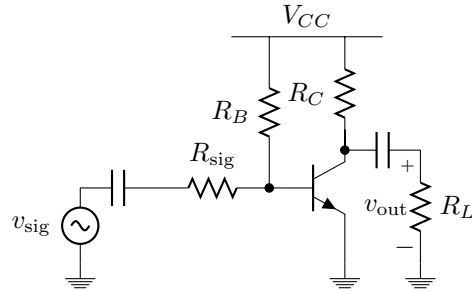# Common Emitter

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

$$V_C = V_{CC} - I_C R_C > 0.3\text{V}$$

$$g_m = {I_C}/{V_t}$$

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

$$r_0 = {V_A}/{I_C}$$

$$R_{\text{in}} = R_B \parallel r_\pi$$

$$R_{\text{out}} = R_C \parallel r_0$$

$$A_V = -g_m R_{\text{out}}$$

$$A_{\text{overall}} = A_V \frac{R_{\text{in}}}{R_{\text{sig}} + R_{\text{in}}} \frac{R_L}{R_{\text{out}} + R_L}$$

$$G_m = -g_m$$

Emitter Degeneration
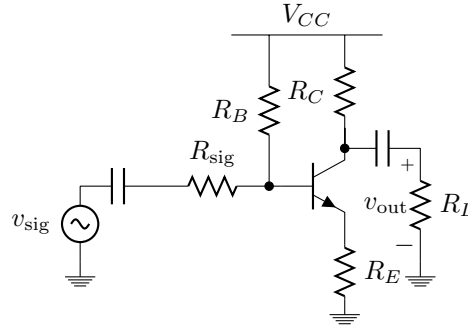
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta R_E}$$

$$I_C = \beta I_B$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E) > 0.3\text{V}$$

$$g_m = {I_C}/{V_t}$$

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

$$r_0 = {V_A}/{I_C}$$

$$R_{\text{in}} = R_B \parallel [r_\pi(1 + g_m R_E)]$$

$$R_{\text{out}} = R_C$$

$$A_V = \frac{-\beta R_C}{r_\pi + (\beta + 1)R_E}$$

$$A_{\text{overall}} = A_V \frac{R_{\text{in}}}{R_{\text{sig}} + R_{\text{in}}} \frac{R_L}{R_{\text{out}} + R_L}$$

$$G_m = \frac{-\beta}{r_\pi + (\beta + 1)R_E}$$

Emitter Follower
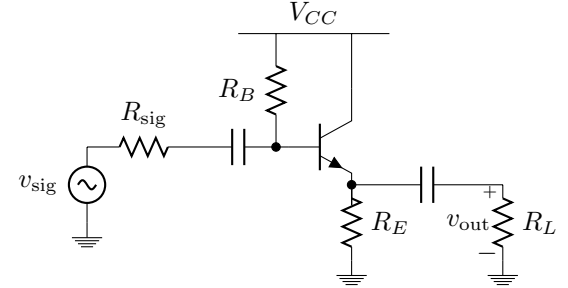
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta R_E}$$

$$I_C = \beta I_B$$

$$V_B = V_{CC} - I_B R_B$$

$$V_E = V_B - V_{BE}$$

$$g_m = {I_C}/{V_t}$$

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

$$r_0 = {V_A}/{I_C}$$

$$R_{\text{in}} = R_B \parallel [r_\pi + (\beta + 1)(R_E \parallel R_L \parallel r_0)]$$

$$R_{\text{out}} = \left(\frac{r_\pi + R_{\text{sig}} \parallel R_B}{\beta + 1}\right) \parallel R_E \parallel r_0$$

$$A_{\text{overall}} = \frac{g_m(R_E \parallel R_L \parallel r_0)}{(1 + \frac{R_{\text{sig}}}{R_B})[1 + g_m(R_E \parallel R_L \parallel r_0)] + g_m \frac{R_{\text{sig}}}{\beta}}$$

