Frequency Response

(Part 2)

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The Time Constant Method

- It is an approximate method to calculate ω_L and ω_H
- Works well for most amplifiers
- Assumes that all the poles are real, that there is a dominant pole and no dominant zero
- No poles and zeros calculations required
- Very suitable for deriving design formulas

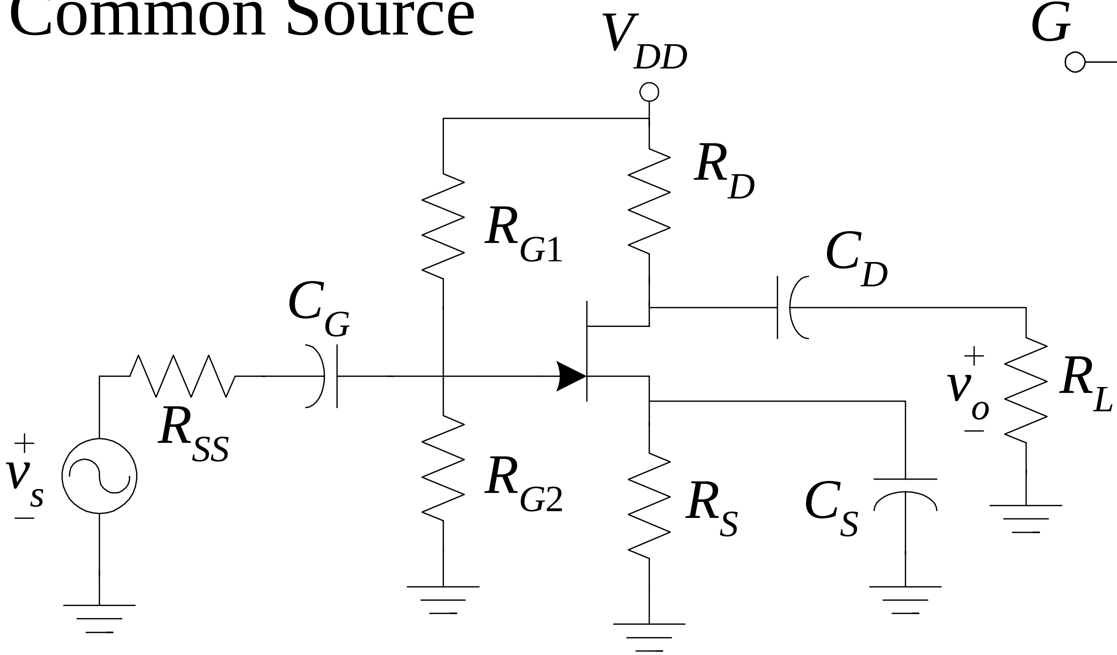
The Short-Circuit Time Constant Method (LF)

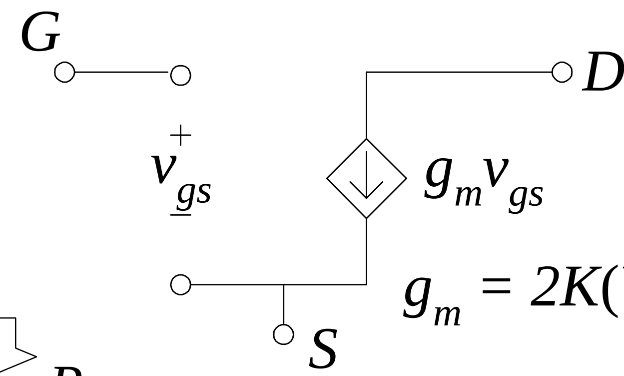
1) Replace the amplifier by its low frequency model
2) Calculate the resistance R_i in parallel with the capacitor C_i, considering all the remaining capacitors as short circuits
3) Repeat step 2) for each capacitor (i = 1, 2, ..., n_L)
4) Calculate ω_L using

