WAVELENGTH ELECTRONICS

How is Temperature Stability Measured?

HOW STABLE IS A TEMPERATURE CONTROLLER?

Typically, a controller manufacturer will give temperature stability specifications over one hour and stability over 24 hours. There are several caveats to the testing that can only be exposed by understanding the test protocol as it compares to your application.

Our testing is standardized so you can compare specifications across units with your own configuration.

We use three specifications:

* Stability 1-hour, off-ambient
* Stability 24-hour, off-ambient
* Stability 1-hour, on-ambient

Stability is how close the actual load temperature stays to the setpoint temperature over time. We operate a temperature controller with a thermoelectric, laser diode, and thermistor. We monitor actual temperature of the sensor. Error is the difference between actual sensor and setpoint temperatures. Our *typical* (TYP) stability specification is three times the standard deviation of the error over the specified time period.

WHY DOES WAVELENGTH ELECTRONICS SPECIFY ON-AMBIENT STABILITY?

More and more applications work on or near ambient temperature. Controllers are inherently least stable under these conditions. Signal to noise ratio is lowest and different configurations of output stage affect performance. It is important to know how the controller operates if you plan to scan your device across ambient (where setpoint equals environmental temperature).

In developing small, more efficient controllers, we have developed proprietary circuitry that does not exhibit loss of control around ambient. We specify two types of stability, on- and off-ambient, because stability off-ambient is still slightly better than on-ambient for our optimized linear controllers.

Note that our proprietary linear circuit does not introduce PWM noise. It has been designed for low noise applications. Scanning a narrow linewidth laser system across ambient temperature is now feasible with our small controllers.

TECHNICAL BACKGROUND

A typical linear output circuit drives current one direction then switches direction as the setpoint crosses ambient and the error changes sign, with the amount of current proportional to the amount of error.

For example, if ambient is 25°C, and a laser diode wavelength is controlled by temperature, to vary wavelength, the temperature might be scanned from 15 to 35°C. Initially the controller will drive cooling current to drop the laser temperature from ambient to 15°C. During the scan, when the laser temperature reaches 25°C, the current is lower and the controller smoothly switches to heating. The trade-off for a smooth transition is lower efficiency. Stability is specified once for both on- and off-ambient control.

With a higher efficiency circuit, the heating current source is independent from the cooling current source. The sources are turned on and off as needed. The transition between heating and cooling is critical. There can be a “dead band” right at ambient where the controller drives no current – neither heating nor cooling – and the laser drifts until its temperature exits the dead band and controls again.

TEST SETUP

On a test bench, set up the controller, a load (laser with thermoelectric and 10 kΩ thermistor), linear power supply, and monitoring equipment. Note that we do not hold the controller, load or monitoring equipment at constant temperature in a temperature chamber. The typical ambient temperature in our lab can shift up to 10 degrees over time. We believe this is a more robust test for a controller.

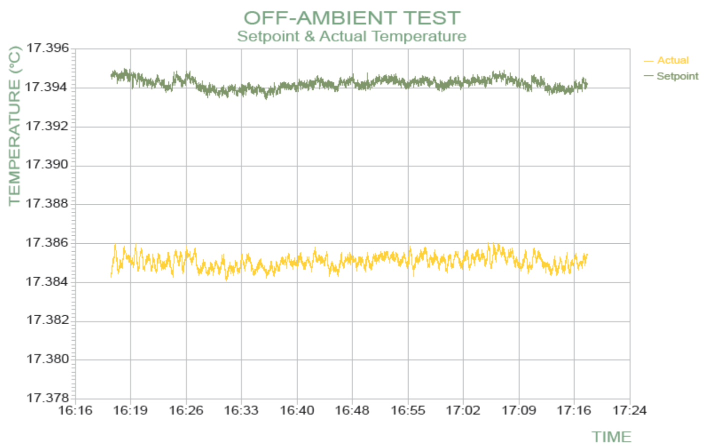
OFF-AMBIENT TESTING

Set the setpoint temperature five to seven degrees below ambient conditions. Monitor the actual temperature output voltage from the controller and the setpoint voltage with an acquisition cadence of one second. Set the proportional gain low enough such that it does not overdrive the error signal and cause oscillations.

Monitor the system for an hour after it has reached setpoint. Analyze the data. For each data point, convert thermistor voltage to temperature using the Steinhart-Hart equation to compute the temperature, in units of °C, for both actual temperature and setpoint.

$$T = \frac{1}{A + B\ln\left(\frac{V}{100\ \mu A}\right) + C\ln\left(\frac{V}{100\ \mu A}\right)^3} - 273.15$$

Where T is the temperature in °C, A, B and C are the Steinhart-Hart sensor coefficients (located in the TCS610 data sheet), V is the measured voltage, 100µA is the sensor bias current used, and the constant 273.15 is the offset between the Kelvin and Celsius scales.

