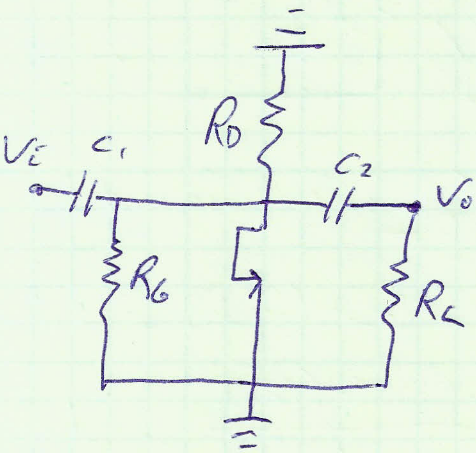
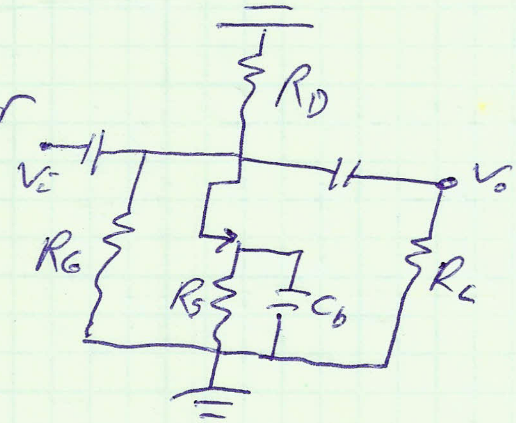
Common Source Amplifiers

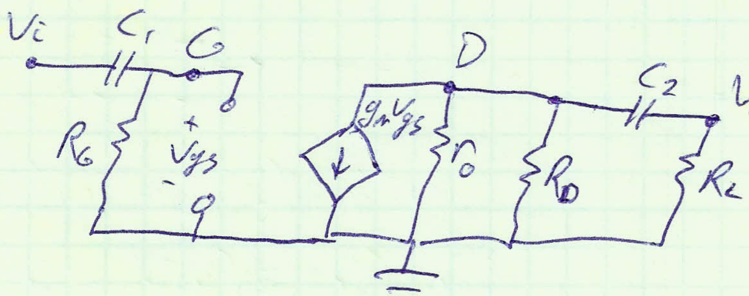


or



bypass capacitor eliminates R_S for small signal

Small signal model:



take $R_L' = R_D \| R_L$ as before

$V_o = -g_m V_{gs} (r_o \| R_L')$ note $V_{gs} = V_i$

$A_v = \frac{V_o}{V_i} = -g_m (r_o \| R_L')$

$A_{vo} = -g_m r_o$ (set $R_L' = \infty$)

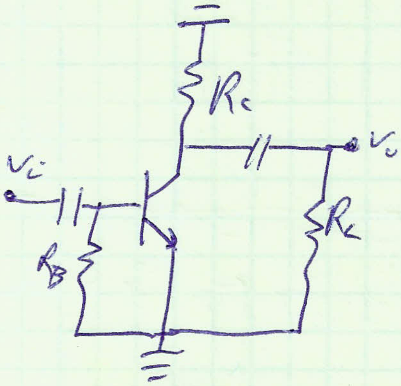
$\boxed{\text{negative sign means } 180^\circ \text{ phase shift}}$

$R_i = R_G$ (by inspection)

$R_o = r_o$ (by inspection - set $R_L' = \infty$)

note $R_o' = R_D \| R_o$ (some books, e.g. Sedra+Smith define it this way)

Common Emitter Amplifiers



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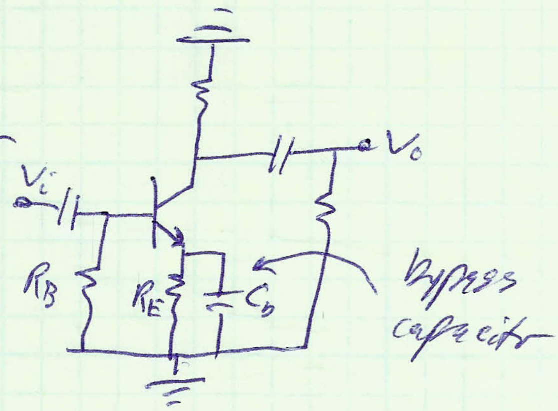
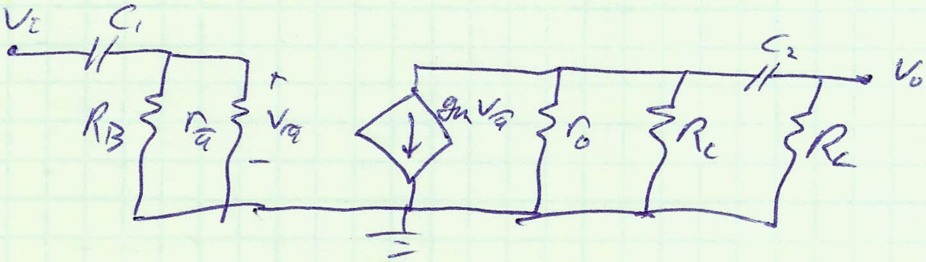