$$\omega_L \approx \sum_{i=1}^{n_L} \frac{1}{R_i C_i}$$

Low-Frequency Response of FET Amplifiers

Common Source





$$g_m = 2K(V_{GS} - V_t)$$

$$R_{C_G} = R_{SS} + R_{G1} \| R_{G2}$$

$$R_{C_S} = R_S \| \frac{1}{g_m}$$

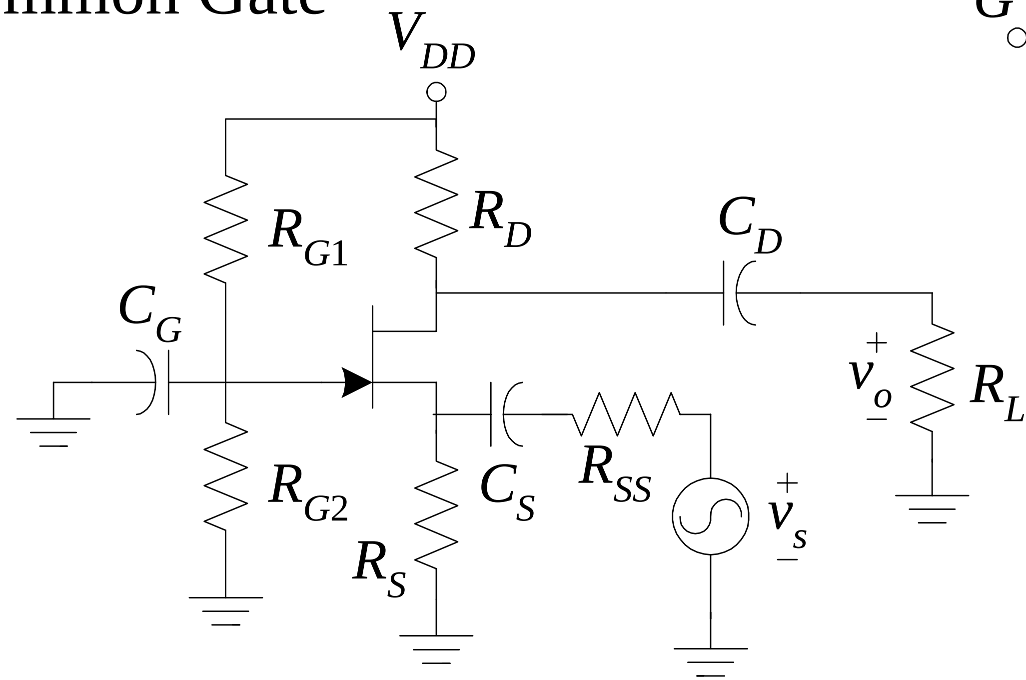
$$R_{C_D} = R_L + R_D$$

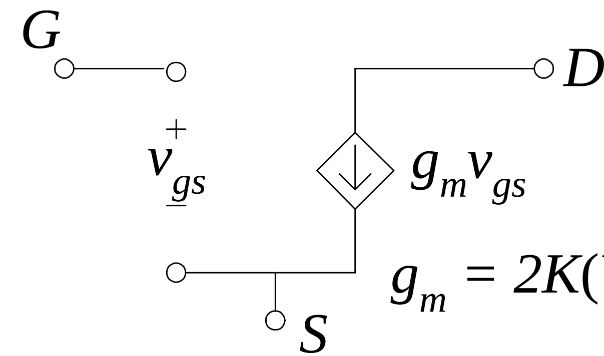
$$\omega_L \approx \frac{1}{R_{C_G} C_G} + \frac{1}{R_{C_S} C_S} + \frac{1}{R_{C_D} C_D}$$

