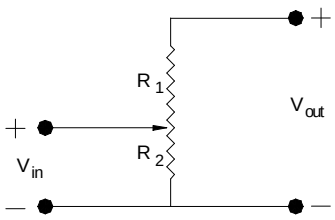
MAE 106 Midterm Exam
Winter 1999

University of California, Irvine
Department of Mechanical and Aerospace Engineering

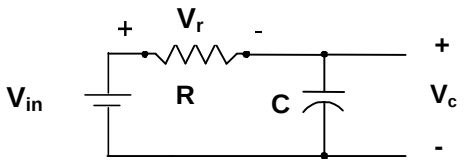
1) Based on your experience in laboratory and lecture, provide brief answers to the following questions:

a) Why is it wrong to use a potentiometer in the following configuration?

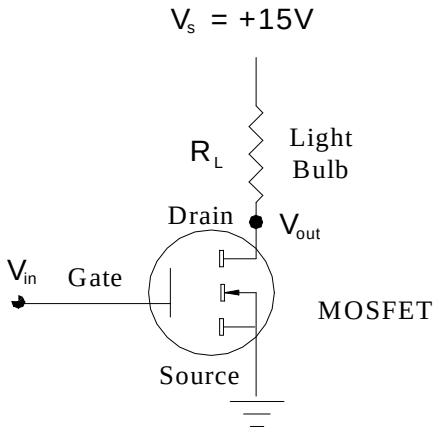


b) A motor can also be used as what kind of sensor?

c) What kind of filter is the following circuit? (Assume V_c is the output)



2) A circuit for controlling a light bulb with a MOSFET is shown below. The light bulb is modeled as a resistor. By changing the input gate voltage to the MOSFET, the light bulb can be turned on and off. A table of the MOSFET's drain/source resistance (like the one you generated in lab) is also shown.



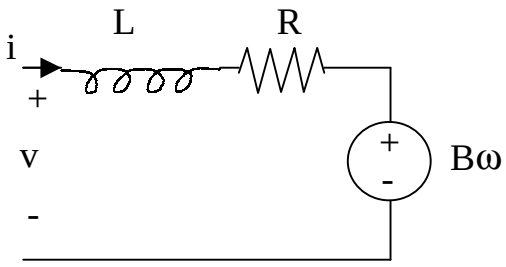
V_{in} (volts)	R_{DS} (K□ □
0	100
1	100
2	90
3	80
3.4	75
3.6	41
3.9	4
4.2	0.1
5.5	0.01

a) To turn the light bulb on, should the input gate voltage (V_{in}) to the MOSFET be high or low?

b) Assume R_L = 1KΩ. Calculate V_{out} corresponding to an input gate voltage of 3.9 volts.

c) How many watts of power will the light bulb consume with the input gate voltage equal to 3.9 volts?

3) A circuit model of a DC Brush motor is:



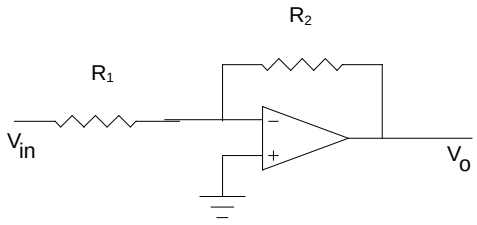
where ω is the angular velocity of the motor shaft.

a. Write the differential equation that describes the relationship between input voltage and current for this circuit. (Hint: use Kirchoff's voltage law).

b. Solve this differential equation for the current through the motor as a function of time when:
   - the shaft of the motor is held fixed
   - a constant voltage v is applied across the motor at time = 0
   - the initial current i(t = 0) through the inductor is zero

c. Plot the torque that the motor generates as a function of time for the conditions described in part b. Label the axes, the final value of the torque, and the time at which the torque has reached 63% of its final value. Assume the motor's torque constant is some constant B.

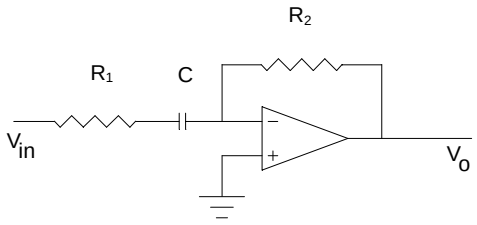
4) Consider the following op-amp circuit:



a) Derive the relationship of the output to the input:

b) What function does this circuit perform if $R_2 > R_1$?

Problem 4 continued: If we add a capacitor, the circuit becomes a filter:



c) Derive the transfer function of the filter using the impedance of the capacitor, Kirchoff's laws, and your knowledge of how the Op-Amp works.

d) What are the time constant and corner frequency of this filter?

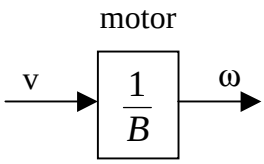
e) Find the filter's gain (i.e. the magnitude of the transfer function):

f) Assume we input a sinusoid to this filter. For frequencies much greater than the corner frequency, what is the filter's gain?

g) For frequencies much less than the corner frequency, what is the filter's gain?

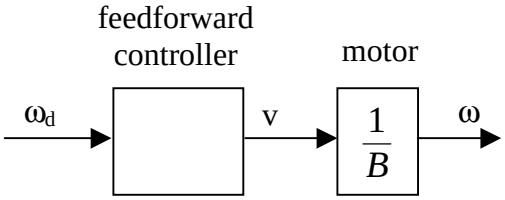
h) What kind of filter is this?

5) Consider the problem of controlling the velocity of a motor. A simple model of the motor is given by the following block diagram:



where v is the voltage input to the motor and ω is the angular velocity of the shaft.

a) Shown below is a block diagram of an open-loop (i.e. feedforward) controller for the motor, where ω_d is the desired output of the motor. What gain value should the controller box have to make the output equal the desired output? Write the gain in the controller box.



b) What is a disadvantage of an open-loop controller like this one?

c) Draw a block diagram of a feedback controller for the motor, label all arrows, including the error signal.

d) What hardware (beside the motor) that we have discussed in class could you use to implement this feedback controller?