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Optimizing TEC Current

APPLICATION NOTE

ILX Lightwave

Photonic Test and Measurement

Optimizing TEC Drive Current

This Application Note discusses methods for optimizing the TEC drive current for optimum operation in heating and cooling applications.

BACKGROUND

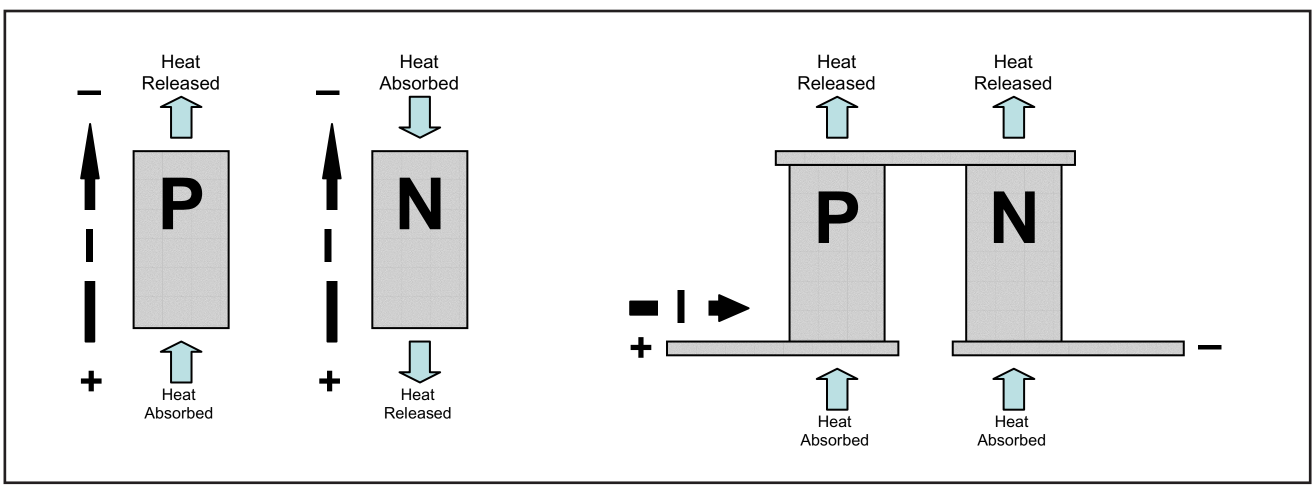
Thermoelectric coolers (TECs) are widely used for controlling the temperature of a variety of laser packages and chip sizes by pumping away thermal energy (heat) that would otherwise cause the chip temperature to rise uncontrollably. TECs rely on the Peltier Effect, whereby driving current through P- and N-type semiconductor materials will cause them to transfer heat. Figure 1 illustrates the concept.

Notice that the P and N materials pump heat in opposite directions when the current flow is in the same direction. To get the two materials to pump heat in the same direction, one of the materials must be reverse biased relative to the other. This is very simply accomplished by connecting the adjacent ends in series, and real TEC modules are constructed by connecting strings of these P-N “couples” in series.

The number and configuration of couples determines the electrical and heat pump properties of the TEC module.

TECs are frequently used to keep lasers at a constant temperature during continuous operation, and are also used to swing the laser chip temperature over a wide range for parametric test. In other applications, the requirement is to reach a certain temperature in the shortest possible amount of time.

In addition to cooling temperature-sensitive loads, TEC modules are frequently used as heaters. Their ability to both heat and cool a load makes them ideal for life-test and burn-in test racks, where the majority of the test is run at an elevated temperature. When the temperature of the load must be reduced, perhaps for in-situ L/I/V testing, the TEC current is reversed and the load quickly cooled. Large TECs are also used at parametric test stations where the device is tested at a number of different temperatures. In order to reduce test



cycle time, it is critical that the TEC is able to swing the device temperature as rapidly as possible.

Perhaps the most important point to consider when using TECs is that they are heat pumps. In other words, they pump heat from the laser, which generates heat, to the heat sink, which dissipates heat. In order to achieve this heat pump action, current must be driven to the TEC in the proper direction.

Regardless of the application, the TEC configuration must meet certain requirements to work correctly:

1) **Properly sized TEC.** If the TEC is too small for the application it will not have adequate heat pump capacity, and no matter how the TEC is driven the load temperature will be difficult or impossible to control. If a TEC is used in a heating application and is too small, the temperature ramp time may be unacceptably long.

