QUIZ 2 : Solutions

Note Title 10/21/2007

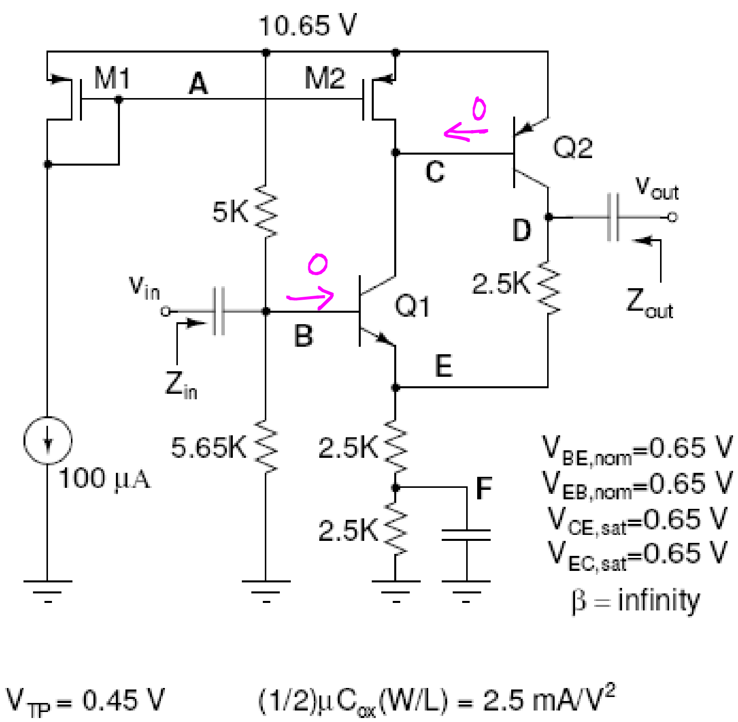


Figure 1: Circuit diagram for Problem 1.

(a)

