Temperature Controller Calibration Procedures

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Introduction

This document outlines the calibration process for 5235 and 5300 Temperature Controllers. It is up to the calibration technician to ensure all test equipment used during the calibration sufficiently exceeds the desired measurement accuracies. As a general guideline, the test equipment should exceed the temperature controller specifications by 4X but the actual requirement is to be defined by your specific calibration needs.

Test Equipment Required

The following test equipment is needed for calibration of the temperature controller:

1. A voltage meter capable of at least 6½ digit performance, with > 10GΩ input impedance.
2. A precision current sense resistor, typically around 0.05Ω, used for current calibration. The value of this resistor must be well known. A 4-wire Kelvin type sense resistor is recommended.
3. Precision, well known resistors of the following approximate values: 40kΩ and 100kΩ.
4. Stable resistors with values of 4kΩ, 40kΩ, and 400kΩ (value does not need to be well known).
5. 1Ω power resistor rated to at least 100W.
6. 14Ω power resistor rated to at least 5W.
7. For 5300 calibration, additionally need:
    a. Stable resistors with values of 80Ω and 140Ω (value does not need to be well known).
    b. Precision, well known resistors of the following approximate values: 170Ω, 14kΩ, 20kΩ.

In addition, for verification, the following test equipment is needed for verification:

1. Precision, well known resistors of the following approximate values: 1kΩ, 2kΩ, 4kΩ, 10Ω, 20kΩ, 40kΩ, 100kΩ, 200kΩ, and 400kΩ. These are for thermistor verification.
2. Precision, well known resistors of the following approximate values: 80Ω, 100Ω, 125Ω, 150Ω, and 175Ω. These are for RTD verification.
3. Precision, well known resistors of the following approximate values: 12kΩ, 14kΩ, 16kΩ, 20kΩ, and 24kΩ. These are for AD590 verification.
4. Potentiometer, with a range of 0 to 10kΩ. This is for LM335 verification.
5. A 4Ω power resistor, rated to at least 25W. This is for voltage verification.

Calibrated Resistors

The test and verification process requires a number of calibrated resistors. You do not need to match the values indicated in the list above *exactly*, just get close. The more critical element is how well known the value is.

In most cases, you can simply purchase precision, low ppm/°C resistors, and use your DMM to measure their value. Most precision DMMs offer a 4-wire sense measurement mode for resistors, and this should be used to determine the value of each resistor, especially for low resistance values (200Ω and below).

At Arroyo Instruments, we use 25ppm/°C resistors for all values except the current sense resistor, and these can be found at DigiKey and Mouser, as well as many other component distributors. For the current sense resistor, we use an Alpha PCW0R0500 resistor, which is a precision, 15ppm/°C 4-wire resistor mounted on a heat sink (to minimize self-heating during calibration).

The power resistors can be any type, they just need to be sufficiently large enough to handle the thermal load that will be placed on them. Some power resistors have both heat-sinked and free air ratings, so if you will ***not*** be mounting to a heat sink, make sure the resistor's free-air rating is sufficient. Make sure you understand what is required to achieve the thermal rating of your power resistors, or they may get extremely hot. DigiKey and Mouser both offer a wide selection of power resistors.

General Setup Information

All calibrations are done via the computer interface, so you will need either a USB or RS-232 NULL cable, and verify you have communications with the temperature controller. All test connections are made through the DB15-F **Output** connector on the rear of the temperature controller.

Throughout the process, the required temperature controller commands will be shown in `Courier` font. Any values to be taken from the DMM or resistor values will be shown in chevrons (i.e., "**<voltage measurement>**"). Make sure the values are entered with sufficient resolution, which is typically the full resolution of the DMM's display (or greater).

The DMM must set to high input impedance mode (> 10GΩ input impedance). Many meters only offer 10MΩ impedance, which will adversely affect the calibration process, and should not be used to calibrate the temperature controller.

Once a calibration has been started, it can be canceled (without affecting the existing calibration data) using the **TEC:CAL:CANCEL** command. The **TEC:CAL?** command can be used to determine if a calibration is in process; a return of 0 indicates no, while a return of 1 indicates yes.

