

TCD-3 THERMAL CONDUCTIVITY DETECTOR

USER MANUAL



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VERSION 2.0



APPLICABLE MODELS

This manual is applicable to the following models:

- TCD-3 Microthermal

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VERSION HISTORY

VERSION	DATE	COMMENT/CHANGE
1.0		Initial Release - VICI Valco
2.0	11/2024	New layout/design - VICI Gig Harbor Group

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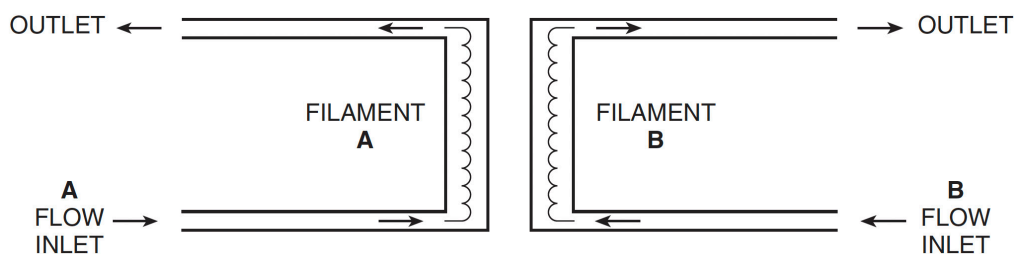
1. INTRODUCTION

1.1. DESCRIPTION

The TCD-3 is designed to operate either as a standalone test unit or as a component in a larger chromatographic system. The unit consists of a detector cell and a controller module, plus the required interconnecting cables.

The detector cell includes two separate filaments, A and B, with outputs designated as Channel A and Channel B. Cell volume has been minimized to accommodate capillary column chromatography and optimize the sensitivity of the detector at low flow rates. (Carrier flow rates of 1 – 10 mL/min are recommended for best sensitivity.)

Figure 1: Unique dual filament design



The controller incorporates the electrometer and temperature controls, with a status light on the front of the controller to indicate system status. The various states of this bi-color indicator are listed in Table 2 on page 10, along with an explanation of the indicated status. Digital control lines are provided for monitoring system readiness and initiating output channel adjustment routines. In addition, a serial RS-232 port is available for full unit configuration, control, and monitoring.

Thermal stability is maintained in the detector to within 0.010°C, producing a stable, low-noise signal. Two sets of analog output signals are available for each channel: a 10V output signal (with nominal output signals ranging from -10V to +10V) and a 1V output signal (with nominal output signals ranging from -1V to +1V). The two signals are identical, other than the 1:10 voltage scaling. A third channel, Channel AB, is the referenced or differential output, derived from the difference of the two filament energy states (i.e., Channel A – Channel B).

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1.2. OPERATING PRINCIPLE

The principal of operation is based on the relative change in the thermal conductivity of the gas passing across the detector filament as components elute from the column. Heat is lost continuously by the filament through the carrier gas to the cell wall of the detector. By measuring the amount of current required to maintain a constant filament temperature as gases of varying thermal conductivities cross the filament, a chromatographic signal is produced. This process is non-destructive of the sample and is concentration dependent.

The TCD-3 is unique in its implementation. Since changes in conductivity are measured only by the change in current required to keep the filament at a constant temperature, each of the two filaments can be operated independently without referencing these changes to a matched filament with reference gas. This constant temperature provides longer filament life and safeguards it from the extremely high temperatures and oxidation which can occur with high concentrations of oxidative or corrosive components. Optional signal referencing is provided to minimize background variables such as column bleed and temperature programming.

1.3. OPERATIONAL OVERVIEW

System parameters such as detector cell temperature, filament power levels, output channel nominal voltage levels, and communication settings must be entered through the serial communications port. This can be done either with the included Graphical User Interface (GUI) or by entering direct commands with a terminal emulator program.

New parameters entered into the TCD-3 are saved in non-volatile memory, becoming the values referenced the next time the controller is turned on. Once parameters are stored, the TCD-3 may be operated without a serial port connection, unless testing criteria change and new parameters must be entered.

By default, these stored settings are implemented immediately when the controller is turned on. However, this default behavior can be altered through serial port commands. A start-up delay may be added, allowing other system components to initialize before the TCD-3 is enabled. Or, the TCD-3 may be configured to power-up in an idle mode, in which no power is applied to the detector heating elements until a serial command is received. Refer to "Appendix B: Basic TCD Operation via Serial Commands" on page 40 for further details on these options.

Once the TCD-3 is enabled, the controller applies power to the detector heaters until the detector reaches its target temperature setting. The TCD-3 then monitors the temperature until it is within the minimum accuracy setting for 30 minutes, at which point the system is reported as stable. System stability is indicated via the controller's front panel status LED, the READY digital output signal (available on the rear on the unit), and through the RS-232 communication port.

After the detector has reached thermal stability (with constant carrier gas flow), the filament channels of the detector achieve a low-drift, low-noise operational state. Measurements of the energy states of the detector filaments are available from the controller's three analog output channels. Output Channels A and B reflect the energy state of filaments A and B, respectively. The third analog output, Channel AB, is a referenced output derived from the difference of the two filament energy states (i.e., Channel A – Channel B).

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Each of these analog signals has a very narrow bandwidth, and is generated as an offset from a reference voltage. The level of this reference voltage varies, as it is dependent upon system temperature, filament power, environment, carrier gas, etc. Because of this variance, the output channels must occasionally be adjusted so that their signals are within the output limits of the unit. This adjustment process, which tunes the reference voltage until the differential output signal level matches the desired voltage, is often referred to as “zeroing” (although the process can actually be used to adjust the output levels to values other than 0 V).

The zeroing routine should be initiated before each chromatographic test to correct for any signal drift between tests. The routine should not be executed until the detector temperature has had adequate time to settle and stabilize. If the signal is currently out of range, the routine may take up to 10 seconds to complete. However, once the channel is within the control band, the adjustment routine should complete within 2 seconds.

Once the TCD-3 system has been properly plumbed, the detector has reached thermal stability, and the output channels have been “zeroed”, the TCD-3 system is ready for use.

1.4. Safety Notes and Information

1.4.1. Symbol Definitions

SYMBOL	DESCRIPTION
	ATTENTION: General warning. Caution is necessary when operating the device or control close to where the symbol is placed, or to indicate that the current situation needs operator awareness or operator action in order to avoid undesirable consequences. The manual must be consulted in all cases where this symbol is marked on the device.
	HOT SURFACE: The surface of the detector body may be hot while in operation (possibly in excess of 250°C). Caution should be observed.
	PROTECTIVE EARTH: This internal connection provides protection against electric shock from mains voltages and should not be removed.

1.4.2. Installation Category

This equipment has been designed for installation (overvoltage) II, pollution degree 2. It has been approved for use only in heavy industrial environments and may not be used in the residential, commercial, or light-industrial environment.

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1.4.3. Safety

This instrument has been designed and tested in accordance with the product safety standard, EN61010. It has left the factory in a safe condition. This instruction manual contains important information and warnings which must be followed by the user to ensure safe operation and to retain the instrument in a safe condition. The case, chassis, and measuring terminals are connected to the protective earth contact of the power inlet. The instrument operates with a DC power cord having a protective earthing shield conductor. This shield ring must be connected to an earth ground, either by direct connection or through the external power supply module. Any such power supply module must have a mains line plug inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by the use of an extension cord without a protective conductor. Use only with an approved mains supply cord having a rating of 2A, 250V, or greater. Do not use this equipment in a manner not specified herein.

1.4.4. Maintenance

The exterior of the instrument should be cleaned regularly with a dusting brush. If necessary, the casing can be cleaned with a moistened cloth (99% water + 1% mild detergent). Spirit or petroleum ether can be used to remove greasy dirt. Any other cleaning agents can attack the plastic and painted surfaces.

Under no circumstances should the cleaning fluid get into the instrument. Petroleum ether is flammable, and care should be taken in its use.

The detector must be returned to the factory when filament replacement is required. Call VICI Tech Support for return authorization.

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1.5. Components of the Detector System

Components of the detector system are listed in **Table 1**. Check the contents of the package(s) to verify that everything is present. Contact the factory if anything is missing or damaged. (NOTE: Damaged shipments must remain with the original packaging for freight company inspection.)

Table 1: Components of TCD-3 System

QTY	DESCRIPTION			
1	Detector cell/oven module	with nickel-iron filaments	TCD3-NIFED	
		with tungsten-rhenium filaments	TCD3-WRED	
1	Controller unit		TCD3-C	
1*	Power supply, 120w AC/DC, 48 V		I-25850	
1*	Power supply cord	115 VAC	I-W-17600	
		230 VAC	I-W-17850	
3	Analog output cables		I-25847	
1	RS-232 cable		I-W-RS232-4K	
1	Digital I/O connector		I-T1790124	
1	Fittings kit		TCD3-KIT	
	<i>Includes:</i>	2	1/16" zero dead volume union	ZU1C
		2	1/16" zero dead volume nut	ZN1
		2	1/16" zero dead volume ferrule	ZF1
		2	Fused silica adapter for 0.8 mm OD capillary column	FS1R.8

*Models TCD3-NIFED-X and TCD3-WRED-X include no power supply or power cord. They ship with a 48V unterminated power cable with plug, product number I-W-R7B-4.

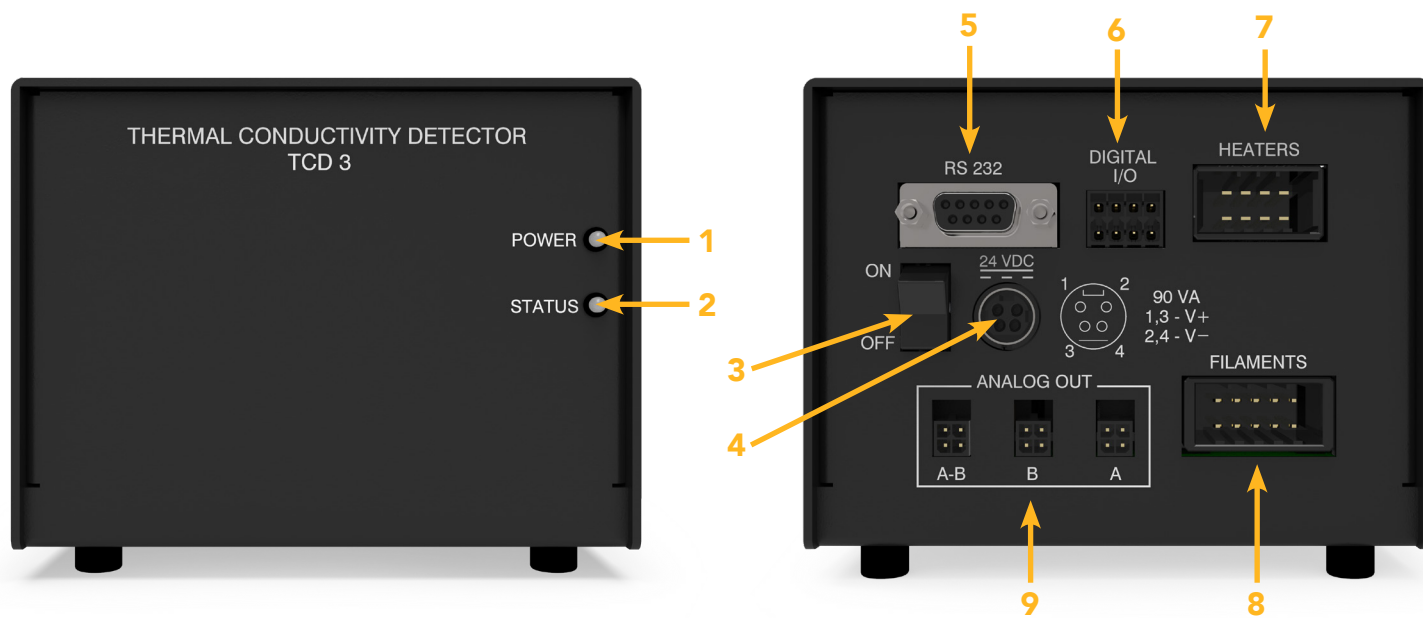
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Figure 2: Components of TCD-3 system



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Figure 3: Front (left) and Rear (right) panels of the TCD-3 controller



1.6. Description of Controls, Indicators, and Connectors

Front Panel Indicators

1. **POWER** indicator
This green LED will be illuminated when power is connected to the unit and the power switch is on (rear panel).
2. **STATUS** indicator
This LED conveys the status of the TCD-3 system. Table 2 lists the various states indicated by this LED.

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Table 2: Status Indicator Explanations

LED MODE	EXPLANATION
Steady green	Detector temperature stable; system ready
Slow green blink	Detector cell temperature not yet stable
Red with green flash	BAUD rate change initiated; waiting for user confirmation
Red/green toggle (fast)	Parameter save in progress (do not power-off unit)
Fast red blink	Detector cell not found
Fast green blink	Auto-zeroing operation in progress
Red/green alternating	Auto-zeroing function failure
Green with red flash	Output channel(s) off scale
Steady red	Hardware initialization failure



CAUTION: Make sure the ON/OFF switch is in the OFF position when making power, heater, and filament connections. Hot-plugging these system elements is not recommended.

