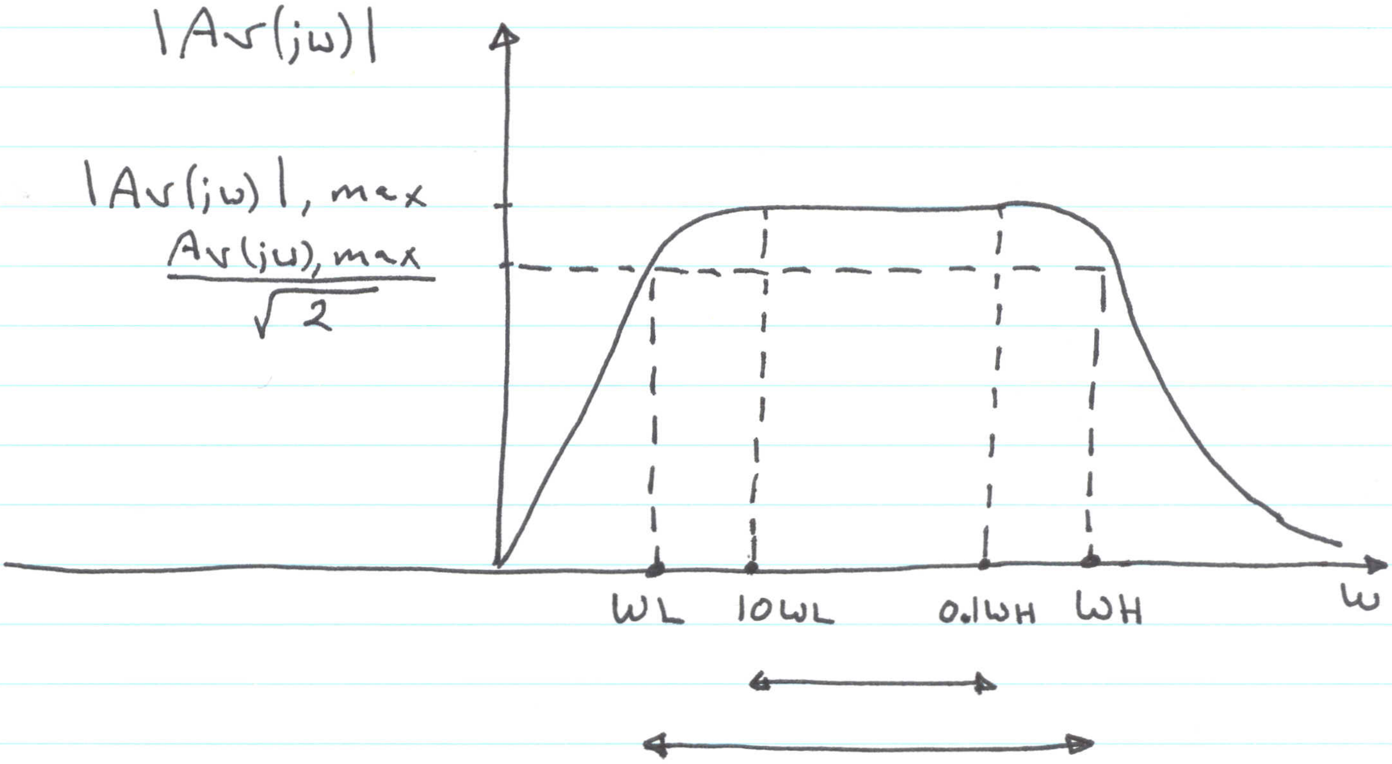
Frequency Response



ω_L : Lower cutoff frequency

ω_H : Upper cutoff frequency

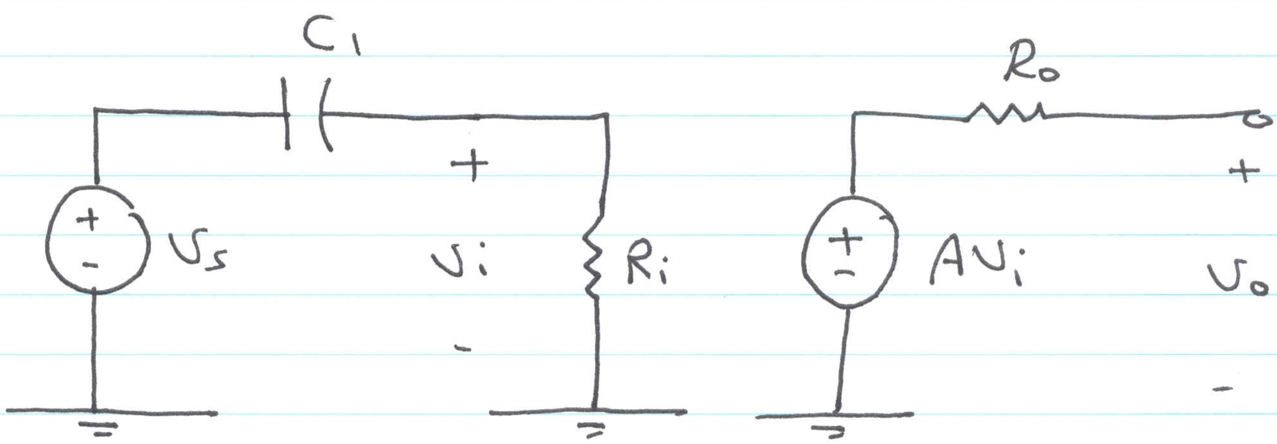
$$\left| A_v(j\omega) \right|_{\substack{\omega = \omega_L \\ \omega = \omega_H}} = \frac{|A_v(j\omega)|,_{max}}{\sqrt{2}} = \frac{|A_v|,_{mid}}{\sqrt{2}}$$

Bandwidth $= \omega_H - \omega_L$

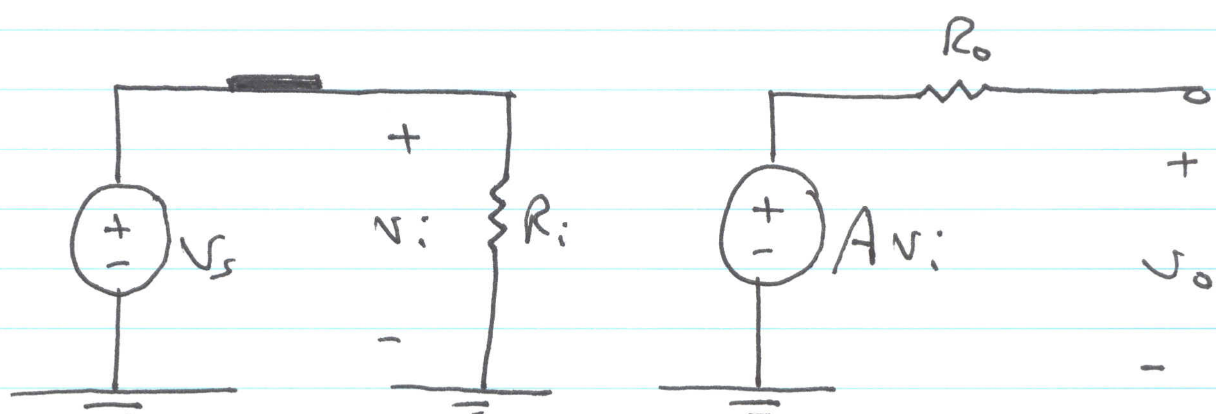
Midband range $= 0.1\omega_H - 10\omega_L$

- The signal passed through an ac amplifier is usually a Complex waveform Containing many different frequency Components, rather than a single frequency sinewave. For example, audio-frequency signal such as speech and music are Combination of many different sinewaves occuring simultaneously with different amplitude and different frequencies in the range from 20 Hz to 20 KHz.
- In order for an output to be an amplified version of the input, an amplifier must amplify every frequency Component in the Signal by the same amount.
- Bandwidth must Cover the entire range of frequency Components if undistorted amplification is to be achieved.

