Common-Emitter Amplifier Frequency Response Example

$R_P(x,y) := \frac{x \cdot y}{x+y}$ Function for calculating parallel resistors.

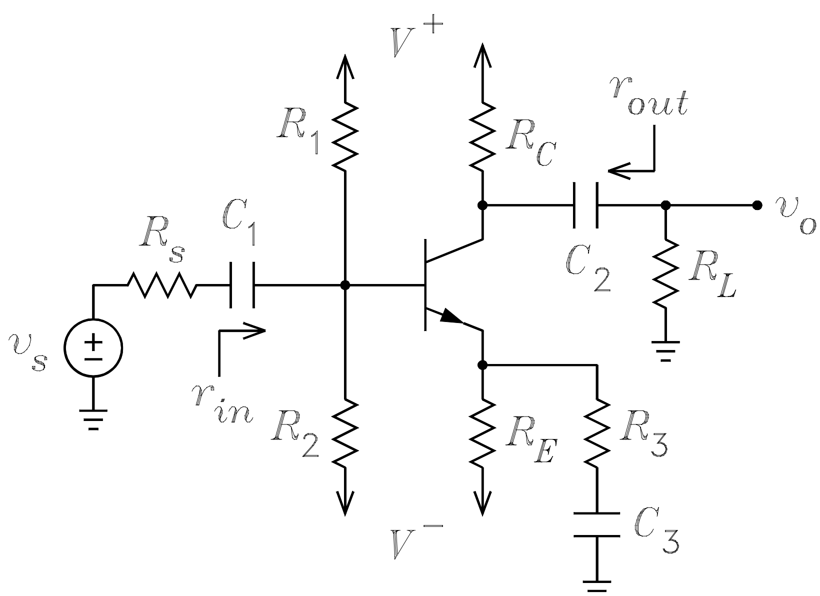
$R_1 := 100000$ $R_2 := 120000$ $R_C := 4300$ $R_E := 5600$ $R_S := 5000$ $R_L := 10000$

$V_p := 15$ $V_m := -15$ $V_{BE} := 0.65$ $V_T := 0.025$ $\beta := 99$ $\alpha := 0.99$

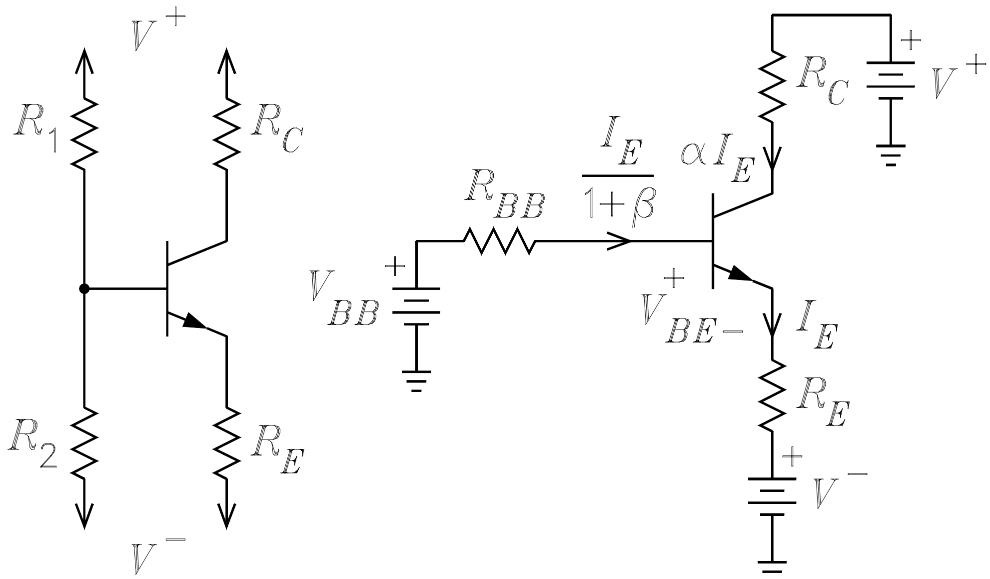
$r_x := 20$ $r_0 := 50000$ $R_3 := 100$

$v_s := 1$ With $v_s = 1$, the voltage gain is equal to v_o.