3. ON/OFF switch

This is the main power switch for the TCD-3 system. When the switch is in the OFF position, there is no power to the TCD-3 electronics, detector filaments, and heater.

4. 48 VDC connector

The 4' cable from the 48 VDC power supply is plugged into this connector.

5. RS 232 connector

Connect the controller to a PC via a standard DE9 extension cable (M-F). This DE-9F connector conforms to EIA-232C standard pin-outs for a DCE device.

6. DIGITAL I/O connector

This connector provides three digital inputs and one digital output signal. Refer to "Appendix A: Digital I/O Control" on page 39.

7. HEATERS connector

The heater cable from the detector mates with this connector.

8. FILAMENTS connector

The filaments cable from the detector mates with this connector.

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9. ANALOG OUT connector

This is normally connected to a data acquisition system or other recording device. For convenience, full-scale 0 - 1V and 0 - 10V outputs are provided, with an internal signal reference (-) at zero volts. For best noise performance, the shield (earth) and signal reference (-) should not be connected together.

1.7. Hardware Specifications

Table 3: Hardware Specifications

PARAMETER	MIN.	NOMINAL	MAX.	UNITS	NOTES
Controller input voltage	44	48	52	V	
Controller input current	0.1		1.5	A	Vin = 48 Vdc
Input fusing		2.0		A	Internal fuse, time delay type
Operating temperature	-10		40	°C	
Storage temperature	-25		70	°C	
Humidity	0		95	%	Non-condensing
Controller weight		1.4		lbs.	Without cables
Detector cell weight		3.0		lbs.	Standard configuration
Detector temperature	ambi- ent		300	°C	
Detector pressure	1		1000	psi	Working pressure
Heater power			60	W	Vin = 48 Vdc
Analog output (1V)	-1.2		1.2	V	1V output signal
Analog output (10V)	-12		12	V	10V output signal
Analog out impedance		100		Ω	
Digital inputs	-0.5		5.5	V	Internal 4.7k Ω pull-up to +5V
Digital input, logic high	2.0			V	Minimum logic-high threshold
Digital input, logic low			0.8	V	Maximum logic-high threshold
Digital output, voltage	-50		50	V	Open contacts; maximum volts
Digital output, current	-0.5		0.5	A	Continuous current rating

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2. SYSTEM REQUIREMENTS

2.1. Components Not Included with the Detector System

- Carrier gas (99.999% purity is recommended)
- Ultra high purity grade gas pressure regulator with stainless steel diaphragm (recommended)
- Any special adapters required for connection to the gas regulator
- Flow measuring device

2.2. PC System Requirements

Configuration of the TCD-3 system requires a PC or similar device with a dedicated asynchronous serial port. This port will operate at 115200 BAUD (8N1).

If the unit will be configured using the console interface, the PC must have terminal emulation software installed. There are numerous such emulators available for free on the internet.

If the Graphical User Interface is to be used for system configuration, the PC must be running the Windows 7/8/10 operating system.

2.3. System Purity

Since detection of low concentrations depends in part on the purity of the carrier, the purest carrier available must be used in order to achieve the lowest possible detection limit. To maintain carrier purity, extra care must be taken to assure that the delivery system is clean and free of leaks. Use stainless steel tubing (cleaned to removed manufacturing solvents) instead of nylon or PTFE tubing, which can diffuse contaminants into the carrier.

2.4. GC Column Selection

Cell volume has been minimized to accommodate capillary, megabore, and micropacked columns, and to optimize the sensitivity of the detector at low flow rates. However, standard packed columns may also be used if sensitivity is not an issue.

2.5. Recommended Carrier Gas Purifiers

The Valco Helium Purifier (product number HP2) and Nitrogen Purifier (product number NP2), which utilize a rare earth gettering alloy to effectively remove contaminants, are recommended for ppm level analysis of permanent gases. For other applications, economical and convenient VICI Metronics purifiers are appropriate. Order the P300-1 for nitrogen, P200-1 for hydrogen, or P100-1 for helium and other inert carrier gases.

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2.6. Carrier Gas Selection

The detector's response to a component is based upon the difference between the thermal conductivities of the component and the carrier gas; the greater the difference, the greater the response. The table below shows thermal conductivities for a variety of light gases, given in units of milliwatts per meter per degree Kelvin. The values listed are given for test conditions at 300°K and 100 kPa.

As an example, note in the table that the thermal conductivity of hydrogen is 186.6 and helium is 155.7, while nitrogen is only 26.0. Argon is even lower, at 17.7. Since the largest difference in thermal conductivity yields the best response, detection of small amounts of hydrogen is better done with argon or nitrogen carrier than with helium.

However, while nitrogen as a carrier yields excellent response to hydrogen, the response to oxygen and carbon dioxide is diminished compared to the levels that could be achieved with helium or hydrogen. Argon would yield poor response to carbon dioxide and water, but would be adequate for other components.

There is no absolute "best choice" of carrier gas. For any situation, the choice must take into account all of the parameters involved: column characteristics, components of interest and their concentrations, safety considerations, carrier cost, etc.

Table 4: Thermal Conductivities of Common Gases

GAS ¹	THERMAL CONDUCTIVITY (mW/m/°K)
Hydrogen	186.6
Helium	155.7
Neon	49.4
Methane	34.4
Oxygen	26.5
Air	26.4
Nitrogen	26.0
Carbon Monoxide	25.0
Water	18.6
Argon	17.7
Carbon Dioxide	16.8

¹ Harvey, Allan H. & Huber, Marcia L., 06 June 2011, *Thermal Conductivity of Gasses*, CRC Handbook of Chemistry and Physics, 92nd Ed., 6-240, www.nist.gov/node/599951

3. INSTALLATION

The detector is usually mounted on top of the GC column oven. The cord for the TCD controller is 3 m (10') long (AC cord + desktop supply + power cord); the detector cable and the signal output are 1.2 m (4') long.

3.1. General Precautions

- Do not turn the unit on until the carrier gas is flowing through the detector.

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- Do not shut off or disconnect the carrier gas when the detector is hot, even if the unit is turned off. Turn off the power switch on the back of the controller and allow the detector to cool down naturally before disconnecting or shutting off the carrier gas.
- Position the controller unit where the power switch on the rear panel can be reached easily

3.2. Component Dimensions

Figure 4: TCD-3 Controller Dimensions

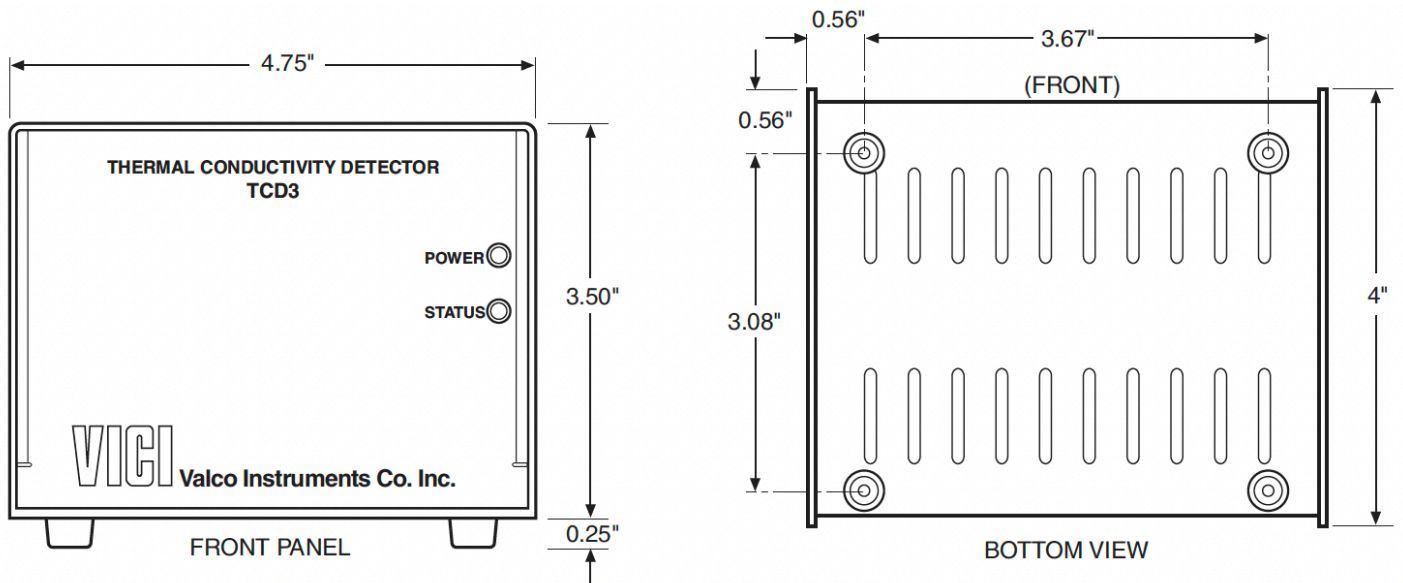
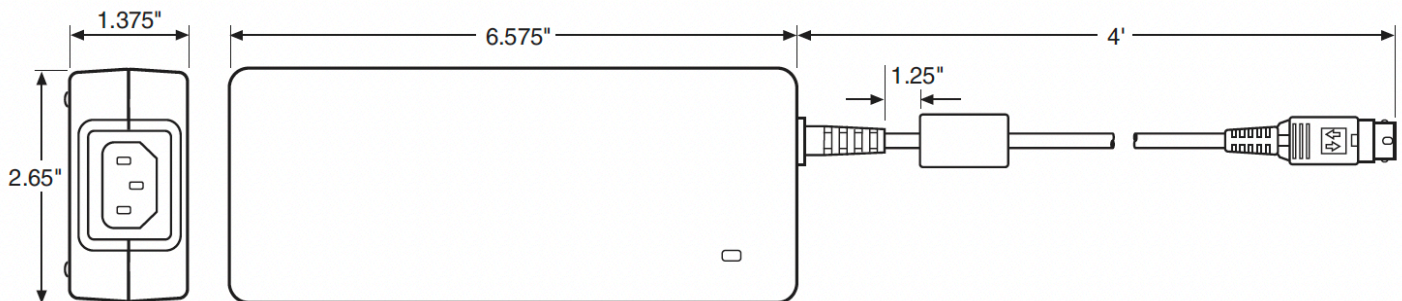
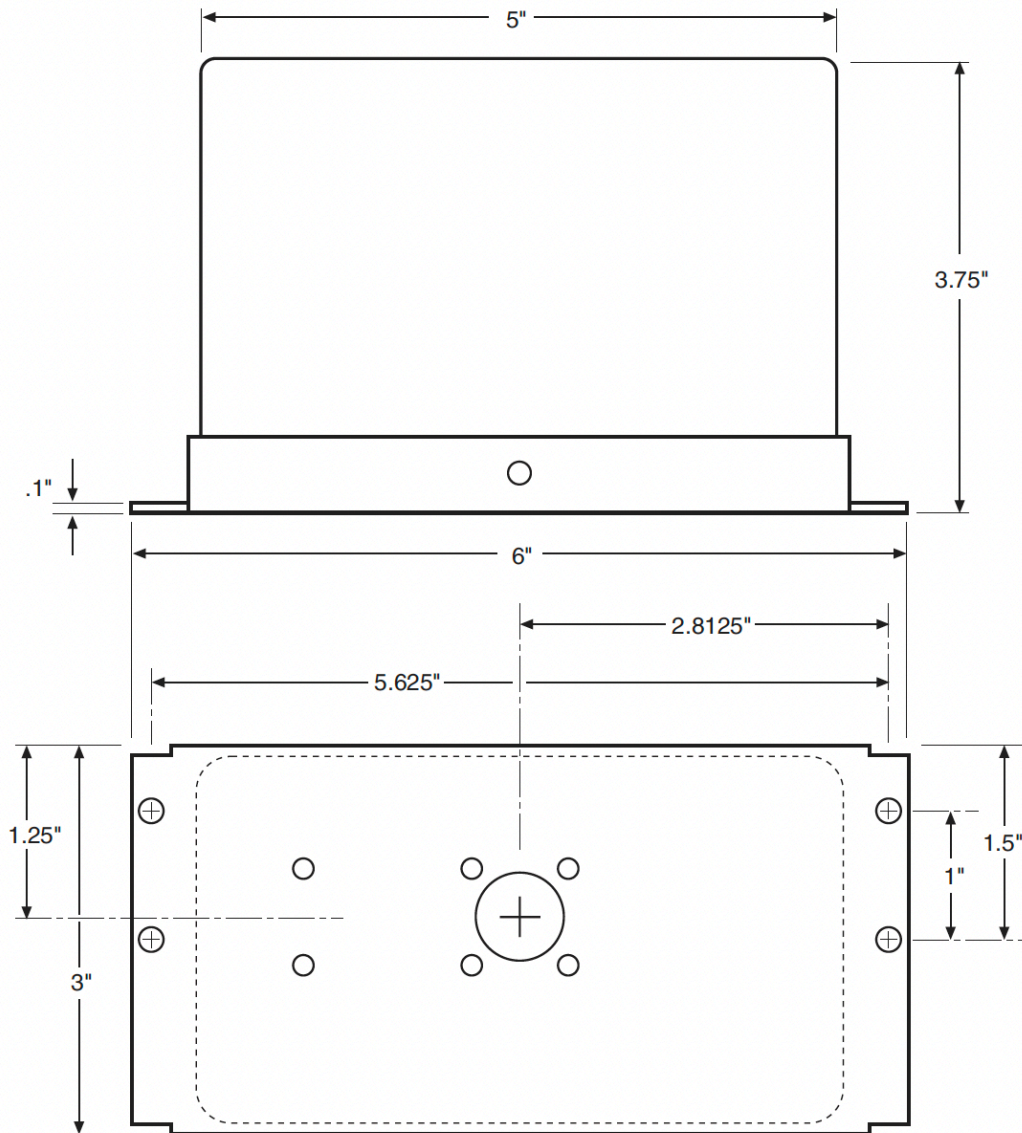


Figure 5: TCD-3 Power Supply Dimensions



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Figure 6: TCD-3 detector cell/oven module dimensions



3.3. Detector Mounting

3.3.1. Vertical Mounting

The detector has no particular orientation requirements, but it should have adequate thermal isolation from the column oven and injection port. Most GCs have an existing opening which will allow the TCD-3 detector module to sit vertically on top of the column oven with the column inlet extending into the oven. If an existing detector is being replaced, the TCD-3 can usually be set in its place. If not, use a drill or chassis punch to make a hole of the proper size, and set the detector in position.

