Analog & Digital Electronics

Course No: PH-218

Lec-11: Frequency Response of BJT Amplifiers

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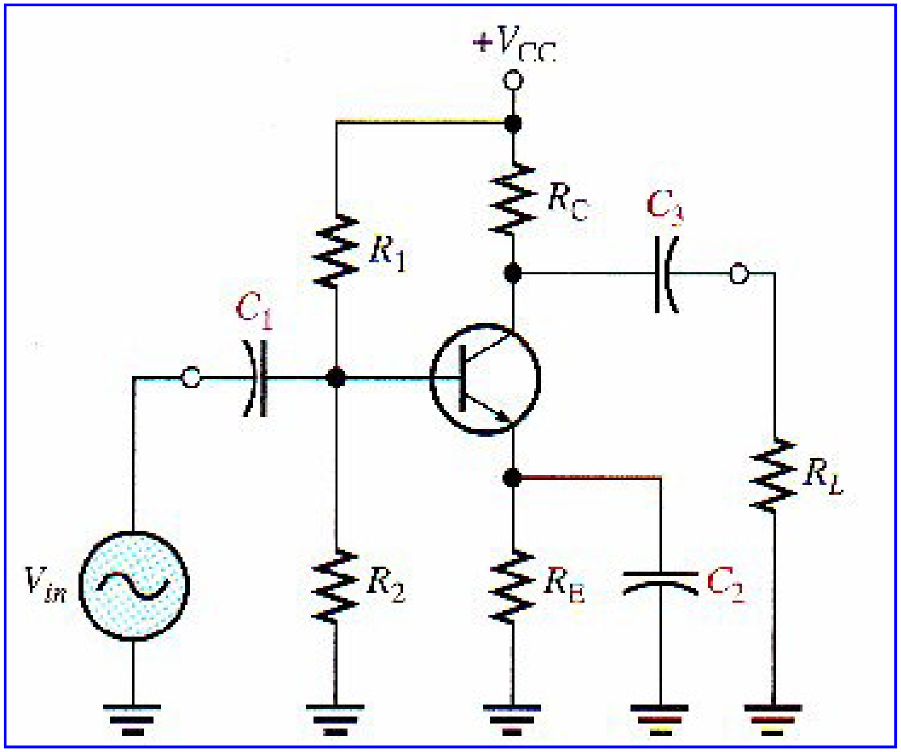
Frequency Response of CE BJT Amplifier



$$X_C = \frac{1}{2\pi \times f \times C}$$

Assuming that the coupling and bypass capacitors are ideal shorts at the midrange signal frequency, the midrange voltage gain can be determined by

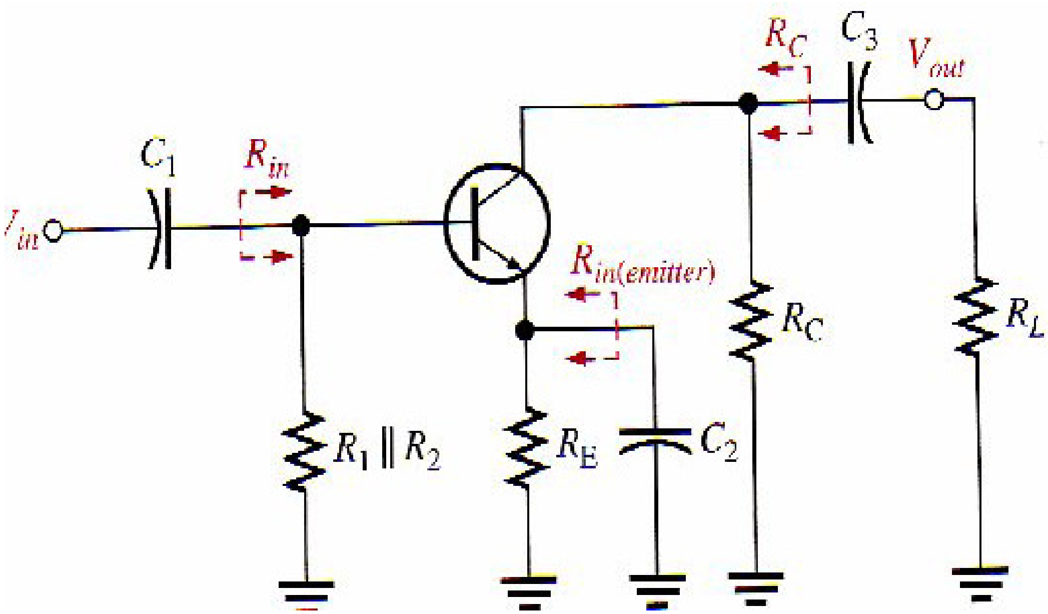
$$A_{v,mid} = \frac{(R_C \backslash\backslash R_L)}{r_e'}$$

