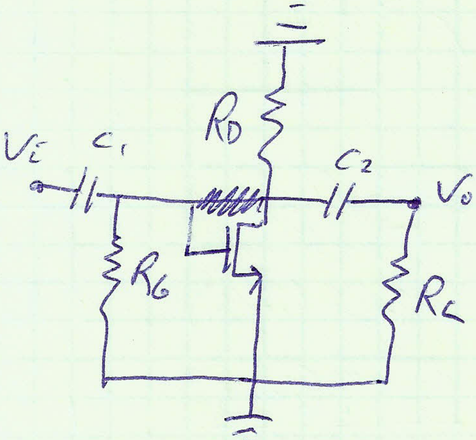
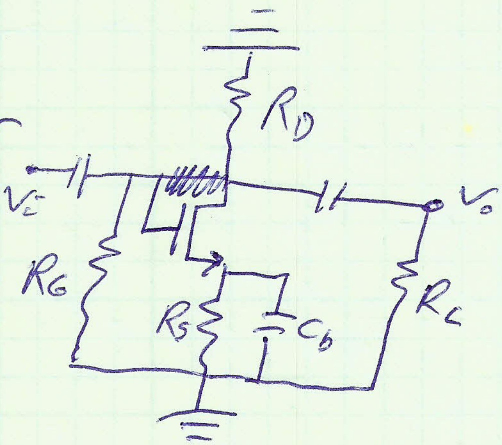
## Common Source Amplifiers

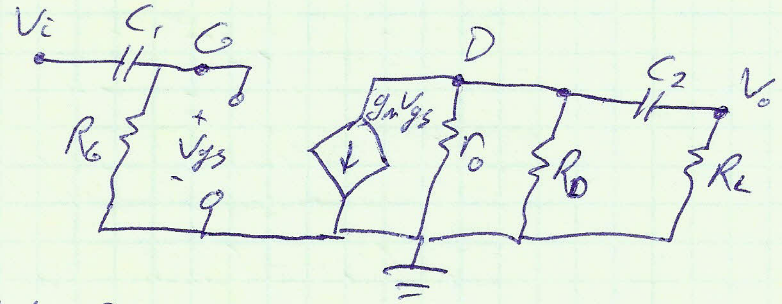



or




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 $V_{gs} = V_i$

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

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

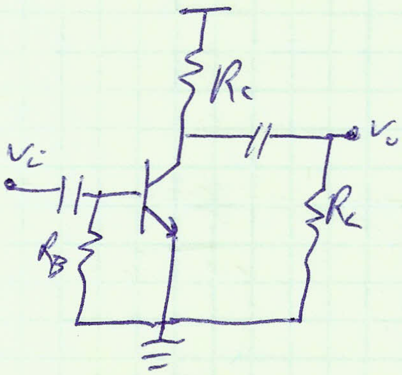
$A_{vo} = -g_m r_o$ (set $R_L' = \infty$)

$R_i = R_G$ (by inspection)

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

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

## Common Emitter Amplifiers

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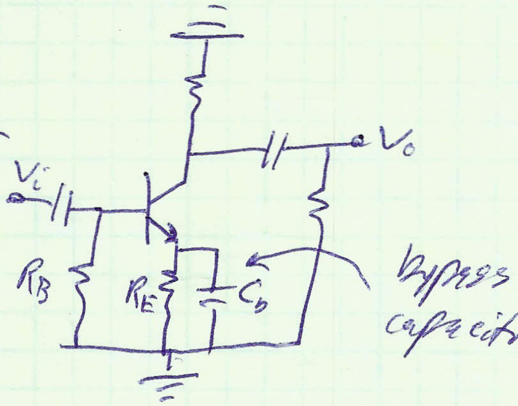
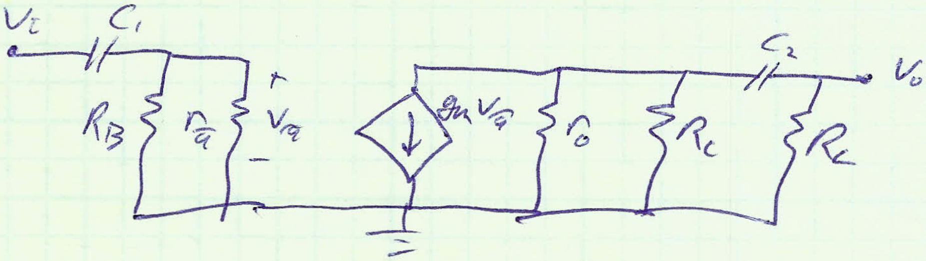