$c_\mu := 15 \cdot 10^{-12}$ $c_\pi := 75 \cdot 10^{-12}$ $C_1 := 0.2 \cdot 10^{-6}$ $C_2 := 5 \cdot 10^{-6}$ $C_3 := 100 \cdot 10^{-6}$



DC Bias Solution



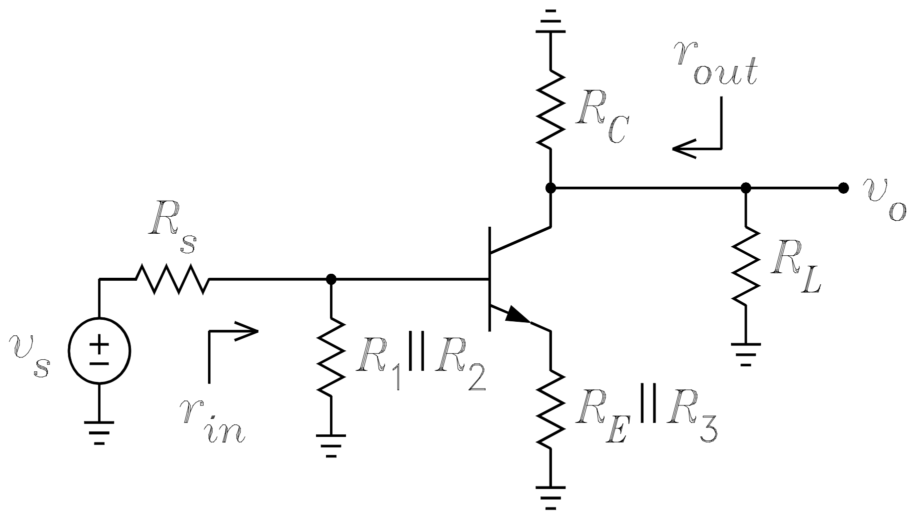
$V_{BB} := \frac{V_p \cdot R_2 + V_m \cdot R_1}{R_1 + R_2}$ $V_{BB} = 1.3636$ $R_{BB} := R_P(R_1, R_2)$ $R_{BB} = 5.4545 \cdot 10^4$

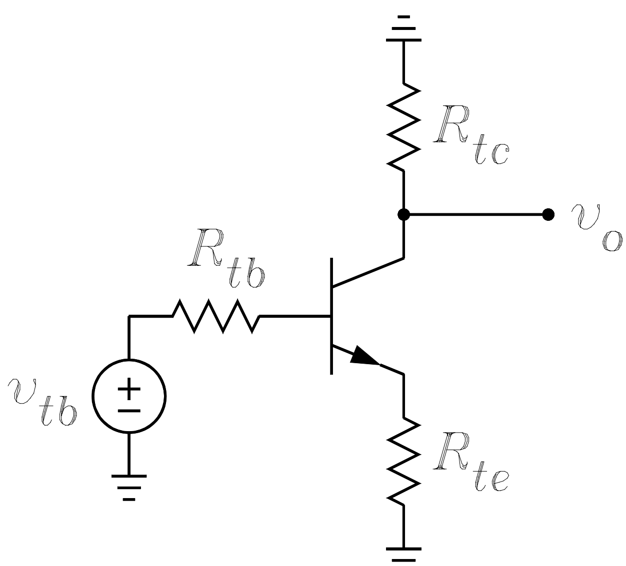
$I_E := \frac{V_{BB} - V_{BE} - V_m}{\frac{R_{BB}}{1+\beta} + R_E}$ $I_E = 2.557 \cdot 10^{-3}$ $V_C := V_p - \alpha \cdot I_E \cdot R_C$ $V_C = 4.1151$

$V_B := V_{BE} + I_E \cdot R_E + V_m$ $V_B = -0.0311$ $V_C - V_B = 4.1461$ Thus active mode.

