Chapter 2: Sensors, Actuators, & Microcontrollers

IoT Fundamentals
Connecting Things 2.0
Instructor Training

Education Service Center Region 11
Academy Support/Instructor Training Center

Chapter 2: Sensors, Actuators, and Microcontrollers

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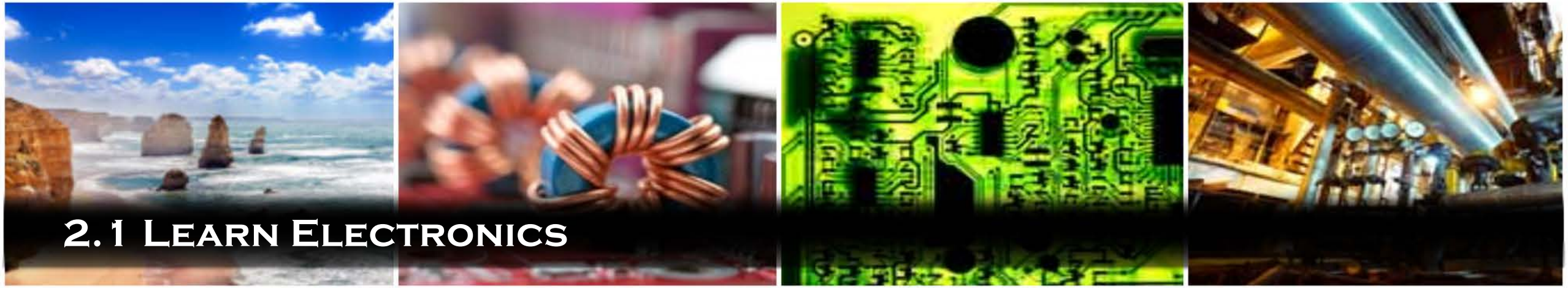
Connecting Things 2.0

Chapter 2 - Sections & Objectives

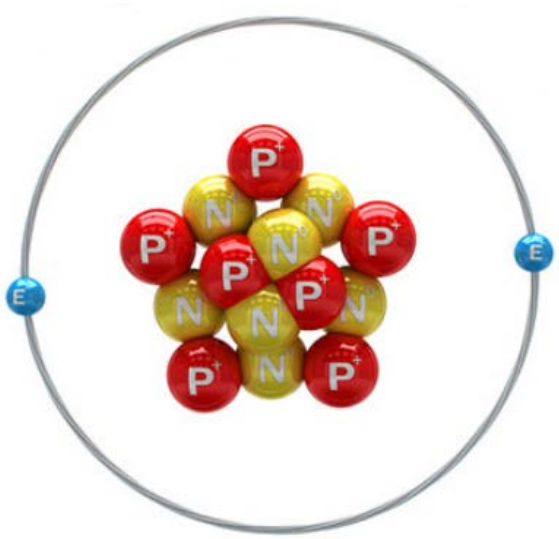
- 2.1 Learn Electronics
  - Explain how components and devices are used to build and measure values in electronic circuits.
- 2.2 Microcontrollers: The SparkFun Inventor's Kit
  - Create circuits and microcontroller programs with the Arduino and a variety of components.
- 2.3 Packet Tracer 7.0 and the IoT
  - Explain how Packet Tracer models IoT systems.



2.1 Learn Electronics

2.1.1 Basic Electronic Terminology & Concepts

- Electronics is an important part of the IoT.
- What is Electronics?
  - Electronics is the field of study focused on the control of electricity and the physical components and circuits that help direct electrical energy.
- IoT devices are often built from scratch; therefore, understanding electronics concepts, components and terminology is critical. It is also important for an IoT professional to be able to read and create electronics schematics.
- Definitions
  - Terms commonly used in electronics include:
    - Electrons, atoms, and chemical elements
    - Electric current
    - Electrical conductors, insulators, and circuits
    - Voltage, Amperes (amps), Resistance, and Power