100uA Thermistor Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Set the temperature controller into resistance (R) mode, and select the 100uA sensor. Send the following command to start the calibration process:

   ```
   TEC:MODE:R
   TEC:SENS 1
   TEC:CAL:SENS
   ```

2. Connect a 4kΩ resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

3. Connect a 40kΩ resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

4. Connect a precision, well known 40kΩ resistor across the Sensor+ and Sensor– pins (do not connect the DMM), then send the following command:

   ```
   TEC:CAL:ISENS
   TEC:CAL:R <resistor value in kilo-ohms>
   ```

5. Calibration is complete.

10uA Thermistor Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Set the temperature controller into resistance (R) mode, and select the 10uA sensor. Send the following command to start the calibration process:

   ```
   TEC:MODE:R
   TEC:SENS 2
   TEC:CAL:SENS
   ```

2. Connect a 40kΩ resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

3. Connect a 400kΩ resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

4. Connect a precision, well known 100kΩ resistor across the Sensor+ and Sensor– (do not connect the DMM), then send the following command:

   ```
   TEC:CAL:ISENS
   TEC:CAL:R <resistor value in kilo-ohms>
   ```

5. Calibration is complete.

RTD Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Set the temperature controller into resistance (R) mode, and select the RTD sensor. Send the following command to start the calibration process:

   ```
   TEC:SENS 5
   TEC:MODE:R
   TEC:CAL:SENS
   ```

2. Connect a 80Ω resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

3. Connect a 140Ω resistor across the Sensor+ and Sensor– pins, and measure the voltage across the temperature controller, then send the following command:

   ```
   TEC:CAL:R <voltage measurement>
   ```

4. Connect a precision, well known 175Ω resistor across the Sensor+ and Sensor– (do not connect the DMM), then send the following command:

```
TEC:CAL:ISENS
TEC:CAL:R <resistor value in ohms>
```

5. Calibration is complete.

AD590 Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Set the temperature controller into resistance (R) mode, and select the AD590 sensor. Send the following command to start the calibration process:

   ```
   TEC:SENS 4
   TEC:MODE:R
   TEC:CAL:SENS
   ```

2. Connect a precision, 20kΩ well known resistor across the Sensor+ and Sensor– pins, and measure the voltage across the resistor. Calculate the actual current using the I=V/R formula, where V is the measured voltage, and R is the resistor value, and I is the calculated current. Because the temperature controller uses microamps as the native unit, multiple the calculated current by 1E6 to obtain the current in microamps, then send the following command:

   ```
   TEC:CAL:R <current in microamps>
   ```

3. Using a 14kΩ well known resistor, repeat step 2

4. Calibration is complete.

ITE Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Connect a precision, 0.05Ω well known resistor in series with a 1Ω power resistor across the TE+ and TE– pins.

2. Set the temperature controller into ITE mode, and select the 10uA sensor. Send the following command to start the calibration process:

   ```
   TEC:SENS 1
   TEC:ENABLE:OUTOFF 0
   TEC:LIM:ITE 3.5
   TEC:MODE:ITE
   TEC:CAL:ITE
   ```

3. Measure the voltage across the precision sense resistor, and wait for value to fully stabilize. Convert the voltage measurement to current using the formula I = V/R, where V is the measured voltage, and R is the current sense resistor value, and I is the calculated current. The value should be approximately 2.9A.

   ```
   TEC:CAL:R <current>
   ```

4. The temperature controller will automatically step the current to a lower value. Once stable, repeat step 3. Calculated current should be around 0.1A to 0.2A.

5. Calibration is complete.

VTE Calibration

At each step, make sure the displayed and/or measured value is ***completely*** settled to the final value before sending commands to the temperature controller. This may take several seconds to occur.

1. Connect a 14Ω power resistor across the TE+ and TE– pins.

2. Set the temperature controller into ITE mode, and select the 10uA sensor. Send the following command to start the calibration process:

```
TEC:SENS 1
TEC:ENABLE:OUTOFF 0
TEC:LIM:ITE 3.5
TEC:ITE 0.5
TEC:MODE:ITE
TEC:OUT 1
TEC:CAL:VTE
```

3. Measure the voltage across the resistor, and wait for value to fully stabilize. The value should be approximately 7V.

```
TEC:CAL:R <voltage measurement>
```

4. The temperature controller will automatically step the current (and therefore voltage) to a lower value. Once stable, repeat step 3. Voltage should be around 1.7V.

