UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2017

Module Number: EE3301 **Module Name: Analog Electronics**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

All notations have their usual meanings.

Q1 a) Figure Q1 a) shows a bias circuit of an amplifier with load R_L. The voltage gain of the amplifier is $(- r_L/r_e)$ where $r_L = R_C//R_L$ and r_e is the internal emitter resistance of the transistor.

i) State the parameters that can affect the bias point of the circuit in Figure Q1 a).

ii) Give a bias point stabilized amplifier circuit based on Figure Q1 a).

iii) Explain the stabilization procedure in the circuit for an increase in collector current Ic.

iv) Give the AC equivalent circuit and express the voltage gain for the bias stabilized amplifier.

v) Modify the circuit in part a) ii) to minimize the reduction in voltage gain for AC signals while maintaining the DC bias.

[5 Marks]

b) Figure Q1 b) shows a RC coupled two stage amplifier circuit. Derive an expression for overall voltage gain (V_L/V_S) for this mutistage amplifier. Assume the transistors Q1 and Q2 are identical.

[5 Marks]

Q2 a) i) State two differences between a JFET (Junction Field Effect Transistor) and a MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

ii) Explain why the self-bias technique is more stable than the fixed-bias technique for a JFET.

[2 Marks]

b) The JFET in the common source amplifier circuit shown in Figure Q2 b) has $I_{DSS} = 10$ mA, $V_P = -4$ V and $r_d = 98$ kΩ.

i) Find the Q point values of I_D and V_{DS} and confirm that the Q point is in the active region.

ii) Find the value of Transconductance (g_m).

iii) Draw the small signal ac equivalent circuit and find the voltage gain.

iv) Redraw the small signal AC equivalent circuit if the source resistor (1 kΩ) is un-bypassed.

[6 Marks]

c) i) Explain how an N-Channel Depletion type MOSFET can be operated in Enhancement mode.

ii) Reproduce the N-Channel Enhancement type MOSFET drain and transfer characteristics and indicate the different regions of the curve.

[2 Marks]

Q3 a) i) Give an operational amplifier based ideal integrator circuit and demonstrate the integration process.

ii) Give an operational amplifier based practical integrator circuit, its frequency response and indicate the integration region.

iii) Give a circuit based on passive electronic components that has a frequency response similar to that of the practical integrator in part a) ii).

[4 Marks]

b) i) Describe the use of an operational amplifier as a comparator.

ii) Calculate the input offset voltage that will cause the output to switch from - 8 V to + 8 V for an open loop gain value of A=20,000.

[2 Marks]

c) i) Give the circuit based on a single operational amplifier for voltage subtraction of two signals.

ii) Evaluate the limitations imposed by the circuit in part i).

iii) Synthesize a circuit that removes the limitations in part ii)

[4 Marks]

Q4 a) Sketch a block diagram of an oscillator and state the necessary conditions for oscillation.

[1 Mark]

b) Figure Q4 b) shows the circuit for a RC phase shift oscillator. The feedback ratio β is given by

$$\beta = \frac{R^3}{(R^3 - 5RX_c^2) + j(X_c^3 - 6R^2X_c)}$$

where $X_c = (1/\omega C)$ and ω is the angular frequency.

i) Evaluate a value for the operating frequency of the oscillator.

ii) Show that the amplifier must provide a gain of 29 to satisfy the condition for oscillation.

[3.5 Marks]

c) Explain the difference between a Butterworth and a Chebyshev filter considering their frequency responses.

[2 Marks]

d) Using the data in Table 4 and the circuit in Figure Q4 d), design a second order lowpass Chebyshev filter with a cut-off frequency 2.5 kHz and a gain in the passband of 1. The constant $K = 10^{-4}/(fC)$ where f is the desired cut-off frequency in Hz and take $C = 0.05\ \mu F$.

[3.5 Marks]

Q5 a) **Use the Figure Q5 for your answers and attach it to your answer script.**

Figure Q5 shows the first three stages of a basic operational amplifier circuit. The inputs to the circuit are grounded. Assume Q1 and Q2 and the IC is Silicon based.

i) Name the three stages included in the circuit.

ii) Perform the DC analysis to show that the DC voltage at the collectors of Q1 and Q2 are +10 V.

iii) State the other two stages needed to complete the basic operational amplifier circuit.

