UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2008/2009

November 2008

EEE 510 – ANALOG CIRCUIT DESIGN

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **NINE (9)** printed pages and **SIX (6)** questions before answering.

Answer **FIVE (5)** questions.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

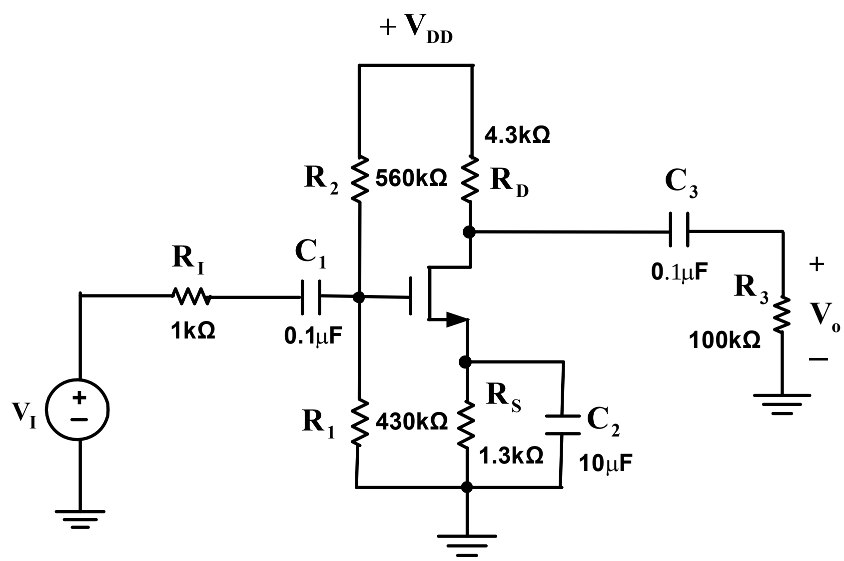

Figure 1

1. Given in Figure 1 a common source amplifier with source degeneration. Assuming negligible output impedance, r_o, ignoring the gate-to-drain capacitance, and occurring at low enough frequency that you can ignore gate-to-source capacitance C_{gs},

   (a) draw the equivalent small signal model (5 marks)

   (b) derive the gain to yield the following expression.

$$A_v(s) = \frac{V_o(s)}{V_I(s)} = A_{mid}\ F_L(s)$$

$$= \left[-g_m(R_3 \| R_D) \frac{R_G}{R_I + R_G} \right] \frac{s^2 \left[s + \frac{1}{C_2 R_S} \right]}{\left[s + \frac{1}{C_1(R_1 + R_G)} \right] \left[s + \frac{1}{C_2(\frac{1}{g_m} \| R_S)} \right] \left[s + \frac{1}{C_3(R_D + R_3)} \right]}$$

(15 marks)

2. Given a BJT circuit as shown in Figure 2 and it has the following I-V characteristic:

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

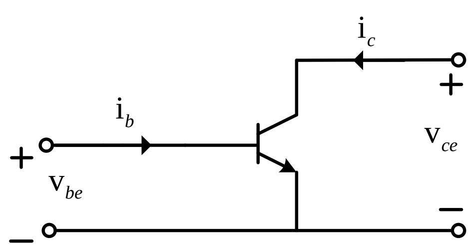

Figure 2 : BJT Circuit

Using a 2-port y-network, we also have the following relation:

$$i_b = y_{11} v_{be} + y_{12} v_{ce} \qquad (1)$$

$$i_c = y_{21} v_{be} + y_{22} v_{ce} \qquad (2)$$

The hybrid-pi model is as shown in Figure 3 below:

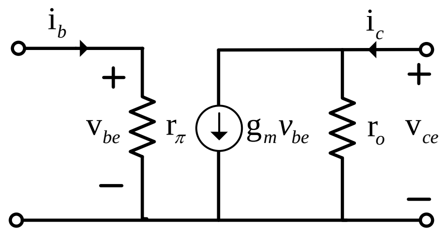

Figure 3 : Hybrid-pi model for BJT circuit

(a) Convert equations (1) and (2) to the h-parameter network. Draw the corresponding h-parameter hybrid-pi model.

(5 marks)

(b) Find the input resistance using h-parameter that we have defined in part (a).

(5 marks)

(c) Find the output resistance using h-parameter that we have defined in part (a).

(5 marks)

(d) Find the forward current gain using h-parameter that we have defined in part (a).

