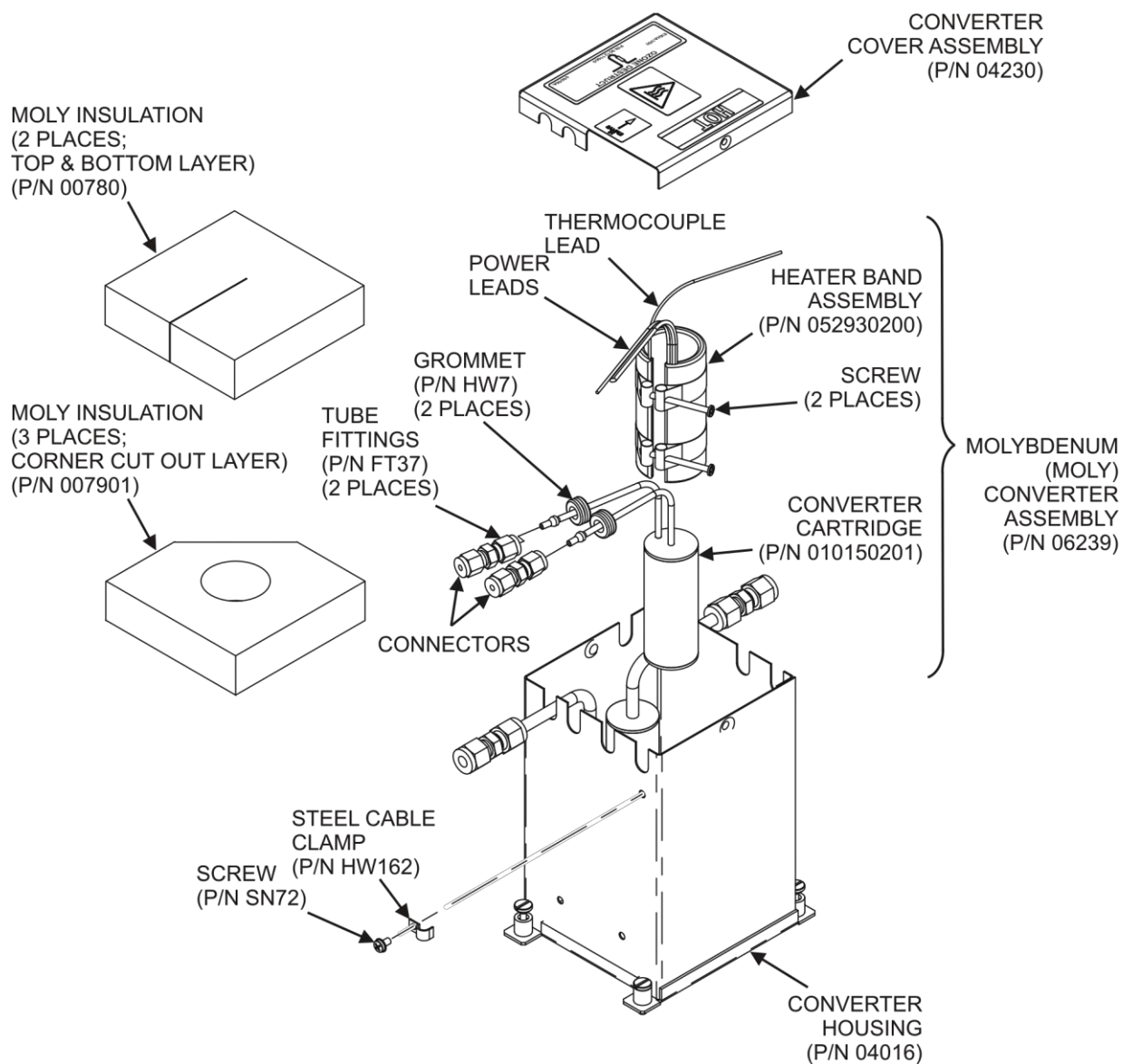


#### CAUTION HOT SURFACE HAZARD

**The converter operates at 315° C. Severe burns can result if the assembly is not allowed to cool.**

**Do not handle the assembly until it is at room temperature. This may take several hours**

4. Remove the tube fittings from the Moly converter assembly.
5. Disconnect the power and the thermocouple from the Moly converter assembly.
6. Unscrew the steel cable clamp (for the power leads) from the converter housing with a Phillips-head screw driver.
7. Remove the Moly converter assembly (converter cartridge and band heater) from the converter housing.
  - Make a note of the orientation of the tubes relative to the heater cartridge.
8. Unscrew the band heater and loosen it.
9. Remove the old converter cartridge.



P/N 0187202G

**Figure 11-5: NO<sub>2</sub> Converter Assembly**

10. Wrap the band heater around the new replacement converter cartridge and tighten the screws using a high-temperature anti-seize agent (Teledyne API P/N CH42) such as copper paste.
  - Ensure to use proper alignment of the heater with respect to the converter tubes.
11. Replace the Moly converter assembly by routing the cables through the holes in the converter housing and reconnecting them properly.
12. Reconnect the steel cable clamp around the power leads for safe operation.
13. Reattach the tube fittings to the converter and replace the Moly insulation (top layer and corner cut out layers).
14. Reinstall the converter assembly cover.
15. Reinstall the instrument cover and power up the analyzer.
16. Allow the converter to burn-in for 24 hours, and then recalibrate the instrument.

### 11.3.9. CLEANING THE REACTION CELL

A dirty reaction cell will cause excessive noise, drifting zero or span values, low response or a combination of all.

To clean the reaction cell, it is necessary to remove it from the sensor housing.

1. Turn off the instrument power and vacuum pump. Refer to Figure 11-6 for the following procedure.
2. Disconnect the black 1/4" exhaust tube and the 1/8" sample and ozone air tubes from the reaction cell. Disconnect the heater/thermistor cable.
3. Remove two screws (Teledyne API P/N SN144) and two washers holding the reaction cell to the PMT housing and lift the cell and manifold out.

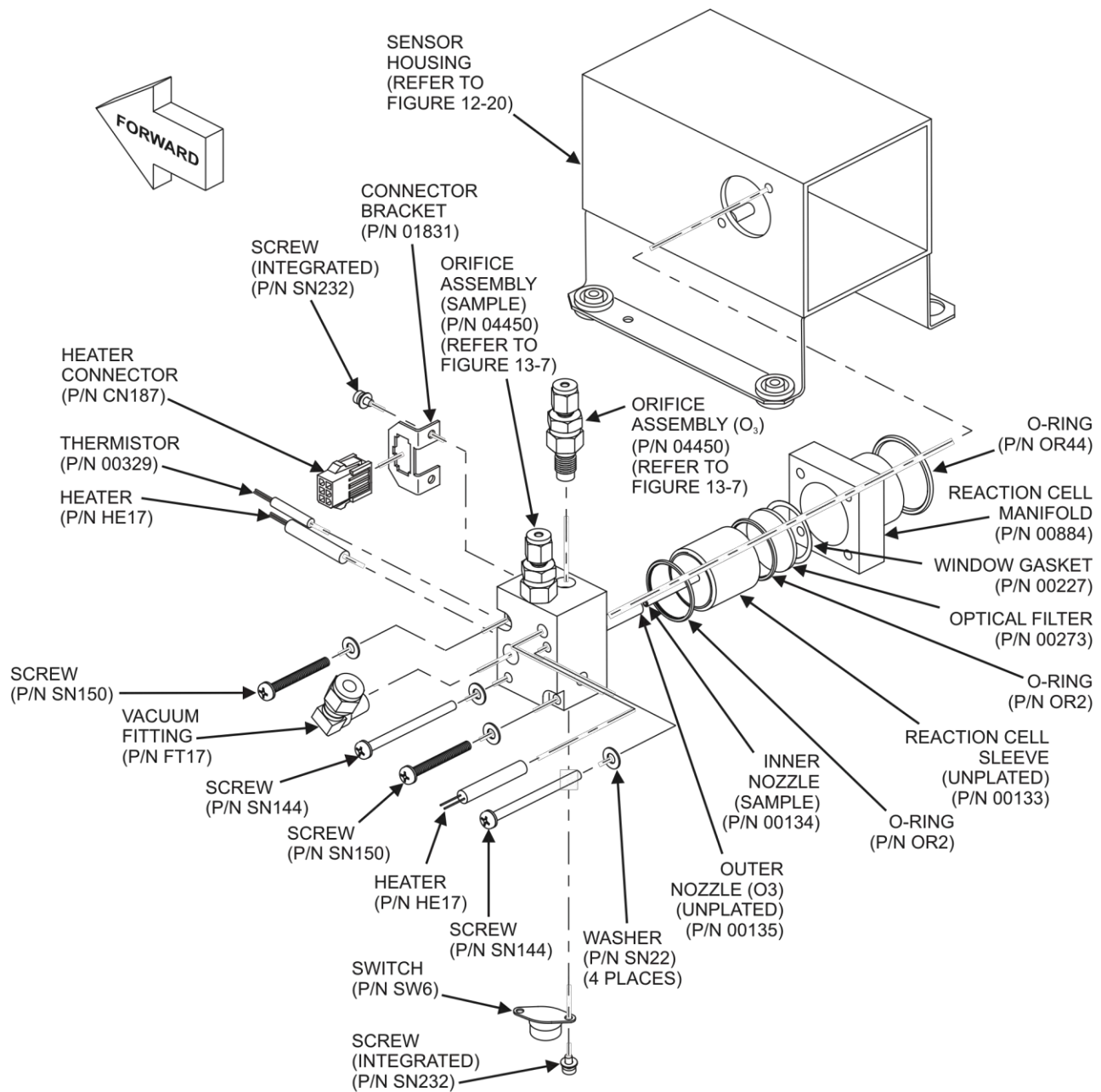
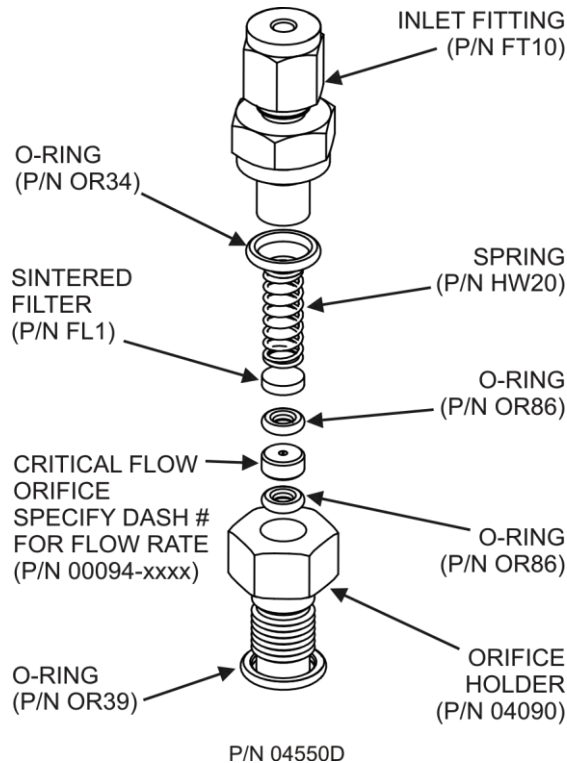


Figure 11-6: Reaction Cell Assembly

4. Remove two screws (Teledyne API P/N SN150) and two washers.
5. The reaction cell will separate into two halves, the stainless steel manifold assembly and the black plastic reaction cell with window gasket, stainless steel reaction cell sleeve, optical filter and O-rings.
6. The reaction cell (both plastic part and stainless steel sleeve) and optical filter should be cleaned with Distilled Water (DI - Water) and a clean tissue, and dried thereafter.
7. Usually it is not necessary to clean the sample and ozone flow orifices since they are protected by sintered filters.
  - If tests show that cleaning is necessary, refer to Section 11.3.10 on how to clean the critical flow orifice.
8. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for reassembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.
9. Reassemble in proper order and re-attach the reaction cell to the sensor housing. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly and the cleaning procedure is complete.
10. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical as described in Section 11.3.3.
11. After cleaning, the analyzer span response may drop 10 - 15% in the first 10 days as the reaction cell window conditions. This is normal and does not require another cleaning.

### 11.3.10. REPLACING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the T200 (see Figure 13-7 for a pneumatic location of each orifice). Despite the fact that these flow restrictors are protected by sintered stainless steel filters, they can, on occasion, clog up, particularly if the instrument is operated without sample filter or in an environment with very fine, sub-micron particle-size dust.



**Figure 11-7: Critical Flow Orifice Assembly**

To clean or replace a critical flow orifice:

1. Turn off power to the instrument and vacuum pump.
2. Remove the analyzer cover and locate the reaction cell (Figure 11-5 and Figure 11-6).
3. Unscrew the 1/8" sample and ozone air tubes from the reaction cell.
4. For orifices on the reaction cell (Figure 11-6): Unscrew the orifice holder with a 9/16" wrench.
  - This part holds all components of the critical flow assembly as shown in Figure 11-7.
  - Appendix B contains a list of spare part numbers.
5. For orifices in the vacuum manifold: the assembly is similar to the one shown in Figure 11-7, except:
  - Without the orifice holder, P/N 04090, and bottom O-ring, P/N OR34 and;
  - With an NPT fitting in place of the FT 10 fitting.
6. After taking off the connecting tube, unscrew the NPT fitting.



7. Take out the components of the assembly:
  - spring
  - sintered filter
  - two O-rings
  - the orifice

**Note**

**For the vacuum manifold only, you may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.**

8. Discard the two O-rings and the sintered filter and install new ones.
9. Reassemble the parts as shown in Figure 11-7.
10. Reinstall the critical flow orifice assembly into the reaction cell manifold or the vacuum manifold.
11. Reconnect all tubing, power up the analyzer and pump. After a warm-up period of 30 minutes, carry out a leak test as described in Section 13.3.12.

### 11.3.11. CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the T200 can develop small gaps around the PMT, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the procedures below.



#### CAUTION – QUALIFIED PERSONNEL ONLY

**This procedure is carried out with the analyzer running and its cover removed.**

1. Scroll the front panel display to show then test function to **PMT**.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover.



#### WARNING – ELECTRICAL SHOCK HAZARD

**Do NOT touch any of the inside wiring with the metal cover or with your body.  
Do NOT drop screws or tools into a running analyzer.**

4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the reaction cell as well as around the PMT housing.
  - The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise floor.
5. If there is a PMT response to the external light, symmetrically tighten the reaction cell mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent).

**Note**

**Often, light leaks are also caused by O-rings being left out of the assembly.**

6. If, during this procedure, the black PMT housing end plate for the Sensor Assembly is removed, ensure to replace the 5 desiccant bags inside the housing.
7. Carefully replace the analyzer cover. If tubing was changed, carry out a pneumatic leak check.

### 11.3.12. CHECKING FOR PNEUMATIC LEAKS



#### CAUTION - TECHNICAL INFORMATION

Do not exceed 15 psi when pressurizing the system during either Simple or Detailed checks.

#### 11.3.12.1. SIMPLE VACUUM LEAK AND PUMP CHECK

Leaks are the most common cause of analyzer malfunction. This section presents a simple leak check, whereas the next section details a more thorough procedure. The method described here is easy, fast and detects, but does not locate, most leaks. It also verifies the sample pump condition.

1. Turn the analyzer ON, and allow at least 30 minutes for flows to stabilize.
2. Cap the sample inlet port (cap must be wrench-tight).
3. After several minutes, when the pressures have stabilized, note the SAMP (sample pressure) and the RCEL (vacuum pressure) readings.
  - If both readings are equal to within 10% and less than 10 in-Hg-A, the instrument is free of large leaks.
  - It is still possible that the instrument has minor leaks.
  - If both readings are < 10 in-Hg-A, the pump is in good condition.
  - A new pump will create a pressure reading of about 4 in-Hg-A (at sea level).

#### 11.3.12.2. DETAILED PRESSURE LEAK CHECK

If a leak cannot be located by the above procedure, obtain a leak checker that contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to  $\leq 15$  psi, a shutoff valve and a pressure gauge may be used.

#### ATTENTION

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or reapply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

1. Turn OFF power to the instrument and remove the instrument cover.
2. Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.
3. Disconnect the pump tubing on the outside rear panel and cap the pump port.
  - If IZS or zero/span valves are installed, disconnect the tubing from the zero and span gas ports and plug them (Figure 3-3).
  - Cap the DFU particle filter on the dryer.
4. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.
  - Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.

- Once the fittings have been wetted with soap solution, do not reapply vacuum as it will draw soap solution into the instrument and contaminate it.
  - Do not exceed 15 psi pressure.
5. If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked.
    - Connect the leak checker to the normally closed ports and check with soap bubble solution.
  6. If the analyzer is equipped with an IZS Option, connect the leak checker to the Dry Air inlet and check with soap bubble solution.
  7. Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.
  8. Clean surfaces from soap solution, reconnect the sample and pump lines and replace the instrument cover.
  9. Restart the analyzer.

### 11.3.12.3. PERFORMING A SAMPLE FLOW CHECK

#### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

**Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm<sup>3</sup>/min to measure the gas flow rate through the analyzer. Do not use the built in flow measurement viewable from the front panel of the instrument.**

**This value is only calculated, not measured.**

---

Sample flow checks are useful for monitoring the actual flow of the instrument, as the front panel display shows only a calculated value. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. To perform a sample flow check:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel.
  - Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 500 cm<sup>3</sup>/min ± 10%.
  - If a combined sample/ozone air dryer is installed (optional equipment), the flow will be 640 cm<sup>3</sup>/min ± 10% (500 cm<sup>3</sup>/min for the sample and 80 cm<sup>3</sup>/min for the ozone generator supply air and 60 cm<sup>3</sup>/min for the purge flow).
  - Low flows indicate blockage somewhere in the pneumatic pathway.

## 12. TROUBLESHOOTING & SERVICE

This section contains a variety of methods for identifying the source of performance problems with the analyzer. Also included in this section are procedures that are used in repairing the instrument.

**Note:**

To support your understanding of the technical details of maintenance, Section 13, *Principles of Operation*, provides information about how the instrument works.



### CAUTION

The operations outlined in this section must be performed by qualified maintenance personnel only.



### WARNING RISK OF ELECTRICAL SHOCK

Some operations need to be carried out with the analyzer open and running.

Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the analyzer.

Do not drop tools into the analyzer or leave those after your procedures.

Do not short or touch electric connections with metallic tools while operating inside the analyzer.

Use common sense when operating inside a running analyzer.

**Note**

The front panel of the analyzer is hinged at the bottom and may be opened to gain access to various components mounted on the panel itself or located near the front of the instrument (such as the particulate filter).

Remove the locking screw located at the right-hand side of the front panel.

## 12.1. GENERAL TROUBLESHOOTING

The T200 has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps:

1. Note any **WARNING MESSAGES** and take corrective action as necessary.
2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.
  - Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.
  - Note that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
4. Suspect a leak first!
  - Customer service data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.
  - Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged / malfunctioning pumps, etc.
5. Follow the procedures defined in Section 3.4.3 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touchscreen, PMT cooler, etc.).
  - See Figure 3-5 or the general layout of components and sub-assemblies in the analyzer.
  - See the wiring interconnect diagram and interconnect list in Appendix D.

### 12.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 12-1 lists warning messages, along with their meaning and recommended corrective action.

It should be noted that if more than two or three warning messages occur at the same time, it is often an indication that some fundamental sub-system (power supply, relay PCA, motherboard) has failed rather than an indication of the specific failures referenced by the warnings.

The analyzer will alert the user that a Warning Message is active by flashing the FAULT LED and displaying the Warning message in the Param field along with the CLR button (press to clear Warning message). The MSG button displays if there is more than one warning in queue or if you are in the TEST menu and have not yet cleared the message.

The following display/touch screen examples provide an illustration of each:



The analyzer will also alert the user via the Serial I/O COM port(s).

To view or clear the various warning messages press:

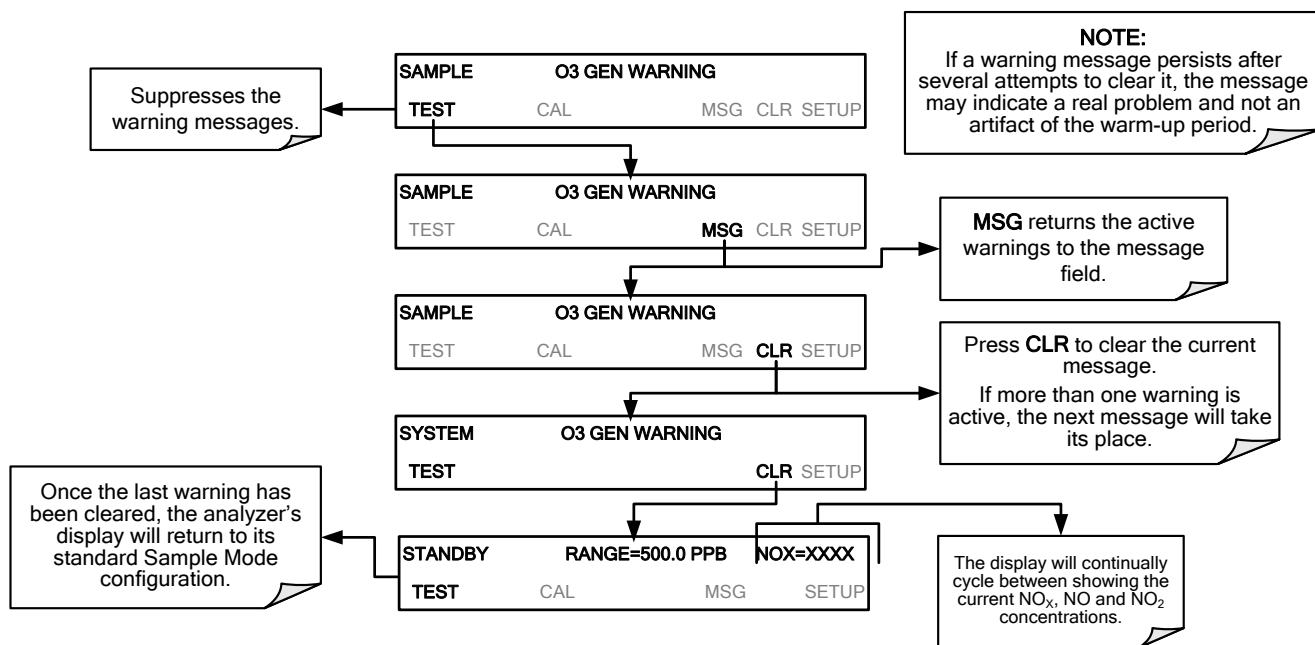


Table 12-1: Front Panel Warning Messages

WARNING	FAULT CONDITION	POSSIBLE CAUSES
<b>AZERO WARN XXX.X MV</b>	Auto-zero reading above 200 mV. Value shown in message indicates auto-zero reading at time warning was displayed.	AZERO valve not working Valve control driver failed Bad Relay PCA Failed +12 VDC power supply Gas leak across AZERO Valve ports Dirty Reaction Cell O <sub>3</sub> flow problem to RCELL
<b>BOX TEMP WARNING</b>	Box Temp is < 7°C or > 48°C.	Box Temperature typically runs ~7°C warmer than ambient temperature Poor/blocked ventilation to the analyzer Stopped Exhaust-Fan Ambient Temperature outside of specified range
<b>CANNOT DYN SPAN</b>	Dynamic Span operation failed.	Measured concentration value is too high or low Concentration Slope value to high or too low
<b>CANNOT DYN ZERO</b>	Dynamic Zero operation failed.	Measured concentration value is too high Concentration Offset value to high
<b>CONFIG INITIALIZED</b>	Configuration and Calibration data reset to original Factory state.	Failed Disk on Module User erased data
<b>CONV TEMP WARNING</b>	NO <sub>2</sub> → NO Converter temperature < 305°C or > 325°C.	Heater configured for wrong voltage type Failed converter Temperature Sensor Relay controlling the Heater is not working Failed Relay Board
<b>DATA INITIALIZED</b>	Data Storage in DAS was erased.	Failed Disk-on-Module User cleared data.
<b>HVPS WARNING</b>	High voltage power supply output outside of warning limits.	No +15 VDC power supply to Preamplifier PCA Drive voltage not adjusted properly Failed PMT Preamplifier PCA Dirty reaction cell Bad pneumatic flow
<b>IZS TEMP WARNING</b>	Permeation tube oven temperature is < 45°C or > 55°C.	Heater configured for wrong voltage type Failed permeation tube Temperature Sensor Relay controlling the Heater is not working Failed Relay Board
<b>OZONE FLOW WARNING</b>	O <sub>3</sub> flow rate is < 50 cc/min or > 150 cc/min.	Failed Sample Pump Blocked O <sub>3</sub> dryer Blocked inlet/outlet to O <sub>3</sub> purifier Dirty O <sub>3</sub> dryer DFU Leak downstream of RCELL Failed O <sub>3</sub> Flow Sensor
<b>OZONE GEN OFF</b>	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on.	O <sub>3</sub> generator override is turned ON. Electrical connection between motherboard and generator is faulty. Bad +15VDC power supply
<b>PMT TEMP WARNING</b>	Sample temperature is < 5°C or > 12°C.	PMT fan not operating Failed PMT Temperature Sensor TEC not functioning Failed PMT Preamp PCA

WARNING	FAULT CONDITION	POSSIBLE CAUSES
<b>RCELL PRESS WARN</b>	Sample Pressure is <15 in-Hg or > 35 in-Hg Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).	If Sample Pressure is < 15 in-HG: <ul style="list-style-type: none"> <li>•Blocked Particulate Filter</li> <li>•Blocked Sample Inlet/Gas Line</li> <li>•Failed Pressure Sensor/circuitry</li> </ul> If Sample Pressure is > 35 in-HG: <ul style="list-style-type: none"> <li>•Bad Pressure Sensor/circuitry</li> <li>•Pressure too high at Sample Inlet.</li> </ul>
<b>RCELL TEMP WARNING</b>	RCELL temperature is < 45°C or > 55°C.	Heater configured for wrong voltage type Failed RCELL Temperature Sensor Relay controlling the heater is not working Failed Relay Board I <sup>2</sup> C Bus
<b>REAR BOARD NOT DET</b>	Motherboard not detected on power up.	This WARNING only appears on Serial I/O COM Port(s) Front Panel Display will be frozen, blank or will not respond. Failure of Motherboard
<b>RELAY BOARD WARN</b>	The CPU cannot communicate with the Relay Board.	I <sup>2</sup> C Bus failure Failed Relay Board Loose connectors/wiring
<b>SAMPLE FLOW WARN</b>	Sample flow rate is < 350 cc/min or > 600 cc/min.	Failed Sample Pump Blocked Sample Inlet/Gas Line Dirty Particulate Filter Leak downstream of RCELL Critical Flow Orifice Failed Sample Pressure Sensor Failed Vacuum Pressure Sensor
<b>SYSTEM RESET</b>	The computer has rebooted.	This message occurs at power on. If it is confirmed that power has not been interrupted: Failed +5 VDC power Fatal Error caused software to restart Loose connector/wiring

**Note**

A failure of the analyzer's CPU, motherboard or power supplies can result in any or ALL of the above messages.



### 12.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

In addition to being useful as predictive diagnostic tools, the test functions viewable from the analyzers front panel can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer’s principles of operation (see Section 13).

The acceptable ranges for these test functions are listed in the “Nominal Range” column of the analyzer *Final Test and Validation Data Sheet* (P/N 04490) shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the analyzer’s subsystems. Functions whose values are still within acceptable ranges but have significantly changed from the measurement recorded on the factory data sheet may also indicate a failure.

A worksheet has been provided in Appendix C to assist in recording the value of these test functions.

**Note** A value of –XXXX” displayed for any of these TEST functions indicates an OUT OF RANGE reading.

**Note** Sample Pressure measurements are represented in terms of ABSOLUTE pressure because this is the least ambiguous method reporting gas pressure.

Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 1000 ft gain in altitude. A variety of factors such as air conditioning systems, passing storms, and air temperature, can also cause changes in the absolute atmospheric pressure.

Table 12-2: Test Functions - Indicated Failures

TEST FUNCTION	INDICATED FAILURE(S)
NOX STB	Unstable concentrations; leaks
SAMP FIW	Leaks; clogged critical flow orifice
OZONE FL	Leaks; clogged critical flow orifice
PMT	Calibration off; HVPS problem; no flow (leaks)
NORM PMT	Auto Zero too high
AZERO	Leaks; malfunctioning NO, NO <sub>x</sub> or Auto Zero valve; O <sub>3</sub> air filter cartridge exhausted
HVPS	Calibration off; preamp board circuit problems
RCELL TEMP	Malfunctioning heater; relay board communication (I <sup>2</sup> C bus); relay burnt out
BOX TEMP	Environment out of temperature operating range; broken thermistor
PMT TEMP	TEC cooling circuit broken; relay board communication (I <sup>2</sup> C bus); 12 V power supply
IZS TEMP (option)	Malfunctioning heater; relay board communication (I <sup>2</sup> C bus); relay burnt out
MOLY TEMP	Malfunctioning heater; disconnected or broken thermocouple; relay board communication (I <sup>2</sup> C bus); relay burnt out; incorrect AC voltage configuration
RCEL (pressure)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices
SAMP (pressure)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet

TEST FUNCTION	INDICATED FAILURE(S)
	overpressure
<b>NOX SLOPE</b>	HVPS out of range; low-level (hardware) calibration needs adjustment; span gas concentration incorrect; leaks
<b>NOX OFFset</b>	Incorrect span gas concentration; low-level calibration off
<b>NO SLOPE</b>	HVPS out of range; low-level calibration off; span gas concentration incorrect; leaks
<b>NO OFFSet</b>	Incorrect span gas concentration; low-level calibration off
<b>TIME</b>	Internal clock drifting; move across time zones; daylight savings time?

### 12.1.3. DIAG → SIGNAL I/O: USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The signal I/O diagnostic mode allows access to the digital and analog I/O in the analyzer. Some of the digital signals can be controlled through the touchscreen. These signals, combined with a thorough understanding of the instrument's principles of operation (Section 13), are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.
- Many of the components and functions that are normally under algorithmic control of the CPU can be manually exercised.
- The technician can directly control the signal level Analog and Digital Output signals.

This allows the technician to observe systematically the effect of directly controlling these signals on the operation of the analyzer. Following is an example of how to use the Signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal.

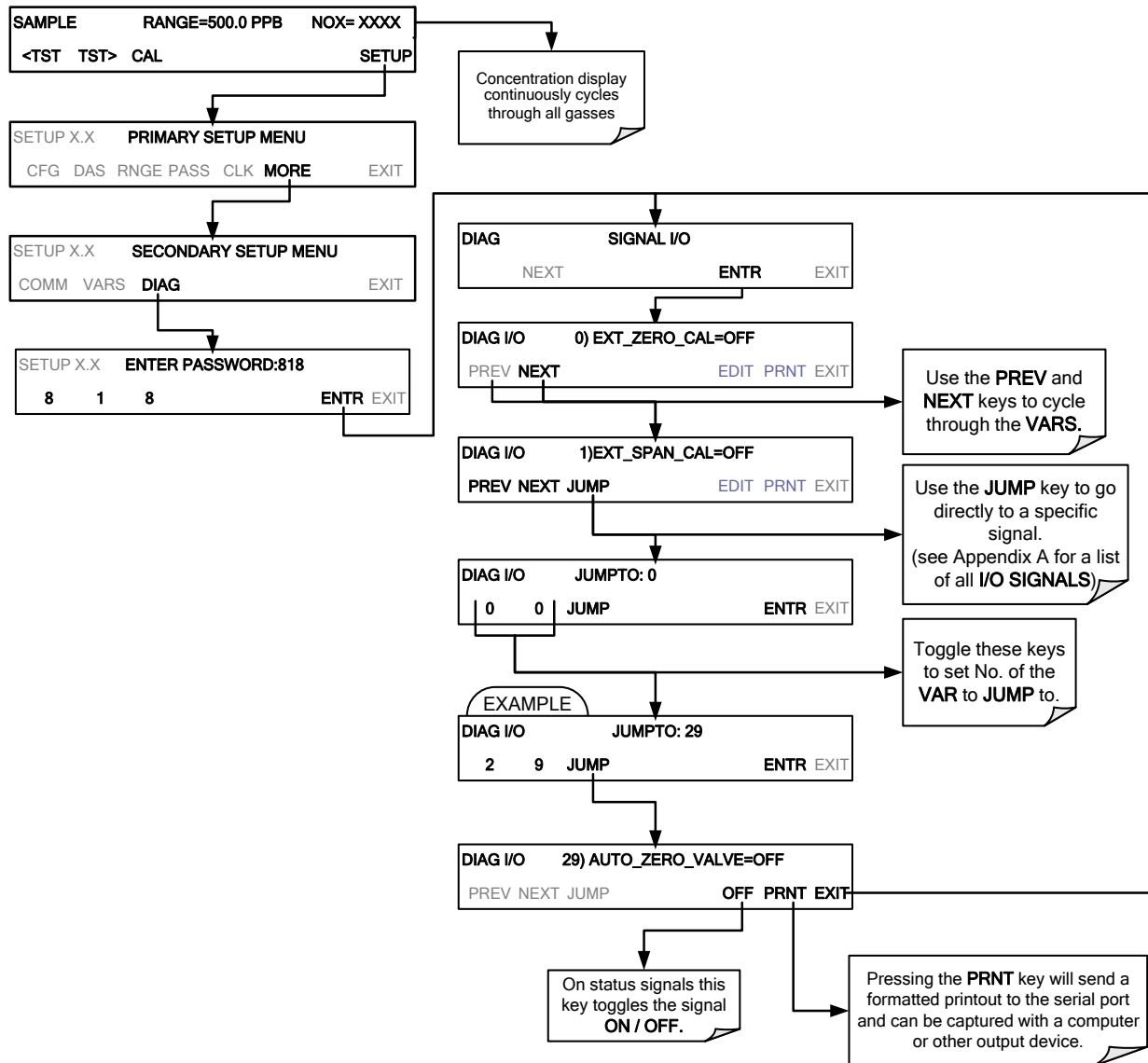


Figure 12-1: Example of Signal I/O Function

**Note**

Any I/O signals changed while in the signal I/O menu will remain in effect **ONLY** until signal I/O menu is exited. The Analyzer regains control of these signals upon exit.

See Appendix A for a complete list of the parameters available for review under this menu.

## 12.2. USING THE ANALOG OUTPUT TEST CHANNEL

The signals available for output over the T200's analog output channel can also be used as diagnostic tools. See Section 5.9.2 for instruction on activating the analog output and selecting a function.

Table 12-3: Test Channel Outputs as Diagnostic Tools

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
<b>PMT DETECTOR</b>	The output of the PMT detector converted to a 0 to 5 VDC scale.	<b>0 mV</b>	<b>5000 mV</b>	Failed PMT PMT Temperature too High/Low Bad PMT Preamp PCA Failed HVPS Misadjusted HVPS drive Voltage Light Leak in reaction cell
<b>OZONE FLOW</b>	The flow rate of O <sub>3</sub> through the analyzer as measured by the O <sub>3</sub> flow sensor	<b>0 cm<sup>3</sup>/min</b>	<b>1000 cm<sup>3</sup>/min</b>	Check for Gas Flow problems in the O <sub>3</sub> gas lines.
<b>SAMPLE FLOW</b>	The calculated flow rate for sample gas through the analyzer.	<b>0 cm<sup>3</sup>/min</b>	<b>1000 cm<sup>3</sup>/min</b>	Check for Gas Flow problems in the sample gas lines.
<b>SAMPLE PRESSURE</b>	The pressure of the sample gas measured upstream of the Auto Zero Valve	<b>0 In-Hg-A</b>	<b>40 In-Hg-A</b>	Check for Gas Flow problems in the sample gas lines.
<b>RCELL PRESSURE</b>	The pressure of gas inside the reaction cell of the sensor module	<b>0 In-Hg-A</b>	<b>40 In-Hg-A</b>	Check for Gas Flow problems in all gas lines.
<b>RCELL TEMP</b>	The temperature of gas inside the reaction cell of the sensor module	<b>0 °C</b>	<b>70 °C</b>	Same as <b>RCELL TEMP WARNING</b> in Table 12-1.
<b>IZS TEMP</b>	The temperature of the permeation tube oven of the optional internal span gas generator.	<b>0 °C</b>	<b>70 °C</b>	Same as <b>IZS TEMP WARNING</b> in Table 12-1.
<b>CONV TEMP</b>	The temperature NO <sub>2</sub> → NO converter	<b>0 mV</b>	<b>5000 mV</b>	Same as <b>CONV TEMP WARNING</b> in Table 12-1.
<b>PMT TEMP</b>	The temperature inside PMT	<b>0 °C</b>	<b>50 °C</b>	Same as <b>PMT TEMP WARNING</b> in Table 12-1.
<b>BOX TEMP</b>	The temperature inside the T200's chassis	<b>0 °C</b>	<b>70 °C</b>	Same as <b>BOX TEMP WARNING</b> in Table 12-1.
<b>HVPS VOLTAGE</b>	Represents the output voltage of the PMT's high voltage power supply	<b>0 mV</b>	<b>5000 mV</b>	Same as <b>HVPSWARNING</b> in Table 12-1.

## 12.3. USING THE INTERNAL ELECTRONIC STATUS LEDES

Several LEDs are located inside the instrument to assist in determining if the analyzer’s CPU, I<sup>2</sup>C bus and Relay PCA are functioning properly.

### 12.3.1. CPU STATUS INDICATOR

DS5, a red LED, that is located on upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program loop. After power-up, approximately 30 – 60 seconds, DS5 should flash on and off. If characters are written to the front panel display but DS5 does not flash then the program files have become corrupted, contact Teledyne API’s Customer Service Department (see Section 12.10) because it may be possible to recover operation of the analyzer. If after 30 – 60 seconds, neither DS5 is flashing nor have any characters been written to the front panel display then the CPU is bad and must be replaced.

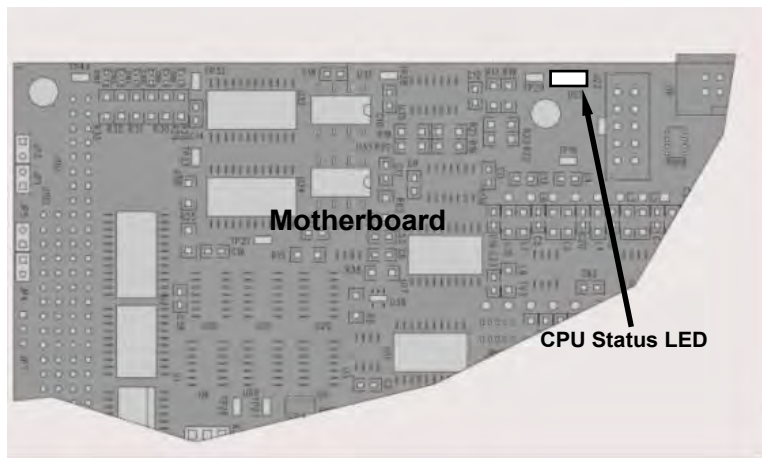


Figure 12-2: CPU Status Indicator

### 12.3.2. RELAY PCA STATUS LEDES

There are sixteen LEDs located on the Relay PCA. Some are not used on this model.

#### 12.3.2.1. I<sup>2</sup>C BUS WATCHDOG STATUS LEDES

The most important is D1 (see Figure 12-3), which indicates the health of the I<sup>2</sup>C bus.

Table 12-4: Relay PCA Watchdog LED Failure Indications

LED	Function	Fault Status	Indicated Failure(s)
D1 (Red)	I <sup>2</sup> C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty Motherboard, Touchscreen or Relay PCA Faulty Connectors/Wiring between Motherboard, Touchscreen or Relay PCA Failed/Faulty +5 VDC Power Supply (PS1)

If D1 is blinking, then the other LEDs can be used in conjunction with **DIAG** Menu Signal I/O to identify hardware failures of the relays and switches on the Relay PCA.

12.3.2.2. RELAY PCA STATUS LEDS

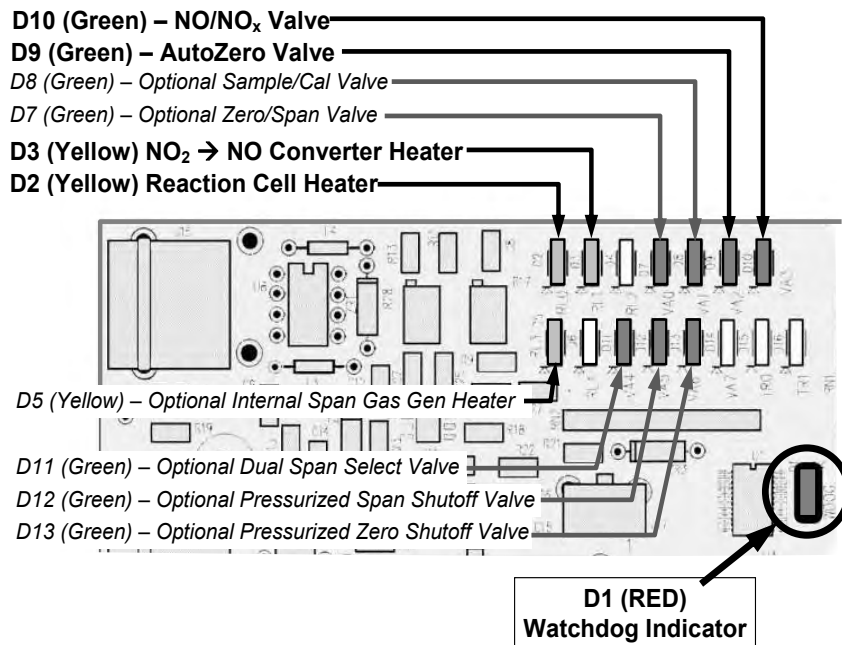


Figure 12-3: Relay PCA Status LEDS Used for Troubleshooting

Table 12-5: Relay PCA Status LED Failure Indications

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
<b>LED ROW 1</b>				
D2	Yellow	Reaction Cell heater	Continuously ON or OFF	Heater broken, thermistor broken
D3	Yellow	NO <sub>2</sub> converter heater	Continuously ON or OFF	Heater broken, thermocouple broken
D7	Green	Zero/Span valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D8	Green	Sample/Cal valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D9	Green	Auto-zero valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D10	Green	NO/NO <sub>x</sub> valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
<b>LED ROW 2</b>				
D5	Yellow	Internal span gas generator perm tube heater	Continuously ON or OFF	Heater broken, thermistor broken
D11	Green	Dual span select valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D12	Green	Pressurized Span shutoff valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D13	Green	Pressurized Zero shutoff valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
Note: D4, D6, and D14-16 are not indicated as they are not used.				

## 12.4. GAS FLOW PROBLEMS

The T200 has two main flow paths, the sample flow and the flow of the ozone supply air. With IZS or zero/span valve option installed, there is a third (zero air) and a fourth (span gas) flow path, but either one of those is only controlled by critical flow orifices and not displayed on the front panel or stored to the DAS.

- Flow is too high
- Flow is greater than zero, but is too low, and/or unstable
- Flow is zero (no flow)

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer's flow display. The use of an independent, external flow meter to perform a flow check as described in Section 11.3.12.3 is essential. Refer to the pneumatic flow diagrams as needed for reference.

### 12.4.1. ZERO OR LOW FLOW PROBLEMS

#### 12.4.1.1. SAMPLE FLOW IS ZERO OR LOW

The T200 does not actually measure the sample flow but rather calculates it from a differential pressure between sample and vacuum manifold. On flow failure, the unit will display a **SAMPLE FLOW WARNING** on the front panel display and the respective test function reports **XXXX** instead of a value "0". This message applies to both a flow rate of zero as well as a flow that is outside the standard range (350-600 cm<sup>3</sup>/min).

If the analyzer displays **XXXX** for the sample flow, confirm that the external sample pump is operating and configured for the proper AC voltage.

- Whereas the T200 can be internally configured for two different power regimes (100-120 V and 220-240 V, either 50 or 60 Hz), the external pump is physically different for each of three power regimes (100 V / 50 Hz, 115 V / 60 Hz and 230 V / 50 Hz).
- If the pump is not running, use an AC Voltmeter to ensure that the pump is supplied with the proper AC power. If AC power is supplied properly, but the pump is not running, replace the pump.

#### Note

**Sample and vacuum pressures mentioned in this chapter refer to operation of the analyzer at sea level. Pressure values need to be adjusted for elevated locations, as the ambient pressure decreases by about 1 in-Hg per 300 m / 1000 ft.**

If the pump is operating but the unit reports a **XXXX** gas flow, take the following three steps:

1. Check for actual sample flow.
  - To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument.
  - Ensure that the unit is in basic **SAMPLE** mode.
  - Place a finger over the inlet and see if it gets sucked in by the vacuum or, more properly, use a flow meter to measure the actual flow.
  - If there is proper flow of around 450-550 cm<sup>3</sup>/min, contact customer service.

- If there is no flow or low flow, continue with the next step.
2. Check pressures.
    - Check that the sample pressure is at or around 28 in-Hg-A at sea level (adjust as necessary when in elevated location, the pressure should be about 1" below ambient atmospheric pressure) and that the **RCEL** pressure is below 10 in-Hg-A.
    - The T200 will calculate a sample flow up to about 14 in-Hg-A **RCEL** pressure but a good pump should always provide less than 10 in.
    - If both pressures are the same and around atmospheric pressure, the pump does not operate properly or is not connected properly. The instrument does not get any vacuum.
    - If both pressures are about the same and low (probably under 10 in-Hg-A, or ~20" on sample and 15" on vacuum), there is a cross-leak between sample flow path and vacuum, most likely through the dryer flow paths. See troubleshooting the dryer later in this chapter.
    - If the sample and vacuum pressures are around their nominal values (28 and <10 in-Hg-A, respectively) and the flow still displays **XXXX**, carry out a leak check as described in Section 13.3.12.
    - If gas flows through the instrument during the above tests but goes to zero or is low when it is connected to zero air or span gas, the flow problem is not internal to the analyzer but likely caused by the gas source such as calibrators/generators, empty gas tanks, clogged valves, regulators and gas lines.
    - If an IZS or Zero/Span valve option is installed in the instrument, press **CALZ** and **CALS**. If the sample flow increases, suspect a bad Sample/Cal valve.
  3. If none of these suggestions help, carry out a detailed leak check of the analyzer as described in Section 11.3.12.2.

#### 12.4.1.2. OZONE FLOW IS ZERO OR LOW

If there is zero or a low (<50 cm<sup>3</sup>/min) ozone flow, the unit displays an **OZONE FLOW WARNING** message on the front panel and a value between 0.0 and 50 cm<sup>3</sup>/min for the actual ozone flow as measured by the internal mass flow meter. In this case, carry out the following steps:

1. Check the actual flow rate through the ozone dryer by using an external flow meter to the inlet port of the dryer.
  - This inlet port is inside the analyzer at the end of the plastic particle filter (Section 11.3.2 for illustration).
  - If there is nominal flow (about 160 cm<sup>3</sup>/min from 80 cm<sup>3</sup>/min O<sub>3</sub> flow and 80 cm<sup>3</sup>/min purge flow), consult customer service as there is a problem with the firmware or electronics.
2. If the actual flow is low or zero, check if the pump operates properly. The RCEL pressure should be below 10 in-Hg-A at sea level.
  - If it is above 10", rebuild the pump (Section 11.3.4.1). Check the spare parts list in Appendix B on how to order pump rebuild kits.
3. Check if the particle filter is clogged.
  - Briefly remove the particle filter to see if this improves the flow.



- Be very cautious when handling the dryer fittings (see Section 11.3.2 on proper handling instructions).
  - If the filter is clogged, replace it with a new unit.
  - If taking off this filter does not solve the problem, continue to the next step.
  - Do not leave the dryer without filter for more than a few seconds, as you may draw in dust, which will reduce the performance of the dryer.
4. A leak between the flow meter and the reaction cell (where the flow-determining critical orifice is located) may cause a low flow (the system draws in ambient air through a leak after the flow meter).
- Check for leaks as described in Section 11.3.12.
  - Repair the leaking fitting, line or valve and re-check.
5. The most likely cause for zero or low ozone flow is a clogged critical flow orifice or sintered filter within the orifice assembly.
- The orifice that sets the ozone flow is located on the reaction cell.
  - Check the actual ozone flow by disconnecting the tube from the reaction cell and measuring the flow going into the cell.
    - If this flow is correct (~80 cm<sup>3</sup>/min), the orifice works properly.
    - If this flow is low, replace the sintered filter.
  - The orifice holder assembly allows a quick and easy replacement of the filter (see Section 11.3.5 and on for replacement procedures).
  - Appendix B lists a spare part kit with a complete orifice assembly that allows a quick replacement with minimum instrument down-time.

### 12.4.1.3. HIGH FLOW

Flows that are significantly higher than the allowed operating range (typically  $\pm 10$ -11% of the nominal flow) should not occur in the T200 unless a pressurized sample, zero or span gas is supplied to the inlet ports.

- Ensure to vent excess pressure and flow just before the analyzer inlet ports.

When supplying sample, zero or span gas at ambient pressure, a high flow would indicate that one or more of the critical flow orifices are physically broken (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications.

- If the flows are within 15% higher than normal, we recommend measuring and recalibrating the flow electronically using the procedure in Section 10, followed by a regular review of these flows over time to see if the new setting is retained properly.
- Also, check the flow assembly o-rings and replace as needed.

### 12.4.1.4. SAMPLE FLOW IS ZERO OR LOW BUT ANALYZER REPORTS CORRECT FLOW

Note that the T200 analyzer can report a correct flow rate even if there is no or a low actual sample flow through the reaction cell.

- The sample flow on the T200 is only calculated from the sample pressure and critical flow condition is verified from the difference between sample pressure and vacuum pressure.

- If the critical flow orifice assembly is partially or completely clogged, both the sample and vacuum pressures are still within their nominal ranges (the pump keeps pumping, the sample port is open to the atmosphere), but there is no flow possible through the reaction cell.

Although measuring the actual flow is the best method, in most cases, this fault can also be diagnosed by evaluating the two pressure values.

- Since there is no longer any flow, the sample pressure should be equal to ambient pressure, which is about 1 in-Hg-A higher than the sample pressure under normal operation.
- The reaction cell pressure, on the other hand, is significantly lower than under normal operation, because the pump no longer has to remove 500 cm<sup>3</sup>/min of sample gas and evacuates the reaction cell much better.
- Those two indicators, taken together with a zero or low actual flow, indicate a clogged sample orifice.

The T200 features a new orifice holder, which makes switching sample and ozone flow orifices very easy; refer to Section 11.3.10 on how to change the sample orifices and to Appendix B for part numbers of these assemblies.

Again, monitoring the pressures and flows regularly will reveal such problems, because the pressures would slowly or suddenly change from their nominal, mean values. Teledyne API recommends to review all test data once per week and to do an exhaustive data analysis for test and concentration values once per month, paying particular attention to sudden or gradual changes in all parameters that are supposed to remain constant, such as the flow rates.

## 12.5. CALIBRATION PROBLEMS

This section describes possible causes of calibration problems.

### 12.5.1. NEGATIVE CONCENTRATIONS

Negative concentration values can be caused for several reasons:

- A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero calibration point.
  - This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -20 ppb, but should randomly alternate with similarly high, positive values.
  - The T200 has a built-in Auto Zero function, which should take care of most of these deviations from zero, but may yield a small, residual, negative value.
  - If larger, negative values persist continuously, check if the Auto Zero function was accidentally turned off using the remote variables in Appendix A-2.
  - In this case, the sensitivity of the analyzer may be drifting negative.
- A corruption of the Auto Zero filter may also cause negative concentrations.
  - If a short, high noise value was detected during the Auto Zero cycle, that higher reading will alter the Auto Zero filter value.
  - As the value of the Auto Zero filter is subtracted from the current PMT response, it will produce a negative concentration reading.
  - High Auto Zero readings can be caused by
    - a leaking or stuck Auto Zero valve (replace the valve),
    - by an electronic fault in the preamplifier causing it to have a voltage on the PMT output pin during the Auto Zero cycle (replace the preamplifier),
    - by a reaction cell contamination causing high background (>40 mV) PMT readings (clean the reaction cell),
    - by a broken PMT temperature control circuit, allowing high zero offset (repair the faulty PMT cooler). After fixing the cause of a high Auto Zero filter reading, the T200 will take 15 minutes for the filter to clear itself, or
    - by an exhausted chemical in the ozone cleanser (see Section 11.3.3).
- Calibration error is the most likely explanation for negative concentration values.
  - If the zero air contained some NO or NO<sub>2</sub> gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as "zero", the analyzer may report negative values when measuring air that contains little or no NO<sub>x</sub>.
  - The same problem occurs, if the analyzer was zero-calibrated using zero gas that is contaminated with ambient air or span gas (cross-port leaks or leaks in supply tubing or user not waiting long enough to flush pneumatic systems).
- If the response offset test functions for NO (**NO OFFS**) or NO<sub>x</sub> (**NOX OFFS**) are greater than 150 mV, a reaction cell contamination is indicated.
- Clean the reaction cell as described in Section 11.3.9.

## 12.5.2. NO RESPONSE

If the instrument shows no response (display value is near zero) even though sample gas is supplied properly and the instrument seems to perform correctly.

1. Carry out an electrical test with the ELECTRICAL TEST procedure in the diagnostics menu, see Section 12.7.12.2.
  - If this test produces a concentration reading, the analyzer's electronic signal path is correct.
2. Carry out an optical test using the OPTIC TEST procedure in the diagnostics menu, see Section 12.7.12.1.
  - If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly.
  - If the T200 passes both ETEST and OTEST, the instrument is capable of detecting light and processing the signal to produce a reading.
  - Therefore, the problem must be in the pneumatics or the ozone generator.
3. Check if the ozone generator is turned on.
  - Usually, the analyzer issues a warning whenever the ozone generator is turned off.
  - Go to **SETUP-MORE-DIAG-ENTR**, then scroll to the **OZONE GEN OVERRIDE** and see if it shows ON.
    - If it shows OFF, turn it ON and **EXIT** the **DIAG** menu.
    - If this is done and the ozone flow is correct, the analyzer should be properly supplied with ozone unless the generator itself is broken.
4. Confirm the lack of response by supplying NO or NO<sub>2</sub> span gas of about 80% of the range value to the analyzer.
5. Check the sample flow and ozone flow rates for proper values.
6. Check for disconnected cables to the sensor module.
7. If NO<sub>2</sub> signal is zero while NO signal is correct, check the NO/NO<sub>x</sub> valve and the NO<sub>2</sub> converter for proper operation.

## 12.5.3. UNSTABLE ZERO AND SPAN

Leaks in the T200 or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

1. Check for leaks in the pneumatic systems as described in Section 11.3.12.
2. Consider pneumatic components in the gas delivery system outside the T200 such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.
3. Once the instrument passes a leak check, do a flow check (this chapter) to ensure that the instrument is supplied with adequate sample and ozone air.
4. Confirm the sample pressure, sample temperature, and sample flow readings are correct and steady.
5. Verify that the sample filter element is clean and does not need to be replaced.

### 12.5.4. INABILITY TO SPAN - NO SPAN BUTTON (CAL5)

In general, the T200 will not display certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a **SPAN** button when carrying out a span calibration, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

1. Verify that the expected concentration is set properly to the actual span gas concentration in the CONC sub-menu.
2. Confirm that the NO<sub>x</sub> span gas source is accurate.
  - This can be done by comparing the source with another calibrated analyzer, or by having the NO<sub>x</sub> source verified by an independent traceable photometer.
3. Check for leaks in the pneumatic systems as described in Section 11.3.12.
  - Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the CONC sub-menu.
4. If the low-level, hardware calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values.
  - One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 to 150 for offsets). See Section 12.8.4 on how to carry out a low-level hardware calibration.

### 12.5.5. INABILITY TO ZERO - NO ZERO BUTTON (CALZ)

In general, the T200 will not display certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a **ZERO** button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which may be for any of several reasons.

1. Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to a zero air source using NOX-free air. Check any zero air scrubber for performance. It may need to be replaced (Section 11.3.4.2).
2. Check to ensure that there is no ambient air leaking into zero air line. Check for leaks in the pneumatic systems as described in Section 11.3.12.

### 12.5.6. NON-LINEAR RESPONSE

The T200 was factory calibrated to a high level of NO and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system:
  - Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed.
  - Check for leaks as described in Section 11.3.12.
- The calibration device is in error:

- Check flow rates and concentrations, particularly when using low concentrations.
- If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.
- The standard gases may be mislabeled as to type or concentration.
  - Labeled concentrations may be outside the certified tolerance.
- The sample delivery system may be contaminated.
  - Check for dirt in the sample lines or reaction cell.
- Calibration gas source may be contaminated (NO<sub>2</sub> in NO gas is common).
- Dilution air contains sample or span gas.
- Ozone concentration too low because of wet air in the generator.
  - Generator system needs to be cleaned and dried with dry supply air.
  - Check the dryer for leaks.
  - This mostly affects linearity at the low end.
- Ozone stream may be contaminated with impurities.
  - An exhausted ozone cleanser chemical will let compounds such as HNO<sub>3</sub> and ammonia derivatives break through to the reaction cell.
  - Check the contents of the ozone cleanser and replace as necessary (Section 11.3.3).
  - This also will affect linearity mostly at the low level.
- Sample inlet may be contaminated with NO<sub>x</sub> exhaust from this or other analyzers.
  - Verify proper venting of the pump exhaust.
- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port.
  - Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line.
  - Ensure to create and properly vent excess span gas.
- Diffusion of oxygen into Teflon-type tubing over long distances.
  - PTFE or related materials can act as permeation devices. In fact, the permeable membrane of NO<sub>2</sub> permeation tubes is made of PTFE.
  - When using very long supply lines (> 1 m) between high concentrations span gases and the dilution system, oxygen from ambient air can diffuse into the line and react with NO to form NO<sub>2</sub>.
- This reaction is dependent on NO concentration and accelerates with increasing NO concentration, hence, affects linearity only at high NO levels.
- Using stainless steel for long span gas supply lines avoids this problem.

### 12.5.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree with the value reported on the front panel, you may need to recalibrate the analog outputs.

- This becomes more likely when using a low concentration or low analog output range.
- Analog outputs running at 0.1 V full scale should always be calibrated manually.
- See Section 5.9.3.2 for a detailed description of this procedure.

## 12.5.8. DISCREPANCY BETWEEN NO AND NO<sub>x</sub> SLOPES

If the slopes for NO and NO<sub>x</sub> are significantly different after software calibration (more than 1%), consider the following three problems:

- NO<sub>2</sub> impurities in the NO calibration gas. NO gases often exhibit NO<sub>2</sub> on the order of 1-2% of the NO value.
  - This will cause differences in the calibration slopes. If the NO<sub>2</sub> impurity in NO is known, it can easily be accounted for by setting the expected values for NO and NO<sub>2</sub> accordingly to different values, e.g., 448 ppb NO and 450 ppb NO<sub>x</sub>.
  - This problem is worse if NO gas is stored in a cylinder with balance air instead of balance gas nitrogen or large amounts of nitrous oxide (N<sub>2</sub>O).
  - The oxygen in the air slowly reacts with NO to yield NO<sub>2</sub>, increasing over time.
- The expected concentrations for NO and NO<sub>x</sub> in the calibration menu are set to different values.
  - If a gas with 100% pure NO is used, this would cause a bias.
  - See Section 9.2.3.1 on how to set expected concentration values.
- The converter efficiency parameter has been set to a value not equal to 1.000 even though the conversion efficiency is 1.0.
  - The actual conversion efficiency needs to match the parameter set in the CAL menu.
  - See Section 9.1.4 for more information on this feature.

An instrument calibration with the IZS option (and expected concentrations set to the same amount) will always yield identical slopes for NO and NO<sub>x</sub>, as the instrument measures only NO<sub>x</sub> and assumes NO to be the same (with NO<sub>2</sub> being zero).

## 12.6. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems that only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. The following section provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

### 12.6.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself. Ensure that the sample or span gas supply is leak-free and carry out a detailed leak check as described earlier in this chapter.

Another possibility of excessive signal noise may be the preamplifier board, the high voltage power supply and/or the PMT detector itself.

- Contact the factory on troubleshooting these components.

### 12.6.2. SLOW RESPONSE

If the analyzer starts responding too slow to any changes in sample, zero or span gas, check for the following:

- Dirty or plugged sample filter or sample lines.
- Sample inlet line is too long.

- Leaking NO/NO<sub>x</sub> valve. Carry out a leak check.
- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (Section 11.3.10).
- Wrong materials in contact with sample - use glass, stainless steel or Teflon materials only. Porous materials, in particular, will cause memory effects and slow changes in response.
- Dirty reaction cell. Clean the reaction cell.
- Insufficient time allowed for purging of lines upstream of the analyzer. Wait until stability is low.
- Insufficient time allowed for NO or NO<sub>2</sub> calibration gas source to become stable. Wait until stability is low.
- NO<sub>2</sub> converter temperature is too low. Check for proper temperature.

### 12.6.3. AUTO ZERO WARNINGS

Auto Zero warnings occur if the signal measured during an Auto Zero cycle is higher than 200 mV.

#### Note

**The Auto-Zero warning displays the value of the Auto Zero reading when the warning occurs.**

- If this value is higher than 150 mV, check that the Auto Zero valve is operating properly.
  - To do so, use the **SIGNAL I/O** functions in the **DIAG** menu to toggle the valve on and off.
  - Listen if the valve is switching, see if the respective LED on the relay board is indicating functionality.
- Scroll the **TST** functions until **PMT** is displayed and observe the PMT value change between the two valve states.
  - If the valve is operating properly, you should be able to hear it switch (once a minute under normal operation or when manually activated from the **SIGNAL I/O** menu):
    - the PMT value should drop from span gas reading (e.g., 800-900 mV at 400 ppb NO) to less than 150 mV and;
    - the LED on the relay board should light up when the valve is activated.
  - If the PMT value drops significantly but not to less than 150 mV, the valve is probably leaking across its ports.
    - In this case, replace the valve.
  - If the PMT value does not change at all, the valve is probably not switching at all.
    - Check the power supply to the valve (12 V to the valve should turn on and off when measured with a voltmeter).

#### Note

**It takes only a small leak across the ports of the valve to show excessive Auto Zero values when supplying high concentrations of span gas.**



Another reason for high (although not necessarily out-of-range) values for Auto Zero could be the ozone air filter cartridge, if its contents have been exhausted and needs to be replaced.

- This filter cartridge chemicals that can cause chemiluminescence and, if saturated, these chemicals can break through to the reaction cell, causing an erroneously high Auto Zero value (background noise).

A dirty reaction cell can cause high Auto Zero values.

- Clean the reaction cell according to Section 11.3.9.

Finally, a high **HVPS** voltage value may cause excess background noise and a high **AZERO** value.

- The HVPS value changes from analyzer to analyzer and could show nominal values between 450 and 800 V.
- Check the low-level hardware calibration of the preamplifier board and, if necessary, recalibrate exactly as described in Section 12.8.4 in order to minimize the **HVPS**.

## 12.7. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the analyzer. In most cases this included a list of possible causes and, in some cases, quick solutions or at least a pointer to the appropriate sections describing them. This section describes how to determine if a certain component or subsystem is actually the cause of the problem being investigated.

### 12.7.1. AC MAIN POWER

The T200 analyzer's electronic systems will operate with any of the specified power regimes. As long as system is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display.

- Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.
- If they do not, check the circuit breaker built into the ON/OFF switch on the instruments front panel.
- If the instrument is equipped with an internal pump, it will begin to run. If it does not:
  - Verify that the pump power configuration plug is properly wired (see Section 13.7.1.1 and Figure 13-24)
  - If the configuration plug is set for 230 VAC and the instrument is plugged into 115 VAC or 100 VAC the sample pump will not start.
- If the configuration plug is set for 115 or 100 VAC and the unit is plugged into a 230 VAC circuit, the circuit breaker built into the ON/OFF Switch on the front panel will trip to the OFF position immediately after power is switched on.
- T200's without internal pumps that are configured for 230 V will still turn on at 115 V, but the heaters may burn out or not heat up fast enough.

**WARNING – ELECTRICAL SHOCK HAZARD**

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.

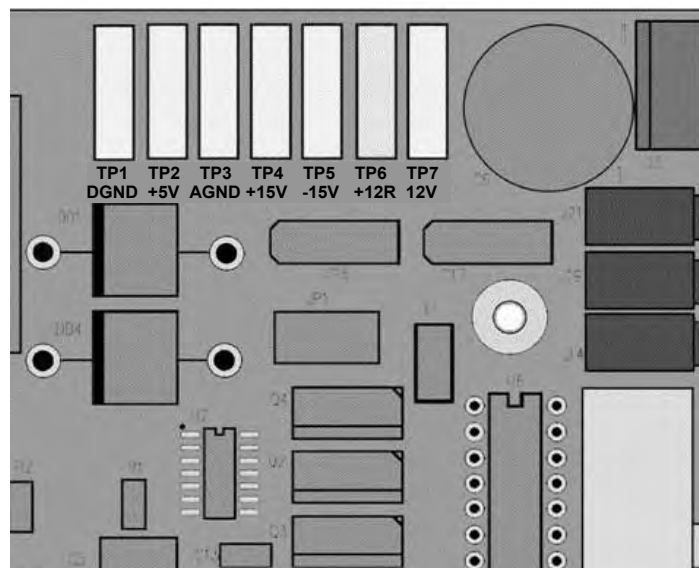
**12.7.2. DC POWER SUPPLY**

If you have determined that the analyzer's AC mains power is working, but the unit is still not operating properly, there may be a problem with one of the instrument's switching power supplies. The supplies can have two faults, namely no DC output, and noisy output.

To assist tracing DC Power Supply problems, the wiring used to connect the various printed circuit assemblies and DC Powered components and the associated test points on the relay PCA follow a standard color-coding scheme as defined in the following table.

**Table 12-6: DC Power Test Point and Wiring Color Codes**

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12R	6	Purple	12 V return (ground) line
+12V	7	Orange	

**Figure 12-4: Location of DC Power Test Points on Relay PCA**

A voltmeter should be used to verify that the DC voltages are correct per the values in the table below, and an oscilloscope, in AC mode, with band limiting turned on, can be used to evaluate if the supplies are producing excessive noise (> 100 mV p-p).

**Table 12-7: DC Power Supply Acceptable Levels**

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM Test Point		TO Test Point			
	NAME	#	NAME	#			
PS1	+5	DGND	1	+5	2	+4.85	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0
PS1	-15	AGND	3	-15V	5	-13.5	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.8	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.05	+0.05

### 12.7.3. I<sup>2</sup>C BUS

Operation of the I<sup>2</sup>C bus can be verified by observing the behavior of D1 on the relay PCA & D2 on the Valve Driver PCA. Assuming that the DC power supplies are operating properly, the I<sup>2</sup>C bus is operating properly if D1 on the relay PCA and D2 of the Valve Driver PCA are flashing

There is a problem with the I<sup>2</sup>C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

### 12.7.4. LCD/DISPLAY MODULE

#### TOUCHSCREEN INTERFACE

Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

### 12.7.5. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 12.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 12.1.3) to toggle each LED **ON** or **OFF**.

If D1 on the Relay PCA is flashing and the status indicator for the output in question (Heater power, Valve Drive, etc.) toggles properly using the Signal I/O function, then the associated control device on the Relay PCA is bad.

