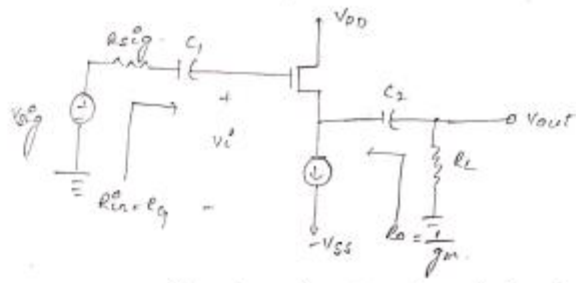
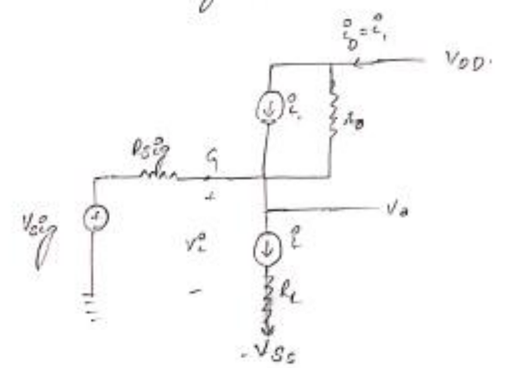
1. Determine the G_v, A_v, R_{out}, R_{in}, and A_{v0} for a common Drain Amplifier.

In common drain amplifier circuit, the ~~gat~~ drain is provided signal ground and it acts as a common terminal b/w input and output ports. The input is ~~provided with~~ supplied to the gate terminal with a capacitor C_1 coupled to it. The output is drawn from the source and a capacitor C_2 is present.



As the drain is directly connected to ground signal, resistance R_D can be removed.

The small signal equivalent circuit of the above circuit is as follows.



Looking at the small signal equivalent circuit, we can say that

$$R_{in} = R_G$$

$$v_i = \frac{V_{sig}\, R_{in}}{R_{in} + R_{sig}}$$

$$v_i = \frac{V_{sig}\, R_G}{R_G + R_{sig}}.$$

The value of $R_{sig} >> R_{in}$.

The output voltage

$$V_o = \frac{v_{in}\,(R_o \parallel R_L)}{(r_o \parallel R_L) + \frac{1}{g_m}}.$$

From the above equation voltage gain A_v can be obtained

$$A_v = \frac{(r_o \| R_L)}{(r_o \| R_L) + \frac{1}{g_m}}$$

The overall voltage gain, denoted by A_{vo} is given by

$$A_{v_o} = \frac{r_o}{r_o + \frac{1}{g_m}}$$

The total voltage gain G_v is given by

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_v$$

$$G_v = \frac{R_G}{R_G + R_{sig}} \left(\frac{r_o \| R_L}{(r_o \| R_L) + 1/g_m} \right)$$

The output resistance R_o is given by

$$R_o = \frac{1}{g_m}$$ without r_o

$$R_o = \frac{1}{g_m} \| r_o$$ with r_o

2. For the CG Amplifier g_m =1mA/V & R_D =15kΩ. Find R_{in} , R_{out} , A_V , A_{V0} and G_V, for R_L =15kΩ and R_{sig} =50Ω. Calculate the overall voltage gain become for R_{sig}=1kΩ? 10K Ω? 100K Ω?

$$R_{in} = \frac{1}{g_m}$$

$$= \frac{1}{10^{-3}}$$

$$= 1 \times 10^{3} \Omega$$

$$R_{in} = 1 k\Omega$$

$$R_{out} = (R_L \| R_D)$$

$$= (15k \| 15k)$$

$$R_{out} = 7.5 k\Omega$$

$$A_v = g_m (R_D \| R_L)$$
$$A_v = 10^{-3} (7.5 \times 10^3)$$
$$\boxed{A_v = +7.5 V/V}$$

$$A_{vo} = g_m R_D$$
$$= 10^{-3} (15 \times 10^3)$$
$$\boxed{A_{vo} = +15 V/V}$$

$$G_v = \frac{A_v}{(1 + g_m R_{sig})}$$

i) when $R_{sig} = 50\,\Omega$

$$G_v = \frac{7.5}{(1 + (10^{-3} \times 50))}$$
$$\boxed{G_v = +7.14 V/V}$$

ii) when $R_{sig} = 1 k\Omega$.

$$G_v = \frac{7.5}{1 + (10^{-3} \times 10^3)}$$
$$G_v = \frac{7.5}{(1+1)} = \frac{7.5}{2}$$
$$\boxed{G_v = +3.75 V/V}$$

iii) when $R_{sig} = 10 k\Omega$

$$G_v = \frac{7.5}{1 + (10^{-3} \times 10 \times 10^3)}$$
$$G_v = \frac{7.5}{(1+10)}$$
$$G_v = \frac{7.5}{11}$$
$$\boxed{G_v = +0.68 V/V}$$

iv) when $R_{sig} = 100 k\Omega$

$$G_v = \frac{7.5}{1 + (10^{-3} \times 100 \times 10^3)}$$
$$G_v = \frac{7.5}{101}$$
$$\boxed{G_v = +0.074 V/V}$$

3. Consider a source follower having g_m=1mA/V, r_0=150KΩ, R_{sig}=1MΩ, and R_l=15KΩ calculate R_{in}, R_{out} (with and without r_0), A_{v0}, A_v and overall small signal voltage gain G_v

$g_m = 1mA/V$; $r_o = 150k\Omega$; $R_{sig} = 1M\Omega$; $R_L = 15k\Omega$.

$R_{in} = R_G = 4.74M\Omega$.

