Chapter 2: Sensors, Actuators, and Microcontrollers

IoT Fundamentals

Connecting Things 2.01

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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

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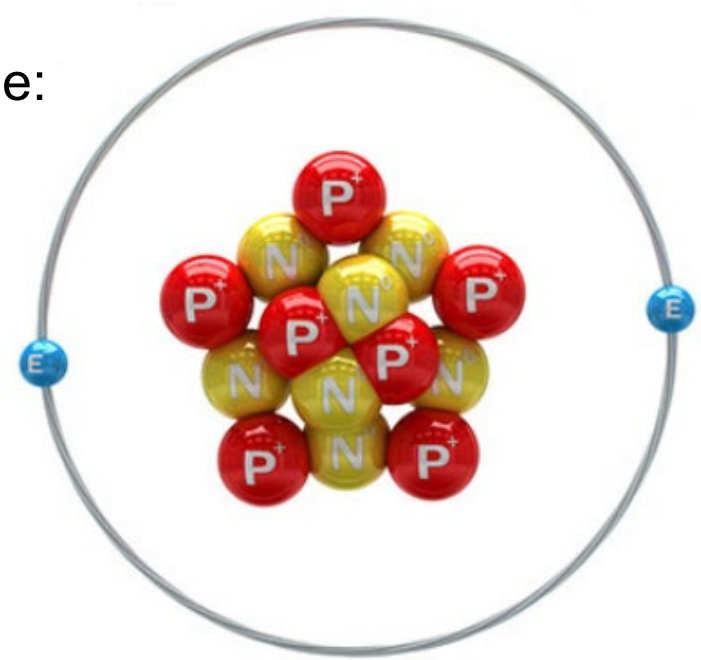
2.1.1 Basic Electronic Terminology & Concepts

- 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.
- Definitions
  - Terms commonly used in electronics include:
    - Electrons, atoms, and chemical elements
    - Electric current
    - Electrical conductors, insulators, and circuits
    - Voltage, Amperes (amps), and Power



Definition - 1

- **Electric current** is created from the movement of electrons. Current flows in a closed loop and is constant everywhere in that loop.
- **Electrons** along with protons and neutrons are what make up atoms. The basic charge on an electron is measured in terms of coulombs. One coulomb of charge is equal to the amount of charge carried by one ampere in one second.
- **Atoms** are the building blocks of all elements and matter. Electrons carry negative charges and are attracted to the positively charged protons within the nucleus of the atom.
- **Chemical elements** on the periodic table are made up of different types of atoms. The attraction between atoms and their outer electrons is stronger in some elements than in others.
- **Electrical conductors** are materials with elements that have a weak attraction between atoms and their electrons. In conductive elements, electrons tend to move from atom to atom. Examples of electrically conductive materials are metals like copper, gold, and silver.

Definition - 2

- **Electrical insulators** are materials made up of elements that strongly attract their electrons and in which the electrons never leave the atom. Examples of materials that are electrical insulators are dried wood, glass, and various rubber materials.
- **Voltage** is the force that drives current. It can also be referred to as electric pressure. Voltage is measured as the difference in electric potential energy between two points.
- **Amperes (Amps)** measure the strength of electric current. Amperes are a measure of the number of electrons in an electric current. One ampere per second is equivalent to one coulomb traveling through a circuit in one second. This is roughly equivalent to the flow of 6.241509 × 10^18 electrons per second.
- **Power** is the amount of energy consumed over time. Power is measured in **Watts**. The basic formulation of power is power = voltage x current.
- An **electrical circuit** is a physical network (or model of a physical network) of interconnected electrical components including batteries, resistors, capacitors, inductors, and switches.

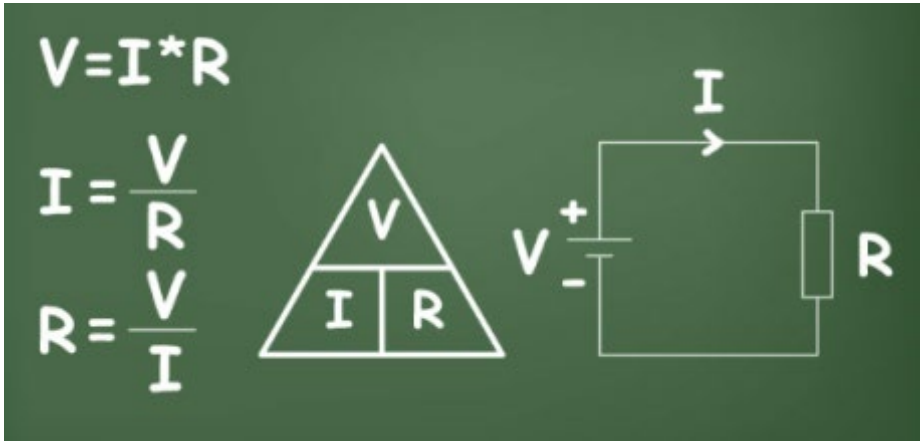
Basic Electronic Terminology / Concepts (cont'd)

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

$$V \equiv I \times R$$

$$R \equiv V / I$$

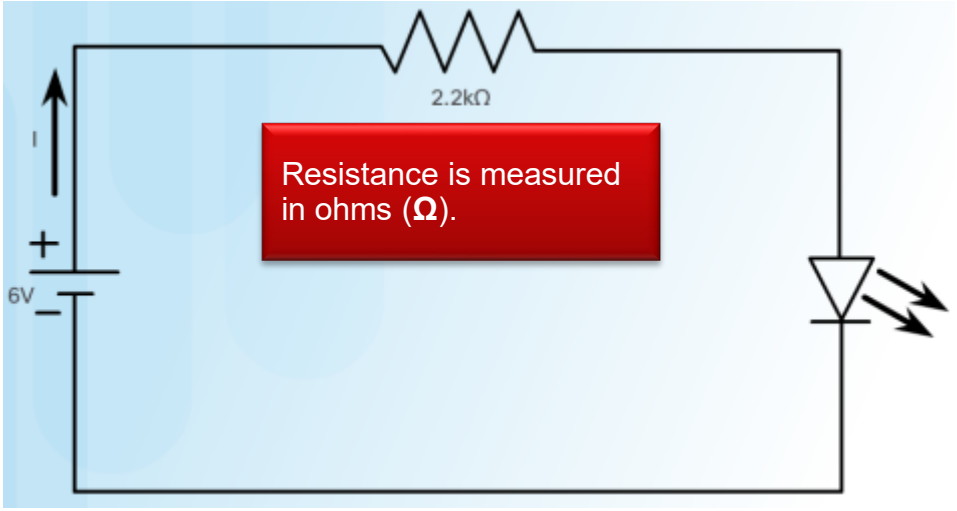
$$I \equiv V / R$$



Basic Electronic Terminology / Concepts (cont'd)

- Basic Circuit (Cont.)
  - 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 light-emitting diode (LED)

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

Basic Circuit

- Electronic devices all share a fine level of control of electrical energy. This control happens through the electronic circuit. A circuit is a closed conductive path that allows electrons to flow and create an electric current. To create an electric current the circuit also needs an electrical energy source like a battery to start the flow of electricity.
- Whereas a closed circuit allows current to flow, an open circuit has a break in the pathway which stops the current from flowing. An open circuit can be created by placing a switch along the circuit pathway. Any electrical device with an on/off switch creates a circuit which can be closed or opened.
- In contrast to closed circuits and open circuits, a short circuit is usually not created by design. A short circuit happens when an unintended connection between two points in the circuit bypass the normal pathway. Because electrical current normally takes the path of least resistance, short circuits can cause too much current to overload components. This causes overheating and results in unsafe scenarios like melting wires, component failure, and the possibility of electrical fire.

