UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: May 2023

Module Number: EE5207 **Module Name: Electronic Circuit Design**

[Three Hours]

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

Q1 a) Summarize the types of PCBs based on their applications.

[1.5 Marks]

b) i) What are the two types of double-sided PCB connections? Explain with diagrams.

ii) State the three basic rules in layout designing.

[3.5 Marks]

c) Draw a simple sketch to illustrate the placement of the following types of components.

i) High-Speed components
ii) Medium-Speed components
iii) Slow-Speed components
iv) Connectors
v) External cables/ wires

[2.5 Marks]

d) Define the two etching techniques and two problems that could occur during the etching process.

[4.0 Marks]

e) State two advantages of PCB designing.

[1.0 Mark]

Q2 a) Table 1 lists the parameter values used to determine the potential resultant effect of a CLR capacitor drift on circuit applications. Using the given table calculate the following.

i) The total negative, positive, and random variations of the capacitor.
ii) Worst case minimum and maximum.
iii) Worst case minimum and maximum capacitances.

[4.0 Marks]

b) Considering the following circuit given in Figure Q2.1, find the possible voltage range across the A and B points when the tolerance value for both resistors is 5 %.

[4.0 Marks]

c) Calculate the maximum and minimum Zener currents in the voltage regulator circuit given below in Figure Q2.2.

$V_{IN} = 8\ V \sim 12\ V\ \pm 10\ \%$
$R_S = 3\ k\Omega\ \pm 10\ \%$
$R_L = 10\ k\Omega\ \pm 10\ \%$
$V_{Zener\ (ON)} = 5\ V$

[4.5 Marks]

Q3 a) Define the following modes of an N-type MOSFET.
i) Depletion mode
ii) Enhancement mode

[1.0 Mark]

b) Draw the transfer characteristics curve of an N-type enhancement MOSFET (eMOSFET) and briefly explain its operation in possible regions.

[2.0 Marks]

c) Consider the N-type eMOSFET amplifier implied with the voltage divider bias method, given in Figure Q3. Answer the following questions assuming that $V_{TH} = 1.8\ V$, $\beta = 0.9\ mA/V^2$, $r_d = 60\ k\Omega$ and $I_{D(ON)} = 2.5\ mA$.
i) Show that NMOSFET is in its biased mode.
ii) Find the transconductance of the NMOSFET.
iii) Simplify the circuit shown in Figure 01, into an AC equivalent circuit.
iv) Derive the equations for input resistance (r_{in}) and voltage gain (A_V) of the equivalent circuit.
v) Calculate r_{in} and A_V.

[9.5 Marks]

Q4 a) i) Sketch the response curve for a first-order low-pass filter and mark critical frequency, roll-off rate, bandwidth, and transition region on the curve.

ii) Draw a second-order low-pass filter using Sallen Key topology and state the specific component that affects the shaping of the response curve near to the edge of the pass band.

[2.0 Marks]

b) Design a fifth-order unity gain Butterworth low pass filter with a 50 kHz critical frequency. Assume that the capacitor value of the 1st pole is 10 nF, 3rd pole is 680 pF, and 5th pole is 220 pF. (You may use the tables and value charts attached at the end of the paper.)

[6.0 Marks]

c) List one benefit and one drawback for each active filtering approach in the list below.
i) Butterworth
ii) Bessel
iii) Chebyshev

[1.5 Marks]

d) Design a third-order unity gain Bessel high pass filter with a 3 kHz corner frequency. The capacitor value is 220 nF.
(You may use the tables and value charts attached at the end of the paper. State any assumption you make.

[3.0 Marks]

Table 1: Parameter values of a 100 µF CLR capacitor.

Parameters (Capacitance)	Bias (%)		Random (%)
	Negative	Positive	
Initial Tolerance at 25 °C			20
Low Temperature (-30 °C)	35		
High Temperature (+85 °C)		22	
Other-Envt's (Hard Vacuum)	20		
Radiation (10KR, 10^{13} N/cm^2)		17	
Aging			6

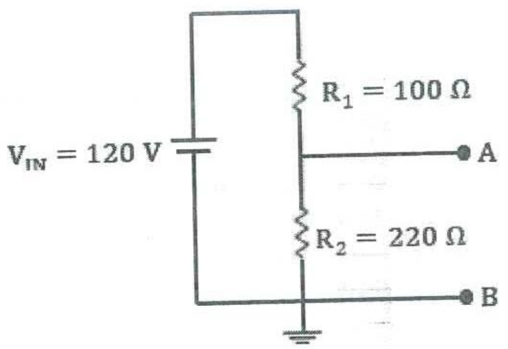

Figure Q2.1: Voltage divider circuit.

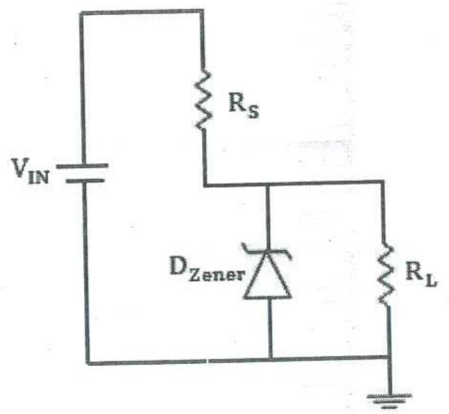

Figure Q2.2: Zener regulator circuit.

