LabSmith Application Note

uProcess™ Thermal Control

By Christine Cummings
LabSmith, Inc. Livermore, CA 94550

This application note describes how to use the uProcess™ thermal devices, including tips for getting the best results from your sensors and controllers, and detailed temperature regulation examples.

Introduction

uProcess™ uTS temperature sensors, uTE thermal module, and uProcess software make it easy to monitor and control your micro-process application. For the examples below, the temperature is measured on the top surface of a glass microscope slide that is bonded to the uTE thermal module. An additional temperature sensor is used to record the temperature on the back side of the module (between the Peltier and the heat sink).

Table 1 and Figure 1 show the equipment used in this application:

Table 1. Components

LabSmith Part Number	Description	Qty
uPB-5	uProcess Breadboard	1
EIB200	Electronic Interface Board	1
4PM01	4 Channel Power Manifold	1
4AM01	4 Channel Analog Manifold	1
uTE01 -132020	Thermo-electric Peltier module	1
2020HS	Heat sink for uTE01	1
uTS01-STD	Temperature Sensor	2
-	M2-6 screw	2
LS-Screws.25	2-28x1/4" screws	2
-	Glass Microscope Slide	1
-	Thermal Tape	~10 cm

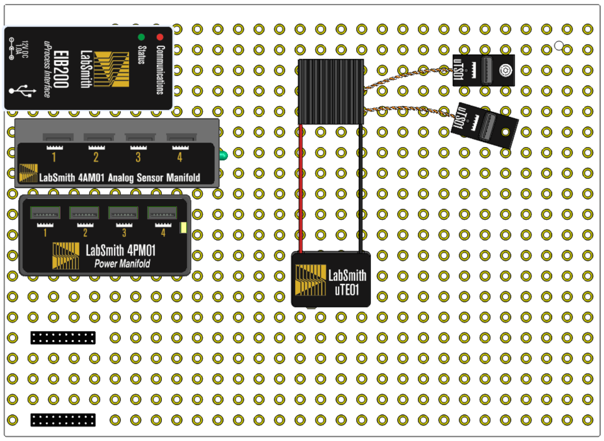
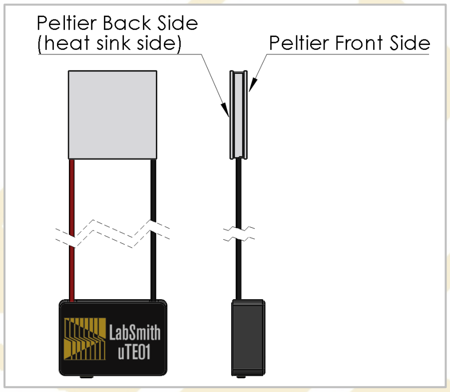


Figure 1. Experimental setup.

Set up the uProcess Breadboard

1) Prepare the uTE01 Peltier:

   a) Cover the back side of the **uTE01 Peltier** with thermal tape, preferably using tape that is at least 0.25mm thick.

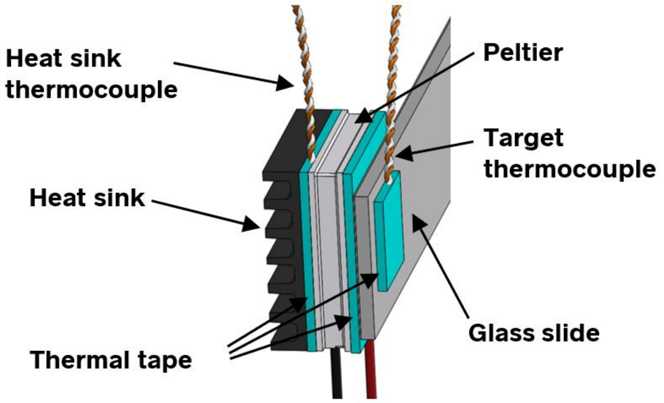


   b) Attach the end of a **uTS01-STD** temperature sensor to the thermal tape and cover with a 2020HS heat sink. Make sure the heat sink/thermal tape interface has good contact across the entire Peltier surface.

   c) Connect the glass microscope slide to the front side of the **uTE01 Peltier** using thermal tape.

   d) Connect the end of a **uTS01-STD** temperature sensor thermocouple to the top of the glass microscope slide using thermal tape.

e) The completed assembly should look like this:



2) Attach the **uTE01 controller** to the breadboard using two M2 screws.