$$V_B = \frac{5.65K}{5.65K + 5K} \, 10.65 = 5.65\,V$$

$$V_E = V_B - 0.65\,V = 5\,V$$

$$V_F = \frac{V_E \cdot 2.5k}{2.5k + 2.5k} = 2.5\,V$$

$$V_C = 10.65 - 0.65\,V = 10\,V$$

For M1,
$$100\,\mu A = 2500 \frac{\mu A}{V^2} (V_{SG} - 0.45)^2$$

$$\Rightarrow V_{SG} - 0.45 = 0.2\,V$$

$$\Rightarrow V_{SG} = 0.65\,V$$

$$V_A = 10.65 - V_{SG} = 10\,V$$

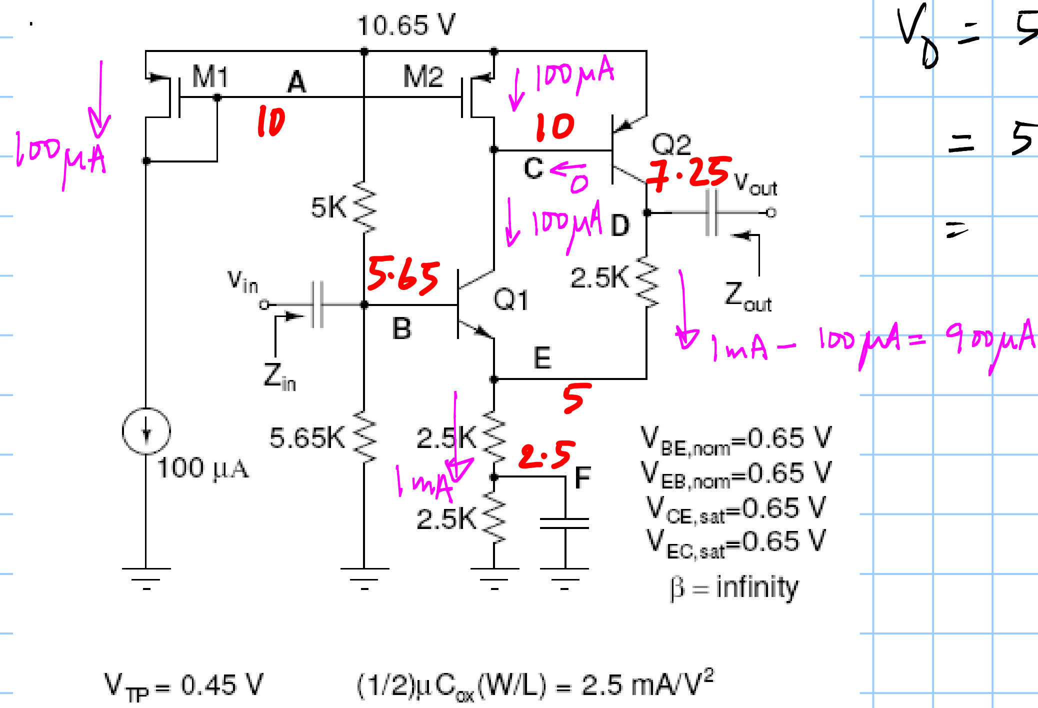


Figure 1: Circuit diagram for Problem 1.

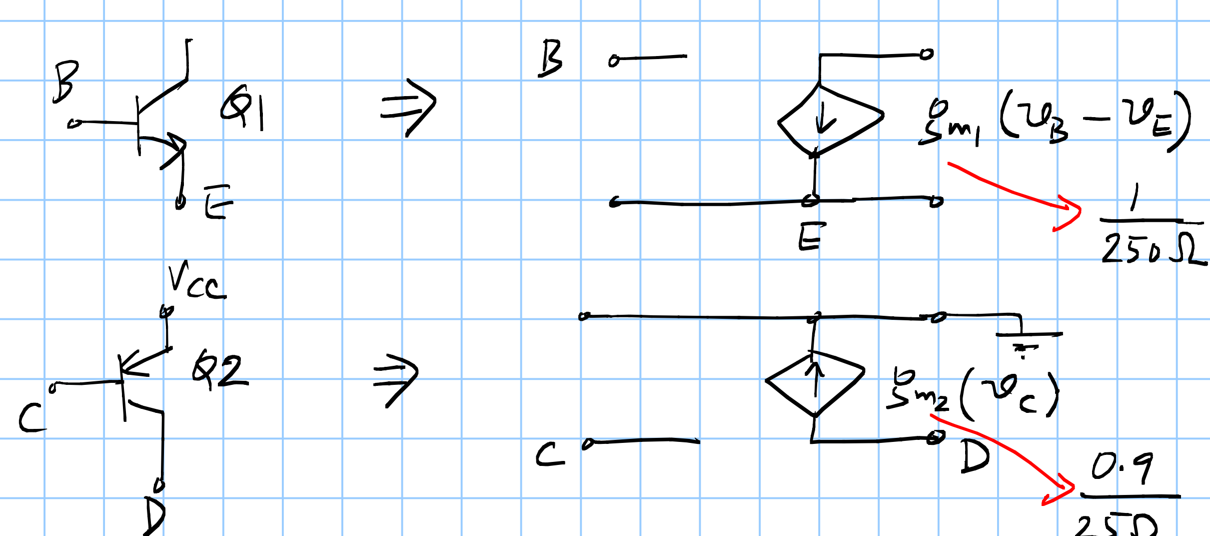
$$V_D = 5 + 0.9\text{mA} \cdot 2.5\text{K}$$
$$= 5 + 2.25$$
$$= 7.25\text{V}$$

(b) Quiescent currents:

M1 = 100 μA   M2 = 100 μA

Q1 = 100 μA   Q2 = 900 μA

(c) Now replace all devices by their small signal equivalent circuits.



