
EECS 16A Designing Information Devices and Systems I
 Summer 2020 Homework 3B

This homework is due Sunday, July 19, 2020, at 23:59.

Self-grades are due Wednesday, July 22, 2020, at 23:59.

Submission Format

Your homework submission should consist of a single PDF file that contains all of your answers (any hand-written answers should be scanned).

***Homework Learning Goals:** The objective of this homework is to familiarize you with the use of resistive dividers in the design of useful, real-world applications, introduce the concepts of power dissipation, and voltage and current measurement. Finally, it will give you some practice on the superposition circuit analysis technique .*

1. 1-D Resistive Touchscreen

Figure 1 shows the top view of a resistive touchscreen consisting of a conductive layer with resistivity ρ_{t1} , thickness t , width W , and length L . At the top and bottom it is connected to good conductors ($\rho = 0$), represented in the figure by two rectangles. The touchscreen is wired to voltage source V_s .

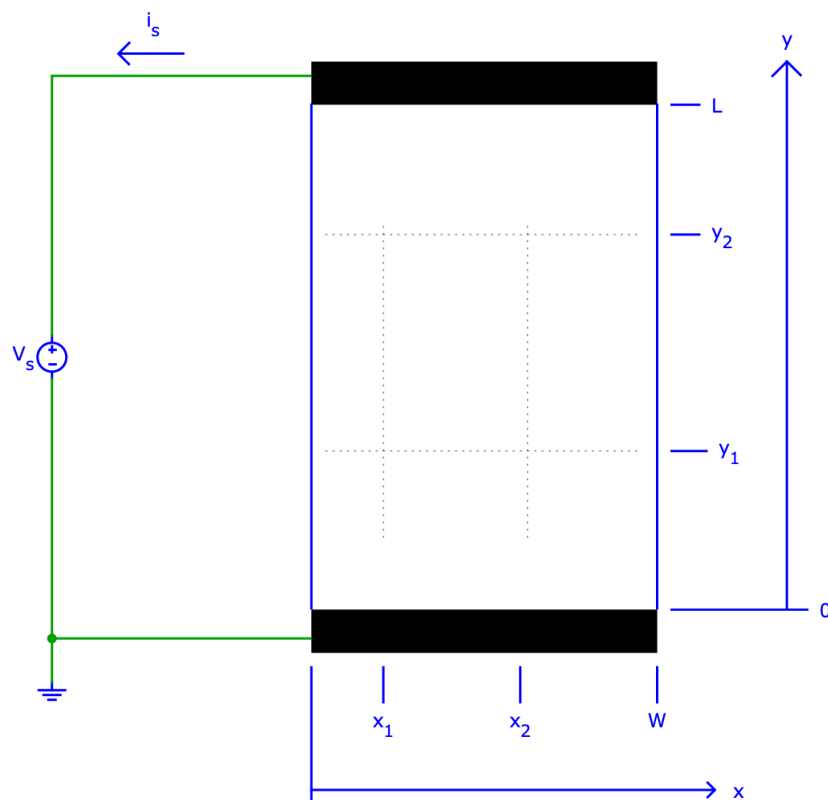


Figure 1: Top view of 1-D resistive touchscreen (not to scale).

Use the following numerical values in your calculations: $W = 50$ mm, $L = 80$ mm, $t = 1$ mm, $\rho_{t1} = 0.5 \Omega\text{m}$, $V_s = 5\text{V}$, $x_1 = 20$ mm, $x_2 = 45$ mm, $y_1 = 30$ mm, $y_2 = 60$ mm.

