UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2025 SEMESTER

COURSE : EFB2053 - MICROELECTRONIC CIRCUITS

DATE : 12 APRIL 2025 (SATURDAY)

TIME : 2.30 PM - 5.30 PM (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SEVEN (7)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. Consider a typical BJT amplifier connected to an active load as shown in **FIGURE Q1**. Assume that the circuit has a supply of $V^{+} = 5$ V and has the following transistor parameters: $I_{SQ(0)} = I_{SQ(1)} = I_{SQ(2)} = 1 \times 10^{-12}$ A, $V_{AN} = 110$ V and $V_{AP} = 90$ V

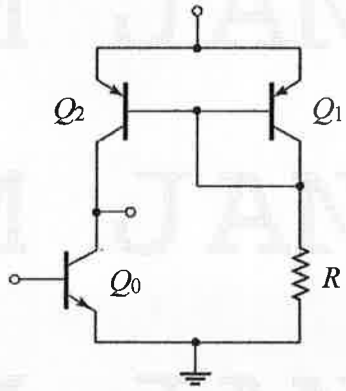

FIGURE Q1

a. Redraw the circuit in **FIGURE Q1** and label all voltages and currents. Show clearly the current directions and terminal polarities. Determine which elements form the active load circuit, which transistor is the active load driver and for which transistor.

[9 marks]

b. Determine the values of emitter-base voltage, V_{EB2}, and R such that $I_{REF} = 0.5$ mA.

[5 marks]

c. Assuming the following equation for the BJT amplifier with active load, evaluate the value of the small-signal input voltage, v_I, to produce $v_{CE0} = v_{EC2}$.

$$I_{S0}\left[\exp\left(\frac{v_I}{V_T}\right)\right]\left(1+\frac{v_{CE0}}{V_{AN}}\right) = I_{REF} \times \frac{\left(1+\frac{v_{EC2}}{V_{AP}}\right)}{\left(1+\frac{v_{EB2}}{V_{AP}}\right)}$$

[6 marks]

d. Evaluate the open-circuit, small-signal voltage gain of a BJT amplifier with an active load.

[6 marks]

2. A differential amplifier is a fundamental building block of analog circuits commonly used as the input stage of an op-amp. **FIGURE Q2** shows a differential amplifier with the following transistor parameters: $\beta = 95$, $V_{BE}(\text{on}) = 0.65$ V, and $V_A = \infty$.

a. For $v_1 = v_2 = 0$, find I_{C1} , I_{C2} , I_E , V_{CE1} and V_{CE2} .

[10 marks]

b. Determine the maximum and minimum values of the common-mode input voltage, v_{cm} .

[4 marks]

c. State the equations for forward-transconductance, g_f , and the transistor transconductances, g_m , in terms of I_E and V_T .

[4 marks]

d. Evaluate the differential-mode gain, A_d , for a one-sided output at the collector of Q_2 .

[6 marks]

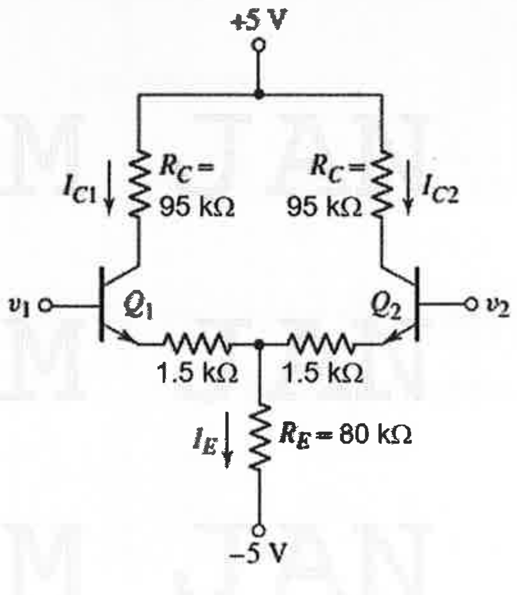

FIGURE Q2

3. a. **FIGURE Q3a** shows a Common-Source MOSFET amplifier without source bypass capacitor which is an example of a series–series feedback circuit. The amplifier is supplied by a 10 VDC supply, and the I_{DSS} , $V_{GS(Q)}$ and V_p (pinch-off voltage), of the device are given as 8 mA, -1.4 V and - 4 V respectively. Assume that the output resistance of the MOSFET, r_{ds} is very large (infinity).