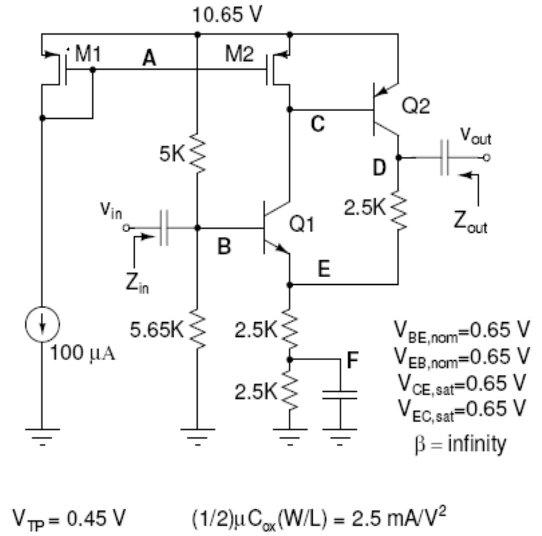
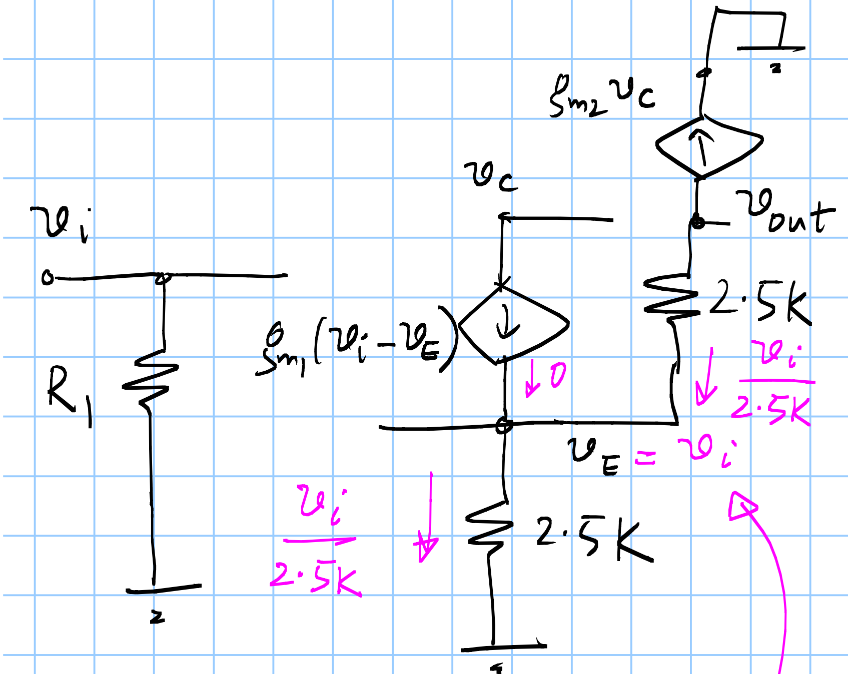


Figure 1: Circuit diagram for Problem 1.



$R_1 = 5.65k \| 5K$

KCL at v_c

$$g_m(v_i - v_E) = 0$$

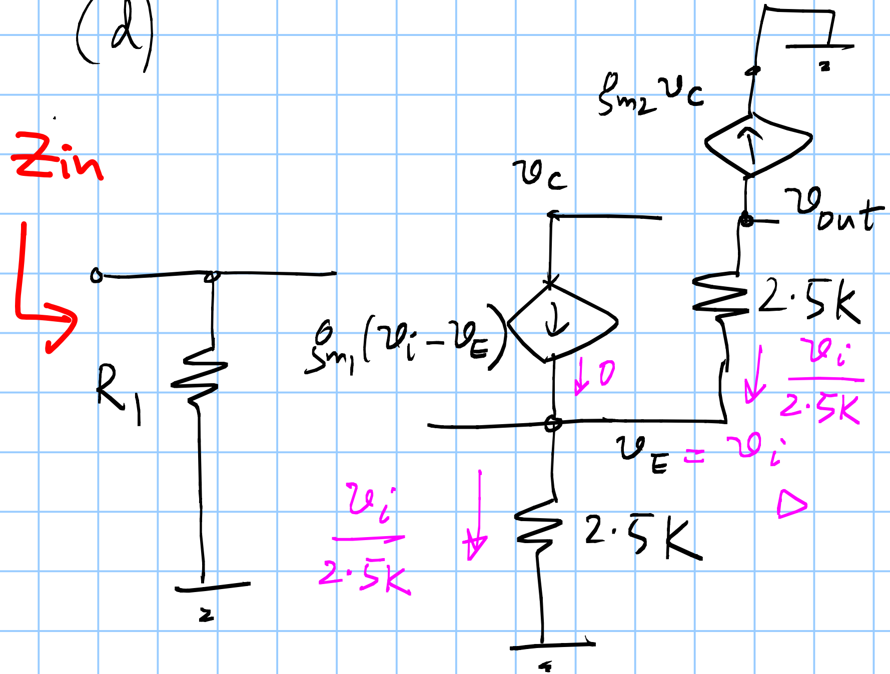
$$\Rightarrow \quad v_E = v_i$$

$$v_{out} = v_E + \frac{v_E}{2.5K} \cdot 2.5K$$

$$= v_i + v_i = 2v_i$$

$\Rightarrow$ Incremental Gain = 2

(d)



