TELEDYNE API
Everywhere**you**look™

User Manual

Models T360, T360M
Carbon Dioxide Analyzers

with NumaView™ software

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NOTICE OF COPYRIGHT

TRADEMARKS

SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol and is placed throughout this manual; the safety symbols are also located inside the instrument. It is imperative that you pay close attention to these messages, the descriptions of which are as follows:

WARNING: Electrical Shock Hazard

HAZARD: Strong oxidizer

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

CAUTION: Hot Surface Warning

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

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

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

CAUTION

This product should only be installed, commissioned, and used strictly for the purpose and in the manner described in this manual. If you improperly install, commission, or use this instrument in any manner other than as instructed in this manual or by our Technical Support team, unpredictable behavior could ensue with possible hazardous consequences.

Such risks, whether during installation and commission or caused by improper installation/commissioning/use, and their possible hazardous outcomes include but are not limited to:

RISK	HAZARD
Liquid or dust/debris ingress	Electrical shock hazard
Improper or worn power cable	Electrical shock or fire hazard
Excessive pressure from improper gas bottle connections	Explosion and projectile hazard
Sampling combustible gas(es)	Explosion and fire hazard
Improper lift & carry techniques	Personal injury

Note that the safety of a system that may incorporate this product is the end user's responsibility.

For Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product, contact Teledyne API's Technical Support Department:

Telephone: +1 800-324-5190 (toll free) or +1 858-657-9800
Email: api-techsupport@teledyne.com

or access any of the service options on our website at http://www.teledyne-api.com/

CONSIGNES DE SÉCURITÉ

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

AVERTISSEMENT : Risque de choc électrique

DANGER : Oxydant puissant

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

MISE EN GARDE : Surface chaude

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

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

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

MISE EN GARDE

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

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

MISE EN GARDE

Ce produit ne doit être installé, mis en service et utilisé qu'aux fins et de la manière décrites dans le présent manuel. Si vous installez, mettez en service ou utilisez cet instrument de manière incorrecte autre que celle indiquée dans ce manuel ou sous la direction de notre équipe de soutien technique, un comportement imprévisible pourrait entraîner des conséquences potentiellement dangereuses.

Ce qui suit est une liste, non exhaustive, des risques et résultats dangereux possibles associés avec une mauvaise utilisation, une mise en service incorrecte, ou causés mauvaise commission.

RISQUE	DANGER
Pénétration de liquide ou de poussière/débris	Risque de choc électrique
Câble d'alimentation incorrect, endommagés ou usé	Choc électrique ou risque d'incendie
Pression excessive due à des connexions de bouteilles de gaz incorrectes	Risque d'explosion et d'émission de projectile
Échantillonnage de gaz combustibles	Risque d'explosion et d'incendie
Techniques de manutention, soulevage et de transport inappropriées	Blessure corporelle

Notez que la sécurité d'un système qui peut incorporer ce produit est la responsabilité de l'utilisateur final.

WARRANTY

WARRANTY POLICY (02024J)

Teledyne API (TAPI), a business unit of Teledyne Instruments, Inc., provides that:

Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available. (For the instrument-specific warranty period, please refer to the "Limited Warranty" Section in the Terms and Conditions of Sale on our website at www.teledyne-api.com).

COVERAGE

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

NON-TAPI MANUFACTURED EQUIPMENT

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

PRODUCT RETURN

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

The complete Terms and Conditions of Sale can be reviewed at our website.

CAUTION – Avoid Warranty Invalidation

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

ABOUT THIS MANUAL

Along with this manual, support manuals are available on the CD of Instrument User Manuals and on the TAPI website http://www.teledyne-api.com, including:

- NumaView™ Remote Software User Guide, part number 08492

- Hessen Protocol Manual, part number 04585

- Fundamentals of ESD Manual, part number 04786 (to prevent Electro-Static Discharge and consequent damage to instrument)

- Pump Pack Manual, part number 07900 (if option installed)

NOTE	**We recommend that all users read this manual in its entirety before operating the instrument.**

CONVENTIONS USED

In addition to the safety symbols as presented in the *Safety Messages* page, this manual provides *special notices* related to the careful and effective use of the instrument and related, pertinent information.

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY** **This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.**

IMPORTANT	**IMPACT ON READINGS OR DATA** **Provides information about that which could either affect accuracy of instrument readings or cause loss of data.**

NOTE	**Provides information pertinent to the proper care, operation or maintenance of the instrument or its parts.**

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION, SPECIFICATIONS, APPROVALS, & COMPLIANCE

The Teledyne API Models T360 and T360M differ only in specifications; unless clearly differentiated, both models in this manual are referred to as the T360 for simplification. The T360/T360M measures carbon dioxide CO_2 by comparing infrared energy absorbed by a sample to that absorbed by a reference according to the Beer-Lambert law. This is accomplished by using a Gas Filter Wheel which alternately allows a high energy infrared (IR) light source to pass through a CO_2 filled chamber and a chamber with no CO_2 present.

The IR light then travels through the sample cell, which has a folded path. Energy loss through the sample cell is compared with the zero reference signal provided by the gas filter to produce an output proportional to concentration, with little effect from interfering gases within the sample. A nitrogen purge system is pro-vided for the GFC wheel assembly to eliminate the effects of ambient CO_2, if necessary.

This design produces superior zero and span stability and a high signal-to-noise ratio, allowing excellent sensitivity. Multi-tasking software gives real time indication of numerous operating parameters and provides automatic alarms if diagnostic limits are exceeded.

Proprietary software allows configurable data acquisition capability that can be triggered conditionally or periodically, enabling operators to perform predictive diagnostics and enhanced data analysis by tracking parameter trends. Reports can be downloaded onto a USB flash drive or via the I/O ports. Operators can also view real-time graphing with one touch of the interface screen.

1.1 SPECIFICATIONS

Table 1-1. Basic Unit Specifications

PARAMETER	SPECIFICATION	
Ranges (Physical Analog Output)	T360	T360M
	Min: 0-2 ppm Full scale Max: 0-2,000 ppm Full scale	Min: 0-4 ppm Full scale Max: 0-4000 ppm Full scale
	(user selectable, dual range supported)	
Measurement Units	ppb, ppm, µg/m^3, mg/m^3 (user selectable)	
Zero Noise	< 0.1 ppm (RMS)	< 0.2 ppm (RMS)
Span Noise	< 1% of reading (RMS)	
Lower Detectable Limit	< 0.2 ppm[1]	< 0.4 ppm[1]
Zero Drift (24 hours)	< 0.25 ppm[1]	< 0.5 ppm[1]
Span Drift (24 hours)	< 0.5% of reading [1]	
Response Time	< 70 seconds to 95%	
Linearity	1% of full scale	
Precision	0.5% of reading	
Sample Flow Rate	800 cc/min ±10% O$_2$ Sensor option adds 110 cc/min, ±20% to total flow when installed.	
Temperature Coefficient	< 0.1% of Full Scale per °C	
Voltage Coefficient	< 0.05% of Full Scale per V	
AC Power Requirements	Power Rating & Typical Power Consumption (TPC) 100V-120V~, 60Hz, 3.0A, TPC: 142W 220V – 240V~, 50/60Hz, 3.0A, TPC: 147W	
Analog Output Ranges	10V, 5V, 1V, 0.1V (selectable)	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage	
Recorder Offset	±10%	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital status outputs 6 opto-isolated digital control inputs (3 defined, 3 spare) 4 analog outputs	
Optional I/O	1 USB com port 1 RS485 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs	
Environmental	Installation category (over-voltage category) II; Pollution degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m	
Temperature Range	5-40°C	
Humidity Range	0 - 95% RH, non-condensing	
Dimensions H x W x D	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)	
Weight	40 lbs. (18.1 kg)	

[1] At constant temperature and voltage.

Table 1-2. O$_2$ Sensor Option Specifications

PARAMETER	DESCRIPTION
Ranges	0-1% to 0-100% user selectable. Dual ranges and auto-ranging supported.
Zero Noise[1]	< 0.02% O$_2$
Lower Detectable Limit[2]	< 0.04% O$_2$
Zero Drift (24 hours) [3]	<± 0.02% O$_2$
Span Noise[1]	<± 0.05% O$_2$
Accuracy	(intrinsic error) <± 0.1% O$_2$
Linearity	<± 0.1 % O$_2$
Temp Coefficient	<± 0.05% O$_2$ /°C,
Rise and Fall Time	< 60 seconds to 95%

[1] As defined by the USEPA
[2] Defined as twice the zero noise level by the USEPA
[3] Note: zero drift is typically <± 0.1% O$_2$ during the first 24 hrs of operation

1.2 COMPLIANCE AND CERTIFICATIONS

This product is CE compliant and adheres to the Low Voltage and ElectroMagnetic Compatibility directives.

For any other certifications, please refer to this product's specifications sheet on our website.

2. GETTING STARTED

This Section addresses unpacking, connecting, and initializing the instrument, getting an overview of the menu system, and setting up/configuring the functions.

2.1   UNPACKING

	CAUTION - GENERAL SAFETY HAZARD
⚠️	To avoid personal injury, always use two persons and proper lift and carry techniques to move/relocate the analyzer.

ATTENTION	COULD DAMAGE INSTRUMENT AND VOID WARRANTY
	Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use Electro-Static Discharge (ESD) protection when working with electronic assemblies will void the instrument warranty. Refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at http://www.teledyne-api.com.

ATTENTION	COULD DAMAGE INSTRUMENT AND VOID WARRANTY
	Do not operate this instrument without first removing dust plugs from SAMPLE and EXHAUST ports on the rear panel.

Note	Teledyne API recommends that you store shipping containers and materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty statement in this manual and Return Merchandise Authorization (RMA) on our Website at http://www.teledyne-api.com.

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

Included with your instrument 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, is an important quality assurance and calibration record and should be placed in the quality records file for this instrument.

> ⚠ **WARNING – ELECTRICAL SHOCK HAZARD**
>
> **Never disconnect or reconnect PCAs, wiring harnesses or electronic subassemblies while instrument is under power.**

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

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

2.1.1 VENTILATION CLEARANCE

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

Table 2-1. Ventilation Clearance

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

Various rack mount kits are available for this analyzer. Contact Sales for more information.

2.2 INSTRUMENT LAYOUT

Instrument layout includes front panel, rear panel connectors, and internal chassis layout.

2.2.1 FRONT PANEL

The front panel (Figure 2-1) includes two USB ports for peripheral device connections, which can be used with mouse and keyboard as alternatives to the touchscreen interface, or with flash drive for uploads/downloads (devices not included).
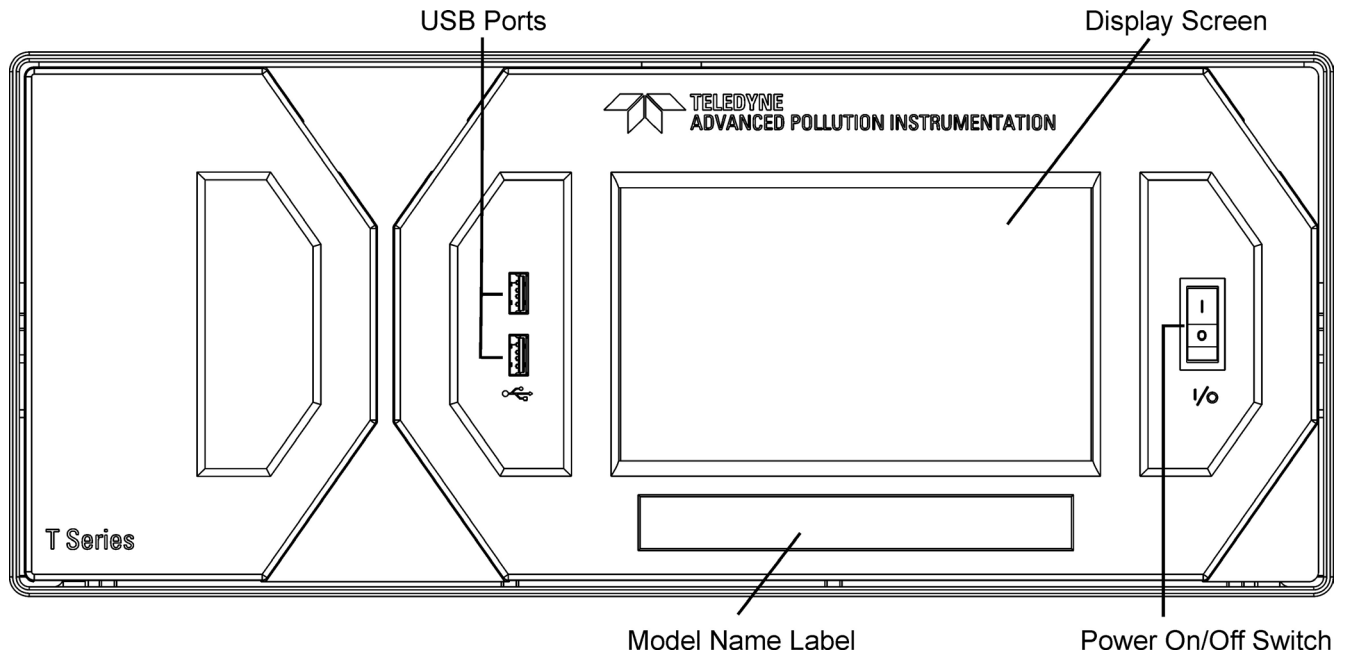
Figure 2-1. Front Panel Layout

2.2.2 REAR PANEL

Figure 2-2 shows the layout of the rear panel.
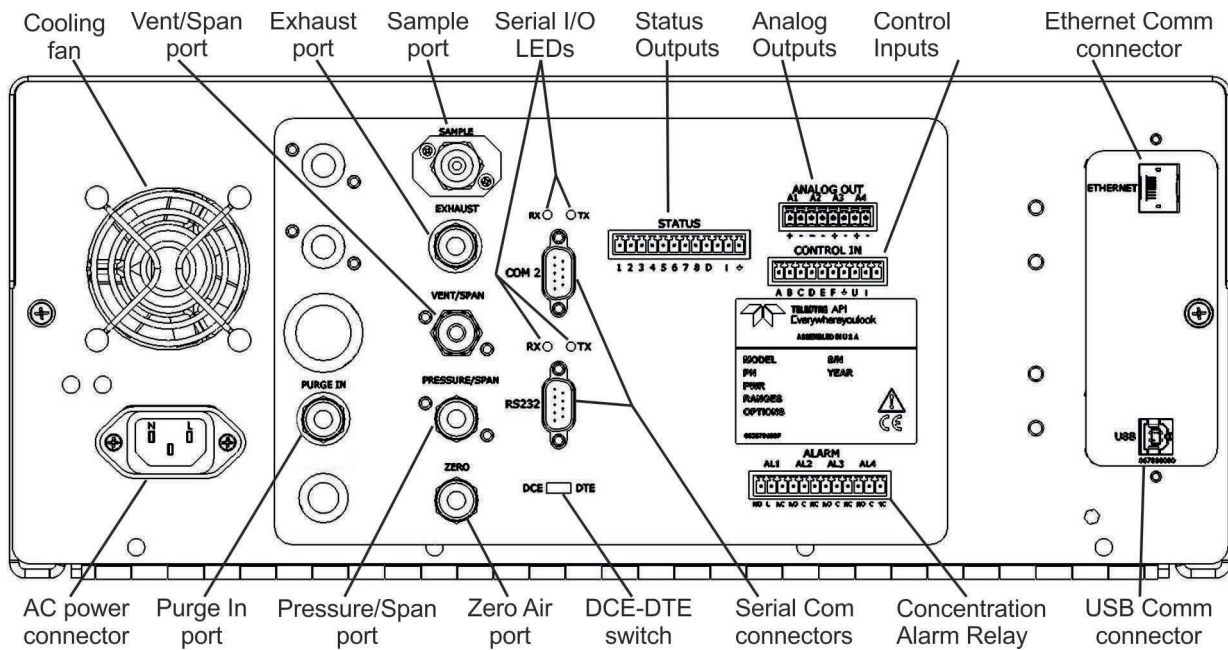
Figure 2-2. Rear Panel Layout

Table 2-2 provides a description of each component on the rear panel.

Table 2-2. Rear Panel Description

COMPONENT	FUNCTION
cooling fan	Pulls ambient air into chassis through side vents and exhausts through rear
AC power connector	Connector for three-prong cord to apply AC power to the analyzer **CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label**
Model/specs label	Identifies the analyzer model number and provides power specs
PURGE IN	Connect a source of dried air that has been scrubbed of CO_2. This inlet supplies purge air to the GFC wheel housing.
SAMPLE	Connect a gas line from the source of sample gas here. Calibration gases are also inlet here on units without zero/span valve options installed.
EXHAUST	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument.
VENT/SPAN	Span gas vent outlet for units with zero/span valve options installed. Connect an exhaust gas line of not more than 10 meters long here.
PRESSURE/SPAN	On units with zero/span valve options installed, connect a gas line to the source of calibrated span gas here.
ZERO	Internal Zero Air: On units with zero/span valve options installed but no internal zero air scrubber, attach a gas line to the source of zero air here.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
COM 2	Serial communications port for RS-232 or RS-485.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication.
STATUS	For outputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ALARM	Option for concentration alarms and system warnings.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable.
USB (option)	Com port optional connector for direct connection to laptop computer, using USB cable.
Information Label	Includes voltage and frequency specifications.

2.2.3 INTERNAL CHASSIS

This section shows the internal layout.
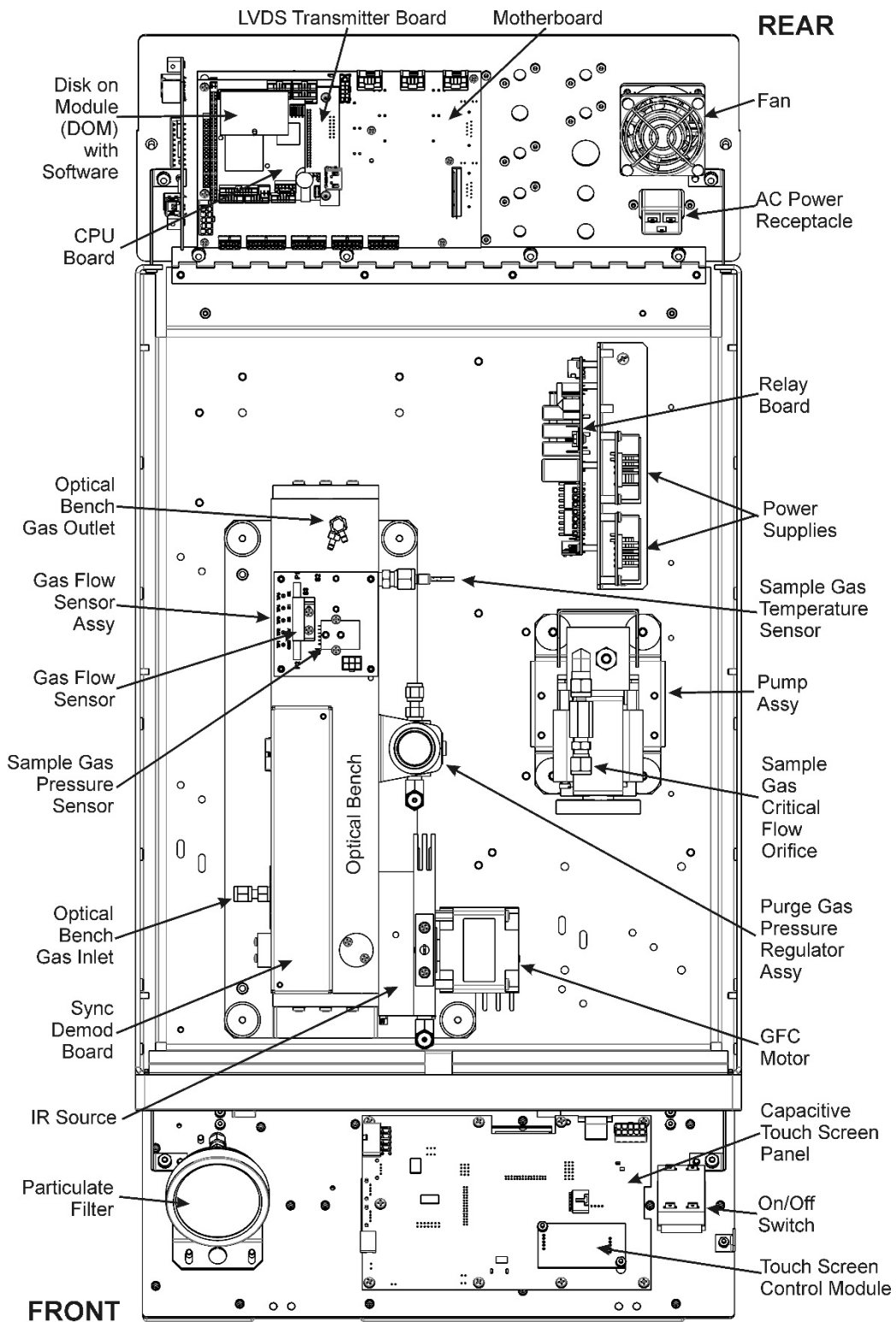
Figure 2-3. Internal Layout
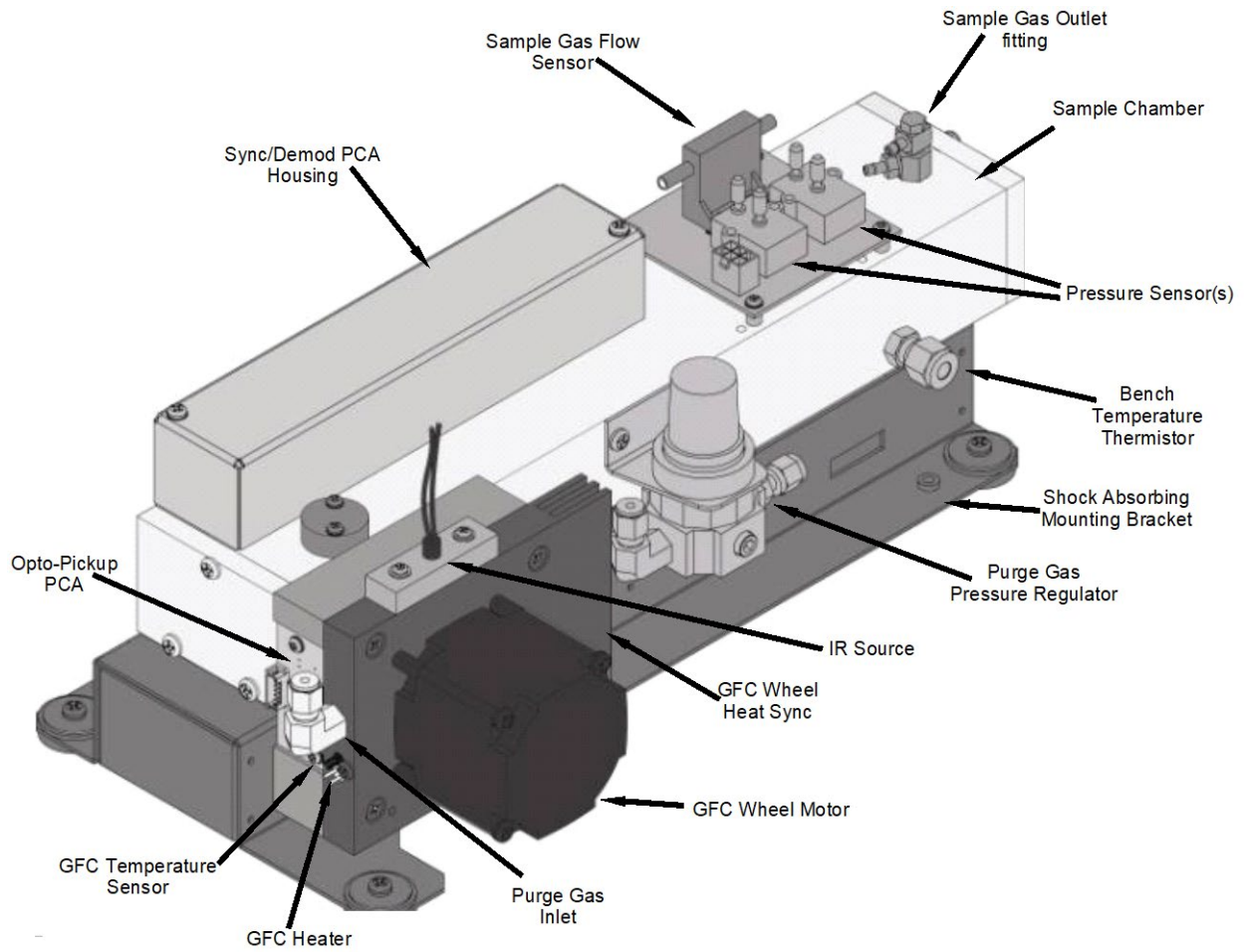
Figure 2-4. Optical Bench Layout

2.3 CONNECTIONS AND STARTUP

This Section presents the electrical (Section 2.3.1) and pneumatic (Section 2.3.2) connections for setup and preparing for instrument operation.

2.3.1 ELECTRICAL CONNECTIONS

Note	To maintain compliance with EMC standards, cable must be no longer than 3 meters for all I/O connections.

WARNING – Electrical Shock Hazard
- **High Voltages are present inside the instrument's case.**
- **Power connection must have functioning ground connection.**
- **Do not defeat the ground wire on power plug.**
- **Turn off instrument power before disconnecting or connecting electrical subassemblies.**
- **Do not operate with cover off.**

CAUTION – Avoid Damage to the Instrument
Ensure that the AC power voltage matches the voltage indicated on the instrument's model/specs label before plugging it into line power.

2.3.1.1 CONNECTING POWER

Attach the power cord between the instrument's AC power connector and a power outlet capable of carrying at least the rated current at your AC voltage range and ensure that it is equipped with a functioning earth ground. It is important to adhere to all safety and cautionary messages.

2.3.1.2 CONNECTING ANALOG OUTPUTS

The rear panel Analog Output channels A1 through A4 can be mapped to reflect various operating values in the analyzer, including concentration values, temperatures, pressures, etc. These mappings are not configured by default and must be set by the user.

An optional Current Loop output (Section 2.3.1.3) is available for A1, A2 and A3 only.

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

ConFigure through the Setup>Analog Outputs menu (Section 2.5.8).
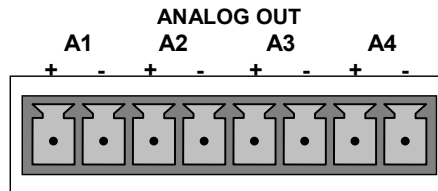
Figure 2-5. Analog Output Connector

Table 2-3. Analog Output Pin-Outs

PIN	ANALOG OUTPUT	SIGNAL OUT	STANDARD VOLTAGE OUTPUT	CURRENT LOOP OPTION
1	A1	User-selected through the Setup>Analog Outputs menu.	V Out	I Out +
2	A1		Ground	I Out -
3	A2		V Out	I Out +
4	A2		Ground	I Out -
5	A3		V Out	I Out +
6	A3		Ground	I Out -
7	A4		V Out	I Out +
8	A4		Ground	I Out -

2.3.1.3 CURRENT LOOP ANALOG OUTPUTS (OPTION 41) SETUP

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

Figure 2-6 provides installation instructions and illustrates a sample configuration of one current output and two voltage outputs. Following Figure 2-6 are instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs. To calibrate or adjust these outputs use the Setup>Analog Outputs menu (Section 2.5.8).

⚠	**CAUTION – Avoid Invalidating Warranty** **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. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at http://www.teledyne-api.com.**

J19, J21, J23 Analog Output Setup:

J19, J21, J23

- For **voltage** output of any one, two, or all:
    1. Jumper two leftmost pins.
    2. Jumper next two leftmost pins.
    3. Calibrate per Analog I/O Configuration menu.

- For **current** output of any one, two, or all:
    1. Remove jumper shunts.
    2. Install Current Loop option.
    3. Calibrate per Analog I/O Configuration menu.
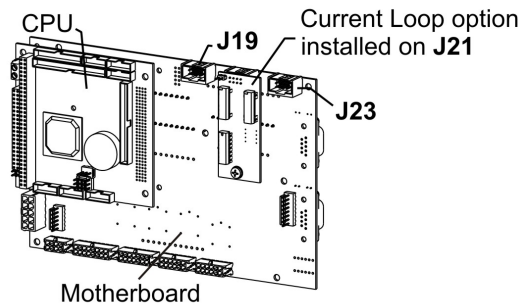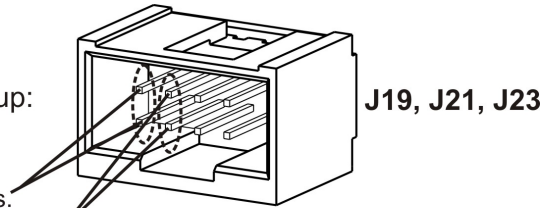
Example setup: install jumper shunts for voltage output on J19 and J23; remove jumper shunts and install Current Loop option for current output on J21.

Figure 2-6. Current Loop Option Installed on Motherboard

CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

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

1. Turn off power to the analyzer.
2. If a recording device was connected to the output being modified, disconnect it.
3. Remove the top cover.

    - Remove the screws fastening the top cover to the unit (both sides).

    - Slide the cover back and lift straight up.

4. Remove the screw holding the current loop option to the motherboard.
5. Disconnect the current loop option PCA from the appropriate connector on the motherboard (see Figure 2-6).

6. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left-most pins and the second shunt on the two pins next to it (see Figure 2-6).

7. Reattach the top case to the analyzer.

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

8. Calibrate the analog output in the Setup>Analog Outputs>Analog Output Cal menu.

2.3.1.4 CONNECTING THE STATUS OUTPUTS (DIGITAL OUTPUTS)

The 12-pin STATUS connector allows the digital status outputs to report analyzer conditions (configured through the Setup>Digital Outputs menu) 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 pin D (see Figure 2-7).

ATTENTION COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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.

STATUS

1 2 3 4 5 6 7 8 D +

Map the digital outputs 1 thru 8 through the Setup>Digital Outputs menu.

+5V to external device
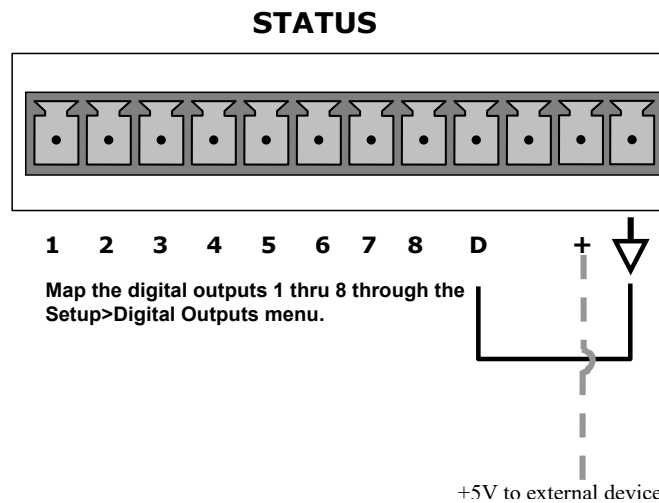
Figure 2-7. Status Output Connector for Digital Outputs

Table 2-4. Status Output Pin Assignments

PIN	STATUS DEFINITION	CONDITION
1-8	Configurable through the Setup>Digital Outputs menu	Collector side of individual status output opto-isolators.
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
Blank	NO CONNECTION	
+	DC Power	+ 5 VDC, 300 mA source maximum
⏚	Digital Ground	The ground level from the analyzer's internal DC power supplies. This connection should be used as the ground return when +5VDC power is used.

2.3.1.5 CONNECTING THE CONTROL INPUTS (DIGITAL INPUTS)

With zero and span valves option installed, their digital control inputs are provided through the rear panel 10-pin **CONTROL IN** connector to remotely activate the zero and span calibration modes.

Energize the Control Inputs either by the internal +5V available from the pin labeled "+" (more convenient), or by a separate external 5 VDC power supply (ensures that these inputs are truly isolated). Refer to Figure 2-8
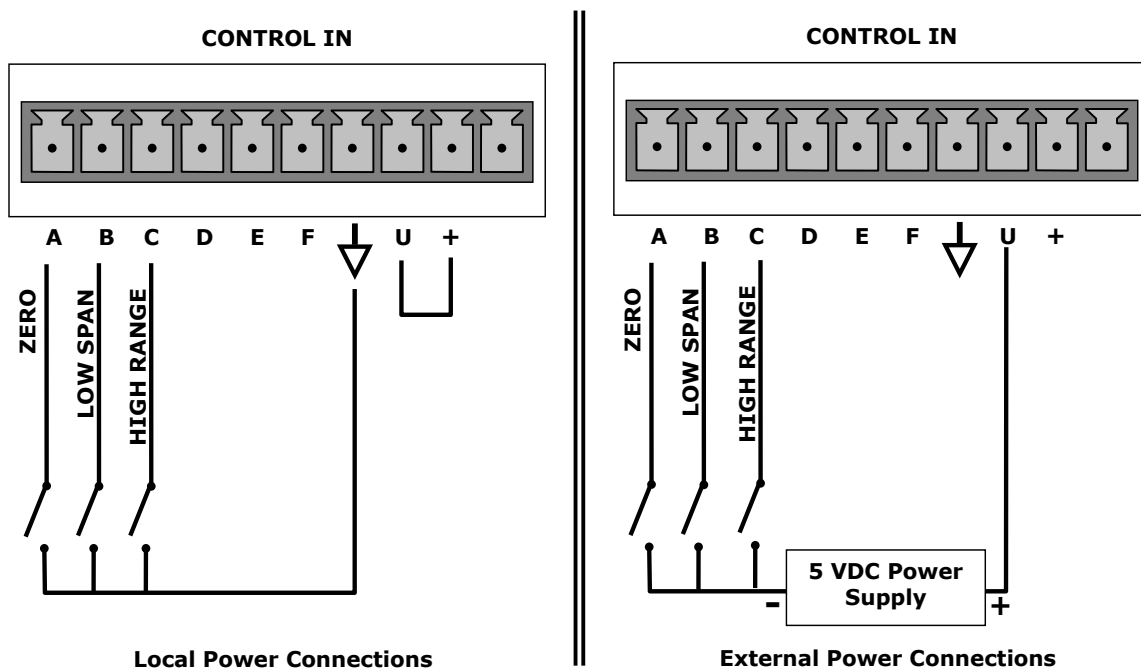
Figure 2-8. Control Input Connector

Table 2-5. Control Input Signals

INPUT #	STATUS DEFINITION	ON CONDITION
A	**REMOTE ZERO CAL**	The analyzer is placed in Zero Calibration mode.
B	**REMOTE SPAN CAL**	The analyzer is placed in span calibration mode as part of performing a low span (midpoint) calibration.
C	**REMOTE CAL HIGH RANGE**	The analyzer is forced into high range for zero or span calibrations. This only applies when the range mode is either DUAL or AUTO.
D, E & F	SPARE	
▽	Digital Ground	The ground level from the analyzer's internal DC power supplies (same as chassis ground).
U	External Power input	Input pin for +5 VDC required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the "U" pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

2.3.1.6 CONNECTING THE CONCENTRATION ALARM RELAY (OPTION 61)

The concentration alarm option provides four (4) "dry contact" relays on the rear panel (Figure 2-9) , each with 3 pins: Common (C), Normally Open (NO), and Normally Closed (NC). The Relays can be mapped to reflect various internal instrument conditions and states.   ConFigure these outputs through the Setup>Digital Outputs menu (Section 2.5.7) under MB Relay [1 thru 4].
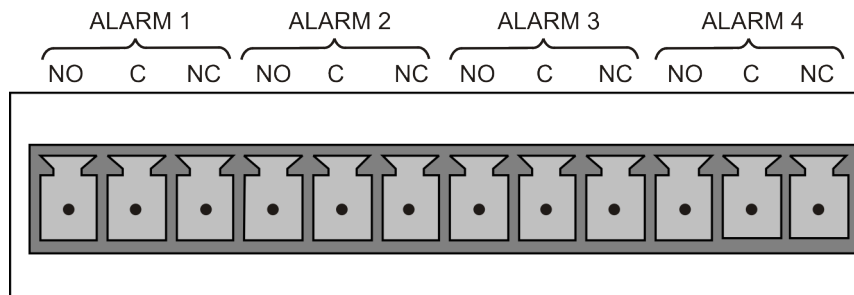
Figure 2-9. Concentration Alarm Relay

2.3.1.7 CONNECTING THE COMMUNICATION INTERFACES

For remote communications, the rear panel provides **Ethernet**, **USB**, **RS-232**, optional **RS-232 Multidrop**, and optional **RS-485** connectors. In addition to using the appropriate cables, each type of communication method must be configured using the SETUP>COMM menu, Section 2.5.10).

LAN OR ETHERNET CONNECTION

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer's rear panel Ethernet interface connector to an Ethernet access port. Although Ethernet is DHCP-enabled by default, it should be manually configured (Section 2.5.10.5) with a static IP address.

USB (OPTION) CONNECTION

The rear panel USB option can be used for direct communication between the analyzer and a PC; connect a USB cable between the analyzer and computer USB ports (ensure baud rates match). A USB driver is required for complete configuration.

Note	If this option is installed, the rear panel RS232 (COM2) port cannot be used for anything other than Multidrop communication.

RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A), as applicable, from the analyzer's rear panel RS-232 port to the device. Adjust the rear panel DCE-DTE switch (Figure 2-2) to select DTE or DCE as appropriate.

Configuration: Section Section 3.2.1 and/or Section 3.4.2 (for Hessen protocol).

IMPORTANT	IMPACT ON READINGS OR DATA
	Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 2-10) before using.

RS-232 COM PORT CONNECTOR PIN-OUTS

Electronically, the difference between the DCE and DTE 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.
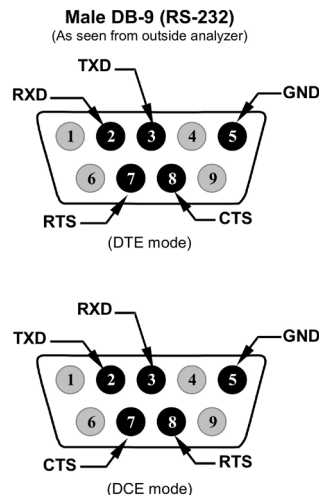
Figure 2-10. Rear Panel Connector Pin-Outs for RS-232 Mode

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 (COM1) and J12 (COM2) (Figure 2-11).
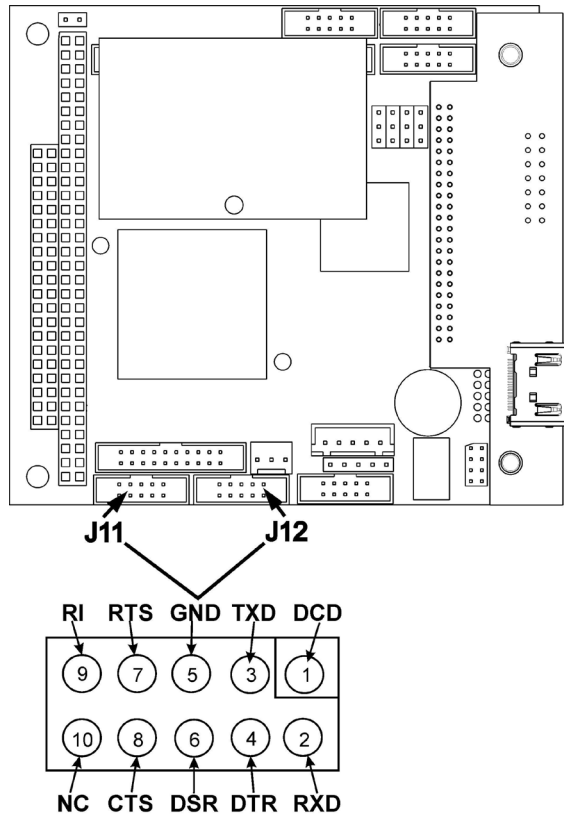
Figure 2-11. Default Pin Assignments for CPU COM Port connector (RS-232)

RS-232 COM PORT DEFAULT SETTINGS

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. (View these parameters in the Setup>Comm>COM1[COM2] menu).

- **RS-232 (COM1)**: RS-232 (fixed) DB-9 male connector.
  - **Baud rate**: 115200 bits per second (baud)
  - **Data Bits**: 8 data bits with 1 stop bit
  - **Parity**: None
- **COM2**: RS-232 (configurable to RS-485), DB-9 female connector.
  - **Baud rate**: 19200 bits per second (baud)
  - **Data Bits**: 8 data bits with 1 stop bit
  - **Parity**: None

RS-232 MULTIDROP OPTION CONNECTION

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

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

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

In each instrument with the Multidrop option there is a shunt jumpering two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 2-12. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the Multidrop/LVDS PCA, which is seated on the CPU.

2. On the Multidrop/LVDS PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).

3. Check that the following cable connections are made in *all* instruments (again refer to Figure 2-12):
   - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector
     (Note that the CPU's COM2 connector is not used in Multidrop)
   - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
   - J1 on the Multidrop/LVDS PCS to the front panel LCD

JP2 has a shunt on Pins 21-22. Remove this shunt from all analyzers except the last analyzer in the chain; leave the shunt installed on Pins 21-22 on the last analyzer.
Adjust accordingly if new instrument(s) added later.

Disk on Module (DOM)

J3

JP2

Serial multi-drop and LVDS board (seated on CPU)

Cable PN 06738 J3 to J11

Cable PN 04671

J4

J4 to J12 on motherboard

video cable to front panel LCD

J1

CPU COM1 (J11) connector

(CPU COM2 is not used in Multidrop).

Figure 2-12. Jumper and Cables for Multidrop Mode

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

4. Close the instrument.

5. Referring to Figure 2-13 use straight-through DB9 male $\rightarrow$ DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.

6. On the rear panel of each analyzer, adjust the DCE DTE switch so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables internally wired specifically for RS-232 communication; see Section 2.3.1.7: Connecting the Communications Inerfaces, "RS-232 Connection").
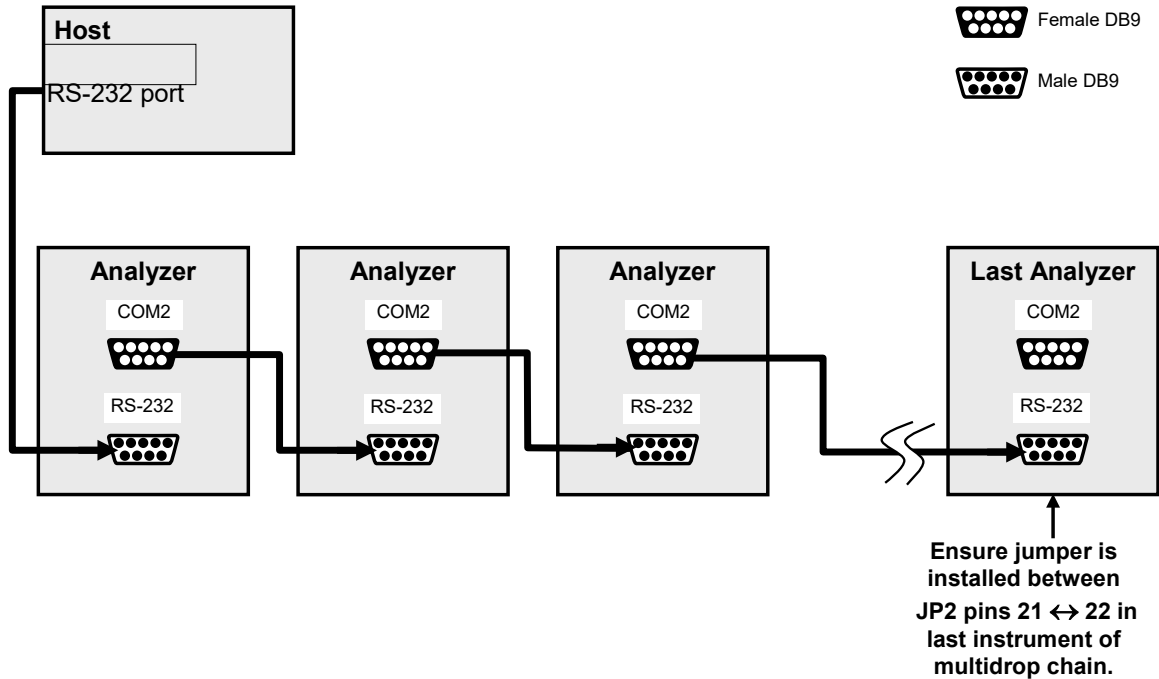
Figure 2-13. RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

7. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each. In the Setup>Vars menu, check Instrument ID in the list of variables. To change, select the variable and press the Edit button; once changed, press the Enter button.

