ComboPak™

685 SERIES

USER'S MANUAL

LASER DIODE CONTROLLER

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Introduction

Thank you for choosing the **ComboPak** from Arroyo Instruments. The **ComboPak** combines the features of our **LaserPak** and **TECPak** into a single, powerful instrument. The **ComboPak** represents years of experience in the field of current and temperature control.

The **ComboPak** was designed for system integration applications, or simply where a user interface, like that found on the **6300 Series ComboSource**, is not required or desired. With a range of power options, USB computer interface, analog interface, and small footprint, the **ComboPak** will fit into almost any laser control application.

ComboPak's analog interface provides a way of both controlling and monitoring the instrument, with analog laser modulation input, stable indicators, and on/off control and status. This allows for control in applications that do not have a computer interface.

The **ComboPak** offers all the features you would expect from a modern precision laser controller, including:

- Laser driver:
  - o 10ppm current stability
  - o 100mA to 2A current ranges
  - o Comprehensive laser protection circuitry, including hardware voltage and current limits.
  - o External analog modulation
  - o Power mode control, both in photodiode current (AMC) or computed photodiode power (APC) modes.

- Temperature Controller:
  - o AutoTune for automatic PID parameter calculation
  - o 0.004°C temperature stability and 0.01°C set point resolution
  - o Automatic shutdown of laser on temperature error

What's in the Box

Along with the **ComboPak** 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, a power cord is not included, and an IEC-60320-C13 rated AC power cord must be provided.

Accessories

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

- **1220B LaserSource Cable, 4A, 2m**
  This cable has DB-9 male/female connectors for interfacing to the LaserMount or other connectorized fixtures, and shielded twisted pair conductors for improved modulation performance. A pigtailed version of this cable, with tinned ends for soldering into custom solutions, is available as p/n **1221B**.
- **1260B TECSource Cable, 5A, 2m**
  This cable has DB-15 male/female connectors for interfacing to the LaserMount or other connectorized fixtures, and supports up to 5A of TE current and connections for the fan interface. A pigtailed version of this cable, with tinned ends for soldering into custom solutions, is available as p/n **1261B**.
- **Pak Series Rack Mount Kit, 3 or 5 units (p/n 1402B-RM)**
  For installing your **ComboPak** into a standard 19" rack. The kit accepts either 3 units for a 2U installation, or 5 units for a 3U installation.
- **1600-10K 10kΩ Thermistor**
  Accurate to ±0.2°C.
- **1200-NULL RS-232 NULL Cable, 2m**
- **1201 USB Cable, 3m**

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.
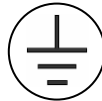
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Symbols

◯   Power Off | Power On

⚠   Caution, refer to manual   ⏚   Earth ground

⚡   Caution, risk of electric shock

General Warnings

> ### WARNING
> Potentially lethal voltages exist within this instrument. 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 **ComboPak** was designed with ease of use in mind, and you will likely have little need for this manual for most of the features the unit offers. This section will show how you can quickly get the unit up and running.

Plug the AC cord into the unit and into the wall outlet. The **ComboPak** has a universal AC input, so no voltage selection is required. Turn on the power switch located next to the AC input, and the green power light will illuminate, indicating the unit is on. Next, connect a USB cable between the instrument and your computer to allow for control of the instrument.

Because the **ComboPak** has no user interface, you will need to use a software program to adjust the parameters of the instrument. It is recommended you start with **ArroyoControl**, the free software program included on the CD with your instrument. After installing **ArroyoControl,** connect to the instrument and click on the *Settings* button to configure the limits of the instrument per the requirements of your laser and TEC:

- In the Laser tab:
    - o Current limit – set just above the maximum operating current of your laser
    - o Voltage limit – set 0.5V above the maximum laser voltage

- In the TEC tab:
    - o ITE current limit – set to the maximum TEC current
    - o Temperature low limit – 5 degrees below the lowest operating point
    - o Temperature high limit – 5 degrees above the highest operating point
    - o Gain – start with 5 or 10, may need to be adjusted (see below)
    - o Sensor coefficients – ensure they match your device. If using an Arroyo Instruments mount with a thermistor sensor, the unit is already preprogrammed for that sensor.
    - o Fan – enable if your mount has a fan

Next, connect the cables between your **LaserMount** or other fixture and the **LASER** and **TEC OUTPUT** connectors of the **ComboPak**. We recommend using our cables as they have been designed to work well with the **ComboPak**, but if using your own cables, ensure they have been properly wired according to the pin-out of the **ComboPak** and your fixture.

Finally, change the set points to an appropriate current and temperature. You will want to turn the TEC on first, allow it to stabilize, and then turn on the laser. When turning on the laser for the first time, it is a good idea to start with a set

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point of zero and ramp up to the desired set point in steps. In this way, if the laser is wired incorrectly, the safety circuits will trip earlier and minimize any chance of damaging the laser. Once you have confirmed proper operation, the set point can be left at the desired operating point, and the output turned on and off.

If you notice the temperature is oscillating around the set point and not stabilizing, you may need to adjust the **Gain** setting in the TEC tab of 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. If you 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.

Continue reading for more detailed operating and installation instructions.

Installation

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

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

Powering Up the Unit

Connect the AC power cord to the unit. You must properly ground the unit by plugging the supplied power cord into a three prong grounded outlet, or using a three-to-two prong adapter and connecting the ground tab to earth ground.

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.

Press the power switch, located adjacent to the AC input, into the on (|) position. The Power LED will light, indicating the unit is operational and return to the last known operating state.

Ventilation

The **ComboPak** has vent holes on the front, back, and sides of the unit. While unlikely, you must not block these vent holes or overheating may occur, causing damage to the unit. The only exception is you may block the vent holes on one side of the unit (such as when using the 1402B-RM), but not both.

> **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 unit may occur.

Rack Mounting

Rack mounting kits (**p/n 1402B-RM**) for standard 19" racks are available for the **ComboPak**. The kit accepts either 3 units for a 2U installation, or 5 units for a 3U installation.

The **1402B-RM** can also be used with **LaserPak** and **TECPak** instruments in a mixed use configuration.

> **WARNING**
>
> Ensure that any screw used to secure the ComboPak to the 1402B-RM rack mount tray or any other surface does not exceed the maximum penetration depth specified in the mechanical drawings section later in this manual.

Warm-up and Environmental Considerations

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

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Settings

All parameters of the **ComboPak** can be accessed 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.

Details on how to communicate with the **ComboPak** using your own program can be found in the *Computer Interfacing Manual* which is included on the CD that accompanied this product.

Menu	Description	Factory Default	Computer Command
	Basic Laser Settings		
Mode	As described in the *Laser Control Modes* section below, the unit offers five control modes: Io (ACC), Io HiBW (ACC), Im (AMC), Po (APC), and Vf (AVC). Change this setting to select a new mode.	Io (ACC)	LAS:MODE
Io limit	This setting controls the maximum amount of forward current that can be delivered to the laser diode. This limit is implemented in hardware for immediate response. For more information about limits, see *Using the Laser Limits* below.	Maximum	LAS:LIM:LDI
Im limit	This setting controls the maximum amount of monitor photodiode current the unit will allow. This limit is implemented in software. For more information about limits, see *Using the Laser Limits* below.	Maximum	LAS:LIM:MDI
Po limit	This setting controls the maximum amount of monitor photodiode power the unit will allow. This limit is implemented in software. For more information about limits, see *Using the Laser Limits* below.	Maximum	LAS:LIM:MDP

