

INSTRUCTION MANUAL
TML41M/H
NITROGEN OXIDES ANALYZER



TELEDYNE
MONITOR LABS

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SAFETY MESSAGES

Your safety and the safety of others are very important. We have provided many important safety messages in this manual. Please read these messages carefully.

A safety message alerts you to potential hazards that could hurt you or others. Each safety message is associated with a safety alert symbol. These symbols are found in the manual and inside the instrument. The definition of these symbols is described below:

	GENERAL SAFETY HAZARD: Refer to the instructions for details on the specific hazard.
	CAUTION: Hot Surface Warning.
	CAUTION: Electrical Shock Hazard.
	TECHNICIAN SYMBOL: All operations marked with this symbol are to be performed by qualified maintenance personnel only.

CAUTION

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

NOTE

Technical Assistance regarding the use and maintenance of the TML41M/H NO_x Analyzer or any other Teledyne Instruments product can be obtained by:

Contacting Teledyne Instruments' Customer Service Department at 800-846-6062

Or

Via the internet at <http://www.teledyne-ml.com>

USER NOTES:

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USER NOTES:

1. TML41M/H DOCUMENTATION

Thank you for purchasing the TML41M/H Nitrogen Oxides Analyzer!

The documentation (part number 045210000) for this instrument is available in several different formats:

- Printed format, or;
- Electronic format on a CD-ROM.

The electronic manual is in Adobe® Systems Inc. “Portable Document Format” (PDF). The Adobe® Acrobat Reader® software, which is necessary to view these files, can be downloaded for free from the internet at <http://www.adobe.com/>.

The electronic version of the manual has many advantages:

- Keyword and phrase search feature
- Figures, tables and internet addresses are linked so that clicking on the item will display the associated feature or open the website.
- A list of chapters and sections as well as thumbnails of each page is displayed to the left of the text.
- Entries in the table of contents are linked to the corresponding locations in the manual.
- Ability to print sections (or all) of the manual

Additional documentation for the TML41M/H Nitrogen Oxides Analyzer is available from Teledyne Instruments’ website at <http://www.teledyne-ml.com>

- sensor-e.com software manual, part number 039450000
- iDAS manual, part number 028370000.

1.1. USING THIS MANUAL

This manual has the following data structures:

1.0 Table of Contents:

Outlines the contents of the manual in the order the information is presented. This is a good overview of the topics covered in the manual. There is also a list of appendices, figures and tables. In the electronic version of the manual, clicking on any of these table entries automatically views that section.

2.0 Specifications and Warranty Procedure

A list of the analyzer’s performance specifications and a description of the conditions and configuration under which EPA equivalency was approved.

3.0 Getting Started

Concise instructions for setting up, installing and running your analyzer for the first time.

4.0 FAQ & Glossary:

Answers to the most frequently asked questions about operating the analyzer and a glossary of acronyms and technical terms.

5.0 Optional Hardware & Software

A description of optional equipment to add functionality to your analyzer.

6.0 Operation Instructions

Step by step instructions for operating the analyzer.

7.0 Calibration Procedures

General information and step by step instructions for calibrating your analyzer.

8.0 EPA Protocol Calibration

Because there is no single, standard method for EPA equivalency in application where high concentrations of NO_x are measured, no specific EPA calibration/validation method is included in this manual.

9.0 Instrument Maintenance

Description of preventative maintenance procedures that should be regularly performed on your instrument to assure good operating condition. This includes information on using the iDAS to predict possible component failures before they happen.

10.0 Theory of Operation

An in-depth look at the various principals by which your analyzer operates as well as a description of how the various electronic, mechanical, and pneumatic components of the instrument work and interact with each other. A close reading of this section is invaluable for understanding the instrument's operation.

11.0 Troubleshooting & Repair

This section includes pointers and instructions for diagnosing problems with the instrument, such as excessive noise or drift, as well as instructions on performing repairs of the instrument's major subsystems.

12.0 Electro-static Discharge Primer

This section describes how static electricity occurs; why it is a significant concern and; how to avoid it and avoid allowing ESD to affect the reliable and accurate operation of your analyzer.

Appendices

For easier access and better updating, some information has been separated out of the manual and placed in a series of appendices at the end of this manual. These include version-specific software menu trees, warning messages, definitions of iDAS & serial I/O variables as well as spare part listings, repair questionnaire, interconnect drawing, detailed pneumatic and electronic schematics.

NOTE

Throughout this manual, words printed in capital, bold letters, such as **SETUP** or **ENTR** represent messages as they appear on the analyzer's front panel display.

NOTE

The flowcharts in this manual contain typical representations of the analyzer's display during the various operations being described. These representations are not intended to be exact and may differ slightly from the actual display of your instrument.

USER NOTES:

2. SPECIFICATIONS AND APPROVALS

2.1. TML41M/H OPERATING SPECIFICATIONS

Table 2-1: TML41M/H Basic Unit Specifications

Min/Max Range (Physical Analog Output)	TML41H: Min: 0-5 ppm; Max: 0-5000 ppm TML41M: Min: 0-1 ppm; Max: 0-200 ppm
Measurement Units	ppm, mg/m ³ (user selectable)
Zero Noise	<20 ppb (RMS)
Span Noise	<0.2% of reading above 20 ppm
Lower Detectable Limit	40 ppb (2x noise as per USEPA)
Zero Drift (24 hours)	<20 ppb (at constant temperature and voltage.)
Zero Drift (7 days)	<20 ppb (at constant temperature and voltage.)
Span Drift (7 Days)	<1% of reading (at constant temperature and voltage.)
Linearity	1% of full scale
Precision	0.5% of reading
Lag Time	20 s
Rise/Fall Time	95% in <60 s (~10 s in NO only or NO _x only modes)
Gas Flow Rates	TML41H: -40 cm ³ /min sample gas through NO ₂ converter & sensor module -250 cm ³ /min ± 10% though bypass manifold; -290 cm ³ /min total flow TML41M: -250 cm ³ /min sample gas through NO ₂ converter & sensor module O ₂ Sensor option adds 80 cm ³ /min to total flow though TML41M/H when installed;
Temperature Range	5 - 40 °C operating range
Humidity Range	0-95% RH non-condensing
Dimensions H x W x D	18 cm x 43 cm x 61 cm (7" x 17" x 23.6")
Weight, Analyzer	18 kg (40 lbs) without options
Weight, Ext Pump Pack	7 kg (16 lbs)
AC Power Rating	100 V, 50/60 Hz (3.25A); 115 V, 60 Hz (3.0 A); 220 - 240 V, 50/60 Hz (2.5 A)
Power, Ext Pump	100 V, 50/60 Hz (3.25A); 115 V, 60 Hz (3.0 A); 220 - 240 V, 50/60 Hz (2.5 A)
Environmental	Installation category (over-voltage category) II; Pollution degree 2
Analog Outputs	4 user configurable outputs
Analog Output Ranges	All Outputs: 0.1 V, 1 V, 5 V or 10 V Three outputs convertible to 4-20 mA isolated current loop. All Ranges with 5% under/over-range
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)
Status Outputs	8 Status outputs from opto-isolators, 7 defined, 1 spare
Control Inputs	6 Control inputs, 4 defined, 2 spare
Alarm outputs	2 relay alarms outputs (Optional equipment) with user settable alarm limits - 1 Form C: SPDT; 3 Amp @ 125 VAC
Serial I/O	1x RS-232; 1x RS-485 or RS-232 (configurable) Communication speed: 300 - 115200 baud (user selectable)
Certifications	CE: EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A.

2.2. CE MARK COMPLIANCE

Emissions Compliance

The Teledyne Instruments Nitrogen Oxides Analyzers TML41 and TML41M/H were tested and found to be fully compliant with:

EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A.

Tested on January 02-06, 2003 at CKC Laboratories, Inc., Report Number CE03-005.

Safety Compliance

The Teledyne Instruments Nitrogen Oxides Analyzers TML41 and TML41M/H were tested and found to be fully compliant with:

IEC 61010-1:90 + A1:92 + A2:95,

Tested on January 27-20, 2003.

2.3. WARRANTY PROCEDURE

- Customer shall notify TML of a defect within the warranty period and request a return authorization number and designated TML repair facility. Customer shall return the defective part or parts to the designated TML Customer Service Facility as set forth below, freight prepaid by the customer. TML will prepay the return freight.
- TML will notify the customer of TML's decision to repair or replace the defective part and the expected shipment date.
- At the customer's request, TML may elect to repair defective product(s) located in North America on site, in which case travel expenses, travel time, and related expenses incurred by TML personnel (excluding repair time) shall be paid by the customer.

TELEDYNE MONITOR LABS SERVICE RESPONSE CENTER 1-800-846-6062 WWW.TELEDYNE-ML.COM

35 Inverness Drive East, Englewood, Colorado 80112-5189 USA
Tel: 303-792-3300, Fax: 303-799-4853

USER NOTES:

3. GETTING STARTED

3.1. UNPACKING AND INITIAL SETUP

**CAUTION**

THE TML41M/H WEIGHS ABOUT 17 KG (40 POUNDS) WITHOUT OPTIONS INSTALLED. TO AVOID PERSONAL INJURY, WE RECOMMEND USING TWO PERSONS TO LIFT AND CARRY THE ANALYZER.

Inspect the received packages for external shipping damage. If damaged, please advise the shipper first, then Teledyne Instruments.

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 04413) is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

Carefully remove the top cover of the analyzer and check for internal shipping damage.

- Remove the set-screw located in the top, center of the Front panel.
- Remove the 2 screws fastening the top cover to the unit (one per side towards the rear).
- Slide the cover backwards until it clears the analyzer's front bezel.
- Lift the cover straight up.

NOTE

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.

See Chapter 12 for more information on preventing ESD damage.

**CAUTION**

NEVER DISCONNECT ELECTRONIC CIRCUIT BOARDS, WIRING HARNESSSES OR ELECTRONIC SUBASSEMBLIES WHILE THE UNIT IS UNDER POWER.

Inspect the interior of the instrument to make sure all circuit boards and other components are in good shape and properly seated.

Check the connectors of the various internal wiring harnesses and pneumatic hoses to make sure they are firmly and properly seated.

Verify that all of the optional hardware ordered with the unit has been installed. These are checked on the paperwork (Form 04490) accompanying the analyzer.

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

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	10 cm / 4 inches
Sides of the instrument	2.5 cm / 1 inch
Above and below the instrument.	2.5 cm / 1 inch

Various rack mount kits are available for this analyzer. See Chapter 5 of this manual for more information.

3.1.1. TML41M/H LAYOUT

Figure 3-1 shows a top-down view of the analyzer. The shown configuration includes the Ethernet board, IZS option, zero-air scrubber, and an additional sample dryer. See Chapter 5 for optional equipment. Figure 3-2 shows the rear panel configuration with optional zero-air scrubber mounted to it and two optional fittings for the IZS option. Figure 3-3, finally shows the front panel layout of the analyzer.

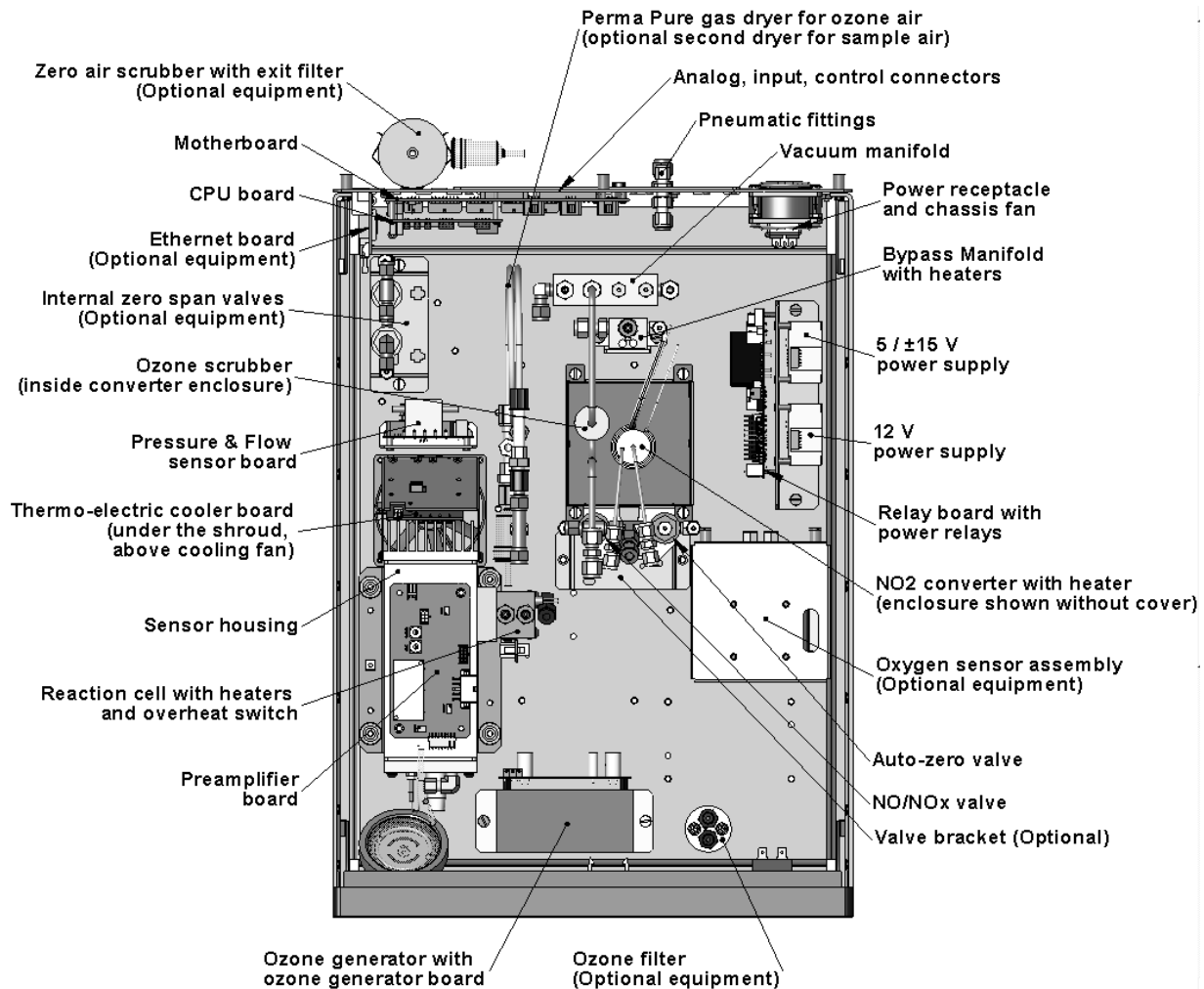


Figure 3-1: TML41M/H Layout

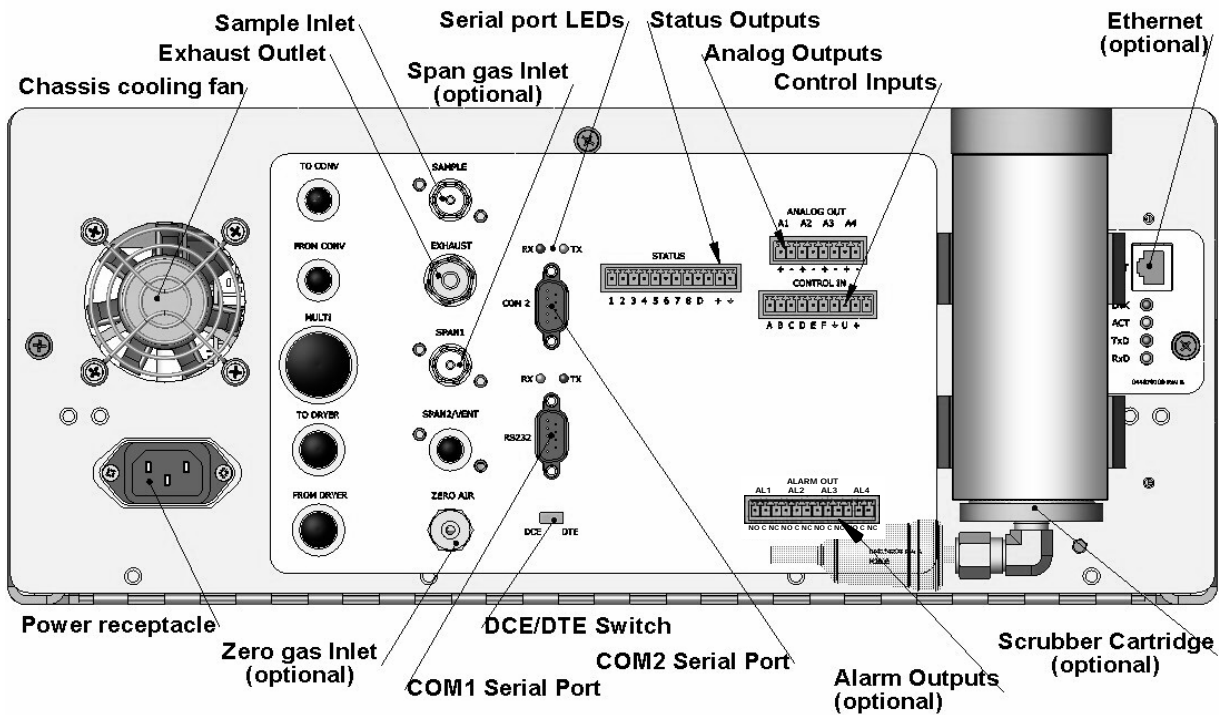


Figure 3-2: TML41M/H Rear Panel Layout

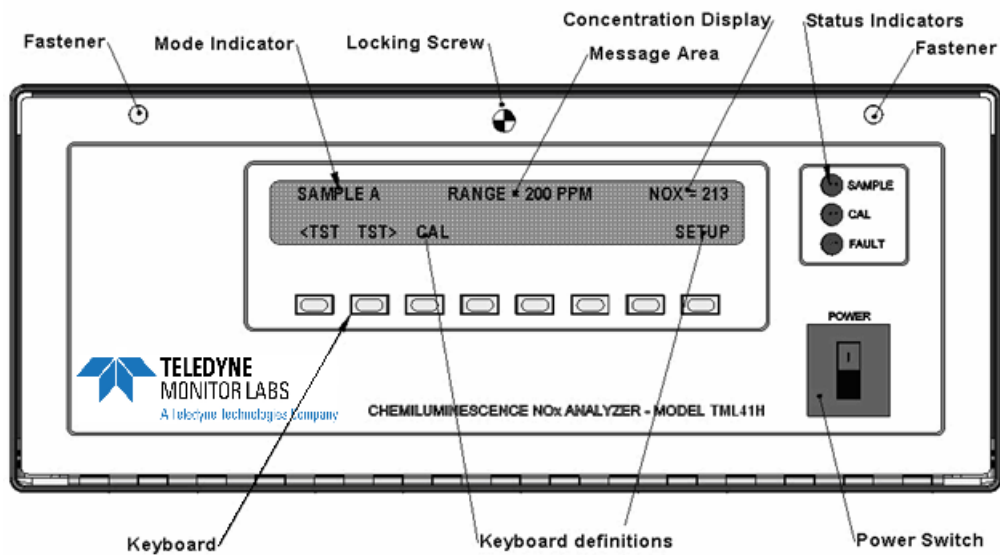



Figure 3-3: TML41M/H Front Panel Layout


3.1.2. ELECTRICAL CONNECTIONS

Refer to Figure 3-2 for the location of the rear panel electrical and pneumatic connections.

3.1.2.1. Power Connection

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.

	<p style="text-align: center;">CAUTION</p> <p>CHECK THE VOLTAGE AND FREQUENCY LABEL ON THE REAR PANEL OF THE INSTRUMENT (SEE FIGURE 3-2 FOR COMPATIBILITY WITH THE LOCAL POWER BEFORE PLUGGING THE TML41M/H INTO LINE POWER.</p> <p>Do not plug in the power cord if the voltage or frequency is incorrect.</p>
---	--

	<p style="text-align: center;">CAUTION</p> <p>POWER CONNECTION MUST HAVE FUNCTIONING GROUND CONNECTION.</p> <p>DO NOT DEFEAT THE GROUND WIRE ON POWER PLUG.</p> <p>TURN OFF ANALYZER POWER BEFORE DISCONNECTING OR CONNECTING ELECTRICAL SUBASSEMBLIES.</p> <p>DO NOT OPERATE WITH COVER OFF.</p>
--	--

The TML41M/H analyzer can be configured for both 100-130 V and 210-240 V at either 50 or 60 Hz. To avoid damage to your analyzer, make sure that the AC power voltage matches the voltage indicated on the rear panel serial number label and that the frequency is between 47 and 63 Hz.

3.1.2.2. Analog Output Connections

The TML41M/H is equipped with four analog output channels accessible through a connector on the back panel of the instrument. Each of these outputs may be set to reflect the value of any of the instrument's iDAS data types. (See Table A-6 of TML41M/H Appendix A).

The following table lists the default settings for each of these channels. To change these settings, see 6.13.5.

Table 3-1: Analog Output Data Type Default Settings

PARAMETER	CHANNEL DEFAULT SETTING			
	A1	A2	A3	A4 ³
DATA TYPE ¹	NXCNC1	NOCNC1	N2CNC1	NXCNC2
RANGE	0 - 5 VDC ²			
REC OFS	0 mVDC			
AUTO CAL.	ON			
CALIBRATED	NO			
OUTPUT	ON			
SCALE	100 ppm			
UPDATE	5 sec			
¹ See Table A-6 of TML41M/H Appendix A for definitions of these iDAS data types ² Optional current loop outputs are available for analog output channels A1-A3. ³ On analyzers with O ₂ sensor options installed, iDAS parameter O2CONC is assigned to output A4.				

To access these signals attach a strip chart recorder and/or data-logger to the appropriate contacts of the analog output connector on the rear panel of the analyzer.

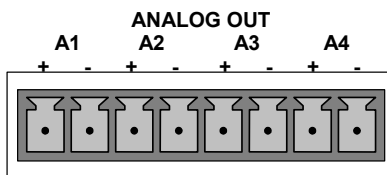


Figure 3-4: Analog Output Connector

Table 3-2: Analog Output Pin-Outs

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	I Out +
8		Ground	I Out -

3.1.2.3. Connecting the Status Outputs

If you wish to utilize the analyzer's status outputs to interface with a device that accepts logic-level digital inputs, such as programmable logic controller (PLC) chips, you can access them through a 12 pin connector on the analyzer's rear panel labeled STATUS.

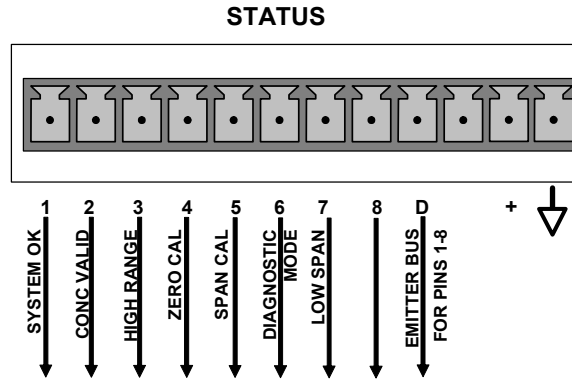


Figure 3-5: Status Output Connector

NOTE

Most PLCs have internal provisions for limiting the current the input will draw. When connecting to a unit that does not have this feature, external resistors must be used to limit the current through the individual transistor outputs to $\leq 50\text{mA}$ ($120\ \Omega$ for 5V supply).

Table 3-3: Status Output Signals

PIN #	STATUS	CONDITION (ON = CONDUCTING)
1	SYSTEM OK	ON if no faults are present.
2	CONC VALID	ON if concentration measurement (NO, NO ₂ or NO _x) is valid. OFF any time the hold-off feature is active.
3	HIGH RANGE	ON if unit is in high range of the Auto Range Mode.
4	ZERO CAL	ON whenever the instrument is in ZERO point calibration mode.
5	SPAN CAL	ON whenever the instrument is in SPAN point calibration mode.
6	DIAG MODE	ON whenever the instrument is in diagnostic mode.
7	LOW SPAN CAL	ON when in low span calibration (optional equipment necessary)
8	Unused	
D	EMITTER BUS	The emitters of the transistors on pins 1-8 are tied together.
	Unused	
+	DC POWER	+ 5 VDC, 300 mA (combined rating with Control Output, if used).
⏚	Digital Ground	The ground level from the analyzer's internal DC power supplies

3.1.2.4. Connecting the Control Inputs

If you wish to use the analyzer to remotely activate the zero and span calibration modes, several digital control inputs are provided through a 10-pin connector labeled CONTROL IN on the analyzer's rear panel.

There are two methods for energizing the control inputs. The internal +5V available from the pin labeled "+" is the most convenient method. However, if full isolation is required, an external 5 VDC power supply should be used.

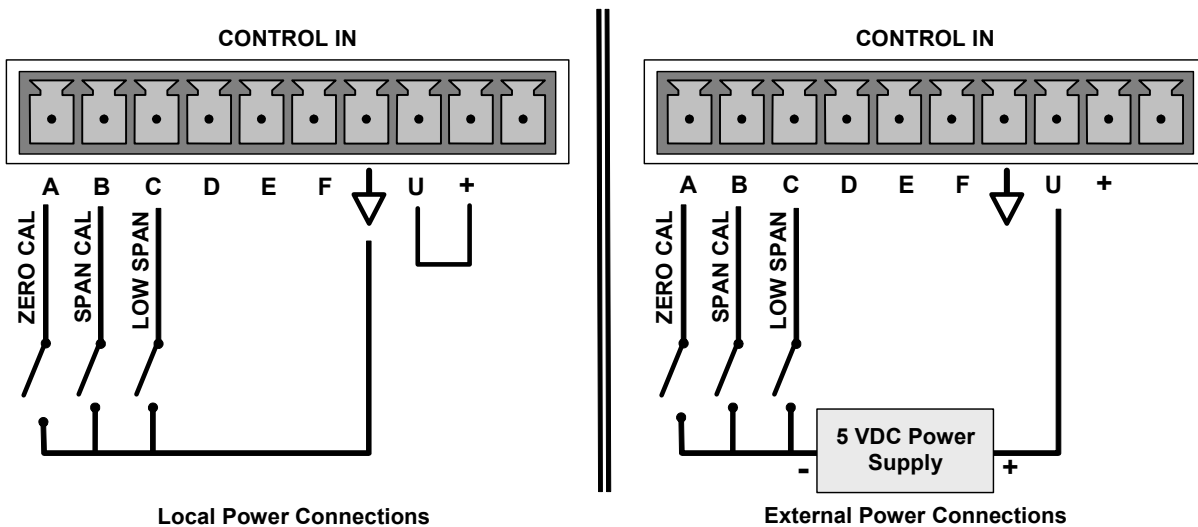


Figure 3-6: Control Input Connector

Table 3-4: Control Input Signals

INPUT #	STATUS DEFINITION	ON CONDITION
A	REMOTE ZERO CAL	The analyzer is placed in Zero Calibration mode. The mode field of the display will read ZERO CAL R.
B	REMOTE SPAN CAL	The analyzer is placed in Span Calibration mode. The mode field of the display will read SPAN CAL R.
C	REMOTE LO SPAN CAL	The analyzer is placed in low span calibration mode as part of performing a low span (midpoint) calibration. The mode field of the display will read LO CAL R.
D	REMOTE RANGE HI	The analyzer is placed into high range when configured for dual ranges.
E	SPARE	
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).

3.1.2.5. Connecting the Serial Ports

If you wish to utilize either of the analyzer's two serial interfaces, refer to Section 6.11 and 6.15 of this manual for instructions on configuration and usage.

3.1.2.6. Connecting to a LAN or the Internet

If your unit has a Teledyne Instruments Ethernet card (Option 63), plug one end of a 7' CAT5 cable into the appropriate place on the back of the analyzer (see Figure 5-11 in Section 5.9.3) and the other end into any nearby Ethernet access port.

NOTE:

The TML41M/H firmware supports dynamic IP addressing or DHCP.

If your network also supports DHCP, the analyzer will automatically configure its LAN connection appropriately,

If your network does not support DHCP, see Section 6.11.6.3 for instructions on manually configuring the LAN connection.

3.1.2.7. Connecting to a Multidrop Network

If your unit has a Teledyne Instruments RS-232 multidrop card (Option 62), see Section 6.11.7 for instructions on setting it up.

3.1.3. PNEUMATIC CONNECTIONS

NOTE

To prevent dust from getting into the analyzer, it was shipped with small plugs inserted into each of the pneumatic fittings on the rear panel. Make sure that all dust plugs are removed before attaching exhaust and supply gas lines.

Table 3-5: Inlet / Outlet Connector Nomenclature

REAR PANEL LABEL	FUNCTION
SAMPLE	Connects the sample gas to the analyzer. When operating the analyzer without zero span option, this is also the inlet for any calibration gases.
EXHAUST	Connects the exhaust of the analyzer with the external vacuum pump.
SPAN	On Units with zero/span valve or IZS option installed, this port connects the external calibration gas to the analyzer.
ZERO AIR	On Units with zero/span valve or IZS option installed, this port connects the zero air gas or the zero air cartridge to the analyzer.

Figure 3-7 and Figure 3-8 show the internal pneumatic flow of the standard configuration of the TML41H and TML41M respectively.

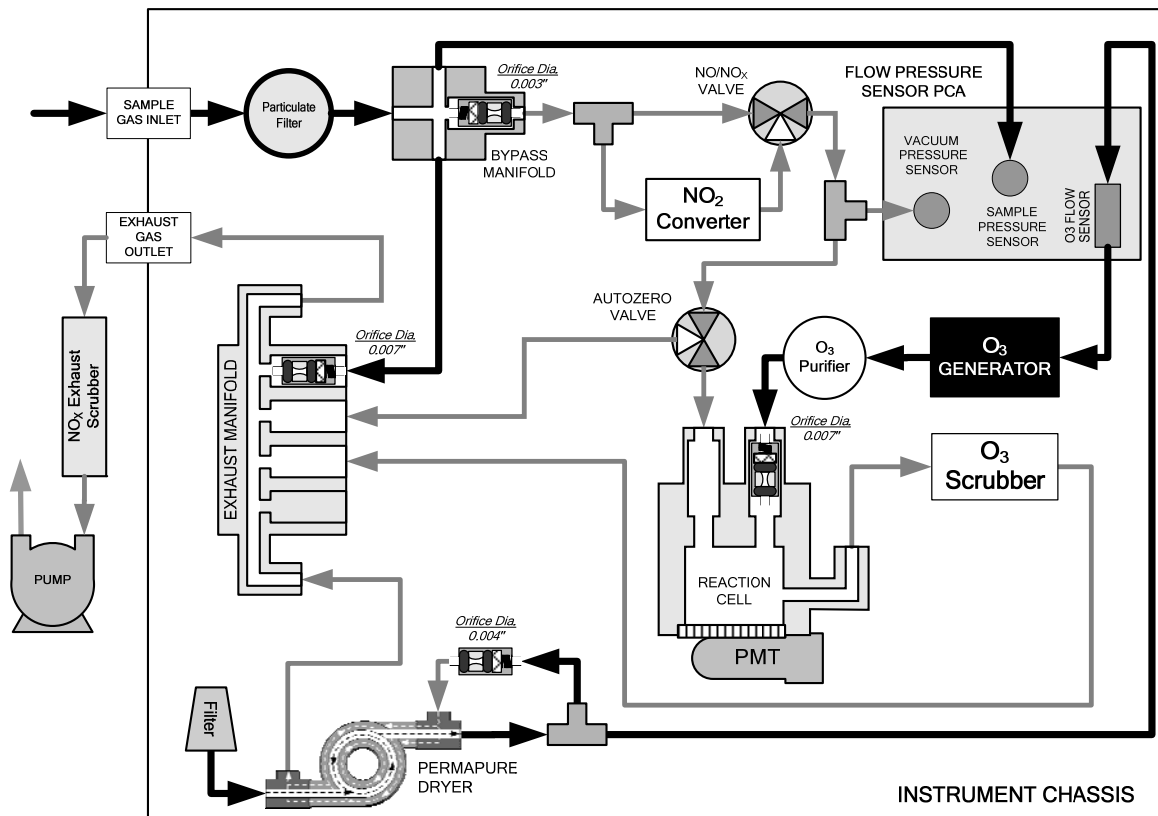


Figure 3-7: TML41H Internal Pneumatic Block Diagram - Standard Configuration

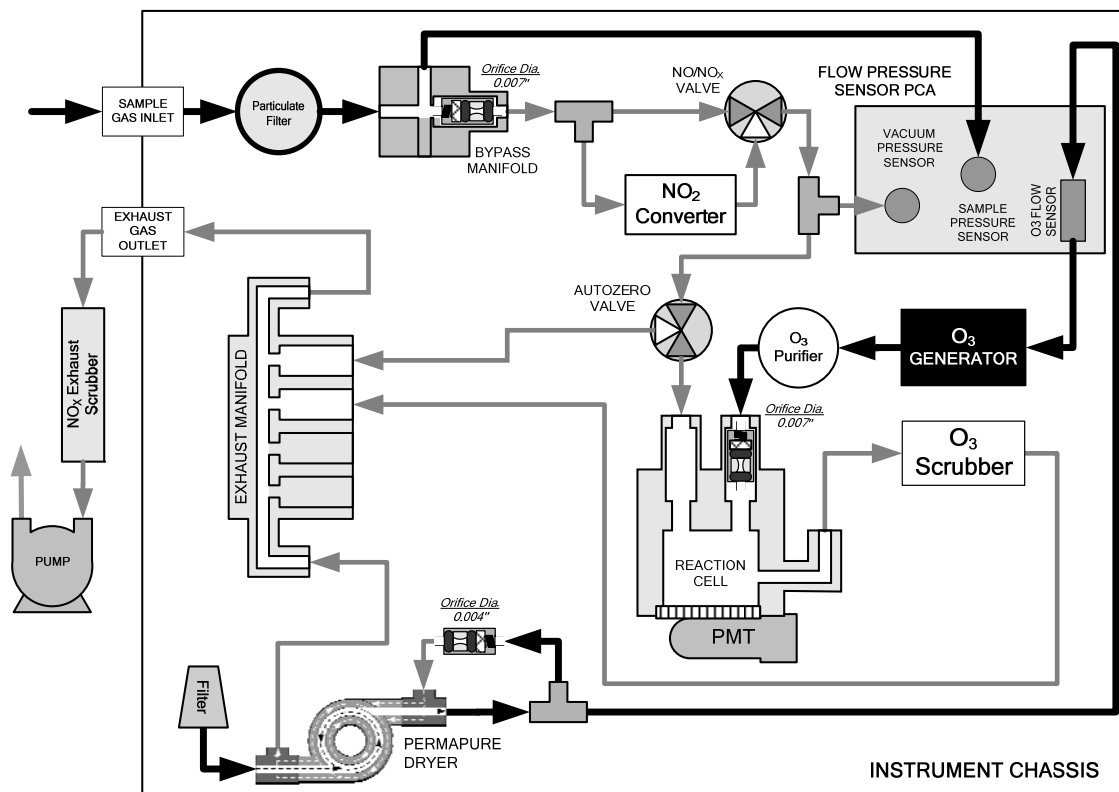


Figure 3-8: TML41M Internal Pneumatic Block Diagram - Standard Configuration

Note:

Pneumatic Diagrams do not reflect the physical layout of the instrument.

The most significant differences between the TML41H and TML41M versions in regards to pneumatic flow are:

- A bypass line leading directly from the bypass manifold to the exhaust manifold is present on the TML41H, but not in the TML41M.
- The Diameter of the critical flow orifice controlling the gas flow into the sample chamber is smaller and therefore the flow rate of sample gas through the instrument is lower.

See Section 10.3.2 for more information on these differences

See Chapter 5 for or information on the pneumatic flow though instruments with one of the TML41M/H's available options installed.

3.1.3.1. Calibration Gases

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, in this case NO and NO₂. 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 matrix of the measured medium. Pure nitrogen could be used as a zero gas for applications where NO_x is measured in nitrogen. Special considerations apply if measuring NO_x in a matrix that does not contain oxygen, see Section 10.3.11 for more information.

Span Gas

A gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range. In this case, NO_x , NO and NO_2 measurements made with the TML41M/H, 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 between 0 ppm and 500 ppm, an appropriate span gas concentration would be 400 ppm NO_x .

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_2 or H_2O). The span gas should match all concentrations of all gases of the measured medium as closely as possible.

Cylinders of calibrated NO gas traceable to NIST-standard reference materials specifications (also referred to as EPA protocol calibration gases) are commercially available.

Table 3-6: NIST-SRM's Available for Traceability of NO_x Calibration Gases

NIST-SRM ⁴	TYPE	NOMINAL CONCENTRATION
2627a	Nitric Oxide (NO) in N ₂	5 ppm
2628a	Nitric Oxide (NO) in N ₂	10 ppm
2629a	Nitric Oxide (NO) in N ₂	20 ppm
1683b	Nitric Oxide (NO) in N ₂	50 ppm
1684b	Nitric Oxide (NO) in N ₂	100 ppm
1685b	Nitric Oxide (NO) in N ₂	250 ppm
1686b	Nitric Oxide (NO) in N ₂	5000 ppm
1687b	Nitric Oxide (NO) in N ₂	1000 ppm
2630	Nitric Oxide (NO) in N ₂	1500 ppm
2631a	Nitric Oxide (NO) in N ₂	3000 ppm
2635	Nitric Oxide (NO) in N ₂	800 ppm
2636a	Nitric Oxide (NO) in N ₂	2000 ppm
2656	Oxides of Nitrogen (NO _x) in Air	2500 ppm
2660a	Oxides of Nitrogen (NO _x) in Air	100 ppm

NOTE:

If a dynamic dilution system such as the Teledyne Instruments model 700 is used to dilute high concentration gas standards to low, ambient concentrations, make sure that:

The NO concentration of the reference gas matches the dilution range of the calibrator.

Choose a NO gas concentration that is in the middle of the dilution system's range.

3.1.3.2. Pneumatic Connections to TML41M/H Basic Configuration:

Figure 3-7: TML41H Internal Pneumatic Block Diagram - Standard Configuration and Figure 3-8: TML41M Internal Pneumatic Block Diagram - Standard Configuration show the most common configurations for gas supply and exhaust lines to the TML41M/H Analyzer. Please refer to Figure 3-2 for the locations of pneumatic connections on the rear panel and Table 3-5 for nomenclature.

NOTE

Sample and calibration gases should only come into contact with PTFE (Teflon) or glass or materials. They should not come in contact with FEP or stainless steel materials.

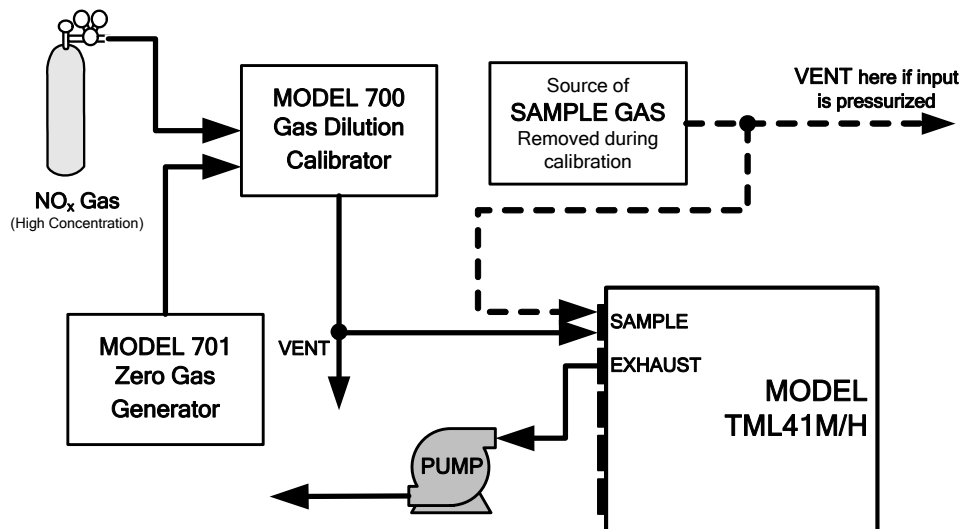


Figure 3-9: Pneumatic Connections—Basic Configuration—Using Gas Dilution Calibrator

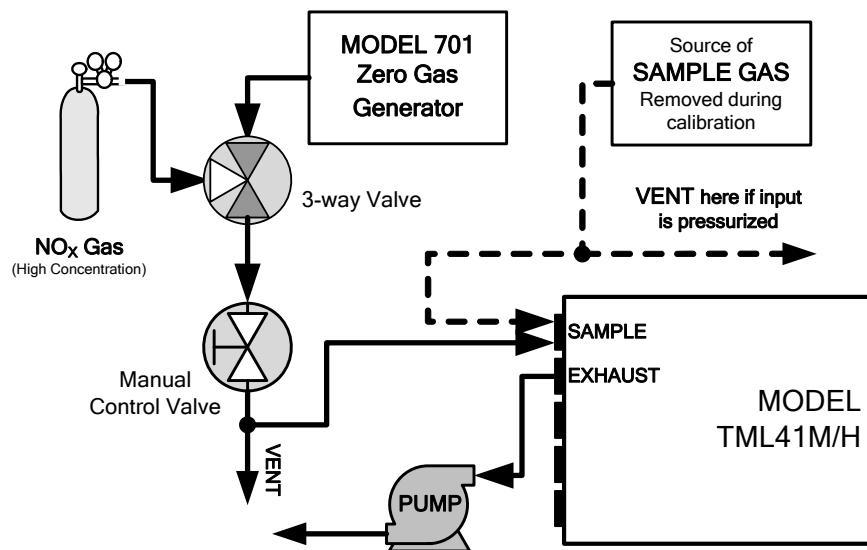



Figure 3-10: Pneumatic Connections—Basic Configuration—Using Bottled Span Gas

1. Attach a 1/4" exhaust line between the external pump and exhaust port of the analyzer.

Attach an additional 1/4" exhaust port of the pump.

	CAUTION
<p>The exhaust from the analyzer needs to be vented outside the shelter or immediate area surrounding the instrument and conform to all safety requirements using a maximum of 10 meters of 1/4" PTFE tubing.</p>	

Attach a sample inlet line to the sample inlet port. Ideally, the pressure of the sample gas should be equal to ambient atmospheric pressure.

NOTE
<p>Maximum pressure of any gas at the sample inlet should not exceed 1.5 in-Hg above ambient pressure and ideally should equal ambient atmospheric pressure.</p> <p>In applications where the sample gas is received from a pressurized manifold, a vent must be provided to equalize the sample gas with ambient atmospheric pressure before it enters the analyzer. The vented gas needs to be routed outside the immediate area or shelter surrounding the instrument.</p>

Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using a procedure similar to that defined in Section 11.5.1.

3.1.3.3. Connections with Internal Valve Options Installed

If your analyzer is equipped with either the zero/span valve option (50) or the 2-span point valve option (52), the pneumatic connections should be made as shown in Figure 3-11: Pneumatic Connections–With Zero/Span Valve Option (50) & Figure 3-12: Pneumatic Connections–With 2-Span point Option (52) –Using Bottled Span Gas:

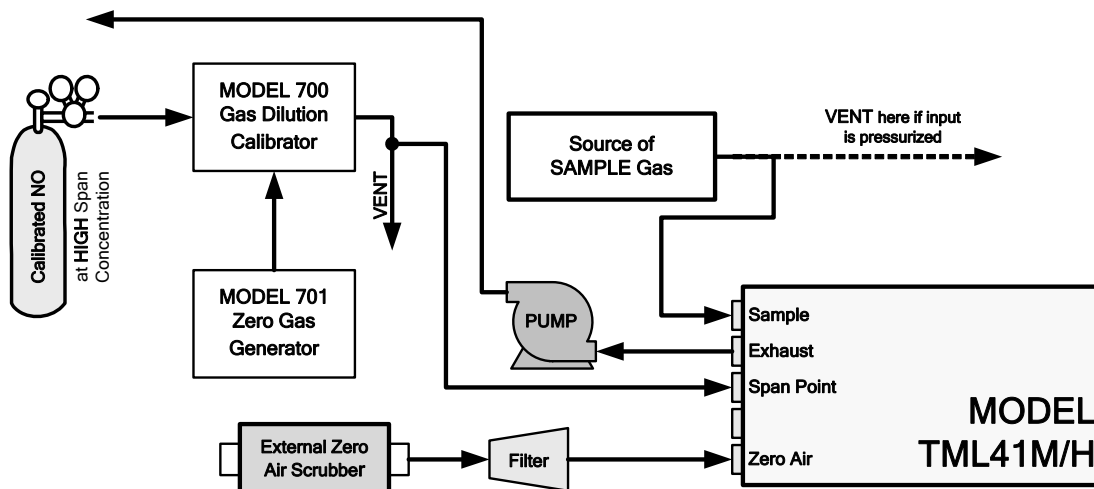


Figure 3-11: Pneumatic Connections–With Zero/Span Valve Option (50)

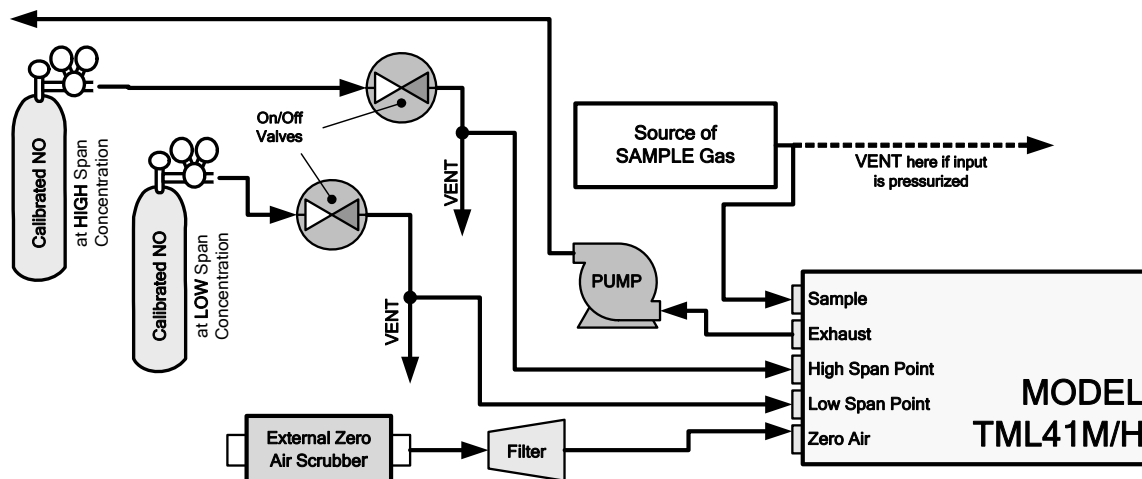


Figure 3-12: Pneumatic Connections—With 2-Span point Option (52) –Using Bottled Span Gas

Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Section 11.5.2.

3.2. INITIAL OPERATION

If you are unfamiliar with the theory of operation of the TML41M/H analyzer, we recommend that you read Chapter 10 before proceeding. For information on navigating the analyzer's software menus, see the menu trees described in Appendix A-1.

3.2.1. STARTUP

After electrical and pneumatic connections are made, turn on the instrument and supply power to the external pump.

- The exhaust and PMT cooler fans should start.
- The display should immediately display a single, horizontal dash in the upper left corner of the display. This will last approximately 30 seconds while the CPU loads the operating system.

Once the CPU has completed this activity, it will begin loading the analyzer firmware and configuration data. During this process, a string of messages will appear on the analyzer's front panel display as shown in Figure 3-13. The analyzer should automatically switch to **SAMPLE** mode after completing the boot-up sequence and start monitoring NO_x, NO, NO₂ gases.

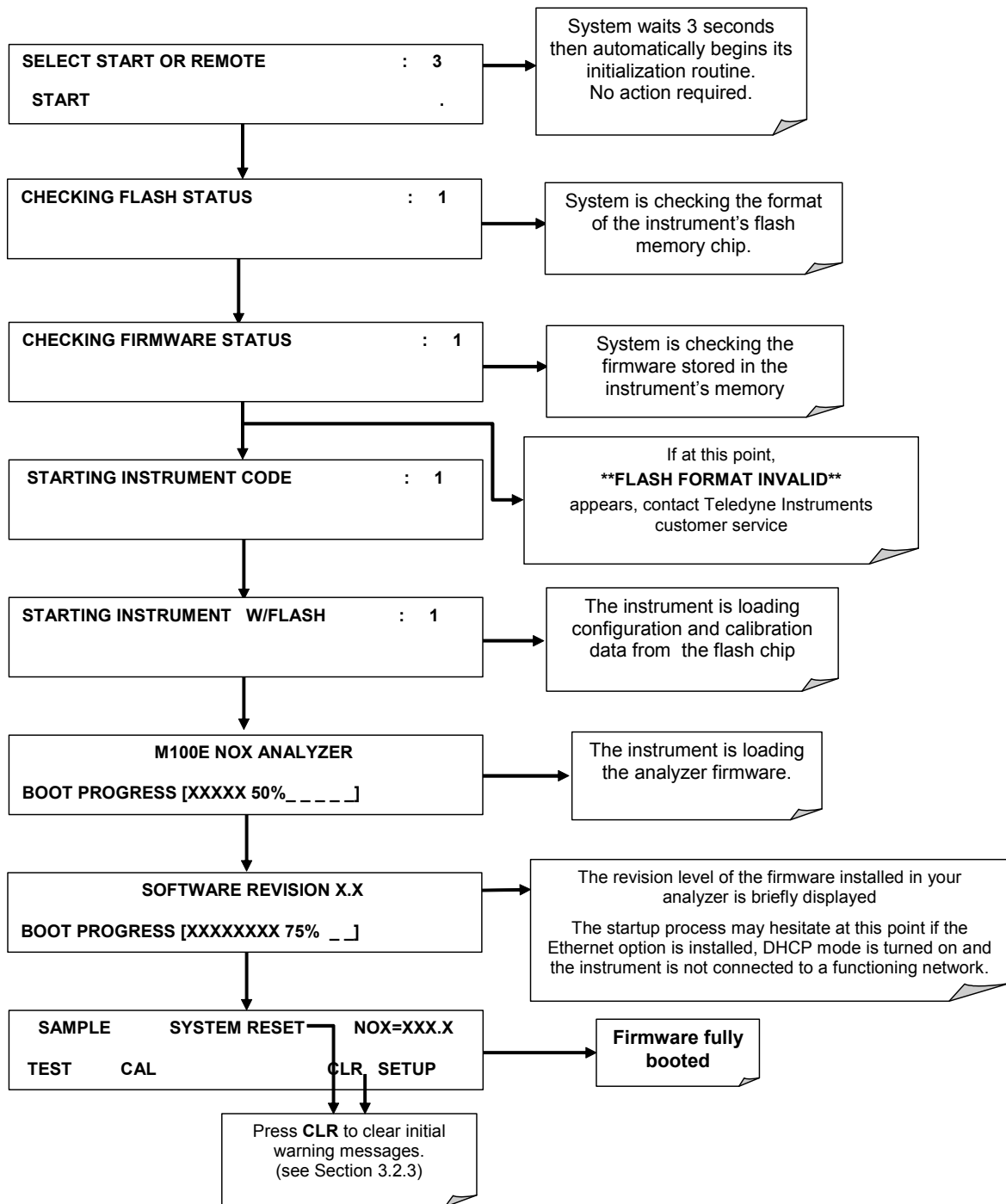


Figure 3-13: Front Panel Display During Startup Sequence

3.2.2. WARM-UP

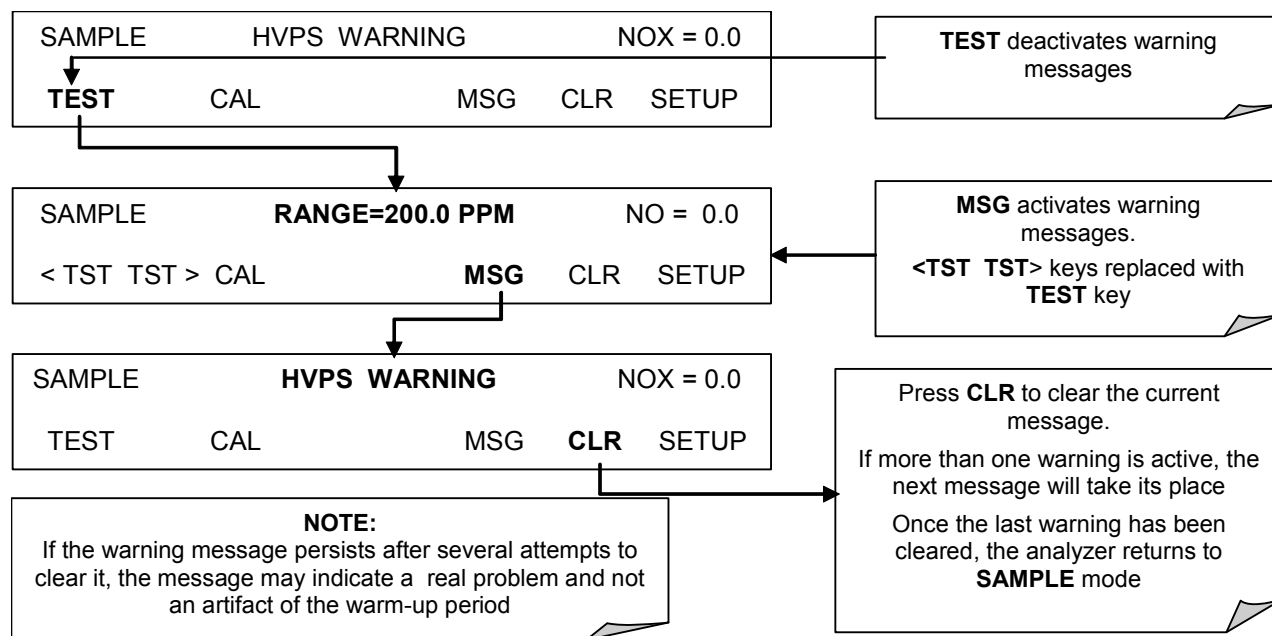
The TML41M/H requires about 45 minutes warm-up time before reliable NO_x, NO and NO₂ measurements can be taken. During that time, various portions of the instrument's front panel will behave as follows.

Table 3-7: Front Panel Display During System Warm-Up

NAME	COLOR	BEHAVIOR	SIGNIFICANCE
Concentration Field	N/A	Switches between NO _x , NO and NO ₂	This is normal operation.
Mode Field	N/A	Displays blinking "SAMPLE"	Instrument is in sample mode but is still in the process of warming up (hold-off period is active).
STATUS LEDs			
Sample	Green	On	Unit is operating in sample mode; front panel display is continuously updated.
Cal	Yellow	Off	The instrument's calibration is not enabled.
Fault	Red	Blinking	The analyzer is warming up and out of specification for a fault-free reading.
See Figure 3-3 for locations			

3.2.3. WARNING MESSAGES

During warm-up, internal temperatures and other parameters may be outside of specified limits. The software will suppress most warning conditions for 30 minutes after power up.



The following table includes a brief description of the various warning messages that may appear after the warm-up time. If warning messages persist after 30 minutes, investigate their cause using the troubleshooting guidelines in Chapter 11.

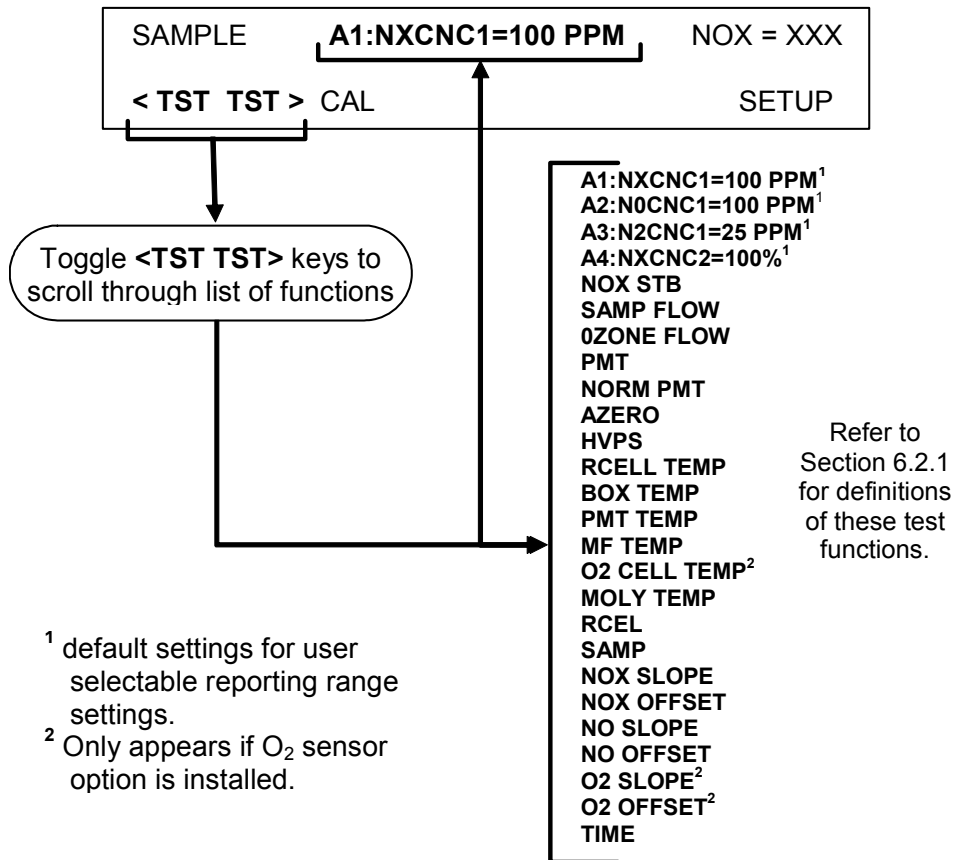
Table 3-8: Possible Warning Messages at Start-Up

MESSAGE	DEFINITION
ANALOG CAL WARNING	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
AZERO WRN XXX.X MV	The reading taken during the auto-zero cycle is outside of specified limits. The value XXX.X indicates the auto-zero reading at the time of the warning.
BOX TEMP WARNING	The temperature inside the TML41M/H chassis is outside the specified limits.
CANNOT DYN SPAN	Remote span calibration failed while the dynamic span feature was ON
CANNOT DYN ZERO	Remote zero calibration failed while the dynamic zero feature was ON.
CONFIG INITIALIZED	Configuration was reset to factory defaults or was erased.
CONV TEMP WARNING	NO2 converter temperature is outside of specified limits.
DATA INITIALIZED	iDAS data and settings were erased.
FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
HVPS WARNING	High voltage power supply for the PMT is outside of specified limits.
IZS TEMP WARNING	On units with IZS options installed: The permeation tube temperature is outside of specified limits (if installed).
MANIFOLD TEMP WARN	Bypass manifold temperature is outside of warning limits.
O2 CELL TEMP WARN	O2 sensor cell temperature is outside of warning limits (if installed).
OZONE FLOW WARNING	Ozone flow is outside of specified limits.
OZONE GEN OFF	Ozone generator is off, which is intentional for the warm-up period. This is the only warning message that automatically clears itself after warm up.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL PRESS WARN	Reaction cell pressure is outside of specified limits.
RCELL TEMP WARNING	Reaction cell temperature is outside of specified limits.
REAR BOARD NOT DET	The CPU is unable to communicate with the motherboard.
RELAY BOARD WARN	The firmware is unable to communicate with the relay board.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SYSTEM RESET	This message appears every time the analyzer was powered up.

3.2.4. FUNCTIONAL CHECK

After the analyzer's components have warmed up for at least 30 minutes, verify that the software properly supports any hardware options that were installed.

Check to make sure that the analyzer is functioning within allowable operating parameters. Appendix A and C include 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 performance problems with your analyzer (Chapter 11). The enclosed *Final Test and Validation Data Sheet* (part number 04490) lists these values before the instrument left the factory. To view the current values of these test functions press the <TST TST> keys:



3.3. CALIBRATION

3.3.1. BASIC NO_x CALIBRATION PROCEDURE

The initial calibration should be carried out using the same reporting range set up as used during the analyzer's factory calibration. This will allow you to compare your calibration results to the factory calibration as listed on the *Final Test and Validation Data Sheet*.

The following procedure assumes that the instrument does not have any of the available zero/span (Z/S) or Two-Point Span valve options installed. Chapter 7 contains instructions for calibrating instruments with these options.

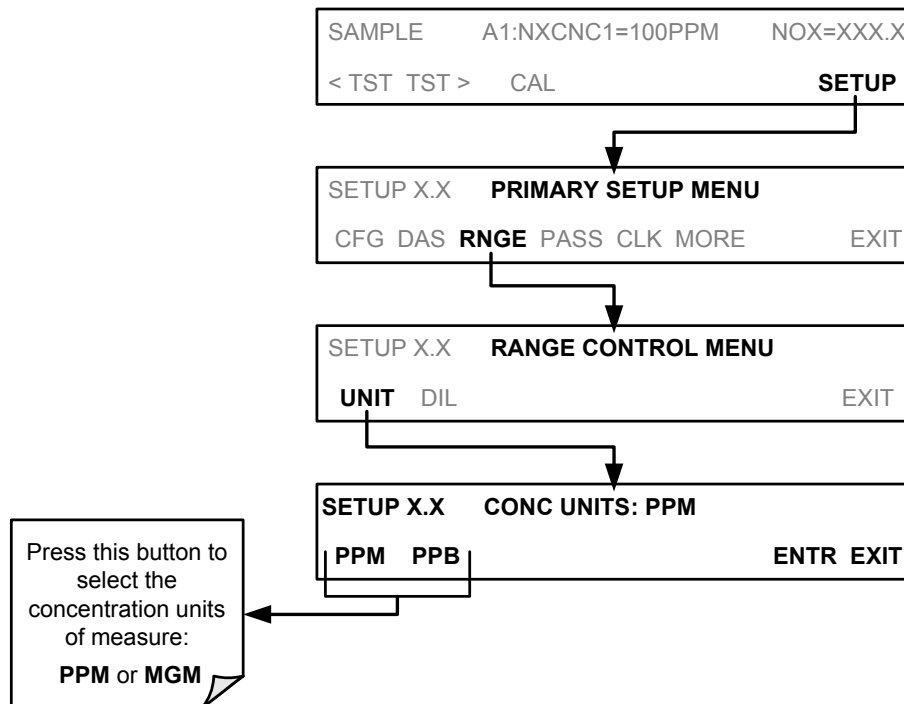
If both available iDAS parameters for a specific gas type are being reported via the instrument's analog outputs e.g. NXCNC1 and NXCNC2, separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Section 6.13.4 & 6.13.5 for more information on analog output reporting ranges

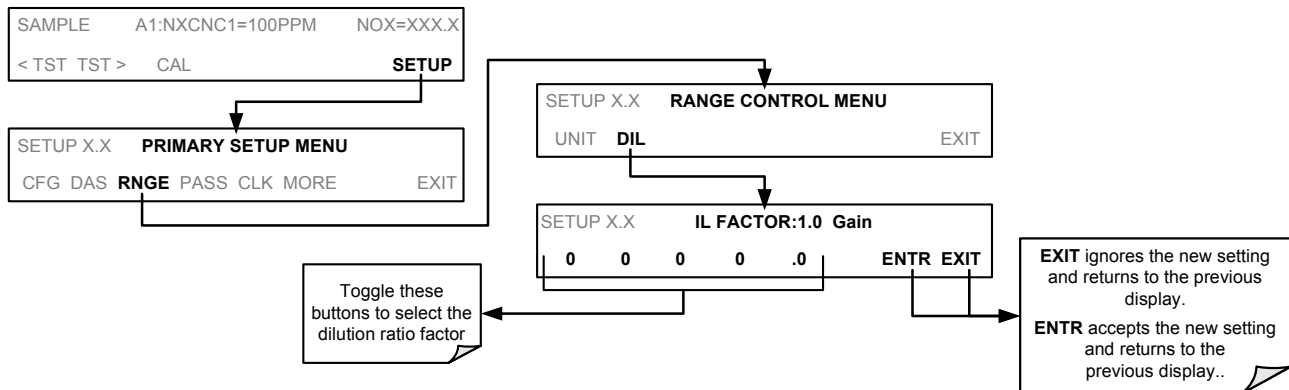
STEP 1 - Set Units:

To select the concentration units of measure press:



STEP 2 - Dilution Ratio:

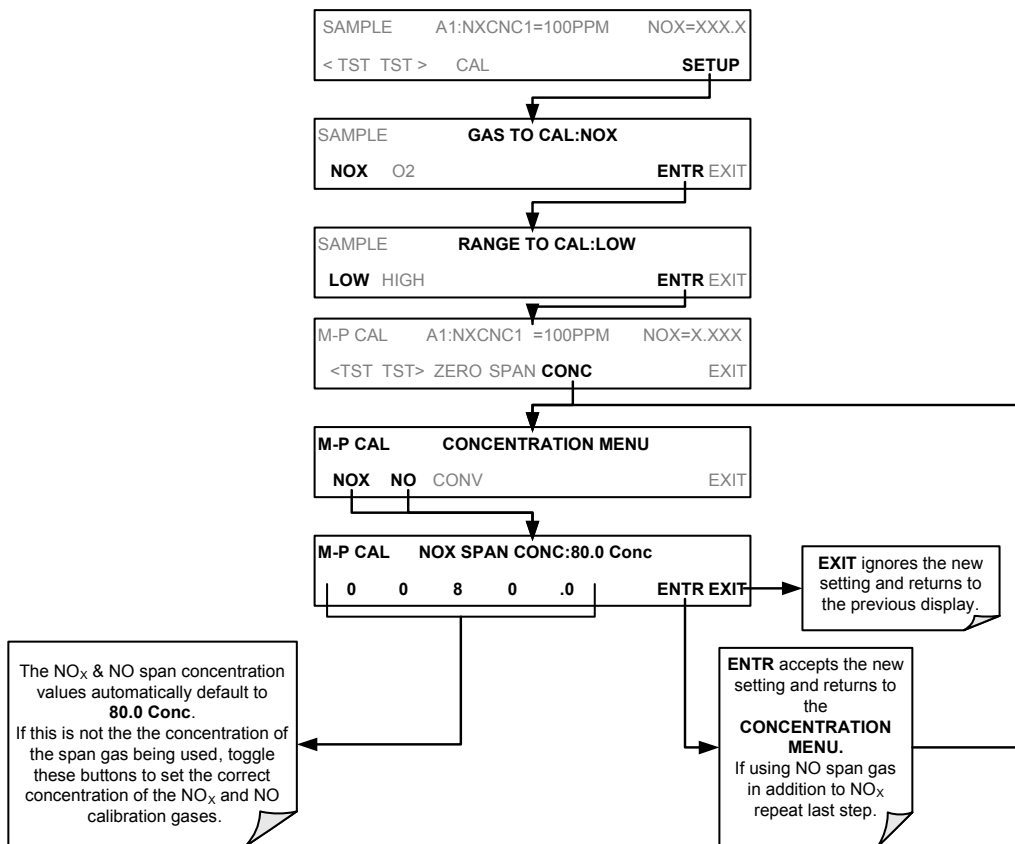
If the dilution ratio option is enabled on your TML41M/H and your application involves diluting the sample gas before it enters the analyzer, set the dilution ratio as follows:



STEP 3 – Set NO_x and NO span gas concentrations:

Set the expected NO and NO_x span gas concentration. These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output (see Section 6.13.4.2)

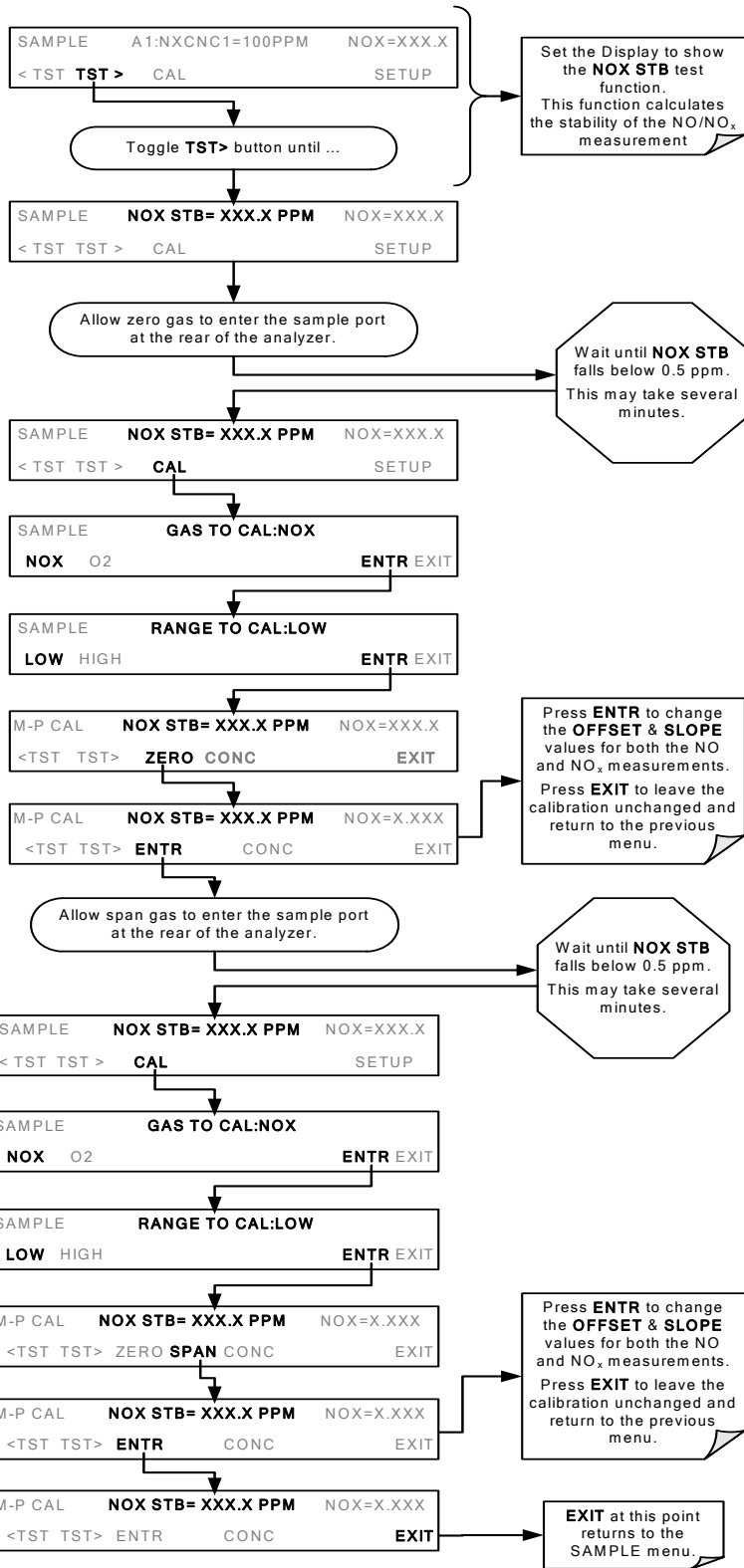
If you supply NO span gas to the analyzer as well as NO_x, the values for expected NO and NO_x span gas concentrations need to be identical.



STEP 4 – Zero/Span Calibration:

To perform the zero/span calibration procedure:

Analyzer continues to cycle through NO_x, NO, and NO₂ measurements throughout this procedure.



Set the Display to show the **NOX STB** test function. This function calculates the stability of the NO/NO_x measurement

Wait until **NOX STB** falls below 0.5 ppm. This may take several minutes.

Press **ENTR** to change the **OFFSET & SLOPE** values for both the NO and NO_x measurements. Press **EXIT** to leave the calibration unchanged and return to the previous menu.

Wait until **NOX STB** falls below 0.5 ppm. This may take several minutes.

The **SPAN** key now appears during the transition from zero to span. You may see both keys. If either the **ZERO** or **SPAN** buttons fail to appear see Section 11 for troubleshooting tips.

Press **ENTR** to change the **OFFSET & SLOPE** values for both the NO and NO_x measurements. Press **EXIT** to leave the calibration unchanged and return to the previous menu.

EXIT at this point returns to the **SAMPLE** menu.

3.3.2. BASIC O₂ SENSOR CALIBRATION PROCEDURE

If your instrument has an O₂ sensor option installed, that should be calibrated as well.

3.3.2.1. O₂ Calibration Setup

The pneumatic connections for calibrating are as follows:

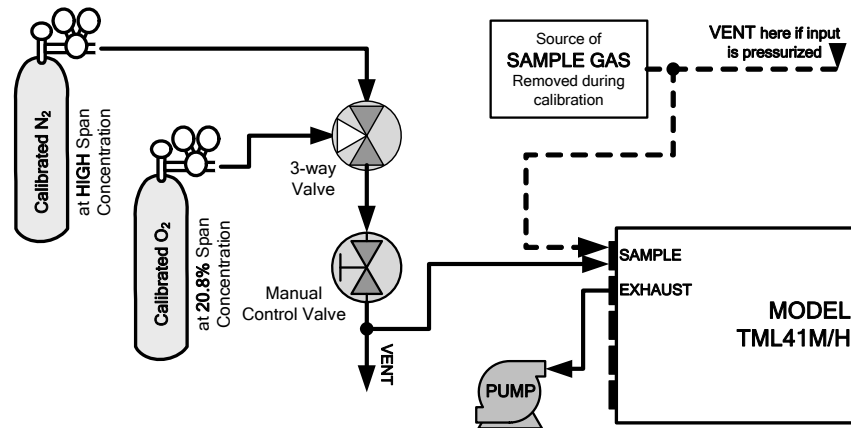


Figure 3-14: O₂ Sensor Calibration Set Up

O₂ SENSOR ZERO GAS: Teledyne Instruments' recommends using pure N₂ when calibration the zero point of your O₂ sensor option.

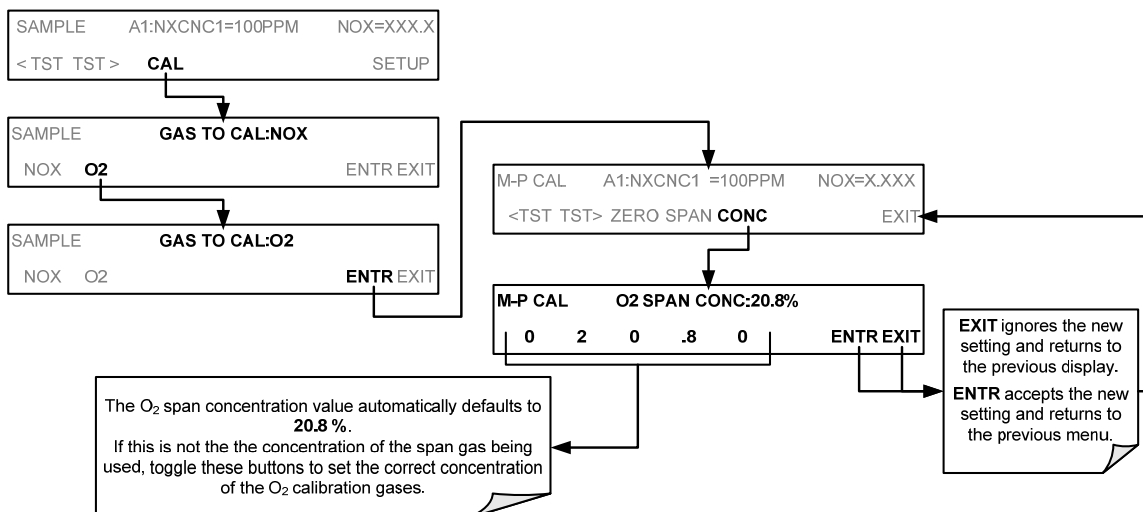
O₂ SENSOR SPAN GAS: Teledyne Instruments' recommends using 21% O₂ in N₂ when calibration the span point of your O₂ sensor option.

3.3.2.2. O₂ Calibration Method

STEP 1 – Set O₂ span gas concentration:

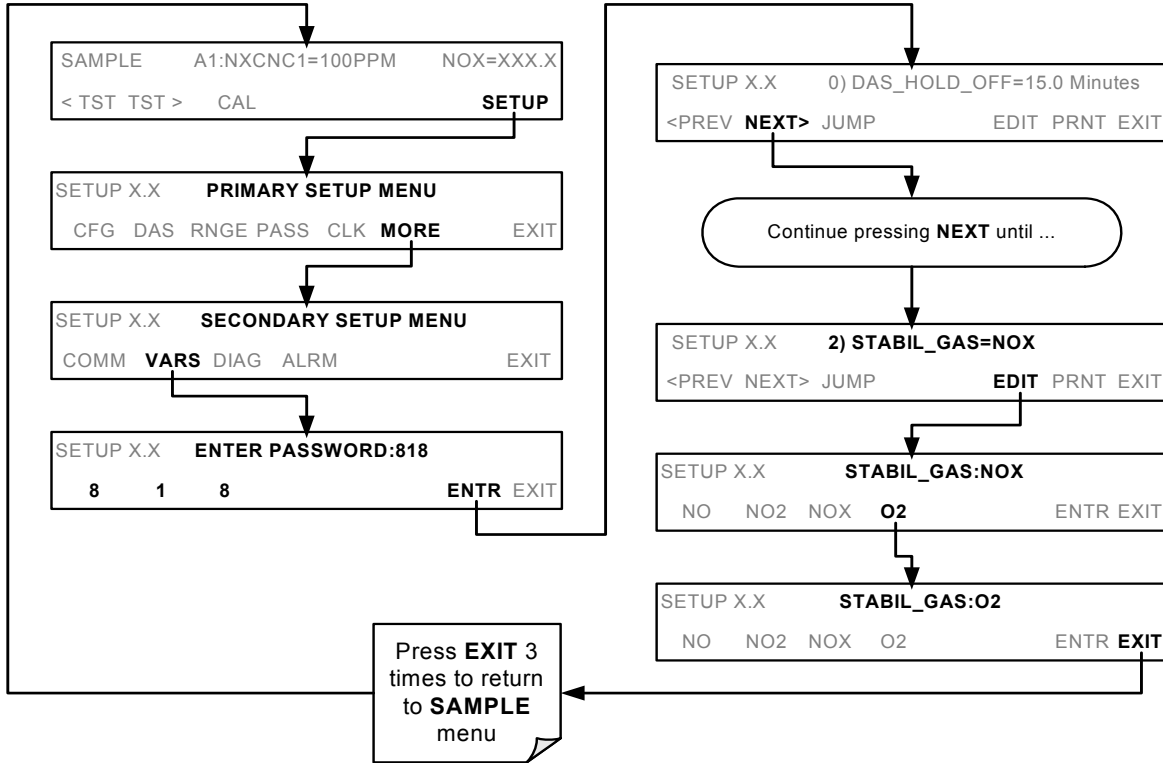
Set the expected O₂ span gas concentration.

This should be equal to the percent concentration of the O₂ span gas of the selected reporting range (default factory setting = 20.8%; the approximate O₂ content of ambient air).



STEP 2 – activate O₂ sensor stability function

To change the stability test function from NO_x concentration to the O₂ sensor output, press:

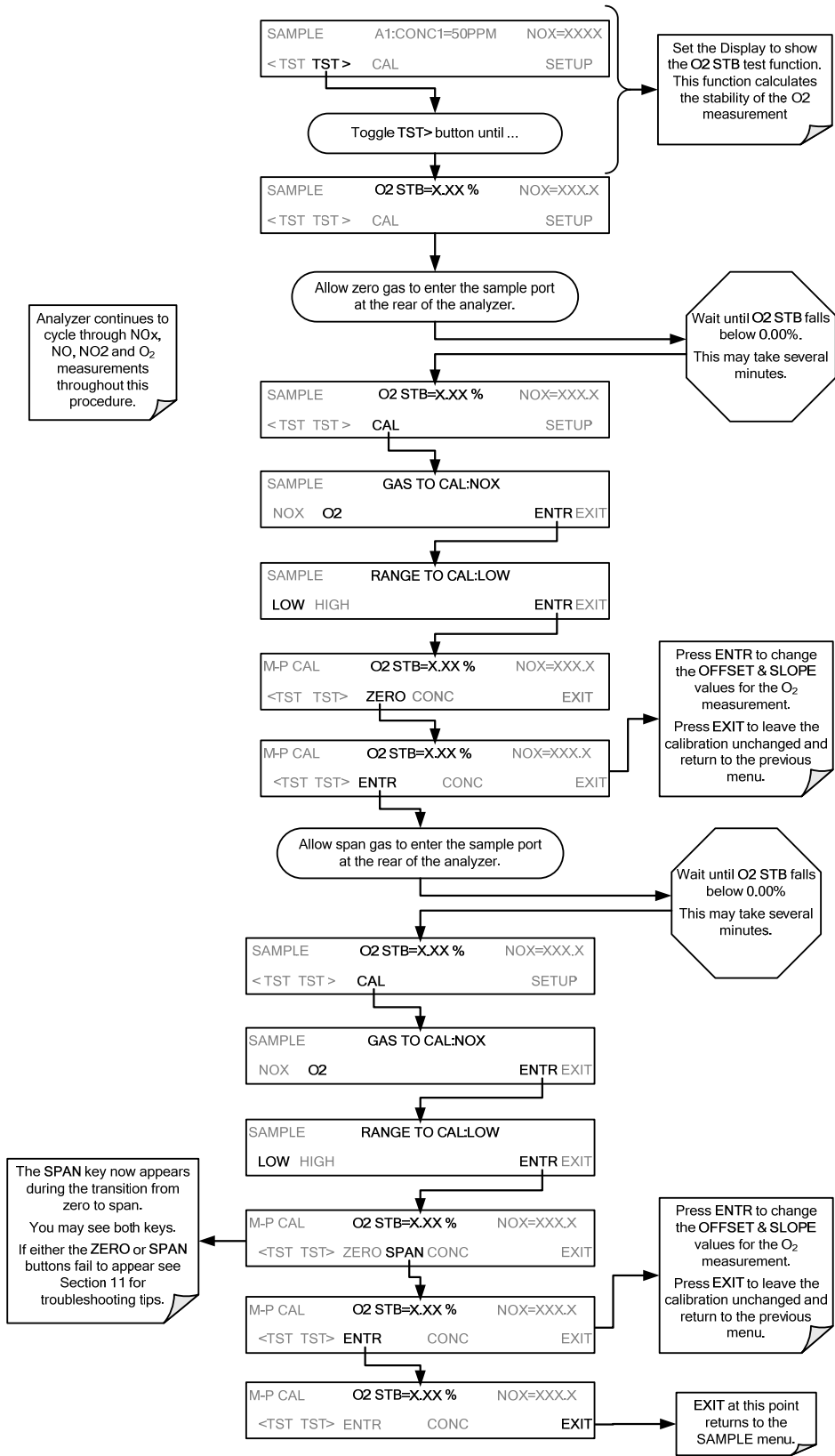


NOTE

Use the same procedure to reset the STB test function to NO_x when the O₂ calibration procedure is complete.

STEP 4 – O₂ ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure:



The TML41M/H 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 Instruments. This information is vital to our efforts in continuously improving our service and our products. Thank you.

3.3.3. INTERFERENCES FOR NO_x MEASUREMENTS

The chemiluminescence method for detecting NO_x is subject to interference from a number of sources including water vapor (H₂O), ammonia (NH₃), sulfur dioxide (SO₂) and carbon dioxide (CO₂) but the TML41M/H has been designed to reject most of these interferences. Section 10.2.4 contains more detailed information on interferences.

Ammonia is the most common interferent, which is converted to NO in the analyzer's NO₂ converter and creates a NO_x signal artifact. If the TML41M/H 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 Instruments offers a sample gas conditioning option to remove ammonia and water vapor (Section 5.10).

Carbon dioxide diminishes the NO_x signal when present in high concentrations. If the analyzer is used in an application with excess CO₂, contact Teledyne Instruments customer service for possible solutions. Excess water vapor can be removed with one of the dryer options described in Section 5.10. In ambient air applications, SO₂ interference is usually negligible.

Interferences are discussed in more detail in Section 10.2.4.

USER NOTES:

4. FREQUENTLY ASKED QUESTIONS & GLOSSARY

4.1. FREQUENTLY ASKED QUESTIONS

The following list contains some of the most commonly asked questions relating to the TML41M/H NO_x Analyzer.

Q: Why is the **ZERO** or **SPAN** key not displayed during calibration?

A: The TML41M/H disables certain keys whenever the chosen value is out of range for that particular parameter. In this case, the expected span or zero value is too different from the actually measured value and the instrument does not allow spanning or zeroing to that point. If, for example, the span set point is 80 ppm and the measurement response is only .5 ppm, the SPAN button will not appear to prevent the user from spanning to an out-of-range response curve. Chapter 11 describes this in detail.

Q: Why does the **ENTR** key sometimes disappear on the front panel display?

A: Sometimes the **ENTR** key 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 TML41H reporting range to less than more than 5000 ppm (200 ppm for a TML41M). Once you adjust the setting to an allowable value, the **ENTR** key will re-appear.

Q: Why does the analyzer not respond to span gas?

A: There are several reasons why this can happen. Section 11.3.2 has some possible answers to this question.

Q: Can I automate the calibration of my analyzer?

A: Any analyzer with zero/span valve options can be automatically calibrated using the instrument's AutoCal feature.

Q: What do I do if the concentration on the instrument's front panel display does not match the value recorded or displayed on my data logger even if both instruments are properly calibrated?

A: This most commonly occurs for one of the following reasons: (1) a difference in circuit ground between the analyzer and the data logger or a wiring problem; (2) a scale problem with the input to the data logger. The analog outputs of the analyzer can be manually calibrated to compensate for either or both of these effects, see Section 6.13.5; analog outputs are not calibrated, which can happen after a firmware upgrade (Section 6.13.6).

Q: How do I measure the sample flow?

A: Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating.

- For the TML41H in its basic configuration, the sample flow should be 290 cm³/min ±10%.
- For the TML41M in its basic configuration, the sample flow should be 250 cm³/min ±10%.

See Table 10-3 for more detailed information about gas flow rates.

Chapter 11 includes detailed instructions on performing a check of the sample gas flow.

Q: How often do I need to change the particulate filter?

A: Once per week. Table 9-1 contains a maintenance schedule listing the most important, regular maintenance tasks. Highly polluted sample air may require more frequent changes.

Q: How long does the sample pump last?

A: The sample pump should last one to two years and the pump head should be replaced when necessary. Use the **RCEL** pressure indicator on the front panel to see if the pump needs replacement. If this value goes above 10 in-Hg-A, on average, the pump head needs to be rebuilt.

Q: Do I need a strip chart recorder or external data logger?

A: No, the TML41M/H is equipped with a very powerful internal data acquisition system (iDAS). Section 6.7 describes the setup and operation in detail.

Q: Why does my RS-232 serial connection not work?

A: There are many possible reasons: 1) the wrong cable, please use the provided or a generic “straight-through” cable (do not use a “null-modem” type cable), 2) The DCE/DTE switch on the back of the analyzer is not set properly; make sure that both green and red lights are on, 3) the baud rate of the analyzer’s COM port does not match that of the serial port of your computer/data logger. See Section 11.5.11 more trouble-shooting information.

4.2. GLOSSARY

Acronym – A short form or abbreviation for a longer term. Often artificially made up of the first letters of the phrase’s words.

ASSY - Acronym for *Assembly*.

cm³- metric abbreviation for *cubic centimeter*. Same as the obsolete abbreviation “cc”.

Chemical formulas used in this document:

- CO₂ – carbon dioxide
- H₂O – water vapor
- HNO₃ – nitric acid
- NO_x – nitrogen oxides, here defined as the sum of NO and NO₂
- NO – nitric oxide
- NO₂ – nitrogen dioxide
- NO_y – nitrogen oxides, often called odd nitrogen, the sum of NO, NO₂ (NO_x) plus other compounds such as HNO₃. Definitions vary widely and may include nitrate (NO₃-), PAN, N₂O and other compounds.
- NH₃ – ammonia
- O₂ - molecular oxygen
- O₃ - ozone
- SO₂ – sulfur dioxide

DAS - Acronym for *Data Acquisition System*, the old acronym of iDAS

DIAG - Acronym for *diagnostics*, the diagnostic menu, or settings of the analyzer

DHCP: acronym for *dynamic host configuration protocol*. 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.

DOC – Acronym for *Disk on Chip*, the analyzer's central storage area for analyzer operating system, firmware, and data. This is a solid state device without mechanical, moving parts that acts as a computer hard disk drive under DOS with disk drive label "C". DOC chips come with 8 mb space in TML E-series analyzer standard configuration but are available in larger sizes

DOS - *Disk Operating System*. The E-series analyzers use DR DOS

EEPROM - also referred to as a FLASH chip.

FEP - Acronym for Fluorinated Ethylene Propylene polymer, one of the polymers that *du Pont* markets as *Teflon*[®] (along with PFA and PTFE).

FLASH - flash memory is non-volatile, solid-state memory.

I²C bus – read: I-square-C bus. A serial, clocked serial bus for communication between individual analyzer components

IC – Acronym for *Integrated Circuit*, 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.

iDAS - Acronym for *Internal Data Acquisition System*, previously referred to as DAS.

LAN - acronym for *local area network*

LED - Acronym for *Light Emitting Diode*.

PCA - Acronym for *Printed Circuit Assembly*, this is the → PCB with electronic components installed and ready to use

PCB - Acronym for *printed circuit board*, the bare circuit board without components

PLC – Acronym for *programmable logic controller*, a device that is used to control instruments based on a logic level signal coming from the analyzer

PFA – Acronym for Per-Fluoro-Alkoxy, an inert polymer. One of the polymers that *du Pont* markets as *Teflon*[®] (along with FEP and PTFE).

PTFE – Acronym for Poly-Tetra-Fluoro-Ethylene, a very inert polymer material used to handle gases that may react on other surfaces. One of the polymers that *du Pont* markets as *Teflon*[®] (along with FEP and PFA).

PVC – Acronym for *Poly Vinyl Chloride*, a polymer used for downstream tubing in the TML41M/H.

RS-232 - An electronic communication protocol of a serial communications port

RS-485 - An electronic communication protocol of a serial communications port

sensor-e.com – Name of a remote control program offered by Teledyne-ML to its customers

TCP/IP - Acronym for *Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices and the Internet

VARS - Acronym for *variables*, the variables menu, or settings of the analyzer

USER NOTES:

USER NOTES:

5. OPTIONAL HARDWARE AND SOFTWARE

This section includes a description of the hardware and software options available for the TML41M/H Nitrogen Oxides Analyzer. For assistance with ordering these options please contact the sales department of Teledyne – Monitor Labs, Inc. at:

TOLL-FREE SUPPORT: 800-846-6062
 FAX: 303-799-4853
 TEL: 303-792-3300
 E-MAIL: tml_support@teledyne.com

5.1. EXTERNAL PUMPS (OPT 10)

The TML41M/H comes equipped with an external pump specified upon ordering. Whereas the analyzer can be re-configured for other voltages, operation at other than the original voltage/frequency may require a different external pump. A variety of external pumps are available for the TML41M/H series analyzers. The range of available pump options meets all typical AC power supply standards while exhibiting the same pneumatic performance.

TELEDYNE INSTRUMENTS PART NO.	DESCRIPTION
009810300	External pump for 115 VAC / 60 Hz power supply
009810400	External pump for 230 VAC / 50 Hz power supply
009810500	External pump for 110 VAC / 50 Hz power supply
009810600	External pump for 100 VAC / 50 Hz power supply
009810700	External pump for 220-240 VAC / 50-60 Hz power supply

5.2. RACK MOUNT KITS (OPTS 20-23)

There are several options for mounting the analyzer in standard 19" racks. The slides are three-part extensions; one mounts to the rack, one mounts to the analyzer chassis and the middle part remains on the rack slide when the analyzer is taken out. The analyzer locks into place when fully extended and cannot be pulled out without pushing two buttons, one on each side.

The rack mount brackets for the analyzer require that you have a support structure in your rack to support the weight of the analyzer. The brackets cannot carry the full weight of an analyzer and are meant only to affix the analyzer to the front of a rack and to prevent it from sliding out of the rack through user intervention or vibration.

OPTION NUMBER	DESCRIPTION
OPT 20A	Rack mount brackets with 26 in. chassis slides.
OPT 20B	Rack mount brackets with 24 in. chassis slides.
OPT 21	Rack mount brackets only
OPT 23	Rack mount for external pump (no slides).

5.3. CARRYING STRAP HANDLE (OPT 29)

The chassis of the TML41M/H analyzer allows attaching a strap handle for carrying the instrument (Figure 5-1). The handle is located on the right side and pulls out to accommodate a hand for transport. When pushed in, the handle is nearly flush with the chassis, only protruding out about 9 mm (3/8").



Figure 5-1: TML41M/H with Carrying Strap Handle and Rack Mount Brackets

NOTE:

Installing the strap handle prevents the use of the rack mount slides, although the rack mount brackets, Option 21, can still be used.

CAUTION

THE TML41M/H WEIGHS ABOUT 17 KG (40 POUNDS) WITHOUT OPTIONS INSTALLED.

TO AVOID PERSONAL INJURY:

- **WE RECOMMEND TWO PERSONS LIFT AND CARRY THE ANALYZER.**
- **MAKE SURE TO DISCONNECT ALL CABLES AND TUBING FROM THE ANALYZER BEFORE CARRYING IT.**



5.4. 6.13.6.3 CURRENT LOOP ANALOG OUTPUTS (OPT 41)

This option adds isolated, voltage-to-current conversion circuitry to the analyzer's analog outputs. This option may be ordered separately for the first three of the analog outputs and can be installed at the factory or added later. Call Teledyne Instruments sales for pricing and availability.

The current loop option can be configured for any output range between 0 and 20 mA (for example 0-20, 2-20 or 4-20 mA). Information on calibrating or adjusting these outputs can be found in 6.13.6.3.

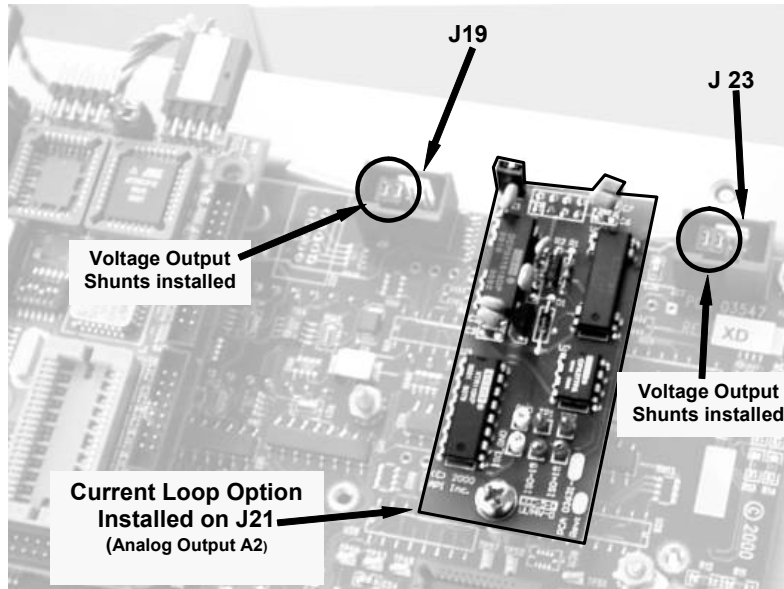


Figure 5-2: Current Loop Option Installed on the Motherboard

5.4.1. CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

NOTE

Servicing 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.

See Chapter 12 for more information on preventing ESD damage.

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

2. Turn off power to the analyzer.

If a recording device was connected to the output being modified, disconnect it.

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 (four per side).
- Lift the cover straight up.

Disconnect the current loop option PCA from the appropriate connector on the motherboard.

Place a shunt between the leftmost two pins of the connector (two shunts required - see Figure 5-1).

- 6 spare shunts (P/N CN0000132) were shipped with the instrument attached to JP1 on the back of the instruments keyboard and display PCA

Reattach the top case to the analyzer.

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

5.5. PARTICULATE FILTER KIT (OPT 42A)

This option includes a one-year supply of 50 replacement, Teflon membrane, particulate filters, 47 mm in diameter, 1 micrometer pore size. Operation of the particulate filter and weekly maintenance are mandatory on the TML41M/H.

5.6. CALIBRATION VALVE OPTIONS

5.6.1. ZERO/SPAN VALVES (OPT 50)

The TML41M/H NO_x analyzer can be equipped with a zero/span valve option for controlling the flow of calibration gases generated from external sources. This option contains two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor.

The user can control these valves from the front panel keyboard either manually or by activating the instrument's CAL or AutoCal features (Section 7.7). The valves may also be opened and closed remotely through the serial ports (Section 6.15.2) or through the external, digital control inputs (Section 6.15.1.2).

This option also includes a two-stage, external zero air scrubber assembly that removes all NO and NO₂ from the zero air source (ambient air). The scrubber is filled with 50% Purafil Chemisorbant[®] (for conversion of NO to NO₂) and 50% activated charcoal (for removal of NO₂). This assembly also includes a small particle filter to prevent scrubber particles from entering the analyzer as well as two more rear panel fittings so each gas can enter the analyzer separately.

Figure 5-3 & Figure 5-4 show the internal, pneumatic layouts the zero/span valve option installed for a Model TML41H and TML41M respectively.

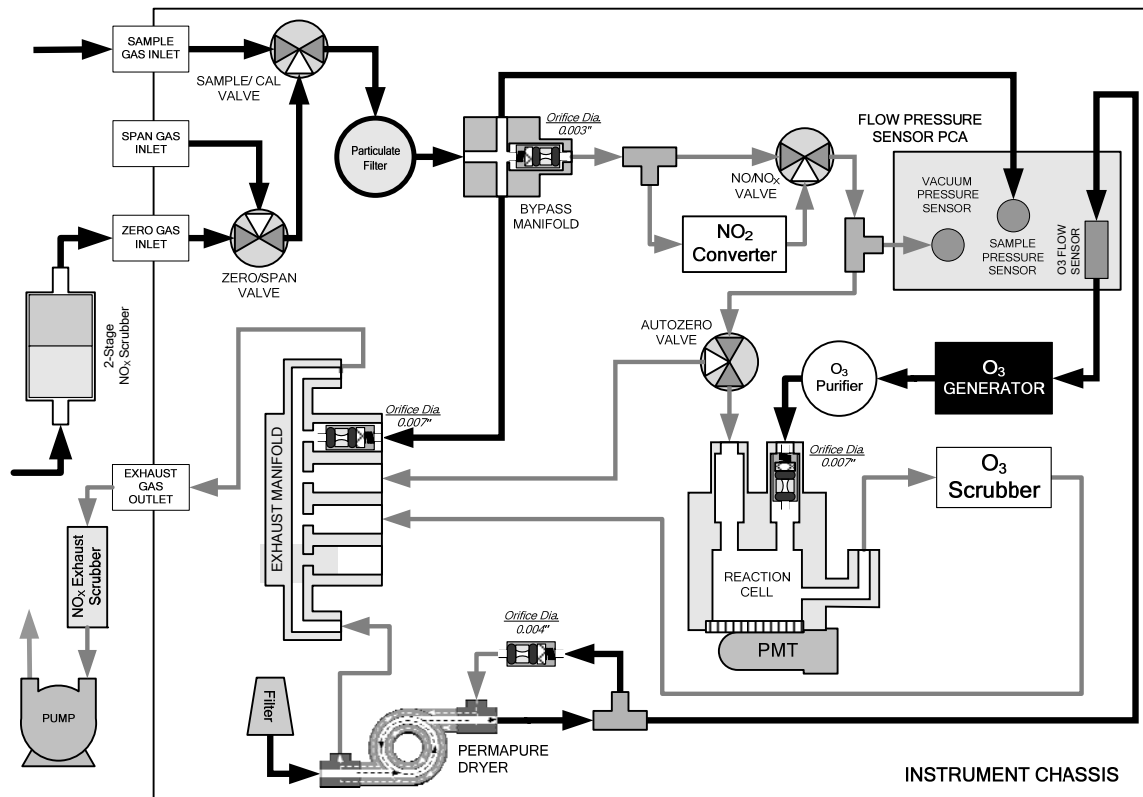


Figure 5-3: TML41H – Internal Pneumatics with Zero-Span Valve Option 50

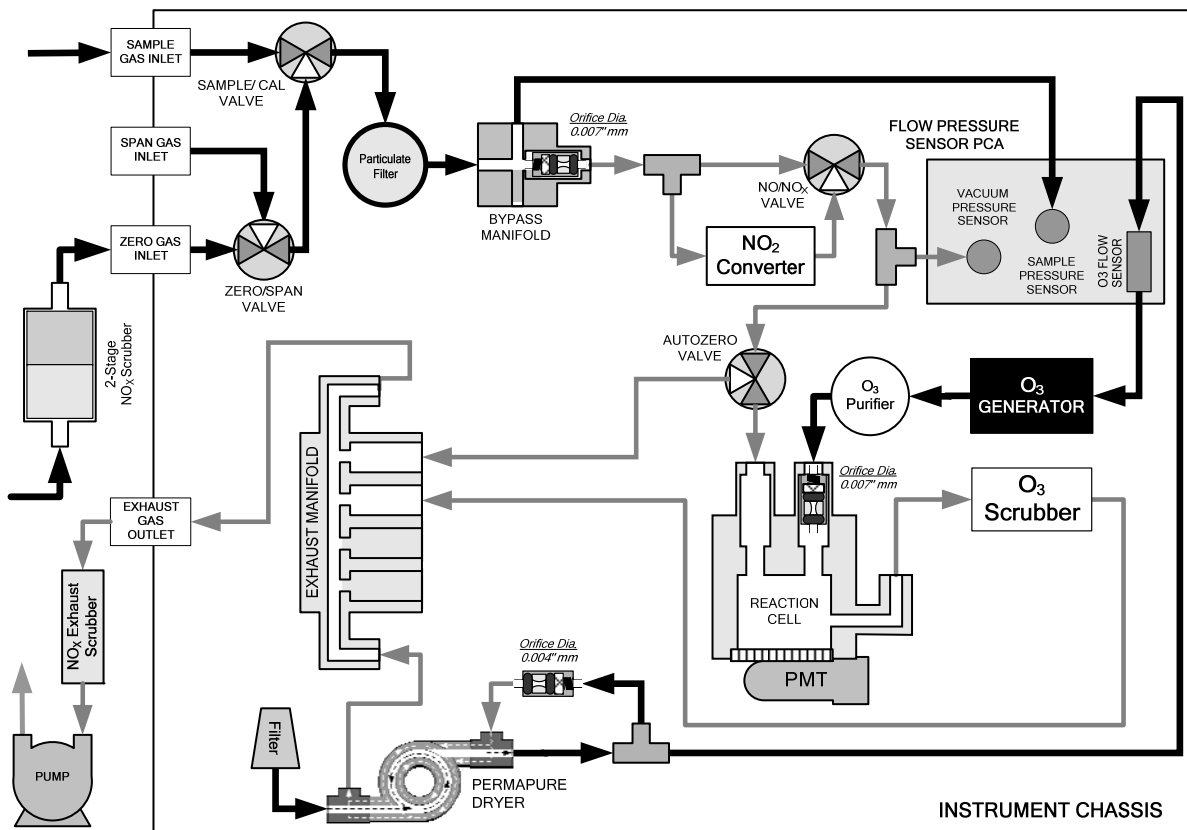


Figure 5-4: TML41M – Internal Pneumatics with Zero-Span Valve Option 50

Table 5-1: Zero/Span Valve States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to sample gas inlet
	Zero/Span	Open to zero air inlet
ZERO CALIBRATION	Sample/Cal	Open to zero/span inlet (activated)
	Zero/Span	Open to zero air inlet
SPAN CALIBRATION	Sample/Cal	Open to zero/span inlet (activated)
	Zero/Span	Open to span gas inlet / IZS gas (activated)

The state of the zero/span valves can also be controlled:

- Manually from the analyzer's front panel by using the **SIGNAL I/O** controls located under the **DIAG** Menu (Section 6.13.2),
- By activating the instrument's AutoCal feature (Section 7.7),
- Remotely by using the external digital control inputs (Section 6.15.1.2) or Ethernet option.
- Remotely through the RS-232/485 serial I/O ports (Section 6.15.2).

All supply lines should be vented outside of the analyzer's enclosure. In order to prevent back-diffusion and pressure drop effects, these vent lines should be between 2 and 10 meters in length.

5.6.2. SECOND RANGE SPAN VALVE (OPT 52)

This option includes a special set of valves that allows two separate NO_x mixtures to enter the analyzer from two independent sources. Typically these two gas mixtures will come from two, separate, pressurized bottles of certified calibration gas: one mixed to produce a NO, NO₂ or NO_x concentration equal to the expected span calibration value for the application and the other mixed to produce a concentration at or near the midpoint of the intended measurement range. Individual gas inlets, labeled HIGH SPAN and LOW SPAN are provided at the back on the analyzer.

The valves allow the user to switch between the two sources via keys on the front panel or from a remote location by way of either the analyzer's digital control inputs or by sending commands over its serial I/O port(s).

NOTE

The analyzer's software only allows the **SLOPE** and **OFFSET** to be calculated when sample is being routed through the **HIGH SPAN** inlet.

The **LOW SPAN** gas is for midpoint reference checks only.

The state of the optional valves can be controlled:

- Manually from the analyzer's front panel by using the **SIGNAL I/O** controls located under the **DIAG** Menu (6.13.2),
- By activating the instrument's CAL or AutoCal features (Section 7.7),
- Remotely by using the external digital control inputs (Section 6.15.1.2) or Ethernet option.
- Remotely through the RS-232/485 serial I/O ports (Section 6.15.2).

Table 5-2: Two-Point Span Valve Operating States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
ZERO CAL	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Open to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
HIGH SPAN CAL	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Open to HIGH SPAN inlet
	Low Span Valve	Closed to LOW SPAN inlet
Low Span Check	Sample/Cal	Closed to SAMPLE inlet
	Zero Gas Valve	Closed to ZERO AIR inlet
	High Span Valve	Closed to HIGH SPAN inlet
	Low Span Valve	Open to LOW SPAN inlet

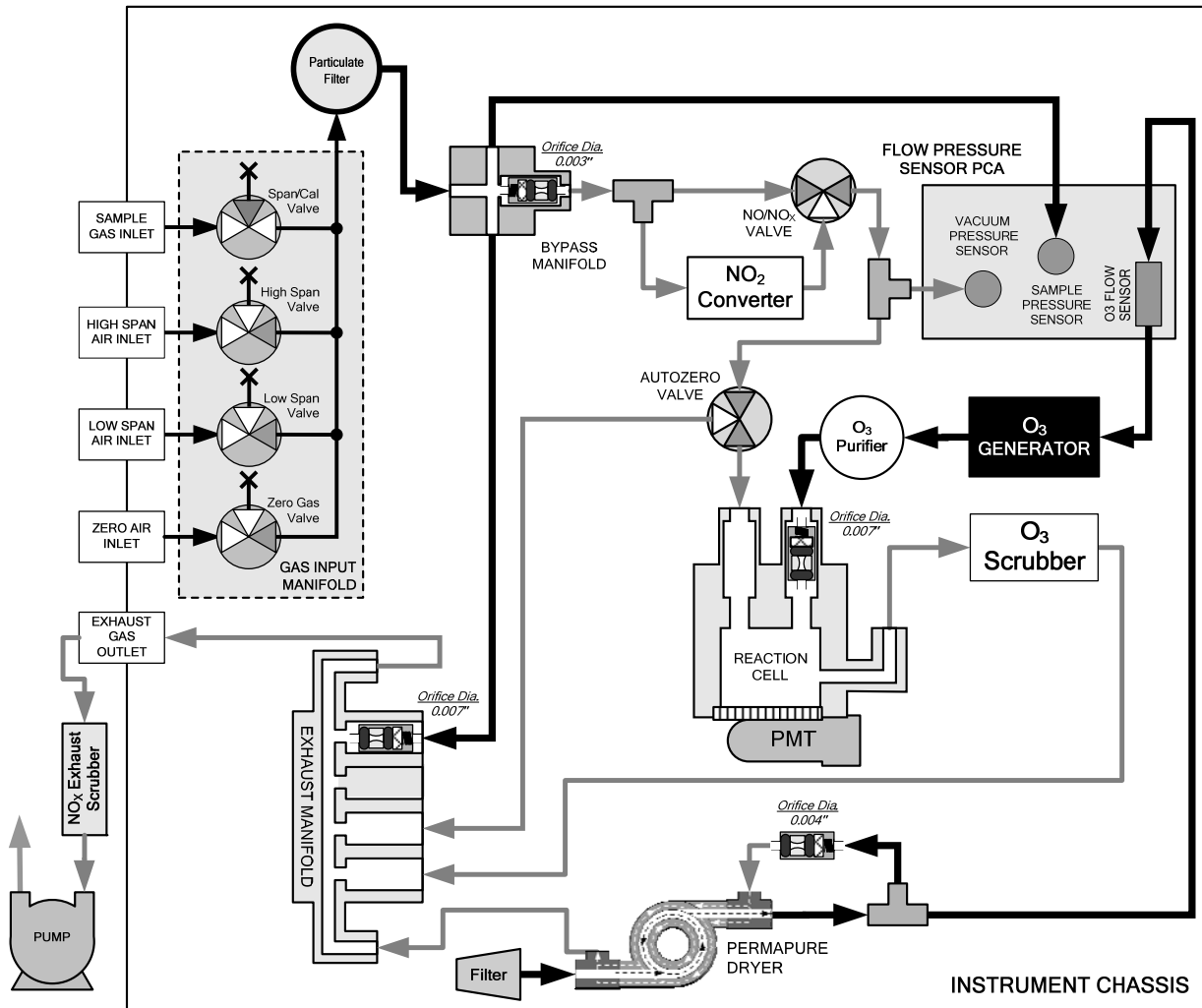


Figure 5-5: TML41H – Internal Pneumatics with Second Span Point Valve Option 52

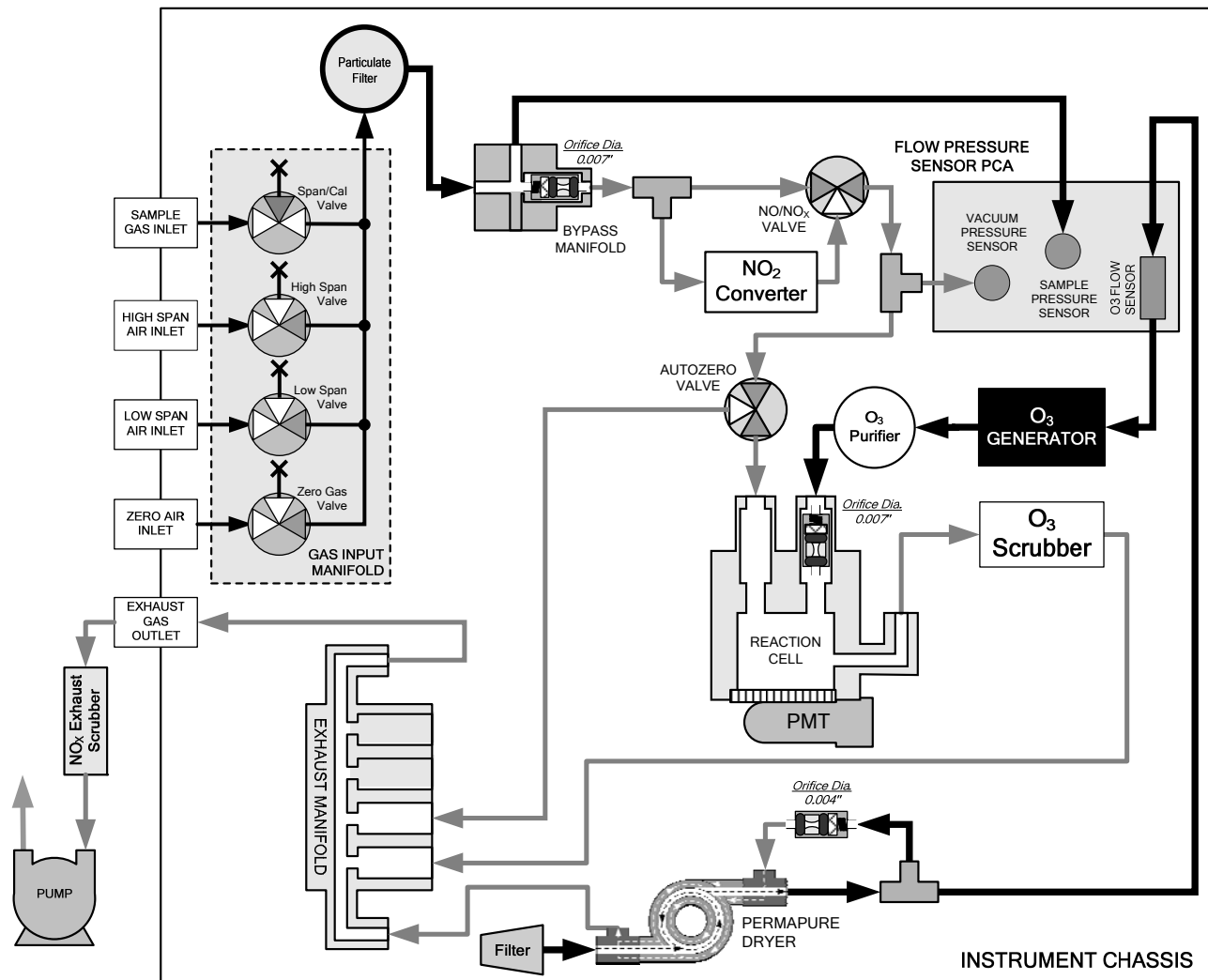


Figure 5-6: TML41M – Internal Pneumatics with Second Span Point Valve Option 52

5.7. OXYGEN SENSOR (OPT 65)

5.7.1. THEORY OF OPERATION

5.7.1.1. Paramagnetic measurement of O₂

The oxygen sensor used in the TML41M/H analyzer utilizes the fact that oxygen, unlike most other gases, is attracted by a strong magnetic field to obtain fast, accurate oxygen measurements.

The sensor's core is made up of two nitrogen filled glass spheres, which are mounted on a rotating suspension within a magnetic field (Figure 5-7). A mirror is mounted centrally on the suspension and a light source is reflected from the mirror to a pair of photocells. The signal generated by the photocells is passed to a feedback loop, which outputs a current to a wire winding (in effect, a small DC electric motor) mounted on the suspended mirror.

Oxygen from the sample stream is attracted into the magnetic field displacing the nitrogen filled spheres and causing the suspended mirror to rotate, which changes the amount of light reflected onto the photocells and therefore the output levels of the photocells. The feedback loop increases the amount of current fed into the winding in order to move the mirror back into its original position. The more O₂ present, the more the mirror moves and the more current is fed into the winding by the feedback control loop.

A sensor measures the amount of current generated by the feedback control loop which is directly proportional to the concentration of oxygen within the sample gas mixture (see Figure 5-7).

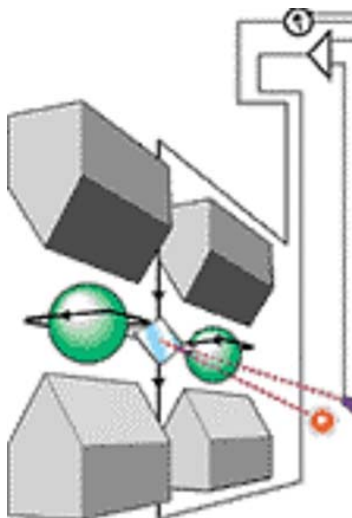


Figure 5-7: Oxygen Sensor - Principle of Operation

5.7.1.2. Operation Within the TML41M/H Analyzer

The oxygen sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel, just like the functions for NO_x.

- The O₂ concentration is displayed in the upper right-hand corner, alternating with NO_x, NO and NO₂ concentrations.
- Test functions for O₂ slope and offset are viewable from the front panel along with the analyzer's other test functions.
- O₂ sensor calibration is performed via the front panel **CAL** function and is performed in a nearly identical manner as the standard NO_x/NO calibration. See Chapter 3 for more details.
- Stability of the O₂ sensor can be viewed (see Sections 6.2.1 and 6.12)

The O₂ concentration range is 0-100% (user selectable) with 0.1% precision and accuracy and is available to be transmitted via one of the instrument's four user-selectable analog outputs (see Section 6.13.5).

The temperature of the O₂ sensor is maintained at a constant 50° C by means of a PID loop and can be viewed on the front panel as test function **O2 TEMP**.

The O₂ sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

5.7.1.3. Pneumatic Operation of the O₂ Sensor

Pneumatically, the O₂ sensor is connected to the bypass manifold and draws a flow of about 80 cm³/min in addition to the normal sample flow rate (See Table 10-3 for nominal sample inlet gas flow rates) and is separately controlled with its own critical flow orifice located inside the vacuum manifold.

Figure 5-8: TML41H – Internal Pneumatics with O₂ Sensor Option 65 shows the internal pneumatics of the TML41H with the O₂ Sensor installed.

Figure 5-9: TML41M – Internal Pneumatics with O₂ Sensor Option 65 shows the internal pneumatics of the TML41M with the O₂ Sensor installed.

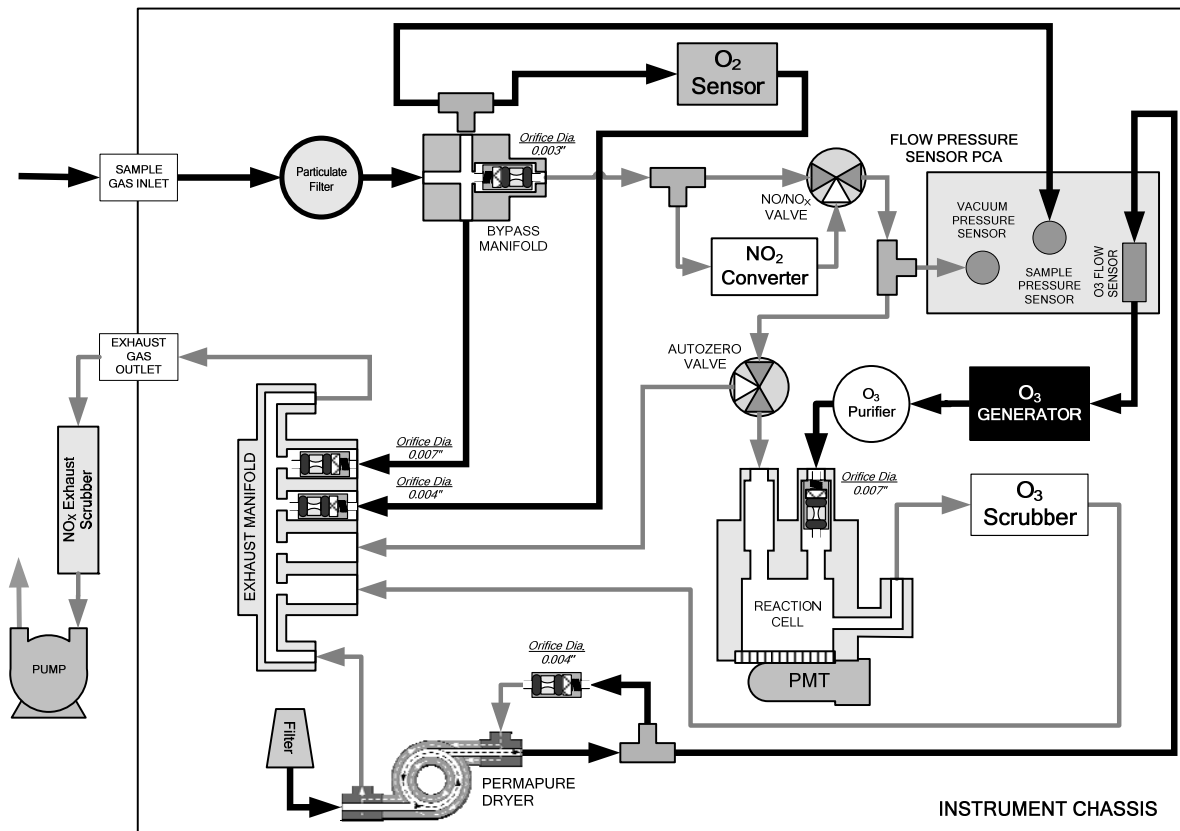


Figure 5-8: TML41H – Internal Pneumatics with O₂ Sensor Option 65

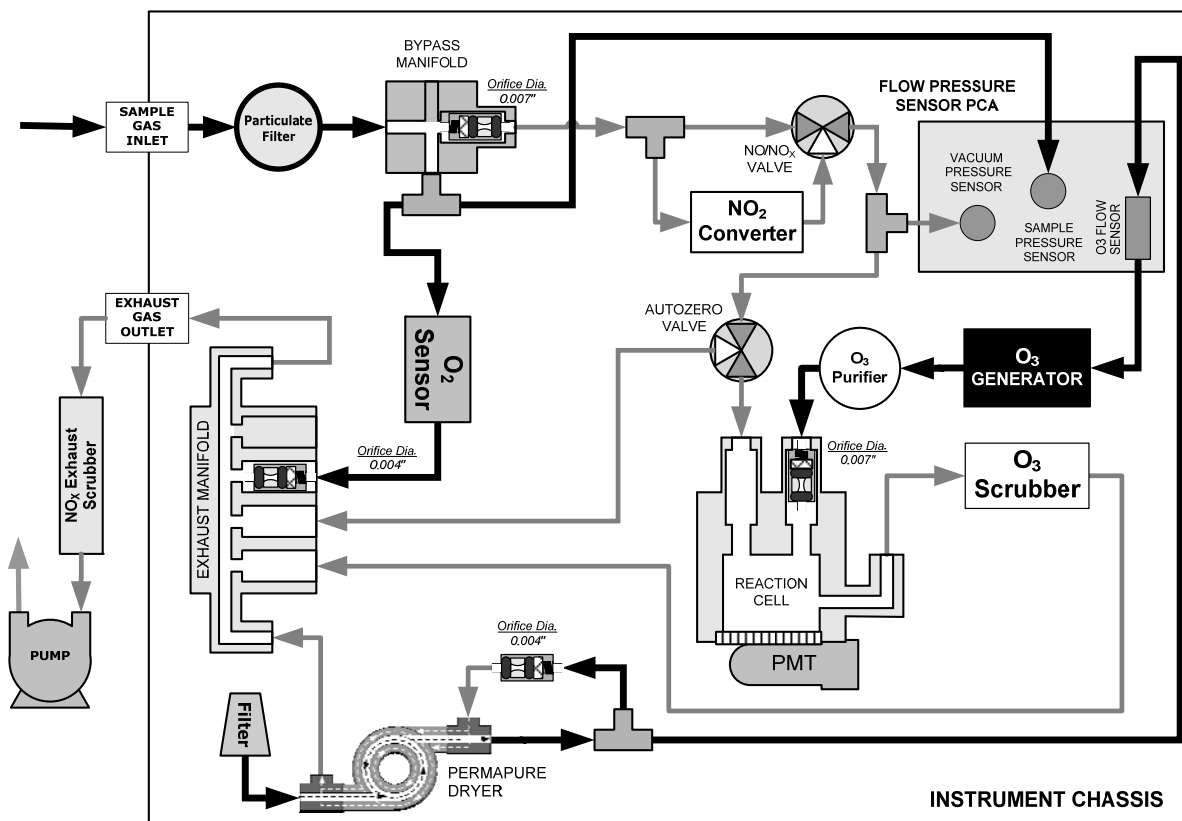


Figure 5-9: TML41M – Internal Pneumatics with O₂ Sensor Option 65

5.7.2. CHARCOAL SCRUBBER (OPT 64A)

This kit includes a charcoal scrubber cartridge, which is used to remove NO₂ from an exhaust port. Applications include, but are not limited to, the removal of NO₂ from the pump exhaust if that exhaust cannot be vented outside the analyzer shelter or if the vent line is not far enough away from the analyzer inlet port (in which case the exhaust would be measured again by the analyzer). The kit does not include any mounting clips, filters or tubing. To order a refill for this cartridge, specify the refill kit listed below.

