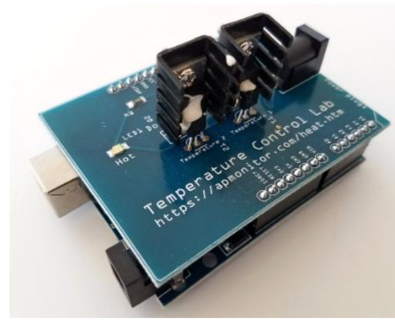
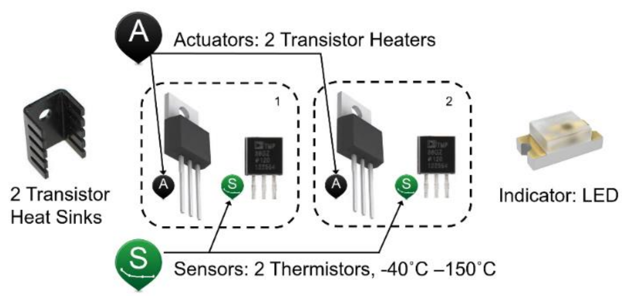
Temperature Control Lab C: Optimize Energy Balance Parameters



With the transient model between the two heater power outputs and the two temperature sensors, optimize the value of select model parameters or model equations derived from an energy balance to improve the agreement between model and measured values. Use data from a 10 minute data collection period that includes asynchronous (staggered) steps of the heaters with varying magnitude and direction. The optimizer may not be able to estimate all of the unknown or uncertain parameters in the energy balance because several of the parameters are co-linear. This means that adjusting both parameters may give the same temperature profile but not improve the model fit. If possible (not required), include statistical confidence intervals on the parameter value results. *Report the final sum of absolute errors between the two predicted temperatures and the two measured temperatures.*

Quantity	**Value (SI Units)**	**Final Value**
Initial temperature (T_0)	296.15 K	
Ambient temperature (T_∞)	296.15 K	
Heater Factor (α_1)	0.0100 W/%	
Heater Output (Q_1)	0 to 100%	
Heater Factor (α_2)	0.0075 W/%	
Heater Output (Q_2)	0 to 100%	
Heat Capacity (C_p)	500 J/kg-K	
Surface Area Not Between Heat Sinks (A)	$1\text{x}10^{-3}$ m^2	
Surface Area Between Heat Sinks (A_s)	$2\text{x}10^{-4}$ m^2	
Mass (m)	0.004 kg	
Overall Heat Transfer Coefficient (U)	10 W/m^2-K	
Emissivity (ε)	0.9	
Stefan Boltzmann Constant (σ)	$5.67\text{x}10^{-8}$ W/m^2-K^4	



Use the multiple temperature model with convective heat transfer, radiative heat transfer, and the heater energy inputs. Parameters that are lumped together in the same terms may be indistinguishable from each other such as the convective heat transfer coefficient (U) and the surface area (A). Letting the optimizer adjust both of these parameters may lead to a non-intuitive solution or to parameters that have a large joint-confidence uncertainty region. Suggested parameters for optimization are α_1, α_2, U, and C_p. Other parameters may be able to be updated directly such as using the measured initial temperature (when cool) to update the ambient temperature.

$$mC_p \frac{dT_1}{dt} = UA\,(T_\infty - T_1) + \epsilon\,\sigma\,A\,(T_\infty^4 - T_1^4) + UA_s\,(T_2 - T_1) + \epsilon\,\sigma\,A_s\,(T_2^4 - T_1^4) + \alpha_1 Q_1$$

$$mC_p \frac{dT_2}{dt} = UA\,(T_\infty - T_2) + \epsilon\,\sigma\,A\,(T_\infty^4 - T_2^4) + UA_s\,(T_1 - T_2) + \epsilon\,\sigma\,A_s\,(T_1^4 - T_2^4) + \alpha_2 Q_2$$

Questions for consideration:

What parameter(s) would be unobservable (not able to estimate) if only heater 1 was active and heater 2 was off during the entire data collection?

Why have step changes in the heaters that persist before another change and not random values at every time point or more frequent changes?

With optimized parameters, how well does the model fit the **steady state** (overall change magnitude) response? How well does the model fit the **transient response** immediately after a step change in the heaters?

See http://apmonitor.com/pdc/index.php/Main/ArduinoEstimation2 for source code solutions (if needed).