(Q.1) Ignoring body effect and channel length modulation,

(A) $$Z_{in} = \frac{1}{g_{m_2} + g_{m_3}}$$ (0.5)

where $g_m = \sqrt{2 \mu_n C_{ox} W/L \; I_D \times m}$;

and $I_B = I_{D_2} + I_{D_3}$ and $I_{D_3} = 4 I_{D_2}$ (based on multiplier ratio)

$$\Rightarrow I_{D_2} = \frac{I_B}{5} \; ; \quad I_{D_3} = \frac{4 I_B}{5}$$ (0.5)

So, $$Z_{in} = \frac{1}{\sqrt{2 \mu_n C_{ox} W/L}\left[\sqrt{\frac{I_B}{5}} + \sqrt{\frac{4 I_B}{5} \times 4}\right]}$$

(0.5)p

$$= \frac{1}{\sqrt{2 \mu_n C_{ox} W/L \cdot \frac{I_B}{5}}\,(1+4)}$$

$$Z_{in} = \frac{1}{\sqrt{10 \cdot \mu_n C_{ox} W/L \; I_B}} \; \Omega$$ (0.5)

(B) Based on multipliers ratio,

$I_{D_1} = 6 I_{D_2}$ and $I_{D_4} = \frac{10}{4} I_{D_3}$ - Because of mirroring. (2)

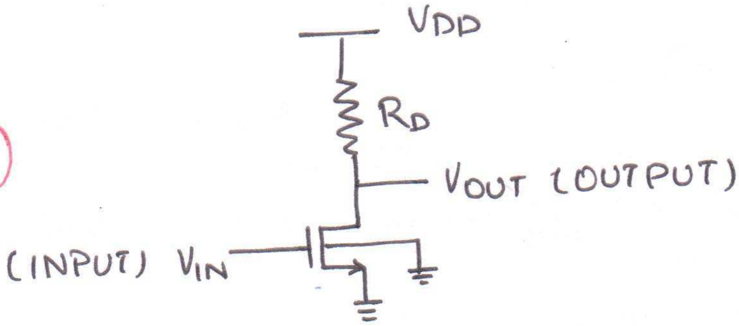
$$V_{B_1} = V_{DD} - R_D I_D = V_{DD} - \frac{6 I_B R_D}{5}$$ (1)

and similarly.

$$V_{B_2} = V_{DD} - R_D I_D = V_{DD} - 2 R_D I_B$$ (1)