usually $1/(R_{C_S} C_S)$ is the dominant pole

Low-Frequency Response of FET Amplifiers

Common Gate





$$g_m = 2K(V_{GS} - V_t)$$

$$R_{C_G} = R_{G1} \| R_{G2}$$

$$R_{C_S} = R_{SS} + (R_S \| \frac{1}{g_m})$$

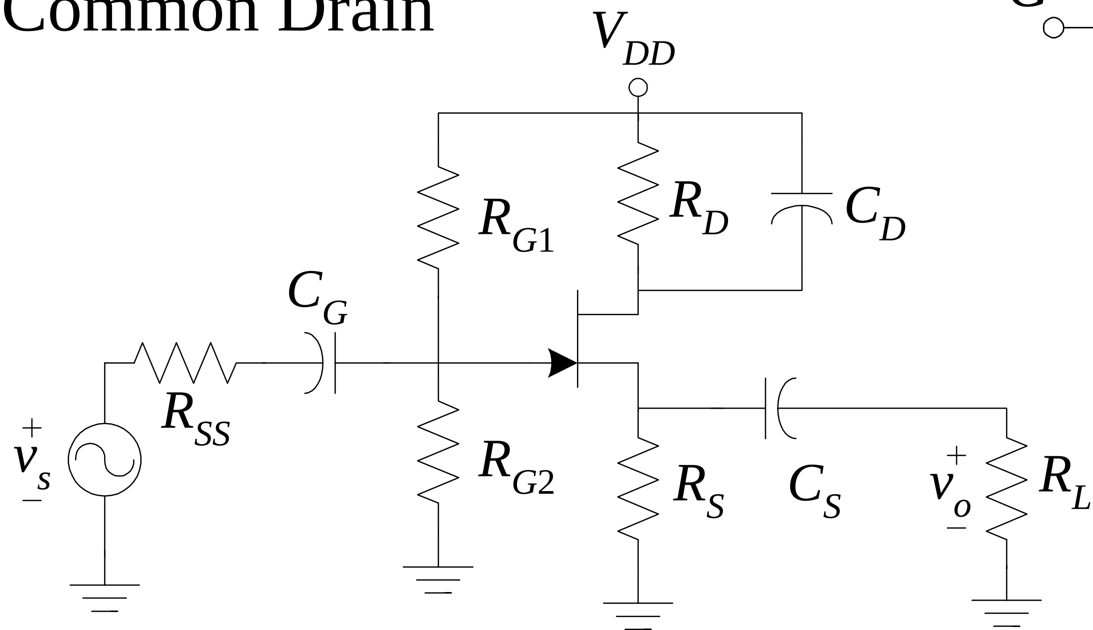
$$R_{C_D} = R_D + R_L$$

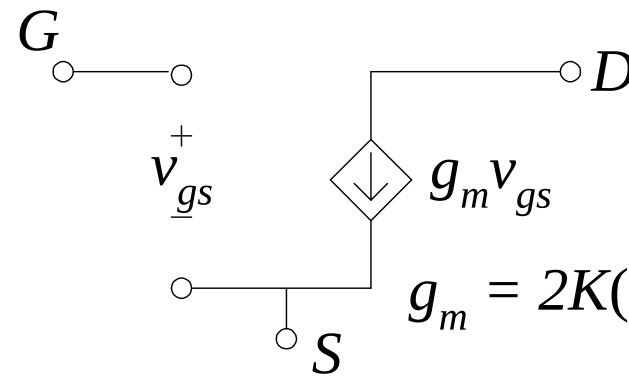
$$\omega_L \approx \frac{1}{R_{C_G} C_G} + \frac{1}{R_{C_S} C_S} + \frac{1}{R_{C_D} C_D}$$