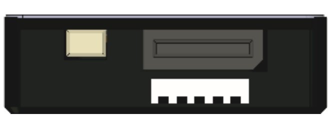
3) Attach the **uTS01 sensors** to the breadboard using one 2-28x1/4" screw for each sensor.

4) Plug the **EIB200** into a breadboard connector.

5) Plug the **4PM** manifold into a breadboard connector.

6) Use the flat flex ribbon cable to connect the **4PM01** to the **uTE01 controller**.

NOTE: Refer to the label on the 4PM and the uTE01 drawing below to make sure the cable orientation is correct for both sides.



7) Plug the **4AM** manifold into a breadboard connector.

8) Use the flat flex ribbon cables to connect the **4AM** to the **uTS01 sensors**.

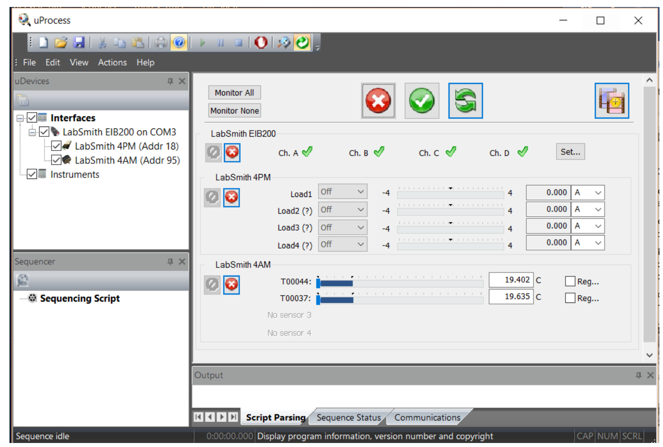
Set up the Experiment in uProcess Software

1) Connect the **EIB200** to your computer via the micro-USB cable (provided with the EIB200).

2) Connect power to the EIB200 and start the uProcess software.

3) Right-click on *Interfaces* and select *New Interface...* to connect to the EIB200 (see the uProcess Quick Start Guide for detailed instructions).

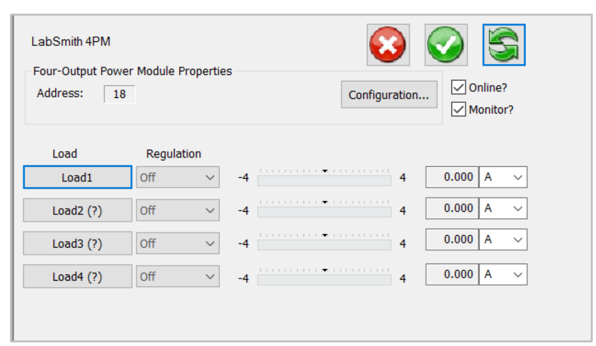
4) The uProcess software screen should look similar to the following:



Set the uTE01 Load Type

When using a uTE01 load, the load configuration must be set in uProcess.

5) To set the load configuration, click on the 4PM icon in the Interface tree to bring up the **4PM Module window.**



6) Click on the *Load* button for the channel to which the uTE01 is connected (in this case channel 1, or Load1).

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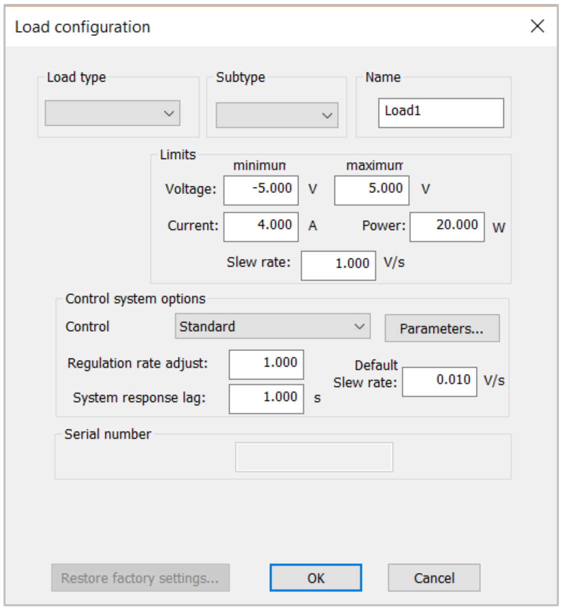


7) Using the dropdown menus, set the Load type to *uTE Peltier*, and then select the appropriate Subtype from the dropdown window.

8) Optional: Change the Name for more description. For example, since a 13-2020 uTE Peltier is used, the Name is changed to uTE2020.