- **In the low frequency range, BJT amplifier *has three high-pass RC circuits, namely input, bypass and output RC circuit, that affect its gain.***

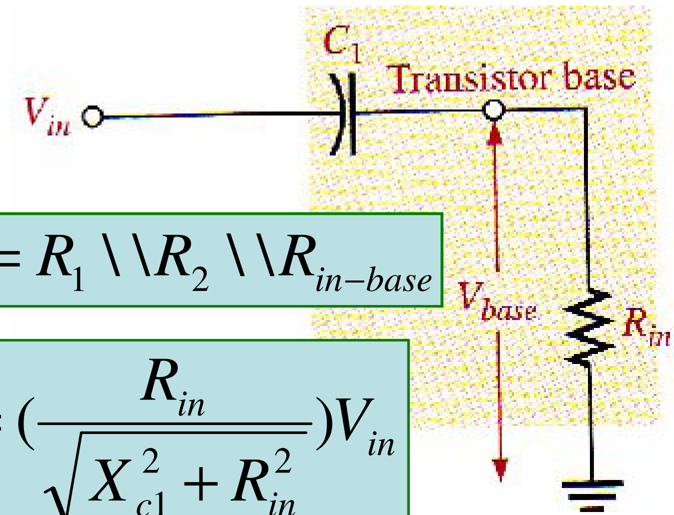
- **The lower cutoff frequency of a given common emitter amplifier will be given by the highest of the individual RC circuits.**

$$f_{C\text{-low}} = MAX(f_{c\text{-input}}, f_{c\text{-output}}, f_{c\text{-bypass}})$$

Low Frequency Response of Input RC circuit



The input RC Circuit



$$R_{in} = R_1 \backslash\backslash R_2 \backslash\backslash R_{in-base}$$

$$V_B = \left(\frac{R_{in}}{\sqrt{X_{c1}^2 + R_{in}^2}}\right) V_{in}$$

- ***As the signal frequency decreases, X_{C1} increase, This causes less voltage across the input resistance of the amplifier at the base and because of this, the overall voltage gain of the amplifier is reduced.***

Decibel

Bel is a form of gain measurement and is commonly used to express amplifier response.

The Bel is a logarithm measurement of the ratio of one power to another or one voltage to another.

$$G = \log_{10}(P_2 / P_1)$$

$$G(dB) = 10\log_{10}(P_2 / P_1)$$

$$G(dB) = 20\log_{10}(V_2 / V_1)$$

It was found, that the Bel was too large a unit of measurement for practical purposes, so the decibel (dB) was defined such that 1B =10dB