Basic Circuit

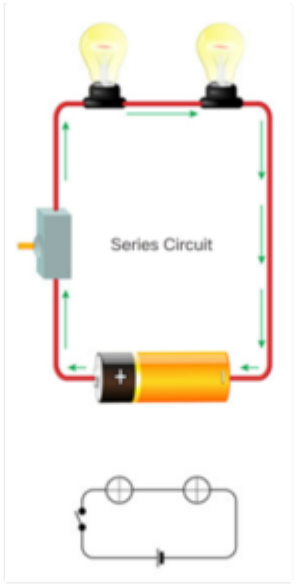
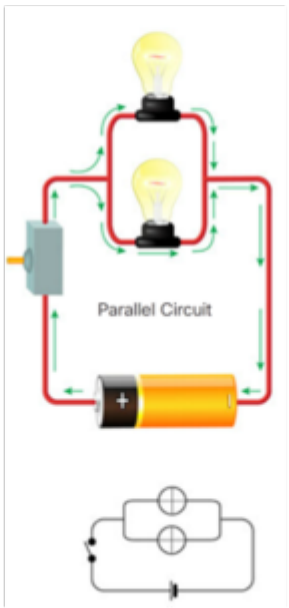
- The figure depicts a simple circuit using a battery to power a light-emitting diode (LED). In the figure, you see a circuit diagram, or **schematic**, that shows all the components of the circuit and how they are connected.
- The battery supplies 6 volts of direct current to the circuit. The plus sign near the battery symbol indicates the positive terminal of the battery. According to an early understanding of electricity known today as conventional current, electric current is positively charged, and flows from the positive terminal to the negative terminal. This is indicated in schematics that use conventional current by an arrow and the letter **I**. This labelling convention is still used today, even though it is now understood that the flow of current is the exact opposite: electric current flows from the negative terminal to the positive terminal and is made up of negatively charged electrons. Most schematics will use conventional current even though the flow of electrons is the opposite of what is shown. In this course, we will use conventional current to describe the flow of current but remember that, in actuality, the electron flow is the exact opposite.

Basic Circuit

- The lines in the circuit diagram show how the circuit components are connected, using wire or other connectors. Electronic components are usually made with leads. **Leads** are protruding wires that connect to the inside of the component and provide the means to connect the component to other circuit elements.
- The zigzag symbol at the top of the diagram represents a resistor. The role of the **resistor** is to limit the amount of current that flows through the circuit. Resistance is measured in ohms (symbolized as Ω) and the resistor in this circuit helps to keep the LED from receiving too much current and being destroyed.
- The LED is symbolized by a triangle with a line segment on one end and two arrows pointing outward. The triangular part of the symbol represents a **diode**, and the two arrows facing out represent the fact that this diode emits light. Diodes are part of a special class of electronic components known as **semiconductors**.

2.1.2 Advanced Electronic Terminology /Concepts

- Series and Parallel Circuits

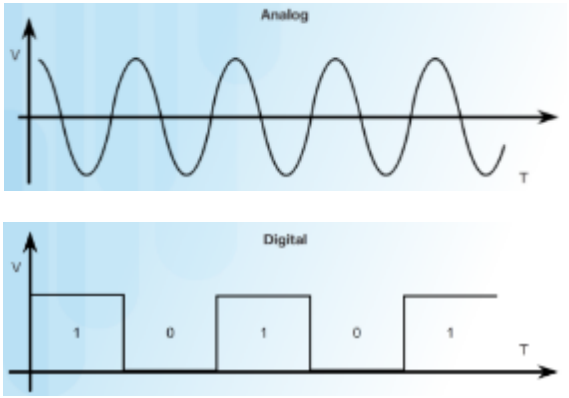
Series Circuit:	**Parallel Circuit:**
• Components are interconnected one after another in a path between the positive and negative terminals of the power source	• Current flows from the battery terminal but splits at a junction which leads to parallel pathways through the circuit. • Components connected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

Advanced Electronic Terminology/Concepts (cont'd)

- 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; components incapable of controlling current flow.
  - 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.

Advanced Electronic Terminology/Concepts (cont'd)

- 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 can be 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.



Passive, Active, Linear, and Nonlinear Circuits

- Simply stated, electronic components that produce energy are active and create nonlinear circuits. Components that store or maintain energy are passive and create linear circuits.
- In a circuit, an active component is a device that can control electric current with an external source of energy, either electric voltage or electric current. The part of the circuit that provides energy to the active component is called the direct current (DC) part of the circuit. An active circuit is a circuit with at least one active component. Active components provide power gain or amplification that produces voltage signaling that is discontinuous or nonlinear. Active components include diodes, transistors, and silicon controlled rectifiers (SCRs). Examples of nonlinear circuits are mixers, modulators, and digital logic circuits.

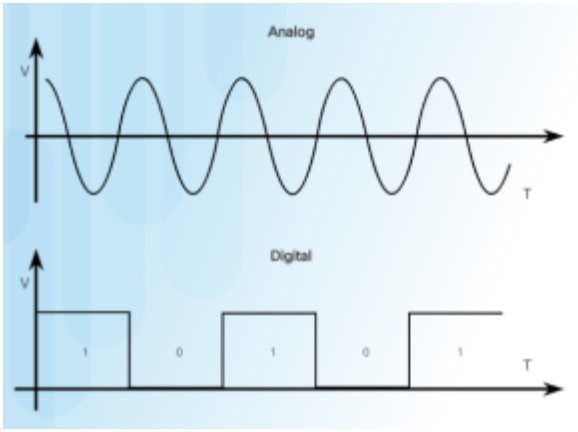
Passive, Active, Linear, and Nonlinear Circuits

- Components that are incapable of controlling current by means of another electrical signal are called passive devices. An electronic circuit consisting entirely of passive components is called a passive circuit. Resistors, capacitors, inductors, and transformers are all considered passive devices. Passive components cannot introduce energy into a circuit. They also cannot rely on a source of power, except for what is available to them from the circuit they are connected to. Passive components cannot amplify the power of a signal, although they may increase the voltage or current. The signal processing in a passive circuit is continuous or analog.
- Analog circuits are circuits where the signal is contiguous; it can assume any value between no power to full power. Digital circuits present a discrete signaling, assuming either no power or full power values (“all or nothing”), with no intermediate steps. A linear circuit is one in which the values of the electronic components (resistors, capacitors, inductors, etc.) do not change with the level of voltage or current in the circuit. Linear circuits are important because they can amplify and process electronic signals without distortion. An example of an electronic device that uses linear circuits is a sound system. A linear circuit is one that has no nonlinear electronic components in it. Examples of linear circuits include amplifiers, differentiators, integrators, and linear electronic filters.

Direct Current vs. Alternating Current

- **Direct current (DC)** is a type of current in which the flow of electrons goes one way only. Direct current is produced by sources such as batteries, power supplies, thermocouples, solar cells, or dynamos. Direct current is used to charge batteries and as power supply for electronic systems. Direct current can be obtained from alternating current by using a rectifier to convert AC into DC. Rectifiers force current to flow in one direction only and are commonly found in an AC to DC power supply.
- **Alternating current (AC)** is an electric current in which the flow of electric current periodically reverses direction. AC is the form in which electric power is delivered to businesses and residences. The usual waveform of alternating current in most electric power circuits is a sine wave. In certain applications, different waveforms are used, such as triangular or square waves. Alternate current is produced in the electrical power plant by taking advantage of various forms of mechanical energy (water flowing from a dam or the spin of a wind turbine) to move large scale alternators. The alternators then transform the mechanical energy into electricity. Direct current produced by a solar plant may be converted into alternating current with an inverter or a motor-generator set.
- https://www.youtube.com/watch?v=vN9aR2wKv0U

Analog Circuits vs. Digital Circuits



- Analog circuits are circuits in which current or voltage may vary continuously with time to correspond to the information being represented. Analog circuits are used in power management circuits, sensors, amplifiers, and filters.
- Digital circuits have electric signals that take on two discrete values corresponding to the level of voltage. These values are binary and are represented as 1/0, on/off, or high/low. In digital circuits, binary encoding is used: one voltage represents a binary 1 and another voltage usually a value near the ground potential, or 0 volts, represents a binary 0, as shown in the figure. Digital circuits can be designed to provide both logic and memory by interconnecting these binary signals, enabling them to perform arbitrary computational functions.
- Integrated circuits are miniaturized circuits produced on a single piece of semiconductor. Integrated circuits are often referred to as chips and can have hundreds to billions of electronic components embedded into a single chip.