2) **Adequate heat sinking.** Failure to install a properly sized heat sink can cause many different problems. The heat sink must be sized to dissipate the heat pumped away from the load and it must also dissipate the heat generated by the TEC module. In cooling applications, an inadequate heat sink will cause a "thermal runaway" once the heat sink temperature starts to rise uncontrollably.

3) **Proper TEC selection.** TEC modules are available in a wide variety of sizes, couple configurations, and drive current ranges. The TEC must be chosen according to the application requirements, physical size limitations, controller capabilities, and required temperature range.

4) **Appropriate drive current.** If the TEC controller is not capable of driving the TEC with enough current, the optimum heat pump capacity won't be achieved and the load temperature will be difficult to control to the desired set point. In cooling applications too much TEC control current will cause the TEC module to operate inefficiently and, if the heat sink is marginal, may lead to thermal runaway.

These points can be addressed using the TEC selection tools available on some of the more comprehensive websites posted by TEC manufacturers. A list of websites is included at the end of this Application Note.

This Application Note primarily addresses point #4, drive current requirements. Optimizing the drive current is an often overlooked aspect of TEC applications, and can lead to disappointing TEC performance even when all the other application parameters have been carefully optimized.

Figure 2 shows the experimental configuration used to understand how TECs operate at different drive currents. The experiment used an LDC-3926559 TEC module with 6 A maximum current, to drive a 15 mm x 30 mm, 35-couple TEC module. The thermal load was a power resistor, driven to dissipate approximately 2.65 W. A high-volume ducted fan was used to remove heat from the large aluminum heat sink. A computer was connected to the LDC-3926 High Power Laser Diode Controller mainframe to collect data.

Another high-power temperature controller, such as the ILX LDT-5980, could also be used for this experiment.

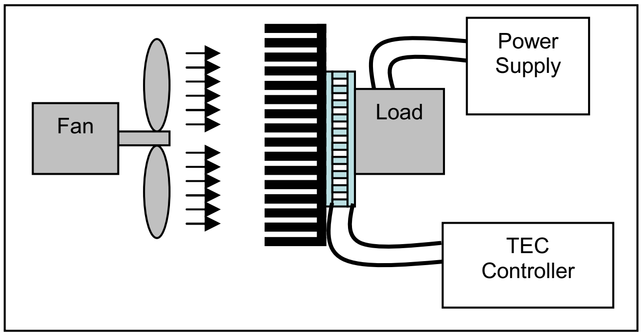


Figure 2 Experiment Setup

EXPERIMENT #1

OPTIMUM TEC OPERATING CURRENT FOR COOLING

The first experiment was designed to demonstrate the minimum achievable load temperature under a variety of TEC drive currents. Figure 3 and Table 1 show the results from running the TEC at a constant current of 4 A, 5 A, and 6 A.

Perhaps the most surprising conclusion from this test is that the load does not reach the lowest temperature with the highest TEC drive current. At 6 A TEC current (27.9 W input power) the load was cooled to just below 0°C. At 5 A TEC current (19.1 W), the load reached -0.8°C. Reducing the TEC input power by nearly 32% actually increased the cooling capability of the TEC.

This somewhat surprising result can be explained by examining the heat sink temperature plot and understanding another fundamental of TEC module operation: TECs pump heat most efficiently when the load and heat sink sides of the module are at the same temperature. As the temperature differential increases the heat pump capability decreases.

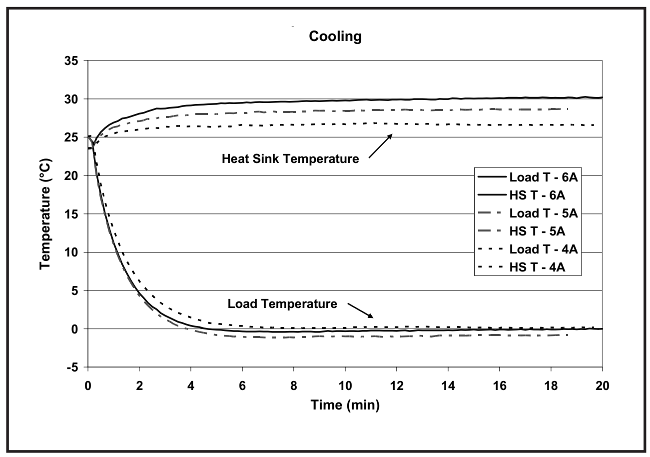


Figure 3 Graphical Summary Results

Table 1
Tabular Results

Drive Current	Load Temp (Steady State)	Max H.S. Temp (°C)	TEC Input Power (W)	Ambient Temp. (°C)	Heat Sink R_{Therm} (°C/W)
6 A	-0.1°C	30.3	27.9	23.7	0.21
5 A	-0.8°C	28.7	19.1	23.7	0.23
4 A	0.2°C	26.8	12.1	23.7	0.21