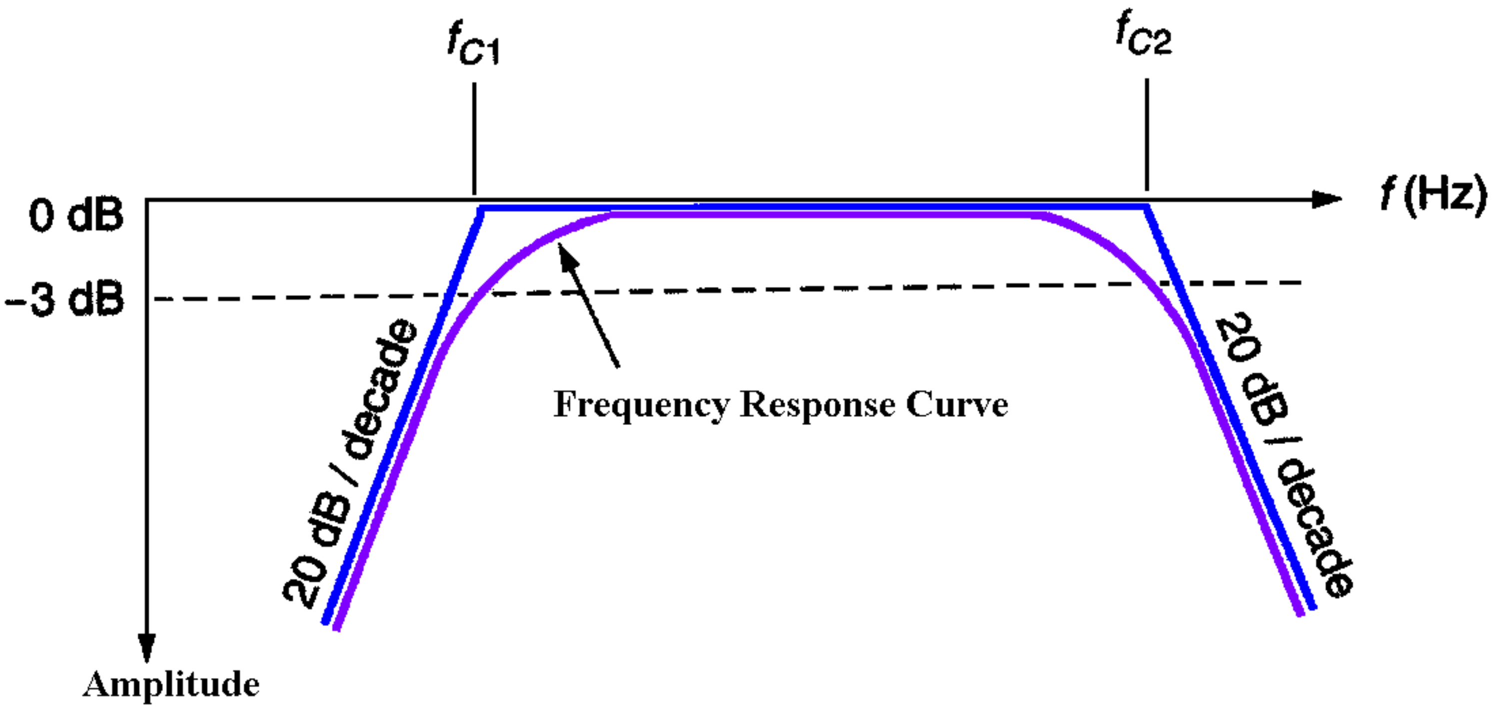
0 dB reference

It is often convenient in amplifiers to assign a certain value of gain as the 0 dB reference This does not mean that the actual voltage gain is 1 (which is 0 dB); it means that the reference gain, is used as a reference with which to compare other values of gain and is therefore assigned a 0 dB value. The maximum gain is called the midrange gain and is assigned a 0 dB value. Any value of gain below midrange can be referenced to 0 dB and expressed as a negative dB value.

Bode Plots

A plot of dB voltage gain versus frequency on semilog graph paper is called a bode plot.

The Bode Plot is a variation of the basic frequency response curve. A Bode plot assumes the amplitude is zero until the cutoff frequency is reached. Then the gain of the amplifier is assumed to drop at a set rate of 20 dB/decade (or one RC time constant).



Low Frequency Response of Input RC ckt

- **A critical point in the amplifier's response occurs when the output voltage is 70.7% of its midrange value. This condition occurs in the input RC circuit when $X_{C1} = R_{in}$**

$$V_B = \left(\frac{R_{in}}{\sqrt{X_{c1}^2 + R_{in}^2}}\right)V_{in}$$

In terms of measurement in decibels:

$$20\log(V_{out}/V_{in}) = 20\log(0.707) = -3dB$$

Lower critical frequency

The condition where the gain is down 3 dB is called the -3dB point of the amplifier response; The frequency f_c at which the overall gain is 3dB less than at midrange is called the lower cutoff frequency.

$$X_{C_1} = \frac{1}{2\pi \times f_c \times C_1} = R_{in}$$

$$f_C = \frac{1}{2\pi \times (R_s + R_{in}) \times C_1}$$

Where R_s is the signal internal resistance and $\mathrm{R}_{\mathrm{in}} = R_1 \backslash\backslash R_2 \backslash\backslash R_{in-base}$

Voltage Gain Roll Off for input ckt at low frequency

➢ **The input RC circuit reduces the overall voltage gain of an amplifier by 3 dB when the frequency is reduced to the critical value f_C.**

