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Wavelength Electronics™

LFI-3500 Series
Temperature Controllers



User's Guide

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LFI-3500 Series
Temperature Controller
User's Guide

Publication number 92-130002D
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Thermoelectric Temperature Controllers

The 3500 series advanced design offers an unprecedented combination of features, performance, and value. A variety of sensors including thermistors, IC sensors (AD590 and LM335), and RTDs are supported. A versatile I/O analog interface is provided at no additional cost. Connect a standard 12 V fan to the 3500 series and cool your TE's heatsink.

The fast PID control circuitry provides low noise, stable performance for even the most stringent temperature control situations. With four proportional gains, two integral time constants, and an optional derivative time constant, the PI/PID control loop can stabilize virtually any load. The 3500 series utilizes Wavelength's "Smart Integrator" circuit to reduce overshoot and improve settling time.

Extensive protection features are incorporated into the 3500 series to protect your thermoelectric and temperature controlled device from damage. Easy to read LEDs indicate temperature limit, open thermoelectric, and sensor open/short conditions. Temperature and current limits are readily adjustable from front panel trimpots. For additional safety, use the analog interface to disable an LFI-4500's laser diode driver output if the temperature controller output is turned off for *any* reason.

Interlock any combination of LFI-3500 series temperature controllers or LFI-4500 series laser diode drivers without additional hardware. Two or more modules mount into a 19" rack with optional rack mount kits.

KEY FEATURES...

- Ultra stable temperature control (< 0.002 °C)
- Compatible with Thermistors, AD590, LM335, and RTDs
- Four models deliver 15, 22, 25, and 40 W
- Wide temperature control range from – 60°C to > +150°C
- Easy to adjust operating temperature and current limit
- Linear, low noise, bipolar current source

...THE WAVELENGTH ADVANTAGE

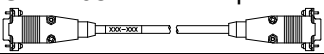
- Low cost, flexible instrument
- *Fast* PID control with "Smart Integrator" overshoot suppression
- Adjustable "LOW" or "HIGH" temperature limit protection
- Auxiliary thermistor monitors heatsink or ambient temperature
- Connect an external fan and cool your TE's heatsink
- Display thermoelectric voltage and current
- Interlocking enclosures for complete laser drive solutions
- Comprehensive Analog Interface includes:

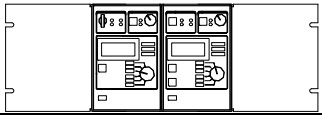
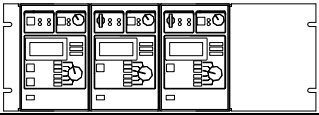
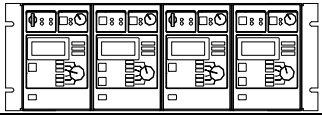
  TE V, TE I, TEMP SET, and ACTUAL TEMP outputs
  Remote output ON/OFF control
  External control of operating temperature
  "Open Drain" ON/OFF and error status outputs
  Directly integrates with LFI-4500 series laser diode drivers
  Booster signal can drive higher powered amplifiers

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LFI 3500 Series Selection Guide	
Model	**Description**
LFI-3525	15 W, **2.5 Amp**, 6 Volt, Temperature Controller
LFI-3526	22 W, **2.5 Amp**, 9 Volt, Temperature Controller
LFI-3550	25 W, **5.0 Amp**, 5 Volt, Temperature Controller
LFI-3551	40 W, **5.0 Amp**, 8 Volt, Temperature Controller

Each model includes: 9&15 pin D-sub receptacles with shielded covers and hardware, user guide, and AC power cord.

Cable - Selection Guide	
Model	**Description**
CAT-204	Output cable, single connector (9 pin D-sub rec)  One end connectorized one end unterminated
CAT-205	Output cable, double connector (9 pin D-sub rec's)  Both ends connectorized
All cables are 1 meter long.	

Rack Mount Kits- Selection Guide	
Model	**Description**
RMK-502	Rack mount kit for two LFI modules  Includes two 5 1/4" panels
RMK-503	Rack mount kit for three LFI modules  Includes one 1" panel and one 5 1/4" panel
RMK-504	Rack mount kit for four LFI modules  Includes two 1" panels
All RMK kits include (4)- 1/4-20 screws. No additional hardware is required to attach rack mount brackets to LFI modules.	

Thermistor Selection Guide								
MODEL	**R @ 25°C**	**10 µA RANGE**			**100 µA RANGE**			
TCS-602	**2.252 kΩ**	**–60°C**	**to**	**–12°C**	**–33°C**	**to**	**+15°C**
TCS-605	**5 kΩ**	**–55°C**	**to**	**–2°C**	**–20°C**	**to**	**+33°C**
TCS-610	**10 kΩ**	**–45°C**	**to**	**+13°C**	**–8°C**	**to**	**+50°C**
TCS-620	**20 kΩ**	**–35°C**	**to**	**+28°C**	**+6°C**	**to**	**+69°C**
TCS-650	**50 kΩ**	**–18°C**	**to**	**+49°C**	**+25°C**	**to**	**+92°C**
TCS-651	**100 kΩ**	**–6°C**	**to**	**+67°C**	**+41°C**	**to**	**+114°C**

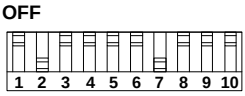
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Default Configuration from the Factory

The following are the factory default settings.

Rear Panel:

CONFIGURATION SWITCH:



CONFIGURATION

Sensor setting: Thermistor, 100μA reference current
Loop Direction: NTC, for thermistors
PID Constants: P = 32, I = 1 second, D = OFF
Temperature Limit = HIGH

Front Panel:

LIMITS:

Temperature Limit: set at 7.72kΩ
(7.72kΩ corresponds to 30°C for a TCS-610 10kΩ thermistor)

Current Limit: 500 mA for LFI-3525 & LFI-3526
1 Amp for LFI-3550 & LFI-3551

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Safety Summary

Do not install substitute parts or perform any unauthorized modification to the product. Return the product to Wavelength Electronics for service and repair to ensure that safety features are maintained.

Do not use this product beyond its specifications.

SYMBOL	DEFINITION OF SYMBOL
	**WARNING** Calls attention to a procedure, practice, or condition that could possibly cause bodily injury or death. **ATTENTION** Ce symbole signale une procédure ou des conditions dangereuses pouvant entraîner des blessures corporelles ou la mort. **VORSICHT!** Nichtbeachtung der Hinweise können die körperliche Unversehrtheit beeinträchtigen oder zum Tod führen.
NOTE!	Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or devices being operated by this equipment.
	**CAUTION Risk of Electric Shock** **ATTENTION Risque d'Electrocution** **VORSICHT Hochspannung**
	Earth Ground Symbol
	Chassis Ground Symbol

