GATE

Instrumentation Engineering

(Previous Years Solved Paper 1994 - 1995)

Contents

MADE EASY PUBLICATIONS

1 Sensors and Industrial Instrumentation

1. Basics of Transducers

1.1 Bellow's expansion is usually against a spring. The spring is provided to
(a) increase sensitivity
(b) increase operating range
(c) increase linearity
(d) decrease hysteresis effect

[1994 : 1 M]

2. Resistive and Inductive Transducers

2.1 A unity ratio quarter bridge strain measuring circuit produces an output of 1 mV for a strain of 500 microstrain when the bridge excitation is 4 Volts. The gauge factor of the element is then
(a) 1 (b) 2
(c) 3 (d) 4

[1994 : 1 M]

2.2 The output of LVDT with input mechanical motion of 10 Hz and excitation frequency 400 Hz will contain frequencies.
(a) 10 Hz and 400 Hz (b) 400 Hz only
(c) 10 Hz only (d) 390 Hz and 410 Hz

[1994 : 2 M]

3. Velocity, Acceleration, Force, Torque & Seismic Measurement

3.1 A weight of 4.9 N rests on a rough horizontal floor that has a coefficient of friction of 0.5. If $g = 9.8$ m/s^2, the smallest horizontal force that gives the weight an acceleration of 4 m/s^2 is approximately
(a) 2.0 N (b) 2.5 N
(c) 4.5 N (d) 19.6 N

[1995 : 2 M]

3.2 With the stroboscope, synchronism has been obtained at the flashing rates of 25 and 20 pulses per second. The speed of rotation is
(a) 0.6 rev/min. (b) 50 rev/min.
(c) 100 rev/min. (d) 6000 rev/min.

[1995 : 2 M]

■■■■

Answers Sensors and Industrial Instrumentation

1.1	(d)	2.1	(b)	2.2	(d)	3.1	(c)	3.2	(d)

Explanations Sensors and Industrial Instrumentation

1. Basics of Transducers

1.1 (d)

Bellows element consists of a cylindrical metal box with corrugated walls of thin springly material like brass or stainless steel. When the pressure inside the bellows in small the springness of the corrugated bellows walls is enough the bring it back in size.

But when pressure to be measured is large, the springness of the corrugated wall is not enough to bring it back in its original size, so springs are installed inside it to avoid hysteresis error and bring it back in size after the removal of the applied pressure.

2. Resistive and Inductive Transducers

2.1 (b)

$$V_0 = \frac{GF}{4} \times \varepsilon \times e_i$$

$$1 \times 10^{-3} = \frac{GF}{4} \times 500 \times 10^{-6} \times 4$$

$$\therefore \quad GF = \frac{4 \times 1 \times 10^{-3}}{500 \times 10^{-6} \times 4} = 2$$

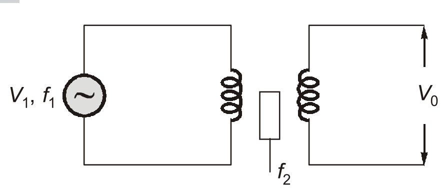
Note:

$$V_0 = \frac{GF \cdot \varepsilon \cdot e_i}{4} \quad \text{(Quarter bridge)}$$

$$V_0 = \frac{GF \cdot \varepsilon \cdot e_i}{2} \quad \text{(Half bridge)}$$

$$V_0 = GF \cdot \varepsilon \cdot e_i \quad \text{(Full bridge)}$$

2.2 (d)



Let excitation be f_1 and mechanical input frequency be f_2.

i.e., $V_i = V_m \sin(2\pi f_1 t)$

and $\chi_i = \chi_m \sin(2\pi f_2 t)$

For LVDT (in linear range)

$$V_0 \propto \chi_i \quad \text{...(i)}$$

also,

$$V_0 \propto V_i \quad \text{...(ii)}$$

$$V_0 = k\chi_i V_i$$

$$\Rightarrow V_0 = k\chi_m \sin(2\pi f_2 t)\, V_m \sin(2\pi f_1 t)$$

$$\Rightarrow V_0 = k' \sin(2\pi f_2 t) \sin(2\pi f_1 t)$$

$$\Rightarrow V_0 = \frac{k'}{2}\left[\cos[2\pi(f_1 - f_2)t]\right] - \cos\left[2\pi(f_1 + f_2)t\right]$$

So, frequencies present in V_0 are,

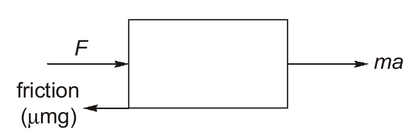
$(f_1 - f_2)$ and $(f_1 + f_2)$

Here, f_1 = 400 Hz and f_2 = 10 Hz

Frequencies present in V_0 are 390 Hz and 410 Hz.

3. Velocity, Acceleration, Force, Torque & Seismic Measurement

3.1 (c)



$$F = \mu mg + ma$$

$$4.9 = mg$$

$$m = \frac{4.9}{g} = \frac{4.9}{9.8} = 0.5 \text{ kg}$$

$$\therefore \quad F = 0.5 \times 0.5 \times 9.8 + 0.5 \times 4$$

$$= 2.45 + 2 = 4.45 \approx 4.5 \text{ N}$$

3.2 (d)

$$\text{Speed of rotation} = \frac{f_1 f_2}{(f_1 - f_2)}$$

$$= \frac{25 \times 20}{25 - 20} = 100 \text{ rev/sec}$$

$$= 6000 \text{ rev/min}$$

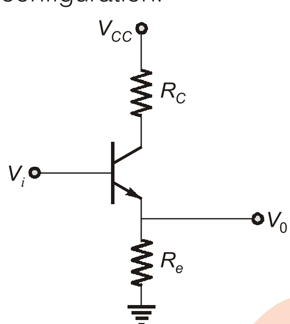
■■■■

2 Analog Electronics

1. BJT, JFET, MOSFET, their Biasing & Frequency Response

1.1 The common collector transistor configuration has the following property:
(a) High input and low output resistances
(b) High input and high output resistances
(c) Low input and low output resistances
(d) low input and high output resistances
[1994 : 1 M]