Older models of the nitrogen oxides analyzer used this type of charcoal scrubber to remove both NO₂ and excess ozone from the exhaust. However, we do not recommend this particular application because of the potentially explosive nature of the mixture.

5.7.3. CHARCOAL REFILL KIT (PART# 00596)

This refill kit contains two plastic bottles with a total of 2.5 kg (5.5 pounds) charcoal, which lasts for about five refills of Option 64A.

5.7.4. ZERO AIR SCRUBBER (OPT 64B)

This kit includes a zero air scrubber cartridge, which can be used to produce and supply zero air to the analyzer's ZERO inlet port. The cartridge mounts to the outside rear panel by means of two rubberized clips and contains two chemicals, 50% volume of Purafil Chemisorbant to convert NO to NO₂, followed 50% volume of charcoal to absorb NO₂.

The zero air scrubber exit contains a particle filter that retains any dust coming from the cartridge and connects with 0.25" PVC tubing to the ZERO inlet port. The chemicals need to be exchanged periodically (use Option 43) to prevent saturation and break-through of NO_x into the zero air stream. This kit is recommended if no other

zero air source is available and if the analyzer is equipped with the zero/span valve option (Section 5.7.1). The kit is included in the IZS option but not in the zero/span valve option.

5.7.5. ZERO AIR SCRUBBER MAINTENANCE KIT (OPT 43)

This kit includes the items needed to refurbish the external zero air scrubber.

Table 5-3: Contents of Zero Air Scrubber Maintenance Kit

TELEDYNE INSTRUMENTS PART NO.	DESCRIPTION
005960000	Activated charcoal refill
059700000	Purafil Chemisorbant [®] refill
FL0000001 ¹	Sintered filter for critical orifice port
FL0000003	Replacement particulate filter for zero air inlet fitting
OR0000001 ¹	O-Ring (qty:2) for critical orifice port
¹ These items are required for units with IZS option only. They are used for rebuilding the IZS-exhaust critical flow orifice on the analyzer's exhaust manifold.	

5.7.6. TML41M/H EXPENDABLES KIT (OPT 42)

This kit includes a recommended set of expendables for one year of operation of the TML41M/H. See Appendix B for a detailed listing of the contents.

5.7.7. TML41M/H SPARE PARTS KIT (OPT 43)

This kit includes a recommended set of spare parts for 2-3 years of operation of the TML41M/H. It includes items such as the orifice holder, a spare PMT and other items that are recommended as backups to minimize down-time in case of component failures. See Appendix B for a detailed listing of the contents.

5.8. COMMUNICATION OPTIONS

5.8.1. RS232 MODEM CABLES (OPTS 60 AND 60A)

The analyzer can have come standard with a shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length, which should fit most computers of recent build. This cable can be ordered as Option 60.

Option 60A consists of a shielded, straight-through serial cable of about 1.8 m length to connect the analyzer's COM1 port to a computer, a code activated switch or any other communications device that is equipped with a DB-25 female connector. The cable is terminated with one DB-9 female connector and one DB-25 male connector. The DB-9 connector fits the analyzer's COM1 port.

5.8.2. RS-232 MULTIDROP (OPT 62)

The multidrop option is used with any of the RS-232 serial ports to enable communications of up to eight analyzers with the host computer over a chain of RS-232 cables via the instruments COM1 Port. It is subject to the distance limitations of the RS 232 standard.

The option consists of a small printed circuit assembly, which is plugs into to the analyzer's CPU card (see Figure 5-10) and is connected to the RS-232 and COM2 DB9 connectors on the instrument's back panel via a cable to the motherboard. One option 62 is required for each analyzer along with one 6' straight-through, DB9 male → DB9 Female cable (P/N WR0000101).

This option can be installed in conjunction with the Ethernet option (Option 63) allowing the instrument to communicate on both types of networks simultaneously. For more information on using and setting up this option, see Section 6.11.7)

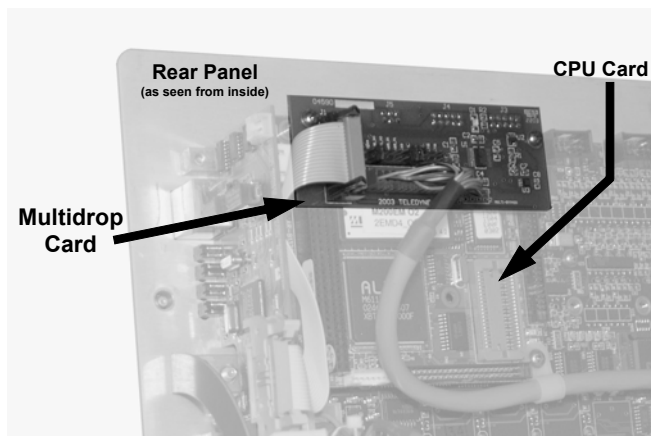


Figure 5-10: TML41M/H Multidrop Card

5.8.3. ETHERNET (OPT 63)

The Ethernet option allows the analyzer to be connected to any Ethernet local area network (LAN) running TCP/IP. The local area network must have routers capable of operating at 10BaseT. If Internet access is available through the LAN, this option also allows communication with the instrument over the public Internet.

When installed, this option is electronically connected to the instrument's COM2 serial port making that port no longer available for RS-232/RS-485 communications through the COM2 connector on the rear panel. The option consists of a Teledyne Instruments designed Ethernet card (see Figure 5-11), which is mechanically attached to the instrument's rear panel (see Figure 5-12). A 7-foot long CAT-5 network cable, terminated at both ends with standard RJ-45 connectors, is included as well. Maximum communication speed is limited by the RS-232 port to 115.2 kBaud.

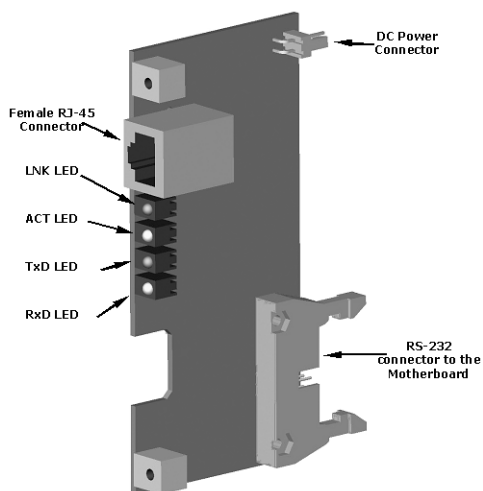


Figure 5-11: TML41M/H Ethernet Card

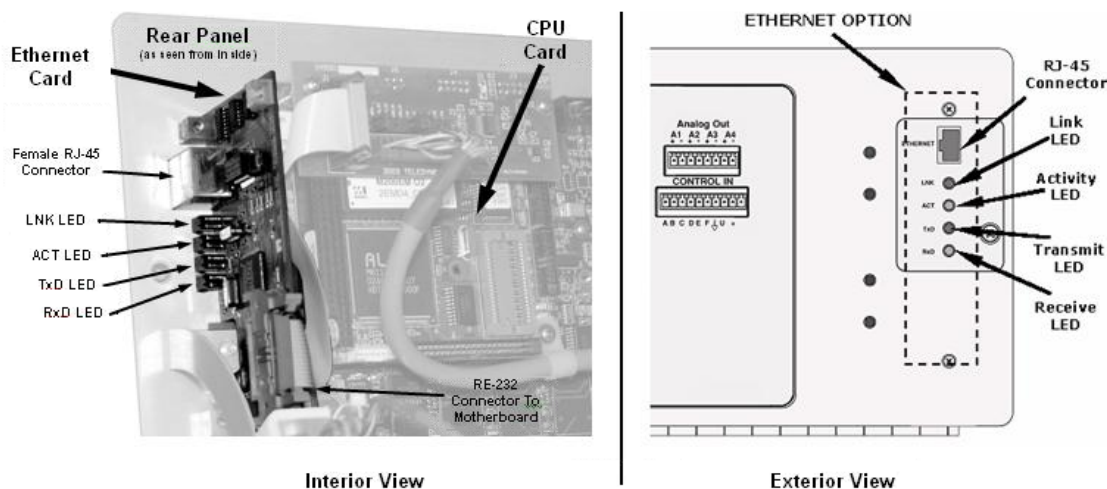


Figure 5-12: TML41M/H Rear Panel with Ethernet Installed

This option can be installed in conjunction with the RS-2323 multidrop (option 62) allowing the instrument to communicate on both types of networks simultaneously. For more information on using and setting up this option, see Section 6.11.6)

5.9. SAMPLE GAS CONDITIONERS (OPTS 86 & 88)

Several permeation devices using Nafion[®] permeation gas exchange tubes are available for applications with high moisture and/or moderate levels of NH₃ in the sample gas. This type of sample conditioner is part of the standard TML41M/H equipment to remove H₂O and NH₃ from the ozone generator supply gas stream but can be purchased for the sample gas stream as well. All gas conditioners remove water vapor to a dew point of about – 20° C (~600 ppm H₂O) and effectively remove concentrations of ammonia up to about 1 ppm. More information about these dryers and their performance is available at <http://www.permasure.com/>.

The following options include the hardware required to install the dryers.

Table 5-4: Dryer and NH₃ Removal Options

OPTION NUMBER	DESCRIPTION
STANDARD EQUIPMENT	Single gas conditioner (dryer / NH ₃ removal) for ozone generator supply gas stream only. Includes mounting bracket for two dryers (Option 86 mounts on the back).
OPT 86	Single gas conditioner (dryer / NH ₃ removal) for sample gas stream only. Mounts on the back of the existing dryer bracket. Converts analyzer to dual-conditioner instrument.
OPT 88	Single combination gas conditioner (dryer / NH ₃ removal) for both the sample gas and ozone supply air. Replaces the standard dryer for O ₃ air and comes with mounting bracket.

The combination conditioner is a low-cost option for drying both the sample gas and ozone supply air with one dryer. This dryer can only be used in applications where sample and calibration gases (after dilution) are at or near ambient and constant concentrations of oxygen (about 21%); the ozone generator needs a high and steady concentration of oxygen to generate ozone properly. Stack applications or industrial applications in which the sample gas has a significantly reduced or highly variable concentration of oxygen need to use the separate dryer option 86. The combination conditioner needs to be specified upon ordering the analyzer.

5.10. ALARM RELAY OPTION (OPT 67)

The TML41M/H can be equipped with a set of 2 concentration alarms. Each alarm can be independently enabled or disabled as well as programmed with its own, individual alarm limit point (see Section 6.14 for details on programming the alarms).

The status of each alarm is available via a set of alarm relay outputs located on the lower right hand corner of the analyzer's rear panel (see Figure 3-2). While there are four relay outputs on the back of the analyzer, only two of the outputs correspond to the instrument's two concentration alarms.

Table 5-5: Alarm Relay Output Assignments

RELAY NAME	AL1	AL2	AL3	AL4
ASSIGNED ALARM	ST_SYSTEM_OK2 ¹	CONCENTRATION ALARM 1	CONCENTRATION ALARM 2	SPARE

¹ST_SYSTEM_OK2 is a second system OK status alarm available on some analyzers.

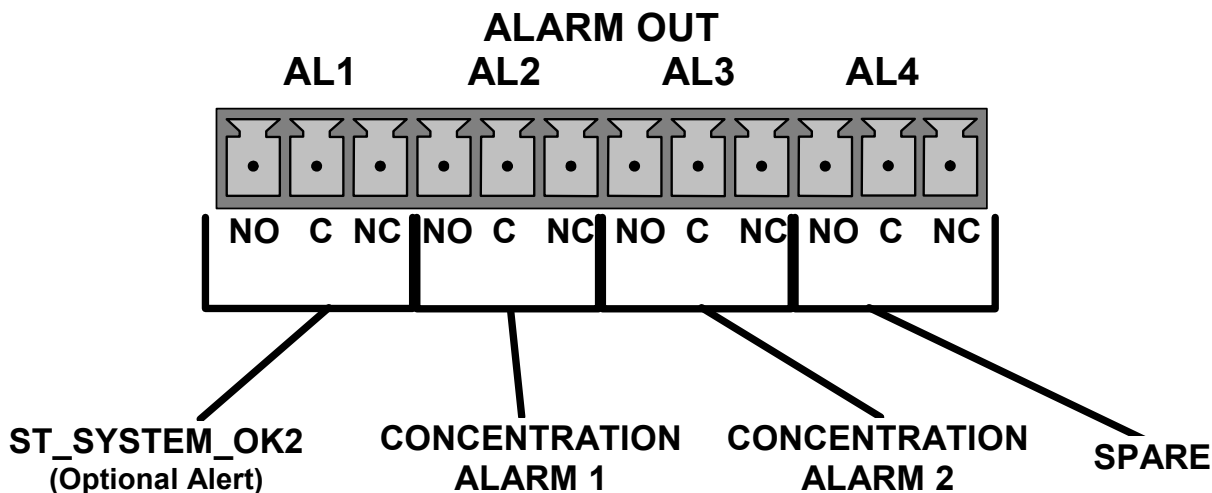


Figure 5-13: Alarm Relay Output Pin Assignments

Each of the two concentration relay outputs has 3-pin connections that allow the relay to be connected for either normally open or normally closed operation. Table 5-6 describes how to connect the alarm relays.

Table 5-6: Concentration Alarm Relay Output Operation

RELAY	FUNCTION	RELAY PIN STATE ¹			COMMENTS
		N O	C	N C	
AL2	Concentration Alarm 1 Active				Gas concentration level is above the trigger limit set for CONC_ALARM_1 <ul style="list-style-type: none"> iDAS Trigger CONCW1 ACTIVATED CONC ALARM1 WARN appears on Analyzer Display
	Concentration Alarm 1 Inactive				
AL3	Concentration Alarm 2 Active				Gas concentration level is above the trigger limit set for CONC_ALARM_2 <ul style="list-style-type: none"> iDAS Trigger CONCW2 ACTIVATED CONC ALARM2 WARN appears on Analyzer Display
	Concentration Alarm 2 Inactive				
¹ NO = Normally Open operation. C = Common NC = Normally Closed operation.					

5.11. SPECIAL SOFTWARE FEATURES

5.11.1. MAINTENANCE MODE SWITCH

Teledyne Instruments analyzers are equipped with a switch that places the instrument in maintenance mode. This switch is accessed by opening the hinged front panel. It is located on the rear facing side of the display/keyboard driver PCA, to the left side near the particulate filter.

When in maintenance mode the instrument ignores all commands received via the COMM ports that alter the operation state of the instrument. This includes all calibration commands, diagnostic menu commands and the reset instrument command. The instrument continues to measure gas concentration and send data when requested.

This feature is of particular use for instruments connected to multidrop or Hessen protocol networks.

5.11.2. SECOND LANGUAGE SWITCH

Teledyne Instruments analyzers are equipped with a switch that activates an alternate set of display messages in a language other than the instrument's default language. This switch is accessed by opening the hinged front panel and is located on the rear facing side of the display/keyboard driver PCA on the right side.

To activate this feature, the instrument must also have a specially programmed Disk on Chip containing the second language. Contact Teledyne Instruments Customer Service personnel for more information.

5.11.3. DILUTION RATIO OPTION

The dilution ration feature is a software option that is designed for applications where the sample gas is diluted before being analyzed by the TML41M/H. 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, NO₂ and NO_x concentration calculations so that the measurement range and concentration values displayed on the instrument's front panel display and reported via the instruments various outputs reflect the undiluted values.

Contact Teledyne Instruments Customer Service personnel for information on activating this feature.

Instructions for using the dilution ratio option can be found in Section 6.8.2.

5.12. ADDITIONAL MANUAL (OPT 70)

Additional copies of the printed user's manual can be purchased from the factory. Please specify the serial number of your analyzer so that we can match the manual version.

This operator's manual is also available on CD. The electronic document is stored in Adobe Systems Inc. *Portable Document Format* (PDF) and is viewable with Adobe Acrobat Reader[®] software, which can be downloaded for free at <http://www.adobe.com/>

The electronic version of this manual can also be downloaded for free at <http://www.teledyne-ml.com>. Note that the online version is optimized for fast download and may not print with the same quality as the manual on CD.

5.13. EXTENDED WARRANTY (OPTS 92 & 93)

Two options are available for extending the standard manufacturer's warranty. Both options have to be specified upon ordering the analyzer.

OPTION NUMBER	DESCRIPTION
OPT 92	Extends warranty to cover a two (2) year period from the date of purchase.
OPT 93	Extends warranty to cover a five (5) year period from the date of purchase.

USER NOTES:

USER NOTES:

6. OPERATING INSTRUCTIONS

To assist in navigating the analyzer's software, a series of menu trees can be found in Appendix A of this manual.

NOTE

The flow charts appearing in this section contain typical representations of the analyzer's display during the various operations being described. These representations may differ slightly from the actual display of your instrument.

The ENTR key may 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. Once you adjust the setting to an allowable value, the ENTR key will re-appear.

6.1. OVERVIEW OF OPERATING MODES

The TML41M/H software has a variety of operating modes. Most commonly, the analyzer will be operating in **SAMPLE** mode. In this mode, continuous read-outs of the NO, NO₂ and NO_x concentrations are displayed on the front panel and are available to be sent as analog signals from the analyzer's rear panel terminals. Also, calibrations can be performed, and **TEST** functions and **WARNING** messages can be examined.

The second most important operating mode is **SETUP** mode. This mode is used for performing certain configuration operations, such as for the iDAS system, configuring the reporting ranges, or the serial (RS-232/RS-485/Ethernet) communication channels. The **SET UP** mode is also used for performing various diagnostic tests during troubleshooting.

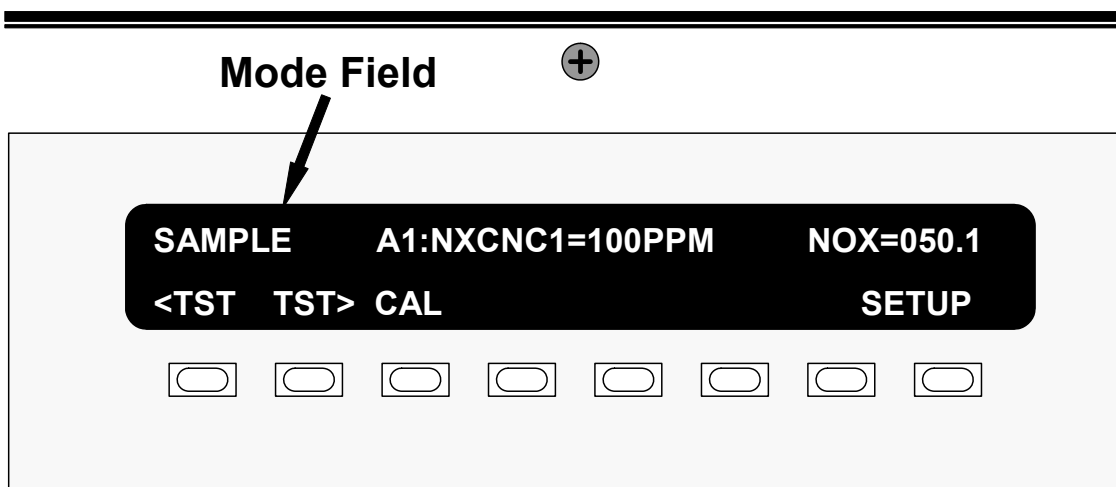


Figure 6-1: Front Panel Display

The mode field of the front panel display indicates to the user which operating mode the unit is currently running.

Besides **SAMPLE** and **SETUP**, other modes the analyzer can be operated in are:

Table 6-1: Analyzer Operating modes

MODE	EXPLANATION
SAMPLE	Sampling normally, flashing text indicates adaptive filter is on.
M-P CAL	This is the basic calibration mode of the instrument and is activated by pressing the CAL key.
SETUP X.#²	SETUP mode is being used to configure the analyzer. The gas measurement will continue during this process.
SAMPLE A	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
ZERO CAL M¹	Unit is performing ZERO calibration procedure initiated manually by the user.
ZERO CAL A¹	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature.
ZERO CAL R¹	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.
LO CAL A	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer's AUTOCAL feature.
LO CAL R	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
SPAN CAL M¹	Unit is performing SPAN calibration initiated manually by the user.
SPAN CAL A¹	Unit is performing SPAN calibration initiated automatically by the analyzer's AUTOCAL feature.
SPAN CAL R¹	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
DIAG	One of the analyzer's diagnostic modes is active (Section 6.13).
¹ Only Appears on units with Z/S valve or IZS options.	
² The revision of the analyzer firmware is displayed following the word SETUP , e.g., SETUP F.0 .	

The third operating mode is the **CAL** mode, which allows calibration of the analyzer in various ways. Because of its importance, this mode is described separately in Chapter 7.

6.2. SAMPLE MODE

This is the analyzer's standard operating mode. In this mode, the instrument is analyzing NO and NO_x and calculating NO₂ concentrations.

6.2.1. TEST FUNCTIONS

A series of test functions is available at the front panel while the analyzer is in SAMPLE mode. These parameters provide information about the present operating status of the instrument and are useful during troubleshooting (Section 11.1.2). They can also be recorded in one of the iDAS channels (Section 6.7) for data analysis or transmitted on one of the configurable analog outputs.

Table 6-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
Analog output range configuration	A1:NXCNC1=100 PPM A2:NO_xCNC1=100 PPM A3:N2CNC1=25 PPM A4:NXCNC2=100%		These functions show the default settings for the enabled analog output channels. See section 6.13.5.7 for more information.
NOX STB	STABILITY	PPM, MGM	The stability is a standard deviation of the NO _x concentration over 25 samples, each recorded every 10 seconds. A low NOX STB value indicates low variability in NO _x .
SAMP FLW	SAMPLE FLOW	cm ³ /min (cc/m)	The flow rate of the sample gas through the reaction cell. This value is not measured but calculated from the sample pressure.
OZONE FL	OZONE	cm ³ /min (cc/m)	Flow rate of the O ₃ gas stream as measured with a flow meter
PMT	PMT Signal	MV	The raw output voltage of the PMT.
NORM PMT	NORMALIZED PMT Signal	MV	The output voltage of the PMT after normalization for auto-zero offset and temperature/pressure compensation (if activated).
AZERO	AUTO-ZERO	MV	The PMT signal with zero NO _x , which is usually slightly different from 0 V. This offset is subtracted from the PMT signal and adjusts for variations in the zero signal.
HVPS	HVPS	V	The PMT high voltage power supply.
RCELL TEMP	REACTION CELL TEMP	°C	The current temperature of the reaction cell.
BOX TEMP	BOX TEMPERATURE	°C	The ambient temperature of the inside of the analyzer case.
PMT TEMP	PMT TEMPERATURE	°C	The current temperature of the PMT.
IZS TEMP	IZS TEMPERATURE ¹	°C	The current temperature of the internal zero/span option. Only appears when IZS option is enabled.
MOLY TEMP	CONV TEMPERATURE	°C	The current temperature of the NO ₂ converter.
RCEL	REACTION CELL PRESSURE	in-Hg-A	The current gas pressure of the reaction cell as measured at the vacuum manifold. This is the vacuum pressure created by the external pump.
SAMP	SAMPLE PRESSURE	in-Hg-A	The current pressure of the sample gas as it enters the reaction cell, measured between the NO/NO _x and Auto-Zero valves.
NOX SLOPE	NO _x SLOPE	--	The slope of the current NO _x calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NOX OFFS	NO _x OFFSET	MV	The offset of the current NO _x calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO SLOPE	NO SLOPE	--	The slope of the current NO calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO OFFS	NO OFFSET	MV	The offset of the current NO calibration as calculated from a linear fit during the analyzer's last zero/span calibration.
NO2	NO ₂ concentration	PPM, MGM	The current NO ₂ concentration in the chosen unit.
NOX	NO _x concentration	PPM, MGM	The current NO _x concentration in the chosen unit.
NO	NO concentration	PPM, MGM	The current NO concentration in the chosen unit.
TEST	TEST SIGNAL ²	MV	Signal of a user-defined test function on output channel A4.
TIME	CLOCK TIME	hh:mm:ss	The current day time for iDAS records and calibration events.

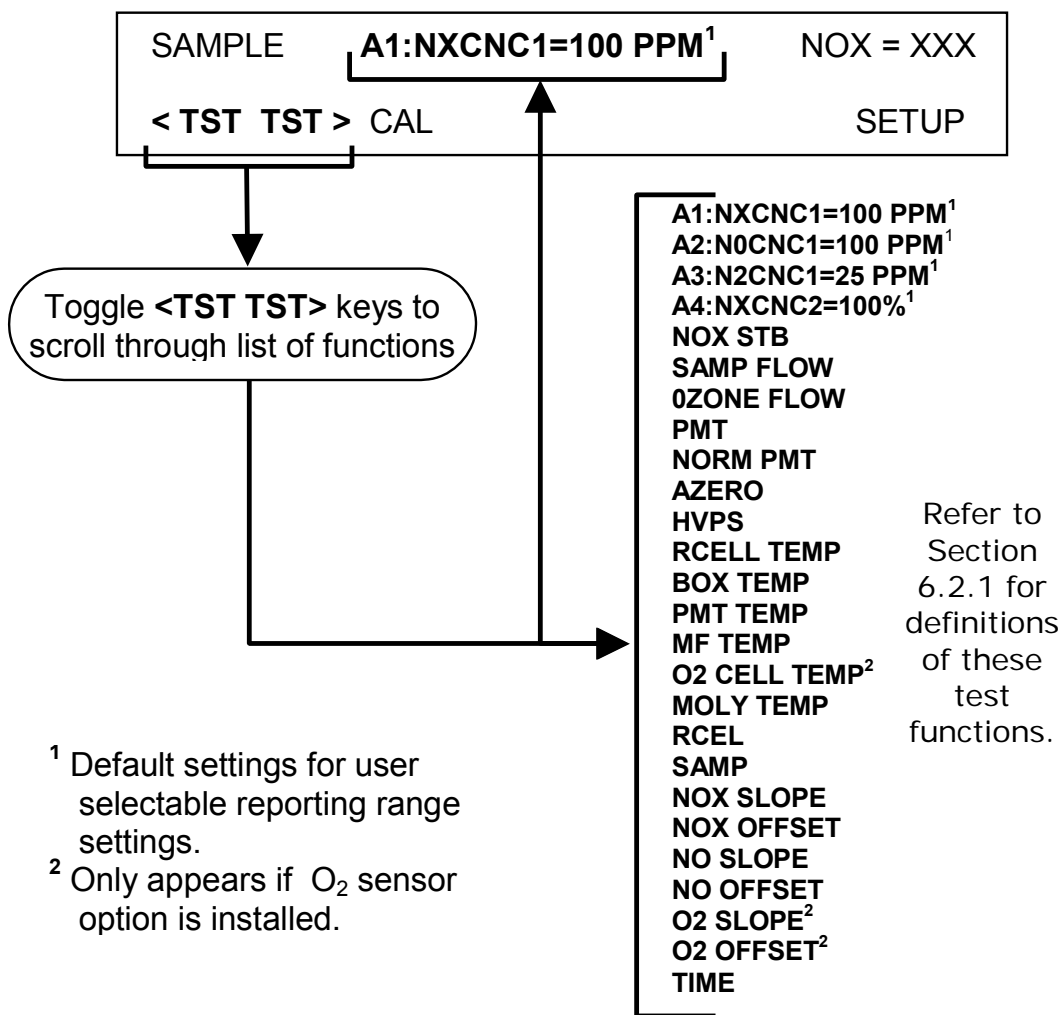


Figure 6-2: Viewing TML41M/H TEST Functions

NOTE

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.

6.2.2. WARNING MESSAGES

The most common instrument failures will be reported as a warning on the analyzer's front panel and through the COM ports. Section 11.1.2 explains how to use these messages to troubleshoot problems. Figure 6-3 shows how to view and clear warning messages.

Table 6-3: List of Warning Messages Revision F.0

MESSAGE	MEANING
ANALOG CAL WARNING	The instrument's analog-to-digital converter (A/D) circuitry or one of the analog outputs are not calibrated.
AZERO WRN XXX.X MV	The reading taken during the Auto-zero cycle is outside the specified limits. The value shown here as "XXX.X" indicates the actual auto-zero reading at the time of the warning.
BOX TEMP WARNING	The temperature inside the TML41M/H chassis is outside the specified limits.
CANNOT DYN SPAN	Remote span calibration failed while the dynamic span feature was ON.
CANNOT DYN ZERO	Remote zero calibration failed while the dynamic zero feature was ON.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or was erased.
CONV TEMP WARNING	NO ₂ converter temperature is outside of specified limits.
DATA INITIALIZED	iDAS data storage was erased.
HVPS WARNING	High voltage power supply for the PMT is outside of specified limits.
IZS TEMP WARNING	On units with IZS option installed: The IZS temperature is outside of specified limits.
OZONE FLOW WARNING	Ozone flow is outside of specified limits.
OZONE GEN OFF	Ozone generator is off. This is the only warning message that automatically clears itself when the ozone generator is turned on.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL PRESS WARN	Reaction cell pressure is outside of specified limits.
RCELL TEMP WARNING	Reaction cell temperature is outside of specified limits.
REAR BOARD NOT DET	The firmware is unable to communicate with the motherboard.
RELAY BOARD WARN	The firmware is unable to communicate with the relay board.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SYSTEM RESET	The computer rebooted or was powered up.

To view and clear warning messages

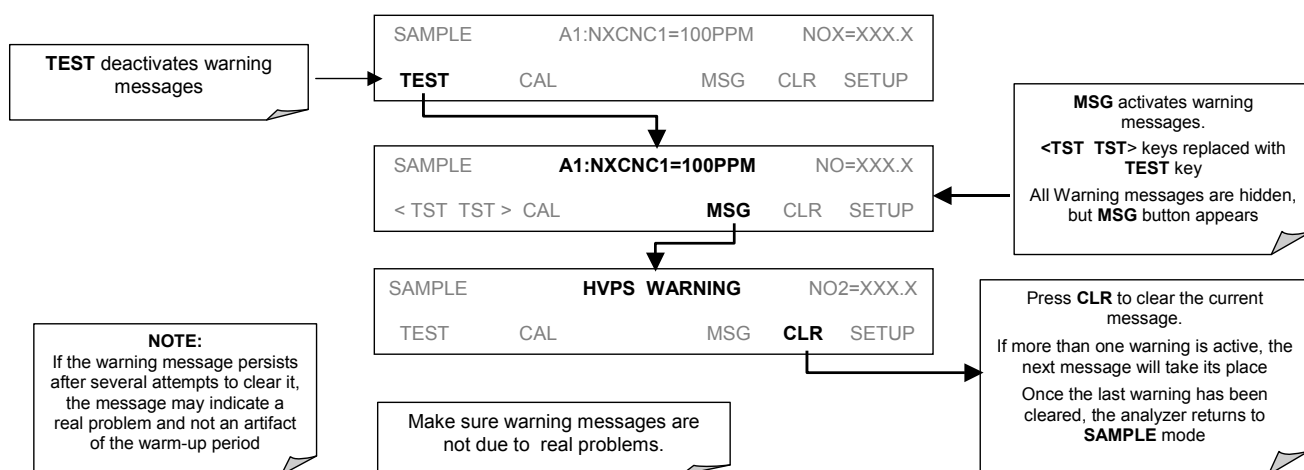


Figure 6-3: Viewing and Clearing TML41M/H WARNING Messages

6.3. CALIBRATION MODE

6.3.1. CALIBRATION FUNCTIONS

Pressing the **CAL** key switches the TML41M/H into calibration mode. In this mode, the user can calibrate the instrument with the use of calibrated zero or span gases.

If the instrument includes either the zero/span valve option or IZS option, the display will also include **CALZ** and **CALS** keys. Pressing either of these keys also puts the instrument into multipoint calibration mode.

- The **CALZ** key is used to initiate a calibration of the zero point.
- The **CALS** key is used to calibrate the span point of the analyzer. It is recommended that this span calibration is performed at 90% of full scale of the analyzer's currently selected reporting range.

Because of their critical importance and complexity, calibration operations are described in detail in other sections of the manual:

- Chapter 7 details basic calibration and calibration check operations.

For more information concerning the zero/span, zero/span/shutoff valve options, see Section 5.7.

6.4. SETUP MODE

The **SETUP** mode contains a variety of choices that are used 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 (iDAS). The areas accessed under the Setup mode are:

Table 6-4: Primary Setup Mode Features and Functions

MODE OR FEATURE	KEYPAD LABEL	DESCRIPTION	MANUAL SECTION
Analyzer Configuration	CFG	Lists key hardware and software configuration information	6.5
Auto Cal Feature	ACAL	Used to set up and operate the AutoCal feature. Only appears if the analyzer has one of the internal valve options installed	7.7
Internal Data Acquisition (iDAS)	DAS	Used to set up the iDAS system and view recorded data	6.7
Analog Output Reporting Range Configuration	RNGE	Used to set the units of measure for the display and set the dilution ratio on instruments with that option active.	6.8
Calibration Password Security	PASS	Turns the password feature ON/OFF	6.9
Internal Clock Configuration	CLK	Used to Set or adjust the instrument's internal clock	6.10
Advanced SETUP features	MORE	This button accesses the instrument's secondary setup menu	See Table 6-5

Table 6-5: Secondary Setup Mode Features and Functions

MODE OR FEATURE	KEYPAD LABEL	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	COMM	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.	6.11 & 6.15
System Status Variables	VARs	Used to view various variables related to the instrument's current operational status	6.12
System Diagnostic Features and Analog Output Configuration	DIAG	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 instrument's Analog outputs are located here.	6.13
Alarm Limit Configuration ¹	ALRM	Used to turn the instrument's two alarms on and off as well as set the trigger limits for each.	6.14

¹ Only present if the optional alarm relay outputs (Option 67) are installed.

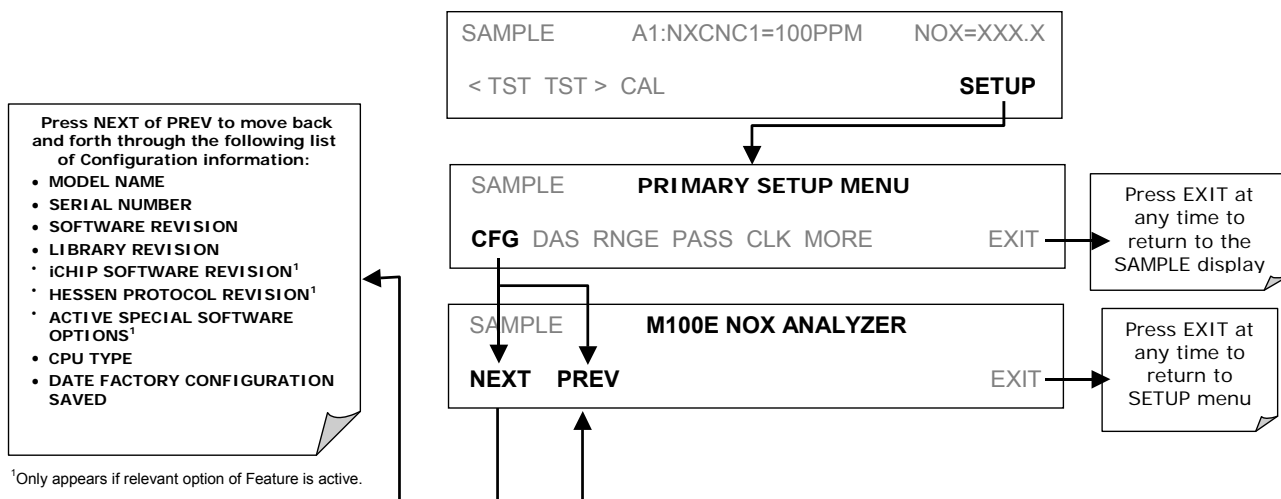
NOTE

Any changes made to a variable during one of the following procedures is not acknowledged by the instrument until the ENTR Key is pressed.

If the EXIT key is pressed before the ENTR key, the analyzer will beep, alerting the user that the newly entered value has not been accepted.

6.5. SETUP → CFG: VIEWING THE ANALYZER'S CONFIGURATION INFORMATION

Pressing the CFG key displays the instrument configuration information. This display lists the analyzer model, serial number, firmware revision, software library revision, CPU type and other information. Use this information to identify the software and hardware when contacting customer service. Special instrument or software features or installed options may also be listed here.



6.6. SETUP → ACAL: AUTOMATIC CALIBRATION

Instruments with one of the internal valve options installed can be set to automatically run calibration procedures and calibration checks. These automatic procedures are programmed using the submenus and functions found under the **ACAL** menu.

A menu tree showing the **ACAL** menu's entire structure can be found in Appendix A-1 of this manual.

Instructions for using the **ACAL** feature are located in the Section 7.7 of this manual along with all other information related to calibrating the TML41M/H analyzer.

6.7. SETUP → DAS - USING THE DATA ACQUISITION SYSTEM (iDAS)

The TML41M/H analyzer contains a flexible and powerful, internal data acquisition system (iDAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The iDAS of the TML41M/H can store up to about one million data points, which can cover days, weeks or months of valuable measurements. The data 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 spreadsheet-type programs).

NOTE:

Please be aware that all stored data will be erased if the analyzer's disk-on-chip, CPU board or configuration is replaced or reset.

The iDAS is designed to be flexible. Users have full control over the type, length and reporting time of the data. The iDAS permits users to access stored data through the instrument's front panel or its communication ports. Teledyne Instruments also offers sensor-e.com, a program that provides a visual interface for configuration and data retrieval of the iDAS or using a remote computer. Additionally, the analyzer's four analog output channels can be programmed to carry data related to any of the available iDAS parameters.

The principal use of the iDAS 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.

IDAS STATUS

The green SAMPLE LED on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the iDAS status:

Table 6-6: Front Panel LED Status Indicators for iDAS

LED STATE	IDAS 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. IDAS channels can be enabled or disabled for this period. Concentration data are typically disabled whereas diagnostic should be collected.
On	Sampling normally.

The iDAS can be disabled only by disabling or deleting its individual data channels.

6.7.1. IDAS STRUCTURE

The iDAS is designed around the feature of a “record”, an automatically stored single data point. (e.g. concentration, PMT signal level, etc.). Records are organized into data channels which are defined by properties that characterize the:

- Type of data recorded (e.g. concentration, PMT signal level, etc.);
- Trigger event that causes the record to be made (e.g. every minute, upon exiting calibration mode, etc.);
- How many records to be stored, as well as;
- How the information is to be stored (e.g. average over 1 hour, individual points, minimum value over last 5 minutes, etc.).

The configuration of each iDAS channel is stored in the analyzer's memory as a script, which can be edited from the front panel or downloaded, edited and uploaded to the instrument in form of a string of plain-text lines through the communication ports.

6.7.1.1. iDAS Channels

The key to the flexibility of the iDAS 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. For each channel one triggering event is selected and one or all of the TML41M/H's 25 data parameters are allowed. The number of parameters and channels is limited by available memory.

The properties that define the structure of an iDAS data channel are:

Table 6-7: iDAS Data Channel Properties

PROPERTY	DESCRIPTION	DEFAULT	SETTING RANGE
NAME	The name of the data channel.	“NONE”	Up to 6 letters or digits ¹ .
TRIGGERING EVENT	The event that triggers the data channel to measure and store the datum	ATIMER	Any available event (see Appendix A-5).
NUMBER AND LIST OF PARAMETERS	A User-configurable list of data types to be recorded in any given channel.	1 - PMTDET	Any available parameter (see Appendix A-5).
REPORT PERIOD	The amount of time between each channel data point.	000:01:00	000:00:01 to 366:23:59 (Days:Hours:Minutes)
NUMBER OF RECORDS	The number of reports that will be stored in the data file. Once the limit is exceeded, the oldest data is over-written.	100	1 to 1 million, limited by available storage space.
RS-232 REPORT	Enables the analyzer to automatically report channel values to the RS-232 ports.	OFF	OFF or ON
CHANNEL ENABLED	Enables or disables the channel. Allows a channel to be temporarily turned off without deleting it.	ON	OFF or ON
CAL HOLD OFF	Disables sampling of data parameters while instrument is in calibration mode ² .	OFF	OFF or ON

¹ More with sensor-e.com, but only the first six are displayed on the front panel).

² When enabled records are not recorded until the **DAS HOLD OFF** period is passed after calibration mode. **DAS HOLD OFF** set in the VARS menu (see Section 6.7.2.11.)

6.7.1.2. iDAS Parameters

Data parameters are types of data that may be measured by the analyzer's instrumentality, such as concentrations of measured gases, temperatures of heated zones, pressures and flows of the pneumatic subsystem as well as calibration data such as slope and offset for each gas. For each Teledyne Instruments analyzer model, the list of available data parameters is different, fully defined and not customizable (see Appendix A.5 for a list of TML41M/H parameters).

Most data parameters have associated measurement units, such as mV, ppm, cm³/min, etc., although some parameters have no units. The only units that can be changed are those of the concentration readings according to the **SETUP-RANGE** settings.

NOTE

The iDAS does not keep track of the unit of each concentration value and iDAS data files may contain concentrations in multiple units if the unit was changed during data acquisition.

Each data parameter has user-configurable functions that define how the data are recorded.

Table 6-8: iDAS Data Parameter Functions

FUNCTION	EFFECT
PARAMETER	Instrument-specific parameter name.
SAMPLE MODE	INST: Records instantaneous reading. AVG: Records average reading during reporting interval. MIN: Records minimum (instantaneous) reading during reporting interval. MAX: Records maximum (instantaneous) reading during reporting interval. SDEV: Records the standard deviation of the data points recorded during the reporting interval.
PRECISION	Decimal precision of parameter value (0-4).
STORE NUM. SAMPLES	OFF: stores only the average (default). ON: stores the average and the number of samples in each average for a 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.

6.7.1.3. iDAS Triggering Events

Triggering events define when and how the iDAS records a measurement of any given data channel. Triggering events are firmware-specific and are listed in Appendix A-5. The most common triggering events are:

- **ATIMER:** Sampling occurs at regular intervals specified by an automatic timer. Trending information is often stored via such intervals, as either individual datum or averaged.
- **EXITZR, EXITSP, SLPCHG** (exit zero, exit span, slope change): Sampling at the end of an irregularly occurring event such as calibration or when the slope changes. These events create individual data points. Zero and slope values can be used 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. This is helpful for trouble-shooting by monitoring when a particular warning occurred.

6.7.2. DEFAULT IDAS CHANNELS

The TML41M/H is configured with a basic iDAS configuration, which is enabled by default. New data channels are also enabled by default but each channel may be turned off for later or occasional use. Note that iDAS operation is suspended while its configuration is edited through the front panel. To prevent such data loss, it is recommended to use the sensor-e.com graphical user interface for iDAS changes.

A set of default data channels has been included in the analyzer's software for logging nitrogen oxides concentrations, calibration, and predictive diagnostic data. They are:

- **CONC:** Samples NO_x, NO and NO₂ concentration at one minute intervals and stores an average every hour with a time and date stamp along with the number of (1-minute) samples within each average (for statistical evaluation). Readings during calibration and calibration hold off are not included in the data. By default, the last 800 hourly averages are stored.
- **CALDAT:** Every time a zero or span calibration is performed **CALDAT** logs concentration, slope and offset values for NO_x and NO with a time and date stamp. The NO_x stability (to evaluate calibration stability) as well as the converter efficiency (for reference) are also stored. This data channel will store data from the last 200 calibrations and can be used to document analyzer calibration. The slope and offset data can be used to detect trends in instrument response.
- **CALCHECK:** This channel logs concentrations and the stability each time a zero or span *check* (not calibration) is finished. This allows 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 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). These data are useful for predictive diagnostics and maintenance of the TML41M/H. 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 TML41M/H. 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. This data channel is disabled by default but may be turned on when needed such as for trouble-shooting problems with the analyzer.

The default data channels can be used as they are, or they can be customized from the front panel or through sensor-e.com to fit a specific application. The Teledyne Instruments website contains this default and other sample iDAS scripts for free download. We recommend that the user backs up any iDAS configuration and its data before altering it.

NOTE

Teledyne-ML recommends downloading and storing existing data and the iDAS configurations regularly for permanent documentation and future data analysis.

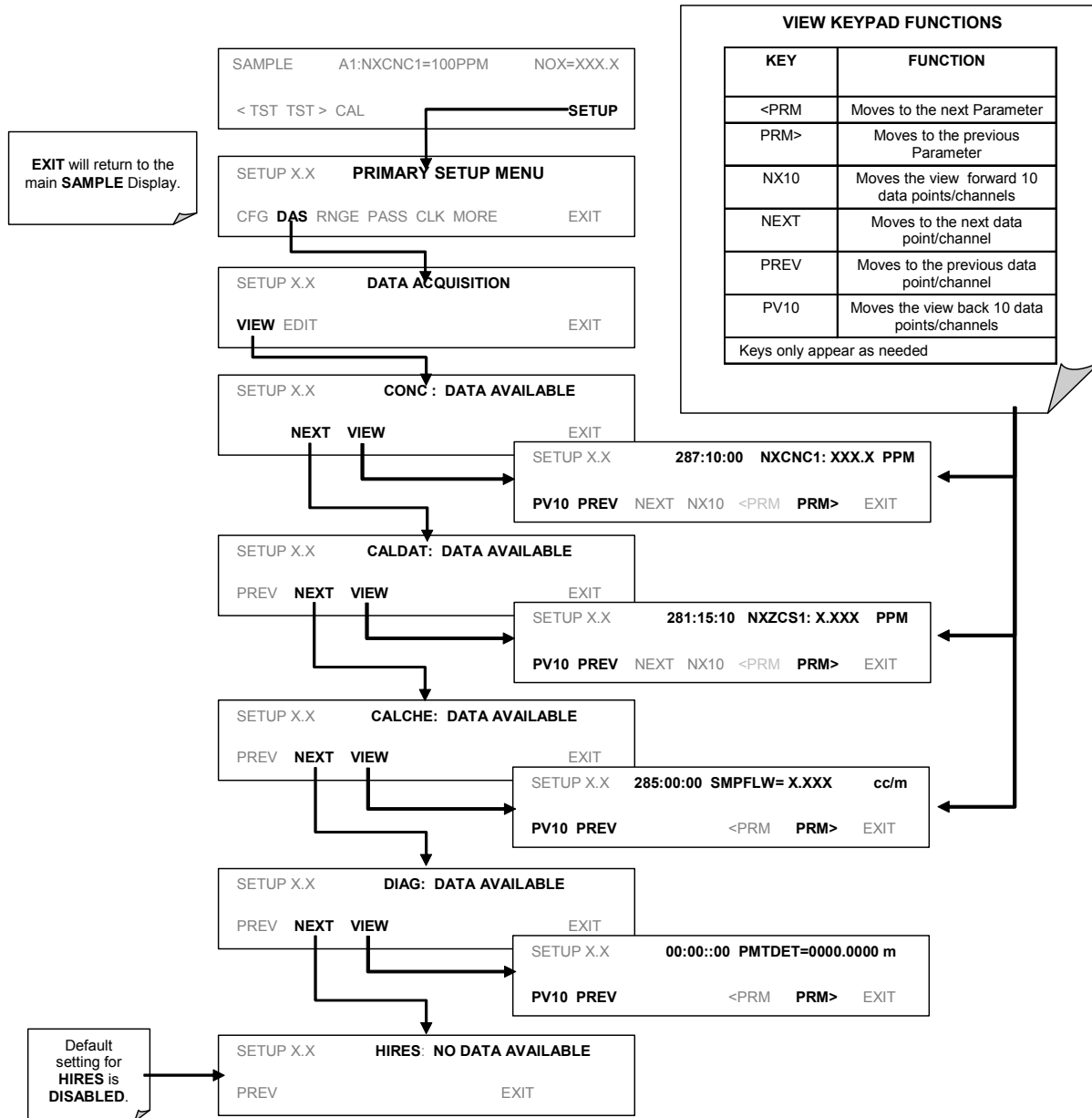
Sending an iDAS configuration to the analyzer through its COM ports will replace the existing configuration and will delete all stored data.

Table 6-9: TML41M/H Default iDAS Configuration

CHANNELS with PROPERTIES	PARAMETERS				
	NAME	MODE	EVENT	PRECISION	STORE NUM SAMPLES
Name: CONC Event: ATIMER Sample Period: 000:00:01 Report Period: 000:01:00 Number of Records: 800 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: ON	NOXCNC1	AVG	--	4	OFF
	NOCNC1	AVG	--	4	OFF
	N2CNC1	AVG	--	4	OFF
	STABIL	AVG	--	4	OFF
Name: CALDAT Event: SLPCHG Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	NXZSC1	--	SLPCHG	4	OFF
	NOXSPL1	--	SLPCHG	4	OFF
	NOXOFFS1	--	SLPCHG	4	OFF
	NOZSC1	--	SLPCHG	4	OFF
	NOSLP1	--	SLPCHG	4	OFF
	NOOFFS1	--	SLPCHG	4	OFF
	N2ZSC1	--	SLPCHG	4	OFF
	CNVEF1	--	SLPCHG	4	OFF
Name: CALCHECK Event: EXITMP Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	NXZSC1	--	EXITMP	4	OFF
	NOZSC1	--	EXITMP	4	OFF
	N2ZSC1	--	EXITMP	4	OFF
	STABIL	--	EXITMP	4	OFF
Name: DIAG Event: EXITMP Number of Records: 200 RS-232 report: OFF Channel enabled: ON DAS HOLDOFF: OFF	SMPFLW	AVG	--	2	OFF
	O3FLOW	AVG	--	2	OFF
	RCPRESS	AVG	--	2	OFF
	SMPPRES	AVG	--	2	OFF
	RCTEMP	AVG	--	2	OFF
	PMTTMP	AVG	--	2	OFF
	CNVTMP	AVG	--	2	OFF
	BOXTMP	AVG	--	2	OFF
	HVPS	AVG	--	2	OFF
AZERO	AVG	--	2	OFF	
Name: HIRES Event: ATIMER Sample Period: 000:00:01 Report Period: 000:00:01 Number of Records: 1500 RS-232 report: OFF Channel enabled: OFF DAS HOLDOFF: OFF	NOXCNC1	AVG	--	4	OFF
	NOCNC1	AVG	--	4	OFF
	N2CNC1	AVG	--	4	OFF
	STABIL	AVG	--	4	OFF
	SMPFLW	AVG	--	2	OFF
	O3FLOW	AVG	--	2	OFF
	RCPRESS	AVG	--	2	OFF
	SMPPRES	AVG	--	2	OFF
	RCTEMP	AVG	--	2	OFF
	PMTTMP	AVG	--	2	OFF
	CNVTMP	AVG	--	2	OFF
	BOXTMP	AVG	--	2	OFF
	HVPS	AVG	--	1	OFF
	AZERO	AVG	--	2	OFF
REFGND	AVG		1	OFF	
REF4096	AVG		1	OFF	

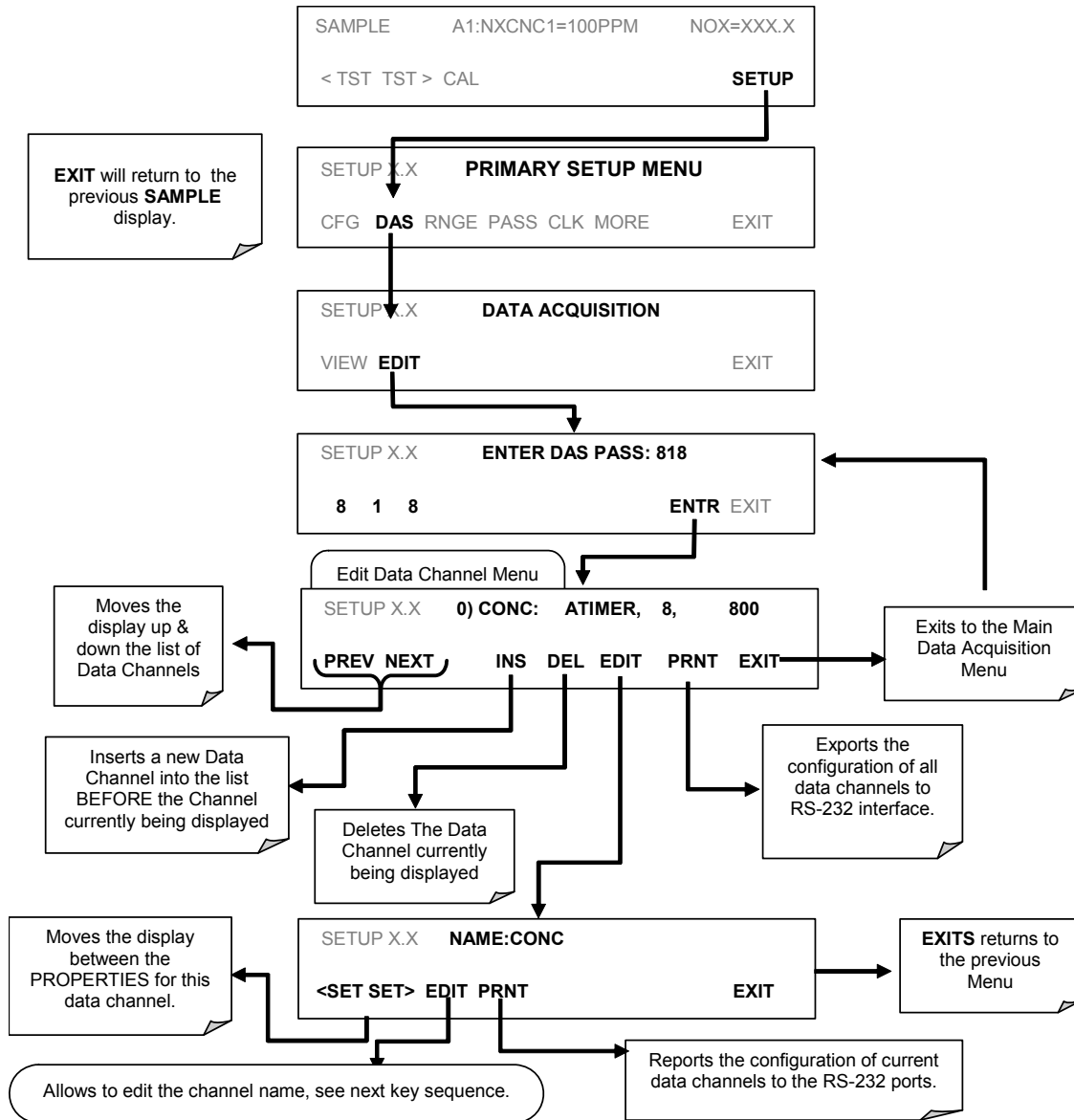
6.7.2.1. Viewing iDAS Data and Settings

iDAS data and settings can be viewed on the front panel through the following keystroke sequence.



6.7.2.2. Editing iDAS Data Channels

iDAS configuration is most conveniently done through the sensor-e.com remote control program. The following list of key strokes shows how to edit using the front panel.



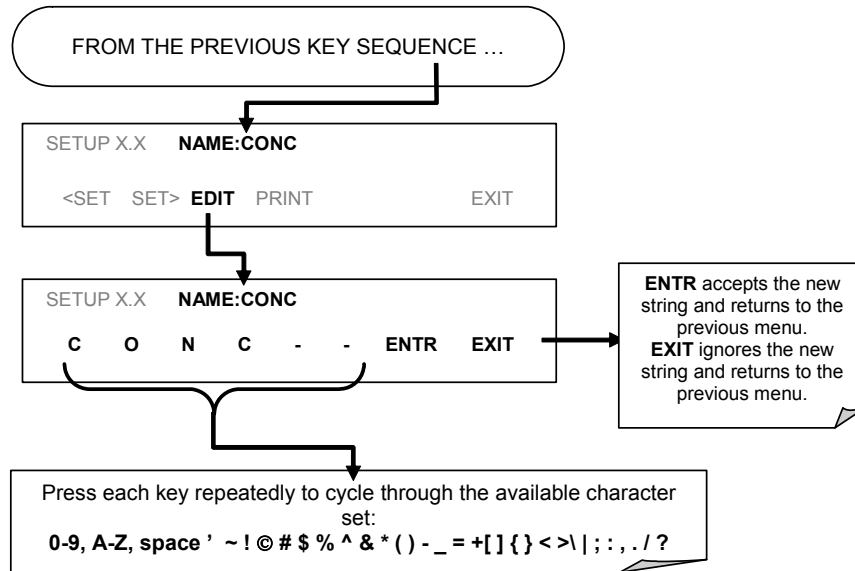
When editing the data channels, the top line of the display indicates some of the configuration parameters. For example, the display line:

0) CONC: ATIMER, 4, 800

Translates to the following configuration:

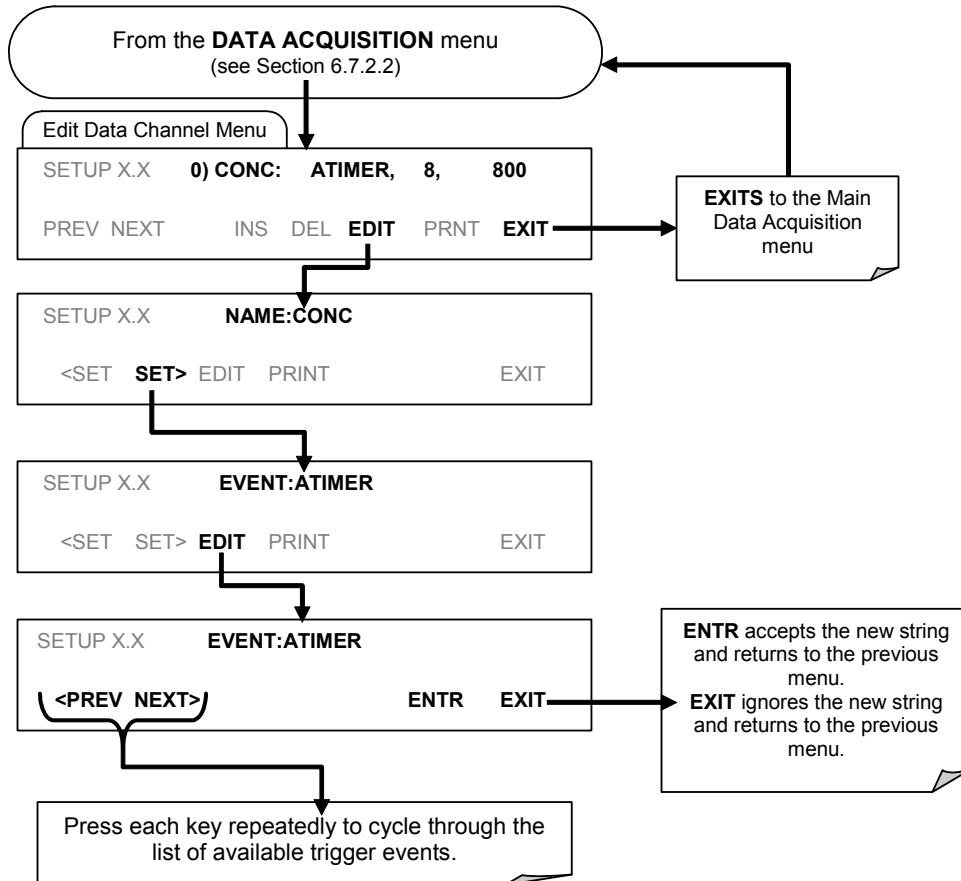
Channel No.: 0
 NAME: CONC
 TRIGGER EVENT: ATIMER
 PARAMETERS: Four parameters are included in this channel
 EVENT: This channel is set up to record 800 data points.

To edit the name of a data channel, follow the above key sequence and then press:



6.7.2.3. Trigger Events

To edit the list of data parameters associated with a specific data channel, press:

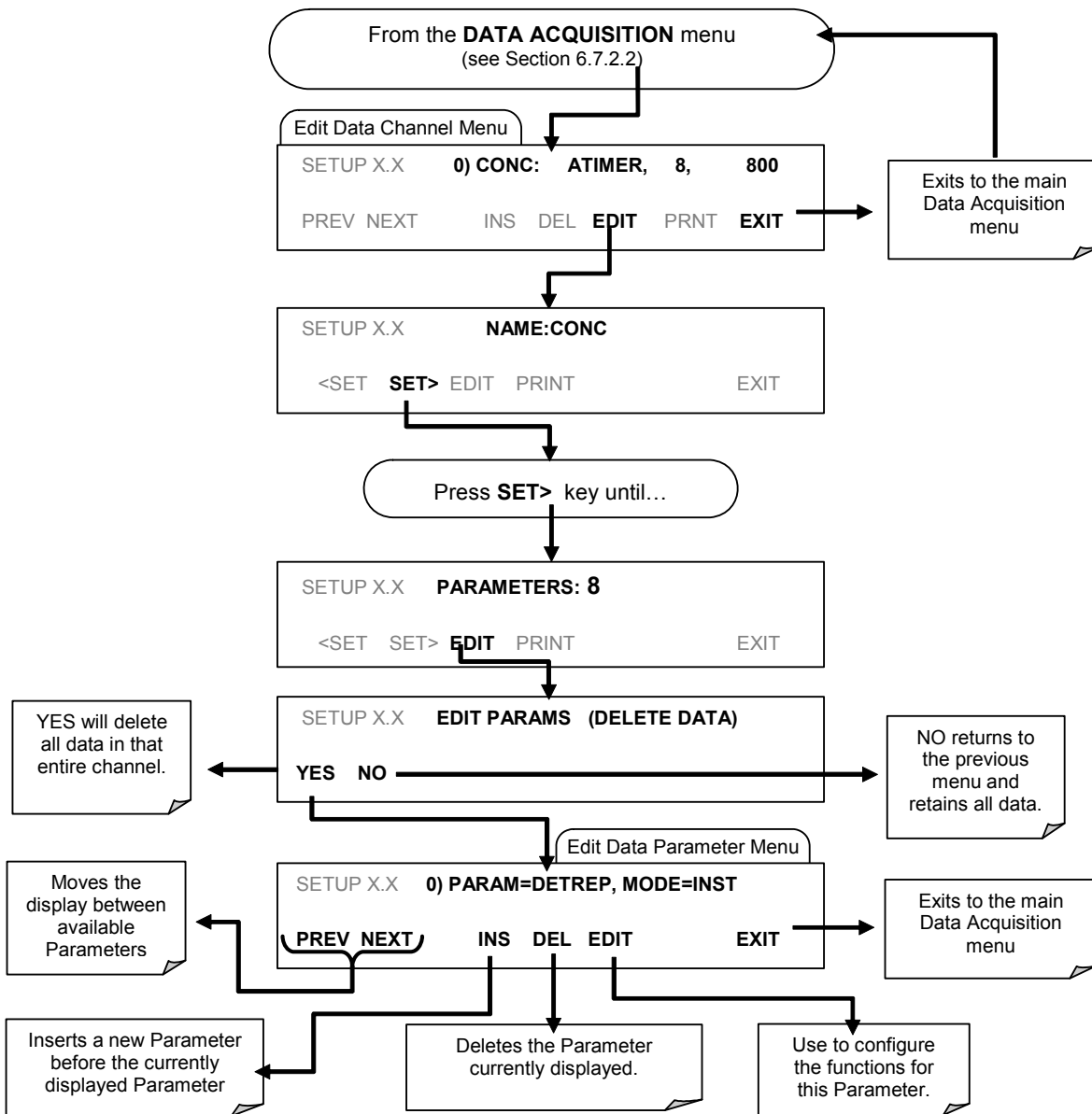


See Appendix A-5 for list of iDAS trigger events available on the TML41M/H.

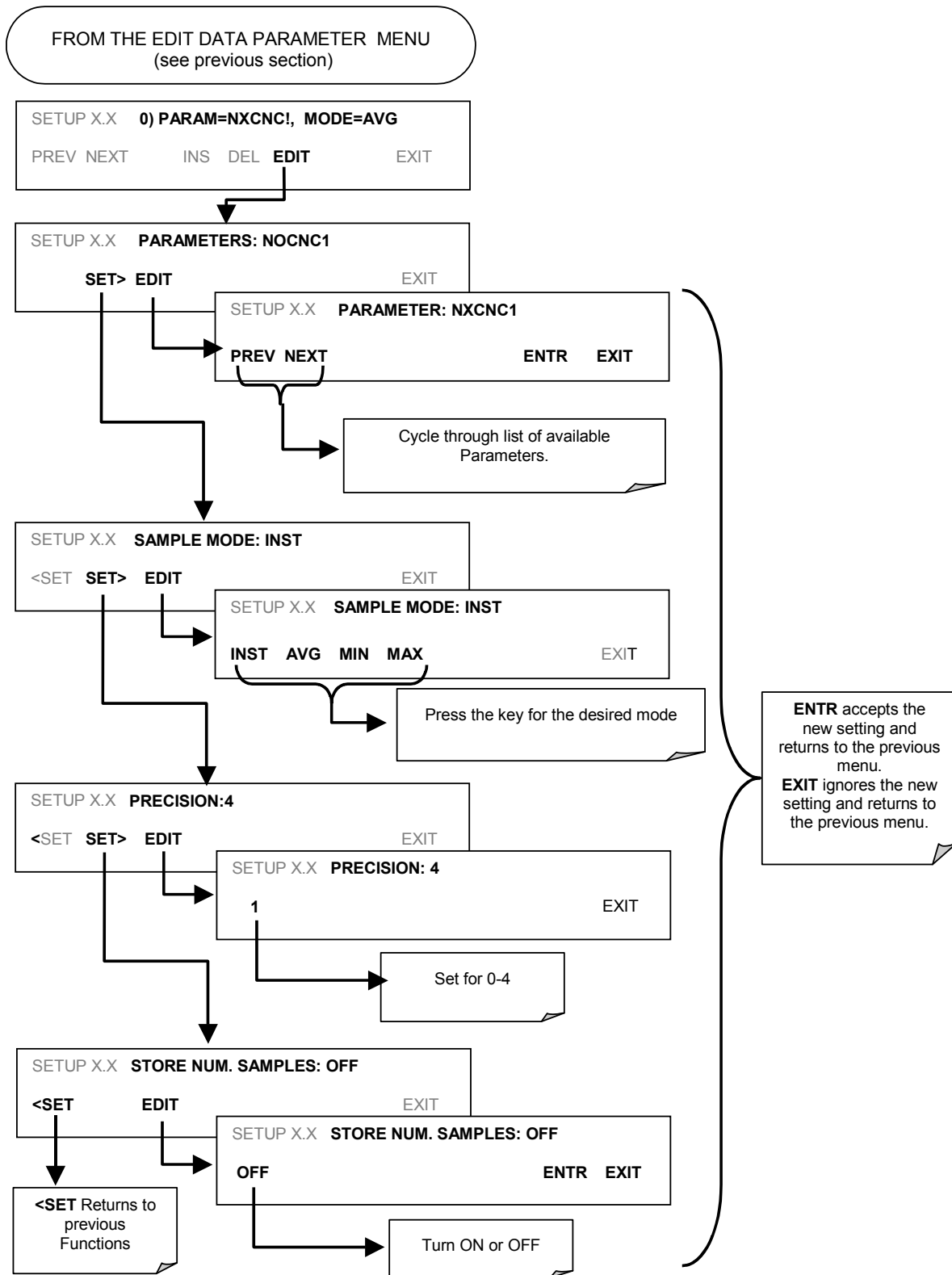
6.7.2.4. Editing iDAS Parameters

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 iDAS can store only data of one format (number of parameter columns etc.) for any given channel. In addition, an iDAS configuration can only be uploaded remotely as an entire set of channels. Hence, remote update of the iDAS will always delete all current channels and stored data.

To modify, add or delete a parameter, follow the instruction shown in section 6.7.2.2 then press:



To configure the parameters for a specific data parameter, press:



See Appendix A-5 for list of iDAS parameters available on the TML41M/H.

6.7.2.5. Sample Period and Report Period

The iDAS defines two principal time periods by which sample readings are taken and permanently recorded:

- **SAMPLE PERIOD:** Determines how often iDAS temporarily records a sample reading of the parameter in volatile memory. The **SAMPLE PERIOD** is set to one minute by default and generally cannot be accessed from the standard iDAS front panel menu, but is available via the instruments communication ports by using sensor-e.com or the analyzer's standard serial data protocol.
SAMPLE PERIOD is only used when the iDAS parameter's sample mode is set for **AVG, MIN** or **MAX**.
- **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 instrument's Disk-on-Chip 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**

In **AVG, MIN** or **MAX** sample modes, the settings for the **SAMPLE PERIOD** and the **REPORT PERIOD** determine the number of data points used each time the average, minimum or maximum is calculated, stored and reported to the COMM ports. The actual sample readings are not stored past the end of the of the chosen **REPORT PERIOD**.

Also, the **SAMPLE PERIOD** and **REPORT PERIOD** intervals are synchronized to the beginning and end of the appropriate interval of the instrument's internal clock.

- If **SAMPLE PERIOD** were 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** were 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 iDAS were 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.

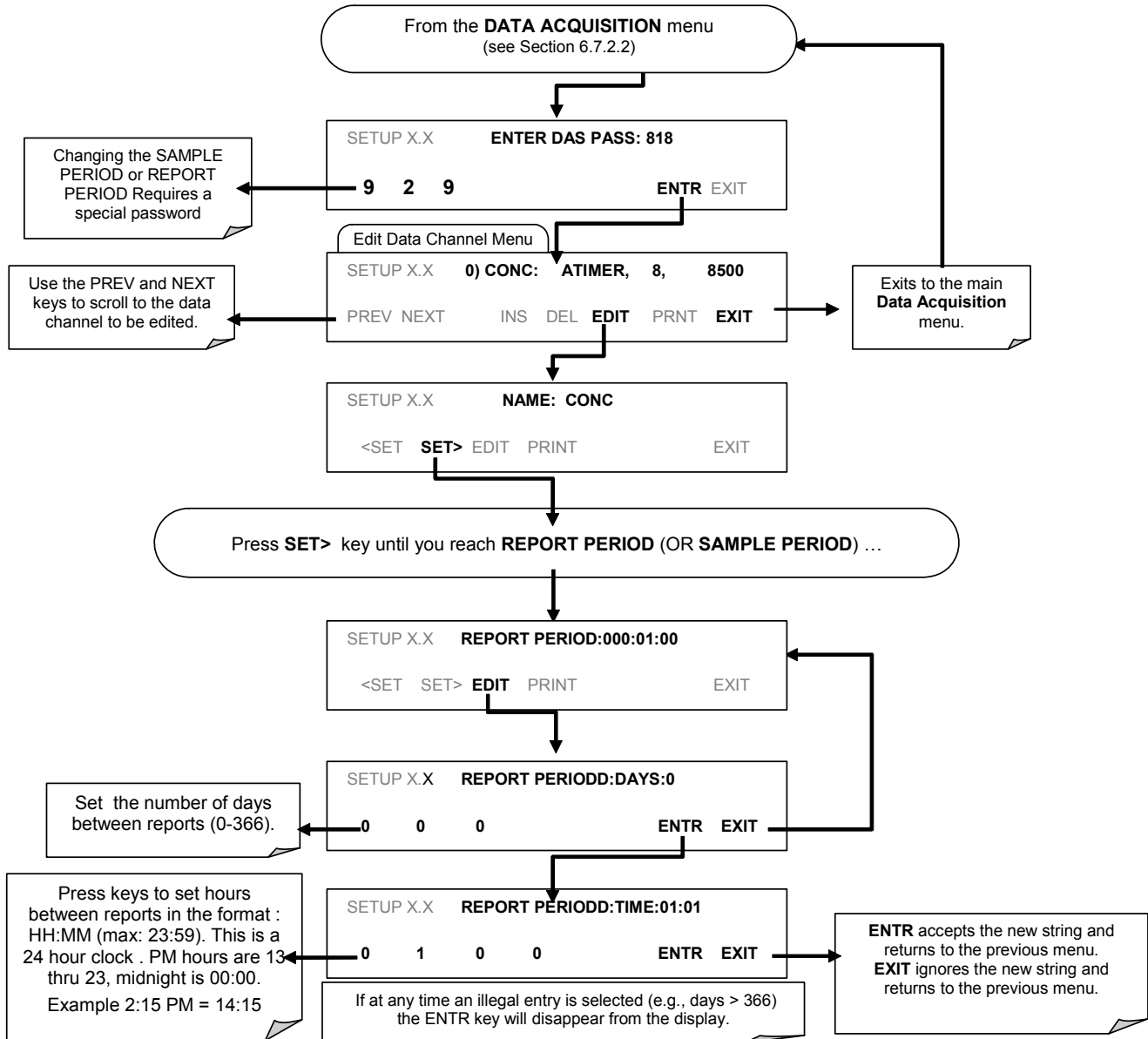
During the next hour (from 8:01 to 9:00) the instrument will take a sample reading every minute and include 60 sample readings.

When the **STORE NUM. SAMPLES** feature is turned on the instrument will also store how many sample readings were used for the **AVG, MIN** or **MAX** calculation but not the readings themselves.

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 so far during that period are lost. Once the instrument is turned back on, the iDAS 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, MIN** or **MAX** calculation. Also, the **STORE NUM. SAMPLES** feature will report the number of sample readings taken since the instrument was restarted.

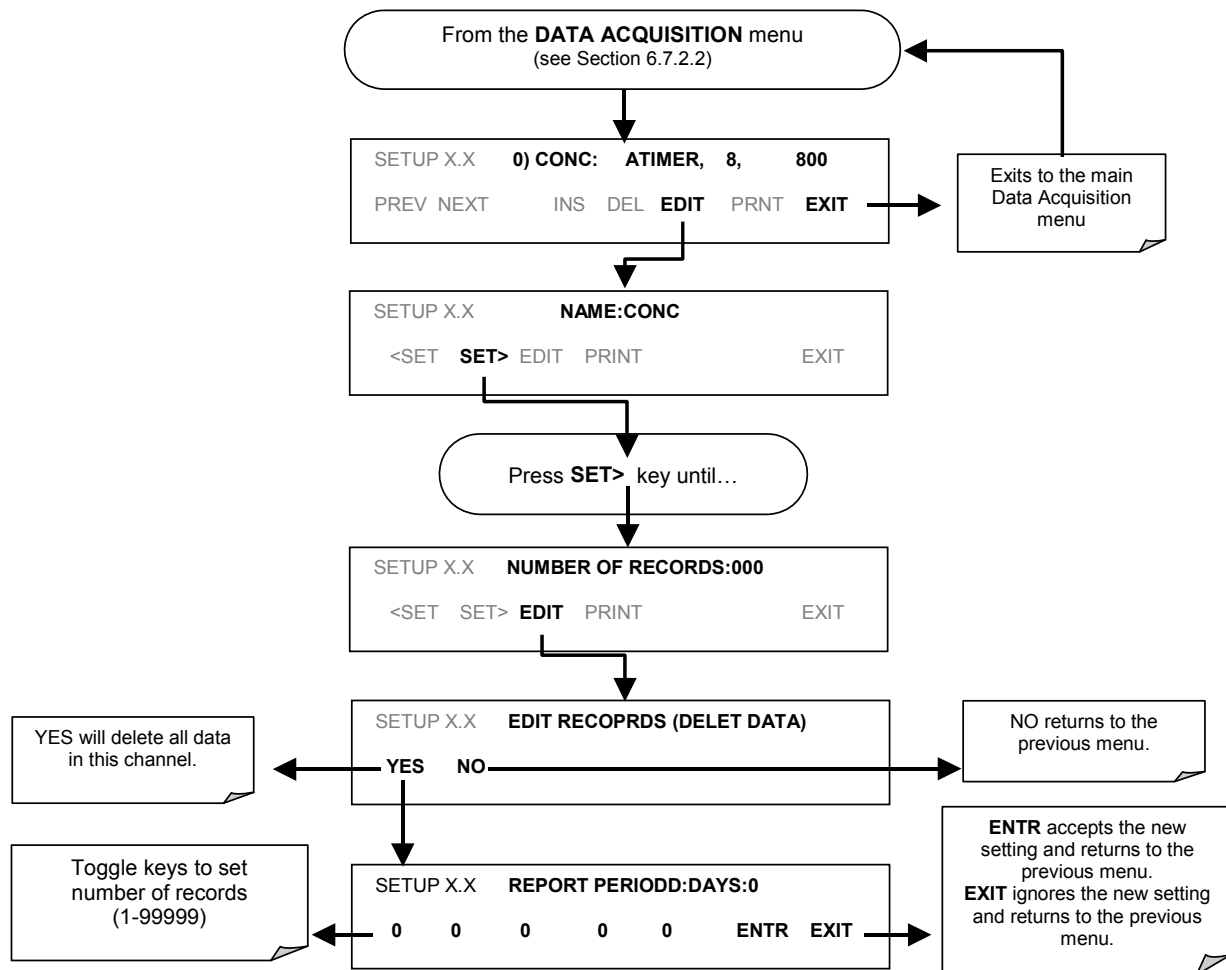
To define the **REPORT PERIOD**, follow the instruction shown in section 6.7.2.2 then press:



6.7.2.6. Number of Records

The number of data records in the TML41M/H is limited to cumulative one million data points in all channels (one megabyte of space on the disk-on-chip). However, the actual number of records is also limited by the total number of parameters and channels and other settings in the iDAS configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points somewhat. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

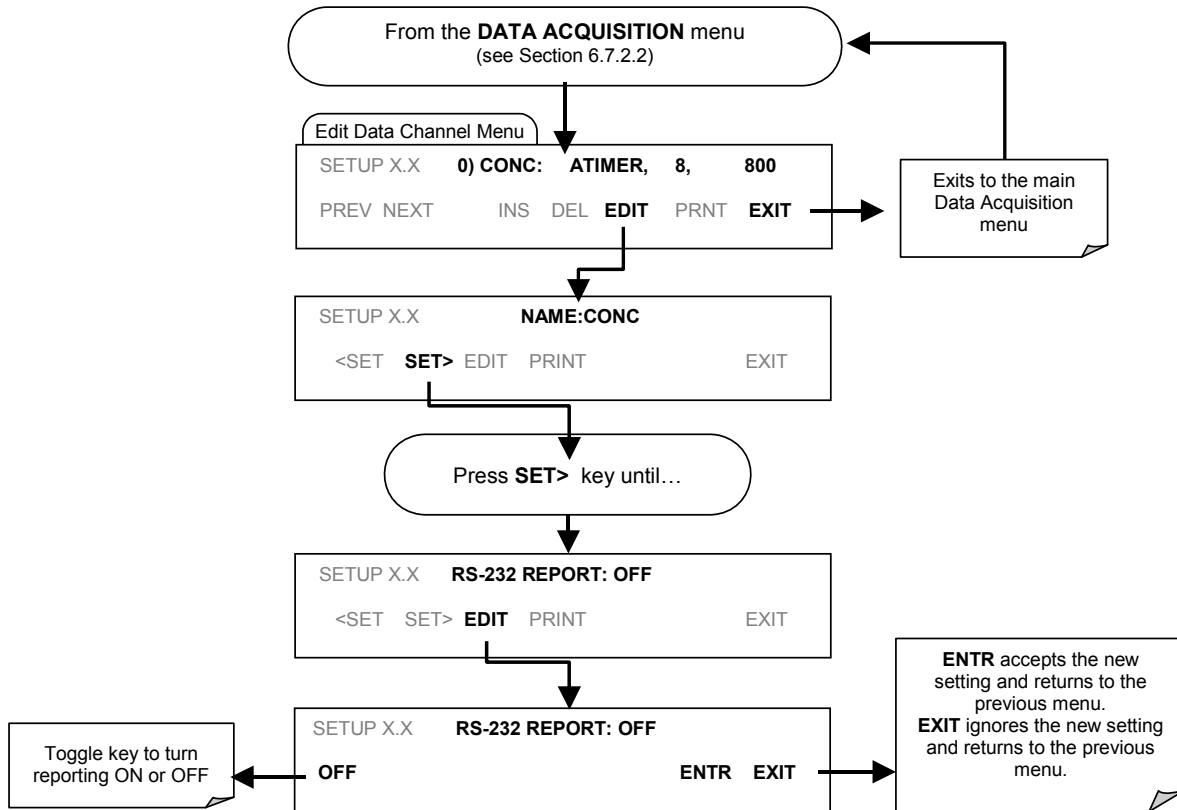
The iDAS will check the amount of available data space and prevent the user from specifying too many records at any given point. If, for example, the iDAS memory space can accommodate 375 more data records, the ENTR key will disappear when trying to specify more than that number of records. This check for memory space may also make an upload of an iDAS configuration with sensor-e.com or a Terminal program fail, if the combined number of records would be exceeded. In this case, it is suggested to either try from the front panel to determine what the maximum number of records can be or use trial-and-error in designing the iDAS script or calculate the number of records using the DAS or sensor-e.com manuals. To set the number of records for one channel from the front panel, follow the instruction shown in section 6.7.2.2 then press.



6.7.2.7. RS-232 Report Function

The TML41M/H iDAS can automatically report data to the communications ports, where they can be captured with a terminal emulation program or simply viewed by the user.

To enable automatic COM port reporting, follow the instruction shown in section 6.7.2.2 then press:



6.7.2.8. Compact Report

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, instead. For example, channel DIAG would report its record in two lines (10 parameters) instead of 10 lines. Individual lines carry the same time stamp and are labeled in sequence.

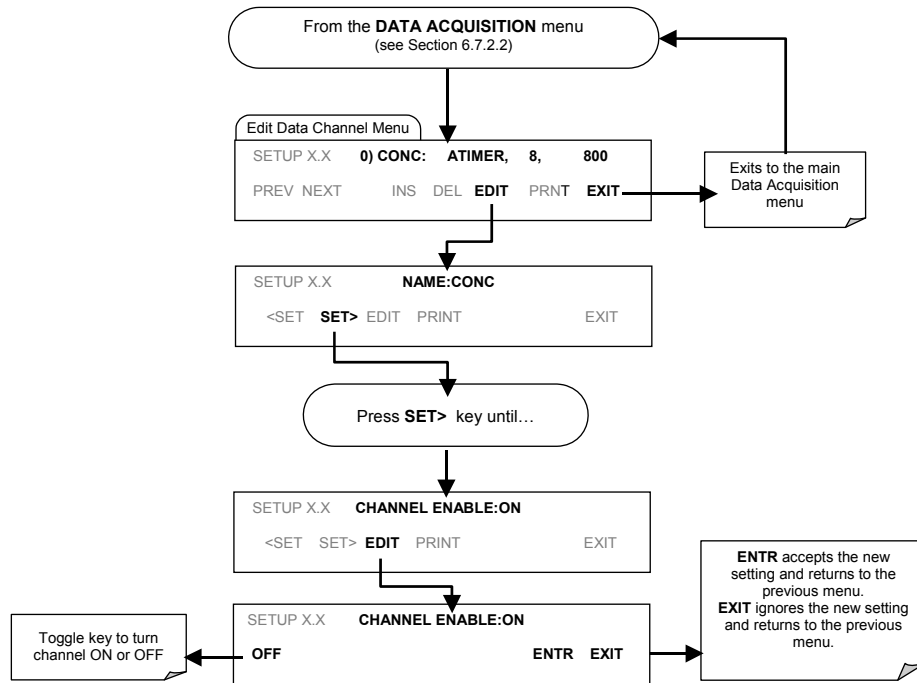
6.7.2.9. Starting Date

This option allows one to specify a starting date for any given channel in case the user wants to start data acquisition only after a certain time and date. If the **Starting Date** is in the past, the iDAS ignores this setting.

6.7.2.10. Disabling/Enabling Data Channels

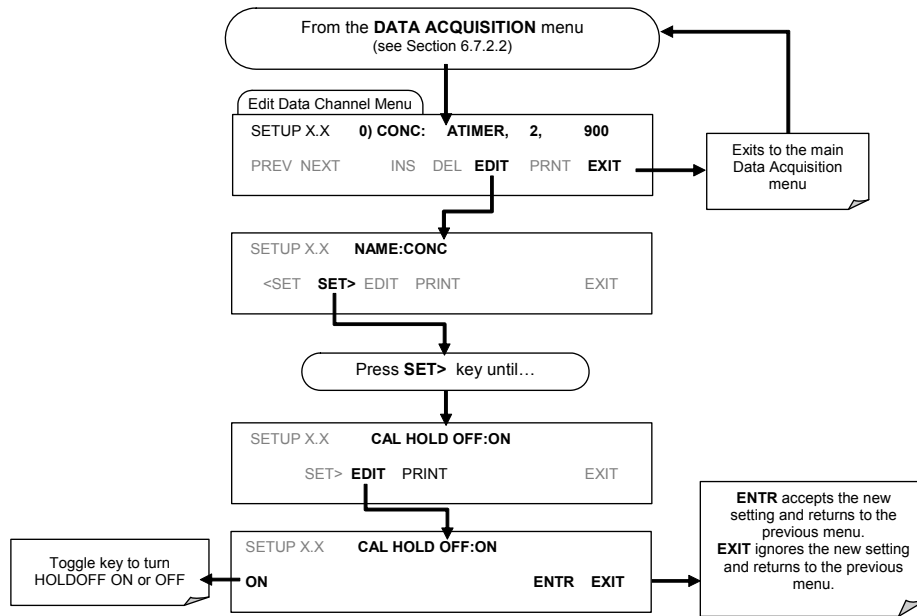
Data channels can be temporarily disabled, which can reduce the read/write wear on the disk-on-chip. The HIRES channel of the TML41M/H, for example, is disabled by default.

To disable a data channel, follow the instruction shown in section 6.7.2.2 then press:



6.7.2.11. HOLDOFF Feature

The iDAS HOLDOFF feature suspends data collection during calibrations and during the DAS_HOLD OFF period which is enabled and specified in the VARS (Section 6.12). To enable or disable the HOLDOFF for any one iDAS channel, follow the instruction shown in section 6.7.2.2 then press:



6.7.3. REMOTE IDAS CONFIGURATION

Editing channels, parameters and triggering events as described in Section 6.7 is much more conveniently done in one step through the sensor-e.com remote control program using the graphical interface shown in Figure 6-4. Refer to Section 6.15 for details on remote access to the TML41M/H analyzer.

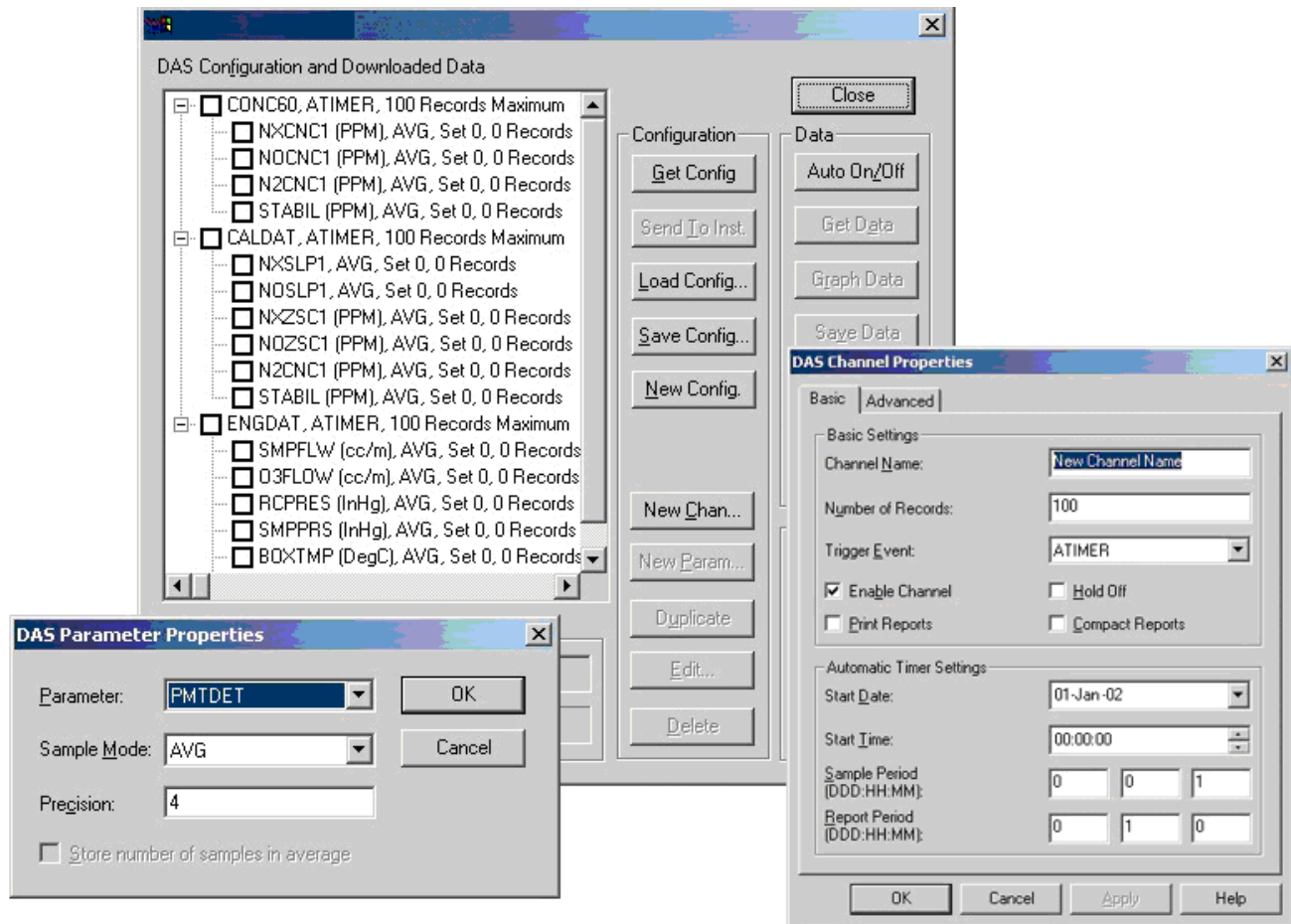


Figure 6-4: sensor-e.com Graphical User Interface for Configuring the iDAS

Once an iDAS 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. Refer to the sensor-e.com manual for details on these procedures. The sensor-e.com user manual (Teledyne Instruments part number 039450000) is included in the sensor-e.com installation file, which can be downloaded at <http://www.teledyne-ml.com>

Although Teledyne Instruments recommends the use of sensor-e.com, the iDAS can also be accessed and configured through a terminal emulation program such as HyperTerminal (Figure 6-5). However, all configuration commands must be created following a strict syntax or be pasted in from of a text file, which was edited offline and then uploaded through a specific transfer procedure.

```

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=REFGND, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF

```

Figure 6-5: iDAS Configuration Through a Terminal Emulation Program

Both procedures are best started by downloading the default iDAS 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.

CAUTION

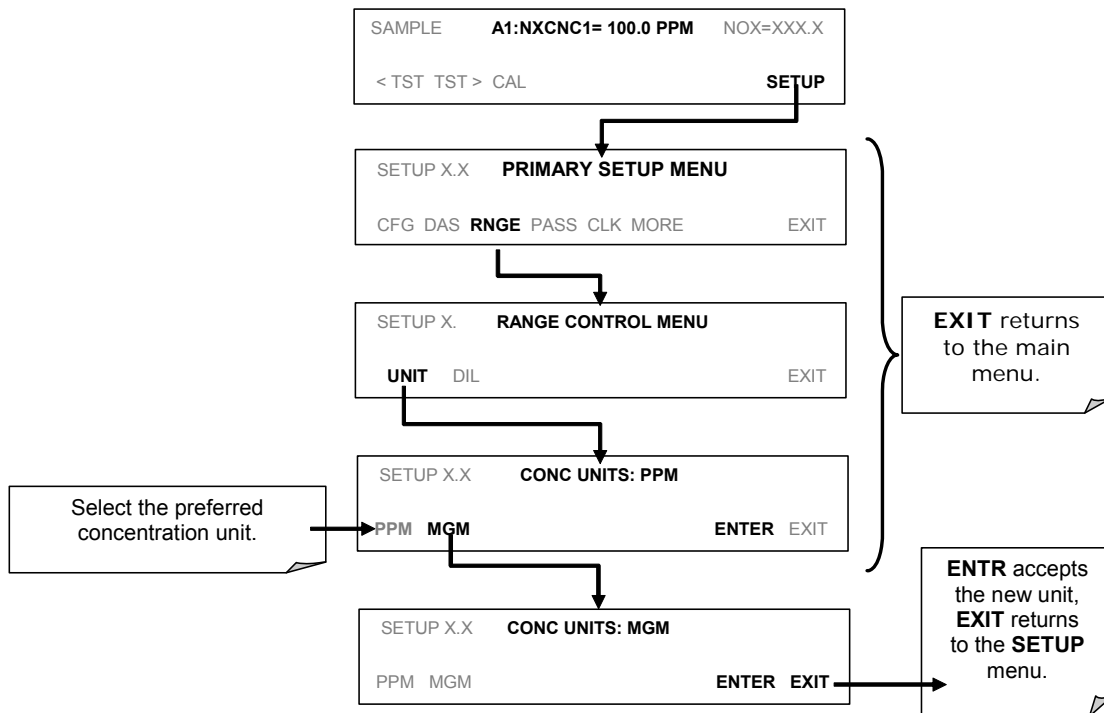
Whereas the editing, adding and deleting of iDAS channels and parameters of one channel through the front-panel keyboard can be done without affecting the other channels, uploading an iDAS configuration script to the analyzer through its communication ports will erase all data, parameters and channels by replacing them with the new iDAS configuration. It is advised to download and backup all data and the original iDAS configuration before attempting any iDAS changes.

6.8. SETUP → RNGE: RANGE UNITS AND DILUTION CONFIGURATION

This Menu is used to set the units of measure to be associated with the analyzer’s reporting ranges. See Section 6.13.4.2 for more information on reporting ranges vs. physical ranges and for instruments with the sample gas dilution option operating, to set the dilution ratio.

6.8.1. RANGE UNITS

The TML41M/H can display concentrations in parts per million (10^6 mols per mol, PPM) or milligrams per cubic meter (mg/m^3 , MG). Changing units affects all of the display, COM port and iDAS values for all reporting ranges regardless of the analyzer’s range mode. To change the concentration units:



Conversion factors from volumetric to mass units used in the TML41M/H:

$$\text{NO: ppm} \times 1.34 = \text{mg}/\text{m}^3$$

$$\text{NO}_2: \text{ppm} \times 2.05 = \text{mg}/\text{m}^3$$

Concentrations displayed in mg/m^3 and $\mu\text{g}/\text{m}^3$ use 0°C and 760 Torr as standard temperature and pressure (STP). Consult your local regulations for the STP used by your agency. EPA protocol applications, for example, use 25°C as the reference temperature. Changing the units may cause a bias in the measurements if standard temperature and pressure other than 0°C and 760 Torr are used. This problem can be avoided by recalibrating the analyzer after any change from a volumetric to a mass unit or vice versa.

CAUTION

In order to avoid a reference temperature bias, the analyzer must be recalibrated after every change in reporting units.

6.8.2. DILUTION RATIO

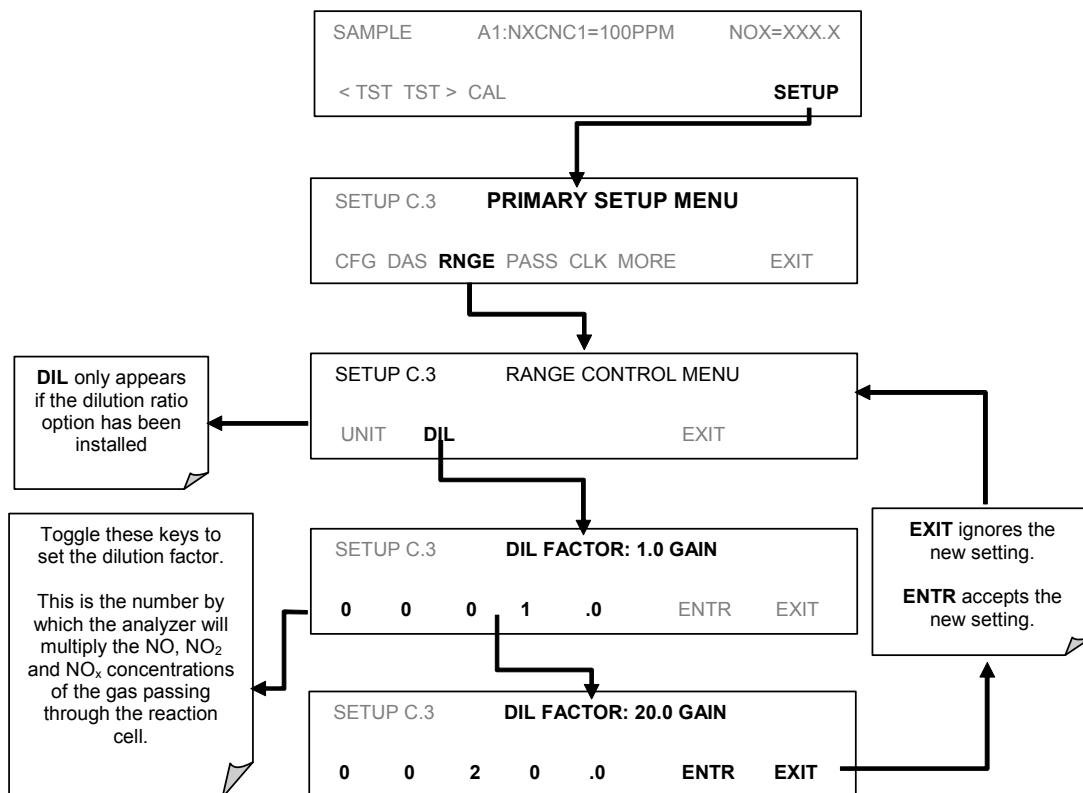
The dilution ratio is a software option that allows the user to compensate for any dilution of the sample gas before it enters the sample inlet.

- The **SPAN** value entered during calibration is the maximum expected concentration of the undiluted calibration gas
- The span gas should be either supplied through the same dilution inlet system as the sample gas or be supplied at an appropriately lower actual concentration.

For example, with a dilution set to 100, a 1 ppm gas can be used to calibrate a 100 ppm sample gas if the span gas is not routed through the dilution system.

On the other hand, if a 100 ppm span gas is used, it needs to pass through the same dilution steps as the sample gas.

- Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):
- The analyzer will multiply the measured gas concentrations with this dilution factor and displays the result.



The analyzer multiplies the measured gas concentrations with this dilution factor and displays the result.

Calibrate the analyzer. Once the above settings have been entered, the instrument needs to be recalibrated using one of the methods discussed in Chapter 7.

6.9. SETUP → PASS: PASSWORD FEATURE

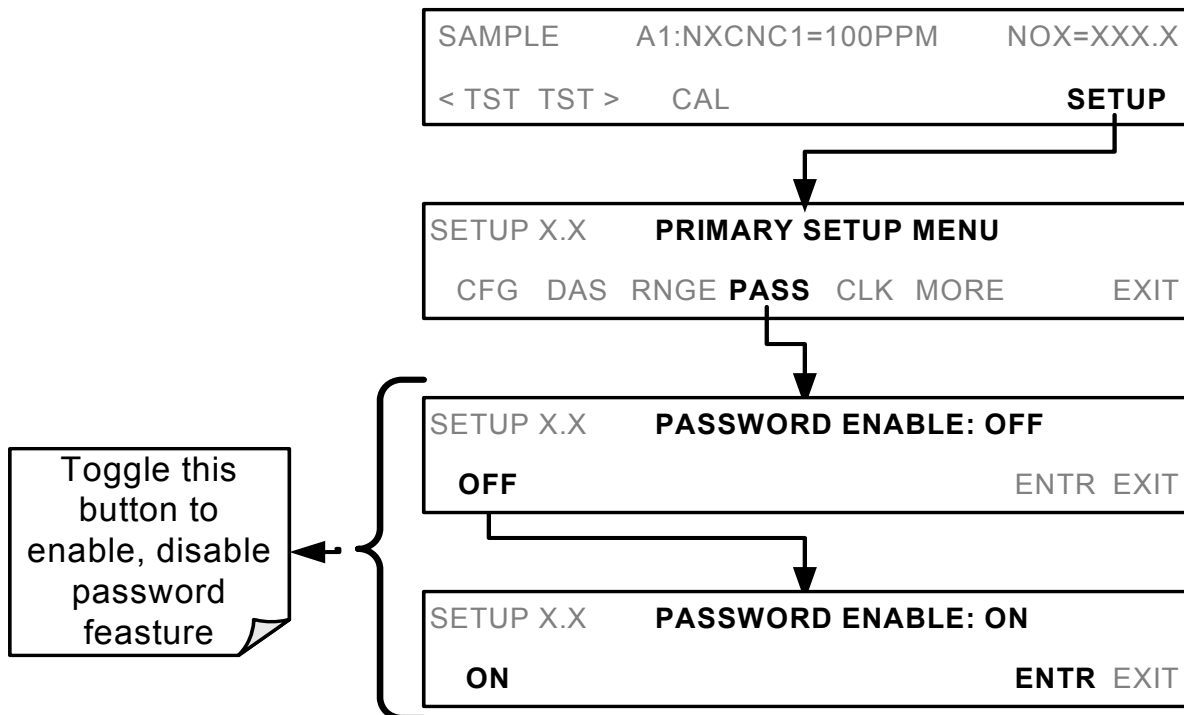
The TML41M/H provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function is requested.

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.

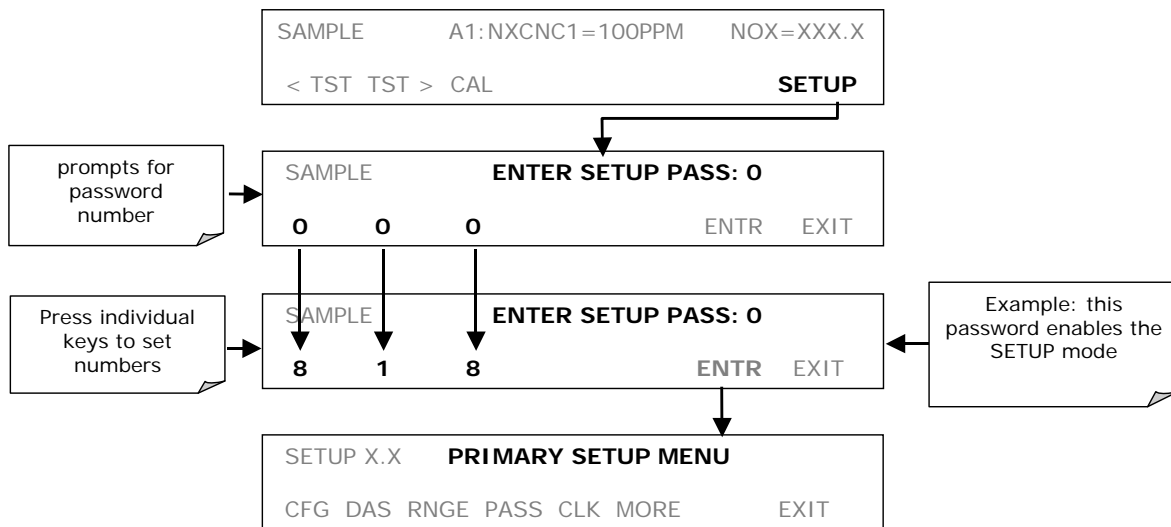
Table 6-10: Password Levels

PASSWORD	LEVEL	MENU ACCESS ALLOWED
No password	Operator	TEST, MSG, CLR
101	Maintenance	CAL, CALZ, CALS
818	Configuration	SETUP, VARS, DIAG

To enable or disable passwords, press the following keystroke sequence:



Example: If all passwords are enabled, the following keypad sequence would be required to enter the SETUP menu:

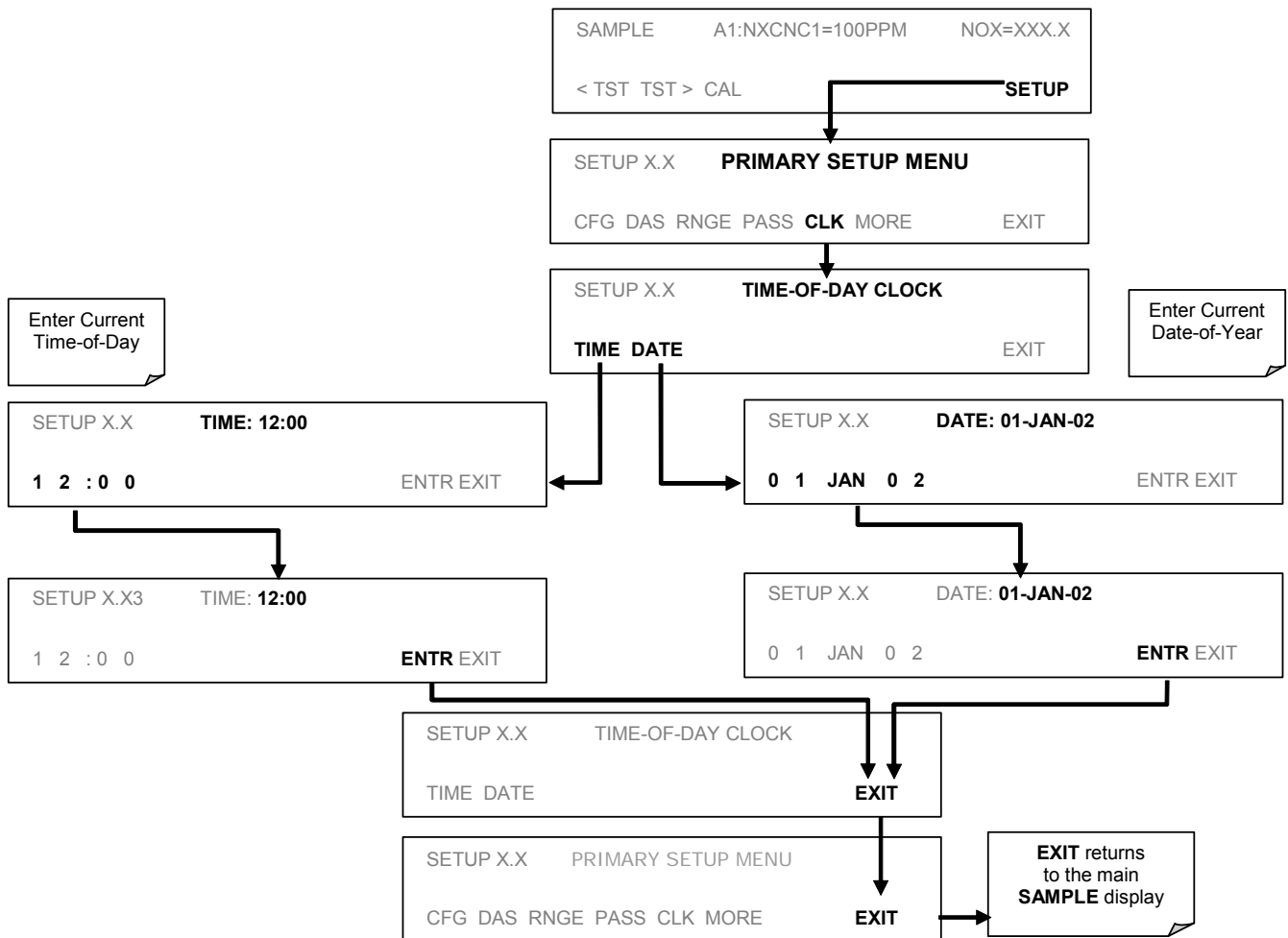


Note that the instrument still prompts for a password when entering the VARS and DIAG menus, even if passwords are disabled, but it displays the default password (818) upon entering these menus. The user only has to press ENTR to access the password-protected menus but does not have to enter the required number code.

6.10. SETUP → CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK

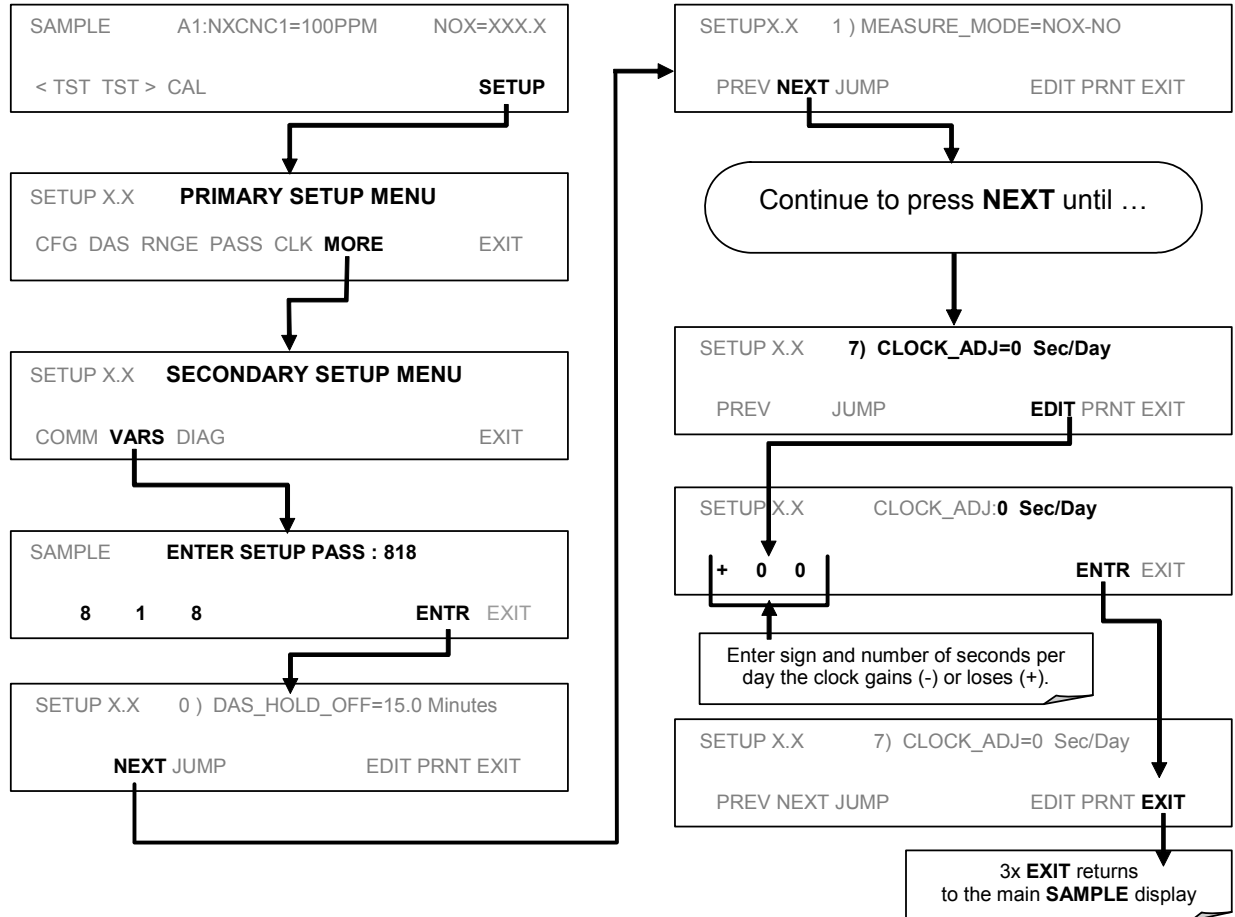
The TML41M/H has a built-in clock for the AutoCal timer, Time **TEST** function, and time stamps on COM port messages and iDAS data entries.

To set the time-of-day, press:



In order to compensate for CPU clocks which run fast or slow, there is a variable to speed up or slow down the clock by a fixed amount every day.

To change this variable, press:



6.11. SETUP → MORE → COMM: SETTING UP THE ANALYZER'S COMMUNICATION PORTS

The TML41M/H is equipped with two serial communication ports located on the rear panel (see Figure 3-2). Both ports operate similarly and give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal. By default, both ports operate on the RS-232 protocol.

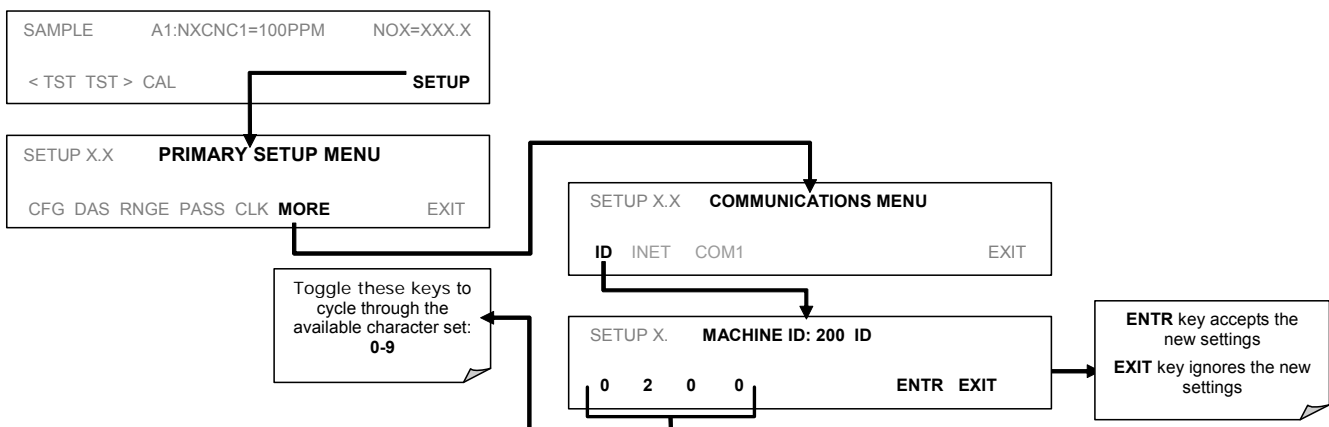
The COM1 port can also be configured to operate in single or RS-232 multidrop mode (option 62; See Section 5.9.2 and 6.11.7).

The COM2 port can be configured for standard RS-232 operation, half-duplex RS-485 communication or for access via a LAN by installing the Teledyne Instruments Ethernet interface card (option 63; see Section 5.9.3 and 6.11.6).

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, dataloggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne Instruments sales for more information on CAS systems.

6.11.1. ANALYZER ID

Each type of Teledyne Instruments analyzer is configured with a default ID code. The default ID code for all TML41M/H analyzers is **200**. The ID number is only important if more than one analyzer is connected to the same communications channel such as when several analyzers are on the same Ethernet LAN (see Section 6.11.6); in a RS-232 multidrop chain (see Section 6.11.7) or operating over a RS-485 network (see 6.11.4). If two analyzers of the same model type are used on one channel, the ID codes of one or both of the instruments needs to be changed so that they are unique to the instruments. To edit the instrument's ID code, press:



The ID can be any 4 digit number and can also be used to identify analyzers in any number of ways (e.g. location numbers, company asset number, etc.)

6.11.2. COM PORT DEFAULT SETTINGS

As received from the factory, the analyzer is set up to emulate a DCE or modem, with pin 3 of the DB-9 connector designated for receiving data and pin 2 designated for sending data.

- **COM1:** RS-232 (fixed) DB-9 male connector.
 - **Baud rate:** 19200 bits per second (baud).
 - **Data Bits:** 8 data bits with 1 stop bit.
 - **Parity:** None.
- **COM2:** RS-232 (configurable), DB-9 female connector.
 - **Baud rate:** 115000 bits per second (baud).
 - **Data Bits:** 8 data bits with 1 stop bit.
 - **Parity:** None.

CAUTION

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

6.11.3. RS-232 COM PORT CABLE CONNECTIONS

In its default configuration, the TML41M/H analyzer has two available RS-232 Com ports accessible via 2 DB-9 connectors on the back panel of the instrument. The COM1 connector is a male DB-9 connector and the COM2 is a female DB9 connector.

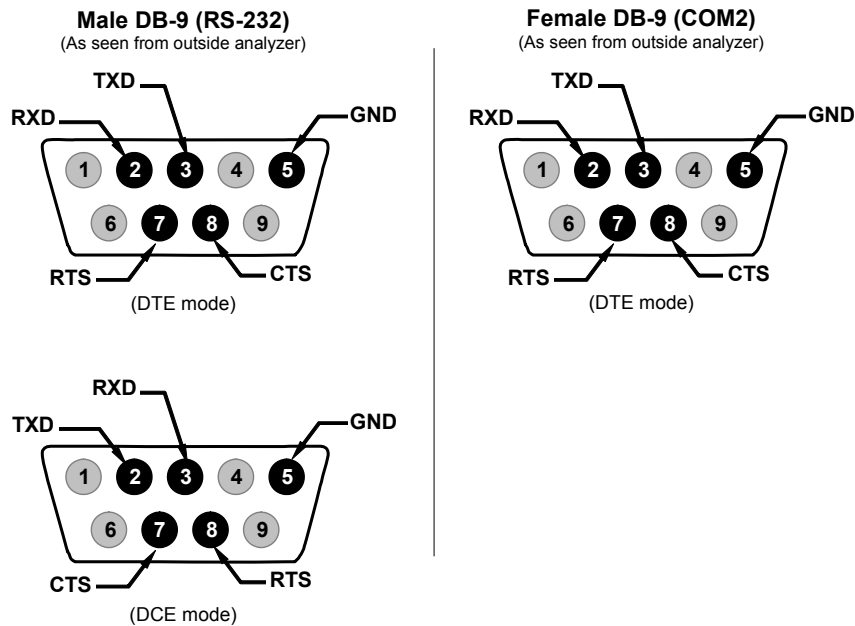


Figure 6-6: Back Panel connector Pin-Outs for COM1 & COM2 in RS-232 mode.

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, CN3 (COM1) and CN4 (COM2).

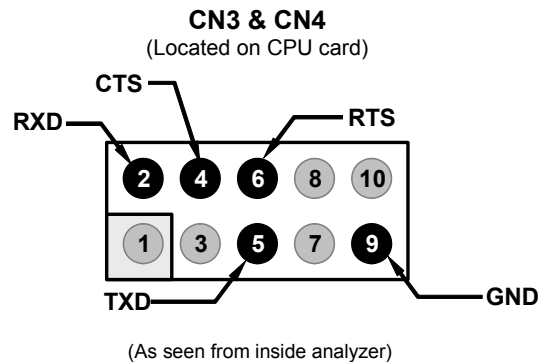


Figure 6-7: CPU connector Pin-Outs for COM1 & COM2 in RS-232 mode.

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

- Part number WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of COM1 with the serial port of most personal computers. Also available as Option 60 (see Section 5.9.1).
- Part number 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.

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 for COM 1 are not lit, use small switch on the rear panel to switch it between DTE and DCE modes (see 16.10.5). If both LEDs are still not illuminated, check the cable for proper wiring.

6.11.4. RS-485 CONFIGURATION OF COM2

As delivered from the factory, COM2 is configured for RS-232 communications. This port can be re-configured for operation as a non-isolated, half-duplex RS-485 port capable of supporting up to 32 instruments with a maximum distance between the host and the furthest instrument being 4000 feet. If you require full-duplex or isolated operation, please contact Teledyne Instruments Customer Service.

- To reconfigure COM2 as an RS-485 port, set switch 6 of SW1 to the ON position (see Figure 6-8).
- The RS-485 port can be configured with or without a 150 Ω termination resistor. To include the resistor, install jumper at position JP3 on the CPU board (see Figure 6-8). To configure COM2 as an un-terminated RS-485 port leave JP3 open.

