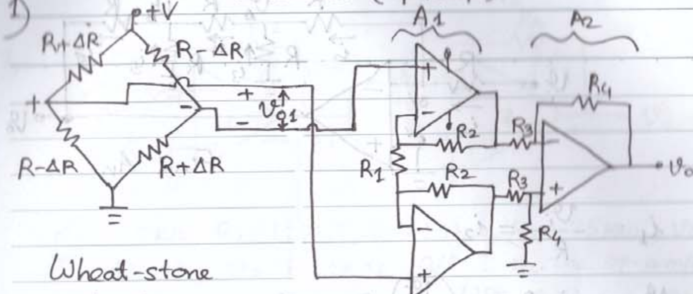
Tutorial (Op-Amps)

1)



Wheat-stone bridge

→ Calc. values of R

$R = 10k\Omega$, $\Delta R = 50\Omega$, $+V = 3.5V$

Design an amp. for $v_o = 5V$ when $\Delta R = 50\Omega$

Sol^n: $v_{o1} = \left[\dfrac{R-\Delta R}{(R-\Delta R)+(R+\Delta R)} - \dfrac{R+\Delta R}{(R+\Delta R)+(R-\Delta R)}\right] \cdot V$

(V-divider eq^{n}s.)

$$= \left[\frac{R-\Delta R}{2R} - \frac{R+\Delta R}{2R}\right] \cdot +V$$

$$= -\frac{\Delta R}{R} \cdot (+V) = -\frac{50}{10\times10^3}(3.5) = -1.75\times10^{-2}$$

$$= 17.5\,mV$$

$$\text{Required gain} = A_d = \frac{v_o}{v_i} = \frac{5}{17.5m} = 285.714$$

For an instrumentation amp.,

$$|A_d| = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right) = 285.714$$

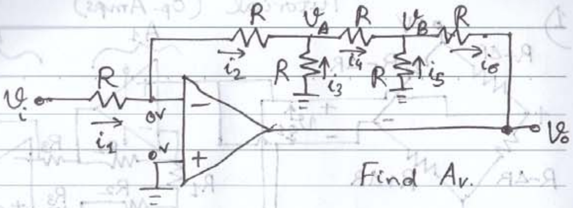
Assume, $R_3 = 10k\Omega$ & $R_4 = 150k\Omega$

$$\therefore \frac{R_2}{R_1} = 9.02$$

Let, $R_2 = 100k\Omega$, $\therefore R_1 = 11.1k\Omega$

(Ans)

2.



Find A_v.

$i_1 = \frac{v_i}{R} = i_2$

$v_A = -i_2 . R = -\left(\frac{v_i}{R}\right). R = -v_i$

$i_3 = -\frac{v_A}{R} = +\frac{v_i}{R}$

$i_4 = i_2 + i_3 = -\frac{v_A}{R} - \frac{v_A}{R} = \frac{-2.v_A}{R} = +\frac{2.v_i}{R}$

$v_B = v_A - i_4 . R = -v_i - \left[+\frac{2\,v_i}{R}\right].R = -3.v_i$

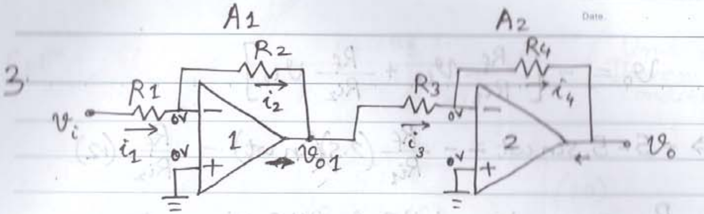
$i_5 = -\frac{v_B}{R} = -\frac{-3.v_i}{R} = \frac{3.v_i}{R}$

$i_6 = i_4 + i_5 = \frac{2v_i}{R} + \frac{3.v_i}{R} = \frac{5.v_i}{R}$

$v_o = v_B - i_6 . R = -3.v_i - \left(\frac{5.v_i}{R}\right).R = -8.v_i$

$\Rightarrow \frac{v_o}{v_i} = A_V = -8$ (Ans)

3.



