Week 6 - introductory electronics

PREP WORK

1. *Examples for demonstration*
    - Bring in Prusa Mendel i2 printer to show controller board
    - Bring in KANEKO PLAY control panel(s)
    - Bring in openSip+Puff prototype
    - Bring in Eyewriter prototype
2. *Squishy Circuits activity*
    - Create enough Squishy Circuits dough within 24 hours before class
    - Gather components for needed for activity
        i. 2x or 3x AA battery holders, batteries (variety of 9V, AA, AAA and coin cells), LEDs, motors
3. *Parts identification activity*
    - Prepare and print out label sheets for each electronic component type with names, value units and schematic symbols (one per student + 1 for teacher)
    - Gather components for demonstration
        i. Resistors, capacitors, switches/buttons, diodes, LEDs, transistors, ICs, wire
    - Obtain a random assortment of common components
4. *Breadboarding activity*
    - Gather tools and accessories needed for activity
        i. Breadboards, jumper wires, 9V batteries with breadboard-friendly clips
    - Prepare and print out handouts for each circuit with schematics, IC pinouts and any other relevant information.
    - Gather all components for example circuits (one set per student)
        i. Circuit #1 = LED, 100ohm resistor
        ii. Circuit #2 = breadboard-friendly momentary-on tactile switch
        iii. Circuit #3 = breadboard-friendly potentiometer (10k)
        iv. Circuit #4 = 555 timer, 2 x 1k resistor, 470k resistor, 1uF electrolytic capacitor

Outline

1. *Discussion of Curiosity Handbook work since last class session*
2. Big picture introduction to electronics - why it's important and what you can do
3. *Squishy Circuits activity*
    a. Fundamentals of electricity = electrical flow, conductors vs insulators, voltage, current, resistance, AC vs DC
    b. Fundamentals of circuits = series, parallel, shorts, path of least resistance
4. Overview of electronics components - resistors, capacitors, switches/buttons, diodes, transistors, ICs, wire
5. *Grab bag sorting activity*
6. Fundamentals of schematics = what they are and why we use them
7. *Breadboarding activity*
    a. Introduction to breadboarding circuits and working with components
    b. Understanding basic schematics by example
8. Going further - how and where to learn more

HOUR 1

Big picture introduction to electronics

1. What is electronics = the study of how to control the flow of electricity
2. Why it's important
    a. We live in a world of increasingly complex physical objects that either contain electronics or are made by machines that are controlled by electronics.
    b. Software needs hardware to run on. Therefore, new developments in hardware make new developments in software possible.
    c. Simple repairs of electronics that break (maybe).
3. What you can do with electronics
    a. Control systems = "brains" that make machines work.
        i. Example: 3D printer controller boards, motherboards in computers
    b. Interactive projects = use electronics to make lights, motors, speakers, etc. do interesting things whenever a person presses a button, turns a knob, etc.

        i. Example: KANEKO PLAY control panels
    c. Solve tangible, real-world problems in situations where access to complex data networks, powerful computers and even reliable grid power is difficult or impossible
        i. Examples: assistive technology with openSip+Puff and Eyewriter
4. Don't be discouraged!
    a. Electronics is a very complex field that people from many different fields and backgrounds use. As a result, there are an overwhelming number of possible ways to learn electronics, some of which are fun and some that aren't, depending on your personal learning style and interests.
    b. Learning electronics requires lots of **experimentation** and **failure**.
    c. Take criticism and guidance from "internet experts" with a grain of salt. Don't let them discourage you, but also don't dismiss them entirely.
    d. Learn electronics through making things that are relevant and interesting to you. Focus on the end goal, and learn things as needed to achieve those goals.

Squishy Circuits activity

Fundamentals of electricity

1. Discuss electricity and electrical current flow
    a. Electricity is the flow of electrons being exchanged between atoms (illustrate on whiteboard)
    b. For now, think of electricity as being like water
2. Conductors vs insulators
    a. Electricity flows through conductors, not through insulators
    b. Conductors contain atoms whose electrons are easily moved
        i. Include metals like copper and aluminum, as well as some materials like water and people
        ii. Some conductors are better than others, and are rated by **conductivity**
    c. Insulators contain atoms whose electrons don't move easily
        i. Examples include glass, plastic, ceramics, rubber and paper
3. Distribute Squishy Circuits conducting and conductive dough
4. Voltage activity
    a. Voltage is...
        i. Similar to "water pressure" > more pressure = more power
        ii. The "pressure" that pushes electrons from positive to negative.
            1. Positive = where there are lots of spare electrons (full reservoir of water)
            2. Negative = where there are far fewer electrons (empty reservoir of water)

        iii. Sometimes referred to as “electrical potential” by people with physics backgrounds
        iv. Measured in **volts (V)**
    b. Distribute and discuss variety of batteries
        i. Ask students to identify voltage of each battery
    c. Distribute one AA battery pack to each student and have them insert batteries
    d. Ask students to create to blobs of conductive dough, connecting the positive and negative wires of their battery pack to each respectively

5. Current activity
    a. Current is…
        i. The “flow rate” of electrons in conductors
        ii. Similar to water flow rates => more current = larger volume of water
        iii. Measured in **amperes (A)**
        iv. Most hobby circuits use small amounts of current, measured in **milliamperes (mA)**
    b. Distribute LEDs and very briefly discuss polarity
    c. Ask students to install LEDs between the two blobs of dough to observe flow of current.
        i. Discuss how polarity of LED can demonstrate direction of current flow

6. AC vs DC note
    a. AC = alternating current. Positive and negative wires swap.
    b. DC = direct current. Positive and negative wires do not swap.