Series Capacitance and Low-frequency Response



1) At midband range

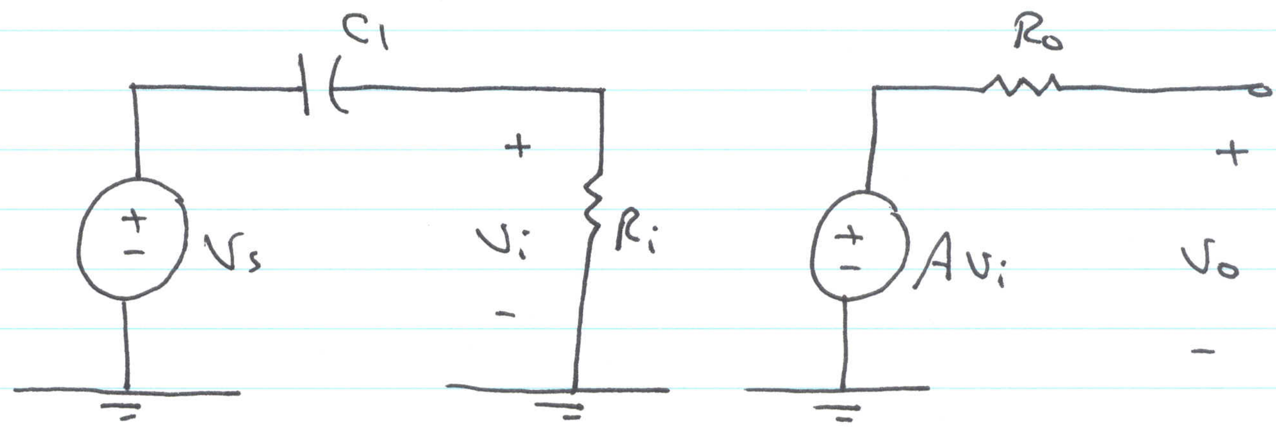


$$v_o = Av_i$$

$$v_i = v_s$$

$$\therefore \quad \frac{v_o}{v_i} = A = A_v(\text{mid})$$

2) At Low-frequency



$$\vec{V}_o = A\,\vec{V}_i$$

$$\vec{V}_i = \frac{R_i}{R_i + \frac{1}{j\omega C_1}}\,\vec{V}_s$$

$$\frac{\vec{V}_o}{\vec{V}_s} = A_v(j\omega) = A\,\frac{R_i}{R_i + \frac{1}{j\omega C_1}}$$

$$A_v(j\omega) = A\,\frac{1}{1 + \frac{1}{jR_i\omega C_1}}$$

$$|A_v(j\omega)| = A\,\frac{1}{\sqrt{1 + \left(\frac{1}{R_i\omega C_1}\right)^2}}$$