Menu	Description	Factory Default	Computer Command
Vf limit	This setting controls the maximum amount of forward voltage that can be delivered to the laser diode. This limit is implemented in hardware for immediate response. For more information about limits, Using the Laser Limits *and Software Limits* below.	Maximum	LAS:LIM:LDV
Cable R	The cable resistance, in ohms. This setting can be used to compensate for voltage losses in the cable due to cable and connector resistances. **Cable R** is ignored in Vf (AVC) Mode. For more information about this feature, see *Compensating for Voltage Loss* below.	0.0000 Ω	LAS:CABLER
PD Resp	This factor is used by the unit to convert from monitor photodiode current into optical power. The value is in terms of microamps per milliwatt (μA/mW), such that power = photodiode current divided by the factor.	0.00μA/mW	LAS:CALPD
Tol Time	Tolerance time is the amount of time, in seconds, that the measured value (current, voltage, etc.) must be within the set point +/- the tolerance for the unit to be considered in tolerance. In Io modes, the tolerance is defined by **Tol Io**. For Im/Po modes, the tolerance is fixed at 50uA. For Vf mode, the tolerance is fixed at 50mV.	5 seconds	LAS:TOL
Tol Io	Tolerance current is a band (in mA) around the set point. When the actual current is within this band for longer than the Tol Time setting, then the unit is considered to be in tolerance.	10.0mA	LAS:TOL
On Delay	The delay, from the time the output is turned on with the LAS:OUTPUT command or the analog interface to when the output is actually energized.	3000ms	ONDELAY

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Menu	Description	Factory Default	Computer Command
	Basic TEC Settings		
Mode	This set the operating mode (*T Mode*, *R Mode*, or *Ite Mode*) of the temperature controller.	T Mode	TEC:MODE
Mount	Specify the mount connected to the **ComboPak**. If using a **LaserMount**, select the appropriate model. Otherwise, select *User*.	User	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. A higher gain value will cause the controller to respond more quickly to the difference between the set point and the actual temperature, while a lower value will cause it to respond more slowly. Select *PID* 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 *PID*.	1	TEC:P
PID I	The integral term of the PID loop. Will only be available if **Gain** is set to *PID*.	0.01	TEC:I
PID D	The derivative term of the PID loop. Will only be available if **Gain** is set to *PID*.	0	TEC:D
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

Menu	Description	Factory Default	Computer Command
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
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 ComboPak. See the *Resistive Heaters and Heat/Cool Only Modes*, below, for more information.	Heat/Cool	TEC:HEATCOOL

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Menu	Description	Factory Default	Computer Command
Ext Fan	This selects the voltage for the auxiliary fan power supply. See the *External Fan Control* section below for more information.	Off	TEC:FAN
Ext Fan Pwr	When **Ext Fan** is set to *Custom*, this sets the specific fan voltage from 4.0 to 12.0 volts. See the *External Fan Control* section below for more information.	12.0	TEC:FAN
Ext Fan Mode	Controls when the fan operates. See the *External Fan Control* section below for more information.	Auto	TEC:FAN
Ext Fan Off	When **Ext Fan Mode** is set to *Delay*, this setting defines the number of minutes to delay turning off the fan after the TEC output has been turned off. See the *External Fan Control* 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
TEC Sensor Settings			
Thermistor coefficients	Thermistor coefficients in the Steinhart-Hart equation.	A= 1.12924E-03 B= 2.34108E-04 C= 0.87755E-07	TEC:CONST
Communications Settings			
Err While Rmt	To turn off the display of errors while in remote mode, set this value to "No". To display errors while in remote mode, set this value to "Yes".	Yes	REMERR

Menu	Description	Factory Default	Computer Command
Terminal Mode	Terminal mode simply echoes any characters received over the serial or USB interfaces.	No	TERMINAL
Msg Term	This controls the output message termination, and can be set to CR/LF, CR, LF, or None.	CR/LF	TERM

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Connecting Your Device to the ComboPak

A laser diode is very sensitive to electro-static discharge (ESD), over-voltage, and over-current conditions. When connecting a laser to the **ComboPak**, make sure proper ESD procedures are taken. In addition, it is critical that the proper current limit and voltage limit be set for the laser diode. Exceeding the laser diode's rated current or voltage can damage or destroy the laser diode, and the **ComboPak's** hardware protection features can only protect the laser diode if these limits are properly set.

CAUTION

The interlock connections must be kept isolated from all other connections and from earth ground. Failure to do so may damage the instrument.

The laser anode and cathode outputs are electrically isolated from ground, as are the photodiode inputs.

NOTE

Connections to the **ComboPak** and the laser diode fixture must be secure. Tighten any screws on the DB-9 connectors, and make sure all connections are in good condition. Poor or intermittent connections can damage or destroy the laser diode.

A cable is required for both the TEC and Laser outputs. Arroyo Instruments carries cables specifically designed for these applications, both with a DB connector on the device end or with a bare wire pigtail for terminating the connection into a custom mount or device:

Function	DB to DB p/n	DB to Pigtail p/n
Laser	1220B	1221B
TEC	1260B	1261B

NOTE

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

See the manual of your laser (and fixture) for additional safety and operational information.

Power and Cable Connections

ComboPak TEC (Left) and Laser (Right) Connectors

Laser Output Connector

The **Laser Output** connector is a female DB-9, and has the following pin-out:

DB-9 Pin	Description
1	Interlock+
2	Interlock –
3	Earth Ground
4	Laser Cathode Voltage Sense
5	Laser Cathode
6	Photodiode (PD) Cathode
7	Photodiode (PD) Anode
8	Laser Anode Voltage Sense
9	Laser Anode
Shell	Earth Ground

Laser Output Connector (DB-9 Female)

Arroyo Instruments has followed industry conventions for laser DB-9 connections, and is compatible with pin-outs from other vendors, such as ILX and Newport. However, care should still be taken when interfacing the **ComboPak** to other vendors' products, and if you have any questions, please contact your distributor or the factory.

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TEC Output Connector

The TEC Output connection is a female DB-15, and has the following pin-out:

DB-15 Pin	Description
1, 2, & 9	TE (+)
3, 4, & 10	TE (–)
5 & 6	Earth Ground
7	Sensor+
8	Sensor –
11	Fan+
12	Fan –
13 thru 15	Reserved (no connect)
Shell	Earth Ground

TEC Output Connector (DB-15 Female)

ComboPak IPC and Control Connectors, LEDs

Input Power Connector (IPC)

The Input Power Connector (IPC) accept a IEC-60320-C13 power cord, the same type of power cord used with most computers.

Control I/O Connector

The Control I/O connection is a male DB-15, and has the following pin-out:

DB-15 Pin	Description
1	Laser On/Off Control Input
2	Laser On/Off Status Output
3	Laser Stable Output
5	Modulation (+)
6	Modulation (−)
7	+5V Auxiliary Supply
8	Ground
9	TEC On/Off Control Input
10	TEC On/Off Status Output
11	TEC Stable Output

Control I/O Connector (DB-15 Male)

The +5V auxiliary supply is provided for external low-power electronics. Current draw on this supply should not exceed 100mA. The Ground pin provides the ground reference for the logic inputs as well as the auxiliary power supply. The modulation input provides a separate negative/ground reference (pin 6) which should only be used with the modulation signal. The control interface is described in detail in the *Using the Control Interface* section below.

Modulation Input

The modulation input is made on pins 5 (+) and 6 (−) of the Control I/O connector, and accepts a 0-10V input signal for analog set point control of the driver. The modulation input is not optically isolated from the control circuit, and care should be taken to prevent ground loops.

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.

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Grounding and Wiring Considerations

The **ComboPak** electrically isolates the control circuitry from Earth Ground, allowing the laser anode or laser cathode to be connected to earth ground and still allow proper operation.

However, care needs to be taken when connecting the **ComboPak** to your module, especially when using the Control I/O Interface, to prevent damage to the **ComboPak** or to your laser module.

> **CAUTION**
>
> Excluding the AC and USB ground connection, making more than one earth ground connection to any signal or control pin may cause damage to the instrument or your device.

> **CAUTION**
>
> Never connect the Control ground (pin 8) to the laser or TEC output pins, or damage to the instrument or your device may result.

Always follow these rules when connecting to the **ComboPak**:

1. Never have more than one earth ground connection to any Laser, TEC, or Control I/O pin.
2. Never connect any Control I/O pin to any Laser or TEC output pin.
3. Never connect TE+ or TE− to anything but the TEC module.
4. Never connect Sensor+ or Sensor− to anything but the thermistor sensor.
5. Never connect Fan+ or Fan− to anything but the fan.