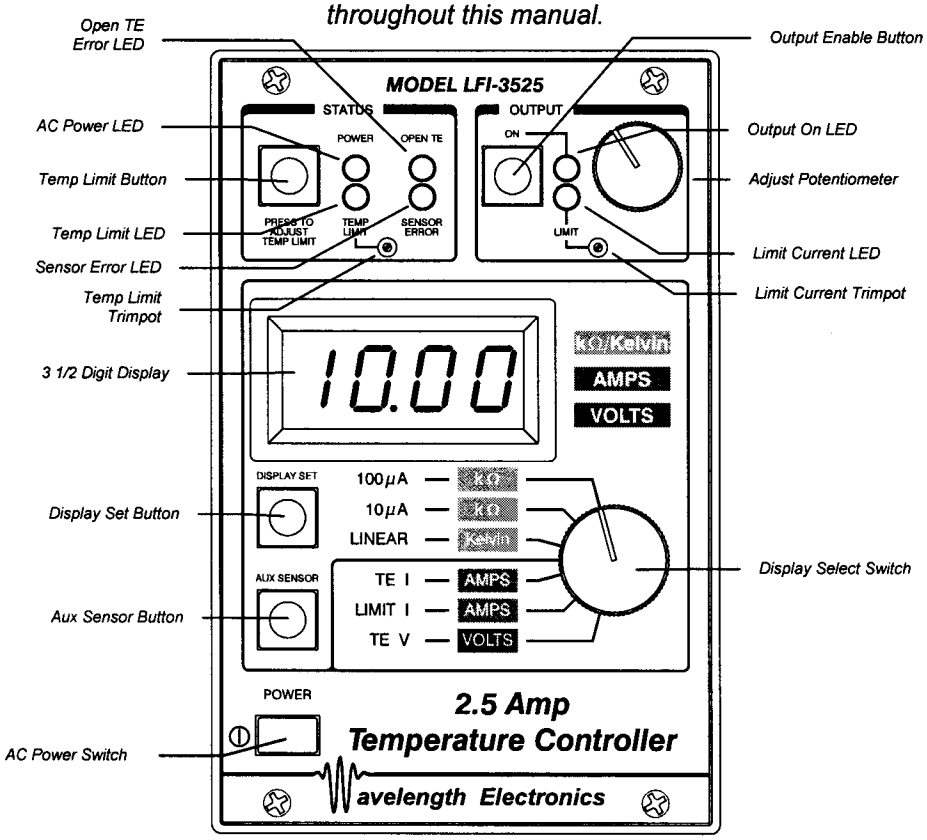
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NOTE!	Complete all operational steps in the order provided. Skipping a step can result in damage to the device being controlled or the Thermoelectric Module. Start with the section appropriate to the type of sensor you are using
	**WARNING** For continued protection against fire, replace line fuse only with fuse specified, type and rating. **ATTENTION** Pour une protection permanente contre les risques d'incendie, ne remplacer les fusibles secteur que par des fusibles conformes aux spécifications. **VORSICHT** Defekte Sicherungen sind nur durch die angegeben Typen und mit den spezifizierten Werten zu ersetzen um die Sicherheit des Gerätes zu gewährleisten.
	**CAUTION** RISK OF ELECTRICAL SHOCK. Do not power on this instrument if the case is damaged or any of the covers or panels are removed. NO USER SERVICEABLE PARTS INSIDE. **ATTENTION** Risque d'Electrocution. Ne pas mettre sous tension cet instrument si le boîtier est endommagé ou si les capots ou les faces sont retirés. Aucun composant réparable par l'utilisateur. **VORSICHT** Hochspannung. Im Falle eines Gerätedefektes oder bei geöffneter Verkleidung Netzstecker ziehen! Gerät kann und braucht vom Anwender nicht gewartet werden.
	**CAUTION** POSSIBLE ELECTRICAL SHOCK OR FIRE HAZARD. Do not expose the LFI Temperature Controller to rain or moisture. Do not operate this instrument in the presence of flammable gases or fumes. **ATTENTION** Risque d'électrocution ou d'incendie. Ne pas exposer l'alimentation LFI à la pluie ou à l'humidité. Ne pas utiliser cet instrument en présence de gaz inflammable ou de fumée. **VORSICHT** Brandgefahr und Gefahr eines elektrischen Schocks! Setzen Sie das Gerät nicht dem Regen oder der Feuchtigkeit aus. Schalten Sie das Gerät in der Gegenwart entflammbarer Gase oder Dämpfe nicht ein!

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Front Panel At A Glance

The following terms for the front panel components will be referenced throughout this manual.



Status Section:

AC Power LED: This LED lights green whenever AC power is supplied to the unit and the AC Power Switch is activated.

Open TE Error LED: This LED lights red whenever the voltage measured across the thermoelectric module exceeds the compliance voltage of the LFI controller. This condition can occur if the impedance of the TE is too high for the amount of current being sourced through the TE, or if there is no thermoelectric connected to the Output Connector. This condition does not switch the output off; it is provided to indicate a possible output connection problem.

Temp Limit Button: This button is held in while rotating the Temp Limit Trimpot to adjust the Temp Limit Setpoint. On the rear panel, the configuration switch sets whether an error will be triggered at a HIGH or LOW temperature. When the Temp Limit error is triggered, the output is shut off. For example, if a device can be damaged by excessive temperature, the HIGH limit can be set below the damage point. If the load overheats (thermal runaway situations), the output current will be turned off when the temperature exceeds the HIGH limit.

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Temp Limit LED: This LED lights red whenever the load temperature exceeds the limit temperature set by the Temp Limit Trimpot. The output current is switched off when this error occurs.

Temp Limit Trimpot: This adjusts the Temp Limit Setpoint.

Sensor Error LED: This LED lights red whenever the sensor voltage is either greater than 5V or less than 0.2V. This refers only to the feedback sensor, not the auxiliary sensor. This condition can occur if the impedance of the sensor is too high or too low, or if the sensor is disconnected from the Output Connector. The output current is automatically switched off when this error occurs.

Output Section:

Output Enable Button: This button enables and disables the thermoelectric current source output. When the output is enabled, the current is determined by the load conditions. If the output is disabled, the output current is brought to a very low standby current. If an error occurs that shuts off the output, the button must be pressed once to clear the error and again to enable the current.

Output On LED: This LED lights green whenever the output is enabled and current flows through the TE module.

Adjust Potentiometer: This ten-turn linear potentiometer is provided to adjust the Temperature Setpoint. It can adjust beyond the displayed temperature. See page 33 (Pins 14 & 15 on the Analog Interface Connector -Temperature Monitor) for more information.

Limit Current LED: This LED lights red whenever the output thermoelectric current is limited to the adjustment set by the Limit Current Trimpot. This condition will remain until the current required to achieve temperature falls below the Limit Current Trimpot setting. This condition does not create an error to shut the output off.

Limit Current Trimpot: This trimpot adjusts the thermoelectric Limit Current Setpoint. Adjusting the trimpot clockwise increases the Limit Current.

Beeper: A single “beep” indicates when the output is turned on or off.

Display Section:

3 ½ Digit Display: This can be used to display the actual sensor temperature, setpoint temperature, auxiliary zone temperature, output thermoelectric current, thermoelectric limit current, and output thermoelectric voltage.

Display Select Switch: The position of this switch determines what value is displayed on the 3 ½ digit LED display.

100µA, 10µA, and LINEAR: To display the resistance or temperature of the sensor, the switch is set to one of these three positions. The first two positions are for thermistors and RTDs. The switch position should be coordinated with the reference current setting on the Configuration Switch on the rear panel. The third position (LINEAR) is used for IC Sensors such as the LM335 or AD590. To read the auxiliary sensor resistance, set the position to **100µA** and hold in the Aux Sensor Button. To display the setpoint, set the position to the one appropriate to the sensor being used and hold in the Display Set Button.

TE I: This position displays the amount of current being sourced through the thermoelectric.

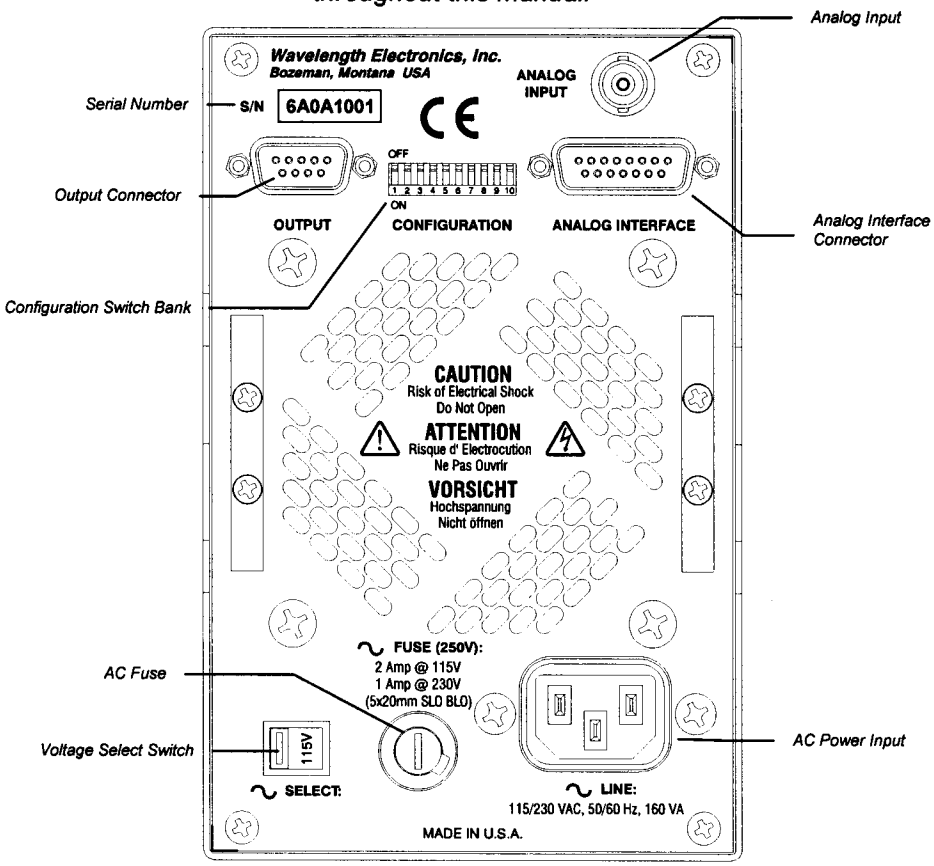
LIMIT I: This position displays the Limit Current Setpoint as set by the Limit Current Trimpot.