a) If $\omega \longrightarrow 0$; $|A_v(j\omega)| \longrightarrow 0$

b) If $\omega \longrightarrow \infty$; $|A_v(j\omega)| \longrightarrow A$

c) If $\omega = \frac{1}{R_i C}$; $|A_v(j\omega)| = \frac{A}{\sqrt{2}}$

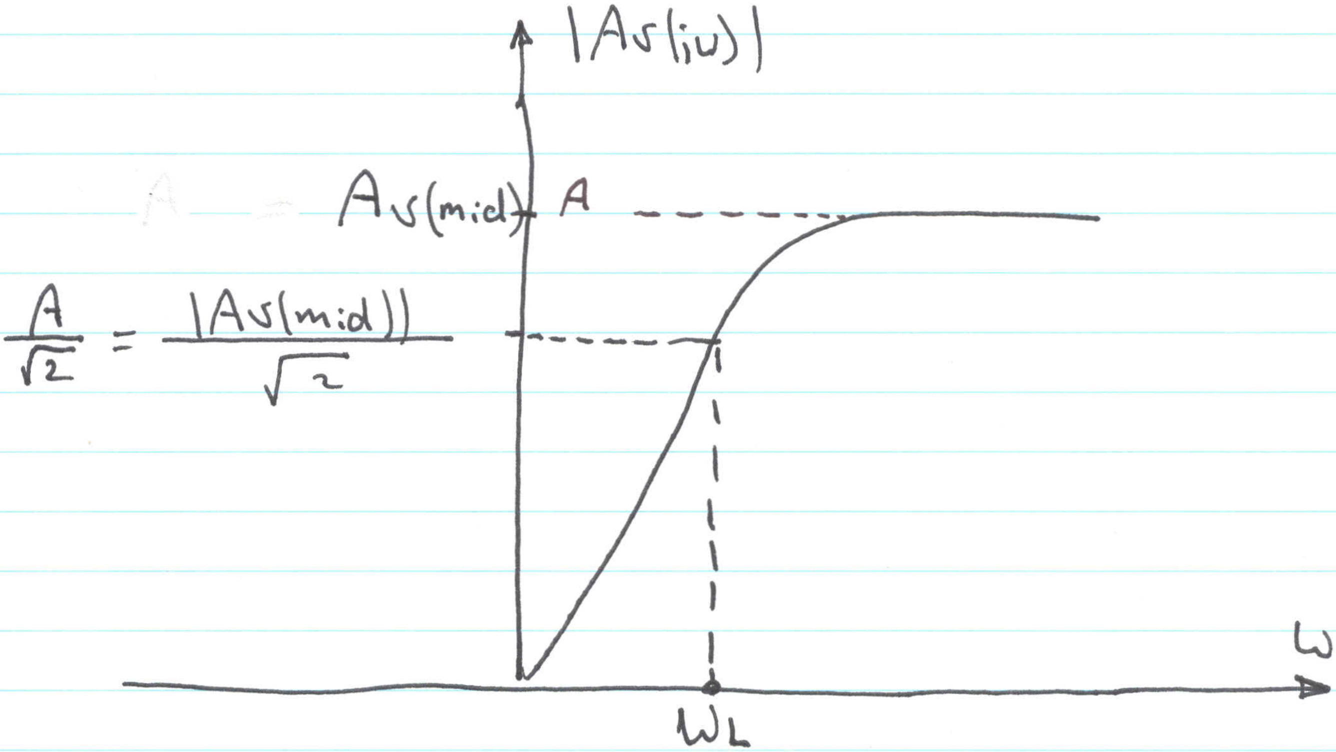
$$\therefore \quad \omega_L = \frac{1}{R_i C}$$

