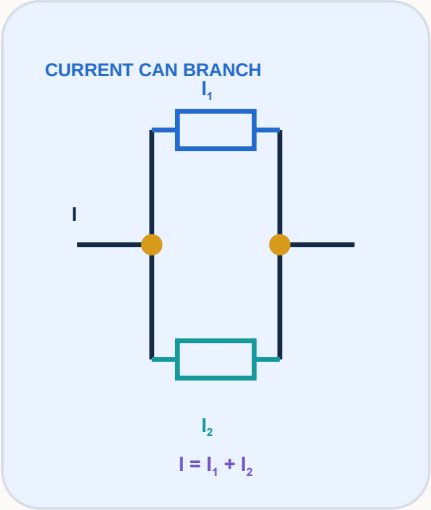
LESSON 2.2.4

Series, Parallel

and Potential Divider Circuits

Charge conservation controls current. Energy conservation controls potential difference. Together they determine every circuit rule.



THE CONSERVATION STARTING POINT

CHARGE CONSERVATION

current into a junction = current out

ENERGY CONSERVATION

sum of p.d.s around a loop = supply p.d.

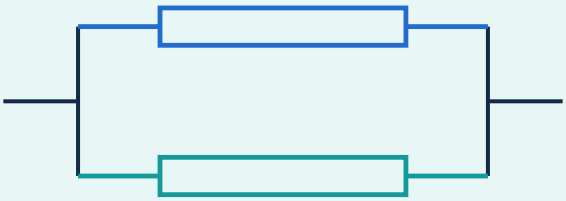
SERIES AND PARALLEL RULES

SERIES



- Current: $I = I_1 = I_2$
- Potential difference: $V = V_1 + V_2$
- Resistance: $R = R_1 + R_2$

PARALLEL



- Potential difference: $V = V_1 = V_2$
- Current: $I = I_1 + I_2$
- Resistance: $1/R = 1/R_1 + 1/R_2$

A parallel equivalent resistance is always smaller than the smallest branch resistance.

1 Derive the rules, then calculate

Start with conservation, replace each potential difference by IR, and simplify.

WHY THE RESISTANCE RULES WORK

SERIES DERIVATION

1. $V = V_1 + V_2$
2. $IR = IR_1 + IR_2$
3. divide every term by I

$$R = R_1 + R_2$$

PARALLEL DERIVATION

1. $I = I_1 + I_2$
2. $V/R = V/R_1 + V/R_2$
3. divide every term by V

$$1/R = 1/R_1 + 1/R_2$$

WORKED COMPARISONS

SERIES: 2.0 Ω AND 4.0 Ω ON 12 V

$R = 2.0 + 4.0 = 6.0\ \Omega$

$I = V/R = 12/6.0 = 2.0\ A$

$V_2 = IR_2 = 2.0 \times 4.0 = 8.0\ V$

CHECK: 4.0 V + 8.0 V = 12 V

PARALLEL: 6.0 Ω AND 3.0 Ω ON 12 V

$1/R = 1/6.0 + 1/3.0$

$R = 2.0\ \Omega$; $I = 12/2.0 = 6.0\ A$

$I_1 = 2.0\ A$; $I_2 = 4.0\ A$

CHECK: 2.0 A + 4.0 A = 6.0 A

FAST SENSE CHECKS

SERIES

adding a resistor increases total R and reduces supply current

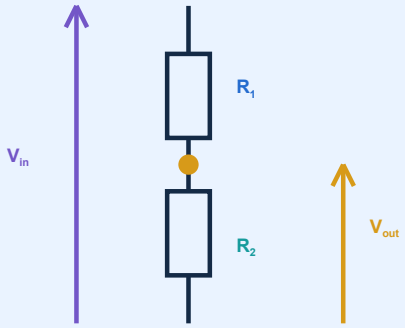
PARALLEL adding a branch decreases total R and increases supply current

Do not add parallel resistances directly; add their reciprocals.

2 Potential dividers and sensors

Two series resistors share the supply potential difference in proportion to their resistances.

THE DIVIDER EQUATION



OUTPUT ACROSS LOWER RESISTOR

$$V_{out} = V_{in} \times R_2/(R_1 + R_2)$$

The named output resistor goes in the numerator.

WORKED EXAMPLE

V_{in} = 9.0 V, R_1 = 2.0 kΩ, R_2 = 4.0 kΩ; find V_{out} across R_2.

$$V_{out} = 9.0 \times 4.0/(2.0 + 4.0) = 6.0 \text{ V}$$

UNIFORM RESISTANCE WIRE

Potential varies linearly with distance along a uniform current-carrying wire.



SENSOR POSITION CONTROLS THE RESPONSE

LDR AS LOWER RESISTOR

light ↑ → R_2 ↓ → V_{out} ↓

Bright light reduces the fraction of the supply across the LDR.

NTC AS LOWER RESISTOR

temperature ↑ → R_2 ↓ → V_{out} ↓

Put the sensor in the upper position if you want output to rise instead.

Always mark the two points between which Vout is measured before choosing the formula.