

ECE 215/S – Principles of Electronic Cyber Warfare

Block 1: Resistive Circuits and Power Distribution

Lesson 5: Circuit Protection

Department of Electrical and Computer Engineering
United States Air Force Academy

Fall 2026

Objective 1.2

- Today's lesson covers a single learning objective, assessed on **Quiz 1**

I can determine appropriate circuit breaker values for adequate system protection.

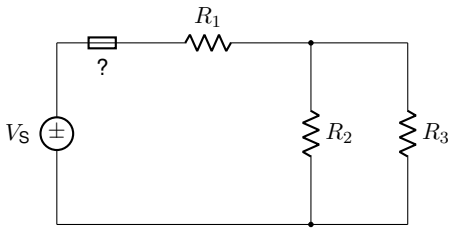
- Everything you need is circuit analysis you already have from Objective 1.1 — the new part is what you *do* with the answer
- After today, Objectives 1.1–1.2 are both complete. This is the **last new material before Quiz 1**

Where We Are Going

By the end of this lesson, you will be able to:

- Explain what a **short circuit** is and why it is dangerous
- Describe how a **fuse** and a **circuit breaker** protect a circuit, and when each is used
- State the **two rules** that bound an acceptable protection rating
- Find the source current I_S for a circuit and **select a rating** from a table of available parts

Don't Let the Smoke Out



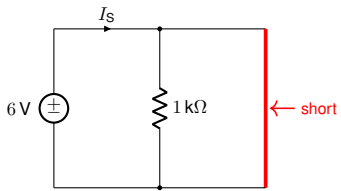
Before we energize anything, we owe the design three questions:

- Are the **components** protected from a failure elsewhere in the circuit?
- Are the **load** voltages and currents inside their operational limits?
- What rating goes in the box marked **?**

All three are answered by analyzing the circuit first.

The Failure Mode: A Short Circuit

A **short circuit** connects the source terminals through (near) zero resistance.



The source now "sees" only the short:

$$R_{EQ} = \frac{(1\,\text{k}\Omega)(0\,\Omega)}{1\,\text{k}\Omega + 0\,\Omega} = 0\,\Omega$$

$$I_S = \frac{V_S}{R_{EQ}} = \frac{6\,\text{V}}{0\,\Omega} \to \infty$$

Real wire has small but nonzero resistance, so the current is finite — and still large enough to melt insulation, destroy components, and start fires.

This is the failure that protection exists to interrupt.

Two Devices, One Job

- **Fuse** — a deliberately thin wire in series with the load
  - Below its rating it behaves as an ordinary wire
  - Above its rating it heats, melts, and severs the circuit
  - One-time use; must be replaced after it blows
  - Still standard in automotive and many avionics applications
- **Circuit breaker** — a spring-loaded switch held closed by a catch
  - Same protective function, but **resettable** — flip a lever or push a button
  - Higher up-front cost, cheaper over a service life
  - Standard in modern house and aircraft wiring

Both carry a printed **rating**: the maximum current the device will pass indefinitely without opening.

Choosing a Rating: Two Rules

A usable rating is bounded on *both* sides:

1. The rating must be **higher than the expected current** in the circuit.
   - Otherwise the protection opens during normal operation and the system never works
2. The rating must be **lower than the failure point of the wiring**.
   - Otherwise the wire fails before the protection does — and the protection is pointless

Rule 2 in practice depends on wire gauge (AWG) and conductor material: larger diameter carries more current, and copper carries more than aluminum of the same size.

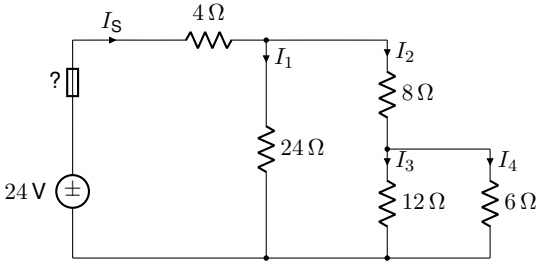
The Method We Will Use

You will not consult an AWG chart on a quiz. Instead:

1. Model the fuse or breaker as a **short** (assume it has not opened)
2. Label nodes and combine resistors working back toward the source
3. Solve for the **source current** I_S
4. Form the acceptable window $[\,1.1\,I_S,\ \ 1.5\,I_S\,]$
5. Select a rating from the **provided table** that falls inside that window — then, if the question also asks for a voltage or current *inside* a group you collapsed, **expand back out** with the divider rules (Lesson 4's method)

Rating window: 10% to 50% above the nominal source current.

Worked Example — Find I_S and Select a Fuse



Available ratings

Rating
2 A
2.5 A
3 A
3.5 A
4 A

Work it before you turn the page: find I_S, then the window, then the part.

Worked Example — Solution

Collapse one group at a time. The $12\,\Omega$ and $6\,\Omega$ are *nested* — behind the $8\,\Omega$ — so they go first.

(a) Same two nodes, so parallel:

$$12 \parallel 6 = \tfrac{(12)(6)}{12+6} = 4\,\Omega$$

(b) In series with the $8\,\Omega$ in front of it:
$8 + 4 = 12\,\Omega$

(c) That branch and the $24\,\Omega$ share two nodes:

$$12 \parallel 24 = \tfrac{(12)(24)}{12+24} = 8\,\Omega$$

(d) Add the series $4\,\Omega$: $R_{\text{EQ}} = 4 + 8 = 12\,\Omega$

Source current

$$I_{\text{S}} = \frac{24\,\text{V}}{12\,\Omega} = 2.00\,\text{A}$$

Rating window

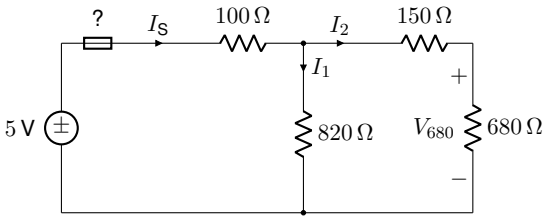
$$[1.1(2.00),\ 1.5(2.00)] = [2.2,\ 3.0]\ \text{A}$$

Select from the table

- 2.5 A and 3 A both land inside the window
- Take the **smaller**: the lowest rating in the window opens soonest in a fault

Two parts qualify — take 2.5 A, the smallest rating inside the window.

Your Turn



Find:

1. R_{EQ} seen by the source
2. I_S
3. The acceptable rating window
4. V_{680}, the voltage across the $680\,\Omega$ load
5. A 15 mA fuse is installed instead. For what source voltages does it blow?

Wrap-Up

Key ideas:

- A **short circuit** collapses R_{EQ} and drives current toward its physical limit
- **Fuses** open once; **breakers** reset. Same job, different service model
- A rating must sit **above the expected current** and **below the wiring's failure point**
- In this course: solve for I_{S}, form $[1.1\, I_{\text{S}},\ 1.5\, I_{\text{S}}]$, then pick from the table

Next lesson:

- **Lesson 6 — Objective 1.3: AC Circuit Analysis** — the wall outlet's kind of power, and why 120 V is not the whole story
- **Quiz 1** (Objectives 1.1–1.2) is due at Lesson 6 — everything on it is now behind you