A_{vo} (with r_o) $= \frac{r_o}{r_o + 1/g_m} = \frac{150\times10^3}{150\times10^3 + 1/10^{-3}} = 0.993 V/V$

A_{vo} (without r_o) $= 1 V/V$. as $r_o >> 1/g_m$

A_v(with r_o) $= \frac{r_o \| R_L}{(r_o \| R_L) + 1/g_m} = \frac{(150\times10^3)\|(15\times10^3)}{(150\times10^3)\|(15\times10^3) + 1/10^{-3}}$

$= 0.9316 V/V$.

A_v (without r_o)

$A_v = \frac{R_L}{R_L + 1/g_m} = \frac{15\times10^3}{15\times10^3 + 1/10^{-3}}$

$= 0.9375 V/V$.

R_{out} without r_o:-

$R_{out} = 1/g_m = 1k\Omega$.

R_{out} with r_o :-

$R_{out} = (1/g_m) \| r_o = (1/10^{-3}) \| (150\times10^3)$

$R_{out} = 0.993 k\Omega$.

$G_v = \frac{R_G}{R_G + R_{sig}} \left(\frac{(r_o \| R_L)}{(r_o \| R_L) + 1/g_m} \right)$

$G_v = 0.769 V/V$

4. A current mirror circuit has V_{DD}=3V, I_{ref}=100uA, I_O= 100uA. calculate the value of R if Q_1 and Q_2 are matched and L=1µm and W=10µm, V_t=0.7V and $\mu_n C_{ox}$=200µA/V^2. Also find the r_0 of the Isource if V_A'=20V/µM

$$I_{ref} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$$

$$100\times10^{-6} = \left(\frac{200\times10^{-6}}{2}\right)\left(\frac{10\times10^{-6}}{1\times10^{-6}}\right)(V_{GS}-0.7)^2$$

$$V_{GS} = 1.016V$$

$$I_{ref} = \frac{V_{DD}-V_{GS}}{R}$$

$$R = \frac{V_{DD}-V_{GS}}{I_{ref}}$$

$$R = \frac{3V-1.016}{100\times10^{-6}} = 20k\Omega$$

$$V_A = V_A' \times L$$

$$= 20\times10^{6} \times 1\times10^{-6}$$

$$V_A = 20V$$

$$r_{o_2} = \frac{20}{100\times10^{-6}} = 200k\Omega$$

5. For a Common Gate amplifier with active load, which has $W/L = 7.2\mu m / 0.36\mu m$, $\mu_n C_{ox} = 387\mu A/V^2$, $r_0 = 18K\Omega$, $I_D = 100uA$, $g_m = 1.25mA/V$, $\chi = 0.2$, $R_s = 10K\Omega$, $R_L = 100K\Omega$, $C_{gs} = 20fF$, $C_{gd} = 5fF$, $C_L = 0$, determine A_{v0}, R_{in}, R_{out}, G_v and f_H

$$g_m + g_{mb} = 1.25 + 0.2 \times 1.25 = 1.5 \text{ mA/V}$$

$$A_{vo} = 1 + (g_m + g_{mb})r_o = 1 + 1.5 \times 18 = 28 \text{ V/V}$$

$$R_{in} = \frac{r_o + R_L}{A_{vo}} = \frac{18 + 100}{28} = 4.2 \text{ k}\Omega$$

$$R_{out} = r_o + A_{vo}R_s = 18 + 28 \times 10 = 298 \text{ k}\Omega$$

$$G_v = G_{vo}\frac{R_L}{R_L + R_{out}} = A_{vo}\frac{R_L}{R_L + R_{out}} = 28\frac{100}{100 + 298} = 7 \text{ V/V}$$

$$G_{is} = \frac{A_{vo}R_s}{R_{out}} = \frac{28 \times 10}{298} = 0.94 \text{ A/A}$$

$$G_i = G_{is}\frac{R_{out}}{R_{out} + R_L} = 0.94\frac{298}{298 + 100} = 0.7 \text{ A/A}$$

$$R_{gs} = R_s \| R_{in} = 10 \| 4.2 = 3 \text{ k}\Omega$$

$$R_{gd} = R_L \| R_{out} = 100 \| 298 = 75 \text{ k}\Omega$$

$$\tau_H = C_{gs}R_{gs} + C_{gd}R_{gd}$$
$$= 20 \times 3 + 5 \times 75$$
$$= 60 + 375 = 435 \text{ ps}$$

$$f_H \cong \frac{1}{2\pi\tau_H} = \frac{1}{2\pi \times 435 \times 10^{-12}} = 366 \text{ MHz}$$

6. Determine the small signal voltage gain for a common source amplifier with an active load having V_{dd}=3V, V_{tn}=$|V_{tp}|$=0.6V, $\mu_n C_{ox}$=200μA/V^2, $\mu_p C_{ox}$=65μA/V^2. Length of all transistors are 0.4μm and Width is 4μm with V_{an}= 20V, $|V_{ap}|$=10V and Iref=100uA.

$$I_D = I_{REF} = 100\ \mu A = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)V_{OV}^2$$

$$100 = \frac{1}{2} \times 387 \times \left(\frac{7.2}{0.36}\right)V_{OV}^2$$

$$V_{OV} = 0.16\ V$$

$$g_m = \frac{I_D}{V_{OV}/2} = \frac{100\ \mu A}{(0.16/2)\ V} = 1.25\ mA/V$$

$$r_{o1} = \frac{V_{An}}{I_D} = \frac{5 \times 0.36}{0.1} = 18\ k\Omega$$

$$r_{o2} = \frac{|V_{Ap}|}{I_D} = \frac{6 \times 0.36}{0.1} = 21.6\ k\Omega$$

$$R_L' = r_{o1} \parallel r_{o2} = 18 \parallel 21.6 = 9.82\ k\Omega$$

$$A_M = -g_m R_L' = -1.25 \times 9.82 = -12.3\ V/V$$