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While trying to match base plate mounting holes to every GC on the market is impractical, the mounting holes for the TCD-3 have been located so that at least two of them should align with existing holes on the GC (**Figure 6**). Orient the detector to allow for easy cable and gas connections. The inlet lines installed into the detector must enter the column oven and permit column connection. Temperature loss between the column outlet and the detector should be minimized to prevent possible condensation of the sample.



CAUTION: Do not mount the detector near the column oven cool-down vents.

3.3.2. Horizontal Mounting

Some older GCs have access to the column oven through the side of the GC. This does not present a problem as far as operation of the TCD-3 is concerned. Drill a hole at the appropriate location, orient the detector for convenient connection, and mark the position of the mounting holes. Drill the mounting holes and secure the detector to the side of the GC with four sheet metal screws (not supplied).

3.4. Gas Connections

When making gas connections, remember these three points:

- All surfaces that contact the gas stream must be glass or stainless steel
- Do not use copper tubing or brass fittings
- All tubes must be thoroughly cleaned and baked before use.

The instructions below assume that the detector carrier will be supplied from a nearby cylinder. Since the distance from the carrier supply to the GC will vary from installation to installation, tubing is not supplied for the supply-to-GC connection. Consult the VICI catalog or vici.com for any fittings and tubing required.

The figures on the next page illustrate gas connections for a typical TCD-3 detector system in unreferenced (**Figure 7**) and referenced (**Figure 8**) modes.

3.5. Installing and Purging the Gas Regulator

1. Make sure the on/off valve on the carrier gas cylinder is completely closed. Screw the CGA fitting nut of the regulator into the gas cylinder. Go beyond finger-tight, but do not tighten the nut all the way – some leakage is required for the purging operation.
2. Turn the output pressure regulating knob completely counterclockwise.
3. Open the cylinder on/off valve slightly and quickly close it again.
4. Adjust the tightness of the regulator connecting nut to allow a pressure reduction of ~690 kPa/sec (100 psi/sec). With a new bottle, the gauge should start out at about 14 MPa (2000 psi).
5. When the pressure drops into the 1.4 - 3.4 MPa (200 - 500 psi) range, open the cylinder on/off valve slightly and quickly close it again.

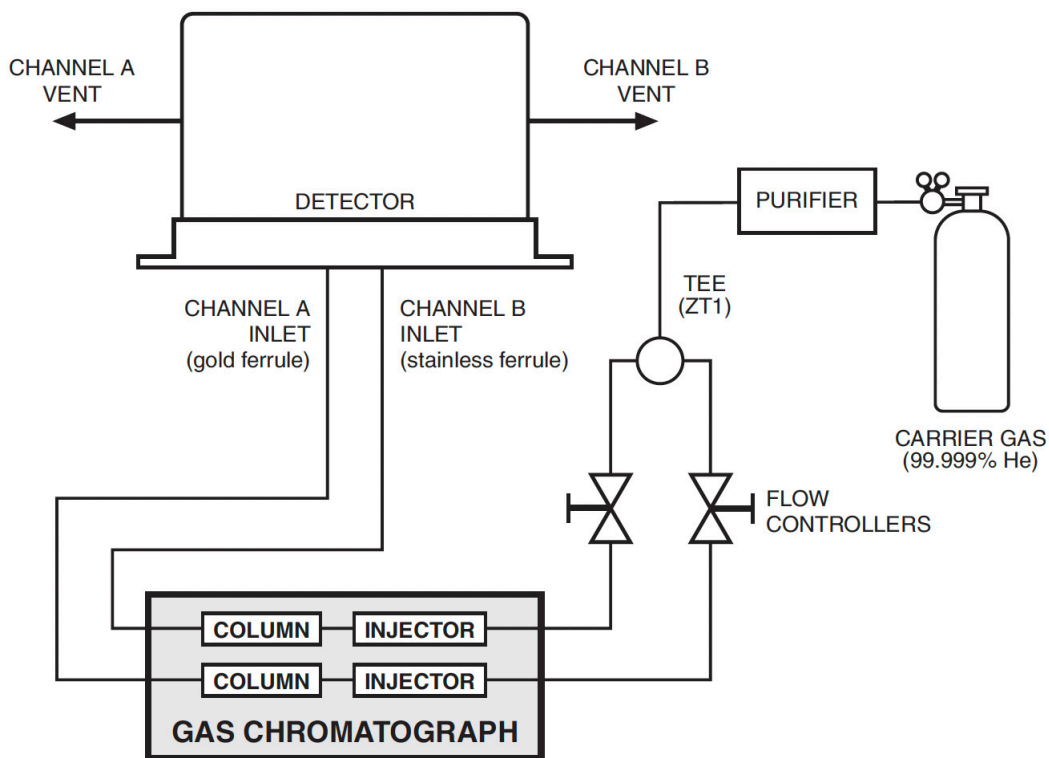
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- Repeat Step 5 eight or ten times to be certain that all the air is purged. On the final purge, tighten the regulator connecting nut very securely as the pressure approaches the 2.1 - 3.4 MPa (300 - 500 psi) range.
- Open the cylinder valve to pressurize the regulator once again, then close it and observe the high pressure gauge needle for 15 minutes. If it doesn't move, there is no critical leak on the high pressure side of the regulator.



CAUTION: Never use leak detecting fluids on any part of the TCD-3 system.

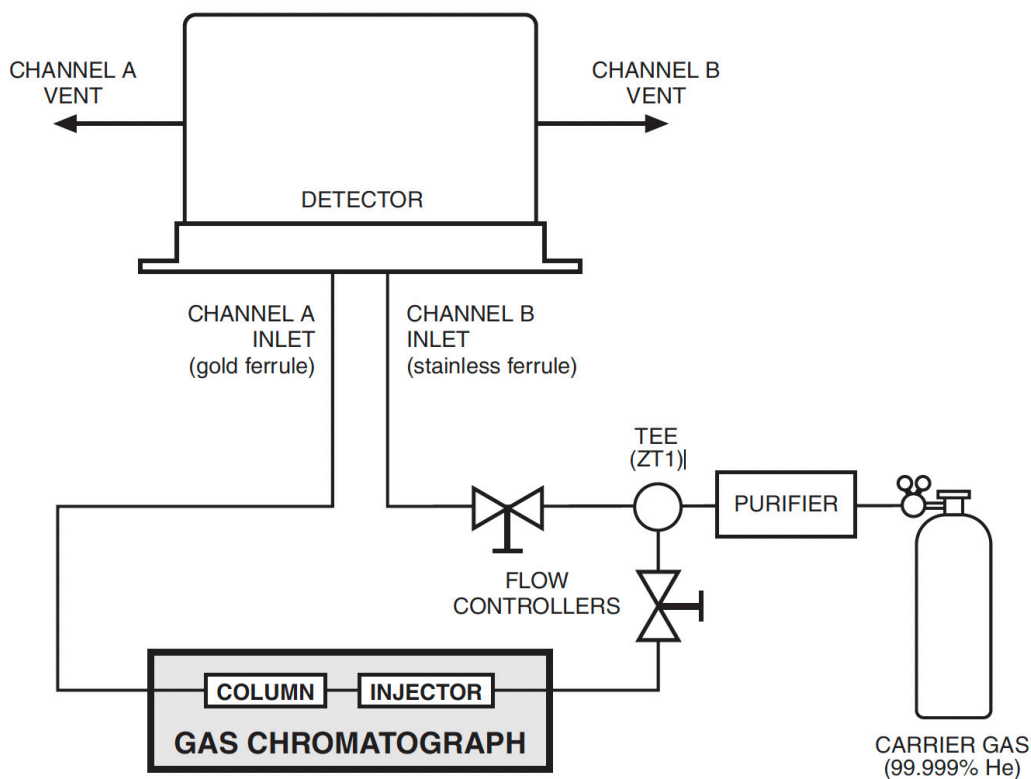
Figure 7: TCD-3 plumbed for operation in unreferenced mode



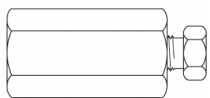
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Figure 8: TCD-3 plumbed for operation in referenced mode (A-B)



3.6. Installing and Purging a Purifier



EZR21

1. If the pressure regulator has a 1/8" male cone-type outlet port, install a Valco 1/8" external to 1/16" internal reducer (EZR21); if it has a 1/4" male cone-type outlet port, install a Valco 1/4" external to 1/16" internal reducer (EZR41). For other regulator outlet fittings, a wide variety of Valco adapters are available.
2. While keeping the outlet tube capped, remove the cap from the inlet tube of the Valco helium purifier and insert the tube fitting into the 1/16" reducer port. Use a 1/4" wrench to turn the nut one-quarter turn past the point where the ferrule first starts to grab the tubing. Do not remove the fitting. When made up properly, it should be leak-tight.
3. Turn the output pressure regulating knob clockwise until the gauge registers 345 KPA (50 psi).
4. Allow five minutes for equilibration, then turn the regulating knob all the way counterclockwise.
5. Observe the needle of the output pressure gauge for 15 minutes. There will be a slight initial drop, but if

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it doesn't move after that, consider that all the connections are tight.

6. If necessary, use an electronic leak detector to locate any leaks. If a leak detector is not available, tighten all the fittings (including the output pressure gauge), and repressurize the system for another test.
7. Uncap the outlet tube of the purifier and purge the system for 15 to 30 minutes at 60 to 80 mL/min to eliminate air from the purifier getter material.

3.7. Column Connection



To prevent detector contamination, it is strongly recommended that the column be disconnected from the detector during column bake-out procedures.

3.7.1. Referenced Mode

In the referenced mode, the column is connected to the Channel A inlet, and the carrier gas stream is split and used as a reference in channel B. The gas flow rate from both channels must be the same (flow balanced). This mode of operation provides the best baseline stability and the least background noise.

3.7.2. Unreferenced Mode

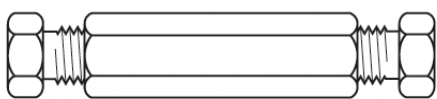
In the unreferenced mode, Channels A and B are used independently. One column connects to the Channel A inlet, and the other to Channel B. The carrier gas must be the same for both channels. It is also possible to use only one channel with the other capped off, as long as the filament temperature control of the unused channel is set to minimum.

The unreferenced mode has certain limitations. There is a possibility of detector cross-talk (interference) if compound concentrations exceed 1%. Also, baseline drift and background noise are greater compared with the referenced mode.

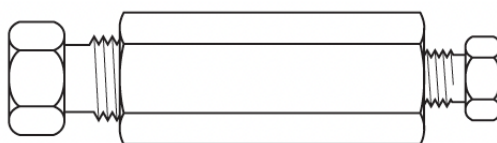
To make column connection as convenient as possible, each TCD is shipped with two Valco 1/16" unions (Product No. B-ZU1C), with nuts and ferrules (Product numbers ZN1 and ZF1). Also included are two fused silica adapters (FSR1.8) for use with .53 mm ID wide bore capillary columns (.8 mm OD). Refer to the information below to determine the correct Valco fitting for use with other columns.

3.7.3. Packed Columns

A 1/16" packed column requires only the ZU1C which comes with the TCD3. For 1/8" columns, a ZRU21 fitting is required.



ZU1C
Used with 1/16" column



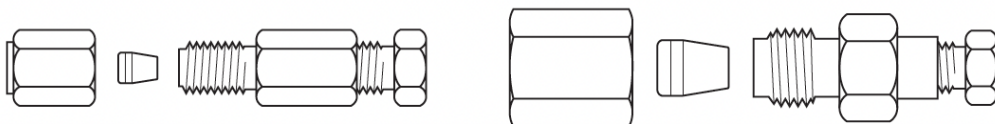
ZRU21
Used with 1/8" column

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3.7.4. Packed Columns with Swagelok®-type Female Nut

The connection of these columns is similar to that for standard packed columns, but requires a union which adapts the female nut to the Valco fitting.