The most common potential wiring issue is the first item, where the laser has the anode or cathode connected to earth ground and one of the signals on the Control I/O is also earth grounded (such as the modulation source or the digital I/O pins). This causes a ground path through the laser module that, at a minimum, can disrupt proper operation of the **ComboPak**, or, at worst, damage your laser. In situations like this, you must break one of the ground paths, either by isolating the laser module from earth ground, or by breaking the ground path on the instrument connected to the Control I/O interface.

The second item typically happens along with the first item, where the ground for the Control I/O signals is earth ground and the laser is also earth grounded.

However, the broader rule is that you can never connect any pins on the Control I/O interface to any pins on the Laser or TEC pins.

The last three requirements are typically not a problem, as these signals are almost always isolated signals from the laser or mount.

Installing the USB Drivers

Using the **ComboPak** via USB is just as simple as using a 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 **ComboPak** and follow the on-screen instructions. In many cases, the CD may not even be required, as your computer may download the drivers automatically using the Windows Update service.

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 a **USB Serial Port** is the **ComboPak**. In the event you have multiple Arroyo Instruments products plugged in simultaneously, you will need to experiment to see which instrument was assigned to which port.

Arroyo Control

While most of the settings of the **ComboPak** 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 full operating control of the **ComboPak**, 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).

Saving and Restoring Configurations

Using the *SAV and *RCL commands, the **ComboPak** allows you to save up to four configurations. Each configuration will store all of the instrument settings

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(except scripts and the function key definitions), 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 restore a unit to factory defaults, use the *RST (or *RST 0) command, however, scripts and configurations are *not* erased, and user calibration data is *not* cleared. To reset the unit, including erasing scripts, configurations, and user calibration data, you must use the *RST 1 command.
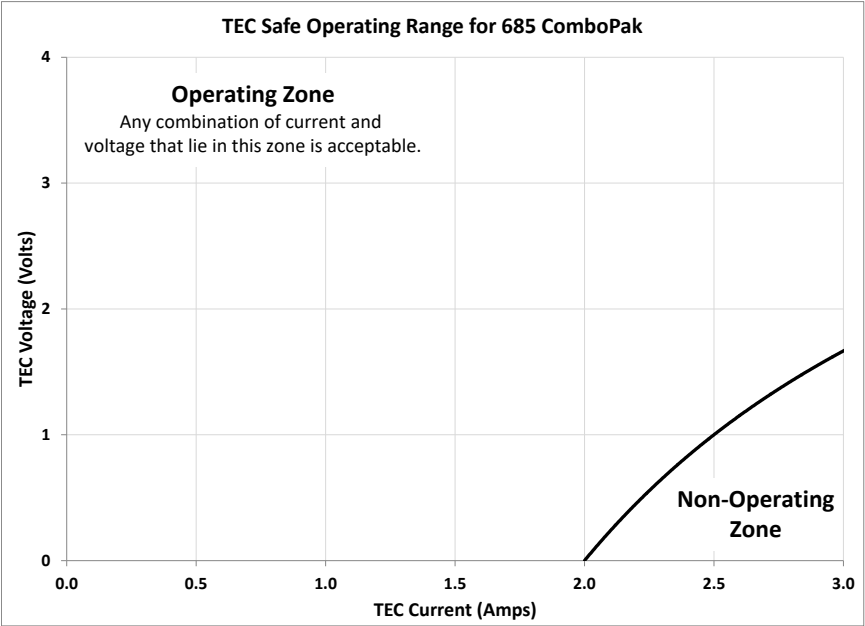
Thermal Considerations

The **ComboPak** is designed to provide high power in a small enclosure. Both the laser and TEC sections of the **ComboPak** can be thermally overloaded if operated at high currents with a low voltage, and each section handles the thermal overload condition differently.

For the laser section, only the 2 Amp model of the **ComboPak** is at risk of a thermal overload, and only when driving nearly a dead short at maximum current. In this case, the driver will always respond by turning the output off and generating an E-537 error message in an overload condition. Lower current models (1 Amp and below) have no risk of thermal overload.

For the TEC section, the **ComboPak** will automatically protect itself by lowering the TEC current until it is no longer in an overload condition. This may lower the deliverable power to your TEC, but it will prevent any damage to the **ComboPak**. One exception to this is if you are operating in ITE (or constant current) mode. In this mode, because you are specifying a specific drive current for the TEC, if there is a thermal overload condition, the output will be turned off and an E-438 error message will be generated.

If your output thermally trips, you can add a small series resistor (to the laser or TEC, as appropriate) to remove some of the power from inside the unit. Typically, a 10W 1Ω load resistor in series with the output is sufficient, but higher resistances and or power handling may be needed, depending on the voltage and current configuration of your **ComboPak**. Please feel free to contact the factory for more information and support.

Below is a graph that illustrates the minimum voltage requirements for the TEC section of all **ComboPak** controllers:

TEC Safe Operating Range for 685 ComboPak

Operating Zone
Any combination of current and
voltage that lie in this zone is acceptable.

**Non-Operating
Zone**

TEC Voltage (Volts)

TEC Current (Amps)

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Using the Laser Driver

Laser Control Modes

The **ComboPak** offers five laser control modes: **Io (ACC)**, **Io HiBW (ACC)**, **Im (AMC)**, **Po (APC)**, and **Vf (AVC)**.

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

Io and **Io HiBW** modes (referred to collectively as ACC, or automatic current control modes) are used to drive a specific current through the laser diode. When in this mode, the set point will be in milliamps, and the **ComboPak** will drive the desired current through the laser diode as long as the voltage at the chosen set point does not exceed the voltage limit. In **Io** mode, you will be limited to less than a 10 Hz bandwidth. To modulate above that rate, use the **Io HiBW**, which is a high bandwidth current mode supporting modulation. For improved noise performance in high bandwidth mode, the analog filter can be enabled, see *Analog Filter* below for more details.

Im mode (also referred to as AMC, or automatic monitor photodiode control, mode) is used to control the laser diode using the monitor diode feedback. You select the target monitor diode current, and the **ComboPak** will drive exactly enough forward current through the laser diode to generate the selected monitor diode current. Only low frequency modulation (10Hz or less) is possible in **Im** mode due to the feedback latencies of the photodiode itself.

Po mode (also referred to as APC, or automatic power control, mode) is simply **Im** mode with a mathematical constant applied to the set point, providing a convenient way of operating in milliwatts. Using the **PD Resp** factor (in µA/mW), a **Po** set point is internally converted to an equivalent **Im** set point by the driver, which is then used to control the photodiode feedback. For example, if the **PD Resp** factor was 10, then a set point of 1mW would be the same as a set point of 10µA.

Vf mode (also referred to as AVC, or automatic voltage control, mode) is used to control the voltage driven through the device. Unlike ACC mode, AVC mode allows the current to drive to whatever current is necessary to achieve the voltage set point, so long as it does not exceed the current limit. As with **Im** mode, only low frequency modulation (10Hz or less) is possible in **Vf** mode.

Using the Laser Limits

Both the laser current and voltage limits are implemented in hardware, providing for fast response to changes in laser diode operation. When a voltage limit is detected, the output is immediately shutdown. Because of the sensitivity of the voltage limit, operating near the limit (within one to two hundred millivolts) is not recommended. In general, you should set the voltage limit to 0.3V to 0.5V higher than any anticipated operating point. The voltage limit is tested against *the voltage at the connector*, unless in remote voltage sense mode. Any **Laser Cable R** value is ignored, as **Laser Cable R** is a software only calculation, and the voltage limit is implemented in hardware. See *Compensating for Voltage Loss* for more information on the **Laser Cable R** setting.

Unlike the voltage limit, the current limit simply prevents the **ComboPak** from delivering more current than the limit is set to. When the current limit engages, the output will remain on.

The photodiode current and photodiode power limits are implemented in software and may take up to one second to trigger when these conditions occur, and therefore should not be relied on to provide fast protection of the laser diode.

