UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2021

Module Number: EE3301   **Module Name: Analog Electronics (N/C)**

[Three Hours]

[Answer all questions, each question carries 10 marks]

Q1 a) Draw the following circuit diagrams and draw comparison of input/output waveforms with amplitude
- i)   Half Wave Rectifier Circuit with silicon diode with $\pm V_m$ as input
- ii) Series negative clipping circuit with ideal diode with $\pm V_m$ as input
- iii) Negative parallel clipping circuit with silicon diode with $\pm V_m$ as input

[3.0 Marks]

b) The input to a full wave rectifier circuit is a sine wave with peak to peak voltage of 20 V centered at zero. Calculate the root mean square (rms) voltage of the output.

[1.0 Mark]

c) i)   Draw the circuit for a silicon diode used in a parallel negative clipper circuit with biasing.

[1.0 Mark]

   ii) In the circuit in c) i), assume a sine wave input with peak-peak voltage of 10 V, biasing voltage of 6 V, with a load of 10 kΩ and a series resistance of 10 kΩ. Draw the input and output waveform and indicate significant voltage values. Show the calculations for the voltage values.

[2.0 Marks]

d) i)   State two possible ways of reducing ripple in a bridge rectifier?

[1.0 Mark]

   ii) Derive the root mean square (rms) voltage for a saw tooth ripple with period of T and peak to peak voltage of V_{pp} shown in Figure Q1. Show all the steps in the derivation.

[2.0 Marks]

Q2 a) i)   Give the circuit of a Non-Inverting amplifier and derive an expression for its voltage gain.
   ii) Give a voltage follower based on a) i).
   iii) Evaluate the feedback model for the Non-Inverting amplifier in a) i) and show that the voltage gain is $1/\beta$ where β is the feedback ratio.

[5.0 Marks]

b) Sketch the frequency response characteristic of an operation amplifier and define the Gain Bandwidth Product (GBP) in relation to the sketch.

[1.0 Mark]

c) i) An operational amplifier has gain A and is driven by a sinusoidal input signal $E \sin(\omega t)$. Derive a general expression for the slew rate of the amplifier as a function of frequency f of the input signal.

ii) An amplifier has gain = 10 and slew rate = 1 V/ µs. Calculate the highest frequency of a sinusoidal signal that can be amplified without distortion.

[4.0 Marks]

Q3 a) To minimize input offset currents in operational amplifier circuits a compensating resistor R_c is used. Calculate a value for R_c.

[3.0 Marks]

b) If the input offset voltage is V_{io} derive an expression for the output offset voltage V_{os} and comment on your result.

[1.0 Mark]

c) Figure Q3 shows the pin configuration layout for the popular 741 operational amplifier.
   i) Number the pin configuration and denote the input, output and DC supply pins.
   ii) Show the other pins that are normally used and there function.
   iii) Assuming the 741 amplifier to be ideal, state the desired values for Gain, Input and output resistance, GBP and input offset voltage.

[3.0 Marks]

d) i) Give the circuit and derive the output for an operational amplifier based ideal integrator and explain its operation for a sinusoidal input signal $E \sin(\omega t)$.
   ii) Explain the modification to the circuit in d) i) to realize a practical integrator and explain the effect of the modifications in the frequency response characteristics.

[3.0 Marks]

Q4 a) i) Sketch the ideal and practical frequency response characteristics for the four basic types of filters.
   ii) Explain the effect of the order of the filter in low-pass and high-pass filters.
   iii) For an ideal band-pass filter, define the cutoff frequencies ω_l and ω_u, center frequency ω_0, bandwidth B and quality factor Q.

[3.0 Marks]

b) i) The transfer function $H(j\omega)$ of a second order band-pass filter is given by

$$H(j\omega) = \frac{K}{1 + jQ\left(\dfrac{\omega}{\omega_0} - \dfrac{\omega_0}{\omega}\right)}$$

Calculate the lower and upper cutoff frequencies for this filter.

Hint: The cutoff frequencies are at $|H(j\omega c)| = K / \sqrt{2}$

ii) Sketch Bode plots (magnitude and phase) for this filter for $Q = 1$ and $Q = 3$.

[4.0 Marks]

c) An example of a wideband band-pass filter is two RC low-pass and high-pass filters put back to back.
  i) Give the circuit for this wideband band-pass filter.
  ii) Specify under what conditions the filter transfer function can be described by the product of the individual transfer functions and the resultant transfer function.

[3.0 Marks]

Q5 a) i) State the difference between a passive and an active filter.
  ii) Describe the difference between a Butterworth and a Chebyshev filter.
  iii) Figure Q5 a) gives the VCVS or Sallen-Key design for second-order Butterworth and Chebyshev filters. Table 5 gives tables for determining the component values for the circuit.
  Design a second-order low-pass Chebyshev filter with cut-off frequency 2.5 kHz. The gain in the pass band should be 2.

