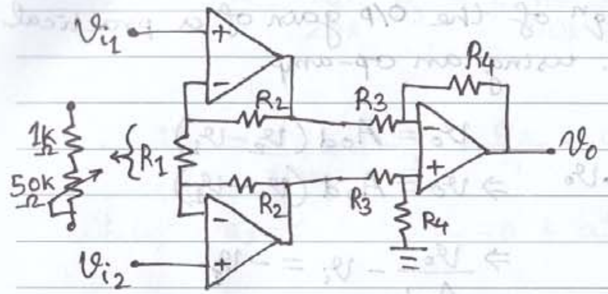
12. Consider an instrumentation amp.



$R_2 = 100k\Omega$

$R_3 = R_4 = 20k\Omega$

$R_1 = 1k + 50k$ (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. $\Rightarrow R_1 = 1k\Omega$

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

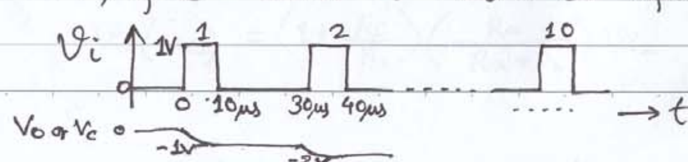
Max. $R_1 \Rightarrow$ Min. gain $\Rightarrow R_1 = 51k\Omega$

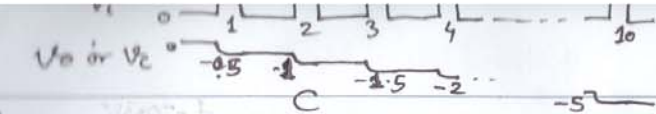
$\therefore A_{d_{min}} = \frac{20k}{20k}\left(1+\frac{2(100k)}{51k}\right) = 4.92$

$\therefore$ Range of differential gain:

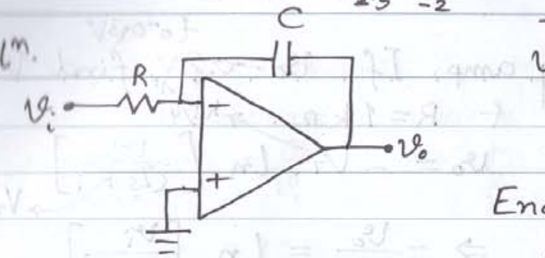
$A_{od} = 4.92$ to 201 (Ans)

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





Solⁿ.



$v_o = \frac{1}{\underbrace{RC}_{\tau}}\int_0^t v_i(t).dt$ & $\tau = RC$

End of 1st pulse:

$v_o = \left. -\frac{1}{\tau}.t \right|_0^{10\mu s}$

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

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

$\Rightarrow \tau = 20\mu s$

$\Rightarrow RC = 20\mu s$

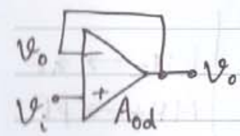
$\Rightarrow R = \frac{20\mu s}{C}$

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

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



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

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

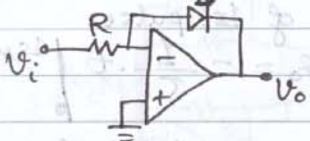
If $A_{od} = 10^4$, $\frac{v_o}{v_i} = 0.999$ ← Precision op-amp

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

$$\Rightarrow v_i = 20\times10^{-15} \times 1\times10^3 \cdot e^{\left(\frac{+0.3}{0.026}\right)}$$

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

Also, @ $v_o = -0.6V$

$$v_i = 20\times10^{-15}\times1\times10^3 \cdot e^{\frac{0.6}{0.026}}$$
$$= 0.210V$$

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

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

$\therefore$ 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. $f_r = \frac{1}{2\pi RC} = 5.2\times10^3$

kHz → nF
MHz → pF

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

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

$$\therefore R = R_1 = R_2 = \frac{1}{2\pi f_r.C} = \frac{1}{2\pi\times5.2\times10^3\times3\times10^{-9}}$$
$$= 10.2k\Omega$$

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, $R_f = 100k\Omega$

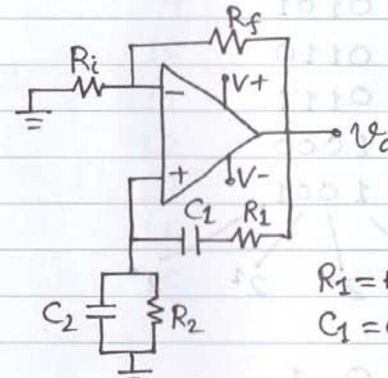
$$\Rightarrow R_i = \frac{R_f}{(A_v - 1)} = \frac{100\times10^3}{3-1} = 50k\Omega$$

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

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

$R_i = 50k\Omega$

(Ans) Calculated



$R_1 = R_2 = R$

$C_1 = C_2 = R$

MOSFET Tutorial (cont.)

