UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: October 2019

Module Number: EE5208 **Module Name: Electronic Circuit Design**

[Three Hours]

[Answer **all questions**, each question carries **12.5** marks]

Q1 a) Compare "Worst Case Design" and "Non-Worst Case Design" in electronic circuits.

[1.5 Marks]

b) A Zener regulator circuit is shown in Figure Q1 b). The tolerance of R is ± 6%. Input voltage V_{in} = 12 V ± 5% and the output voltage V_o = 7 V ± 5%. You are given two Zener diodes having the rated values given in Table Q1 b). The maximum load current should be kept to 120 mA while the minimum to 0 mA.

i) Stating any assumptions you make, select the suitable zener diode.

ii) Determine a suitable value for R from $E12$ series.

Table Q1 b)

Zener Diode	Rated Voltage	Rated Power
Z_1	7.5 V	1.5 W
Z_2	7.5 V	0.5 W

[6.0 Marks]

c) A BJT (Bipolar Junction Transistor) amplifier circuit is shown in Figure Q1 c). The parameter specifications are given in Table Q1 c). All notations have their usual meaning.

i) Assuming the tolerance of r is ± 5%, derive the worst case equations in order to operate the transistor in its active region.
Hint: Minimum values of I_C and V_{CE} should be greater than their given limits respectively.

ii) Determine a suitable value for r from $E12$ series.

Table Q1 c)

Parameter	Value
V_{CC}	+12 V ± 0.5 V
V_E	1 V ± 0.1 V
β	$\beta_{min} = 110$ and $\beta_{max} = 220$
$I_{C,cut-off}$	1.1×10^{-4} A
$V_{CE,sat}$	0.25 V
R	56 kΩ ± 5%

[5.0 Marks]

Q2 a) A PCB (Printed Circuit Board) provides both a physical structure for mounting

Q2 a) A PCB (Printed Circuit Board) provides both a physical structure for mounting and holding electronic components and the electrical interconnection between components.

i) State three advantages of PCBs.

ii) Classify PCBs according to layers of wiring and compare them considering the component placement, manufacturing cost and complexity.

iii) Give two mechanisms to provide interconnections for a double sided non-plated through hole with relevant sketches.

iv) Discuss the evolution of PCB design techniques.

[4.5 Marks]

b) State two design concerns for each of the followings in a PCB design.

i) Component placement.

ii) Conductor spacing.

[2.0 Marks]

c) The dimensions of two copper conductors used in a PCB design is given in Table Q2 c). The resistivity of copper at room temperature ($T_0 = 20$ °C) is 1.724 μΩcm and the temperature coefficient α of copper is +0.0039 °C^{-1}. Due to the joule effect, maximum temperature T_1 of the conductors rise to 80 °C. Discuss the electrical considerations of the copper conductors when designing the PCB.

Hint: Thermal resistance R_t of a conductor is given by, $R_t = R_0\left[1+\alpha(T_1 - T_0)\right]$ where, R_0 is the conductor resistance at room temperature.

Table Q2 c)

Dimension	Conductor 1	Conductor 2
Width of the conductor	1 mm	0.3 mm
Copper thickness	35 μm	35 μm
Length of the conductor	5 mm	10 cm

[3.0 Marks]

d) State the two basic capacitor considerations involved in PCB design. Give at least one precaution to minimize the corresponding capacitance in each consideration.

[3.0 Marks]

Q3 a) i) Explain with relevant sketches, how a Depletion type NMOSFET (N-channel Metal Oxide Semiconductor Field Effect Transistor) can be used both in Depletion and Enhancement modes.

ii) Explain why self-bias is impossible with Enhancement type NMOSFETs.

[2.5 Marks]

b) i) Reproduce the Enhancement type NMOSFET drain and transfer characteristics.

ii) Prove that the Transconductance g_m for an Enhancement type NMOSFET is given by,

$$g_m = \beta\left(V_{GS} - V_T\right) \text{ Siemens with the usual notations.}$$

Hint: Use the transfer characteristic curve in Q3 b) i).

[2.0 Marks]

c) Figure Q3 c) shows an Enhancement type NMOSFET circuit where the threshold voltage $V_T = 2$ V and ac drain resistance $r_d = 75$ kΩ. The coefficients of the quadratic equation for the drain current I_D are, $A = 2.5 \times 10^5$, $B = -7.74 \times 10^3$ and $C = 13.98$. All notations have their usual meaning.

i) Verify that the MOSFET is operating as an amplifier.
ii) Determine the value of transconductance coefficient β.
iii) Determine the value of transconductance g_m.
iv) Determine the input resistance of the MOSFET.
v) Draw the small signal ac equivalent circuit.
vi) Determine the overall voltage gain.
vii) Explain with relevant sketches, how an Enhancement type NMOSFET can be used as a nonlinear resistor.

