Lab 14: P-I heater controller (Version 1.3)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Lab preparation

An assigned LabView VI simulates a P-I temperature controller. Heating is performed by a control current and cooling is via constant conductive and/or convective heat flow to a fixed temperature reference. The user specifies a single temperature setpoint. The VI performs a proportional (P) or proportional + integral (P+I) control operation based on the error signal (Error = Setpoint – Actual Temperature). The VI will be modified to incorporate an analog heater current and an analog temperature sensor. The LabView assignment simulates a cryostat with temperature measured in Kelvin (K). The lab uses a room temperature metal-oxide resistor as a heater and units of Celsius (C).

Heater & Temperature Sensor

Hardware setup is almost identical to Lab 13. Please consult those instructions to install and test the resistive heater and LM335 temperature sensor. The only difference in the heater circuit used here is the base resistor on the 2N2222 transistor is increased from 300 Ω to 1.8--2 kΩ. This is done to provide finer control of the transistor current.

Modifying your LabView VI for DAQmx Read

The sub-VI heater2.vi, temperature shift-register, ambient temperature input, control for multiple heater currents, etc are all removed and replaced with interfaces to input/output hardware. The DAQmx read operation is identical to Lab 13 and detailed instructions for setup can be found there. The VI will acquire a floating point voltage signal from the LM335 connected to one of the analog input lines (be sure to connect both + and – terminals) on the Elvis board. The modified block diagram should look similar to what is shown in the sketch below.
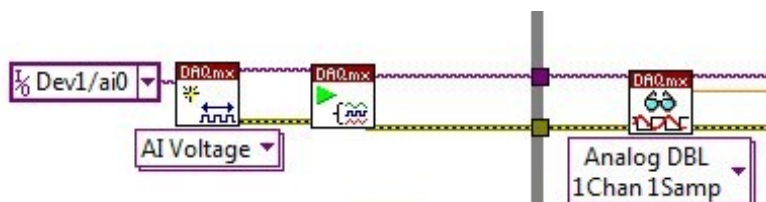
Better temperature resolution may be possible by specifying the minimum and maximum input voltage expected on the channel. Terminals for setting these values are on the top

of the Create Virtual Channel VI.

The DAQmx read interface should be cleared after it executes with the Clear function outside the While Loop. Create an indicator for the analog voltage (V_Z) on the LM335 by right-clicking on the **data** output terminal of the Read VI. This voltage (V_Z) must be converted to temperature (T) in LabView by programming this linear equation:

$$T = \left(\frac{\text{deg}}{10 \text{ mV}} \right) (V_Z - V_{REF}) + T_{REF}$$

V_{REF} is the LM335 voltage measured in the unheated circuit. It should be very close to 3V and is a constant in the equation. T_{REF} is room temperature that can also be set as a constant $T_{REF} = 22C$. Wire the calculated temperature (T) to the input logic used to control the heater as well as a digital temperature display and waveform chart.

Modifying your LabView VI for DAQmx Write

Select a second Create Virtual Channel VI and place it on the left-outside of the While Loop. On the menu immediately below the icon, select AO Voltage. Normally a bipolar-junction transistor such as the 2N2222 is controlled by current, but current output is unavailable on the Elvis board so voltage control will be used. Find the **physical inputs** connection on the left side of the icon; right-click and create a constant. Clicking on the blank constant should display the two available analog output lines on the left side of the Elvis board (example: Dev1/ao0). Select one of these lines and make a physical connection to the 2 kΩ base resistor of the 2N2222 transistor. The output voltage on this channel should be limited to a range of 0—5V. Use the terminals on the top of the icon to wire constants of 0 and 5 to the minimum and maximum values, respectively. Place a Start Task VI adjacent to the Create Virtual Channel VI, but outside the While Loop and wire them together:
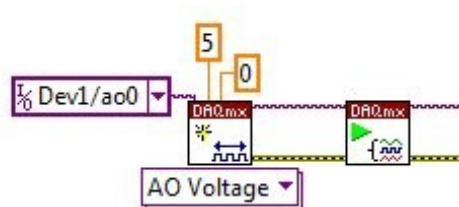
In the Data Acquisition palette, select the Write VI and place it inside the While Loop. Configure it as Analog: Single Channel: Single Sample: DBL. Now make the connections from the DAQmx Start Task VI output terminals (task out, error out) to the corresponding input connections on the Write VI. Be sure to clear the DAQmx write task in the same way as done for the analog read above.

Your P-I temperature control VI should have a floating-point (orange) output wire for operating the heater. This represents the voltage that will be applied to the 2 kΩ resistor on the base of the 2N2222 transistor. There should be logic in place to force the control signal to zero if it is negative. The control signal may also be an excessively large positive value that would drive the output greater than 5V. This will cause an error and must be prevented. Add logic to clamp the value at +5 for a control input ≥ 5. Connect this floating-point voltage control line to the **data** input terminal of the Write VI. Also create a numerical indicator of your choice on the front panel (examples: progress bar, tank, thermometer) so you can tell what the heater voltage is doing. Under Properties, select the Scale menu and set the range at 0—5.

Operating the P-I temperature controller

Select a setpoint above room temperature; around 32C should be good. Set the While Loop interval at 500 ms. Configure the program as proportional only by setting the integral coefficient (K_I) to zero. Experiment with the proportional coefficient (K_P) to get the temperature just below the setpoint. If it occasionally exceeds the setpoint, the system is unstable and K_p should be reduced. Performance should improve if the wait time of the While Loop (Δt) decreases.

Keep the wait time fixed and attempt to gain more stability by reducing K_P and introducing a non-zero K_I coefficient. The integral term should significantly improve temperature stability, but will require trial-and-error experimentation with both P and I coefficients. Temperature stability of around ± 0.05 degree should be possible with a loop time of 200 ms. Demonstrate the working circuit for the instructor.

Troubleshooting: Operation of the heater circuit can be checked by placing a DMM voltmeter on the analog output terminal and confirming that the control voltage matches the display in your VI. If this is OK, measure the collector voltage of the transistor and verify that it changes inversely with the control voltage.

Writeup

None.