$Z_{in} = R_1$

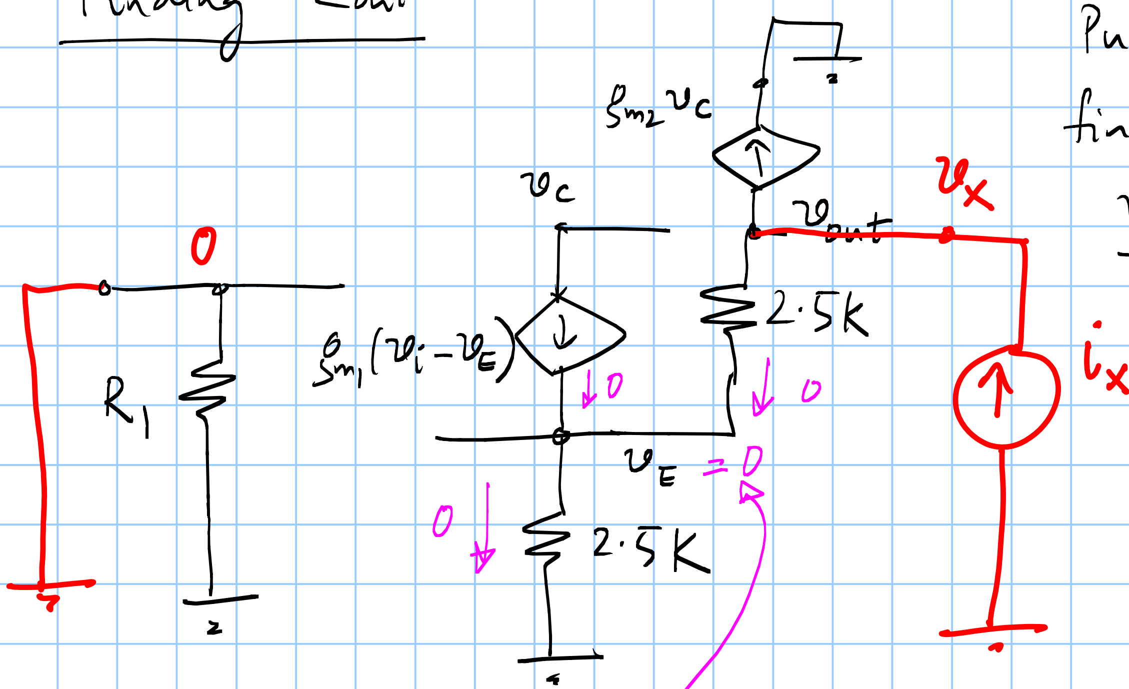
$= 5.65K \| 5K$

$= \frac{5.65 \times 5}{10.65}$

$= 2.653\ K\Omega$

$R_1 = 5.65K \| 5K$

Finding Z_{out}



Push i_x, find v_x.

