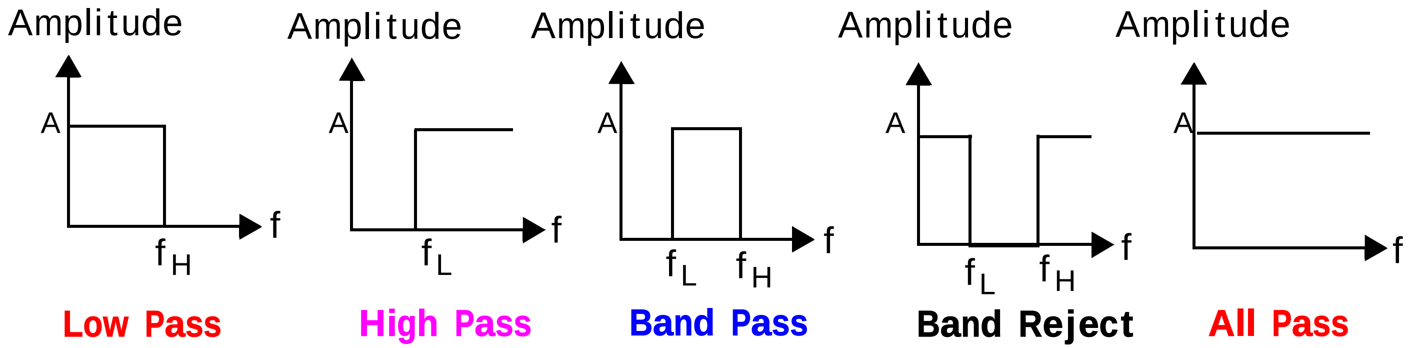
Amplifier Transfer function

$$A_V(s) = \frac{V_o(s)}{V_i(s)} = K\frac{(s+z_1)(s+z_2)(s+z_3)\cdot\quad\cdot\quad\cdot(s+z_m)}{(s+p_1)(s+p_2)(s+p_3)\cdot\quad\cdot\quad\cdot(s+p_n)} \Rightarrow \frac{zeros}{poles}$$

$$A_V(j\omega) = |A_V(j\omega)| \bullet \angle A_V(j\omega) \text{ and } A_V(s) = -20\frac{s^2+10^{12}}{s^2+10^4 s+10^{12}}$$

Describe amplifier frequency response

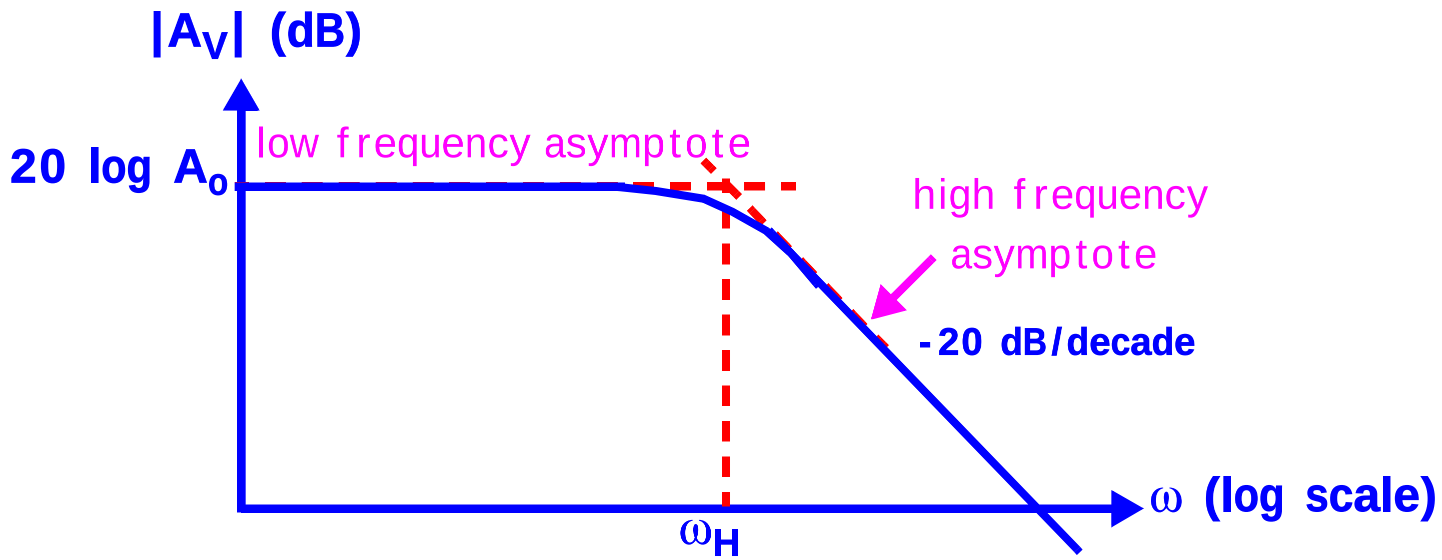
Low pass, high pass, band pass, band reject, all pass



