MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

6.002 Circuits and Electronics Quiz #2

November 10, 2004

YOUR NAME_____

Recitation Instructor / TA _____

General Instructions:

1. Please verify that there are 18 pages in your exam booklet.
2. Please do all of your work in the spaces provided in this examination booklet. In particular, try to do your work for each question within the boundaries of the question, or on the back side of the page preceding the question. Extra pages are also available at the end of the booklet. Place the answer to each question within the appropriate answer box.
3. You may use two double-sided pages of notes and a calculator while taking this exam.

For examiner's use only:

Part	**1**	**2A**	**2B**	**2C**	**2D**
Score					

Part	**3A**	**3B**	**4**	**5A**	**5B**
Score					

TOTAL SCORE_____

Problem 1 (12 Points)

Find a Thévenin equivalent model of the circuit shown in Figure 1 as viewed from the terminal pair at the right of the circuit. (That is, find the Thévenin voltage and resistance V_{TH}, R_{TH} that characterize the system.) You may ignore the degenerate case that occurs when $\alpha = -(R_1+R_2)$.

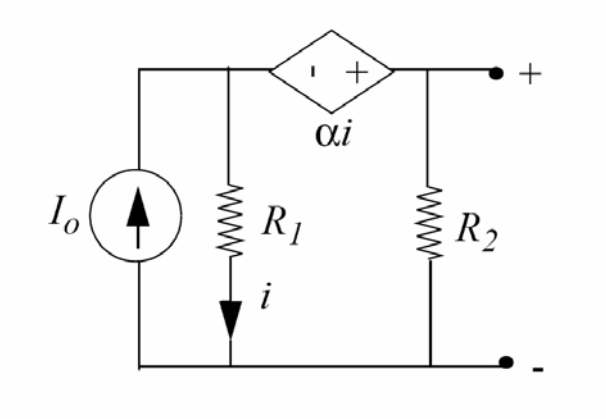


Figure 1

V_{TH} =

R_{TH} =

Problem 2 (25 Points)

This problem concerns the MOSFET amplifier shown in Figure 2.

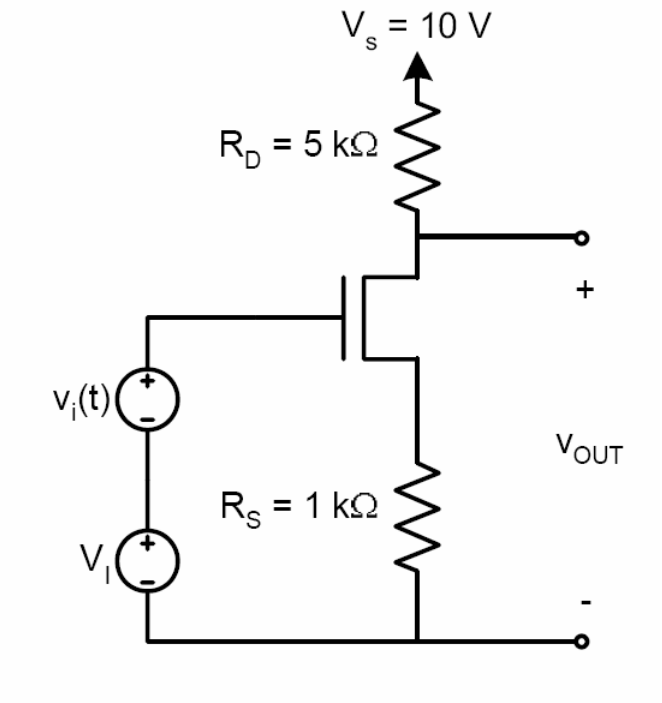


Figure 2

(2A) Find the value of the dc input voltage V_I such that the dc output voltage $V_{OUT} = 5$ V. Assume that the MOSFET operates in the saturation region $i_D = ½k(v_{GS} - V_T)^2$, and has parameters $k = 2$ mA/V^2 and $V_T = 1$ V.

V_I =

(2B) Validate or disprove the assumption that the MOSFET operates in the saturation region for the proposed operating condition.

MOSFET saturation region satisfied? Justification?

(**2C**) Given the small-signal model for the MOSFET shown in Figure 3, draw the small-signal model for the amplifier. Make sure to label all important circuit parameters and variables.

