

3.2 Voltage, current, switches, and transistors

Voltage and current

Electrical systems are ubiquitous, in appliances, computers, cars, etc. An **electrical system** involves movement of charged through wires.

- **Voltage** is the potential for charge to move. Voltage is measured in **Volts**.
- **Current** is the amount of charge flow. Current is measured in **Amps**.
- **Resistance** is a wire's opposition to flow. Resistance is measured in **Ohms**.

An example electrical system is a lamp that passes current through a glowing resistor in a light bulb. The more current, the glow.

PARTICIPATION ACTIVITY

3.2.1: Voltage and current.

Start ☐ 2x speed

6 V



0 V

Above, the zigzag line represents a resistor.

Voltage is like the water pressure in a faucet for a garden hose. Current is like the amount of water actually flowing through. Resistance is like a thin hose more-strongly resisting flow than a thick hose.

Current flows from a higher-voltage point to a lower-voltage point on a wire. 0 V is commonly called **ground** and drawn as three horizontal segments, as above.

Voltage (V), current (I), and resistance (R) are related as $V = IR$, called **Ohm's Law**.

PARTICIPATION ACTIVITY		3.2.2: Terminology: Electrical systems.					
Ohms	Volts	V = IR	Resistance	Current	Voltage	Amps	
					Potential for charge to move		
					Amount of charge flow		
					Opposition to flow		
					Units of voltage		
					Units of current		
					Units of resistance		
					Ohm's Law		

**PARTICIPATION
ACTIVITY**

3.2.3: Voltage, current, and resistance.

1) Increasing voltage does what to current?

- ☐ Increases
- ☐ Decreases
- ☐ Doesn't change

2) Decreasing resistance does what to current.

- ☐ Increases
- ☐ Decreases
- ☐ Doesn't change

3) If V is 6 V and R is 2 Ohms, $I = ?$

- ☐ 12
- ☐ 6
- ☐ 3

4) If V is 6 V and R is 1 Ohm, $I = ?$

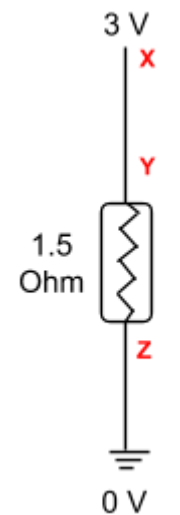
- ☐ 12
- ☐ 6
- ☐ 3

5) If V is 6 V and R is 0 Ohms, $I = ?$

- ☐ 6

☐ 3☐ Infinity6) If V is 6 V and R is infinite, $I = ?$ ☐ 0☐ 3☐ Infinity

The voltage on a wire with no resistance is the same everywhere on the wire. But voltage drops across a resistor as $V = IR$.

**PARTICIPATION
ACTIVITY**3.2.4: $V = IR$.1) What is the current I ? A**Check****Show answer**

2)

What is the voltage at X?

 V

Check

Show answer

3) What is the voltage at Y?

 V

Check

Show answer

4) What is the voltage at Z?

 V

Check

Show answer

Note: Nearly every wire has some tiny resistance (with the exception of superconductors), but that resistance is commonly

Note: Convention is to show current flowing from higher voltage to lower voltage, even though actual flow is in the other dir electrons having negative charge. But the net effect is the same.

Switches

A **switch** is an electronic device that acts like a wire (a.k.a. "conducts") between two terminals if the switch is configured to switch is an example.

PARTICIPATION ACTIVITY

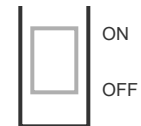
3.2.5: Switches can be configured to conduct.

Start



2x speed

5 V



0 V

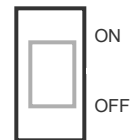
An **electronically-controlled switch** has another input terminal whose voltage can turn the switch on. The terminal that controls an electronically-controlled switch is known as the **control input**.

PARTICIPATION ACTIVITY

3.2.6: An electronically-controlled switch is controlled by a control input.

Start ☐ 2x speed

5 V

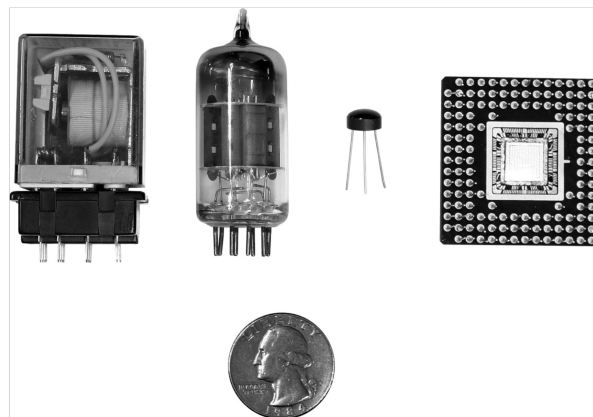


0 V



0 V

Figure 3.2.1: Switches: Relay, vacuum tube, discrete transistor, and integrated circuit (having millions of switches inside).



Switches in the early 1900s were large, each being several inches long. A **transistor** is a smaller simpler switch with no mechanical parts, invented in 1947.

A **circuit** is a group of connected devices. In a circuit of switches, some wires have a high voltage, some have low voltage. Low is usually 0. (High is usually not 1 V; high could be 1.3 V, for example). A **digital** system has voltages that are either high or low, in an *analog* system where voltages can have infinite values like 0.15, 0.2, 0.333, etc.

A **digital circuit** is a connection of switches. Digital circuits form the basis of useful systems like smartphones, computers, and more.

PARTICIPATION ACTIVITY

3.2.7: Digital circuit terminology.

1) A basic ____ either conducts or doesn't.

Check**Show answer**

- 2) An ____-controlled switch has another input whose voltage turns the switch on or off.

Check**Show answer**

- 3) A ____ is a connection of devices.

Check**Show answer**

- 4) An ____ system's voltages can assume infinite values.

Check**Show answer**

- 5) A ____ system's values can assume just two values, labeled 1 and 0.

Check**Show answer**

Transistors

A **CMOS transistor** is a popular transistor type. Two types of CMOS transistors are pMOS and nMOS. An **nMOS** transistor's control input is 1. A **pMOS** transistor conducts when its control input is 0.

**PARTICIPATION
ACTIVITY**

3.2.8: CMOS transistors.

Start



2x speed

nMOS

1

Conducts when 1

pMOS

0



Conducts when 0

**PARTICIPATION
ACTIVITY**

3.2.9: pMOS and nMOS transistors.

- 1) Does a pMOS conduct if the control input is 0?
☐ Yes
☐ No
- 2) Does an nMOS conduct if the control input is 0?
☐

Yes

☐ No

3) Does a pMOS conduct if the control input is 1?

☐ Yes

☐ No

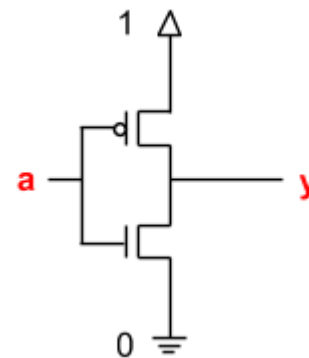
4) Does an nMOS conduct if the control input is 1?

☐ Yes

☐ No

**PARTICIPATION
ACTIVITY**

3.2.10: A simple circuit of pMOS and nMOS transistors.



1) What is y when a is 0?

☐ 1

☐ 0

2) What is y when a is 1?

☐

1
○ 0

Exploring further:

- [Transistor \(Wikipedia\)](#)
- [CMOS \(Wikipedia\)](#)

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