Bode Plot - magnitude (dB) and phase of transfer function versus freq.

Low Pass Amplifier

Magnitude response



$$A_V(s) = A_o \bullet \frac{\omega_H}{s + \omega_H} \quad ; \quad |A_V(j\omega)| = \frac{|A_o \omega_H|}{\sqrt{\omega^2 + \omega_H^2}}$$

$$|A_V(j\omega)|_{\omega \ll \omega_H} \Rightarrow \frac{|A_o \omega_H|}{\sqrt{\omega_H^2}} = |A_o|, \quad |A_V(j\omega)|_{\omega \gg \omega_H} \Rightarrow \frac{|A_o \omega_H|}{\sqrt{\omega^2}} = \frac{|A_o \omega_H|}{\omega}$$

Explain how to evaluate the magnitude response, the mid-band gain, the upper 3dB frequency or upper cut-off frequency and the bandwidth of the low pass amplifier.

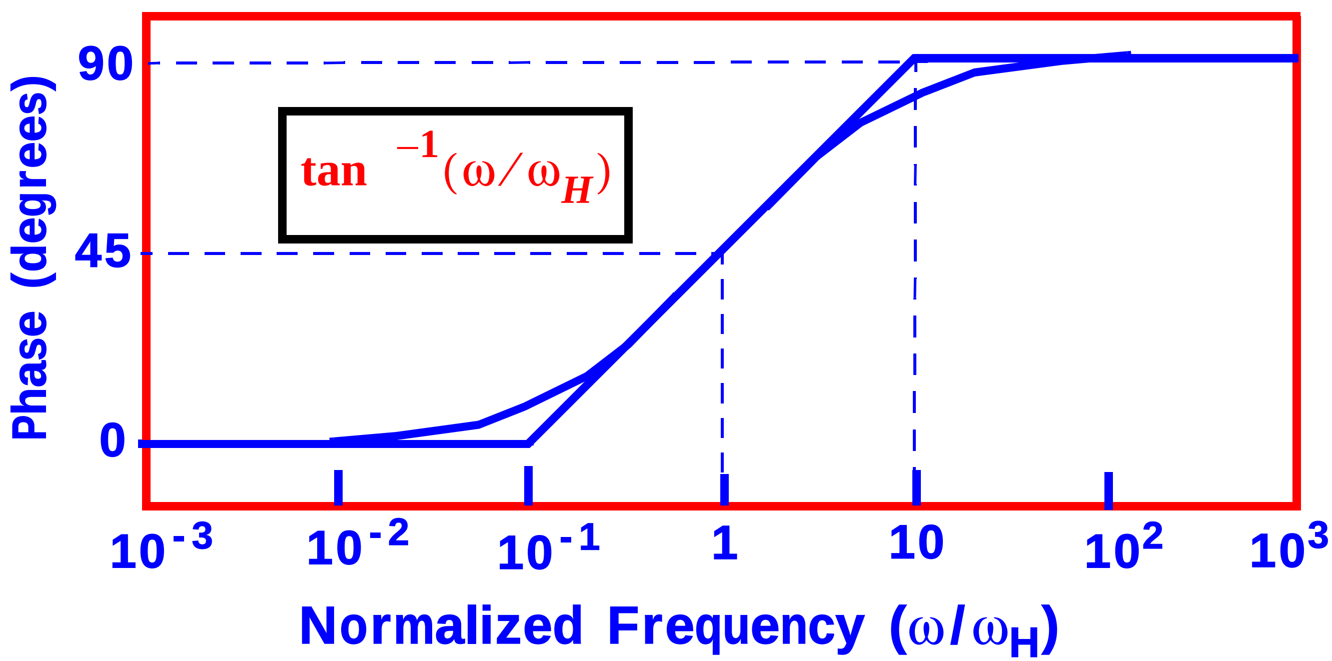
Phase response of low-pass amplifier

Table 2: Inverse Tangent

ω	$\tan^{-1}(\omega/\omega_H)$
$0.01\omega_H$	0.057^0
$0.1\omega_H$	5.7^0
ω_H	45^0
$10\omega_H$	84.3^0
$100\omega_H$	89.4^0

