Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	ELECTRONIC CIRCUITS ANALYSIS AND DESIGN
COURSE CODE	:	BEJ 30403
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 Answer the following questions:

(a) List **THREE (3)** modes of operation of operational amplifier.

(3 marks)

(b) Assume that $R_2 = R_1$ and $R_3 = R_f$. Analyze R_f in terms of R_1 if the output voltage, V_o is triple the difference of input voltages, $V_o = 3(V_2 - V_1)$ for the circuit in **Figure Q1.1**.

(7 marks)

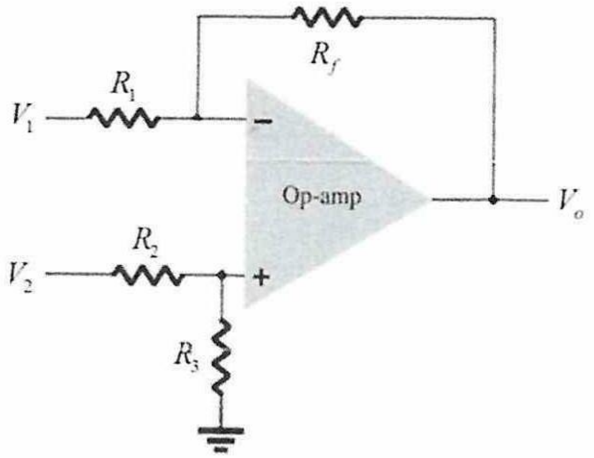

Figure Q1.1

(c) The saturated output voltage are $\pm V_{sat}$ for the Schmitt Trigger circuit in **Figure Q1.2**.

(i) Derive the upper and lower threshold voltage expressions, V_{UTP} and V_{LTP}.

(4 marks)

(ii) Determine R_A, if $V_{sat} = 12$ V, $V_{ref} = -10$ V and $R_B = 10$ kΩ. Given that the hysteresis width is 2 V.

(3 marks)

(iii) Sketch and label the values of the voltage transfer characteristics of the Schmitt trigger circuit.

(3 marks)

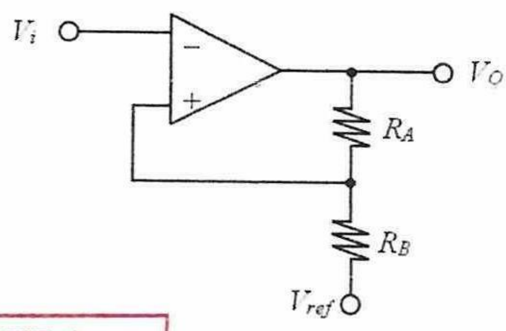

Figure Q1.2

Q2 Answer the following questions:

(a) The transition band is one of three bands that describe the frequency response of an active filter. Explain how the slope in the transition band represents the quality of the frequency response.

(3 marks)

(b) Answer the following questions:

(i) Calculate the cut-off frequency, f_c and overall gain, A_v for the circuit in **Figure Q2.1**.

(4 marks)

(ii) Analyze the effect on the cut-off frequency if the capacitor value is tripled.

(3 marks)

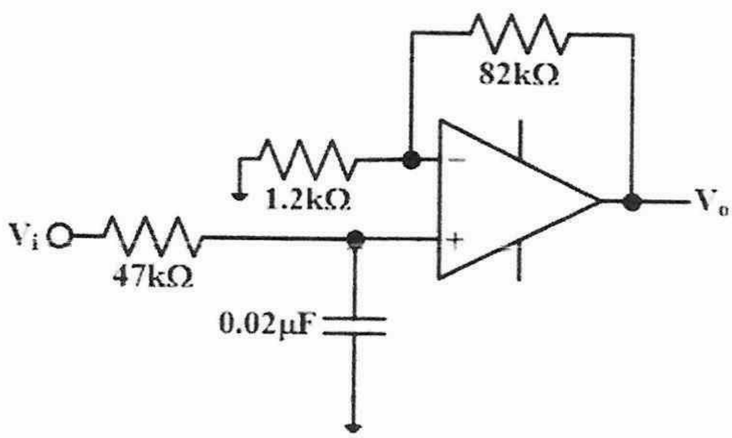

Figure Q2.1

(c) Answer the following questions:

(i) Design a first-order high-pass Butterworth filter with a cut-off frequency, f_c of 100 Hz and pass band gain, A of 30 dB. Used feedback resistor of 100 kΩ.

