KEITHLEY

Application Note Series

Number 2352

Extending the Output Range of the Model 2510 TEC SourceMeter® Instrument with a Bipolar Operational Power Supply

Introduction

The operation of many devices, such as laser diodes, modulators, and semiconductor-based optical amplifiers, is very sensitive to temperature changes. Even minor temperature fluctuations can produce thermal effects such as mode hopping, wavelength drift, output power variation, and reduced Mean Time Before Failure (MTBF). Excessive heat can damage or destroy these devices. Yield management and accurate production testing also require accurate temperature control.

Thermoelectric coolers (TECs) are a popular method of temperature control. TECs are active semiconductor heat pumps that provide reliable temperature control in a small and economical package. A TEC requires a stable power supply with a current output that's controlled by a feedback loop. The feedback loop's input is the temperature of the device as measured by a transducer, such as a thermistor, RTD, or semiconductor temperature sensor. Keithley's solution for TEC control is the Model 2510 TEC SourceMeter instrument.

Typical Applications for the Model 2510

The Model 2510 is a precision voltage source that uses P-I-D (Proportional, Integral, Derivative) loop control with a 50W (10V, 5A) output limit. While its primary purpose is to provide tight control of TECs used to control laser diode temperature during production testing, it is also suitable for use in testing CCD arrays and many other applications. With the addition of the Model 2510-RH Resistive Heater Adapter, the Model 2510 can also be used to control the temperature of devices with resistive heaters.

Applications That Require Higher Output Power

Typically, a laser diode module uses a relatively low power TEC (< 5A, <10V) to control diode temperature. However, high power devices, such as EDFA and Raman pump modules, place a greater current demand on the temperature control system. Drive currents for these devices are typically 1–2A, and will reach 5A in the near future. The energy may be expressed as $P = (I^2 * R)$, where P is the power (heat) in watts generated by the current (I) flowing through the resistance (R). A typical laser diode has a resistance of 2Ω. When powered by a 2A drive current, an object the size of a grain of table salt can produce eight watts of heat. Due to the high energy density of these devices, applications involving EDFA and Raman pump modules require temperature control for both the device and test fixture. Large area, high powered TECs (>50W) and arrays of TECs wired in series and/or parallel are typically employed to remove the heat.

The Model 2510 is designed to provide accurate temperature control of TECs with power requirements less than or equal to 50W (5A, 10V). For applications that exceed 50W, an external bipolar power supply can be connected to the output of the Model 2510 as a high current voltage follower. Bipolar Operational Amplifiers (BOPs) are available in a wide variety of sizes (i.e., power output ratings), as well as output voltage and current ratings, to satisfy virtually any temperature control requirement.

Test Descriptions/Procedures

How Does It Work?

A bipolar power supply (***Figure 1***) may be modeled as an inverting operational amplifier, with:

$$E_O = -\left(\frac{R_f}{R_i}\right)E_{ref}$$

where $E_0 = V_{out}$ of amplifier
R_f = resistance of feedback resistor in amplifier
R_i = input resistance
E_{ref} is the input signal.

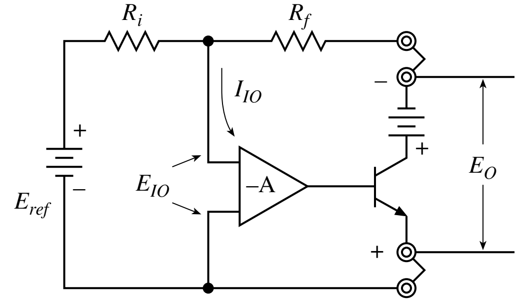

Figure 1. Bipolar power supply

The gain of the power supply is G = R_f/R_i. If $R_f = R_i$, (G = 1), then the power supply will invert the E_{ref} signal or $E_0 = -E_{ref}$. In addition, the gain of the power supply varies with input resistance (R_i). For example, if R_f = 100kΩ, Ri = 10kΩ, then the gain

(G) = R_f/R_i = 100kΩ/10kΩ = 10. If the input voltage (E_{ref}) = 10V, then the power supply output is (E_0) = –10 × 10V = –100V.

As mentioned previously, the Model 2510 is a voltage source controlled by a P-I-D loop. If the voltage output of the Model 2510 is E_{ref}, the output (E_o) is the inverse polarity. The output of the combined system, properly connected, will be limited by the performance of the BOP.

Test System Configuration

If possible, keep the TECs, fixture, and device available for the configuration procedure to expedite test setup and troubleshooting.

Power Supply Selection

The TEC arrangement will determine the power requirements for an application. It is important to select a power supply with an output rating (voltage and current) that covers the operating range of the TEC.

Adequate supply output bandwidth is critical for this application. Output bandwidth is a figure of merit that represents how quickly the power supply output reacts to changes in input voltage (E_{ref}). The power supply must be able to "keep up" with the output of the Model 2510. Practice has shown power supplies with a bandwidth equal to or greater than 18kHz (a slew rate of 11V/Ωsec) are adequate. Power supplies with a lower bandwidth may also be acceptable, but it's always wise to evaluate different supplies for performance and suitability before making a final choice.

Excessive current ripple (>10%) or output noise will lower the efficiency of the TEC and may cause unstable temperature control. Experience has shown that a power supply with a current ripple specification of 0.1% or less is adequate.

