

TECPak™

586 SERIES

USER'S MANUAL



TEMPERATURE
CONTROLLER

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Introduction

Thank you for choosing the **586 TECPak** from Arroyo Instruments. Your **TECPak** is a combination of leading edge technology combined with years of experience in the field of temperature control, and based on the proven designs found in the **5300 Series TECSources**.

The **TECPak** was design for system integration applications, or simply where a user interface like that found on the **5300 Series TECSources** is not required or desired. With high TEC power options, a USB computer interface, and small footprint, the **TECPak** will fit into almost any temperature control application.

The **586 TECPak** offers all the features you would expect from a modern temperature controller, including:

- Support for thermistor, LM335, and RTD (both 100 Ω and 1k Ω) sensors.
- 4-wire measurement mode for RTD sensors.
- AutoTune for automatic PID parameter calculation
- 0.004 $^{\circ}$ C temperature stability
- 0.01 $^{\circ}$ C resolution for both set point and actual temperatures

What's in the Box

Along with the **586 TECPak** itself, a CD with electronic copies of this manual, the **Computer Interfacing Manual**, and USB drivers are included. For USA customers, a power cord is included. For non-USA customers, an IEC-60320-C13 rated AC power cord must be provided.

Accessories

Arroyo Instruments also sells several accessories designed to work with the **TECPak**. These include:

- **TECSource Cable, 30A, 2m (p/n 1264)**
This cable has 17W2 male/female connectors for interfacing to the **LaserMount** or other connectorized fixtures, includes wiring for the fan interface, and supports up to 30A of TEC current. A pigtailed version of this cable is available as **p/n 1265**.
- **TECSource Cable, 17W2 to DB15, 15A, 2m (p/n 1264-DB15)**
This cable has a 17W2 male connector for the instrument end and a DB15 female connector for the mount end, and is used to connect the 5400 to mounts that utilize the DB15 TEC connector, such as the **274 TECMount**. The 1264-DB15 supports up to 15A of TEC current.
- **Pak Series Rack Mount Kit, 3 or 5 units (p/n 1402C-RM)**
For installing your **TECPak** or **LaserPak** into a standard 19" rack. The

kit accepts either 3 units for a 2U installation, or 5 units for a 3U installation.

- **10k Ω Thermistor** (p/n 1600-10K)
- **100 Ω Platinum RTD** (p/n 1600-100RTD)
- **USB Cable, 3m** (p/n 1201)

Safety Terms and Symbols

The following safety-related terms are used in this manual:

- **Warnings** (noted by the WARNING heading) explain dangers that could result in physical injury or death;
- **Cautions** (noted by the CAUTION heading) explain conditions that could result in damage to the instrument, other equipment, or your device.
- **Notes** (noted by the NOTES heading) are *not* safety-related, and are intended simply to point out important information.

If, at any time, any of the following conditions exist, or are suspected of existing, discontinue use of the unit until it can be inspected by qualified service personnel:

- Visible damage to the unit, including damage or stress caused during product shipment;
- Storage of the unit outside the standard storage temperature or humidity rating, or prolonged storage under harsh conditions;
- Failure to operate properly.

If needed, contact your distributor or Arroyo Instruments for service or repair to ensure the safety of the product is maintained.

Symbols



Power Off



Power On



Caution, refer to manual



Earth ground



Caution, risk of electric shock

General Warnings

WARNING

This instrument is intended for use by qualified personnel who understand the shock and laser hazards and are familiar with safety procedures required to avoid injury. Read this manual completely before attempting to use this product.

WARNING

To avoid electrical shock, ensure a 3-prong power cord is used, and is plugged into a earth-grounded receptacle. Failure to do so can result in severe injury or death.

CAUTION

There are no user-serviceable parts inside. All service and repair work shall be done by Arroyo Instruments or personnel authorized by Arroyo Instruments. Modifications done by non-authorized personnel will void the warranty. Please see the Service section later in this manual for instructions on how to obtain service for this instrument.

Quick Start

The **586 TECPak** was designed with ease of use in mind, and you will likely have little need for this manual for almost all of the features the unit offers. This section will show how you can quickly get the unit up and running in almost no time.

The **TECPak** has a universal input power supply, accepting 90 to 240 VAC, and 50 or 60 Hz. This covers all conventional power worldwide, but ensure your AC power meets these requirements.

Plug the AC cord into the unit and into the wall outlet. Turn on the power switch located on the IPC, and the unit will power up. The AC Power LED should light, and the On / Error LED should remain dark.

Install the **Arroyo Control** software located on the CD that came with the instrument (it can also be downloaded from our web site), located in the **Software** folder on the CD. Once the software is installed, plug the instrument into the USB interface. The instrument may also ask for drivers, which are also found on the CD.

Launch **Arroyo Control**, and in the TECSource panel (if one is not visible, click Add Panel in the lower right of the window, and click Add a TEC Panel), select the communications port to which your **TECPak** is connected. This will usually be the highest numbered port in the list. Click Connect, and **Arroyo Control** will begin controlling the **TECPak**. Once connected, you will be able to adjust settings, limits, and turn the output on or off.

Next, connect the cable between your LaserMount or other fixture and the **Output** connector of the **TECPak**. We recommend using our cables as they have been designed to work well with the **TECPak**. If using your own cables, ensure they have been properly wired according to the pin-out of the **TECPak** and your fixture.

Finally, set the set point to an appropriate temperature and turn the output on. You will see the voltage and current begin driving the fixture to the set point you have chosen. Depending on the thermal size of your fixture, it may take seconds or several minutes to reach the set point.

If you notice the temperature is oscillating around the set point and not stabilizing, you may need to adjust the **Gain** setting in the **Settings...** dialog. You can use the AutoTune feature to automatically calculate the best PID values, or select from a set of eight factory preset values that typically cover most applications. To use the factory gains, if the temperature is quickly jumping up and down, the **Gain** will typically need to be reduced. If the temperature is slowly moving up and down, try a higher **Gain**. You may need to experiment with

several gain settings to find the ideal value, and for even finer control, you can set the **Gain** to *PID* and directly set the PID control values.

Installation

Installation of the **586 TECPak** is very straightforward, as the quick start section above illustrated. This section will provide additional details and considerations for installing your **TECPak**.

After unpacking the unit, make sure all packing materials have been removed and nothing obscures the ventilation ports on the front and back of the unit.

The **TECPak** has a universal input power supply, accepting 90 to 240 VAC, and 50 or 60 Hz. This covers all conventional power worldwide, but ensure your AC power meets these requirements.

CAUTION

Do not exceed 250VAC on the line input.

It is critical to maintain the proper voltage input into the unit. If the actual voltage exceeds 250VAC, damage to the unit may occur.

Powering Up the Unit

Connect the AC power cord to the unit. Turn the power switch, located on the AC power input power connector, into the on (|) position. The unit will go through a quick power-up self-test, and return to the last known operating state. The AC Power LED will light up, and the On / Error LED should remain dark until the TEC output is turned on (if **Automatic Output On** has been enabled, the On LED may light without user intervention).

Ventilation

The **TECPak** has vent holes on the front and rear and sides of the unit. You must not block these vent holes, or overheating may occur, causing damage to the unit.

CAUTION

Do not operate the unit above +40°C ambient, and ensure the instrument is properly ventilated, or the unit may overheat and possible damage to the instrument may occur.

