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.

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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.
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.
Surface-Mount Resistors (also called chip resistors)

- Temperature-stable and rugged
- Their end electrodes are soldered directly to a circuit board.
- Much smaller than conventional resistors with axial leads.
- Power dissipation rating is usually 1/8 to 1/4 W
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.

Color Code

<table>
<thead>
<tr>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0  Black</td>
</tr>
<tr>
<td>1  Brown</td>
</tr>
<tr>
<td>2  Red</td>
</tr>
<tr>
<td>3  Orange</td>
</tr>
<tr>
<td>4  Yellow</td>
</tr>
<tr>
<td>5  Green</td>
</tr>
<tr>
<td>6  Blue</td>
</tr>
<tr>
<td>7  Violet</td>
</tr>
<tr>
<td>8  Gray</td>
</tr>
<tr>
<td>9  White</td>
</tr>
</tbody>
</table>
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.

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2-2: Resistor Color Coding

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

Violet = 7
Red = 2
Gold = 5%

Yellow = 4

5% of 4700 = 235
4700 - 235 = 4465
4700 + 235 = 4935

The actual value can range from 4465 to 4935 Ω.

4700Ω is the nominal value.
2-2: Resistor Color Coding

- 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)
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.
Problem 2-6

Using the five-band code, indicate the colors of the bands for each of the following resistors:

a) $110 \, \Omega \pm 1\%$

b) $34 \, k\Omega \pm 0.5\%$

c) $82.5 \, k\Omega \pm 2\%$

<table>
<thead>
<tr>
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<th>0</th>
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<tr>
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<td>8</td>
<td>Gray</td>
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<tr>
<td></td>
<td>9</td>
<td>White</td>
</tr>
</tbody>
</table>

**Tolerance**

- Brown = 1%
- Red = 2%
- Green = 0.5%
- Blue = 0.25%
- Violet = 0.1%.
2-2: Resistor Color Coding

- **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.
Chip Resistor Coding System

- Body color is usually white or off-white
- End terminals are C-shaped
- Three (four) digits on the body or on the film
- First 2 (3) digits indicate the first two (three) numbers
- Third (fourth) digit indicates the multiplier
- Are available in tolerances of ±1% ±5% but tolerances are not indicated on the chip
- The letter R is used to signify a decimal point for values between 1 to 10 ohms (1R5 means 1.5 ohms)
2-3: Variable Resistors

- A variable resistor is a resistor whose resistance value can be changed.

![Variable Resistor (Generic symbol) (2-terminals)]
Variable resistors

- Decade resistance box
  - Provides any R within a wide range of values
  - First dial is the units or $R \times 1$ dial.
  - Second dial is the tens or $R \times 10$ dial.
  - The hundreds or $R \times 100$ dial has an R of 0 to 900Ω
  - Etc.
  - Dials are connected internally so that their values add to one another.
Indicate the total resistance of a decade resistor whose dial settings are as follows:

- R × 100 k is set to 6
- R × 10 k is set to 8
- R × 1 k is set to 0
- R × 100 is set to 2
- R × 10 is set to 8
- R × 1 is set to 0
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.

![Diagram of Rheostat](image1)

**Rheostat (2 terminals)**
R increases as wiper is moved up

![Diagram of Potentiometer](image2)

**Rheostat (2 terminals)**
R decreases as wiper is moved up
2-4: Rheostats and Potentiometers

- 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.

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.

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Problem 2-8

- Show two different ways to wire a potentiometer so that it will work as a rheostat.
A potentiometer may be used as a rheostat by simply using the wiper terminal and one of the other terminals, the third terminal is left unconnected and unused.

Another method is to wire the unused terminal to the center terminal.
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.
Maximum allowable current for any resistance setting is calculated as:

\[ I_{\text{max}} = \sqrt{\frac{P}{R}} \]

Maximum voltage which produces the rated power dissipation can be calculated as:

\[ V_{\text{max}} = \sqrt{P \cdot R} \]

\( P \) and \( R \) are the rated value of rheostat

Q. What is \( I_{\text{max}} \) of a 5-KΩ 2-W rheostat?
2-6: 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.
An open resistor measures infinite resistance.

∞ Ω

An example of an out-of-tolerance resistor:

1 kΩ, 5% nominal

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.
2-6: Resistor Troubles

- All experienced technicians have seen a burnt resistor.
- 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.
A manufacturer of carbon-film resistors specifies a maximum working voltage of 250V for all its ¼-W resistors. Exceeding 250 V causes internal arcing within the resistor.

Above what minimum resistance will the maximum working voltage be exceeded before its ¼-W power dissipation is exceeded?