Small Signal model



define $R_c' = R_c \| R_L$

note $v_i = v_\pi$

$$v_o = -g_m v_\pi (r_o \| R_c')$$

$$A_v = \frac{v_o}{v_i} = -g_m (r_o \| R_c') = \frac{-r_o \| R_c'}{r_e}$$

$$A_{vo} = -g_m r_o = \frac{-r_o}{r_e}$$

$$R_i = R_B \| r_\pi$$

$R_o = r_o$ and $R_o' = R_c \| R_o$

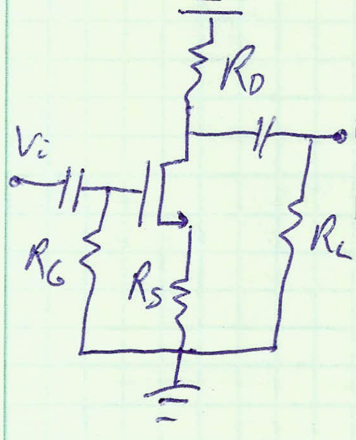
Both Common Source and Common Emitter have large open loop voltage gain

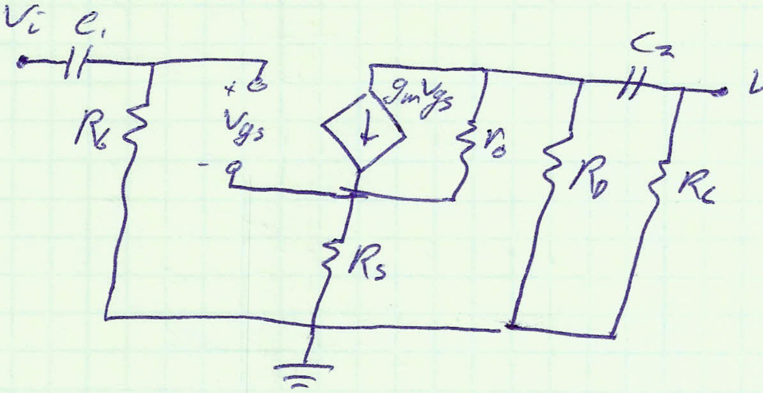
Common Source has large input resistance (can be infinite)

Common Emitter has medium input resistance

Both have medium to large output resistance

Common Source with Source Resistor





at source node:

$$\frac{V_S}{R_S} + \frac{V_S - V_o}{r_o} - g_m V_{gs} = 0$$

at drain node:

$$\frac{V_o}{R_L'} + \frac{V_o - V_S}{r_o} + g_m V_{gs} = 0$$

$$\rightarrow \frac{V_S}{R_S} + \frac{V_o}{R_L'} = 0$$

(sum the two equations)

substitute $V_{gs} = V_i - V_S \rightarrow$ ~~find~~ eliminate V_S, find V_o, V_i

$$A_V = \frac{V_o}{V_i} = \frac{-r_o(g_m R_L')}{R_L' + r_o + R_S(1 + r_o g_m)} \simeq \frac{-r_o(g_m R_L')}{R_L' + r_o + R_S r_o g_m}$$

$$A_V = \frac{-g_m R_L'}{1 + g_m R_S + R_L'/r_o} \rightarrow A_{V_o} = -g_m r_o$$

(let $R_L' \to \infty$)

if $r_o >> R_L'$

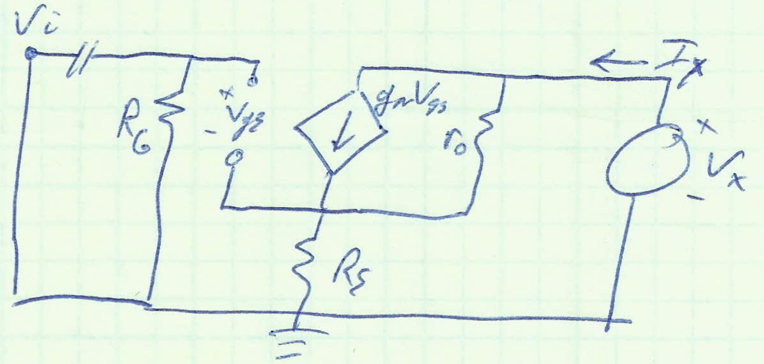
$$A_V \simeq \frac{-g_m R_L'}{1 + g_m R_S}$$

gain is reduced, but less sensitive to g_m

$R_i = R_G$ by inspection

For R_o:

- take off R_L and attach V_x
- short out V_i



current i_x should flow in R_S

current $i_x - g_m V_{gs}$ should flow in r_o

$V_{gs} = -R_S i_x$

KVL:

$$V_x = r_o(i_x - g_m V_{gs}) + R_S i_x = r_o(i_x + g_m R_S i_x) + R_S i_x$$
$$= i_x(r_o + g_m R_S r_o + R_S)$$

$$R_o = \frac{V_x}{i_x} = r_o + R_S + g_m r_o R_S$$

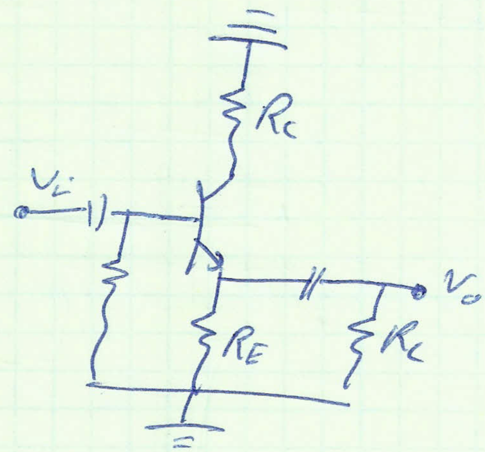
$$R_o \simeq r_o(1 + g_m R_S)$$

Common Emitter with Emitter Resistor

same basic idea as for common source

$$A_v \simeq \frac{-g_m R_L'}{1+g_m R_E}$$

$$= \frac{-R_L'}{R_E + r_e}$$



$$R_i = R_B \| \left[r_\pi + (1+\beta) R_E\right]$$

$$R_o = r_o \left(1 + \frac{\beta R_E}{r_\pi + R_E}\right)$$

analysis is similar to common source, but with addition of r_π