Introduction and Outline

- **All materials of this workshop are available for download at:**

  http://www.sqrwear.com

- **What is wearable electronics?**

Wearable Electronics

- **Nike Mag Back to the Future Shoes**

Wearable Electronics

- **iCuffLinks and iNecklace**

Wearable Electronics

- **Heart-Felt T-Shirt**

Wearable Electronics

- **Jawbone Up Band**

Wearable Electronics

- **FitBit Tracker:**

Wearable Electronics

- **Google Glass**

Introduction

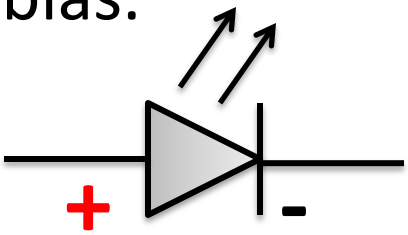
- **Demos**
  - LED Heart
  - LED Tote Bag
  - Halloween Costume
  - Temperature Sensing
  - Pulse Sensing

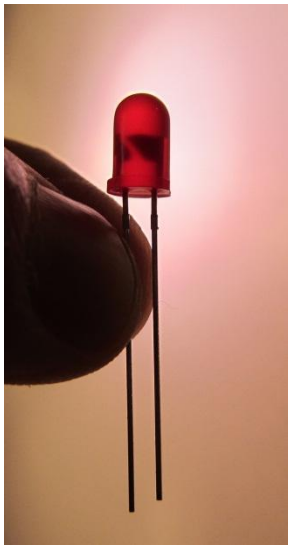
Ingredients

- **Basic Electronics**
  - LED, battery, resistor, button, parallel connection
- **Microcontroller (MCU)**
  - Digital I/O, analog I/O, serial communication, interrupts…
- **Sewing**
  - Conductive thread
  - Sewing electronic components

Basic Electronics – **LED**

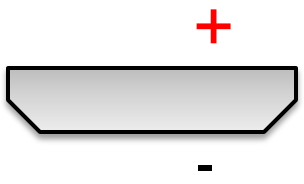
- **LED (Light Emitting Diode)**
  - Polarized:
    - Long lead positive (**+**), short lead negative
  - Forward voltage drop: **2 to 3V**
    - **Depends on the LED color.**
  - So a single AA (1.5V) battery cannot light up the LED.
  - Reverse bias.





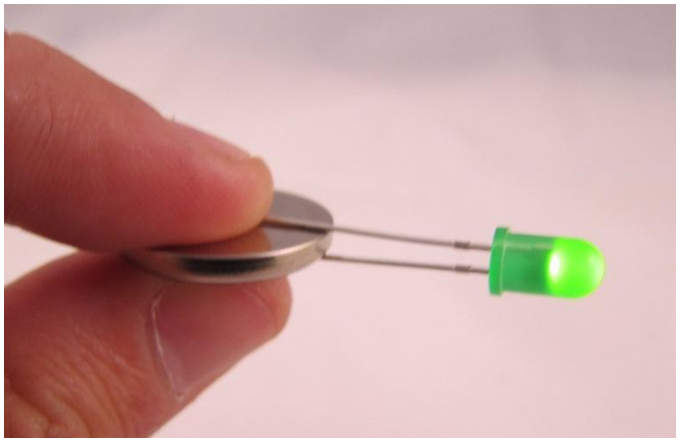
Basic Electronics – **Battery**

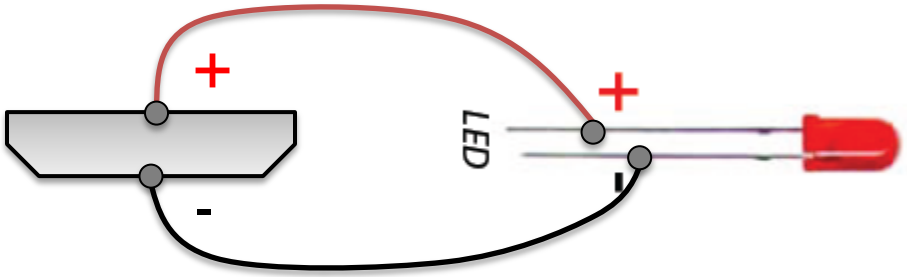
- Many different types, shapes, voltages.
  - Zinc-carbon, Alkaline, Lithium…
- The type we use here is **3V Lithium Coin (button)** Battery
  - Positive side marked by **+**