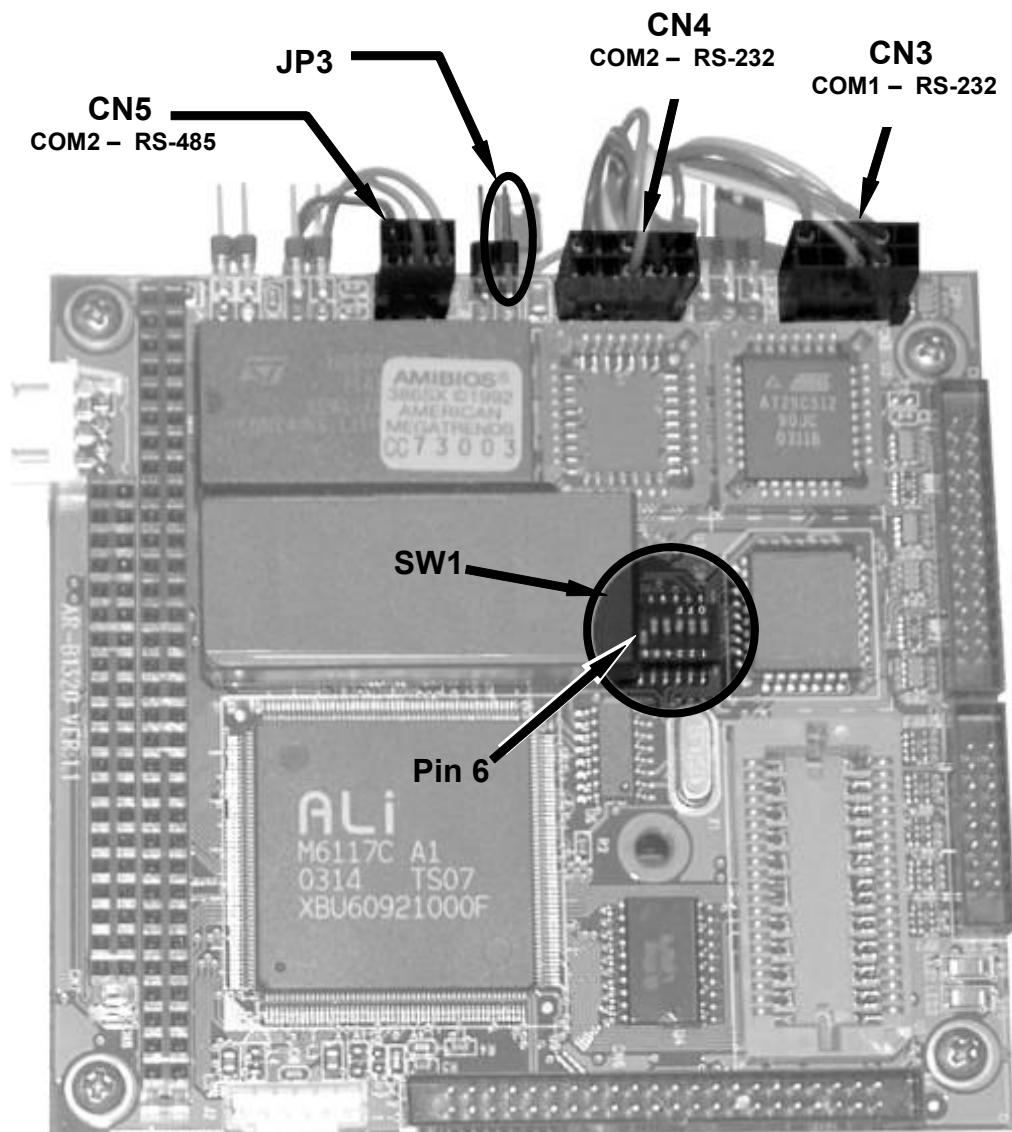


Figure 6-8: CPU card Locations of RS-232/485 Switches, Connectors and Jumpers

When COM2 is configured for RS-485 operation the port uses the same female DB-9 connector on the back of the instrument as when COM2 is configured for RS-232 operation, however, the pin assignments are different.

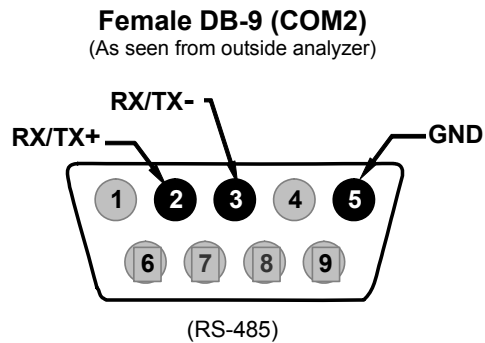


Figure 6-9: Back Panel connector Pin-Outs for COM2 in RS-485 mode.

The signal from this connector is routed from the motherboard via a wiring harness to a 6-pin connector on the CPU card, CN5.

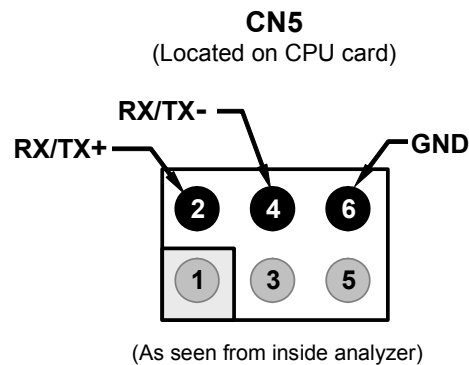


Figure 6-10: CPU connector Pin-Outs for COM2 in RS-485 mode.

6.11.5. DTE AND DCE COMMUNICATION

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 allows the user to set the configuration of COM1 for one of these two modes. This switch exchanges the receive and transmit lines on COM1 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

6.11.6. ETHERNET CARD CONFIGURATION

When equipped with the optional Ethernet interface, the analyzer can be connected to any standard 10BaseT 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 internet to the analyzer using sensor-e.com, terminal emulators or other programs.

The firmware on board the Ethernet card automatically sets the communication modes and baud rate (115 200 kBaud) for the **COM2** port. Once the Ethernet option is installed and activated, the **COM2** submenu is replaced by a new submenu, **INET**. This submenu is used to manage and configure the Ethernet interface with your LAN or Internet Server(s).

The card has four LEDs that are visible on the rear panel of the analyzer, indicating its current operating status.

Table 6-11: Ethernet Status Indicators

LED	FUNCTION
LNK (green)	ON when connection to the LAN is valid.
ACT (yellow)	Flickers on any activity on the LAN.
TxD (green)	Flickers when the RS-232 port is transmitting data.
RxD (yellow)	Flickers when the RS-232 port is receiving data.

6.11.6.1. Ethernet Card COM2 Communication Modes and Baud Rate

The firmware on board the Ethernet card automatically sets the communication modes for the COM2 port. The baud rate is also automatically set at 115 200 kBaud.

6.11.6.2. Configuring the Ethernet Interface Option using DHCP

The Ethernet option for your TML41M/H uses Dynamic Host Configuration Protocol (DHCP) to automatically configure its interface with your LAN. This requires your network servers also be running DHCP. The analyzer will do this the first time you turn the instrument on after it has been physically connected to your network. Once the instrument is connected and turned on it will appear as an active device on your network without any extra set up steps or lengthy procedures.

Should you need to, the Ethernet configuration properties are viewable via the analyzer's front panel See Table 6-12.

Table 6-12: LAN/Internet Configuration Properties

PROPERTY	DEFAULT STATE		DESCRIPTION
DHCP STATUS	On	Editable	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	Configured by DHCP	EDIT key disabled when DHCP is ON	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	Configured by DHCP	EDIT key disabled when DHCP is ON	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	Configured by DHCP	EDIT key disabled when DHCP is ON	Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN the device is connected to. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent by devices with different masks and assumed to be outside of the LAN and are routed through gateway computer onto the Internet.
TCP PORT¹	3000	Editable	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne Instruments' sensor-e.com.
HOST NAME	M200EH (EM)	Editable	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. While the default setting for all Teledyne Instruments analyzers is the model number, the host name may be changed to fit customer needs.
¹ Do not change the setting for this property unless instructed to by Teledyne Instruments Customer Service personnel.			

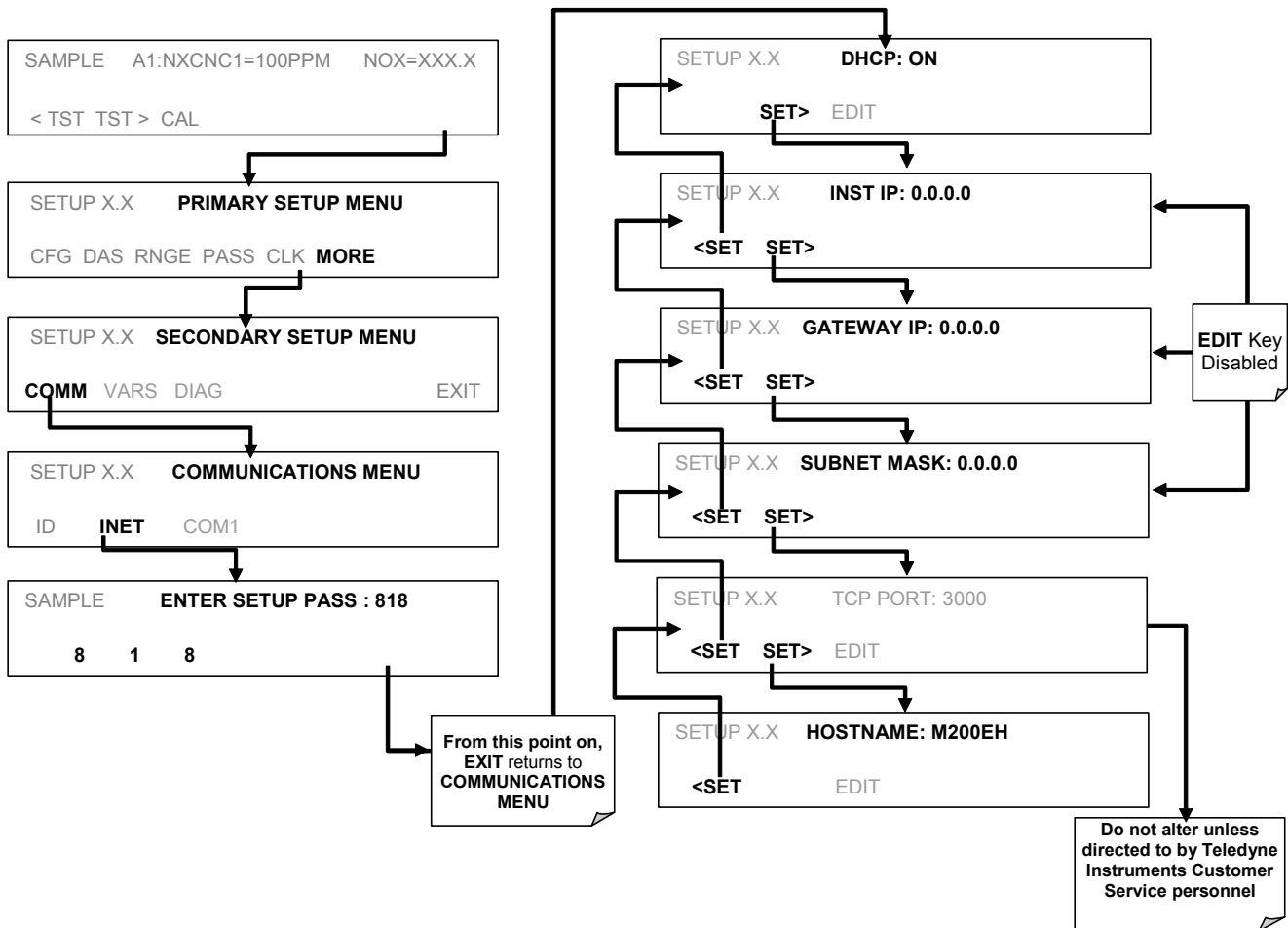
NOTE

It is a good idea to check these settings the first time you power up your analyzer after it has been physically connected to the LAN/Internet to make sure that the DHCP has successfully downloaded the appropriate information from your network server(s).

If the gateway IP, instrument IP and the subnet mask are all zeroes (e.g. "0.0.0.0"), the DHCP was not successful.

You may have to manually configure the analyzer's Ethernet properties. See your network administrator.

To view the above properties, press:



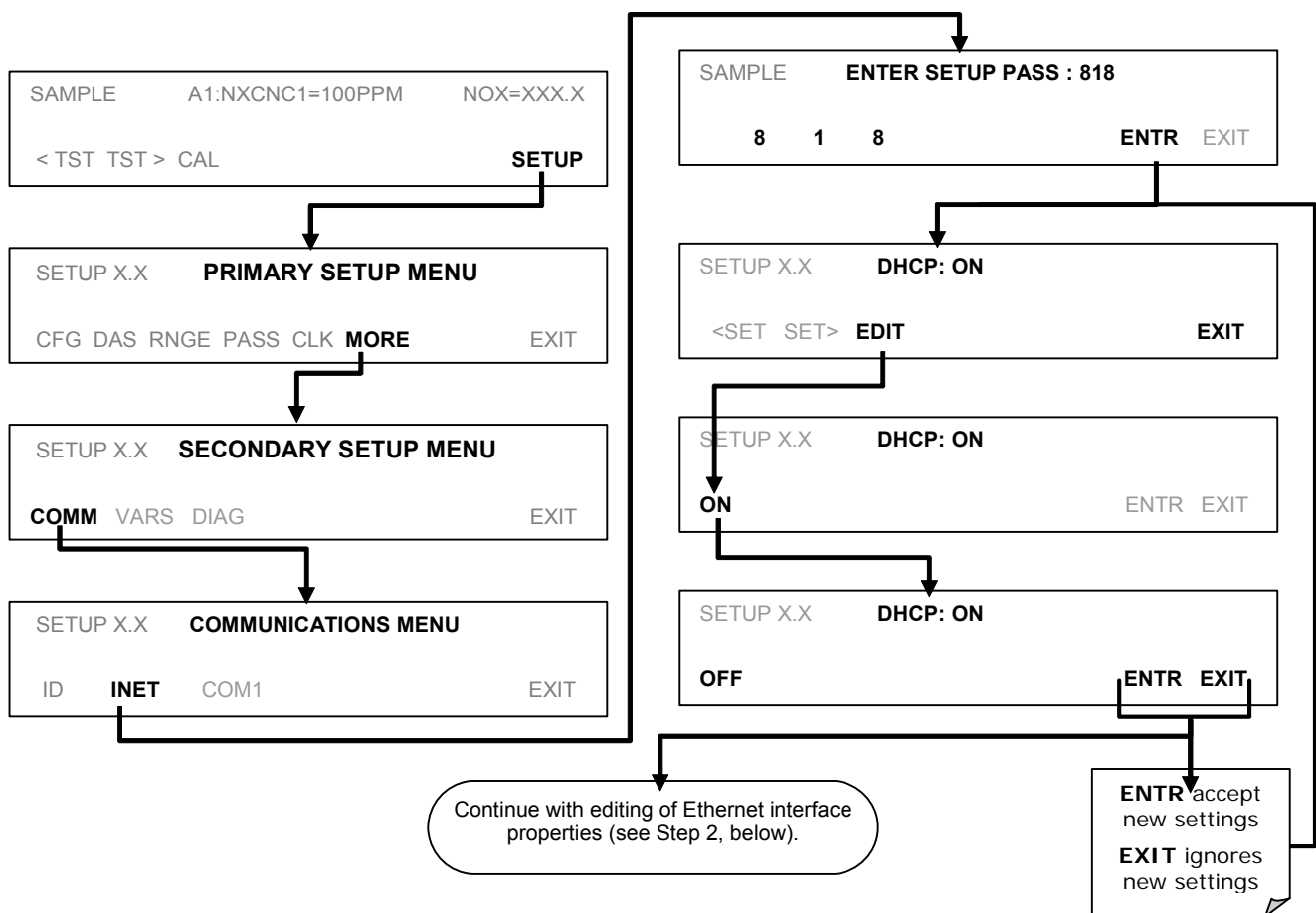
6.11.6.3. Manually Configuring the Network IP Addresses

There are several circumstances when you may need to manually configure the interface settings of the analyzer's Ethernet card. The **INET** sub-menu may also be used to edit the Ethernet card's configuration properties

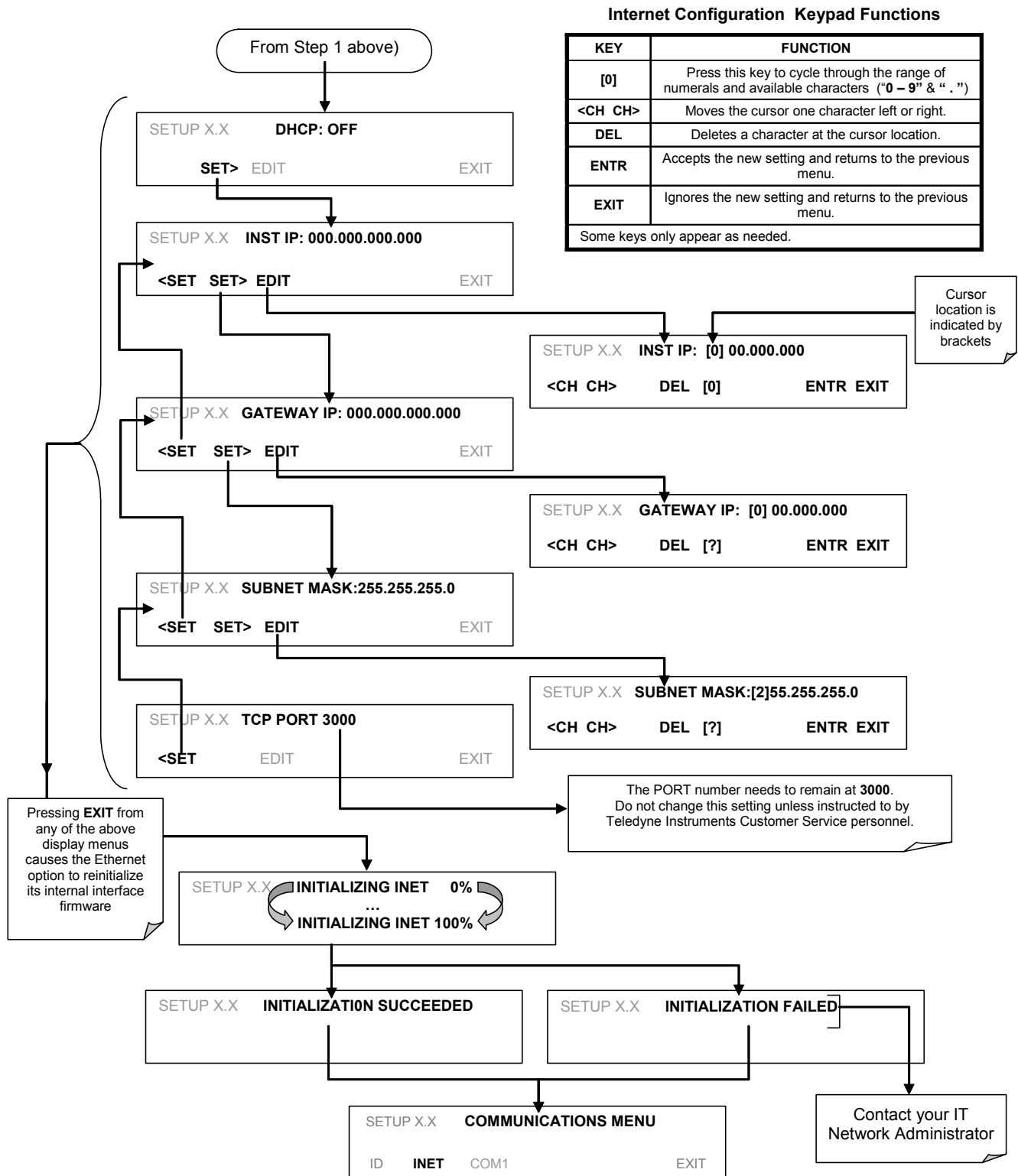
- Your LAN is not running a DHCP software package,
- The DHCP software is unable to initialize the analyzer's interface;
- You wish to program the interface with a specific set of IP addresses that may not be the ones automatically chosen by DHCP.

Editing the Ethernet Interface properties is a two step process.

STEP 1: Turn DHCP OFF: While DHCP is turned **ON**, the ability to manually set **INSTRUMENT IP**, **GATEWAY IP** and **SUBNET MASK** is disabled



STEP 2: Configure the **INSTRUMENT IP**, **GATEWAY IP** and **SUBNET MASK** addresses by pressing:



6.11.6.4. Changing the Analyzer's HOSTNAME

The **HOSTNAME** is the name by which the analyzer appears on your network. The default name for all Teledyne Instruments TML41M/HE analyzers is **M200E**. To change this name, particularly if you have more than one TML41M/H analyzer on your network, press.

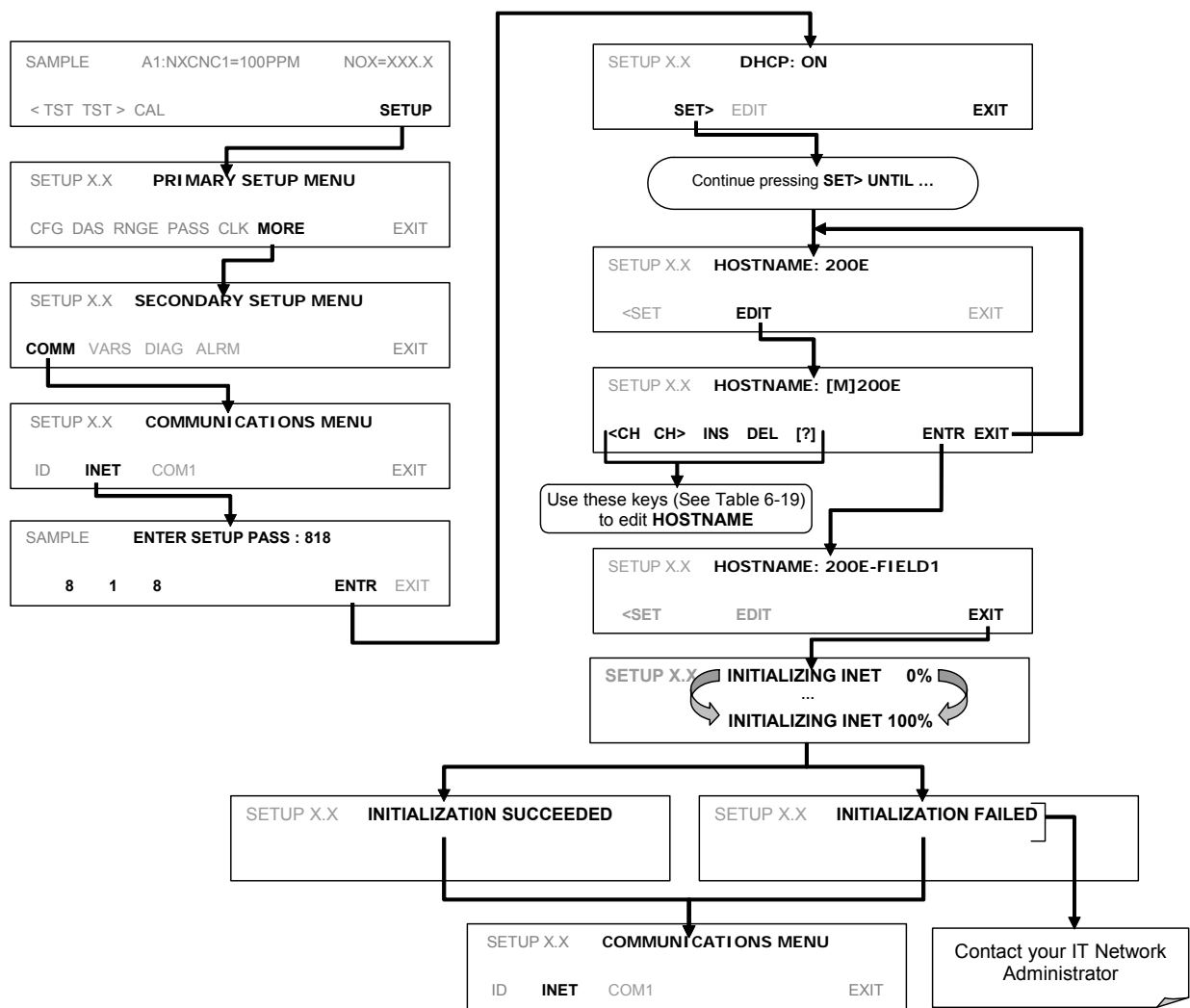


Table 6-13: Internet Configuration Keypad Functions

KEY	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this key to cycle through the range of numerals and characters available for insertion. 0-9, A-Z, space, ' ~ ! @ # \$ % ^ & * () - _ = + [] { } < > \ ; : , . / ?
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.
Some keys only appear as needed.	

6.11.7. MULTIDROP RS-232 SET UP

The RS-232 multidrop consists of a printed circuit assembly that plugs onto the CN3, CN4, and CN5 connectors of the CPU card (see Figure 6-11) and the cabling to connect it to the analyzer's motherboard. This PCA includes all circuitry required to enable your analyzer for multidrop operation. It converts the instrument's COM1 port to multidrop configuration allowing up to eight analyzers to be connected the same I/O port of the host computer.

Because both of the DB9 connectors on the analyzer's back panel are needed to construct the multidrop chain, COM2 is no longer available for separate RS-232 or RS-485 operation, however, with the addition of an Ethernet Option (option 63, see Sections 5.9.3 and 6.11.6) the COM2 port is available for communication over a 10BaseT LAN.

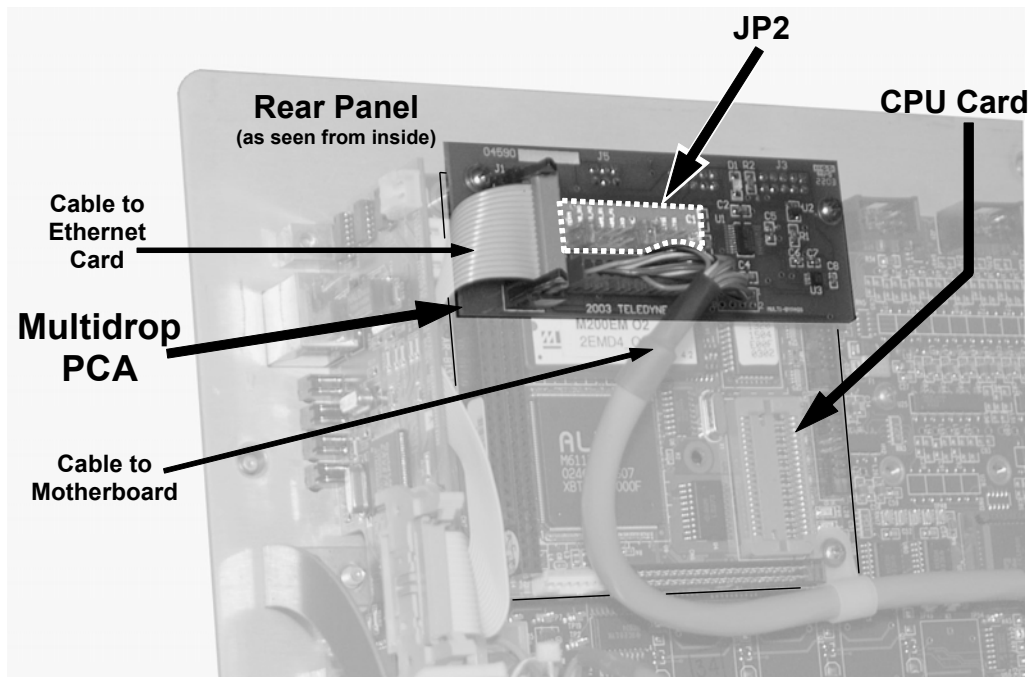


Figure 6-11: Location of JP2 on RS232-Multidrop PCA (option 62)

Each analyzer in the multidrop chain must have:

- One Teledyne Instruments option 62 installed.
- One 6' straight-through, DB9 male → DB9 Female cable (Teledyne Instruments P/N WR0000101) is required for each analyzer.

To set up the network, for each analyzer:

1. Turn the analyzer on and change its ID code (see Section 6.11.1) to a unique 4-digit number.

Remove the top cover (see Section 3.1) of the analyzer and locate JP2 on the multidrop PCA (see Figure 6-11)

Make sure that the jumpers are in place connecting pins 9 ↔ 10 and 11 ↔ 12.

If the analyzer is to be the last instrument on the chain, make sure a jumper is in place connecting pins 21 ↔ 22.

If you are adding an analyzer to the end of an already existing chain, don't forget to remove JP2, pins 21 ↔ 22 on the multidrop PCA on the analyzer that was previously the last instrument in the chain.

Close the instrument.

Using straight-through, DB9 male → DB9 Female cables interconnect the host and the analyzers as shown in Figure 6-12.

NOTE:

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

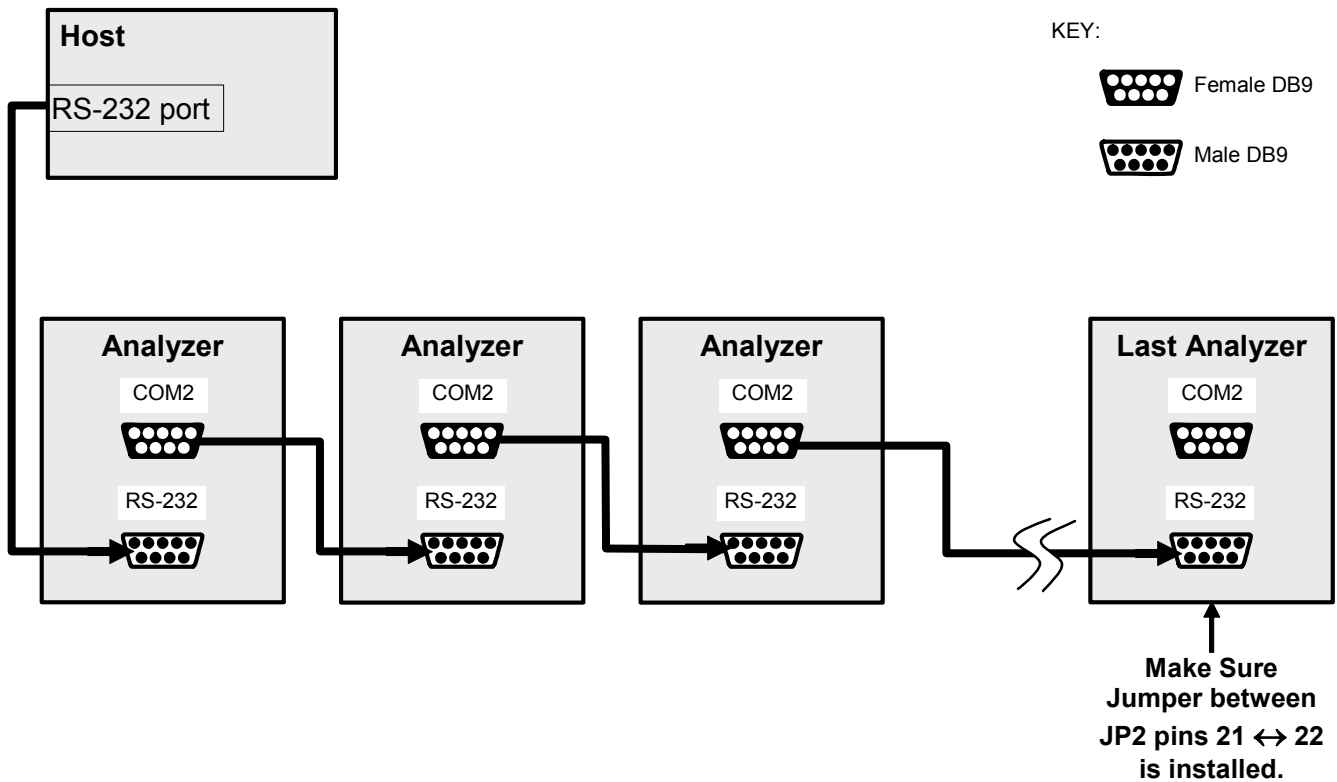


Figure 6-12: RS232-Multidrop PCA Host/Analyzer Interconnect Diagram

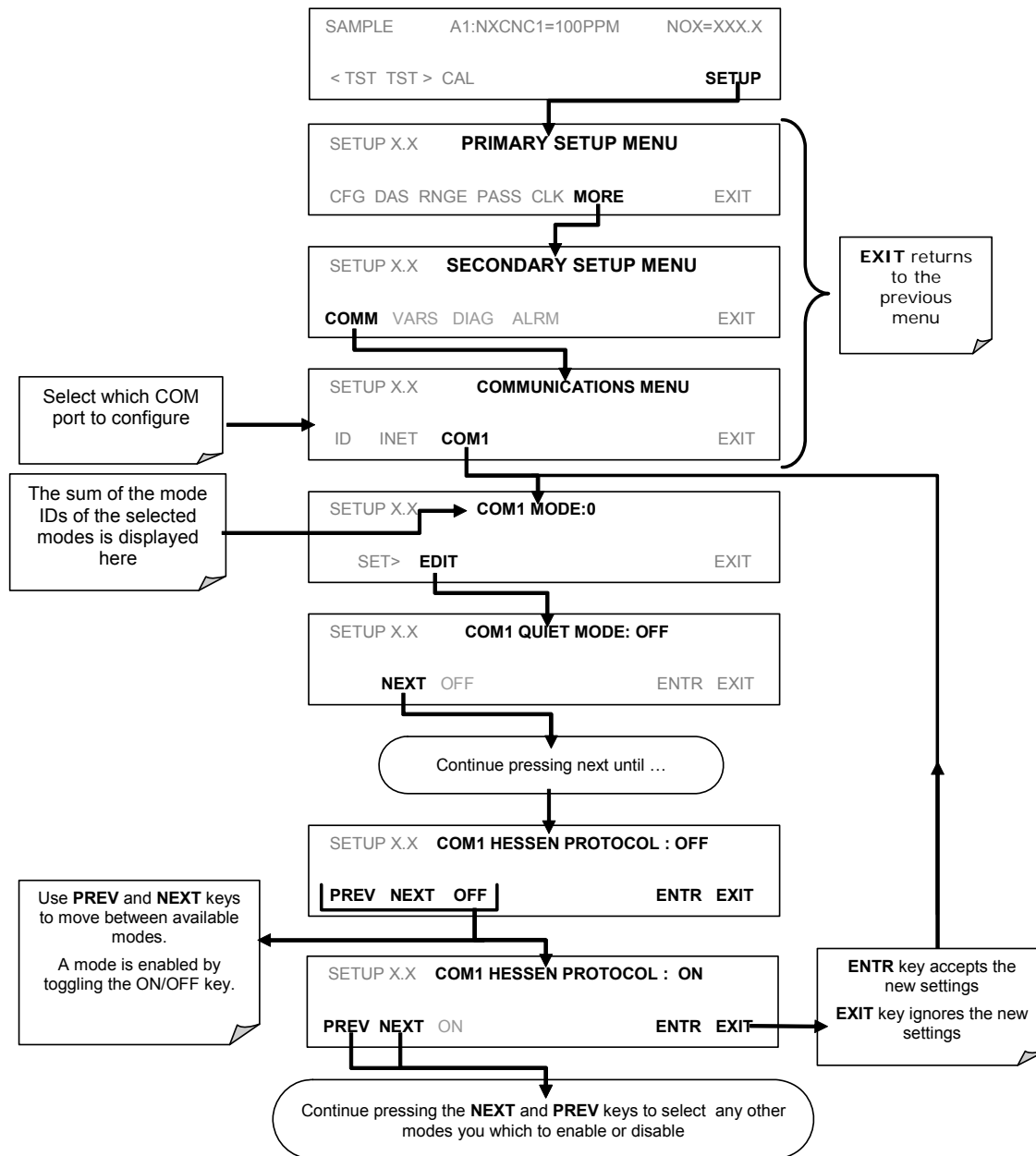
6.11.8. COM PORT COMMUNICATION MODES

Each of the analyzer's serial ports can be configured to operate in a number of different modes, which are listed in the following table. Each COM port needs to be configured independently.

Table 6-14: COMM Port Communication modes

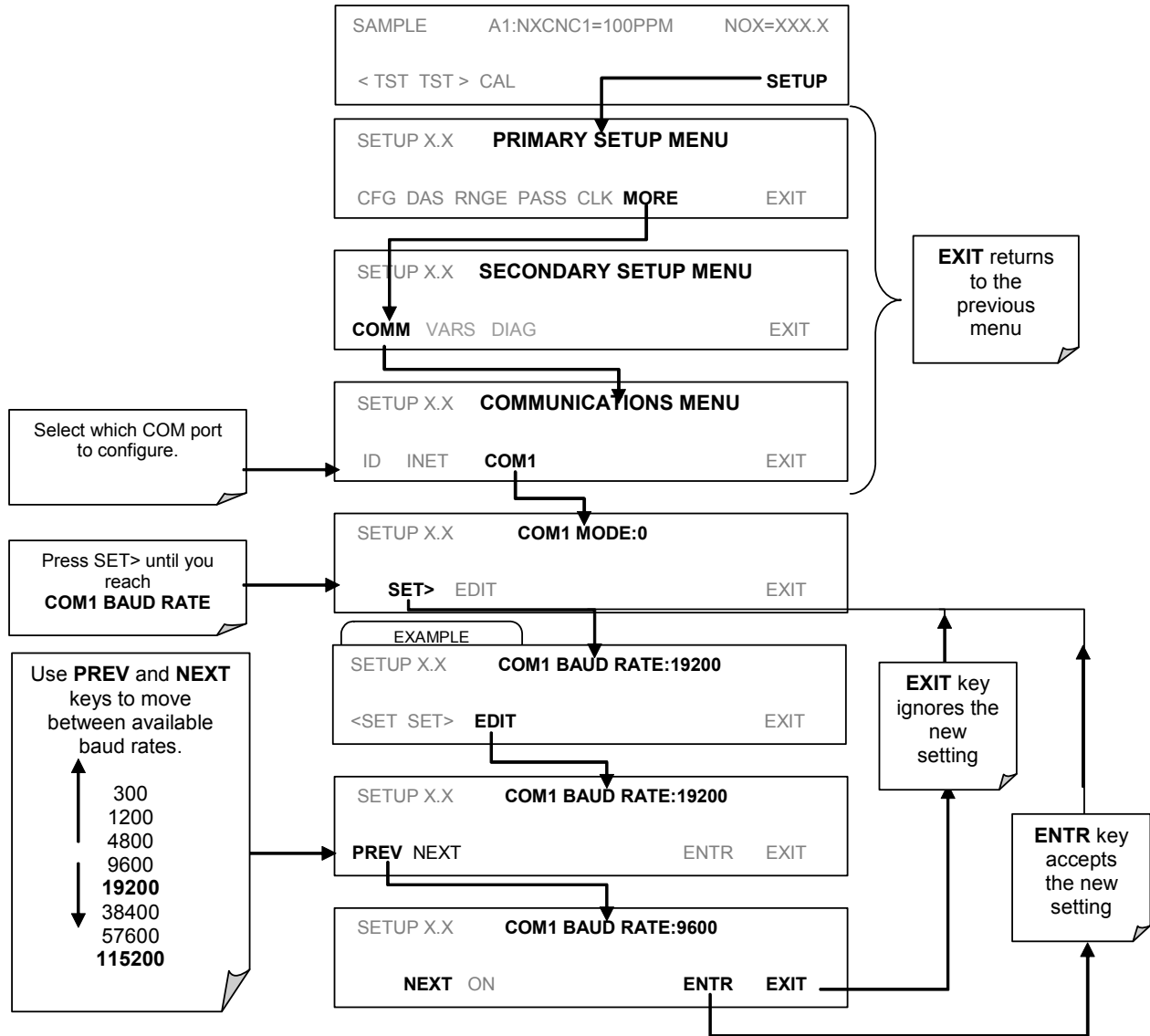
MODE ¹	ID	DESCRIPTION
QUIET	1	Quiet mode suppresses any feedback from the analyzer (iDAS reports, and warning messages) to the remote device and is typically used when the port is communicating with a computer program such as sensor-e.com. Such feedback is still available but a command must be issued to receive them.
COMPUTER	2	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer program, such as sensor-e.com.
SECURITY	4	When enabled, the serial port requires a password before it will respond. The only command that is active is the help screen (? CR).
HESSEN PROTOCOL	16	The Hessen communications protocol is used in some European countries. Teledyne Instruments part number 02252 contains more information on this protocol.
E, 7, 1	2048	When turned on this mode switches the COMM 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 COM2 Port for RS-485 communication. RS-485 mode has precedence over multidrop mode if both are enabled.
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 sending a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING ²	128	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF HANDSHAKE ²	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 sensor-e.com software.
HARDWARE FIFO ²	512	Improves data transfer rate when on of the COMM ports.
COMMAND PROMPT	4096	Enables a command prompt when in terminal mode.
<p>¹ Modes are listed in the order in which they appear in the SETUP → MORE → COMM → COM[1 OR 2] → MODE menu</p> <p>² The default sting for this feature is ON. Do not disable unless instructed to by Teledyne Instruments Customer Service personnel.</p>		

Press the following keys to select a communication mode for a one of the COMM Ports, such as the following example where **HESSEN PROTOCOL** mode is enabled:



6.11.9. COM PORT BAUD RATE

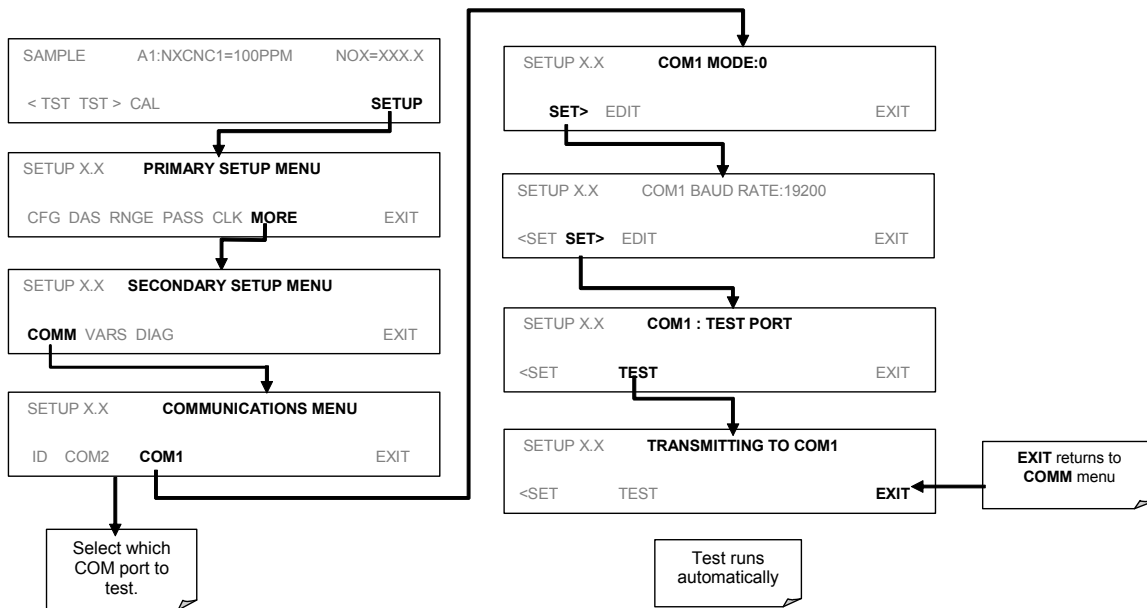
To select the baud rate of one of the COM Ports, press:



6.11.10. COM PORT TESTING

The serial ports can be tested for correct connection and output in the **COMM** 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 key sequence.



6.12. SETUP → MORE → VARS: INTERNAL VARIABLES (VARS)

The TML41M/H has several-user adjustable software variables, which 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 6-15 lists all variables that are available within the 818 password protected level. See Appendix A2 for a detailed listing of all of the TML41M/H variables that are accessible through the remote interface.

Table 6-15: Variable Names (VARS)

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES
0	DAS_HOLD_OFF	Duration of no data storage in the iDAS. This is the time when the analyzer returns from one of its calibration modes to the SAMPLE mode. The DAS_HOLD_OFF can be disabled in each iDAS channel.	Can be between 0.5 and 20 minutes Default=15 min.
1	MEASURE_MODE	Selects the gas measurement mode in which the instrument is to operate. NO _x only, NO only or dual gas measurement of NO _x and NO simultaneously. Dual gas mode requires that a special switching optional be installed.	NO; NO _x ; NO _x -NO
2	STABIL_GAS	Selects which gas measurement is displayed when the STABIL test function is selected.	NO; NO _x ; NO ₂ ; O ₂ ¹
3	TPC_ENABLE	Enables or disables the temperature and pressure compensation (TPC) feature (Section 10.7.3).	ON/OFF Default=ON
4	DYN_ZERO	Dynamic zero automatically adjusts offset and slope of the NO and NO _x response when performing a zero point calibration during an AutoCal (Chapter 7.7).	ON/OFF Default=OFF
5	DYN_SPAN	Dynamic span automatically adjusts the offsets and slopes of the NO and NO _x response when performing a span point calibration during an AutoCal (Chapter 7.7). Note that the DYN_ZERO and DYN_SPAN features are not allowed for applications requiring EPA equivalency.	ON/OFF Default=OFF
6	CONC_PRECISION	Sets the number of decimal points of the concentration and stability parameters displayed on the front panel.	AUTO, 1, 2, 3, 4 Default=AUTO
7	CLOCK_ADJ	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast.	-60 to +60 s/day Default=0

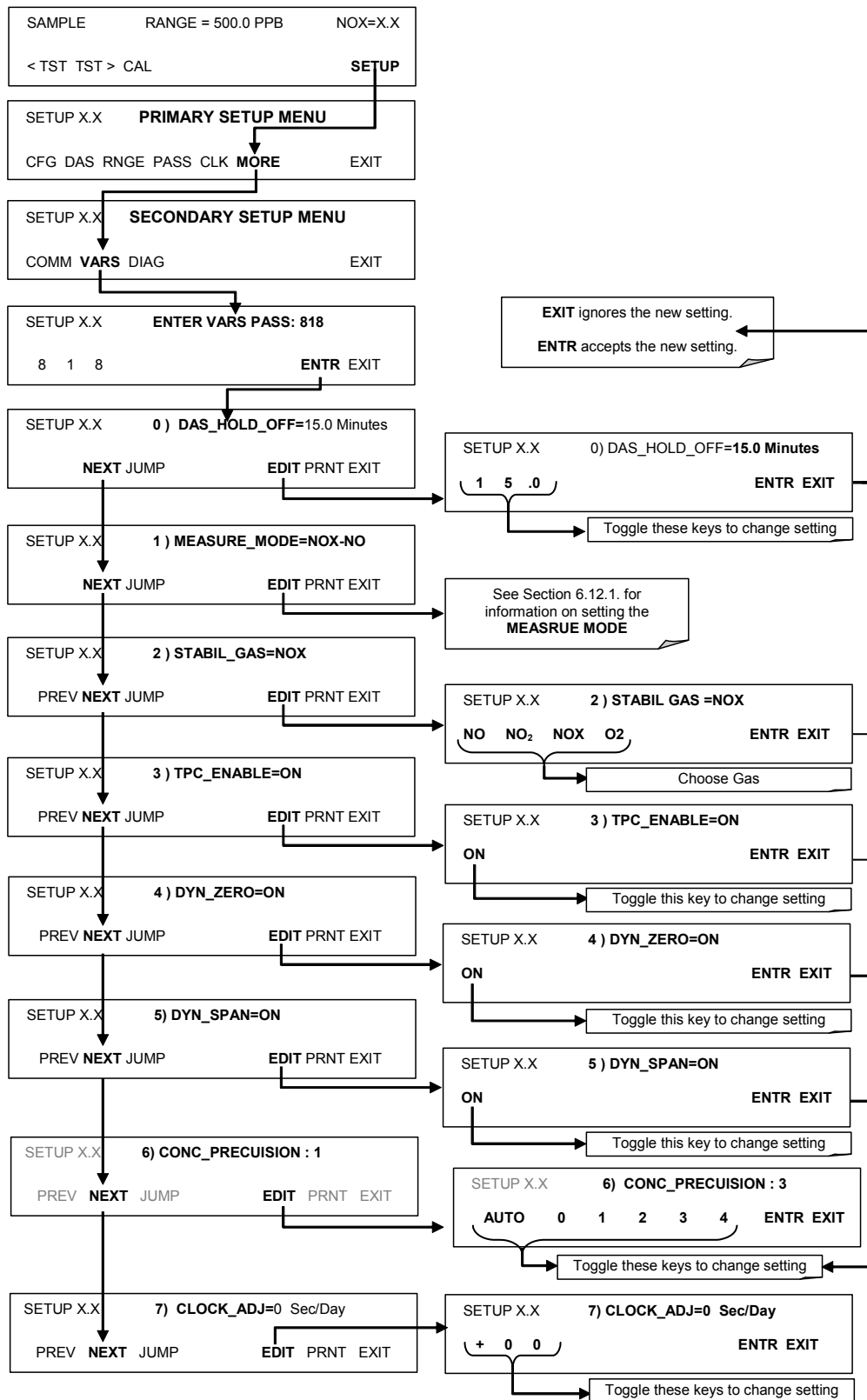
¹ Only available in analyzer's with O₂ sensor options installed.

NOTE:

There is a 2 second latency period between when a VARS value is changed and the new value is stored into the analyzer's memory.

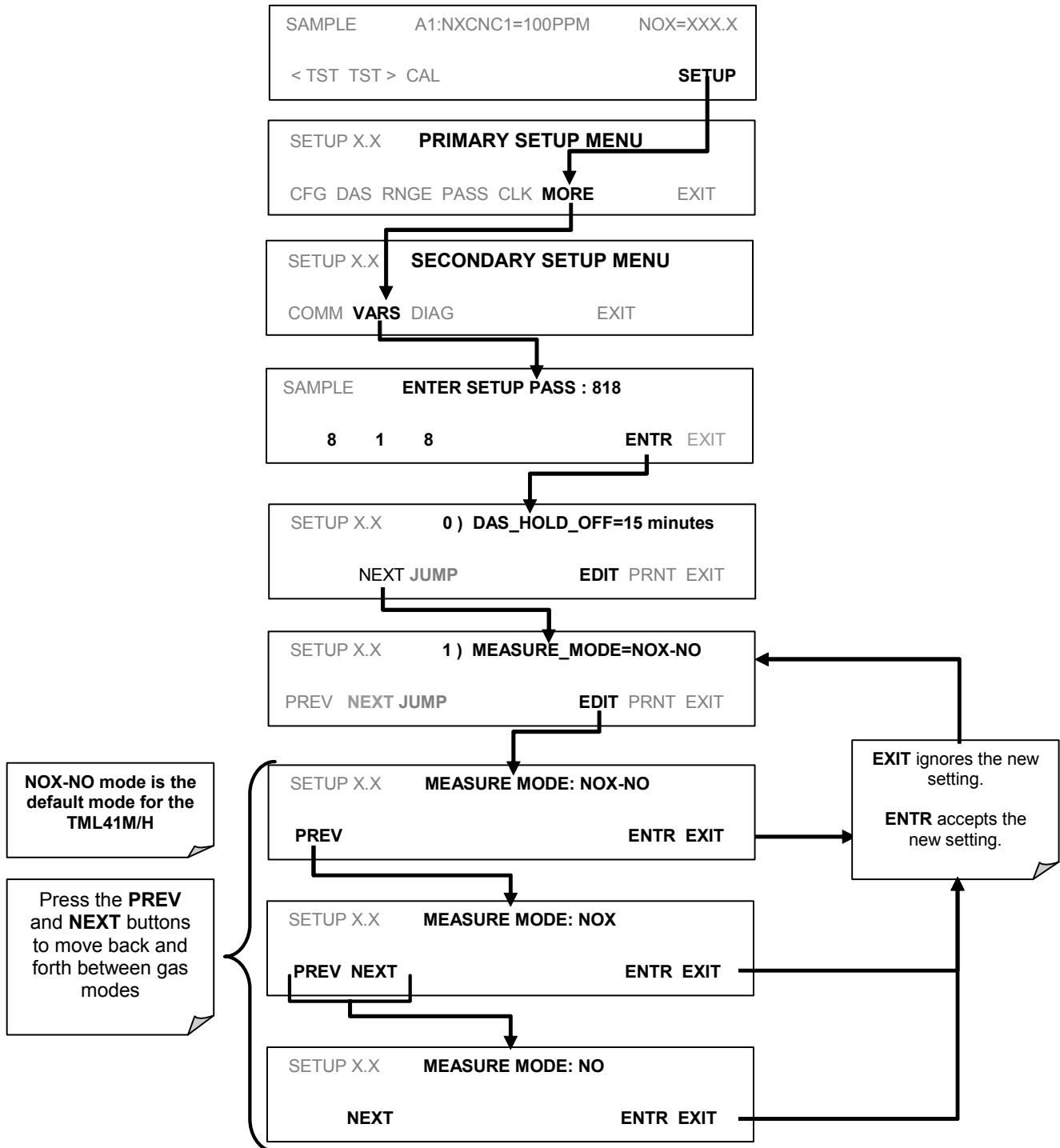
DO NOT turn the analyzer off during this period or the new setting will be lost.

To access and navigate the VARS menu, use the following key sequence:



6.12.1. SETTING THE GAS MEASUREMENT MODE

In its standard operating mode the TML41M/H measures NO, NO₂ and NO_x. It can also be set to measure only NO or only NO_x. To select one of these three measurement modes, press:



6.13. SETUP → MORE → DIAG: DIAGNOSTICS MENU

A series of diagnostic tools is grouped together under the **SETUP-MORE-DIAG** menu. These parameters are dependent on firmware revision. These tools can be used in a variety of troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and trouble-shooting sections.

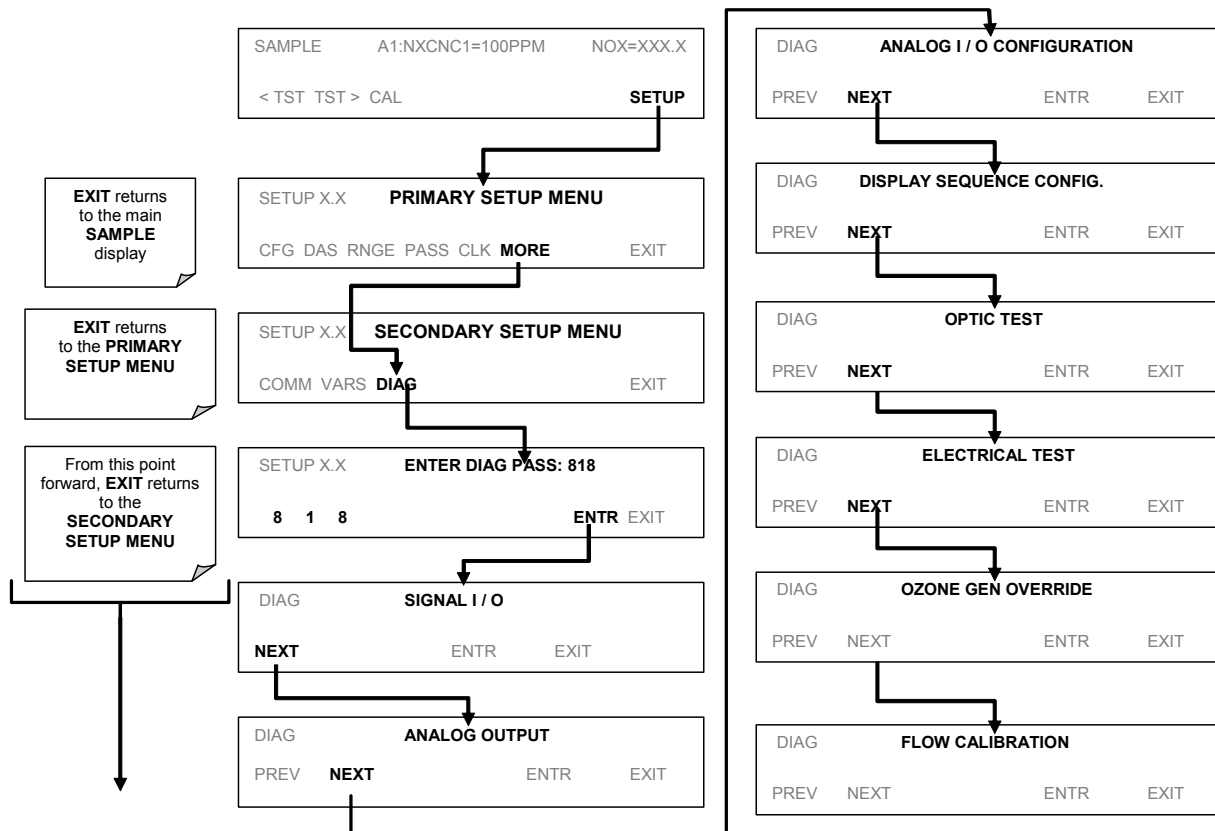
An overview of the entire **DIAG** menu can be found in menu tree A-6 of Appendix A.1.

Table 6-16: TML41M/H Diagnostic (DIAG) Functions

DIAGNOSTIC FUNCTION AND MEANING	FRONT PANEL MODE INDICATOR	SECTION
SIGNAL I/O: Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled ON and OFF.	DIAG I/O	6.13.2
ANALOG I/O: 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.	DIAG AOUT	6.13.3
ANALOG I/O CONFIGURATION: This submenu allows the user to configure the analyzer's four analog output channels, including choosing what parameter will be an output on each channel. Instructions that appear here allow adjustment and calibration of the voltage signals associated with each output as well as calibration of the analog to digital converter circuitry on the motherboard.	DIAG AIO	6.13.4, through 6.13.6
DISPLAY SEQUENCE CONFIGURATION: Allows the user to program which concentration values are displayed in the front panel's concentration field.	DIAG DISP	6.13.7.1
OPTIC TEST: When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT (Fig. 10-15). This diagnostic tests the response of the PMT without having to supply span gas.	DIAG OPTIC	6.13.7.2
ELECTRICAL TEST: When activated, the analyzer performs an electric test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	DIAG ELEC	6.13.7.3
OZONE GEN OVERRIDE: Allows the user to manually turn the O ₃ generator on or off. This setting is retained when exiting DIAG .	DIAG OZONE	6.13.7.4
FLOW CALIBRATION: This function is used to calibrate the gas flow output signals of sample gas and ozone supply. These settings are retained when exiting DIAG .	DIAG FCAL	6.13.7.5

6.13.1. ACCESSING THE DIAGNOSTIC FEATURES

To access the DIAG functions press the following keys:



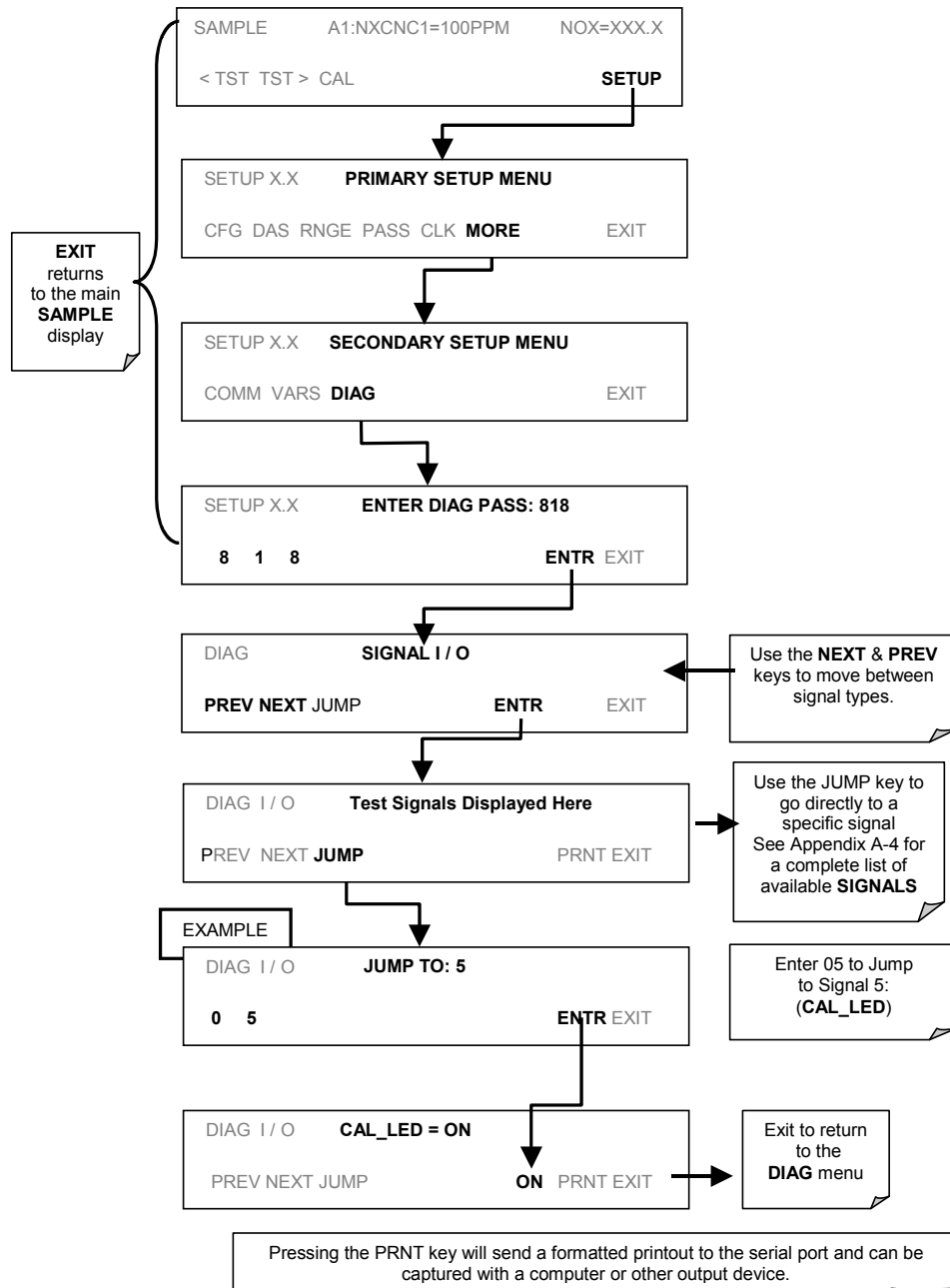
6.13.2. SIGNAL I/O

The signal I/O diagnostic mode allows one to review and change the digital and analog input/output functions of the analyzer. See Appendix A-4 for a complete list of the parameters available for review under this menu.

NOTE

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.

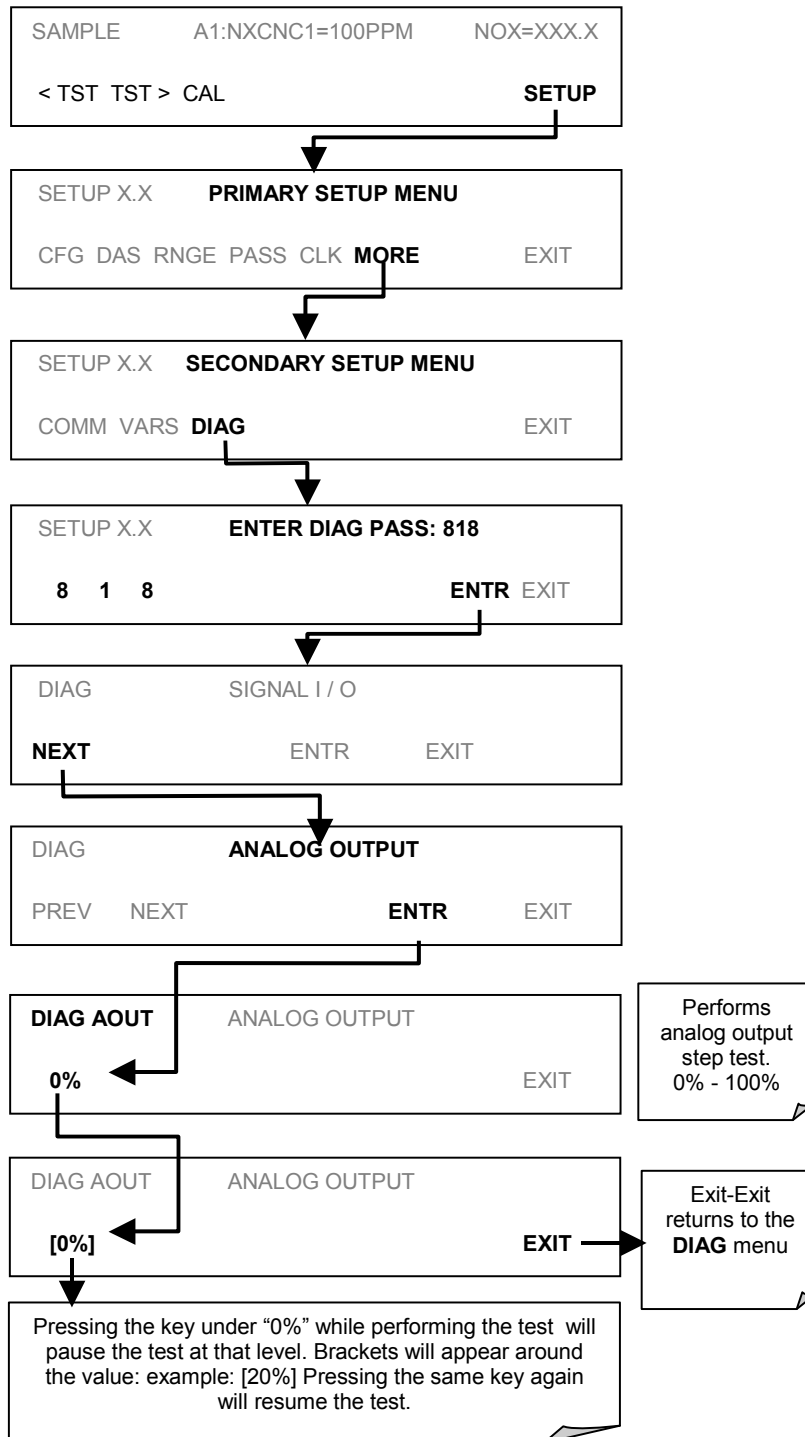
To enter the signal I/O test mode, press:



6.13.3. ANALOG OUTPUT STEP TEST

This test can be used to check the accuracy and proper operation of the analog outputs. The test forces all four 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.

To begin the Analog Output Step Test press:



6.13.4. ANALOG OUTPUTS AND REPORTING RANGES

6.13.4.1. Analog Output Signals Available on the TML41M/H

The analyzer has four analog output signals, accessible through a connector on the rear panel.

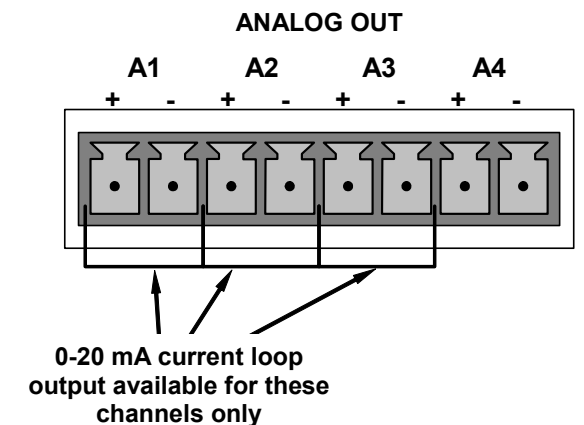


Figure 6-13: Analog Output Connector Key

The signal levels of each output can be independently configured as follows. An over-range feature is available that allows each range to be usable from -5% to + 5% of its nominal scale:

Table 6-17: Analog Output Voltage Ranges with Over-Range Active

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-0.1 V	-5 mV	+105 mV
0-1 V	-0.05 V	+1.05 V
0-5 V	-0.25 V	+5.25 V
0-10 V	-0.5 V	+10.5 V

The default offset for all ranges is 0 VDC.

Pin assignments for the ANALOG output connector at the rear panel of the instrument:

Table 6-18: Analog Output Pin Assignments

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	I Out +
8		Ground	I Out -

Additionally **A1**, **A2** and **A3** may be equipped with optional 0-20 mA current loop drivers. **A4** is not available for the current loop option.

Table 6-19: Analog Output Current Loop Range

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-20 mA	0 mA	20 mA
These are the physical limits of the current loop modules, typical applications use 2-20 or 4-20 mA for the lower and upper limits. Please specify desired range when ordering this option. The default offset for all ranges is 0 mA.		

All of these outputs can be configured output signals representing any of the iDAS parameters available on this model (See Table A-6 of Appendix A.5 for a complete list).

The ability to select any one of the TML41M/H's 40+ iDAS data types coupled with the ability to select from a variety of signal ranges and scales makes the analog outputs of the TML41M/H extremely flexible.

Table 6-20: Example of Analog Output configuration for TML41M/H

OUTPUT	IDAS PARAMETER ASSIGNED	SIGNAL SCALE
A1	NXCNC1	0-5 V
A2	N2CNC2	4-20 mA
A3	PMTDET	0 - 1 V
A4	O2CONC	0-10 V
¹ With current loop option installed		

6.13.4.2. Physical Range versus Analog Output Reporting Ranges

The entire measurement range of the analyzer is quite large, 0 – 5,000 ppm for the TML41H and 0-200 PPM for the TML41M, but many applications use only a small part of the analyzer's full measurement range. This creates two performance challenges:

1. The width of the analyzer's physical range can create data resolution problems for most analog recording devices. For example, in an application where a TML41H is being used to measure an expected concentration of typically less than 200 ppm NO_x, the full scale of expected values is only 4% of the instrument's full 5000 ppm measurement range. Unmodified, the corresponding output signal would also be recorded across only 4% of the range of the recording device.

The TML41M/H solves this problem by allowing the user to select a scaled reporting range for the analog outputs that only includes that portion of the physical range relevant to the specific application. Only the reporting range of the analog outputs is scaled, the physical range of the analyzer and the readings displayed on the front panel remain unaltered.

Applications where low concentrations of NO, NO₂ and NO_x are measured require greater sensitivity and resolution than typically necessary for measurements of higher concentrations.

The TML41M/H solves this issue by using two hardware physical ranges that cover the instruments entire measurement range. The analyzer's software automatically selects which physical range is in effect based on the analog output reporting range selected by the user:

FOR THE TML41M:

- Low range spans 0 to 20 ppm NO_x (20 ppm = 5 V);
- High range spans 0-200 ppm NO_x (200 ppm = 5 V).

If the high end of the selected reporting range is ≤ 20 ppm. The low physical range is selected. If the high end of the selected reporting range is > 20 ppm. The high physical range is selected.

FOR THE TML41H:

- Low range spans 0 to 500 ppm NO_x (500 ppm = 5 V);
- High range spans 0-5000 ppm NO_x (5000 ppm = 5 V).

If the high end of the selected reporting range is ≤ 500 ppm. The low physical range is selected. If the high end of the selected reporting range is > 500 ppm. The high physical range is selected.

Once properly calibrated, the analyzer's front panel will accurately report concentrations along the entire span of its 0 and 20,000 ppb physical range regardless of which reporting range has been selected for the analog outputs and which physical range is being used by the instruments software.

Both reporting ranges need to be calibrated independently to the same span gas concentrations in order to allow switching back and forth between high and low ranges.

6.13.5. ANALOG I/O CONFIGURATION

6.13.5.1. The Analog I/O Configuration Submenu

Table 6-21 lists the analog I/O functions that are available in the TML41M/H.

Table 6-21: DIAG - Analog I/O Functions

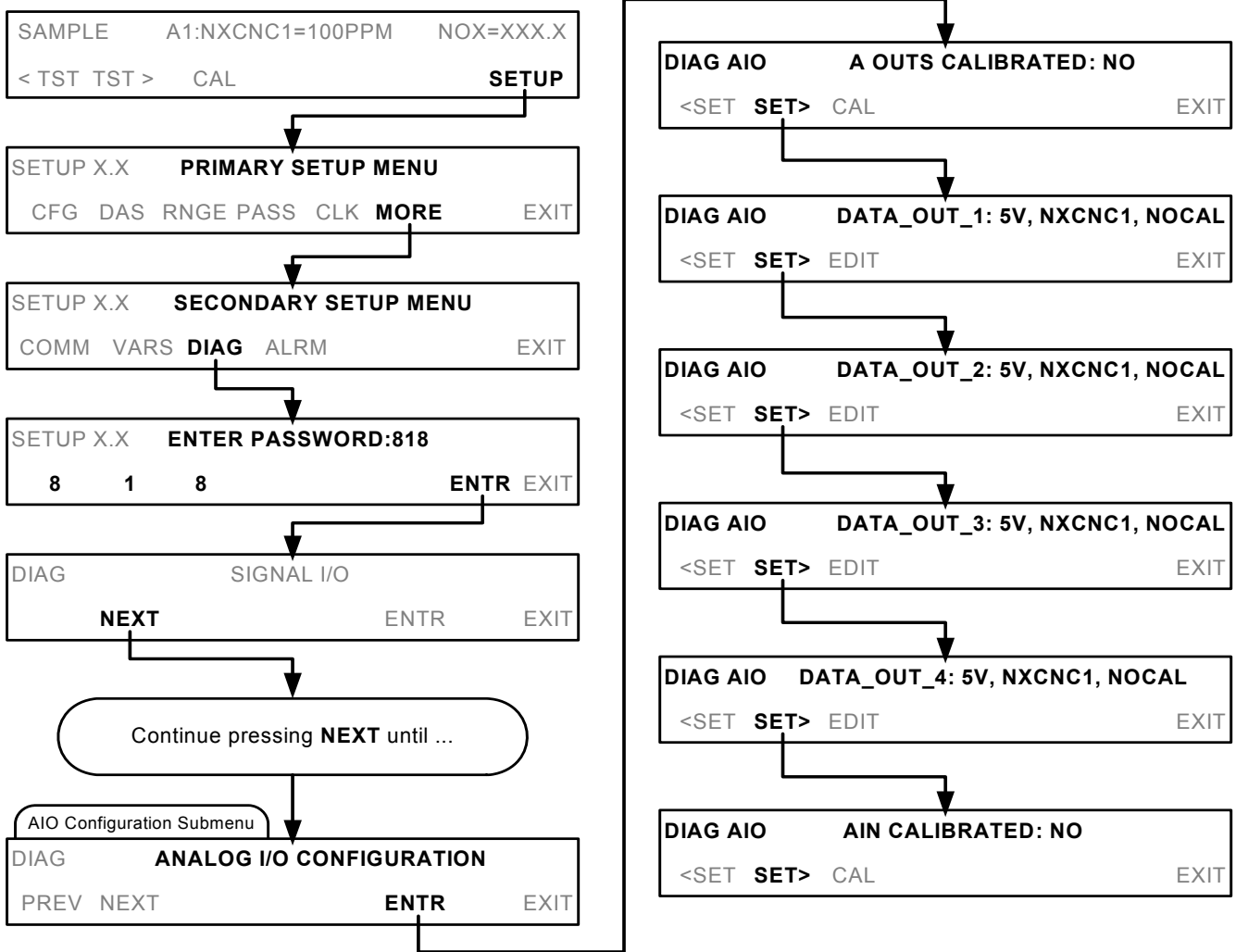
SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
DATA_OUT_1:	Configures the A1 analog output: RANGE ¹ : Selects the signal type (voltage or current loop) and full scale value of the output. OVERRANGE : Turns the $\pm 5\%$ over-range feature ON/OFF for this output channel. REC_OFS ¹ : Sets a voltage offset (not available when RANGE is set to CURRENT loop). AUTO_CAL ¹ : Sets the channel for automatic or manual calibration CALIBRATED ¹ : Performs the same calibration as AOUT CALIBRATED , but on this one channel only. OUTPUT : Turns the output channel ON/OFF. When off, a signal equal to the low end of the output scale (zero point) is still transmitted by the analyzer, but no data is sent. DATA : Allows the user to select which iDAS parameter is to be the output. SCALE : Sets the top end of the reporting range scale for this channel. The analyzer automatically chooses the units of measure appropriate for the iDAS parameter chosen (e.g. ppm for concentration parameters; in-Hg-A for pressure measurements, etc.) UPDATE : Sets the time interval at which the analyzer updates the data being transmitted on the channel.
DATA_OUT_2	Same as for DATA_OUT_1 but for analog channel 2 (NO)
DATA_OUT_3	Same as for DATA_OUT_1 but for analog channel 3 (NO ₂)
DATA_OUT_4	Same as for DATA_OUT_1 but for analog channel 3 (NO ₂)
TEST OUTPUT	Same as for DATA_OUT_1 but for analog channel 4 (TEST)
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog to digital converter circuit on the motherboard.
¹ Changes to RANGE or REC_OFS require recalibration of this output.	

To configure the analyzer's four analog outputs, set the electronic signal type of each channel and calibrate the outputs. This consists of:

1. Selecting an output type (voltage or current, if an optional current output driver has been installed) and the signal level that matches the input requirements of the recording device attached to the channel.
2. Determine if the over-range feature is needed and turn it on or off accordingly.
3. If a Voltage scale is in use, a bipolar recorder offset may be added to the signal if required (Section 6.13.5.4).
4. Choose an iDAS parameter to be the output of the channel.
5. Set the reporting range scale for the data type chosen.
6. Set the update rate for the channel.

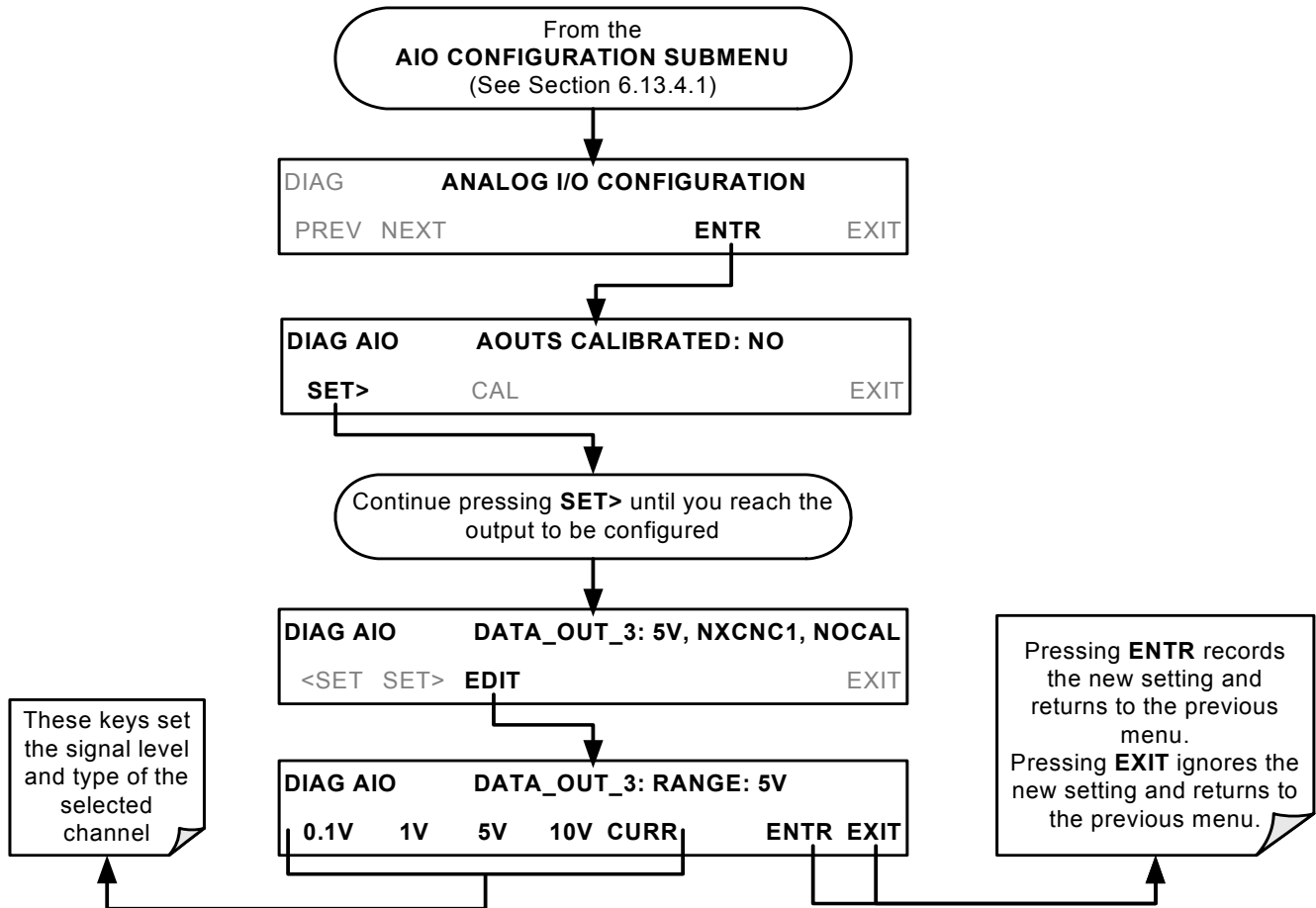
- Calibrating the output channel. This can be done automatically or manually for each channel (see Section 6.13.6).

To access the analog I/O configuration sub menu, press:



6.13.5.2. Analog Output Signal Type and Range Selection

To select an output signal type (DC Voltage or current) and level for one output channel press:



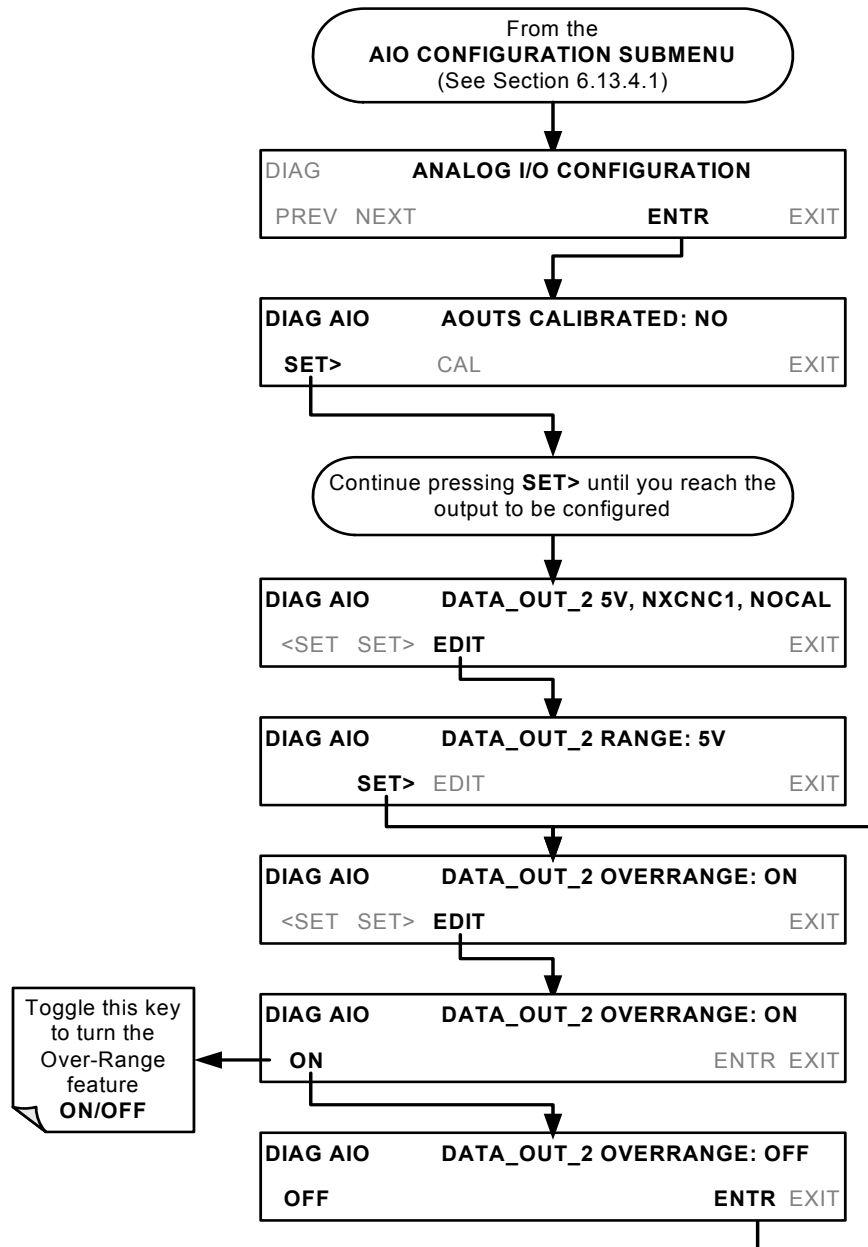
6.13.5.3. Turning the Analog Output Over-Range Feature ON/OFF

In its default configuration a $\pm 5\%$ over-range is available on each of the TML41M/H's analog output channels. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

NOTE:

Instruments with current range options installed on one or more of the outputs often are delivered from the factory with the over-range feature turned OFF on those channels.

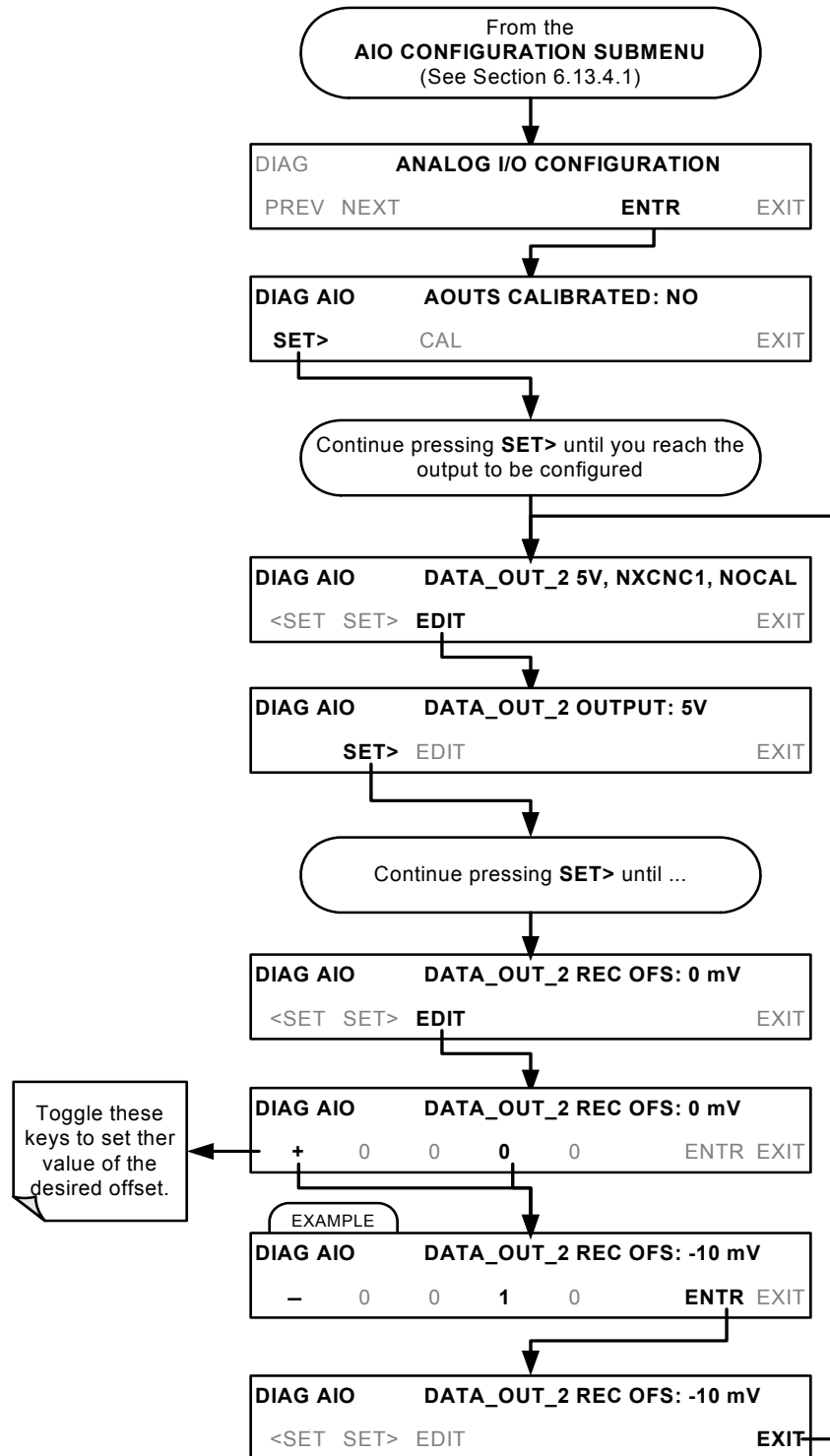
To Turn the over-range feature on or off, press:



6.13.5.4. Adding a Recorder Offset to an Analog Output

Some analog signal recorders require that the zero signal is 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 TML41M/H by defining a zero offset, a small voltage (e.g., 10% of span).

To add a zero offset to a specific analog output channel, press:



6.13.5.5. Assigning an iDAS parameter to an Analog Output Channel

The TML41M/H analog output channels can be assigned to transmit data from any of the 40+ available iDAS parameters (see Table A-6 of Appendix A.5). The default settings for the four output channels are:

Table 6-22: Analog Output Data Type Default Settings

PARAMETER	CHANNEL DEFAULT SETTING			
	A1	A2	A3	A4 ³
DATA TYPE ¹	NXCNC1	NOCNC1	N2CNC1	NXCNC2
RANGE	0 - 5 VDC ²			
REC OFS	0 mVDC			
AUTO CAL.	ON			
CALIBRATED	NO			
OUTPUT	ON			
SCALE	100 ppm			
UPDATE	5 sec			
¹ See Table A-6 of TML41M/H Appendix A for definitions of these iDAS data types ² Optional current loop outputs are available for analog output channels A1-A3. ³ On analyzers with O ₂ sensor options installed, iDAS parameter O2CONC is assigned to output A4.				

6.13.5.6. Reporting Gas Concentrations via the TML41M/H Analog Output Channels

While the iDAS parameters available as outputs via the analog channels A1 thru A4 include a wide variety internal temperatures, gas flows and pressures as well as certain key internal voltage levels, most of the iDAS parameters are related to gas concentration levels.

Two parameters exist for each gas type measured by the TML41M/H. They are generally referred to as range 1 and range 2 (e.g. NXCNC1 and NXCNC2; NOCNC1 and NOCNC2; etc.). These take the place of the high and low concentration ranges of previous versions of the analyzer software. Concentrations for each range are computed using separate slopes and offsets which are also stored via separate iDAS parameters.

NOTE

If an analog output channel is set to report a gas concentration (e.g. NXCNC1; NO_x concentration; Range 1) it is generally a good idea to use 80% of the reporting range for that channel for the span point calibration.

If both available parameters for a specific gas type are being reported (e.g. NXCNC1 and NXCNC2), separate Calibrations should be carried out for each parameter.

The gas concentration iDAS parameters available as outputs for output via the TML41M/H analog output channels are:

Table 6-23: Analog Output iDAS Parameters Related to Gas Concentration Data

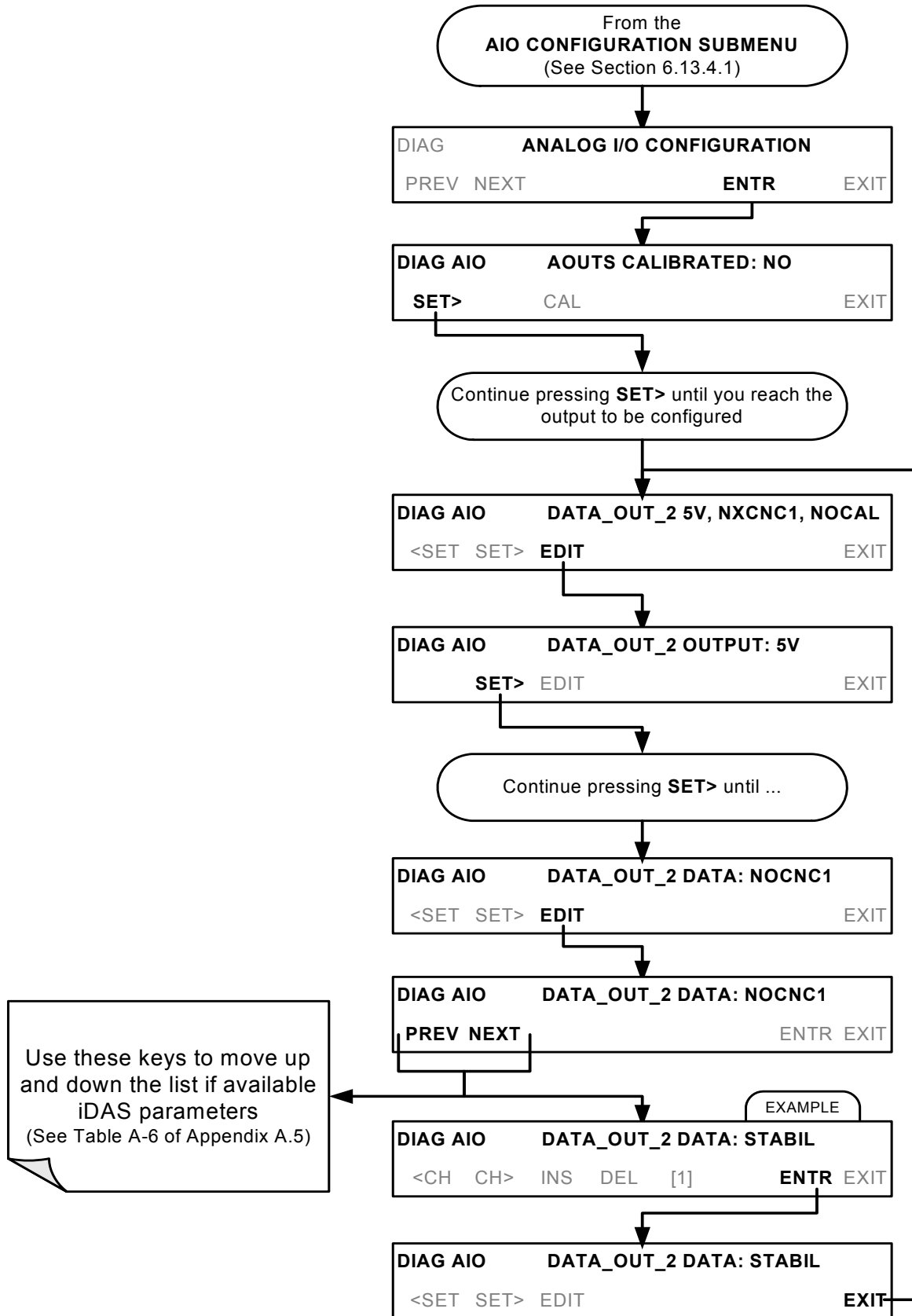
REPORTING RANGE	PARAMETER NAME ¹	DESCRIPTION
NO _x Range 1 (LOW)	NXCNC1	Concentration
	NXSLP1	Slope
	NXOFS1	Offset
	NXZSC1	Concentration during calibration, prior to computing new slope and offset
NO _x RANGE 2 (HIGH)	NXCNC2	Concentration
	NXSLP2	Slope
	NXOFS2	Offset
	NXZSC2	Concentration during calibration, prior to computing new slope and offset
NO Range 1 (LOW)	NOCNC1	Concentration
	NOSLP1	Slope
	NOOFS1	Offset
	NOZSC1	Concentration during calibration, prior to computing new slope and offset
NO RANGE 2 (HIGH)	NOCNC2	Concentration
	NOSLP2	Slope
	NOOFS2	Offset
	NOZSC2	Concentration during calibration, prior to computing new slope and offset
NO ₂ Range 1 ² (LOW)	N2CNC1	Concentration - Computed with data from NO _x Range 1 and NO Range 1
	N2ZSC1	Concentration during calibration, prior to computing new slope and offset
NO ₂ RANGE 2 ² (HIGH)	N2CNC2	Concentration - Computed with data from NO _x Range 2 and NO Range 2
	N2ZSC2	Concentration during calibration, prior to computing new slope and offset
O ₂ Range ³	O2CONC³	Concentration
	O2OFST³	Slope
	O2SLPE³	Offset
	O2ZSCN³	Concentration during calibration, prior to computing new slope and offset

¹ Parameters are not listed in the order they appear on the iDAS list (see Table A-6 or Appendix A.5 for the proper order of the full list of parameters)

² Since NO₂ values are computed rather than measured directly, no separate slope or offset exist.

³ Only available on instruments with O₂ sensor options installed.

To assign an iDAS parameter to a specific analog output channel, press,



6.13.5.7. Setting the Reporting Range Scale for an Analog Output

Once the iDAS parameter has been set, the top end of the scale must be selected. For concentration values this should be equal to the expected maximum value for the application. The analog channel will scale its output accordingly.

EXAMPLE:

IDAS parameter being output: NXCNC1

Maximum value expected: 800 ppm

Output range; 10 V

Output:	0 ppm.....	0.000 V
	100 ppm.....	1.250 V
	200 ppm.....	2.500 V
	400 ppm.....	5.000 V
	750 ppm.....	9.375 V

NOTE

Regardless of how the reporting range for an analog output channel is set, the instrument will continue to measure NO, NO₂ and NO_x accurately for the entire physical range of the instrument (See Section 6.13.4.2 for information on Physical range versus reporting range)

Each output channel can be programmed for a separate gas with independent reporting range.

EXAMPLE:

A1 → NXCNC1 (NO_x Range 1) → 0-1000 ppm NO_x.

A1 → NXCNC2 (NO_x Range 2) → 0-1250 ppm NO_x.

A3 → NOCNC1 (NO_x Range 1) → 0-500 ppm NO.

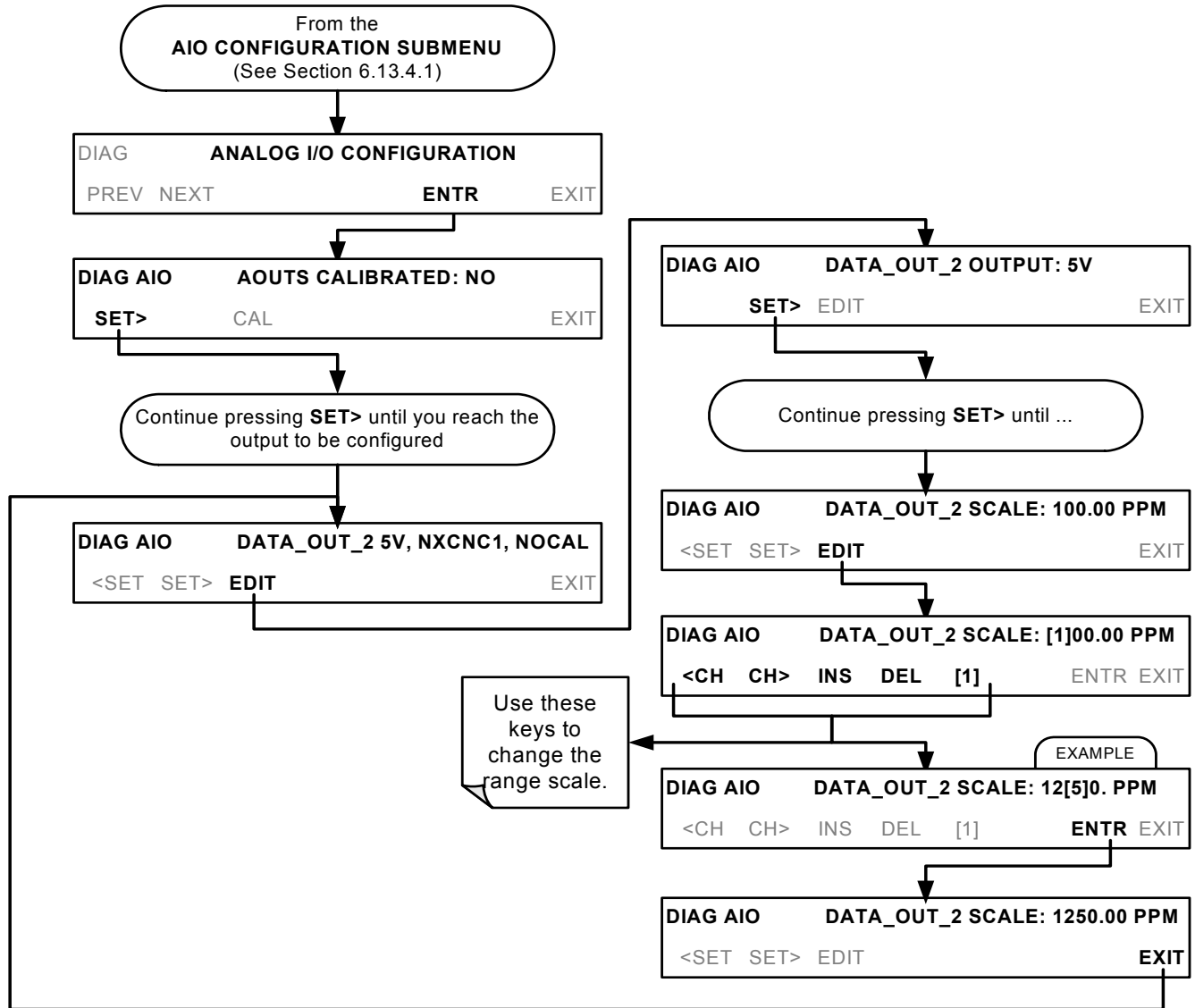
A4 → N2CNC1 (NO₂ Range 1) → 0-750 ppm NO₂.

NOTE:

While Range 1 for each gas type is often referred to as the LOW range and Range 2 as the HIGH range, this is simply a naming convention. The upper limit for each range can be set to any value.

EXAMPLE: A1 → NXCNC1 (NO_x Range 1) → 0-1500 ppm NO_x
A2 → NXCNC2 (NO_x Range 2) → 0-1000 ppm NO_x.

To set the reporting range for an analog output, press:



RANGE SELECTION KEYPAD FUNCTIONS

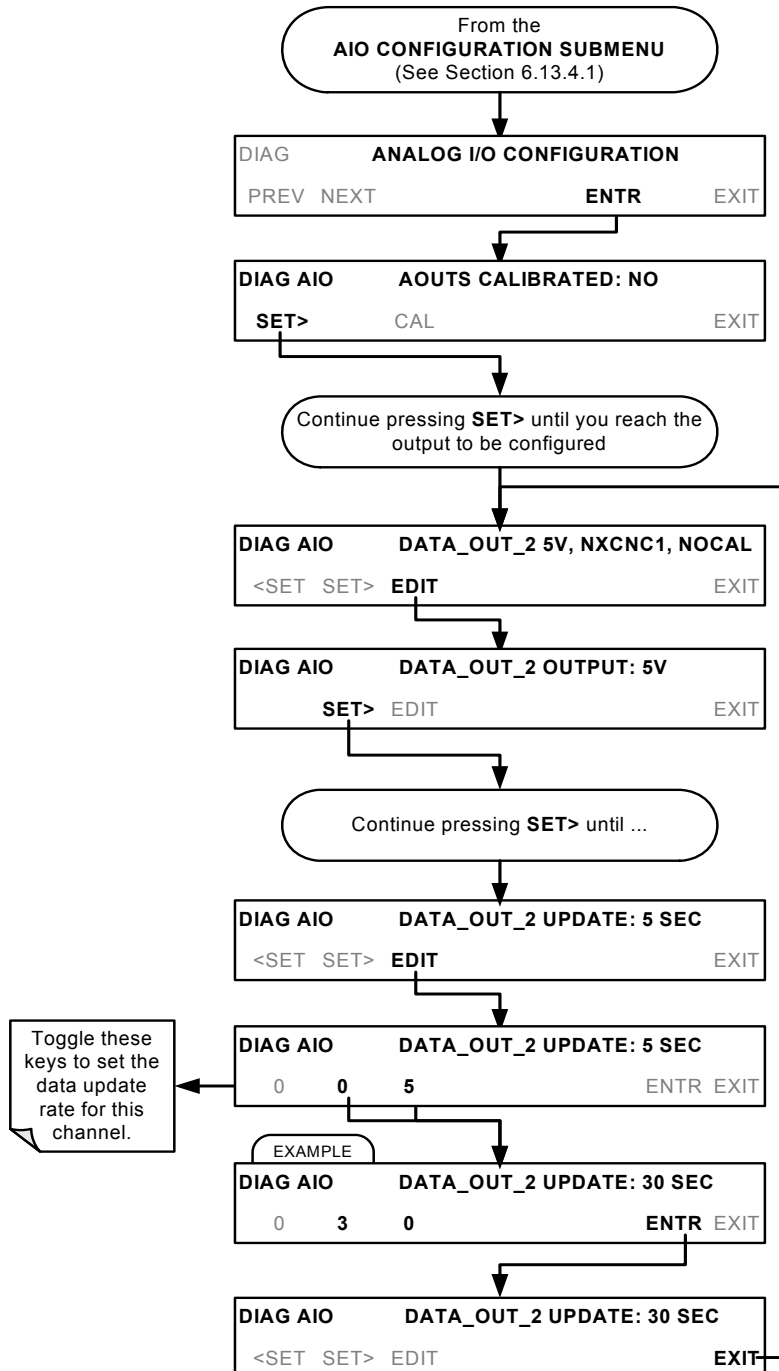
KEY	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this key to cycle through the range of numerals and characters available for insertion: 0-9; as well as "+" & "-".
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.

Some keys only appear as needed.

6.13.5.8. Setting Data Update Rate for an Analog Output

The data update rate for the TML41M/H analog outputs can be adjusted to match the requirements of the specific iDAS parameter chosen for each channel. For instance, if the parameter NXCNC1 (NO_x concentration; Range 1) is chosen for channel A1 on an instrument set for dual gas measurement mode, it would be meaningless to have an update rate of less than 30 seconds, since the NO_x-NO measurement cycle takes that long to complete. On the other hand, if the channel was set to output the PMTDET voltage or the temperature of the moly converter it might be useful to have output updated more frequently.

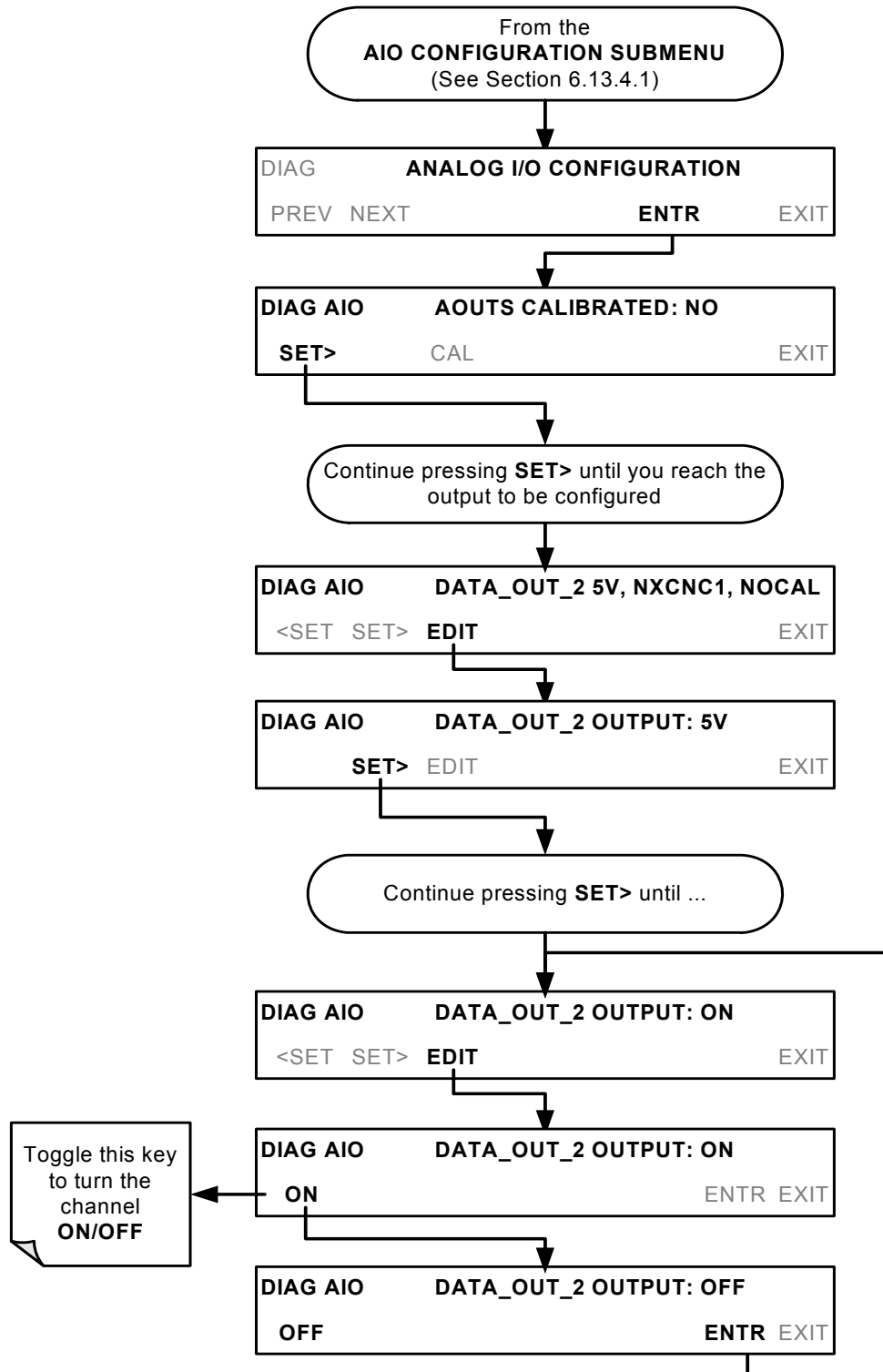
To change the update rate for an individual analog output channel, press:



6.13.5.9. Turning an Analog Output On or Off

Each output can be temporarily turned off. When off no data is sent to the output. Electronically, it is still active; there is simply no data so the signal level at the rear of the instrument will fall to zero.

To turn an individual analog output channel ON/OFF, press:



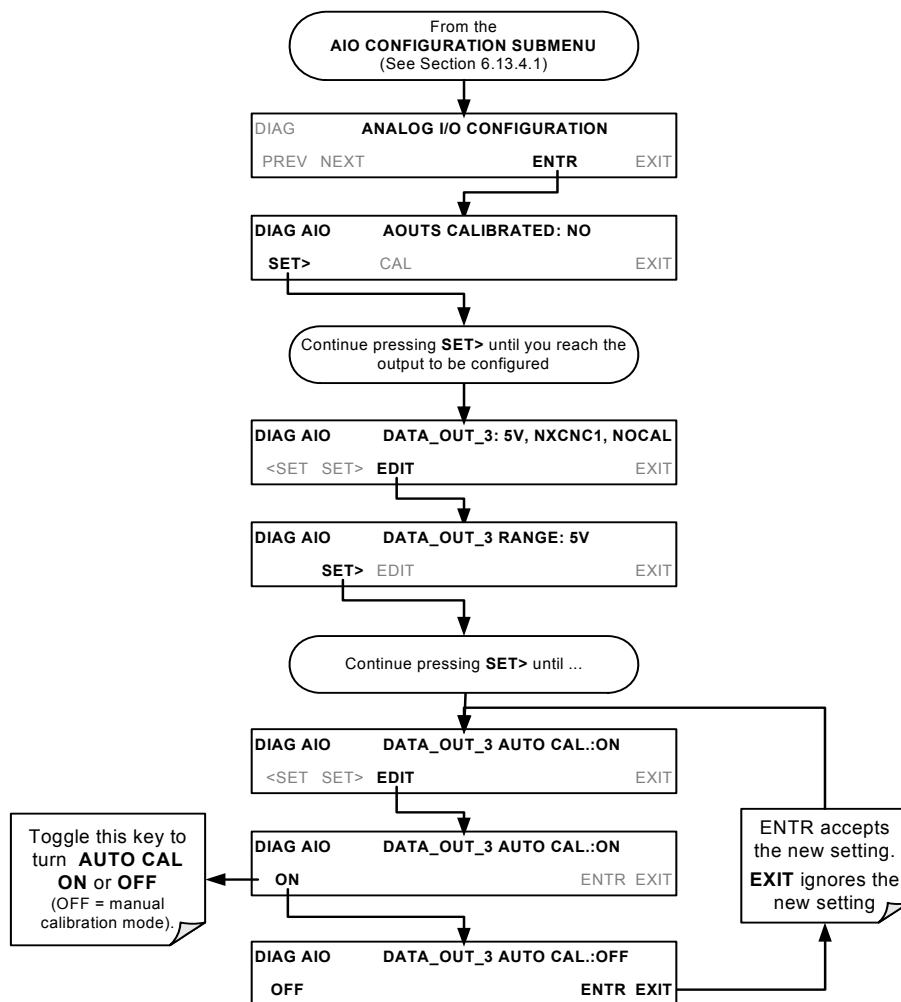
6.13.6. ANALOG OUTPUT CALIBRATION

Analog calibration needs to be carried out on first startup of the analyzer (performed in the factory as part of the configuration process) or whenever re-calibration is required.

The analog outputs can be calibrated automatically or adjusted manually (see Section 6.13.6). During automatic calibration the analyzer tells the output circuitry to generate a zero mV signal and high-scale point signal (usually about 90% of chosen analog signal scale) then measures actual signal of the output. Any error at zero or high-scale is corrected with a slope and offset.

Automatic calibration can be performed a group via the **AOUTS CALIBRATION** command, or individually by using the **CAL** button located inside each output channels submenu. By default, the analyzer is configured so that calibration of all four of the outputs can be initiated with the **AOUTS CALIBRATION** command.

To enable or disable the Auto-Cal feature for one output channel, press.



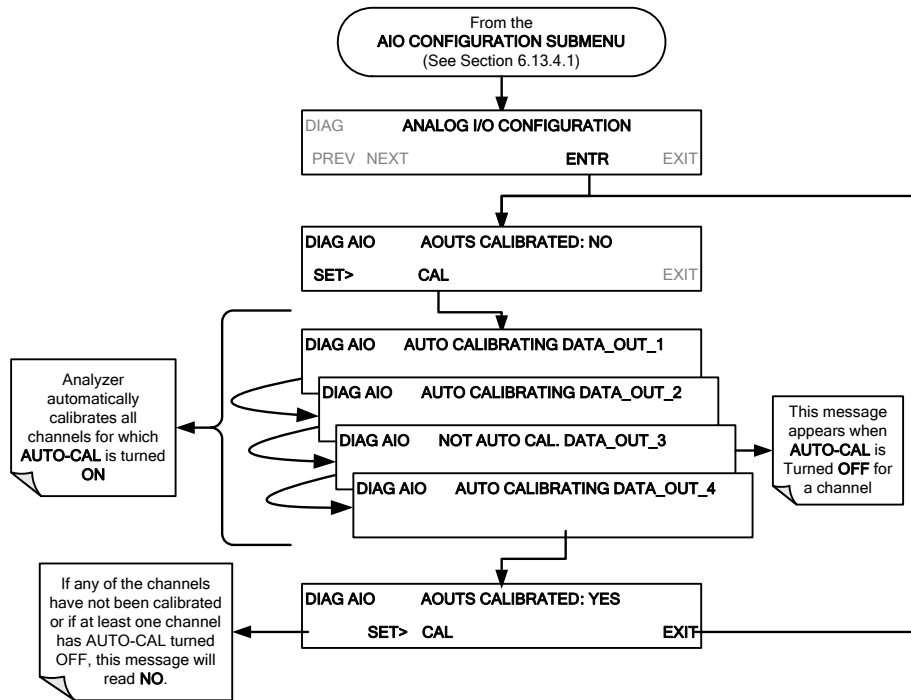
NOTE:

Channels with current loop output options cannot be calibrated automatically.

Outputs Configured for 0.1V and 10V full scale should always be calibrated manually.

6.13.6.1. Automatic Analog Output Calibration

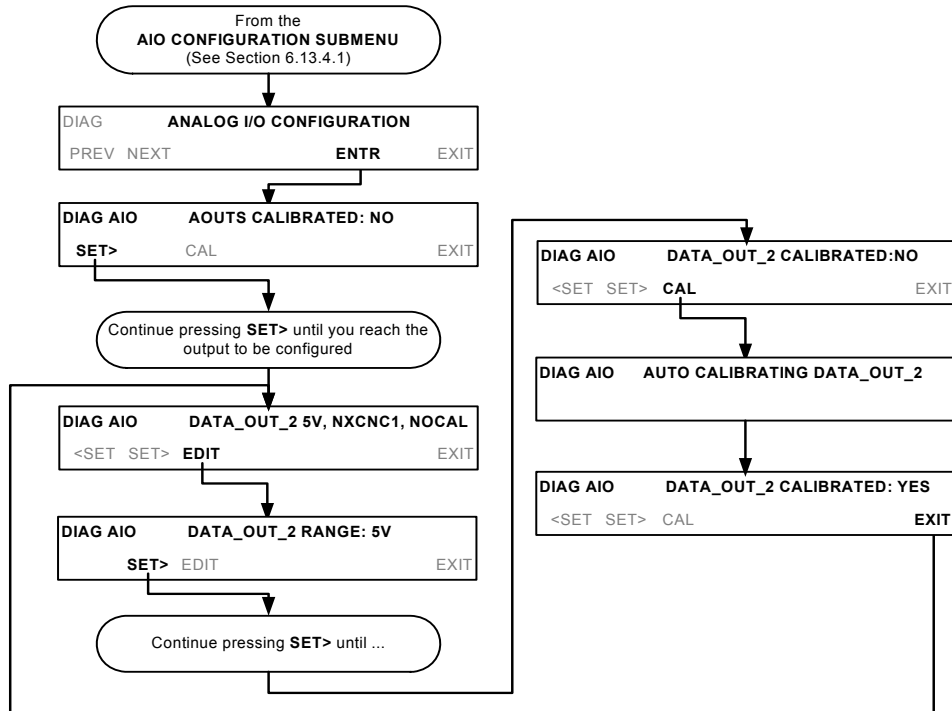
To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, press:



NOTE:

Manual calibration should be used for the 0.1V and 10V ranges or in cases where the outputs must be closely matched to the characteristics of the recording device.

To initiate an automatic calibration for an individual output channel, press:



6.13.6.2. Manual Calibration of Analog Output 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 6.13.5.1)

Calibration is performed with a voltmeter connected across the output terminals (See Figure 6-14) and by changing the actual output signal level using the front panel keys in 100, 10, or 1 count increments.

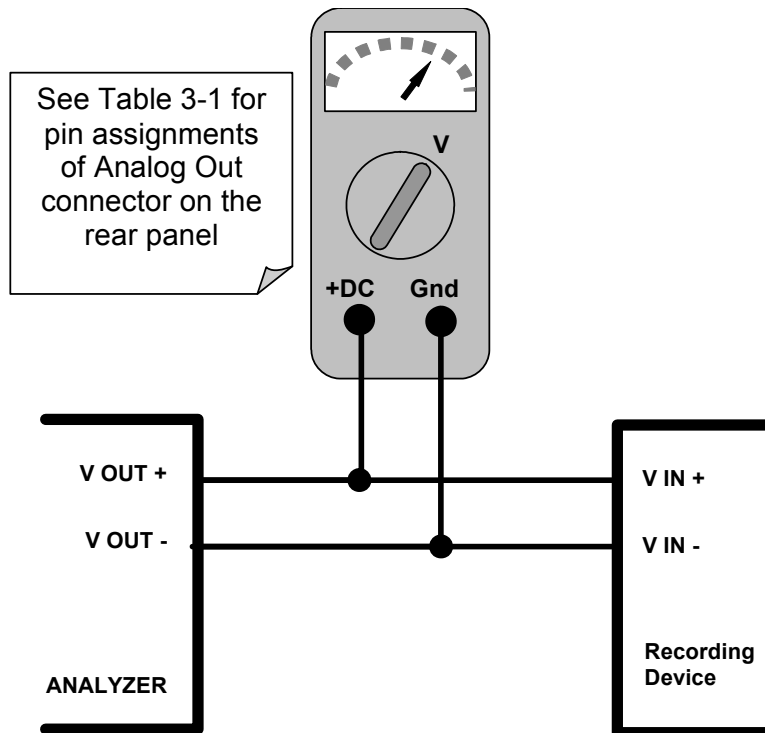
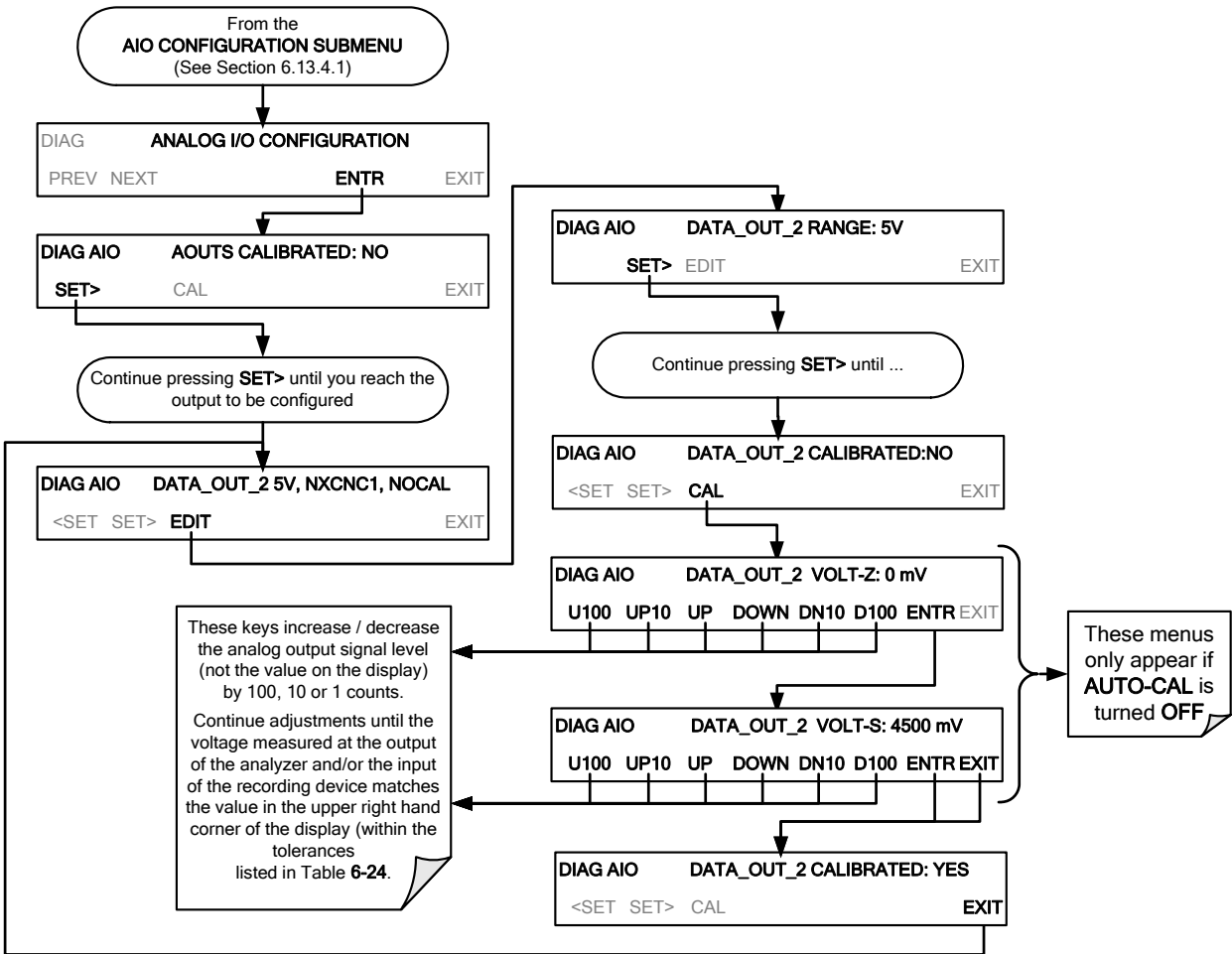


Figure 6-14: Setup for Calibrating Analog Outputs

Table 6-24: Voltage Tolerances for Analog Output 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	9000 mV	±0.006V	2.44 mV

To manually adjust the signal levels of an analog output channel, press:



6.13.6.3. Manual Calibration of Analog Outputs configured for Current Loop Ranges

The current loop output option (see Section 5.4) uses a small converter assembly to change the DC voltage output by the standard voltage output to a current signal ranging between 0-20 mA. Since the exact current increment per voltage count varies from converter to converter and from instrument to instrument, analog outputs with this option installed cannot be calibrated automatically and must be adjusted manually.