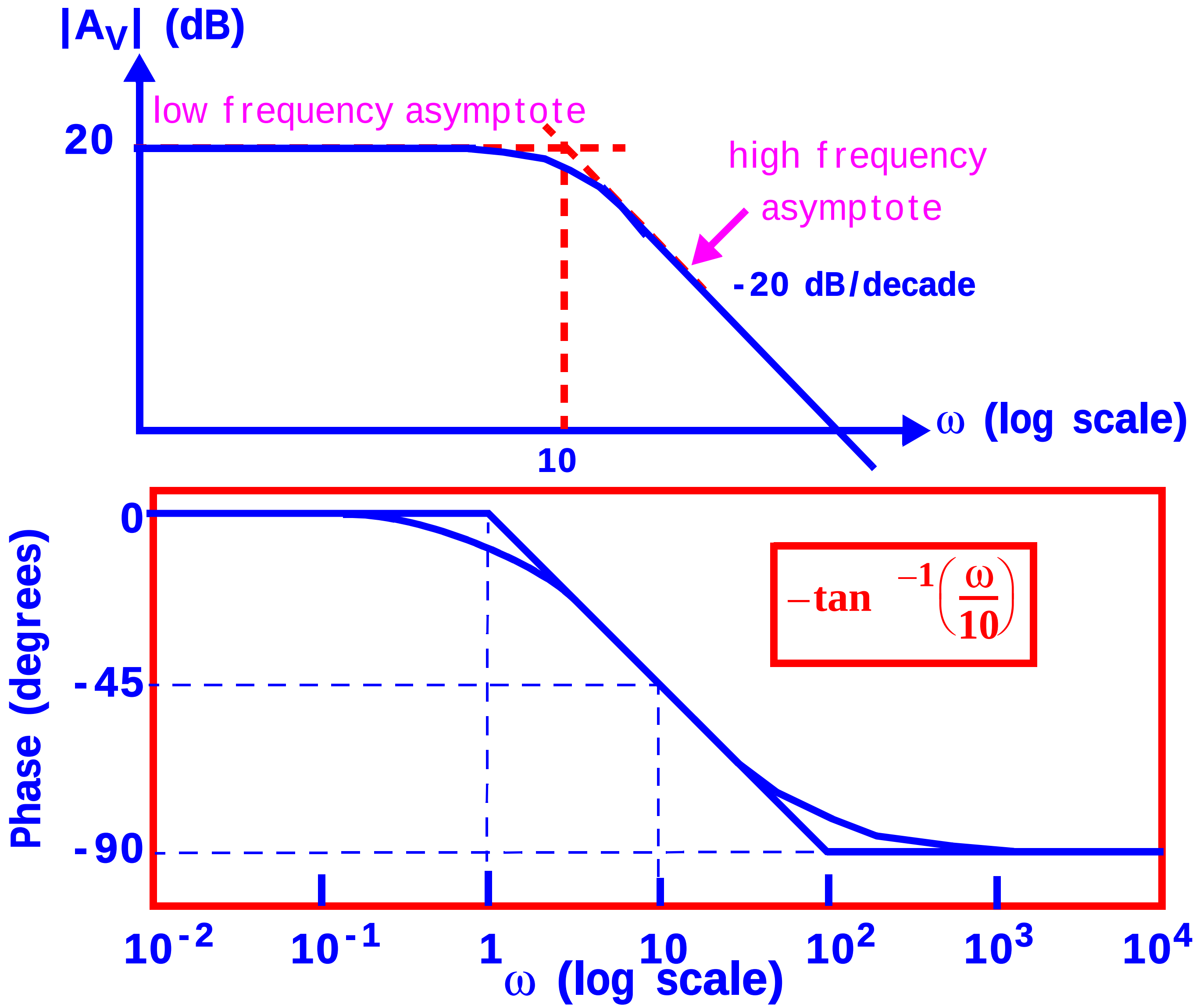
$$A_V(\omega) = A_o \bullet \frac{\omega_H}{j\omega + \omega_H}$$

$$\angle A_V(j\omega) = \angle \frac{A_o}{1 + j\frac{\omega}{\omega_H}} = \angle A_o - \tan^{-1}\left(\frac{\omega}{\omega_H}\right)$$