Components

- Electronic components are specialized devices used in a circuit to control current. Some examples of electronic components are wires, switches, resistors, capacitors, diodes, transistors, inductors, and integrated circuits, as shown in the figure. Electronic components have two or more electrical terminals or leads. The leads connect to create an electronic circuit with a particular function like an amplifier, radio receiver, or oscillator. Electronic components can be individual items, arrays or networks of like components, or integrated inside of packages such as integrated circuits.

Larger Electronic Building Blocks

- There are electronic components that can be used to provide greater amounts of electric current to run large motors and machinery. The magnetic field produced by current running through a coil of wire can be used to exert a mechanical force on any magnetic object. The magnetic force can be turned on or off by switching the current on or off through the coil.
- If you place a magnetic object near the coil for the purpose of making the object move when you energize the coil, you have a solenoid. The movable magnetic object is called an armature. Solenoids can be used to electrically open door latches, open or shut valves, move robotic limbs, and even actuate electric switch mechanisms. If a solenoid is used to actuate a set of switch contacts, this is called a relay.
- Relays are extremely useful when you have a need to control a large amount of current and/or voltage with a small electrical signal. The relay coil which produces the magnetic field may only consume fractions of a watt of power, while the contacts closed or opened by that magnetic field may be able to conduct hundreds of times that amount of power to a load.
- In the figure, the relay's coil is energized by the low-voltage (12 VDC) source, while the single-pole, single-throw (SPST) contact interrupts the high-voltage (480 VAC) circuit. It is quite likely that the current required to energize the relay coil will be hundreds of times less than the current rating of the contact. Typical relay coil currents are well below 1A (1 ampere), while typical contact ratings for industrial relays are at least 10A (10 amperes).

Design Phase

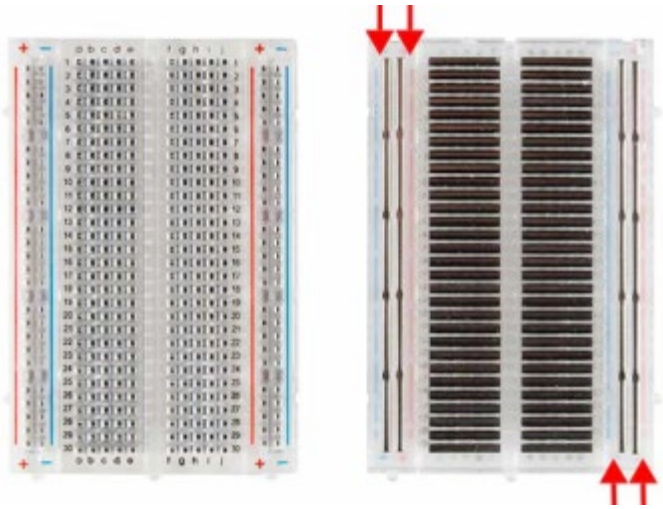
- The design phase consists of the following steps:
- 1. Concept - This is the initial idea.
- 2. Research - This is the detailed research regarding the technology required, possible vendors, material and design costs, and a feasibility study.
- 3. Circuit Design - This is the schematic diagrams, printed circuit layouts, and product enclosure designs.

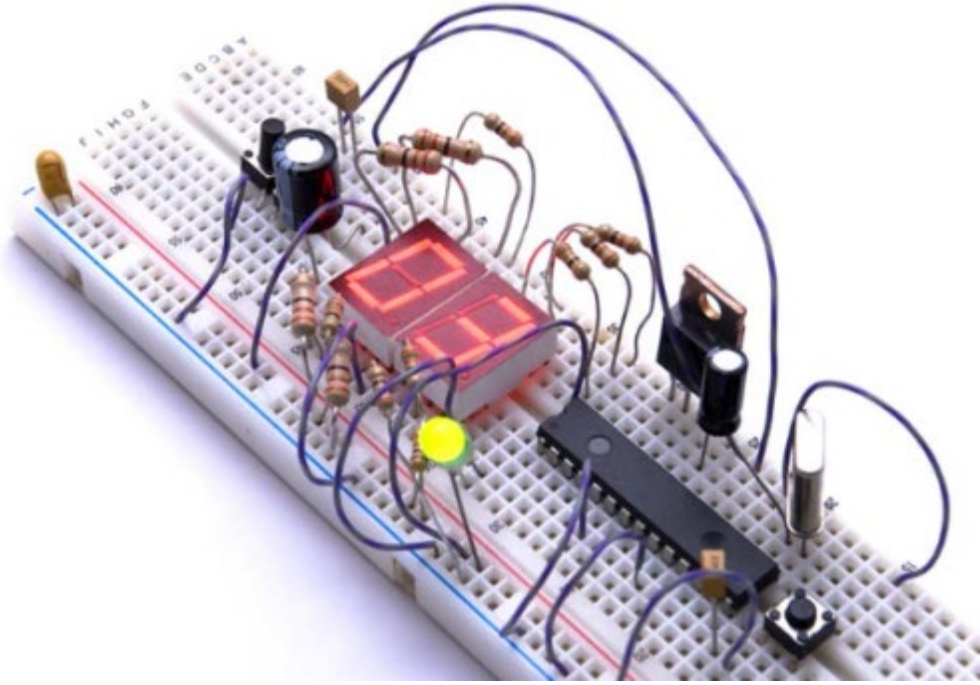
- The schematic in the figure is known as a circuit diagram. It is a graphical representation of an electrical circuit. A circuit diagram shows the components and interconnections of the circuit using standardized symbolic representations. The presentation of the connections between the circuit components in the diagram does not necessarily correspond to their physical arrangement in the finished device. A pictorial circuit diagram uses simple images of the components and their physical connection.

Prototype Phase

- The prototype phase consists of the following steps:
- 1. **Hardware, Mechanical, and Software Development** - Software is a significant part of the project. Like the hardware, it should start with the high level design.
- 2. **PCB layout** - The printed circuit board (PCB) design is a major element in electronics hardware development. Signal integrity tests should be carried out as part of this activity. Normally PCB CAD software packages are used to create the designs.
- 3. **Build prototypes** - Build the prototype of the finished product including graphics and packaging.
- 4. **Product Testing** - Thorough product testing and Test Readiness Review (TRR) is required before moving on to the next phase.

Solderless Breadboard





- A solderless breadboard is a tool commonly used in electronic prototyping. The solderless breadboard provides the ability to create temporary circuits by plugging components into holes arranged in rows and columns across the surface, as shown in Figure 1. Circuits can be quickly created and taken apart by plugging and unplugging components like resistors and LEDs into the various rows and columns. The holes in the breadboard are contact holes with copper rails underneath the plastic surface, shown in Figure 2. Because the breadboard is solderless, it is a reusable prototyping tool making it easy to create temporary prototypes and experiment with circuit design.

Production Phase

- The production phase consists of the following steps:
- 1. **Production Readiness Review** - This step should be undertaken before the product is launched into full production.
- 2. **Production** - At this point all of the equipment should have been tested.
- 3. **On-going Maintenance** - Even when a product has entered production, on-going design maintenance is needed. Component obsolescence, design problems previously unnoticed, minor enhancements and other issues will all need to be addressed.

