Frequency Response Curve of an Amplifier

The curve drawn for voltage versus frequency is known as frequency response curve. The frequency response of an amplifier may be divided into three regions as —

i) Midband region where the gain is reasonably constant say A_0. Here, we consider the normalized value as $A_0 = 1$

ii) Low-frequency band :- Below the mid-frequency region, the voltage gain is not uniform and amplifier behaves like simple High-Pass filter. In this low-frequency range frequency response decreases with decrease in frequency.

Low Frequency Response :-

Let, us consider a simple High-Pass filter as shown in adjecent fig. consisting of capacitor C and a resistor R.

Here, ckt does not allow to pass a signal of low frequency because the capacitor offers high impedance to signal of lower frequency and no output appears across load R.

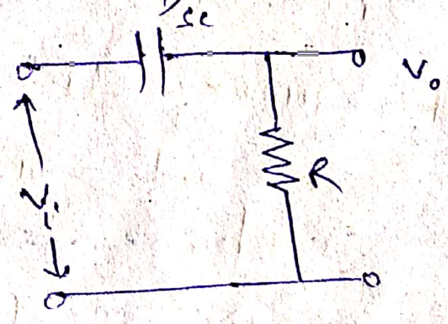

fig-1.

On the other hand, ckt offers very small or negligible resistive path to the frequency of high frequency signal. Hence, it HPF.

(2) Now, applying KVL —

Low-pass filter does not have zero at origin.

$$V_i = V_c + V_o = I\left(\frac{1}{j\omega C}\right) + IR$$

$$V_o = IR$$

$$\therefore \frac{V_i}{V_o} = \frac{\cancel{I}\left[R + \frac{1}{j\omega C}\right]}{\cancel{I}R}$$

$$\text{or, } A_{v_L} = \frac{V_o}{V_i} = \frac{R}{R + \frac{1}{j\omega C}} = \frac{1}{1 + \frac{1}{jRC\omega}}$$

$$\text{or, } A_{v_L} = \frac{1}{1 - j\frac{1}{2\pi f RC}} = \frac{1}{1 - j\frac{1/2\pi RC}{f}}$$

Here, $f_L = \frac{1}{2\pi RC}$ = Lower cut-off frequency

$$\therefore \boxed{A_{v_L} = \frac{1}{1 - \frac{jf_L}{f}}}$$

$$|A_{v_L}| = \frac{1}{\sqrt{1 + (f_L/f)^2}}, \quad \angle A_v = \angle(1 + 0 \cdot j) - \angle(1 - j\,f_L/f)$$

$$= \tan^{-1}\left(\frac{0}{1}\right) - \tan^{-1}\left\{\frac{-f_L/f}{+1}\right\}$$

$$\theta_L = \tan^{-1}(f_L/f) = \angle A_v$$

$$|A_{v_L}|_{dB} = 20\log\left[1 + \left(\frac{f_L}{f}\right)^2\right]^{-1/2} = -10\log\left[1 + \left(\frac{f_L}{f}\right)^2\right]$$

Since here, $f << f_L$ i.e. frequency is very low

$$\therefore \frac{f_L}{f} >> 1 \Rightarrow \left(\frac{f_L}{f}\right)^2 >> 1$$

$$\therefore |A_{v_L}|_{dB} = -10\log\left[1 + \left(\frac{f_L}{f}\right)^2\right] \simeq -10\log\left(f_L/f\right)^2 = -20\log\left(\frac{f_L}{f}\right)$$

$$|A_{v_l}|_{dB} = -20\log\left(\frac{f_L}{f}\right)$$

Let,

$f = 0.01 f_L$, $|A_{v_l}|_{dB} = -20\log\left(\frac{\cancel{f_L}\times 100}{0.01\cancel{f_L}}\right) = -40$ dB

When,

$f = 0.05 f_L$, $|A_{v_l}|_{dB} = -20\log\left(\frac{\cancel{f_L}\times \cancel{100}^{20}}{\cancel{0.05}\cancel{f_L}}\right) = -20\log 20$

$= -20\log 2 - 20\log 10 = -20\times 0.301 - 20$

$= -26$ dB.