Several of the control devices are in sockets and can be easily replaced. The following table lists the control device associated with a particular function:

**Table 12-8: Relay PCA Control Devices**

FUNCTION	CONTROL DEVICE	SOCKETED
All valves	U5	Yes
Reaction Cell Heater	K1	Yes
NO <sub>2</sub> → NO Converter heater	K2	Yes
Permeation Tube Heater for Optional Internal Span Gas Generator	K4	Yes

## 12.7.6. MOTHERBOARD

### 12.7.6.1. TEST CHANNEL / ANALOG OUTPUTS VOLTAGE

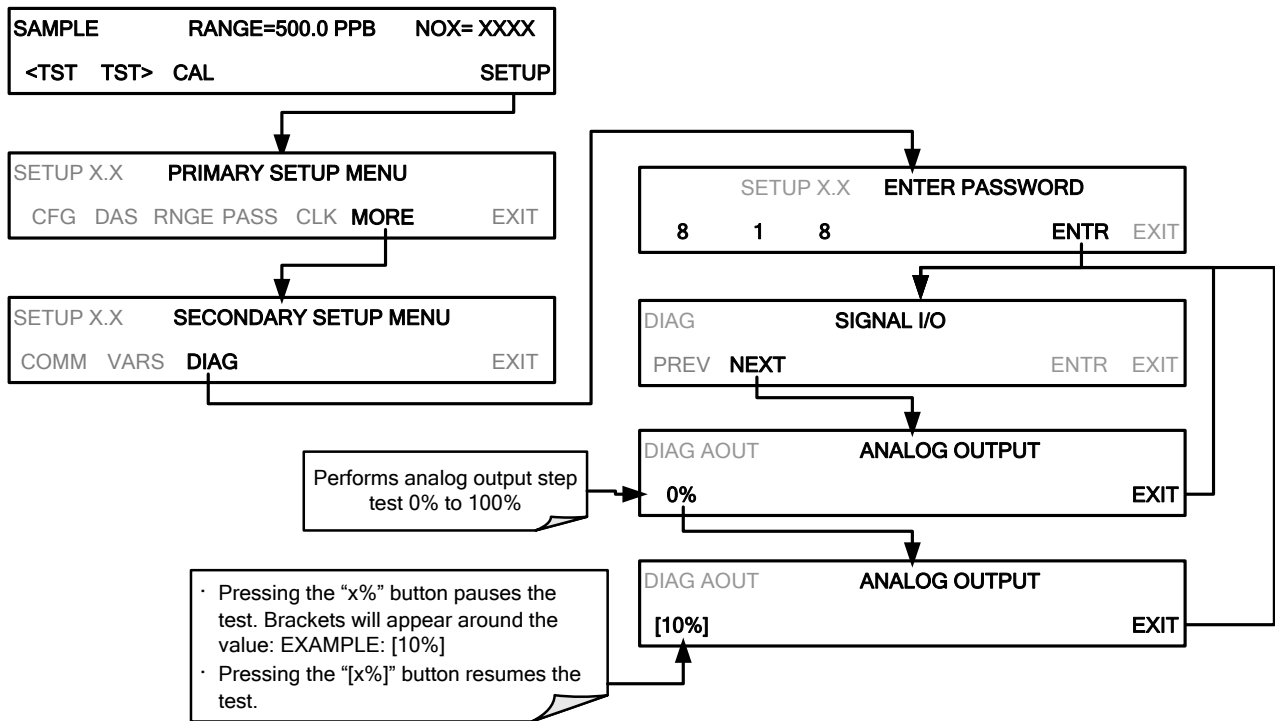
The **ANALOG OUTPUT** submenu, located under the **SETUP → MORE → DIAG** menu is used to verify that the T200 analyzer's three analog outputs are working properly. The test generates a signal on all three outputs simultaneously as shown in the following table:

**Table 12-9: Analog Output Test Function - Nominal Values Voltage Outputs**

		FULL SCALE OUTPUT OF VOLTAGE RANGE (see Section 5.9.3.1)			
		100MV	1V	5V	10V*
STEP	%	NOMINAL OUTPUT VOLTAGE			
1	0	0	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10
* For 10V output, increase the Analog Output Calibration Limits (AOUT CAL LIM in the DIAG>Analog I/O Config menu) to 4% (offset limit) and 20% (slope limit).					

For each of the steps the output should be within 1% of the nominal value listed except for the 0% step, which should be within 0mV ±2 to 3 mV. Ensure you take into account any offset that may have been programmed into channel (See Section 5.9.3.9).

If one or more of the steps fails to be within these ranges, it is likely that there has been a failure of the either or both of the Digital-to-Analog Converters (DACs) and their associated circuitry on the motherboard. To perform the test connect a voltmeter to the output in question and perform an analog output step test as follows:



### 12.7.6.2. A/D FUNCTIONS

The simplest method to check the operation of the A-to-D converter on the motherboard is to use the Signal I/O function under the **DIAG** menu to check the two A/D reference voltages and input signals that can be easily measured with a voltmeter.

1. Use the Signal I/O function (see Section 12.1.3 and Appendix A) to view the value of **REF\_4096\_MV** and **REF\_GND**.
  - If both are within 3 mV of nominal (4096 and 0), and are stable,  $\pm 0.2$  mV then the basic A/D is functioning properly. If not then the motherboard is bad.
2. Choose a parameter in the Signal I/O function list (see Section 12.1.3) such as **OZONE\_FLOW**.
  - Compare this voltages at its origin (see the interconnect drawing and interconnect list in Appendix D) with the voltage displayed through the signal I/O function.
  - If the wiring is intact but there is a large difference between the measured and displayed voltage ( $\pm 10$  mV) then the motherboard is bad.

## 12.7.6.3. STATUS OUTPUTS

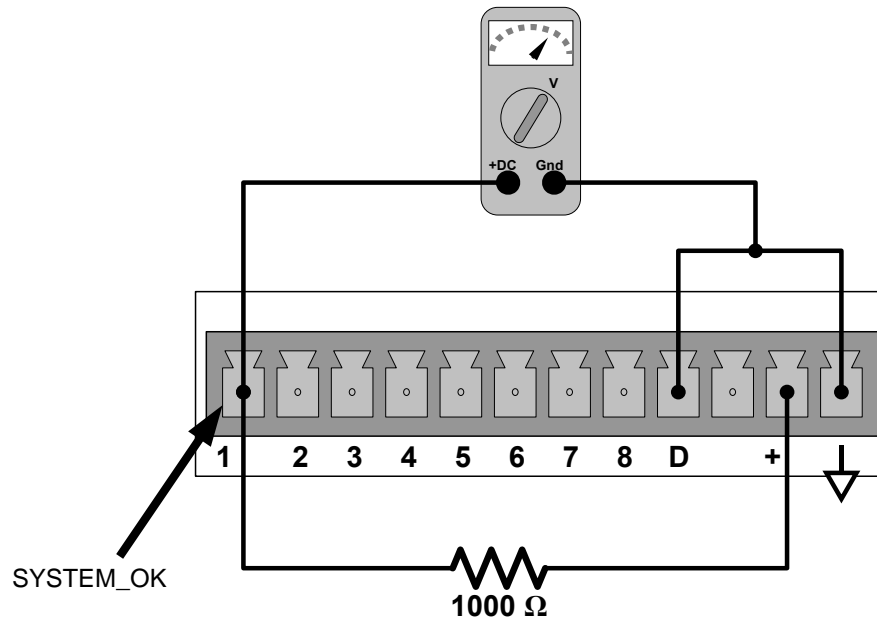


Figure 12-5: Typical Set Up of Status Output Test

To test the status output electronics:

1. Connect a jumper between the “D” pin and the “∇” pin on the status output connector.
2. Connect a 1000 ohm resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “∇” pin and the pin of the output being tested.
4. Under the DIAG → Signal I/O menu (see Section 12.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternately, turn on and off the output noting the voltage on the voltmeter.
  - It should vary between 0 volts for ON and 5 volts for OFF.

Table 12-10: Status Outputs Check

PIN (LEFT TO RIGHT)	STATUS
1	ST_SYSTEM_OK
2	ST_CONC_VALID
3	ST_HIGH_RANGE
4	ST_ZERO_CAL
5	ST_SPAN_CAL
6	ST_DIAG_MODE
7	<i>Not Used on T200</i>
8	ST_O2_CAL

**12.7.6.4. CONTROL INPUTS**

The control input bits can be tested by applying a trigger voltage to an input and watching changes in the status of the associated function under the **SIGNAL I/O** submenu:

EXAMPLE: to test the “A” control input:

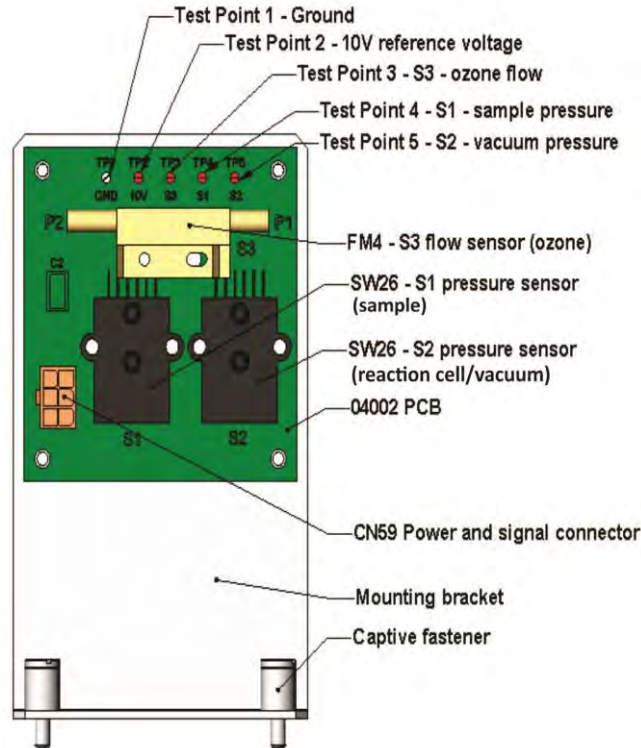
1. Under the **DIAG**→ Signal I/O menu (see Section 12.1.3), scroll through the inputs and outputs until you get to the output named **EXT\_ZERO\_CAL**.
2. Connect a jumper from the “+” pin on the appropriate connector to the “U” on the same connector.
3. Connect a second jumper from the “▽” pin on the connector to the “A” pin.
4. The status of EXT\_ZERO\_CAL should change to read “ON”.
5. Connect a second jumper from the “▽” pin on the connector to the “B” pin.
6. The status of EXT\_ZERO\_CAL should change to read “ON”.

**Table 12-11: T200 Control Input Pin Assignments and Corresponding Signal I/O Functions**

INPUT	CORRESPONDING I/O SIGNAL
A	EXT_ZERO_CAL
B	EXT_SPAN_CAL1
C, D, E & F	NOT USED

## 12.7.7. PRESSURE / FLOW SENSOR ASSEMBLY

The flow and pressure sensors of the T200 are located on a PCA just behind the PMT sensor (see Figure 3-5) can be checked with a voltmeter.



**Figure 12-6: Pressure / Flow Sensor Assembly**

The following procedure assumes that the wiring is intact and that the motherboard and power supplies are operating properly:

### 12.7.7.1. BASIC PCA OPERATION CHECK:

- Measure the voltage between TP2 and TP1. It should be 10 VDC  $\pm$  0.25 VDC. If not then the board is bad. Replace the PCA.

### 12.7.7.2. SAMPLE PRESSURE SENSOR CHECK:

1. Measure the pressure on the inlet side of S1 with an external pressure meter.
2. Measure the voltage across TP4 and TP1.
  - The expected value for this signal should be:

$$\text{Expected mVDC} = \left( \frac{\text{Pressure}}{30.0_{\text{Hg-In-A}}} \times 4660_{\text{mVDC}} \right) + 250_{\text{mVDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE: If the measured pressure is 20 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 2870 mVDC and 3510 mVDC.

EXAMPLE: If the measured pressure is 25 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 3533 mVDC and 4318 mVDC.



- If this voltage is out of range, then either pressure transducer S1 is bad, the board is bad or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly. Replace the PCA.

### 12.7.7.3. VACUUM PRESSURE SENSOR CHECK

- Measure the pressure on the inlet side of S2 with an external pressure meter.
- Measure the voltage across TP5 and TP1.
  - Evaluate the reading in the same manner as for the sample pressure sensor.

### 12.7.7.4. O<sub>3</sub> FLOW SENSOR CHECK

- Measure the voltage across TP3 and TP1.
  - With proper flow (80 cc<sup>3</sup>/min through the O<sub>3</sub> generator), this should be approximately 2V ± 0.25 (this voltage will vary with altitude).
  - With flow stopped (photometer inlet disconnected or pump turned OFF) the voltage should be approximately 1V.
  - If the voltage is incorrect, the flow sensor S3 is bad, the board is bad (replace the PCA) or there is a leak upstream of the sensor.

## 12.7.8. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk On Module (DOM). If either of these failures occurs, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on, the watchdog LED on the motherboard is not flashing.

- In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be invalid.
- If the analyzer stops during initialization (the front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

## 12.7.9. RS-232 COMMUNICATIONS

### 12.7.9.1. GENERAL RS-232 TROUBLESHOOTING

Teledyne API's analyzers use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer-based equipment. RS-232 has been used for many years and as equipment has become more advanced, connections between various types of hardware have become increasingly difficult. Generally, every manufacturer observes the signal and timing requirements of the protocol very carefully.

Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. See Section 3.3.1.8, Figure 3-13 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 6.2.2.

- If a modem is being used, additional configuration and wiring rules must be observed. See Section 8.3
- Incorrect setting of the DTE – DCE Switch. See Section 6.1 to set correctly.
- Verify that cable (P/N 03596) that connects the serial COM ports of the CPU to J12 of the motherboard is properly seated.

### 12.7.9.2. TROUBLESHOOTING ANALYZER/MODEM OR TERMINAL OPERATION

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API's analyzer.

1. Check cables for proper connection to the modem, terminal or computer.
2. Check to ensure that the DTE-DCE is in the correct position as described in Section 6.1.
3. Check to ensure that the set up command is correct (see Section 8.3).
4. Verify that the Ready to Send (RTS) signal is at logic high. The T200 sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
5. Ensure that the BAUD rate, word length, and stop bit settings between modem and analyzer match. See Section 6.2.2.
6. Use the RS-232 test function to send "w" characters to the modem, terminal or computer. See Section 6.2.3.
7. Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way); the green LED should flicker as the instrument is receiving data.
8. Ensure that the communications software or terminal emulation software is functioning properly.

#### Note

Further help with serial communications is available in a separate manual –RS-232 Programming Notes” Teledyne API's P/N 01350.

### 12.7.10. NO<sub>2</sub> → NO CONVERTER

Provided that oxygen was present in the Sample stream during operation for the NO<sub>2</sub> converter to function properly, the NO<sub>2</sub> converter assembly can fail in two ways:

- An electrical failure of the band heater and/or the thermocouple control circuit and;
- A performance failure of the converter itself.

#### 12.7.10.1. NO<sub>2</sub> → NO CONVERTER ELECTRICAL SYSTEM

NO<sub>2</sub> converter heater failures can be divided into two possible problems:

- Temperature is reported properly but heater does not heat to full temperature.
  - In this case, the heater is either disconnected or broken or the power relay is broken.
    - Disconnect the heater cable coming from the relay board and measure the resistance between any two of the three heater leads with a multi-meter.
    - The resistance between A and B should be about 1000 Ω.

- That between A and C should be the same as between B and C, about 500 Ω each.
- If any of these resistances is near zero or without continuity, the heater is broken.
- Temperature reports zero or overload (near 500° C).
  - This indicates a disconnected or failing thermocouple or a failure of the thermocouple circuit.
    - Check that the thermocouple is connected properly and the wire does not show signs of a broken or kinked pathway.
    - If it appears to be properly connected, disconnect the yellow thermocouple plug (marked K) from the relay board and measure the voltage (not resistance) between the two leads with a multi-meter capable of measuring in the low mV range.
    - The voltage should be about 12 mV (ignore the sign) at 315° C and about 0 mV at room temperature.
- Measure the continuity with an Ohm-meter.
  - It should read close to zero Ω. If the thermo-couple does not have continuity, it is broken.
  - If it reads zero voltage at elevated temperatures, it is broken.
- To test the thermocouple at room temperature, heat up the converter can (e.g., with a heat gun) and see if the voltage across the thermocouple leads changes.
  - If the thermocouple is working properly, the electronic circuit is broken.

**ATTENTION**

**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

**If the thermocouple is broken, do NOT replace the thermocouple without first consulting the factory; using the wrong Type could cause permanent damage to the instrument. The Type K thermocouple has a red and a yellow wire. If in doubt, consult the factory.**

**12.7.10.2. NO<sub>2</sub> CONVERSION EFFICIENCY**

The efficiency at which the NO<sub>2</sub> → NO converter changes NO<sub>2</sub> into NO directly effects the accuracy of the T200's NO<sub>x</sub>, NO and NO<sub>2</sub> measurements. The T200 firmware includes a Converter Efficiency (CE) gain factor that is multiplied by the NO<sub>2</sub> and NO<sub>x</sub> measurements to calculate the final concentrations for each. This gain factor is stored in the analyzer's memory.

The default setting for the NO<sub>2</sub> converter efficiency is 1.0000. Over time, the molybdenum in the NO<sub>2</sub> → NO converter oxidizes and it becomes less efficient at converting NO<sub>2</sub> into NO.

To ensure accurate operation of the T200, it is important to check the NO<sub>2</sub> conversion efficiency periodically and to update this value as necessary.

- For the analyzer to function correctly, the converter efficiency must be greater than 0.9600 (96% conversion efficiency) as per US-EPA requirements.
- If the converter's efficiency is below this limit, the NO<sub>2</sub> converter should be replaced.
- The current converter efficiency level is also recorded along with the calibration data in the DAS for documentation and performance analysis (Section 7).

### 12.7.10.3. CALCULATING / CHECKING CONVERTER EFFICIENCY

The T200 automatically calculates the current NO<sub>2</sub> conversion efficiency by comparing a known starting concentration of NO<sub>2</sub> gas to the measured NO output of the converter. This can be accomplished through Gas Phase Titration (GPT), which is the recommended method (see Section 12.7.11), or by using bottled NO<sub>2</sub>.

There are three steps to performing the bottled NO<sub>2</sub> method:

#### Step 1:

Supply the analyzer with a known concentration of NO<sub>2</sub> gas, to the analyzer.

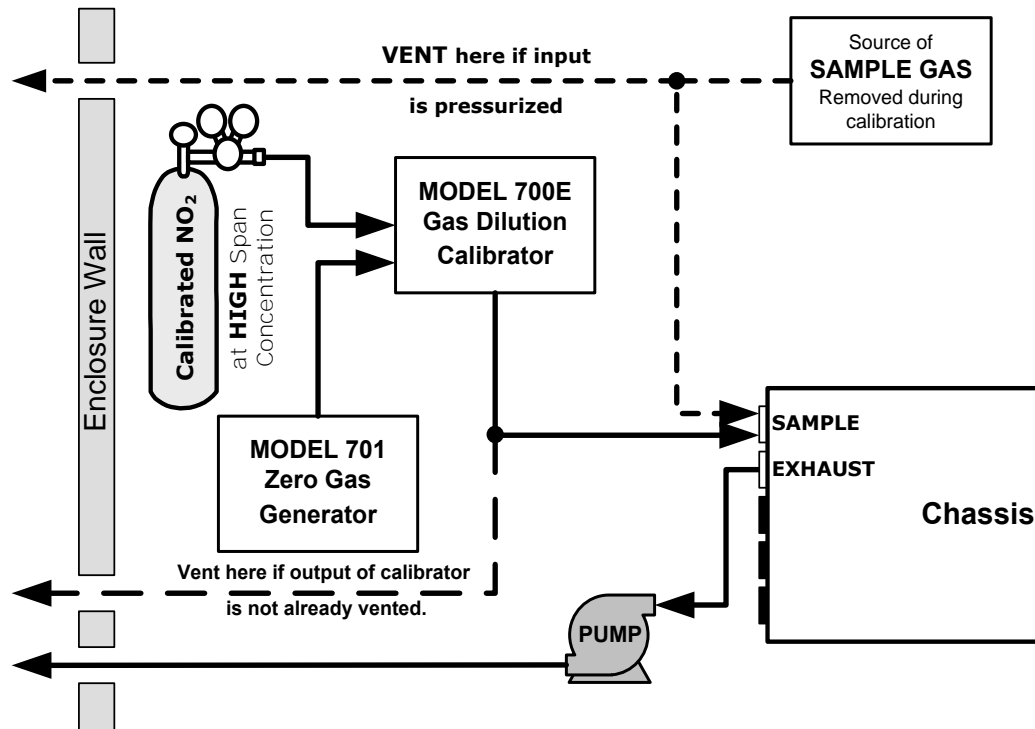
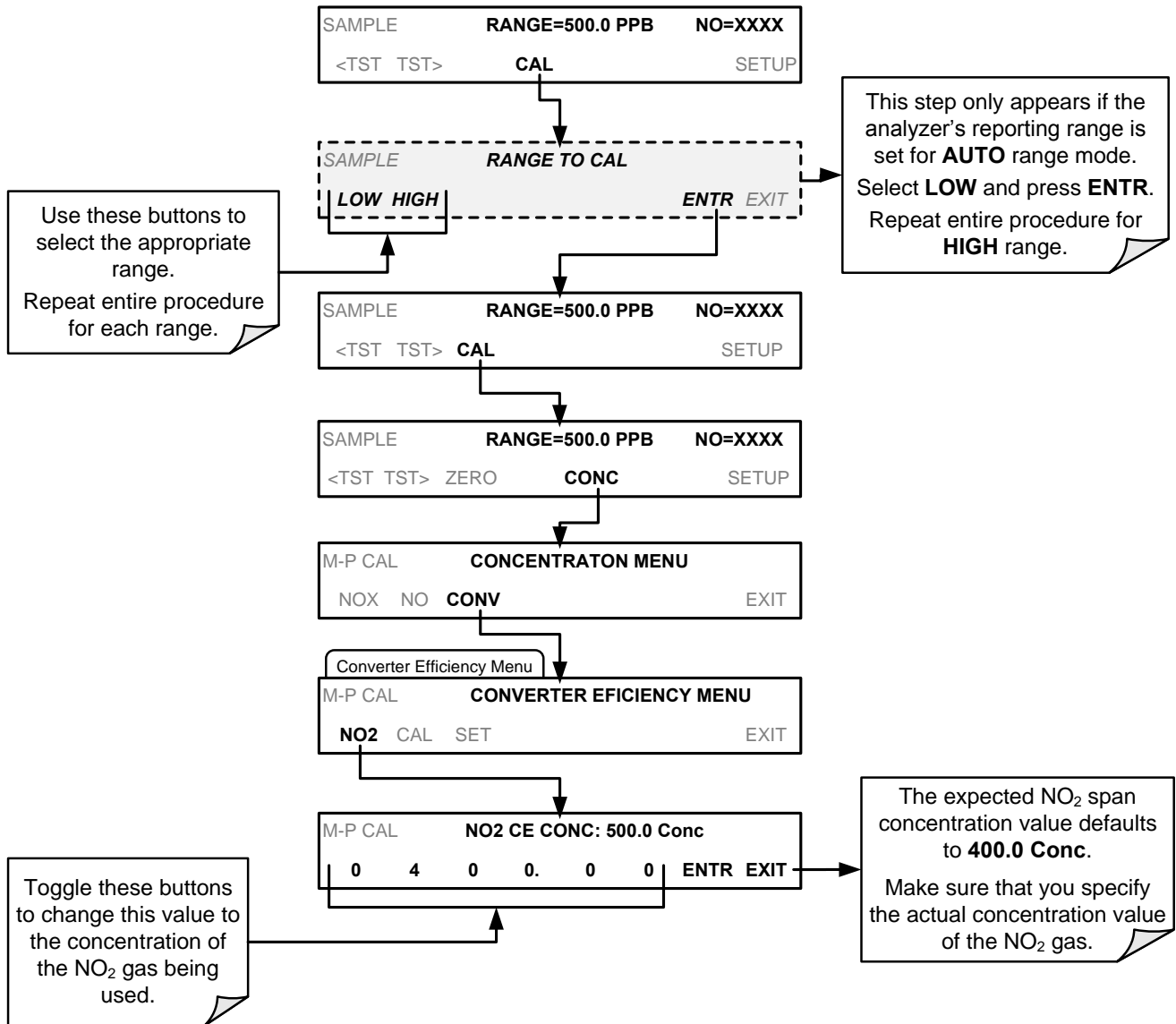


Figure 12-7: Setup for determining NO<sub>2</sub> → NO Efficiency – T200 Base Configuration

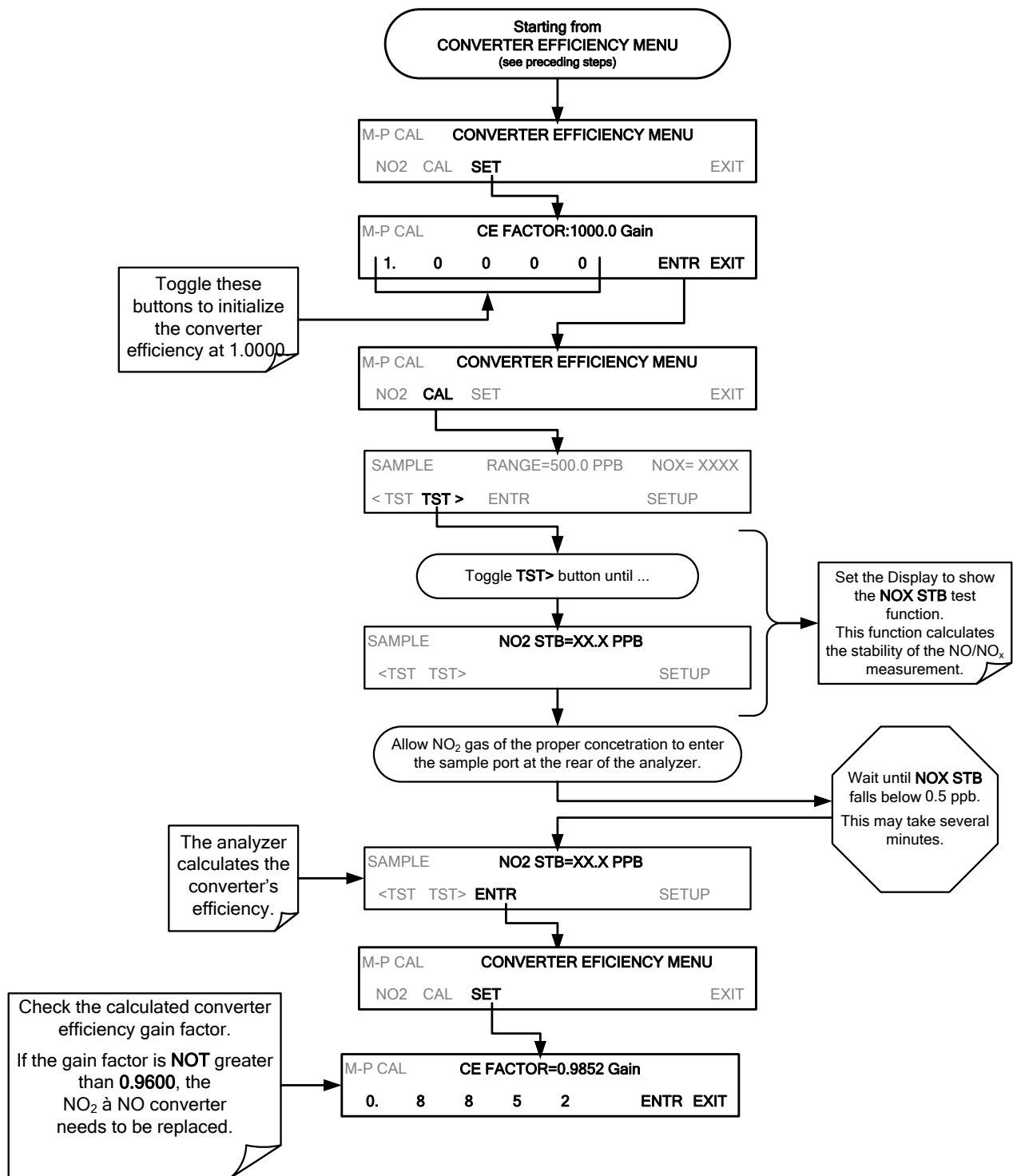
#### Step 2:

Input the starting NO<sub>2</sub> concentration value into the T200 by pressing:



**STEP 3:**

To cause the analyzer to calculate and record the NO<sub>2</sub> → NO converter efficiency, press:



**12.7.10.4. EVALUATING NO<sub>2</sub> → NO CONVERTER PERFORMANCE**

If the converter appears to have performance problems (conversion efficiency is less than 96%), check the following:

- Recalculate the converter efficiency (see previous section)
- Accuracy of NO<sub>2</sub> source (GPT or gas tank standard).
  - NO<sub>2</sub> gas standards are typically certified to only ±2% and often change in concentrations over time. You should get the standard re-certified every year.
  - If you use the GPT calibration, check the accuracy of the ozone source.
- Age of the converter.
  - The NO<sub>2</sub> converter has a limited operating life and may need to be replaced every ~3 years or when necessary (e.g., earlier if used with continuously high NO<sub>2</sub> concentrations).
  - We estimate a lifetime of about 10000 ppm-hours (a cumulative product of the NO<sub>2</sub> concentration times the exposure time to that concentration).
  - This lifetime heavily depends on many factors such as:
    - Absolute concentration (temporary or permanent poisoning of the converter is possible).
    - Sample flow rate and pressure inside the converter.
    - Converter temperature.
    - Duty cycle.
  - This lifetime is only an estimated reference and not a guaranteed lifetime.
- In some cases with excessive sample moisture, the oxidized molybdenum metal chips inside the converter cartridge may bake together over time and restrict air flow through the converter, in which case it needs to be replaced.
  - To avoid this problem, we recommend the use of a sample gas conditioner (Section 3.3.2.6).
  - Section 11.3.8 describes how to replace the NO<sub>2</sub> converter cartridge.
- With no NO<sub>2</sub> in the sample gas and a properly calibrated analyzer, the NO reading is negative, while the NO<sub>2</sub> reading remains around zero.
- The converter is destroying NO and needs to be replaced.
- With no NO<sub>2</sub> in the sample gas and a properly calibrated analyzer, the NO<sub>x</sub> reading is significantly higher than the actual (gas standard) NO concentration.
- The converter is producing NO<sub>2</sub> and needs to be replaced.

### 12.7.11. DETERMINING CE BY SIMPLIFIED GPT CALIBRATION

This section describes how to determine the NO<sub>2</sub> → NO converter's efficiency using a GPT method where the actual concentration of ozone is not a factor in the accuracy of the calculation.

- This procedure is based on the Code of Federal Regulations, Title 40, Chapter I, subchapter C, Part 50, Appendix F.
- In the following example a reference point of 450 ppb NO gas will be used. This is only an example. Any other reference points within measurement range of the instrument may be used.
- For this procedure use a calibrated O<sub>3</sub> generator, such as a Teledyne API's T700.

**Note**

-----  
**There must be a minimum of 10% more NO than O<sub>3</sub> produced.**  
**Example, if the Ozone concentration used is 400 ppb then the NO concentration must be used must be 440 ppb or more.**  
 -----

**PART 1: PREPARATION**

1. Leak check machine to ensure that there are no leaks in the analyzer.
2. Calibrate the instrument at the same NO span gas value as being used in this method.
  - For this example 450 ppb NO span gas
3. If you have input a converter efficiency (CE) factor into the instrument firmware (see Section 12.7.10.3) other than 100%, change this back to 100% for the duration of this test. (CAL>CONC>CONV>SET).

**PART 2: DETERMINE THE AMOUNT OF NO OUTGASSED BY THE NO<sub>2</sub> → NO CONVERTER.**

4. Bypass the NO<sub>2</sub> → NO converter by placing a short piece of tubing in the gas stream in place of the converter.
5. Perform a straight dilution with 445 ppb NO gas & air as a diluent gas.
6. Input the NO gas into the analyzer.
7. Allow the machine to stabilize & write down the NO<sub>x</sub> value on line 2 of GPT data sheet (Section 12.7.11.1).
8. Remove the converter bypass so that the NO gas is flowing through the NO<sub>2</sub> → NO converter
9. Allow the machine to stabilize.
10. Write down your NO<sub>x</sub> value on your data sheet on lines 3 AND line 5 of the GPT data sheet.
11. Subtract line 2 from line 3 & write that number down on line 4. Also write the NO value on line 8 of the data sheet.
  - The specification shown on the data sheet is the value that is used by Teledyne API when performing the procedure on new NO<sub>2</sub> → NO converters.
  - Older NO<sub>2</sub> → NO converters might outgas a bit more NO, therefore a slightly wider specification might be in order.
  - If this value is a constant or changes only slightly over time, this is not a problem the machine will calibrate this out.

**PART 3: PERFORM THE SIMPLIFIED GPT CALCULATION.**

12. Generate the same 450 ppb NO gas & input 400 ppb of O<sub>3</sub> (or generate 450 ppb NO & 400 ppb NO<sub>2</sub>, if that's what your calibrator says).
13. Allow the instrument to stabilize for 10 minutes.
14. Write down the NO<sub>x</sub> value on line 6 & the NO value on line 9.
15. Subtract line 6 from line 6 & put that onto line 7.
16. Subtract line 8 from line 7 & put that onto line 10.
17. Write the number from line 7 into the blank next to letter A on line 11 & put the number from line 10 into the blank next to letter B on line 11.
18. Divide A by B & multiply it by 100.
19. Write this value it into the blank next to letter C on lines 11 and 12.
20. Subtract that value from 100 & write it in the blank next to the letter D on line 12.
21. This is the converter efficiency.
  - This value should be >96%.



12.7.11.1. SIMPLIFIED GPT DATA SHEET

Line #	TEST	RESULT
1	<b>LEAK-CHECK</b> (WHEN HOT)	YES / NO
2	NO <sub>x</sub> RESPONSE (MOLY BYPASSED)	_____
3	NO <sub>x</sub> RESPONSE (MOLY IN-LINE)	_____
4	<b>OUT-GASSING</b> (NO – NOX)	_____ (>-5 ppb, <5 ppb)
5	(NO <sub>x</sub> ORIG) (NO <sub>x</sub> mode, O <sub>3</sub> off)	_____ ppb
6	(NO <sub>x</sub> REM) (NO <sub>x</sub> mode, O <sub>3</sub> on)	_____ ppb
7	NO <sub>x</sub> <b>LOSS</b>	_____ <b>(A)</b> (<4% of NO <sub>x</sub> ORIG: for 450PP 4% is 18 ppb)
8	(NO ORIG) (NO mode, O3 off)	_____ ppb
9	(NO REM) (NO mode, O3 on)	_____ ppb
10	NO <sub>2</sub> _____ <b>(B)</b> (>300ppb)	
11	Efficiency LOSS [ ( <b>A</b> / <b>B</b> ) x 100 ] = [ ( _____ <b>A</b> / _____ <b>B</b> ) x 100 ] = _____ <b>C</b> %	
12	Total Conv Eff [ 100% – <b>C</b> ] = 100% - _____ <b>C</b> = _____ <b>D</b> % (> 96%)	

## 12.7.12. PHOTOMULTIPLIER TUBE (PMT) SENSOR MODULE

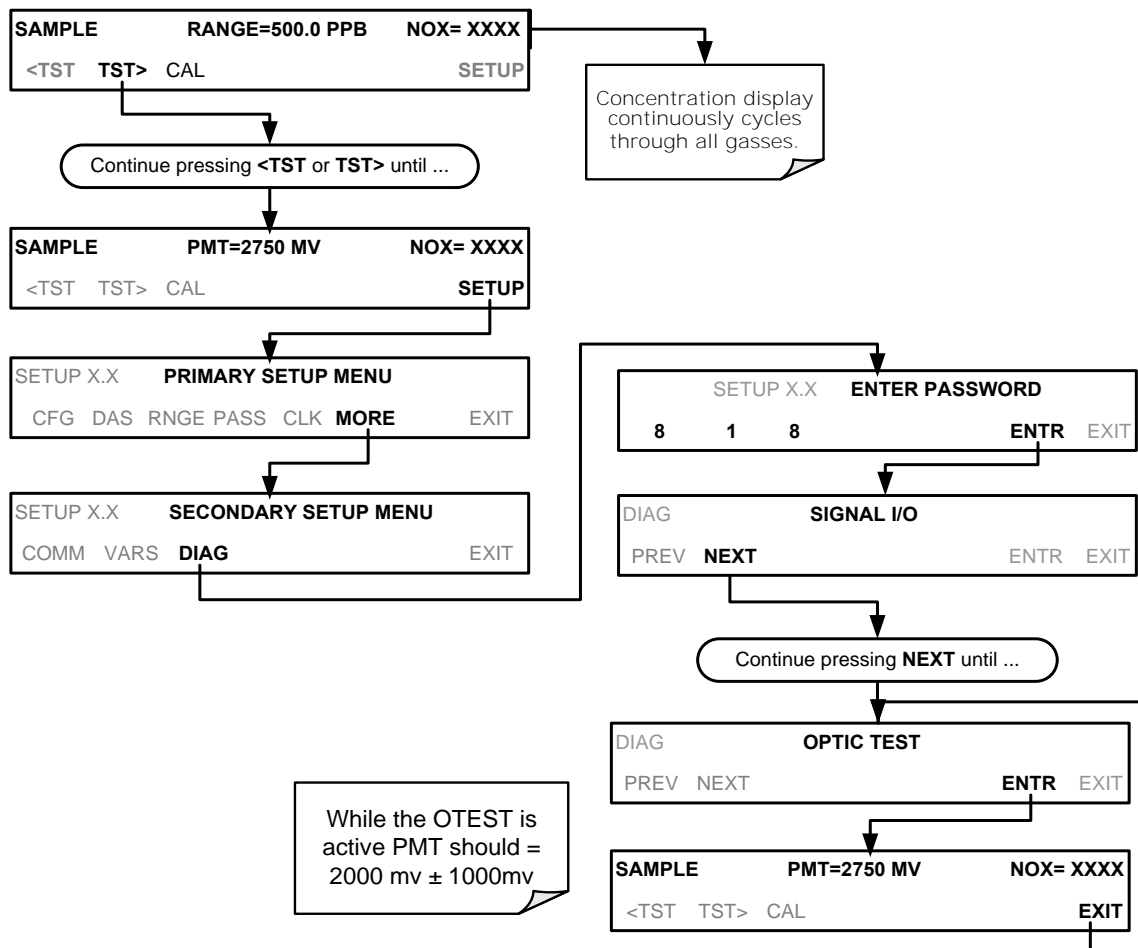
The PMT detects the light emitted by the reaction of NO with ozone. It has a gain of about 500000 to 1000000. It is not possible to test the detector outside of the instrument in the field. The basic method to diagnose a PMT fault is to eliminate the other components using **E**TEST, **O**TEST and specific tests for other sub-assemblies.

### 12.7.12.1. OPTIC TEST

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (see Figure 12-9). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board.

- To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air.
- The optic test should produce a PMT signal of about 2000±1000 mV.

To activate the optics test, press:



**Note**

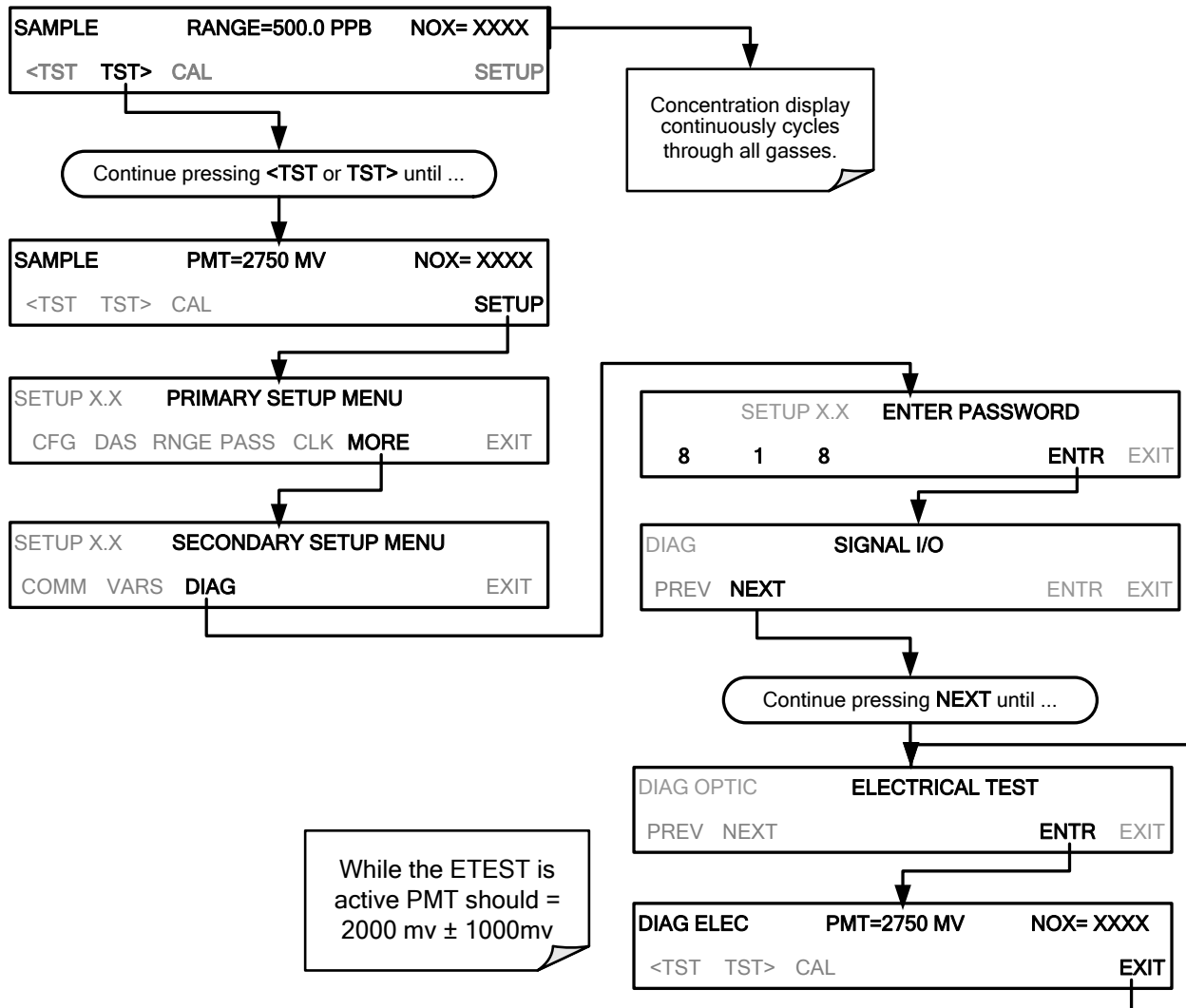
**This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.**

### 12.7.12.2. ELECTRICAL TEST

The electrical test function creates a current, which is substituted for the PMT signal and feeds it into the preamplifier board.

- This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard.
- It does not test the PMT itself.
- The electrical test should produce a PMT signal of about  $2000 \pm 1000$  mV.

To activate the electrical test, press:



## 12.7.13. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, perform an optics test (OTEST) and an electrical test (ETEST) described in Sections 12.7.12.1 and 12.7.12.2 above.

- If the instrument passes the OTEST but fails the ETEST, the preamplifier board may be faulty or need a hardware calibration.

### 12.7.13.1. HIGH VOLTAGE POWER SUPPLY

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube. It requires 2 voltage inputs.

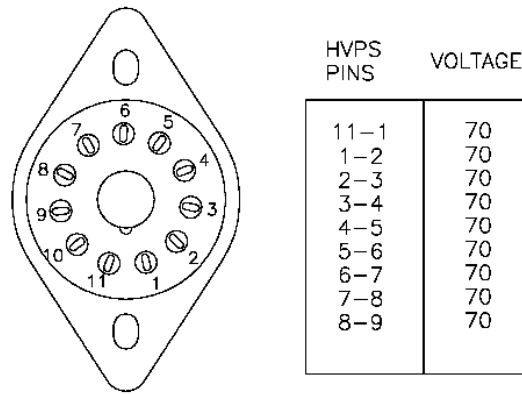
- The first is +15 V, which powers the supply.
- The second is the programming voltage which is generated on the preamplifier board.
- Adjustment of the HVPS is covered in the factory calibration procedure in Section 12.8.4.

This power supply has 10 independent power supply steps, one to each pin of the PMT. The following test procedure below allows you to test each step.

1. Turn off the instrument.
2. Remove the cover and disconnect the 2 connectors at the front of the NOX sensor module.
3. Remove the end cap from the sensor (4 screws).
4. Remove the HVPS/PMT assembly from the cold block inside the sensor (2 plastic screws).
5. Disconnect the PMT from the HVPS.
6. Re-connect the 7 pin connector to the sensor end cap, and power-up the instrument.
7. Scroll the front panel display to the HVPS test parameter.
8. Divide the displayed HVPS voltage by 10 and test the pairs of connector points as shown in the figure below.
9. Check the overall voltage (should be equal to the HVPS value displayed on the front panel and the voltages between each pair of pins of the supply

#### EXAMPLE

If the HVPS signal is 700 V the pin-to-pin voltages should be 70 V.



1. Turn off the instrument power, and reconnect the PMT, and then reassemble the sensor.
  - If any faults are found in the test, you must obtain a new HVPS as there are no user serviceable parts inside the supply.

### 12.7.14. PMT TEMPERATURE CONTROL PCA

The TEC control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan.

If the red LED located on the top edge of this assembly is not glowing the control circuit is not receiving power. Check the analyzers power supply, the relay board’s power distribution circuitry and the wiring connecting them to the PMT temperature control PCA.

#### TEC Control Test Points

Four test points are also located at the top of this assembly they are numbered left to right start with the T1 point immediately to the right of the power status LED. These test points provide information regarding the functioning of the control circuit.

- To determine the current running through the control circuit, measure the voltage between T1 and T2. Multiply that voltage by 10.
- To determine the drive voltage being supplied by the control circuit to the TEC, measure the voltage between T2 and T3.
  - If this voltage is zero, the TEC circuitry is most likely open.

Or,

- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 and T2 = 0 VDC there is most likely an open circuit or failed op amp on control PCA itself.
- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 to T2 is some voltage other than 0 VDC, the TEC is most likely shorted.
- T4 is tied directly to ground. To determine the absolute voltage on any one of the other test points make a measurement between that test point and T4.

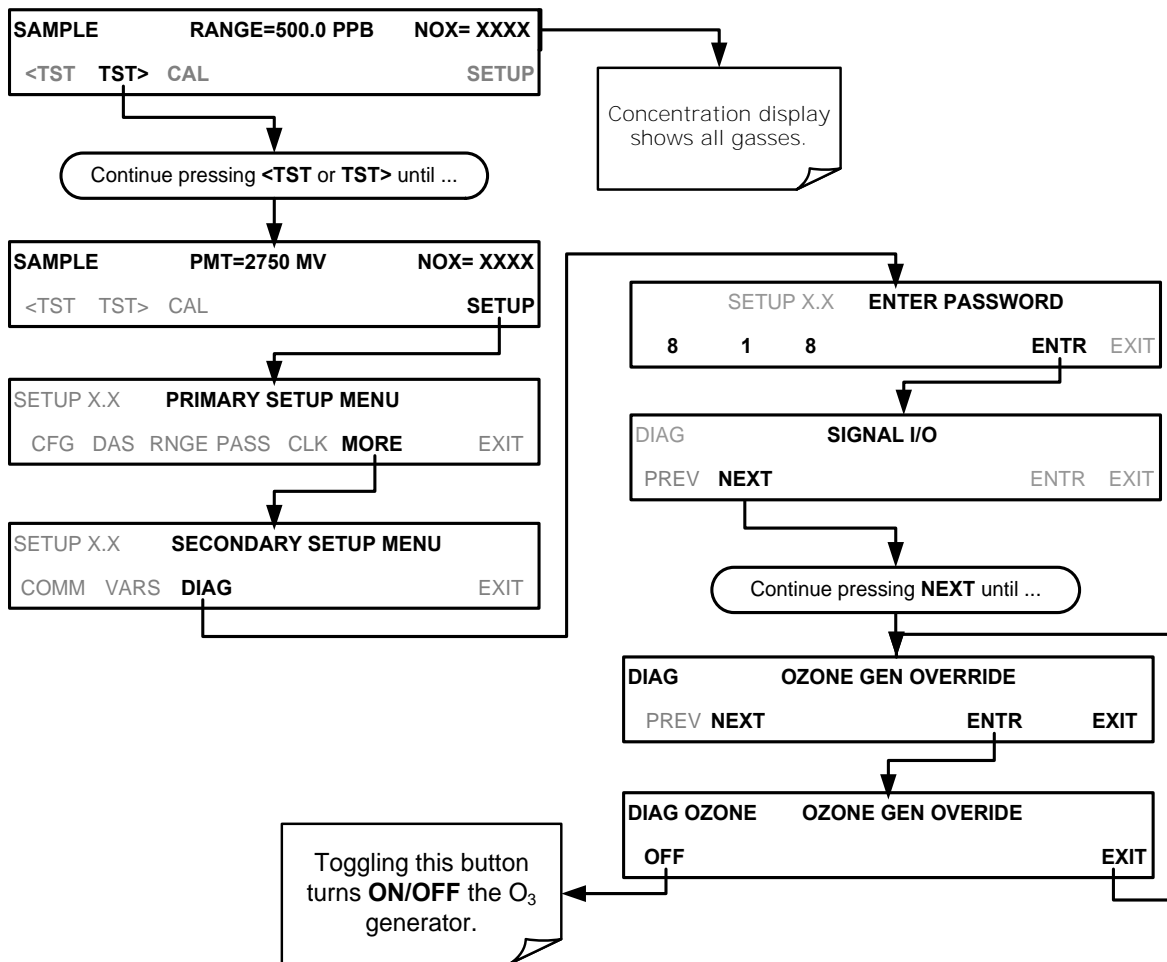
## 12.7.15. O<sub>3</sub> GENERATOR

The ozone generator can fail in two ways, electronically (printed circuit board) and functionally (internal generator components). Assuming that air is supplied properly to the generator, the generator should automatically turn on 30 minutes after the instrument is powered up or if the instrument is still warm. See Section 13.2.3 for ozone generator functionality. Accurate performance of the generator can only be determined with an ozone analyzer connected to the outlet of the generator. However, if the generator appears to be working properly but the sensitivity or calibration of the instrument is reduced, suspect a leak in the ozone generator supply air.

A leak in the dryer or between the dryer and the generator can cause moist, ambient air to leak into the air stream, which significantly reduces the ozone output. The generator will produce only about half of the nominal O<sub>3</sub> concentration when run with moist, ambient air instead of dried air. In addition, moist supply air will produce large amounts of nitric acid in the generator, which can cause analyzer components downstream of the generator to deteriorate and/or causes significant deposit of nitrate deposits on the reaction cell window, reducing sensitivity and causing performance drift. Carry out a leak check as described earlier in this Section.

### 12.7.15.1. O<sub>3</sub> GENERATOR OVERRIDE

This feature allows the user to manually turn the ozone generator off and on. This should be done before disconnecting the generator, to prevent ozone from leaking out, or after a system restart if the user does not want to wait for 30 minutes during warm-up time. To access this feature press the following buttons: (Also note that the ozone generator does not turn on if the ozone flow conditions are out of specification (e.g., if there is no flow through the system or the pump is broken).



**Note**

This is one of the two settings in the DIAG menu that is retained after you exit the menu.

### 12.7.16. INTERNAL SPAN GAS GENERATOR AND VALVE OPTIONS

The zero/span valves and internal span gas generator options need to be enabled in the software (contact the factory on how to do this).

- Check for the physical presence of the valves or the IZS option.
- Check front panel for correct software configuration. When the instrument is in SAMPLE mode, the front panel display should show CALS and CALZ buttons in the second line of the display. The presence of the buttons indicates that the option has been enabled in software. In addition, the IZS option is enabled if the TEST functions show a parameter named IZS TEMP.

The semi-permeable PTFE membrane of the permeation tube is severely affected by humidity. Variations in humidity between day and night are usually enough to yield very variable output results. If the instrument is installed in an air-conditioned shelter, the air is usually dry enough to produce good results. If the instrument is installed in an environment with variable or high humidity, variations in the permeation tube output

will be significant. In this case, a dryer for the supply air is recommended (dew point should be  $-20^{\circ}\text{C}$  or less).

The permeation tube of the internal span gas generator option is heated with a proportional heater circuit and the temperature is maintained at  $50^{\circ}\text{C} \pm 1^{\circ}\text{C}$ . Check the front panel display or the **IZS\_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (Section 5.9.1). At  $50^{\circ}\text{C}$ , the temperature signal from the IZS thermistor should be around 2500 mV.

## 12.7.17. TEMPERATURE SENSOR

### 12.7.17.1. BOX TEMPERATURE SENSOR

The box temperature sensor (thermistor) is mounted on the motherboard below the bottom edge of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance.

- Box temperature will vary with, but will usually read about  $5^{\circ}\text{C}$  higher than, ambient (room) temperature because of the internal heating zones from the NO<sub>2</sub> converter, reaction cell and other devices.
- To check the box temperature functionality, we recommend checking the **BOX\_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (Section 12.1.3).
- At about  $30^{\circ}\text{C}$ , the signal should be around 1500 mV.
- To check the accuracy of the sensor, use a calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature by:
  - Placing it inside the chassis, next to the thermistor labeled **XT1** (above connector J108) on the motherboard.
  - Compare its reading to the value of the test function **PMT TEMP**.

### 12.7.17.2. PMT TEMPERATURE SENSOR CONTROL

The temperature of the PMT should be low and constant. It is more important that this temperature is maintained at a constant level than it is to be a specific temperature.

The PMT cooler uses a Peltier, thermo-electric cooler element supplied with 12 V DC power from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board.

- Voltages applied to the cooler element vary from 0.1 to 12 VDC.
- The temperature set point (hard-wired into the preamplifier board) will vary by  $\pm 2$
- The actual temperature will be maintained to within  $0.1^{\circ}\text{C}$  around that set point.

To check the operation of the PMT temperature control system:

1. Turn off the analyzer and let its internal components cool / heat to ambient temperature.
2. Turn on the analyzer.
3. Set the front panel to show the **PMT TEMP** test function (see Section 4.1.1).
  - The temperature should fall steadily to  $6-10^{\circ}\text{C}$ .
  - If the temperature fails to reach this point after 60 minutes, there is a problem in the cooler circuit.
  - If the control circuit on the preamplifier board is faulty, a temperature of  $-1^{\circ}\text{C}$  will be reported.



## 12.8. SERVICE PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement.

**Note**

Maintenance procedures (e.g., replacement of regularly changed expendables) are discussed in Section 11 (Instrument Maintenance) and are not listed here).

Also, there may be more detailed service notes for some of the below procedures. Contact Teledyne API's Customer Service Department.



**WARNING – ELECTRICAL SHOCK HAZARD**

Unless the procedure being performed requires the instrument be operating, turn it off and disconnect power before opening the analyzer and removing, adjusting or repairing any of its components or subsystems.



**CAUTION – QUALIFIED TECHNICIAN**

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

### 12.8.1. DISK-ON-MODULE REPLACEMENT PROCEDURE

**Note**

Servicing of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM.
2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.

3. While looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.
5. Remove the nylon standoff clip that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.
6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.
7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the chip all the way in.
8. Close the rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

### 12.8.2. O<sub>3</sub> GENERATOR REPLACEMENT

The ozone generator is a black, brick-shaped device with printed circuit board attached to its rear and two tubes extending out the right side in the front of the analyzer (see Figure 3-5). The board has a red LED that, when lit, indicates ozone is being generated. To replace the ozone generator:

1. Turn off the analyzer power, remove the power cord and the analyzer cover.
2. Disconnect the 1/8" black tube from the ozone cleanser and the 1/4" clear tube from the plastic extension tube at the brass fitting nearest to the ozone generator.
3. Unplug the electrical connection on the rear side of the brick.
4. Unscrew the two mounting screws that attach the ozone generator to the chassis and take out the entire assembly.
5. If you received a complete replacement generator with circuit board and mounting bracket attached, simply reverse the above steps to replace the current generator.

#### Note

-----  
**Ensure to carry out a leak check (11.3.12) and a recalibration after the analyzer has warmed up for about 60 minutes.**  
-----

### 12.8.3. SAMPLE AND OZONE DRYER REPLACEMENT

The T200 standard configuration is equipped with a dryer for the ozone supply air. An optional dryer is available for the sample stream and a combined dryer for both gas streams can also be purchased. To change one or both of these dryers:

1. Turn off power to the analyzer and pump, remove the power cord and the analyzer cover.
2. Locate the dryers in the center of the instrument, between sensor and NO<sub>2</sub> converter (see Figure 3-5).
  - They are mounted to a bracket, which can be taken out when unscrewing the two mounting screws (if necessary).
3. Disconnect all tubing that extends out of the dryer assembly.
  - Take extra care not to twist any of the white plastic fittings on the dryer.
  - These connect the inner drying tube to the outer purge tube and are delicate. See Sections 13.3.1 and 11.3.2.

4. Note the orientation of the dryer on the bracket.
5. Cut the tie wraps that hold the dryer to the mounting bracket and take out the old dryer.
  - If necessary, unscrew the two mounting screws on the bracket and take out the entire assembly.
6. Attach the replacement dryer to the mounting bracket in the same orientation as the old dryer.
7. Fix the dryer to the bracket using new tie wraps.
8. Cut off excess length of the wraps.
9. Put the assembly back into the chassis and tighten the mounting screws.
10. Re-attach the tubes to vacuum manifold, flow meter and/or NO/NO<sub>x</sub> valve using at least two wrenches.
  - Take extra care not to twist the dryer's white plastic fittings, as this will result in large leaks that are difficult to trouble-shoot and fix.
11. Carry out a detailed leak check (see Section 11.3.12.2),
12. Close the analyzer.
13. Power up pump and analyzer and re-calibrate the instrument after it stabilizes.

#### 12.8.4. PMT SENSOR HARDWARE CALIBRATION

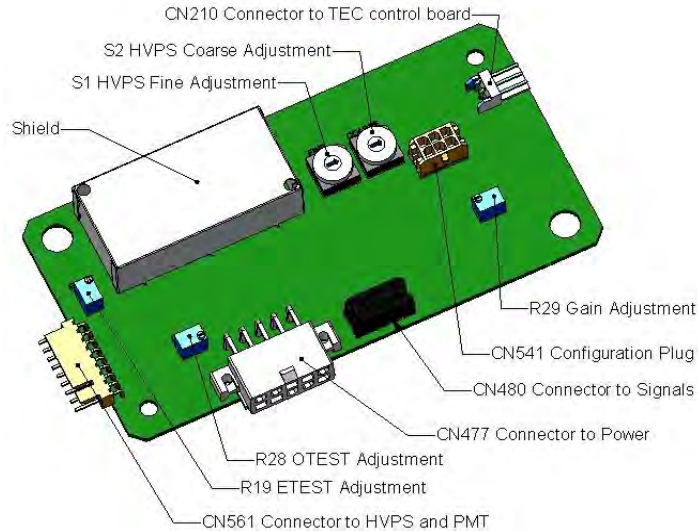
The sensor module hardware calibration is used in the factory to adjust the slope and offset of the PMT output and to optimize the signal output and HVPS.

- If the instrument's slope and offset values are outside of the acceptable range and all other more obvious causes for this problem have been eliminated, the hardware calibration can be used to adjust the sensor as has been done in the factory.
- This procedure is also recommended after replacing the PMT or the preamplifier board.

To calibrate the PMT preamplifier PCA:

1. Perform a full zero point calibration using zero air (see Section 9).
2. Display the NO<sub>x</sub> STB test function on the front panel (Section 4.1.1).
3. Locate the preamplifier board (see Figure 3-5).
4. Locate the following components on the preamplifier board (Figure 12-8):
  - HVPS coarse adjustment switch (Range 0-9, then A-F).
  - HVPS fine adjustment switch (Range 0-9, then A-F).
  - Gain adjustment potentiometer (Full scale is 10 turns).
5. Turn the gain adjustment potentiometer 12 turns clockwise or to its maximum setting.
6. Feed NO gas into the analyzer.
  - This should be 90% of the upper limit setting for the T200's reporting range:  
 EXAMPLE: if the reporting range is set at 500 ppb, use 450 ppb NO.

- Wait until the **STB** value is below 0.5 ppb



**Figure 12-8: Pre-Amplifier Board Layout**

- Scroll to the **NORM PMT** test function on the analyzer's front panel.
- With the NO gas concentrations mentioned in Step 5 above, the norm pmt value should be 900 mV.
- Set the HVPS coarse adjustment to its minimum setting (0).
- Set the HVPS fine adjustment switch to its maximum setting (F).
  - Set the HVPS coarse adjustment switch to the lowest setting that will give you just above the target value for **NORM PMT** signal.
- Adjust the HVPS fine adjustment such that the **NORM PMT** value is close to the target value.
  - It may be necessary to go back and forth between coarse and fine adjustments if the proper value is at the threshold of the min/max coarse setting.

## ATTENTION

### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. Start at the lowest setting and increment slowly. Wait 10 seconds between adjustments.

## Note

During these adjustments, the **NORM PMT** value will fluctuate as the analyzer continues to switch between NO and NO<sub>x</sub> streams as well as between measure and Auto Zero modes.

- Perform a span point calibration (see Section 9) to normalize the sensor response to its new PMT sensitivity.
- Review the slope and offset values:
  - The slope values should be  $1.000 \pm 0.300$ .
  - The offset values should be approximately 0.0 (-20 to +150 mV is allowed).

## 12.8.5. REPLACING THE PMT, HVPS OR TEC

The photo multiplier tube (PMT) should last for the lifetime of the analyzer, however, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) components may fail. Replacing any of these components requires opening the sensor module. This is a delicate assembly and it is recommend that you ensure the PMT, HVPS or TEC modules are, indeed, faulty before unnecessarily opening of the module.

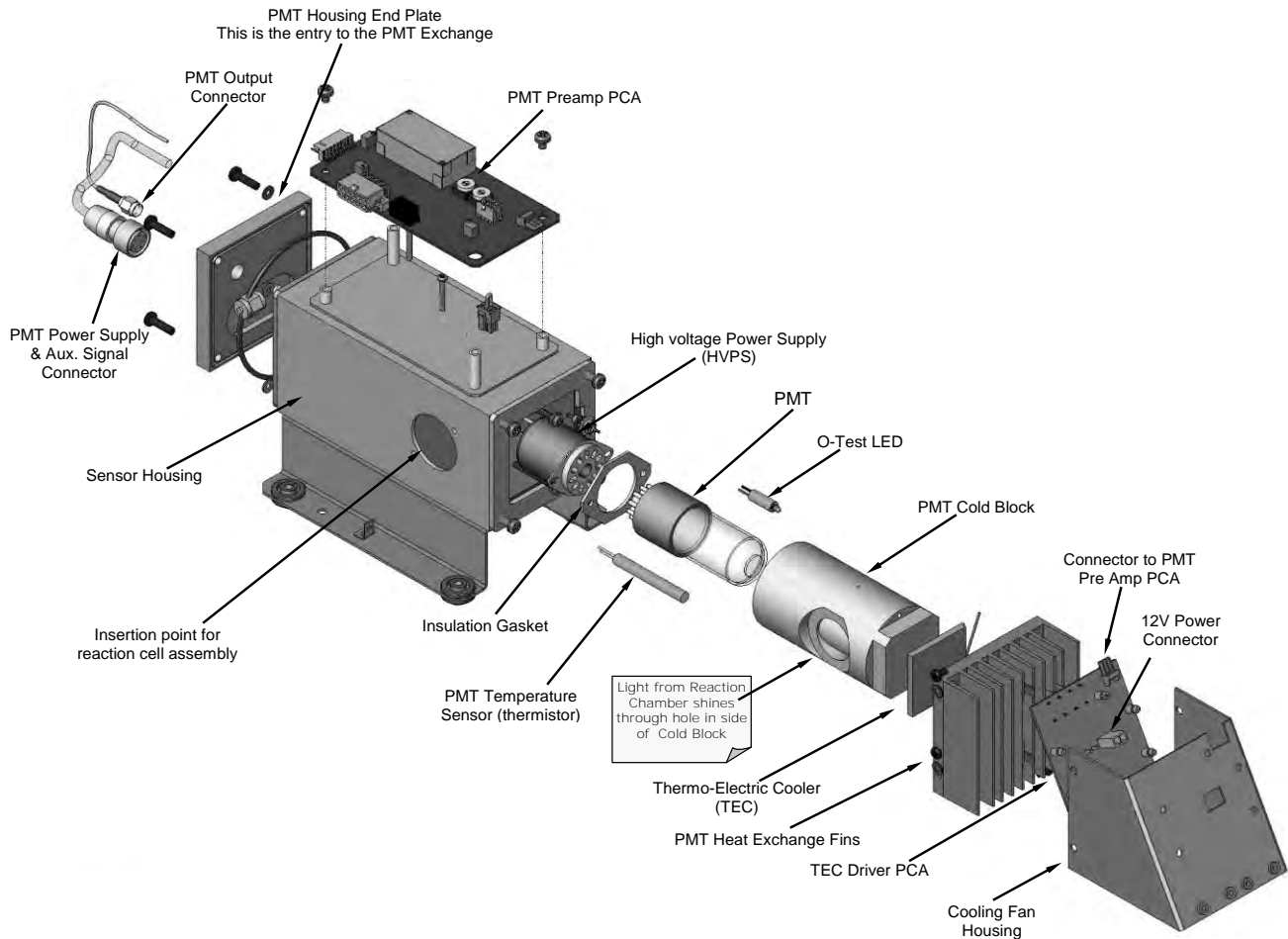


### CAUTION QUALIFIED PERSONNEL

While the PMT or HVPS can be removed through the front panel without un-mounting the entire sensor module, we recommend turning off the instrument, opening its top cover and removing the entire assembly so that further repairs can be carried out at an anti-ESD workstation.

Follow the guidelines for preventing electrostatic damage to electronic components, defined in the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section..

1. Turn OFF the analyzer and disconnect the power cord.
2. Remove the cover.
3. Disconnect all pneumatic and electrical connections from the sensor assembly.
4. Remove the sensor assembly.
5. If the TEC is to be replaced, remove the reaction cell assembly at this point by unscrewing two holding screws.
  - This is necessary only if the repair being performed involves removing the PMT cold block.



**Figure 12-9: T200 Sensor Assembly**

6. Remove the two connectors on the PMT housing end plate facing towards the front panel.
7. Remove the end plate itself (4 screws with plastic washers).

### Note

**If the black PMT housing end plate for the Sensor Assembly is removed, ensure to replace the 5 desiccant bags inside the housing.**

8. Remove the desiccant bags from the PMT housing.
9. Unscrew the PMT assembly, which is held to the cold block by two plastic screws.
10. Discard the plastic screws and replace with new screws at the end of this procedure (the threads get stripped easily and it is recommended to use new screws).
11. Along with the plate, slide out the optic test (O-Test) LED and the thermistor that measures the PMT temperature.
  - Thermistor will be coated with a white, thermal conducting paste.
  - Do not contaminate the inside of the housing with this grease, as it may contaminate the PMT glass tube on re-assembly.
12. Carefully take out the assembly consisting of the HVPS, the insulation gasket and the PMT.
13. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and do not touch it after cleaning.

14. If the cold block or TEC is to be changed:
  - Disconnect the TEC driver board from the preamplifier board, remove the cooler fan duct (4 screws on its side) including the driver board.
  - Disconnect the driver board from the TEC and set the sub-assembly aside.
15. Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.
16. Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.
17. Reassemble this TEC subassembly in reverse order.
  - Ensure to use thermal grease between TEC and cooling fins as well as between TEC and cold block and that the side opening in the cold block will face the reaction cell when assembled.
  - Evenly tighten the long mounting screws for good thermal conductivity.



**CAUTION**  
**QUALIFIED PERSONNEL**

**The thermo-electric cooler needs to be mounted flat to the heat sink. If there is any significant gap, the TEC might burn out. Ensure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.**

18. Reinsert the TEC subassembly in reverse order.
  - Ensure that the O-ring is seated properly and the assembly is tightened evenly.
19. Insert the O-Test LED and thermistor into the cold block, insert new desiccant bags and carefully replace the end plate by making sure that the O-ring is properly in place.
  - Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler and likely cause a short in the HVPS.
20. Reinsert the PMT/HVPS subassembly in reverse order.
  - Don't forget the insulation gasket between HVPS and PMT.
  - Use new plastic screws to mount the PMT assembly on the PMT cold block.
21. Install new silica gel packets (desiccant bags).
22. Reconnect the cables and the reaction cell (evenly tighten these screws).
23. Replace the sensor assembly into the chassis and fasten with four screws and washers.
24. Reconnect all electrical and pneumatic connections.
25. Leak check the system (see Section 13.3.12).
26. Turn ON the analyzer.
27. Verify the basic operation of the analyzer using the ETEST(12.7.12.2) and OTEST features (12.7.12.1) or zero and span gases, then carry out a hardware calibration of the analyzer followed by a zero/span point calibration (See Section 9.4.3.2).