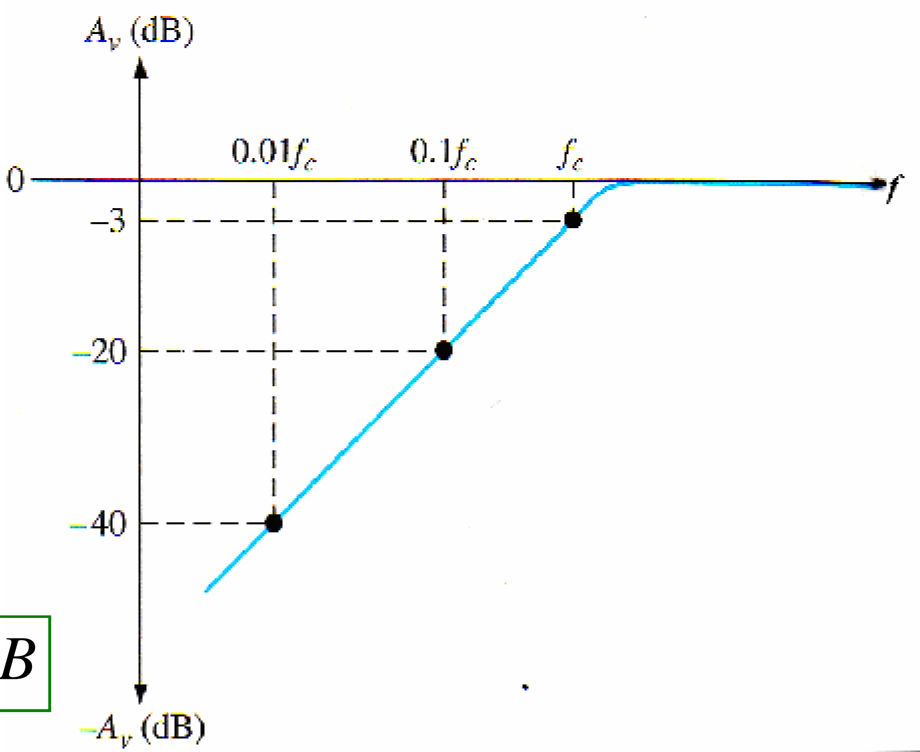
➢ **As the frequency continues to decrease below f_C the overall voltage gain also continues to decrease. The decrease in voltage gain with frequency is called roll-off.**

➢ **For each ten times reduction in frequency below f_C there is a 20dB reduction in voltage gain.**

At f_c, $X_{C1} = R_{in}$, so $X_{C1} = 10\ R_{in}$ at $0.1f_c$,

$$\frac{V_B}{V_{in}} = \frac{R_{in}}{\sqrt{X_{c1}^2 + R_{in}^2}} = 0.1$$

$$20\log(V_B / V_{in}) = 20\log(0.1) = -20dB$$



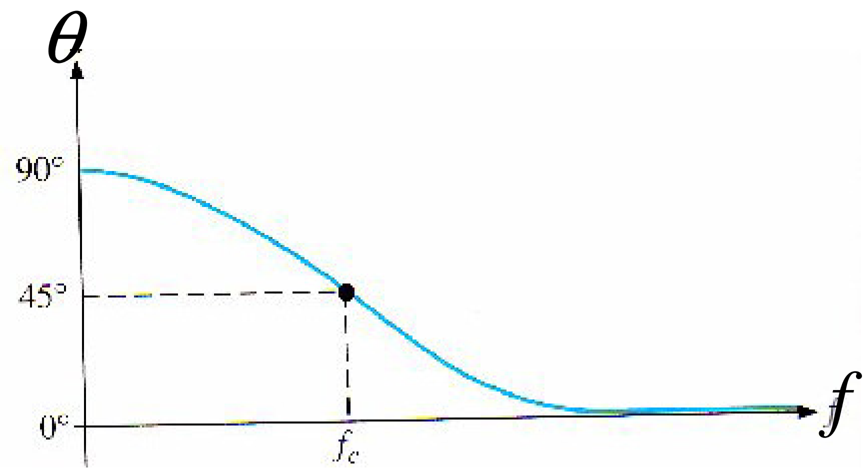
Phase shift for input RC ckt at low frequency

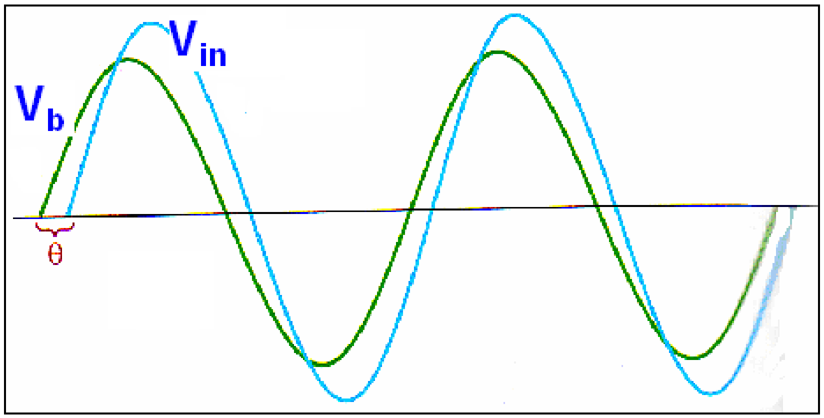
- ***At lower frequencies, higher values of X_{C1} cause a phase shift to be introduced, and the output voltage leads the input voltage.***