8. Next, in the Setup>Comm>COM1 menu (do not use the COM2 menu for multidrop), use the Edit button to set COM1 Quiet Mode and COM1 Multidrop to ENABLED; then press the Accept button.

9. Also check the COM1 Baud Rate to ensure it reads the same for all instruments (edit if needed and press the Accept button).

Note	
	• **Instrument ID's must not be duplicated.**
	• **The (communication) Host instrument can only address one instrument at a time.**
	• **Teledyne API recommends setting up the first link, between the Host and the first analyzer, and testing it before setting up the rest of the chain.**

2.3.2 PNEUMATIC CONNECTIONS

This Section provides pneumatic connection information; Section 2.3.3 shows the pneumatic flow diagrams for the analyzer in its basic configuration and with options. Before making the pneumatic connections, carefully note the following cautionary and special messages:

> **CAUTION**
>
> **Venting should be outside the shelter or immediate area surrounding the instrument..**

IMPORTANT	Sample and calibration gases should only come into contact with PTFE (Teflon), FEP, glass, stainless steel or brass.

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

Maximum Pressure:

Ideally the maximum pressure of any gas at the sample inlet should equal ambient atmospheric pressure (0 psig) and should NEVER exceed 1.5 in-hg above ambient pressure.

Venting Pressurized Gas:

In applications where any gas (span gas, zero air supply, sample gas is) received from a pressurized manifold, a vent must be provided to equalize the gas with ambient atmospheric pressure before it enters the analyzer to ensure that the gases input do not exceed the maximum inlet pressure of the analyzer, as well as to prevent back diffusion and pressure effects. These vents should be:
* **at least 0.2 m long**
* **no more than 2.0 m long**
* **vented outside the shelter or immediate area surrounding the instrument.**

Dust Plugs:

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

IMPORTANT	**LEAK CHECK**
	Run a leak check once the appropriate pneumatic connections have been made; check all pneumatic fittings for leaks using the procedures defined in Section 5.6.3.

See Figure 2-2 and Table 2-2 for the location and descriptions of the various pneumatic inlets/outlets referenced in this section.

2.3.2.1 IMPORTANT INFORMATION ABOUT CALIBRATION GASES

Zero air and span gas are required for accurate calibration.

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. In the case of CO_2 measurements this means less than 0.1 ppm of CO_2 and Water Vapor (when dew point <-15˚C). Zero Air can be purchased in pressurized canisters.

SPAN GAS

Span Gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range, and can be purchased in pressurized canisters or created using Dynamic Dilution Calibrator such as the Teledyne Instruments Model T700 and a source of dried air scrubbed of CO_2 such as a bottle of N_2. In the case of CO_2 measurements made with the Teledyne API's Model T360 Analyzer, it is recommended that you use a gas calibrated to have a CO_2 content equaling 80% of the range of compositions being measured.

EXAMPLE: If the application is to measure between 0 ppm and 500 ppm, an appropriate Span Gas would be 400 ppm. If the application is to measure between 0 ppm and 100 ppm, an appropriate Span Gas would be 80 ppm.

2.3.2.2 PNEUMATIC CONNECTIONS: BASIC CONFIGURATION

1. Attach a sample inlet line to the sample inlet port. The SAMPLE input line should not be more than 2 meters long.

2. Attach sources of zero air and span gas (see Figures 3-3 through 3-8 inclusive).

3. Attach an exhaust line to the exhaust outlet port.

   - The exhaust from the pump and vent lines should be vented to atmospheric pressure using maximum of 10 meters of ¼" PTEF tubing.

4. Attach a source of dried air scrubbed of CO_2 to the purge inlet port.

5. Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks

Note   The purge air source should be capable of delivering a
continuous flow of at least 0.5 L/min.The minimum gas
pressure of the source of purge air should be 7.5 psig. If
the source of the purge air is shared by a Teledyne
Instruments T700, the minimum gas pressure should be 25
psig and should not exceed 35 psig.
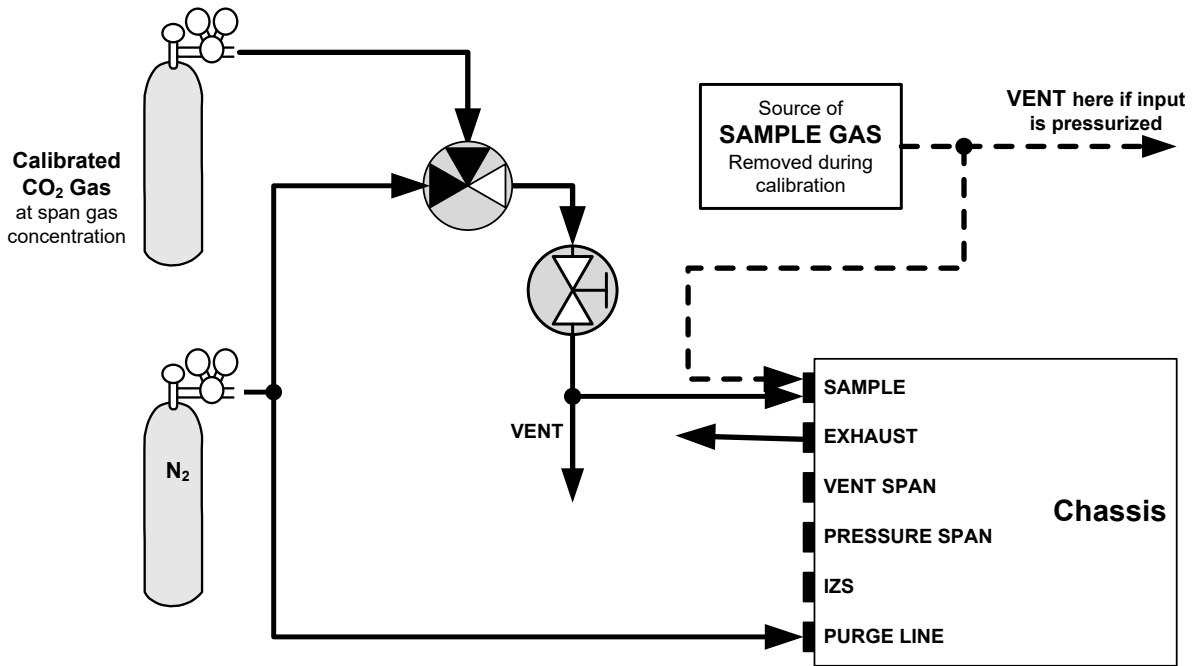
Figure 2-14. Pneumatic Connections–Basic Configuration–Using Bottled Span Gas
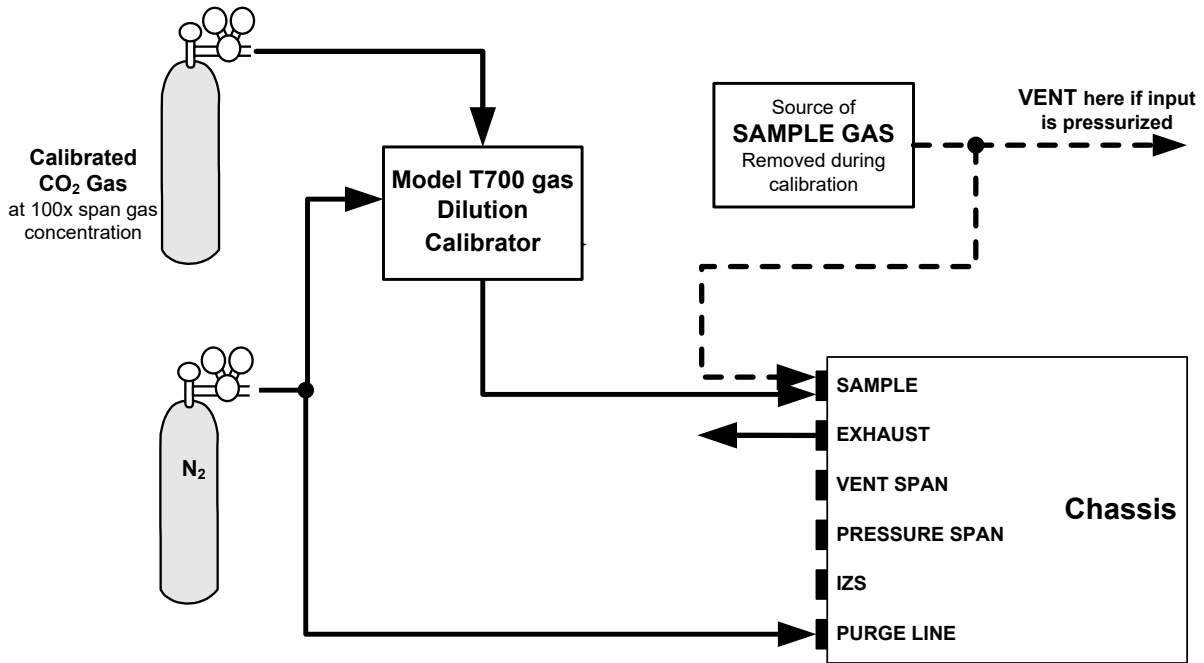
Figure 2-15. Pneumatic Connections–Basic Configuration–Using Gas Dilution Calibrator

2.3.2.3 PNEUMATIC CONNECTIONS: AMBIENT ZERO/AMBIENT SPAN OPTION (50A)

The following illustrations show the pneumatic connections for the ambient zero and ambient span valve option (Option 50A). The minimum span gas flow rate required for this option is 800 cm^3/min.
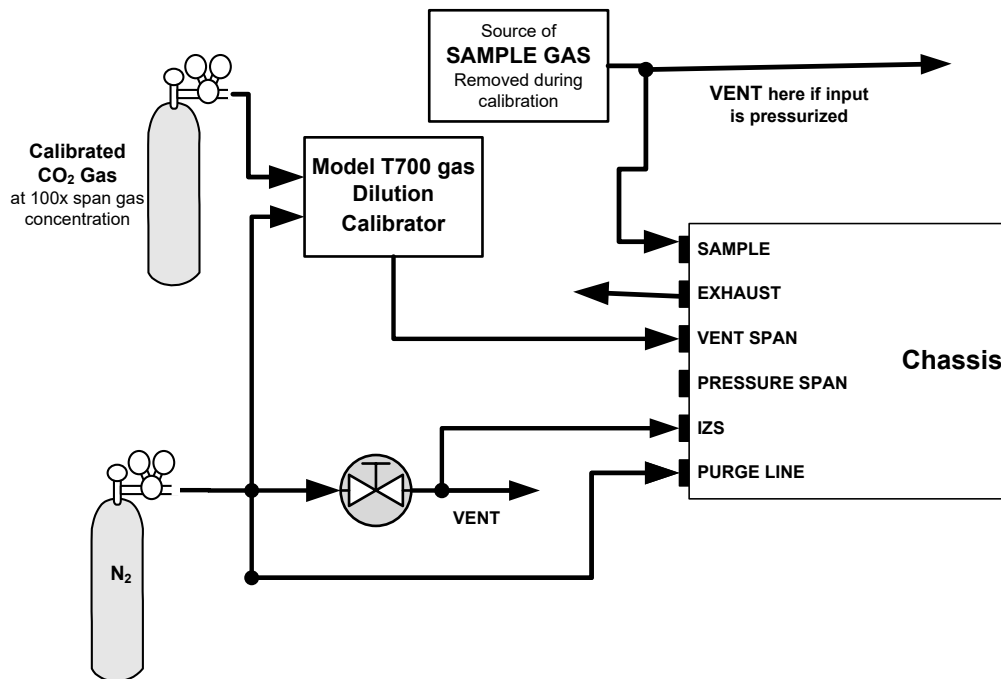
Figure 2-16. Pneumatic Connections with Ambient Zero/Ambient Span Valves (OPT 50A)
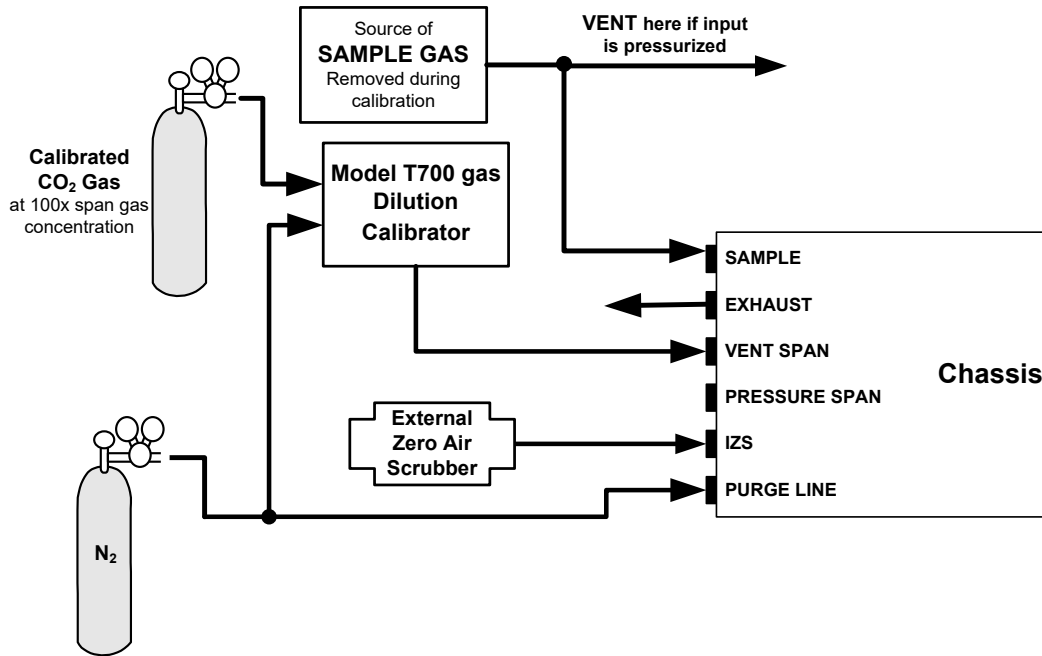
Figure 2-17. Pneumatic Connections with Ambient Zero/Ambient Span Valves (Opt 50A) and External Zero Air Scrubber

This valve option is intended for applications where zero air is supplied by a zero air generator like a bottle of N_2 and span gas are being supplied by Gas Dilution Calibrator like the Teledyne Instruments Model 700 or 702. Internal zero/span and sample/cal valves control the flow of gas through the instrument, but because the calibrator limits the flow of span gas no shutoff valve is required.

In order to ensure that span gas does not migrate backwards through the vent line and alter the concentration of the span gas, a gas line not less than 2 meters in length should be attached to the vent span outlet on the rear panel of the analyzer. To prevent the buildup of back pressure, this vent line should not be greater than 10 meters in length.

2.3.2.4 PNEUMATIC CONNECTIONS: AMBIENT ZERO/PRESSURIZED SPAN OPTION (50B)

The following illustrations show the pneumatic connections for the ambient zero and pressurized span valve option (Option 50B). The minimum span gas flow rate required for this option is 800 cm^3/min.
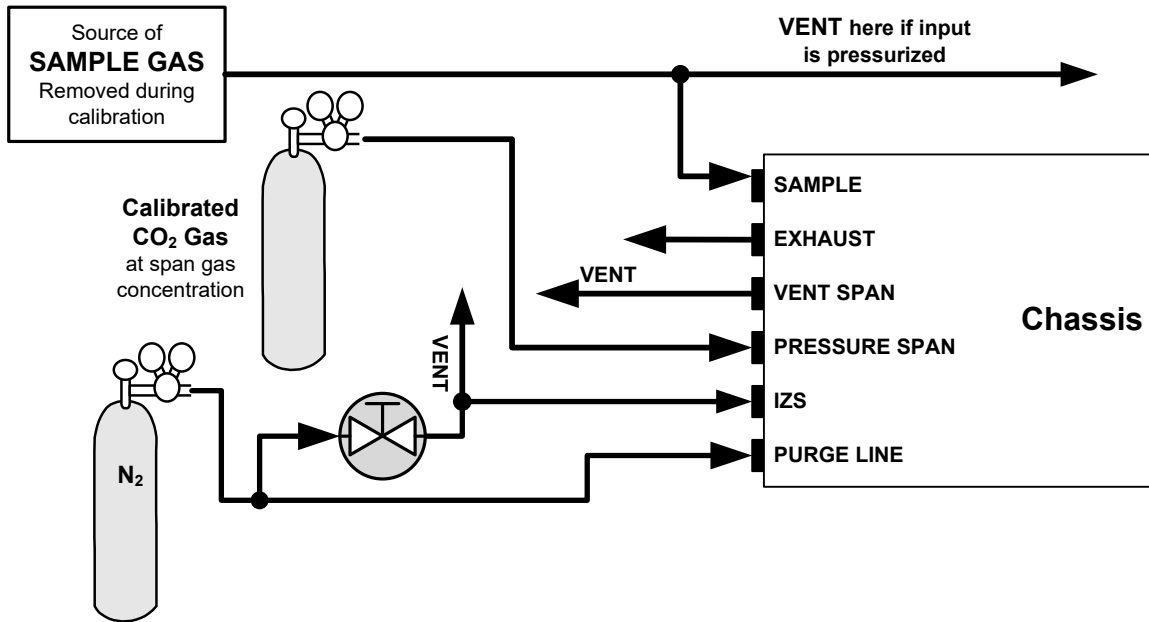
Figure 2-18. Pneumatic Connections with Ambient Zero/Pressurized Span Valves (OPT 50B)
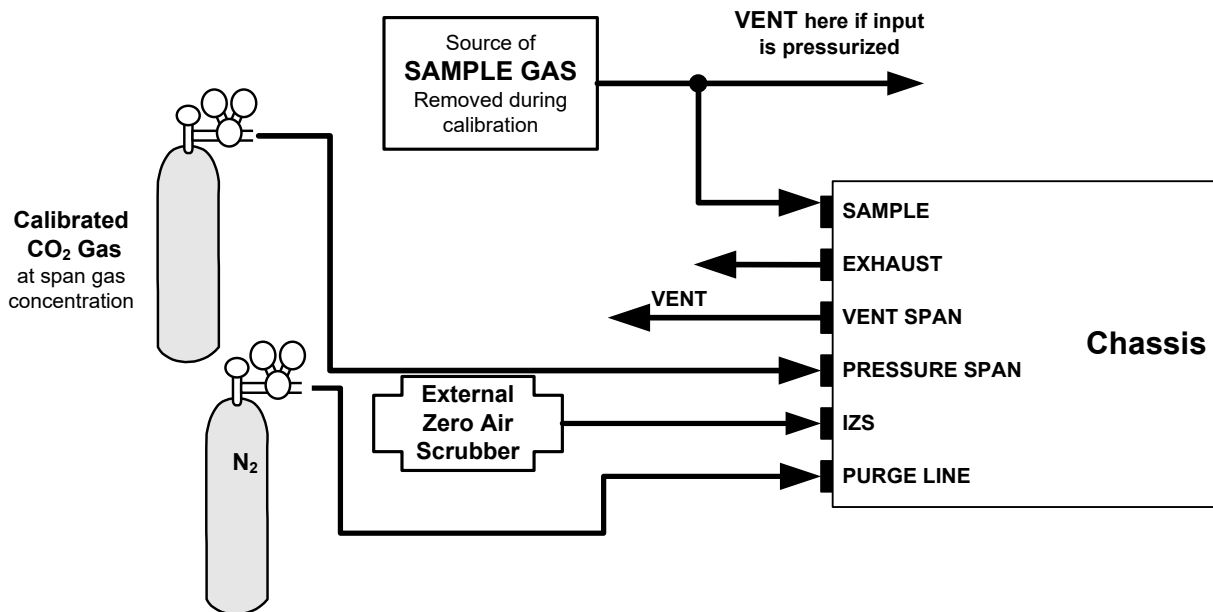
Figure 2-19. Pneumatic Connections with Ambient Zero/Pressurized Span Valves (Opt 50B) and External Zero Air Scrubber

This option requires that both zero air and span gas be supplied from external sources. It is specifically designed for applications where span gas will be supplied from a pressurized bottle of calibrated CO_2 gas. A critical flow control orifice, internal to the

instrument ensures that the proper flow rate is maintained. An internal vent line, isolated by a shutoff valve ensures that the gas pressure of the span gas is reduced to ambient atmospheric pressure. Normally zero air would be supplied from zero air modules such as a Teledyne Instruments Model 701.

In order to ensure that span gas does not migrate backwards through the vent line and alter the concentration of the span gas, a gas line not less than 2 meters in length should be attached to the vent span outlet on the rear panel of the analyzer. To prevent the buildup of back pressure, this vent line should not be greater than 10 meters in length.

2.3.2.5 PNEUMATIC CONNECTIONS: MULTIPOINT CALIBRATION APPLICATIONS

Some applications may require multipoint calibration checks where span gas of several different concentrations is needed. We recommend using high-concentration, certified, calibration gas supplied to the analyzer through a Gas Dilution Calibrator such as a Teledyne Instruments Model T700. This type of calibrator precisely mixes Span Gas and Zero Air to produce any concentration level between 0 ppm and the concentration of the calibrated gas.

Figure 2-20 depicts the pneumatic set up in this sort of application of a Model T360 CO_2 Analyzer with ambient zero/ambient span valve option installed (a common configuration for this type of application).
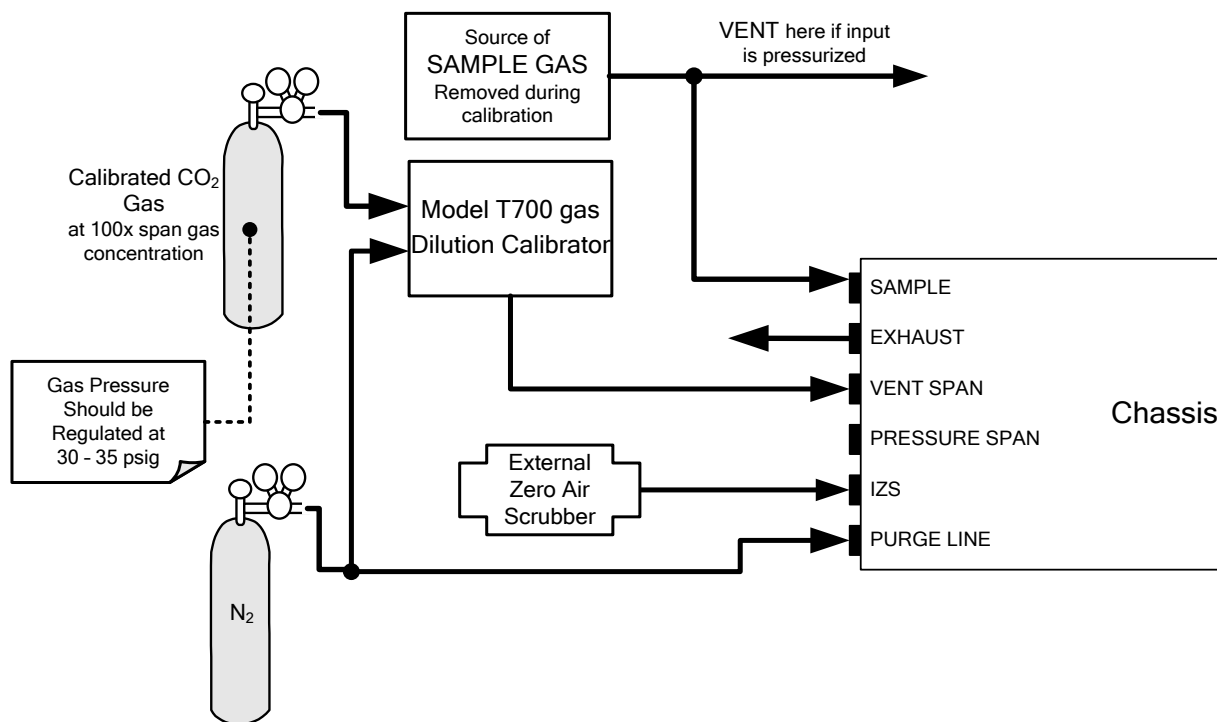
Figure 2-20. Example of Pneumatic Set up for Multipoint Calibration

2.3.2.6 SETTING THE INTERNAL PURGE AIR PRESSURE

In order to maintain proper purge air flow though the GFC wheel housing, a manually adjustable pressure regulator is provided. This regulator includes two output ports. One is used to supply purge air to the GFC wheel. The other may be used to attach a pressure gauge.

To adjust the internal purge air pressure of the T360:

1. Turn off the instrument.

2. Remove the source of zero air attached to the purge line inlet port at the back of the analyzer.

3. Remove the analyzer's top cover.

4. Remove the cap from the second, unused, output port on the pressure regulator.

5. Attach a pressure gauge capable of measuring in the 5-10 psig range with 0.5 psig resolution to the port.

6. Turn the instrument on.

7. Make sure the zero air supply to the analyzer's purge line inlet is supplying gas at a stable pressure above 7.5 psig.

8. Adjust the T360's pressure regulator until the attached gauge reads 7.5 psig.

9. Turn off the instrument.

10. Remove the source of zero air attached to the purge line inlet port at the back of the analyzer.

11. Remove the pressure gauge and reattach the end cap removed in step 4 above.

12. Replace the analyzer's top cover.

2.3.3 PNEUMATIC FLOW DIAGRAMS

This Section shows the basic pneumatic flow diagram followed by flow diagrams with options 50A Ambient Zero/Ambient Span, 50B Ambient Zero/Pressurized Span, 50E Zero Scrubber/Pressurized Span, and 50H Zero Scrubber/Ambient Span.

2.3.3.1 PNEUMATIC FLOW: BASIC CONFIGURATION
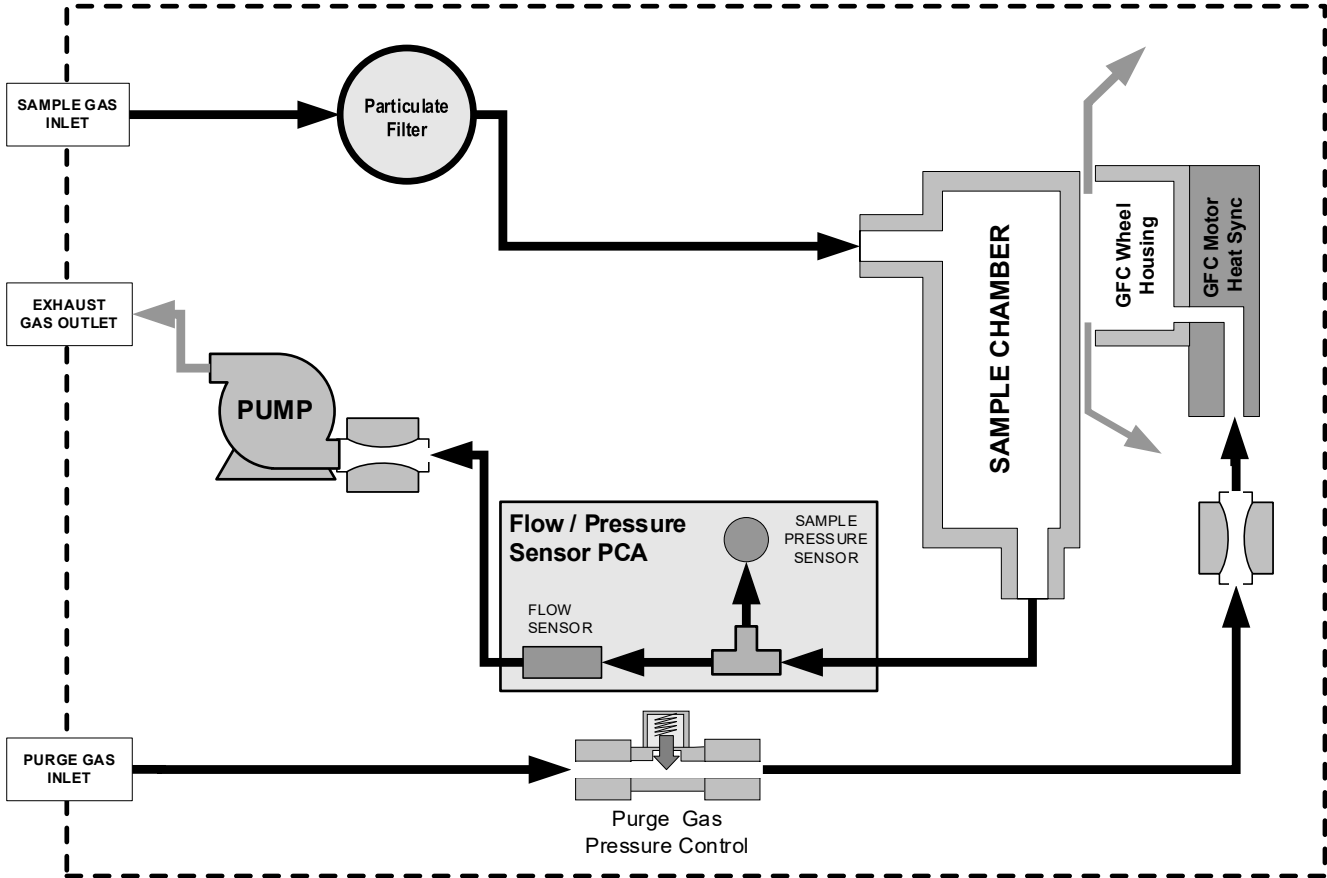
Figure 2-21. Basic Configuration Internal Gas Flow

2.3.3.2 PNEUMATIC FLOW: AMBIENT ZERO/AMBIENT SPAN VALVE OPTION (50A)
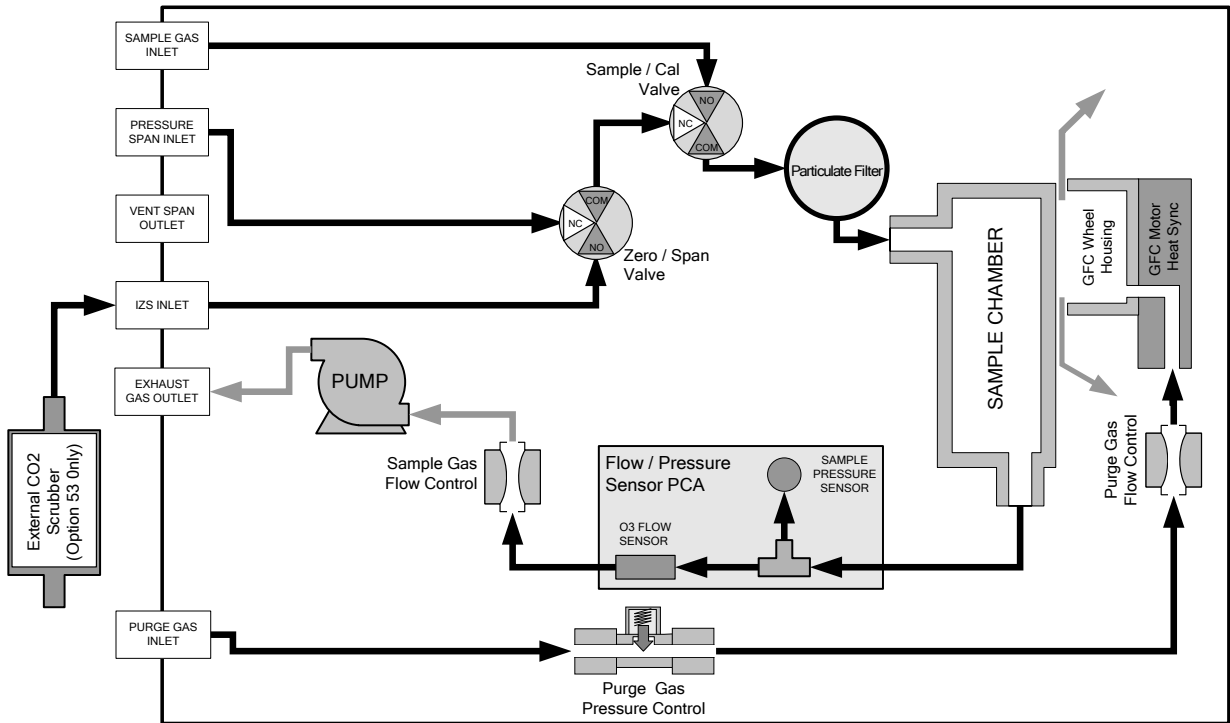
Figure 2-22. Pneumatic Flow Option 50A – Ambient Zero/Span Valves

The following table describes the state of each valve during the analyzer's various operational modes.

Table 2-6. Ambient Zero/Ambient Span Valve Operating States

MODE	VALVE	CONDITION
SAMPLE (Normal State)	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to IZS inlet
ZERO CAL	Sample/Cal	Open to ZERO/SPAN valve
	Zero/Span	Open to IZS inlet
SPAN CAL	Sample/Cal	Open to ZERO/SPAN valve
	Zero/Span	Open to PRESSURE SPAN inlet

2.3.3.3 PNEUMATIC FLOW: AMBIENT ZERO/PRESSURIZED SPAN OPTION (50B)
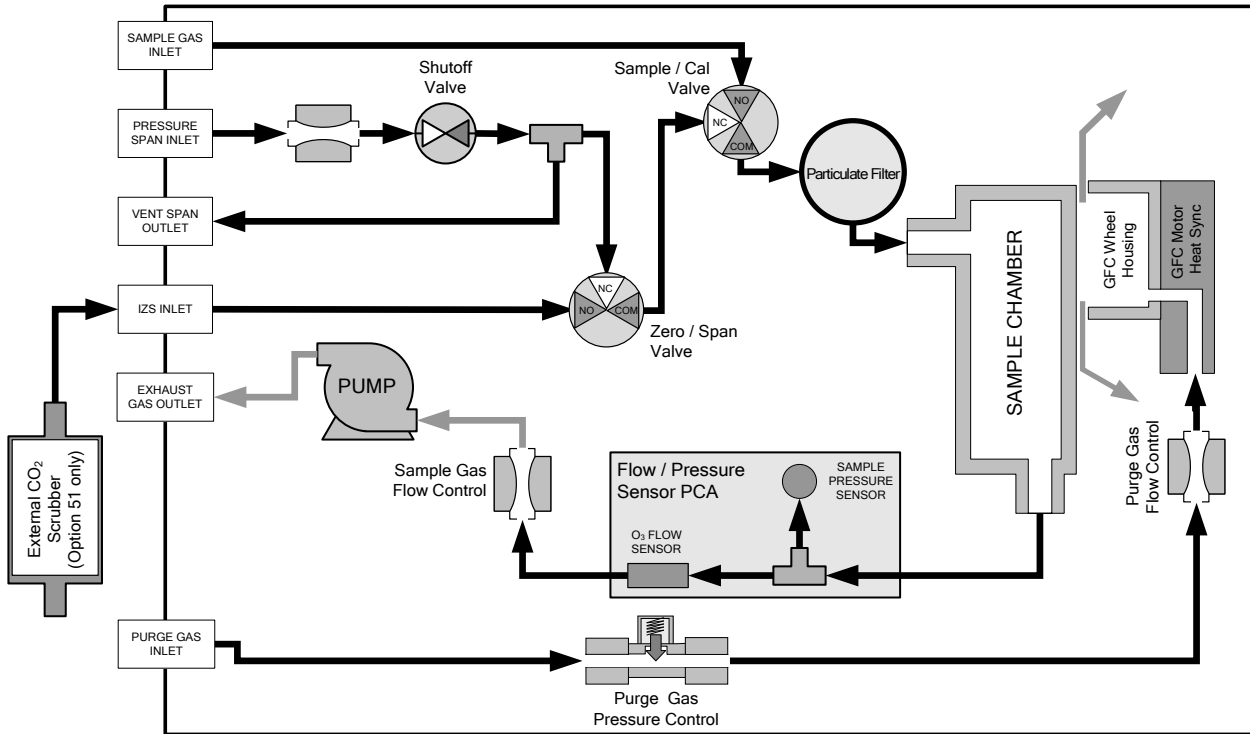
Figure 2-23. Pneumatic Flow Option 50B – Ambient Zero/Pressurized Span Valves

The following table describes the state of each valve during the analyzer's various operational modes.

Table 2-7. Ambient Zero/Pressurized Span Valve Operating States

MODE	VALVE	CONDITION
SAMPLE (Normal State)	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to IZS inlet
	Shutoff Valve	Closed
ZERO CAL	Sample/Cal	Open to ZERO/SPAN valve
	Zero/Span	Open to IZS inlet
	Shutoff Valve	Closed
SPAN CAL	Sample/Cal	Open to ZERO/SPAN valve
	Zero/Span	Open to SHUTOFF valve
	Shutoff Valve	Open to PRESSURE SPAN Inlet

The minimum span gas flow rate required for this option is 800 cm^3/min.

2.3.3.4 PNEUMATIC FLOW: O₂ SENSOR OPTION
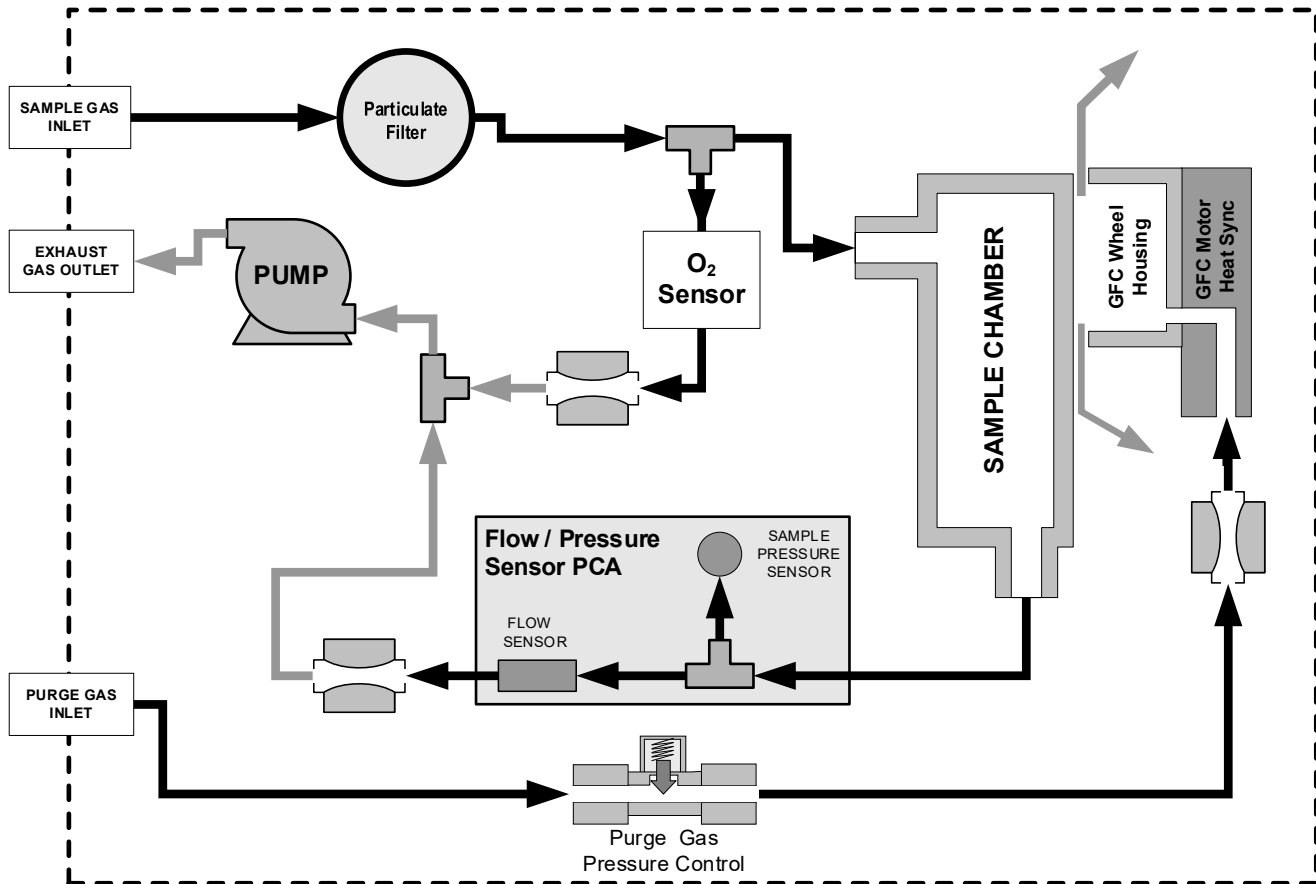
Figure 2-24. Pneumatic Flow with the O₂ Sensor Option

2.3.4 STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION

IMPORTANT   **Impact on Readings or Data**

The analyzer's cover must be installed to ensure that the temperatures of the GFC Wheel and absorption cell assemblies are properly controlled.

We recommend reading Section 6 to become familiar with the principles of operation.

When the instrument is first started (Section 2.3.4.1, check its functionality (Section 2.3.4.3) and run an initial calibration (Section 4). Section 2.4 introduces the menu system, and Section 2.5 provides setup/customization instructions.

2.3.4.1 STARTUP

Upon initial startup, a sequence of status screens (Figure 2-25) appear prior to the Home page (Figure 2-26).
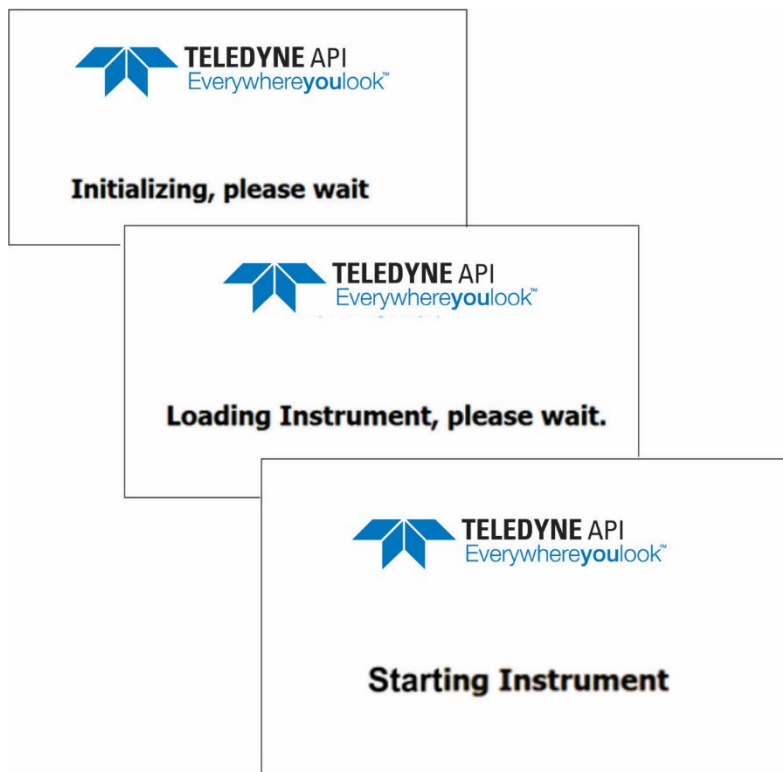
Figure 2-25. Status Screens at Startup

Upon any startup, this instrument should warm up for approximately one hour before reliable measurements can be taken.
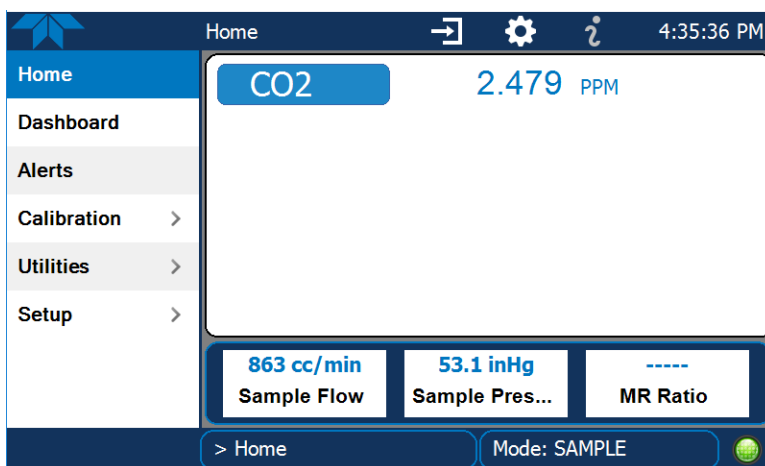
Figure 2-26. Home Page Example

2.3.4.2 ALERTS: WARNINGS AND OTHER MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the analyzer's warm-up period, the software will suppress most Alerts for 30 minutes after power up. The Alerts page (Figure 2-27) shows the status of any active warning conditions or user-configured Events. (Section 2.4.3 provides more detailed information about Alerts, and Section 2.5.2 addresses Events).