## 12.8.6. REMOVING / REPLACING THE RELAY PCA FROM THE INSTRUMENT

This is the most commonly used version of the Relay PCA. It includes a bank of solid state AC relays. This version is installed in analyzers where components such as AC powered heaters must be turned ON & OFF.

A retainer plate is installed over the relay to keep them securely seated in their sockets.

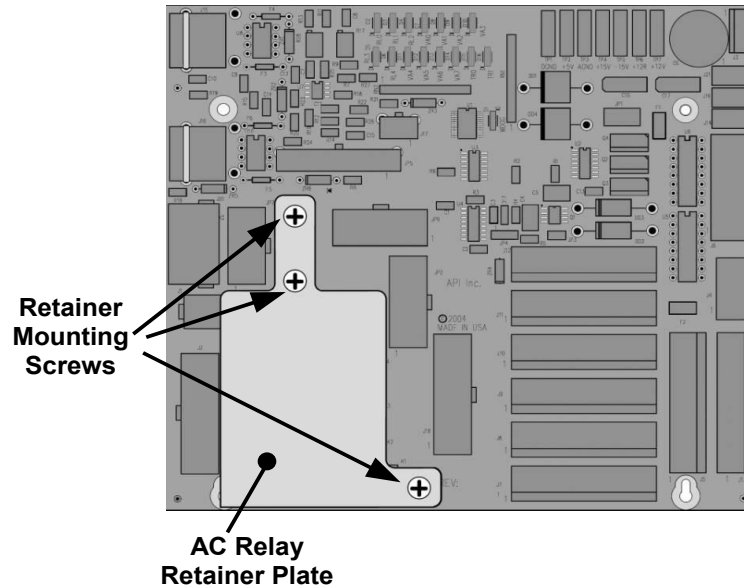


Figure 12-10: Relay PCA with AC Relay Retainer In Place

The Relay retainer plate installed on the relay PCA covers the lower right mounting screw of the relay PCA. Therefore, when removing the relay PCA, the retainer plate must be removed first.

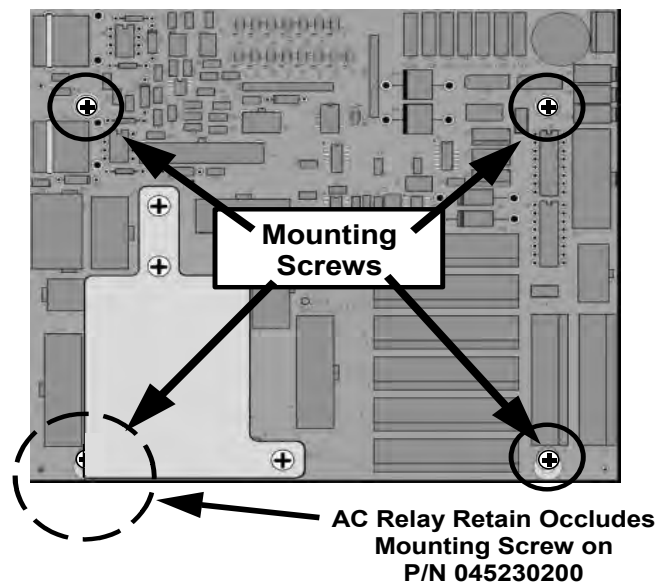


Figure 12-11: Relay PCA Mounting Screw Locations



## 12.9. FREQUENTLY ASKED QUESTIONS

The following list was compiled from the Teledyne API's Customer Service Department's 10 most commonly asked questions relating to the T200 NO<sub>x</sub> Analyzer.

QUESTION	ANSWER
Why does the <b>ENTR</b> button sometimes disappear on the front panel display?	Sometimes the <b>ENTR</b> button will disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00 or a range to less than 1 or more than 20000 ppb. Once you adjust the setting to an allowable value, the <b>ENTR</b> button will re-appear.
Why is the <b>ZERO</b> or <b>SPAN</b> button not displayed during calibration?	The T200 disables these buttons during calibration when the measured gas concentration differs significantly from the span or zero gas concentration value entered by the user. This prevents accidental recalibration of the analyzer to an out-of-range response curve.  EXAMPLE: The span set point is 400 ppb but gas concentration being measured is only 50 ppb.
How do I enter or change the value of my Span Gas?	Press the <b>CONC</b> button found under the <b>CAL</b> or <b>CALS</b> buttons of the main SAMPLE display menus to enter the expected NO <sub>x</sub> span concentration.  See Section 9.2.3.1 or for more information.
Can I automate the calibration of my analyzer?	Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature.
Can I use the IZS option to calibrate the analyzer?	Yes. However, the accuracy of the IZS option's permeation tube is only ±5%. To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source.
How do I measure the sample flow?	Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating. The sample flow should be 500 cm <sup>3</sup> /min ±10%.  Section 13.3.12.3 includes detailed instructions on performing a check of the sample gas flow.
Can I use the DAS system in place of a strip chart recorder or data logger?	Yes. Section 7 describes the setup and operation of the DAS system in detail.
How often do I need to change the particulate filter?	Once per week or as needed. Section 11 contains a maintenance schedule listing the most important, regular maintenance tasks. Highly polluted sample air may require more frequent changes.

QUESTION	ANSWER
How long does the sample pump last?	<p>The sample pump should last one to two years and the pump head should be replaced when necessary. Use the <b>RCEL</b> pressure indicator on the front panel to see if the pump needs replacement.</p> <p>If this value goes above 10 in-Hg-A, on average, the pump head needs to be rebuilt.</p>
Why does my RS-232 serial connection not work?	<p>There are several possible reasons:</p> <ul style="list-style-type: none"> <li>• The wrong cable: please use the provided or a generic “straight-through” cable (do not use a “null-modem” type cable) and ensure the pin assignments are correct (Sections 3.3.1.8 and 6.3).</li> <li>• The DCE/DTE switch on the back of the analyzer is not set properly; ensure that both green and red lights are on (Section 6.1).</li> <li>• The baud rate of the analyzer’s COM port does not match that of the serial port of your computer/data logger (Section 6.2.2).</li> </ul>
How do I make the instrument’s display and my data logger agree?	<p>This most commonly occurs when an independent metering device is used besides the data logger/recorder to determine gas concentration levels while calibrating the analyzer. These disagreements result from the analyzer, the metering device and the data logger having slightly different ground levels.</p> <p>Use the data logger itself as the metering device during calibration procedures.</p>
Do the critical flow orifices of my analyzer require regular replacement?	<p>No. The o-rings and the sintered filter associated with them require replacement once a year, but the critical flow orifices do not.</p> <p>See Section 11 for instructions.</p>
How do I set up and use the Contact Closures (Control Inputs) on the Rear Panel of the analyzer?	<p>See Section 3.3.1.6.</p>

## 12.10. TECHNICAL ASSISTANCE

If this manual and its troubleshooting & service section do not solve your problems, technical assistance may be obtained from:

**Teledyne API, Technical Support,  
9480 Carroll Park Drive  
San Diego, California 92121-5201USA**

**Toll-free Phone:** 800-324-5190

**Phone:** 858-657-9800

**Fax:** 858-657-9816

**Email:** [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

**Website:** <http://www.teledyne-api.com/>

Before you contact Teledyne API's Tech Support, fill out the problem report form in Appendix C, which is also available online for electronic submission at <http://www.teledyne-api.com/manuals/>.

## 13. PRINCIPLES OF OPERATION

The T200 Nitrogen Oxides Analyzer is a microprocessor controlled instrument that determines the concentration of nitric oxide (NO), total nitrogen oxides (NO<sub>x</sub>, the sum of NO and NO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) in a sample gas drawn through the instrument.

- It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O<sub>3</sub>), initiating a chemical reaction that gives off light (hv).
- The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas.
- A catalytic-reactive converter converts NO<sub>2</sub> in the sample gas to NO which, along with the NO present in the sample is reported as NO<sub>x</sub>. NO<sub>2</sub> is calculated as the difference between NO<sub>x</sub> and NO.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO<sub>2</sub> are supplied and stores these results in memory. The microprocessor uses these calibration values along with the signal from the sample gas and data of the current temperature and pressure of the gas to calculate a final NO<sub>x</sub> concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system (DAS Section 7) and are reported to the user through a vacuum fluorescence display or several output ports.

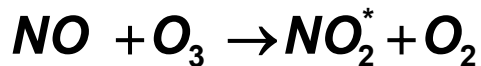
### 13.1. MEASUREMENT PRINCIPLE

#### 13.1.1. CHEMILUMINESCENCE CREATION IN THE T200 REACTION CELL

The T200's measures the amount of NO present in a gas by detecting the chemiluminescence which occurs when nitrogen oxide (NO) is exposed to ozone (O<sub>3</sub>). This reaction is a two-step process:

- In the first step, one molecule of NO and one molecule of O<sub>3</sub> collide and chemically react to produce one molecule of oxygen (O<sub>2</sub>) and one molecule of nitrogen dioxide (NO<sub>2</sub>). Some of the NO<sub>2</sub> molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO<sub>2</sub> molecule resides in a higher energy state than normal (denoted by an asterisk in the following equation).

Equation 13-1



- The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available, therefore the excited NO<sub>2</sub> molecule quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light ( $h\nu$ ). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.

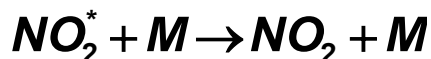
Equation 13-2



All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum (see Figure 13-2) the amount of NO present can be determined.

In addition, sometimes the excited NO<sub>2</sub> collides with other gaseous molecules in the reaction cell chamber or even the molecules of the reaction cell walls and transfers its excess energy to this collision partner (represented by  $M$  in the equation 12-3 below) without emitting any light at all. In fact, by far the largest portion of the excited NO<sub>2</sub> returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.

Equation 13-3



The probability of a collision between the NO<sub>2</sub>\* molecule and a collision partner  $M$  increases proportionally with the reaction cell pressure. This non-radiating collision with the NO<sub>2</sub>\* molecules is usually referred to as *third body quenching*, an unwanted process further described in Section 13.1.5.2.

Even under the best conditions only about 20% of the NO<sub>2</sub> that is formed by the reaction described in equation 12-1 is in the excited state. In order to maximize chemiluminescence, the reaction cell is maintained at reduced pressure (thereby reducing the amount of available collision partners) and is supplied with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

## 13.1.2. CHEMILUMINESCENCE DETECTION IN THE T200 REACTION CELL

### 13.1.2.1. THE PHOTO MULTIPLIER TUBE (PMT)

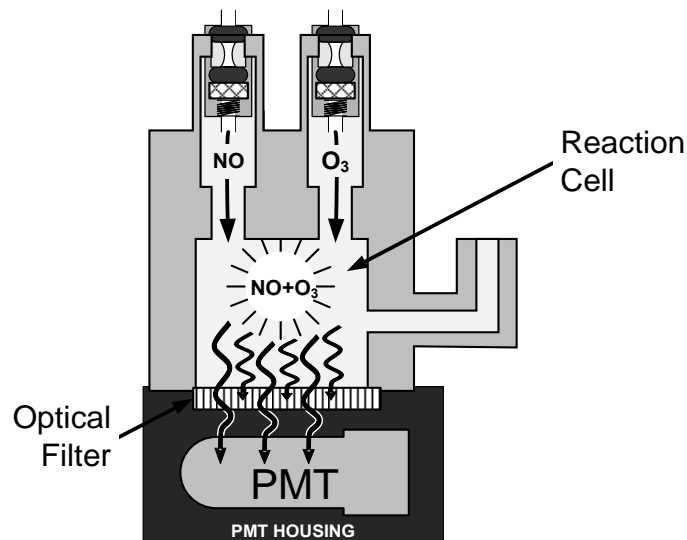
The T200 uses a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O<sub>3</sub> reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated (see Section 13.5 for a more detailed description). The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage and amplified by the preamplifier board and then communicated to the T200's CPU via the A → D converter circuitry on the analyzer.

### 13.1.2.2. OPTICAL FILTER

A high pass optical filter, only transparent to wavelengths of light above 645nm, placed between the reaction cell and the PMT (see Figure 13-1) in conjunction with the response characteristics of the PMT creates a very narrow window of wavelengths of light to which the T200 will respond.



**Figure 13-1: Reaction Cell with PMT Tube and Optical Filter**

The narrowness of this band of sensitivity allows the T200 to ignore extraneous light and radiation that might interfere with the T200's measurement. For instance, some oxides of sulfur can also be chemiluminescent emitters when in contact with O<sub>3</sub> but give off light at much shorter wavelengths (usually around 260nm to 480nm).

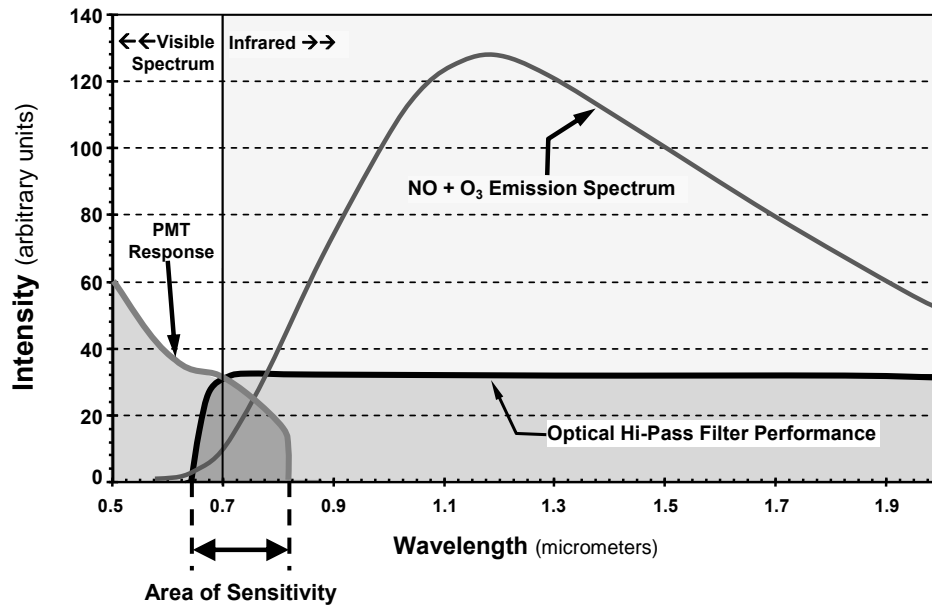
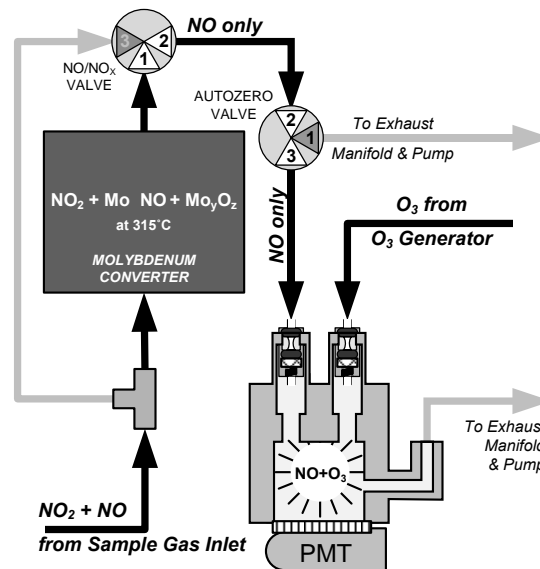


Figure 13-2: T200 Sensitivity Spectrum

### 13.1.3. NO<sub>x</sub> AND NO<sub>2</sub> DETERMINATION

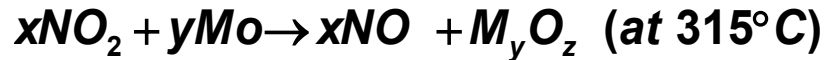
The only gas that is actually measured by the T200 is NO. NO<sub>2</sub>, and therefore NO<sub>x</sub> (which is defined here as the sum of NO and NO<sub>2</sub> in the sample gas), contained in the gas is not detected because NO<sub>2</sub> does not react with O<sub>3</sub> to create chemiluminescence.

In order to measure the concentration of NO<sub>2</sub>, and therefore the concentration of NO<sub>x</sub>, the T200 periodically switches the sample gas stream so that the pump pulls it through a special converter cartridge filled with molybdenum (Mo, “moly”) chips that are heated to a temperature of 315°C.

Figure 13-3: NO<sub>2</sub> → NO Conversion

The heated molybdenum reacts with NO<sub>2</sub> in the sample gas and produces a NO gas and a variety of molybdenum.

Equation 13-4



Once the NO<sub>2</sub> in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in Equation 13-1 and Equation 13-2.

By converting the NO<sub>2</sub> in the sample gas into NO, the analyzer can measure the total NO<sub>x</sub> content of the sample gas (i.e. the NO present + the converted NO<sub>2</sub> present). By switching the sample gas stream in and out of the “moly” converter every 6 - 10 seconds, the T200 analyzer is able to quasi-continuously measure both the NO and the total NO<sub>x</sub> content.

Finally, the NO<sub>2</sub> concentration is not directly measured but calculated by subtracting the known NO content of the sample gas from the known NO<sub>x</sub> content.

#### 13.1.4. AUTO ZERO

Inherent in the operation of any PMT is a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, unit to unit variations in the PMT units and even the constant universal background radiation that surrounds us at all times. In order to reduce this amount of noise and offset, the PMT is kept at a constant 7° C (45° F) by a Thermo-Electric Cooler (TEC).

While this intrinsic noise and offset is significantly reduced by cooling the PMT, it is not eradicated. To determine how much noise remains, once every minute for about 8 seconds the T200 diverts the sample gas flow directly to the vacuum manifold without passing the reaction cell.

During this time, only O<sub>3</sub> is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the chamber is completely dark, the T200 records the output of the PMT and keeps a running average of these **AZERO** values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NO<sub>x</sub> to arrive at an Auto Zero corrected reading.



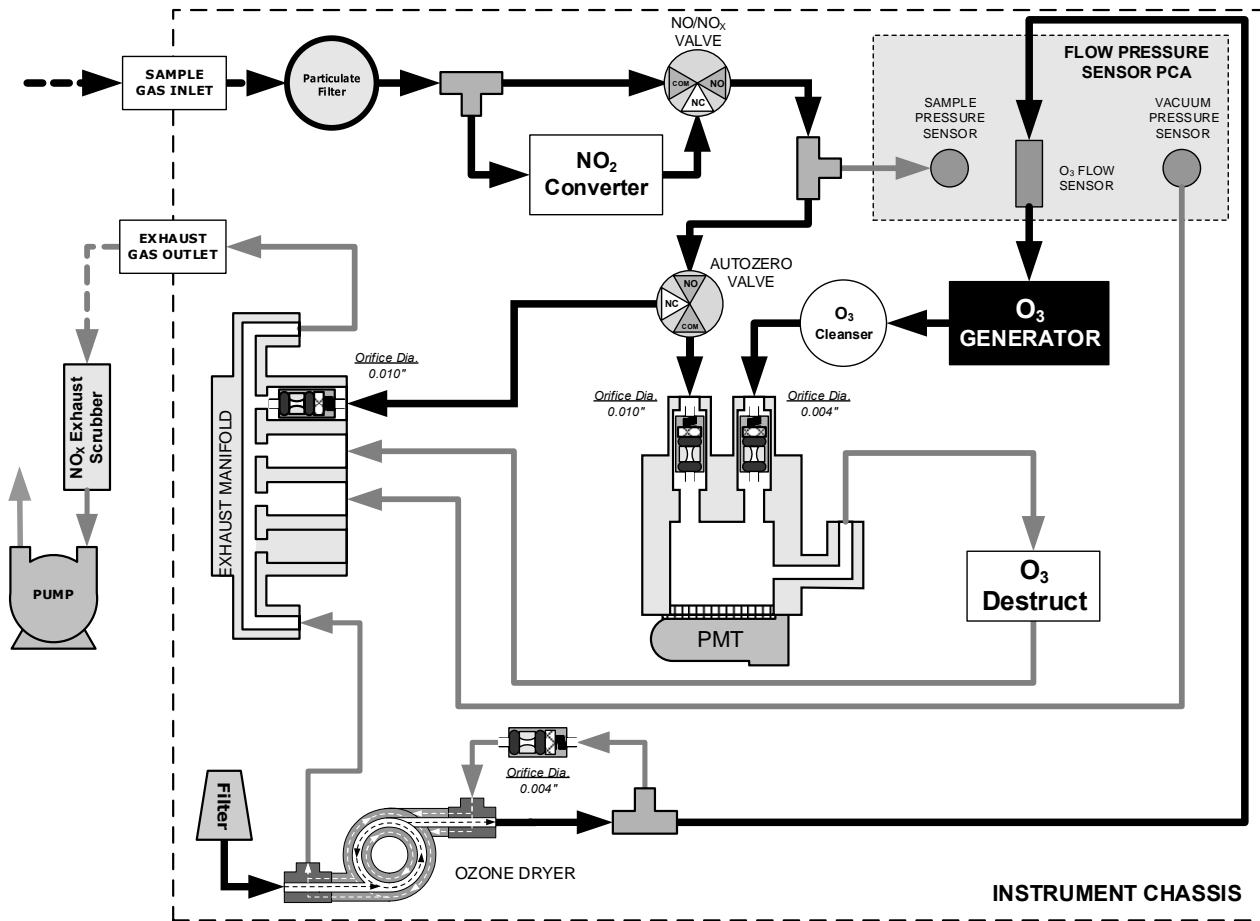


Figure 13-4: Pneumatic Flow During the Auto Zero Cycle

### 13.1.5. MEASUREMENT INTERFERENCES

It should be noted that the chemiluminescence method is subject to interferences from a number of sources. The T200 has been successfully tested for its ability to reject interference from most of these sources. Table 13-1 list the most common types of interferences that could affect the performance of your T200.

#### 13.1.5.1. DIRECT INTERFERENCE

Some gases can directly alter the amount of light detected by the PMT due to chemiluminescence in the reaction cell. This can either be a gas that undergoes chemiluminescence by reacting with O<sub>3</sub> in the reaction cell or a gas that reacts with other compounds and produces excess NO upstream of the reaction cell.

#### 13.1.5.2. THIRD BODY QUENCHING

As described by Equation 13-3, other molecules in the reaction cell can collide with the excited NO<sub>2</sub><sup>\*</sup>, causing the excited NO<sub>2</sub><sup>\*</sup> to return to its ground state without releasing a photon of light. This is known as third party quenching.

Quenching is an unwanted phenomenon and the extent to which it occurs depends on the properties of the collision partner.

- Larger, more polarized molecules such as H<sub>2</sub>O and CO<sub>2</sub> are the most significant quenching interferents of NO chemiluminescence.
  - The influence of water vapor on the T200 measurement can be eliminated with an optional, internal sample gas dryer (see Section 3.3.2.6).
  - The interference of varying CO<sub>2</sub> amounts at low concentrations (less than 0.5%) is negligible.
  - In cases with excessively high CO<sub>2</sub> concentrations (larger than 0.5%), the effect can be calibrated out by using calibration gases with a CO<sub>2</sub> content equal to the measured air.
  - Only very high and highly variable CO<sub>2</sub> concentrations will then cause a measurable interference. For those applications, it is recommended to use other analyzer models. Please consult Teledyne API's Sales Department or our website (see Section 12.10).
- Smaller less polar and electronically "harder" molecules such as N<sub>2</sub> and O<sub>2</sub> can cause interference of this type as well, however, the concentrations of N<sub>2</sub> and O<sub>2</sub> are virtually constant in ambient air measurements, hence provide a constant amount of quenching that is accounted for in the calibration of the instrument .

### 13.1.5.3. LIGHT LEAKS

The T200 sensitivity curve includes a small portion of the visible light spectrum (see Figure 13-2), therefore it is important to ensure that the reaction cell is completely sealed with respect to light. To ensure this:

- All pneumatic tubing leading into the reaction cell is opaque in order to prevent light from entering the cell.
- Light penetration is prevented by stainless steel filters and orifices.

Table 13-1: List of Interferents

Gas	Interference Type	Rejection Method
CO <sub>2</sub>	Dilution: Viscosity of CO <sub>2</sub> molecules causes them to collect in aperture of Critical Flow Orifice altering flow rate of NO.	If high concentrations of CO <sub>2</sub> are suspected, special calibration methods must be performed to account for the affects of the CO <sub>2</sub> .
	3 <sup>rd</sup> Body Quenching: CO <sub>2</sub> molecules collide with NO <sub>2</sub> * molecules absorbing excess energy kinetically and preventing emission of photons.	Contact Teledyne API's Customer Service Department (see Section 12.10) for details.
SO <sub>x</sub>	Some SO <sub>x</sub> variants can also initiate a chemiluminescence reaction upon exposure to O <sub>3</sub> producing excess light.	Wavelengths of light produced by chemiluminescence of SO <sub>x</sub> are screened out by the Optical Filter.
	Chemically reacts with NH <sub>3</sub> , O <sub>2</sub> and H <sub>2</sub> O in O <sub>3</sub> generator to create (NH <sub>3</sub> ) <sub>2</sub> SO <sub>4</sub> (ammonium sulfate) and NH <sub>3</sub> NO <sub>2</sub> (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO <sub>3</sub> (Nitric Acid)	Most of the ammonium sulfate and ammonium nitrate produced is removed from the sample gas by an air purifier located between the O <sub>3</sub> Generator and the reaction cell.
	3 <sup>rd</sup> Body quenching: SO <sub>x</sub> molecules collide with NO <sub>2</sub> * molecules absorbing excess energy kinetically and preventing emission of photons.	If high concentrations of SO <sub>x</sub> are suspected, special calibration methods must be performed to account for the affects of the SO <sub>2</sub> . Contact Teledyne API's Customer Service Department (see Section 12.10) for details.
H <sub>2</sub> O	3 <sup>rd</sup> Body quenching: H <sub>2</sub> O molecules collide with NO <sub>2</sub> * molecules absorbing excess energy kinetically and preventing emission of light.	Analyzer's operating in high humidity areas must have some drying applied to the sample gas (see Section 3.3.2.6 for more details).
	Water also reacts with NH <sub>3</sub> and SO <sub>x</sub> in the O <sub>3</sub> generator to create (NH <sub>3</sub> ) <sub>2</sub> SO <sub>4</sub> (ammonium sulfate) and NH <sub>3</sub> NO <sub>2</sub> (ammonium nitrate) which form opaque white deposits on the optical filter window. This also forms highly corrosive HNO <sub>3</sub> (nitric acid)	Water is effectively removed from the O <sub>3</sub> gas stream by the Sample Dryer (Section 13.2.3.2 for more details). We offer several Sample dryers for the sample stream (see Section 3.3.2.6 for more details).
NH <sub>3</sub>	Direct Interference: NH <sub>3</sub> is converted to H <sub>2</sub> O and NO by the NO <sub>2</sub> converter. Excess NO reacts with O <sub>3</sub> in the reaction cell creating a chemiluminescence artifact.	If a high concentration of NH <sub>3</sub> is suspected, steps must be taken to remove the NH <sub>3</sub> from the sample gas prior to its entry into the NO <sub>2</sub> converter (see Section 3.3.2.6 for more details).
	NH <sub>3</sub> also reacts with H <sub>2</sub> O, O <sub>2</sub> and SO <sub>x</sub> in the O <sub>3</sub> generator to create (NH <sub>3</sub> ) <sub>2</sub> SO <sub>4</sub> (ammonium sulfate) and NH <sub>3</sub> NO <sub>2</sub> (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO <sub>3</sub> (nitric acid).	The Sample dryer built into the T200 is sufficient for removing typical ambient concentration levels of NH <sub>3</sub> .

#### 13.1.5.4. REACTION CELL TEMPERATURE CONTROL

The stability of the chemiluminescence reaction between NO and O<sub>3</sub> can be affected by changes in the temperature and pressure of the O<sub>3</sub> and sample gases in the reaction cell. In order to reduce temperature effects, the reaction cell is maintained at a constant 50° C, just above the high end of the instrument's operation temperature range.

Two AC heaters, one embedded into the bottom of the reaction cell, the other embedded directly above the chamber's exhaust fitting, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board (see Section 13.3.4.4).

A thermistor, also embedded in the bottom of the reaction cell, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard (see Section 13.3.3.3).

## 13.2. PNEUMATIC OPERATION

### IMPORTANT

#### IMPACT ON READINGS OR DATA

Could either affect accuracy of instrument readings or cause loss of data.

### Note

**The sample gas is the most critical flow path in the analyzer. At any point before and in the reaction cell, the integrity of the sample gas cannot be compromised. Therefore, it is important that the sample airflow system is both leak tight and not pressurized over ambient pressure.**

Regular leak checks should be performed on the analyzer as presented in the maintenance schedule, Table 13-1. Procedures for correctly performing leak checks can be found in Section 13.3.12.

### 13.2.1. SAMPLE GAS FLOW

### Note

**In this section of the manual vacuum readings are given in inches of mercury absolute (In-Hg-A). This pressure value is referenced against zero (a perfect vacuum).**

The gas flow for the T200 is created by a pump that is pneumatically downstream from the rest of the instrument's components. This is either:

- An external pump pneumatically connected to the analyzer's exhaust port located on the rear panel. This is the most common configuration for the T200 or,
- An optional internal pump pneumatically connected between the vacuum manifold and the exhaust outlet (special order).

In either case, the pump creates a vacuum of approximately 5 in-Hg-A at one standard liter/minute, which is provided to various pneumatic components by a vacuum manifold located just in front of the rear panel (see Figure 3-5).

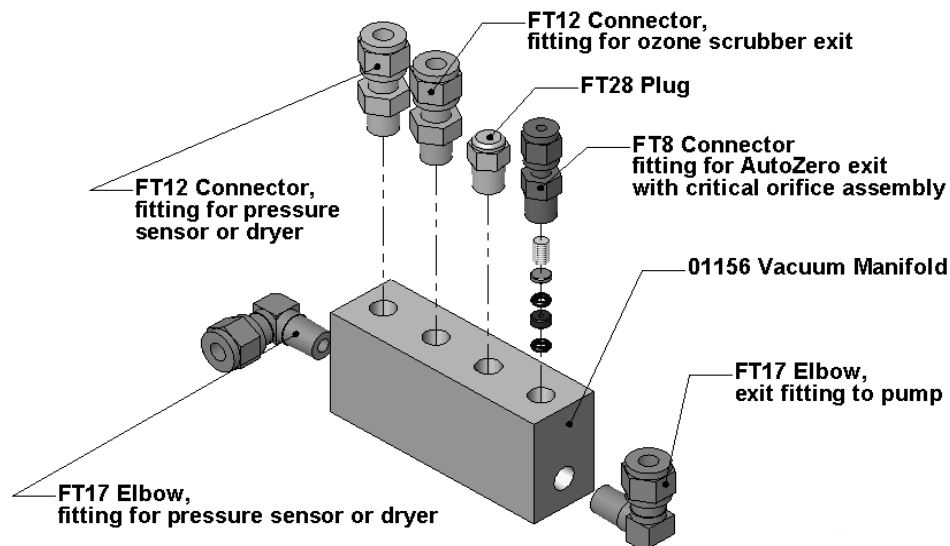
Gas flow is created by keeping the analyzer's sample gas inlet near ambient pressure, usually by means of a small vent installed in the sample line at the inlet, in effect pulling the gas through the instrument's pneumatic systems.

By placing the pump downstream from the analyzer's reaction cell, several problems are avoided.

- First, the pumping process heats and compresses the sample air complicating the measurement process.
- Additionally, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas.
- Finally, in certain applications where the concentration of the target gas might be high enough to be hazardous, maintaining a negative gas pressure relative to ambient means that should a minor leak occur, no sample gas would be pumped into the atmosphere surrounding the analyzer.

### 13.2.1.1. VACUUM MANIFOLD

The vacuum created by the analyzer's pump is supplied to all of the gas streams for the T200 analyzer through the vacuum manifold (also called the exhaust manifold).



**Figure 13-5. Vacuum Manifold, Standard Configuration**

Configurations will vary depending on the optional equipment that is installed. For example:

- An T200 with the optional internal span gas generator installed will add another FT8 connector and orifice assembly to the manifold where the FT28 fitting is shown in the above drawing.
- An optional sample gas dryer will add a Tee-fitting so that two ¼" tubes can be connected to the same port.

### 13.2.1.2. SAMPLE GAS FLOW VALVES AND ROUTING

As discussed in Section 13.1, the measurement of NO<sub>x</sub>, NO and NO<sub>2</sub> requires that the sample gas flow cycles through different routes that include and exclude various scrubbers and converters. There are several valves that perform this function:

- The NO/NO<sub>x</sub> valve directs the sample gas either directly to the reaction cell or through the unit's NO<sub>2</sub> converter, alternating every ~8 sec.
- The Auto Zero valve directs the sample gas stream to completely bypass the reaction cell for dark noise measurement once every minute, which is then subtracted as a measurement offset from the raw concentration signal.

Table 13-2: T200 Valve Cycle Phases

Phase	NO/ NO <sub>x</sub> Valve Status	Auto Zero Valve Status	Time Index	Activity	Figure
NO Measure	Open to Auto Zero valve	Open to reaction cell	0 - 2 s	Wait period (NO dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 13-3
			2 - 4 s	Analyzer measures chemiluminescence in reaction cell.	
NO <sub>x</sub> Measure	Open to NO <sub>2</sub> converter	Open to reaction cell	4 - 6 s	Wait period (NO <sub>x</sub> dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 13-3
			6 - 8 s	Analyzer measures NO + O <sub>3</sub> chemiluminescence in reaction cell.	
Cycle repeats every ~8 seconds					
Auto Zero	Open to Auto Zero valve	Open to vacuum manifold	0 - 4 s	Wait period (AZERO dwell time). Ensures reaction cell has been flushed of sample gas and chemiluminescence reaction is stopped.	Figure 13-4
			4 - 6 s	Analyzer measures background noise without sample gas	
Cycle repeats every minute					

### 13.2.2. FLOW RATE CONTROL - CRITICAL FLOW ORIFICES

Sample gas flow in the T200 analyzer is created via the use of several flow control assemblies (see Figure 13-6 for an example) located in various places in the gas streams of the instrument. These assemblies consist of:

- a critical flow orifice
- two o-rings, Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice
- a sintered filter
- a spring (applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing)

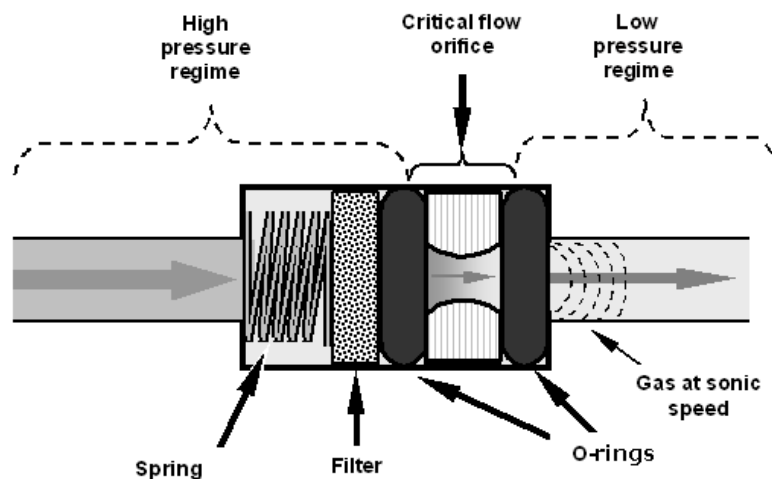


Figure 13-6: Flow Control Assembly & Critical Flow Orifice

### 13.2.2.1. CRITICAL FLOW ORIFICE

The most important component of each flow control assembly is the critical flow orifice. Critical flow orifices are a simple means to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential, created by the analyzer's external pump, draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows through the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1, the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the hole, the more gas molecules (moving at the speed of sound) pass through the orifice.

In addition to controlling the gas flow rates into the reaction cell, the two critical flow orifices at the inlets of the reaction cell also maintain an under-pressure inside it, effectively reducing the number of molecules in the chamber and the corresponding incidence of third body quenching (see Section 13.1.5.2) and therefore increasing the chemiluminescence yield.

- The T200 reaches its peak sensitivity at about 2 in-Hg-A, below which the sensitivity drops due to there being too few molecules present and a corresponding decrease in chemiluminescence.

### 13.2.2.2. LOCATIONS AND DESCRIPTIONS OF CRITICAL FLOW ORIFICES INSIDE THE T200

The T200 uses several of the following critical flow orifices (Figure 13-7) to create and maintain the proper flow rate of gas through its various components. (Please note that Figure 13-7 represents the standard configuration and is provided for reference).

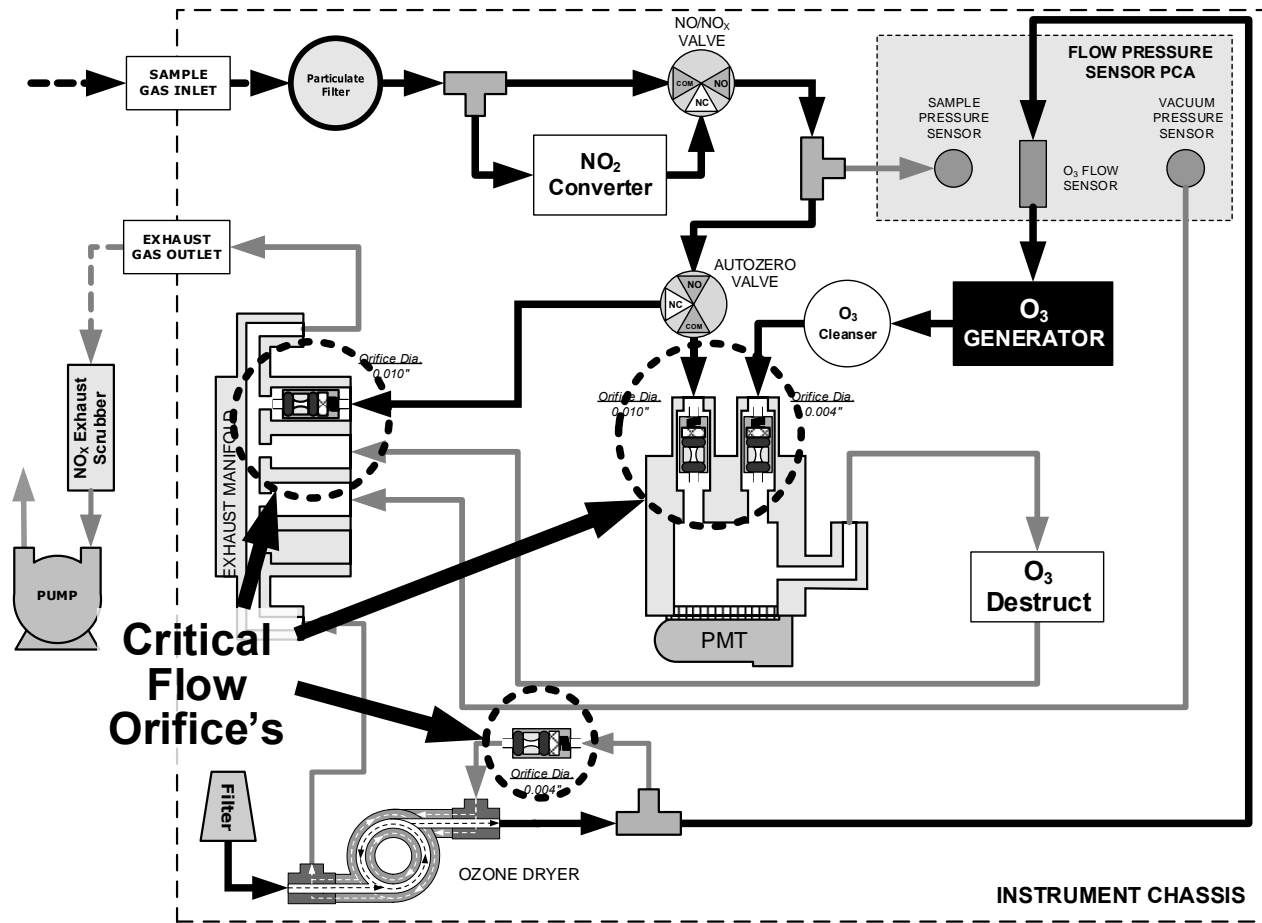


Figure 13-7: Location of Flow Control Assemblies & Critical Flow Orifices

Table 13-3: T200 Gas Flow Rates

Location	Purpose	Orifice Diameter	Flow rate (nominal)
Sample gas inlet of reaction cell	Controls rate of flow of sample gas into the reaction cell.	0.010" (0.25 mm)	500 cm <sup>3</sup> /min
O <sub>3</sub> supply inlet of reaction cell	Controls rate of flow of ozone gas into the reaction cell.	0.004" (0.10 mm)	80 cm <sup>3</sup> /min
Dry air return of Sample dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004" (0.10 mm)	80 cm <sup>3</sup> /min
Vacuum manifold, Auto Zero port.	Controls rate of sample gas flow when bypassing the reaction cell during the Auto Zero cycle.	0.010" (0.25 mm)	500 cm <sup>3</sup> /min
Vacuum manifold, Internal span gas generator exhaust port	Controls rate of flow of zero purge gas through the optional Internal span gas generator when it is installed.	0.003" (0.10 mm)	60 cm <sup>3</sup> /min

The necessary 2:1 ratios across the critical flow orifices is largely exceeded by the pumps supplied with the analyzer which are designed to accommodate a wide range of possible variability in atmospheric pressure and age related degradation of the pump itself. Once the pump does degrade the ratio between sample and vacuum pressures may fall to less than 2:1. At this point, the instrument will display an invalid sample flow rate measurement (XXXX).




**Note**

The diameter of a critical flow orifice may change with temperature because of expansion of the orifice material and, hence, the most crucial critical flow orifices in the T200 (those controlling the sample gas and O<sub>3</sub> flow into the cell itself) are located in the reaction cell where they can be maintained at a constant temperature.

### 13.2.3. OZONE GAS GENERATION AND AIR FLOW

The excess ozone needed for reaction with NO in the reaction cell is generated inside the analyzer because of the instability and toxicity of ozone. Besides the ozone generator itself, this requires a dry air supply and filtering of the gas before it is introduced into the reaction cell.

Due to its toxicity and aggressive chemical behavior, O<sub>3</sub> must also be removed from the gas stream before it can be vented through the exhaust outlet.

	<b>CAUTION</b> <b>GENERAL SAFETY HAZARD</b>
	<p>Ozone (O<sub>3</sub>) is a toxic gas. Obtain a Material Safety Data Sheet (MSDS) for this gas. Read and rigorously follow the safety guidelines described there. Always ensure that the plumbing of the O<sub>3</sub> generation and supply system is maintained and leak-free.</p>

#### 13.2.3.1. THE O<sub>3</sub> GENERATOR

The T200 uses a dual-dielectric, Corona Discharge (CD) tube for creating its O<sub>3</sub>, which is capable of producing high concentrations of ozone efficiently and with low excess heat (see Figure 13-8). The primary component of the generator is a glass tube with hollow walls of which the outermost and innermost surfaces are coated with electrically conductive material.

Air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O<sub>3</sub>. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O<sub>2</sub> molecules in the air stream splitting them into elemental oxygen.

Some of these oxygen atoms recombine with O<sub>2</sub> to O<sub>3</sub>. The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O<sub>2</sub> molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

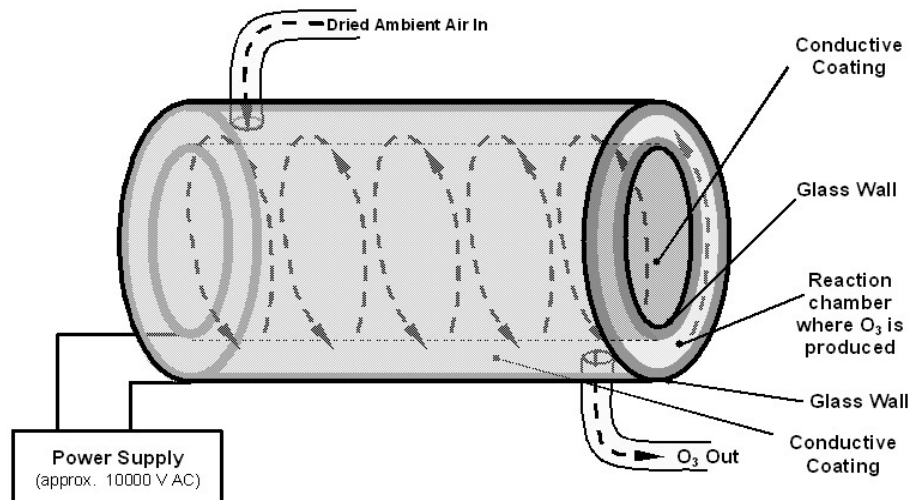


Figure 13-8: Ozone Generator Principle

### 13.2.3.2. OZONE GENERATOR DRY AIR SUPPLY

Ambient air usually contains enough water vapor to greatly diminishes the yield of ozone produced by the ozone generator. Water also reacts with chemicals inside the O<sub>3</sub> Generator to produce caustic substances such as ammonium sulfate or highly corrosive nitric acid that will damage the optical filter located between the reaction cell and the PMT.

To prevent this, the air supply for the O<sub>3</sub> generator is dried using a special single tube permeation dryer. The dryer consists of a single tube of Nafion<sup>®</sup> that is mounted within an outer, flexible plastic tube. Nafion<sup>®</sup> is a co-polymer that absorbs water very well but not most other chemicals. As gas flows through the inner Nafion<sup>®</sup> tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporated into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.

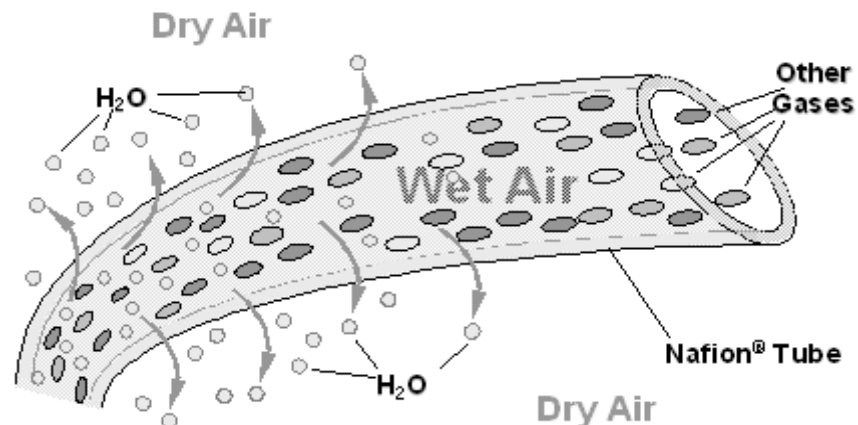


Figure 13-9: Semi-Permeable Membrane Drying Process

The process by which the water vapor molecules are collected and transported through Nafion<sup>®</sup> material is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which

transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds.

Because this chemical reaction is based on hydrogen bonds between the water molecule and the Nafion<sup>®</sup> material most other chemical components of the gas to be dried are usually unaffected. Specifically, the gases of interest for the T200, NO and NO<sub>2</sub>, do not get absorbed and pass the dryer unaltered.

On the other hand, other small polar gases that are capable of hydrogen bonds such as ammonia (NH<sub>3</sub>) can be absorbed this way, too. This is an advantage since gases such as NH<sub>3</sub> can cause interference for the measurement of NO<sub>x</sub>, NO and NO<sub>2</sub> (see Table 13-1).

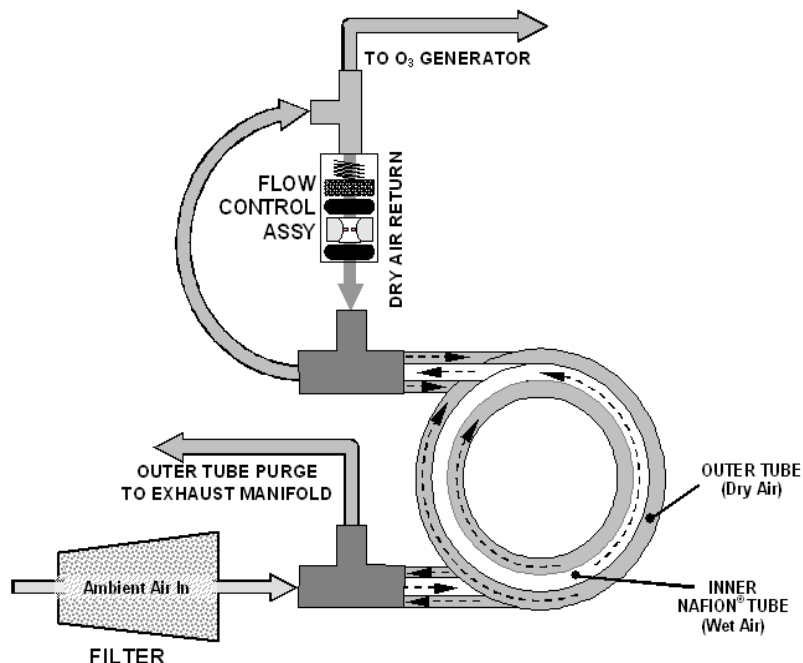


Figure 13-10: T200 Sample Dryer

To provide a dry purge gas for the outer side of the Nafion tube, the T200 returns some of the dried air from the inner tube to the outer tube. This means that any time the analyzer is turned on after having been OFF for 30 minutes or more, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low. Since it takes a certain amount of time for the humidity gradient to become large enough for the Sample Dryer operate efficiently, in such cold start cases the O<sub>3</sub> Generator is not turned on until 30 minutes has passed in order to ensure that it is not operating until its air supply is properly dry. During this 30 minute duration the O<sub>3</sub> GEN OVERRIDE menu displays "TMR" on the front panel screen.

#### Note

**When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.**

The Sample Dryer used in the T200 is capable of adequately drying ambient air to a dew point of  $\leq -5^{\circ}\text{C}$  ( $\sim 4000$  ppm residual H<sub>2</sub>O) at a flow rate of 1 standard liter per minute (slpm) or down to  $\leq -15^{\circ}\text{C}$  ( $\sim 1600$  ppm residual H<sub>2</sub>O) at 0.5 slpm. The Sample Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

### 13.2.3.3. OZONE SUPPLY AIR FILTER

The T200 uses ambient air as the supply gas for the O<sub>3</sub> generator and may produce a variety of byproducts. Small amounts of water, ammonia and various sulfur oxides can combine to create ammonium sulfate, ammonium nitrate, nitric acid and other compounds. Whereas sulfates and nitrates can create powdery residues inside the reaction cell causing sensitivity drift, nitric acid is a very aggressive compound, which can deteriorate the analyzer's components. In order to remove these chemical byproducts from the O<sub>3</sub> gas stream, the output of the O<sub>3</sub> generator flows through a special filter between the generator and the reaction cell.

The small amount of NO<sub>x</sub> produced in the generator (from the reaction of O<sub>2</sub> or O<sub>3</sub> and N<sub>2</sub> in the air) will not affect the T200's ability to measure NO<sub>x</sub>, NO and NO<sub>2</sub> as it is accounted for and removed from the concentration calculations by the analyzer's Auto Zero feature (see Section 13.1.4).

### 13.2.3.4. OZONE DESTRUCT

Even though ozone is unstable and typically reacts to form O<sub>2</sub>, the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream of the T200 by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O<sub>3</sub>, a highly efficient catalytic converter scrubs or converts all of the O<sub>3</sub> from the gas exiting the reaction cell. The conversion process is very safe. It only converts ozone to oxygen and does not produce any toxic or hazardous gases.

The O<sub>3</sub> destruct is located just inside the NO<sub>2</sub> converter. As this is a true catalytic converter, there are no maintenance requirements as would be required for charcoal-based ozone destructs.

A certain amount of fine, black dust may exit the catalyst, particularly if the analyzer is subjected to sudden pressure drops (for example, when disconnecting the running pump without letting the analyzer properly and slowly equilibrate to ambient pressure). To prevent the dust from entering the reaction cell or the pump, the ozone destruct is equipped with a quartz wool filter material.

## 13.2.4. PNEUMATIC SENSORS

### Note

The T200 displays all pressures in inches of mercury absolute (in-Hg-A), i.e. absolute pressure referenced against zero (a perfect vacuum).

The T200 uses three pneumatic sensors to verify the flow and pressure levels of its gas streams. They are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board, located just behind the sensor assembly. The measurements made by these sensors are used for a variety of important calculations and diagnostics.

### 13.2.4.1. SAMPLE PRESSURE SENSOR

An absolute pressure transducer connected to the input of the NO/NO<sub>x</sub> valve is used to measure the pressure of the sample gas before it enters the analyzer's reaction cell.

- In conjunction with the measurement made by the vacuum pressure sensor, this "upstream" measurement is used to compute the sample gas sample flow rate and to validate the critical flow condition (2:1 pressure ratio) through the sample gas critical flow orifice (Section 13.2.2).
- If the Temperature/Pressure Compensation (TPC) feature is turned on (Section 13.9.2), the output of this sensor is also used to supply pressure data for that calculation.
- The actual pressure value is viewable through the analyzer's front panel display as the test function **SAMP**.
- The flow rate of the sample gas is displayed as **SAMP FLW** and the **SIGNAL I/O** function **SAMPLE\_PRESSURE**.

### 13.2.4.2. VACUUM PRESSURE SENSOR

An absolute pressure transducer connected to the exhaust manifold is used to measure the pressure downstream from and inside the instrument's reaction cell.

- The output of the sensor is used by the CPU to calculate the pressure differential between the gas upstream of the reaction cell and the gas downstream from it and is also used as the main diagnostic for proper pump operation.
- If the ratio between the upstream pressure and the downstream pressure falls below 2:1, a warning message (**SAMPLE FLOW WARN**) is displayed on the analyzer's front panel (see Section 4.1.2) and the sample flow rate will display **XXXX** instead of an actual value.
- If this pressure exceeds 10 in-Hg-A, an **RCEL PRESS WARN** is issued, even though the analyzer will continue to calculate a sample flow up to ~14 in Hg.
- If the Temperature/Pressure Compensation (TPC) feature is turned on (see Section 13.9.2), the output of this sensor is also used to supply pressure data for that calculation.
- This measurement is viewable through the analyzer's front panel as the test function **RCEL** and the **SIGNAL I/O** function **RCELL\_PRESSURE**.

### 13.2.4.3. SAMPLE GAS FLOW CALCULATION

Sample gas flow in the T200 analyzer is not a directly measured value, but is rather calculated based on the measured pressure differential across the sample gas critical flow orifice. Specifically, the upstream reading of the sample pressure sensor is compared to the downstream pressure reading of the vacuum pressure sensor and this differential is used, by the analyzer's CPU, to derive the gas flow rate through the reaction cell.

- The results of this calculation are viewable from the instruments front panel via the test function **SAMP FLW**.
- Since this is a calculated value and not a measured reading there is no corresponding **SIGNAL I/O** function.

### 13.2.4.4. O<sub>3</sub> SUPPLY AIR FLOW SENSOR

In contrast to the sample gas flow, the ozone flow is measured with a mass flow sensor, which is mounted on the flow/pressure sensor PCA just behind the PMT sensor assembly. Pneumatically, it lies between the Sample dryer and the O<sub>3</sub>. This mass flow sensor has a full scale range of 0-1000 cm<sup>3</sup>/min and can be calibrated through software to its span point (Section 9.7).

Since the flow value displayed on the front panel is an actual measurement (and not a calculated value), short term variability in the measurement may be higher than that of the sample flow, which is based on a calculation from (more stable) differential pressures. On the other hand, any sustained drift, i.e. long-term change, in the ozone flow rate may usually indicate a flow problem.

This information is used to validate the O<sub>3</sub> gas flow rate.

- If the flow rate exceeds  $\pm 15\%$  of the nominal flow rate (80 cm<sup>3</sup>/min), a warning message **OZONE FLOW WARNING** is displayed on the analyzer's front panel (see Section 4.1.2) and the O<sub>3</sub> generator is turned off.
  - A second warning, **OZONE GEN OFF** is also displayed.
- This flow measurement is viewable through instrument's front panel display as the test function **OZONE FL** and the **SIGNAL I/O** function **OZONE\_FLOW**.

As with all other test parameters, we recommend to monitor the ozone flow over time for predictive diagnostics and maintenance evaluation.

# 13.3. ELECTRONIC OPERATION

## 13.3.1. OVERVIEW

Figure 13-11 shows a block diagram of the major electronic components of the analyzer.

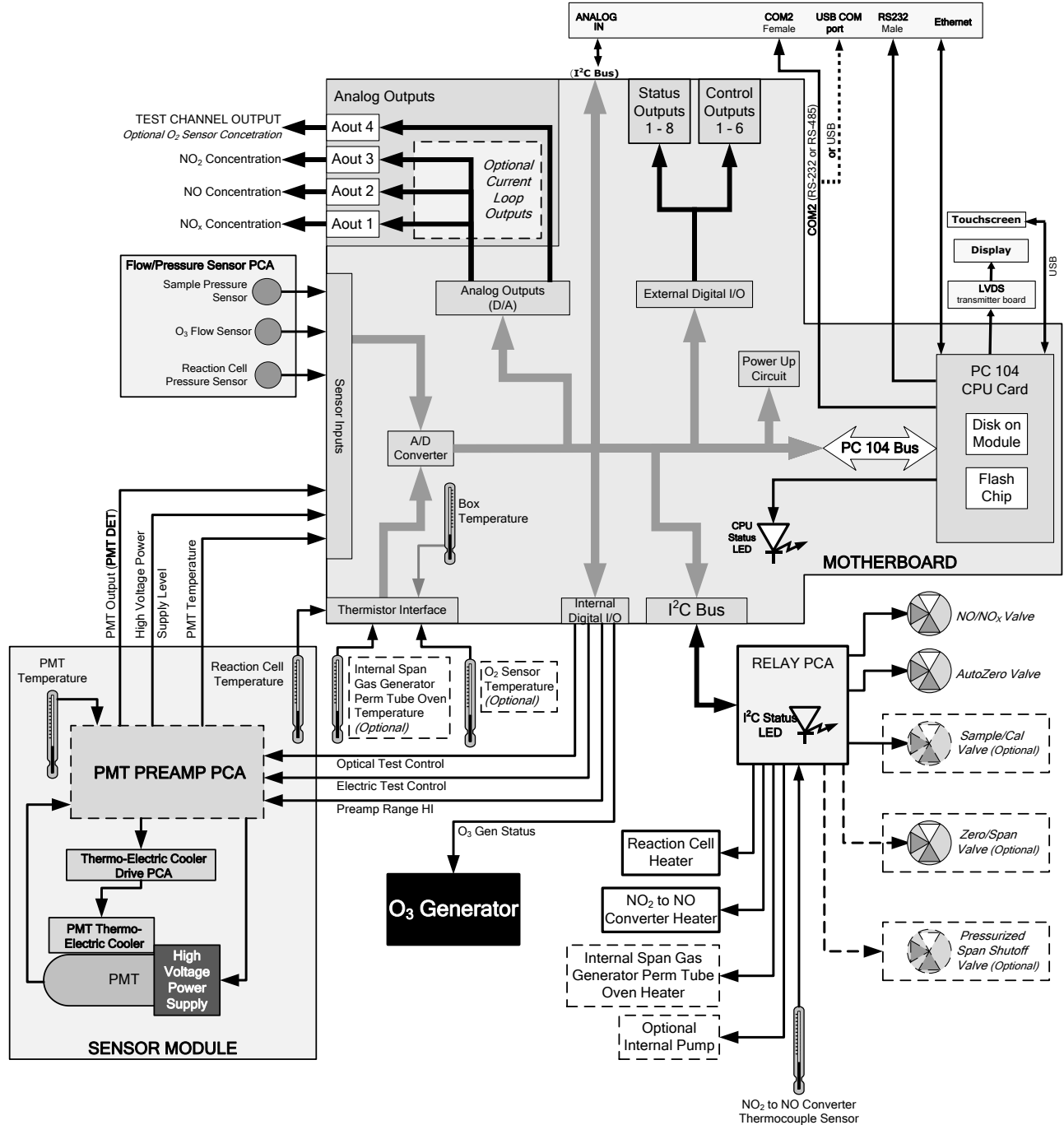


Figure 13-11: T200 Electronic Block Diagram

The core of the analyzer is a microcomputer/central processing unit (CPU) that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices via a separate printed circuit assembly onto which the CPU is mounted: the motherboard.

The motherboard is directly mounted to the inside rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Data are generated by the sensor module which outputs an analog signal corresponding to the amount of chemiluminescence present in the reaction cell. This signal is converted into digital data by a unipolar, analog-to-digital converter, located on the motherboard.

A variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the various concentration calculations and as trigger events for certain warning messages and control commands issued by the CPU. This information is stored in memory by the CPU and in most cases can be viewed by the user via the front panel display.

The CPU issues commands via a series of relays and switches (also over the I<sup>2</sup>C bus) located on a separate printed circuit assembly, called the relay PCA, to control the function of key electromechanical devices such as heaters and valves. It also issues some commands directly to the Sensor module (e.g. initiate Electric Test or Optical Test).

By controlling the state of various valves the CPU directs the flow of sample gas through the various gas paths of the analyzer (NO measurement path; NO<sub>x</sub> measurement path; Auto Zero Path). Based on which path is active, the CPU interprets the sensor output to derive raw data representing concentrations for NO<sub>x</sub>, NO and zero (dark condition), accesses the operational data stored in memory then calculates final concentrations for NO<sub>x</sub>, NO and NO<sub>2</sub>.

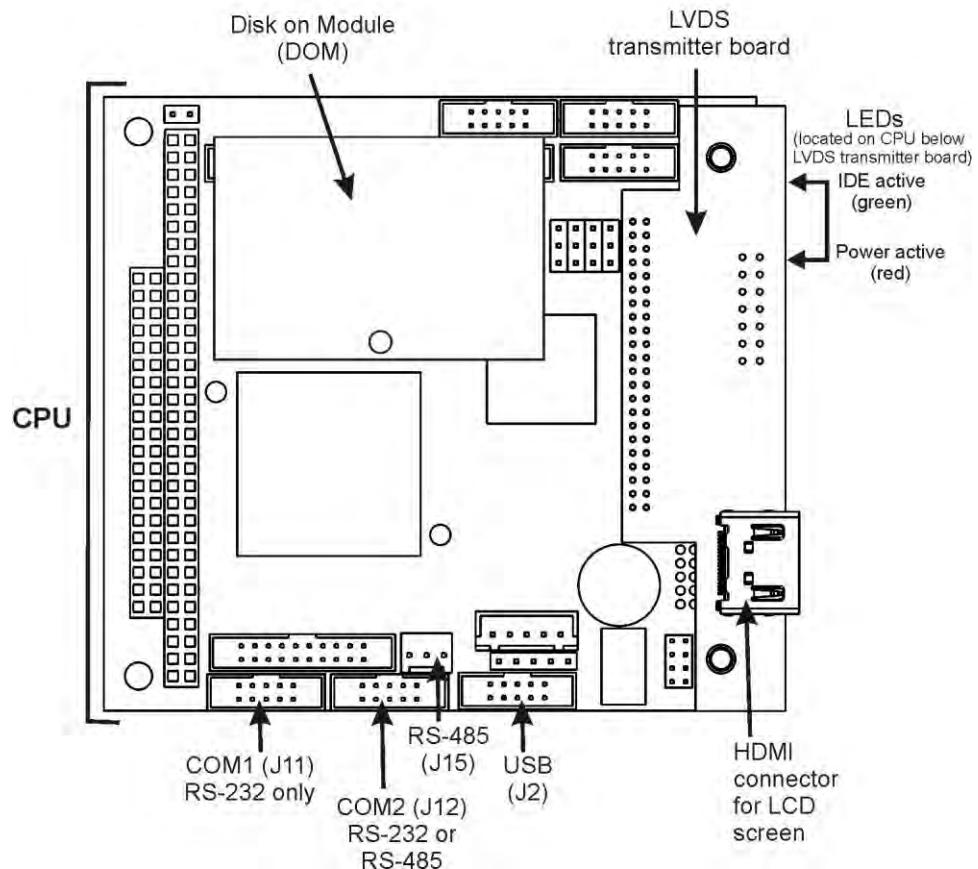
The CPU communicates with the user and the outside world in several ways:

- Through the analyzer's front panel LCD touch-screen interface
- Through the serial I/O channels
- Various analog voltage and current outputs
- Several sets of Digital I/O channels
- Ethernet



### 13.3.2. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification.



**Figure 13-12: CPU Board**

The CPU includes two types of non-volatile data storage: a Disk-on-Module (DOM) and an embedded flash chip.

#### 13.3.2.1. DISK-ON-MODULE

The DOM is a 44-pin IDE flash drive with storage capacity to 128 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS).

#### 13.3.2.2. FLASH CHIP

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data on a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring that the unit be recalibrated.

### 13.3.3. MOTHERBOARD

This PCA provides a multitude of functions including, A/D conversion, digital input/output, PC-104 to I<sup>2</sup>C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

#### 13.3.3.1. A TO D CONVERSION

Analog signals, such as the voltages received from the analyzers various sensors, are converted into digital signals that the CPU can understand and manipulate by the analog to digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.

The A/D consists of a Voltage-to-Frequency (V-F) converter, a Programmable Logic Device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time, and sends the result of that count, in the form of a binary number, to the CPU.

The A/D can be configured for several different input modes and ranges but in the T200 it is used in unipolar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from -0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions. See Section 5.9.3.10 for instructions on performing this calibration.

#### 13.3.3.2. SENSOR INPUTS

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

**PMT DETECTOR OUTPUT:** The PMT detector output from the PMT preamplifier is used in the computation of the NO, NO<sub>x</sub> and NO<sub>2</sub> concentrations displayed on the front panel display and reported through the instrument's analog outputs and COM ports.

This information is available in several forms:

- As a raw voltage signal via the test function **PMTDET** and the SIGNAL I/O function **PMT\_SIGNAL**, or;
- Normalized for temperature, pressure and auto-zero offset via the front panel test function **NORM PMT**.
- It is recorded by the DAS system in the following parameters:
  - **PMTDET** – The same as the test function **PMT DET**.
  - **RAWNOX** – The raw PMT output when the instrument is measuring NO<sub>x</sub>.
  - **RAW NO** – The raw PMT output when the instrument is measuring NO.

**HIGH VOLTAGE POWER SUPPLY LEVEL:** The PMT high voltage is based on the drive voltage from the preamplifier board. It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS.

- The value of this signal is viewable via the front panel test function HVPS and the SIGNAL I/O function HVPS\_VOLTAGE.
- It is recorded by the DAS system as the parameter **HVPS**.

**PMT TEMPERATURE:** The PMT temperature is measured with a thermistor inside the PMT cold block. Its signal is amplified by the PMT temperature feedback circuit on the preamplifier board and is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

- The value of this signal is viewable via the front panel test function **PMT TEMP** and the SIGNAL I/O function **PMT\_TEMP**.
- It is recorded by the DAS system as the parameter **PMTTMP**.

**SAMPLE GAS PRESSURE SENSOR:** This sensor, located on the flow/pressure sensor PCA, measures the gas pressure in the sample chamber upstream of the sample gas stream flow control assembly. Its functions are described in Section 13.2.4.1.

- The value of this signal is viewable via the front panel test function **SAMP** and the SIGNAL I/O function **SAMPLE\_PRESSURE**.
- It is recorded by the DAS system as the parameter **SMPPRS**.