1.2 The circuit shown in figure is said to be in common _______ configuration.

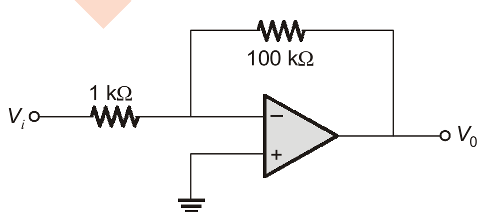


[1995 : 1 M]

1.3 As a switching device, JFET has a very low offset Voltage in the ON state as compared to BJT. (TRUE / FALSE).
[1995 : 1 M]

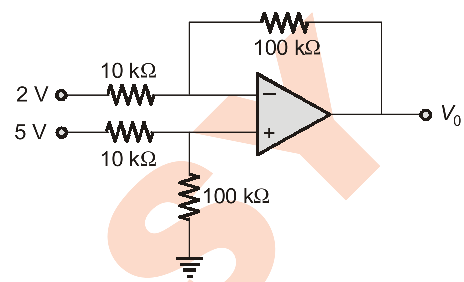
2. Op-Amp and Instrumentation Amplifier

2.1 The input resistance of the op-amp circuit shown in figure is



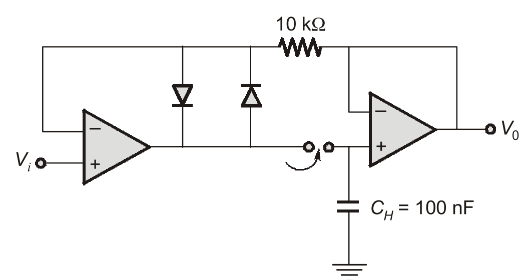
(a) 100 kΩ (b) 99 kΩ
(c) 1 kΩ (d) 101 kΩ
[1994 : 1 M]

2.2 The output voltage V_0 of the circuit shown in the figure is



(a) – 20 V (b) 20 V
(c) – 30 V (d) 30 V [1995 : 1 M]

2.3 For the sample and hold circuit shown in figure both the op-amps have input bias current of 1 nA. The maximum leakage current through the switch is 0.5 nA. The worst case drop rate during the hold operation is ____ mV/m sec.



[1995 : 1 M]

2.4 The Common Mode Rejection Ratio (CMRR) of an op-amp with a common mode gain of 0.01 and a differential mode gain of 10^5 is _____ dB
[1995 : 1 M]

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Answers Analog Electronics

1.1	(a)	1.2	(Sol.)	1.3	(True)	2.1	(c)	2.2	(d)	2.3	(0.15)	2.4	(140)

Explanations Analog Electronics

1. BJT, JFET, MOSFET, their Biasing & Frequency Response

1.1 (a)

Characteristics of common collector transistor configuration are:

Voltage gain low ($A_V < 1$)

High input resistance

Low output resistance

Current gain very high

1.2 Sol.

Circuit shown below is a common collector configuration.

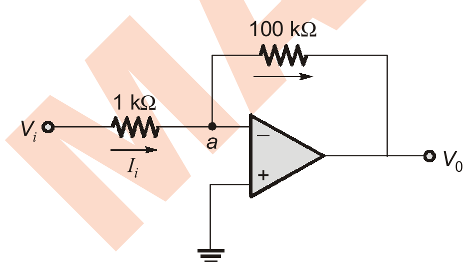
1.3 (True)

2. Op-Amp and Instrumentation Amplifier

2.1 (c)

From the given op-amp circuit input resistance

$$R_i = \frac{V_i}{I_i}$$



KCL at node a

$$\frac{V_i - V_a}{1} = \frac{V_a - V_0}{100}$$

$$\Rightarrow \quad \boxed{V_0 = -100\, V_i} \quad \text{...(i)}$$

$$\because \quad V_a = 0 \quad \text{[Because of virtual ground]}$$

also,
$$I_i = \frac{0 - V_0}{100} \times 10^{-3}$$

$$\Rightarrow \quad V_0 = I_i \times 100 \times 10^3 \quad \text{...(ii)}$$

equating equation (i) and (ii) we get,

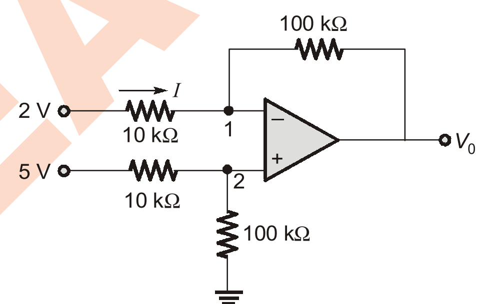
$$\Rightarrow \quad -I_i \times 100 \times 10^3 = -V_0 \times 100$$

$$\Rightarrow \quad \frac{V_i}{I_i} = 10^3$$

$$\boxed{\frac{V_i}{I_i} = 1\,\text{k}\Omega}$$

Hence, option (c) is correct.