[8.0 Marks]

Q4 a) In an audio amplifier, there is a requirement to separate the amplified output based on frequency. Further, one of the outputs should include frequencies from 0 kHz to 12 kHz of the signal. You are asked to design a Butterworth low-pass filter for the above requirement. Assume that the allowed transition band is from 12 kHz to 17 kHz and the stopband introduces an attenuation of -8 dB. For the Butterworth filter, the magnitude of the transfer function is given by,

$$|H(j\omega)| = \frac{1}{\sqrt{1+\omega^{2n}}}$$ where, ω is the normalized frequency.

i) Determine the value of n which satisfies the above requirement.
ii) Select the integer number for the filter order based on the findings in Q4 a) i). Give reasons for the answer.

[2.5 Marks]

b) i) Give the first order low-pass and high-pass active filter circuits for the non-inverting case.
ii) Give the second order low-pass and high-pass active filter circuits for the non-inverting case using the Sallen-Key topology.

[2.0 Marks]

c) i) Design a practical third order unity-gain Chebyshev low-pass filter with cutoff frequency f_c = 100 kHz using the Sallen-Key topology with the following directions.

Directions: The coefficients and the capacitance values for the filters are shown in Table Q4 c). Design each partial filter and draw them as a combination by specifying the available capacitor values and the resistor values. Make necessary assumptions if required. Refer to Table Q4 c1) and Table Q4 c2) to find the available resistor and capacitor values respectively.

Table Q4 c)

Type	a_i	b_i	Capacitance
Filter 1	$a_1 = 1.8636$	$b_1 = 0.0000$	33 nF
Filter 2	$a_2 = 0.0640$	$b_2 = 1.1931$	680 pF

ii) You are asked to design a practical band-pass filter to include frequencies from 50 kHz to 100 kHz. Design the required band-pass filter by cascading a third order unity-gain Chebyshev high-pass filter to your design in Q4 c) i). Assume you are given 100 nF capacitors for the high-pass filter section.

[8.0 Marks]

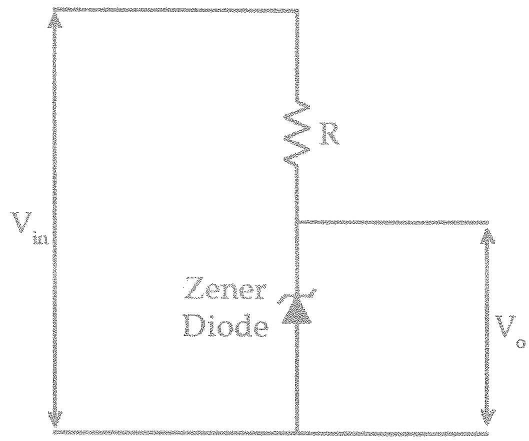

Figure Q1 b)

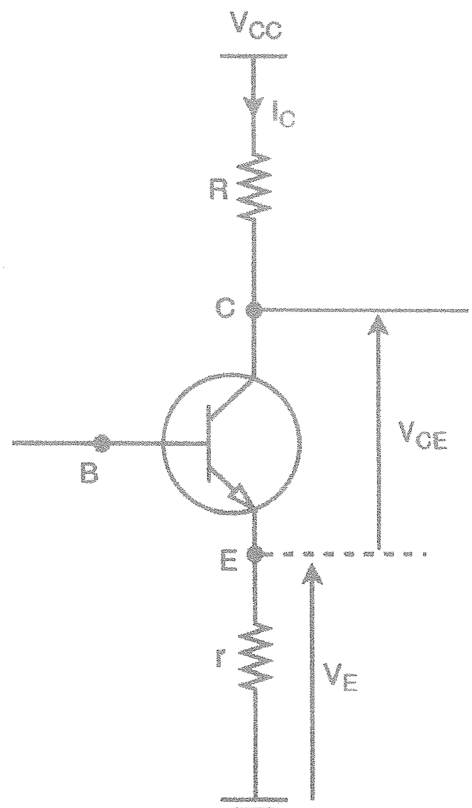

Figure Q1 c)