usually $1/(R_{C_S} C_S)$ is the dominant pole

Low-Frequency Response of FET Amplifiers

Common Drain





$$g_m = 2K(V_{GS} - V_t)$$

$$R_{C_G} = R_{SS} + R_{G1} \parallel R_{G2}$$

$$R_{C_S} = (R_S \parallel \frac{1}{g_m}) + R_L$$

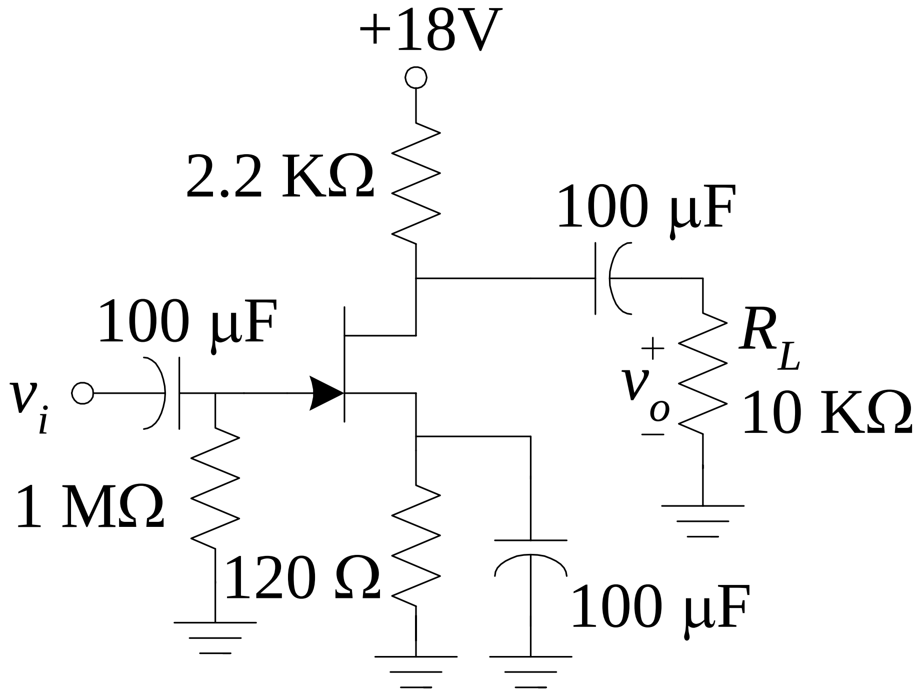
$$R_{C_D} = R_D$$

$$\omega_L \approx \frac{1}{R_{C_G} C_G} + \frac{1}{R_{C_S} C_S} + \frac{1}{R_{C_D} C_D}$$