2.2 (d)



Given circuit is

$$V_1 = V_2$$

(Because of very high input impedance of the op-amp)

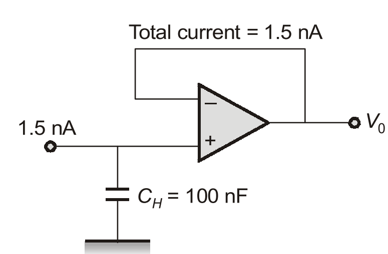
also,
$$V_2 = \frac{100}{110} \times 5 = \frac{500}{110} = \frac{50}{11}\text{ V}$$

$$V_0 = -\frac{100}{10} \times 2\,V + \left(1 + \frac{100}{10}\right) V_2$$

$$= -20 + \left(11 + \frac{50}{11}\right) = -20 + 50 = 30\text{ V}$$

2.3 (0.15)

Redraw the circuit during hold op-amp



During holding,

$$C_H \frac{dV_c}{dt} = 1.5 \text{ nA}$$

$$\frac{dV_c}{dt} = \frac{1.5 \times 10^{-9}}{C} = \frac{1.5 \times 10^{-9}}{100 \times 10^{-9}}$$

$$= 0.15 \text{ V/sec} = 0.15 \text{ mV/m-sec}$$

2.4 **(140)**

Given, $A_{CM} = 0.01$,

$$A_d = 10^6$$

$$\text{CMRR} = \left|\frac{A_d}{A_{CM}}\right| = \frac{10^5}{0.01} = 10^7$$

$$(\text{CMRR})_{\text{dB}} = 20 \log_{10} 10^7 = 140 \text{ dB}$$

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3 Control Systems and Process Control

1. Basics of Control System and Transfer Function

1.1 In a second order instrument, 'K' is the spring constant, 'M' is the mass of the instrument, and 'B' is the damping constant. The damping constant necessary to just prevent overshoot in the step response is

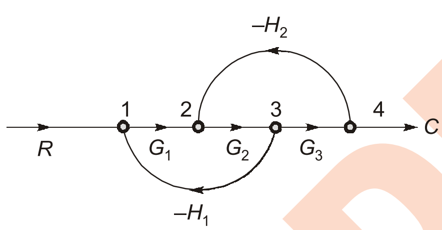
(a) equal to $\sqrt{KM}$ (b) less than $\sqrt{KM}$

(c) greater than $\sqrt{KM}$ (d) equal to $2\sqrt{KM}$

[1994 : 1 M]

2. Block Diagram and Signal Flow Graph

2.1 For the signal flow graph show in figure, the transfer function is $C(s)/R(s)$ = ______.



[1995 : 2 M]

3. Time Response Analysis

3.1 A unity feedback closed loop second order system has a transfer function

$\frac{8}{s^2 + 0.6s + 9}$ and is excited by a step input of 1 unit. The steady state error of the output is

(a) 10 (b) 0.0

(c) 1.0 (d) 0.1 [1994 : 1 M]

3.2 For a unit step input, a system with a closed loop transfer function of

$G(s) = \frac{20}{s^2 + 2s + 5}$ has a steady-state output of

(a) 10 (b) 5

(c) 2 (d) 4 [1995 : 1 M]

4. Stability Analysis

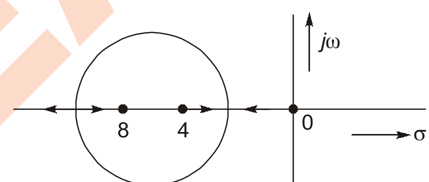
4.1 The condition for stability of a closed-loop system with a characteristic equation $s^3 + bs^2 + cs + 1 = 0$, with positive coefficients is

(a) $b + c > 1$ (b) $bc > 1$

(c) $b = c$ (d) $b > c$ [1995 : 1 M]

5. Root Locus

5.1 The root locus plot of the a unity feedback system is shown in figure. The system transfer function has the form



(a) $\frac{K}{s(s+4)(s+8)}$ (b) $\frac{K(s+8)}{s(s+4)}$

(c) $\frac{K(s+4)}{s(s+8)}$ (d) $\frac{Ks}{(s+4)(s+8)}$

[1994 : 1 M]

5.2 The break away point of the root locus on the real axis for a closed-loop system with a loop gain

$G(s)\,H(s) = \frac{K(s+10)}{(s+2)(s+5)}$ lies

(a) between –2 and origin

(b) between –2 and –5

(c) between – 10 and – ∞

(d) at – ∞ [1995 : 1 M]

6. Frequency Response Analysis, Bode Plot and Nyquist Plot

6.1 A first order system with a transfer function $\frac{1}{1+s}$ is excited by a signal 10 sin$t$. Its steady state output will be

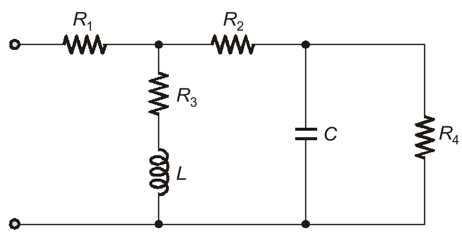
(a) $10\sin\left(2t-\frac{\pi}{4}\right)$ (b) $10\sin\left(t-\frac{\pi}{4}\right)$

(c) $\frac{10}{\sqrt{2}}\sin\left(t-\frac{\pi}{4}\right)$ (d) $\frac{10}{\sqrt{2}}\sin\left(t+\frac{\pi}{4}\right)$

[1994 : 1 M]

7. State Space Analysis

7.1 The minimum number of states required to describe the network shown in the figure is



(a) 1 (b) 2
(c) 3 (d) 4

[1994 : 1 M]

7.2 A first order matrix differential equation of a system is given as

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\ 2\end{bmatrix}u\ ;\ y=[1\ \ 1]\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

(a) Find the transfer function of the system.
(b) Find the solution of the states and the output when the input is a unit step and the initial condition of the states is $\begin{bmatrix}0\\ 1\end{bmatrix}$.