**VACUUM PRESSURE SENSOR:** This sensor, also located on the flow/pressure sensor PCA, is pneumatically located downstream from the reaction cell and measures the pressure of the gas mixture inside the reaction cell. Its functions are described in Section 13.2.4.2.

- The value of this signal is viewable via the front panel test function **RCEL** and the SIGNAL I/O function **RCEL\_PRESSURE**.
- It is recorded by the DAS system as the parameter **RCPRES**.

**O<sub>3</sub> FLOW SENSOR:** This sensor, located on the flow/pressure sensor PCA, measures the flow rate of the O<sub>3</sub> gas stream as it is supplied to the reaction cell. Its functions are described in Section 13.2.4.4.

- The value of this signal is viewable via the front panel test function **OZONE FLOW** and the SIGNAL I/O function **OZONE\_FLOW**.
- It is recorded by the DAS system as the parameter **O3FLOW**.

### 13.3.3.3. THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative coefficient, thermistor temperature sensors located inside the analyzer. They are:

**REACTION CELL TEMPERATURE SENSOR:** The reaction cell temperature sensor is a thermistor embedded in the reaction cell manifold. This temperature is used by the CPU to control the reaction cell heating circuit and as a parameter in the temperature/pressure compensation algorithm.

- The value of this signal is viewable via the front panel test function **RCEL TEMP** and the SIGNAL I/O function **RCELL\_TEMP**.
- It is recorded by the DAS system as the parameter **RCTEMP**.

**BOX TEMPERATURE SENSOR:** A thermistor is attached to the motherboard. It measures the analyzer's inside temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes through the front panel display. It is also used as part of the NO, NO<sub>x</sub> and NO<sub>2</sub> calculations when the instrument's Temperature/Pressure Compensation feature is enabled.

- The value of this signal is viewable via the front panel test function **BOX TEMP** and the SIGNAL I/O function **BOX\_TEMP**.
- It is recorded by the DAS system as the parameter **BOXTMP**.

**INTERNAL SPAN GAS GENERATOR OVEN\_TEMPERATURE:** This thermistor reports the temperature of the optional internal span gas generator's NO<sub>2</sub> permeation source to the CPU as part of a control loop that keeps the tube at a high constant temperature (necessary to ensure that the permeation rate of NO<sub>2</sub> is constant). It is stored and reported as test function **IZS TEMP**.

- The value of this signal is viewable via the front panel test function **IZS TEMP** and the SIGNAL I/O function **IZS\_TEMP**.
- It is recorded by the DAS system as the parameter **IZTEMP**.

#### Note

-----  
**There are two thermistors that monitor the temperature of the PMT assembly:**

**One is embedded in the cold block of the PMT's TEC. Its signal is conditioned by the PMT preamplifier PCA and reported to the CPU via the motherboard (see Section 13.3.3.2).**

**The second is located on the PMT Preamplifier PCA and is used only as a reference for the preamplifier circuitry. Its output is neither reported nor stored.**  
-----

### 13.3.3.4. ANALOG OUTPUTS

The analyzer comes equipped with four analog outputs. On the instrument's rear panel analog connector (see Figure 3-4), they are labeled **A1**, **A2**, **A3** and **A4**.

**CONCENTRATION OUTPUTS:** Outputs labeled **A1**, **A2** and **A3** carry the concentration signals of NO<sub>x</sub>, NO and NO<sub>2</sub>, respectively. A variety of scaling measurement and electronic factors apply to these signals.

- See Sections 3.3.1.3 and 5.4 for information on setting the reporting range type and measurement range scaling factors for these output channels.
- See Sections 5.9.3.2 for instructions calibrating and scaling the electronic output of these channels.

**TEST OUTPUT:** The fourth analog output, labeled **A4** is special. It can be set by the user (see Section 5.9.4) to carry the current signal level of most of the parameters accessible through the **TEST** menu of the unit's software.

- In its standard configuration, the T200 comes with all four of these channels set up to output a DC voltage. However, 4-20mA current loop drivers can be purchased for the first three of these outputs, **A1**, **A2** and **A3**.

**OUTPUT LOOP-BACK:** All of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures (see Section 5.9.3.4).

### 13.3.3.5. EXTERNAL DIGITAL I/O

This external digital I/O performs two functions.

**STATUS OUTPUTS:** Logic-Level voltages (0-5 VDC) are output through an optically isolated 8-pin connector located on the rear panel of the analyzer (see Figure 3-4). These outputs convey good/bad and on/off information about certain analyzer conditions. They can be used to interface with certain types of programmable devices.

- For information on setting up the status outputs (see Section 3.3.1.4).

**CONTROL INPUTS:** By applying 5V DC power to these digital inputs from an external source such as a PLC or Data logger zero point and span point calibrations can be remotely initiated. .

- For information on setting up the status inputs (see Section 3.3.1.6).

### 13.3.3.6. INTERNAL DIGITAL I/O

There are several internal digital control signals that are generated by the motherboard under CPU control and used to control subsystems of the analyzer.

**ELECTRICAL TEST CONTROL:** When the CPU sets this control signal to high (**ON**) the electric test feature (**ETEST**) is initiated (see Section 8.3).

- The **ETEST** can be initiated by following the procedure in Section 12.7.12.2, or by setting the SIGNAL I/O Function **ELEC\_TEST** to **ON**.

**OPTICAL TEST (OTEST) CONTROL:** When the CPU sets this control signal to high (**ON**) the optical test feature is initiated (see Section 8.3).

- The **OTEST** can be initiated by following the procedure in 12.7.12.1, or by setting the SIGNAL I/O Function **OPTIC\_TEST** to **ON**.

**PMT PREAMPLIFIER RANGE CONTROL:** The CPU uses this control switch the instrument between its LOW and HIGH physical ranges (see Section 5.4.1).

- The instrument can be forced into its HIGH physical range setting the SIGNAL I/O function **PREAMP\_RANGE\_HI** to **ON**.

**O<sub>3</sub> GEN STATUS:** The CPU uses this control signal to turn the O<sub>3</sub> generator **ON/OFF** by setting it to HIGH/LOW respectively. The CPU turns **OFF** the O<sub>3</sub> generator if there is no or low air flow to it as measured by the O<sub>3</sub> flow sensor or if the instrument has been turned off for more than 30 minutes.

- The O<sub>3</sub> generator can be manually turned **ON/OFF** by using the **OZONE GENERATOR OVERRIDE** feature (See Section 12.7.15.1) or by setting the SIGNAL I/O function **O3GEN\_STATUS** to **ON** or **OFF**.

**Note**

Any I/O signals changed while in the signal I/O menu will remain in effect **ONLY** until signal I/O menu is exited.

The analyzer regains control of these signals upon exit and returns them to their normal value/setting.

### 13.3.3.7. I<sup>2</sup>C DATA BUS

I<sup>2</sup>C is a two-way, clocked, bi-directional digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the Motherboard converts data and control signals from the PC-104 bus to I<sup>2</sup>C format. The data is then fed to the relay board, optional analog input board and valve driver board circuitry.

### 13.3.3.8. POWER-UP CIRCUIT

This circuit monitors the +5V power supply during start-up and sets the analog outputs, external digital I/O ports, and I<sup>2</sup>C circuitry to specific values until the CPU boots and the instrument software can establish control.

### 13.3.4. RELAY PCA

The CPU issues commands via a series of relays and switches located on a separate printed circuit assembly, called the relay PCA (Figure 13-13), to control the function of key electromechanical devices such as heaters and valves. The relay PCA receives instructions in the form of digital signals over the I<sup>2</sup>C bus, interprets these digital instructions and activates its various switches and relays appropriately.

The relay PCA is located in the right-rear quadrant of the analyzer and is mounted vertically on the backside of the same bracket as the instrument's DC power supplies.

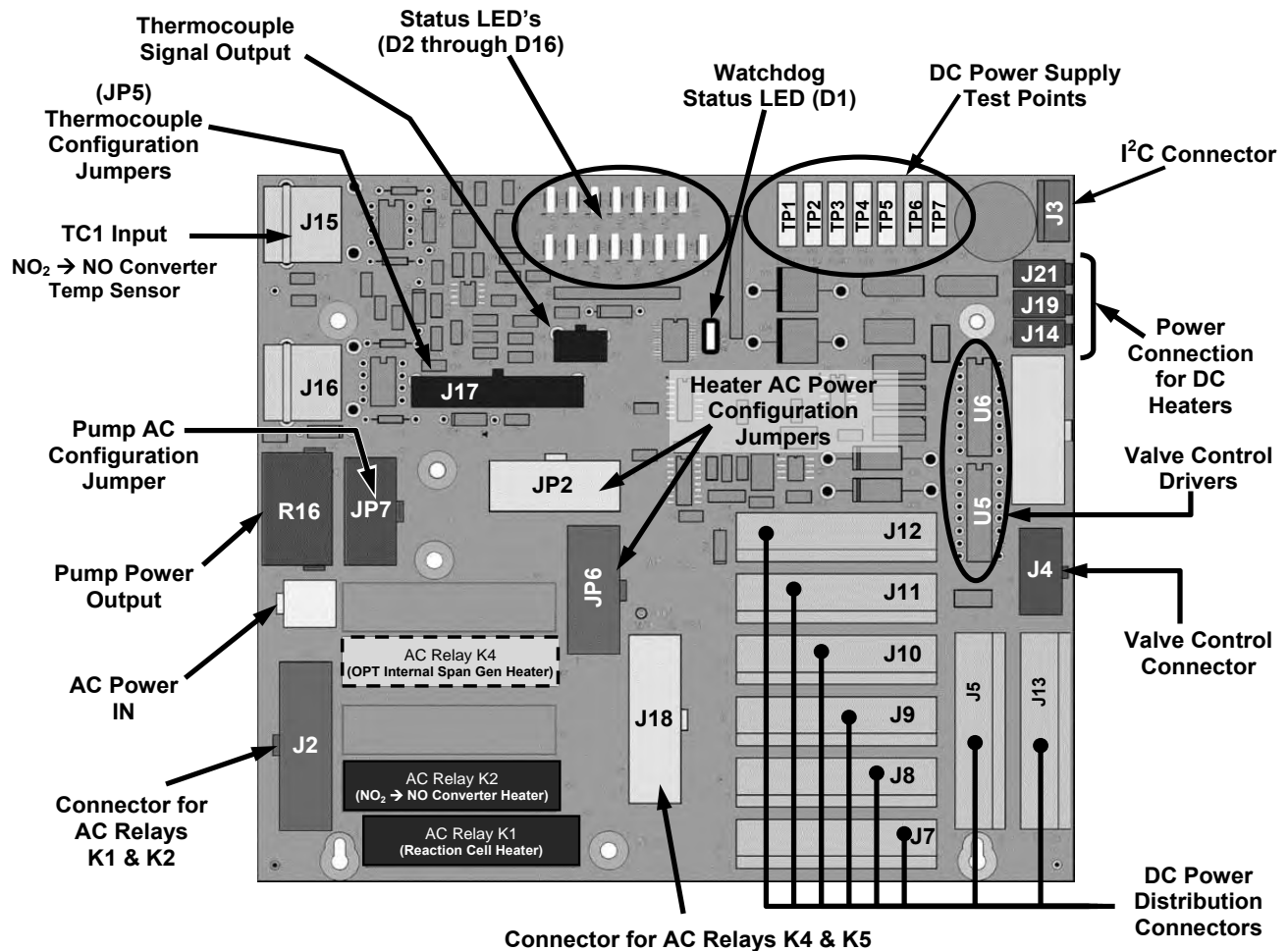


Figure 13-13: Relay PCA Layout (P/N 045230100)

#### CAUTION

#### ELECTRICAL SHOCK HAZARD

Only those relays actually required by the configuration of the T200 are populated. A protective retainer plate is installed over the ac power relay to keep them securely seated in their sockets and prevent accidental contact with those sockets that are not populated see Figure 13-14).

Never remove this retainer while the instrument is plugged in and turned on. The contacts of the AC relay sockets beneath the shield carry high AC voltages even when no relays are present.



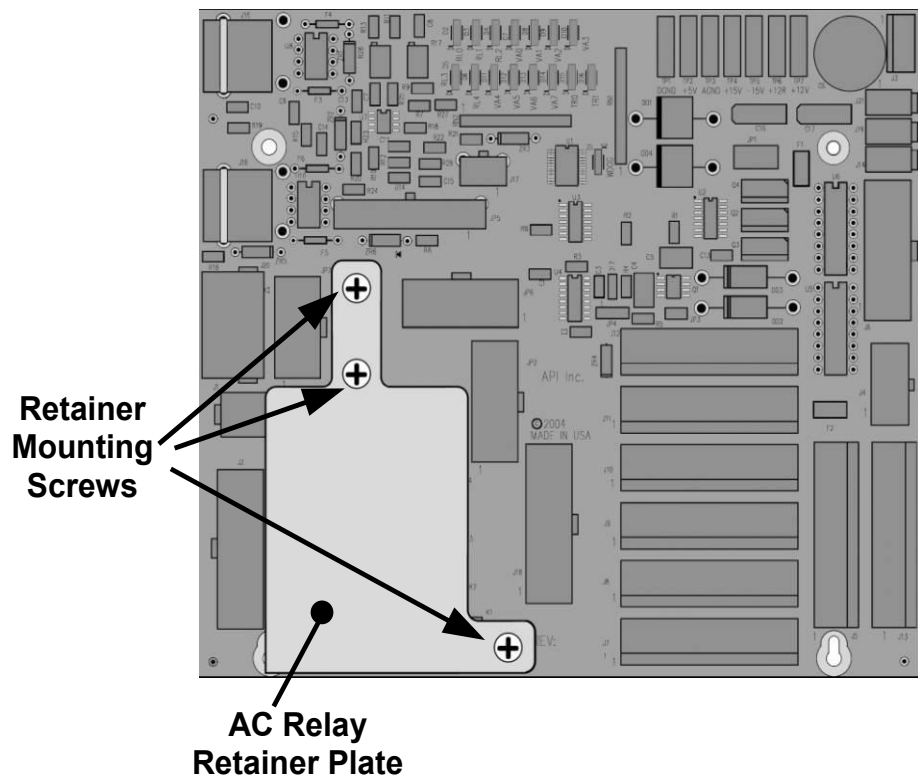


Figure 13-14: Relay PCA P/N 045230100 with AC Relay Retainer in Place

#### 13.3.4.1. STATUS LED'S

Sixteen LED's are located on the analyzer's relay PCA (some are designated "spare" and are not used) to show the current status on the various control functions performed by the relay PCA (see Figure 13-15). The LED's are described in Table 13-4).



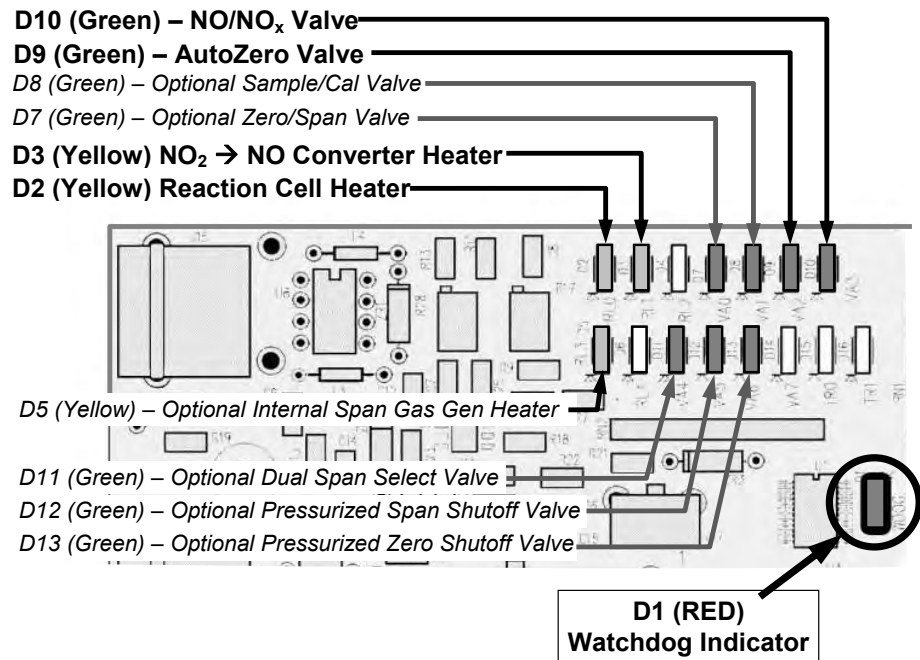


Figure 13-15: Status LED Locations – Relay PCA

Table 13-4: Relay PCA Status LED's

LED	Color	Function	Status When Lit (Energized State)	Status When Unlit (Default State)
D1	Red	Watchdog Circuit	Cycles <b>ON/OFF</b> every 3 Seconds under direct control of the analyzer's CPU.	
D2	Yellow	Reaction Cell Heater	Heating	Not Heating
D3	Yellow	NO <sub>2</sub> → NO Converter Heater	Heating	Not Heating
D4		SPARE		
D5 <sup>1</sup>	Yellow	Internal Span Gas Generator Perm Tube Oven Heater	Heating	Not Heating
D6		SPARE		
D7	Green	Zero/Span Valve	Valve <b>OPEN</b> to span gas flow	Valve <b>OPEN</b> to zero gas flow
D8	Green	Sample/Cal Valve	Valve <b>OPEN</b> to calibration gas flow	Valve <b>OPEN</b> to sample gas flow
D9	Green	Auto Zero Valve	Sample gas flow <b>BYPASSES</b> the reaction cell	Sample gas flow is routed <b>THROUGH</b> the reaction cell
D10	Green	NO/NO <sub>x</sub> Valve	Gas flow routed <b>THROUGH</b> NO <sub>2</sub> → NO converter	Gas Flow <b>BYPASSES</b> NO <sub>2</sub> → NO converter
D11 <sup>2</sup>	Green	Dual Span Gas Select Valve	Valve <b>OPEN</b> to <b>SPAN 1</b> gas inlet	Valve <b>OPEN</b> to <b>SPAN2</b> inlet
D12 <sup>3</sup>	Green	Pressurized Span Shutoff Valve	Span gas flow <b>SHUTOFF</b>	Span gas flow <b>OPEN</b>
D13 <sup>4</sup>	Green	Pressurized Zero Shutoff Valve	Zero gas flow <b>SHUTOFF</b>	Zero gas flow <b>OPEN</b>
D14 - 16		SPARE		

<sup>1</sup> Only active when the optional internal span gas generator is installed.  
<sup>2</sup> Only active when the dual pressurized span option is installed.  
<sup>3</sup> Only active when one of the pressurized span gas options is installed.  
<sup>4</sup> Only active when one of the pressurized zero gas options is installed.

### 13.3.4.2. WATCHDOG CIRCUITRY

The most important of the status LED's on the relay board is the red I<sup>2</sup>C bus watch-dog LED. It is controlled directly by the analyzer's CPU over the I<sup>2</sup>C bus. Special circuitry on the relay PCA watches the status of D1. Should this LED ever stay ON or OFF for 30 seconds, indicating that the CPU or I<sup>2</sup>C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters.

### 13.3.4.3. VALVE CONTROL

The relay board also hosts two valve driver chips, each of which can drive up four valves. The main valve assembly in the T200 is the NO/NO<sub>x</sub> - Auto-zero solenoid valve component mounted right in front of the NO<sub>2</sub> converter housing (see Figure 3-5).

- These two valves are actuated with 12 V supplied from the relay board and under the control of the CPU through the I<sup>2</sup>C bus.

Additional valve sets also controlled by the CPU via the I<sup>2</sup>C bus and the relay PCA can be included in the T200 (see Table 1-1 and Sections 3.3.2.3, 3.3.2.4, and 3.3.2.5 for descriptions of these valve sets).

### 13.3.4.4. HEATER CONTROL

For a variety of reasons such as, efficiency of certain chemical reactions, stabilization of sample gas temperature and pressure, etc., various subcomponents of the T200 are heated/cooled.

Two types of sensors are used to gather temperature data for the CPU:

- THERMISTORS:** These are used in areas where the temperature control point is at or near ambient temperature (e.g. the reaction cell temperature, internal chassis temperature).
  - Thermistors change resistance as they heat up and cool down. A DC signal is sent from the Mother board of a set voltage and current. As the thermistor changes resistance, the returning voltage rises and falls in direct relationship to the change in temperature.
  - The output signal from the thermistors is received by the motherboard, converted into digital data which is forwarded to the CPU.
- THERMOCOUPLES:** These are used where the target temperature is high such as the NO<sub>2</sub> → NO converter.
  - Thermocouples generate DC voltage that rises and falls as the thermocouple heats up and cools down.
  - This DC signal interpreted, conditioned and amplified by the Relay PCA then transmitted to the motherboard where it is also converted into digital data and forwarded to the CPU.

All of the heaters used in the T200 are AC powered which are turned ON/OFF by AC Relays located on the relay PCA in response to commands issued by the CPU.

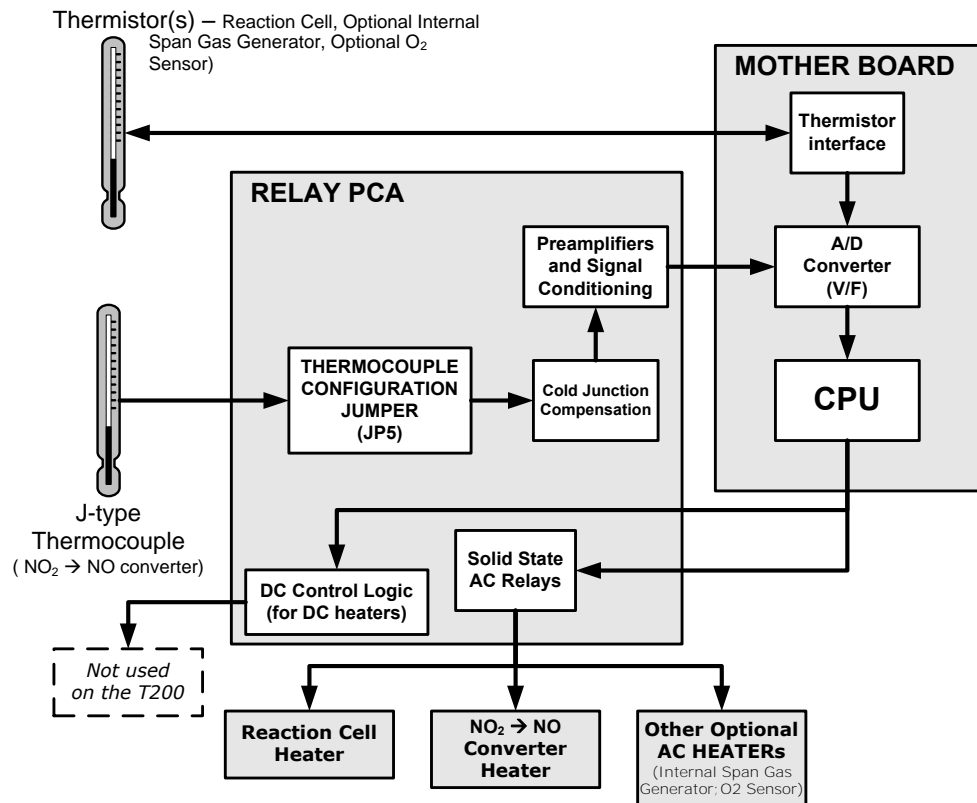


Figure 13-16: Heater Control Loop Block Diagram.

**Note**

The PMT temperature is maintained by a separate control loop that does not involve the relay PCA (see Section 13.5.2).

**13.3.4.5. THERMOCOUPLE INPUTS AND CONFIGURATION JUMPER (JP5)**

Although the relay PCA supports two thermocouple inputs, the current T200 analyzers only utilize one. It is used to sense the temperature of the NO<sub>2</sub> → NO converter.

- This single thermocouple input is plugged into the TC1 input (J15).
- TC2 (J16) is currently not used (see Figure 13-13 for location of J15 and J16).

The type and operating parameters of this thermocouple are set using a jumper plug (JP5).

The default configuration for this thermocouple is:

- Type-K
- Temperature compensated for Type-K
- Isolated

**Table 13-5: Thermocouple Configuration Jumper (JP5) Pin-Outs**

TC INPUT	JUMPER PAIR	DESCRIPTION	FUNCTION
<b>TC1</b>	<b>1 – 11</b>	<b>Gain Selector</b>	Selects preamp gain factor for J or K TC <b>OUT = K TC gain factor;</b> <i>IN = J TC gain factor</i>
	2 – 12	<i>Output Scale Selector</i>	Selects preamp gain factor for J or K TC <i>OUT = 10 mV / °C; IN = 5 mV / °C</i>
	3 – 13	<i>Type J Compensation</i>	<i>When present, sets Cold Junction Compensation for J type Thermocouple</i>
	<b>4 – 14</b>	<b>Type K Compensation</b>	When present, sets Cold Junction Compensation for K type Thermocouple
	<b>5 – 15</b>	<b>Termination Selector</b>	Selects between Isolated and grounded TC <b>IN = Isolate TC;</b> <i>OUT = Grounded TC</i>
<b>TC2</b>	<b>NOT USED</b>		

**ATTENTION****COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

The correct Thermocouple Type must be used if there is ever the need for replacement. If in doubt please consult Teledyne API Customer Service.

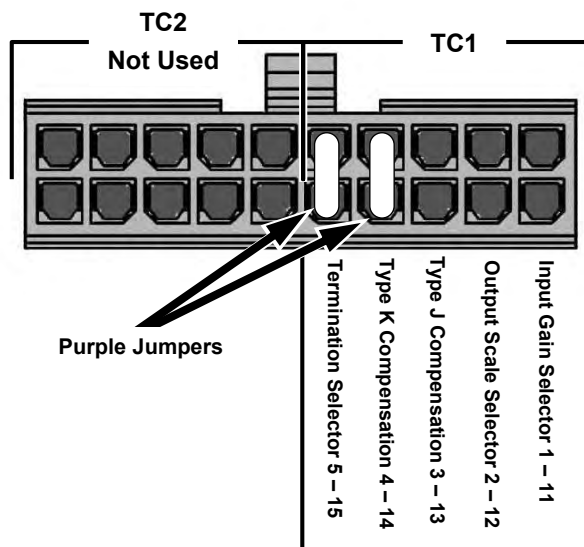


Figure 13-17: Thermocouple Configuration Jumper (JP5) Pin-Outs

## 13.4. SENSOR MODULE

The T200 sensor assembly (Figure 12-9) consists of several subassemblies, each with different tasks:

- The Photo Multiplier Tube (PMT) detects the intensity of the light from the chemiluminescence reaction between NO and O<sub>3</sub> in the reaction cell. It outputs a current signal that varies in relationship with the amount of light in the reaction cell.
- The PMT Preamplicifier PCA converts the current output by the PMT into a voltage and amplifies it to a signal strong enough to be usable by the motherboard's A → D converter. It also supplies the drive voltage and gain adjustment for the PMT's High Voltage Power Supply (HVPS)
- The Thermo-Electric Cooler (TEC) controls the temperature of the PMT to ensure the accuracy and stability of the measurements.

## 13.5. PHOTO MULTIPLIER TUBE (PMT)

The T200 uses a photo multiplier tube (Figure 12-9) to detect the amount of chemiluminescence created in the Reaction Cell.

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes.

The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased number of electrons emitted from one end of electron multiplier are collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.

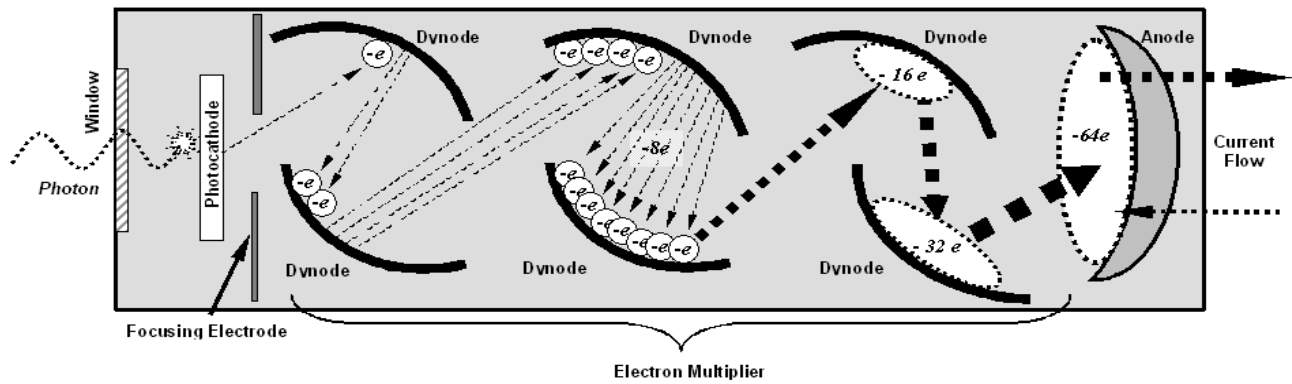


Figure 13-18: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater the number of electrons emitted from each dynode of the electron multiplier, in effect, making the PMT more sensitive and responsive to smaller variations in light intensity but also more noisy (this is referred to as “dark noise”).

- The gain voltage of the PMT used in the T200 is usually set between 400 V and 800 V.
- This parameter is viewable through the front panel as test function **HVPS** (see Section 4.1.1).
- For information on when and how to set this voltage, see Section 12.8.4.

The PMT is housed inside the PMT module assembly (see Figure 12-9). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument’s optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the TEC.

### 13.5.1. PMT PREAMPLIFIER

The PMT preamplifier board provides a variety of functions:

- It amplifies the PMT signal into a useable analog voltage (**PMTDET**) that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the NO, NO<sub>2</sub> and NO<sub>x</sub> concentrations of the gas in the sample chamber.
- It supplies the drive voltage for the HVPS.
- It includes the circuitry for switching between the two physical ranges.
- It amplifies the signal output by the PMT temperature sensor and feeds it back to the thermoelectric cooler driver PCA. This amplified signal is also sent to the Motherboard to be digitized and forwarded to the CPU. It is viewable via the front panel as the test function **PMT TEMP**.
- It provides means for adjusting the electronic signal output from the PMT by:
  - Adjusting this voltage directly the sensitivity of the PMT’s dynode array and therefore the strength of the signal output by the PMT through the use of two hexadecimal switches.
  - Directly adjusting the gain of the output signal.

**Note**

These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. See Section 12.8.4 for more information about this hardware calibration.

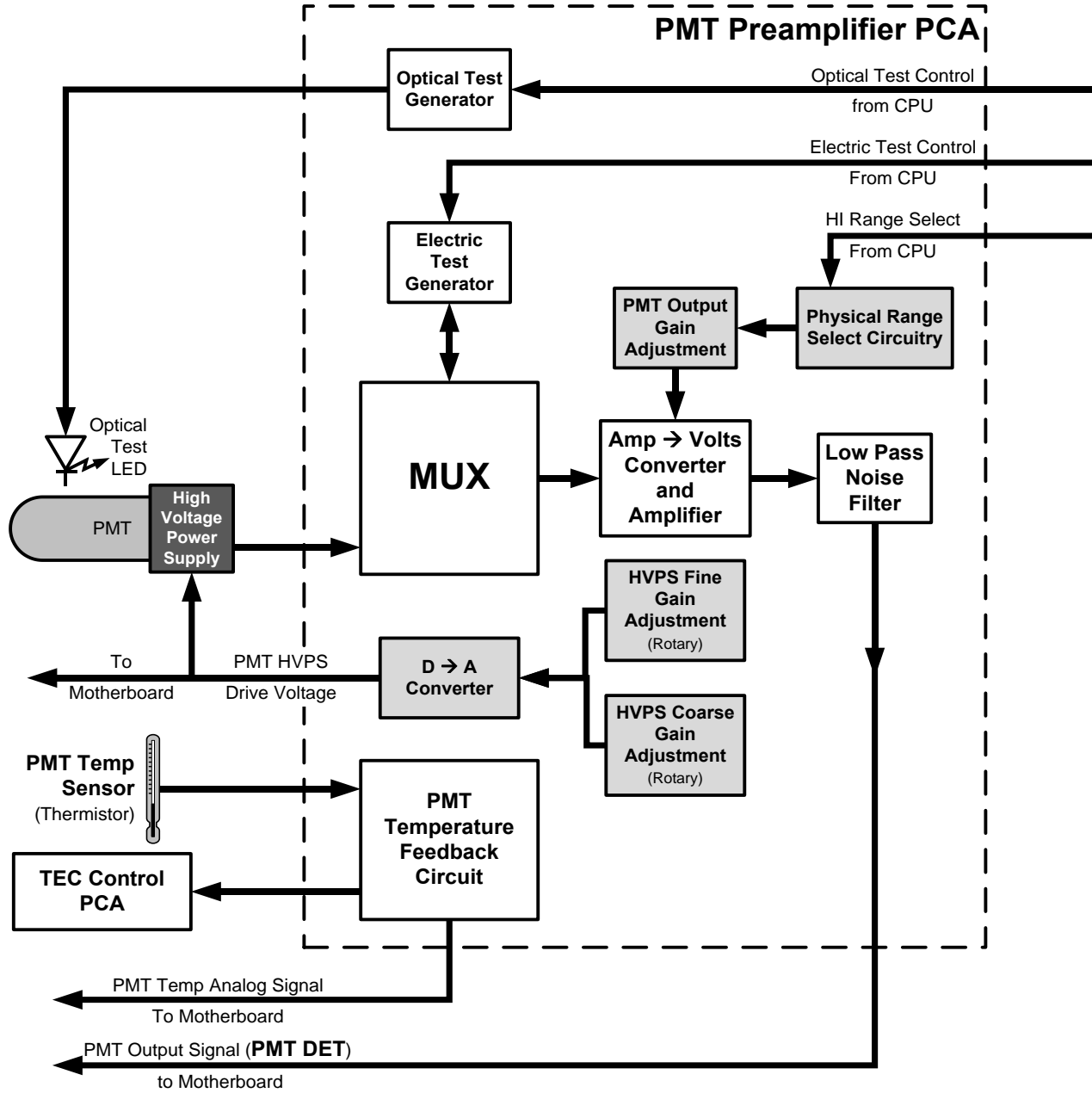


Figure 13-19: PMT Preamp Block Diagram

The PMT preamplifier PCA also operates two different tests used to calibrate and check the performance of the sensor module.

- The electrical test (**ETEST**) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector's actual signal, it is possible to test most of the signal handling and conditioning circuitry on the PMT preamplifier board. See section 12.7.12.2 for instructions on performing this test.
- The optical test (**OTEST**) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer, the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. See Section 12.7.12.1 for instructions on performing this test.

### 13.5.2. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer the PMT is, the noisier its signal becomes until the noise renders the concentration signal useless.

To alleviate this problem a special cooling system exists utilizing a type of electronic heat pump called a thermo-electric cooler (TEC). A TEC is a solid-state active heat pump which transfers heat from a heat absorbing "cool" side to a heat releasing "hot" side via a series of DC powered semiconductor junctions. The effectiveness of the pump at moving heat away from the cold side is reliant on the amount of current flowing through the semiconductor junctions and how well the heat from the hot side can be removed.

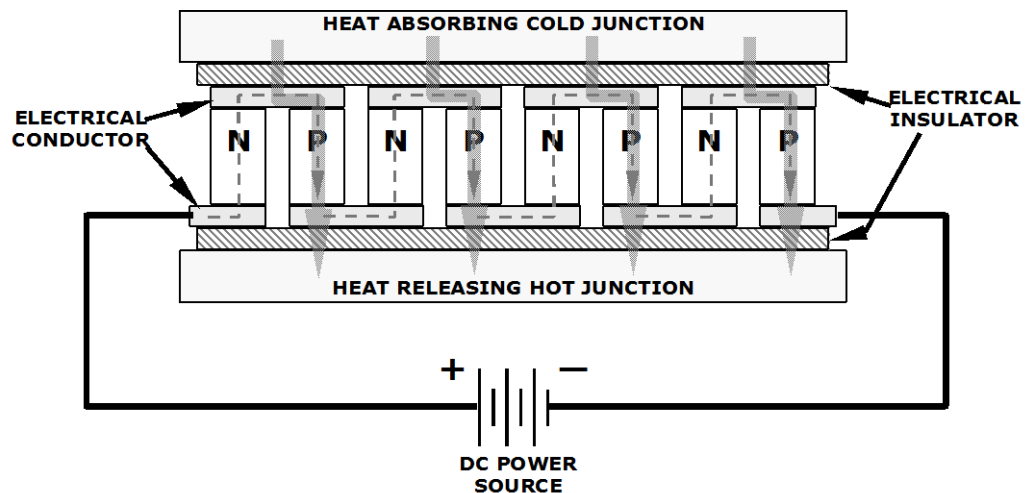
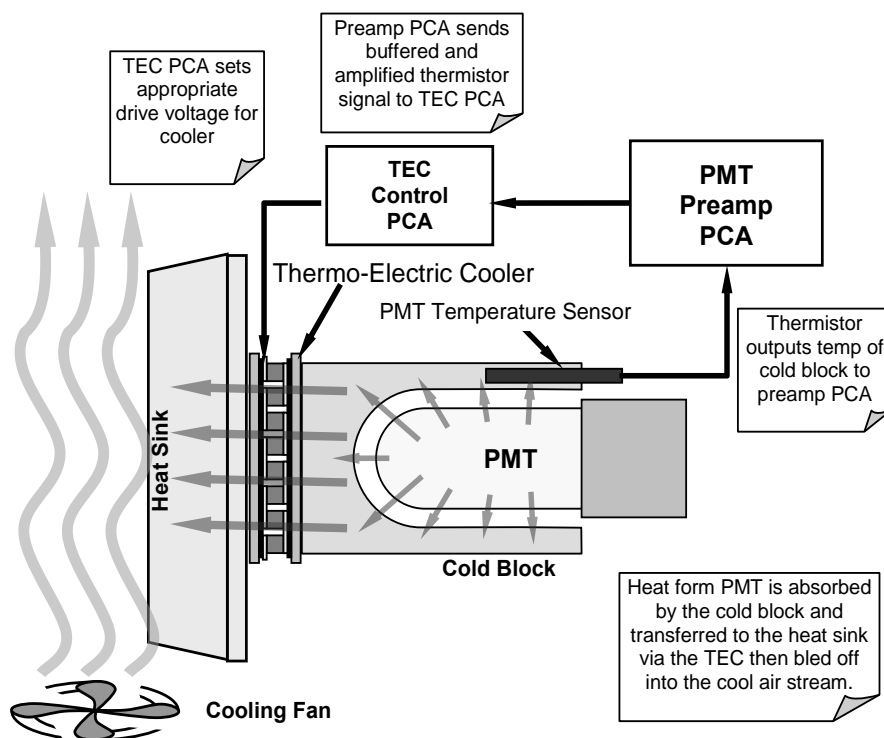


Figure 13-20: Typical Thermo-Electric Cooler

In the case of the T200, the current flow is controlled by the TEC Control PCA which adjusts the amount of current applied to the TEC based on the temperature sensed by a thermistor embedded in the PMT's cold block. The higher the temperature of the PMT, the more current is pumped through the TEC. The "hot" side of the TEC is cooled by a constant flow of ambient air that is directed across a set of heat sinks by a fan.





**Figure 13-21: PMT Cooling System Block Diagram**

The target temperature at which the TEC system keeps the PMT is approximately 8.0°C. Arriving at this temperature may take up to 30 minutes after the instrument is turned on.

The actual temperature of the PMT can be viewed via the front panel as the test function **PMT TEMP** (see Section 4.1.1).

### 13.5.2.1. TEC CONTROL BOARD

The TEC control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (see Section 10.4.5), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

- A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power.
- Four test points are also located at the top of this assembly.
- For the definitions and acceptable signal levels of these test points see 12.7.14.

## 13.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the T200 are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 12.7.6.1 for a figure and on how to test this assembly. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel.

## 13.7. POWER SUPPLY/CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50 Hz or 60Hz. Individual instruments are set up at the factory to accept any combination of these five attributes. A 6.75 amp circuit breaker is built into the **ON/OFF** switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.

- Under normal operation, the T200 draws about 1.5 A at 115 V and 2.0 A during start-up.



### **WARNING ELECTRICAL SHOCK HAZARD**

**Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.**

Power enters the analyzer through a standard International Electrotechnical Commission (IEC) 320 power receptacle located on the rear panel of the instrument. From there it is routed through the **ON/OFF** Switch located in the lower right corner of the front panel. AC Line power is stepped down and converted to DC power by two DC power supplies (PS).

- One PS provides +5 VDC (3 A) and  $\pm 15$  VDC (1.5/0.5 A) for logic and analog circuitry as well as the power for the O<sub>3</sub> generator.
- A second PS provides +12 VDC (5 A), for the PMT's thermoelectric cooler, fans and as well as the various gas stream valves (both standard and optional).

All AC and DC Voltages are distributed via the relay PCA.

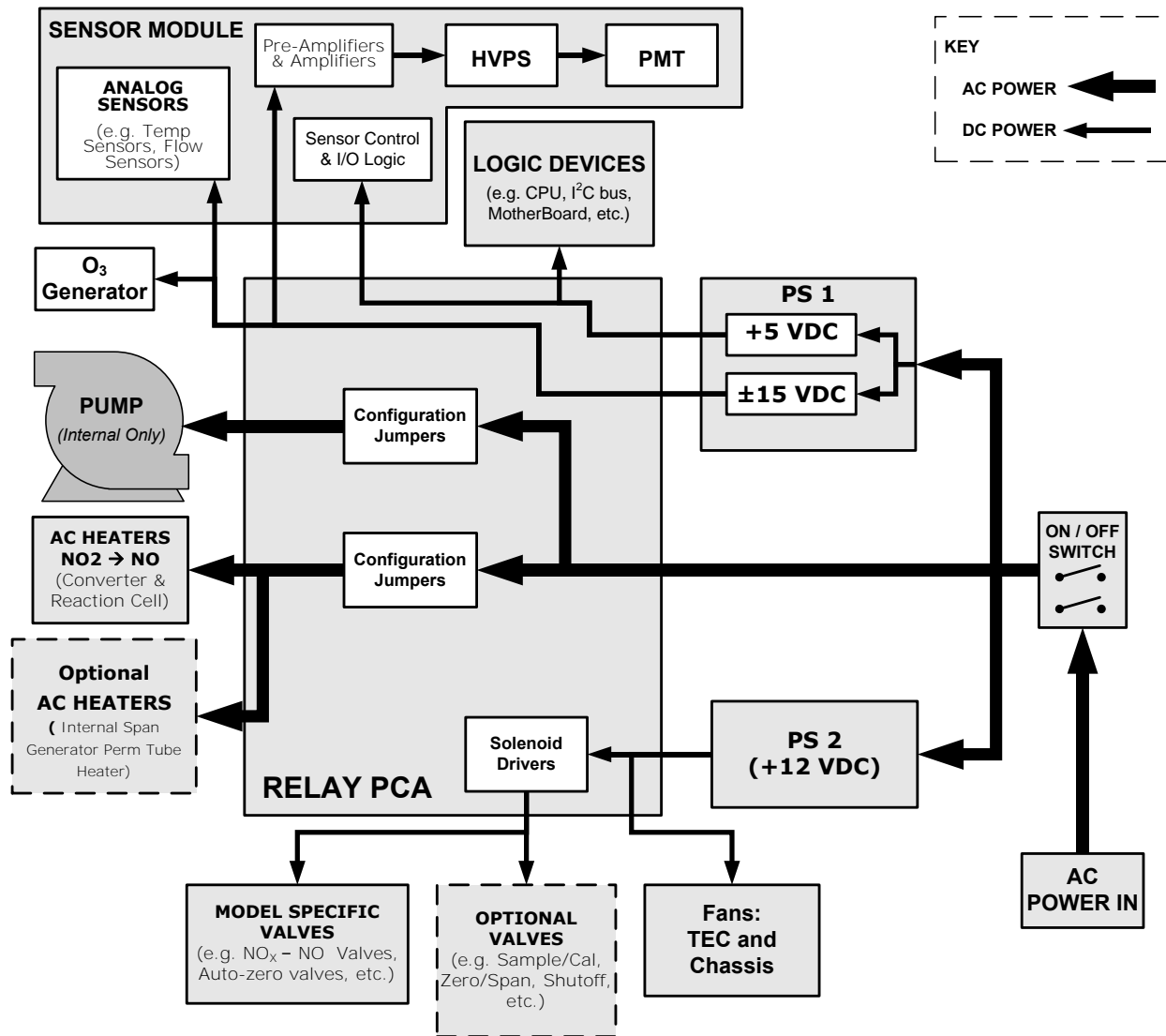


Figure 13-22: Power Distribution Block Diagram

### 13.7.1. AC POWER CONFIGURATION

The T200 analyzer's digital components will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz,. Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

However, some of the analyzer's non-digital components, such as the various internal pump options or the AC powered heaters for the NO<sub>2</sub> → NO converter the reaction cell and some of the T200's must be properly configured for the type of power being supplied to the instrument.

Configuration of the power circuits is set using several jumper sets located on the instruments relay PCA.

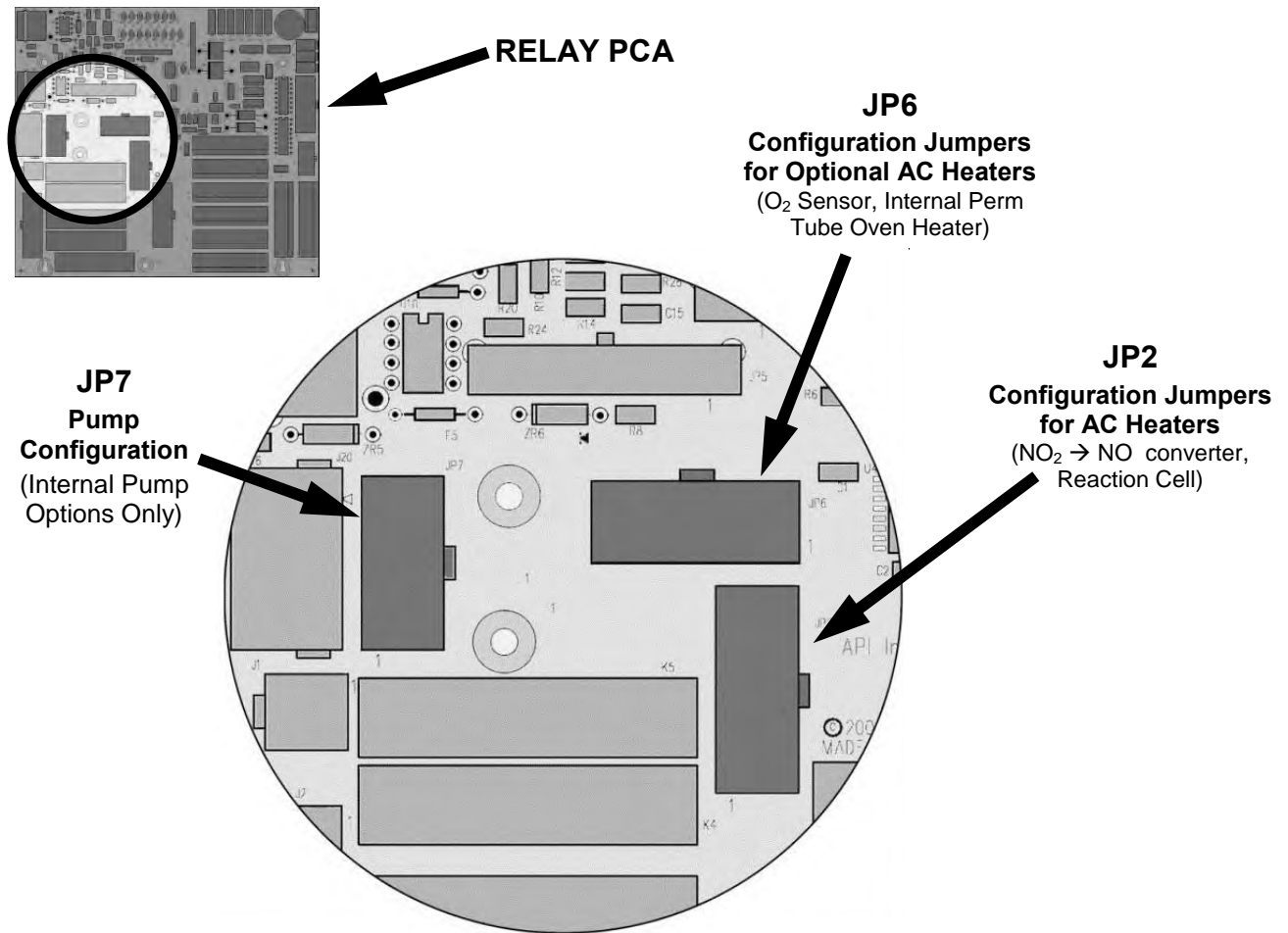


Figure 13-23: Location of AC power Configuration Jumpers

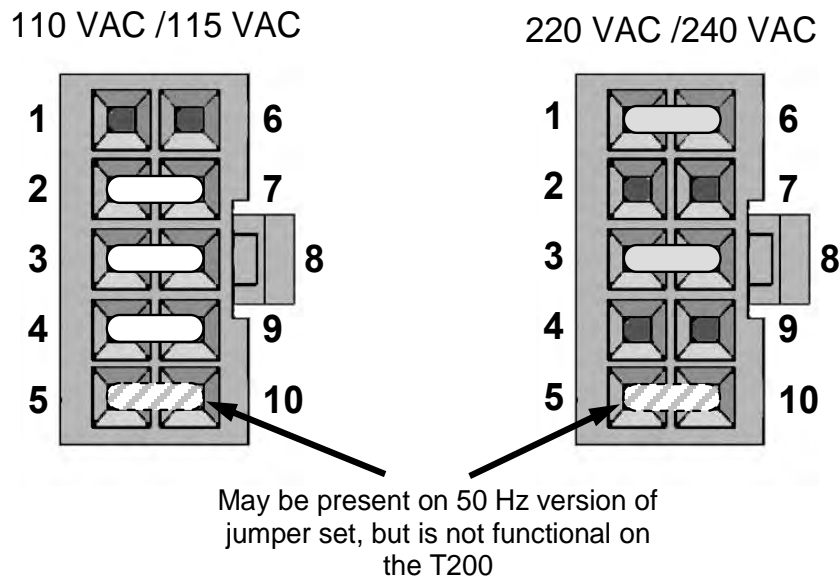
### 13.7.1.1. AC CONFIGURATION – INTERNAL PUMP (JP7)

If your T200 includes an internal pump the following table, jumper set JP7 is used to configure the power supplied to it as shown in Figure 13-24.

**Table 13-6: AC Power Configuration for Internal Pumps (JP7)**

LINE POWER	LINE FREQUENCY	JUMPER COLOR	FUNCTION	JUMPER BETWEEN PINS
110VAC 115 VAC	60 HZ	WHITE	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
	50 HZ <sup>1</sup>	BLACK	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
220VAC 240 VAC	60 HZ	BROWN	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8
	50 HZ <sup>1</sup>	BLUE	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8

<sup>1</sup> A jumper between pins 5 and 10 may be present on the jumper plug assembly, but has no function on the Model T200.



**Figure 13-24: Pump AC Power Jumpers (JP7)**

13.7.1.2. AC CONFIGURATION – STANDARD HEATERS (JP2)

Power configuration for the AC the standard heaters is set using Jumper set JP2 (see Figure 13-25 for the location of JP2).

Table 13-7: Power Configuration for Standard AC Heaters (JP2)

LINE VOLTAGE	JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
110 VAC / 115 VAC 50Hz & 60 Hz	WHITE	Reaction Cell / Sample Chamber Heaters	1 to 8	Common
			2 to 7	Neutral to Load
			4 to 9	Neutral to Load
		Moly Converter	3 to 10	Common
			4 to 9	Neutral to Load
			6 to 11	Neutral to Load
220 VAC / 240 VAC 50Hz & 60 Hz	BLUE	Reaction Cell / Sample Chamber Heaters	1 to 7	Load
		Moly Converter	3 to 9	Load

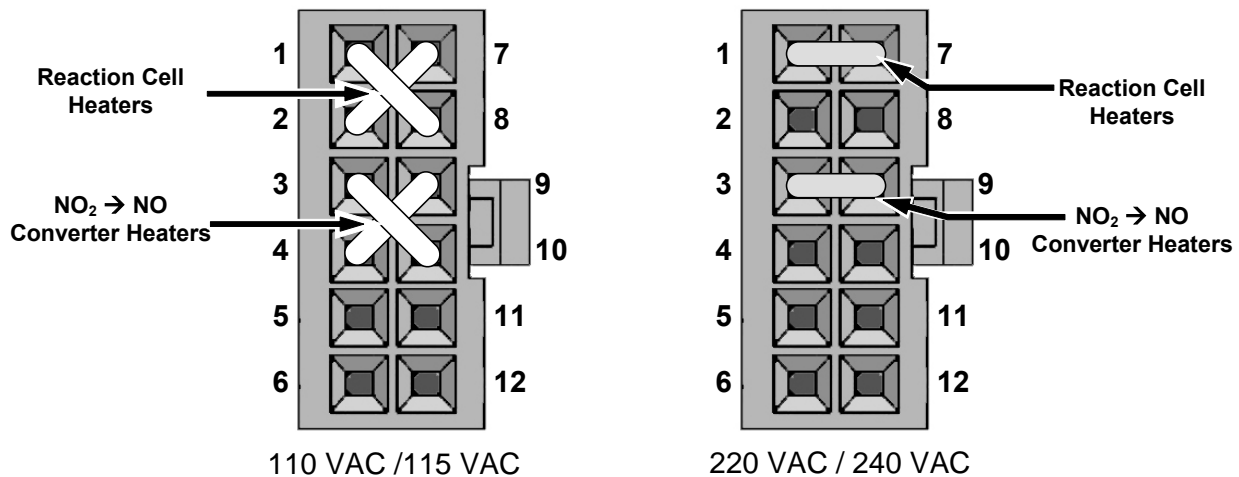


Figure 13-25: Typical Set Up of AC Heater Jumper Set (JP2)

13.7.1.3. AC CONFIGURATION – HEATERS FOR OPTION PACKAGES (JP6)

The IZS valve option includes an AC heaters that maintain an optimum operating temperature for key components of those options. Jumper set JP6 is used to connect the heaters associated with those options to AC power. Since these heaters work with either 110/155 VAC or 220/240 VAC, there is only one jumper configuration.

Table 13-8: Power Configuration for Optional Heaters (JP6)

JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
RED	Internal Permeation Tube Oven Heater	1 to 8	Common
		2 to 7	Neutral to Load

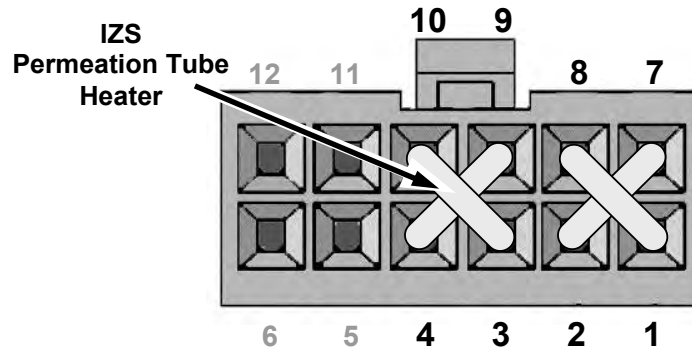


Figure 13-26: Typical Jumper Set (JP2) Set Up of Heaters

### 13.8. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touchscreen display. The LCD display is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.

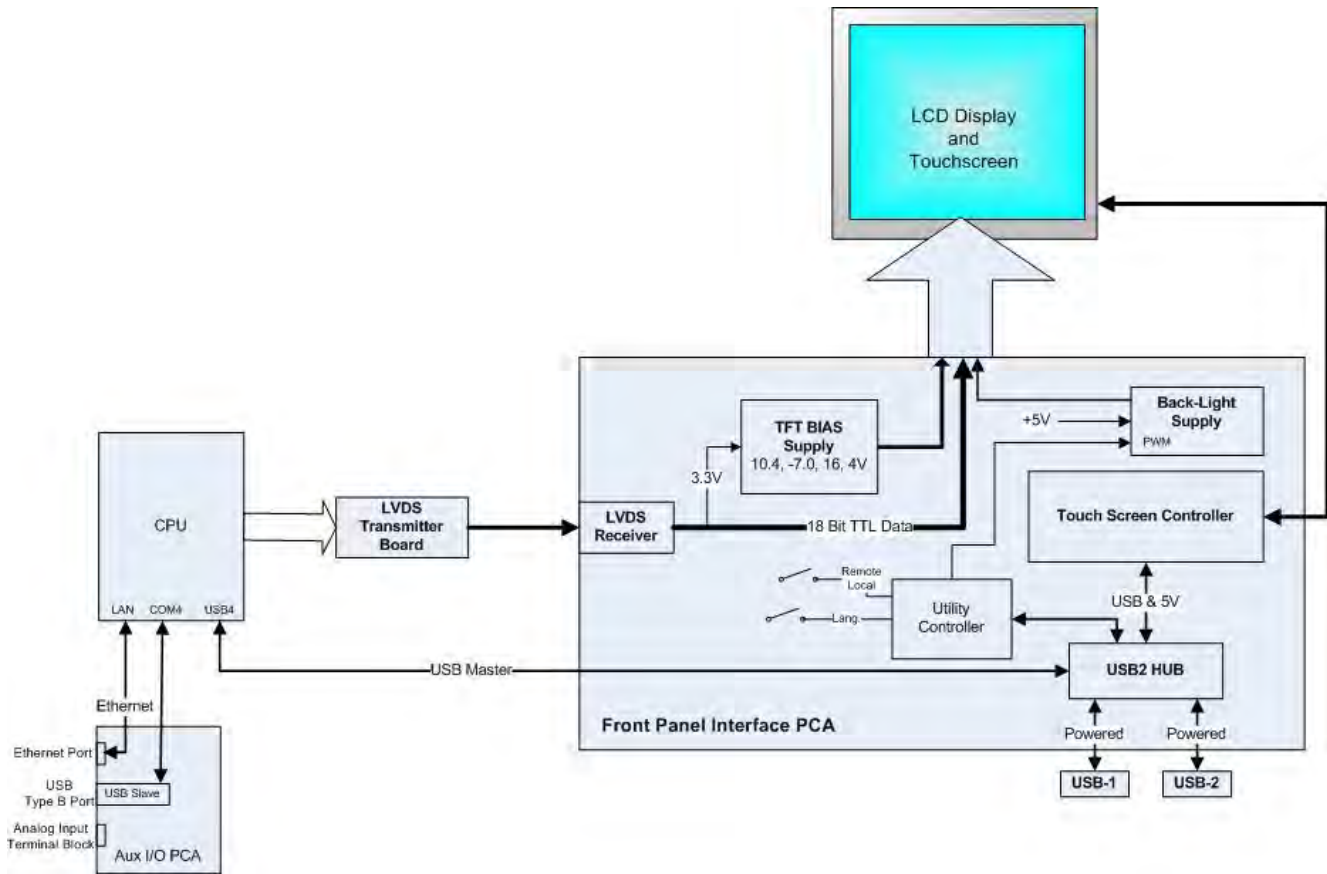


Figure 13-27: Front Panel and Display Interface Block Diagram



### 13.8.1. LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA.

### 13.8.2. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE PCA

The front panel interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- a USB hub that is used for communications with the touchscreen controller and the two front panel USB device ports
- the circuitry for powering the display backlight

## 13.9. SOFTWARE OPERATION

The T200 has a high performance, VortexX86-based microcomputer running WINDOWS CE. Inside the WINDOWS CE shell, special software developed by Teledyne API interprets user commands via the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the sample gas.

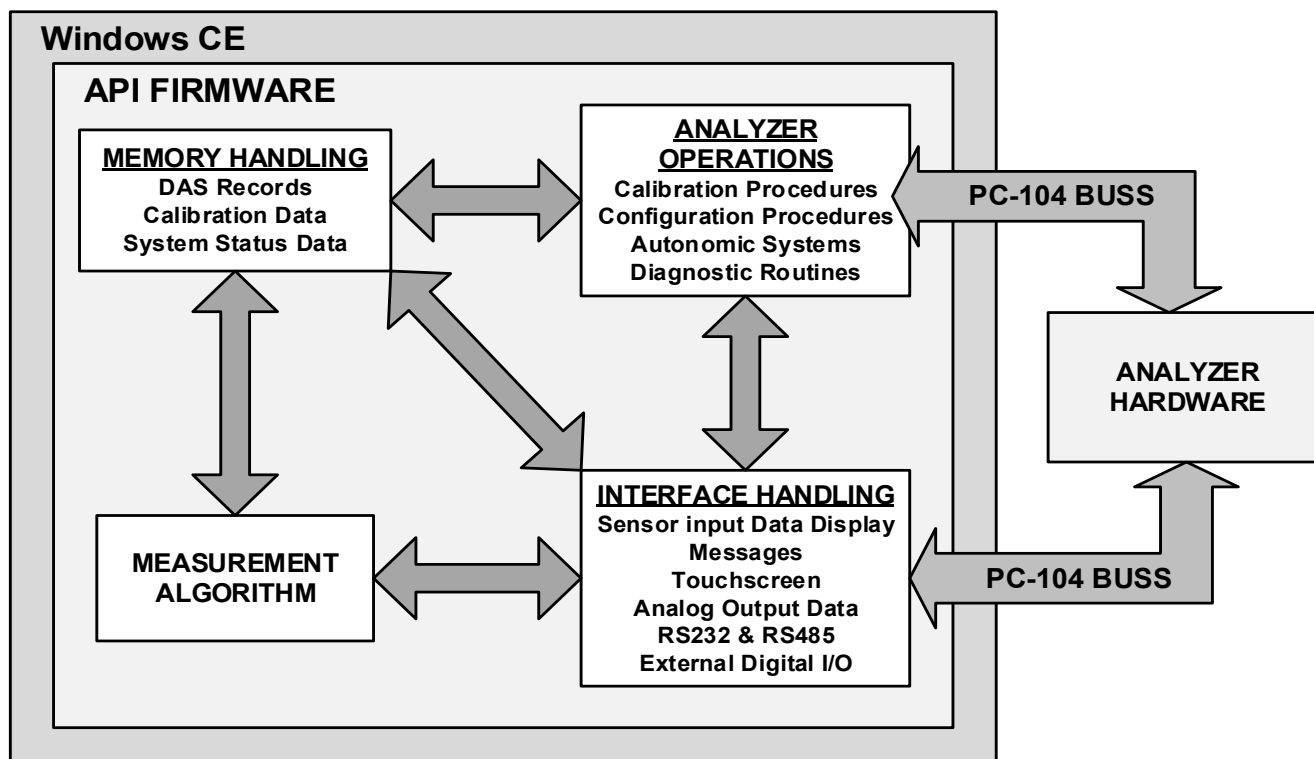


Figure 13-28: Basic Software Operation

### 13.9.1. ADAPTIVE FILTER

The T200 NO<sub>x</sub> analyzer software processes sample gas concentration data through a built-in adaptive filter. Unlike other analyzers that average the output signal over a fixed time period, the T200 averages over a defined number of samples, with samples being about 8 seconds apart (reflecting the switching time of 4 s each for NO and NO<sub>x</sub>). This technique is known as boxcar filtering. During operation, the software may automatically switch between two different filters lengths based on the conditions at hand.

During constant or nearly constant concentrations, the software, by default, computes an average of the last 42 samples, or approximately 5.6 minutes. This provides smooth and stable readings and averages out a considerable amount of random noise for an overall less noisy concentration reading.

If the filter detects rapid changes in concentration the filter reduces the averaging to only 6 samples or about 48 seconds to allow the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must differ from the average in the long filter by at least 50 ppb. Second, the instantaneous concentration must differ from the average in the long filter by at least 10% of the average in the long filter.

### 13.9.2. TEMPERATURE/PRESSURE COMPENSATION (TPC)

The T200 software includes a feature that compensates for some temperature and pressure changes that might affect measurement of NO and NO<sub>x</sub> concentrations.

When the TPC feature is enabled (default setting), the analyzer divides the value of the PMT output signal (**PMTDET**) by a value called **TP\_FACTOR**, which is calculated using the following four parameters:

- **BOX TEMP**: The temperature inside the analyzer's case measured in K. This is typically about 5 K higher than room temperature.
- **RCELL TEMP**: The temperature of the reaction cell, measured in K.
- **RCEL**: The pressure of the gas in the vacuum manifold, measured in in-Hg-A.
- **SAMP**: The pressure of the sample gas before it reaches the reaction cell, measured in in-Hg-A. This measurement is ~1 in-Hg-A lower than atmospheric pressure.

As **RCEL TEMP**, **BOX TEMP**, **RCELL** and **SAMP** pressure increase, the value of **TP\_FACTOR** increases and, hence, the **PMTDET** value decreases. These adjustments are meant to counter-act changes in the concentrations caused by these parameters.

- The current value of all four of these measurements are viewable as **TEST FUNCTIONS** through the instrument's front panel display (see Section 4.1.1).
- The preset gain parameters are set at the factory and may vary from analyzer to analyzer. The TPC feature is enabled or disabled by setting the value of the variable **TPC\_ENABLE** (see Section 5.8).

### 13.9.3. CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in software. During instrument calibration, (see Sections 9 and 10) the user enters expected values for zero and span via the front panel touchscreen control and commands the instrument to make readings of calibrated sample gases for both levels.

- The readings taken are adjusted, linearized and compared to the expected values.
- With this information, the software computes values for instrument slope and offset and stores these values in memory for use in calculating the NO<sub>x</sub>, NO and NO<sub>2</sub> concentrations of the sample gas.

The instrument slope and offset values recorded during the last calibration can be viewed via the instrument's front panel (see Section 4.1.1).