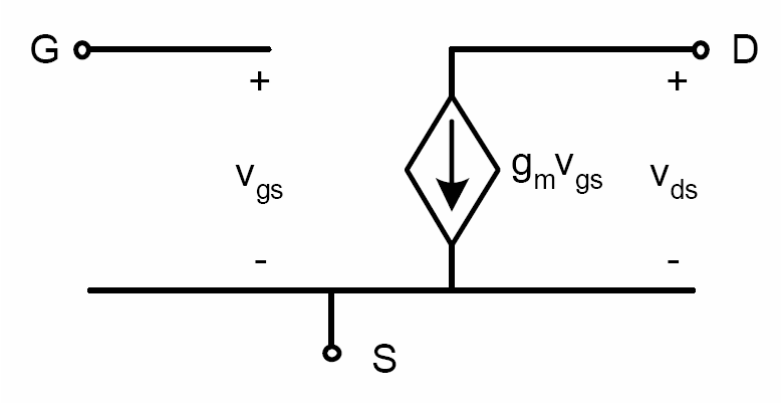


Figure 3

Draw the small-signal circuit model for the amplifier

(2D) Calculate the small-signal voltage gain for the amplifier and express it in terms of g_m, R_D, and R_S.

$$\frac{v_{out}}{v_i}$$

Problem 3 (25 Points)

For the circuits below, please find expressions for the specified voltage over the indicated time ranges in terms of the circuit parameters. Plot the waveform on the provided axes, and clearly identify the key parameters in your graph.

(3A) Consider the circuit of Fig. 4. The switch is open for $t < 0$, closed for $0 \leq t < t_1$, and open for $t \geq t_1$, where $t_1 = 3RC$. Find and plot the voltage $v_C(t)$.

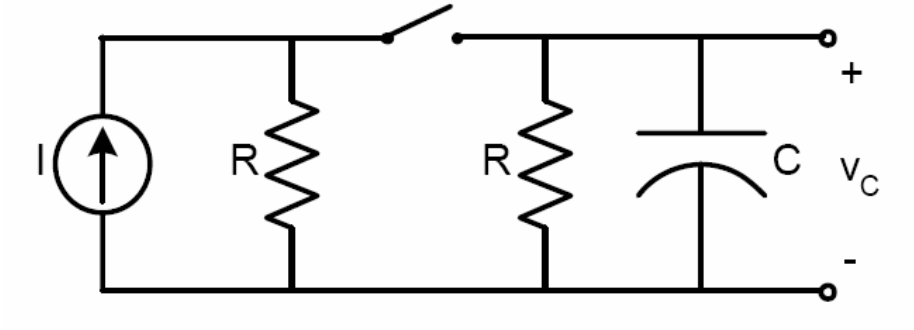


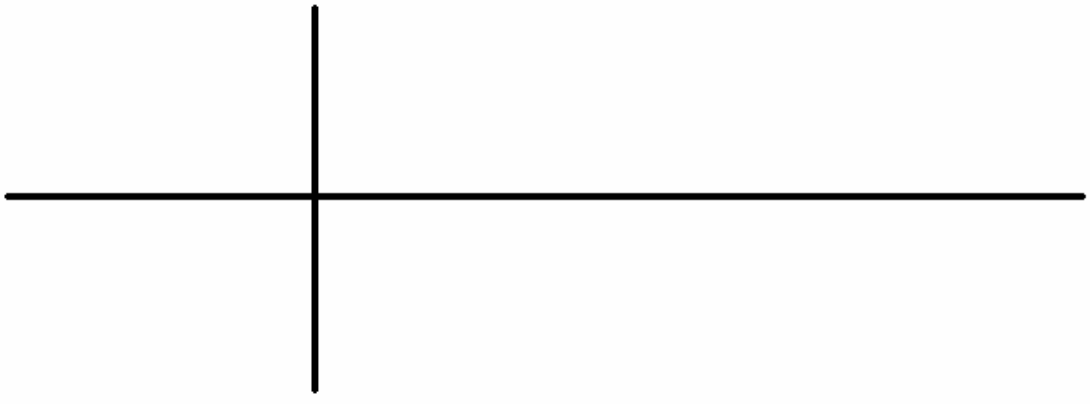
Figure 4

$v_C(t)$, $t < 0$ =

$v_C(t)$, $0 \leq t < t_1$ =

$v_C(t)$, $t \geq t_1$ =

Plot $v_C(t)$ over all time, indicating important waveform parameters.



(3B) Consider the circuit of Figure 5, in which $\alpha > -1$. The switch is open for $t < 0$, and closed for $t \geq 0$. $v_C(0^-) = V_0$. Find and plot the voltage $v_1(t)$.