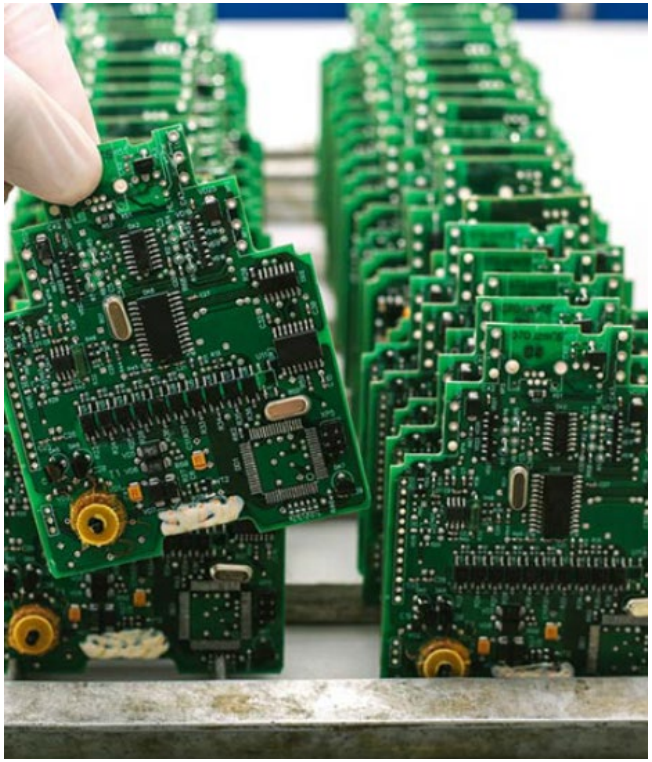
Printed Circuit Board (PCB)

Image from yahoo

- A printed circuit board (PCB), shown in the figure, mechanically supports and electrically connects electronic components. A PCB uses conductive tracks, pads and other features etched from copper sheets and laminated onto a non-conductive substrate. Components, such as capacitors, resistors or active devices, are generally soldered on the PCB.
- PCBs can be single-sided (one copper layer), double-sided (two copper layers) or multi-layer (outer and inner layers). Conductors on different layers are connected using small opening in the board called **vias.** Multi-layer PCBs allow for many more components than single- or double-sided PCBs of the same size.
- PCBs are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods, as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

2.1.3 From Schematic Diagram to Breadboard to Soldered PCB

- Design Phase:
  - Consists of three steps: Concept, Research, Circuit Design.
  - 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.
- Production Phase:
  - Consists of three steps: Production Readiness Review, Production, On-going Maintenance.
  - Often employ on printed circuit boards (PCBs).



Sensors

- https://en.wikipedia.org/wiki/List_of_sensors
  - Geophone (detecting earth movement)
  - Hydrophone (detecting water sound/pressure change)
  - Microphone (detecting sound)
  - Air-flow sensor (detecting air)
  - Light sensor (detecting light)
  - Electronic nose

2.2 Microcontrollers: The SparkFun Inventors Kit

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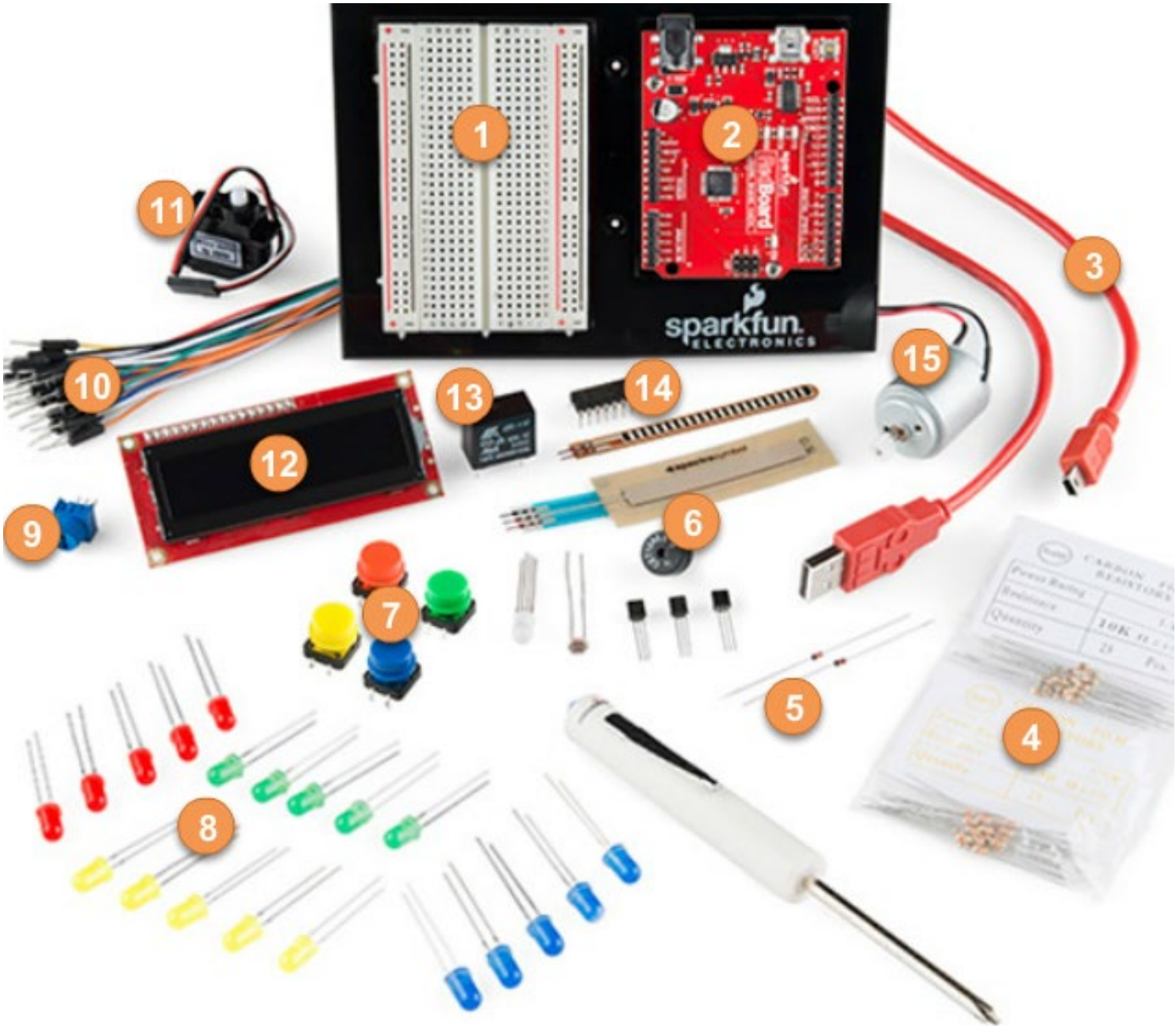
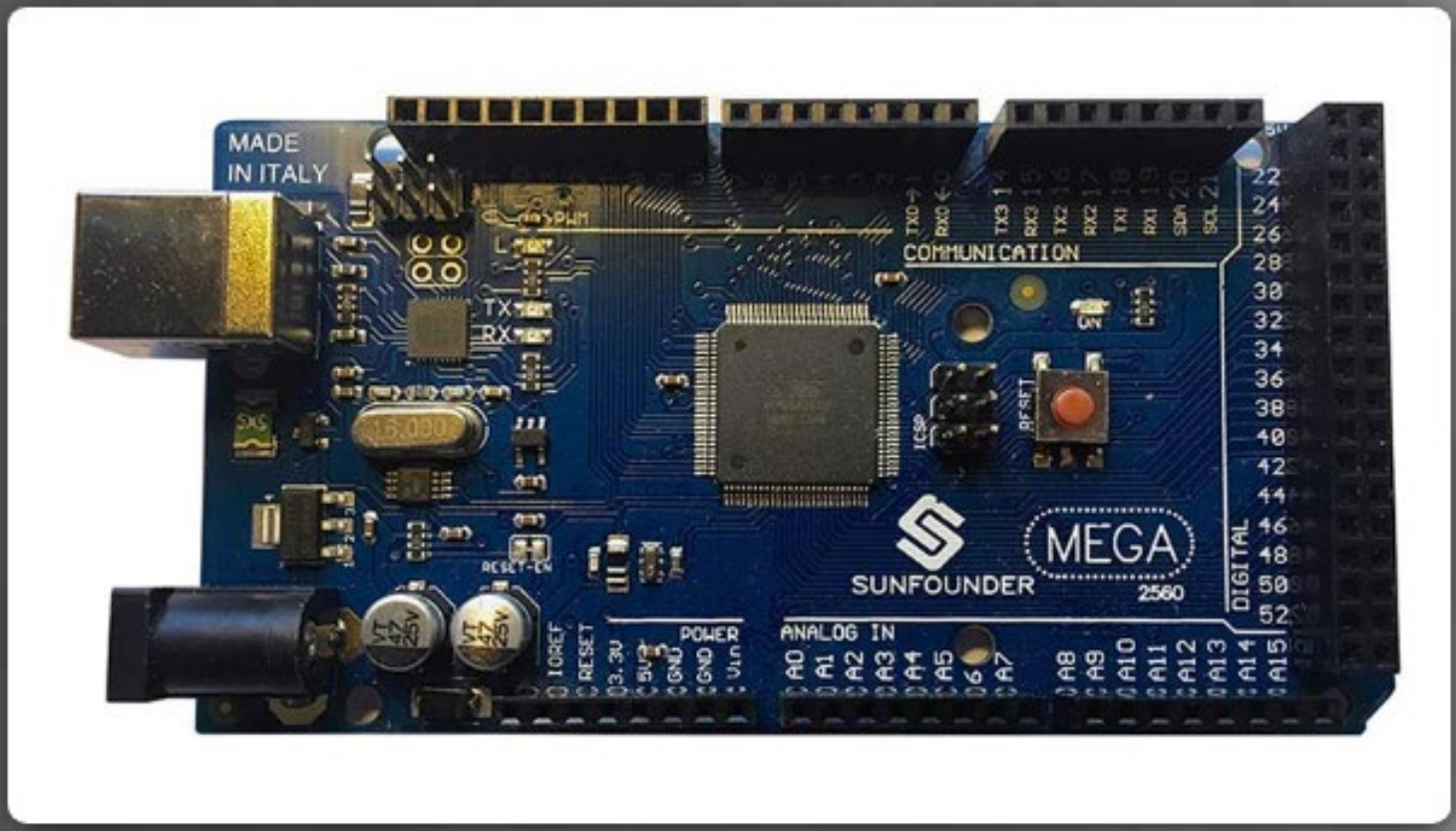
2.2.1 Introducing the Kit