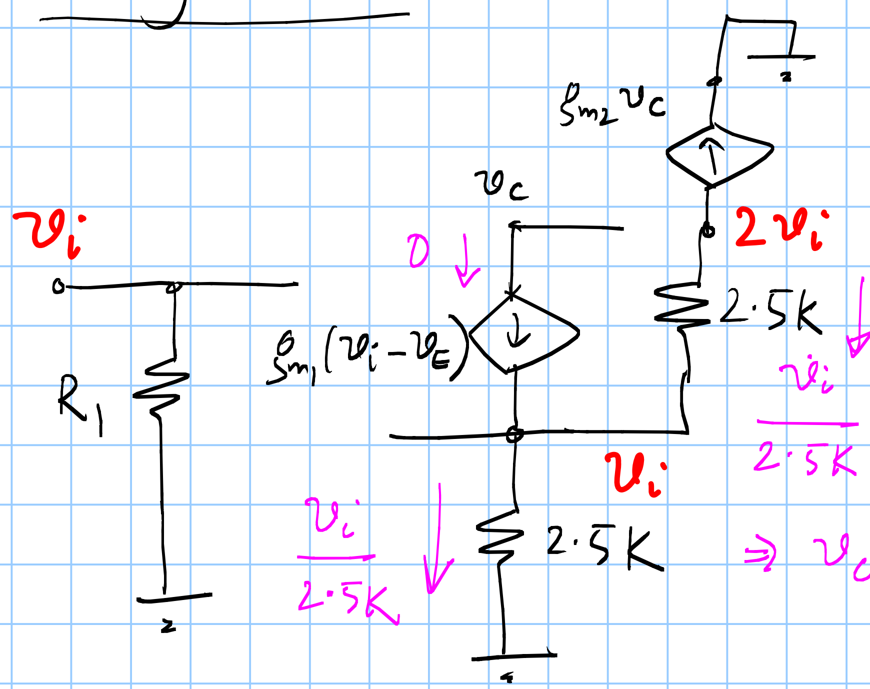
$\frac{v_x}{i_x} = Z_{out}$

Remember, $v_E = v_i = 0 \Rightarrow v_x = 0 \Rightarrow Z_{out} = 0$

(What happens to i_x?)

(e). Swing Limits

First, find all small signal quantities



$$\frac{v_i}{2.5K} = -g_{m2} v_c$$

$$\Rightarrow v_c = -\frac{v_i}{2.5K\, g_{m2}} = \frac{-v_i}{2.5K \frac{0.9}{25\Omega}} = -v_i/90$$

M1 is not effected by v_i

$\Rightarrow$ It cannot influence swings

M2 : Total drain current = Quiescent } 100μ
+ Incremental } 0

$\Rightarrow \quad I_{M2} = \text{Constant}$

$V_{SD,M2} = 10.65 - [\text{Quiescent drain voltage} + \text{Incremental drain voltage}]$

$$= 10.65 - \left[\begin{matrix} 10 \\ + v_c \end{matrix}\right] = 0.65 - v_c = 0.65 + v_i/90$$

For M2 to get into triode,

$$\boxed{v_i = 90 \times 0.65 \simeq 58.5V \ !}$$

Q1:

$$I_c = \left.\begin{matrix} 100\mu A \\ + \text{Increment} \end{matrix}\right\} = 100\mu A$$

Q1 does not go into cutoff.

$$V_{CE} = V_C - V_E$$

$$= 10 + \frac{v_i}{90} - \left[5 + v_i\right]$$

$$= 5 - \frac{89}{90} v_i$$

⇒ Q1 gets saturated when $V_{CE} = 0.65$

$$5 - \frac{89}{90} v_i = 0.65$$

$$\Rightarrow \boxed{v_i \simeq 4.35\ V}$$

Q2:

$$I_c = \underbrace{900\mu A}_{\text{Quiescent}} + \underbrace{\frac{v_i}{2.5K}}_{\text{Increment}}$$

For cutoff, $v_i = 2.5K \cdot 0.9\ mA$

$$\Rightarrow \boxed{v_i = 2.25\ V}$$

Base potential of Q2 $= 10 + \frac{v_i}{90}$

Collector potential $= 7.25 + 2v_i$

⇒ Q2 is saturated when $7.25 + 2v_i = 10 + \frac{v_i}{90}$

$$\Rightarrow v_i = 2.75 / (2 + 1/90)$$

$$\Rightarrow \boxed{v_i = 1.37\ V}$$

The largest amplitude of the Sinewave that results in distortion free operation is $\min\{58.5,\ 4.35,\ 2.25,\ 1.37\}$

Largest permissible amplitude is 1.37 V

Problem 1 Answers

(a)	A 10 V	B 5.65 V	1
	C 10 V	D 7.25 V	1
	E 5 V	F 2.5 V	1
(b)	M1 100 μA	M2 100 μA	1
	Q1 100 μA	Q2 900 μA	1
(c)	v_{out}/v_{in}	2	5
(d)	Z_{in} = 2.653 K	Z_{out} = 0	4
(e)	Max. amplitude	1.37 V	6