Analog Modulation

The instrument supports external analog modulation using the modulation pins on the analog interface connector. Modulation rates vary by model, so see your model's specification for the maximum modulation rates. Only **Io HiBW** mode supports high speed modulation. All other modes of operation have a modulation bandwidth of 10Hz or less. See *Using Modulation* below for more details, especially with regards to wiring considerations.

The analog modulation input on pins 5 and 6 of the Control I/O interface allows for external control of the current set point using a 0 to 10V analog signal. 10V equals the maximum operating range. For example, a 500mA model of the **ComboPak** will attempt to drive 500mA when 10V is applied to the modulation input (so the "transfer function" is 50mA/V).

In addition, the set point **adds** to the modulation input, so using the same **ComboPak** example, if you were to apply 5V and the set point was 100mA, then the resulting drive current would be 350mA (5V = 250mA plus the 100mA set point).

You must also consider that the modulation input is not a precision input, so for accurate current control, you should calibrate the modulation input using a one

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point or two point calibration and apply the calibration to your voltage input. The instrument will measure actual current flowing, so turn the output on with the current set point at 0mA, apply a modulation input signal, and the instrument will measure the actual current, which you can use to calibrate your voltage set point.

When modulating at higher frequencies (>1 kHz), it is critical that high quality, shielded twisted pair cabling be used, and wire size suitable for the applied current (or the equivalent if using a multi-conductor cable). See the chart below for suggested sizes. Failure to do so may result in current oscillations that may damage your laser. When operating in these modes, always use shielded cable and never use individual wires to connect the instrument to your laser. If in doubt, use a current probe attached to an oscilloscope to monitor actual performance.

The **1220B** or **1221B** cables recommended by Arroyo Instruments are shielded twisted pair, and will provide good modulation performance.

Current (A)	Recommend Wire Gauge
1 or less	24 AWG
2	22 AWG

Compensating for Voltage Loss

All cables and connectors have a small, but measurable, resistance. When driving current through them, this resistance causes a voltage loss in the cable, and if not compensated for, will result in errors in laser or LED voltage measurement. In many cases, this is not a problem, as highly accurate voltage measurement are typically not required and the error can be ignored. However, if accurate voltage measurements are required, the **ComboPak** offers two methods to compensate for this loss: the **Cable R** setting and remote voltage sense. **Cable R** compensation is software only, so it requires no special wiring to implement. Remote voltage sense, on the other hand, does require additional wiring, but is the most accurate method. Details on both are found below.

Using Remote Voltage Sense

The **ComboPak** supports remote (4-wire type) voltage measurement of the laser diode, providing a higher accuracy voltage measurement by directly measuring voltage at the diode itself. While the **Cable R** setting described below can provide some of the same benefits of remote voltage sense, remote voltage sense is a superior method, and remote voltage sense differs from the **Cable R** method in a few key ways:

1. No need to calculate cable resistance
2. Voltage measurement is accurate even if the cable resistance changes

3. The hardware safety circuits use the remote voltage, providing for a greater degree of protection (**Vf Limit** works on the remote voltage at the laser rather than the local voltage at the connector)
4. Works in voltage control mode

The diagram below shows conceptually how to wire the laser to the **ComboPak**, using a 4-wire connection:
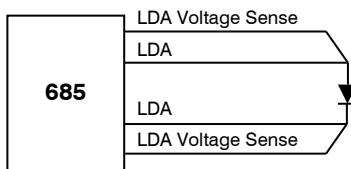
However, remote voltage sense does have a few drawbacks:

1. If the remote sense wires are disconnected, it disables the hardware voltage limit as well as the measurement of laser voltage.
2. Requires two additional wires to be run to the device.

It is the first of these two drawbacks that is of the biggest concern. In order to protect against this fault, the instrument always monitors the local voltage at the connector as well as the remote voltage, and if the difference is too great, a warning message is generated. Once the warning is generated, it will not be generated again until the output is turned off and back on.

Using remote voltage sense is very simple. First connect pin 4 of the **Laser Output** DB-9 to the laser cathode, and pin 8 to the laser anode, then in the menu, set **Vf Sense** to *Remote* (LASER:VSENSE 1). Indicated voltage will now be the remote diode voltage.

When using remote voltage sense, any **Cable R** setting is ignored.

Using the 'Cable R' Setting

The **Cable R** setting allows you to calculate the voltage at the laser by subtracting the voltage loss through the cable and connectors. This is done by measuring or calculating the cable resistance and setting the value, in ohms, using the LASER:CABLER command. The instrument will then use the $V = I * R$ formula to calculate the voltage loss in the cable and subtract that from the actual measured voltage, returning the result as Vf.

Common values for **Cable R** range from 0.0300 Ω to 0.0900 Ω, but can be significantly higher if you have long runs, many connector interfaces, or small gauge wire.

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While it is possible to use a DMM to measure the resistance of the cable, because resistance is so small, you will not typically get proper readings (most DMMs are not designed to properly measure small resistances). A better approach is to use the instrument to drive current through the system and then measure the voltage loss to determine resistance. There are two ways to best calculate the voltage loss:

Measure the Voltage at the Laser

Using an accurate voltage meter, take two voltage measurements: one across the anode and cathode pins of the laser, and a second across pin 5 and pin 9 of the **Laser Output** connector. The difference between the measured voltages is the voltage loss in the cable. Use this formula to calculate resistance:

$$Cable\,R = \frac{V_{Output} - V_{Laser}}{I_{Amps}}$$

Note that the current is expressed in *amps*, not *milliamps*, so divide the set point by 1000 before using it in this equation.

Short the Connection at the End of the Cable

A second method, which does not require a DMM and can be done with just the **ComboPak** itself, is to short the anode and cathode wires at the end of the cable (nearest the laser diode), drive current through the cable and note the measured laser voltage (LASER:LDV?). The resistance is found using a simpler version of the formula above:

$$Cable\,R = \frac{Vf}{I_{Amps}}$$

Note that the current is expressed in *amps*, not *milliamps*. The easiest way is to drive 1A of current. When I_{Amps} equals 1A (1000mA), the measured voltage is also the resistance of the cable.

To short the cable, disconnect the laser and short the anode and cathode together as close to the end of the cable as possible. Ideally, the short should be done by soldering the anode and cathode wires together to minimize the resistance in the short itself.

How the Calculation Is Used

The **ComboPak** continuously takes the measured current, multiplies it by the resistance (**Cable R**), subtracts the result from the actual voltage at the output

connector, and returns this value laser the measured laser voltage (LASER:LDV?). However, there are some limitations to how the cable loss calculation is used:

1. The value for **Vf Limit** *is always the voltage at the connector* (except when using remote voltage sense, see above). This means that the **Vf Limit** must take into account all the voltage required, including the cable loss (i.e., the voltage measured if the **Cable R** value were zero).
2. **Cable R** is ignored in Vf mode. This means that the set point and measured voltage are always the voltages at the connector, and **Cable R** is not used.

Using the Temperature Controller

TEC Control Modes

TEC Control Modes

The **ComboPak** 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 by sending the appropriate TEC:MODE command, or through **Arroyo Control**.

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 the TEC Limits

The **ComboPak** supports three different types of limits: temperature, sensor, and TEC 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.

Temperature and sensor limits are implemented in software, so reaction time to a limit may be several tenths of a second. Limits can be enabled or disabled using the TEC:ENABLE:OUTOFF command. Temperature and sensor limits are enabled by default.

Selecting the Fixture

The **ComboPak** 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 change the **Mount** selection using the TEC:MOUNT command. By selecting a mount, the current limit, temperature limits, default gain, and sensor settings are automatically adjusted to values appropriate to the mount.

Adjusting the **Mount** setting to *User Defined* (TEC:MOUNT USER) removes all software limits, allowing unrestricted operation of the **ComboPak**.