Adjusting the signal zero and full scale values of the current loop output is done in a similar manner as manually adjusting analog outputs configured for voltage output except that:

- In this case calibration is performed with a current meter connected in series with the output circuitry (See Figure 6-15).
- Adjustments to the output are made using the front panel keys, also in 100, 10 or 1 count increments, but the change in the voltage driving the converter assembly is displayed on the front panel.
- As before, adjustment of the output is performed until the current reading of the meter reaches the desired point (e.g. 2 mA, 4 mA, 20 mA, etc.)

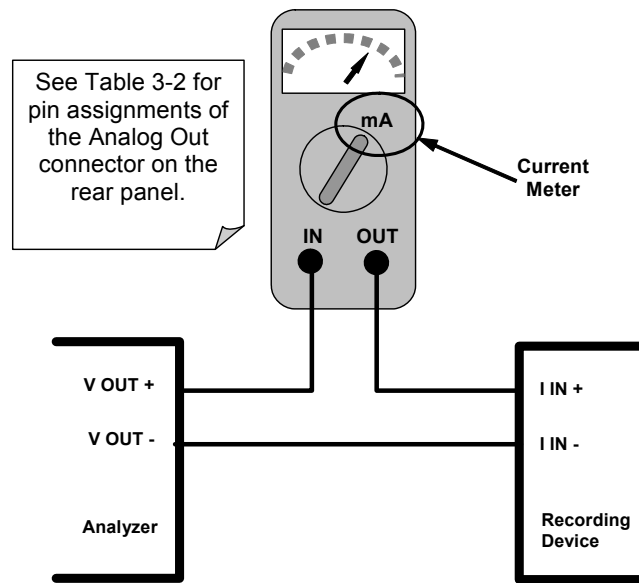


Figure 6-15: Setup for Calibrating Current Outputs

CAUTION

Do not exceed 60 V between current loop outputs and instrument ground.

If a current meter is not available, an alternative method for calibrating the current loop outputs is to connect a $250 \Omega \pm 1\%$ resistor across the current loop output. Using a voltmeter, connected across the resistor, follow the procedure above, but adjust the output to the following values:

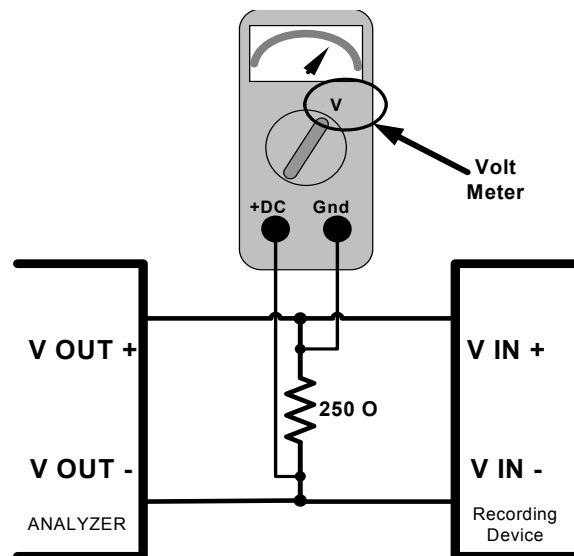
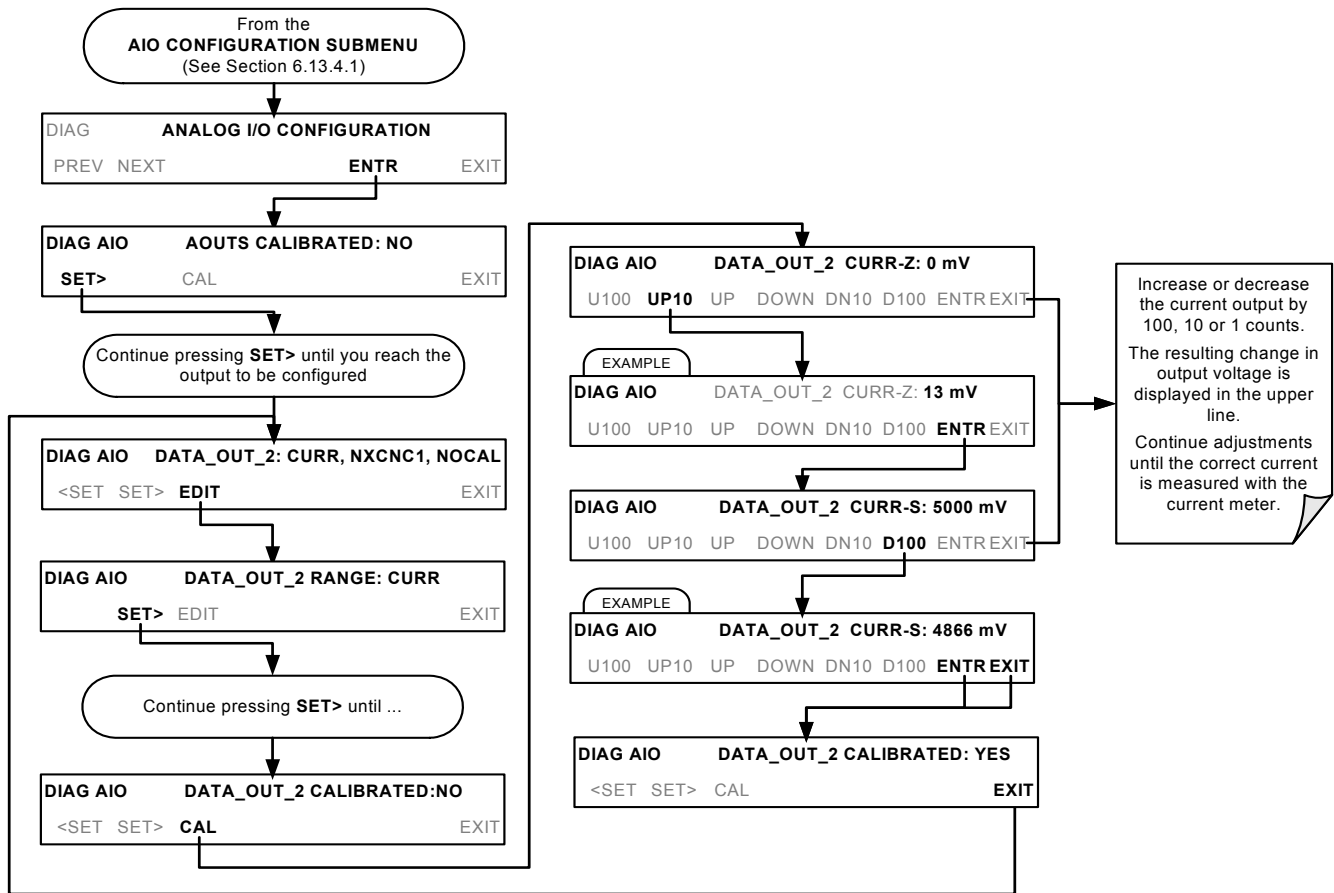


Figure 6-16: Alternative Setup for Calibrating Current Outputs

Table 6-25: Current Loop Output Calibration with Resistor

FULL SCALE	VOLTAGE FOR 2-20 MA (measured across 250Ω resistor)	VOLTAGE FOR 4-20 MA (measured across 250Ω resistor)
0%	0.5 V	1.0 V
100%	5.0 V	5.0 V

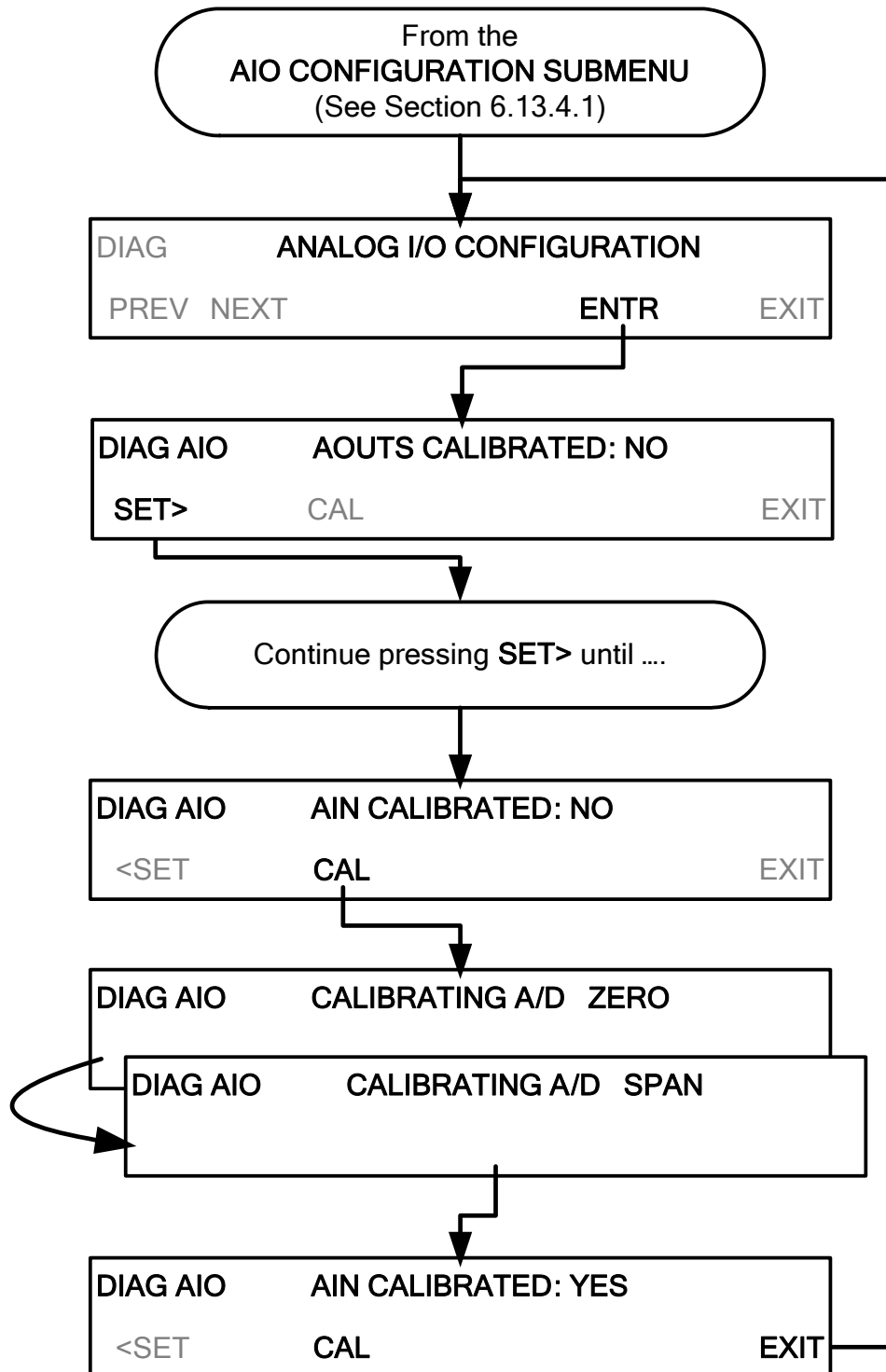
To adjust the zero and span values of the current outputs, press:



6.13.6.4. AIN Calibration

This is the sub-menu calibrates the analyzer's A-to-D conversion circuitry. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies.

To perform a **AIN CALIBRATION**, press:



6.13.7. OTHER DIAG MENU FUNCTIONS

6.13.7.1. Display Sequence Configuration

The model TML41M/H analyzer allows the user to choose which gas concentration measurement and reporting range is to be displayed in the concentration field on the instrument's front panel display as well as what order and how long each will appear before the analyzer cycles to the next item on the display list.

NOTE

This TML41M/H is constantly monitoring all of the gas measurements it is configured to make regardless of which range is being displayed. This feature merely changes how that display sequence occurs, not how the instrument makes measurements.

The software permits the user to choose from the following list of display values:

Table 6-26: TML41M/H Available Concentration Display Values

DISPLAY VALUE	DESCRIPTION	ASSOCIATED iDAS PARAMETER
NOX	NO _x value computed with the slope and offset values for the currently selected NO _x range. ¹	--
NXL	NO _x value computed with the slope and offset values for NO _x reporting range 1 (Low)	NXCNC1
NXH	NO _x value computed with the slope and offset values for NO _x reporting range 2 (High)	NXCNC2
NO	NO value of computed with the slope and offset values for the currently selected NO range ¹	--
NOL	NO value computed with the slope and offset values for NO reporting range 1 (Low)	NOCNC1
NOH	NO value computed with the slope and offset values for NO reporting range 2 (High)	NOCNC2
N2	NO ₂ value of computed with the slope and offset values for the currently selected NO ₂ range ¹	--
N2L	NO ₂ value computed for with the slope and offset values for NO _x reporting range 1 (Low) & NO reporting range 1 (Low)	N2CNC1
N2H	NO ₂ value computed for with the slope and offset values for NO _x reporting range 2 (High) & NO reporting range 2 (High)	N2CNC2
O2	O ₂ concentration value.	O2CONC ²

¹ With the following exceptions this will be reporting range 1 (Low) for the appropriate gas type:

- If the analyzer is in calibration mode, this will be the concentration value computed with the slope and offset for which ever range is being calibrated.
- If the instrument is in either E-Test or O-Test mode, this will be the value computed with the slope and offset values used by those tests.

² Only appears if O2 sensor option is installed.

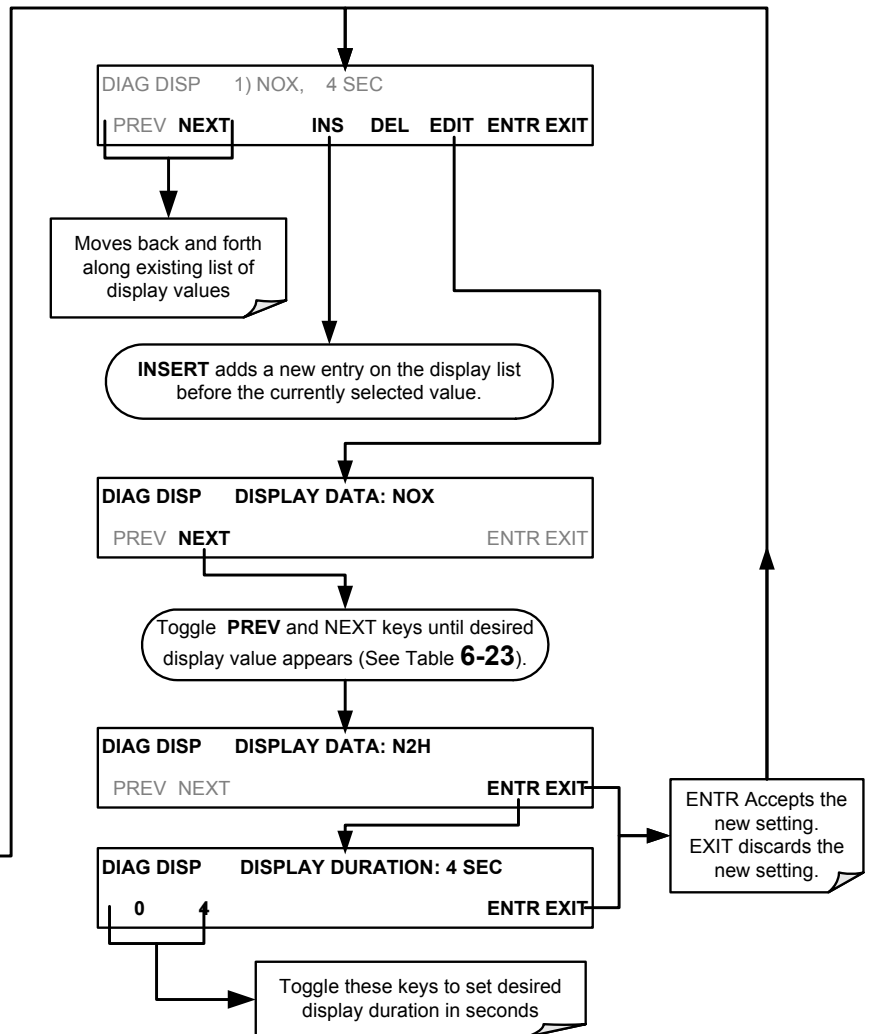
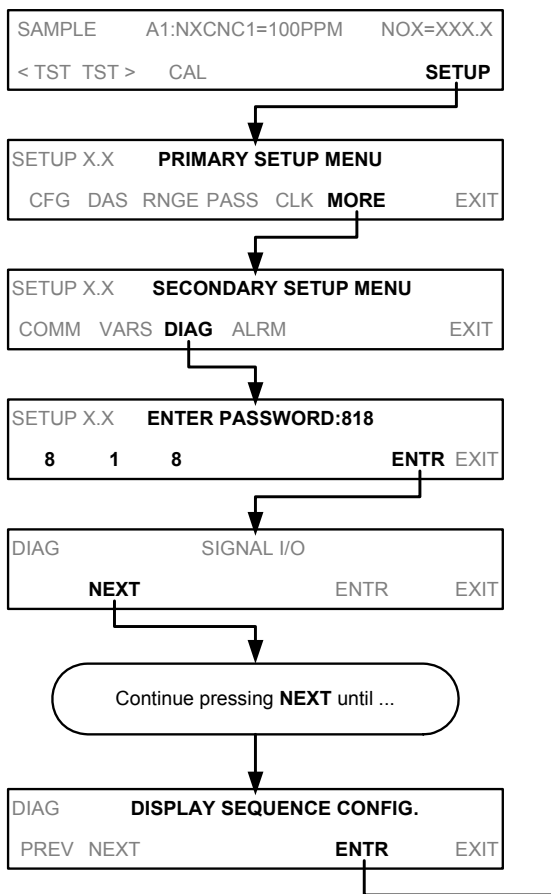
The default settings for this feature are:

Table 6-27: TML41M/H Concentration Display Default Values

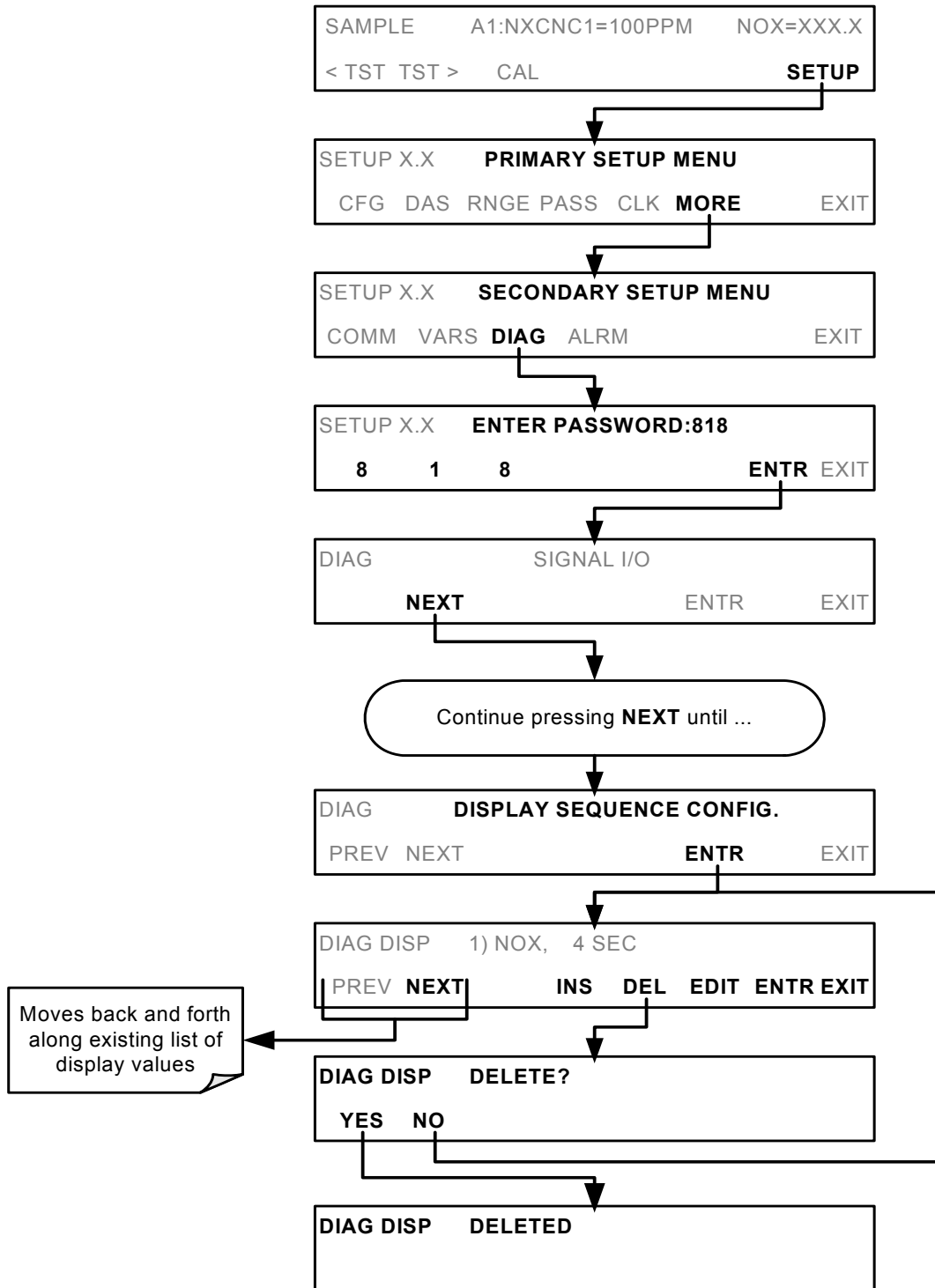
DISPLAY VALUE	DISPLAY DURATION
NOX	4 sec.
NO	4 sec.
NO2	4 sec.
O2	4 sec.

¹ Only appears if O2 sensor option is installed.

To change these settings, press:

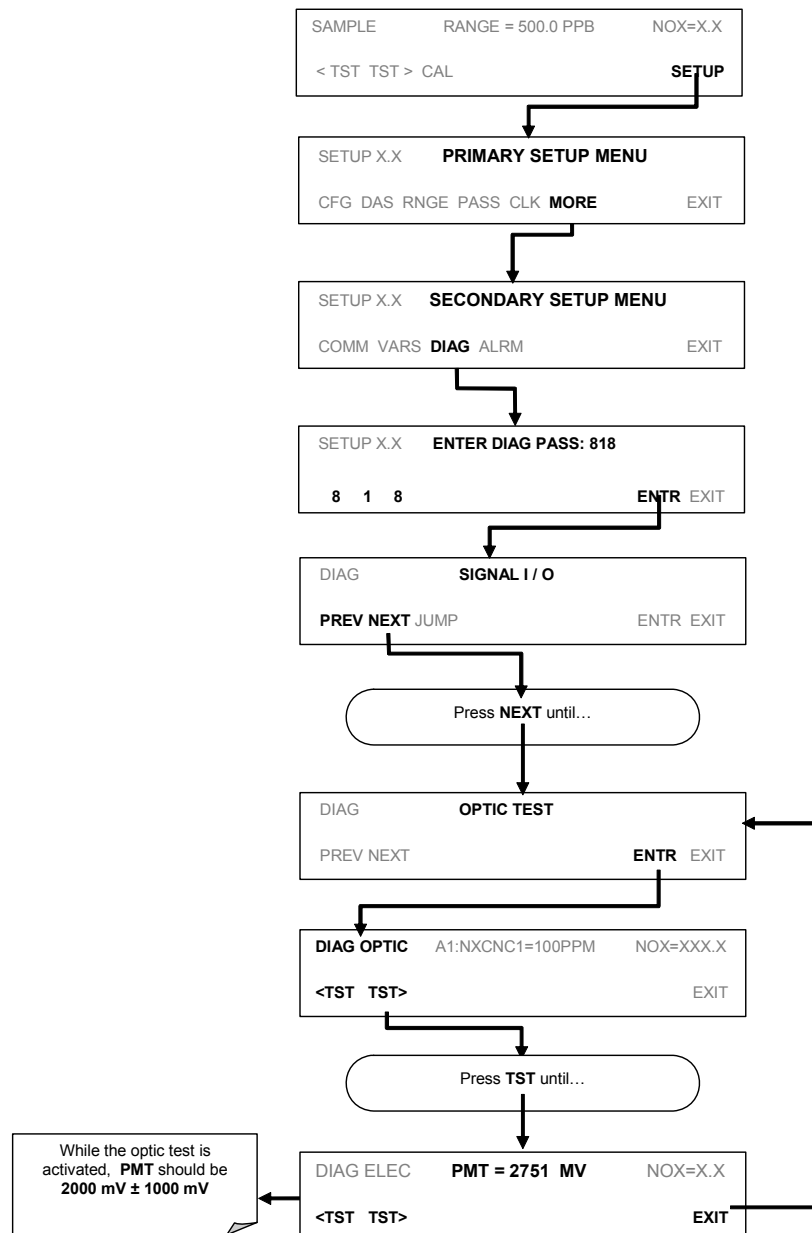


To delete an entry in the display value list, press:



6.13.7.2. 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 (Fig. 10-15). 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 make sure 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 electrical test press the following key sequence.



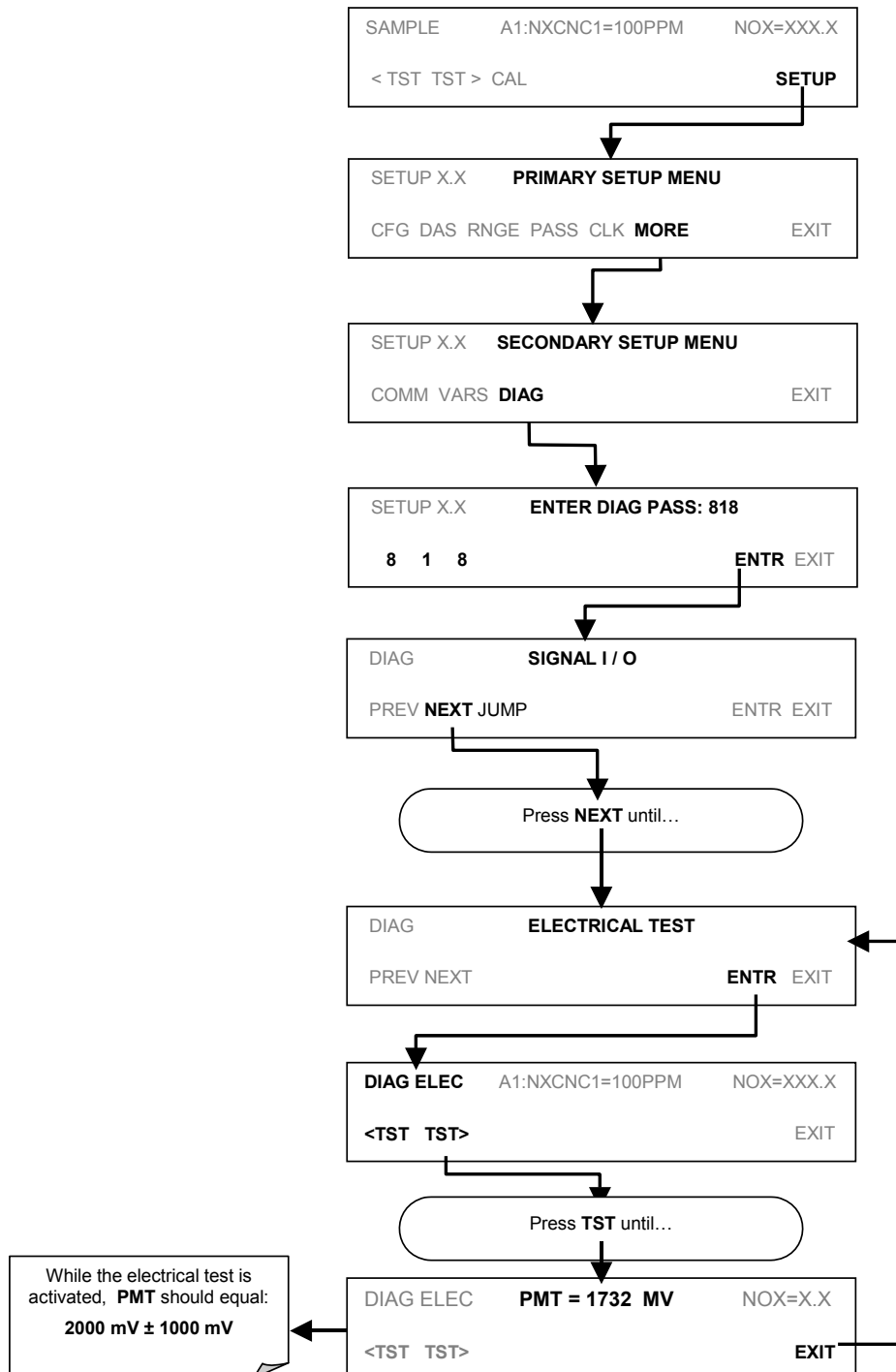
NOTE

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.

6.13.7.3. Electrical Test

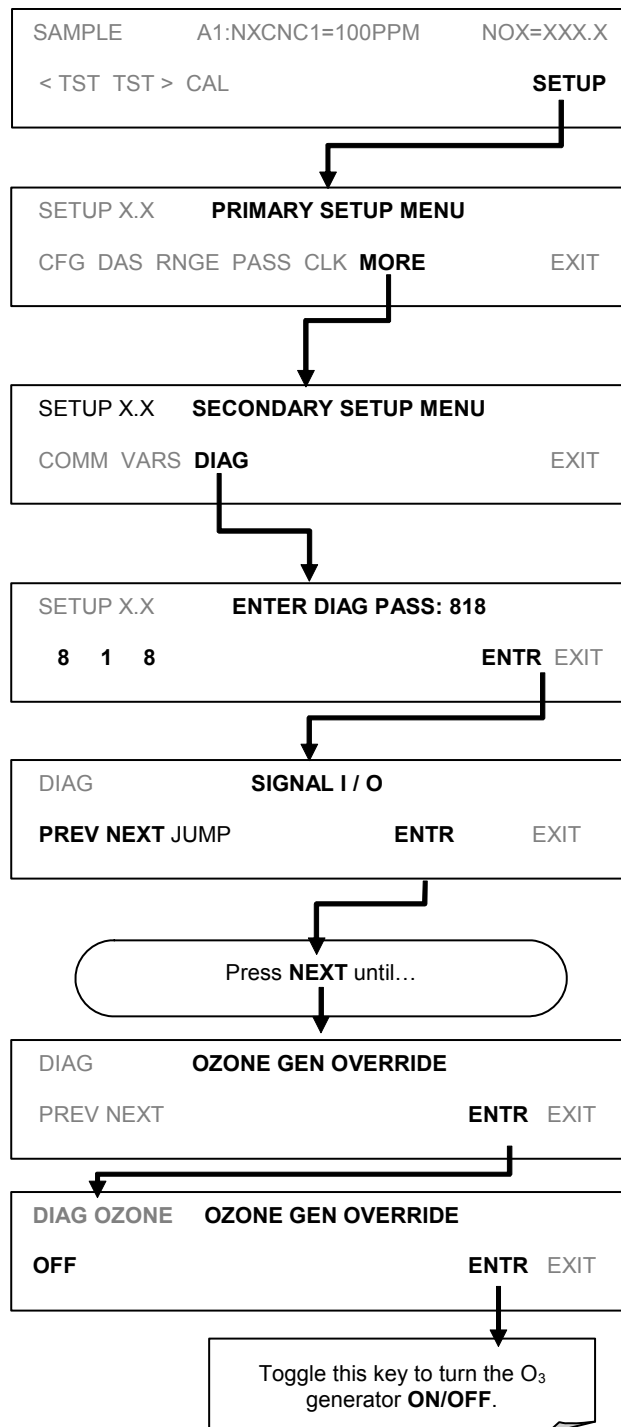
The electrical test function creates a current, which substitutes the PMT signal, and feeds it into the preamplifier board. This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard. It does not test the PMT itself. The electrical test should produce a PMT signal of about 2000 ± 1000 mV.

To activate the electrical test press the following keys.



6.13.7.4. Ozone Generator Override

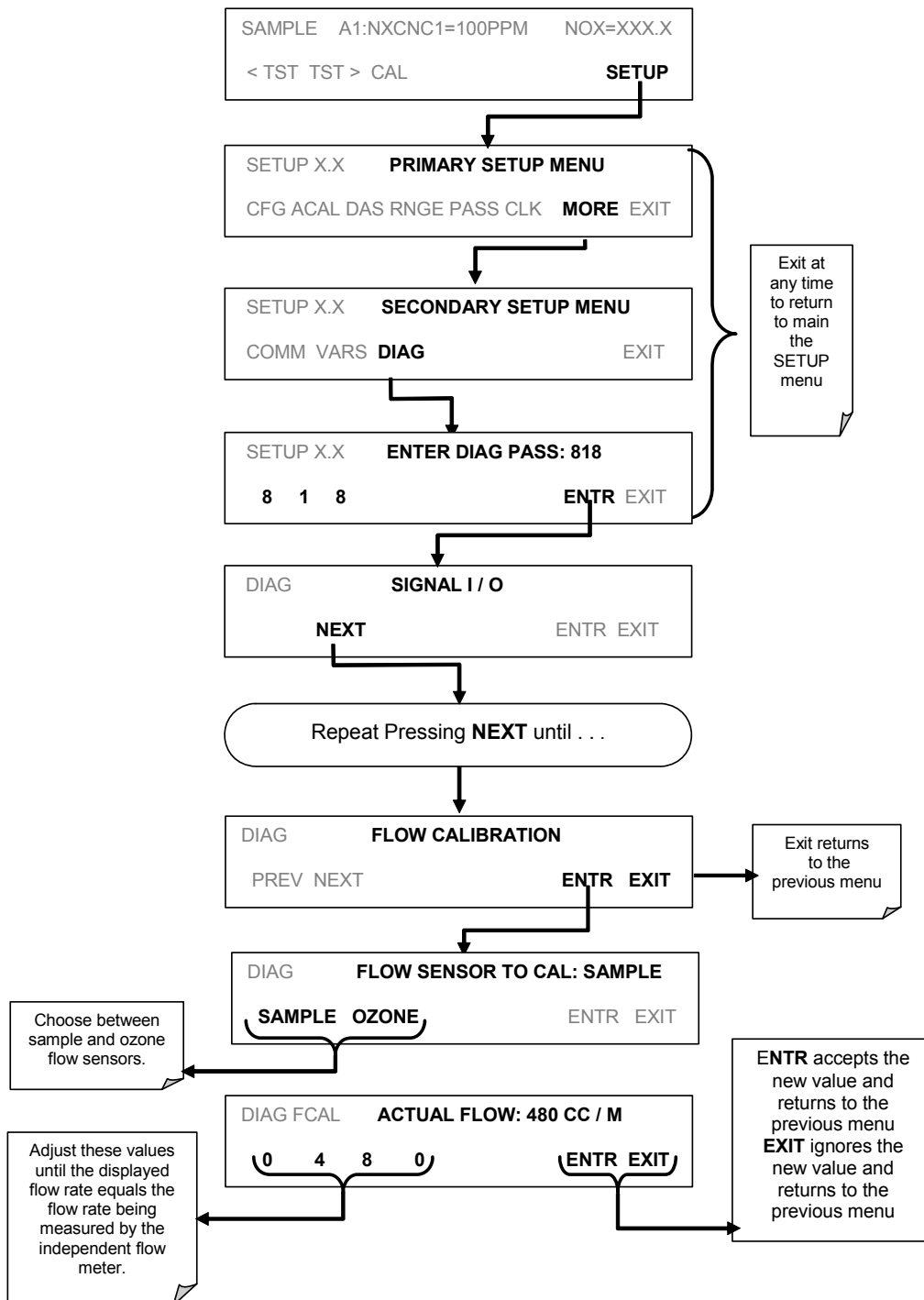
This feature allows the user to manually turn the ozone generator off and on. This can be done before disconnecting the generator, to prevent ozone from leaking out, or after a system restart if the user does not want to wait for 30 minutes during warm-up time. Note that this is one of the two settings in the **DIAG** menu that is retained after you exit the menu. To access this feature, press the following keys. 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).



6.13.7.5. Flow Calibration

The flow calibration allows the user to adjust the values of the sample flow rates as they are displayed on the front panel and reported through COM ports to match the actual flow rate measured at the sample inlet. This does not change the hardware measurement of the flow sensors, only the software-calculated values.

To carry out this adjustment, connect an external, sufficiently accurate flow meter to the sample inlet (see Chapter 11 for more details). Once the flow meter is attached and is measuring actual gas flow, press:



6.14. SETUP – ALRM: USING THE OPTIONAL GAS CONCENTRATION ALARMS (OPT 67)

The optional alarm relay outputs (Option 67) include two concentration alarms. Each alarm has a user settable limit, and is associated with an opto-isolated TTL relay accessible via the status output connector on the instrument's back panel (see Section 6.15.1.1). If the concentration measured by the instrument rises above that limit, the alarm's status output relay is closed.

The default settings for **ALM1** and **ALM2** are:

Table 6-28: Concentration Alarm Default Settings

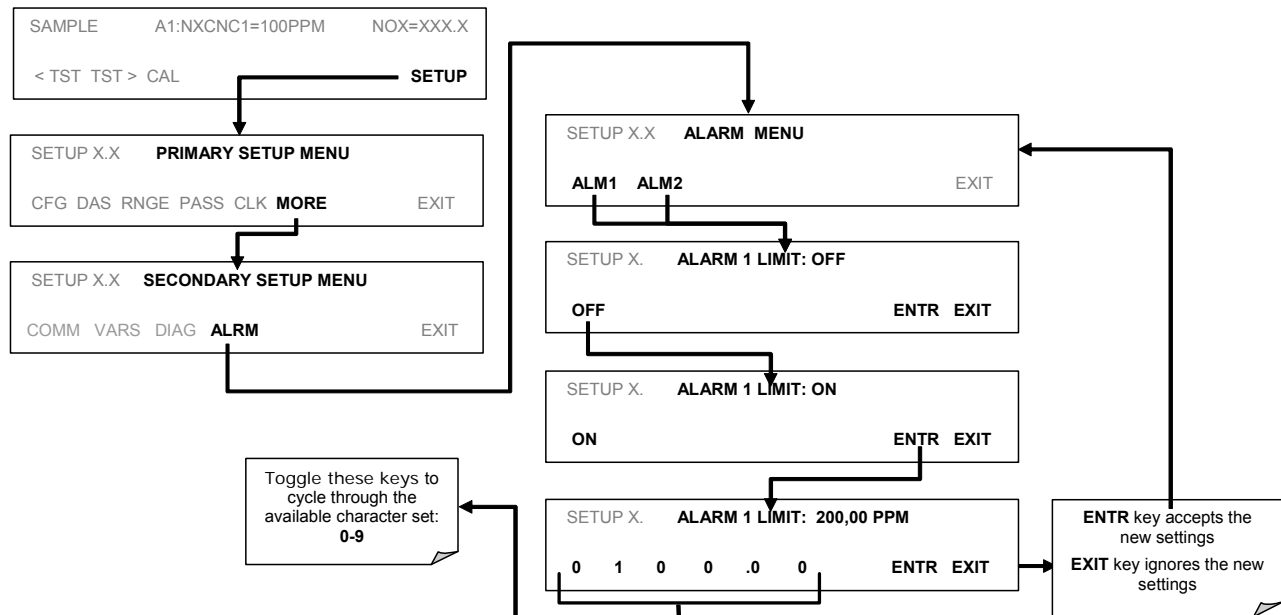
ALARM	STATUS	LIMIT SET POINT ¹		OUTPUT RELAY DESIGNATION
ALM1	Disabled	100 ppm	133.9 mg/m ³	AL2
ALM2	Disabled	300 ppm	401.6 mg/m ³	AL3

¹ Set points listed are for PPM. Should the reporting range units of measure be changed (see Section 6.13.4.2) the analyzer will automatically scale the set points to match the new range unit setting.

NOTE

To prevent the concentration alarms from activating during span calibration operations make sure to press **CAL** or **CALS** button prior to introducing span gas into the analyzer.

To enable either of the concentration alarms and set the Limit points, press:



6.15. REMOTE OPERATION OF THE ANALYZER

6.15.1. REMOTE OPERATION USING THE EXTERNAL DIGITAL I/O

6.15.1.1. Status Outputs

The status outputs report analyzer conditions via optically isolated NPN transistors, which 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 D.

NOTE

Most PLCs 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 accessed through a 12 pin connector on the analyzer's rear panel labeled STATUS (see Figure 6-17). The function of each pin is defined in Table 6-29

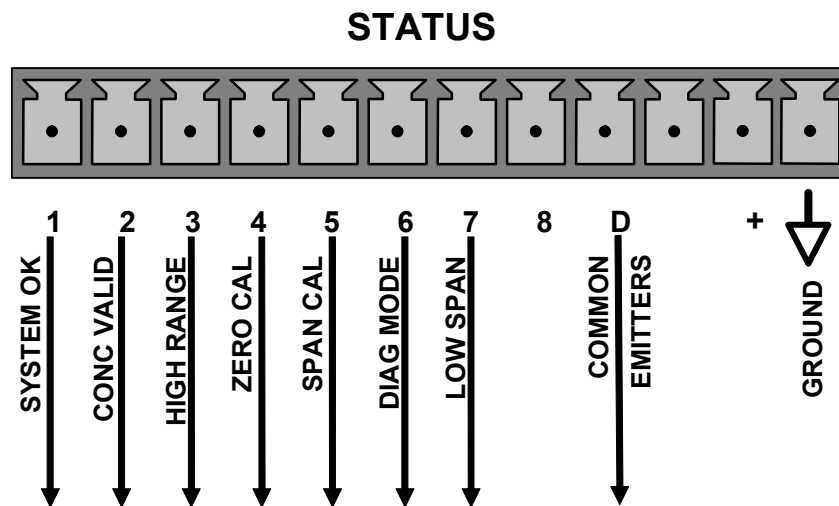



Figure 6-17: Status Output Connector


Table 6-29: Status Output Pin Assignments

CONNECTOR PIN	STATUS	CONDITION (ON=CONDUCTING)
1	SYSTEM OK	ON if no faults are present.
2	CONC VALID	ON if concentration measurement is valid, OFF when invalid.
3	HIGH RANGE	ON if unit is in high range of any AUTO range mode.
4	ZERO CAL	ON whenever the instrument is in ZERO calibration mode.
5	SPAN CAL	ON whenever the instrument is in SPAN calibration mode.
6	DIAG MODE	ON whenever the instrument is in DIAGNOSTIC mode.
7	LOW RANGE	ON if unit is in low range of any AUTO range mode.
8		Unused.
D	EMITTER BUS	The emitters of the transistors on pins 1-8 are bussed together. For most applications, this pin should be connected to the circuit ground of the receiving device.
+	DC POWER	+ 5 VDC, 30 mA maximum (combined rating with Control Inputs).
	DIGITAL GROUND	The ground from the analyzer's internal, 5/±15 VDC power supply.

6.15.1.2. Control Inputs

Control inputs which allow the user to remotely initiate ZERO and SPAN calibration modes are provided through a 10-pin connector labeled CONTROL IN on the analyzer's rear panel. These are opto-isolated, digital inputs that are activated when a 5 VDC signal from the "U" pin is connected to the respective input pin.

Table 6-30: Control Input Pin Assignments

INPUT	STATUS	CONDITION WHEN ENABLED
A	EXTERNAL ZERO CAL	Zero calibration mode is activated. The mode field of the display will read ZERO CAL R.
B	EXTERNAL SPAN CAL	Span calibration mode is activated. The mode field of the display will read SPAN CAL R.
C	EXTERNAL LOW SPAN CAL	Low span (mid-point) calibration mode is activated. The mode field of the display will read LO CAL R.
D, E & F		Unused
	DIGITAL GROUND	Provided to ground an external device (e.g., recorder).
U	DC power for Input pull ups	Input for +5 VDC required to activate inputs A - F. This voltage can be taken from an external source or from the "+" pin.
+	Internal +5V Supply	Internal source of +5V which can be used to activate inputs when connected to pin U.

There are two methods to activate control inputs. The internal +5V available from the “+” pin is the most convenient method (see Figure 6-18). However, to ensure that these inputs are truly isolated, a separate, external 5 VDC power supply should be used (see Figure 6-19).

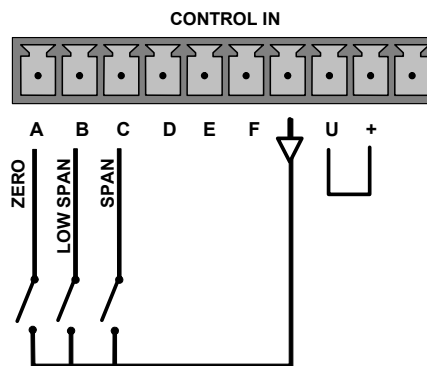


Figure 6-18: Control Inputs with local 5 V power supply

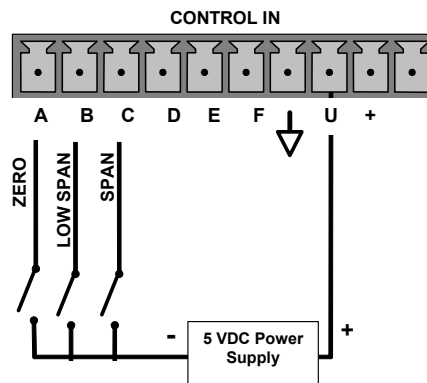


Figure 6-19: Control Inputs with external 5 V power supply

6.15.2. REMOTE OPERATION USING THE EXTERNAL SERIAL I/O

6.15.2.1. Terminal Operating Modes

The TML41M/H can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the analyzer supports two communication modes specifically designed to interface with these two types of devices.

- **Computer mode** is used when the analyzer is connected to a computer with a dedicated interface program such as sensor-e.com. More information regarding sensor-e.com can be found in later in this section or on the Teledyne Instruments website at <http://www.teledyne-ml.com>
- **Interactive mode** is used with a terminal emulation programs such as HyperTerminal or a “dumb” computer terminal. The commands that are used to operate the analyzer in this mode are listed in Table 6-31 and in Appendix A-6.

6.15.2.2. Help Commands in Terminal Mode

Table 6-31: Terminal Mode Software Commands

COMMAND	FUNCTION
Control-T	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.
Control-C	Switches the analyzer to computer mode (no echo, no edit).
CR (carriage return)	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 key.
BS (backspace)	Erases one character to the left of the cursor location.
ESC (escape)	Erases the entire command line.
? [ID] CR	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.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

6.15.2.3. Command Syntax

Commands are not case-sensitive and all arguments within one command (i.e. ID numbers, keywords, 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 6-31 and Appendix A-6.
- [ID] is the analyzer identification number (see Section 6.11.1.). 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 key on a computer).

Table 6-32: Command Types

COMMAND	COMMAND TYPE
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

6.15.2.4. 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 keywords `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, such as iDAS data channels, by name. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

6.15.2.5. 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 (see Section 6.11.8, Table 6-14).

Status reports include iDAS data (when reporting is enabled), warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the possible messages, and this section for information on controlling the instrument through the RS-232 interface.

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 6-32. |
| 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, iDAS reports, 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 trouble-shooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

6.15.2.6. Remote Access by Modem

The TML41M/H 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 Instruments with part number WR0000024).

Once the cable has been connected, check to make sure the DTE-DCE switch is in the correct position. Also make sure the TML41M/H COM port is set for a baud rate that is compatible with the modem, which needs to operate with an 8-bit word length with one stop bit.

The first step is to turn on the **MODEM ENABLE** communication mode (Mode 64, Section 6.11.8). 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

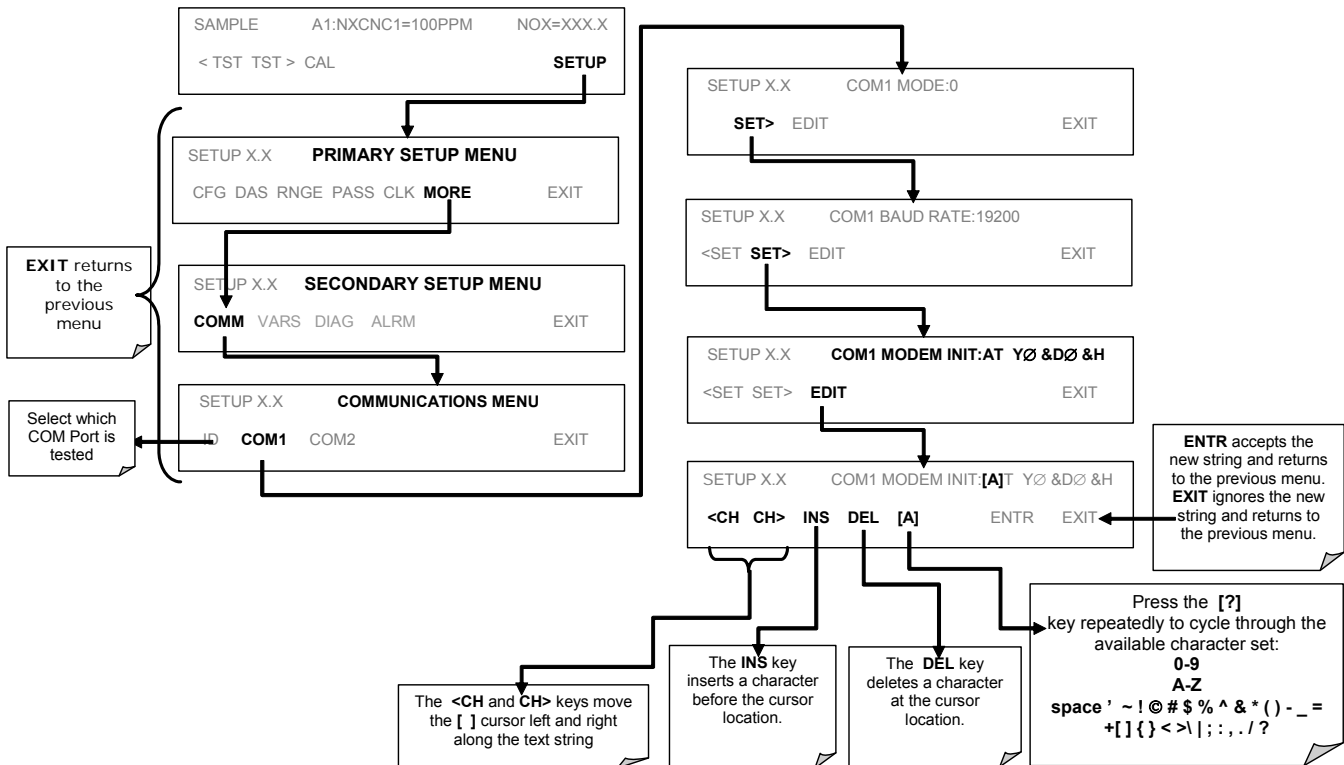
```
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0
```

This string can be altered to match your modem's initialization and can be up to 100 characters long.

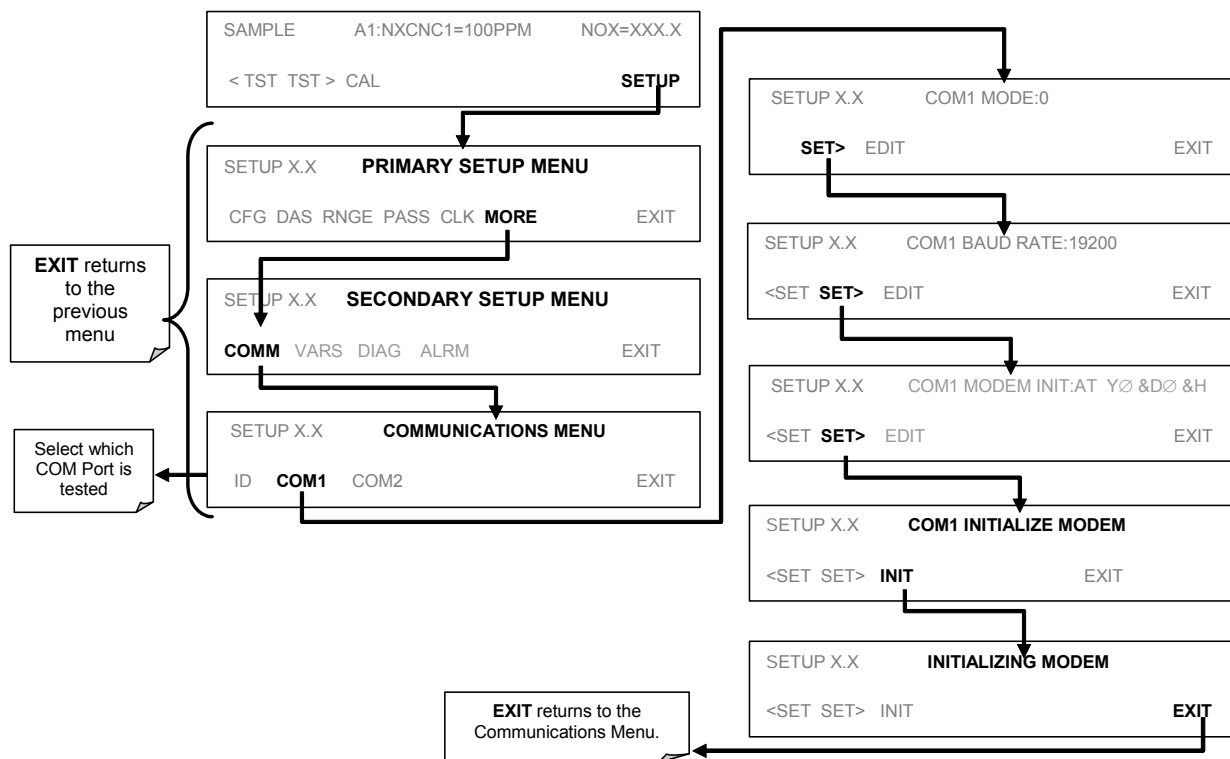
NOTE:

If Hessen Protocol Mode is active for a COMM port, operation via a modem is not available on that port.

To change this setting press:



To initialize the modem press:



6.15.2.7. COM Port Password Security

In order to provide security for remote access of the TML41M/H, 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** (see Section 6.11.8). 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 TML41M/H analyzer with **SECURITY MODE** feature enabled, type:

LOGON 940331

940331 is the default password. To change the default password, use the variable RS232_PASS issued as follows:

V RS232_PASS=NNNNNN

Where N is any numeral between 0 and 9.

6.15.2.8. sensor-e.com Remote Control Program

sensor-e.com is an easy-to-use, yet powerful interface program that allows accessing and controlling any of Teledyne Instruments' main line of ambient and stack-gas instruments from a remote connection through direct cable, modem, or Ethernet. Running sensor-e.com, a user can:

- Establish a link from a remote location to the TML41M/H 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 when standing in front of 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 iDAS configurations.
- Check on system parameters for trouble-shooting and quality control.

sensor-e.com is very helpful for initial setup, data analysis, maintenance and trouble-shooting. Figure 6-20 shows examples of sensor-e.com's main interface, which emulates the look and functionality of the instrument's actual front panel

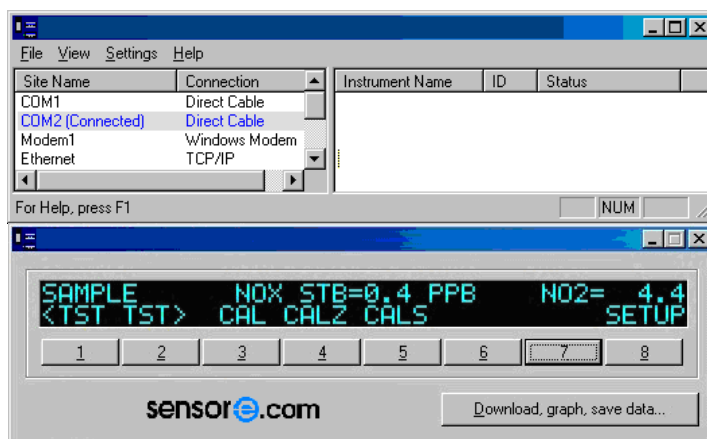


Figure 6-20: sensor-e.com Remote Control Program Interface

sensor-e.com is included free of cost with the analyzer and the latest versions can also be downloaded for free at <http://www.teledyne-ml.com>.

6.15.3. ADDITIONAL COMMUNICATIONS DOCUMENTATION

Table 6-33: Serial Interface Documents

Interface / Tool	Document Title	Part Number	Available Online*
sensor-e.com	sensor-e.com User Manual	039450000	YES
Multi-drop	RS-232 Multi-drop Documentation	021790000	YES
DAS Manual	Detailed description of the iDAS.	028370000000 0	YES

* These documents can be downloaded at <http://www.teledyne-ml.com>

6.15.4. USING THE TML41M/H WITH A HESSEN PROTOCOL NETWORK

6.15.4.1. General Overview of Hessen Protocol

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 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. TML's implementation supports both of these principal features.

The Hessen protocol is not well defined; therefore while TML's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

The following subsections describe the basics for setting up your instrument to operate over a Hessen Protocol network. For more detailed information as well as a list of host computer commands and examples of command and response message syntax, download the *Manual Addendum for Hessen Protocol* from the Teledyne Instruments' web site: <http://www.teledyne-ml.com>.

6.15.4.2. Hessen COMM Port Configuration

Hessen protocol requires the communication parameters of the TML41M/H's COMM ports to be set differently than the standard configuration as shown in the table below.

Table 6-34: RS-232 Communication Parameters for Hessen Protocol

Parameter	Standard	Hessen
Data Bits	8	7
Stop Bits	1	2
Parity	None	Even
Duplex	Full	Half

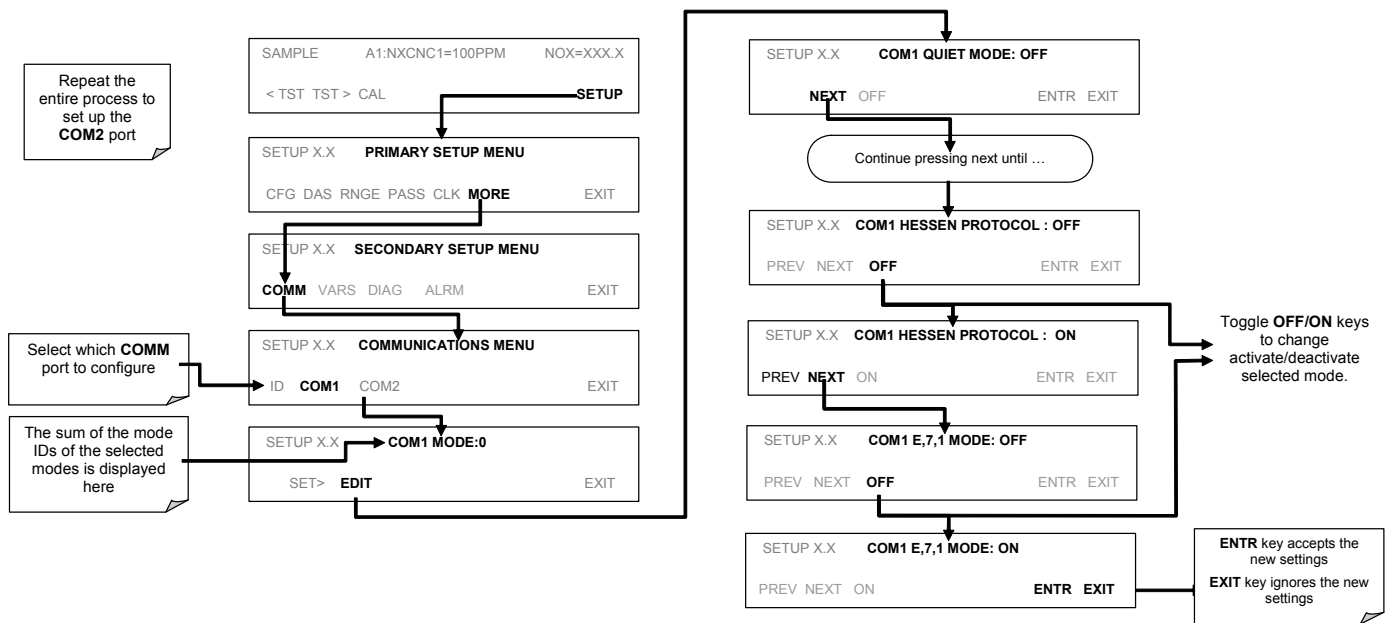
To change the rest of the COMM port parameters and modes see Section 6.11.8.

To change the baud rate of the TML41M/H's COMM ports see Section 6.11.9.

NOTES

- **Make sure that the communication parameters of the host computer are properly set.**
- **The instrument software has a 200 ms. latency before it responds to commands issued by the host computer.**
- **Operation via modem is not available over any COMM port on which HESSEN protocol is active.**

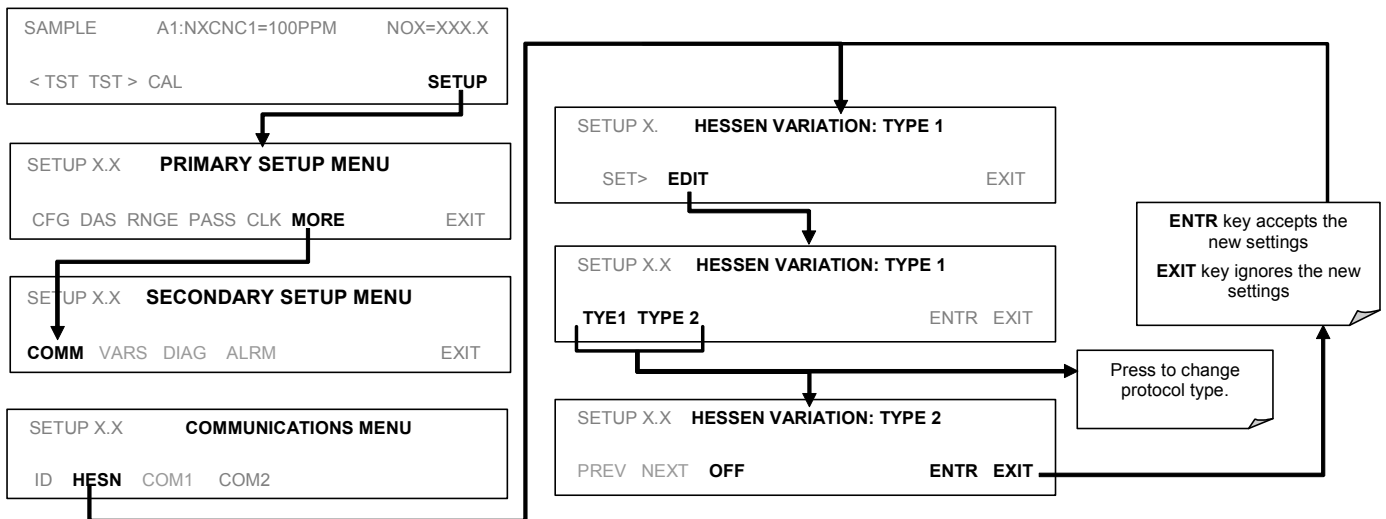
The first step in configuring the TML41M/H to operate over a Hessen protocol network is to activate the Hessen mode for COMM ports and configure the communication parameters for the port(s) appropriately. Press:



6.15.4.3. Selecting a Hessen Protocol Type

Currently there are two version 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 Instruments' web site: <http://www.teledyne-ml.com>.

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.

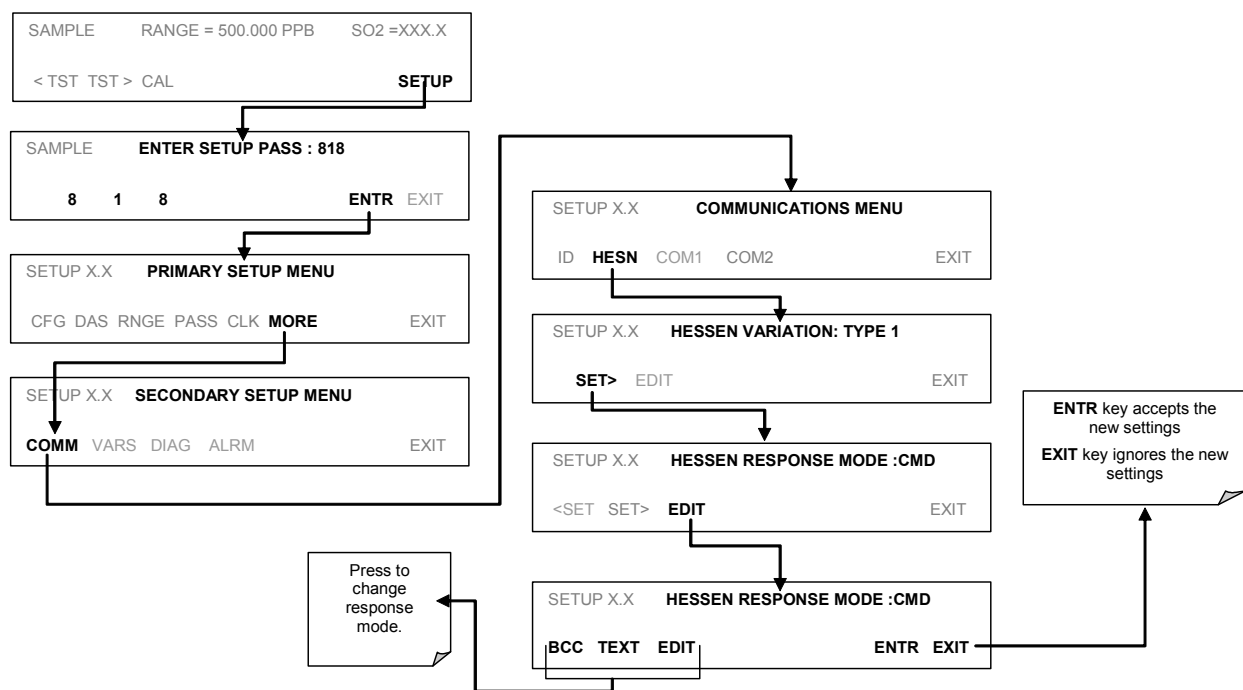
6.15.4.4. Setting The Hessen Protocol Response Mode

The Teledyne Instruments' implementation of Hessen Protocol allows the user to choose one of several different modes of response for the analyzer.

Table 6-35: TML41M/H Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	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.
BCC	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.
TEXT	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:



6.15.4.5. Hessen Protocol Gas ID

Since the TML41M/H measures NO_x, NO₂, NO and O₂ (if the optional sensor is installed), all of these gases are listed in the Hessen protocol gas list. In its default state the Hessen protocol firmware assigns each of these gases a Hessen ID number and actively reports all of them even if the instrument is only measuring one (see **MEASURE_MODE**, Section 6.12.1).

To change or edit these settings press:

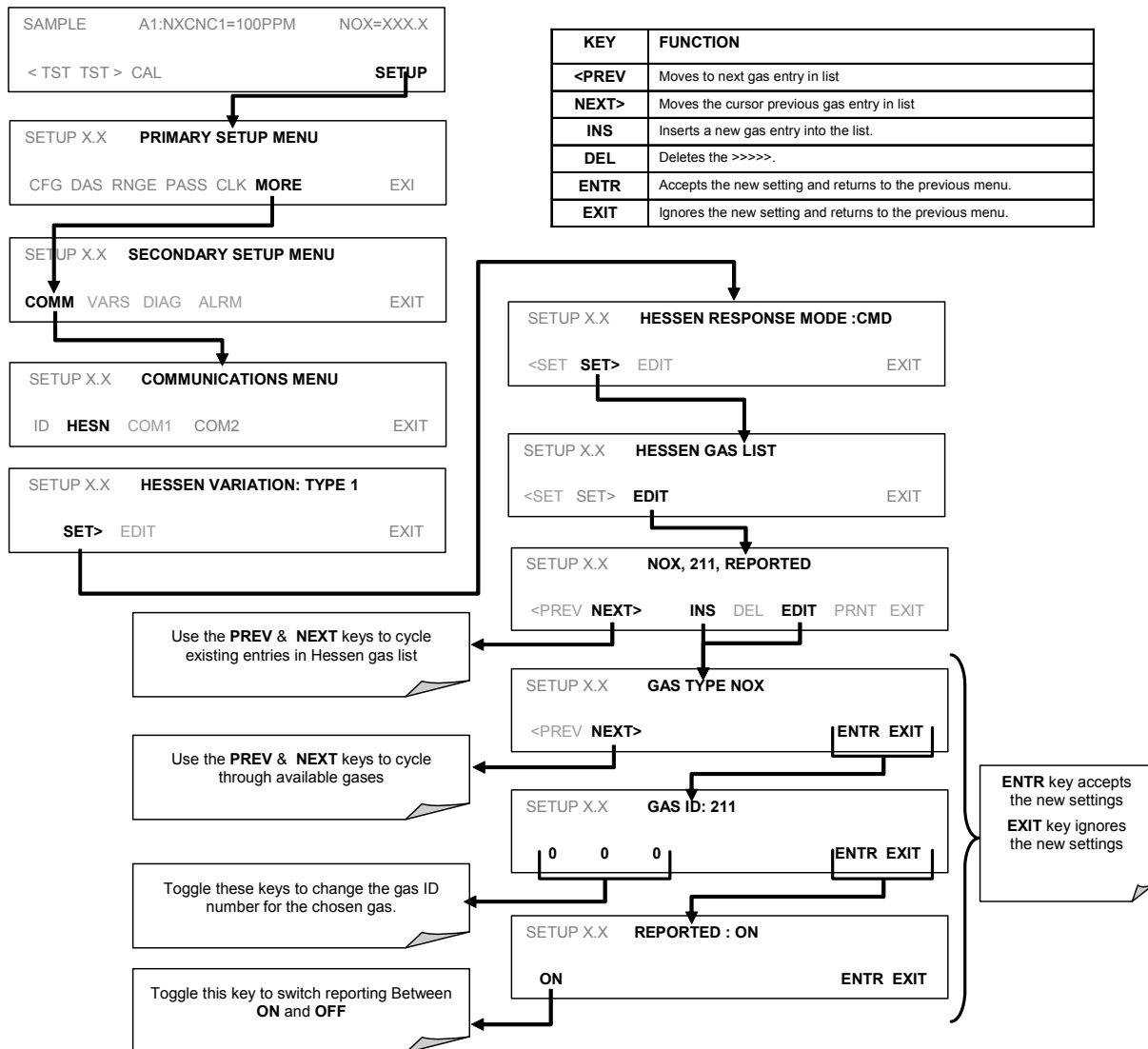


Table 6-36: TML41M/H Hessen GAS ID List

GAS DEFAULT	HESSEN GAS ID
NOx	211
NO	212
NO ₂	213
O ₂	214

6.15.4.6. Setting Hessen Protocol Status Flags

Teledyne Instruments' implementation of Hessen protocols includes a set of status bits that are included in responses to inform the host computer of the TML41M/H's condition. The default settings for these bit/flags are:

Table 6-37: Default Hessen Status Bit Assignments

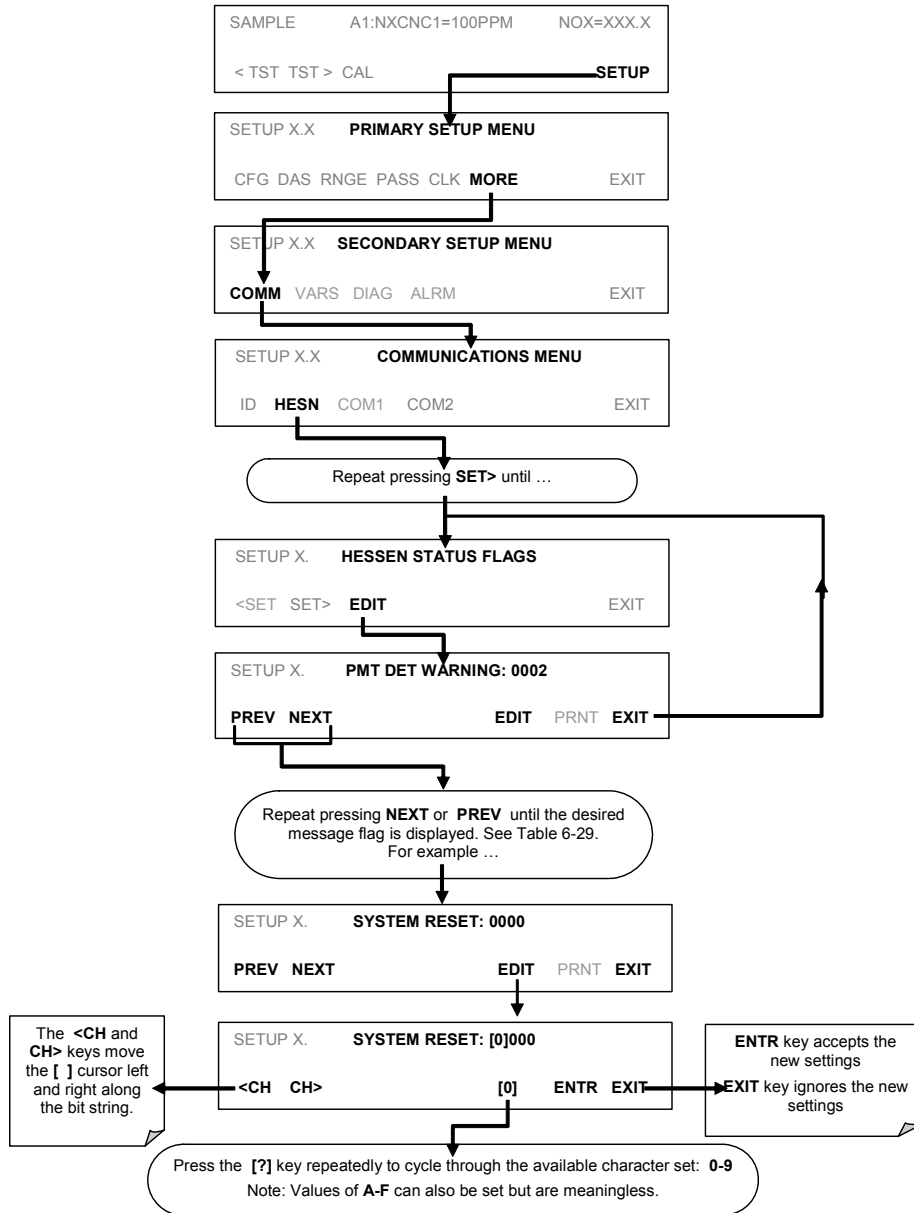
STATUS FLAG NAME	DEFAULT BIT ASSIGNMENT
WARNING FLAGS	
SAMPLE FLOW WARNING	0001
OZONE FLOW WARNING	0002
RCELL PRESS WARN	0004
BOX TEMP WARNING	0008
RCELL TEMP WARNING	0010
PMT TEMP WARNING	0040
CONVERTER TEMP WARNING	0080
WARMUP MODE	1000
INVALID CONC	8000
OPERATIONAL FLAGS	
In Manual Calibration Mode	0200
In O ₂ Calibration Mode	0400
In Zero Calibration Mode	0400
In Low Span Calibration Mode	0800
In Span Calibration Mode	0800
UNITS OF MEASURE FLAGS	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
SPARE/UNUSED BITS	0020, 0100
UNASSIGNED FLAGS	
Box Temp Warning	Front Panel Warning
System Reset	Analog Cal Warning
Rear Board Not Detected	Cannot Dyn Zero
Relay Board Warning	Cannot Dyn Span
Manifold Temp Warn	O ₂ Cell Temp Warn
Ozone Gen Off	AutoZero Warning
Conc Alarm 1	Conc Alarm 2
HVPS Warning	In MP Calibration Mode

NOTES:

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:



6.15.4.7. Instrument ID Code

Each instrument on a Hessen Protocol network must have a unique ID code. The TML41M/H is programmed with a default ID code of **200**. To change this code, see Section 6.11.1

User Notes:

USER NOTES:

7. CALIBRATION PROCEDURES

This chapter describes calibration procedures for the TML41M/H. All of the methods described here can be initiated and controlled through the front panel or the COM ports.

NOTE

CALIBRATION vs. CALIBRATION CHECK

Pressing the ENTR key during the following procedures re-calculates the stored values for OFFSET and SLOPE and alters the instrument's calibration.

If you wish to perform a calibration check, DO NOT press the ENTR button.

7.1. CALIBRATION PREPARATIONS

7.1.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the TML41M/H analyzer requires a certain amount of equipment and supplies. These include, but are not limited to, the following:

- Zero-air source (defined in Section 7.1.2).
- Span gas source (defined in Section 7.1.3).
- 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 with O₂ 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 can be used.

7.1.2. ZERO AIR

Zero air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. For NO_x measuring devices, zero air should be devoid of NO_x and large amounts of CO₂, NH₃ and water vapor. Water vapor and moderate amounts of NH₃ can be removed using a sample gas conditioner (Section 5.10).

Devices such as the Model 701 zero air generator that condition ambient air by drying and removal of pollutants are available. We recommend this type of device for generating zero air. Please contact our sales department for more information on this.

7.1.3. SPAN CALIBRATION GAS STANDARDS & TRACEABILITY

NOTE

We strongly recommend that span calibration is carried out with NO span gas, although it is possible to use NO₂ or a gas phase titration (GPT) system.

Quick span checks may be done with either NO, NO₂ or a mixture of NO and NO₂ as is used in GPT.

Span gas is specifically mixed to match the chemical composition of the gas being measured at about 80% of the desired full measurement range. For example, if the measurement range is 120 ppm, the span gas should have an NO concentration of about 96 ppm.

Span gases should be certified to a specific accuracy to ensure accurate calibration of the analyzer. Typical gas accuracy for NO_x gases is 1 or 2%. NO standards should be mixed in nitrogen (to prevent oxidation of NO to NO₂ over time), whereas NO₂ standards should be mixed in air (to keep it oxidized).

For oxygen measurements, we recommend a reference gas of 21% O₂ in N₂. The user can utilize the NO_x standards (if mixed in air). For quick checks, ambient air can be used at an assumed concentration of 20.8%. Generally, O₂ concentration in dry, ambient air varies by less than 1%.

7.1.3.1. Traceability

All equipment used to produce calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend acquiring cylinders of working gas that are certified to be traceable to NIST standard reference materials (SRM). These are available from a variety of commercial sources.

Table 7-1: NIST-SRM's Available for Traceability of NO_x Calibration Gases

NIST-SRM ⁴	TYPE	NOMINAL CONCENTRATION
2627a	Nitric Oxide (NO) in N ₂	5 ppm
2628a	Nitric Oxide (NO) in N ₂	10 ppm
2629a	Nitric Oxide (NO) in N ₂	20 ppm
1683b	Nitric Oxide (NO) in N ₂	50 ppm
1684b	Nitric Oxide (NO) in N ₂	100 ppm
1685b	Nitric Oxide (NO) in N ₂	250 ppm
1686b	Nitric Oxide (NO) in N ₂	5000 ppm
1687b	Nitric Oxide (NO) in N ₂	1000 ppm
2630	Nitric Oxide (NO) in N ₂	1500 ppm
2631a	Nitric Oxide (NO) in N ₂	3000 ppm
2635	Nitric Oxide (NO) in N ₂	800 ppm
2636a	Nitric Oxide (NO) in N ₂	2000 ppm
2656	Oxides of Nitrogen (NO _x) in Air	2500 ppm
2660a	Oxides of Nitrogen (NO _x) in Air	100 ppm
2659a	Oxygen in Nitrogen (O ₂)	21 mol %

7.1.4. 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 TML41M/H. 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 TML41M/H provides an internal data acquisition system (iDAS), which is described in detail in Section 6.7. sensor-e.com, a remote control program, is also provided as a convenient and powerful tool for data handling, download, storage, quick check, and plotting.

7.1.5. NO₂ CONVERSION EFFICIENCY

To ensure accurate operation of the TML41M/H, it is important to check the NO₂ conversion efficiency (CE) periodically and to update this value as necessary.

The default setting for the NO₂ converter efficiency is 1.0000. For the analyzer to function correctly, the converter efficiency must be between 0.9600 and 1.0200 (96-102% conversion efficiency) as per US-EPA requirements. If the converter's efficiency is outside these limits, the NO₂ converter should be replaced.

NOTE

The currently programmed CE is recorded along with the calibration data in the iDAS for documentation and performance analysis.

7.1.5.1. Determining / Updating the NO₂ Converter Efficiency

The following procedure will cause the TML41M/H to automatically calculate the current NO₂ conversion efficiency.

STEP ONE:

Connect a source of calibrated NO₂ span gas as shown below.

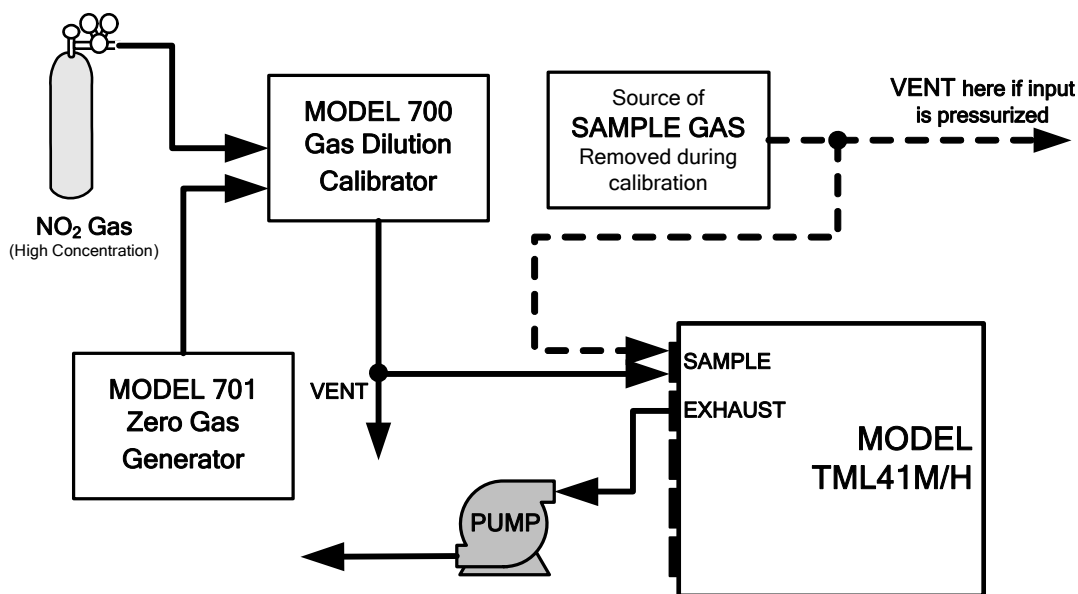
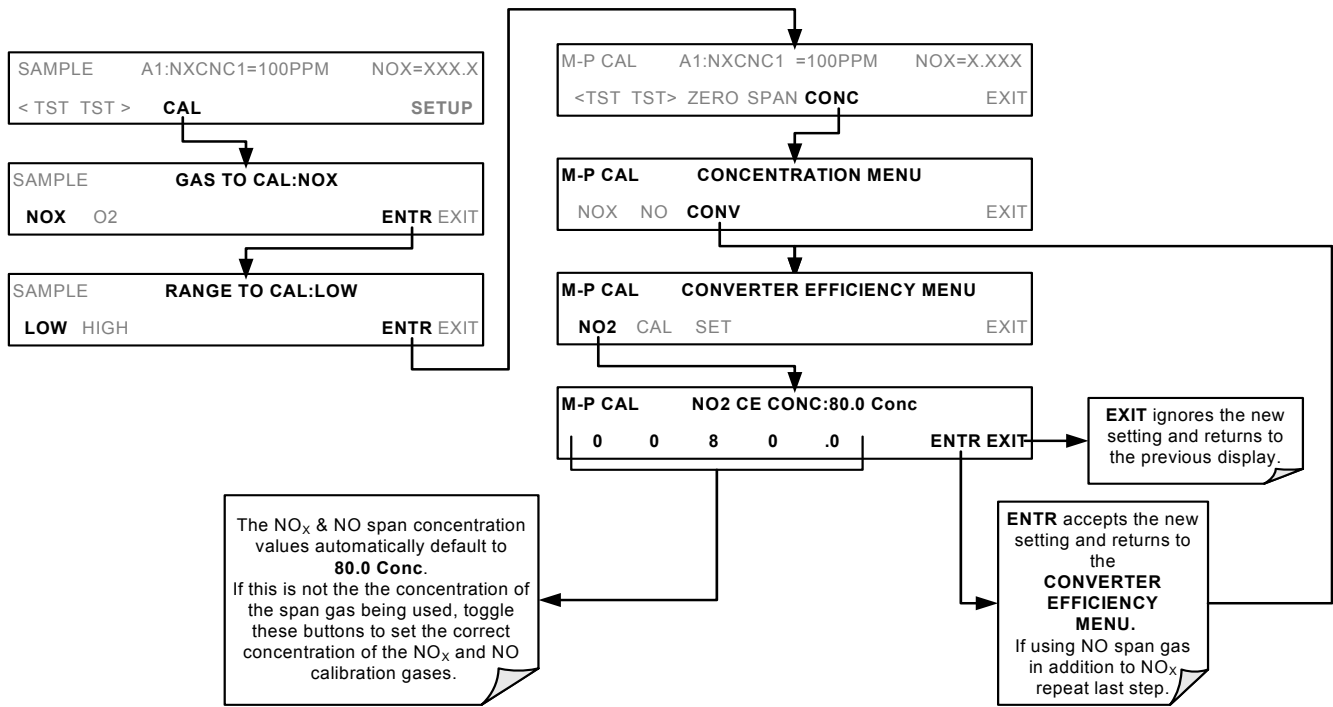


Figure 7-1: Gas Supply Setup for Determination of NO₂ Conversion Efficiency

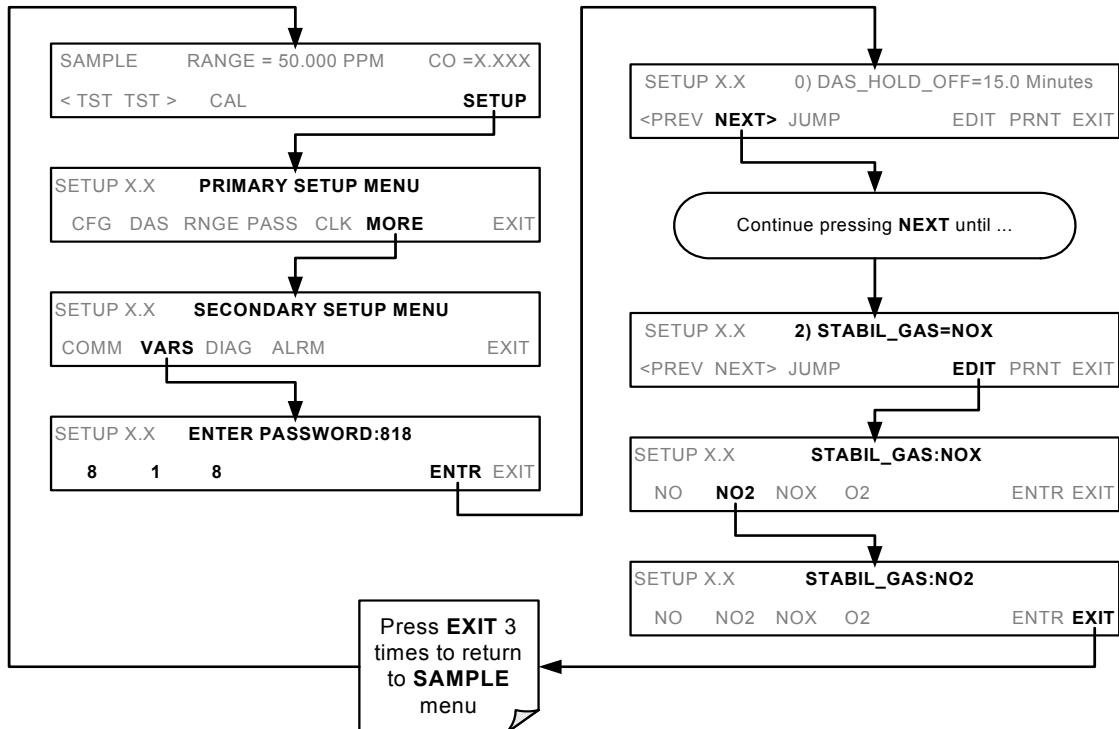
STEP TWO:

Set the expected NO₂ span gas concentration:



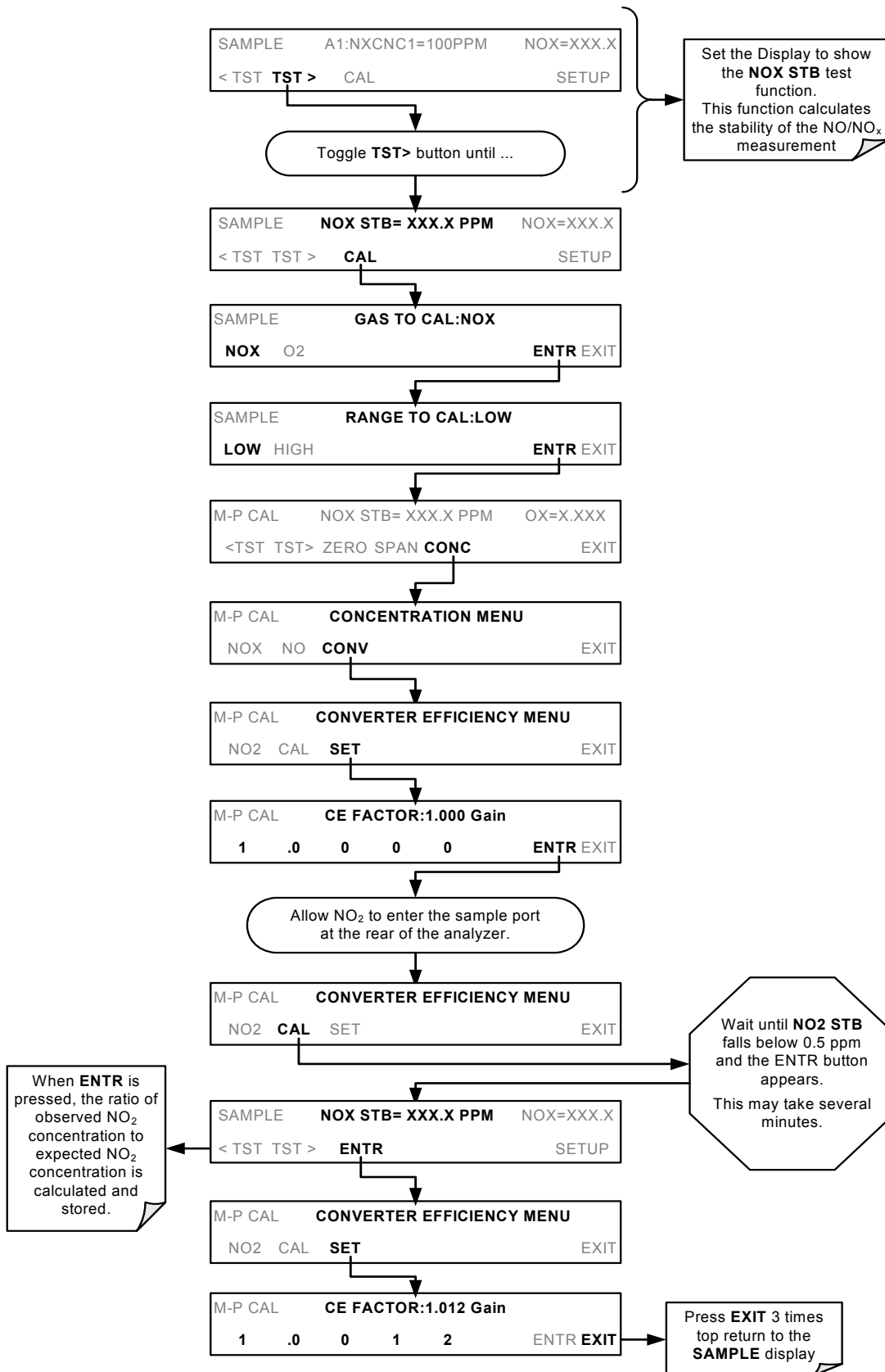
STEP THREE

Activate NO₂ measurement stability function.



STEP FOUR:

Perform the converter efficiency calculation procedure:



7.2. MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the TML41M/H NO_x analyzer.

If both available iDAS parameters for a specific gas type are being reported via the instrument's analog outputs (e.g. NXCNC1 and NXCNC2), separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Section 6.13.4 for more information on analog output reporting ranges

STEP ONE: Connect the sources of zero air and span gas as shown below.

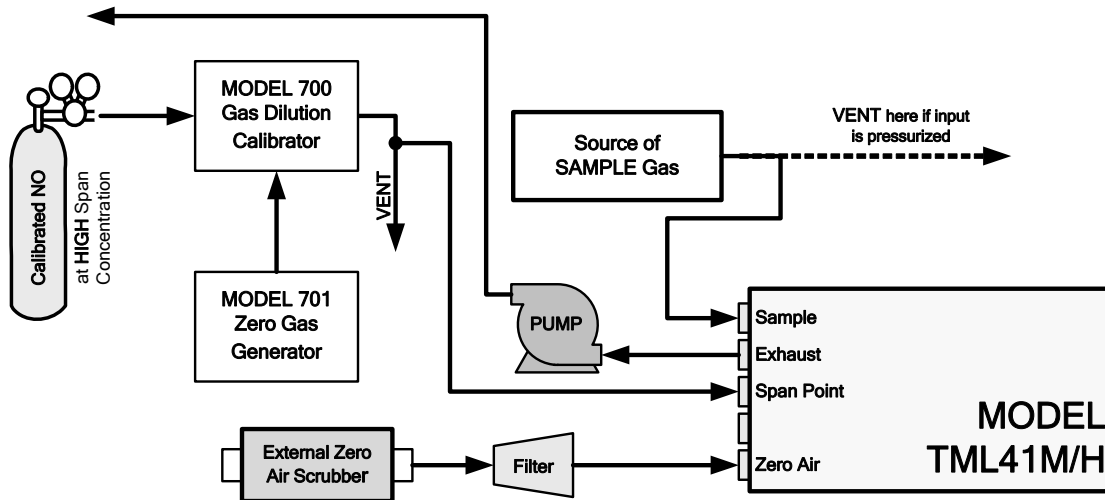


Figure 7-2: Pneumatic Connections—With Zero/Span Valve Option (50)

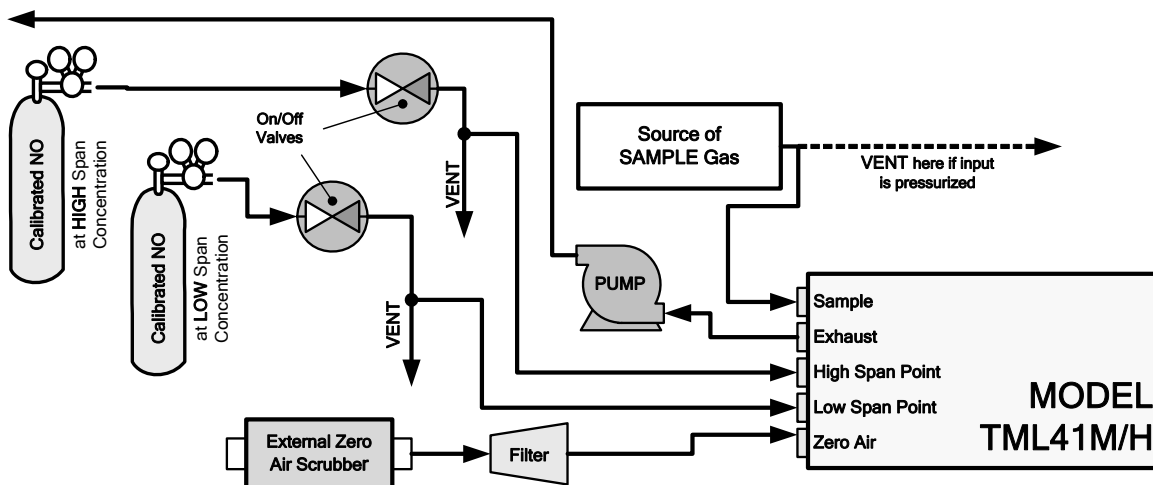
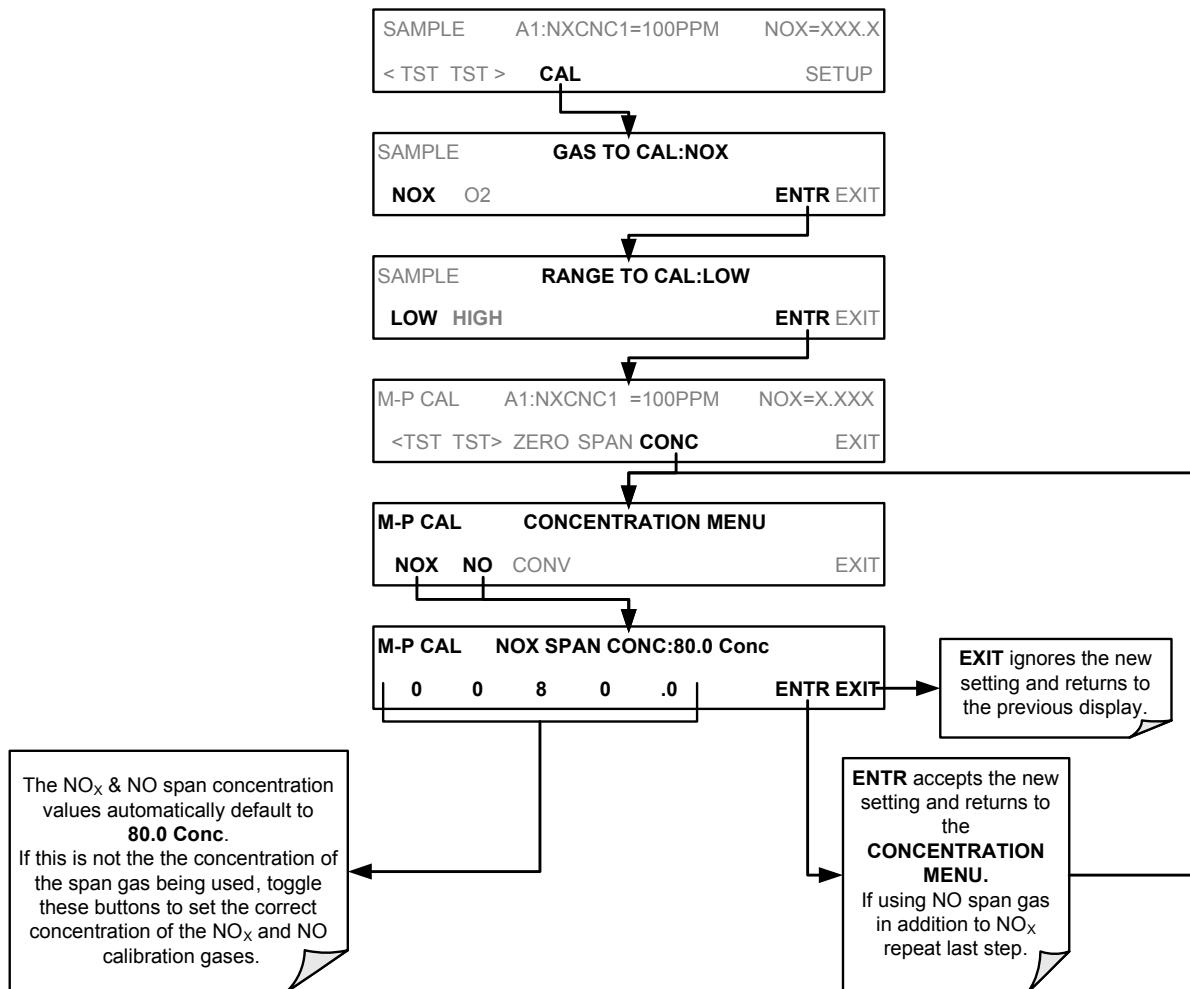


Figure 7-3: Pneumatic Connections—With 2-Span point Option (52) –Using Bottled Span Gas

STEP TWO: Set Expected NO and NO_x Span Gas Concentrations

Set the expected NO and NO_x span gas concentration. These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output (see Section 6.13.4.2)

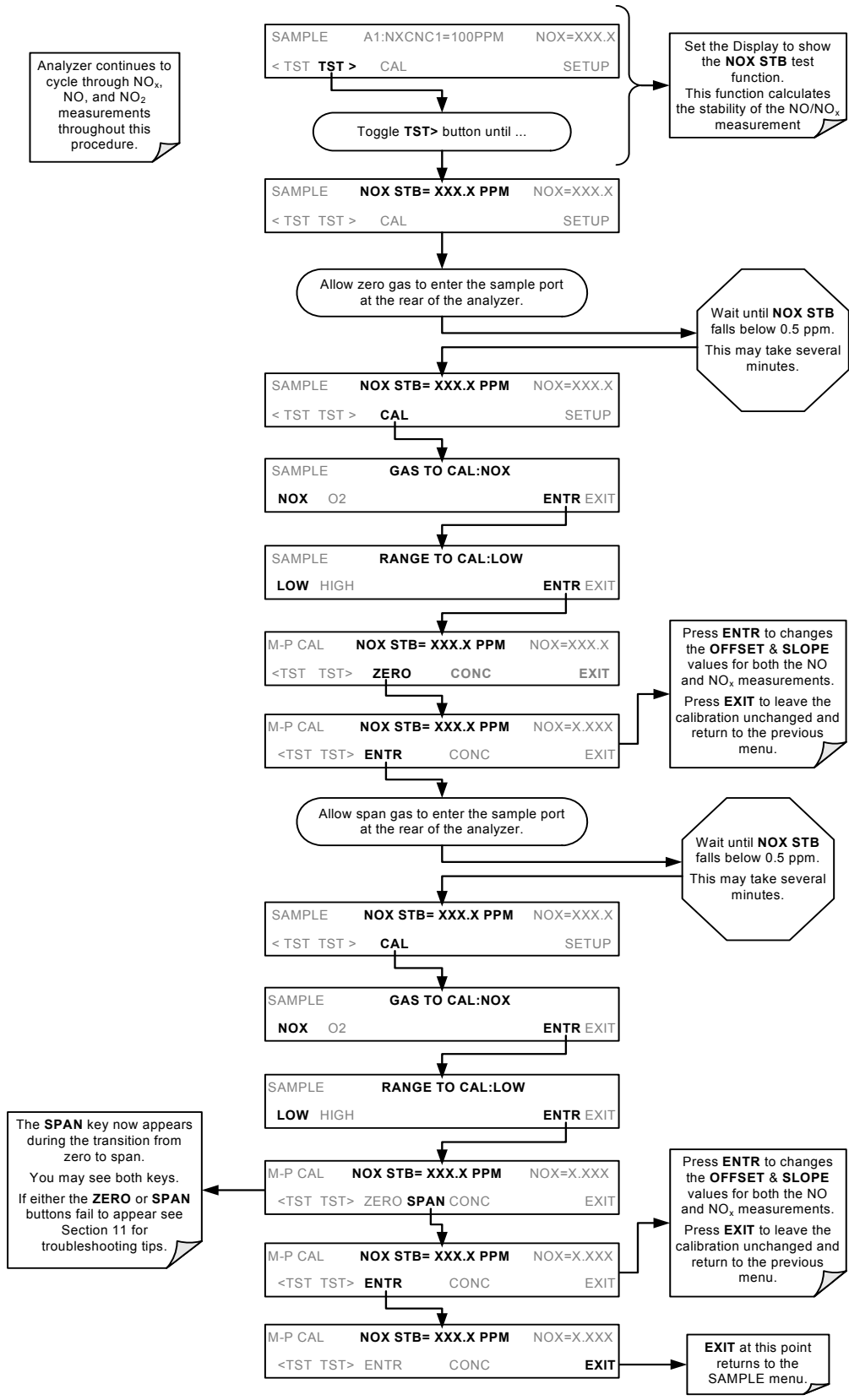


NOTE

The expected concentrations for both NO_x 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 (NO often contains 1-3% NO₂ and vice versa).

STEP THREE: Perform Zero/Span Calibration:

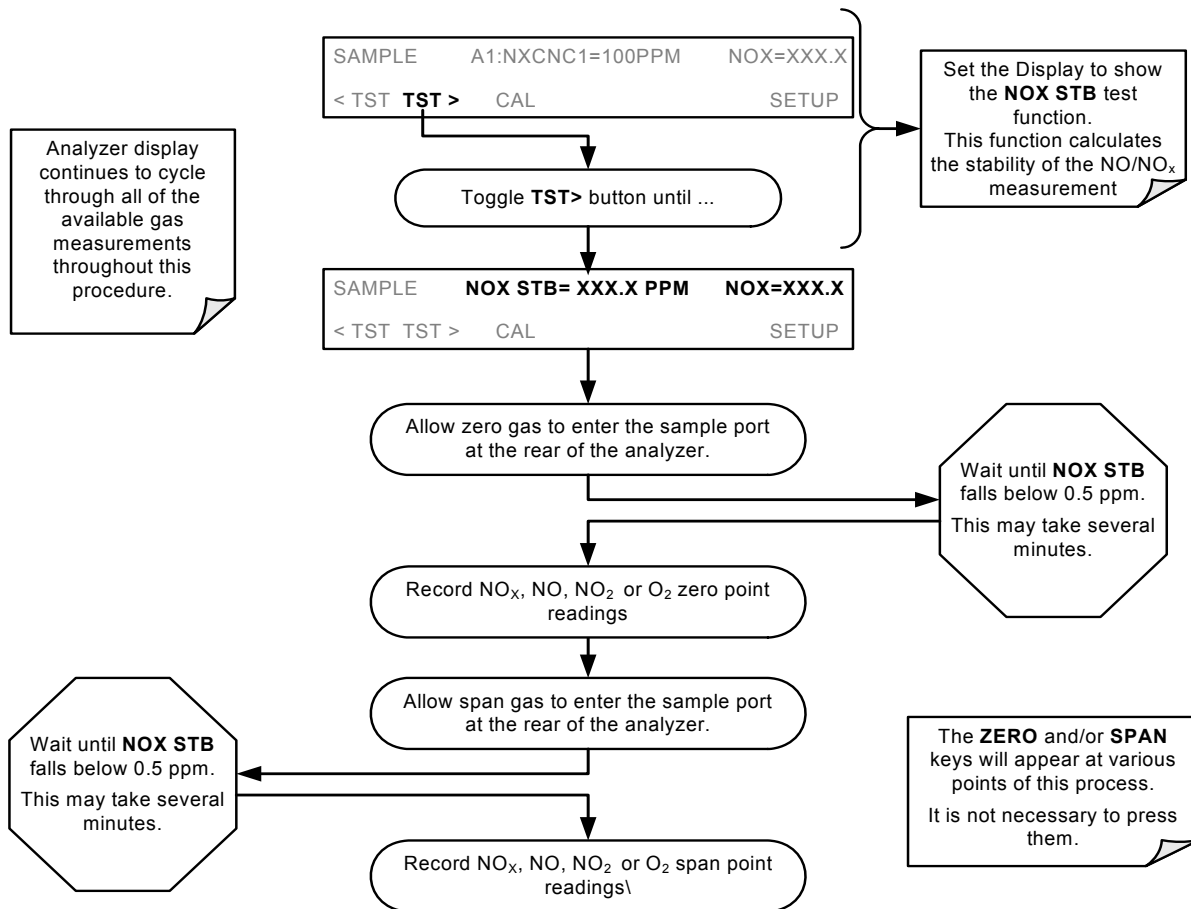


7.3. CALIBRATION CHECKS

Informal calibration checks, which only evaluate but do not alter the analyzer’s response curve, are recommended as a regular maintenance item and in order to monitor the analyzer’s performance. To carry out a calibration check rather than a full calibration, follow these steps.

STEP ONE: Connect the sources of zero air and span gas as shown in Figure 7-2 or Figure 7-3.

STEP TWO: Perform the zero/span calibration check procedure:



7.4. MANUAL CALIBRATION WITH ZERO/SPAN VALVES

Zero and Span calibrations using the Zero/Span Valve option are similar to that described in Section 7.2, except that:

- Zero air and span gas is supplied to the analyzer through the zero gas and span gas inlets rather than through the sample inlet.
- The zero and cal operations are initiated directly and independently with dedicated keys (**CALZ** & **CALS**)

If both available iDAS parameters for a specific gas type are being reported via the instrument's analog outputs (e.g. NXCNC1 and NXCNC2), separate calibrations should be carried out for each parameter.

- Use the LOW button when calibrating for NXCNC1
- Use the HIGH button when calibrating for NXCNC2.

See Section 6.13.4 for more information on analog output reporting ranges

STEP ONE: Connect the sources of zero air and span gas to the respective ports on the rear panel (Figure 3-1) as shown below.

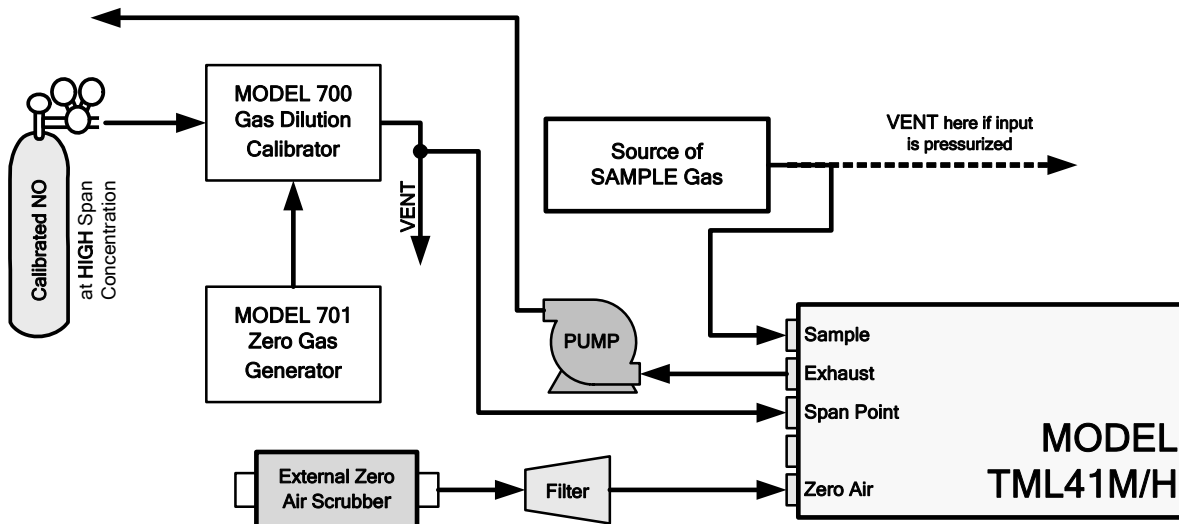
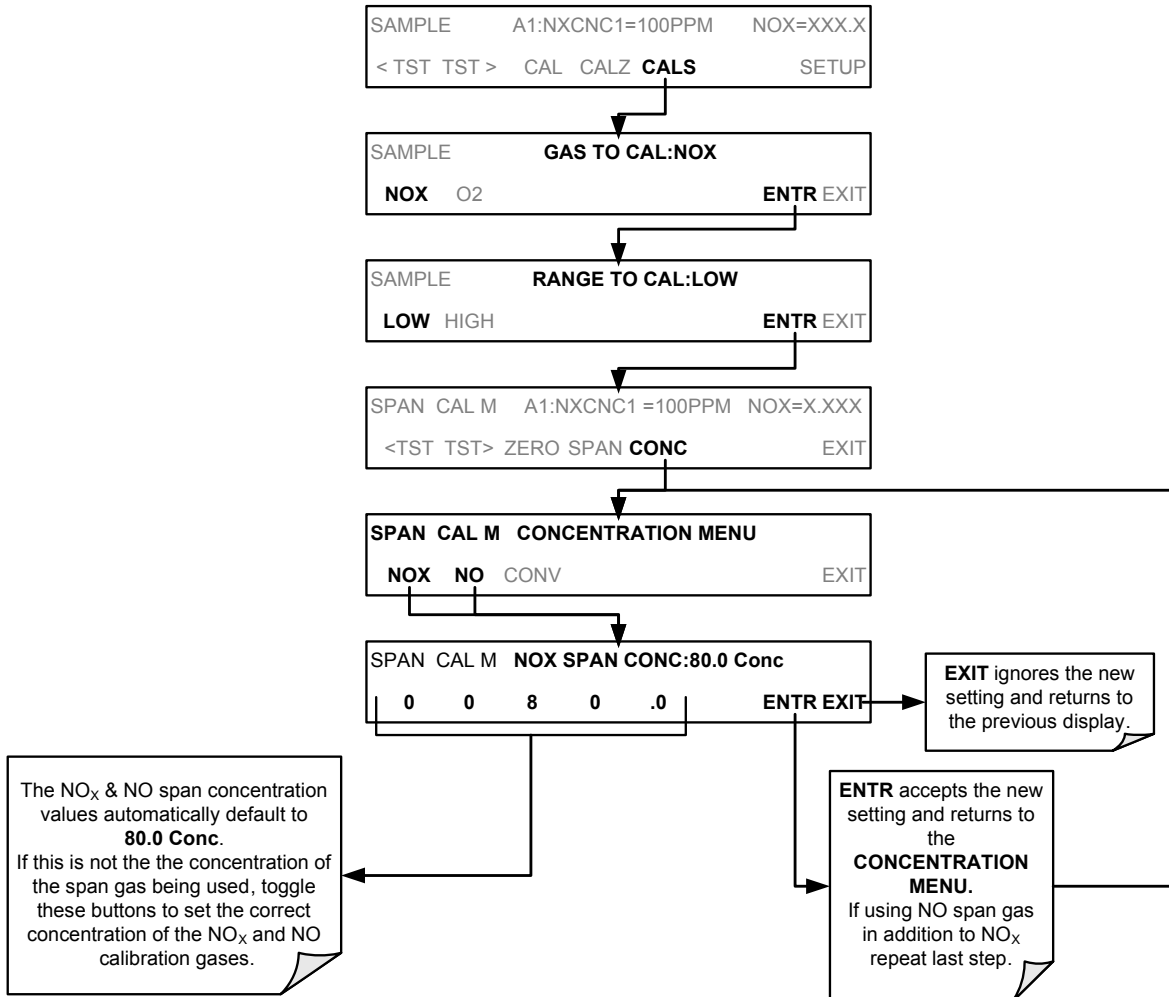


Figure 7-4: Pneumatic Connections—With Zero/Span Valve Option (50)

STEP TWO: Set Expected NO and NO_x Span Gas Concentrations.

Set the expected NO and NO_x span gas concentration. These should be 80% of range of concentration values likely to be encountered in this application. The default factory setting is 100 ppm. If one of the configurable analog outputs is to be set to transmit concentration values, use 80% of the reporting range set for that output (see Section 6.13.4.2)

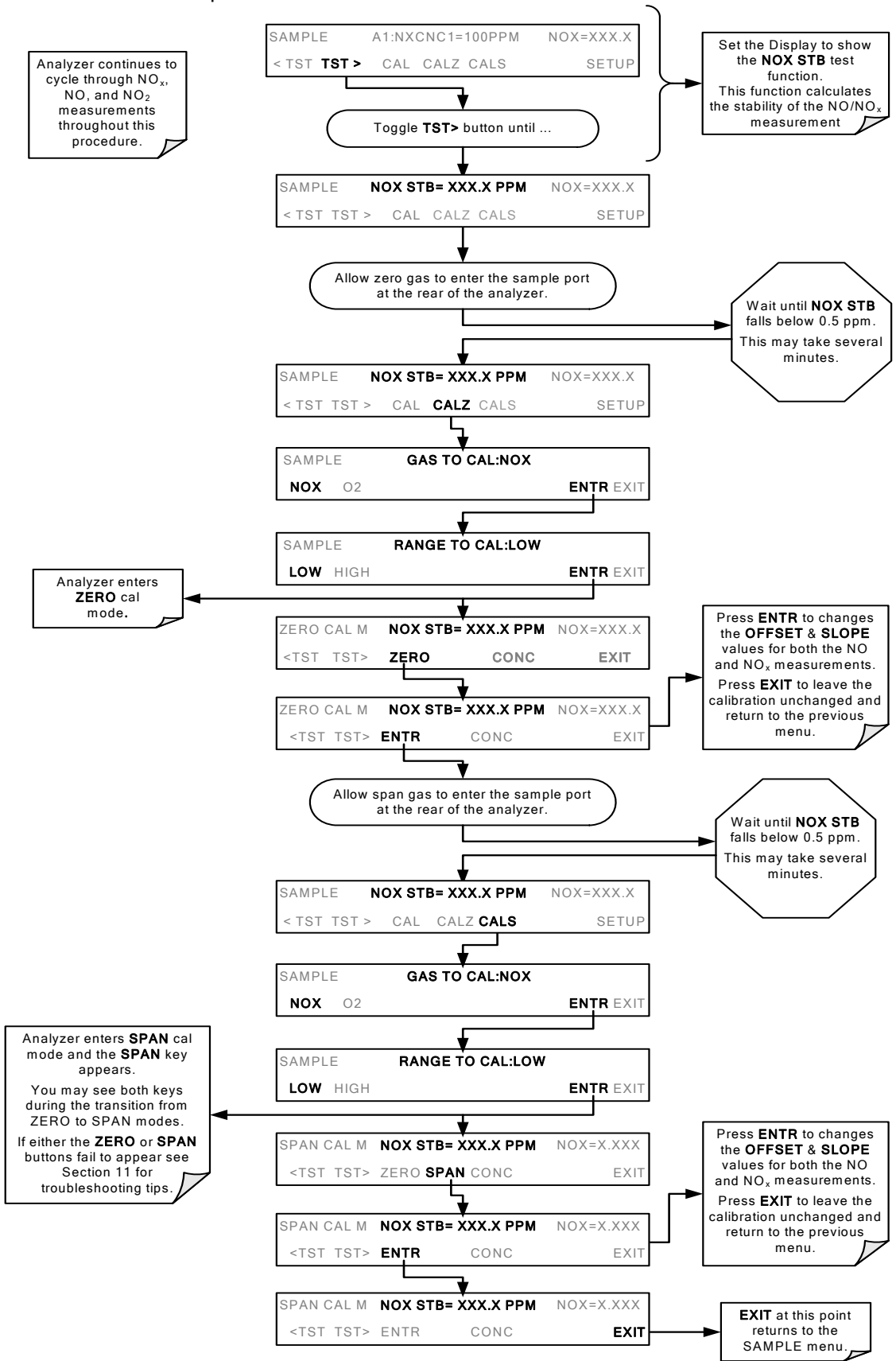


NOTE

The expected concentrations for both NO_x 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 (NO often contains 1-3% NO₂ and vice versa).

