Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Spring 2024

Exam #2

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are **5** pages in your exam
- Good Luck!

Problem	Score	Max Score
1		10
2		20
3		35
4		35
Total		**100**

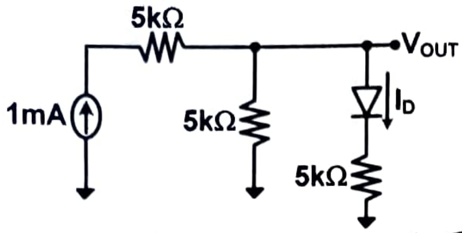
Name: SAM PALERMO

UIN:

Problem 1 (10 points)

For all the circuits below, use the constant-voltage-drop diode model (V_D=0.7V), V_{th}=25.9mV, and n=1.

a) Find V_{OUT}, I_D, and the small signal diode resistance, r_d. (~~15~~ 10 points)

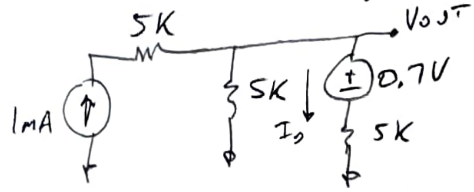


If diode is OFF ⇒ $V_{OUT} = 5V = V_D$ ⇒ inconsistent

Diode is ON

KCL @ VOUT

$$-1mA + \frac{V_{OUT}}{5K} + \frac{V_{OUT} - 0.7V}{5K} = 0$$



$$2V_{OUT} = 5.7V$$

$$V_{OUT} = 2.85V$$

$$I_D = \frac{2.85V - 0.7V}{5K} = 430\mu A \qquad r_d = \frac{25.9mV}{430\mu A} = 60.2\Omega$$

V_{OUT} = 2.85V

I_D = 430μA

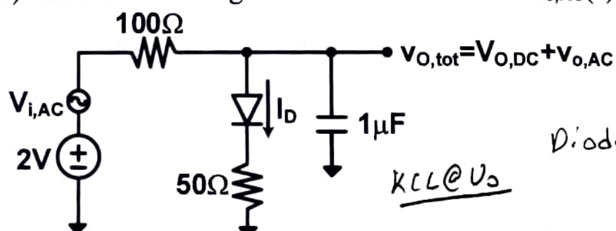
r_d = 60.2Ω

Problem 2 (20 points)

The following circuit has a small-signal AC signal, $v_{i,AC}$, in series with a DC voltage.

a) Find the DC output voltage, $V_{O,DC}$, DC diode current I_D, and small-signal diode r_d (10 points)

b) Find the small-signal AC transfer function $v_{o,AC}(s)/v_{i,AC}(s)$ (10 points)

