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Important Questions for GATE 2022

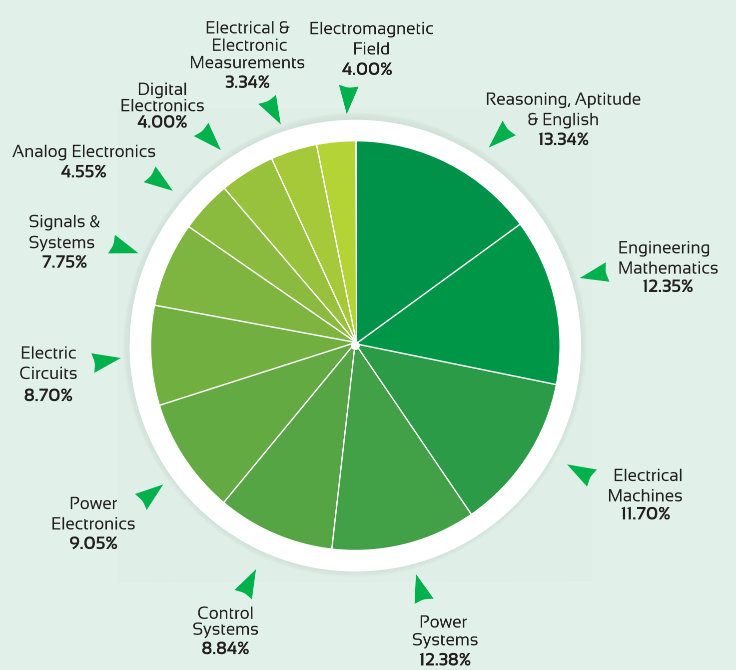
ELECTRICAL ENGINEERING

Day 7 of 8

Q.151 - Q.175 (Out of 200 Questions)

Control Systems & Analog Electronics

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Reasoning, Aptitude & English	13.34%
Engineering Mathematics	12.35%
Electrical Machines	11.70%
Power Systems	12.38%
Control Systems	8.84%
Power Electronics	9.05%
Electric Circuits	8.70%
Signals & Systems	7.75%
Analog Electronics	4.55%
Digital Electronics	4.00%
Electrical & Electronic Measurements	3.34%
Electromagnetic Fields	4.00%
Total	**100%**

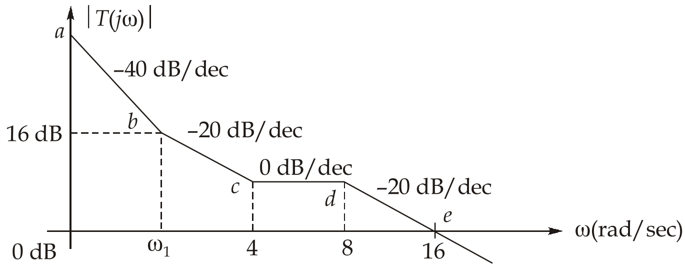
Control Systems & Analog Electronics

Q.151 The open loop transfer function of a dc motor is given as $\frac{\omega(s)}{V_a(s)} = \frac{4}{1+3s}$. When connected with feedback, the time constant is reduced by 80% then feedback factor of feedback block is ________.

Q.152 A unit step response test conducted on a second-order system yielded peak overshoot $M_p = 0.12$ and peak time $t_p = 0.2s$. The resonant peak (M_r) is

(a) 2.148
(b) 1.079
(c) 0.1018
(d) 1.981

Q.153 The asymptotic log-magnitude curve for open loop transfer function is sketched below,



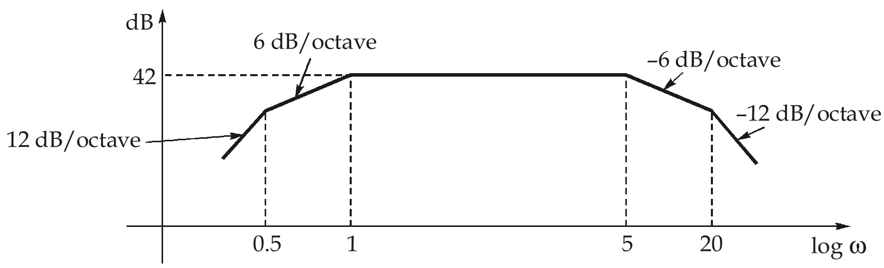
Open loop transfer function is

(a) $T(s) = \frac{10(s+8)(s+4)}{s^2(s+1.268)}$
(b) $T(s) = \frac{16(s+1.268)(s+4)}{s^2(s+8)}$
(c) $T(s) = \frac{10(s+1.268)(s+8)}{s^2(s+4)}$
(d) $T(s) = \frac{8(s+1.268)(s+8)}{s^2(s+4)}$

Q.154 $G(s)\,H(s) = \frac{32}{s\left(s+\sqrt{6}\right)^3}$. The gain crossover frequency for the above system is $\sqrt{2}$ rad/sec. The gain margin and phase margin respectively are

(a) 0 db and 0°
(b) 20 db and 60°
(c) –10 db and –60°
(d) 20 db and 30°

Q.155 Find the transfer function for the given bode diagram.



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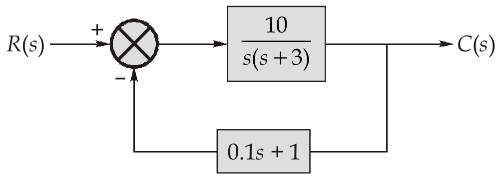
(a) $\dfrac{251.19(j\omega)^2}{(1+2j\omega)(1+j\omega)(1+0.2j\omega)(1+0.05j\omega)}$

(b) $\dfrac{625(j\omega)^2}{(1+2j\omega)(1+j\omega)(1+0.2j\omega)(1+0.05j\omega)}$

(c) $\dfrac{125.9}{(j\omega)^2(1+2j\omega)(1+j\omega)(1+0.2j\omega)(1+0.05j\omega)}$

(d) $\dfrac{625}{(j\omega)^2(1+2j\omega)(1+j\omega)(1+0.2j\omega)(1+0.05j\omega)}$

Q.156 Response of the system for unit step input.