# GLOSSARY

Term	Description/Definition
10BaseT	an Ethernet standard that uses twisted ("T") pairs of copper wires to transmit at 10 megabits per second (Mbps)
100BaseT	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	<i>Assembly</i>
CAS	<i>Code-Activated Switch</i>
CD	<i>Corona Discharge</i> , a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	<i>Converter Efficiency</i> , the percentage of the total amount that is actually converted (e.g., light energy into electricity; NO <sub>2</sub> into NO, etc.)
CEM	<i>Continuous Emission Monitoring</i>
Chemical elements that may be included in this document:	
CO <sub>2</sub>	carbon dioxide
C <sub>3</sub> H <sub>8</sub>	propane
CH <sub>4</sub>	methane
H <sub>2</sub> O	water vapor
HC	general abbreviation for hydrocarbon
HNO <sub>3</sub>	nitric acid
H <sub>2</sub> S	hydrogen sulfide
NO	nitric oxide
NO <sub>2</sub>	nitrogen dioxide
NO <sub>x</sub>	nitrogen oxides, here defined as the sum of NO and NO <sub>2</sub>
NO <sub>y</sub>	nitrogen oxides, often called odd nitrogen: the sum of NO <sub>x</sub> plus other compounds such as HNO <sub>3</sub> (definitions vary widely and may include nitrate (NO <sub>3</sub> ), PAN, N <sub>2</sub> O and other compounds as well)
NH <sub>3</sub>	ammonia
O <sub>2</sub>	molecular oxygen
O <sub>3</sub>	ozone
SO <sub>2</sub>	sulfur dioxide
cm <sup>3</sup>	metric abbreviation for <i>cubic centimeter</i> (replaces the obsolete abbreviation "cc")
CPU	<i>Central Processing Unit</i>
DAC	<i>Digital-to-Analog Converter</i>
DAS	<i>Data Acquisition System</i>
DCE	<i>Data Communication Equipment</i>
DFU	<i>Dry Filter Unit</i>

Term	Description/Definition
DHCP	<i>Dynamic Host Configuration Protocol.</i> A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DIAG	<i>Diagnostics</i> , the diagnostic settings of the analyzer.
DOM	<i>Disk On Module</i> , a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
DOS	<i>Disk Operating System</i>
DRAM	<i>Dynamic Random Access Memory</i>
DR-DOS	<i>Digital Research DOS</i>
DTE	<i>Data Terminal Equipment</i>
EEPROM	<i>Electrically Erasable Programmable Read-Only Memory</i> also referred to as a FLASH chip or drive
ESD	<i>Electro-Static Discharge</i>
EATEST	<i>Electrical Test</i>
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	<i>Fluorinated Ethylene Propylene</i> polymer, one of the polymers that Du Pont markets as <i>Teflon</i> <sup>®</sup>
Flash	non-volatile, solid-state memory
FPI	<i>Fabry-Perot Interface</i> : a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	<i>Gas Filter Correlation</i>
I <sup>2</sup> C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	<i>Integrated Circuit</i> , a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	<i>Internet Protocol</i>
IZS	<i>Internal Zero Span</i>
LAN	<i>Local Area Network</i>
LCD	<i>Liquid Crystal Display</i>
LED	<i>Light Emitting Diode</i>

Term	Description/Definition
LPM	<i>Liters Per Minute</i>
MFC	<i>Mass Flow Controller</i>
M/R	<i>Measure/Reference</i>
NDIR	<i>Non-Dispersive Infrared</i>
MOLAR MASS	<p>the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance.</p> <p>EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams.</p> <p>Atomic weights can be found on any Periodic Table of Elements.</p>
NDIR	<i>Non-Dispersive Infrared</i>
NIST-SRM	<i>National Institute of Standards and Technology - Standard Reference Material</i>
PC	<i>Personal Computer</i>
PCA	<i>Printed Circuit Assembly</i> , the PCB with electronic components, ready to use
PC/AT	<i>Personal Computer / Advanced Technology</i>
PCB	<i>Printed Circuit Board</i> , the bare board without electronic component
PFA	<i>Per-Fluoro-Alkoxy</i> , an inert polymer; one of the polymers that <i>Du Pont</i> markets as <i>Teflon</i> <sup>®</sup>
PLC	<i>Programmable Logic Controller</i> , a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	<i>Programmable Logic Device</i>
PLL	<i>Phase Lock Loop</i>
PMT	<i>Photo Multiplier Tube</i> , a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	<i>Part Number</i>
PSD	<i>Prevention of Significant Deterioration</i>
PTFE	<i>Poly-Tetra-Fluoro-Ethylene</i> , a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that <i>Du Pont</i> markets as <i>Teflon</i> <sup>®</sup>
PVC	<i>Poly Vinyl Chloride</i> , a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	<i>Storage and Retrieval of Aerometric Data</i>

Term	Description/Definition
SLAMS	<i>State and Local Air Monitoring Network Plan</i>
SLPM	<i>Standard Liters Per Minute of a gas at standard temperature and pressure</i>
STP	<i>Standard Temperature and Pressure</i>
TCP/IP	<i>Transfer Control Protocol / Internet Protocol, the standard communications protocol for Ethernet devices</i>
TEC	<i>Thermal Electric Cooler</i>
TPC	<i>Temperature/Pressure Compensation</i>
USB	<i>Universal Serial Bus: a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop</i>
VARS	<i>Variables, the variable settings of the instrument</i>
V-F	<i>Voltage-to-Frequency</i>
Z/S	<i>Zero / Span</i>

# INDEX

## A

AC Power, 19, 322, 324  
  **115 VAC**, 324  
  **50 HZ**, 324  
  60 Hz, 19, 248, 322, 324  
AIN, 118  
**AMBIENT ZERO/SPAN VALVE OPTION**, 53  
AMBIENT ZERO/SPAN VALVE OPTION  
  Flow Diagram, 56  
  INTERNAL PNEUMATICS, 56  
  Valve States, 56  
Ambient Zero/Span Valve Options  
  Rear Panel, 54  
Ammonia (NH<sub>3</sub>), 63  
**ANALOG CAL WARNING**, 66, 77, 145  
Analog Inputs, 118  
Analog Outputs, 19, 34, 35, 36, 38, 76, 79, 80, 82,  
  83, 102, 235, 251, 308  
  AIN Calibration, 118  
  Configuration & Calibration, 80, 106, 107, 108, 109,  
  110, 112, 114, 116, 117, 118  
  *Automatic*, 27, 79, 110  
  *Manual-Current Loop*, 113, 115  
  *MANUAL-VOLTAGE*, 111  
  Converting Voltage to Current Output, 36  
  Current Loop, 83  
  Electronic Range Selection, 85, 107  
  IND Mode Assignments, 86  
  **OUTPUT LOOP-BACK**, 308  
  Reporting Range, 69, 75, 76, 79  
  Test Channel, 34, 35, 120, 235, 251, 308  
APICOM, 124, 169  
  and DAS, 147, 149, 151, 154, 159, 161, 163, 165, 167  
  and Ethernet, 129  
  and Failure Prediction, 209  
Approvals, 19  
ATIMER, 149, 154, 156  
AUTO, 89, 177  
AutoCal, 20, 76, 79, 177, 197, 198, 199  
AutoZero, 214, 232, 242, 247, 248, 275, 287, 293,  
  295, 299  
  Pneumatic Flow, 288, 303  
  Test Function, 75  
  Valve, 76, 120, 187, 213, 232, 235, 247, 292, 293, 312  
  Warnings, 66, 247  
AUTOZERO  
  WARNINGS, 145  
**AZERO**, 66, 75, 77, 150, 209, 230, 232, 248, 287,  
  293  
  DAS Parameter, 150  
AZERO WARN, 66, 77

## B

Baud Rate, 138

**BOX TEMP**, 66, 76, 77, 120, 145, 235  
**BOX TEMP WARNING**, 66, 77, 145

## C

CAL Button, 78, 280  
CAL\_ON\_NO2, 100  
CALCHEK, 150  
CALDAT, 150  
Calibration  
  AIN, 118  
  Analog Outputs, 27, 79, 110  
  ANALOG OUTPUTS  
    *Current Loop*, 113, 115  
    *VOLTAGE*, 111  
  Initial Calibration  
    *Basic Configuration*, 68, 69, 71  
  Calibration Checks, 181, 182, 194  
  Calibration Gases, 179  
    Span Gas, 49, 51, 55, 57, 58, 68, 70, 82, 102, 177,  
    178, 179, 180, 182, 184, 190, 195, 199, 280  
    *Dilution Feature*, 92  
    Standard Reference Materials (SRM's)  
      *NO<sub>x</sub>/NO Span Gas*, 49, 180  
    Zero Air, 30, 48, 51, 177, 178, 179, 182, 199  
  Calibration Mode, 78  
**CALS BUTTON**, 78, 193, 280  
**CALZ Button**, 78, 193  
**CANNOT DYN SPAN**, 66, 77, 145  
**CANNOT DYN ZERO**, 66, 77, 145  
chemiluminescence, 15, 68, 248, 283, 284, 286,  
  287, 288, 289, 290, 293, 294, 303, 316  
Chemiluminescence, 284, 285, 293, 294, 316  
Circuit Breaker, 321  
**CLOCK\_ADJ**, 97, 100  
CO<sub>2</sub>, 49, 68, 180  
COMM PORT  
  Default Settings, 43  
**COMM Ports**, 124  
  and DAS System, 163  
  Baud Rate, 126  
  **COM1**, 44, 140  
  **COM2**, 44, 124, 140  
  Communication Modes, 124, 125  
  Machine ID, 46  
  Parity, 124, 138  
  Testing, 126  
**CONC**, 150  
**CONC Button**, 100, 253, 280  
CONC\_PRECISION, 100  
Concentration Field, 27  
**CONFIG INITIALIZED**, 66, 77  
Continuous Emission Monitoring (CEM), 91  
Control Buttons Definition Field, 27  
Control Inputs, 38, 177, 197, 254, 281, 308  
  SPAN\_CAL 1, 254



ZERO\_CAL, 254  
**CONV TEMP WARNING**, 66, 77, 145  
 CPU, 42, 43, 66, 77, 97, 105, 118, 228, 231, 233,  
 236, 248, 256, 257, 303, 304, 305, 308, 309, 310,  
 312, 322, 328  
 Analog to Digital Converter, 66, 77, 105, 252, 305, 308  
 STATUS LED'S, 236  
 Critical Flow Orifices, 223, 293, 294, 295  
 CriticalflowOrifices, 295  
 CriticalFlowOrifices, 281, 294  
 Current Loop Outputs, 34, 36, 83, 113, 115  
 Converting from Voltage Output, 36  
 Manual Calibration, 113

## D

DAS System, 27, 66, 73, 76, 77, 79, 96, 230  
 and APICOM, 166, 168  
 and Terminal Emulation Programs, 168  
 Channel Names, 155  
 Channels, 148, 152  
   *CALCHEK*, 150  
   *CALDAT*, 150  
   **CONC**, 150  
   *Defaults*, 150  
   *DIAG*, 150  
   *HIRES*, 150  
 Compact Data Report, 165  
 Default Settings, 150  
 HOLD OFF, 100, 149, 164  
**Number of Records**, 149, 162  
 Parameters, 148, 149, 157  
   *AZERO*, 150  
   *HVPS*, 150  
   **NXCNC1**, 154  
   *PMTDET*, 149  
   *STABIL*, 150  
 Precision, 157  
**Report Period**, 149, 160, 165  
 Sample Mode  
   *AVG*, 157, 158, 159, 161  
   *INST*, 157, 158, 159, 161  
   *MAX*, 157  
   *MIN*, 157, 158, 159, 161  
   *SDEV*, 157, 158, 159, 161  
 Sample Period, 160  
 Starting Date, 165  
 Store Number of Samples, 157, 158, 159, 161  
 Triggering Events, 148, 149, 156  
   *ATIMER*, 149, 154, 156  
   *EXITZR*, 156  
   *SLPCHG*, 150, 156  
 DAS\_HOLD\_OFF, 100  
**DATA INITIALIZED**, 66, 77  
 DB-25M, 18  
 DB-9F, 18  
 DC Power, 37, 38, 249, 250, 321  
 DC Power Test Points, 249  
 Default Settings  
   COMM PORT, 43  
   **DAS**, 149, 150  
   Hessen Protocol, 141, 145  
   **VARS**, 100

Desorber  
   HNO<sub>3</sub>, 62  
 DHCP, 131  
 DIAG  
   DAS Channel, 150  
**DIAG AIO**, 102  
**DIAG AOUT**, 102  
**DIAG ELEC**, 102  
**DIAG FCAL**, 102  
**DIAG I/O**, 102  
**DIAG OPTIC**, 102  
**DIAG TCHN**, 102  
**DIAGNOSTIC MENU (DIAG)**, 80, 93, 94, 95, 251  
   **Accessing**, 103  
   AIN Calibrated, 105  
   AIN CALIBRATED, 118  
   Analog I/O  
     **AOUT CALIBRATED Configuration**, 105, 109  
     *CONC\_OUT\_1*, 105  
     *CONC\_OUT\_2*, 105  
     *CONC\_OUT\_3*, 105  
   Analog I/O Configuration, 102, 106, 107, 108, 109, 110,  
     112, 114, 116, 117, 118  
   Analog Output Step Test, 102, 251  
   Electrical Test, 102  
   Flow Calibration, 102  
   Optic Test, 102  
   OZONE GEN OVERRIDE, 102  
   Signal I/O, 102  
   SIGNAL I/O, 233, 234, 236, 250, 252, 253, 254, 309  
   Test Chan Ouptut, 102  
   Test Output, 105  
   **TEST OUTPUT**, 308  
 Diagnostics, 209  
 Dilution Ratio, 49  
 Display Precision, 100  
 DUAL, 177  
 DYN\_SPAN, 100  
 DYN\_ZERO, 100  
 Dynamic Span, 20, 100  
 Dynamic Zero, 20, 100

## E

EEPROM  
   Disk on Module, 159, 230  
 Electrical Connections  
   AC Power, 322, 323  
   Analog Outputs, 34, 35, 83  
     *Current Loop*, 36, 113  
     *Voltage Ranges*, 111  
   Control Inputs, 38, 254  
   Ethernet, 80, 129  
   Modem, 172, 257  
   Multidrop, 47  
   Serial/COMM Ports, 41, 43  
 Electrical Test, 102, 243, 266, 319  
 Electro-Static Discharge, 23, 44  
**ENTR Button**, 80, 95, 161, 202, 207  
 Environmental Protection Agency (EPA)  
   Calibration, 49

Environmental Protection Agency(EPA), 20, 49,  
178, 180  
Calibration, 68, 78, 177, 180  
EPA Equivalency  
  *Software Settings*, 20  
EATEST, 278  
Ethernet, 73, 129  
  Configuration  
  *using DHCP*, 131  
  DHCP, 131  
  HOSTNAME, 133  
Exhaust Gas, 30  
**Exhaust Gas Outlet**, 30, 52, 55, 59  
Exhaust Manifold, 61  
**EXIT Button**, 80  
EXITZR, 156

## F

Final Test and Validation Data Sheet, 24, 67, 209  
Flash Chip, 304  
flow control assemblies, 293  
Flow Diagram  
  Pressurized Span Gas Inlet Option, 59  
  Pressurized Zero Air Inlet, 59  
**FROM DRYER OUTLET**, 60  
Front Panel, 25, 281, 328  
  Concentration Field, 27  
  **Display**, 102, 120, 230, 231  
  Message Field, 27  
  Mode Field, 27  
  Status LED's, 27, 147  
  Touchscreen Definition Field, 27  
**FRONT PANEL WARN**, 145

## G

g  
  Temperature, 76  
Gas Inlets, 231  
  Sample, 30  
  **Span**, 30  
  SPAN, 53, 57  
  ZERO AIR, 53, 55, 57, 60  
  **ZERO AIR**, 30  
Gas Outlets, 33, 68  
  Exhaust, 30, 52, 55, 59  
  FROM DRYER, 60

## H

H<sub>2</sub>O, 49, 68, 180  
Heaters, 102, 157, 219, 220, 221, 222, 231, 232,  
237, 248, 250, 257, 271, 279, 290, 303, 310, 313,  
314, 322, 325, 326  
Hessen Protocol, 124, 138, 140, 141, 145  
  and Reporting Ranges, 142  
  Default Settings, 141  
  Gas List, 143, 144  
  Latency Period, 138  
  SETUP Parameters, 138

Status Flag  
  *Default Settings*, 145  
  *Modes*, 145  
  *Unassigned Flags*, 145  
  *Unused Bits*, 145  
  *Warnings*, 145  
types, 140  
High voltage power supply (HVPS), 66, 76  
HIRES, 150  
HNO<sub>3</sub>, 60, 62  
  Desorber, 62  
HVPS, 76  
  DAS Parameter, 150  
HVPS WARNING, 66, 77, 145

## I

I<sup>2</sup>C, 236, 303, 309, 310  
  Status LED, 236  
IND Range Mode, 86, 88  
Interferents, 68  
Internal Pneumatics  
  Sample Gas Dryer, 63  
  Scrubber  
  NH<sub>3</sub>, 63  
Internal Pump, 324  
internal span gas Generator, 76  
Internal Span Gas Generator, 60, 66, 100  
  and Nitric Acid (HNO<sub>3</sub>), 62  
  AutoCal, 198, 199  
  EPA Equivalency, 21  
  Hessen Flags, 145  
  Valve States, 63  
  Warning Messages, 66, 77  
Internal Zero Air (IZS), 30  
INVALID CONC, 145  
IZE TEMP, 76  
IZS TEMP WARNING, 66, 77, 145  
IZS\_SET, 100

## M

Machine ID, 46  
Maintenance Schedule, 150, 207, 280, 291  
MANIFOLD TEMP WARN, 145  
Material Safety Data Sheet, 296  
MEASURE\_MODE, 100  
Menu Buttons  
  CAL, 78, 280  
  **CALS**, 78, 193, 280  
  **CALZ**, 78, 193  
  CONC, 100, 253, 280  
  **ENTR**, 80, 95, 161, 202, 207  
  **EXIT**, 80  
Message Field, 27  
**Metal Wool Scrubber**, 120, 235  
microcomputer, 303, 328  
Mode Field, 27  
Modem, 172, 257  
MOLY TEMP, 76

Motherboard, 77, 105, 113, 231, 236, 248, 251,  
303, 305, 309, 322  
Multidrop, 46, 124, 138

## N

Nafion<sup>®</sup>, 63, 297, 298  
National Institute of Standards and Technology  
(NIST), 199  
Standard Reference Materials (SRM), 49, 57, 180  
NH<sub>3</sub>, 48, 63, 68, 179, 290, 298  
(NH<sub>3</sub>)<sub>2</sub>SO<sub>4</sub>, 290  
nitric acid, 60, 62  
NO OFFSET, 76  
NO SLOPE, 76  
NO<sub>2</sub> → NO Converter, 66, 68, 76, 77, 187, 208, 219,  
237, 243, 247, 257, 258, 262, 271, 273, 290, 292,  
293, 299, 313  
NORM PMT, 75  
NOX OFFSET, 76  
**NXCNC1**, 154

## O

O2CELL TEMP WARN, 145  
O<sub>3</sub> Generator, 102, 211, 212, 230, 290, 297, 299,  
301, 309  
O3 Option  
Relay PCA  
Status LED's, 236, 237  
Offset, 113, 230, 330  
OFFSET, 207, 330  
ON/OFF Switch, 248, 321  
Operating Modes, 102  
Calibration Mode, 78, 145  
Diagnostic Mode (DIAG), 102  
M-P CAL Mode, 145  
Sample Mode, 27  
SAMPLE mode, 73, 74, 100, 197  
**SAMPLE Mode**, 56, 60, 63  
Secondary Setup, 80  
**SPAN CAL**, 56, 60, 63  
Warm Up Mode, 145  
**ZERO CAL**, 56, 60, 63  
Optic Test, 102  
Optical Test, **265**  
O TEST, 278  
Ozone, 15, 63, 66, 77, 102, 120, 122, 208, 212,  
221, 222, 223, 226, 230, 235, 238, 239, 240, 241,  
242, 243, 245, 248, 262, 265, 269, 273, 283, 284,  
295, 296, 297, 299, 301  
OZONE FL, 75  
**OZONE FLOW WARNING**, 66, 77, 145  
OZONE GEN OFF, 66, 77, 145, 230, 301  
Ozone Generator, 66  
OZONE\_FLOW, 252, 301, 306

## P

Particulate Filter, 210, 230, 231, 280

Perma Pure<sup>®</sup>, 290, 295, 297, 298, 301  
Permeation Rate, 61, 100  
Permeation Tube, 60, 61, 62, 76, 100, 280  
Photometer  
Sensor  
Flow, 256  
PPressure, 255  
Physical Range, 75, 82  
High Range, 82  
Low Range, 82  
PMT, 66, 232, 235, 255, 265, 271, 274, 275, **285**,  
288, 297, 301, 305, 306, 316, 320  
(TEC), 228, 268, 276, 307, 316, 319, 320, 321  
Sensor Control, 271  
AZERO, 209, 242  
Calibration, 274  
Detector, 120  
Electric Test, 102  
Electrical Test, 266  
Gain Voltage, 317  
Housing, 221, 224  
HVPS, 267, 276, 278, 316  
HVPS Voltage, 120, 235  
Light Leaks, 224  
Maintenance, 208, 224  
Noise, 242, 287  
NORM PMT, 75, 275, 305  
Offset, 287  
Optic Test, 102, 265, 319  
Output, 82, 287, 305, 317, 319  
PMT TEMP, 76, 232, 271, 306  
**PMT TEMP WARNING**, 77, 145, 230, 235  
PMTDET, 235, 305, 317, 329  
Preamplifier, 230, 267, 307, 309, 317, 318  
PReamplifier, 274  
Reaction Cell, 285  
Replacement, 276  
**TEMP**, 306  
Temperature, 66, 277, 315, 317, 320  
Test Function, 75, 224, 232, 247  
Theory of Operation, 316, 317  
Thermistors, 307  
Troubleshooting, 230, 242, 243, 244, 246  
With Zero NO<sub>x</sub>, 75  
PMT Preamp PCA, 102  
PMT TEMP, 76  
PMT TEMP WARNING, 66, 145  
PMTDET, 149  
Pneumatic Sensors  
O<sub>3</sub> Flow, 301  
Sample Gas Flow, 301  
Sample Pressure, 300  
Vacuum Pressure, 300  
Pneumatic Setu  
Basic T200  
Bottled Gas, 51  
Pneumatic Setup  
Basic, 50  
Preamplifier, 230, 267, 307, 316, 317  
Predictive Diagnostics, 147, 150, 169  
Using DAS, 150  
Pressurized Span Gas Inlet Option  
Rear Panel, 57

Valve States, 60  
 Pressurized Zero Air Inlet  
 Valve States, 60  
 PTEF, 51, 52, 54, 55, 58, 59  
 Pump  
 Sample, 230, 231, 324  
 Purafil Chemisorbant, 60

## R

RANGE, 75, 142  
 HIGH, 75  
 LOW, 75  
 Range Mode  
 AUTO, 89, 177  
 DUAL, 177  
 IND, 86, 88  
 SNGL, 69, 84  
 RANGE1, 75, 142  
 AUTO, 89  
 IND, 86  
 RANGE2, 75, 142  
 AUTO, 89  
 IND, 86  
 RANGE3, 75, 86  
 RCELL, 76  
 RCELL PRESS WARN, 66, 77, 145  
 RCELL TEMP, 76  
 RCELL TEMP WARNING, 66, 77, 145  
 Reaction Cel  
 direct Interferencel, 288  
 Reaction Cell, 76, 214, 222, 223, 224, 269, 276,  
 278, 290, 291, 293, 295, 297, 299, 303, 306, 322  
 Auto Zero, 287  
 Auto Zero Valve, 292, 312  
 AutoZero, 295  
 AZERO, 293  
 Chemiluminescence, 285, 293  
 Cleaning, 221, 242, 247, 248  
 Contamination, 242  
 Critical Flow Orifice  
 Cleaning, 223  
 Critical Flow Orifices, 294, 296  
 Dirty, 221, 230, 242, 245, 247, 248  
 Dwell Time, 293  
 Gas Flow  
 Troubleshooting, 240  
 Gas Flow Caclulation, 301  
 Gas Inlets, 295  
 Heater, 271, 290  
 Interferents, 68  
 Light Leaks, 235, 289  
 Mounting Screws, 224  
 NH<sub>3</sub>, 290  
 NO/NO<sub>x</sub> valve, 292  
 Optical Filter, 285  
 Ozone, 75, 295, 296  
 Scrubber, 299  
 PMT, 316  
 Pneumatic Leaks, 240  
 Principles of Operation, 284  
 RCELL PRESS WARN, 66  
 RCELL PRESSURE, 235

RCELL TEMP, 235, 329  
 RCELL TEMP WARN, 66  
 SAMP, 329  
 SAMP FLOW, 75  
 Sample Pressure Sensor, 300  
 SO<sub>x</sub>, 290  
 Temperature, 314  
 Temperature Control, 290  
 Temperature Sensor, 307  
 Test Functions, 120  
 Theory of Operation, 284, 285, 287  
 Thermistor, 290  
 Third Body Quenching, 288  
 Troubleshooting, 245, 248  
 Vacuum Pressure Sensor, 300  
 Reaction Cell Temperature, 76  
 REAR BOARD NOT DET, 66, 77  
 Rear Panel  
 Ambient Zero/Span Valve Options, 54  
 Analog Outputs, 83  
 Pressurized Span Gas Inlet Option, 57  
**REF\_4096\_MV**, 252  
**REF\_GND**, 252  
**RELAY BOARD WARN**, 66, 77, 145  
 relay PCA, 66, 77, 228, 249, 279, 303, 310, 311,  
 313, 314, 315, 321, 322  
 Relay PCA, **309–16**  
 DC Power Test Points, 249  
 Status LED's, 236, 237, 311, 312, 322  
 Troubleshooting, 236, 237, 248, 249, **250**  
 Reporting Range, 69, 79, 82, 84  
 Configuration, 79  
 Dilution Feature, 91  
 HIGH, 89  
 LOW, 89  
 Modes, 92  
 AUTO, 89  
 IND, 86  
 SNGL, 84  
 Upper Span Limit, 75, 82, 85, 86, 88, 92  
 RJ45, 18  
 RS-232, 15, 44, 45, 46, 73, 80, 128, 148, 149, 163,  
 165, 169, 305  
 Activity Indicators, 43  
 Troubleshooting, 256  
 RS-485, 73, 124, 128, 305

## S

Safety Messages  
 ELECTRIC SHOCK, 33, 207, 224, 249, 272, 310  
 General, 17, 23, 33, 47, 113, 296  
**SAMP**, 76  
 SAMP FLW, 75  
 Sample Flow Sensor, 230  
**SAMPLE FLOW WARNING**, 66, 77, 145  
 Sample Gas Dryer  
 Internal Pneumatics, 63  
 Sample Gas Line, 51, 55, 58  
**Sample Inlet**, 30  
 Sample Mode, 27  
 SAMPLE mode, 73, 74, 100, 197

Sample Pressure Sensor, 231  
 Sample Temperature Sensor, 230, 231  
 Scrubber  
   NH<sub>3</sub>  
     *Internal Pneumatics*, 63  
 Scubber  
   Zero Air, 15, 48, 179  
 Sensors  
   Sample Flow, 230  
   Sample Pressure, 231, 306  
   Sample Temperature, 230, 231  
   Thermistors, 307  
     *Box Temperature*, 307  
     **IZS Oven Temperature**, 307  
     *Reaction Cell Temperature*, 307  
     *Sample Temperature*, 230, 231  
   Thermocouples  
     *Inputs*, 315  
   VACUUM PRESSURE, 306  
 Serial I/O Ports, 20, 229, 231, 303  
   Modem, 172, 257  
   Multidrop, 46, 124  
   RS-232, 15, 44, 73, 80, 148, 149, 163, 165, 169, 305  
     *Troubleshooting*, 256  
   RS-485, 73, 124, 305  
 Shutoff Valve  
   Span Gas, 57, 60  
   Zero Air, 60  
**Signal I/O**  
   OZONE\_FLOW, 252  
   REF\_4096\_MV, 252  
   REF\_GND, 252  
 Sintered Filter, 281  
 Slope, 230, 330  
 SLOPE, 207, 330  
 SLPCHG, 150, 156  
 SNGL, 69, 84  
 SNGL Range Mode, 84  
 SO<sub>2</sub>, 68  
**SO<sub>3</sub> FLOW SENSOR**, 306  
 Span Gas, 30, 49, 51, 55, 57, 58, 68, 70, 82, 102, 177, 178, 179, 180, 182, 184, 190, 195, 199, 280  
   Dilution Feature, 92  
   Standard Reference Materials (SRM's)  
     NO<sub>x</sub>/NO Span Gas, 49, 180  
**Span Inlet**, 30, 53, 57  
 SPAN\_CAL 1, 254  
 Specifications, 19  
 STABIL  
   DAS Parameter, 150  
 STABIL\_GAS, 100  
 Standard Reference Materials (SRM), 57, 58  
 Standard Temperature and Pressure, 91  
 status LED's, 313  
 Status LED's  
   CPU, 236  
   I<sup>2</sup>C, 236  
   Relay PCA, 236, 311, 312, 322  
     O<sub>3</sub> Option, 237  
   Watchdog, 236, 312  
 Status Outputs, 37, 89, 253, 308  
   **ST\_CONC\_VALID**, 253

**ST\_DIAG**, 253  
**ST\_HIGH\_RANGE**, 253  
**ST\_O2\_CAL**, 253  
**ST\_SPAN\_CAL**, 253  
**ST\_SYSTEM\_OK**, 253  
**ST\_ZERO\_CAL**, 253  
 STB (Stability Test function), 75, 100  
**SYSTEM**  
   **DEFAULT SETTINGS**, 149  
**SYSTEM RESET**, 66, 77, 145

## T

### Teledyne Contact Information

**Email Address**, 22, 282  
**Fax**, 22, 282  
**Phone**, 22, 282  
 Technical Assistance, 282  
**Website**, 282  
 Temperature and Pressure Compensation (TPC), 100  
 Terminal Mode, 170  
   Command Syntax, 170  
   Computer mode, 124  
 Test Channel, 34, 35, 102, 105, 120, 235, 251  
**Test Functions**, 67, 74, 75, 76, 105, 120, 209, 232, 251  
 AZERO, 75  
**BOX TEMP**, 66, 76, 77, 145  
 HVPS, 76  
 IZE TEMP, 76  
 MOLY TEMP, 76  
 NO OFFSET, 76  
 NO SLOPE, 76  
 NORM PMT, 75  
 NOX OFFSET, 76  
 OFFSET, 207, 330  
 OZONE FL, 75  
 PMT, 75  
 PMT TEMP, 76  
 RANGE, 75, 142  
 RANGE1, 75, 142  
   **AUTO**, 89  
   **IND**, 86  
 RANGE2, 75, 142  
   **AUTO**, 89  
   **IND**, 86  
 RANGE3, 75, 86  
 RCEL, 76  
 RCELL TEMP, 76  
**SAMP**, 76  
 SAMP FLW, 75  
 SLOPE, 207, 330  
 STB (Stability), 75, 100  
<sup>TEST4</sup>, 76  
**TIME**, 76, 199  
<sup>TEST4</sup>, 76  
 Thermistors, 307, 314  
 Thermocouples, 219, 232, 237, 257, 258, 314, 315  
   Inputs, 315  
 Thermo-Electric Cooler, 287, 316, 317, 319, 320,  
   See  
**TIME**, 76, 199

TPC\_ENABLE, 100

## U

Units of Measurement, 69, 91, 92  
 Volumetric Units vs Mass Units, 91

## V

vacuum manifold, 215, 223, 224, 238, 274, 287,  
 291, 292, 293

Vacuum Manifold, 76, 224, 329

Valve Options, 30, 68, 194, 195

Ambient Zero/Span Valve Option, 53

*Flow Diagram, 56*

*INTERNAL PNEUMATICS, 56*

*Rear Panel, 54*

*Valve States, 56*

Internal Span Gas Generator, 60, 66, 100

*AC Power, 326*

*AutoCal, 198, 199*

*EPA Equivalency, 21*

*Flow Diagram, 62*

*Hessen Flags, 145*

*Internal Span Gas Generation, 61*

*Test Channel Functions, 120, 235*

*Valve States, 63*

*Warning Messages, 66, 77*

Pressurized Span Gas Inlet Option

*Flow Diagram, 59*

*Rear Panel, 57*

Pressurized Zero Air Inlet

*Flow Diagram, 59*

*Valve States, 60*

Shutoff Valve

*Span Gas, 57, 60*

*Zero Air, 60*

Zero/Span

*and AutoCal, 177, 197*

*Calibration, 68, 193*

*EPA Equivalency, 21*

*with Remote Contact Closure, 197*

**VARS MENU**, 80, 93, 94, 95, 97, 100, 101, 149,  
 164

**VARIABLE DEFAULT VALUES**, 100

Variable Names

*CAL\_ON\_NO2, 100*

*CLOCK\_ADJ, 100*

*CONC\_PRECISION, 100*

*DAS\_HOLD\_OFF, 100*

*DYN\_SPAN, 100*

*DYN\_ZERO, 100*

*IZS\_SET, 100*

*MEASURE\_MODE, 100*

*STABIL\_GAS, 100*

*TPC\_ENABLE, 100*

Ventilation Clearance, 24

Venting, 51, 52, 55, 58

visible light spectrum, 289

## W

warm-up period, 64

Warning Messages, 64, 66, 77, 228, 230

**ANALOG CAL WARNING**, 66, 77, 145

**AUTOZERO WARNING**, 145

**AZERO WARN**, 66, 77

**BOX TEMP WARNING**, 66, 77, 145

**CANNOT DYN SPAN**, 66, 77, 145

**CANNOT DYN ZERO**, 66, 77, 145

**CONFIG INITIALIZED**, 66, 77

**CONV TEMP WARNING**, 66, 145

**DATA INITIALIZED**, 66, 77

**FRONT PANEL WARN**, 145

**HVPS WARNING**, 66, 77, 145

**INVALID CONC**, 145

**IZS TEMP WARNING**, 66, 77, 145

**MANIFOLD TEMP WARN**, 145

**O2 CELL TEMP WARN**, 145

**OZONE FLOW WARNING**, 66, 77, 145

**OZONE GEN OFF**, 66, 77, 145

**PMT TEMP WARNING**, 66, 77, 145

**RCELL PRESS WARN**, 66, 77, 145

**RCELL TEMP WARNING**, 66, 77, 145

**REAR BOARD NOT DET**, 66, 77

**RELAY BOARD WARN**, 66, 77, 145

**SAMPLE FLOW WARNING**, 66, 77, 145

**SYSTEM RESET**, 66, 77, 145

**WARNING MESSAGES**

**CONV TEMP WARNING**, 77

Watchdog Circuit, 236

Status LED, 236, 312

## Z

Zero Air, 30, 48, 51, 61, 122, 177, 178, 179, 182,  
 199

**ZERO AIR INLET**, 53, 55, 57, 60

**ZERO AIR Inlet**, 30

Zero Air Scrubber, 48

**ZERO/SPAN valve**, 197

**ZERO\_CAL**, 254

This page intentionally left blank.

## APPENDIX A: Version Specific Software Documentation

APPENDIX A-1: SOFTWARE MENU TREES, VERSION 1.1.0 (T200, T204)/KB7 (200E) .....	3
APPENDIX A-2: SETUP VARIABLES .....	9
APPENDIX A-3: WARNINGS AND TEST MEASUREMENTS .....	10
APPENDIX A-4: SIGNAL I/O DEFINITIONS .....	16
APPENDIX A-5: TRIGGER EVENTS AND DAS PARAMETERS.....	22
APPENDIX A-6: TERMINAL COMMAND DESIGNATORS .....	26
APPENDIX A-7: MODBUS REGISTER MAP .....	28





APPENDIX A-1: Software Menu Trees, Version 1.1.0 (T200, T204)/Kb7 (200E)

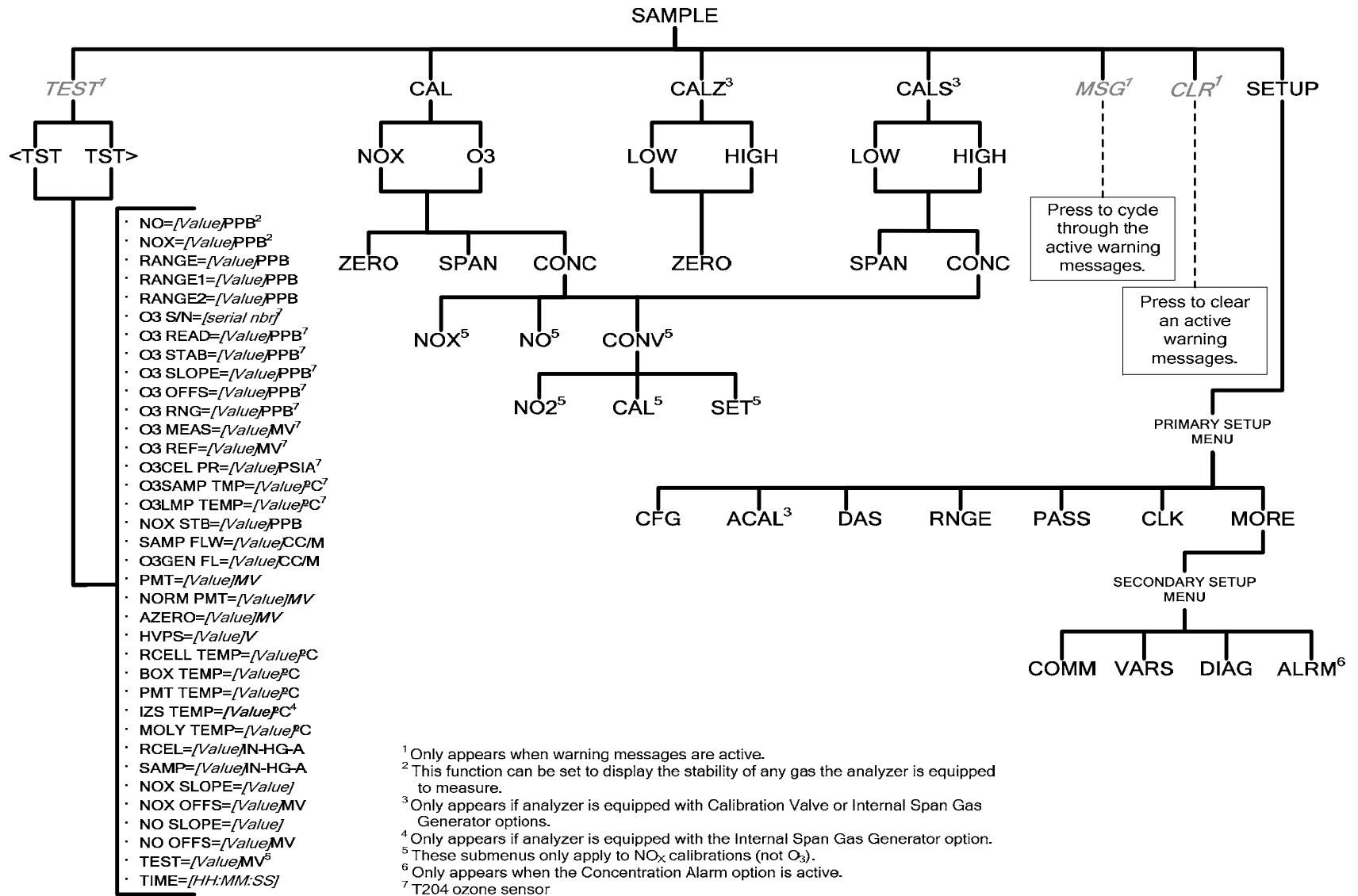
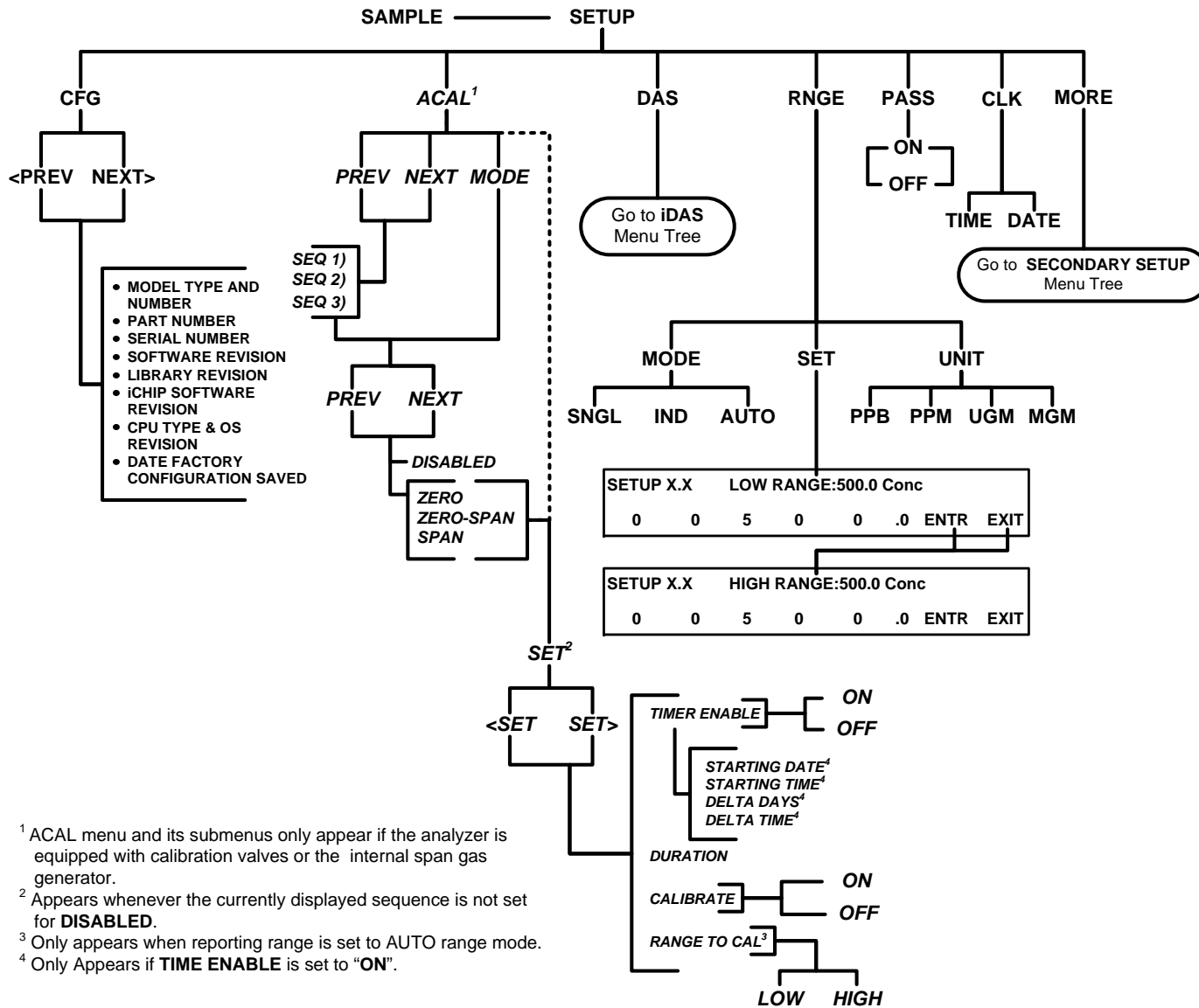


Figure A-1: Basic Sample Display Menu



<sup>1</sup> ACAL menu and its submenus only appear if the analyzer is equipped with calibration valves or the internal span gas generator.  
<sup>2</sup> Appears whenever the currently displayed sequence is not set for **DISABLED**.  
<sup>3</sup> Only appears when reporting range is set to AUTO range mode.  
<sup>4</sup> Only Appears if **TIME ENABLE** is set to "ON".

Figure A-2: Primary Setup Menu (Except DAS)

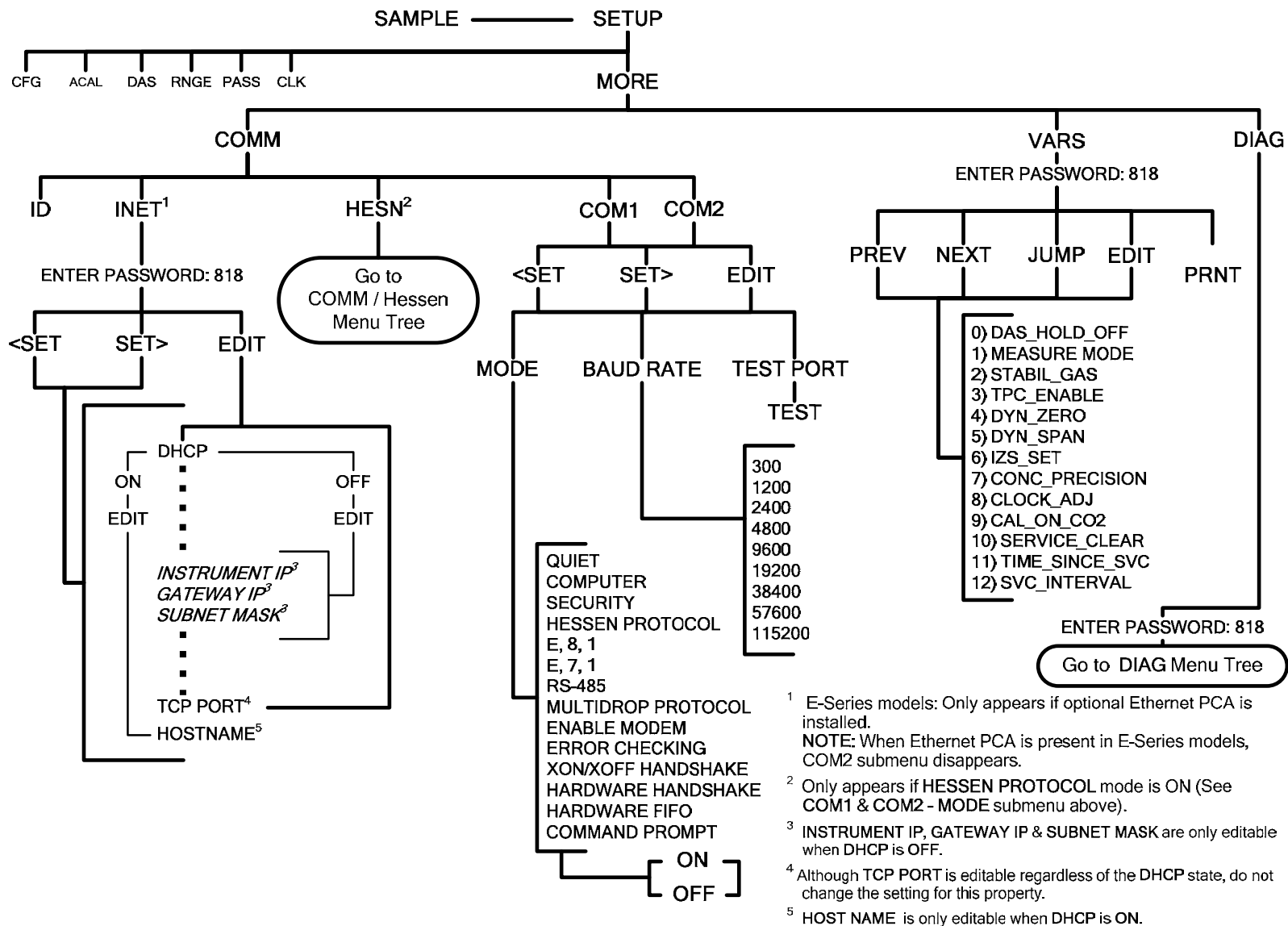


Figure A-3: Secondary Setup Menu (COMM & VARS)

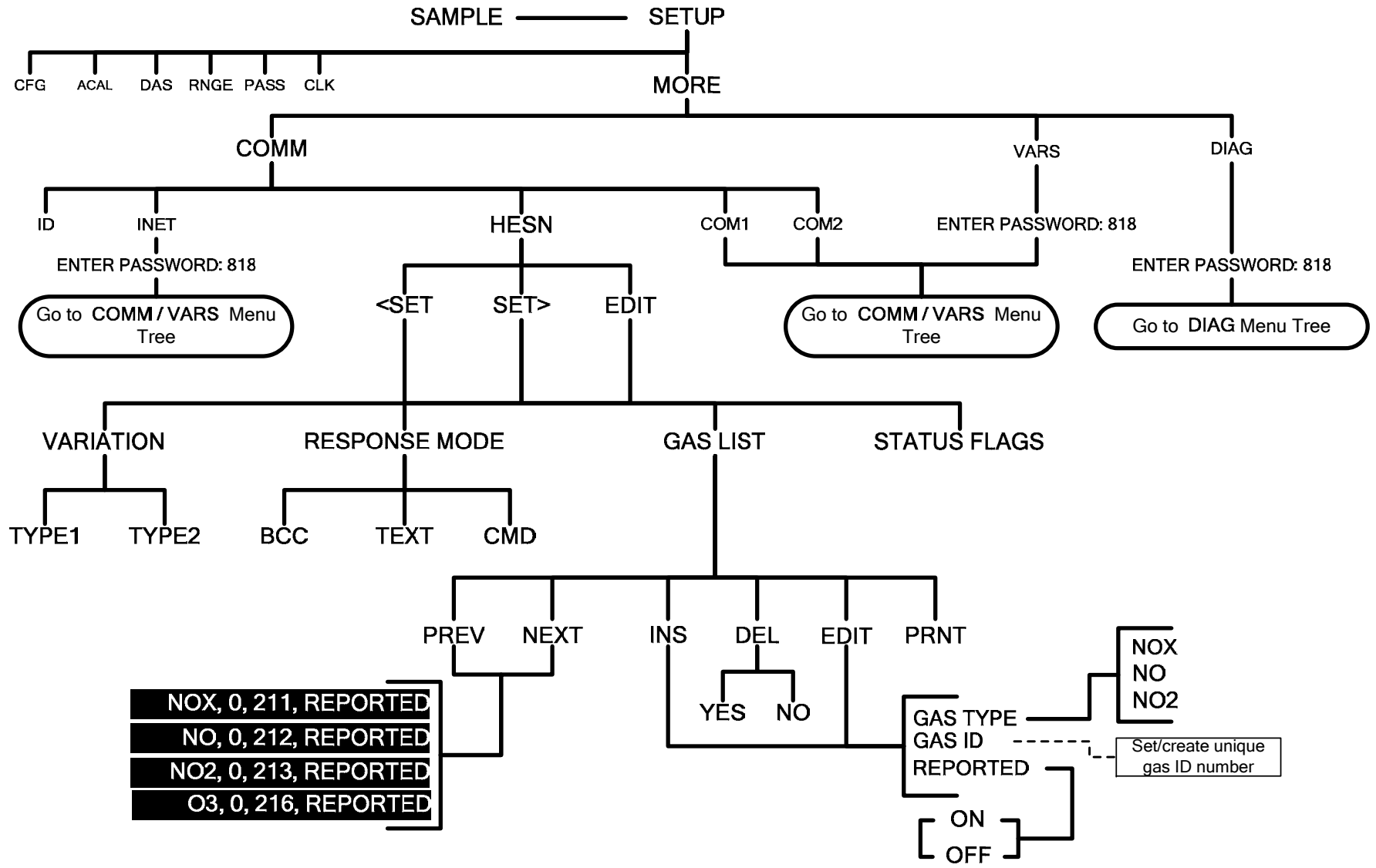


Figure A-4: Secondary Setup Menu (HESSEN)

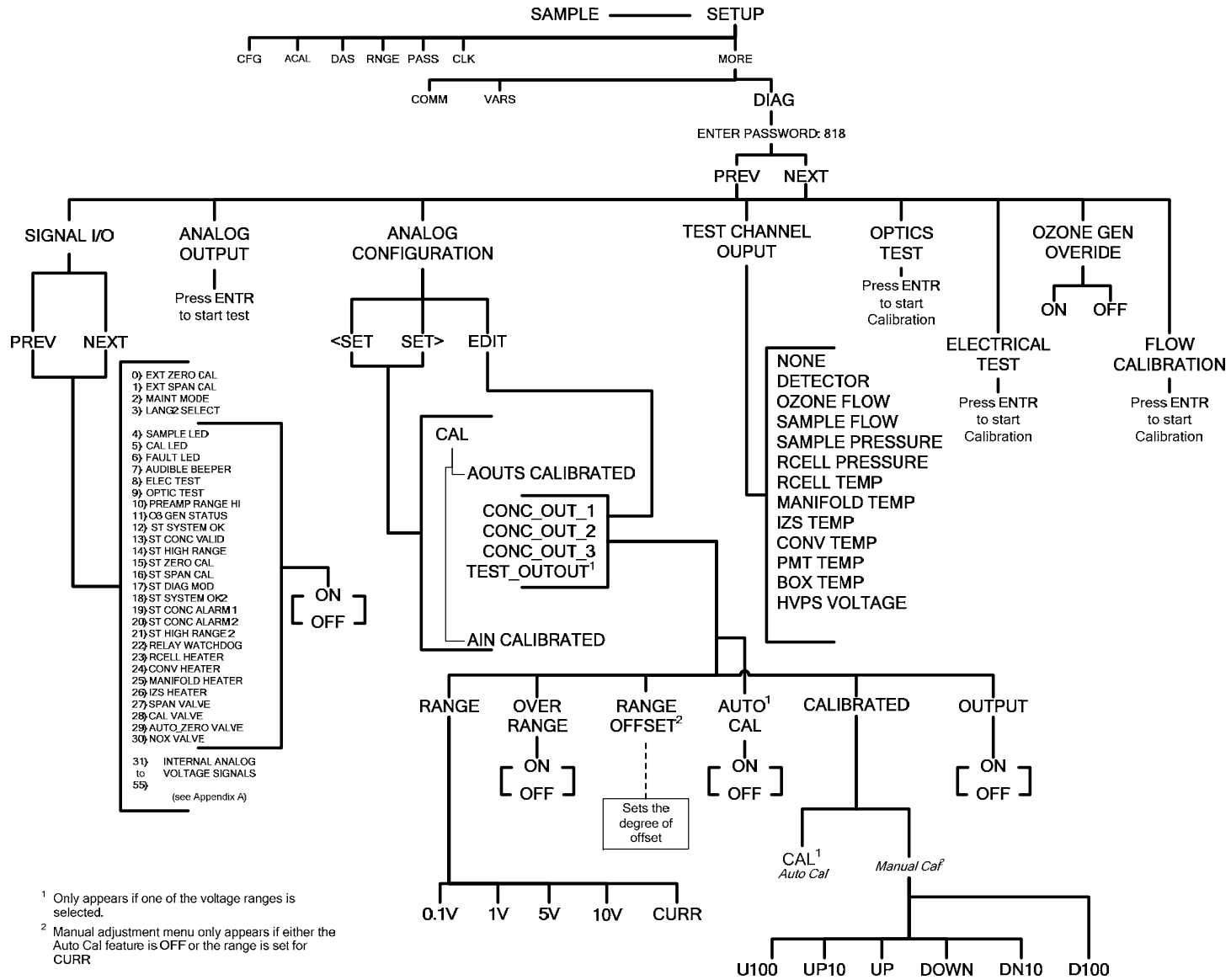


Figure A-5: Secondary Setup Menu (DIAG)

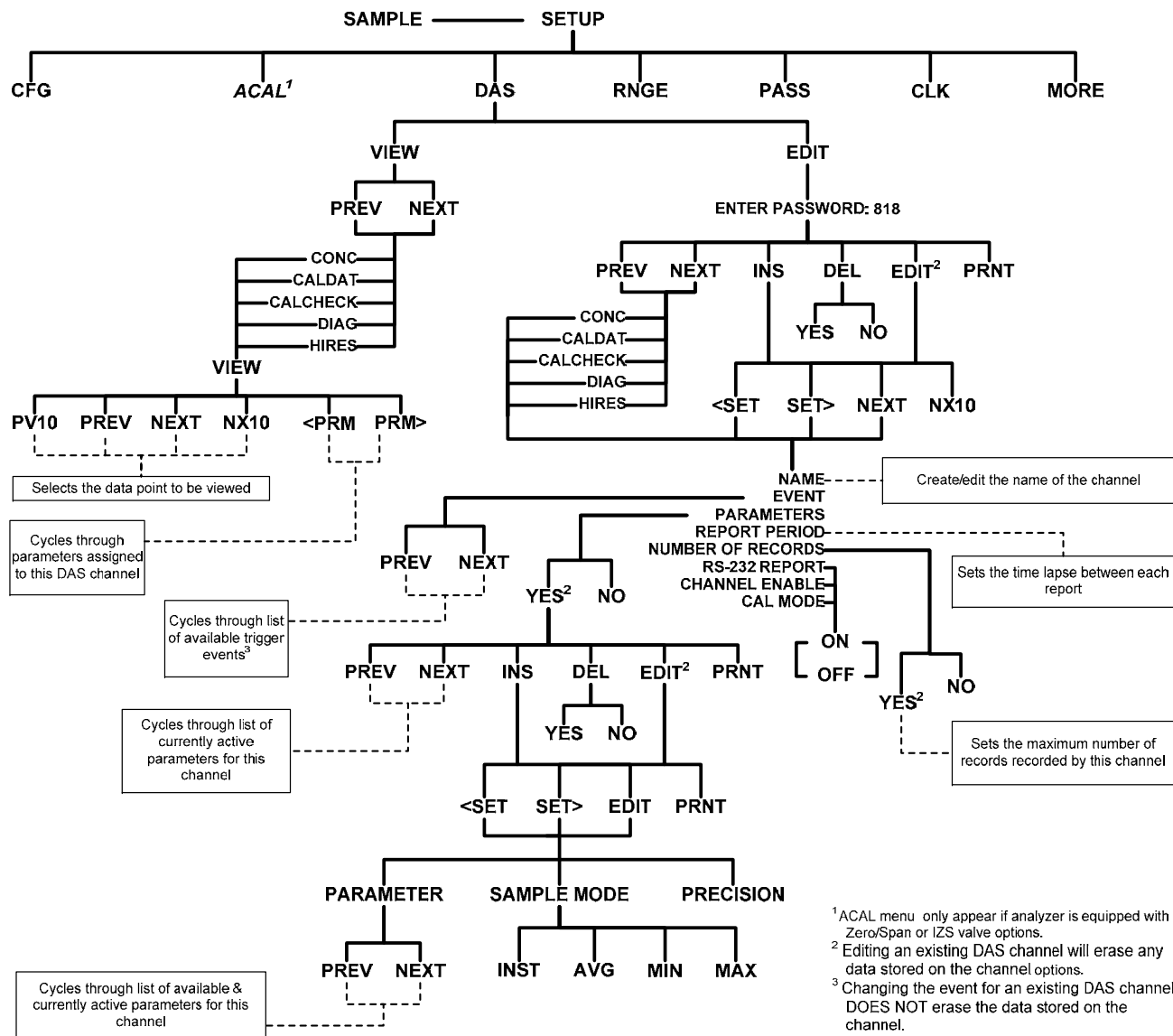


Figure A-6: Internal Data Acquisition (DAS) Menu

## APPENDIX A-2: Setup Variables

Table A-1: Setup Variables

Setup Variable	Numeric Units	Default Value	Value Range	Description
DAS_HOLD_OFF	Minutes	15	0.5–20	Duration of DAS hold off period.
MEASURE_MODE	—	NO-NOX, NOX <sup>4</sup>	NO, NOX, NOX-NO, NON-OX	Gas measure mode. Enclose value in double quotes (") when setting from the RS-232 interface.
STABIL_GAS	—	NOX	NO, NO2, NOX, O2 <sup>5</sup> , CO2 <sup>6</sup>	Selects gas for stability measurement. Enclose value in double quotes (") when setting from the RS-232 interface.
TPC_ENABLE	—	ON	OFF, ON	ON enables temperature/ pressure compensation; OFF disables it.
DYN_ZERO	—	OFF	ON, OFF	ON enables remote dynamic zero calibration; OFF disables it.
DYN_SPAN	—	OFF	ON, OFF	ON enables remote dynamic span calibration; OFF disables it.
IZS_SET <sup>1</sup>	°C	51 Warnings: 50–52	30–70	IZS temperature set point and warning limits.
CONC_PRECISION	—	AUTO <sup>1</sup> , 3 <sup>2,3</sup>	AUTO, 0, 1, 2, 3, 4	Number of digits to display to the right of the decimal point for concentrations on the display. Enclose value in double quotes (") when setting from the RS-232 interface.
STAT_REP_GAS <sup>4</sup>	—	NOX	NO, NO2, NOX, CO2 <sup>6</sup> , O2 <sup>5</sup>	Selects gas to report in TAI protocol status message. Enclose value in double quotes (") when setting from the RS-232 interface.
REM_CAL_DURATION <sup>4</sup>	Minutes	20	1–120	Duration of automatic calibration initiated from TAI protocol.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
CAL_ON_NO2 <sup>1</sup>	—	OFF	ON, OFF	ON enables span calibration on pure NO <sub>2</sub> ; OFF disables it.
SERVICE_CLEAR	—	OFF	OFF ON	ON resets the service interval timer.
TIME_SINCE_SVC	Hours	0	0–500000	Time since last service.
SVC_INTERVAL	Hours	0	0–100000	Sets the interval between service reminders.
<sup>1</sup> T200 and M200E. <sup>2</sup> T200H and M200EH. <sup>3</sup> T200U and M200EU. <sup>4</sup> TAI protocol <sup>5</sup> O <sub>2</sub> option. <sup>6</sup> CO <sub>2</sub> option.				



**APPENDIX A-3: Warnings and Test Measurements****Table A-2: Warning Messages**

<b>Warning Name <sup>1</sup></b>	<b>Message Text</b>	<b>Description</b>
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WNOXALARM1 <sup>9</sup>	NOX ALARM 1 WARN	NO <sub>x</sub> concentration alarm limit #1 exceeded
WNOXALARM2 <sup>9</sup>	NOX ALARM 2 WARN	NO <sub>x</sub> concentration alarm limit #2 exceeded
WNOALARM1 <sup>9</sup>	NO ALARM 1 WARN	NO concentration alarm limit #1 exceeded
WNOALARM2 <sup>9</sup>	NO ALARM 2 WARN	NO concentration alarm limit #2 exceeded
WNO2ALARM1 <sup>9</sup>	NO2 ALARM 1 WARN	NO <sub>2</sub> concentration alarm limit #1 exceeded
WNO2ALARM2 <sup>9</sup>	NO2 ALARM 2 WARN	NO <sub>2</sub> concentration alarm limit #2 exceeded
WO2ALARM1 <sup>5+9</sup>	O2 ALARM 1 WARN	O <sub>2</sub> concentration alarm limit #1 exceeded
WO2ALARM2 <sup>5+9</sup>	O2 ALARM 2 WARN	O <sub>2</sub> concentration alarm limit #2 exceeded
WCO2ALARM1 <sup>8+9</sup>	CO2 ALARM 1 WARN	CO <sub>2</sub> concentration alarm limit #1 exceeded
WCO2ALARM2 <sup>8+9</sup>	CO2 ALARM 2 WARN	CO <sub>2</sub> concentration alarm limit #2 exceeded
WO3ALARM1 <sup>13</sup>	O3 ALARM1 WARNING	O <sub>3</sub> concentration alarm limit #1 exceeded
WO3ALARM2 <sup>13</sup>	O3 ALARM2 WARNING	O <sub>3</sub> concentration alarm limit #2 exceeded
WSAMPFLOW	SAMPLE FLOW WARN	Sample flow outside of warning limits.
WOZONEFLOW	OZONE FLOW WARNING	Ozone flow outside of warning limits.
WOZONEGEN	OZONE GEN OFF	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on.

Warning Name <sup>1</sup>	Message Text	Description
WRCELLPRESS	RCELL PRESS WARN	Reaction cell pressure outside of warning limits.
WBOXTEMP	BOX TEMP WARNING	Chassis temperature outside of warning limits.
WRCELLTEMP	RCELL TEMP WARNING	Reaction cell temperature outside of warning limits.
WMANIFOLDTEMP <sup>4</sup>	MANIFOLD TEMP WARN	Bypass or dilution manifold temperature outside of warning limits.
WCO2CELLTEMP <sup>8</sup>	CO2 CELL TEMP WARN	CO <sub>2</sub> sensor cell temperature outside of warning limits.
WO2CELLTEMP <sup>5</sup>	O2 CELL TEMP WARN	O <sub>2</sub> sensor cell temperature outside of warning limits.
WO3CELLTEMP <sup>13</sup>	O3 CELL TEMP WARN	O <sub>3</sub> sensor sample temperature outside of warning limits.
WO3PHOTOREF <sup>13</sup>	O3 CELL PHOTOREF WARN	O <sub>3</sub> sensor photometer reference signal warning.
WO3LAMPTEMP <sup>13</sup>	O3 CELL LAMP WARN	O <sub>3</sub> cell lamp temperature warning.
WO3PRESSURE <sup>13</sup>	O3 CELL PRESS WARN	O <sub>3</sub> cell pressure warning.
WIZSTEMP	IZS TEMP WARNING	IZS temperature outside of warning limits.
WCONVTEMP	CONV TEMP WARNING	Converter temperature outside of warning limits.
WPMTTEMP	PMT TEMP WARNING	PMT temperature outside of warning limits.
WAUTOZERO WPREREACT <sup>11</sup>	AZERO WRN XXX.X MV PRACT WRN XXX.X MV <sup>11</sup>	Auto-zero reading above limit. Value shown in message indicates auto-zero reading at time warning was displayed.
WHVPS	HVPS WARNING	High voltage power supply output outside of warning limits.
WDYNZERO	CANNOT DYN ZERO	Contact closure zero calibration failed while <i>DYN_ZERO</i> was set to <i>ON</i> .
WDYNSPAN	CANNOT DYN SPAN	Contact closure span calibration failed while <i>DYN_SPAN</i> was set to <i>ON</i> .
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.

Warning Name <sup>1</sup>	Message Text	Description
WFRONTPANEL	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.

<sup>1</sup> The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".

<sup>2</sup> Engineering firmware only.

<sup>3</sup> Current instrument units.

<sup>4</sup> Factory option.

<sup>5</sup> O<sub>2</sub> option.

<sup>6</sup> User-configurable D/A output option.

<sup>7</sup> Optional.

<sup>8</sup> CO<sub>2</sub> option.

<sup>9</sup> Concentration alarm option.

<sup>10</sup> M200EUP.

<sup>11</sup> M200EU and M200EU\_NO<sub>y</sub>.

<sup>12</sup> External analog input option.

<sup>13</sup> O<sub>3</sub> option

Table A-3: Test Measurements

Test Name <sup>1</sup>	Message Text	Description
NONOXCONC	NO=396.5 NOX=396.5 <sup>3</sup>	Simultaneously displays NO and NOX concentrations.
RANGE <sup>not 6</sup>	RANGE=500.0 PPB <sup>3</sup>	D/A range in single or auto-range modes.
RANGE1 <sup>not 6</sup>	RANGE1=500.0 PPB <sup>3</sup>	D/A #1 range in independent range mode.
RANGE2 <sup>not 6</sup>	RANGE2=500.0 PPB <sup>3</sup>	D/A #2 range in independent range mode.
RANGE3 <sup>not 6</sup>	RANGE3=500.0 PPB <sup>3</sup>	D/A #3 range in independent range mode.
O3SN	O3 S/N=0123	O <sub>3</sub> sensor serial number.
O3READ	O3 READ=100.0 PPB	O <sub>3</sub> concentration.
O3STAB	O3 STAB=0.0 PPB	O <sub>3</sub> concentration stability.
O3SLOPE	O3 SLOPE=1.000	O <sub>3</sub> calibration slope.
O3OFFSET	O3 OFFS=0.0 PPB	O <sub>3</sub> calibration offset.
O3RANGE	O3 RNG=500.0 PPB	O <sub>3</sub> analog output range.
PHOTOMEAS	O3 MEAS=1230.0 MV	O <sub>3</sub> photometer measurement signal.
PHOTOREF	O3 REF=1230.0 MV	O <sub>3</sub> photometer reference signal.
CELLPRESS	O3CEL PR=14.7 PSIA	O <sub>3</sub> cell pressure.
CELLTEMP	O3SAMP TMP=25.0 C	O <sub>3</sub> sample temperature.
LAMPTEMP	O3LMP TEMP=52.0 C	O <sub>3</sub> photometer lamp temperature.
STABILITY	NOX STB=0.0 PPB <sup>3</sup> O2 STB=0.0 PCT <sup>5</sup> CO2 STB=0.0 PCT <sup>8</sup>	Concentration stability (standard deviation based on setting of <i>STABIL_FREQ</i> and <i>STABIL_SAMPLES</i> ). Select gas with <i>STABIL_GAS</i> variable.
RESPONSE <sup>2</sup>	RSP=8.81(1.30) SEC	Instrument response. Length of each signal processing loop. Time in parenthesis is standard deviation.
SAMPFLOW	SAMP FLW=460 CC/M	Sample flow rate.
OZONEFLOW	OZGEN FL=87 CC/M	Ozone flow rate.
PMT	PMT=800.0 MV	Raw PMT reading.
NORMPMT	NORM PMT=793.0 MV	PMT reading normalized for temperature, pressure, auto-zero offset, but not range.
AUTOZERO	AZERO=1.3 MV	Auto-zero offset.
HVPS	HVPS=650 V	High voltage power supply output.
RCELLTEMP	RCELL TEMP=50.8 C	Reaction cell temperature.
BOXTEMP	BOX TEMP=28.2 C	Internal chassis temperature.
REMBOXTEMP <sup>10</sup>	REM BOX TMP=30.1 C	Remote chassis temperature.
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
MANIFOLDTEMP <sup>4</sup>	MF TEMP=50.8 C	Bypass or dilution manifold temperature.

