

$$i_1 = i_{\frac{1}{2}} + g_m v_A$$

$$v_1 = v_A$$

$$i_2 = g_m v_A + 0.5 v_2$$

$$v_2 = v_A \Rightarrow i_2 = g_m v_A + 0.5 v_2$$

$$i_1 = 0 = 0.5 v_1 + 0.5 v_2 \Rightarrow v_2 = -v_1$$

$$i_2 = g_m v_1 + 0.5 v_2 = g_m v_1 - 0.5 v_1 = (g_m - 0.5) v_1$$

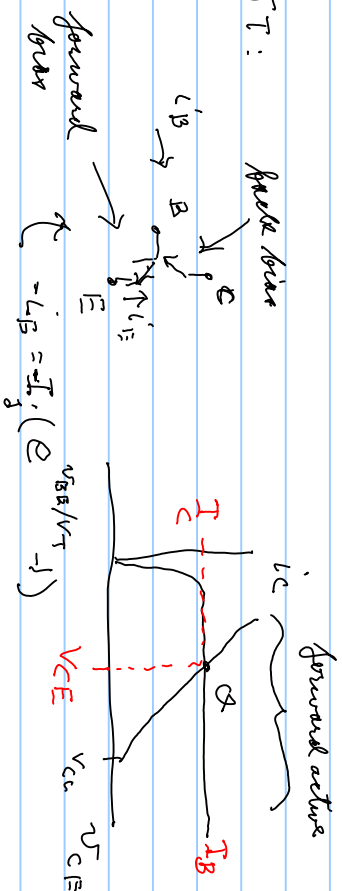
$$Y = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix} = \text{admittance matrix}$$

if load in $R_L = 1/G_L \Rightarrow v_2 = -R_L i_2 \Rightarrow i_2 = -G_L v_2$

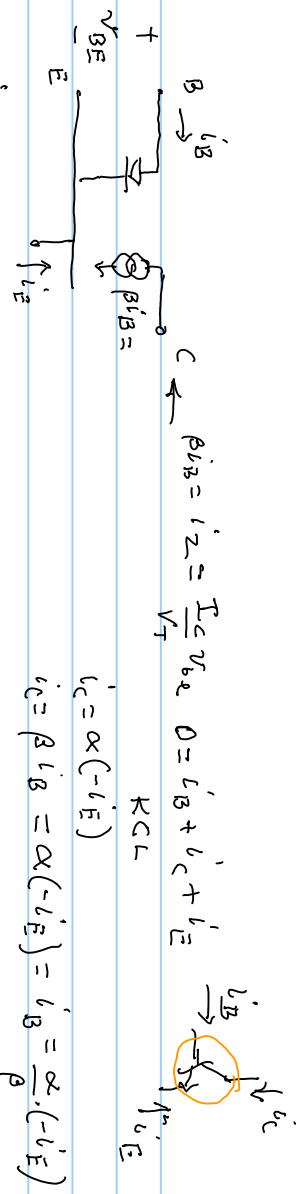
$$i_2 = -G_L v_2 = g_m v_1 + 0.5 v_2 \Rightarrow v_2 = -\frac{g_m}{G_L + 0.5} v_1$$

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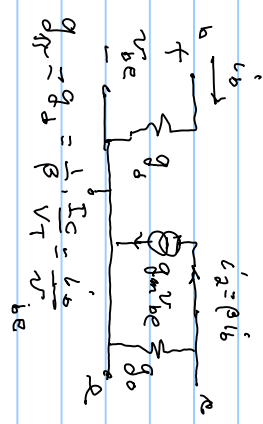
for BJT:



$$g = \frac{\partial(i_C)}{\partial v_{BE}} = \frac{-I_E}{V_T} \left(e^{v_{BE}/V_T} - 1 \right) \approx \frac{-I_E}{V_T}$$



small signal equivalent



$$g_m = \frac{I_C}{V_T}$$

$$g_d = \frac{v_b}{v_{be}} = \frac{(-\alpha I_E)}{\beta V_T} \approx \frac{I_C}{V_T} \cdot \frac{1}{\beta}$$



$V_A = -\text{Early voltage (large)}$

$$Y_1 = \begin{bmatrix} g_m & 0 \\ 0 & g_o \end{bmatrix}$$

$$Y_2 = \begin{bmatrix} 0 & 0 \\ g_m & g_o \end{bmatrix}$$

$$Y = Y_1 + Y_2 = \begin{bmatrix} g_m & 0 \\ g_m & g_o \end{bmatrix}$$

$$\left. \frac{v_2}{v_1} \right|_{\text{load in } r_L} = \frac{-g_m}{G_L + g_o}$$

frequency behavior

$$i = C \frac{dv}{dt}, \quad C = \text{constant capacitance}$$

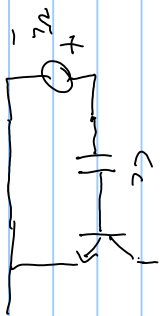
note if $i = I e^{st}$, $-\infty < t < \infty$
 then $v = V e^{st}$ imposed $I e^{st} = C V s e^{st} \Rightarrow I = s C V, \Rightarrow g(s) = s C$

$$e^{j\omega t} = \cos \omega t + j \sin \omega t, \quad g = \sqrt{-1} \Rightarrow s = j\omega \text{ if sine wave}$$

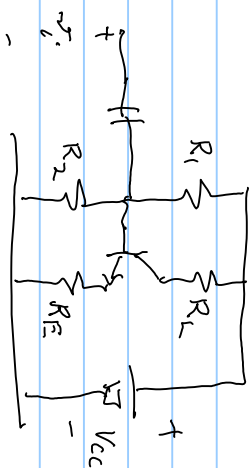
coupling to isolate signal from bias

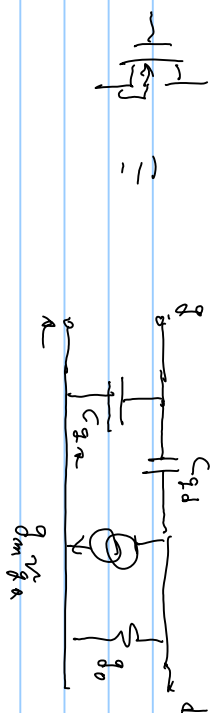
$$g(j\omega) = \frac{1}{j\omega C} \Rightarrow \text{impedance}$$

C opens as $\omega \rightarrow 0$



Bias





$$C_{gs} = \frac{2}{3} \text{ of gate capacitance} = C_{ox} W L = \frac{C_{ox} \cdot W L}{3}$$

$$C_{gd} = C_{gate} - C_{gs} = \frac{1}{3} \text{ of gate cap.}$$