- Introduction to the SparkFun Inventor's Kit (SIK)
  - This is a starter kit for building circuits and includes:
    - Solderless breadboard
    - SparkFun RedBoard (Arduino-like board)
    - Various resistors, diodes, LEDs, sensors and actuators
    - Connecting wires (jumper wires, mini-B cable, …)
- 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 RedBoard is an Arduino-like board that can be programmed using Arduino IDE.



Arduino Microcontroller

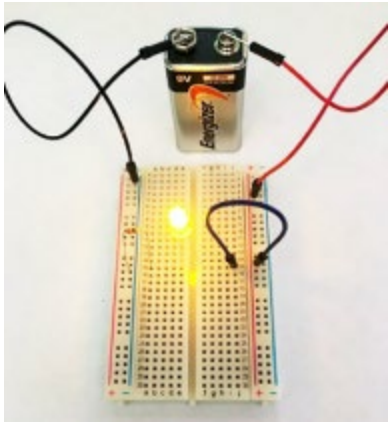


Arduino Microcontroller

- A computer can be programmed to detect an event that was triggered by a sensor, and then perform an action based on that event. Microcontrollers are a great platform for performing these tasks due to their miniature size and meager power requirements. A microcontroller unit (MCU) is a simple computer designed and built in a small form factor. When paired with sensors or actuators, microcontrollers can be programmed to act based on triggers. The Arduino, shown in Figure 1, is a popular microcontroller for prototyping.
- Arduino boards are able to read inputs, such as light on a sensor, a finger on a button, or a Twitter message. They can then turn the input into an output, such as activating a motor, turning on an LED, or publishing something online. All of this is defined by a set of instructions programmed through the Arduino integrated development environment (IDE).
- The SparkFun RedBoard, shown in Figure 2, is an Arduino-like board with an ATmega328 microcontroller that can be programmed over a USB Mini-B cable using the Arduino IDE. It is capable of taking inputs (such as the reading of a light sensor or the push of a button) and then performing various actions (like blinking an LED or moving an actuator) based on how you program it.

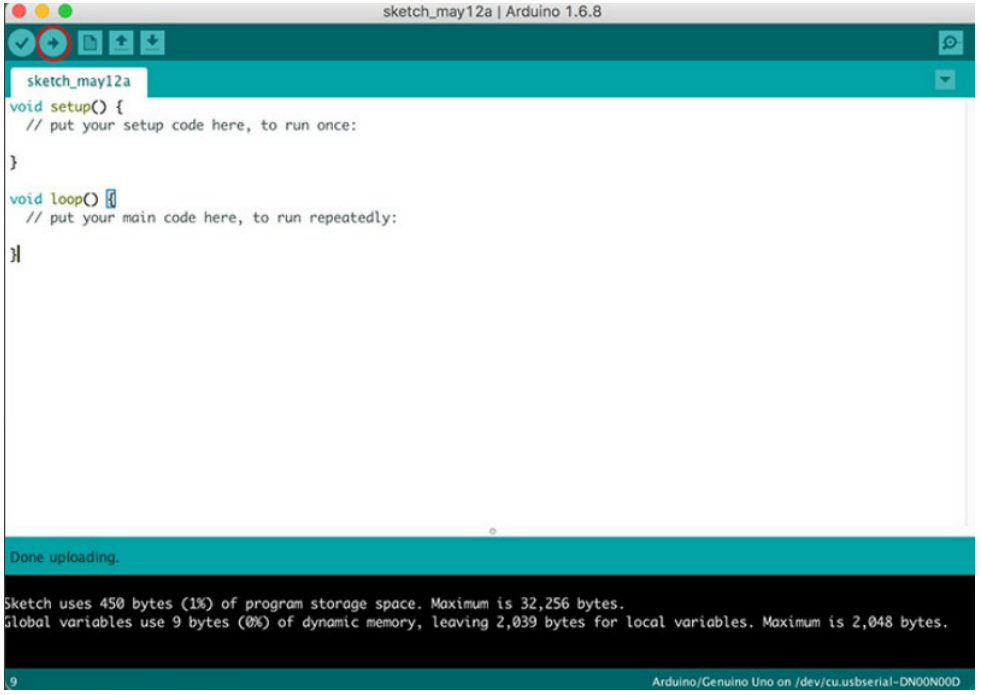
2.2.2 Simple Circuits

- 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 lower 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.
- 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), and functions.
  - Keywords used include void, setup(), loop() function, and more.