usually $1/(R_{C_S} C_S)$ is the dominant pole

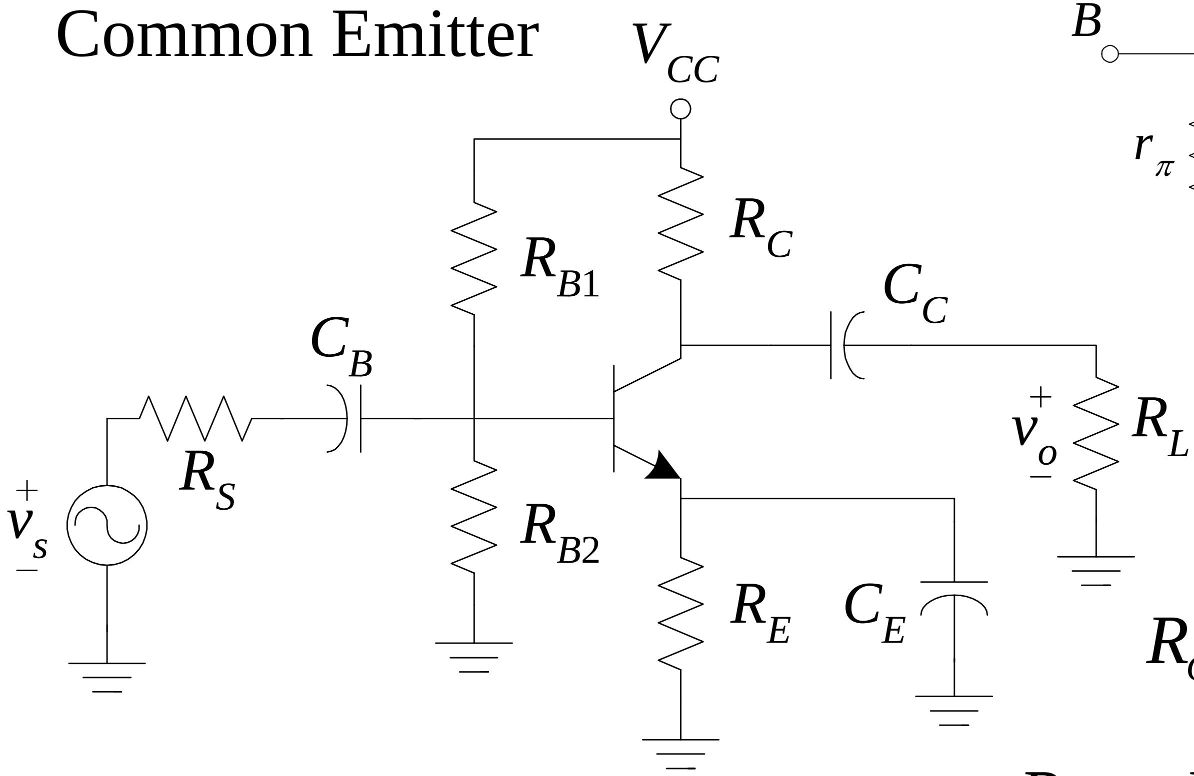
Example

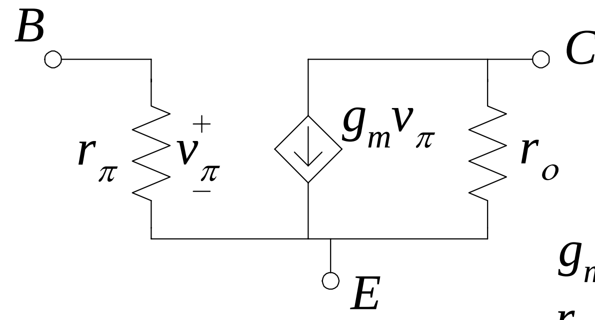
Calculate the cutoff low-frequency for the following JFET amplifier (assume V_P = –3 V, I_{DSS} = 7 mA)