Let $\omega_{C_1} = \dfrac{1}{R_{TH} C_1}$

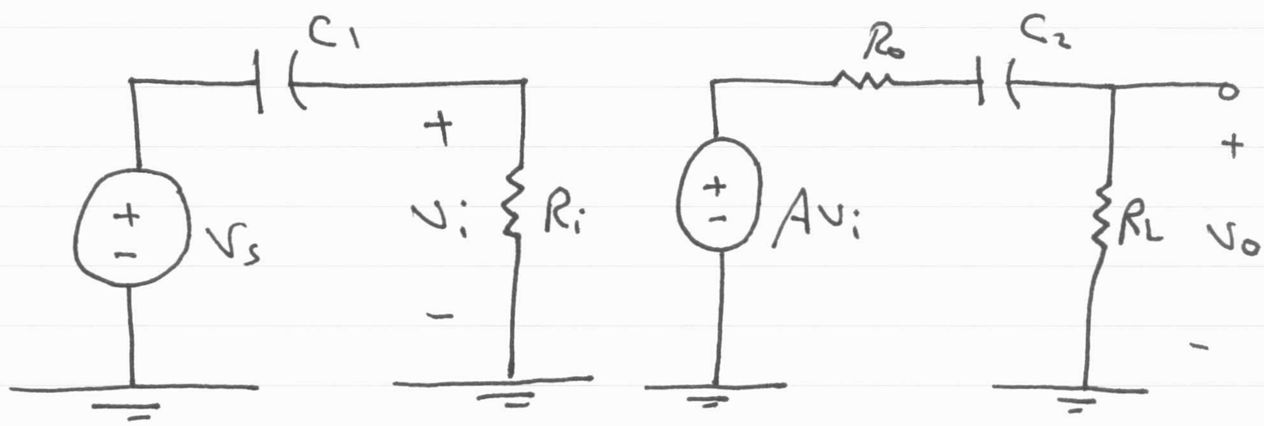
$$\omega_{C_1} = \frac{1}{R_i C_1}$$

$$\therefore \quad \omega_L = \omega_{C_1}$$

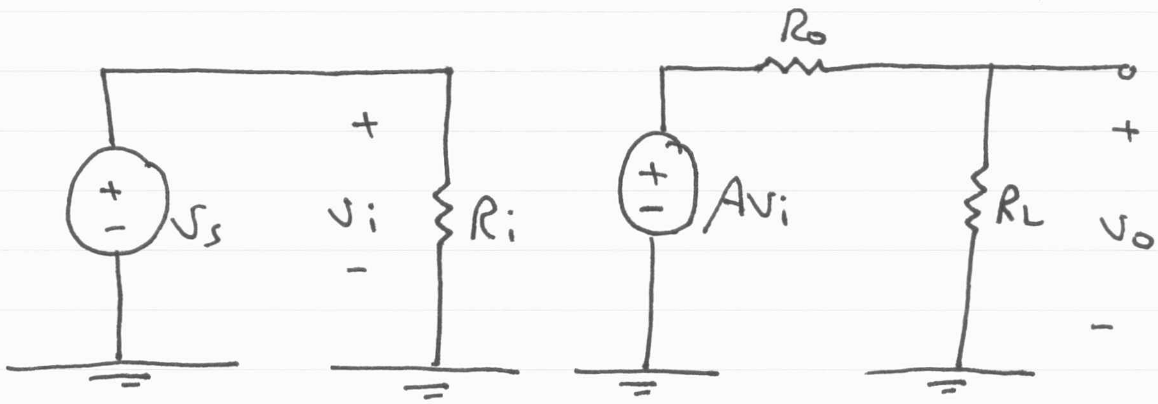
Where ω_{C_1} is the Corner frequency of C_1.



Input and output Coupling Capacitors



1) At midband range

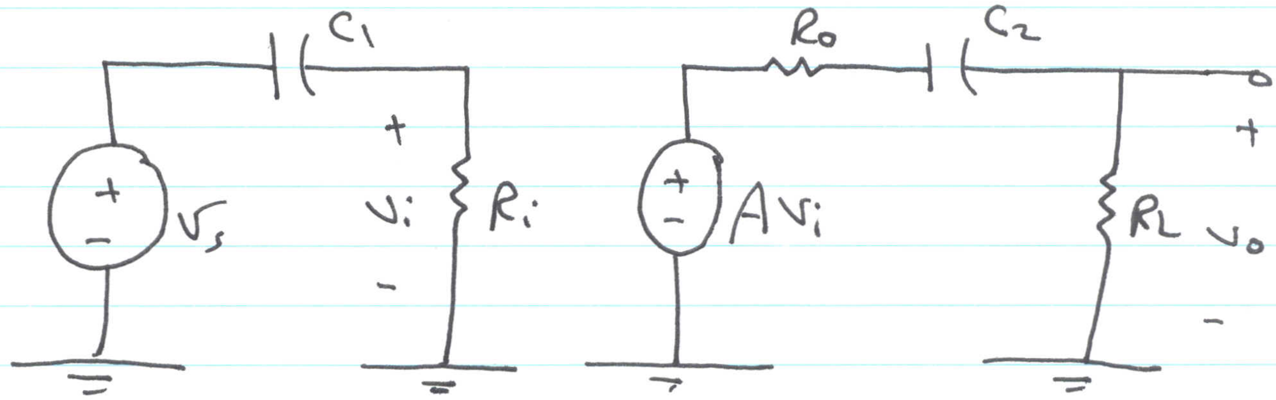


$$v_o = \frac{R_L}{R_L + R_o} A v_i$$

$$v_i = v_s$$

$$A_v(mid) = \frac{v_o}{v_s} = A \frac{R_L}{R_L + R_o}$$

2) At Low-frequency



$$\vec{V_o} = \frac{R_L}{R_L + R_o + \frac{1}{j\omega C_2}} A \vec{V_i}$$

$$\vec{V_i} = \frac{R_i}{R_i + \frac{1}{j\omega C_1}} V_s$$

$$A_v(j\omega) = \frac{\vec{V_o}}{\vec{V_s}} = A \frac{R_L}{R_L + R_o} \left(\frac{1}{1 + \frac{\omega_{c_1}}{j\omega}} \right) \left(\frac{1}{1 + \frac{\omega_{c_2}}{j\omega}} \right)$$

where $\omega_{c_1} = \frac{1}{R_i C_1}$

$$\omega_{c_2} = \frac{1}{(R_o + R_L) C_2}$$

$$\therefore A_v(j\omega) = A_v(\text{mid}) \left(\frac{1}{1 + \frac{\omega_{c_1}}{j\omega}} \right) \left(\frac{1}{1 + \frac{\omega_{c_2}}{j\omega}} \right)$$