Working With Thermistors

The **ComboPak** 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:
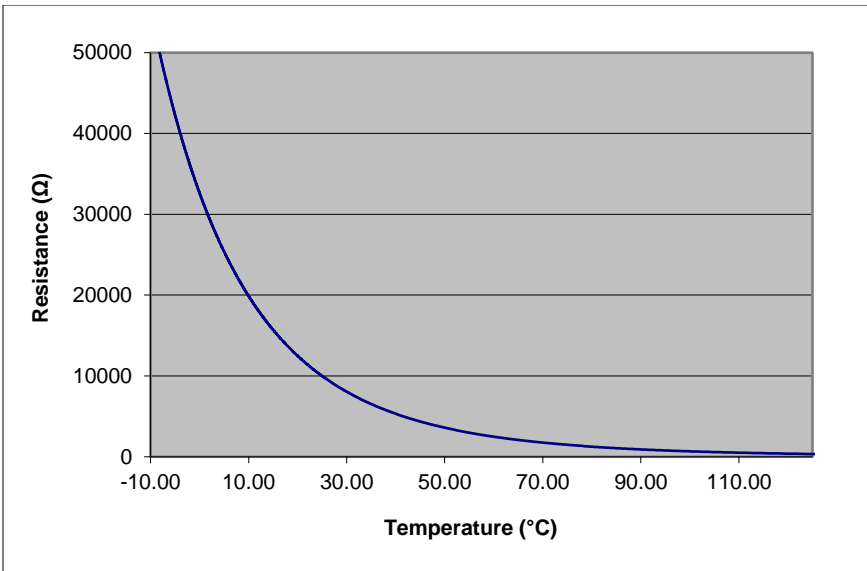
Typical Resistance vs. Temperature Graph

As can be seen on the graph, the resistance of the thermistor drops very quickly. In the typical control range (0°C to 40°C), 10K thermistors offer good sensitivity to changes in temperature, and this is the range in which most 10K thermistors are 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

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the resistance sensitivity of the thermistor at your application temperature, which varies greatly by temperature and thermistor types.

The **ComboPak** measures sensor resistance using a 100µA constant current source, with an upper measurement range of 45kΩ. This will limit low temperature range operation depending on the thermistor type. For Arroyo Instruments' standard thermistors, this means a lower operating range of about –7°C.

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 **ComboPak** defaults to the coefficients for the BetaTHERM 10K3A1 thermistor (A = 1.12924×10^{-3}, B = 2.34108×10^{-4}, C = 0.87755×10^{-7}). You can change the coefficients using the TEC:CONST command.

External Fan Control

The **ComboPak** has a built-in user adjustable 4-12V DC power supply designed to provide up to 250mA to an external fan, such as those built into the **200** and **240 Series Series LaserMounts**. When using the **ComboPak** with mounts that require a fan, no additional external power supply is needed, however, the cable must include the wiring needed for the fan. The **1260B**, **1261B**, **1262B**, and **1263B** cables include the necessary wiring.

Fan control is set using the TEC:FAN command. The fan can be set to *Off*, *Slow*, *Medium*, *Fast*, or to a specific fan voltage. When set to *Off*, the fan power is never turned on. *Slow*, *Medium*, and *Fast* correspond to 9V, 10.5V, and 12V.

The fan on/off mode can be controlled using five different modes:

Auto   Fan is turned on whenever the TEC output is on, and turns off when the TEC output is turned off.
On   Fan is always on.
Delay   Similar to the *Auto* mode, 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.

Cool   Fan is turned on whenever the TEC output is on and cooling, off otherwise.

Heat   Fan is turned on whenever the TEC output is on and heating, off otherwise.

For more details, see the TEC:FAN command in the *Computer Interfacing Manual*.

Resistive Heaters and Heat/Cool Only Modes

The **ComboPak** supports temperature control using resistive heaters instead of Peltier coolers. With resistive heaters, cooling is obviously not possible, and the **ComboPak** 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 **ComboPak** to operate in a cool-only mode. This is only possible with Peltier coolers, as resistive heaters will heat regardless of the direction of current.

To change the cooling mode use the TEC:HEATCOOL command.

Gain Control and the PID Loop

The **ComboPak** supports a fully configurable PID loop, allowing full customization of the PID control parameters. To simplify control, eight standard gain settings are 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* (specifically, 1, 3, 5, 10, 30, 50, 100, 300) and set 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 use the TEC:PID command to set the individual P, I, and D values.

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

$$Output = P * \varepsilon + I * \sum \varepsilon dt + D * \frac{d\varepsilon}{dt}$$

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

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

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The controller can calculate 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 **ComboPak** is capable of automatically determining PID parameters for most applications. Using a form of the Ziegler-Nichols method, the **ComboPak** 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 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 ambient temperature (23°C). While this starting point 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, turning the output on, if necessary. 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 never started the AutoTune process.

Once the AutoTune process is complete, the output will remain on. The three PID parameters can be retrieved with the TEC:PID? query.

More details on the use of the command can be found in the *Computer Interfacing Manual*.

The typical temperature profile of an AutoTune process is shown in the graph below. The first step, which is the calculation of the P and D parameters, completes at around 68 seconds, then the mount is allowed to stabilize with the new P and D parameters. The second step begins, which is the determination of the I term. This completes around 200 seconds into the test, and then the output stabilizes with the calculated set of PID parameters for the remaining portion of the graph.
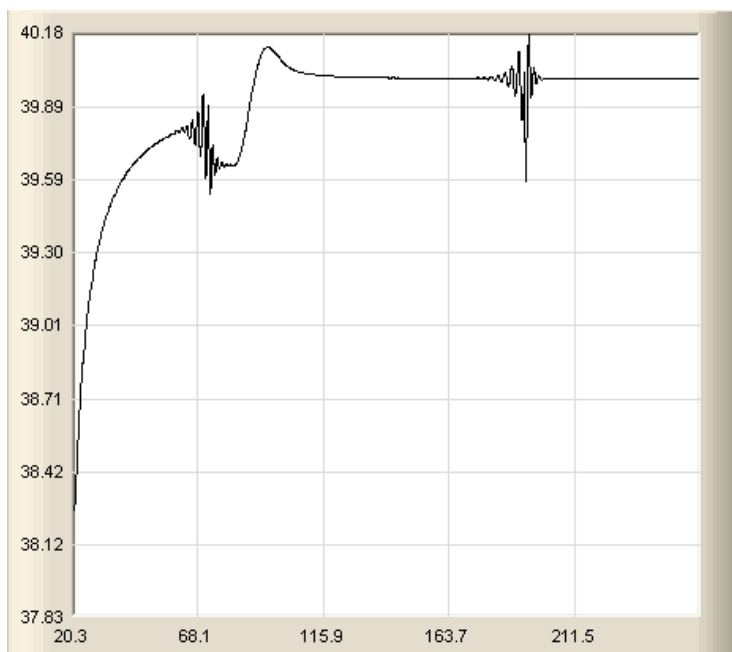
If the AutoTune process fails, the instrument will generate an E-436 AutoTune Failed error message and turn the output off. Any of the following can cause the AutoTune to fail:

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

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If AutoTune fails due to system limitations, you will need to manually modify the PID parameters as described in the section above or select a factory gain setting.

You can turn the output off at any time to cancel the AutoTune process, and the PID parameters will remain unchanged (an E-436 will also be generated).

Compensating for TEC Cable Resistance

Because the high currents the **ComboPak** can drive through the Peltier, the voltage loss through the cable and connectors of the system can 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 compensation, the cable resistance setting (TEC:CABLER) allows you to specify the cable resistance, which is then used to dynamically subtract the voltage drop by simply using the formula $V = I * R$ to calculate the voltage loss, where I is the TEC ITE current, and R is the cable resistance setting. This value is then removed from the voltage measurement to display a more accurate TEC voltage measurement.

The safest method of calculating cable resistance is to short the ITE+ and ITE− connections, making sure whatever you are using to short the terminals is not itself adding resistance to the circuit. 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 DB15 connector and soldering the ITE+ and ITE− 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 1 Amp. Depending on your setup, you may first need to change the Mount to User Defined and adjust the limit to 1A. Turn on the output and after the voltage has stabilized, make a note of it and turn the output off. Because the TEC current is 1 Amp, the TEC voltage is also the cable resistance ($V=I * R$) value.