Example: Sketch the bode diagram for the transfer function

$$A_v(s) = \frac{100}{s+10} = \frac{10}{1+s/10} \Rightarrow |A_v(\omega)| = \frac{10}{\sqrt{1^2+\omega^2/10^2}}$$



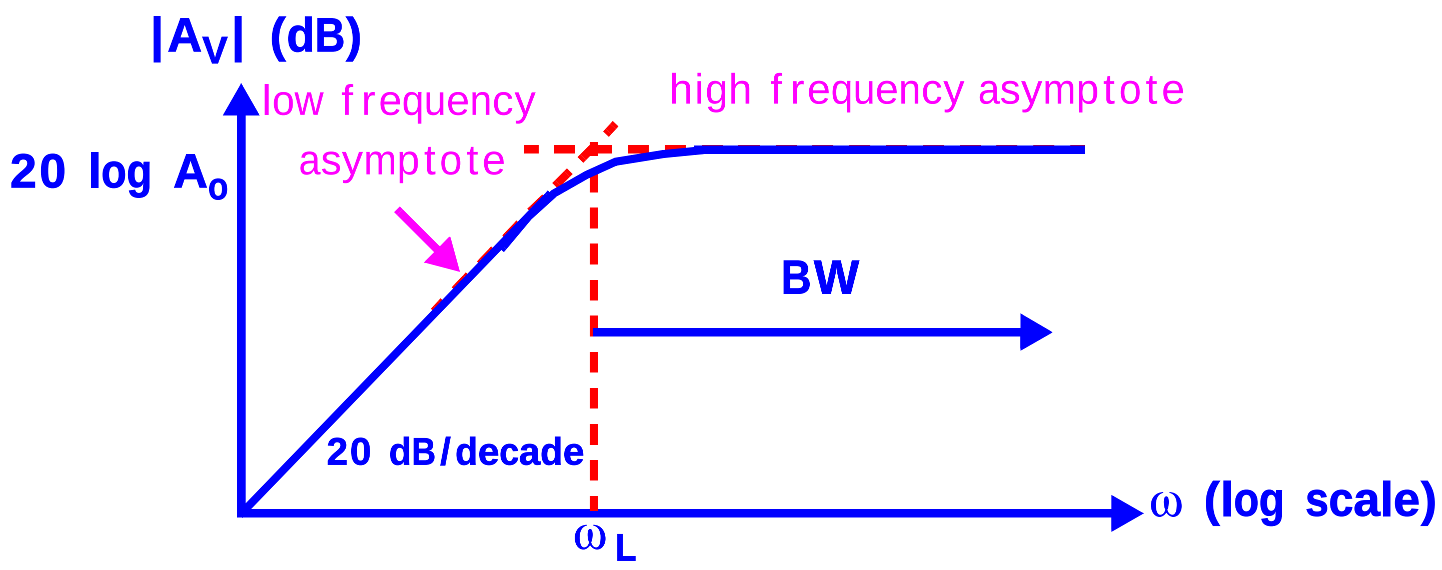
Response of high-pass amplifier

$$A_V(s) = A_o \bullet \frac{s}{s+\omega_L}. \quad |A_V(j\omega)| = \left|\frac{A_o j\omega}{j\omega + \omega_L}\right| = \frac{A_o\omega}{\sqrt{\omega^2+\omega_L^2}} = \begin{pmatrix} \left.\frac{A_o\omega}{\omega_L}\right|_{\omega \ll \omega_L} \\ \left.A_o\right|_{\omega \gg \omega_L} \end{pmatrix}$$