- Draw a circuit diagram representing the touchscreen shown in Figure 1. Remember that circuit diagrams consist of only circuit elements (resistors, current sources, etc) represented by symbols, connecting wires, and the reference symbol.
- Calculate the value of current I_s . Do not forget to specify the correct unit as always.
- What is the node voltage u_{12} (with respect to the reference node) of the touchscreen at coordinates (x_1, y_2) ? Redraw the circuit diagram from part (a) to include node u_{12} . Specify all component values (resistances, ...) in the diagram. Hint: you need more than one resistor to represent this situation.
- Calculate (absolute value of) voltage V_{ab} between touchscreen coordinates (x_1, y_1) and coordinates (x_1, y_2) . Suggestion: Draw an augmented circuit diagram and calculate all component values.
- Calculate (absolute value of) the voltage between touchscreen coordinates (x_1, y_1) and coordinates (x_2, y_1) .
- Calculate (absolute value of) the voltage between touchscreen coordinates (x_1, y_1) and coordinates (x_2, y_2) .
- Figure 2 shows a new arrangement with two touchscreens. The second touchscreen is identical to the one shown in Figure 1, except for different width, W_2 , and resistivity, ρ_{t2} . Use the following numerical values in your calculations: $W = 50$ mm, $L = 80$ mm, $t = 1$ mm, $\rho_{t1} = 0.5 \Omega\text{m}$, $V_s = 5\text{V}$, $x_1 = 20$ mm, $x_2 = 45$ mm, $y_1 = 30$ mm, $y_2 = 60$ mm, which are the same values as before, with $W_2 = 85$ mm, $\rho_{t2} = 0.6 \Omega\text{m}$ for the new touchscreen.

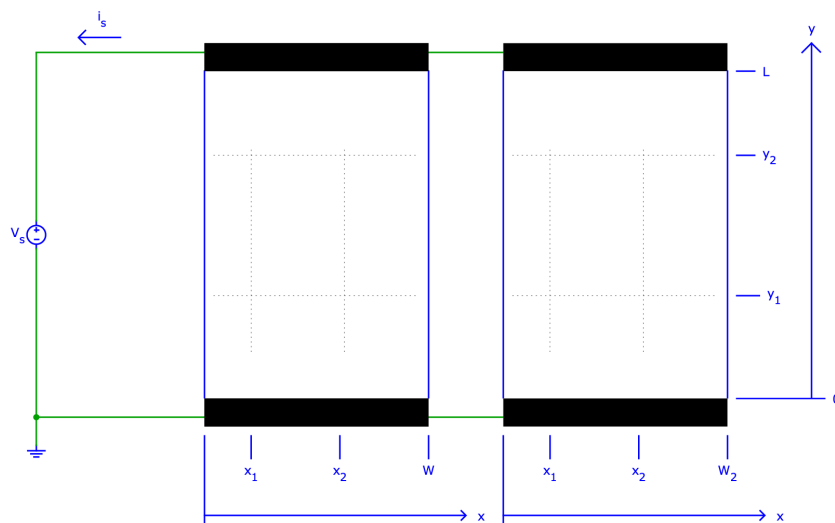


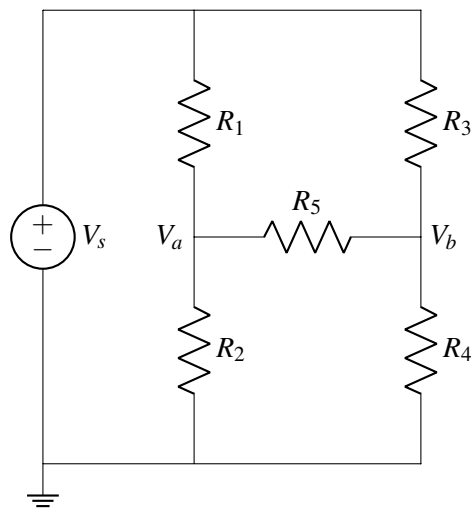
Figure 2: Top view of two touchscreens wired in parallel (not to scale).

Draw a circuit diagram representing the two touchscreens shown in Figure 2.

- Calculate the value of current I_s for the two touchscreen arrangement.
- Now assume a wire is connected between coordinates (x_1, y_2) in the touchscreen on the left, and (x_2, y_2) in the touchscreen on the right. Calculate the current I_{12} flowing through this wire.

2. Volt and ammeter

Use the following numerical values in your calculations: $R_1 = 1\text{ k}\Omega$, $R_2 = 2\text{ k}\Omega$, $R_3 = 3\text{ k}\Omega$, $R_4 = 4\text{ k}\Omega$, $R_5 = 5\text{ k}\Omega$, $V_s = 10\text{ V}$.



