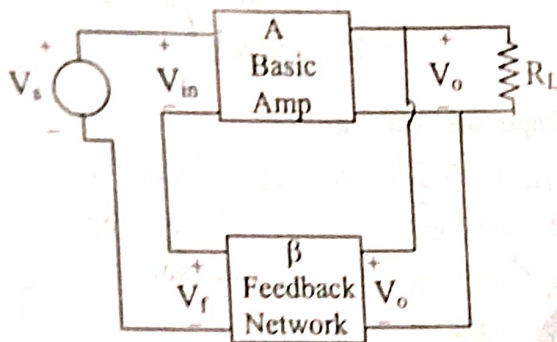


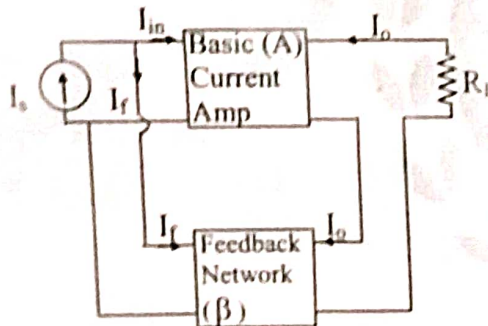
Chapter 4 Feedback Amplifiers

Practice Questions

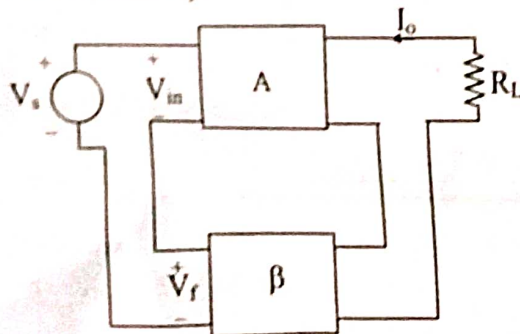
01. In the circuit shown below given $V_s = 100 \text{ mV}$, $V_f = 95 \text{ mV}$, $V_o = 10 \text{ V}$. Find A , β and $A_f = \frac{A}{1 + A\beta}$?



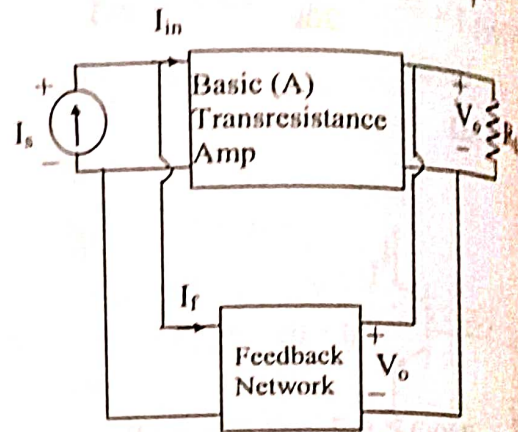
02. In the circuit shown below given $I_s = 100 \mu\text{A}$, $I_f = 95 \mu\text{A}$, $I_o = 10 \text{ mA}$. Find A , β and A_f ?



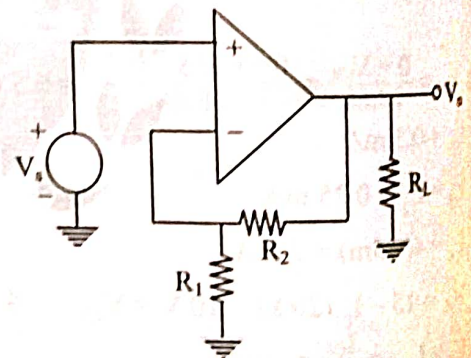
03. In the circuit shown below given $V_s = 100 \text{ mV}$, $V_f = 95 \text{ mV}$, $I_o = 10 \text{ mA}$. Find A , β and A_f ?



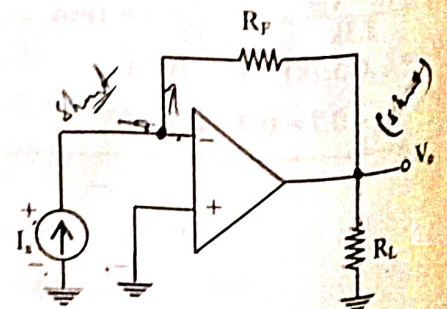
04. In the circuit shown below given $I_s = 100 \mu\text{A}$, $I_f = 95 \mu\text{A}$, $V_o = 10 \text{ V}$. Find A , β and A_f ?



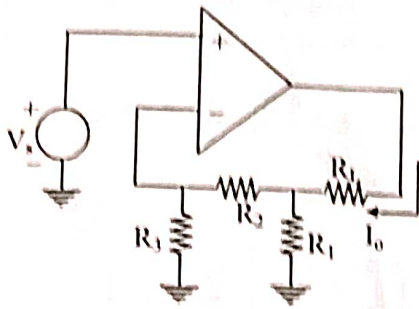
05. A negative feedback amplifier has a closed gain $A_f = 100$ and open loop gain $A = 10^4$. Find feedback factor β ?
06. Find the type of feedback topology, feedback factor β , and Gain V_o/V_s for the amp.



07. Recognize the type of feedback topology, feedback factor β , and Gain V_o/I_s .

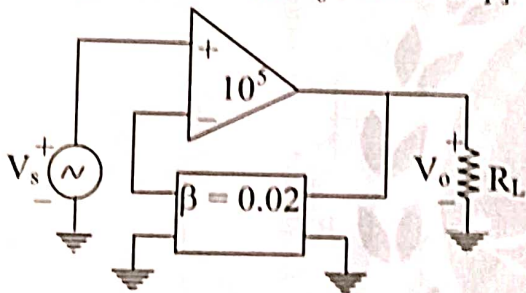


08. Find feedback topology β , Gain $(A_f) = I_o/V_s$



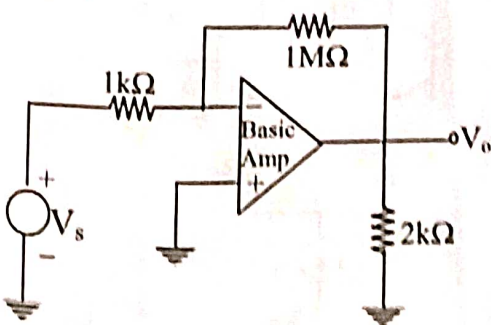
Linked data question:

09. The circuit shown below, given $A = 10^5$
 $\beta = 0.02$ for the basic Amplifier
 $Z_{in} = 10 \text{ k}\Omega$, $Z_o = 500 \Omega$.
Find Z_{in} [Closed loop], Z_o [Closed loop]

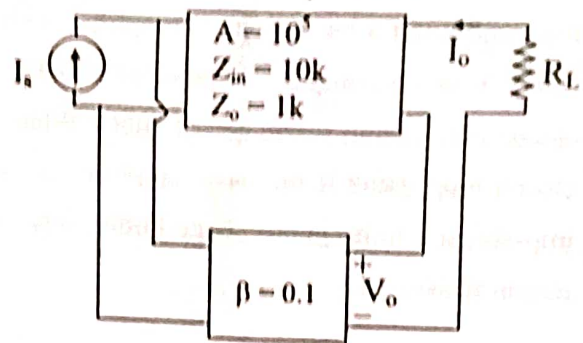


10. Assuming $V_s = 0.1 \sin 2\pi 500t$, what is V_o for the circuit shown in problem (09).

11. Given the basic amplifier (op-amp) has $A = 10^4$,
 $R_{in} = 10^5 \Omega$, $R_o = 1 \text{ k}\Omega$
Find V_o/V_s



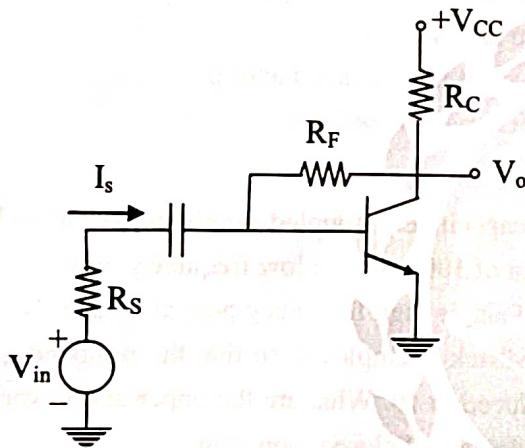
12. Find Z_{in} feedback and Z_o feedback



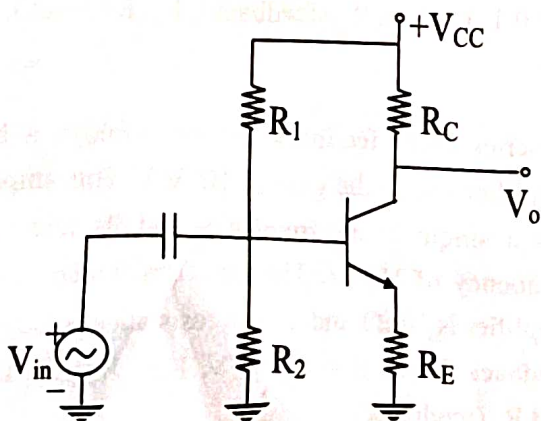
13. An Amplifier with open loop gain $A_o = 1000 \pm 100$ is available. It is required to have an amplifier whose voltage gain varies by no more than 0.1%. Find
(a) value of feedback factor β
(b) Gain with feedback
14. A capacitively coupled amplifier has a midband gain of 100, a single low frequency pole at 100 Hz and single high frequency pole at 10 kHz. Negative feedback is employed so that the midband gain is reduced to 10. What are the upper and lower 3 dB frequency of closed loop gain?
15. A series-shunt feedback amplifier employs a basic amplifier with input and output resistance each of $1 \text{ k}\Omega$ and $A = 2000 \text{ V/V}$. The feedback factor $\beta = 0.1$. Find A_f , R_{in} (feedback), R_o (feedback).
16. A series-shunt feedback circuit employs a basic amplifier with a d.c gain of 10^4 V/V . This amplifier has a single break frequency and its unity gain frequency of 1 MHz. The input resistance of basic amplifier is $10 \text{ k}\Omega$ and output resistance is $1 \text{ k}\Omega$. The feedback factor $\beta = 0.1 \text{ V/V}$. Find R_{in} (feedback) and R_o (feedback).

17. A feedback amplifier utilizing voltage sampling and employing a basic voltage amplifier with gain 100 V/V and an output resistance of 1000Ω , has a closed loop output resistance of 100Ω . What is the closed loop gain? If the basic amplifier is used to implement a unity gain voltage buffer, what is the output resistance.