The conclusion from this experiment is that driving the TEC module at maximum rated current does not necessarily give the best heat pump capability. In fact, by reducing the TEC input power to less than half of the maximum rated power nearly the same load temperature can be achieved. The most positive benefit of this operating characteristic if that the TEC is over-sized, and then operated at less than maximum current, far less waste heat is generated in the thermal system.

Another example showing that the optimum drive current is substantially lower than the TEC maximum operating current, uses ILX's LDM-4984 Telecom Laser Diode Mount with the case temperature control option installed. Figure 4 shows the results of an experiment where a 0.5 W load was mounted on the hot plate and the TEC driven at various currents. For this particular configuration, the lowest temperature was reached at 2.5 A and the worst performance was at 4.0 A. The maximum current specification of the TEC used in the mount is 6.0 A.

EXPERIMENT #2

OPTIMUM TEC DRIVE CURRENT FOR HEATING

Reversing the current flow through the heat sink causes the heat pump to work in reverse so that heat is pumped to the load instead of away from it. Figure 5 shows the results of three different test runs with fixed drive current levels. Since the TEC also pumps its own heat to the hot side, the fastest heating results are achieved at the highest input power.

The TEC controller was operated at a constant current for this experiment. If the controller is operated in temperature-control mode, the drive current will be gradually reduced as the temperature nears the set point, and the ramp time will be somewhat extended.

Even when operated in "heat mode" the TEC is a heat pump, which means that it must pull heat from some source to pump it to the load. In this case, the heat sink was adequately sized, and acted as a heat reservoir.

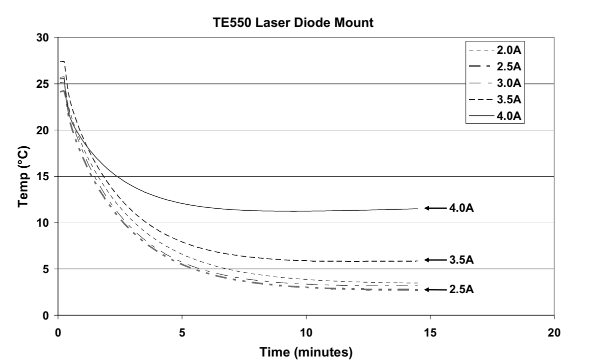


Figure 4. LDM-4984 with Case Temperature Control Option

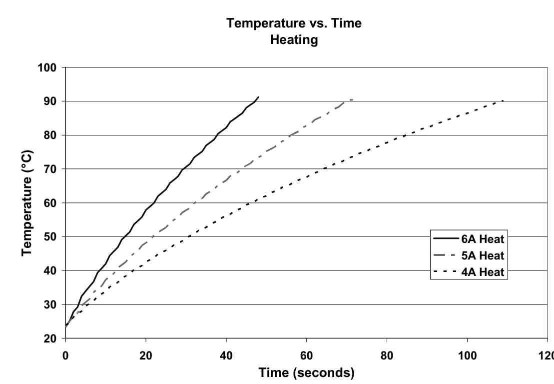


Figure 5. Heat Mode Tamp Times

While the load was heating the heat sink temperature dropped slightly, but no more than 0.5°C.

CONCLUSION

The experiments described in this Application Note demonstrate the following two points:

- If the TEC is appropriately sized and has adequate heat sinking, the TEC module is most efficiently operated in cooling mode with substantially less input power than the rated maximum.

- When TECs are used in heating applications, operation at maximum input power is desirable for the fastest ramp time.

A temperature controller with independent heating and cooling current limits gives the flexibility to take advantage of this peculiar operating characteristic.

In order for the TEC module and temperature controller to function as intended, the remaining components of the system must be optimized, of course. The size of the heat sink, the power delivered by the TEC power supply, and the electrical and heat transfer capabilities of the TEC module must all be considered.

Visit these TEC manufacturer websites for more information on TEC module selection:

www.ferrotec-america.com
www.melcor.com
www.marlow.com

The following publications are available for download on at www.ilxlightwave.com.