Rack Mounting

A rack mount kit (p/n 1402C-RM) for standard 19" racks is available for the **586 TECPak**, and supports the rack mount of up to three units in a 2U high opening. The units primarily ventilate from the front and rear, with some ventilation on the sides, so some air gap is required to the sides of the unit to ensure proper air flow. No air gapping is required above or below the units, and they can be rack mounted immediately above other equipment (no rack spacers required).



Warm-up and Environmental Considerations

In order to achieve the highest level of accuracy, the **TECPak** should be powered on for at least one hour prior to taking measurements. In addition, ensure that the unit is not operating outside the ambient temperature range or humidity conditions.

Operating Modes

Control Modes

The **TECPak** offers three control modes: constant temperature mode (T Mode), constant resistance mode (R Mode), and constant current mode (Ite Mode).

Changing the control mode can only be done through the computer interface, either through **Arroyo Control**, or by sending the appropriate TEC:MODE command.

Constant temperature mode uses the sensor constants to calculate the resistance of the sensor at the desired or actual temperature.

While most users will only need the temperature control mode, the constant resistance mode allows you to bypass the sensor equation and directly select the sensor set point. This can be useful when only the desired sensor value is known, or when the sensor-to-temperature conversion values are not available for your sensor.

Using Limits

The **TECPak** supports three different types of limits: temperature, sensor, and current. There is both a temperature high and temperature low limit, and if the actual temperature exceeds either of these limits, the output will be shut off. Likewise, both high and low limits exist for the sensor (R limits), and the output will be shut off if the sensor measurement exceeds either of these limits.

It is important to properly set these limits to protect your device from damage. If you are uncertain on how to set the limits, please consult with your local distributor or directly with the factory.

Settings

All parameters of the **TECPak** can be viewed and changed over the computer interface.

Most parameters can be changed using a standard command, as defined in the *Computer Interfacing Manual* or through the **Settings...** dialog within **Arroyo Control**. Below is a list of the most common settings and the corresponding computer command to change it.

Name	Description	Factory Default	Computer Command
Basic Settings			
Mode	This set the operating mode (<i>T Mode</i> , <i>R Mode</i> , or <i>Ite Mode</i>) of the temperature controller.	T Mode	TEC:MODE
Mount	Specify the mount connected to the TECPak . If using a LaserMount , select the appropriate model. Otherwise, select <i>User Defined</i> .	User Defined	TEC:MOUNT
I Lim	I Lim sets the current limit of the temperature controller. The limit should be set to a value that is suitable for your Peltier device.	3A	TEC:LIM:ITE
Gain	Gain controls the response of the temperature controller. Select <i>PID</i> for direct access to the PID parameters. Read more on setting gain below.	30	TEC:GAIN
PID P	The proportional term of the PID loop. Will only be available if Gain is set to <i>PID</i> .	1	TEC:PID
PID I	The integral term of the PID loop. Will only be available if Gain is set to <i>PID</i> .	0.01	TEC:PID
PID D	The derivative term of the PID loop. Will only be available if Gain is set to <i>PID</i> .	0	TEC:PID

Name	Description	Factory Default	Computer Command
Sensor	Sets the temperature measurement sensor. Can be <i>Therm 100uA</i> , <i>Therm 10uA</i> , <i>Therm</i> , <i>LM335</i> , <i>RTD</i> , or <i>RTD (4-wire)</i> , <i>RTD 1k</i> , or <i>RTD 1k (4-wire)</i> .	Therm 100uA	TEC:SENS
Active Sensor	Selects sensor 1 or sensor 2 for feedback control.	1	TEC:ACTIVESENS
T-Low Lim	T-Low Lim is the lower temperature limit. If operating in T Mode and the actual temperature drops below this value, the output will be turned off. Temperature limits not monitored in R Mode or Ite Mode. Limit monitoring can also be disabled in software (see TEC:ENAB:OUTOFF command).	-99°C	TEC:LIM:TLO
T-High Lim	T-High Lim is the upper temperature limit. If operating in T Mode and the actual temperature rises above this value, the output will be turned off. Temperature limits not monitored in R Mode or Ite Mode. Limit monitoring can also be disabled in software (see TEC:ENAB:OUTOFF command).	125°C	TEC:LIM:THI
R-Low Lim	R-Low Lim is the sensor low limit. If operating in R Mode and the actual sensor measurement drops below this value, the output will be turned off. R limits are not monitored in Ite Mode. Limit monitoring can also be disabled in software (see TEC:ENAB:OUTOFF command).	0.01kΩ	TEC:LIM:RLO

Name	Description	Factory Default	Computer Command
R-High Lim	R-High Lim is the sensor high limit. If operating in R Mode and the actual sensor measurement exceeds this value, the output will be turned off. R limits are not monitored in Ite Mode. Limit monitoring can also be disabled in software (see TEC:ENAB:OUTOFF command).	45kΩ	TEC:LIM:RHI
Tol Time	Tolerance time is the amount of time, in seconds, that the actual temperature must be within the set point temperature +/- the Tol Temp value for the unit to be considered in tolerance.	5 seconds	TEC:TOL
Tol Temp	Tolerance temperature is a temperature band (in °C) around the set point temperature. When the actual temperature is within this band for longer than the Tol Time setting, then the unit is considered to be in tolerance.	0.1°C	TEC:TOL
H/C Mode	This selects the heating and/or cooling mode of the TECPak . See the section below titled “Resistive Heaters and Heat/Cool Only Modes” for more information.	Heat/Cool	TEC:HEATCOOL
Ext Fan	This selects the voltage for the auxiliary fan power supply. See the <i>External Fan Control</i> section below for more information.	Off	TEC:FAN
Ext Fan Pwr	When Ext Fan is set to <i>Custom</i> , this sets the specific fan voltage from 4.0 to 12.0 volts. See the <i>External Fan Control</i> section below for more information.	12.0	TEC:FAN

Name	Description	Factory Default	Computer Command
Ext Fan Mode	Controls when the fan operates. See the <i>External Fan Control</i> section below for more information.	Auto	TEC:FAN
Ext Fan Off	When Ext Fan Mode is set to <i>Delay</i> , this setting defines the number of minutes to delay turning off the fan after the TEC output has been turned off. See the <i>External Fan Control</i> section below for more information.	5 minutes	TEC:FAN
Cable R	The resistance of the cable and connectors, in ohms. This setting allows for accurate voltage measurement at the TEC by removing the voltage loss of the cable.	0.0080Ω	TEC:CABLER
T Rate	Selects a desired temperature ramp rate in degrees Celsius per minute. Set to 0.0°C/min to disable rate limiting.	0.0°C/min	TEC:TRATE
Sensor Settings			
ThermA	A term in thermistor equation.	1.12924E-03	TEC:CONST
ThermB	B term in thermistor equation.	2.34108E-04	TEC:CONST
ThermC	C term in thermistor equation.	0.87755E-07	TEC:CONST
RTD A	A term in the RTD equation.	3.98480E-03	TEC:CONST
RTD B	B term in the RTD equation.	-0.58700E-06	TEC:CONST
RTD C	C term in the RTD equation.	4.00000E-12	TEC:CONST
RTD R ₀	R ₀ term in the RTD equation.	100.00	TEC:CONST

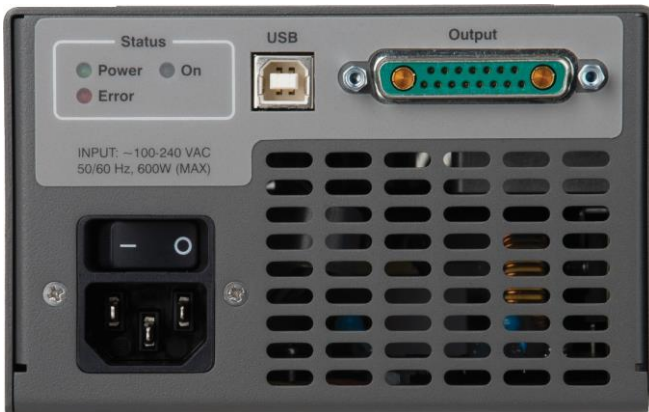
Arroyo Control

While most of the settings of the **TECPak** can be changed over the computer interface using your own program (see the *Computer Interfacing Manual* for more detail), in many cases you simply want to operate the instrument from the PC like any other bench-top instrument.