Low-Frequency Response of BJT Amplifiers

Common Emitter





$$g_m = I_C/V_T$$
$$r_\pi = \beta/g_m$$
$$r_o = V_A/I_C$$

$$R_{C_B} = R_S + (R_{B1} \| R_{B2} \| r_\pi)$$

$$R_{C_E} = R_E \| \frac{r_\pi + (R_S \| R_{B1} \| R_{B2})}{\beta + 1}$$

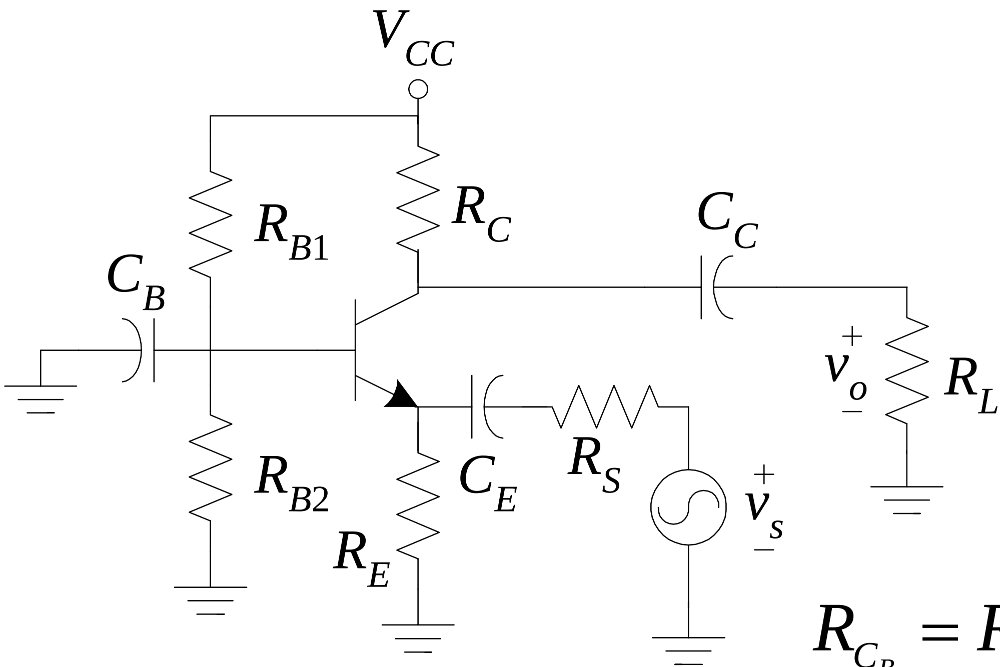
$$R_{C_C} = R_L + (R_C \| r_o)$$

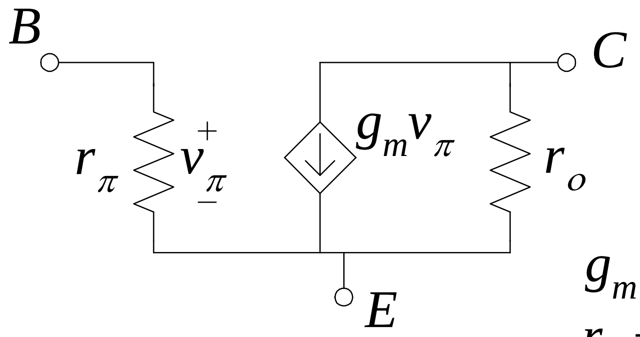
$$\omega_L \approx \frac{1}{R_{C_B} C_B} + \frac{1}{R_{C_E} C_E} + \frac{1}{R_{C_C} C_C}$$

usually $1/(R_{C_E} C_E)$ is the dominant pole

Low-Frequency Response of BJT Amplifiers

Common Base





$$g_m = I_C/V_T$$
$$r_\pi = \beta/g_m$$
$$r_o = V_A/I_C$$

$$R_{C_E} = R_S + R_E \parallel r_\pi \parallel 1/g_m$$

$$R_{C_B} = R_{B1} \parallel R_{B2} \parallel [r_\pi + (1+\beta)(R_E \parallel R_S)]$$