AC Solution

$r_e := \frac{V_T}{I_E}$ $r_e = 9.7773$ $g_m := \frac{\alpha \cdot I_E}{V_T}$ $g_m = 0.1013$ $r_\pi := \frac{\beta \cdot V_T}{\alpha \cdot I_E}$ $r_\pi = 977.7264$

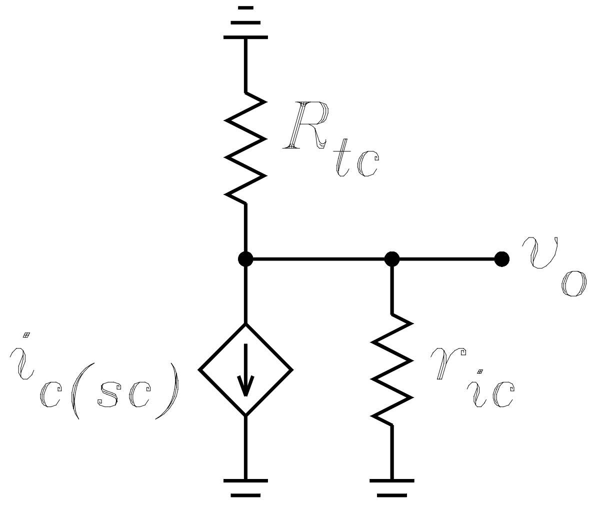




$v_{tb} := v_s \cdot \frac{R_P(R_1, R_2)}{R_S + R_P(R_1, R_2)}$ $\quad v_{tb} = 0.916$ $\quad R_{tb} := R_P(R_S, R_P(R_1, R_2))$ $\quad R_{tb} = 4.5802 \cdot 10^3$

$R_{te} := R_P(R_E, R_3)$ $\quad R_{te} = 98.2456$ $\quad r'_e := \frac{R_{tb} + r_x}{1 + \beta} + r_e$ $\quad r'_e = 55.7788$

$R_{tc} := R_P(R_C, R_L)$ $\quad R_{tc} = 3.007 \cdot 10^3$



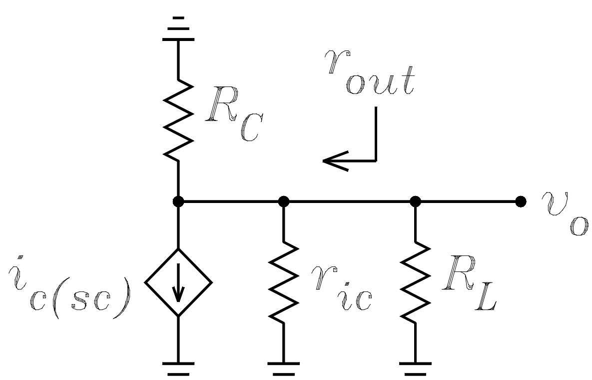
$$r_{ic} := \frac{r_0 + R_P(r'_e, R_{te})}{1 - \frac{\alpha \cdot R_{te}}{r'_e + R_{te}}}$$

$$r_{ic} = 1.3577 \cdot 10^5$$

$$v_o := v_s \cdot \frac{\alpha}{\frac{R_{tb} + r_x}{1+\beta} + r_e + R_{te}} \cdot -R_P(R_C, R_P(r_{ic}, R_L)) \qquad v_o = -18.9088$$

$A_v := v_o \qquad A_v = -18.9088$ This is the midband voltage gain.

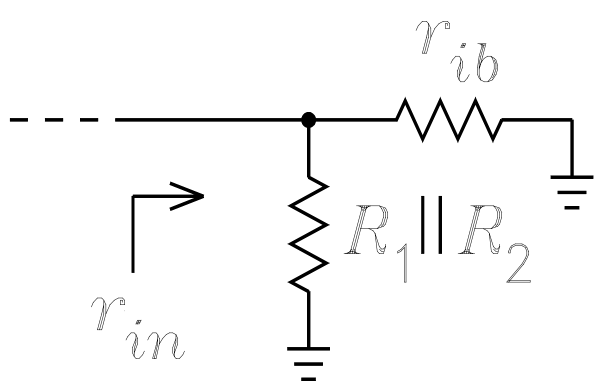
Circuit for r_{out}.



$$r_{out} := R_P(R_C, r_{ic})$$

$$r_{out} = 4.168 \cdot 10^3$$

Circuit for r_{in}.



