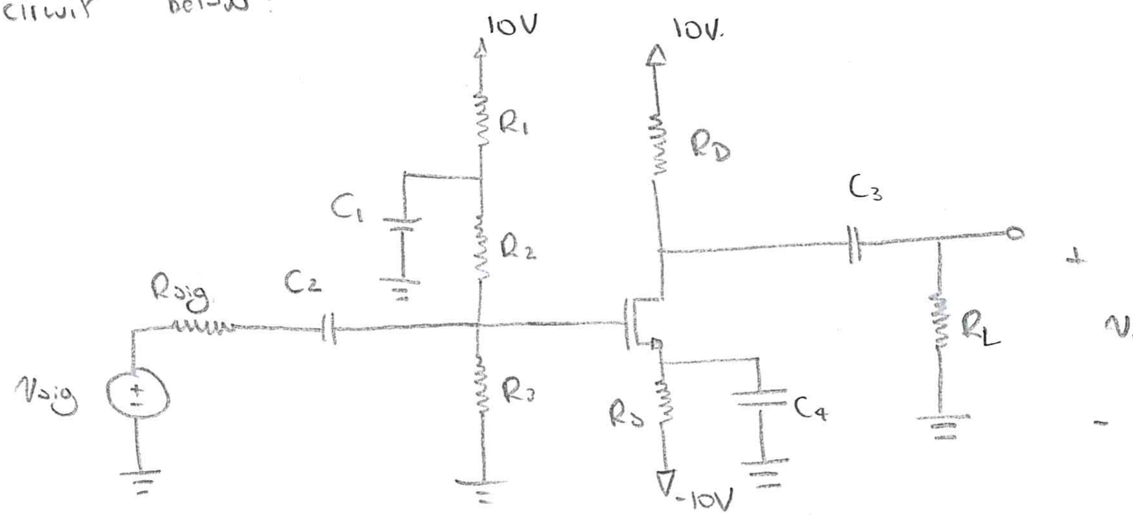
Experiment 1 ENG Analog Devices

Consider the amplifier circuit below:

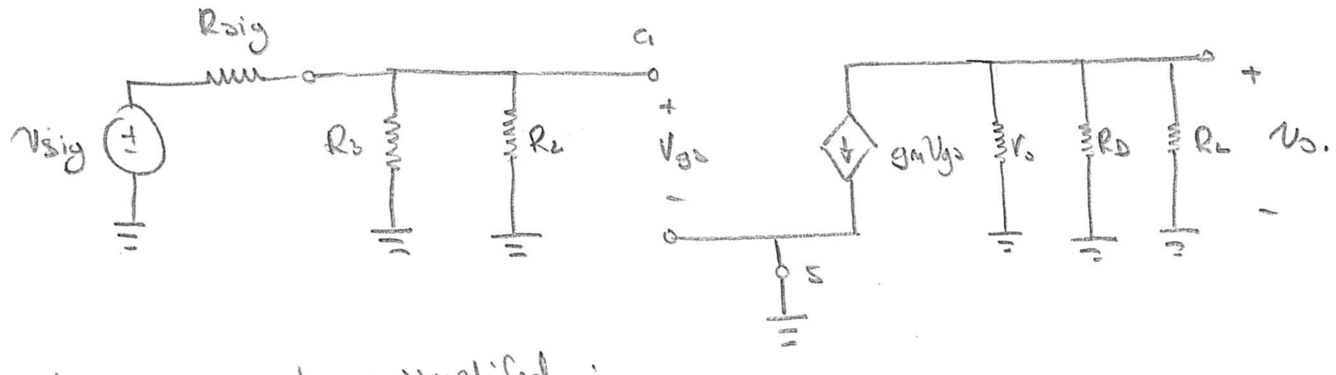


If we consider a small signal model, the capacitors act as short circuits, since

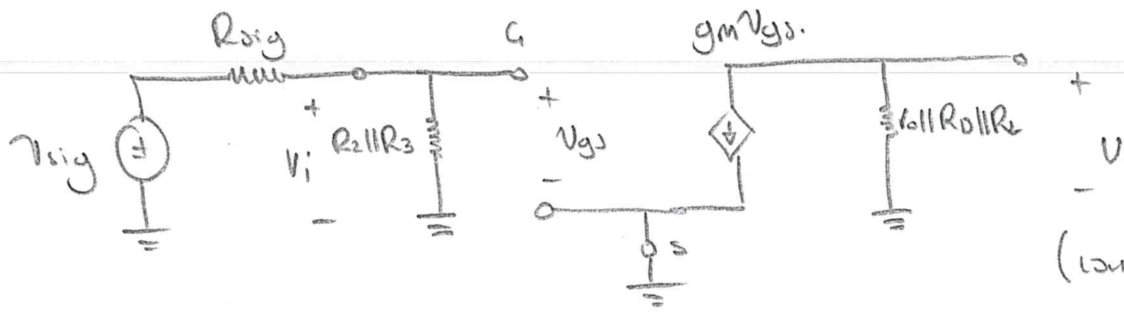
$Z_c = \frac{1}{j\omega C}$ & as $\omega \to \infty$ $Z_c \to 0$.

We ground the DC voltage sources.