2.1.1 Basic Electronic Terminology & Concepts

- **Ohm's Law**
  - Ohm's Law states that within a circuit, voltage (V) is directly proportional to the strength of current (I) multiplied by resistance (R).
- Units of measurement with the associated electronic concept:
  - **Power is measured in Watts (W)** – electrical energy per unit time generated or dissipated
  - **Current is measured in Amps (A)** – flow of charged particles' often electrons
  - **Voltage is measured in Volts (V)** – electrical potential difference or "electrical pressure"
  - **Resistance is measured in Ohms (Ω)** – opposition to flow of charged particles (usually DC)
  - **Impedance (Z) is measured in Ohms (Ω)** – opposition to changes in voltage or current due to electrical and magnetic interactions (usually AC)
- A **multimeter** measures the ratio of voltage to current across an object
- An **oscilloscope** has the ability to measure the signals that travel from sensors to microcontrollers as a function of time

$$V = I \times R$$

$$R = V / I$$

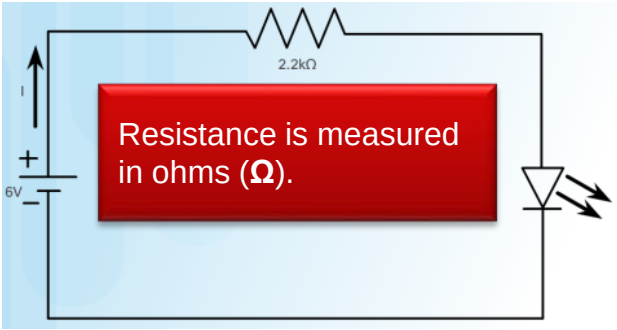
$$I = V / R$$

$$W = V \times A$$

2.1.1 Basic Electronic Terminology & Concepts

- **Basic Circuit**
  - An electrical circuit is a closed conductive path that allows electrons to flow and create an electric current.
  - A circuit also needs an electrical energy source like a battery to start the flow of electricity.
  - The following circuit diagram (schematic) consists of:
    - 6 volt (V) battery provides current
    - 2.2 kΩ resistor (protects the LED from receiving too much current and being destroyed)
    - A resistor is used to limit the amount of current that flows through the circuit
    - A light-emitting diode (LED)

Current (I) flows from the negative terminal to the positive terminal

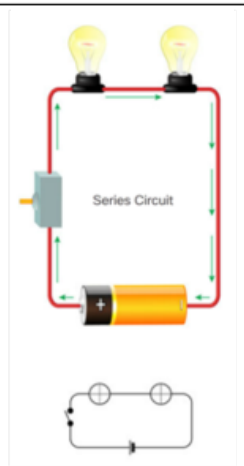
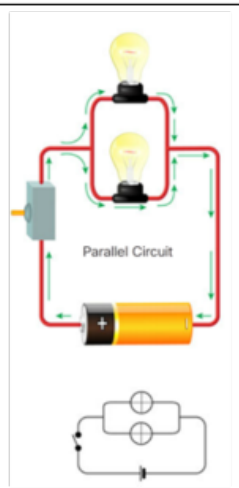


Resistance is measured in ohms (**Ω**).

The triangular part represents a diode and the two arrows facing out represent the fact that this diode emits light.

2.1.2 Advanced Electronic Terminology & Concepts

- **Series and Parallel Circuits**
  - A **series circuit** will stop working when a single electronic component is damaged or remove
  - A **parallel circuit** provides multiple paths for current flow so that the failure of a single component will not affect the operation of the entire circuit

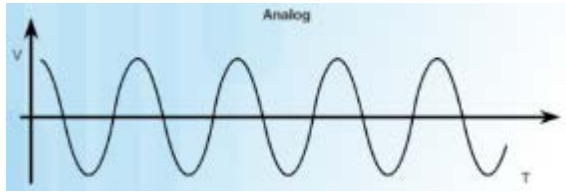
Series Circuit:	**Parallel Circuit:**
• Components are interconnected one after another in a path between the positive and negative terminals of the power source	• Current flows from the battery terminal but splits at a junction which leads to parallel pathways through the circuit. • Components connected along each pathway each get their own share of current
	

2.1.2 Advanced Electronic Terminology & Concepts

- **Passive, Active, Linear, and Nonlinear Circuits**
  - Active circuits contain active components; components that rely on external power source to control current flow
  - Passive circuits contain passive components incapable of controlling current flow
  - A passive component has no effect on gain or control over voltage or current
  - Analog circuits are circuits where the signal is contiguous