2 A Common-Source Amplifier

1

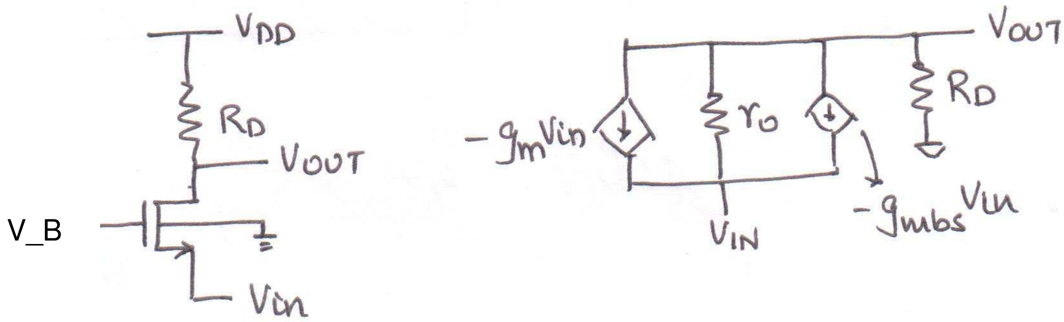


* No Body Effect because body and source are both grounded

3 $\boxed{A_V = -g_m (R_D \parallel r_o)}$

B Common-Gate Amplifier

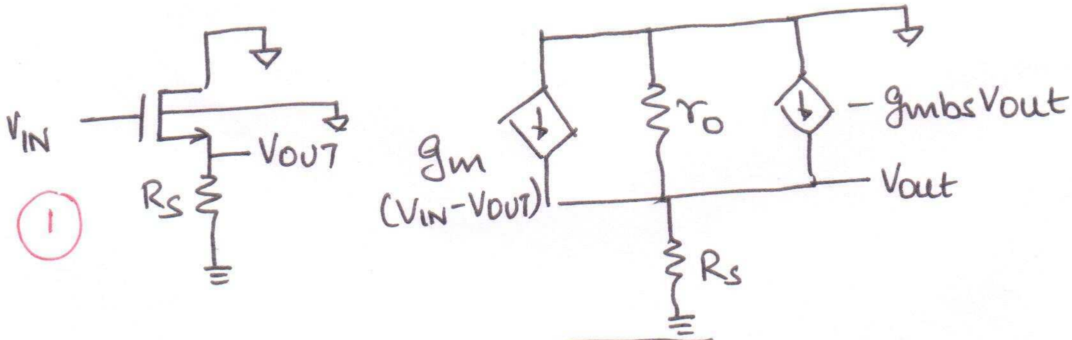
1



3 $$\boxed{A_V = \left(\frac{(g_m + g_{mbs}) r_o + 1}{r_o + R_D}\right) R_D}$$

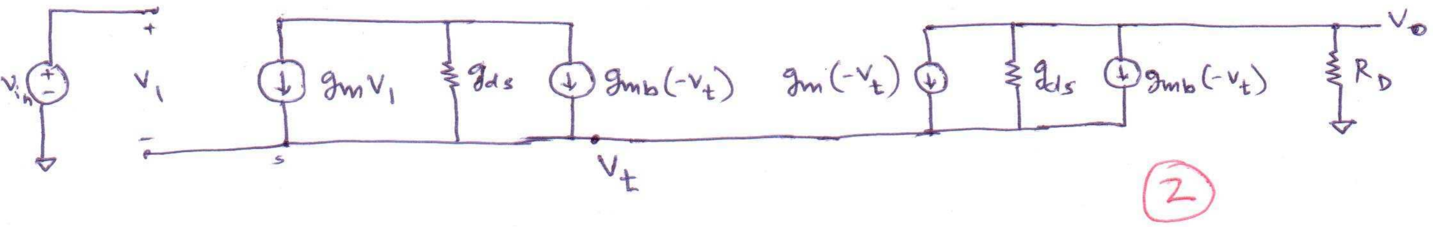
C Common-Drain Amplifier

1



3 $$\boxed{A_V = \frac{g_m R_s}{1 + R_s(g_m + g_{mbs} + g_{ds})}}$$

3. Small - Signal Model



2

$V_1 = V_{in} - V_t$

writing KCL, at node V_t:

$$g_m(V_{in} - V_t) + g_{mb}(-V_t) + g_{ds}(-V_t) = g_m \cdot V_t + g_{ds} \cdot (V_t - V_{out}) + g_{mb} \cdot V_t \quad — (1)$$

1

KCL at node V_o:

$$\frac{V_o}{R_D} = g_m \cdot V_t + (V_t - V_o) \cdot g_{ds} + g_{mb} \cdot V_t$$

1

$$\Rightarrow V_o \cdot \left[\frac{1}{R_D} + g_{ds}\right] = [g_m + g_{ds} + g_{mb}] \cdot V_t$$

$$\Rightarrow V_t = \frac{V_o \cdot [g_{ds} + 1/R_D]}{g_m + g_{mb} + g_{ds}} \quad — (2)$$

Put equation (2) ~~(1)~~ in (1),

$$\Rightarrow g_m V_{in} = \left[\frac{2\,\cancel{(g_m + g_{mb} + g_{ds})} \cdot [g_{ds} + 1/R_D]}{\cancel{(g_m + g_{mb} + g_{ds})}} - g_{ds}\right] V_{out}$$

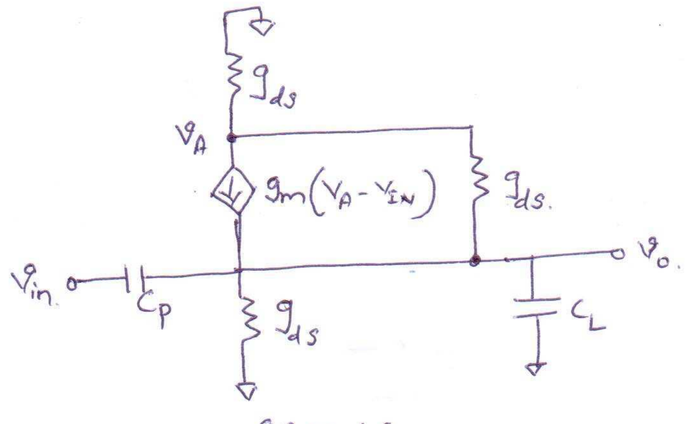
$$\Rightarrow g_m V_{in} = \left[g_{ds} + 2/R_D\right] \cdot V_{out}$$

$$\Rightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{g_m}{g_{ds} + \frac{2}{R_D}}}$$