## Small Signal model




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 $R_o' = R_c \| R_o$

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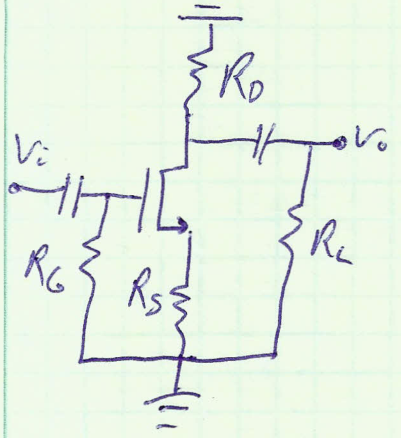
Both Common Source and Common Emitter have large open loop voltage gain

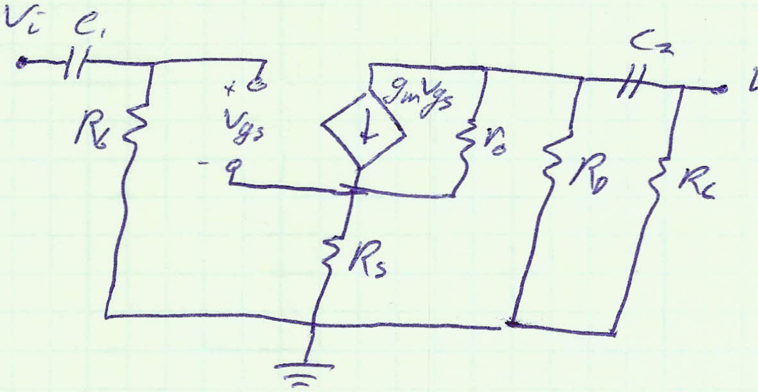
Common Source has large input resistance (can be infinite)

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 $v_{gs} = v_i - v_s$ → ~~find~~ eliminate $v_s$, find $v_o$, $v_i$

$$A_v = \frac{v_o}{v_i} = \frac{-r_o (g_m R_L')}{R_L' + r_o + R_S(1 + r_o g_m)} \simeq \frac{-r_o (g_m R_L')}{R_L' + r_o + R_S r_o g_m}$$

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

(let $R_L' \rightarrow \infty$)

if $r_o \gg R_L'$

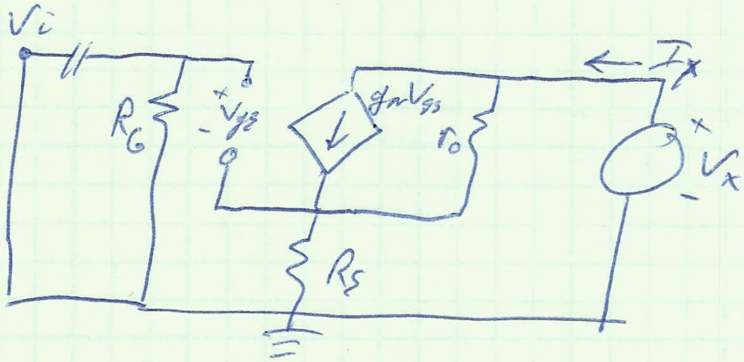
$$A_v \simeq \frac{-g_m R_L'}{1 + g_m R_S}$$

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:

$$v_x = r_o(i_x - g_m v_{gs}) + R_S i_x = r_o(i_x + g_m R_S i_x) + R_S i_x$$
$$= i_x(r_o + g_m R_S r_o + R_S)$$