5. Calibration is complete.

100uA Thermistor Verification

1. Place the temperature controller in resistance (R) mode, and select the 100uA thermistor. Send the following command to start the calibration process:

```
TEC:SENS 1
TEC:MODE:R
```

2. Use the precision, well known resistor values of 1kΩ, 2kΩ, 4kΩ, 10Ω, 20kΩ, and 40kΩ. One at a time, connect each across the Sensor+ and Sensor– pins, and verify each is measured within the accuracy specification of the temperature controller.

3. Verification is complete.

10uA Thermistor Verification

1. Place the temperature controller in resistance (R) mode, and select the 10uA thermistor. Send the following command to start the calibration process:

```
TEC:SENS 2
```

```
TEC:MODE:R
```

2. Use the precision, well known resistor values of 1kΩ, 4kΩ, 10Ω, 40kΩ, 100kΩ, 200kΩ, and 400kΩ. One at a time, connect each across the Sensor+ and Sensor– pins, and verify each is measured within the accuracy specification of the temperature controller.

3. Verification is complete.

RTD Verification

1. Place the temperature controller in resistance (R) mode, and select the RTD. Send the following command to start the calibration process:

```
TEC:SENS 5
TEC:MODE:R
```

2. Use the precision, well known resistor values of 80Ω, 100Ω, 125Ω, 150Ω, and 175Ω. One at a time, connect each across the Sensor+ and Sensor– pins, and verify each is measured within the accuracy specification of the temperature controller.

3. Verification is complete.

LM335 Verification

1. Place the temperature controller in resistance (R) mode, and select the LM335. Send the following command to start the calibration process:

```
TEC:SENS 3
TEC:MODE:R
```

2. Using a potentiometer with a range of 0Ω to 10kΩ, connect it across the the Sensor+ and Sensor– pins and measure the voltage across the resistor. Adjust the potentiometer until 2V is measured. Continue to increase the resistance, take measures as needed, until the voltage reads 4V. For each measurement, verify the voltage matches the temperature controller's displayed reading within the accuracy specification of the temperature controller.

3. Verification is complete.

AD590 Verification

1. Place the temperature controller in resistance (R) mode, and select the AD590. Send the following command to start the calibration process:

```
TEC:SENS 4
TEC:MODE:R
```

2. Use the precision, well known resistor values of 12kΩ, 14kΩ, 16kΩ, 20kΩ, and 24kΩ. One at a time, connect each across the Sensor+ and Sensor– pins, and measure the voltage across the resistor. For each value, calculate the actual current using the I=V/R formula, where V is the measured voltage, and R is the current sense resistor value, and I is the calculated current. Because the temperature controller uses microamps as the native unit, multiple the calculated current by 1E6 to obtain the current in microamps. Verify each calculated current matches the temperature controller's displayed reading within the accuracy specification of the temperature

controller.

3. Verification is complete.

ITE Verification

1. Connect a precision, 0.05Ω well known resistor in series with a 1Ω power resistor across the TE+ and TE– pins.

2. Set the temperature controller into ITE mode, and select the 10uA sensor. For the limit command, enter the maximum current of the temperature controller.

```
TEC:SENS 1
TEC:ENABLE:OUTOFF 0
TEC:LIM:ITE <maximum current>
TEC:MODE:ITE
TEC:ITE 0
TEC:OUT 1
```

3. Measure the voltage across the precision sense resistor, and wait for value to fully stabilize. Convert the voltage measurement to current using the formula I = V/R, where V is the measured voltage, and R is the current sense resistor value, and I is the calculated current. The value should be very close to 0A.

4. Repeat step 3, but with sufficient set points through the operating range of the temperature controller. The **`TEC:ITE`** command can be used to change the set point remotely. Verify each calculated current matches the temperature controller's displayed reading within the accuracy specification of the temperature controller.

5. Verification is complete.

VTE Verification

1. Connect a 4Ω power resistor across the TE+ and TE– pins.

2. Set the temperature controller into ITE mode, and select the 10uA sensor. Send the following command to start the verification process:

```
TEC:SENS 1
TEC:ENABLE:OUTOFF 0
TEC:LIM:ITE 3.5
TEC:ITE 0
TEC:MODE:ITE
TEC:OUT 1
```

3. Measure the voltage across the resistor, and wait for value to fully stabilize. The value should be approximately 0V.

4. Repeat step 3, using ITE set point values to generate sufficient voltage measurements across the operating range. Verify each voltage measurement matches the temperature controller's displayed reading within the accuracy specification of the temperature controller.

5. Verification is complete.

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