Common Source

$$V_{GS} = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}} > V_{th}$$

$$I_D = \mu_n C_{ox} \left(W/L\right) \, ^1/_2 (V_{GS} - V_{th})^2$$

$$V_D = V_{DD} - I_D R_D > V_G - V_{th}$$

$$g_m = \frac{2I_D}{V_{GS} - V_{th}}$$
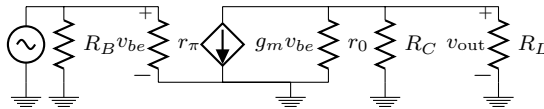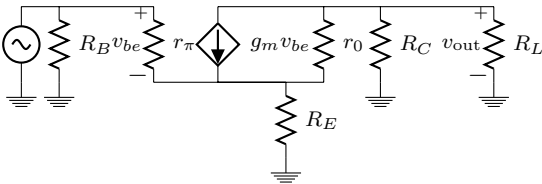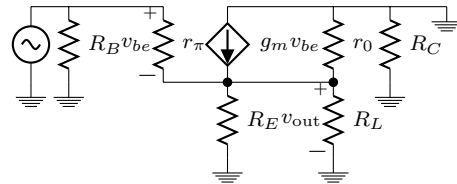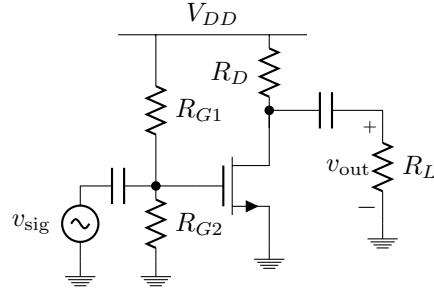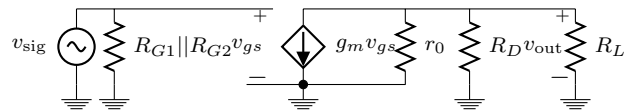
$$r_0 = {}^{V_A}/_{I_D}$$

$$R_{in} = R_{G1} \parallel R_{G2}$$
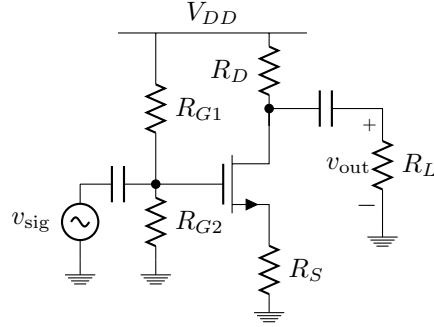
$$R_{out} = R_D \parallel r_0$$

$$A_V = -g_m R_{out}$$

$$A_{overall} = A_V \frac{R_{in}}{R_{sig} + R_{in}} \frac{R_L}{R_{out} + R_L}$$

$$G_m = -g_m$$

Source Degeneration

$$I_D = \mu_n C_{ox} \left(W/L\right) \, ^1/_2 (V_{GS} - V_{th})^2$$

$$V_S = I_D R_S$$

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}}$$

$$V_D = V_{DD} - I_D R_D$$

$$g_m = \frac{2I_D}{V_{GS} - V_{th}}$$
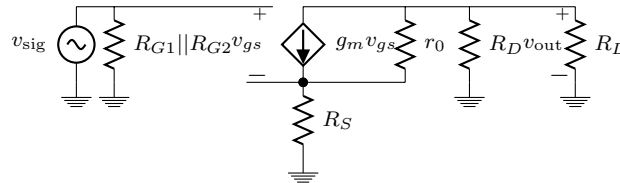
$$r_0 = {}^{V_A}/_{I_D}$$

$$R_{in} = R_{G1} \parallel R_{G2}$$
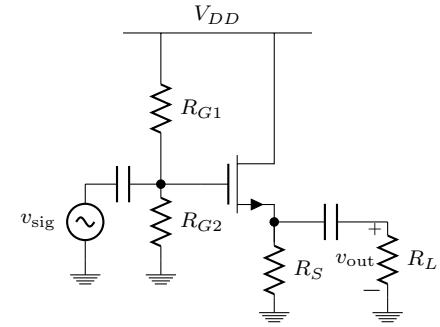
$$R_{out} = R_D$$

$$A_V = \frac{-g_m R_D}{1 + g_m R_S}$$

$$A_{overall} = -g_m R_D \parallel r_0 \parallel R_L$$

$$G_m = \frac{-g_m}{1 + g_m R_D}$$

Source Follower

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1} + R_{G2}}$$

$$V_S = I_D R_S$$

$$I_D = \mu_n C_{ox} \left(W/L\right) \, ^1/_2 (V_{GS} - V_{th})^2$$
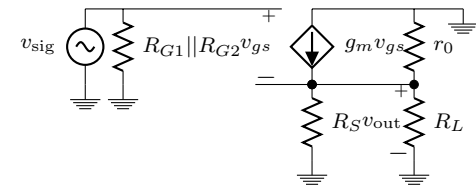
$$g_m = \frac{2I_D}{V_{GS} - V_{th}}$$

$$r_0 = {}^{V_A}/_{I_D}$$

$$R_{in} = R_{G1} \parallel R_{G2}$$

$$R_{out} = R_S \parallel r_0 \parallel {}^1/_{g_m}$$

$$A_V = g_m R_{out}$$

$$A_{overall} = A_V \frac{R_{in}}{R_{sig} + R_{in}} \frac{R_L}{R_{out} + R_L}$$

$$V_t = 26\text{mV@300K}$$

$$\rho = \frac{n_i^2}{n}, \quad n_i = 1.45 \times 10^{10} \text{ cm}^3$$

$$I_C = I_S e^{V_{BE}/V_t}$$