- **Direct Current vs. Alternating Current**
  - In DC current, electron flow is only in one direction
  - Batteries, power supplies, thermocouples, solar cells, or dynamos generate DC
  - In AC current, electron flow periodically reverses direction
  - Hydroelectric plants generate AC

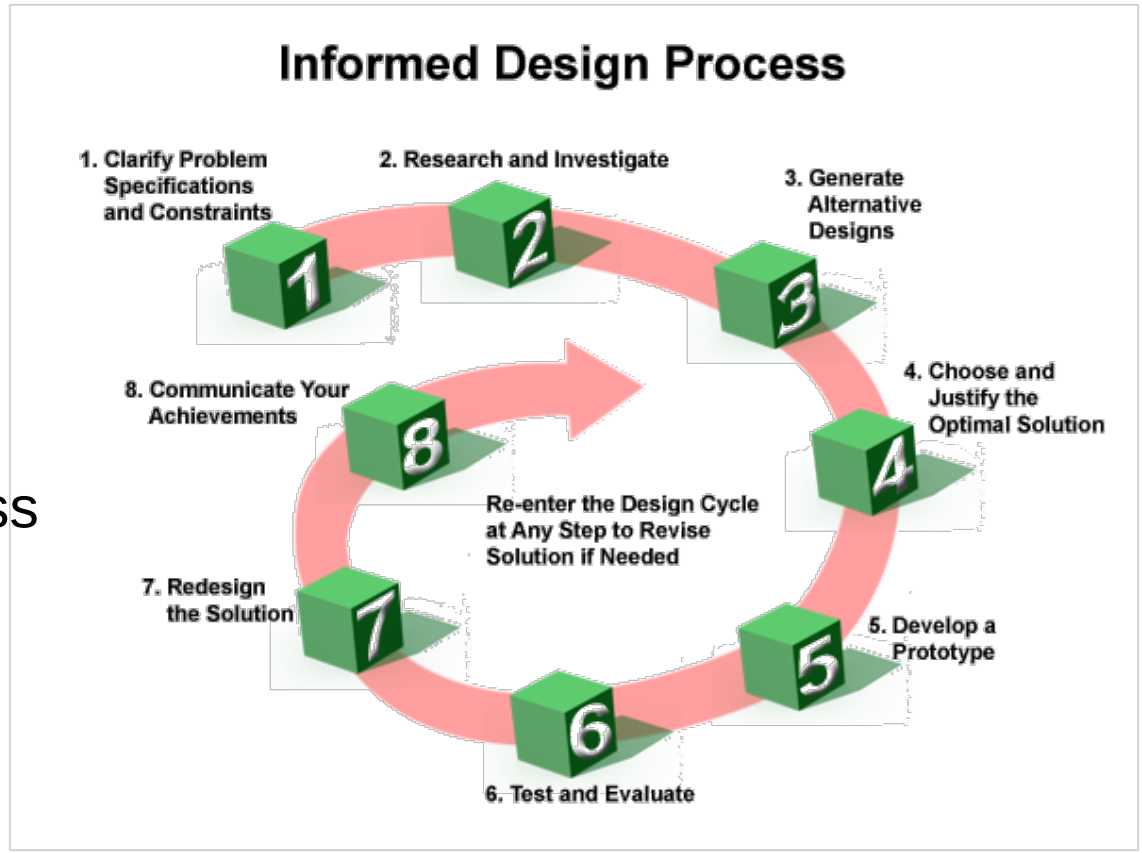
2.1.2 Advanced Electronic Terminology & Concepts



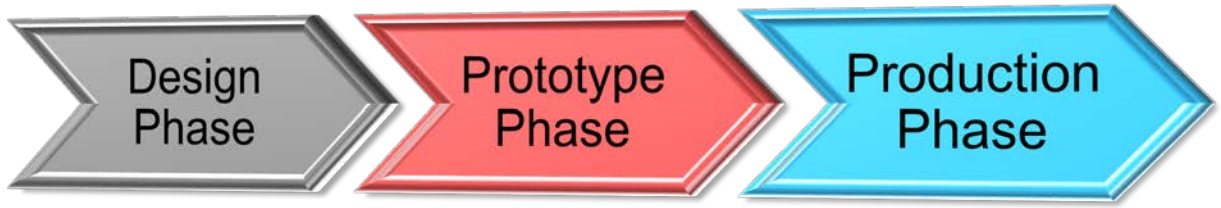
- **Analog Circuits vs. Digital Circuits**
  - **Analog Circuits**: Circuits in which signals vary continuously with time
  - **Digital circuits**: Circuits in which signals that take one of two discrete values
- **Components**
  - Electronic components are specialized devices used in a circuit to control current
  - Components have two or more electrical terminals (leads) that enable them to connect to an electronic circuit
- **Larger Electronic Building Blocks**
  - **Solenoids** – used to electrically open door latches, open or shut valves, move robotic limbs, and even actuate electric switch mechanisms
  - **Relays** – allow for controlling a large amount of current and/or voltage with a small electrical signal