As mentioned earlier in this manual, **Arroyo Control** is a free software application that gives you 100% operating control of the **TECPak**, allowing you to change limits, settings, and set points, as well as monitor the operation of the instrument. You can install **Arroyo Control** from the CD or download it from our web site (go to the Software section).

Interfacing to the TECPak

The **TECPak** features just two connections (in addition to the input power connector): the USB and output connector. Both are located on the front of the unit. In addition, the front of the unit has the input power connector and two status LEDs. The rear of the unit has the cooling fan, which pulls air in and exhausts it out the front.



586 **TECPak** Interface Panel

TEC Output Connector

The Output connector is a female 17W2, and has the following pin-out:

Pin	Description	Pin	Description
A1	TE (+)	A2	TE (-)
1	LED/Interlock+	8	LED/Interlock -
2	VTE Sense+	9	VTE Sense -
3	Sensor 1 -	10	Remote Sensor 1 -
4	Sensor 1+	11	Remote Sensor 1+
5	n/c	12	n/c
6	Sensor 2-	13	Earth Ground
7	Fan+	14	Sensor 2+
		15	Fan - (Signal Ground)

Output Connector (17W2 Female)

Inverting the TE Output

In the event the polarity of the TE pins is backwards, it is possible to reverse the direction of the TEC current by using the `TEC:INVERTITE` command. While not recommended as it can lead to confusion when the controller is used later in properly wired setups, this allows for correct operation of system when the TE pins are wired backwards and rewiring is not possible or feasible.

USB Connector

The USB connector is a standard Type B female connector, and can be plugged into any USB 1.1 or USB 2.0 port. For more information on using the USB interface, see the ***Computer Interfacing Manual*** which is included on the CD that accompanied this product.

LED Indicators

There are three LEDs: the upper green AC Power LED that is lit whenever the AC power is turned on; and a red Error LED that will light when an error has occurred, and a blue Output On LED that will light whenever the TEC output is on.

Connecting to the **TECPak**

Arroyo Instruments carries two cable assemblies specifically designed for connecting the **586 TECPak** to temperature controlled fixtures or devices. The **1264 TECSorce Cable** (not included) is a two meter cable, designed for use with Arroyo Instruments mounts, and has 17W2 connectors on both ends.

For custom applications, a two-meter cable with a male 17W2 on one end and stripped and tinned leads on the other is available as part number **1265**.

NOTE

Connections to the **586 TECPak** and the fixture must be secure. Tighten any screws on the 17W2 connectors, and make sure all connections are in good condition.

See the manual for your fixture for additional safety and operational information.

Installing the USB Drivers

Using the **TECPak** via USB is just as simple as using the serial port. In fact, once you have installed the USB drivers, the instrument will appear as a virtual serial port that you can use just like a normal serial port.

To install the drivers, simply plug in the instrument to your computer. When the Add New Hardware wizard appears, insert the CD you received with the **TECPak** and follow the on-screen instructions.

Once the drivers are installed, to determine the COM port number, go to **Control Panel** and select **System**. Once the **System Properties** dialog appears, choose the **Hardware** tab then click on the **Device Manager** button. When the **Device Manager** appears, click on the plus sign to the left of **Ports**. The port identified as an **USB Serial Port** is the **TECPak**. In the event you have multiple **TECPaks** plugged in simultaneously, you will need to experiment to see which instrument was assigned to which port. For example, you could change the set point when the output was off to see which unit's set point changed.

Saving and Restoring Configurations

Using the the *SAV and *RCL commands over the computer interface, **TECPak** allows you to save up to four configurations. Each configuration will store all of the instrument settings (except scripts and user calibration data), and allow you

to quickly recall them. This is particularly useful when the instrument is used in multiple setups, and the particular configuration of each setup can be stored and later recalled for a quick reconfiguration.

To store a configuration, use the *SAV command over the computer interface. To recall a configuration, use the *RCL command.

Using the TEC Interlock/LED Interface

The **TECPak** features a combination digital input/digital output/LED interface on pins 1 & 8. The most common use of this interface is to turn on an LED when the output is on, but other functions can be assigned to the LED operation. It can also be used as a digital input to remotely control the on/off state of the channel, or to act as an interlock function.

The TEC:DIO:INMODE command controls how the digital input is to be used:

- *Off* – ignore the digital input
- *Interlock* – prevent operation until circuit is closed
- *Output On* – turn on the output when circuit is closed

You can also invert the logic level of the input using the same command. For example, if the function was inverted, and set to *Output On*, the output would turn on when the circuit was opened.

Of special note is the *Output On* function: this action is taken only on a transition from open to closed state of the circuit. This allows the output to be turned off via the front panel or remote commands even when the circuit is closed.

You can also drive an LED using the output function setting accessed via the TEC:DIO:OUTMODE command. For example, this could be used to turn on a LED whenever the output is on, but there are several functions to choose from:

- *Off* – turn the output off (this is the default setting)
- *On* – turn the output on
- *Out On* – whenever the channel output is on
- *Stable* – when the channel output has stabilized
- *T Limit* – the temperature exceeds the limits
- *I Limit* – operating at the current limit
- *Remote* – the unit is in remote mode
- *V Limit* – operating at the voltage limit

Like the digital input, the output function can be inverted for active low signals.

For purposes of the TEC:DIO commands, this dual-purpose input/output function is considered both digital input 1 *and* digital output 1.

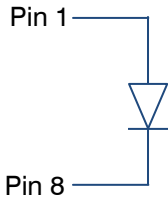
Closing the Circuit

A +5V supply is used to bias the LED and goes through a 200Ω series resistor. To close the circuit, there must be 4.5V or less across pins 1 and 8. A short circuit can be used, but an LED can optionally be connected.

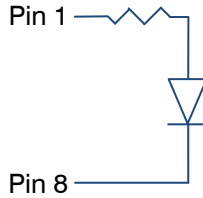
Depending on the type of LED, no resistor, series resistor, or parallel resistor can be used. Red, green, and yellow LEDs may require no resistor. Blue LEDs are too efficient to be wired with a series resistor and must use the parallel resistor option.

When using a series resistor, the higher the resistor value, the dimmer the LED. Do not use too high of a resistance value or it may always register as an open circuit.

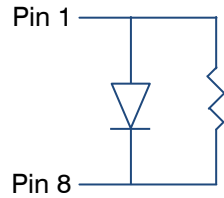
When using a parallel resistor, the lower the resistor value, the dimmer the LED. Red, green, and yellow LEDs will typically use higher resistances (1kΩ or more), while blue LEDs will use smaller resistor values (typically around 100Ω).



No Resistor



Series Resistor



Parallel Resistor

Isolation and Multiple Interlocks

The LED/TEC Interlock Interface is electrically isolated from all other control signals, and interlocks from multiple **TECPaks** can be wired in parallel through a single switch.

