


# ECE 215/S – Principles of Electronic Cyber Warfare

## Block 1: Resistive Circuits and Power Distribution

## Lesson 4: Series, Parallel, and Dividers

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# Objective 1.1 (completing)

**I can calculate the voltages, currents, and power associated with devices in a simple DC-powered circuit using tools such as KVL, KCL, voltage and current dividers, Ohm's Law, and the power equation.**

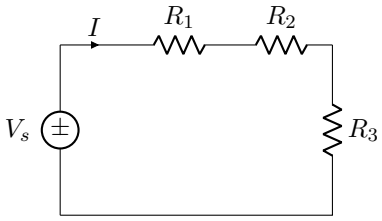
- KVL and KCL always work, but they cost you a system of equations
- Today: **series/parallel reduction** and the **divider rules** — the shortcuts you will actually use
- After today, Objective 1.1 is complete. **Quiz 1** covers it with Objective 1.2

# Where We Are Going

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

- Combine resistors in **series** and in **parallel** to find an equivalent resistance
- Apply the **voltage divider** and **current divider** rules
- Reduce a multi-resistor circuit to a single $R_{\text{EQ}}$ and work back out to any element
- Recognize which real-world circuits are series and which are parallel, and why it matters

# Resistors in Series




Elements are **in series** when they carry the *same current* — they sit end to end with nothing branching off between them.

$$R_{\text{EQ}} = R_1 + R_2 + R_3 + \cdots$$

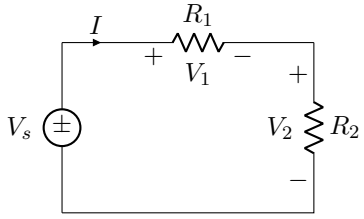
- Series resistance always **increases**
- Same current through every element
- Voltage *divides* among them

# Series Circuits in Practice

- **Old Christmas lights** — one bulb burns out, the whole string goes dark. That is series
- **A fuse or breaker** must be in series with the load it protects, so all the load current passes through it (Objective 1.2, next lesson)
- **An ammeter** goes in series — you break the circuit to insert it
- **Batteries stacked end to end** — four 1.5 V cells in series give 6 V

**Series means shared current and divided voltage.**

# Voltage Division




Nothing new — Ohm's Law plus KVL. The *same* $I$ flows through every element, so $V_k = IR_k$ and $V_s = IR_{\text{EQ}}$. Divide one by the other and $I$ cancels:

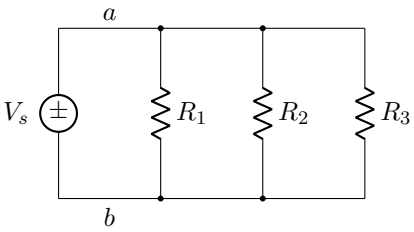
$$V_k = V_s \cdot \frac{R_k}{R_{\text{EQ}}}$$

Each resistor takes a share of $V_s$ proportional to its own resistance. For the two above:

$$V_2 = V_s \cdot \frac{R_2}{R_1 + R_2}$$

**Sanity check:** the biggest resistor always gets the biggest voltage.

# Resistors in Parallel




Elements are **in parallel** when they share the *same two nodes* — here $a$ and $b$ — so they see the *same voltage*.

$$\frac{1}{R_{\text{EQ}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

For exactly two resistors, written $R_1 \parallel R_2$:

$$R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

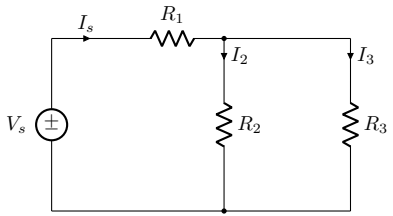
- Parallel resistance is always **smaller** than the smallest branch
- Current *divides* among the branches

# Parallel Circuits in Practice

- **Every outlet in a building** is in parallel — that is why unplugging a lamp does not kill the rest of the room, and why they all see the same 120 V (an AC value — defined properly in Lesson 6)
- **Adding loads in parallel lowers** $R_{\mathbf{EQ}}$, which *raises* the current drawn from the source. This is exactly how a circuit gets overloaded
- **A voltmeter** goes in parallel — across the device, without breaking anything
- **Batteries in parallel** keep the same voltage but supply more current for longer

**Parallel means shared voltage and divided current.**

# Current Division




The parallel branches $R_2$ and $R_3$ span the same two nodes, so both see the same voltage. Let $I_{\text{total}}$ be the current *into* the parallel group and $R_{\text{EQ,par}}$ its equivalent:

$$I_X R_X = I_{\text{total}}\, R_{\text{EQ,par}} \;\Rightarrow\; I_X = \frac{R_{\text{EQ,par}}}{R_X}\, I_{\text{total}}$$

That **general rule** takes any number of branches. With $R_{\text{EQ,par}} = R_2 \parallel R_3$ it becomes the two-branch form:

$$I_2 = I_{\text{total}} \cdot \frac{R_3}{R_2 + R_3}$$

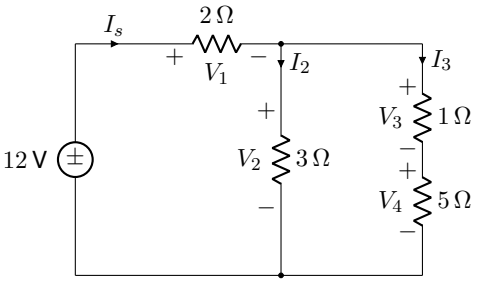
**The swap holds for two branches only.** In general, own $R_X$ on the *bottom*.