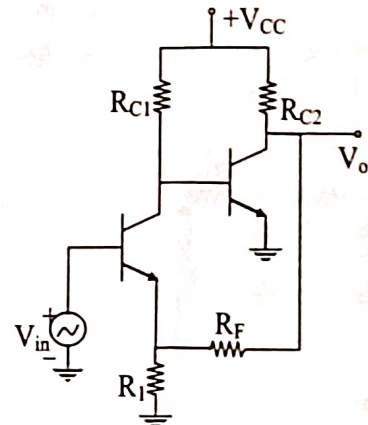
18. (a) Find the feedback topology given by R_F
(b) Find the approximate voltage gain V_o/V_{in}



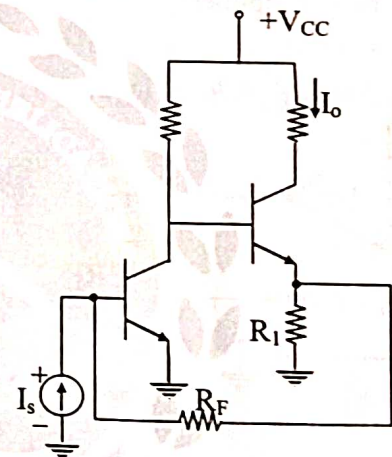
19. Find the feedback topology and voltage gain V_o/V_{in} ,
If $\gamma_\pi \ll \beta R_E$ (or) $R_E \gg 1/g_m$



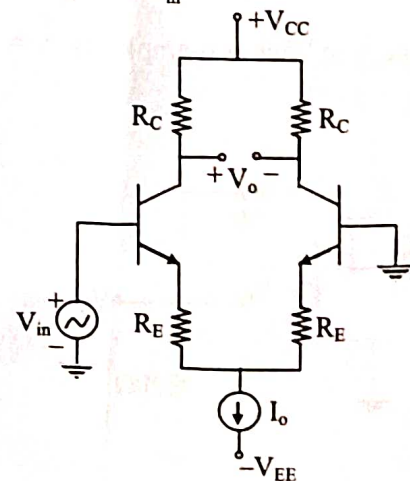
20. Find the feedback topology and feedback factor β



21. Find I_o/I_s and the feedback topology

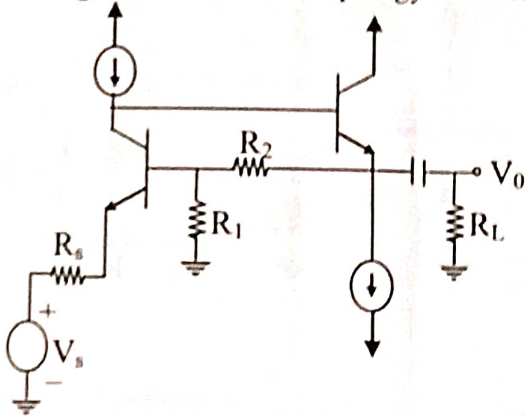


22. Find the approximate voltage gain V_o/V_{in}
if $R_E \gg 1/g_m$

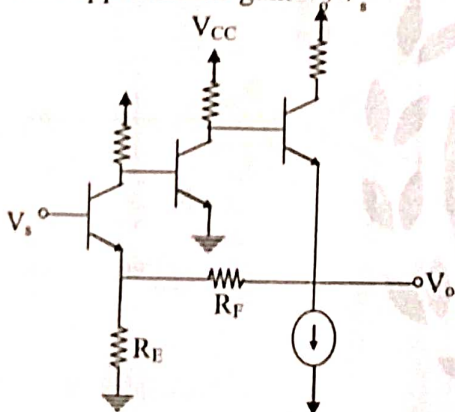


23. An amplifier with gain 1000 feedback with $\beta = 0.1$ has a gain change of 20% due to temperature, what is the change in gain of the feedback amplifier?

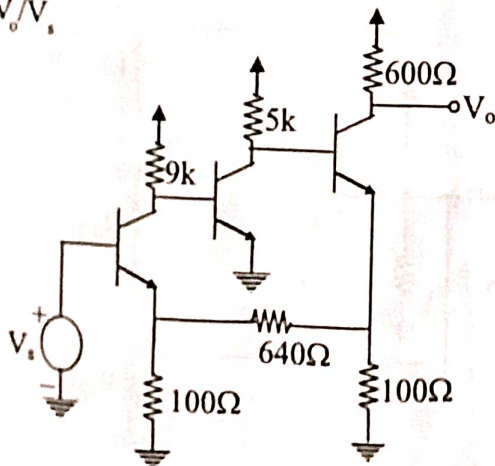
24. Recognize the feedback topology and find β



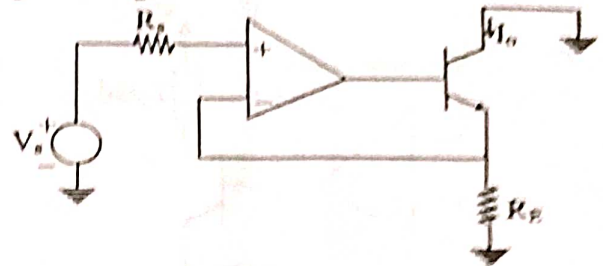
25. Find approximate gain V_o/V_s



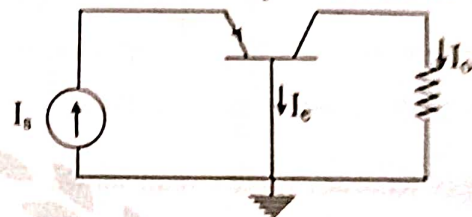
26. Recognize the feedback topology, find β and gain V_o/V_s



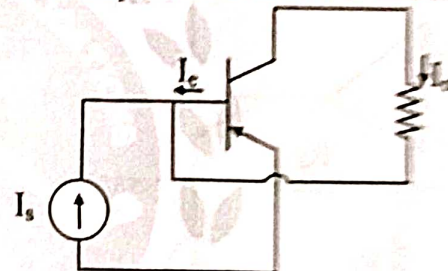
27. Recognize the feedback, and find I_o/V_s if the loop gain is large



28. A common base amplifier is shown

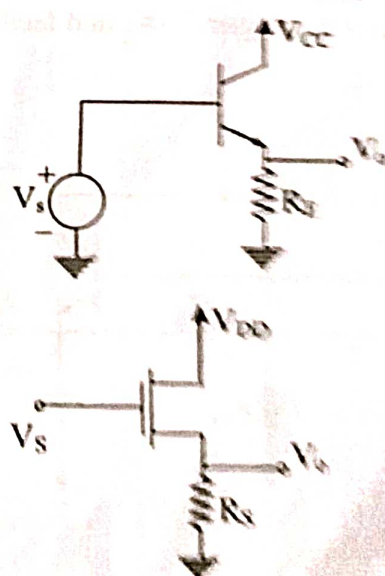


This amplifier is redrawn in this fashion.

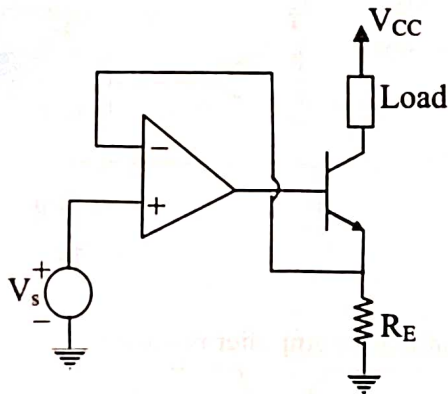


Recognize the feedback in this discrete element

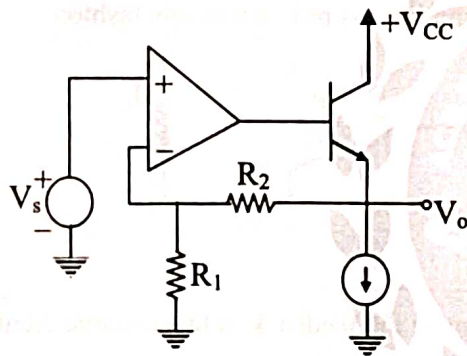
29. Recognize the feedback in basic emitter follower and source follower circuit



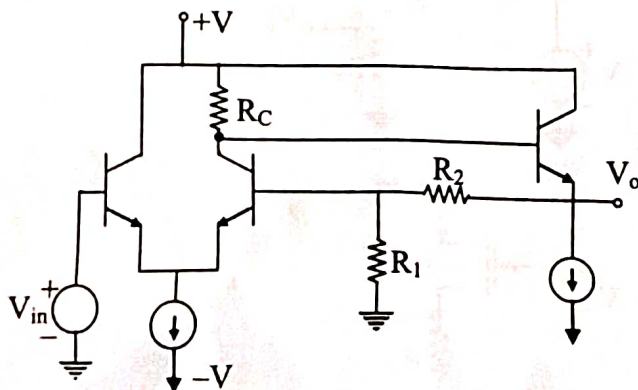
30. Recognize the feedback topology



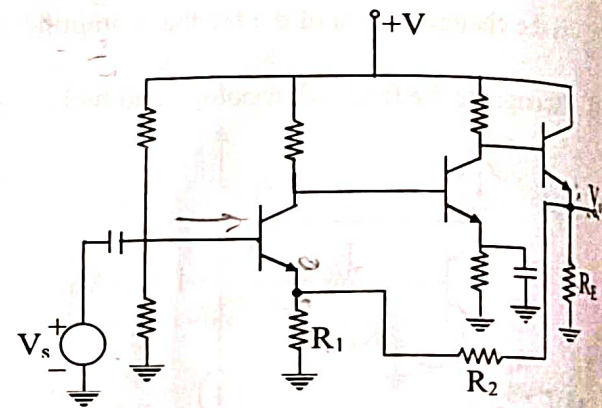
31. What type of feedback is the circuit shown?



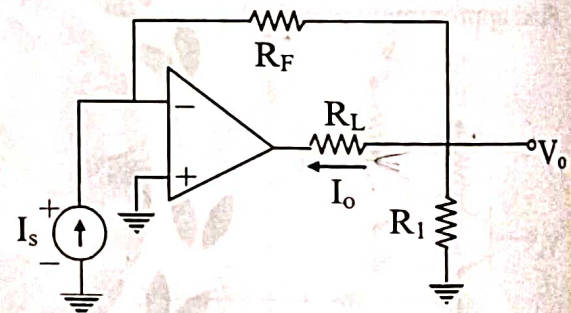
32. Find approximate voltage gain V_o/V_{in} and feedback topology?