NOTE: The Load settings are saved in the 4PM memory. If a different type of load is used in the 4PM channel, or if the load is moved to a different channel, the 4PM Load Configuration must be updated. The Load Configuration sets the channel voltage and power limits; using an incorrect configuration can damage the uTE01 Peltier.

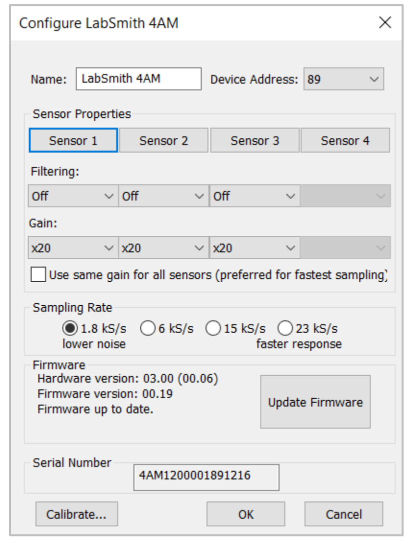
Set the uTS Sensor Name

9) The factory setting for the temperature sensors uses the sensor serial number as the sensor name. If desired, rename your temperature sensors based on their placement location. This is especially useful if more than one sensor is used, such as the 2 sensors used in this application.

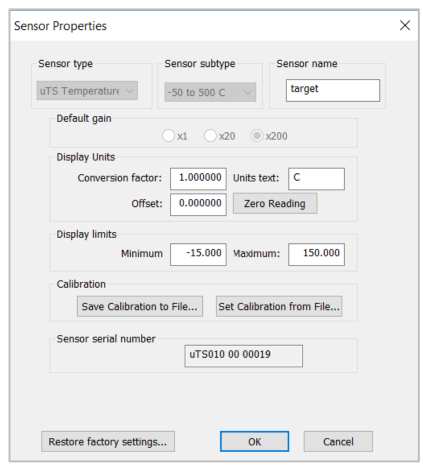
   a) The uTS located on top of the chip is renamed "target".

   a) The uTS located between the Peltier and heat sink is renamed "heat sink".

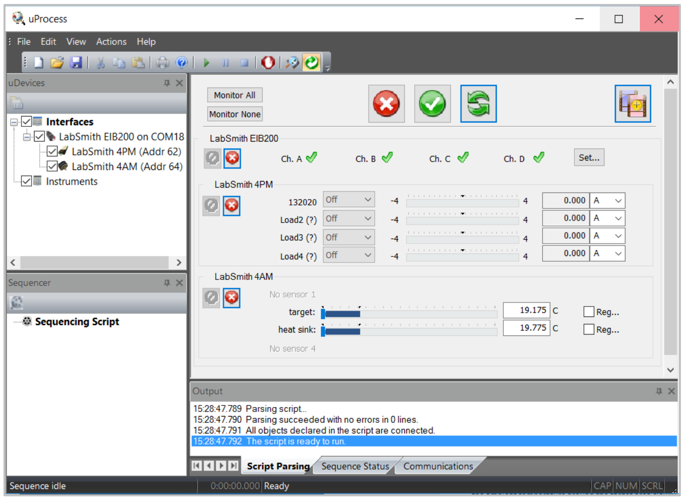
10) To change the sensor name, click on the **4AM** in the Interface tree and select *Configuration…*.



11) Select the correct sensor under *Sensor Properties* and change the sensor name (trace the communication cable back from the 4AM to each uTS to be sure you have selected the correct sensor).



Your setup is now ready to start controlling temperatures.



NOTE: The uTE can be easily damaged if the temperature on either side of the Peltier exceeds the maximum ratings. Unregulated control should be closely monitored to ensure temperatures stay within the limits.

Measure the Thermal Response Lag Time

The response lag time is the time delay between applying power to the **uTE controller** and when the temperature change is observed at the target location. The uTE controllers are shipped with a default thermal response lag time of 0.5 seconds. The actual lag time is application dependent and will vary with the location of the thermal sensor. For the most accurate temperature feedback control, the lag time should be measured and adjusted for each application.

For this example, the uTS temperature sensor (renamed 'target') is attached at the target location.

1) To measure the thermal lag time, select File>Log Status/Measurements... to start recording a log file. Select a file name and location when prompted to enter (if not prompted, the log is set as autoname; go to View>Status/Meas Logging Options... to change).

2) Click on the **4PM** in the interface tree to bring up the 4PM uDevice™ window.