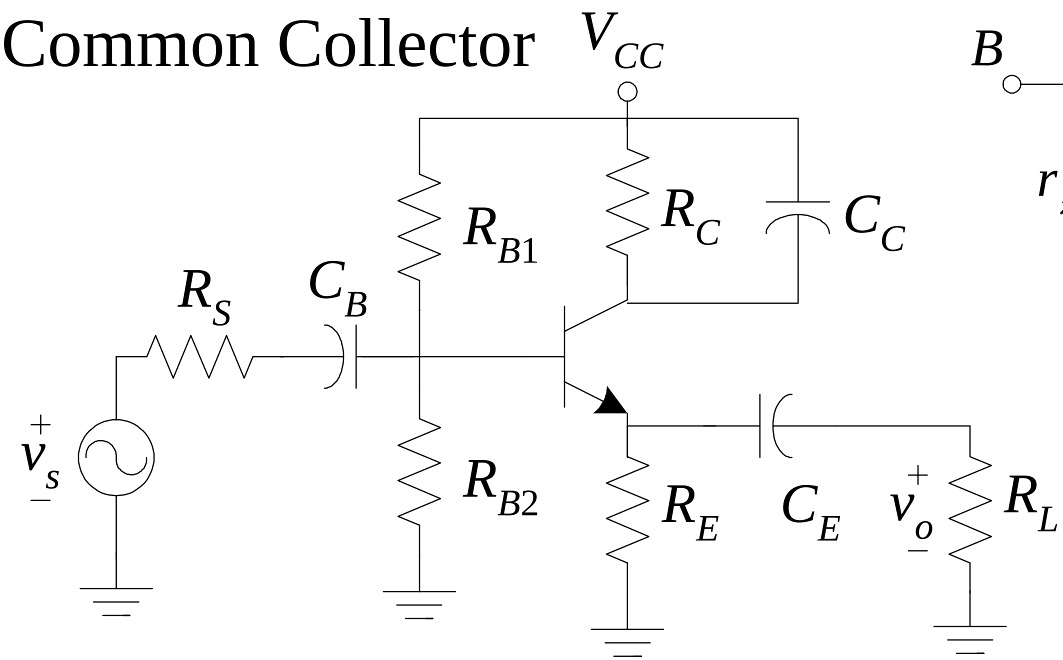
$$R_{C_C} = R_L + (R_C \parallel r_o)$$

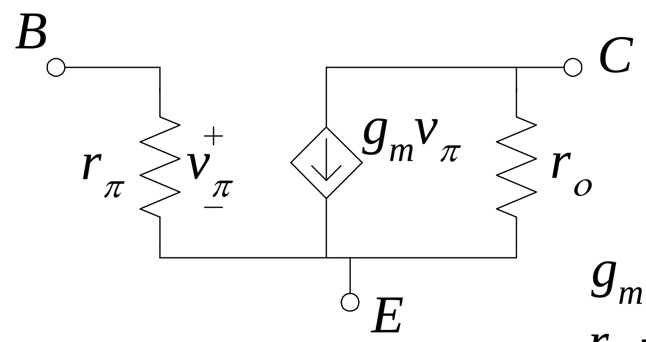
$$\omega_L \approx \frac{1}{R_{C_B} C_B} + \frac{1}{R_{C_E} C_E} + \frac{1}{R_{C_C} C_C}$$

usually $1/(R_{C_E} C_E)$ is the dominant pole

Low-Frequency Response of BJT Amplifiers

Common Collector





$$g_m = I_C / V_T$$
$$r_\pi = \beta / g_m$$
$$r_o = V_A / I_C$$

$$R_{C_C} = R_C \,\|\, [r_o + (R_E \,\|\, R_L)]$$

$$R_{C_E} = R_L + R_E \,\|\, \frac{r_\pi + (R_S \,\|\, R_{B1} \,\|\, R_{B2})}{\beta + 1}$$

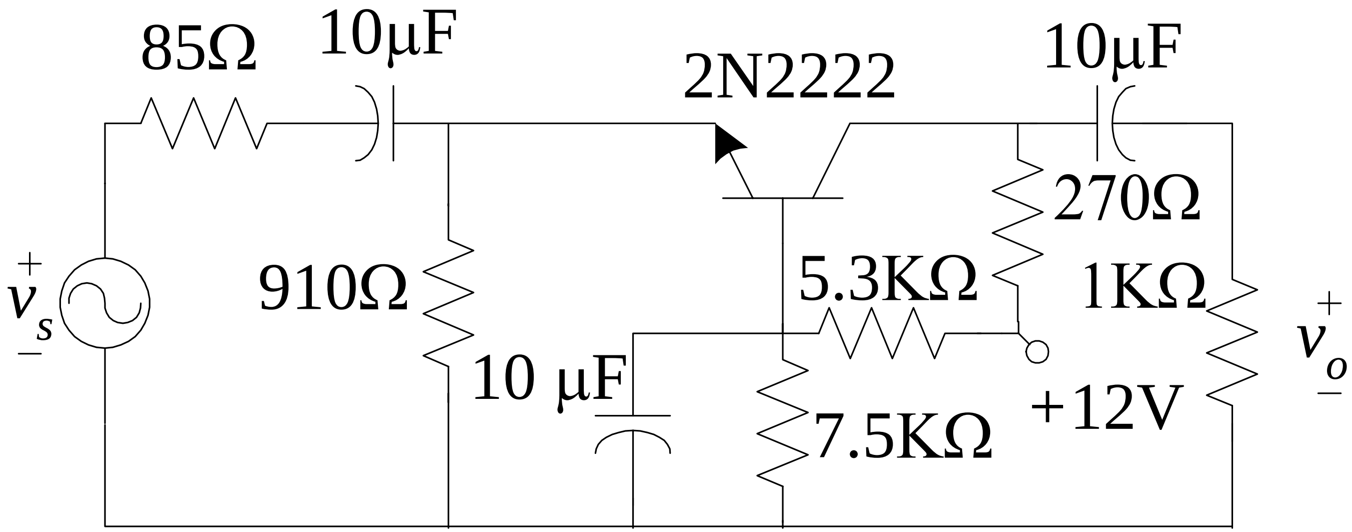
$$R_{C_B} = R_S + R_{B1} \,\|\, R_{B2} \,\|\, [r_\pi + (1+\beta)(R_E \,\|\, R_L)]$$