- ***The phase angle in an input RC circuit is expressed as:***

$$\theta = \tan^{-1}\left(\frac{X_{C1}}{R_{in}}\right)$$

- **At midrange frequencies the phase shift through the input RC circuit is zero because $X_{C1} \approx 0\Omega$.**

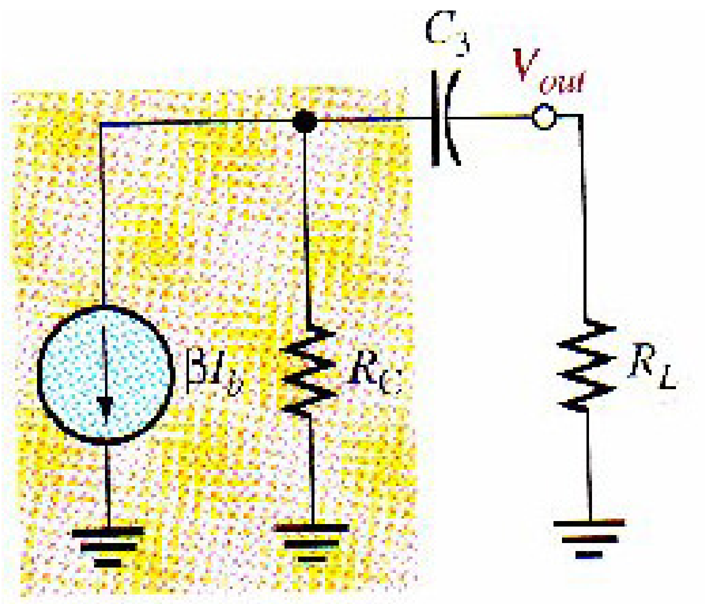


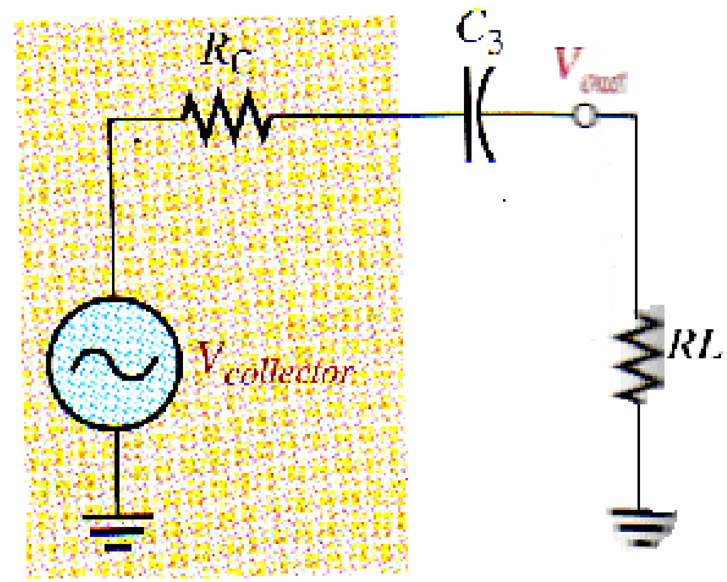


Output RC circuit at low frequency

$$X_{C_3} = \frac{1}{2\pi \times f_c \times C_3} = R_C + R_L$$

$$f_C = \frac{1}{2\pi \times (R_C + R_L) \times C_3}$$





As the signal frequency decreases, X_{C3} increases. This causes less voltage across the load resistance because more voltage is dropped across C_3.
The signal voltage is reduced by a factor of 0.707 when frequency is reduced to the lower critical value, f_C, for the circuit. This corresponds to a 3 dB reduction in voltage gain