- Redraw the circuit diagram shown in Figure 1 by adding a voltmeter (letter V in a circle and plus and minus signs indicating direction) to measure voltage V_{ab} from node V_a (positive) to node V_b (negative). Calculate the value of V_{ab} .
Hint: You have analyzed a very similar circuit in a previous assignment, reuse the result.
- Suppose you inadvertently connected an ammeter in part (a) above, rather than a voltmeter (we all goof sometimes). Calculate the value of V_{ab} with the ammeter connected. Note: it differs from the value calculated in part (a).
- Redraw the circuit diagram shown in Figure 1 by adding an ammeter (letter A in a circle and plus and minus signs indicating direction) to measure the current I_{R_5} through resistor R_5 . Calculate the value of I_{R_5} .
- Your friend inadvertently connected a voltmeter in part (c) above, rather than an ammeter. Calculate the value of I_{R_5} with the voltmeter connected. Note: it differs from the value calculated in part (c).

3. Maximum Power Transfer

Smartphones use "bars" to indicate strength of the cellular signal. Few "bars" translate to slow or no connectivity.

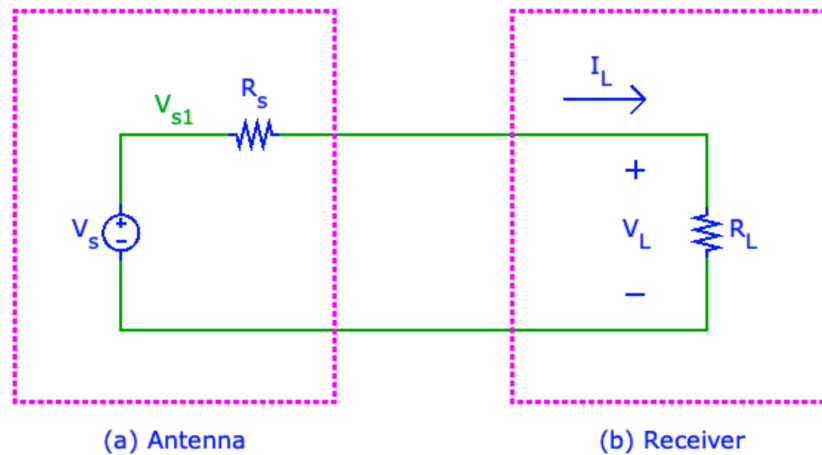
But what do these "bars" actually stand for? Voltage, current? Well, not quite. Good radio (and a cellular modem is nothing but a particular kind of radio) reception depends on the **power** received from the transmitter.

In this assignment we design a receiver that maximizes the power received, and hence connection speed.

The figure below shows electronic circuit models for the antenna (a) and the receiver (b). The antenna consists of source V_s , typically in the range of micro- or milli-Volts (10^{-6} and 10^{-3} , respectively) depending on transmitter strength and resistance R_s , usually 50Ω or 75Ω , depending on the particular antenna design.

The radio receiver is represented by resistor R_L and chosen carefully by the designer to maximize the received power (i.e. the "number of bars").

Figure 3: Electronic circuit models for radio antenna and receiver.



It is important to understand that these are *models*. For example, the complete receiver circuit consists of many more elements. Likewise, the antenna consists of several appropriately shaped conductors. The resistor R_s is nowhere to be found, and neither is V_s physically present (i.e. you cannot connect a wire to it). However, these simple models *act* like the devices they represent. In other words, the voltages and currents at their terminal are identical to the voltages and currents at the terminals of the actual circuits.

Models are very important in engineering design for their ability to abstract away details when they are not needed and are the key to successful design of complex systems.

We will discuss the use and properties of electronic circuit models further in class.

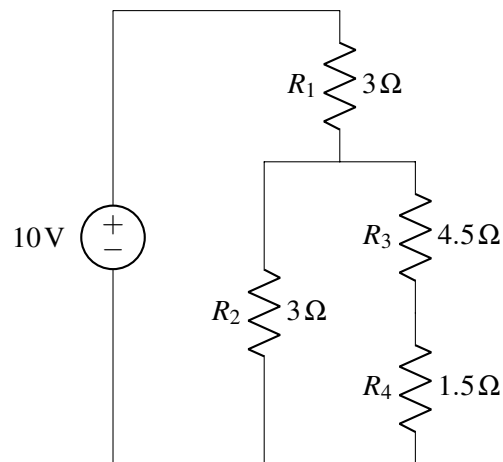
Use the following component values for your calculations: $V_s = 100\mu V$, and $R_s = 50\Omega$.