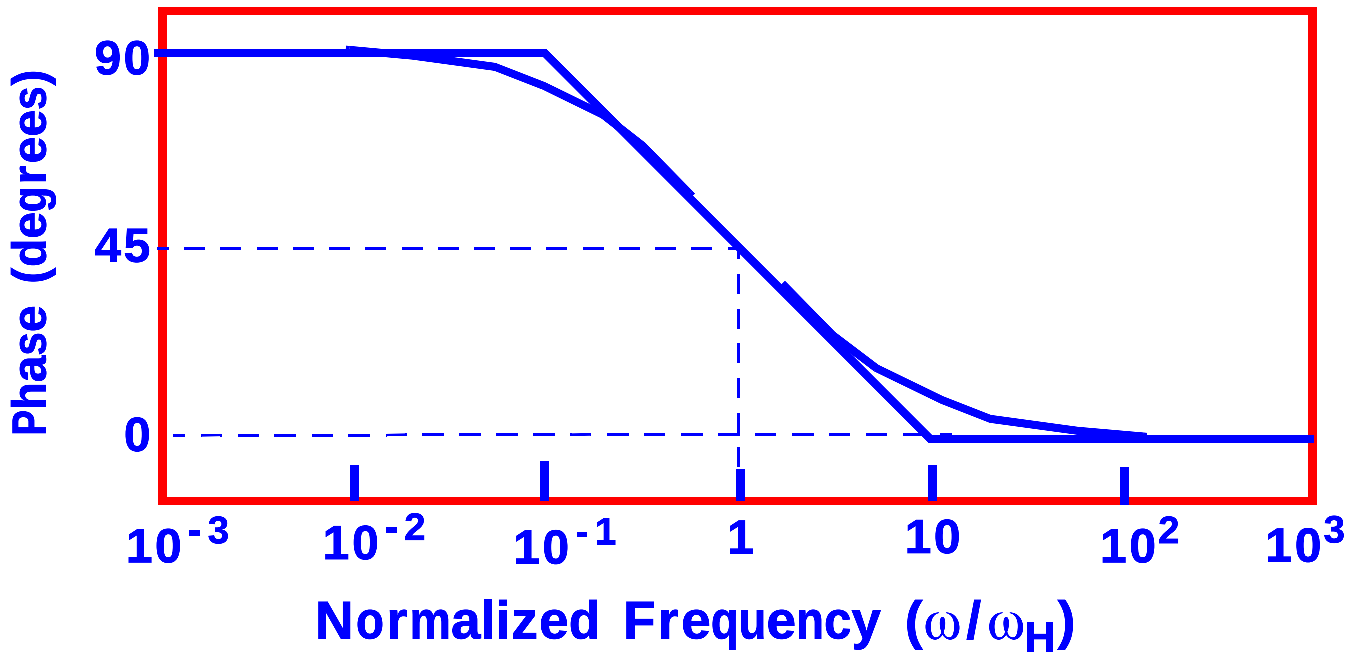
$$\angle A_V(j\omega) = \angle\frac{A_o j\omega}{j\omega + \omega_L} = \angle A_o + 90^0 - \tan^{-1}\left(\frac{\omega}{\omega_L}\right)$$

Provides uniform gain for all frequencies above ω_L.

Explain - Bode plot, 3 dB frequency (ω_L) and bandwidth ∞ of HPA.



$$\angle A_V(j\omega) = \angle \frac{A_o j\omega}{j\omega + \omega_L} = \angle A_o + 90^0 - \tan^{-1}\left(\frac{\omega}{\omega_L}\right)$$