[7 Marks]

b) i) Give the inverting operational amplifier circuit and its corresponding feedback block diagram.

ii) Express the feedback ratio β in terms of the resistors in the circuit.

iii) Show that the voltage gain of the amplifier is given by (1/ β).

[3 Marks]

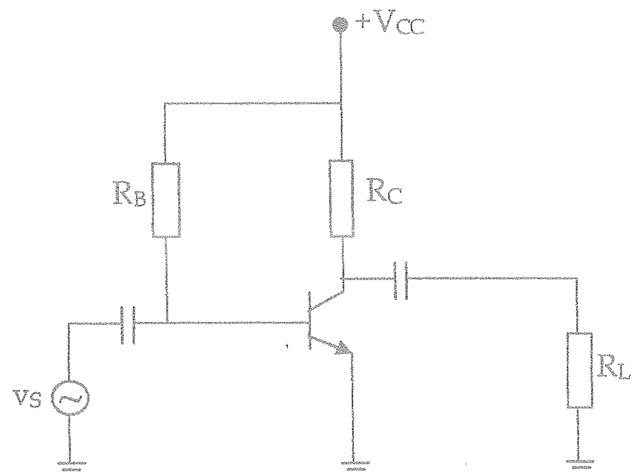

Figure Q1 a)

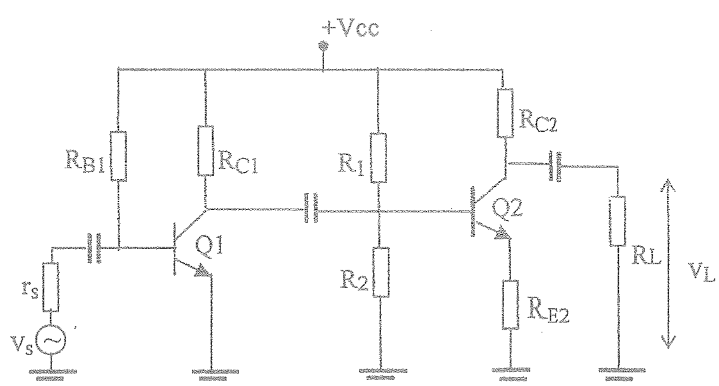

Figure Q1 b)

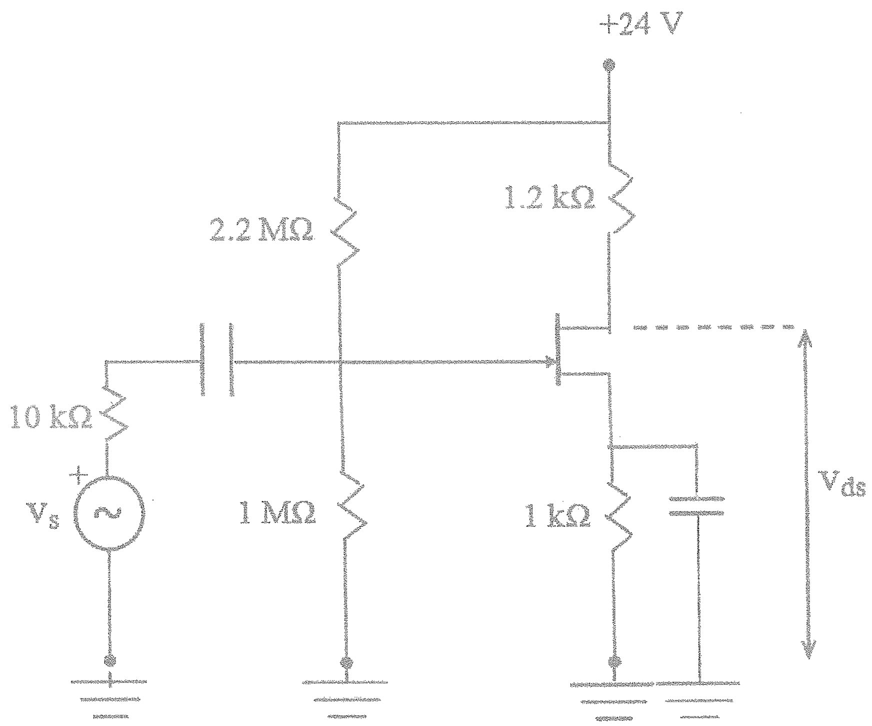

Figure Q2 b)