2.1.3 From Schematic Diagram to Breadboard to Soldered PCB

- The **Informed Design Process** – a contemporary approach to design pedagogy as the core process in technology
- Developed for the National Science Foundation by the Hofstra University Center for Technological Literacy
- Similar to the Scientific Method or the Problem Solving Process, the **Informed Design Process Model** is used to show clearly defined eight phases
- Each phase is typically repeated multiple times to obtain the best and final result
- Designers tend to skip around inside the process with multiple iterations of the various steps as needed



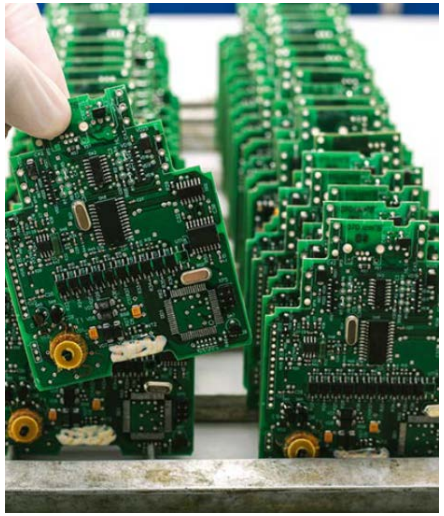
2.1.3 From Schematic Diagram to Breadboard to Soldered PCB



- The simplified three step model:
  - **Design Phase:**
    - Consists of three steps:
      Research – finds possible vendors and material costs
      Concept – the initial idea
      Circuit Design – symbolic representations of the circuits and components
    - A circuit diagram shows the components and interconnections of the circuit using standardized symbolic representations
  - **Prototype Phase:**
    - Consists of four steps:
      Hardware, Mechanical, and Software Development
      PCB layout
      Build prototypes
      Product Testing
    - A solderless breadboard is a tool commonly used in electronic prototyping

2.1.3 From Schematic Diagram to Breadboard to Soldered PCB

- **Production Phase:**
  - Consists of three steps:
    - Production Readiness Review
    - Production
    - On-going Maintenance
  - Often employed on printed circuit boards (PCBs)



  - Optional Resource: https://www.instructables.com/class/Circuit-Board-Design-Class/

2.2 Microcontrollers: The SparkFun Inventors Kit

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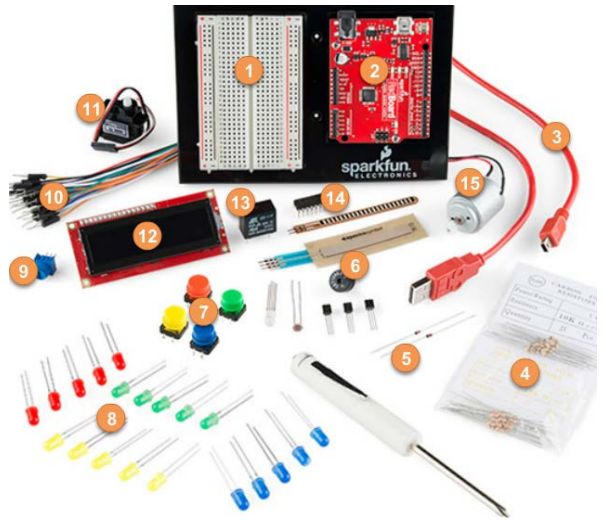
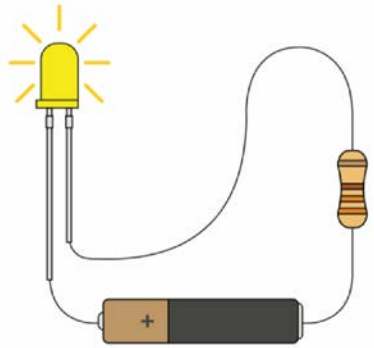
2.2.1 Introducing the SparkFun Inventor's Kit (SIK)

