Chapter 3

Resistance

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Resistance of Conductors

- Resistance of material is dependent on several factors:
  - Type of Material
  - Length of the Conductor
  - Cross-sectional area
  - Temperature

Type of Material

- Atomic differences of materials cause variations in how electron collisions affect resistance
- Differences produce resistivity

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Type of Material

- Represented by the symbol ρ
  - (Greek letter rho)
- Units of ρ
  - Ohms x meters ($\Omega \cdot m$) or (circular mils x ohms)/feet ($\Omega \cdot CM/ft$)

Length

- Resistance of a conductor
  - Directly proportional to its length
  - If you double the length of the wire, the resistance will double
- ℓ = length
  - In meters or feet

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Area

- Resistance of a conductor
  - Inversely proportional to cross-sectional area of the conductor
- If cross-sectional area is doubled
  - Resistance will be one half as much

Area

- ***A*** =
  - Cross-sectional area, in m^2 or circular mils (CM)

Resistance Formula

- At a given temperature (usually 20 ^{o} C)

$$R = \frac{\rho \ell}{A}$$

- Formula can be used with both circular and rectangular conductors

Electrical Wire Tables

- American Wire Gauge is primary system to denote wire diameters
- The higher the AWG number, the smaller the diameter

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Electrical Wire Tables

- A given length of AWG 22 wire will have more resistance than the same length of AWG 14 wire
- Larger gauge wires can handle more current

Circular Mils (CM)

- Length may also be in mils (0.001 inch)
- Area may be in circular mils (CM)
- 1 CM
  - Area of a circle having a diameter of 1 mil

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Circular Mils (CM)

- 1 square mil
  - Area of a square having sides of 1 mil
- 1 CM =
  - $\pi/4$ square mils

Temperature Effects

- For most conductors, a temperature increase causes an increase in resistance
- Increase is relatively linear
- In semiconductors and insulators
  - Increase in temperature results in decrease in resistance

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Temperature Effects

- Any material for which the resistance increases with temperature is said to have a positive temperature coefficient
- If it decreases, it has a negative coefficient

Temperature Effects

- Temperature coefficient
  - Rate of change of resistance with respect to temperature
- It is represented by α (Greek letter alpha)

Temperature Effects

- Resistance at a specific temperature (***R***) may be calculated from resistance at a different temperature ($\boldsymbol{R}_1$) by the formula:

$$R = R_1\left[1+\alpha\Delta T\right]$$

Temperature Effects

- Where ΔT =
  - $T - T_1$ is the difference between the two temperatures in Celsius degrees

Fixed Resistors

- Resistance of a fixed resistor is constant over a wide temperature range
- Rated by amount of resistance
  - Measured in ohms (Ω)
- Also rated by power
  - Measured in watts (W)

Fixed Resistors

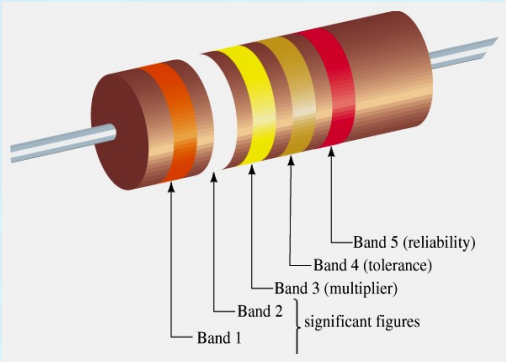
- Different resistors for different applications
  - Molded carbon composition
  - Carbon film
  - Metal film
  - Metal Oxide
  - Wire-Wound
  - Integrated circuit packages

Variable Resistors

- Resistance may be changed (varied)
  - Adjust volume, set level of lighting, adjust temperature
- Have three terminals
  - Center terminal connected to wiper arm
- Potentiometers
- Rheostats

Color Code

- Colored bands on a resistor provide a code for determining
  - Value
  - Tolerance
  - Reliability



Measuring Resistance

- Ohmmeter
- Remove all power sources to circuit
- Isolate component
- Connect probes across component
- No need to worry about polarity
- Ohmmeter determines shorts and opens

Thermistors

- Two-terminal transducer
  - Resistance changes with temperature
- Applications include electronic thermometers and thermostatic control circuits for furnaces

Thermistors

- Most have negative temperature coefficients

Photoconductive Cells

- Two-terminal transducers
  - Resistance determined by amount of light
- May be used to measure light intensity or to control lighting
- Used in security systems
- Linear response (negative slope)

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Diodes

- Semiconductor devices
  - Conduct in one direction only
  - In forward direction, has very little resistance
  - In reverse direction, resistance is very high
    - Open circuit

Varistors

- Resistors sensitive to voltage
- High resistance when voltage is below breakdown value
- Low resistance when voltage is above breakdown value
- High power ratings
  - When used in surge protectors

Conductance

- Measure of a material's ability to allow flow of electrical current
- Conductance is reciprocal of resistance
- $G = 1/R$
- Unit is siemens (S)

Superconductors

- Low temperatures
  - Resistance of some materials goes to almost zero
- Temperature is called critical temperature

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Superconductors

- Meissner Effect
  - Cooled below its critical temperature
  - Magnetic fields may surround but not enter the superconductor