[1994 : 2 M]

8. Process Control

8.1 A first order process has a static gain of 1, a time constant of 1 sec and transport delay of 0.1 sec. Its transfer function is

(a) $\frac{e^{-s}}{1+0.1s}$ (b) $\frac{e^{-10s}}{1+s}$

(c) $\frac{e^{-0.1s}}{1+s}$ (d) $\frac{e^{-0.1s}}{1+0.1s}$

[1994 : 1 M]

8.2 Match the elements and the transfer functions :

(a) pneumatic actuator (e) e^{-sT}
(b) a transport delay (f) K
(c) a servomotor (g) $\frac{K}{as^2+bs+c}$
(d) a nozzle-flapper (h) $\frac{K}{s(1+as)}$

[1994 : 2 M]

8.3 The Laplace transform of a 4 second transportation lag element is

(a) $\frac{1}{s+4}$ (b) e^{4s}

(c) e^{-4s} (d) $e^{-s/4}$ [1995 : 1 M]

■■■■

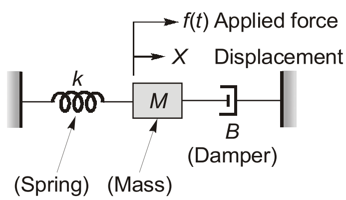
Answers Control Systems and Process Control

1.1	(d)	2.1	(Sol.)	3.1	(d)	3.2	(d)	4.1	(b)	5.1	(b)	5.2	(b)
6.1	(c)	7.1	(b)	7.2	(Sol.)	8.1	(c)	8.2	Sol.	8.3	(c)		

Explanations Control Systems and Process Control

1. Basics of Control System and Transfer Function

1.1 (d)



Application of force $f(t)$ to the mass results in a displacement x(meters). The equation of motion for the system is obtained by applying Newton's second law of transaction motion.

Inertia force = Force acting on the mass

$$M\frac{d^2x}{dt^2}+B\frac{dx}{dt}+k\,x=f(t)$$

$$\therefore \quad Ms^2X(s)+Bs\,X(s)+k\,X(s)=F(s)$$

$$\frac{X(s)}{F(s)}=\frac{1}{Ms^2+Bs+k}=\frac{1/M}{s^2+\frac{B}{M}s+\frac{k}{M}}$$

$$\therefore \quad \omega_n=\sqrt{\frac{k}{M}}$$

and $$\zeta=\frac{B}{2\sqrt{kM}}$$

overshoot will be there if $\zeta > 1$.

So, the upper limit of ζ to prevent damping is, $\zeta = 1$

$$\frac{B}{2\sqrt{kM}}=1$$

$$\therefore \quad B=2\sqrt{kM}$$

2. Block Diagram and Signal Flow Graph

2.1 Sol.

There is one forward path and two loops,

$$P_1 = G_1G_2G_3$$

$$L_1 = -H_1G_1G_2,$$

$$L_2 = -H_2G_2G_3$$

$$\text{T.F.}=\frac{P_1\Delta_1}{\Delta}$$

$$=\frac{G_1G_2G_3[1-0]}{1+H_1G_1G_2+H_2G_2G_3}$$

$$=\frac{G_1G_2G_3}{1+G_1G_2H_1+G_2G_3H_2}$$

3. Time Response Analysis

3.1 (d)

$$\frac{G}{1+GH}=\frac{8}{s^2+0.6s+9}$$

but, $H = 1$ (as unity feedback)

$$G[s^2+0.6s+9]=8[1+G]$$

$$G[s^2+0.6s+1]=8$$

$$\therefore \quad G=\frac{8}{s^2+0.6s+1}$$

$$e_{ss}=\lim_{s\to0}\frac{s\cdot\left(\frac{1}{s}\right)}{1+\frac{8}{s^2+0.6s+1}}$$

$$=\frac{1}{1+\frac{8}{1}}=\frac{1}{9}$$

34.2 (d)

Output at steady state

$$=\lim_{s\to0}s\cdot\frac{1}{s}\cdot\frac{20}{s^2+2s+5}=\frac{20}{5}=4.0$$

4. Stability Analysis

4.1 (b)

For the system to be stable.
By Routh Hurwitz criteria

s^3	1	c
s^2	b	1
s^1	$\frac{bc-1}{b}$	
s^0	1	

$\therefore$ for the system to be stable, all the elements of the column 1 should be > 0

$$\therefore \quad \frac{bc-1}{b} > 0$$

$$\therefore \quad bc - 1 > 0$$

$$\boxed{bc > 1}$$

5. Root Locus

5.1 (b)

For $$G(s) = \frac{K(s+8)}{s(s+4)}$$

$$1 + G(s)H(s) = 1 + \frac{K(s+8)}{s(s+4)} = 0$$

$$\therefore \quad K = \frac{-s(s+4)}{(s+8)}$$

$$\frac{dk}{ds} = \left\{\frac{(s+8)[2s+4] - s(s+4)}{(s+8)^2}\right\} = 0$$

$\therefore (s + 8)(2s + 4) = s(s + 4)$

$2s^2 + 4s + 16s + 32 = s^2 + 4s$

$s^2 + 16s + 32 = 0$

$$s = -\frac{16 \pm \sqrt{256-128}}{2}$$

$$= -\frac{16 \pm 11.3}{2}$$

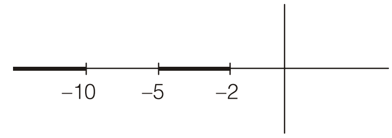
$\Rightarrow$ –13.65 and –2.35

Thus, it is the only option that satisfy the given plot.

5.2 (b)

The singularities are at,

$$s = -2, -5, -10$$



so, the break away point can lie only in the range between (–5, –2) or (–∞, –10)

$$1 + \frac{K(s+10)}{(s+2)(s+5)} = 0$$

$$\therefore \quad K = \frac{-(s+2)(s+5)}{(s+10)}$$

$$\frac{dK}{ds} = -\left\{\frac{(s+10)[s+2+s+5] - (s+2)(s+5)}{(s+10)^2}\right\} = 0$$

$\therefore \quad (s + 10)(2s + 7) = (s + 2)(s + 5)$

$2s^2 + 7s + 20s + 70 = s^2 + 7s + 10$

$\therefore \quad s^2 + 20s + 60 = 0$

$$s = \frac{-20 \pm \sqrt{400-240}}{2} = \frac{-20 \pm 12.64}{2}$$

$s = -3.68, -16.32$

$\therefore$ the breakaway point is –3.68 as the –16.32 do not lie in the set interval.