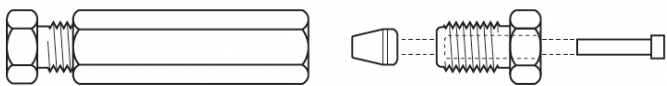


EZU1
Used with 1/16" column

EZRU21
Used with 1/8" column

3.7.5. Capillary Columns

Connection of these columns requires the use of the ZU1C with the appropriate fused silica adapter. For a .53 mm ID x .8 mm OD column, use the FSR1.8 supplied with the TCD. For other sizes, use this table to determine the proper adapter:



ZU1C
with fused silica adapter

COLUMN SIZE	ADAPTER REQUIRED
.32 mm ID x .5 mm OD	FS1R.5
.25 mm ID x .4 mm OD	FS1R.4
< .2 mm ID	FS1R.2

3.8. Testing for Leaks

It is critical for the system to be leak-tight, and an additional check at this point can prevent issues later on. To test for leaks:

1. Ensure that both outlets are capped.
2. Pressurize the entire system with helium to 138 kPa (20 psi).
3. If the system does not hold pressure, check all the fittings with an electronic helium leak detector. DO NOT use leak detecting liquids.

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3.9. Cable Connections



Before connecting the any detector cables to the control module, make sure that the control module power cord is unplugged and the TCD3 controller power switch is off. Hot-plugging system elements is not recommended.

NOTE: The HEATER and FILAMENTS connectors carry live voltages, and should only be used with equipment having no accessible live parts

3.9.1. Heater and Filament Connections

The heater and filament connections from the detector to the rear panel of the controller are made via two cables. (Figure 8) Cable functions are clearly marked on the detector, as are the connectors are the controller. After making sure that the controller power cord is not plugged in, connect the cables to the appropriate connectors on the control module. The cable connectors should be inserted into the controller sockets until they latch securely into place. Pin assignments are indicated below.

3.9.2. Data Output Cable(s)

Connect the data output cable(s). The A / B / A-B outputs are typically used with an integrator or PC-based data acquisition system. Polarities and full scale range are indicated in Figure 8. Set the recorder (DAQ) for the same voltage scale.

3.9.3. Serial Data Extension Cable

The TCD-3 connects to a PC/laptop via a RS-232C connection. The provided DE-9F port on the rear panel of the TCD3-C unit uses industry standard (EIA-232-C) pin-outs for a DCE device. Connect this port to a standard PC serial port using a standard RS-232C serial data extension cable (male to female).

3.9.4. Digital I/O Cable (optional)

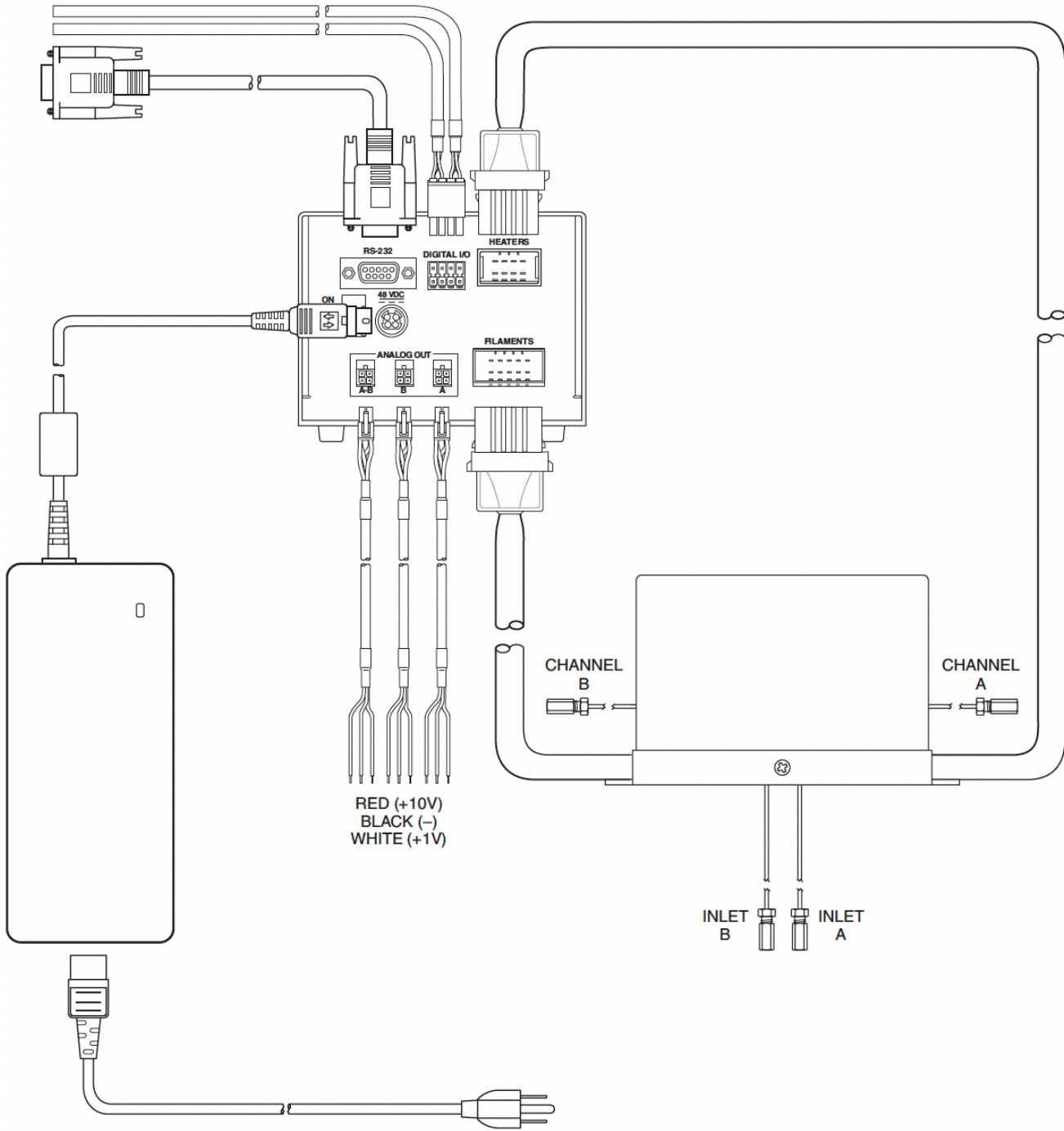
In addition to the serial communication port described above, the TCD-3 controller also provides digital signals for monitoring and control of the system. Refer to "Digital I/O Control" on page 30.

3.9.5. Power Cable

Plug the 4' cable from the 48 VDC power supply into the connector labeled 48VDC on the rear panel of the controller, but do not plug the power supply into the 110 or 230 VAC source.

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Figure 9: TCD-3 cable connections



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3.10. Flow Rate Settings

Since the TCD-3 is a concentration-dependent detector, the lower the flow rate through the detector, the higher the sensitivity. Column diameter will determine the optimum column flow rate.

The microvolume TCD-3 is designed for the lower flow rates typical for capillary columns, and achieves best sensitivity at rates below 10 mL/min. Since the filaments are maintained at constant temperature, the detector can be operated at extremely low flow rates (less than 0.5 mL/min) without damage to the filaments.

1. Measure the column flow at the detector's Channel A out. The optimum flow rate is in the range of 4 – 20 mL/min, with the actual rate dependent on the type of column used.
2. Measure the reference gas flow at Channel B out. It should be as close as possible to the GC column flow. Use a fixed flow restrictor or a good quality flow controller to match the carrier gas and reference gas flows.

3.11. Installing the Graphical User Interface (GUI) Software

If you prefer to program and operate the TCD-3 via console port commands instead of the GUI, refer to "Appendix B: Basic TCD Operation via Serial Commands on page 40."

A PC/laptop operating under Windows 7/8/10 is required to use the TCD-3 Graphical User Interface (GUI) program. The computer will also need a serial communication (COM) port for communication with the TCD-3 controller.

Locate the TCD-3 software installer program on the USB key included with the TCD-3 system, and run the setup.exe file. (The software may also be downloaded from the support area of VICI.com). The self-extracting installer will automatically install two programs in addition to the TCD GUI—LabView 2013 Runtime Engine and LabView VISA Runtime Engine—applications from National Instruments which are required to run the GUI.

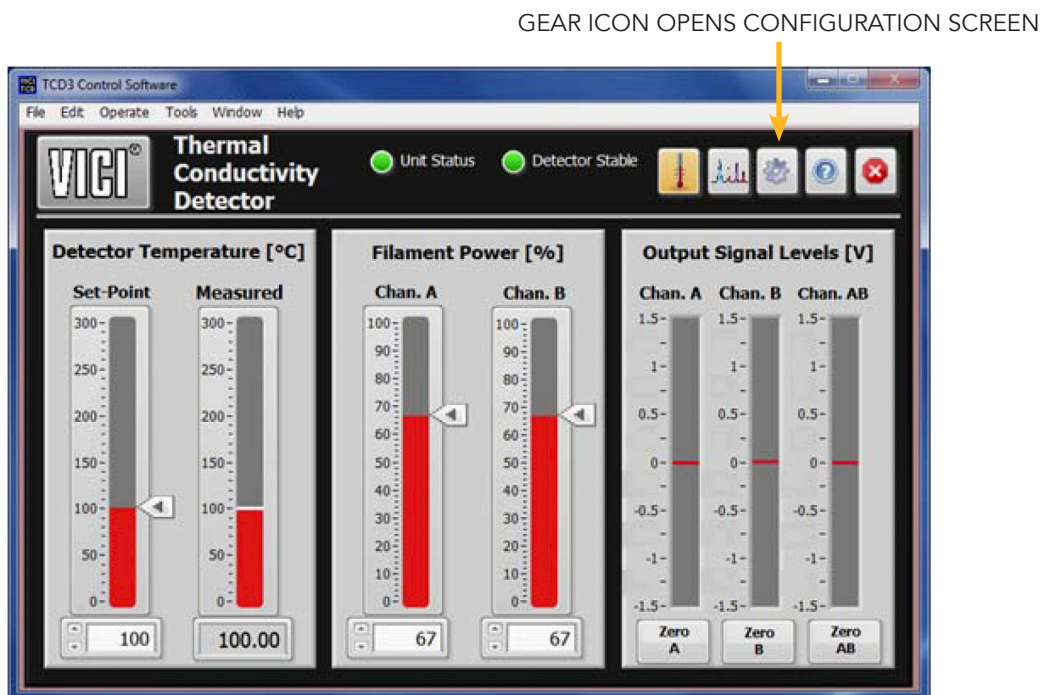
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3.12. Establishing Communication

1. With carrier gas still flowing, turn on the TCD controller with the on/off switch on the rear panel.
2. Find TCD-3 Control GUI on the Windows Start menu and click to open it. After the splash screen, the Control screen (**Figure 10**) will appear.

Figure 10: Control Screen

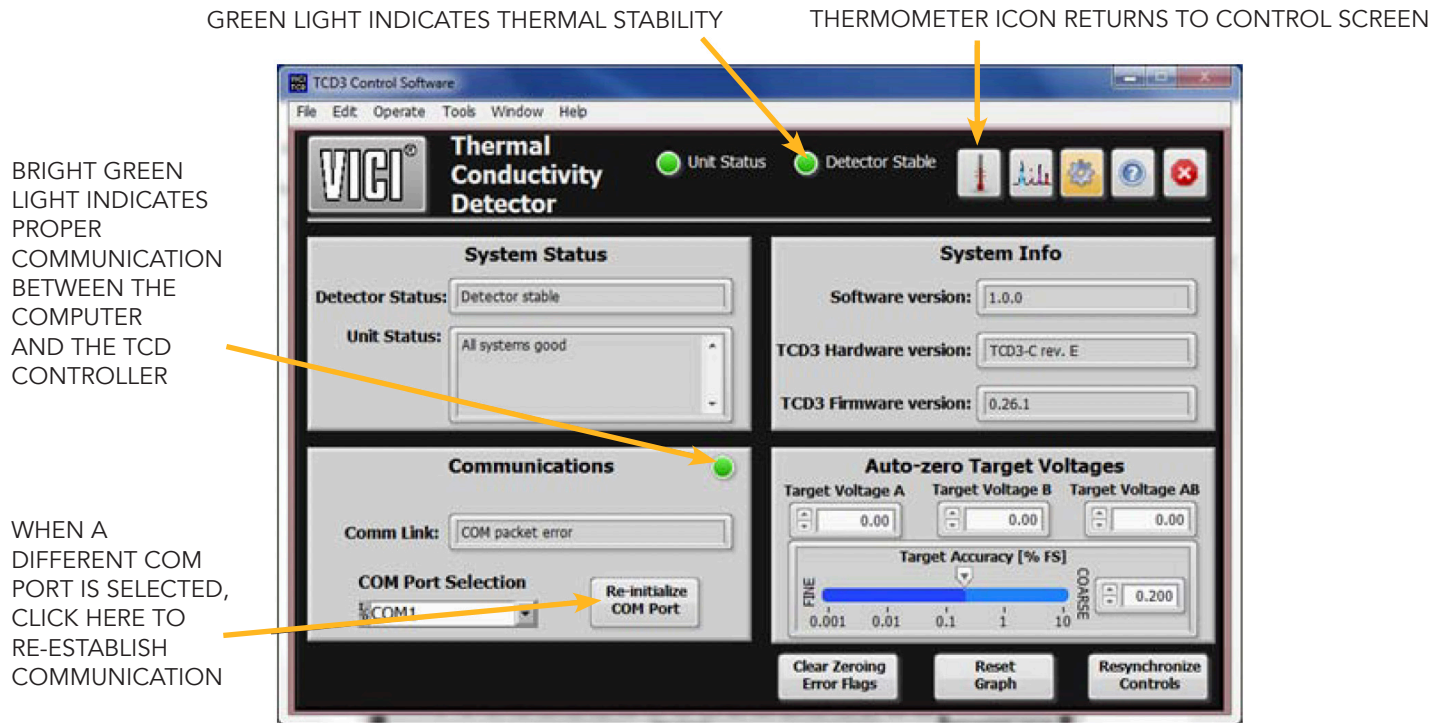


3. Once the flows have been established, connect the 48VDC power supply to the TCD controller unit, plug it into an appropriate source, and turn the power on via the rear panel switch.