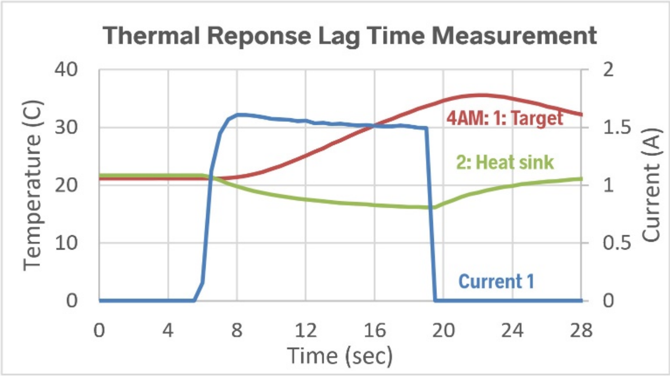
3) Select *Power* in the Regulation dropdown menu to set the regulation mode to constant power.

4) Set the power to 2W and apply settings using the *Apply All Settings Now* button (✅).

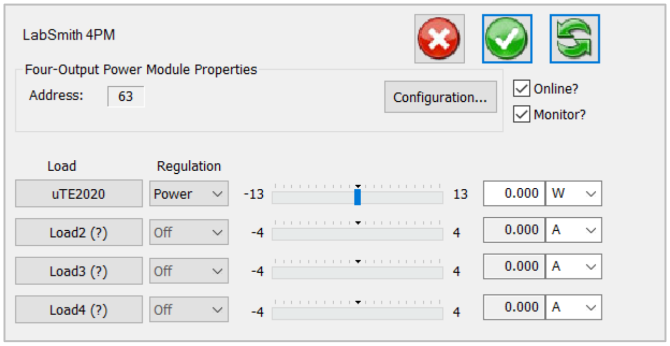
5) The target temperature will rise, and the heat sink temperature will fall. Wait until the target temperature has increased approximately 10°C then click *Stop All uDevices* (❌).

6) Go to File>Log Status/Measurements... to uncheck and stop recording the log file.

7) Open the **Log File** in Microsoft Excel or another data processing software. Plot the target temperature and current vs. time. If your uTE is plugged into channel 1 of your 4PM, select *Current 1*. Note the time from when the power is stopped to when the temperature stops rising. This is your thermal response lag time. The figure below shows an example lag time of 3 seconds.



8) Select the **4PM** from the Interface tree to bring up the 4PM control window.



9) Click on the Load Configuration and select the appropriate load (13-2020 in this example).

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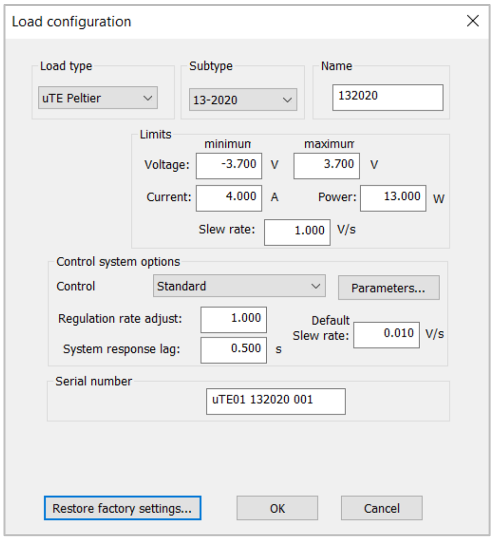
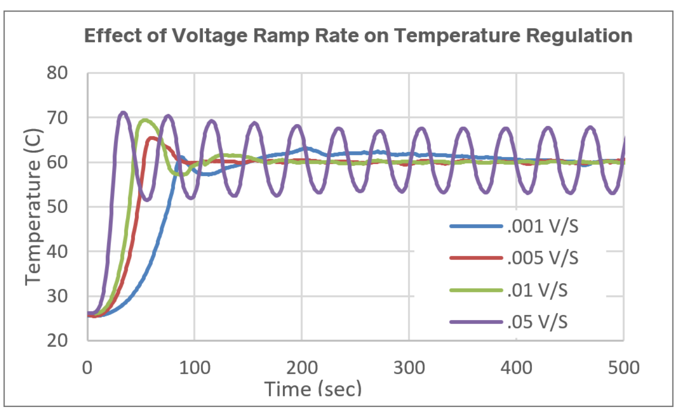


10) Change the System response lag time to the correct value and click OK.

Selecting a Voltage Ramp Rate for Temperature Regulation

When regulating temperatures, the voltage ramp rate (V/s) can be adjusted to optimize temperature ramp rate, overshoot, and error. The figure below shows various voltage ramp rates for a set temperature of 60°C.