Connection and Calibration

The Test Fixture

Wire two TECs in series and attach them to the heat sink with a thermally conductive material such as tape, grease, etc. Next, attach the appropriate temperature sensor (thermistor, thermocouple, etc.) to the heat sink. The temperature sensor, which provides temperature feedback information to the Model 2510, should be placed on the surface to be cooled.

In this example, the TECs have I_{max} = 2A and V_{max} = 10V each and, in a series configuration, the total voltage drop (V_{max}) is equal to the sum of the voltage drop of each element.

$$V_{max} = V_1 + V_2 = 10V + 10V = 20V$$

The Model 2510 has a 10V output limit, so, in this case, it is unable to provide sufficient output voltage to produce the desired operating temperature range of this TEC configuration. A bipolar operational power supply with a rating of at least 40W (20V @ 2A), a bandwidth of >18kHz, and a ripple value of 0.1% is adequate.

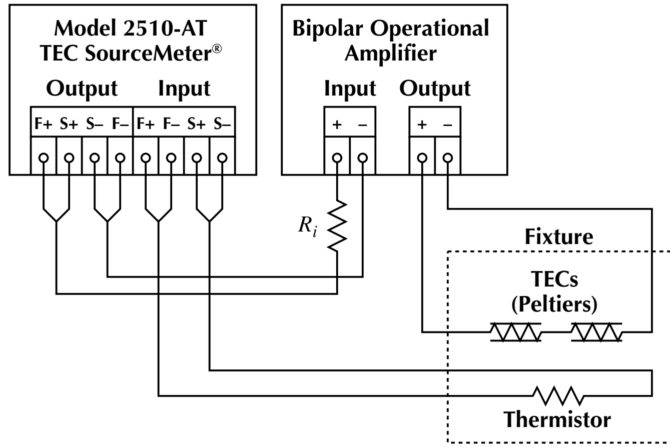

Figure 2. Connection schematic

Wiring

Connect all the components as shown in ***Figure 2***. The potentiometer functions as a tunable R_i and changing the value of R_i alters the gain of the amplifier and, finally, E_0. In this example, our TECs require 20V and a gain factor of two, given that the maximum output of the Model 2510 is 10V.

Attach the negative Force and Sense leads of the Model 2510 to the negative voltage input of the amplifier. Connect the temperature sensor leads to the inputs of the Model 2510. Next, attach the positive lead of the TEC (Peltier) to the negative output of the power supply and the negative lead of the TEC to the positive output of the power supply. This wiring arrangement is due to the voltage inversion (sign change) of the operational amplifier at the BOP input.

Voltage Offset and Gain Tuning

The tuning process begins with minimizing the voltage offset. A non-zero output voltage when the Model 2510 output is off will cause a current flow, supplied by the BOP, through the TEC. This current flow may produce undesirable temperature changes and can damage the fixture/DUT. First, allow the instruments to achieve the specified warm-up period and verify the TECs, temperature sensor, etc. are at ambient temperature. Next, attach a voltmeter to the amplifier outputs. With the Model 2510 powered on and the Output OFF, adjust the amplifier's voltage control to reduce the voltage output to zero if possible. Double check the voltage offset by sourcing 0V with the Model 2510 in voltage mode (i.e., press V, setpoint 0.0000V, and press output ON/OFF.) The voltmeter reading and the output offset voltage should be identical.

Next, the voltage gain is adjusted by sourcing a voltage with the Model 2510 and varying the potentiometer to achieve the desired ratio of E_0/E_i. The gain of the power supply is G = R_f/R_i and, in this case, R_i must be half the value of R_f.

Therefore, set an output voltage with the Model 2510 and measure the voltage. Change the resistance of the potentiometer (R_i) until the desired ratio of E_0/E_i is achieved.

For help in selecting appropriate P-I-D coefficients, refer to the Model 2510 or 2510-AT user's manual for details.

Common Sources of Error

Performance may be affected by:

- The use of improper P-I-D coefficients
- Variations or drift in any of a number of parameters:
  - Offset voltage or non-zero voltage output of the power supply with the Model 2510 output "OFF"
  - Drift in the gain or R_f/R_i ratio
  - Change in thermal characteristics of the fixture and/or DUT

Equipment List

- Model 2510 TEC SourceMeter instrument
- Model 2000 Digital Multimeter or other DMM or digital voltmeter with equal resolution
- Bipolar Operational Power supply
- Potentiometer
- TECs, fixturing, DUTs
- 2510-CAB (optional, depending on test cabling requirements)

Test System Safety

Many electrical test systems or instruments are capable of measuring or sourcing hazardous voltage and power levels. It is also possible, under single fault conditions (e.g., a programming error or an instrument failure), to output hazardous levels even when the system indicates no hazard is present.

These high voltage and power levels make it essential to protect operators from any of these hazards at all times. Protection methods include:

- Design test fixtures to prevent operator contact with any hazardous circuit.
- Make sure the device under test is fully enclosed to protect the operator from any flying debris. For example, capacitors and semiconductor devices can explode if too much voltage or power is applied.
- Double insulate all electrical connections that an operator could touch. Double insulation ensures the operator is still protected, even if one insulation layer fails.
- Use high reliability, fail-safe interlock switches to disconnect power sources when a test fixture cover is opened.
- Where possible, use automated handlers so operators do not require access to the inside of the test fixture or have a need to open guards.
- Provide proper training to all users of the system so they understand all potential hazards and know how to protect themselves from injury.

It is the responsibility of the test system designers, integrators, and installers to make sure operator and maintenance personnel protection is in place and effective.

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