

**EE105 - Fall 2005**  
**Microelectronic Devices and Circuits**

**Lecture 18**

**Frequency-Domain Analysis**  
**Second-Order Circuits**

**Announcements**

- › **Homework 8 due next Tuesday**
- › **Lab 6 this week**
- › **Lab 7 next week**
- › **Reading: Chapter 10 (10.1)**

## Lecture Material

- › Last lecture
  - › Frequency-domain analysis
  - › Bode plots
- › This lecture
  - › More Bode plots
  - › Second order functions

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## Power Flow

- › **The instantaneous power flow into any element is the product of the voltage and current:**  $P(t) = i(t)v(t)$
- › **For a periodic excitation, the average power is:**

$$P_{av} = \int_T i(\tau)v(\tau)d\tau$$

- › **In terms of sinusoids we have**

$$P_{av} = \int_T |i| \cos(\omega t + \phi_i) |V| \cos(\omega t + \phi_v) dt$$

$$= |i| \cdot |V| \int_T (\cos \omega t \cos \phi_i - \sin \omega t \sin \phi_i) \cdot (\cos \omega t \cos \phi_v - \sin \omega t \sin \phi_v) dt$$

$$= |i| \cdot |V| \int_T dt \cos^2 \omega t \cos \phi_i \cos \phi_v + \sin^2 \sin \phi_i \sin \phi_v + c \sin \omega t \cos \omega t$$

$$= \frac{|i| \cdot |V|}{2} (\cos \phi_i \cos \phi_v + \sin \phi_i \sin \phi_v) = \frac{|i| \cdot |V|}{2} \cos(\phi_i - \phi_v)$$

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## Power Flow with Phasors

$$P_{av} = \frac{|I| \cdot |V|}{2} \cos(\phi_i - \phi_v)$$

↑  
Power Factor

- › **Note that if  $(\phi_i - \phi_v) = \frac{\pi}{2}$ , then**  $P_{av} = \frac{|I| \cdot |V|}{2} \cos(\pi/2) = 0$
- › **From the previous slide:**

$$P = \frac{|I| \cdot |V|}{2} \cos(\phi_i - \phi_v) = \frac{1}{2} \operatorname{Re}[I \cdot V^*] = \frac{1}{2} \operatorname{Re}[I^* \cdot V]$$

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## More Power

- › **In terms of the circuit impedance we have:**

$$\begin{aligned} P &= \frac{1}{2} \operatorname{Re}[I \cdot V^*] = \frac{1}{2} \operatorname{Re}\left[\frac{V}{Z} \cdot V^*\right] = \frac{|V|^2}{2} \operatorname{Re}[Z^{-1}] \\ &= \frac{|V|^2}{2} \operatorname{Re}\left[\frac{Z^*}{|Z|^2}\right] = \frac{|V|^2}{2|Z|^2} \operatorname{Re}[Z^*] = \frac{|V|^2}{2|Z|^2} \operatorname{Re}[Z] \end{aligned}$$

- › **Check the result for a real impedance (resistor)**
- › **Also, in terms of current:**

$$P = \frac{1}{2} \operatorname{Re}[I^* \cdot V] = \frac{1}{2} \operatorname{Re}[I^* \cdot I \cdot Z] = \frac{|I|^2}{2} \operatorname{Re}[Z]$$

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