In the Communications box (lower left section of the Configuration screen), note the indicator at the top right of the box. A bright green light indicates that communication has been established between the unit and the computer.

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Figure 11: Configuration Screen



4. INITIAL BAKEOUT AND EQUILIBRATION

The basic procedures and temperature settings described below are for referenced mode operation, but they can also be applied to operation in the single filament or independent mode. Just make sure that both channels have the same carrier gas; for instance, do not use helium carrier in one channel and nitrogen in the other. Also be aware of the possibility of detector cross-talk when components elute from the columns in concentrations greater than 1%.

Initial Conditioning

1. On the Control screen, set the detector temperature to 220°C.
2. Also on the Control screen, set the power level of both filaments to 90%.
3. Condition the detector by allowing it to bake at these settings for at least 12 hours.

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Temperature Settings

4. After the initial bake-out period, set the detector temperature to 100°C or to the column temperature plus 30°C, whichever is higher.
5. Set the filament temperatures to at least 50°C and as much as 100°C higher than the detector temperature. Refer to Figure 11, which outlines the relationship between the filament power settings and the actual filament temperature.

Detector sensitivity increases as the temperature differential between the detector and the filaments increases; however, the lifetime of the filament decreases as its temperature increases. Thus, the detector temperature should be set as low as possible, determined by the boiling point of the highest boiling component of the sample.

6. Once all temperatures are set, allow plenty of time for the system to equilibrate, evidenced by a stable baseline. Typical equilibration time for going from a cold start-up to 130°C detector temperature is approximately five hours. Detector temperature changes take much longer to equilibrate than do filament temperature changes.

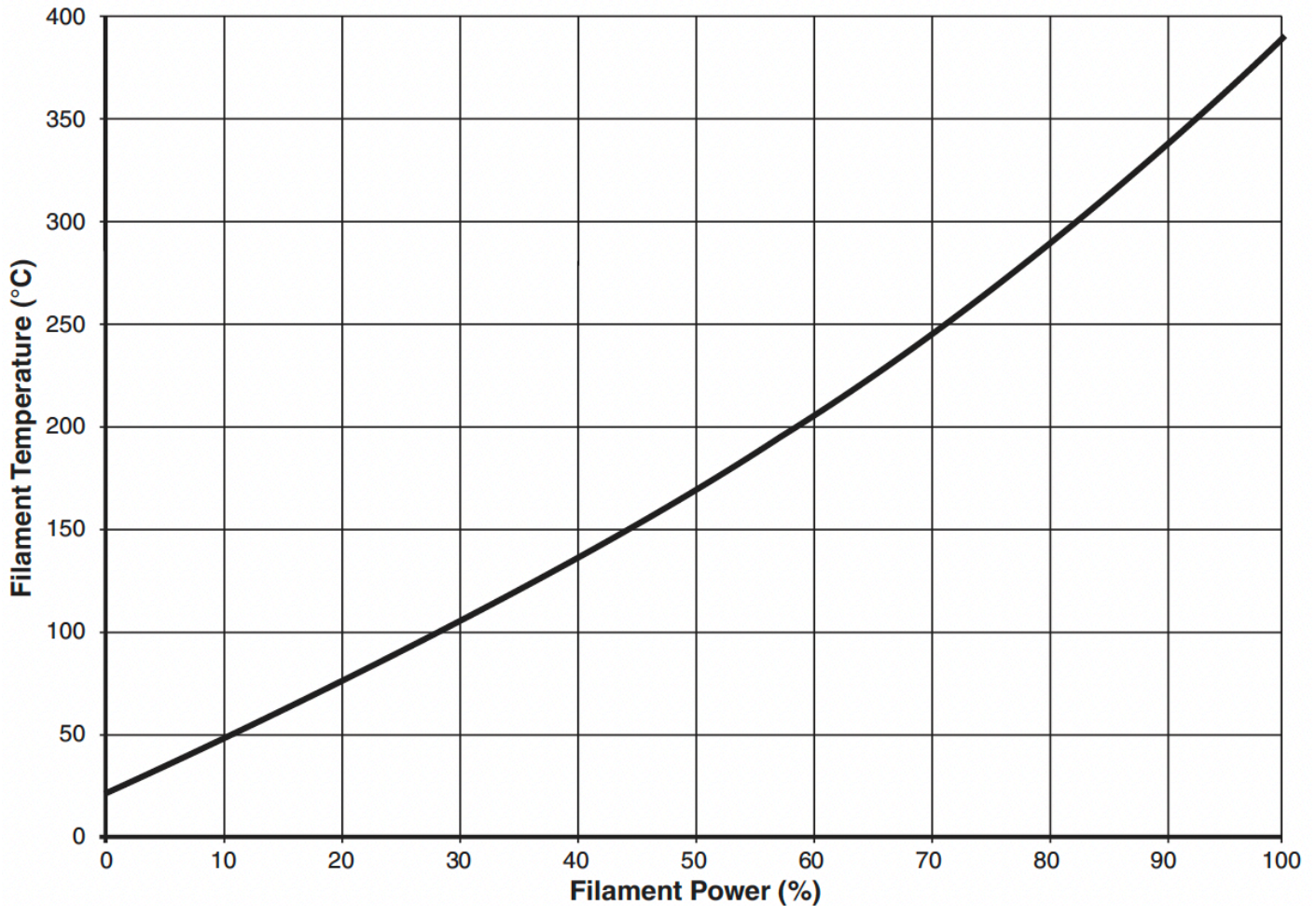
The test chromatogram accompanying your TCD was obtained under the following conditions:

SAMPLE	~100 ppm blend in helium balance
SAMPLE VOLUME	250 µL
COLUMN	10' x 1/16" x 0.040" molecular sieve 5Å micropacked
COLUMN FLOW	6 mL/min
REFERENCE FLOW	6 mL/min
COLUMN TEMPERATURE	65°C
DETECTOR TEMPERATURE	100°C
FILAMENT TEMPERATURE	230°C (a power setting of 67%)
CARRIER GAS	Helium

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Figure 12: Approximate Filament Temperature vs. Filament Power Setting



4.1. Balancing the Channels

The output channel voltage levels vary greatly depending upon factors such as temperature, filament power, gas concentration, pressure, flow rate, etc. Due to these factors, the TCD-3 output channels must be periodically leveled, which adjusts their output state to a desired voltage level (typically 0 Volts).

As the filaments are very sensitive, this adjustment can only be done within a thermally stable system, indicated by the Detector Status LED glowing bright green. Stabilization can take several hours when starting from a cold detector.

Once the system is stable, press the Zero A button to calibrate the Channel A output to the preset voltage level for that channel. When that process is complete, press the Zero B button to repeat the

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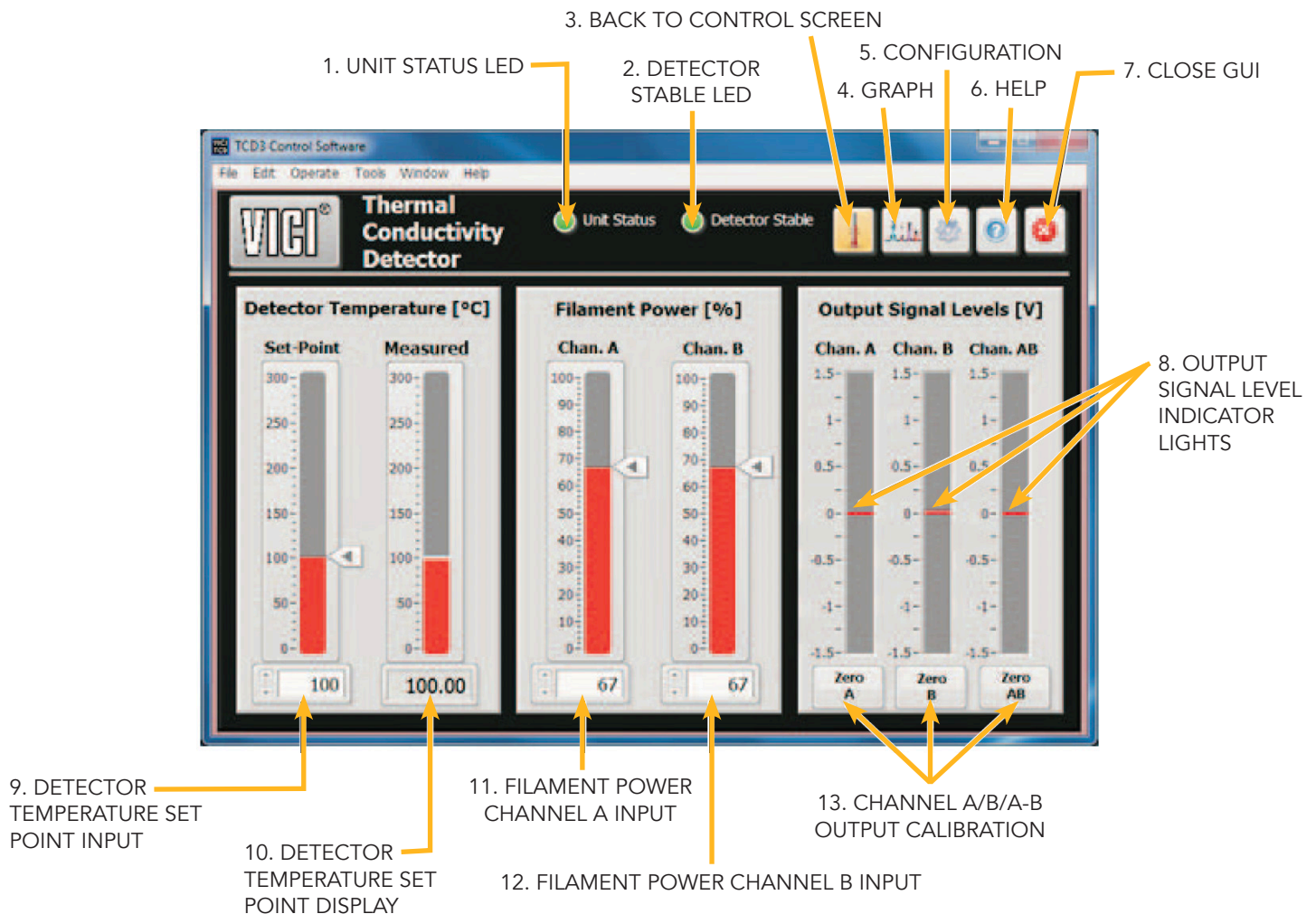
5. TCD OPERATION WITH THE GRAPHICAL USER INTERFACE

The steps of establishing communication and performing the initial bakeout and equilibration have already demonstrated some of the functionality of the GUI. A fuller explanation follows. Much of the GUI functionality is intuitive from the context, but included here in the interest of providing a complete reference.

5.1. Control Screen

Access the Control screen by pressing the thermometer icon at the top-right of the screen. Fields on this screen allow the user to change the cell temperature and the filament power levels. It also has simple controls for auto-leveling the output channels.

Figure 13: Control screen of the TCD-3 GUI



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1. UNIT STATUS LED

Table 5: Statuses of the bi-color Unit Status LED

RED	The selected COM port could not be opened.
DARK GREEN	The selected COM port opened, but cannot establish good communication with the TCD-3.
LIGHT GREEN	Communication is good, the unit is functioning correctly, and the output status is good.
YELLOW	Yellow Communications are good, but there is an issue with the unit. Typically this means that the output channels need to be adjusted. The Unit Status window on the Configuration screen will show the exact reason for the yellow indicator.

2. DETECTOR STABLE LED

A green light indicates that temperature stability has been reached after a change in the detector temperature setting, or after the detector has been turned back on after a power-down period.

3. THERMOMETER ICON

Clicking the thermometer on the Graph or Configuration screen returns the GUI to this Control screen. On the Control screen, it has no functionality.

4. GRAPH ICON

Clicking the graph opens the Graph screen (page 35).

5. GEAR ICON

Clicking the gear opens the Configuration screen (page 30).

6. QUESTION MARK ICON

Clicking the question mark opens a help section.

7. X ICON

Click to close the TCD-3 GUI program.

8. OUTPUT SIGNAL LEVEL INDICATORS

The red lines indicate the voltage level settings for each channel. These are set on the Configuration screen (page 30).

9. DETECTOR TEMPERATURE SET POINT INPUT FIELD

Enter the desired temperature set point in this box.

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10. DETECTOR TEMPERATURE SET POINT DISPLAY FIELD

This number indicates the current actual measured temperature of the detector.