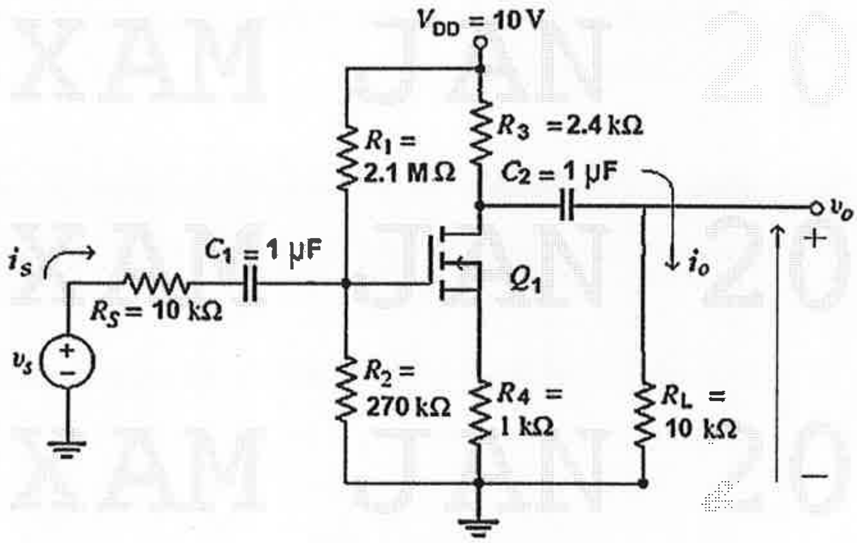

FIGURE Q3a

i. Draw a hybrid-π model of the circuit.

[5 marks]

ii. Evaluate the current gain, $A_{is} = \frac{i_o}{i_s}$, using the small-signal analysis of **part a(i)**.

[10 marks]

b. Consider the voltage series feedback amplifier shown in **FIGURE Q3b**. The gain of the amplifier without feedback is A. Negative feedback is then applied by feeding a fraction β of the output voltage, V_o, back to the amplifier input.

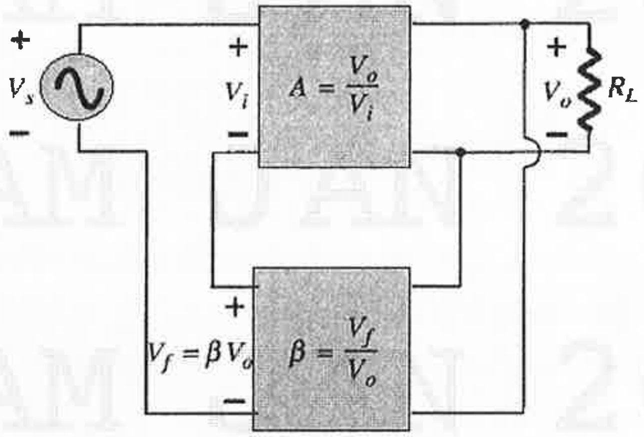

FIGURE Q3b

i. The voltage gain of the amplifier without feedback, A, is 100. Determine, A_f , the voltage gain of the amplifier if negative voltage feedback is introduced in the circuit. Assume that feedback transfer factor, $\beta = 0.01$.

[4 marks]

ii. After prolonged use, the voltage gain of the amplifier without feedback falls by 6 dB. Evaluate the percentage change in the overall gain of the system given that the feedback transfer factor β is maintained at 0.01.