STEP THREE: Perform Zero/Span Calibration:



7.5. CALIBRATION CHECKS WITH ZERO/SPAN VALVES

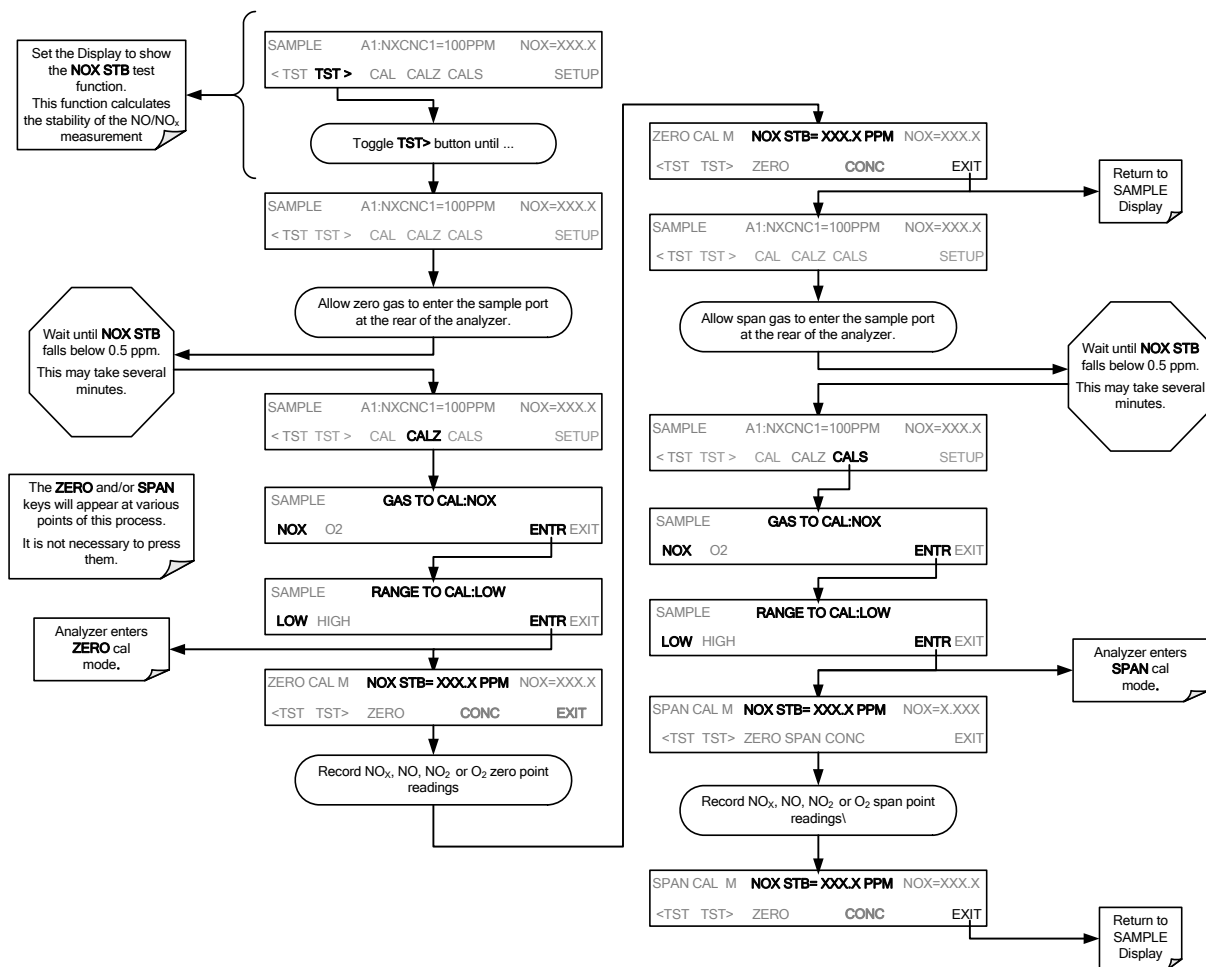
Zero and span checks using the zero/span valve option are similar to that described in Section 7.3, except that zero air and span gas are supplied to the analyzer through the zero gas and span gas inlets from two different sources.

Informal calibration checks, which only evaluate but do not alter the analyzer's response curve, are recommended as a regular maintenance item and in order to monitor the analyzer's performance. To carry out a calibration check rather than a full calibration, follow these steps.

To perform a manual calibration check with zero/span valve or IZS option installed:

STEP ONE: Connect the sources of Zero Air and Span Gas as shown in section 7.4.

STEP TWO: Perform the zero/span check.



7.6. CALIBRATION WITH REMOTE CONTACT CLOSURES

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 can be found in Section 6.15.1.2.

When the appropriate contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and internal zero/span valves (if installed) 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 used in conjunction with the analyzer's AutoCal (Section 7.7) feature and the AutoCal attribute **CALIBRATE** is enabled, the TML41M/H will not re-calibrate the analyzer until 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.

7.7. AUTOMATIC CALIBRATION (AUTOCAL)

The AutoCal feature allows unattended, periodic operation of the zero/span valve options by using the analyzer's internal time of day clock. The AutoCal feature is only available on the front panel menu (**ACAL**) if either the zero/span valve or the IZS option is installed.

AutoCal operates by executing user-defined sequences to initiate the various calibration modes of the analyzer and to 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 7-2).

Table 7-2: AutoCal Modes

MODE	ACTION
DISABLED	Disables the sequence
ZERO	Causes the sequence to perform a zero calibration or check
ZERO-LO¹	Causes the sequence to perform a zero calibration or check followed by a mid-span concentration calibration or check
ZERO-LO-HI¹	Causes the sequence to perform a zero calibration or check followed by a mid-span concentration calibration or check and finally a high-span point calibration or check.
ZERO-HI	Causes the sequence to perform a zero calibration or check followed by a high-span point calibration or check.
LO¹	Causes the sequence to perform a mid-span concentration calibration or check
LO-HI¹	Causes the sequence to perform a mid-span concentration calibration or check followed by a high-span point calibration or check
HI	Causes the sequence to perform a high-span point calibration or check.
O₂ -ZERO²	Causes the sequence to do a zero-point calibration for the O ₂ sensor.
O₂ ZERO-SP²	Causes the sequence to perform a zero calibration or check the O ₂ sensor followed by a mid-span concentration calibration or check of the O ₂ sensor.
O₂ SPAN²	Causes the sequence to perform a zero calibration or check of the O ₂ sensor.
¹ Only applicable if analyzer is equipped with the second span point valve option (52)	
² Only applicable if instrument is equipped with the O ₂ sensor option (65)	

Each mode has seven parameters that control operational details of the sequence (Table 7-3).

Table 7-3: AutoCal Attribute Setup Parameters

PARAMETER	ACTION
TIMER ENABLED	Turns on the sequence timer
STARTING DATE	Sequence will operate on Starting Date
STARTING TIME	Sequence will operate at Starting Time
DELTA DAYS	Number of days between each sequence trigger. If set to 7, for example, the AutoCal feature will be enabled once every week on the same day.
DELTA TIME	Incremental delay on each delta day that the sequence starts. If set to 0, the sequence will start at the same time each day. Delta Time is added to Delta Days for the total time between cycles. 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.
DURATION	Duration of each sequence step in minutes. This parameter needs to be set such that there is enough time for the concentration signal to stabilize. The STABIL parameter shows if the analyzer response is stable at the end of the calibration. This parameter is logged with calibration values in the iDAS.
CALIBRATE	Enable to do a true, dynamic zero or span calibration; disable to do a calibration <i>check</i> only.
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.

The following example sets sequence #2 to carry out a zero-span calibration every other day starting at 14:00 on 01 January, 2003, lasting 30 minutes (15 for zero and 15 for span). This sequence will start 30 minutes later each day.

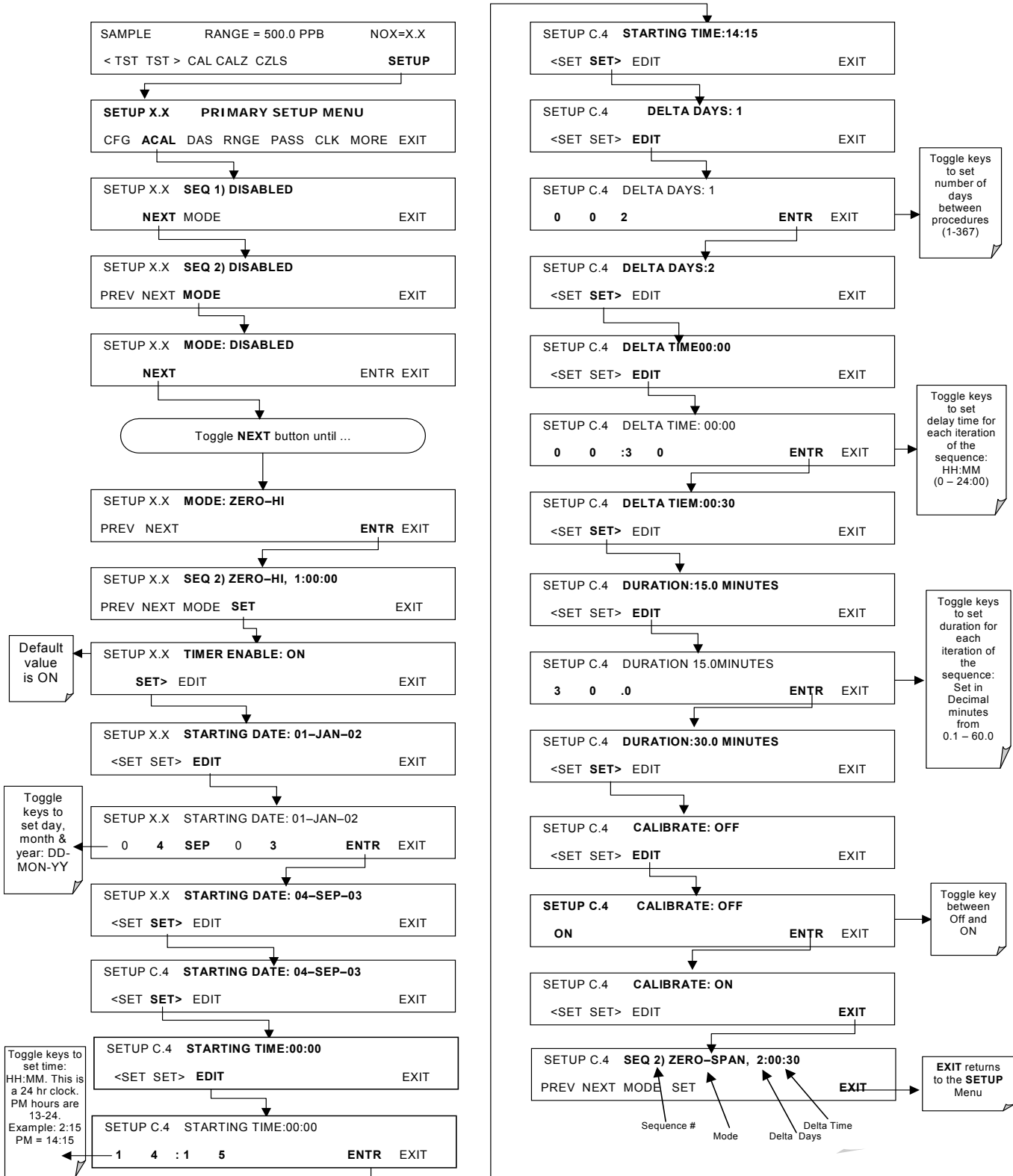
Table 7-4: Example Auto-Cal Sequence

MODE AND ATTRIBUTE	VALUE	COMMENT
SEQUENCE	2	Define sequence #2
MODE	ZERO-HI	Select zero and span mode
TIMER ENABLE	ON	Enable the timer
STARTING DATE	01-JAN-03	Start on or after 01 January 2003
STARTING TIME	14:00	First sequence starts at 14:00 (24-hour clock format)
DELTA DAYS	2	Repeat this sequence every 2 days
DELTA TIME	00:30	Repeat sequence 30 minutes later each time (every 2 days and 30 minutes)
DURATION	15.0	Each sequence step will last 15 minutes (total of 30 minutes when using zero-span mode)
CALIBRATE	ON	The instrument will recalculate the slope and offset values for the NO and NO _x channel at the end of the AutoCal sequence.

Please note the following suggestions for programming the AutoCal feature.

- The programmed **Starting Time** must be 5 minutes later than the real time clock (Section 6.10).
- Avoid setting two or more sequences at the same time of the day. Any new sequence which is initiated from a timer, the COM ports, or the contact closures will override any sequence in progress. Note that two sequences with different daily increments may eventually overlap.
- If at any time an illegal entry is selected, (for example: Delta Days > 366) the ENTR key will disappear from the display.
- With **CALIBRATE** turned on, the state of the internal setup variables **DYN_SPAN** and **DYN_ZERO** is set to **ON** and the instrument will reset the slope and offset values for the NO and NO_x response each time the AutoCal program runs. This continuous re-adjustment of calibration parameters can often mask subtle fault conditions in the analyzer. It is recommended that, if **CALIBRATE** is enabled, the analyzer's test functions, slope and offset values be checked frequently to assure high quality and accurate data from the instrument.

To program the sample sequence shown above, follow this flow chart:



7.8. 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_x. 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 (Section 6.2.1 or Appendix A-3), all of which are automatically stored in the iDAS channel **CALDAT** for data analysis, documentation and archival.

- **NO OFFS**
- **NO SLOPE**
- **NOX OFFS**
- **NOX SLOPE**

Make sure that these parameters are within the limits listed in Table 7-5 and frequently compare them to those values on the *Final Test and Checkout Sheet* that came attached to your manual, which should not be significantly different. If they are, refer to the troubleshooting Chapter 11.

Table 7-5: 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 iDAS 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 STABIL value (standard deviation of NO_x 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.

USER NOTES:

8. EPA PROTOCOL CALIBRATION

To ensure high quality, accurate measurements at all times, the TML41M/H analyzer must be calibrated prior to use. A quality assurance program centered on this aspect and including attention to the built-in warning features of the analyzer, periodic inspection, regular zero/span checks, regular evaluation of test parameters for predictive diagnostics and data analysis and routine maintenance of the instrument are paramount to achieving this goal.

The US EPA strongly recommends obtaining a copy of the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I* (abbreviated *Q.A. Handbook Volume II*). A new revision of this handbook is in progress⁸. A draft version of Section 2.3 can be downloaded online⁸ and should be consulted as the latest reference about NO₂ measurements.

Special attention should be paid to Section 2.3 of the handbook⁸ which covers the measurement of NO₂. Specific regulations regarding the use and operation of ambient NO_x analyzers can be found in Reference 1 at the end of this chapter.

If the TML41M/H is used for EPA compliance monitoring, it must be calibrated in accordance with the instructions in this section.

8.1. CALIBRATION OF EQUIPMENT

In general, calibration is the process of adjusting the gain and offset of the TML41M/H against a standard with certified, traceable concentration. The reliability of data derived from the analyzer depends primarily upon its state of calibration. In this section the term *dynamic calibration* is used to express a multipoint calibration against known standards. It involves introducing gas samples of known concentration into the instrument in order to adjust the instrument to a predetermined sensitivity and to produce a calibration relationship. This relationship is derived from the instrumental response to successive samples of different, known concentrations. As a minimum, three reference points and a zero point are recommended to define this relationship. The true values of the calibration gas must be traceable to NIST-SRM (Section 2.0.7, Q.A. Handbook).

All monitoring systems are subject to some drift and variation in internal parameters and cannot be expected to maintain accurate calibration over long periods of time. Therefore, it is necessary to dynamically check the calibration relationship on a predetermined schedule. Zero and span checks must be used to document that the data remain within control limits. These checks are also used in data reduction and validation. The internal data acquisition system of the TML41M/H allows to store all calibration checks (as well as full calibrations) over long periods of time for documentation. Table 8-1 summarizes the initial quality assurance activities for calibrating equipment. Table 8-2 is a matrix for the actual, dynamic calibration procedure.

Calibrations should be carried out at the field monitoring site. The analyzer should be in operation for at least several hours (preferably overnight) before calibration so that it is fully warmed up and its operation has stabilized. During the calibration, the TML41M/H should be in the CAL mode, and therefore sample the test atmosphere through all components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable. If the instrument will be used on more than one range, it should be calibrated separately on each applicable range, see Section 7. Calibration documentation should be maintained with each analyzer and also in a central backup file.

Table 8-1: Activity Matrix for EPA Calibration Equipment and Supplies

Equipment/Supplies	Acceptance Limits	Frequency And Method Of Measurement	Action If Requirements Are Not Met
Recorder	Compatible with output signal of analyzer; min chart width of 150 mm (6 in) is recommended	Check upon receipt	Return equipment to supplier
Sample line and manifold	Constructed of PTFE, glass or stainless steel	Check upon receipt	Return equipment to supplier
Calibration equipment	Meets guidelines and Section 2.3.2 of Q. A. Handbook	See Section 2.3.9 of Q. A. Handbook	Return equipment/ supplies to supplier or take corrective action
Working standard NO cylinder gas	Traceable to NIST-SRM. Meets limits in traceability protocol for accuracy and stability. Section 2.0.7 of Q. A. Handbook	Analyzed against NIST-SRM; see protocol in Section 2.0.7, Q.A. Handbook	Obtain new working standard and check for traceability
Recording forms	Develop standard forms	N/A	Revise forms as appropriate
Audit equipment	Cannot be the same as used for calibration	System must be checked out against known standards	Locate problem and correct or return to supplier

Table 8-2: Activity Matrix for Calibration Procedure

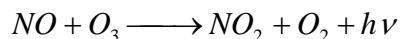
Equipment/Supplies	Acceptance Limits	Frequency And Method Of Measurement	Action If Requirements Are Not Met
Calibration gases	Sec. 2.0.7, Q.A. Handbook	Assayed against an NIST-SRM quarterly, Sec. 2.0.7 (Q.A. Handbook)	Working gas standard is unstable, and/or measurement method is out of control; take corrective action such as obtaining new calibration gas
Dilution gas	Zero air, free of contaminants; TAD ² and Sec. 2.0.7, Subsec. 7.1, Q.A. Handbook	See TAD ²	Return to supplier or take appropriate action with generation system
Multi-point calibration (GPT)	$t_R < 2$ minutes $P_R > 2.75$ ppm/min Use calibration procedure in Q.A Handbook; also CFR ¹ Converter efficiency $> 96\%$	Method: Section 8.3 of this manual) CFR Title 40 ¹ , Appendix F	Adjust flow conditions and/or reaction cell volume to meet suggested limits Repeat the calibration Replace or service the converter

8.2. GAS PHASE TITRATION (GPT)

8.2.1. GPT PRINCIPLE OF OPERATION

Gas phase titration (GPT) is recommended for calibration of the TML41M/H. Those using a NO₂ permeation tube should refer to the CFR¹.

The principle of GPT is based on the rapid gas phase reaction between NO and O₃ which produces stoichiometric quantities of NO₂ as shown by the following equation:



Given that the O₃ concentration is known for this reaction, the resultant concentration of NO₂ can be determined. Ozone is added to excess NO in a dynamic calibration system as shown in Figure 8-1, and the NO channel of the chemiluminescence analyzer detects the changes in NO concentration. After the addition of O₃, the observed decrease in NO concentration on the calibrated NO channel is equivalent to the concentration of NO₂ produced. The amount of generated NO₂ may be varied by adding varying amounts of O₃ from a stable O₃ generator. All zero air used in this procedure should conform to the requirements stated in Section 8.1 of this manual.

Dynamic calibration systems based on this principle are commercially available, or may be assembled by the user. A recommended calibration system is described in the Federal Register¹ CFR¹.

8.2.2. GPT CALIBRATOR CHECK PROCEDURE

It has been empirically determined that the NO-O₃ reaction is complete (<1% residual O₃) if the NO concentration in the reaction cell (ppm) multiplied by the residence time (min.) of the reactants in the chamber is >2.75 ppm min. The theory behind the development of this equation is in the Federal Register¹. The following procedures and equations should be used to determine whether an existing GPT calibration system will meet required conditions for a specific calibration.

For calibrators that have known pre-set flow rates, use equations 8-5 and 8-6 of steps 7 and 8 (below) to verify the required conditions. If the calibrator does not meet specifications, follow the complete procedure to determine what flow modifications must be made.

Select an NO standard gas that has a nominal concentration in the range of 50 to 100 ppm. Determine the exact concentration [NO]_{STD} by referencing against an NIST-SRM, as discussed in the Q.A. Handbook.

Determine the volume (cm³) of the calibrator reaction cell (V_{RC}). If the actual volume is not known, estimate the volume by measuring the approximate dimensions of the chamber and using an appropriate formula.

Determine the required minimum total flow output (F_T) using Equation 8-1:

$$F_T = \text{analyzer flow demand (cm}^3/\text{min)} \times 110/100 \quad \text{Eq 8-1}$$

If more than one analyzer is to be calibrated at the same time, multiply F_T by the number of analyzers.

Calculate the NO concentration [NO]_{OUT} needed to approximate 90% of the URL of the NO₂ analyzer to be calibrated, using Equation 8-2:

$$[\text{NO}]_{\text{OUT}} = \text{URL of analyzer (ppm)} \times 90/100 \quad \text{Eq 8-2}$$

Calculate the NO flow (F_{NO}) required to generate the NO concentration [NO]_{OUT}, using Equation 8-3:

$$F_{NO} = \frac{[NO]_{OUT} \times F_T}{[NO]_{STD}} \quad \text{Eq 8-3}$$

Calculate the required flow through the ozone generator (F_O), using Equation 8-4:

$$F_O = \sqrt{\frac{[NO]_{STD} \times F_{NO} \times V_{RC}}{2.75 \text{ ppm} \cdot \text{min}}} - F_{NO} \quad \text{Eq 8-4}$$

Verify that the residence time (t_R) in the reaction cell is <2 min, using Equation 8-5:

$$t_R = \frac{V_{RC}}{F_O + F_{NO}} \leq 2 \text{ min} \quad \text{Eq 8-5}$$

Verify that the dynamic parameter specification (P_R) of the calibrator's reaction cell is >2.75 ppm-min using Equation 8-6:

$$P_R = [NO]_{STD} \times \frac{F_{NO}}{F_O + F_{NO}} \times \frac{V_{RC}}{F_O + F_{NO}} \geq 2.75 \quad \text{Eq 8-6}$$

NOTE

If t_r is >2 minutes or if P_R is <2.75 ppm min, changes in flow conditions (F_T , F_O , F_{NO}) or in the reaction cell volume (V_{RC}), or both will have to be made, and t_r and P_R will have to be recalculated.

After equations 8-5 and 8-6 are satisfied, calculate the diluent air flow (F_D) using Equation 8-7:

$$F_D = F_T - F_O - F_{NO} \quad \text{Eq 8-7}$$

8.2.3. EXAMPLE GPT CALCULATION

Following is an example calculation that can be used to determine whether an existing GPT calibrator will meet the required conditions for a specific calibration. For this example, it is assumed that only the volume of the reaction cell, V_{RC} , and the concentration of the NO standard, $[NO]_{STD}$, are known. All flow settings (F_{NO} , F_O , F_T , and F_D) will be calculated. In many uses, these flow settings are known and need only to be substituted in Equations 8-5 and 8-6 to verify the required conditions. Before doing any calculations, the URL and flow demand of the analyzer being calibrated must be known. Operating parameters are determined from the operations manual:

Upper range limit = 0.5 ppm, and

Flow demand = 500 cm³/min.

Volume of calibrator reaction cell is determined by physical measurement: $V_{RC} = 180 \text{ cm}^3$

The concentration of the NO standard gas to be used is determined by reference against an NIST-SRM (Section 2.0.7, Q.A. Handbook): $[NO]_{STD} = 50.5 \text{ ppm}$

Determine the minimum total flow (F_T) required at the output manifold using Equation 8-1:

$$F_T = 500 \text{ cm}^3/\text{min} (110/100) = 550 \text{ cm}^3/\text{min}$$

Because low flows are difficult to control and measure, it is often advantageous to set total flow higher than needed. In this example, we will set F_T to $2750 \text{ cm}^3/\text{min}$.

Determine the highest NO concentration, $[\text{NO}]_{\text{OUT}}$, required at the output manifold, using Equation 8-2:

$$[\text{NO}]_{\text{OUT}} = 0.5 \text{ ppm} (90/100) = 0.45 \text{ ppm}$$

Calculate the NO flow (F_{NO}) required to generate the NO concentration $[\text{NO}]_{\text{OUT}}$, using Equation 8-3:

$$F_{\text{NO}} = \frac{0.45 \text{ ppm} \times 2750 \text{ cm}^3 / \text{min}}{50.5 \text{ ppm}} = 24.5 \text{ cm}^3 / \text{min}$$

Calculate the required flow rate through ozone generator (F_O) using Equation 8-4:

$$F_O = \sqrt{\frac{50.5 \text{ ppm} \times 24.5 \text{ cm}^3 / \text{min} \times 180 \text{ cm}^3}{2.75 \text{ ppm} \cdot \text{min}}} - 24.5 \text{ cm}^3 / \text{min}$$

$$= \sqrt{80984 \text{ cm}^6 / \text{min}^2} - 24.5 \text{ cm}^3 / \text{min} = 260 \text{ cm}^3 / \text{min}$$

Verify that the residence time (t_R) in the reaction cell is $<2 \text{ min}$ using Equation 8-5:

$$t_R = \frac{180 \text{ cm}^3}{260 \text{ cm}^3 / \text{min} + 24.5 \text{ cm}^3 / \text{min}} = 0.63 \text{ min}$$

Verify the dynamic parameter specification (P_R) of the calibrator reaction cell using Equation 8-6:

$$P_R = 50.5 \text{ ppm} \times \frac{24 \text{ cm}^3 / \text{min}}{260 \text{ cm}^3 / \text{min} + 24.5 \text{ cm}^3 / \text{min}} \times \frac{180 \text{ cm}^3}{260 \text{ cm}^3 / \text{min} + 24.5 \text{ cm}^3 / \text{min}} = 2.75 \text{ ppm} \cdot \text{min}$$

Calculate the diluent air flow (F_D) required at the mixing chamber, using Equation 8-7:

$$F_D = 2750 \text{ cm}^3/\text{min} - 260 \text{ cm}^3/\text{min} - 24.5 \text{ cm}^3/\text{min} = 2465.5 \text{ cm}^3/\text{min}$$

8.3. MULTIPOINT CALIBRATION PROCEDURE

The procedure for calibration of chemiluminescence NO_x analyzers by GPT is specified in the Federal Register.¹ This section applies the general procedure to the specific case of the TML41M/H.

Calibration must be performed with a calibrator that meets all conditions specified in the Q.A. Handbook. Flow settings used in the GPT calibration for NO_2 must be determined as illustrated in Section 3.3, this manual.

The user should be sure that all flow meters are calibrated under the conditions of use against a reliable standard. All volumetric flow rates should be corrected to 25°C (78°F) and 760 mm (29.92 in.) Hg. Calibrations of flow meters are discussed in the QA Handbook, Vol. II, Part 1, Appendix 12⁶.

Gas Phase Titration (GPT) requires the use of the NO channel of the analyzer to determine the amount of NO_2 generated by titration. Therefore it is necessary to calibrate and determine the linearity of the NO channel before proceeding with the NO_2 calibration. It is also necessary to calibrate the NO_x channel. This can be done

simultaneously with the NO calibration. During the calibration the TML41M/H should be operating in its normal sampling mode, and the test atmosphere should pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and as much of the ambient air inlet system as is practicable. All operational adjustments to the TML41M/H should be completed prior to the calibration. The following software features must be set into the desired state before calibration.

Automatic converter efficiency compensation. See Section 7.1.5 of this manual.

Independent reporting range selection.¹

Automatic temperature/pressure compensation.

Alternate units, make sure ppb units are selected for EPA monitoring.

Auto ranging reporting range option.¹

¹ Some versions of firmware may not have these range selections.

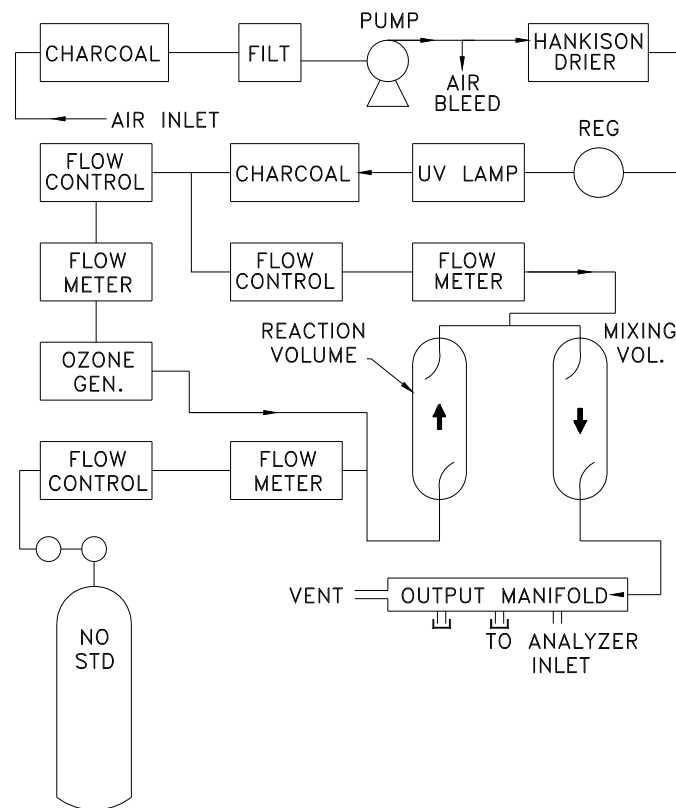


Figure 8-1: GPT Calibration System

Converter efficiency should be set prior to calibration since its value is used in the computation of the NO_x and NO₂ concentration outputs.

The analyzer should be calibrated on the same range used for monitoring.

If auto ranging or independent range options are selected the highest of the ranges will result in the most accurate calibration, and should be used.

Make sure the GPT calibration system can supply the range of concentrations at a sufficient flow over the whole range of concentrations that will be encountered during calibration.

8.3.1. ZERO CALIBRATION

The zero point calibration procedure is identical to that described in Sections 7.2, or 7.4 of this manual.

8.3.2. SPAN CALIBRATION

Adjust the NO concentration to approximately 80% of the URL of the NO channel. The expected NO and NO_x span concentrations can be determined by measuring the cylinder and diluent flows and computing the resulting concentrations. If there is any NO₂ impurity in the NO standard gas it should be taken into account when the NO_x concentration is entered during the NO/NO_x channel calibration. This is done by ADDING the impurity concentration to the NO concentration to get the NO_x concentration for calibration. Calculate the exact NO and NO_x concentrations as follows:

$$[NO]_{OUT} = \frac{F_{NO} \times [NO]_{STD}}{F_T} \quad \text{Eq 8-8}$$

Enter the respective concentrations using the procedure in Section 7.2. The expected span concentrations need not be re-entered each time a calibration is performed unless they are changed.

Enter the expected NO_x and NO span gas concentrations:

Sample the generated concentration until the NO and the NO_x responses have stabilized.

Span the instrument by the following the same method as Sections 7.2, or 7.4:

The analog voltage output should measure 80% of the voltage range selected. (e.g. 4.00 VDC if 0-5V output is selected.) The readings on the front panel display should be equal to the expected NO and NO_x concentrations entered in the procedure given in Sections 7.2, 7.4 or 7.5 above. See the Troubleshooting Chapter 11 if there are problems. Also see the Calibration Quality Check procedure Section 7.8.

After the zero and the 80% URL points have been set, generate five approximately evenly spaced calibration points between zero and 80% URL without further adjustment to the instrument. Allow the instrument to sample these intermediate concentrations for about 10 minutes each and record the instrument NO and NO_x responses.

Plot the analyzer NO and NO_x responses versus the corresponding calculated concentrations to obtain the calibration relationships. Determine the straight line of best fit ($y = mx + b$) determined by the method of least squares.

After the best-fit line has been drawn for the NO and the NO_x calibrations, determine whether the analyzer response is linear. To be considered linear, no calibration point should differ from the best-fit line by more than 2% of full scale.

8.3.3. GPT NO₂ CALIBRATION

The TML41M/H computes the NO₂ concentration by subtracting the NO from the NO_x concentration. Unlike analog instruments, this difference is calculated by the TML41M/H's internal computer software. It is extremely unlikely that the NO₂ concentration will be in error. Therefore this procedure is a confirmation that the NO₂ subtraction algorithm in the computer is operating correctly.

NOTE

Do not make any adjustments to the instrument during this procedure.

Generate an NO concentration near 90% of the URL. Dilution air and O₃ generator air flows should be the same as used in the calculation of specified conditions of the dynamic parameter according to Section 8.2. Sample this NO concentration until the NO and NO_x responses stabilize. Record the NO and NO_x concentrations.

Second, turn on and adjust the O₃ generator in the calibrator to produce sufficient O₃ to decrease the NO concentration to about 10% of full scale. This will be equivalent to 80% of the URL of the NO₂ channel. After the analyzer responses stabilize, record the resultant NO, NO_x, and NO₂ concentrations.

NO₂ CONVERTER EFFICIENCY

If the NO_x reading should drop to less than 96% of its starting value during this step, it indicates the NO₂ converter is in need of troubleshooting or replacement. See Chapter 11 for further details.

While maintaining all other conditions, adjust the ozone generator to obtain several other concentrations of NO₂ evenly spaced between the 80% URL point and the zero point. Record the NO, NO_x, and NO₂ concentrations for each additional point.

Calculate the resulting NO₂ concentrations as follows:

$$[NO_2]_{OUT} = [NO]_{ORIG} - [NO]_{REM} + \frac{F_{NO} * [NO_2]_{IMP}}{F_T} \quad \text{Eq 8-9}$$

Where [NO]_{ORIG} is the NO concentration before the GPT ozone is turned on, and [NO]_{REM} is the NO remaining after GPT.

Plot the NO₂ concentration output by the instrument on the y-axis against the generated NO₂ [NO₂]_{OUT} on the x-axis. The plot should be a straight line within the ± 2% linearity criteria given for the NO_x and NO channels. If the plot is not linear the most likely cause is that the converter needs replacing. See Section 7.1.5 on NO₂ converter efficiency.

8.4. CALIBRATION FREQUENCY

To ensure accurate measurements of the NO, NO_x, and NO₂ concentrations, calibrate the analyzer at the time of installation, and re-calibrate it:

- No later than three months after the most recent calibration or performance audit which indicated the analyzer calibration was acceptable.
- An interruption of more than a few days in analyzer operation.
- Any repairs which might affect its calibration.
- Physical relocation of the analyzer.
- Any other indication (including excessive zero or span drift) of possible significant inaccuracy of the analyzer.

Following any of the activities listed above, the zero and span should be checked to determine if a calibration is necessary. If the analyzer zero and span drifts exceed the calibration limits in Section 12 of the Q.A. Handbook⁶, a calibration should be performed.

8.5. OTHER QUALITY ASSURANCE PROCEDURES

Precision is determined by a one-point check at least once every two weeks. Accuracy is determined by a three-point audit once each quarter.

Essential to quality assurance are scheduled checks for verifying the operational status of the monitoring system. The operator should visit the site at least once each week. Every two weeks a Level 1 zero and span

check must be made on the analyzer. Level 2 zero and span checks should be conducted at a frequency desired by the user. Definitions of these terms are given in Table 8-3.

Table 8-3: Definition of Level 1 and Level 2 Zero and Span Checks

LEVEL 1 ZERO AND SPAN CALIBRATION	LEVEL 2 ZERO AND SPAN CHECK
<p>A Level 1 zero and span calibration is a simplified, two-point analyzer calibration used when analyzer linearity does not need to be checked or verified. (Sometimes when no adjustments are made to the analyzer, the Level 1 calibration may be called a zero/span check, in which case it must not be confused with a Level 2 zero/span check.) Since most analyzers have a reliably linear or near-linear output response with concentration, they can be adequately calibrated with only two concentration standards (two-point concentration). Furthermore, one of the standards may be zero concentration, which is relatively easily obtained and need not be certified. Hence, only one certified concentration standard is needed for the two-point (Level 1) zero and span calibration. Although lacking the advantages of the multipoint calibration, the two-point zero and span calibration--because of its simplicity--can be (and should be) carried out much more frequently. Also, two-point calibrations are easily automated. Frequency checks or updating of the calibration relationship with a two-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any changes (drifts) in the analyzer response.</p>	<p>A Level 2 zero and span check is an "unofficial" check of an analyzer's response. It may include dynamic checks made with uncertified test concentrations, artificial stimulation of the analyzer's detector, electronic or other types of checks of a portion of the analyzer, etc.</p> <p>Level 2 zero and span checks are not to be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustment of ambient data. They are intended as quick, convenient checks to be used between zero and span calibrations to check for possible analyzer malfunction or calibration drift. Whenever a Level 2 zero or span check indicates a possible calibration problem, a Level 1 zero and span (or multipoint) calibration should be carried out before any corrective action is taken.</p> <p>If a Level 2 zero and span check is to be used in the quality control program, a "reference response" for the check should be obtained immediately following a zero and span (or multipoint) calibration while the analyzer's calibration is accurately known. Subsequent Level 2 check responses should then be compared to the most recent reference response to determine if a change in response has occurred. For automatic Level 2 zero and span checks, the first scheduled check following the calibration should be used for the reference response. It should be kept in mind that any Level 2 check that involves only part of the analyzer's system cannot provide information about the portions of the system not checked and therefore cannot be used as a verification of the overall analyzer calibration.</p>

In addition, an independent precision check between 0.08 and 0.10 ppm must be carried out at least once every two weeks. Table 8-4 summarizes the quality assurance activities for routine operations. A discussion of each activity appears in the following sections.

To provide for documentation and accountability of activities, a checklist should be compiled and then filled out by the field operator as each activity is completed.

For information on shelter and sample inlet system, an in-depth study is in Field Operations Guide for Automatic Air Monitoring Equipment, Publication No. APTD-0736, PB 202-249 and PB 204-650, U.S. Environmental Protection Agency, Office of Air Programs, October 1972.

8.6. SUMMARY OF QUALITY ASSURANCE CHECKS

The following items should be checked on a regularly scheduled basis to assure high quality data from the TML41M/H. See Table 8-4 for a summary of activities; also the QA Handbook should be checked for specific procedures.

Table 8-4: Activity Matrix for Data Quality

Characteristic	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Shelter temperature	Mean temperature between 22°C and 28°C (72° and 82° F), daily fluctuations not greater than $\pm 2^\circ\text{C}$	Check thermograph chart weekly for variations greater than $\pm 2^\circ\text{C}$ (4°F)	Mark strip chart for the affected time period Repair or adjust temperature control
Sample introduction system	No moisture, foreign material, leaks, obstructions; sample line connected to manifold	Weekly visual inspection	Clean, repair, or replace as needed
Recorder	Adequate ink & paper Legible ink traces Correct chart speed and range Correct time	Weekly visual inspection	Replenish ink and paper supply Adjust time to agree with clock; note on chart
Analyzer operational settings	TEST measurements at nominal values TML41M/H in SAMPLE mode	Weekly visual inspection	Adjust or repair as needed
Analyzer operational check	Zero and span within tolerance limits as described in Section 12 of the Q.A. Handbook ⁶	Level 1 zero/span every 2 weeks; Level 2 between Level 1 checks at frequency desired by user	Find source of error and repair After corrective action, re-calibrate analyzer
Precision check	Assess precision as described in Sections 15&18 of the Q.A. Handbook ⁶	Every 2 weeks, Subsec. 3.4.3 (Ibid.)	Calc, report precision, Section 12 of the Q.A. Handbook ⁶

8.7. SHORT CALIBRATION CHECKS

A system of Level 1 and Level 2 zero/span checks (Table 8-3) is recommended. These checks must be conducted in accordance with the specific guidance given in Section 12 of the Q.A. Handbook⁶. Level 1 zero and span checks must be conducted every two weeks. Level 2 checks should be conducted in between the Level 1 checks at a frequency desired by the user. Span concentrations for both levels should be between 70 and 90% of the measurement range.

Zero and span data are to be used to:

- Provide data to allow analyzer adjustment for zero and span drift;
- Provide a decision point on when to calibrate the analyzer;
- Provide a decision point on invalidation of monitoring data.

These items are described in detail in Sections 15&18 of the Q.A. Handbook⁶. Refer to Chapter 11 of this manual if the instrument is not within the allowed margins. We recommend using sensor-e.com and the iDAS for analysis and documentation of zero/span check data.

8.7.1. ZERO/SPAN CHECK PROCEDURES

The Zero and span calibration can be checked in a variety of different ways. They include:

- Manual zero/span checks can be done from the front panel keyboard. The procedure is in Section 7.3 or 7.5 of this manual.
- Automatic zero/span checks can be performed every night. See Section 7.7 of this manual for setup and operation procedures.

Zero/Span checks through remote contact closure can be initiated through remote contact closures on the rear panel. See Section 7.6 of this manual.

Zero/span checks can also be controlled through the RS-232 port. See Section 6.15.2 of this manual for more details on setting up and using the analyzer's RS-232 port.

8.7.2. PRECISION CHECK

A periodic check is used to assess the data for precision. A one-point precision check must be carried out at least once every 2 weeks on each analyzer at an NO₂ concentration between 0.08 and 0.10 ppm. The analyzer must be operated in its normal sampling mode, and the precision test gas must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling. The standards from which precision check test concentrations are obtained must be traceable to NIST-SRM. Those standards used for calibration or auditing may be used.

8.7.3. PRECISION CHECK PROCEDURE

Connect the analyzer to a precision gas that has an NO₂ concentration between 0.08 and 0.10 ppm. An NO₂ precision gas may be generated by either GPT or a NO₂ permeation tube. If a precision check is made in conjunction with a zero/span check, it must be made prior to any zero or span adjustments.

Allow the analyzer to sample the precision gas until a stable trace is obtained.

Record this value. NO and NO_x precision checks should also be made if those data are being reported. Information from the check procedure is used to assess the precision of the monitoring data; see in Section 12 of the Q.A. Handbook⁶ for procedures for calculating and reporting precision.

8.8. CERTIFICATION OF WORKING STANDARDS

The NO content of the NO working standard must be periodically assayed against NIST-traceable NO or NO₂ standards. Any NO₂ impurity in the cylinder must also be assayed. Certification of the NO working standard should be made on a quarterly basis or more frequently, as required. Procedures are outlined below for certification against NO traceable standard which is the simplest and most straightforward procedure.

To assure data of desired quality, two considerations are essential:

The measurement process must be in statistical control at the time of the measurement and;

Any systematic errors, when combined with the random variation in the measurement process, must result in a suitably small uncertainty.

Evidence of good quality data includes documentation of the quality control checks and the independent audits of the measurement process by recording data on specific forms or on a quality control chart and by using materials, instruments, and measurement procedures that can be traced to appropriate standards of reference.

To establish traceability, data must be obtained routinely by repeated measurements of standard reference samples (primary, secondary, and/or working standards). More specifically, working calibration standards must be traceable to standards of higher accuracy.

8.8.1. CERTIFICATION PROCEDURES OF WORKING STANDARDS

This procedure requires the use of calibrated NO gas traceable to an NIST-SRM and the gas phase titration calibration procedure (Section 8.2) to calibrate the NO, NO_x, and NO₂ responses of the analyzer. Also the efficiency of the analyzer's NO₂ converter must be determined (Section 7.1.5).

Generate several NO concentrations by diluting the NO working standard. Use the nominal NO cylinder concentration, [NO]_{NOM}, to calculate the diluted concentrations. Plot the analyzer NO response (in ppm) versus

the nominal diluted NO concentration and determine the slope, S_{NOM} . Calculate the NO concentration of the working standard $[\text{NO}]_{\text{STD}}$ from:

$$[\text{NO}]_{\text{STD}} = [\text{NO}]_{\text{NOM}} \times S_{\text{NOM}}$$

A more detailed procedure is presented in Reference 1.

8.8.1.1. Other Methods of Establishing Traceability

Methods of establishing traceability are:

- Using a NO working standard traced to NIST NO₂ standard
- Using a NO₂ working standard traced to NIST NO₂ standard
- Using a NO₂ working standard traced to NIST NO standard

NOTE

If the NO₂ impurity in the NO cylinder, $[\text{NO}_2]_{\text{imp}}$ is greater than the 1 ppm value allowed in the calibration procedure, check that the NO delivery system is not the source of contamination before discarding the NO standard.

For further information on calibration by GPT and NO₂ permeation devices, refer to part 50 of Chapter 1, Title 40 CFR, Appendix F Reference 13 of that Appendix.

8.9. REFERENCES

1. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 50, Appendix F, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).
2. Ellis, Elizabeth C. Technical Assistance Document for the Chemiluminescence Measurement of Nitrogen Dioxide, U.S. Environmental Protection Agency, Research Triangle Park, NC. 83 pages, December 1975. Available online at <http://www.epa.gov/ttn/amtic/files/ambient/criteria/reldocs/4-75-003.pdf>.
3. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 58, Appendix A, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).
4. Mavrodineanu, R., and Gills, T. E., Standard Reference Materials: Summary of Gas Cylinder and Permeation Tube Standard Reference Materials Issued by the National Bureau of Standards, Document SP260-108, May 1987.
And: Taylor, J. K., Standard Reference Materials: Handbook for SRM Users, Document number SP260-100, February 1993. Available online at:
http://patapsco.nist.gov/srmcatalog/sp_publications/publications.htm
5. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume I, "A Field Guide to Environmental Quality Assurance," EPA-600/R-94/038a, April 1994. Available online at:
<http://www.epa.gov/ttn/amtic/qabook.html>.
6. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume II, Ambient Air Specific Methods. EPA-600/4-77/027a, December 1986. US EPA Order Number: 454R98004, available at the National Technical Information Service (NTIS), 5285 Port Royal Rd Springfield, VA 22151. Portions are also available at: <http://www.epa.gov/ttn/amtic/qabook.html>.

7. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 58, Appendix B, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).
8. Quality Assurance Guidance Document. Reference Method for the Determination of Nitrogen Dioxide in the Atmosphere (Chemiluminescence). Draft document, 58 pages, February 2002. Office of Air Quality Planning and Standards, Research Triangle Park NC 27711, draft document available at <http://www.epa.gov/ttn/amtic/qabook.html>. Guidelines about the measurement of NO₂ in this document replace those in the old QA Handbook and should be consulted as the latest reference.

USER NOTES:

9. INSTRUMENT MAINTENANCE

Predictive diagnostic functions, including data acquisition records, failure warnings and test functions built into the analyzer, allow the user to determine when repairs are necessary without performing unnecessary, preventative maintenance procedures. There is, however, a minimal number of simple procedures that, when performed regularly, will ensure that the analyzer continues to operate accurately and reliably over its lifetime. Repair and troubleshooting procedures are covered in Chapter 11 of this manual.

NOTE

A span and zero calibration check must be performed following some of the maintenance procedures listed below. Refer to Chapter 7.



CAUTION

Risk of electrical shock. Disconnect power before performing any operations that require entry into the interior of the analyzer.



NOTE

The operations outlined in this chapter must be performed by qualified maintenance personnel only.

9.1. MAINTENANCE SCHEDULE

Table 9-1 shows the recommended maintenance schedule for the TML41M/H. Please note that in certain environments with high levels of dust, humidity, or pollutant levels some maintenance procedures may need to be performed more often than shown.

Table 9-1: TML41M/H Preventive Maintenance Schedule

ITEM	ACTION	FREQUENCY	CAL CHECK	MANUAL SECTION	DATE PERFORMED						
¹ Particulate Filter	Change filter	Weekly	No	9.3.1							
Verify Test Functions	Review and evaluate	Weekly	No	9.2; Appendix C							
Zero/Span Check	Evaluate offset and slope	Weekly	--	7.3, 7.5, 7.7							
¹ Zero/Span Calibration	Zero and span calibration	Every 3 months	--	7.2, 7.4, 7.6, 7.7, 7.8							
NO ₂ Converter	Replace converter & check efficiency	Every 3 years or if conversion efficiency < 96%	Yes if CE factor is used	--							
¹ External Zero Air Scrubber (Optional)	Exchange chemical	Every 3 months	No	0							
External Dryer (Optional)	Replace chemical	When indicator color changes	No								
¹ Reaction Cell Window	Clean optics, Change O-rings	Annually or as necessary	Yes	9.3.8							
¹ Air Inlet Filter Of Perma Pure Dryer	Change particle filter	Annually	No	9.3.2							
Pneumatic Sub-System	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	Yes on leaks, else no	11.5							
¹ All Critical Flow Orifice O-Rings & Sintered Filters	Replace	Annually	Yes	9.3.9							
^{1,2} Pump	Rebuild head	Annually	Yes	9.3.4							
Pmt Sensor Hardware Calibration	Low-level hardware calibration	On PMT/ preamp changes & if $0.7 < \text{SLOPE} > 1.3$	Yes	11.6.5							

¹ These Items are required to maintain full warranty; all other items are strongly recommended.

² A pump rebuild kit is available from Teledyne Instruments Customer Service including all instructions and required parts (see Appendix B for part numbers).

9.2. PREDICTIVE DIAGNOSTICS

The analyzer's test functions can be used to predict failures by looking at trends in their values. Initially it may be useful to compare the state of these test functions to the values measured on your instrument at the factory and recorded on the *TML41M/H Final Test and Validation Data Form* (Teledyne Instruments part number 04490, attached to the manual). Table 9-2 can be used as a basis for taking action as these values change with time. The internal data acquisition system (iDAS) is a convenient way to record and track these changes. sensor-e.com control software can be used to download and review these data even from remote locations (Section 6.15.2.8 describes sensor-e.com).

Table 9-2: Predictive Uses for Test Functions

FUNCTION	EXPECTED	ACTUAL	INTERPRETATION & ACTION
RCEL pressure	Constant to within ± 0.5	Fluctuating	Developing leak in pneumatic system. Check for leaks
		Slowly increasing	Pump performance is degrading. Replace pump head when pressure is above 10 in-Hg-A
SAMPLE 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
Ozone Flow	Constant to within ± 15	Slowly decreasing	Flow path is clogging up. Replace orifice filters
AZERO	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. Leak check.
			O ₃ air filter cartridge is exhausted. Change chemical
NO ₂ CONC	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Replace converter.
NO ₂ CONC (IZS)	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
NO ₂ CONC (IZS)	Constant response from day to day	Heavily fluctuating from day to day	Ambient changes in moisture are affecting the performance. Add a dryer to the zero air inlet.
NO CONC	Constant for constant concentration	Decreasing over time	Drift of instrument response; clean RCEL window, change O ₃ air filter chemical.

9.3. MAINTENANCE PROCEDURES

The following procedures need to be performed regularly as part of the standard maintenance of the TML41M/H.

9.3.1. CHANGING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or excess dirt. It should be replaced according to the service interval in Table 9-1 even without obvious signs of dirt. Filters with 1 μ m pore size can clog up while retaining a clean look. We recommend handling the filter and the wetted surfaces of the filter housing with gloves and tweezers. We recommend not touching any part of the housing, filter element, PTFE retaining ring, glass cover, and the O-ring with bare hands as this may cause the pores to clog quicker and surfaces to become dirty due to possible oils from your hands.

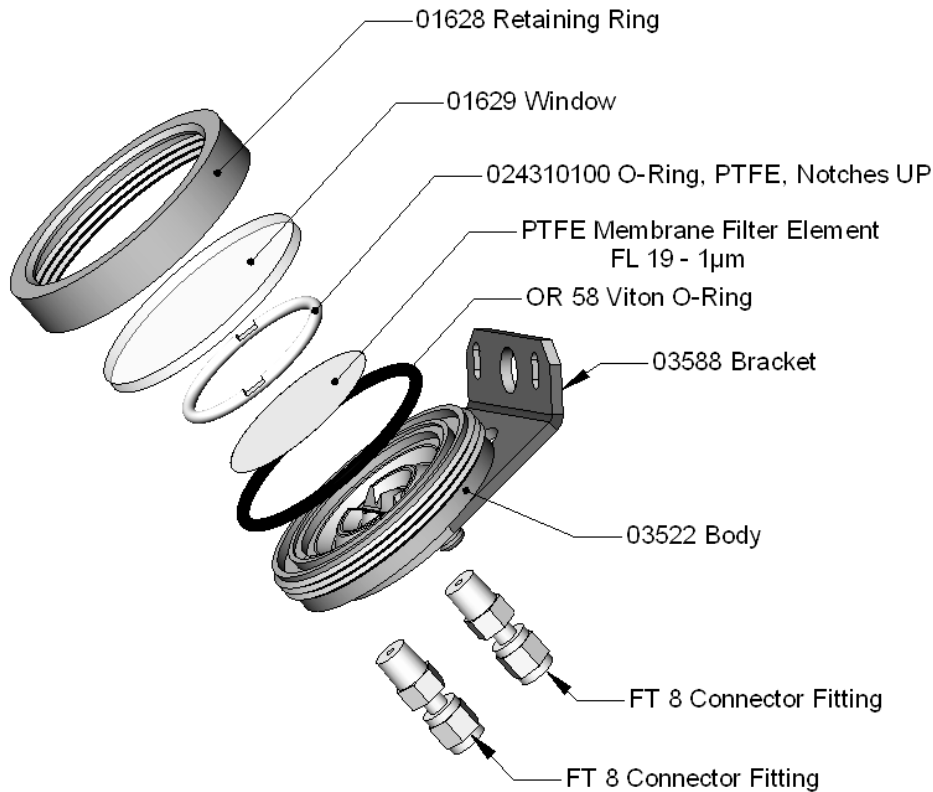


Figure 9-1: Sample Particulate Filter Assembly

To change the filter according to the service interval in Table 9-1, follow this procedure:

1. Turn OFF the pump to prevent drawing debris into the sample line.
2. Remove the CE Mark locking screw in the center of the front panel and open the hinged front panel and unscrew the knurled retaining ring of the filter assembly.
3. Carefully remove the retaining ring, glass window, PTFE O-ring and filter element. We recommend cleaning the glass and O-rings at least once monthly, weekly in very polluted areas.
4. Install a new filter element, carefully centering it in the bottom of the holder.
5. Re-install the PTFE O-ring with the notches facing up (important!), the glass cover, then screw on the hold-down ring and hand-tighten the assembly. Inspect the (visible) seal between the edge of the glass window and the O-ring to assure proper gas tightness.
6. To fulfill CE Mark safety requirements, the front panel locking screw must be installed at all times during operation of the analyzer.
7. Re-start the analyzer.

9.3.2. CHANGING THE O₃ DRYER PARTICULATE FILTER

The air for the O₃ generator passes through a Perma Pure[®] dryer, which is equipped with a small particulate filter at its inlet. This filter prevents dust from entering the Perma Pure[®] dryer and degrading the dryer's performance over time. To change the filter according to the service interval in Table 9-1:

1. Check and write down 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 5/8" and 9/16" wrenches and by holding the actual fitting body steady with a 7/16" wrench.

CAUTION

Risk of significant leak. Make sure to use proper wrenches and to not turn the fitting against the Perma Pure[®] dryer. This may loosen the inner tubing and cause large leaks.

Take off the old filter element and replace it with a suitable equivalent (TML part# FL-3).

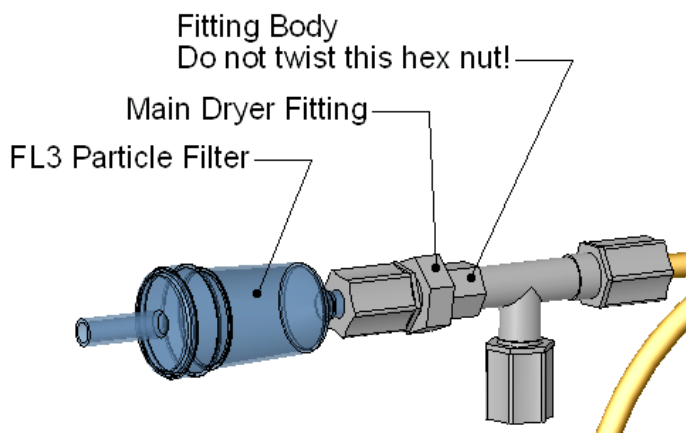


Figure 9-2: Particle Filter on O₃ Supply Air Dryer

Holding the fitting steady with a 5/8" wrench, tighten the nut with your hands. If necessary use a second wrench but do not over-tighten the nut.

Replace the cover, plug in the power cord, and restart the analyzer.

Check the O₃ flow rate; it should be around 80 cm³/min ± 15. Check the RCEL pressure; it should be the same value as before.

9.3.3. REBUILDING THE EXTERNAL SAMPLE 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. Appendix B of this manual lists the part numbers of the pump rebuild kit. 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.

9.3.4. CHANGING THE PUMP AND IZS DUST FILTERS

The exhaust air from the analyzer passes a small particle filter (*DFU* filter, part # FL3) before entering the pump. When this particle filter becomes visibly dirty or the pressure drop between SAMP and RCEL pressure increases significantly, it needs replacement in order to prevent a large pressure drop with degraded analyzer performance.

1. Power down the analyzer and pump.
2. For internally mounted filters, skip the next two steps.
3. For externally mounted filters on the pump housing, remove the analyzer exhaust tube from the dust filter. Remove the particle filter from the pump. To do so, push the white plastic ring into the fitting and pull the filter out of the fitting. If necessary, use needle-nose pliers to pry the filter out of the fittings.
4. Push a new filter into the pump fitting and make sure that the arrow on the filter points towards the pump. Push the exhaust tubing onto the filter. Skip the next two steps.
5. For internally mounted filters at the inside rear panel, open the chassis and locate the filter between the vacuum manifold and the exhaust port fitting.
6. 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 and tightening them until a good seal is achieved.
7. Restart the pump and clear any error warnings from the front panel display.
8. 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.

9.3.5. CHANGING THE EXTERNAL ZERO AIR SCRUBBER

The external zero air scrubber contains two chemicals, pink Purafil[®] (Part # CH 9) and black, charcoal (Part # CH 1). The Purafil[®] converts NO in the ambient air to NO₂ and the following charcoal absorbs any NO₂. The chemicals need to be replaced periodically according to Table 9-1 or as needed. This procedure can be carried out while the instrument is running. Make sure that the analyzer is not in ZERO calibration mode.

1. Locate the scrubber on the outside rear panel. Figure 3-4 shows the location, Figure 9-4 the exploded assembly.
2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the particle filter using 9/16" and 1/2" wrenches.
3. Remove the particle filter from the cartridge using 9/16" wrenches.
4. Unscrew the top of the scrubber canister and discard the Purafil[®] and charcoal contents. Make sure 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. Refill the scrubber with charcoal at the bottom and the Purafil[®] chemical at the top and use three, white retainer pads to separate the chemicals as shown in Figure 9-3.
6. Replace the screw-top cap and tighten the cap - hand-tight only.
7. If necessary, replace the DFU filter with a new unit and discard the old. The bottom retainer pad should catch most of the dust, the filter should not be visibly dirty (on the inside)
8. Replace the scrubber assembly into its clips on the rear panel.
9. Reconnect the plastic tubing to the fitting of the particle filter.
10. 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.

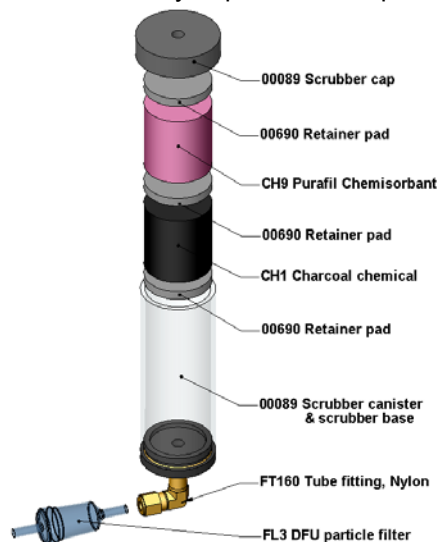


Figure 9-3: Zero Air Scrubber Assembly

9.3.6. CHANGING THE NO₂ CONVERTER

The NO₂ converter is located in the center of the instrument, see Figure 3-1 for location, and Figure 9-4 for the assembly. The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple can be reused.

1. Turn off the analyzer power, remove the cover, and allow the converter to cool.
2. Remove the top lid of the converter as well as the top layers of the insulation until the converter cartridge can be seen.



CAUTION

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.

3. Remove the tube fittings from the converter.
4. Disconnect the power and the thermocouple of the converter. Unscrew the grounding clamp of the power leads with a Phillips-head screw driver.
5. Remove the converter assembly (cartridge and band heater) from the can. Make a note of the orientation of the tubes relative to the heater cartridge.
6. Unscrew the band heater and loosen it, take out the old converter cartridge.

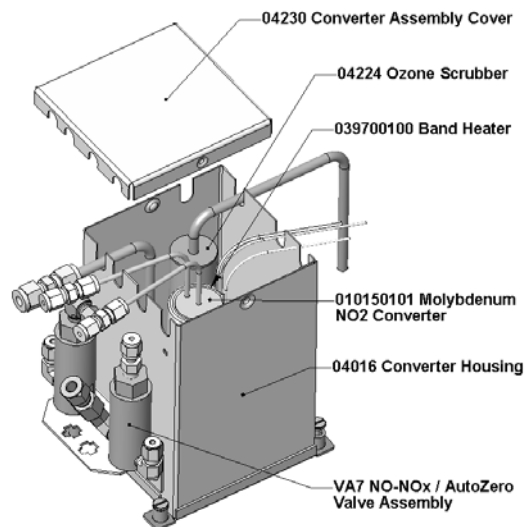


Figure 9-4: NO₂ Converter Assembly

7. Wrap the band heater around the new replacement cartridge and tighten the screws using a high-temperature anti-seize agent such as copper paste. Make sure to use proper alignment of the heater with respect to the converter tubes.
8. Replace the converter assembly, route the cables through the holes in the can and reconnect them properly. Reconnect the grounding clamp around the heater leads for safe operation.

9. Re-attach the tube fittings to the converter and replace the insulation and cover.
10. Replace the instrument cover and power up the analyzer.
11. Allow the converter to burn-in for 24 hours, and then re-calibrate the instrument.

9.3.7. CLEANING THE REACTION CELL

The reaction cell should be cleaned whenever troubleshooting suggests. 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. Refer to Section 11.6.6. for an overview of the entire sensor assembly. Use the following guide to clean the reaction cell:

1. Turn off the instrument power and vacuum pump. Refer to the Figure 9-5 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 four screws holding the reaction cell to the PMT housing and lift the cell and manifold out as shown in the inset of Figure 9-5.

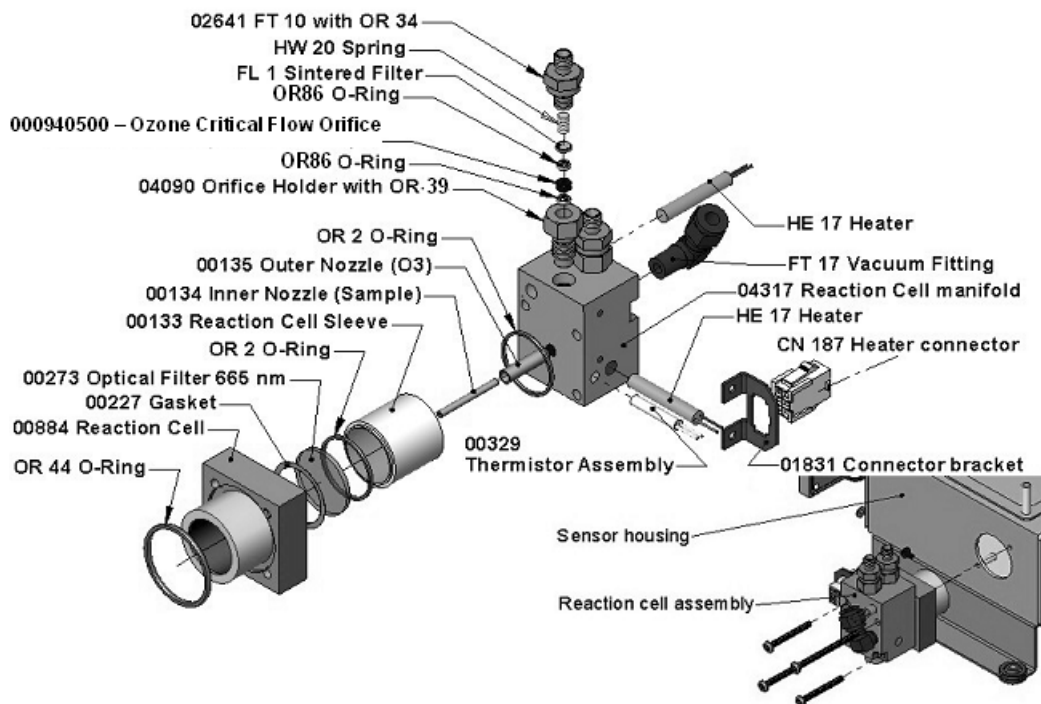


Figure 9-5: Reaction Cell Assembly

4. The reaction cell will separate into two halves, the stainless steel manifold assembly, and the black plastic reaction cell with window, stainless steel cylinder, and O-rings.
5. The reaction cell (both plastic part and stainless steel cylinder) and optical glass filter should be cleaned with methanol and a clean tissue and dried thereafter.
6. Usually it is not necessary to clean the ozone flow orifice since it is protected by a sintered filter. If tests show that cleaning is necessary, refer to Section 9.3.9 on how to clean the critical flow orifice.

7. 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.
8. 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.
9. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical as described in Section 9.3.3.
10. 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.

9.3.8. CHANGING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the TML41M/H, Figure 9-6 shows one of the two most important orifice assemblies, located on the reaction cell. Refer to Section 10.3.3 for a detailed description on functionality and locations. 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.

The TML41M/H introduces an orifice holder that makes changing the orifice very easy. In fact, it is recommended to keep spare orifice holder assemblies at hand to minimize downtime and swap orifices in a matter of a few minutes. Appendix B lists several complete spare part kits for this purpose.

To replace a critical flow orifice, do the following:

1. Turn off power to the instrument and vacuum pump. Remove the analyzer cover and locate the reaction cell (Figure 9-5, Figure 11-22 and Figure 3-4).
2. Unscrew the 1/8" sample and ozone air tubes from the reaction cell
3. For orifices on the reaction cell (Figure 9-5): Unscrew the orifice holder with a 9/16" wrench. This part holds all components of the critical flow assembly as shown in Figure 9-7. Appendix B contains a list of spare part numbers.
4. For orifices in the vacuum manifold, the assembly is similar to the one shown in Figure 9-6, but without the orifice holder, part number 04090, and bottom O-ring OR34 a NPT fitting is substituted for the FT 10 fitting. After taking off the connecting tube, unscrew the NPT fitting.

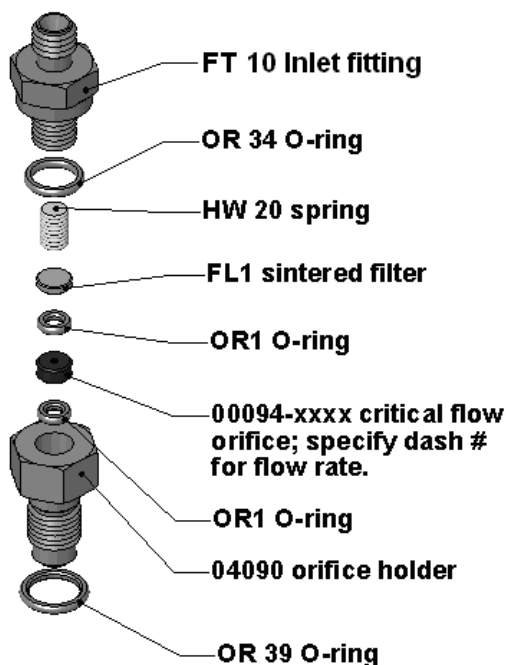


Figure 9-6: Critical Flow Orifice Assembly

5. Take out the components of the assembly: a spring, a sintered filter, two O-rings and the orifice. 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.
6. Discard the two O-rings and the sintered filter and the critical flow orifice.
7. Re-assemble the flow control assembly with new the parts (see Appendix B for part number or replacement kit) as shown in Figure 9-6 and re-connect them to the reaction cell manifold or the vacuum manifold.
8. Reconnect all tubing, power up the analyzer and pump and - after a warm-up period of 30 minutes, carry out a leak test as described in Chapter 11.

9.3.9. CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the TML41M/H can develop small leaks around the PMT, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the below procedures. **CAUTION:** this procedure can only be carried out with the analyzer running and its cover removed. This procedure should only be carried out by qualified personnel.

1. Scroll the TEST functions to PMT.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover. Take extra care not to touch any of the inside wiring with the metal cover or 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.

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). Often, light leaks are also caused by O-rings being left out of the assembly.
6. Carefully replace the analyzer cover.
7. If tubing was changed, carry out a leak check (Chapter 11).

USER NOTES:

10. THEORY OF OPERATION

The TML41M/H Nitrogen Oxides Analyzer is a microprocessor controlled instrument that determines the concentration of nitric oxide (NO), total nitrogen oxides (NO_x, the sum of NO and NO₂) and nitrogen dioxide (NO₂) 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 (O₃), 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 NO₂ in the sample gas to NO, then – including the NO in the sample gas – is then reported as NO_x. NO₂ is calculated as the difference between NO_x and NO.

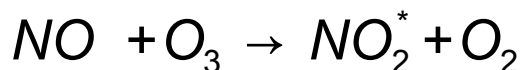
Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO₂ are supplied and stores these results in memory. The microprocessor 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_x concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system (iDAS Section 6.7.2) and are reported to the user through a vacuum fluorescence display or several output ports.

10.1. MEASUREMENT PRINCIPLE

10.1.1. CHEMILUMINESCENCE

The principle of the TML41M/H's measurement method is the detection of chemiluminescence, which occurs when nitrogen oxide (NO) reacts with ozone (O₃). This reaction is a two-step process. In the first step, one molecule of NO and one molecule of O₃ collide and chemically react to produce one molecule of oxygen (O₂) and one molecule of nitrogen dioxide (NO₂). Some of the NO₂ 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 NO₂ molecule resides in a higher energy state than is normal (denoted by an asterisk in Equation 10-1).



(Equation 10-1)

Thermodynamics requires that systems seek the lowest stable energy state, hence, the NO₂ molecule quickly returns to its ground state in a subsequent step, releasing the excess energy in form of a quantum of light ($h\nu$) with wavelengths between 600 and 3000 nm, with a peak at about 1200 nm (Equation 10-2, Figure 10-1).



(Equation 10-2)

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 (Figure 10-1). In order to maximize the yield of reaction (1), the TML41M/H supplies the reaction cell with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

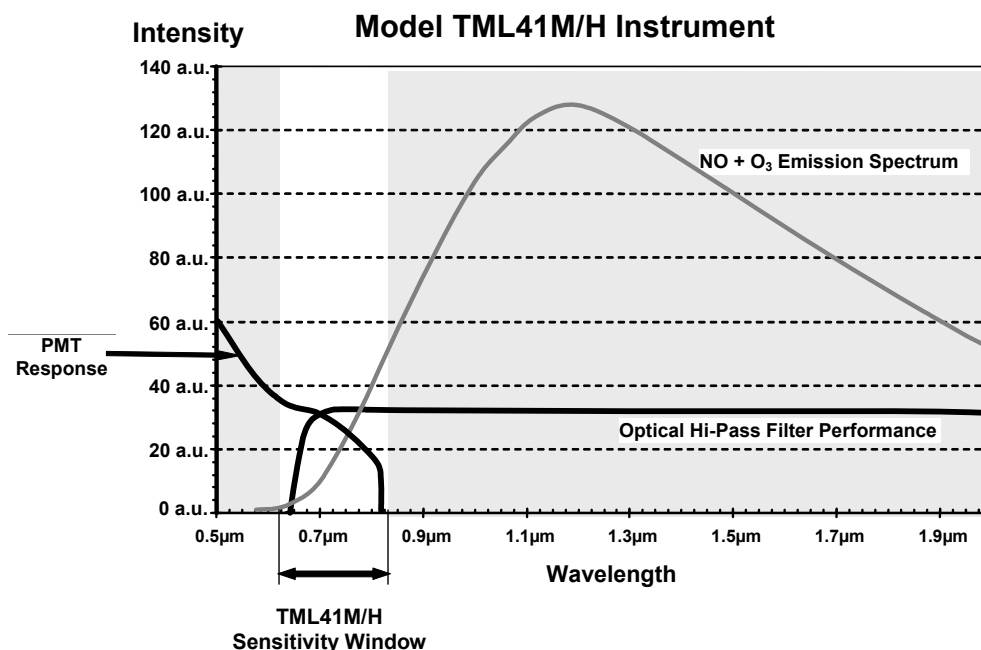
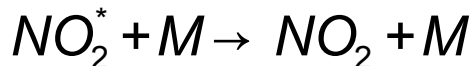


Figure 10-1: TML41M/H Sensitivity Spectrum

However, only about 20% of the NO_2 that is formed through reaction 10-1 is in the excited state. In addition, the excited NO_2 can collide with another collision partner M in the reaction cell (mostly other molecules but also cell walls) and transfer its excess energy to its collision partner without emitting any light at all (Equation 10-3). In fact, by far the largest portion of the NO_2^* returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.



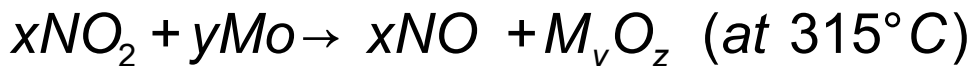
(Equation 10-3)

In order to enhance the light yield of the reaction, the reaction cell is maintained at reduced pressure. The probability of a collision between the NO_2^* molecule and a collision partner M increases proportionally with the reaction cell pressure. This non-radiating collision with the NO_2^* molecules is usually referred to as *quenching*, an unwanted process further described in Section 10.2.4.2.

10.1.2. NO_x AND NO_2 DETERMINATION

The only gas that is truly measured in the TML41M/H is NO. Any NO_2 contained in the gas is not detected in the above process since NO_2 does not react with O_3 to undergo chemiluminescence.

In order to measure the concentration of NO or NO_x (which is defined here as the sum of NO and NO_2 in the sample gas), the TML41M/H periodically switches the sample gas stream through a converter cartridge filled with molybdenum (Mo, "moly") chips heated to a temperature of 315° C. The heated molybdenum reacts with NO_2 in the sample gas and produces a variety of molybdenum oxides and NO according to Equation 10-4.



(Equation 10-4)

Once the NO_2 in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in Equations 10-1 and 10-2.

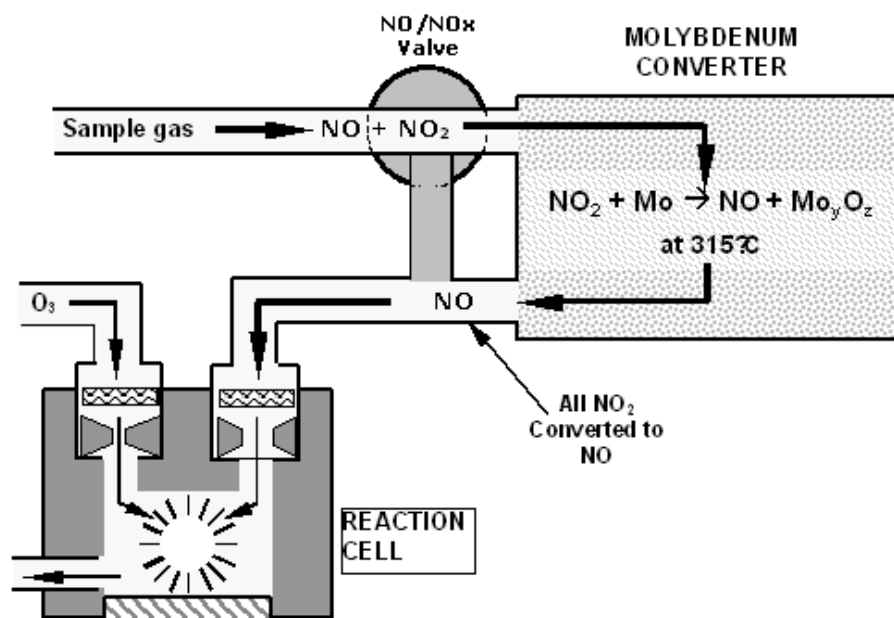


Figure 10-2: NO₂ Conversion Principle

By converting the NO₂ in the sample gas into NO, the analyzer can measure the total NO_x (NO+NO₂) content of the sample gas. By switching the NO₂ converter in and out of the sample gas stream every 6 - 10 seconds, the TML41M/H analyzer is able to quasi-continuously measure both the NO and the total NO_x content.

The NO₂ concentration, finally, is not measured but calculated by simply subtracting the known NO content of the sample gas from the known NO_x content.

10.2. CHEMILUMINESCENCE DETECTION

10.2.1. THE PHOTO MULTIPLIER TUBE

The TML41M/H uses a photo-multiplier tube (PMT) to detect the amount of light created by the NO and O₃ 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, which increases or decreases with the amount of detected light, is converted to a voltage and amplified by the preamplifier board. It is then reported to the motherboard's analog inputs.

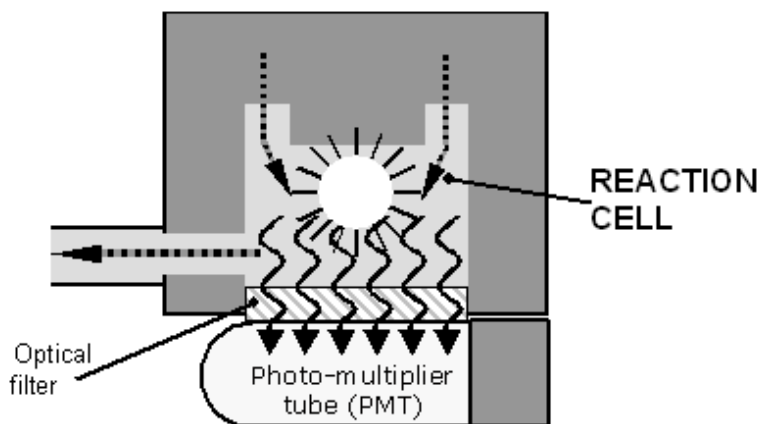


Figure 10-3: Reaction Cell with PMT Tube

10.2.2. OPTICAL FILTER

Another critical component in the method by which your TML41M/H detects chemiluminescence is the optical filter that lies between the reaction cell and the PMT (Figure 10-3). 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 TML41M/H will respond (Figure 10-1).

The narrow band of sensitivity allows the TML41M/H to ignore extraneous light and radiation that might interfere with the TML41M/H's measurement. For instance, some oxides of sulfur can also undergo chemiluminescence when in contact with O₃ but emit light at shorter wavelengths (usually around 260 nm to 480 nm).

10.2.3. 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, the TML41M/H diverts the sample gas flow directly to the vacuum manifold without passing the reaction cell once every minute for about 5 seconds (Figure 10-4). During this time, only O₃ is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the chamber is completely dark, the TML41M/H 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_x to arrive at a auto-zero corrected reading.

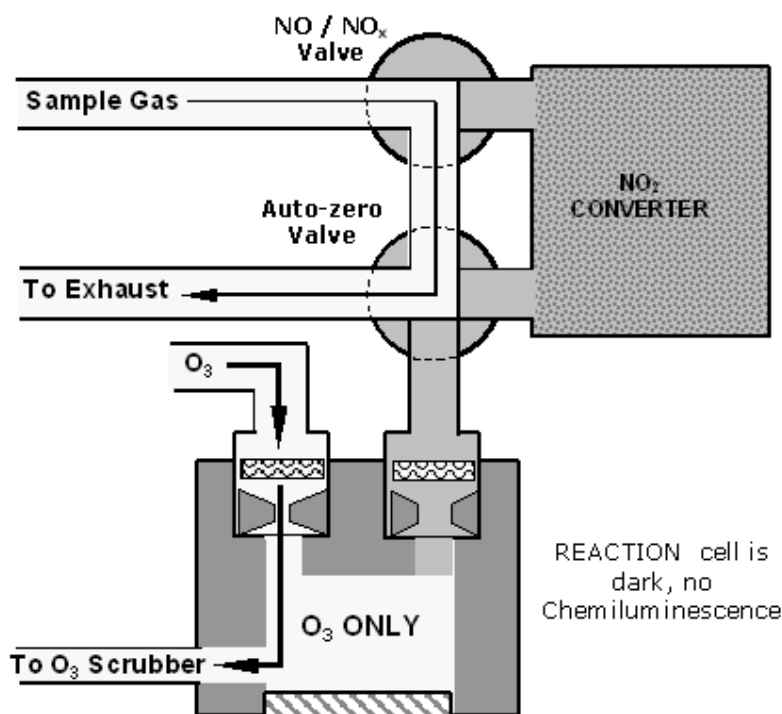


Figure 10-4: Reaction Cell During the AutoZero Cycle.

10.2.4. MEASUREMENT INTERFERENCES

It should be noted that the chemiluminescence method is subject to interferences from a number of sources. The TML41M/H has been successfully tested for its ability to reject interference from most of these sources. Table 10-1 lists the most important gases, which may interfere with the detection of NO in the TML41M/H.

10.2.4.1. 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 O₃ in the reaction cell or a gas that reacts with other compounds and produces excess NO upstream of the reaction cell.

10.2.4.2. Third Body Quenching

As shown in Equation 10-3, other molecules in the reaction cell can collide with the excited NO₂^{*}, preventing the chemiluminescence of Equation 10-2, a process known as quenching. CO₂ and H₂O are the most common quenching interferences, but N₂ and O₂ also contribute to this interference type.

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 H₂O and CO₂ quench NO chemiluminescence more effectively than smaller, less polar and electronically “harder” molecules such as N₂ and O₂.

The influence of water vapor on the TML41M/H measurement can be eliminated with an optional, internal sample gas dryer. The concentrations of N₂ and O₂ are virtually constant in ambient air measurements, hence provide a constant amount of quenching and the interference of varying CO₂ amounts is negligible at low concentrations.

The TML41H and TML41M analyzers are typically used in high CO₂ concentration environments. The pneumatic setup of these two analyzer models minimizes the interference from CO₂ such that the analyzers conform to the standards set forth by the US-EPA in Method 20 - NO_x from Stationary Gas Turbines, available at <http://www.epa.gov/ttn/emc/promgate.html>

Table 10-1: List of Interferents

GAS	INTERFERENCE TYPE	REJECTION METHOD
CO ₂	Dilution: Viscosity of CO ₂ molecules causes them to collect in aperture of Critical Flow Orifice altering flow rate of NO.	If high concentrations of CO ₂ are suspected, special calibration methods must be performed to account for the affects of the CO ₂ .
	3 rd Body Quenching: CO ₂ molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	Contact Teledyne Instruments Customer Service department for details.
SO _x	Some SO _x variants can also initiate a chemiluminescence reaction upon exposure to O ₃ producing excess light.	Wavelengths of light produced by chemiluminescence of SO _x are screened out by the Optical Filter.
	Chemically reacts with NH ₃ , O ₂ and H ₂ O in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (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 ₃ Generator and the reaction cell.
	3 rd Body quenching: SO _x molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	If high concentrations of SO _x are suspected, special calibration methods must be performed to account for the affects of the SO ₂ . Contact Teledyne Instruments Customer Service department for details.
H ₂ O	3 rd Body quenching: H ₂ O molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	Analyzer's operating in high humidity areas must have some method of drying applied to the sample gas supply (Section 5.10 for more details).
	Chemically reacts with NH ₃ and SO _x in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter Window. Also forms highly corrosive HNO ₃ (nitric acid)	Removed from the O ₃ gas stream by the Perma Pure [®] Dryer (Section 10.3.7 for more details).
NH ₃	Direct Interference: NH ₃ is converted to H ₂ O and NO by the NO ₂ converter. Excess NO reacts with O ₃ in reaction cell creating excess chemiluminescence.	If a high concentration of NH ₃ is suspected, steps must be taken to remove the NH ₃ from the sample gas prior to its entry into the NO ₂ converter.
NH ₃	Chemically reacts with H ₂ O, O ₂ and SO _x in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (nitric acid).	The Perma Pure [®] dryer built into the TML41M/H is sufficient for removing typical ambient concentration levels of NH ₃ .

In cases with excessively high CO₂ concentrations (larger than 0.5%), the effect can be calibrated out by using calibration gases with a CO₂ content equal to the measured air. Only very high and highly variable CO₂ concentrations will then be cause of measurable interference. For those applications, we recommend to use other analyzer models. Please consult sales or our website.

10.2.4.3. Light Leaks

The TML41M/H sensitivity curve includes a small portion of the visible light spectrum (Figure 10-1), hence, it is important to make sure than the reaction cell is completely sealed with respect to light. To ensure this, all pneumatic tubing leading into the reaction cell is either opaque (vacuum exit tubing) in order to prevent light from entering the cell or light penetration is prevented by stainless steel filters and orifices (gas entries).

10.3. PNEUMATIC OPERATION

CAUTION

It is important that the sample airflow system is leak-tight and not pressurized over ambient pressure. Regular leak checks should be performed on the analyzer as described in the maintenance schedule, Table 9-1. Procedures for correctly performing leak checks can be found in Section 11.5.1.

10.3.1. PUMP AND EXHAUST MANIFOLD

NOTE

Relative Pressure versus absolute pressure. In this manual vacuum readings are given in inches of mercury absolute pressure (in-Hg-A), i.e. indicate an absolute pressure referenced against zero (a perfect vacuum).

The gas flow for the TML41M/H is created by an external pump (Figure 10-5) that is pneumatically connected through a 6.4 mm / 0.25" tube to the analyzer's exhaust port located on the rear panel (Figure 3-1). This 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 (Figure 3-1). 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.

There are several advantages to this external pump / pull-through configuration.

- By using an external pump, it is possible to remove a significant source of acoustic noise and vibration from the immediate vicinity of the sensor. The PMT can act as a "microphone", amplifying noise and vibration within the chassis. This is one of the main reasons, why the TML41M/H has an external pump.
- Pumping heats and compresses the sample air, complicating the measurement process if the pump is upstream.
- Most importantly, however, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas. Placing the pump downstream of the reaction cell avoids these problems.

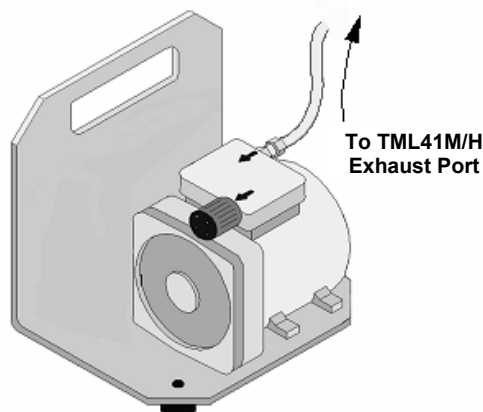


Figure 10-5: External Pump Pack

Finally, the TML41M/H requires a steady, high under-pressure, which cannot be achieved reliably over extended periods of time with small vacuum pumps. The external pump used for the TML41M/H has a very long lifetime and duty cycle and provides a very good vacuum for its entire lifetime. However, the pump is too large to fit into the chassis of the analyzer.

10.3.2. SAMPLE GAS FLOW

The sample gas is the most critical flow path in the analyzer, as the medium has to be routed through a variety of valves and tubes for the measurement of zero offset and concentrations of both NO and NO_x (and possibly the drying of the gas if the optional sample dryer is installed). At any point before and in the reaction cell, the integrity of the sample gas cannot be compromised.

Sample gas flow in the TML41M/H analyzer is not a directly measured value, but is rather calculated from the sample pressure using the flow principle across a critical orifice. In general, the differential pressure ratio between sample pressure and reaction cell pressure needs to exceed 2:1 to allow critical flow. The actual flow rate is then only dependent on the size of the orifice and the upstream pressure. Refer to Section 10.3.3 for a detailed description of the instrument's method of gas flow rate control.

10.3.2.1. NO/NO_x and AutoZero cycles

For the routing of the sample gas flow, the analyzer uses a variety of valves. The NO/NO_x valve directs the sample gas either directly to the reaction cell or through the unit's NO₂ converter, alternating every ~4 s. The AutoZero 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. The valve cycle phases are summarized in the following table.

Table 10-2: TML41M/H Valve Cycle Phases

PHASE	NO/ NO _x VALVE STATUS	AUTOZERO VALVE STATUS	TIME INDEX	ACTIVITY	FIGURE
NO Measure	Open to AutoZero valve	Open to reaction cell	0 - 2 s	Wait period (NO dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 10-2
			2 - 4 s	Analyzer measures chemiluminescence in reaction cell.	
NOX Measure	Open to NO ₂ converter	Open to reaction cell	4 - 6 s	Wait period (NOX dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 10-2
			6 - 8 s	Analyzer measures NO + O ₃ chemiluminescence in reaction cell.	
Cycle repeats every ~8 seconds					
AutoZero	Open to AutoZero 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 10-4
			4 - 6 s	Analyzer measures background noise without sample gas	
Cycle repeats every minute					

10.3.3. FLOW RATE CONTROL - CRITICAL FLOW ORIFICES

The TML41M/H analyzers use special flow control assemblies located at various locations around the instrument to maintain constant flow rates for both the O₃ supply air and the sample gas. 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 spring: Applies mechanical force needed to form the seal of the o-rings, the critical flow orifice and the assembly housing.

See Figure 10-6: Location of Gas Flow Control Assemblies for TML41H through Figure 10-9:

Location of Gas Flow Control Assemblies for TML41H with Second Span Point Option 52 for the location of these flow control assemblies:

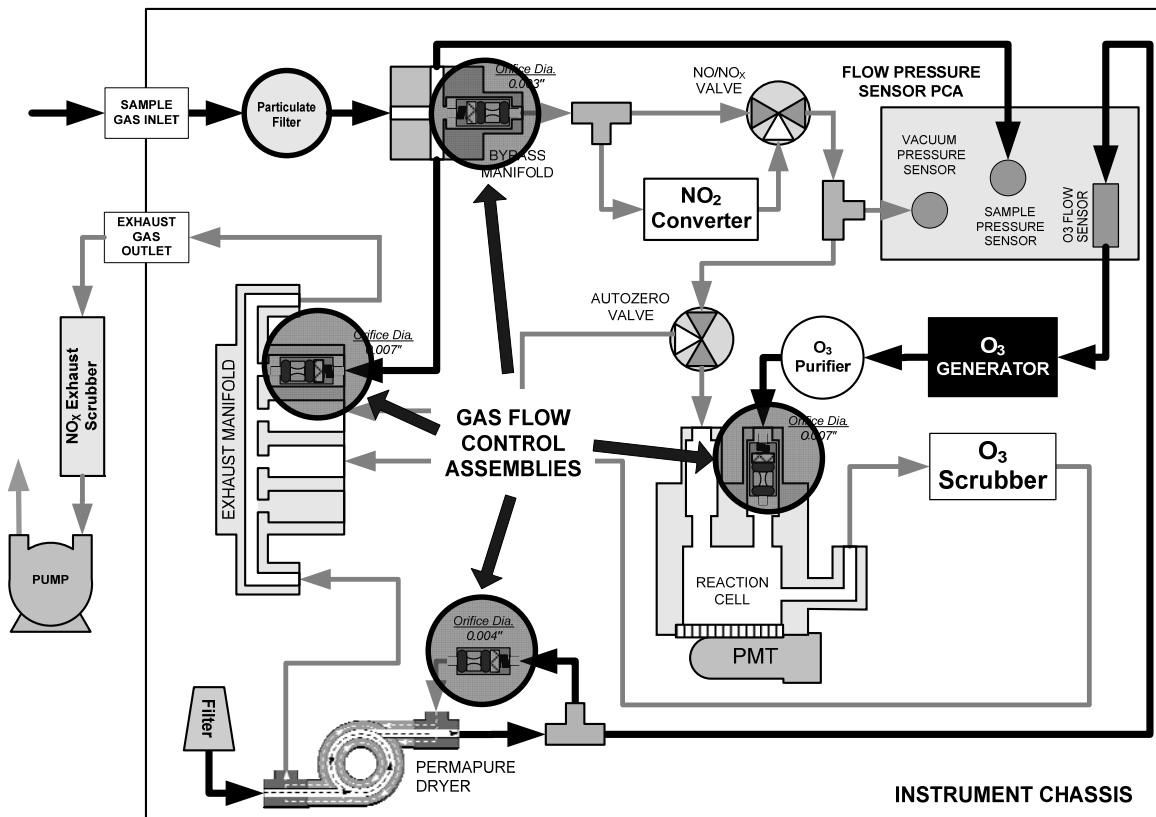


Figure 10-6: Location of Gas Flow Control Assemblies for TML41H

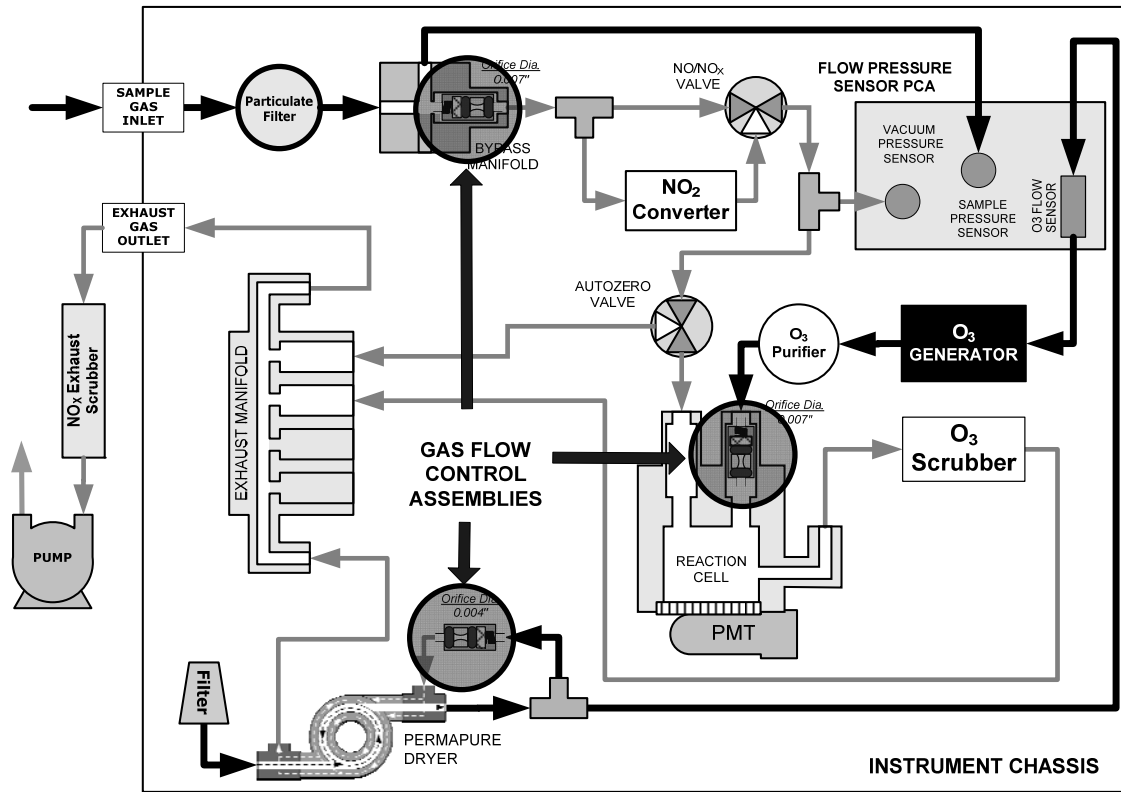


Figure 10-7: Location of Gas Flow Control Assemblies for TML41M

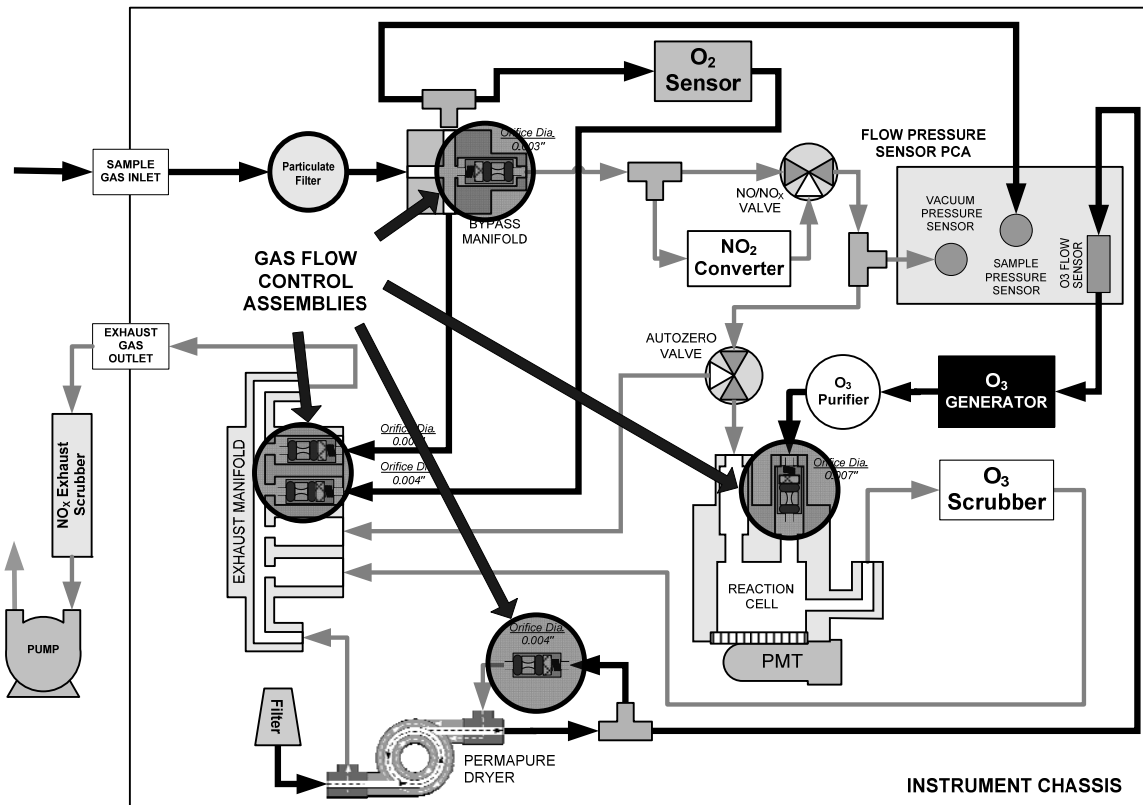


Figure 10-8: Location of Gas Flow Control Assemblies for TML41H with O₂ sensor Option 65

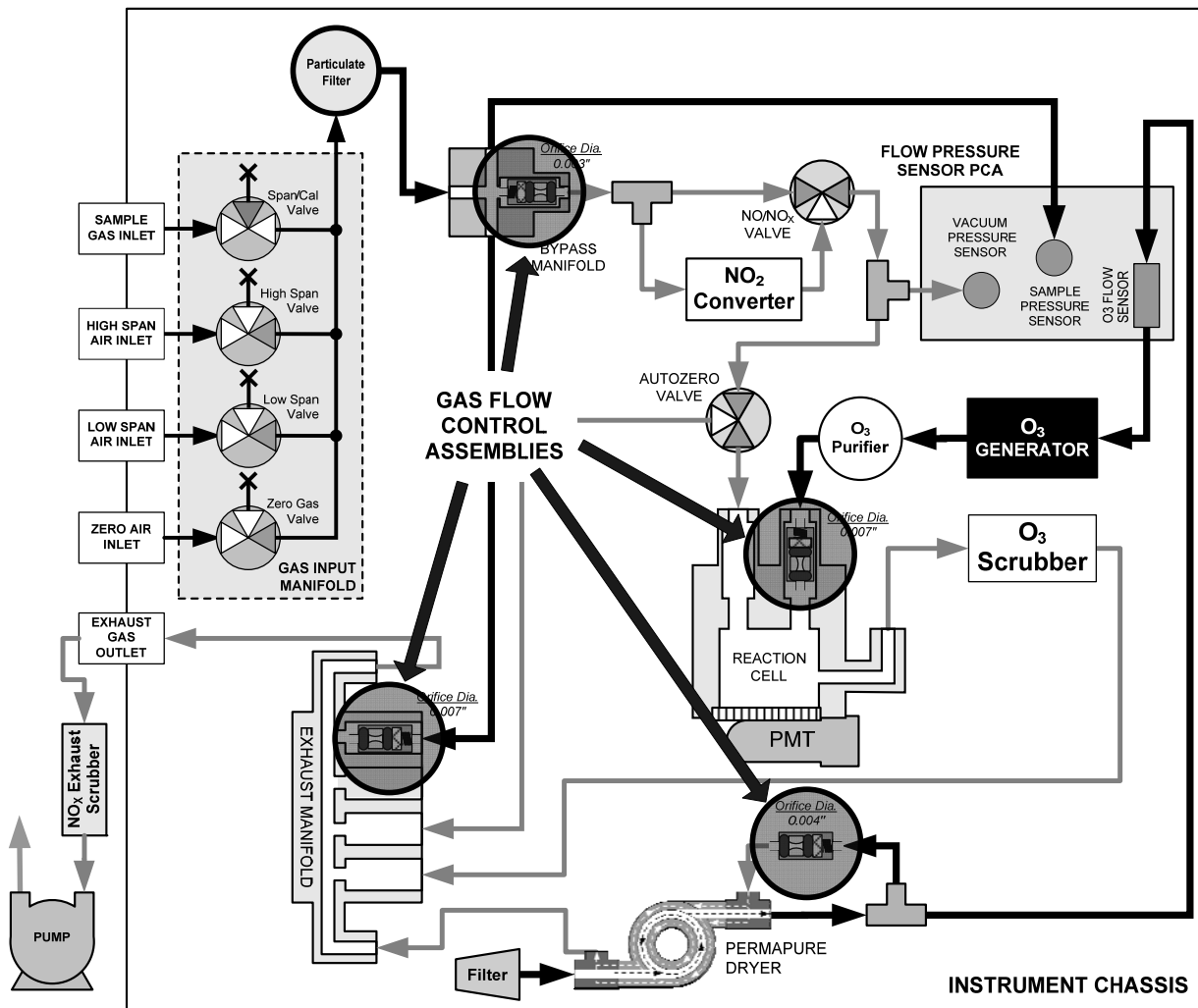


Figure 10-9: Location of Gas Flow Control Assemblies for TML41H with Second Span Point Option 52

NOTE:

Location of flow control assemblies in the TML41M/H with zero/span option 50 installed is the same as shown in Figure 10-6: Location of Gas Flow Control Assemblies for TML41H and Figure 10-7: Location of Gas Flow Control Assemblies for TML41M.

10.3.3.1. Critical Flow Orifice

The most important component of the flow control assemblies is the critical flow orifice.

Critical flow orifices are a remarkably simple way 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 combined with the action of the analyzer's 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.

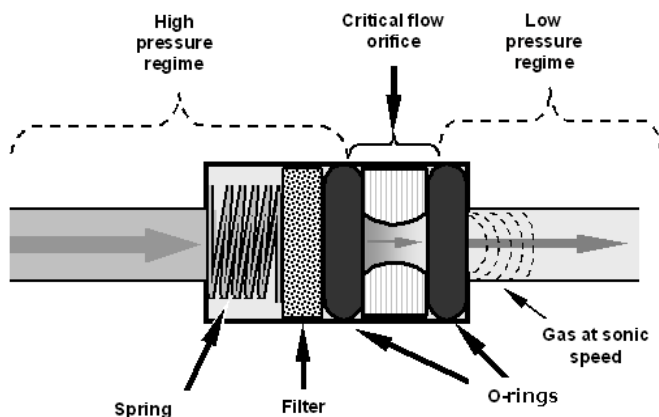


Figure 10-10: Flow Control Assembly & Critical Flow Orifice

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.

With nominal pressures of 28 and 4 in-Hg-A for the sample and reaction cell pressures respectively, the necessary ratio of sample to reaction cell pressure of 2:1 is largely exceeded and accommodates a wide range of possible variability in atmospheric pressure and pump degradation extending the useful life of the pump. Once the pump degrades to the point where the vacuum pressure exceeds 14 in-Hg-A so that the ratio between sample and vacuum pressures is less than 2:1 a critical flow rate can no longer be maintained. At this point, the instrument will display "XXXX" indicating an invalid sample flow rate.

The following table lists the gas flow rates of the critical flow orifices in the standard TML41M/H

Table 10-3: TML41M/H Critical Flow Orifice Diameters and Gas Flow Rates

LOCATION	PURPOSE	ORIFICE DIAMETER		NOMINAL FLOWRATE (cm ³ /min)	
		TML41H	TML41M	TML41H	TML41M
Bypass Manifold out to NO/NO _x valve and NO ₂ converter	Controls rate of flow of sample gas into the NO ₂ converter and reaction cell.	0.003"	0.007"	40	250
Vacuum Manifold: Bypass Manifold Port	Controls rate of sample gas flow that bypasses the analyzer when bypassing the reaction cell during the auto-zero cycle.	0.007"	N/A	250	N/A
TOTAL INLET GAS FLOW – Standard Configuration				290	250
Vacuum manifold: O ₂ sensor port	Controls rate of flow of zero purge gas through the O ₂ sensor (when installed and enabled) when inactive.	0.004"	0.004"	80	80
TOTAL INLET GAS FLOW – With O₂ Sensor Option				370	330
O ₃ supply inlet of reaction cell.	Controls rate of flow of ozone gas into the reaction cell.	0.007"	0.007"	250	250
Dry air return of Perma Pure [®] dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004"	0.004"	80	80

In addition to controlling the gas flows to the inlets of the reaction cell, the two critical flow orifices at the inlets of the reaction cell also maintain an under-pressure inside the reaction cell, effectively reducing the number of molecules in the chamber and therefore increasing the chemiluminescence yield as the likelihood of third body quenching is reduced (Section 10.2.4.1). The TML41M/H sensitivity reaches a peak at about 2 in-Hg-A, below which the sensitivity drops due to a low number of molecules and decreased yield in the chemiluminescence reaction.

EFFECT OF TEMPERATURE ON CRITICAL FLOW

Changes in temperature will cause the critical flow orifice materials to expand or contract. Even though these changes are extremely small, they can alter the diameter of the critical flow orifice enough to cause noticeable changes in the flow rate through the orifice. To alleviate this problem the two most important of the flow assemblies (those controlling the sample gas and O₃ gas flow) in the TML41M/H are maintained at a constant temperature.

10.3.4. SAMPLE PARTICULATE FILTER

To remove particles in the sample gas, the analyzer is equipped with a PTFE membrane filter of 47 mm diameter (also referred to as the sample filter) with a 1 µm pore size. The filter is accessible through the front panel, which folds down (after removal of the CE Mark safety screw), and should be changed according to the maintenance schedule in Table 9-1.

10.3.5. OZONE GAS 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, O₃ must also be removed from the gas stream before it can be vented through the exhaust outlet.

In contrast to the sample flow, the ozone flow is measured with a mass flow sensor, which is mounted on the pneumatic sensor board (Figure 11-20), just behind the PMT sensor assembly. This mass flow sensor has a full scale range of 0-1000 cm³/min and can be calibrated through software to its span point (Section 6.13.7.5). As the flow value displayed on the front panel is an actual measurement (and not a calculated value), the flow variability may be higher than that of the sample flow, which is based on a calculation from (more stable) differential pressures. On the other hand, the drift, i.e. long-term change, in the ozone flow rate may be higher and usually indicates a flow problem. As with all other test parameters, we recommend to monitor the ozone flow over time for predictive diagnostics and maintenance evaluation.



CAUTION

Ozone (O₃) is a toxic gas. Obtain a Material and Safety Data Sheet (MSDS) for this gas. Read and rigorously follow the safety guidelines described there. Always make sure that the plumbing of the O₃ generation and supply system is maintained and leak-free.

10.3.6. O₃ GENERATOR

The TML41M/H uses a corona discharge (CD) tube for creating its O₃. Corona discharge generation is capable of producing high concentrations of ozone efficiently and with low excess heat. Although there are many cell designs, the fundamental principle remains the same (Figure 10-11).

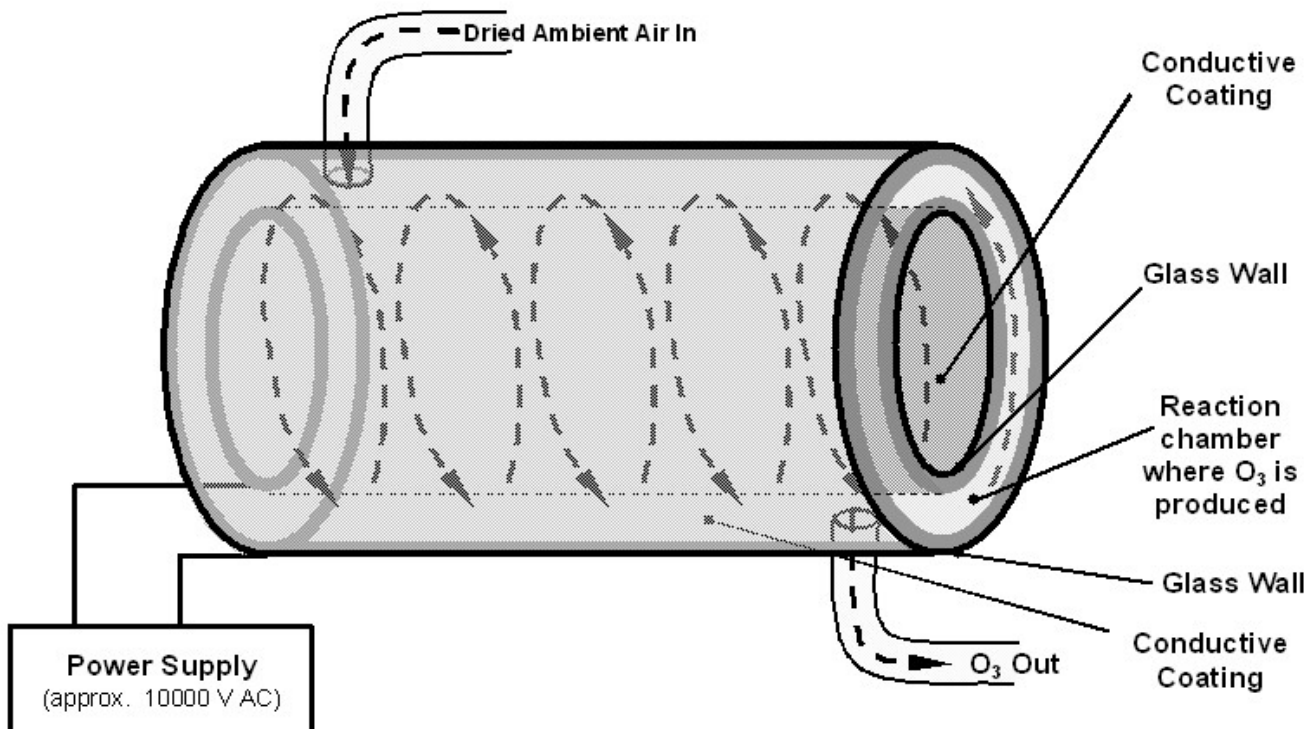


Figure 10-11: Ozone Generator Principle

The TML41M/H 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 O₃. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O₂ molecules in the air stream splitting them into elemental oxygen. Some of these oxygen atoms recombine with O₂ to form O₃.

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 O₂ molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

10.3.7. PERMA PURE[®] DRYER

The air supplied to the O₃ 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 ozone generator. Also, water can react with other chemicals inside the O₃ Generator to produce chemicals that damage the optical filter located in the reaction cell (Table 10-1) such as ammonium sulfate or highly corrosive nitric acid.

To accomplish this task the TML41M/H 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 (Figure 10-12).

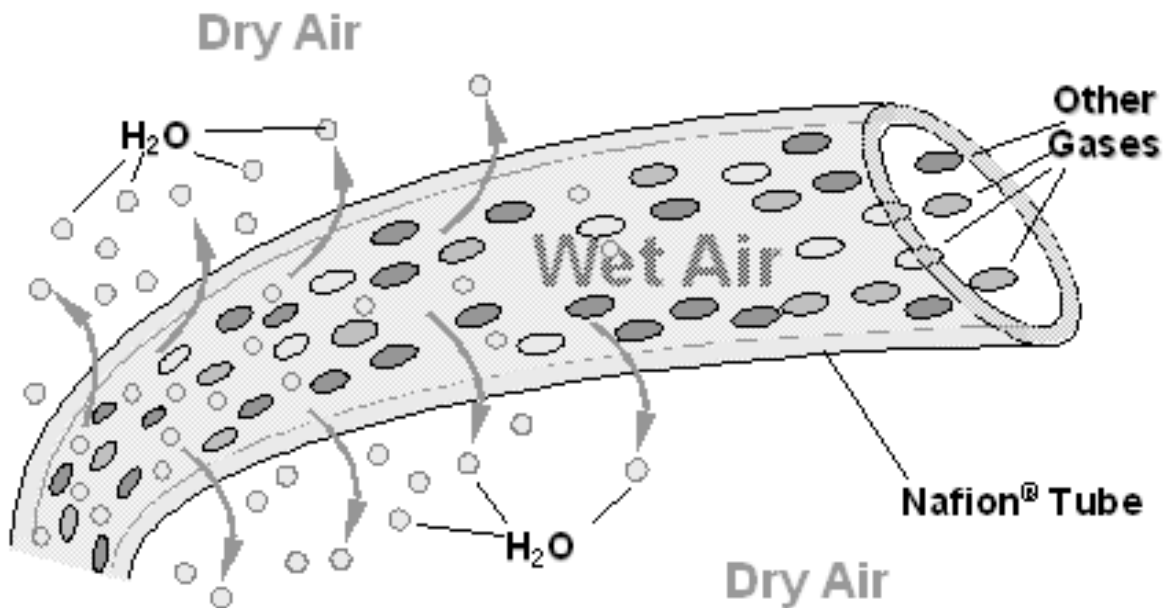


Figure 10-12: Semi-Permeable Membrane Drying Process

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 (NH₃) and some low molecular amines. The gases of interest, NO and NO₂, do not get absorbed and pass the dryer unaltered.

To provide a dry purge gas for the outer side of the Nafion tube, the TML41M/H returns some of the dried air from the inner tube to the outer tube (Figure 10-13). 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.

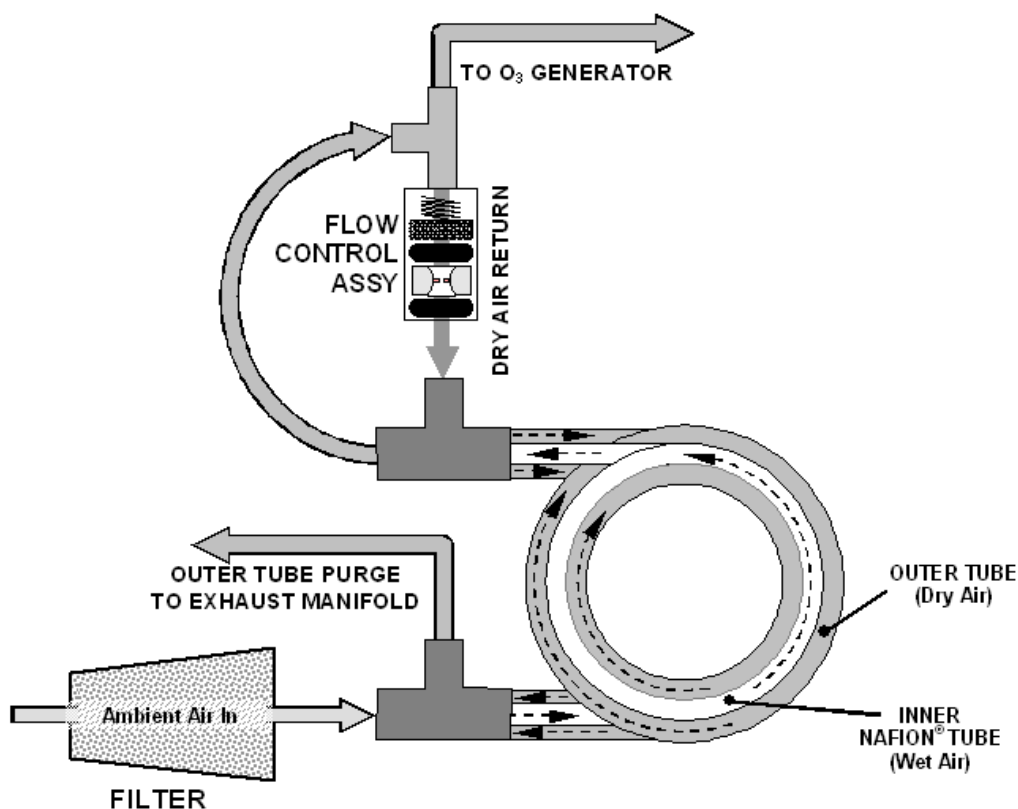


Figure 10-13: TML41M/H Perma Pure® Dryer

Just like on startup, if the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the humidity gradient to become large enough for the Perma Pure® Dryer to adequately dry the air. In this case, called a cold start, the O₃ Generator is not turned on for 30 minutes. When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.

The Perma Pure® Dryer used in the TML41M/H is capable of adequately drying ambient air to a dew point of $\leq -5^{\circ}\text{C}$ (~4000 ppm residual H₂O) at a flow rate of 1 standard liter per minute (slpm) or down to $\leq -15^{\circ}\text{C}$ (~1600 ppm residual H₂O) at 0.5 slpm. The Perma Pure® Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

10.3.8. OZONE SCRUBBER

Even though ozone is unstable and typically reacts to form O_2 , the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream of the TML41M/H by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O_3 , a special catalytic ozone scrubber is used to remove all of the O_3 exiting the reaction cell. Besides its efficient destruction of O_3 , 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_3 scrubber is located inside the NO_2 converter housing next to the NO_2 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.

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 avoid the dust from entering the reaction cell or the pump, the scrubber is equipped with sintered stainless steel filters of 20 μm pore size on either end and on some models, an additional dust filter may be attached to the exhaust port.

10.3.9. PNEUMATIC SENSORS

NOTE

The TML41M/H displays all pressures in inches of mercury absolute (in-Hg-A), i.e. absolute pressure referenced against zero (a perfect vacuum).

The TML41M/H uses three pneumatic sensors to verify gas streams. These sensors are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board, located just behind the sensor assembly.

10.3.9.1. Vacuum Manifold

The vacuum manifold is the central exit port for all analyzer pneumatics. All gas streams of the analyzer exit through this assembly and connect to the instrument's pump. Figure 10-14 shows the standard configuration. Configurations will vary depending on the optional equipment that is installed. An IZS option, for example, will add another FT8 connector and orifice assembly to the manifold; an optional sample dryer may add a Tee-fitting so that two 1/4" tubes can be connected to the same port.

At this time, the vacuum manifold does not yet support the orifice holder shown in Figure 9-7. To exchange the critical orifice installed in the vacuum manifold, the user needs to either blow the orifice out with reversed pressure or remove the entire manifold for this task. However, orifices installed in the vacuum manifold should not have to be cleaned under normal circumstances.

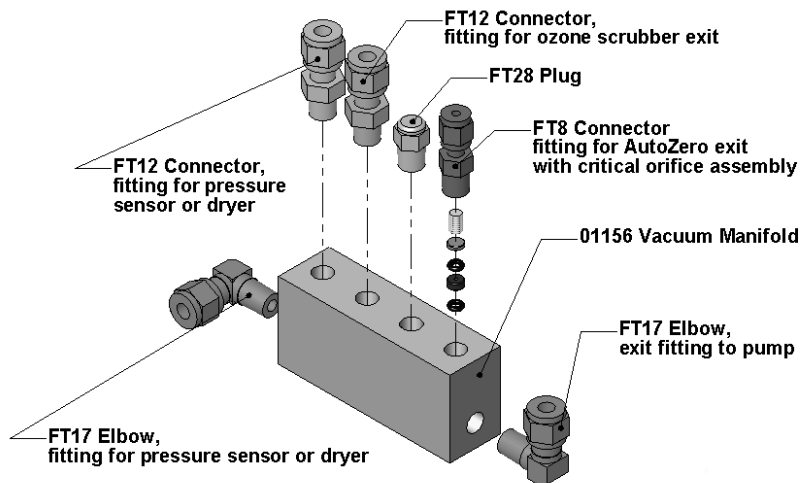


Figure 10-14: Vacuum Manifold

10.3.9.2. Sample Pressure Sensor

An absolute pressure transducer connected to the input of the NO/NO_x valve is used to measure the pressure of the sample gas before it enters the analyzer's reaction cell. This is the "upstream" pressure mentioned above, which is used to compute sample flow rate. In conjunction with the vacuum pressure sensor, it is also used to validate the critical flow condition (2:1 pressure ratio) through the sample gas critical flow orifice (Section 10.3.3). If the temperature/pressure compensation (TPC) feature is turned on (Section 10.7.3), 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**.

10.3.9.3. 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 (Section 6.2.2) and the sample flow rate will display **XXXX** instead of an actual value. If this pressure exceeds 10 in-Hg-A, an **RCEL PRESSURE WARNING** is issued, even though the analyzer will continue to calculate a sample flow up to ~14 in Hg.

Also, if the temperature/pressure compensation (TPC) feature is turned on (Section 10.7.3), the output of this sensor is used to supply pressure data for that calculation. This measurement is viewable through the analyzer's front panel as the test function **RCEL**.

10.3.9.4. O₃ Supply Air Flow Sensor

A mass flow meter connected between the Perma Pure[®] dryer and the O₃ generator measures the flow rate of O₃ supply air through the analyzer. This information is used to validate the O₃ gas flow rate. If the flow rate exceeds $\pm 15\%$ of the nominal flow rate (80 cm³/min), a warning message **OZONE FLOW WARNING** is displayed on the analyzer's front panel (Section 6.2.2) and the O₃ generator is turned off. As second warning, **OZONE GEN OFF** is displayed. This flow measurement is viewable through instrument's front panel display as the test function **OZONE FL**.

10.3.10. DILUTION MANIFOLD

Certain applications are required to measure NO_x in sample gases that do not contain any oxygen. However, the molybdenum NO₂ converter requires a minimum amount of oxygen to operate properly and to ensure constant conversion efficiency. For these special applications, the TML41M/H analyzer may be equipped with a dilution manifold (Figure 10-15) to provide the instrument with an internal sample stream that contains about 2.5% O₂. This manifold is mounted between converter housing and vacuum manifold on a small mounting bracket. If the dilution manifold is to be mounted in the TML41M/H analyzer, it will fit on the back of the shown bracket as the front of the bracket is occupied by the bypass manifold.