Set the cable resistance value using the TEC:CABLER command and return the instrument to its original configuration. Typical values for cable resistance are 0.008 to 0.040, but depend on your actual configuration.

Field Calibration (User Cal)

The **ComboPak** is typically calibrated annually. Calibration can be done one of two ways: the instrument can be returned to the factory for a full recalibration, or the user calibration commands can be used for simple slope/offset calibration.

<div style="border:1px solid black; border-radius:15px; padding:10px;">

CAUTION

Because user calibration directly affects the performance of the instrument, it must be performed by a qualified technician with sufficiently accurate meters and test loads to properly measure the actual performance of the instrument. Failure to do so could significantly degrade the performance of the instrument or damage your device.

</div>

Factory calibration has the benefit of a full multi-point calibration and verification of instrument performance against NIST-traceable instrumentation, using equipment and test loads designed specifically for the application.

However, field (or user) calibration is possible, and often desirable, as it allows the user to meet certification or calibration requirements not available through a factory calibration.

This field or user calibration is accessible through the **LASER:USERCAL** and **TEC:USERCAL** commands over the computer interface.

Basic steps for user calibration:

1. Take measurements to generate slope and offset values for elements you wish to calibrate.
2. Enable user calibration editing using the TEC:USERCAL:EDIT or LASER:USERCAL:EDIT command.
3. Update the user calibration data using the TEC:USERCAL:PUT or LASER:USERCAL:PUT command.

The above is a very abbreviated list of commands. See the LASER:USERCAL and TEC:USERCAL commands in the *Computer Interfacing Manual* for more detail.

For each set point or measurement, there is a corresponding slope and offset calibration. For example, the **ComboPak** laser current uses the "high" calibration range (index 2 for set point, and index 7 for measurement) − see the TEC:USERCAL:PUT or LASER:USERCAL:PUT commands for a complete list of indexes.

When the slope is 1 and the offset is zero, this is considered an "uncompensated" measurement. If you change either the slope or offset, the

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value becomes "compensated" based on these values. The compensation formula (a linear equation) is very simple:

$$Compensated = Slope * Uncompensated + Offset$$

Depending on how you wish to calibrate, a simple offset calibration may be sufficient, where only the offset value is adjusted and the slope is left at 1. This level of calibration can be done using a single measurement, and if absolute accuracy is only critical at a single point, this may be sufficient. For a slope and offset calibration, you will need at least two points to compute the slope and offset, and greater than two points can be used in a least-squares-fit algorithm.

Single Point Offset Calibration

Let's say that you want to precisely calibrate the laser drive current at 300mA. You set the instrument at 300mA, observe that the actual current is 298.6mA and the current measured by the **ComboPak** is 301.2mA.

To correct the set point, you need to adjust the offset value for the high range Io set point, which is index 2. Considering that you need to *raise* the set point by 1.4mA, then index should be adjusted to +1.4mA. The command would look like:

```
LASER:USERCAL:PUT 2,1,1.4
```

This will compensate the set point by *increasing* it 1.4mA and bring it closer to 300.0mA.

The measurement adjustment is similar, but in this case, you need to adjust index 7 to −1.2mA to bring *down* the measurement to 300mA:

```
LASER:USERCAL:PUT 7,1,-1.2
```

In both cases, the slope was left at 1, and only the offset was adjusted.

Multi-Point Calibration

Multiple point calibration is mathematically more complex but improves calibration to operate across a range of values rather than at a single point. This addresses a downside of single point offset calibration where it can cause the instrument to no longer be in calibration at points away from the single calibration point. To keep the math simple in our example, we will only do a two point calibration, but a higher number of points are possible, and the slope can be calculated using a least-squares-fit algorithm (offset calculation is the same in either case).

Consider the following two data points, where 'actual' is what you are measuring with your meter, and 'measured' is the measured current as reported by the **ComboPak**:

Set point	Actual	Measured
100	101.5	100.6
300	298.6	301.2

As stated above, correction is done using a linear equation, and we need to calculate the slope and offset. Slope must be calculated first, and is calculated using the following formula:

$$\text{Slope} = (y_2 - y_1) / (x_2 - x_1)$$

For the set point calibration, 'x' is the actual current and 'y' is the set point. For the measurement calibration, 'x' is the measurement and 'y' is the actual current. Make sure to note how the actual current changes position depending on what you are calibrating.

The offset is equally simple to calculate:

$$\text{Offset} = y_1 - \text{Slope} * x_1$$

So for the set point calibration, you would have the following two calculations:

$$\text{Slope} = (300 - 100)(298.6 - 101.5) = 200 / 197.1 = 1.0147 \text{ (slightly rounded)}$$
$$\text{Offset} = 100 - 1.0147 * 101.5 = -2.9934$$

You can validate your calculations by applying the formula to one or both of the data points to confirm the compensation is correct. Consider the 300mA set point … if we apply the values just calculated, we should get a compensation that increases the set point by slightly over 1.4mA to bring it up to 300mA. Let's check:

$$300\text{mA test point} = 1.0147 * 300 - 2.9934 = 301.4166\text{mA} - \text{check!}$$

Likewise, the 100mA set point should be *lowered* by slightly more than 1.5mA:

$$100\text{mA test point} = 1.0147 * 100 - 2.9934 = 98.4766\text{mA} - \text{check!}$$

You can enter this calibration by sending the following command:

```
LASER:USERCAL:PUT 2,1.0147,-2.9934
```

You can make the same tests of the measurement side. By using the multiple point calibration, you benefit from the calibration across a much wider operating range. When choosing your two data points, you can either calibrate specifically

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for your application, where the upper point should be the maximum current you plan to operate, and the lower data point near the minimum current you plan to operate (but above zero). Alternatively, you can take two generalized data points of 80% of the range of the instrument as the upper point and 20% of the range as the lower point… this latter approach provides a more general calibration that will function across the full range of the instrument.

Accuracy Requirements

When calibrating the instrument, we recommend that the accuracy of your meter is four times greater than the accuracy you are trying to achieve with the instrument. For example, if you want to calibrate the laser current to within 0.1mA, then your meter would have an accuracy of 0.025mA or better. Using lower accuracy meters could actually degrade the accuracy of the instrument rather than improve it.

Considerations for Calibrating the Laser Current

For current calibration, many meters have poor current measurement performance. A alternate approach is to measure the voltage across a known resistor value. However, this introduces two measurement errors: the measurement error of the resistance of the current sense resistor and the measurement error of the voltage across the current sense resistor, so both must be considered when determining the overall accuracy of your measurement system.

