AME40453Automation and Controls C2 Pre-Lab Assignment

For the following questions, please **express your answers as algebraic equations** in terms of the variables in the lab handout. Write or typeset your answers on a separate sheet of paper, and show your work.

**IMPORTANT:** transcribe the equations you derive into your lab notebook. You will need them to do the lab exercise.

- 1. Refer to the circuit in Figure 1 of the lab handout. The  $5k\Omega$  potentiometer is used to adjust the desired temperature or "set point". Analyze the circuit and compute the following.
  - a. Make a plot of the high threshold voltage  $V_{HS}$  as a function of the potentiometer resistance (over a range of 0 to 5k $\Omega$ ). Assume the heater is on and the output of the Op-Amp (pin 6) is at +12V.
  - b. On the same plot as part a, plot the low threshold voltage  $V_{LS}$  as a function of the potentiometer resistance. Assume the heater is OFF and the output of the Op-Amp (pin 6) is at 0V or ground.
  - c. Use your formula from last week's lab to convert the voltages  $V_{HS}$  and  $V_{LS}$  to temperature set points  $T_{HS}$  and  $T_{LS}$ . Plot them together as a function of potentiometer resistance on a new graph.
  - d. What circuit element would you change to change the amount of hysteresis  $(T_{HS} T_{LS})$ ?
- 2. When the heater is left OFF, the temperature T will eventually cool down to a *constant* value. Use Eq. (3) to determine the steady state minimum temperature  $T_{min}$  that the system will eventually reach when allowed to cool for a long time.
- 3. When the heater is left ON, the temperature T will eventually heat up to a *constant* value. Use Eq. (4) to determine the steady state maximum temperature  $T_{max}$  that the system will eventually reach when heated for a long time.
- 4. Solve Eq. (3) for the temperature vs. time T(t) if the initial temperature is  $T(0) = T_{HS}$ .
- 5. Solve Eq. (4) for the temperature vs. time T(t) if the initial temperature is  $T(0) = T_{LS}$ .
- 6. Use your answer from #4 to derive an equation for the amount of time it will take to cool down from  $T_{HS}$  to  $T_{LS}$ .
- 7. Use your answer from #5 to derive an equation for the amount of time it will take to heat up from  $T_{LS}$  to  $T_{HS}$ .
- 8. Add your equations from #6 and #7 to derive an equation for the total period of the thermostats' oscillations.
- 9. Use your answers from #7 and #8 to derive an equation for the "duty cycle", which is defined as the amount of time that the heater is ON divided by the period of oscillations.