The manifold is equipped with two orifice holders that control the flow of the O₂-free sample gas and bleeds in a small amount of zero air before the combined sample stream goes to the NO/NO_x valve for measurement. The zero air is produced by an external zero air scrubber cartridge, mounted on the rear panel (Figure 3-2 and Figure 9-4).

The dilution manifold is not temperature controlled, although the residual heat of the NO₂ converter housing provides some temperature stability. Tight temperature stability is not critical to the dilution application.

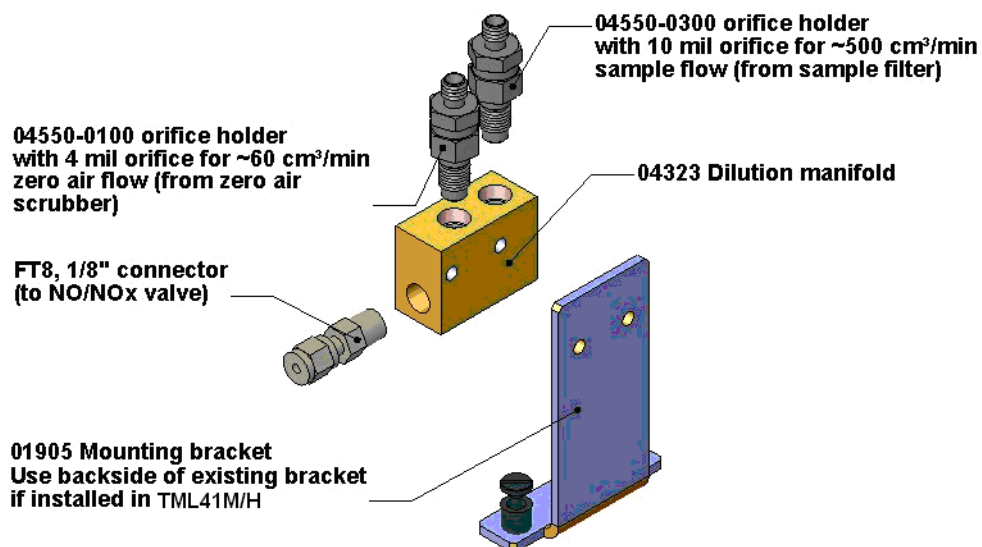


Figure 10-15: Dilution Manifold

Please inquire with Teledyne-ML sales if the TML41M/H can be modified to fit your application.

10.4. ELECTRONIC OPERATION

Figure 10-16 shows a block diagram of the major electronic components of the TML41M/H.

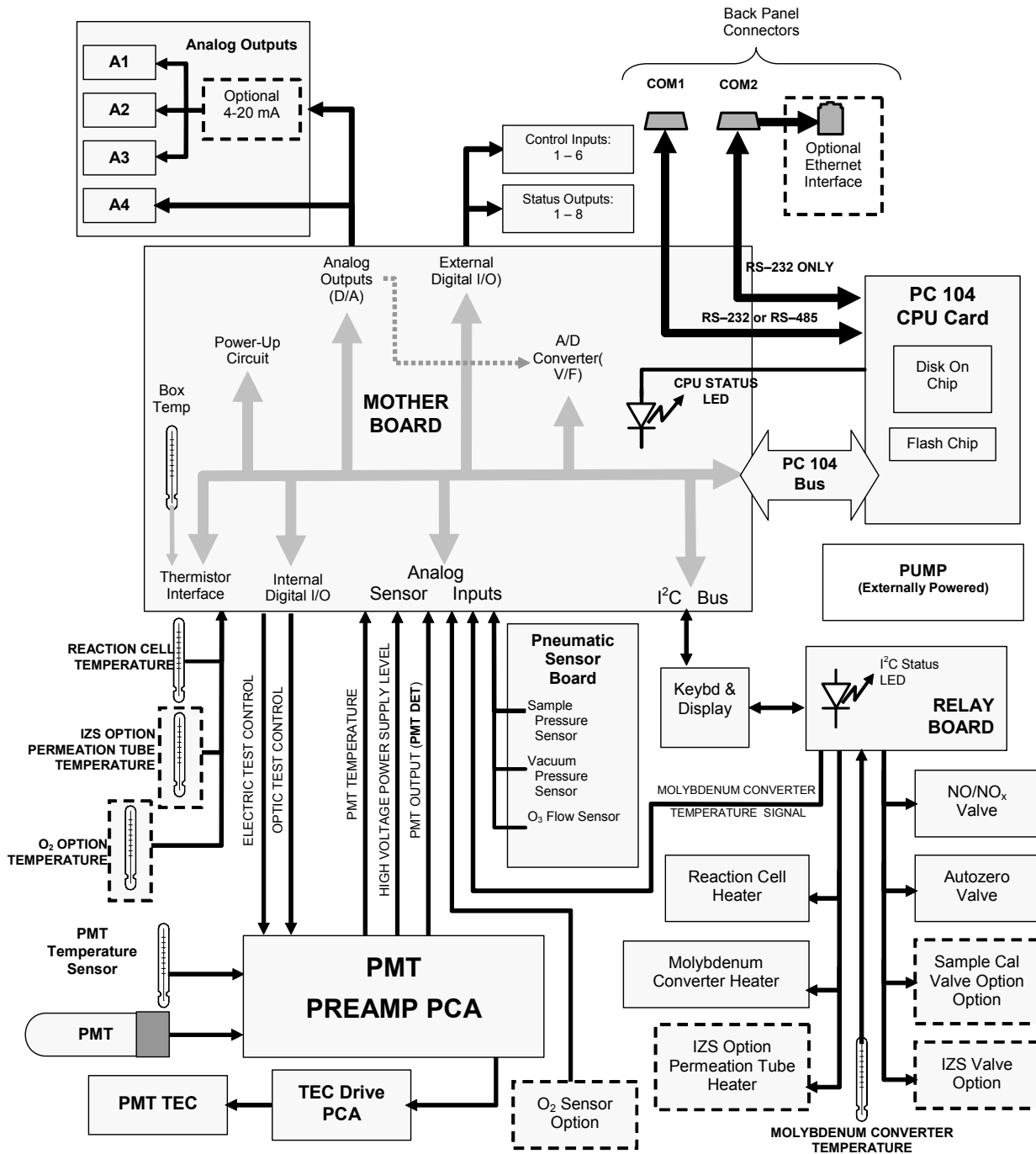


Figure 10-16: TML41M/H Electronic Block Diagram

The core of the analyzer is a microcomputer (CPU) that controls various internal processes, interprets data, calculates data, and reports results using specialized firmware developed by Teledyne Instruments. It communicates with the user, receives data from and issues commands to a variety of peripheral devices through the motherboard, the main printed circuit assembly on the rear panel (Figure 3-1).

10.4.1. CPU

The CPU is a low power (5 VDC, 0.8A max), high performance, 386-based microcomputer running a version of the DOS operating system. Its operation and assembly conform to the PC-104 specification, version 2.3 for embedded PC and PC/AT applications. It has 2 MB of DRAM memory on board and operates at 40 MHz clock rate over an internal, 32-bit data and address bus. Chip to chip data handling is performed by two 4-channel, direct memory access (DMA) devices over data busses of either 8-bit or 16-bit bandwidth. The CPU supports both RS-232 and RS-485 serial protocols. Figure 10-17 shows the CPU board.

- The CPU communicates with the user and the outside world in a variety of ways:
- Through the analyzer's keyboard and vacuum fluorescence display over a clocked, digital, serial I/O bus using the I²C protocol (read *I-square-C bus*)
- RS-232 and/or RS-485 serial ports (one of which can be connected to an Ethernet converter)
- Various analog voltage and current outputs
- Several digital I/O channels

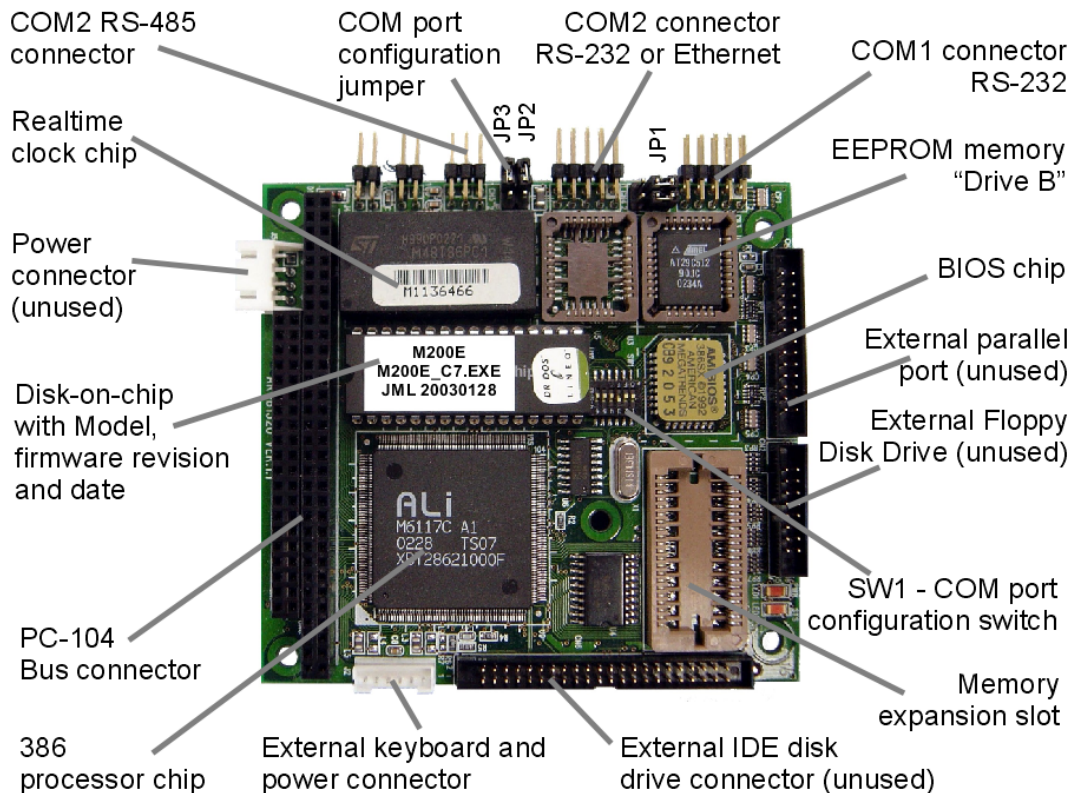


Figure 10-17: TML41M/H CPU Board Annotated

Finally, the CPU issues commands (also over the I²C bus) to a series of relays and switches located on a separate printed circuit assembly, the relay board (located in the right rear of the chassis on its own mounting bracket) to control the function of heaters and valves. The CPU includes two types of non-volatile data storage, one disk-on-chip and one or two flash chips.

10.4.1.1. Disk On Chip

Technically, the disk-on-chip is an EEPROM, but appears to the CPU as, behaves as, and performs the same functions in the system as an 8 mb disk drive, internally labeled as DOS drive C:\. It is used to store the computer's operating system files, the Teledyne Instruments firmware and peripheral files, and the operational data generated by the analyzer's internal data acquisition system (iDAS - Sections 10.7.5 and 6.7).

10.4.1.2. Flash Chip

The flash chip is another, smaller EEPROM with about 64 kb of space, internally labeled as DOS drive B:\. The TML41M/H CPU board can accommodate up to two EEPROM flash chips. The TML41M/H standard configuration is one chip with 64 kb of storage capacity, which is used to store the analyzer configuration as created during final checkout at the factory. Separating these data onto a less frequently accessed chip significantly decreases the chance of data corruption through drive failure.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOC. However, all configuration information will be lost, requiring the unit to be recalibrated.

10.4.2. SENSOR MODULE, REACTION CELL

Electronically, the TML41M/H sensor assembly (see Figure 9-6) consists of several subassemblies with different tasks: to detect the intensity of the light from the chemiluminescence reaction between NO and O₃ in the reaction cell, to produce a current signal proportional to the intensity of the chemiluminescence, to control the temperature of the PMT to ensure the accuracy and stability of the measurements and to drive the high voltage power supply that is needed for the PMT. The individual functions are described individually below. Section 11.6.6 shows the sensor assembly and its components.

10.4.2.1. Reaction Cell Heating Circuit

The stability of the chemiluminescence reaction between NO and O₃ can be affected by changes in the temperature and pressure of the O₃ 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 and 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 (Section 10.4.7). 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 (Section 10).

10.4.3. PHOTO MULTIPLIER TUBE (PMT)

The TML41M/H uses a photo multiplier tube (PMT) to detect the amount of chemiluminescence created in the sample chamber.

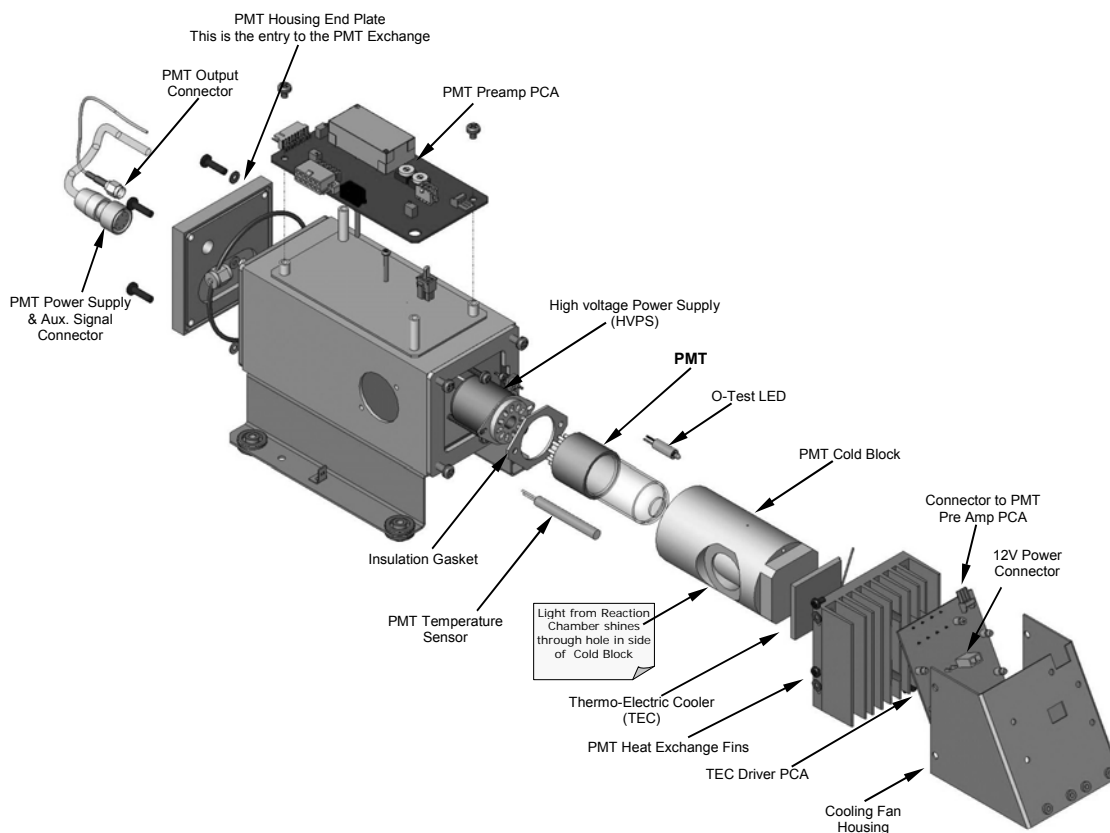


Figure 10-18: PMT Housing Assembly

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 is 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.

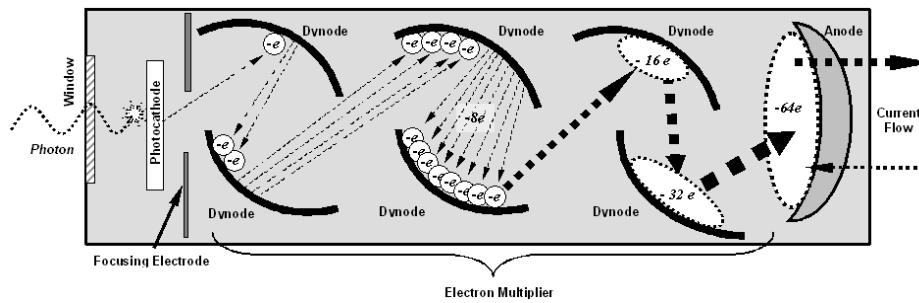


Figure 10-19: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater is the number of electrons emitted from each dynode of the electron multiplier, making the PMT more sensitive and responsive to small variations in light intensity but also more noisy (dark noise). The gain voltage of the PMT used in the TML41M/H is usually set between 450 V and 800 V. This parameter is viewable through the front panel as test function **HVPS** (see Section 6.2.1). For information on when and how to set this voltage, see Section 11.6.5.

The PMT is housed inside the PMT module assembly (see Figure 10-18). 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 thermo-electric cooler (TEC).

10.4.4. 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 that maintains the PMT temperature at a stable, low level

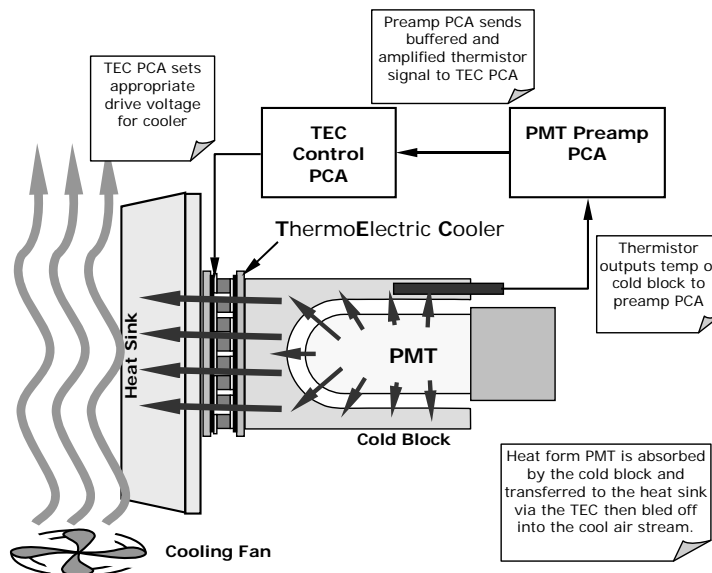


Figure 10-20: PMT Cooling System

10.4.4.1. TEC Control Board

The TEC control printed circuit assembly is located in 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 Chapter 11.

10.4.5. PMT PREAMPLIFIER

The PMT preamplifier board amplifies the PMT signal into a useable analog voltage (**PMT**) that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the NO, NO₂ and NO_x concentrations of the gas in the sample chamber.

The output signal of the PMT is controlled by two different adjustments. First, the voltage across the electron multiplier array of the PMT is adjusted with a set of two hexadecimal switches. Adjusting this voltage directly affects the HVPS voltage and, hence, the signal from the PMT. Secondly, the gain of the amplified signal can further be adjusted through a potentiometer. These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. See Section 11.6.5 for this hardware calibration.

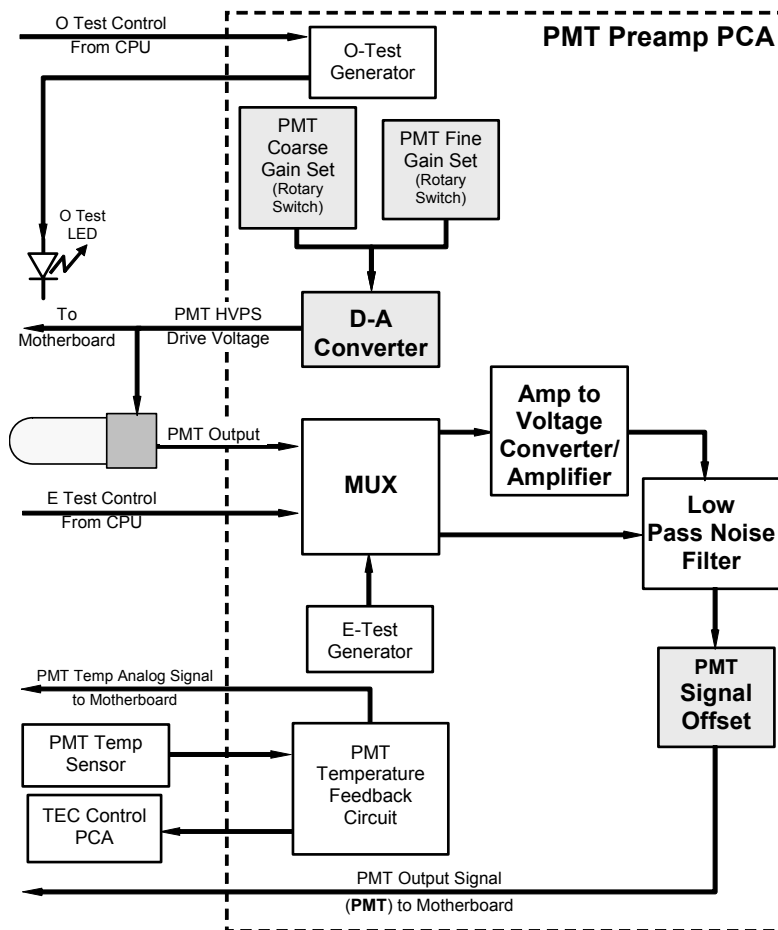


Figure 10-21: PMT Preamp Block Diagram

The PMT temperature control loop maintains the PMT temperature around 7° C and can be viewed as test function **PMT TEMP** on the front panel (see Section 6.2.1).

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 6.13.7.3 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 6.13.7.2 for instructions on performing this test.

10.4.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the TML41M/H are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 11.5.15 for information 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.

10.4.7. RELAY BOARD

The relay board is the central switching and power distribution unit of the analyzer. It contains power relays, valve drivers and status LEDs for all heated zones and valves, as well as thermocouple amplifiers, power distribution connectors and the two switching power supplies of the analyzer. The relay board communicates with the motherboard over the I²C bus and can be used for detailed trouble-shooting of power problems and valve or heater functionality. See Figure 11-4 for an annotated view of the relay board.

10.4.7.1. Relay PCA Location and Layout

Generally the relay PCA is located in the right-rear quadrant of the analyzer and is mounted vertically on the back side of the same bracket as the instrument's DC power supplies; however, the exact location of the relay PCA may differ from model to model (see Figure 3-1)

10.4.7.2. Heater Control

The heater control loop is illustrated in Figure 10-22. Two T/C inputs can be configured for either type-T or type-K thermocouples. Additionally:

- Both T/C's can be configured as either grounded or ungrounded thermocouples.
- Standard configuration of the both type of thermocouples is 10 mV/°C. In order to accommodate the TML41H's Mini High-Con converter option, a type-K; 5mV/°C output configuration has been added.

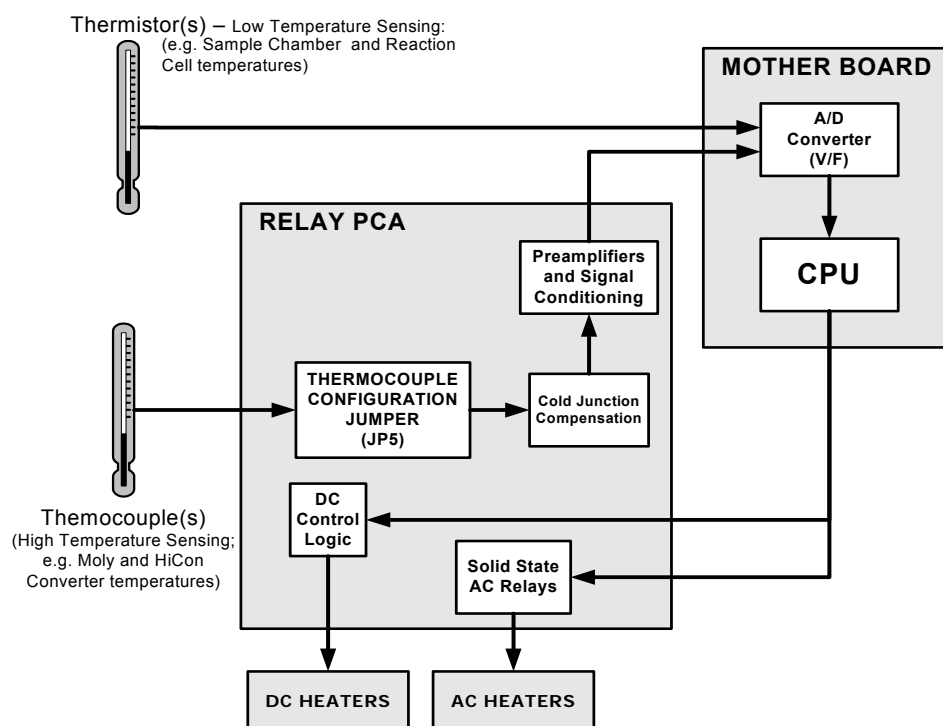


Figure 10-22: Heater Control Loop Block Diagram.

10.4.7.3. Thermocouple Inputs and Configuration Jumper (JP5)

Although the relay PCA supports two thermocouple inputs, the current TML41M/H series analyzers only utilize one. By default, this single thermocouple input is plugged into the TC1 input (J15). TC2 (J16) is currently not used. See Figure 11-4 for location of J15 and J16

Table 10-4: Thermocouple Configuration Jumper (JP5) Pin-Outs

TC INPUT	JUMPER PAIR	DESCRIPTION	FUNCTION
TC1	1 – 11	Gain Selector	Selects preamp gain factor for J or K TC - IN = J TC gain factor - OUT = K TC gain factor
	2 – 12	Output Scale Selector	Selects preamp gain factor for J or K TC - IN = 5 mV / °C - OUT = 10 mV / °C
	3 – 13	Type J Compensation	When present, sets Cold Junction Compensation for J type Thermocouple
	4 – 14	Type K Compensation	When present, sets Cold Junction Compensation for K type Thermocouple
	5 – 15	Termination Selector	Selects between Isolated and grounded TC - IN = Isolate TC - OUT = Grounded TC
TC2	6 – 16	Gain Selector	Same as Pins 1 – 11 above.
	7 – 17	Output Scale Selector	Same as Pins 2 – 12 above.
	8 – 18	Type J Compensation	Same as Pins 3 – 13 above.
	9 – 19	Type K Compensation	Same as Pins 4 – 14 above.
	10 – 20	Termination Selector	Same as Pins 5 – 15 above.

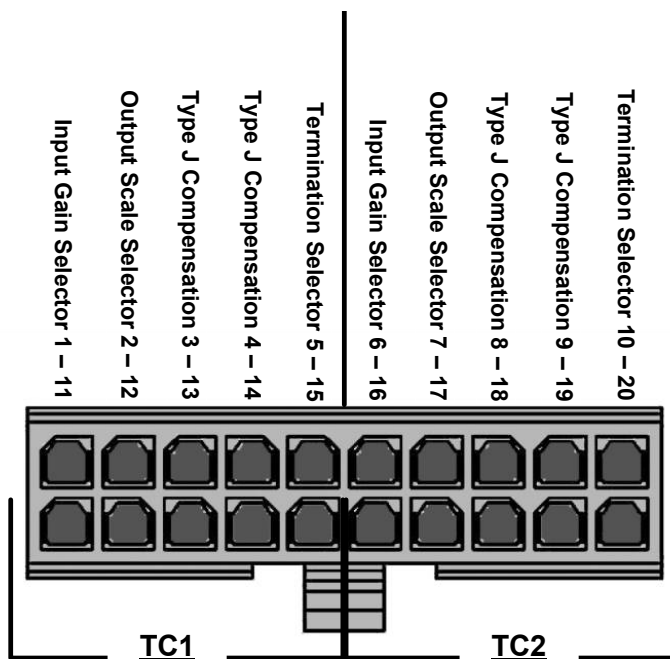


Figure 10-23: Thermocouple Configuration Jumper (JP5) Pin-Outs

Table 10-5: Typical Thermocouple Settings For M200E Series Analyzers

TC TYPE	TERMINATION TYPE	OUTPUT SCALE TYPE	JUMPER BETWEEN PINS	USED ON	JUMPER COLOR
INPUT TC1 (J15)					
K	GROUNDING	5mV / °C	2 – 12 4 – 14	TML41M/H with Mini HiCon Converter	BROWN
K	ISOLATED	5mV / °C	2 – 12 4 – 14 5 – 15	TML41M/H with Mini HiCon Converter	GREY
K	ISOLATED	10mV / °C	4 – 14 5 – 15	TML41M/H models with Moly Converter	PURPLE
J	ISOLATED	10mV / °C	1 – 11 3 – 13 5 – 15	TML41M/H models with Moly Converter	RED
J	GROUNDING	10mV / °C	1 – 11 3 – 13	TML41M/H models with Moly Converter	GREEN

10.4.7.4. 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 TML41M/H is the NO/NO_x - Auto-zero solenoid valve component mounted right in front of the

NO₂ converter housing. These two valves are actuated with 12 V supplied from the relay board and driven by the CPU through the I²C bus.

A second set of valves may be installed if the zero/span valve or the IZS option is enabled in the analyzer. Specialty manifold valves may be present in the analyzer.

10.4.8. STATUS LEDS & WATCH DOG CIRCUITRY

Thirteen LEDs are located on the analyzer's relay board to indicate the status of the analyzer's heating zones and valves as well as a general operating watchdog indicator. Table 11-2 shows the states of these LEDs and their respective functionality.

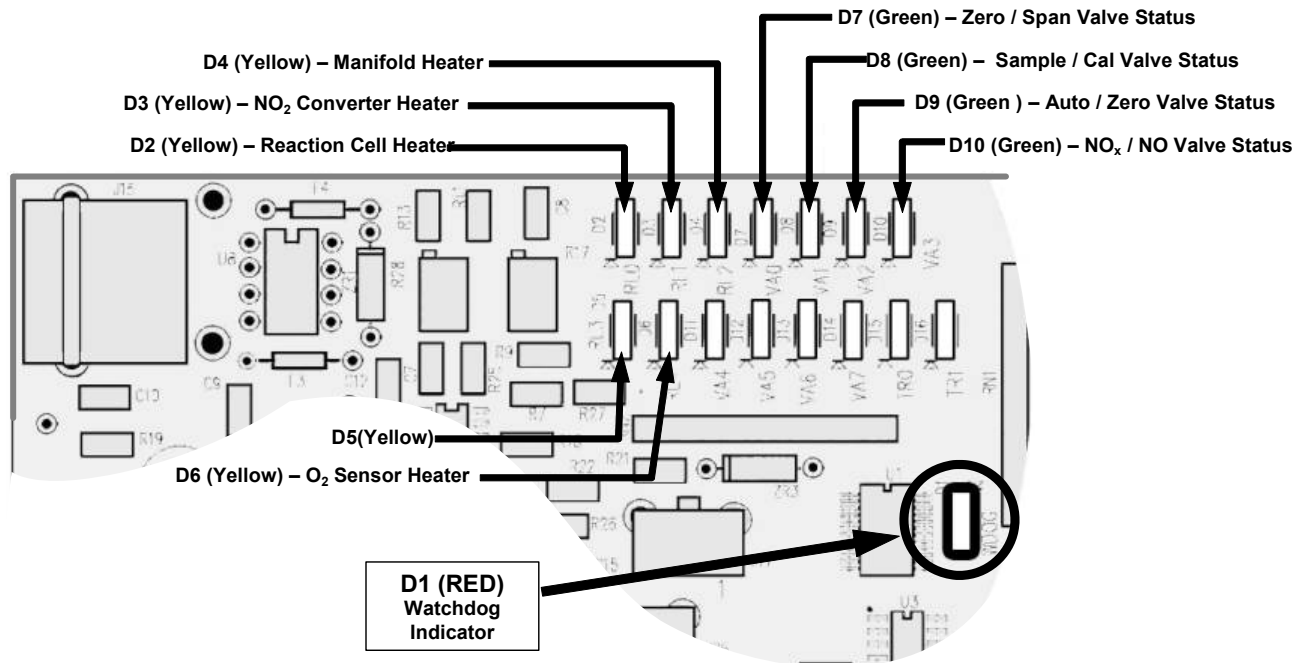


Figure 10-24: Status LED Locations – Relay PCA

10.4.8.1. Watchdog Indicator (D1)

The most important of the status LED's on the relay board is the red I²C Bus watch-dog LED. It is controlled directly analyzer's CPU over the I²C 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 I²C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters and lamps.

10.4.9. MOTHERBOARD

This is the largest electronic assembly in the analyzer and is mounted to the rear panel as the base for the CPU board and all I/O connectors. This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I²C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

10.4.9.1. A to D Conversion

Analog signals, such as the voltages received from the analyzer's 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 period, 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 is used in the 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 and sends their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope. These factors are used for subsequent conversions. See Section 6.13.6.4 for instructions on performing this calibration.

10.4.9.2. Sensor Inputs

The key analog sensor signals are coupled to the A/D converter through the master multiplexer from two connectors on the motherboard. Terminating resistors (100 k Ω) on each of the inputs prevent cross-talk between the sensor signals.

PMT DETECTOR OUTPUT: This signal, output of the PMT preamp PCA, is used in the computation of the NO, NO₂ and NO_x concentrations displayed at the top right hand corner of the front panel display. They are transmitted through the instrument's analog outputs and **COMM** ports.

PMT HIGH VOLTAGE POWER SUPPLY LEVEL: This input is based on the drive voltage supplied by the PMT preamp board to the PMT's high voltage power supply (HVPS). It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS. It is stored in the instrument's memory as the test function **HVPS**. **HVPS** is viewable as a test function (see Section 6.2.1) through the analyzer's front panel.

PMT TEMPERATURE: This signal is the output of the thermistor attached to the PMT cold block amplified by the PMT temperature feedback circuit on the PMT preamp board. It is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

This measurement is stored in the analyzer memory as the test function **PMT TEMP** and is viewable as a test function (see Section 6.2.1) through the analyzer's front panel.

NO₂ CONVERTER TEMPERATURE: This parameter is measured with a Type-K thermocouple attached to the NO₂ converter heater and its analog signal is amplified by the circuitry on the relay board. It is sent to the CPU and then digitized and is used to calculate the current temperature of the NO₂ converter. It is also stored in the iDAS and reported as test function **MOLY TEMP**.

SAMPLE GAS PRESSURE: This is measured upstream of the reaction cell, stored in the iDAS and reported as **SAMPLE**. The vacuum gas pressure is measured downstream of the reaction cell and is stored in the iDAS and reported as **RCEL**. For more information on these sensor functions see Section 10.3.10.

O₃ GAS FLOW This sensor measures the gas flow upstream of the ozone generator is stored in the iDAS and reported as test function **OZONE FL**. For more information on this sensor's function see Section 10.3.10.

10.4.9.3. Thermistor Interface

This circuit provides excitation, termination, and signal selection for several negative-coefficients, thermistor temperature sensors located inside the analyzer. They are:

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. This measurement is stored in the analyzer's iDAS and reported as test function **RCEL TEMP**.

BOX TEMPERATURE SENSOR is 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_x and NO₂ calculations when the instrument's Temperature/Pressure Compensation feature is enabled. This measurement is stored in the analyzer memory as the test function **BOX TEMP** and is viewable as a test function (Section 6.2.1) through the analyzer's front panel.

PMT TEMPERATURE: The outputs of the thermistor inside the PMT cold block as well as the thermistor located on the preamplifier board are both converted to analog signals on the preamplifier board before being sent to the motherboard's A/D converter.

O₂ SENSOR TEMPERATURE: For instruments with the oxygen sensor option installed, the thermistor measuring the temperature of the heating block mounted to the sensor is reported as test function **O2 TEMP** on the front panel. This temperature is maintained at 50° C.

10.4.10. ANALOG OUTPUTS

The analyzer comes equipped with four Analog Outputs: **A1**, **A2**, **A3** and a fourth that is a spare.

A1 and A2 Outputs: The first two, **A1** and **A2** are normally set up to operate in parallel so that the same data can be sent to two different recording devices. While the names imply that one should be used for sending data to a chart recorder and the other for interfacing with a datalogger, either can be used for both applications.

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 6.13.6.1)

10.4.11. EXTERNAL DIGITAL I/O

The external digital I/O performs two functions.

The **STATUS** outputs carry logic-level (5V) signals through an optically isolated 8-pin connector on the rear panel of the analyzer. These outputs convey on/off information about certain analyzer conditions such as **CONC VALID**. They can be used to interface with certain types of programmable devices (Section 6.15.1.1).

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 6.15.1.2). Zero and span calibrations can be initiated by contact closures on the rear panel.

10.4.12. I²C DATA BUS

I²C is a two-wire, clocked, 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 I²C. The data are then fed to the keyboard/display interface and finally onto the relay board.


Interface circuits on the keyboard/display interface and relay board convert the I²C data to parallel inputs and outputs. An additional interrupt line from the keyboard to the motherboard allows the CPU to recognize and service key strokes on the keyboard.

10.4.13. POWER-UP CIRCUIT

This circuit monitors the +5V power supply during analyzer start-up and sets the analog outputs, external digital I/O ports, and I²C circuitry to specific values until the CPU boots and the instrument software can establish control.

10.5. POWER DISTRIBUTION & CIRCUIT BREAKER

The analyzer operates in two main AC power ranges: 100-120 VAC and 220-240 VAC (both $\pm 10\%$) between 47 and 63 Hz. A 5 ampere 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.



CAUTION

Should the power circuit breaker trip; correct the condition causing this situation before turning the analyzer back on.

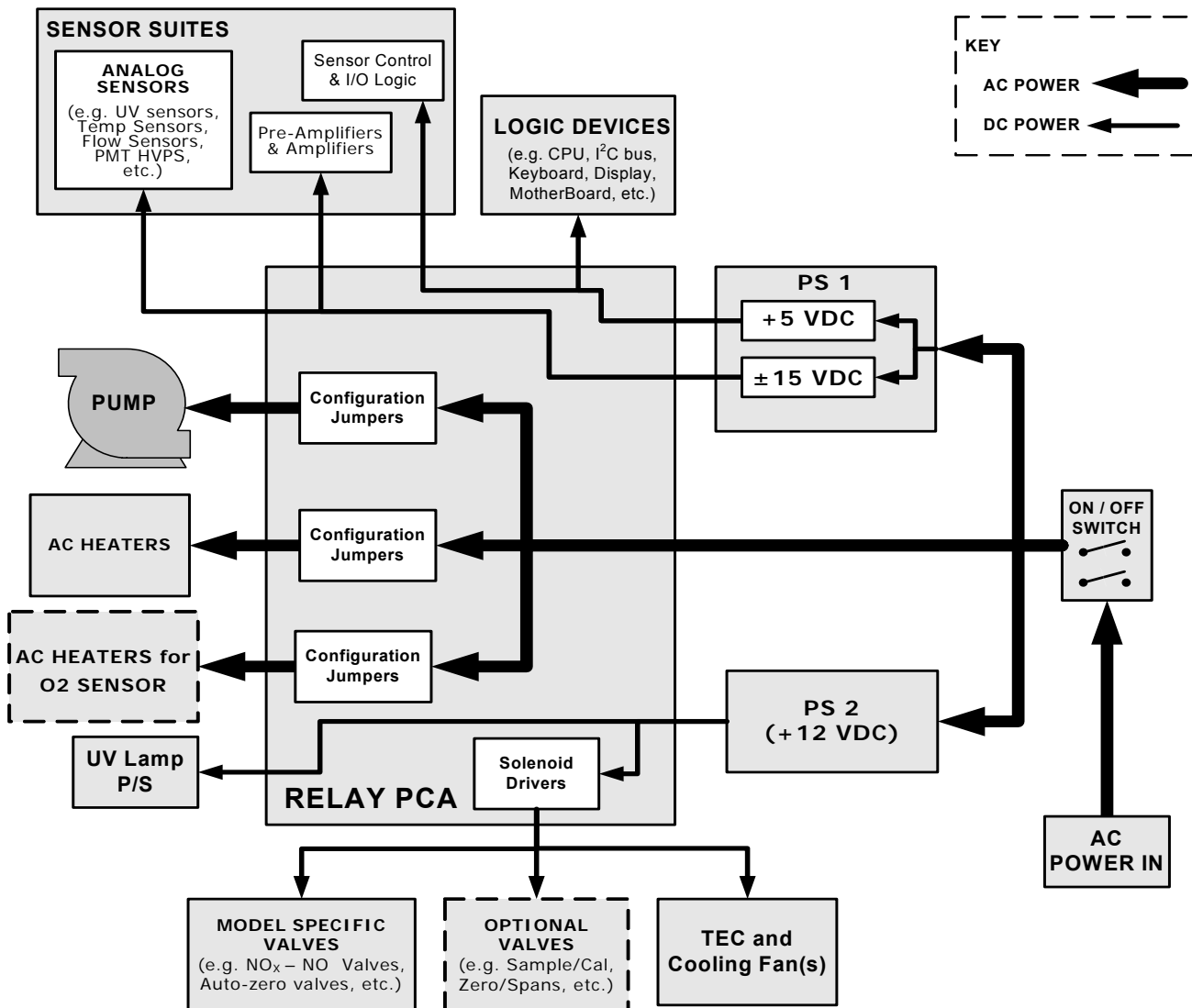


Figure 10-25: Power Distribution Block Diagram

Under normal operation, the TML41M/H draws about 1.5 A at 115 V and 2.0 A during start-up.

10.6. COMMUNICATIONS INTERFACE

The analyzer has several ways to communicate the outside world, see Figure 10-26. Users can input data and receive information directly through the front panel keypad and display. Direct, two-way communication with the CPU is also available by way of the analyzer's RS232 & RS485 I/O ports (see Section 6.11 and 6.15). Alternatively, an Ethernet communication option can be substituted for one of the COMM ports.

The analyzer can also send status information and data via the eight digital status output lines (see Section 6.15.1.1) and the three analog outputs (see Section 6.13.4) located on the rear panel as well as receive commands by way of the six digital control inputs also located on the rear pane (see Section 6.15.1.2).

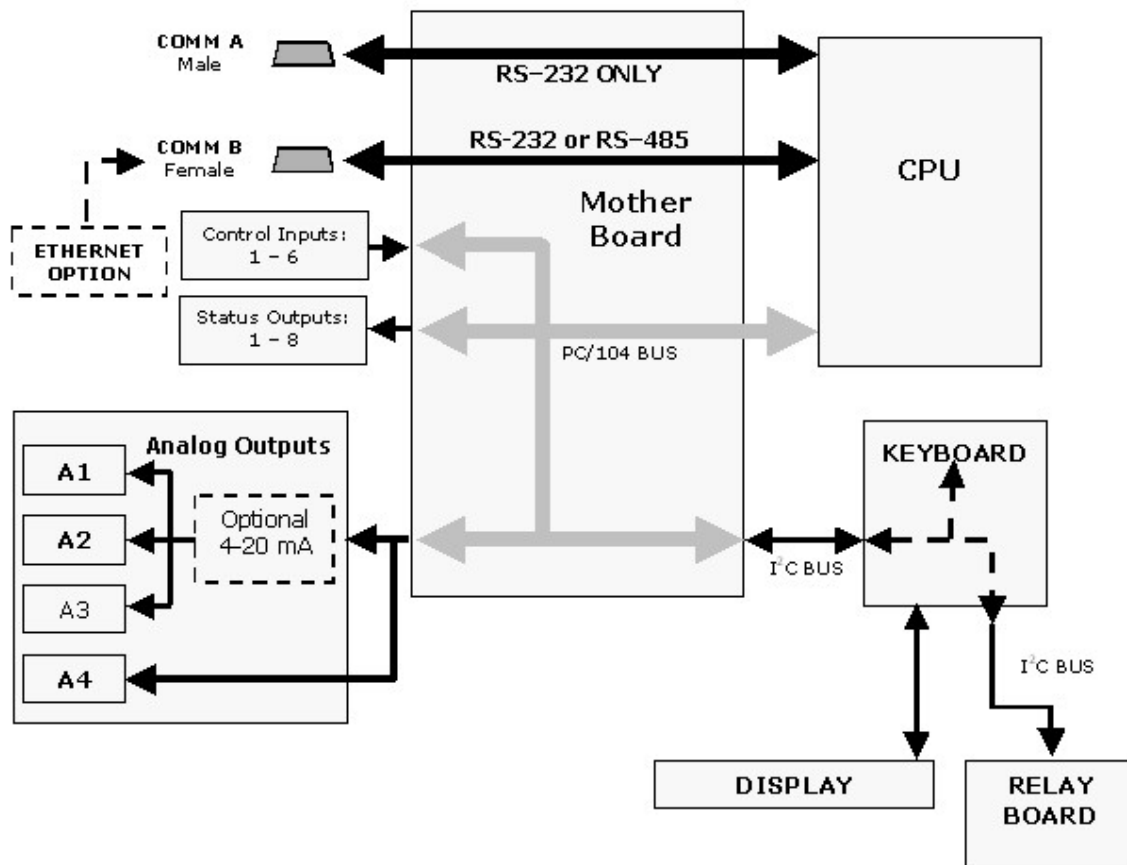


Figure 10-26: Interface Block Diagram

10.6.1. FRONT PANEL INTERFACE

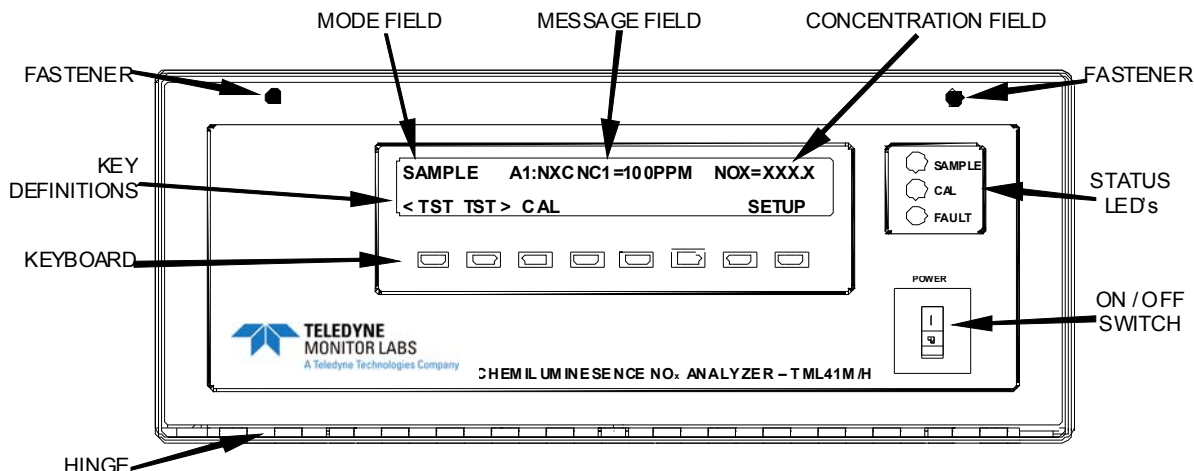


Figure 10-27: TML41M/H Front Panel Layout

The most commonly used method for communicating with the TML41M/H UV Chemiluminescence NO_x Analyzer is via the instrument’s front panel which includes a set of three status LEDs, a vacuum florescent display and a keyboard with 8 context sensitive keys.

10.6.1.1. Analyzer Status LED’s

Three LEDS are used to inform the user of the instrument’s basic operating status

Table 10-6: Front Panel Status LED’s

NAME	COLOR	STATE	DEFINITION
SAMPLE	Green	Off	Unit is not operating in sample mode, iDAS is disabled.
		On	Sample Mode active; Front Panel Display being updated, iDAS data being stored.
		Blinking	Unit is operating in sample mode, front panel display being updated, iDAS hold-off mode is ON, iDAS disabled
CAL	Yellow	Off	Auto Cal disabled
		On	Auto Cal enabled
		Blinking	Unit is in calibration mode
FAULT	Red	Off	No warnings exist
		Blinking	Warnings exist

10.6.1.2. Keyboard

A row of eight keys just below the vacuum fluoresce display (see Figure 10-27) is the main method by which the user interacts with the analyzer. As the software is operated, labels appear on the bottom row of the display directly above each active key, defining the function of that key as it is relevant for the operation being performed. Pressing a key causes the associated instruction to be performed by the analyzer.

Note that the keys do not auto-repeat. In circumstances where the same key must be activated for two consecutive operations, it must be released and re-pressed.

10.6.1.3. Display

The main display of the analyzer is a vacuum florescent display with two lines of 40 text characters each. Information is organized in the following manner (see Figure 10-27):

- **MODE FIELD:** Displays the name of the analyzer's current operating mode.
- **MESSAGE FIELD:** Displays a variety of informational messages such as warning messages, operation data and response messages during interactive tasks.
- **CONCENTRATION FIELD:** Displays the actual concentration of the sample gas currently being measured by the analyzer
- **KEYPAD DEFINITION FIELD:** Displays the definitions for the row of keys just below the display. These definitions are dynamic, context sensitive and software driven.

10.6.1.4. Keyboard/Display Interface Electronics

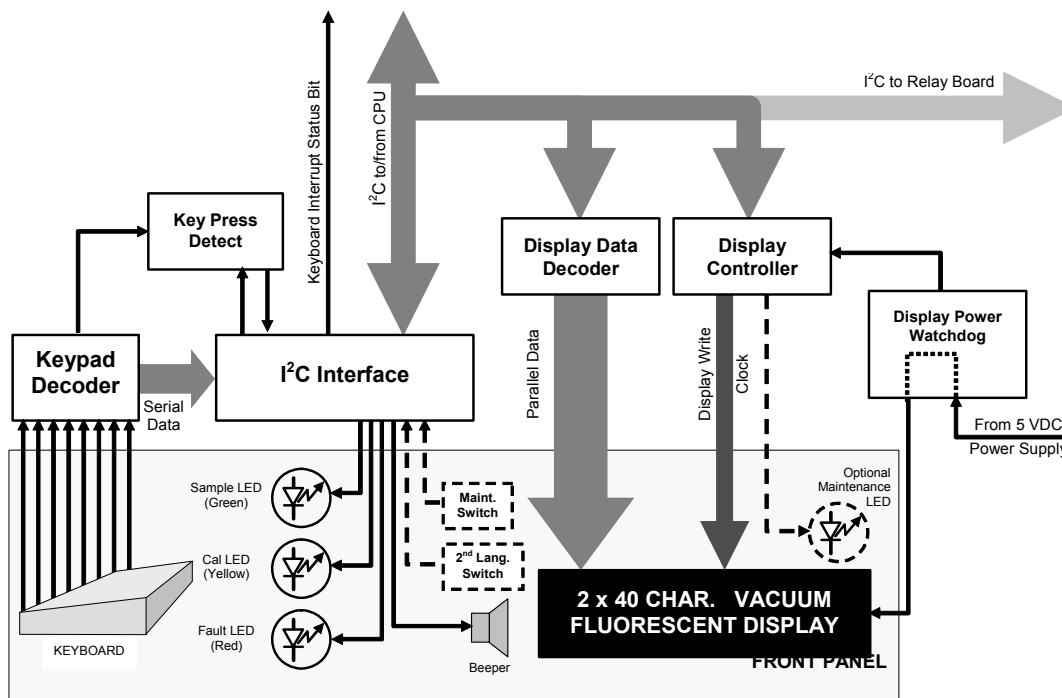


Figure 10-28: Keyboard and Display Interface Block Diagram

The keyboard/display interface electronics of the TML41M/H Analyzer watches the status of the eight front panel keys, alerts the CPU when keys are depressed, translates data from parallel to serial and back, and manages communications between the keyboard, the CPU and the front panel display. Except for the keyboard interrupt status bit, all communication between the CPU and the keyboard/display is handled by way of the instrument's I²C buss. The CPU controls the clock signal and determines when the various devices on the bus are allowed to talk or required to listen. Data packets are labeled with addresses that identify for which device the information is intended.

KEYPAD DECODER

Each key on the front panel communicates with a decoder IC via a separate analog line. When a key is depressed the decoder chip notices the change of state of the associated signal, latches and holds the state of all eight lines (in effect creating an 8-bit data word), alerts the key-depress-detect circuit (a flip-flop IC) translates the 8-bit word into serial data and sends this to the I²C interface chip.

KEY-DEPRESS-DETECT CIRCUIT

This circuit flips the state of one of the inputs to the I²C interface chip causing it to send an interrupt signal to the CPU

I²C INTERFACE CHIP

- This IC performs several functions:
- Using a dedicated digital status bit, it sends an interrupt signal alerting the CPU that new data from the keyboard is ready to send.
- Upon acknowledgement by the CPU that it has received the new keyboard data, the I²C interface chip resets the key-depress-detect flip-flop.
- In response to commands from the CPU, it turns the front panel status LEDs on and off and activates the beeper.
- Informs the CPU when the optional maintenance and second language switches have been opened or closed (see Chapter 5 for information on these options).

DISPLAY DATA DECODER

This decoder translates the serial data sent by the CPU (in TTY format) into a bitmapped image which is sent over a parallel data bus to the display.

DISPLAY CONTROLLER

This circuit manages the interactions between the display data decoder and the display itself. It generates a clock pulse that keeps the two devices synchronized. It can also, in response to commands from the CPU, turn off and/or reset the display.

Additionally, for analyzers with the optional maintenance switch installed (See Chapter 5), the display controller turns on an LED located on the back of the keyboard interface PCA whenever the instrument is placed in maintenance mode.

DISPLAY POWER WATCHDOG

The TML41M/H's display can begin to show garbled information or lock-up if the DC voltage supplied to it falls too low, even momentarily. To alleviate this, a brown-out watchdog circuit monitors the level of the power supply and in the event that the voltage level falls below a certain level resets the display by turning it off, then back on.

I²C LINK TO THE RELAY PCA

While the CPU's I²C communication with the relay board is also routed through the keyboard/display interface, information passed to and from the relay board via this channel is not recognized by, acted upon or affected by the circuitry of the keyboard.

10.7. SOFTWARE OPERATION

The TML41M/H NO_x analyzer's core module is a high performance, 386-based microcomputer running a version of DOS. On top of the DOS shell, special software developed by Teledyne Instruments interprets user commands from various interfaces, performs procedures and tasks, stores data in the CPU's memory devices and calculates the concentrations of NO_x in the sample gas. Figure 10-29 shows a block diagram of this software functionality.

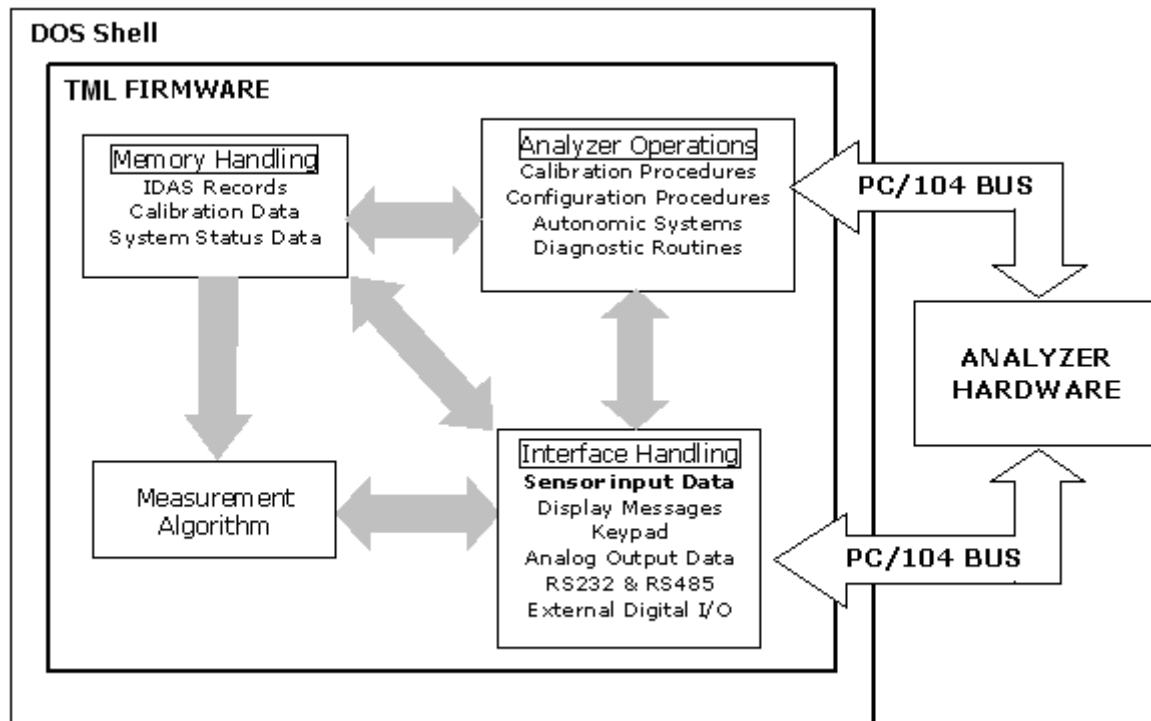


Figure 10-29: Schematic of Basic Software Operation

10.7.1. ADAPTIVE FILTER

The TML41M/H NO_x 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 TML41M/H averages over a defined number of samples, with samples being about 8 seconds apart (reflecting the switching time of 4 seconds each for NO and NO_x). This technique is known as boxcar filtering. During operation, the software may automatically switch between two different filter 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.

If necessary, these boxcar filter lengths can be changed between 1 (no averaging) and 1000 samples but with corresponding tradeoffs in rise time and signal-to-noise ratio. Signal noise increases accordingly when in adaptive filter mode, but remains within the official TML41M/H specifications as long as the filter size remains at or above 3 samples.

In order to avoid frequent switching between the two filter sizes, the analyzer has a delay of 120 seconds before switching out of adaptive filter mode, even if the two threshold conditions are no longer met.

Note that the filter settings are NO_x only or NO only

10.7.2. CALIBRATION - SLOPE AND OFFSET

Aside from the hardware calibration of the preamplifier board (Section 11.6.5) upon factory checkout, calibration of the analyzer is usually performed in software. During instrument calibration (Chapters 7) the user enters expected values for span gas concentration through the front panel keypad and supplies the instrument with sample gas of known NO and NO_x concentrations. The readings are then compared to the expected values and the software computes values for the new instrument slope and offset for both NO and NO_x response. These values are stored in memory for use in calculating the NO, NO_x and NO₂ concentrations of the sample gas. By default, the iDAS stores 200 software calibration settings for documentation, review and data analysis.

Instrument slope and offset values recorded during the last calibration can be viewed on the front panel. **NO SLOPE, NOX SLOPE, NO OFFS, and NOX OFFS** are four of the test parameters accessible through the <TST TST> buttons.

10.7.3. TEMPERATURE/PRESSURE COMPENSATION (TPC)

The software features a compensation of some temperature and pressure changes critical in the measurement of NO and NO_x concentration. 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**. **TP_FACTOR** is calculated according to the following equation.

$$TP_FACTOR = A \left[\frac{RCELLTEMP(K)}{323(K)} \right] \times B \left[\frac{7(\text{in Hg})}{RCEL(\text{in Hg})} \right] \times C \left[\frac{SAMP(\text{in Hg})}{29.92(\text{in Hg})} \right] \times D \left[\frac{BOXTEMP(K)}{298(K)} \right]$$

(Equation 10-5)

Where A, B, C, D are gain functions. The four parameters used to compute TP_FACTOR are:

- **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.
- **BOX TEMP**: The temperature inside the analyzer's case measured in K. This is typically about 5 K higher than room temperature.

The current value of all four of these measurements is viewable as **TEST FUNCTIONS** through the instrument's front panel display.

Note that, as **RCEL TEMP**, **BOX TEMP** and **SAMP** pressure increase, the value of **TP_FACTOR** increases and, hence, the **PMTDET** value decreases. Conversely, increases in the reaction cell pressure (**RCEL**) decrease **TP_FACTOR** and, hence increase the **PMTDET** value. These adjustments are meant to counter-act changes in the concentrations caused by these parameters.

Each of the terms in the above equation is attenuated by a gain function with a numerical value based on a preset gain parameter (shown below in *CMLTALIZED ITALICS*) normalized to the current value of the parameter being attenuated. The gain functions A, B, C and D are defined as:

$$A = 1 + \left[\left(\frac{rcell_temp(K)}{323(K)} - 1 \right) \times RCTEMP_TPC_GAIN \right]$$

(Equation 10-6)

$$B = 1 + \left[\left(\frac{5(\text{in Hg})}{rcell_pressure(\text{in Hg})} - 1 \right) \times RCPRESS_TPC_GAIN \right]$$

(Equation 10-7)

$$C = 1 + \left[\left(\frac{rcell_temp(K)}{323(K)} - 1 \right) \times SPRESS_TPC_GAIN \right]$$

(Equation 10-8)

$$D = 1 + \left[\left(\frac{box_temp(K)}{298(K)} - 1 \right) \times BXTEMP_TPC_GAIN \right]$$

(Equation 10-9)

The preset gain parameters are set at the factory and may vary from analyzer to analyzer. Section 6.12 describes the method for enabling/disabling the TPC feature.

10.7.4. NO₂ CONVERTER EFFICIENCY COMPENSATION

Over time, the molybdenum in the NO₂ converter oxidizes and loses its original capacity of converting NO₂ into NO, eventually resulting in decreased converter efficiency (CE). Even though we recommend replacing the converter if CE drops below 96%, the analyzer's firmware allows adjusting minor deviations of the CE from 1.000 and enables reporting the true concentrations of NO₂ and NO_x. Converter efficiency is stored in the instrument's memory as a decimal fraction that is multiplied with the NO₂ and NO_x measurements to calculate the final concentrations for each. Periodically, this efficiency factor must be measured and - if it has changed from previous measurements - entered into the analyzer's memory (Section 7.1.5).

10.7.5. INTERNAL DATA ACQUISITION SYSTEM (IDAS)

The iDAS is designed to implement predictive diagnostics that store trending data for users to anticipate when an instrument will require service. Large amounts of data can be stored in non-volatile memory and retrieved in plain text format for further processing with common data analysis programs. The iDAS has a consistent user interface among all Teledyne Instruments A- and E-series instruments. New data parameters and triggering events can be added to the instrument as needed. Section 6.7 describes the iDAS and its default configuration in detail, Chapter 8 shows the parameters that can be used for predictive diagnostics.

Depending on the sampling frequency and the number of data parameters, the iDAS can store several months of data, which are retained even when the instrument is powered off. However, if new firmware or a new iDAS configuration is uploaded to the analyzer, we recommend retrieving data before doing so to avoid data loss. The iDAS permits users to access the data through the instrument's front panel or the remote interface. The latter can automatically report stored data for further processing. sensor-e.com, a user-friendly remote control program is the most convenient way to view, retrieve, and store iDAS data (Section 6.15.2.8)

USER NOTES:

USER NOTES:

11. TROUBLESHOOTING & REPAIR

This section contains a variety of methods for identifying and solving performance problems with the analyzer.



NOTE

The operations outlined in this chapter must be performed by qualified maintenance personnel only.



CAUTION

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 shorten or touch electric connections with metallic tools while operating inside the analyzer. Use common sense when operating inside a running analyzer.

11.1. GENERAL TROUBLESHOOTING

The analyzer has been designed so that problems can be rapidly detected, evaluated, and repaired. During operation, the analyzer 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:

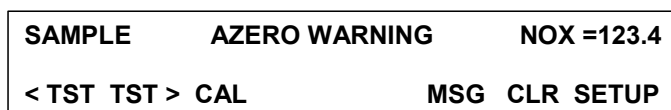
- Note any warning messages and take corrective action as necessary.
- Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
- Use the internal electronic status LED's to determine whether the electronic communication channels are operating properly. Verify that the DC power supplies are operating properly by checking the voltage test points on the relay board. 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 board.
- Suspect a leak first! Customer service data indicate that the majority of all problems are eventually traced to leaks in the pneumatic system of the analyzer (including the external pump), the source of zero air or span gases or the sample gas delivery system. Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged pump diaphragm, etc.
- Follow the procedures defined in Section 11.5 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay board, keyboard, PMT cooler, etc.). See Figure 3-1, Figure 3-2, and Figure 3-3 for general layout of components and sub-assemblies in the analyzer. See the wiring interconnect diagram (document 04504) and interconnect list (document 04496) in Appendix D.

11.1.1. WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message displayed on the front panel. Table A-2 in Appendix A.3 contains a list of 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 analyzer sub-system (power supply, relay board, motherboard) has failed rather than an indication of the specific failures referenced by the warnings. In this case, a combined-error analysis needs to be performed.

The analyzer will alert the user that a warning is active by displaying the keypad labels **MSG** and **CLR** on the front panel and a text message in the top center line of the display as shown in this example:



The analyzer will also issue a message to the serial port and cause the red FAULT LED on the front panel to blink.

To view or clear a warning messages press:

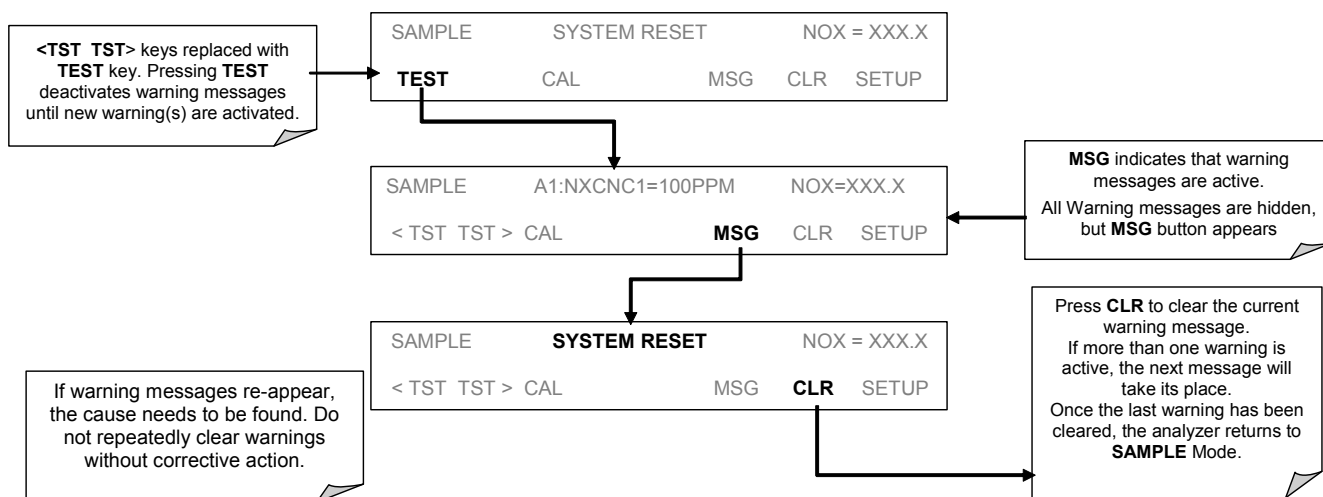


Figure 11-1: Viewing and Clearing Warning Messages

11.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the TEST functions, viewable from the front panel, can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer's theory of operation (Chapter 10). We recommend using the sensor-e.com remote control program to download, graph and archive TEST data for analysis and long-term monitoring of diagnostic data (Section 6.15.2.8).

The acceptable ranges for these test functions are listed in Appendix A-3. The actual values for these test functions on checkout at the factory were also listed in the *Final Test and Validation Data Sheet*, which was shipped with the instrument. Values outside the acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions with values that are within the acceptable range but have significantly changed from the measurements recorded on the factory data sheet may also indicate a failure or a

maintenance item. A problem report worksheet has been provided in Appendix C to assist in recording the value of these test functions. The following table contains some of the more common causes for these values to be out of range.

Table 11-1: Test Functions - Possible Causes for Out-Of-Range Values

TEST FUNCTION	INDICATED FAILURE(S)
NOX STB	Unstable concentrations; leaks
SAMPLE FL	Leaks; clogged critical flow orifice
OZONE FL	Leaks; clogged critical flow orifice
PMT	Calibration off; HVPS problem; no flow (leaks)
NORM PMT	AutoZero too high
AZERO	Leaks; malfunctioning NO/NOx or AutoZero valve; O ₃ air filter cartridge exhausted
HVPS	HVPS broken; calibration off; preamp board circuit problems
RCELL TEMP	Malfunctioning heater; relay board communication (I ² 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 ² C bus); 12 V power supply
IZS TEMP (OPTION)	Malfunctioning heater; relay board communication (I ² C bus); relay burnt out
MOLY TEMP	Malfunctioning heater; disconnected or broken thermocouple; relay board communication (I ² 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 overpressure;
NOX SLOPE	HVPS out of range; low-level (hardware) calibration needs adjustment; span gas concentration incorrect; leaks
NOX OFF	Incorrect span gas concentration; low-level calibration off
NO SLOPE	HVPS out of range; low-level calibration off; span gas concentration incorrect; leaks
NO OFFS	Incorrect span gas concentration; low-level calibration off
TIME OF DAY	Internal clock drifting; move across time zones; daylight savings time?

11.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The signal I/O parameters found under the diagnostics (DIAG) menu combined with a thorough understanding of the instrument's theory of operation (Chapter 10) are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.
- All of the components and functions that are normally under instrument control can be manually changed.
- Analog and digital output signals can be manually controlled.

This allows to systematically observing the effect of these functions on the operation of the analyzer. Figure 11-2 shows 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. The specific parameter will vary depending on the situation.

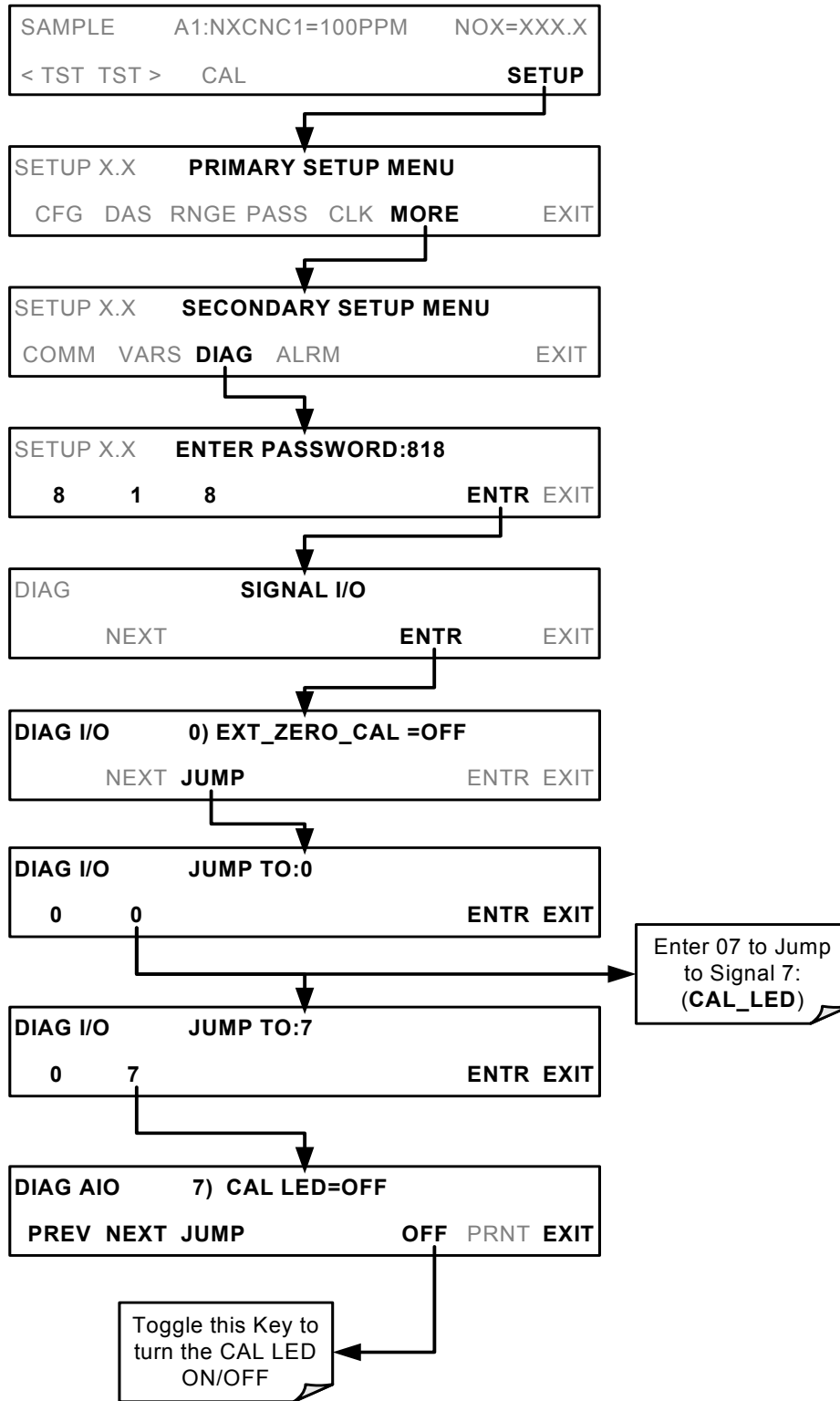


Figure 11-2: Switching Signal I/O Functions

11.1.4. STATUS LED'S

Several color-coded, light-emitting diodes (LED) are located inside the instrument to determine if the analyzer's CPU, I²C communications bus and the relay board are functioning properly.

11.1.4.1. Motherboard Status Indicator (Watchdog)

A red LED labeled DS5 in the upper portion of the motherboard (Figure 11-3), just to the right of the CPU board, flashes when the CPU is running the main program. After power-up, DS5 should flash on and off about once per second. If characters are visible on the front panel display but DS5 does not flash then the program files have become corrupted. Contact customer service because it may be possible to recover operation of the analyzer. If 30 - 60 seconds after a restart, neither DS5 is flashing nor any characters are visible on the front panel display, the firmware may be corrupted or the CPU may be defective. If DS5 is permanently off or permanently on, the CPU board is likely locked up and the analyzer should not respond (either with locked-up or dark front panel).

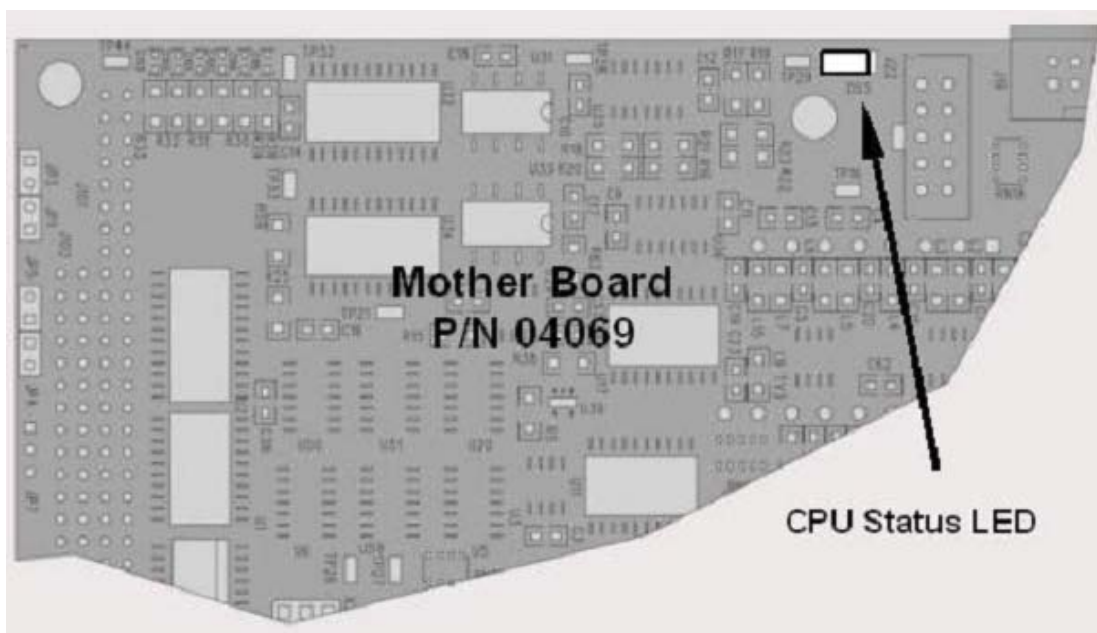


Figure 11-3: Motherboard Watchdog Status Indicator

11.1.4.2. CPU Status Indicator

The CPU board has two red LEDs, the lower of which is the watchdog timer (the device that pulses the motherboard watchdog). This LED is labeled **LED2** and blinks about twice per second (twice as fast as the motherboard LED) when operating normally. LED1 above LED2 should always be on. However, both CPU LEDs only indicate if the CPU is powered up properly and generally working. The lower LED can continue to blink even if the CPU or firmware is locked up.

11.1.4.3. Relay Board and Status LEDs

The most important status LED on the relay board is the red I²C Bus watch-dog LED, labeled **D1**, which indicates the health of the I²C communications bus. This LED is the left-most in LED row 1 in the center of the relay board when looking at the electronic components. If **D1** is blinking, then the other LEDs can be used in

conjunction with the **DIAG** menu I/O functions to test hardware functionality by manually switching devices on and off and watching the corresponding LED go on or off.

Figure 11-4 illustrates the relay board layout including the two rows of LEDs,

Table 11-2 lists the individual LED functions and the menu tree below shows how to access the manual control of the I/O functions. Note that only some of the LEDs may be functional in your analyzer model; the relay board layout is conceptualized for spare, future functionality and is also common to many of the E-series analyzers.

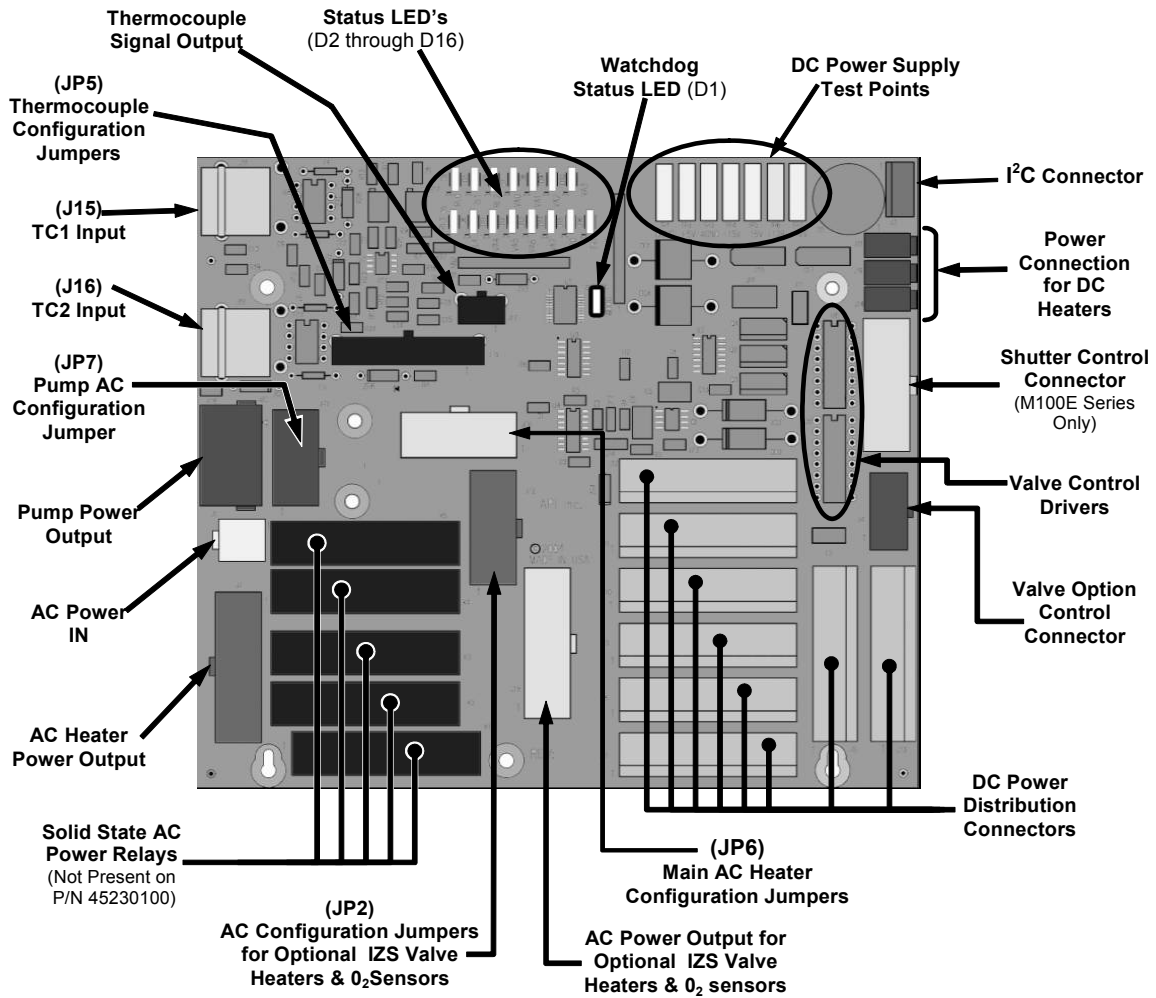


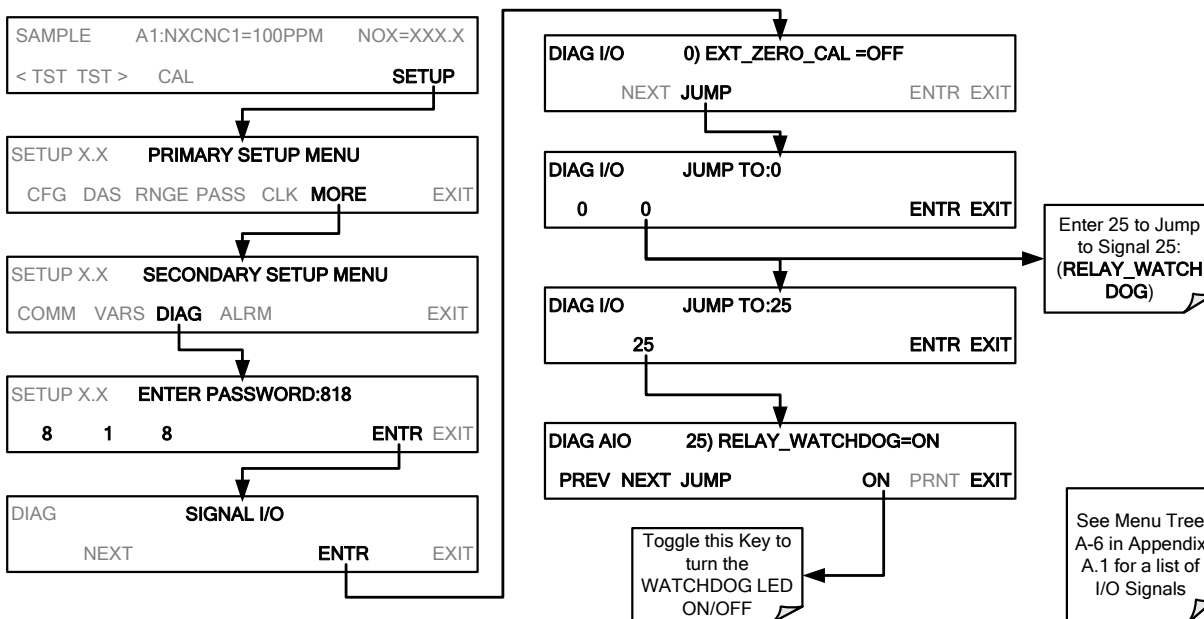
Figure 11-4: Relay Board PCA

Table 11-2: Relay Board Status LEDs

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
LED ROW 1				
D1	Red	Watchdog Circuit; I ² C bus operation.	Continuously ON or OFF	Failed or halted CPU; faulty motherboard, keyboard, relay board; wiring between motherboard, keyboard or relay board; +5 V power supply
D2	Yellow	Relay 0 - reaction cell heater	Continuously ON or OFF	Heater broken, thermistor broken
D3	Yellow	Relay 1 - NO ₂ converter heater	Continuously ON or OFF	Heater broken, thermocouple broken
D4	Yellow	Relay 2 - manifold heater	Continuously ON or OFF	Heater broken, thermistor broken
D7 ¹	Green	Valve 0 - zero/span valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D8 ¹	Green	Valve 1 - sample/cal valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D9	Green	Valve 2 - auto-zero valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D10	Green	Valve 3 - NO/NO _x valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
LED ROW 2				
D5	Yellow	Relay 3 - IZS heater	Continuously ON or OFF	Heater broken, thermistor broken
D6	Yellow	Relay 4 – (O ₂ sensor heater TML41M/H)	N/A	N/A
D11- 16	Green	Spare	N/A	N/A

¹ Only active for instruments with Z/S valve options installed

To enter the signal I/O test mode to manually control I/O functions such as valves and heaters, press the following keys while observing the relay board LEDs when toggling:



11.2. GAS FLOW PROBLEMS

The TML41M/H 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 iDAS. The full flow diagrams of the standard configuration and with options installed (Appendix D) help in troubleshooting flow problems. In general, flow problems can be divided into three categories:

- 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 6.13.7.5 is essential.

The flow diagrams found in a variety of locations within this manual depicting the TML41H and TML41M in their standard configuration and with options installed can help in troubleshooting flow problems. For your convenience they are shown in Sections 11.2.1 (TML41H) and 11.2.2 (TML41M)

11.2.1. TML41H INTERNAL GAS FLOW DIAGRAMS

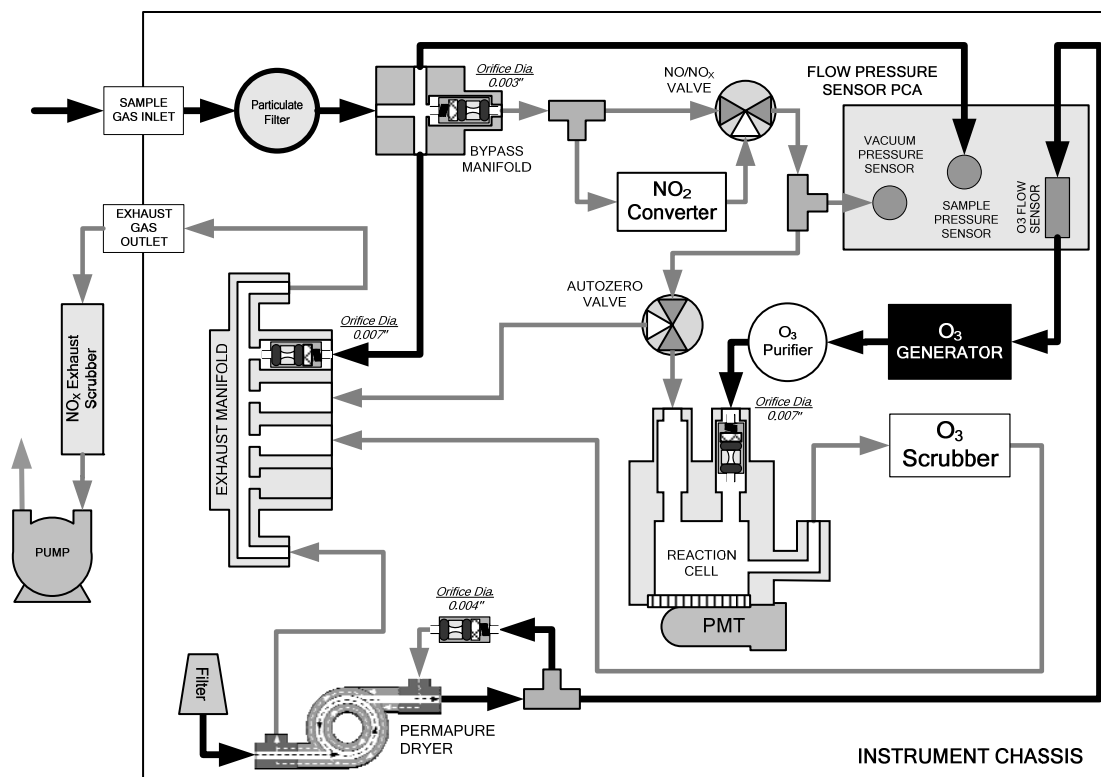


Figure 11-5: TML41H – Basic Internal Gas Flow

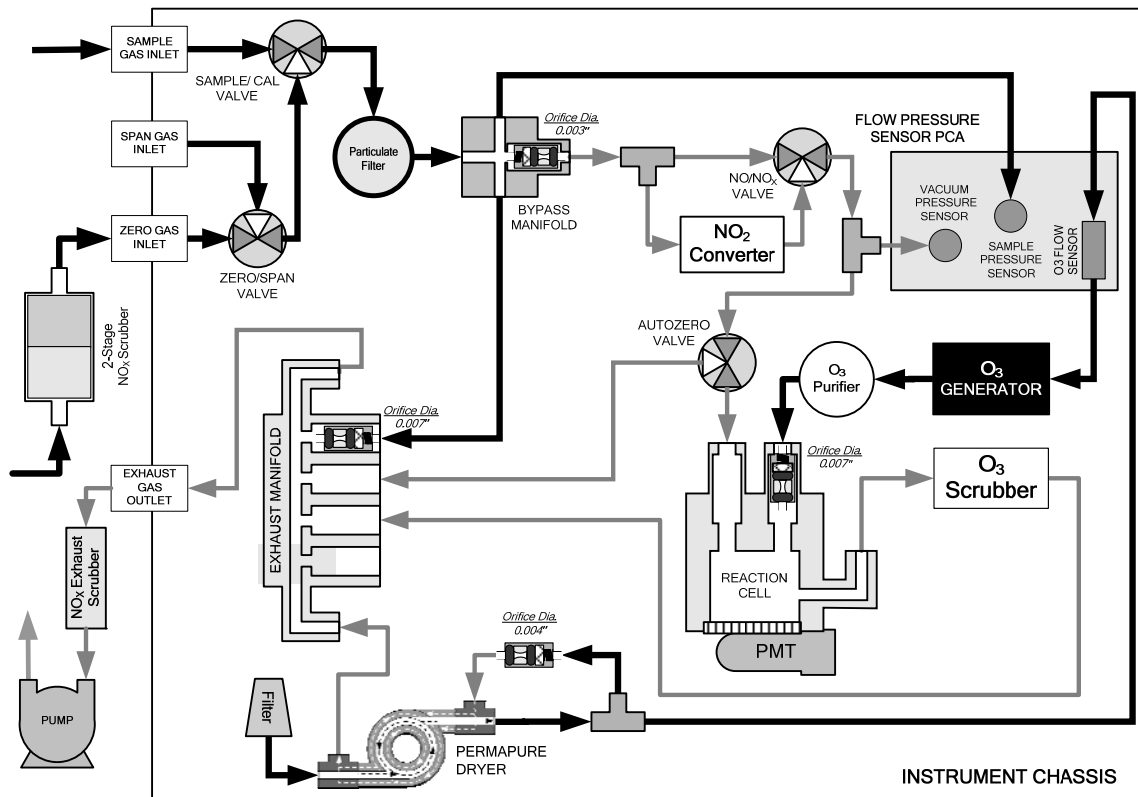


Figure 11-6: TML41H – Internal Gas Flow With OPT 50

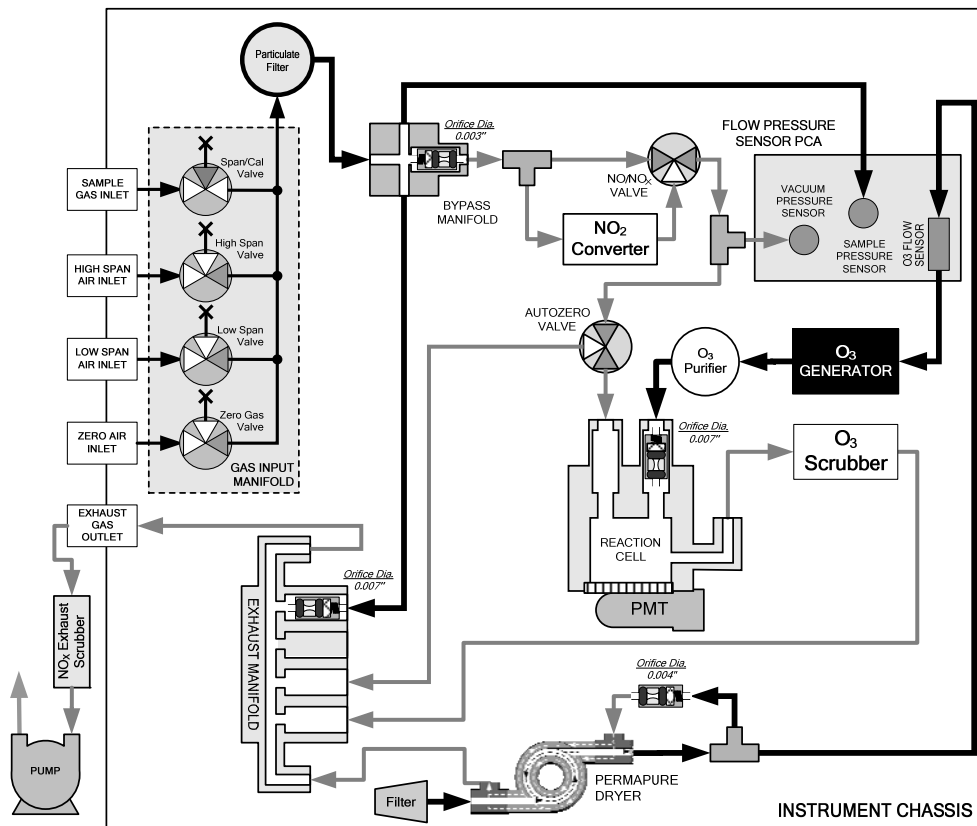


Figure 11-7: TML41H – Internal Gas Flow With OPT 52

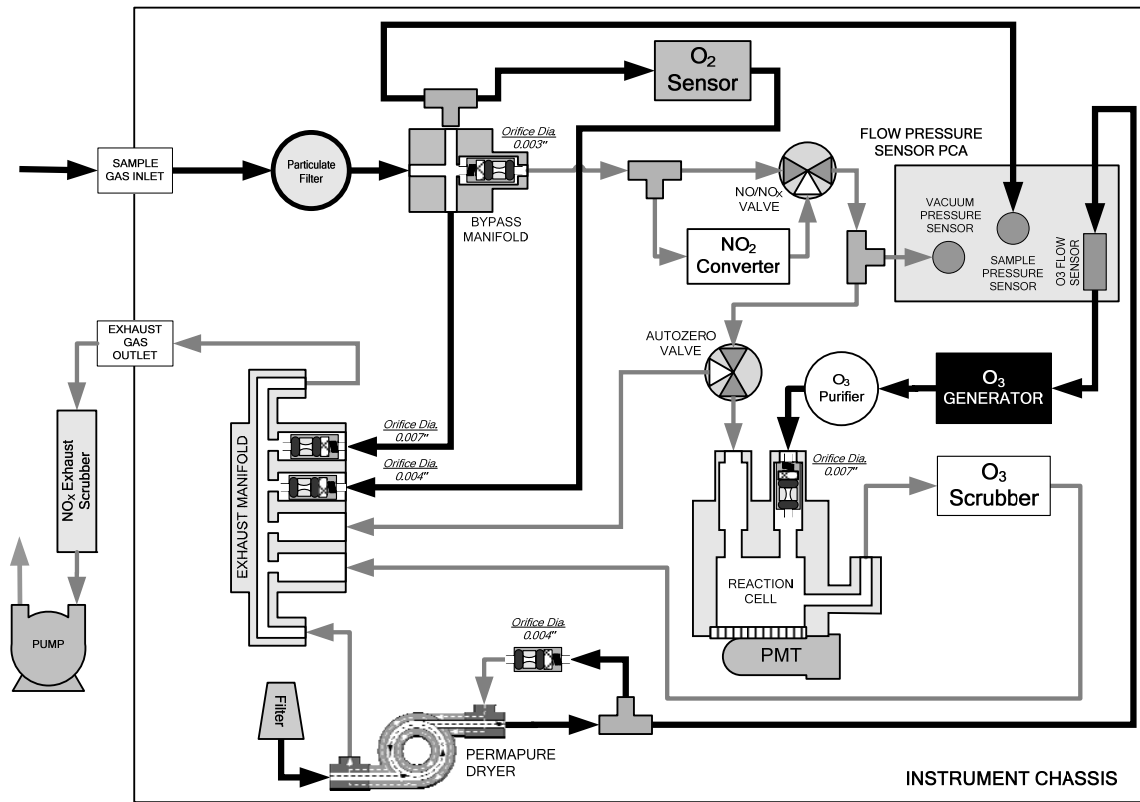


Figure 11-8: TML41H – Internal Gas Flow With OPT 65

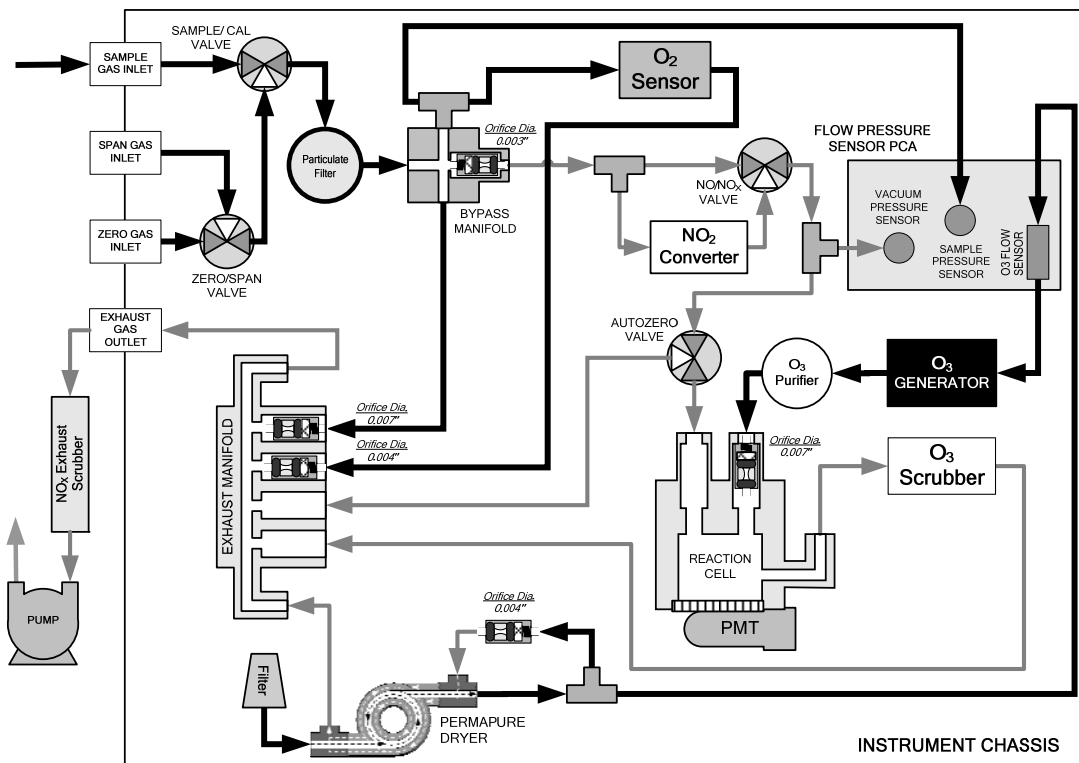


Figure 11-9: TML41H – Internal Gas Flow With OPT 50 + OPT 65

11.2.2. TML41M INTERNAL GAS FLOW DIAGRAMS

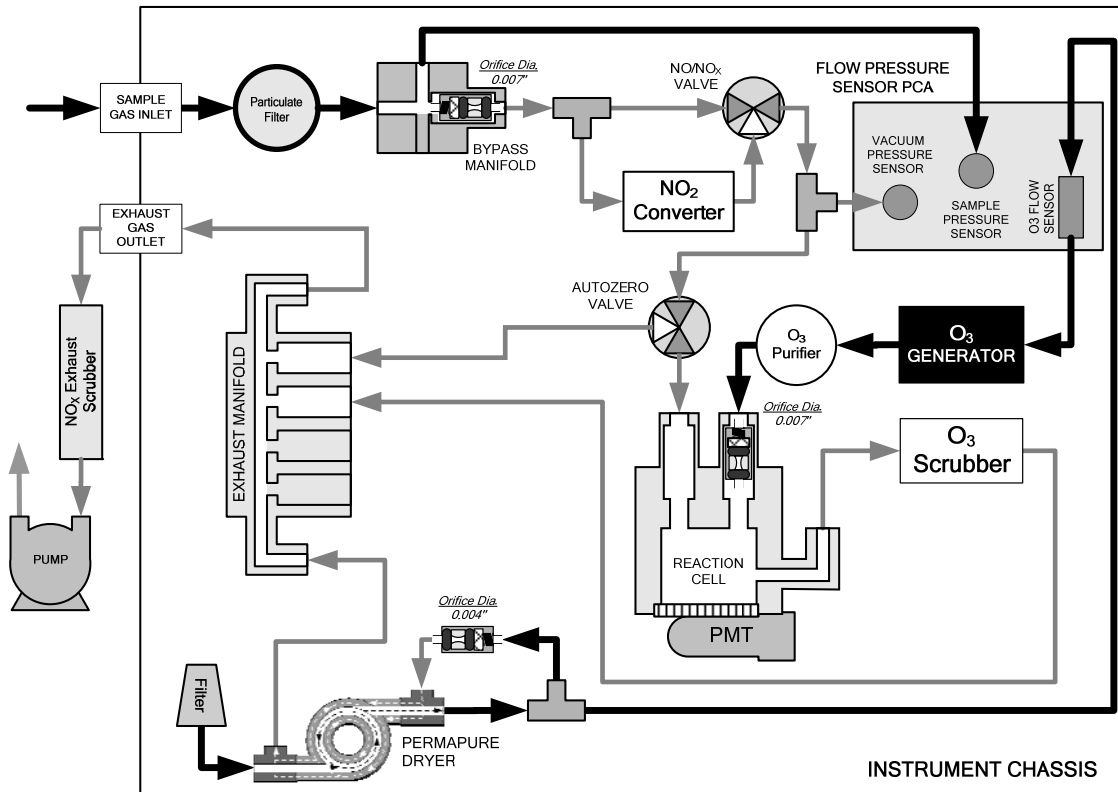


Figure 11-10: TML41M – Basic Internal Gas Flow

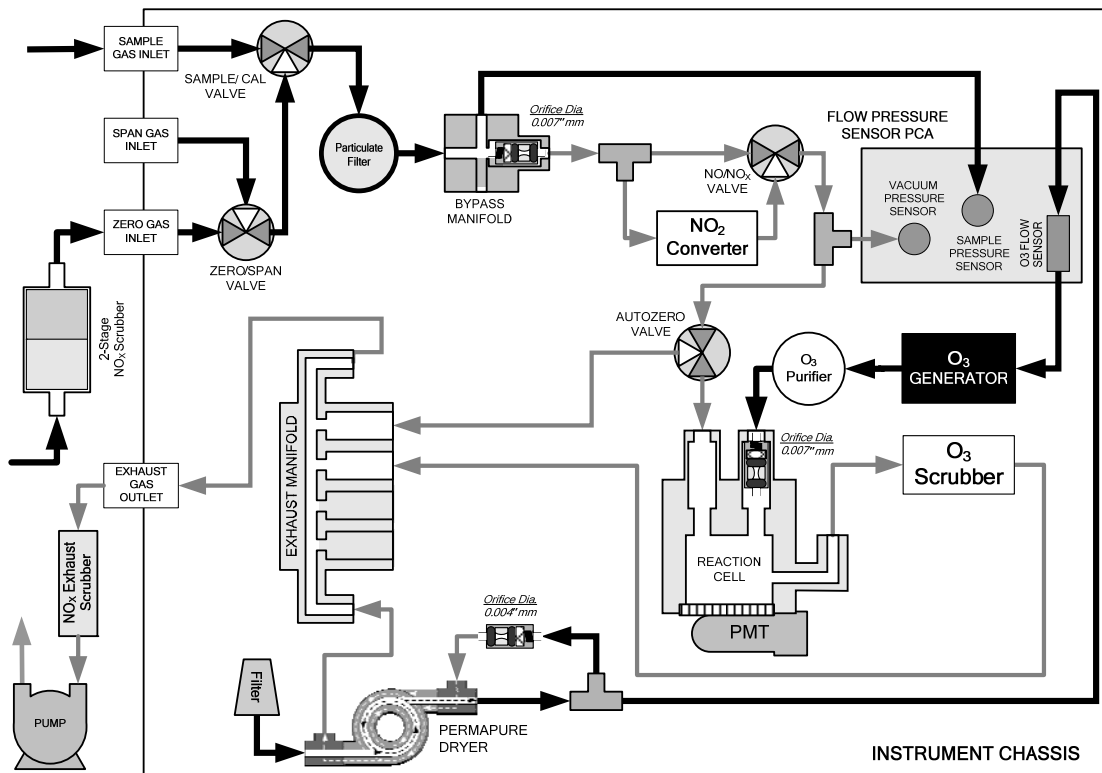


Figure 11-11: TML41M – Internal Gas Flow With OPT 50

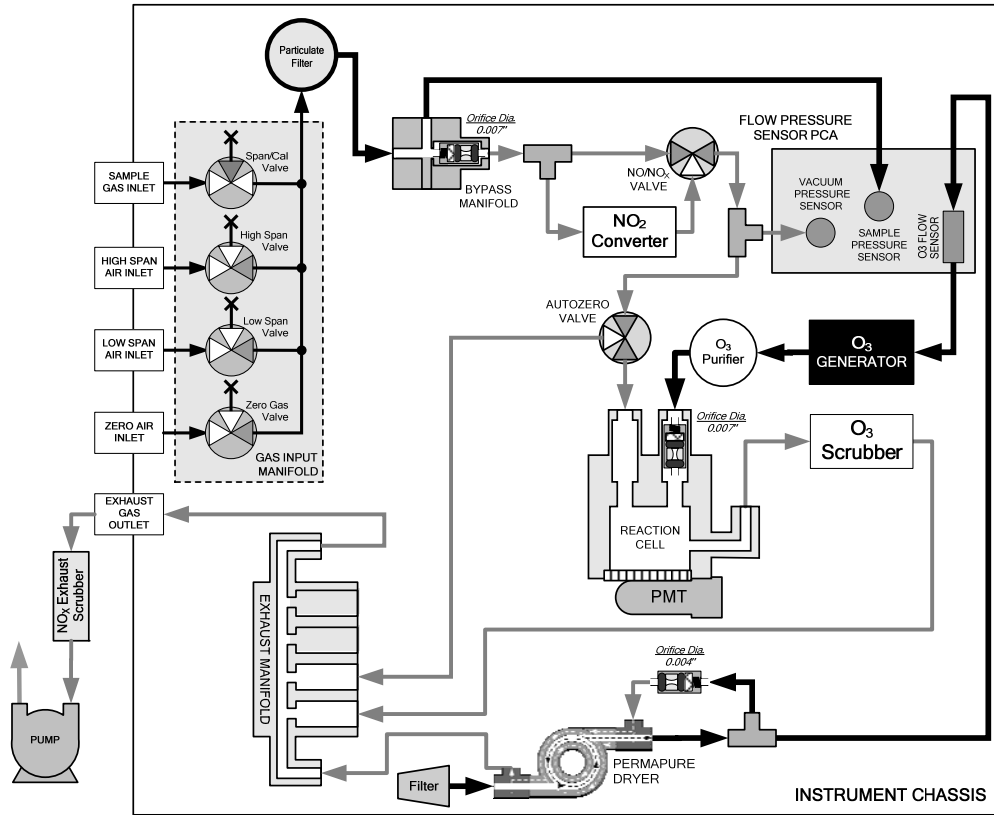


Figure 11-12: TML41M – Internal Gas Flow With OPT 52

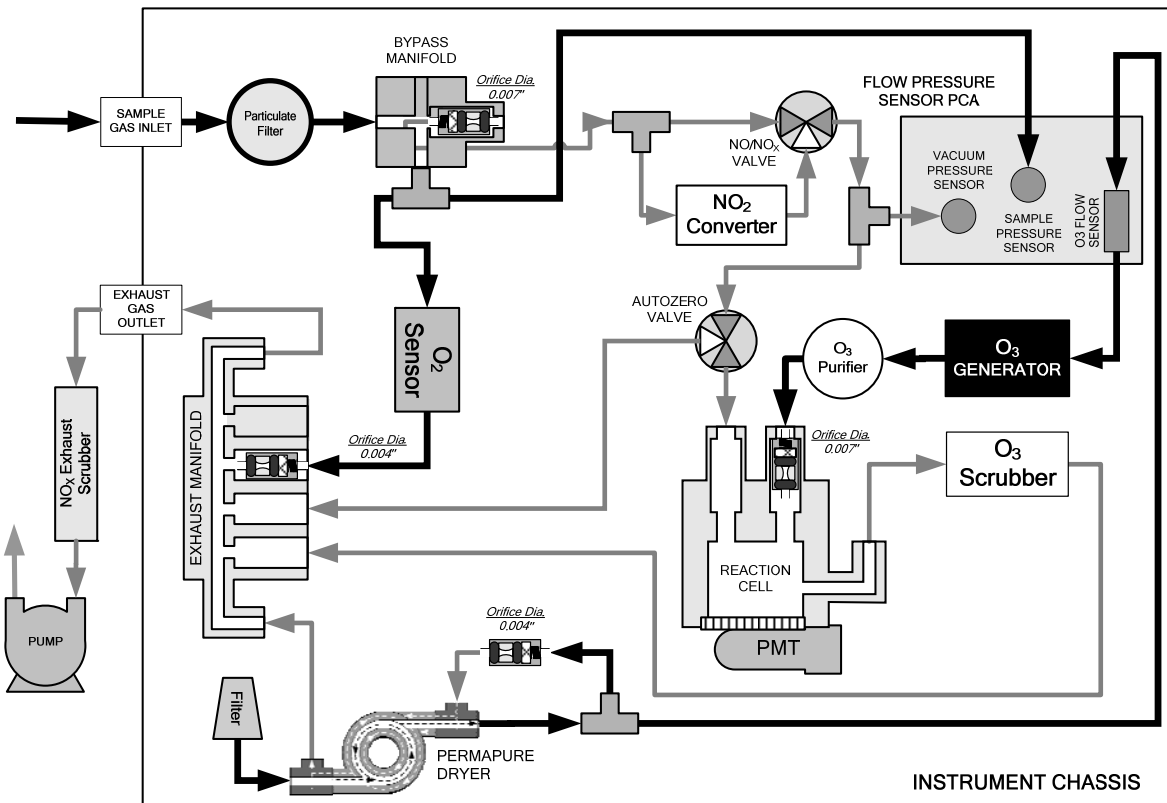


Figure 11-13: TML41M – Internal Gas Flow With OPT 65

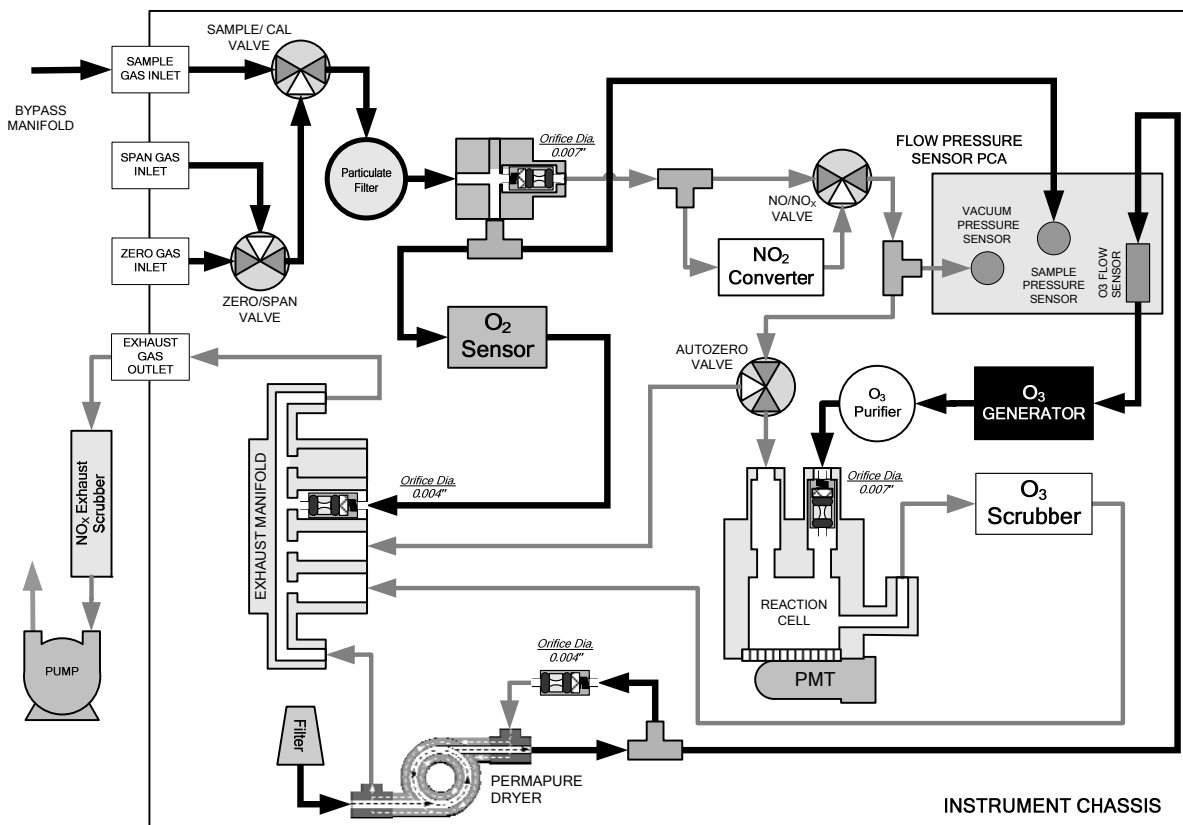


Figure 11-14: TML41M – Internal Gas Flow With OPT 50 + OPT 65

11.2.3. ZERO OR LOW FLOW PROBLEMS

11.2.3.1. Sample Flow is Zero or Low

The TML41M/H 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 (200-600 cm³/min; 300-700 cm³/min with O₂ option installed).

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 TML41M/H 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 make sure 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, do the following steps:

- 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. Make sure 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 (see Table 10-3 for flow rates), contact customer service. If there is no flow or low flow, continue with the next step.
- 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 TML41M/H 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 Perma Pure dryer flow paths. See troubleshooting the Perma Pure 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 11.5.1
- 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.
- If none of these suggestions help, carry out a detailed leak check of the analyzer as described in Section 11.5.2.

11.2.3.2. Ozone Flow is Zero or Low

If there is zero or a low (<200 cm³/min) ozone flow, the unit displays an **OZONE FLOW WARNING** message on the front panel and a value between 0.0 and 200 cm³/min for the actual ozone flow as measured by the internal mass flow meter. In this case, carry out the following steps:

- 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 9.3.2 for illustration). If there is nominal flow (see Table 10-3 for flow rates), consult customer service as there is a problem with the firmware or electronics.
- 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 9.3.4). Check the spare parts list in Appendix B on how to order pump rebuild kits.
- Check if the particle filter is clogged. **Briefly** remove the particle filter to see if this improves the flow. Be very cautious about handling the Perma Pure dryer fittings - refer to Section 9.3.2 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 Perma Pure dryer without filter for more than a few seconds, as you may draw in dust, which will reduce the performance of the dryer.

- 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 11.5. Repair the leaking fitting, line, or valve and re-check.
- 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 (see Table 10-3 for flow rates), the orifice works properly. If this flow is low, replace or clean the orifice. The orifice holder assembly allows a quick and easy replacement of the orifice, refer to Section 9.3.8 on how to do this. Appendix B lists a spare part kit with a complete orifice assembly that allows a quick replacement with minimum instrument down-time. The clogged orifice can then be cleaned while the instrument is running with the replacement.

11.2.4. 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 TML41M/H 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 re-calibrating the flow electronically using the procedure in Section 6.13.7.5 followed by a regular review of these flows over time to see if the new setting is retained properly.

11.2.5. SAMPLE FLOW IS ZERO OR LOW BUT ANALYZER REPORTS CORRECT FLOW

Note that the TML41M/H 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 TML41M/H is only calculated from the sample pressure and critical flow condition and is verified from the difference between sample pressure and vacuum pressure. If the critical flow orifice 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 cm³/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 TML41M/H features a new orifice holder, which makes switching sample and ozone flow orifices very easy, refer to Section 9.3.8 on how to change the sample orifices and 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 Instruments recommends reviewing all test data once per week and doing 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.

11.3. CALIBRATION PROBLEMS

11.3.1. NEGATIVE CONCENTRATIONS

Negative concentration values can be caused by 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 -0.2 ppm, but should randomly alternate with similarly high, positive values. The TML41M/H 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 AutoZero 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 AutoZero readings can be caused by
 - a leaking or stuck AutoZero valve (replace the valve),
 - by an electronic fault in the preamplifier causing it to have a voltage on the PMT output pin during the AutoZero 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 TML41M/H will take 15 minutes for the filter to clear itself, or
 - by an exhausted chemical in the ozone scrubber cartridge (Section 9.3.3).
- Miscalibration is the most likely explanation for negative concentration values. If the zero air contained some NO or NO₂ 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_x. 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_x (**NOX OFFS**) are greater than 150 mV, a reaction cell contamination is indicated. Clean the reaction cell according to Section 9.3.7.

11.3.2. 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.

- 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. A more detailed description of the ozone generator subsystem checks are in Section 11.5.17.
- Confirm the lack of response by supplying NO or NO₂ span gas of about 80% of the range value to the analyzer.
- Check the sample flow and ozone flow rates for proper values.

- Check for disconnected cables to the sensor module.
- Carry out an electrical test with the **ELECTRICAL TEST** procedure in the diagnostics menu, see Section 6.13.7.3. If this test produces a concentration reading, the analyzer's electronic signal path is correct.
- Carry out an optical test using the **OPTIC TEST** procedure in the diagnostics menu, see Section 6.13.7.2. If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly. If the TML41M/H 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.
- If NO₂ signal is zero while NO signal is correct, check the NO/NO_x valve and the NO₂ converter for proper operation.

11.3.3. UNSTABLE ZERO AND SPAN

Leaks in the TML41M/H or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

- Check for leaks in the pneumatic systems as described in Section 11.5. Consider pneumatic components in the gas delivery system outside the TML41M/H 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.
- Once the instrument passes a leak check, do a flow check (this chapter) to make sure that the instrument is supplied with adequate sample and ozone air.
- Confirm the sample pressure, sample temperature, and sample flow readings are correct and steady.
- Verify that the sample filter element is clean and does not need to be replaced.

11.3.4. INABILITY TO SPAN - NO SPAN KEY

In general, the TML41M/H will not display certain keyboard choices 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 key 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.

- Verify that the expected concentration is set properly to the actual span gas concentration in the **CONC** sub-menu.
- Confirm that the NO_x span gas source is accurate. This can be done by comparing the source with another calibrated analyzer, or by having the NO_x source verified by an independent traceable photometer.
- Check for leaks in the pneumatic systems as described in Section 11.5. 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.
- 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 11.6.5 on how to carry out a low-level hardware calibration.

11.3.5. INABILITY TO ZERO - NO ZERO KEY

In general, the TML41M/H will not display certain keyboard choices 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 key when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

- 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 NO_x-free air. Check any zero air scrubber for performance. It may need to be replaced (Section 9.3.5).
- Check to make sure that there is no ambient air leaking into zero air line. Check for leaks in the pneumatic systems as described in Section 11.5.

11.3.6. NON-LINEAR RESPONSE

The TML41M/H 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 11.5.
- 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 (NO₂ 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 Perma Pure dryer for leaks. This mostly affects linearity at the low end.
- Sample inlet may be contaminated with NO_x 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. Make sure 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 NO₂ 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 NO₂. 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.

11.3.7. 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 re-calibrate 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 6.13.6 for a detailed description of this procedure.

11.3.8. DISCREPANCY BETWEEN NO AND NO_x SLOPES

If the slopes for NO and NO_x are significantly different after software calibration (more than 1%), consider the following two problems

- NO₂ impurities in the NO calibration gas. NO gases often exhibit NO₂ on the order of 1-2% of the NO value. This will cause differences in the calibration slopes. If the NO₂ impurity in NO is known, it can easily be accounted for by setting the expected values for NO and NO₂ accordingly to different values, e.g., 0.448 ppm NO and 0.45 ppm NO_x. 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 (N₂O). The oxygen in the air slowly reacts with NO to yield NO₂, increasing over time.
- The expected concentrations for NO and NO_x 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 7.2 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 7.1.5 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_x, as the instrument measures only NO_x and assumes NO to be the same (with NO₂ being zero).

11.4. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems which 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.

11.4.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself. Make sure that the sample or span gas supply is leak-free and carry out a detailed leak check as described later 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 trouble-shooting these components.

11.4.2. 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_x valve. Carry out a leak check.
- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (Section 9.3.8).

- 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 NO₂ calibration gas source to become stable. Wait until stability is low.
- NO₂ converter temperature is too low. Check for proper temperature.

11.4.3. AUTO-ZERO WARNINGS

Auto-zero warnings occur if the signal measured during an auto-zero cycle is lower than -20 mV or higher than 200 mV. 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 its nominal reading for span gas level measurements 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 that 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.

- A dirty reaction cell can cause high AutoZero values. Clean the reaction cell according to Section 9.3.7.
- 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 11.6.5 in order to minimize the **HVPS**.

11.5. 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.

11.5.1. SIMPLE VACUUM LEAK AND PUMP CHECK

Leaks are the most common cause of analyzer malfunction; this section presents a simple leak check, whereas Section 11.5.2 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.