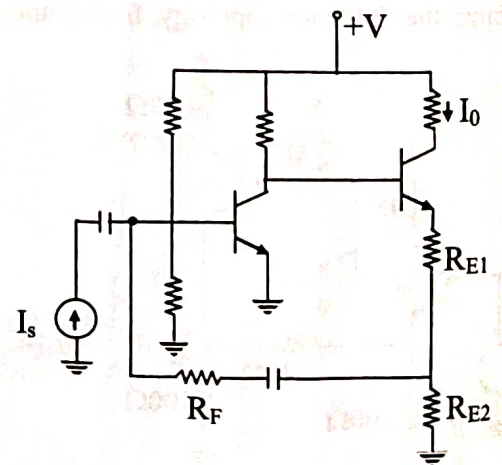
33. Recognize the feedback topology?



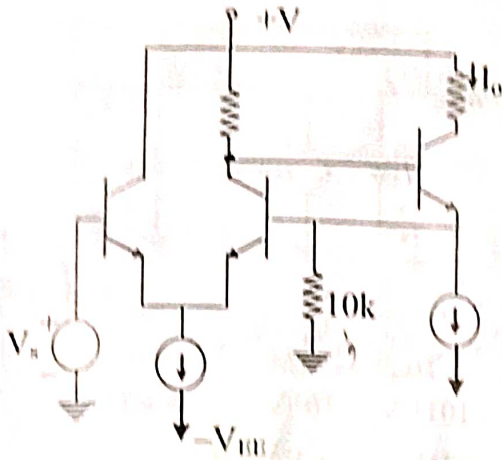
34. Find the feedback topology



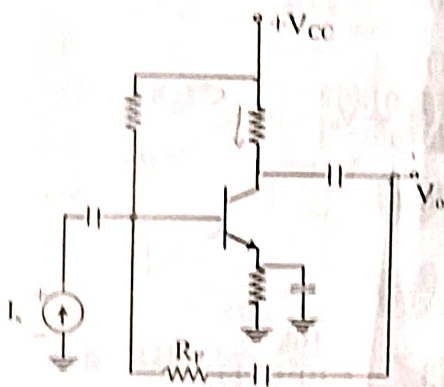
35. Find the feedback topology



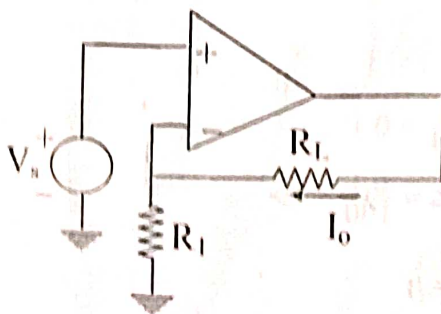
36. Recognize the feedback topology



37. Find the feedback topology



38. Find the feedback topology



Solutions

01.

$$\text{Sol: } A = \frac{V_o}{V_{in}} = \frac{10}{5\text{mV}} = 2000 \text{ V/V}$$

$$\beta = \frac{V_f}{V_o} = \frac{95\text{mV}}{10} = 0.0095 \text{ V/V}$$

$$A_f = \frac{A}{1 + A\beta} = \frac{2000}{1 + (2000 \times 95 \times 10^{-4})} = 100$$

02.

$$\text{Sol: } A = \frac{I_o}{I_{in}}$$

$$A = \frac{I_o}{I_s - I_f} = \frac{10\text{mA}}{5\mu\text{A}} = 2000$$

$$\beta = \frac{I_f}{I_o} = \frac{95\mu\text{A}}{10\text{mA}} = 95 \times 10^{-4}, A_f = \frac{A}{1 + A\beta} = 100$$

03.

$$\text{Sol: } A = \frac{I_o}{V_s - V_f} = \frac{10\text{mA}}{5\text{mV}} = 2 \text{ A/V}$$

$$\beta = \frac{V_f}{I_o} = 9.5 \text{ A/V}$$

$$A_f = \frac{A}{1 + A\beta} = 0.1 \text{ mA/V}$$

04.

$$\text{Sol: } A = \frac{V_o}{I_s - I_f} = \frac{10}{(100 - 95)10^{-6}} = 2 \times 10^6 \text{ V/A}$$

$$\beta = \frac{I_f}{V_o} = 9.5 \mu\text{A/V}$$

$$A_f = \frac{A}{1 + A\beta} = \frac{2 \times 10^6}{1 + (2 \times 10^6 \times 9.5 \times 10^{-6})} = 10^5 \text{ V/A}$$

05.

$$\text{Sol: } A_f = \frac{A}{1 + A\beta} \Rightarrow 1 + A\beta = \frac{A}{A_f} = \frac{10^5}{100} = 1000$$

$$A\beta = 999$$

$$\beta = \frac{999}{10^5} = 9.99 \times 10^{-3}$$

06.

Sol: Series - Shunt [VCVS]

$$\beta = \frac{R_1}{R_1 + R_2}$$

$$\frac{V_o}{V_s} = \frac{1}{\beta} = 1 + \frac{R_2}{R_1}$$

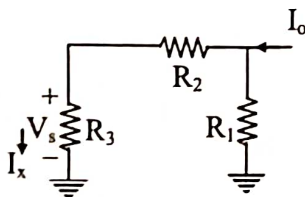
07.

Sol: Shunt - Shunt [CCVS]

$$\begin{aligned} V_o &= (-R_F) I_s \\ \rightarrow \beta &= \frac{1}{\text{Gain}} = -\frac{1}{R_F} \\ \rightarrow \text{Gain} &= \frac{V_o}{I_s} = -R_F \end{aligned}$$

08.

Sol: Series - Series [VCCS]



$$\begin{aligned} V_s &= I_x R_3 \\ &= \frac{I_o R_1}{R_1 + R_2 + R_3} \cdot R_3 \\ \text{Gain } (g_m) &= \frac{I_o}{V_s} = \frac{R_1 + R_2 + R_3}{R_1 R_3} \\ \beta &= \frac{1}{\text{gain}} = \frac{R_1 R_3}{R_1 + R_2 + R_3} \end{aligned}$$

$A\beta > 1$
 $F \approx \frac{1}{A}$

09.

Sol: $Z_{inf} = Z_{in} [1 + A\beta]$

$$\begin{aligned} &= 10 \text{ k} [1 + 10^5 (0.02)] \\ &= 20 \text{ M}\Omega \\ Z_{of} &= \frac{Z_o}{1 + A\beta} \\ &= \frac{500}{1 + 10^5 (0.02)} \\ &= 0.25 \Omega \end{aligned}$$

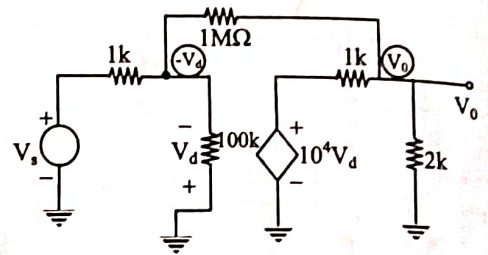
10.

Sol: $V_o = A_f \cdot V_{in}$

$$\begin{aligned} &= \left[\frac{A}{1 + A\beta} \right] V_{in} \\ &= (50) (0.1 \sin 2\pi 500t) \\ &= 5 \sin 2\pi 500t \end{aligned}$$

11.

Sol:



KCL

$$\begin{aligned} \frac{-V_d - V_s}{1\text{k}} - \frac{V_d}{100\text{k}} - \frac{V_d - V_o}{1\text{M}} &= 0 \\ \rightarrow V_o &= -1011 V_d - 10^3 V_s \quad \text{---- (1)} \\ \frac{V_o - 10^4 V_d}{1\text{k}} + \frac{V_o + V_d}{1\text{m}} + \frac{V_o}{2\text{k}} &= 0 \\ \rightarrow V_d &= \frac{1501}{10^7} V_o \quad \text{---- (2)} \end{aligned}$$

Sub (2) in (1)

$$\begin{aligned} V_o &= -1011 \left[\frac{1501}{10^7} V_o \right] - 10^3 V_s \\ \Rightarrow \frac{V_o}{V_s} &= -868.2 \end{aligned}$$

12.

Sol: $Z_{inf} = \frac{Z_{in}}{1 + A\beta} = \frac{10\text{k}}{1 + 10^5 (0.1)} = 1\Omega$

$$\begin{aligned} Z_{of} &= Z_o [1 + A\beta] = 10^3 [1 + 10^5 (0.1)] \\ &= 10 \text{ M}\Omega \end{aligned}$$

13.

Sol: $\frac{dA_o}{A_o} = \frac{100}{1000} = 0.1$

$$\begin{aligned} \frac{dA_f}{A_f} &= 0.1\% = \frac{0.1}{100} \\ \frac{dA_f}{A_f} &= \frac{dA/A}{1 + A\beta} \\ \Rightarrow 1 + A\beta &= \frac{0.1}{0.1/100} = 100 \\ A\beta &= 99 \\ \Rightarrow \beta &= \frac{99}{1000} = 0.099 \\ A_f &= \frac{A}{1 + A\beta} = \frac{1000}{1 + 1000[0.099]} = 10 \end{aligned}$$

14.

Sol: $f_L = \frac{f_L}{1 + A\beta} = \frac{100}{10} = 10\text{Hz}$

Where $1 + A\beta = \frac{A}{A_f} = \frac{100}{10} = 10$

$f_H = f_H[1 + A\beta] = 10\text{k}[10] = 100\text{kHz}$

15.