White Papers

- A Standard for Measuring Transient Suppression of Laser Diode Drivers
- Degree of Polarization vs. Poincaré Sphere Coverage
- Improving Splice Loss Measurement Repeatability

Technical Notes

- Attenuation Accuracy in the 7900 Fiber Optic Test System
- Automatic Wavelength Compensation of Photodiode Power Measurements Using the OMM-6810B Optical Multimeter
- Bandwidth of OMM-6810B Optical Multimeter Analog Output
- Broadband Noise Measurements for Laser Diode Current Sources
- Clamping Limit of a LDX-3525 Precision Current Source
- Control Capability of the LDC-3916371 Fine Temperature Resolution Module
- Current Draw of the LDC-3926 16-Channel High Power Laser Diode Controller
- Determining the Polarization Dependent Response of the FPM-8210 Power Meter
- Four-Wire TEC Voltage Measurement with the LDT-5900 Series Temperature Controllers
- Guide to Selecting a Bias-T Laser Diode Mount
- High Power Linearity of the OMM-6810B and OMH-6780/6790/6795B Detector Heads
- Large-Signal Frequency Response of the 3916338 Current Source Module
- Laser Wavelength Measuring Using a Colored Glass Filter
- Long-Term Output Drift of a LDX-3620 Ultra Low-Noise Laser Diode Current Source
- Long-Term Output Stability of a LDX-3525 Precision Current Source
- Long-Term Stability of an MPS-8033/55 ASE Source
- LRS-9424 Heat Sink Temperature Stability When Chamber Door Opens
- Measurement of 4-Wire Voltage Sense on an LDC-3916 Laser Diode Controller
- Measuring the Power and Wavelength of Pulsed Sources Using the OMM-6810B Optical Mutlimeter
- Measuring the Sensitivity of the OMH-6709B Optical Measurement Head
- Measuring the Wavelength of Noisy Sources Using the OMM-6810B Optical Multimeter
- Output Current Accuracy of a LDX-3525 Precision Current Source
- Pin Assignment for CC-305 and CC-505 Cables
- Power and Wavelength Stability of the 79800 DFB Source Module
- Power and Wavelength Stability of the MPS-8000 Series Fiber Optic Sources
- Repeatability of Wavelength and Power Measurements Using the OMM-6810B Optical Multimeter
- Stability of the OMM-6810B Optical Multimeter and OMH-6727B InGaAs Power/Wavehead
- Switching Transient of the 79800D Optical Source Shutter
- Temperature Controlled Mini-DIL Mount
- Temperature Stability Using the LDT-5948
- Thermal Performance of an LDM-4616 Laser Diode Mount
- Triboelectric Effects in High Precision Temperature Measurements
- Tuning the LDP-3840 for Optimum Pulse Response
- Typical Long-Term Temperature Stability of a LDT-5412 Low-Cost TEC
- Typical Long-Term Temperature Stability of a LDT-5525 TEC
- Typical Output Drift of a LDX-3412 Loc-Cost Precision Current Source
- Typical Output Noise of a LDX-3412 Precision Current Source
- Typical Output Stability of the LDC-3724B
- Typical Output Stability of a LDX-3100 Board-Level Current Source
- Typical Pulse Overshoot of the LDP-3840/03 Precision Pulse Current Source
- Typical Temperature Stability of a LDT-5412 Low-Cost Temperature Controller
- Using Three-Wire RTDs with the LDT-5900 Series Temperature Controllers
- Voltage Drop Across High Current Laser Interconnect Cable
- Voltage Drop Across High Current TEC Interconnect Cable
- Voltage Limit Protection of an LDC-3916 Laser Diode Controller
- Wavelength Accuracy of the 79800 DFB Source Module

Application Notes

- App Note 1: Controlling Temperatures of Diode Lasers and Detectors Thermoelectrically
- App Note 2: Selecting and Using Thermistors for Temperature Control
- App Note 3: Protecting Your Laser Diode
- App Note 4: Thermistor Calibration and the Steinhart-Hart Equation
- App Note 5: An Overview of Laser Diode Characteristics
- App Note 6: Choosing the Right Laser Diode Mount for Your Application
- App Note 8: Mode Hopping in Semiconductor Lasers
- App Note 10: Optimize Testing for Threshold Calculation Repeatability
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- App Note 21: High Performance Temperature Control in Laser Diode Test Applications

For application assistance or additional information on our products or services you can contact us at:

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