ELEE 5700: CONTROLS II

Professor Hill

University of Detroit Mercy, Fall 2012

Homework #1
Assigned: September 5, 2012
Due: September 12, 2012

Review ENGR 4220/5220 or AEV 5020, introductory control systems type material. Chapter 1 and Appendix A of the book could be helpful.

1. (15 points) For the following complex variable calculations, express the result both in real/imaginary form $(a + bj)$ and magnitude/phase form $me^{j\phi}$. Plot the resulting complex numbers in the complex plane.

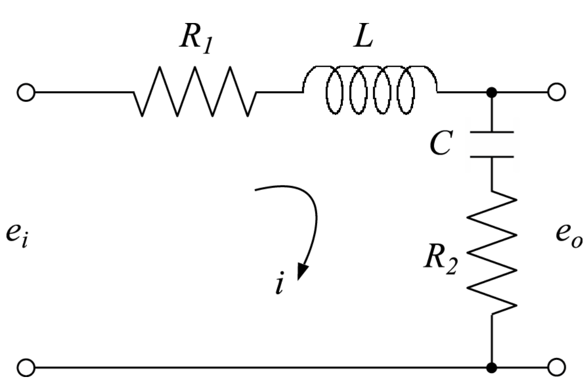
   (a) $(-3 + 5j)(-6 + 7j)$

   (b) $\dfrac{-3 + 5j}{-6 + 7j}$

2. (10 points) The electrical circuit given below is modeled by the following set of differential equations.

$$\begin{aligned} e_i(t) &= R_1 i(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int_0^t i(t)dt + R_2 i(t) \\ e_o(t) &= \frac{1}{C}\int_0^t i(t)dt + R_2 i(t) \end{aligned}$$

   For this system, find the transfer function $E_o(s)/E_i(s)$. After taking the Laplace transform of the given differential equations you will need to algebraically eliminate the current $I(s)$ from between the two equations in order to obtain the form of transfer function requested. Also find the output voltage $E_o(s)$ in the Laplace domain when the input voltage signal is $e_i(t) = \sin \omega t$. You may use the tables of Laplace transform pairs and properties found in Appendix A of your textbook.



3. (25 points) Consider that a battery in an electric vehicle is installed in a rectangular package such that all but one side of the package is well insulated. It is given that the battery package generates heat at a rate $\dot{q}$ and has some thermal capacity C. Also, the process of the heat escaping through the uninsulated wall is described by a thermal resistance R that is a function of the wall material and its geometry. Therefore, the equation describing the battery temperature T_B is as follows, where T_O is the ambient temperature outside of the package.

$$C\dot{T}_B = \frac{1}{R}(T_O - T_B) + \dot{q}$$

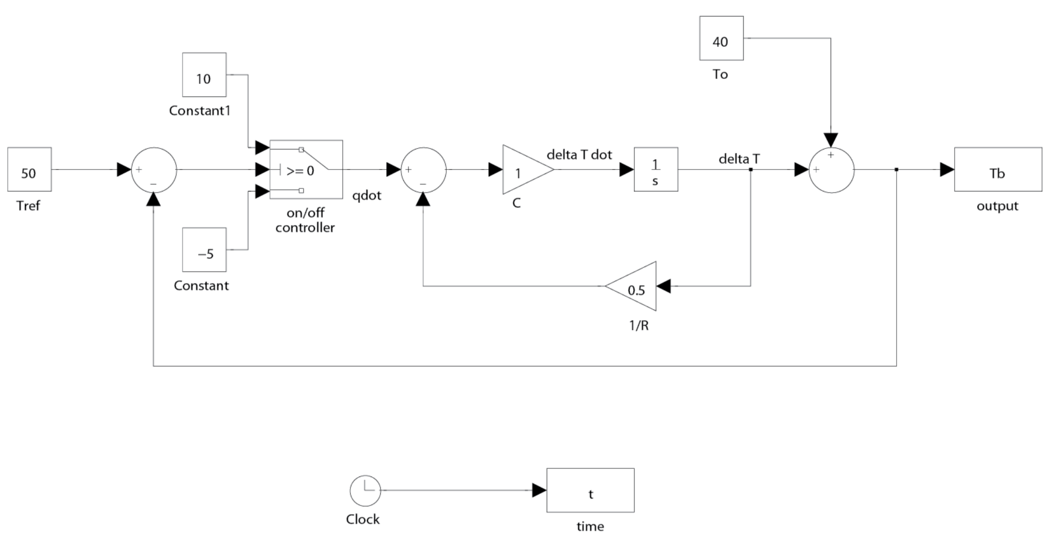
Rewriting the given differential equation in terms of the difference between the battery's temperature and the ambient temperature, $d = T_B - T_O$, the above equation becomes

$$C\dot{d} + \frac{1}{R}d = \dot{q}$$

assuming that the ambient temperature T_O is constant. Assuming values for C and R the above differential equation becomes