TEC Control Modes

The **TECPak** offers three TEC control modes: constant temperature mode (T Mode), and constant resistance mode (R Mode), and constant current mode (Ite Mode).

Changing the control mode is done using the TEC:MODE commands.

Constant temperature mode uses the sensor constants to calculate the resistance of the thermistor at the desired or actual temperature.

While most users will only need the temperature control mode, the constant resistance mode allows you to bypass the sensor equation and directly select the sensor set point. This can be useful when only the desired sensor value is known, or when the sensor-to-temperature conversion values are not available for your sensor.

Using the Current Limit

The current limit in the **TECPak** is used to limit the amount of current that is delivered to the mount. Because the **TECPak** has a hardware current-controlled output, the current will not exceed the limit at any time in any mode. Set the limit by using the TEC:LIM:ITE command.

Operating at the current limit is common, especially when transitioning from one temperature to another. There is no harm or danger to the **TECPak** when operating in this condition.

Using the Voltage Limit

The **TECPak** also supports a software-controlled voltage limit. In most applications, the voltage limit is not needed, and can be left at the maximum setting, as the **TECPak** is a current output controller, and the voltage simply goes to whatever voltage is required by the TEC. By default, the voltage limit is set to the rating of the instrument plus 2 volts, so it will not engage unless adjusted lower.

It is important to understand that the voltage limit is a *software-imposed* limit, which means that the response time to over-limit conditions can be several hundred milliseconds or longer. During that response time, a significant over-voltage condition can persist. However, with a properly set current limit, the device is still protected from excessive power conditions, and should not pose

any danger to TEC devices due to the relatively short duration of the over-voltage condition.

For the voltage limit to engage, the following conditions must be met:

- TEC:LIM:V is set to 1V or higher
- At least 25mA of TEC current

The second point is to ensure there is a sufficient current signal that can be used in calculating the load impedance (and therefore limit the current to correctly limit the voltage).

Operating at the voltage limit is common, especially when transitioning from one temperature to another. There is no harm or danger to the **TECPak** when operating in this condition.

Understanding the Sensor Inputs

The **586 TECPak** supports two primary sensor inputs, and either input can be used to control the temperature of your device or mount.

The two sensor inputs support:

- Sensor 1 supports thermistor, LM335, RTD and 4-wire RTD (both 100 Ω and 1k Ω) sensors.
- Sensor 2 supports thermistor and RTD (100 Ω only) sensors.

One or both can be enabled for monitoring, but only one can be used for the control loop. The primary sensor selected for the control loop is called the **Active Sensor**. Use the TEC:ACTIVESENSOR command to change the active sensor.

The **TECPak** has no auxiliary sensor inputs.

For best system performance, unused sensor inputs should be disabled.

Applying Sensor Limits

With the wide range of sensor connectivity options, the **586 TECPak** is designed with a series of temperature protection limits and options to allow for flexibility when meeting the demands of different applications.

Each sensor has a dedicated high and low temperature limit, set using the TEC:LIM:THI or TEC:LIM:TLO commands. When the temperature input exceeds these limits, that sensor is considered to be in limit, either high or low. Limit

conditions are also activated when the sensor is open. For thermistors, an open circuit will trigger a low limit, while all other sensors will trigger a high limit.

How the instrument reacts to these limits depends on two settings:

- **Outoff Settings (TEC:ENABLE:OUTOFF)**
- **Apply Nonactive (TEC:ENABLE:NONACTIVELIMITS)**

Apply Nonactive is used to include the temperature limits of the non-active primary sensor when determining if a temperature limit condition exists. When enabled, and the non-active primary sensor is also enabled, a limit condition on the non-active primary sensor will cause a temperature limit condition. If disabled, the non-active primary sensor will not be used in determining if a limit condition exists.

By default, **Apply Nonactive** is disabled, which means only a temperature limit of the active sensor will cause the temperature to shut down.

Once a determination is made that a temperature limit condition exists, the settings in the **OUTOFF** register will determine if the output will be shutdown. If enabled and an appropriate high or low limit condition exists, the output will be turned off.

In all cases, limits are only applied to enabled sensors. When a sensor is disabled, it will not be evaluated for limit conditions.

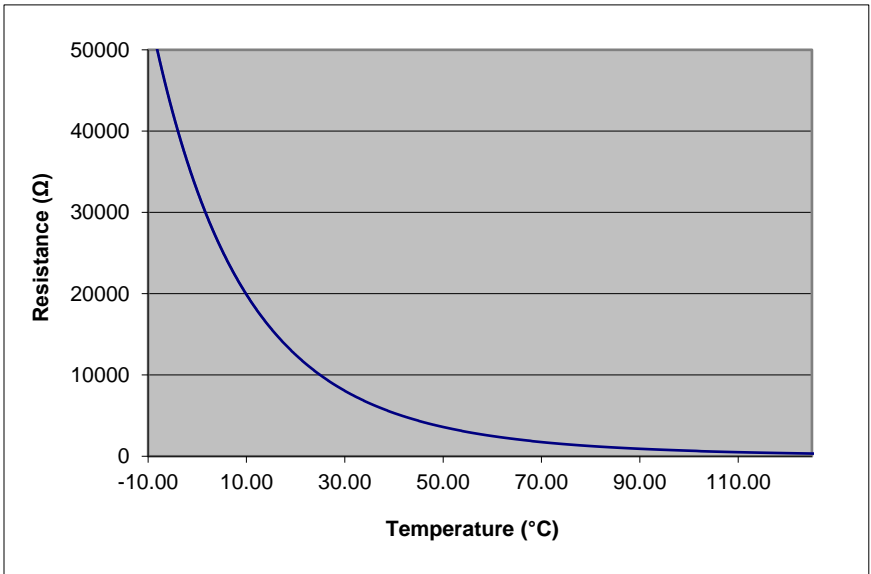
Selecting the Fixture

The **586 TECPak** has integrated support for many of the mounts offered by Arroyo Instruments, such as the **205 TEC Butterfly LaserMount**. To simplify operation when using these mounts, you can use the **TEC:MOUNT** command to change the mount type you are using. By selecting a mount, the current limit, temperature limits, default gain, and sensor settings are automatically adjusted to values appropriate to the mount, and menu settings limited to the capabilities of the mount.

Working With Thermistors

The **586 TECPak** is designed to work with negative temperature coefficient (NTC) thermistors, such as the BetaTHERM 10K3A1 thermistor used in the **LaserMounts**. A thermistor works by translating temperature into resistance, with resistance decreasing as temperature increases (hence the 'negative coefficient').

Here is a typical response curve of a thermistor:



Typical Resistance vs. Temperature Graph

As can be seen by the graph, the resistance of the thermistor drops very quickly. In the typical control range (0°C to 70°C), typical 10K thermistors offer good sensitivity to changes in temperature, and this is the range in which most 10K thermistors are typically used. 10K thermistors can be used at much higher temperatures, but will suffer poorer temperature stability performance because of the lower sensitivity. When evaluating the performance of a thermistor, it is important to understand the resistance sensitivity of the thermistor at your application temperature, which varies greatly by temperature and thermistor types.

The **TECPak** supports operation using a 10µA or 100µA constant current source, which limits the upper control range to 450kΩ and 45kΩ, respectively. To minimize noise and maximize stability, you should select highest current while still allowing you full operation across your required temperature range. The typical setting is 100µA, but your application will determine the actual needs.

