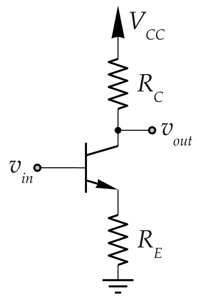
Single Transistor Amplifiers

Common Emitter Amplifier

Reasonable Gain. Adjustable input impedance. Relatively high output impedance. Good inverting voltage amp (If the load is known!)



$$A_{vo} = \frac{-g_m(R_C \parallel r_o)}{1 + g_m(R_C \parallel r_o)R_E/R_C} \overset{\text{large } r_0}{\approx} \frac{-g_m R_C}{1 + g_m R_E} \overset{\text{large } g_m R_E}{\approx} \frac{-R_C}{R_E}$$

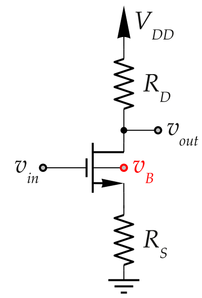
$$A_{is} = \beta$$

$$R_{in} = r_\pi + (\beta + 1)R_E$$

$$R_{out} = R_C \parallel \{r_o + (1 + g_m r_o)(R_E \parallel r_\pi)\}$$

Common Source Amplifier

Reasonable Gain. Adjustable input impedance. Relatively high output impedance. Good inverting voltage amp (If the load is known!)



$$A_{vo} = \frac{-g_m(R_D \parallel r_o)}{1 + g_m(1+\chi)(R_D \parallel r_o)R_S/R_D} \overset{\text{large } r_0}{\approx} \frac{-g_m R_D}{1 + g_m(1+\chi)R_S} \overset{\text{large } g_m R_E}{\approx} \frac{-R_D}{(1+\chi)R_S}$$

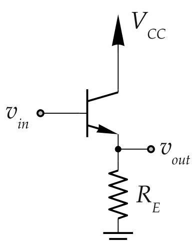
$$A_{is} = \infty$$

$$R_{in} = \infty$$

$$R_{out} = R_D \parallel \{r_o + (1 + g_m(1+\chi)r_0)R_S\}$$

Common Collector Amplifier

Nice voltage buffer: High R_{in} and low R_{out}. "Copies the input voltage to an unknown load".



$$A_{vo} = \frac{R_E \parallel r_o}{r_e + R_E \parallel r_o} \approx 1$$

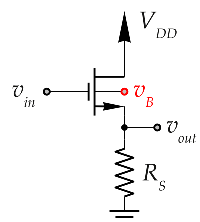
$$A_{is} = \beta + 1$$

$$R_{in} = r_\pi + (\beta + 1)(R_E \parallel r_o)$$

$$R_{out} = r_e \parallel R_E \parallel r_o \approx r_e$$

Common Drain Amplifier

Nice voltage buffer: Infinite R_{in} and low R_{out}. "Copies the input voltage to an unknown load".



$$A_{vo} = \frac{g_m(R_S \parallel r_o)}{1 + g_m(1+\chi)(R_S \parallel r_o)} \approx \frac{1}{1+\chi}$$

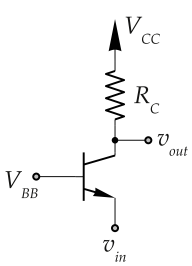
$$A_{is} = \infty$$

$$R_{in} = \infty$$

$$R_{out} = \frac{1}{g_m(1+\chi)} \parallel R_S \parallel r_o \approx \frac{1}{g_m(1+\chi)}$$

Common Base Amplifier

Nice current buffer: Low R_{in} and high R_{out}. "Copies the input current to an unknown load". Also used as a noninverting voltage amp—IF you know the load, and need a low input resistance.



$$A_{vo} = g_m(r_o \parallel R_C)$$

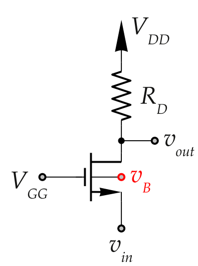
$$A_{is} = \alpha \approx 1$$

$$R_{in} = r_e + \frac{R_C}{g_m r_o} \overset{r_0 \gg R_C}{\approx} r_e$$

$$R_{out} = R_C \parallel r_o$$

Common Gate Amplifier

Nice current buffer: Low R_{in} and high R_{out}. "Copies the input current to an unknown load". Also used as a noninverting voltage amp—*if* you know the load, and need a low input resistance.