Basic Electronics – **Battery**

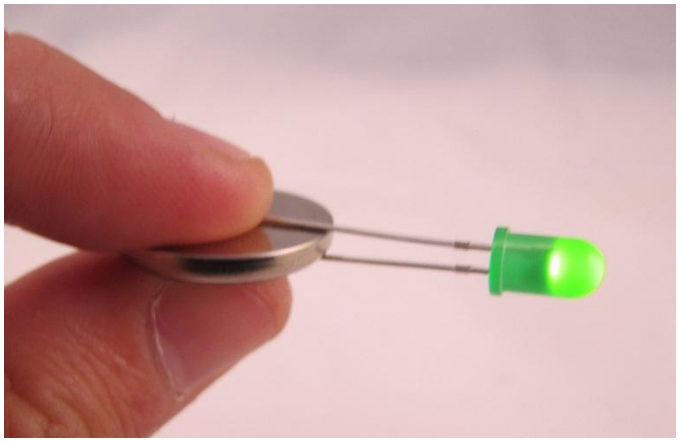
- **Connect battery with LED (exercise)**
  - Positive to positive, and negative to negative
  - Typical LED has an operating current of **1~30mA**, but can withstand higher current for a short amount of time.
  - **The more current, the brighter.**

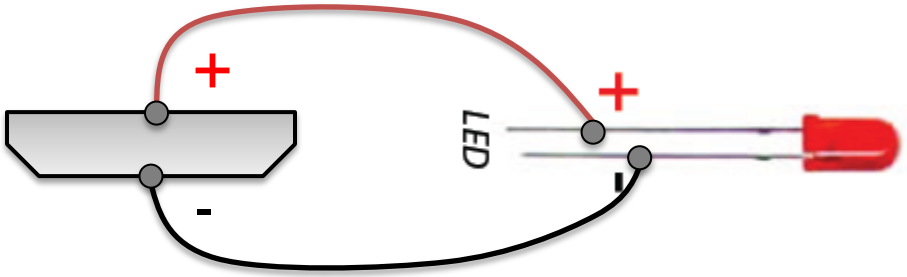




Basic Electronics – **Battery**

- **Connect battery with LED (exercise)**
  - **Try more than one LEDs at the same time.**
  - **Should I be connecting LED to battery directly like this?**
    - Battery's internal resistance.



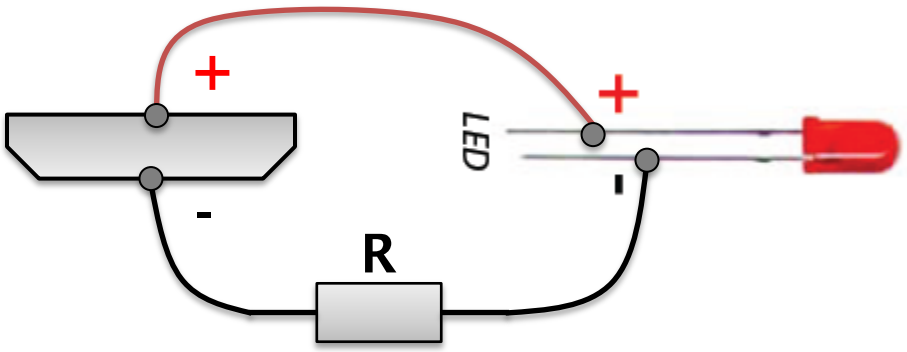


Basic Electronics – **Resistor**

- Often used to **limit current** in a circuit
  - **Resistance** (Ω, or ohm)
  - **Ohm's law**: $I\ (current) = \frac{V\ (voltage)}{R\ (resistance)}$
  - Think about a water pipe with a certain thickness.