TE V: This position displays the voltage across the thermoelectric.

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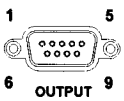
Rear Panel At A Glance

The following terms for the rear panel components will be referenced throughout this manual.



Output Connector Description

9 pin D-sub plug



Pins 1 & 2: **(TEC+, TEC-)** These pins supply current to the TE Cooler.

Pins 3 & 4: **(Aux Sens+, Sens-)** These pins source 100 μA to the auxiliary thermistor.

Pins 4 & 5: **(Sens-, Sens+)** These pins source 10, 100, or 1000 μA to bias thermistors, LM135 / LM335, and RTDs.

Pins 5 & 6: **(Sens+, AD590+)** Connect AD590/AD592 sensors across these pins.

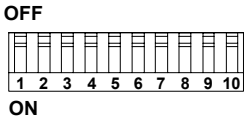
Pins 7 & 8: **(Fan-, Fan+)** Connect an external 12V fan here to cool the TE's heatsink. (sources 120 mA max.)

Pin 9: **(Chassis Gnd)** This pin connects directly to the enclosure and earth ground when the unit is properly grounded.

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Configuration Switch Bank:

This ten position switch bank configures the type of sensor used, the feedback P, I, and D terms, and sets the temperature limit to a HIGH or LOW limit.



Switches 1, 2, & 3: **(10µA, 100µA, and 1000µA)** Determines reference current through the sensor. If more than one switch is ON, the current will be the sum of the respective currents. These switches should always be in the OFF position for AD590 sensors.

Switch Position	Reference Current
1	10µA
2	100µA
3	1000µA (1mA)

Switch 4: **(AD590)** In the ON position, this switch connects a 10kΩ resistance between pin 5 (Sensor 1+) and pin 4 (Sensor -) on the output connector. This resistance will create a voltage proportional to the current supplied by the AD590 sensor. This should be in the OFF position for any other sensors.

Switch 5: **(NTC/PTC)** This switch determines loop polarity. Since a thermistor is a negative temperature coefficient (NTC) sensor, the switch should be in the OFF position when using a thermistor. The use of a PTC sensor, such as the LM335, AD590, or RTD requires that this switch be in the ON position.

Switch 6: **(Integral Term)** This switch configures the integral time constant to be either one or ten seconds. In the OFF position, the integral time constant is one second. In the ON position, it is 10 seconds. The larger time constant should be selected for those loads that cannot be stabilized using the one second time constant. See page **Error! Bookmark not defined.** for a discussion of the P, I, and D terms.

Switches 7 & 8: **(Proportional Term)** Four gain choices are available- 16, 32, 64, and 84. The following table applies:

Gain	Switch 7	Switch 8
16	OFF	OFF
32	ON	OFF
64	OFF	ON
84	ON	ON

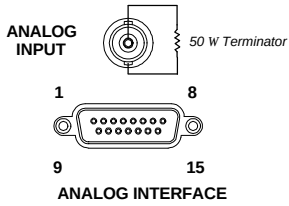
Switch 9: **(Derivative Term)** The LFI can operate as a PID or PI controller. In the OFF position, the derivative term is removed. In the ON position, a differential time constant of 250 milliseconds is used. The D term should be selected for large or hard to stabilize loads.

Switch 10: **(Temp Limit HIGH / LOW)** The LFI can trigger an error to shut off the output if the sensor temperature exceeds a HIGH temperature or falls below a LOW temperature. The function of this switch changes depending on the type of sensor used. The following table applies:

	Sensor Type	
Temp Limit	NTC	PTC
LOW	ON	OFF
HIGH	OFF	ON

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Analog Interface Connector:



BNC & 15 pin D-sub plug

Pins 1 & 2: **(Mod+, Mod-)** External analog input. The BNC input is in parallel, but isolated by two 1kΩ resistors. Either of the inputs can be used, but not simultaneously.

Pins 3 & 4: **(Boost+, Boost-)** Booster output.

Pins 5 & 6: **(Err+, Err-)** Connect to LFI-4500 laser diode drivers.

Pin 7: **(Error Detect)** Error status.

Pin 8: **(On/Off Detect)** On/Off status.

Pin 9: **(Common)** Common for pins 7, 8, & 10.

Pin 10: **(Remote On/Off)** Remote On/Off control.

Pin 11: **(TE V)** TE voltage monitor.

Pin 12: **(TE I)** TE current monitor.

Pin 13: **(SET TEMP)** Setpoint temperature monitor.

Pin 14: **(ACT TEMP)** Actual temperature monitor.

Pin 15: **(Monitor Common)** Common for pins 11-14.

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Preparing the Temperature Controller for Use

Check the list of supplied items:

- ☐ One Power cord
- ☐ One 9 pin D-Sub receptacle (solder cup), hood, and connecting hardware
- ☐ One 15 pin D-Sub receptacle (solder cup), hood, and connecting hardware
- ☐ One AC Fuse installed
- ☐ One AC Fuse is shipped separately.
- ☑ This User's Guide

Verify that the correct power-line fuse is installed and the power-line voltage setting is correct.

The factory sets the following defaults based on the country of destination for initial shipment:

Destination	Voltage Setting	Fuse Rating
US, Canada	115V	2 A
UK	230V	1 A
Continental Europe	230V	1 A
Japan	115V	2 A

For operation between 100 and 120VAC, install a 2 Amp slo-blow 5 x 20 mm fuse. Set the Voltage Select Switch to 115.

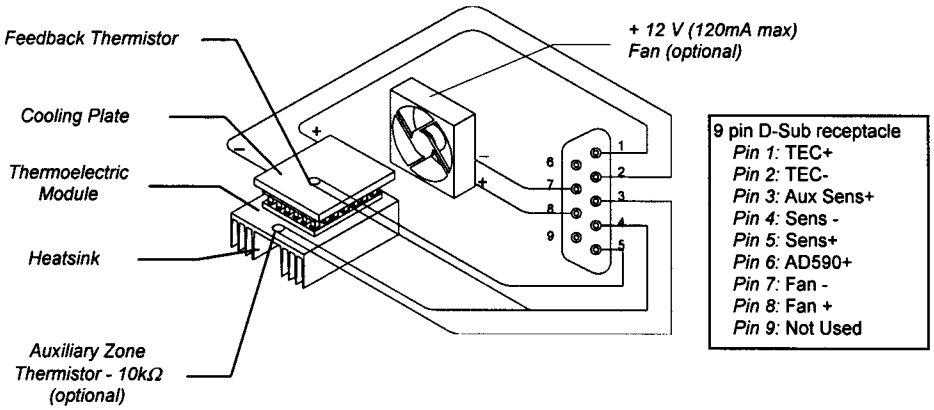
For operation between 220 and 240V operation, install a 1 Amp slo-blow 5 x 20 mm fuse. Set the Voltage Select Switch to 230.

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Operation with Thermistors

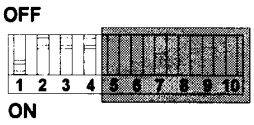
Step 1: Cabling the Output Connector

NOTE! **DISCONNECT AC POWER UNTIL STEP 5.**

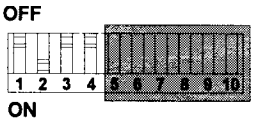


Step 2: Select the proper thermistor Current

Based on your control temperature range and thermistor value, select a thermistor current to produce between 0.2 and 5 V.