(6 marks)

(ii) Draw the circuit of the filter.

(2 marks)

(iii) Sketch the frequency response graph for the filter.

(2 marks)

Q3 Answer the following questions:

(a) Gain with feedback, A_f is independent of amplifier gain, A. A_f depends on feedback network, β. A system without feedback has a mid-band gain of A = 63.98 dB and a high cut-off frequency of f_H = 75 kHz. If the system has a feedback network with a feedback factor, β = 0.0048. Analyze the amplifier performance.

(i) Evaluate the mid-band gain with feedback, A_f.

(4 marks)

(ii) Determine the new high cut-off frequency, f_{Hf}.

(2 marks)

(iii) Draw the frequency response for both systems.

(2 marks)

(b) An amplifier system without feedback has the following specifications. Open loop gain, A = 200, input impedance, Z_i = 60 kΩ and output impedance, Z_o = 1.5 kΩ. If the system has negative feedback and the feedback factor is β = 0.1. Analyze the system through the followings, calculate the closed-loop gain, A_f, input impedance, Z_{if} and output impedance, Z_{of} for the amplifier with:

(i) Voltage series feedback.

(6 marks)

(ii) Voltage shunt feedback.

(6 marks)

Q4 Answer the following questions:

(a) Referring to the oscillator circuit depicted in **Figure Q4.1**, determine the value of R_F to sustain the oscillation given the condition that $R_1 = 0.5R_2$, calculate both R_1 and R_2 if the oscillating frequency, $f_o = 15$ kHz.

(7 marks)

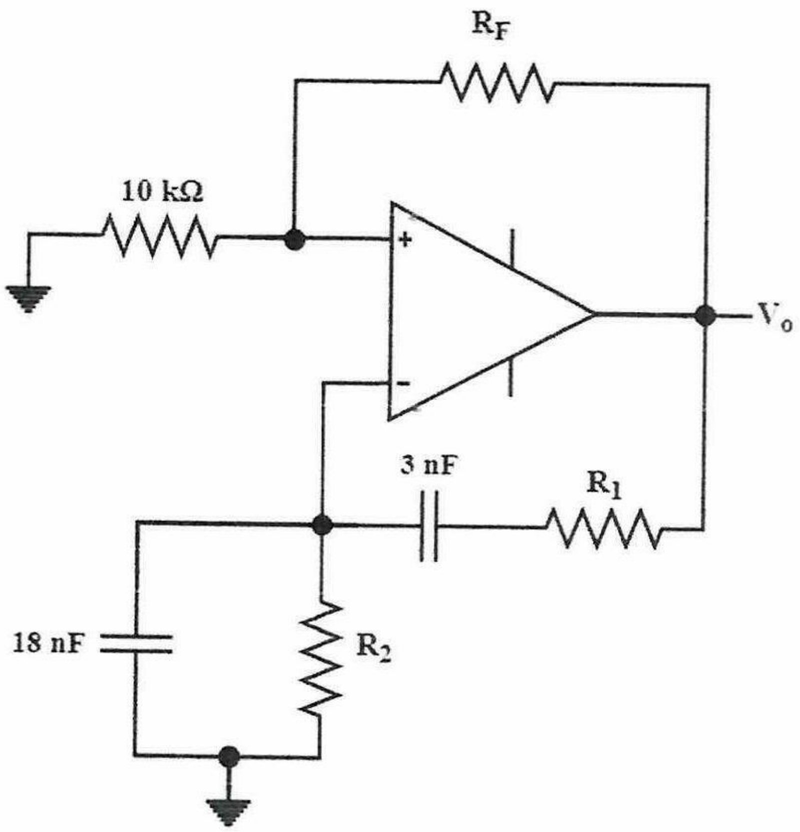

Figure Q4.1

(b) In **Figure Q4.2**, if the range of oscillating frequency is 5 kHz < f < 20 kHz, determine the range of R_2 to produce those frequency values.

