

# EC2010-ANALOG CIRCUITS : PROBLEM SET 2

shanthi@ee.iitm.ac.in

## Problem 1

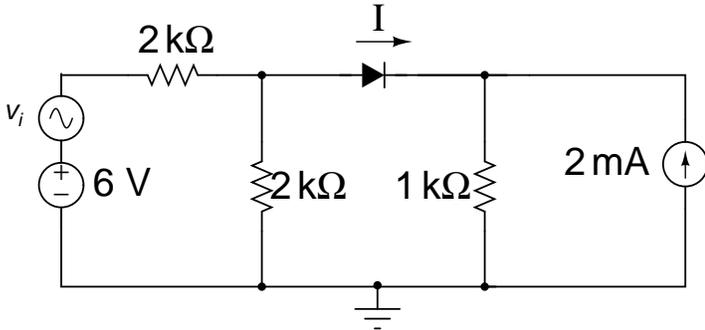


Figure 1: Circuit for Problem 1

For the circuit of Figure 1, assume that  $v_i$  is an incremental voltage source. Determine the operating point of the network. Find also the small signal voltage across the 1 kΩ resistor.

## Problem 2

In this problem, we delve deeper into the notion of “small signal”. Consider two nonlinear amplifiers, with input-output characteristics given by  $V_{out} = \frac{V_{in}^2}{V_A}$  and  $V_{out} = V_A \exp(\frac{V_{in}}{V_A})$ .

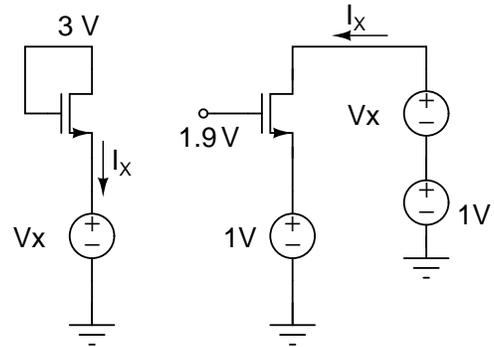
- An incremental gain of 10 is desired of both amplifiers. Determine the operating points so that this gain may be achieved.
- We saw in class that the “small signal” approximation is valid only when the higher order terms in the Taylor series can be safely neglected in relation to the linear term. Compare the second order derivative of the two amplifiers around the operating point. What can you say about the relative magnitudes of the incremental inputs for each of the amplifiers which qualify as small signals?

## Problem 3

For each of the circuits shown above, plot  $I_x$  as  $V_x$  varies from 0-3 V.

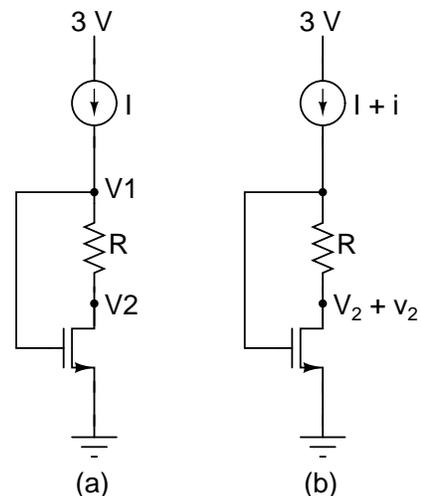
## Problem 4

For the circuit (a) shown above, determine the minimum value of  $I$  required to make the MOSFET operate at the edge



$$k = \mu_n C_{ox} = 100 \mu\text{A}/\text{V}^2, (W/L) = 10, V_T = 0.7 \text{ V}$$

Figure 2: Circuit for Problem 3

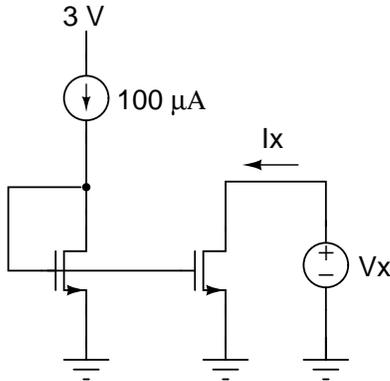


$$k = \mu_n C_{ox} = 100 \mu\text{A}/\text{V}^2, (W/L) = 10, V_T = 0.7 \text{ V}$$

Figure 3: Circuit for Problem 4

of the active region. In the circuit (b) shown above, determine the incremental voltage  $v_2$  in terms of the incremental current  $i$ , assuming the device is in saturation. How will you choose  $R$  to make  $v_2$  independent of  $i$ ?

### Problem 5

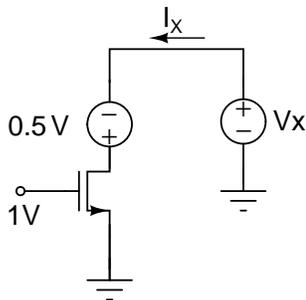


$$k = 100 \mu\text{A}/\text{V}^2, (W/L) = 10, V_T = 0.7 \text{ V}$$

Figure 4: Circuit for Problem 5

For the circuit shown above, sketch  $I_x$  as  $V_x$  varies in the range 0-3V.