$R_1 = 20k\Omega$, $R_2 = 120k\Omega$, $R_3 = 15k\Omega$, $R_4 = 75k\Omega$, $v_i = 0.2V$

Find: v_{o1}, v_o, i_1 to i_4, O/P I in the op-amps.

Sol^n $v_{o1} = -\frac{R_2}{R_1}. v_i = -\frac{120k}{20k}.(0.2) = -1.2V$ (Ans)

$v_o = -\frac{R_4}{R_3}. v_{o1} = -\frac{75k}{15k}.(-1.2) = +6V$ (Ans)

$i_1 = i_2 = \frac{0.2}{20k} = 10\mu A$ (Ans) v_i, R_1

$i_3 = i_4 = \frac{v_{o1}}{R_3} = \frac{-1.2}{15k} = -80\mu A$ (Ans)

Sink I

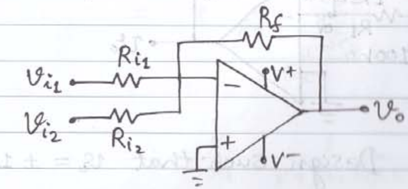
O/P I (op-amp. 1) $= -(10\mu + 80\mu) = -90\mu A$

O/P I (op-amp. 2) $= +80\mu A$ (Ans)

Source I

4. Design a summing amp: $v_{i1} = (2.5)\sin\omega t$ (V), $v_{i2} = +2V$, $v_o = -5(1+\sin\omega t)$(V). Largest R is $200k\Omega$.

Sol^n.



$$v_0 = -\left[\frac{R_f}{R_{i_1}} v_{i_1} + \frac{R_f}{R_{i_2}} v_{i_2}\right]$$

$$\Rightarrow -5 - 5.\sin\omega t = -\frac{R_f}{R_{i_1}}(2.5)(\sin\omega t) - \frac{R_f}{R_{i_2}}(+2)$$

By separating LHS & RHS elements,

$$\cancel{-}5 = \cancel{-}\frac{R_f}{R_{i_2}} \cdot 2$$

$$\Rightarrow \frac{R_f}{R_{i_2}} = 2.5$$

Indicates $\Rightarrow R_f > R_{i_2}$

$\therefore R_f = 200\,k\Omega$ (largest R in the ckt)

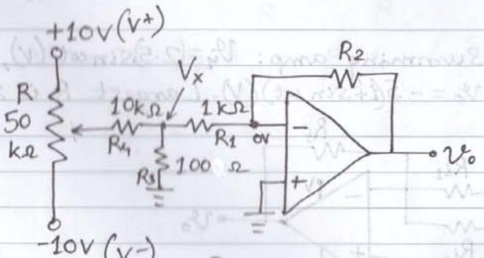
Now,

$$\cancel{-}5.(\sin\omega t) = \cancel{-}\frac{200k}{R_{i_1}} \cdot (2.5)(\sin\omega t)$$

$$\Rightarrow R_{i_1} = \frac{200k.(2.5)}{5} = 100\,k\Omega \quad \text{(Ans)}$$

Also, $R_{i_2} = \frac{R_f}{2.5} = \frac{200k}{2.5} = 80\,k\Omega$ (Ans)

5.



Design such that $v_0 = \pm 10V$.

Sol^n. $V_{x(max)} = \frac{R_3 // R_1}{R_3 // (R_1 + R_4)} \cdot V^+$ (Under Thevenin's condition)

$$= \frac{\frac{(0.1)(1)}{0.1+1}}{\frac{(0.1)(1+10)}{0.1+1+10}} \cdot (10)$$

$= 0.090\ V$

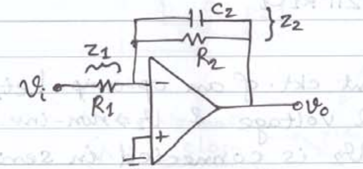
Now,

$$|v_0| = \frac{R_2}{R_1} \cdot V_{x(max)}$$

$$\Rightarrow 10 = \frac{R_2}{1k}(0.090)$$

$$\Rightarrow R_2 = 111\,k\Omega \quad \text{(Ans)}$$

6. Derive V- transfer func^n (Gain)



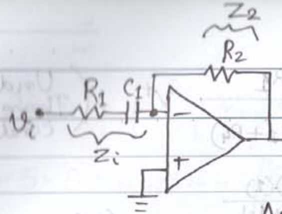
Active Integrator (LPF)