When,

$f = 0.1 f_L$, $|A_{v_l}|_{dB} = -20\log\left(\frac{\cancel{f_L}\times 10}{0.1\cancel{f_L}}\right) = -20$ dB.

When, $f = f_L$ then $A_{v_l} = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}}$

And, $|A_{v_l}|_{dB} = 20\log\frac{1}{\sqrt{2}} = -10\log 2 = -10\times 0.30 = -3$ dB.

When, $f >> f_L$, i.e in mid-band region —— , $\left(\frac{f_L}{f}\right)^2 << 1$

$$A_{v_l} = \frac{1}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}} \simeq \frac{1}{\sqrt{1}} \rightarrow 1$$

i.e. $A_{v_l} \rightarrow 1$

which is the normalized gain in mid-band frequency region and in this region,

$A_{v_m} = 1$

$|A_{v_m}|_{dB} = 20\log 1 = 0$ dB.

When, we plote these quantity on logarithmic scale taking frequency along x-axis and $|A_{v_l}|_{dB}$ along y-axis, then we get a curve as shown in fig-2. This curve is called frequency response in Low-freq. range.

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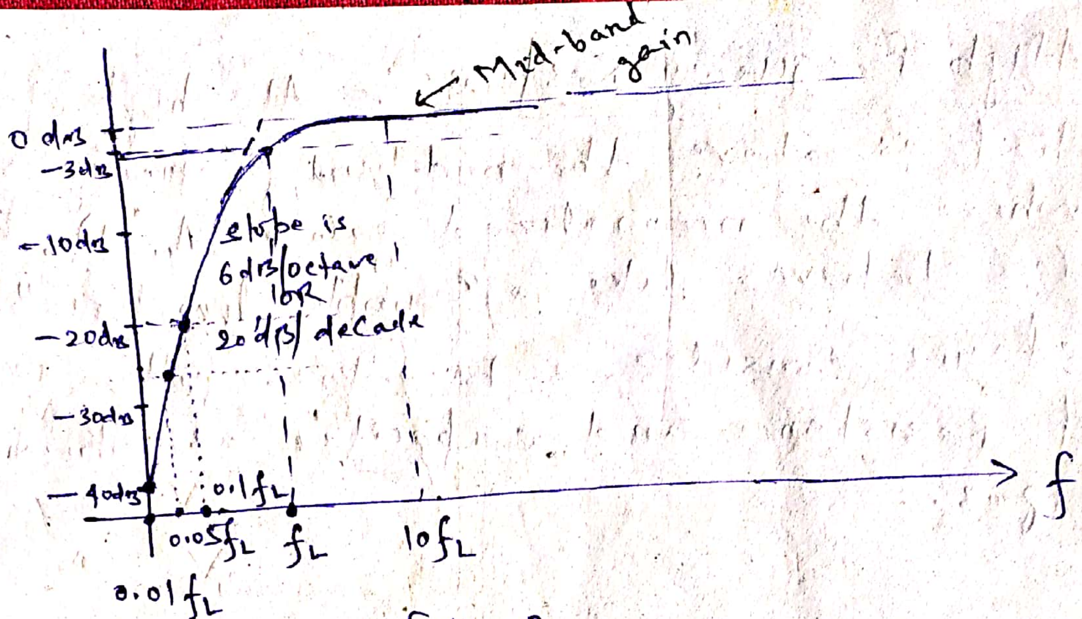

fig-2

From curve, it is clear that lower cut-off freq. f_L is the frequency at which the gain has fallen to $\frac{1}{\sqrt{2}}$ times of mid-band gain and corresponding to this frequency gain is -3dB. This frequency is also known as 3dB ~~cut-off~~ lower cut-off frequency. It is also obvious that gain linearly increase and not uniform below the mid-band frequency and above the 3dB cut-off frequency i.e in mid-band range frequency response is constant and gain becomes 0 dB.

Note:- i) Here when we change the frequency by 10 times then gain change by 20dB. Hence slope is called 20dB/decade.

ii) If we change the frequency by 2 times then gain changes by 6dB. Hence it may also be called that slope is 6dB/octave