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

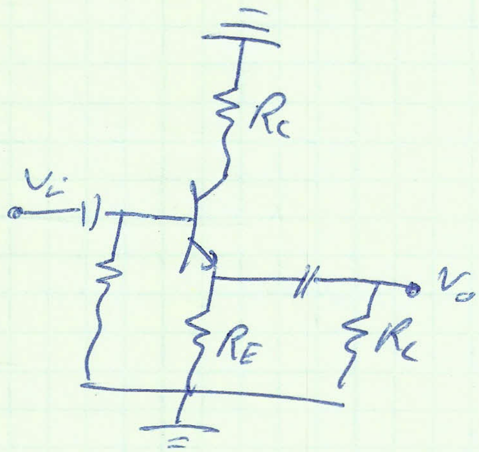
$$R_o \simeq r_o(1 + g_m R_S)$$

## Common Emitter with Emitter Resistor

same basic idea as for common source

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

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

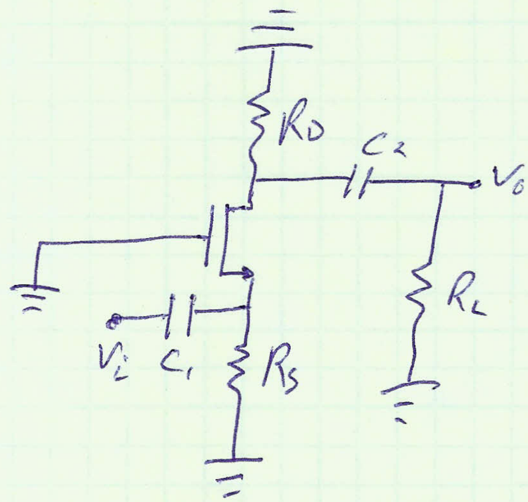



$$R_i = R_B \,||\, [r_\pi + (1+\beta)R_E]$$

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

analysis is similar to common source, but with addition of $r_\pi$

# Common Gate Amplifiers

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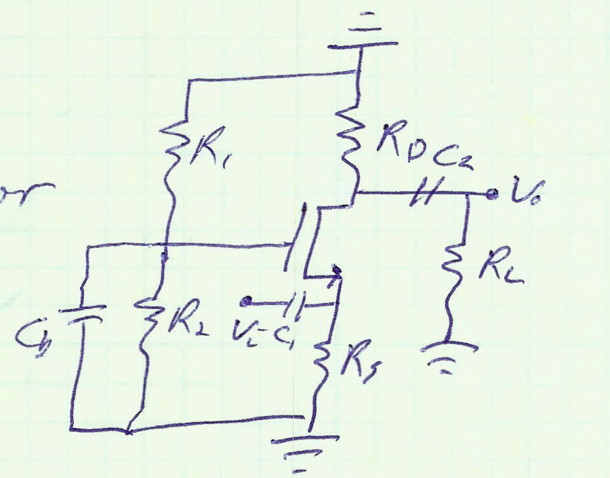
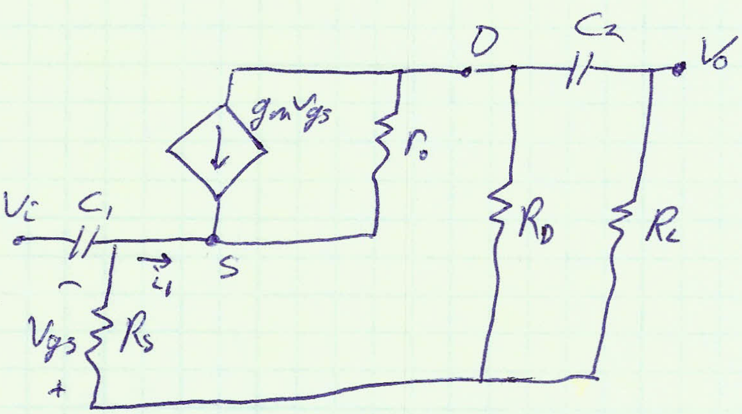



- Define $R_L' = R_D \| R_L$
- Note $V_i = -V_{gs}$




at node $V_o$:

$$\frac{V_o}{R_L'} + \frac{V_o - V_i}{r_o} + g_m(-V_i) = 0$$

$$V_o\left(\frac{1}{R_L'} + \frac{1}{r_o}\right) = V_i \cdot \frac{1 + g_m r_o}{r_o}$$

$$\simeq V_i \cdot \frac{g_m r_o}{r_o} = V_i g_m$$

$$A_v = \frac{v_o}{v_i} = g_m (R_L' \| r_o)$$

$$A_{vo} = g_m r_o$$

To find $R_i$: write $R_i = R_S \parallel \frac{v_i}{i_1}$

note current $i_1 + g_m v_{gs}$ flows in $r_o$
current $i_1$ flows in $R_L'$

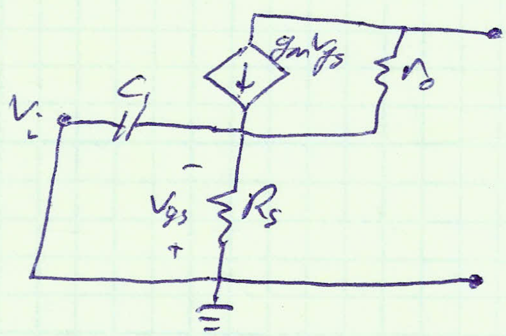
$$v_i = (i_1 + g_m v_{gs}) r_o + i_1 R_L'$$

$$v_i = i_1 r_o + g_m r_o v_i + i_1 R_L'$$

$$\frac{v_i}{i_1} = \frac{r_o + R_L'}{1 + g_m r_o} \simeq \frac{1 + R_L'/r_o}{g_m}$$

$$R_i = R_S \parallel \frac{1 + R_L'/r_o}{g_m}$$ → note: this amplifier is not unilateral
input resistance depends on load