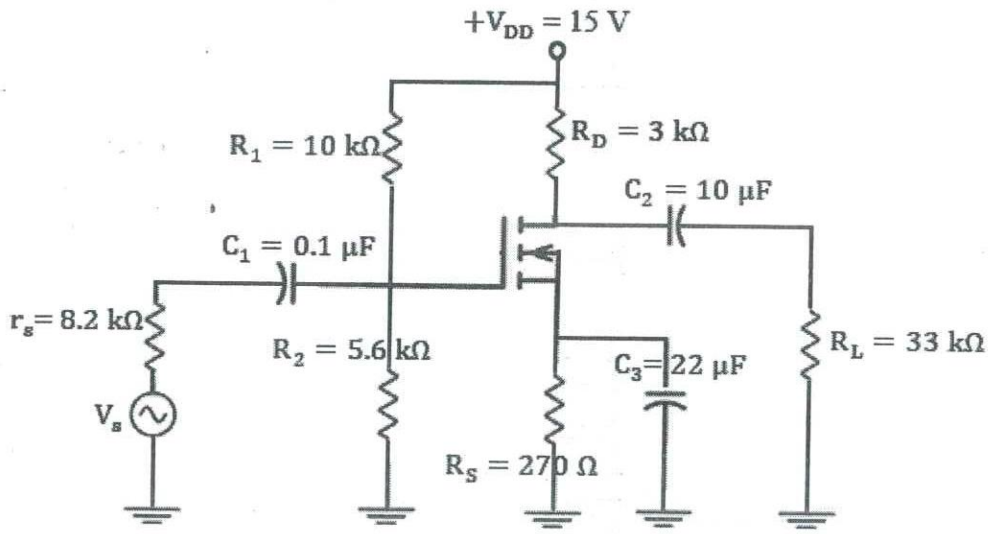

Figure Q3: N-type eMOSFET amplifier implied with the voltage divider bias method.

Table 2: Standard Resistor Values

1.0	10	100	1.0 k	10 k	100 k	1.0 M
1.1	11	110	1.1 k	11 k	110 k	1.1 M
1.2	12	120	1.2 k	12 k	120 k	1.2 M
1.3	13	130	1.3 k	13 k	130 k	1.3 M
1.5	15	150	1.5 k	15 k	150 k	1.5 M
1.6	16	160	1.6 k	16 k	160 k	1.6 M
1.8	18	180	1.8 k	18 k	180 k	1.8 M
2.0	20	200	2.0 k	20 k	200 k	2.0 M
2.2	22	220	2.2 k	22 k	220 k	2.2 M
2.4	24	240	2.4 k	24 k	240 k	2.4 M
2.7	27	270	2.7 k	27 k	270 k	2.7 M
3.0	30	300	3.0 k	30 k	300 k	3.0 M
3.3	33	330	3.3 k	33 k	330 k	3.3 M
3.6	36	360	3.6 k	36 k	360 k	3.6 M
3.9	39	390	3.9 k	39 k	390 k	3.9 M
4.3	43	430	4.3 k	43 k	430 k	4.3 M
4.7	47	470	4.7 k	47 k	470 k	4.7 M
5.1	51	510	5.1 k	51 k	510 k	5.1 M
5.6	56	560	5.6 k	56 k	560 k	5.6 M
6.2	62	620	6.2 k	62 k	620 k	6.2 M
6.8	68	680	6.8 k	68 k	680 k	6.8 M
7.5	75	750	7.5 k	75 k	750 k	7.5 M
8.2	82	820	8.2 k	82 k	820 k	8.2 M
9.1	91	910	9.1 k	91 k	910 k	9.1 M

Table 3: Standard Capacitor Values

Picofarad pf	Nanofarad nf	Microfarad uf	Code	Picofarad pf	Nanofarad nf	Microfarad uf	Code
10	0.01	0.00001	100	4700	4.7	0.0047	472
15	0.015	0.000015	150	5000	5	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	0.01	104
330	0.33	0.00033	331	150000	150	0.15	154
470	0.47	0.00047	471	200000	200	0.2	204
560	0.056	0.00056	561	220000	220	0.22	224
680	0.068	0.00068	681	330000	330	0.33	334
750	0.075	0.00075	751	470000	470	0.47	474
820	0.082	0.00082	821	680000	680	0.68	684
1000	1	0.001	102	1000000	1000	1	105
1500	1.5	0.0015	152	1500000	1500	1.5	155
2000	2	0.002	202	2000000	2000	2	205
2200	2.2	0.0022	222	2200000	2200	2.2	225
3300	3.3	0.0033	332	3300000	3300	3.3	335

Table 4: Butterworth Coefficients

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.4142	1.0000	1.000	0.71
3	1	1.0000	0.0000	1.000	—
	2	1.0000	1.0000	1.272	1.00
4	1	1.8478	1.0000	0.719	0.54
	2	0.7654	1.0000	1.390	1.31
5	1	1.0000	0.0000	1.000	—
	2	1.6180	1.0000	0.859	0.62
	3	0.6180	1.0000	1.448	1.62
6	1	1.9319	1.0000	0.676	0.52
	2	1.4142	1.0000	1.000	0.71
	3	0.5176	1.0000	1.479	1.93
7	1	1.0000	0.0000	1.000	—
	2	1.8019	1.0000	0.745	0.55
	3	1.2470	1.0000	1.117	0.80
	4	0.4450	1.0000	1.499	2.25

Table 5: Bessel Coefficients

n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.3617	0.6180	1.000	0.58
3	1	0.7560	0.0000	1.323	—
	2	0.9996	0.4772	1.414	0.69
4	1	1.3397	0.4889	0.978	0.52
	2	0.7743	0.3890	1.797	0.81
5	1	0.6656	0.0000	1.502	—
	2	1.1402	0.4128	1.184	0.56
	3	0.6216	0.3245	2.138	0.92