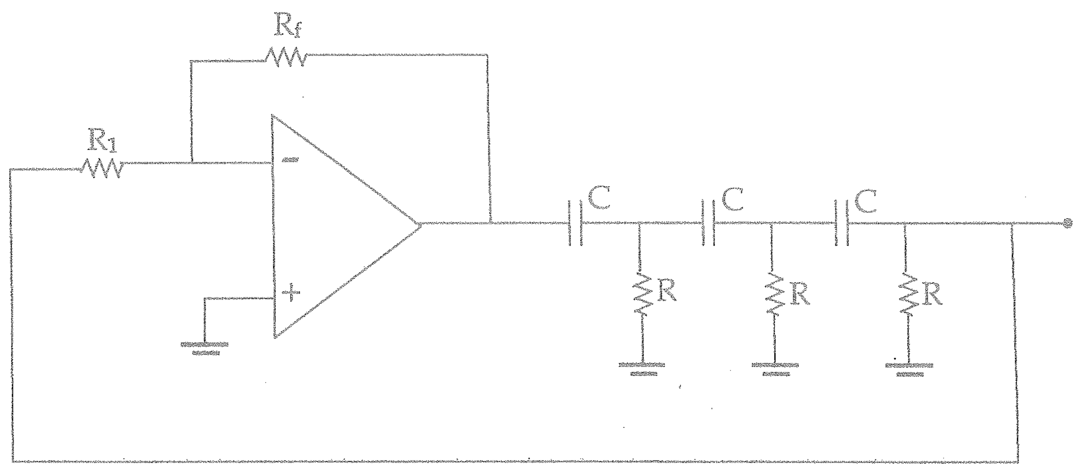

Figure Q4 b)

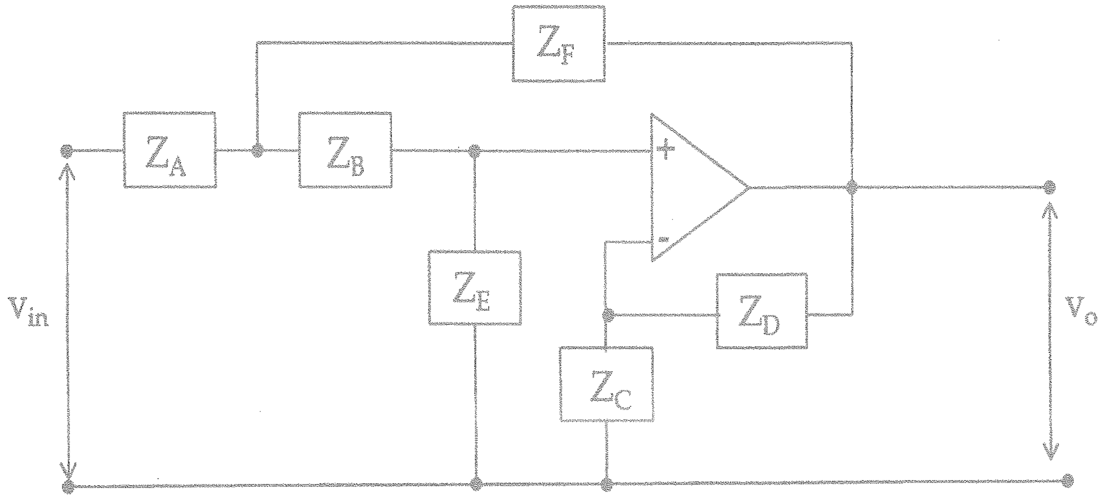

Figure Q4 d)

TABLE 4

Table 14–1
VCVS Filter Components

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low-Pass Filter	R_1	R_2	R_3	R_4	C_1	C
High-Pass Filter	C	C	R_3	R_4	R_2	R_1

Table 14–2
Second-Order Low-Pass Butterworth VCVS Filter Designs

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	1.422	1.126	0.824	0.617	0.521	0.462
R_2	5.399	2.250	1.537	2.051	2.429	2.742
R_3	Open	6.752	3.148	3.203	3.372	3.560
R_4	0	6.752	9.444	16.012	23.602	32.038
C_1	0.33C	C	2C	2C	2C	2C

[a] Resistances in kilohms for a *K* parameter of 1.