$\therefore$ the breakaway point lies in the interval –2 and –5.

6. Frequency Response Analysis, Bode Plot and Nyquist Plot

6.1 (c)

$$\text{Input} = 10 \sin t$$

$$\therefore \quad \omega = 1 \text{ rad/sec}$$

output of the system for the input of $\frac{1}{s+1}$, is

$$10 \sin t \rightarrow \frac{1}{s+1} \rightarrow \frac{10}{\sqrt{1+\omega^2}} \angle \tan^{-1}\frac{\omega}{1}$$

$$= \frac{10}{\sqrt{2}} \angle -45°$$

$$= \frac{10}{\sqrt{2}} \sin\left[t - \frac{\pi}{4}\right]$$

7. State Space Analysis

7.1 (b)

The number of states requires to describe a network is equal to the number of energy storing elements in the networks. Here there are two energy storage elements L and C thus the number of states required are two.

7.2 Sol.

$$G(s) = C(SI - A)^{-1} B$$

$$= [1 \quad 1]\begin{bmatrix} s & -1 \\ 2 & s+3 \end{bmatrix}^{-1}\begin{bmatrix} 0 \\ 2 \end{bmatrix}$$

$$= [1 \quad 1]\frac{\begin{bmatrix} (s+3) & 1 \\ -2 & s \end{bmatrix}\begin{bmatrix} 0 \\ 2 \end{bmatrix}}{s(s+3)+2}$$

$$= \frac{[(s+1)\,(s+1)]\begin{bmatrix} 0 \\ 2 \end{bmatrix}}{s^2 + 3s + 2}$$

$$= \frac{2(s+1)}{(s+2)\,(s+1)} = \frac{2}{s+2}$$

8. Process Control

8.1 (c)

Transfer function of a first order system, with delay t_d is,

$$T(s) = \frac{K e^{-t_d s}}{1 + \tau s}$$

where, $k \to$ static gain and $\tau \to$ time constant

$$\Rightarrow \qquad T(s) = \frac{1 \cdot e^{-0.1s}}{1 + 1 \cdot s} = \frac{e^{-0.1s}}{1+s}$$

8.2 Sol.

(a)-(f), (b)-(e), (c)-(h), (d)-(g)

8.3 (c)

For a system having a transportation lag of t_d sec. the transfer function is $e^{-t_d s}$

$\therefore$ for 4 sec. transportation lag.

Transfer function = e^{-4s}

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4 Digital Electronics and Microprocessors

1. Boolean Algebra and Minimization of Boolean Expression

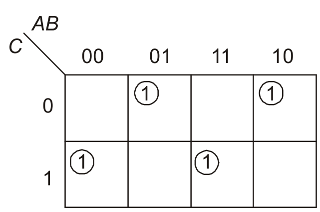
1.1 The Boolean expression $\overline{A+B+C}$ is equal to

(a) $\bar{A}+\bar{B}+\bar{C}$ (b) $\bar{A}\cdot\bar{B}\cdot\bar{C}$

(c) $\overline{A+B+C}$ (d) $A\cdot(B+C)$

[1994 : 1 M]

1.2 A combinatorial circuit has inputs A, B and C and its Karnaugh map is given in Fig. The output of the circuit is



(a) $(\bar{A}B+A\bar{B})C$ (b) $(\bar{A}B+A\bar{B})\bar{C}$

(c) $A\oplus B\oplus C$ (d) $\bar{A}\bar{B}\bar{C}$ [1995 : 1 M]

2. Logic Gates

2.1 Any Boolean function can be realized using only NAND gates. [1994 : 2 M]

2.2 If A and B are the inputs to a logic gate, then match the logic with its output

(a) NAND (i) $\overline{\bar{A}+\bar{B}}$

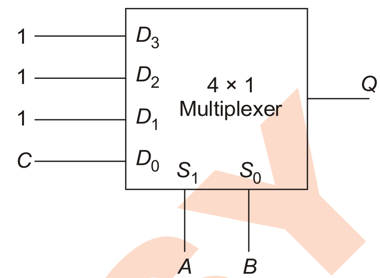
(b) NOR (ii) $\bar{A}+\bar{B}$

(c) XNOR (iii) $\bar{A}\bar{B}+AB$

(d) AND (h) $\overline{AB}$ [1995 : 1 M]

3. Combinational Circuits

3.1 The combinational circuit shown in the figure employs a 4 to 1 multiplexer. The output Q of the circuit is



(a) $\bar{A}\bar{B}C$ (b) $A+B+C$

(c) $A\oplus B\oplus C$ (d) $\bar{A}B\bar{C}$

[1995 : 1 M]

4. Sequential Circuits

4.1 The output Q_{n+1} of a J-K flip-flop for the input $J = 1$, $K = 1$ is

(a) 0 (b) 1

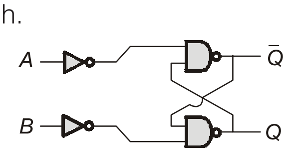
(c) Q_n (d) $\bar{Q}_n$ [1994 : 1 M]

4.2 The minimum number of flip-flop required to design a MOD - 10 counter is

(a) 3 (b) 10

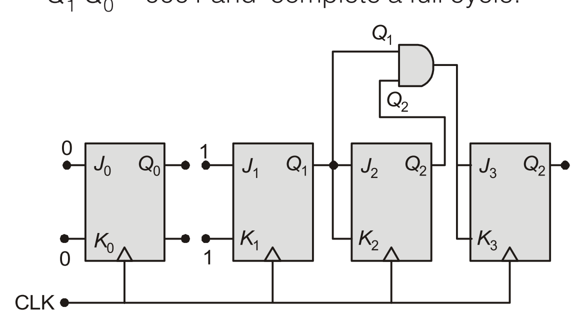
(c) 4 (d) 5 [1994 : 2 M]

4.3 The circuit shown in figure is that of an R–S latch.



[1995 : 2 M]

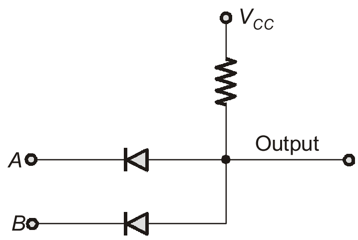
4.4 Figure shows a sequential circuit with four J-K flip-flops. Generate a table of output (Q_3 Q_2 Q_1 Q_0) changes with each clock pulse. Start with Q_3 Q_2 Q_1 Q_0 = 0001 and complete a full cycle.