Test Name <sup>1</sup>	Message Text	Description
CO2CELLTEMP <sup>8</sup>	CO2 CELL TEMP=50.8 C	CO <sub>2</sub> sensor cell temperature.
O2CELLTEMP <sup>5</sup>	O2 CELL TEMP=50.8 C	O <sub>2</sub> sensor cell temperature.
IZSTEMP	IZS TEMP=50.8 C	IZS temperature.
CONVTEMP	MOLY TEMP=315.0 C	Converter temperature. Converter type is <i>MOLY</i> , <i>CONV</i> , or <i>O3KL</i> .
SAMPRESTTEMP <sup>10</sup>	SMP RST TMP=49.8 C	Sample restrictor temperature.
RCELLPRESS	RCEL=7.0 IN-HG-A	Reaction cell pressure.
SAMPRESS	SAMP=29.9 IN-HG-A	Sample pressure.
NOXSLOPE	NOX SLOPE=1.000	NOX slope for current range, computed during zero/span calibration.
NOXOFFSET	NOX OFFS=0.0 MV	NOX offset for current range, computed during zero/span calibration.
NOSLOPE	NO SLOPE=1.000	NO slope for current range, computed during zero/span calibration.
NOOFFSET	NO OFFS=0.0 MV	NO offset for current range, computed during zero/span calibration.
NO2	NO2=0.0 PPB <sup>3</sup>	NO <sub>2</sub> concentration for current range.
NO2_1 <sup>7</sup>	NO2_1=0.0 PPB <sup>3</sup>	NO <sub>2</sub> concentration for range #1.
NO2_2 <sup>7</sup>	NO2_2=0.0 PPB <sup>3</sup>	NO <sub>2</sub> concentration for range #2.
NOX	NOX=396.5 PPB <sup>3</sup>	NOX concentration for current range.
NOX_1 <sup>7</sup>	NOX_1=396.5 PPB <sup>3</sup>	NOX concentration for range #1.
NOX_2 <sup>7</sup>	NOX_2=396.5 PPB <sup>3</sup>	NOX concentration for range #2.
NO	NO=396.5 PPB <sup>3</sup>	NO concentration for current range.
NO_1 <sup>7</sup>	NO_1=396.5 PPB <sup>3</sup>	NO concentration for range #1.
NO_2 <sup>7</sup>	NO_2=396.5 PPB <sup>3</sup>	NO concentration for range #2.
CO2RANGE <sup>8, not 6</sup>	CO2 RANGE=100.00 PCT	D/A #4 range for CO <sub>2</sub> concentration.
CO2SLOPE <sup>8</sup>	CO2 SLOPE=1.000	CO <sub>2</sub> slope, computed during zero/span calibration.
CO2OFFSET <sup>8</sup>	CO2 OFFSET=0.000	CO <sub>2</sub> offset, computed during zero/span calibration.
CO2 <sup>8</sup>	CO2=15.0 %	CO <sub>2</sub> concentration.
O2RANGE <sup>5, not 6</sup>	O2 RANGE=100.00 PCT	D/A #4 range for O <sub>2</sub> concentration.
O2SLOPE <sup>5</sup>	O2 SLOPE=1.000	O <sub>2</sub> slope computed during zero/span calibration.
O2OFFSET <sup>5</sup>	O2 OFFSET=0.00 %	O <sub>2</sub> offset computed during zero/span calibration.
O2 <sup>5</sup>	O2=0.00 %	O <sub>2</sub> concentration.
TESTCHAN <sup>5,6,8</sup>	TEST=3627.1 MV	Value output to <i>TEST_OUTPUT</i> analog output, selected with <i>TEST_CHAN_ID</i> variable.

Test Name <sup>1</sup>	Message Text	Description
XIN1 <sup>12</sup>	AIN1=37.15 EU	External analog input 1 value in engineering units.
XIN2 <sup>12</sup>	AIN2=37.15 EU	External analog input 2 value in engineering units.
XIN3 <sup>12</sup>	AIN3=37.15 EU	External analog input 3 value in engineering units.
XIN4 <sup>12</sup>	AIN4=37.15 EU	External analog input 4 value in engineering units.
XIN5 <sup>12</sup>	AIN5=37.15 EU	External analog input 5 value in engineering units.
XIN6 <sup>12</sup>	AIN6=37.15 EU	External analog input 6 value in engineering units.
XIN7 <sup>12</sup>	AIN7=37.15 EU	External analog input 7 value in engineering units.
XIN8 <sup>12</sup>	AIN8=37.15 EU	External analog input 8 value in engineering units.
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.
<p><sup>1</sup> The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".</p> <p><sup>2</sup> Engineering firmware only.</p> <p><sup>3</sup> Current instrument units.</p> <p><sup>4</sup> Factory option.</p> <p><sup>5</sup> O<sub>2</sub> option.</p> <p><sup>6</sup> User-configurable D/A output option.</p> <p><sup>7</sup> Optional.</p> <p><sup>8</sup> CO<sub>2</sub> option.</p> <p><sup>9</sup> Concentration alarm option.</p> <p><sup>10</sup> M200EUP.</p> <p><sup>11</sup> M200EU and M200EU_NO<sub>y</sub>.</p> <p><sup>12</sup> External analog input option.</p> <p><sup>13</sup> O<sub>3</sub> option</p>		

**APPENDIX A-4: Signal I/O Definitions****Table A-4: Signal I/O Definitions**

Signal Name	Bit or Channel Number	Description
<b>Internal inputs, U7, J108, pins 9–16 = bits 0–7, default I/O address 322 hex</b>		
	0–7	Spare
<b>Internal outputs, U8, J108, pins 1–8 = bits 0–7, default I/O address 322 hex</b>		
ELEC_TEST	0	1 = electrical test on 0 = off
OPTIC_TEST	1	1 = optic test on 0 = off
PREAMP_RANGE_HI	2	1 = select high preamp range 0 = select low range
O3GEN_STATUS	3	0 = ozone generator on 1 = off
	4–5	Spare
I2C_RESET	6	1 = reset I <sup>2</sup> C peripherals 0 = normal
I2C_DRV_RST	7	0 = hardware reset 8584 chip 1 = normal
<b>Control inputs, U11, J1004, pins 1–6 = bits 0–5, default I/O address 321 hex</b>		
EXT_ZERO_CAL	0	0 = go into zero calibration 1 = exit zero calibration
EXT_SPAN_CAL	1	0 = go into span calibration 1 = exit span calibration
EXT_LOW_SPAN <sup>20</sup>	2	0 = go into low span calibration 1 = exit low span calibration
REMOTE_RANGE_HI <sup>21</sup>	3	0 = remote select high range 1 = default range
CAL_MODE_0 <sup>5</sup> CAL_MODE_1 CAL_MODE_2	0 1 2	Three inputs, taken as binary number (CAL_MODE_2 is MSB) select calibration level and range: 0 & 7 = Measure 1 = Zero, range #3 2 = Span, range #3 3 = Zero, range #2 4 = Span, range #2 5 = Zero, range #1 6 = Span, range #1
	4–5	Spare
	6–7	Always 1
<b>Control inputs, U14, J1006, pins 1–6 = bits 0–5, default I/O address 325 hex</b>		
	0–5	Spare
	6–7	Always 1

Signal Name	Bit or Channel Number	Description
<b>Control outputs, U17, J1008, pins 1–8 = bits 0–7, default I/O address 321 hex</b>		
	0–7	Spare
<b>Control outputs, U21, J1008, pins 9–12 = bits 0–3, default I/O address 325 hex</b>		
	0–3	Spare
<b>Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex</b>		
ST_SYSTEM_OK2 <sup>12</sup>	4	1 = system OK 0 = any alarm condition or in diagnostics mode
MB_RELAY_36 <sup>18</sup>		Controlled by MODBUS coil register
OUT_CAL_MODE <sup>13</sup>		1 = calibration mode 0 = measure mode
ST_CONC_ALARM_1 <sup>17</sup>	5	1 = conc. limit 1 exceeded 0 = conc. OK
MB_RELAY_37 <sup>18</sup>		Controlled by MODBUS coil register
OUT_SPAN_CAL <sup>13</sup>		1 = span calibration 0 = zero calibration
ST_CONC_ALARM_2 <sup>17</sup>	6	1 = conc. limit 2 exceeded 0 = conc. OK
MB_RELAY_38 <sup>18</sup>		Controlled by MODBUS coil register
OUT_PROBE_1 <sup>13</sup>		0 = select probe #1 1 = not selected
ST_HIGH_RANGE2 <sup>19</sup>	7	1 = high auto-range in use (mirrors <i>ST_HIGH_RANGE</i> status output) 0 = low auto-range
MB_RELAY_39 <sup>18</sup>		Controlled by MODBUS coil register
OUT_PROBE_2 <sup>13</sup>		0 = select probe #2 1 = not selected



Signal Name	Bit or Channel Number	Description
<b>A status outputs, U24, J1017, pins 1–8 = bits 0–7, default I/O address 323 hex</b>		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition
ST_CONC_VALID	1	0 = conc. valid 1 = conc. filters contain no data
ST_HIGH_RANGE	2	0 = high auto-range in use 1 = low auto-range
ST_ZERO_CAL	3	0 = in zero calibration 1 = not in zero
ST_SPAN_CAL	4	0 = in span calibration 1 = not in span
ST_DIAG_MODE	5	0 = in diagnostic mode 1 = not in diagnostic mode
ST_LOW_SPAN_CAL <sup>20</sup>	6	0 = in low span calibration 1 = not in low span
ST_O2_CAL <sup>11</sup>	7	0 = in O <sub>2</sub> calibration mode 1 = in measure or other calibration mode
ST_CO2_CAL <sup>15</sup>	7	0 = in CO <sub>2</sub> calibration mode 1 = in measure or other calibration mode
ST_O3_CAL <sup>23</sup>	7	0 = in O <sub>3</sub> calibration mode 1 = in measure or other calibration mode
<b>B status outputs, U27, J1018, pins 1–8 = bits 0–7, default I/O address 324 hex</b>		
	0–7	Spare
<b>Front panel I<sup>2</sup>C keyboard, default I<sup>2</sup>C address 4E hex</b>		
MAINT_MODE	5 (input)	0 = maintenance mode 1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language 1 = select first language (English)
SAMPLE_LED	8 (output)	0 = sample LED on 1 = off
CAL_LED	9 (output)	0 = cal. LED on 1 = off
FAULT_LED	10 (output)	0 = fault LED on 1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only) 1 = off

Signal Name	Bit or Channel Number	Description
<b>Relay board digital output (PCF8575), default I<sup>2</sup>C address 44 hex</b>		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
RCELL_HEATER	1	0 = reaction cell heater on 1 = off
CONV_HEATER	2	0 = converter heater on 1 = off
MANIFOLD_HEATER <sup>10</sup>	3	0 = bypass or dilution manifold heater on 1 = off
IZS_HEATER	4	0 = IZS heater on 1 = off
CO2_CELL_HEATER <sup>15</sup>		0 = CO <sub>2</sub> sensor cell heater on 1 = off
O2_CELL_HEATER <sup>11</sup>	5	0 = O <sub>2</sub> sensor cell heater on 1 = off
SPAN_VALVE	6	0 = let span gas in 1 = let zero gas in
ZERO_VALVE <sup>3</sup>		0 = let zero gas in 1 = let sample gas in
CAL_VALVE	7	0 = let cal. gas in 1 = let sample gas in
AUTO_ZERO_VALVE	8	0 = let zero air in 1 = let sample gas in
NOX_VALVE	9	0 = let NO <sub>x</sub> gas into reaction cell 1 = let NO gas into reaction cell
NO2_CONVERTER <sup>4</sup>		0 = turn on NO <sub>2</sub> converter (measure NO <sub>x</sub> ) 1 = turn off NO <sub>2</sub> converter (measure NO)
LOW_SPAN_VALVE <sup>20</sup>	10	0 = let low span gas in 1 = let high span/sample gas in
SPAN_VALVE <sup>3</sup>	11	0 = let span gas in 1 = let sample gas in
NO2_VALVE <sup>16</sup>	12	0 = let NO <sub>2</sub> gas into reaction cell 1 = let NO <sub>x</sub> /NO gas into reaction cell
VENT_VALVE <sup>7</sup>		0 = open vent valve 1 = close vent valve
	13–15	Spare

Signal Name	Bit or Channel Number	Description
<b>Rear board primary MUX analog inputs, MUX default I/O address 32A hex</b>		
PMT_SIGNAL	0	PMT detector
HVPS_VOLTAGE	1	HV power supply output
PMT_TEMP	2	PMT temperature
CO2_SENSOR <sup>15</sup>	3	CO <sub>2</sub> concentration sensor
	4	Temperature MUX
	5	Spare
O2_SENSOR <sup>11</sup>	6	O <sub>2</sub> concentration sensor
SAMPLE_PRESSURE	7	Sample pressure
RCELL_PRESSURE	8	Reaction cell pressure
REF_4096_MV	9	4.096V reference from MAX6241
OZONE_FLOW	10	Ozone flow rate
TEST_INPUT_11	11	Diagnostic test input
SAMP_REST_TEMP <sup>4</sup>		Sample restrictor temperature
CONV_TEMP	12	Converter temperature
TEST_INPUT_13	13	Diagnostic test input
	14	DAC loopback MUX
REF_GND	15	Ground reference
<b>Rear board temperature MUX analog inputs, MUX default I/O address 326 hex</b>		
BOX_TEMP	0	Internal box temperature
RCELL_TEMP	1	Reaction cell temperature
IZS_TEMP	2	IZS temperature
CO2_CELL_TEMP <sup>15</sup>		CO <sub>2</sub> sensor cell temperature
	3	Spare
O2_CELL_TEMP <sup>11</sup>	4	O <sub>2</sub> sensor cell temperature
TEMP_INPUT_5	5	Diagnostic temperature input
REM_BOX_TEMP <sup>4</sup>		Remote box temperature
TEMP_INPUT_6	6	Diagnostic temperature input
MANIFOLD_TEMP <sup>10</sup>	7	Bypass or dilution manifold temperature
<b>Rear board DAC MUX analog inputs, MUX default I/O address 327 hex</b>		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback

Signal Name	Bit or Channel Number	Description
<b>Rear board analog outputs, default I/O address 327 hex</b>		
CONC_OUT_1	0	Concentration output #1 (NO <sub>x</sub> )
DATA_OUT_1 <sup>6</sup>		Data output #1
CONC_OUT_2	1	Concentration output #2 (NO)
DATA_OUT_2 <sup>6</sup>		Data output #2
CONC_OUT_3	2	Concentration output #3 (NO <sub>2</sub> )
DATA_OUT_3 <sup>6</sup>		Data output #3
TEST_OUTPUT	3	Test measurement output
CONC_OUT_4 <sup>11, 15</sup>		Concentration output #4 (CO <sub>2</sub> , O <sub>2</sub> , or O <sub>3</sub> )
DATA_OUT_4 <sup>6</sup>		Data output #4
<b>External analog input board, default I<sup>2</sup>C address 5C hex</b>		
XIN1 <sup>22</sup>	0	External analog input 1
XIN2 <sup>22</sup>	1	External analog input 2
XIN3 <sup>22</sup>	2	External analog input 3
XIN4 <sup>22</sup>	3	External analog input 4
XIN5 <sup>22</sup>	4	External analog input 5
XIN6 <sup>22</sup>	5	External analog input 6
XIN7 <sup>22</sup>	6	External analog input 7
XIN8 <sup>22</sup>	7	External analog input 8
<sup>1</sup> Hessen protocol. <sup>2</sup> M200EH. <sup>3</sup> M200EU. <sup>4</sup> M200EUP. <sup>5</sup> Triple-range option. <sup>6</sup> User-configurable D/A output option. <sup>7</sup> Pressurized zero/span option. <sup>8</sup> Dual NO <sub>x</sub> option. <sup>9</sup> MAS special. <sup>10</sup> Factory option. <sup>11</sup> O <sub>2</sub> option. <sup>12</sup> Optional <sup>13</sup> Probe-select special. <sup>15</sup> CO <sub>2</sub> option. <sup>16</sup> NO <sub>2</sub> valve option. <sup>17</sup> Concentration alarm option. <sup>18</sup> MODBUS option. <sup>19</sup> High auto range relay option <sup>20</sup> Low span option. <sup>21</sup> Remote range control option <sup>22</sup> External analog input option. <sup>23</sup> O <sub>3</sub> option		

**APPENDIX A-5: Trigger Events and DAS Parameters****Table A-5: DAS Trigger Events**

Name	Description
ATIMER	Automatic timer expired
EXITZR	Exit zero calibration mode
EXITLS <sup>1</sup>	Exit low span calibration mode
EXITHS	Exit high span calibration mode
EXITMP	Exit multi-point calibration mode
EXITC2 <sup>4</sup>	Exit CO <sub>2</sub> calibration mode
EXITO2 <sup>3</sup>	Exit O <sub>2</sub> calibration mode
EXITO3 <sup>6</sup>	Exit O <sub>3</sub> calibration mode
SLPCHG	Slope and offset recalculated
CO2SLC <sup>4</sup>	CO <sub>2</sub> slope and offset recalculated
O2SLPC <sup>3</sup>	O <sub>2</sub> slope and offset recalculated
O3SLPC <sup>6</sup>	O <sub>3</sub> slope and offset recalculated
EXITDG	Exit diagnostic mode
CONC1W <sup>5</sup>	Concentration exceeds limit 1 warning
CONC2W <sup>5</sup>	Concentration exceeds limit 2 warning
AZEROW	Auto-zero warning
OFLOWW	Ozone flow warning
RPRESW	Reaction cell pressure warning
RTEMPW	Reaction cell temperature warning
MFTMPW <sup>2</sup>	Bypass or dilution manifold temperature warning
C2TMPW <sup>4</sup>	CO <sub>2</sub> sensor cell temperature warning
O2TMPW <sup>3</sup>	O <sub>2</sub> sensor cell temperature warning
O3TMPW <sup>6</sup>	O <sub>3</sub> sensor cell temperature warning
O3LMPW <sup>6</sup>	O <sub>3</sub> sensor lamp temperature warning
O3REFW <sup>6</sup>	O <sub>3</sub> sensor photometer reference warning
O3PRSW <sup>6</sup>	O <sub>3</sub> sensor pressure warning
IZTMPW	IZS temperature warning
CTEMPW	Converter temperature warning
PTEMPW	PMT temperature warning
SFLOWW	Sample flow warning
BTEMPW	Box temperature warning
HVPSW	HV power supply warning
<sup>1</sup> Low span option. <sup>2</sup> Factory option. <sup>3</sup> O <sub>2</sub> option. <sup>4</sup> CO <sub>2</sub> option. <sup>5</sup> Concentration alarm option. <sup>6</sup> O <sub>3</sub> option.	

**Table A-6: DAS Parameters**

<b>Name</b>	<b>Description</b>	<b>Units</b>
PMTDET	PMT detector reading	mV
RAWNOX <sup>6</sup>	Raw PMT detector reading for NOX	mV
RAWNO <sup>6</sup>	Raw PMT detector reading for NO	mV
NXSLP1	NO <sub>x</sub> slope for range #1	—
NXSLP2	NO <sub>x</sub> slope for range #2	—
NXSLP3 <sup>7</sup>	NO <sub>x</sub> slope for range #3	—
NOSLP1	NO slope for range #1	—
NOSLP2	NO slope for range #2	—
NOSLP3 <sup>7</sup>	NO slope for range #3	—
NXOFS1	NO <sub>x</sub> offset for range #1	mV
NXOFS2	NO <sub>x</sub> offset for range #2	mV
NXOFS3 <sup>7</sup>	NO <sub>x</sub> offset for range #3	mV
NOOFS1	NO offset for range #1	mV
NOOFS2	NO offset for range #2	mV
NOOFS3 <sup>7</sup>	NO offset for range #3	mV
CO2SLP <sup>5</sup>	CO <sub>2</sub> slope	—
CO2OFS <sup>5</sup>	CO <sub>2</sub> offset	%
O2SLPE <sup>3</sup>	O <sub>2</sub> slope	—
O2OFST <sup>3</sup>	O <sub>2</sub> offset	%
NXZSC1	NO <sub>x</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
NXZSC2	NO <sub>x</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
NXZSC3 <sup>7</sup>	NO <sub>x</sub> concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
NOZSC1	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
NOZSC2	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
NOZSC3 <sup>7</sup>	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
N2ZSC1	NO <sub>2</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
N2ZSC2	NO <sub>2</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
N2ZSC3 <sup>7</sup>	NO <sub>2</sub> concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB <sup>2</sup>
CO2ZSC <sup>5</sup>	CO <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
O2ZSCN <sup>3</sup>	O <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
NXCNC1	NO <sub>x</sub> concentration for range #1	PPB <sup>2</sup>

Name	Description	Units
NXCNC2	NO <sub>x</sub> concentration for range #2	PPB <sup>2</sup>
NXCNC3 <sup>7</sup>	NO <sub>x</sub> concentration for range #3	PPB <sup>2</sup>
NOCNC1	NO concentration for range #1	PPB <sup>2</sup>
NOCNC2	NO concentration for range #2	PPB <sup>2</sup>
NOCNC3 <sup>7</sup>	NO concentration for range #3	PPB <sup>2</sup>
N2CNC1	NO <sub>2</sub> concentration for range #1	PPB <sup>2</sup>
N2CNC2	NO <sub>2</sub> concentration for range #2	PPB <sup>2</sup>
N2CNC3 <sup>7</sup>	NO <sub>2</sub> concentration for range #3	PPB <sup>2</sup>
CO2CNC <sup>5</sup>	CO <sub>2</sub> concentration	%
O2CONC <sup>3</sup>	O <sub>2</sub> concentration	%
STABIL	Concentration stability	PPB <sup>2</sup>
AZERO	Auto zero offset (range de-normalized)	mV
O3FLOW	Ozone flow rate	cc/m
RCPRES	Reaction cell pressure	"Hg
RCTEMP	Reaction cell temperature	°C
MFTEMP <sup>1</sup>	Bypass or dilution manifold temperature	°C
C2TEMP <sup>5</sup>	CO <sub>2</sub> sensor cell temperature	°C
O2TEMP <sup>3</sup>	O <sub>2</sub> sensor cell temperature	°C
IZTEMP	IZS block temperature	°C
CNVEF1	Converter efficiency factor for range #1	—
CNVEF2	Converter efficiency factor for range #2	—
CNVEF3 <sup>7</sup>	Converter efficiency factor for range #3	—
CNVTMP	Converter temperature	°C
PMTTMP	PMT temperature	°C
SMPFLW	Sample flow rate	cc/m
SMPPRS	Sample pressure	"Hg
SRSTMP <sup>8</sup>	Sample restrictor temperature	°C
BOXTMP	Internal box temperature	°C
RBXTMP <sup>8</sup>	Remote box temperature	°C
HVPS	High voltage power supply output	Volts
REFGND	Ground reference (REF_GND)	mV
XIN1 <sup>9</sup>	Channel 1 Analog In	
XIN1SLPE <sup>9</sup>	Channel 1 Analog In Slope	
XIN1OFST <sup>9</sup>	Channel 1 Analog In Offset	
XIN2 <sup>9</sup>	Channel 2 Analog In	
XIN2SLPE <sup>9</sup>	Channel 2 Analog In Slope	
XIN2OFST <sup>9</sup>	Channel 2 Analog In Offset	
XIN3 <sup>9</sup>	Channel 3 Analog In	
XIN3SLPE <sup>9</sup>	Channel 3 Analog In Slope	
XIN3OFST <sup>9</sup>	Channel 3 Analog In Offset	

Name	Description	Units
XIN4 <sup>9</sup>	Channel 4 Analog In	
XIN4SLPE <sup>9</sup>	Channel 4 Analog In Slope	
XIN4OFST <sup>9</sup>	Channel 4 Analog In Offset	
XIN5 <sup>9</sup>	Channel 5 Analog In	
XIN5SLPE <sup>9</sup>	Channel 5 Analog In Slope	
XIN5OFST <sup>9</sup>	Channel 5 Analog In Offset	
XIN6 <sup>9</sup>	Channel 6 Analog In	
XIN6SLPE <sup>9</sup>	Channel 6 Analog In Slope	
XIN6OFST <sup>9</sup>	Channel 6 Analog In Offset	
XIN7 <sup>9</sup>	Channel 7 Analog In	
XIN7SLPE <sup>9</sup>	Channel 7 Analog In Slope	
XIN7OFST <sup>9</sup>	Channel 7 Analog In Offset	
XIN8 <sup>9</sup>	Channel 8 Analog In	
XIN8SLPE <sup>9</sup>	Channel 8 Analog In Slope	
XIN8OFST <sup>9</sup>	Channel 8 Analog In Offset	
RF4096	4096 mV reference (REF_4096_MV)	mV
TEST11	Diagnostic test input (TEST_INPUT_11)	mV
TEST13	Diagnostic test input (TEST_INPUT_13)	mV
TEMP5	Diagnostic temperature input (TEMP_INPUT_5)	°C
TEMP6	Diagnostic temperature input (TEMP_INPUT_6)	°C
<sup>1</sup> Factory option. <sup>2</sup> Current instrument units. <sup>3</sup> O <sub>2</sub> option. <sup>4</sup> Optional. <sup>5</sup> CO <sub>2</sub> option. <sup>6</sup> Engineering firmware only. <sup>7</sup> Triple-range option. <sup>8</sup> M200EUP. <sup>9</sup> Analog In option, T-Series only.		



## APPENDIX A-6: Terminal Command Designators

Table A-7: Terminal Command Designators

Command	Additional Command Syntax	Description
? [ID]		Display help screen and this list of commands
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL name hexmask	Display test(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL name hexmask	Disable test(s)
W [ID]	SET ALL name hexmask	Display warning(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL name hexmask	Clear warning(s)
C [ID]	ZERO LOWSPAN SPAN [1 2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
	PRINT ["name"] [SCRIPT]	Print DAS configuration
	RECORDS ["name"]	Print number of DAS records
	REPORT ["name"] [RECORDS=number] [FROM=<start date>][TO=<end date>][VERBOSE COMPACT HEX] (Print DAS records)(date format: MM/DD/YYYY(or YY) [HH:MM:SS])	Print DAS records
	CANCEL	Halt printing DAS records
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode
	DASBEGIN [<data channel definitions>] DASEND	Upload DAS configuration
	CHANNELBEGIN propertylist CHANNELEND	Upload single DAS channel
	CHANNELDELETE ["name"]	Delete DAS channels

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

<b>Terminal Key Assignments</b>	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
<b>Computer Mode Key Assignments</b>	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

**APPENDIX A-7: MODBUS Register Map**

<b>MODBUS Register Address (decimal, 0-based)</b>	<b>Description <sup>10</sup></b>	<b>Units</b>
<b>MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)</b>		
0	Instantaneous PMT detector reading	mV
2	NO <sub>x</sub> slope for range #1	—
4	NO <sub>x</sub> slope for range #2	—
6	NO slope for range #1	—
8	NO slope for range #2	mV
10	NO <sub>x</sub> offset for range #1	mV
12	NO <sub>x</sub> offset for range #2	mV
14	NO offset for range #1	mV
16	NO offset for range #2	mV
18	NO <sub>x</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
20	NO <sub>x</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
24	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
26	NO <sub>2</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	NO <sub>2</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	NO <sub>x</sub> concentration for range #1	PPB
32	NO <sub>x</sub> concentration for range #2	PPB
34	NO concentration for range #1	PPB
36	NO concentration for range #2	PPB
38	NO <sub>2</sub> concentration for range #1	PPB
40	NO <sub>2</sub> concentration for range #2	PPB
42	Concentration stability	PPB
44	Auto zero offset (range de-normalized) Pre React <sup>11</sup>	mV
46	Ozone flow rate	cc/m
48	Reaction cell pressure	"Hg
50	Reaction cell temperature	°C
52	Manifold temperature	°C
54	Converter efficiency factor for range #1	—
56	Converter efficiency factor for range #2	—
58	Converter temperature	°C
60	PMT temperature	°C

MODBUS Register Address (decimal, 0-based)	Description <sup>10</sup>	Units
62	Sample flow rate	cc/m
64	Sample pressure	"Hg
66	Internal box temperature	°C
68	High voltage power supply output	Volts
70	Ground reference (REF_GND)	mV
72	4096 mV reference (REF_4096_MV)	mV
74	Diagnostic test input (TEST_INPUT_13)	mV
76	Diagnostic temperature input (TEMP_INPUT_6)	°C
78	IZS temperature	°C
80 <sup>9</sup>	Sample restrictor temperature	°C
82 <sup>9</sup>	Remote box temperature	°C
80	Diagnostic test input (TEST_INPUT_11)	mV
82	Diagnostic temperature input (TEMP_INPUT_5)	°C
84 <sup>1</sup>	Raw PMT detector reading for NO <sub>x</sub>	mV
86 <sup>1</sup>	Raw PMT detector reading for NO	mV
100 <sup>3</sup>	NO <sub>x</sub> slope for range #3	—
102 <sup>3</sup>	NO slope for range #3	mV
104 <sup>3</sup>	NO <sub>x</sub> offset for range #3	mV
106 <sup>3</sup>	NO offset for range #3	mV
108 <sup>3</sup>	NO <sub>x</sub> concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
110 <sup>3</sup>	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
112 <sup>3</sup>	NO <sub>2</sub> concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
114 <sup>3</sup>	NO <sub>x</sub> concentration for range #3	PPB
116 <sup>3</sup>	NO concentration for range #3	PPB
118 <sup>3</sup>	NO <sub>2</sub> concentration for range #3	PPB
120 <sup>3</sup>	Converter efficiency factor for range #3	—
130 <sup>12</sup>	External analog input 1 value	Volts
132 <sup>12</sup>	External analog input 1 slope	eng unit /V
134 <sup>12</sup>	External analog input 1 offset	eng unit
136 <sup>12</sup>	External analog input 2 value	Volts
138 <sup>12</sup>	External analog input 2 slope	eng unit /V
140 <sup>12</sup>	External analog input 2 offset	eng unit
142 <sup>12</sup>	External analog input 3 value	Volts
144 <sup>12</sup>	External analog input 3 slope	eng unit /V
146 <sup>12</sup>	External analog input 3 offset	eng unit
148 <sup>12</sup>	External analog input 4 value	Volts

MODBUS Register Address (decimal, 0-based)	Description <sup>10</sup>	Units
150 <sup>12</sup>	External analog input 4 slope	eng unit /V
152 <sup>12</sup>	External analog input 4 offset	eng unit
154 <sup>12</sup>	External analog input 5 value	Volts
156 <sup>12</sup>	External analog input 5 slope	eng unit /V
158 <sup>12</sup>	External analog input 5 offset	eng unit
160 <sup>12</sup>	External analog input 6 value	Volts
162 <sup>12</sup>	External analog input 6 slope	eng unit /V
164 <sup>12</sup>	External analog input 6 offset	eng unit
166 <sup>12</sup>	External analog input 7 value	Volts
168 <sup>12</sup>	External analog input 7 slope	eng unit /V
170 <sup>12</sup>	External analog input 7 offset	eng unit
172 <sup>12</sup>	External analog input 8 value	Volts
174 <sup>12</sup>	External analog input 8 slope	eng unit /V
176 <sup>12</sup>	External analog input 8 offset	eng unit
188 <sup>13</sup>	Converter efficiency factor slope for range #1	—
190 <sup>13</sup>	Converter efficiency factor offset for range #1	—
192 <sup>13</sup>	Converter efficiency factor slope for range #2	—
194 <sup>13</sup>	Converter efficiency factor offset for range #2	—
196 <sup>13, 3</sup>	Converter efficiency factor slope for range #3	—
198 <sup>13, 3</sup>	Converter efficiency factor offset for range #3	—
200 <sup>5</sup>	O <sub>2</sub> concentration	%
202 <sup>5</sup>	O <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
204 <sup>5</sup>	O <sub>2</sub> slope	—
206 <sup>5</sup>	O <sub>2</sub> offset	%
208 <sup>5</sup>	O <sub>2</sub> sensor cell temperature	°C
300 <sup>6</sup>	CO <sub>2</sub> concentration	%
302 <sup>6</sup>	CO <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
304 <sup>6</sup>	CO <sub>2</sub> slope	—
306 <sup>6</sup>	CO <sub>2</sub> offset	%
308 <sup>6</sup>	CO <sub>2</sub> sensor cell temperature	°C
400 <sup>14</sup>	O <sub>3</sub> concentration	PPB
402 <sup>14</sup>	O <sub>3</sub> concentration during zero/span calibration, just before computing new slope and offset	PPB
404 <sup>14</sup>	O <sub>3</sub> slope	—
406 <sup>14</sup>	O <sub>3</sub> offset	PPB
408 <sup>14</sup>	O <sub>3</sub> sensor cell temperature	°C
410 <sup>14</sup>	O <sub>3</sub> photometer reference potential	mV

<b>MODBUS Register Address (decimal, 0-based)</b>	<b>Description <sup>10</sup></b>	<b>Units</b>
412 <sup>14</sup>	O <sub>3</sub> photometer measurement potential	mV
414 <sup>14</sup>	O <sub>3</sub> cell pressure	PSIA
416 <sup>14</sup>	O <sub>3</sub> lamp temperature	°C
418 <sup>14 + 15</sup>	O <sub>3</sub> bench serial number	—
420 <sup>14</sup>	O <sub>3</sub> bench firmware revision	—
<b>MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)</b>		
0	Maps to <i>NOX_SPAN1</i> variable; target conc. for range #1	Conc. units
2	Maps to <i>NO_SPAN1</i> variable; target conc. for range #1	Conc. units
4	Maps to <i>NOX_SPAN2</i> variable; target conc. for range #2	Conc. units
6	Maps to <i>NO_SPAN2</i> variable; target conc. for range #2	Conc. units
100 <sup>3</sup>	Maps to <i>NOX_SPAN3</i> variable; target conc. for range #3	Conc. units
102 <sup>3</sup>	Maps to <i>NO_SPAN3</i> variable; target conc. for range #3	Conc. units
200 <sup>5</sup>	Maps to <i>O2_TARG_SPAN_CONC</i> variable; target conc. for range O <sub>2</sub> gas	%
300 <sup>6</sup>	Maps to <i>CO2_TARG_SPAN_CONC</i> variable; target conc. for range CO <sub>2</sub> gas	%
400 <sup>14</sup>	Maps to <i>ID_VAR_O3_TARG_SPAN_CONC</i> variable; O <sub>3</sub> target span concentration	PPB
402 <sup>14</sup>	Maps to <i>ID_VAR_O3_PRESSURE_OFFSET</i> variable; O <sub>3</sub> cell pressure compensation offset	PSIA
404 <sup>14</sup>	Maps to <i>ID_VAR_O3_PRESSURE_SLOPE</i> variable; O <sub>3</sub> cell pressure slope compensation	—
406 <sup>14</sup>	Maps to <i>ID_VAR_O3_TEMP_SET</i> variable; O <sub>3</sub> temperature setpoint	°C
408 <sup>14</sup>	Maps to <i>ID_VAR_O3_DWELL</i> variable; O <sub>3</sub> dwell time	Seconds
410 <sup>14</sup>	Maps to <i>ID_VAR_O3_RANGE</i> variable; O <sub>3</sub> analog output range	PPB
<b>MODBUS Discrete Input Registers (single-bit; read-only)</b>		
0	Manifold temperature warning	
1	Converter temperature warning	
2	Auto-zero warning	
3	Box temperature warning	
4	PMT detector temperature warning	
5	Reaction cell temperature warning	
6	Sample flow warning	
7	Ozone flow warning	
8	Reaction cell pressure warning	
9	HVPS warning	
10	System reset warning	

MODBUS Register Address (decimal, 0-based)	Description <sup>10</sup>	Units
11	Rear board communication warning	
12	Relay board communication warning	
13	Front panel communication warning	
14	Analog calibration warning	
15	Dynamic zero warning	
16	Dynamic span warning	
17	Invalid concentration	
18	In zero calibration mode	
19	In span calibration mode	
20	In multi-point calibration mode	
21	System is OK (same meaning as <i>SYSTEM_OK</i> I/O signal)	
22	Ozone generator warning	
23	IZS temperature warning	
24 <sup>8</sup>	In low span calibration mode	
25 <sup>7</sup>	NO concentration alarm limit #1 exceeded	
26 <sup>7</sup>	NO concentration alarm limit #2 exceeded	
27 <sup>7</sup>	NO <sub>2</sub> concentration alarm limit #1 exceeded	
28 <sup>7</sup>	NO <sub>2</sub> concentration alarm limit #2 exceeded	
29 <sup>7</sup>	NO <sub>x</sub> concentration alarm limit #1 exceeded	
30 <sup>7</sup>	NO <sub>x</sub> concentration alarm limit #2 exceeded	
200 <sup>5</sup>	Calibrating O <sub>2</sub> gas	
201 <sup>5</sup>	O <sub>2</sub> sensor cell temperature warning	
202 <sup>5+7</sup>	O <sub>2</sub> concentration alarm limit #1 exceeded	
203 <sup>5+7</sup>	O <sub>2</sub> concentration alarm limit #2 exceeded	
300 <sup>6</sup>	Calibrating CO <sub>2</sub> gas	
301 <sup>6</sup>	CO <sub>2</sub> sensor cell temperature warning	
302 <sup>6+7</sup>	CO <sub>2</sub> concentration alarm limit #1 exceeded	
303 <sup>6+7</sup>	CO <sub>2</sub> concentration alarm limit #2 exceeded	
400 <sup>14</sup>	Calibrating O <sub>3</sub> gas	
401 <sup>14</sup>	O <sub>3</sub> cell temperature warning	
402 <sup>14</sup>	O <sub>3</sub> concentration alarm limit #1 exceeded	
403 <sup>14</sup>	O <sub>3</sub> concentration alarm limit #2 exceeded	
<b>MODBUS Coil Registers (single-bit; read/write)</b>		
0	Maps to relay output signal 36 ( <i>MB_RELAY_36</i> in signal I/O list)	
1	Maps to relay output signal 37 ( <i>MB_RELAY_37</i> in signal I/O list)	
2	Maps to relay output signal 38 ( <i>MB_RELAY_38</i> in signal I/O list)	
3	Maps to relay output signal 39 ( <i>MB_RELAY_39</i> in signal I/O list)	
20 <sup>2</sup>	Triggers zero calibration of NO <sub>x</sub> range #1 (on enters cal.; off exits cal.)	

MODBUS Register Address (decimal, 0-based)	Description <sup>10</sup>	Units
21 <sup>2</sup>	Triggers span calibration of NO <sub>x</sub> range #1 (on enters cal.; off exits cal.)	
22 <sup>2</sup>	Triggers zero calibration of NO <sub>x</sub> range #2 (on enters cal.; off exits cal.)	
23 <sup>2</sup>	Triggers span calibration of NO <sub>x</sub> range #2 (on enters cal.; off exits cal.)	
<p><sup>1</sup> Engineering firmware only.</p> <p><sup>2</sup> Set <i>DYN_ZERO</i> or <i>DYN_SPAN</i> variables to <i>ON</i> to enable calculating new slope or offset. Otherwise a calibration check is performed.</p> <p><sup>3</sup> Triple-range option.</p> <p><sup>4</sup> Optional.</p> <p><sup>5</sup> O<sub>2</sub> option.</p> <p><sup>6</sup> CO<sub>2</sub> option.</p> <p><sup>7</sup> Concentration alarm option.</p> <p><sup>8</sup> Low span option.</p> <p><sup>9</sup> M200EUP.</p> <p><sup>10</sup> All NO<sub>x</sub> references become NO<sub>y</sub> for M200EU_NO<sub>y</sub>.</p> <p><sup>11</sup> M200EU and M200EU_NO<sub>y</sub>.</p> <p><sup>12</sup> External analog input option.</p> <p><sup>13</sup> M200EU_PHOTO.</p> <p><sup>14</sup> O<sub>3</sub> option.</p> <p><sup>15</sup> 32-bit integer value stored in high/low word order (i.e. <b>not</b> a floating-point value).</p>		



This page intentionally left blank.

## APPENDIX B - Spare Parts

---

**Note** Use of replacement parts other than those supplied by T-API may result in non compliance with European standard EN 61010-1.

---

---

**Note** Due to the dynamic nature of part numbers, please refer to the Website or call Customer Service for more recent updates to part numbers.

---

This page intentionally left blank.

## T200 Spare Parts List

Reference: PN 06847 02/28/2013

1 of 3 page(s)

Part Number	Description
000940100	ORIFICE, 3 MIL, DILUTION & VACUUM MANIFOLDS & IZS
000940400	ORIFICE, 4 MIL, OZONE FLOW & O2 OPTION
000940500	CD, ORIFICE, .007 ORANGE (KB)
000940600	ORIFICE, 10 MIL, SAMPLE FLOW & DILUTION & VACUUM MANIFOLDS
001330000	SLEEVE, REACTION CELL
001761800	ASSY, FLOW CTL, 90CC, OZONE DRYER
002270100	AKIT, GASKETS, WINDOW, (12 GASKETS = 1)
002730000	CD, FILTER, 665NM (KB)
004330000	ZERO AIR SCRUBBER (NO/NO2)
005960000	KIT, EXPENDABLE, ACTIVATED CHARCOAL (6 LBS)
005970000	KIT, EXPENDABLE, PURAFIL (6 LBS)
008830000	COLD BLOCK (KB)
009690200	AKIT, TFE FLTR ELEM (FL19,100=1) 47mm
009690300	AKIT, TFE FLTR ELEM (FL19, 30=1) 47mm
009810300	ASSY, PUMP PK, 115V/60HZ w/FL34/NO/SO
009810600	ASSY, PUMP PACK, 100V/60HZ w/FL34
009811000	ASSY, PUMP, NOX, 220-240V/50-60HZ FL34
011310000	ASSY, OZONE DRYER W/FLOW CONTROL
011340500	ASSY, SENSOR
011420500	ASSY, NOX REACTION CELL
011630000	HVPS INSULATOR GASKET (KB)
011930000	CD, PMT (R928), NOX, (KB)
013140000	ASSY, COOLER FAN (NOX/SOX)
014030000	AKIT, NOX EXPENDABLES, IZS
014080100	ASSY, HVPS, SOX/NOX
016290000	WINDOW, SAMPLE FILTER, 47MM (KB)
016300800	ASSY, SAMPLE FILTER, 47MM, ANG BKT, 1UM
018720100	ASSY, MOLY CONVERTER, W/O3 DESTRUCTOR
018720200	ASSY, MOLYCON, w/O3 DEST - EXH *
037860000	ORING, TFE RETAINER, SAMPLE FILTER
039700100	HEATER, BAND, TYPE K, DUAL VOLTAGE(KB)
040010000	ASSY, FAN REAR PANEL
040030800	PCA, FLOW/PRESSURE
040400000	ASSY, HEATERS/THERMAL SWITCH, REACTION CELL
040410100	ASSY, VACUUM MANIFOLD
040420200	ASSY, O3 GEN BRK, HIGH-O/P
040900000	ORIFICE HOLDER, REACTION CELL (KB)
041800500	PCA, PMT PREAMP, VR
041920000	ASSY, THERMISTOR, REACTION CELL
042680100	ASSY, VALVE (SS)
043170000	MANIFOLD, RCELL, (KB) *
043420000	ASSY, HEATER/THERM, O2 SEN
044530000	OPTION, O2 SENSOR ASSY,(KB)
044600000	AKIT, SPARES, NOX

## T200 Spare Parts List

Reference: PN 06847 02/28/2013

2 of 3 page(s)

Part Number	Description
044610000	ASSY, VALVES, MOLY/HICON
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >467
045500100	ASSY, ORIFICE HOLDER, 4 MIL, OZONE FLOW
045500300	ASSY, ORIFICE HOLDER, 10 MIL, SAMPLE FLOW & DIL MANIFOLD
045500400	ASSY, ORIFICE HOLDER, 3 MIL, DIL MANIFOLD
046030000	KIT, EXPENDABLE, DESSICANT, OZONE FILTER
046480000	ASSY, DILUTION MANIFOLD, (KB)
047150000	AKIT, EXPENDABLES, NOX
048830000	AKIT, EXP KIT, EXHAUST CLNSR, SILCA GEL
049310100	PCA, TEC CONTROL, E SERIES
049760300	ASSY, TC PROG PLUG, MOLY, TYP K, TC1
050610700	CONFIGURATION PLUGS, 115V, M200E
050610900	CONFIGURATION PLUGS, 220-240V, M200E
050611100	CONFIGURATION PLUGS, 100V, M200E
050700200	KIT, RELAY BD NOX CONFIGURATION
051210000	ASSY, OZONE DESTRUCTOR
051990000	ASSY, SCRUBBER, INLINE, PUMP PACK
052820000	ASSY, IZS, HEATER/THERM, NOX
052930200	ASSY, BAND HEATER TYPE K, NOX
055290000	AKIT, PUMP REBUILD, THOMAS 688, SNGL HD
055740000	ASSY, PUMP, NOx PUMP PACK, 115V/60HZ
055740100	ASSY, PUMP, NOx PUMP PACK, 220V/60HZ
055740200	ASSY, PUMP, NOx PUMP PACK, 220V/50HZ
058021100	PCA, E-SERIES MOTHERBD, GEN 5-ICOP (ACCEPTS ACROSSER OR ICOP CPU)
058230000	ASSY, O3 CLEANSER, ALUMINUM
059940000	OPTION, SAMPLE GAS CONDITIONER, NOX*
062390000	ASSY, MOLY GUTS w/WOOL
062420200	PCA, SER INTRFACE, ICOP CPU, E- (OPTION) (USE WITH ICOP CPU 062870000)
064540000	ASSY, PUMP NOX INTERNAL, 115V/60HZ
064540100	ASSY, PUMP NOX INTERNAL, 230V/60HZ
064540200	ASSY, PUMP NOX INTERNAL, 230V/50HZ
066970000	PCA, INTRF. LCD TOUCH SCRIN, F/P
067240000	CPU, PC-104, VSX-6154E, ICOP *
067300000	PCA, AUX-I/O BD, ETHERNET, ANALOG & USB
067300100	PCA, AUX-I/O BOARD, ETHERNET
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067900000	LCD MODULE, W/TOUCHSCREEN
068240100	DOM, w/SOFTWARE, T200 *
068580000	MANUAL, T200, OPERATORS
068810000	PCA, LVDS TRANSMITTER BOARD
069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	CONNECTOR, REAR PANEL, 12 PIN
CN0000520	CONNECTOR, REAR PANEL, 10 PIN
FL0000001	FILTER, FLOW CONTROL

## T200 Spare Parts List

Reference: PN 06847 02/28/2013

3 of 3 page(s)

Part Number	Description
FL0000003	FILTER, DFU (KB)
FM0000004	FLOWMETER (KB)
FT0000010	FITTING, FLOW CONTROL
HW0000005	FOOT, CHASSIS/PUMP PACK
HW0000020	SPRING, FLOW CONTROL
HW0000030	ISOLATOR, SENSOR ASSY
HW0000031	FERRULE, SHOCKMOUNT
HW0000099	STANDOFF, #6-32X.5, HEX SS M/F
HW0000101	ISOLATOR, PUMP PACK
HW0000453	SUPPORT, CIRCUIT BD, 3/16" ICOP
KIT000051	KIT, REACTION CELL REBUILD
KIT000095	AKIT, REPLACEMENT COOLER
KIT000207	KIT, RELAY RETROFIT
KIT000218	KIT, RELAY RETROFIT, MOLY PLUG
KIT000219	AKIT, 4-20MA CURRENT OUTPUT
KIT000231	KIT, RETROFIT, Z/S VALVE
KIT000253	ASSY & TEST, SPARE PS37
KIT000254	ASSY & TEST, SPARE PS38
OP0000030	OXYGEN TRANSDUCER, PARAMAGNETIC
OR0000001	ORING, FLOW CONTROL/IZS
OR0000002	ORING, REACTION CELL SLEEVE
OR0000025	ORING, ZERO AIR SCRUBBER
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK
OR0000034	ORING, (USED W/ FT10)
OR0000039	ORING, FLOW CONTROL
OR0000044	ORING, REACTION CELL MANIFOLD
OR0000046	ORING, PERMEATION OVEN
OR0000058	ORING, SAMPLE FILTER
OR0000083	ORING, PMT SIGNAL & OPTIC LED
OR0000086	ORING, 2-006, CV-75 COMPOUND(KB)
OR0000094	ORING, SAMPLE FILTER
PU0000005	PUMP, THOMAS 607, 115V/60HZ (KB)
PU0000011	REBUILD KIT, THOMAS 607(KB)
PU0000052	PUMP, THOMAS 688, 220/240V 50HZ/60HZ
PU0000054	PUMP, THOMAS 688, 100V, 50/60HZ
PU0000083	KIT, REBUILD, PU80, PU81, PU82
RL0000015	RELAY, DPDT, (KB)
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *
SW0000059	PRESSURE SENSOR, 0-15 PSIA, ALL SEN
WR0000008	POWER CORD, 10A(KB)

This page intentionally left blank.

CUSTOMER: \_\_\_\_\_ PHONE: \_\_\_\_\_

CONTACT NAME: \_\_\_\_\_ FAX NO. \_\_\_\_\_

SITE ADDRESS: \_\_\_\_\_

MODEL SERIAL NO.: \_\_\_\_\_ FIRMWARE REVISION: \_\_\_\_\_

1. ARE THERE ANY FAILURE MESSAGES? \_\_\_\_\_

PLEASE COMPLETE THE FOLLOWING TABLE: (NOTE: *DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS SHOWN BELOW WILL BE AVAILABLE IN YOUR INSTRUMENT*)

\*IF OPTION IS INSTALLED

PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE
<b>RANGE</b>	PPB/PPM	50 PPB TO 20 PPM
<b>NOx STAB</b>	PPB/PPM	≤ 1 PPB WITH ZERO AIR
<b>SAMPLE FLOW</b>	CM <sup>3</sup>	500 ± 50
<b>OZONE FLOW</b>	CM <sup>3</sup>	80 ± 15
<b>PMT SIGNAL WITH ZERO AIR</b>	MV	-20 TO 150
<b>PMT SIGNAL AT SPAN GAS CONC</b>	MV PPB	0-5000MV 0-20,000 PPB
<b>NORM PMT SIGNAL AT SPAN GAS CONC</b>	MV PPB	0-5000MV 0-20000PPB
<b>AZERO</b>	MV	-20 TO 150
<b>HVPS</b>	V	400 – 900
<b>RCELL TEMP</b>	°C	50 ± 1
<b>BOX TEMP</b>	°C	AMBIENT ± 5°C
<b>PMT TEMP</b>	°C	7 ± 2°C
<b>IZS TEMP*</b>	°C	50 ± 1°C
<b>MOLY TEMP</b>	°C	315 ± 5°C
<b>RCEL PRESS</b>	IN-HG-A	<10
<b>SAMP PRESS</b>	IN-HG-A	~ 1" < AMBIENT
<b>NOx SLOPE</b>		1.0 ± 0.3
<b>NOx OFFSET</b>		-50 TO 150
<b>NO SLOPE</b>		1.0 ± 0.3
<b>NO OFFSET</b>		-50 TO 150
<b>ETEST</b>	PMT MV	2000 ± 1000
<b>OTEST</b>	PMT MV	2000 ± 1000
Values are in the Signal I/O		
<b>REF_4096_MV</b>	MV	4096mv ±2mv and Must be Stable
<b>REF_GND</b>	MV	0± 0.5 and Must be Stable

TELEDYNE API CUSTOMER SERVICE  
 EMAIL: SDA\_techsupport@teledyne.com  
 PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816





2. WHAT ARE THE RCELL & SAMPLE PRESSURES WITH THE SAMPLE INLET ON REAR OF MACHINE CAPPED?

RCELL PRESS - \_\_\_\_\_ IN-HG-A SAMPLE PRESSURE - \_\_\_\_\_ IN-HG-A

3. WHAT ARE THE FAILURE SYMPTOMS? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

4. WHAT TEST(S) HAVE YOU DONE TRYING TO SOLVE THE PROBLEM? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. IF POSSIBLE, PLEASE INCLUDE A PORTION OF A STRIP CHART PERTAINING TO THE PROBLEM. CIRCLE PERTINENT DATA.

THANK YOU FOR PROVIDING THIS INFORMATION. YOUR ASSISTANCE ENABLES TELEDYNE API TO RESPOND FASTER TO THE PROBLEM THAT YOU ARE ENCOUNTERING.

## **APPENDIX D – Wire List and Electronic Schematics**

This page intentionally left blank.

## T200X INTERCONNECT LIST

(Reference: 0691101B DCN5936)

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
<b>0364901</b>	<b>CBL, AC POWER</b>								
	AC Line	Power Entry	CN0000073		L	Power Switch	SW0000025		L
	AC Neutral	Power Entry	CN0000073		N	Power Switch	SW0000025		N
	Power Grnd	Power Entry	CN0000073			Shield	SW0000025		
	Power Grnd	Power Entry	CN0000073			Chassis			
	AC Line Switched	Power Switch	SW0000025		L	PS2 (+12)	060820000	SK2	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS2 (+12)	060820000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS2 (+12)	060820000	SK2	2
	AC Line Switched	Power Switch	SW0000025		L	PS1 (+5, ±15)	068010000	SK2	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS1 (+5, ±15)	068010000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS1 (+5, ±15)	068010000	SK2	2
	AC Line Switched	Power Switch	SW0000025		L	Relay PCA	045230100	J1	1
	AC Neutral Switched	Power Switch	SW0000025		N	Relay PCA	045230100	J1	3
	Power Grnd	Power Entry	CN0000073			Relay PCA	045230100	J1	2
<b>03829</b>	<b>CBL, DC POWER TO MOTHERBOARD</b>								
	DGND	Relay PCA	045230100	P7	1	Motherboard	058021100	P15	1
	+5V	Relay PCA	045230100	P7	2	Motherboard	058021100	P15	2
	AGND	Relay PCA	045230100	P7	3	Motherboard	058021100	P15	3
	+15V	Relay PCA	045230100	P7	4	Motherboard	058021100	P15	4
	AGND	Relay PCA	045230100	P7	5	Motherboard	058021100	P15	5
	-15V	Relay PCA	045230100	P7	6	Motherboard	058021100	P15	6
	+12V RET	Relay PCA	045230100	P7	7	Motherboard	058021100	P15	7
	+12V	Relay PCA	045230100	P7	8	Motherboard	058021100	P15	8
	Chassis Gnd	Relay PCA	045230100	P7	10	Motherboard	058021100	P15	9
<b>04022</b>	<b>CBL, DC POWER, FANM KEYBOARD, TEC, SENSOR PCA</b>								
	TEC +12V	TEC PCA	049310100	P1	1	Relay PCA	045230100	P10	8
	TEC +12V RET	TEC PCA	049310100	P1	2	Relay PCA	045230100	P10	7
	DGND	Relay PCA	045230100	P10	1	LCD Interface PCA	066970000	P14	8
	+5V	Relay PCA	045230100	P10	2	LCD Interface PCA	066970000	P14	1
	DGND	LCD Interface PCA	066970000	P14	2	Relay PCA	045230100	P11	1
	+5V	LCD Interface PCA	066970000	P14	3	Relay PCA	045230100	P11	2
	+12V RET	Relay PCA	045230100	P11	7	Chassis fan	040010000	P1	1
	+12V	Relay PCA	045230100	P11	8	Chassis fan	040010000	P1	2
	P/Flow Sensor AGND	Relay PCA	045230100	P11	3	P/Flow Sensor PCA	040030800	P1	3
	P/Flow Sensor +15V	Relay PCA	045230100	P11	4	P/Flow Sensor PCA	040030800	P1	6
	Pressure signal 1	P/Flow Sensor PCA	040030800	P1	2	Motherboard	058021100	P110	6
	Pressure signal 2	P/Flow Sensor PCA	040030800	P1	4	Motherboard	058021100	P110	5
	Flow signal 1	P/Flow Sensor PCA	040030800	P1	5	Motherboard	058021100	P110	4
	Flow signal 2	P/Flow Sensor PCA	040030800	P1	1	Motherboard	058021100	P110	3
	Shield	P/Flow Sensor PCA	040030800	P1	S	Motherboard	058021100	P110	12
	Shield	Motherboard	058021100	P110	9	Relay PCA	045230100	P17	S
	Thermocouple signal 1	Motherboard	058021100	P110	2	Relay PCA	045230100	P17	1
	TC 1 signal DGND	Motherboard	058021100	P110	8	Relay PCA	045230100	P17	2
	Thermocouple signal 2	Motherboard	058021100	P110	1	Relay PCA	045230100	P17	3
	TC 2 signal DGND	Motherboard	058021100	P110	7	Relay PCA	045230100	P17	4
<b>04023</b>	<b>CBL, I2C, RELAY PCA TO MOTHERBOARD</b>								
	I2C Serial Clock	Motherboard	058021100	P107	3	Relay PCA	045230100	P3	1
	I2C Serial Data	Motherboard	058021100	P107	5	Relay PCA	045230100	P3	2
	I2C Reset	Motherboard	058021100	P107	2	Relay PCA	045230100	P3	4
	I2C Shield	Motherboard	058021100	P107	6	Relay PCA	045230100	P3	5
<b>04024</b>	<b>CBL, NOX, ZERO/SPAN, IZS VALVES</b>								
	Zero/Span valve +12V	Relay PCA	045230100	P4	1	Zero/Span valve	042680100	P1	1
	Zero/Span valve +12V RET	Relay PCA	045230100	P4	2	Zero/Span valve	042680100	P1	2
	Sample valve +12V	Relay PCA	045230100	P4	3	Sample valve	042680100	P1	1
	Sample valve +12V RET	Relay PCA	045230100	P4	4	Sample valve	042680100	P1	2
	AutoZero valve +12V	Relay PCA	045230100	P4	5	AutoZero valve	042680100	P1	1
	AutoZero valve +12V RET	Relay PCA	045230100	P4	6	AutoZero valve	042680100	P1	2
	NONOx valve +12V	Relay PCA	045230100	P4	7	NONOx valve	042680100	P1	1
	NONOx valve +12V RET	Relay PCA	045230100	P4	8	NONOx valve	042680100	P1	2

## T200X INTERCONNECT LIST

(Reference: 0691101B DCN5936)

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
<b>0402603</b>	<b>CBL, IZS &amp; O2 SENSOR HEATERS/THERMISTORS, REACTION CELL &amp; MANIFOLD THERMISTORS</b>								
	Rcell thermistor A	Reaction cell thermistor	041920000	P1	2	Motherboard	058021100	P27	7
	Rcell thermistor B	Reaction cell thermistor	041920000	P1	1	Motherboard	058021100	P27	14
	IZS or CO2 thermistor A	Motherboard	058021100	P27	6	IZS or CO2 thermistor/htr	05282\06693	P1	2
	IZS or CO2 thermistor B	Motherboard	058021100	P27	13	IZS or CO2 thermistor/htr	05282\06693	P1	3
	IZS or CO2 heater L	IZS or CO2 thermistor/htr	05282\06693	P1	4	Relay PCA	045230100	P18	1
	IZS or CO2 heater L	IZS or CO2 thermistor/htr	05282\06693	P1	1	Relay PCA	045230100	P18	2
	Shield					Relay PCA	045230100	P18	11
	O2 sensor heater	Relay PCA	045230100	P18	6	O2 sensor therm./heater	043420000	P1	4
	O2 sensor heater	Relay PCA	045230100	P18	7	O2 sensor therm./heater	043420000	P1	2
	Shield	Relay PCA	045230100	P18	12	O2 sensor therm./heater	043420000	P1	
	O2 sensor thermistor A	O2 sensor therm./heater	043420000	P1	3	Motherboard	058021100	P27	4
	O2 sensor thermistor B	O2 sensor therm./heater	043420000	P1	1	Motherboard	058021100	P27	11
	By/dil. man. thermistor A	Motherboard	058021100	P27	1	Manifold thermistor	043420000	P1	1
	By/dil. man. thermistor B	Motherboard	058021100	P27	8	Manifold thermistor	043420000	P1	2
	Configuration jumper intern.	Relay PCA	045230100	P18	3	Relay PCA	045230100	P18	4
	Configuration jumper intern.	Relay PCA	045230100	P18	8	Relay PCA	045230100	P18	9
<b>04027</b>	<b>CBL, NO2 CONVERTER, REACTION CELL &amp; MANIFOLD HEATERS</b>								
	Bypass/dil. manifold heater L	Manifold heater 1	044340000	P1	1	Relay PCA	045230100	P2	11
	Bypass/dil. manifold heater N	Manifold heater 1	044340000	P1	2	Relay PCA	045230100	P2	12
	Bypass/dil. manifold heater L	Relay PCA	045230100	P2	11	Manifold heater 2	044340000	P1	1
	Bypass/dil. manifold heater N	Relay PCA	045230100	P2	15	Manifold heater 2	044340000	P1	2
	Moly heater A	Relay PCA	045230100	P2	7	Moly heater A	039700100	P1	1
	Moly heater C	Relay PCA	045230100	P2	6	Moly heater C	039700100	P1	2
	Moly heater B	Relay PCA	045230100	P2	10	Moly heater B	039700100	P1	3
	Configuration jumper intern.	Relay PCA	045230100	P2	13	Relay PCA	045230100	P2	14
	Configuration jumper intern.	Relay PCA	045230100	P2	8	Relay PCA	045230100	P2	9
	Reaction cell heater/switch	Relay PCA	045230100	P2	1	Reaction cell heater 1B	040400000	P1	4
	Reaction cell heater/switch	Relay PCA	045230100	P2	1	Reaction cell heater 2B	040400000	P1	6
	Reaction cell heater/switch	Relay PCA	045230100	P2	2	Reaction cell heater 1A	040400000	P1	3
	Reaction cell heater/switch	Relay PCA	045230100	P2	3	Reaction cell heat switch	040400000	P1	1
	Reaction cell heater/switch	Relay PCA	045230100	P2	4	Reaction cell heat switch	040400000	P1	2
	Reaction cell heater/switch	Relay PCA	045230100	P2	5	Reaction cell heater 2A	040400000	P1	5
<b>04105</b>	<b>CBL, KEYBOARD, DISPLAY TO MOTHERBOARD</b>								
	Kbd Interrupt	LCD Interface PCA	066970000	J1	7	Motherboard	058021100	J106	1
	DGND	LCD Interface PCA	066970000	J1	2	Motherboard	058021100	J106	8
	SDA	LCD Interface PCA	066970000	J1	5	Motherboard	058021100	J106	2
	SCL	LCD Interface PCA	066970000	J1	6	Motherboard	058021100	J106	6
	Shld	LCD Interface PCA	066970000	J1	10	Motherboard	058021100	J106	5
<b>04176</b>	<b>CBL, DC POWER TO RELAY PCA</b>								
	DGND	Relay PCA	045230100	P8	1	Power Supply Triple	068010000	J1	3
	+5V	Relay PCA	045230100	P8	2	Power Supply Triple	068010000	J1	1
	+15V	Relay PCA	045230100	P8	4	Power Supply Triple	068010000	J1	6
	AGND	Relay PCA	045230100	P8	5	Power Supply Triple	068010000	J1	4
	-15V	Relay PCA	045230100	P8	6	Power Supply Triple	068010000	J1	5
	+12V RET	Relay PCA	045230100	P8	7	Power Supply Single	068020000	J1	3
	+12V	Relay PCA	045230100	P8	8	Power Supply Single	068020000	J1	1
<b>04433</b>	<b>CBL, PREAMPLIFIER TO RELAY PCA</b>								
	Preamplifier DGND	Relay PCA	045230100	P9	1	Preamp PCA	041800500	P5	1
	Preamplifier +5V	Relay PCA	045230100	P9	2	Preamp PCA	041800500	P5	2
	Preamplifier AGND	Relay PCA	045230100	P9	3	Preamp PCA	041800500	P5	3
	Preamplifier +15V	Relay PCA	045230100	P9	4	Preamp PCA	041800500	P5	4
	Preamplifier -15V	Relay PCA	045230100	P9	6	Preamp PCA	041800500	P5	6
<b>04437</b>	<b>CBL, PREAMPLIFIER TO TEC</b>								
	Preamp TEC drive VREF	Preamp PCA	041800500	J1	1	TEC PCA	049310100	J3	1
	Preamp TEC drive CTRL	Preamp PCA	041800500	J1	2	TEC PCA	049310100	J3	2
	Preamp TEC drive AGND	Preamp PCA	041800500	J1	3	TEC PCA	049310100	J3	3

## T200X INTERCONNECT LIST

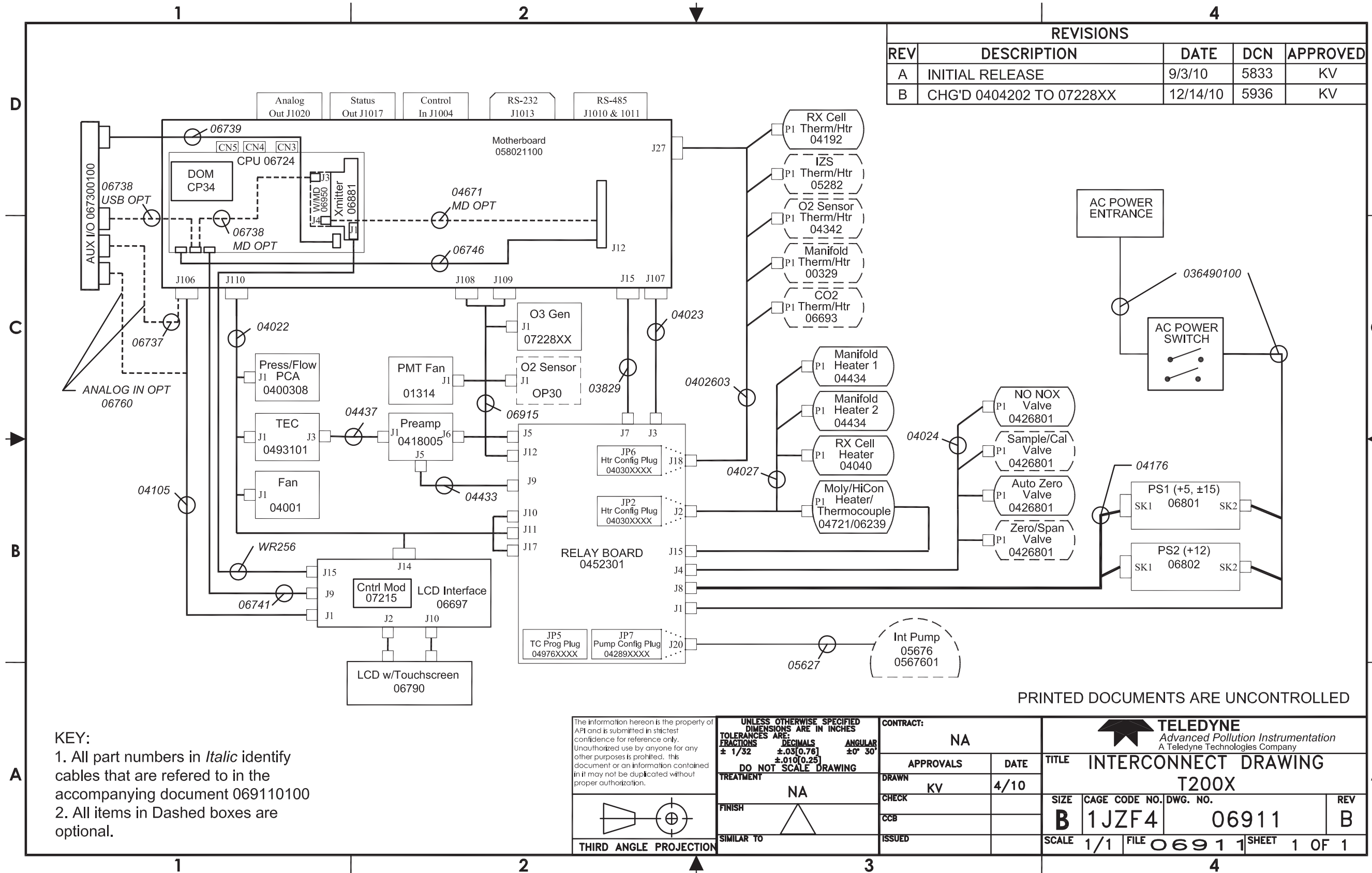
(Reference: 0691101B DCN5936)

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
<b>04671</b>	<b>CBL, MOTHERBOARD TO XMITTER BD (MULTIDROP OPTION)</b>								
	GND	Motherboard	058021100	P12	2	Xmitter bd w/Multidrop	069500000	J4	2
	RX0	Motherboard	058021100	P12	14	Xmitter bd w/Multidrop	069500000	J4	14
	RTS0	Motherboard	058021100	P12	13	Xmitter bd w/Multidrop	069500000	J4	13
	TX0	Motherboard	058021100	P12	12	Xmitter bd w/Multidrop	069500000	J4	12
	CTS0	Motherboard	058021100	P12	11	Xmitter bd w/Multidrop	069500000	J4	11
	RS-GND0	Motherboard	058021100	P12	10	Xmitter bd w/Multidrop	069500000	J4	10
	RTS1	Motherboard	058021100	P12	8	Xmitter bd w/Multidrop	069500000	J4	8
	CTS1/485-	Motherboard	058021100	P12	6	Xmitter bd w/Multidrop	069500000	J4	6
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
<b>06737</b>	<b>CBL, I2C to AUX I/O (ANALOG IN OPTION)</b>								
	ATX+	AUX I/O PCA	067300000	J2	1	Motherboard	058021100	J106	1
	ATX-	AUX I/O PCA	067300000	J2	2	Motherboard	058021100	J106	2
	LED0	AUX I/O PCA	067300000	J2	3	Motherboard	058021100	J106	3
	ARX+	AUX I/O PCA	067300000	J2	4	Motherboard	058021100	J106	4
	ARX-	AUX I/O PCA	067300000	J2	5	Motherboard	058021100	J106	5
	LED0+	AUX I/O PCA	067300000	J2	6	Motherboard	058021100	J106	6
	LED1+	AUX I/O PCA	067300000	J2	8	Motherboard	058021100	J106	8
<b>06738</b>	<b>CBL, CPU COM to AUX I/O (USB OPTION)</b>								
	RXD1	CPU PCA	067240000	COM1	1	AUX I/O PCA	0673000 or -02	J3	1
	DCD1	CPU PCA	067240000	COM1	2	AUX I/O PCA	0673000 or -02	J3	2
	DTR1	CPU PCA	067240000	COM1	3	AUX I/O PCA	0673000 or -02	J3	3
	TXD1	CPU PCA	067240000	COM1	4	AUX I/O PCA	0673000 or -02	J3	4
	DSR1	CPU PCA	067240000	COM1	5	AUX I/O PCA	0673000 or -02	J3	5
	GND	CPU PCA	067240000	COM1	6	AUX I/O PCA	0673000 or -02	J3	6
	CTS1	CPU PCA	067240000	COM1	7	AUX I/O PCA	0673000 or -02	J3	7
	RTS1	CPU PCA	067240000	COM1	8	AUX I/O PCA	0673000 or -02	J3	8
	RI1	CPU PCA	067240000	COM1	10	AUX I/O PCA	0673000 or -02	J3	10
<b>06738</b>	<b>CBL, CPU COM to AUX I/O (MULTIDROP OPTION)</b>								
	RXD	CPU PCA	067240000	COM1	1	Xmitter bd w/Multidrop	069500000	J3	1
	DCD	CPU PCA	067240000	COM1	2	Xmitter bd w/Multidrop	069500000	J3	2
	DTR	CPU PCA	067240000	COM1	3	Xmitter bd w/Multidrop	069500000	J3	3
	TXD	CPU PCA	067240000	COM1	4	Xmitter bd w/Multidrop	069500000	J3	4
	DSR	CPU PCA	067240000	COM1	5	Xmitter bd w/Multidrop	069500000	J3	5
	GND	CPU PCA	067240000	COM1	6	Xmitter bd w/Multidrop	069500000	J3	6
	CTS	CPU PCA	067240000	COM1	7	Xmitter bd w/Multidrop	069500000	J3	7
	RTS	CPU PCA	067240000	COM1	8	Xmitter bd w/Multidrop	069500000	J3	8
	RI	CPU PCA	067240000	COM1	10	Xmitter bd w/Multidrop	069500000	J3	10
<b>06739</b>	<b>CBL, CPU LAN TO AUX I/O PCA</b>								
	ATX-	CPU PCA	067240000	LAN	1	AUX I/O PCA	06730XXXX	J2	1
	ATX+	CPU PCA	067240000	LAN	2	AUX I/O PCA	06730XXXX	J2	2
	LED0	CPU PCA	067240000	LAN	3	AUX I/O PCA	06730XXXX	J2	3
	ARX+	CPU PCA	067240000	LAN	4	AUX I/O PCA	06730XXXX	J2	4
	ARX-	CPU PCA	067240000	LAN	5	AUX I/O PCA	06730XXXX	J2	5
	LED0+	CPU PCA	067240000	LAN	6	AUX I/O PCA	06730XXXX	J2	6
	LED1	CPU PCA	067240000	LAN	7	AUX I/O PCA	06730XXXX	J2	7
	LED1+	CPU PCA	067240000	LAN	8	AUX I/O PCA	06730XXXX	J2	8
<b>06741</b>	<b>CBL, CPU USB to Front Panel</b>								
	GND	CPU PCA	067240000	USB	8	LCD Interface PCA	066970000	JP9	
	LUSBD3+	CPU PCA	067240000	USB	6	LCD Interface PCA	066970000	JP9	
	LUSBD3-	CPU PCA	067240000	USB	4	LCD Interface PCA	066970000	JP9	
	VCC	CPU PCA	067240000	USB	2	LCD Interface PCA	066970000	JP9	

## T200X INTERCONNECT LIST

(Reference: 0691101B DCN5936)

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
<b>06746</b>	<b>CBL, MB TO 06154 CPU</b>								
	GND	Motherboard	058021100	P12	2	Shield			
	RX0	Motherboard	058021100	P12	14	CPU PCA	067240000	COM1	1
	RTS0	Motherboard	058021100	P12	13	CPU PCA	067240000	COM1	8
	TX0	Motherboard	058021100	P12	12	CPU PCA	067240000	COM1	4
	CTS0	Motherboard	058021100	P12	11	CPU PCA	067240000	COM1	7
	RS-GND0	Motherboard	058021100	P12	10	CPU PCA	067240000	COM1	6
	RTS1	Motherboard	058021100	P12	8	CPU PCA	067240000	COM2	8
	CTS1/485-	Motherboard	058021100	P12	6	CPU PCA	067240000	COM2	7
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	COM2	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	COM2	4
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	COM2	6
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	485	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	485	2
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	485	3
<b>06915</b>	<b>CBL, PREAMP, O2 SENSOR, O3 GEN, FAN, RELAY PCA &amp; MOTHERBOARD</b>								
	+15V	Relay PCA	045230100	P12	4	Ozone generator	07228XXXX	P1	4
	AGND	Relay PCA	045230100	P12	3	Ozone generator	07228XXXX	P1	5
	+12V	Relay PCA	045230100	P12	8	PMT cooling fan	013140000	P1	1
	+12V RET	Relay PCA	045230100	P12	7	PMT cooling fan	013140000	P1	2
	O3GEN enable signal	Ozone generator	07228XXXX	P1	6	Motherboard	058021100	P108	15
	ETEST	Motherboard	058021100	P108	8	Preamp PCA	041800500	P6	1
	OTEST	Motherboard	058021100	P108	16	Preamp PCA	041800500	P6	2
	PHYSICAL RANGE	Motherboard	058021100	P108	7	Preamp PCA	041800500	P6	4
	PMT TEMP	Preamp PCA	041800500	P6	5	Motherboard	058021100	P109	4
	HVPS	Preamp PCA	041800500	P6	6	Motherboard	058021100	P109	5
	PMT SIGNAL+	Preamp PCA	041800500	P6	7	Motherboard	058021100	P109	6
	AGND	Preamp PCA	041800500	P6	S	Motherboard	058021100	P109	11
	AGND	Motherboard	058021100	P109	9	O2 Sensor (optional)	OP0000030	P1	S
	O2 SIGNAL -	Motherboard	058021100	P109	7	O2 Sensor (optional)	OP0000030	P1	9
	O2 SIGNAL +	Motherboard	058021100	P109	1	O2 Sensor (optional)	OP0000030	P1	10
	DGND	O2 Sensor (optional)	OP0000030	P1	5	Relay PCA	045230100	P5	1
	+5V	O2 Sensor (optional)	OP0000030	P1	6	Relay PCA	045230100	P5	2
<b>WR256</b>	<b>CBL, TRANSMITTER TO INTERFACE</b>								
		LCD Interface PCA	066970000	J15		Transmitter PCA	068810000	J1	



REVISIONS				
REV	DESCRIPTION	DATE	DCN	APPROVED
A	INITIAL RELEASE	9/3/10	5833	KV
B	CHG'D 0404202 TO 07228XX	12/14/10	5936	KV

**KEY:**  
 1. All part numbers in *Italic* identify cables that are referred to in the accompanying document 069110100  
 2. All items in Dashed boxes are optional.