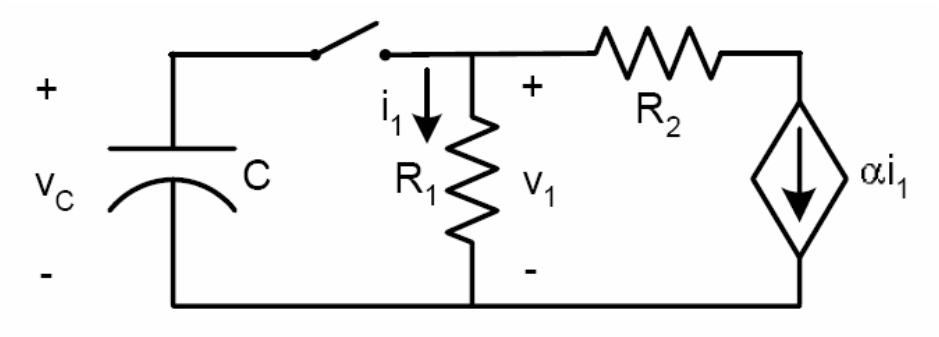
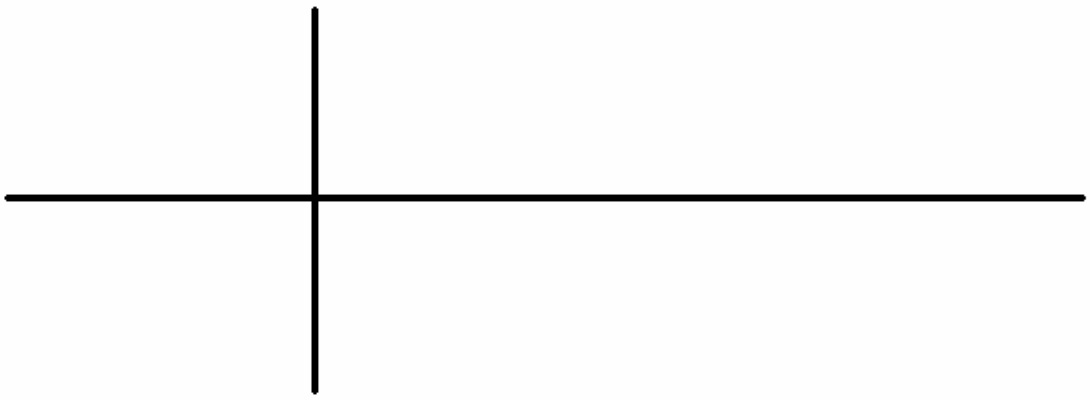


Figure 5

$v_1(t)$, $t < 0$ =

$v_1(t)$, $t \geq 0$ =

Plot $v_1(t)$ over all time, indicating important waveform parameters.



Problem 4 (13 Points)

After years of research, the FUBAR division of Bellyup Labs has created a new three-terminal semiconductor device that they name the "Dualistor". The proposed symbol for the device is shown in Fig. 6, along with a large-signal circuit model that the Bellyup researchers tell you is valid over the range of interest.

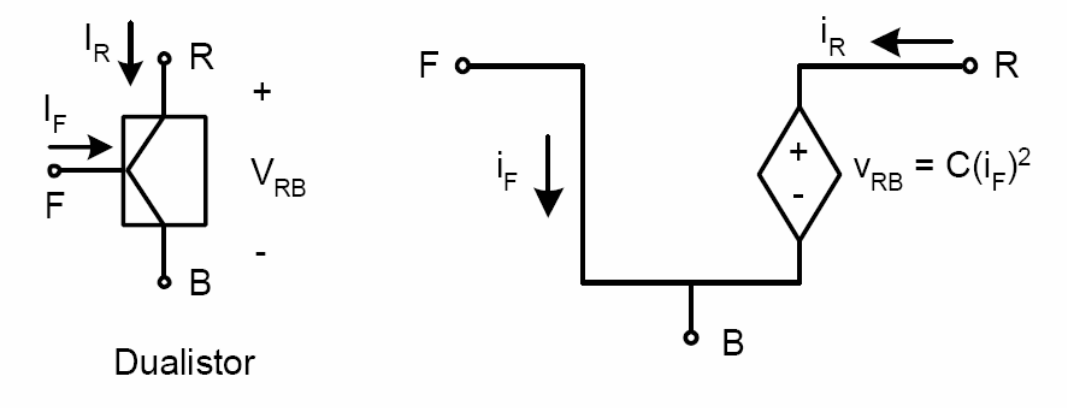


Figure 6

The researchers at Bellyup Labs have asked your assistance in developing a small-signal circuit model for the Dualistor. Derive a small-signal circuit model for the Dualistor operating about a bias point $i_F = I_F$. Draw and label the small-signal circuit, making sure to indicate all important terminal variables and parameters.

Draw and label the small-signal circuit model for the Dualistor. Make sure to provide values for any circuit parameters that are introduced.

Problem 5 (25 Points)

Figure 7 shows a relay driver circuit. The low-power switch S is used to activate and deactivate the relay (which can control much more power). The relay is considered "activated" whenever the relay current i_L exceeds 25 mA, and is "deactivated" otherwise. The relay is modeled as the series connection of a resistor R_R = 100 Ω and an inductor L_R = 200 μH. To protect the switch S driving the relay, a resistor R_F = 100 Ω is placed across the relay as shown.