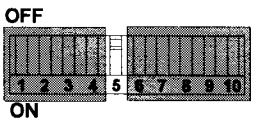
10μA Thermistor Current (recommended for 50kΩ or 100kΩ thermistors)



100μA Thermistor Current (recommended for 2.252kΩ, 5kΩ, 10kΩ, or 20kΩ thermistors)

Step 3: Select the proper Loop Direction

Thermistors are Negative Temperature Coefficient Sensors (NTC Sensors). This means that the thermistor resistance increases as temperature decreases. The PID loop must be properly configured for the NTC sensor type. Switch 5 must be OFF.



CONFIGURATION

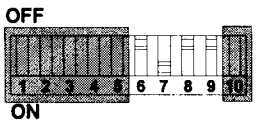
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Step 4: Select the PID Constants

The most common PID settings for thermistors are:

P - Gain = 32
I - Integral Time Constant = 1 second
D - Differential Time Constant = NONE
For more detailed PID setup, see page 28.



CONFIGURATION

Step 5: Set the HIGH or LOW Temperature Limit

See page 26 for this operation detail.

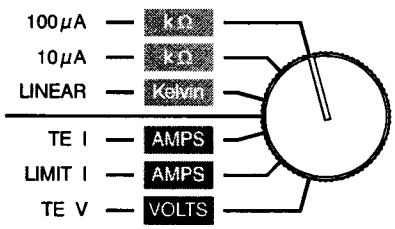
Step 6: Adjust the LIMIT Current

See page 25 for this operation detail.

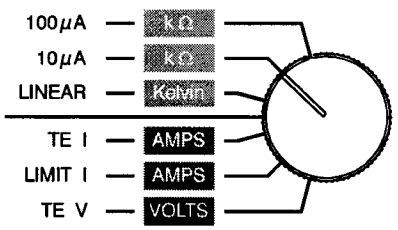
Step 7: Adjust the Temperature Setpoint

Rotate the Display Select Switch to the position corresponding to the thermistor reference current setting (see page 16 for configuration switch setting). The value displayed will be the resistance of the thermistor at ambient temperature.

NOTE: The Adjust Potentiometer range is greater than the 3 ½ digit display range for thermistors.



100μA Reference Current Display Setting

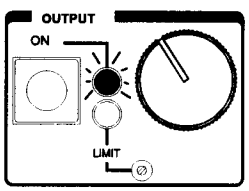


10μA Reference Current Display Setting

Press and hold the Display Set Button. Rotate the Adjust Potentiometer until the desired setpoint resistance is displayed.

Step 8: Enable the Output Current

Press and release the Output On Button. The Output On LED will light green. For a small load, the Limit Current LED will briefly light red. More current is required to initially change the load temperature than to maintain it once it is cool.

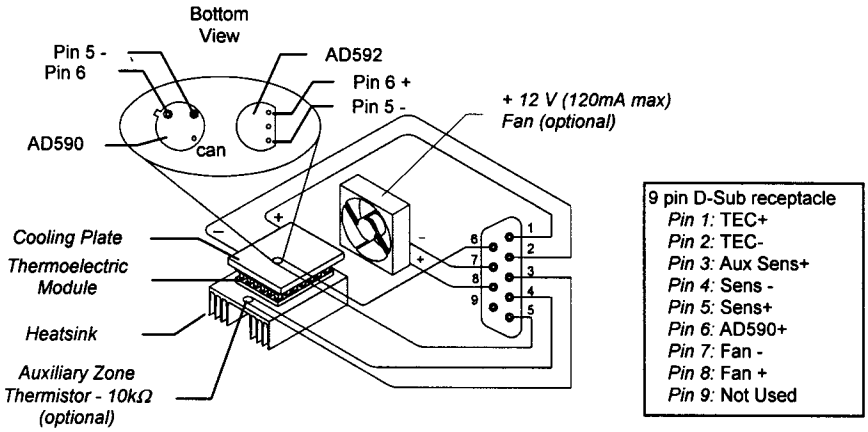




Operation with the AD590

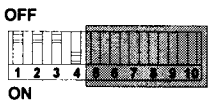
Step 1: Cabling the Output Connector

NOTE! **DISCONNECT AC POWER UNTIL STEP 5.**



Step 2: Configure for the AD590

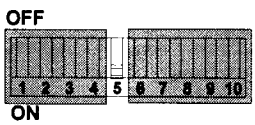
Pin 6 of the Output Connector provides a positive bias voltage to the AD590 while Switch 4 connects a 10kΩ resistor across pins 4 and 5 of the Output Connector to detect the sensor's current. Since the AD590 provides a 1μA / Kelvin signal, the 10kΩ sense resistor will create a 10mV / Kelvin or 10mV / Celsius response. Set the first three switches to OFF so no current flows from the reference source and Switch 4 to ON.



CONFIGURATION

Step 3: Select the proper Loop Direction

AD590s are Positive Temperature Coefficient Sensors (PTC Sensors). This means that the AD590 output current increases as temperature increases. The PID loop must be properly configured for the PTC sensor type. Switch 5 must be ON.



CONFIGURATION

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Step 4: Select the PID Constants

The most common PID settings for the AD590 are:

P - Gain = 64
I - Integral Time Constant = 10 seconds
D - Differential Time Constant = NONE
For more detailed PID setup, see page 28.

Step 5: Set the HIGH or LOW Temperature Limit

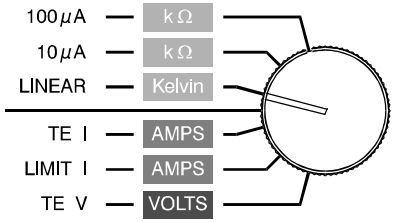
See page 26 for this operation detail.

Step 6: Adjust the LIMIT Current

See page 25 for this operation detail.

Step 7: Adjust the Temperature Setpoint

Rotate the Display Select Switch to the LINEAR position. The value displayed will be the ambient temperature in Kelvin.

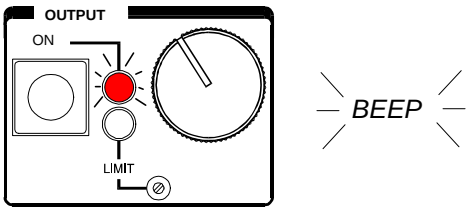


LINEAR IC Sensor Display Setting

Press and hold the Display Set Button. Rotate the Adjust Potentiometer until the desired setpoint temperature is displayed.

Step 8: Enable the Output Current

Press and release the Output On Button. The Output On LED will light green. For a small load, the Limit Current LED will briefly light red. More current is required to initially change the load temperature than to maintain it once it is cool.

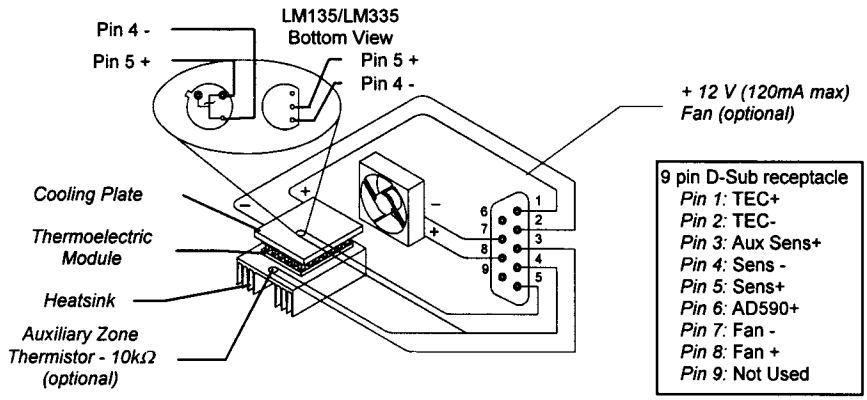


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Operation with the LM335

Step 1: Cabling the Output Connector

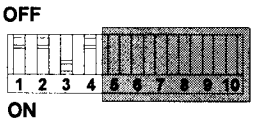
NOTE! **DISCONNECT AC POWER UNTIL STEP 5.**



Step 2: Select the proper LM335 Bias Current

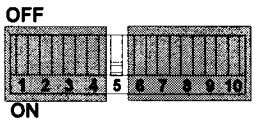
A 1000μA current is provided for operation with LM335 type sensors. The LM335 has a 10mV / Kelvin output. Just like the AD590, the LM335 will create a 10mV / Kelvin or 10mV / Celsius response.

1000μA (1 mA) Bias Current (recommended for LM135 or LM335 sensors)



Step 3: Select the proper Loop Direction

LM335s are Positive Temperature Coefficient Sensors (PTC Sensors). This means that the LM335 output voltage increases as temperature increases. The PID loop must be properly configured for the PTC sensor type. Switch 5 must be ON.