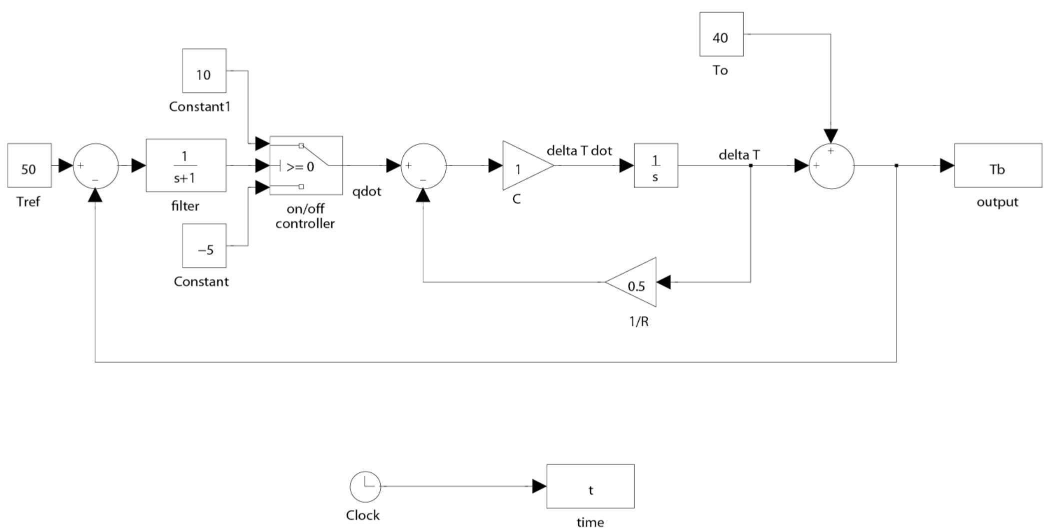
$$\dot{d} + \frac{1}{2}d = \dot{q}$$

(a) Consider the `Simulink` model of a feedback control system shown below that is designed to manage the battery's temperature. In this model, an "on/off" controller is implemented to attempt to keep the battery operating at its optimal temperature, $50°$C. The controller is implemented using a **Switch** block. When the battery is too cool (T_B is less than T_{ref}) the battery is used normally such that it generates heat at a rate of $\dot{q} = 10$. When the battery is too hot (T_B is greater than T_{ref}) the cooling system is switched on such that the amount of heat flow is $\dot{q} = -5$, that is, the net amount of heat flow is out of the battery package.

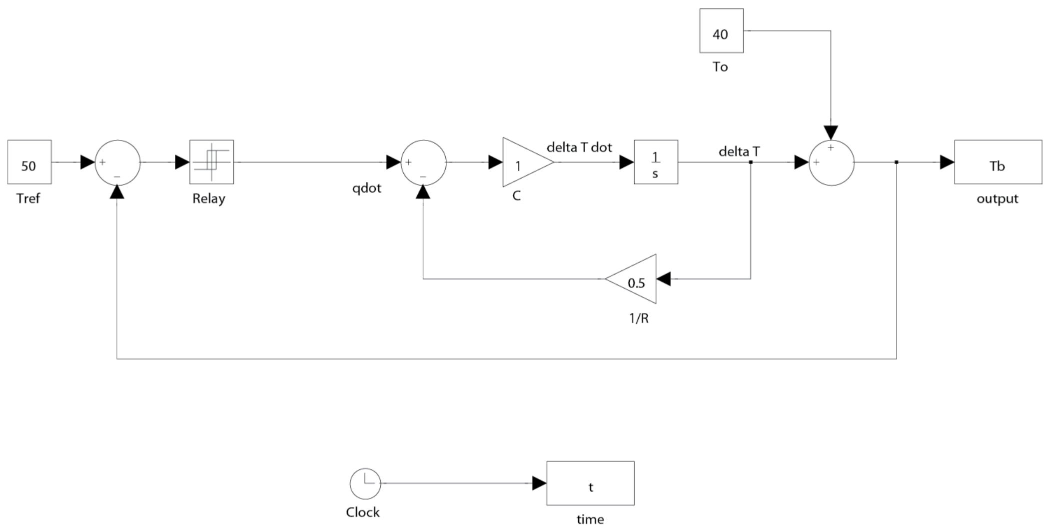


Build a `Simulink` model to match the one given. If you need help with `Simulink`, refer to the given figure and to the tutorial at
`http://ctms.engin.umich.edu/CTMS/index.php?aux=Basics_Simulink`.
Make sure to change the "To Workspace" blocks to have Array outputs (not Structure outputs). If you attempt to run this model, you will get an error since the switch will turn "on" and "off" very rapidly once the battery temperature reaches $50°C$.

(b) One option for slowing down the frequency with which the controller switches, the cooling system is turned on and off, is to add a low-pass filter as shown in the figure below (implemented using a **Transfer Fcn** block). Build this model and run it. Hand in a printout of your `Simulink` model as well as a plot of the battery's temperature response versus time. If you are having trouble plotting figures in `MATLAB`, you may also refer to the tutorial at
`http://ctms.engin.umich.edu/CTMS/index.php?aux=Basics_Matlab`
and follow the link to plotting.



(c) An alternative to employing a low-pass filter is to add a deadband so that the switch "on" and the switch "off" occur at different temperatures. Specifically, replace the Switch block with a Relay block and make the switch on point occur at $48°C$ (error = $2°C$) and the switch off point occur at $52°C$ (error = $-2°C$). The completed model is shown below. Again hand in a printout of your `Simulink` model as well as a plot of the battery's temperature response versus time.



(d) Discuss the tradeoffs associated with employing the original controller as compared to employing a filter and employing a deadband.

(e) Each of these controllers employed a closed-loop architecture. How would you implement a battery temperature controller without feedback? What would be the advantages and disadvantages of such an open-loop approach to control? Be specific to this example.