

Analog & Digital Electronics

Course No: PH-218

Lec-12: Frequency Response of BJT Amplifiers

Course Instructors:

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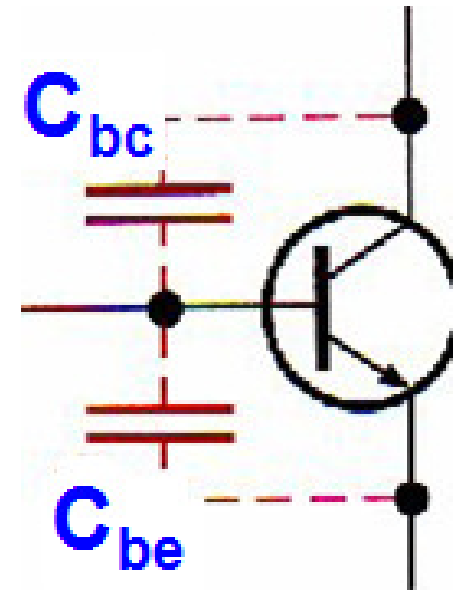


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High frequency Response of CE Amplifier

➤ At high frequencies, internal transistor junction capacitances do come into play, reducing an amplifier's gain and introducing phase shift as the signal frequency increases.

In BJT, C_{be} is the B-E junction capacitance, and C_{bc} is the B-C junction capacitance. (output to input capacitance)

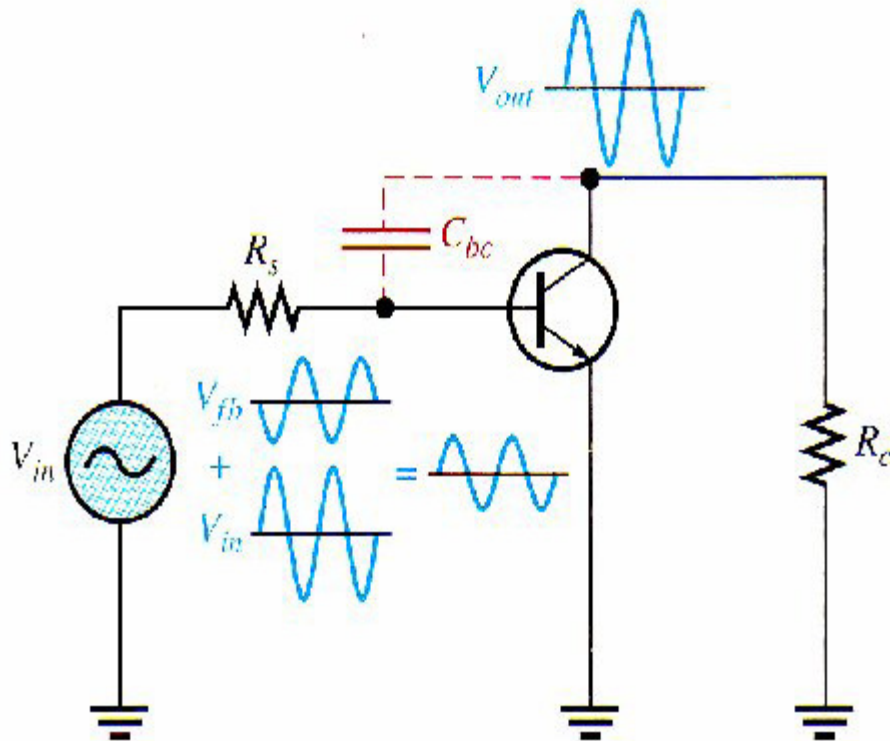
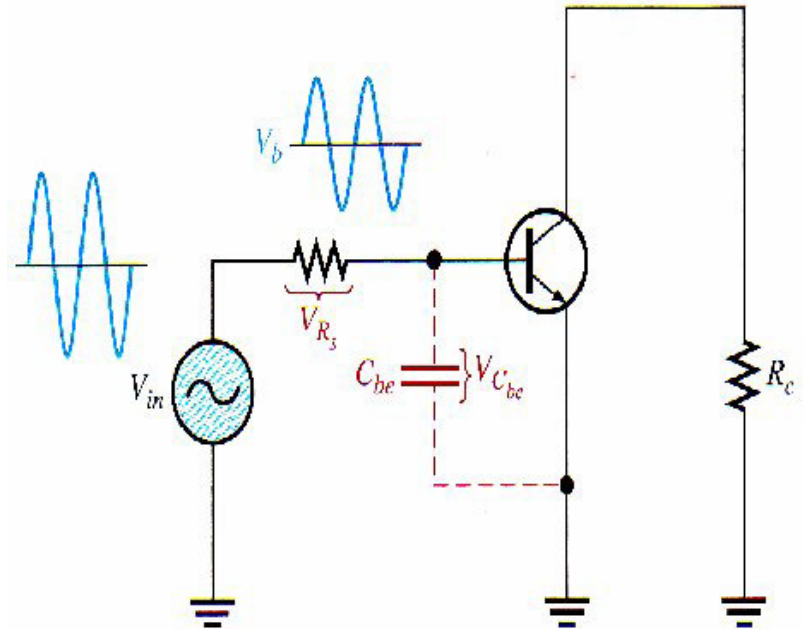