Basic Electronics – **Resistor**

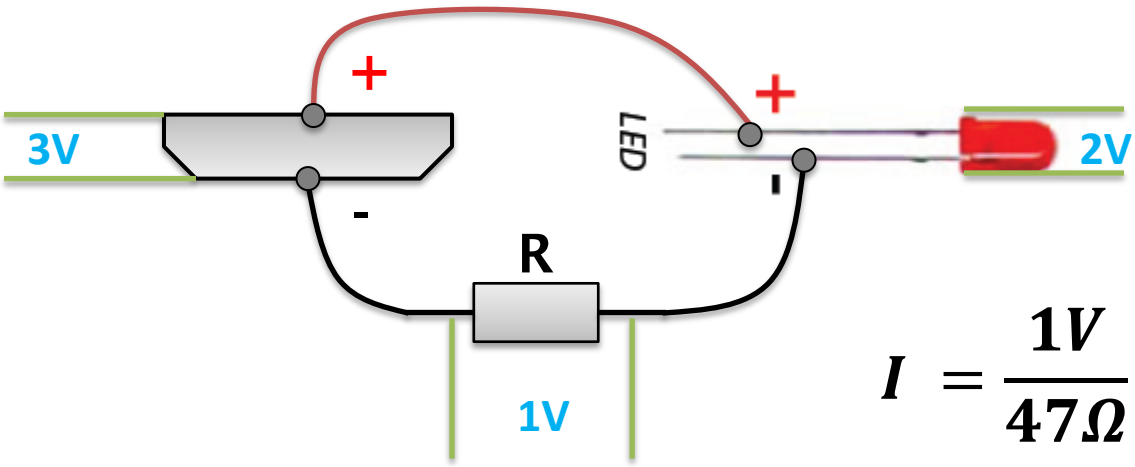
- Often used to **limit current** in a circuit
  - **Resistance** (Ω, or ohm)
  - **Ohm's law**: $I\ (current) = \frac{V\ (voltage)}{R\ (resistance)}$



Connect resistor with LED in series.

Basic Electronics – **Resistor**

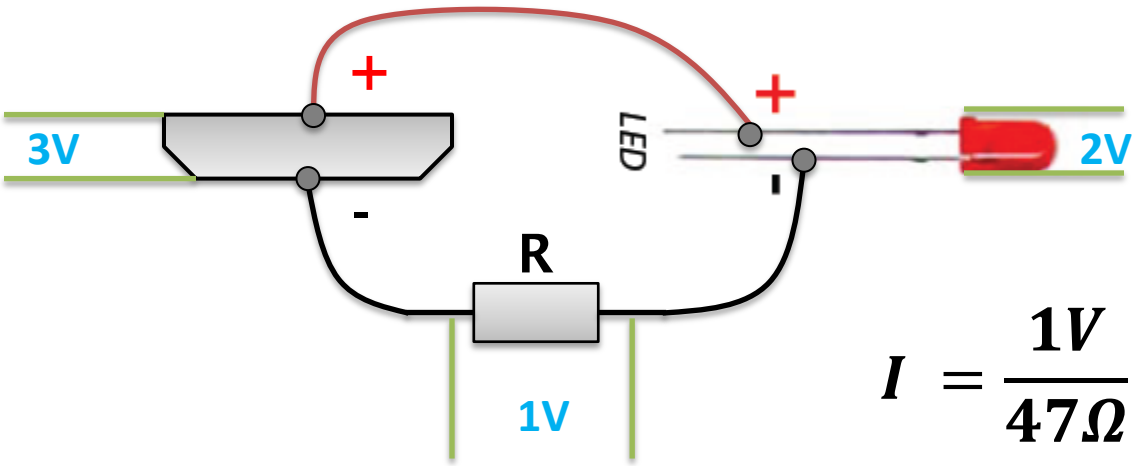
- Often used to **limit current** in a circuit
  - **Resistance** (Ω, or ohm)
  - **Ohm's law**: $I\ (current) = \frac{V\ (voltage)}{R\ (resistance)}$