If precise temperature regulation is required, use a low the voltage ramp rate (~0.001–0.005 V/s). If the time to reach the set temperature is crucial, a higher ramp rate should be used (~0.01 V/s).

If both speed and accuracy are critical, a multi-step regulation routine can be written (refer to Example 3).

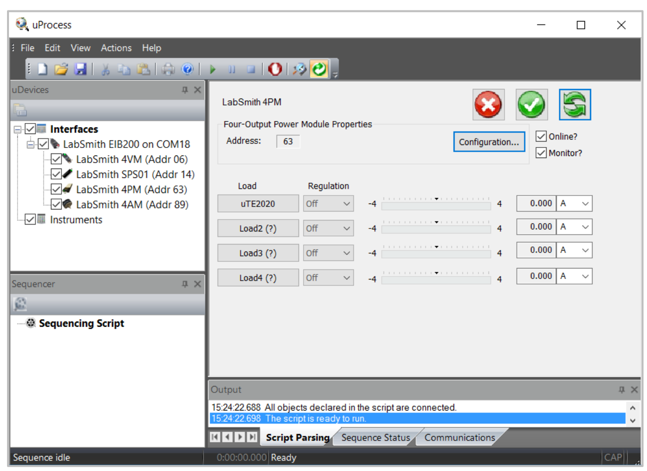
Active vs. Passive Cooling

The uProcess thermal products support both active cooling and passive cooling. The default voltage settings for the uTE controllers allow both positive and negative voltage for heating and cooling, respectively. Caution must be used with active cooling (negative voltage), as the back side of the Peltier module can easily be overheated if the steps are not taken to cool the module. If active cooling is to be used, it is best to use a heat sink, fan, and a temperature sensor mounted between the Peltier and heat sink.

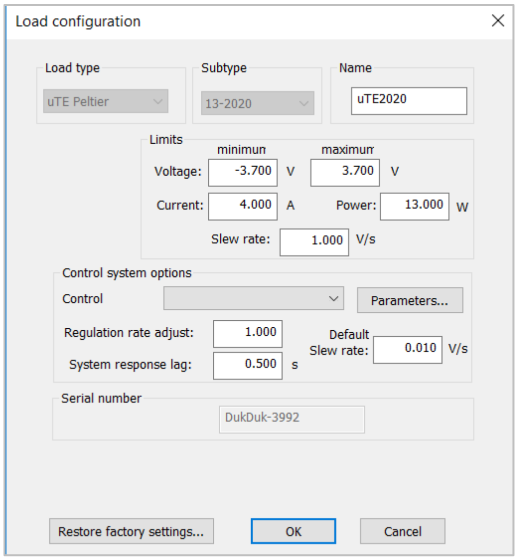
Passive cooling is sufficient for many applications where the application temperatures are above ambient. With passive cooling, the uTE controller minimum voltage is set to 0, and the uTE voltage is reduced or turned off. This eliminates the possibility of overheating the back side of the uTE Peltier.

Changing the uTE controller voltage settings:

1) Click on the **4PM** in the Interface tree to bring up the 4PM uDevice Window.



2) Select the load to change (in this case uTE2020).



3) Change the minimum voltage to 0 and click OK.

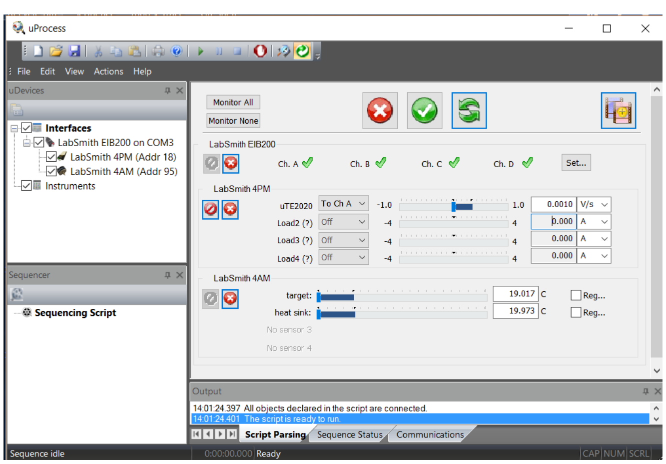
Example 1: Maintaining a Set Temperature

This application shows how to use the **uTE controller** and **uTS sensor** to maintain a constant, set temperature.

The automated script uses the **uTE** to regulate the "target" thermocouple temperature to 37.5°C.

