Chapter 20

AC Network Theorems

Superposition Theorem

- Voltage across (or current through) an element
  - Determined by summing voltage (or current) due to each independent source
- All sources (except dependent sources) other than the one being considered are eliminated

Superposition Theorem

- Replace current sources with opens
- Replace voltage sources with shorts

Superposition Theorem

- Circuit may operate at more than one frequency at a time
- Superposition is the only analysis method that can be used in this case
- Reactances must be recalculated for each different frequency

Superposition Theorem

- Diode and transistor circuits will have both dc and ac sources
- Superposition can still be applied

5

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Superposition Theorem

- Superposition theorem can be applied only to voltage and current
- It cannot be used to solve for total power dissipated by an element
- Power is not a linear quantity
  - Follows a square-law relationship

6

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Superposition for Dependent Sources

- If controlling element is external to the circuit under consideration
  - Method is the same as for independent sources

Superposition for Dependent Sources

- Simply remove sources one at a time and solve for desired voltage or current
- Combine the results

Superposition for Dependent Sources

- If the dependent source is controlled by an element located in the circuit
  - Analysis is different
  - Dependent source cannot be eliminated

Superposition for Dependent Sources

- Circuit must be analyzed by considering all effects simultaneously

Thévenin’s Theorem

- Converts an ac circuit into a single ac voltage source in series with an equivalent impedance
- First, identify and remove the element or elements across which the equivalent circuit is to be found

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Thévenin’s Theorem

- Label two open terminals
- Set all sources to zero
  - Replace voltage sources with shorts
  - Current sources with opens

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Thévenin's Theorem

- Calculate the Thévenin equivalent impedance
- Replace the sources and determine open-circuit voltage

Thévenin's Theorem

- If more than one source is involved
  - Superposition may be used
- Draw resulting Thévenin equivalent circuit
  - Including the portion removed

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Norton's Theorem

- Converts an ac network into an equivalent circuit
  - Consists of a single current source and a parallel impedance
- First, identify and remove the element or elements across which the Norton circuit is to be found

15

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Norton's Theorem

- Label the open terminals
- Set all sources to zero

16

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Norton’s Theorem

- Determine Norton equivalent impedance
- Replace sources and calculate short-circuit current

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Norton’s Theorem

- Superposition may be used for multiple sources
- Draw resulting Norton circuit
  – Including portion removed

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Thévenin and Norton Circuits

- Possible to find Norton equivalent circuit from Thévenin equivalent circuit
  - Use source transformation method
- $\mathbf{Z}_N = \mathbf{Z}_{Th}$
- $\mathbf{I}_N = \mathbf{E}_{Th}/\mathbf{Z}_{Th}$

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Thévenin's and Norton's Theorems

- If a circuit contains a dependent source controlled by an element outside the area of interest
  - Previous methods can be used to find the Thévenin or Norton circuit

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Thévenin’s and Norton’s Theorems

- If a circuit contains a dependent source controlled by an element in the circuit
  - Other methods must be used

Thevenin’s and Norton’s Theorems

- If a circuit has a dependent source controlled by an element in the circuit
  - Use following steps to determine equivalent circuit

Thevenin's and Norton's Theorems

- First
  - Identify and remove branch across equivalent circuit is to be determined
- Label the open terminals

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Thevenin's and Norton's Theorems

- Calculate open-circuit voltage
  - Dependent source cannot be set to zero
  - Its effects must be considered
- Determine the short-circuit current

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Thevenin's and Norton's Theorems

- $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{E}_{Th}/\mathbf{I}_N$
- Draw equivalent circuit, replacing the removed branch

Thevenin's and Norton's Theorems

- A circuit may have more than one independent source
- It is necessary to determine the open-circuit voltage and short-circuit current due to each independent source

Thevenin's and Norton's Theorems

- Effects of dependent source must be considered simultaneously

Maximum Power Transfer Theorem

- Maximum power
  - Delivered to a load when the load impedance is the complex conjugate of the Thévenin or Norton impedance

Maximum Power Transfer Theorem

- $\mathbf{Z}_{Th} = 3\Omega + j4\Omega$ $\mathbf{Z}_L = \mathbf{Z}_{Th}^* = 3\Omega - j4\Omega$
- $\mathbf{Z}_{Th} = 10\ \Omega\angle 30°$ $\mathbf{Z}_L = \mathbf{Z}_{Th}^* = 10\ \Omega\angle -30°$

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Maximum Power Transfer Theorem

- If the $\mathbf{Z}_L$ is the complex conjugate of $\mathbf{Z}_{Th}$ or $\mathbf{Z}_N$

$$P_L = \frac{E_{Th}^2 R_L}{(R_{Th} + R_L)^2}$$

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}}$$

$$P_{max} = \frac{I_N^2 Z_N^2}{4R_N}$$

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Relative Maximum Power

- If it is not possible to adjust reactance part of a load
  - A relative maximum power will be delivered
- Load resistance has a value determined by

$$R_L = \sqrt{R_{\mathbf{Th}}^{\ 2} + \left(X \pm X_{\mathbf{Th}}\right)^2}$$

31

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