To find $R_o$: take off $R_L'$, set $v_i = 0$




note: $v_{gs} = 0$
$R_S$ is shorted

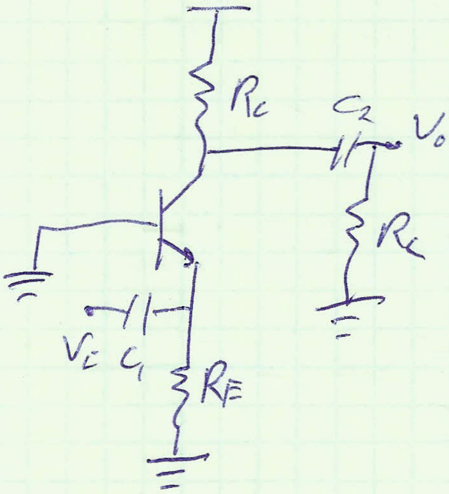
→ $R_o = r_o$

Characteristics:

- Large open-loop gain
- Small input resistance
- Medium output resistance

} Usually used for specialized applications, or in combination with other amplifiers

## Common Base Amplifiers



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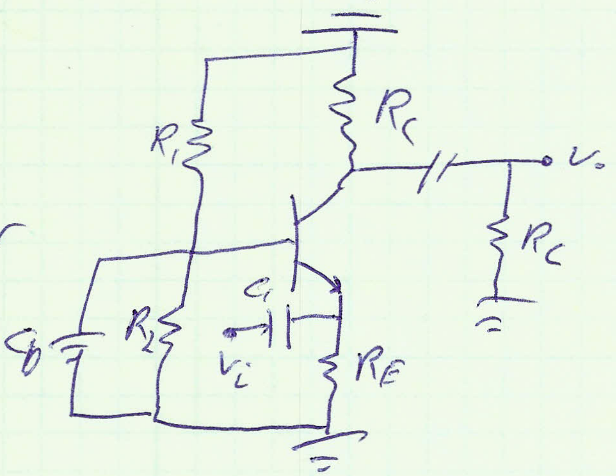

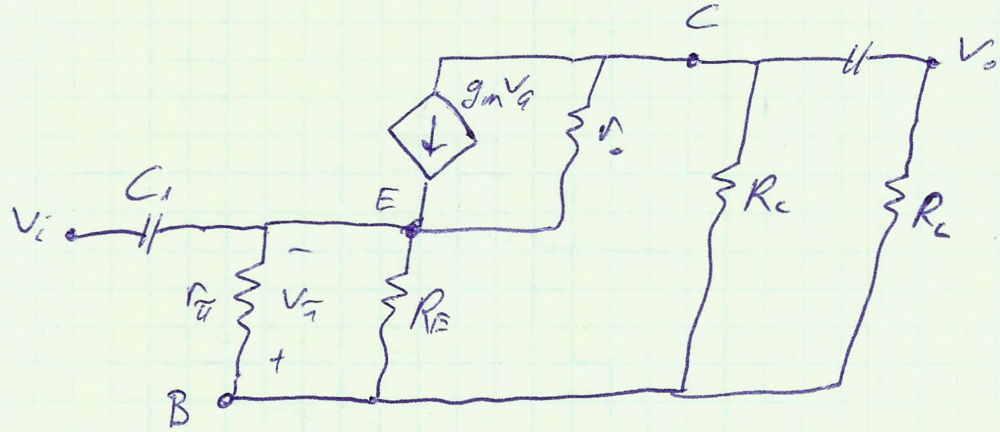

Note that this is identical to small signal model for common gate except that now $r_\pi$ is in parallel with $R_E$

$$A_v = \frac{v_o}{v_i} = g_m (R_L' \| r_o)$$

$$A_{vo} = g_m r_o$$

$$R_i = R_E \| r_\pi \| \frac{1 + R_L'/r_o}{g_m}$$

$$R_o = r_o$$

only change from common gate