(9 marks)

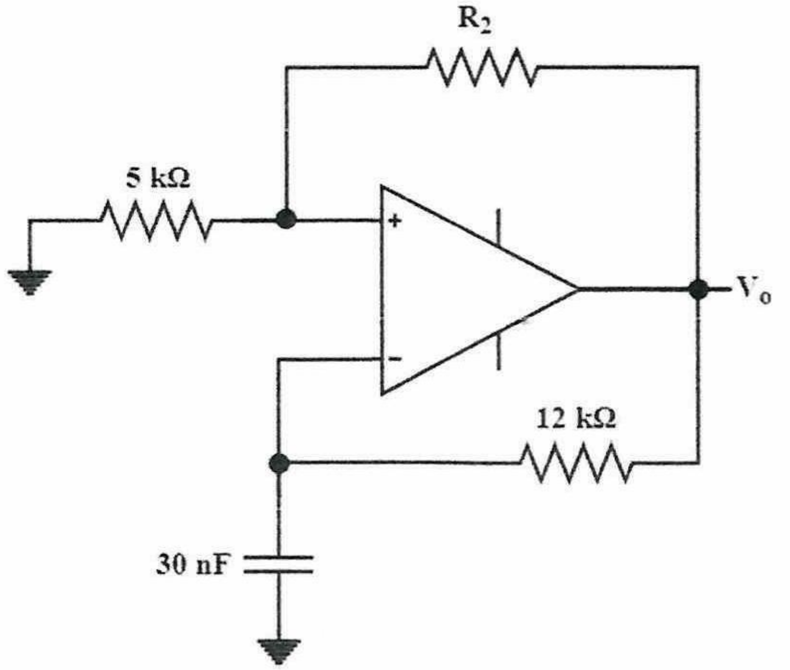

Figure Q4.2

(c) Describe the importance of input trigger signal in monostable operation of 555 timer. Use the appropriate formula in your analysis.

(4 marks)

Q5 Answer the following questions.

(a) **Figure Q5.1** shows a full wave bridge circuit with a capacitor filter. Given capacitor, C = 2200 μF, forward diode voltage, V_{diode} = 0.7 V and DC current, I_{dc} = 0.1 V.

(i) Calculate the peak voltage at secondary winding, $V_{p(sec)}$, output average voltage, V_{dc} and peak-to-peak ripple voltage, $V_{r(p-p)}$.

(6 marks)

(ii) Draw the output waveforms of V_{sec} and V_o.

(4 marks)

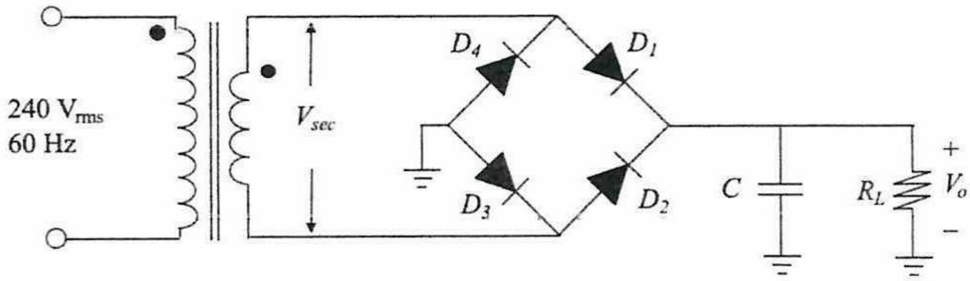

Figure Q5.1

(b) An additional RC filter is connected to the circuit in **Figure Q5.1**. Compare and conclude on the old and new ripple factor, r(%) if the value R and C are 100 Ω and 470 μF, respectively. Use R_L = 200 Ω.

(6 marks)

(c) Determine the minimum and maximum output voltages for voltage regulator in **Figure Q5.2** if given R_1 = 150 Ω and R_2 is a potentiometer with maximum resistance of 5 kΩ. Assume I_{ADJ} = 70 μA and V_{ref} = 2.5 V.