Alerts can be viewed and cleared via either the Alerts menu or the Alerts shortcut (Caution symbol, bottom right corner of the screen). Although these alerts can be cleared from the Active Alerts page, a history of all alerts remains in the Utilities>Alerts Log page.
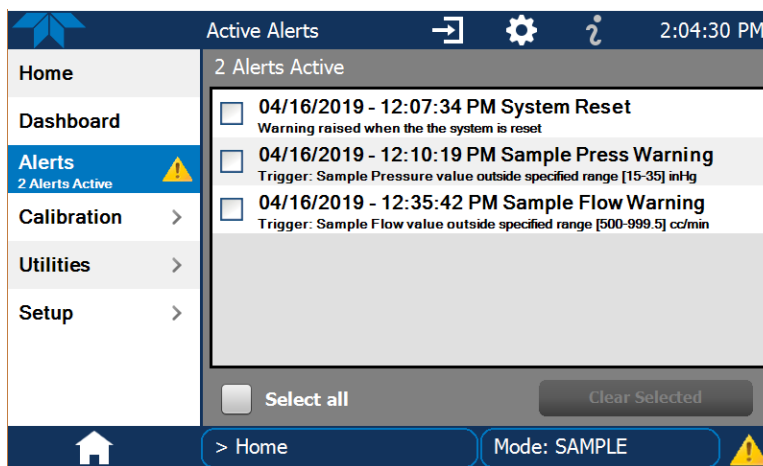
Figure 2-27. Viewing Active Alerts Page

If Alerts about warning conditions persist after the warm up period or after being cleared, investigate their cause using the troubleshooting guidelines in Section 5.7.

2.3.4.3 FUNCTIONAL CHECKS

After warm-up, verify that the software properly supports any hardware options that are installed (Setup>Instrument menu), and that the instrument is functioning within allowable operating parameters. Check the Dashboard page against the instrument's Final Test and Validation Data sheet, which lists these values as they appeared before the instrument left the factory. (If any functional parameters are not displayed, conFigure the Dashboard through the Setup>Dashboard menu to add them; see Section 2.4.2).

These functions are also useful tools for diagnosing problems (information provided in Section 5.7.2).
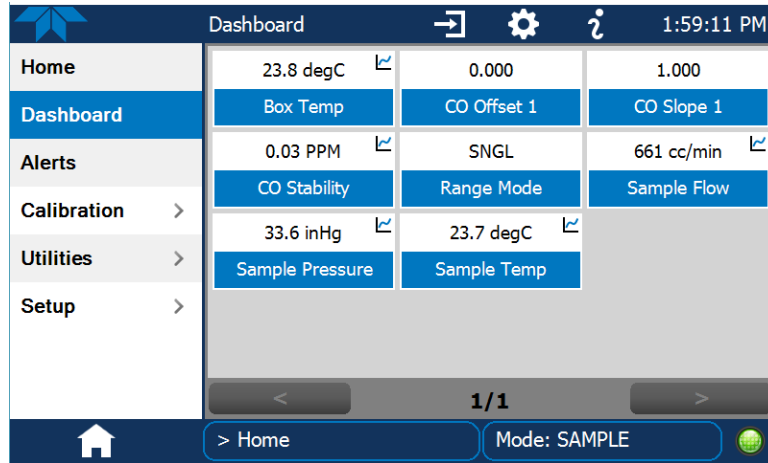
Figure 2-28. Sample Dashboard Page

2.3.4.4 INITIAL CALIBRATION

Before operation begins, the analyzer requires initial calibrations for the location in which it will perform any of the gas analyses. Also, any time an analyzer is moved or its configuration changed, it must be calibrated. The method for performing a calibration differs slightly depending on whether or not any of the available internal zero air or valve options are installed. Follow the appropriate calibration instructions in Section 4.

2.4 MENU OVERVIEW

Table 2-8 describes the main menus and provides cross-references to the respective sections with configuration details.

Table 2-8. Menu Overview

MENU		DESCRIPTION	LOCATION
Home		View and plot concentration readings and other selectable parameter values (Figure 2-30).	Section 2.4.1
Dashboard		View user-selected parameters and their values, some of which can be displayed in a live-plot graph (Figure 2-31).	Section 2.4.2
Alerts		View and clear active Alerts that were triggered by factory-defined Events as well as user-defined Events. (Active and past Alerts are recorded in the Utilities>Alerts Log).	Section 2.4.3
Calibration		Run a multipoint calibration on the gas (or additional gas if 2nd sensor option installed), and span and zero calibrations (if valve option installed).	Section 4
Utilities		View logs, download data and firmware updates, copy configurations between instruments, and run diagnostics.	Section 2.4.5
Setup		ConFigure a variety of features and functions through these submenus for customized operation.	Section 2.5
	Datalogging	Track and record concentration and calibration data and selectable diagnostic parameters, the reports for which can be viewed in the Utilities>Datalog View menu (Section 2.4.5) and downloaded to a flash drive via the Utilities>USB Utilities menu (Section 2.4.5). Also, select configured Events (Section 2.5.2) and create customized triggers for data logging functions.	Section 2.5.1
	Events	Select parameters and define the conditions by which they are to be flagged and recorded in the Alerts log (Section 2.4.3) when they are triggered. Once configured, Events can be used to trigger Datalogs. (Section 2.5.1). Note that some Events are predefined and are not editable.	Section 2.5.2
	Dashboard	Monitor instrument functionality (**Figure 2-28**) via selectable parameters.	Section 2.5.3
	Auto Cal (with valve options)	When zero/span valve options installed, conFigure sequences for automatic calibration functions.	Section 4.3
	Vars	Manually adjust several software variables that define specific operational parameters.	Section 2.5.5
	Homescreen	Select up to three parameters to be displayed in the meters (Figure 2-29).	Section 2.5.6
	Digital Outputs	Map the rear-panel digital outputs to a variety of signals present in the instrument to monitor the status of operating conditions or custom Events.	Section 2.5.7
	Analog Outputs	Send user-selected parameter readings in the form of user-defined voltage or current loop signals as outputs to a strip chart recorder and/or the data logger.	Section 2.5.8
	Instrument	View product and system information, including list of options, if any; view network settings; view/adjust Date and Time settings*; and check for firmware updates when connected to a network that is connected to the Internet. *Time Zone change requires special procedures (Section **5.5**).	Section 2.5.9
	Comm	View and conFigure network and serial communications.	Section 2.5.10

2.4.1 HOME PAGE

Figure 2-29 presents an orientation to the main display screen; Figure 2-30 shows that pressing the gas name or its concentration value or a meter below displays a live plot of their respective readings. Section 2.5.6 provides configuration instructions.
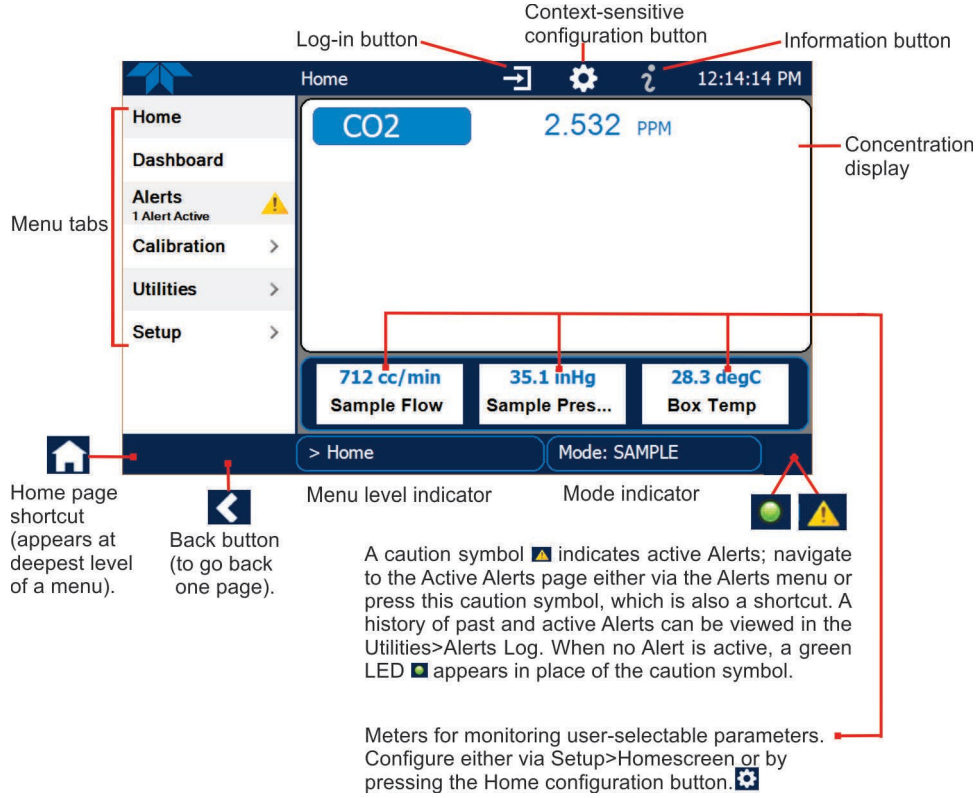
Figure 2-29. User Interface Orientation

Select either a gas name or its reading to display graph.

Change parameters for display in these meters using Home configuration (⚙).

Select a meter to display graph.
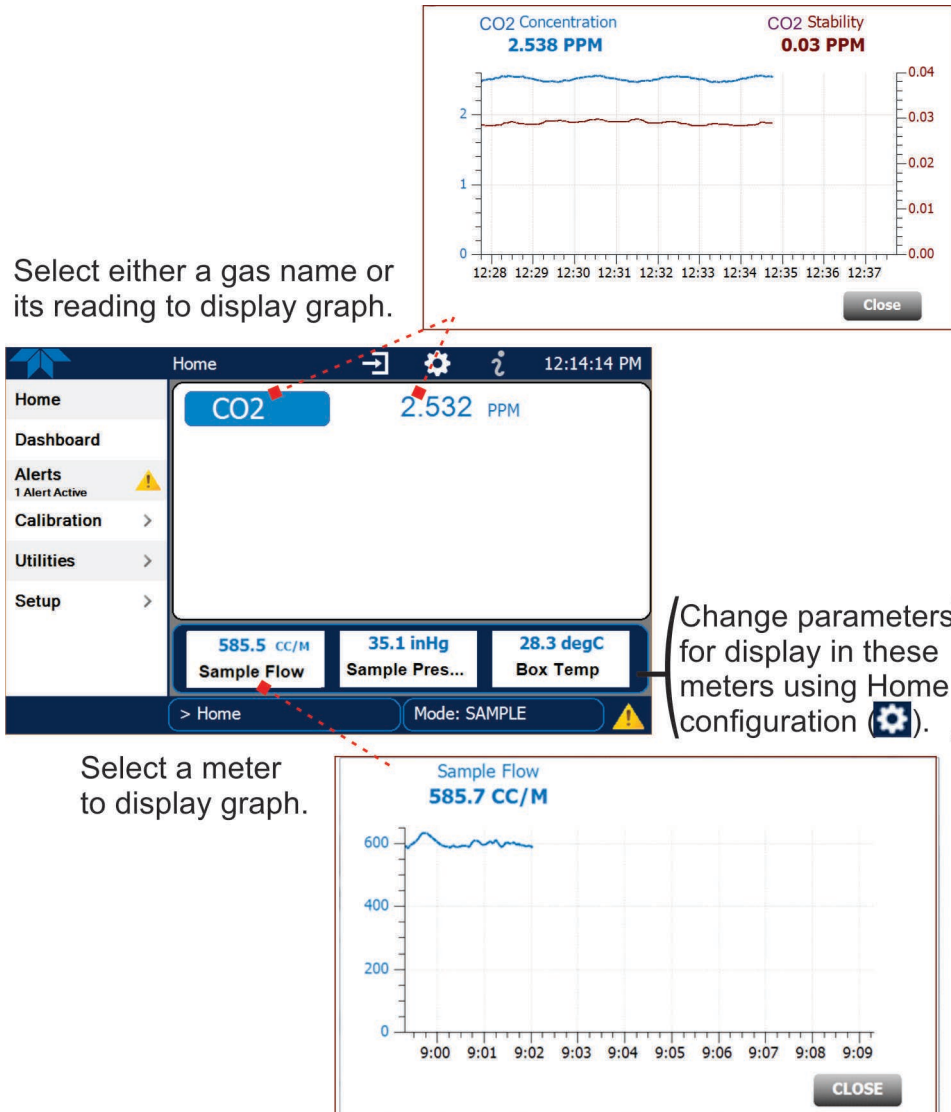
Figure 2-30. Concentration and Stability Graph (top) and Meter Graph (bottom)

2.4.2 DASHBOARD

The Dashboard displays an array of user-selectable parameters and their values (Section 2.5.3 provides configuration instructions). If there is a graphing icon in the upper right corner of a parameter, pressing that parameter displays a live plot of its readings as in Figure 2-31.
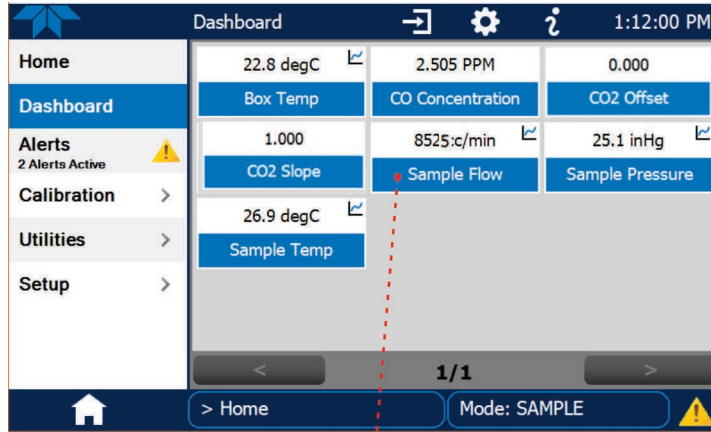
Select a graphable parameter in the Dashboard page to view a live plot.
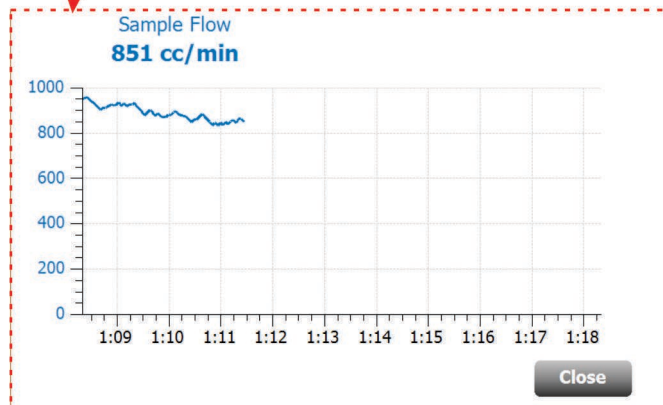
Figure 2-31. Dashboard Page

2.4.3 ALERTS

Alerts are notifications triggered by specific criteria having been met by either factory-defined conditions (standard and not editable) or user-defined Events (Section 2.5.2). The Active Alerts page shows the status of any active warning conditions or Events that have been triggered.

When Alerts are triggered, a caution symbol appears in both the Alerts menu tab and in the bottom right corner of the software interface, which serves as a shortcut to the Alerts page from any other page. View a list of currently active Alerts by pressing either the Alerts menu on the Home screen or by pressing the Alerts shortcut (Figure 2-32).

While Alerts can be cleared from the Active Alerts page, they remain recorded in the Utilities>Alerts Log menu.

Figure 2-32. Navigating to the Active Alerts Page

Alerts can be configured as either latching (appears in Active Alerts screen when Event is triggered and must be cleared by the user) or non-latching (Active Alerts screen continuously updates based on the Event criteria, clearing on its own). See Section 2.5.2.

To clear Alerts from the Active Alerts page, either check individual boxes to choose specific Alerts, or check the Select All box to choose all Alerts, then press the Clear Selected button.

When all Alerts are cleared, the Alerts menu tab no longer shows the caution symbol, and a green LED replaces the caution symbol in the bottom right corner of the interface (Figure 2-33). However, Alerts can reappear if the conditions causing them are not resolved. For troubleshooting guidance, refer to Section 5.7.
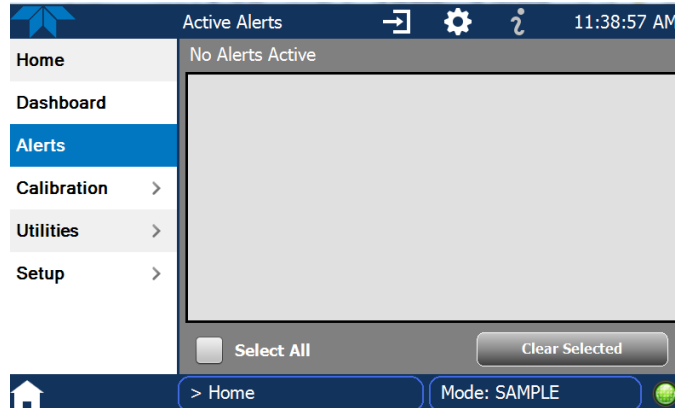
Figure 2-33. Active Alerts Cleared

Alerts and Events remain recorded in the Utilities>Alerts Log (Figure 2-34).
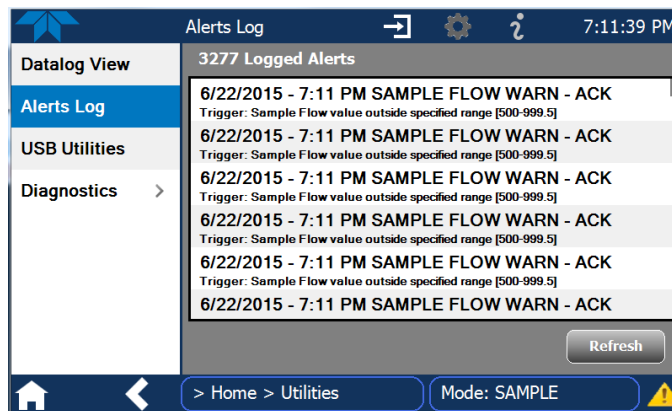
Figure 2-34. Utilities>Alerts Log of Active and Past Alerts and Events

2.4.4 CALIBRATION

The Calibration menu is used for multipoint calibrations as well as calibrations for zero and span with valve options, and for external calibration with valve options installed. Calibration procedures are presented in Section 4.

2.4.5 UTILITIES

The Utilities menu has a variety of functions as described next in Table 2-9.

Table 2-9. Utilities Submenu Descriptions

UTILITIES MENU		DESCRIPTION
Datalog View		Displays the data logs that were configured via the Setup>Data Logging menu. From this list a log can be selected and filters applied to view the desired data. (For details on setting up and running the Data Logger, see Section 2.5.1).
Alerts Log		Displays a history of alerts that are triggered by factory-defined and user-defined Events, such as warnings and alarms (See Section 2.5.2 for Events configuration).
USB Utilities		Serves multiple purposes using a flash drive connected to the instrument's front panel USB port: • download data from the instrument's Data Acquisition System (DAS), the Data Logger, to a flash drive (Section 2.5.1.3) • update firmware (Section 5.3) • transfer instrument configuration from/to other same-model instruments (Section 2.6) • download a basic operation functionality report (Section 5.3).
Diagnostics		Provides access to various pages that facilitate troubleshooting.
	Analog Inputs	Measure voltage signals of several analog input parameters. These can be logged in the internal data acquisition system (DAS), by configuring the Data Logger in the Setup>Data Logging menu (Section 2.5.1).
	Analog Outputs	Show the voltage signals for the functions selected and configured in the Setup>Analog Outputs menu (Section 2.5.8).
	Digital Inputs	Show whether specific available features are turned ON or OFF; for example, whether or not Maintenance Mode input or Language selection can be controlled through the front panel, or whether a zero or span calibration can be activated remotely when an external source is connected to the rear panel Control In connector.
	Digital Outputs	Show the function of user-specified parameters configured in the Setup>Digital Outputs menu (Section 2.5.7).
	Flow Cal	Used to calibrate the sample gas flow reading with actual flow measured by an external device. (See Section 4.5.3).
	Dark Calibration	Compensate for any voltage levels inherent in the sync/demod circuitry that might affect the CO_2 concentration calculation (Section 4.5.1).
	Pressure Cal	Used for compensating for changes in atmospheric pressure (Section 4.5.2).

2.4.6 SETUP

The Setup menu is used to conFigure the instrument's various features, functions, and data log. Section 2.5 provides details for the menus under Setup.

2.5 SETUP MENU: FEATURES/FUNCTIONS CONFIGURATION

Use the Setup menu to conFigure the instrument's software features, to gather information on the instrument's performance, and to conFigure and access data from the Datalogger, the instrument's internal data acquisition system (DAS). Once the setups are complete, the saved configurations can be downloaded to a USB drive through the Utilities>USB Utilities menu and uploaded to other instruments of the same model (Section 2.6).

2.5.1 SETUP>DATA LOGGING (DATA ACQUISITION SYSTEM, DAS)

The Datalogger can be configured to capture and store user-defined data, which then can be viewed in the Alerts page, if elected, as well as downloaded from the instrument to a USB flash drive or using NumaView™ Remote software for examination and analysis.

Figure 2-35 shows a new log; Figure 2-36 shows a sample existing log, which can be edited or deleted, and Figure 2-37 provides illustrated instructions for setting up a new log, with Sections 2.5.1.1 and 2.5.1.2 providing additional details.

To transfer captured instrument data to a flash drive see Section 2.5.1.3.
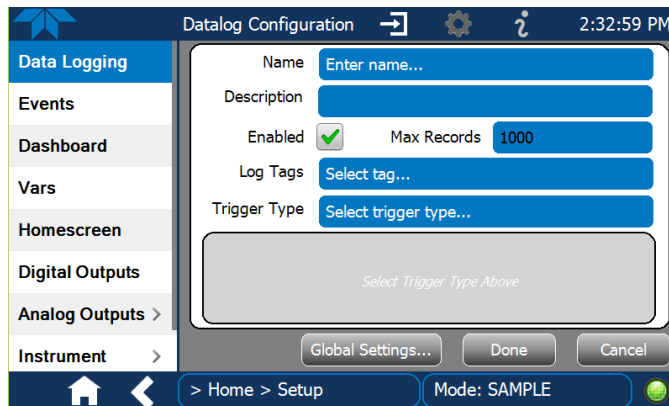
Figure 2-35. Datalog Configuration, New Log Page
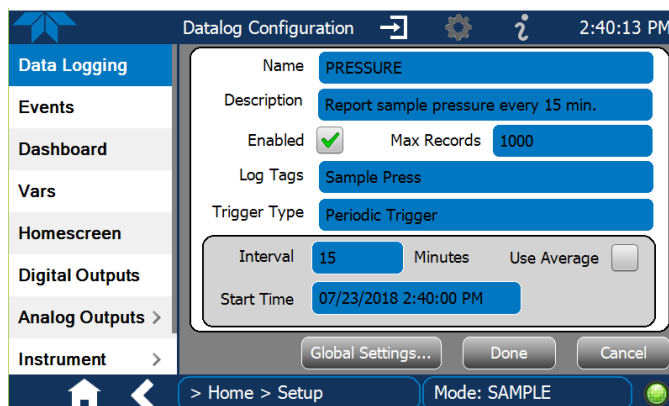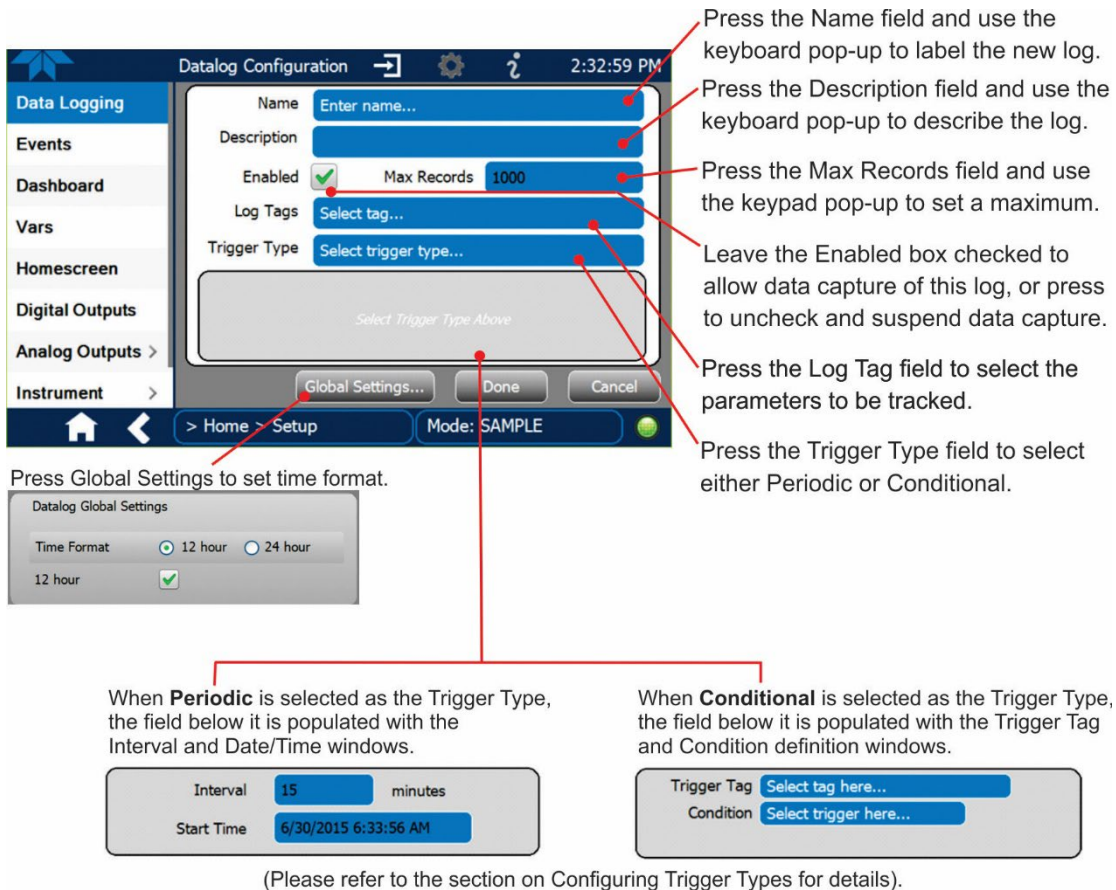
Figure 2-36. Datalog Configuration, Existing Log

Press the Name field and use the keyboard pop-up to label the new log.

Press the Description field and use the keyboard pop-up to describe the log.

Press the Max Records field and use the keypad pop-up to set a maximum.

Leave the Enabled box checked to allow data capture of this log, or press to uncheck and suspend data capture.

Press the Log Tag field to select the parameters to be tracked.

Press the Trigger Type field to select either Periodic or Conditional.

Press Global Settings to set time format.

When **Periodic** is selected as the Trigger Type, the field below it is populated with the Interval and Date/Time windows.

When **Conditional** is selected as the Trigger Type, the field below it is populated with the Trigger Tag and Condition definition windows.
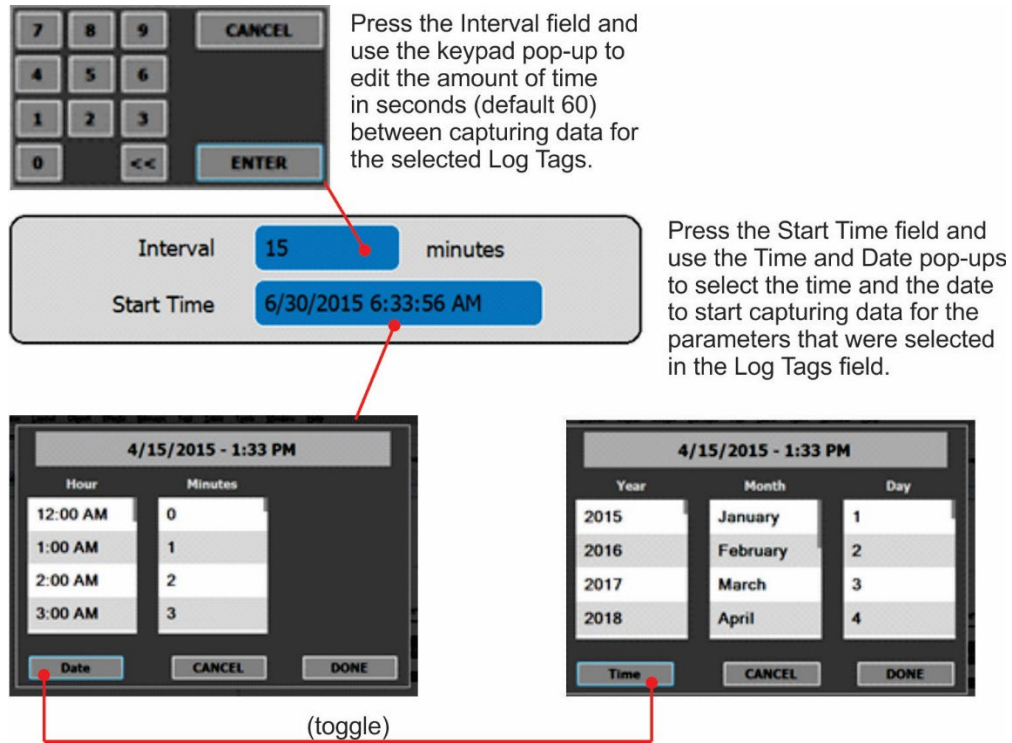
(Please refer to the section on Configuring Trigger Types for details).

Figure 2-37. Creating a New Data Log

The parameters available in the list of Log Tags include the names of Events configured in the Events page (Section 2.5.2).

2.5.1.1 CONFIGURING TRIGGER TYPES: PERIODIC

The Periodic trigger is a timer-based trigger that is used to log data at a specific time interval. Periodic Trigger requires an interval that is set to number of minutes and a start time that is set to date and clock time.

Figure 2-38. Datalog Periodic Trigger Configuration

2.5.1.2 CONFIGURING TRIGGER TYPES: CONDITIONAL

Conditional Trigger tracks/records data for user-selected parameters that meet specified conditions.

Figure 2-39. Datalog - Conditional Trigger Configuration

2.5.1.3 DOWNLOADING DAS (DATA ACQUISITION SYSTEM) DATA

To download DAS data collected by the Datalogger from the instrument to a flash drive, navigate to the Utilities>USB Utilities>DAS Download menu.

1. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected; available buttons will be enabled.

Figure 2-40. DAS Download Page

2. Select all or define a period from which to download the collected data.

3. Press the Download button, and when complete, as indicated in the Status field, press the Done button (changed from "Cancel") and remove the flash drive.

2.5.2 SETUP>EVENTS

Events are occurrences that relate to any operating function, and are used to define the conditions that can be set to trigger Alerts (Section 2.4.3). Events can provide diagnostic information about the instrument, typically referred to as "Warnings", or they can provide other information on instrument functionality, such as concentration alarms. Some Events are standard and not editable while others are user-configurable, described here. Existing Events are listed in the Events page (Figure 2-41) under the Setup menu.
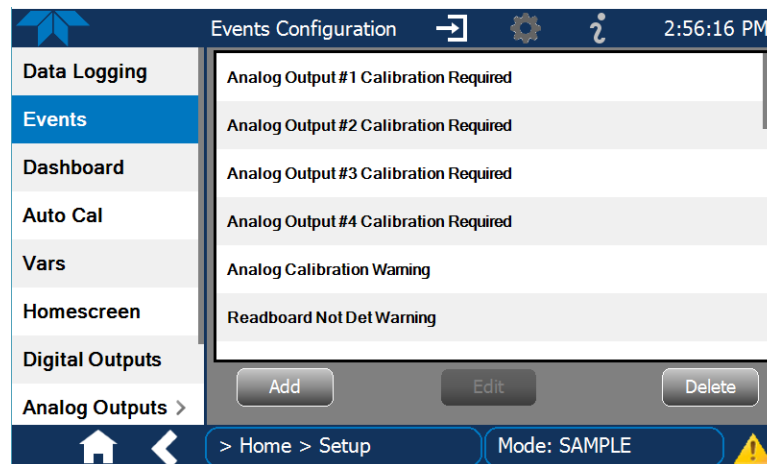
Figure 2-41. Events List

Access the Events Configuration page either from the Active Alerts page (Alerts Menu) by pressing the configuration button, or through the Home>Setup>Events menu

(Figure 2-41). Press ADD to create a new Event (refer to Figure 2-42 for details), or select an existing Event to either Edit or Delete it (Figure 2-44).

Figure 2-42. Event Configuration

- Enabled ☑ allows the choice of whether to track and record the Event (uncheck this box to "turn off" or deactivate the Event without deleting it). An Event must be enabled in order to use the Visible and the Latching options.

- Visible ☑ allows the choice of whether or not to display the Event in the Alerts page when it is triggered (it will still be recorded and can be viewed in the Utilities>Alerts Log).To use this option, the Event must be enabled.

- Latching ☑ allows the choice of whether or not to keep an Event visible even if the conditions that triggered it were to correct themselves. (Latching requires that the user interact with the Active Alerts screen to manually clear the Alert and internal Event state. Non-latching allows the entry in the Active Alerts screen and the internal Event state to continuously update based on the Event criteria, requiring no user interaction to clear the Alert or Event state).
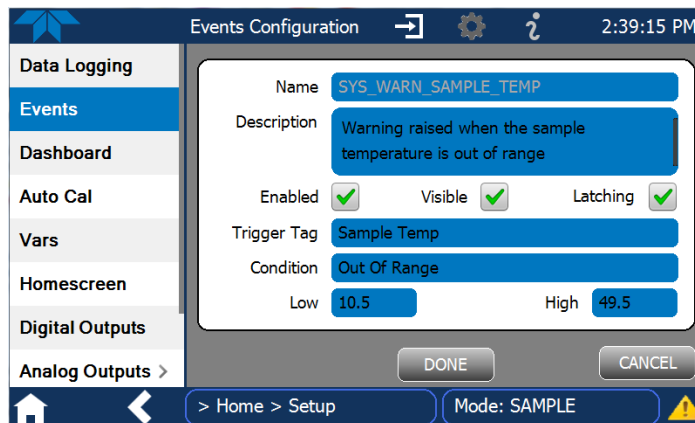
Figure 2-43. Configured Event Sample

2.5.2.1 EDITING OR DELETING EVENTS

Select an Event from the list (Figure 2-41) and press the Edit button to view or edit the details (Figure 2-43), or press the Delete button to delete the Event.
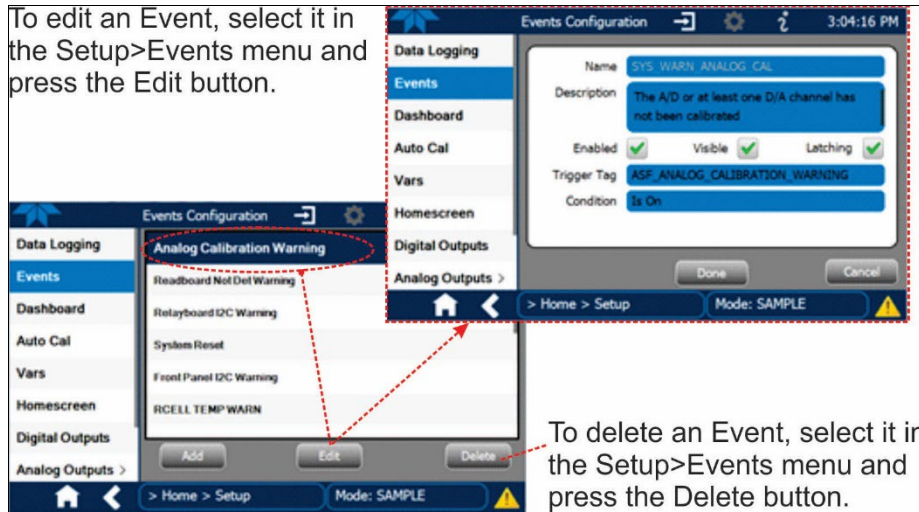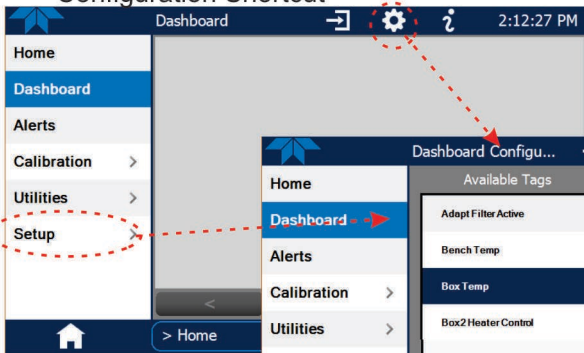
Figure 2-44. Edit or Delete an Event

2.5.2.2 USING EVENTS AS TRIGGERS FOR DATA LOGGING

Events can also be used to create customized triggers for data logging functions. The name entered in the Name field of the Events Configuration page will appear in the list of Log Tags of the Datalog Configuration page. The Data Logger is presented in Section 2.5.1.

2.5.3 SETUP>DASHBOARD

To navigate to Dashboard Configuration, either press the configuration shortcut in the Dashboard page, or use the Setup>Dashboard menu.

Configuration Shortcut
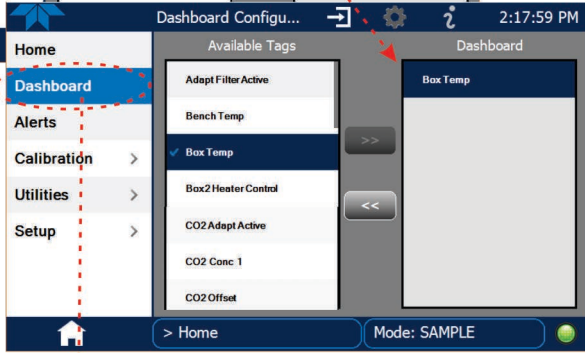
Configuration editing:

To add a parameter to the Dashboard, select it in the "Available Tags" list and press the right-pointing arrows button. (Checkmarks in the "Available Tags" list indicate parameters that are currently in the Dashboard).
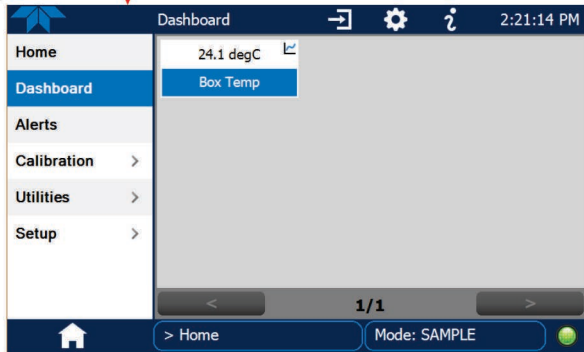
To remove a parameter from the Dashboard, select it from the "Dashboard" list and press the left-pointing arrows button.

Figure 2-45. Dashboard Display and Configuration

2.5.4 SETUP>AUTOCAL (WITH VALVE OPTION)

Auto Cal, automatic zero/span calibration or calibration check, is available with installed valve options (see Sections 2.3.2 and 4.3).

2.5.5 SETUP>VARS

Vars are software variables that define operational parameters automatically set by the instrument's firmware, and are user-adjustable through this menu. Access the menu to see the list of variables; select a variable to view its description; touch the Edit button to change its setting(s).

Table 2-10. List of Variables with Descriptions

VARIABLE	DESCRIPTION
NOTE: This list includes several of the more common Vars; selecting any Var in the NumaView™ software interface will display its description in the information field to its right. Depending on configuration, some, all, or more of these variables appear in your instrument's Vars menu.	
Conc Precision (or PRIGAS/SECGAS Precision)	Sets the number of significant digits to the right of the decimal point display of concentration and stability values. ("PRIGAS" = primary gas with two or more other gases; "SECGAS" = secondary gas)
Daylight Savings Enable	Enable or disable Daylight Savings Time (also see Setup>Instrument>Date/Time Settings)
Dilution Factor Option	Sets the instrument to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Once the degree of dilution is known, this feature allows the user to add an appropriate scaling factor to the analyzer's CO_2 concentration calculations so that the undiluted values for measurement range and concentration are shown on the instrument's front panel display and reported via the instrument's various outputs.
Dynamic Zero Enable	Dynamic zero automatically adjusts offset and slope of the CO_2 response when performing a zero point calibration during an AutoCal (Section 4.3).
Dynamic Span Enable	Dynamic span automatically adjusts the offset and slope of the CO_2 response when performing a span point calibration during an AutoCal (Section 4.3).
[Enable] Software Maintenance Mode	Set instrument to continue sampling, while ignoring calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop (Section 2.3.1.7) or Hessen protocol networks (see Sections 2.5.10, 3.4.2).
Instrument ID	Set unique identifier number for the instrument when it is connected with other instruments in multidrop configuration or on the same Ethernet LAN, or when applying MODBUS or Hessen protocols. (Setup>Vars>Instrument ID)
Range Mode	Controls range mode, single (SNGL) or dual (DUAL).
System Hours	Total system runtime hours
TPC Enable	Enables or disables the Temperature and Pressure Compensation (TPC) feature (For information on TPC, see Section 6.6.4).
User Conc Units	Change the concentration units of measure.

2.5.6 SETUP>HOMESCREEN

To select a parameter ("tag") for display in each of the three meters at the bottom of the Home page, navigate to the Homescreen configuration page through either the Setup>Homescreen menu or from Home page using the configuration icon (Figure 2-46).
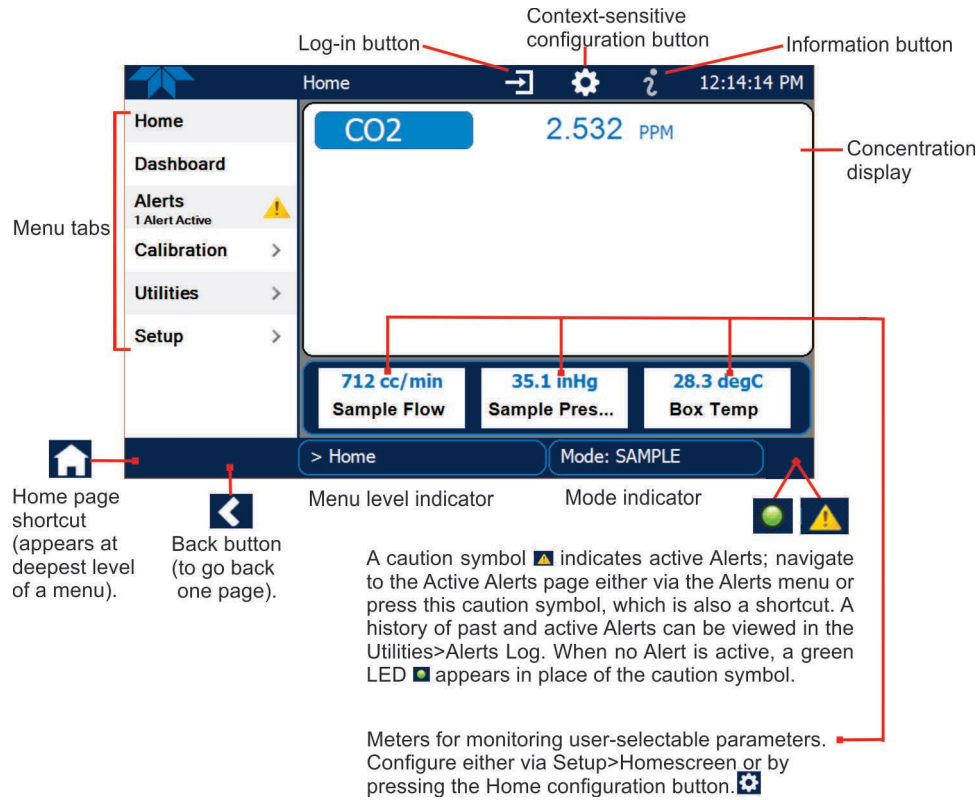
Figure 2-46. Homescreen Configuration

An orientation to the Homescreen was presented in Section 2.4.1, including Figure 2-29 and Figure 2-30.

