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 Ω 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: $A_{Vo} = A_V$ with $R_L/R_{out} \to \infty$.

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

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

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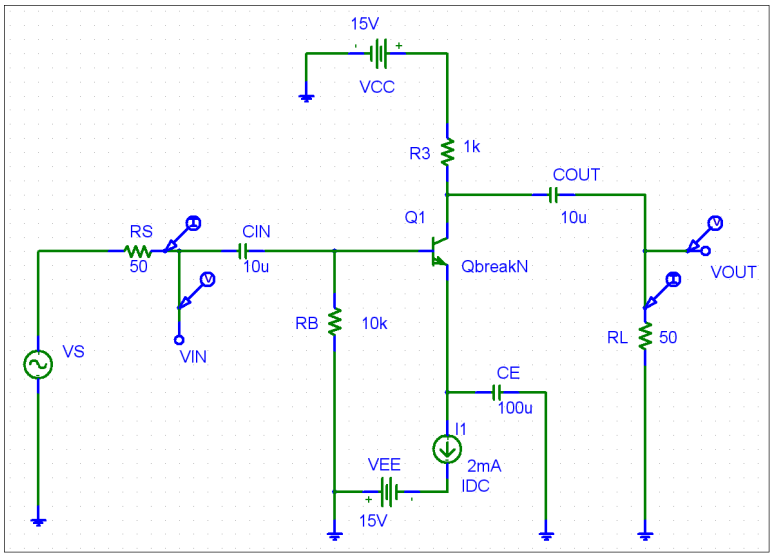
Current gain: $A_i = \frac{i_{out}^{(ac)}}{i_{in}^{(ac)}}$.



Common Emitter Amplifier

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

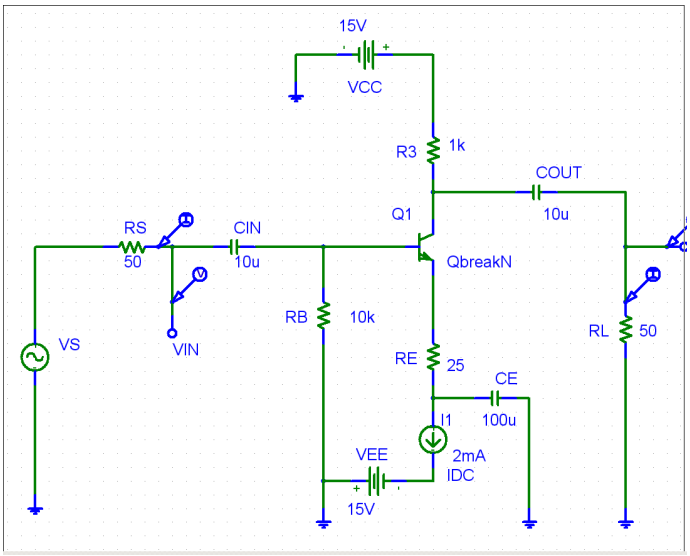
$R_{out} = R_C \quad (R_C = R_3 \text{ in Figure})$

