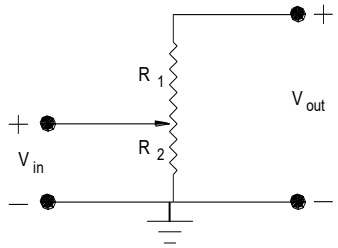
MAE 106 Midterm Exam
Winter 2002

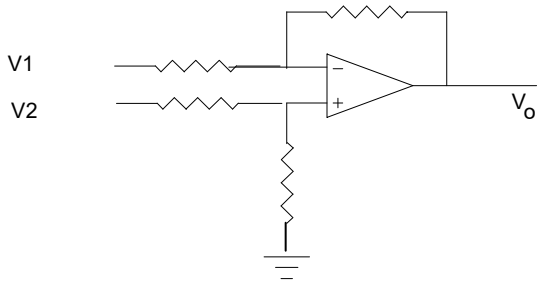
University of California, Irvine
Department of Mechanical and Aerospace Engineering

Problem 1: Circuits (25 pts)

a) Shown below is a 10Kohm potentiometer wired incorrectly. Assume Vin is 10 V and is provided by a 100 Watt power supply. Assume the potentiometer is rated at 1 Watt. Assume the shaft can rotate 180 degrees, and define 0 degrees rotation as the shaft angle when the resistance between the wiper and the ground is 10Kohm. At what shaft angle do you expect to smell smoke?



b) What does the following circuit do? (give proof) Assume the four resistors have equal values.



c) Why are op amps such as the ones used in lab unsatisfactory for powering most motors?

d) Assume that you have a low-power control signal from a computer, and that you would like to make a motor spin when the control signal is +5 v, and to stop spinning when the control signal is 0 V. Design a circuit using a MOSFET to achieve this control.

Problem 2: Motors (25 pts)

A DC brushed motor has an internal resistance of 10 ohms. You hold the motor shaft fixed and apply 10 V, and find that the stall torque is 0.1 Nm, and that it takes 1.5 s to generate 0.063 Nm of torque. Assume the motor's torque constant equals the back EMF constant.

a) How fast will the unloaded motor shaft turn if you let it go?

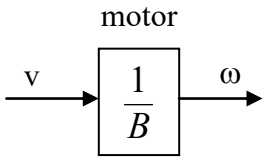
b) What is the inductance of the motor windings?

c) The motor takes 5 seconds to reach its no-load speed. If you double the shaft inertia, how much longer will the motor take to reach 99% of it's no-load speed?

d) Why does a DC brushed motor have brushes? (Explain in 15 words or less).

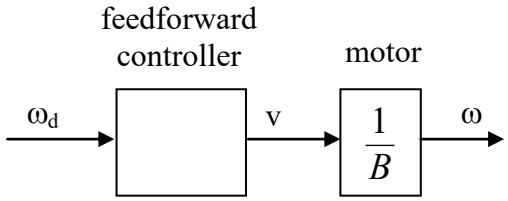
Problem 3: Control Theory (25 pts)

1) 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.



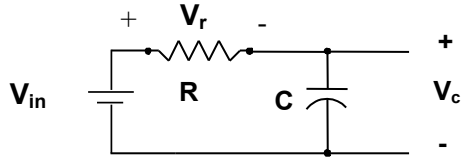
b) Name <u>two</u> disadvantages and <u>two</u> advantages of an open-loop controller like this one.

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

d) Prove that your feedback controller cancels an additive disturbance V_d to the voltage input to the motor, given a high enough feedback gain.

Problem 4: Signal Processing, Differential Equations, and Frequency Analysis (25 pts)

a) Describe a practical situation in which the following circuit would be useful:



b) Assume V_{in} is a step input at time zero and $V_c(0) = 0$. Find $V_c(t)$.

c) Find the transfer function for the above circuit.

d) Find the frequency response of the above circuit. Be sure to provide equations for how the circuit scales and phase shifts a sinusoidal input.

e) Assume R = 100 ohm, C = .01 F. How much more attenuated will a 1000 Hz sinusoidal input signal be than a 100 Hz input signal? (Provide proof).