The Steinhart-Hart Equation

As can be seen from the temperature versus resistance graph above, resistance varies inversely with temperature in a non-linear fashion. This relationship can be accurately modeled by polynomial equations, and one such being the Steinhart-Hart equation:

$$\frac{1}{T} = A + B * \ln(R) + C * \ln(R)^3$$

The coefficients A, B, and C can usually be obtained from the thermistor manufacturer. The **TECPak** defaults to the coefficients for the BetaTHERM 10K3A1 thermistor (A = 1.12924x10⁻³, B = 2.34108x10⁻⁴, C = 0.87755x10⁻⁷). You can change the coefficients using the TEC:CONST command, or through the **Settings...** dialog within **Arroyo Control**.

Working With RTDs

Like thermistors, RTDs also function by converting temperature into resistance, but unlike thermistors, RTDs increase in resistance as temperature increases. RTDs are also a fairly linear device, meaning they can be used across a much broader temperature control range.

According to IEC751, the resistance/temperature relationship is determined using one of two equations, dependent on the temperature or resistance value being measured. For resistances above the R₀ value (resistance at 0°C) of the RTD, the following equation is used:

$$R = R_0(1 + AT + BT^2)$$

Below R₀, an additional term is added to the equation:

$$R = R_0[1 + AT + BT^2 + C(T - 100)T^3]$$

In both of these equations, R₀ is the resistance of the RTD at 0°C, and A, B, and C are the coefficients as defined by IEC751, through regression analysis, or by

using the Callendar-van Dusen method. By default, the **TECPak** uses the Laboratory standard coefficients for 100Ω RTD, which are for a $0.003926\Omega/\Omega/^\circ\text{C}$ curve ($A = 3.9848 \times 10^{-3}$, $B = -0.58700 \times 10^{-6}$, $C = 4.0000 \times 10^{-12}$, and $R_0 = 100$).

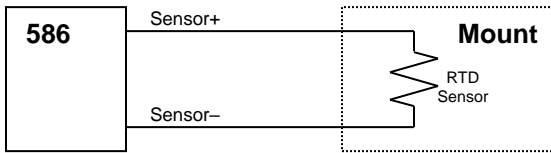
The **TECPak** automatically determines which equation to use based on the conditions at the time of the measurement.

2-Wire versus 4-Wire Measurements

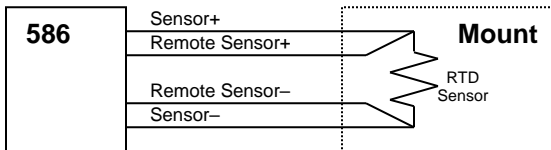
One concern in using RTDs, particularly 100Ω RTDs, are their relatively low resistance and small $\Omega/^\circ\text{C}$. Because of these two factors, the resistance of the cable used to connect to the sensor can become a significant error in the sensor measurement. The **TECPak** offers two RTD measurement modes: a conventional two wire measurement mode, which is subject to this error, and a four wire measurement mode that uses separate sensor and source lines to remotely sense the actual resistance of the RTD and eliminate the cable or connector resistances.

When using 4-wire measurement mode, you must select 'RTD (4-wire)' as the sensor type, and then connect the Sensor+ and Remote Sensor+ at one side of the RTD, and Sensor- and Remote Sensor- to the other side of the RTD. Make these connections as close to the sensor as possible.

The drawings below illustrate how 2-wire and 4-wire connections work. Note that 4-wire measurements require all four wires to be brought through the cable to the mount.



RTD 2-wire Measurement



RTD 4-wire Measurement

User Calibration of Resistance Sensors

In some applications, having the ability to compensate, or calibrate, the sensor measurement is desired, such as referencing to an internal standard or to match the readings of another instrument. This is supported on the **TECPak** by using the `TEC:USERCAL:PUT` command to apply an offset and/or slope compensation to thermistor or RTD readings.

NOTE

The calibration is applied to the resistance measurement of the sensor, not the temperature. To adjust the resistance-to-temperature conversion, change the thermistor or RTD coefficients as needed.

To prevent accidental modification of the sensor calibration, calibration must first be enabled with the `TEC:USERCAL:EDIT` command. By default, the slope and offset values are 1.000 and 0.00, respectively, but can be adjusted to change the sensor measurement. The calibrated measurement is computed as follows:

$$\text{User calibrated reading} = \text{slope} * \text{reading} + \text{offset}$$

The offset is kilo-ohms (k Ω) for thermistors, and ohms (Ω) for RTDs.

Controlling the Temperature Rate of Change

Some applications require that temperature is changed at a specific rate to prevent damage that might otherwise come from rapid changes in device temperature. Using the `TEC:TRATE` command, it is possible to control the temperature ramp rate of the controller, limiting the rate of change to specific degrees Celsius per minute.

Because the temperature rate function relies on the instrument tracking a gradually changing set point, a proper gain setting (or PID values) is important to achieve a smooth and continuous temperature transition.

To disable the temperature rate function, simply set the rate to 0 with a `'TEC:TRATE 0'` command.

Gain Control and the PID Loop

The **586 TECPak** supports a fully configurable PID loop, allowing full customization of the PID control parameters. To simplify control, eight standard gain settings are also defined, and many applications can achieve acceptable performance with these predefined gain settings, eliminating the need to understand and adjust the PID loop.

The predefined gains are numbered 1 through 300, and set using the Gain setting in the **Settings...** dialog in **Arroyo Control**, or by using the TEC:GAIN command. Increasing the gain value will increase the speed of the control loop. For full access to the PID parameters, change the gain setting to *PID*, and the individual P, I, and D values can be set with the TEC:PID command.

The PID parameters function within a mathematical formula as described below:

$$\text{PID Formula: } \textit{Output} = P * \varepsilon + I * \sum \varepsilon dt + D * \frac{d\varepsilon}{dt}$$

Where ε is the error in the system, expressed as:

$$\varepsilon = \text{Target} - \text{Actual}$$

The controller can calculate ideal PID values using the AutoTune function, discussed in detail in the next section.

To manually adjust the PID, start by changing the I and D values to zero, and adjust the P value so that it reaches the set point as quickly as possible without overshooting the set point an unacceptable amount. Gradually increase the I value until the set point is achieved without oscillation. In many systems, the D term is not needed and may be left at zero.

For additional information on PID loop tuning, consult online resources such as Wikipedia (http://en.wikipedia.org/wiki/PID_controller) or search for terms such as “Ziegler-Nichols method”, or “PID Loop”.

Using the AutoTune Function

The **586 TECPak** is capable of automatically determining PID parameters for most applications. Using a form of the Ziegler-Nichols method, the **TECPak** will step through a process to determine the thermal response of the mount, which can then be used in a mathematical model to calculate the PID parameters.

The PID parameters generated by AutoTune are not necessarily the *ideal* PID parameters, and small improvements may be possible by further refining the results manually.

Before starting the AutoTune function, it is best to begin from ambient conditions, either with the TEC off and the mount stabilized at ambient, or the TEC on and the set point around 25°C. While this is not required, it can produce better results. AutoTune only functions in temperature mode. PID parameters must be manually determined for R mode.

Make sure the current and temperature limits are set prior to starting AutoTune. AutoTune will intentionally cause your mount to oscillate, so the temperature limit should be at least 5 to 10 degrees away from the test point to avoid tripping a limit during the process.