Table 14–3
Second-Order Low-Pass Chebyshev VCVS Filter Designs (2 dB)

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	2.328	1.980	1.141	0.786	0.644	0.561
R_2	13.220	1.555	1.348	1.957	2.388	2.742
R_3	Open	7.069	3.320	3.292	3.466	3.670
R_4	0	7.069	9.959	16.460	24.261	33.031
C_1	0.1C	C	2C	2C	2C	2C

[a] Resistances in kilohms for a *K* parameter of 1.

Table 14–4
Second-Order High-Pass Chebyshev VCVS Filter Designs (2 dB)

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	0.640	1.390	2.117	2.625	3.040	3.399
R_2	3.259	1.500	0.985	0.794	0.686	0.613
R_3	Open	3.000	1.313	0.953	0.784	0.681
R_4	0	3.000	3.939	4.765	5.486	6.133

[a] Resistances in kilohms for a *K* parameter of 1.

Source: Reprinted from *Rapid Practical Designs of Active Filters*, D. Johnson and J. Hilburn.

Use the Figure Q5 for your answer to Q5 a) and attach to your answer script.

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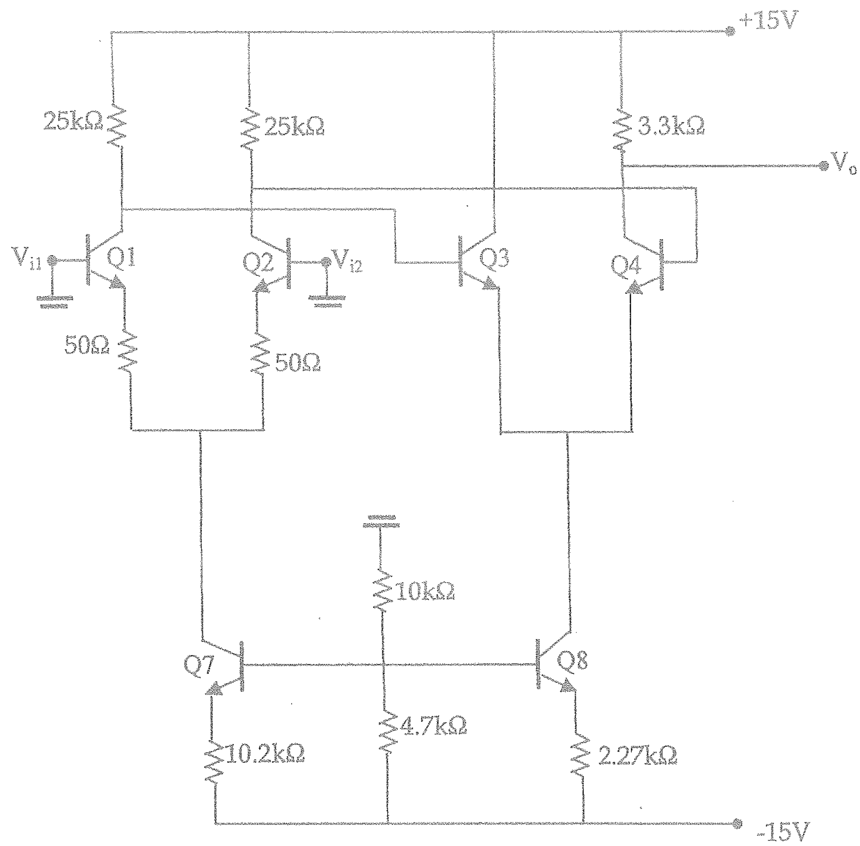

Figure Q5