2.5.7 SETUP>DIGITAL OUTPUTS

Specify the function of each digital output (connected through the rear panel STATUS connector) by mapping the output to a selection of "Signals" present in the instrument. Create custom "Signals" in the Setup>Events menu (Section 2.5.2). (If the Motherboard Relay Option was installed, the four additional relays can also be mapped).

To map Digital Outputs to Signals, select a pin in the Outputs list, then make a selection from the Signals list and press the Map button; if/as needed, change the polarity by pressing the Polarity button. Save any changes by pressing the Apply button, or discard the changes by pressing the Home or the back button (a pop-up provides a warning that the changes will be lost, and will prompt for confirmation to apply changes or not).

Go to the Utilities>Diagnostics>Digital Outputs menu to change the state (ON/OFF) of individual digital outputs.
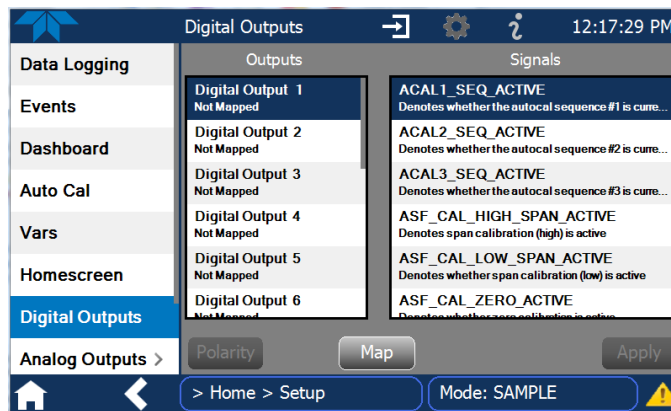
Figure 2-47. Digital Outputs Setup

2.5.8 SETUP>ANALOG OUTPUTS

Map the four user-configurable Analog Outputs to any of a wide variety of "Signals" present in the instrument and customize their respective configurations.
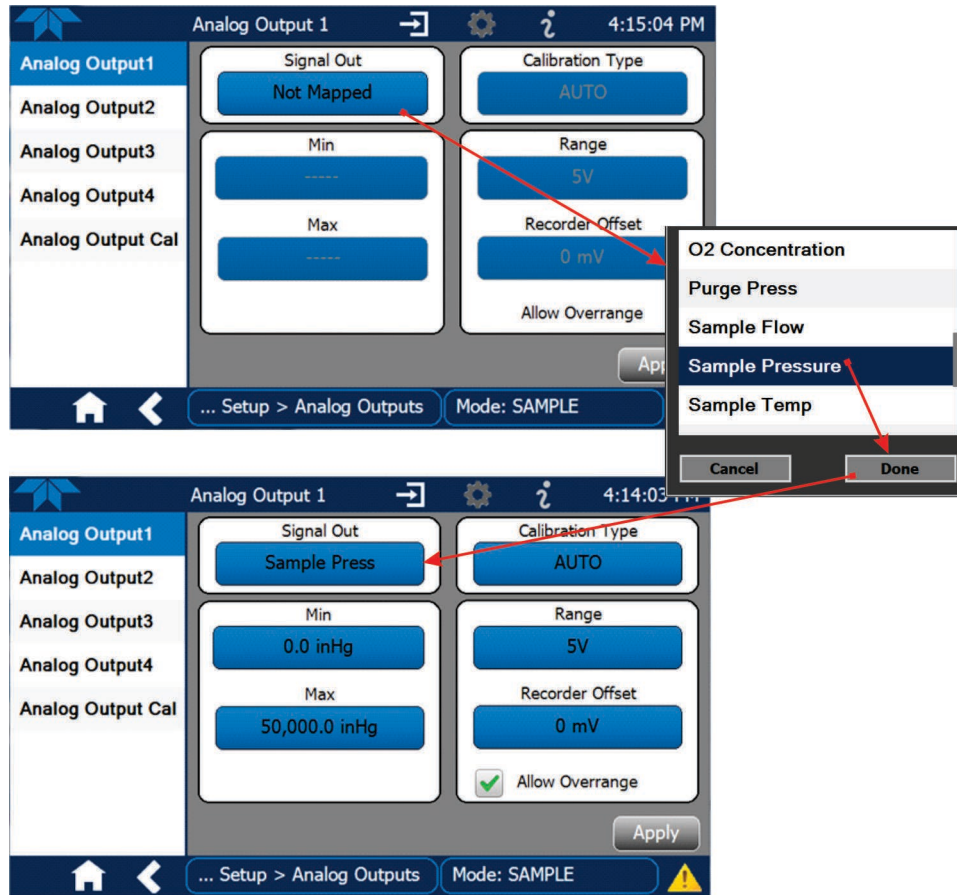
Figure 2-48. Analog Output Configuration Example

Refer to Figure 2-48 for the following:

- Signal Out: select a Signal for the output.

- Min/Max: edit minimum and maximum values associated with the selected Signal.

- Calibration Type:

  - AUTO for group calibration (Figure 2-49) of the analog outputs (cannot be selected when Current is selected for the Range)

  - MANUAL for individual calibration (Figure 2-50) of analog outputs where manual adjustments can be made (the only calibration type allowed when Current is selected for the Range). See Sections 2.5.8.1 and 2.5.8.2 .

- Range: assign a voltage or select Current (refer to Table 2-11).

- Recorder Offset: add a zero offset for recording slightly negative readings from noise around the zero point.

- Allow Overrange: check to allow a ± 5% over-range; uncheck to disable over-range if the recording device is sensitive to excess voltage or current.
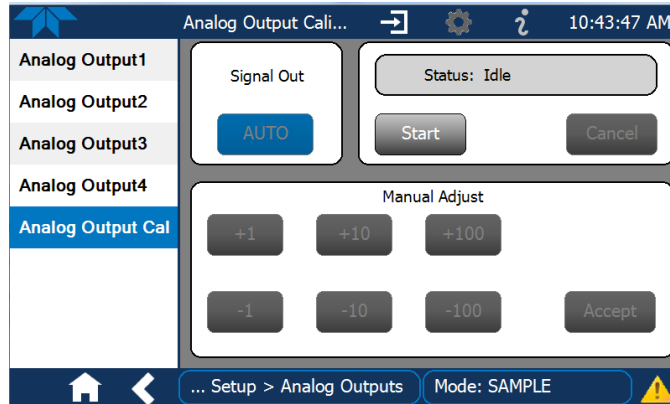
Figure 2-49. Analog Outputs Group Calibration Screen
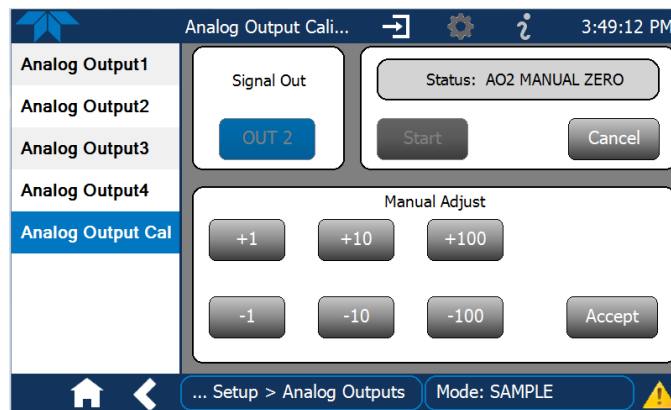
Figure 2-50. Analog Outputs Manual Calibration Screen (AOUT2 Example)

Table 2-11. Analog Output Voltage/Current Range

RANGE[1]	RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
100mV	0-100 mVDC	-5 mVDC	105 mVDC
1V	0-1 VDC	-0.05 VDC	1.05 VDC
5V	0-5 VDC	-0.25 VDC	5.25 VDC
10V	0-10 VDC	-0.5 VDC	10.5 VDC
Current[2]	0-20 mA	0 mA	20 mA

[1] Each range is usable from -5% to +5% of the rated span.

[2] While these are the physical limits of the current loop modules, typical applications use 2-20 mA or 4-20 mA for the lower and upper limits.

For manual calibration adjustments, see Section 2.5.8.1 for voltage and Section 2.5.8.2 for current.

2.5.8.1 MANUAL CALIBRATION OF VOLTAGE RANGE ANALOG OUTPUTS

It is possible to manually calibrate the voltages by using a voltmeter connected across the output terminals (Figure 2-51) and changing the output signal level in the Manual Adjust field of the Analog Outputs Calibration screen (Figure 2-50). Refer to Table 2-12 for voltage tolerances.
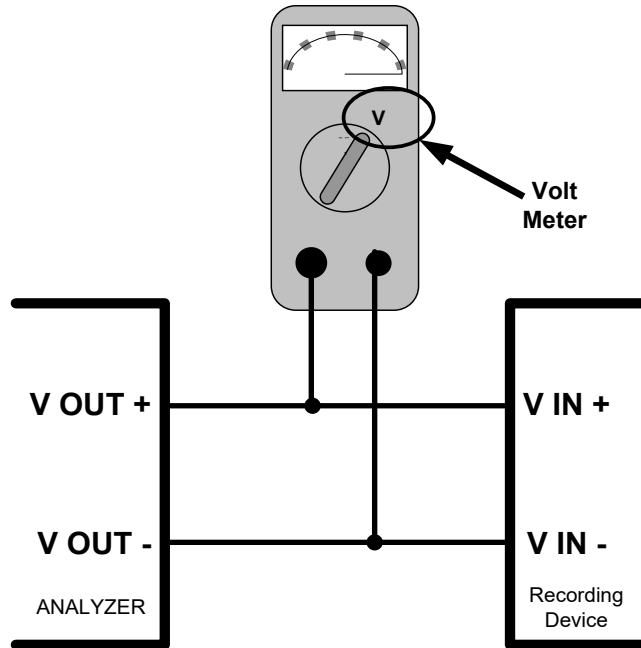
Figure 2-51. Setup for Checking / Calibrating DCV Analog Output Signal Levels

Table 2-12. Voltage Tolerances

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE	MINIMUM ADJUSTMENT (1 count)
0.1 VDC	±0.0005V	90 mV	±0.001V	0.02 mV
1 VDC	±0.001V	900 mV	±0.001V	0.24 mV
5 VDC	±0.002V	4500 mV	±0.003V	1.22 mV
10 VDC	±0.004V	4500 mV	±0.006V	2.44 mV

2.5.8.2 MANUAL ADJUSTMENT OF CURRENT RANGE ANALOG OUTPUTS

These instructions assume that the Current Loop Option is installed (Section 2.3.1.3).

This option places circuitry in series with the output of the D-to-A converter on the motherboard that changes the normal DC voltage output to a 0-20 milliamp signal.

Adjusting the signal zero and span levels of the current loop output is done by raising or lowering the voltage output of the D-to-A converter circuitry on the analyzer's motherboard. This raises or lowers the signal level produced by the current loop option circuitry.

The software allows this adjustment to be made in 100, 10 or 1 count increments. Since the exact amount by which the current signal is changed per D-to-A count varies from

output-to-output and instrument–to–instrument, you will need to measure the change in the signal levels with a separate, current meter placed in series with the output circuit. See Figure 2-5 for pin assignments and diagram of the analog output connector.

> **CAUTION!**
> Do not exceed 60 V peak voltage between current loop outputs and instrument ground.
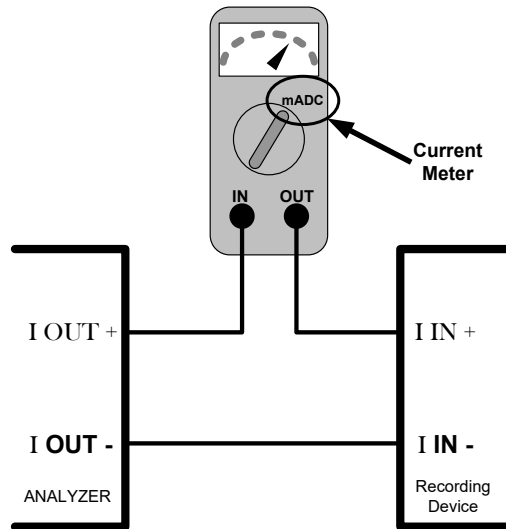
Figure 2-52. Setup for Checking / Calibration Current Output Signal Levels

An alternate method for measuring the output of the Current Loop converter is to connect a 250 ohm ±1% resistor across the current loop output in lieu of the current meter (see Figure 2-5 for pin assignments and diagram of the analog output connector). This allows the use of a voltmeter connected across the resistor to measure converter output as VDC or mVDC.
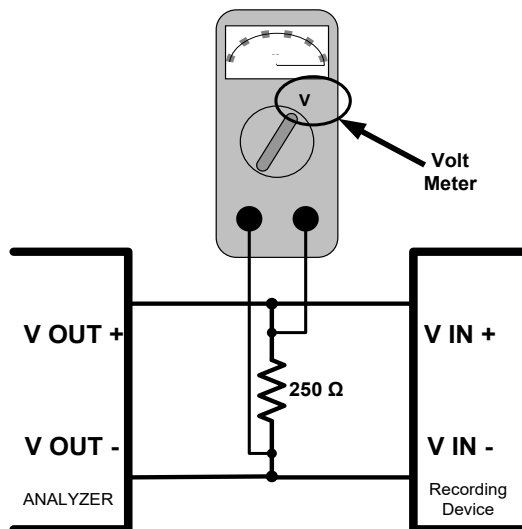
Figure 2-53. Alternative Setup Using 250Ω Resistor for Checking Current Output Signal Levels

In this case, follow the procedure above but adjust the output for the following values:

Table 2-13. Current Loop Output Check

% FS	Voltage across Resistor for 2-20 mA	Voltage across Resistor for 4-20 mA
0	500 mVDC	1000 mVDC
100	5000 mVDC	5000 mVDC

2.5.9 SETUP>INSTRUMENT

As presented in Table 2-14, view product and system information and network settings, edit network settings, and perform certain maintenance tasks.

Table 2-14. Setup>Instrument Menu

MENU	DESCRIPTION
Product Info	View Model, Part, and Serial Numbers and Package and Driver Versions, and options information.
System Info	View Windows and RAM information.
Network Settings	View the network settings (configurable through the Setup>Comm>Network Settings menu).
Date/Time Settings	Adjust date, hour, and minutes, select a time zone*, and set the system clock to automatically adjust for Daylight Savings Time or not. (Also see Setup>Vars>Daylight Savings Enable). *Time Zone change requires a special procedure; see Maintenance Section 5.5.
NTP Time Settings	ConFigure Network Time Protocol settings for clock synchronization.
Language	Select an available language.
Remote Update	When an instrument is connected to a network that is connected to the Internet, follow the instructions on this Remote Update page to check for and activate software/firmware updates. (Also refer to Section **5.3**).

2.5.10   SETUP>COMM (COMMUNICATIONS)

This menu is for specifying the various communications configurations.

2.5.10.1   COM1/COM2

ConFigure the instrument's COM1 or COM2 ports to operate in modes listed in Table 2-15.

Table 2-15. COM1/COM2 Configuration

MODE	DESCRIPTION
Baud Rate	Set the baud rate for the COM1 or COM2 port being configured.
Command Prompt Display	Enable/disable a command prompt to be displayed when in terminal mode.
Data Bits	Set the data bits to 7 or 8 (typically set in conjunction with Parity and Stop bits).
Echo and Line Editing	Enable/disable character echoing and line editing.
Handshaking Mode	Choose SOFTWARE handshaking for data flow control (do NOT use SOFTWARE handshaking mode when using MODBUS RTU for Protocol mode; select only HARDWARE or OFF for MODBUS RTU), or HARDWARE for CTS/RTS style hardwired transmission handshaking. (This style of data transmission handshaking is commonly used with modems or terminal emulation protocols). Or choose to turn OFF handshaking.

MODE	DESCRIPTION
Hardware Error Checking	Enable/disable hardware error checking.
Hardware FIFO	Enable/disable the hardware First In – First Out (FIFO) for improving data transfer rate for that COM port.
Modem Connection	Select either a modem connection or a direct cable connection.
Modem Init String	Input an initialization string to enable the modem to communicate.
Multidrop	Enable/disable multidrop mode for multi-instrument configuration on a single communications channel. Multidrop requires a unique ID for each instrument in the chain (Setup>Vars>Instrument ID).
Parity	Select odd, or even, or no parity (typically set in conjunction with Data Bits and Stop Bits).
Protocol	Select among the communications protocols: TAPI, Hessen, MODBUS RTU, or MODBUS ASCII (MODBUS: Section 3.4.1; Hessen: Section 3.4.2).
Quiet Mode	Enable/disable Quiet mode, which suppresses any feedback from the analyzer (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is still available, but a command must be issued to receive them.
RS-485	Enable/disable the rear panel COM2 Port for RS-485 communication. RS-485 mode has precedence over Multidrop mode if both are enabled. Also, RS-485 configuration disables the rear panel USB port.
Security	Enable/disable the requirement for a password for this serial port to respond. The only command that is active is the request-for-help command (? CR).
Stop bits	Select either 0 or 1 stop bit (typically set in conjunction with Parity and Data bits).

2.5.10.2   TCP PORT1

TCP Port1 allows choosing whether or not to display the command prompt, editing the Port 1 number for defining the terminal control port by which terminal emulation software addresses the instrument, such as Internet or NumaView™ Remote software, and enabling or disabling security on this port.

2.5.10.3   TCP PORT2

TCP Port2 is configured with the port number for MODBUS.

2.5.10.4   TCP PORT3

TCP Port3 is configured with the port number for Hessen.

2.5.10.5   NETWORK SETTINGS

The Setup>Comm>Network Settings menu is for Ethernet configuration. The address settings default to automatic configuration by Dynamic Host Configuration Protocol (DHCP). Most users will want to conFigure the instrument with a static IP address: click the Static radio button to manually assign a static IP address (consult your network administrator, and see Table 2-16 for information).
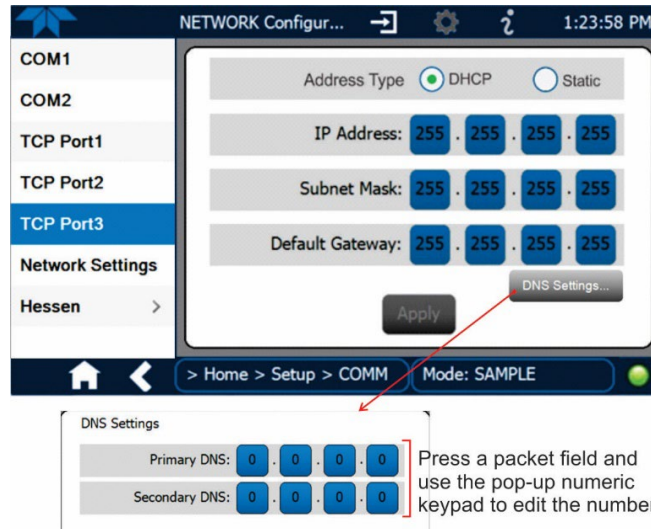
Figure 2-54. Communications Configuration, Network Settings

Table 2-16. LAN/Ethernet Configuration Properties

PROPERTY	DESCRIPTION
IP address	A string of four numbers, 1 to 3 digits each (e.g. 192.168.76.55.) is the internet protocol address of the instrument itself.
Subnet Mask	A string of four numbers, 1 to 3 digits each (e.g. 255.255.252.0) number that masks an IP address, and divides the IP address into network address and host address and identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
Default Gateway	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 and serves as a router to access the Internet or another network.

2.6 TRANSFERRING CONFIGURATION TO OTHER INSTRUMENTS

Once an instrument is configured, the same configuration can be copied to other instruments of the same Model. This encompasses essentially anything the user can conFigure and does not apply to instrument-specific settings such as those that are configured at the factory for calibration.
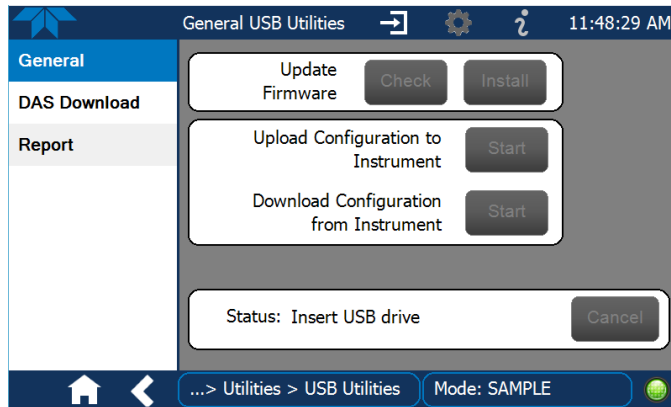
Figure 2-55. Configuration Transfer

1. In the source instrument, go to the Home>Utilities>USB Utilities>General page.

2. Insert a flash drive into either of the two front panel USB ports.

3. When the Status field indicates that the USB drive has been detected, press the "Download Configuration from Instrument" Start button.

4. When the Status field indicates that the download is complete, remove the flash drive.

5. In the target instrument, go to the Home>Utilities>USB Utilities>General page.

6. Insert a flash drive into either of the two front panel USB ports.

7. When the Status field indicates that the USB drive has been detected, press the "Upload Configuration to Instrument" Start button.

8. When the Status field indicates that the upload is complete, remove the flash drive.

3 COMMUNICATIONS AND REMOTE OPERATION

This instrument's rear panel connections can include an Ethernet port, a USB port (option) and two serial communications ports labeled RS232, which is the COM1 port in the software menu, and COM2 (refer to Figure 2-2). These ports allow the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal. Connection instructions were provided in Section 2.3.1.7. Configuration information was provided in Section 2.5.10.

This Section provides pertinent information regarding communication equipment, the communications ports, and communications protocol. Data acquisition is set up through the Datalogger (Section 2.5.1).

3.1 DATA TERMINAL/COMMUNICATION EQUIPMENT (DTE DCE)

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic terminals always fall into the DTE category whereas modems are always considered DCE devices. The difference between the two is the pin assignment of the Data Receive and Data Transmit functions.

- DTE devices receive data on pin 2 and transmit data on pin 3.
- DCE devices receive data on pin 3 and transmit data on pin 2.

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel, labeled DCE DTE (Figure 2-2), allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

3.2 MODES, BAUD RATE AND SERIAL COMMUNICATION

Referring to Table 2-15, use the SETUP>COMM menu to configure COM1 (labeled RS232 on instrument rear panel) and/or COM2 (labeled COM2 on instrument rear panel) for communication modes, baud rate and serial communications. The instrument's baud rate and personal computer baud rate must match.

3.2.1   SERIAL COMMUNICATION: RS-232

The RS232 and COM2 communications ports operate on the RS-232 protocol (default configuration). Configurations possible for these two ports are:

- RS232 port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section 2.3.1.7.

- COM2 port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

| Note | **When the rear panel COM2 port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, COM2 port cannot be used except for multidrop).** |

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne API Sales (front cover, this manual) for more information on CAS systems.

3.2.2   SERIAL COMMUNICATION: RS-485 (OPTION)

The COM2 port of the instrument's rear panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Technical Support for reconfiguration unless this option was elected at the time of purchase, then the rear panel was preconfigured at the factory.

3.3   ETHERNET

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using NumaView™ Remote, terminal emulators or other programs.

The Ethernet connector has two LEDs that are on the connector itself, indicating its current operating status.

Table 3-1. Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server; however, it should be configured with a Static IP address as soon as practical. See Section 2.5.10.5 for configuration details.

3.4   COMMUNICATIONS PROTOCOLS

MODBUS (Section 3.4.1) and Hessen (Section 3.4.2) are available with the analyzer. MODBUS registers are provided in Appendix A.

3.4.1 MODBUS

These instructions assume that the user is familiar with MODBUS communications, and provide minimal information to get started. Please refer to the Teledyne API MODBUS manual, PN 06276, and to www.modbus.org for MODBUS communication protocols.

Minimum Requirements:

- Instrument firmware with MODBUS capabilities installed
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see www.modbustools.com)
- Personal computer with communications cable (Ethernet or USB or RS232), and possibly a null modem adapter or cable

3.4.1.1 MODBUS COM PORT CONFIGURATION

MODBUS communications can be configured for transmission over Ethernet or serial COM port through the Setup>Comm menu. Make the appropriate cable connections (Ethernet or COM port) between the instrument and a PC.

Check the instrument's Modbus Units selection in the Setup>Vars menu and edit if needed.

Ethernet: MODBUS is available on TCP port 502. By default, port 502 is assigned to the instrument's TCP Port 2. (Setup>Comm> TCP Port2, Figure 3-1).
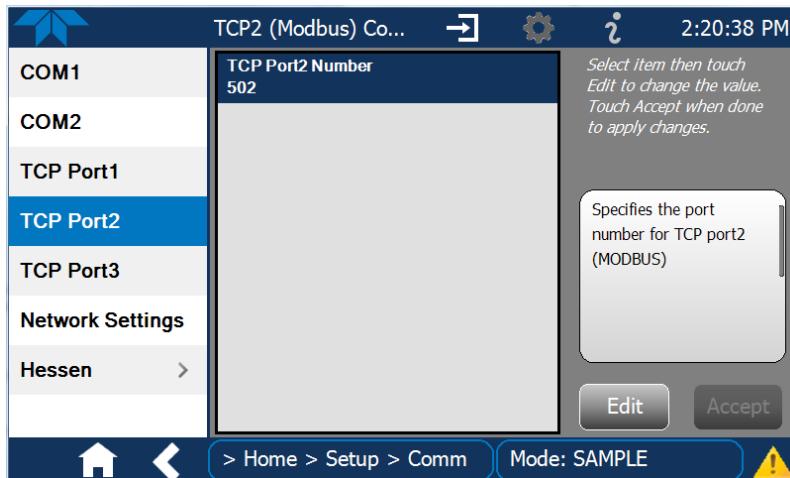
Figure 3-1. MODBUS via Ethernet

Serial COM: Both COM1 (labeled "RS232" on the instrument's rear panel) and COM2 are configurable for RS-232 or RS-485 communication with either MODBUS RTU or MODBUS ASCII transmission modes. In the Setup>Comm COM1[COM2] menu, edit the Protocol parameter to select a MODBUS transmission mode; edit Baud Rate, Parity, Data Bits, etc., if necessary (see descriptions in Table 2-15).

Important	When using MODBUS RTU, ensure that the COM1[COM2] Handshaking Mode is set to either Hardware or OFF. Do NOT set it to Software.

Press the Accept button to apply the settings. (Figure 3-2 shows an example for MODBUS RTU).
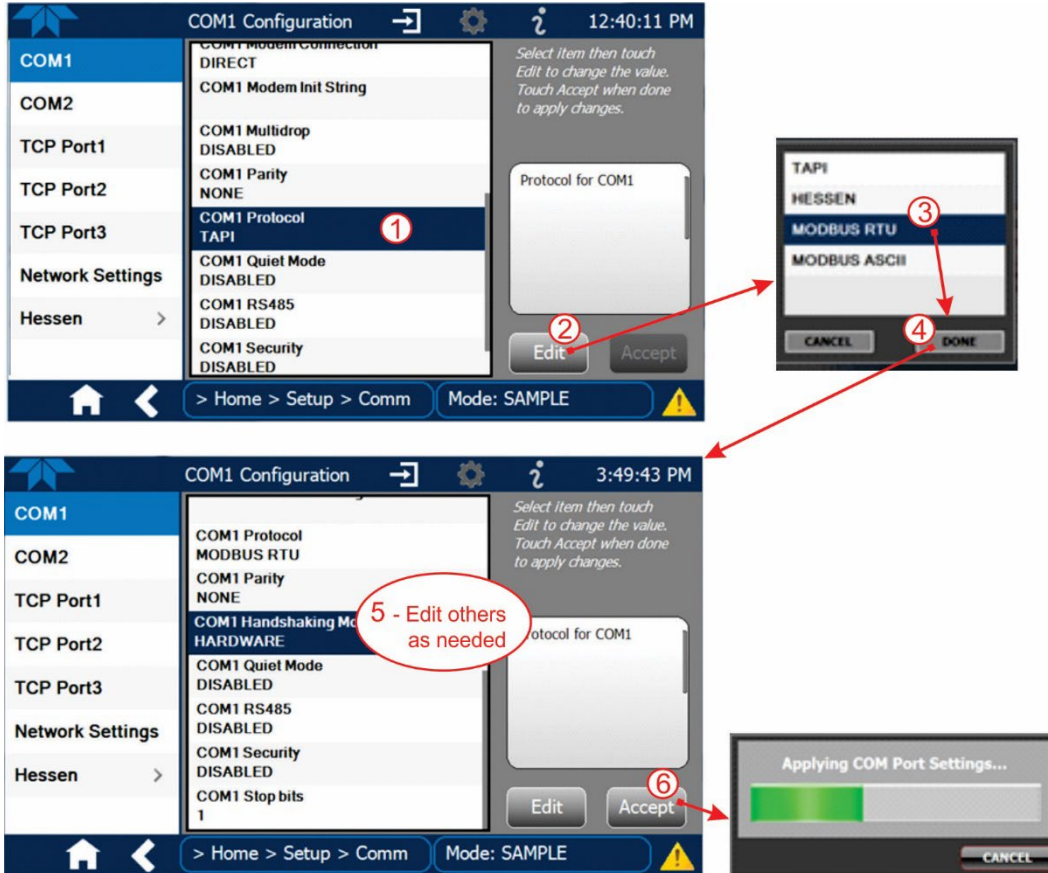
Figure 3-2. MODBUS via Serial Communication (example)

Important	When more than one analyzer is connected to the network, create a unique identification number for each in the Setup>Vars>Instrument ID menu.

Next, for the settings to take effect, power off the analyzer, wait 5 seconds, and power it on again.

3.4.2 HESSEN

Hessen is a multidrop protocol, in which several remote instruments (slaves) are connected via a common communications channel to a host computer. Slaves respond only to commands sent by the host using their unique identification.

Important	**Create a unique identification number for each instrument in the multidrop chain via the Setup>Vars>Instrument ID menu.**

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

3.4.2.1 HESSEN COM PORT CONFIGURATION

ConFigure the COM1/COM2 port for Hessen protocol through the Setup>Comm>COM1[COM2] menu: select COM1[COM2] Protocol and press Edit to select HESSEN, then press Accept.

Ensure that the communication parameters of the host computer are also properly set.
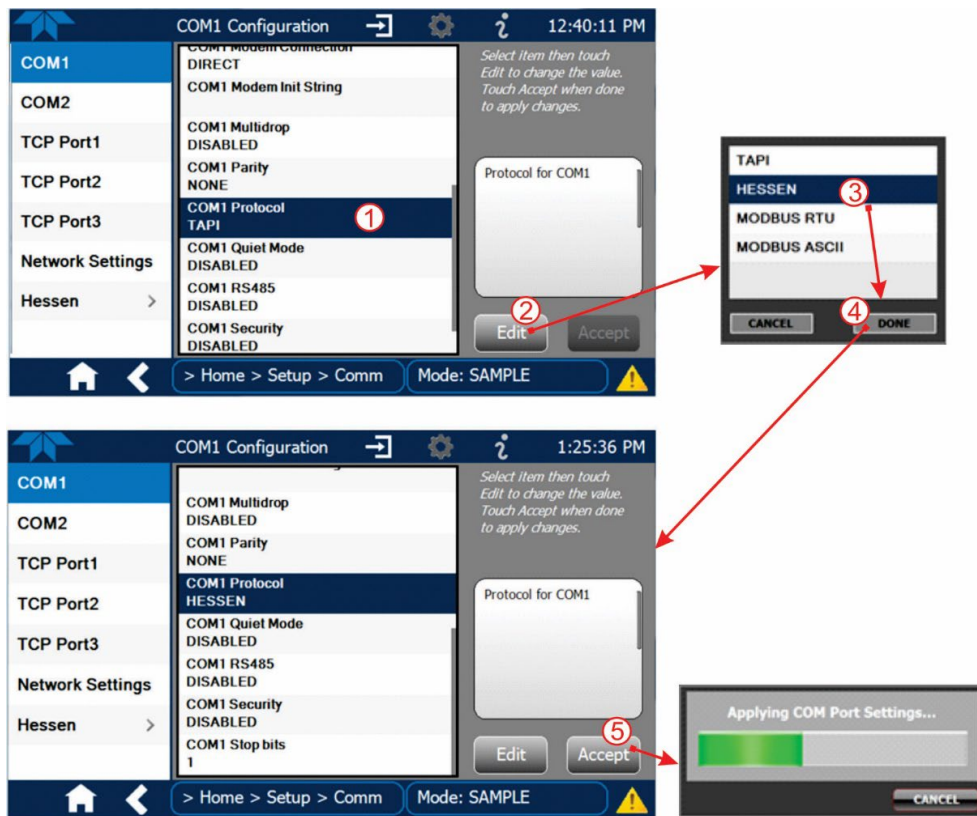
Figure 3-3. Serial Communication, Setting Hessen Protocol

Note	**The instrument software has a 200 ms latency period before it responds to commands issued by the host computer. This latency should present no problems, but be mindful of issuing commands to the instrument too frequently.**

3.4.2.2 HESSEN SETTINGS CONFIGURATION

Hessen configuration includes settings for alarms, version, response mode, status flags and gas list. Locate the alarms in the Hessen Settings list (Setup>Comm>Hessen>Hessen Settings) and edit as desired.

HESSEN VARIATION

For the Hessen Variation setting, there are two versions.

- TYPE 1 is the original implementation.

- TYPE 2 has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between the two versions, download the *Manual Addendum for Hessen Protocol* from the Teledyne API's web site: http://www.teledyne-api.com/manuals/.

HESSEN PROTOCOL RESPONSE MODE

Set the response mode under Hessen Response Mode, referring to Table 3-2 for descriptions.

Table 3-2. Teledyne API's Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	This is the default setting. Reponses 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.

HESSEN STATUS FLAGS

Locate the various status flags in the Hessen Settings list and edit as needed. They are listed by status flag name with their default bit assignments. (Those with unassigned flags are listed as "0x0000").

- The status bits are included in the instrument's responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag.

- 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.

- Assigning conflicting flags to the same bit will cause each status bit to be triggered if any of the assigned flags is active.

Table 3-3. Default Hessen Status Flag Assignments

STATUS FLAG NAME	DEFAULT BIT ASSIGNMENT
WARNING FLAGS	
SAMPLE FLOW WARNING	0001
BENCH TEMP WARNING	0002
SOURCE WARNING	0004
BOX TEMP WARNING	0008
WHEEL TEMP WARNING	0010
SAMPLE TEMP WARNING	0020
SAMPLE PRESSURE WARNING	0040
INVALID CONC (The Instrument's Front Panel Display Will Show The Concentration As "XXXX")	0080
OPERATIONAL FLAGS	
Instrument Off	0100
In Manual Calibration Mode	0200
In Zero Calibration Mode	0400
In Span Calibration Mode	0800
UNITS OF MEASURE FLAGS	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
SPARE/UNUSED BITS	100, 1000, 8000
UNASSIGNED FLAGS (0000)	

Sync Warning	Relay Board Warning
Conc Alarm 1	Analog Cal Warning
Conc Alarm 2	Cannot Dyn Zero
Photo Temp Warning	Cannot Dyn Span
System Reset	Invalid Conc
Rear Board Not Detected	

4 CALIBRATION

This Section is organized into subsections as follows:

SECTION 4.1 – Important Precalibration Information: contains important information you should know before calibrating the instrument.

SECTION 4.2 – Calibration Procedures: provides procedures for both calibration and calibration checks of basic and valve option configurations.

SECTION 4.3 – Automatic Zero/Span Cal/Check (Auto Cal): describes the procedure for using the AutoCal feature to check calibration or to calibrate the instrument. (The AutoCal feature requires that either the zero/span valve option or the internal span gas generator option be installed and operating).

SECTION 4.4 – Calibration Quality: describes how to evaluate the quality of each calibration.

SECTION 4.5 – Calibration of the Electronic Subsystems: describes what these subsystem calibrations do and where to activate them.

SECTION 4.6 – Calibration of Optional Sensors: contains setup and calibration procedures when the instrument has the optional sensors installed.

4.1 IMPORTANT PRECALIBRATION INFORMATION

Note	**A start-up period of one hour is recommended prior to calibration.**

4.1.1 CALIBRATION REQUIREMENTS

Calibration of the analyzer requires specific equipment and supplies. These include, but are not limited to, the following:

- Zero-air source

- Span gas source

- Gas lines - All Gas lines should be PTFE (Teflon), FEP, glass, stainless steel or brass

- Optionally, a recording device such as a strip-chart recorder and/or data logger. (For electronic documentation, the internal data acquisition system DAS can be used by configuring the Datalogger through the Setup>Data Logging menu, Section 2.5.1).

- Traceability Standards

4.1.2 ZERO AIR

Zero air or zero calibration gas is defined as a gas that is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. Zero air should contain less than 25 ppb of CO_2 and other major interfering gases such as CO and Water Vapor. It should have a dew point of -5°C or less.

4.1.3 CALIBRATION (SPAN) GAS

Span Gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range and should be certified traceable to NIST Standard Reference Materiald (SRM). It is recommended that the span gas used have a concentration equal to 80% of the full measurement range.

If Span Gas is sourced directly from a calibrated, pressurized bottle, use the exact concentration value printed on the bottle; the gas mixture should be CO_2 mixed with Zero Air or N_2 at the required ratio.

4.1.4 INTERFERENTS

It should be noted that the gas filter correlation method for detecting CO_2 is subject to interference from a number of other gases that absorb IR in a similar fashion to CO_2. Most notable of these are water vapor and CO. These analyzers have been successfully tested for their ability to reject interference from of these sources.

For a more detailed discussion of this topic, see Section 6.2.1.4.

4.1.5 DILUTION RATIO OPTION SOFTWARE SET UP

If your application involves diluting the sample gas before it enters the analyzer, and the Dilution Ratio Option is enabled:

1. Set the appropriate units of measure (Setup>Vars>User Units).
2. Select the reporting range mode (Setup>Vars>Range Mode [Single or Dual]).
3. Set the reporting range (Setup>Analog Output>CO2 Concentration, Min Max). Ensure that the upper span limit entered for the reporting range (in the Max field) is the maximum expected concentration of the undiluted gas.
4. Set the dilution factor as a gain, e.g., a value of 20 means 20 parts diluent and 1 part sample gas (Setup>Vars>Dilution Factor).
5. Calibrate the analyzer; ensure that the calibration span gas is either supplied through the same dilution system as the sample gas or has an appropriately lower actual concentration.

   EXAMPLE: If the reporting range limit is set for 100 ppm and the dilution ratio of the sample gas is 20 gain, either:

   - a span gas with the concentration of 100 ppm can be used if the span gas passes through the same dilution steps as the sample gas, or;
   - a 5 ppm span gas must be used if the span gas IS not routed through the dilution system.

4.1.6 SECOND GAS SENSOR OPTIONS CALIBRATION

For the optional O_2 sensor, calibrate per Section 4.6.1 during installation of the instrument.

4.1.7 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 analyzer.

- 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, make use of the internal data acquisition system (DAS) by setting up the Data Logger.

4.2 CALIBRATION PROCEDURES

Check that the pneumatic connections for the specific instrument configuration are as instructed in Section 2.3.2.

Verify/change (if needed) the settings as follows:

- User Units (unit of Measure): PPB (Setup>Vars>User Conc Units)
- Min and Max Concentration Range (Max should be highest concentration expected to measure) (Setup>Analog Outputs>Analog Output[#], Signal Out, [Gas] Concentration)
- Range Mode: SNGL (Setup>Vars>Range Mode)

Note	Tips for Setting the Expected Span Gas Concentration:
	• **When setting expected concentration values, consider impurities in your span gas source.**
	• **The expected CO2 span gas concentration should be 80% of the reporting range of the instrument.**

To calibrate or to perform a calibration check for basic configuration instruments, see Section 4.2.1.

To calibrate or to perform a calibration check for instruments with valve options, see Section 4.2.2.

To perform automatic calibration check for instruments with the internal span gas generator, see Section 4.3.

4.2.1 CALIBRATION AND CHECK PROCEDURES FOR BASIC CONFIGURATION

Although this Section uses the Calibration menu for both check and actual calibration, a check does not require the Calibration menu. Instead, while in Home page, simply flow the zero air or the span gas through the Sample port, and check the reading after the Stability falls below 1.0 PPB (either in the gas graph or in the Dashboard).

Otherwise, follow the steps presented in Sections 4.2.1.1 and 4.2.1.2.
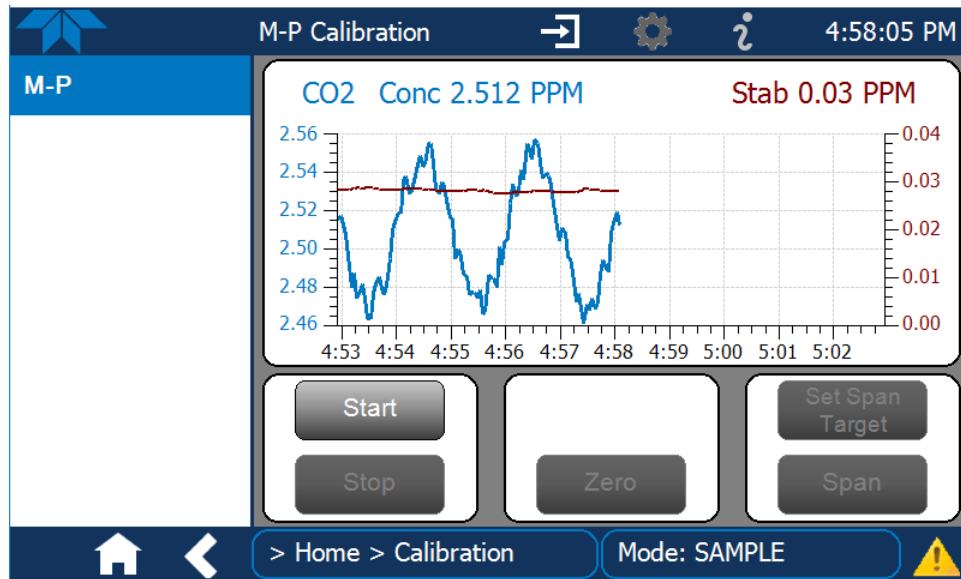
Figure 4-1. Multi-Point Calibration Page

4.2.1.1 ZERO CALIBRATION CHECK AND ACTUAL CALIBRATION

13. Go to the Calibration>M-P menu.

14. Input Zero air through the Sample port and press the Start button.

15. Either check or calibrate as follows:

CHECK ONLY:	ACTUAL CALIBRATION:
a. Wait for reading to stabilize.	a. Press the Zero button.
b. Press Stop and check the reading.	b. Press Stop and check the reading.

4.2.1.2 SPAN CALIBRATION CHECK AND ACTUAL CALIBRATION

1. While still in the Calibration>M-P menu, input CO_2 Span gas through the Sample port and press the Start button.

2. Either check or calibrate as follows:

<table>
<tr><td>**CHECK ONLY:**</td><td>**ACTUAL CALIBRATION:**</td></tr>
<tr><td>a. Wait to reach stability, then press Stop.</td><td>a. Press the Set Span Target button and enter the CO_2 concentration.</td></tr>
<tr><td>b. Record the reading(s).</td><td>b. Verify the concentration reading is the same as the CO_2 concentration being supplied.</td></tr>
<tr><td></td><td>c. If correct, wait to reach stability, then press the Span button.</td></tr>
<tr><td></td><td>d. In the Cal Result window, press OK.</td></tr>
</table>

3. Press the Stop button and return to Home screen.

4. In the Dashboard, check and record the Slope(s) and the Offset(s). (See Table 4-4 in Section 4.4 for expected/acceptable values).