This example is optimized for temperature precision rather than expedient changes in temperature. Using a voltage ramp rate of 0.001 V/s will minimize overshoot.

1) Click on *Interfaces* in the uDevices tree to view the uDevice window.

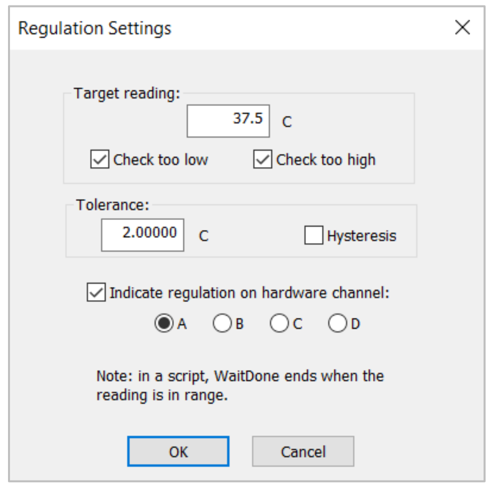


2) Click on the *Reg...* box next to the target temperature listing to bring up the Regulation Settings window.

3) Using the dropdown menu, change the uTE Peltier load to To Ch A.

4) Set the uTE voltage ramp rate to 0.001 V/s.

5) Set the regulation settings as shown in the following window and click OK.



NOTE: Hysteresis is not typically used with temperature regulation. Checking the Hysteresis box would force the regulation routine to regulate towards the far tolerance limit (if regulating up, it would regulate to the the maximum limit, if regulating down it would regulate to the minimum limit). This is often desirable for pressure regulation but will cause instability and overshoots for temperature regulation.

6) Click on *Save as New Sequence Step* ( ) and click OK to save the settings to the script.

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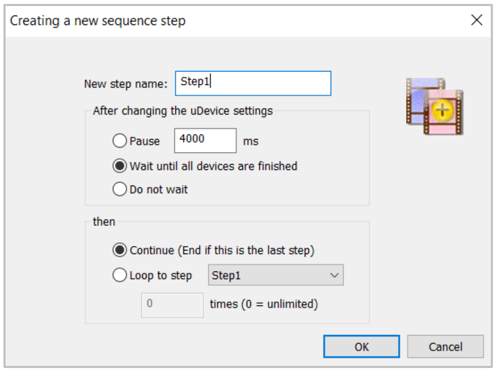
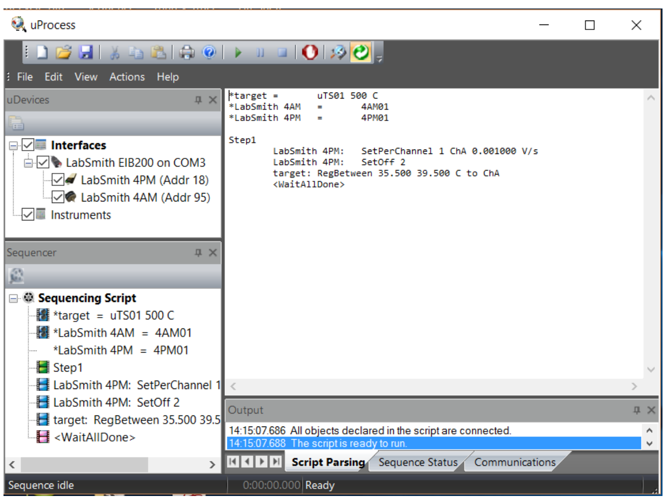


7) Click on *Sequencing Script* in the Sequencer tree to view the Sequence Window and see the script. This script will regulate the target temperature up (or down) to 37.5°C and maintain that temperure until the script is stopped.



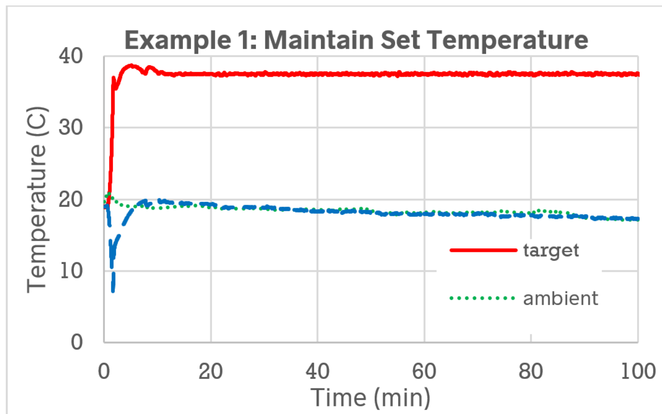
8) Go back to the uDevice window (click on *Interfaces* in uDevice tree) to monitor temperatures before starting the script.