The $\boxed{\text{small signal model}}$ is as follows:



This can be simplified:



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Experiment 1 ENG Analog Devices

We want to find the voltage gain:

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

Now, by voltage divider:

$$v_i = \left[\frac{R_2 \| R_3}{R_2 \| R_3 + R_{sig}}\right] \cdot v_{sig}$$

Also, we note that $v_i = v_{gs}$.

Now,

$$v_o = -g_m v_{gs} (r_o \| R_D \| R_L)$$

$$v_o = -g_m v_i (r_o \| R_D \| R_L).$$

$$\therefore A_v = \frac{v_o}{v_i} = -g_m (r_o \| R_D \| R_L)$$

Voltage Gain : $A_v = -g_m (r_o \| R_D \| R_L)$.

Now, overall voltage gain

$$G_{vo} = \frac{v_o}{v_{sig}} = -g_m (r_o \| R_D \| R_L) \left[\frac{R_2 \| R_3}{R_{sig} + R_2 \| R_3}\right].$$

Overall Voltage Gain : $G_{vo} = -g_m (r_o \| R_D \| R_L) \left[\frac{R_2 \| R_3}{R_{sig} + R_2 \| R_3}\right].$

To calculate both voltage gain + overall voltage gain, we need the parameters for r_o + g_m, which we find by working out the DC bias point.

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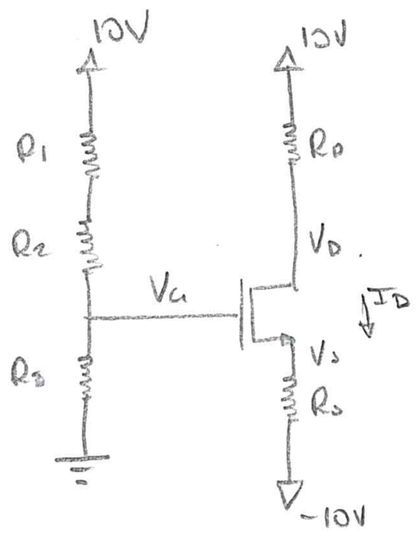
Experiment 1 ENG Analog Devices

If we consider large signals only then the impedence for the capacitor gets very large.

$\Leftarrow$ $X_c = \frac{1}{j\omega C}$ $X_c \to \infty$ as $\omega \to 0$.

Hence, the capacitors act as short circuits and we get the following $\boxed{\text{large signal model.}}$



We want to find V_G

$$V_G = \left[\frac{R_3}{R_1 + R_2 + R_3}\right] \cdot 10V.$$

$$\therefore V_G = \frac{145.5}{500} \cdot 10$$

$$V_G = 2.91V.$$

Now, $-V_S + I_D R_S - 10V = 0.$

$$V_S = I_D R_S - 10 \quad -1)$$

Further, if the device is is saturation, we get that:

$$I_D = \frac{1}{2} k_n (V_{GS} - V_T)^2.$$

$$\therefore I_D = \frac{1}{2} k_n (V_G - V_S - V_T)^2 \quad -2).$$

Sub in equ^{n} 1) to equ^{n} 2) to get:

$$I_D = \frac{1}{2} k_n (2.91 - I_D . R_S + 10 - 2)^2$$

$$I_D = \frac{2.4e-3}{2} (2.91 - 10K. I_D + 10 - 2)^2$$

Cont'd over)

Experiment 1 ENG Analog Device.

Large Signal Analysis.

$$\therefore \frac{I_D}{1.2e-3} = (10.91 - 10k.I_D)^2.$$

$$833.33 I_D = 119.02 - 218200 I_D + 100e6 I_D^2$$

$$100e6 I_D^2 - 219033.33 I_D + 119.02 = 0.$$

$$I_D = 9.999 e-4 A$$

$$\therefore I_D = 10 e-4 A$$

$$I_D = 1mA.$$

{Note: $I_D < 0$ for the other sol^n & was thus discarded}.

If $I_D = 1mA$,

then $V_D = 10 - 1mA.7k$

$V_D = 10 - 7$

$V_D = 3$

also, $V_S = -10 + 1mA.10k.$

$V_S = 0V.$

$$\therefore V_D - V_S > V_G - V_S - V_T$$

=> Device is actually in saturation, w/ Bias current $I_D = 1mA$.

Hence, $g_m = \mu_n C_{ox} \frac{W}{L} V_{ov} = 2.4mA/V^2.(2.91 - 2)$

$g_m = 2.4e-3(0.91)$ S

$= 2.184e-3$ S

(cont'd over).

Finally, ignoring the effect of ro the voltage gain is:

$$A_v = -g_m (R_D \| R_L)$$

$$= -2.184e{-3} \left(\frac{1}{7k} + \frac{1}{10k}\right)^{-1}$$

$$= -8.9929.$$

$$\boxed{A_v = -9 \ V/V}$$

Overall voltage gain is:

$$G_{vo} = -g_m (R_D \| R_L) \left[\frac{R_2 \| R_3}{R_{sig} + R_2 \| R_3}\right].$$

$$= -9. \left[\frac{79.5k}{2k + 79.5k}\right].$$

$$= -8.77 \ V/V.$$

$$\boxed{G_{vo} = -8.77 \ V/V.}$$

The max value of the voltage gain in the Pspice simulation is approx 20 V/V, which doesn't reconcile $\overline{w}$ the results derived here.