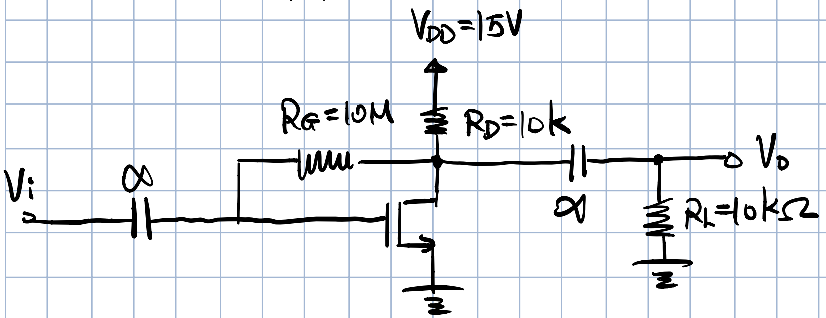
MOS amplifier example.



$V_t = 1.5V$, $k_n'(\frac{W}{L}) = 0.25 mA/V^2$

$V_A = 50V$

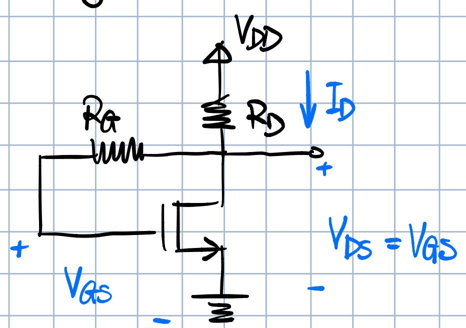
a) small-signal gain

b) input resistance

c) largest allowable input signal

a)

DC Analysis:



$$I_D = \frac{V_{DD} - V_{GS}}{R_D} \quad (1)$$

V_{DS}

transistor in saturation mode.

$$I_D = \frac{1}{2} k_n'(\frac{W}{L})(V_{GS} - V_t)^2 \quad (2)$$

$$100 I_D^2 - 278 I_D + 182.25 = 0$$

Solve $\boxed{I_D = 1.06 mA}$ or $I_D = 1.40 mA$

$V_{GS} = V_{DD} - I_D R_D = 1V < V_t$ ✗

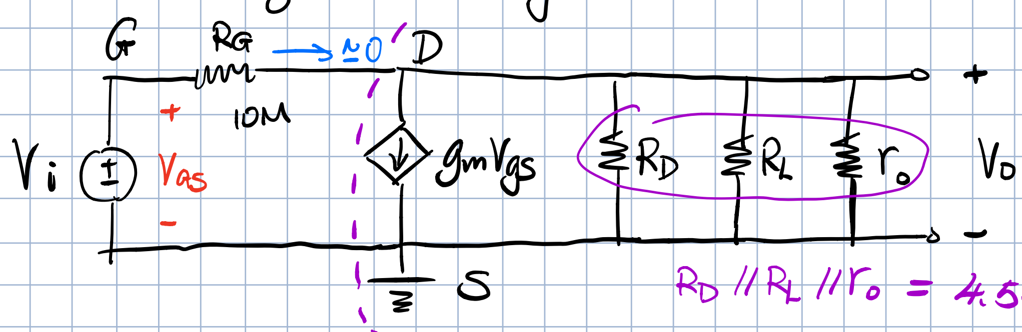
$V_{GS} = V_{DD} - I_D R_D = 4.4V$ ✓

(transistor is on & in saturation)

Compute $g_m = k_n'(\frac{W}{L})(V_{GS} - V_t) = 0.725 mA/V$

$r_o = \frac{V_A}{I_D} = \frac{50}{1.06mA} = 47k\Omega$

Small signal model (hybrid-π)



$R_D // R_L // r_o = 4.52k\Omega$

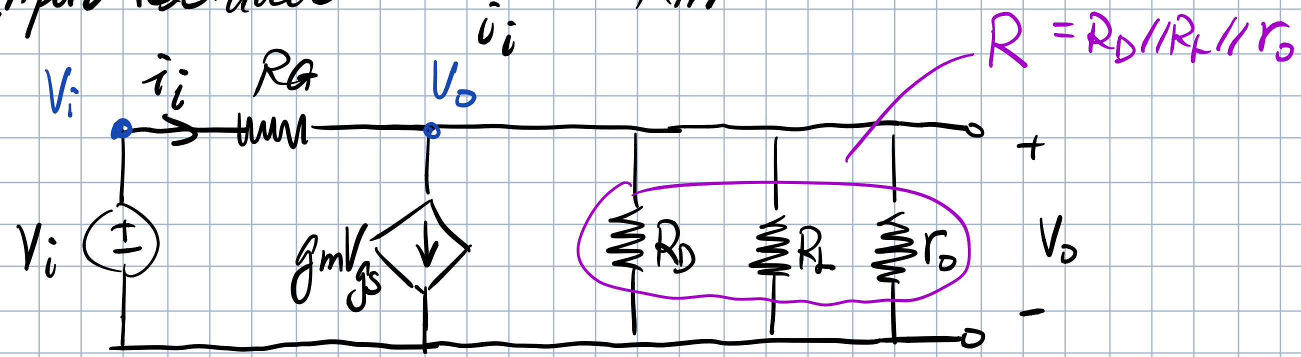
$$V_o = -g_m V_{gs} (R_D // R_L // r_o)$$

small-signal gain $= V_o/V_{gs} = \frac{V_o}{V_i} = -g_m(R_D//R_L//r_o) = -3.3 V/V$