Sol^n. $A_v = \frac{v_0}{v_i} = -\frac{Z_2}{Z_1} = \frac{R_2 // \frac{1}{j\omega C_2}}{R_1}$

$$= \frac{\frac{R_2 . \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}}}{R_1}$$

$$= -\frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega R_2 . C_2} \quad \text{(Ans)}$$

Corner (-3 db) freq. (w.r.t. pass-band gain) $= f_c = \frac{1}{2\pi R_2 . C_2}$

7. 

← Differentiator (Active HPF)

Derive for $\frac{v_o}{v_i}$

Assume the op-amp is an ideal one.

Solⁿ. $$\frac{v_o}{v_i} = -\frac{Z_2}{Z_1} = -\frac{R_2}{R_1 + \frac{1}{j\omega C_1}}$$

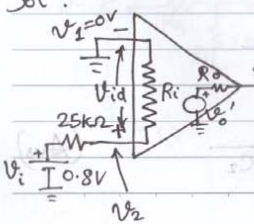
$$= -\frac{R_2 (j\omega C_1)}{1 + j\omega R_1 C_1}$$

$$= -\frac{R_2}{R_1} \cdot \frac{j\omega R_1 C_1}{1 + j\omega R_1 C_1} \quad \text{(Ans)}$$

Corner (−3 db w.r.t. pass-band gain) freq: $f_c = \frac{1}{2\pi R_1 C_1}$

8. Draw an equivalent ckt. of an op-amp. Let, $v_1 \Rightarrow$ Inv. terminal voltage & $v_2 \Rightarrow$ non-inv. terminal voltage. v_2 is connected in series with a 25kΩ resistor from a source of 0.8V & $v_1 = 0$ V. What is $R_{i\,min}$ (op-amp) such that $v_{id} = 0.79$ V?

Solⁿ.



$$v_{id} = v_2 - v_1 = \left(\frac{R_i}{R_i + 25k\Omega}\right) \cdot v_i$$

$$\Rightarrow 0.79 = \frac{R_i}{R_i + 25k} \cdot (0.8)$$

$$\Rightarrow R_i = 1975\ k\Omega \quad \text{(Ans)}$$

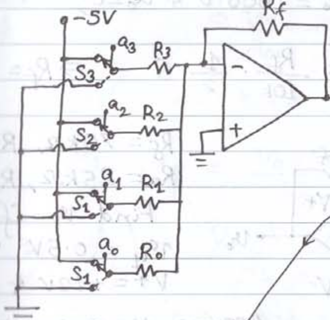
9. Draw the circuit of a digital-to-analog converter (DAC) by using op-amp. Write the expression for its O/P voltage as a function of digital logic. Find the feedback resistor's value such that $v_o = +2.5$V while digital I/Ps are: $a_3 a_2 a_1 a_0 = 1000$, where, a_3 is the most significant bit (MSB), & a_0 is the least significant bit (LSB).

I/P code → O/P V

Closed loop

Solⁿ.

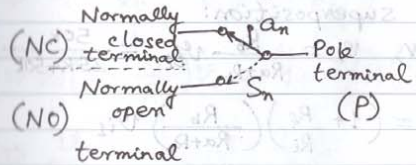
$R_3 = R$
$R_2 = 2R$
$R_1 = 4R$
$R_0 = 8R$



← Modified Summing amp.