$$\omega_L \approx \frac{1}{R_{C_B} C_B} + \frac{1}{R_{C_E} C_E} + \frac{1}{R_{C_C} C_C}$$

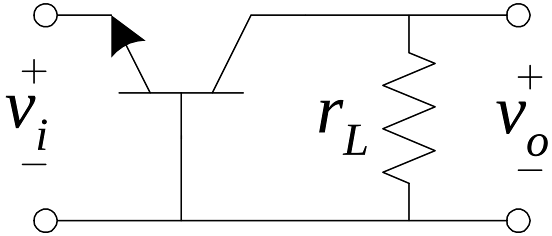
usually $1/(R_{C_E} C_E)$ is the dominant pole

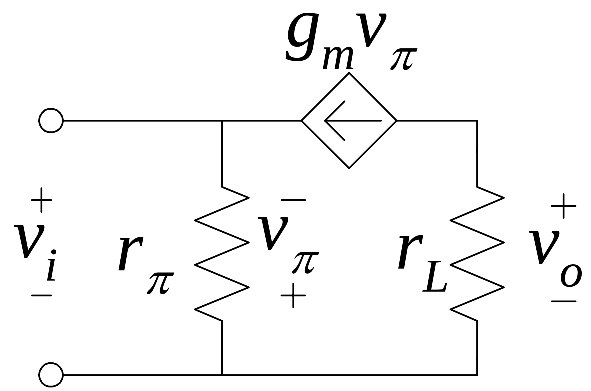
Example

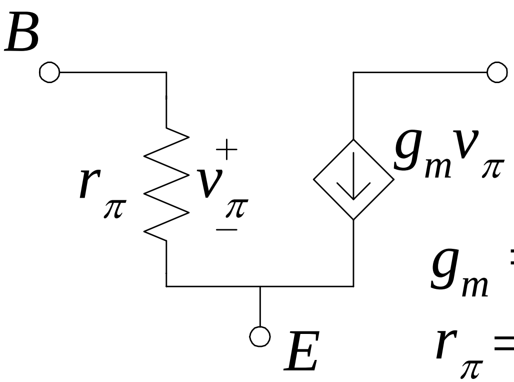
Calculate the cutoff low-frequency for the following BJT amplifier



Base Común (repaso)







$$g_m = I_C / V_T$$

$$r_\pi = \beta / g_m$$

$$v_o = -g_m v_\pi r_L \qquad v_i = -v_\pi$$

$$A_V = \frac{v_o}{v_i} = g_m r_L$$

$$Z_{in} = r_\pi \parallel \frac{v_\pi}{g_m v_\pi} = r_\pi \parallel \frac{1}{g_m} \approx \frac{1}{g_m}$$

Assignment

Solve problems 7.29 and 7.31 from the textbook