[1995 : 2 M]

5. Logic Families

5.1 The diode circuit shown in figure functions as



(a) AND gate (b) OR gate
(c) NAND gate (d) NOR gate

[1994 : 1 M]

6. Memories and Interfacing

6.1 In a 8-bit microprocessor with 16 address lines, the range of signed integers that can be processed is ______.

[1994 : 2 M]

7. ADC & DAC

7.1 The percent resolution of a 10 bit D/A converter is ______.

[1994 : 2 M]

8. Basics of Microprocessor and Instruction Set

8.1 The contents of the STACK memory in a microprocessor system are retrieved on first-in-first out basis.

[1994 : 2 M]

8.2 The program counter on a 8-bit microprocessor is always a 8-bit register.

[1994 : 2 M]

■■■■

Answers Digital Electronics and Microprocessors

1.1	(b)	1.2	(c)	2.1	(sol.)	2.2	(sol.)	3.1	(b)	4.1	(d)	4.2	(c)
4.3	(sol.)	4.4	(sol.)	5.1	(a)	6.1	(Sol.)	7.1	(0.097)	8.1	(Sol.)	8.2	(Sol.)

Explanations Digital Electronics and Microprocessors

1. Boolean Algebra and Minimization of Boolean Expression

1.1 (b)

By Demorgan's theorem

$$\overline{A+B+C} = \bar{A}\cdot\bar{B}\cdot\bar{C}$$

Hence option (b) is correct.

1.2 (c)

From the *K*-map,

Output $F = \Sigma(1, 2, 4, 7)$ since, (as MSB)

$$= C\bar{A}\bar{B} + CAB + \bar{C}\bar{A}B + \bar{C}A\bar{B}$$

$$= C(\bar{A}\bar{B} + AB) + \bar{C}(\bar{A}B + A\bar{B}) = C(A \odot B) + \bar{C}(A \oplus B)$$

$$= C(\overline{A \oplus B}) + \bar{C}(A \oplus B) \qquad (\text{using } A \odot B = \overline{A \oplus B})$$

$$f = A \oplus B \oplus C$$

2. Logic Gates

2.1 Sol.

True, Since NAND and NOR gates are universal gates, so any boolean function can be realized using these universal gates.

2.2 Sol.

(a-ii) (b-iv) (c-iii) (d-i)

NAND $\rightarrow \overline{AB} = \bar{A} + \bar{B}$ (using Demorgan's theorem)

NOR $\rightarrow \overline{A+B} = \bar{A}\cdot\bar{B}$

XNOR $\rightarrow \bar{A}\bar{B} + AB$

AND $\rightarrow A \cdot B = \overline{\overline{AB}} = \overline{\bar{A} + \bar{B}}$

3. Combinational Circuits

3.1 (b)

The output of the MUX is

$$Q = \bar{S}_1\bar{S}_0 D_0 + \bar{S}_1 S_0 D_1 + S_1\bar{S}_0 D_2 + S_1 S_0 D_3$$

from given circuit,

$$Q = \bar{A}\bar{B}C + \bar{A}B + A\bar{B} + AB$$

$$= B(A+\bar{A}) + A\bar{B} + \bar{A}\bar{B}C$$

$$= B + \bar{B}(A + \bar{A}C)$$

$$= B + \bar{B}(A+\bar{A})(A+C)$$

$$= B + \bar{B}(A+C)$$

$$= B + \bar{B}A + \bar{B}C$$

$$= (B+\bar{B})(B+A) + \bar{B}C$$

$$= B + A + \bar{B}C$$

$$= A + (B+\bar{B})(B+C)$$

$$= A + B + C$$

Hence, option (b) is correct.

4. Sequential Circuits

4.1 (d)

The truth table of JK-FF is

J	K	Q_{n+1}
0	0	Q_n
0	1	0
1	0	1
1	1	$\bar{Q}_n$

for $J = K = 1$

$$Q_{n+1} = \bar{Q}_n$$

Hence option (d) is correct.

4.2 (c)

For N states

$$N \le 2^n$$

where n is number of flip-flops

$\therefore$ For $N = 10$

$$10 \le 2^n$$

$$\Rightarrow \quad \boxed{n = 4}$$

4.3 Sol.

True, the truth table of above circuit is

A	B	Q	$\bar{Q}$
0	0	previous state	
0	1	0	1
1	0	1	0
1	1	intermediate	

4.4 Sol.

From the given sequential circuit

$J_3 = Q_2\,Q_1 = K_3,\ J_2 = K_2 = Q_1,\ J_1 = K_1 = 1,$

$J_0 = Q_0 = 0$

the table of the given sequential circuit is

CLK	Q_0	Q_1	Q_2	Q_3	J_3	K_3	J_2	K_2	J_1	K_1	J_0	Q_0
Initial content	0	0	0	1	0	0	0	0	1	1	0	0
1st →	0	0	1	1	0	0	1	1	1	1	0	0
2nd →	0	1	0	1	0	0	0	0	1	1	0	0
3rd →	0	1	1	1	1	1	1	1	1	1	0	0
4th →	1	0	0	1	0	0	0	0	1	1	0	0
5th →	1	0	1	1	0	0	1	1	1	1	0	0
6th →	1	1	0	1	0	0	0	0	1	1	0	0
7th →	1	1	1	1	1	0	1	1	1	1	0	0
8th →	0	0	0	1								

5. Logic Families

5.1 (a)

Logic followed by given circuit is

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Hence it functions as a AND gate.