(4 marks)

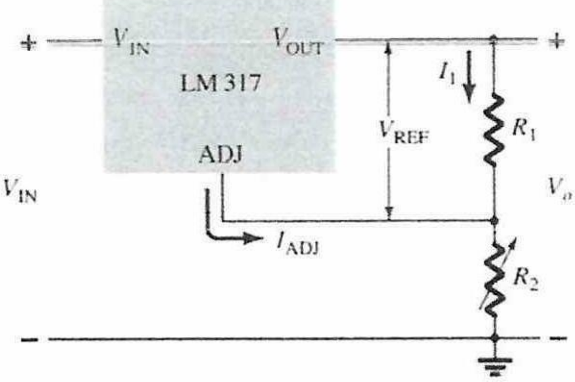

Figure Q5.2

- END OF QUESTIONS -

APPENDIX A

Table APPENDIX A.1 List of Formula

Item	Formula
Inverting Amplifier	$A_V = \frac{V_o}{V_i} = -\frac{R_f}{R_1}$
Non-Inverting Amplifier	$A_V = \frac{V_o}{V_i} = 1 + \frac{R_f}{R_1}$
Inverting Summing Amplifier	$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$
Non-Inverting Summing Amplifier	$V_o = \left(1 + \frac{R_f}{R_1}\right)\left(\frac{R_B}{R_A + R_B}V_A + \frac{R_A}{R_A + R_B}V_B\right)$
Subtracting Amplifier	$V_o = \left(1 + \frac{R_f}{R_1}\right)\left(\frac{R_3}{R_2 + R_3}V_2 - \frac{R_f}{R_1 + R_f}V_1\right)$
Instrumentation Amplifier	$A_T = A_1 A_2 = \frac{v_o}{v_{in}} = \left(1 + \frac{2R}{R_x}\right)\left(\frac{R_4}{R_3}\right)$
Integrator	$V_o(t) = -\frac{1}{RC}\int_{t_0}^{t_1} V_i(t)\, dt + V_o(t_0)$
Differentiator	$V_o(t) = -RC\frac{dV_i(t)}{dt}$
Schmitt Trigger	$V_{UTP \text{ or } LTP} = \frac{R_2}{R_1 + R_2}(\pm V_{out(\max)}) + \frac{R_1}{R_1 + R_2}(V_{REF})$
Cut-Off Frequency for a Filter	$f_c = \frac{1}{2\pi RC}$
1st Order Low Pass Filter	$A_V(s) = \frac{V_o}{V_i} = \left(1 + \frac{R_F}{R_1}\right)\left(\frac{1}{1 + sRC}\right)$
2nd Order Low pass filter	$A_V(s) = \frac{V_o}{V_i}(s) = \frac{A_{VO}}{(RCs)^2 + (3 - A_{VO})RCs + 1}$
1st Order High Pass Filter	$A_V(s) = \frac{V_o}{V_i} = \left(1 + \frac{R_F}{R_1}\right)\left(\frac{1}{1 + \frac{1}{sRC}}\right)$