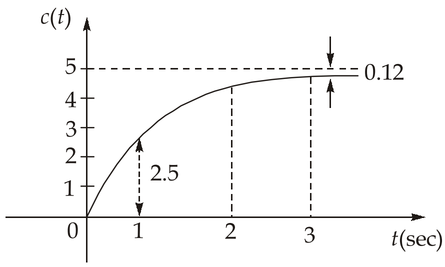
(a) $1-e^{-2t}\cos 6t-\dfrac{2}{\sqrt{6}}e^{-2t}\sin 6t$

(b) $1-e^{-2t}\cos\sqrt{6}\,t-\dfrac{2}{\sqrt{6}}e^{-2t}\sin\sqrt{6}\,t$

(c) $1-e^{-\sqrt{6}\,t}\cos 2t-\dfrac{2}{\sqrt{6}}e^{-\sqrt{6}\,t}\sin 2t$

(d) $1-e^{-2t}\sin\sqrt{6}\,t-\dfrac{2}{\sqrt{6}}e^{-2t}\cos\sqrt{6}\,t$

Q.157 The step response of a system is shown below, the forward path gain is _____.



Q.158 Consider the open loop transfer function of a system given below,

$$G(s)H(s) = \frac{K}{(s^2+2s+2)(s^2+6s+10)}$$

The number of breakaway points in root locus plot for the system is/are _____.

Q.159 For a given state model

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

$$y = x_1$$

The system has following properties

(a) observable and controllable

(b) observable and not controllable

(c) not observable but controllable

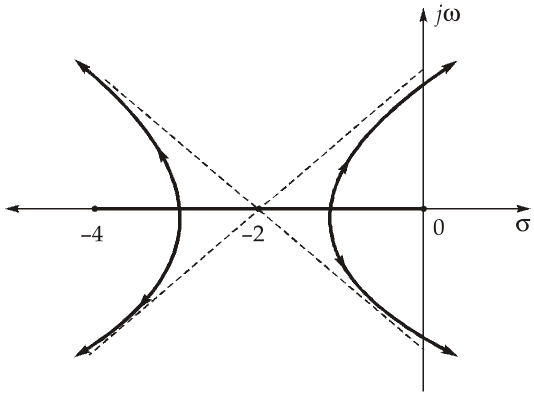
(d) not observable not controllable

Q.160 A system is described by the following equation,

$$A = \begin{bmatrix} -5 & 1 & 0 \\ 0 & -2 & 1 \\ 20 & -10 & 1 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, C = \begin{bmatrix} -1 & 1 & 0 \end{bmatrix}$$

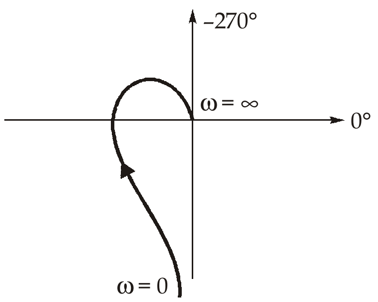
The steady state error for unit step input is ________.

Q.161 The root locus diagram of a control system is shown below :

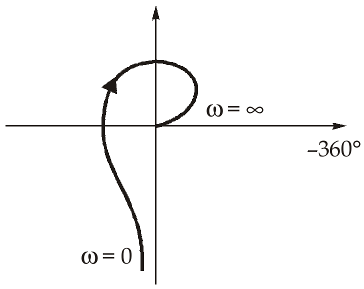


The polar plot of the same system is

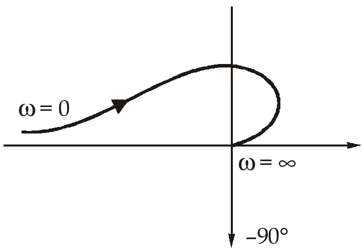
(a)



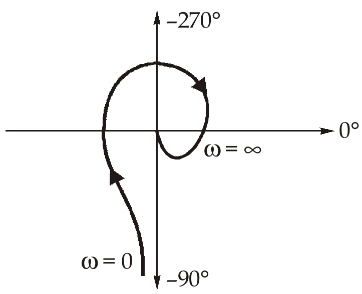
(b)



(c)



(d)



Q.162 Consider a unity gain closed-loop transfer function with forward path gain,

$$G(s) = \frac{K(s+1)}{s^3 + 0.5s^2 + 3s + 1}$$

If the system is producing undamped oscillations, then value of K and corresponding frequency of oscillations are respectively

(a) 2.5 and 1 rad/s
(b) 1 and 2 rad/s
(c) 1 and 2.5 rad/s
(d) 2 and 1 rad/s

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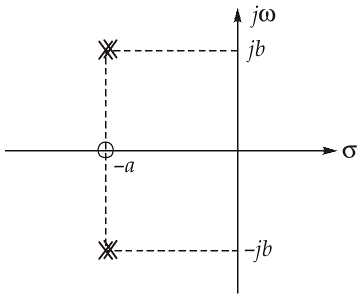
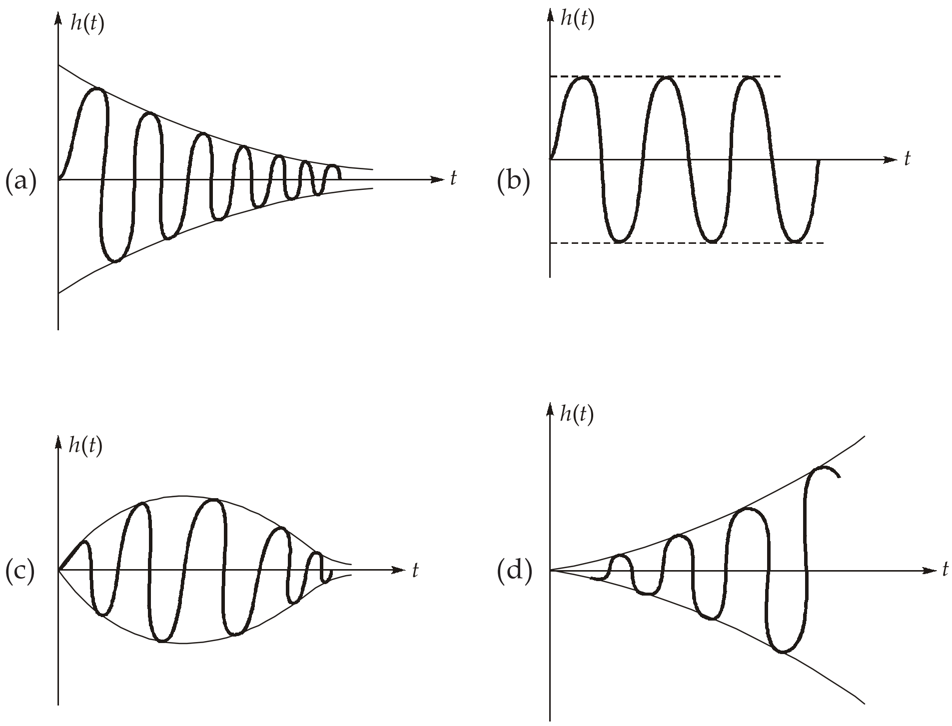
Q.163 A system shown below has multiple poles and a zero as shown below.