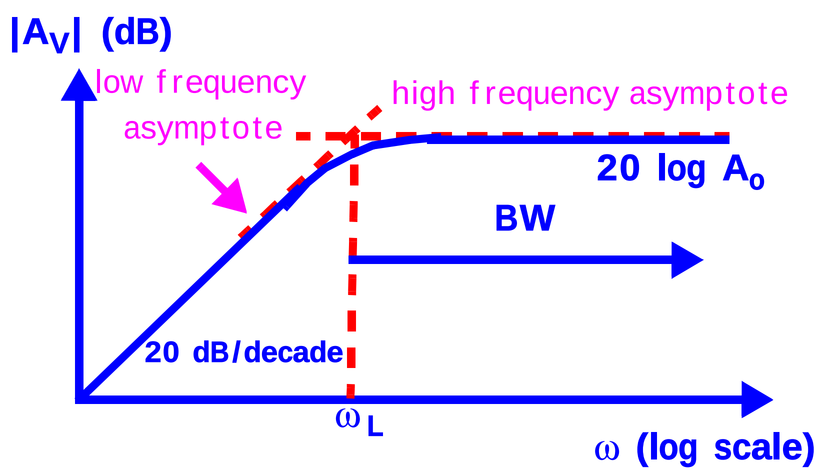
Response of band-pass amplifier

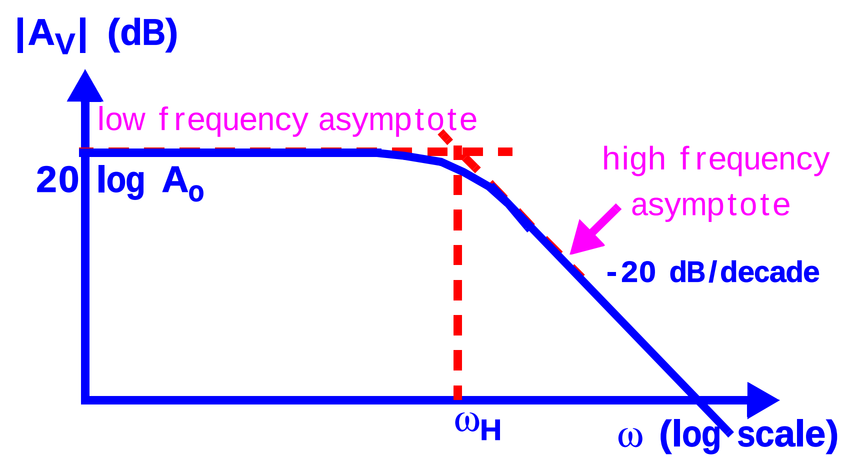
Low Pass Amplifier $A_V(s) = A_o \bullet \dfrac{\omega_H}{s + \omega_H}$

$$|A_V(j\omega)| = \frac{|A_o \omega_H|}{\sqrt{\omega^2 + \omega_H^2}} \quad \text{and} \quad \angle A_V(j\omega) = \angle \frac{A_o}{1 + j\dfrac{\omega}{\omega_H}} = \angle A_o - \tan^{-1}\left(\frac{\omega}{\omega_H}\right)$$

Response of high-pass amplifier $A_V(s) = A_o \bullet \dfrac{s}{s + \omega_L}$.

$$|A_V(j\omega)| = \left|\frac{A_o j\omega}{j\omega + \omega_L}\right| \quad \text{and} \quad \angle A_V(j\omega) = \angle \frac{A_o j\omega}{j\omega + \omega_L} = \angle A_o + 90^0 - \tan^{-1}\left(\frac{\omega}{\omega_L}\right)$$





Low pass $A_V(s) = A_o \bullet \frac{\omega_H}{s + \omega_H}$; high-pass amplifier $A_V(s) = A_o \bullet \frac{s}{s + \omega_L}$

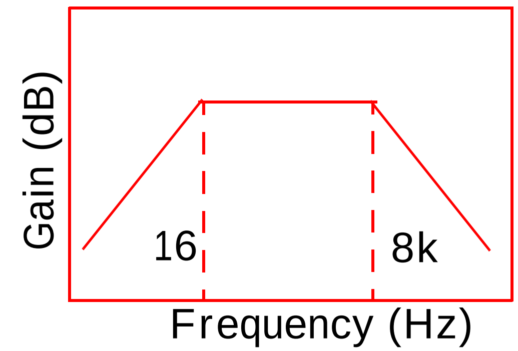
Response of band-pass amplifier

$$A_V(s) = A_o \bullet \frac{s\omega_H}{(s + \omega_L)(s + \omega_H)} = A_o \bullet \frac{s}{(s + \omega_L)\left(\frac{s}{\omega_H} + 1\right)}.$$

For midband range of frequencies $\omega_L \le \omega \le \omega_H$, $|A_V(j\omega)| \approx A_o$.