- **Microcontrollers** – low power requirements that makes them well-suited for IoT
  - Arduino Microcontroller
    - The Arduino is a popular microcontroller for prototyping
    - Instructions for the Arduino are programmed using the Arduino integrated development environment (IDE)
- The SparkFun kit contains a number of devices and parts to help a beginner to get started with electronics and microcontrollers
- It introduces important concepts such as electronic circuits and how to program Arduino microcontrollers
- Learn how to program sensors to monitor the environment
- The SparkFun Inventor's Kit (SIK) is a starter kit for building circuits

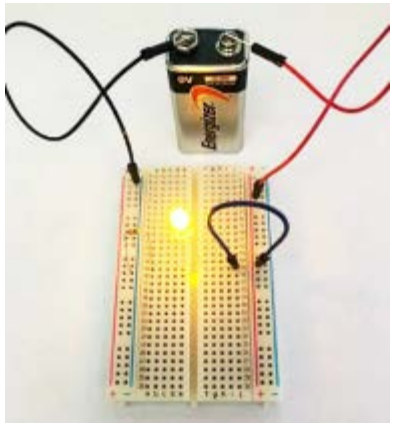


2.2.2 Simple Circuits

- **Building a Circuit**
  - A simple circuit can be created by:
    - Connecting electronic components (LED, resistor, and jumper wires) in series along a row on the breadboard.
    - Connecting the power source to the red (+) and black (-) jumper wires
    - This should complete the circuit and light the LED
- **The Arduino IDE**
  - Free, downloadable software used to interact with the Arduino board
  - Used to create programs for the Arduino
- **Writing code**
  - Programs written using the Arduino IDE are called **sketches** and are saved with the file extension of **.ino**
  - Arduino sketch keywords can be divided in three main category types:
    - Structures
    - Values (variables and constants)
    - Functions
  - Keywords used include void, setup(), loop() function, and more

