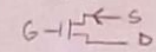


MOSFET PMOS



- Cutoff $i_D = 0, V_{GS} \geq V_t, V_{DS} < 0$
- Linear $i_D = \mu C_{ox} \frac{W}{L} [(V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2]$
 $\rightarrow V_{GS} < V_t, V_{DS} \geq V_{GS} - V_t$
- Sat/Active $i_D = \frac{1}{2} \mu C_{ox} \frac{W}{L} [V_{GS} - V_t]^2$
 $\rightarrow V_{GS} < V_t, V_{DS} \leq V_{GS} - V_t$

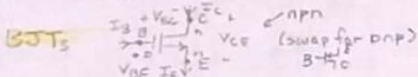
MOSFET Small Sig

- Split into DC + AC
- Assume state \rightarrow solve DC
 \rightarrow if sat \rightarrow find $Q(V_{GS}, I_D)$
- Redraw AC (put DC sources)
- $V_{GS} = V_t + \frac{1}{g_m} i_D$
 \rightarrow gate, source, drain

- Solve AC
- Recombine w DC+AC $r_o = \frac{V_A}{I_D} (1 + \lambda)$

$$r_s = V_A / I_D, \lambda = 1/V_A, A_v = V_o / V_{gs}$$

- $g_m = \frac{1}{V_{GS}} = 2k(V_{GS} - V_t) = 2\sqrt{I_D k}$
- DC blocking capacitor
 \rightarrow blocks current in DC
 \rightarrow no affect in AC (short)



$$I_B + I_C = I_E, V_{BE} = V_B - V_E, V_{CE} = V_C - V_E, V_{CB} = V_C - V_B$$

- Cutoff $I_B = I_C = I_E = 0$

$$V_{BE} < 0, V_{CE} < 0$$

$$\text{Sat. } I_C = I_{SC} = V_{BE} / V_t - I_{EC} = V_{BE} / V_t$$

$$I_B = \frac{I_C}{\beta} = \frac{V_{BE}}{\beta V_t} + I_{EC}$$

$$V_{BE} > 0, V_{CE} > 0$$

$$\text{Active } I_C = I_{EC} = \beta I_B = \alpha I_E$$

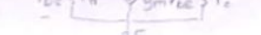
$$I_B = \frac{I_C}{\beta} = (1 - \alpha) I_E$$

$$I_E = \frac{I_C}{\alpha} = (\beta + 1) I_B$$

$$\alpha = \beta / (\beta + 1)$$

$$V_{BE} > 0, V_{CE} < 0$$

BJT Small Signal

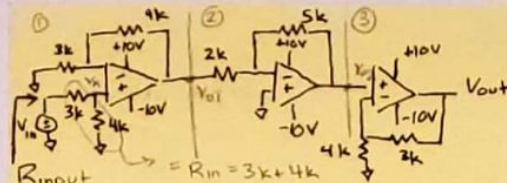


$$r_s = V_A / I_C, g_m = \frac{I_C}{V_t}$$

$$r_{\pi} = V_t / I_B = \beta / g_m$$

$$\text{if } V_{BE} > 0, \text{ in active } \rightarrow V_{BE} = 0.7V$$

$$V_{CE} = V_C - V_E = \frac{\sqrt{2} k_n R_D V_{DD} + 1}{k_n R_D}$$



R_{input}

$$V_x = \frac{4k \cdot V_{in}}{4k + 3k} = \frac{4}{7} V_{in}$$

$$\frac{V_{o1}}{V_{in}} = \left(\frac{V_x}{V_{in}} \right) \left(\frac{V_{o1}}{V_x} \right) = 4 \cdot \frac{4}{7} = \frac{16}{7}$$

$$\frac{V_{o2}}{V_{o1}} = \frac{-5k}{2k} = -\frac{5}{2}$$

$$\frac{V_o}{V_{o2}} = 1 + \frac{3k}{4k} = \frac{7}{4}$$

$$\rightarrow \frac{V_o}{V_{in}} = \left(\frac{V_{o1}}{V_{in}} \right) \left(\frac{V_{o2}}{V_{o1}} \right) \left(\frac{V_o}{V_{o2}} \right) = \left(\frac{16}{7} \right) \left(-\frac{5}{2} \right) \left(\frac{7}{4} \right) = -10$$

$$V_{inmax} \text{ to be in linear} = 1, -1$$

$$R_{input} = 7k \Omega$$



Assume ideal

Assume all but

D_z FB

$$\frac{V_A - 5.3}{1k} + \frac{V_A + 1.3}{1.5k} + \frac{V_A - 0}{4k} = 0$$

$$12V_A - 63.6 + 8V_A + 15.6 + 3V_A = 0$$

$$23V_A - 48 = 0$$

$$V_A = 2.086V$$

$$I_4 = \frac{V_A + 1.3}{1.5k} = 2.257mA$$

$$I_3 = \frac{V_A - 0}{4k} = 0.5215mA$$

$$I_2 = 0$$

$$I_1 = \frac{5.3 - V_A}{1k} = 3.214mA$$

$$V_4 = 3.386$$

$$V_3 = 2.086$$

$$V_2 = 0$$

$$V_1 = 3.214$$

$$V = -3 + 3 = 0V$$

$$I = 2mA$$

$$I_2 = 1mA$$

$$I_1 = 3mA$$

$$I = 2mA$$

$$I = 2mA$$

$$I = 2mA$$

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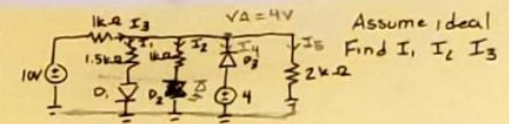
$$I = 2mA$$

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Assume ideal

Find I_1, I_2, I_3

Assuming FB

$$\frac{V_A - 10}{1k} = -6mA$$

nope

Assume $D_1 \rightarrow FB, D_2, D_3 \rightarrow RB$

$$\left[\frac{V_A - 10}{1k} + \frac{V_A - 0}{1.5k} + \frac{V_A - 0}{2k} \right] 3k$$

$$3V_A - 30 + 2V_A + 1.5V_A = 0$$

$$6.5V_A = 30 \rightarrow V_A = 4.6153V$$

$$I_4 = 0, I_2 = 0, I_1 = \frac{V_A - 0}{1.5k} = 0.00307A$$

$$I_3 = 0.00307 \cdot \frac{V_A - 0}{2000} = 0.00538A$$

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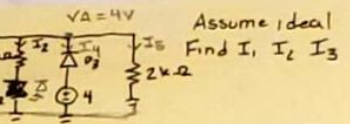
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Assume ideal

Find I_1, I_2, I_3

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