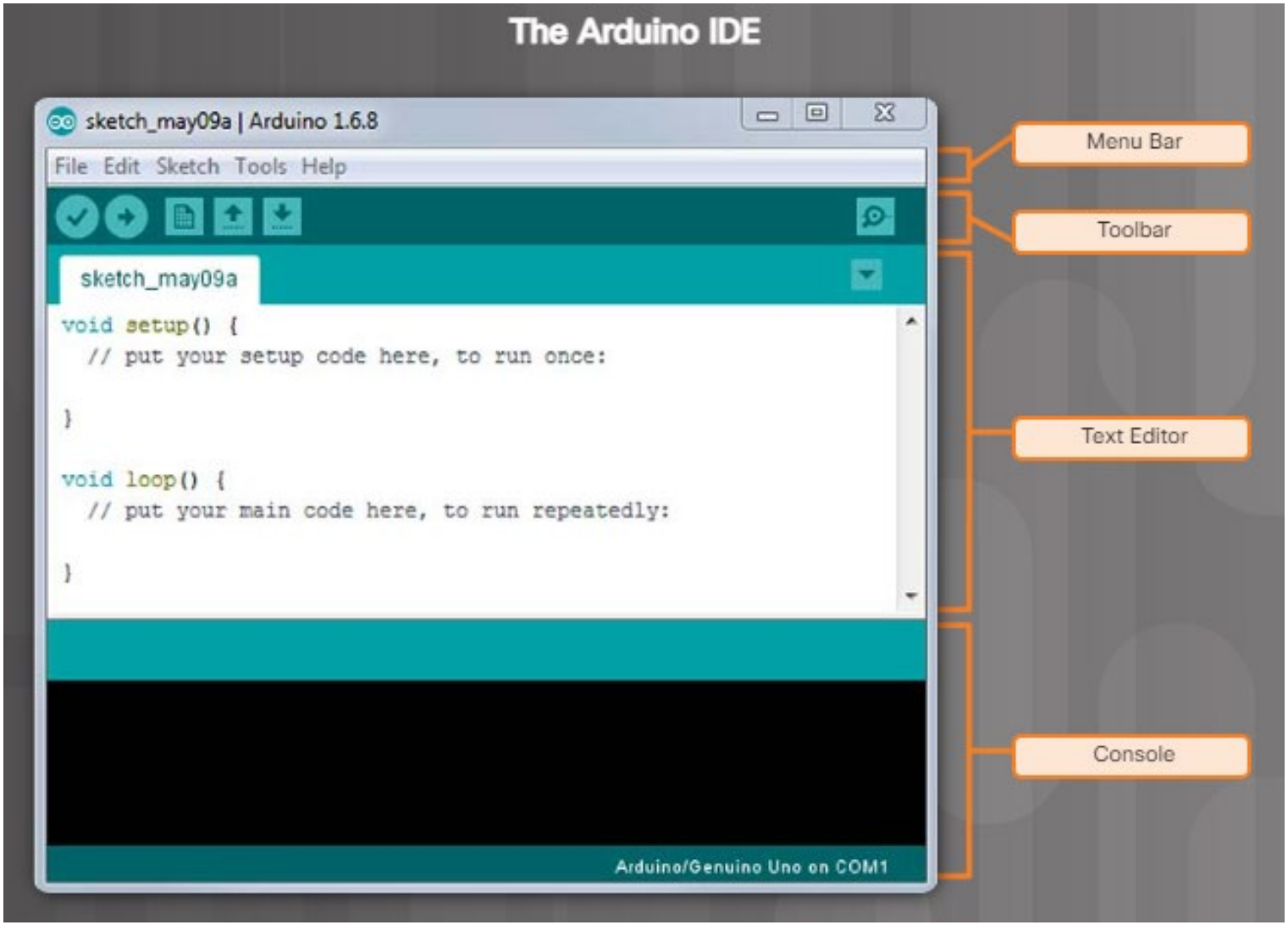


Simple Circuits (cont'd)

- 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 (⇨)



The Arduino IDE



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- The Arduino IDE software package is a program that allows you to interact with the Arduino board. It is free software that can be downloaded at the Arduino web site:
- https://www.arduino.cc/en/Main/Software
- The Arduino IDE software package contains the integrated development environment (IDE) as well as the required drivers for the Arduino boards. After the software has been downloaded, unzip the file and install the Arduino IDE software and drivers.

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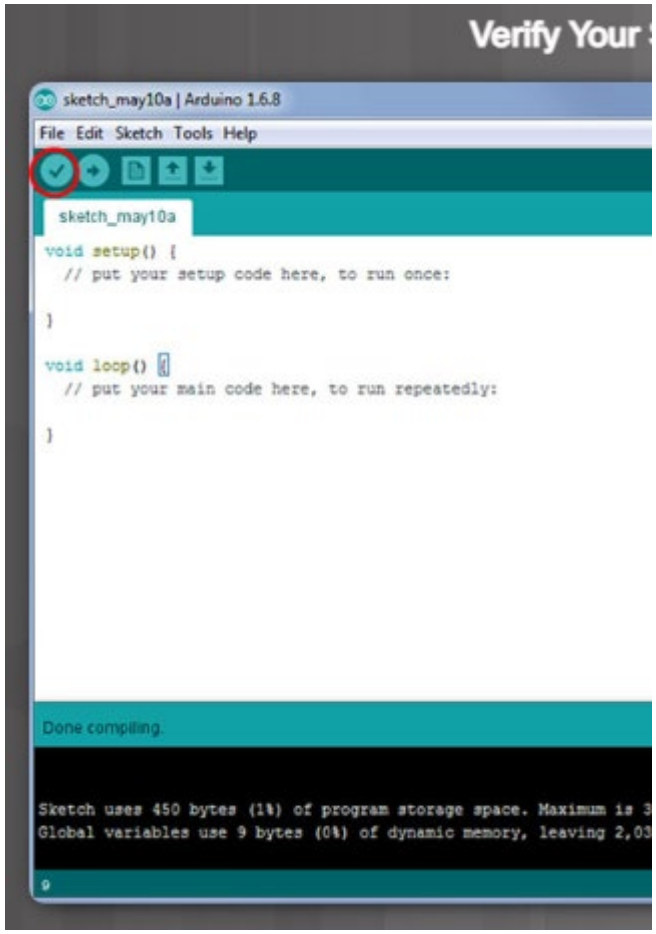
- The Arduino IDE can be divided into four main areas, as shown in the figure.
- The **MenuBar** contains five menus: **File, Edit, Sketch, Tools,** and **Help**. These menu items provide access to additional context-sensitive commands that are only available if they are relevant to the work currently being carried out.
- The **Toolbar** contains icons that provide tools to **Verify** the code in a program, **Upload** a program to the Arduino board, create a **New** program, **Open** an existing program, **Save** a program, and open a Serial **Monitor**.
- The **Text Editor** is similar to other editors that you may have used. It provides the usual text editing features, including cut & paste and search & replace.
- The **Console** displays text output, including program feedback, error messages, and other useful information.
- Programs written using the Arduino IDE are called sketches and are saved with the file extension of **.ino**. Sketches can be stored into a sketchbook that can be opened from the **File > Sketchbook** menu or from the **Open** button on the toolbar. You can view and modify your default sketchbook folder location by clicking **File > Preferences**.
- **Note**: It is recommended that you also download the SparkFun coding examples from http://sparkfun.com/sikcode. When they are downloaded, unzip the file and copy the **SIK_Guide _Code_32** folder into the Arduino's example folder (**Program Files (x86) > Arduino > examples**).

Writing code

- Arduino sketch keywords can be divided in three main category types: **structures**, **values** (variables and constants), and **functions**. A complete list of sketch keywords can be found at https://www.arduino.cc/en/Reference/HomePage.
- The first time you run the Arduino IDE software, or when you create a new sketch, you will be presented with a beginning shell of a sketch in the Text Editor section of the IDE. The following is an explanation of the keywords used in this beginning shell.
- The **void** keyword is used only in function declarations. It indicates that the function is expected to return no information.
- The **setup()** function is used to initialize variables, pin modes, start using libraries, etc. The **setup()** function will only run once, after each power up or reset of the Arduino board.
- **Note**: The curly braces (**{}**) after the **setup()** function delimits the beginning and ending of the setup() function. All code contained within these braces will be executed only once.
- The **loop() function** is the main section of a sketch and loops consecutively, allowing your program to change and respond.
- **Comments** are lines in the program that are used to inform someone viewing the code. Comments are ignored by the Arduino board. Comments come in two forms: Single line and Multiple line. A Single line comment is designated by two forward slashes (**//**). Everything from the two slashes to the end of the line is considered part of the comment and ignored when the sketch is compiled. Multiple line comments start with a forward slash and an asterisk (**/***) and end with an asterisk and forward slash (***/**). All text between those delimiters is considered part of the comment. The comment can span many lines.
- **Note**: Using the multiline comment delimiters to comment out a section of code can be useful for troubleshooting.