➤ At lower frequencies, the internal capacitances have a very high reactance because of their low capacitance value (usually only a few pf) and the low frequency value. Therefore, they look like opens and have no effect on the transistor's performance.

➤ As the frequency goes up, the internal capacitive reactance's go down, and at some point they begin to have a significant effect on the transistor's gain.

High frequency Response of CE Amplifier

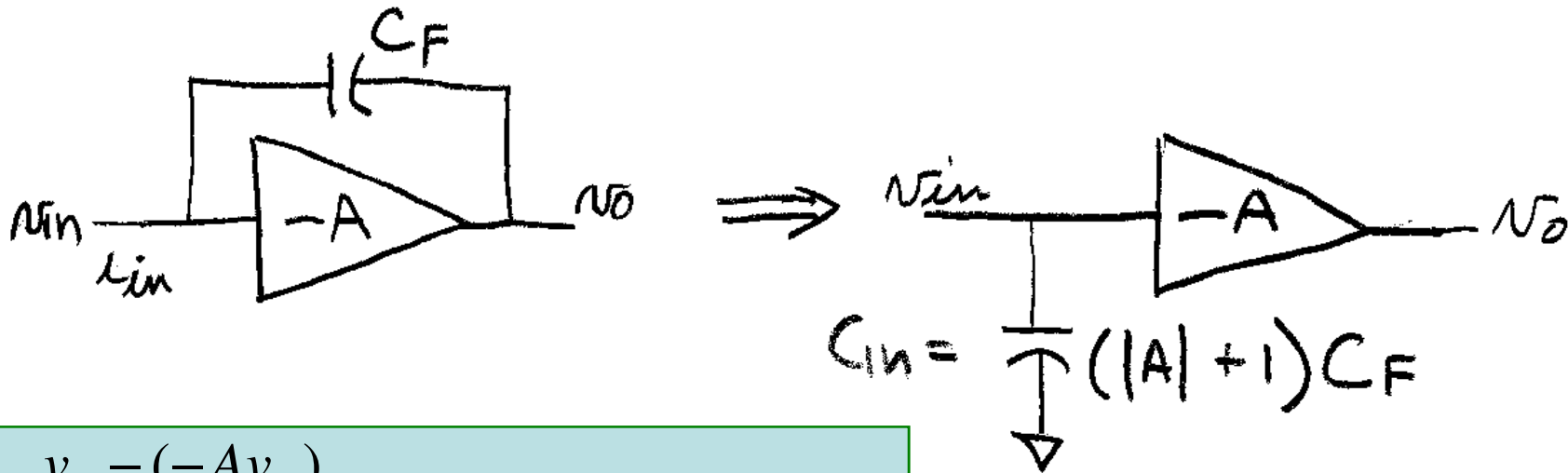
➤ When the reactance of C_{be} becomes small enough, a significant amount of the signal voltage is lost due to a voltage-divider effect of the source resistance and the reactance of C_{be} .



➤ When the reactance of C_{bc} becomes small enough, a significant amount of output signal voltage is fed back out of phase with the input (negative feedback), thus effectively reducing the voltage gain.

Millers Theorem

The Miller effect occurs only in inverting amplifiers –it is the inverting gain that magnifies the feedback capacitance.