6. Memories and Interfacing

6.1 Sol.

8-bit microprocessor has 8 data lines.

The range of signed numbers which can be represented, are

$= [-(2^{8-1} - 1) \text{ to } + (2^{8-1} - 1)] = (-127 \text{ to } +127)$

7. ADC & DAC

7.1 (0.097)

$$\%\ \text{resolution} = \frac{1}{2^n - 1} \times 100 = \frac{100}{2^{10} - 1} = 0.097$$

8. Basics of Microprocessor and Instruction Set

8.1 Sol.

FALSE, contents of the stack memory are retrieved on last in first out basis in a microprocessor system.

8.2 Sol.

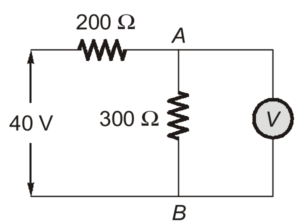
PC contains the address of next instruction to be fetched thus it is a 16-bit register.

■■■■

5 Measurements

1. Digital Voltmeter (DVM)

1.1 In the circuit shown in figure below the voltmeter is connected across *AB*. If the voltmeter has a resistance of 1200 Ω the measured value differs from true value by ..... V.



[1994 : 2 M]

1.2 The type of A/D converter normally used in a $3\frac{1}{2}$ digit multi meter is

(a) Dual-slope integrating type
(b) Voltage to frequency converter type
(c) Flash (or parallel) type
(d) Successive approximation type

[1995 : 1 M]

2. Galvanometers, Voltmeters and Ammeters

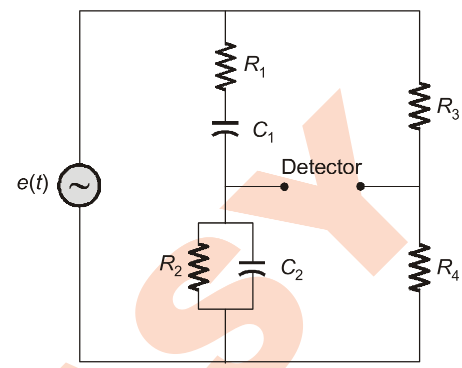
2.1 An electronic voltmeter consisting of a full wave precision rectifier and an average circuit gives correct R.M.S value for square wave inputs. It's reading for a 2 V peak to peak sinusoidal input will be

(a) $\frac{2}{\pi}$ V (b) $\frac{1}{\pi}$ V
(c) $\frac{2}{\sqrt{2\pi}}$ V (d) $\frac{\sqrt{2}}{\pi}$ V

[1995 : 1 M]

3. Measurement of Inductance Capacitance, AC Bridges & Q-meter

3.1 Find the excitation frequency (Hz) and the value of the resistance R_2 in the ac bridge shown in figure under balanced condition. The circuit component values are given as



$R_1 = 100\ k\Omega$, $R_3 = R_4 = 100\ k\Omega$, $C_1 = 2C_2 = 10nF$.

[1995 : 2 M]

4. CRO & Electronic Measurements

4.1 An amplitude modulated signal can be observed on a CRO by applying the following waveforms to the external trigger input:

(a) the modulated waveform itself
(b) derivative of the modulated waveform
(c) the modulating waveform
(d) the modulated waveform [1995 : 1 M]

5. Static and Dynamic Characteristics, Error Analysis and Statistical Analysis of Data

5.1 An ammeter has a range of 0 to 30 A. The instrument gave the following readings

Current flow (A)	0	5	10	15	20	25
Ammeter reading	1	4	12	14	22	28

The non-linearity of the instrument in terms of full scale reading (FSR) is ....% FSR.

[1994 : 2 M]

5.2 True or False
The null deflection method of measurement is superior to the deflection type of measurement.

[1994 : 2 M]

5.3 A thermometer possessing a thermal time constant of 0.5 min is introduced in a bath where the temperature is increasing at a constant rate of 5°C/min. The steady state error

(a) 10°C (b) 2.5°C
(c) 0.1°C (d) 0.4°C [1994 : 1 M]

5.4 The thermometer is initially at a temperature of 70°C and is suddenly placed in a liquid which is at 170°C. The thermometer indicates 133.2°C after the time interval of 3s. The time constant of the thermometer is _____s.

[1994 : 2 M]

■■■■

Answers Measurements

1.1 (–2.18) 1.2 (a) 2.1 (a) 3.1 (159.15) 4.1 (c)

5.1 (10) 5.2 (True) 5.3 (b) 5.4 (3)

Explanations Measurements

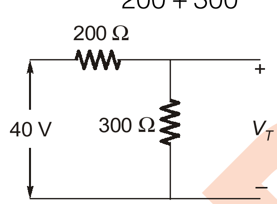
1. Digital Voltmeter (DVM)

1.1 (–2.18)

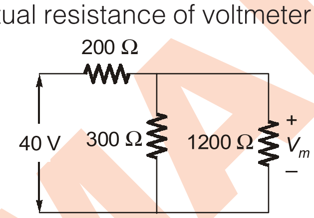
Voltmeter will read true value if its resistance is infinite.

So,

True voltage, $V_T = \dfrac{40 \times 300}{200 + 300} = 24$ V



But actual resistance of voltmeter is 1200 Ω



For parallel combination of 300 Ω and 1200 Ω,

$$R_{eq} = \frac{1200 \times 300}{1200 + 300} = 240$$

$$V_m = \frac{40 \times 240}{200 + 240} = 21.82 \text{ V}$$

$\Rightarrow$ Error = Measured value – True value = –2.18 V

1.2 (a)

Because of highest accuracy, highest stability and highest noise rejection. Dual-slope integrating type A/D converter is normally used in $3\frac{1}{2}$ digit multimeter.