$$I = \frac{1V}{47\Omega} = 21mA$$

Basic Electronics – **Resistor**

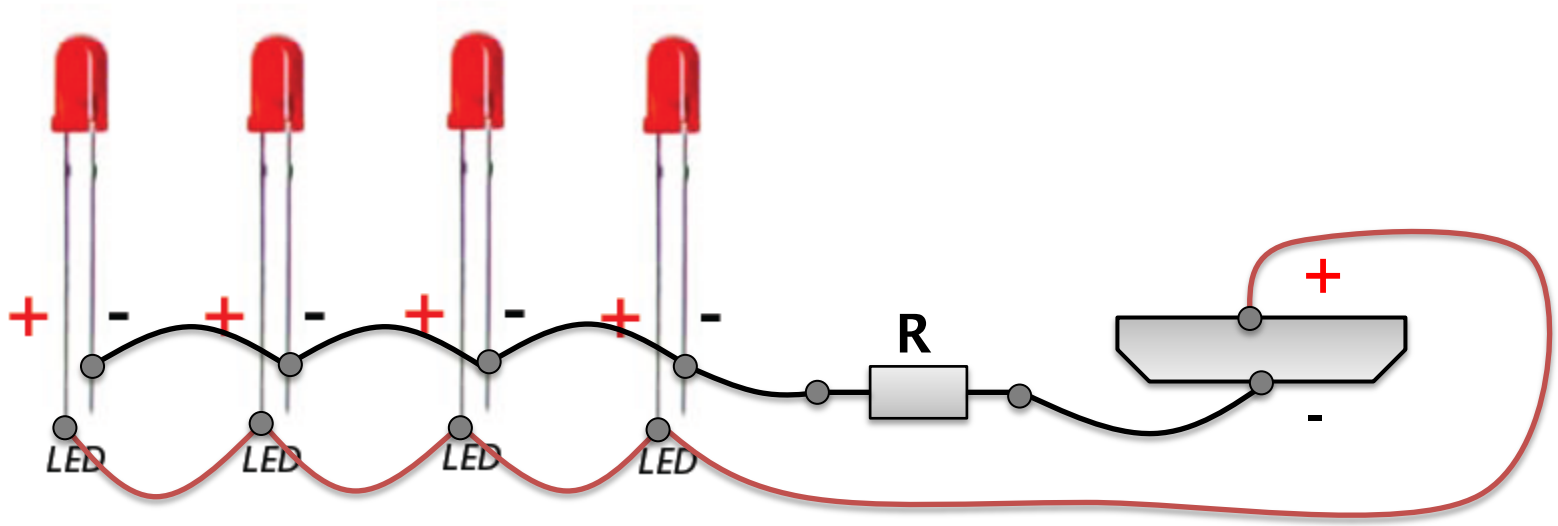
- Often used to **limit current** in a circuit
  - **Resistance** (Ω, or ohm)
  - **Ohm's law**: $I\ (current) = \frac{V\ (voltage)}{R\ (resistance)}$
  - Conductive thread has a considerable amount of resistance



$$I = \frac{1V}{47\Omega} = 21mA$$

Basic Electronics – **Parallel Connection**

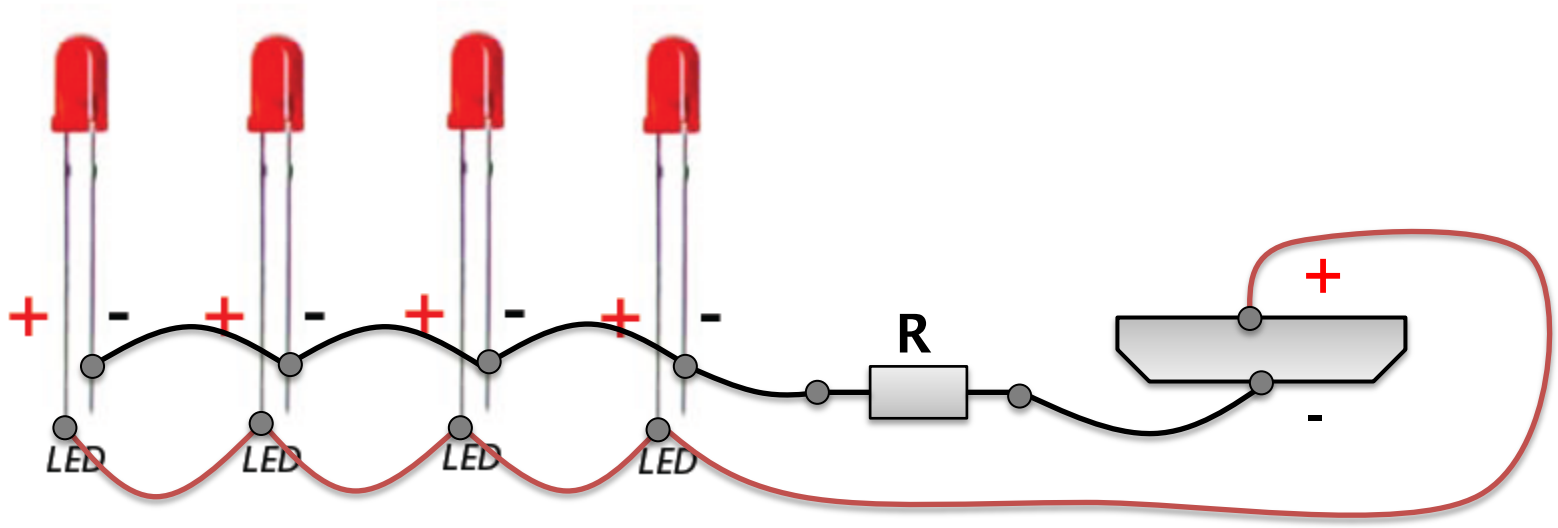
- Connecting multiple LEDs **in parallel**