Sol: $A_f = \frac{A}{1 + A\beta} = \frac{2 \times 10^3}{1 + 2 \times 10^3(0.1)} = 9.95$

$R_{inf} = 1\text{k}[1 + A\beta] = 201\text{ k}\Omega$

$R_{of} = 1\text{k}/1 + A\beta = 4.975\text{ }\Omega$

16. $f_t = A \cdot f_{3dB} \Rightarrow 1\text{M} = 10^4 \cdot f_{3dB}$

Sol: $A = \frac{A_0}{1 + \frac{s}{\omega_{3dB}}} = \frac{A_0}{1 + j \frac{f}{f_{3dB}}} = \frac{10^4}{1 + j \frac{f}{100}}$

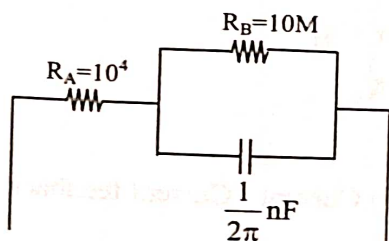
$\beta = 0.1$

$R_{inf} = R_{in}[1 + A\beta] = 10\text{k} \left[1 + \frac{10^4}{1 + j \frac{f}{100}} (0.1) \right]$

$= 10^4 + \frac{10^7}{1 + j \frac{f}{100}}$

$= 10^4 + \frac{1}{\frac{1}{10^7} + j \frac{f}{10^9}}$

$= R_A + \frac{1}{\frac{1}{R_B} + j\omega C}$



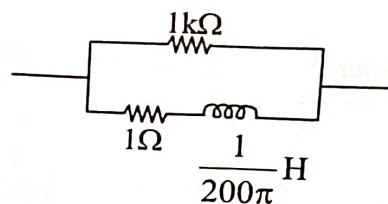
$R_A = 10^4$

$R_B = 10\text{ M}$

$j\omega C = j \frac{f}{10^9} \Rightarrow j2\pi fC = j \frac{f}{10^9}$

$\rightarrow C = \frac{1}{2\pi} \text{ nF}$

$R_{of} = \frac{R_o}{1 + A\beta} = \frac{1\text{k}}{1 + \frac{10^4}{1 + j \frac{f}{100}}} = \frac{1}{1\text{k} + \frac{1}{1 + j \frac{f}{100}}}$



$= \frac{1}{\frac{1}{R_A} + \frac{1}{R_B + j\omega L}}$

$j\omega L = j \frac{f}{100}$

$L = \frac{1}{200\pi}$

17.

Sol: $A = 100$

$R_o = 1000\Omega$

$R_{of} = 100\Omega$

$A_f = \frac{A}{1 + A\beta}$

$R_{of} = \frac{R_o}{1 + A\beta} \Rightarrow 1 + A\beta = \frac{1000}{100} = 10\Omega$

$\therefore A_f = \frac{A}{1 + A\beta} = \frac{100}{10} = 10$

Buffer $\beta = 1$

$\therefore R_o = \frac{R_o}{1 + A\beta} = \frac{1000}{1 + 100(1)} = 9.9\Omega$

18.

Sol: Shunt - Shunt [CCVS]

$V_o = -R_F I_s = -R_F \frac{V_{in}}{R_S}$

$\Rightarrow \frac{V_o}{V_{in}} = -\frac{R_F}{R_S}$

19.

Sol: Series - Series [VCCS]

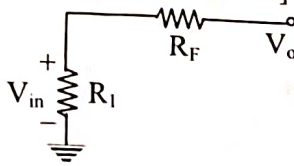
$V_o = -I_o R_C$

$V_o = -\frac{V_{in}}{R_E} R_C$

$\Rightarrow \frac{V_o}{V_{in}} = -\frac{R_C}{R_E}$

20.

Sol: VCVS [Series - Shunt]

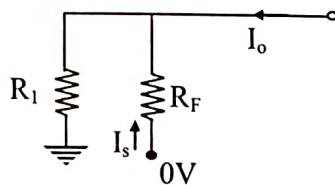


$$V_{in} = \frac{V_o R_1}{R_F + R_1}$$

$$\frac{V_o}{V_{in}} = 1 + \frac{R_F}{R_1}$$

21.

Sol:



$$\Rightarrow -I_s = \frac{I_o R_1}{R_F + R_1}$$

$$\frac{I_o}{I_s} = -\left[1 + \frac{R_F}{R_1}\right]$$

22.

Sol: $\frac{V_o}{V_{in}} = -\frac{R_C}{R_E}$ [Gain of single ended and differential stage are same]

23.

Sol: $A = 1000$

$$\beta = 0.1$$

$$\frac{dA}{A} = 20\%$$

$$\frac{dA_f}{A_f} = \frac{dA/A}{1 + A\beta}$$

$$= \frac{20\%}{1 + 10^3(0.1)} = 0.2\%$$

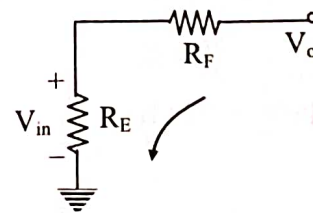
24.

Sol: VCVS [Series - Shunt]

$$\beta = \frac{R_1}{R_2 + R_1}$$

25.

Sol:



$$V_s = \frac{V_o R_E}{R_F + R_E}$$

$$\frac{V_o}{V_s} = 1 + \frac{R_F}{R_E}$$

26.

Sol: VCCS [Series - Series]

$$\beta = \frac{R_1 R_3}{R_1 + R_2 + R_3} = 11.9$$

$$R_1 = 100 \Omega$$

$$R_2 = 640 \Omega$$

$$R_3 = 100 \Omega$$

$$\text{Gain} \left[\frac{I_o}{V_s} \right] = \frac{1}{\beta}$$

$$\frac{V_o}{V_s} = \frac{-I_o(600)}{V_s} = \frac{-600}{11.9} = -50.2$$

27.

Sol: Series - Series [VCCS]

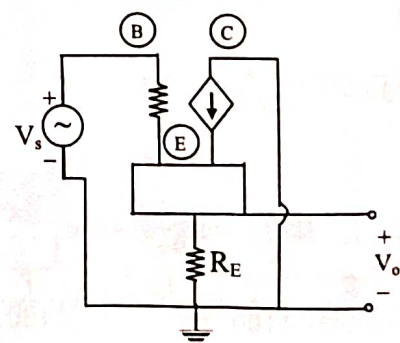
$$I_o = \frac{V_s}{R_E} \Rightarrow \frac{I_o}{V_s} = \frac{1}{R_E}$$

28.

Sol: Shunt - Series (or) Current - Current feedback

29.

Sol: Series - Shunt



30.

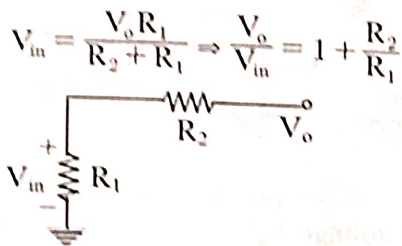
Sol: Voltage at input Current at output [Series - Series]

31.

Sol: Series - Shunt

32.

Sol: Series - Shunt



33.

Sol: Series - Shunt

34.

Sol: Shunt - Series

35.

Sol: Shunt - Series

36.

Sol: Series - Series [VCCS]

37.

Sol: Shunt - Shunt

38.

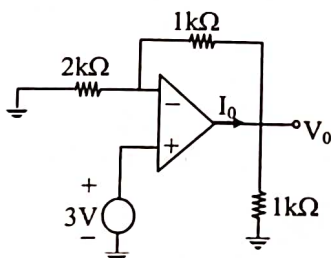
Sol: Series - Series [VCCS]

$$I_o = \frac{V_s}{R_1}$$

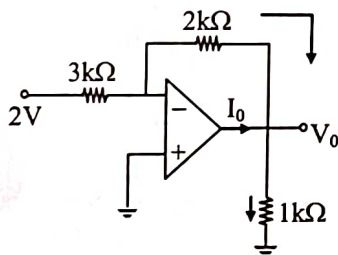
Chapter 5 Operational Amplifiers

Practice Questions

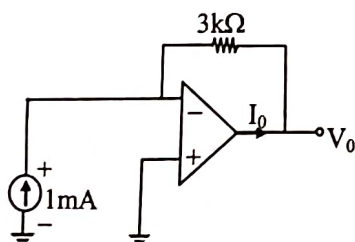
01. In the circuit shown below, find I_0 and V_0 ?



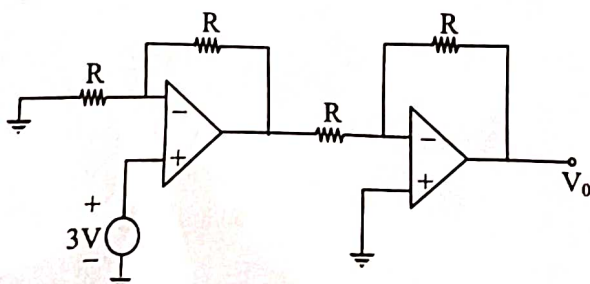
02. In the circuit shown below, find V_0 and I_0 ?



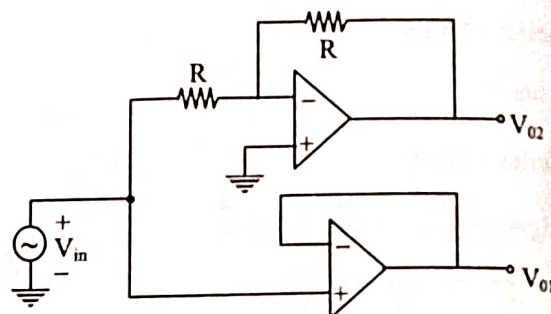
03. For the circuit shown below, find output voltage (V_0) and output current (I_0)?



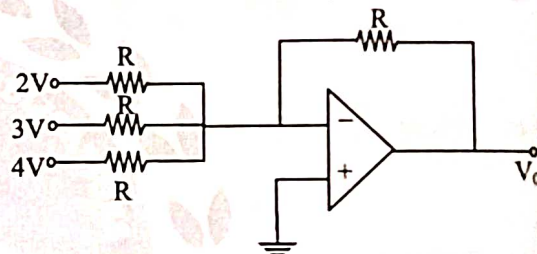
04. Find the output voltage V_0 ?



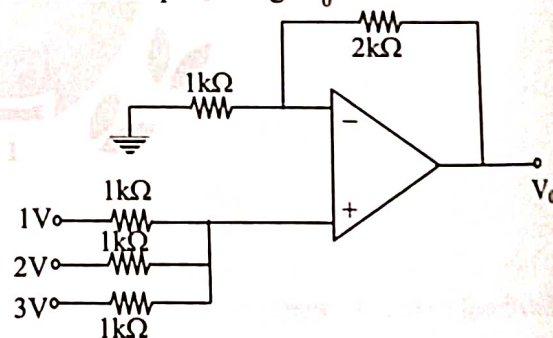
05. Find relation between V_{01} and V_{02} in the circuit shown below.



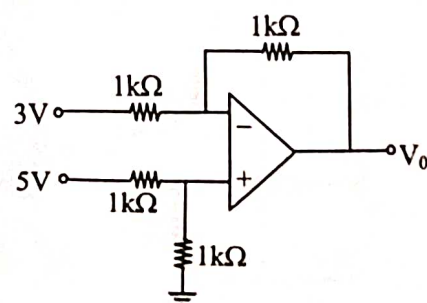
06. Find the output voltage V_0 ?