- Find the value of R_L that maximizes the **voltage** V_L across resistor R_L . Calculate the values of V_L , I_L , and the power P_L delivered to (i.e. dissipated in) resistor R_L .
- Find the value of R_L that maximizes the **current** I_L through resistor R_L . Calculate the values of V_L , I_L , and the power P_L delivered to resistor R_L .
- Find the value of R_L that maximizes the **power** P_L delivered to resistor R_L . Calculate the values of V_L , I_L , and the power P_L delivered to resistor R_L . (*Hint*: The power optimization is best performed algebraically by setting the derivative of P_L with respect to R_L to zero. Alternatively you can do the optimization graphically. Plot P_L versus R_L and find the maximum.)
- What's the best value of R_L that optimizes cellular connectivity (i.e. provides the most amount of received power)?

The next step is to design the receiver circuit such that it behaves like a resistor R_L and extracts the information sent. How to do this is taught in EE142, "Integrated Circuits for Communications."

4. Mechanical Circuits

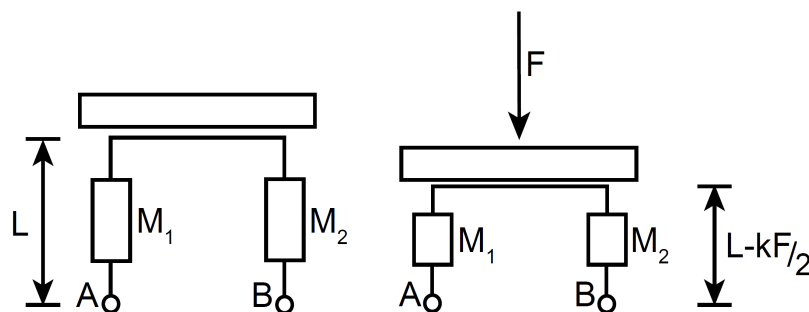
Find the voltages across and currents flowing through all of the resistors.



5. Fruity Fred

Fruity Fred just got back from Berkeley Bowl with a bunch of mangoes, pineapples, and coconuts. He wants to sort his mangoes in order of weight, so he decides to use his knowledge from EECS16A to build a scale. He finds two identical bars of material (M_1 and M_2) of length L (meters) and cross-sectional area A_c (meters²), which are made of a material with resistivity ρ . He knows that the length of these bars decreases by k meters per Newton of force applied, while the cross-sectional area remains constant.

He builds his scale as shown below, where the top of the bars are connected with an ideal electrical wire. The left side of the diagram shows the scale at rest (with no object placed on it), and the right side shows it when the applied force is F (Newtons), causing the length of each bar to decrease by $kF/2$ meters. Fred's mangoes are not very heavy, so $L \gg kF/2$.

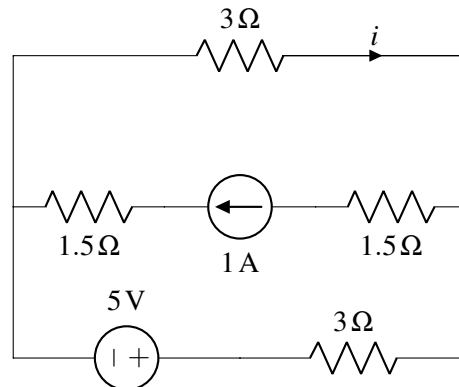


- Let R_{AB} be the resistance between nodes A and B . Write an expression for R_{AB} as a function of A_c , L , ρ , F , and k .
- Fred's scale design is such that the resistance R_{AB} changes depending on how much weight is placed on it. However, he really wants to measure a voltage rather than a resistance.

Design a circuit for Fred that outputs a voltage that is some function of the weight. Your circuit should include R_{AB} , and you may use any number of voltage sources and resistors in your design. Be sure to label where the voltage should be measured in your circuit. Also provide an expression relating the output voltage of your circuit to the force applied on the scale.

6. Superposition

Find the current i indicated in the circuit diagram below using superposition.



7. Homework Process and Study Group

Who else did you work with on this homework? List names and student ID's. (In case of homework party, you can also just describe the group.) How did you work on this homework?