The impulse response of the system is



Q.164 A system having transfer function, $\frac{C(s)}{R(s)} = \frac{1}{s^2 + 1.5s + 4}$ is subjected to a step input having strength of 2 units. The steady state value of the respective output will be ______.

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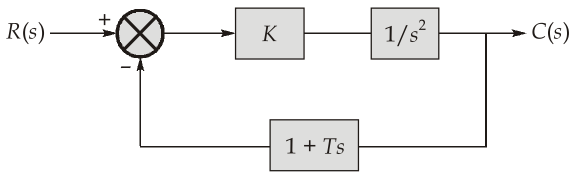
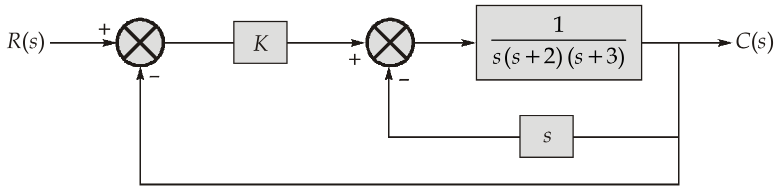
Q.165 The control system is represented by the block diagram shown below. The maximum overshoot to the unit step input is 20% and time to peak is 2.4 seconds then ratio of constants K and T will be ______.

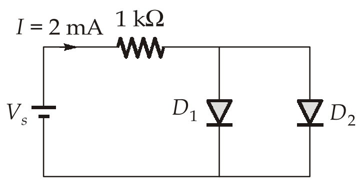


Q.166 A control system has given below block diagram.



If the system is oscillatory, then frequency of oscillation will be _____ rad/sec. (Answer upto 2 decimal place)

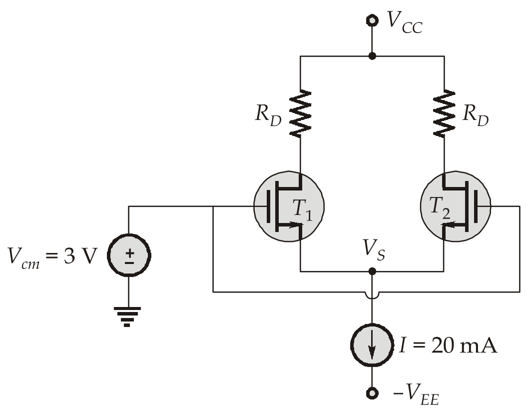
Q.167 Consider the circuit shown in the figure below:



A diode D_1 is connected in parallel with a diode D_2 with reverse saturation current equal to 10^{-12} A and 10^{-10} A respectively. The diodes are connected across a voltage source (V_s) in series with a resistance of 1 kΩ. Then the value of voltage 'V_s' is approximately equal to (Assuming η = 1 and V_T = 26 mV)

(a) 5.241 V
(b) 2.004 V
(c) 2.436 V
(d) 4.444 V

Q.168 Consider a differential amplifier circuit shown in the figure below:



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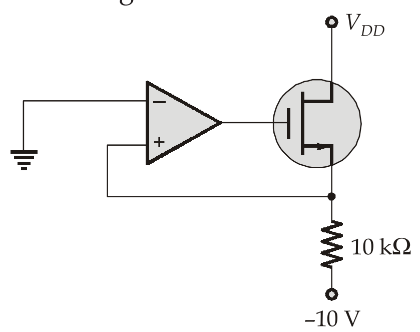
The two transistors are exactly matched with V_t = 0.5 V, $\mu_n C_{ox}$ = 500 μA/V^2 and $\left(\frac{W}{L}\right) = 100$.

Then the value of voltage V_s is equal

(Assuming T_1 and T_2 are operating in saturation region)

(a) 1.868 V
(b) 2.413 V
(c) 3 V
(d) –1.124 V

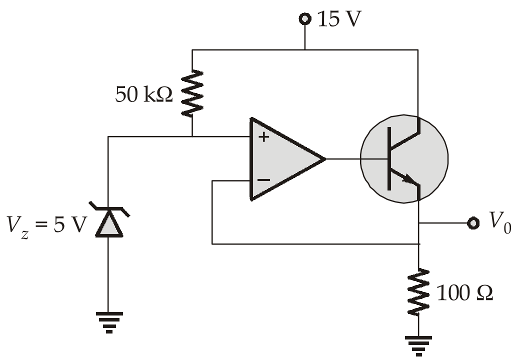
Q.169 Consider the circuit shown in the figure below:



The MOSFET is biased in saturation region having V_T = 2.5 V and $\frac{\mu_n C_{ox} W}{L} = 0.5\ \text{mA/V}$. The minimum value of V_{DD} for which the MOSFET will remain in saturation region is _______ V.