The information hereon is the property of API and is submitted in strictest confidence for reference only. Unauthorized use by anyone for any other purposes is prohibited. This document or an information contained in it may not be duplicated without proper authorization.

THIRD ANGLE PROJECTION

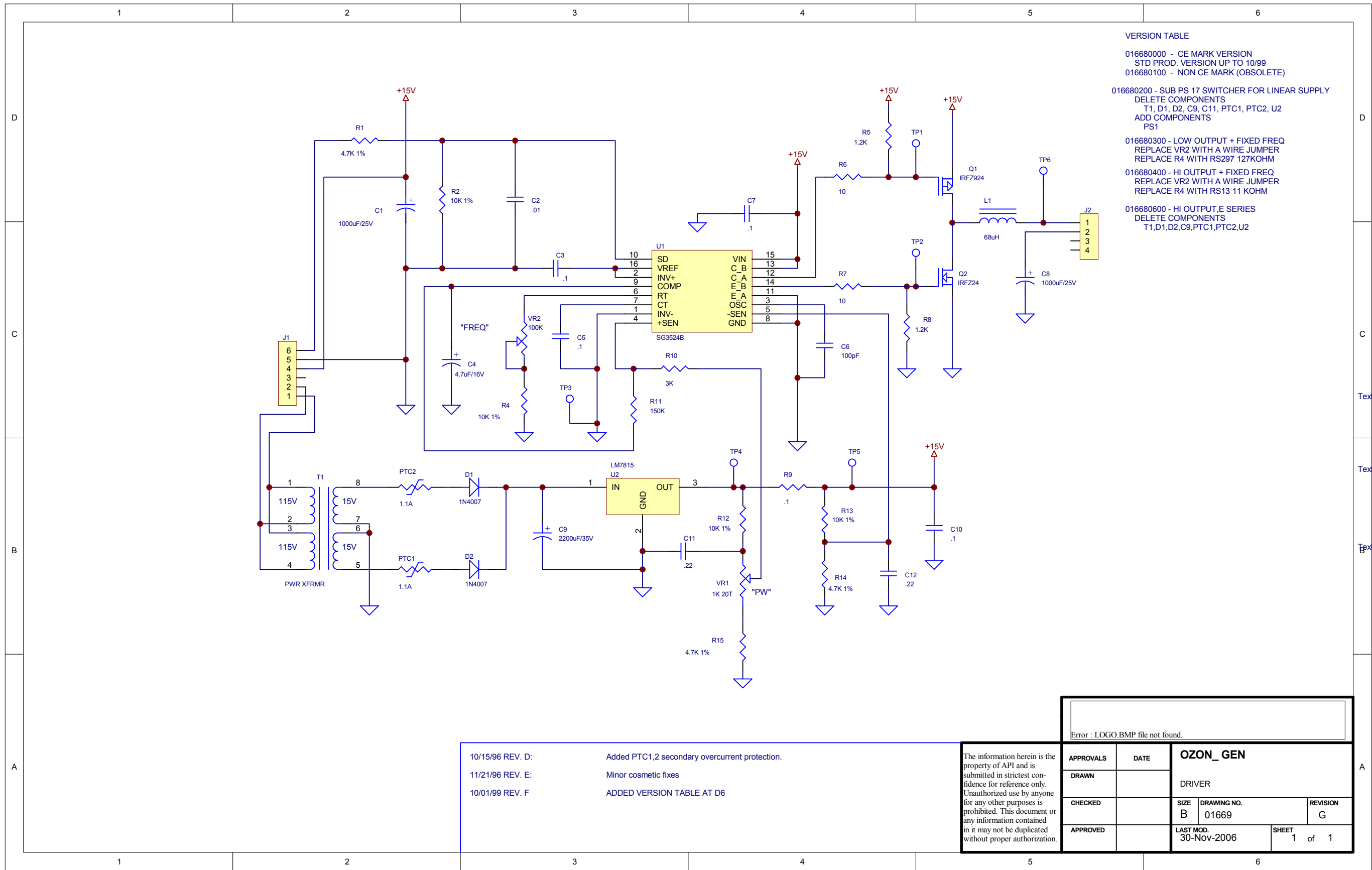
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		
TOLERANCES ARE:	FRACTIONS	DECIMALS
	± 1/32	± .03[0.76]
		± .010[0.25]
DO NOT SCALE DRAWING		
TREATMENT	NA	
FINISH	▲	
SIMILAR TO		

CONTRACT: NA	
APPROVALS	DATE
DRAWN KV	4/10
CHECK	
CCB	
ISSUED	

TELEDYNE Advanced Pollution Instrumentation A Teledyne Technologies Company	
TITLE INTERCONNECT DRAWING T200X	
SIZE	CAGE CODE NO. DWG. NO.
B	1JZF4 06911
SCALE 1/1	FILE 06911 SHEET 1 OF 1

PRINTED DOCUMENTS ARE UNCONTROLLED





VERSION TABLE

016680000 - CE MARK VERSION  
 STD PROD. VERSION UP TO 10/99  
 016680100 - NON CE MARK (OBSOLETE)

016680200 - SUB PS 17 SWITCHER FOR LINEAR SUPPLY  
 DELETE COMPONENTS  
 T1, D1, D2, C9, C11, PTC1, PTC2, U2  
 ADD COMPONENTS  
 PS1

016680300 - LOW OUTPUT + FIXED FREQ  
 REPLACE VR2 WITH A WIRE JUMPER  
 REPLACE R4 WITH RS297 127KOHM

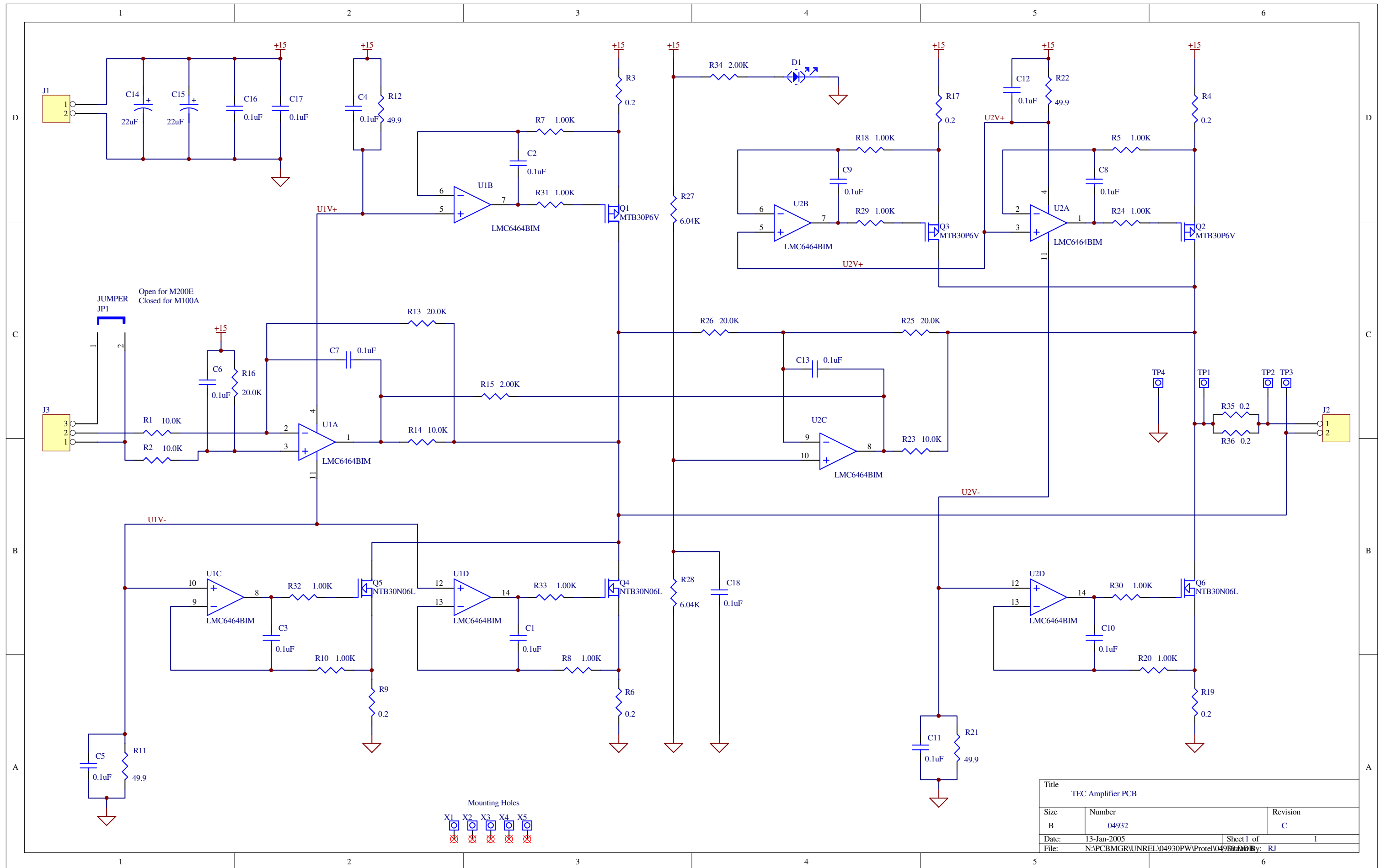
016680400 - HI OUTPUT + FIXED FREQ  
 REPLACE VR2 WITH A WIRE JUMPER  
 REPLACE R4 WITH RS13 11 KOHM

016680600 - HI OUTPUT, E SERIES  
 DELETE COMPONENTS  
 T1, D1, D2, C9, PTC1, PTC2, U2

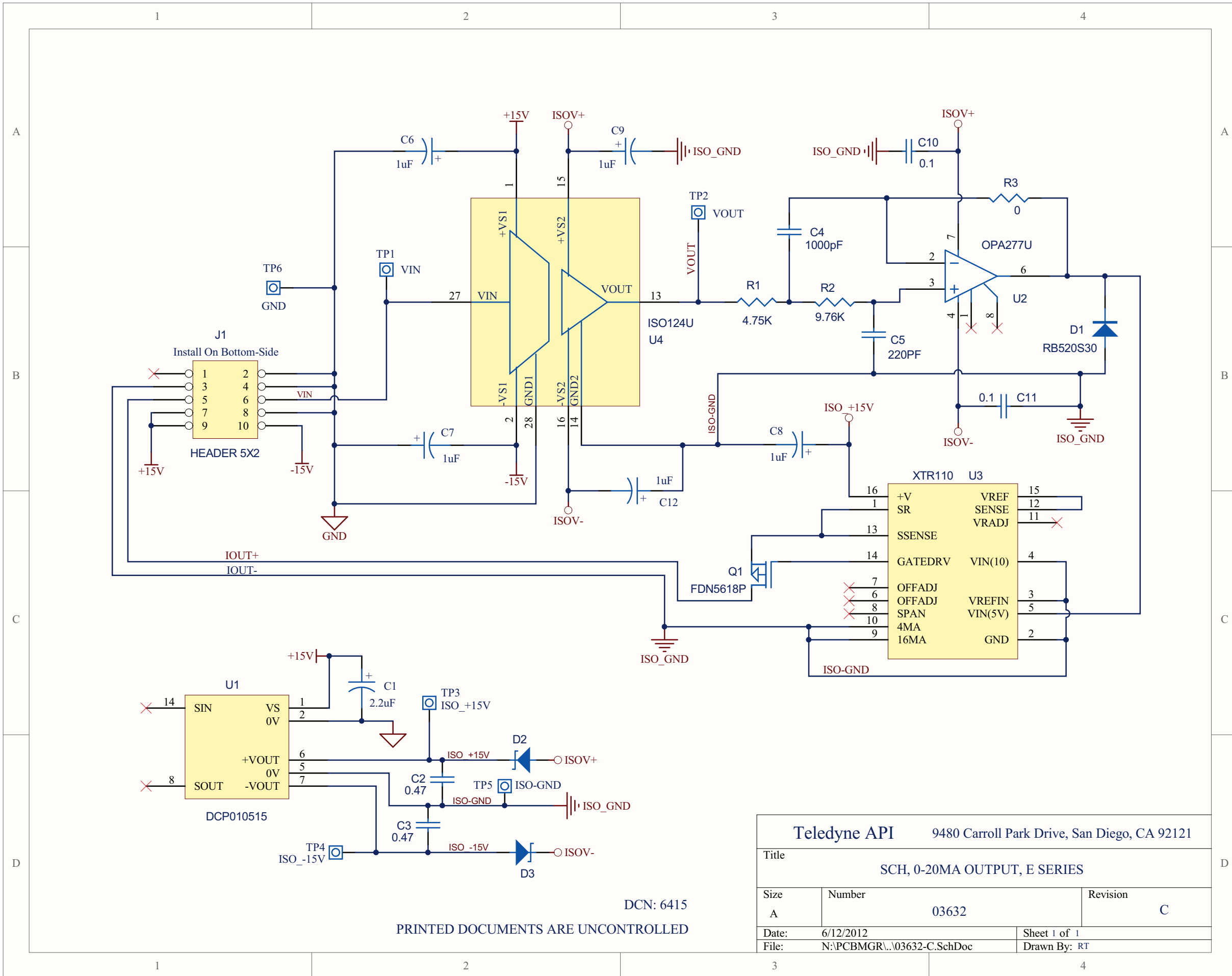
10/15/96 REV. D: Added PTC1,2 secondary overcurrent protection.  
 11/21/96 REV. E: Minor cosmetic fixes  
 10/01/99 REV. F: ADDED VERSION TABLE AT D6

The information herein is the property of API and is submitted in strictest confidence for reference only. Unauthorized use by anyone for any other purposes is prohibited. This document or any information contained in it may not be duplicated without proper authorization.

Error : LOGO.BMP file not found.		OZON_GEN	
APPROVALS	DATE	DRIVER	
DRAWN		SIZE	DRAWING NO.
CHECKED		B	01669
APPROVED		LAST MOD.	REVISION
		30-Nov-2006	G
		SHEET	1 of 1



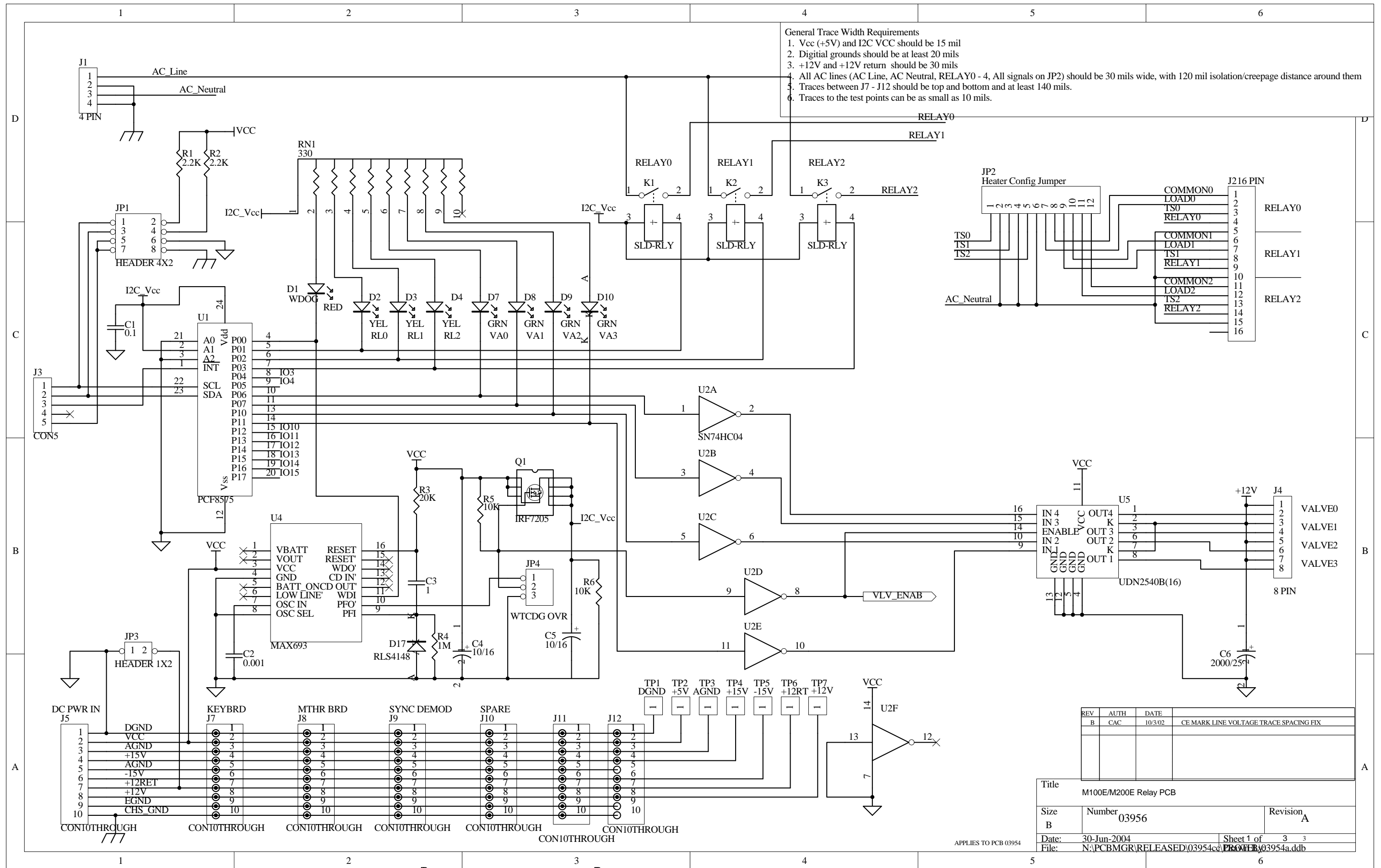
Title		
TEC Amplifier PCB		
Size	Number	Revision
B	04932	C
Date:	13-Jan-2005	Sheet 1 of 1
File:	N:\PCBMGR\UNREL\04930PWP\Protel\04930PWP.dwg By: RJ	



DCN: 6415

PRINTED DOCUMENTS ARE UNCONTROLLED

Teledyne API		9480 Carroll Park Drive, San Diego, CA 92121	
Title			
SCH, 0-20MA OUTPUT, E SERIES			
Size	Number	Revision	
A	03632	C	
Date:	6/12/2012	Sheet 1 of 1	
File:	N:\PCB\MGR\...\03632-C.SchDoc	Drawn By: RT	

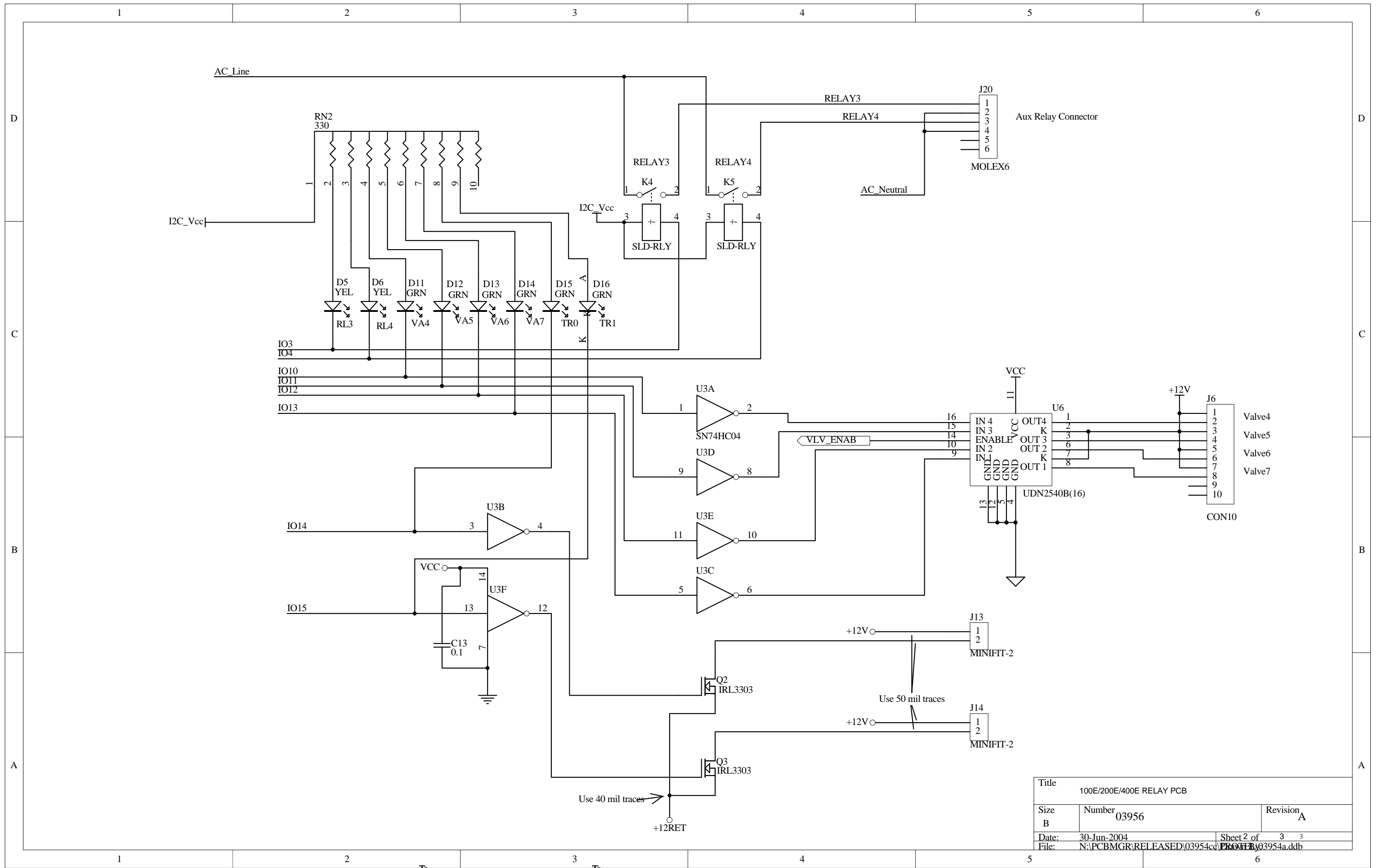


REV	AUTH	DATE	
B	CAC	10/3/02	CE MARK LINE VOLTAGE TRACE SPACING FIX

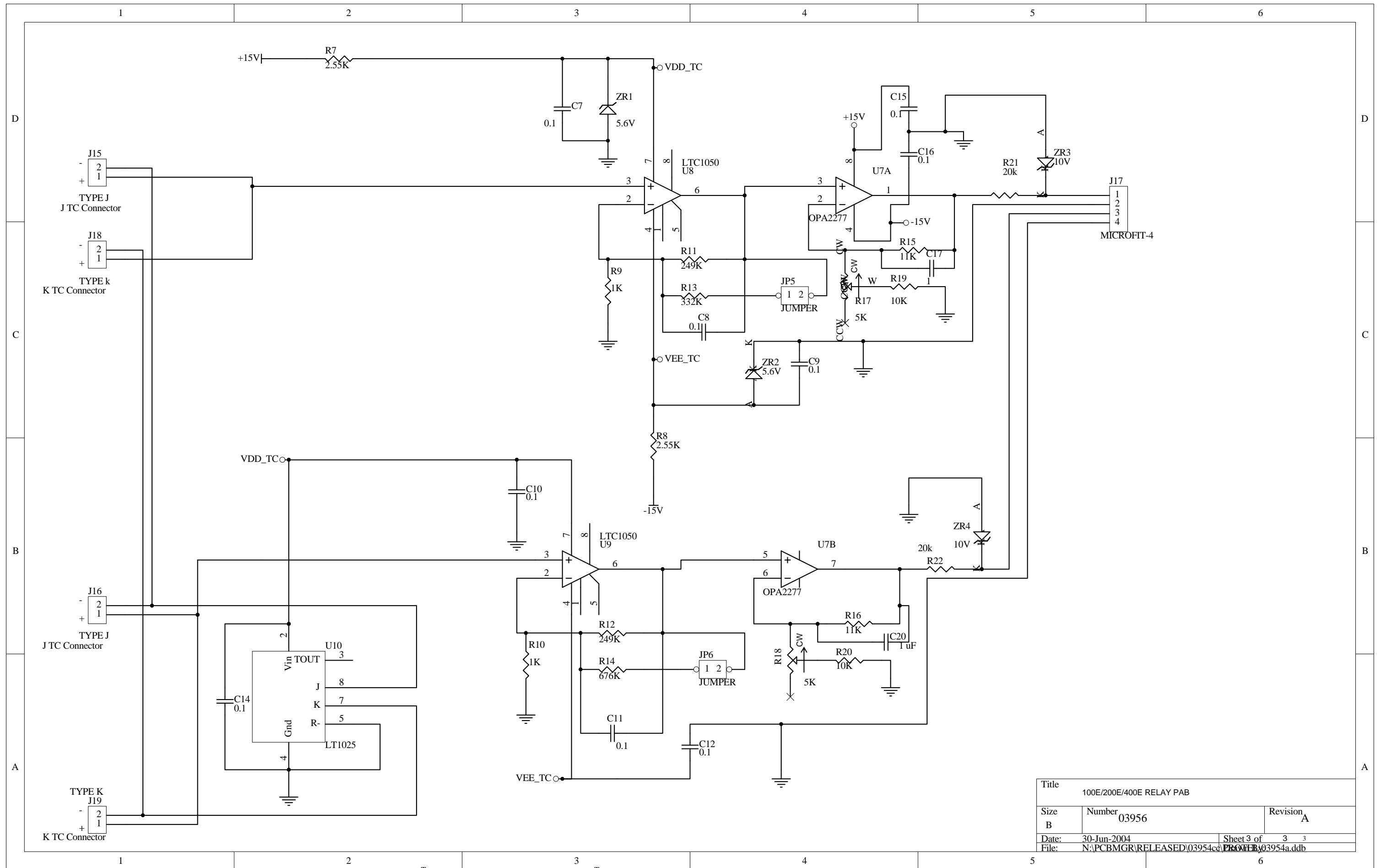
  

Title		
M100E/M200E Relay PCB		
Size	Number	Revision
B	03956	A
Date:	30-Jun-2004	Sheet 1 of 3
File:	N:\PCBMGR\RELEASED\03954cd\PROJECT\03954a.ddb	

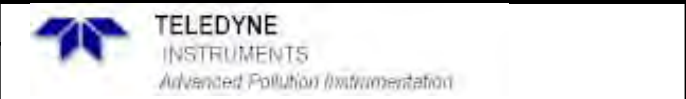
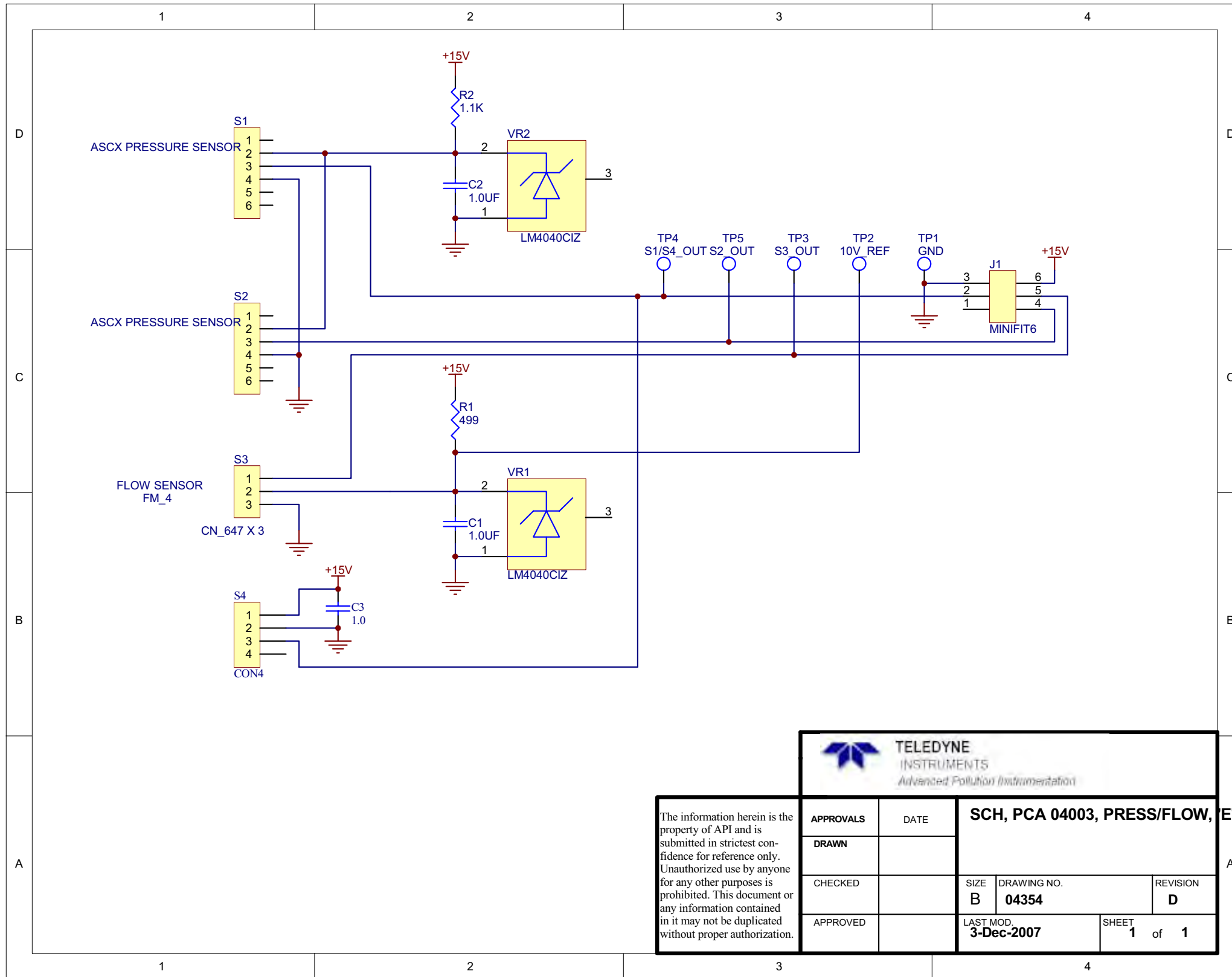
APPLIES TO PCB 03954



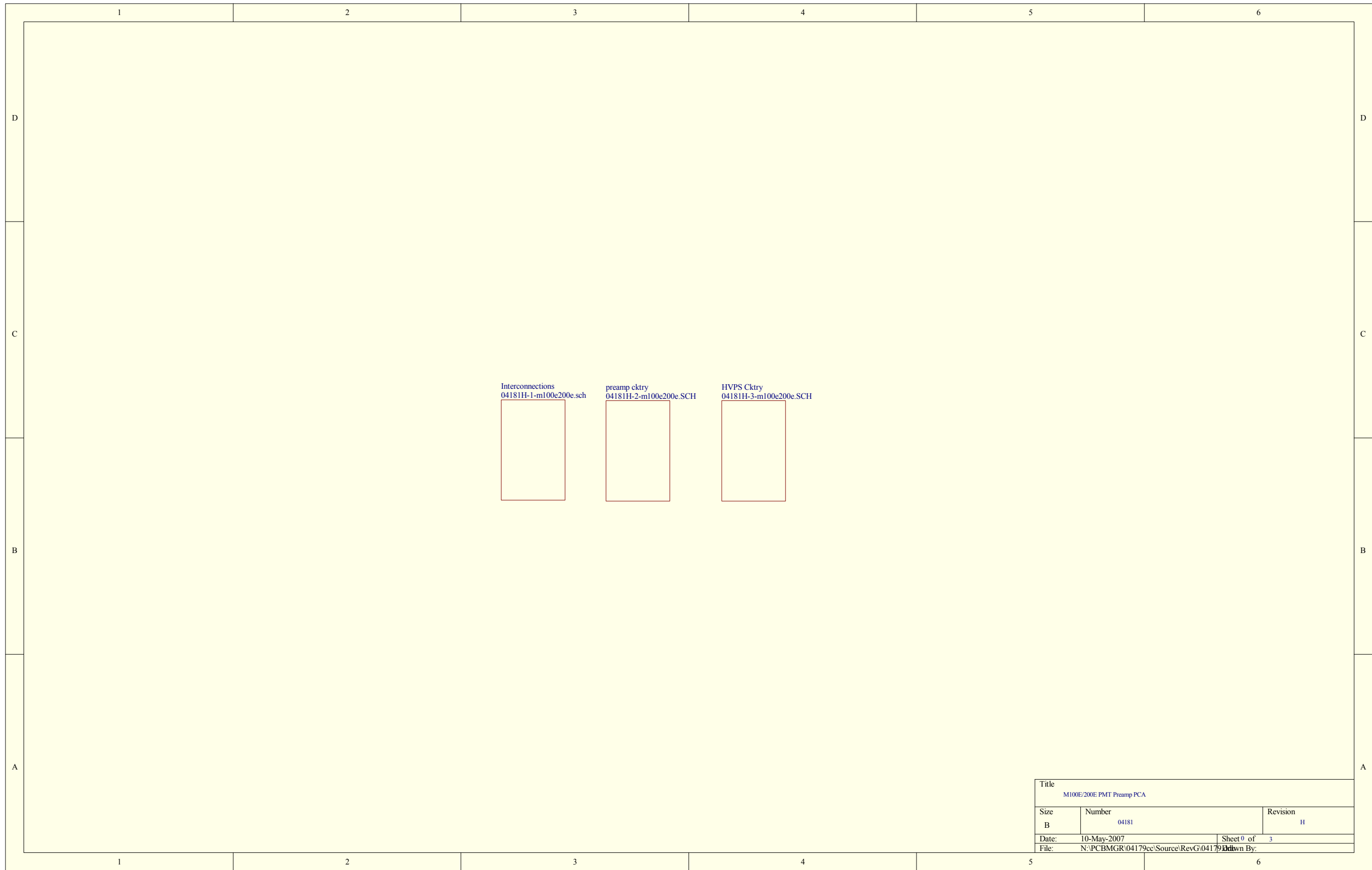
Title		100E/200E/400E RELAY PCB	
Size	Number	Revision	
B	03956	A	
Date:	30-Jun-2004	Sheet 2 of	3 3
File:		N:\PCBMGR\RELEASED\03954cd\PROJ\03954a.ddb	



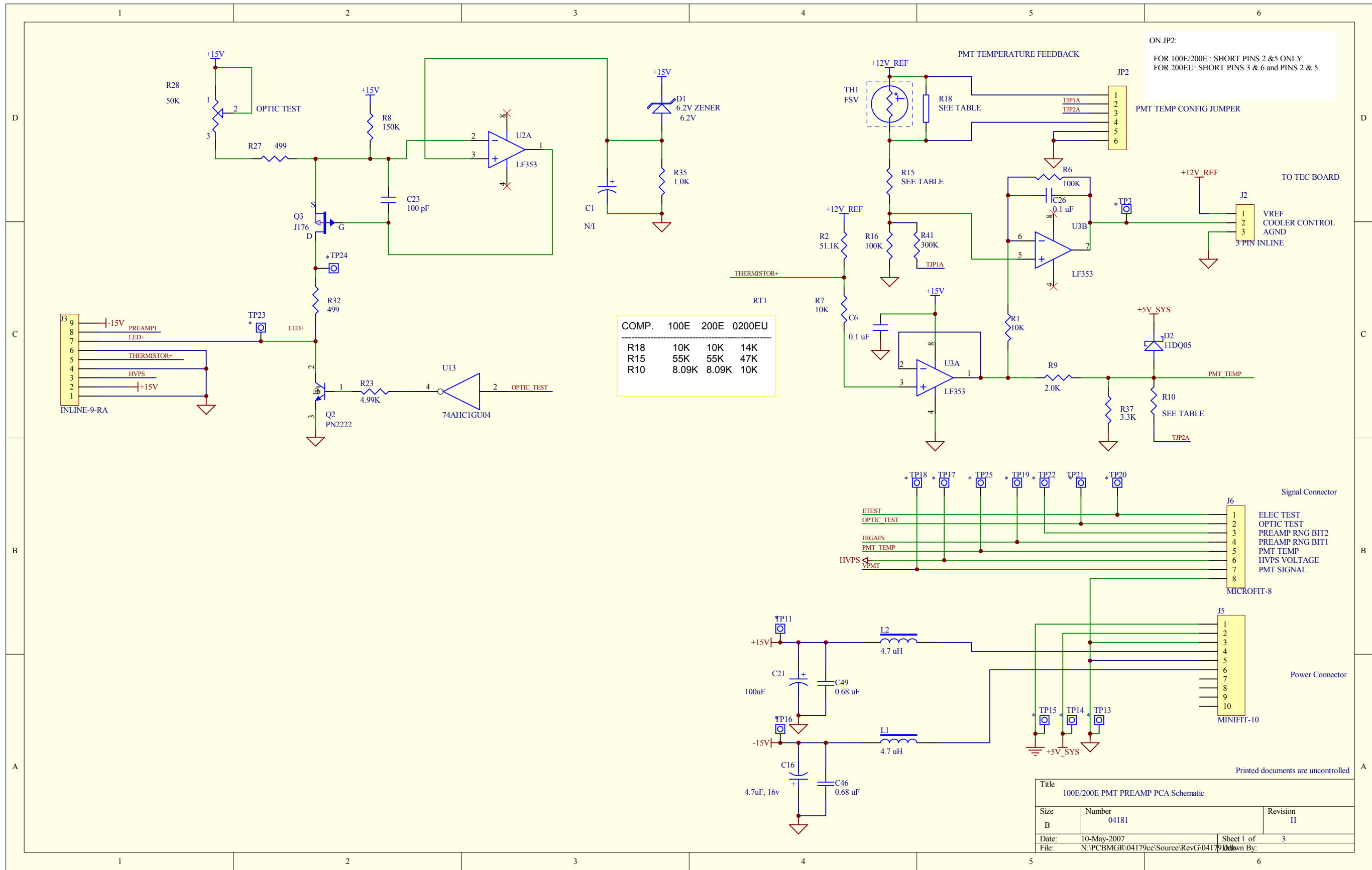
Title			100E/200E/400E RELAY PAB		
Size	Number	Revision			
B	03956	A			
Date:	30-Jun-2004	Sheet 3 of	3	3	
File:	N:\PCBMGR\RELEASED\03954cd\PROJ\03954a.ddb				

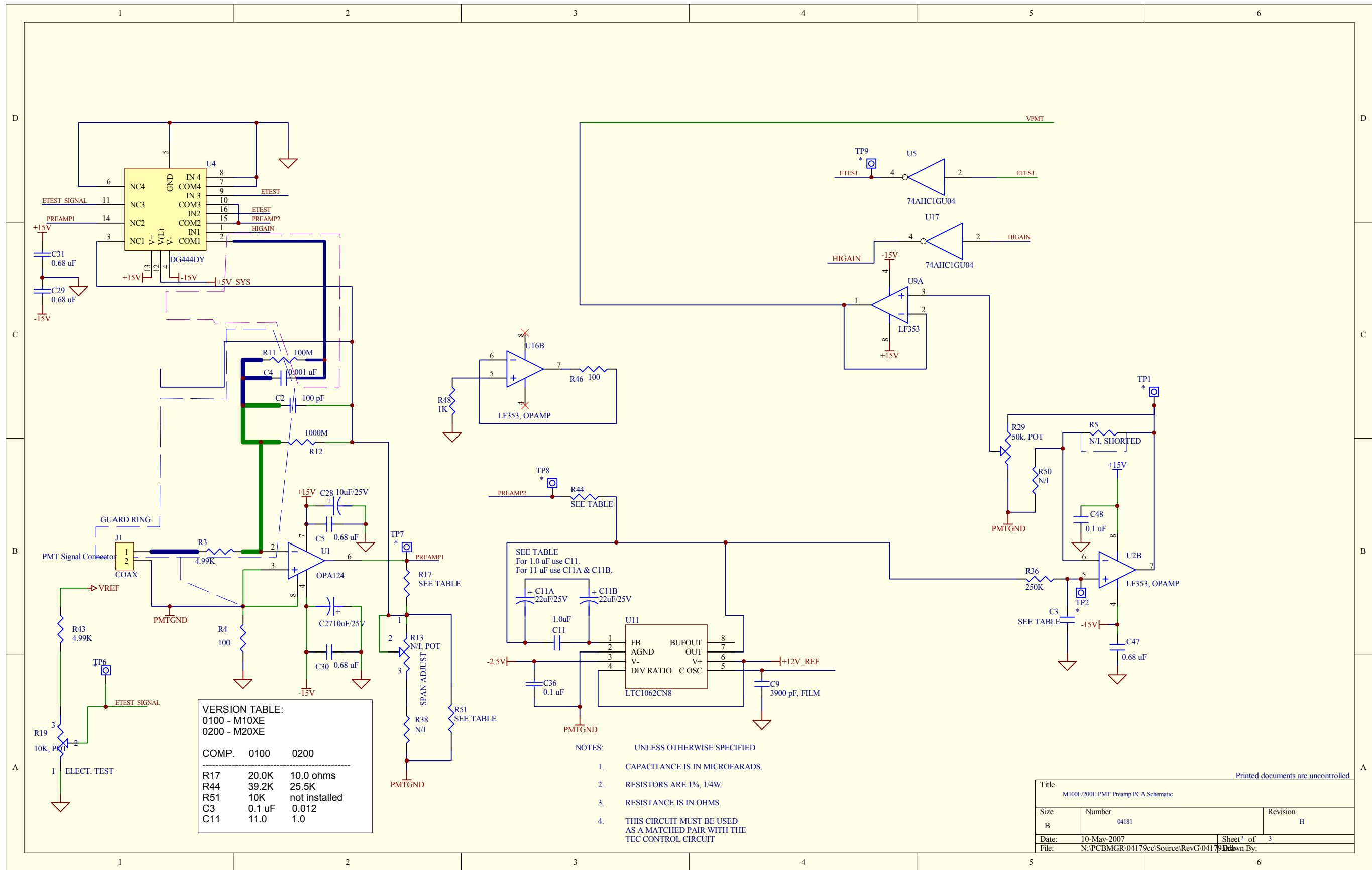


<p>The information herein is the property of API and is submitted in strictest confidence for reference only. Unauthorized use by anyone for any other purposes is prohibited. This document or any information contained in it may not be duplicated without proper authorization.</p>	APPROVALS	DATE	<b>SCH, PCA 04003, PRESS/FLOW, 'E' SERIES</b>		
	DRAWN				
	CHECKED		SIZE	DRAWING NO.	REVISION
	APPROVED		B	04354	D
		LAST MOD.	SHEET		
		3-Dec-2007	1 of 1		



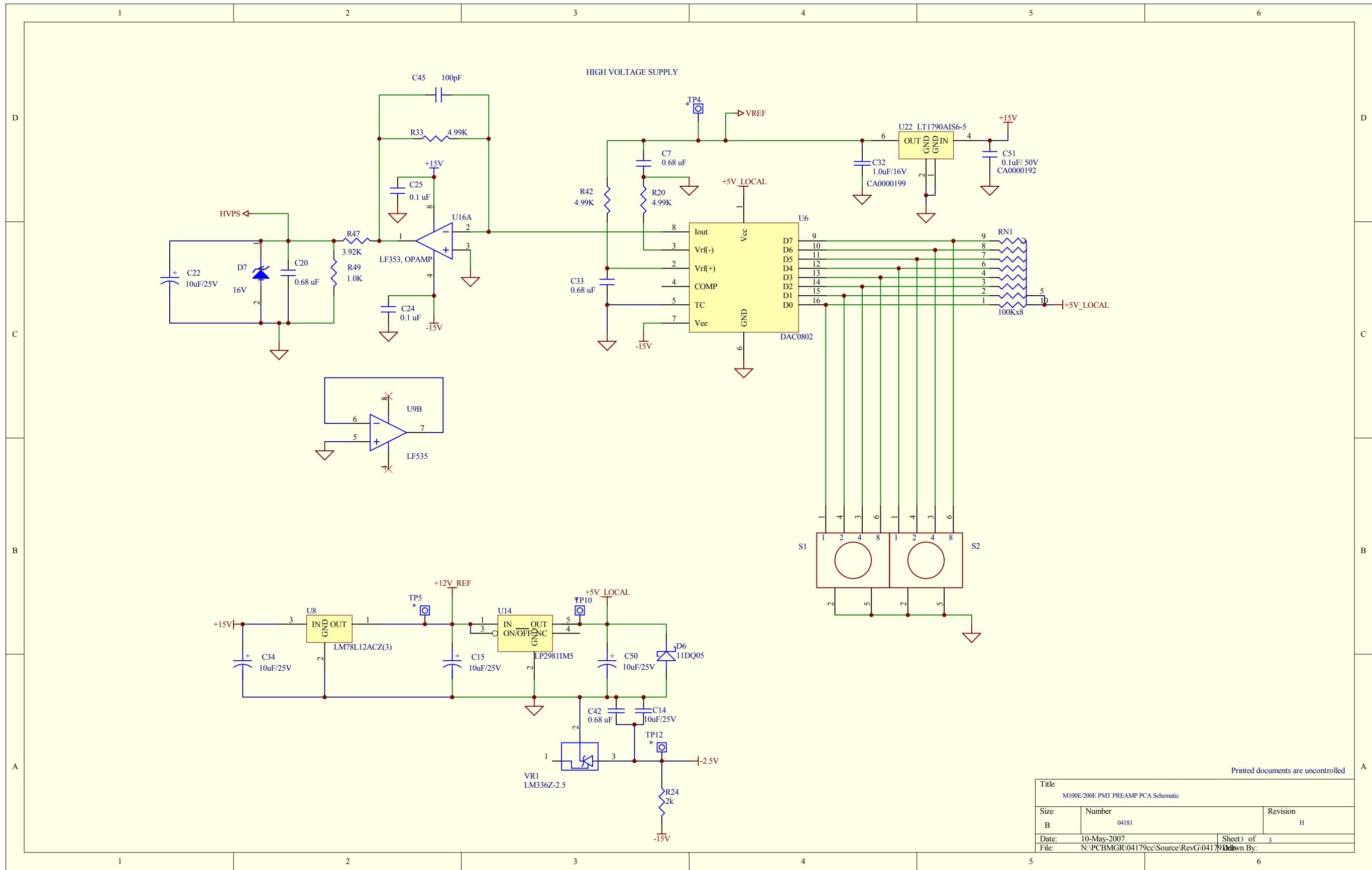






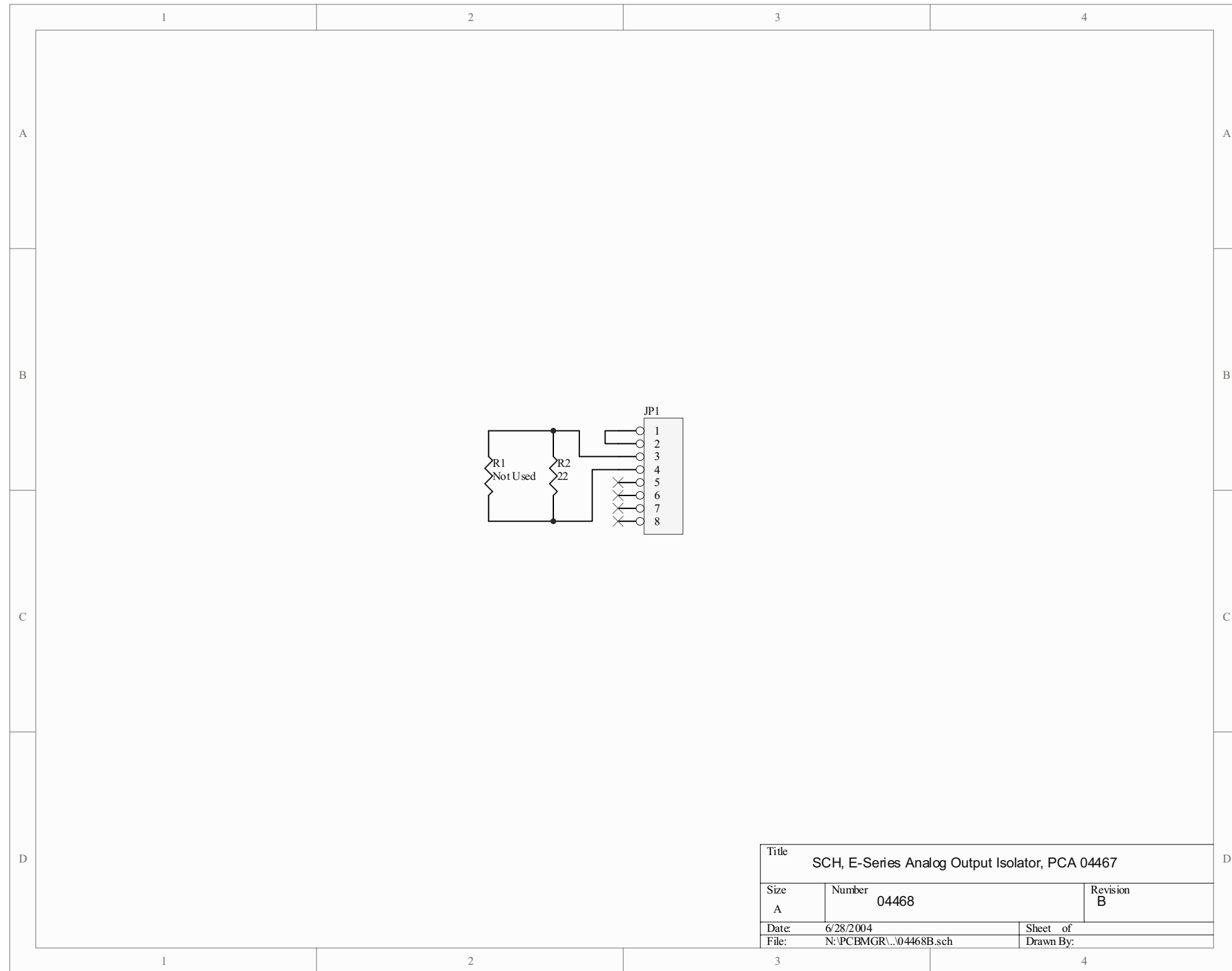
Printed documents are uncontrolled

Title M100E/200E PMT Preamp PCA Schematic		
Size B	Number 04181	Revision H
Date: 10-May-2007	Sheet 2 of 3	
File: N:\PCBMGR\04179cc\Source\RevG\04179	Drawn By:	

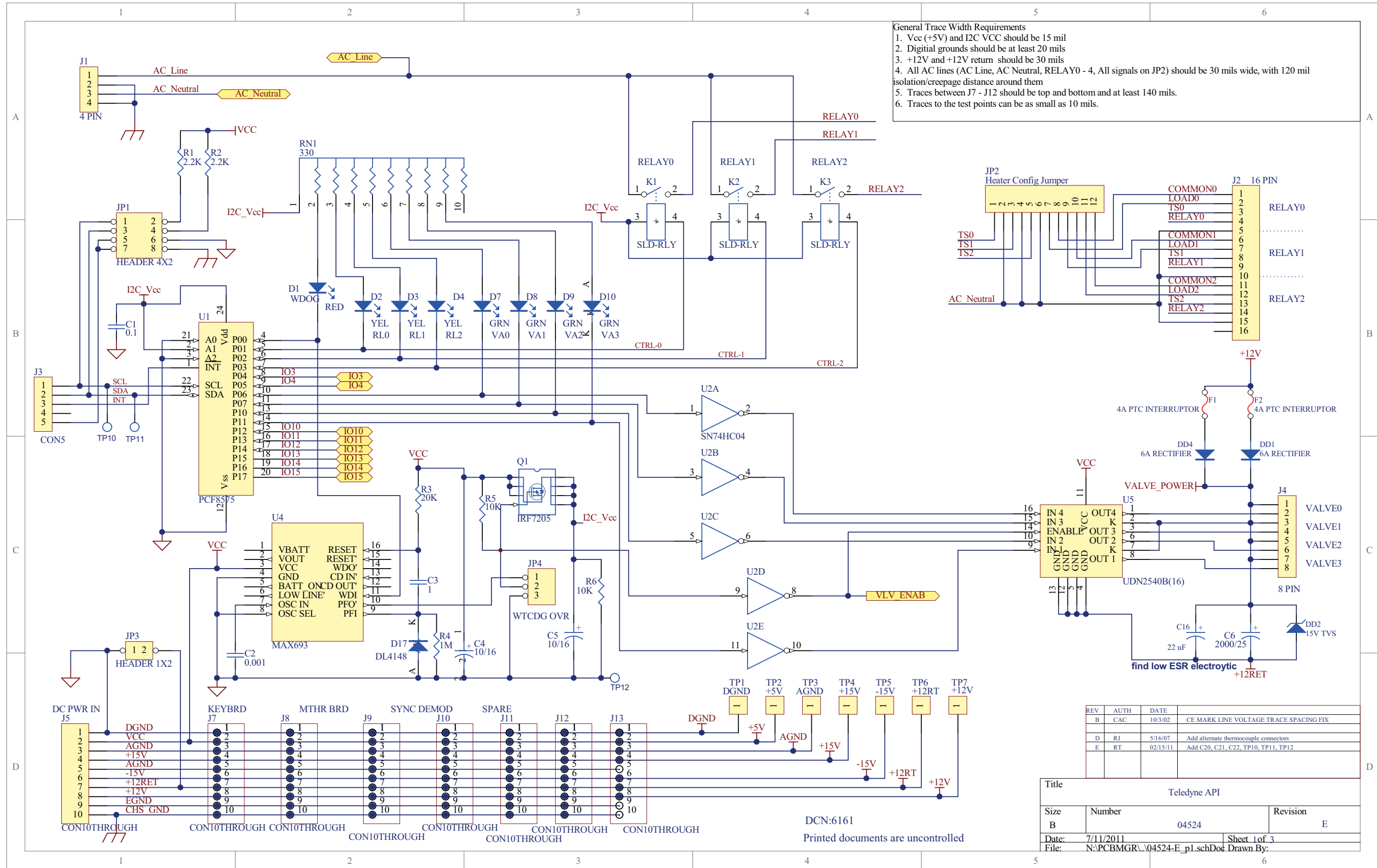


Printed documents are uncontrolled

Title		
M100E/200E PMT PREAMP PCA Schematic		
Size	Number	Revision
B	04181	H
Date:	10-May-2007	Sheet 3 of 3
File:	N:\PCBMGR\04179cc\Source\RevG\0417901.dwg	
Drawn By:		



Title		
SCH, E-Series Analog Output Isolator, PCA 04467		
Size	Number	Revision
A	04468	B
Date:	6/28/2004	Sheet of
File:	N:\PCBMGR\..04468B.sch	Drawn By:



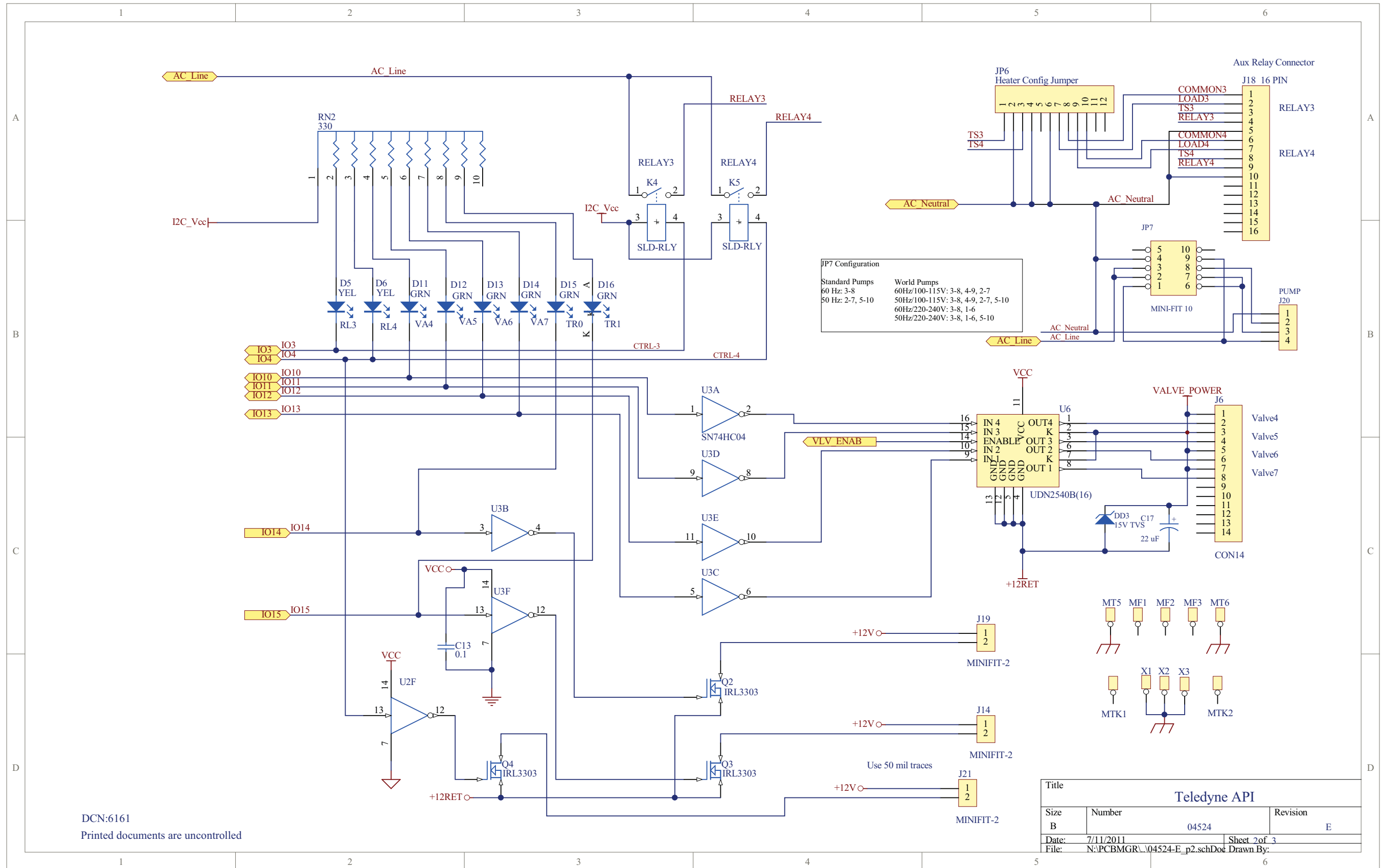
**General Trace Width Requirements**

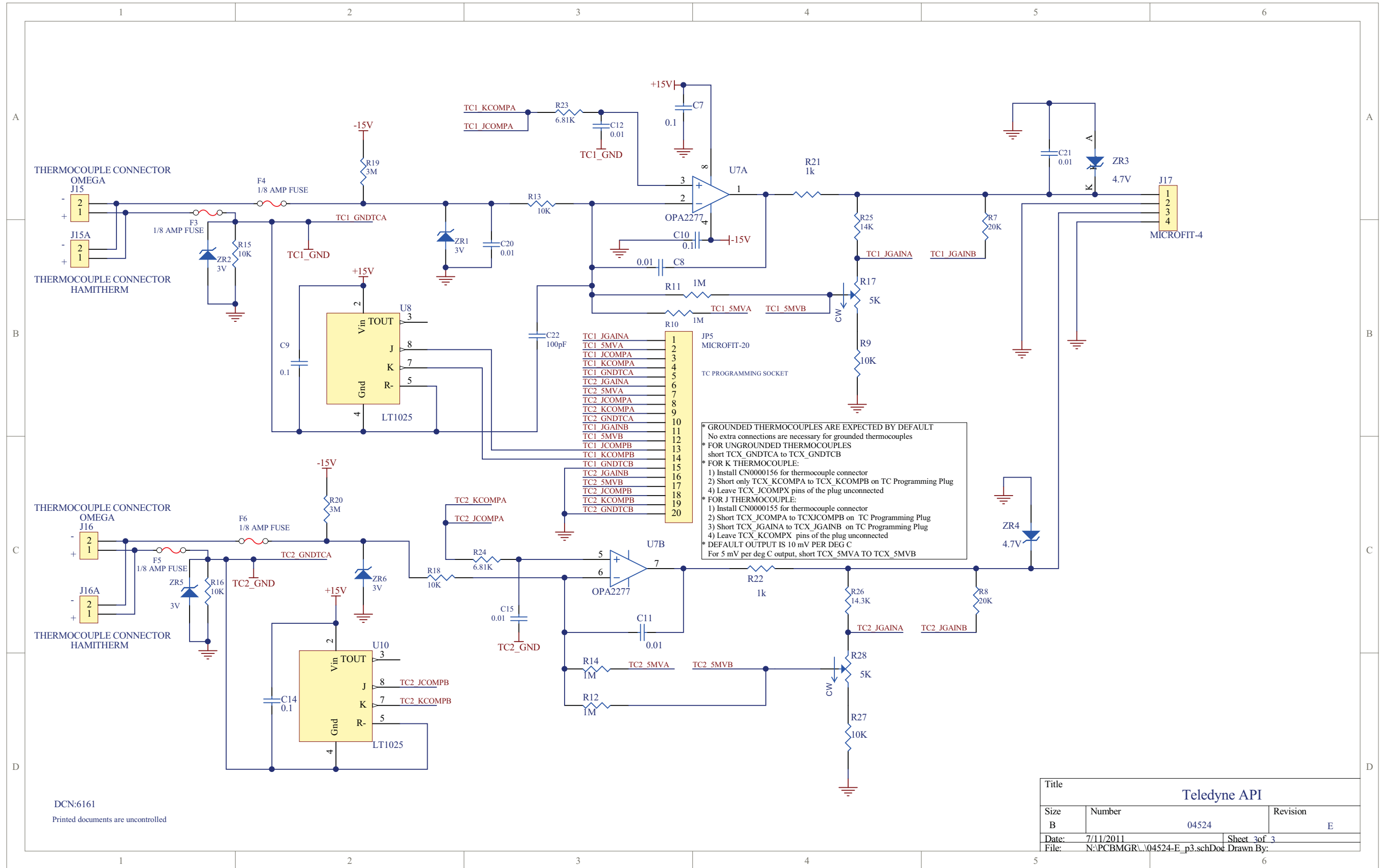
1. Vcc (+5V) and I2C VCC should be 15 mil
2. Digital grounds should be at least 20 mils
3. +12V and +12V return should be 30 mils
4. All AC lines (AC Line, AC Neutral, RELAY0 - 4, All signals on JP2) should be 30 mils wide, with 120 mil isolation/creepage distance around them
5. Traces between J7 - J12 should be top and bottom and at least 140 mils.
6. Traces to the test points can be as small as 10 mils.