  Notes: $K = 10^{-4}/fC$ and take $C = 0.05$ μF and use sub Table 14-2 in Table 5 for the gain.

  iv) Explain the value (2 dB) appearing in sub Tables 14-3 and 14-4 in Table 5.

[4.0 Marks]

b) i) Describe the Berkhausen Criterion for a system to oscillate.
  ii) Give the circuit of a RC phase shift oscillator where the feedback path consists of three RC networks in cascade.
  iii) The feedback ratio in the RC phase shift oscillator circuit in b) ii) circuit is given by

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

where $Xc = 1/\omega C$

Calculate the oscillator frequency and the gain required of the amplifier.

[4.0 Marks]

c) i) State the difference between an oscillator and a Multivibrator.
  ii) Figure Q5 b) shows an Astable Multivibrator circuit. Explain its operation.
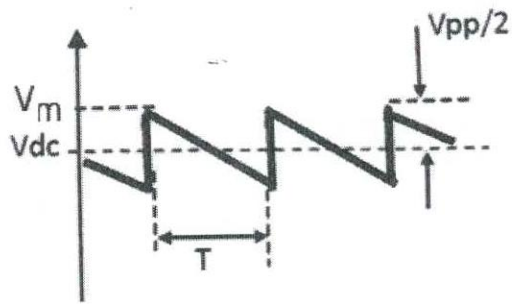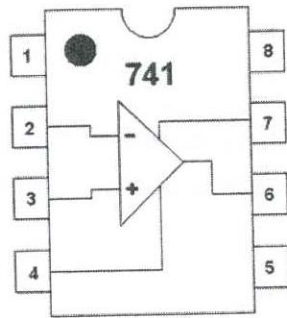
[2.0 Marks]

Figure Q1
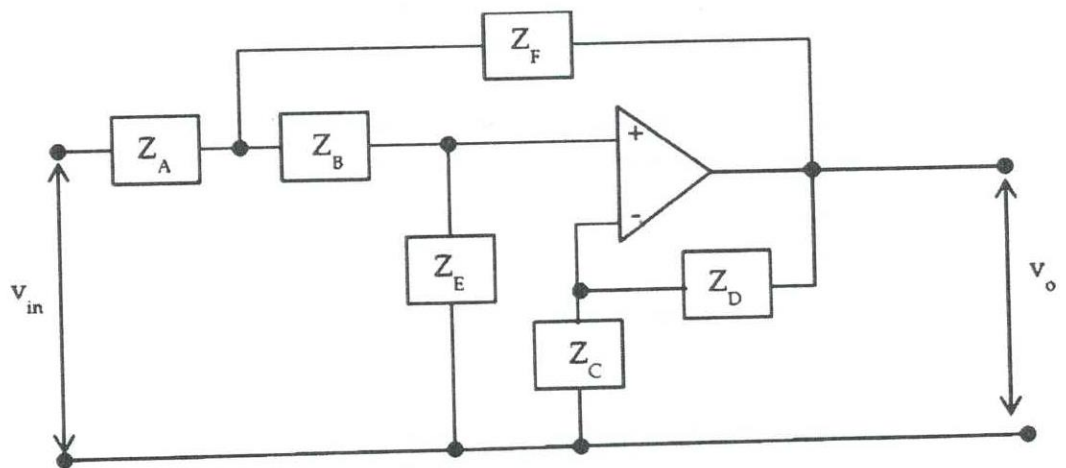

Figure Q3: 741 Operational amplifier pin layout

Figure Q5 a): Sallen-Key circuit
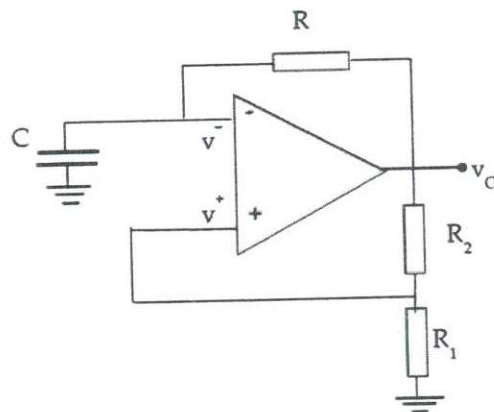
Figure Q5 b): Astable Multivibrator

Table 5.

Table 14–1
VCVS Filter Components

	Z_A	Z_B	Z_C	Z_D	Z_E	Z_F
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

Gain	Circuit Element Values[a]					
	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)

Gain	Circuit Element Values[a]					
	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)

Gain	Circuit Element Values[a]					
	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.