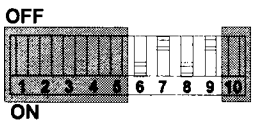


CONFIGURATION

Step 4: Select the PID Constants

The most common PID settings for the LM335 are:

P - Gain = 64
I - Integral Time Constant = 10 seconds
D - Differential Time Constant = NONE
For more detailed PID setup, see page 28.



CONFIGURATION

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Step 5: Set the HIGH or LOW Temperature Limit

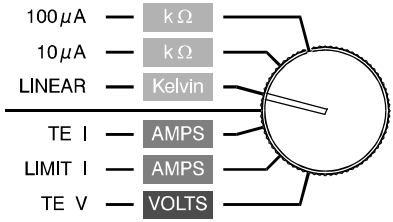
See page 26 for this operation detail.

Step 6: Adjust the LIMIT Current

See page 25 for this operation detail.

Step 7: Adjust the Temperature Setpoint

Rotate the Display Select Switch to the LINEAR. The value displayed will be the ambient temperature in Kelvin.

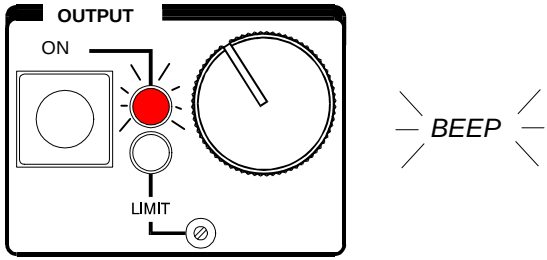


LINEAR IC Sensor Display Setting

Press and hold the Display Set Button. Rotate the Adjust Potentiometer until the desired setpoint temperature is displayed.

Step 8: Enable the Output Current

Press and release the Output On Button. The Output On LED will light green. For a small load, the Limit Current LED will briefly light red. More current is required to initially change the load temperature than to maintain it once it is cool.

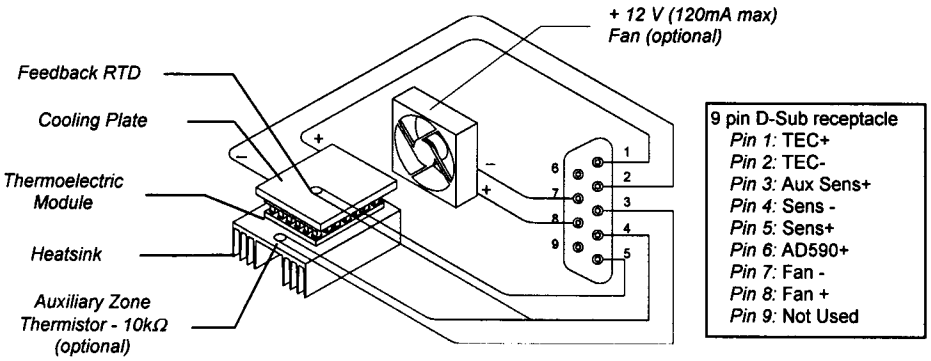


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Operation with RTDs

Step 1: Cabling the Output Connector

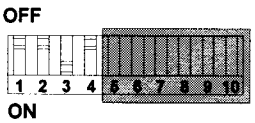
NOTE! **DISCONNECT AC POWER UNTIL STEP 5.**



Step 2: Select the proper RTD Current

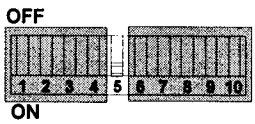
The 1000µA current is provided for operation with RTDs. Most RTDs have between 1 Ω / °C to 3 Ω / °C sensitivity. This will create a 1mV / °C to 3mV / °C response.

1000µA (1mA) RTD Current (recommended for 500Ω or 1kΩ RTDs)



Step 3: Select the proper Loop Direction

RTDs are Positive Temperature Coefficient Sensors (PTC Sensors). This means that the RTD resistance increases as temperature increases. The PID loop must be properly configured for the PTC sensor type. Switch 5 must be ON.

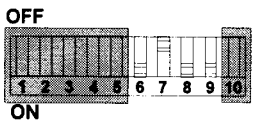


CONFIGURATION

Step 4: Select the PID Constants

The most common PID settings for RTDs are:

P - Gain = 64
I - Integral Time Constant = 10 seconds
D - Differential Time Constant = 250 msec
For more detailed PID setup, see page 28.



CONFIGURATION

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Step 5: Set the HIGH or LOW Temperature Limit

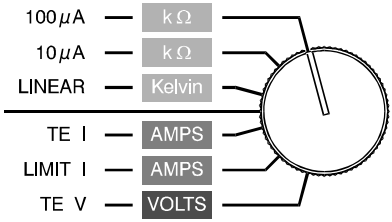
See page 26 for this operation detail.

Step 6: Adjust the LIMIT Current

See page 25 for this operation detail.

Step 7: Adjust the Temperature Setpoint

Rotate the Display Select Switch to either the 10µA or 100µA position. The value displayed will be the resistance of the RTD at ambient temperature. **NOTE: Ignore the decimal point on the 3½ digit display and the resistance of the RTD is indicated in ohms.**

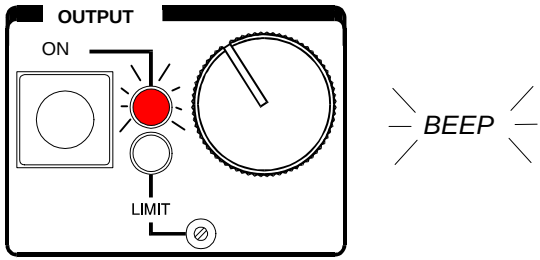


RTD Display Setting

Press and hold the Display Set Button. Rotate the Adjust Potentiometer until the desired setpoint resistance is displayed.

Step 8: Enable the Output Current

Press and release the Output On Button. The Output On LED will light green. For a small load, the Limit Current LED will briefly light red. More current is required to initially change the load temperature than to maintain it once it is cool.



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Set the Thermoelectric Current Limit

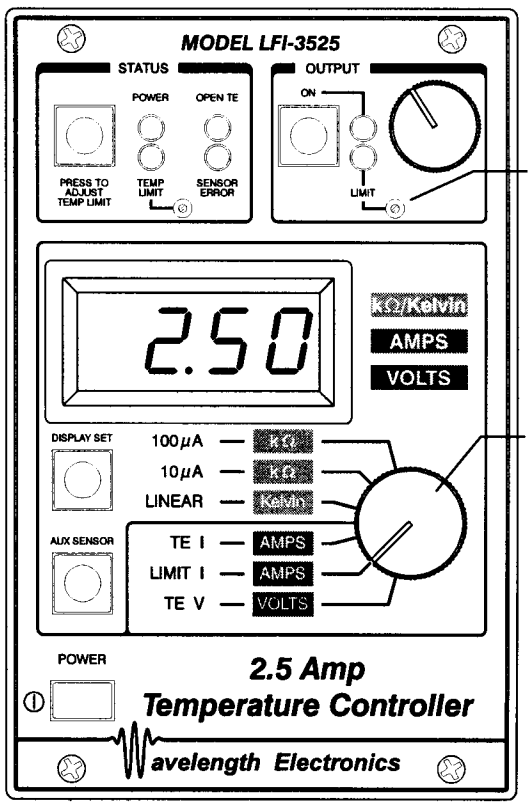
NOTE! **Do not enable the output current until the limit is properly set!**

Step 1: Determine the maximum current for the thermoelectric

Determine the maximum current through the thermoelectric from specifications provided by the thermoelectric manufacturer. Setting the current limit just above the steady state current level may result in long settling times. If you set the limit at or above the maximum, the power dissipated in the thermoelectric may overheat the load being controlled.

Step 2: Turn on AC power and Adjust the Limit Current

Depress the red AC Power Switch to complete system setup. Rotate the Display Select Switch to LIMIT I. Use a small flat blade screwdriver to rotate the Limit Current Trimpot to the proper setting (in Amps).



Adjust with small screwdriver until the desired TE limit current is displayed.