(1) With approximation

(2) Without approximation

4 A) Ignoring Body Effect.



S.S model

(2)

B) At DC, all capacitances are open.

$$g_m(v_A - v_{in}) + (v_A - v_o) g_{ds} = v_o g_{ds} = -v_A g_{ds}$$

$$\Rightarrow v_A = -v_o$$

$$\Rightarrow g_m(-v_o - v_{IN}) + (-2v_o) g_{ds} = v_o g_{ds}$$

$$\Rightarrow -g_m v_{in} = (g_m + 3g_{ds}) v_o$$

(1)

$$\boxed{A_v = -\left[\frac{g_m}{g_m + 3g_{ds}}\right] \approx -1}$$

(1)

c) $g_m(-V_{in} + V_A) + (V_A - V_o) g_{ds} = -g_{ds} V_A$ —— (1) (1)

$$-g_{ds} V_A + (V_{in} - V_o) sC_p = V_o(g_{ds} + sC_L)$$

$\Rightarrow -g_{ds} V_A = V_o(g_{ds} + s(C_L + C_p)) - sC_p V_{IN}$ —— (2) (1)

using (1)

$$V_A = \frac{g_m V_{IN} + V_o g_{ds}}{g_m + 2g_{ds}}$$

Substituting in 2

$$-g_{ds}(g_m V_{IN} + V_o g_{ds}) = (g_m + 2g_{ds})(g_{ds} + s(C_L + C_p))V_o - sC_pV_{IN}(g_m + 2g_{ds})$$

Using approximation,

$$-g_{ds}(g_m V_{IN} + V_o g_{ds}) = (V_o(g_{ds} + s(C_L + C_p)) - sC_pV_{IN})g_m$$

2

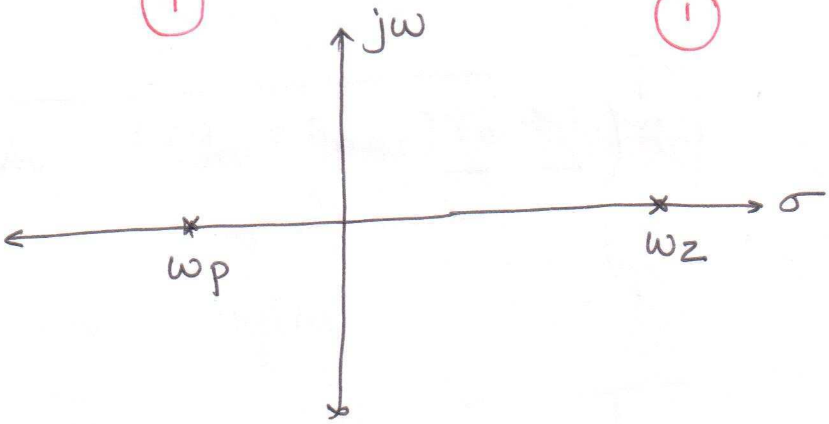
$$\Rightarrow (s\,g_m C_p - g_m g_{ds})V_{IN} = V_o(g_{ds}^2 + g_{ds}g_m + s g_m(C_L + C_p))$$

$$\Rightarrow (s\cancel{g_m}C_p - \cancel{g_m}g_{ds})V_{IN} \approx V_o(g_{ds}\cancel{g_m} + s\cancel{g_m}(C_L + C_p))$$

$$\Rightarrow \boxed{\frac{V_o}{V_{IN}} = \frac{-g_{ds} + sC_p}{g_{ds} + s(C_L + C_p)}}$$ 2