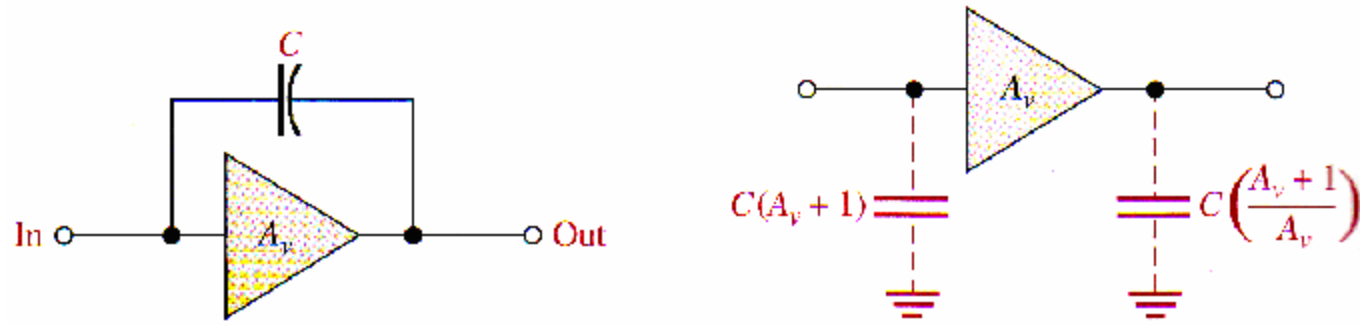
$$i_{in} = \frac{v_{in} - (-Av_{in})}{X_C} = v_{in} (1 + A) \times 2\pi \times f \times C_F$$

$$Z_{in} = \frac{v_{in}}{i_{in}} = \frac{1}{(1 + A) \times 2\pi \times f \times C_F} = \frac{1}{2\pi \times f \times C_{in}}$$

$$C_{in} = (1 + A) \times C_F$$

Here C_F represents C_{bc}

High frequency Response of CE Amp.: Millers Theorem



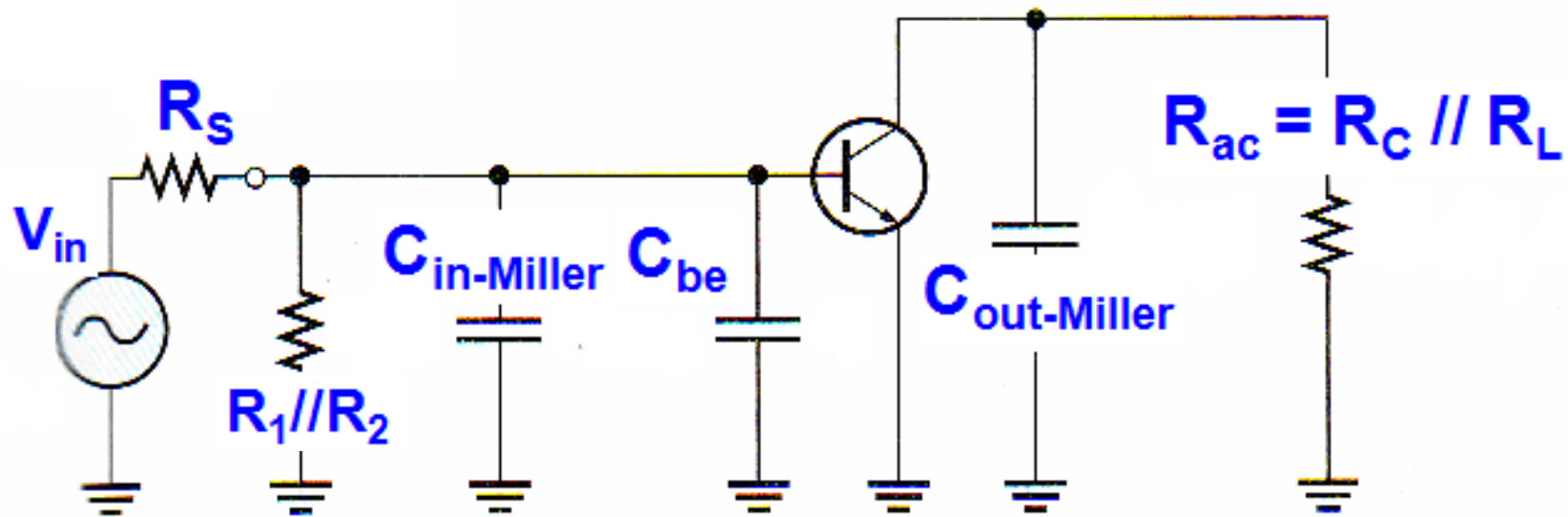
- Miller's theorem is used to simplify the analysis of inverting amplifiers at high-frequencies where the internal transistor capacitances are important. A_v is the voltage gain of the amplifier at midrange frequencies, and C represents C_{bc}