S_3 to S_0: Single pole double throw switches (SPDT)

a_3 to a_0: Swith control I/Ps (logic values)



When, $a_n = '0' \Rightarrow$ 'P' is connected to 'NC'
" $a_n = '1' \Rightarrow$ 'P' " " 'NO'

$$v_o = -\frac{R_f}{R_3} \cdot a_3 \cdot (-5) - \frac{R_f}{R_2} \cdot a_2 \cdot (-5) - \frac{R_f}{R_1} \cdot a_1 (-5) - \frac{R_f}{R_1} \cdot a_0 (-5)$$

$$= \frac{R_f}{R} \cdot a_3 (5) + \frac{R_f}{2R} \cdot a_2 (5) + \frac{R_f}{4R} \cdot a_1 \cdot (5) + \frac{R_f}{8R} \cdot a_0 \cdot (5)$$

Let, $R = 20k\Omega$,

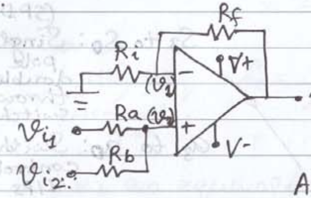
$$\therefore v_o = \frac{R_f}{20k} \cdot a_3 \cdot 5 + \frac{R_f}{40k} \cdot a_2 \cdot 5 + \frac{R_f}{80k} \cdot a_1 \cdot 5 + \frac{R_f}{160k} a_0 \cdot 5$$

$$\therefore v_o = \frac{R_f}{10k}\left[\frac{a_3}{2} + \frac{a_2}{4} + \frac{a_1}{8} + \frac{a_0}{16}\right](5) \quad \text{(Ans)}$$

While, $a_3 = 1,\ a_2 = 0,\ a_1 = 0$ & $a_0 = 0$;

$$v_o = 2.5 = \frac{R_f}{10k} \cdot \frac{1}{2} \cdot 5 \Rightarrow R_f = 10k\Omega \quad \text{(Ans)}$$

10.



$R_f = 70k\Omega$, $R_i = 5k\Omega$, $R_a = 25k\Omega$, $R_b = 50k\Omega$
Find v_o if $v_{i1} = 0.5V$ & $v_{i2} = 0.8V$
$V^+ = +12V$ & $V^- = -12V$

Assume the op-amp is ideal.

Soln. Apply superposition:

For, $v_{i2} = 0V$, $v_2 = \frac{R_b}{R_a + R_b} v_{i1} = \frac{50k}{25k + 50k} \cdot v_{i1}$

$$v_o(v_{i1}) = \left(1 + \frac{R_f}{R_i}\right)\left(\frac{R_b}{R_a + R_b}\right) v_{i1}$$

$$= \left(1 + \frac{70k}{5k}\right)\left(\frac{50k}{25k + 75k}\right) v_{i1} = 10\, v_{i1}$$

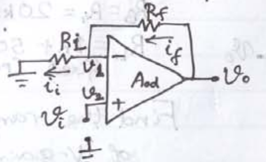
For, $v_{i1} = 0V$, $v_2 = \frac{R_a}{R_a + R_b} v_{i2}$

$$v_o(v_{i2}) = \left(1 + \frac{R_f}{R_i}\right)\left(\frac{R_a}{R_a + R_b}\right) v_{i2} = 5\, v_{i2}$$

$$\therefore v_o = v_o(v_{i1}) + v_o(v_{i2})$$
$$= 10\, v_{i1} + 5\, v_{i2} \checkmark$$
$$= 10(0.5) + 5(0.8) = 9V \quad \text{(Ans)}$$

11. Derive the eqn of the gain of a practical non-inv. amp. using an op-amp.

Soln.



$$v_o = A_{od}(v_2 - v_1)$$
$$\Rightarrow v_o = A_{od}(v_i - v_1)$$
$$\Rightarrow \frac{v_o}{A_{od}} - v_i = -v_1$$
$$\text{or, } v_1 = v_i - \frac{v_o}{A_{od}}$$