11. FILAMENT POWER CHAN. A INPUT FIELD

Enter the desired Channel A filament power setting here. Refer to **Figure 11** to view the relationship between the filament power setting and the filament temperature.

12. FILAMENT POWER CHAN. B INPUT FIELD

Enter the desired Channel B filament power setting here. Refer to **Figure 11** to view the relationship between the filament power setting and the filament temperature.

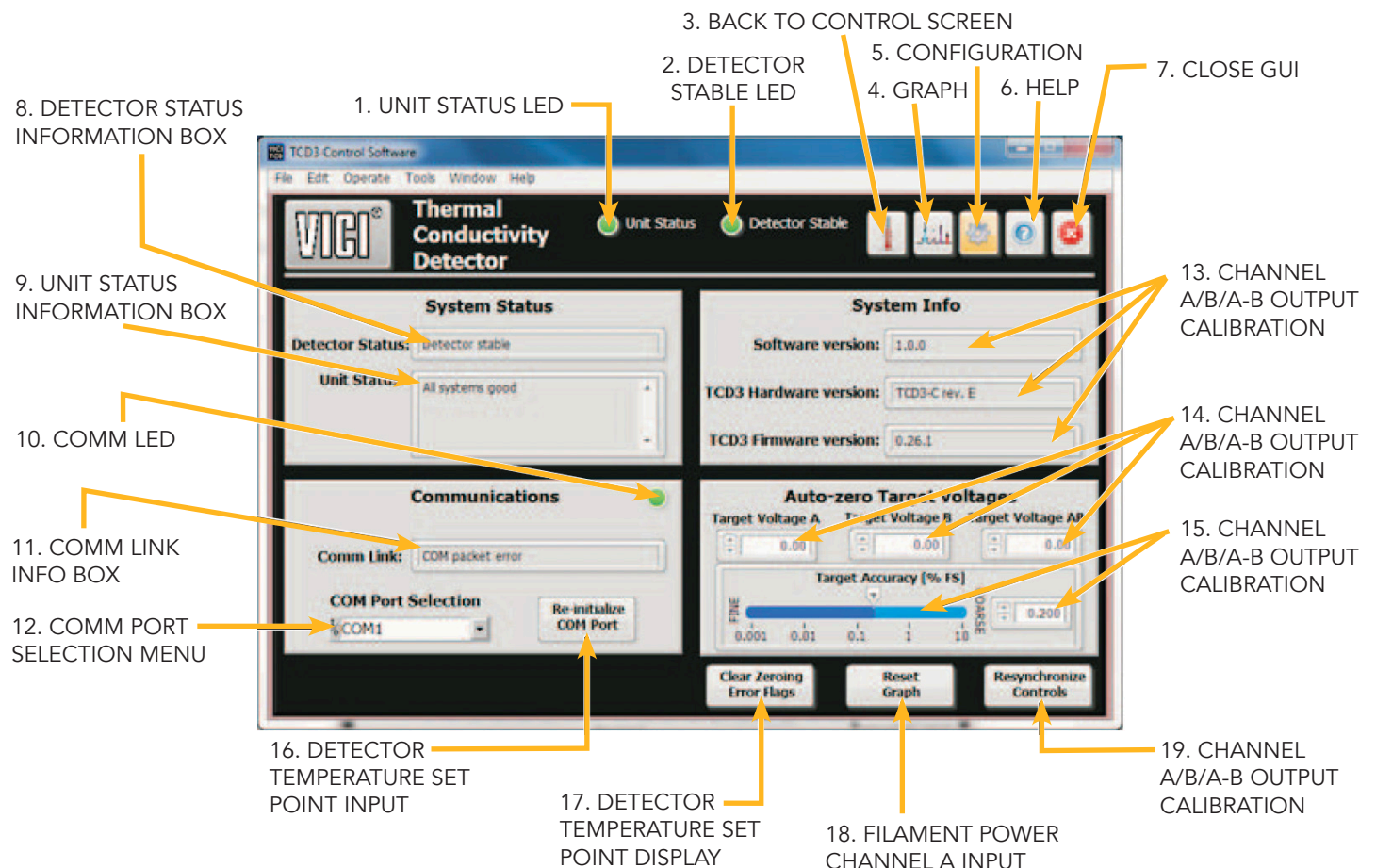
13. ZERO A, ZERO B, AND ZERO A-B BUTTONS

Click the appropriate button to calibrate the Channel A, B, or A-B output to the preset voltage level for that channel (0 volts in this illustration). Refer to "Balancing the Channels" on page 27.

5.2. Configuration Screen

Navigate to the Configuration screen (**Figure 13**) by clicking on the gear icon at the top-right of the screen.

Figure 14: Configuration screen of the TCD-3 GUI



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1. UNIT STATUS LED

The various states of this bi-color indicator, along with their explanations, are listed on page 29.

2. DETECTOR STABLE LED

A green light indicates that temperature stability has been reached after a change in the detector temperature setting, or after the detector has been turned back on after a power-down period.

3. THERMOMETER ICON

Clicking the thermometer screen returns the GUI to the Control screen (page 29).

4. GRAPH ICON

Clicking the graph opens the Graph screen (page 27).

5. GEAR ICON

Clicking the gear on the Control or Graph screen returns the GUI to this Configuration screen. On the Configuration screen, it has no functionality.

6. QUESTION MARK ICON

Clicking the question mark opens a help section.

7. X ICON

Click to close the TCD-3 GUI program.

8. DETECTOR STATUS INFO BOX

This box is empty until communication has been established. Then it will display one of the messages below:

Table 6: Possible messages in the Detector Status info box

Detector not found	The detector unit was not sensed by the TCD-3 controller. Check that the detector unit is connected to the controller, and that both cables are fully seated in their sockets.
Temperature not yet stable	The detector has not yet reached full temperature stability. Note that the minimum time to stability is 30 minutes.
Detector stable	The detector has reached thermal stability, and is ready for analysis.

9. UNIT STATUS INFO BOX

This box is empty until communication has been established. Then it will display one of the messages below:

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Table 7: Possible messages in the Unit Status info box

All systems good	The unit is working correctly, and output channels are properly adjusted.
Output channel(s) out of range	One or more of the output channels is not currently within the control band of the unit. These channels will need to be adjusted on the Control screen to be within range.
Heater output failure	The TCD controller is not able to sense the correct voltage on the detector's heater elements. This may indicate that an internal fuse has blown.
Other hardware indicators	The TCD controller is a complex mixed-signal component, with numerous devices and sub-systems. These systems are constantly monitored by the controller's core processor. If any of these devices fail to operate correctly, a message indicating the fault will be displayed here. This is unusual, and the customer should contact VICI support for assistance.

10. COMMUNICATIONS LED

A green light indicates functioning communication between the TCD controller and the computer. If it is not on, refer to "Establishing Communication" on page 24.

11. COMM LINK INFO BOX

This field indicates the current status of the communication link between the PC and the TCD controller.

Table 8: Possible messages in the Comm Link info box

Port not initialized	This is displayed before the user tries to establish the com link.
Could not open COM port	The software could not open the port. Either the selected port does not exist, or another program is currently using that port.
COM port opened	The COM port has been opened; software is attempting to communicate with the TCD-3 now.
COM packet error	Communication is established, but a bad/corrupted data packet was received. Assuming there is not a constant stream of errors, this message will only appear briefly, then the text window will return to "COM link established."
COM link established	Communication is established and working with the TCD-3 (normal operational mode).

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COM port closed

User has used the “Re-initialize COM Port” button on an open port. (This message will appear very briefly, as the program will then try to open the new port connection).

12. COM PORT SELECTION MENU

Select the serial port which the RS-232 cable from the TCD controller is connected to. TCD Operation with the Graphical User Interface 25

13. SYTEM INFO BOXES

These contain information about the hardware, software, and firmware version you are running.

14. AUTO ZERO TARGET VOLTAGES INPUT FIELDS

Since output levels are usually adjusted to 0 Volts, the phrase “Auto-Zero” is often used to describe any adjustment of the output channels to a specified DC voltage level. These three fields allow for channels to be adjusted to 0 Volts or to any value from 1.0 Volts to +1.0 Volts, with a setting for each of the output channels—A, B, and AB. Once set, these values are stored in the TCD3 controller’s memory. All subsequent auto-adjustment routines will use these values for the target voltage level.

Auto-adjustment routines on the referenced output channel AB (Channel A minus Channel B) occur in two stages. First, the Channel B output is adjusted to the selected voltage level for that channel. After Channel B is adjusted, Channel A is adjusted until the referenced output channel (AB) meets its target voltage. The value set in the Channel A target is ignored.

For example, assume the target voltages for Channels A, B, and AB are set to 0.8V, 0.5V, and 0.1V, respectively. When the Auto-adjust control for Channel AB is activated, the TCD adjusts Channel B to 0.5V. Next, to meet the target of 0.1V for Channel AB, the unit will adjust Channel A to 0.6V ($AB = A - B = 0.6 - 0.5 = 0.1$). The target of 0.8V for Channel A was ignored.

If the target voltages for Channel B and Channel AB would result in an invalid (out-of-range) value for Channel A, the command will generate an error and be ignored. For instance, if the target levels for both Channels B and AB are set to 0.8V, an auto-adjustment request for Channel AB would be impossible, as Channel A would have to be set to 1.6V to meet that requirement, and the maximum adjustment range is $\pm 1.0V$.

15. TARGET ACCURACY INDICATOR AND INPUT FIELD

Read or set the minimum accuracy required for completion of any output level adjustments initiated by clicking the Zero A, Zero B, or Zero A-B on the Control screen. The controller will adjust (and then verify) the indicated output channel to within the minimum accuracy band. The factory default for this value is 1.0%, but the valid range is from 0.001% to 10.000% of full scale.

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When using the 1V output channels (-1.0V to +1.0V output range), this accuracy range spans an actual signal voltage range of $\pm 10.0\mu\text{V}$ to $\pm 100.0\text{mV}$. Using the 10V output channels (-10.0V to +10.0V), this accuracy range spans $\pm 100.0\mu\text{V}$ to $\pm 1.0\text{V}$.

Note that the smaller the accuracy setting, the tighter the band. The adjustment may take longer with a tighter band; also, system instability has a greater impact on the adjustment routine with very tight accuracy bands.

16. RE-INITIALIZE COM PORT BUTTON

Whenever the COM port is changed in the COM Port Selection menu, this button must be clicked to re-initialize communication.

17. CLEAR ZEROING ERROR FLAGS BUTTON

Clicking this button will clear any error flags generated when an adjustment routine is unable to meet the minimum accuracy requirement setting. When a flag is generated, the Unit Status LED alternates between red and green.

The error flag can also be cleared by re-executing the adjustment routine, perhaps with a wider accuracy band. The flag will be cleared and the Unit Status LED will turn green if the routine successfully completes.

18. RESET GRAPH BUTTON

Clicking the Reset Graph button clears all history from the graph and begins a new data collection cycle.

19. RESYNCHRONIZE CONTROLS BUTTON

The Resynchronize Controls button forces the GUI software to re-read all the settings and states from the TCD-3 controller and update the software's indicators to match. This is automatically done when communication is established and should not generally be required, but the function is included as a utility.

5.3. Graph Screen

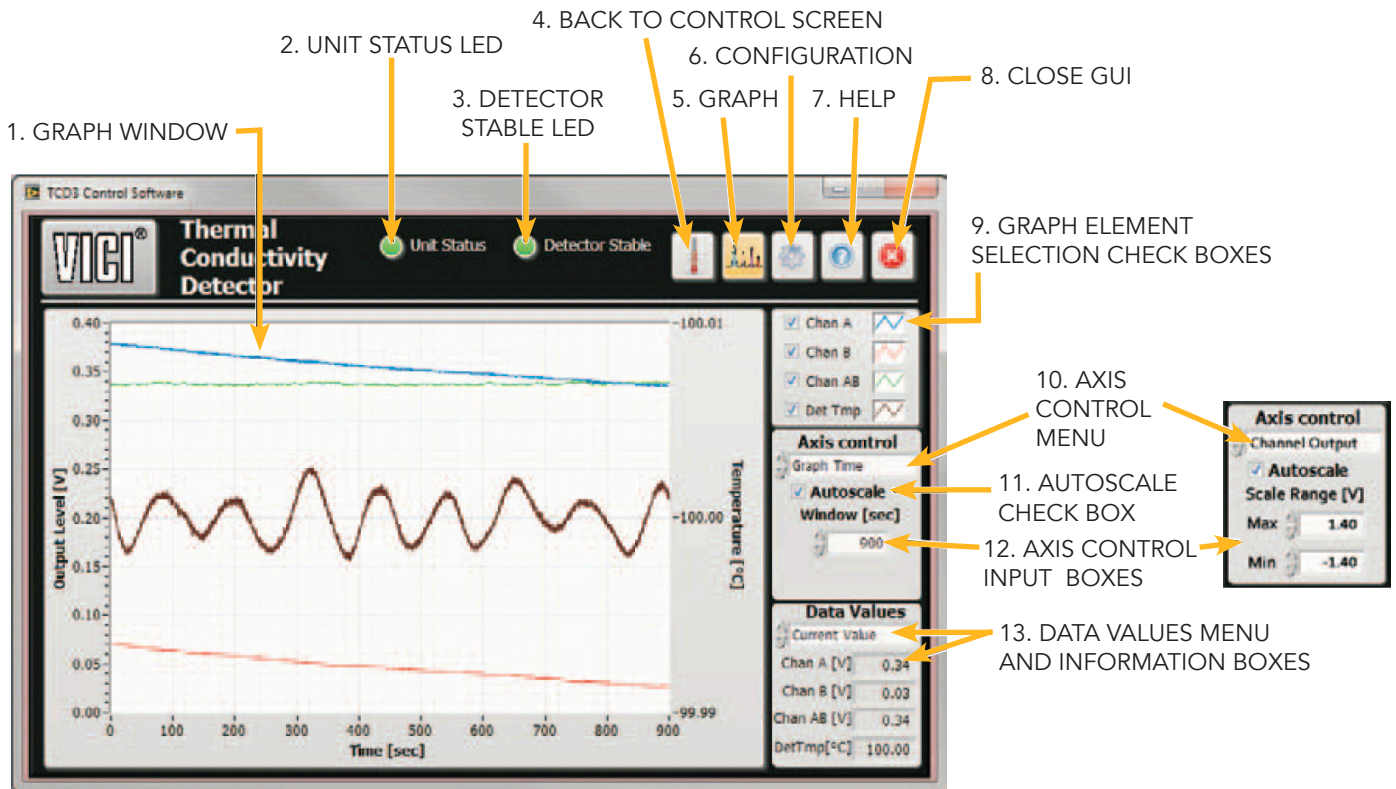
The Graph screen (Figure 14) is used to monitor the unit's runtime performance. Access this screen by clicking the graph icon at the top right of the GUI.

