Resistors

Topics Covered in Chapter 2
2-1: Types of Resistors
2-2: Resistor Color Coding
2-3: Variable Resistors
2-4: Rheostats and Potentiometers
2-5: Power Ratings of Resistors
2-6: Resistor Troubles
2-1: Types of Resistors

- The two main characteristics of a resistor are its resistance, $R$, in ohms and its power rating, $P$, in Watts.

- The resistance, $R$, provides the required reduction in current or the desired drop in voltage.

- The wattage rating indicates the amount of power the resistor can safely dissipate as heat. The wattage rating is always more than the actual amount of power dissipated by the resistor, as a safety factor.
2-1: Types of Resistors

- Types of Resistors
  - Wire-wound resistors
  - Carbon-composition resistors
  - Film-type resistors
    - Carbon film
    - Metal film
  - Surface-mount resistors (chip resistors)
  - Fusible resistors
  - Thermistors
2-1: Types of Resistors

- Wire Wound Resistor
  - Special resistance wire is wrapped around an insulating core, typically porcelain, cement, or pressed paper.
  - These resistors are typically used for high-current applications with low resistance and appreciable power.

Fig. 2-3: Large wire-wound resistors with 50-W power ratings. (a) Fixed $R$, length of 5 in. (b) Variable $R$, diameter of 3 in.
2-1: Types of Resistors

- Carbon Composition Resistors
  - Made of carbon or graphite mixed with a powdered insulating material.
  - Metal caps with tinned copper wire (called axial leads) are joined to the ends of the carbon resistance element. They are used for soldering the connections into a circuit.
  - Becoming obsolete because of the development of carbon-film resistors.

Fig. 2-2: Carbon resistors with the same physical size but different resistance values. The physical size indicates a power rating of ½ W.
2-1: Types of Resistors

Carbon Film Resistors

- Compared to carbon composition resistors, carbon-film resistors have tighter tolerances, are less sensitive to temperature changes and aging, and generate less noise.

Fig. 2-4: Construction of a carbon film resistor.
2-1: Types of Resistors

- Metal Film Resistors
  - Metal film resistors have very tight tolerances, are less sensitive to temperature changes and aging, and generate less noise.

Fig. 2-5: Construction of a metal film resistor.
2-1: Types of Resistors

- Surface-Mount Resistors (also called chip resistors)
  - These resistors are:
    - Temperature-stable and rugged
    - Their end electrodes are soldered directly to a circuit board.
    - Much smaller than conventional resistors with axial leads.

Fig. 2-6: Typical chip resistors.
2-1: Types of Resistors

- Fusible Resistors:
  
  Fusible resistors are wire-wound resistors made to burn open easily when the power rating is exceeded. They serve a dual function as both a fuse and a resistor.
2-1: Types of Resistors

- Thermistors:
  - **Thermistors** are temperature-sensitive resistors whose resistance value changes with changes in operating temperature.
  - Used in electronic circuits where temperature measurement, control, and compensation are desired.

Fig. 2-7b: Typical thermistor shapes and sizes.
Carbon resistors are small, so their $R$ value in ohms is marked using a color-coding system.

- Colors represent numerical values.

- Coding is standardized by the Electronic Industries Alliance (EIA).
2-2: Resistor Color Coding

- Resistor Color Code

![Resistor Color Code Diagram]

Fig. 2-8: How to read color stripes on carbon resistors for $R$ in ohms.
2-2: Resistor Color Coding

- Resistors under 10 Ω:
  - The multiplier band is either gold or silver.
  - For gold, multiply by 0.1.
  - For silver, multiply by 0.01.

Fig. 2-9: Examples of color-coded $R$ values, with percent tolerance.
2-2: Resistor Color Coding

- Applying the Color Code

- The amount by which the actual $R$ can differ from the color-coded value is its tolerance. Tolerance is usually stated in percentages.

Yellow = 4

4700Ω is the nominal value.
What is the nominal value and permissible ohmic range for each resistor shown?

- 1 kΩ (950 to 1050 Ω)
- 390 Ω (370.5 to 409.5 Ω)
- 22 kΩ (20.9 to 23.1 kΩ)
- 1 MΩ (950 kΩ to 1.05 MΩ)
2-2: Resistor Color Coding

- Five-Band Color Code
  - Precision resistors often use a five-band code to obtain more accurate $R$ values.
  - The first three stripes indicate the first 3 digits in the $R$ value.
  - The fourth stripe is the multiplier.
  - The tolerance is given by the fifth stripe.
    - Brown = 1%
    - Red = 2%
    - Green = 0.5%
    - Blue = 0.25%
    - Violet = 0.1%.

Fig. 2-10: Five-band code.
Zero-Ohm Resistor

- Has zero ohms of resistance.
- Used for connecting two points on a printed-circuit board.
- Body has a single black band around it.
- Wattage ratings are typically 1/8- or 1/4-watt.

Fig. 2-11: A zero-ohm resistor is indicated by a single black color band around the body of the resistor.
2-3: Variable Resistors

- A variable resistor is a resistor whose resistance value can be changed.
2-4: Rheostats and Potentiometers

- Rheostats and potentiometers are variable resistances used to vary the amount of current or voltage in a circuit.
  - Rheostats:
    - Two terminals.
    - Connected in series with the load and the voltage source.
    - Varies the current.
Potentiometers:
- Three terminals.
- Ends connected across the voltage source.
- Third variable arm taps off part of the voltage.
Rheostats are two-terminal devices.

- Wiper arm
- Wiping contact
- Fixed contact
Using a Rheostat to Control Current Flow

- The rheostat must have a wattage rating high enough for the maximum $I$ when $R$ is minimum.

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Fig. 2-17: Rheostat connected in series circuit to vary the current $I$. Symbol for the current meter is A, for amperes. (a) Wiring diagram with digital meter for $I$. (b) Schematic diagram.
2-4: Rheostats and Potentiometers

- Potentiometers
  - Potentiometers are three-terminal devices.
  - The applied $V$ is input to the two end terminals of the potentiometer.
  - The variable $V$ is output between the variable arm and an end terminal.

Fig. 2-18: Potentiometer connected across voltage source to function as a voltage divider. (a) Wiring diagram. (b) Schematic diagram.
2-5: Power Rating of Resistors

- In addition to having the required ohms value, a resistor should have a wattage rating high enough to dissipate the power produced by the current without becoming too hot.
- Power rating depends on the resistor’s construction.
- A larger physical size indicates a higher power rating.
- Higher-wattage resistors can operate at higher temperatures.
- Wire-wound resistors are physically larger and have higher power ratings than carbon resistors.
Resistor Troubles

- Resistors can become open or they can drift out of tolerance.

- Some controls (especially volume and tone controls) may become noisy or scratchy-sounding, indicating a dirty or worn-out resistance element.

- Due to the very nature of their construction, resistors can short out internally. They may, however, become short-circuited by another component in the circuit.
2-6: Resistor Troubles

An open resistor measures infinite resistance.

\[ \infty \Omega \]

An example of an out-of-tolerance resistor:

1 kΩ, 5% nominal

[Diagram representing a resistor with a nominal resistance of 1 kΩ and an actual resistance of 1.5 kΩ]
2-6: Resistor Troubles

- Resistance measurements are made with an ohmmeter.

- The ohmmeter has its own voltage source, so voltage must be off in the circuit being tested. Otherwise the ohmmeter may become damaged.
All experienced technicians have seen a burnt resistor. (See burnt resistor below.)

This is usually caused by a short somewhere else in the circuit which causes a high current to flow in the resistor.

When a resistor’s power rating is exceeded, it can burn open or drift way out of tolerance.