$$A_{vo} = g_m(1+\chi)(R_D \parallel r_o)$$

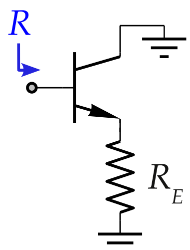
$$A_{is} = 1$$

$$R_{in} = \frac{1}{g_m(1+\chi)} + \frac{R_D}{g_m(1+\chi)r_o} \overset{r_o \gg R_D}{\approx} \frac{1}{g_m(1+\chi)}$$

$$R_{out} = R_D \parallel r_o$$

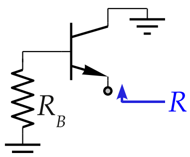
(All expressions assume v_B is constant. If $v_{BS} = 0$, set $\chi = 0$.)

Small-Signal Impedance Measured at Transistor Terminals



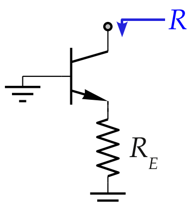
Emitter Impedances seen through the base of a BJT are *increased* by a factor of $\beta + 1$.

$$R \approx r_\pi + (\beta + 1) R_E$$



Base Impedances seen through the emitter of a BJT are *decreased* by a factor of $\beta + 1$.

$$R \approx \frac{r_\pi + R_B}{\beta + 1} = r_e + \frac{R_B}{\beta + 1}$$

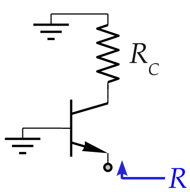


Impedances seen through the collector of a BJT are *increased* by the intrinsic gain of the transistor. Loads attached to the emitter are in parallel with r_π.

$$R = r_0 + (1 + g_m r_0)(R_E \parallel r_\pi)$$

With a base resistor, R_B is added to r_π, and g_m is scaled by $\left(\frac{r_\pi}{r_\pi + R_B}\right)$:

$$R = r_0 + \left(1 + \left(\frac{r_\pi}{r_\pi + R_B}\right) g_m r_0\right)(R_E \parallel (r_\pi + R_B))$$

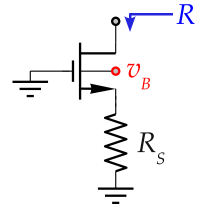


Collector impedances seen through the emitter of a BJT are are *decreased* by the intrinsic gain of the transistor.

$$R = r_\pi \parallel \left(\frac{1}{g_m} \parallel r_0 + \frac{R_C}{1 + g_m r_0}\right)$$
$$\approx r_\pi \parallel \left(\frac{1}{g_m} + \frac{R_C}{g_m r_0}\right)$$
$$\overset{r_0 \gg R_C}{\approx} r_\pi \parallel \frac{1}{g_m} = r_e$$

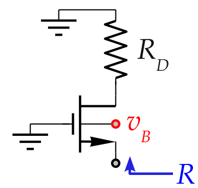
With a base resistor, R_B is added to r_π, and g_m is scaled by $\left(\frac{r_\pi}{r_\pi + R_B}\right)$:

$$R = (r_\pi + R_B) \parallel \left(\frac{1}{\left(\frac{r_\pi}{r_\pi + R_B}\right) g_m} \parallel r_0 + \frac{R_C}{1 + \left(\frac{r_\pi}{r_\pi + R_B}\right) g_m r_0}\right)$$



Impedances seen through the drain of a MOSFET are *increased* by the intrinsic gain of the transistor. Use $g_m' = g_m + g_{mb} = (1 + \chi) g_m$:

$$R = r_0 + (1 + g_m' r_0) R_S$$



Impedances seen through the source of a MOSFET are *reduced* by the intrinsic gain of the transistor. Use $g_m' = g_m + g_{mb} = (1 + \chi) g_m$:

$$R = \frac{1}{g_m'} \parallel r_0 + \frac{R_D}{1 + g_m' r_0}$$
$$\approx \frac{1}{g_m'} + \frac{R_D}{g_m' r_0} \overset{r_0 \gg R_D}{\approx} \frac{1}{g_m'}$$

All expressions assume v_B is constant.
$g_m' = g_m + g_{mb} = g_m(1 + \chi)$
If $v_{BS} = 0$, set $\chi = 0$.