CENG4480
Lecture 03 Review

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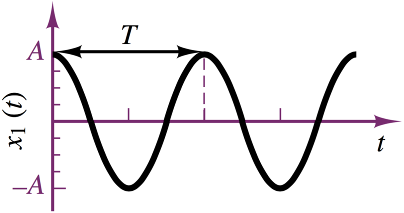
Sinusoidal Signal

$$x(t) = Acos(\omega t + \phi)$$

- Periodic signals
- A: amplitude
- ω: radian frequency
- ϕ: phase

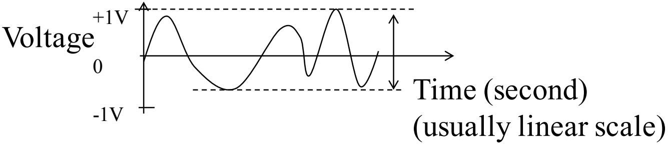


Time Domain

- Voltage gain against time

For sinusoidal signal:

$$v(t) = Acos(\omega t + \phi)$$

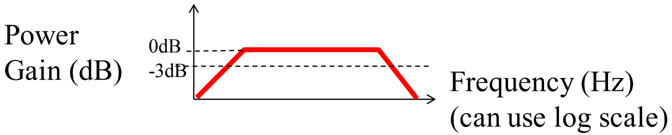


Frequency Domain

- Voltage gain against frequency

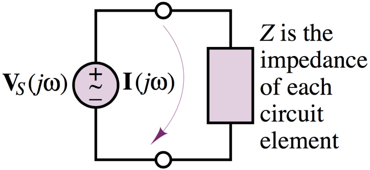
For sinusoidal signal:

$$\mathbf{V}(j\omega) = Ae^{j\phi} = A\angle\phi = Acos\phi + jAsin\phi$$



Impedance

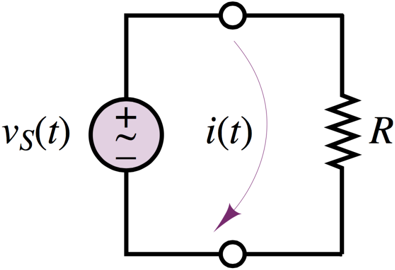
A complex resistance or *frequency-dependent resistance*. That is, as resistors whose resistance is a function of the frequency of the sinusoidal excitation.



AC circuits in phasor/impedance form

Resistor Impedance

- $\mathbf{V}(j\omega) = A\angle 0$
- $\mathbf{I}(j\omega) = \frac{A}{R}\angle 0$

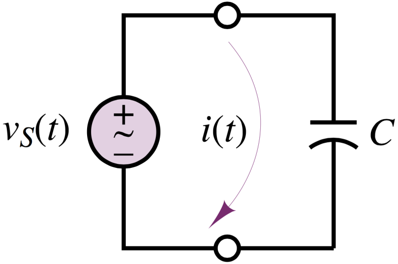


Impedance of A Resistor

$$Z_R(j\omega) = \frac{\mathbf{V}(j\omega)}{\mathbf{I}(j\omega)} = R\angle 0 = R$$

Capacitor Impedance

$$\mathbf{V}(j\omega) = A\angle 0$$
$$\mathbf{I}(j\omega) = \omega CA\angle \pi/2$$

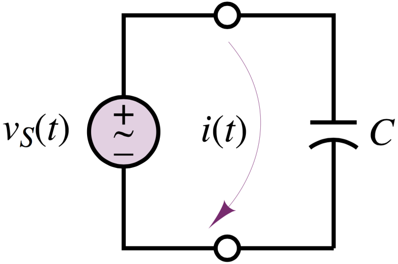


Impedance of A Capacitor

$$Z_C(j\omega) = \frac{\mathbf{V}(j\omega)}{\mathbf{I}(j\omega)}$$

Capacitor Impedance

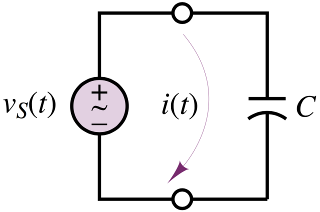
$$\mathbf{V}(j\omega) = A\angle 0$$
$$\mathbf{I}(j\omega) = \omega C A \angle \pi/2$$