4.2.2 CALIBRATION AND CHECK PROCEDURES WITH VALVE OPTIONS INSTALLED

Calibration>Span Calibration screen

Calibration>Zero Calibration screen

Figure 4-2. Zero and Span Calibration Screens
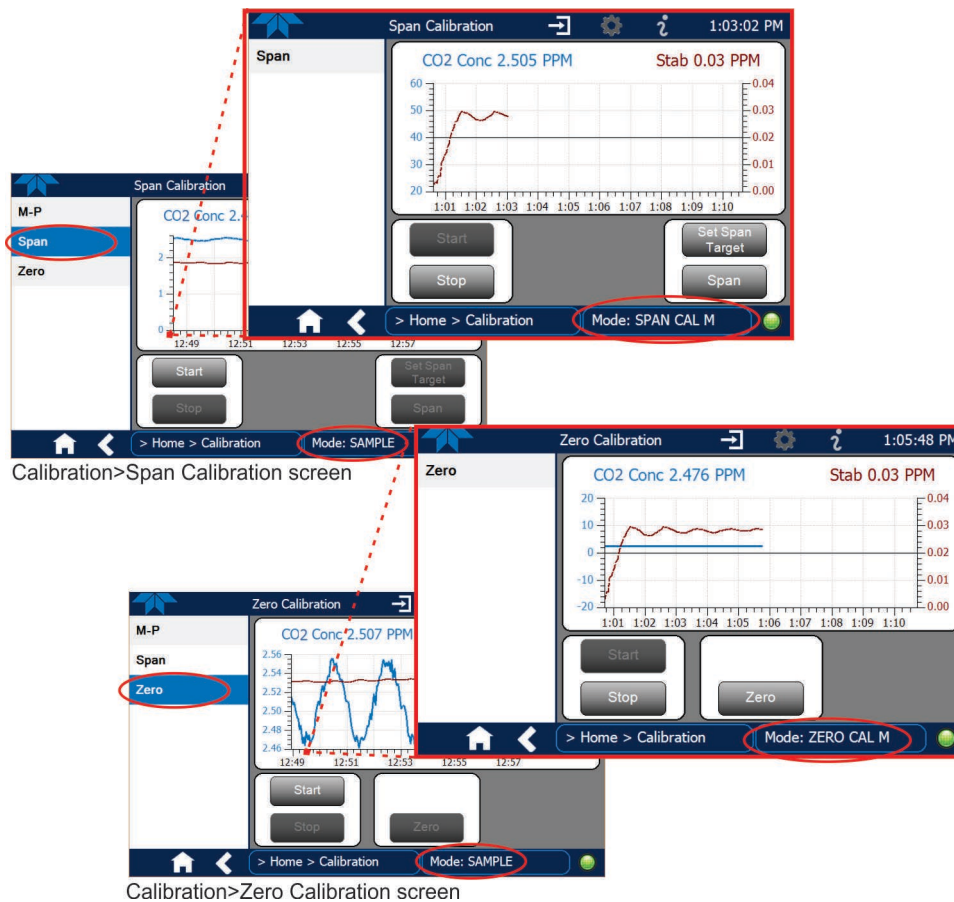
Follow the instructions in Section 4.2.1, except instead of the M-P menu, go to the Calibration>Zero menu for Zero cal and to the Calibration>Span menu for CO_2 Span cal.

4.2.2.1 USE OF ZERO/SPAN VALVE WITH REMOTE CONTACT CLOSURE

Contact closures for controlling calibration and calibration checks are located on the rear panel CONTROL IN connector. Instructions for setup and use of these contacts are in Section 2.3.1.5.

When the contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and the internal zero/span valves will be automatically switched to the appropriate configuration.

- The remote calibration contact closures may be activated in any order.
- It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading.
- The instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are being used in conjunction with the analyzer's AutoCal (see Section 4.3) feature and the AutoCal attribute "Calibrate" is enabled (selection box is checked), the analyzer will not recalibrate 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 (selection box is unchecked), the instrument will return to SAMPLE mode, leaving the instrument's internal calibration variables unchanged.

4.3   AUTOMATIC ZERO/SPAN CAL/CHECK (AUTO CAL)

The Auto Cal feature allows unattended periodic operation of the ZERO/SPAN valve options by using the instrument's internal time of day clock. Auto Cal operates by executing preprogrammed calibrations or calibration checks set up by the user to initiate the various calibration states of the analyzer and to open and close valves appropriately. It is possible to set up and run up to three separate preprogrammed calibrations or calibration checks (labeled # **1**, **2** and **3**). Each calibration or check can operate in one of three modes (Zero, Low or High), or be disabled.

Table 4-1 and Table 4-2 show how to set up the operating states of each calibration or check, and Table 4-3 shows how to program the execution of each.
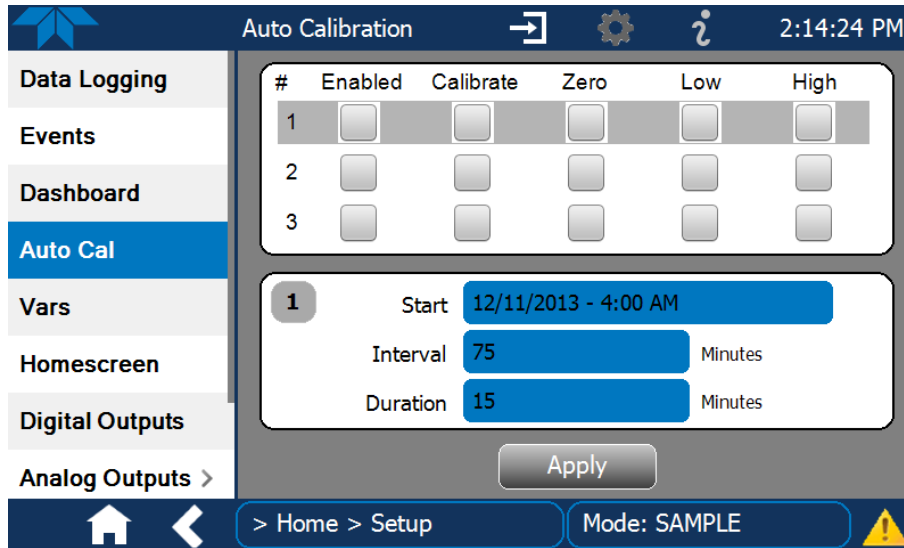
Figure 4-3. Auto Cal Page

Table 4-1. AUTO CAL States

MODE NAME	ACTION
Enabled	☑ enables the sequence; ☐ disables the sequence.
Calibrate	☑ enables an actual calibration when the Enabled box is also ☑. ☐ allows a calibration check when the Enabled box is also ☑.
Zero	☑ causes the sequence to perform a Zero calibration when both the Calibrate and Enabled boxes are also ☑. ☑ causes a Zero check when the Enabled box is also ☑ and the Calibrate box is unchecked (☐). ☐ disables Zero calibration and check
Low	☑ causes the sequence to perform a Low Span calibration when both the Calibrate and Enabled boxes are also ☑. ☑ causes a Low Span check when the Enabled box is also ☑ and the Calibrate box is unchecked (☐). ☐ disables Low Span calibration and check
High	☑ causes the sequence to perform a High Span concentration calibration when both the Calibrate and Enabled boxes are also ☑. ☑ causes a High Span check when the Enabled box is also ☑ and the Calibrate box is unchecked (☐). ☐ disables the High Span calibration and check.

Table 4-2 shows how the selection boxes would be enabled/disabled for calibration checks and calibrations.

Table 4-2. Auto Cal Setup Combinations

MODE	ACTION	STATE				
		Enabled	Calibrate	Zero	Low	High
Zero	Check	✓	☐	✓	☐	☐
	Calibrate	✓	✓	✓	☐	☐
Low	Check	✓	☐	☐	✓	☐
	Calibrate	✓	✓	☐	✓	☐
High	Check	✓	☐	☐	☐	✓
	Calibrate	✓	✓	☐	☐	✓
Zero Low High	Check	✓	☐	✓	✓	✓
	Calibrate	✓	✓	✓	✓	✓

For each sequence, there are four parameters that control operational details: Date, Time (both in the Start field), Interval, and Duration, as presented in Table 4-3.

Table 4-3. Auto Cal Programming Sequence Execution

ATTRIBUTE	ACTION
Start	When the Enabled box is "on" ✓, the Sequence (identified by its number) begins on the date and time shown in the configurable Start field. (Click the field for the pop-up window and toggle between the Time (Hour/Minutes) and the Date (Year/Month/Day) attributes to edit as needed).
Interval	Number of minutes to skip between each Sequence execution. (Click the field to input the number of minutes in the pop-up window).
Duration	Number of minutes that each Sequence execution is to run. (Click the field to input the number of minutes in the pop-up window).

IMPORTANT

IMPACT ON READINGS OR DATA

- The programmed STARTING_TIME must be a minimum of 5 minutes later than the real time clock for setting real time clock (Setup>Instrument, Section 2.5.9).

- Avoid setting two or more sequences at the same time of the day.

- Any new sequence that is initiated whether from a timer, the COM ports or the contact closure inputs will override any sequence that is in progress.

- **It is recommended that calibrations be performed using external sources of Zero Air and Span Gas whose accuracy is traceable to EPA standards.**

4.4 CALIBRATION QUALITY

After completing any 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. The values for these terms, both individually and relative to each other, indicate the quality of the calibration.

To perform this quality evaluation, check that these parameters are within the limits listed in Table 4-4 below and frequently compare them to those values on the *Final Test and Validation Data Sheet* that was shipped with your instrument, which should not be significantly different. If they are, refer to the Troubleshooting content in Section 5.

Table 4-4. Calibration Data Quality Evaluation

FUNCTION	MINIMUM VALUE	OPTIMUM VALUE	MAXIMUM VALUE
SLOPE	0.700	1.000	1.300
OFFSET	-0.500	0.000	0.500

4.5 CALIBRATION OF THE ELECTRONIC SUBSYSTEMS

These calibrations include Dark Cal, Pressure Cal and Flow Cal, all located under the Utilities>Diagnostics menu.

4.5.1 DARK CALIBRATION TEST

The dark calibration test interrupts the signal path between the IR photo-detector and the remainder of the sync/demod board circuitry. This allows the instrument to compensate for any voltage levels inherent in the sync/demod circuitry that might affect the calculation of CO_2 concentration.

Performing this calibration returns dark offset voltages for **MEAS** and for **REF** that are automatically added to the CPU's calculation routine. The two offset voltages from the last calibration procedure may be viewed in the Dashboard as Meas Detector and Ref Detector.

Activate this procedure in the Utilities>Diagnostics>Dark Calibration menu.

4.5.2 PRESSURE CALIBRATION

A sensor at the exit of the sample chamber continuously measures the pressure of the sample gas. The data for Sample Pressure are used to compensate the final CO_2 concentration calculation for changes in atmospheric pressure and are stored in the CPU's memory.

IMPORTANT	**IMPACT ON READINGS OR DATA**
	This calibration must be performed when the pressure of the sample gas is equal to ambient atmospheric pressure. Before performing the following pressure calibration procedure, disconnect the sample gas pump and sample gas-line vent from the rear panel sample gas inlet.

Activate this procedure in the Utilities>Diagnostics>Pressure Cal menu.

4.5.3 FLOW CALIBRATION

The flow calibration allows the user to adjust the values of the sample flow rates as they appear in the Dashboard 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, calibrated, volumetric flow meter to the sample inlet per Section 5.6.4. Once the flow meter is attached and is measuring actual gas flow, use the Utilities>Diagnostics>Flow Cal menu to input the flow meter reading and calibrate.

4.6   CALIBRATION OF OPTIONAL SENSORS

This Section provides the calibration setup and procedures for the O_2 Sensor and the CO_2 Sensor options.

4.6.1 O_2 SENSOR CALIBRATION

Set up the O_2 pneumatics connections as follows:
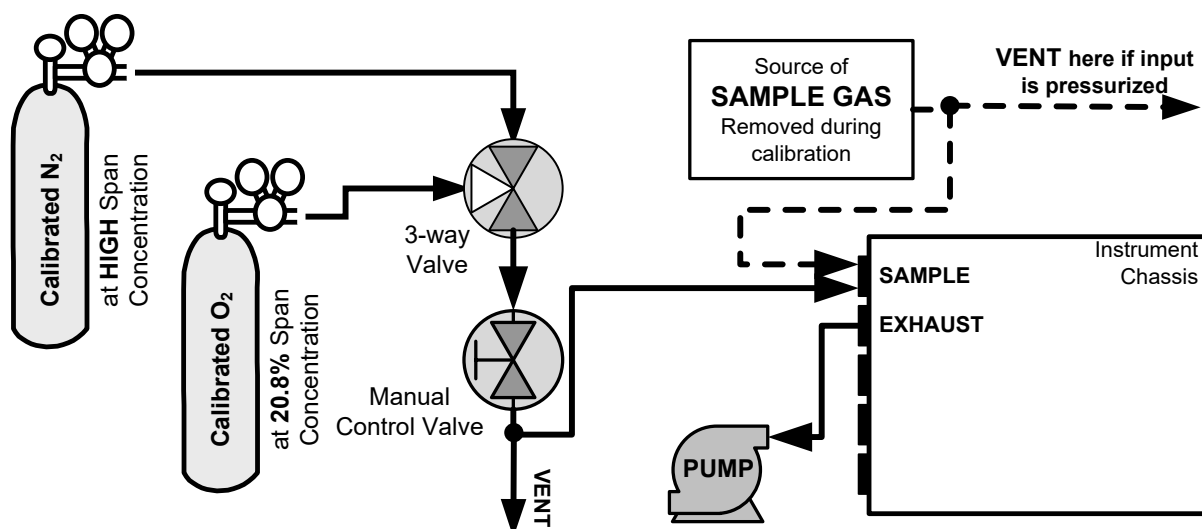
Figure 4-4. O_2 Sensor Calibration Set Up

O_2 **SENSOR ZERO GAS:** Teledyne API recommends using pure N_2 when calibration the zero point of your O_2 sensor option.

O_2 **SENSOR SPAN GAS:** Teledyne API recommends using 20.8% O_2 in N_2 when calibration the span point of your O_2 sensor option.

In the Calibration>O2 menu, follow the steps in Section 4.2.1.2, this time setting the expected O_2 span gas concentration. This should be equal to the percent concentration of the O_2 span gas of the selected reporting range (default factory setting = 20.8%; the approximate O_2 content of ambient air).

5. MAINTENANCE AND SERVICE

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. A minimal number of simple, regularly performed maintenance procedures (Section 5.1) will ensure that the analyzer continues to operate accurately and reliably over its lifetime. Repairs and troubleshooting are covered in Section 5.7 of this manual.

5.1 MAINTENANCE SCHEDULE

Table 5-1 shows a typical maintenance schedule for the analyzer. The actual frequency of performing these procedures can vary depending on the operating environment. Additionally, in some cases, there are local regulations or standards that also need to be considered. Please note that in certain environments (i.e. dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.

⚠️	**WARNING – Electrical Shock Hazard** **Disconnect power before performing any of the following operations that require entry into the interior of the analyzer.**

⚠️	**Caution – Qualified Personnel** **These maintenance procedures must be performed by qualified technicians only.**

Important	**IMPACT ON READINGS OR DATA** **A Span and Zero Calibration Check (see CAL CHECK REQ'D Column of Table 5-1) must be performed following certain of the maintenance procedure listed below. To perform a CHECK of the instrument's Zero or Span Calibration, refer to Sections 4.2.1.1 and 4.2.1.2, respectively.** **Alternatively, use the Auto Cal feature described in Section 4.3 with the CALIBRATE attribute set to OFF (not enabled).**

Table 5-1. Maintenance Schedule

ITEM	ACTION	FREQ	CAL CHECK REQ'D	MANUAL	DATE PERFORMED											
Particulate Filter	Replace	Weekly or As Needed	No													
Verify Functions	Record and Analyze	Weekly or after any Maintenance or Repair	No													
Pump Diaphragm	Replace	Annually	Yes													
Perform Flow Check	Check Flow	Annually	No													
Perform Leak Check	Verify Leak Tight	Annually or after any Maintenance or Repair	No													
Pneumatic lines	Examine and Clean	As Needed	Yes if cleaned													
Cleaning	Clean	As Needed	Only if cover removed													

Table 5-2. Functions Verifications Record

FUNCTION	OPERATING MODE*	DATE RECORDED											
STABILITY	ZERO CAL												
CO2 MEAS	ZERO CAL												
MR RATIO	ZERO CAL												
	SPAN CAL												
PRES	SAMPLE												
PHT DRIVE	SAMPLE AFTER WARM-UP												
SLOPE	SPAN CAL												
OFFSET	ZERO CAL												

5.2 PREDICTING DIAGNOSTICS

These Functions can be used to predict failures by looking at how their values change over time. Initially it may be useful to compare the state of these functions to the values recorded on the printed record of the Final Test and Validation Data Sheet for your instrument. Table 5-3 can be used as a basis for taking action as these values change with time. The Data Logger (internal data acquisition system or DAS) is a convenient way to record and track these changes (Section 2.5.1). Use NumaView™ Remote to download and review this data from a remote location.

Table 5-3. Predictive Uses for Dashboard Functions

FUNCTION	CONDITION	BEHAVIOR	INTERPRETATION
STABILITY	Zero Cal	Increasing	• Pneumatic Leaks – instrument & sample system • Detector deteriorating
MEAS DETECTOR	Zero Cal	Decreasing	• Source Aging • Detector deteriorating • Optics getting dirty or contaminated
MR RATIO	Zero Cal	Increasing	• Source Aging • Detector deteriorating • Contaminated zero gas (H_2O)
		Decreasing	• Source Aging • Detector deteriorating • GFC Wheel Leaking • Pneumatic Leaks • Contaminated zero gas (CO)
	Span Cal	Increasing	• Source Aging • Pneumatic Leaks – instrument & sample system • Calibration system deteriorating • GFC Wheel Leaking
		Decreasing	• Source Aging • Calibration system deteriorating
SAMPLE PRESSURE	Sample	Increasing > 1"	• Pneumatic Leak between sample inlet and Sample Cell • Change in sampling manifold
		Decreasing > 1"	• Dirty particulate filter • Pneumatic obstruction between sample inlet and Sample Cell • Obstruction in sampling manifold
PHT DRIVE	Any, but with Bench Temp at 48°C	Increasing	• Mechanical Connection between IR-Detector and Sample Cell deteriorating • IR-Photodetector deteriorating
OFFSET	Zero Cal	Increasing	• See above, MR Ratio - Zero Cal Decreasing
		Decreasing	• See above, MR Ratio - Zero Cal Increasing
SLOPE	Span Cal	Increasing	• See above, MR Ratio - Span Cal Decreasing
		Decreasing	• See above, MR Ratio – Span Cal Increasing

5.3 OPERATIONAL HEALTH CHECKS

Navigate to the Utilities>USB Utilities>Report menu (Figure 5-1) to download a report on the basic operations of the instrument. To download the report for your own viewing on a computer or to send to others, insert a flash drive into a front panel USB port and press the Download button, which is enabled when the instrument detects the flash drive.
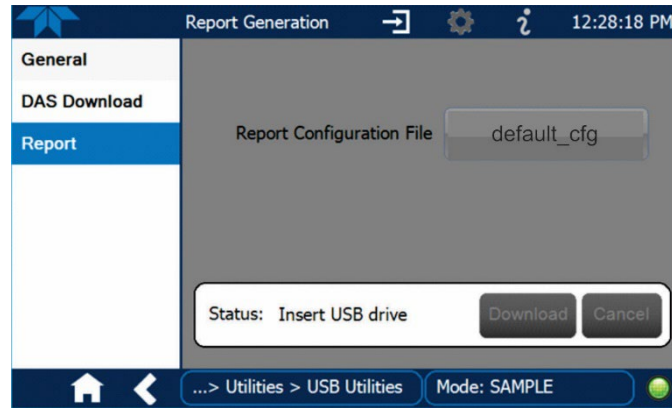
Figure 5-1: Report Generation Page

The report can also be set to generate periodically and sent to a Web services "cloud" where it is available for viewing by Teledyne API technical support personnel. Set this function with two Vars:

Setup>Vars>Upload Report to Cloud: set to True.

Setup>Vars>Report Upload>Interval: edit the number of hours between report uploads.

5.4 SOFTWARE/FIRMWARE UPDATES

There are two ways to check for and acquire updates: either remotely or manually.

5.4.1 REMOTE UPDATES

The instrument must be connected to a network that is connected to the Internet. In the Setup>Instrument menu, select the Remote Update menu and press the Check for Updates button. If an update is available, it can be downloaded through this page.
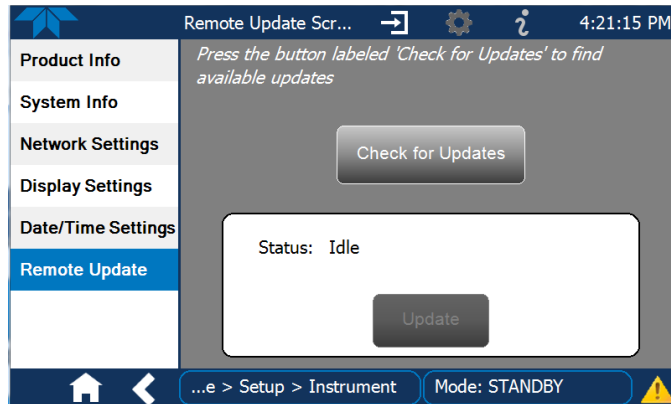
Figure 5-2. Remote Update Page

5.4.2 MANUAL RELOAD/UPDATE PROCEDURES

To reload or update firmware, first contact Technical Support to obtain the applicable file(s):

api-techsupport@teledyne.com (email), +1 800-324-5190 (toll free), +1 858-657-9800 (phone).

1. Follow Technical Support's instructions for copying the firmware files to a flash drive.

2. Go to the Utilities>USB Utilities>General menu.
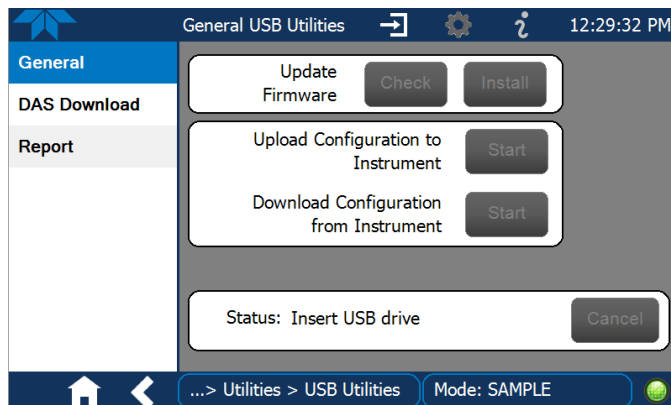
Figure 5-3. Manual Update Page (and other utilities)

3. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected.

4. In the Update Firmware field, press the Check button for the instrument to determine whether the firmware on the flash drive is more recent than what is

currently installed. Once it's been determined that the firmware is new, the Install button will be enabled; if the firmware version on the flash drive is the same as or older than the current firmware of the instrument, the Install button will not be enabled.

5. Press the Install button, and note the messages in the Status field at the bottom of the page. Use the Cancel button if necessary.

6. When complete, as indicated in the Status field, press the Done button, which replaces the Cancel button, and remove the flash drive.

7. Power off and restart the instrument to complete the new firmware installation.

5.4.3 INSTRUMENT DISPLAY CALIBRATION (FOR EARLIER INSTRUMENTS)

This Section applies to instruments shipped before January 2017. Although unlikely, if ever the touchscreen appears unresponsive or responds incorrectly, the screen can be calibrated via the Setup>Instrument>Display Settings menu.
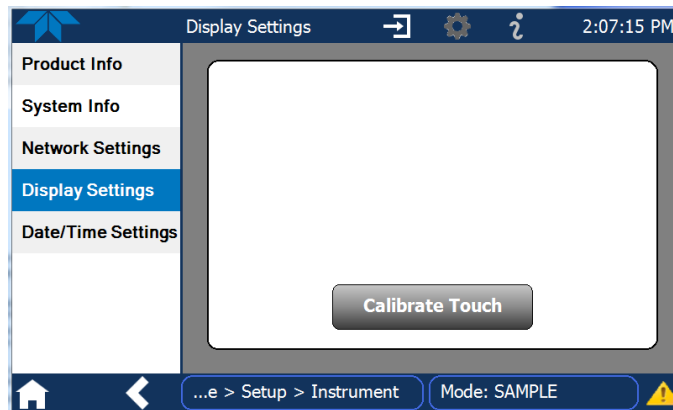
Figure 5-4. Touchscreen Calibration Page

1. Connect a mouse to either of the front panel USB ports.

2. Navigate with the pointer to Setup>Instrument>Display Settings.

3. Click on "Calibrate Touch" and a crosshair appears in the center of the display screen.

   • Note that a timer function is enabled, allowing only 15 seconds to start the calibration process. If the timer expires, the instrument will exit the calibration screen and return to normal operation.

4. Click the very center of the crosshair.

5. When a new crosshair appears in the upper left corner of the screen, carefully and accurately click and hold the very center of that crosshair until it finishes shrinking, then release.

6. Repeat Step 5 for each of the corners.

7. Once the process is completed, a CANCEL and an ACCEPT button appear in the lower left corner: Test the accuracy of the calibration by touching parts of the screen and see that the mouse pointer follows your touches.

8. If you press the CANCEL button, the calibration won't be altered. Otherwise, press the ACCEPT button.

5.5 TIME ZONE CHANGES

There is an option to change between 12-hour and 24-hour format in the Setup>Vars menu (System Time Format). Effectively changing the Time Zone requires a specific procedure as follows:

1. In Setup>Instrument>Date/Time Settings select the applicable Time Zone.

1. Allow adequate time for the selected Time Zone to be properly accepted.

2. Verify: return to Home page then back to the Date/Time Settings page, and check that the selected Time Zone is now highlighted.

3. Without making any other changes, power OFF the instrument and power ON again.

4. Once restarted, return to the Date/Time Settings page where the newly selected Time Zone should be highlighted. (If not, it means that not enough time had passed for the instrument to accept the change before the power was cycled OFF).

5. After the Time Zone is implemented first (Steps 1 through 4), then other changes to the date and/or time can be made, and recycling the power is not necessary.
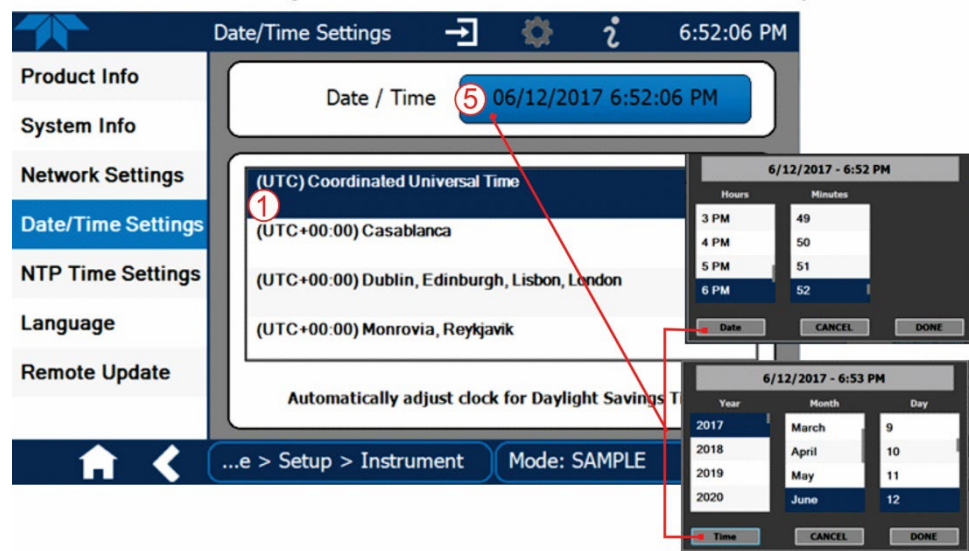
Figure 5-5. Time Zone Change Requirements

5.6 MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the analyzer.

5.6.1 REPLACING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or contamination. We recommend that the filter and the wetted surfaces of the filter housing are handled as little as possible when you change the filter. Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the o-ring.

To change the filter:

1. Turn OFF the analyzer to prevent drawing debris into the instrument.
2. Unscrew the knurled retaining ring on the filter assembly.
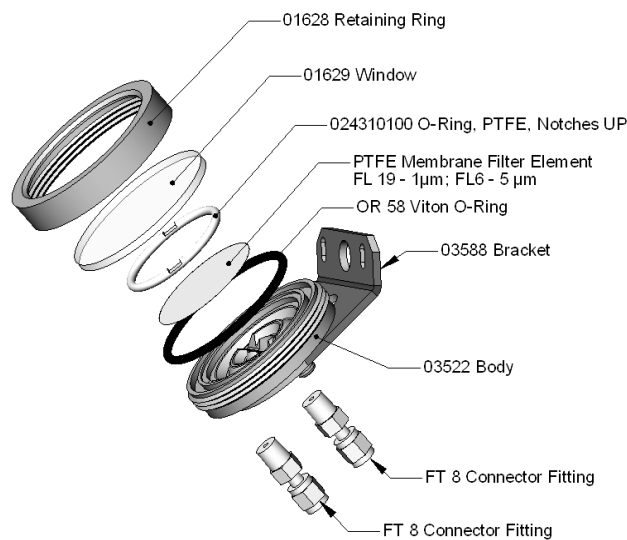
Figure 5-6. Sample Particulate Filter Assembly

3. Carefully remove the retaining ring, PTFE o-ring, glass filter cover and filter element.
4. Replace the filter, being careful that the element is fully seated and centered in the bottom of the holder.
5. Re-install the PTFE o-ring (with the notches up), the glass cover, then screw on the retaining ring and hand tighten. Inspect the seal between the edge of filter and the o-ring to assure a proper seal.
6. Re-start the Analyzer.

5.6.2 REBUILDING THE SAMPLE PUMP

The diaphragm in the sample pump periodically wears out and must be replaced. A sample rebuild kit is available – see label on the pump itself for the part number of the pump rebuild kit. Instructions and diagrams are included with the kit.

Always perform a Flow and Leak Check after rebuilding the Sample Pump.

5.6.3 PERFORMING LEAK CHECKS

Leaks are the most common cause of analyzer malfunction; Section 5.6.3.1 presents a simple leak check procedure. Section 5.6.3.2 details a more thorough procedure.

5.6.3.1   VACUUM LEAK CHECK AND PUMP CHECK

This method is easy and fast. It detects, but does not locate most leaks. It also verifies that the sample pump is in good condition.

1. Turn the analyzer ON, and allow enough time for flows to stabilize.
2. Cap the sample inlet port.
3. After several minutes, when the pressure has stabilized, scroll through   the **TEST** menu, note the SAMPLE PRESSURE reading.
4. If the reading is < 10 in-Hg, the pump is in good condition and there are no large leaks.
5. Check the sample gas flow. If the flow is <10 cm^3/min and stable, there are no large leaks in the instrument's pneumatics.

5.6.3.2   PRESSURE LEAK CHECK

If you can't locate the leak by the above procedure, use the following procedure. Obtain a leak checker similar to the Teledyne API P/N 01960, which contains a small pump, shut-off valve and pressure gauge. Alternatively, a convenient source of low-pressure gas is a tank of span gas, with the two-stage regulator adjusted to less than 15 psi with a shutoff valve and pressure gauge.

⚠	**CAUTION** **General Safety Hazard** **Do not use bubble solution with vacuum applied to the analyzer. The solution may contaminate the instrument. Do not exceed 15 PSIG pressure.**

1. Turn OFF power to the instrument.
2. Install a leak checker or tank of gas as described above on the sample inlet at the rear panel.
3. Remove the instrument cover and locate the inlet side of the sample pump. Remove the flow assembly from the pump and plug it with the appropriate gas-tight fitting.
4. Pressurize the instrument with the leak checker, allowing enough time to fully pressurize the instrument through the critical flow orifice. Check each fitting with soap bubble solution, looking for bubbles. Once the fittings have been wetted with

soap solution, do not re-apply vacuum, as it will suck soap solution into the instrument and contaminate it. Do not exceed 15 psi pressure.

5. If the instrument has one of the zero and span valve options, the normally closed ports on each valve should also be separately checked. Connect the leak checker to the normally closed ports and check with soap bubble solution.

6. Once the leak has been located and repaired, the leak-down rate should be < 1 in-Hg (0.4 psi) in 5 minutes after the pressure is shut off.

5.6.4 PERFORMING A SAMPLE FLOW CHECK

> **CAUTION**
> **General Safety Hazard**
>
> **Always use a separate calibrated volumetric flow meter capable of measuring flows in the analyzer's specified flow range to measure the gas flow rate though the analyzer.**
>
> **DO NOT use the built in flow measurement viewable from the Front Panel of the instrument. This measurement is only for detecting major flow interruptions such as clogged or plugged gas lines.**
>
> **See Figure 2-2 for SAMPLE port location.**

1. Attach the Flow Meter to the sample inlet port on the rear panel. Ensure that the inlet to the Flow Meter is at atmospheric pressure.

2. Sample flow should be per specifications (Table 1-1) $\pm$ 10%.

3. Once an accurate measurement has been recorded by the method described above, adjust the analyzer's internal flow sensors (See Section 4.5.3).

Low flows indicate blockage somewhere in the pneumatic pathway, typically a plugged sintered filter or critical flow orifice in one of the analyzer's flow control assemblies. High flows indicate leaks downstream of the Flow Control Assembly.

5.6.5 CLEANING THE OPTICAL BENCH

The sensor assembly and optical bench are complex and delicate. Disassembly and cleaning is not recommended. Please check with the factory before disassembling the optical bench.

5.7   SERVICE AND TROUBLESHOOTING

This contains a variety of methods for identifying the source of performance problems with the analyzer. Also included in this are procedures that are used in repairing the instrument.

> **Qualified Personnel**
>
> **The operations outlined in this Section must be performed by qualified maintenance personnel only.**

	WARNING - Risk of Electrical Shock
⚡	**Some operations need to be carried out with the instrument 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.

The analyzer has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps (some are listed in :

1. Note Alerts and take corrective action as necessary.

2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.

3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.
   - Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.
   - Note that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.

4. **SUSPECT A LEAK FIRST!**
   - Technical Support data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.
   - Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged / malfunctioning pumps, etc.

5. Follow the procedures defined in Section 5.7.14 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touchscreen, etc.).

5.7.1 CLEANING EXTERIOR SURFACES OF THE ANALYZER

If necessary, the exterior surfaces of the analyzer can be cleaned with a clean damp cloth. Do NOT submerge any part of the instrument and do NOT use any cleaning solution.

5.7.2 FAULT DIAGNOSIS WITH ALERTS

The most common and/or serious instrument failures will result in a warning message, called an Alert. Table 5-4 lists some of the more common Alert messages, along with their meaning and recommended corrective action.

It should be noted that if more than two or three warning Alerts 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 being an indication of the specific failures referenced by the warning Alerts.

Table 5-4. Alerts - Indicated Failures

ALERT MESSAGE	FAULT CONDITION	POSSIBLE CAUSES
BENCH TEMP WARNING	The optical bench temp is controlled at 48 ± 2 ˚C.	Bad bench heater Bad bench temperature sensor Bad relay controlling the bench heater Entire relay board is malfunctioning I^2C bus malfunction
BOX TEMP WARNING	Box Temp is < 5 ˚C or > 48 ˚C.	NOTE: Box temperature typically runs ~7ºC warmer than ambient temperature. Poor/blocked ventilation to the analyzer. Stopped exhaust-fan Ambient temperature outside of specified range
CANNOT DYN SPAN	Dynamic Span operation failed. (Contact closure span calibration failed while *DYN_SPAN* was set to *ON*).	Measured concentration value is too high or low. Concentration slope value too high or too low
CANNOT DYN ZERO	Dynamic Zero operation failed	Measured concentration value is too high. Concentration offset value too high.
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	Failed disk on module User erased data
DATA INITIALIZED	Data Storage in DAS was erased	Failed disk on module User cleared data
OVEN TEMP WARNING	The temperature of the insulated convection oven area of the analyzer is outside of the specified limits.	Oven temperature outside of specified range Failed oven heater (s) Failed oven fan(s) Failed oven temperature sensor Relay controlling the one of the oven heater Failed relay board
PHOTO TEMP WARNING	PHT DRIVE is >4800 mVDC	Failed IR photo-detector Failed sync/demod board IR photo-detector improperly attached to the sample chamber Bench temp too high.
REAR BOARD NOT DET	Motherboard not detected on power up.	Warning only appears on serial I/O com port(s) Front panel display will be frozen, blank or will not respond. Massive failure of motherboard
RELAY BOARD WARNING	The CPU cannot communicate with the Relay Board.	I^2C bus failure Failed relay board Loose connectors/wiring
SAMPLE FLOW WARNING	Sample flow rate is out of range, either below minimum or above maximum	Failed sample pump Blocked sample inlet/gas line Dirty particulate filter Leak downstream of critical flow orifice Failed flow sensor/circuitry
SAMPLE PRESSURE WARNING	Sample Pressure is <10 in-Hg or > 35 in-Hg Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).	If sample pressure is < 10 in-hg: • Blocked particulate filter • Blocked sample inlet/gas line • Failed pressure sensor/circuitry If sample pressure is > 35 in-hg: • Pressurized sample gas. Install vent • Blocked vent line on pressurized sample/zero/span gas supply • Bad pressure sensor/circuitry

ALERT MESSAGE	FAULT CONDITION	POSSIBLE CAUSES
SAMPLE TEMP WARN	Sample temperature is < 10°C or > 100°C.	Ambient temperature outside of specified range Failed bench heater Failed bench temperature sensor Relay controlling the bench heater Failed relay board I²C bus
SOURCE WARNING	Occurs when Ref Detector is <1250 mVDC or >4950 mVDC. Either of these conditions will result in an invalid M/R ratio.	GFC Wheel stopped Failed sync/demod board If status LEDs on the sync/demod board <u>ARE</u> flashing the cause is most likely a failed: • IR source • Relay board • I²C bus • IR photo-detector
SYSTEM RESET	The computer has rebooted.	This message occurs at power on. If you have not cycled the power on your instrument: • Failed +5 VDC power, • Fatal error caused software to restart • Loose connector/wiring
WHEEL TEMP WARNING	The filter wheel temperature is outside specified limits.	Blocked cooling vents below GFC Assembly. Make sure that adequate clear space beneath the analyzer. Analyzer's top cover removed Wheel heater Wheel temperature sensor Relay controlling the wheel heater Entire relay board I²C bus

5.7.3 FAULT DIAGNOSIS WITH DASHBOARD 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 (see Section 6).

The acceptable ranges for these test functions are listed in the "Nominal Range" column of the analyzer's *Final Test and Validation Data Sheet* shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions whose values are still within the acceptable range but have significantly changed from the measurement recorded on the factory data sheet may also indicate a failure.

The following table contains some of the more common causes for these values to be out of range.

Table 5-5. Dashboard Functions - Indicated Failures

FUNCTION	INDICATED FAILURE(S)
RANGE	Incorrectly configured measurement range(s) could cause response problems with a Data logger or chart recorder attached to one of the analog output. If the Range selected is too small, the recording device will over range. If the Range is too big, the device will show minimal or no apparent change in readings.
STABIL	Indicates noise level of instrument or CO_2 concentration of sample gas (see Section 5.7.13 for causes).

FUNCTION	INDICATED FAILURE(S)
CO2	If the value displayed is too high the IR Source has become brighter. Adjust the variable gain potentiometer on the sync/demod board (see Section 5.7.14.7). If the value displayed is too low or constantly changing and the **REF DETECTOR** is OK: - Failed multiplexer on the motherboard - Failed sync/demod board - Loose connector or wiring on sync/demod board If the value displayed is too low or constantly changing and the REF DETECTOR is bad: - GFC Wheel stopped or rotation is too slow - Failed sync/demod board IR source - Failed IR source - Failed relay board - Failed I^2C bus - Failed IR photo-detector
MR Ratio	When the analyzer is sampling zero air and the ratio is too low: - The reference cell of the GFC Wheel is contaminated or leaking. - The alignment between the GFC Wheel and the segment sensor, the M/R sensor or both is incorrect. - Failed sync/demod board When the analyzer is sampling zero air and the ratio is too high: - Zero air is contaminated - Failed IR photo-detector
PRES	See Table 5-4 for **SAMPLE PRES WARN.**
SAMPLE FL	Check for gas flow problems (see Section 5.7.9).
SAMP TEMP	SAMPLE TEMP should be close to BENCH TEMP. Temperatures outside of the specified range or oscillating temperatures are cause for concern.
BENCH TEMP	Bench temp control improves instrument noise, stability and drift. Temperatures outside of the specified range or oscillating temperatures are cause for concern. Table 5-4 for BENCH TEMP WARNING.
WHEEL TEMP	Wheel temp control improves instrument noise, stability and drift. Outside of set point or oscillating temperatures are causes for concern. See Table 5-4 for WHEEL TEMP WARNING.
BOX TEMP	If the box temperature is out of range, check fan in the power supply module. Areas to the side and rear of instrument should allow adequate ventilation. See Table 5-4 for BOX TEMP WARNING.
PHT DRIVE	If this drive voltage is out of range it may indicate one of several problems: - A poor mechanical connection between the photodetector, its associated mounting hardware and the absorption cell housing; - An electronic failure of the IR Photo-Detector's built-in cooling circuitry, or; - A temperature problem inside the analyzer chassis. In this case other temperature warnings would also be active.
SLOPE	Values outside range indicate Contamination of the zero air or span gas supply Instrument is miscalibrated Blocked gas flow Contaminated or leaking GFC Wheel (either chamber) Faulty IR photo-detector Faulty sample faulty IR photo-detector pressure sensor (P1) or circuitry Invalid M/R ratio (see above) Bad/incorrect span gas concentration due.
OFFSET	Values outside range indicate Contamination of the zero air supply Contaminated or leaking GFC Wheel (either chamber) Faulty IR photo-detector

5.7.4 THE DIAGNOSTIC SIGNAL I/O FUNCTION

The signal I/O diagnostic mode allows access to the digital and analog I/O in the analyzer. Some of the digital signals can be controlled through the touchscreen. These signals, combined with a thorough understanding of the instrument's Theory of Operation (Section 6), are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.

- Many of the components and functions that are normally under algorithmic control of the CPU can be manually exercised.

- The technician can directly control the signal level Analog and Digital Output signals.

This allows the technician to observe systematically the effect of directly controlling these signals on the operation of the analyzer.

5.7.5 STATUS LEDS

Several color-coded light-emitting diodes (LEDs) are located inside the instrument to assist in determining if the analyzer's CPU, I^{2}C bus and relay board, GFC Wheel and the sync/demodulator board are functioning properly.