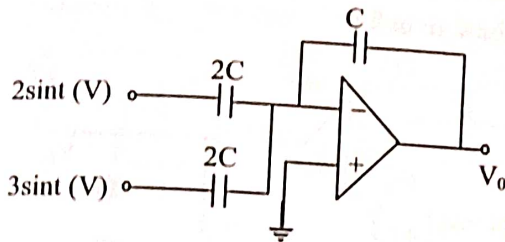
07. Find the output voltage V_0 ?



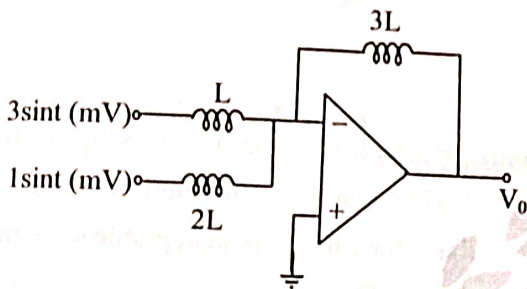
08. Find the output voltage V_0 ?



09. Find the output voltage V_o ?

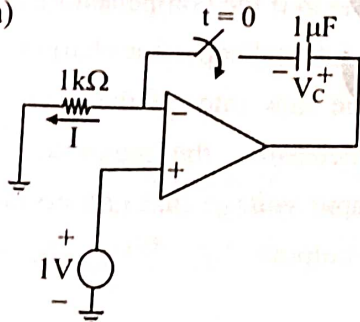


10. Find the output voltage V_o ?



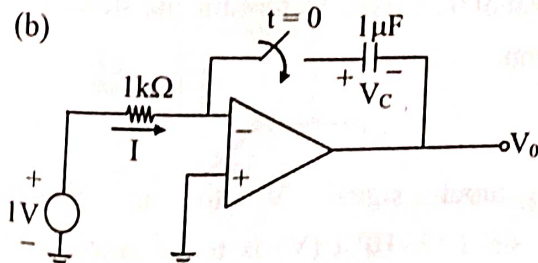
11.

(a)



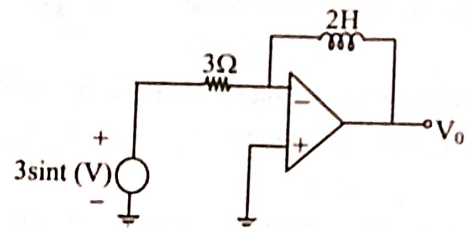
Find V_c at $t = 1\text{msec}$, if capacitor is initially uncharged?

(b)

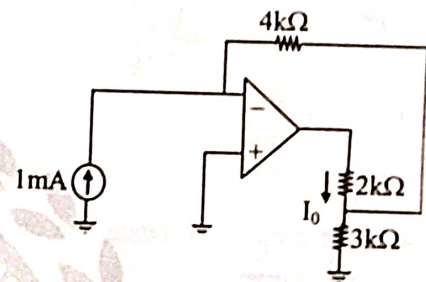


Find V_c and V_o at $t = 0.5\text{msec}$, if capacitor is initially uncharged?

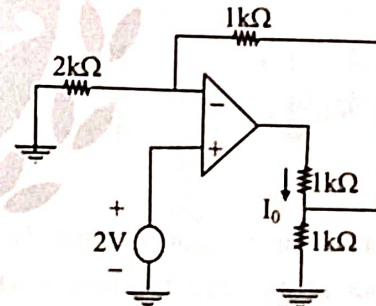
12. Find output voltage V_o ?



13. For the ideal op-amp circuit find the output current I_o ?



14. Find the output current in figure shown below. Assume op-amp to be ideal.



15. An Amplifier has an output signal of 2V for an input of 50mV. Find its voltage gain A_v ? Find $A_{v(\text{in dB})}$?

16. An amplifier has power gain of 800. What is the decibel power gain?

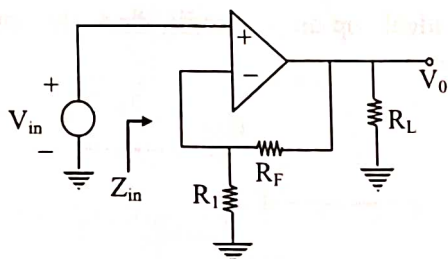
17. An attenuator reduces signal power by a factor of 10,000. What is this loss expressed in dB.

18. An amplifier has a power gain of 23dB. If the input is 1mW, what is the output?

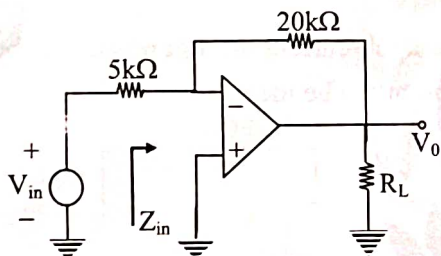
19. A 3 stage amplifier has gains of 10 dB, 16dB and 14dB per section. What is the total dB gain?

20. An amplifier has a gain of 26dB. If the input signal is 10mV, what is the output?

21. Determine the input impedance of the circuit shown?

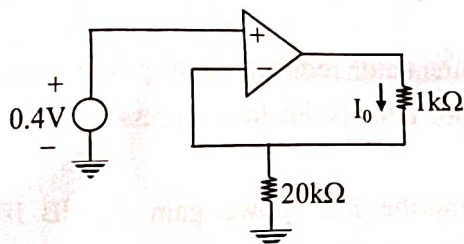


22. Determine the input impedance and output voltage for the circuit shown.

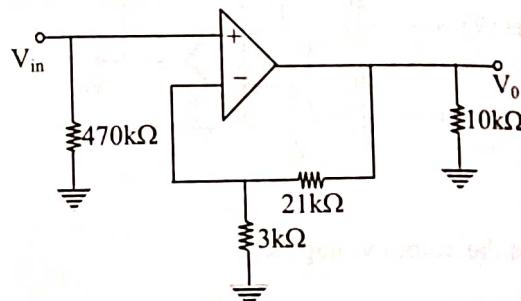


23. An amplifier for an input current of $50\mu\text{A}$ produces an output of 4V, find the transresistance of the circuit?

24. Given an input voltage of 0.4V in the circuit, what is the load current and the transconductance (g_m) of the circuit?



25. What is the input impedance and voltage gain for the circuit given?



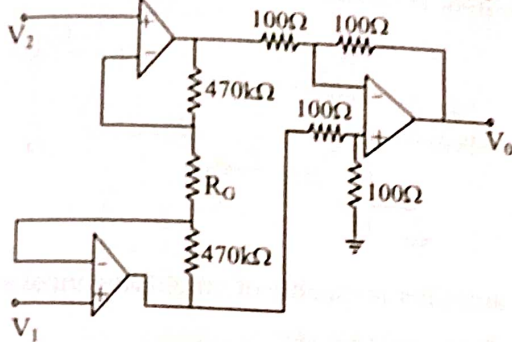
26. An audio preamplifier needs to reproduce signals as high as 20 kHz. The maximum output swing is 10V peak. What is the minimum acceptable slew rate for the op-amp used?

27. For a typical op-amp if the compensating capacitor is 35pF and this internal capacitor charging current is $15\mu\text{A}$, find the slew rate? If the peak value of input is 12V, determine the maximum possible frequency of input voltage that can be applied to get undistorted output?

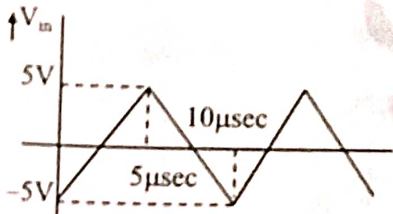
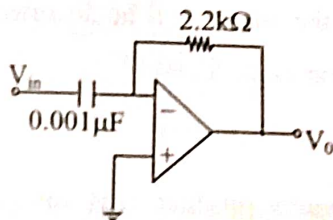
28. In response to a square wave input, the output of an op-amp changed from -3V to $+3\text{V}$ over a time interval of $0.25\mu\text{s}$. Determine the slew rate of the op-amp.

29. The input signal V_i to an op-amp is $0.04 \sin 1.13 \times 10^5 t$ (V) is to be amplified to the maximum extent. How much maximum gain can be had by using op-amp with slew rate of $0.4 \text{ V}/\mu\text{s}$?

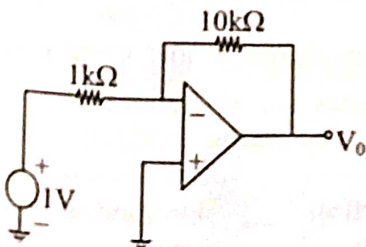
30. For the instrumentation amplifier, determine the value of R_G if the gain required is 1000?



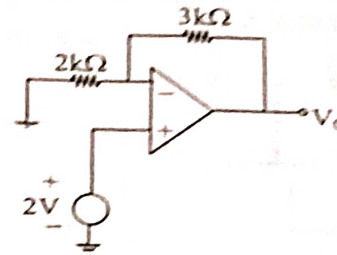
31. Determine the output voltage of the op-amp differentiator for the triangular wave input?



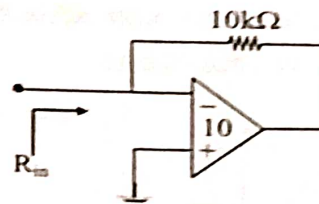
32. An op-amp has a poor gain = 5 (open loop gain) find its output voltage V_0 ?



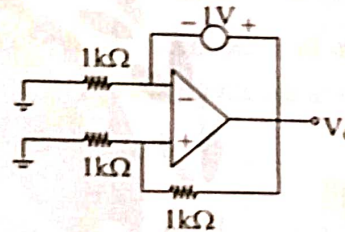
33. An op-amp has a poor open loop gain $A = 10$, find V_0 ?