5 (cont.) By solving the quadratic equation,

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

$$= +3.04V \quad \text{(Ans)}$$ (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)

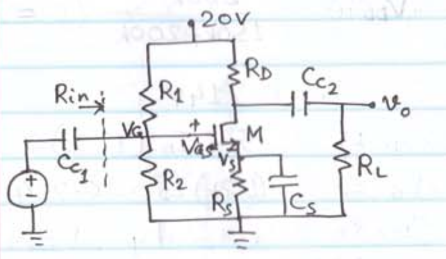
For confirmation about saturation mode,

$V_{SD(sat.)} = V_{SG} + V_{TP} = 3.04 + 1$

$= 2.04V$

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

6.



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

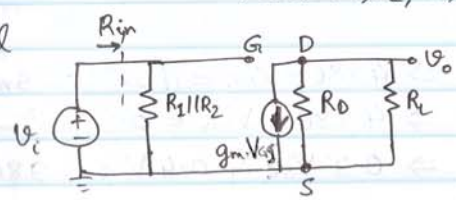
$R_L = 20k\Omega$, $R_{in} = 200k\Omega$,

$I_{DQ} = 1mA$, $V_{DSQ} = 10V$,

$V_{Tn} = 2V$, $\lambda = 0$

Find R_1, R_2, R_D, R_S.

Sol^n. Small signal equv. 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: $I_{DQ} = K_n(V_{GS} - V_{Tn})^2$

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

$\Rightarrow V_{GS} = 3.14V$

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

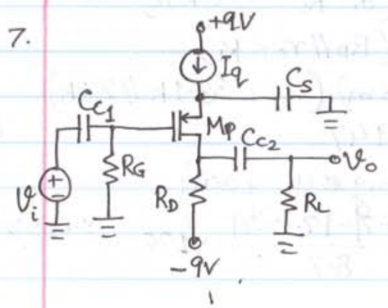
& $V_G = \frac{1}{R_1} \cdot R_{in} \cdot V_{DD} = \frac{1}{R_1}(200k)(20) = 5.14V$

$\Rightarrow R_1 = 778k\Omega$ (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.



$R_G = 500k\Omega$, $V_{TP} = -1.5V$,

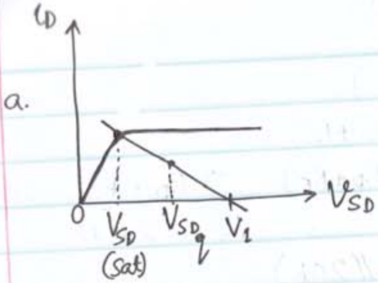
$K_p = 2mA/V^2$, $\lambda = 0.01V^{-1}$,

$R_L = 20k\Omega$, $R_D \leq 0.1 R_L$

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.



$V_1 = 9 + V_{SG}$

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

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

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

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

$= 3.75 + V_{SG}$

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

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

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

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

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

$= 4.58 mA/V$

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

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 $R_L = 20k\Omega$)

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

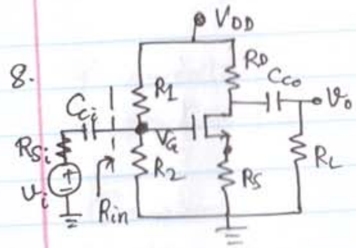
$= -(4.58m)(2k // 38.1k // 20k)$

$= -7.947$ (Ans)

$\therefore$ Percentage change in gain:

$100 \times \dfrac{Av_{Noload} - Av_{Load}}{Av_{No\ load}} = \dfrac{|8.7| - |7.947|}{8.7} \times 100 = 8.655\%$ (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. $V_G = \dfrac{R_2}{R_1+R_2} V_{DD} = \dfrac{200k}{200k+300k} \cdot 12 = 4.8V$

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

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

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

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

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)

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

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

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

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

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

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

$= 1.92 mA/V$

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

$\Rightarrow A_V < 1$ (attenuat