Now,
$$i_i = \frac{v_1}{R_i} = i_f = \frac{v_o - v_i}{R_f}$$

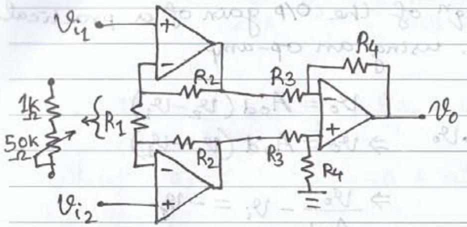
$$\therefore v_1\left(\frac{1}{R_i}\right) = \frac{v_o - v_i}{R_f}$$

$$\Rightarrow v_1\left(\frac{1}{R_i} + \frac{1}{R_f}\right) = \frac{v_o}{R_f}$$

$$\Rightarrow v_o = \left(1 + \frac{R_f}{R_i}\right) v_1 = \left(1 + \frac{R_f}{R_i}\right)\left(v_i - \frac{v_o}{A_{od}}\right)$$

$$\Rightarrow \frac{v_o}{v_i} = \frac{\left(1 + \frac{R_f}{R_i}\right)}{1 + \frac{1}{A_{od}}\left(1 + \frac{R_f}{R_i}\right)} \quad \text{(Ans)}$$

12. Consider an instrumentation amp.



$R_2 = 100k\Omega$
$R_3 = R_4 = 20k\Omega$
$R_1 = 1k + 50k$
(fixed) (pot)

Find the range of V-gain.

Soln. $v_o = -\frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)(v_{i2} - v_{i1})$

Differential gain $= \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)$

Gain is inversely proportional to R_1.

Min. $R_1 \Rightarrow$ Max. gain. $\Rightarrow R_1 = 1k\Omega$

$\therefore A_{d_{max}} = \frac{20k}{20k}\left(1 + \frac{2(100k)}{1k}\right) = 201$

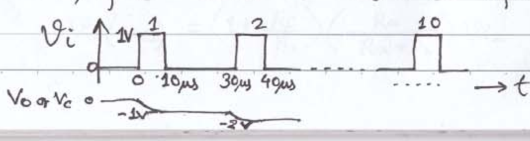
Max. $R_1 \Rightarrow$ Min. gain $\Rightarrow R_1 = 51k\Omega$

$\therefore A_{d_{min}} = \frac{20k}{20k}\left(1 + \frac{2(100k)}{51k}\right) = 4.92$

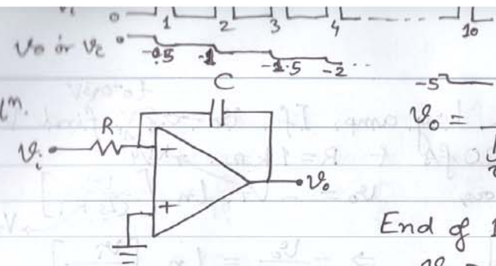
$\therefore$ Range of differential gain:

$A_{od} = 4.92$ to 201 (Ans)

13. Consider an op-amp. integrator (ideal). Find R, if $C = 10nF$ & $v_o = -5V$ after 10's pulse.
→ LPF



Solm.



$v_o = \frac{1}{RC}\int v_i(t).dt$ & $\tau = RC$

End of 1st pulse:

$v_o = -\frac{1}{\tau}.t\Big|^{10\mu s}_{0}$

$= \frac{-10\times10^{-6}}{\tau}$

After 10^{th} pulse, $v_o = -5 = \frac{-10(10\times10^{-6})}{\tau}$

$\Rightarrow \tau = 20\mu s$

$\Rightarrow RC = 20\mu s$

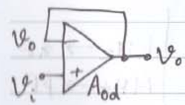
$\Rightarrow R = \frac{20\mu s}{C}$

$= \frac{20\mu s}{10nF} = 2k\Omega$

(Assume, 'C' does not discharge while $v_i = 0$) (Ans)

14. Draw a V-follower & find closed loop gain if the open loop differential gain (A_{od}) is 10^4 & 10.

Soln. $v_o = A_{od}(v_i - v_o)$



$\Rightarrow \left(\frac{1}{A_{od}} + 1\right)v_o = v_i$

$\Rightarrow \frac{v_o}{v_i} = \frac{1}{1 + \frac{1}{A_{od}}} = A_v$

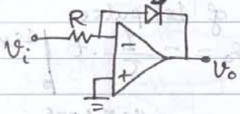
If $A_{od} = 10^4$, $\frac{v_o}{v_i} = 0.999$ ← Precision op-amp