Set to LIMIT I

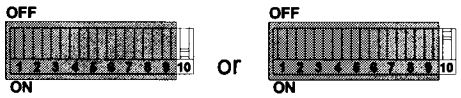
Set the Temperature Limit

NOTE! **Make sure the output is NOT enabled during this step!**

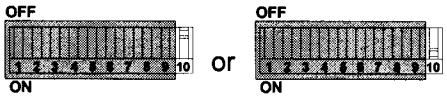
Step 1: Set the Configuration Switch to HIGH or LOW limit

The LFI 3500 will shut down the output if the HIGH temperature limit is exceeded or the temperature falls below the LOW temperature limit. Determine which limit is appropriate for your system. For example, to extend the lifetime of a laser diode, it is recommended that it not heat more than 5°C above room temperature. Setting a HIGH temperature limit would disable the output and shutdown the output thermoelectric current if the main sensor temperature exceeds the limit. When the LFI 3500 is interfaced to the LFI-4500 Laser Diode Driver, the laser driver output will also be disabled.

For NTC sensors (thermistor):



For PTC sensors (AD590, LM335, RTD):



Step 2: Set the Display to the Appropriate Sensor

Set the Display Select Switch to one of the first three positions (green background) according to the sensor current (thermistor or RTD) or sensor type (LINEAR = AD590 or LM335). Determine the corresponding sensor resistance or temperature at the temperature limit.

Step 3: Adjust the Temperature Setpoint to the Limit Temperature

Press and hold the Display Set Button. Rotate the Adjust Potentiometer until the proper resistance or voltage is displayed.

Step 4: Adjust the Temperature Limit Trimpot

Press and hold the Temp Limit Button and with a small screwdriver, rotate the Temp Limit Trimpot until the Temp Limit LED lights red.

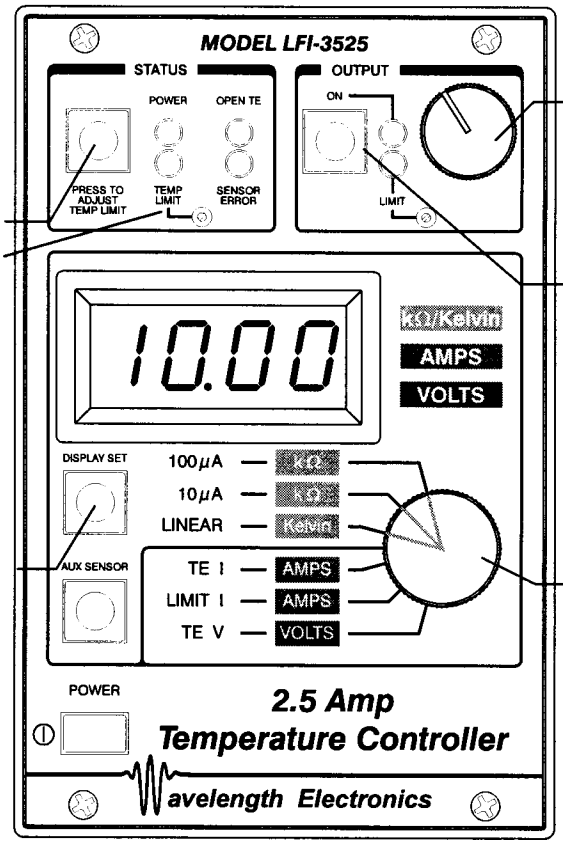
Step 5: Clear Temperature Limit Error

Press the Output On Button once to clear the Temperature Limit Error.

Once set, if the temperature reaches this setpoint during normal operation, the LFI-3500 will turn the output off.

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Step 4- *Press and hold the Temp Limit Button then rotate the Temp Limit Trimpot until the Temp Limit LED lights red.*

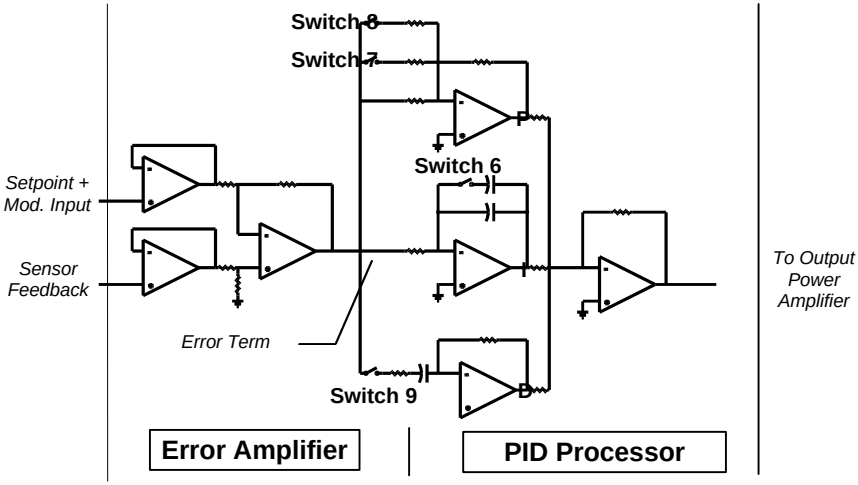
Step 3b- *Press and hold while rotating the Adjust Potentiometer until correct resistance or voltage is displayed.*

Step 3a- *Rotate while holding the Display Set Button until correct resistance or voltage is displayed.*

Step 5- *Press Output On Button once to Clear Temp. Limit Error*

Step 2- *Set to appropriate sensor*

Configure the PID Constants



ERROR AMPLIFIER: The error amplifier section provides the difference between the setpoint temperature and the actual temperature of the load device as sensed by the temperature sensor. This difference is known as the error term. This error term is fed to the PID processor. The range of the setpoint temperature signal and the gain of the temperature sensor amplifier typically determines the temperature range of the controller for a given sensor.

The sensitivity of the error amplifier is determined by the temperature sensor amplifier gain and the sensitivity of the temperature sensor. For example, the error terms generated when using a 10kΩ thermistor and an AD590 at 15 °C are quite different. With a thermistor current source of 100μA, the thermistor will produce a 76 mV/°C variation on the error term. The AD590 with a 10kΩ sense resistor will change the error term by 10 mV/°C. The AD590 will allow you to operate over a wider temperature range than the thermistor, but the thermistor will be more sensitive to temperature changes.

PID PROCESSOR: The PID processor section consists of a proportional gain amplifier, an integrator, and a differentiator, all of which can be implemented using simple op-amp circuits. In most PID controllers, the integrator time constant (I) and differentiator time constant (D) are fixed and only the proportional gain (P) is variable. Often, (D) is not even used, even though it is necessary for an optimal system.

Simpler control loops utilize only the proportional gain stage. Proportional controllers are inherently stable for low gains, but cannot produce a zero error between the temperature setpoint and sensor feedback. A non-zero error must be maintained to produce a finite output control signal. The addition of the integrator function reduces the error to zero, but also reduces the stability of the control loop. The integrator produces a finite output even when the error term is zero because the output of the integrator is a function

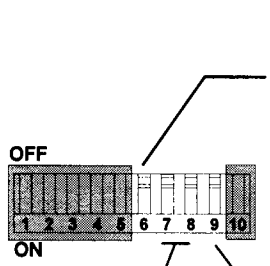
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the integral term usually results in larger overshoots due to integrator windup, PI or PID controllers with adaptive control loops or anti-windup circuitry are preferable. The LFI implements Wavelength's "Smart Integrator" anti-windup circuitry.

The PID controller loop stability (dynamic response) is determined by the P, I, and D settings. In general, increasing the proportional gain (P) and decreasing the integral time constant (I) reduces errors, but increasing the integrator time constant and differential time constant (D) increases loop stability.

Adjusting the PID Constants



I:
Integral Time Constant
6 OFF = 1 second
6 ON = 10 seconds

D:
Differential Time Constant
9 OFF = NONE
9 ON = 250 msec

P:
Proportional Gain

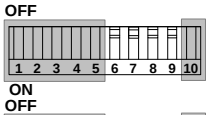
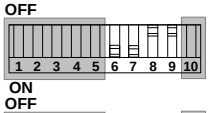
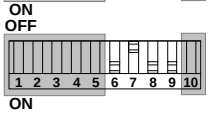
GAIN	7	8
16	OFF	OFF
32	ON	OFF
60	OFF	ON
84	ON	ON

Practical PID Setups:

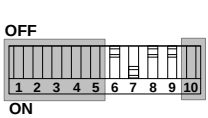
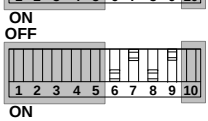
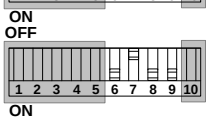
Definitions:

Small Thermal Load: $Q_c < 5$ Watts
Medium Thermal Load: $5 W < Q_c < 20$ Watts
Large Thermal Load: $Q_c > 20$ Watts
Q_c is the heat pumped from the TE's cold surface.

