11.1 Electronics and digital systems

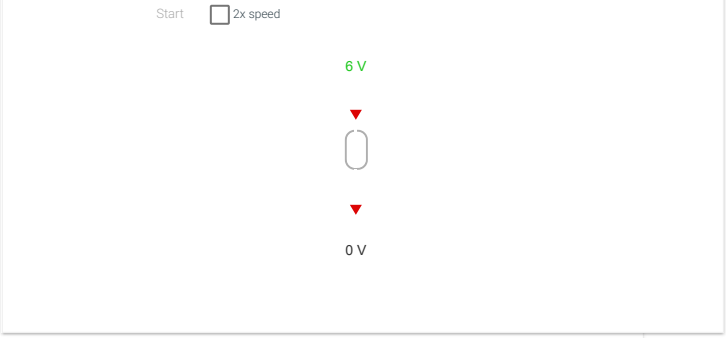
Voltage and current

Electrical systems are ubiquitous, in appliances, computers, cars, etc. An ***electrical system*** involves movement of charged electrons 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 brighter the glow.

PARTICIPATION ACTIVITY 11.1.1: Voltage and current.



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 the hose. 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 line segments, as above.

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

PARTICIPATION ACTIVITY 11.1.2: Terminology: Electrical systems.

Ohms | Voltage | V = IR | Volts | Resistance | Current | 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

Reset

PARTICIPATION ACTIVITY 11.1.3: 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

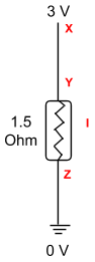
4) If V is 6 V and R is 1 Ohm, I = ?
- 12
- 6
- 3

5) If V is 6 V and R is 0 Ohms, I = ?
- 6
- 3
- Infinity

6) 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 11.1.4: 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

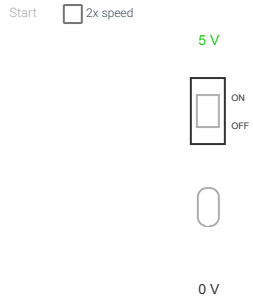
Note: Nearly every wire has some tiny resistance (with the exception of superconductors), but that resistance is commonly ignored.

Note: Convention is to show current flowing from higher voltage to lower voltage, even though actual flow is in the other direction, due to 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 on. A light-switch is an example.

PARTICIPATION ACTIVITY 11.1.5: Switches can be configured to conduct.



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

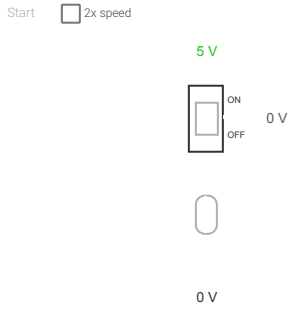
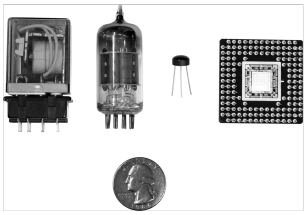


Figure 11.1.1: Switches: Relay, vacuum tube, discrete transistor, and integrated circuit (having millions of switches inside).



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.

PARTICIPATION ACTIVITY 11.1.7: Switches.

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

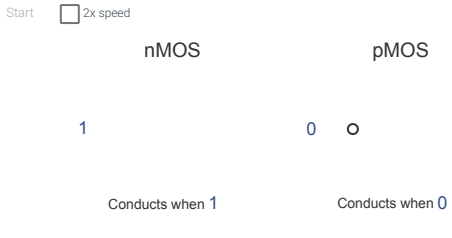
3) A _____ is a small switch with no mechanical parts.

Check Show answer

CMOS transistors

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

PARTICIPATION ACTIVITY 11.1.8: CMOS transistors.



PARTICIPATION ACTIVITY 11.1.9: pMOS and nMOS transistors.

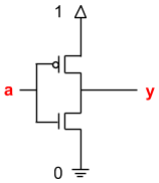
1) Does a pMOS conduct if the control input is 0?
   - Yes
   - No

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 11.1.10: 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

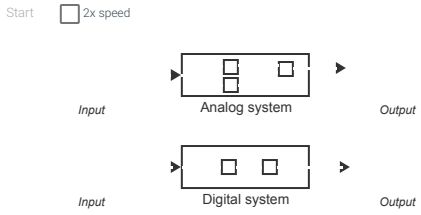
Digital systems

A ***circuit*** is a path through which electrical current can flow. In a circuit of switches, some wires have a high voltage, some have low voltage. High is labeled 1, low 0. (High is usually not 1 V; high could be 1.3 V, for example). A ***digital circuit*** has voltages that are treated as either high or low, and is typically built as a connection of switches. In contrast, an ***analog system*** has voltages that are treated as having infinite values like 0.15, 0.2, 0.333, etc. Digital circuits form the basis of useful systems like smartphones, computers, medical devices, and more.

The word "system" means a set of connected things forming a complex whole. Thus, digital circuits are often referred to more generally as ***digital systems***

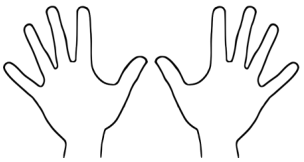
This material focuses on ***digital design***: Creating digital circuits to achieve desired digital system behavior that converts digital inputs into desired digital outputs.

PARTICIPATION ACTIVITY 11.1.11: Digital systems.



Why the name 'digital'?

The term "digit" literally means finger (or toe) (see Oxford dictionary definition). Because people have a finite number of fingers, and digital circuits have a finite number of voltages (usually just two: high and low), the term "digital" is used. (Digit is also used to refer to a place in a number, such as 97 having two digits; that use of digit stems from people counting with their fingers).



PARTICIPATION ACTIVITY 11.1.12: Digital circuits.

1) A _____ is path through which electrical current can flow.

Check **Show answer**

2) An _____ system's voltages can assume infinite values.

Check **Show answer**

3) A _____ system's values can assume just two values, labeled 1 and 0.

Check **Show answer**

Exploring further:

- Transistor (Wikipedia)
- CMOS (Wikipedia)

Provide feedback on this section