REV	AUTH	DATE	DESCRIPTION
B	CAC	10/3/02	CE MARK LINE VOLTAGE TRACE SPACING FIX
D	RJ	5/16/07	Add alternate thermocouple connectors
E	RT	02/15/11	Add C20, C21, C22, TP10, TP11, TP12

Title: Teledyne API			
Size	Number	Revision	
B	04524	E	
Date:	7/11/2011	Sheet	1 of 3
File:	N:\PCBMGR\...04524-E_p1.schDoc Drawn By:		

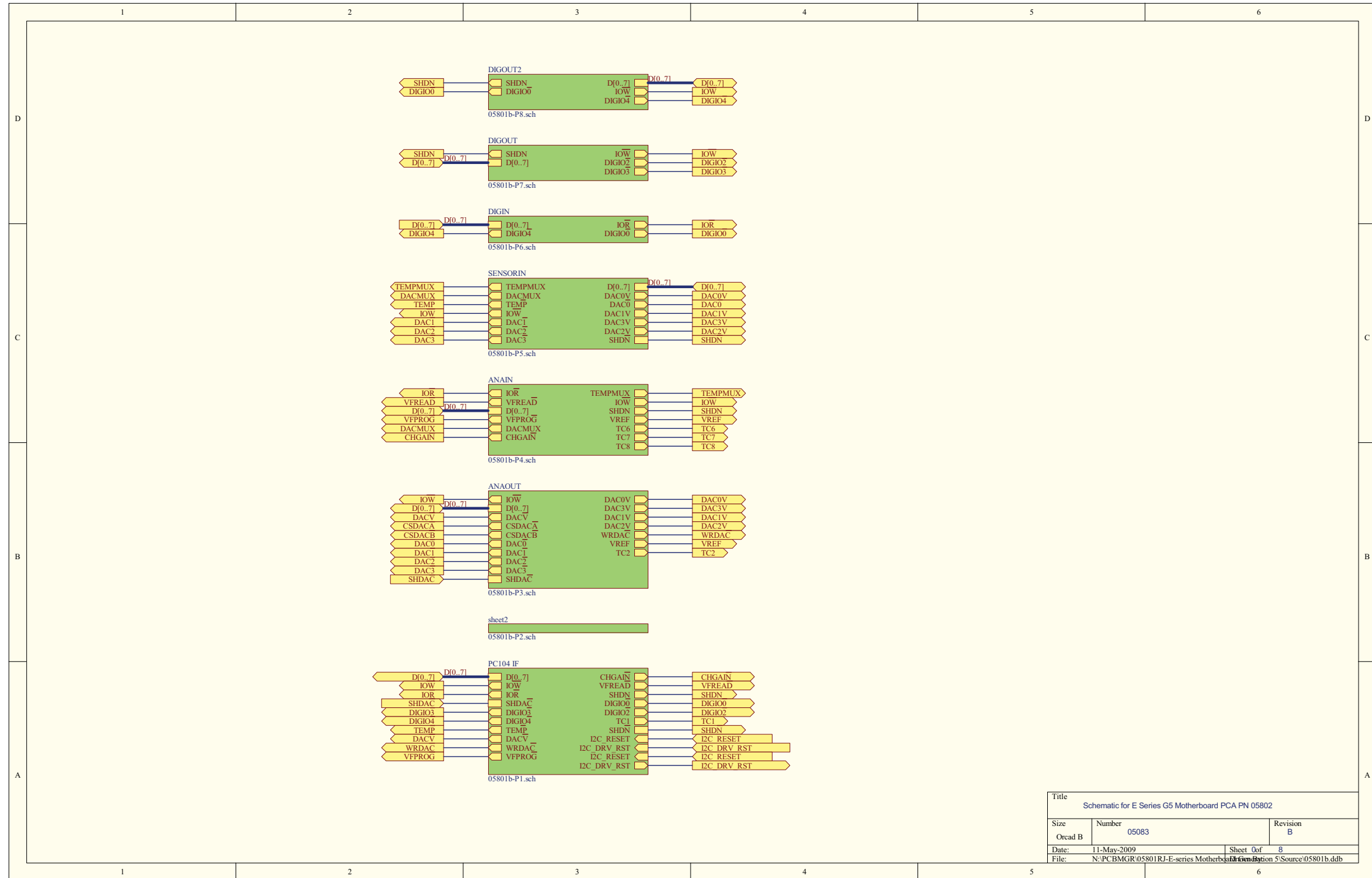
DCN:6161  
Printed documents are uncontrolled





DCN:6161  
Printed documents are uncontrolled

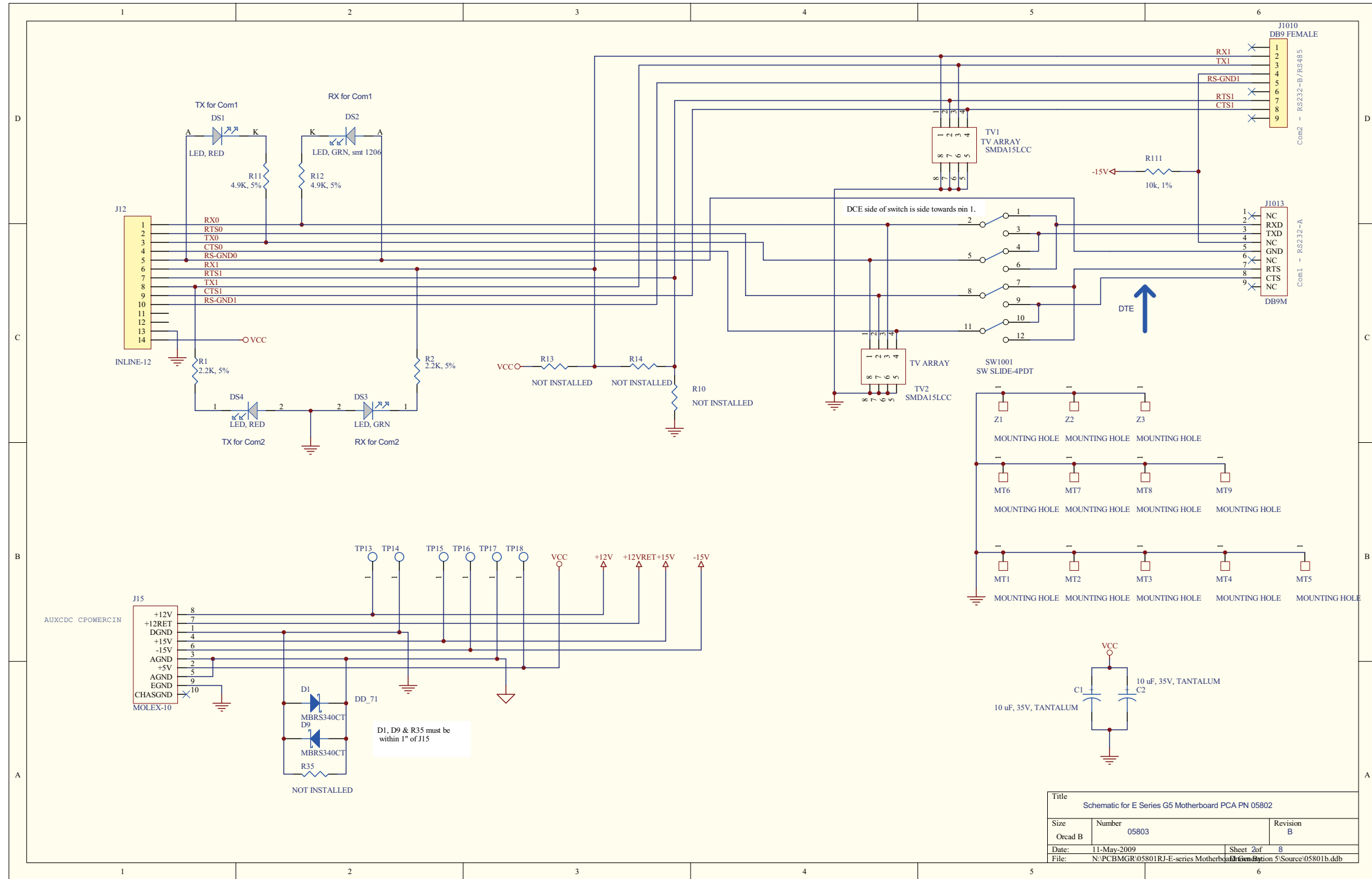
Title			Teledyne API		
Size	Number	Revision			
B	04524	E			
Date:	7/11/2011	Sheet 3 of 3			
File:	N:\PCBMGR\...04524-E_p3.schDoc Drawn By:				

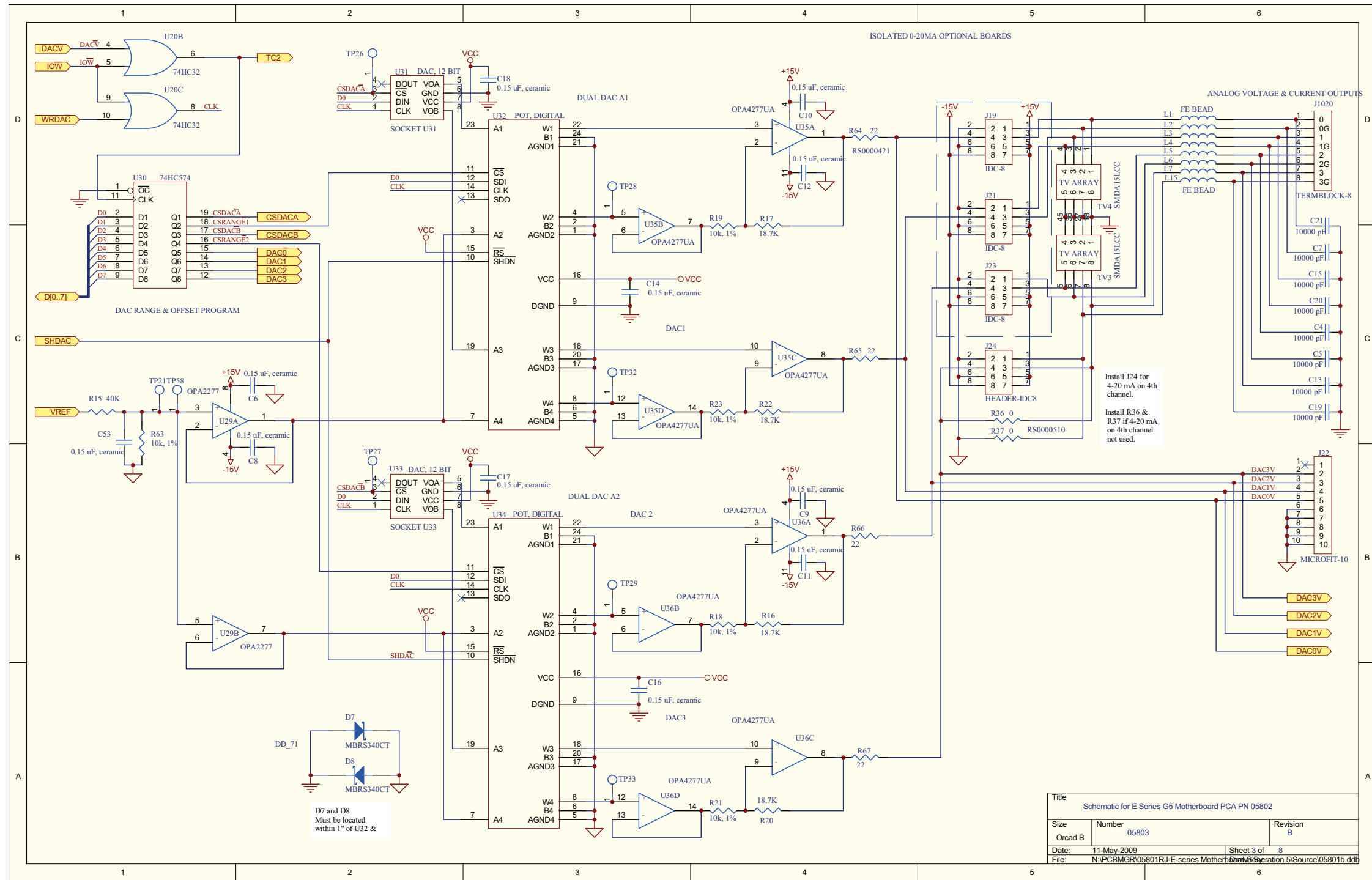


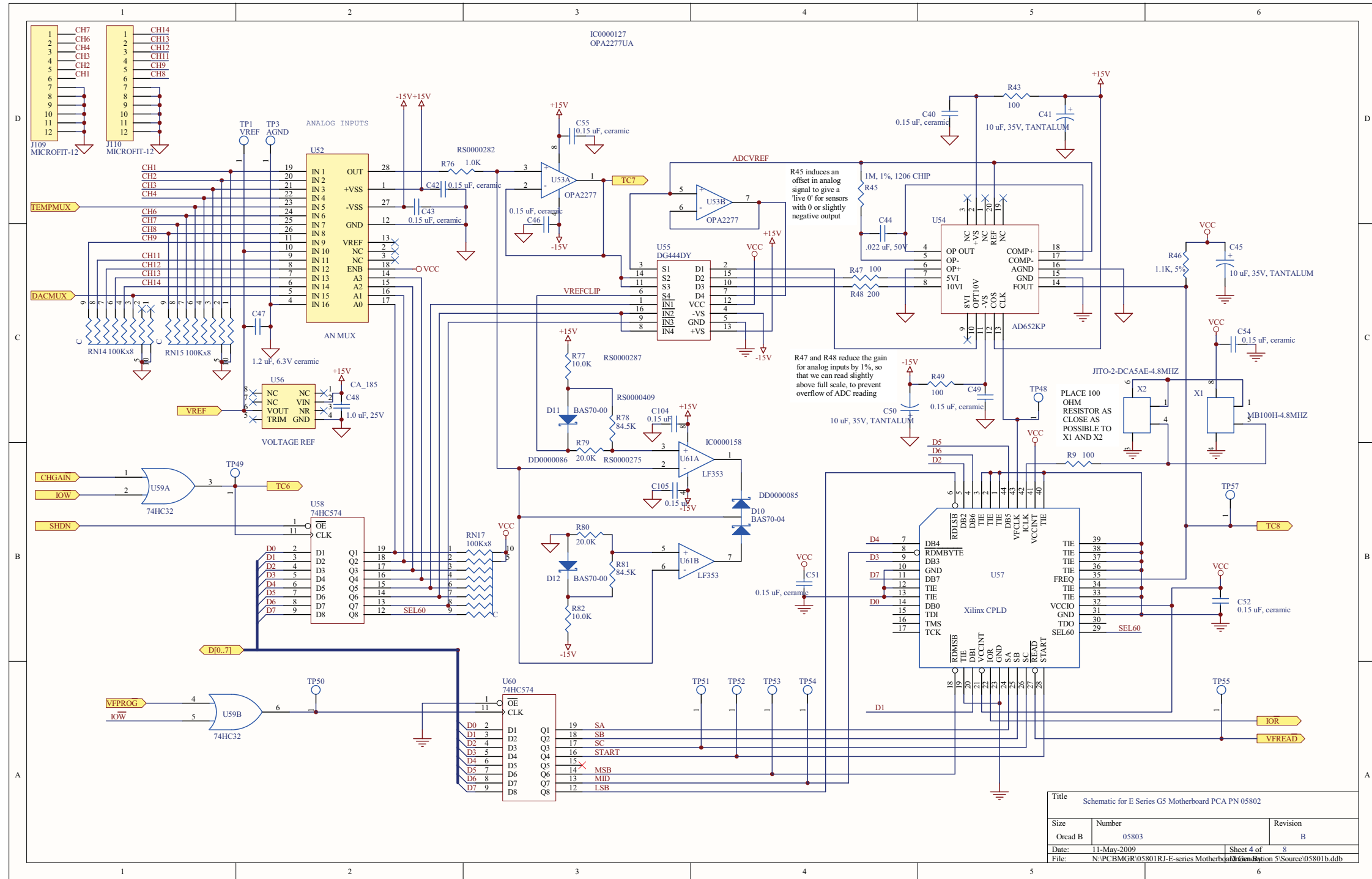
Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05083	B
Date:	11-May-2009	Sheet Of 8
File:	N:\PCBMGR\05801RJ-E-series Motherboard\05801b.ddb	

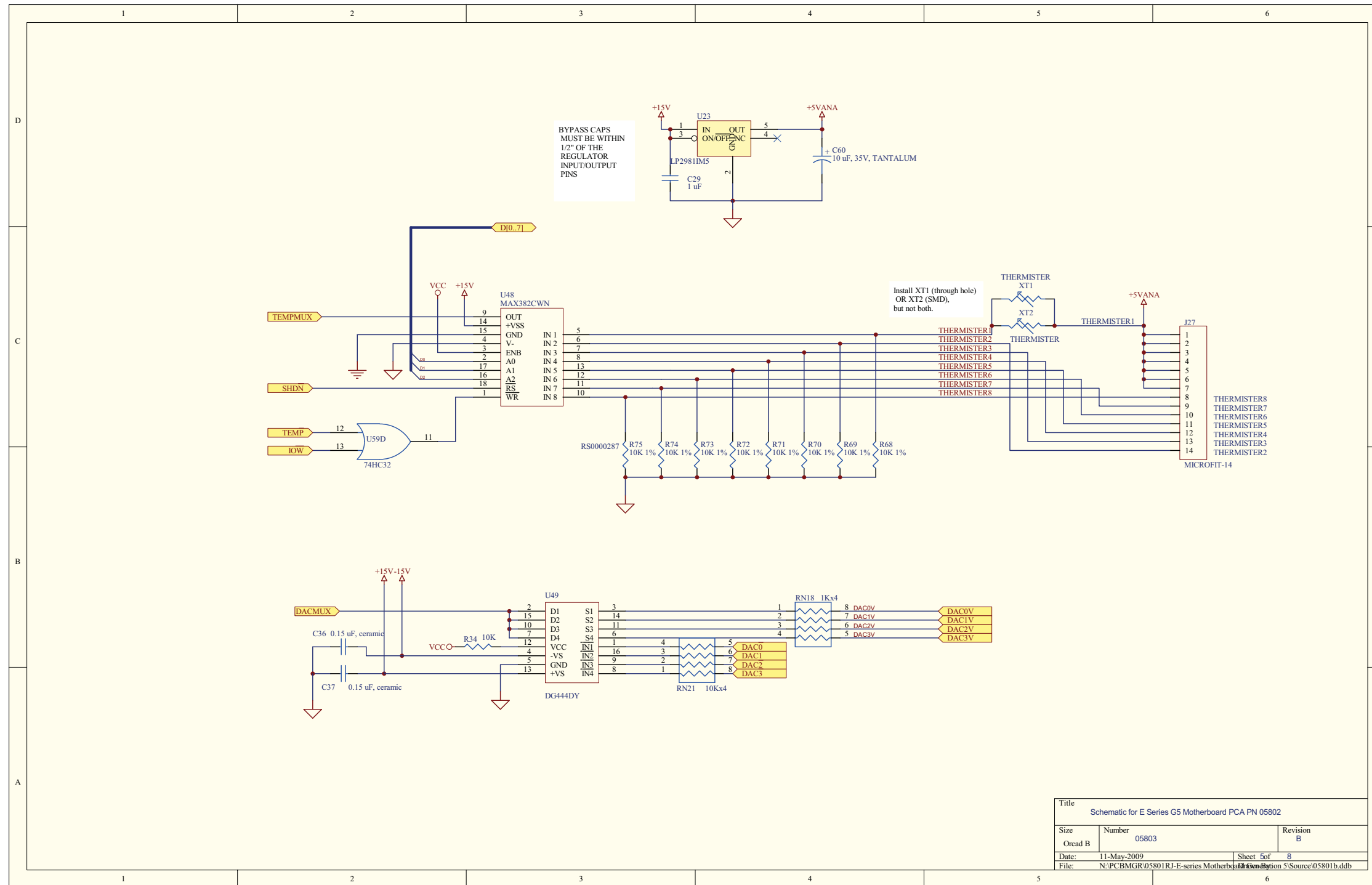




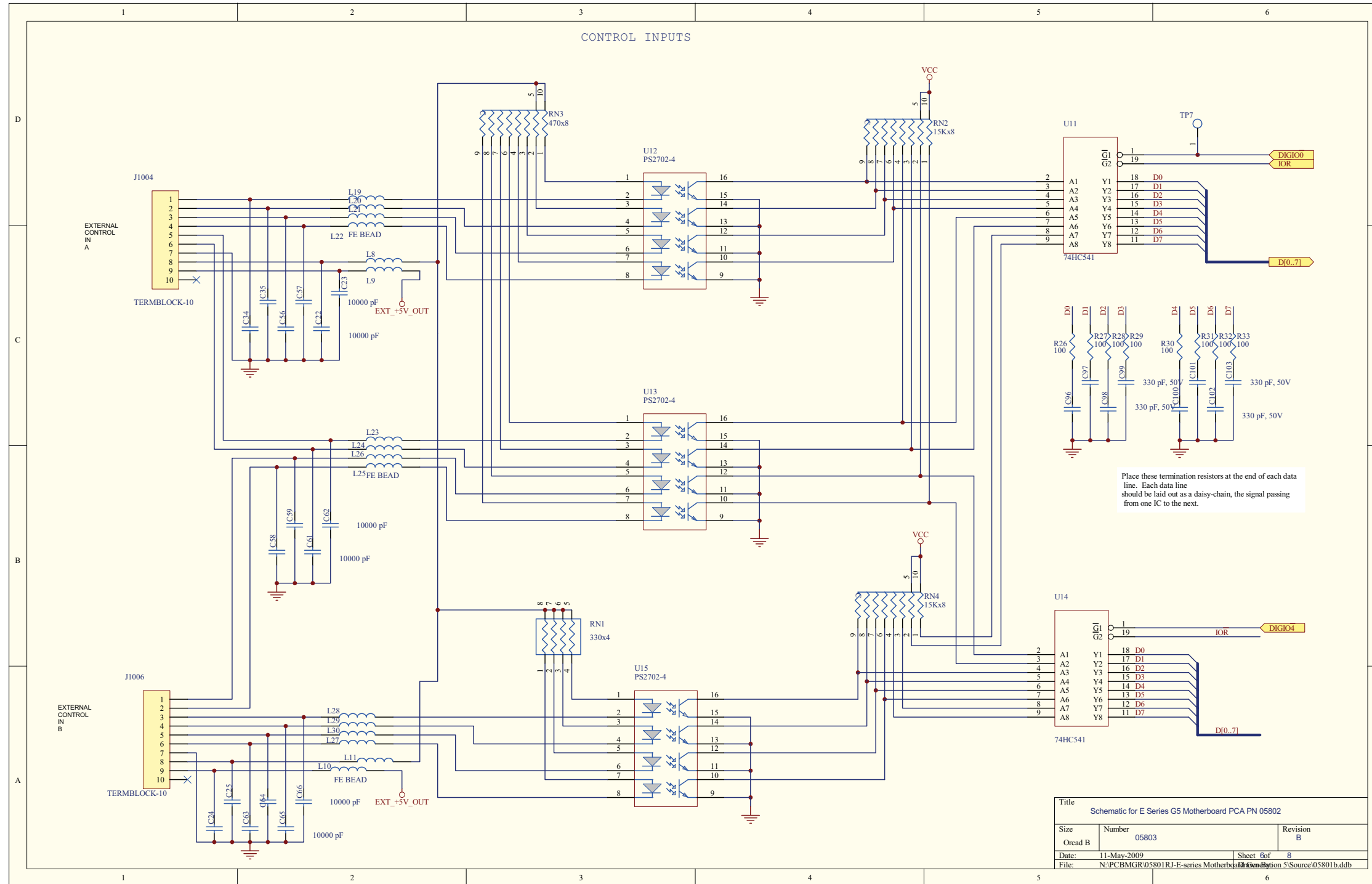


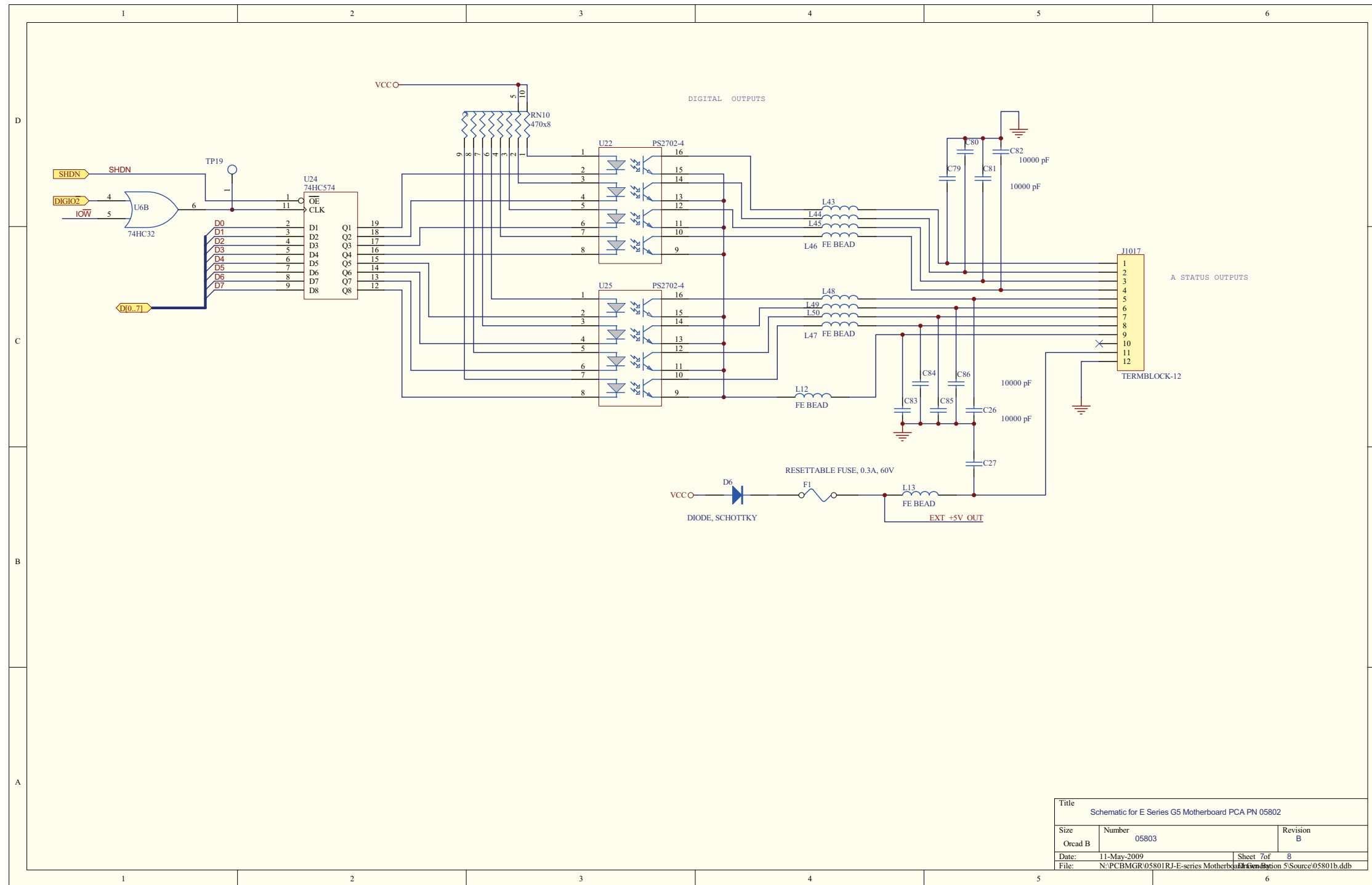




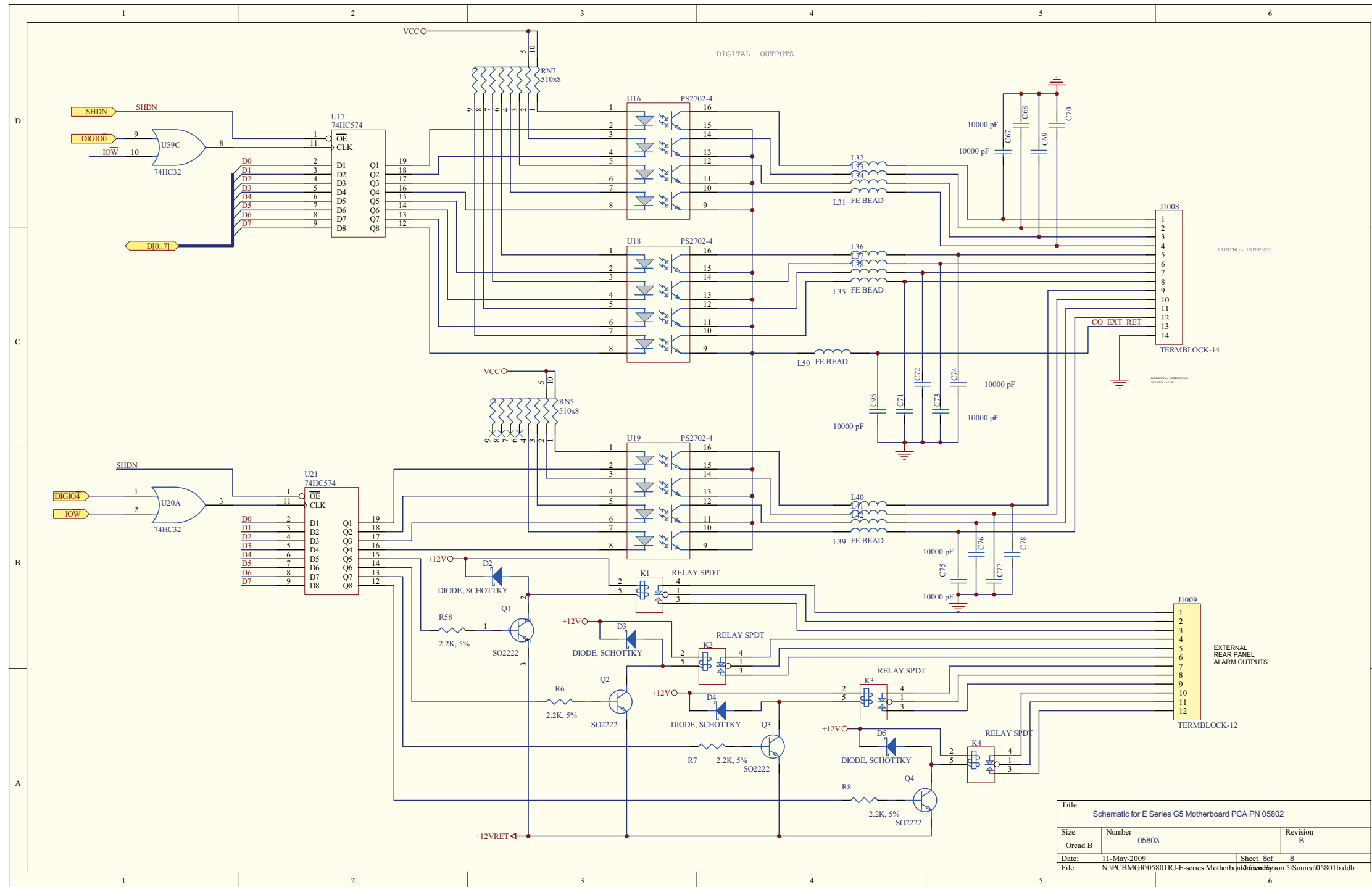


Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05803	B
Date:	11-May-2009	Sheet 5 of 8
File:	N:\PCBMGR\05801RJ-E-series Motherboard\05801b.ddb	



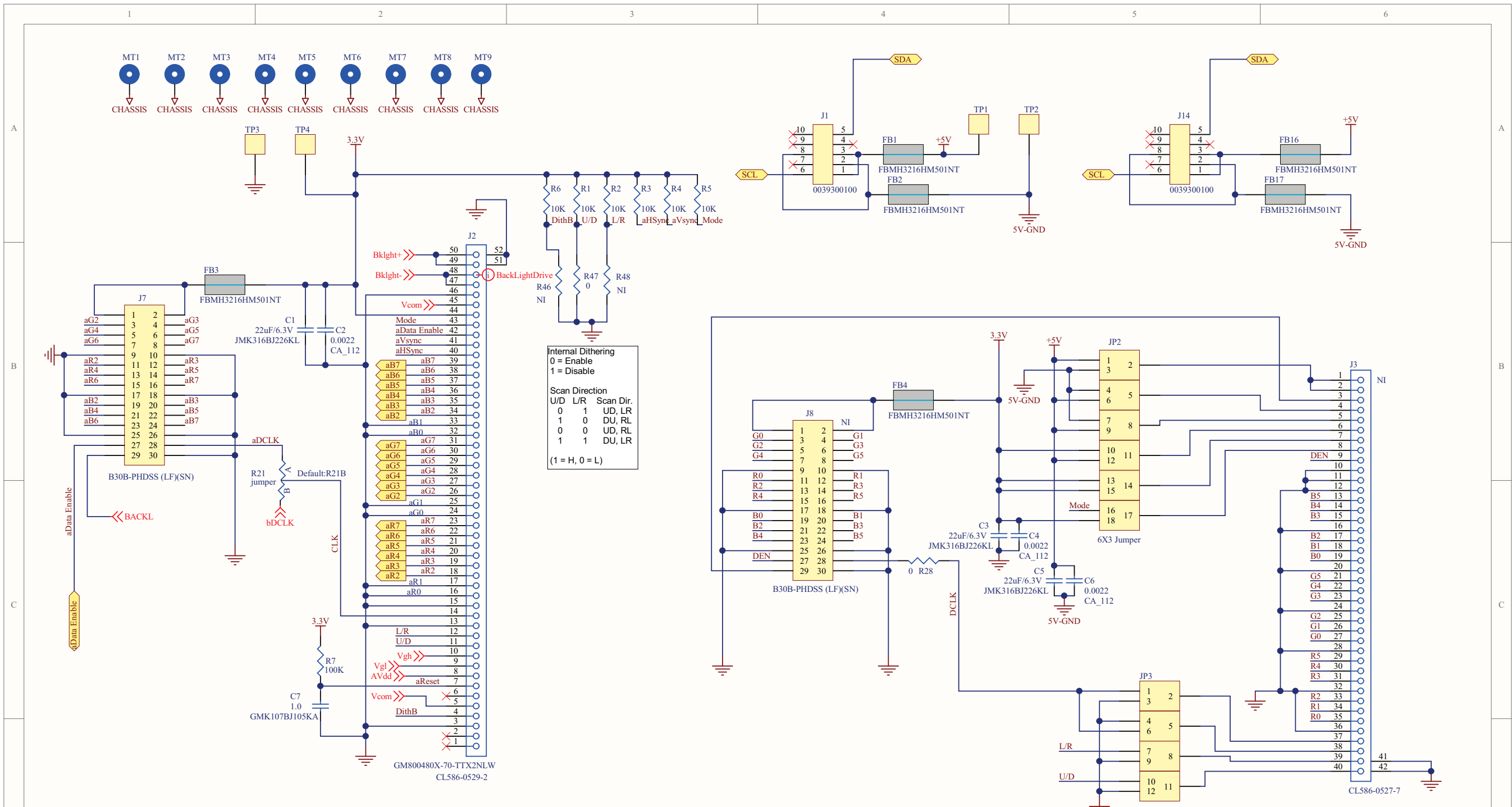


Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05803	B
Date:	11-May-2009	Sheet 7 of 8
File:	N:\PCBMGR\05801RJ-E-series Motherboard\05801b.ddb	

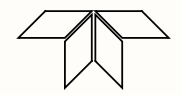


Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05803	B
Date:	11-May-2009	Sheet 8 of 8
File:	N:\PCBMGR\05801RJ-E-series Motherboards\05801b.ddb	

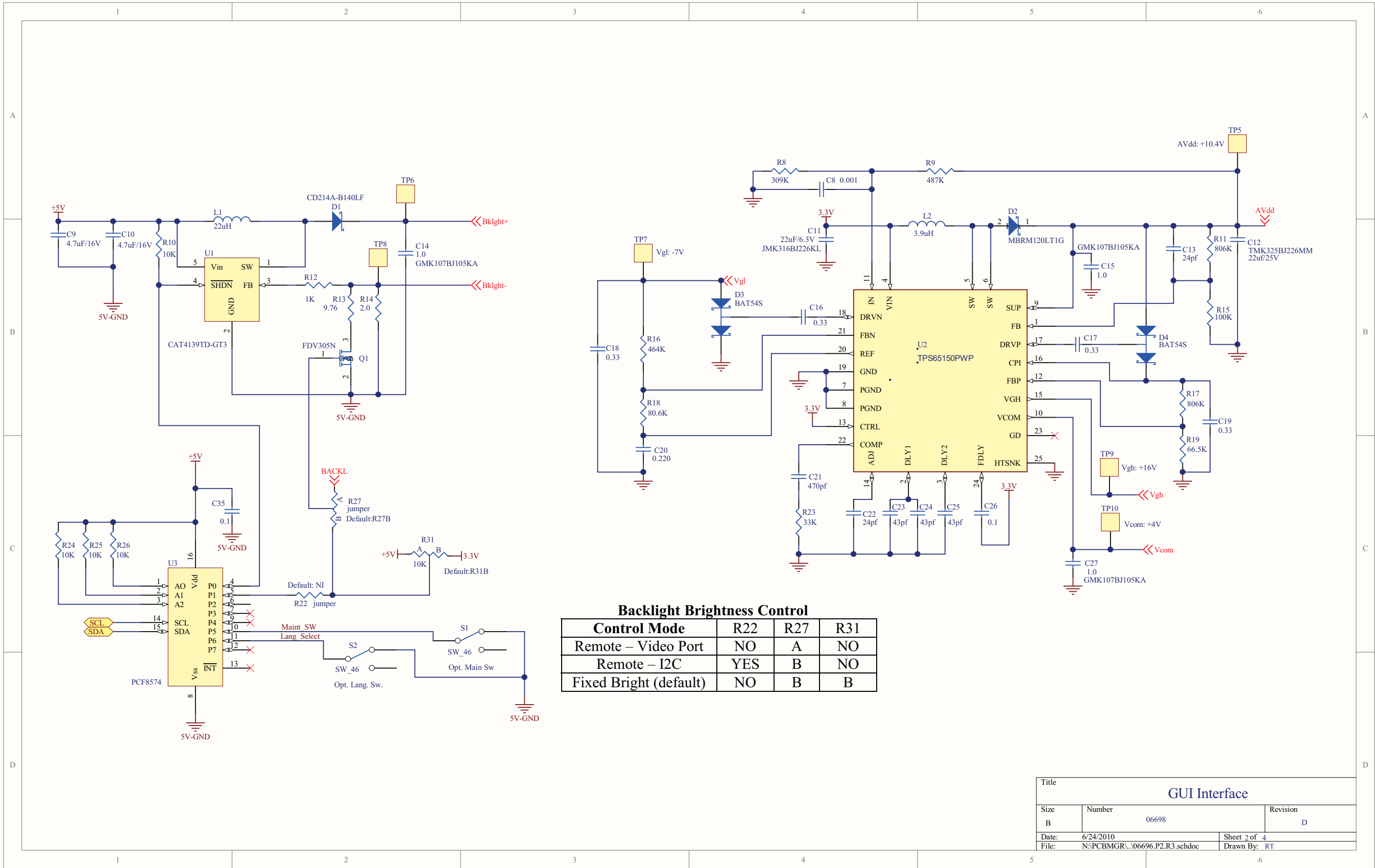




Make	Model	JP2	JP3
FEMA	GM800480W	1-2, 4-5, 7-8, 10-11, 13-14, 16-17	1-2, 4-5, 7-8, 10-11
Data Image	FG0700A0DS/VBG01	3-2, 6-5, 9-8, 12-11, 15-14, 18-17	2-3, 5-6, 8-9, 11-12
United Radiant Tech.	UMSF-8173MD-11	2-3, 4/5/6 NC, 7/8/9 NC, 10-11, 13-14, 16/17/18 NC	2-3, 5-6, 8-9, 11-12



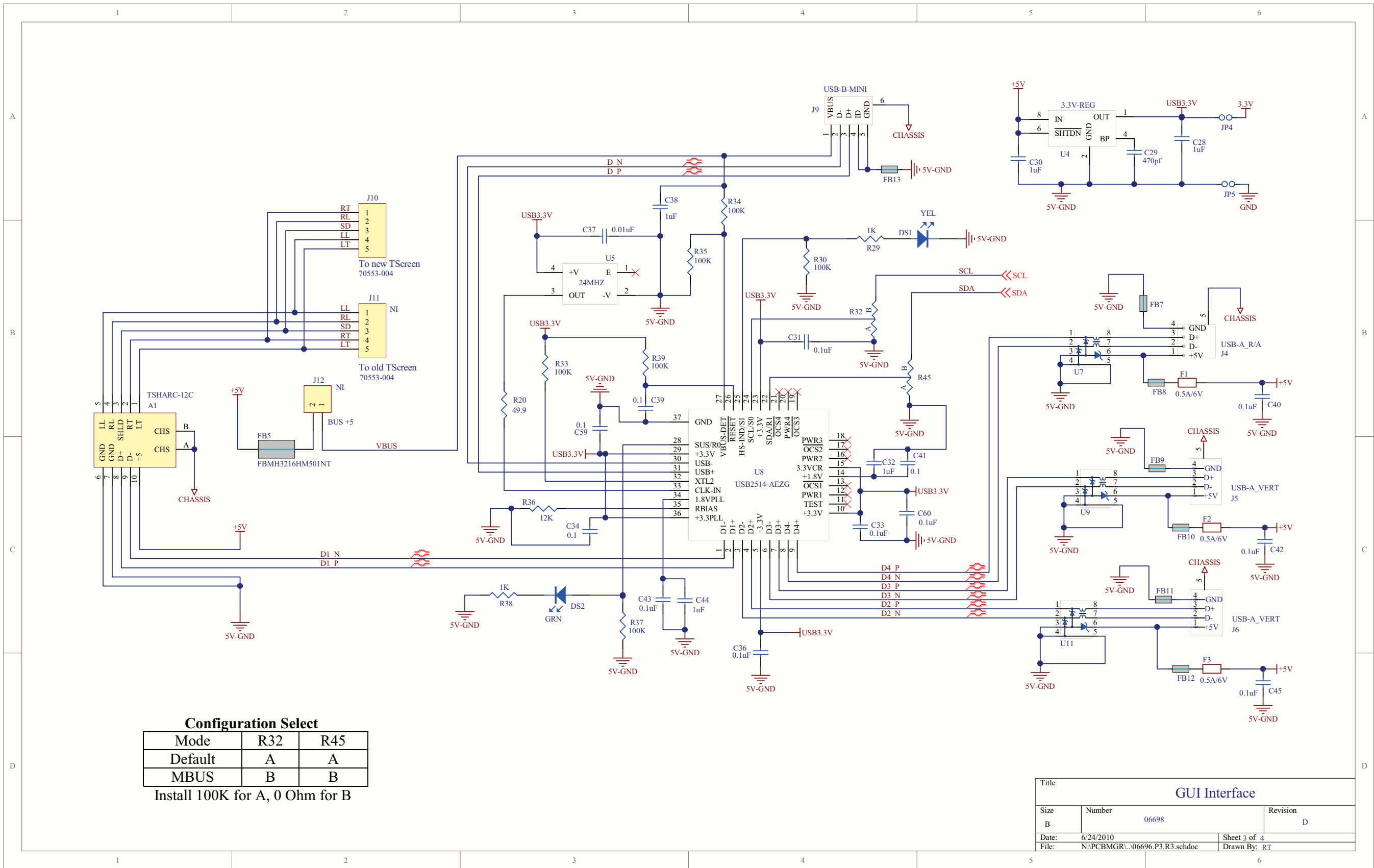
Title			GUI Interface		
Size	Number	Revision			
B	06698	D			
Date:	6/24/2010	Sheet 1 of 4			
File:	N:\PCBMGR\06696.P1.R3.schdoc	Drawn By:		RT	



**Backlight Brightness Control**

Control Mode	R22	R27	R31
Remote – Video Port	NO	A	NO
Remote – I2C	YES	B	NO
Fixed Bright (default)	NO	B	B

Title			GUI Interface		
Size	Number	Revision			
B	06698	D			
Date:	6/24/2010	Sheet 2 of 4			
File:	N:\PCBMGR\06696.P2.R3.schdoc	Drawn By: RT			



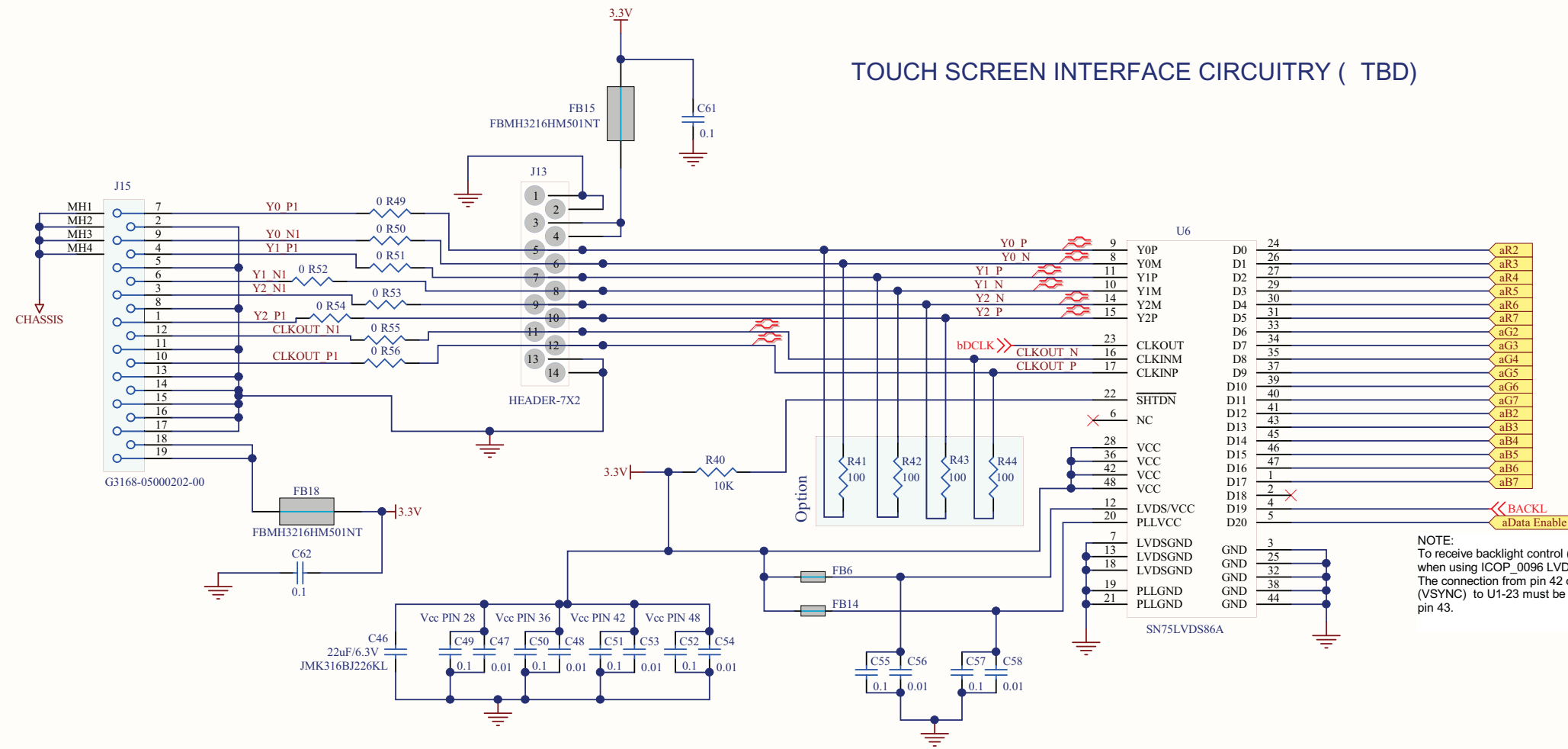
**Configuration Select**

Mode	R32	R45
Default	A	A
MBUS	B	B

Install 100K for A, 0 Ohm for B

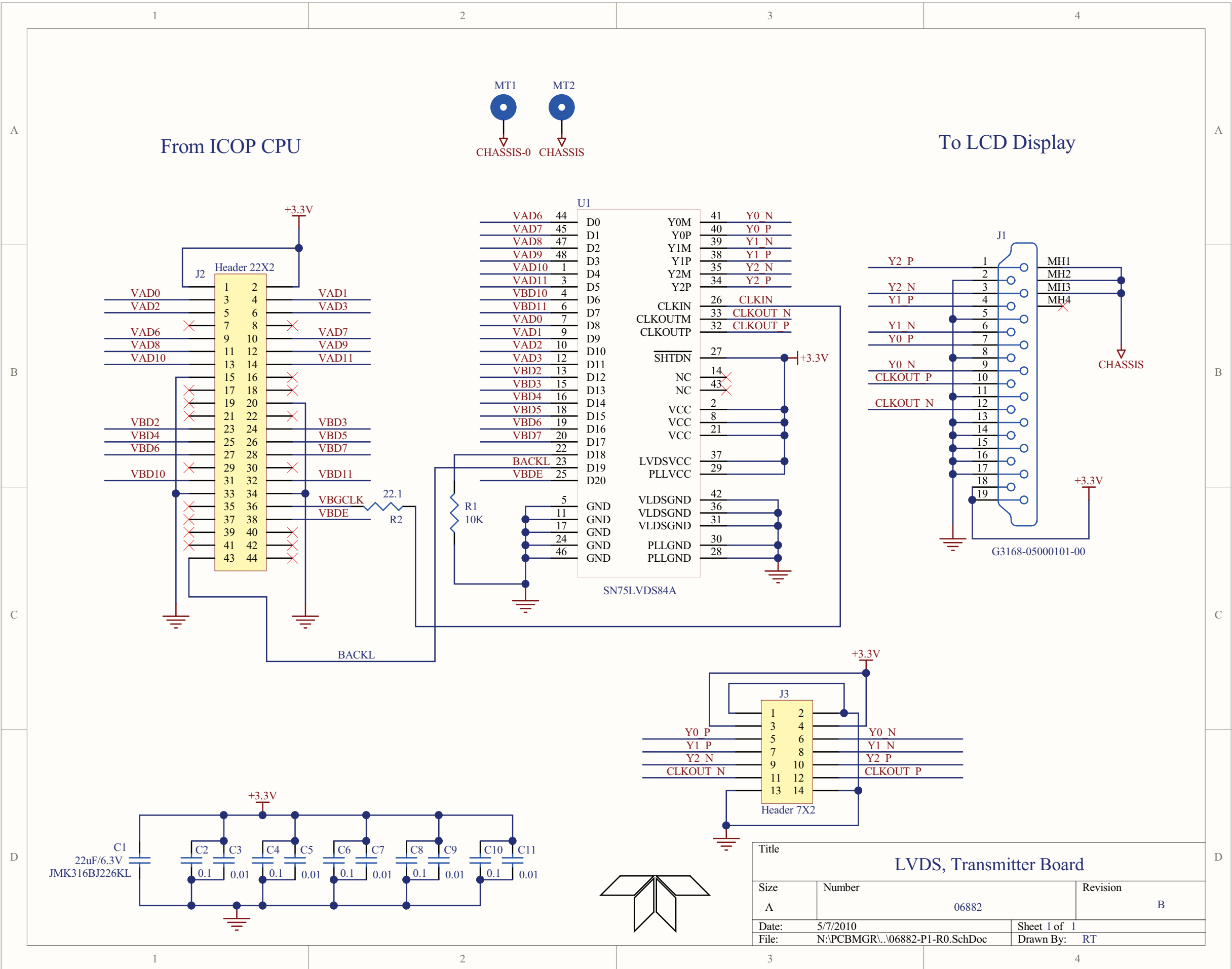
Title			GUI Interface		
Size	Number	Revision			
B	06698	D			
Date:	6/24/2010	Sheet 3 of 4			
File:	N:\PCBMGR\06696.P3.R3.schdoc	Drawn By: RT			

## TOUCH SCREEN INTERFACE CIRCUITRY ( TBD)

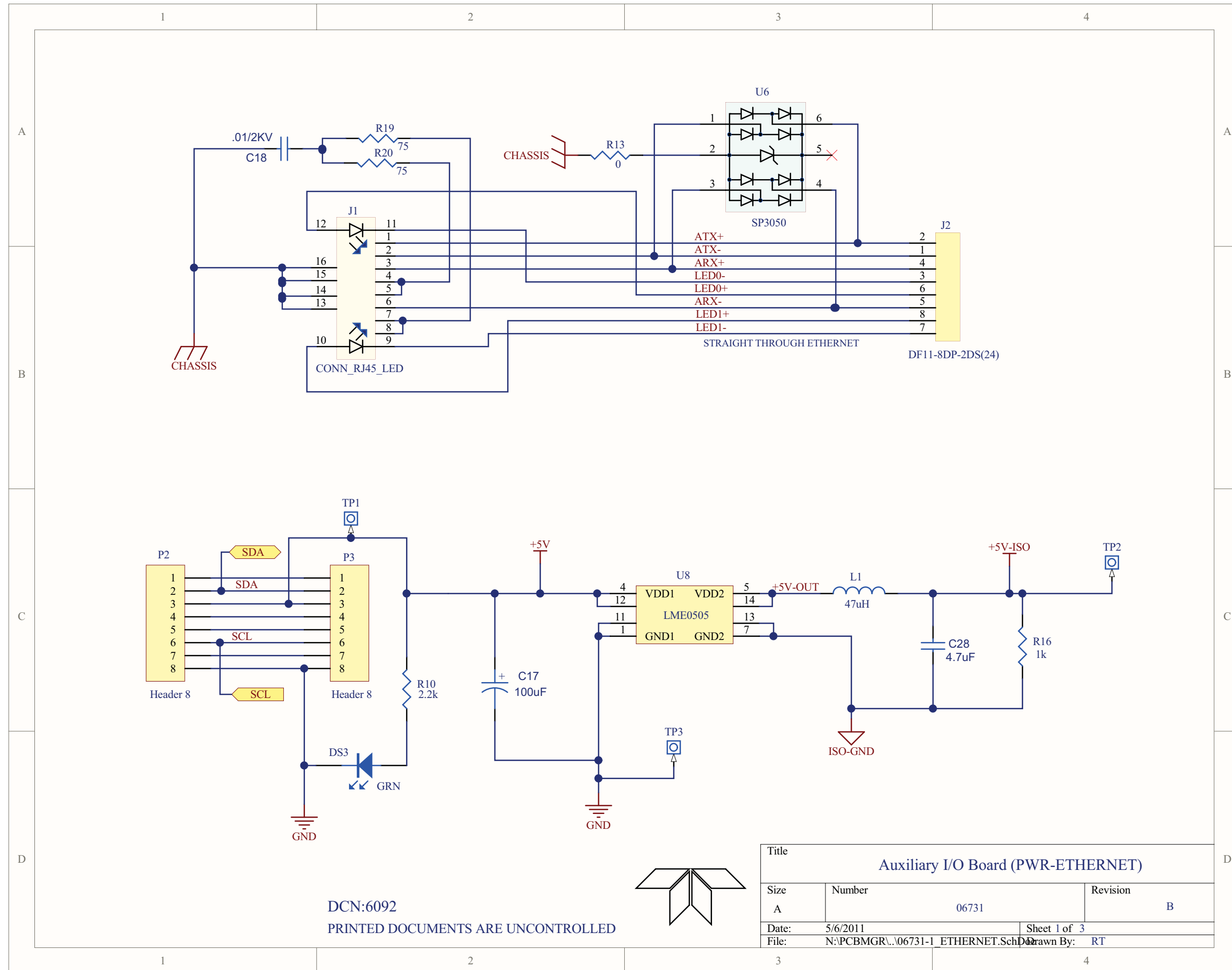


**NOTE:**  
To receive backlight control (BACKL) from CPU board when using ICOP\_0096 LVDS Transmitter. The connection from pin 42 on the TTL video connector (VSYNC) to U1-23 must be broken and connected to pin 43.

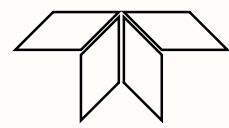
Title			<b>GUI Interface</b>		
Size	Number			Revision	
B	06698			D	
Date:	6/24/2010	Sheet 4 of 4			
File:	N:\PCBMGRU\06696.P4.R3.schdoc	Drawn By: RT			



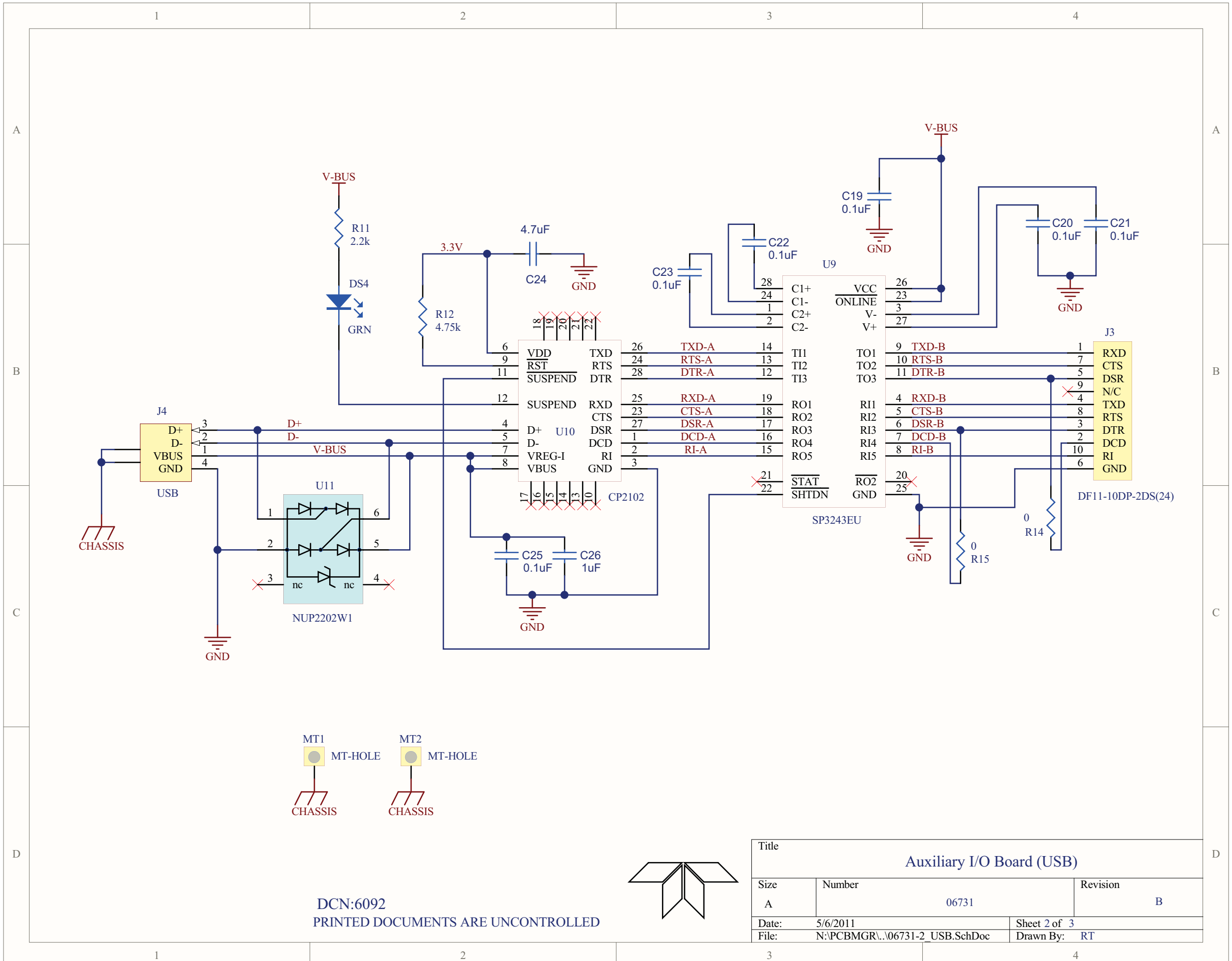
Title		
LVDS, Transmitter Board		
Size	Number	Revision
A	06882	B
Date:	5/7/2010	Sheet 1 of 1
File:	N:\PCBMGR\..06882-P1-R0.SchDoc	Drawn By: RT



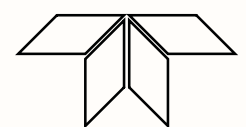
DCN:6092  
 PRINTED DOCUMENTS ARE UNCONTROLLED



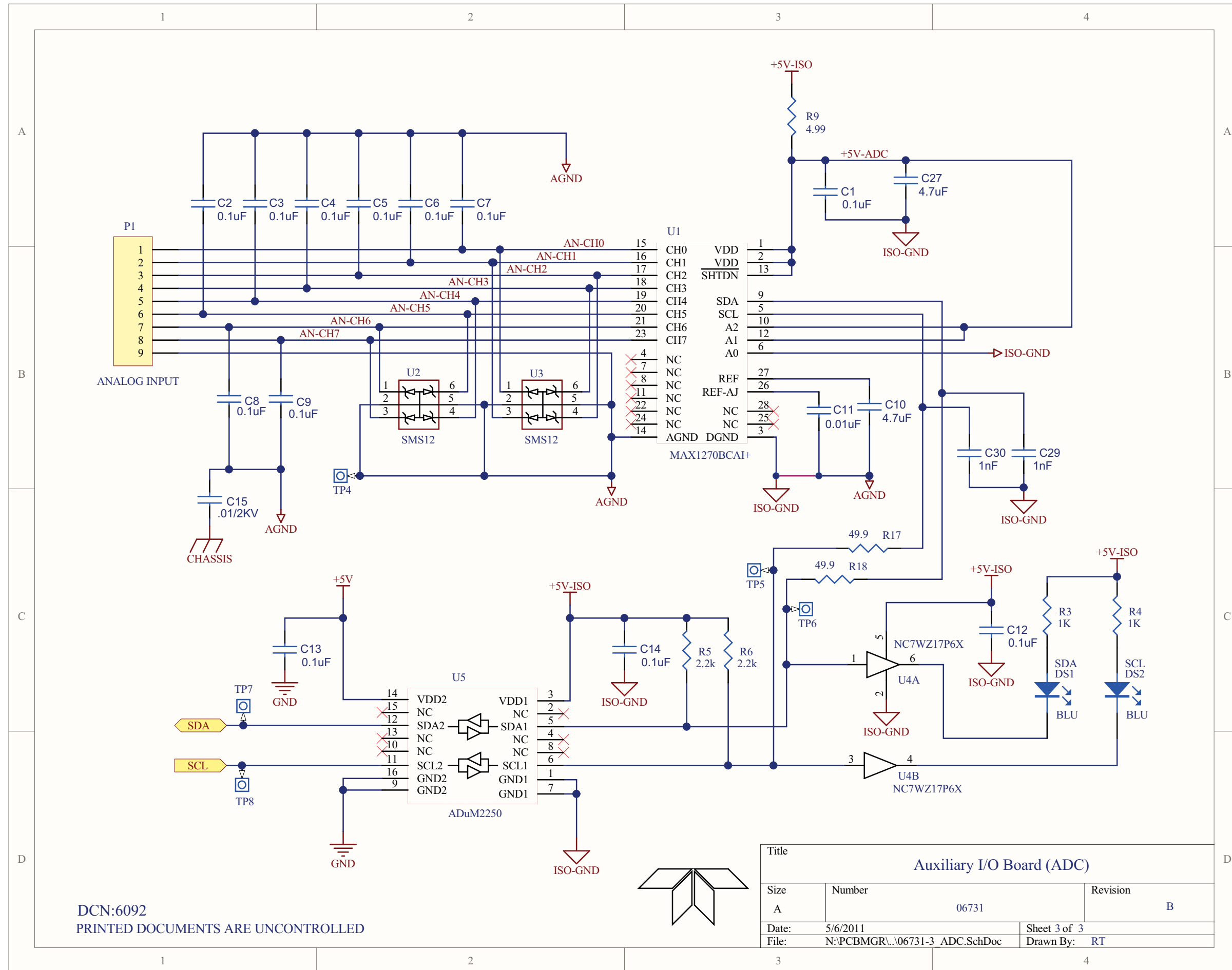
Title			Auxiliary I/O Board (PWR-ETHERNET)		
Size	Number	Revision			
A	06731	B			
Date:	5/6/2011	Sheet 1 of 3			
File:	N:\PCBMGR\..06731-1_ETHERNET.SchDoc	Drawn By:		RT	



DCN:6092  
PRINTED DOCUMENTS ARE UNCONTROLLED



Title			Auxiliary I/O Board (USB)		
Size	Number		Revision		
A	06731		B		
Date:	5/6/2011	Sheet 2 of 3			
File:	N:\PCBMGR\...06731-2 USB.SchDoc	Drawn By:	RT		



DCN:6092  
 PRINTED DOCUMENTS ARE UNCONTROLLED

Title			
Auxiliary I/O Board (ADC)			
Size	Number	Revision	
A	06731	B	
Date:	5/6/2011	Sheet 3 of 3	
File:	N:\PCBMGR\..06731-3_ADC.SchDoc	Drawn By: RT	