The TEC:AUTOTUNE command starts the process, and requires one parameter, which is the AutoTune temperature test point. The command will immediately put the instrument into AutoTune mode. The TEC:AUTOTUNE? query can be used to monitor the process of AutoTune. A response of 1 indicates AutoTune is in progress. Once complete, the instrument will respond with a 2 if AutoTune failed or a 3 if AutoTune succeeded. A response of 0 is returned if the instrument has never started an AutoTune process.

The AutoTune process can take several minutes, and even longer on larger mounts with higher thermal mass.

Once the AutoTune process is complete, the output will remain on. If the AutoTune process fails, an E-436 AutoTune Failed error will be generated and the output turned off. Any of the following can cause the AutoTune to fail:

- Noisy temperature measurements, which make it difficult to accurately measure oscillations
- Any condition that causes the output to turn off (temperature limits, sensor limits, etc.)
- Systems with very low P or I terms

In the Auto-Tune fails due to thermal system limitations, you will need to manually modify the PID parameters as described in the section above or select factory gain setting.

Turning the output off remotely will cancel the AutoTune process and generate an E-436 error.

External Fan Control

The **586 TECPak** has a built-in user adjustable DC power supply designed to provide up to 350mA to an external fan, such as those built into the **240 and 280 Series LaserMounts**. When using the **TECPak** with mounts that require a fan, no additional external power supply is needed, but a cable with appropriate wiring for the fan, such as the **1264 TECSource Cable**, must be used.

The fan is controlled via the TEC:FAN command, or via the **Settings...** dialog in **Arroyo Control**.

Speed can be set to *Off*, *Slow*, *Medium*, *Fast*, or a value between 4 and 12 (volts). When set to *Off*, the fan power is never turned on. *Slow*, *Medium*, and *Fast* correspond to 6.5V, 7.5V, and 8.5V, respectively.

There are five modes:

- 1 Fan is turned on whenever the TEC output is on, and turns off when the TEC output is turned off.
- 2 Fan is always on.
- 3 Similar to mode 1, the fan is turned on whenever the TEC output is on, but when the TEC is turned off, the fan will remaining running for an addition number of minutes as defined by the **delay** setting.
- 4 Fan is turned on whenever the TEC output is on and cooling, off otherwise.
- 5 Fan is turned on whenever the TEC output is on and heating, off otherwise.

When used, *Delay* is in minutes, and can be from 1 to 240.

Resistive Heaters and Heat/Cool Only Modes

The **586 TECPak** supports temperature control using resistive heaters instead of Peltier coolers. With resistive heaters, cooling is obviously not possible, and the **TECPak** must be configured to not attempt to cool the output, or a run-away condition will occur when the cooling current actually causes additional heating.

If your application requires, you can also configure the **TECPak** to operate in a cool-only mode. This is only possible with Peltier coolers.

To change the cooling mode, change Heat/Cool Mode setting in the **Settings...** dialog in **Arroyo Control**, or use the TEC:HEATCOOL command.

Correcting the TEC Voltage Measurement

Because the high currents the **586 TECPak** can drive through the Peltier, the voltage loss through the cable and connectors of the system can significantly affect the TEC voltage measurement. In most cases, accurate voltage measurements are not needed, and the default compensation of the instrument is sufficient. To improve the accuracy of voltage measurements, the **TECPak** provides two methods to compensate for voltage loss: a software compensation that requires no additional wiring, or a 4-wire measurement (sometimes called a “Kelvin” measurement), where the voltage of the TEC is measured with an independent set of wires.

Software Compensation

For software compensation, the TEC:CABLER command allows you to specify the cable resistance, which is then used to dynamically subtract the voltage drop by simply using the formula $V = IR$ to calculate the voltage loss, where I is the TEC ITE current, and R is the TEC:CABLER setting. This value is then removed from the voltage measurement to display an accurate TEC voltage measurement.

The safest method of calculating cable resistance is to short the TE+ and TE- connections, making sure whatever you are using to short the terminals is not itself adding resistance to the circuit, and is rated for the current you intend to use as the test current. Use short, heavy gauge wires, preferably soldered onto the terminals to minimize any resistance the short might add. Place the short as close to the Peltier as is reasonable. A simple approach is to unplug the cable from the mount and place a shorting plug on the mount end of the cable, which is easily made from a male connector and a soldering iron to solder the TE+ and TE- pins together. Make sure the Peltier is disconnected to protect it from current overloading during the test.

Change the instrument to ITE mode and set the current to 5A. Depending on your setup, you may first need to change the mount to *User Defined* (TEC:MOUNT USER) and adjust the limit higher. Turn on the output and after the voltage has stabilized, make a note of it and turn the output off. Enter the measured voltage into the following equation to calculate *Cable R*:

$$\text{Cable R} = \text{Voltage} / \text{Current}$$

Set the resulting value using the TEC:CABLER command. Typical values for are 0.008 to 0.040, but depend on your actual configuration. Once entered, the displayed TEC voltages will be adjusted based on the above formula.

4-Wire Measurement

For the best performance in accurate voltage measurement, the **TECPak** supports remote voltage measurement for the TEC using a 4-wire Kelvin connection. To use remote TEC voltage sense, wire pins 2 (+) and 9 (-) to the corresponding terminals as close to the TEC module as is reasonable.

To enable the remote TEC voltage sense function, send a TEC:VENSE 1. The reported TEC voltage will now be measured through pins 2 and 9 instead of TEC+ and TEC- at the instrument. When VSENSE is enabled, the TEC:CABLER setting is ignored.

CAUTION

Do not confuse remote TEC voltage sense with the remote sensor input (pins 10 & 11 on the 17W2 connector), as they are two very different functions, and crossing their functionality could damage the instrument or the mount.

Specifications

All values relate to a one-hour warm-up period.
Specifications for standard models. Custom models may vary.

Description	586-04-56	586-08-26	586-08-56	586-15-28
Drive Channel				
Current				
Range (A)	4	8	8	15
Compliance Voltage (V)	56	26	56	28
Max Power (W)	190	190	392	345
Resolution (A)	0.01	0.01	0.01	0.01
Accuracy (\pm [% set point + A])	0.5 + 0.01	0.5 + 0.01	0.5 + 0.01	0.5 + 0.01
Noise/Ripple (mA, rms)	< 15	< 15	< 20	< 25
Temperature Control				
Range ($^{\circ}$ C) ¹	-99 to 250			
Resolution ($^{\circ}$ C)	0.001 ²			
Thermistor Accuracy (\pm $^{\circ}$ C) ³	0.05 ⁴			
LM335 Accuracy (\pm $^{\circ}$ C) ³	0.05			
100 Ω RTD Accuracy (\pm $^{\circ}$ C) ³	0.33			
1k Ω RTD Accuracy (\pm $^{\circ}$ C) ³	0.40			
Short Term Stability (1hr) (\pm $^{\circ}$ C) ⁵	0.004			
Short Term Stability (24hr) (\pm $^{\circ}$ C) ⁵	0.01			
Measurement Channels				
Current				
Resolution (mA)	10			
Accuracy (\pm mA)	10	20	20	30
Voltage				
Resolution (mV)	10			
Accuracy (\pm V)	0.05			
Sensor ⁶				
10 μ A Thermistor				
Range (k Ω)	0.1 – 450			
Resolution (k Ω)	0.01			
Sensor 1 Accuracy (\pm [% read + k Ω])	0.05 + 0.05			
Sensor 2 Accuracy (\pm [% read+ k Ω])	0.20 + 0.05			
100 μ A Thermistor				
Range (k Ω)	0.05 – 45			

¹ Software limits. Actual range dependent on sensor type and system dynamics

² RTD and auxiliary sensor resolution 0.01 $^{\circ}$ C

³ Accuracy figures are the additional error the 586 TECPak adds to the measurement and does not include the sensor uncertainties.