The graph provides a real-time indicator of detector performance. The three output channels (A, B, AB) and detector cell temperature can be monitored. If any of the output channels are observed to be out of scale (above +1V or below -1V), the channels will need to be balanced according to the instructions on page 27.

Once the system is thermally stable, and the output channels have been balanced, the graph of the output signals should look similar to the graph in Figure 15.

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Figure 15: Graph screen of the TCD3 GUI



1. GRAPH WINDOW

Displays the monitored values of the functions selected in item 9. In the example above, the graph is displaying the output levels of Channel A, Channel B, Channel A-B, and the detector temperature.

2. UNIT STATUS LED

The various states of this bi-color indicator, along with their explanations, are listed on page 28.

3. DETECTOR STABLE LED

A green light indicates that temperature stability has been reached after a change in the detector temperature setting, or after the detector has been turned back on after a power-down period.

4. THERMOMETER ICON

Clicking the thermometer screen returns the GUI to the Control screen (page 28).

5. GRAPH ICON

Clicking the graph on the Control or Configuration screen opens the Graph screen. On the Graph screen, it has no functionality.

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6. GEAR ICON

Clicking the gear screen returns the GUI to the Configuration screen.

7. QUESTION MARK ICON

Clicking the question mark opens a help section.

8. X ICON

Click to close the TCD-3 GUI program.

9. GRAPH ELEMENT SELECTION CHECK BOXES

By checking the boxes in this field, you can select which functions will be graphed. The options are as follows: output voltage levels of Channel A, Channel B, and Channel A-B, or the temperature of the detector.

10. AXIS CONTROL MENU

The three axes on the graph are "Output Channel" (vertical axis, left side), "Block Temperature" (vertical axis, right side), and "Graph time" (horizontal axis)." Select each of these in turn to enter relevant parameters in item 12. Two of the three examples are shown in the example.

11. AUTOSCALE CHECK BOX

When the Autoscale box is checked, the graph will automatically adjust the axes to best fit the data points in the window. If the box is not checked, then the graph will use the range limits as entered in the Max and Min value boxes as the axis limits for the graph.

12. AXIS CONTROL INPUT BOXES

For the "Output Channel", the range for max/min is $\pm 1.5V$. For "Block Temperature", the range is 0 to 500°C. For "Graph time", it is 0 to 2600 seconds.

13. DATA VALUES MENU AND INFO BOXES

The Data Values menu has two options: for "Current Value", the info boxes display the most recent values for the channel output voltages and detector temperature; if "Average Value" is selected, the average value of all the signals displayed on the graph is displayed (i.e., if 900 seconds of data is displayed on the graph, then these average values for channel output voltages and temperature span the most recent 900 seconds.)

6. STATUS LED STATES AND TROUBLESHOOTING

The STATUS LED on the front of the unit functions in parallel with the Unit Status LED of the GUI, and allows the system status to be monitored without a serial data link. The various states of this bi-color indicator are listed below, along with an explanation of its indicated status. The table is listed in order of priority (highest to lowest).

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Red w/green flash	<p>BAUD rate change</p> <p>If the BAUD rate setting of the serial port is changed, the TCD-3 controller waits 30 seconds for a new valid command to be received before making the BAUD change permanent. Once a valid command is received, the new BAUD rate is saved to non-volatile memory. If the 30 second window expires without a valid command being received, the controller reverts to the previous BAUD rate. No terminal message is displayed for either result. During this 30 second grace period, the LED will be red, with a green flash every half-second.</p>
Could not open COM port Red/green toggle (fast) (.125 sec flash duration))	<p>Parameter save</p> <p>When parameters are changed through the serial port interface, the TCD-3 controller saves the new settings in on-board, non-volatile memory. This process takes a few seconds, during which the status LED will quickly flash red and green. Do not power-off the unit during this time.</p>
Steady red	<p>Hardware failure</p> <p>If the TCD-3 controller cannot properly initialize its onboard hardware devices or software modules, the status LED will illuminate constant red. In this state, the unit will only operate in an unpowered mode (no heater or filament power). Please contact VICI technical support for assistance.</p>
Fast red blink	<p>Detector not found</p> <p>If the TCD-3 controller cannot detect that a TCD3-NIFED or similar detector is connected, the status LED will blink red at a fast rate. Check that the detector cables are properly connected.</p>
Fast green blink	<p>Auto-leveling in progress</p> <p>When an auto-zeroing operation is in progress, the status LED blinks green at a fast rate.</p>
Slow green blink	<p>Temperature stabilizing</p> <p>The status LED flashes green at a slow cadence (one flash every 1.5 seconds) while the detector block is being heated to the set-point temperature. From a unit power-on, this process takes a minimum of 30 minutes, but may take several hours depending on environmental conditions.</p>
Red/green alternating (.5 sec flash duration)	<p>Auto-leveling failure</p> <p>When an auto-leveling process is initiated, the TCD-3 controller attempts to adjust the selected output channel to a certain voltage level, within the required accuracy band. If the unit cannot meet these adjustment criteria within the timeout period of 30 seconds, the operation will be aborted, and the status LED will alternate red to green in 0.5 second periods. Note that this state will not be shown if the temperature is not yet stable. To reset this state, either re-run the operation or clear the error flags.</p>

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Green w/red flash	Output Channel(s) off scale If any of the output channels are currently out of range (greater than +1.2V, or less than -1.2V), the status indicator will show green, with a red flash every 0.5 seconds. When this occurs, an auto-leveling process is required.
Steady green	System ready The status LED is steady green when the detector temperature is stable, the output channels are in range, and there are no other system processes underway. The TCD-3 system is now ready for analysis.

7. MAINTENANCE

7.1. Cleaning the Enclosure

The exterior of the instrument should be cleaned regularly with a dusting brush. If necessary, the casing can be cleaned with a moistened cloth (99% water + 1% mild detergent). Spirit or petroleum ether can be used to remove greasy dirt. Any other cleaning agents can attack the plastic and painted surfaces.



Under no circumstances should the cleaning fluid get into the instrument. Petroleum ether is flammable, and care should be taken in its use.

7.2. Bakeout Procedure

Under normal conditions, the TCD-3 requires no routine maintenance. However, if the detector is exposed to chemicals which may condense or polymerize within the detector and adversely affect performance, the detector cell can be baked out at elevated temperatures (up to 300°C). Inert carrier gas flow (other than hydrogen, oxygen, or air) should be maintained during the reconditioning procedure. Filament temperature should also be increased to approximate the setpoint of the bake out temperature. If a 24 hour bake out is not sufficient to remove the contamination, the unit must be returned to the factory for disassembly and cleaning.

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8. APPENDIX A: DIGITAL I/O CONTROL

The TCD-3 controller provides digital signals for monitoring and control of the system. Note that system parameters such as detector temperature and filament power levels will still require a serial link to set. After being set, the TCD-3 can act in a stand-alone mode.

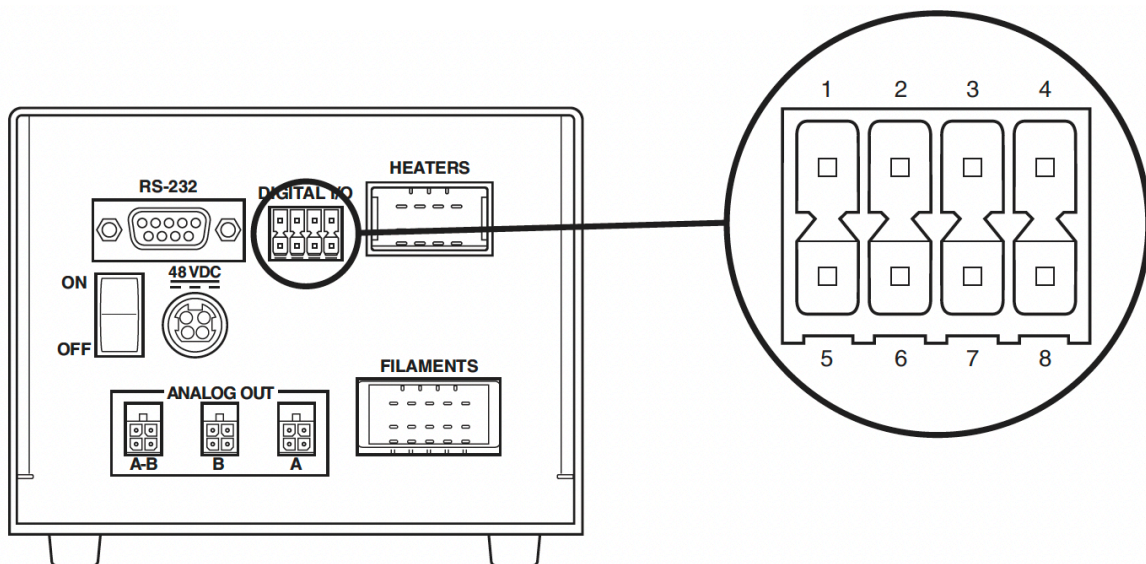
Digital IO Port

The Digital IO port is on the rear panel of the TCD-3 controller. This 8-position port (2x4) contains three digital input signals and one digital output signal.

Table 9: Digital I/O Port Pin Assignments

PIN	SIGNAL	PIN	SIGNAL
1	Digital Input 1	5	Input Signal Ground
2	Digital Input 2	6	Input Signal Ground
3	Digital Input 3	7	Input Signal Ground
4	Digital Output - Contact A	8	Digital Output - Contact B

Figure 16: Digital I/O Port Location and Pin Numbering



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Digital IO Connector

The TCD-3 system includes a removable plug for use with the Digital I/O port, equipped with attached 4-foot wire leads. The 8-position plug uses spring clamp connectors. If the need arises to change wire connections, use a small, flat-blade screwdriver to insert or remove the leads.

Digital Input Signals

The three digital inputs are provided to allow basic external control of the TCD-3 without the need of a serial link.

These 5V CMOS inputs have internal pull-up resistors (4.7k Ω) to +5V, allowing them to be driven by external digital logic, or to use a contact closure driver, such as a relay. The inputs are active-low signals, and thus require the signal to be driven to ground (0V) to trigger their associated function.

Note that the digital inputs are latched, and the signals must return to their idle state (i.e., high logic) before they can be triggered again. Additionally, re-triggering an input before the previous function initiated by that input signal has completed will have no effect.

The three digital inputs, as well as the communication port, share the same ground reference. This ground reference is electrically isolated from the rest of the TCD-3 unit.

Default Input Functions:

Digital Input 1: System Auto-adjust

When Digital Input 1 is activated (i.e., driven to Input Signal Ground), the TCD-3 will initiate a system auto-adjust routine. First, the TCD-3 controller will adjust output Channel B to its saved target voltage level (set through the COM port, using the ZB command). The TCD-3 controller will then adjust output Channel AB to its saved target voltage level (set through the COM port, using the ZR command). The process triggered from this digital input is identical to the console command ZS.

Digital Input 2: Reset Error Flags

When Digital Input 2 is activated (i.e., driven to Input Signal Ground), the TCD-3 will clear any current error flags from previous auto-adjustment attempts. This process is identical to that of the console command RF.

Digital Input 3:

Reserved for future implementation

Digital Output Signal

The TCD-3 controller has a single digital output, available across pins 4 and 8 of the Digital I/O connector. This signal is generated by an unreferenced solid-state relay contact pair. This contact can withstand up to $\pm 50V$ and 0.5A of continuous load.

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The output pair is active-low. When the output is not active, the relay contacts are open. When the output is active, the relay contacts are closed (i.e., shorted together).

Default output function

The digital output acts as a system-ready flag. For the output to activate (i.e., close contacts), several criteria must be met: the detector temperature must be stable, no auto-adjustments may be in progress, and all output channels must be in operational range.