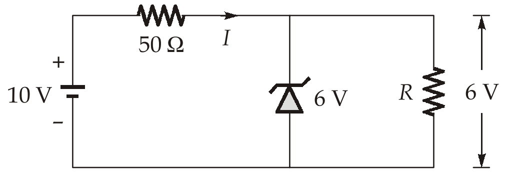
Q.170 If the op-amp in the circuit shown below is considered as an ideal op-amp then the value of current supplied by the 15 V battery is

(Assuming β of the transistor to be very large)



(a) 50.2 mA
(b) 15 mA
(c) 0.5 mA
(d) 65.2 mA

Q.171 The 6 V zener diode shown below has zero zener resistance and a knee current of 5 mA. The minimum value of R, so that the voltage across it does not fall below 6 V is



(a) 1.2 kΩ
(b) 50 Ω
(c) 80 Ω
(d) 0 Ω

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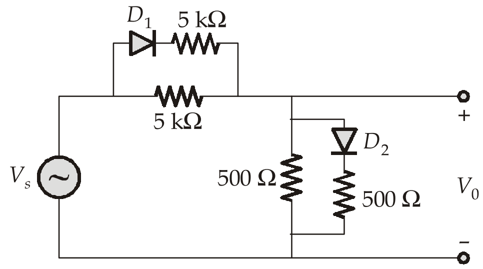
Q.172 Consider the circuit shown in the figure below.



The diode D_1 and D_2 are identical with cut in voltage $V_D > 0.6$ V. Then which of the following statements are true?

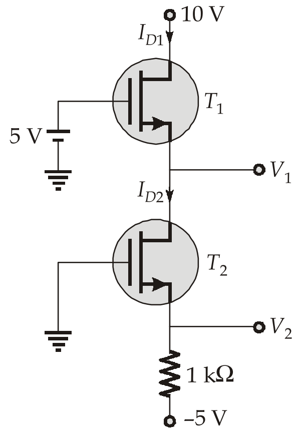
(a) $V_0 = \frac{1}{11}V_s + \frac{54}{220}$ for $V_s > 3.9$ V

(b) $V_0 = \frac{2}{11}V_s + \frac{32}{110}$ for $V_s > 4$ V

(c) $V_0 = \frac{5}{11}V_s + \frac{41}{140}$ for $V_s > 3$ V

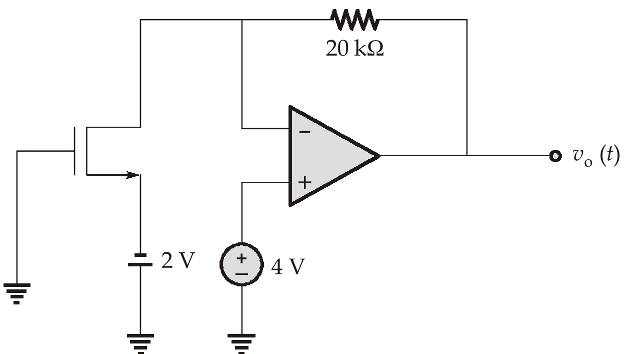
(d) $V_0 = \frac{5}{8}V_s + \frac{6}{36}$ for $V_s > 4.9$ V

Q.173 Consider the MOS transistor circuit shown in the figure below



The two N-MOS transistor are identical with threshold voltage V_T = 1 V and $\frac{\mu_n C_{ox} W}{L} = 2\ \text{mA/V}^2$. Assuming the value of λ = 0, the value of drain to source voltage for transistor T_2 (V_{DS2}) is equal to ________ V.

Q.174 In the circuit shown below, if the op-amp is ideal op-amp and MOSFET parameters are $\mu_n C_{ox} = 100\ \mu\text{A/V}^2$, $V_T = 1$ V, $W = 10\ \mu$m and $L = 2.5\ \mu$m, then the output voltage $V_0(t)$ = ___ V.



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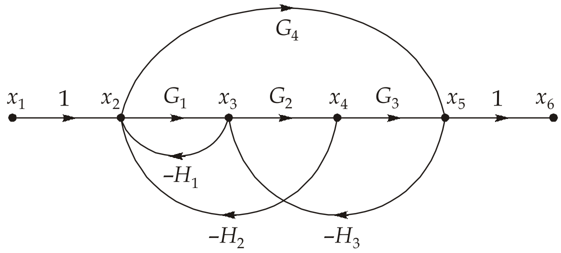
Multiple Select Questions (MSQ)

Q.175 Which of the following is/are correct for the system whose signal flow graph is shown below:



(a) The number of forward path is 2.

(b) The number of loops is 5.

(c) There are one pair of two non-touching loops.

(d) The transfer function $\frac{x_6}{x_1} = \frac{G_1G_2G_3 + G_4}{1 + G_1H_1 + G_1G_2H_2 + G_2G_3H_3 - G_4H_3H_1 - G_4G_2H_3H_2}$.

■■■■

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Detailed Explanations

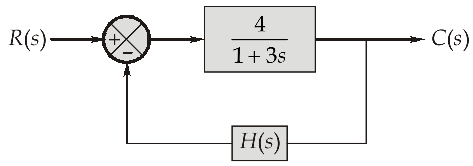
151. (1)

Time constant of open loop system is 3 sec.

It is desired to reduce time constant by 80%

$$-0.8 = \frac{T_2 - 3}{3} = 0.6 \text{ sec}$$

Block diagram of closed loop system



$$\text{Transfer function} = \frac{C(s)}{R(s)} = \frac{4}{1+3s+4H(s)}$$

$$= \frac{4}{(1+4H(s))\left(1+\dfrac{3s}{1+4H(s)}\right)}$$

On comparing, we get

$$T_2 = 0.6 = \frac{3}{1+4H(s)}$$

$$H(s) = 1$$

152. (b)

The peak overshoot M_p is given by

$$M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}}$$

Taking natural logarithm on both sides,

$$\ln M_p = \frac{-\pi\xi}{\sqrt{1-\xi^2}}$$

squaring both sides, we get

$$(\ln M_p)^2 = \frac{\pi^2\xi^2}{1-\xi^2}$$

on cross multiplying, we get

$$(1 - \xi^2)\,(\ln M_p)^2 = \pi^2\xi^2$$

$$\Rightarrow \qquad \xi^2 = \frac{(\ln M_p)^2}{\pi^2 + (\ln M_p)^2}$$

for $\qquad M_p = 0.12,$

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$$\ln M_p = -2.12$$
$$(\ln M_p)^2 = 4.494$$
$$\xi^2 = 0.3128$$
$$\xi = 0.559$$

∴, resonant peak,
$$M_r = \frac{1}{2\xi\sqrt{1-\xi^2}}$$
$$= \frac{1}{2\times 0.559\sqrt{1-0.559^2}} = 1.079$$