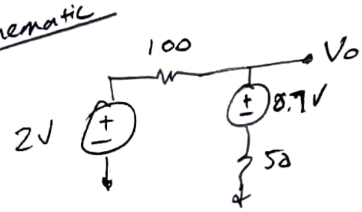


If diode is OFF ⇒ $V_o = V_D = 2V$ ⇒ inconsistent

Diode is ON

KCL @ Vo

DC schematic



$$\frac{V_o - 2}{100} + \frac{V_o - 0.7}{50} = 0$$

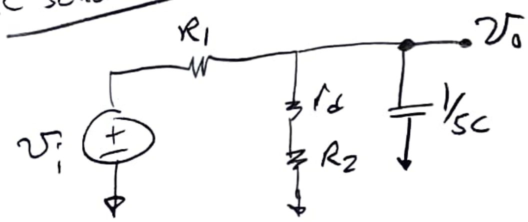
$$3V_o = 3.4V$$

$$V_o = 1.13V$$

$$I_D = \frac{1.13V - 0.7V}{50} = 8.67mA$$

$$r_d = \frac{25.9mV}{8.67mA} = 2.99\Omega$$

AC schematic



$$\frac{v_o}{v_i} = \frac{Z_C \| [r_d + R_2]}{R_1 + Z_C \| [r_d + R_2]}$$

$$= \frac{\dfrac{r_d + R_2}{R_1 + r_d + R_2}}{1 + sC[R_1 \| (r_d + R_2)]}$$

$V_{O,DC}$ = 1.13V

I_D = 8.67mA

r_d = 2.99Ω

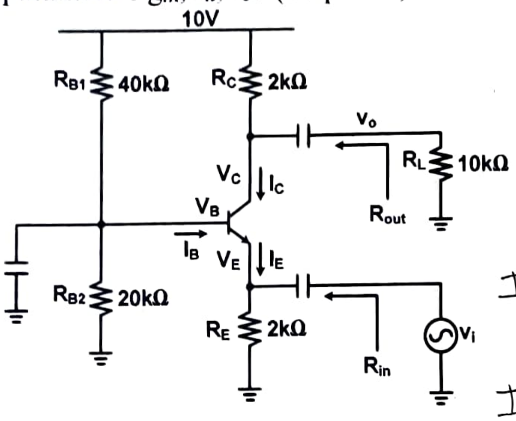
AC Transfer Function:

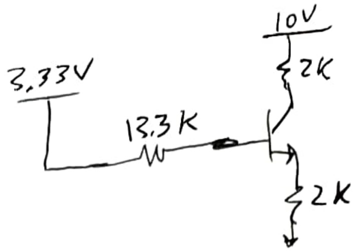
$$= \frac{\dfrac{2.99 + 50}{100 + 2.99 + 50}}{1 + s(1\mu F)(100 \| (2.99 + 50))} = \frac{0.346}{1 + s(3.46 \times 10^{-5})}$$

Problem 3 (35 points)

Assume for Problem 3 that the transistor β=150, V_{BE}=0.7V, and V_T=25.9mV.

a) Calculate the DC values for V_C, V_B, V_E, I_C, I_B, and I_E. Compute the AC small signal parameters g_m, r_π, r_e. (18 points)





$I_E = \frac{3.33V - 0.7V}{2K + \frac{13.3K}{151}} = 1.26mA$

$I_B = \frac{1.26mA}{151} = 8.34\mu A$

$I_C = 8.34\mu A (150) = 1.25mA$

$V_E = 1.26mA (2k) = 2.52V$

$V_B = 2.52V + 0.7V = 3.22V$

$V_C = 10V - 1.25mA(2k) = 7.5V$

$g_m = \frac{1.25mA}{25.9mV} = 48.3 \, mA/V$

$r_\pi = \frac{25.9mV}{8.34\mu A} = 3.11k\Omega$ $r_e = \frac{25.9mV}{1.26mA} = 20.6\Omega$

I_C = 1.25mA

I_B = 8.34μA

I_E = 1.26mA

V_C = 7.5V

V_B = 3.22V

V_E = 2.52V

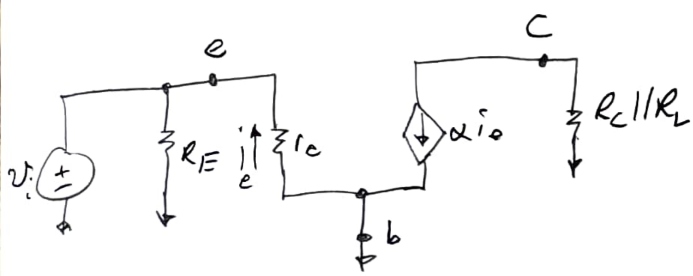
g_m = 48.3 mA/V

r_π = 3.11kΩ

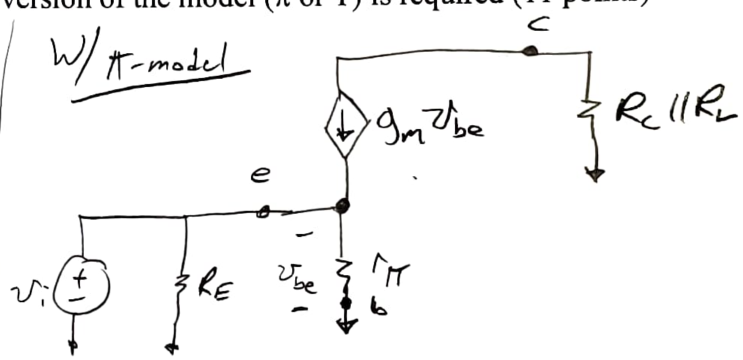
r_e = 20.6Ω

b) Sketch the small-signal model of the circuit. Assume that the capacitors act as AC shorts and that the transistor's r_o is infinite. Only **ONE** version of the model (π or T) is required (11 points)