If $A_{od} = 10$, $\frac{v_o}{v_i} = 0.909$ ← Poorly designed

(Ans)

15. Consider a log amp. If $v_o = -0.3V$ (to $-0.6V$), find v_i if $I_{S(D)} = 20\,fA$ & $R = 1k\Omega$.

Sol^n. We know, $v_o = -V_T \ln\left[\dfrac{v_i}{I_S.R}\right]$ (V_T = kT/q; $I_S.R$ → V_{ref})



$$\Rightarrow -\frac{v_o}{V_T} = \ln\left[\frac{v_i}{I_S.R}\right]$$

$$\Rightarrow I_S.R.e^{\left(-\frac{v_o}{V_T}\right)} = v_i$$

@ $v_o = -0.3V$ & @ 27°C

$$\Rightarrow v_i = 20\times10^{-15}\times1\times10^3 e^{\left(\frac{+0.3}{0.026}\right)}$$

$$\therefore v_i = 2.051\,\mu V$$

Also, @ $v_o = -0.6V$

$$v_i = 20\times10^{-15}\times1\times10^3.e^{\frac{0.6}{0.026}}$$

$$= 0.210V$$

$\therefore$ $v_i = 2.051\,\mu V \Rightarrow v_o = -0.3V$; $A_{v(0.3)} =$

$v_i = .210\,V \Rightarrow v_o = -0.6V$; $A_{v(0.6)} =$

$\therefore$ Log amp. acts like a data/value compressor.

18 A Wein-bridge oscillator is required to generate a 5.2kHz sine wave. Calculate the resistor values & the capacitor values. Find the min. values of the gain setting resistors as well.

Sol^n. $f_r = \dfrac{1}{2\pi RC} = 5.2\times10^3$

kHz → nF
MHz → pF

Let $R_1 = R_2$ & $C_1 = C_2$

Let, $C = C_1 = C_2 = 3\,nF$

$$\therefore R = R_1 = R_2 = \frac{1}{2\pi f_r.C} = \frac{1}{2\pi\times5.2\times10^3\times3\times10^{-9}}$$

$$= 10.2\,k\Omega$$

For a sine-wave oscillation, $A_v \geq 3$ (Wein bridge only)

While considering a non-inv. op-amp amp:

$$A_v = \frac{v_o}{v_i} = 1 + \frac{R_f}{R_i} \geq 3$$ (op-amp is an ideal)

Let, $R_f = 100k\Omega$

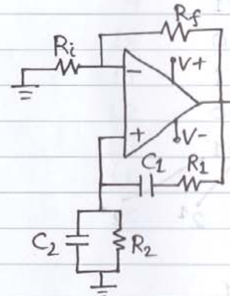
$$\Rightarrow R_i = \frac{R_f}{(A_v - 1)} = \frac{100\times10^3}{3-1} = 50k\Omega$$

$\therefore$ $R_1 = R_2 = 10.2k\Omega$

Assumed $\begin{cases} C_1 = C_2 = 3\,nF \\ R_f = 100k\Omega \end{cases}$

$R_i = 50k\Omega$ ← Calculated

(Ans)



$R_1 = R_2 = R$
$C_1 = C_2 = R$

MOSFET Tutorial (cont.)

5 (cont.) By solving the quadratic equation,

$$V_{SG} = \frac{-0.4 \pm \sqrt{(0.4)^2 + 4(0.3)(3.986)}}{2\cdot(0.3)}$$

$= +3.04V$ (Ans) (Considering the +ve answer only).