$$|A_V(j\omega)| = \left|\frac{A_o j\omega\omega_H}{(j\omega + \omega_L)(j\omega + \omega_H)}\right| = \frac{A_o\omega\omega_H}{\sqrt{(\omega^2 + \omega_L^2)(\omega^2 + \omega_H^2)}} = \frac{A_o}{\sqrt{\left(1 + \frac{\omega_L^2}{\omega^2}\right)\left(1 + \frac{\omega^2}{\omega_H^2}\right)}}$$

$$\angle A_V(j\omega) = \angle\frac{A_o j\omega\omega_H}{(j\omega + \omega_L)(j\omega + \omega_H)} = \angle A_o + 90^0 - \tan^{-1}\left(\frac{\omega}{\omega_L}\right) - \tan^{-1}\left(\frac{\omega}{\omega_H}\right)$$



Example: Determine the characteristics of an amplifier with a transfer function of

$$A_V(s) = \frac{-2 \times 10^7 s}{(s + 100)(s + 5000)}$$

$$|A_V(j\omega)| = \left|\frac{A_o j\omega\omega_H}{(j\omega + \omega_L)(j\omega + \omega_H)}\right| = \frac{400(50000)s}{(s + 100)(s + 50000)}$$

$$|A_o| = 20 \bullet \log(400) = 52.0dB;\quad f_L = \frac{100}{2\pi} = 15.9Hz;\quad f_H = \frac{50000}{2\pi} = 7.96kHz$$

$$Bandwidth = f_H - f_L = 7.94kHz$$

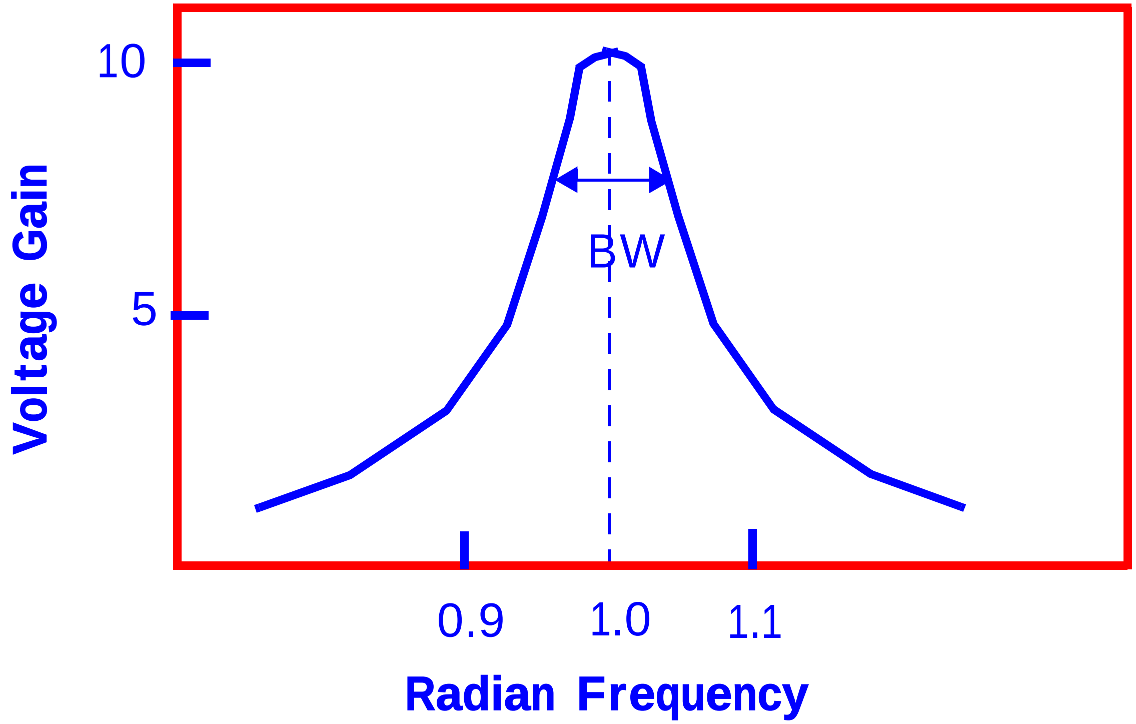
$$\angle A_V(j\omega) = \angle\frac{A_o j\omega\omega_H}{(j\omega + \omega_L)(j\omega + \omega_H)} = \angle A_o + 90^0 - \tan^{-1}\left(\frac{\omega}{\omega_L}\right) - \tan^{-1}\left(\frac{\omega}{\omega_H}\right)$$

$$\angle A_V(j\omega) = -90^0 - \tan^{-1}\left(\frac{\omega}{100}\right) - \tan^{-1}\left(\frac{\omega}{50000}\right)$$