All LEDs will light up at the same time. So you can arrange them in interesting spatial patterns.

Basic Electronics – **Parallel Connection**

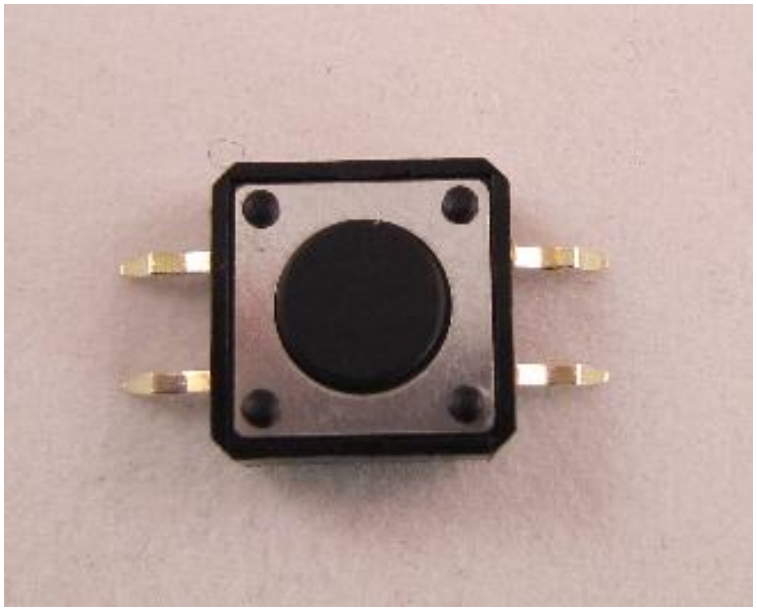
- Connecting multiple LEDs **in parallel**



However, each LED now shares a fraction (e.g. 1/4) of the total current restricted by R, thus they will look darker.