(5 marks)

3. Given a common-source circuit as shown in Figure 4 and it has the following I-V characteristic:

$$I_D = \frac{k_n}{2}(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$$

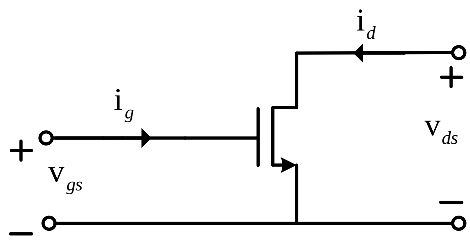

Figure 4 : MOSFET Circuit

Using a 2-port y-network, we also have the following relation:

$$i_g = y_{11} v_{gs} + y_{12} v_{ds}$$
$$i_d = y_{21} v_{gs} + y_{22} v_{ds}$$

The solutions for the above equalities are as follows:

$$y_{11} = \left.\frac{i_g}{v_{gs}}\right|_{v_{ds}=0} = 0$$
$$y_{12} = \left.\frac{i_g}{v_{ds}}\right|_{v_{gs}=0} = 0$$
$$y_{21} = \left.\frac{i_d}{v_{gs}}\right|_{v_{ds}=0} = \frac{2I_D}{V_{GS} - V_{TN}}$$
$$y_{22} = \left.\frac{i_d}{v_{ds}}\right|_{v_{gs}=0} = \frac{I_D}{\frac{1}{\lambda} + V_{DS}}$$

(a) From the above expression, convert the small signal hybrid-pi model showing g-parameter.

(5 marks)

(b) Derive the forward current gain from the g-parameter as in part (a).

(5 marks)

(c) Derive the forward voltage gain from the g-parameter as in part (a).

(5 marks)

(d) Derive the output resistance from the g-parameter as in part (a).

(5 marks)

4. Given a class A emitter-follower as shown in Figure 5. Transistor Q_1 is the emitter follower with Q_2, R_1, R_2, and R_3 set up the biasing. Find the efficiency of the class A circuit using the following methodologies:

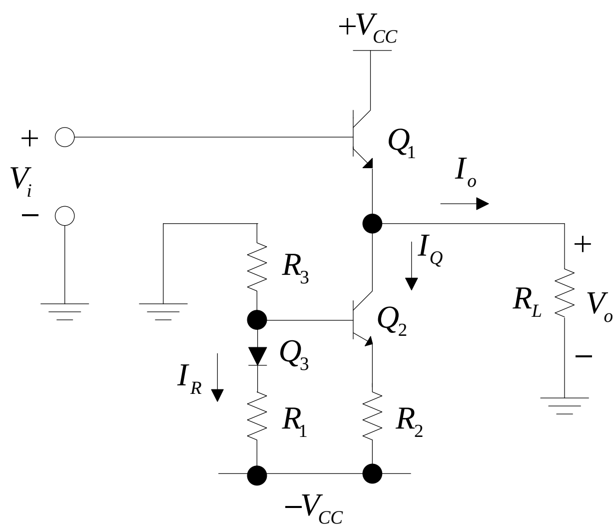

Figure 5 : Emitter-Follower Class A Output Stage

(a) Using the Kirchoff's voltage law (KVL), find the voltage transfer characteristic (VTC) relating between the output voltage, V_o to the input voltage, V_i.

(5 marks)

(b) Draw the voltage transfer characteristics (VTC) with proper labelling.

(5 marks)

(c) Express the load power, P_L and the power due to DC power supply, P_{DC}.

(5 marks)

(d) Find the efficiency, η which is the ratio between the load power to the power due to DC supply. Show that the maximum efficiency is approximately 25 %.

(5 marks)

5.

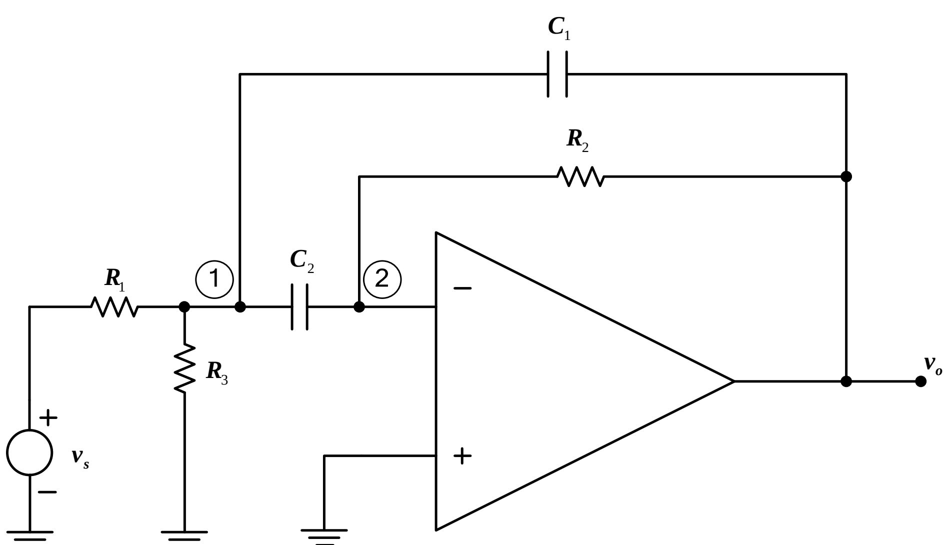

Figure 6 : Inverting Amplifier as a Bandpass Filter

Figure 6 shows the diagram of a bandpass filter built from an inverting op-amp. Prove that the following expression holds true:

$$A_{BP}(s) = -\left(\frac{2Q}{1+\frac{R_1}{R_3}}\right)\left(\frac{s\omega_o}{s^2 + s\frac{\omega_o}{Q} + \omega_o{}^2}\right)$$