(A_v)

b)

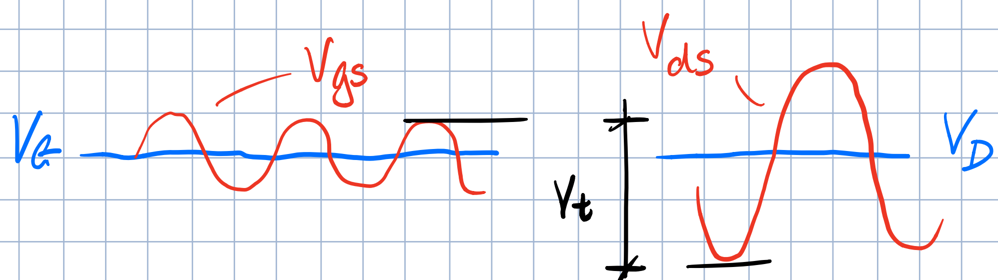
Input resistance $= \dfrac{V_i}{i_i} = R_{in}$



$$i_i = \frac{V_i - V_o}{R_G} = \frac{V_i - A_v V_i}{R_G} = \frac{(1-A_v)V_i}{R_G}$$

$$R_{in} = \frac{V_i}{i_i} = \frac{R_G}{1-A_v} = \frac{10M}{1+3.3} = 2.33M\Omega$$

C)



$$(V_{GS} + \hat{V}_{gs}) - (V_D - \hat{V}_{ds}) = V_t$$

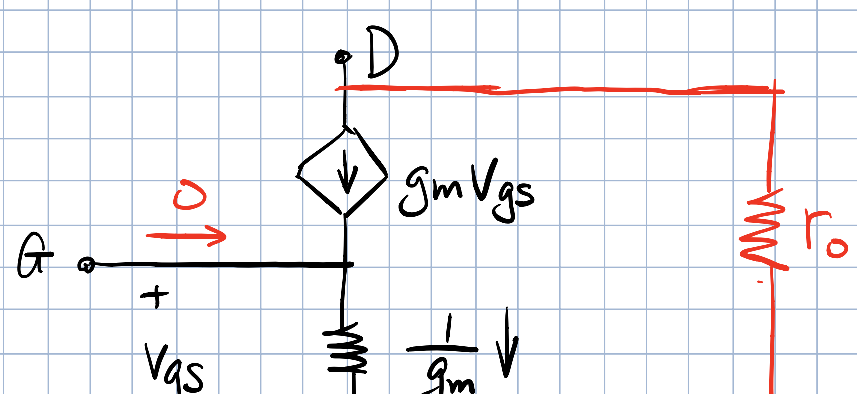
$$\hat{V}_{ds} = A_v V_{gs}$$

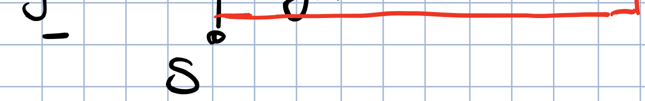
$$4.4 + \hat{V}_{gs} - (4.4 - 3.3\hat{V}_{gs}) = 1.5$$

$$\hat{V}_{gs} = 0.35V \ (V_i)$$

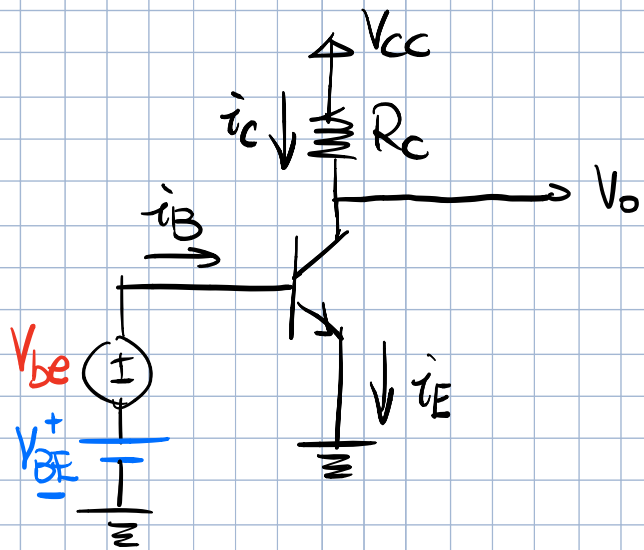
Another small signal model.

T-model





BJT small-signal-model



trans. must be in active mode

$$i_C = I_S e^{V_{BE}/V_T} = I_S e^{(V_{BE}+v_{be})/V_T}$$

$$= \underbrace{I_S e^{V_{BE}/V_T}}_{I_C} \cdot e^{v_{be}/V_T}$$

$$= I_C e^{v_{be}/V_T} \quad (\text{if } v_{be} \ll V_T)$$

$$\simeq I_C\left(1 + \frac{v_{be}}{V_T}\right)$$

$$\simeq I_C + \underbrace{\frac{I_C}{V_T}}_{g_m \text{ (trans-conductance)}} v_{be}$$

$$\simeq I_C + i_c$$

$$\boxed{i_c = g_m v_{be}}$$