5.7.6 MOTHERBOARD STATUS INDICATOR (WATCHDOG)

DS5, a red LED, that is located on upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program loop. After power-up, approximately 30 to 60 seconds, DS5 should flash on and off. If characters are written to the front panel display but DS5 does not flash then the program files have become corrupted. If after 30 – 60 seconds neither the DS5 is flashing or no characters have been written to the front panel display then the CPU is bad and must be replaced.
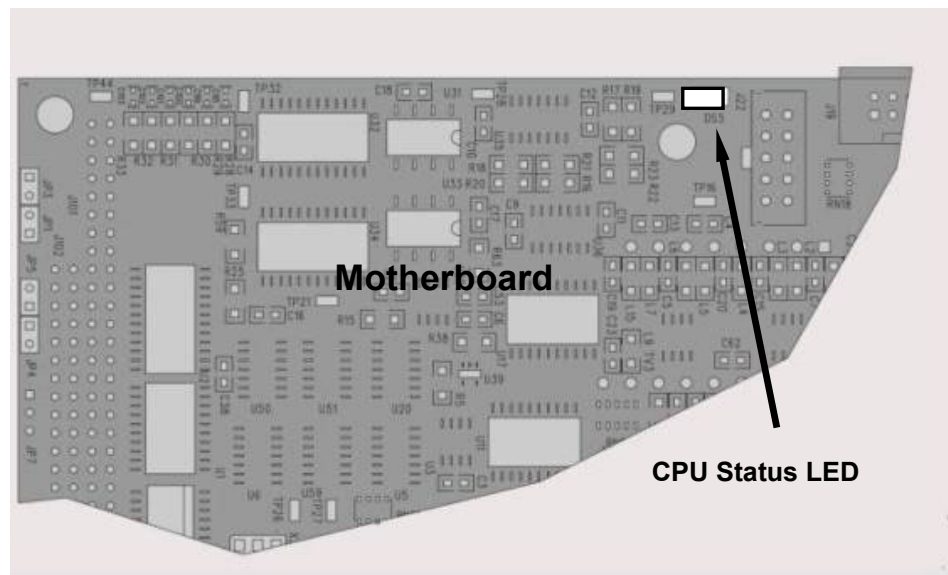
Figure 5-7. CPU Status Indicator

5.7.7 SYNC DEMODULATOR STATUS LEDS

Two LEDs located on the Sync/Demod Board are there to make it obvious that the GFC Wheel is spinning and the synchronization signals are present:

Table 5-6. Sync/Demod Board Status Failure Indications

LED	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
D1	M/R Sensor Status (Flashes slowly)	LED is stuck ON or OFF	GFC Wheel is not turning M/R Sensor on Opto-Pickup Board failed Sync/Demod Board failed JP 4 Connector/Wiring faulty Failed/Faulty +5 VDC Power Supply (PS1)
D2	Segment Sensor Status (Flashes quickly)	LED is stuck ON or OFF	GFC Wheel is not turning Segment Sensor on Opto-Pickup Board failed Sync/Demod Board failed JP 4 Connector/Wiring faulty Failed/Faulty +5 VDC Power Supply (PS1)
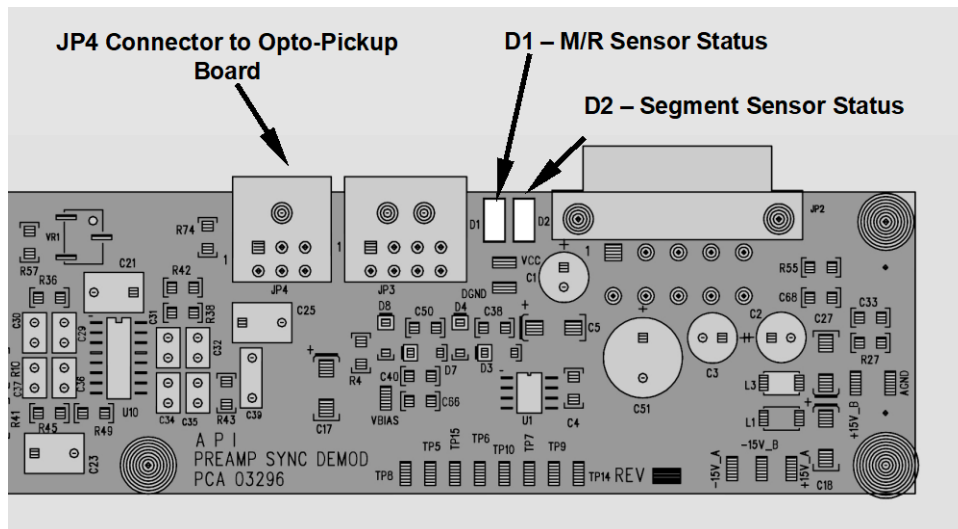
Figure 5-8. Sync/Demod Board Status LED Locations

5.7.8 RELAY BOARD STATUS LEDS

There are eight LEDs located on the Relay Board. The most important of which is D1, which indicates the health of the I^2C bus. If D1 is blinking the other faults following LEDs can be used in conjunction with **DIAG** menu signal I/O to identify hardware failures of the relays and switches on the relay (see Section 5.7.4 and Appendix D).

Table 5-7. I^2C Status LED Failure Indications

LED	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)

LED	SIGNAL I/O PARAMETER		DIAGNOSTIC TECHNIQUE
D1 (Red)	I²C bus Health (Watch Dog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty Motherboard, Touchscreen or Relay Board Faulty Connectors/Wiring between Motherboard, Touchscreen or Relay Board Failed/Faulty +5 VDC Power Supply (PS1)
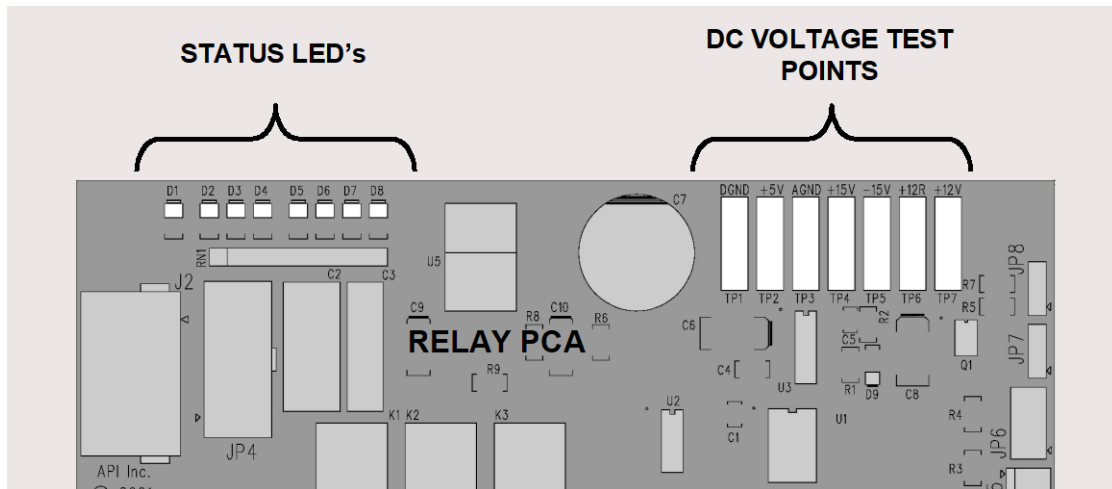
Figure 5-9. Relay Board Status LEDs

Table 5-8. Relay Board Status LED Failure Indications

LED	FUNCTION	SIGNAL I/O PARAMETER		DIAGNOSTIC TECHNIQUE
		ACTIVATED BY	VIEW RESULT	
D2 Yellow	Wheel Heater	**WHEEL_HEATER**	**WHEEL_TEMP**	Voltage displayed should change. If not: Failed Heater Faulty Temperature Sensor Failed AC Relay Faulty Connectors/Wiring
D3 Yellow	Bench Heater	**BENCH_HEATER**	**BENCH_TEMP**	Voltage displayed should change. If not: Failed Heater Faulty Temperature Sensor Failed AC Relay Faulty Connectors/Wiring
D4 Yellow	Spare	**N/A**	**N/A**	N/A
D5 Green	Sample/Cal Gas Valve Option	**CAL_VALVE**	**N/A**	Sample/Cal Valve should audibly change states. If not: Failed Valve Failed Relay Drive IC on Relay Board Failed Relay Board Faulty +12 VDC Supply (PS2) Faulty Connectors/Wiring
D6 Green	Zero/Span Gas Valve	**SPAN_VALVE**	**N/A**	Zero/Span Valve should audibly change states. If not:

| LED | FUNCTION | SIGNAL I/O PARAMETER | | DIAGNOSTIC TECHNIQUE |
		ACTIVATED BY	VIEW RESULT	
	Option			Failed Valve Failed Relay Drive IC on Relay Board Failed Relay Board Faulty +12 VDC Supply (PS2) Faulty Connectors/Wiring
D7 Green	Shutoff Valve Option	**SHUTOFF_VALVE**	**N/A**	Shutoff Valve should audibly change states. If not: Failed Valve Failed Relay Drive IC on Relay Board Failed Relay Board Faulty +12 VDC Supply (PS2) Faulty Connectors/Wiring
D8 Green	IR SOURCE	**IR_SOURCE**	**CO2_MEASURE**	Voltage displayed should change. If not: Failed IR Source Faulty +12 VDC Supply (PS2) Failed Relay Board Failed IR Photo-Detector Failed Sync/Demod Board Faulty Connectors/Wiring

5.7.9 FLOW PROBLEMS

When troubleshooting flow problems, it is a good idea to first confirm that the actual flow and not the analyzer's flow sensor and software are in error, or the flow meter is in error. Use an independent, calibrated, volumetric flow meter to perform a flow check as described in Section 5.6.4. If this test shows the flow to be correct, check the pressure sensors as described in Section 5.7.14.11.

The analyzer has two main gas flow paths, the sample gas flow path and the GFC purge gas flow path. Both are controlled by a critical flow orifice. Only the sample gas path is measured and reported. With the IZS or zero/span valve option installed, there are several subsidiary paths but none of those are displayed on the front panel or stored by the DAS.

With the O_2 sensor option installed, third gas flow controlled with a critical flow orifice is added, but this flow is not measured or reported.

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 crucial to confirm the actual flow rate without relying on the analyzer's flow display. The use of an independent, external, volumetric flow meter to perform a flow check as described in Section 5.6.4 is essential.

The flow diagrams found in Section 2.3.3 of this manual can help in trouble-shooting flow problems.

5.7.9.1 FLOW IS ZERO

The unit displays a SAMPLE FLOW warning message on the front panel display or the SAMPLE FLOW test function reports a zero or very low flow rate.

Confirm that the sample pump is operating (turning). If not, use an AC voltmeter to make sure that power is being supplied to the pump if no power is present at the electrical leads of the pump.

1. If AC power is being supplied to the pump, but it is not turning, replace the pump.
2. If the pump is operating but the unit reports no gas flow, perform a flow check as described in Section 5.6.4.
3. If no independent flow meter is available:
   - Disconnect the gas lines from both the sample inlet and the exhaust outlet on the rear panel of the instrument.
   - Make sure that the unit is in basic SAMPLE Mode.
   - Place a finger over an Exhaust outlet on the rear panel of the instrument.
   - If gas is flowing through the analyzer, you will feel pulses of air being expelled from the Exhaust outlet.
4. If gas flows through the instrument when it is disconnected from its sources of zero air, span gas or sample gas, the flow problem is most likely not internal to the analyzer. Check to make sure that:
   - All calibrators/generators are turned on and working correctly.
   - Gas bottles are not empty or low.
   - Valves, regulators and gas lines are not clogged or dirty.

5.7.9.2 LOW FLOW

1. Check if the pump diaphragm is in good condition. If not, rebuild the pump (see Section 5.6.2). Check the Spare Parts List for information on pump rebuild kits.
2. Check for leaks as described in Section 5.6.3. Repair the leaking fitting, line or valve and re-check.
3. Check for the sample filter and the orifice filter for dirt. Replace filters (see 5.6.1).
4. Check for partially plugged pneumatic lines, or valves. Clean or replace them.
5. Check for plugged or dirty critical flow orifices. Replace them.
6. If an IZS option is installed in the instrument, calibrate zero and span. If the flow increases, then suspect a bad sample/cal valve.

5.7.9.3 HIGH FLOW

The most common cause of high flow is a leak in the sample flow control assembly or between there and the pump. If no leaks or loose connections are found in the fittings or the gas line between the orifice and the pump, replace the critical flow orifice(s) inside the sample flow control assembly.

5.7.9.4   DISPLAYED FLOW = "WARNINGS"

This warning means that there is inadequate gas flow. There are four conditions that might cause this:

1. A leak upstream or downstream of the flow sensor
2. A flow obstruction upstream or downstream of the flow sensor
3. Bad Flow Sensor Board
4. Bad pump

To determine which case is causing the flow problem, view the sample pressure and sample flow functions on the front panel. If the sample pressure is reading abnormally low, then the cause is likely a flow obstruction upstream of the flow sensor. First, check the sample filter and make sure it is not plugged and then systematically check all the other components upstream of the orifice to ensure that they are not obstructed.

If the sample pressure is reading normal but the sample flow is reading low then it is likely that the pump diaphragm is worn or there is an obstruction downstream of the flow sensor.

5.7.9.5   ACTUAL FLOW DOES NOT MATCH DISPLAYED FLOW

If the actual flow measured does not match the displayed flow but is within the limits of 720-880 cc/min, adjust the calibration of the flow measurement as described in Section 5.6.4.

5.7.9.6   SAMPLE PUMP

The sample pump should start immediately after the front panel power switch is turned ON. With the Sample Inlet plugged, the Sample Pressure should read about 10 in-Hg for a pump that is in good condition. The pump needs rebuilding if the reading is above 10 in-Hg. If the test function Sample Flow is greater than 10 cc/min there is a leak in the pneumatic lines.

5.7.9.7   POOR OR STOPPED FLOW OF PURGE GAS

If sufficient purge gas is not supplied to the GFC wheel housing, cyclical fluctuations in readings at zero or low CO_2 concentrations, such as < 100 ppm, may occur. These fluctuations are the result of changes in the CO_2 concentration of the ambient atmosphere throughout the course of the day and night. In isolated areas with relatively few people working nearby the ambient CO_2 concentration will fall during the day and rise during the night as rate of photosynthesis of the plants in the surrounding area decreases and increases. In a lab environment with a relatively high human occupancy the ambient CO_2 concentration will increase during those parts of the day when the highest number of workers are present. If the GFC wheel housing is allowed to fill with ambient air, these natural, diurnal fluctuations might be detected by the instrument and cause it's in its calculation of the CO2 concentration of the sample gas to drift.

Another possible symptom of poor or stopped purge gas flow would be the inability to measure zero concentrations accurately at the end of a work day on a system that was calibrated at the beginning of a workday. Although this could also be due to local fluctuations in ambient CO_2 concentration during the day.

5.7.10 CALIBRATION PROBLEMS

5.7.10.1 MISCALIBRATED

There are several symptoms that can be caused by the analyzer being miscalibrated. This condition is indicated by out of range Slopes and Offsets as displayed through the test functions and is frequently caused by the following:

1. Bad span gas. This can cause a large error in the slope and a small error in the offset. Delivered from the factory, the analyzer's slope is within ±15% of nominal. Bad span gas will cause the analyzer to be calibrated to the wrong value. If in doubt have the span gas checked by an independent lab.

2. Contaminated zero gas. Excess H_2O can cause a positive or negative offset and will indirectly affect the slope.

3. Dilution calibrator not set up correctly or is malfunctioning. This will also cause the slope, but not the zero, to be incorrect. Again, the analyzer is being calibrated to the wrong value.

4. Too many analyzers on the manifold. This can cause either a slope or offset error because ambient gas with its pollutants will dilute the zero or span gas.

5.7.10.2 NON-REPEATABLE ZERO AND SPAN

As stated earlier, leaks are a common source of unstable and non-repeatable readings.

1. Check for leaks in the pneumatic systems as described in Section 5.6.3. Don't forget to consider pneumatic components in the gas delivery system outside the analyzer such as:

   - A change in zero air source such as ambient air leaking into zero air line, or;

   - A change in the span gas concentration due to zero air or ambient air leaking into the span gas line.

2. Once the instrument passes a leak check, perform a flow check (see Section 5.6.4) to make sure adequate sample is being delivered to the sensor assembly.

3. A failing IR photo-detector may be at fault. Check the Meas Detector and Ref Detector functions via the front panel display to make sure the signal levels are in the normal range and are quiet.

4. Confirm the sample pressure, wheel temperature, bench temperature, and sample flow readings are correct and have steady readings.

5. Disconnect the exhaust line from the optical bench near the rear of the instrument and plug this line into the SAMPLE inlet creating a pneumatic loop. The CO_2 concentration (either zero or span) now must be constant. If readings become quiet, the problem is in the external pneumatics supplies for sample gas, span gas or zero air.

6. If pressurized span gas is being used with a zero/span valve option, make sure that the venting is adequate.

7. If it is the zero point that is non-repeatable, and if that non-repeatability seems to only occur at a certain time of day, such as when worker occupancy is highest or lowest, make sure the flow of purge gas to the GFC wheel housing has not stopped (see Sections 5.7.9.7 and 5.7.14.9 for additional information).

5.7.10.3 INABILITY TO SPAN – NO SPAN BUTTON

1. Confirm that the carbon dioxide span gas source is accurate; this can be done by switching between two span-gas tanks. If the CO_2 concentration is different, there is a problem with one of the tanks.

2. Check for leaks in the pneumatic systems as described in Section 5.6.3.

3. Make sure that the expected span gas concentration entered into the instrument during calibration is the correct span gas concentration and not too different from expected span value. This can be viewed via the CONC submenu of the Sample Displays.

4. Check to make sure that there is no ambient air or zero air leaking into span gas line.

5.7.10.4 INABILITY TO ZERO – NO ZERO BUTTON

1. Confirm that there is a good source of zero air. Dilute a tank of span gas with the same amount of zero air from two different sources. If the CO_2 Concentration of the two measurements is different, there is a problem with one of the sources of zero air.

2. Check for leaks in the pneumatic systems as described in 5.6.3.

3. If the analyzer has had zero/span valve options, the CO_2 scrubber may need maintenance.

4. Check to make sure that there is no ambient air leaking into zero air line.

5.7.11 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 provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

5.7.12 TEMPERATURE PROBLEMS

Individual control loops are used to maintain the set point of the absorption bench, filter wheel and IR photo-detector temperatures. If any of these temperatures are out of range or are poorly controlled, the analyzer will perform poorly.

5.7.12.1 BOX TEMPERATURE

The box temperature sensor is mounted to the motherboard and cannot be disconnected to check its resistance. Rather check the **BOX TEMP** signal using the signal voltage in the Utilities>Diagnostics>Analog Inputs menu (Section 5.7.4). This parameter will vary with ambient temperature, but at ~30ºC (6-7° above room temperature) the signal should be ~1450 mV.

5.7.12.2 SAMPLE TEMPERATURE

The Sample Temperature should closely track the bench temperature. If it does not, locate the sensor, which is located at the midpoint of the optical bench in a brass fitting. Unplug the connector labeled "Sample", and measure the resistance of the thermistor; at room temperature (25°C) it should be ~30K Ohms; at operating temperature, 48°C, it should be ~ 12K Ohms

5.7.12.3   BENCH TEMPERATURE

WARNING - Electrical Shock Hazard

Hazardous Voltages are present during this test.

There are three possible failures that could cause the Bench temperature to be incorrect.

1. The heater mounted to the bottom of the Absorption bench is electrically shorted or open.

   - Check the resistance of the two heater elements by measuring between pin 2 and 4 (~76 Ohms), and pin 3 and 4 (~330 Ohms), of the white five-pin connector just below the sample temperature sensor on the Bench (pin 1 is the pointed end).

2. Assuming that the I^2C bus is working and that there is no other failure with the relay board, the solid-state relay (K2) on the relay board may have failed.

   - Using the BENCH_HEATER parameter under the signal I/O function, as described above, turn on and off K2 (D3 on the relay board should illuminate as the heater is turned on).

   - Check the AC voltage present between pins 2 and 4 in a 100 or 115 VAC model, and pins 3 and 4 in a 220-240 VAC model.

3. If the relay has failed there should be no change in the voltage across pins 2 and 4 or 3 and 4. Note: K2 is in a socket for easy replacement.

4. If K2 checks out OK, the thermistor temperature sensor located on the optical bench near the front of the instrument could be at fault.

   - Unplug the connector labeled "Bench" and measure the resistance of the thermistor.

   - At room temperature it should have approximately 30K Ohms resistance; near the 48°C set point it should have ~12K ohms.

5.7.12.4   GFC WHEEL TEMPERATURE

WARNING - Electrical Shock Hazard

Hazardous Voltages are present during this test.

Like the bench heater above there are three possible causes for the GFC Wheel temperature to have failed.

1. The wheel heater has failed.

   - Check the resistance between pins 1 and 4 on the white five-pin connector just below the sample temperature sensor on the bench (pin 1 is the pointed end).

   - It should be approximately 275 ohms.

2. Assuming that the I^2C bus is working and that there is no other failure with the relay board; the solid-state relay (K1) on the relay board may have failed.

   - Using the **WHEEL_HEATER** parameter under the signal I/O function, as described above, turn on and off K1 (D2 on the relay board should illuminate as the heater is turned on).

   - Check the AC voltage present between pin 1 and 4.

- If the relay has failed, there should be no change in the voltage across pins 1 and 4.
- K1 is socketed for easy replacement.

3. If K1 checks out OK, the thermistor temperature sensor located at the front of the filter wheel assembly may have failed.

4. Unplug the connector labeled "Wheel" and measure the resistance of the thermistor. The resistance near the 68°C set point is ~5.7k ohms.

5.7.12.5 IR PHOTO-DETECTOR TEC TEMPERATURE

If the PHT DRIVE test parameter described in Table 5-3 is out of range, there are four possible causes of failure.

1. The screws retaining the IR photo detector to the absorption bench have become loose.
   - Carefully tighten the screws, hand-tight and after the analyzer has come up to operating temperature, note whether the **PHT DRIVE** voltage has returned to an acceptable level.

2. The two large transistor-type devices mounted to the side of the Absorption Bench have come loose from the bench.
   - Tighten the retaining screws and note whether there is an improvement in the **PHT DRIVE** voltage.

3. The photo-detector has failed.
   - Contact the factory for instructions.

4. The sync demodulator circuit board has failed.
   - Contact the factor for instructions.

5.7.13   EXCESSIVE NOISE

Noise is continuously monitored as shown in the Stability reading and only becomes meaningful after sampling a constant gas concentration for at least 10 minutes. Compare the current Stability reading with that recorded at the time of manufacture (included in the instrument's *Final Test and Validation Data Sheet* shipped with the unit from Teledyne API).

1. The most common cause of excessive noise is leaks. Leak check and flow check the instrument described in Section 5.6.3 and 5.6.4.

2. Detector failure – caused by failure of the hermetic seal or over-temperature due to poor heat sinking of the detector can to the optical bench.
   - In addition to increased noise due to poor signal-to-noise ratio, another indicator of detector failure is a drop in the signal levels of the Meas Detector signal and Ref Detector signal.

3. Sync/Demod Board failure. There are many delicate, high impedance parts on this board. Check the Meas Detector and Ref Detector functions via the front panel display.

4. The detector cooler control circuit can fail for reasons similar to the detector itself failing. Symptoms would be a change in **MR RATIO** function when zero air is being sampled.

5. Also check the SIGNAL I/O parameter **PHT DRIVE**.
   - After warm-up and at 25°C ambient, if **PHT DRIVE** < 4800 mV, the cooler is working properly.

- If **PHT DRIVE** is > 4800 mV, there is a malfunction.

6. The +5 and ±15 VDC voltages in the instrument are provided by switching power supplies.
    - Switch mode supplies create DC outputs by switching the input AC waveform at high frequencies.
    - As the components in the switcher age and degrade, the main problem observed is increased noise on the DC outputs.
    - If a noisy switcher power supply is suspected, attach an oscilloscope to the DC output test points located on the top right hand edge of the Relay board.
    - Look for short period spikes > 100 mV p-p on the DC output

5.7.14   SUBSYSTEM CHECKOUT

The preceding subsections 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. If the problem is not resolved at this point, the next step is to check the subsystems.

5.7.14.1   AC MAINS CONFIGURATION

The analyzer is correctly configured for the AC mains voltage in use if:

- The Sample Pump is running.

- The GFC Wheel motor is spinning. LEDs D1 & D2 (located on the sync/demod PCA) should be flashing.

- If incorrect power is suspected, check that the correct voltage and frequency is present at the line input on the rear panel.

> **Note**
> - **If the unit is set for 230 VAC and is plugged into 115VAC, or 100VAC the sample pump will not start, and the heaters will not come up to temperature.**
> - **If the unit is set for 115 or 100 VAC and is plugged into a 230 VAC circuit, the circuit breaker built into the front panel ON/OFF switch will trip to the OFF position immediately after power is switched on.**

5.7.14.2   DC POWER SUPPLY

If you have determined that the analyzer's AC mains power is working, but the unit is still not operating properly, there may be a problem with one of the instrument's switching power supplies. The supplies can have two faults, namely no DC output, and noisy output.

To assist tracing DC Power Supply problems, the wiring used to connect the various printed circuit assemblies and DC Powered components and the associated test points on the relay board follow a standard color-coding scheme as defined in the following table.

Table 5-9. DC Power Test Point and Wiring Color Codes

NAME	TEST POINT#	TP AND WIRE COLOR
Dgnd	1	Black
+5V	2	Red
Agnd	3	Green
+15V	4	Blue
-15V	5	Yellow
+12R	6	Purple
+12V	7	Orange

A voltmeter should be used to verify that the DC voltages are correct per the values in the table below, and an oscilloscope, in AC mode, with band limiting turned on, can be used to evaluate if the supplies are producing excessive noise (> 100 mV p-p).

Table 5-10. DC Power Supply Acceptable Levels

POWER SUPPLY ASSY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM TEST POINT		TO TEST POINT			
		NAME	#	NAME	#		
PS1	+5	Dgnd	1	+5	2	4.8	5.25
PS1	+15	Agnd	3	+15	4	13.5	16V
PS1	-15	Agnd	3	-15V	5	-14V	-16V
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	11.75	12.5
PS2	Dgnd	+12V Ret	6	Dgnd	1	-0.05	0.05

5.7.14.3 I^{2}C BUS

Operation of the I^{2}C bus can be verified by observing the behavior of D1 LED on the relay PCA and D2 LED on the Valve Driver PCA. Assuming that the DC power supplies are operating properly, the I^{2}C bus is operating properly if both LEDs are flashing.

5.7.14.4 TOUCHSCREEN INTERFACE

Verify the functioning of the touchscreen by observing the display when pressing a touchscreen control button. Assuming that there are no wiring problems and that the DC power supplies are operating properly, if pressing a control button on the display does not change the display, any of the following may be the problem:

- The touchscreen controller may be malfunctioning.
- The internal USB bus may be malfunctioning.

You can verify this failure by logging on to the instrument using the NumaView™ Remote application or a terminal program to any of the communications ports. If the analyzer responds to remote commands and the display changes accordingly, the touchscreen interface may be faulty.

5.7.14.5 LCD DISPLAY MODULE

Verify the functioning of the front panel display by observing it when power is applied to the instrument. Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen with logo and other indications of its state as the CPU goes through its initialization process.

5.7.14.6 RELAY BOARD

The relay board PCA (P/N 04135) can be most easily checked by observing the condition of the its status LEDs on the relay board, as described in Section 5.7.8, and the associated output when toggled on and off through signal I/O function in the diagnostic menu, see Section 5.7.4.

1. If the front panel display responds to button presses and D1 on the relay board is NOT flashing then either the wiring between the touchscreen and the relay board is bad, or the relay board is bad.

2. If D1 on the relay board is flashing and the status indicator for the output in question (heater power, valve drive, etc.) toggles properly using the signal I/O function, then the associated control device on the relay board is bad.
    *   Several of the control devices are in sockets and can be easily replaced.

    *   The table below lists the control device associated with a particular function:

Table 5-11. Relay Board Control Devices

FUNCTION	CONTROL DEVICE	IN SOCKET
Wheel Heater	K1	Yes
Bench Heater	K2	Yes
Spare AC Control	K3	Yes
IZS Valves	U4	Yes
IR Source Drive	U5	No

The IR source drive output can be verified by measuring the voltage at J16 with the IR source disconnected. It should be 11.5 ± 0.5 VDC.

5.7.14.7   SYNC/DEMODULATOR ASSEMBLY

To verify that the Sync/Demodulator Assembly is working:

1. Verify that D1 and D2 are flashing.
    *   If not, check the opto pickup assembly, Section 5.7.14.8 and the GFC Wheel drive, Section 5.7.14.9.
    *   If the wheel drive and opto pickup are working properly then verify that there is 2.4 ±0.1 VAC and 2.5 ±0.15 VDC between digital ground and TP5 on the sync/demod board. If not, then check the wiring between the sync/demod and opto pickup assembly (see interconnect drawing Appendix B). If good, then the sync/demod board is bad.

2. Verify that the IR source is operating, Section 5.7.14.10.

3. With the analyzer connected to zero air, measure between TP11 (measure) and analog ground, and TP12 (reference) and analog ground.
    *   If they are similar to values recorded on the factory data sheet, then there is likely a problem with the wiring or the A/D converter.

- If they are not, then either the sync demodulator board or the IR-photodetector are bad. See Section 5.7.12.5 for problems with the IR-photodetector TEC drive.

5.7.14.8 OPTO PICKUP ASSEMBLY

Operation of the opto pickup PCA (P/N 04088) can be verified with a voltmeter. Measure the AC and DC voltage between digital ground on the relay board, or touchscreen and TP2 and TP4 on the sync pickup PCA. For a working board, with the GFC motor spinning, they should read 2.4 ±0.1 VAC and 2.5 ±0.15 VDC.

Further confirmation that the pickups and motor are operating properly can be obtained by measuring the frequency at TP2 and TP4 using a frequency counter, a digital voltmeter with a frequency counter, or an oscilloscope, per Table 5-12.

Table 5-12. Opto Pickup Board Nominal Output Frequencies

AC MAINS FREQ.	NOMINAL MEASURED FREQUENCY	
	TP2	TP4
50 Hz	25	300
60 Hz	30	360

5.7.14.9 GFC WHEEL DRIVE

If the D1 and D2 on the sync demodulator board are not flashing then:

1. Check for power to the motor by measuring between pins 1 and 3 on the connector feeding the motor.
   - For instruments configured for 120 or 220-240VAC there should be approximately 88 VAC for instruments configured for 100VAC, it should be the voltage of the AC mains, approximately 100VAC.

2. Verify that the frequency select jumper, JP4, is properly set on the relay board.
   - For 50 Hz operation it should be installed.

   - For 60 Hz operation may either be missing or installed in a vertical orientation.

3. If there is power to the motor and the frequency select jumper is properly set, then the motor is likely bad.
   - See Section 5.8.2 for instructions on removing and replacing the GFC assembly that the motor is bolted to.

5.7.14.10 IR SOURCE

The IR source can be checked using the following procedure:

1. Disconnect the source and check its resistance when cold. When new, the source should have a cold resistance of more than 1.5 Ohms but less than 3.5 Ohms. If not, then the source is bad.

2. With the source disconnected, energize the analyzer and wait for it to start operating.
   - Measure the drive Voltage between pins 1 and 2 on the jack that the source is normally connected to; it should be 11.5 ± 0.25 VDC.

   - If not, then the problem is with the wiring, the relay board, or the +12V power supply.

3. If the drive voltage is correct, then remove the source from the heat sink assembly (2 screws on top) and connect to its mating connector.
   - Look for light being emitted from the source.
   - It should be centered at the bottom of the U-shaped element.
   - If there is either no emission or a badly centered emission, then the source is bad.

5.7.14.11 PRESSURE/FLOW SENSOR ASSEMBLY

The pressure/flow sensor PCA, located on the top of the absorption bench, 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.

FOR PRESSURE RELATED PROBLEMS:

1. Measure the voltage across C1:
   - - it should be 5 ± 0.25 VDC
   - If not, then the board is bad.

2. Measure the voltage across TP4 and TP1.
   - With the sample pump disabled it should be 4500 mV ±250 mV.
   - With the pump energized it should be approximately 200 mV less.
   - If the voltage is incorrect, then S1, the pressure transducer is bad, the board is bad, or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly.

FOR FLOW RELATED PROBLEMS:

1. Measure the voltage across TP2 and TP1 - it should be 10 ±0.25 VDC.
   - If not, then the board is bad.

2. Measure the voltage across TP3 and TP1:
   - With proper flow (800 cc/min at the sample inlet) this should be approximately 4.5V (this voltage will vary with altitude).
   - With flow stopped (sample inlet blocked) the voltage should be approximately 1V.
   - If the voltage is incorrect, the flow sensor is bad, the board is bad, or there is a leak upstream of the sensor.

5.7.15 MOTHERBOARD

5.7.15.1 A/D FUNCTIONS

The simplest method to check the operation of the A-to-D converter on the motherboard is to view the Signal I/O function under the Utilities>Diagnostics>Analog Inputs menu to check the two A/D reference voltages and input signals that can be easily measured with a voltmeter.

1. View the values of Ref 4096mV and Ref Ground.
   - If both are within 3 mV of nominal (4096 and 0), and are stable, ±0.5 mV, then the basic A/D is functioning properly. If not, then the motherboard is bad.

2. Choose another function under the Utilities>Diagnostics>Analog Inputs menu.
   - Compare these voltages at their origin (see interconnect drawing, P/N 04215 and interconnect list, P/N 04216) with the voltage displayed through this function.

   - If the wiring is intact but there is a large difference between the measured and displayed voltage (±10 mV) then the motherboard is bad.

See also Section 5.7.4.

5.7.15.2   STATUS OUTPUTS
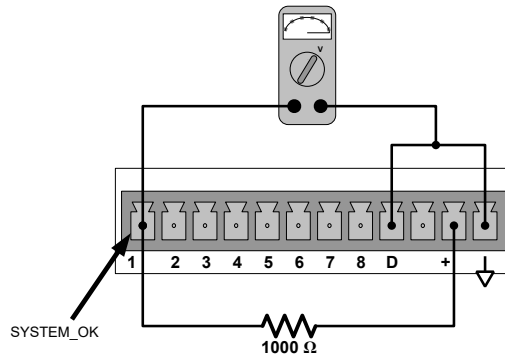
Figure 5-10. Typical Set Up of Status Output Test

The procedure below can be used to test the Status outputs:

1. Connect a jumper between the "D" pin and the "▽" pin on the status output connector.
2. Connect a 1000 ohm resistor between the "+" pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the "▽" pin and the pin of the output being tested (see table below).
4. In the Utilities>Diagnostics>Digital Outputs menu (see Section 5.7.4), scroll through the outputs until you get to the output in question.
5. Alternatively, turn on and off the output noting the voltage on the voltmeter.
   - It should vary between 0 volts for ON and 5 volts for OFF.

5.7.15.3   CONTROL INPUTS – REMOTE ZERO, SPAN

The control input bits can be tested by the following procedure:

1. Jumper the +5 pin on the Status connector to the U on the Control In connector.
2. 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.
3. 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.
4. In each case, the analyzer should return to Sample Mode when the jumper is removed.

5.7.16 CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk On Module (DOM). If either of these failures occurs, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on, the watchdog LED on the motherboard is not flashing.

In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be invalid.

If the analyzer stops during initialization (the front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

5.7.17 RS-232 COMMUNICATIONS

5.7.17.1 GENERAL RS-232 TROUBLESHOOTING

Teledyne API analyzers use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer-based equipment. RS-232 has been used for many years and as equipment has become more advanced, connections between various types of hardware have become increasingly difficult. Generally, every manufacturer observes the signal and timing requirements of the protocol very carefully.

Problems with RS-232 connections usually center around the following general areas:

1. Incorrect cabling and connectors. See Section 2.3 for connector and pin-out information.

2. The BAUD rate and protocol are incorrectly configured. See Section 2.3.1.7 under RS-232.

3. Incorrect setting of the DTE-DCE Switch. Ensure that switch is set correctly. See Section 3.1.

4. Verify that the cable that connects the serial COM ports of the CPU to J12 of the motherboard is properly seated.

5.8 SERVICE PROCEDURES

This contains procedures that might need to be performed on rare occasions when a major component of the analyzer requires repair or replacement.

5.8.1 SERVICING THE SAMPLE FLOW CONTROL ASSEMBLY

The critical flow orifice is housed in the flow control assembly (Teledyne API P/N 001760400) located on the top of the optical bench. A sintered filter protects the jewel orifice so it is unusual for the orifice to need replacing, but if it does, or the filter needs replacement please use the following procedure (contanct Technical Support for part numbers and kits):

1. Turn off power to the analyzer.
2. Locate the assembly attached to the sample pump.
3. Disconnect the pneumatic connection from the flow assembly and the assembly from the pump.
4. Remove the fitting and the components as shown in the exploded view below.
5. Replace the o-rings (P/N OR0000001) and the sintered filter (P/N FL0000001).
6. If replacing the critical flow orifice itself (P/N 000941000), make sure that the side with the colored window (usually red) is facing downstream to the gas flow.
7. Apply new Teflon® tape to the male connector threads.
8. Re-assemble in reverse order.
9. After reconnecting the power and pneumatic lines, flow check the instrument as described in Section 5.6.4.
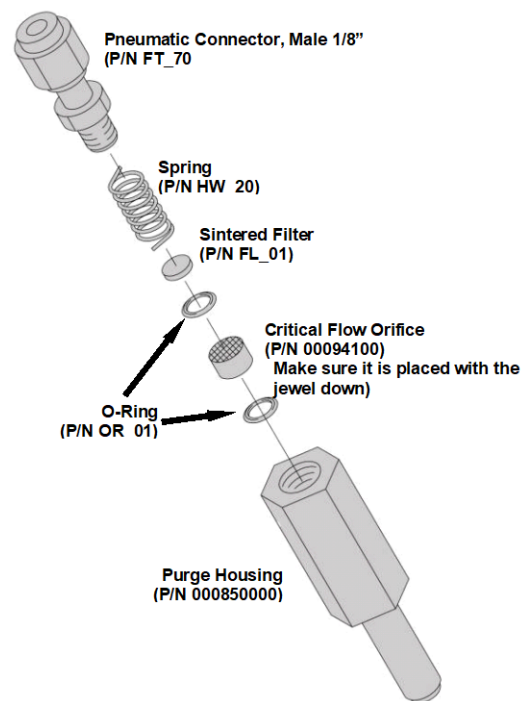
Figure 5-11. Critical Flow Restrictor Assembly/Disassembly

5.8.2 REMOVING/REPLACING THE GFC WHEEL

When removing or replacing the GFC Wheel it is important to perform the disassembly in the following order to avoid damaging the components:

1. Turn off the analyzer.
2. Remove the top cover.
3. Open the instrument's hinged front panel.
4. Locate the GFC Wheel/motor assembly.
5. Unplug the following electronic components:
   - GFC Wheel housing temperature sensor
   - GFC Wheel heater
   - GFC Wheel motor power supply
   - IR source
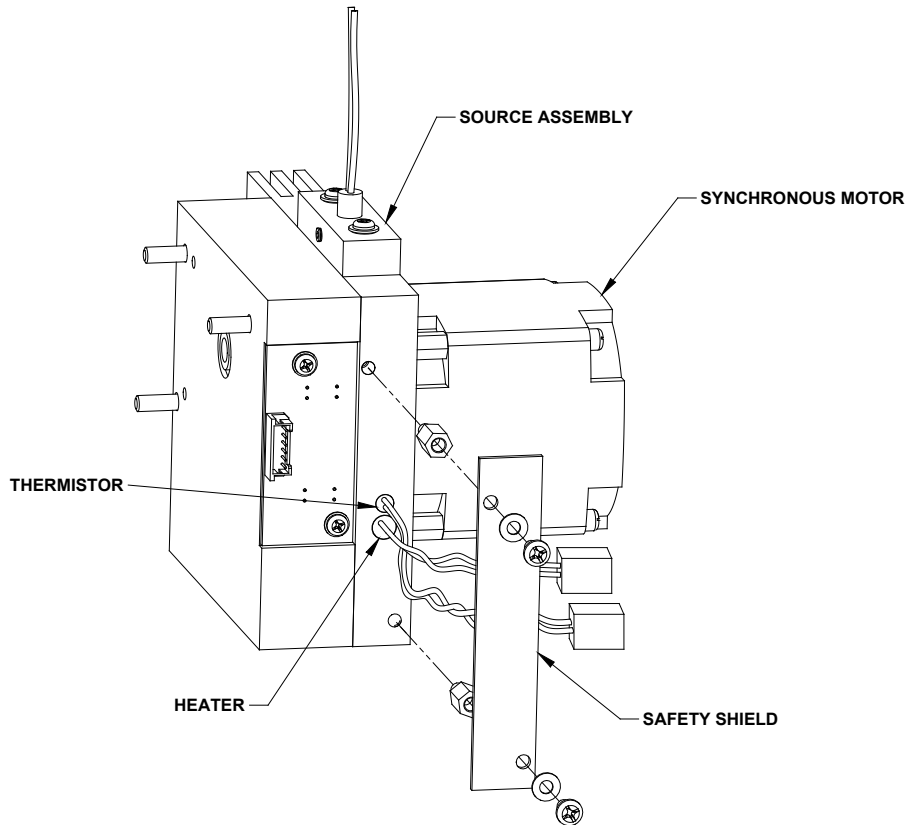
Figure 5-12. Opening the GFC Wheel Housing

6. Remove the two (2) screws holding the opto-pickup printed circuit assembly to the GFC Wheel housing.
7. Carefully remove the opto-pickup printed circuit assembly.
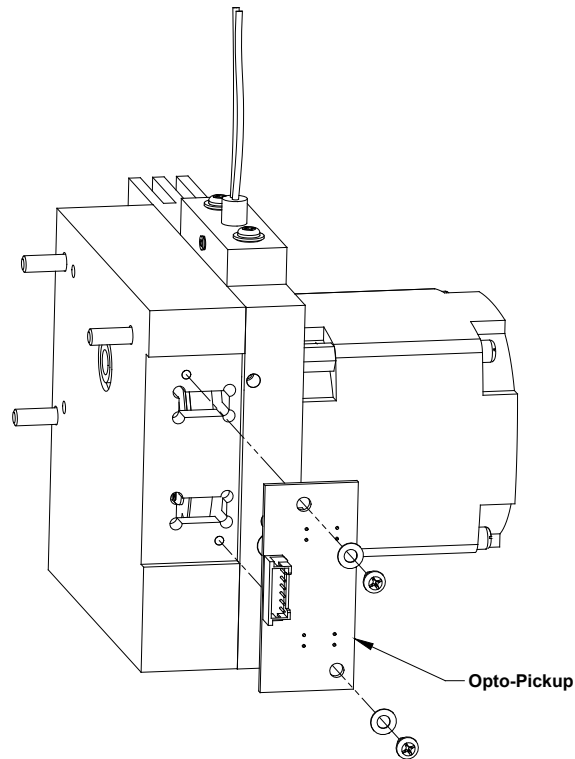
Figure 5-13. Removing the Opto-Pickup Assembly

8. Remove the three (3) screws holding the GFC Wheel motor/heat sink assembly to the GFC Wheel housing.

9. Carefully remove the GFC Wheel motor/heat sink assembly from the GFC Wheel housing.
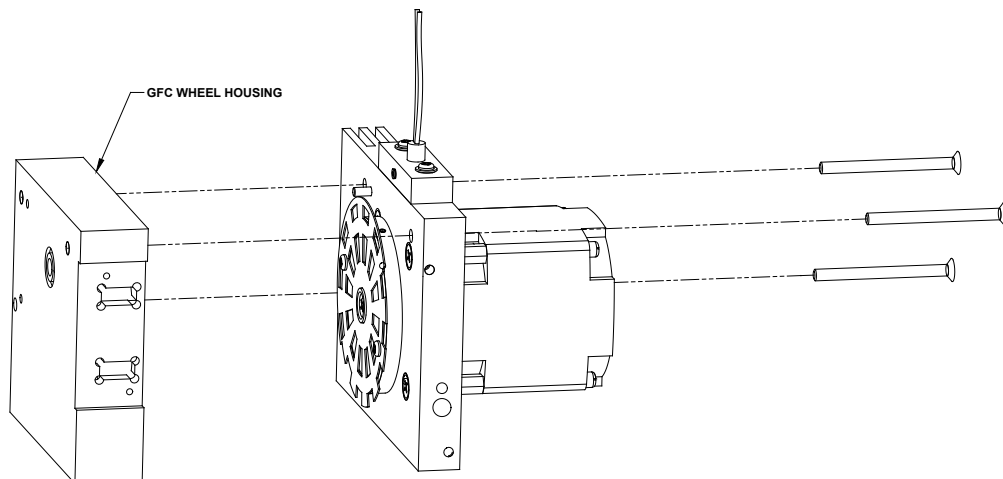
Figure 5-14. Removing the GFC Wheel Housing

10. Remove the one (1) screw fastening the GFC Wheel/mask assembly to the GFC motor hub.
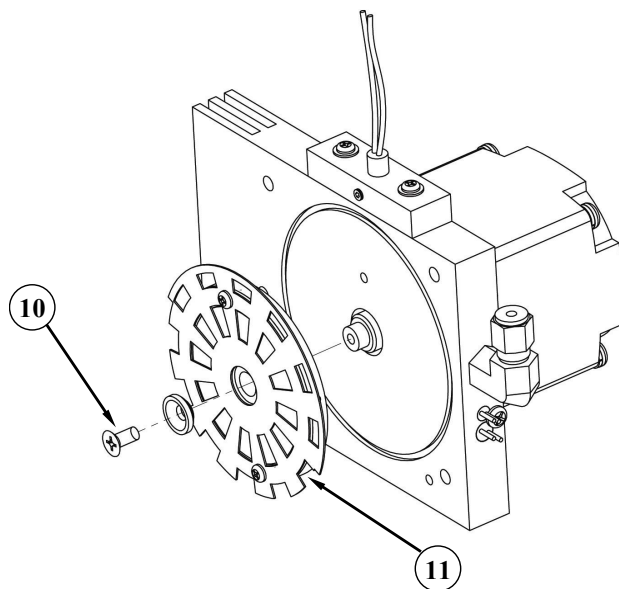
Figure 5-15. Removing the GFC Wheel

11. Remove the GFC Wheel/mask assembly.
12. Follow the previous steps in reverse order to put the GFC Wheel/motor assembly back together.