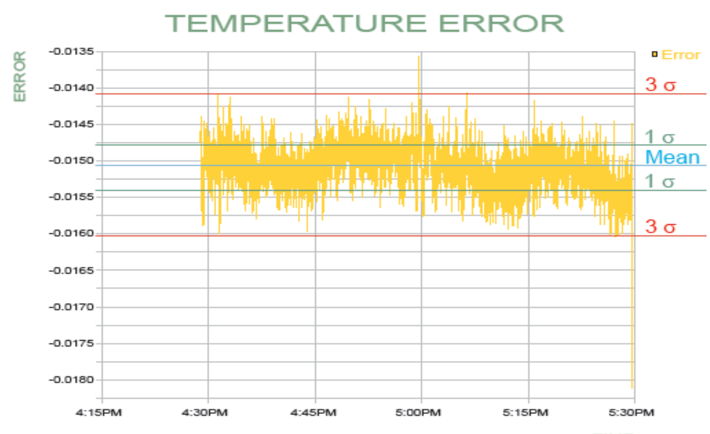


Once converted, calculate the error signal between actual and setpoint temperatures.

$$T_{ERR} = T_{ACT} - T_{SET}$$

Where T_{ERR} is the error, T_{ACT} is the Actual Temperature, and T_{SET} is the Setpoint Temperature.

Plot a graph where the X-axis represents the time for each data point, and the Y-axis represents the values from the Error column. Using this graph verify the point in the acquired data set at which error has stabilized and is no longer fluctuating, indicating that the Unit Under Test (UUT) and load have stabilized at a controlled setpoint.

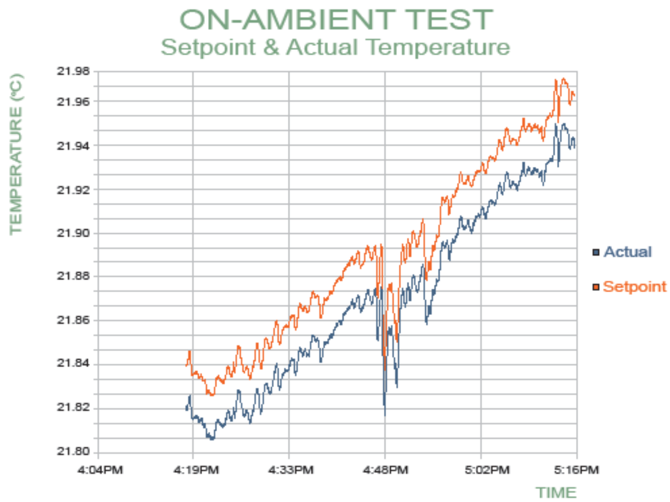


Determine the approximate time from the X-axis that this point occurs. This point is the origin marker in the data set for computing the temperature stability. For 1-hour stability, ensure that the data set duration is at least 1 hour. For 24-hour stability, ensure that the data set duration is at least 24 hours.

Compute the standard deviation of the Error in the near-Gaussian data set. This is the 1-sigma stability value. This value can then be multiplied by 3 to arrive at the stability band within which the error will remain for 99.73% of the time the load is controlled. This 3-sigma value is then published in the data sheet as the *typical* (TYP) temperature stability.

ON-AMBIENT TESTING

To measure the on-ambient stability, we use a 10 kΩ thermistor with 100 µA bias current as the setpoint input. We monitor the data and process it the same way as the off-ambient test. The setpoint follows the ambient conditions of the lab and the controller is forced to operate in worst-case control conditions.



Again, the controller and load are not in a temperature controlled chamber. They are out on a test bench experiencing ambient fluctuations with air conditioning and heating changes. These specifications are deliberately measured this way to show robustness.

STABILITY: LINEAR VS. SWITCHING POWER SUPPLY

Our most recent results indicate some change in stability – about 0.001°C decrease – using a switching supply instead of a linear supply. It is highly dependent on choice of supply, load, sensor, and the overall configuration. Another factor to consider is whether or not the switching frequency will interfere with other elements of the design.

REVISION HISTORY

REV	DATE	NOTES
A	5-May-09	Initial Release

HELPFUL HINTS TO OPTIMIZE STABILITY

First, sensor sensitivity (resistance change per °C) is critical. Our tests use a 10 kΩ thermistor with 100 µA bias current with nominal voltage of 1 V at 25°C. This voltage is mid-range in the feedback loop. At 25°C, the TCS-610 thermistor signal moves about 45 mV for each degree Celsius change. At 0°C, the TCS610 signal changes 167 mV / °C.

Second, we use a load where the sensor is directly mounted to the laser diode that is being temperature controlled. There is minimal time delay between sensor signal change and controller response. If the sensor is a distance away from what is being controlled or the thermoelectric is not directly coupled to what is being controlled, delays can lead to oscillations in the output current and essentially an inability to stabilize the control loop. Separation can also lead to an offset between actual laser temperature and sensor temperature.

Third, we use an active load where both heating and cooling current are present. If you use a resistive heater, only heating current is active. Passively losing heat to the surroundings constitutes cooling and the controller has no involvement.

Fourth, if the controller is not tuned, stability might be affected. For example, if the proportional gain is too high, the controller will drive a large current for a small error condition. This appears as an oscillation or an offset in the actual temperature of the laser diode. For more detail on tuning a system, refer to Technical Note TN-TC01: *Optimizing Thermoelectric Temperature Control Systems*. It is available online.

Fifth, good contact between sensor and load is critical. For good thermal transfer, use a high conductivity paste, such as Wavelength Electronics THERM-PST, or thermal epoxy.

STABILITY IN YOUR SYSTEM

Understanding how a temperature stability specification is determined allows you to predict how the controller will perform in your system.

If you have any questions, Wavelength Electronics offers free technical support. Please call us at (406) 587-4910 or email techsupport@teamwavelength.com.

KEYWORDS

Temperature controller, pid temperature controller, tec controllers, thermistor, thermo electric, thermo-electric, thermoelectric, thermoelectric control, thermoelectric cooler, Peltier device, Peltier cooler, heat pump, temperature stability, laser temperature control.