2. Galvanometers, Voltmeters and Ammeters

2.1 (a)

Given : $(V_{pp})_{input} = 2$ V

$$\Rightarrow \quad (V_p)_{input} = \frac{2}{2} = 1 \text{ V}$$

For full wave rectifier

$$(V_{dc})_{ouput} = \frac{2}{\pi}(V_p)_{input}$$

$$= \frac{2}{\pi} \times 1 = \frac{2}{\pi} \text{ V}$$

Now,

$$V_{out} = (\text{Form Factor of Square wave}) \times \frac{2}{\pi}$$

$$= 1 \times \frac{2}{\pi} = \frac{2}{\pi} \text{V}$$

3. Measurement of Inductance Capacitance, AC Bridges & Q-meter

3.1 (159.15)

At balance,

$$\left[R_1 + \frac{1}{j\omega C_1}\right]R_4 = R_3\left[\frac{R_2}{1 + j\omega C_2 R_2}\right]$$

Given, $R_3 = R_4$

$$\Rightarrow [j\omega R_1 C_1 + 1] = j\omega C_1\left[\frac{R_2}{1 + j\omega C_2 R_2}\right]$$

$$\Rightarrow [j\omega R_1 C_1 + 1]\,[j\omega R_2 C_2 + 1] = j\omega C_1 R_2$$

$\Rightarrow [1-\omega^2 R_1R_2C_1C_2] + j[\omega(R_1C_1 + R_2C_2)] = j\omega C_1R_2$

Equating real and imaginary parts at LHS and RHS.

$\Rightarrow 1-\omega^2R_1R_2C_1C_2 = 0$

$\Rightarrow \quad 1 = \omega^2R_1R_2C_1C_2$ ...(i)

and $\omega R_1C_1 + \omega R_2C_2 = \omega C_1R_2$

$$\Rightarrow \quad R_2 = \frac{R_1C_1}{(C_1-C_2)}$$

Given,

$C_1 = 2C_2$

$$\Rightarrow \quad R_2 = \frac{R_1 \cdot 2C_1}{C_2} \Rightarrow R_2 = 2R_1 = 200\ \text{k}\Omega$$

Substituting R_2 in (i),

$1 = \omega^2 \times 100\ \text{k}\Omega \times 200\ \text{k}\Omega \times 10\ \text{nF} \times 5\ \text{nF}$

$\Rightarrow \quad \omega = 1000$ rad/sec

$$\Rightarrow \quad f = \frac{1000}{2\pi} = 159.15\ \text{Hz}$$

5. Static and Dynamic Characteristics, Error Analysis and Statistical Analysis of Data

5.1 (10)

$$\text{Non-linearity} = \frac{\text{Maximum deviation}}{\text{F.S.R.}}$$

$$\%\ \text{N.L.} = \frac{3}{30} \times 100 = 10\%$$

5.2 True

Null detector method is independent to meter accuracy so considered superior to deflection type method.

5.3 (b)

$\tau = 0.5$ min

$k = 5$ °C/min

the system acts as if a ramp input of value 5°C/min in applied as the input.

error due to $= k\tau$

ramp input $= 5 \times 0.5 = 2.5$°C

5.4 (3)

$\theta_t = \theta_f[1-e^{-t/\tau}] + \theta_i e^{-t/\tau}$

$133.2 = 170[1-e^{-3/\tau}] + 70 e^{-3/\tau}$

$133.2 - 170 = -100\ e^{-3/\tau}$

$100\ e^{-3/\tau} = 36.8$

$e^{-3/\tau} = 0.368$

$\therefore \quad \tau = 3$ sec

■■■■

6 Optical Instrumentation

1. Interferometer, Applications in Metrology (Optical)

1.1 In a wave propagation, a path difference of x_0 corresponds to a phase difference of

(a) λx_0 (b) πx_0

(c) $\left(\frac{2\pi}{\lambda}\right)x_0$ (d) $\frac{x_0}{\lambda}$

[1995 : 2 M]

2. Miscellaneous (Optical)

2.1 Two crossed polarizer's are placed in the part of a light beam. The light output is

(a) zero (b) plane polarized

(c) circularly polarized (d) elliptically polarized

[1994 : 2 M]

3. Mass Spectrometry, X-Ray and Nuclear Measurement (Analytical)

3.1 The Geiger Counter has high quantum efficiency in the wavelength (*A*) range

(a) 0.2 to 0.3 (b) 0.4 to 0.5

(c) 1.5 to 2.1 (d) 6 to 7 [1995 : 2 M]

3.2 The Duane-Hunt law represents the minimum wavelength λ(Å) of *X*-rays generated for an applied voltage V(volts) and given by

(a) $V = \frac{12400}{\lambda}$ (b) $V = 12400\,\lambda$

(c) $V = \frac{12400}{\lambda^2}$ (d) $V = 12400\,\lambda^2$

[1995 : 2 M]

■■■■

Answers Optical Instrumentation

1.1 (c) 2.1 (a) 3.1 (d) 3.2 (a)

Explanations Optical Instrumentation

1. Interferometer, Applications in Metrology (Optical)

1.1 (c)

$$\frac{\text{Phase difference}}{2\pi}\lambda = \text{Path difference}$$

i.e. $$\frac{\phi_0}{2\pi}\lambda = x_0$$

$$\Rightarrow \quad \phi_0 = \frac{2\pi}{\lambda}x_0$$

3. Mass Spectrometry, X-Ray and Nuclear Measurement (Analytical)

3.1 (d)

The quantum efficiency of a Geiger counter is highest in the wavelength range 6 to 7 Å range.

■■■■