5.8.3 CHECKING AND ADJUSTING THE SYNC/DEMODULATOR, CIRCUIT GAIN (MEAS DETECTOR)

5.8.3.1   CHECKING THE SYNC/DEMODULATOR CIRCUIT GAIN

The analyzers will operate accurately as long as the sync/demodulator circuit gain is properly adjusted. To determine if this gain factor is correct:

1. Make sure that the analyzer is turned on and warmed up.
2. Set the display to show the Stability and the Meas Detector functions.
3. Apply Zero Air to the Sample inlet of the analyzer.
4. Wait until the stability reading falls below 1.0 ppm.
5. Read the Meas Detector value.
   - The value of must be > 2800 mV and < 4800 mV for the instrument to operate correctly.
   - Optimal value for is 4500 mV ± 300 mV. If it is not, adjust the value.

5.8.3.2   ADJUSTING THE SYNC/DEMODULATOR, CIRCUIT GAIN

To adjust the sync/demodulator circuit gain:

1. Make sure that the analyzer is turned on and warmed up.
2. Set the display to show the Stability and the Meas Detector functions.
3. Apply Zero Air to the Sample inlet of the analyzer.
4. Wait until the stability reading falls below 1.0 ppm.
5. Remove the Sync/Demod Housing
    *   Remove the two mounting screws.

    *   Carefully lift the housing to reveal the sync/demod PCA.
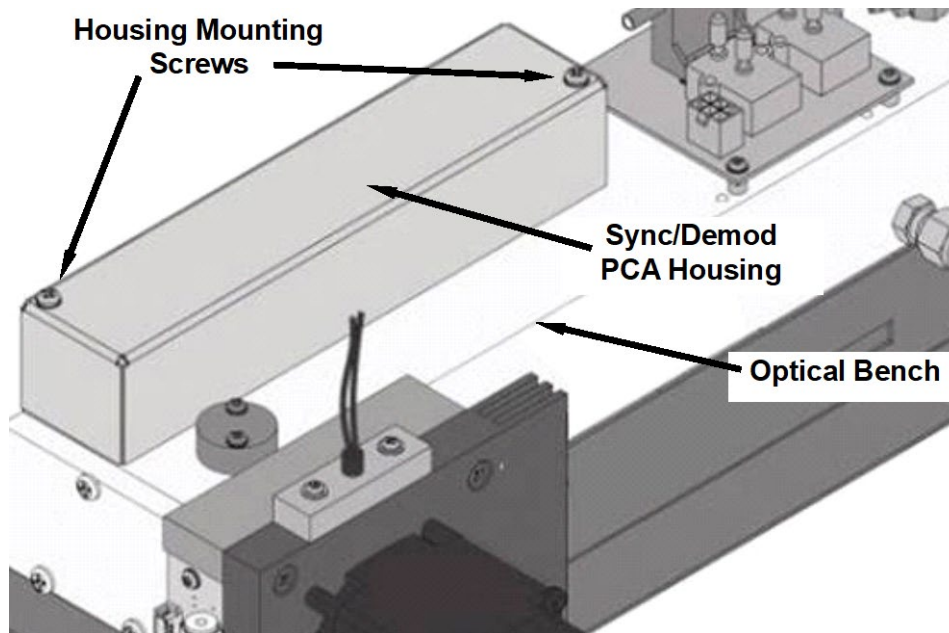
Figure 5-16. Location of Sync/Demod Housing Mounting Screws

6. Adjust potentiometer VR1 until the Meas Detector value reads 4500 mV ± 300 mV
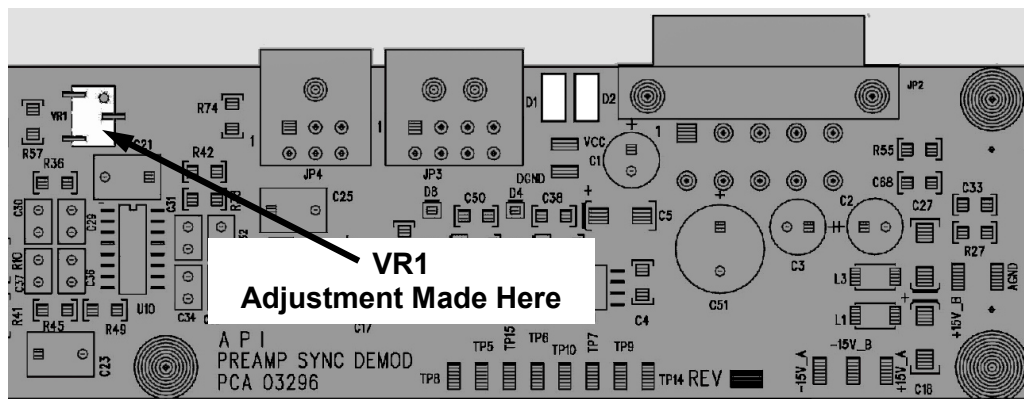
Figure 5-17. Location of Sync/Demod Gain Potentiometer

5.8.4 DISK-ON-MODULE REPLACEMENT

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

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

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM

2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.

3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.

4. The DOM should carry a label with firmware revision, date and initials of the programmer.

5. Remove the nylon standoff clip that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.

6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.

7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the chip all the way in.

8. Close the rear panel and turn on power to the machine.

9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

5.9 FREQUENTLY ASKED QUESTIONS

The following is a list from the Teledyne API's Technical Support Department of the most commonly asked questions relating to the analyzer.

QUESTION	ANSWER
Why does the **ENTR** button sometimes disappear on the Front Panel Display?	During certain types of adjustments or configuration operations, the **ENTR** button will disappear if you select a setting that is out of the allowable range for that parameter (such as trying to set the 24-hour clock to 25:00:00, or selecting a DAS hold off period of more than 20 minutes). Once you adjust the setting in question to an allowable value, the **ENTR** button will re-appear.
Why is the **ZERO** or **SPAN** button not displayed during calibration?	This happens when the measured gas concentration differs significantly from the span or zero gas concentration value entered by the user. This prevents accidental recalibration of the analyzer to an out-of-range response curve. EXAMPLE: The span set point is 40 ppm but gas concentration being measured is only 5 ppm. For more information, see Sections 5.7.10.3 and 5.7.10.4.
How do I enter or change the value of my Span Gas?	See Section 4.2.1.2.
Why does the analyzer not respond to span gas?	There could be something wrong with a span gas tank, or a span gas concentration was entered incorrectly, or there could be a pneumatic leak. Section 5.7.10.3 addresses these issues.
Is there an optional midpoint calibration?	There is an optional mid-point linearity adjustment; however, midpoint adjustment is applicable only to applications where CO_2 measurements are expected above 100 ppm. Call Teledyne API's Technical Support Department for more information on this topic.
What do I do if the concentration displayed does not match the value recorded or displayed on my data logger even if both instruments are calibrated?	This most commonly occurs when an independent metering device is used besides the data logger/recorder to determine gas concentration levels while calibrating the analyzer. These disagreements result from the analyzer, the metering device and the data logger having slightly different ground levels.
How do I perform a leak check?	Section 5.6.3 provides leak check instructions.
How do I measure the sample flow?	Sample flow is measured by attaching a calibrated rotameter, wet test meter, or other flow-measuring device to the sample inlet port when the instrument is operating. The sample flow should be at spec $\pm 10\%$ (Table 1-1). See Section 5.6.4.
How long does the IR source last?	Typical lifetime is about 2-3 years.
Can I automate the calibration of my analyzer?	Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature (Section 4.3).
Can I use the IZS option to	Yes. However, whereas this may be acceptable for basic calibration

QUESTION	ANSWER
calibrate the analyzer?	checks, the IZS option is not as accurate as the external span and zero gas bottles. To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source.
Q: What is the averaging time for the analyzer?	**A:** The default averaging time, optimized for ambient pollution monitoring, is 150 seconds for stable concentrations and 10 seconds for rapidly changing concentrations (see Section 6.6.1 for more information). However, it is adjustable over a range of 0.5 second to 200 seconds (please contact Technical Support for more information).

5.10 TECHNICAL ASSISTANCE

If this manual and its troubleshooting / repair sections do not solve your problems, technical assistance may be obtained from:

Teledyne API Technical Support
9970 Carroll Canyon Road
San Diego, California 92131-1106 USA

Toll-free Phone: +1 800-324-5190
Phone: +1 858-657-9800
Fax: +1 858-657-9816
Email: api-techsupport@teledyne.com
Website: http://www.teledyne-api.com/

Before contacting Teledyne API Tech Support, please fill out the problem report form, available online for electronic submission at http://www.teledyne-api.com.

6. THEORY OF OPERATION

The Model T360 Gas Filter Correlation Carbon Dioxide Analyzer is a microprocessor-controlled analyzer that determines the concentration of carbon dioxide (CO_2) in a sample gas drawn through the instrument. It requires that the sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a stable gas flow through the sample chamber where the gases ability to absorb infrared radiation is measured.

Calibration of the instrument is performed in software and does not require physical adjustments to the instrument. During calibration, the microprocessor measures the current state of the IR Sensor output and various other physical parameters of the instrument and stores them in memory.

The microprocessor uses these calibration values, the IR absorption measurements made on the sample gas along with data regarding the current temperature and pressure of the gas to calculate a final CO_2 concentration.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system (DAS), the Data Logger.

6.1 MEASUREMENT METHOD

This Section presents measurement principles and fundamentals for this instrument.

6.1.1 BEER'S LAW

The basic principle by which the analyzer works is called the Beer-Lambert Law or Beer's Law. It defines how light of a specific wavelength is absorbed by a particular gas molecule over a certain distance. The mathematical relationship between these three parameters is:

$$I = I_o \, e^{-\alpha L c}$$

Equation 6-1

Where:

I_o is the intensity of the light if there was no absorption.

I is the intensity with absorption.

e is the mathematical constant (Euler's number)

L is the absorption path, or the distance the light travels as it is being absorbed.

c is the concentration of the absorbing gas (in the case of this analyzer, Carbon Dioxide (CO_2)).

α is the absorption coefficient that tells how well CO_2 absorbs light at the specific wavelength of interest.

6.2 MEASUREMENT FUNDAMENTALS

In the most basic terms, the analyzer uses a high-energy heated element to generate a beam of broad-band IR light with a known intensity (measured during instrument calibration). This beam is directed through a multi-pass cell filled with sample gas. The sample cell uses mirrors at each end to reflect the IR beam back and forth through the sample gas a number of times to generate a 2.5 meter absorption path (see Figure 6-1). This length was chosen to give the analyzer maximum sensitivity to fluctuations in CO_2 density.
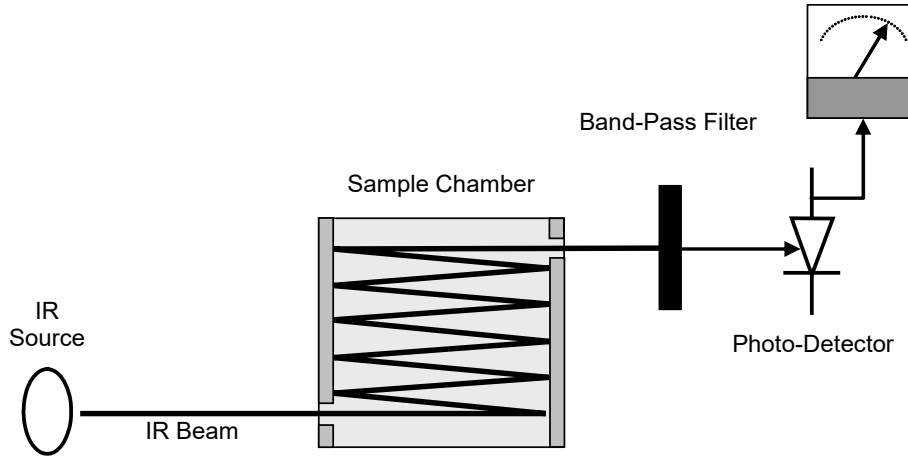
Figure 6-1. IR Beam Path

.

Upon exiting the sample cell, the beam shines through a band-pass filter that allows only light at a wavelength of 4.7 μm to pass. Finally, the beam strikes a solid-state photo-detector that converts the light signal into a modulated voltage signal representing the attenuated intensity of the beam.

6.2.1 GAS FILTER CORRELATION

Unfortunately, water vapor absorbs light at 4.7 μm too. To overcome the interfering effects of water vapor the analyzer adds another component to the IR light path called a Gas Filter Correlation (GFC) Wheel.
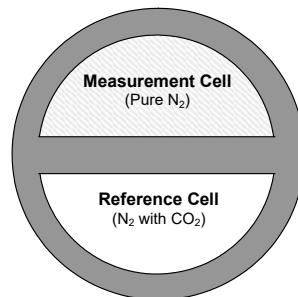
Figure 6-2. GFC Wheel

6.2.1.1 THE GFC WHEEL

A GFC Wheel is a metallic wheel into which two chambers are carved. The chambers are sealed on both sides with material transparent to 4.3 μm IR radiation creating two airtight cavities. Each cavity is mainly filled with composed gases. One cell is filled with pure N_2 (the measurement cell). The other is filled with a combination of N_2 and a high concentration of CO_2 (the reference cell).

IR unaffected by N_2 in Measurement Cell

IR IS affected by CO_2 in Reference Cell

Δ H

IR Source

M

R

GFC Wheel

Photo-Detector
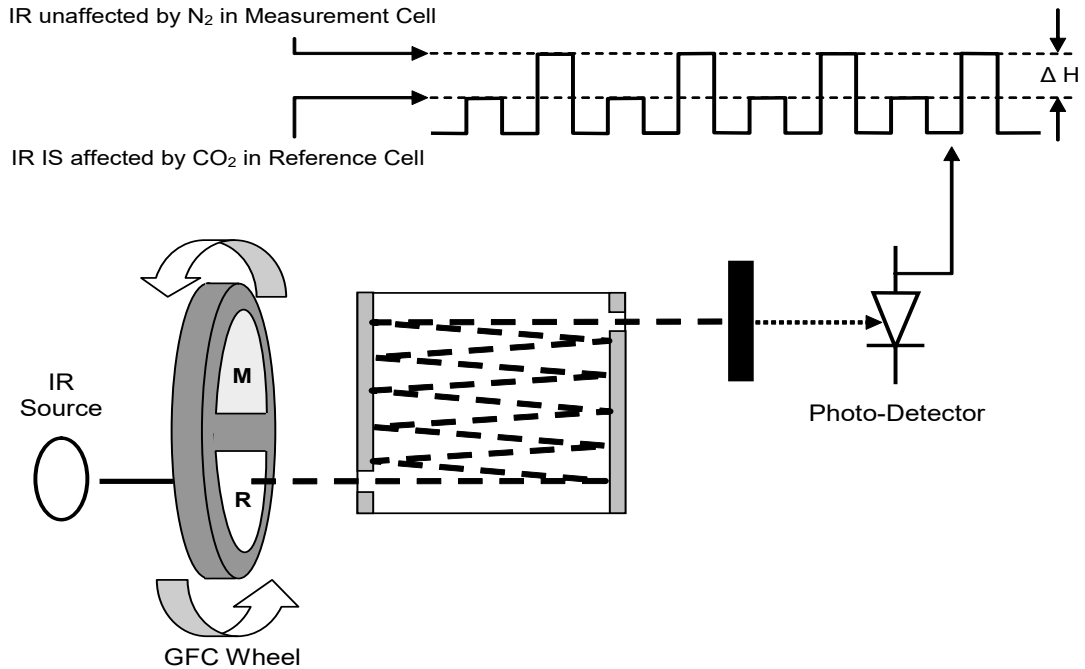
Figure 6-3. Measurement Fundamentals with GFC Wheel

As the GFC wheel spins, the IR light alternately passes through the two cavities. When the beam is exposed to the reference cell, the CO_2 in the gas filter wheel strips the beam of most of the IR at 4.3μm. When the light beam is exposed to the measurement cell, the N_2 in the filter wheel does not absorb IR light. This causes a fluctuation in the intensity of the IR light striking the photo-detector which results in the output of the detector resembling a square wave.

6.2.1.2   THE MEASURE REFERENCE RATIO

The Model T360 determines the amount of CO_2 in the sample chamber by computing the ratio between the peak of the measurement pulse (Meas Detector) and the peak of the reference pulse (Ref Detector).

If no gases exist in the sample chamber that absorb light at 4.3μm, the high concentration of CO_2 in the gas mixture of the reference cell will attenuate the intensity of the IR beam by 60% giving a M/R ratio of approximately 2.4:1.

Adding CO_2 to the sample chamber causes the peaks corresponding to both cells to be attenuated by a further percentage. Since the intensity of the light passing through the measurement cell is greater, the effect of this additional attenuation is greater. This causes Meas Detector to be more sensitive to the presence of CO_2 in the sample chamber

than Ref Detector and the ratio between them (MR Ratio) to move closer to 1:1 as the concentration of CO_2 in the sample chamber increases.

IR unaffected by N_2 in Measurement Cell of
the GFC Wheel and no additional CO_2 in
the Sample Chamber

CO2 MEAS

CO2 REF

IR affected by CO_2 in Reference Cell
with no interfering gas in the Sample
Chamber

IR shinning through Measurement Cell of
the GFC Wheel is reduced by additional
CO_2 in the Sample Chamber

M/R
is reduced

IR shining through Reference Cell is
also reduced by additional CO_2 in the
Sample Chamber, but to a lesser extent

Figure 6-4. Effect of CO2 in the Sample on Meas Detector and Ref Detector

Once the analyzer has computed this ratio, a look-up table is used, with interpolation, to linearize the response of the instrument. This linearized concentration value is combined with calibration SLOPE and OFFSET values to produce the CO_2 concentration which is then normalized for changes in sample pressure.

6.2.1.3   INTERFERENCE AND SIGNAL TO NOISE REJECTION

If an interfering gas, such as H_2O vapor is introduced into the sample chamber, the spectrum of the IR beam is changed in a way that is identical for both the reference and the measurement cells, but without changing the ratio between the peak heights of Meas Detector and Ref Detector. In effect, the difference between the peak heights remains the same.
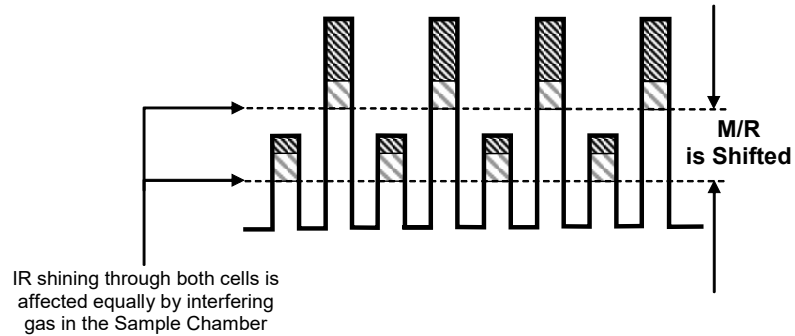
Figure 6-5. Effects of Interfering Gas on Meas Detector and Ref Detector

Thus, the difference in the peak heights and the resulting MR Ratio is only due to CO_2 and not to interfering gases. In this way, Gas filter correlation rejects the effects of interfering gases and so that the analyzer responds only to the presence of CO_2.

To improve the signal-to-noise performance of the IR photo-detector, the GFC wheel also incorporates an optical mask that chops the IR beam into alternating pulses of light and dark at six times the frequency of the measure/reference signal. This limits the detection bandwidth helping to reject interfering signals from outside this bandwidth improving the signal to noise ratio.
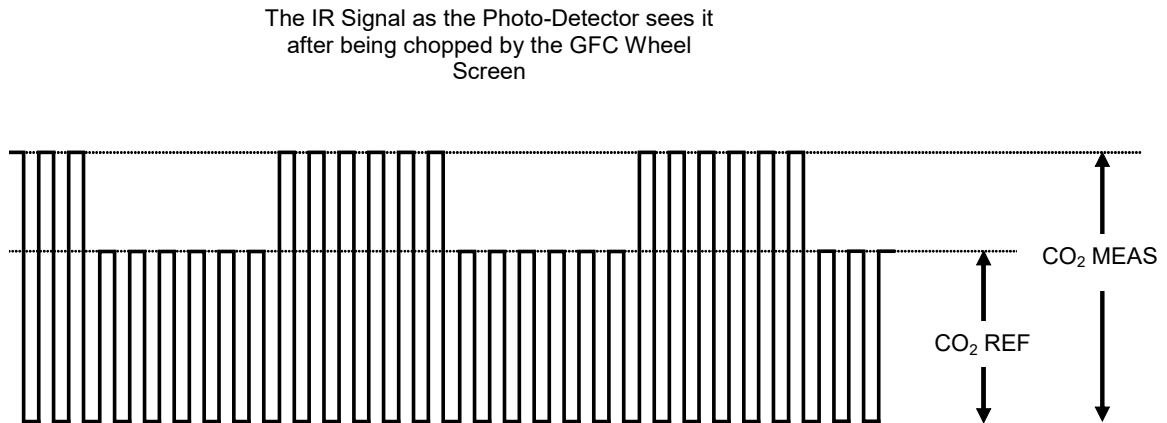
Figure 6-6. Chopped IR Signal

6.2.1.4 SUMMARY INTERFERENCE REJECTION

CO_2 absorbs IR light so well that even the narrow volume of ambient air between the IR source and the sample chamber is enough to alter the analyzer's measured concentration of CO_2. Also, ambient air, which averages around 350 ppm to 400 ppm, will vary significantly over the course of the day. The ambient CO_2 concentration can rise as high as 1 000 ppm during the time of the day when people are present. It can fluctuate $\pm$ 300

ppm as the photosynthesis of plant life in the nearby area increases during the day and decreases at night.

The basic design of the analyzer rejects most of this interference at a 100:1 ratio; however, this still can allow small fluctuations in CO_2 concentration during the course of the day. To completely remove all effects of ambient CO_2 from the analyzer's measurement of CO_2, dried air, scrubbed of all CO_2 is pumped into the GFC wheel housing to purge all ambient CO_2.

6.3 OXYGEN SENSOR (OPT 65)

6.3.1 PARAMAGNETIC MEASUREMENT OF O_2

The oxygen sensor measures O_2 based in the science that oxygen is attracted into strong magnetic field; most other gases are not, 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 6-7). A mirror is mounted centrally on the suspension, and light is shone onto the mirror that reflects the light onto 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. This 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 O_2 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.
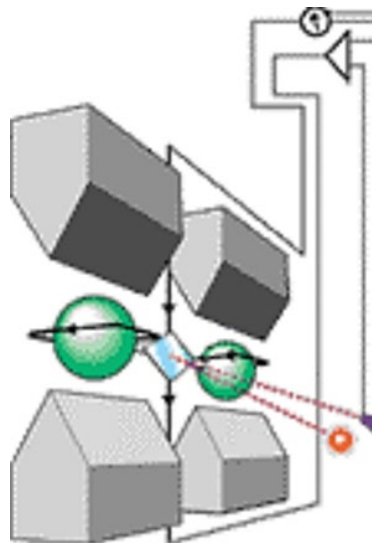
Figure 6-7. Oxygen Sensor - Principle of Operation

6.3.1.1   O$_2$ SENSOR OPERATION WITHIN THE T360 ANALYZER

The oxygen sensor option is transparently integrated into the core analyzer operation. Its parameters and functions are accessed through the same menu system as the CO$_2$ Sensor.

The O$_2$ concentration range is 0-100% (user selectable) with 0.1% precision and accuracy and is available to be output via the instrument's analog output (see Section 2.5.8).

The temperature of the O$_2$ sensor is maintained at a constant 50° C through a PID loop.

The O$_2$ sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

6.4   PNEUMATIC OPERATION

Pneumatic flow diagrams were presented in Section 2.3.3

> ⚠️ **CAUTION – General Safety Hazard**
>
> **It is important that the sample airflow system is both leak tight and not pressurized over ambient pressure.**
>
> **Regular leak checks should be performed on the analyzer as described in the maintenance schedule, Table 5-1. Leak test procedures are located in Section 5.6.3.**

An internal pump evacuates the sample chamber creating a small vacuum that draws sample gas into the analyzer. Normally the analyzer is operated with its inlet near ambient pressure either because the sample is directly drawn at the inlet or a small vent is installed at the inlet. There are several advantages to this "pull through" configuration. By placing the pump down stream from the sample chamber several problems are avoided:

- First, the pumping process heats and compresses the sample air complicating the measurement process.
- Additionally, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas.
- Finally, in certain applications where the concentration of the target gas might be high enough to be hazardous, maintaining a negative gas pressure relative to ambient means that should a minor leak occur, no sample gas will be pumped into the atmosphere surrounding analyzer.

6.4.1 FLOW RATE CONTROL

To maintain a constant flow rate of the sample gas through the instrument, the analyzer uses special flow control assemblies located in the purge gas line at the entrance to the GFC wheel housing and in the exhaust gas line just before the pump. In instruments with the O$_2$ sensor installed, a second flow control assembly is located between the O$_2$ sensor assembly and the pump. 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 between the o-rings, the critical flow orifice and the assembly housing.

6.4.1.1 CRITICAL FLOW ORIFICE

The most important component of this flow control assembly 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 though 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.
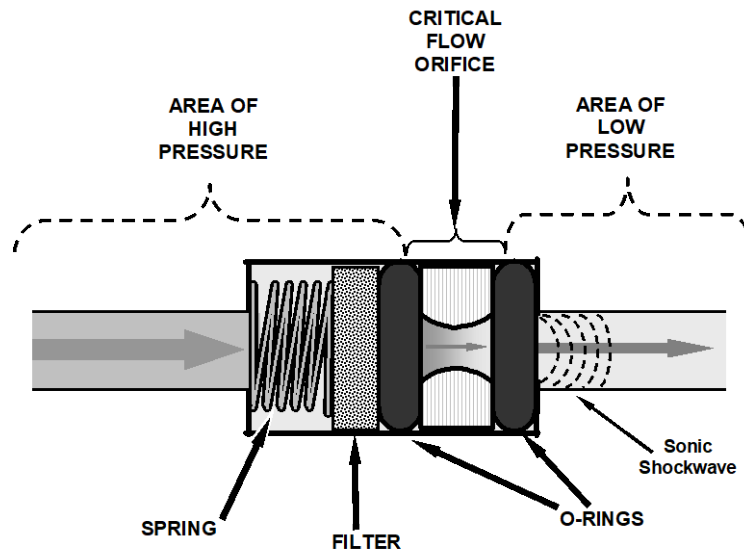
Figure 6-8. Flow Control Assembly & Critical Flow Orifice

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 the gas molecules move at the speed of sound and pass through the orifice. Because the flow rate of gas through the orifice is only related to the minimum 2:1 pressure differential and not absolute pressure, the flow rate of the gas is also unaffected by degradations in pump efficiency due to age.

The critical flow orifice used in the analyzer is designed to provide a flow rate per specification (Table 1-1).

6.4.2 PURGE GAS PRESSURE CONTROL

In order to ensure that all of the ambient CO_2 is purged from the GFC Wheel housing an adequate supply of dried air, scrubbed of CO_2 must be supplied to the **PURGE AIR** inlet on the instrument's rear panel.

- The purge air source should be capable of delivering a continuous flow of at least 0.5 L/min.
- The minimum gas pressure of the source of purge air should be 7.5 psig.
- If the source of the purge air is shared by a Teledyne API's T700 the minimum gas pressure should be 25 psig and should not exceed 35 psig.

In order to maintain the proper pressure differential between the inside of the GFC wheel housing and ambient air, the T360 design includes a manually adjustable pressure regulator that maintains the pressure of the purge air feed at 7.5 psig.

6.4.3 PARTICULATE FILTER

The analyzer comes equipped with a 47 mm diameter, Teflon particulate filter with a 5 micron pore size. The filter is accessible through the front panel, which folds down to allow access, and should be changed according to the suggested maintenance schedule described in Table 5-1.

6.4.4 PNEUMATIC SENSORS

There are two pneumatic sensors: one each to measure sample pressure and flow.

6.4.4.1 SAMPLE PRESSURE SENSOR

An absolute value pressure transducer plumbed to the outlet of the sample chamber is used to measure sample pressure. The output of the sensor is used to compensate the concentration measurement for changes in air pressure. This sensor is mounted to a printed circuit board with the Sample Flow Sensor on the sample chamber (see Section 6.4.4.2 and Figure 3-4).

6.4.4.2 SAMPLE FLOW SENSOR

A thermal-mass flow sensor is used to measure the sample flow through the analyzer. The sensor is calibrated at the factory with ambient air or N_2 but can be calibrated to operate with samples consisting of other gases such as CO_2. This sensor is mounted to a printed circuit board with the Sample Pressure Sensor on the sample chamber (see Section 6.4.4.1 and Figure 3-4).

6.4.5 PNEUMATIC OPERATION OF THE O_2 SENSOR

Pneumatically, the O_2 sensor is connected to the bypass manifold and draws a flow of about 120 cc/min in addition to the normal sample flow rate and is separately controlled with its own critical flow orifice. Figure 2-24 in Section 2.3.3.4 shows the internal pneumatics of the analyzer with the O_2 sensor installed.

6.5 ELECTRONIC OPERATION

Figure 6-9 shows a block diagram of the major electronic components of the analyzer.

The core of the analyzer is a microcomputer/central processing unit (CPU) that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices via a separate printed circuit assembly called the motherboard.

The motherboard is directly mounted to the inside rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Data are generated by a gas-filter-correlation optical bench which outputs an analog signal corresponding to the concentration of CO_2 in the sample gas. This analog signal is transformed into two, pre-amplified, DC voltages (Meas Detector and Ref Detector) by a synchronous demodulator printed circuit assembly. Meas Detector and Ref Detector are converted into digital data by a unipolar, analog-to-digital converter, located on the motherboard.

A variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the CO_2 concentration calculation and as trigger events for certain control commands issued by the CPU. This information is stored in memory by the CPU and in most cases can be viewed but the user via the front panel display.

The CPU issues commands via a series of relays and switches (also over the I^2C bus) located on a separate printed circuit assembly to control the function of key electromechanical devices such as heaters, motors and valves.

The CPU communicates with the user and the outside world in several ways:

- Through the analyzer's front panel LCD touch-screen interface
- RS-232 and RS-485 serial I/O channels
- Various analog voltage and current outputs
- Several digital I/O channels
- Ethernet
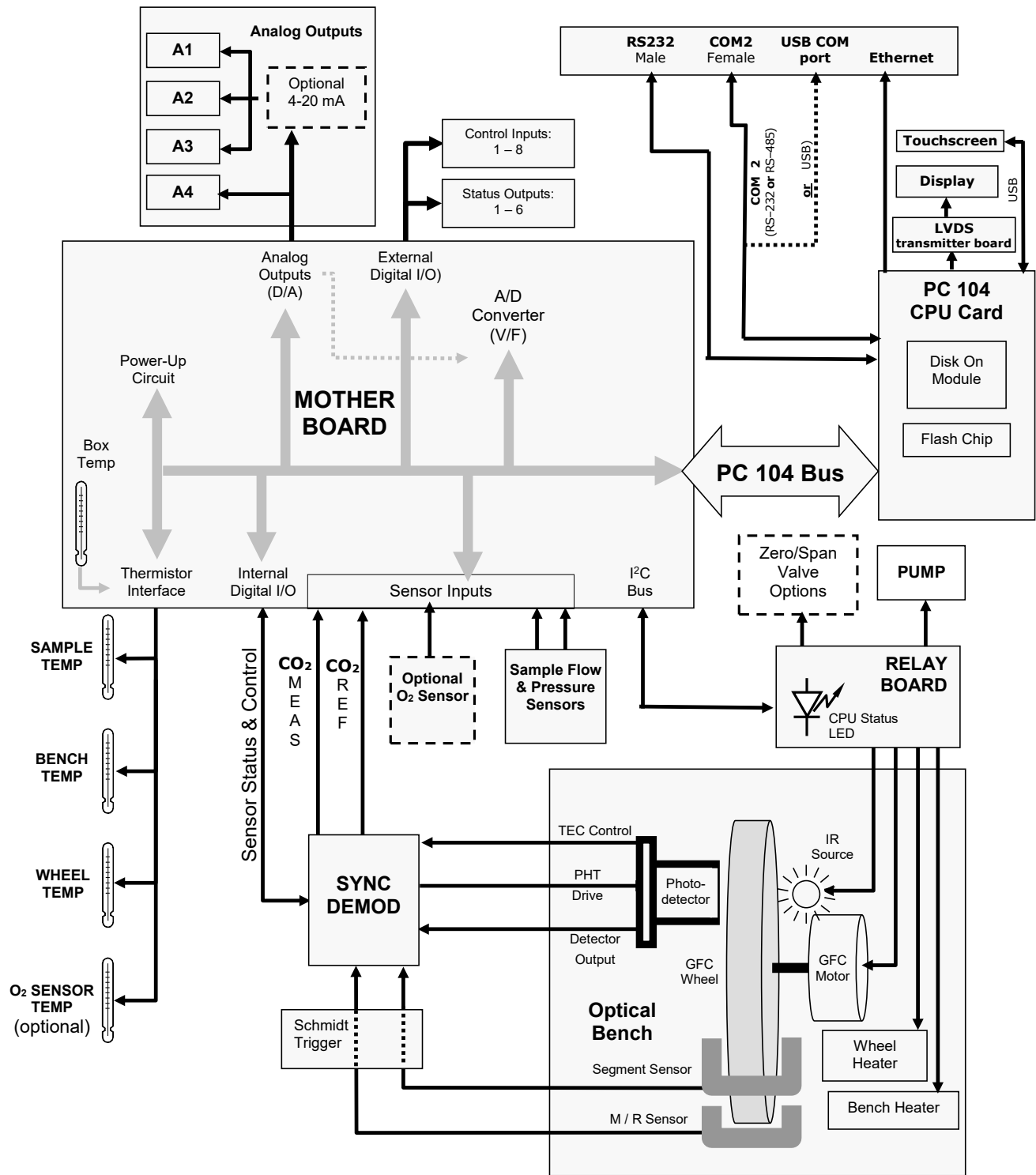
Figure 6-9. Electronic Block Diagram

6.5.1 CPU

The unit's CPU card is installed on the motherboard located inside the rear panel. It is a low power (5 VDC, 720mA max), high performance, Vortex 86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC/104 specification.
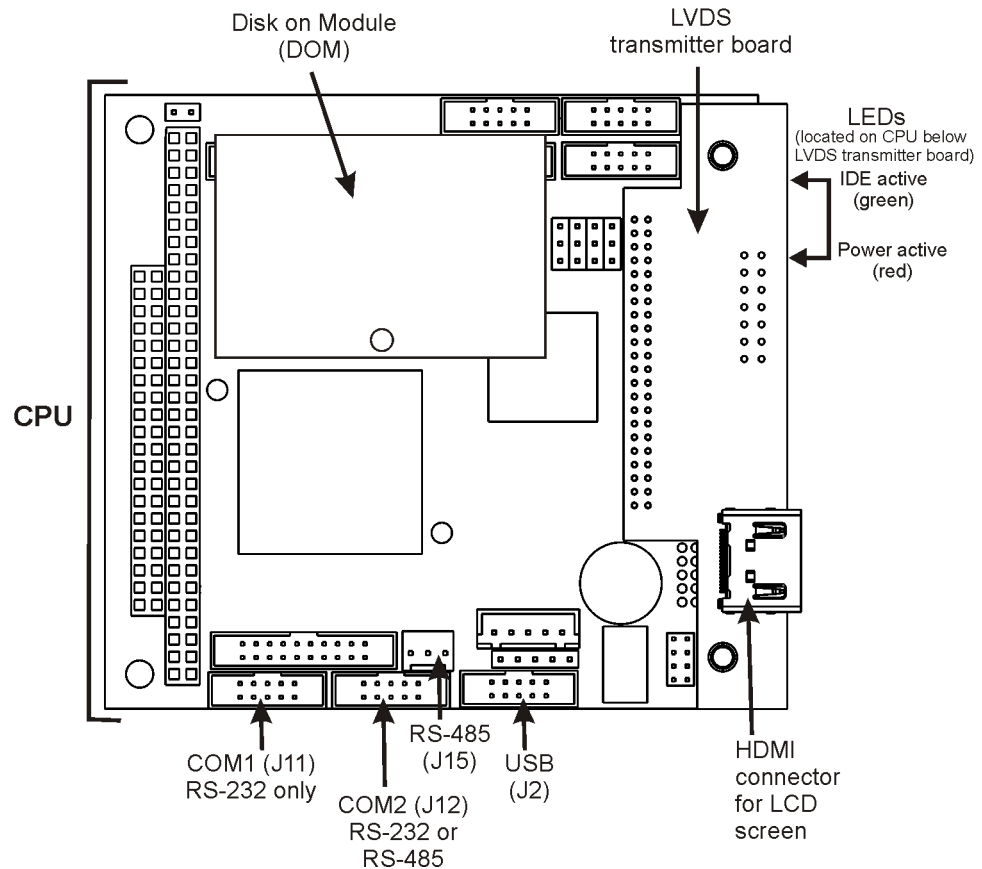
Figure 6-10. CPU Board

The CPU includes two types of non-volatile data storage: a Disk-On-Module (DOM) and an embedded flash chip.

6.5.1.1   DISK-ON-MODULE (DOM)

The DOM is a 44-pin IDE flash drive with a storage capacity up to 128 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS).

6.5.1.2   FLASH CHIP

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data on a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring that the unit be recalibrated.

6.5.2 OPTICAL BENCH & GFC WHEEL

Electronically, in the case of the optical bench, the GFC Wheel and associated components do more than simply measure the amount of CO_2 present in the sample chamber. A variety of other critical functions are performed here as well.

6.5.2.1 TEMPERATURE CONTROL

Because the temperature of a gas affects its density resulting in the amount of light absorbed by that gas, it is important to reduce the effect of fluctuations in ambient temperature on the measurement of CO_2 for the analyzer. To accomplish this both the temperature of the sample chamber and the GFC Wheel are maintained at constant temperatures above their normal operating ranges.

BENCH TEMPERATURE

To minimize the effects of ambient temperature variations on the sample measurement, the sample chamber is heated to 48°C (8 degrees above the maximum suggested ambient operating temperature for the analyzer). A strip heater attached to the underside of the chamber housing is the heat source. The temperature of the sample chamber is sensed by a thermistor, also attached to the sample chamber housing.

WHEEL TEMPERATURE

To minimize the effects of temperature variations caused by the near proximity of the IR Source to the GFC Wheel on the gases contained in the wheel, it is also raised to a high temperature level. Because the IR Source itself is very hot, the set point for this heat circuit is 68°C. A cartridge heater implanted into the heat sync on the motor is the heat source. The temperature of the wheel/motor assembly is sensed by a thermistor also inserted into the heat sync.

Both heaters operate off of the AC line voltage supplied to the instrument.

6.5.2.2 IR SOURCE

The light used to detect CO_2 in the sample chamber is generated by an element heated to approximately 1100°C producing infrared radiation across a broad band. This radiation is optically filtered after it has passed through the GFC Wheel and the sample chamber and just before it reaches the photo-detector to eliminate all black body radiation and other extraneous IR emitted by the various components of those components.

6.5.2.3   GFC WHEEL

A synchronous AC motor turns the GFC Wheel motor. For analyzers operating on 60Hz line power this motor turns at 1800 rpm. For those operating on 50Hz line power the spin rate is 1500 rpm. The actual spin rate is unimportant within a large range since a phase lock loop circuit is used to generate timing pulses for signal processing.

In order to accurately interpret the fluctuations of the IR beam after it has passed through the sample gas, the GFC Wheel several other timing signals are produced by other photo emitters/detectors. These devices consist of a combination LED and detector mounted so that the light emitted by the LED shines through the same mask on the GFC Wheel that chops the IR beam.

KEY:

Detection Beam shining through MEASUREMENT side of GFC Wheel

Detection Beam shining through REFERENCE side of GFC Wheel

IR Detection Ring
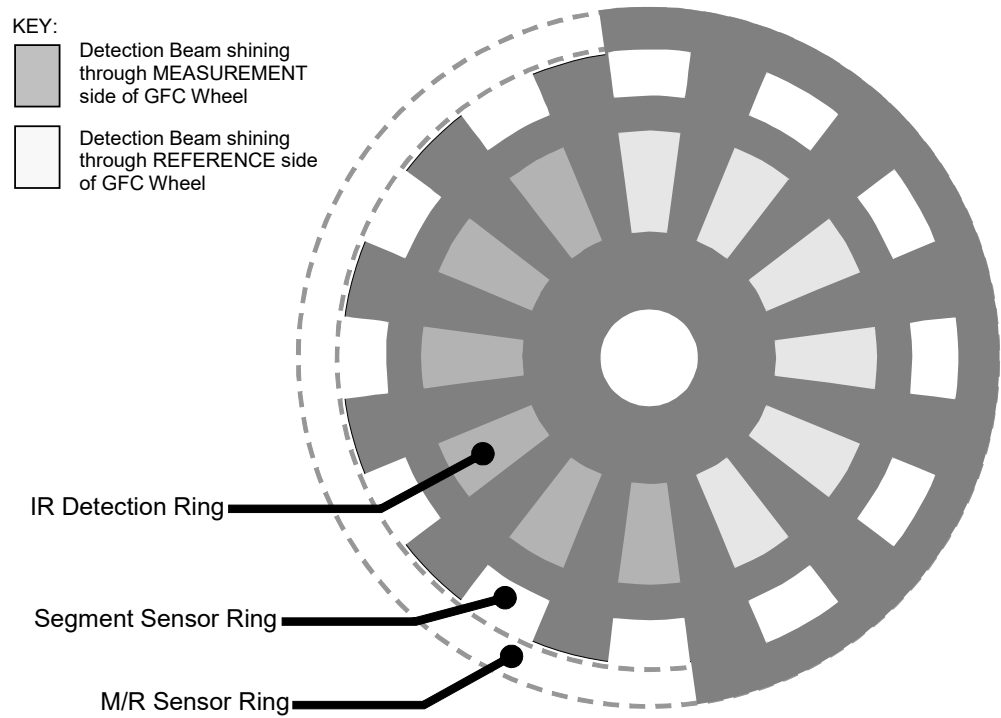
Segment Sensor Ring

M/R Sensor Ring

Figure 6-11. GFC Light Mask

M/R SENSOR

This emitter/detector assembly produces a signal that shines through a portion of the mask that allows light to pass for half of a full revolution of the wheel. The resulting light signal tells the analyzer whether the IR beam is shining through the measurement or the reference side of the GFC Wheel.

Light from this emitter/detector pair shines through a portion of the mask that is divided into the same number of segments as the IR detector ring. It is used by the synchronous/demodulation circuitry of the analyzer to latch onto the most stable part of each measurement and reference IR pulse.
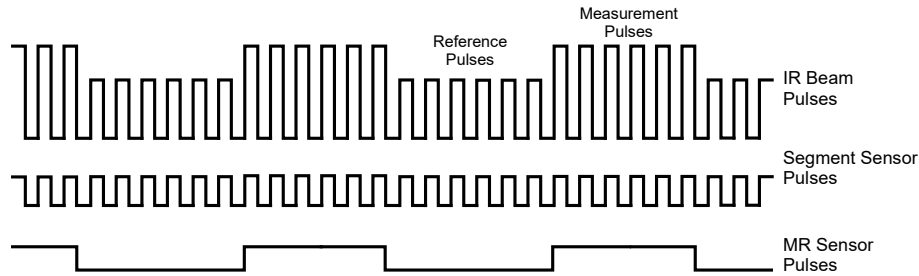
Figure 6-12. Segment Sensor and M/R Sensor Output

SCHMIDT TRIGGERS

To ensure that the waveforms produced by the Segment Sensor and the M/R Sensor are properly shaped and clean, these signals are passed through a set of Schmidt Triggers circuits.

6.5.2.4   IR PHOTO-DETECTOR

The IR beam is converted into an electrical signal by a cooled solid-state photo-conductive detector. The detector is composed of a narrow-band optical filter, a piece of lead-salt crystal whose electrical resistance changes with temperature, and a two-stage thermo-electric cooler.

When the analyzer is on, a constant electrical current is directed through the detector. The IR beam is focused onto the detector surface, raising its temperature and lowering its electrical resistance that results in a change in the voltage drop across the detector.

During those times that the IR beam is bright, the temperature of the detector is high; the resistance of the detector is correspondingly low and its output voltage output is low. During those times when the IR beam intensity is low or completely blocked by the GFC Wheel mask, the temperature of the detector is lowered by the two-stage thermo-electric cooler, increasing the detector's resistance and raising the output voltage.