9. Appendix B: Basic TCD Operation via Serial Commands

NOTE: For more thorough documentation of the serial control possibilities designed into the TCD-3 controller, contact VICI tech support.

Establishing Serial Communication

Serial communication must be established with the TCD-3 controller unit to set system parameters, including detector temperature and filament power levels. The interface is available by means of a RS-232C link. Once established, the serial communications link can be used either through a direct command console terminal, or by the provided Graphical User Interface (GUI).

Serial communication requires a terminal emulation or communication software (such as Tera Term, PuTTY, Qodem, Procomm Plus, etc.) Though the programs vary, in general you will be asked to select "Serial" from among various types of connections, select the COM port which will be used for the TCD, name the connection, and set some parameters; set the serial port at 115200 BAUD, using 8 data bits, no parity bits, 1 stop bit, and no flow control (115200-8N1).

Confirming Communication

With the software running, turn the On/Off switch on the controller to the ON position. If the link is functioning, the following welcome message will appear on your monitor. This message lists the unit designation, the firmware and hardware revisions, and the unit serial number.

```
Valco Instruments Company Incorporated
Thermal Conductivity Detector, Version 3
Firmware revision: 1.0.0
Hardware revision: TCD3-C rev. F
Unit serial number: 100
Use ?? for command listing
```

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Following the welcome message, the TCD-3 will begin its hardware initialization sequence. By default, the console port will display the status of this procedure (this listing can be disabled with the WM command):

```
Configuring hardware modules:  
* Parameters restored  
* Digital pot 1 initialized.  
* Digital pot 2 initialized.  
* MCU ADC configured  
* RTD ADC configured (device ID 0x23)  
* Ext ADC configured (device ID 0x23)  
* DAC1 converter configured (device ID 0x1)  
* DAC2 converter configured (device ID 0x1)  
* PID controller initialized  
* Detector present  
boot-up complete!
```

After the welcome and initialization messages, the command prompt will be displayed. This 2-character prompt sequence (": ") is also displayed after any commands are processed, and indicates that the TCD-3 unit is ready to accept a new command.

Initial Bakeout and Equilibration

Initial Conditioning

- Set the detector temperature to 220°C: Type TS 220<enter> on the command line.
- Set the power level of both filaments to 90%; Type FA 90<enter> for filament A. Type FB 90<enter> for filament B.
- Condition the detector by allowing it to bake at these settings for at least 12 hours.

Temperature Settings

- After the initial bake-out period, set the detector temperature to 100°C or to the column temperature plus 30°C, whichever is higher.
- Set the filament temperatures to at least 50°C and as much as 100°C higher than the detector temperature. Refer to Figure 8 on page 18, which outlines the relationship between the filament power settings and the actual filament temperature.

Detector sensitivity increases as the temperature differential between the detector and the filaments increases; however, the lifetime of the filament decreases as its temperature increases. Thus, the detector temperature should be set as low as possible, determined by the boiling point of the highest boiling component of the sample.

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- Once all temperatures are set, allow plenty of time for the system to equilibrate, evidenced by a stable baseline. Typical equilibration time for going from a cold start-up to 130°C detector temperature is approximately five hours. Detector temperature changes take much longer to equilibrate than do filament temperature changes.

The test chromatogram accompanying your TCD was obtained under the following conditions:

SAMPLE	~100 ppm blend in Helium balance
SAMPLE VOLUME	250 µL
COLUMN	10' x 1/16" x 0.040" molecular sieve 5Å micropacked
COLUMN FLOW	6 mL/min
REFERENCE FLOW	6 mL/min
COLUMN TEMPERATURE	65°C
DETECTOR TEMPERATURE	100°C
FILAMENT TEMPERATURE	230°C (a power setting of 67%)
CARRIER GAS	Helium

Balancing the Channels

- Use the console command "ZS" to "zero" the system, which automatically adjusts Channel B, then adjusts Channel A-B to 0 Volts.
An alternate method, if you need to set the outputs to something other than 0 volts, is to use the "ZA" and "ZB" to set the level of each channel independently.
- The results of the adjustment process will be shown in the console window. After completion, the detector will be ready for analytical use.

Serial Communication Protocols

General Console Port Usage

- Commands issued to the TCD-3 must be terminated with a carriage return character (<CR>). (When using a terminal program for communications, pressing the ENTER key generates the carriage return character.)
- Space characters are used to separate commands and operands in command sequences. Other whitespace characters are ignored by the parser, including tab (<TAB>) and linefeed (<LF>) characters.
- Only printable ASCII characters are accepted by the TCD-3 parser. (In other words, terminal control characters and extended ASCII characters are ignored).

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- Response lines from the TCD-3 will be terminated with a carriage return/linefeed (<CR><LF>) sequence.
- Commands to the TCD3-C unit are not case sensitive.
- The TCD-3 uses VT100 escape sequences for cursor and terminal control.
- Any characters on the input line after the final valid parameter are ignored.
- Multiple commands may be issued on a single command line. The commands must be separated by a semicolon (;) character. These commands will be processed and implemented in a single parsing cycle, and thus will become effective simultaneously.
- A maximum of 80 characters are permitted in a single command line.

Interface Command Editing:

- Use the Escape key (<ESC>) to delete the current command line.
- The Backspace key (<BS>) deletes the previous character on the command line.
- The left and right arrow keys may be used to navigate the cursor within the current command line text.
- The console always acts in "insert" mode. Any new characters entered will be inserted into the command line at the cursor, and will shift any pre-existing characters after the cursor to the right.
- The delete key () deletes the character at the cursor, and with any following characters shifting to the left.
- The TCD3 implements a scroll-back buffer that is ten commands deep. Use the up and down arrow keys to step through the buffer.

Serial Commands

The TCD-3 system uses a simple two character mnemonic command structure. Each command must be followed by the <ENTER> key. Several of the commands are read/set commands. That is, entering the two character command alone asks the TCD to read and respond with the current setting. Entering the two character command followed by a value sets the parameter at that value.

Examples:

To read the current detector temperature set point, type TS and press <enter>.

To set the detector temperature to 150°C, type TS150 and press <enter>.

To read the current filament A power level, type FA and press <enter>.

To set the filament A power level to 85%, type FA85 and press <enter>.

The commands are detailed below.

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System Control

TS [°C]	Reads/sets detector temperature setpoint
FA [%]	Reads/sets filament A power level
FB [%]	Reads/sets filament B power level
P+	Enable power to detector heater and filaments
P-	Disable power to detector heater and filaments

Output Level Adjustment

ZA [volts]	Adjusts channel A to the default voltage level, or to the value specified
ZB [VOLTS]	Adjusts channel B to the default voltage level, or to the value specified
ZR [volts]	Adjusts channel A-B to the default voltage level, or to the value specified
ZS	Initiates an adjustment sequence; channel B, then channel A-B
PF [%]	Reads/sets the minimum accuracy of the adjustment routing
RF	Resets any adjustment routine error flags

System Settings

ST	Checks system status
LL	Reports current measurement data
L+	Enables data log
L-	Disables data log
LP [seconds]	Reads/sets the data logging period
E+	Enables local echo for the COM port
E-	Disables local echo for the COM port
WM [1, 2, or 3]	Reads/sets the welcome message mode (0=off, 1=brief, 2=extended)

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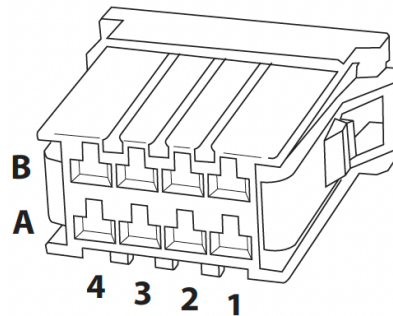
WD [seconds]	Reads/sets the welcome message delay
BM [0 or 1]	Reads/sets the unit boot mode (0=unpowered boot, 1=normal boot)
BR [number]	Reads/sets the BAUD rate for the COM port
VR	Displays unit version information
?? [command]	Shows this command list, or detailed help for a two character command

10. Appendix C: Heater and Filament Connector Signal Descriptions and Connection Matrices

Heater Connector

Signal Definitions

4	3	2	1	
HTR-	HTR+	RTD-	RTD+	B
HTR-	CHSGND	RTD-	RTD+	A



Connection Matrix

pin/ signal	B4/HTR-	B3/HTR+	B2/RTD-	B1/RTD+	A4/HTR-	A3/CHS- GND	A2/RTD-	A1/TRD+
B4/HTR-	-	40 Ω	open	open	SHORT	open	open	open
B3/HTR+	40 Ω	-	open	open	40 Ω	open	open	open
B2/RTD-	open	open	-	1100 Ω	open	open	SHORT	1100 Ω
B1/RTD+	open	open	1100 Ω	-	open	open	1100 Ω	SHORT
A4/HTR-	SHORT	40 Ω	open	open	-	open	open	open
A3/CHSGND	open	open	open	open	open	-	open	open
A2/RTD-	open	open	SHORT	1100 Ω	open	open	-	1100 Ω
A1/RTD+	open	open	1100 Ω	SHORT	open	open	1100 Ω	-

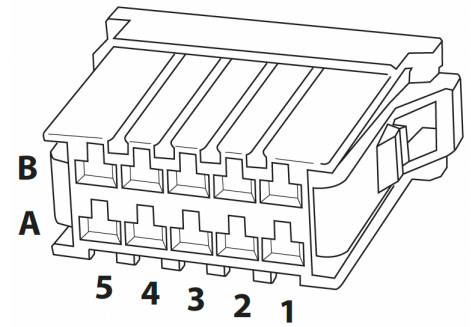
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Filament Connector

Signal Definitions

5	4	3	2	1	
n.c.	Filament B-	Filament B-	Filament B+	Filament B+	B
n.c.	Filament A-	Filament A-	Filament A+	Filament A+	A



Connection Matrix

pin/ signal	B5/n.c.	B4/FIL B-	B3/FIL B-	B2/FIL B+	B1/FIL B+	A5/n.c.	A4/FIL A-	A3/FIL A-	A2/FIL A+	A1/FIL A+
B5/n.c.	-	open	open	open	open	open	open	open	open	open
B4/FIL B-	open	-	SHORT	25Ω	25Ω	open	open	open	open	open
B3/FIL B-	open	SHORT	-	25Ω	25Ω	open	open	open	open	open
B2/FIL B+	open	25Ω	25Ω	-	SHORT	open	open	open	open	open
B1/FIL B+	open	25Ω	25Ω	SHORT	-	open	open	open	open	open
A5/n.c.	open	open	open	open	open	-	open	open	open	open
A4/FIL A-	open	open	open	open	open	open	-	SHORT	25Ω	25Ω
A3/FIL A-	open	open	open	open	open	open	SHORT	-	25Ω	25Ω
A2/FIL A+	open	open	open	open	open	open	25Ω	25Ω	-	SHORT
A1/FIL A+	open	open	open	open	open	open	25Ω	25Ω	SHORT	-

NOTES:

Connections marked as "open" should have no connectivity, and a measured resistance over 10 MΩ.

SHORT connections are measurement loops, and should have a measured resistance under 1 Ω.

25 Ω Measurements across the filaments, at 25°C. Resistance will increase with temperature, to as much as 75 Ω at temperatures exceeding 300°C.

40 Ω Measurements across the heater element, for a 24V system at 25°C.

1100 Ω Measurements across the 1000 Ω platinum RTD sensor. The 1100 Ω value is nominal for the RTD at 25°C.

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11. WARRANTY

This Limited Warranty gives the Buyer specific legal rights, and a Buyer may also have other rights that vary from state to state. For a period of 365 calendar days from the date of shipment, Valco Instruments Company, Inc. (hereinafter Seller) warrants the goods to be free from defect in material and workmanship to the original purchaser. During the warranty period, Seller agrees to repair or replace defective and/or nonconforming goods or parts without charge for material or labor, or, at the Seller's option, demand return of the goods and tender repayment of the price. Buyer's exclusive remedy is repair or replacement of defective and nonconforming goods, or, at Seller's option, the repayment of the price.

Seller excludes and disclaims any liability for lost profits, personal injury, interruption of service, or for consequential incidental or special damages arising out of, resulting from, or relating in any manner to these goods.

This Limited Warranty does not cover defects, damage, or nonconformity resulting from abuse, misuse, neglect, lack of reasonable care, modification, or the attachment of improper devices to the goods. This Limited Warranty does not cover expendable items. This warranty is VOID when repairs are performed by a nonauthorized service center or representative. For information about authorized service centers or representatives, write Customer Repairs, Valco Instruments Company, Inc, P.O. Box 55603, Houston, Texas 77255, or phone (713) 688-9345. At Seller's option, repairs or replacements will be made on site or at the factory. If repairs or replacements are to be made at the factory, Buyer shall return the goods prepaid and bear all the risks of loss until delivered to the factory. If Seller returns the goods, they will be delivered prepaid and Seller will bear all risks of loss until delivery to Buyer. Buyer and Seller agree that this Limited Warranty shall be governed by and construed in accordance with the laws of the State of Texas.

The warranties contained in this agreement are in lieu of all other warranties expressed or implied, including the warranties of merchantability and fitness for a particular purpose.

This Limited Warranty supercedes all prior proposals or representations oral or written and constitutes the entire understanding regarding the warranties made by Seller to Buyer. This Limited Warranty may not be expanded or modified except in writing signed by the parties hereto.