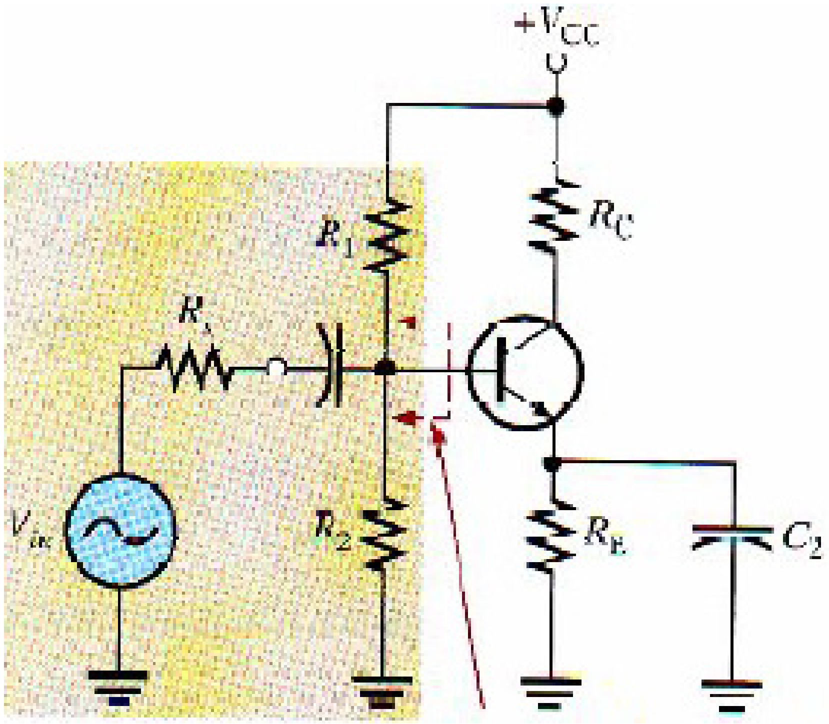
Phase shift for Output RC ckt at low frequency

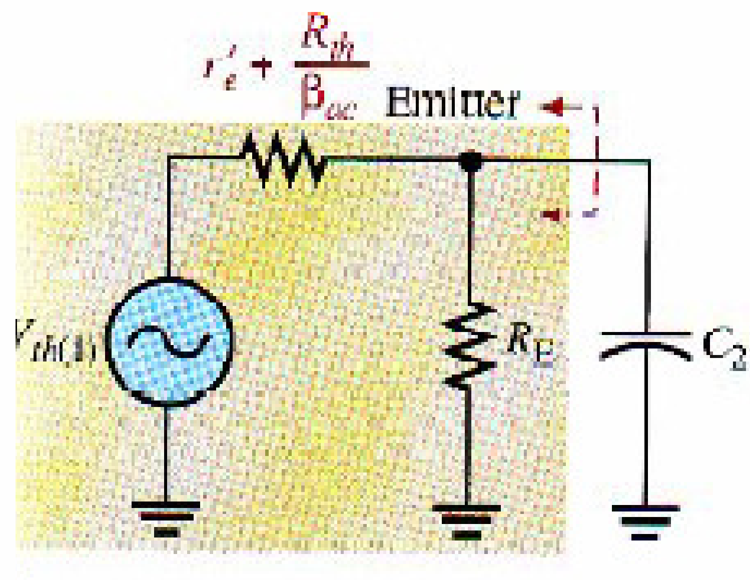
The phase shift in the output RC circuit is

$$\theta = \tan^{-1}\left(\frac{X_{C3}}{R_C + R_L}\right)$$

- **θ ≈ 0 for the midrange frequency and approaches 90º as the frequency approaches zero (X_{C3} approaches infinity).**
- **At the critical frequency f_C , the phase shift is 45º**

Emitter-bypass RC ckt at low frequency





$$R_{in-emitter} = \frac{V_e}{I_e} + r_e^{'}$$

$$R_{in-emitter} = \frac{R_{th} I_b}{\beta I_b} + r_e^{'} = \frac{R_{th}}{\beta} + r_e^{'}$$

$$f_C = \frac{1}{2\pi \times [(r_e^{'} + \frac{R_{th}}{\beta_{ac}}) // R_E] \times C_2}$$

