AD590 and LM335 Sensor Calibration

APPLICATION NOTE

ILX Lightwave
Photonic Test and Measurement

AD590 & LM335 Sensor Calibration

Introduction

The AD590 is a linear thermal sensor which acts as a constant current source. It produces a current, I, which is directly proportional to absolute temperature, over its useful range (-50°C to +150°C). This nominal value can be expressed as:

$$I = 1\mu A / K$$

where I is the nominal current produced by the AD590, and K is temperature in Kelvin. Temperature controllers use I to determine the nominal temperature, T_n, by the formula:

$$T_n = (I / (1\mu A / K)) - 273.15$$

where T_n is in °C.

The LM335 is a linear thermal sensor which acts as a constant voltage source.
It produces a voltage, V, which is directly proportional to absolute temperature, over its useful range (-40°C to +100°C). This nominal value can be expressed as:

$$V = 10mV / K$$

where V is the nominal voltage produced by the LM335 and K is temperature in Kelvin.

Temperature controllers use V to determine the nominal temperature, T_n, by the formula:

$$T_n = (V / (10mV / K)) - 273.15$$

where T_n is in °C.

The AD 590 LM 335 linear thermal sensors can be used with several different models of ILX temperature controllers. These models include the LDC-3900, the LDC- 3700B series, the LDT-5525 and most recently the LDT-5948 and the LDT-5980.

These controllers use two constants (C1 and C2) for calibrating linear thermal sensing devices, such as the Analog Devices AD590, and the National Semiconductor LM335. C1 is used as the linear or zero offset value, and C2 is used as the slope or gain adjustment. Therefore, C1 should be set to a nominal value of 0, and C2 should be set to a nominal value of 1 (for all istruments except the 5948 and 5980) when the appropriate sensor is selected. In order to calibrate a linear sensor device, the sensor must be operated at an accurately known, stable temperature. For example, the sensor may be calibrated at 0°C if the sensor is placed in ice water until its temperature is stable. A highly accurate temperature probe, thermometer, environmental chamber, etc., may also be used to determine the known temperature for calibration. This Application Note contains one and two point calibration methods for these linear sensor devices. These methods will work for either type of device. The sensor calibration proceedure for use with the LDT-5948 and 5980 is described at the end of this Note.

AD590 Sensor Calibration

The temperature, T_d, which is displayed is first calibrated as follows:

$$T_d = C1 + (C2 * T_n)$$

where C1 and C2 are the constants stored for the AD590.

The AD590 measurement is calibrated at the factory with C2 = 1 and C1 = 0 (nominal values). The AD590 grades of tolerance vary, but typically this means that without adjusting C1 or C2, the temperature accuracy is ±1°C over its rated operating range. If C1 and C2 are calibrated, the temperature accuracy is ±0.2°C over its rated operating range.

However, the AD590 is not perfectly linear, and even with C1 accurately known, there is a non-linear absolute temperature error associated with the device. This non-linearity is shown in Figure 1, reprinted from Analog Devices specifications, where the error associated with C1 is assumed to be zero. If a maximum absolute error of 0.8°C is tolerable (over the entire temperature range), the one point calibration of C1 should be used. If C1 is calibrated at 25°C, and the intended operating range is 0 to 50°C, a maximum error of about ±0.2°C may be expected over that operating range. If a
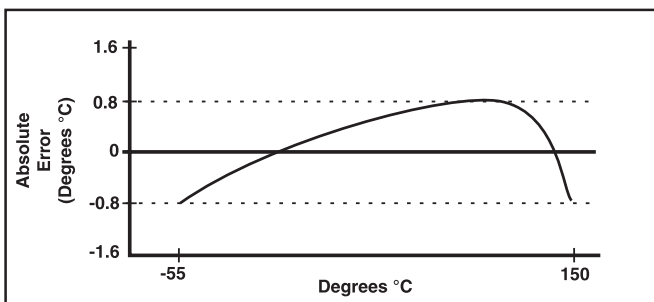

Figure 1. AD590 nonlinearity.

greater accuracy is desired, the two point method of determining C1 and C2 should be used. Note however, the absolute error curve is non-linear, therefore the constant C2 will vary over different temperature ranges.

LM335 Sensor

The temperature, T_d, which is displayed is first calibrated as follows:

$$T_d = C1 + (C2 * T_n)$$

where C1 and C2 are the constants stored for the LM335.

When the LM335 measurement is calibrated, and C1 and C2 are uncalibrated, the temperature accuracy is typically ±0.5°C over the rated operating range. With C1 and C2 calibrated, the temperature accuracy is typically ±0.2°C over the rated operating range. The temperature accuracy may be improved over a narrow temperature range by a two-point calibration of C1 and C2.

However, as with the AD590, the LM335 is also not perfectly linear, and even with C1 accurately known (and C2 uncalibrated) there is a non-linear absolute temperature error associated with the device. This non-linearity caused error is typically ±0.3°C, with the error associated with C1 assumed to be zero.