Miller theorems state that C effectively appears as a capacitance from input to ground and can be expressed as follows: $C_{in}(Miller) = C(A_v + 1)$

Miller's theorems also state that C effectively appears as a capacitance from output to ground and can be expressed: $C_{out}(Miller) = C(A_v + 1)/A_v$

- This indicates that if the voltage gain is 10 or greater C_{out} (Miller) is approximately equal to C_{bc} because $(A_v + 1) / A_v$ is equal to 1

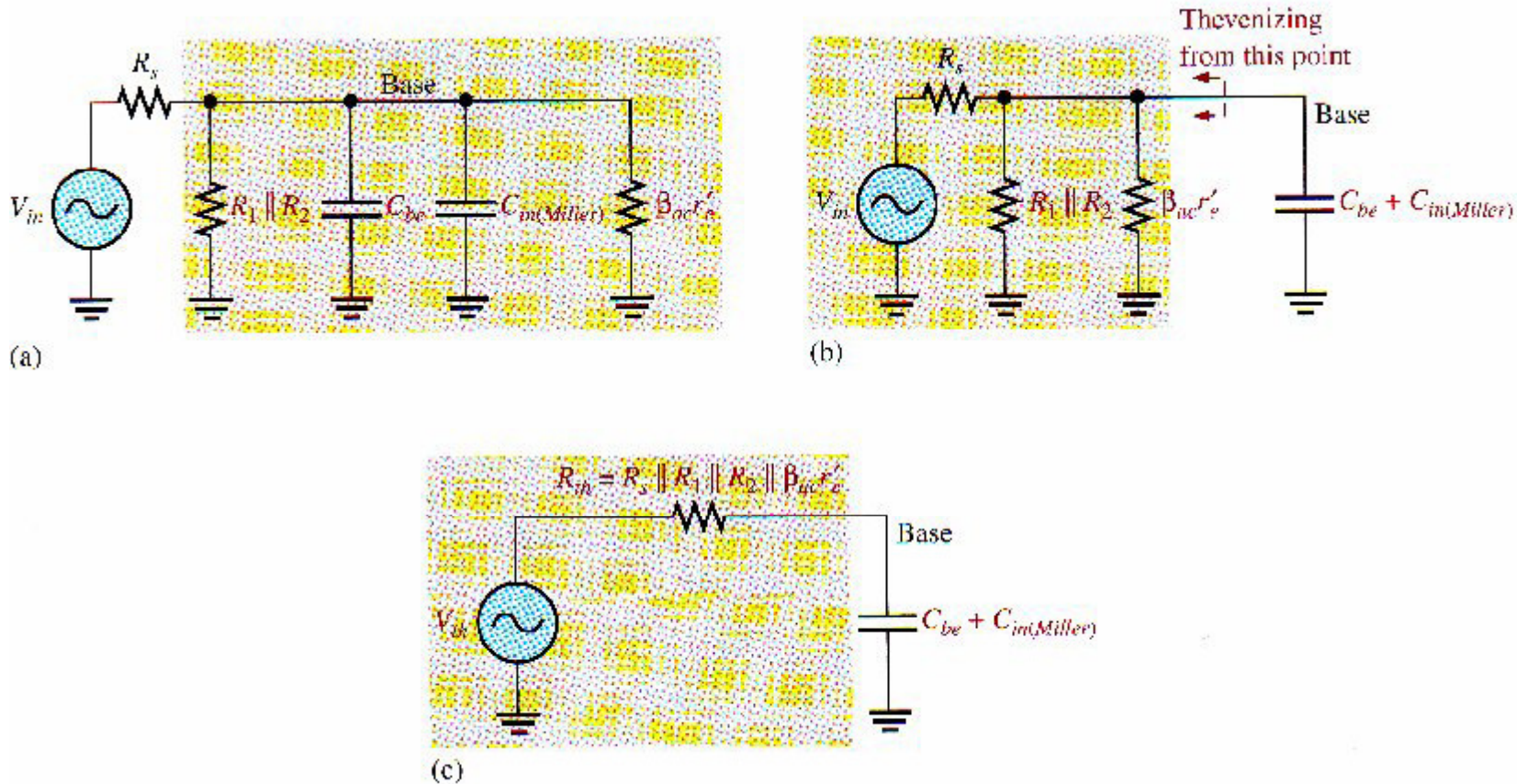
High frequency Response of CE Amp.: Millers Theorem



NOTE: Common base and common collector amplifiers do not suffer from the Miller effect, since in these amplifiers, one side of is connected directly to ground.