9) Run the sequence program (▶).

10) Press *Stop all uDevices* ( ) to stop the regulation.

NOTE: Each **uTS temperature sensor** includes a compensation temperature sensor that is located in the uTS body. This compensation measurement is used as the ambient temperature measurement in this example. The compensation temperature can be monitored via the 4AM uDevice Window (as shown below) and is included in the log data file as 'Comp Temp.'

11) The figure below shows a typical data set from Example 1.

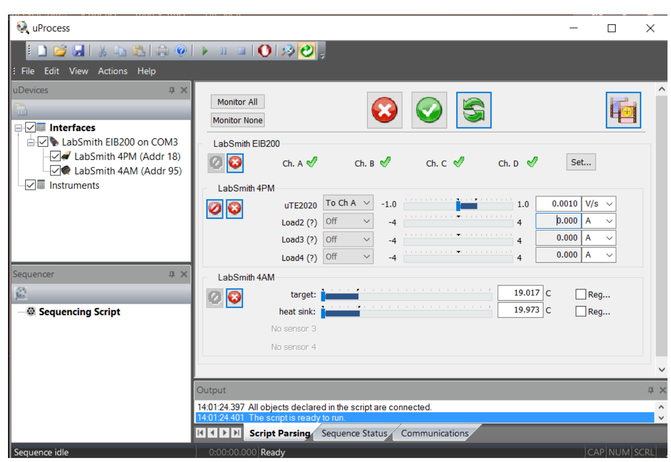


Example 2: Switching Between Two Set Temperatures

Example 2 shows how to use the **uTE controller** and **uTS sensor** to rapidly switch between two temperature settings, 90°C and 50°C, at 5-minute intervals.

A voltage ramp rate of 0.01 V/S is used to optimize temperature ramp rate rather than precision.

1) Click on *Interfaces* in the uDevices tree to view the uDevice window.

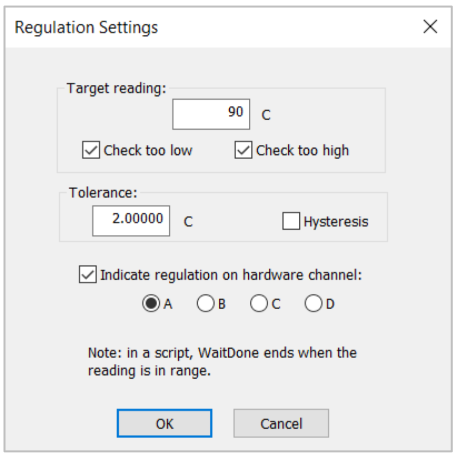


2) Using the dropdown menu, set the uTE Peltier load to “To Ch A.”

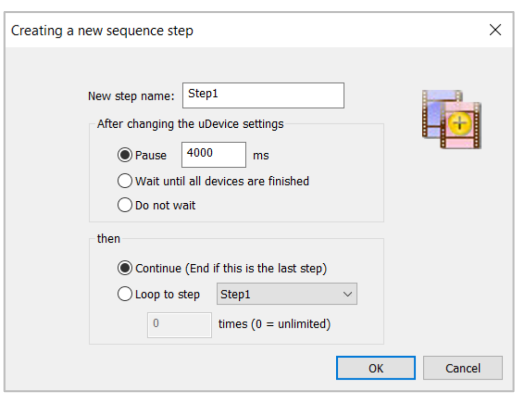
3) Set the uTE voltage ramp rate to 0.01 V/s.

4) Click on the *Reg...* box next to the target temperature listing to bring up the Regulation Settings window.

5) Set the target reading to 90°C and click OK.

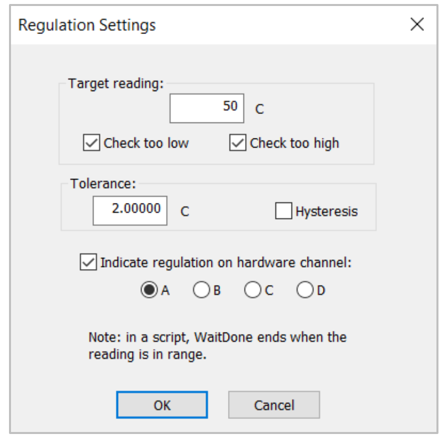


6) Click on *Save as New Sequence Step* ( ) and change the setting to *Pause*. Leave the time at 4000 ms (this will be changed directly in the script). Click OK to save the settings.

