Analyze & Design Circuits to Maximize Power Delivery

Learning goals

- Physical meaning of power
- Compute power delivered to a component
  - Given circuit diagram and component values
  - Compute power (analysis step)
- Design circuits to maximize power delivery to a component
  - Given circuit diagram
  - Determine component values

Physical meaning

- Home electricity bill
  - Bring a bill to class
- Power to run desktop vs. laptop computers
  - Which consumes more?
  - Find how much power a Pentium CPU needs
- Maximizing power: why?
  - Reduce power waste
  - Get better radio reception (more power received)
  - Make speakers sound louder
    - Find speaker input impedance as an exercise

Procedure to compute power

- Compute using general definitions
  - Valid in ALL cases
  - Instantaneous power p(t)
    - Function of time
    - p(t) = v(t) i(t)
  - Average power P_{av}
    - Average value of p(t) over a time interval T (e.g. average power use at home in one month)
    - NOT a function of time

$$P_{ave} = \frac{1}{T}\int_0^T p(t)dt$$

In-class exercises

- Compute average power in components with sinusoidal signals
  - Given $V(t) = V_m \cos(\omega t + \phi)$
  - Average power consumed by R
  - Average power consumed by L
  - Average power consumed by C
- Observations
  - Why $P_{av}=0$ for L and C?
  - Faster way to compute average power for specific case of sinusoidal signals?

P_{av} consumed by R

- DC case
  - $P = V I = V^2/R = RI^2$
- Sinusoidal case from previous calculation
  - $P_{av} = V_m I_m/2 = V_m^2/(2R) = R(I_m^2/2)$
- One 'general formula' for both cases?
  - Use a Root-Mean-Square value for v(t) and i(t)
  - RMS definition for any signal v(t)

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

In-class exercises

- Compute V_{RMS} for
  - $V(t) = V_m \cos(\omega t + \phi)$
- Sinusoidal case with amplitude V_m and I_m

$$V_{RMS} = V_m / \sqrt{2}$$

$$I_{RMS} = I_m / \sqrt{2}$$

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Revisit P_{av} by R

- DC case
  - $P = V I = V^2/R = RI^2$
- Sinusoidal case from previous calculation
  - $P_{av} = V_m I_m/2 = V_m^2/(2R) = R(I_m^2/2)$
- Use RMS value
  - $P_{av} = V_m I_m/2 = V_m^2/(2R) = (V_{RMS}^2)/R = RI_{RMS}^2$
- Same 'general form' using DC value and RMS value

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Superposition note

- Apply 2 or more sources to a component
  - For each source, calculate v(t) and i(t) for the component
  - Sum all v(t) to get total V(t) across the component
  - Sum all i(t) to get total I(t) into the component
  - P(t) = V(t) I(t). Calculate P_{av} from P(t).
- Do NOT calculate p(t) for each source and sum to get P(t)!!!

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Maximum power transfer

- Circuit with sinusoidal signals
  - Thevenin equivalent: V_t, $Z_t = R_t + jX_t$
  - Load: $Z_L = R_L + jX_L$
- Design the load Z_L to maximize power delivered to the load
  - $Z_L = Z_t^*$ or [$R_L = R_t$, $X_L = -X_t$]
  - Calculate maximum power for this case

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Design problem

- R = 800 Ω, L = 1.6H

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