$$\left| A_v(j\omega_L) \right| = \frac{A_v(\text{mid})}{\sqrt{2}}$$

$\therefore$

$$\left|\left(1+\frac{W_{c_1}}{jW_L}\right)\left(1+\frac{W_{c_2}}{jW_L}\right)\right| = \sqrt{2}$$

$$\therefore \quad W_L^2 = \frac{W_{c_1}^2 + W_{c_2}^2}{2} + \frac{\sqrt{W_{c_1}^4 + W_{c_2}^4 + 6W_{c_1}^2 W_{c_2}^2}}{2}$$

a) Let $W_{c_1} = 616$ r/s

$W_{c_2} = 17.86$ r/s

$\therefore W_L = 616.517$ r/s

b) Let $W_{c_1} = 200$ r/s

$W_{c_2} = 750$ r/s

$\therefore W_L = 798$ r/s

$\therefore$ if $W_{c_1} > W_{c_2} > W_{c_3}$

$\therefore W_{c_1} + W_{c_2} + W_{c_3} > W_L > W_{c_1}$

$$A_v(j\omega) = A_v(mid) \frac{1}{\left(1+\frac{\omega_{c1}}{j\omega}\right)\left(1+\frac{\omega_{c2}}{j\omega}\right)}$$

Let $\omega_{c1} > \omega_{c2}$; $\omega_L > \omega_{c1}$

$$\left|A_v(j\omega_L)\right| = \frac{A_v(mid)}{\left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\left(1+\frac{\omega_{c2}}{j\omega_L}\right)\right|}$$

$$\left|A_v(j\omega_L)\right| = \frac{A_v(mid)}{\sqrt{2}}$$

$$\therefore \left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\left(1+\frac{\omega_{c2}}{j\omega_L}\right)\right| = \sqrt{2}$$

since $\omega_{c1} > \omega_{c2}$, and $\omega_L > \omega_{c1}$

$$\left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\left(1+\cancelto{0}{\frac{\omega_{c2}}{j\omega_L}}\right)\right| = \sqrt{2}$$

$$\left|\left(1+\frac{\omega_{c1}}{j\omega_L}\right)\right| = \sqrt{2}$$

$$\sqrt{1+\left(\frac{\omega_{c_1}}{\omega_L}\right)^2} = \sqrt{2}$$

$\therefore \quad \omega_{c_1} = \omega_L$ (Lower Limit)

To find the upper Limit

$$\left| \left(1+\frac{\omega_{c_1}}{j\omega_L}\right)\left(1+\frac{\omega_{c_2}}{j\omega_L}\right) \right| = \sqrt{2}$$

$$\left| 1+\frac{\omega_{c_1}+\omega_{c_2}}{j\omega_L} - \frac{\omega_{c_1}}{\omega_L}\cdot\frac{\omega_{c_2}}{\omega_L} \right| = \sqrt{2}$$

But $\frac{\omega_{c_1}}{\omega_L} < 1$ and $\frac{\omega_{c_2}}{\omega_L} \ll 1$

$$\therefore \quad \frac{\omega_{c_1}}{\omega_L}\cdot\frac{\omega_{c_2}}{\omega_L} <<< 1$$

$$\therefore \text{ Let } \frac{\omega_{c_1}}{\omega_L}\cdot\frac{\omega_{c_2}}{\omega_L} \longrightarrow 0$$

$$\left| \left(1+\frac{\omega_{c_1}+\omega_{c_2}}{j\omega_L}\right) \right| = \sqrt{2}$$

$$\sqrt{1+\left(\frac{\omega_{c1}+\omega_{c2}}{\omega_L}\right)^2} = \sqrt{2}$$

$$\therefore \quad \frac{\omega_{c1}+\omega_{c2}}{\omega_L} = 1$$

$$\therefore \quad \omega_L = \omega_{c1} + \omega_{c2} \qquad \text{(upper Limit)}$$

$\therefore$ if $\omega_{c1} > \omega_{c2}$

$$\omega_{c1}+\omega_{c2} > \omega_L > \omega_{c1}$$