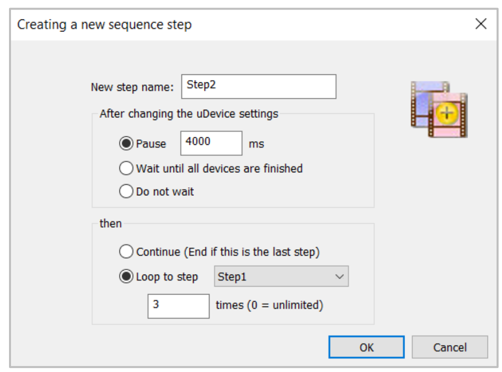


7) Click on the *Reg...* box next to the target temperature listing to bring up the Regulation Settings window.

8) Change the Target reading to 50°C and click OK.



9) Click on *Save as New Sequence Step* ( ). Set the pause time to 4000 ms and select *Loop to Step*. Change the loop to *Step1* for 3 times click OK.



10) Select *Sequencing Script* to view the script. The script should look similar to the following:

```
*target = uTS01
*LabSmith_4AM = 4AM01
*LabSmith_4PM = 4PM01
Step1:
    LabSmith_4PM: SetPerChannel(Out1, DChA, 0.01000 V/s)
    target: RegBetween(88.000 C, 92.000 C, DChA)
    Wait(4000 ms)
Step2:
    LabSmith_4PM: SetPerChannel(Out1, DChA, 0.01000 V/s)
    target: RegBetween(48.000 C, 52.000 C, DChA)
    Wait(4000 ms)

Loop Step1 3
```

The script will start to regulate the target temperature to 90°C. After 4 seconds it will start to regulate down to 50°C. This cycle will be repeated for a total of 3 iterations. At this point, the script will be complete, but the uTE will continue to regulate to 50 °C (the last

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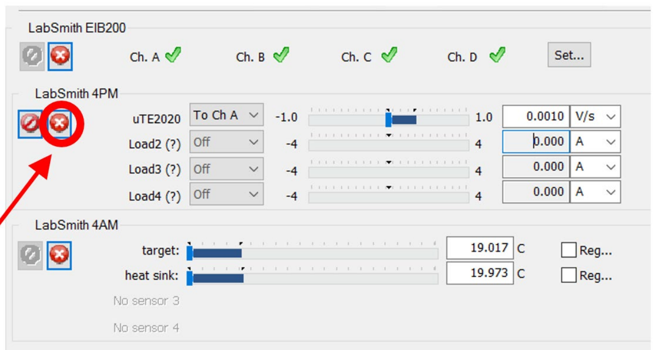
setting) until the script is manually stopped by pressing *Stop All uDevices* ( ).

Two changes will improve the script:

- An end condition added to turn off the regulation after the script is done.
- The pause time can be adjusted to 5 minutes. The pause clock will not start until the target temperature is in range.

11) To add the end condition, click on *Stop this Device* located in the 4PM panel.



Then, click on *Save as New Sequence Step* ( ) before clicking OK to create Step3.

12) Click *Sequencing Script* to bring up the sequencing script control window. Delete '4000 ms' and type '5 min' in both Step1 and Step2.

13) Adding a WaitDone() command before the <Pause> command will delay the start of the <Pause> timer until the target temperature reaches the specified temperature range.

14) The sequencing script should now match the following (items changed are in bold):

```
*target = uTS01
*LabSmith_4AM = 4AM01
*LabSmith_4PM = 4PM01
Step1:
    LabSmith_4PM: SetPerChannel(Out1, DChA, 0.01000 V/s)
    target: RegBetween(88.000 C, 92.000 C, DChA)
    WaitDone()
    Wait(5 min)
Step2:
    LabSmith_4PM: SetPerChannel(Out1, DChA, 0.01000 V/s)
    target: RegBetween(48.000 C, 52.000 C, DChA)
    WaitDone()
    Wait(5 min)
Loop Step1 3

Step3:
    LabSmith_4PM: Stop()

    WaitDone()
```

15) Go back to the uDevice window (click on *Interfaces* in uDevice tree) to monitor temperatures before starting the script.

16) To log the temperature data, click on *File>Log Status/Measurements...* to open a log file. uProcess will prompt you to name the file, unless uProcess is set to autoname the file in *View>Status Meas Logging Options...*

17) Run the sequence program ( ). The graph below shows the dataplot obtained using this example code.