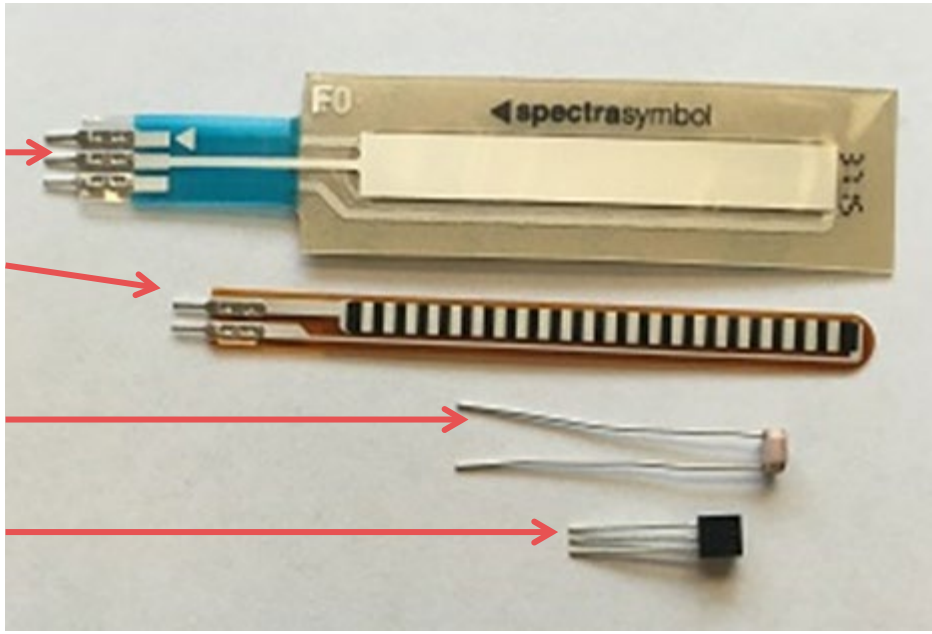
Testing



- When your prototype circuit has been built and your code has been written and saved, click the first icon on the toolbar to verify your code. The IDE will compile your code and check for syntax errors. Review any messages that you receive in the Console area of the IDE, shown in Figure 1.
- To test the code, click the second icon on the toolbar to upload your sketch to the Arduino board, shown in Figure 2. Every time you make a change to your sketch, you will need to compile and upload the new version to the Arduino board again. After a sketch is uploaded to the Arduino board it will remain there until you change it, even if you reset or power off the Arduino.

2.2.3 Sensing the Environment

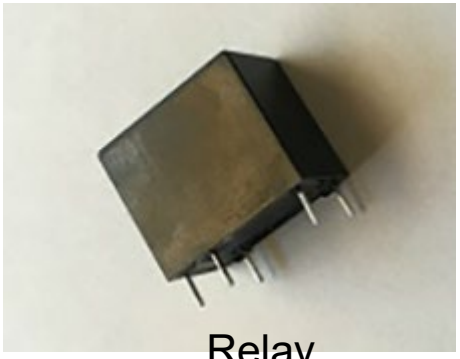
- Sensors
  - Devices that detect an event from the physical environment and respond with electrical or optical signals as output.
  - The SIK contains various sensors including Soft potentiometer, Flex sensor, Photo resistor and Temperature sensor.



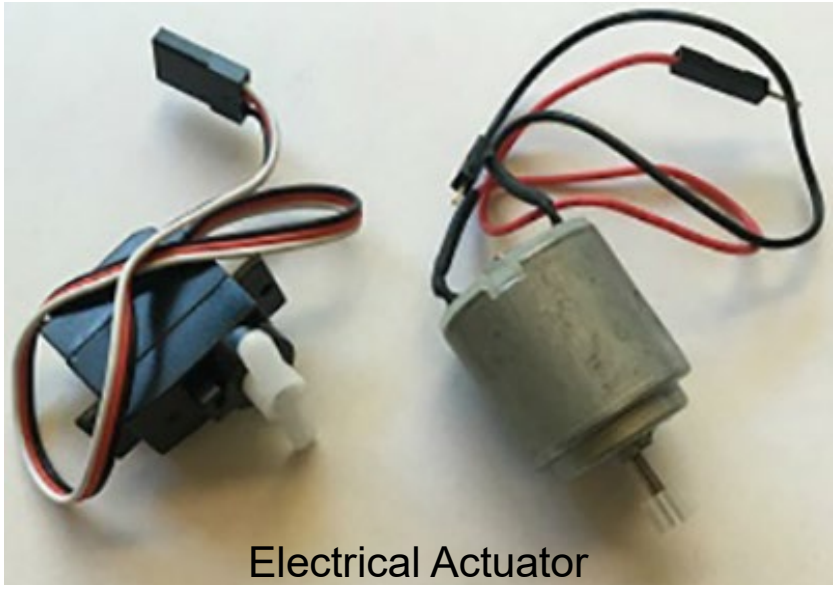
*SIK: SparkFun Inventor Kit

2.2.4 Making it Happen

- Actuators and Relays
  - An actuator is a type of motor that is responsible for creating movement.
  - The SIK includes two types of electric actuators that convert electrical energy into mechanical torque. Actuators can also use Hydraulic (Oil), Pneumatic (Air), and Mechanical power.
  - 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.



Relay



Electrical Actuator

2.3 Packet Tracer 7.x and the IoT

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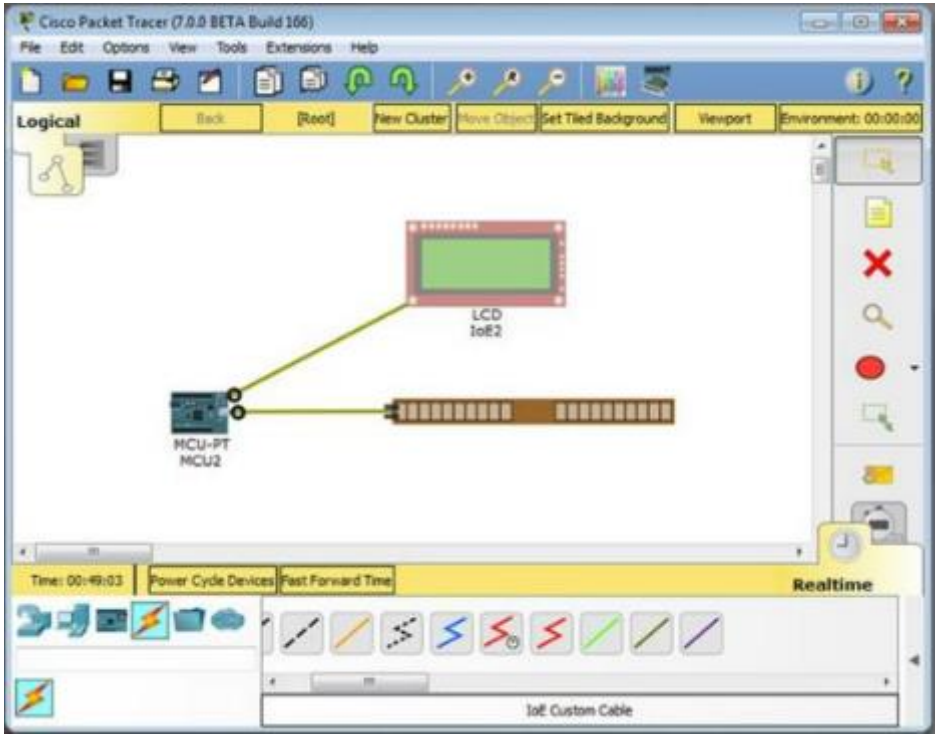
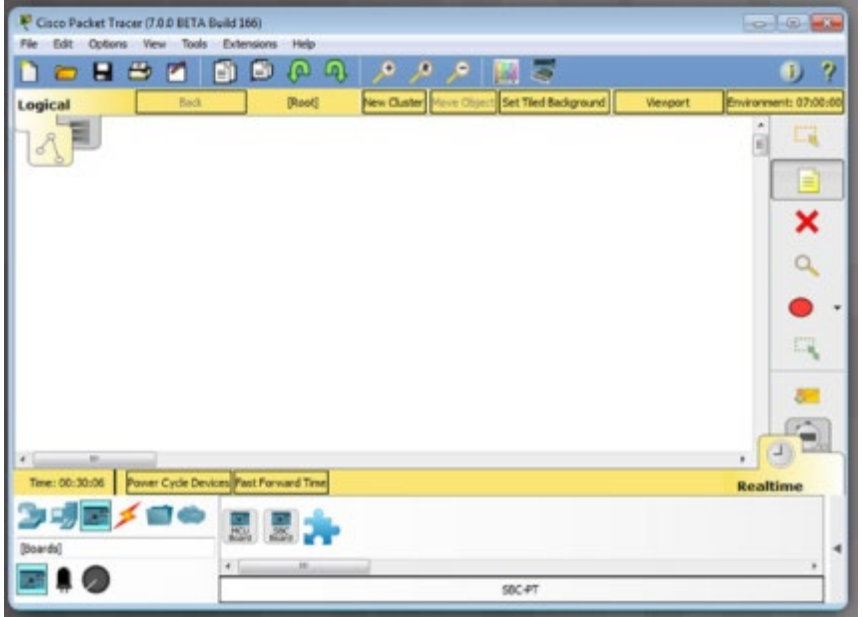
PT 7.x – End-to-End IoT System Model