⁴ 25 $^{\circ}$ C, 100 μ A thermistor

⁵ Stability measurements done at 25 $^{\circ}$ C using a 10k Ω thermistor on the 100 μ A setting. The number is 1/2 the peak-to-peak deviation from the average over the measurement period.

⁶ Specifications apply to both primary and auxiliary sensors unless otherwise indicated.

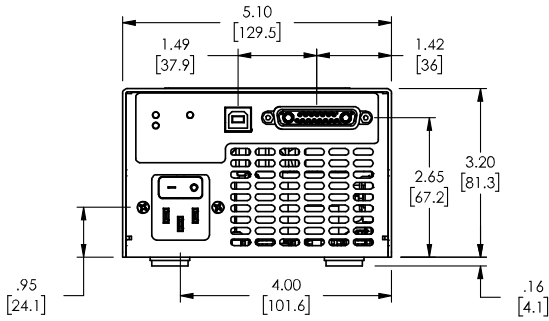
Description	586-04-56	586-08-26	586-08-56	586-15-28
Resolution (kΩ)	0.001			
Sensor 1 Accuracy (± [% read + kΩ])	0.05 + 0.005			
Sensor 2 Accuracy (± [% read + kΩ])	0.20 + 0.005			
<i>LM335</i>				
Bias (mA)	1			
Range (mV)	1730 – 4250			
Resolution (mV)	0.1			
Accuracy (± [% reading + mV])	0.3 + 1			
<i>100Ω RTD</i>				
Range (Ω)	20 – 192			
Resolution (Ω)	0.01			
Accuracy (± [% reading + Ω])	0.03 + 0.1			
<i>1kΩ RTD</i>				
Range (Ω)	100 – 4500			
Resolution (Ω)	0.1			
Accuracy (± [% reading + Ω])	0.05 + 1			
Current Limit				
Resolution (A)	0.1			
Accuracy (±A)	0.2			
Other				
Fan Supply	8 – 12V, 350mA max			
TEC Connector	17W2, Female			
Computer Interface	USB 2.0 Full Speed (Type B)			
Power	90 – 240 V, 50/60 Hz			
	250W	250W	600W	600W
Size (H x W x D) [inches (mm)]	3.5 (89) x 12 (305) x 14 (356)			
Weight [lbs (kg)]	11.6 [5.3]			
Operating Temperature	+10°C to +40°C			
Storage Temperature	-20°C to +60°C			

Error Messages

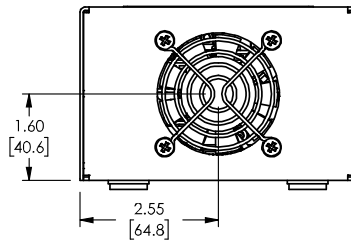
Error Code	Description	Cause
E-100	General Error	The error code is non-specific, and is generally used when no other error code is suitable.
E-102	Message too long	The message is too long to process (USB/Serial only).
E-104	Type not allowed	The RADix type was invalid
E-123	Path not found	The message used an invalid path command (USB/Serial only).
E-124	Data mismatch	The message contained data that did not match the expected format (USB/Serial only).
E-126	Too few or too many elements	The command requires more or less than the number of parameters actually supplied.
E-127	Change not allowed	An attempt was made to change a parameter that cannot be changed, or is currently read-only.
E-201	Data out of range	The message attempted to set a value that was outside the allowable range (USB/Serial only).
E-202	Invalid data type	When trying to parse the message, the data was in an invalid format (USB/Serial only).
E-204	Suffix not valid	An invalid number base suffix (radix) was encountered when parsing a number (USB/Serial only).
E-217	Configuration Recall Failed	Recall failed, typically due to attempted recall on an empty bin.
E-218	Configuration Save Failed	Save failed, either due to an out-of-range bin, or write error to the EEPROM.
E-402	Sensor open, output turned off	A sensor open circuit was detected and the output was turned off.
E-403	Module open, output turned off	A Peltier module open circuit was detected and the output was turned off.
E-404	I limit, output turned off	A current limit was detected and the output was turned off.
E-405	V limit, output turned off	A voltage limit was detected and the output was turned off.
E-406	Sensor limit, output turned off	The sensor limit (high or low) was exceeded and the output was turned off.

Error Code	Description	Cause
E-407	Temperature limit, output turned off	The temperature limit (high or low) was exceeded and the output was turned off.
E-409	Sensor changed, output turned off	The sensor type was changed, causing the output to be turned off.
E-410	Temperature was out of tolerance, output turned off	The temperature went out of tolerance and the output was turned off.
E-415	Sensor short, output turned off	A sensor short circuit was detected and the output was turned off.
E-416	Cal failed	An error occurred during calibration that caused the calibration to fail. The unit is no longer in calibration mode.
E-419	TEC not stable	The TEC is considered stable if the temperature has changed less than 0.02°C for more than 20 seconds.
E-433	Not a TEC	The TEC:CHAN command attempted to select a non-TEC channel
E-435	Mode Change	A mode change occurred when the output was on, forcing the output off.
E-436	Auto Tune Failed	AutoTune was cancelled for whatever reason.
E-437	Auto Tune Required T Mode	AutoTune can only start in T mode.
E-439	Thermal Runaway	System detected a thermal runaway and shutdown the output.
E-997	Control error, cycle power	A hardware control error occurred, cycle power to resolve. If error continues to occur, contact factory.
E-998	Command not supported	A command was received that is not supported by this instrument.
E-999	Non-specific error	A non-specific error was encountered.