Now, $I_D = (0.25m)[3.04+1]^2$
$= 1.04\ mA$ (Ans)

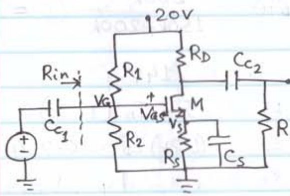
Also, $V_{SD} = (V_{SS} - V_{DD}) - I_D(R_S + R_D)$
$= 10 - [(1.04m)(1.2k + 4k)]$
$= 4.59V$ (Ans)

For confirmation about saturation mode,

$V_{SD(sat)} = V_{SG} - V_{Tp} = 3.04 - 1$
$= 2.04V$

$\therefore V_{SD} > V_{SD(sat)}$

6.

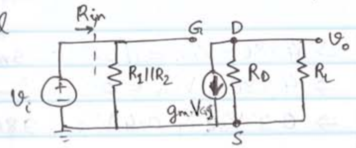


$A_v = \frac{v_o}{v_i} = -10$

$R_L = 20k\Omega$, $R_{in} = 200k\Omega$,
$I_{Dq} = 1mA$, $V_{DSq} = 10V$,
$V_{Tn} = 2V$, $\lambda = 0$

Find R_1, R_2, R_D, R_S.

Sol^n. Small signal equ. ckt. (AC)



$A_v = -g_m(R_D \| R_L)$ ← 180° phase shift

$V_{DSq} = V_{DD} - I_{Dq}(R_D + R_S)$

$\Rightarrow 10 = 20 - (1m)(R_D + R_S) \quad \Rightarrow R_D + R_S = 10k\Omega$ [$R_D > R_S$]

Let, $R_D = 8k\Omega \quad \therefore R_S = 2k\Omega$ (Ans)

$\Rightarrow -10 = -g_m(8k \| 20k)$

$\Rightarrow g_m = 1.75\ mA/V = 2\sqrt{K_n \cdot I_{Dq}} = 2\sqrt{K_n(1m)}$

$\Rightarrow K_n = 0.766\ mA/V^2$

Now,

$V_S = I_{Dq} \cdot R_S = (1m)(2k) = 2V$

Saturation current: $I_{Dq} = K_n(V_{GS} - V_{Tn})^2$

$\Rightarrow 1m = 0.766(V_{GS} - 2)^2$

$\Rightarrow V_{GS} = 3.14V$

$V_G = V_{GS} + V_S = 3.14 + 2 = 5.14V$

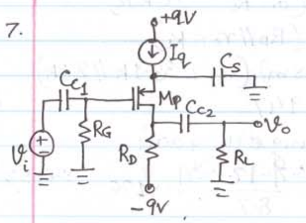
& $V_G = \frac{1}{R_1} \cdot R_{in} \cdot V_{DD} = \frac{1}{R_1}(200k)(20) = 5.14V$

$\Rightarrow R_1 = 778k\Omega$ (Ans)

Also, $R_{in} = \frac{R_1 \cdot R_2}{R_1 + R_2}$ [$\because R_{in} = R_1 \| R_2$]

$\Rightarrow 200k = \frac{778k \cdot R_2}{778k + R_2} \quad \Rightarrow R_2 = 269k\Omega$ (Ans)

7.

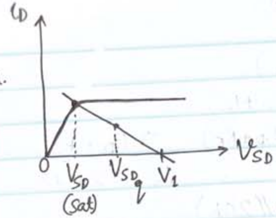


$R_G = 500k\Omega$, $V_{Tp} = -1.5V$,
$K_p = 2mA/V^2$, $\lambda = 0.01\ V^{-1}$,
$R_L = 20k\Omega$, $R_D \leq 0.1\ R_L$

a) Find I_Q for q-pt at the center of the saturation reg.

b) Open ckt ($R_L = \infty$) & closed load ckt gain

Sol^n. a.