6.5.3 SYNCHRONOUS DEMODULATOR (SYNC/DEMOD) ASSEMBLY

While the photo-detector converts fluctuations of the IR beam into electronic signals, the Sync/Demod Board amplifies these signals and converts them into usable information. Initially the output by the photo-detector is a complex and continuously changing waveform made up of Measure and Reference pulses. The sync/demod board demodulates this waveform and outputs two analog DC voltage signals, corresponding to the peak values of these pulses. Meas Detector and Ref Detector are converted into digital signals by circuitry on the motherboard then used by the CPU to calculate the CO_2 concentration of the sample gas.

Additionally, the sync/demod board contains circuitry that controls the photo-detector's thermoelectric cooler as well as circuitry for performing certain diagnostic tests on the analyzer.
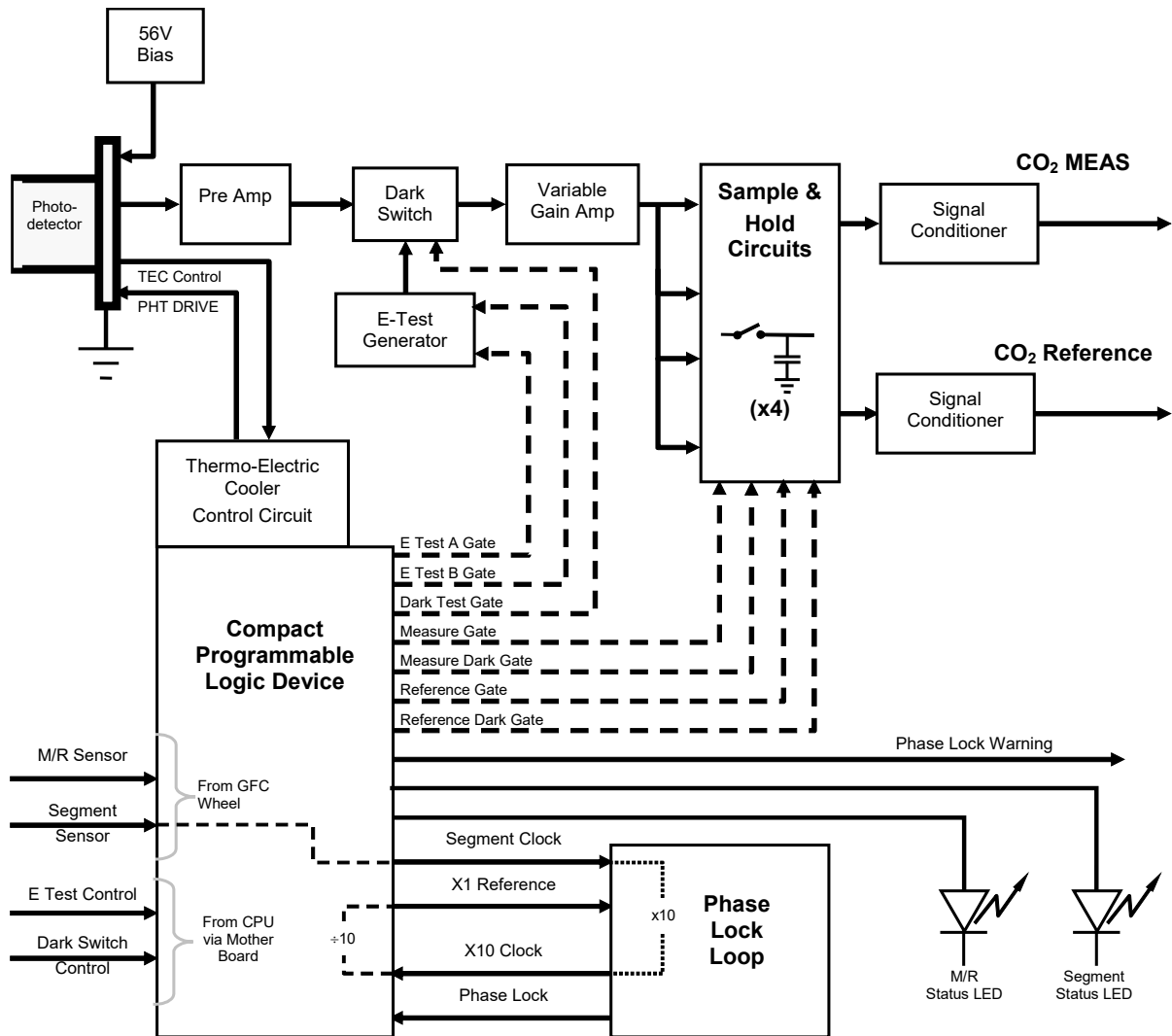
Figure 6-13. Sync/Demod Block Diagram

6.5.3.1   SIGNAL SYNCHRONIZATION AND DEMODULATION

The signal emitted by the IR photo-detector goes through several stages of amplification before it can be accurately demodulated. The first is a pre-amplification stage that raises the signal to levels readable by the rest of the sync/demod board circuitry. The second is a variable amplification stage that is adjusted at the factory to compensate for performance variations of mirrors, detectors, and other components of the optical bench from instrument to instrument.

The workhorses of the sync/demod board are the four sample-and-hold circuits that capture various voltage levels found in the amplified detector signal needed to determine the value of Meas Detector and Ref Detector. They are activated by logic signals under

the control of a compact Programmable Logic Device (PLD), which in turn responds to the output of the Segment Sensor and M/R Sensor as shown in Figure 6-9.

The four sample and hold circuits are designated as follows:

Table 6-1. Sync Demod Sample and Hold Circuits

| DESIGNATION | ACTIVE WHEN: | |
	IR BEAM PASSING THROUGH	SEGMENT SENSOR PULSE IS:
Measure Gate	MEASUREMENT cell of GFC Wheel	HIGH
Measure Dark Gate	MEASUREMENT Cell of GFC Wheel	LOW
Reference Gate	REFERENCE cell of GFC Wheel	HIGH
Reference Dark Gate	REFERENCE cell of GFC Wheel	LOW

Timing for activating the Sample and Hold Circuits is provided by a Phase Lock Loop (PLL) circuit. Using the segment sensor output as a reference signal the PLL generates clock signal at ten times that frequency. This faster clock signal is used by the PLD to make the Sample and Hold Circuits capture the signal during the center portions of the detected waveform, ignore the rising and falling edges of the detector signal.

Sample & Hold Active

Detector Output

Sample & Hold Inactive
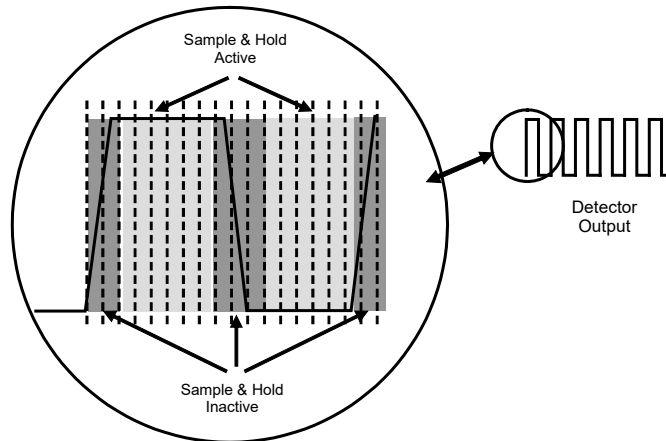
Figure 6-14. Sample & Hold Timing

6.5.3.2   SYNC/DEMOD STATUS LEDS

The following two status LEDs located on the sync/demod board provide additional diagnostic tools for checking the GFC Wheel rotation.

Table 6-2. Sync Demod Status LED Activity

LED	Function	Status OK	Fault Status
D1	M/R Sensor Status	LED flashes approximately 2/second	LED is stuck ON or OFF
D2	Segment Sensor Status	LED flashes approximately 6/second	LED is stuck ON or OFF

See Section 5.7.7 for more information.

6.5.3.3   PHOTO-DETECTOR TEMPERATURE CONTROL

The sync/demod board also contains circuitry that controls the IR photo-detector's Thermal Electric Coolers (TEC). A drive voltage, **PHT DRIVE**, is supplied to the coolers by the sync/demod board which is adjusted by the sync/demod board based on a return signal called TEC control which alerts the sync/demod board of the detector's temperature. The warmer the detector, the harder the coolers are driven.

PHT DRIVE is one of the functions viewable on the Dashboard (may need to be configured: Setup>Dashboard).

6.5.3.4   DARK CALIBRATION SWITCH

This switch initiates the Dark Calibration procedure. When initiated by the user (See Section 4.5.1 for more details), the dark calibration process opens this switch, interrupting the signal from the IR photo-detector. This allows the analyzer to measure any offset caused by the sync/demod board circuitry.

6.5.4 RELAY BOARD

By actuating various switches and relays located on this board, the CPU controls the status of other key components. The relay board receives instructions in the form of digital signals over the I^2C bus, interprets these digital instructions and activates its various switches and relays appropriately.

6.5.4.1   HEATER CONTROL

The two heaters attached to the sample chamber housing and the GFC Wheel motor are controlled by solid state relays located on the relay board.

The GFC Wheel heater is simply turned on or off, however control of the bench heater also includes circuitry that selects which one of its two separate heating elements is activated depending on whether the instrument is running on 100 VAC, 115 VAC or 230 VAC line power.

6.5.4.2   GFC WHEEL MOTOR CONTROL

The GFC Wheel operates from a AC voltage supplied by a multi-input transformer located on the relay board. The step-down ratio of this transformer is controlled by factory-installed jumpers to adjust for 100 VAC, 115 VAC or 230 VAC line power. Other circuitry slightly alters the phase of the AC power supplied to the motor during start up based on whether line power is 50Hz or 60 Hz.

Normally, the GFC Wheel Motor is always turning while the analyzer is on.

6.5.4.3   ZERO/SPAN VALVE OPTIONS

Any zero/span/shutoff valve options installed in the analyzer are controlled by a set of electronic switches located on the relay board. These switches, under CPU control, supply the +12VDC needed to activate each valve's solenoid.

6.5.4.4   IR SOURCE

The relay board supplies a constant 11.5VDC to the IR Source. Under normal operation the IR source is always on. Status LEDs

Eight LEDs are located on the analyzer's relay board to show the current status on the various control functions performed by the relay board. They are listed on Table 6-3.

Table 6-3. Relay Board Status LEDs

| LED	COLOR	FUNCTION	STATUS WHEN LIT	STATUS WHEN UNLIT
D1	RED	Watch Dog Circuit	Cycles On/Off every 3 seconds under direct control of the analyzer's CPU.	
D2	YELLOW	Wheel Heater	HEATING	NOT HEATING
D3	YELLOW	Bench Heater	HEATING	NOT HEATING
D4	YELLOW	Spare	N/A	N/A
D5	GREEN	Sample/Cal Gas Valve Option	Valve Open to CAL GAS FLOW	Valve Open to SAMPLE Gas Flow
D6	GREEN	Zero/Span Gas Valve Option	Valve Open to SPAN GAS FLOW	Valve Open to ZERO GAS FLOW
D7	GREEN	Shutoff Valve Option	Valve Open to CAL GAS FLOW	Valve CLOSED to CAL GAS FLOW
D8	GREEN	IR SOURCE	Source ON	Source OFF
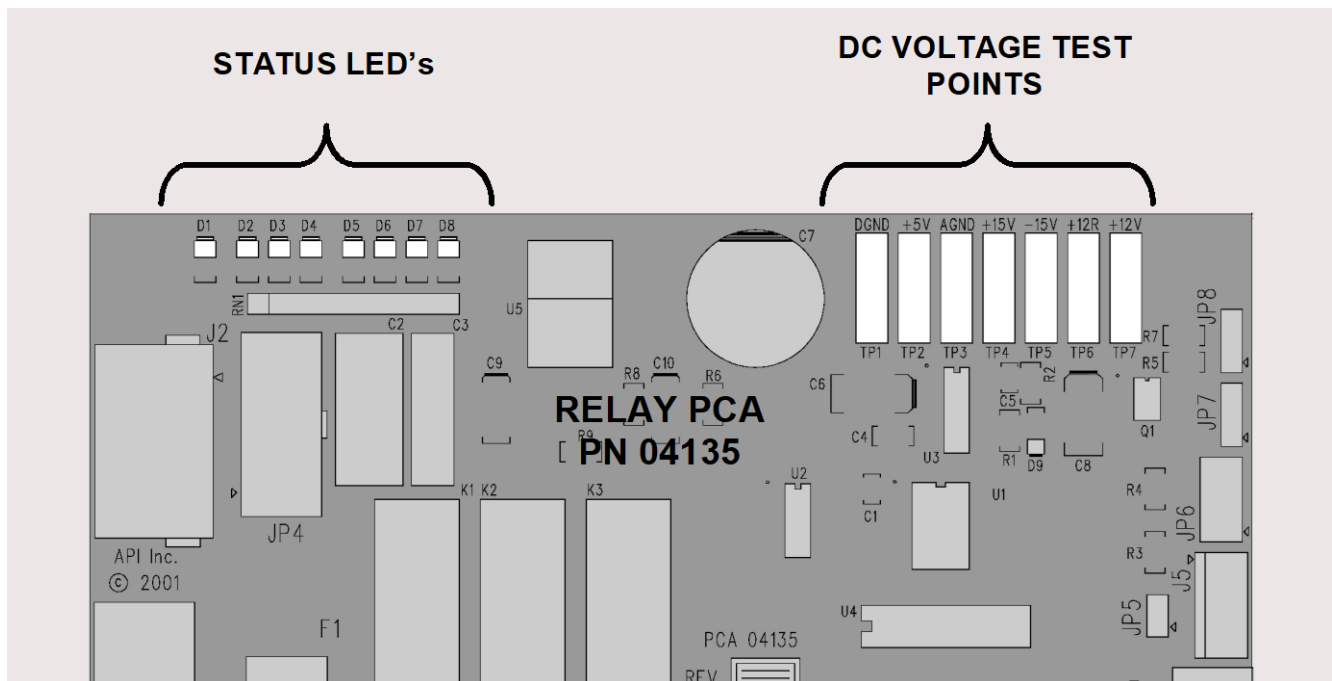
Figure 6-15. Location of Relay Board Status LEDs

6.5.4.5   I²C WATCH DOG CIRCUITRY

Special circuitry on the relay board monitors the activity on the I²C bus and drives LED D1. Should this LED ever stay ON or OFF for 30 seconds, the watch dog circuit will automatically shut off all valves as well as turn off the IR Source and all heaters. The GFC Wheel motor will still be running as will the Sample Pump, which is not controlled by the relay board.

6.5.5 MOTHERBOARD

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.

6.5.5.1   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 is used in uni-polar mode with a +5 V full scale. The converter includes a 1% over and under-range. This allows signals from –0.05 V to +5.05 V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference Ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions.

6.5.5.2   SENSOR INPUTS

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

MEAS DETECTOR AND REFERENCE DETECTOR

These are the primary signals that are used in the computation of the CO_2 concentration. They are the demodulated IR-sensor signals from the sync demodulator board.

SAMPLE PRESSURE AND FLOW

These are analog signals from two sensors that measure the pressure and flow rate of the gas stream at the outlet of the sample chamber. This information is used in two ways. First, the sample pressure is used by the CPU to calculate CO_2 concentration. Second, the pressure and flow rate are monitored as a test function to assist the user in predicting and troubleshooting failures.

6.5.5.3   THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the analyzer. They are as follows:

SAMPLE TEMPERATURE SENSOR

The source of this signal is a thermistor located inside the sample chamber of the Optical Bench. It measures the temperature of the sample gas in the chamber. This data is used to during the calculation of the CO_2 concentration value.

BENCH TEMPERATURE SENSOR

This thermistor is attached to the sample chamber housing. It reports the current temperature of the chamber housing to the CPU as part of the bench heater control loop.

WHEEL TEMPERATURE SENSOR

This thermistor is attached to the heatsink on the GFC Wheel motor assembly. It reports the current temperature of the wheel/motor assembly to the CPU as part of the Wheel Heater control loop.

BOX TEMPERATURE SENSOR

A thermistor is attached to the motherboard. It measures the analyzer's internal temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes via the front panel display (see Section 5.7.3, Box Temp).

6.5.5.4   ANALOG OUTPUTS

The analyzer comes equipped with four analog outputs: **A1**, **A2**, **A3** and **A4**. The type of data and electronic performance of these outputs are configurable by the user (see Section 2.5.8).

OUTPUT LOOP-BACK

All four 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.

6.5.5.5   INTERNAL DIGITAL I/O

This channel is used to communicate digital status and control signals about the operation of key components of the Optical Bench. The CPU sends signals to the sync/demod board that initiate the **DARK CALIBRATION** procedure.

6.5.5.6   EXTERNAL DIGITAL I/O

This External Digital I/O performs two functions: status outputs and control inputs.

STATUS OUTPUTS

Logic-Level voltages are output through an optically isolated 8-pin connector located on the rear panel of the analyzer. These outputs convey good/bad and on/off information about certain analyzer conditions. They can be used to interface with certain types of programmable devices (See Section 2.3.1.3).

CONTROL INPUTS

By applying +5VDC power supplied from an external source such as a PLC or Data logger (See Section 2.3.1.5), Zero and Span calibrations can be initiated by contact closures on the rear panel.

POWER UP CIRCUIT

This circuit monitors the +5V power supply during start-up and sets the analog outputs, external digital I/O ports, and I^2C circuitry to specific values until the CPU boots and the instrument software can establish control.

6.5.6 I^2C DATA BUS

I^2C is a two-wire, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the motherboard converts data and control signals from the PC-104 bus to I^2C. The data is then fed to the relay board and valve driver board circuitry.

6.5.7 POWER SUPPLY/ CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50Hz or 60Hz. Individual units are set up at the factory to accept any combination of these five attributes. As illustrated in Figure 6-16, power enters the analyzer through a standard IEC 320 power receptacle located on the rear panel of the instrument. From there it is routed through the ON/OFF Switch located in the lower right corner of the front panel. A 6.75 Amp circuit breaker is built into the ON/OFF Switch.

AC power is distributed directly to the sample gas pump. The bench and GFC Wheel heaters as well as the GFC Wheel receive AC power via the relay board.

AC Line power is converted stepped down and converted to DC power by two DC power supplies. One supplies +12 VDC, for valves and the IR source, while a second supply provides +5 VDC and ±15 VDC for logic and analog circuitry. All DC voltages are distributed via the relay board.

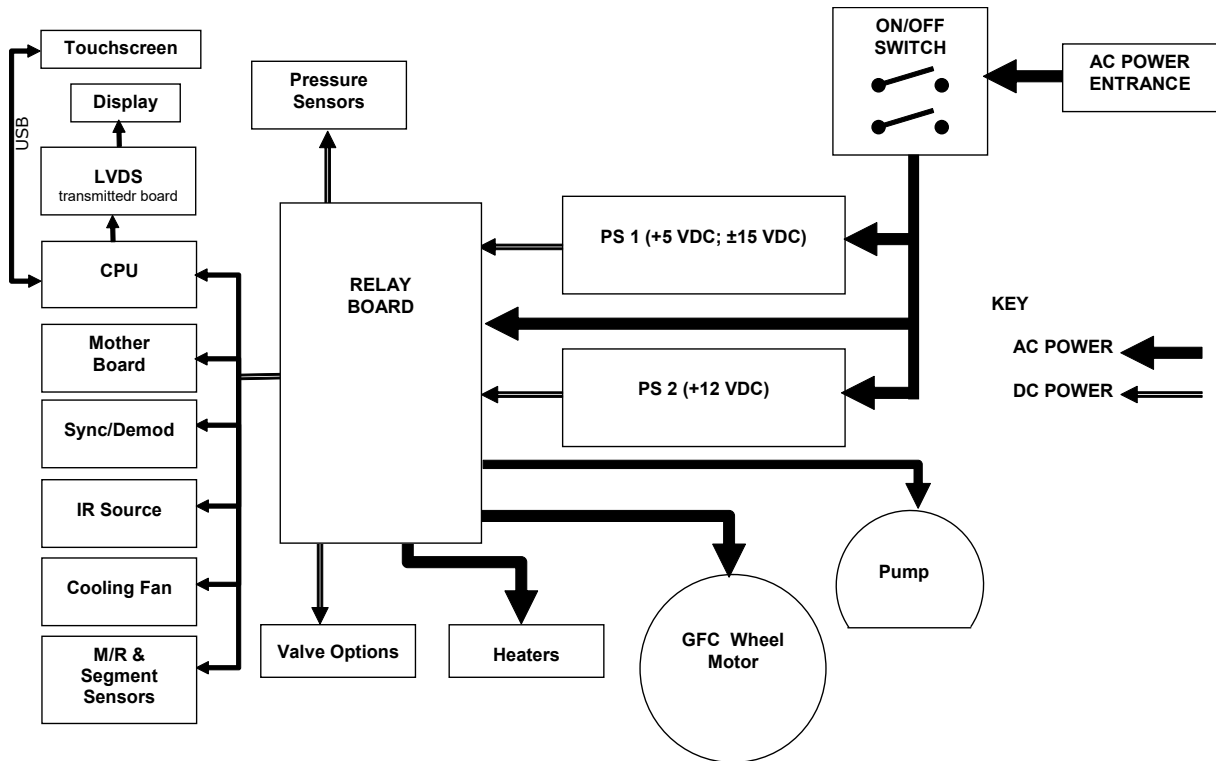|	**CAUTION** **General Safety Hazard**
⚠	**Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.**

Figure 6-16. Power Distribution Block Diagram

6.5.8 FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touchscreen display. The LCD display is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.
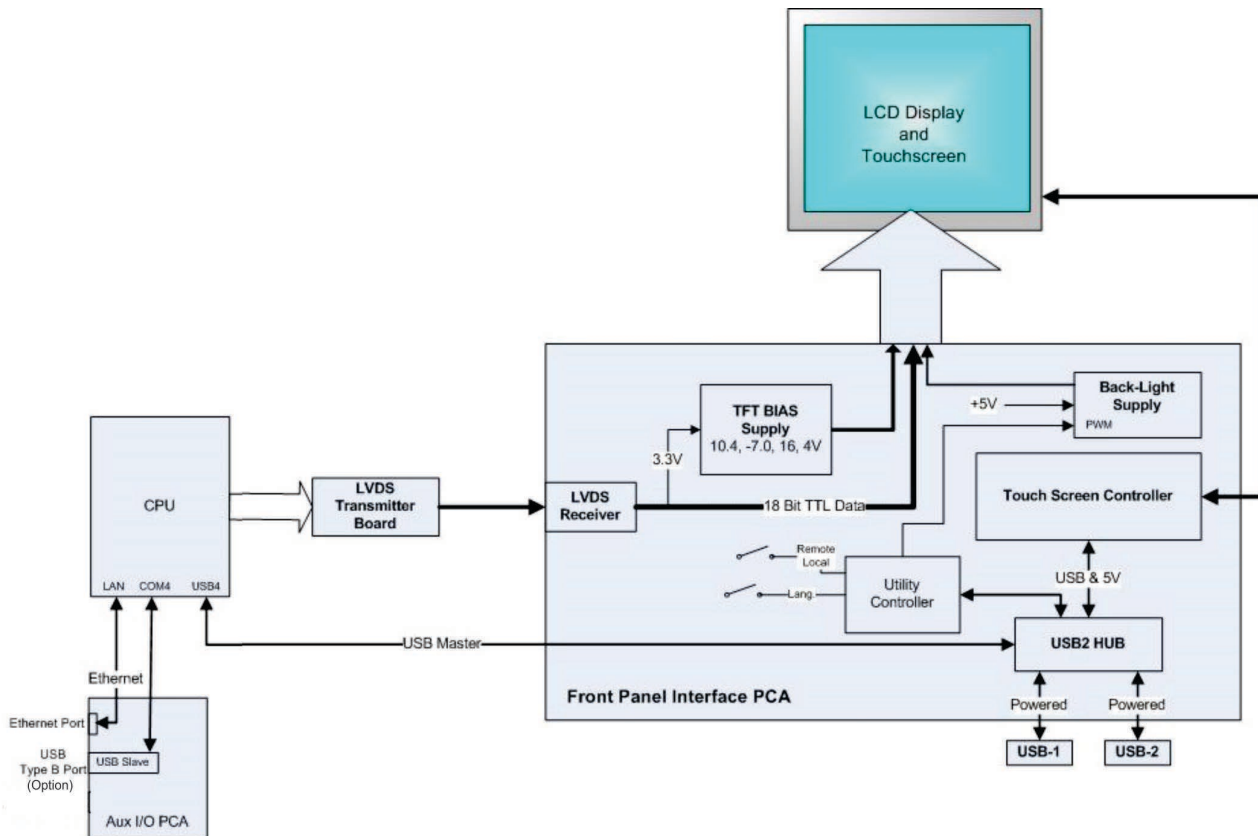
Figure 6-17. Front Panel and Display Interface Block Diagram

6.5.8.1   LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA. (Note that the signals are not HDMI compatible).

6.5.8.2   FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE PCA

The front panel touchscreen/display interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- a USB hub that is used for communications with the touchscreen controller and the two front panel USB device ports
- the circuitry for powering the display backlight

6.6 SOFTWARE OPERATION

The T360/T360M Gas Filter Correlation Carbon Dioxide Analyzer has a high performance, Vortex86-based microcomputer running Windows CE. Inside Windows CE, special software developed by Teledyne API interprets user commands via the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the sample gas.
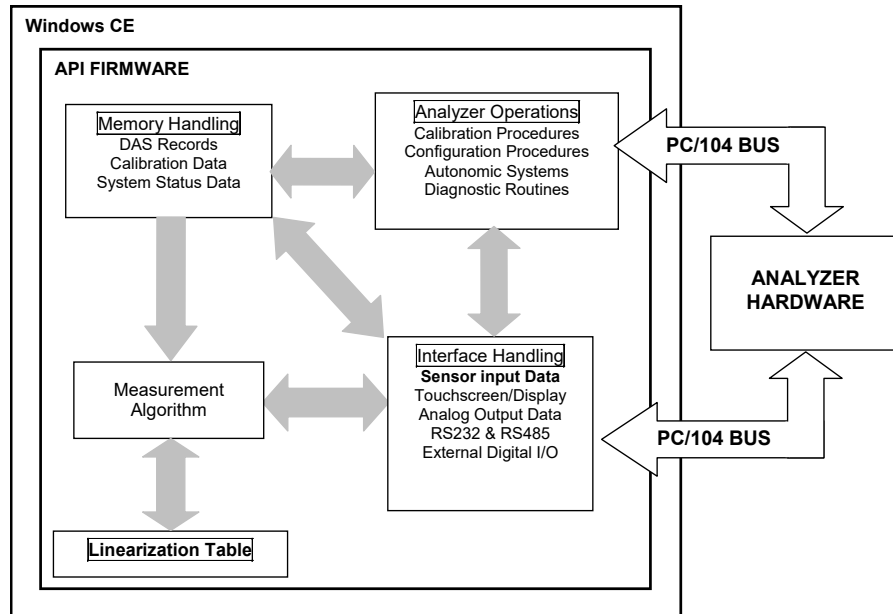

Figure 6-18. Basic Software Operation

6.6.1 ADAPTIVE FILTER

The software processes the Meas Detector and Ref Detector signals, after they are digitized by the motherboard, through an adaptive filter built into the software. Unlike other analyzers that average the output signal over a fixed time period, this analyzer averages over a set number of samples, where each sample is 0.2 seconds. This technique is known as boxcar averaging. During operation, the software automatically switches between two different length filters based on the conditions at hand. Once triggered, the short filter remains engaged for a fixed time period to prevent chattering.

During conditions of constant or nearly constant concentration the software, by default, computes an average of the last 750 samples, or approximately 150 seconds. This provides the calculation portion of the software with smooth stable readings. If a rapid change in concentration is detected the filter includes, by default, the last 48 samples, approximately 10 seconds of data, to allow the analyzer to more quickly respond. If necessary, these boxcar lengths can be changed between 1 and 1000 samples but with corresponding tradeoffs in rise time and signal-to-noise ratio (contact Technical Support for more information).

Two conditions must be simultaneously met to switch to the short filter. First the instantaneous concentration must exceed the average in the long filter by a fixed amount. Second the instantaneous concentration must exceed the average in the long filter by a portion, or percentage, of the average in the long filter.

6.6.2 CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in software.

During instrument calibration (see Section 4) the user enters expected values for zero and span via the front panel control buttonand commands the instrument to make readings of calibrated sample gases for both levels. The readings taken are adjusted, linearized, and compared to the expected values. With this information the software computes values for instrument slope and offset and stores these values in memory for use in calculating the CO_2 concentration of the sample gas.

The instrument slope and offset values recorded during the last calibration are available for viewing from the from the front panel (see Section 2.3.4.3).

6.6.3 MEASUREMENT ALGORITHM

Once the IR photo-detector signal is demodulated into **MEAS DETECTOR** and **REF DETECTOR** by the sync/demod board and converted to digital data by the motherboard, the analytical software calculates the ratio between **MEAS DETECTOR** and **REF DETECTOR**. This value is compared to a look-up table that is used, with interpolation, to linearize the response of the instrument. The linearized concentration value is combined with calibration slope and offset values, then normalized for changes in sample gas pressure to produce the final CO_2 concentration. This is the value that is displayed on the instrument front panel display and is stored in memory by the analyzer's data acquisition system (DAS) system, the Data Logger.

6.6.4 TEMPERATURE AND PRESSURE COMPENSATION (TPC)

Changes in pressure can have a noticeable, effect on the CO_2 concentration calculation. To account for this, the analyzer's software includes a feature which allows the instrument to compensate for the CO_2 calculations based on changes in ambient pressure.

The TPC feature multiplies the analyzer's CO_2 concentration by a factor which is based on the difference between the ambient pressure of the sample gas normalized to standard atmospheric pressure. As ambient pressure increases, the compensated CO_2 concentration is decreased.

GLOSSARY

Note: Some terms in this glossary may not occur elsewhere in this manual.

TERM	DESCRIPTION/DEFINITION
10Base-T	an Ethernet standard that uses twisted ("T") pairs of copper wires to transmit at 10 megabits per second (Mbps)
100Base-T	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	*Assembly*
CAS	*Code-Activated Switch*
CD	*Corona Discharge*, a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	*Converter Efficiency*, the percentage of light energy that is actually converted into electricity
CEM	*Continuous Emission Monitoring*
Chemical formulas that may be included in this document:	
CO_2	carbon dioxide
C_3H_8	propane
CH_4	methane
H_2O	water vapor
HC	general abbreviation for hydrocarbon
HNO_3	nitric acid
H_2S	hydrogen sulfide
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	nitrogen oxides, here defined as the sum of NO and NO_2
NO_y	nitrogen oxides, often called odd nitrogen: the sum of NO_X plus other compounds such as HNO_3 (definitions vary widely and may include nitrate (NO_3), PAN, N_2O and other compounds as well)
NH_3	ammonia
O_2	molecular oxygen
O_3	ozone
SO_2	sulfur dioxide
cm^3	metric abbreviation for *cubic centimeter* (replaces the obsolete abbreviation "cc")
CPU	*Central Processing Unit*
DAC	*Digital-to-Analog Converter*
DAS	*Data Acquisition System*
DCE	*Data Communication Equipment*
DFU	*Dry Filter Unit*
DHCP	*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
DIAG	*Diagnostics*, the diagnostic settings of the analyzer.
DOM	*Disk On Module,* a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
TERM	DESCRIPTION/DEFINITION

DRAM	*Dynamic Random Access Memory*
DTE	*Data Terminal Equipment*
EEPROM	*Electrically Erasable Programmable Read-Only Memory* also referred to as a FLASH chip or drive
ESD	*Electro-Static Discharge*
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	*Fluorinated Ethylene Propylene* polymer, one of the polymers that Du Pont markets as *Teflon*®
Flash	non-volatile, solid-state memory
FPI	*Fabry-Perot Interface*: a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	*Gas Filter Correlation*
I²C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	*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
IP	*Internet Protocol*
IZS	*Internal Zero Span*
LAN	*Local Area Network*
LCD	*Liquid Crystal Display*
LED	*Light Emitting Diode*
LPM	*Liters Per Minute*
MFC	*Mass Flow Controller*
M/R	*Measure/Reference*
MOLAR MASS	the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance. EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams. Atomic weights can be found on any Periodic Table of Elements.
NDIR	*Non-Dispersive Infrared*
NIST-SRM	*National Institute of Standards and Technology - Standard Reference Material*
PC	*Personal Computer*
PCA	P*rinted Circuit Assembly*, the PCB with electronic components, ready to use
PCB	*Printed Circuit Board*, the bare board without electronic component
PFA	*Perfluoroalkoxy*, an inert polymer; one of the polymers that *Du Pont* markets as *Teflon*®
PLC	*Programmable Logic Controller*, a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	*Programmable Logic Device*
PLL	*Phase Lock Loop*
P/N (or PN)	*Part Number*
PSD	*Prevention of Significant Deterioration*
TERM	**DESCRIPTION/DEFINITION**
PTFE	*Polytetrafluoroethylene*, a very inert polymer material used to handle gases that may react on other surfaces; one polymer that *Du Pont* markets as *Teflon*®

PVC	*Poly Vinyl Chloride*, a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	*Storage and Retrieval of Aerometric Data*
SLAMS	*State and Local Air Monitoring Network Plan*
SLPM	*Standard Liters Per Minute* of a gas at standard temperature and pressure
STP	*Standard Temperature and Pressure*
TCP/IP	*Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices
TPC	*Temperature/Pressure Compensation*
USB	*Universal Serial Bus*: a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARS	*Variables*, the variable settings of the instrument
V-F	*Voltage-to-Frequency*
Z/S	*Zero / Span*

INDEX

Default Settings, 83
Latency Period, 82
Status Flag
Default Settings, 84
HIGH RANGE
REMOTE, 32
Hold Off Period, 133

I

I^{2}C bus, 107, 108, 109, 110, 111, 112, 118, 121, 145, 153, 155
Power Up Circuit, 157
Infrared Radiation (IR), 86, 93, 98, 107, 108, 109, 113, 116, 119, 122, 123, 133, 135, 137, 138, 140, 148, 149, 150, 151, 152, 153, 154, 155, 157, 161
Internal Pneumatics
Zero/Span Valves, 47
Zero/Span/Shutoff Valves, 48
Internal Pump, 104, 107, 114, 115, 124, 127, 141, 142, 143, 157
Internal Zero Air (IZS), 24, 114, 122
Gas Flow Problems, 113

M

Machine ID, 37
MEAS Detector, 130
Measure Reference Ratio, 138
Motherboard, 72
MR Ratio, 119
Multidrop, 35, 37, 82

O

O$_2$, 87, 94, 113, 142
O$_2$ sensor, 94, 113, 142
O$_2$ Sensor
Calibration
Setup, 94
O$_2$ Sensor Option
Pneumatic Set Up for Calibration, 94
OFFSET, 109
Operating Modes
SAMPLE mode, 90
Optical Bench, 105, 148, 156
Layout, 26

P

Particulate Filter, 98, 103, 107, 143
PHOTO TEMP WARNING, 107
PHT DRIVE, 109
Pneumatic Set Up
Basic
Bottled Gas, 40

Calibration
with O$_2$ Sensor, 94
Calibration Gasses, 39
PRES, 104
PTFE, 38, 85, 103

R

RANGE, 108
REAR BOARD NOT DET, 107
Relay Board
Status LEDs, 111
Troubleshooting, 122
RELAY BOARD WARN, 107
Reporting Range
Upper Span Limit, 86
RS-232, 33, 34, 36, 37, 79, 126, 155
DCE & DTE, 33
RS-485, 79, 155

S

SAFETY MESSAGES
Electric Shock, 27, 118
GENERAL, 20, 27, 29, 38
General, 106
Qualiified Personnel, 105
Sample Flow Sensor, 144
SAMPLE FLOW WARN, 107
Sample Inlet, 24
Sample Mode, 125
SAMPLE mode, 90
SAMPLE PRESS WARN, 107
Sample Pressure Sensor, 144
SAMPLE TEMP, 117
Schmidt Triggers, 150
Sensor Inputs, 124, 155
Bench Temperature, 156
Box Temperature, 156
Sample Pressure And Flow, 156
Sample Temperature, 156
Thermistor Interface, 156
Wheel Temperature, 156
SERIAL I/O
BENCH_HEATER, 118
PHT_DRIVE, 119
WHEEL_HEATER, 118
Serial I/O Ports
Multidrop, 35, 37
SLOPE, 109
SPAN CAL, 97, 125
Remote, 32
Span Gas, 24, 86, 94, 104, 107, 109, 114, 116, 117, 133
Specifications, 18
STABIL, 108, 119
stainless steel, 38, 85
Status LEDs, 154

CPU, 110
Relay Board, 111
Sync/Demod Board, 111, 120
Status Outputs, 157
Electrical Connections, 30
Pin Assignments, 31
Sync/Demod Board, 93, 107, 108, 109, 122, 150, 151, 152, 153, 156, 161
Photo-Detector Temperature Control, 153
Status LEDs, 111, 120
Troubleshooting, 122, 130, 131

T

Teledyne Contact Information
Email Address, **134**
Fax, **134**
Phone, **134**
Technical Assistance, **134**
Website, **134**
Test Channel, 28
Test Functions
BOX TEMP, 117, 118
MR Ratio, 119
OFFSET, 109
PHT DRIVE, 109
PRES, 104
RANGE, 108
SAMPLE TEMP, 117
SLOPE, 109
STABIL, 108, 119
TIME, 92
TIME, 92
Touch screen Interface Electronics
Troubleshooting, 121

U

Units of Measurement, 87

V

Valve Options, 24, 153
Zero/Span, 117
with Remote Contact Closure, 90
Zero/Span Valve w/ Internal Scrubber, 117
Zero/Span Valves
Internal Pneumatics, 47
Zero/Span/Shutoff Valves
Internal Pneumatics, 48
Ventilation Clearance, 21

W

Warm-up Period, 51
Warnings, 51
BENCH TEMP WARNING, 107
BOX TEMP WARNING, 107
CANNOT DYN SPAN, 107
CANNOT DYN ZERO, 107
CONFIG INITIALIZED, 107
DATA INITIALIZED, 107
PHOTO TEMP WARNING, 107
REAR BOARD NOT DET, 107
RELAY BOARD WARN, 107
SAMPLE FLOW WARN, 107
SAMPLE PRESS WARN, 107
Watch Dog Circuit, 154, 155

Z

Zero Air, 24, 86, 98, 109, 114, 116, 117, 119, 122, 134
ZERO CAL, 97, 125
Remote, 32
Zero/Span Valves
Internal Pneumatics, 47
Zero/Span/Shutoff Valves
Internal Pneumatics, 48

APPENDIX A

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Floating Point Input Registers **(32-bit IEEE 754 format; read in high-word, low-word order; read-only)**		
0	Detector measure reading	mV
2	Detector reference reading	mV
4	M/R ratio.	none
6	Slope for range #1	none
8	Slope for range #2	none
10	Offset for range #1	none
12	Offset for range #2	none
14	Concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPM
16	Concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPM
18	Concentration for range #1	PPM
20	Concentration for range #2	PPM
22	Concentration stability	PPM
24	Bench temperature	°C
26	Bench temperature control duty cycle	Fraction (0.0 = off, 1.0 = on full)
28	Wheel temperature	°C
30	Wheel temperature control duty cycle	Fraction (0.0 = off, 1.0 = on full)
32 [11]	Sample temperature	°C
34	Sample pressure	"Hg
36	Internal box temperature	°C
38	Photometer detector temperature drive	mV
40	Diagnostic test input (TEST_INPUT_7)	mV
42	Diagnostic test input (TEST_INPUT_8)	mV
44	Diagnostic temperature input (TEMP_INPUT_4)	°C
46	Diagnostic temperature input (TEMP_INPUT_5)	°C
48	Ground reference (REF_GND)	mV
50	4096 mV reference (REF_4096_MV)	mV
52 [1]	Purge pressure	PSIG
54 [1]	Sample flow	cc/m
56 [1]	Vacuum pressure	"Hg
58 [1]	Internal box temperature #2/oven	°C

MODBUS Register Address (dec., 0-based)	Description	Units
60 [1]	Internal box temperature #2/oven control duty cycle	Fraction (0.0 = off, 1.0 = on full)
62 [1]	Auto-zero reading	M/R
100 [2]	O_2 concentration	%
102 [2]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
104 [2]	O_2 slope	—
106 [2]	O_2 offset	%
108 [2]	O_2 sensor cell temperature	°C
130 [10]	External analog input 1 value	Volts
132 [10]	External analog input 1 slope	eng unit /V
134 [10]	External analog input 1 offset	eng unit
136 [10]	External analog input 2 value	Volts
138 [10]	External analog input 2 slope	eng unit /V
140 [10]	External analog input 2 offset	eng unit
142 [10]	External analog input 3 value	Volts
144 [10]	External analog input 3 slope	eng unit /V
146 [10]	External analog input 3 offset	eng unit
148 [10]	External analog input 4 value	Volts
150 [10]	External analog input 4 slope	eng unit /V
152 [10]	External analog input 4 offset	eng unit
154 [10]	External analog input 5 value	Volts
156 [10]	External analog input 5 slope	eng unit /V
158 [10]	External analog input 5 offset	eng unit
160 [10]	External analog input 6 value	Volts
162 [10]	External analog input 6 slope	eng unit /V
164 [10]	External analog input 6 offset	eng unit
166 [10]	External analog input 7 value	Volts
168 [10]	External analog input 7 slope	eng unit /V
170 [10]	External analog input 7 offset	eng unit
172 [10]	External analog input 8 value	Volts
174 [10]	External analog input 8 slope	eng unit /V
176 [10]	External analog input 8 offset	eng unit
200 [3]	CO_2 concentration	%
202 [3]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [3]	CO_2 slope	—
206 [3]	CO_2 offset	%

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Floating Point Holding Registers **(32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)**		
0	Maps to *CO_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *CO_SPAN2* variable; target conc. for range #2	Conc. units
100 [2]	Maps to *O2_TARG_SPAN_CONC* variable	%
200 [3]	Maps to *CO2_TARG_SPAN_CONC* variable	%
MODBUS Discrete Input Registers **(single-bit; read-only)**		
0	Source warning	
1	Box temperature warning	
2	Bench temperature warning	
3	Wheel temperature warning	
4 [11]	Sample temperature warning	
5	Sample pressure warning	
6	Photometer detector temperature warning	
7	System reset warning	
8	Rear board communication warning	
9	Relay board communication warning	
10	Front panel communication warning	
11	Analog calibration warning	
12	Dynamic zero warning	
13	Dynamic span warning	
14	Invalid concentration	
15	In zero calibration mode	
16	In span calibration mode	
17	In multi-point calibration mode	
18	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
19 [1]	Purge pressure warning	
20 [1]	Sample flow warning	
21 [1]	Internal box temperature #2/oven warning	
22 [1]	Concentration limit 1 exceeded	
23 [1]	Concentration limit 2 exceeded	
24 [1]	Auto-zero warning	
25 [1]	Sync warning	
26 [1]	In Hessen manual mode	
100 [2]	In O_2 calibration mode	
101 [2]	O_2 cell temperature warning	
102 [1,2]	O_2 concentration limit 1 exceeded	
103 [1,2]	O_2 concentration limit 2 exceeded	

MODBUS Register Address (dec., 0-based)	Description	Units
200 [3]	In CO_2 calibration mode	
201 [1,3]	CO_2 concentration limit 1 exceeded	
202 [1,3]	CO_2 concentration limit 2 exceeded	
MODBUS Coil Registers **(single-bit; read/write)**		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [4]	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 [4]	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 [4]	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 [4]	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	

[1] Optional

[2] O_2 option

[3] CO_2 option

[4] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.

[10] External analog input option.

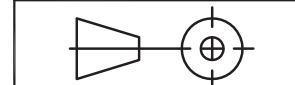[11] Except T300U, 300EU2 and M320EU configurations.

INTERCONNECT DRAWING T300/M & T360/M

KEY:
1. All part numbers in *Italic* identify cables that are refered to in the accompanying document 069120100.
2. All items in Dashed boxes are optional.

REVISIONS

REV	DESCRIPTION	DATE	DCN	APPROVED
A	INITIAL RELEASE	9/3/10	5833	KV
B	ADDED 360 FAMILY	12/30/10	5947	KV

083730360C DCN8606

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