D $\omega_z = +g_{ds}/C_p$; $\omega_p = \dfrac{-g_{ds}}{C_L + C_p}$

1 1



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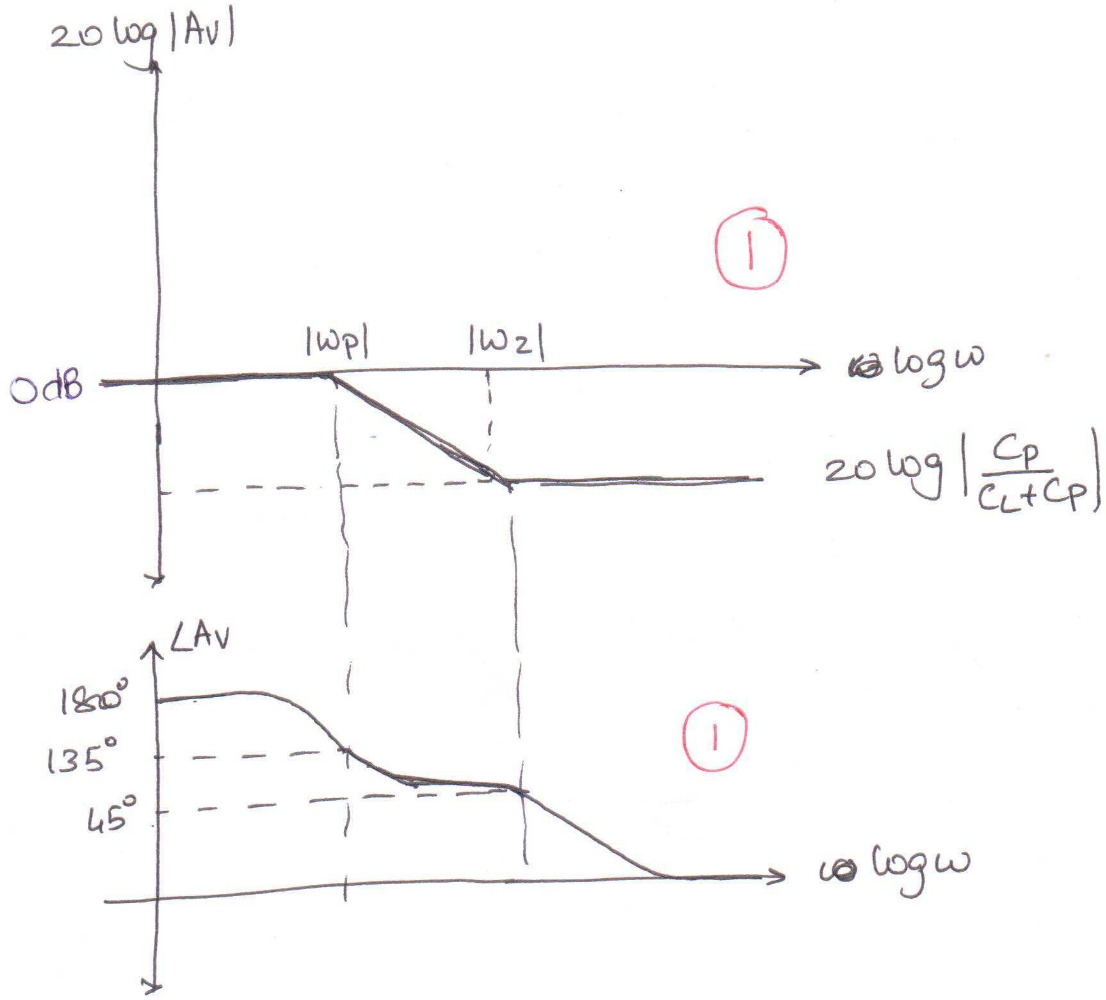

5

A_v = Intrinsic Gain = $g_m r_o$

$$= \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right) I_D} \times \frac{1}{\lambda I_D}$$

$$= \underbrace{\sqrt{\frac{2\mu C_{ox}(W/L)}{I_D}}}_{\text{constant.}} \times \frac{1}{\lambda} \quad 1$$

$\therefore$ $A_v \propto \frac{1}{\lambda}$ and $\lambda \propto 1/L$.

$\Rightarrow A_v \propto L$.

Hence A_v scales up by the same amount as W and L. 1