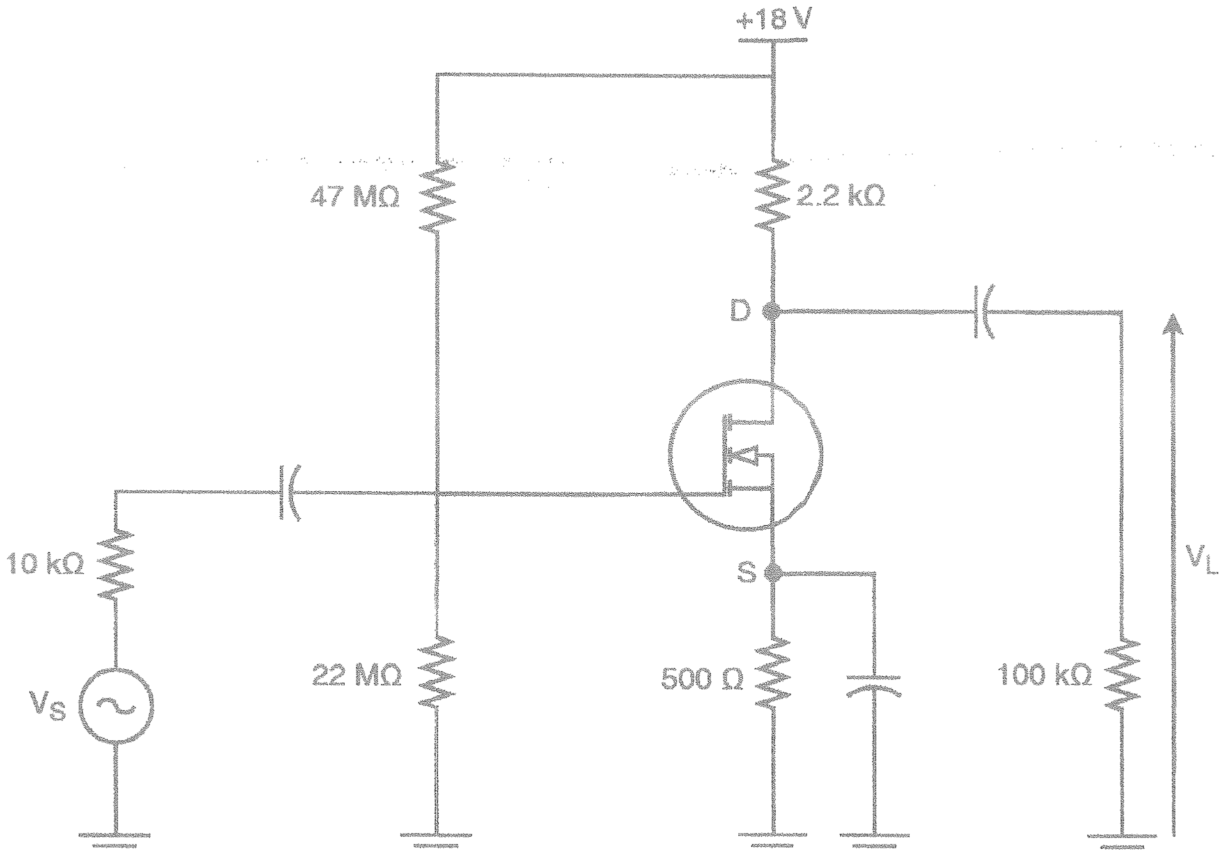

Figure Q3 c)

Table Q4 c1): E96 Resistor Series

100	102	105	107	110	113	115	118	121	124	127	130
133	137	140	143	147	150	154	158	162	165	169	174
178	182	187	191	196	200	205	210	215	221	226	232
237	243	249	255	261	267	274	280	287	294	301	309
316	324	332	340	348	357	365	374	383	392	402	412
422	432	442	453	464	475	487	499	511	523	536	549
562	576	590	604	619	634	649	665	681	698	715	732
750	768	787	806	825	845	866	887	909	931	953	976

Table Q4 c2): Capacitor Letter Codes

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	0.01	0.00001	100	4700	4.7	0.0047	472
15	0.015	0.000015	150	5000	5.0	0.005	502
22	0.022	0.000022	220	5600	5.6	0.0056	562
33	0.033	0.000033	330	6800	6.8	0.0068	682
47	0.047	0.000047	470	10000	10	0.01	103
100	0.1	0.0001	101	15000	15	0.015	153
120	0.12	0.00012	121	22000	22	0.022	223
130	0.13	0.00013	131	33000	33	0.033	333
150	0.15	0.00015	151	47000	47	0.047	473
180	0.18	0.00018	181	68000	68	0.068	683
220	0.22	0.00022	221	100000	100	0.1	104
330	0.33	0.00033	331	150000	150	0.15	154
470	0.47	0.00047	471	200000	200	0.2	254
560	0.56	0.00056	561	220000	220	0.22	224
680	0.68	0.00068	681	330000	330	0.33	334
750	0.75	0.00075	751	470000	470	0.47	474
820	0.82	0.00082	821	680000	680	0.68	684
1000	1.0	0.001	102	1000000	1000	1.0	105
1500	1.5	0.0015	152	1500000	1500	1.5	155
2000	2.0	0.002	202	2000000	2000	2.0	205
2200	2.2	0.0022	222	2200000	2200	2.2	225
3300	3.3	0.0033	332	3300000	3300	3.3	335