When the common base mode is used, the base-collector capacitor does not affect the input since it is grounded at the base end. The input capacitance is equal to C_{be} . (Well, in practise there is a small parasitic capacitance between collector and emitter) Common collector circuit has the collector end grounded (V_{cc} is ground for AC), so the input capacitance equals the base-collector capacitance provided the load has no capacitance of its own.

High frequency Response of CE Amp.: Input RC ckt



As the frequency increases, the capacitive reactance becomes smaller. This cause the signal voltage at the base to decrease, so the amplifier's voltage gain decreases. The reason for this is that the capacitance and resistance act as a voltage divider and, as the frequency increases, more voltage is dropped across the resistance and less across the capacitance.

High frequency Response of CE Amp.: Input RC ckt

At the critical frequency, the gain is 3 dB less than its midrange value. Just as with the low frequency response, the critical high frequency, f_c , is the frequency at which the capacitive reactance is equal to the total resistance

$$X_C = \frac{1}{2\pi \times f_c \times C_{total}} = R_s // R_1 // R_2 // \beta_{ac} r_e'$$

$$f_c = \frac{1}{2\pi \times (R_s // R_1 // R_2 // \beta_{ac} r_e') \times C_{total}}$$

$$C_{total} = C_{be} + C_{in-Miller}$$

As the frequency goes above in the input RC circuit causes the gain to roll off at a rate of -20 dB/decade just as with the low-frequency response.

Phase shift for Input RC ckt at high frequency

Because the output voltage of a high-frequency input RC circuit is across the capacitor, the output of the circuit lags the input.

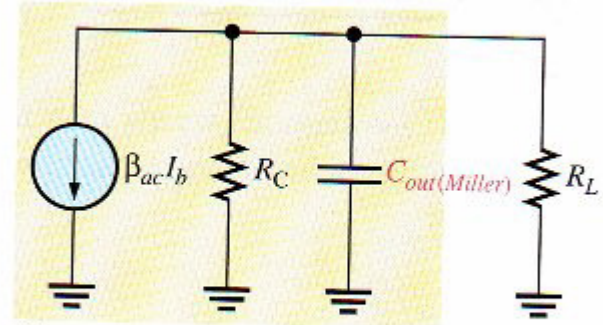
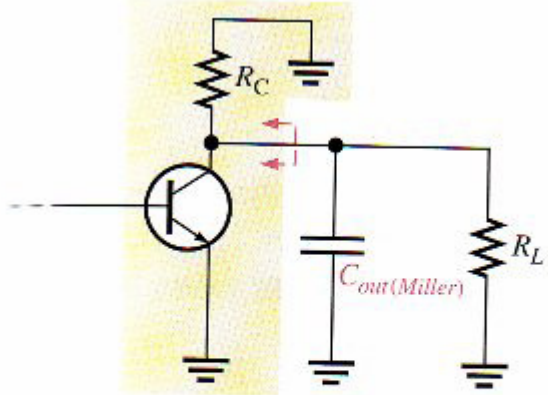
The phase shift in the output RC circuit is

$$\theta = \tan^{-1} \left(\frac{R_s // R_1 // R_2 // \beta_{ac} r_e'}{X_c} \right)$$