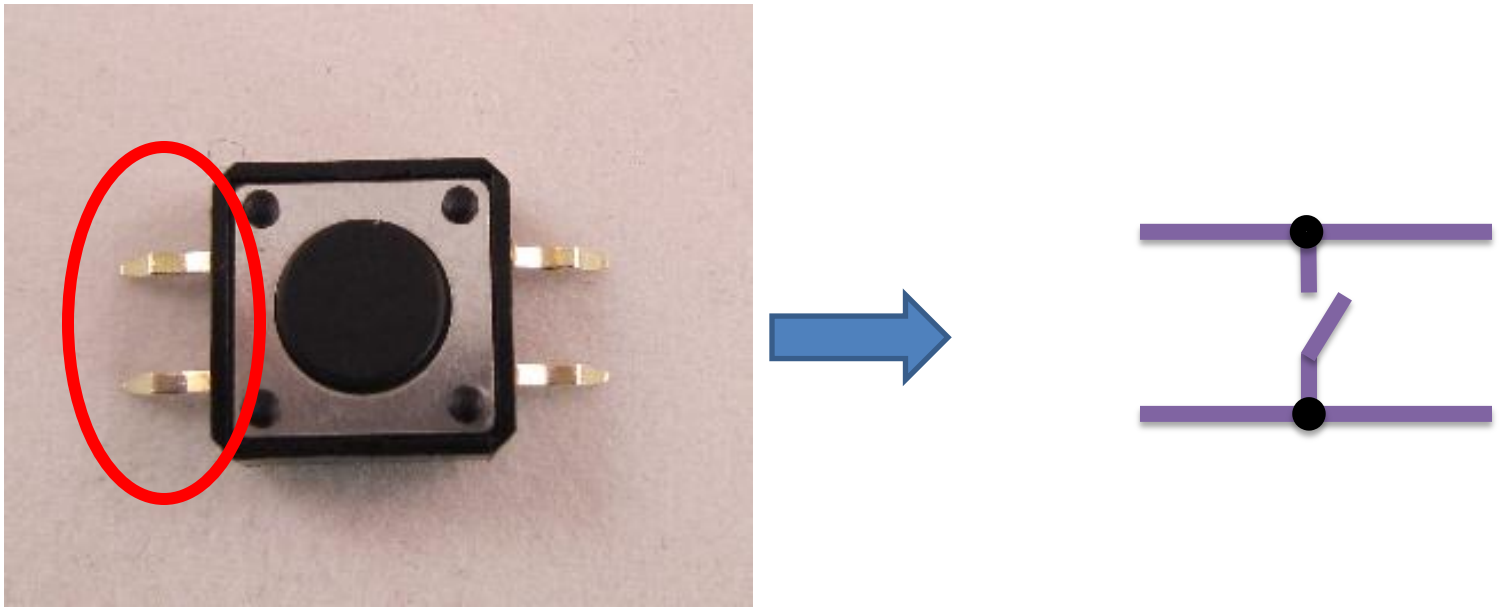
Basic Electronics – **Buttons**

- Can be used to turn power on/off, or as an input component.



Basic Electronics – **Buttons**

- Typically use one pair of pins, such as the left pair or right pair.

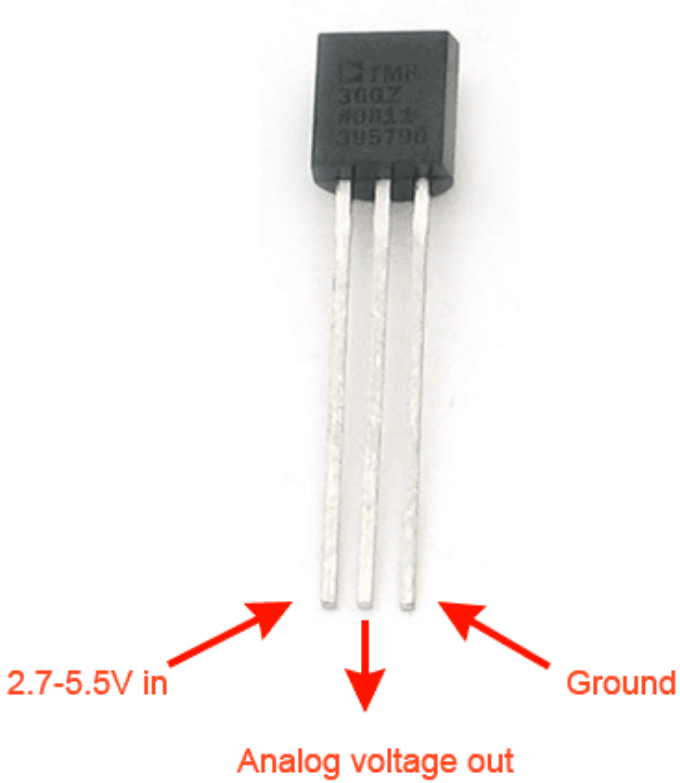


Basic Electronics – Much More

- There are many electronics components
  - **Input**: photoresistors, photodiodes, potentiometers, microphones, all sorts of sensors
    - touch sensors, accelerometers, tilt sensors, GPS sensors, temperature sensors, pressure sensors, range sensors, oxygen sensors, RFID…
  - **Output**: LED matrix, LCD, synthesizers, speakers, servos, motors, solenoids, heat wires…