- Turn the analyzer ON, and allow at least 30 minutes for flows to stabilize.
- Cap the sample inlet port (cap must be wrench-tight).
- 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).

11.5.2. DETAILED PRESSURE LEAK CHECK

If a leak cannot be located by the above procedure, obtain a leak checker similar to Teledyne Instruments part number 01960, which 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 ≤ 15 psi, a shutoff valve and pressure gauge may be used.

CAUTION

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or re-apply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

Do not exceed 15 psi when pressurizing the system.

- Turn OFF power to the instrument and remove the instrument cover.
- 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.
- 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 3-2). Cap the DFU particle filter on the Perma Pure dryer (Figure 9-2).

- 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 re-apply vacuum as it will draw soap solution into the instrument and contaminate it. Do not exceed 15 psi pressure.
- 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.
- If the analyzer is equipped with an IZS Option, connect the leak checker to the Dry Air inlet and check with soap bubble solution.
- 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.
- Clean surfaces from soap solution, re-connect the sample and pump lines and replace the instrument cover. Restart the analyzer.

11.5.3. PERFORMING A SAMPLE FLOW CHECK

CAUTION

Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm³/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:

- Disconnect the sample inlet tubing from the rear panel SAMPLE port shown in Figure 3-2.
- 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.
- The sample flow measured with the external flow meter should be within $\pm 10\%$ of the nominal values shown in Table 10-3.
- Low flows indicate blockage somewhere in the pneumatic pathway.

11.5.4. AC POWER CONFIGURATION

The E-Series digital electronic systems 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 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.

On the other hand, some of the analyzer's non-digital components, such as the pump and the various AC powered heaters must be properly configured for the type of power being supplied to the instrument. Figure 11-16 shows the location of the various sets of AC Configuration jumpers.

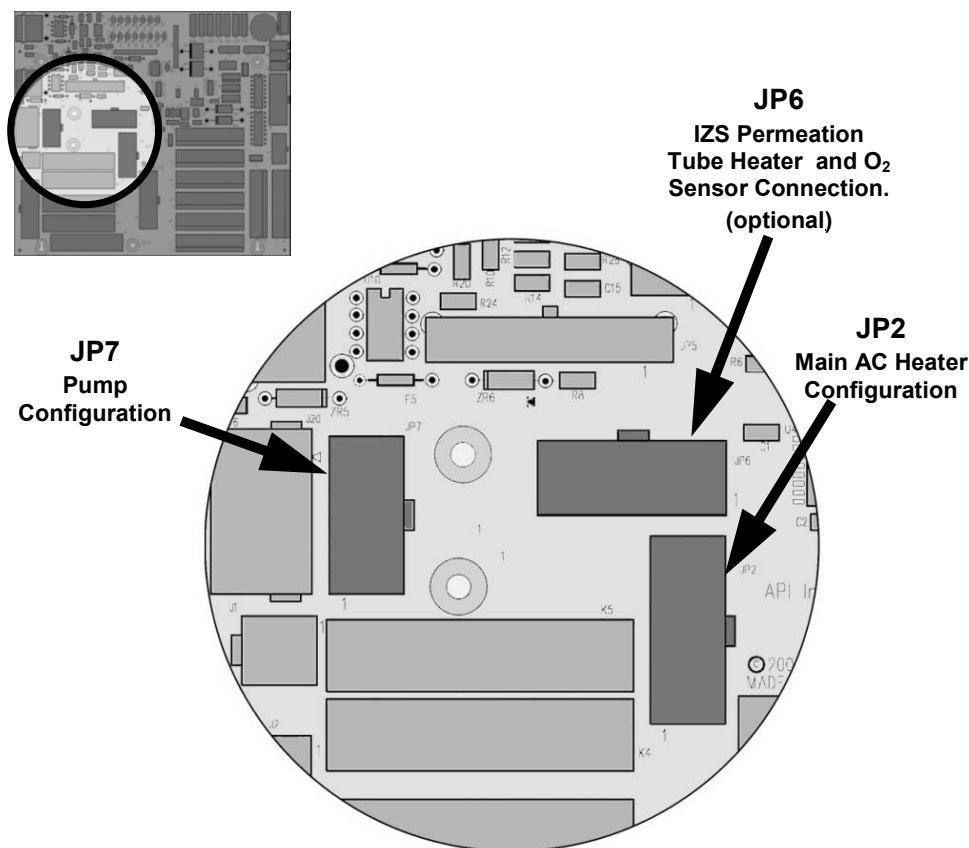


Figure 11-15: Location of AC power Configuration Jumpers

There are several changes between the **Relay PCA 04523** and previous version regarding AC power configuration and distribution.

- Previously, in analyzer models with internal pumps, the AC power for the pump came directly from the instrument back panel. The 04523 version handles all AC and DC power distribution including power to the pump.
- Prior to this change, configuring the pump for compatibility with various line voltages and frequencies was done with a set of hard-wired, in-line connections. The **Relay PCA 04523** now includes a set of jumpers

that perform this function. This change increases reliability and simplifies troubleshooting and repair operations.

- The **Relay PCA 04523** includes a set of jumpers that connect AC power to heaters included in several optional items, such as the zero/span valve options and the O₂ sensor option available on the TML41M/H analyzers. In earlier versions of the relay PCA this was also handled by in-line connections.

11.5.4.1. AC configuration – Internal Pump (JP7)

AC power configuration for internal pumps is set using Jumper set JP7 (see Figure 11-4 for the location of JP7).

Table 11-3: 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 ¹	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 ¹	BLUE	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8

¹ A jumper between pins 5 and 10 may be present on the jumper plug assembly, but is only functional on the TML30 and has no function on the TML41M/H analyzers.

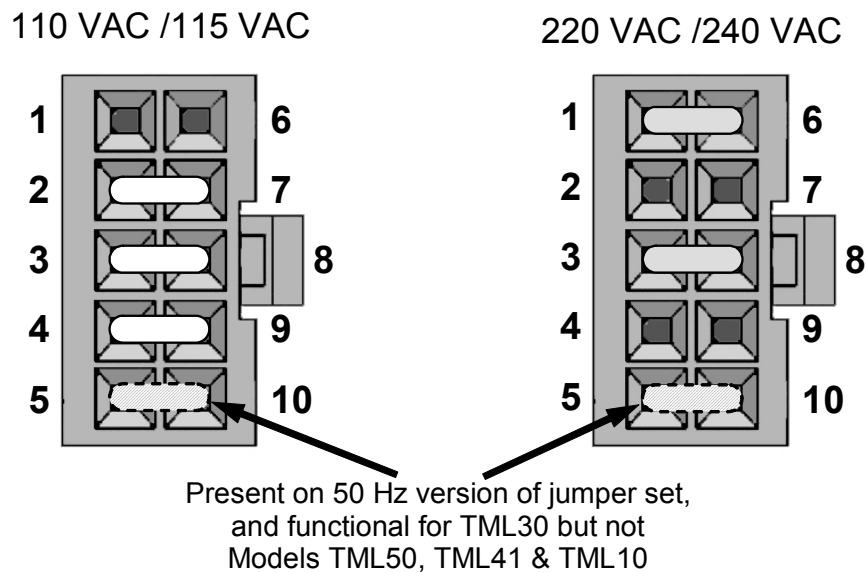


Figure 11-16: Pump AC Power Jumpers (JP7)

11.5.4.2. AC Configuration – Standard Heaters (JP2)

Power configuration for the AC standard heaters is set using Jumper set JP2 (see Figure 11-4 for the location of JP2).

Table 11-4: 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
		Mini Hi-Con Converter	3 to 10	Common
			4 to 9	Neutral to Load
		Moly Converter	3 to 10	Common
			4 to 9	Neutral to Load
		Bypass Manifold	5 to 12	Common
			6 to 11	Neutral to Load
220 VAC / 240 VAC 50Hz & 60 Hz	BLUE	Reaction Cell / Sample Chamber Heaters ²	1 to 7	Load
		Hi Concentration Converter	3 to 9	Load
		Moly Converter	3 to 9	Load
		Bypass Manifold	5 to 11	Load

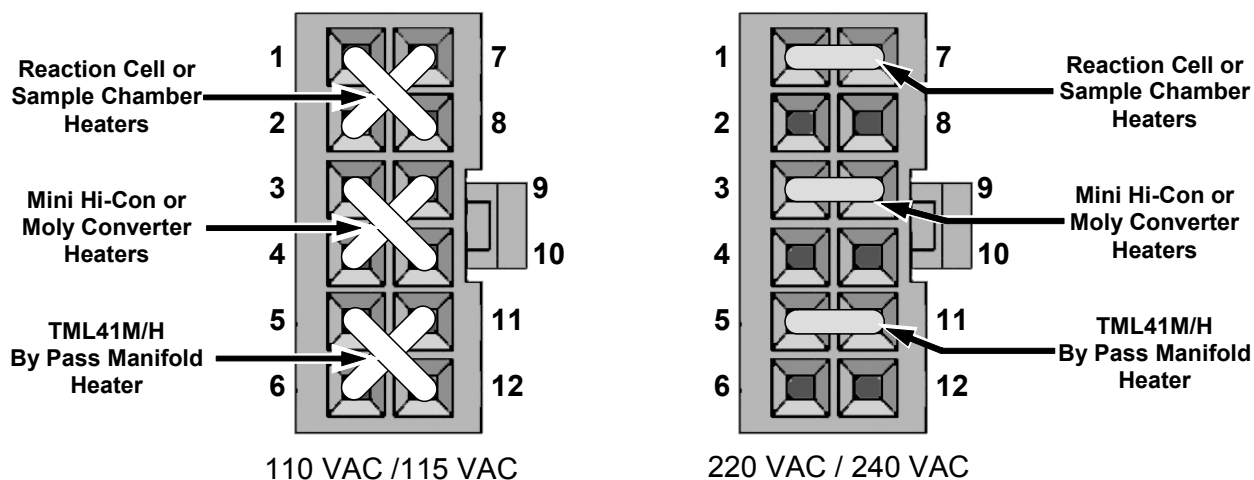


Figure 11-17: Typical Set Up of AC Heater Jumper Set (JP2)

11.5.4.3. AC Configuration –Heaters for Option Packages (JP6)

Both the IZS valve option and an O₂ sensor options include 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 11-5: Power Configuration for Optional AC Heaters (JP6)

JUMPER COLOR	HEATER(S)	MODEL'S USED ON ¹	JUMPER BETWEEN PINS	FUNCTION
RED	IZS ¹ Permeation Tube Heater	TML50's, TML41's & TML10	1 to 8	Common
			2 to 7	Neutral to Load
	O2 Sensor Heater	TML50's & TML41's	3 to 10	Common
			4 to 9	Neutral to Load

¹ This Option Not Available on the TML41M/H

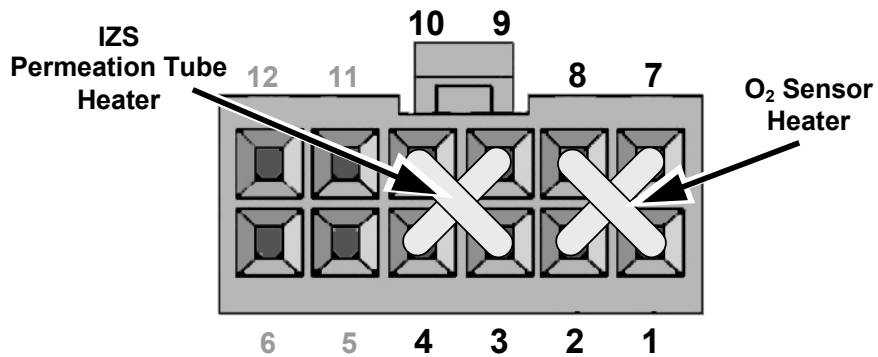


Figure 11-18: Typical Set Up of AC Heater Jumper Set (JP2)

11.5.5. DC POWER SUPPLY TEST POINTS

Table 11-6: DC Power Test Point and Wiring Color Code

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	

Table 11-7: DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK <u>RELAY</u> BOARD TEST POINTS				MIN V	MAX V
		FROM Test Point		TO Test Point			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.80	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0
PS1	-15	AGND	3	-15V	5	-14.0	-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

The test points are located at the top, right-hand corner of the PCA (see Figure 11-4)

11.5.6. I²C BUS

Operation of the I²C bus can be verified by observing the behavior of the LED labeled **D1** on the relay board in conjunction with the performance of the front panel display. Assuming that the DC power supplies are operating properly and the wiring from the motherboard to the keyboard as well as from the keyboard to the relay board is intact, the I²C bus is operating properly if:

- D1 on the relay board is flashing or
- D1 is not flashing but pressing a key on the front panel results in a change to the display.

If the display is locked up or if the analyzer is not booting up at all, the I²C bus may be the cause. Contact customer service if you suspect a problem with the I²C bus.

11.5.7. KEYBOARD / DISPLAY INTERFACE

The front panel keyboard, the display and the keyboard/display circuit board can be verified by observing the operation of the display when power is applied to the instrument and when a key is pressed on the front panel. Assuming that there are no wiring problems and that the DC power supplies are operating properly:

- The vacuum fluorescence display is working properly if, on power-up, a “-“ character is visible on the upper left hand corner of the display.
- If there is no “-“ character on the display at power-up but the **D1** LED on the relay board is flashing, the keyboard/display circuit may be bad.
- If the analyzer starts operation with a normal display but pressing a key on the front panel does not change the display, then there are three possible problems:
 - One or more of the keys is bad,
 - The interrupt signal between the keyboard and the motherboard is broken or
 - The keyboard circuit is bad.

You can verify this failure by logging on to the instrument using sensor-e.com or a terminal program. If the analyzer responds to remote commands and the display changes accordingly, the display wiring or the I²C bus may be faulty.

11.5.8. GENREAL RELAY BOARD DIAGNOSTIC

The relay board circuit can most easily be checked by observing the condition of its status LEDs as described in Section 11.1.4.3, and the associated output when toggled on and off through the **SIGNAL I/O** function in the **DIAG** menu, see Section 6.13.1.

If the front panel display responds to key presses and D1 on the relay board is not flashing, then either the wiring between the keyboard and the relay board is bad, or the relay board itself is bad.

If D1 on the Relay board is flashing and the status indicator for the output in question (heater, valve, etc.) does not toggle properly using the **Signal I/O** function, then the associated device (valve or heater) or its control device (valve driver, heater relay) is malfunctioning. Several of the control devices are in sockets and can easily be replaced. The table below lists the control device associated with a particular function:

Table 11-8: Relay Board Control Devices

Function	Control Device	Socketed
All valves	U5	Yes
All heaters	K1-K5	Yes

11.5.9. MOTHERBOARD

11.5.9.1. A/D functions

A basic check of the analog to digital (A/D) converter operation on the motherboard is to use the **Signal I/O** function under the **DIAG** menu. Check the following two A/D reference voltages and input signals that can be easily measured with a voltmeter.

- Using the **Signal I/O** function (Section 6.13.2), view the value of **REF_4096_MV** and **REF_GND**. If both are within 3 mV of their nominal values (4096 and 0) and are stable to within ± 0.5 mV, the basic A/D converter is functioning properly. If these values fluctuate largely or are off by more than 3 mV, one or more of the analog circuits may be overloaded or the motherboard may be faulty.
- Choose one parameter in the Signal I/O function such as **SAMPLE_PRESSURE** (see previous section on how to measure it). Compare its actual voltage with the voltage displayed through the **SIGNAL I/O** function. If the wiring is intact but there is a difference of more than ± 10 mV between the measured and displayed voltage, the motherboard may be faulty.

11.5.9.2. Analog Output Voltages

To verify that the analog outputs are working properly, connect a voltmeter to the output in question and perform an analog output step test as described in Section 6.13.3.

For each of the steps, taking into account any offset that may have been programmed into the channel (Section 6.13.5.4), the output should be within 1% of the nominal value listed in the table below except for the 0% step, which should be within 2-3 mV. If one or more of the steps is outside of this range, a failure of one or both D/A converters and their associated circuitry on the motherboard is likely.

Table 11-9: Analog Output Test Function - Nominal Values

		FULL SCALE OUTPUT VOLTAGE			
		100mV	1V	5V	10V
STEP	%	NOMINAL OUTPUT VOLTAGE			
1	0	0 mV	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

11.5.9.3. Status Outputs

The procedure below can be used to test the Status outputs.

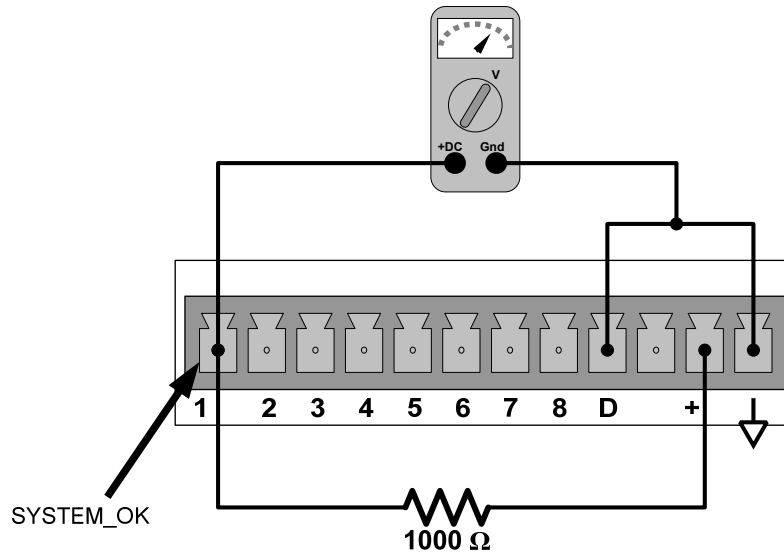


Figure 11-19: Typical Set Up of Status Output Test

1. Connect a cable between the “D” pin and the “▽” pin on the status output connector.
2. Connect a 1000 Ω resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “D” pin and the pin of the output being tested (Table 11-10).
4. Under the **DIAG / SIGNAL I/O** menu (Section 6.13.1), scroll through the inputs and outputs until you get to the output in question. Alternately turn the output on and off.
 - The Voltmeter will read approximately 5 VDC when the output is OFF.
 - The Voltmeter will read approximately 0 VDC when the output is ON.

Table 11-10: Status Outputs Pin Assignments

PIN #	STATUS
1	SYSTEM OK
2	CONC VALID
3	HIGH RANGE
4	ZERO CAL
5	SPAN CAL
6	DIAG MODE
7	LOW
8	SPARE

11.5.9.4. Control Inputs

The control input bits can be tested by the following procedure:

- Connect a jumper from the +5 V pin on the STATUS connector to the +5 V on the CONTROL IN connector.
- Connect a second jumper from the '-' pin on the STATUS connector to the A pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **ZERO CAL R** mode.
- Connect a second jumper from the '-' pin on the STATUS connector to the B pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **SPAN CAL R** mode.

In each case, the TML41M/H should return to SAMPLE mode when the jumper is removed.

11.5.10. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk-On-Chip (DOC). If either of these failures occur, 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 vacuum fluorescence display does not show a dash in the upper left hand corner
- There is no activity from the primary RS-232 port (COM1) on the rear panel even if "? <RETURN>" is pressed.

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 incorrect.

- If the analyzer stops during initialization (the vacuum fluorescence display shows some text), it is likely that the DOC, the firmware or the configuration and data files have been corrupted or that the wrong firmware was uploaded or does not have the correct filename.

11.5.11. RS-232 COMMUNICATION

11.5.11.1. General RS-232 Troubleshooting

Teledyne Instruments analyzers use the RS-232 protocol as the standard, serial communications protocol. RS-232 is a versatile standard, which has been used for many years but, at times, is difficult to configure. Teledyne Instruments conforms to the standard pin assignments in the implementation of RS-232. Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. This is the most common problem. See 6.11.3 for connector and pin-out information.
- The communications (baud) rate and protocol parameters are incorrectly configured. See Section 6.11.9 on how to set the baud rate.
- The COM port communications mode is set incorrectly (Section 6.11.8).
- If a modem is used, additional configuration and wiring rules must be observed. See Section 6.15.2.6.
- Incorrect setting of the DTE - DCE switch. Typically, the red LED is on as soon as you power up the analyzer. If not, contact the factory, as this indicates a problem with the motherboard. As the analyzer is connected to the computer with a cable, the green LED should also illuminate. If not, set the DCE/DTE switch to the other position. See also Section 6.11.5.
- Note that some laptops do not enable their RS-232 port when in power-saving mode. In this case, connect the laptop and start either sensor-e.com or a Hyperterminal window and start communicating with the analyzer. This will enable the serial port on the laptop and the green LED should illuminate. You may have to switch back and forth while communicating to get the right setting.

11.5.11.2. Modem or Terminal Operation

These are the general steps for troubleshooting problems with a modem connected to a Teledyne Instruments analyzer.

- Check cables for proper connection to the modem, terminal, or computer.
- Check the correct position of the DTE/DCE switch as described in Section 6.11.5.
- Check the correct setup command (Section 6.15.2.6).
- Verify that the Ready to Send (RTS) signal is at logic high. The TML41M/H sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
- Make sure the baud rate, word length, and stop bit settings between modem and analyzer match, see Section 6.15.2.6 and 6.11.8.
- Use the RS-232 test function to send “w” characters to the modem, terminal, or computer; See Section 6.11.10.
- Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way). The green LED on the rear panel should flicker as the instrument is receiving data.
- Make sure that the communications software is functioning properly.

Further help with serial communications is available in a separate manual “RS-232 Manual”, Teledyne Instruments part number 013500000, available online at <http://www.Teledyne-ml.com>.

11.5.12. PMT SENSOR

The photo multiplier tube detects the light emitted by the reaction of NO with ozone. It has a gain of about 1: 500000 to 1:1000000. It is not possible to test the detector outside of the instrument in the field. The best way to determine if the PMT is working properly is by using the optical test (**OTEST**), which is described in Section 6.13.7.2. The basic method to diagnose a PMT fault is to eliminate the other components using **ETEST**, **OTEST** and specific tests for other sub-assemblies.

11.5.13. PMT PREAMPLIFIER BOARD

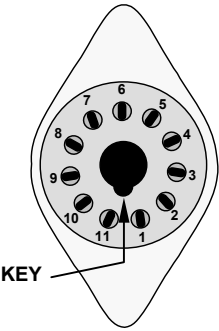
To check the correct operation of the preamplifier board, we suggest carrying out the optical and electrical tests described in Sections 6.13.7.2 and 6.13.7.3. If the ETEST fails, the preamplifier board may be faulty. Refer to Section 11.6.5 on hardware calibration through the preamplifier board.

11.5.14. HIGH VOLTAGE POWER SUPPLY

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube (Section 10.4.2). 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 11.6.5. 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.

- Turn off the instrument.
- Remove the cover and disconnect the 2 connectors at the front of the NO_x sensor module.
- Remove the end cap from the sensor (4 screws).
- Remove the HVPS/PMT assembly from the cold block inside the sensor (2 plastic screws).
- Re-connect the 7 pin connector to the sensor end cap, and power-up the instrument. Scroll the front panel display to the **HVPS** test parameter. Divide the displayed **HVPS** voltage by 10 and test the pairs of connector points as shown in Table 11-11.
- Check the overall voltage (should be equal to the **HVPS** value displayed on the front panel, for example 700 V) and the voltages between each pair of pins of the supply (should be 1/10th of the overall voltage, in this example 70 V):

Table 11-11: Example of HVPS Power Supply Outputs

If HVPS reading = 700 VDC		
PIN PAIR	NOMINAL READING	
1 → 2	70 VDC	
2 → 3	70 VDC	
3 → 4	70 VDC	
4 → 5	70 VDC	
5 → 6	70 VDC	
6 → 7	70 VDC	
7 → 8	70 VDC	

- Turn off the instrument power, 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.

11.5.15. PNEUMATIC SENSOR ASSEMBLY

The pressure/flow sensor circuit board, located behind the sensor assembly, can be checked with a voltmeter using the following procedure, which assumes that the wiring is intact and that the motherboard and the power supplies are operating properly. Refer to Figure 11-20 for trouble-shooting.

Measure the voltage across TP1 and TP2, it should be 10.0 ± 0.25 V. If not, the board is faulty. Measure the voltage across the leads of capacitor C2. It should be 5.0 ± 0.25 V, if not, the board may be faulty.

11.5.15.1. Reaction Cell Pressure

Measure the voltage across test points TP1 and TP5. With the sample pump disconnected or turned off, the voltage should be 4500 ± 250 mV. With the pump running, it should be 800-1700 mV depending on the performance of the vacuum pump. The lower the reaction cell pressure, the lower the resulting voltage is. If this voltage is significantly different, the pressure transducer S1 or the board may be faulty. If this voltage is between 2 and 5 V, the pump may not be performing well, check that the reaction cell pressure is less than 10 in-Hg-A (at sea level). Ensure that the tubing is connected to the upper port, which is closer to the sensor's contacts; the lower port does not measure pressure.

11.5.15.2. Sample Pressure

Measure the voltage across test points TP1 and TP4. With the sample pump disconnected or turned off, this voltage should be 4500 ± 250 mV. With the pump running, it should be about 0.2 V less as the sample pressure drops by about 1 in-Hg-A below ambient pressure. If this voltage is significantly different, the pressure transducer S2 or the board may be faulty. A leak in the sample system to vacuum may also cause this voltage to be between about 0.6 and 4.5. Make sure that the front panel reading of the sample pressure is at about 1 in-Hg-A less than ambient pressure. Ensure that the tubing is connected to the upper port, which is closer to the sensor's contacts; the lower port does not measure pressure.

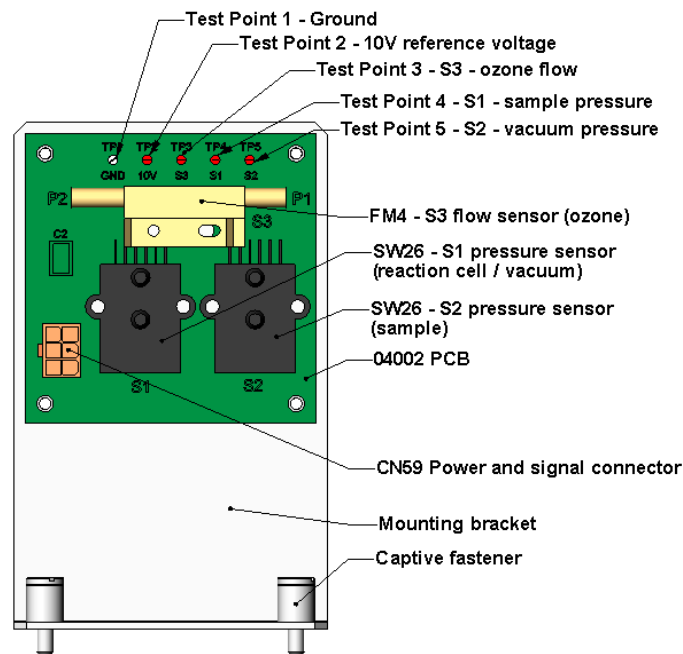


Figure 11-20: Pressure / Flow Sensor Assembly

11.5.15.3. Ozone Flow

Measure the voltage across TP1 and TP3. With proper ozone flow (250 cm³/min), this should be approximately 3.0 ± 0.3 V (this voltage will vary with altitude). With flow stopped (pump turned off), the voltage should be approximately 0 V. If the voltage is incorrect, the flow sensor or the board may be faulty. A cross-leak to vacuum inside the Perma Pure dryer may also cause this flow to increase significantly, and the voltage will increase accordingly. Also, make sure that the gas flows from P1 to P2 as labeled on the flow sensor (“high” pressure P1 to “low” pressure P2 or “Port” 1 to “Port” 2).

11.5.16. NO₂ CONVERTER

The NO₂ 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.

1) NO₂ 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 and 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.
 - First, 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 thermocouple 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. In both cases, consult the factory.

2) If the converter appears to have performance problems (conversion efficiency is outside of allowed range of 96-102%), check the following:

- Conversion efficiency setting in the CAL menu. If this value is different from 1.000, this correction needs to be considered. Section 7.1.5 describes this parameter in detail.
- Accuracy of NO₂ source (GPT or gas tank standard). NO₂ 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 GPT, check the accuracy of the ozone source.
- Age of the converter. The NO₂ 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 NO₂ concentrations). We estimate a lifetime of about 10000 ppm-hours (a cumulative product of the NO₂ concentration times the exposure time to that concentration). However, 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 etc. 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 5.10). Section 9.3.6 describes how to replace the NO₂ converter cartridge.
- With no NO₂ in the sample gas and a properly calibrated analyzer, the NO reading is negative, while the NO₂ reading remains around zero. The converter destroys NO and needs to be replaced.
- With no NO₂ in the sample gas and a properly calibrated analyzer, the NO_x reading is significantly higher than the actual (gas standard) NO concentration. The converter produces NO₂ and needs to be replaced.

11.5.17. O₃ 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 10.3.6 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 O₃ 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 chapter.

11.5.18. BOX TEMPERATURE

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° C higher than, ambient (room) temperature because of the internal heating zones from the NO₂ 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 6.13.2). At about 30° C, the signal should be around 1500 mV.
- We recommend using a certified or 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.

11.5.19. PMT TEMPERATURE

PMT temperature should be low and constant. It is more important that this temperature is maintained constant than it is to maintain it low. 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 ±1° C due to component tolerances. The actual temperature will be maintained to within 0.1° C around that set point. On power-up of the analyzer, the front panel enables the user to watch that temperature drop from about ambient temperature down to its set point of 6-8° C. If the temperature fails to adjust after 30 minutes, there is a problem in the cooler circuit. If the control circuit on the preamplifier board is faulty, a temperature of -1° C is reported.

11.6. REPAIR PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement. Note that maintenance procedures (e.g., replacement of regularly changed expendables) are discussed in Chapter 8 (Maintenance) are not listed here. Also note that Teledyne-ML customer service may have a more detailed service note for some of the below procedures. Contact customer service.

11.6.1. DISK-ON-CHIP REPLACEMENT

Replacing the Disk-on-Chip (DOC) will cause all of the instrument configuration parameters to be lost unless the replacement chip carries the exact same firmware version. iDAS data will always be lost and, if possible, should be downloaded prior to changing the DOC. If the analyzer is equipped with at least one EEPROM flash chip (standard configuration), the configuration settings are stored on the EEPROM. It is recommended to document all analyzer parameters that may have been changed, such as calibration, range, auto-cal, analog output, serial port and other settings before replacing the CPU chip. Refer to Figure 10-17 for locating the DOC and other CPU components.

1. Ground yourself to prevent electrostatic damage to electronic components.

Turn off power to the instrument.

Fold down the rear panel by loosening the mounting screws.

- You may have to lift up the analyzer cover to prevent some connectors on the CPU board from brushing against the cover.

Locate the Disk-on-Chip on the CPU board.

- The chip should carry a label with analyzer model number (TML41M/H), firmware revision (example: TML41M/H_C7.EXE), date and initials of the programmer.

Remove the IC with a dedicated IC removal tool or by gently prying it up from the socket.

- Do not bend the connector pins.

Reinstall the new Disk-on-Chip, making sure the notch at the end of the chip matches the notch in the socket.

- It may be necessary to straighten the pins somewhat to fit them into the socket. Gently but firmly press the chip all the way in. Do not bend the pins.

Close the rear panel. Replace the cover and turn on power to the machine.

Generally, all of the setup information will need to be re-entered, including analog input and output calibration unless the firmware revision has not changed and the analyzer is equipped and properly configured with an EEPROM chip. Note especially that the A/D converter must be re-calibrated, and all information collected in step 1 above must be re-entered before the instrument will function correctly. The analyzer typically issues an **ANALOG CALIBRATION WARNING** if the analog circuitry was not calibrated within 10 minutes after restart.

11.6.2. FLASH CHIP REPLACEMENT OR UPGRADE

The TML41M/H CPU board can accommodate up to two EEPROM flash chips. The standard configuration is one chip with 64 kb of storage capacity, which is used to store the analyzer configuration as created during final checkout at the factory. Replacing this chip will erase that configuration, which will be recreated with a new copy when restarting the analyzer. However, if the firmware and/or the DOC is changed at the same time, all analyzer configuration settings and iDAS data will be lost. Adding a second EEPROM chip to the existing chip will double memory but this procedure will require a BIOS configuration and is not a standard sales option. Also make sure that you receive a fully formatted EEPROM chip for replacement. Contact the factory for details.

1. Ground yourself to prevent electrostatic damage to electronic components.

Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.

- If necessary, lift the cover to prevent the rear panel connectors from brushing against it.

Locate the EEPROM chip in the left-most socket of the CPU board.

- The chip is almost square with one corner cut off, the socket is shaped accordingly and the chip is recessed into the socket.

Remove the old chip by using a special tool or gently pry the chip out using a very fine screwdriver. Make sure not to bend or destroy any of the contacts of the socket.

- When upgrading the CPU with a second chip, no removal is necessary as the second socket should be empty.

Reinstall the new or additional EEPROM chip, making sure the cut-off edge matches that of the socket. Press the chip symmetrically and straight all the way in.

Close the rear panel and cover and turn on power to the machine.

- If a front panel message **Flash Format INVALID** appears on start-up, the EEPROM was not properly formatted. Contact the factory for a proper replacement.

11.6.3. O₃ 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. To replace the ozone generator:

1. Turn off the analyzer power; remove the power cord and the analyzer cover.

Disconnect the 1/8" black tube from the ozone scrubber cartridge and the 1/4" clear tube from the plastic extension tube at the brass fitting nearest to the ozone generator.

Unplug the electrical connection on the rear side of the brick.

Unscrew the two mounting screws that attach the ozone generator to the chassis and take out the entire assembly.

If you received a complete replacement generator with circuit board and mounting bracket attached, simply reverse the above steps to replace the current generator.

Make sure to carry out a leak check and a recalibration after the analyzer warmed up for about 30 minutes.

11.6.4. SAMPLE AND OZONE DRYER REPLACEMENT

The TML41M/H 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 all of these options:

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 NO₂ converter.
 - 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,
 - These are usually the purge tube connecting to the vacuum manifold, the tube from the exit to the ozone flow meter (ozone dryer) or to the NO/NO_x valve (sample dryer) or two tubes to the ozone flow meter and the NO/NO_x valve (combo-dryer).
 - Take extra care not to twist any of the white plastic fittings on the dryer, which connect the inner drying tube to the outer purge tube. See Section 9.3.2 and Figure 9-2.
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_x 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 (Section 11.5.2).
12. Close the analyzer.
13. Power up pump and analyzer and re-calibrate the instrument after it stabilizes.

11.6.5. PMT SENSOR HARDWARE CALIBRATION (FACTORY CAL)

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.

1. Perform a full zero calibration using zero air (Section 7.2, 7.4, or 7.6).

Locate the preamplifier board (Figure 3-1).

Locate the following components on the preamplifier board (Figure 11-21):

- 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).

Turn the gain adjustment potentiometer 12 turns clockwise to its maximum setting.

Feed NO to the analyzer:

- For the TML41H use 450 ppm NO.
- For the TML41M use 18 ppm NO.

Wait until the **STABIL** value is below 0.5 ppm

Scroll to the **NORM PMT** value on the analyzer's front panel.

With the NO gas concentrations mentioned in step 5 above, the **NORM PMT** value should be 3600 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 3600 mV **NORM PMT** signal. The coarse adjustment typically increments the NORM PMT signal in 100-300 mV steps.

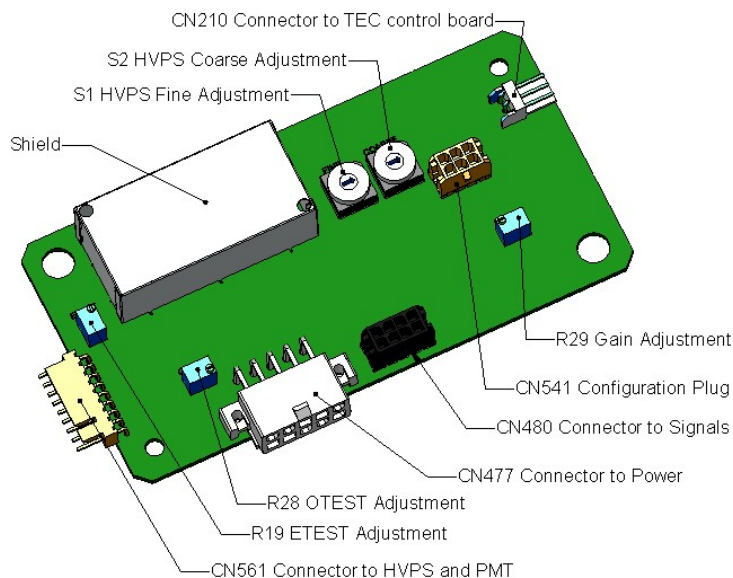


Figure 11-21: Pre-Amplifier Board Layout

Adjust the HVPS fine adjustment such that the **NORM PMT** value is 3600-3700 mV.

- The fine adjustment typically increments the **NORM PMT** value by about 30 mV.
- 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.

NOTE

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.

If the **NORM PMT** value set above is now between 3560-3640 mV, skip this step. Otherwise, adjust the **NORM PMT** value with the gain potentiometer down to 3600 ± 10 mV.

- This is the final very-fine adjustment.

Note that during adjustments, the **NORM PMT** value may be fluctuating, as the analyzer continues to switch between NO and NO_x streams as well as between measure and AutoZero modes.

- You may have to mentally average the values of NO and NO_x response for this adjustment.

Perform a software span calibration (Section 7.2, 7.4, or 7.6) to normalize the sensor response to its new PMT sensitivity.

Review the slope and offset values, the slopes should be 1.000 ± 0.300 and the offset values should be 0.0 ± 20 mV (-20 to +150 mV is allowed).

11.6.6. PMT SENSOR HARDWARE CALIBRATION (FIELD CAL)

- Perform a full zero calibration using nitrogen or zero air.
- Flow span gas to the analyzer and wait until the **STABIL** value is 0.5 or less.

- In the **SETUP-VARS** menu scroll to, and manually set the **SO₂** or **NOx SLOPE** value to 1.000.
- Turn the gain adjustment pot on the PMT preamp board, R29, fully clockwise.
- Set the HVPS fine adjustment switch S1 to its highest setting.
- While observing the gas concentration on the analyzer's display, set the HVPS coarse adjustment switch S1 to the lowest setting that is just above the span gas value.
- Set the HVPS fine adjustment switch S1 to the lowest setting that is just above the span gas value.
- Using the gain adjustment pot, R29, set the analyzer to read the exact span gas value. This value may fluctuate a bit.
- Perform a software span calibration so that the analyzer may set its slope and offset values.
- Review the slope and offset values. The slopes should be 1.000 ± 0.3 , and the offset values should be $0.0 \pm 20\text{mV}$ (-20 to $+150\text{mV}$ is allowed).
- Flow zero gas to the analyzer gas and wait until the **STABIL** value is 0.5 or less. Initiate an optic test (**OTEST**) from the **SETUP – DIAG** menu. Scroll to the **NORM_PMT** value on the analyzer's main display.
- Set the **OTEST** adjustment pot, R28, to obtain a **NORM_PMT** value of approximately 2000mV.
- Initiate an electric test (**ETEST**) from the **SETUP – DIAG** menu. Scroll to the **NORM_PMT** value on the analyzer's main display.
- Set the **ETEST** adjustment pot, R19, to obtain a **NORM_PMT** value of approximately 2000mV.

11.6.7. REPLACING THE PMT, HVPS OR TEC

The photo multiplier tube (PMT) should last for the lifetime of the analyzer. However, in some cases, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) may fail. In case of PMT, HVPS or TEC failure, the sensor assembly needs to be opened in order to change one of these components. Refer to Figure 11-22 for the structure of the TML41M/H sensor assembly and follow the steps below for replacement of one of its components. We recommend ensuring that the PMT, HVPS, or TEC modules are, indeed, faulty to prevent unnecessary opening of the sensor.

NOTE

Whereas it is possible for a skilled technician to change the PMT or HVPS through the front panel with the sensor assembly mounted to the analyzer, we recommend removing the entire assembly and carry this procedure out on a clean, anti-static table with the user wearing an anti-static wrist strap to prevent static discharge damage to the assembly or its circuits.

1. Power down the analyzer, disconnect the power cord.
2. Remove the cover and disconnect all pneumatic and electrical connections from the sensor assembly.
3. 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 PMT cold block is to be removed.

- This step is not necessary if the HVPS or the PMT only are exchanged.

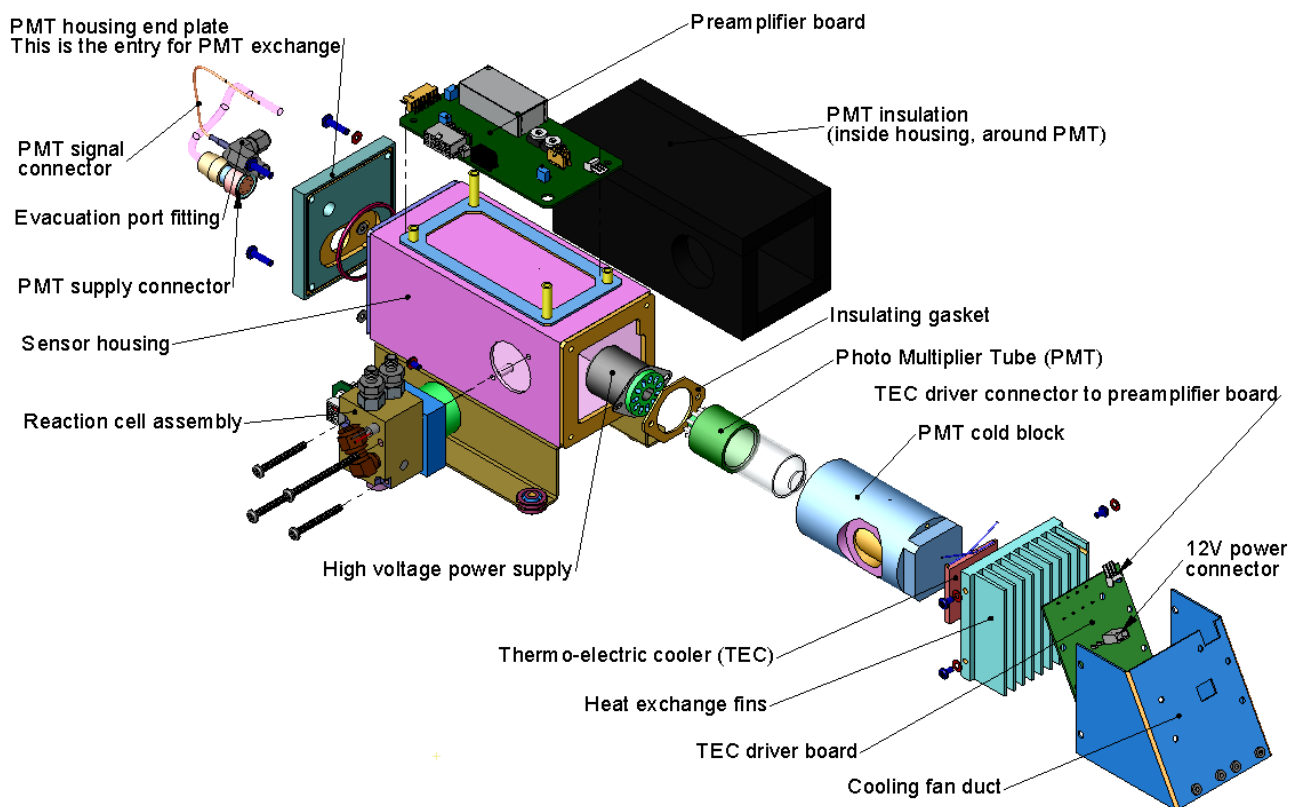


Figure 11-22: TML41M/H Sensor Assembly

Remove the two connectors on the PMT housing end plate facing towards the front panel.

Remove the end plate itself (4 screws with plastic washers).

Remove the dryer packages inside the PMT housing.

Along with the plate, slide out the OPTIC TEST LED and the thermistor that measures the PMT temperature.

- Both may 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.

Unscrew the PMT assembly, which is held to the cold block by two plastic screws.

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).

Carefully take out the assembly consisting of the HVPS, the gasket and the PMT.

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.

If the cold block or TEC is to be changed:

- a) Disconnect the TEC driver board from the preamplifier board; remove the cooler fan duct (4 screws on its side) including the driver board.
- b) Disconnect the driver board from the TEC and set the sub-assembly aside.

Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.

Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.

Re-assemble this TEC subassembly in reverse order.

- Make sure 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

The thermo-electric cooler needs to be mounted flat to the heat sink. If there is any significant gap, the TEC might burn out. Make sure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.

Re-insert the TEC subassembly in reverse order.

- Make sure that the O-ring is placed properly and the assembly is tightened evenly.

Re-insert the PMT/HVPS subassembly in reverse order and don't forget the gasket between HVPS and PMT.

- Use new plastic screws to mount the PMT assembly on the PMT cold block.

Insert the LED and thermistor into the cold block, insert new drying packages 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.

Reconnect the cables and the reaction cell (evenly tighten these screws).

Replace the sensor assembly into the chassis and fasten with four screws and washers.

Reconnect all electrical and pneumatic connections.

leak check the system.

Power up the analyzer.

Verify the basic operation of the analyzer using the ETEST and OTEST features or zero and span gases, then carry out a hardware calibration of the analyzer (Section 11.6.5) followed by a software calibration.

11.7. 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.

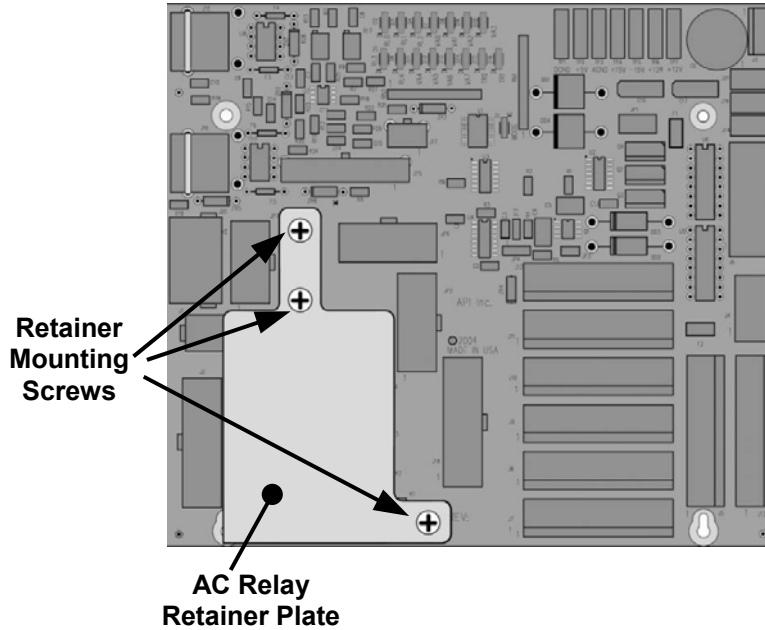


Figure 11-23: Relay PCA with AC Relay Retainer In Place

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.

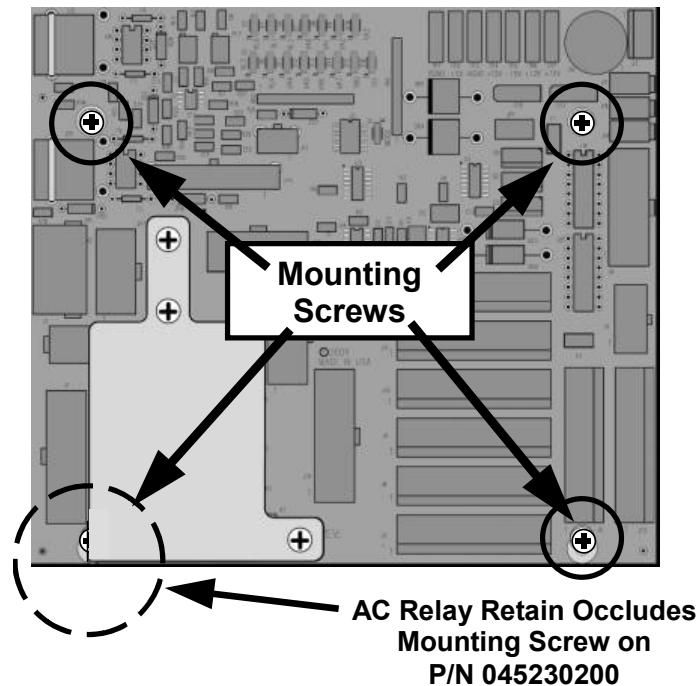


Figure 11-24: Relay PCA Mounting Screw Locations

11.8. TECHNICAL ASSISTANCE

If this manual and its trouble-shooting / repair sections do not solve your problems, technical assistance may be obtained from Teledyne-ML, Customer Service, 35 Inverness Drive East, Englewood, CO 80112. Phone: 800-846-6062. Fax: 303-799-4853. Email tml_support@teledyne.com. Before you contact customer service, fill out the problem report form in Appendix C, which is also available online for electronic submission at <http://www.teledyne-ml.com>

USER NOTES:

12. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne Instruments considers the prevention of damage caused by the discharge of static electricity to be an extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

12.1. HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power, and operate very quickly. Unfortunately the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

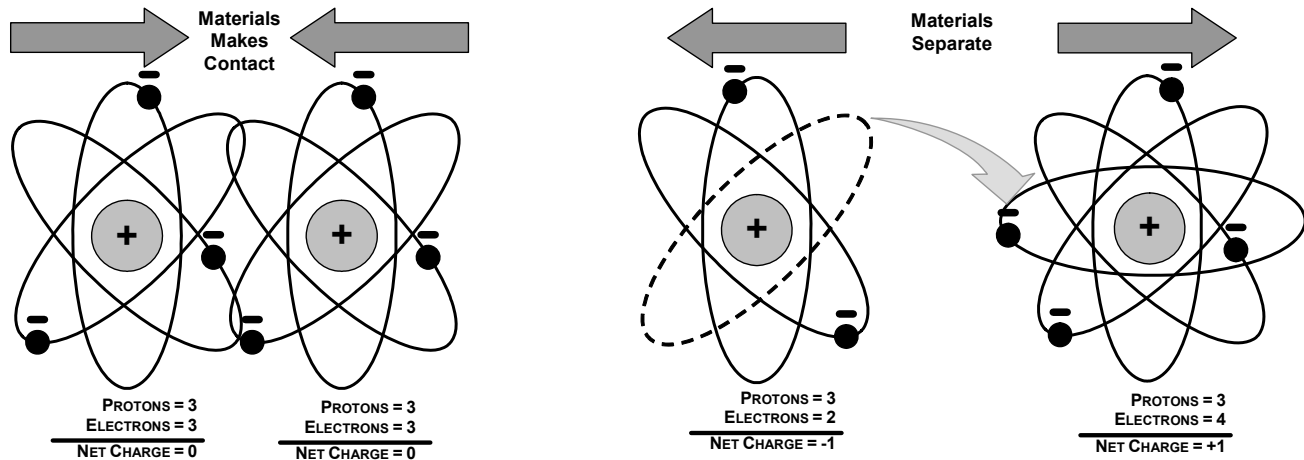


Figure 12-1: Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges

Table 12-1: Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

12.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 12-1 with those shown in the Table 12-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 12-2: Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
Thin Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.
- When static charges accumulated on a sensitive device discharge from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.

A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.

- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

12.3. COMMON MYTHS ABOUT ESD DAMAGE

- **I didn't feel a shock so there was no electro-static discharge:** The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.
- **I didn't touch it so there was no electro-static discharge:** Electro-static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.
- **It still works so there was no damage:** Sometimes the damage caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

- **Static Charges can't build up on a conductive surface:** There are two errors in this statement.

Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

- **As long as my analyzer is properly installed it is safe from damage caused by static discharges:** It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

12.4. BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

12.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation (see Figure 12-2).

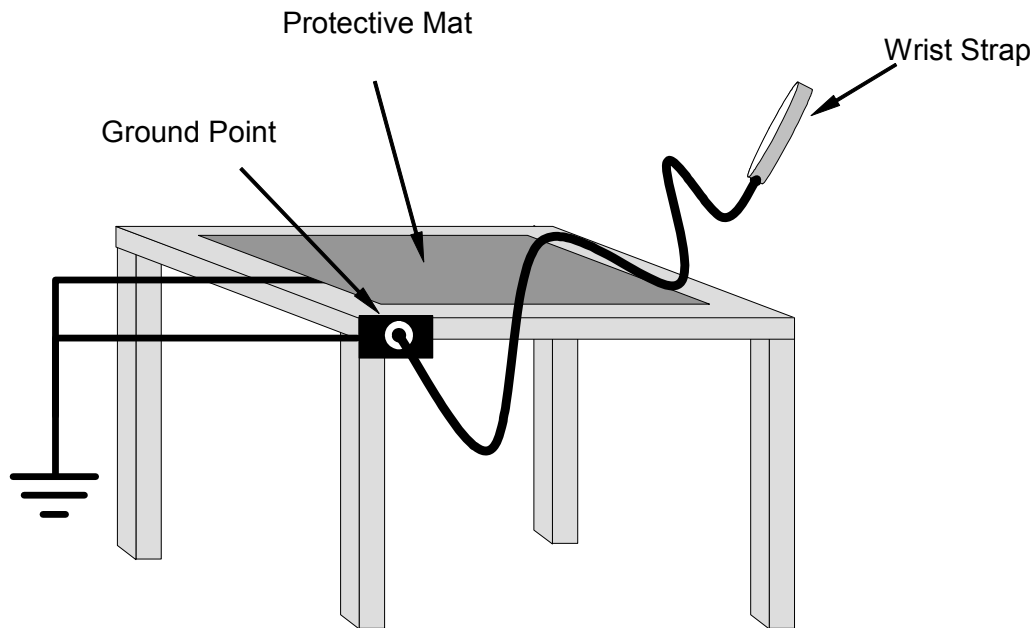


Figure 12-2: Basic anti-ESD Work Station

For technicians who work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

- **Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer.** An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

- **Simply touching a grounded piece of metal is insufficient.** While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions a charge large enough to damage a component can rebuild in just a few seconds.
- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.
- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, pink-poly bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

While this layer may equalize any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

- **Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag.** The act of pulling a piece of standard plastic adhesive tape, such as Scotch[®] tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

12.4.2. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

12.4.2.1. Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply

1. Attach your anti-ESD wrist strap to ground before doing anything else.
 - Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis. This will safely connect you to the same ground level to which the instrument and all of its components are connected.

Pause for a second or two to allow any static charges to bleed away.

Open the casing of the analyzer and begin work. Up to this point the closed metal casing of your analyzer has isolated the components and assemblies inside, from any conducted or induced static charges.

If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.

Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

12.4.2.2. Working at an Anti-ESD Workbench

When working on an electronic assembly of an instrument while it is resting on a anti-ESD workbench

1. Plug your anti-ESD wrist strap into the grounded receptacle of the workstation before touching any items on the workstation and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the workstation.
 - Lay the bag or bin on the workbench surface.
 - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.
 - Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.

5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

12.4.2.3. Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne Instruments analyzer to an Anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
 - In either case wait several seconds.
4. Place the item in the container.
5. Seal the container. If using a bag, fold the end over and fasten it with anti-ESD tape.
 - Folding the open end over isolates the component(s) inside from the effects of static fields.
 - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
 - Connect your wrist strap to ground.
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface
 - In either case wait several seconds
7. Open the container.

12.4.2.4. Opening Shipments from Teledyne Instruments Customer Service


Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne Instruments ships all electronic components and assemblies in properly sealed anti-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped make sure that you always unpack shipments from Teledyne Instruments Customer Service by:

- Opening the outer shipping box away from the anti-ESD work area.
- Carry the still sealed anti-ESD bag, tube or bin to the anti-ESD work area.
- Follow steps 6 and 7 of Section 12.4.2.3 above when opening the anti-ESD container at the workstation.
- Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne Instruments.
- Always pack electronic components and assemblies to be sent to Teledyne Instruments Customer Service in anti-ESD bins, tubes or bags.

12.4.2.5. Packing Components for Return to Teledyne Instruments Customer Service

Always pack electronic components and assemblies to be sent to Teledyne Instruments Customer Service in anti-ESD bins, tubes or bags.

	<p>WARNING</p> <ul style="list-style-type: none"> • DO NOT use pink-poly bags. • NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly • This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape • DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape
---	--

1. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
2. Before using the bag or container allow any surface charges on it to dissipate:
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
 - In either case wait several seconds.

3. Place the item in the container.
4. Seal the container. If using a bag, fold the end over and fasten it with anti-ESD tape.
 - Folding the open end over isolates the component(s) inside from the effects of static fields.
 - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

User Notes:

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ADDENDUM TO THE TML41M/H OPERATORS MANUAL (P/N 04521)

1. PREFACE

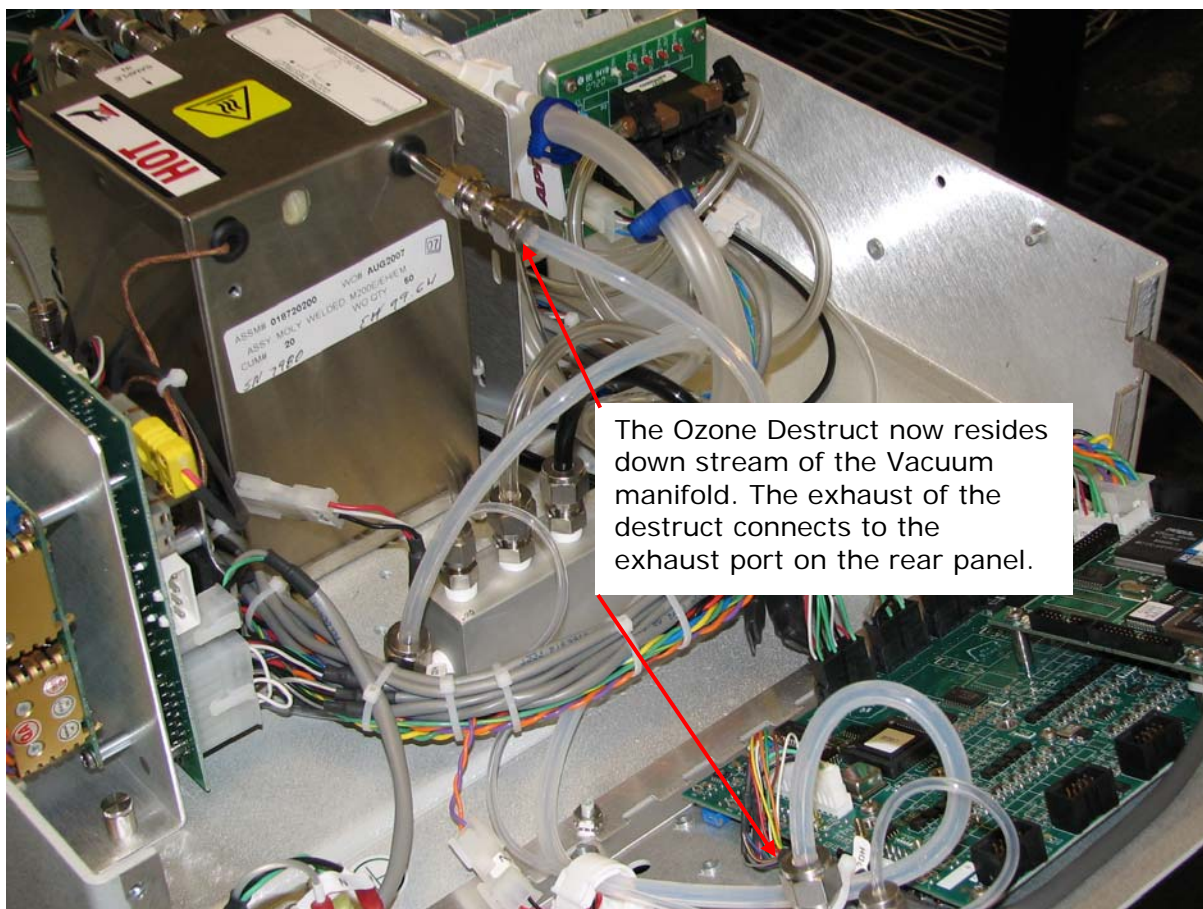
This addendum is an update to the Model TML41M/H Operators Manual. It documents the following improvements:

- STAINLESS STEEL OZONE DESTRUCT P/N 051210000: The Ozone Destruct now resides down stream of the vacuum manifold. Previously, it was located downstream of the reaction cell.
- BYPASS MANIFOLD ASSEMBLY P/N 044430100: As a cost reduction, the bypass manifold is now incorporated into the three port reaction cell.

2. CHANGES AND UPDATES

2.1. OZONE DESTRUCT

The following photograph identifies the Ozone Destruct assembly and pneumatic connections.



The Ozone Destruct now resides down stream of the Vacuum manifold. The exhaust of the destruct connects to the exhaust port on the rear panel.

FIGURE 1.0 - OZONE DESTRUCT ASSY P/N 05121

2.2. THREE PORT REACTION CELL

By incorporating the bypass flow orifice into the reaction cell, the bypass manifold assembly, which previously resided between the vacuum manifold and Molycon container, is no longer required.

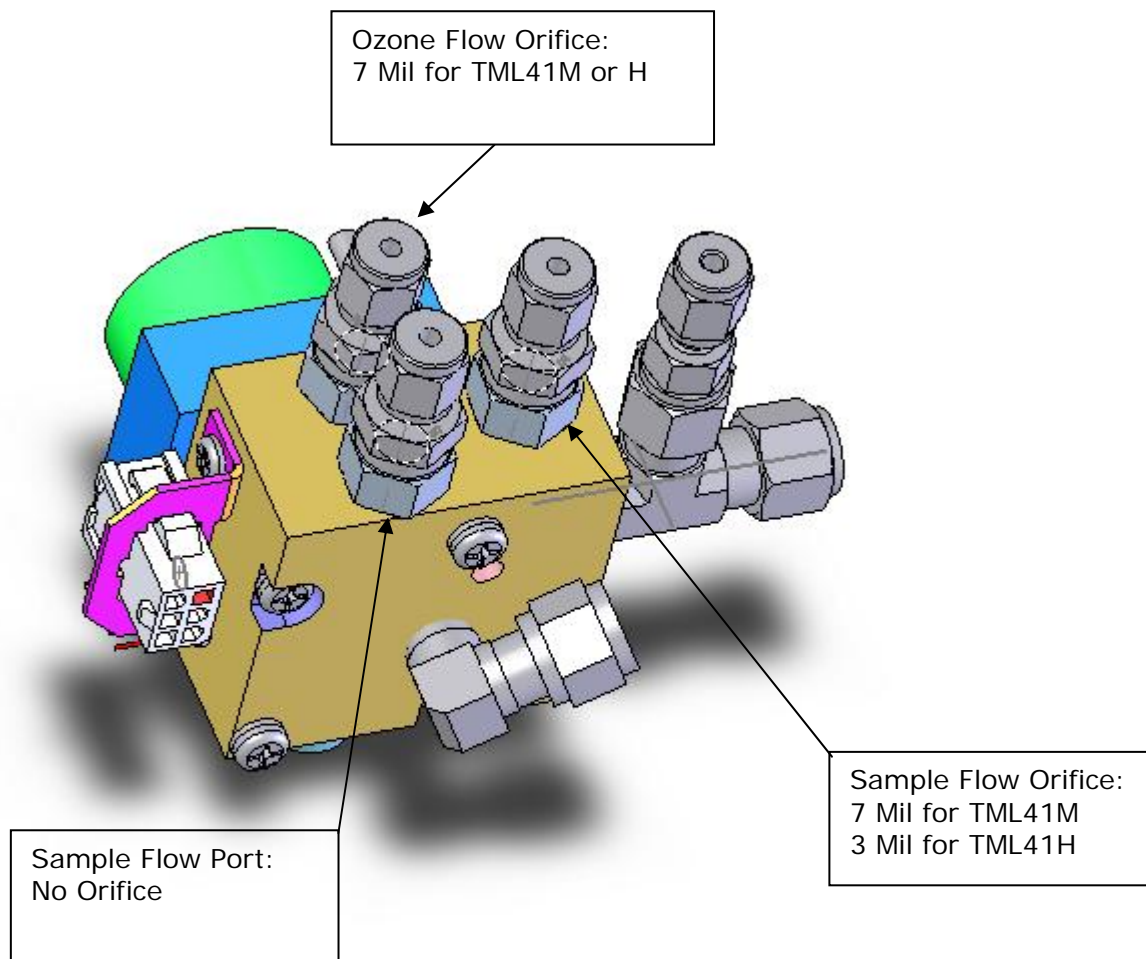


FIGURE 2.0 – THREE PORT REACTION CELL ASSY P/N 06028

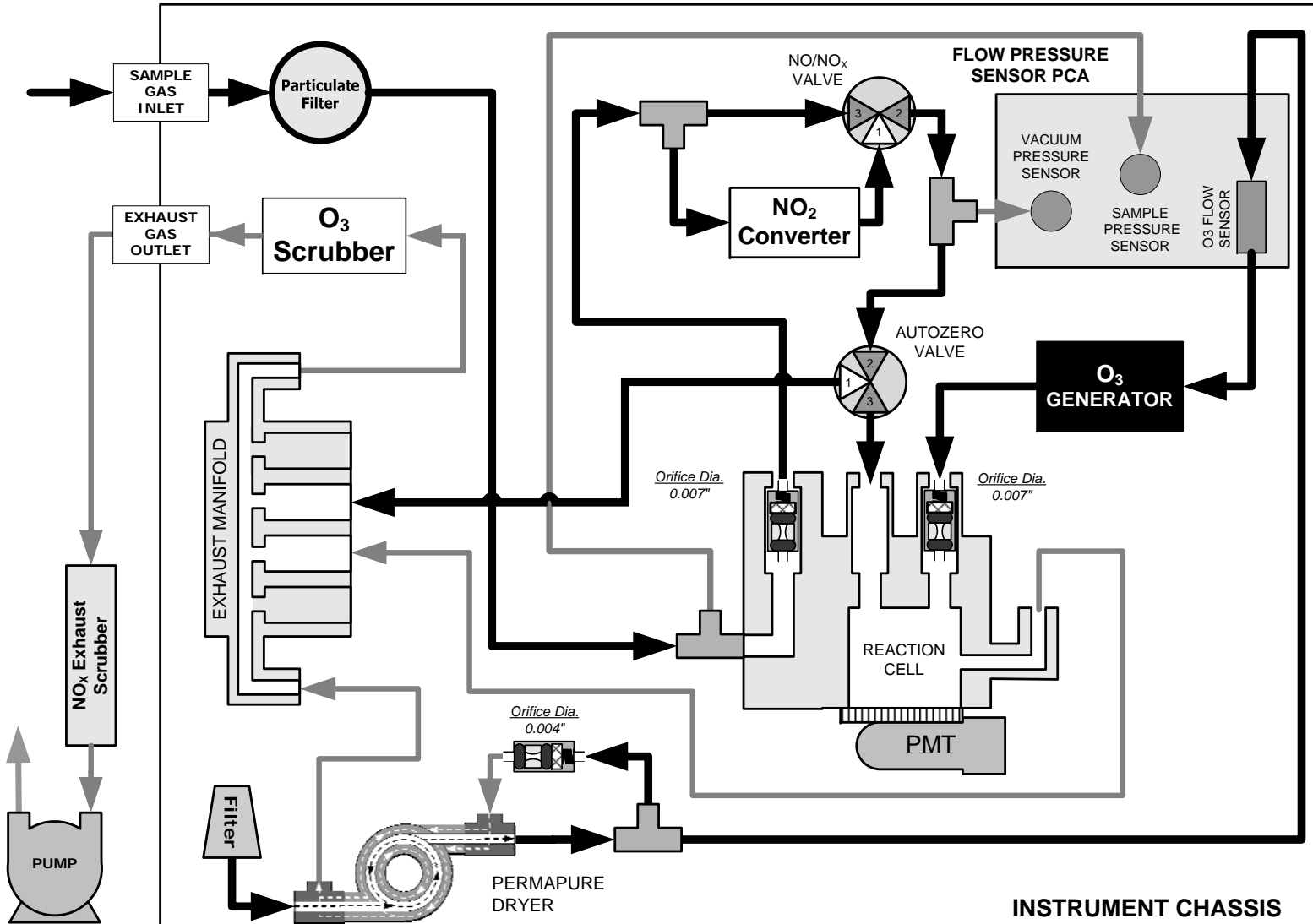


Figure 3.0 TML41M Pneumatic Diagram

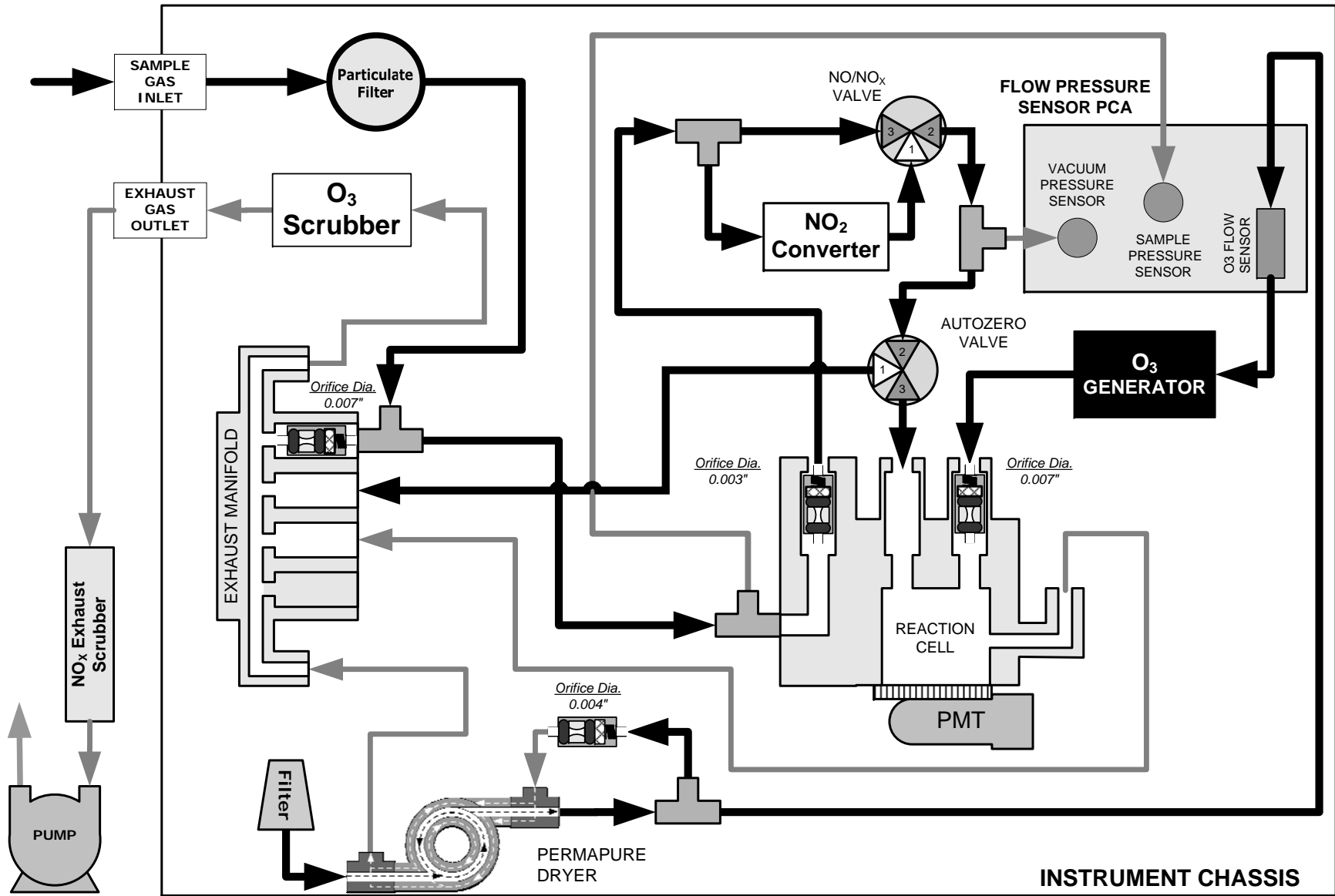


Figure 4.0 TML41H Pneumatic Diagram

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APPENDIX A - Version Specific Software Documentation

APPENDIX A-1: TML41M/H Software Menu Trees

APPENDIX A-2: TML41M/H Setup Variables for Serial I/O

APPENDIX A-3: TML41M/H Warnings and Test Functions

APPENDIX A-4: TML41M/H Signal I/O Definitions

APPENDIX A-5: TML41M/H iDAS Parameters

APPENDIX A-6: Terminal Command Designators

APPENDIX A-7: Setting up Communications

APPENDIX A-1: TML41M/H Software Menu Trees, Revision G

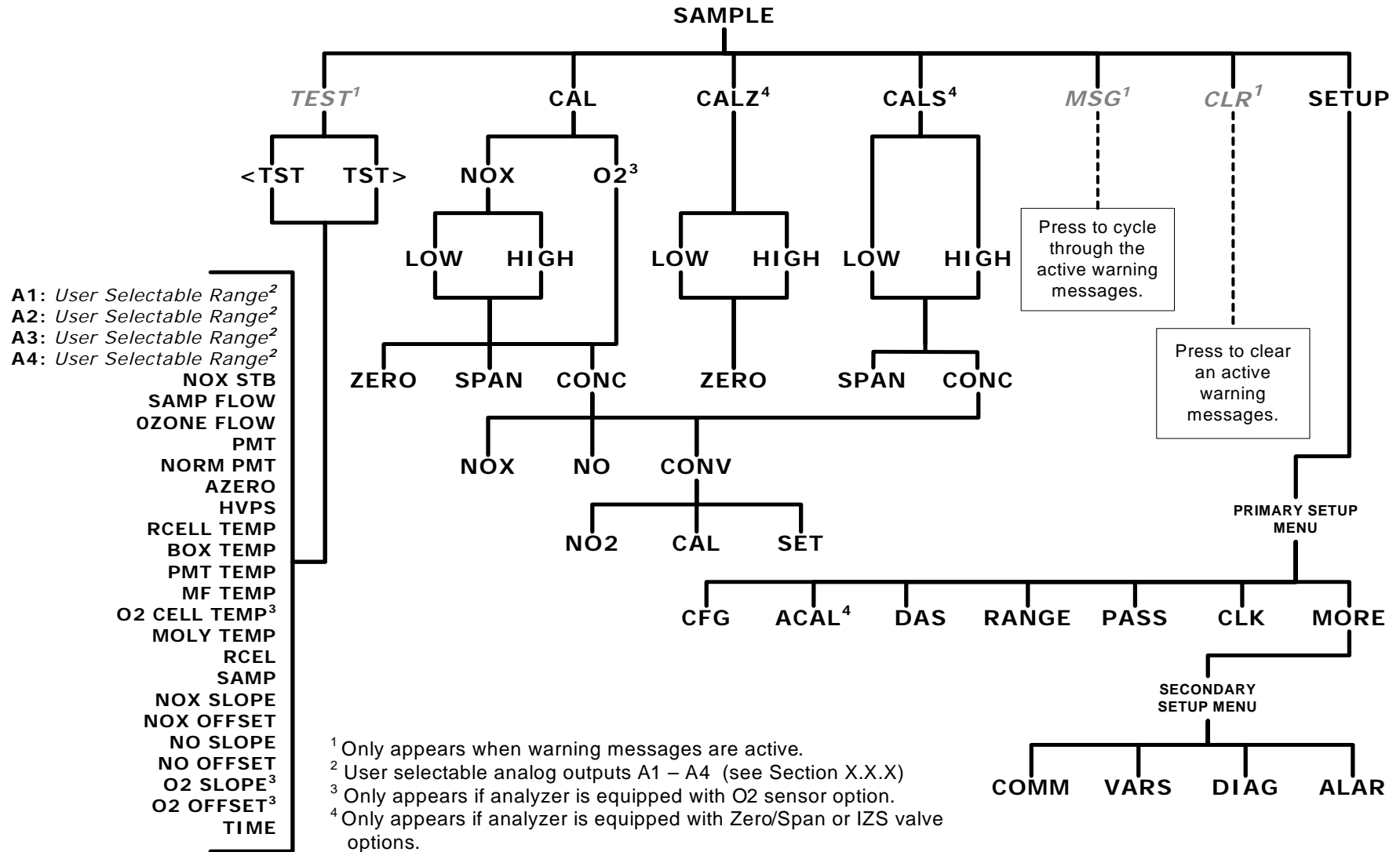


Figure A-1: Basic Sample Display Menu

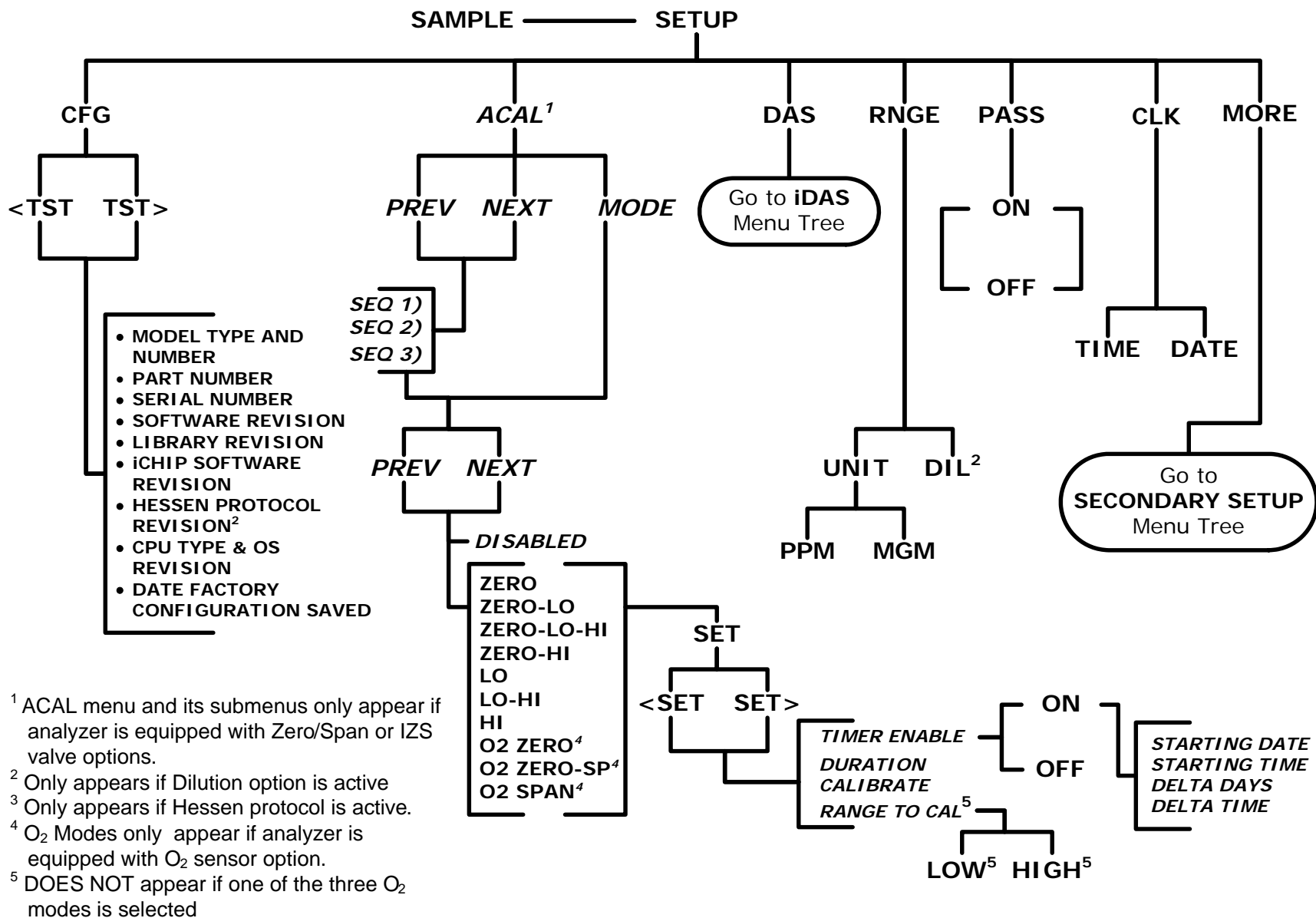


Figure A-2: Primary Setup Menu (Except iDAS)

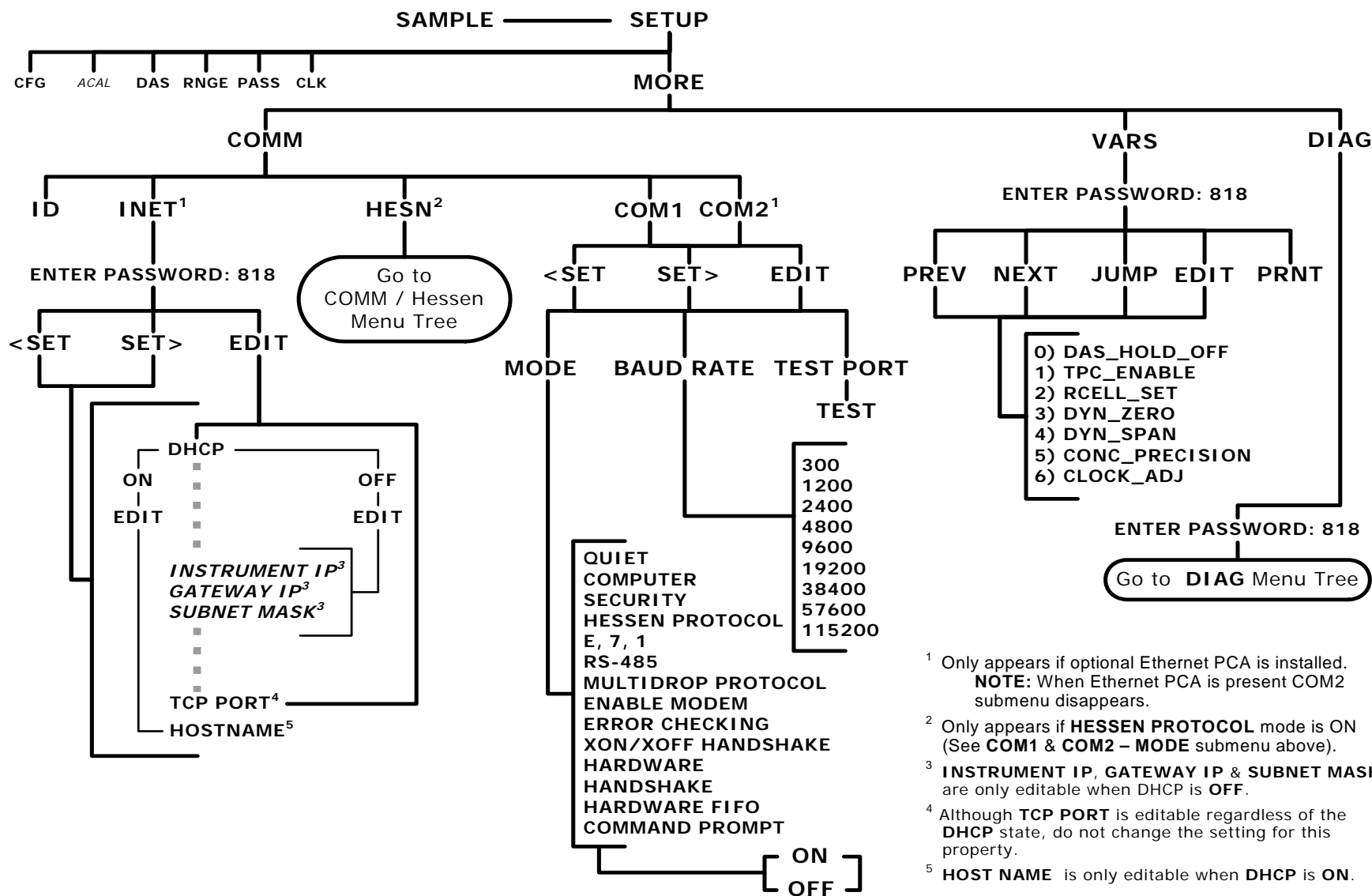


Figure A-4: Secondary Setup Menu → COMM and VARS Submenus

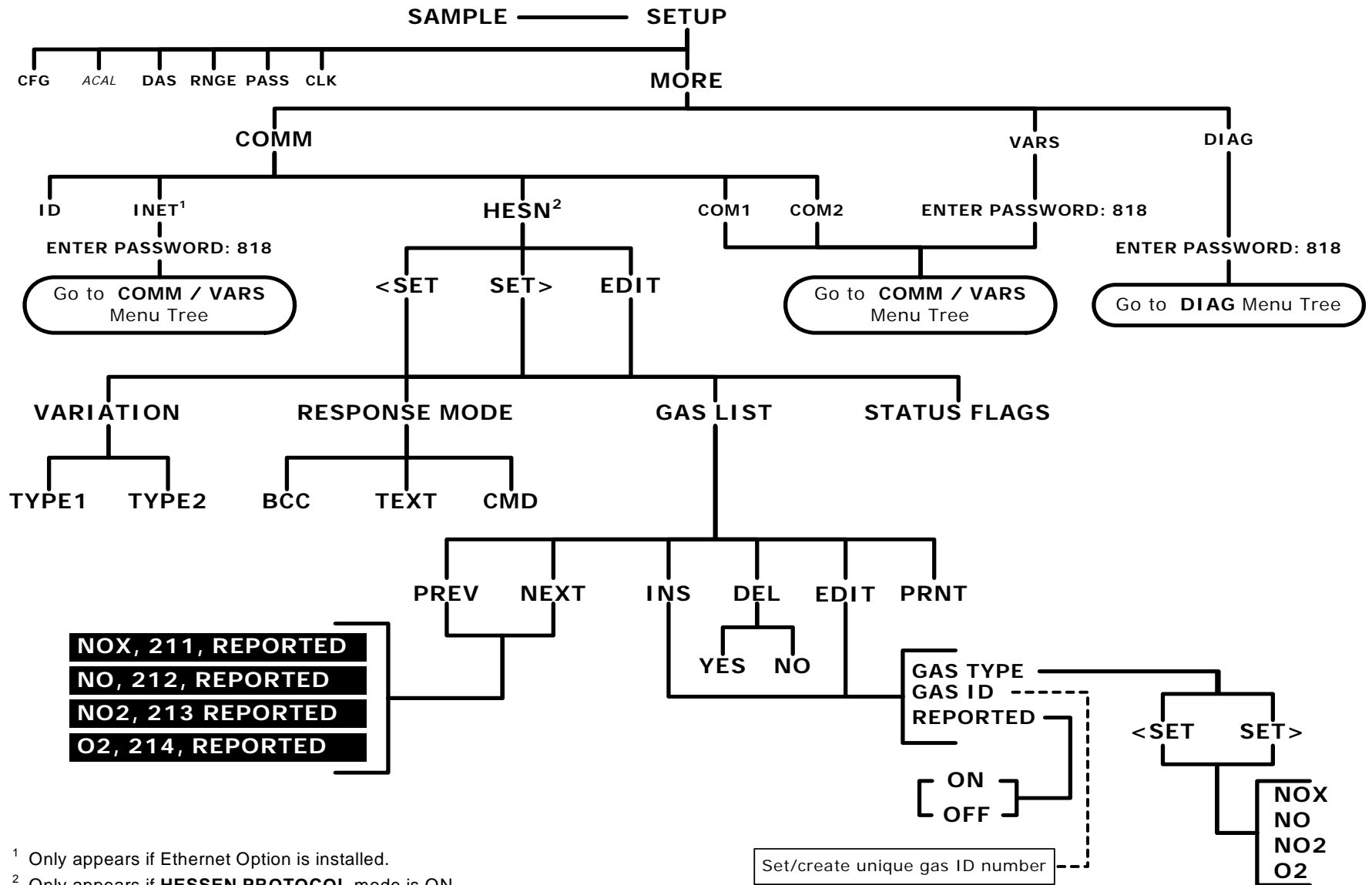


Figure A-5: Secondary Setup Menu → Hessen Protocol Submenu

APPENDIX A-2: TML41M/H Setup Variables For Serial I/O, Revision G

Table A-1: TML41M/H Setup Variables, Revision G

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,	NO, NOX, NOX-NO	Gas measure mode. 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.
CONC_PRECISION	—	3	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.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
LANGUAGE_SELECT	—	ENGL	ENGL, SECD, EXTN	Selects the language to use for the user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
MAINT_TIMEOUT	Hours	2	0.1–100	Time until automatically switching out of software-controlled maintenance mode.
BXTEMP_TPC_GAIN	—	0	0–10	Box temperature compensation attenuation factor.
RCTEMP_TPC_GAIN	—	0	0–10	Reaction cell temperature compensation attenuation factor.
RCPRESS_TPC_GAIN	—	1	0–10	Reaction cell pressure compensation attenuation factor.
SPRESS_TPC_GAIN	—	1	0–10	Sample pressure compensation attenuation factor.
CE_FACTOR1	—	1	0.8–1.2	Moly converter efficiency factor for range 1.
CE_FACTOR2	—	1	0.8–1.2	Moly converter efficiency factor for range 2.
CONV_TIME	—	1 SEC	33 MS, 66 MS, 133 MS, 266 MS, 533 MS, 1 SEC, 2 SEC	Conversion time for PMT detector channel. Enclose value in double quotes (") when setting from the RS-232 interface.
SG_CONV_TIME	—	33 MS	Same as above.	Conversion time for PMT detector channel in single-gas measure modes. Enclose value in double quotes (") when setting from the RS-232 interface.
NEG_NO2_SUPPRESS	—	ON	ON, OFF	ON suppresses negative NO ₂ in during switching mode; OFF does not suppress negative NO ₂ readings
FILT_SIZE	Samples	5 ¹ , 10 ²	1–500	Moving average filter size.

Setup Variable	Numeric Units	Default Value	Value Range	Description
SG_FILT_SIZE	Samples	60	1–500	Moving average filter size in single-gas measure modes.
FILT_ADAPT	—	ON	ON, OFF	ON enables adaptive filter; OFF disables it.
FILT_OMIT_DELTA	PPM	10 ¹ , 0.8 ²	5–100 ¹ , 0.1–100 ²	Absolute change in concentration to omit readings.
FILT_OMIT_PCT	%	10	1–100	Percent change in concentration to omit readings.
FILT_SHORT_DELT	PPM	5 ¹ , 0.5 ²	5–100 ¹ , 0.1–100 ²	Absolute change in concentration to shorten filter.
FILT_SHORT_PCT	%	5 ¹ , 7 ²	1–100	Percent change in concentration to shorten filter.
FILT_ASIZE	Samples	2 ¹ , 3 ²	1–500	Moving average filter size in adaptive mode.
SG_FILT_ASIZE	Samples	10	1–500	Moving average filter size in adaptive mode, in single-gas measure modes.
FILT_DELAY	Seconds	60 ¹ , 80 ²	0–200	Delay before leaving adaptive filter mode.
SG_FILT_DELAY	Seconds	60	0–200	Delay before leaving adaptive filter mode in single-gas measure modes.
O2_FILT_ADAPT ⁴	—	ON	ON, OFF	ON enables O ₂ adaptive filter; OFF disables it.
O2_FILT_SIZE ⁴	Samples	60	1–500	O ₂ moving average filter size in normal mode.
O2_FILT_ASIZE ⁴	Samples	10	1–500	O ₂ moving average filter size in adaptive mode.
O2_FILT_DELTA ⁴	%	2	0.1–100	Absolute change in O ₂ concentration to shorten filter.
O2_FILT_PCT ⁴	%	2	0.1–100	Relative change in O ₂ concentration to shorten filter.
O2_FILT_DELAY ⁴	Seconds	20	0–300	Delay before leaving O ₂ adaptive filter mode.
NOX_DWELL	Seconds	4.2 ¹ , 3.5 ²	0.1–30	Dwell time after switching valve to NO _x position.
SG_NOX_DWELL	Seconds	1	0.1–30	Dwell time after switching valve to NO _x position in single-gas measure modes.
NOX_SAMPLE	Samples	2	1–30	Number of samples to take in NO _x mode.
SG_NOX_SAMPLE	Samples	2	1–30	Number of samples to take in NO _x mode in single-gas measure modes.
NO_DWELL	Seconds	4.2 ¹ , 3.0 ²	0.1–30	Dwell time after switching valve to NO position.
SG_NO_DWELL	Seconds	1	0.1–30	Dwell time after switching valve to NO position in single-gas measure modes.
NO_SAMPLE	Samples	2	1–30	Number of samples to take in NO mode.
SG_NO_SAMPLE	Samples	2	1–30	Number of samples to take in NO mode in single-gas measure modes.
USER_UNITS	—	PPM	PPM, MGM	Concentration units for user interface. Enclose value in double quotes ("") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
DIL_FACTOR	—	1	1–1000	Dilution factor. Used only if is dilution enabled with <i>FACTORY_OPT</i> variable.
AZERO_ENABLE	—	ON	ON, OFF	ON enables auto-zero; OFF disables it.
AZERO_FREQ	Minutes	2	0–60	Auto-zero frequency.
AZERO_DWELL	Seconds	4	0.1–60	Dwell time after opening auto-zero valve.
AZERO_POST_DWELL	Seconds	4	0–60	Dwell time after closing auto-zero valve.
AZERO_SAMPLE	Samples	2	1–10	Number of auto-zero samples to average.
SG_AZERO_SAMP	Samples	2	1–10	Number of auto-zero samples to average in single-gas measure modes.
AZERO_FSIZE	Samples	8	1–50	Moving average filter size for auto-zero samples.
AZERO_LIMIT	mV	200	0–1000	Maximum auto-zero offset allowed.
NOX_SPAN1	Conc.	80 ¹ , 16 ²	1–5000	Target NO _x concentration during span calibration of range 1.
NO_SPAN1	Conc.	80 ¹ , 16 ²	1–5000	Target NO concentration during span calibration of range 1.
NO2_SPAN1	Conc.	80 ¹ , 16 ²	1–5000	Target NO ₂ concentration during converter efficiency calibration of range 1.
NOX_SLOPE1	PPM/mV	1	0.25–4	NO _x slope for range 1.
NOX_OFFSET1	mV	0	-10000–10000	NO _x offset for range 1.
NO_SLOPE1	PPM/mV	1	0.25–4	NO slope for range 1.
NO_OFFSET1	mV	0	-10000–10000	NO offset for range 1.
NOX_SPAN2	Conc.	80 ¹ , 16 ²	1–5000	Target NO _x concentration during span calibration of range 2.
NO_SPAN2	Conc.	80 ¹ , 16 ²	1–5000	Target NO concentration during span calibration of range 2.
NO2_SPAN2	Conc.	80 ¹ , 16 ²	1–5000	Target NO ₂ concentration during converter efficiency calibration of range 2.
NOX_SLOPE2	PPM/mV	1	0.25–4	NO _x slope for range 2.
NOX_OFFSET2	mV	0	-10000–10000	NO _x offset for range 2.
NO_SLOPE2	PPM/mV	1	0.25–4	NO slope for range 2.
NO_OFFSET2	mV	0	-10000–10000	NO offset for range 2.
O2_TARG_SPAN_CONC ⁴	%	20.95	0–100	Target O ₂ concentration during span calibration.
O2_SLOPE ⁴	—	1	0.5–2	O ₂ slope.
O2_OFFSET ⁴	%	0	-10–10	O ₂ offset.
O2_RANGE ⁴	%	100	0.1–500	O ₂ concentration range.
STD_O2_CELL_TEMP ⁴	°K	323	1–500	Standard O ₂ cell temperature for temperature compensation.
PHYS_RANGE1	PPM	500 ¹ , 20 ²	5–5000	Low pre-amp range.
PHYS_RANGE2	PPM	5000 ¹ , 200 ²	5–5000	High pre-amp range.
CONC_RANGE1	Conc.	100 ¹ , 20 ²	5–5000 ¹ , 1–500 ²	D/A concentration range 1 or range for NO _x .

Setup Variable	Numeric Units	Default Value	Value Range	Description
RCELL_SET	°C	50 Warnings: 45–55	30–70	Reaction cell temperature set point and warning limits.
MANIFOLD_SET	°C	50 Warnings: 45–55	30–70	Manifold temperature set point and warning limits.
O2_CELL_SET ⁴	°C	50 Warnings: 45–55	30–70	O ₂ sensor cell temperature set point and warning limits.
CONV_TYPE	—	MOLY	NONE, MOLY, CONV, O3KL	Converter type. "CONV" is mini-hicon. Enclose value in double quotes (") when setting from the RS-232 interface.
CONV_SET	°C	315 Warnings: 305–325	0–800	Converter temperature set point and warning limits.
CONV_TEMP_TRIG	Cycles	10	0–100	Number of converter temperature errors required to trigger warning.
BOX_SET	°C	30 Warnings: 7–48	0–70	Nominal box temperature set point and warning limits.
PMT_SET	°C	7 Warnings: 5–12	0–40	PMT temperature warning limits. Set point is not used.
SFLOW_SET	cc/m	290 ¹ , 360 ¹⁺⁴ , 250 ² , 320 ²⁺⁴ Warnings: 350–600, 200–600 ^{1,2} , 300–700 ^{1+4, 2+4}	100–1000	Sample flow warning limits. Set point is not used.
SAMP_FLOW_SLOPE	—	1	0.001–100	Slope term to correct sample flow rate.
OFLOW_SET	cc/m	250 Warnings: 200–600	100–1000	Ozone flow warning limits. Set point is not used.
OZONE_FLOW_SLOPE	—	1	0.001–100	Slope term to correct ozone flow rate.
RCELL_SAMP_RATIO	—	0.53	0.1–2	Maximum reaction cell pressure / sample pressure ratio for valid sample flow calculation.
STD_BOX_TEMP	°K	298 Valid limits: 278–338	1–500	Standard box temperature and valid limits for temperature compensation.
STD_RCELL_TEMP	°K	323 Valid limits: 278–338	1–500	Standard reaction cell temperature and valid limits for temperature compensation.

Setup Variable	Numeric Units	Default Value	Value Range	Description
STD_RCELL_PRESS	"Hg	5 Valid limits: 0.5–12	0.1–50	Standard reaction cell pressure and valid limits for pressure compensation.
STD_SAMP_PRESS	"Hg	29.92 Valid limits: 0.5–32	0.1–50	Standard sample pressure and valid limits for pressure compensation.
RS232_MODE	—	0	0–65535	RS-232 COM1 mode flags. Add values to combine flags. 1 = quiet mode 2 = computer mode 4 = enable security 16 = enable Hessen protocol ³ 32 = enable multidrop 64 = enable modem 128 = ignore RS-232 line errors 256 = disable XON / XOFF support 512 = reserved 1024 = enable RS-485 mode 2048 = even parity, 7 data bits, 1 stop bit 4096 = enable command prompt
BAUD_RATE	—	19200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM1 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0"	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM1 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_MODE2	BitFlag	0	0–65535	RS-232 COM2 mode flags. (Same settings as RS232_MODE)
BAUD_RATE2	—	19200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM2 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT2	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0"	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM2 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_PASS	Password	940331	0–999999	RS-232 log on password.
MACHINE_ID	ID	200	0–9999	Unique ID number for instrument.
COMMAND_PROMPT	—	"Cmd> "	Any character in the allowed character set. Up to 100 characters long.	RS-232 interface command prompt. Displayed only if enabled with RS232_MODE variable. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
REMOTE_CAL_MODE	—	LOW	LOW, HIGH	Range to calibrate during remote calibration. Enclose value in double quotes (") when setting from the RS-232 interface.
PASS_ENABLE	—	OFF	ON, OFF	ON enables passwords; OFF disables them.
STABIL_GAS	—	NOX	NO, NO2, NOX	Selects gas for stability measurement. Enclose value in double quotes (") when setting from the RS-232 interface.
STABIL_FREQ	Seconds	10	1–300	Stability measurement sampling frequency.
STABIL_SAMPLES	Samples	25	2–40	Number of samples in concentration stability reading.
HVPS_SET	Volts	550 ¹ , 600 ² Warnings: 400–700 ¹ , 450–750 ²	0–2000	High voltage power supply warning limits. Set point is not used.
RCELL_PRESS_SET	In-Hg	6 Warnings: 0.5–15	0–100	Reaction cell pressure warning limits. Set point is not used.
RCELL_CYCLE	Seconds	10	0.5–30	Reaction cell temperature control cycle period.
RCELL_PROP	1/°C	1	0–10	Reaction cell PID temperature control proportional coefficient.
RCELL_INTEG	—	0.1	0–10	Reaction cell PID temperature control integral coefficient.
RCELL_DERIV	—	0 (disabled)	0–10	Reaction cell PID temperature control derivative coefficient.
MANIFOLD_CYCLE	Seconds	5	0.5–30	Manifold temperature control cycle period.
MANIFOLD_PROP	1/°C	0.2	0–10	Manifold PID temperature control proportional coefficient.
MANIFOLD_INTEG	—	0.1	0–10	Manifold PID temperature control integral coefficient.
MANIFOLD_DERIV	—	0.5	0–10	Manifold PID temperature control derivative coefficient.
O2_CELL_CYCLE ⁴	Seconds	10	0.5–30	O ₂ cell temperature control cycle period.
O2_CELL_PROP ⁴	—	1	0–10	O ₂ cell PID temperature control proportional coefficient.
O2_CELL_INTEG ⁴	—	0.1	0–10	O ₂ cell PID temperature control integral coefficient.
O2_CELL_DERIV ⁴	—	0 (disabled)	0–10	O ₂ cell PID temperature control derivative coefficient.
SLOPE_CONST	—	8	0.1–100	Slope constant factor to keep visible slope near 1.
SERIAL_NUMBER	—	"00000000"	Any character in the allowed character set. Up to 100 characters long.	Unique serial number for instrument. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
DISP_INTENSITY	—	HIGH	HIGH, MED, LOW, DIM	Front panel display intensity. Enclose value in double quotes (") when setting from the RS-232 interface.
I2C_RESET_ENABLE	—	ON	OFF, ON	I ² C bus automatic reset enable.
ALARM_TRIGGER	Cycles	10	1–100	Number of valve cycles to trigger concentration alarm.
CLOCK_FORMAT	—	"TIME=%H:%M:%S"	Any character in the allowed character set. Up to 100 characters long.	Time-of-day clock format flags. Enclose value in double quotes (") when setting from the RS-232 interface. "%a" = Abbreviated weekday name. "%b" = Abbreviated month name. "%d" = Day of month as decimal number (01 – 31). "%H" = Hour in 24-hour format (00 – 23). "%I" = Hour in 12-hour format (01 – 12). "%j" = Day of year as decimal number (001 – 366). "%m" = Month as decimal number (01 – 12). "%M" = Minute as decimal number (00 – 59). "%p" = A.M./P.M. indicator for 12-hour clock. "%S" = Second as decimal number (00 – 59). "%w" = Weekday as decimal number (0 – 6; Sunday is 0). "%y" = Year without century, as decimal number (00 – 99). "%Y" = Year with century, as decimal number. "%%" = Percent sign.

Setup Variable	Numeric Units	Default Value	Value Range	Description
FACTORY_OPT	—	0, 512	0–65535	Factory option flags. Add values to combine flags. 1 = enable dilution factor 2 = display units in concentration field 4 = zero/span valves installed 8 = low span valve installed 16 = IZS and zero/span valves installed 32 = enable software-controlled maintenance mode 64 = display temperature in converter warning message 128 = enable switch-controlled maintenance mode 256 = enable simultaneous display of all gas concentrations 512 = enable manifold temperature control 1024 = enable O ₂ sensor cell temperature control (temporarily removed) 2048 = enable Internet option
¹ TML41H. ² TML41M. ³ Must power-cycle instrument for these options to fully take effect. ⁴ O ₂ option.				

APPENDIX A-3: TML41M/H Warnings and Test Functions, Revision G

Table A-2: TML41M/H Warning Messages, Revision G

Name	Message Text	Description
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.
WSAMPFLOW	SAMPLE FLOW WARN	Sample flow outside of warning limits specified by SFLOW_SET variable.
WOZONEFLOW	OZONE FLOW WARNING	Ozone flow outside of warning limits specified by OFLOW_SET variable.
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.
WRCELLPRESS	RCELL PRESS WARN	Reaction cell pressure outside of warning limits specified by RCELL_PRESS_SET variable.
WBOXTEMP	BOX TEMP WARNING	Chassis temperature outside of warning limits specified by BOX_SET variable.
WRCELLTEMP	RCELL TEMP WARNING	Reaction cell temperature outside of warning limits specified by RCELL_SET variable.
WMANIFOLDTEMP	MANIFOLD TEMP WARN	Bypass or dilution manifold temperature outside of warning limits specified by MANIFOLD_SET variable.
WO2CELLTEMP ¹	O2 CELL TEMP WARN	O2 sensor cell temperature outside of warning limits specified by O2_CELL_SET variable.
WIZSTEMP	IZS TEMP WARNING	IZS temperature outside of warning limits specified by IZS_SET variable.
WCONVTEMP	CONV TEMP WARNING	Converter temperature outside of warning limits specified by CONV_SET variable.
WPMTTEMP	PMT TEMP WARNING	PMT temperature outside of warning limits specified by PMT_SET variable.
WAUTOZERO	AZERO WRN XXX.X MV	Auto-zero reading above limit specified by AZERO_LIMIT variable. 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 specified by HVPS_SET variable.
WDYNZERO	CANNOT DYN ZERO	Contact closure zero calibration failed while DYN_ZERO was set to ON.
WDYNSPAN	CANNOT DYN SPAN	Contact closure span calibration failed while DYN_SPAN was set to ON.
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.
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.

¹ O₂ option.

Table A-3: TML41M/H Test Functions, Revision G

TEST Function	Message Text	Description
RNG_DATA_OUT_1	"A1:<data point>=<range> <units>"	D/A #1 range.
RNG_DATA_OUT_2	"A2:<data point>=<range> <units>"	D/A #2 range.
RNG_DATA_OUT_3	"A3:<data point>=<range> <units>"	D/A #3 range.
RNG_DATA_OUT_4	"A4:<data point>=<range> <units>"	D/A #4 range.
NONOXCONC ¹	NO=396.5 NOX=396.5	Simultaneously displays NO and NOX concentrations.
RANGE	RANGE=5000 PPM ³ /200 PPM ⁴	D/A range in single or auto-range modes.
RANGE1	RANGE1=5000 PPM ³ /200 PPM ⁴	D/A #1 range in independent range mode.
RANGE2	RANGE2=5000 PPM ³ /200 PPM ⁴	D/A #2 range in independent range mode.
RANGE3	RANGE3=5000 PPM ³ /200 PPM ⁴	D/A #3 range in independent range mode.
O2RANGE ²	O2 RANGE=200.00 %	D/A #4 range for O ₂ concentration.
STABILITY	NOX STB=0.0 PPB	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.
SAMPFLOW	SAMP FLW=40 ³ /250 ⁴ CC/M	Sample flow rate.
OZONEFLOW	OZONE FL=250 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.
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
MANIFOLDTEMP	MF TEMP=50.8 C	Bypass or dilution manifold temperature.
O2CELLTEMP ²	O2 CELL TEMP=50.8 C	O ₂ 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> .
RCELLPRESS	RCEL=7.0 IN-HG-A	Reaction cell pressure.
SAMPPRESS	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.
NO ₂	NO2=0.0 PPM	NO ₂ concentration for current range.
NOX	NOX=396.5 PPM	NOX concentration for current range.
NO	NO=396.5 PPM	NO concentration for current range.
O2SLOPE ²	O2 SLOPE=1.000	O ₂ slope computed during zero/span calibration.

TEST Function	Message Text	Description
O2OFFSET ²	O2 OFFSET=0.00 %	O ₂ offset computed during zero/span calibration.
O2 ²	O2=0.00 %	O ₂ concentration.
TESTCHAN	TEST=3627.1 MV	Value output to <i>TEST_OUTPUT</i> analog output, selected with <i>TEST_CHAN_ID</i> variable.
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.
¹ Factory option. ³ TML41H. ² O ₂ option. ⁴ TML41M.		

APPENDIX A-4: TML41M/H Signal I/O Definitions, Revision G

Table A-4: TML41M/H Signal I/O Definitions, Revision G

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
Internal inputs, U7, J108, pins 9–16 = bits 0–7, default I/O address 322 hex		
	0–7	Spare
Internal outputs, U8, J108, pins 1–8 = bits 0–7, default I/O address 322 hex		
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 ² C peripherals 0 = normal
I2C_DRV_RST	7	0 = hardware reset 8584 chip 1 = normal
Control inputs, U11, J1004, pins 1–6 = bits 0–5, default I/O address 321 hex		
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	2	0 = go into low span calibration 1 = exit low span calibration
REMOTE_RANGE_HI	3	0 = remote select high range 1 = default range
	4–5	Spare
	6–7	Always 1
Control inputs, U14, J1006, pins 1–6 = bits 0–5, default I/O address 325 hex		
	0–5	Spare
	6–7	Always 1
Control outputs, U17, J1008, pins 1–8 = bits 0–7, default I/O address 321 hex		
	0–7	Spare
Control outputs, U21, J1008, pins 9–12 = bits 0–3, default I/O address 325 hex		
	0–3	Spare
Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex		
ST_SYSTEM_OK ²	4	1 = system OK 0 = any alarm condition or in diagnostics mode
ST_CONC_ALARM_1	5	1 = conc. limit 1 exceeded 0 = conc. OK

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
ST_CONC_ALARM_2	6	1 = conc. limit 2 exceeded 0 = conc. OK
	7	Spare
A status outputs, U24, J1017, pins 1–8 = bits 0–7, default I/O address 323 hex		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition
ST_CONC_VALID	1	0 = conc. valid 1 = hold off or other conditions
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	6	0 = in low span calibration 1 = not in low span
ST_O2_CAL ¹	7	0 = in O ₂ calibration mode 1 = in NO _x calibration mode
B status outputs, U27, J1018, pins 1–8 = bits 0–7, default I/O address 324 hex		
	0–7	Spare
Front panel I²C keyboard, default I²C address 4E hex		
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
Relay board digital output (PCF8575), default I²C address 44 hex		
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	3	0 = bypass or dilution manifold heater on 1 = off

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
IZS_HEATER	4	0 = IZS heater on 1 = off
O2_CELL_HEATER ¹	5	0 = O ₂ sensor cell heater on 1 = off
ZERO_VALVE	6	0 = let zero gas in 1 = let sample gas in
SPAN_VALVE	6	0 = let span gas in 1 = let zero 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 _x gas into reaction cell 1 = let NO gas into reaction cell
LOW_SPAN_VALVE	10	0 = let low span gas in 1 = let sample gas in
HIGH_SPAN_VALVE	11	0 = let high span gas in 1 = let sample gas in
	12–15	Spare
Rear board primary MUX analog inputs, MUX default I/O address 32A hex		
PMT_SIGNAL	0	PMT detector
HVPS_VOLTAGE	1	HV power supply output
PMT_TEMP	2	PMT temperature
	3	Spare
	4	Temperature MUX
	5	Spare
O2_SENSOR ¹	6	O ₂ 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
CONV_TEMP	12	Converter temperature
TEST_INPUT_13	13	Diagnostic test input
	14	DAC loopback MUX
REF_GND	15	Ground reference
Rear board temperature MUX analog inputs, MUX default I/O address 326 hex		
BOX_TEMP	0	Internal box temperature
RCELL_TEMP	1	Reaction cell temperature
IZS_TEMP	2	IZS temperature
	3	Spare
O2_CELL_TEMP ¹	4	O ₂ sensor cell temperature
TEMP_INPUT_5	5	Diagnostic temperature input

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
TEMP_INPUT_6	6	Diagnostic temperature input
MANIFOLD_TEMP	7	Bypass or dilution manifold temperature
Rear board DAC MUX analog inputs, MUX default I/O address 327 hex		
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
Rear board analog outputs, default I/O address 327 hex		
CONC_OUT_1, DATA_OUT_1	0	Concentration output #1 (NO _x), Data output #1
CONC_OUT_2, DATA_OUT_2	1	Concentration output #2 (NO) , Data output #2
CONC_OUT_3, DATA_OUT_3	2	Concentration output #3 (NO ₂) , Data output #3
TEST_OUTPUT, CONC_OUT_4 ¹ , DATA_OUT_4	3	Test measurement output, Concentration output #4 (O ₂) , Data output #4
¹ O ₂ option. ² Optional		

APPENDIX A-5: TML41M/H iDAS Parameters, Revision G

Table A-5: TML41M/H DAS Trigger Events, Revision G

NAME	DESCRIPTION
ATIMER	Automatic timer expired
EXITZR	Exit zero calibration mode
EXITLS	Exit low span calibration mode
EXITHS	Exit high span calibration mode
EXITMP	Exit multi-point calibration mode
EXITO2 ¹	Exit O ₂ calibration mode
SLPCHG	Slope and offset recalculated
O2SLPC ¹	O ₂ slope and offset recalculated
EXITDG	Exit diagnostic mode
CONC1W	Concentration exceeds limit 1 warning
CONC2W	Concentration exceeds limit 2 warning
AZEROW	Auto-zero warning
OFLOWW	Ozone flow warning
RPRESW	Reaction cell pressure warning
RTEMPW	Reaction cell temperature warning
MFTMPW	Bypass or dilution manifold temperature warning
O2TMPW ¹	O ₂ sensor cell temperature 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
¹ O ₂ option.	

Table A-6: TML41M/H Idas Data Types, Revision G

NAME	DESCRIPTION	UNITS
PMTDET	PMT detector reading	mV
NXSLP1	NO _x slope for range #1	—
NXSLP2	NO _x slope for range #2	—
NOSLP1	NO slope for range #1	—
NOSLP2	NO slope for range #2	—
NXOFS1	NO _x offset for range #1	mV
NXOFS2	NO _x offset for range #2	mV
NOOFS1	NO offset for range #1	mV
NOOFS2	NO offset for range #2	mV
O2SLPE ¹	O ₂ slope	—
O2OFST ¹	O ₂ offset	Weight %
NXZSC1	Concentration for NO _x reporting range #1 during zero/span calibration, just before computing new slope and offset	PPB
NXZSC2	Concentration for NO _x reporting range #2 during zero/span calibration, just before computing new slope and offset	PPB
NOZSC1	Concentration for NO reporting range #1 during zero/span calibration, just before computing new slope and offset	PPB
NOZSC2	Concentration for NO reporting range #2 during zero/span calibration, just before computing new slope and offset	PPB
N2ZSC1	Concentration for NO ₂ reporting range #1 during zero/span calibration, just before computing new slope and offset	PPB
N2ZSC2	Concentration for NO ₂ reporting range #2 during zero/span calibration, just before computing new slope and offset	PPB
O2ZSCN ¹	O ₂ concentration during zero/span calibration of the O ₂ sensor, just before computing new slope and offset	Weight %
NXCNC1	Concentration for NO _x reporting range #1	PPB
NXCNC2	Concentration for NO _x reporting range #2	PPB
NOCNC1	Concentration for NO reporting range #1	PPB
NOCNC2	Concentration for NO reporting range #2	PPB
N2CNC1	Concentration for NO ₂ reporting range #1	PPB
N2CNC2	Concentration for NO ₂ reporting range #2	PPB
O2CONC ¹	O ₂ concentration	Weight %
STABIL	Concentration stability	PPB
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	Bypass or dilution manifold temperature	°C
O2TEMP ¹	O ₂ sensor cell temperature	°C
IZTEMP	IZS block temperature	°C
CNVEF1	Converter efficiency factor for range #1	—
CNVEF2	Converter efficiency factor for range #2	—
CNVTMP	Converter temperature	°C

NAME	DESCRIPTION	UNITS
PMTTMP	PMT temperature	°C
SMPFLW	Sample flow rate	cc/m
SMPPRS	Sample pressure	"Hg
BOXTMP	Internal box temperature	°C
HVPS	High voltage power supply output	Volts
REFGND	Ground reference (REF_GND)	mV
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
¹ O ₂ option.		

APPENDIX A-6: Terminal Command Designators, Revision G

Table A-7: Terminal Command Designators, Revision G

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 iDAS configuration
	RECORDS ["name"]	Print number of iDAS 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 iDAS records
	CANCEL	Halt printing iDAS 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 iDAS configuration
	CHANNELBEGIN propertylist CHANNELEND	Upload single iDAS channel
	CHANNELDELETE ["name"]	Delete iDAS 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.

TERMINAL KEY ASSIGNMENTS	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
COMPUTER MODE KEY ASSIGNMENTS	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

USER NOTES:

APPENDIX A-7: Setting up Communications

Setting up the communications for integration with a Teledyne Monitor Labs system.

The following describes the settings that should be entered into the analyzer's COMM sub menus.

Ethernet Communication

The following settings must be entered into the comm. menus in order to achieve Ethernet communication. Analyzers shipped with systems are setup at the factory.

ID: Analyzer specific. See table below.

INET:

DHCP: OFF

INST IP: site specific

GATEWAT IP: leave as factory default or site specific.

SUBNET MASK: leave as factory default or site specific.

TCP PORT: 3000

ONLINE: ON

BAUD RATE: 115200

Analyzer ID Table

	SO ₂	TRS	NO _x	CO	CO ₂
MACHINE ID	100	102	200	300	360
GAS ID	150	160	141	130	120

Serial Communication

Teledyne Monitor Labs systems communicate to the analyzers via the PLC using serial communication. The communication protocol used in the analyzer is the Hessen two protocol. When an analyzer is first turned on, the Hessen variables do not exist in the non-volatile memory. In order to create these variables, the Hessen protocol must be turned on in COM 1 and then the power must be cycled.

HESN:

HESSEN VARIATION: TYP2

HESSEN RESPONSE MODE: BCC

HESSEN GAS LIST:

Any gas to be reported via the serial string needs to be entered here. Enter the gas, a gas ID and whether it is reported or not. Please note that this ID is different from the machine or internet ID stated above. For example: SO₂, 150, reported. See table below for gas ID's

needed for each analyzer. When more than one analyzer is in a system, the second analyzer will be 2XX e.g. SO2, 250, Reported. Refer to system prints for system specific ID's.

HESSEN STATUS FLAGS:

Set any the flag number to 0001 for any warning that should sent out on the serial string as a common analyzer fault. All other flags should be set to 0000 except for the PPM UNITS which should be set to 4000. Please see table below for TML recommended list of analyzer specific flags which should be set to 0001

COM1:

COM1 MODE: *This number is a hexadecimal based on the following settings. It may change with software revisions and therefore is not listed here.

QUITE MODE: ON

COMPUTER MODE: ON

SECURITY MODE: OFF

HESSEN PROTOCOL: ON

E,7,1 MODE: OFF

RS-485 MODE: OFF

MULTIDROP MODE: ON

ENABLE MODEM: OFF

ERROR CHECKING: OFF

XON/XOFF HANDSHAKE: OFF

HARDWARE HANDSHAKE: OFF

HARDWARE FIFO: ON

COMMAND PROMPT: OFF

COM1 BAUD RATE: 2400

Warning / ID	SO ₂	TRS	NO _x	CO	CO ₂
PMT DET	X	X			
UV LAMP	X	X			
BOX TEMP	X	X	X	X	X
PMT TEMP	X	X	X		
RCELL TEMP	X	X	X		
SAMPLE FLOW	X	X	X	X	X
SAMPLE PRESSURE	X	X	X	X	X
HVPS	X	X	X		
MANIFOLD TEMP			X		
CONV TEMP			X		
RCELL PRESSURE	X *High Range		X		
OZONE FLOW			X		
OZONE GEN OFF			X		
SYNC WARN				X	X
SOURCE WARN				X	X
BENCH TEMP				X	X
WHEEL TEMP				X	X
SAMPLE TEMP				X	X
PHOTO TEMP				X	X
ID (machine or internet)	100	102	200	300	360
ID (Hessen Gas)	150	160	141	130	120

APPENDIX B: Spare Parts and Expendables

**NOTE**

Use of replacement parts other than those supplied by Teledyne-ML may result in non-compliance with European standard EN 61010-1.

The following listings contain spare parts for individual ordering as well as recommended stocking levels for operation of multiple analyzers to minimize downtime for any one analyzer unit.

The expendables (chemicals, filters, O-rings etc) are not included in the spare parts listing, neither are optional analyzer components as listed in Chapter 5.