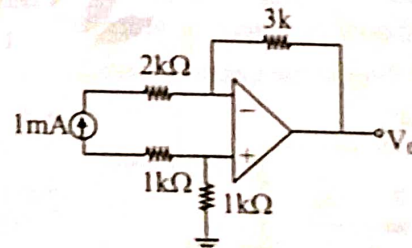
34. Find R_{in} if open loop gain = 10



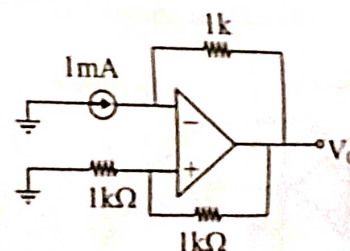
35. Find output voltage V_0 shown in the below circuit



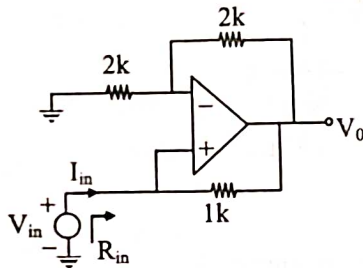
36. Find the output voltage V_0 shown in the circuit below.



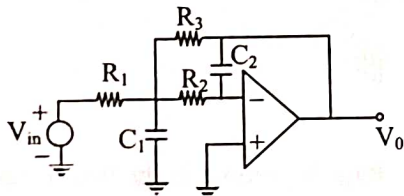
37. Find the output voltage V_0 shown in the circuit below.



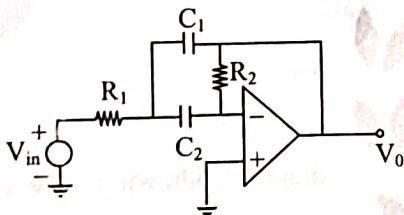
38. Find the input resistance R_{in} ?



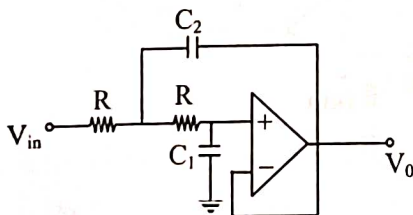
39. The circuit shown is a second order active filter. What type of filter is the circuit shown?



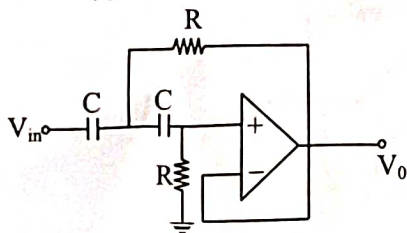
40. The circuit shown is a second order active filter. What type of filter is the circuit shown?



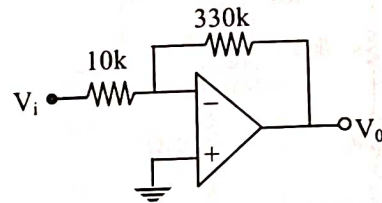
41. The circuit shown is a second order active filter. What type of filter is the circuit shown?



42. The circuit shown is a second order active filter. What type of filter is the circuit shown?



43. The operational amplifier has a slew rate of $0.5V/\mu\text{sec}$ as shown



The amplifier is capable of amplifying input signals

$$V_1 = 0.01 \sin 10^6 t \text{ (V)}$$

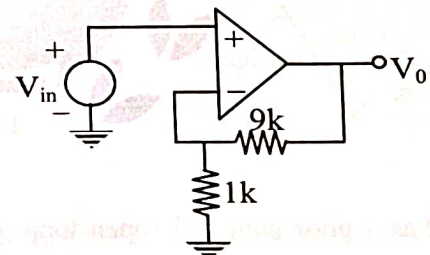
$$V_2 = 0.05 \sin 350 \times 10^6 t \text{ (V)}$$

$$V_3 = 0.1 \sin 200 \times 10^3 t \text{ (V)}$$

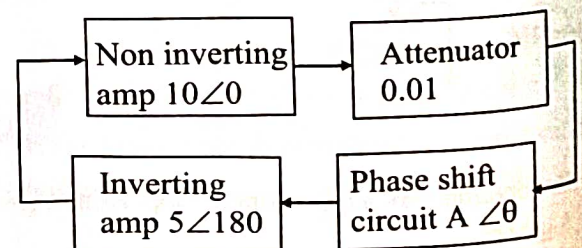
$$V_4 = 0.2 \sin 50 \times 10^3 t \text{ (V)}$$

Determine whether the output will be distorted due to slew rate limitation in each case.

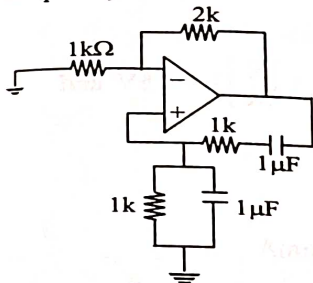
44. The gain - bandwidth product (or) unity gain frequency is 1 MHz for the op-amp. Find the bandwidth of amp.



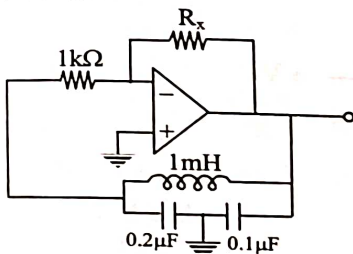
45. The block diagram shown is that of an oscillator find A and θ for sustained oscillations



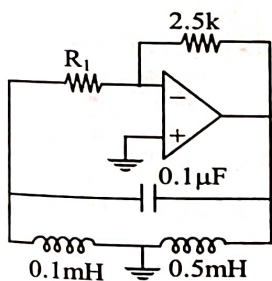
46. For the Wien bridge oscillator find the oscillating frequency



47. Find R_x for sustained oscillations in Colpitts oscillator

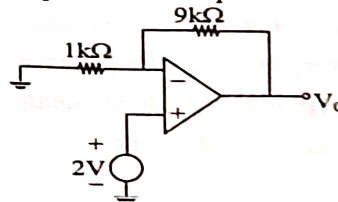


48. Find R_1 for sustained oscillations in Hartley oscillator

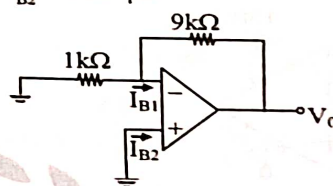


49. What is $\left| \frac{d\phi}{d\omega} \right|$ for an ideal oscillator?
50. What is an amplifier which has high R_{in} and low R_o ?
51. What is amplifier which has low R_{in} and low R_o ?
52. What is an amplifier which has high R_{in} and high R_o ?
53. What is amplifier which has low R_{in} and high R_o ?
54. Which oscillator is used in the audio range from 20 Hz to 100 kHz and it is a variable oscillator?

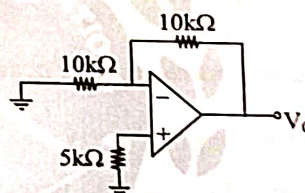
55. Find the output voltage of the non-inverting amplifier if the input offset voltage is 3mV



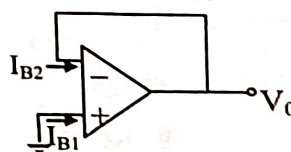
56. Find the output offset voltage if $I_{B1} = 0.3\mu A$ & $I_{B2} = 0.29\mu A$



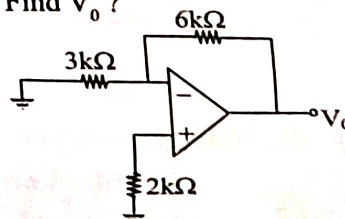
57. Find the output offset voltage if $I_{B1} = 0.3\mu A$ & $I_{B2} = 0.29\mu A$



58. If the input bias current $I_B = 0.3\mu A$ and $I_{os} = 50\text{ nA}$. Find the currents I_{B1} and I_{B2} drawn by op-amp? (Assume $I_{B1} > I_{B2}$)

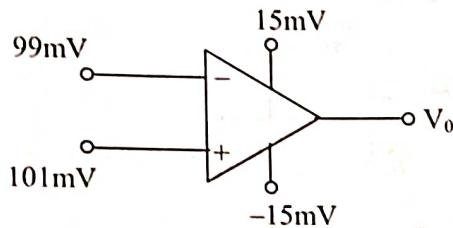


59. Consider a non-inverting amplifier with an input current of 80 nA and input offset voltage of 8mV. Find V_o ?



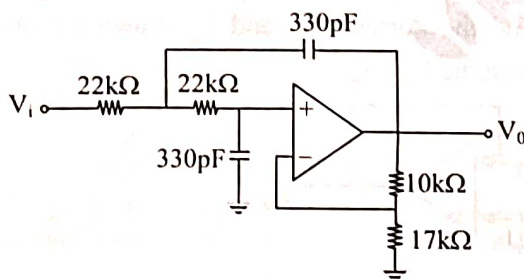
60. Which of the following statements are TRUE about the operational amplifier?
- (a) Op-amps have very low output impedance
 - (b) Op-amps have very high input impedance
 - (c) Op-amps have very high open loop voltage gain
 - (d) Op-amps have very high slew rate

61. For the op-amp shown CMRR is 80dB and common mode voltage gain is 1 then



- (a) Common mode signal is 2mV
- (b) Differential mode signal is 2mV
- (c) Output voltage V_0 is 15V
- (d) The given op-amp operated in negative saturation region

62. For the given circuit, the correct frequency response is:



- (a) The cut-off frequency $f_{3dB} = 21.9\text{kHz}$
- (b) Quality factor, $Q = 0.704$
- (c) The maximum pass band gain = 4dB
- (d) It is butterworth high pass filter

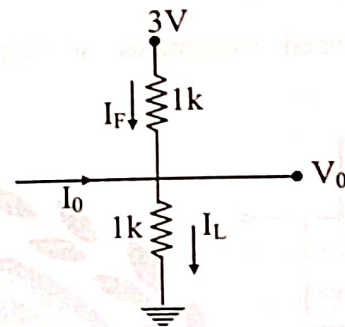
Solutions

01.

$$\text{Sol: } V_0 = \left[1 + \frac{R_F}{R_1}\right] V_s = \left[1 + \frac{1K}{2K}\right] 3 = 4.5V \text{ and}$$

$$I_0 + I_F = I_L$$

$$I_0 = I_L - I_F = \frac{4.5}{1K} - \left[\frac{3 - 4.5}{1K}\right] = 6mA$$



02.

$$\text{Sol: } V_0 = \left[\frac{-R_F}{R_1}\right] V_s = \left[\frac{-2K}{3K}\right] 2 = \frac{-4}{3} V$$

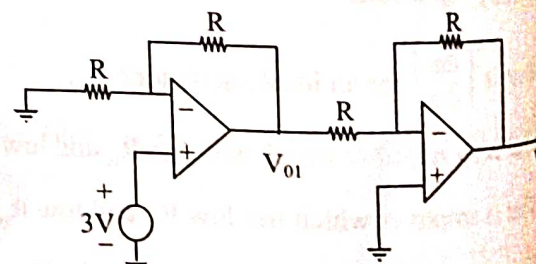
$$I_0 = I_{2K} - I_{1K} = \left[\frac{0 - V_0}{2K}\right] - \left[\frac{V_0}{1K}\right]$$

03.

$$\text{Sol: } V_0 = (-3K) \cdot 1m = -3V \text{ and } I_0 = -1mA$$

04.