$A_V = -g_m \left(r_0 \parallel R_C \parallel R_L\right)$

$A_{Vo} = -g_m \left(r_0 \parallel R_C\right)$

$A_{Vs} = A_V \frac{R_B \| r_\pi}{R_B \| r_\pi + R_s}$

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



Common Emitter Amplifier with R_E

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

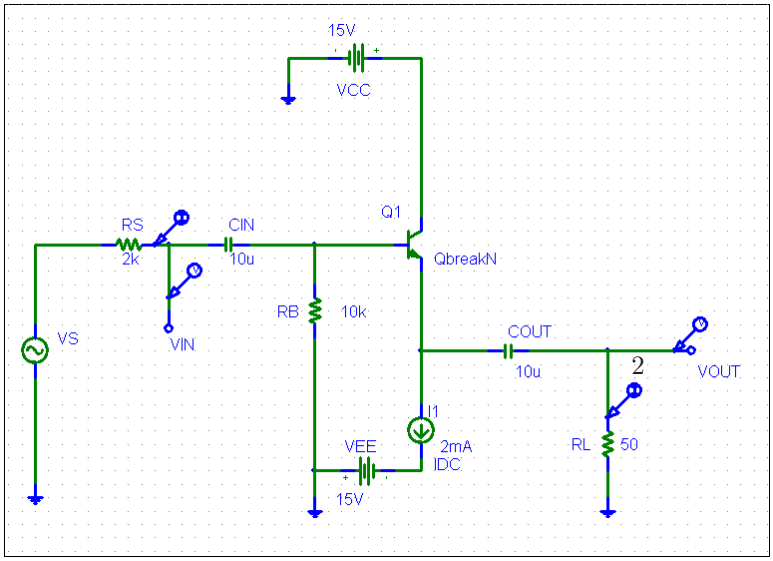
$R_{out} = r_0 \parallel R_C$

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

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

$A_{Vs} = -\frac{\beta (R_C \| R_L)}{r_\pi + (\beta+1) R_E R_s}$

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



Common Collector Amplifier

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

$R_{out} = r_0 \parallel \left(r_e + \frac{R_s \| R_B}{\beta+1}\right)$

$A_V = \frac{r_0 \| R_L}{r_0 \| R_L + r_e}$

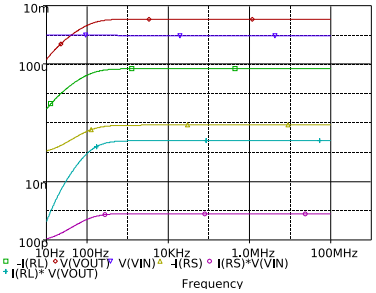
$A_{Vo} = \frac{r_0}{r_0 + r_e} \approx 1$

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

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

3 Applications

Common Emitter Amplifier
For Voltage Gain



$R_{in} = R_B \parallel r_\pi$ Want large 1.5k typical

$R_{out} = R_C$ Want small 10k typical

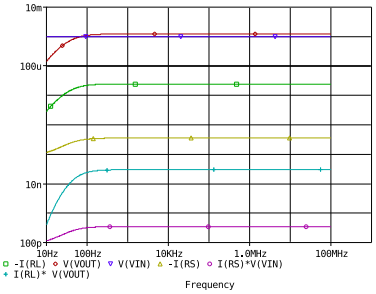
$A_V = -g_m (r_0 \parallel R_C \parallel R_L)$ Want large 100s typical

$A_{Vo} = -g_m (r_0 \parallel R_C)$ Want large 10's to 100's typical

$A_{Vs} = A_V \frac{R_B \| r_\pi}{R_B \| r_\pi + R_s}$

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

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



$R_{in} = R_B \parallel [r_\pi + (\beta + 1) R_E]$ Want very large 100's k typical

$R_{out} = r_0 \parallel R_C \parallel r_0$ Want small 10k typical

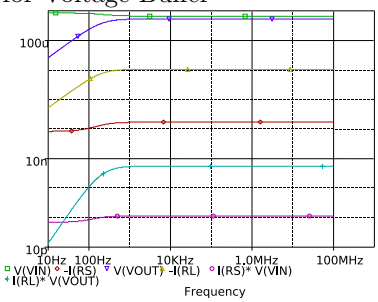
$A_V = -\alpha \frac{R_C \| R_L}{r_e + R_E}$ where $r_e = \frac{r_\pi}{\beta+1}$ Few to 10s Typical

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

$A_{Vs} = -\frac{\beta (R_C \| R_L)}{r_\pi + (\beta+1) R_E R_s}$

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

Common Collector Amplifier
for Voltage Buffer



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

$R_{out} = r_0 \parallel \left(r_e + \frac{R_s \| R_B}{\beta+1} \right)$ Want small $R_s/(\beta + 1)$ typical

$A_V = \frac{r_0 \| R_L}{r_0 \| R_L + r_e}$ Want Unit Gain

$A_{Vo} = \frac{r_0}{r_0 + r_e}$

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

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

Common Base Amplifier
for Current Buffer
(Not shown)

$R_{in} = \frac{1}{g_m} \frac{\beta}{\beta+1}$ Want small 25Ω typical

$R_{out} = R_C$ Want large $k\Omega$ typical

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

$A_{Vo} = -g_m (r_0 \parallel R_C)$

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

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