

# BJT Amplifiers

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## 1 AC Parameters

Transconductance:  $g_m = \frac{I_C^{(DC)}}{V_T}$ , tens of  $mA/V$  typical.

Pi resistance:  $r_\pi = \beta \frac{V_T}{I_C^{(DC)}}$ . few  $k\Omega$  typical.

Emitter Resistance:  $r_e = \frac{r_\pi}{\beta+1}$ , tens of  $\Omega$  typical.

Early-Voltage resistance:  $r_0 = \frac{V_A}{I_C^{(DC)}}$ . tens to hundreds of  $k\Omega$  typical.

## 2 Amplifier Characteristics

Voltage gain:  $A_V = \frac{v_{out}^{(ac)}}{v_{in}^{(ac)}}$ .

Input impedance:  $R_{in} = \frac{v_{in}^{(ac)}}{i_{in}^{(ac)}}$ .

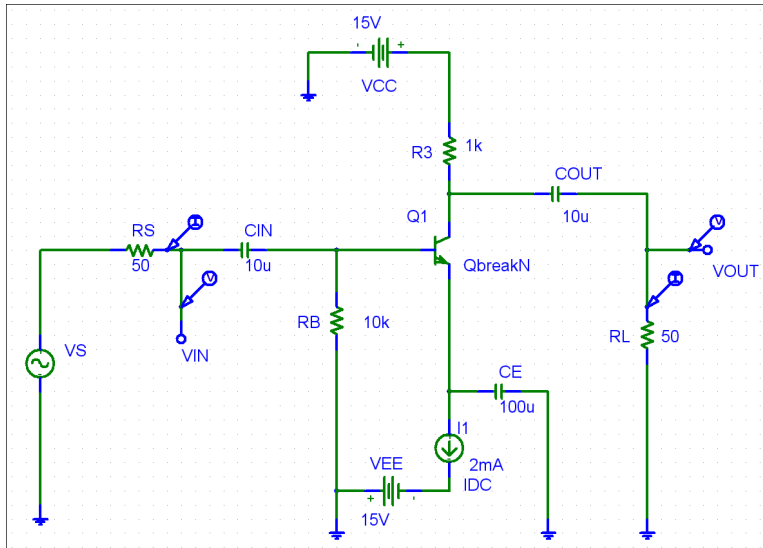
Output impedance:  $R_{out} = \frac{v_{out}^{(ac)}}{i_{out}^{(ac)}}$ .

Open-circuit Voltage gain:  $A_{V_o} = A_V$  with  $R_L/R_{out} \rightarrow \infty$ .

Voltage gain relative to source measured in open-circuit conditions:

$$A_{V_s} = A_V \frac{R_{in}}{R_s + R_{in}}$$

Current gain:  $A_i = \frac{i_{out}^{(ac)}}{i_{in}^{(ac)}}$ .



### Common Emitter Amplifier

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

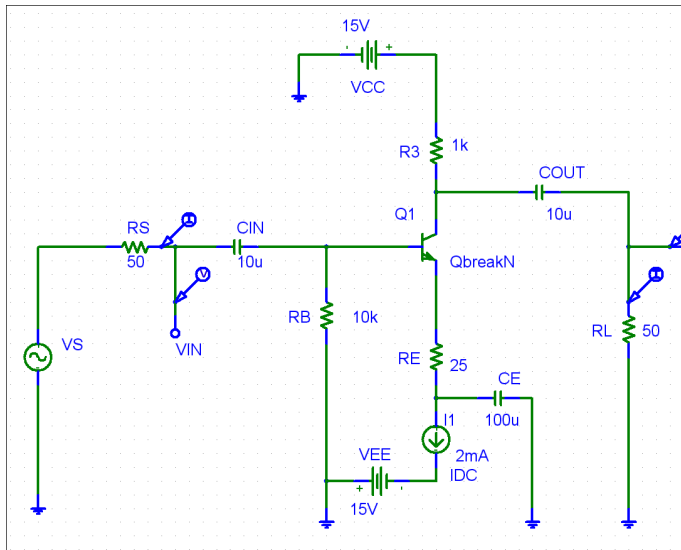
$$R_{out} = R_C \quad (R_C = R_3 \text{ in Figure})$$

$$A_V = -g_m (r_o \parallel R_C \parallel R_L)$$

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

$$A_{V_s} = \frac{R_B \parallel r_{\pi}}{R_B \parallel r_{\pi} + R_s}$$

$$A_i = \frac{R_{in}}{R_L} A_V$$



### Common Emitter Amplifier with $R_E$

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

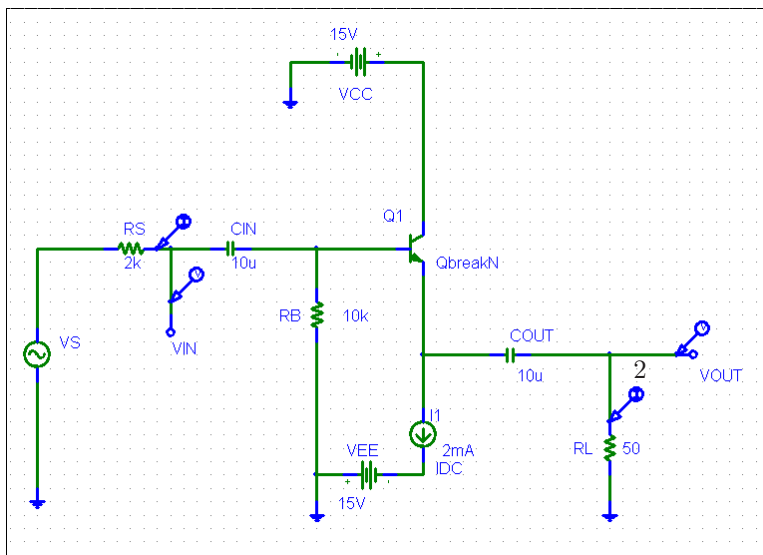
$$R_{out} = r_o \parallel R_C$$

$$A_V = -\alpha \frac{R_C \parallel R_L}{r_e + R_E} \quad \text{where } r_e = \frac{r_{\pi}}{\beta + 1}$$

