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(NEP—2020)

(5th Semester)

ELECTRONICS (MAJOR1)

(Operational Amplifier)

Full Marks : 75

Time : 3 hours

*The figures in the margin indicate full marks for the questions
Employing a simple calculator is required for some of the questions*

(SECTION : A—OBJECTIVE)

(Marks : 10)

Tick (✓) the correct answer in the brackets provided :

1×10=10

1. For an ideal op-amp, the open-loop gain (A_0) tends to

(a) unity ()

(b) infinity ()

(c) zero ()

(d) a finite constant $\sim 10^5$ ()

2. In an inverting amplifier with $R_1 = 10 \text{ k}$ and $R_f = 100 \text{ k}$, the closed-loop gain is approximately

(a) -10 ()

(b) -100 ()

(c) $+10$ ()

(d) $+100$ ()

3. The input impedance of an ideal operational amplifier is

(a) zero ()

(b) very high ()

(c) very low ()

(d) equal to the output impedance ()

4. Slew rate (SR) is the

(a) maximum rate of change of output voltage (V/s) ()

(b) ratio of differential to common-mode gain ()

(c) minimum settling time ()

(d) input offset current ()

5. The -3 dB cut-off frequency of first-order low-pass filter is f_c

(a) $\frac{1}{RC}$ ()

(b) $\frac{RC}{2}$ ()

(c) $\frac{R}{2C}$ ()

(d) $\frac{1}{(2 RC)}$ ()

6. A Butterworth response exhibits magnitude at cutoff equal to

(a) $1/\sqrt{2}$ of passband (-3 dB) ()

(b) one-half of passband (-6 dB) ()

(c) same as passband (0 dB) ()

(d) double the passband ($+6$ dB) ()

7. For an LM317 adjustable regulator (neglect I_{adj}), V_{out} equals

(a) $2.5 (R_1 + R_2)$ ()

(b) $5 (1 + R_1 / R_2)$ ()

(c) $0.7 R_2 / R_1$ ()

(d) $1.25 (1 + R_2 / R_1)$ ()

8. A zero-crossing detector is a comparator whose reference is

(a) $V_{ref} = 5V$ ()

(b) $\frac{V_{CC}}{2}$ ()

(c) $0 V$ ()

(d) $\frac{V_{CC}}{2}$ ()

9. In an n -bit R - $2R$ DAC, the LSB step size equals

(a) $\frac{V_{\text{ref}}}{n}$ ()

(b) $\frac{V_{\text{ref}}}{2^n}$ ()

(c) $\frac{2V_{\text{ref}}}{n}$ ()

(d) $\frac{V_{\text{ref}}}{2^{n-1}}$ ()

10. A successive-approximation ADC typically needs approximately _____ comparisons for an n -bit conversion.

(a) $\log_2 n$ ()

(b) $2n$ ()

(c) n^2 ()

(d) n ()

(SECTION : B—SHORT ANSWERS)

(Marks : 25)

Answer *five* questions, taking at least *one* from each Unit :

5×5=25

UNIT—I

1. Using an inverting summer with $R_1 = R_2 = R_3 = 50 \text{ k}$ and $R_f = 100 \text{ k}$, determine v_0 for inputs $V_1 = 0.25 \text{ V}$, $V_2 = 0.10 \text{ V}$ and $V_3 = 0.15 \text{ V}$ (assume ideal op-amp).

2. A differential amplifier has a differential gain of 500 and a CMRR of 80 dB. If the common-mode input signal is $2 \sin t$ volts, calculate common-mode output voltage.
3. Write concise notes on the slew rate and the full-power bandwidth of an operational amplifier.

UNIT—II

4. Derive the governing expression for a logarithmic amplifier using an operational amplifier, starting from the ideal diode equation and the op-amp virtual ground condition.
5. Design a current source using 7805 voltage regulators to deliver a load current of 0.4 A into a $56 \text{ } / 10 \text{ W}$ load.
6. Using LM317, design an adjustable voltage regulator to satisfy the following specifications :
Output voltage $V_O = 10$ to 12 V and output current $I_O = 200 \text{ mA}$. Draw the complete circuit diagram and incorporate the component values.

UNIT—III

7. An 8-bit D/A converter produces 50 mV output for a digital input of 00000001. Determine its full-scale output and resolution. What is the output voltage for an input of 00101000?
8. A 4-bit successive approximation ADC is driven by 2 MHz clock. Find the conversion time.
9. What is a voltage follower circuit? Briefly describe how an operational amplifier can be configured (a) as a comparator and (b) as a zero-crossing detector.

(SECTION : C—DESCRIPTIVE)

(Marks : 40)

Answer *four* questions, taking at least *one* from each Unit :

10×4=40

UNIT—I

1. Design a summing amplifier and derive the expression for its output voltage. Also design a difference amplifier and state the resistor relationship required for $V_O = (R_2 / R_1)(V_2 - V_1)$.
2. Discuss in detail the ideal characteristics of an operational amplifier. Define the concept of a virtual ground, and derive the voltage-gain expressions for the (a) inverting amplifier and (b) non-inverting amplifier.
3. Explain the differential-mode and common-mode operations of a differential amplifier. Derive expressions for A_d , A_{cm} and CMRR, and discuss the impact of finite CMRR on the output of practical op-amp circuits.

UNIT—II

4. Design an instrumentation amplifier using operational amplifiers, and derive the final expression for its overall gain (A_v).
5. Design first-order low-pass and high-pass Butterworth filters using operational amplifier topologies. Derive the transfer function $H(s)$ and identify the cut-off frequency and pass-band gain for each configuration.
6. Derive the standard formulas for the op-amp differentiator and integrator circuits, explicitly stating assumptions for ideal behaviour.

UNIT—III

7. Explain the complete configuration of a successive-approximation analog-to-digital (A/D) converter implemented using operational amplifiers. Illustrate the working principle in detail.

8. Describe the construction and operation of an R - $2R$ ladder digital-to-analog (D/A) converter utilizing operational amplifiers. Explain how binary inputs are converted into an analog output voltage.
9. Design both inverting and non-inverting Schmitt trigger circuits using operational amplifiers. Derive the mathematical expressions for the threshold voltages (V_{UT} and V_{LT}), and illustrate the input-output waveforms and the voltage transfer characteristics.

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