If a maximum absolute error of ±0.5°C is tolerable, no calibration of C1 or C2 is required, just set C1 = 0, C2 = 1. If a maximum absolute error of ±0.3°C is tolerable, the one point calibration of C1 should be used. If a greater accuracy is desired,

the two point method of determining C1 and C2 should used. Note however, the absolute error associated with the constant C2 may vary over different temperature ranges.

Calibrating the AD-590 and the LM-335 with the LDC-3700, LDC-3900 and the LDT-5525 temperature controllers.

One Point Calibration Method
This procedure will work for any linear temperature sensor. With these instruments the accuracy of this procedure depends on the accuracy of the known temperature, externally measured. It is used to determine the zero offset of the device, and it assumes that the gain offset (slope) is known and is correct.

1. Allow the temperature controller to warm up for at least one hour. Set the SENSOR SELECT switch for the desired sensor type, and RECALL the constants for the particular device to be calibrated. Set the controller in constant temperature mode.

2. Select the C1 parameter. Read and record the value of C1.

3. Place the sensor at an accurately known and stable temperature, T_a. Connect the sensor to the TEC output connector of the temperature controller pins 7 and 8 of 15 pin connector. Allow the instrument to stabilize at the known temperature, T_a and read the displayed temperature, T_d.

4. Determine the new value of C1, $C1_n$, from the formula:

$$C1_n = C1 + T_a - T_d$$

and replace C1 with $C1_n$ by selecting the C1 parameter and entering the new $C1_n$ value.

Two Point Calibration Method
This procedure will work for any linear temperature sensor. The accuracy of this procedure depends on the accuracy of the known temperatures, externally measured. It is used to determine the zero offset of the device and the gain offset (slope).

1. Allow the temperature controller to warm up for at least one hour. Set the SENSOR SELECT switch for the desired sensor type, and RECALL the constants for the particular device to be calibrated. Set the controller in constant temperature mode.

2. Select the C1 parameter. Read and record the value of C1. Select the C2 parameter. Read and record the value of C2.

3. Place the sensor at an accurately known and stable temperature, T_{a1}. Connect the sensor to the TEC output connector of the temperature controller pins 7 and 8 of 15 pin connector. Allow the instrument to stabilize at the known temperature, T_{a1} and read the displayed temperature, T_{d1}. Record these values.

4. Repeat Step 3 for another known temperature, T_{a2}, and the corresponding displayed temperature, T_{d2}. The two known temperatures should be at the bounds of the intended operating range. For best results, make the range between T_{a1} and T_{a2} as narrow as possible.

5. Determine the new value of C1 ($C1_n$) and C2 ($C2_n$) from the following calculations.

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First determine the intermediate values b and m, where

$$m = (T_{a1} - T_{a2}) / (T_{d1} - T_{d2}), \text{ and}$$

$$b = T_{a1} - (T_{d1} * m)$$

Then $C1_n$ and $C2_n$ can be determined by the following:

$$C1_n = b + (m * C1)$$

$$C2_n = m * C2$$

6. Replace C1 with $C1_n$ by selecting the C1 parameter and entering the new $C1_n$ value. Replace C2 with $C2_n$ by selecting the C2 parameter and entering the new $C2_n$ value.

Calibrating the AD590 (IC-I) and the LM335 (IC-V) Sensors for Use with the LDT-5948/5980

The slope and offset calibration constants used for calibration of linear sensors in ILX instruments in the previous section do not exist in the LDT-5948 or LDT-5980. Instead, the constants used are the actual slope (in μA/K or mV/K) and offset (in μA or mV) of the device being used to measure temperature. As with the other calibration procedures, the accuracy of this procedure depends on how accurately the temperatures used for the calibration are known. The pro-ceedure for calculating slope and offset is:

1. Allow the LDT-5948/5980 to warm up a minimum of five minutes. Set the sensor type to the appropriate sensor being used, namely IC-I for the AD590 and IC-V for the LM335.

2. Place the sensor at an accurately known and stable temperature. Record this temperature as T_1.

3. Place the instrument in Temperature mode and then use the ↑ and ↓ arrows next to the display to show the actual sensor output in μA or mV, depending on the sensor type selected. Record this value as X_1.

4. Repeat step 2 for another known temperature. Record this temperature as T_2. Note - in order to obtain the best accuracy, T_1 and T_2 should lie at the edges of the expected temperature range of operation and should be as narrow as possible.

5. Record the new sensor output at T_2 as X_2.

6. Calculate the sensor slope m using the equation $m = \dfrac{X_2 - X_1}{T_2 - T_1}$

7. Calculate the sensor offset b using the equation
$$b = X_2 - mT_2$$

8. Go to the sensor parameter menu and select the appropriate sensor type.

9. Once the sensor has been selected, enter the new sensor slope and offset values, m and b, into the instrument. Be sure to press <Enter> after chang-ing the value to store it.

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

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