7. Resistance activity
    a. Electrical resistance lowers current - less comes out than comes in (the rest is usually turned into heat)
    b. Similar to adding obstacles in a stream of water
    c. Ask students to add, remove and stretch conductive dough between batteries and LED (on the positive side) and observe effect on brightness

8. Quick recap
    a. *What is voltage?*
    b. *What is current?*
    c. *What is resistance?*
    d. *Questions?*

HOUR 2

Fundamentals of circuits

1. Define “circuit” = a continuous path from positive to negative through components
    a. Water analogy = water faucet and drain circulate water through system

2. Short circuit + activity
    a. Positive and negative wires can never touch
    b. Electricity will always take the **path of least resistance**, and will choose to go through the short rather than your circuit.
    c. Short circuits can generate dangerous amounts of heat and destroy batteries and components, so be careful!
    d. Ask students to make their conductive dough balls touch and observe the effect on the LED.
        i. Ask them what they think will happen before doing it.

3. Series circuit + activity
    a. Only one path from positive to negative through whatever components are in circuit
    b. Cheap Christmas tree lights analogy = when one breaks, they all go out.
    c. Point out to students that their current LED circuit is a series circuit

4. Parallel circuit + activity
    a. Multiple paths from positive to negative
    b. Better Christmas tree lights analogy = when one breaks, the rest stay on
    c. Guide or prompt students to create parallel circuit with multiple LEDs

5. Quick recap
    a. What is a circuit?
    b. What is a short circuit?
    c. What is a series circuit?
    d. What is a parallel circuit?
    e. Questions?

Overview of electronics components

*In this section, we want students to **understand**, not **memorize!***
*Encourage students **not** to take notes, and instead think critically and ask questions*

Handout at end will cover all material for future reference.

1. **Present components with labels one at a time, succinctly describing function and use for each**
    a. Resistor
        i. *Made of* = spirals of carbon (charcoal-like material)
        ii. *Function* = limits and reduces flow (current) of electricity
        iii. *Used for* = protecting sensitive components (like LEDs) from spikes in power, directing the flow of electricity by creating more or less “attractive” paths
        iv. *Name of property* = resistance
        v. *Measured in* = ohms (Ω) - commonly in kilo- and Mega-
    b. Capacitor
        i. *Made of* = two pieces of conductive material with space between them, usually filled with a material that can hold electricity, called a dielectric.
            1. Ceramic and aluminum
        ii. *Function* = stores electricity for later use by discharging
        iii. *Used for* = filtering and smoothing signals and power fluctuations, building up large amounts of electricity for instantaneous use
        iv. *Name of property* = capacitance
        v. *Measured in* = farads (F) - commonly pico-, nano-, micro-
        vi. *Special notes* = can be polarized (electrolytic) or not.
    c. Switches and buttons
        i. *Used for* = allows a human to control the flow of electricity in a circuit by opening or closing pathways
        ii. *Terminals ...*
            1. Poles = number of circuits that can be controlled
            2. Throws = number of possible choices that poles can connect to
            3. Shorthand = xPxT - ex. SPDT means single-pole double-throw
        iii. Types ...
            1. Momentary = must be held by user or will return to default state
            2. Maintained = keeps state as user left it
            3. Latching = changes state each time it is pressed
            4. Toggle = thin stick
            5. Slide = small nub that moves along one axis
            6. Rocker = angled like a see-saw

7. Tactile = very small “clicky” switch, used in most consumer devices
8. Rotary = change state by rotating
9. DIP = array of tiny rocker or slide switches
10. Magnetic/reed = glass vessel with metal contacts that connect under external magnetism

d. Diodes
   i. *Function* = allow electricity to only flow in one direction
   ii. *Used for* = protecting electricity from flowing to parts of circuit it shouldn’t, converting from AC to DC

e. LEDs
   i. *Stands for* = **light emitting diode**
   ii. ***Function*** **= emits light**
   iii. ***Properties include ...***
      1. **Forward voltage (V) = minimum amount of voltage required to “turn on”**
      2. **Current draw (mA) = amount of current used when “on”**
      3. **Brightness = measured in millicandela (mcd)**
      4. **Wavelength = color, measured in nanometers (nm)**
      5. **Viewing angle = angle of cone from center of LED that light is visible**
      6. **Dimensions = most common types are 3mm and 5mm**