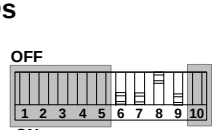
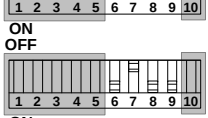
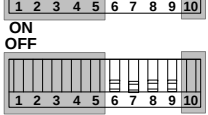
Typical Settings for **Thermistors**

Small Thermal Load		P = 16, I = 1 sec, D = none
Medium Thermal Load		P = 32, I = 1 sec, D = none
Large Thermal Load (cooling below ambient)		P = 32, I = 10 sec, D = none
Large Thermal Load (heating above ambient)		P = 64, I = 10 sec, D = 250 msec

Typical Settings for **AD590** & **LM335**

Small Thermal Load		P = 32, I = 1 sec, D = none
Medium Thermal Load		P = 64, I = 10 sec, D = none
Large Thermal Load		P = 64, I = 10 sec, D = 250 msec

Typical Settings for **RTDs**

Small Thermal Load		P = 32, I = 10 sec, D = 250 msec
Medium Thermal Load		P = 64, I = 10 sec, D = 250 msec
Large Thermal Load		P = 84, I = 10 sec, D = 250 msec

These are recommended setups. Please consult Wavelength's Technical Note #201 for further examination of this topic.

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Error and Status Indicators

Several LED indicators and a beeper are used to determine the status of the controller.

Status Section

Power LED: This LED lights green whenever the AC Power Switch on the front panel is depressed and AC power is supplied to the unit.

Temp Limit LED: This LED lights red whenever the load temperature exceeds the Limit Temperature as set by the Temperature Limit Trimpot (see page 26). The limit can be configured to trigger on a HIGH or LOW limit via the configuration switch on the rear panel. The output current is automatically switched off when a Temp Limit condition occurs. Once the error is corrected, the Output On Button must be pressed once to clear the error and again to enable the output.

Open TE LED: This LED lights red whenever the voltage measured across the thermoelectric module exceeds the compliance voltage of the LFI controller. This condition can occur if the impedance of the thermoelectric is too high for the amount of current being sourced through the device or if there is no thermoelectric connected to the output connector. This condition does not shut down the output current, and is only used to indicate a possible output connection problem.

Sensor Error LED: This LED lights red whenever the main sensor voltage is either greater than 5 V or less than 0.2 V. This condition can occur if the impedance of the sensor is too high or too low for the sensing circuit, or if the sensor is accidentally disconnected from the output connector. The output current is automatically switched off when a Sensor Error condition occurs. Once the error is corrected, the Output On Button must be pressed once to clear the error and again to enable the output.

Output Section

On LED: This LED lights green whenever the Output On Button is toggled on. This LED indicates that the output is now active and current will flow through the output connector.

Limit LED: This LED lights red whenever the output thermoelectric current is limited to the adjustment setting on the Limit Current Trimpot (see page 25). The output current will remain in this condition until the current required to maintain temperature falls below the Limit Current Trimpot setting. This condition does not switch the output current off.

Beeper: The LFI beeps once whenever the output is turned on or off.

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Analog Interface

Pins 1 & 2: **(Mod+, Mod-)** An external analog signal can be directly connected to these pins (or the Analog BNC Input) to remotely control temperature setpoint. This input is configured to accept ± 10 V signals while withstanding inputs as large as ± 40V. Any input on these pins is directly summed with the temperature setpoint determined by the Adjust Potentiometer. Pins 1 & 2 are isolated from the BNC Connector via 1kΩ resistors. This is to protect from accidentally connecting two separate modulation input sources in parallel. The impedance of this input is 60kΩ as measured across these terminals. A total of 30kΩ isolates these inputs from pins 4 (Sensor -) and 7 (Fan Ground) on the Output Connector. See the Transfer Function Table on page 33 for analog input transfer functions.

NOTE! If the thermistor or thermoelectric is earth grounded - only the Analog Input BNC may be used for remote control.

The shield side of the Analog BNC input is chassis grounded. Depending on how the thermistor or thermoelectric is grounded, three options are available:

1. If the analog inputs are not used, install the 50 Ω terminator (provided with the unit) on the BNC input.
2. If the thermistor or thermoelectric is not earth grounded, remove the 50 Ω BNC terminator. The signal can be input through either the Analog Input BNC or the Analog Interface Connector.
3. **Only the Analog Input BNC may be used for controlling the temperature when the thermistor or thermoelectric is earth grounded.** Remove the 50 Ω BNC terminator and replace it with the external modulation source.

Pins 3 , 4, & 15: **(Boost+, Boost-, Monitor Common)** These pins provide true differential buffered outputs that can be used to drive an external power amplifier to "boost" the power output of the controller. In this case, the thermoelectric is connected to the booster power amplifier while the LFI controller provides the PID temperature control. This signal is extracted from the PID section before the current limit section. Either BOOSTER + or BOOSTER - can be referenced to the MONITOR COMMON to provide the proper polarity to the external amplifier for correct current flow through the thermoelectric. If BOOSTER + and BOOSTER - are directly connected to the external amplifier, the amplifier's gain must be reduced by a factor of two since BOOSTER - is the complement of BOOSTER +. *Thermoelectric current and voltage must be monitored using the external power amplifier electronics.*

Pins 5 & 6: **(Error+, Error-)** These outputs were designed to connect to the LFI-4500 series laser diode drivers. Complementary inputs on the laser diode drivers are located on the LFI-4500 analog interface connector. Any LFI-4500 laser diode driver connected via these error lines will be disabled if the temperature controller output is turned off for any reason (Output On Button or Error shutoff). These outputs can source a maximum of 10 mA of current and a total of three LFI-4500 laser diode drivers can be connected at one time.

NOTE! LFI-4500's output will NOT be disabled if the LFI-3500 is in its powered off state via its AC Power Switch.

Pins 7 & 9: **(Error Detect, Common)** This output is an open drain connection that remains in a high impedance state while there are no errors that disable the output. If an error occurs that disables the output, this output is forced into a low impedance state with respect to the common connection (pin 9).

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Pins 8 & 9: **(On/Off Detect, Common)** This pin is an open drain connection that remains in a high impedance state when the output is disabled. When the output is enabled, this output is forced into a low impedance state with respect to the common connection (pin 9).

Pins 9 & 10: **(Common, Remote On/Off)** These pins can be used to enable and disable the output current source and directly effect the front panel Output On LED. A normally open momentary switch with switch bounce less than 500 msec can be connected to these pins. An open drain or open collector output from a digital section can be used to trigger this input also, if the signal is momentary and does not exceed 500 msec.

Pins 11 & 15: **(TE V, Monitor Common)** This pin provides a buffered measurement of the voltage across the thermoelectric (pins 1 and 2 on the Output Connector) and is referenced to pin 15. Its transfer function is 1 V / V. This output is internally limited to 10mA maximum output current.

Pins 12 & 15: **(TE I, Monitor Common)** This pin provides a buffered measurement of the current sourced to the thermoelectric through pins 1 and 2 of the Output Connector and is referenced to pin 15. Its transfer function is 1 A / V. This output is internally limited to 10 mA maximum output current.

Pins 13 & 15: **(Temperature Setpoint, Monitor Common)** This pin provides a buffered measurement of the temperature setpoint determined by the Adjust Potentiometer on the front panel and is referenced to pin 15. Its transfer function is dependent on sensor choice and is given in the following table. This output is internally limited to 10 mA maximum output current.

Pins 14 & 15: **(Temperature Monitor, Monitor Common)** This pin provides a buffered measurement of the sensor voltage measured across pins 4 and 5 of the Output Connector and is referenced to pin 15. Its transfer function is dependent on sensor choice and is given in the following table. This output is internally limited to 10 mA maximum output current. This output can be used to measure output temperature that exceeds the display range as noted on page 35.