W/T-model



W/ π-model



c) Calculate the small signal gain A_v=v_o/v_i, the input resistance R_{in}, the output resistance R_{out}. (6 points)

$A_V = g_m (R_C || R_L) = 48.3 \, mA/V (2k || 10k) = 80.5 \, V/V$

$R_{in} = R_E || r_e = 2k || 20.6 = 20.4\Omega$

$R_{OUT} = R_C = 2K$

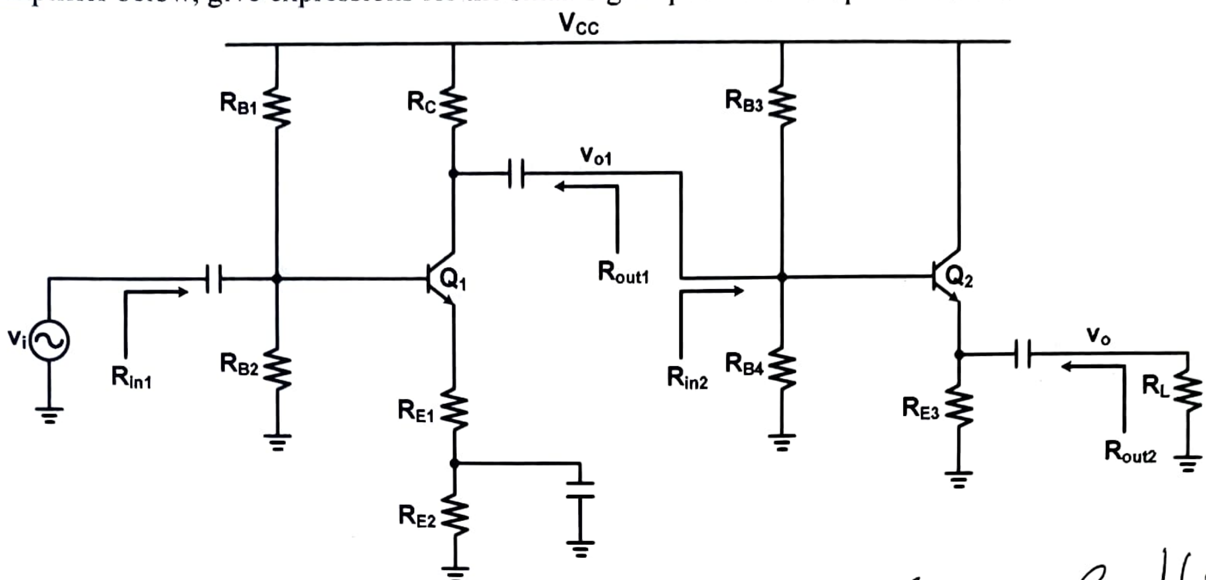
A_v = 80.5 V/V

R_{in} = 20.4Ω

R_{out} = 2kΩ

Problem 4 (35 points)

Assume for Problem 4 that **the transistors are operating in active mode** and that the capacitors act as AC shorts and that the transistors' r_o is infinite (can be neglected). For the 2-stage amplifier below, give expressions for the small signal parameters requested below.



Where $R_{B12} = R_{B1} || R_{B2}$

$R_{B34} = R_{B3} || R_{B4}$

$R_{in1} = R_{B12} || [r_{\pi 1} + (\beta+1) R_{E1}]$

$R_{out1} = R_C$

$R_{in2} = R_{B34} || [r_{\pi 2} + (\beta+1)(R_{E3} || R_L)]$

$R_{out2} = R_{E3} || \left[r_{e3} + \frac{R_C || R_{B34}}{\beta+1} \right]$

$A_{v1} = v_{o1}/v_i = \frac{-g_{m1}(R_C || R_{in2})}{1 + \frac{g_{m1} R_{E1}}{\alpha}} = \frac{-\alpha (R_C || R_{in2})}{r_{e1} + R_{E1}}$

$A_{v2} = v_o/v_{o1} = \frac{R_{E3} || R_L}{r_{e2} + R_{E3} || R_L}$

Total $A_v = v_o/v_i =$

$A_{v1} \cdot A_{v2}$