Considerations for Calibrating the TEC Sensor

For calibration of the thermistor sensor, it is best to use a selection of precisely measured fixed resistors, and then connect them to the sensor input on the instrument.
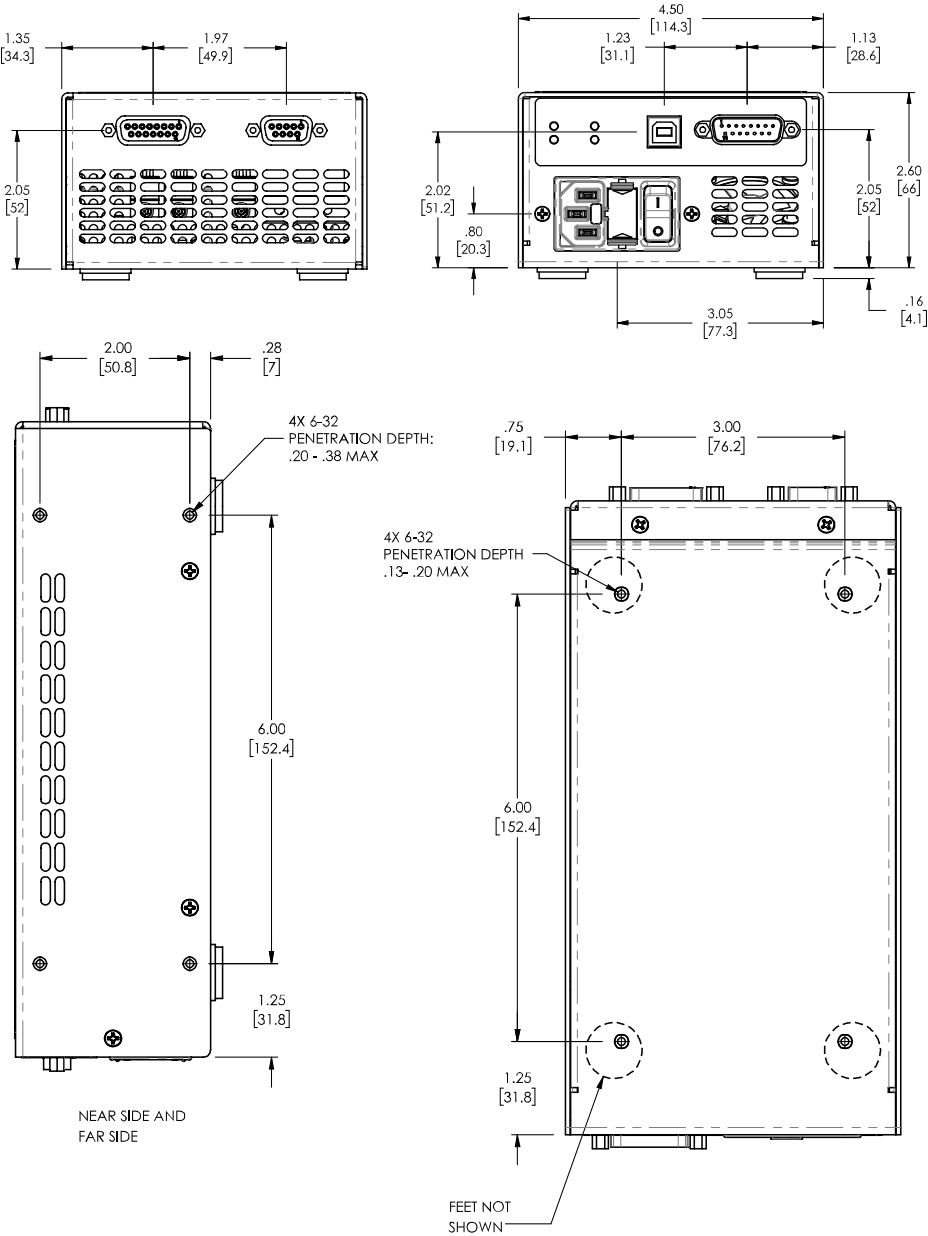
Specifications

Description	Laser Specifications			
	685-0.1	**685-0.5**	**685-01**	**685-02**
LASER				
SETPOINT				
LASER CURRENT				
Range (mA)	100	500	1000	2000
Max Resolution (mA)	0.005	0.02	0.05	0.1
Accuracy (±[% set+mA])	0.025% + 0.03	0.025% + 0.12	0.025% + 0.3	0.025% + 0.5
Stability (ppm, time)	< 10, 1 hour			
Temperature Coeff (ppm/°C)	50			
Noise/Ripple (µA rms)	< 5	< 5	< 10	< 40
Transients (µA)	< 50	< 100	< 150	< 200
Compliance Voltage (V)	10			3.5
PHOTODIODE CURRENT				
Range (µA)	5 – 5,000			
Resolution (µA)	0.1			
Accuracy (±[% set+µA])	0.05% + 1			
Stability (ppm, time)	< 200, 24 hours			
Temperature Coeff (ppm/°C)	< 200			
PD Bias (V)	-2.5V, fixed			
LASER VOLTAGE				
Range (V)	0 - 10			0 - 3.5
Resolution (V)	0.001			
Accuracy (±[% set+V])	0.05% + 0.005			
Stability (ppm, time)	< 50, 1 hour			
Temperature Coeff (ppm/°C)	< 100			
EXTERNAL MODULATION				
Input Range	0 – 10V, 10kΩ			
Modulation Bandwidth (kHz)	150	100	100	100
MEASUREMENT				
LASER CURRENT				
Resolution (mA)	0.005	0.02	0.05	0.1
Accuracy (±[% set+mA])	0.025% + 0.03	0.025% + 0.12	0.025% + 0.3	0.025% + 0.5
LASER VOLTAGE				
Resolution (V)	0.001			
Accuracy (±[% read+V])	0.05% + 0.005			
PHOTODIODE CURRENT				
Resolution (µA)	0.1			
Accuracy (±[% read+µA])	0.05% + 0.5			
LIMITS				
LASER CURRENT				
Resolution (mA)	1			
Accuracy (±mA)	2	5	10	20
LASER VOLTAGE				
Resolution (V)	0.1			
Accuracy (±% FS)	2.5%			

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Description	TEC & General Specifications
TEC	
SETPOINT	
TEMPERATURE	
Range (ºC)[1]	-99 to 250
Resolution (ºC)	0.01
Accuracy (± ºC)[2]	0.05[3]
Stability (1hr) (± ºC)[4]	0.004
Stability (24hr) (± ºC)[4]	0.01
CURRENT	
Range (A)	3
Compliance Voltage (V)	> 3.5
Max Power (W)	> 10.5
Resolution (A)	0.01
Accuracy (±[% set+mA])	0 + 30
Noise/Ripple (mA, rms)	< 5
MEASUREMENT	
CURRENT	
Resolution (mA)	10
Accuracy (±[% read+mA])	0 + 30
VOLTAGE	
Resolution (mV)	10
Accuracy (±[% read V])	0 + 0.05
THERMISTOR	
Range (kΩ)	0.02 – 45
Resolution (kΩ)	0.001
Accuracy (±[% read+kΩ])	0.05 + 5
LIMITS	
CURRENT	
Resolution (mA)	10
Accuracy (±mA)	40
GENERAL	
Laser Connector	DB-9, female
TEC Connector	DB-15, female
Fan Supply	4 – 12V, 350mA max
Computer Interface	USB 2.0 Full Speed (Type B)
Power (50/60 Hz)	90 - 240V, 60W
Size (H x W x D) [inches (mm)]	2.6 [66] x 4.5 (114.3) x 8.5 (215) (excluding connectors)
Operating Temperature	+10°C to +40°C
Humidity	< 70% relative humidity, non-condensing
Storage Temperature	-20°C to +60°C

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[1] Software limits. Actual range dependent on sensor type and system dynamics
[2] Accuracy figures are the additional error the 685 adds to the measurement, and does not include the sensor uncertainties.
[3] At 25°C
[4] Stability measurements done at 25°C. The number is ½ the peak-to-peak deviation from the average over the measurement period.

Mechanical Drawings

4.50
[114.3]

1.35
[34.3]

1.97
[49.9]

1.23
[31.1]

1.13
[28.6]

2.05
[52]

2.02
[51.2]

.80
[20.3]

2.60
[66]

2.05
[52]

3.05
[77.3]

.16
[4.1]

2.00
[50.8]

.28
[7]

4X 6-32
PENETRATION DEPTH:
.20 - .38 MAX

.75
[19.1]

3.00
[76.2]

4X 6-32
PENETRATION DEPTH
.13- .20 MAX

6.00
[152.4]

6.00
[152.4]

1.25
[31.8]

1.25
[31.8]

NEAR SIDE AND
FAR SIDE

FEET NOT
SHOWN

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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-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 received the wrong number of elements.
E-127	Change not allowed	State change not allowed due to hardware limitations or software lockouts.
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	Recall bin failed	A storage bin recall failed because an invalid bin number specified, or nothing in bin.
E-218	Save bin failed	A save to a storage bin failed, likely due to an invalid bin number.
E-220	Script save failed	Unable to save script, possible because script is too long, or bad script index.
E-221	Cannot embed script	Cannot have a SCRIPT command inside another script.
E-222	Cannot execute script	Cannot execute script due to bad index, or no script stored at that index.
E-303	Input buffer overflow	The input command string was too long, or commands received faster than they can be processed.
E-401	TEC interlock, output turned off	A TEC interlock error was detecged and the output was turned off.
E-402	Sensor open, output turned off	A sensor open circuit was detected and the output was turned off.