- TML41MSP – Spare Parts List, TML41M
- TML41HSP – Spare Parts List, TML41H

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TML41M ANALYZER SPARE PARTS LIST

REVISION HISTORY

LTR	DESCRIPTION	DATE	INCORP	APPR
A	Release Per DCN TML41MSPA/ECO 6605	7/14/2006	CAD	JN
B	Skipped to match vendor's REV level	N/A	N/A	N/A
C	Skipped to match vendor's REV level	N/A	N/A	N/A
D	Skipped to match vendor's REV level	N/A	N/A	N/A
E	Release Per DCN TML41MSPE/ECO 6648	2/8/2007	CAD	JN
F	Updated Per DCN TML41MSPF/ECO 6679	10/1/2007	JN	JN
G	Updated Per DCN TML41MSPG/ECO 6700	3/3/2008	CAD	JN
H	Updated Per DCN TML41MSPH/ECO 6723	5/19/2008	CAD	JN
J	Skipped to match vendor's REV level	N/A	N/A	N/A
K	Skipped to match vendor's REV level	N/A	N/A	N/A
L	Updated Per DCN TML41MSPL/ECO 6750	8/6/2008	CAD	JN
M	Updated Per DCN TML41MSPM/ECO 6842	6/25/2009	CAD	JN

TML41M INDIVIDUAL SPARE PARTS LIST

Part Number	Description	Level
000940300	ORIFICE, 20 MIL, (SAMPLE FLOW)	2
000940400	ORIFICE, 4 MIL, PERMAPURE PURGE & O2 OPTION	2
000940500	ORIFICE, 7 MIL, OZONE FLOW/BYPASS FLOW	2
000941200	CD, ORIFICE, .008, RED/NONE	3
001330000	SLEEVE, REACTION CELL	1
001761800	ASSY, FLOW CTL, 90CC, OZONE DRYER	3
002270100	GASKET, WINDOW (PKG OF 12)	2
009690200	KIT, TFE FILTER (FL19) ELEM, 47MM (100)	3
009690300	KIT, TFE FILTER ELEMENT, 47MM, 1 UM (30)	1
011310000	ASSY, OZONE DRYER W/FLOW CONTROL	2
011420600	ASSY, NOX REACTION CELL TML41H/M	3
011630000	GASKET, HVPS INSULATOR	1
011930000	PMT, (R928), NOX	2
013140000	ASSY, COOLER FAN	2
014080100	ASSY, HVPS	2
016290000	WINDOW, SAMPLE FILTER	2
016300800	ASSY, SAMPLE FILTER, 47MM (1 UM)	2
018080000	KIT, DESSICANT BAGGIES (12)	1
018720100	ASSY, MOLY CONVERTER, W/O3 DESTRUCTOR	3
037860000	ORING, TFE RETAINER, SAMPLE FILTER	1
040030800	PCA, FLOW/PRESSURE	3
040300100	ASSY.,CONFIG PLUG FOR 045230200, AC MAIN 100-115V 50/60HZ	3
040300200	ASSY.,CONFIG PLUG FOR 045230200, AC MAIN 220-240V 50/60HZ	3
040300300	ASSY.,CONFIG PLUG FOR 045230200, SINGLE HEATER	3
040410300	ASSY, VACUUM MANIFOLD, TM41M	3
040420200	ASSY, O3 GENERATOR	2
040900000	ORIFICE HOLDER, TML41	3
041710000	ASSY, CPU, CONFIGURATION	3
041920000	ASSY, THERMISTOR, REACTION CELL	2
042580000	PCA, KEYBOARD, E SERIES	3
042680100	ASSY, VALVE	2
042900100	PROGRAMMED FLASH, E SERIES	3
043170000	MANIFOLD, REACTION CELL	3
043940000	PCA, INTERFACE, ETHERNET	3
044340000	ASSY., HTR, BYPASS MANIFOLD, TML41H/M	3
044430200	ASSY., BYPASS MANIFOLD, TML41M	3
044540000	ASSY., THERMISTOR, BYPASS MANIFOLD	2
044610000	ASSY, VALVES, MOLYCON	2
045210000	INSTRUCTION MANUAL, TML41H/M, NOX	2
045500500	ASSY, ORIFICE HOLDER (NO ORIFICE)	1
048620200	PCA, SERIAL INTERFACE W/MD	3
049310100	PCA, TEC CONTROL, E SERIES	3
051210000	ASSY, OZONE DESTRUCTOR	3
052930200	ASSY, BAND HEATER TYPE K	3
054180100	DISK-ON-CHIP, w/SOFTWARE, TML41M	2
058021100	PCA, MOTHERBOARD, E SERIES, GEN 5-I	3
884-017300	PUMP ASSY, EXTERNAL, 115V/60 HZ, THOMAS	2
98415105-1	EXTERNAL SCRUBBER ASSY., CHARCOAL	2
CN0000458	CONNECTOR, REAR PANEL, 12 PIN	3

TML41M INDIVIDUAL SPARE PARTS LIST

Part Number	Description	Level
CN0000520	CONNECTOR, REAR PANEL, 10 PIN	3
DS0000025	DISPLAY	3
FL0000001	FILTER, FLOW CONTROL	2
FL0000003	FILTER, DFU	1
FM0000004	FLOWMETER	3
FT0000010	FITTING, FLOW CONTROL	3
HW0000005	FOOT, CHASSIS	3
HW0000020	SPRING, FLOW CONTROL	2
HW0000030	ISOLATOR, SENSOR ASSY	3
HW0000099	STAND-OFF, #6-32 X .5, HEX, SS	3
KIT000095	KIT, COOLER REPLACEMENT	2
KIT000253	KIT, SPARE PS37, E SERIES	3
KIT000254	POWER SUPPLY, SWITCHING, 12V/60W	3
OR0000001	ORING, FLOW CONTROL	1
OR0000002	ORING, REACTION CELL SLEEVE	1
OR0000034	ORING, (USED W/ FT10)	1
OR0000039	ORING, FLOW CONTROL	1
OR0000086	ORING,2-006, CV-75 COMPOUND	1
OR0000094	ORING, SAMPLE FILTER	1
PU0000071	PUMP, EXTERNAL, ULTRAQUIET, KNF, 115V/60HZ	2
PU0000073	REBUILD KIT FOR PU71	1
SW0000051	SWITCH, POWER, CIRC BR	3
SW0000059	PRESSURE XDUCER, 0-15 PSIA	2
002730000	FILTER, 665NM	R2
040010000	ASSY, FAN, REAR PANEL	R1
040400000	ASSY, HEATERS/THERMAL SWITCH, REACTION CELL	R2
041800500	PCA, PMT PREAMP, TML41	R2
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >467	R2
045500200	ASSY., ORIFICE HOLDER, 7 MIL, OZONE FLOW (2 required)	R1
047150000	KIT, EXPENDABLES, TML41	R1
062390000	ASSY, MOLY GUTS W/WOOL, TML41	R2
98000242	KIT, PUMP SERVICE, THOMAS PUMP	R2
850-056500	REFILL KIT, ACTIVATED CHARCOAL, 1 LB.	R1
KIT000019	REPLACEMENT COOLER ASSY.	R2
KIT000052	KIT, REBUILD REACTION CELL, TML41M	R2
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK	R1
OR0000044	ORING, REACTION CELL MANIFOLD	R1
OR0000058	ORING, SMAPLE FILTER	R1
OR0000083	ORING, PMT SIGNAL & OPTIC LED	R1
RL0000015	RELAY, DPDT, GORDOS PR	R2

INDEX OF OPTIONS FOR TML 41M

Option	Description
41	Current Loop Analog Output
50	Zero/Span Valve
64B	Zero Air Scrubber
65	Oxygen Sensor
CO2	Carbon Dioxide Sensor
DIL	Dilution Option

TML 41M INDIVIDUAL OPTIONS SPARE PARTS LIST

Option	Part Number	Description	Level
41	KIT000219	PCA, 4-20MA OUTPUT, (E-SERIES)	3
50	009450300	ASSY, SAMPLE/CAL VALVE	2
50	042680000	ASSY, VALVE, FOR SAMPLE/CAL VALVE ASSY	2
50	KIT000231	KIT, RETROFIT, TML41M/H Z/S VALVE	3
64B	004330000	ZERO AIR SCRUBBER (NO/NO2)	3
64B	005960000	KIT, EXPENDABLE, ACTIVATED CHARCOAL (6 LBS)	R1
64B	005970000	KIT, EXPENDABLE, PURAFIL (6 LBS)	R1
64B	OR0000025	ORING, ZERO AIR SCRUBBER	R1
65	000940700	ORIFICE, 5 MIL, FLOW CONTROL, O2 OPTION	R2
65	001763000	ASSY., FLOW CTL, 110 CC, 1/8 - B	2
65	043420000	ASSY., HEATER/THERMISTOR, O2 OPTION	3
65	OP0000030	OXYGEN TRANSDUCER	3
86	059940000	OPTION, SAMPLE GAS CONDITIONER, TML41M	3
CO2	054250000	OPTION, CO2 SENSOR 20% VAISALA	3
CO2	OP0000033	CO2 MODULE, 0-20%, VAISALA	R1
CO2	OR0000101	ORING, CO2 OPTION	2
DIL	000940100	ORIFICE, 3 MIL, DILUTION & VACUUM MANIFOLDS & IZS	3
DIL	045500400	ASSY, ORIFICE HOLDER, 3 MIL, DIL MANIFOLD	3
DIL	046480000	ASSY, DILUTION MANIFOLD	

Levels marked with an "R" are TML recommended parts to have on hand for typical repairs and maintenance.

Level 1: General maintenance supplies and expendables such as filters, O-rings, lamps, etc.

Level 2: Critical items that are known from experience to have a higher failure rate, such as pumps, heaters, converters, valves, and circuit boards.

Level 3: Other miscellaneous items not included in Level 1 or 2. This level includes other spare parts that are not expected to fail over a given time frame.

TML41H ANALYZER SPARE PARTS LIST

REVISION HISTORY

LTR	DESCRIPTION	DATE	INCORP	APPR
A	Release Per DCN TML41HSPA/ECO 6605	7/14/2006	CAD	JN
B	Updated Per DCN TML41HSPB/ECO 6626	10/12/2006	CAD	JN
C	Skipped to match vendor's REV level	N/A	N/A	N/A
D	Skipped to match vendor's REV level	N/A	N/A	N/A
E	Updated Per DCN TML41HSPE/ECO 6648	2/23/2007	CAD	JN
F	Updated Per DCN TML41HSPF/ECO 6679	10/1/2007	JN	JN
G	Updated Per DCN TML41HSPG/ECO 6700	3/3/2008	CAD	JN
H	Updated Per DCN TML41HSPH/ECO 6723	5/19/2008	CAD	JN
J	Skipped to match vendor's REV level	N/A	N/A	N/A
K	Skipped to match vendor's REV level	N/A	N/A	N/A
L	Updated Per DCN TML41HSPL/ECO 6750	8/6/2008	CAD	JN
M	Updated Per DCN TML41HSPM/ECO 6842	6/25/2009	CAD	JN

TML41H INDIVIDUAL SPARE PARTS LIST

Part Number	Description	Level
000940100	ORIFICE, 3 MIL, SAMPLE FLOW	2
000940400	ORIFICE, 4 MIL, PERMAPURE PURGE & O2 OPTION	2
001330000	SLEEVE, REACTION CELL	3
001761800	ASSY, FLOW CTL, 90CC, OZONE DRYER	2
002270100	GASKET, WINDOW (PKG OF 12)	1
008830000	COLD BLOCK	3
009690200	KIT, TFE FILTER (FL19) ELEM, 47MM (100)	1
009690300	KIT, TFE FILTER ELEMENT, 47MM, 1 UM (30)	2
011310000	ASSY, OZONE DRYER W/FLOW CONTROL	3
011420600	ASSY, NOX REACTION CELL TML41H/M	1
011630000	GASKET, HVPS INSULATOR	2
011930000	PMT, (R928), NOX	2
013140000	ASSY, COOLER FAN	2
014080100	ASSY, HVPS	2
016290000	WINDOW, SAMPLE FILTER	2
016300800	ASSY, SAMPLE FILTER, 47MM (1 UM)	3
018720100	ASSY, MOLY CONVERTER W/O3 DESTRUCTOR	3
037860000	ORING, TFE RETAINER, SAMPLE FILTER	3
040030800	PCA, FLOW/PRESSURE	3
040300100	ASSY.,CONFIG PLUG FOR 045230200, AC MAIN 100-115V 50/60HZ	3
040300200	ASSY.,CONFIG PLUG FOR 045230200, AC MAIN 220-240V 50/60HZ	3
040300300	ASSY.,CONFIG PLUG FOR 045230200, SINGLE HEATER	3
040410200	ASSY, VACUUM MANIFOLD, TM41H	2
040420200	ASSY, O3 GENERATOR	3
040900000	ORIFICE HOLDER, TML41	3
041710000	ASSY, CPU, CONFIGURATION	3
041920000	ASSY, THERMISTOR, REACTION CELL	2
042580000	PCA, KEYBOARD, E SERIES	2
042680100	ASSY, VALVE	3
042900100	PROGRAMMED FLASH, E SERIES	3
043170000	MANIFOLD, REACTION CELL	3
043430100	DISK-ON-CHIP, w/SOFTWARE, TML41H	3
043940000	PCA, INTERFACE, ETHERNET	2
044340000	ASSY., HTR, BYPASS MANIFOLD, TML41H/M	2
044430100	ASSY., BYPASS MANIFOLD, TML41H	3
044440000	ASSY., HICON CONVERTER W/O3 DISTRUCTOR	3
044540000	ASSY., THERMISTOR, BYPASS MANIFOLD	2
044610000	ASSY, VALVES, MOLYCON	2
045210000	INSTRUCTION MANUAL, TML41H/M, NOX	2
045500500	ASSY, ORIFICE HOLDER (NO ORIFICE)	1
048620200	PCA, SERIAL INTERFACE W/MD	3
049310100	PCA, TEC CONTROL, E SERIES	3
051210000	ASSY, OZONE DESTRUCTOR	3
052930200	ASSY, BAND HEATER TYPE K	3
058021100	PCA, MOTHERBOARD, E SERIES, GEN 5-I	3
884-017300	PUMP ASSY, EXTERNAL, 115V/60 HZ, THOMAS	2
98415105-1	EXTERNAL SCRUBBER ASSY., CHARCOAL	2
CN0000458	CONNECTOR, REAR PANEL, 12 PIN	3

TML41H INDIVIDUAL SPARE PARTS LIST

Part Number	Description	Level
CN0000520	CONNECTOR, REAR PANEL, 10 PIN	3
DS0000025	DISPLAY	3
FL0000001	FILTER, FLOW CONTROL	2
FL0000003	FILTER, DFU	1
FM0000004	FLOWMETER	3
FT0000010	FITTING, FLOW CONTROL	3
HW0000005	FOOT, CHASSIS	3
HW0000020	SPRING, FLOW CONTROL	2
HW0000030	ISOLATOR, SENSOR ASSY	3
KIT000095	KIT, COOLER REPLACEMENT	2
KIT000253	KIT, SPARE PS37, E SERIES	3
KIT000254	POWER SUPPLY, SWITCHING, 12V/60W	3
OR0000001	ORING, FLOW CONTROL	1
OR0000002	ORING, REACTION CELL SLEEVE	1
OR0000034	ORING, (USED W/ FT10)	1
OR0000039	ORING, FLOW CONTROL	1
OR0000086	ORING, 2-006, CV-75 COMPOUND	1
OR0000094	ORING, SAMPLE FILTER	1
PU0000071	PUMP, EXTERNAL, ULTRAQUIET, KNF, 115V/60HZ	2
PU0000073	REBUILD KIT FOR PU71	1
SW0000051	SWITCH, POWER, CIRC BR	3
SW0000059	PRESSURE XDUCER, 0-15 PSIA	2
000940500	ORIFICE, 7 MIL, OZONE FLOW/BYPASS FLOW	R1
002730000	FILTER, 665NM	R1
040010000	ASSY, FAN, REAR PANEL	R2
040400000	ASSY, HEATERS/THERMAL SWITCH, REACTION CELL	R2
041800500	PCA, PMT PREAMP, TML41	R2
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >467	R2
045500200	ASSY., ORIFICE HOLDER, 7 MIL, OZONE FLOW	R1
045500400	ASSY, ORIFICE HOLDER, 3 MIL, SAMPLE, BYPASS MANIFOLD	R1
047150000	KIT, EXPENDABLES, TML41	R1
047210000	ASSY, MINI HICON GUTS, GROUNDED	R2
98000242	KIT, PUMP SERVICE, THOMAS PUMP	R2
850-056500	REFILL KIT, ACTIVATED CHARCOAL, 1 LB.	R1
KIT000019	REPLACEMENT COOLER ASSY.,	R2
KIT000067	KIT, REBUILD REACTION CELL, TML41H	R2
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK	R1
OR0000044	ORING, REACTION CELL MANIFOLD	R1
OR0000058	ORING, SAMPLE FILTER	R1
OR0000083	ORING, PMT SIGNAL & OPTIC LED	R1
RL0000015	RELAY, DPDT, GORDOS PR	R2

INDEX OF OPTIONS FOR TML 41H

Option	Description
41	Current Loop Analog Output
50	Zero/Span Valve
64B	Zero Air Scrubber
65	Oxygen Sensor
CO2	Carbon Dioxide Sensor
DIL	Dilution Option

TML 41H INDIVIDUAL OPTIONS SPARE PARTS LIST

Option	Part Number	Description	Level
41	KIT000219	PCA, 4-20MA OUTPUT, (E-SERIES)	3
50	009450300	ASSY, SAMPLE/CAL VALVE	2
50	042680000	ASSY, VALVE, FOR SAMPLE/CAL VALVE ASSY	2
50	KIT000231	KIT, RETROFIT, TML41H	3
64B	004330000	ZERO AIR SCRUBBER (NO/NO2)	3
64B	005960000	KIT, EXPENDABLE, ACTIVATED CHARCOAL (6 LBS)	R1
64B	005970000	KIT, EXPENDABLE, PURAFIL (6 LBS)	R1
64B	OR0000025	ORING, ZERO AIR SCRUBBER	R1
65	000940700	ORIFICE, 5 MIL, FLOW CONTROL, O2 OPTION	R2
65	001763000	ASSY., FLOW CTL, 110 CC, 1/8 - B	2
65	043420000	ASSY., HEATER/THERMISTOR, O2 OPTION	3
65	OP0000030	OXYGEN TRANSDUCER	3
CO2	054250000	OPTION, CO2 SENSOR 20% VAISALA	3
CO2	OP0000033	CO2 MODULE, 0-20%, VAISALA	3
CO2	OR0000101	ORING, CO2 OPTION	R1
DIL	000940100	ORIFICE, 3 MIL, DILUTION & VACUUM MANIFOLDS & IZS	2
DIL	045500400	ASSY, ORIFICE HOLDER, 3 MIL, DIL MANIFOLD	3
DIL	046480000	ASSY, DILUTION MANIFOLD	3

Levels marked with an "R" are TML recommended parts to have on hand for typical repairs and maintenance.

Level 1: General maintenance supplies and expendables such as filters, O-rings, lamps, etc.

Level 2: Critical items that are known from experience to have a higher failure rate, such as pumps, heaters, converters, valves, and circuit boards.

Level 3: Other miscellaneous items not included in Level 1 or 2. This level includes other spare parts that are not expected to fail over a given time frame.

CUSTOMER: _____ PHONE: _____

CONTACT NAME: _____ FAX NO. _____

SITE ADDRESS: _____

MODEL TYPE: _____ SERIAL NO.: _____ FIRMWARE REVISION: _____

1. Are there any failure messages? _____

_____ (Continue on back if necessary)

PLEASE COMPLETE THE FOLLOWING TABLE:

TEST FUNCTION	RECORDED VALUE	UNITS	ACCEPTABLE VALUE
NO _x STAB		PPB/PPM	≤ 1 PPB WITH ZERO AIR
SAMPLE FLOW		CM ³	500 ± 50
OZONE FLOW		CM ³	80 ± 15
PMT SIGNAL WITH ZERO AIR		MV	-20 to 150
PMT SIGNAL AT SPAN GAS CONC		MV PPB	0-5000MV 0-5,000 PPM ¹ , 200 PPM ²
NORM PMT SIGNAL AT SPAN GAS CONC		MV PPB	0-5000MV 0-5,000 PPM ¹ , 200 PPM ²
AZERO		MV	-20 to 150
HVPS		V	400 to 900
RCELL TEMP		°C	50 ± 1
BOX TEMP		°C	AMBIENT ± 5°C
PMT TEMP		°C	7 ± 2°C
O ₂ CELL TEMP ³		°C	30°C to 70°C
IZS TEMP ³		°C	50 ± 1°C
MOLY TEMP		°C	315 ± 5°C
RCEL		IN-HG-A	<10
SAMP		IN-HG-A	AMBIENT ± 1
NO _x SLOPE			1.0 ± 0.3
NO _x OFFSET		mV	50 to 150
NO SLOPE			1.0 ± 0.3
NO OFFSET		mV	50 to 150
O ₂ SLOPE ³			0.5 to 2.0
O ₂ OFFSET ³		%	-10 to + 10
PMT SIGNAL DURING ETEST		MV	2000 ± 1000
PMT SIGNAL DURING OTEST		MV	2000 ± 1000
REF_4096_MV ⁴		MV	4096mv ±2mv and Must be Stable
REF_GND ⁴		MV	0± 0.5 and Must be Stable

¹ TML41H

² TML41M

³ If option is installed

⁴ Located in Signal I/O list under **DIAG** menu

TELEDYNE ML CUSTOMER SERVICE

EMAIL: tml_support@teledyne.com

PHONE: (303) 792-3300 TOLL FREE: (800) 846-6062 FAX: (303) 799-4853

APPENDIX D: Diagrams and Schematics

Table D-1: List of Included Diagrams and Schematics

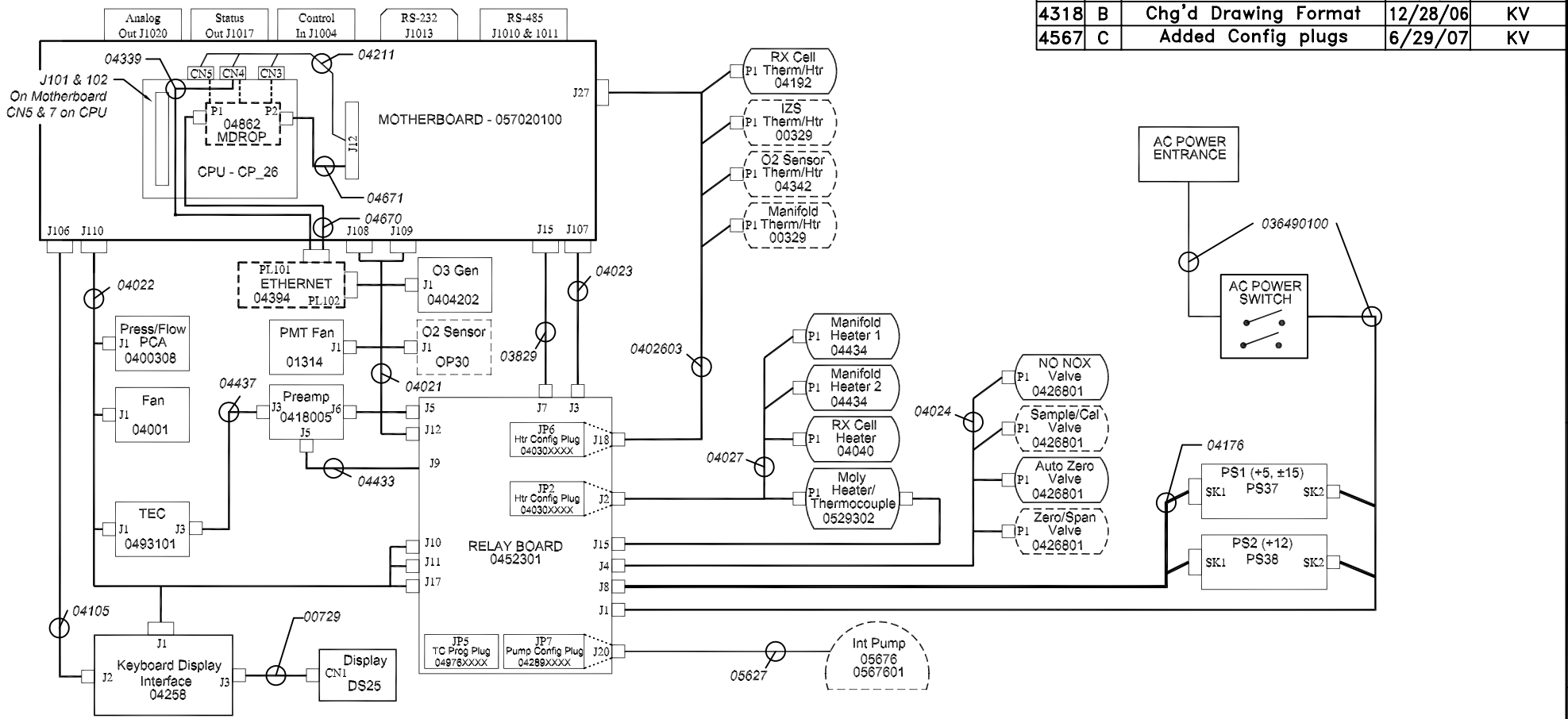
DOCUMENT #	DOCUMENT TITLE
04504	Document, TML41M/H Electronic Interconnect Diagram
04496	Document, TML41M/H Electronic Interconnect Listing
01669	PCA 016680300, Ozone generator board
01840	PCA Thermo-electric cooler board
03632	PCA 03631, 0-20mA Driver
03956	PCA 039550200, Relay Board
05703	PCA 05702, Motherboard, E-series, Gen4
04259	PCA 04258, Keyboard & Display Driver
04354	PCA 04003, Pressure/Flow Transducer Interface
04395	PCA 4394, Ethernet board (optional equipment)
04181	PCA 041800200, PMT pre-amplifier board
04468	PCA, 04467, Analog Output E-Series

USER NOTES:

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REVISIONS

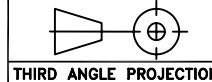
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	Initial release	7/9/02	CAC
4318	B	Chg'd Drawing Format	12/28/06	KV
4567	C	Added Config plugs	6/29/07	KV



PRINTED DOCUMENTS ARE UNCONTROLLED

- KEY:
- All part numbers in *Italic* identify cables that are referred to in the accompanying document 04496
 - All items in Dashed boxes are optional.

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 an information contained in it may not be duplicated without proper authorization.



PART DASH NO	QTY REQD PER ASSY	NEXT FINAL	NEXT ASSY	USED ON	APPLICATION

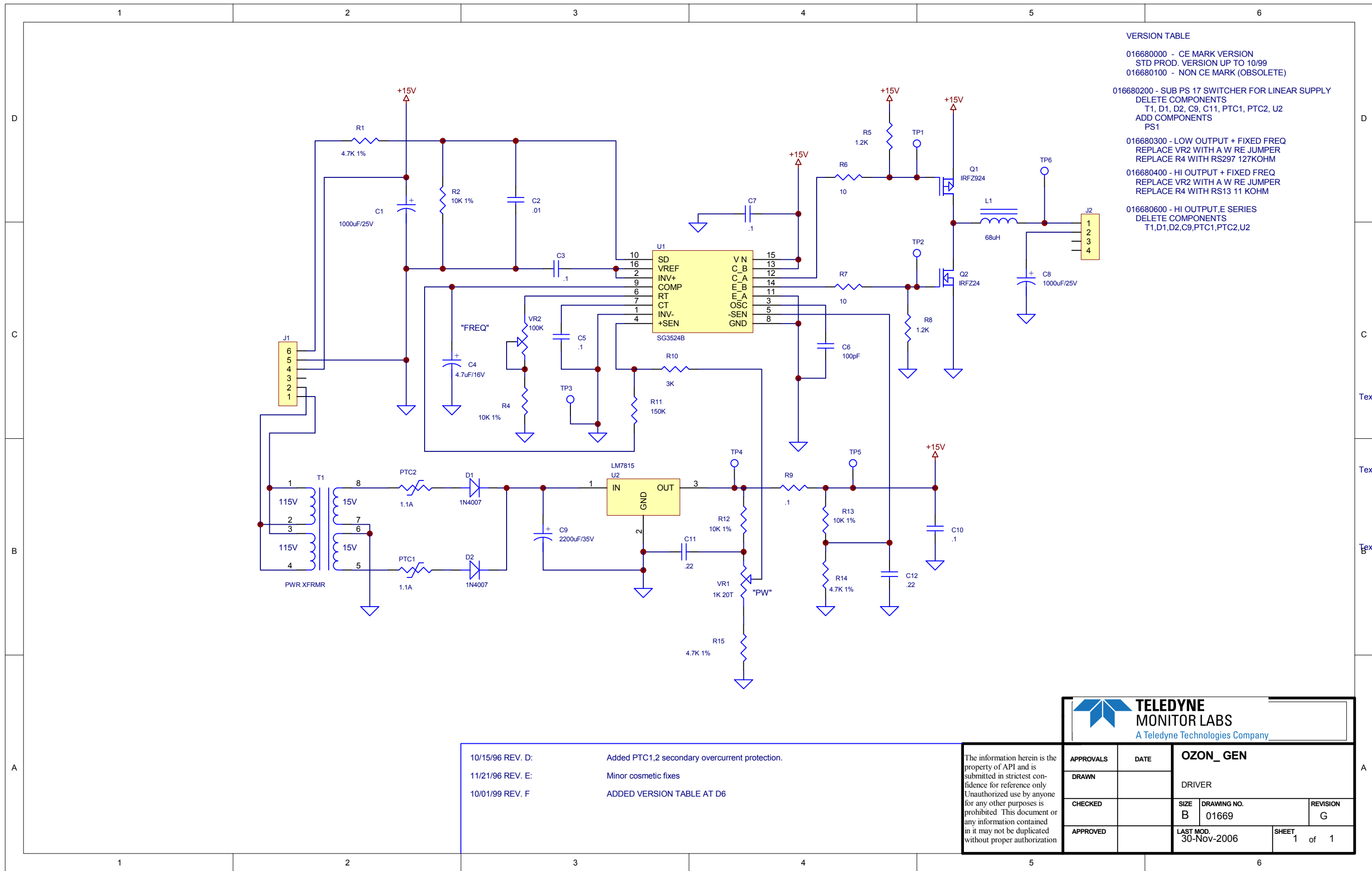
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT: NA
TOLERANCES ARE: FRACTIONS ± 1/32 DECIMALS ± .03 ANGULAR ± 0° 30'	APPROVALS: KV DATE: 12/28/06
DO NOT SCALE DRAWING	DRAWN: KV
TREATMENT: N/A	CHECK: 12/28/06
FINISH: N/A	CCB:
SIMILAR TO:	ISSUED:

TITLE: Interconnect Drawing, TML41	
SIZE: B	CAGE CODE NO. 1JZF4
DWG. NO. 04504	REV C
SCALE: NONE	FILE: 04504 SHEET 1 OF 1

Revision	Description				Checked	Date	DCN		
B	Initial Release as stand-alone document & minor corrections					9/5/2003	2784		
C	Change to expanded relay bd.				KV	7/15/2004	3195		
D	Updated Part Numbers added 00729				KV	12/28/2006	4318		
		CONNECTION FROM				CONNECTION TO			
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
00729	CBL, KEYBOARD/DISPLAY								
D7	Display	Display	DS0000025	CN1	1	Keyboard/Interface	042580000	J3	1
D6	Display	Display	DS0000025	CN1	2	Keyboard/Interface	042580000	J3	2
D5	Display	Display	DS0000025	CN1	3	Keyboard/Interface	042580000	J3	3
D4	Display	Display	DS0000025	CN1	4	Keyboard/Interface	042580000	J3	4
D3	Display	Display	DS0000025	CN1	5	Keyboard/Interface	042580000	J3	5
D2	Display	Display	DS0000025	CN1	6	Keyboard/Interface	042580000	J3	6
D1	Display	Display	DS0000025	CN1	7	Keyboard/Interface	042580000	J3	7
D0	Display	Display	DS0000025	CN1	8	Keyboard/Interface	042580000	J3	8
DISP WRITE	Display	Display	DS0000025	CN1	9	Keyboard/Interface	042580000	J3	9
DGND	Display	Display	DS0000025	CN1	10	Keyboard/Interface	042580000	J3	10
Spare	Display	Display	DS0000025	CN1	11	Keyboard/Interface	042580000	J3	11
DISP_BUSY	Display	Display	DS0000025	CN1	12	Keyboard/Interface	042580000	J3	12
DISP_RETURN	Display	Display	DS0000025	CN1	13	Keyboard/Interface	042580000	J3	13
DISP_RETURN	Display	Display	DS0000025	CN1	14	Keyboard/Interface	042580000	J3	14
DISP_PWR	Display	Display	DS0000025	CN1	15	Keyboard/Interface	042580000	J3	15
DISP_PWR	Display	Display	DS0000025	CN1	16	Keyboard/Interface	042580000	J3	16
0364901	CBL, AC Power, E-series								
AC Line	Power Entry	Power Entry	CN0000073		L	Power Switch	SW0000051		L
AC Neutral	Power Entry	Power Entry	CN0000073		N	Power Switch	SW0000051		N
Power Grnd	Power Entry	Power Entry	CN0000073			Shield	SW0000051		
Power Grnd	Power Entry	Power Entry	CN0000073			Chassis	042190000		
AC Line Switched	Power Switch	Power Switch	SW0000051		L	PS2 (+12)	PS0000038	SK2	1
AC Neutral Switched	Power Switch	Power Switch	SW0000051		N	PS2 (+12)	PS0000038	SK2	3
Power Grnd	Power Entry	Power Entry	CN0000073			PS2 (+12)	PS0000038	SK2	2
AC Line Switched	Power Switch	Power Switch	SW0000051		L	PS1 (+5, ±15)	PS0000037	SK2	1
AC Neutral Switched	Power Switch	Power Switch	SW0000051		N	PS1 (+5, ±15)	PS0000037	SK2	3
Power Grnd	Power Entry	Power Entry	CN0000073			PS1 (+5, ±15)	PS0000037	SK2	2
AC Line Switched	Power Switch	Power Switch	SW0000051		L	Relay Board	045230100	J1	1
AC Neutral Switched	Power Switch	Power Switch	SW0000051		N	Relay Board	045230100	J1	3
Power Grnd	Power Entry	Power Entry	CN0000073			Relay Board	045230100	J1	2
03829	CBL, DC power to motherboard, E-series								
DGND	Relay Board	Relay Board	045230100	P7	1	Motherboard	057020100	P15	1
+5V	Relay Board	Relay Board	045230100	P7	2	Motherboard	057020100	P15	2
AGND	Relay Board	Relay Board	045230100	P7	3	Motherboard	057020100	P15	3
+15V	Relay Board	Relay Board	045230100	P7	4	Motherboard	057020100	P15	4
AGND	Relay Board	Relay Board	045230100	P7	5	Motherboard	057020100	P15	5
-15V	Relay Board	Relay Board	045230100	P7	6	Motherboard	057020100	P15	6
+12V RET	Relay Board	Relay Board	045230100	P7	7	Motherboard	057020100	P15	7
+12V	Relay Board	Relay Board	045230100	P7	8	Motherboard	057020100	P15	8
Chassis Gnd	Relay Board	Relay Board	045230100	P7	10	Motherboard	057020100	P15	9
04021	CBL, Preamp, O2 sensor, O3 generator, fan, relay board, motherboard, TML41								
DGND	Relay Board	Relay Board	045230100	P12	1	Ethernet board	043940000	P102	1
+5V	Relay Board	Relay Board	045230100	P12	2	Ethernet board	043940000	P102	2
+15V	Relay Board	Relay Board	045230100	P12	4	Ozone generator	040420200	P1	4
AGND	Relay Board	Relay Board	045230100	P12	3	Ozone generator	040420200	P1	5
+12V	Relay Board	Relay Board	045230100	P12	8	PMT cooling fan	013140000	P1	1
+12V RET	Relay Board	Relay Board	045230100	P12	7	PMT cooling fan	013140000	P1	2
O3GEN enable signal	Ozone generator	Ozone generator	040420200	P1	6	Motherboard	057020100	P108	15
ETEST	Motherboard	Motherboard	057020100	P108	8	Preamplifier board	041800500	P6	1
OTEST	Motherboard	Motherboard	057020100	P108	16	Preamplifier board	041800500	P6	2
PHYSICAL RANGE	Motherboard	Motherboard	057020100	P108	7	Preamplifier board	041800500	P6	4
PMT TEMP	Preamplifier board	Preamplifier board	041800500	P6	5	Motherboard	057020100	P109	4
HVPS	Preamplifier board	Preamplifier board	041800500	P6	6	Motherboard	057020100	P109	5
PMT SIGNAL+	Preamplifier board	Preamplifier board	041800500	P6	7	Motherboard	057020100	P109	6
AGND	Preamplifier board	Preamplifier board	041800500	P6	S	Motherboard	057020100	P109	11
AGND	Motherboard	Motherboard	057020100	P109	9	O2 Sensor (optional)	OP0000030	P1	S
O2 SIGNAL -	Motherboard	Motherboard	057020100	P109	7	O2 Sensor (optional)	OP0000030	P1	9
O2 SIGNAL +	Motherboard	Motherboard	057020100	P109	1	O2 Sensor (optional)	OP0000030	P1	10
DGND	O2 Sensor (optional)	O2 Sensor (optional)	OP0000030	P1	5	Relay Board	045230100	P5	1
+5V	O2 Sensor (optional)	O2 Sensor (optional)	OP0000030	P1	6	Relay Board	045230100	P5	2

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
04022	CBL, DC Power, fan, keyboard, TEC, sensor board, TML41								
	TEC +12V	TEC board	049310100	P1	1	Relay Board	045230100	P10	8
	TEC +12V RET	TEC board	049310100	P1	2	Relay Board	045230100	P10	7
	DGND	Relay Board	045230100	P10	1	Keyboard	042580000	P1	8
	+5V	Relay Board	045230100	P10	2	Keyboard	042580000	P1	1
	DGND	Keyboard	042580000	P1	2	Relay Board	045230100	P11	1
	+5V	Keyboard	042580000	P1	3	Relay Board	045230100	P11	2
	+12V RET	Relay Board	045230100	P11	7	Chassis fan	040010000	P1	1
	+12V	Relay Board	045230100	P11	8	Chassis fan	040010000	P1	2
	P/Flow Sensor AGND	Relay Board	045230100	P11	3	P/Flow Sensor board	040030800	P1	3
	P/Flow Sensor +15V	Relay Board	045230100	P11	4	P/Flow Sensor board	040030800	P1	6
	Pressure signal 1	P/Flow Sensor board	040030800	P1	2	Motherboard	057020100	P110	6
	Pressure signal 2	P/Flow Sensor board	040030800	P1	4	Motherboard	057020100	P110	5
	Flow signal 1	P/Flow Sensor board	040030800	P1	5	Motherboard	057020100	P110	4
	Flow signal 2	P/Flow Sensor board	040030800	P1	1	Motherboard	057020100	P110	3
	Shield	P/Flow Sensor board	040030800	P1	S	Motherboard	057020100	P110	12
	Shield	Motherboard	057020100	P110	9	Relay Board	045230100	P17	S
	Thermocouple signal 1	Motherboard	057020100	P110	2	Relay Board	045230100	P17	1
	TC 1 signal DGND	Motherboard	057020100	P110	8	Relay Board	045230100	P17	2
	Thermocouple signal 2	Motherboard	057020100	P110	1	Relay Board	045230100	P17	3
	TC 2 signal DGND	Motherboard	057020100	P110	7	Relay Board	045230100	P17	4
04023	CBL, I2C, relay board to motherboard, E-series								
	I2C Serial Clock	Motherboard	057020100	P107	3	Relay Board	045230100	P3	1
	I2C Serial Data	Motherboard	057020100	P107	5	Relay Board	045230100	P3	2
	I2C Reset	Motherboard	057020100	P107	2	Relay Board	045230100	P3	4
	I2C Shield	Motherboard	057020100	P107	6	Relay Board	045230100	P3	5
04024	CBL, Nox, zero/span, IZS valves, TML41								
	Zero/Span valve +12V	Relay Board	045230100	P4	1	Zero/Span valve	042680100	P1	1
	Zero/Span valve +12V RET	Relay Board	045230100	P4	2	Zero/Span valve	042680100	P1	2
	Sample valve +12V	Relay Board	045230100	P4	3	Sample valve	042680100	P1	1
	Sample valve +12V RET	Relay Board	045230100	P4	4	Sample valve	042680100	P1	2
	AutoZero valve +12V	Relay Board	045230100	P4	5	AutoZero valve	042680100	P1	1
	AutoZero valve +12V RET	Relay Board	045230100	P4	6	AutoZero valve	042680100	P1	2
	NONOx valve +12V	Relay Board	045230100	P4	7	NONOx valve	042680100	P1	1
	NONOx valve +12V RET	Relay Board	045230100	P4	8	NONOx valve	042680100	P1	2
0402603	CBL, IZS & O2 sensor heaters/thermistors; reaction cell & manifold thermistors, TML41								
	Rcell thermistor A	Reaction cell thermistor	041920000	P1	2	Motherboard	057020100	P27	7
	Rcell thermistor B	Reaction cell thermistor	041920000	P1	1	Motherboard	057020100	P27	14
	IZS thermistor A	Motherboard	057020100	P27	6	IZS thermistor/heater	003290000	P1	2
	IZS thermistor B	Motherboard	057020100	P27	13	IZS thermistor/heater	003290000	P1	3
	IZS heater L	IZS thermistor/heater	003290000	P1	4	Relay Board	045230100	P18	1
	IZS heater N	IZS thermistor/heater	003290000	P1	1	Relay Board	045230100	P18	2
	Shield					Relay Board	045230100	P18	11
	O2 sensor heater	Relay Board	045230100	P18	6	O2 sensor therm./heater	043420000	P1	4
	O2 sensor heater	Relay Board	045230100	P18	7	O2 sensor therm./heater	043420000	P1	2
	Shield	Relay Board	045230100	P18	12	O2 sensor therm./heater	043420000	P1	
	O2 sensor thermistor A	O2 sensor therm./heater	043420000	P1	3	Motherboard	057020100	P27	4
	O2 sensor thermistor B	O2 sensor therm./heater	043420000	P1	1	Motherboard	057020100	P27	11
	Bypp/dil. man. thermistor A	Motherboard	057020100	P27	1	Manifold thermistor	044530000	P1	1
	Bypp/dil. man. thermistor B	Motherboard	057020100	P27	8	Manifold thermistor	044530000	P1	2
	Configuration jumper intern.	Relay Board	045230100	P18	3	Relay Board	045230100	P18	4
	Configuration jumper intern.	Relay Board	045230100	P18	8	Relay Board	045230100	P18	9
04027	CBL, NO2 converter, reaction cell & manifold heaters, TML41								
	Bypass/dil. manifold heater L	Manifold heater 1	044340000	P1	1	Relay Board	045230100	P2	11
	Bypass/dil. manifold heater N	Manifold heater 1	044340000	P1	2	Relay Board	045230100	P2	12
	Bypass/dil. manifold heater L	Relay Board	045230100	P2	11	Manifold heater 2	044340000	P1	1
	Bypass/dil. manifold heater N	Relay Board	045230100	P2	15	Manifold heater 2	044340000	P1	2
	Moly heater A	Relay Board	045230100	P2	7	Moly heater A	039700100	P1	1
	Moly heater C	Relay Board	045230100	P2	6	Moly heater C	039700100	P1	2
	Moly heater B	Relay Board	045230100	P2	10	Moly heater B	039700100	P1	3
	Configuration jumper intern.	Relay Board	045230100	P2	13	Relay Board	045230100	P2	14
	Configuration jumper intern.	Relay Board	045230100	P2	8	Relay Board	045230100	P2	9
	Reaction cell heater/switch	Relay Board	045230100	P2	1	Reaction cell heater 1B	040400000	P1	4
	Reaction cell heater/switch	Relay Board	045230100	P2	1	Reaction cell heater 2B	040400000	P1	6
	Reaction cell heater/switch	Relay Board	045230100	P2	2	Reaction cell heater 1A	040400000	P1	3
	Reaction cell heater/switch	Relay Board	045230100	P2	3	Reaction cell heat switch	040400000	P1	1
	Reaction cell heater/switch	Relay Board	045230100	P2	4	Reaction cell heat switch	040400000	P1	2
	Reaction cell heater/switch	Relay Board	045230100	P2	5	Reaction cell heater 2A	040400000	P1	5

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
04105	CBL, Keyboard, display to motherboard, E-series								
	Kbd Interrupt	Keyboard	042580000	J2	7	Motherboard	057020100	J106	1
	DGND	Keyboard	042580000	J2	2	Motherboard	057020100	J106	8
	SDA	Keyboard	042580000	J2	5	Motherboard	057020100	J106	2
	SCL	Keyboard	042580000	J2	6	Motherboard	057020100	J106	6
	Shld	Keyboard	042580000	J2	10	Motherboard	057020100	J106	5
04176	CBL, DC power to relay board, E-series								
	DGND	Relay Board	045230100	P8	1	Power Supply Triple	PS0000037	J1	3
	+5V	Relay Board	045230100	P8	2	Power Supply Triple	PS0000037	J1	1
	+15V	Relay Board	045230100	P8	4	Power Supply Triple	PS0000037	J1	6
	AGND	Relay Board	045230100	P8	5	Power Supply Triple	PS0000037	J1	4
	-15V	Relay Board	045230100	P8	6	Power Supply Triple	PS0000037	J1	5
	+12V RET	Relay Board	045230100	P8	7	Power Supply Single	PS0000038	J1	3
	+12V	Relay Board	045230100	P8	8	Power Supply Single	PS0000038	J1	1
04211	CBL, Serial data, motherboard to CPU, E-series								
	RXD(0)	CPU board	CP0000026	CN3	3	Motherboard	057020100	J12	14
	RTS(0)	CPU board	CP0000026	CN3	4	Motherboard	057020100	J12	13
	TXD(0)	CPU board	CP0000026	CN3	5	Motherboard	057020100	J12	12
	CTS(0)	CPU board	CP0000026	CN3	6	Motherboard	057020100	J12	11
	GND(0)	CPU board	CP0000026	CN3	9	Motherboard	057020100	J12	10
	RXD(1)	CPU board	CP0000026	CN4	3	Motherboard	057020100	J12	9
	RTS(1)	CPU board	CP0000026	CN4	4	Motherboard	057020100	J12	8
	TXD(1)	CPU board	CP0000026	CN4	5	Motherboard	057020100	J12	7
	CTS(1)	CPU board	CP0000026	CN4	6	Motherboard	057020100	J12	6
	GND(1)	CPU board	CP0000026	CN4	9	Motherboard	057020100	J12	5
	NET+	CPU board	CP0000026	CN5	2	Motherboard	057020100	J12	9
	NET-	CPU board	CP0000026	CN5	4	Motherboard	057020100	J12	7
	GND	CPU board	CP0000026	CN5	6	Motherboard	057020100	J12	5
	Shield	CPU board	CP0000026	CN5		Motherboard	057020100	J12	2
04339	CBL, CPU to Ethernet (optional), E-series								
	Ethernet DCD	CPU board	CP0000026	CN4	1	Ethernet board	043940000	P101	6
	Ethernet DSR	CPU board	CP0000026	CN4	2	Ethernet board	043940000	P101	4
	Ethernet RXD	CPU board	CP0000026	CN4	3	Ethernet board	043940000	P101	3
	Ethernet RTS	CPU board	CP0000026	CN4	4	Ethernet board	043940000	P101	10
	Ethernet TXD	CPU board	CP0000026	CN4	5	Ethernet board	043940000	P101	8
	Ethernet CTS	CPU board	CP0000026	CN4	6	Ethernet board	043940000	P101	5
	Ethernet DTR	CPU board	CP0000026	CN4	7	Ethernet board	043940000	P101	9
	Ethernet GND	CPU board	CP0000026	CN4	9	Ethernet board	043940000	P101	16
	Ground	CPU board	CP0000026	CN4		Ethernet board	043940000	P101	2
04433	CBL, preamplifier to relay board, TML41								
	Preamplifier DGND	Relay Board	045230100	P9	1	Preamplifier board	041800500	P5	1
	Preamplifier +5V	Relay Board	045230100	P9	2	Preamplifier board	041800500	P5	2
	Preamplifier AGND	Relay Board	045230100	P9	3	Preamplifier board	041800500	P5	3
	Preamplifier +15V	Relay Board	045230100	P9	4	Preamplifier board	041800500	P5	4
	Preamplifier -15V	Relay Board	045230100	P9	6	Preamplifier board	041800500	P5	6
04437	CBL, preamplifier to TEC, TML41								
	Preamp TEC drive VREF	Preamplifier board	041800500	J1	1	TEC board	049310100	J3	1
	Preamp TEC drive CTRL	Preamplifier board	041800500	J1	2	TEC board	049310100	J3	2
	Preamp TEC drive AGND	Preamplifier board	041800500	J1	3	TEC board	049310100	J3	3



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 W RE JUMPER
 REPLACE R4 WITH RS297 127KOHM

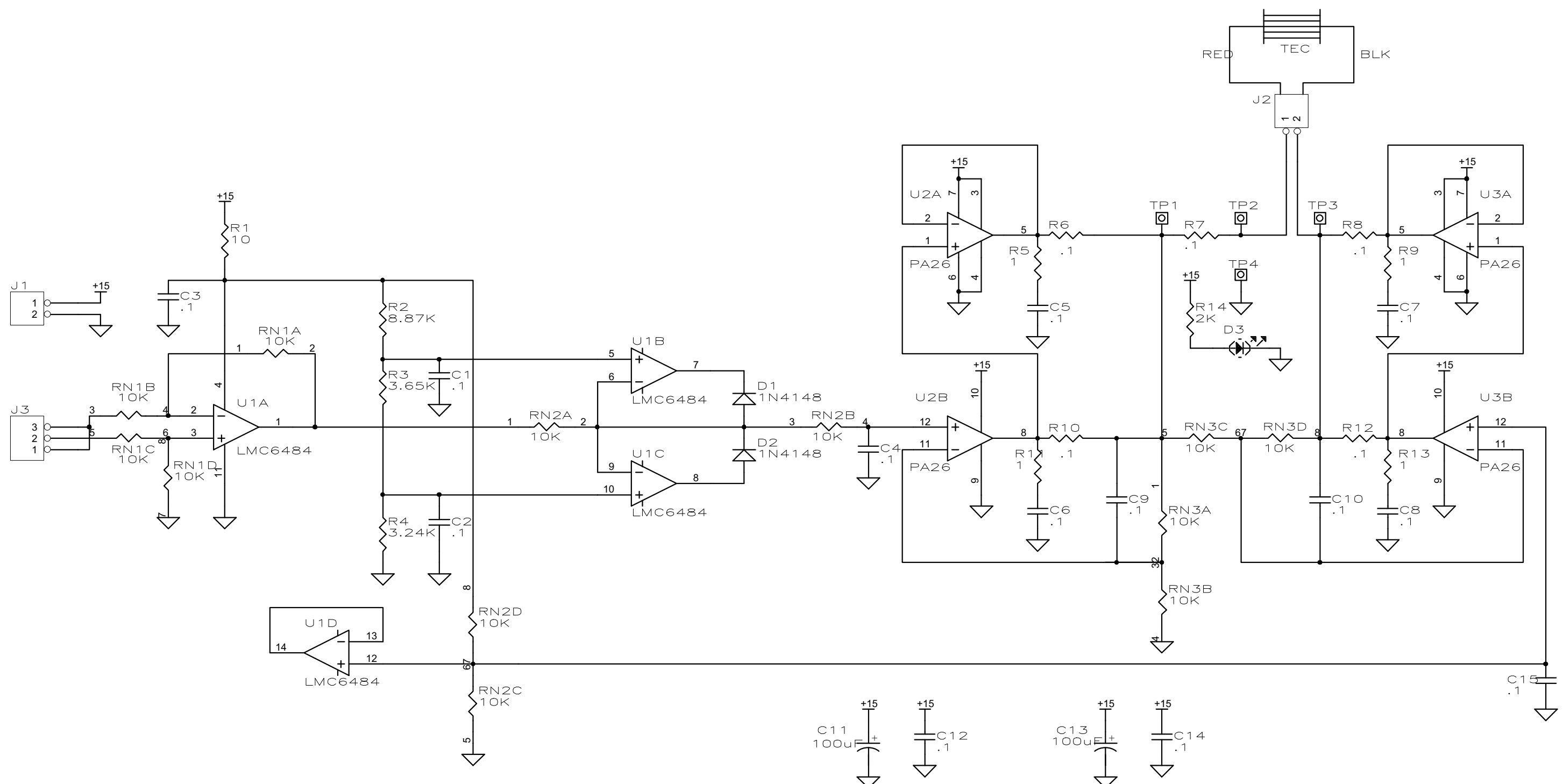
016680400 - HI OUTPUT + FIXED FREQ
 REPLACE VR2 WITH A W RE JUMPER
 REPLACE R4 WITH RS13 11 KOHM

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


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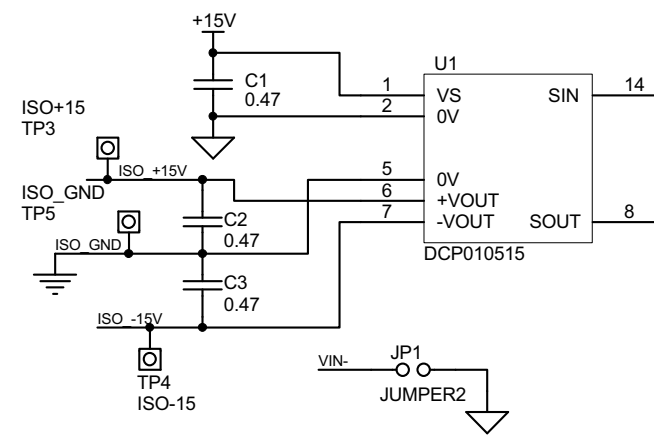
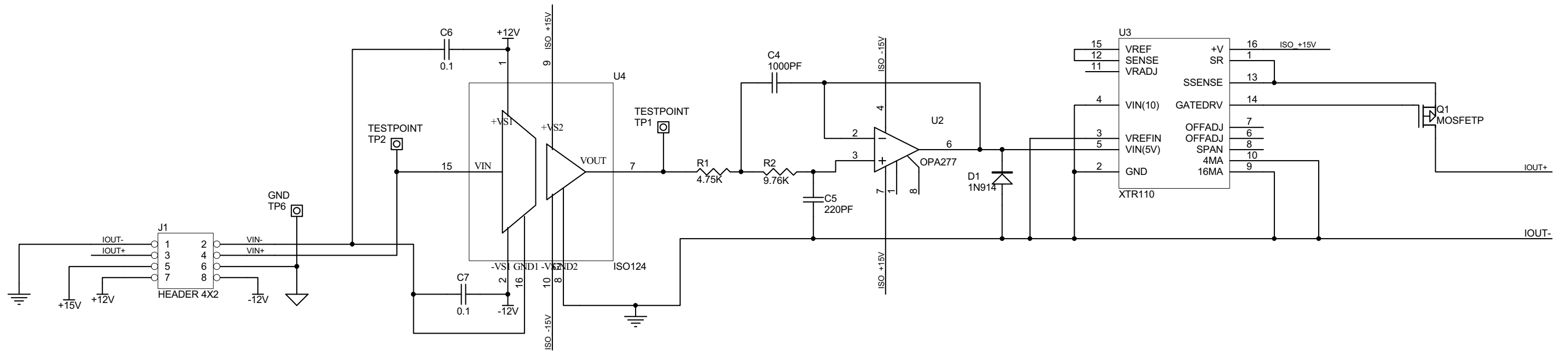
		OZON_GEN	
		DRIVER	
APPROVALS	DATE	SIZE	DRAWING NO.
DRAWN		B	01669
CHECKED		LAST MOD.	REVISION
APPROVED		30-Nov-2006	G
		SHEET	1 of 1



NOTE:
 THIS CIRCUIT MUST BE USED
 AS A MATCHED PAIR WITH THE
 PREAMP CIRCUIT (DWG #02108)


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 TELEDYNE MONITOR LABS A Teledyne Technologies Company		APPROVALS		DATE	THERMOELECT	
		DRAW N			COOLER_CONTROL	
CHECKED		APPROVED		SIZE	DRAWING NO.	REVISION
				B	01840	B
				LAST MOD.	SHEET	
				14-Jul-1999	1 of 1	



Date	Rev.	Change Description	Engineer
8/9/00	A	INITIAL RELEASE (FROM 03039)	KL

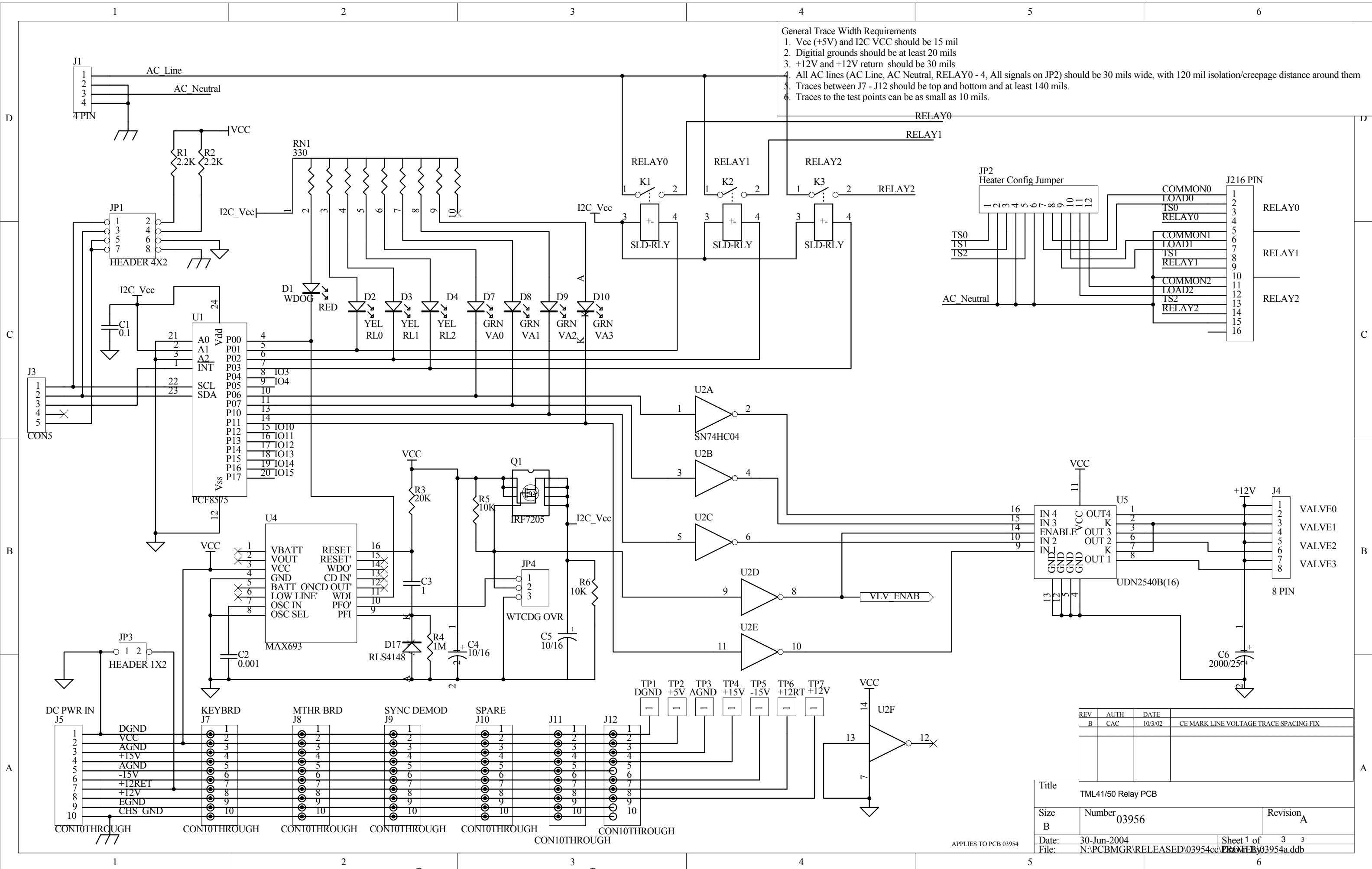
The information herein is the property of TML and is submitted in strictest confidence for reference only. Unauthorized use by anyone for any other purposes is prohibited. This document or any information contained in it may not be duplicated without proper authorization.



**TELEDYNE
MONITOR LABS**
A Teledyne Technologies Company

APPROVALS	DATE	PCA 03631, Isolated 0-20ma, E Series		
DRAWN				
CHECKED		SIZE B	DRAWING NO. 03632	REVISION A
APPROVED		LAST MOD. 19-Jul-2002	SHEET 1 of 1	

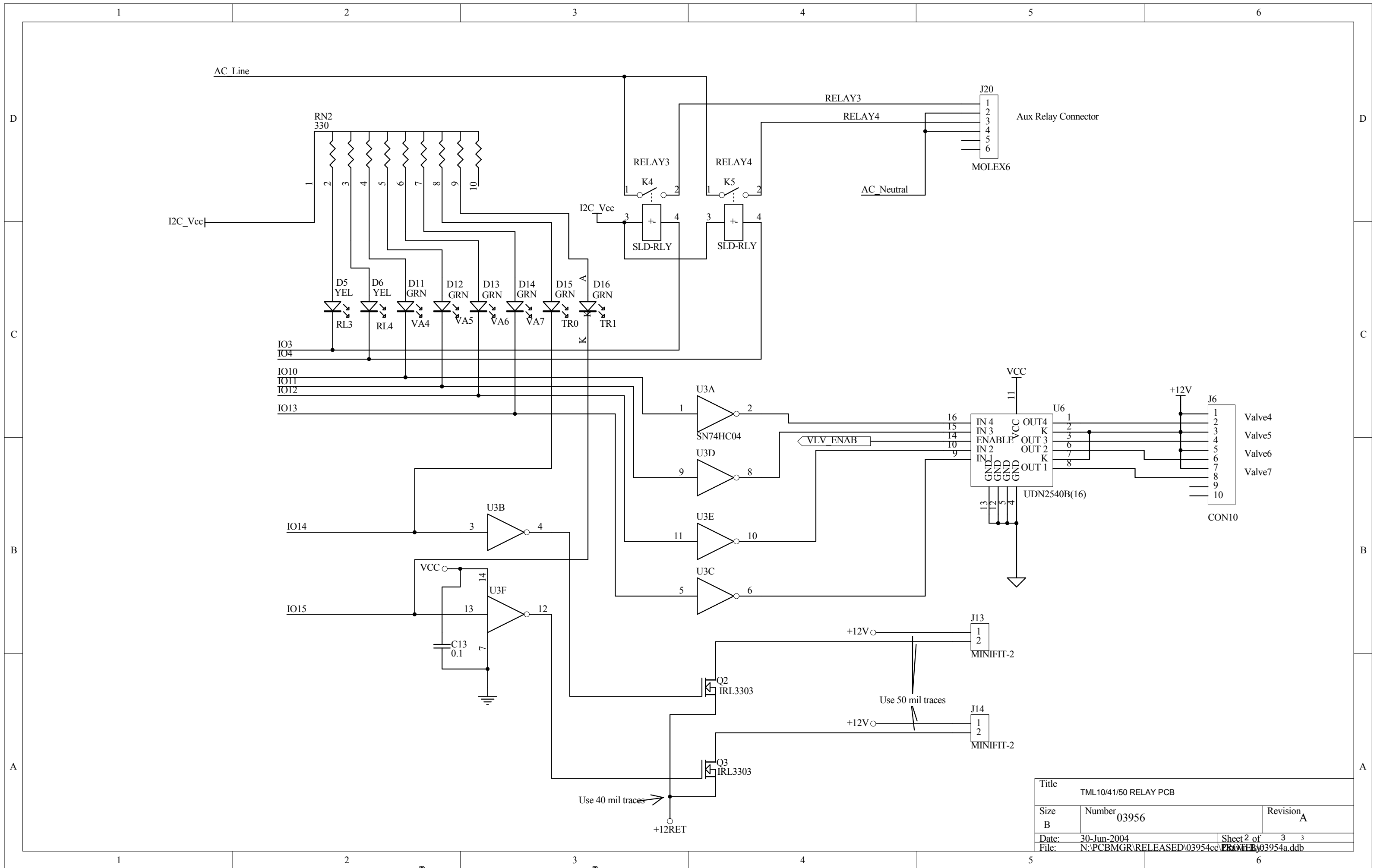
- General Trace Width Requirements
1. Vcc (+5V) and I2C VCC should be 15 mil
 2. Digital grounds should be at least 20 mils
 3. +12V and +12V return should be 30 mils
 4. All AC lines (AC Line, AC Neutral, RELAY0 - 4, All signals on JP2) should be 30 mils wide, with 120 mil isolation/creepage distance 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.



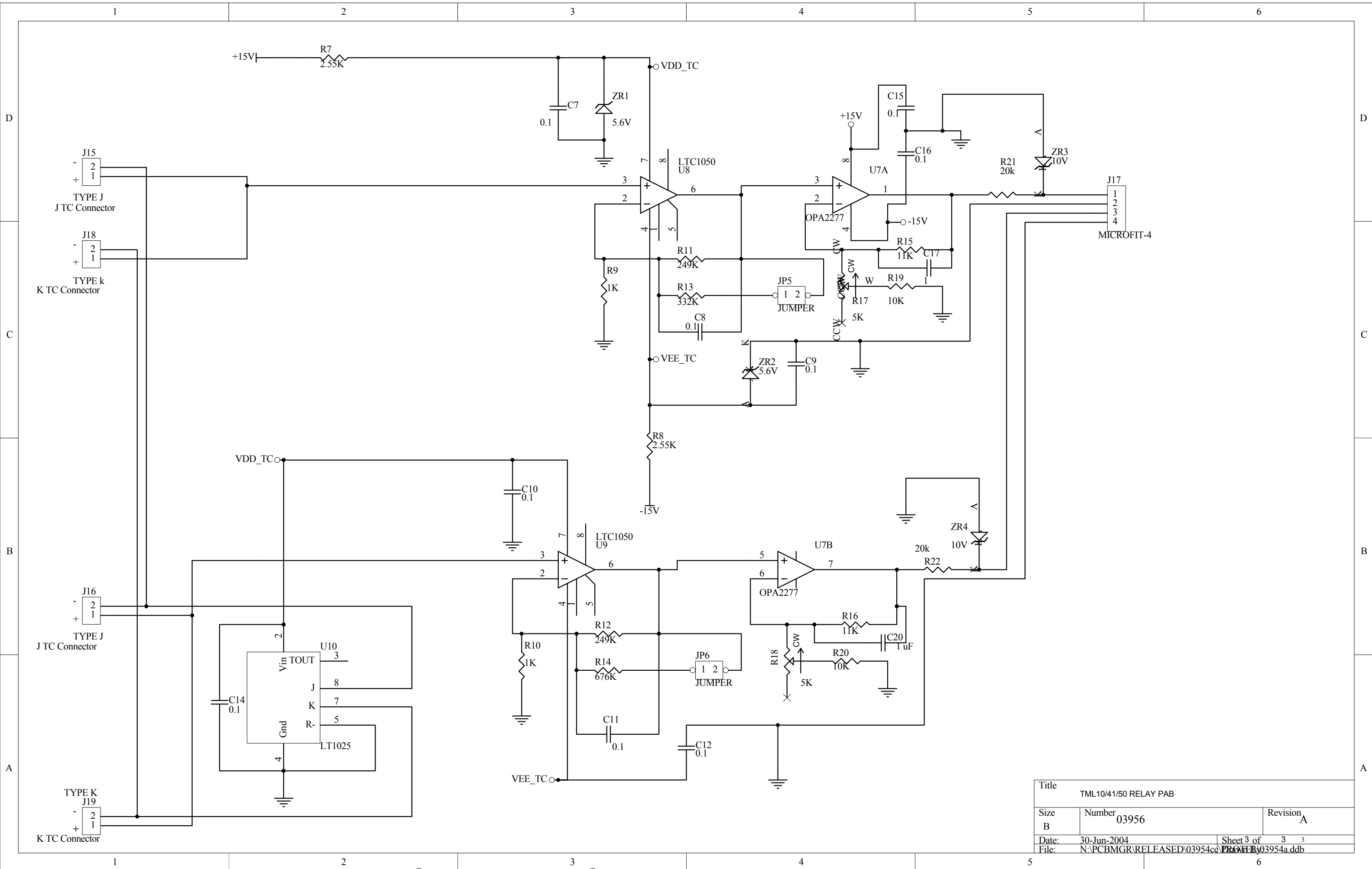
REV	AUTH	DATE	DESCRIPTION
B	CAC	10/3/02	CE MARK LINE VOLTAGE TRACE SPACING FIX

Title		TML41/50 Relay PCB	
Size	Number	Revision	
B	03956	A	
Date:	30-Jun-2004	Sheet 1 of	3 3
File:	N:\PCBMGR\RELEASED\03954a.ddb		

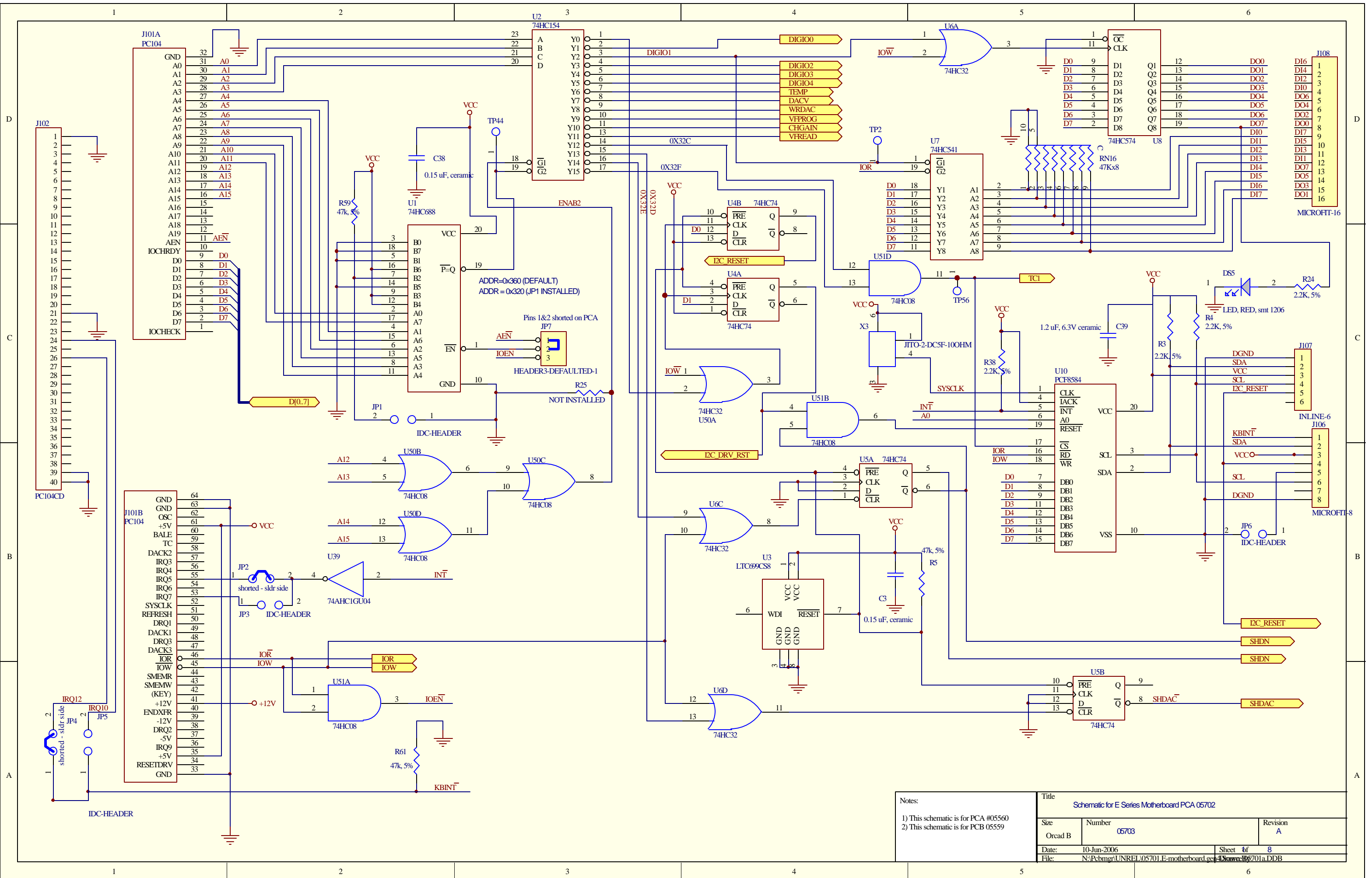
APPLIES TO PCB 03954



Title		TML10/41/50 RELAY PCB	
Size	Number	Revision	
B	03956	A	
Date:	30-Jun-2004	Sheet 2 of	3 3
File:	N:\PCBMGR\RELEASED\03954cd\PROT\03954a.ddb		

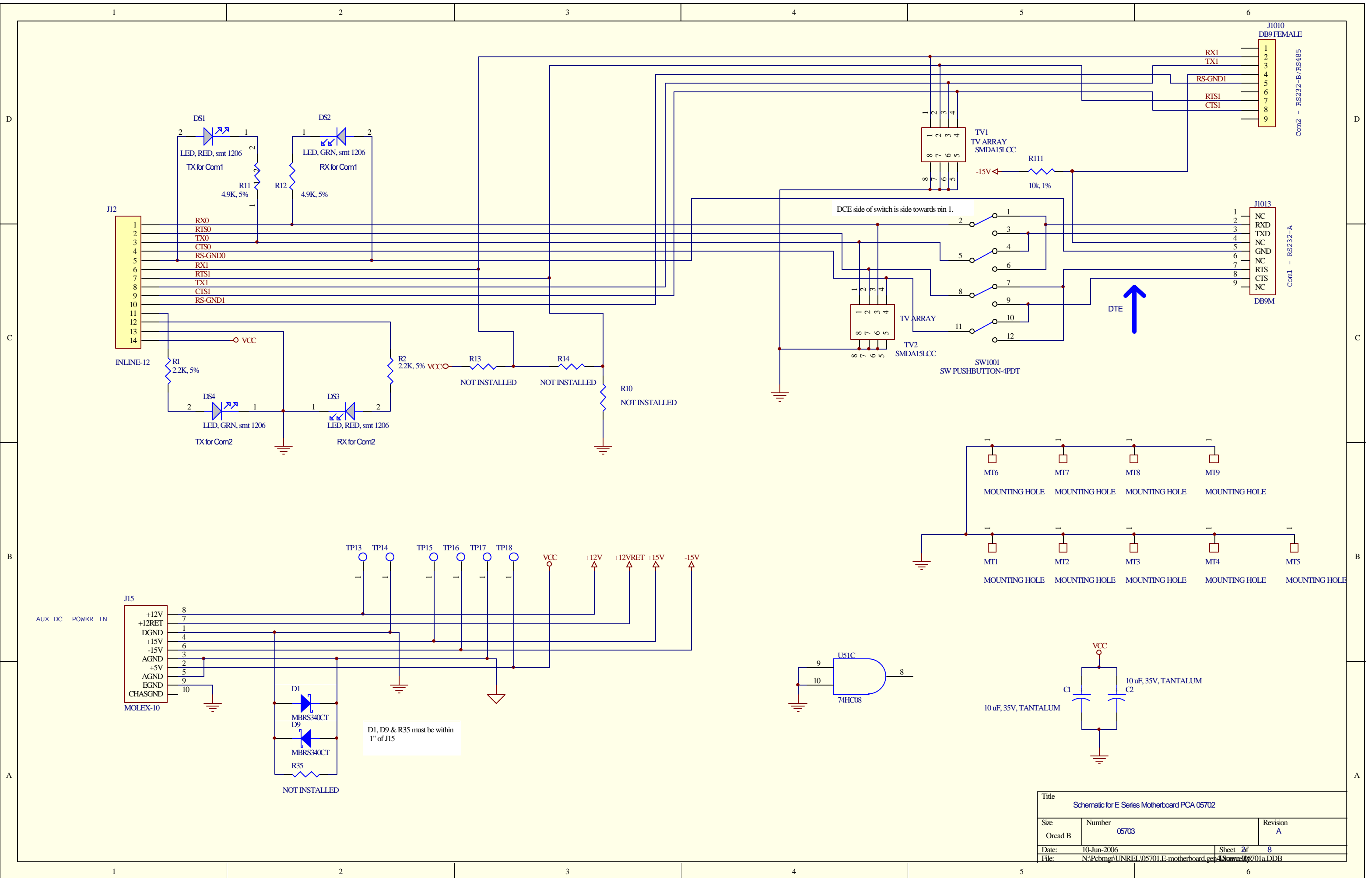


Title		TML10/41/50 RELAY PAB	
Size	Number	Revision	
B	03956	A	
Date:	30-Jun-2004	Sheet 3 of	3 3
File:	N:\PCBMGR\RELEASED\03954a.ddb		

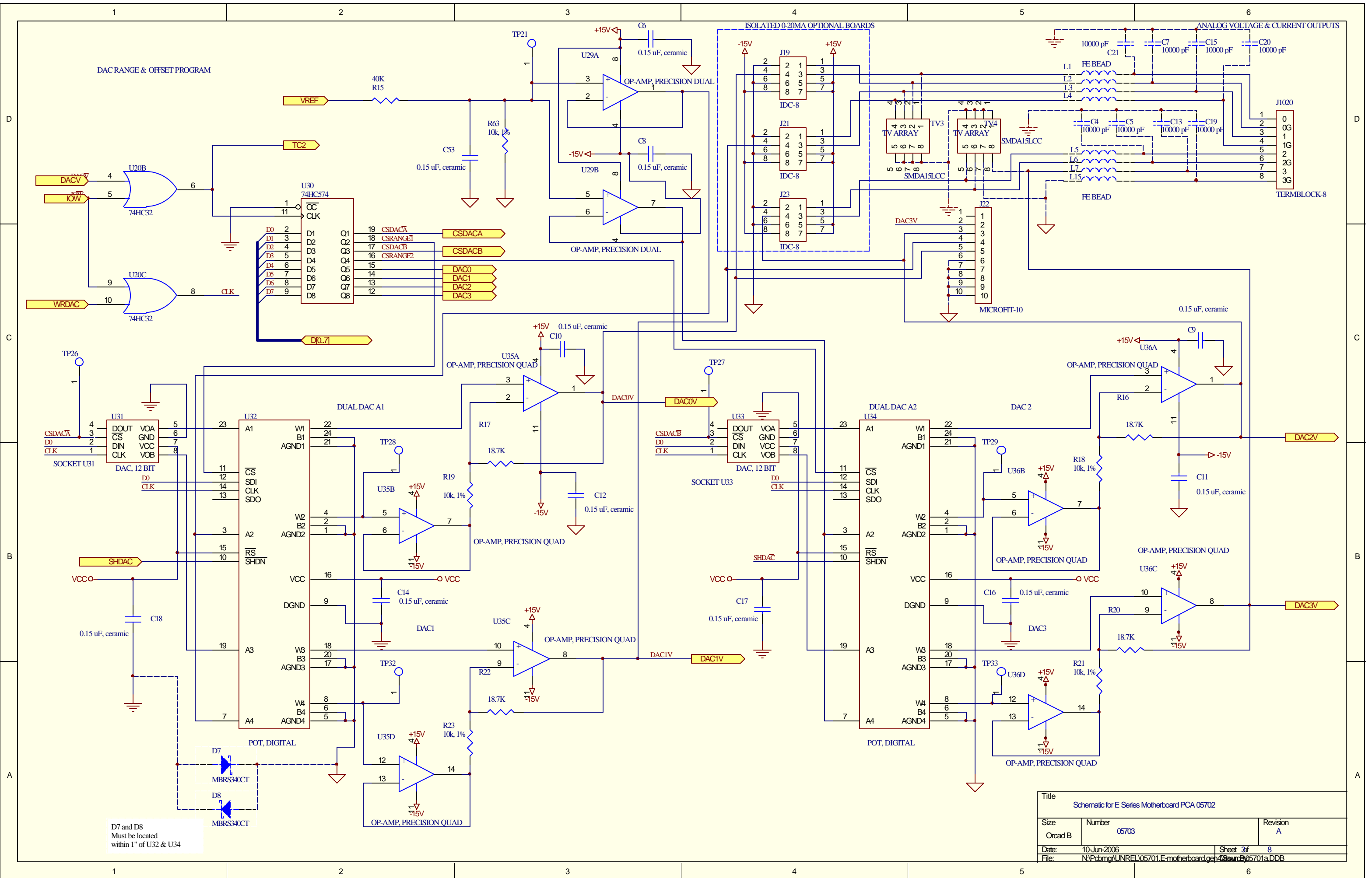


Notes:
 1) This schematic is for PCA #05560
 2) This schematic is for PCB #05559

Title Schematic for E Series Motherboard PCA 05702		
Size Orcad B	Number 05703	Revision A
Date: 10-Jun-2006	Sheet of	8
File: N:\Pcbmgr\UNREL\05701.E-motherboard.cad		



Title Schematic for E Series Motherboard PCA 05702		
Size Orcad B	Number 05703	Revision A
Date: 10-Jun-2006	Sheet 2 of 8	
File: N:\Pcbmgr\UNREL\05701.E-motherboard.g43\Draws\05701a.DDB		



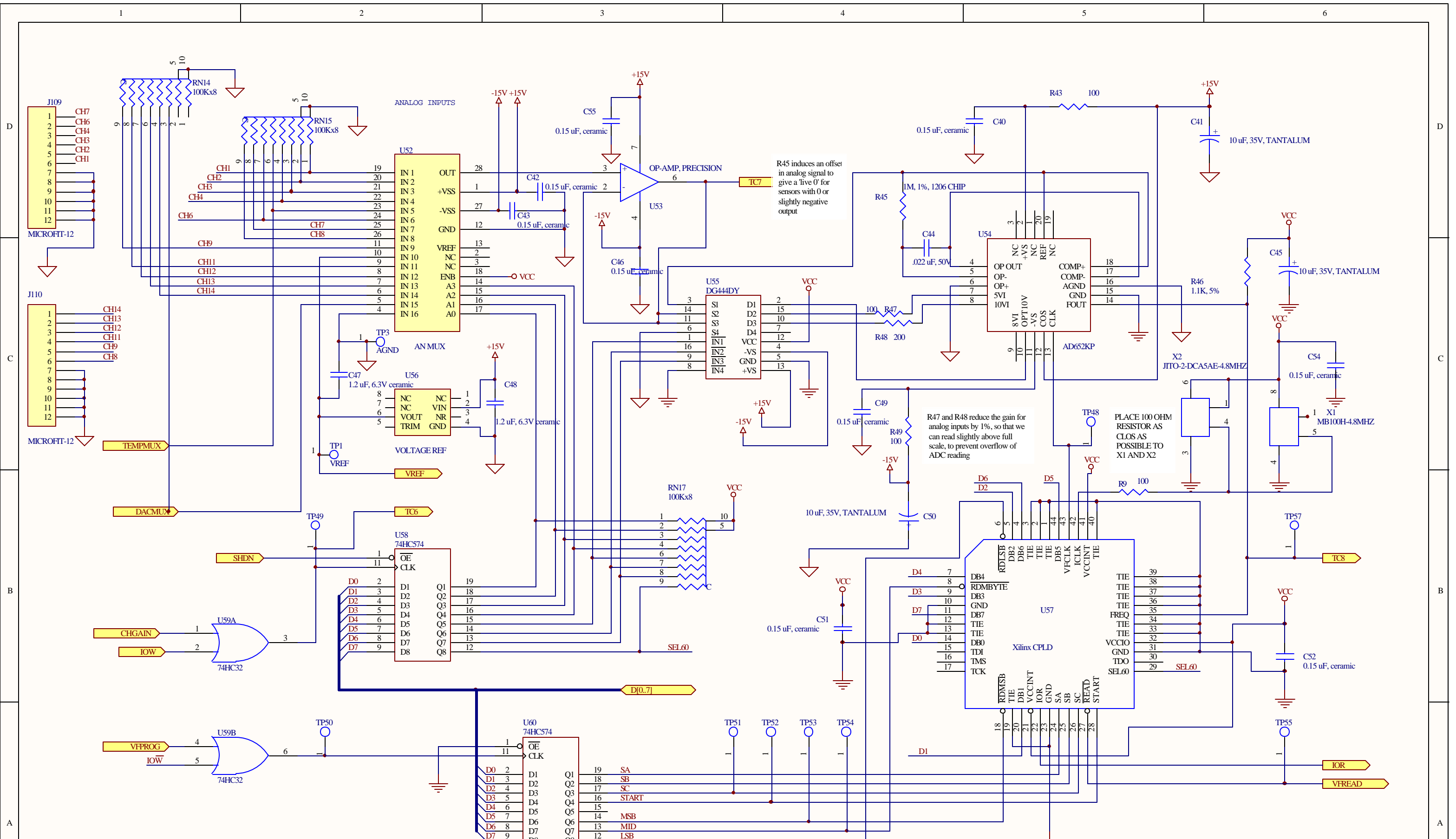
DAC RANGE & OFFSET PROGRAM

ISOLATED 0-20MA OPTIONAL BOARDS

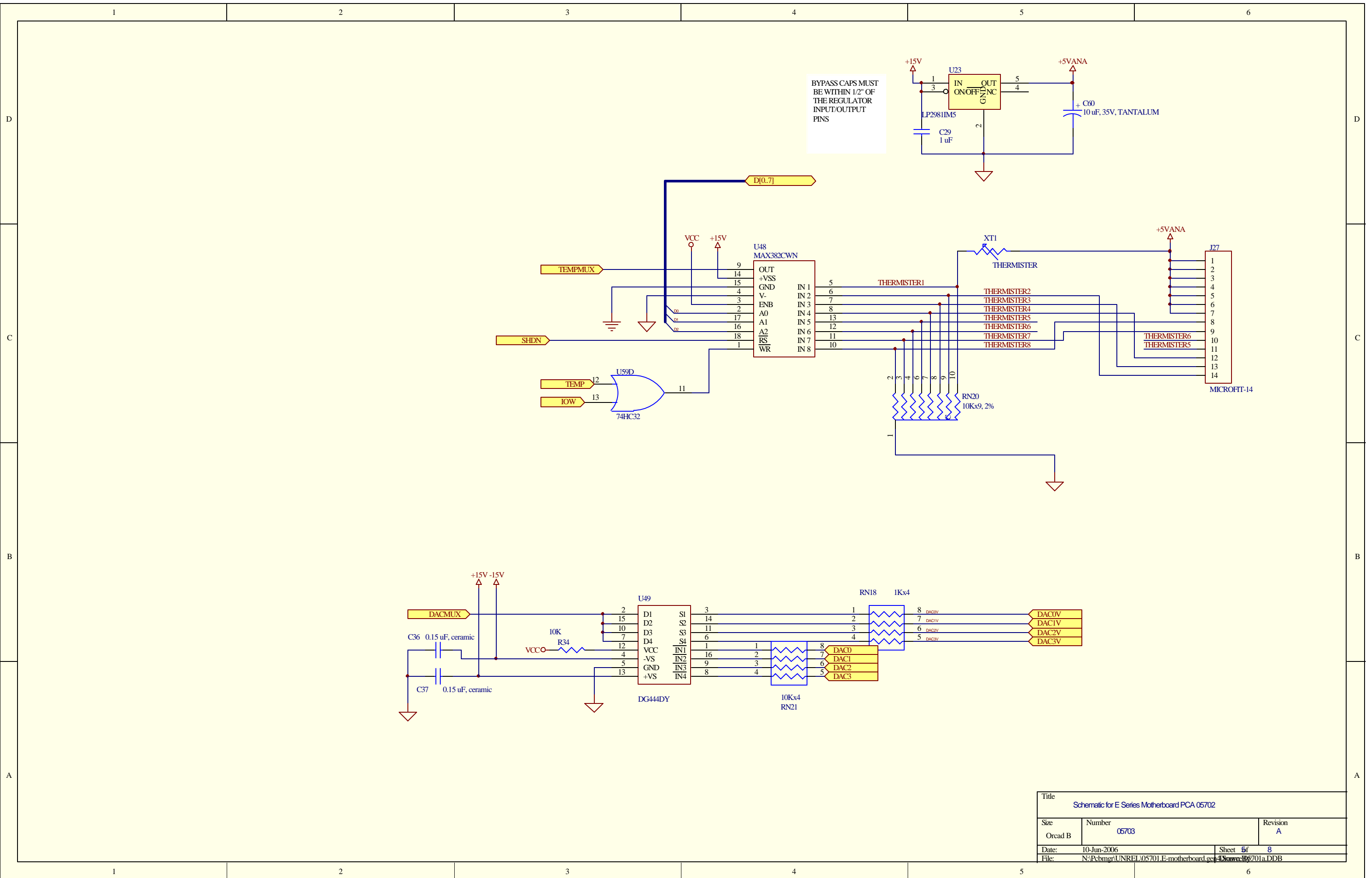
ANALOG VOLTAGE & CURRENT OUTPUTS

D7 and D8
Must be located
within 1" of U32 & U34

Title		
Schematic for E Series Motherboard PCA 05702		
Size	Number	Revision
Orcad B	05703	A
Date:	10-Jun-2006	Sheet 3 of 8
File:	N:\Pcbmg\UNREL\05701.E-motherboard.geda\05701a.DDB	

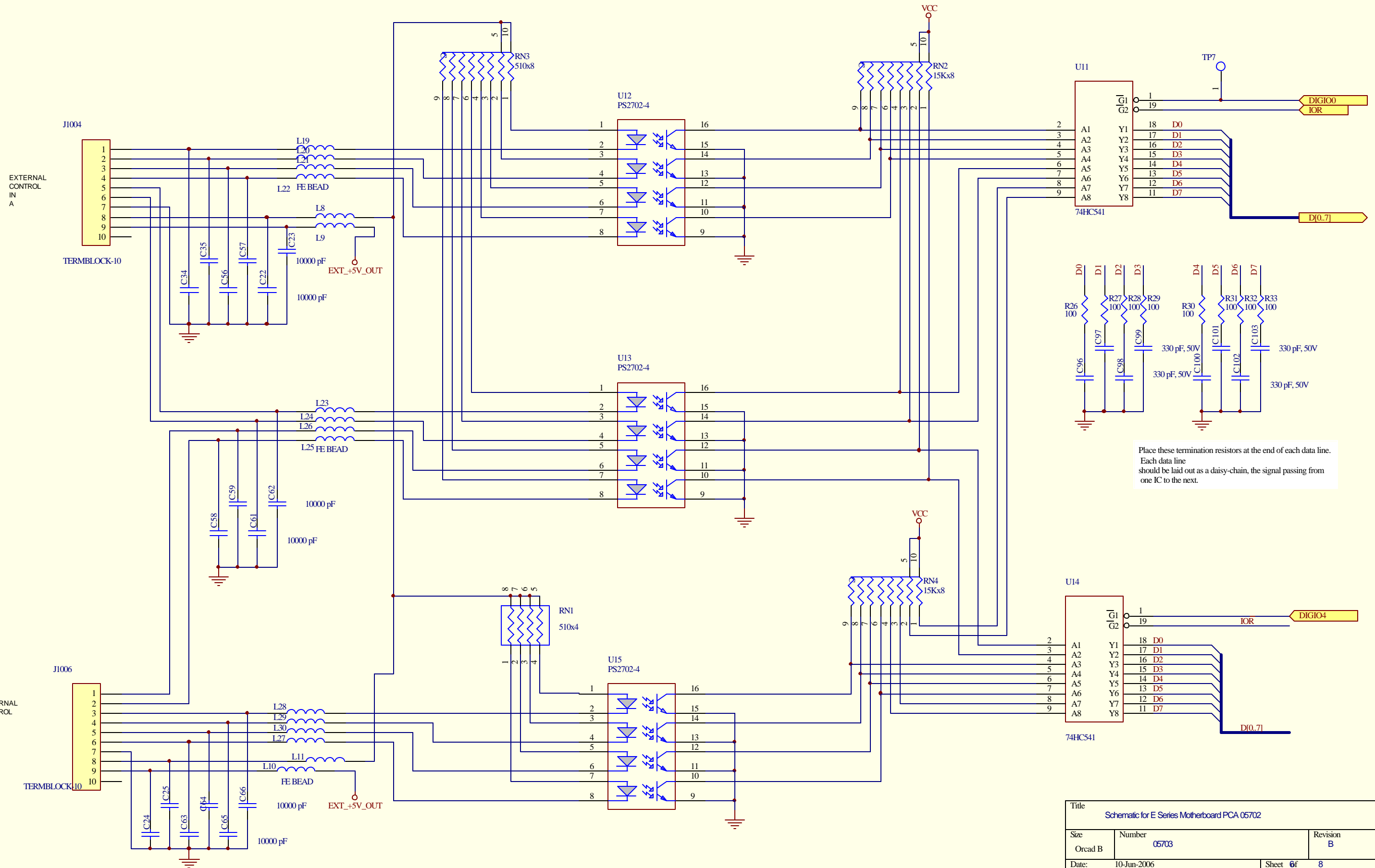


Title		
Schematic for E Series Motherboard PCA 05702		
Size	Number	Revision
Orcad B	05703	A
Date:	10-Jun-2006	Sheet 4of 8
File:	N:\Pcbmgr\UNREL\05701.E-motherboard.cad\Draws\05701a.DDB	

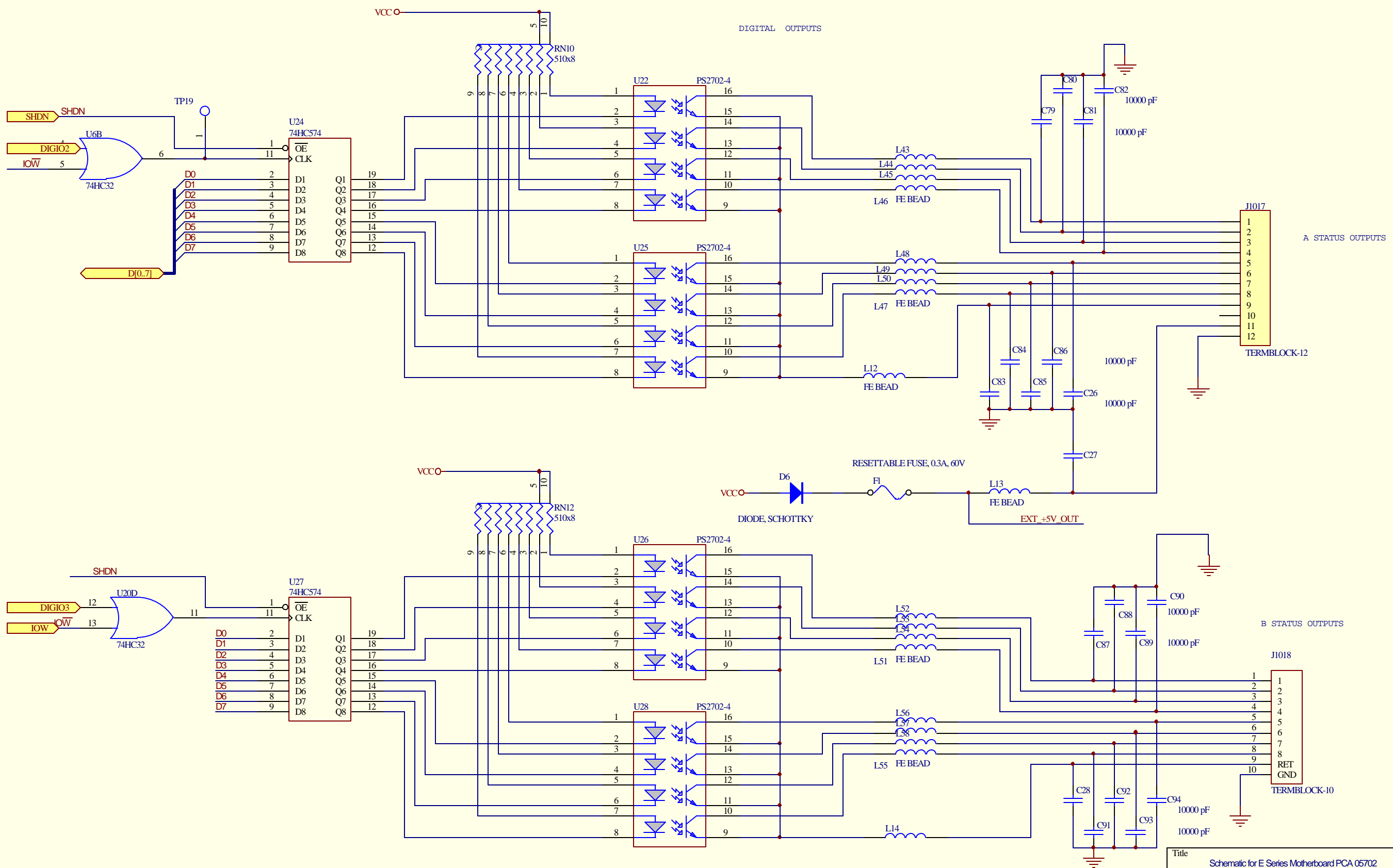


Title Schematic for E Series Motherboard PCA 05702		
Size Orcad B	Number 05703	Revision A
Date: 10-Jun-2006	Sheet 5 of 8	
File: N:\Pcbmgr\UNREL\05701.E-motherboard.g43\Draw\05701a.DDB		

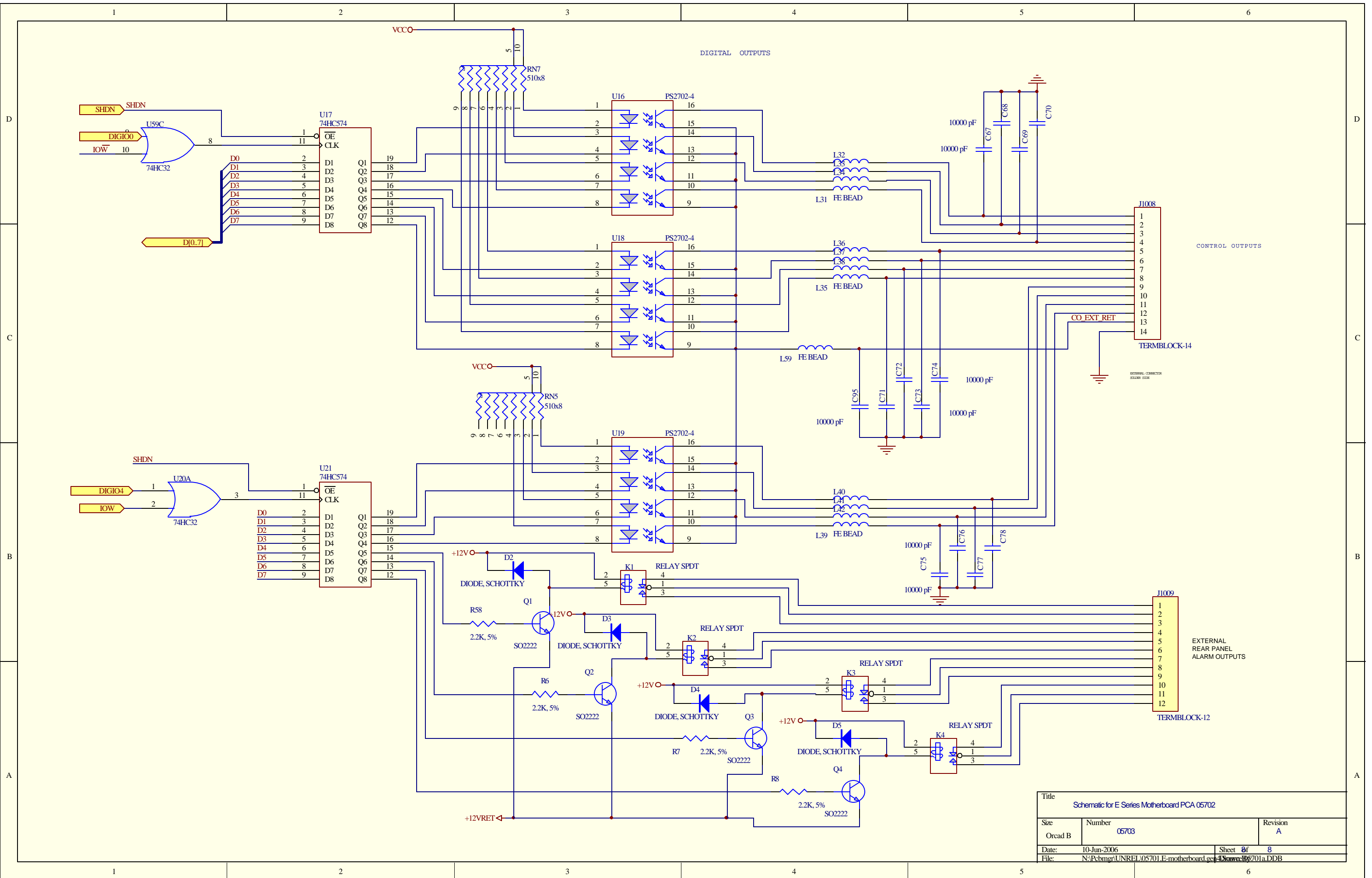
CONTROL INPUTS



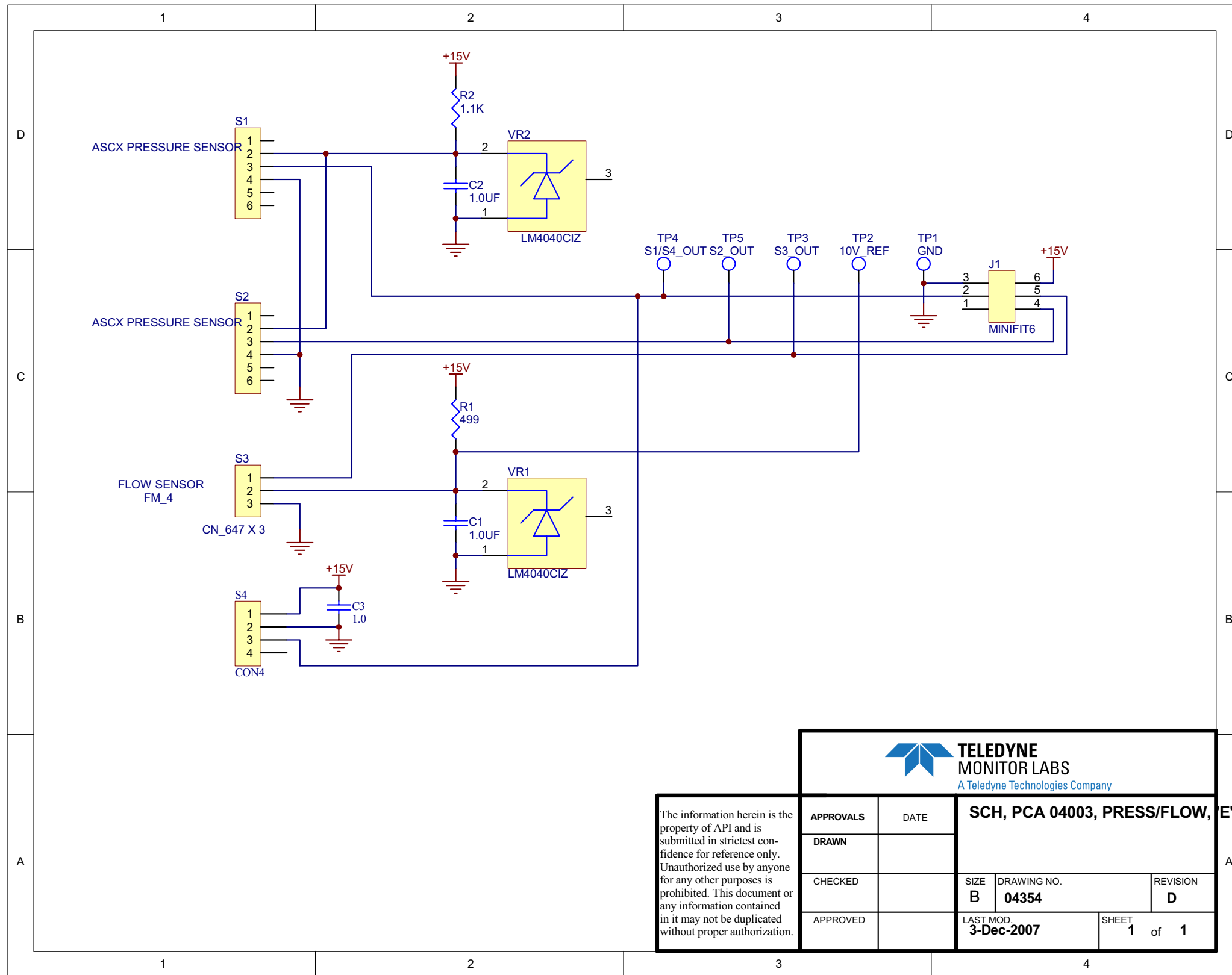
Title		
Schematic for E Series Motherboard PCA 05702		
Size	Number	Revision
Orcad B	05703	B
Date:	10-Jun-2006	Sheet 6 of 8
File:	N:\Pcbmgr\UNREL\05701.E-motherboard.cad\Draws\05701a.DDB	




Title		
Schematic for E Series Motherboard PCA 05702		
Size	Number	Revision
Orcad B	05703	A
Date:	10-Jun-2006	Sheet 7 of 8
File:	N:\Pcbmgr\UNREL\05701.E-motherboard.g43\Draw\05701a.DDB	



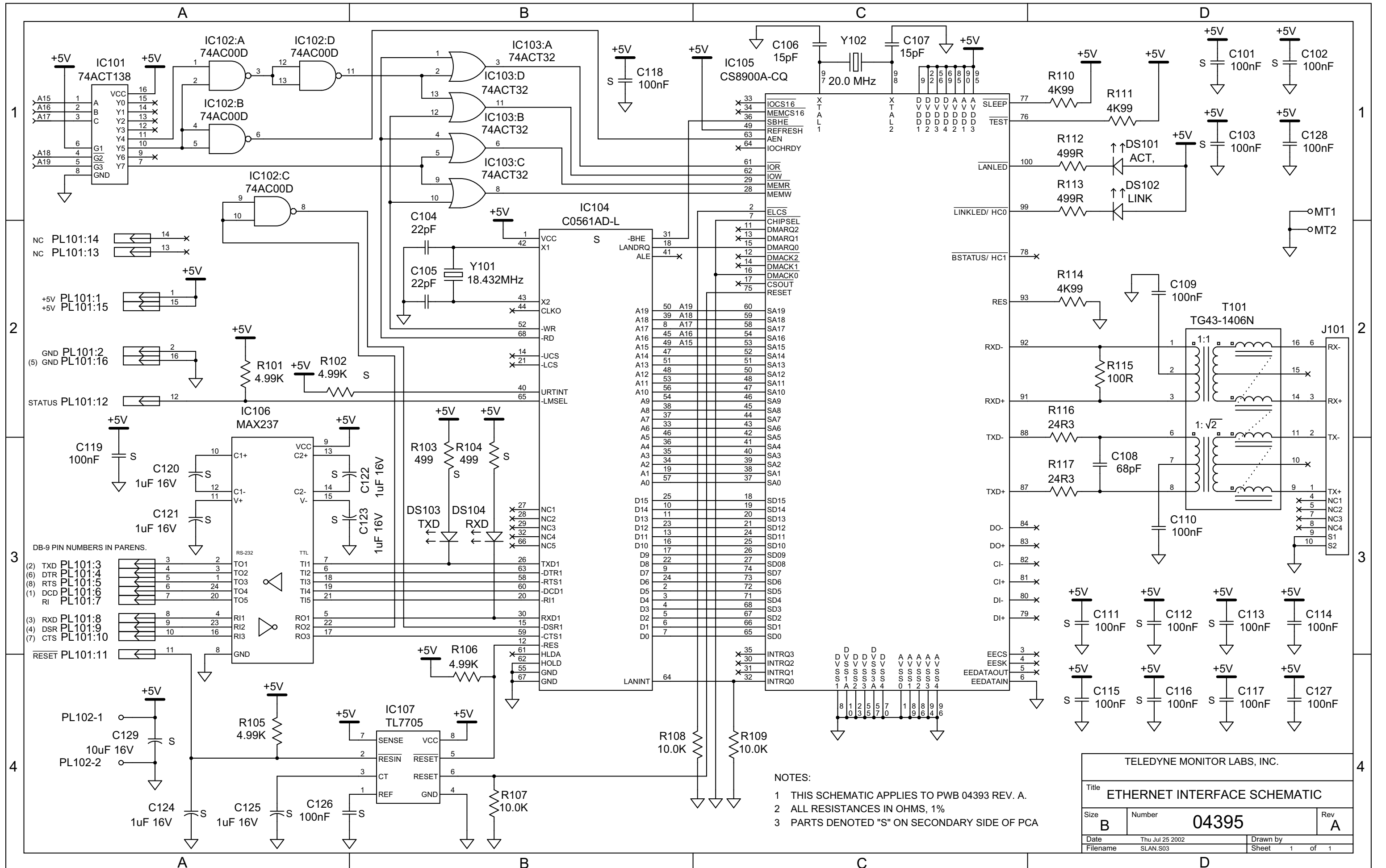
Title		
Schematic for E Series Motherboard PCA 05702		
Size	Number	Revision
Orcad B	05703	A
Date:	10-Jun-2006	Sheet 8 of 8
File:	N:\Pcbmgr\UNREL\05701.E-motherboard.cad\Draws\05701a.DDB	



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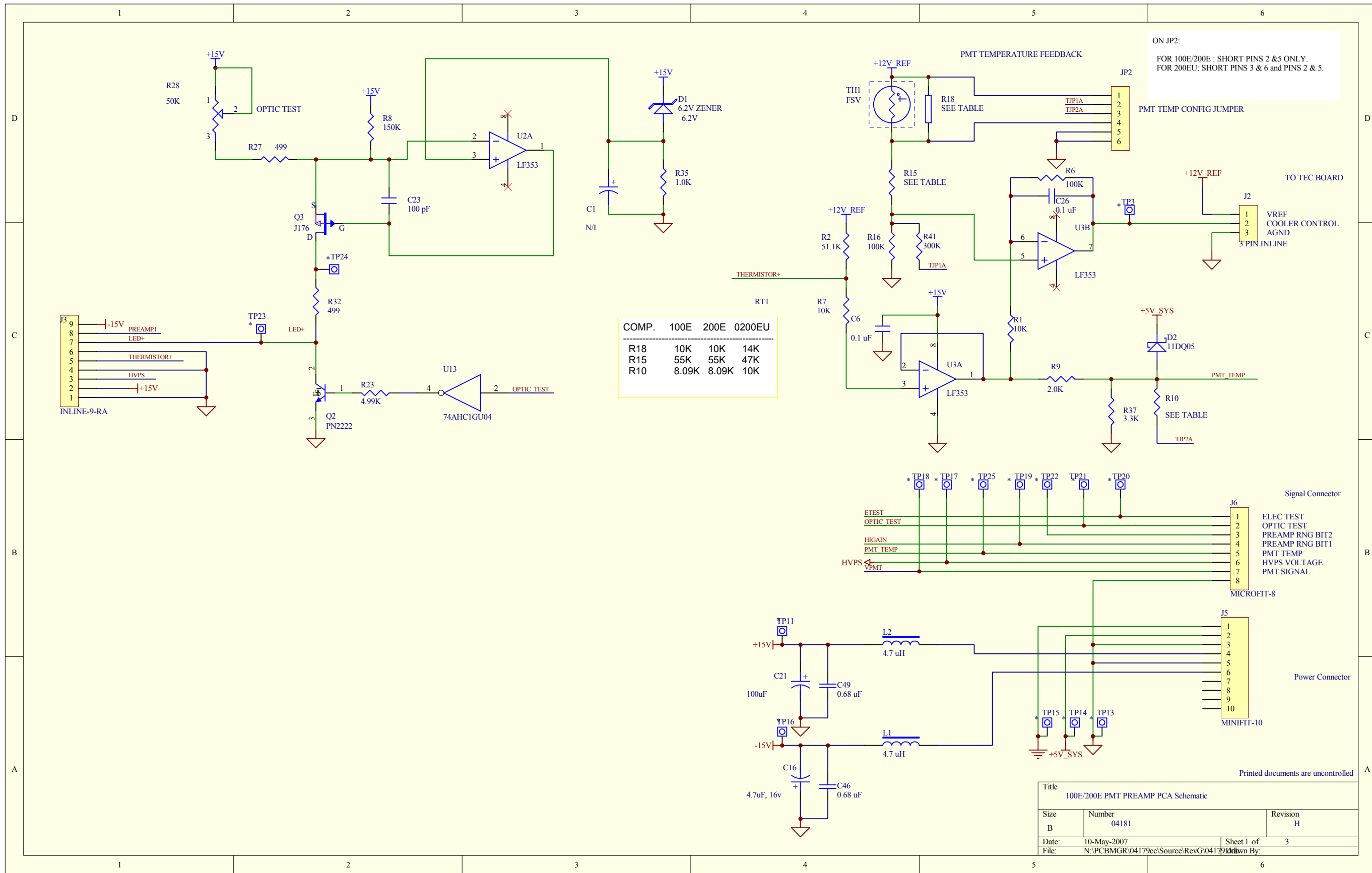
 TELEDYNE MONITOR LABS <small>A Teledyne Technologies Company</small>		SCH, PCA 04003, PRESS/FLOW, 'E' SERIES		
				APPROVALS
DRAWN		SIZE	DRAWING NO.	REVISION
CHECKED		B	04354	D
APPROVED		LAST MOD.	SHEET	
		3-Dec-2007	1 of 1	

'E' SERIES

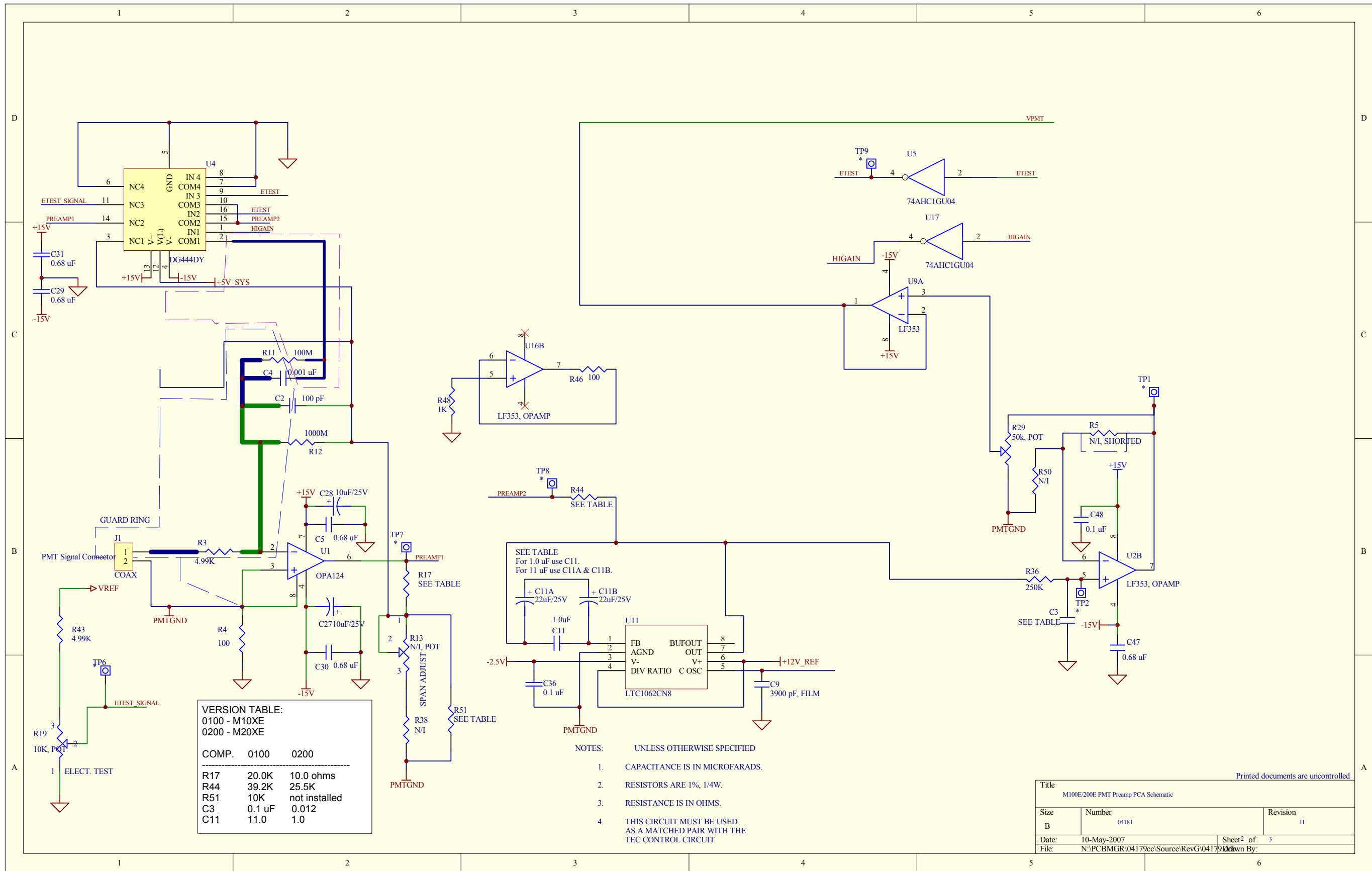


- NOTES:
- 1 THIS SCHEMATIC APPLIES TO PWB 04393 REV. A.
 - 2 ALL RESISTANCES IN OHMS, 1%
 - 3 PARTS DENOTED "S" ON SECONDARY SIDE OF PCA

TELEDYNE MONITOR LABS, INC.			
Title ETHERNET INTERFACE SCHEMATIC			
Size B	Number 04395	Rev A	
Date Thu Jul 25 2002	Drawn by		Sheet 1 of 1
Filename SLAN.S03			



COMP.	100E	200E	0200EU
R18	10K	10K	14K
R15	55K	55K	47K
R10	8.09K	8.09K	10K



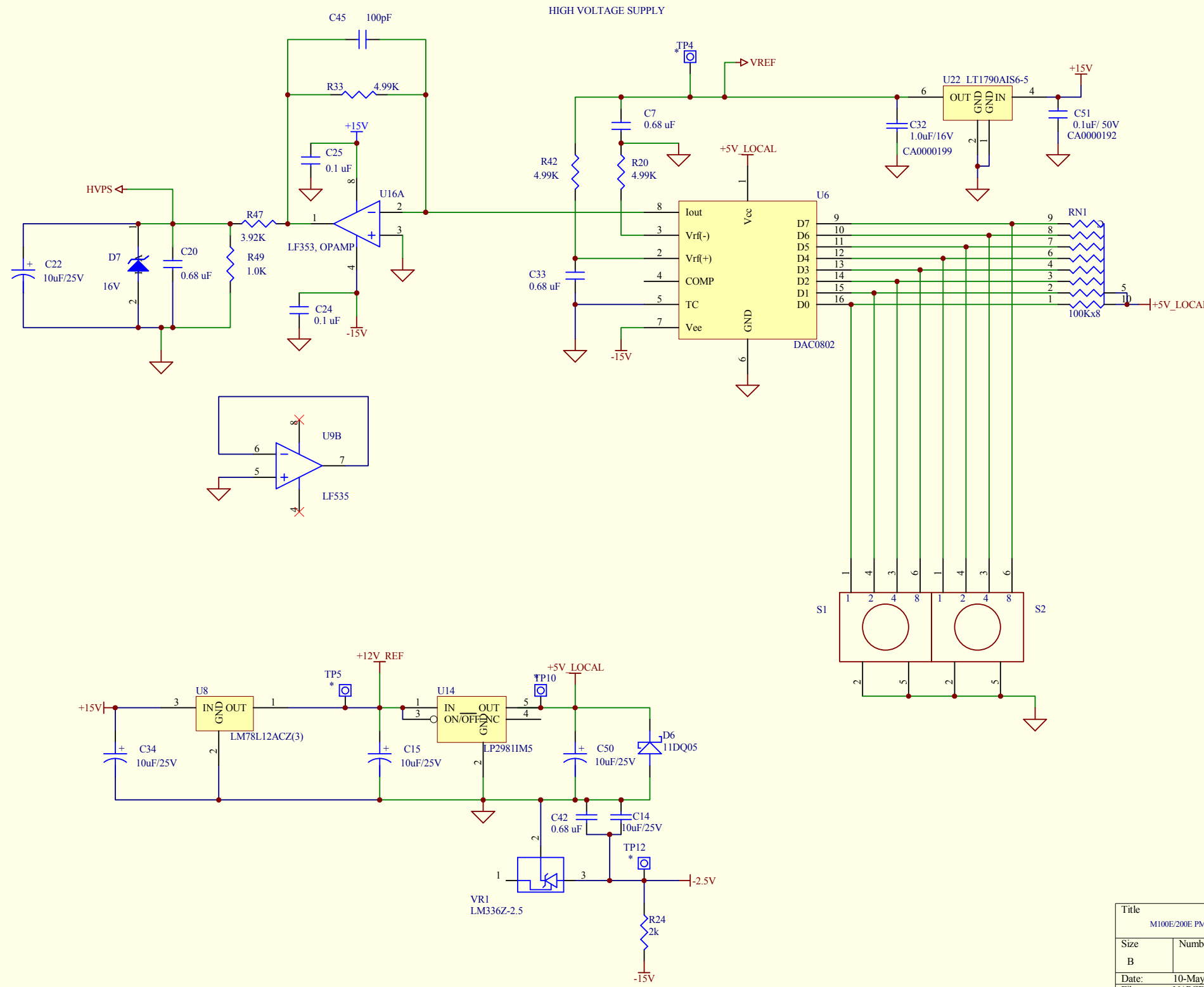
VERSION TABLE:
 0100 - M10XE
 0200 - M20XE

COMP.	0100	0200
R17	20.0K	10.0 ohms
R44	39.2K	25.5K
R51	10K	not installed
C3	0.1 uF	0.012
C11	11.0	1.0

- NOTES:** UNLESS OTHERWISE SPECIFIED
- CAPACITANCE IS IN MICROFARADS.
 - RESISTORS ARE 1%, 1/4W.
 - RESISTANCE IS IN OHMS.
 - THIS CIRCUIT MUST BE USED AS A MATCHED PAIR WITH THE TEC CONTROL CIRCUIT

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\04179cc\Down By:		



Printed documents are uncontrolled

Title		
M100E200E PMT PREAMP PCA Schematic		
Size	Number	Revision
B	04181	H
Date:	10-May-2007	Sheet 3 of 3
File:	N:\PCBMGR\04179ce\Source\RevG\04179ce.dwg	

1

2

3

4

A

A

B

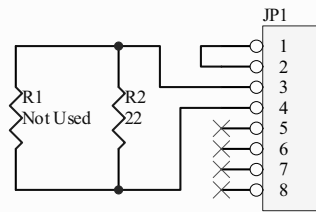
B

C

C

D

D



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:

1

2

3

4