To convert the Temperature Setpoint and Actual Temperature Monitors to sensor units of measure, use the following transfer functions:

TRANSFER FUNCTIONS:

Sensor	Bias Current	Conversions
Thermistor	100µA	10 kΩ / V
Thermistor	10µA	100 kΩ / V
AD590 or LM335	NA	100 Kelvin / V
RTD	1000µA	1 kΩ / V

NOTE!

The voltages on pins 11-15 are also used to drive the front panel 3 ½ digit display. Faults or shorts on these pins directly effect measurements on the display.

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LFI 3500 General Specifications

Power Supply:
115 or 230 VAC ±15% 50 or 60 Hz
(switch selectable on rear panel)

Maximum AC Input:
250VAC

Power Consumption:
160VA Peak

Size (W x D x H)
106 mm x 300 mm x 163 mm
(4.25" x 12" x 6.5")

Weight
4.5 kg (10 lb.)

Operating Temperature:
0 to ≤ 40°C

Storage Environment:
– 40 to +70°C

EMI and Safety:
CE Compliant

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LFI-3500 ELECTRICAL SPECIFICATIONS

MODEL NUMBER	LFI-3525	LFI-3526	LFI-3550	LFI-3551
TEC OUTPUT				
Output Control Loop Type	Bipolar, PID	Bipolar, PID	Bipolar, PID	Bipolar, PID
Maximum Output Current	**± 2.5 A**	**± 2.5 A**	**± 5.0 A**	**± 5.0 A**
Compliance Voltage	**± 6V**	**± 9 V**	**± 5 V**	**± 8V**
Maximum Output Power	**15 W**	**22 W**	**25 W**	**40 W**
Short Term Stability, 1 hr.❶	**< 0.002°C**	**< 0.002°C**	**< 0.002°C**	**< 0.002°C**
Long Term Stability, 24 hr.❶	**< 0.005°C**	**< 0.005°C**	**< 0.005°C**	**< 0.005°C**
Temperature Control Range❷	–60 to > +150°C	–60 to > +150°C	–60 to > +150°C	–60 to > +150°C
DISPLAY				
Resistance 100µA range	0 - 19.99 kΩ	0 - 19.99 kΩ	0 - 19.99 kΩ	0 - 19.99 kΩ
10µA range	0 - 199.9 kΩ	0 - 199.9 kΩ	0 - 199.9 kΩ	0 - 199.9 kΩ
Linear IC Sensors	0 - 1999 Kelvin	0 - 1999 Kelvin	0 - 1999 Kelvin	0 - 1999 Kelvin
TE Current	± 2.50 A	± 2.50 A	± 5.0 A	± 5.0 A
TE Voltage	± 9.99 V max.	± 9.99 V max.	± 9.99 V max.	± 9.99 V max.

TEMPERATURE SENSORS					
	Thermistor (2 wire)	Thermistor (2 wire)	LM135/LM335 ❸	AD590/AD592 ❸	RTD (2 wire)
Range	2 - 50.00 kΩ	20 – 500.0 kΩ	–55°C to + 150°C	–25°C to + 105°C	200 - 5000 Ω
Bias	100 µA	10 µA	1 mA	+12 V, 10 kΩ sense	1 mA

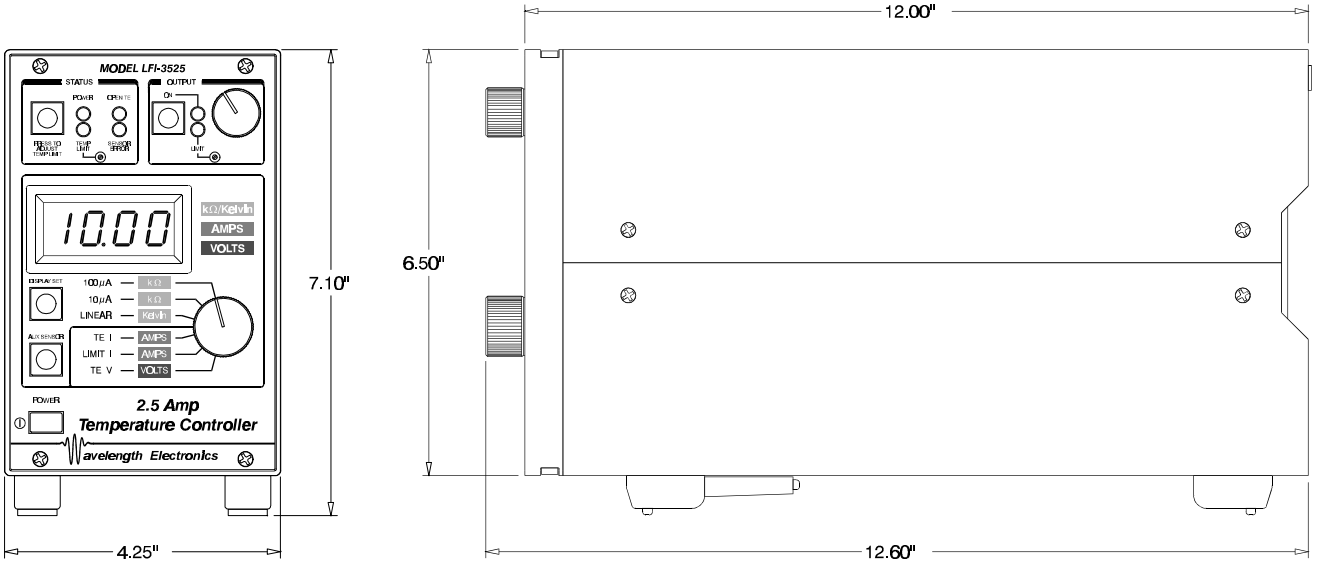
❶ Stability quoted for a typical 10 kΩ thermistor at 100 µA sensing current.

❷ Temperature Control Range depends on the physical load, sensor type, and TE module used.

❸ Ranges quoted are typical. See Sensor Manufacturer specifications for complete operating temperature range and electrical characteristics.

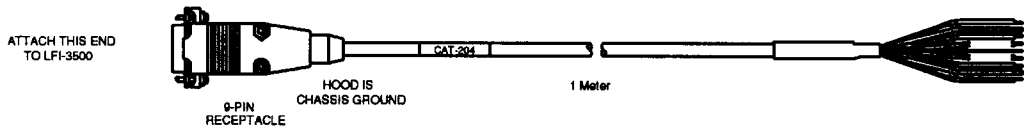
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MECHANICAL SPECIFICATIONS



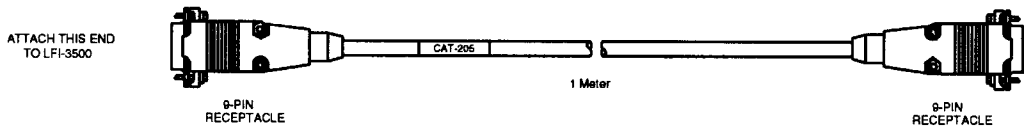
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CAT-204 LFI-3500 Series Output Cable (unterminated)



PIN	WIRE COLOR	TERMINATION
1	RED	TEC +
2	BLACK	TEC -
3	BROWN	AUX SENSE +
4	GREEN	SENSE -
5	WHITE	SENSE +
6	ORANGE	AD590 +
7	YELLOW	FAN -
8	BLUE	FAN +
9	N/A	NOT USED

CAT-205 LFI-3500 Series Output Cable (connectorized)



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WARRANTY

If you have any questions or comments, please call our technical staff at (406) 587-4910. Our hours are 8:00 a.m. to 5:00 p.m. MT.

Wavelength warrants the LFI 3500 Series temperature controllers for one year against defects in materials and workmanship when used within published specifications. This warranty extends only to purchaser and not to users of purchaser's product. If Wavelength receives written notice of such defects during the warranty period, we will either repair or replace products which prove to be defective. It is purchaser's responsibility to determine the suitability of the products ordered for its own use. Wavelength makes no warranty concerning the fitness or suitability of its products for a particular use or purpose; therefore, purchaser should thoroughly test any product and independently conclude its satisfactory performance in purchaser's application. No other warranty exists either expressed or implied, and consequential damages are specifically excluded. The remedies provided herein are the Buyer's sole and exclusive remedies.

All products returned must be accompanied by a Return Material Authorization (RMA) number obtained from the Customer Service Department. Returned product will not be accepted for credit or replacement without our permission. Transportation charges or postage must be prepaid. All returned products must show invoice number and date and reason for return.

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