Prove the above expression by the following methodology:

(a) Express V_S, R_1, and R_3 as a function of Thevenin's voltage, V_{TH} and Thevenin's resistor, R_{TH}. Then, write Kirchoff's current law (KCL) at both nodes 1 and 2. Prove that the ratio of V_O to V_{TH} is

$$\frac{V_O}{V_{TH}} = \frac{\frac{-s}{R_{TH}C_1}}{s^2 + \frac{s}{R_2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) + \frac{1}{R_2 R_{TH} C_1 C_2}}$$

(10 marks)

(b) Using $R_{TH} = R_1||R_3$, and $V_{TH} = \frac{R_3}{R_1+R_3}V_S$, prove that $\frac{V_O}{V_S}$ is given by

$$\frac{V_O}{V_S} = \frac{\frac{-s}{R_1 C_1}}{s^2 + \frac{s}{R_2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) + \frac{R_1 + R_3}{R_2 C_1 C_2 R_1 R_3}}$$

(5 marks)

(c) From the following relation

$$\frac{V_O}{V_S} = K\frac{s\omega_0}{s^2 + s\frac{\omega_0}{Q} + \omega_0{}^2}$$

Find K, ω_0 and Q.

(5 marks)

6. Estimate ω_L for the common-collector (CC) and and the common-drain amplifier as shown in Figure 7 and 8.

(20 marks)

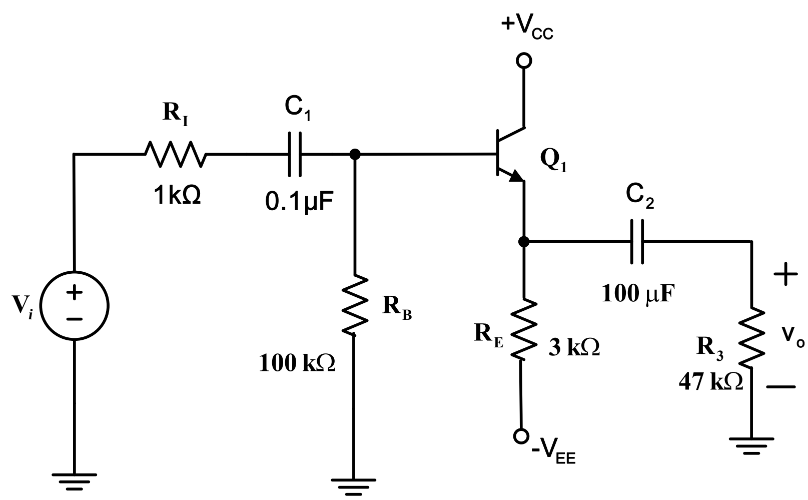

Figure 7 : Common-collector (CC) amplifier

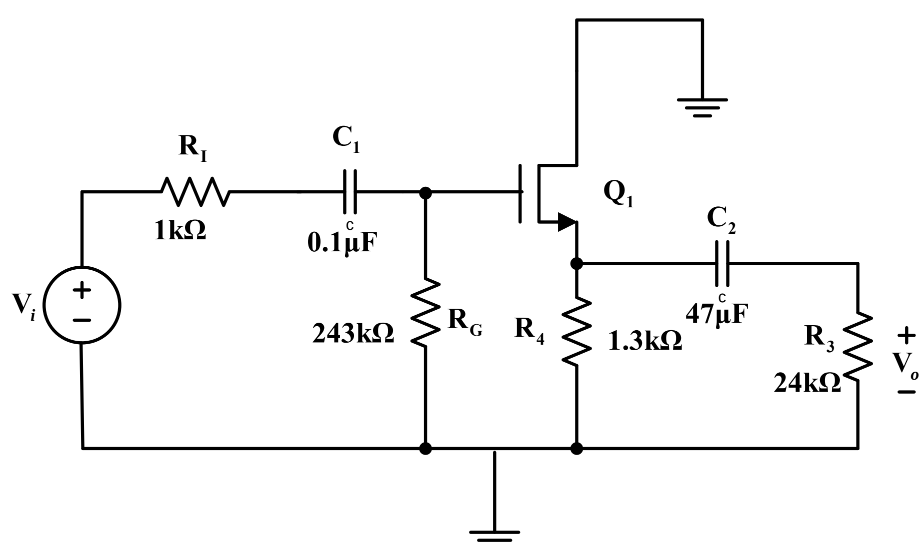

Figure 8 : Common-drain (CD) amplifier

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