# Method: Reduce, Solve, Expand

1. **Label the nodes** so you can see what is genuinely in parallel
2. **Work from the far end back toward the source**, collapsing series and parallel groups one at a time. Redraw after each step
3. Get down to a single $R_{\text{EQ}}$, then find $I_s = V_s / R_{\textbf{EQ}}$
4. **Expand back outward**, using the divider rules to get the voltage or current you were asked for
5. **Check with conservation of power**

**Redraw the circuit after every reduction.**
**It is faster than fixing a wrong answer.**

# Worked Example




**Given:** $V_s = 12\,\text{V}$. Resistor voltages are numbered left to right, then top to bottom.

Find:

1. $R_{\text{EQ}}$ seen by the source, collapsing one group at a time
2. $I_s$
3. $I_2$ and $I_3$
4. $V_4$, the voltage across the $5\,\Omega$
5. Verify conservation of power

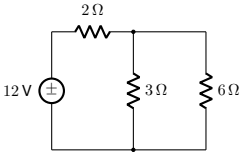
*Try it before the next slide.*

# Worked Example — Solution: Reduce

Work from the far end back toward the source, and **redraw after every collapse**.

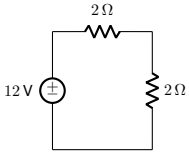
**(a)** Series chain:

$$1 + 5 = 6\,\Omega$$



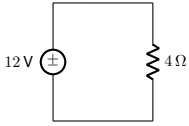

**(b)** Parallel pair:

$$3 \parallel 6 = \frac{(3)(6)}{3+6} = 2\,\Omega$$




**(c)** Last series pair:

$$R_{\text{EQ}} = 2 + 2 = 4\,\Omega$$




Now Ohm's Law on the one remaining resistor: $I_s = \dfrac{12\,\text{V}}{4\,\Omega} = 3\,\text{A}$

# Worked Example — Solution: Expand

**Voltage across the parallel section — KVL**

- Ohm's Law on the $2\,\Omega$: $V_1 = (3)(2) = 6\,\text{V}$
- KVL around the left loop, exactly as in L3: $-12 + V_1 + V_2 = 0 \;\Rightarrow\; V_2 = 6\,\text{V}$

**Branch currents**

- General current divider, with $I_{\text{total}} = I_s = 3\,\text{A}$ into the group and $R_{\text{EQ,par}} = 2\,\Omega$:

$$I_2 = \frac{R_{\text{EQ,par}}}{R_2}\, I_{\text{total}} = \frac{2}{3}(3) = 2\,\text{A}$$

- Both branches sit across that same $V_2 = 6\,\text{V}$, so $6/3 = 2\,\text{A}$ too

**The other branch — KCL**

- $I_3 = I_s - I_2 = 3 - 2 = 1\,\text{A}$ (Ohm's Law agrees: $6/6 = 1\,\text{A}$)
- The $1 + 5$ chain spans those same two nodes, so $V_3 + V_4$ must equal $V_2$: $V_3 = (1)(1) = 1\,\text{V}$ and $V_4 = (1)(5) = 5\,\text{V}$ sum to $6\,\text{V}$ ✓

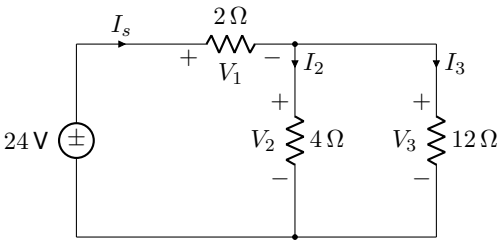
**Conservation of power**

- Supplied: $(12)(3) = 36\,\text{W}$
- Absorbed, one resistor at a time:

$$3^2(2) + 2^2(3) + 1^2(1) + 1^2(5)$$

$$= 18 + 12 + 1 + 5 = 36\,\text{W}\ \checkmark$$

# Your Turn




**Lesson 3's circuit.** There, $I_s$ was *given* to you. Today you can find it yourself — and your answer should match the one L3 handed you.

Find:

1. $R_{\text{EQ}}$ seen by the source
2. $I_s$
3. $I_2$ and $I_3$ by current division
4. Verify conservation of power

# Wrap-Up

Key ideas:

- **Series** — same current, voltage divides, $R_{\text{EQ}} = \sum R$
- **Parallel** — same voltage, current divides, $R_{\text{EQ}}$ smaller than the smallest branch
- **Voltage divider** puts the element's *own* $R$ on top; the general **current divider** puts it on the bottom, $I_X = (R_{\text{EQ,par}}/R_X)\, I_s$
- Reduce toward the source, solve for $I_s$, then expand back out

Next lesson:

- **Lesson 5 — Objective 1.2: Circuit Protection.** You now have everything needed to size a fuse
- **Quiz 1** (Objectives 1.1–1.2) is due at Lesson 6