Sol:



From V_{01} ,

$$\therefore V_{01} = \left[1 + \frac{R}{R}\right] 3 = 6V \text{ and}$$

$$V_0 = \frac{-R}{R} V_{01} = -6V$$

05.

Sol: From the figure,

$$\begin{aligned}\therefore V_{o2} &= -\frac{R}{R} V_{in} = -V_{in} \text{ and} \\ V_{o1} &= V_{in} \\ \therefore V_{o2} &= -V_{o1}\end{aligned}$$

06.

Sol: KCL,

$$\frac{0-2}{R} + \frac{0-3}{R} + \frac{0-4}{R} + \frac{0-V}{R} = 0$$

$$\Rightarrow V_o = -(2+3+4) = -9 \text{ V}$$

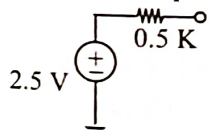
07.

Sol: Let V ,

$$\begin{aligned}\frac{V-1}{1K} + \frac{V-2}{1K} + \frac{V-3}{1K} &= 0 \\ \Rightarrow 3V &= 1+2+3 = 6 \text{ V} \\ \Rightarrow V &= 2 \text{ V and} \\ V_o &= \left[1 + \left[\frac{2K}{1K}\right]\right] 2V = 6V\end{aligned}$$

08.

Sol: Thevenin's equivalent at non-inverting terminal,



KCL at inverting node terminal,

$$\frac{2.5-3}{1k} + \frac{2.5-V_o}{1K} = 0$$

$$\Rightarrow V_o = 2 \text{ V}$$

(OR)

By subtractor,

$$\therefore V_o = 5 - 3 = 2 \text{ V}$$

09.

Sol: $V_o = -10 \sin t \text{ (V)}$

$$\left[\therefore \text{KCL, } \frac{2 \sin t}{sC2} + \frac{3 \sin t}{sC2} = \frac{0 - V_o}{sC} \right]$$

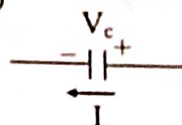
10.

Sol: $V_o = -10.5 \sin(t) \text{ mV}$

$$\left[\therefore \text{KCL, } \frac{3 \sin t}{sL} + \frac{1 \sin t}{s2L} = \frac{0 - V_o}{s(3L)} \right]$$

11.

Sol: (a)



$$V_c = \frac{1}{C} \int I dt = \frac{1m}{10^{-6}} (1m) = 1 \text{ V}$$

$$\begin{aligned}\text{(b) } V_c &= \left[\frac{I}{C} \right] t = \frac{1m}{10^{-6}} (0.5m) = 0.5 \text{ V} \\ \therefore V_o &= -0.5 \text{ V}\end{aligned}$$

12.

Sol: $V_o = -2 \cos t \text{ (V)}$

$$\left[\therefore \frac{V_o}{V_{in}} = -\frac{2s}{3} \Rightarrow V_o = -\frac{2}{3} \frac{d}{dt} V_{in} \right]$$

$$\text{i.e., } V_o = \left[\frac{-2}{3} \right] \frac{d}{dt} (2 \sin t) = -2 \cos t \text{ V}$$

13.

$$\text{Sol: } I_o = -\left[1 + \frac{R_F}{R_1}\right] I_{in} = -\left[1 + \frac{4k}{3k}\right] 1m = -\frac{7}{3} \text{ mA}$$

14.

Sol: KCL,

$$\frac{2}{2K} + \frac{2-V}{1K} = 0$$

$$\Rightarrow V = 3 \text{ V}$$

$$\therefore I_o = \frac{3-2}{1K} + \frac{3}{1K} = 4 \text{ mA}$$

15.

$$\text{Sol: } A_v = \frac{2}{0.05} = 40 \rightarrow A_{v \text{ dB}} = 20 \log 40 = 32 \text{ dB}$$

16.

Sol: An amplifier power gain, $A_p = 800$.

in decibel,

$$A_{p \text{ dB}} = 10 \log 800 = 29.03 \text{ dB}$$

17.

Sol: Loss expressed in db,

$$= 10 \log \frac{1}{10000} = -40 \text{ db}$$

18.

Sol: Power gain in db's, $A_{P(\text{DB})} = 23 \text{ db}$

$$= 10 \log(A_P)$$

Power gain, $A_P = 199.526$ and

$$A_P = \frac{P_0}{P_{in}} \Rightarrow \text{output, } P_0 = A_P \cdot P_{in}$$

$$= 199.526 \times 1 \text{ mW}$$

$$= 199.5 \text{ mW}$$

19.

Sol: Total gain in db,

$$= 10 \text{ db} + 16 \text{ db} + 14 \text{ db} = 40 \text{ db}$$

20.

Sol: Gain in db's = $26 \text{ db} = 20 \log(A)$

$$\therefore A = 19.95$$

$$\text{So, } A = \frac{V_0}{V_{in}}$$

$$\Rightarrow V_0 = 19.95 \times 10 \text{ m}$$

$$= 0.1995 \text{ V}$$

21.

Sol: Given, op-amp draws no Current, i.e., $I_{in} = 0$
 So, input resistance, $R = \frac{V_{in}}{I_{in}} = \infty \Omega$

22.

Sol: From the circuit,

$$R_{in} = 5 \text{ K}\Omega \text{ and}$$

$$V_0 = -\frac{R_F}{R_1} \cdot V_{in} = -\frac{20 \text{ K}}{5 \text{ K}} V_{in}$$

$$\Rightarrow V_0 = -4 V_{in}$$

23.

Sol: Transresistance, $R_m = \frac{4 \text{ V}}{50 \mu \text{ A}} = 80 \text{ k}\Omega$

24.

Sol: By KCL,

$$\therefore \frac{0.4}{20 \text{ K}} - I_0 = 0$$

$$\Rightarrow I_0 = 20 \mu \text{ A}$$
 Transconductance, $g_m = \frac{1}{20 \text{ K}} = 50 \mu \text{ S}$

25.

Sol: From the circuit,
 input resistance, $R_{in} = 470 \text{ k}$
 Voltage gain, $A_v = \frac{V_0}{V_{in}}$
 By KCL,

$$\therefore \frac{V_{in}}{3 \text{ K}} + \frac{V_{in} - V_0}{2 \text{ K}} = 0$$

$$\therefore V_0 = 8 V_{in}$$
 So, $A_v = 8$

26.

Sol: Given, frequency, $f_0 = 20 \text{ KHz}$
 max output swing, $V_{0\text{max}} = 10 \text{ V}$
 Slew rate for the op-amp,

$$\text{S.R} = 2\pi f_{\text{max}} \cdot V_{0\text{max}}$$

$$= 2\pi \times 20 \text{ K} \times 10$$

$$= 1.257 \text{ V}/\mu \text{ sec}$$

27.

Sol: Given, $C = 35 \text{ pF}$
 $I = 15 \mu \text{ A}$
 slew rate,

$$\text{SR} = \frac{dV_c}{dt} = \frac{I}{C} = \frac{15 \mu \text{ A}}{35 \text{ pF}} = 0.4285 \text{ V}/\mu \text{ Sec}$$
 Given, $V_m = 12 \text{ V}$
 maximum possible frequency,

$$f_m = \frac{\text{S.R}}{2\pi V_m} = 5.684 \text{ KHz}$$

28.

Sol: $\text{SR} = \frac{\Delta V}{\Delta t} = \frac{3 - (-3)}{0.25 \mu} = 24 \text{ V}/\mu \text{ sec}$

29.

Sol: Given, $V_i = 0.04 \sin(1.13 \times 10^5 t) \text{ V}$

where, $\omega_m = 1.13 \times 10^5$ rad/sec.

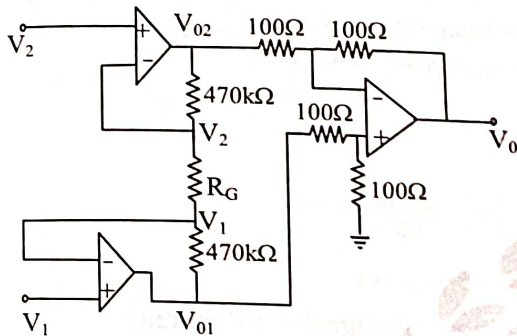
$$\therefore SR = (2\pi f_m) \cdot V_m$$

$$\Rightarrow V_m = \frac{0.4 \times 10^6}{1.13 \times 10^5} = 3.5398V$$

$$\therefore \text{Gain} = \frac{V_m}{V_i} = \frac{3.5398}{0.04} = 88.5$$

30.

Sol:



KCL,

$$\frac{V - V_0}{100} + \frac{V - V_{02}}{100} = 0 \Rightarrow V = \frac{V_0 + V_{02}}{2} \dots\dots(1)$$

$$\frac{V}{100} + \frac{V - V_{01}}{100} = 0 \Rightarrow V = \frac{V_{01}}{2} \dots\dots(2)$$

From (1) & (2)

$$\frac{V_{01}}{2} = \frac{V_0 + V_{02}}{2} \Rightarrow V_0 = [V_{01} - V_{02}] \dots\dots(3)$$

$$\therefore \frac{V_2 - V_{02}}{470k} + \frac{V_2 - V_{01}}{R_G} = 0 \dots\dots(4)$$

$$\frac{V_1 - V_{01}}{470k} + \frac{V_1 - V_2}{R_G} = 0 \dots\dots(5)$$

(4) - (5)

$$\frac{(V_2 - V_{02} - V_1 + V_{01})}{470k} + \frac{[(V_2 - V_1) - V_1 + V_2]}{R_G} = 0$$

$$\frac{(V_2 - V_1) + V_0}{470k} + \frac{2(V_2 - V_1)}{R_G} = 0$$

$$1 + \frac{V_0}{470k} + \frac{2}{R_G} = 0$$

$$1 - \frac{V_0}{470k} + \frac{2}{R_G} = 0$$

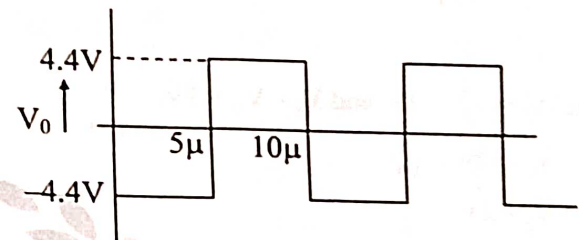
31.

