MAE40 - Linear Circuits - Fall 23 - Section A00
Midterm #2, November 14

Instructions

(i) The exam is open book. You may use your class notes and textbook.
(ii) The exam has 3 questions for a total of 23 points and 4 bonus points.
(iii) You have from 11:00am to 12:20pm to do the exam – but should require less time!
(iv) You can use a calculator with no communication capabilities.
(v) In your responses, clearly articulate your reasoning, and properly justify the steps.
(vi) **Important:** start each part below on a separate page, use only one side, and write your name & PID at the top of each page.

Good luck!

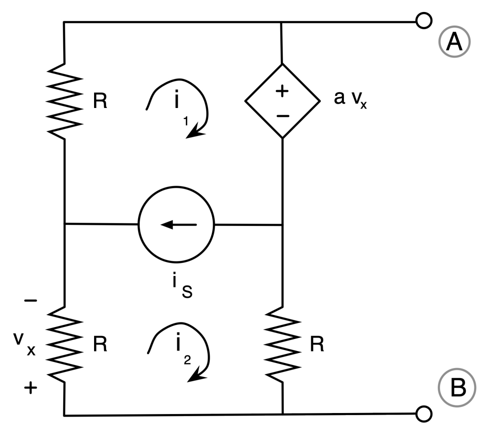

Figure 1: Circuit for Question 1.

1. **Mesh-current analysis with dependent sources**
   For the circuit in Figure 1,

   Part I: [4 points] Use mesh-current analysis to find the open-circuit voltage as seen from terminals Ⓐ and Ⓑ (use the labels provided and notice the presence of the dependent source).

   Part II: [5 points] Connect the terminals Ⓐ and Ⓑ and find the short-circuit current, using again mesh current analysis.

   Part III: [1 point] Given your answers to Parts I and II, can you tell what the Thevenin equivalent of this circuit is?

   Part IV [+ Extra 1 point] If, instead of short-circuiting the circuit as in Part II, you turn off the current source in the circuit of Figure 1, what is the equivalent resistance? Is this the same as R_T in Part III? Why?

2. **OpAmp circuit analysis and design**

   Part I: [5 points] Use node-voltage analysis to determine which one of the following expressions of the output voltage in the circuit in Figure 2 is correct;

$$v_o = -\frac{2}{3}v_S \qquad v_o = -\frac{v_S}{3} \qquad v_o = -\frac{v_S}{2}$$

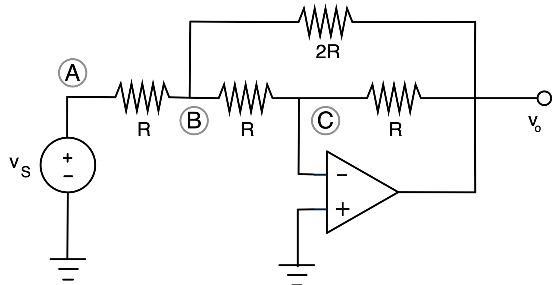

Figure 2: Circuit for Question 2.

Part II: [2 points] Under ideal OpAmp conditions, if you connect a load resistor R_L between the output node and ground, will the output voltage change? Why?

Part III: [2 points] Let $R_L = 10\,\Omega$. An engineer used a voltage source with $v_S = 9V$ and measured the power consumed by the load as $P_L = 0.9W$, as expected. However, when the engineer connected a voltage source with $v_S = 15V$, the power consumed by the load was $P_L = 1.6W$. How do you explain this? Can you deduce what the external power supply $-v_{CC}$ of the Op-Amp is?

Part IV: [+ Extra 1 point] Design your own circuit, using only basic OpAmp building blocks, two resistors with value R and 1 resistor with value $2R$, that generates the same output voltage as the circuit in Figure 2.

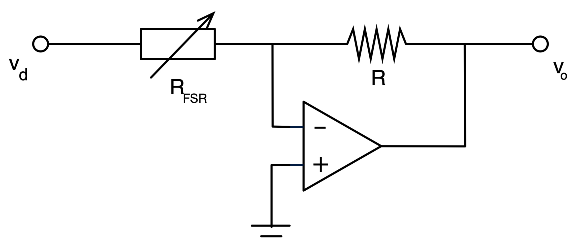

Figure 3: Circuit for Question 3.

3. **Force sensing resistor**

A Force Sensing Resistor (FSR) is a low cost and compact force sensor. The FSR behaves as a variable resistor whose value is a function of the applied force: R_{FSR} drops as force is applied. Figure 3 shows an OpAmp circuit with an FSR and a drive voltage v_d.

Part I: [2 points] Calculate the output voltage as a function of R_{FSR} and R when $v_d = -5V$.

Part II: [2 points] What would happen to v_o if $v_d = 0$? Would this be a good way to measure the force applied on the FSR? Why?

Part III: [+ Extra 2 points] The characteristic of FSR is that the resistance does not vary linearly with applied load. Rather $R_{\text{FSR}} = \frac{a}{b^F}$, where $a > 0$, $b > 1$, and F is the magnitude of the applied force. Do the following to explain the benefit of using the OpAmp circuit shown in Figure 3:

- Freehand sketch R_{FSR} vs F and show the slope for a high value of R_{FSR} that characterizes the change in R_{FSR} for a small change in F;
- For $v_d = -5V$, freehand sketch v_o vs R_{FSR} and show the slope for a high value of R_{FSR} that characterizes the change in v_o for a small change in R_{FSR};
- Describe the effect of using the OpAmp circuit to generate the voltage v_o to represent the applied force (rather than using R_{FSR} directly).