Chapter 07
Series-Parallel Circuits

The Series-Parallel Network

- Complex circuits
  - May be separated both series and/or parallel elements
  - Combinations which are neither series nor parallel
- To analyze a circuit
  - Identify elements in series and elements in parallel

For example:
$R_2$, $R_3$, and $R_4$ are in parallel,
Series with $R_1$ and $R_5$

$R_T = R_1 + \left( R_2 \parallel R_3 \parallel R_4 \right) + R_5$

Analysis of Series-Parallel Circuits

Rules for analyzing series and parallel circuits apply:
- **Same current occurs throughout all series elements**
- **Same voltage occurs across all parallel elements**
- KVL and KCL apply for all circuits

Steps to simplify a circuit:
- Redraw complicated circuits showing the source at the left-hand side and then label all nodes
- Simplify recognizable combinations of components
- Determine equivalent resistance $R_T$ and solve for the total current
- Label polarities of voltage drops on all components
- Calculate how currents and voltages split between elements in a circuit
- Verify your answer by taking a different approach
Example: Analysis of Series-Parallel Circuits

- Combining $R_2$ and $R_3$ in parallel
- Circuit reduces to a series circuit
- Use Voltage Divider Rule to determine $V_{ab}$ and $V_{bc}$
- Note that $V_{bc} = V_2$ is the voltage across $R_2$ and $R_3$
- Calculate all currents from Ohm's Law.

Find the voltage $V_{ab}$

- Redraw circuit in simple form
- Determined by combination of voltages across $R_1$ and $R_2$, or $R_3$ and $R_4$ (use voltage divider rule)

Find currents in the circuit

- First redraw the circuit and move source branch all the way to left and reduce circuit to a series circuit
- Voltages: Use Ohm's Law or Voltage Divider Rule
- Currents: Use Ohm's Law or Current Divider Rule

Find $V_{ab}$

- Redraw circuit in simple form
- Determined by combination of voltages across $R_1$ and $R_2$, or $R_3$ and $R_4$ (use voltage divider rule)
Example: Analysis of Series-Parallel Circuits

Find $V_{ab}$

\[ V_{ab} = V_a - V_b = 8V - 0V = 8V \]

\[ I = \frac{10}{(50+200) // 5k} = \frac{10}{238} = 42.2\,mA \]

Example: Bridge Circuit

- Determine $V_{ab}$ and $I$ if $R_x$ is a short circuit (0 $\Omega$)
  \[ V_{ab} = V_2 - V_1 = 8V - 0V = 8V \]
  \[ I = \frac{10}{(50+200) // 5k} = \frac{10}{238} = 42.2\,mA \]

- Determine $V_{ab}$ and $I$ if circuit has $R_x = 15$ k$\Omega$
  \[ V_{ab} = V_2 - V_1 = 8V - 7.5V = 0.5V \]
  \[ I = \frac{10}{(50+200) / (5k+15k)} = \frac{10}{247} = 40.5\,mA \]

- Determine $V_{ab}$ and $I$ if $R_x$ is open
  \[ V_{ab} = V_2 - V_1 = 8V - 10V = -2V \]
  \[ I = \frac{10}{50+200} = \frac{10}{250} = 40\,mA \]
**Transistor Circuit**

Transistor is a device that amplifies a signal.
- Operating point of a transistor circuit is determined by a dc voltage source.

Determine some dc voltages and currents.
- Apply KVL: $V_{cc} = R_B I_B + V_{be} + R_E I_E$
- Using $I_E = 100 I_B$, we find $I_B = 14.3 \, \mu A$.

**Potentiometers**

- Example of variable resistor used as potentiometer.
- Moveable terminal is at uppermost position then $V_{bc} = 60 \, \text{V}$. 
- At the lowermost position then $V_{bc} = 0 \, \text{V}$.

**Load Effects of Instruments**

Actual value
$V_{RI} = 27 \, \text{V} \times \frac{5 \, \text{M} / (5 \, \text{M} + 10 \, \text{M})}{5 \, \text{M} / (5 \, \text{M} + 10 \, \text{M})} = 6.75 \, \text{V}$

Reading value
$V_{RI} = 27 \, \text{V} \times \frac{3.3 \, \text{M} / (3.3 \, \text{M} + 10 \, \text{M})}{5 \, \text{M} / (5 \, \text{M} + 10 \, \text{M})} = 6.75 \, \text{V}$

Loading effect
$= (9 - 6.75) / 9 = 25\%$
Example: Load Effects of Instruments

Actual value

\[ V_{R2} = 27V \times \frac{10M}{(5M+10M)} = 18V \]

Reading value

\[ V_{R2} = 27V \times \frac{5M}{(5M+5M)} = 13.5V \]

Loading effect

\[ \frac{(18 - 13.5)}{18} = 25\% \]

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Circuit Analysis Using Multisim

Use Multisim to find the following quantities for the circuit shown

a) Total resistance, \( R_T \)

b) Voltages \( V_2 \) and \( V_4 \)

c) Currents \( I_T, I_1 \), and \( I_2 \)

Get \( R_T \) Using Multisim

- Construct the circuit for determining the total resistance \( R_T \)
Get Voltages and currents Using Multisim

Kernel abilities

1. Can recognize which parts are in series or parallel for a series-parallel circuit.
2. Can compute the total resistance $R_t$ of resistors $R_1 \sim R_n$ in series-parallel.
4. Can recognize the voltage divider and current divider for applying a series-parallel circuit.
5. Can recognize the loading effect for measuring voltage and current.

Problem 10: **Find** $R_{ab}$ and $R_{bc}$

Problem 35: **Find** $E$
Problem 37: Find the reading of ammeter