Sol:

$$\frac{2}{R_G} = \frac{\frac{V_0}{V_1 - V_2} - 1}{470k} \left[\because \frac{V_0}{V_1 - V_2} = 1000 \right]$$

$$R_G = 940.9 \Omega$$

$$V_o = -RC \frac{dV_{in}}{dt} = -2.2\mu \left(\frac{10}{5\mu} \right) = -4.4V$$



32.

Sol: Output voltage, $V_o = A \cdot (V_p - V_n)$

$$V_o = (0 - V_n) \cdot A$$

$$\text{So, } V_o = -A \cdot V_n \dots\dots(1)$$

$$\text{By KCL, } \frac{V_n - 1}{1K} + \frac{V_n - V_o}{10K} = 0$$

$$\therefore 11V_n = V_o + 10$$

$$\therefore V_n = \frac{V_o + 10}{11}$$

$$\text{From equation (1), } V_o = -5 \cdot \left[\frac{V_o + 10}{11} \right]$$

$$11V_o = -(5V_o + 50) = -5V_o - 50$$

$$\therefore 16V_o = -50$$

$$\Rightarrow V_o = -\frac{50}{16} V$$

33.

Sol: Output Voltage, $V_o = A \cdot (V_p - V_n)$

$$V_o = 10(2 - V_n) \dots\dots(1)$$

$$\text{KCL, } \frac{V_n}{2K} + \frac{V_n - V_o}{3K} = 0$$

$$\Rightarrow V_o = 2.5 V_n$$

From equation ----- (1),

$$V_o = 10 \left[2 - \frac{V_o}{2.5} \right]$$

$$V_o = 20 = 4V_o$$

$$\Rightarrow V_o = 4V$$

34.

Sol: $R_{in} = \frac{R}{1 + A}$ (millers effect)
 $= \frac{10k}{11}$

35.

Sol: $V_p = \frac{V_o}{2} = V_H$ and $V_o = V_H = 1V$

$$V_o = \frac{V_o}{2} = 1V$$

$$V_o = 2V$$

36.

Sol: $V_p = (-1m) 1k = -1V = V_H$

$$1m = \frac{V_H - V_o}{3k} \Rightarrow 3V = -1 - V_o$$

$$V_o = -4V$$

37.

Sol: $V_p = \frac{V_o}{2} = V_H$

$$1m = \frac{V_H - V_o}{1k}$$

$$1V = \frac{V_o}{2} - V_o$$

$$V_o = -2V$$

38.

Sol: $V_o = \left[1 + \frac{2k}{2k} \right] V_{in} = 2V_{in}$

$$I_{in} = \frac{V_{in} - 2V_{in}}{1k}$$

$$\frac{V_{in}}{I_{in}} = -1k\Omega$$

39.

Sol: $\omega = 0$ cap OC $\rightarrow V_o \neq 0V$
 $\omega = \infty$ cap SC $\rightarrow V_o = 0V$ } LPP

40.

Sol: $\omega = 0$ cap OC $\rightarrow V_o \neq 0V$
 $\omega = \infty$ cap SC $\rightarrow V_o = 0V$ } LPP

41.

Sol: $\omega = 0$ cap OC $\rightarrow V_o \neq 0V$
 $\omega = \infty$ cap SC $\rightarrow V_o = 0V$ } LPP

42.

Sol: $\omega = 0$ cap OC $\rightarrow V_o \neq 0V$
 $\omega = \infty$ cap SC $\rightarrow V_o \neq 0V$ } LPP

43.

Sol: $\left[\frac{V_o}{V_i} \right] = \left[\frac{-330k}{10k} \right] = -33$

$$SR = 0.5 V/\mu sec$$

Condition, $|SR|_{signal} \leq |SR|_{op-amp}$

Slew rate is calculated at output

$$V_{o1} = 33V_1 = 0.33 \sin 10^4 t$$

$$\rightarrow |SR|_{signal} = \omega V_{o1max} = 0.33 V/\mu sec$$

$$V_{o2} = 33V_2 = 1.65 \sin 350 \times 10^4 t$$

$$\rightarrow |SR|_{signal} = \omega V_{o2max} = 0.577 V/\mu sec$$

$$V_{o3} = 33V_3 = 3.3 \sin 200 \times 10^4 t$$

$$\rightarrow |SR|_{signal} = \omega V_{o3max} = 0.66 V/\mu sec$$

$$V_{o4} = 33V_4 = 6.6 \sin 50 \times 10^4 t$$

$$\rightarrow |SR|_{signal} = 0.33 V/\mu sec$$

$$\therefore V_{o1}, V_{o4} \rightarrow \text{no distortion}$$

$$V_{o2}, V_{o3} \rightarrow \text{distortion}$$

44.

Sol: Gain = $1 + \frac{R_2}{R_1} = 10$

$$G.BW = 10, BW = 10^6$$

$$BW = 10^5 \text{ Hz}$$

45.

Sol: Loop gain = $1 \angle 360$

$$10 \angle 0 (0.01) (A \angle 0) 5 \angle 180 = 1 \angle 360$$

$$A = 2, \theta = 180^\circ$$

46.

Sol: $\omega_0 = \frac{1}{RC} = \frac{1}{(1k)(1\mu)} 1k \text{ rad/sec}$

$$f = \frac{1}{2\pi RC} = 159.155 \text{ Hz}$$

47.

Sol: $\frac{R_x}{1k} = \frac{C_1}{C_2}$
 $\Rightarrow R_x = \left[\frac{0.2\mu}{0.1\mu} \right] 1k = 2k\Omega$

48.

Sol: $\frac{R_F}{R_1} = \frac{L_2}{L_1}$
 $\Rightarrow R_1 = \frac{R_F L_1}{L_2} = 2.5k \frac{(0.1)}{0.5} = 500 \Omega$

49.

Sol: $\left| \frac{d\phi}{d\omega} \right| = \infty$

50.

Sol: Voltage amplifier [VCVS]

51.

Sol: Transresistance amplifier [CCVS]

52.

Sol: Transconductance amplifier [VCCS]

53.

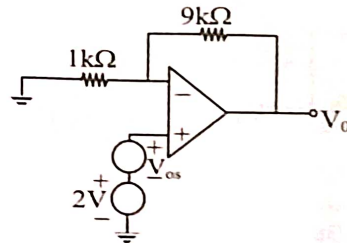
Sol: Current amplifier [CCCS]

54.

Sol: Wien bridge oscillator.

55.

Sol:



$$V_0 = \left[1 + \frac{9k}{1k} \right] (V_{os} + 2)$$

$$= 10(2 + 0.003)$$

$$= 20.03 \text{ V}$$

56.

Sol: $V_0 = I_{B1}(9k)$
 $= 0.3\mu A(9k)$
 $= 2.7 \text{ mV}$

57.

Sol: $V_0 (\text{error}) = 10k I_{os}$ [5k is the compensation resistor]
 $= 10k |I_{B2} - I_{B1}|$
 $= 10k (0.01\mu)$
 $= 0.1 \text{ mV}$

58.

Sol: Bias current $I_B = \frac{I_{B1} + I_{B2}}{2}$
 $\rightarrow I_{B1} + I_{B2} = 2I_B$
 Input offset current $I_{os} = I_{B1} - I_{B2}$
 $\therefore I_{B1} + I_{B2} = 2(0.3\mu) = 0.6 \mu A$
 $I_{B1} - I_{B2} = 50 \text{ nA}$
 $\therefore 2I_{B1} = 0.6\mu + 50 \text{ n}$
 $I_{B1} = \frac{0.6\mu + 50 \text{ n}}{2}$
 $I_{B1} = 0.325 \mu A$
 $\therefore I_{B2} = I_{B1} - 50 \text{ nA}$
 $I_{B2} = 0.275 \mu A$

59.

Sol:



$$\begin{aligned} V_o &= 6kI_{in} + \left[1 + \frac{6k}{3k}\right]V_s \\ &= 6k(80 \text{ nA}) + 3(8 \text{ mV}) \\ &= 24.48 \text{ mV} \end{aligned}$$

60. Ans: (a, b, c, d)

Sol: Op-amps have

- input impedance very high
- output impedance very low
- open loop voltage gain very high
- slew rate very high

61. Ans: (b, c)

Sol: For the Op-amp circuit, $V_d = 2 \text{ mV}$, $V_c = 100 \text{ mV}$

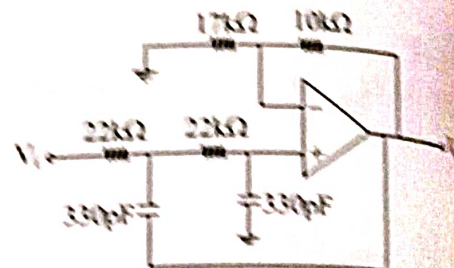
$$\text{CMRR} = 80 \text{ dB} \Rightarrow \text{CMRR} = 10^4 = \frac{A_d}{A_c} \Rightarrow A_d = 10^4$$

$$\begin{aligned} \text{Then } V_o &= A_d V_d + A_c V_c \\ &= 20 + 0.1 \Rightarrow V_o = 20.1 \text{ V} \end{aligned}$$

As V_o exceeds passive supply voltage, it operated in +ve saturation region.

62. Ans: (a, b & c)

Sol: If we could redraw the circuit, it is Sallen key 2nd order LPE.



So, we know, the cut off frequency

$$f_{\text{cut}} = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

$$\begin{aligned} \therefore f_{\text{cut}} &= \frac{1}{2\pi\sqrt{R^2 C^2}} \\ &= \frac{1}{2\pi RC} \\ &= 21.9 \text{ kHz} \end{aligned}$$

As if $R_1 = R_2$ & $C_1 = C_2 \Rightarrow$ Quality factor

$$\begin{aligned} \text{Where } K &\rightarrow \text{DC gain, } K = 1 + \frac{R_2}{R_1} = 1 + \frac{10k}{17k} \\ \therefore K &= 1.58 \end{aligned}$$

$$\Rightarrow \text{In decible, } K_{\text{dB}} = 20 \log_{10} 1.58 = 4 \text{ dB}$$

So, Quality factor, $Q = 0.704$

It is Butterworth low pass filter.