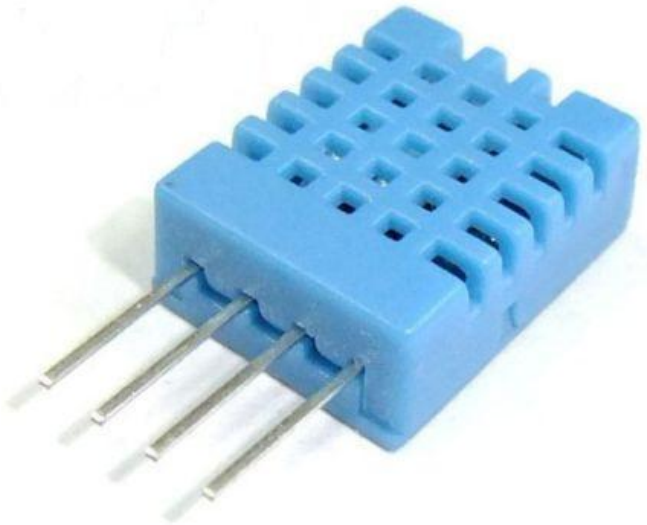
Temperature Sensor

- **Temperature Sensor**



Temperature Sensor

- **Humidity Sensor**

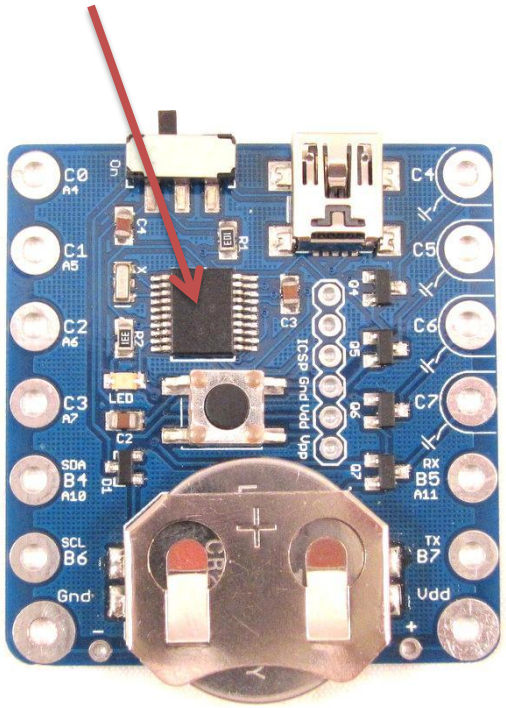


Basic Electronics – Much More

- There are many electronics components
  - **Input**: photoresistors, photodiodes, potentiometers, microphones, all sorts of sensors
    - touch sensors, accelerometers, tilt sensors, GPS sensors, temperature sensors, pressure sensors, range sensors, oxygen sensors, RFID…
  - **Output**: LED matrix, LCD, synthesizers, speakers, servos, motors, solenoids, heat wires…
  - **Brain**: **microcontrollers**!

Microcontroller (MCU)