### Problem 6



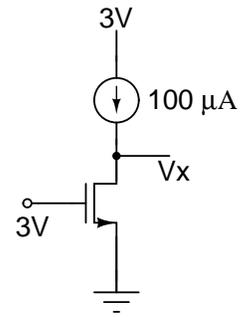
$$k = 100 \mu\text{A}/\text{V}^2, (W/L) = 10, V_T = 0.7 \text{ V}$$

Figure 5: Circuit for Problem 6

For the circuit shown above, sketch  $I_x$  as  $V_x$  varies in the range -0.5-3V.

### Problem 7

For the circuit shown above, determine the region of operation of the transistor. Find  $V_x$ .



$$k = 100 \mu\text{A}/\text{V}^2, (W/L) = 10, V_T = 0.7 \text{ V}$$

Figure 6: Circuit for Problem 7

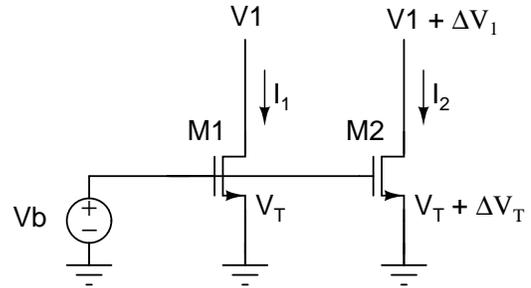


Figure 7: Circuit for Problem 8

### Problem 8

In the circuit shown above, it is known that both M1 & M2 operate in saturation. Further,  $k$  and  $W/L$  for both transistors is the same. The threshold voltage of M2 is *slightly* larger than that of M1, by an amount  $\Delta V_T$ . Determine  $I_2$ . Assume  $\Delta V_1 \ll V_1$ .

### Problem 9

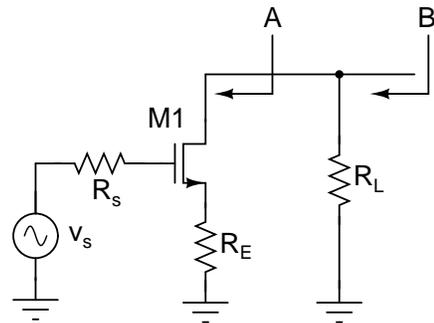


Figure 8: Circuit for Problem 9

The small signal equivalent circuit of an amplifier is shown above. M1 is assumed to be in saturation, with transconductance  $g_m$  and output conductance  $g_o$ . Determine the Norton equivalent looking in at A, as well as the Thevenin equivalent looking in at B. What happens to these equivalents when  $g_m \rightarrow \infty$ ?

## Problem 10

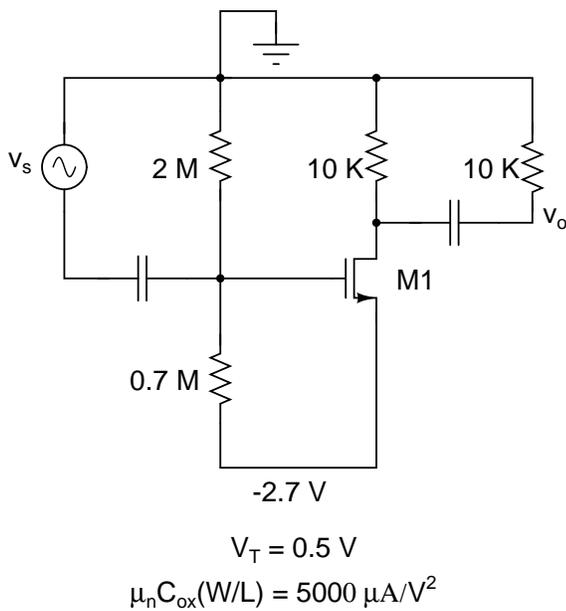


Figure 9: Circuit for Problem 10

Determine the quiescent operating point and small signal gain of the amplifier shown. What is the maximum permissible amplitude of the sinewave input so that clipping of the output is avoided ?

## Problem 11

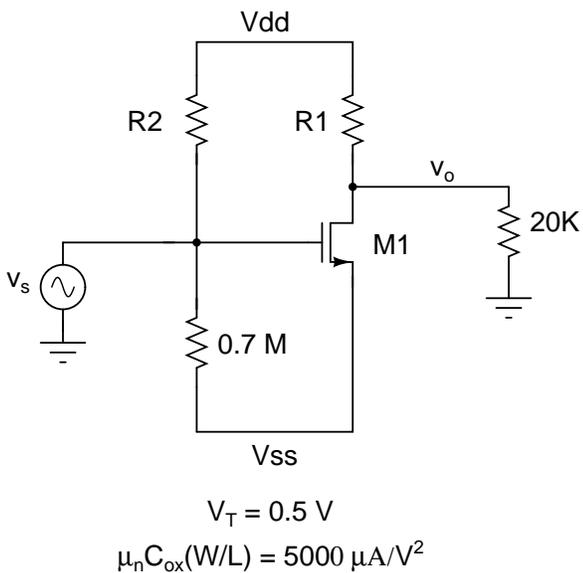


Figure 10: Circuit for Problem 11

The input to the amplifier shown above is a sinusoid of amplitude  $A$ . Determine  $R1$ ,  $R2$ ,  $A$ ,  $V_{dd}$  and  $V_{ss}$  in the circuit to achieve the following.

- There must be no quiescent current flowing through the load and source.

- The incremental gain must be  $-4$ .
- The output sinewave must begin to just begin to clip at both extremes.