Impedance of A Capacitor

$$Z_C(j\omega) = \frac{\mathbf{V}(j\omega)}{\mathbf{I}(j\omega)}$$
$$= \frac{1}{\omega C}\angle -\pi/2 = \frac{1}{\omega C}(cos - \pi/2 + jsin - \pi/2)$$
$$= \frac{-j}{\omega C} = \frac{1}{j\omega C}$$

$$Z_C(j\omega) = \frac{1}{j\omega C}$$



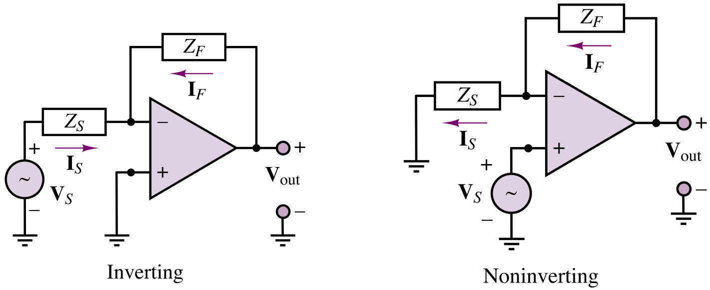
Capacitor Rule 1

Low Frequency $\Rightarrow$ Open circuit

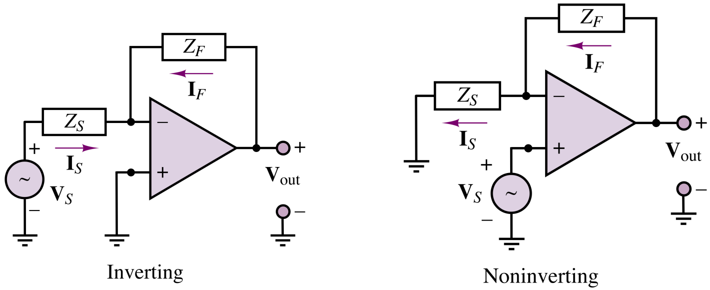
Capacitor Rule 2

High Frequency $\Rightarrow$ Short circuit

Frequency Response of An Op-Amp

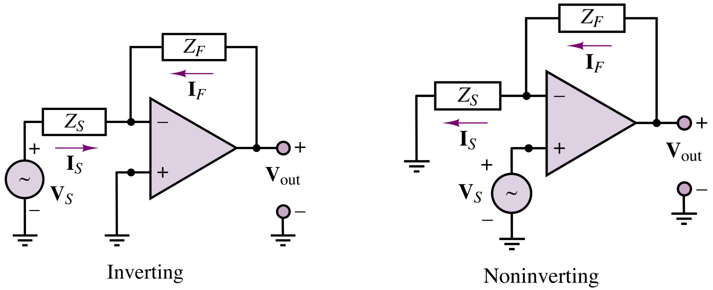


Frequency Response of An Op-Amp



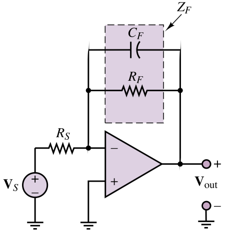
- Inverting amplifier: $\frac{V_{out}}{V_S}(j\omega) = -\frac{Z_F}{Z_S}$

Frequency Response of An Op-Amp

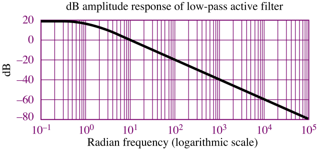


- Inverting amplifier: $\frac{V_{out}}{V_S}(j\omega) = -\frac{Z_F}{Z_S}$
- Non-Inverting amplifier: $\frac{V_{out}}{V_S}(j\omega) = 1 + \frac{Z_F}{Z_S}$

Low-Pass Filter



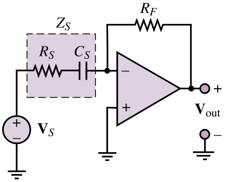
$$|A| = \frac{R_F}{R_S} \cdot \frac{1}{\sqrt{1 + w^2/w_c^2}}$$



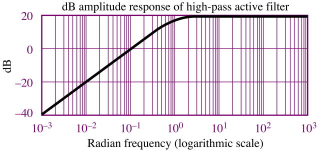
- $w_c = \dfrac{1}{R_F C_F}$
- **3-dB** frequency
- or **cutoff** frequency

BTW, $\lim_{\omega\to 0} |A| = \dfrac{R_F}{R_S}$, $\lim_{\omega\to\infty} |A| = 0$

High-Pass Filter



$$A(j\omega) = -\frac{Z_F}{Z_S} = -\frac{j\omega C_S R_F}{1 + j\omega C_S R_S}$$



$$\lim_{\omega \to 0} |A| = 0$$

$$\lim_{\omega \to \infty} |A| = \frac{R_F}{R_C}$$

High freq. cutoff unintentionally created by Op-amp