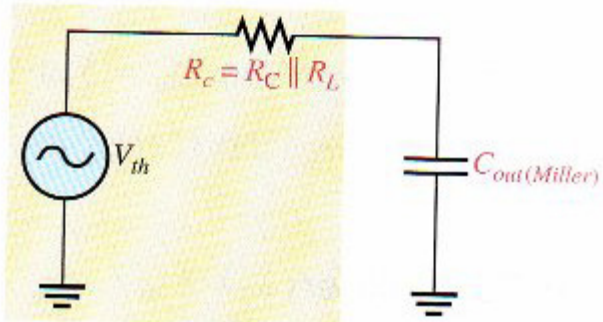
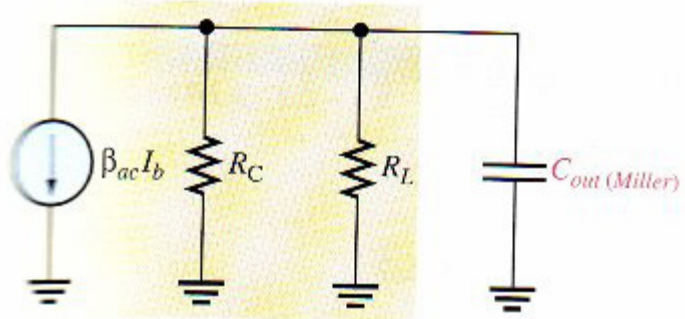
As the frequency increases above f_c , the phase angle increases above 45° and approaches 90° when the frequency is sufficiently high.

At the critical frequency f_c , the phase shift is 45° with the signal voltage at the base of the transistor lagging the input signal.

High frequency Response of CE Amp.: Output RC ckt



(b)



(d)

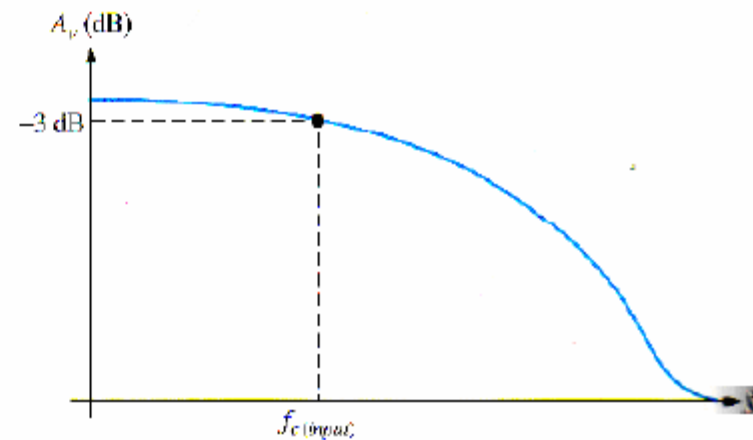
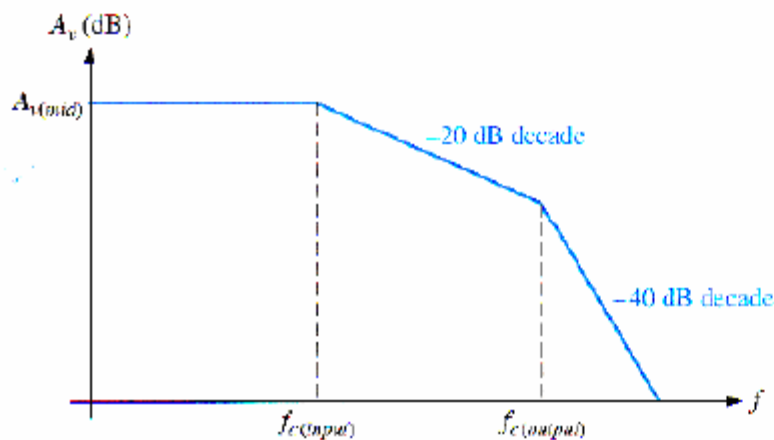
The critical frequency is determine with the following equation, where $R_{ac} = R_C \parallel R_L$

$$f_c = \frac{1}{2\pi \times R_{ac} \times C_{out-Miller}}$$

$$\theta = \tan^{-1} \left(\frac{R_{ac}}{X_{c-out-Miller}} \right)$$

Total High frequency Response of CE Amplifier

The two RC circuits created by the internal transistor capacitances influence the high frequency response of BJT amplifiers. As the frequency increases and reaches the high end of its midrange values, one of the RC will cause the amplifier's gain to begin dropping off. The frequency at which this occurs is the dominant critical frequency; it is the lower of the two critical high frequencies. At $f_c(\text{input})$ the voltage gain begins to roll off at -20dB/decade . At $f_c(\text{output})$, the gain begins dropping at -40 dB/decade because each RC circuit is providing a -20 dB/decade roll-off.



Total frequency Response of CE Amplifier