Total Low frequency Response of CE Amplifier

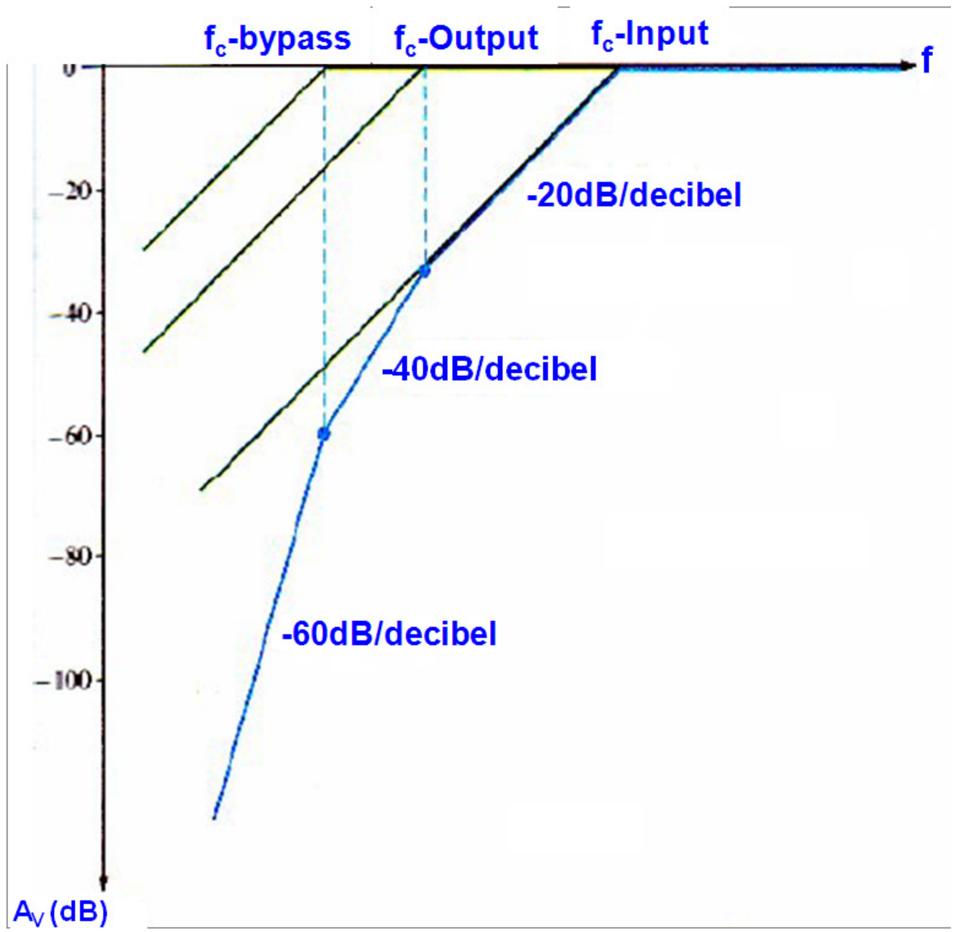
- **The critical frequencies of the three RC circuits are not necessarily all equal. If one of the RC circuits has a critical frequency higher than the other two, then it is dominant RC circuit.**

- **As the frequency is reduced from midrange, the first "break point" occurs at the critical frequency of the input RC circuit, f_c(input) , and the gain begins to drop at -20dB/decade.**

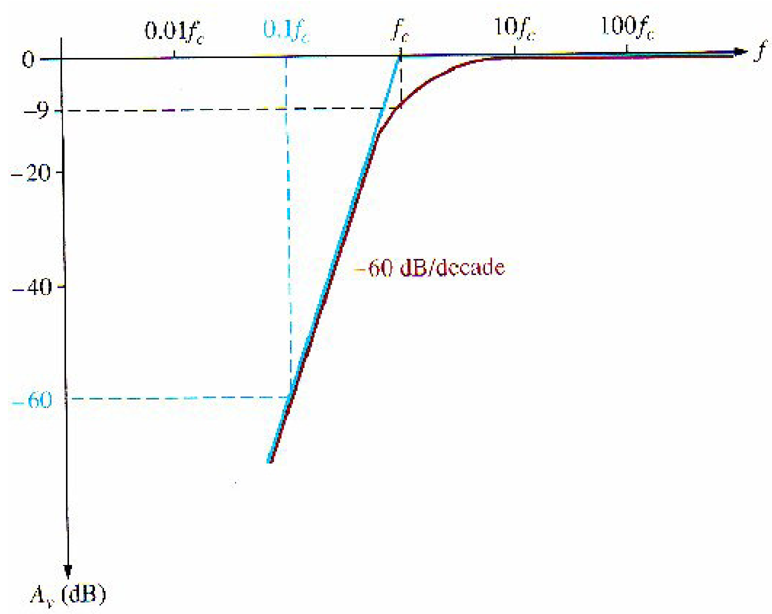
- **This constant roll\off rate continues until the critical frequency of the output RC circuit, f_c(output), is reached. At this break point, the output RC circuit adds another - 20 dB/decade to make a total roll-off of -40 dB/decade.**