$V_1 = 9 + V_{SG}$

$V_{SD(sat)} = V_{SG} + V_{TP}$

$V_{SDq} = \frac{V_1 - V_{SD(sat)}}{2} + V_{SD(sat)}$

$\Rightarrow V_{SDq} = \frac{(9+V_{SG}) - (V_{SG} + V_{TP})}{2} + (V_{SG} + V_{TP})$

$= \frac{9+1.5}{2} + V_{SG} - 1.5$

$= 3.75 + V_{SG}$

$= 9 + V_{SG} - I_{Dq} \cdot R_D$

4 $I_{Dq} = K_p (V_{SG} + V_{TP})^2$

$R_D = 0.1 (R_L) = (0.1)(20k) = 2k\Omega$ (Ans)

$\therefore\ 3.75 = 9 - I_{Dq}(2k) \Rightarrow I_{Dq} = 2.625 mA$

b. $g_m = 2\sqrt{K_p \cdot I_{Dq}} = 2\sqrt{(2m)(2.625m)}$

$= 4.58\ mA/V$

$r_o = \frac{1}{\lambda \cdot I_{Dq}} = \frac{1}{(0.01)(2.625m)} = 38.1 k\Omega$

Gain without R_L (or $R_L = \infty$)

$A_V = -g_m (R_D // r_o)$

$= -(4.58m)(2k // 38.1k) = -8.70$ (Ans)

Gain with R_L (or $R_L = 20k\Omega$)

$A_V = -g_m (R_D // r_o // R_L)$

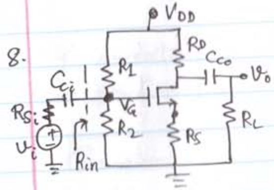
$= -(4.58m)(2k // 38.1k // 20k)$

$= -7.947$ (Ans)

$\therefore$ Percentage change in gain:

$100 \times \frac{A_{V_{No load}} - A_{V_{load}}}{A_{V_{No load}}} = \frac{|8.7| - |7.947|}{8.7} \times 100 = 8.655\%$ (Ans)

8.



$V_{Tn} = 2V$, $K_n = 1mA/V^2$, $\lambda = 0$,
$V_{DD} = 12V$, $R_S = 2k\Omega$, $R_D = 3k\Omega$,
$R_1 = 300k\Omega$, $R_2 = 200k\Omega$, $R_{Si} = 2k\Omega$
$R_L = 3k\Omega$. Find I_{Dq}, V_{DSq}, A_v.

Sol^n. $V_G = \frac{R_2}{R_1 + R_2} V_{DD} = \frac{200k}{200k + 300k} \cdot 12 = 4.8V$

$I_D = \frac{V_G - V_{GS}}{R_S} = K_n (V_{GS} - V_{Tn})^2$ (sat. mode)

$\Rightarrow 4.8 - V_{GS} = (1m)(V_{GS} - 2)^2 (2k)$

$\Rightarrow 2V_{GS}^2 - 7V_{GS} + 3.2 = 0$

$\Rightarrow V_{GS} = \frac{7 \pm \sqrt{7^2 - 4(2)(3.2)}}{2 \cdot 2} \Rightarrow +2.96V = V_{GS}$

Now, $I_{Dq} = (1m)(2.96 - 2)^2 = 0.920\ mA$ (Ans)

Also, $V_{DSq} = V_{DD} - I_D (R_D + R_S)$

$= 12 - (0.92m)[3k + 2k] = 7.4V$ (Ans)

$V_o = \frac{-g_m \cdot V_G (R_D // R_L)}{1 + g_m \cdot R_S}$; $V_{G(AC)} = \frac{R_1 // R_2}{(R_1 // R_2) + R_{Si}} \cdot V_i$

$= \frac{300k // 200k}{(300k // 200k) + 2k} \cdot V_i$

$= \underbrace{(0.9836)}_{\text{Factor for } R_{Si} \text{ V-drop}} V_i$

$\therefore A_V = \frac{-g_m (R_D // R_L)[0.9836]}{1 + g_m \cdot R_S}$

$g_m = 2\sqrt{K_n \cdot I_{Dq}}$

$= 2\sqrt{(1m)(0.92m)}$

$= 1.92\ mA/V$

$\therefore A_V = \frac{(-1.92m)(3k // 2k)[0.9836]}{1 + (1.92m)(2k)} = -0.585$ (Ans)

$\Rightarrow A_V < 1$ (attenuat