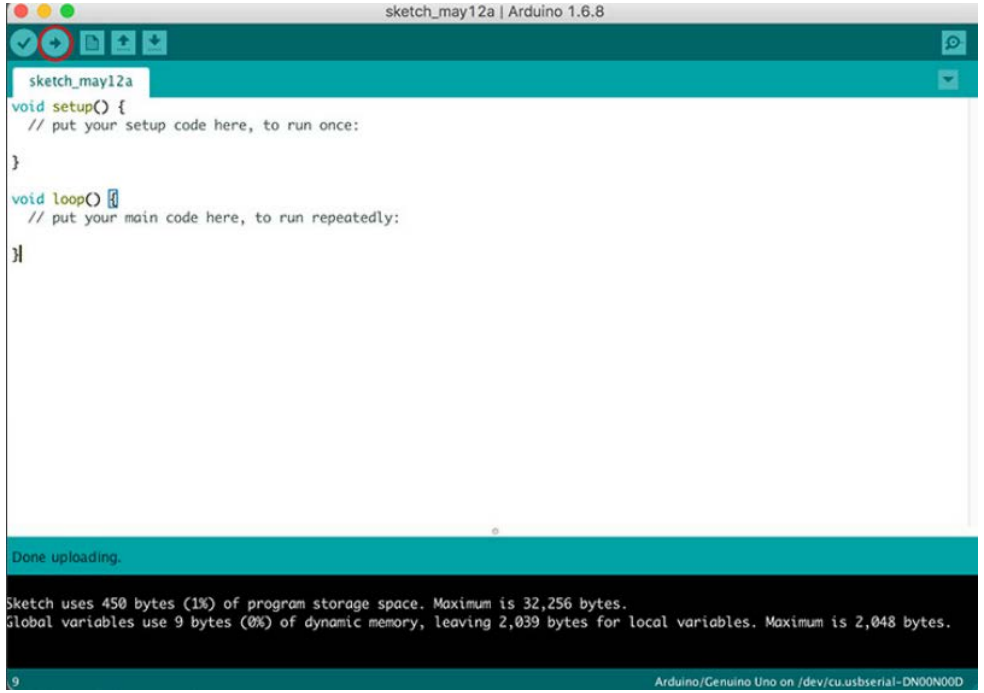


Simple Circuit



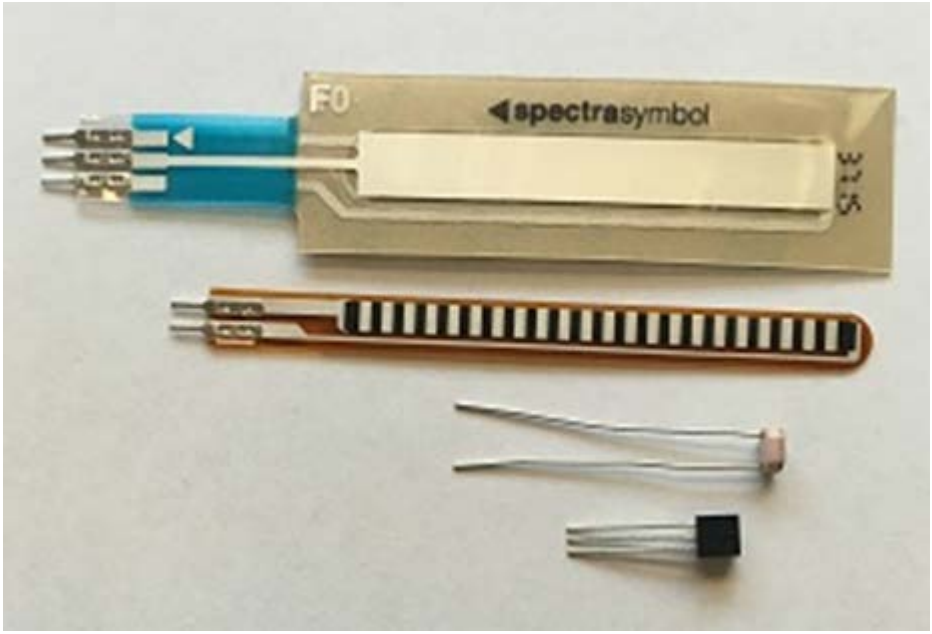
2.2.2 Simple Circuits

- **Testing**
  - To test and verify the sketch code, click on the checkmark toolbar icon
  - The IDE compiles the code and checks for syntax errors
  - To upload the sketch to the Arduino and test the code, click on the second toolbar icon (⇨)



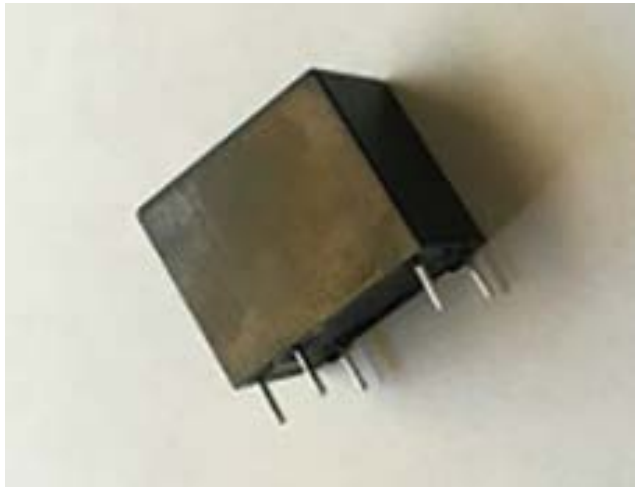
2.2.3 Sensing the Environment

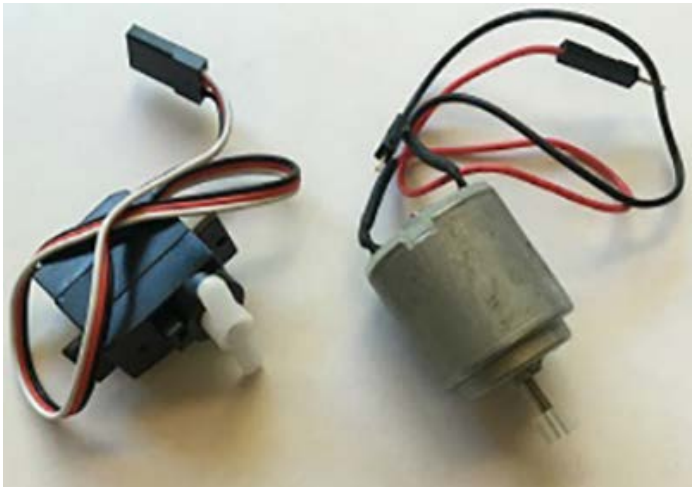
- **Sensors**
  - Detect an event from the physical environment and translate with electrical or optical signals as output to the digitized world
  - The SIK contains various sensors including Soft potentiometer, Flex sensor, Photo resistor and Temperature sensor
  - Items that can serve as inputs to a microcontroller unit such as an Arduino:
    - a sensor
    - a pushbutton
    - a Twitter message