$$A_{V_o} = -\alpha \frac{R_C}{r_e + R_E}$$

$$A_{V_s} = \frac{\beta (R_C \parallel R_L)}{r_{\pi} + (\beta + 1) R_E R_s}$$

$$A_i = \frac{R_{in}}{R_L} A_V$$



### Common Collector Amplifier

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

$$R_{out} = r_o \parallel \left( r_e + \frac{R_s \parallel R_B}{\beta + 1} \right)$$

$$A_V = \frac{r_o \parallel R_L}{r_o + r_e}$$

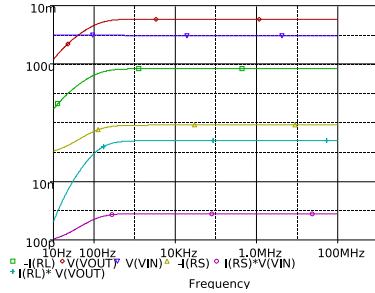
$$A_{V_o} = \frac{r_o}{r_o + r_e}$$

$$A_{V_s} = \frac{R_b}{R_B + R_s} \frac{r_o \parallel R_L}{\frac{R_s \parallel R_B}{\beta + 1} + r_e + (r_o \parallel R_L)}$$

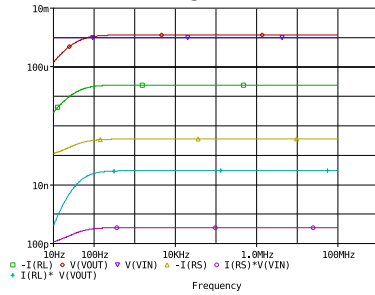
$$A_i = \frac{R_{in}}{R_L} A_V$$

### 3 Applications

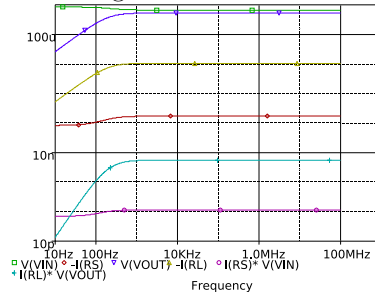
#### Common Emitter Amplifier For Voltage Gain



#### Common Emitter Amplifier with $R_E$ Lower Gain, Higher $R_{in}$



#### Common Collector Amplifier for Voltage Buffer



#### Common Base Amplifier for Current Buffer (Not shown)

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

Want large 1.5k typical

$$R_{out} = R_C$$

Want small 10k typical

$$A_V = -g_m (r_o \parallel R_C \parallel R_L)$$

Want large 100s typical

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

Want large 10's to 100's typical

$$A_{V_s} = \frac{R_B \parallel r_{\pi}}{R_B \parallel r_{\pi} + R_s}$$

$$A_i = \frac{R_{in}}{R_L} A_V$$

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

Want very large 100's k typical

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

Want small 10k typical

$$A_V = -\alpha \frac{R_C \parallel R_L}{r_e + R_E} \text{ where } r_e = \frac{r_{\pi}}{\beta + 1}$$

$$A_{V_o} = -\alpha \frac{R_C}{r_e + R_E}$$

$$A_{V_s} = \frac{\beta (R_C \parallel R_L)}{r_{\pi} + (\beta + 1) R_E R_s}$$

$$A_i = \frac{R_{in}}{R_L} A_V$$

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

Want large  $\beta R_L$  typical

$$R_{out} = r_o \parallel \left( r_e + \frac{R_s \parallel R_B}{\beta + 1} \right)$$

Want small  $R_s / (\beta + 1)$  typical

$$A_V = \frac{r_o \parallel R_L}{r_o \parallel R_L + r_e}$$

Want Unit Gain

$$A_{V_o} = \frac{r_o}{r_o + r_e}$$

$$A_{V_s} = \frac{R_b}{R_B + R_s} \frac{r_o \parallel R_L}{\frac{R_s \parallel R_B}{\beta + 1} + r_e + (r_o \parallel R_L)}$$

$$A_i = \frac{R_{in}}{R_L} A_V$$

$$R_{in} = \frac{1}{g_m} \frac{\beta}{\beta + 1}$$

Want small 25 $\Omega$  typical

$$R_{out} = R_C$$

Want large  $k\Omega$  typical

$$A_V = \frac{\beta}{\beta + 1} \frac{R_C \parallel R_L}{R_s + \frac{1}{g_m}}$$

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

$$A_{V_s} = \frac{R_b}{R_B + R_s} \frac{r_o \parallel R_L}{\frac{R_s \parallel R_B}{\beta + 1} + r_e + (r_o \parallel R_L)}$$

$$A_i = \frac{\beta}{\beta + 1} \frac{R_C}{R_C + R_L}$$

Want Unit Gain