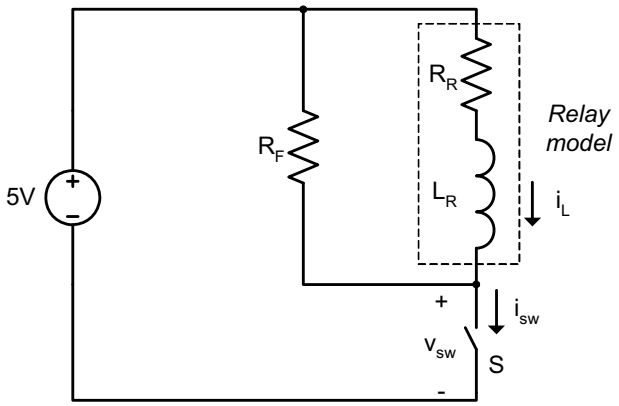
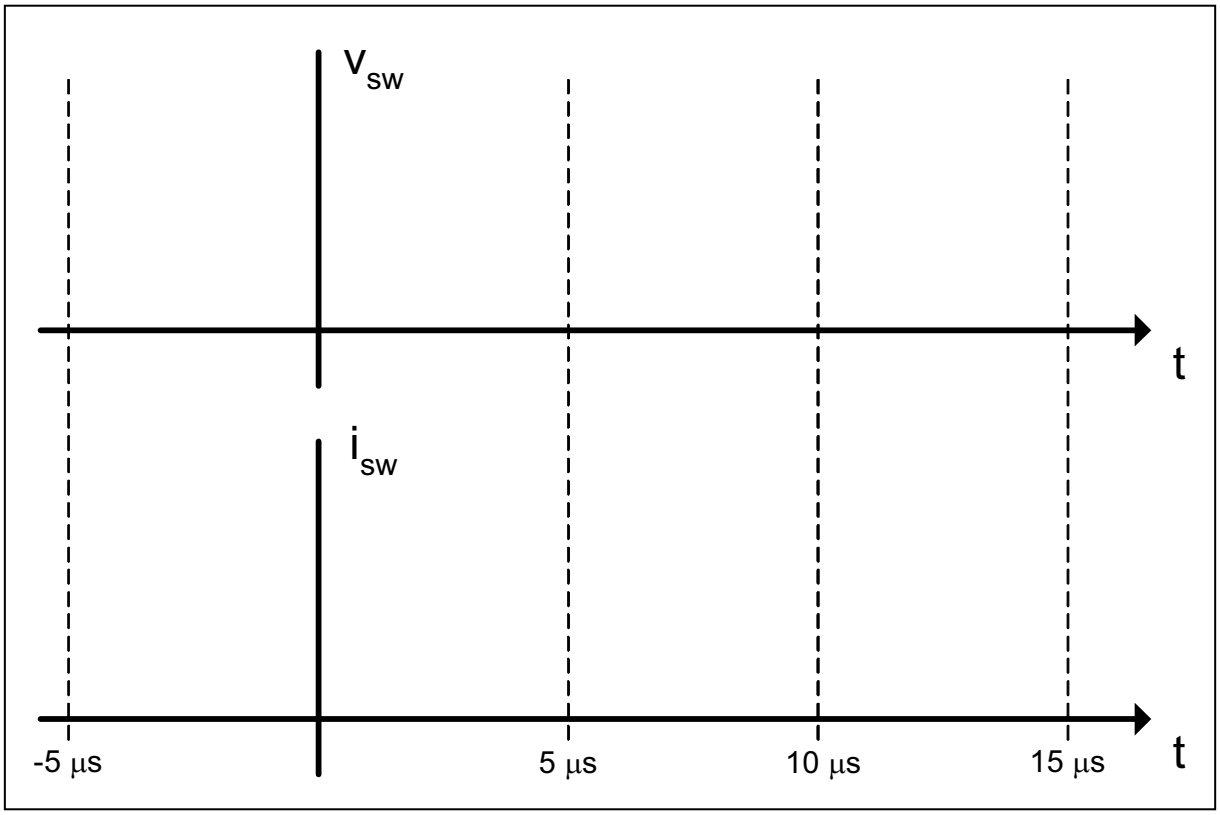


Figure 7

(5A) What will be the delay between the time the switch S is closed (after being open for a long time) and the time the relay is "activated"?

Activation delay =

(5B) After being open for a long time, the switch S is closed at t = 0, then opened at t = 10 μs. On the axes provided, plot the switch voltage v_{sw} and the switch current i_{sw} from t = -5 μs to 15 μs. Clearly label and specify (numerically) all steady-state levels and time constants.



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