- **This constant -40 dB/decade roll-off continues until the critical frequency of the bypass RC circuit, f_c(bypass), is reached. At this break point, the bypass RC circuit adds still another -20dB/decade, making the gain roll-off at - 60 dB/decade**

If all RC circuits have different critical frequency



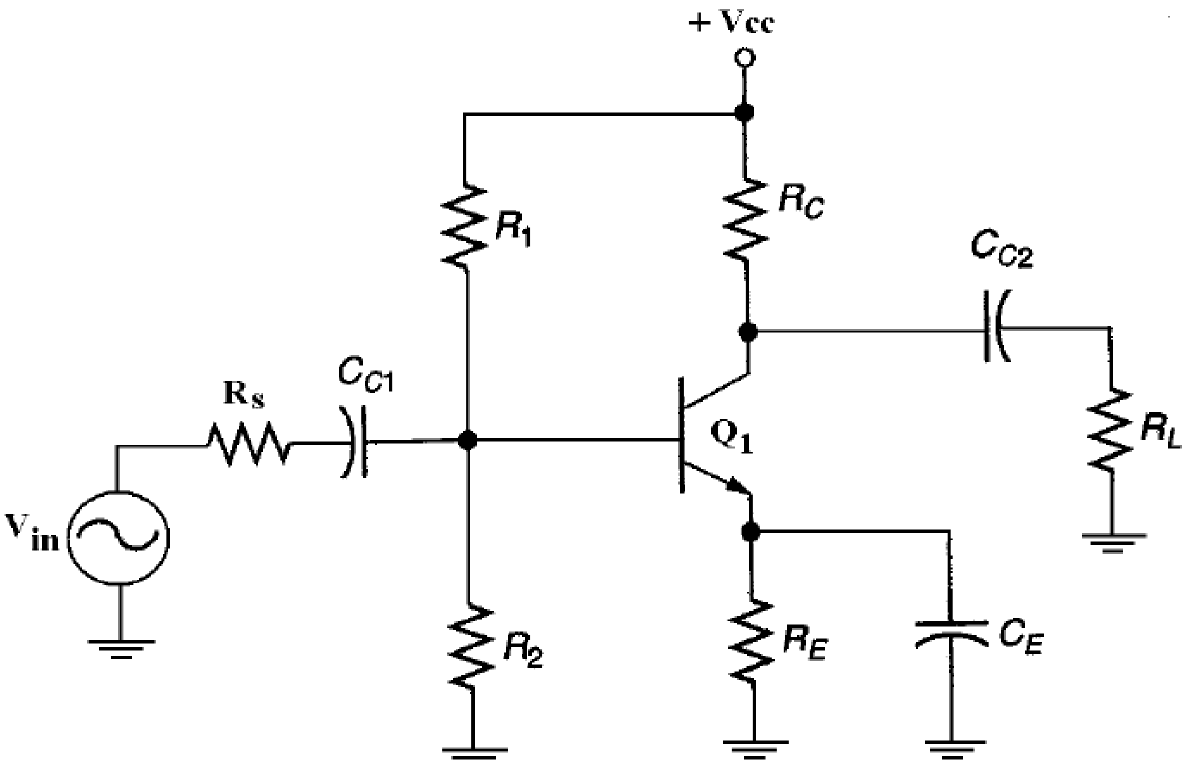
If all RC circuits have the same critical frequency



http://www.uotiq.org/dep-eee/lectures/2nd/Electronics%201/part6.pdf

Low frequency Response of CE Amplifier

Determine the value of the lower cutoff frequency for the following amplifier. Consider the following component values:
R_S = 600 Ω, R_1 = 18 kΩ, R_2 = 4.7 kΩ, R_C = 1.5 kΩ, R_E = 1.2 kΩ, R_L = 5 kΩ, C_{C1} = 1 μF, C_{C2} = 0.22 μF, C_E = 10 μF, h_{fe} = 200, h_{ie} = 4.4 kΩ, V_{cc} = 10 V



$f_{c\text{-input}}$ = 61.2 Hz
$f_{c\text{-output}}$ = 111 Hz
$f_{c\text{-bypass}}$ = 650 Hz

Lower cutoff frequency of the amplifier:

$f_{C\text{-Low}}$ = max (61.2, 111, 650)

$f_{C\text{-Low}}$ = 650 Hz