EECS 16A   Designing Information Devices and Systems I
Spring 2017   Babak Ayazifar, Vladimir Stojanovic   Midterm 2

Exam location: 2050 VLSB, Last Name: Surpenant-Zzz

PRINT your student ID: _____

PRINT AND SIGN your name: _____, _____ _____
                          (last)   (first)   (signature)

PRINT your Unix account login: ee16a-_____

PRINT your discussion section and GSI (the one you attend): _____

Name and SID of the person to your left: _____

Name and SID of the person to your right: _____

Name and SID of the person in front of you: _____

Name and SID of the person behind you: _____

1. What do you enjoy about 16A? (1 point)

2. What do you dislike about 16A? (1 point)

Do not turn this page until the proctor tells you to do so. You may work on the questions above.
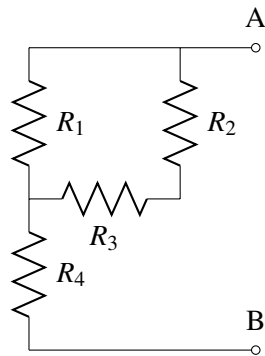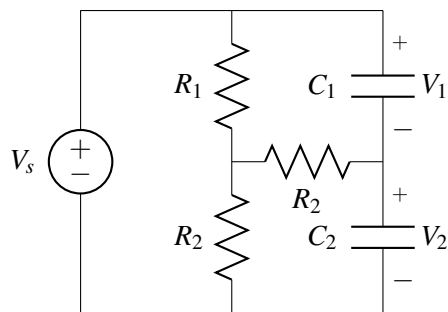
3. Simplifying Resistor Networks (6 Points)

Determine the equivalent resistance between points A and B in the circuit shown below. You may use the parallel operator $\parallel$ in your final answer.
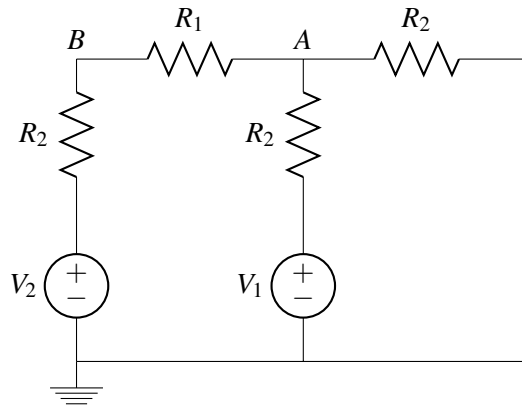
A

R_1 R_2

R_3

R_4

B

4. Capacitors (6 Points)

For the circuit given below, determine the voltage across each capacitor at steady state. $R_2 = 2R_1$, $C_2 = C_1$, and $V_s = 3\,\text{V}$.

R_1 C_1 $+$ V_1 $-$

V_s

R_2

R_2 C_2 $+$ V_2 $-$

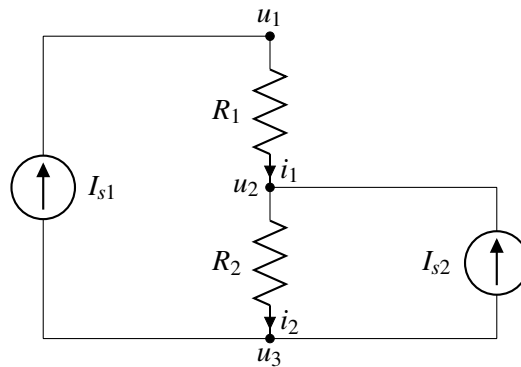**5. Ladder Nodal (8 Points)**

Use nodal analysis to write equations for each node A and B.

Let $R_1 = 1\,\Omega$, $R_2 = 2\,\Omega$, and leave your expressions in terms of V_1, V_2, R_1, R_2, V_A and V_B. Do not simplify.

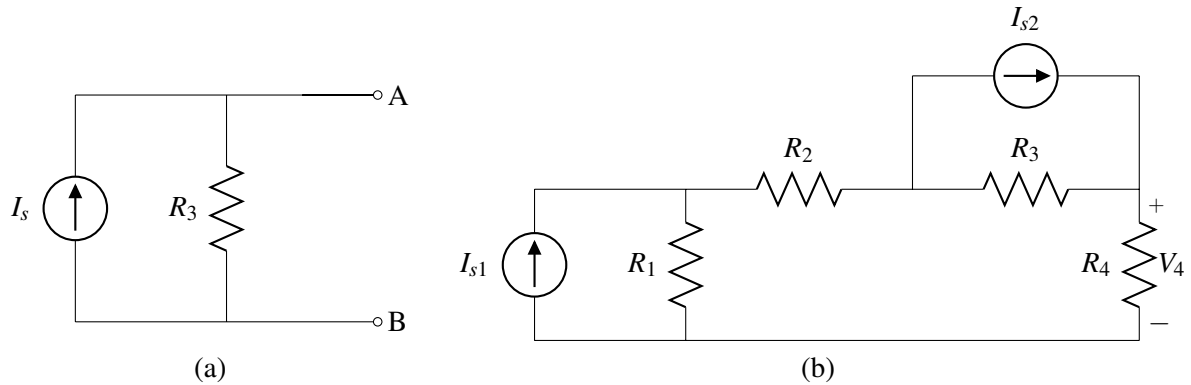## 6. Flows Through Circuits (12 Points)

(a) (2 points) Redraw the circuit shown above with all current sources nulled.