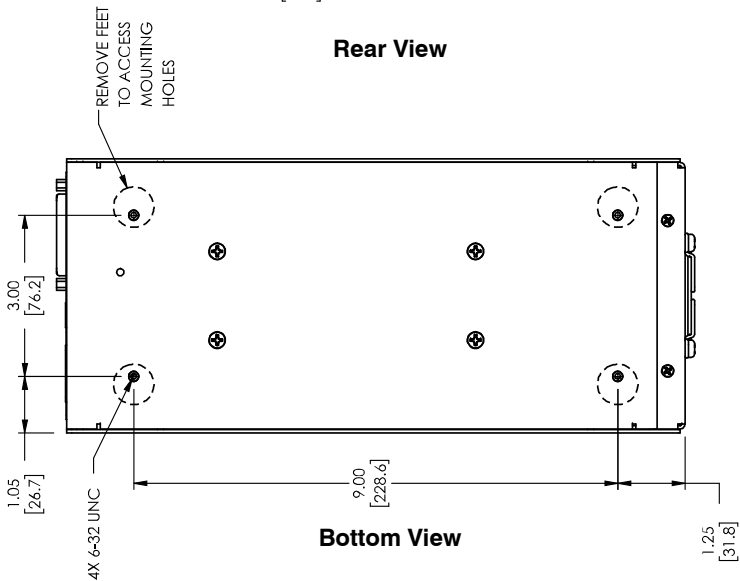
Mechanical Drawings



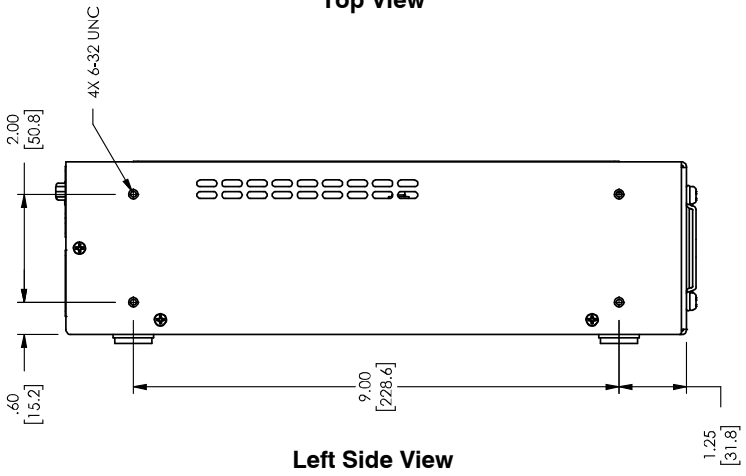
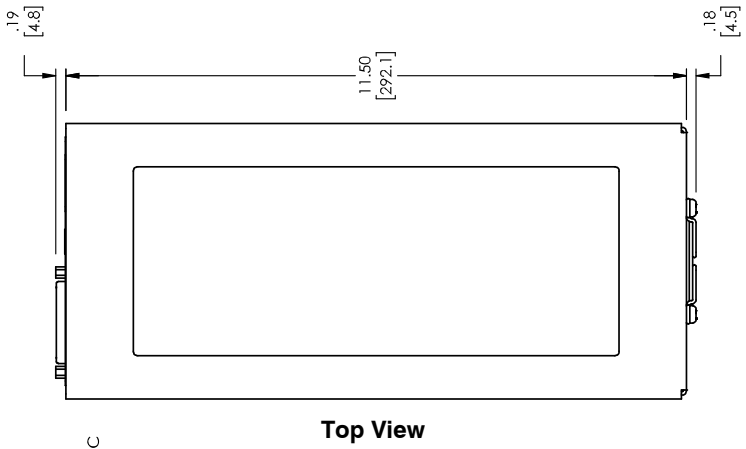
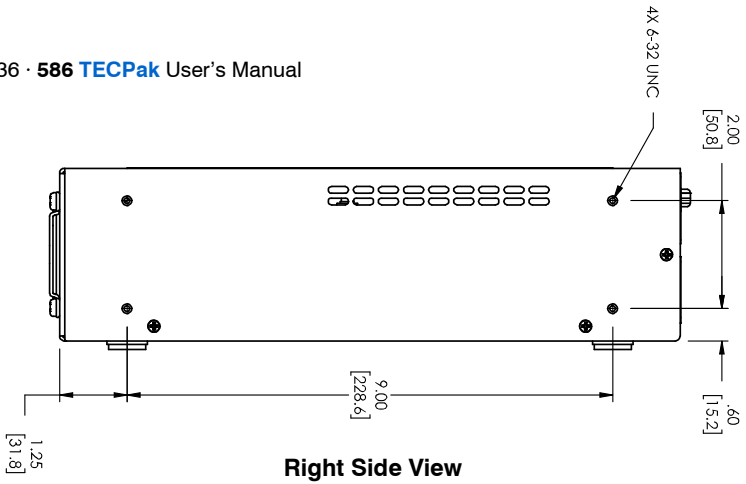
Front View



Rear View



Bottom View



Calibration, Maintenance and Service

Calibration

Arroyo Instruments recommends the annual calibration of the **586 TECPak** to ensure conformance to the published specifications, or as dictated by your quality system. Arroyo Instruments offers NIST-traceable calibration services with data. Contact the factory for more details.

Maintenance

The **586 TECPak** requires no regular maintenance other than product calibration. To clean the instrument, use cotton cloth that is only damp (not wet) with a very light solution of soap and water.

Fuses

The 586 is internally fused, there are no user-serviceable fuses.

Service

Service and repair for the **586 TECPak** can be obtained by contacting the distributor from where you purchased the instrument, or directly from Arroyo Instruments. A complete list of distributors is available on the Arroyo Instruments web site.

You can contact Arroyo Instruments through one of these methods:

By mail:	Arroyo Instruments 1201 Prospect Street San Luis Obispo, CA 93401 USA
By phone:	+1 (805) 543-1302
By fax:	+1 (805) 543-1303
By email:	support@arroyoinstruments.com
On the web:	http://www.arroyoinstruments.com

In all cases, Arroyo Instruments requires a return materials authorization (RMA) number. You must contact Arroyo Instruments and obtain an RMA number prior to returning your instrument, or the shipment may be rejected and sent back to you.

Warranty

Arroyo Instruments warrants that this product will be free from defects in material and workmanship and will comply with Arroyo Instruments' published specifications at the time of sale for a period of one year from date of shipment. If found to be defective during the warranty period, the product will either be repaired or replaced at Arroyo Instruments' option.

To exercise this warranty, write or call your local Arroyo Instruments representative, or contact the factory directly at the address given above. You will be given prompt assistance and return instructions. Send the product, freight prepaid, to the indicated service facility. Repairs will be made and the instrument returned freight prepaid. Repaired products are warranted for the balance of the original warranty period or 90 days, whichever first occurs.

Limitation of Warranty

The above warranties do not apply to products which have been repaired or modified without Arroyo Instruments' written approval, or products subjected to unusual physical, thermal or electrical stress, improper installation, misuse, abuse, accident or negligence in use, storage, transportation or handling. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE. ARROYO INSTRUMENTS SHALL NOT BE LIABLE FOR ANY INDIRECT, SPECIAL, OR CONSEQUENTIAL DAMAGES RESULTING FROM THE PURCHASE OR USE OF ITS PRODUCTS.

European Community Declaration of Conformity

EC Declaration of Conformity



I/We

Arroyo Instruments

of

1201 Prospect Street
San Luis Obispo, CA
USA

declare that

586 Series TECPak

In accordance with the following European Commission Directives:

2014/30/EU - Electromagnetic compatibility (EMC)
2014/35/EU - Low Voltage Directive (LVD)

has been designed and manufactured to the following specifications:

Under 2014/30/EU

In accordance with EN 61326-1:2013, Emission

CISPR 11 Class A, Group 1 radiated and conducted emissions

In accordance with EN 61326-1:2013, Immunity

EN 61000-4-2:2009 Electrostatic Discharge: $\pm 4\text{kV}$ contact, $\pm 8\text{kV}$ air

EN 61000-4-3:2010 Radiated Immunity: $\pm 3\text{V/m}$

EN 61000-4-4:2012 Electrical Fast Transients/Burst: $\pm 1\text{kV AC}$, $\pm 0.5\text{kV I/O}$

EN 61000-4-5:2014 Surges: $\pm 0.5\text{kV}$ differential mode, $\pm 1\text{kV}$ common mode

EN 61000-4-6:2014 Conducted Immunity: 3V

EN 61000-4-11:2004 Supply Dips and Variations: 100%, 100%, 30%

This Certificate is the Manufacturer's Declaration which states that the **586 Series TECPak** is Compliant to the above noted EU Directives and therefore eligible to bear the CE MARK.

I hereby declare that the equipment named above has been designed to comply with the relevant sections of the above referenced specifications. The unit complies with all essential requirements of the Directives.

Paul Corr

(NAME OF AUTHORIZED PERSON)

(SIGNATURE OF AUTHORIZED PERSON)

President

(TITLE OF AUTHORIZED PERSON)

March 8, 2019

(DATE OF ISSUE)



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