153. (b)

From the above Bode plot,

For section de, slope is –20 dB/dec

$$\therefore \quad -20 = \frac{y-0}{\log 8 - \log 16}$$
$$y = 6.02 \text{ dB}$$

Now, for section bc, slope is –20 dB/dec

$$\therefore \quad -20 = \frac{16-6.02}{\log \omega_1 - \log 4}$$
$$\omega_1 = 1.268 \text{ rad/sec}$$

To find value of gain K

$$y = mx + c$$
$$16 = -40 \log 1.268 + 20 \log K$$
$$K = 10.14$$

From all the result, transfer function is,

$$T(s) = \frac{10.14\left(\frac{s}{1.268}+1\right)\left(\frac{s}{4}+1\right)}{s^2\left(\frac{s}{8}+1\right)}$$
$$T(s) = \frac{16(s+1.268)(s+4)}{s^2(s+8)}$$

154. (a)

$$\omega_{gc} = \sqrt{2} \text{ rad/sec}$$
$$\angle G(j\omega)\, H(j\omega) = -90° - 3\tan^{-1}\left(\frac{\omega}{\sqrt{6}}\right)$$

At phase crossover frequency,

$$\angle G(j\omega_{pc})\, H(j\omega_{pc}) = -180°$$
$$-180° = -90° - 3\tan^{-1}\left(\frac{\omega_{pc}}{\sqrt{6}}\right)$$

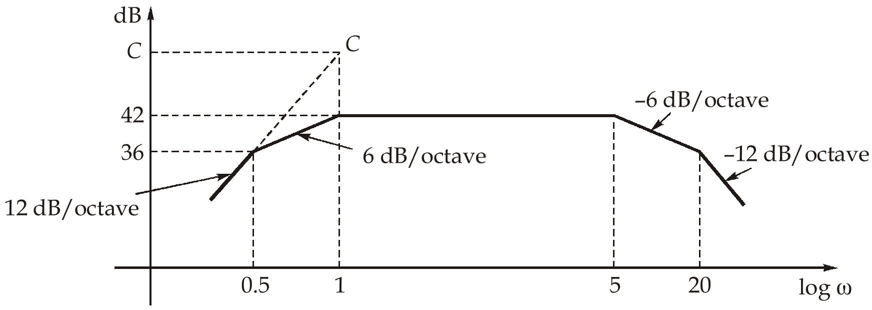
$$\omega_{pc} = \sqrt{2} \text{ rad/sec}$$
$$\omega_{pc} = \omega_{gc}$$
$$GM = 0 \text{ db}$$
$$PM = 0°$$

155. (a)

Since 6 dB/octave is equivalent to 20 dB/decade. Initial slope of 40 dB/decade indicates 2 zeroes at origin.

Another pole lies at 0.5, hence slope reduces to 20 dB/decade, again a pole at 1 and similarly poles lie at 5 and 20.

k is determined by using the intial slope of the line :



Initial slope of line is 12 dB/octave = 40 dB/decode

Finding k:

at $\omega = 0.5$ rad/s, $M = 36$ dB

From initial line, $C = 36 + 12 = 48$ dB

$\because$ $C = 20 \log k$

$48 = 20 \log k$

$\Rightarrow$ $k = 251.19$

156. (b)

$$R(s) = \frac{1}{s}$$

$$\frac{C(s)}{R(s)} = \frac{10/s(s+3)}{1+\frac{10}{s(s+3)}\times(0.1s+1)} = \frac{10}{s^2+4s+10}$$

$$C(s) = \frac{A}{s} + \frac{Bs+C}{s^2+4s+10} = \frac{1}{s} - \frac{s+4}{s^2+4s+10}$$

$$= \frac{1}{s} - \frac{s+2}{(s+2)^2+(\sqrt{6})^2} - \frac{2}{\sqrt{6}}\frac{\sqrt{6}}{(s+2)^2+(\sqrt{6})^2}$$

$$C(t) = 1 - e^{-2t}\cos\sqrt{6}t - \frac{2}{\sqrt{6}}e^{-2t}\sin\sqrt{6}\,t$$

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157. 40.66 (40.00 to 42.00)

The steady state error for step input

$$e_{ss} = \frac{A}{1+K_p} = \frac{5}{1+K_p} = 0.12$$

$\because$ $r(t) = 5\,u(t)$

or $1 + K_p = \frac{5}{0.12} = 41.66$

Hence, $K_p = 41.66 - 1 = 40.66$

158. (0)

Given OLTF of the system,

$$G(s)H(s) = \frac{K}{(s+1+j)(s+1-j)(s+3+j)(s+3-j)}$$

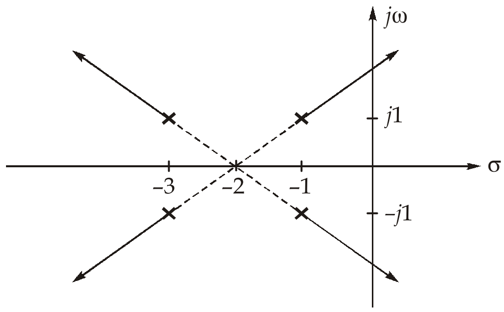
No. of open loop poles, $P = 4$

No. of open loop zeros, $Z = 0$

4 no. of asymptotes with angles of

$= 45°, 135°, 225°, 315°$

We get the root locus of the system as;



Hence there is no breakaway point.

159. (b)

For controllability, using Kalman's test

Controllability matrix $= [B \quad AB]$

$$B = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$$

$$AB = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}\begin{bmatrix} 1 \\ -2 \end{bmatrix} = \begin{bmatrix} -2 \\ 4 \end{bmatrix}$$

$$Q_C = \begin{bmatrix} 1 & -2 \\ -2 & 4 \end{bmatrix}$$

$$|Q_C| = 4 - 4 = 0$$

Hence not controllable.

For observability, $s = [C^T \quad A^T C^T]$

$$C^T = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$A^T C^T = \begin{bmatrix} 0 & -2 \\ 1 & -3 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$Q_O = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$|Q_O| = 1 \neq 0$$

$\therefore$ The system is observable.