(b) (5 points) Translate your circuit from part (a) into a graph and write its incidence matrix $\mathbf{F}$.

(c) (5 points) Recall that KCL can be stated as $\mathbf{F}^T \vec{i} = 0$ when all the sources are turned off. However, for circuits containing independent current sources, the equation is modified to be $\mathbf{F}^T \vec{i} = \vec{b}$. Find $\vec{b}$ such that $\mathbf{F}^T \vec{i} = \vec{b}$ represents the KCL constraint at every node in the above circuit.
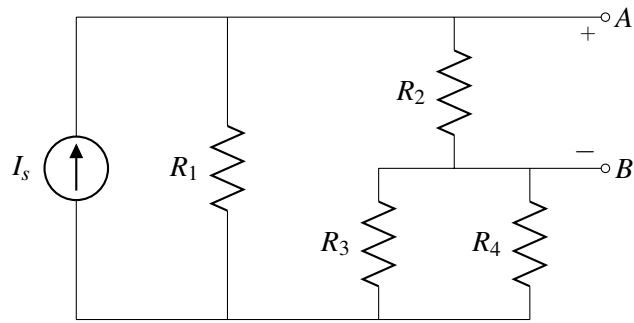
7. One Norton At A Time! (12 Points)

(a)   (b)

(a) (2 points) Given the circuit labeled (a), draw the Thevenin equivalent circuit for $I_s = \frac{1}{5}$A and $R_3 = 20\,\Omega$ and determine V_{th} and R_{th}.

(b) (5 points) Redraw the circuit labeled (b) with the following restrictions: you must use only voltage sources and the given four resistors. Determine the value of the voltage sources given $R_1 = 30\,\Omega$, $R_2 = 10\,\Omega$, $R_3 = 20\,\Omega$, $R_4 = 10\,\Omega$, $I_{s1} = \frac{1}{3}$A, and $I_{s2} = \frac{1}{5}$A. **Circuits drawn without R_1, R_2, R_3, and R_4 will not be given full credit. Do not combine resistors.**

(c) (5 points) Calculate the voltage drop across R_4.

8. Equivalent Circuits (13 Points)

Find V_{th} and R_{th} with respect to nodes A and B for the following circuit in terms of the variables I_s, R_1, R_2, R_3, and R_4. You may leave the parallel operator $\parallel$ in your final answer.

9. Resist the Touch (16 Points)

In this question, we will be re-examining the 2-dimensional resistive touchscreen previously discussed in both lecture and lab. The general touch screen is shown in Figure 1 (a). The touchscreen has length L and width W and is composed of a rigid bottom layer and a flexible upper layer. The strips of a single layer are all connected by an ideal conducting plate on each side. The upper left corner is position $(1,1)$.

The top layer has N vertical strips of denoted by $y_1, y_2, ..., y_N$. These vertical strips have cross sectional area A, and resistivity ρ_y.

The bottom layer has N horizontal strips denoted by $x_1, x_2, ..., x_N$. These horizontal strips all have cross sectional area A as well, and resistivitiy ρ_x.

Assume that all top layer resistive strips and bottom layer resistive strips are spaced apart equally. Also assume that all resistive strips are rectangular as shown by Figure 1 (b).
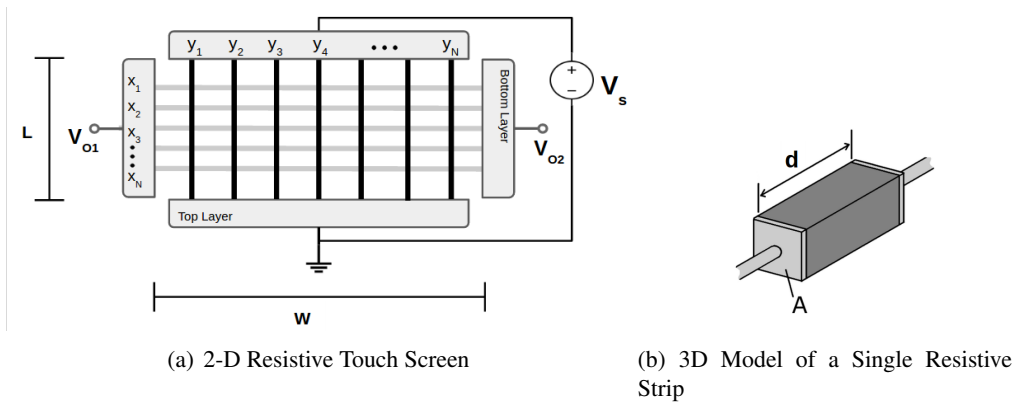