Error Code	Description	Cause
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	Thermistor resistance limit, output turned off	The thermistor resistance limit (high or low) was exceeded and the output was turned off.
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-434	ITE limit exceeds cable rating	The cable plugged into the unit is not rated to carry the current as set by the current limit. Use a 1262B cable, 1263B cable, or custom cable with ID pin connected to analog ground, or reduce the current limit below 5A.
E-435	Mode Change	A mode change occurred when the output was on, forcing the output off.
E-436	AutoTune failed	The AutoTune process failed. See the "Using the AutoTune Function" for more information.
E-437	AutoTune in T mode only	The AutoTune process is only available in T (temperature) mode. In R mode, the PID parameters must be determined manually.
E-438	Thermal trip, output turned off	The output was turned off because excessive internal heat dissipation.
E-439	Thermal run-away, output turned off	A thermal run-away was detected, output turned off.

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Error Code	Description	Cause
E-450	Analog set disconnected, output off	The analog set point input was disconnected, output turned off.
E-501	Interlock shutdown output	The interlock input (pins 1 and 2 of the output connector) were not shorted when the output was on.
E-504	Laser current limit disabled output.	The laser output was turned off because a current limit was detected and the corresponding bit in the OUTOFF register was set.
E-505	Laser voltage limit disabled output	The laser voltage exceeded the voltage limit and the output was turned off.
E-506	Laser photodiode current limit disabled output	The laser output was turned off because a photodiode current limit was detected and the corresponding bit in the OUTOFF register was set.
E-507	Laser photodiode power limit disabled output	The laser output was turned off because a photodiode power limit was detected and the corresponding bit in the OUTOFF register was set.
E-508	TEC off disabled output	The laser output was turned off because the TEC was off and the corresponding bit in the OUTOFF register was set.
E-509	Laser short circuit disabled output	The laser output was turned off because a short condition was detected and the corresponding bit in the OUTOFF register was set.
E-510	Laser out of tolerance disabled output	The laser output was turned off because an out-of-tolerance condition was detected and the corresponding bit in the OUTOFF register was set.
E-511	Laser control error disabled output	A hardware control error was detected which forced a shutdown of the laser output.
E-512	Power failure	A power failure was detected.
E-514	Laser mode change disabled output	A change in the operating mode of the ComboPak while the output was on shutdown the output.
E-516	Incorrect configuration for calibration to start	The ComboPak was not configured properly, including the mode and output on state, to be able to start the desired calibration process.
E-517	Calibration must have the output on to start	The laser output must be on for the calibration process to start.

Error Code	Description	Cause
E-521	TEC temperature limit disabled output	The laser output was turned off because the TEC temperature limit was exceeded corresponding bit in the OUTOFF register was set.
E-534	Po mode selected with PD Response set to zero	Attempted to select Po mode and PD Response was zero, or ComboPak was in Po mode and PD Response was set to zero.
E-535	Calibration cancelled	The active calibration process was cancelled.
E-536	Intermittent contact fault	The instrument detected an intermittent contact and shut down the laser output. If this is triggering falsely (such as in a noisy environment), the intermittent contact detection can be disabled in the main menu.
E-537	Thermal trip	Excessive power dissipated inside unit. Lower voltage limit or add series resistance. See "Thermal Considerations" for more details.
E-538	Internal sensor limit, output off	The auxiliary sensor resistance value exceeds the limits, output turned off.
E-539	Internal temperature limit, output off	The auxiliary temperature exceeds the limits, output turned off.
I-700	User save successful	User save to bin successful.
I-701	User recall successful	User recall of bin successful.
I-703	Laser usercal reset	The user calibration constants for the laser channel were successfully reset.
I-704	TEC usercal reset	The user calibration constants for the TEC channel were successfully reset.
W-800	Remote voltage sense is low	When in remote voltage sense mode, the ComboPak detected a significant difference between the remote voltage and the voltage at the connector, which may indicate a problem with the remote voltage sense connection.
W-803	User reset to factory defaults	The instrument was successful reset to factory defaults during startup.
W-804	Recall bin turned output off	The output was on during a bin recall, output turned off.
W-805	No FKey assigned	A function key was pressed but no function was assigned.

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Error Code	Description	Cause
E-991 thru E-997	Hardware specific error occurred	A hardware error was detected. Contact factory for support in diagnosing this problem.
E-998	Command not supported	A command was recognized but not supported by the ComboPak.
E-999	Non-specific error	A non-specific error was encountered.

Calibration, Maintenance and Service

Calibration

Arroyo Instruments recommends the annual calibration of the **ComboPak** 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 **ComboPak** requires no regular maintenance. To clean the instrument, use cotton cloth that is only damp (not wet) with a light solution of soap and water.

Fuses

Under normal operation, you should never need to replace a fuse. However, if either fuse does blow, use only T 250V, IEC 60127-2 5x20mm metric fuses with a current rating as specified on the unit as replacements.

If, after replacing the fuse, it continues to blow, immediately discontinue use of the instrument and contact your local Arroyo Instruments representative or the factory for support.

Service

Service and repair for the **ComboPak** 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

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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.

EC Declaration of Conformity

EC Declaration of Conformity

$C\epsilon$

I/We

Arroyo Instruments

of

1201 Prospect Street
San Luis Obispo, CA
USA

declare that

685 Series ComboPak

In accordance with the following European Commission Directives:

2014/30/EU - Electromagnetic compatibility (EMC)
2014/35/EU - Low Voltage Directive (LVD)
2015/863/EU - RoHS Directive

has been designed and manufactured to the following specifications:

Under 2014/30/EU

In accordance with EN 61326-1:2013, Emission
EN 55011:2010 Radio-frequency disturbance characteristics
EN 61000-3-2:2001 Harmonic Current emissions

In accordance with EN 61326-1:2013, Immunity
EN 61000-4-2:2009 Electrostatic Discharge
EN 61000-4-3:2010 Radiated Immunity
EN 61000-4-4:2012 Electrical Fast Transients/Burst
EN 61000-4-5:2014 Surges
EN 61000-4-6:2014 Conducted Immunity
EN 61000-4-11:2004 Supply Dips and Variations

Under 2014/35/EU

In accordance with EN 61010-1:2010

This Certificate is the Manufacturer's Declaration which states that the **685 Series ComboPak** 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)

June 17, 2015
(DATE OF ISSUE)

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UK Declaration of Conformity

UK Declaration of Conformity

UK CA

I/We

Arroyo Instruments

of

1201 Prospect Street
San Luis Obispo, CA
USA

declare that

685 Series ComboPak

In accordance with the following U.K. Legislation Regulations:

Electrical Equipment (Safety) Regulations 2016
Electromagnetic Compatibility (EMC) Regulations 2016
The Restriction of the Use of Certain Hazardous Substances in
  Electrical and Electronic Equipment Regulations 2012

has been designed and manufactured to the following specifications:

Under Electromagnetic Compatibility (EMC) Regulations 2016

In accordance with EN 61326-1:2013, Emission
EN 55011:2010 Radio-frequency disturbance characteristics
EN 61000-3-2:2001 Harmonic Current emissions

In accordance with EN 61326-1:2013, Immunity
EN 61000-4-2:2009 Electrostatic Discharge
EN 61000-4-3:2010 Radiated Immunity
EN 61000-4-4:2012 Electrical Fast Transients/Burst
EN 61000-4-5:2014 Surges
EN 61000-4-6:2014 Conducted Immunity
EN 61000-4-11:2004 Supply Dips and Variations

Under Electrical Equipment (Safety) Regulations 2016

In accordance with EN 61010-1:2010

This Certificate is the Manufacturer's Declaration which states that the **685 Series ComboPak** is Compliant to the above noted U.K. Legislation and therefore eligible to bear the UKCA 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 U.K. Legislation Regulations.

Paul Corr
(NAME OF AUTHORIZED PERSON)

(SIGNATURE OF AUTHORIZED PERSON)

President
(TITLE OF AUTHORIZED PERSON)

September 27, 2022
(DATE OF ISSUE)

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