160. 0.8 (0.75 to 0.85)

Given system is described as,

$$\dot{x} = Ax + By \text{ and } y = Cx$$

Where,
$$A = \begin{bmatrix} -5 & 1 & 0 \\ 0 & -2 & 1 \\ 20 & -10 & 1 \end{bmatrix}; \quad B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}; \quad C = \begin{bmatrix} -1 & 1 & 0 \end{bmatrix}$$

$$e_{ss} = \lim_{s\to 0} sE(s)\left[1 - C(sI - A)^{-1}B\right]$$

$$= \lim_{s\to 0} s \times \frac{1}{s}\left[1 - C(sI - A)^{-1}B\right] \qquad \left[R(s) = \frac{1}{s}; \text{unit step}\right]$$

$$= 1 - C(0 - A)^{-1} B$$

$$= 1 + CA^{-1} B; \text{ for unit step input}$$

$$A^{-1} = \frac{\text{Adj } A}{|A|} = \begin{bmatrix} -0.4 & 0.05 & -0.05 \\ -1 & -0.25 & -0.25 \\ -2 & 1.5 & -0.5 \end{bmatrix}$$

Thus steady state error is,

$$e_{ss} = 1 + \begin{bmatrix} -1 & 1 & 0 \end{bmatrix}\begin{bmatrix} -0.4 & 0.05 & -0.05 \\ -1 & -0.25 & -0.25 \\ -2 & 1.5 & -0.5 \end{bmatrix}\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = 1 - 0.2 = 0.8$$

161. (b)

From the figure, the transfer function of the system is,

$$G(s)\,H(s) = \frac{K}{s(s+2)^2(s+4)}$$

$$|G(j\omega)H(j\omega)| = \frac{K}{\omega(4+\omega^2)\sqrt{16+\omega^2}}$$

ω	M	ϕ
0	∞	$-90°$
⋮	⋮	⋮
∞	0	$-360°$

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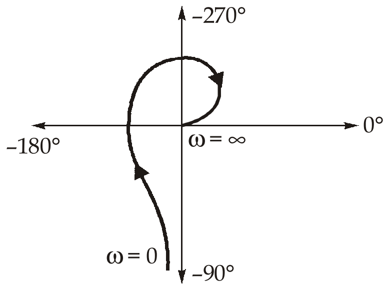
$$\angle G(j\omega)\, H(j\omega) = -90^\circ - 2\tan^{-1}\left(\frac{\omega}{2}\right) - \tan^{-1}\left(\frac{\omega}{4}\right)$$



162. (b)

The characteristic equation is,

$$q(s) = s^3 + 0.5s^2 + (K+3)\,s + (K+1) = 0$$

$$\begin{array}{c|cc} s^3 & 1 & K+3 \\ s^2 & 0.5 & K+1 \\ s^1 & (3+K)-2(K+1) & 0 \\ s^0 & (K+1) & \end{array}$$

For a system to oscillate a row should become zero.

$$\therefore \quad K + 3 - 2K - 2 = 0$$
$$K = 1$$

Given system is third order system $(s + a)\,(s^2 + bs + c) = 0$

For a marginally stable system, $\xi = 0$

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$
$$s^2 + \omega_n^2 = 0$$

Take the coefficients of s^2 row.

$$0.5s^2 + (K+1) = 0$$
$$0.5s^2 + 2 = 0$$
$$s = \pm j2$$
$$\omega = 2 \text{ rad/s}$$

163. (c)

The transfer function of the system is,

$$H(s) = \frac{(s+a)}{[(s-(-a-jb))\,(s-(-a+jb))]^2}$$

$$= \frac{s+a}{[(s+a)^2+b^2]^2} = \frac{1}{2}\cdot\frac{2(s+a)}{[(s+a)^2+b^2]^2}$$

$$H(s) = \frac{1}{2}\left[-\frac{dF(s)}{ds}\right]$$

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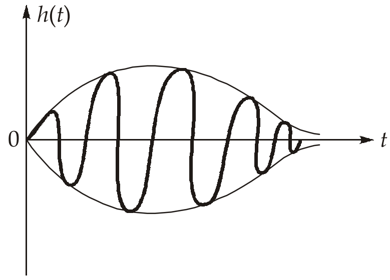
where, $$F(s) = \frac{1}{(s+a)^2+b^2} \xrightleftharpoons[\text{I.L.T.}]{} f(t) = \frac{1}{b}e^{-at}\sin(bt)$$

$$-\frac{d}{ds}F(s) \longleftrightarrow t\,f(t)$$

$$h(t) = \frac{t}{2}f(t) = \frac{t}{2b}e^{-at}\sin(bt)$$

$$h(t) = K\,te^{-at}\sin(bt)$$



164. 0.5 (0.45 to 0.55)

The transfer function,

$$\frac{C(s)}{R(s)} = \frac{1}{s^2+1.5s+4}$$

The Laplace transform of output of the system,

$$C(s) = \frac{R(s)}{s^2+1.5s+4}$$

Given, $$R(s) = \mathcal{L}(2u(t)) = \frac{2}{s}$$

$\therefore$ $$C(s) = \frac{2/s}{s^2+1.5s+4}$$

The steady value of the output is,

$$c(\infty) = \lim_{s\to 0} sC(s) = \lim_{s\to 0}\frac{s\times 2/s}{s^2+1.5s+4} = \frac{2}{4} = \frac{1}{2} = 0.5$$

165. 3.48 (3.10 to 4.00)

For the given system, $$\frac{C}{R} = \frac{K/s^2}{1+\frac{K}{s^2}(1+Ts)} = \frac{K}{s^2+TKs+K}$$

$$\omega_n^2 = K \Rightarrow \omega_n = \sqrt{K}$$

$$2\xi\omega_n = TK$$

Maximum overshoot:

$$0.20 = e^{-\xi\pi/\sqrt{1-\xi^2}}$$

$$-1.609 = -\frac{\xi(3.14)}{\sqrt{1-\xi^2}}$$

$$1-\xi^2 = \left(\frac{3.14}{1.609}\xi\right)^2 = 3.81\xi^2$$

$$1 = 4.81\,\xi^2$$

$$\xi = 0.456$$

Peak time,
$$t_p = \frac{\pi}{\omega_n\sqrt{1-\xi^2}}$$

$$2.4 = \frac{3.14}{\omega_n\sqrt{1-(0.456)^2}}$$

$$\omega_n = \frac{3.14}{2.4\sqrt{1-0.338}} = 1.47 \text{ rad/sec.}$$

$$K = \omega_n^2 = 2.161$$

$$T = \frac{2\xi\omega_n}{K} = \frac{2\times 0.456\times 1.47}{2.161} = 0.6204$$

∴ Ratio,
$$\frac{K}{T} = \frac{2.161}{0.6204} = 3.483$$

166. (2.65) (2.55 to 2.72)