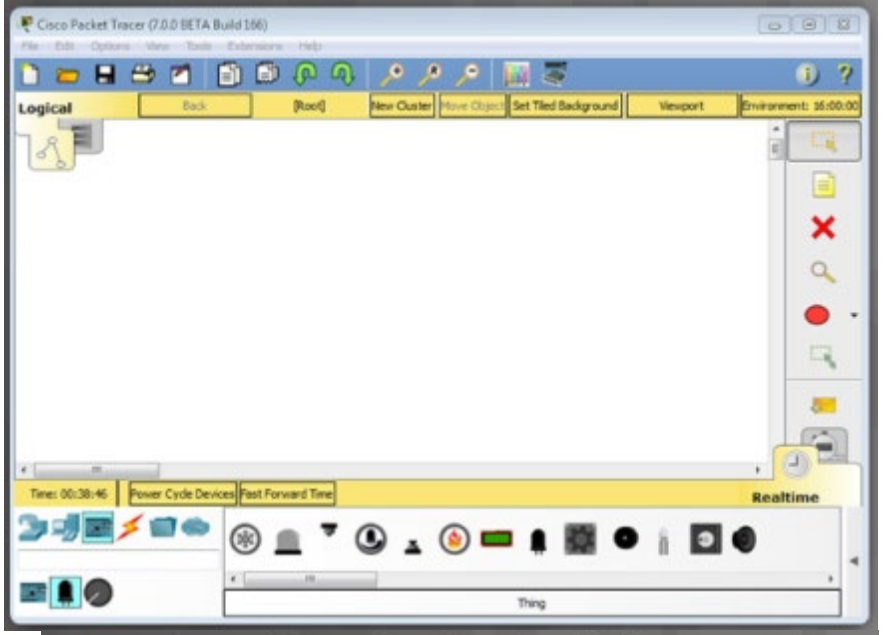
- How Everything Connects in PT
  - Packet Tracer 7.x can be used as a prototyping tool.
  - There is a new group icon contained in Packet Tracer version 7.1 that is labeled Components.
  - The PT IoT boards contains an MCU and a SBC.
  - The MCU and SBC are similar to an Arduino and a Raspberry Pi, respectively.
  - 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.



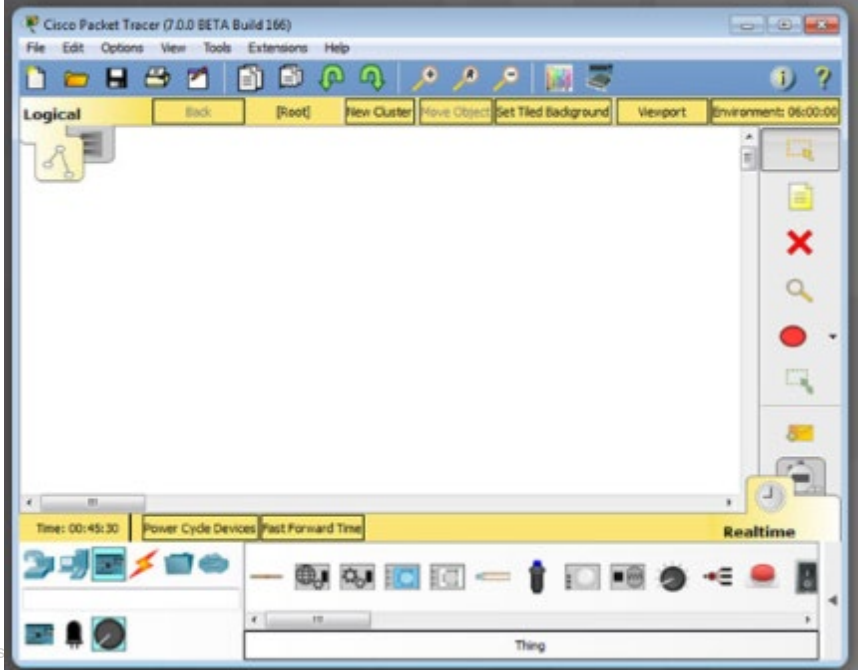
Boards



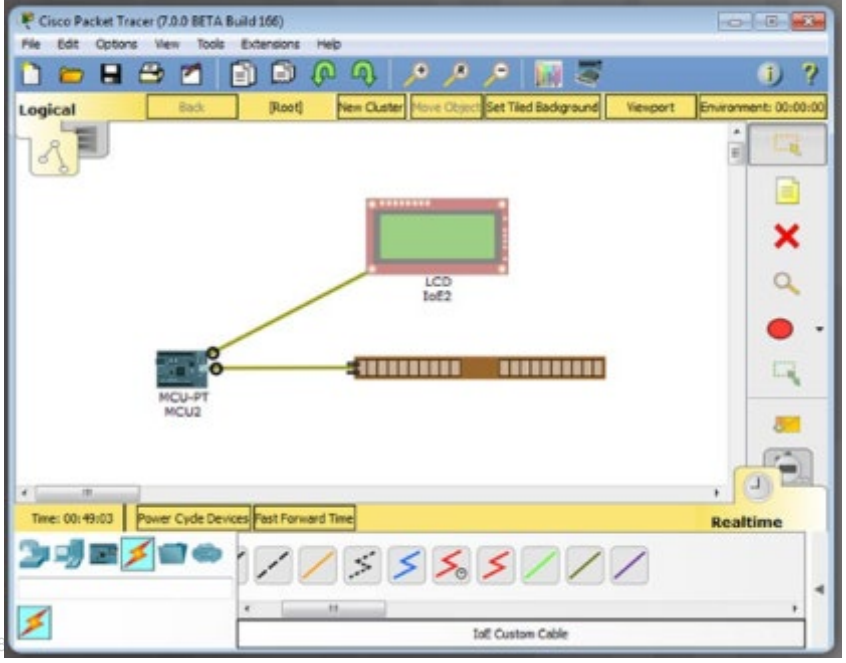
Actuators



Sensors



Connecting things to an MCU



2.4 Chapter Summary

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Summary

- Electronics is an important part of the IoT.
- 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.
- The SparkFun kit contains a number of devices and parts to help a beginner to get started with electronics and microcontrollers. It also introduces important concepts such as electronic circuits and how to program Arduino microcontrollers. Working with the kit, a beginner can also learn how to program sensors to monitor the environment. Actuators and relays are often used to influence the environment or create action.
- Students can use Cisco Packet Tracer 7.x as a tool for modeling and prototyping IoT systems.