f. Transistor
   i. *Made of* = combinations of silicon tweaked to conduct or insulate
   ii. *Function* = electrically-controlled switch, or can amplify current
   iii. *Used for* = enabling and disabling circuits, amplifying signals and varying the amount of power going into a circuit (PWM)
   iv. *Properties include …*
      1. Types = NPN or PNP
      2. Pins = base, collector and emitter

g. Integrated circuits (ICs)
   i. *What are they* = self-contained circuits to do useful tasks efficiently using combinations of all other components inside a single box
   ii. *Function* = extremely varied, generally meant to solve specific problems
   iii. *Used for* = achieving desired functionality in very small format

h. Wire
   i. The “pipes” of the water analogy
   ii. *Properties include …*
      1. Core type
         a. Stranded = more flexible
         b. Solid = less flexible, but fits into breadboards
      2. Thickness = measured using American Wire Gauge (AWG)
         a. The larger the AWG, the smaller the diameter

        b. Smaller wires carry less current
    3. Insulation = most common is PVC.
    4. Conductors = some wires are actually bundles of multiple wires, referred to as conductors
- *iii. Important concepts*
    1. Stripping wires = use either wire stripper tool or needlenose + diagonal cutters. Be careful not to knick the conductor!
    2. Crimping connectors = use crimping tool.
    3. Soldering = will be covered later

2. *Grab bag sorting activity*
    a. Distribute label sheets to students
    b. Evenly distribute random parts for grab bag to students
    c. Ask students to sort parts into piles on their label sheet, using teacher's label sheet as reference if needed.

HOUR 3

Fundamentals of schematics

1. Schematic = map of the electronic components required for a circuit and how they are all connected.
2. Why they are important = allow us to record and share ideas, plan circuits before building them, and troubleshoot problems

Breadboarding activity

1. Introduction to breadboarding
    a. *What is a breadboard* = board used for prototyping circuits without any soldering
    b. *Why breadboarding is useful* = good for testing schematics, learning new parts and trying out new ideas that may require rapid tweaking
    c. *How a breadboard works*
        i. Take apart a breadboard to show internal structure
        ii. Power rails - watch out for disconnections!
        iii. Rows connected internally with metal strips
2. Circuit #1 = simple LED circuit
    a. Distribute printed schematics + worksheets
    b. Distribute breadboards, resistors and LEDs

3. Circuit #2 = LED + switch circuit
    a. Distribute printed schematics + worksheets
    b. Distribute tactile switches
4. Circuit #3 = *LED + potentiometer circuit*
    a. Distribute printed schematics + worksheets
    b. Distribute potentiometers
    c. Challenge = add switch to circuit
5. *Circuit #4 = flashing LED with 555 timer*
    a. Distribute printed schematics
    b. Distribute 555 timers, resistors, capacitors, 9V batteries + clips

Going further

1. Learning about electronics
    a. Sparkfun's learning system - http://learn.sparkfun.com
    b. Adafruit Learning System - https://learn.sparkfun.com/
    c. Basic Electronics Instructable - http://www.instructables.com/id/Basic-Electronics/
2. Where to get parts
    a. Sparkfun = http://sparkfun.com
        i. Denver-based open-source hardware manufacturer and supplier.
        ii. Slightly more focused on engineering contexts, with more products related to robotics, more variety of high-level programmable circuit boards and really cool, unique sensors.
        iii. Great resource for kits, well-made circuit boards, hard-to-find items and
    b. Adafruit - http://adafruit.com
        i. NYC-based open-source hardware manufacturer and supplier.
        ii. Slightly more focused on creative and artistic contexts, with more products related to LEDs, cosplay/costume making/prop making and wearable electronics.
        iii. Hosts weekly live shows that you can get involved with.
            1. World-leader in DIY wearable electronics developments, with live show every Wednesday at 1PM (CST) - http://adafruit.com/beckystern
            2. 3D Hangouts with Noe and Pedro Ruiz every Thursday at 2PM (CST) - https://www.adafruit.com/3dhangouts
        iv. Great complement to Sparkfun - in fact, they sell each other's products whenever they don't have their own version!
    c. Digikey - http://digikey.com

        i. Excellent source of basic electronics components like resistors, capacitors, integrated circuits and so on.
        ii. No minimum order, with very low (<$3) and fast (2-4 days) shipping.
        iii. Not a good place to buy circuit boards or hard-to-find items from.
    d. Note about RadioShack = **never** shop there unless absolutely necessary. Extremely overpriced and low-quality parts.
3. Getting involved in open-source hardware
    a. Arduino forums - http://forum.arduino.cc/
    b. Hang out, learn about new developments and share your own projects with the founders of Adafruit, Limor “ladyada” Freid and Phil Torrone, in their weekly “Ask an Engineer” and “Show-and-Tell” livestreams every Wednesday night at 8PM (CST) - http://www.adafruit.com/ask
4. Books to check out
    a. *The Art of Electronics* by Paul Horowitz and Winfield Hill
    b. *Make: Electronics* by Charles Platt
    c. *Practical Electronics for Inventors* by Paul Scherz and Simon Monk
    d. *Hacking Electronics* by Simon Monk