$r_{ib} := r_x + r_\pi + (1 + \beta) \cdot R_{te}$

$r_{ib} = 1.0822 \bullet 10^4$

$r_{in} := R_P(r_{ib}, R_P(R_1, R_2))$

$r_{in} = 9.0305 \bullet 10^3$

Time constant for C_1

$\tau_1 := (R_S + r_{in}) \cdot C_1$ $\quad \tau_1 = 2.8061 \bullet 10^{-3}$ $\quad f_1 := \frac{1}{2 \cdot \pi \cdot \tau_1}$ $\quad f_1 = 56.7173$

Time constant for C_2

$\tau_2 := (r_{out} + R_L) \cdot C_2$ $\quad \tau_2 = 0.0708$ $\quad f_2 := \frac{1}{2 \cdot \pi \cdot \tau_2}$ $\quad f_2 = 2.2467$

Time constants for C_3 (To simplify the calculation, neglect the effect of r_0).

$\tau_{3p} := (R_P(R_E, r'_e) + R_3) \cdot C_3$ $\quad \tau_{3p} = 0.0155$ $\quad f_{3p} := \frac{1}{2 \cdot \pi \cdot \tau_{3p}}$ $\quad f_{3p} = 10.2529$

$\tau_{3z} := (R_E + R_3) \cdot C_3$ $\quad \tau_{3z} = 0.57$ $\quad f_{3z} := \frac{1}{2 \cdot \pi \cdot \tau_{3z}}$ $\quad f_{3z} = 0.2792$

Approximate lower cutoff frequency

$f_L := \sqrt{f_1^2 + f_2^2 + f_{3p}^2 - 2 \cdot f_{3z}^2}$ $\quad f_L = 57.679$

Calculation of $K = v_o / v'_b$ for the Miller Theorem.

$v'_b := 1$ Thus $K = v_o$

$$K := -\frac{\alpha}{r_e + R_{te}} \cdot R_P\left(R_C, R_P\left(r_{ic}, R_L\right)\right) \qquad K = -26.9612$$

Time constants for c_μ

$$c_{\mu b} := (1 - K) \cdot c_\mu \qquad c_{\mu b} = 4.1942 \bullet 10^{-10}$$

$$\tau_{\mu b} := R_P\left(R_{tb} + r_x, r_{ib} - r_x\right) \cdot c_{\mu b} \qquad \tau_{\mu b} = 1.3531 \bullet 10^{-6}$$

$$c_{\mu c} := c_\mu \qquad c_{\mu c} = 1.5 \bullet 10^{-11} \qquad \tau_{\mu c} := \left(R_P\left(r_{out}, R_L\right)\right) \cdot c_{\mu c} \qquad \tau_{\mu c} = 4.4128 \bullet 10^{-8}$$

$$\tau_\mu := \tau_{\mu b} + \tau_{\mu c} \qquad \tau_\mu = 1.3973 \bullet 10^{-6} \qquad f_\mu := \frac{1}{2 \cdot \pi \cdot \tau_\mu} \qquad f_\mu = 1.139 \bullet 10^{5}$$

Time constants for c_π. (To simplify the calculation, neglect the effect of r_0).

$$\tau_\pi := \frac{R_{tb} + r_x + R_{te}}{R_{tb} + r_x + r_\pi + (1 + \beta) \cdot R_{te}} \cdot r_\pi \cdot c_\pi \qquad \tau_\pi = 2.2369 \bullet 10^{-8}$$

$$f_\pi := \frac{1}{2 \cdot \pi \cdot \tau_\pi} \qquad f_\pi = 7.1151 \bullet 10^{6}$$

Approximate upper cutoff frequency

$$f_H := \left(\sqrt{\frac{1}{f_\mu^{\,2}} + \frac{1}{f_\pi^{\,2}}}\right)^{-1} \qquad f_H = 1.1389 \bullet 10^{5}$$