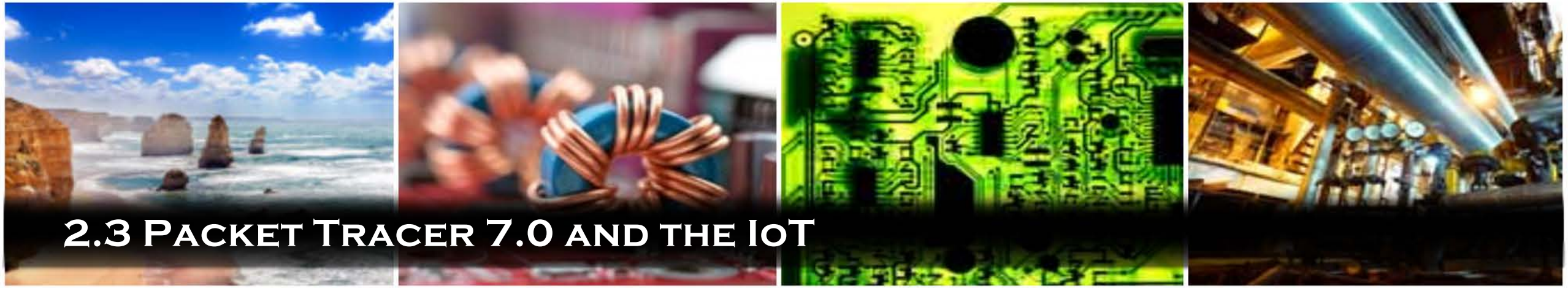


2.2.4 Making it Happen

- **Actuators and Relays**
  - An **actuator** is a type of motor that is responsible for creating physical movement
    - The SIK includes two types of electric actuators that convert electrical energy into mechanical torque
  - A **relay** is an electrically controlled mechanical switch
    - The SIK includes a plastic box that contains an electromagnet that causes a switch to trip when it receives a current
  - Actuators and relays are often used to influence the environment or create action



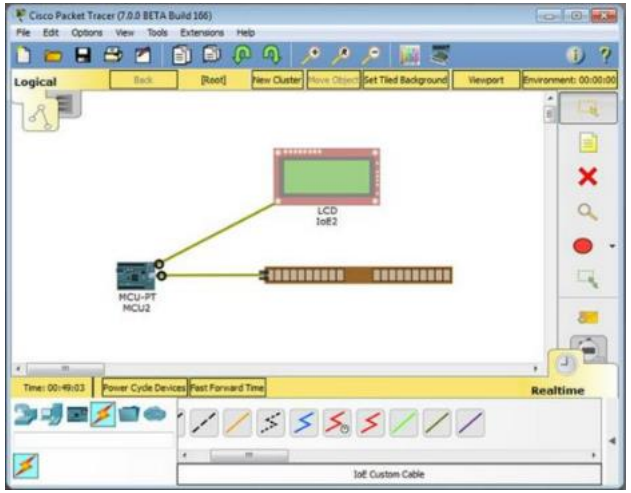




2.3 Packet Tracer 7.0 and the IoT

PT 7.0 – End-to-End IoT System Model

- **How Everything Connects in PT**
  - Packet Tracer 7.x can be used as a modeling and prototyping tool
  - There is a new group icon contained in Packet Tracer version 7.0 that is labeled Components
  - The PT IoT boards contains an MCU (Arduino) and a SBC (Raspberry Pi)
  - There are also actuators and sensors that can be used in prototypes
  - The IoE Custom Cable found in the Connections group can be used to connect IoT things to an MCU board

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