(a) 2-D Resistive Touch Screen

(b) 3D Model of a Single Resistive Strip

Figure 1:

(a) (3 points) Figure 1(b) shows a model for a single resistive strip. Find the equivalent resistance R_y for the vertical strips and R_x for the horizontal strips, as a function of the screen dimensions W and L, the respective resistivities, and the cross-sectional area A.

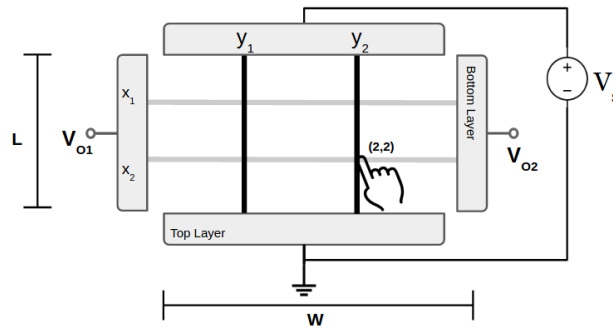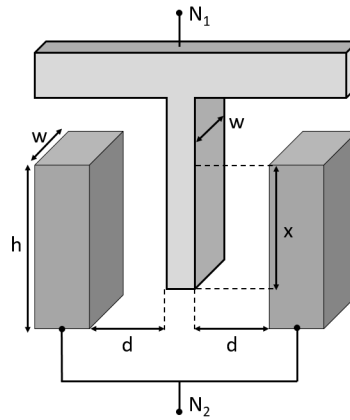(b) (5 points) Consider a 2 × 2 example for the touchscreen circuit.

Figure 2: 2 × 2 Case of the Resistive Touchscreen

Given that $V_s = 3\,\text{V}$, $R_x = 2000\,\Omega$, and $R_y = 2000\,\Omega$, draw the equivalent circuit for when the point $(2,2)$ is pressed and solve for the voltage at terminal V_{O2} with respect to ground.

(c) (8 points) Suppose a touch occurs at coordinates (i, j) in Figure 1(a). Find an expression for V_{O2} as a function of V_s, N, i, and j.
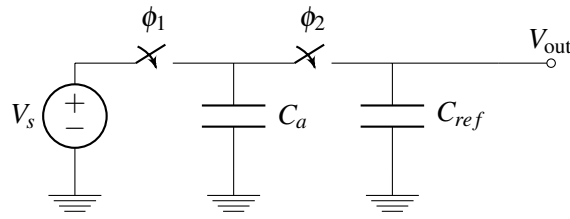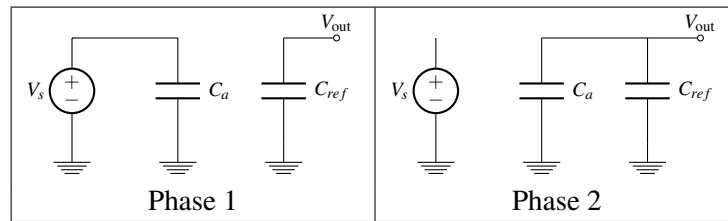
10. MEMS Sensor (20 Points)

Above is the cross section of a MEMS accelerometer, which consists of a T-shaped mass between two sidewalls. When the device accelerates, the T structure, which is held up by springs, displaces up or down. Assume that all the structures are made of metal separated by air, and that the only relevant capacitances in this problem are parallel plate capacitances.

(a) (4 points) Suppose both sidewalls are connected together with an ideal wire. Find the capacitance between the stem of the T mass and a sidewall as a function of x, the displacement of the T mass. Find the net capacitance between the two terminals N_1 and N_2 assuming the only parallel plate capacitance is that of the T mass stem and sidewall.

The above circuit is designed to measure the displacement of the T structure. It cycles through two phases, which are depicted in the diagram below. For this problem, you may assume that switching is controlled through a microcontroller and that all capacitors reach steady state during each phase. Furthermore, assume that the T mass does not move during the measurement cycle and all capacitors are initially uncharged.

(b) (8 points) The circuit above is designed to measure the change in capacitance and to output a voltage. The phases of its operation are shown above. Find V_{out} in Phase 2 as a function of C_a and C_{ref}.

(c) (8 points) Let $V_{out}[i]$ denote V_{out} at the ith measurement cycle. Suppose the circuit had been running for k cycles. What is $V_{out}[k]$ in terms of $V_{out}[k-1]$, C_a and C_{ref}?