[5 marks]

4. **FIGURE Q4a** shows a Schmitt trigger circuit using an operational amplifier (Op-amp) that utilizes positive feedback for use as waveform generator.

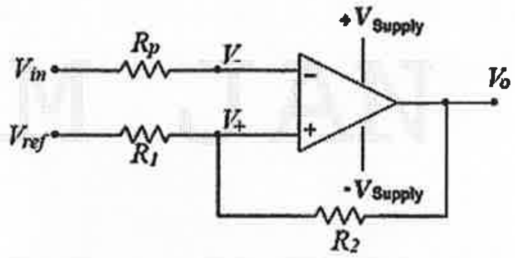

FIGURE Q4a

a. Discuss **TWO (2)** characteristics of a Schmitt trigger circuit that make it useful in a signal conditioning application, which converts noisy waveform signals into clean digital pulses.

[5 marks]

b. A Schmitt trigger is utilized to regenerate clean digital pulses from noisy sensor signals used in industrial machinery. Design a circuit whose nominal reference voltage is -3 V, has a hysteresis width of 10 mV and uses an Op-amp whose power supply is ± 10 V.

[10 marks]

c. Establish the upper crossover voltage, V_{TU}, and the lower crossover voltage, V_{TL} .

[5 marks]

d. Using the results of **part 4(c)**, sketch the output waveforms of the Schmitt trigger, given that the input signal V_{in} is as shown in **FIGURE Q4b**.

[6 marks]

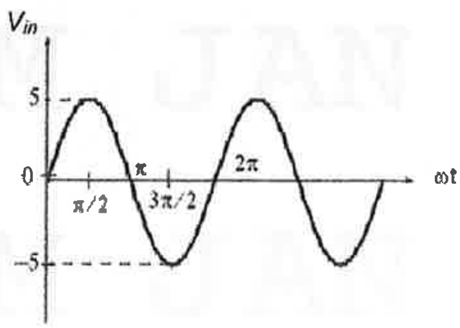

FIGURE Q4b

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APPENDIX I

KEY FORMULAE

Bipolar Junction Transistor (BJT)

DC current gain	$I_C = \beta I_B$
Transistor currents	$I_E = I_B + I_C$; $I_E = (\beta + 1) I_B$
Transconductance	$g_m = \frac{I_C}{V_T}$; (V_T = 25 or 26 mV) $i_c = g_m v_{be}$
Small-signal input resistance between base and emitter	$r_\pi = \frac{\beta}{g_m}$; $r_\pi = \frac{v_{be}}{i_e}$; $r_\pi = (\beta + 1) r_e$
Internal emitter resistance	$r_e = \frac{V_T}{I_E}$; $r_e = \frac{v_{be}}{i_b}$; (V_T = 25 or 26 mV)
Early-effect resistance	$r_o = \frac{V_A}{I_C}$
DC current ratios	$\alpha_{dc} = \frac{I_C}{I_E}$
	$\beta_{dc} = \frac{I_C}{I_B}$
	$\beta = \frac{\alpha}{1-\alpha}$; $\alpha = \frac{\beta}{\beta+1}$
Small-signal voltage gain and current gain	$A_V = \frac{v_o}{v_i}$; $G_V = \frac{v_o}{v_{sig}}$; $A_i = \frac{i_o}{i_i}$
Small-signal input and output impedance	$Z_i = \frac{V_i}{I_i}$ and $Z_o = \frac{V_o}{I_o}$
BJT capacitances	$C_\mu = \frac{C_{\mu 0}}{\left(1 + \frac{V_{CB}}{V_{0c}}\right)^{m_{CBJ}}}$; $C_{je} = 2C_{je0}$; $C_{de} = \tau_F g_m$ $C_\pi = C_{je} + C_{de}$
Unity-gain frequency	$f_T = \frac{g_m}{2\pi(C_\pi + C_\mu)}$