2nd Order High Pass Filter	$A_V(s)=\frac{V_O}{V_i}(s)=\frac{A_{VO}}{\frac{1}{(sRC)^2}+\frac{3-A_{VO}}{sRC}+1}$
Negative Feedback – Gain	$A_f=\frac{V_o}{V_S}=\frac{A}{1+\beta A}$
Positive Feedback – Gain	$A_f=\frac{A}{1-\beta A}$
Phase Shift Oscillator	$\beta=\frac{V_F}{V_o}=\frac{1}{\left(1-\frac{5}{\omega^2R^2C^2}\right)+j\left(\frac{1}{\omega^3R^3C^3}-\frac{6}{\omega RC}\right)}$ or $\beta=\frac{V_F}{V_o}=\frac{1}{\left(1-5\omega^2R^2C^2\right)+j\left(6\omega RC-\omega^3R^3C^3\right)}$ $f_o=\frac{1}{2\pi RC\sqrt{6}}$ or $f_o=\frac{\sqrt{6}}{2\pi RC}$
Wien Bridge Oscillator	$f_o=\frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$
Colpitts Oscillator	$f_o=\frac{1}{2\pi\sqrt{LC_{eq}}}$ $C_{eq}=\frac{C_1C_2}{C_1+C_2}$
Hartley Oscillator	$f_o=\frac{1}{2\pi\sqrt{CL_{eq}}}$ $L_{eq}=L_1+L_2$
UJT Relaxation Oscillator	$f_o=\frac{1}{R_TC_T\ln\left[1/(1-\eta)\right]}$
Square-Wave Oscillator	$f=\frac{1}{T}=\frac{1}{2RC\ln\left(\frac{1+\beta}{1-\beta}\right)}$ $\beta=\frac{R_3}{R_3+R_2}$
Triangular-Wave Oscillator	$f=\frac{1}{4R_1C}\frac{R_2}{R_3}$
Capacitor Voltage	$v_c(t)=v_c(0)+\left(v_c(\infty)-v_c(0)\right)\left(1-e^{-t/\tau}\right)$ $=v_c(\infty)+\left(v_c(0)-v_c(\infty)\right)e^{-t/\tau}$

Astable Multivibrator	$T_m = t_1 = \tau_2 \ln 2 = 0.693\left(R_1 + R_2\right)C_1$ $T_s = t_2 = \tau_2 \ln 2 = 0.693 R_2 C_1$ $T = T_m + T_s$ $f = \dfrac{1.44}{(R_1 + 2R_2)C_1}$ $D = \dfrac{T_m}{T_m + T_s} \times 100\% = \dfrac{R_1 + R_2}{R_1 + 2R_2} \times 100\%$
Monostable Multivibrator	$T = 1.1\, R_1 C_1$
Ripple Factor	$\% r = \dfrac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \dfrac{V_{r(rms)}}{V_{dc}} \times 100$
Half-Wave Rectifier with a Filter	$V_{r(rms)} = \dfrac{V_{r(p-p)}}{2\sqrt{3}} \approx \dfrac{V_{o(p)}}{2\sqrt{3} f C R_L}$ $V_{o(DC)} = V_{o(p)} - \dfrac{V_{r(p\text{-}p)}}{2}$ $\quad V_{r(p\text{-}p)} \approx \dfrac{V_{o(p)}}{fCR_L} = \dfrac{I_{o(DC)}}{fC}$ $r = \dfrac{V_{r(rms)}}{V_{DC}} \approx \dfrac{1}{2\sqrt{3} f C R_L}$
Full-Wave Rectifier with a Filter	$V_{r(rms)} = \dfrac{V_{r(p-p)}}{2\sqrt{3}} \approx \dfrac{V_{o(p)}}{4\sqrt{3} f C R_L} = \dfrac{I_{DC}}{4\sqrt{3} f C}$ $V_{o(DC)} = V_{o(p)} - \dfrac{V_{r(p\text{-}p)}}{2}$ $\quad V_{r(p\text{-}p)} = \dfrac{I_{o(DC)}}{2fC} \approx \dfrac{V_{o(p)}}{2fCR_L}$ $r = \dfrac{V_{r(rms)}}{V_{DC}} \approx \dfrac{1}{4\sqrt{3} f C R_L}$
Rectifier with Additional RC Filter	$V'_{r(rms)} \approx \dfrac{X_C}{R} V_{r(rms)}$
Inductor Filter	$r = \dfrac{R_L}{3\sqrt{2}\omega L}$ TERBUKA

Shunt Regulator	$V_o \cong V_B\left(\dfrac{R_1+R_2}{R_2}\right)$ $V_B = V_Z + V_{BE}$ $V_o \cong \left(\dfrac{R_1+R_2}{R_2}\right)(V_Z)$
Series Regulator	$V_o = \dfrac{R_1+R_2}{R_1}(V_Z + V_{BE})$ $V_o = V_Z\left(\dfrac{R_1+R_2}{R_1}\right)$
Adjustable IC Regulator	$V_o = V_{ref}\left(1+\dfrac{R_2}{R_1}\right) + I_{adj}\,R_2$