Example, $\omega = 0 \Rightarrow \angle A_V(j\omega) = -90^0$; $\omega = 100 \Rightarrow \angle A_V(j\omega) = -135^0$

$\omega = 50,000 \Rightarrow \angle A_V(j\omega) = -225^0$ $\omega = \infty \Rightarrow \angle A_V(j\omega) = -270^0$

Narrow Band or High-Q Bandpass Amplifier (Read)



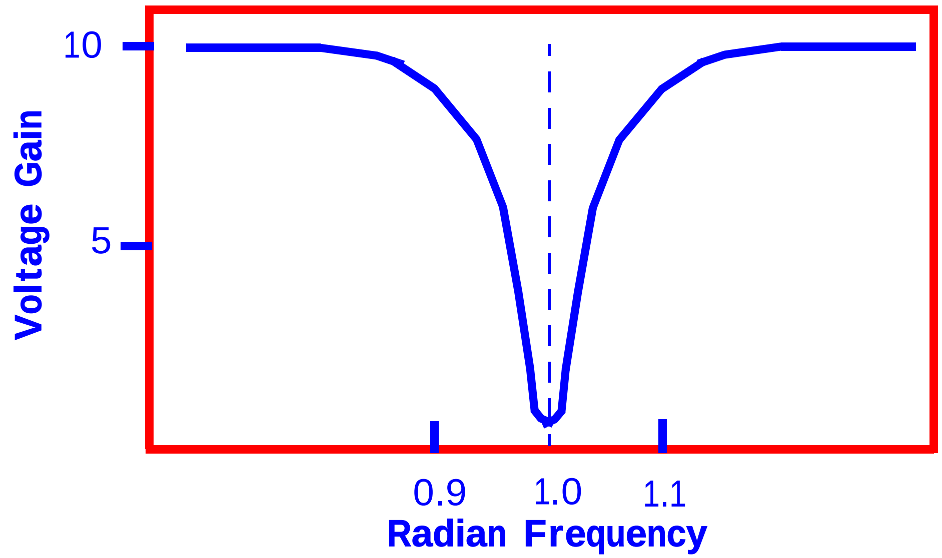
$$Q = \frac{\omega_O}{\omega_H - \omega_L} = \frac{f_O}{f_H - f_L} = \frac{f_O}{BW}.$$

$$A_V(s) = A_o \bullet \frac{s\frac{\omega_O}{Q}}{\left(s^2 + s\frac{\omega_O}{Q} + \omega_O^2\right)}$$

Poles - complex

$$\angle A_V(j\omega) = \angle A_o + 90^0 - \tan^{-1}\left(\frac{1}{Q}\frac{\omega\omega_O}{\omega_O^2 - \omega^2}\right)$$

Band-Rejection Amplifier (Read)



$$A_V(s) = \frac{A_o \bullet (s^2 + \omega_O^2)}{\left(s^2 + s\frac{\omega_O}{Q} + \omega_O^2\right)}$$. **Write expressions for mag. & phase?**

$$|A_V(j\omega)| = \frac{|A_o| \bullet \left|1 - \left(\frac{\omega}{\omega_O}\right)^2\right|}{\sqrt{\left(\left(1 - \frac{\omega^2}{\omega_O^2}\right)^2 + \left(\frac{\omega}{Q\omega_O}\right)^2\right)}} = \frac{A_o}{\sqrt{\left(1 + \frac{\omega_L^2}{\omega^2}\right)\left(1 + \frac{\omega^2}{\omega_H^2}\right)}}.$$

$$\angle A_V(j\omega) = \angle A_o + 90^0 - \tan^{-1}\left(\frac{1}{Q} \cdot \frac{\omega\omega_O}{\omega_O^2 - \omega^2}\right).$$

The All-Pass Function (Read)

$$A_V(s) = A_o\frac{(s-\omega_O)}{(s+\omega_O)}. \quad |A_V(j\omega)| = |A_o|.$$

$$\angle A_V(j\omega) = -2\tan^{-1}\left(\frac{\omega}{\omega_O}\right).$$