For inner loop:

$$\text{Transfer function} = \frac{\dfrac{1}{s(s+2)(s+3)}}{1+\dfrac{1}{(s+2)(s+3)}}$$

$$\Rightarrow \quad \frac{1}{s(s+2)(s+3)}\times\frac{(s+2)(s+3)}{(s+2)(s+3)+1} = \frac{1}{s[(s+2)(s+3)+1]}$$

For overall transfer function:

$$\text{T.F.}_{\text{(overall)}} = \frac{\dfrac{K}{s(s+2)(s+3)+s}}{1+\dfrac{K}{s(s+2)(s+3)+s}} = \frac{K}{s(s+2)(s+3)+s+K}$$

$$= \frac{K}{s(s^2+5s+6)+s+K} = \frac{K}{s^3+5s^2+7s+K}$$

∴ Using characteristic equation:

$$1+G(s)\,H(s) = s^3+5s^2+7s+K$$

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s^3	1	7
s^2	5	K
s^1	$\frac{35-K}{5}$	
s^0	K	

$$K > 0, \qquad \frac{35-K}{5} > 0 \text{ or } K < 35$$

For oscillatory system K can be kept at, $K = 35$.

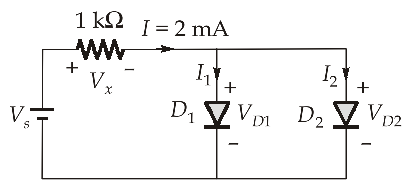
Now using auxiliary equation,

$$5s^2 + K = 0 \text{ or } 5s^2 + 35 = 0$$

$$s^2 + 7 = 0$$

$$s = \pm j2.645 \simeq \pm j2.65 \text{ i.e. } \omega = 2.65 \text{ rad/sec.}$$

167. (c)



$$V_s = V_x + V_{D1} \qquad (\because V_{D1} = V_{D2})$$

and $\quad I = I_1 + I_2$

thus $\quad 2 \times 10^{-3} = 10^{-12}\left[e^{\frac{V_{D1}}{26\times10^{-3}}} - 1\right] + 10^{-10}\left[e^{\frac{V_{D1}}{26\times10^{-3}}} - 1\right]$

$$2 \times 10^{-3} \approx 10^{-10}(1.01)\cdot e^{\frac{V_{D1}}{26\times10^{-3}}}$$

$$\frac{V_{D1}}{26\times10^{-3}} = \ln(1.9801 \times 10^7) = 16.801$$

$\therefore \quad V_{D1} = 0.437$ V

Now, $\quad V_x = 2 \times 10^{-3} \times 1 \times 10^3 = 2$ V

$$V_s = V_x + V_{D1} = 2 + 0.437$$

$$= 2.437 \text{ V}$$

168. (a)

The current of both the transistors are equal since they are perfectly matched.

Thus, $\quad \frac{I}{2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS1} - V_t)^2$

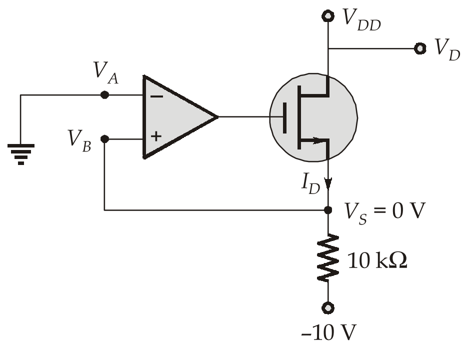
$$10 \times 10^{-3} = \frac{1}{2} \times 500 \times 10^{-6} \times 100(V_{GS1} - 0.5)^2$$

$\therefore \quad V_{GS1} = V_{GS2} = 1.132$ V

Thus, $\quad V_S = V_{cm} - V_{GS1} = 3 - 1.132 = 1.868$ V

169. (2)

For the transistor



$$V_S = V_B = V_A$$

due to virtual ground,

thus, $V_S = 0$ V

Hence, $$I_D = \frac{0-(-10)}{10\times10^3} = 1\text{ mA}$$

$$I_D = \frac{\mu_n C_{ox} W}{2L}(V_{GS}-V_T)^2$$

∴ $$V_{GS} - V_T = \sqrt{\frac{I_D}{\frac{\mu_n C_{ox} W}{2L}}}$$

$$V_{GS} - V_T = \sqrt{\frac{1\times10^{-3}}{\frac{0.5\times10^{-3}}{2}}}$$

$$V_{GS} - V_T = 2\text{ V}$$

For the MOSFET to be in saturation region

$$V_{DS} \geq V_{GS} - V_T$$

∴ at the edge of saturation

$$V_{DS} = V_{GS} - V_T = 2\text{ V}$$

∵ $V_S = 0$

∴ $V_D = V_G - V_T$

⇒ $V_{DD} = 2$ V

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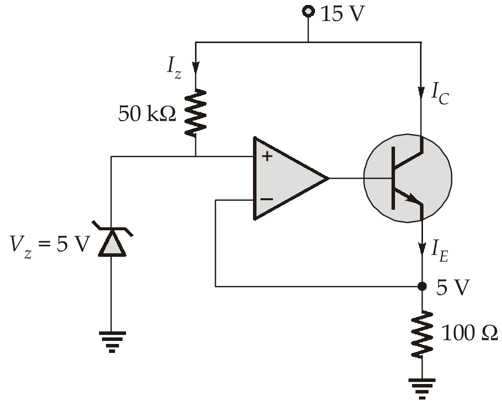
170. (a)



$$V_0 = 5\text{ V}$$

$$\therefore \quad I_E \approx I_C = \frac{5}{100} = 50\text{ mA}$$

$$I_Z = \frac{15-5}{50\text{ k}\Omega} = 0.2\text{ mA} \qquad \text{[Since, } \beta \text{ is very large]}$$

$$\therefore \quad I_{net} = 50 + 0.2 = 50.2\text{ mA}$$

171. (c)

$$I = \frac{10-6}{50} = 80\text{ mA}$$

$$I = I_Z + I_L = I_{Z\,min} + I_{L\,max}$$

$$I_{Z\,min} = 5\text{ mA}$$

$$80 = 5 + I_{L\,max}$$

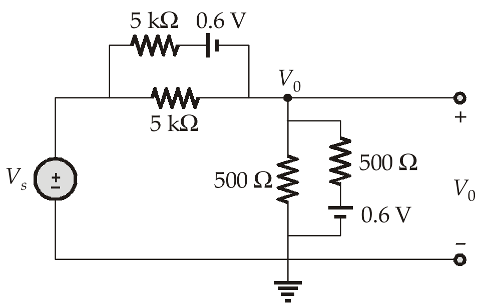
$$I_{L\,max} = 75\text{ mA}$$

$$I_{L\,max} = \frac{V_L}{R_{min}}$$

$$R_{min} = \frac{V_L}{I_{L\,max}} = \frac{6}{75\times 10^{-3}} = 80\ \Omega$$

172. (a)

Assume both the diode to be ON.



Applying the KCL at node V_0, we get,

$$\frac{V_0 + 0.6 - V_s}{5\text{ k}} + \frac{V_0 - V_s}{5\text{ k}} + \frac{V_0}{500} + \frac{V_0 - 0.6}{500} = 0$$

$$\therefore \quad V_0 = \frac{2}{22}V_s + \frac{5.4}{22}$$

$$V_0 = \frac{1}{11}V_s + \frac{54}{220}$$

For diode D_1 to be ON.

$$V_s - V_0 > 0.6$$

$$V_s - \frac{2V_s + 5.4}{22} > 0.6$$

$$V_s > 0.93\text{ V}$$

For diode D_2 to be ON.

$$V_0 > 0.6\text{ V}$$

$$\frac{2V_s + 5.4}{22} > 0.6$$

$$V_s > 3.9\text{ V}$$

173. 5.00 (4.80 to 5.20)

For saturation region the condition is,

$$V_{DS} \geq V_{GS} - V_T \quad \text{...(i)}$$

$$V_{GS\,1} = 5 - V_1$$

$$V_{DS\,1} = 10 - V_1$$

$\therefore$ from equation (i),

$$10 - V_1 > (5 - V_1) - 1$$

$$10 - V_1 > 4 - V_1$$

This indicates T_1 is in saturation,

$$V_{DS2} = V_1 - V_2$$

$$V_{GS2} = -V_2$$

From equation (i),

$$V_1 - V_2 > -V_2 - 1$$

The inequality satisfies, so T_1 and T_2 are in saturation

$$\therefore \quad I_{D1} = I_{D2}$$

$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS1} - V_T)^2 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS2} - V_T)^2$$

$$V_{GS1} = V_{GS2}$$

$$5 - V_1 = -V_2$$

$$V_1 - V_2 = 5 = V_{DS2}$$

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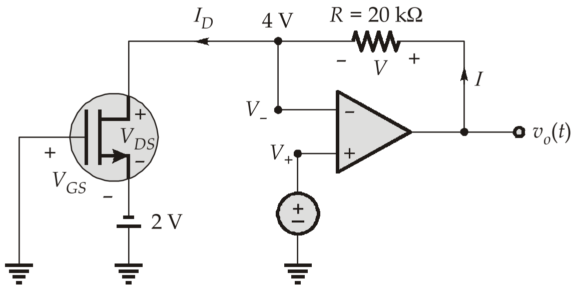
174. (8)



$$V_{DS} = 4 - (-2) = 6 \text{ V}$$

By KVL in gate source loop,

$$V_{GS} - 2 = 0$$
$$V_{GS} = 2$$
$$V_{DS} > V_{GS} - V_T$$

∴ The MOSFET will operate in saturation region,

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_T)^2$$
$$= \frac{1}{2}\times 100\times 10^{-6}\times\frac{10}{2.5}(2-1)^2 = 200 \ \mu\text{A}$$

The output voltage V_0 can be obtained by KVL,

$$-4 - I_D R + V_0 = 0$$
$$V_0 = 4 + (200 \times 10^{-6} \times 20 \times 10^3) = 8 \text{ V}$$

175. (a, b, d)

The SFG shown in figure has two forward paths and five loops. There are no pairs of two loops which are not touching each other, and all the loops are touching both the forward paths. The forward paths and the gains associated with them are as follows:

Forward path $x_1 - x_2 - x_3 - x_4 - x_5 - x_6$;

$$M_1 = (1)\ (G_1)\ (G_2)\ (G_3)\ (1)$$
$$= G_1 G_2 G_3;$$
$$\Delta_1 = 1$$

Forward path $x_1 - x_2 - x_5 - x_6$;

$$M_2 = (1)\ (G_4)\ (1) = G_4$$
$$\Delta_2 = 1$$

The loops and gains are as follows:

Loop $x_2 - x_3 - x_2$; $\quad L_1 = G_1(-H_1) = -G_1H_1$

Loop $x_2 - x_3 - x_4 - x_2$; $\quad L_2 = G_1G_2(-H_2) = -G_1G_2H_2$

Loop $x_3 - x_4 - x_5 - x_3$; $\quad L_3 = G_2G_3(-H_3) = -G_2G_3H_3$

Loop $x_2 - x_5 - x_3 - x_2$; $\quad L_4 = G_4(-H_3)(-H_1) = G_4H_3H_1$

Loop $x_2 - x_5 - x_3 - x_4 - x_2$; $\quad L_5 = G_4(-H_3)(G_2)(-H_2) = G_4G_2H_3H_2$

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Applying Mason's gain formula, the transfer function is

$$\frac{x_6}{x_1} = \frac{M_1\Delta_1 + M_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_3 + G_4}{1 + G_1H_1 + G_1G_2H_2 + G_2G_3H_3 - G_4H_3H_1 - G_4G_2H_3H_2}$$

■■■■

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