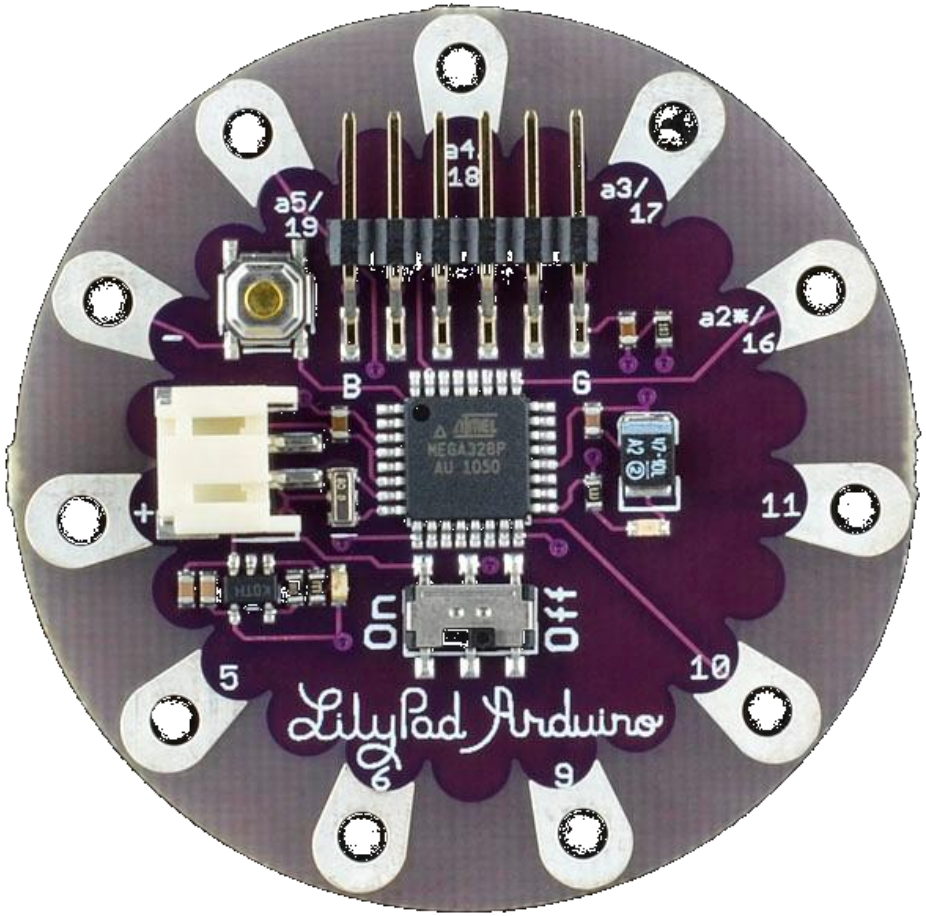
- **What is a microcontroller (MCU)?**
  - Tiny computer on a single integrated circuit
  - Direct control of hardware pins (digital/analog), so it can directly talk to electronic components.
  - Low power consumption, widely used in electronic gadgets



Microcontroller (MCU)

- **LilyPad Arduino**
  - Popular microcontroller board for wearable electronic projects.
  - 16MHz CPU speed, 32KB flash, 14 digital pins
  - Can be programmed using a Java style language (Arduino software)
  - Program is uploaded using external USB FTDI programmer

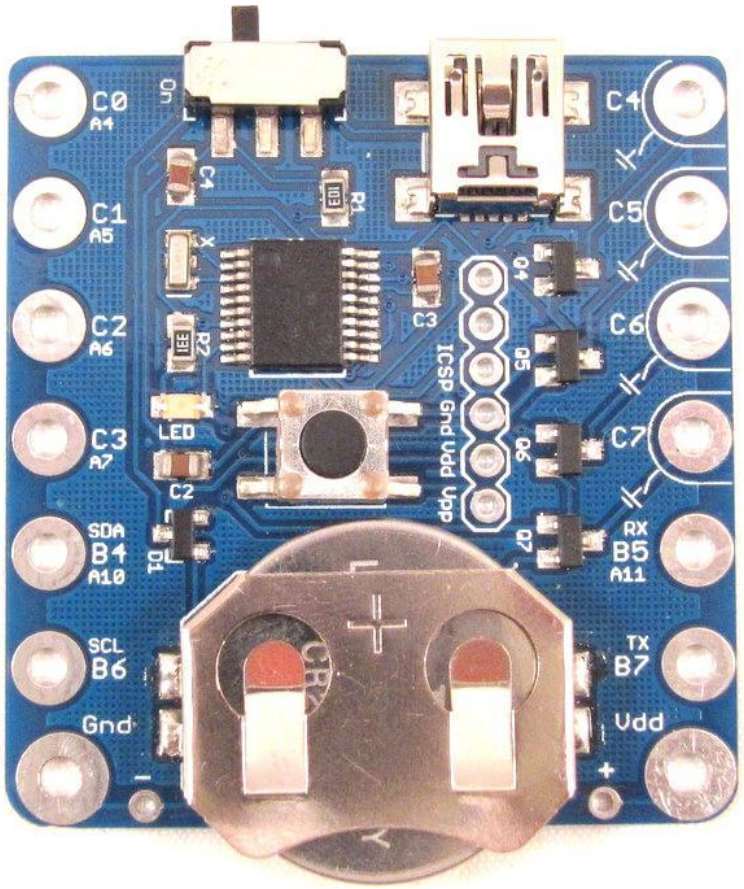
LilyPad Arduino



Microcontroller (MCU)

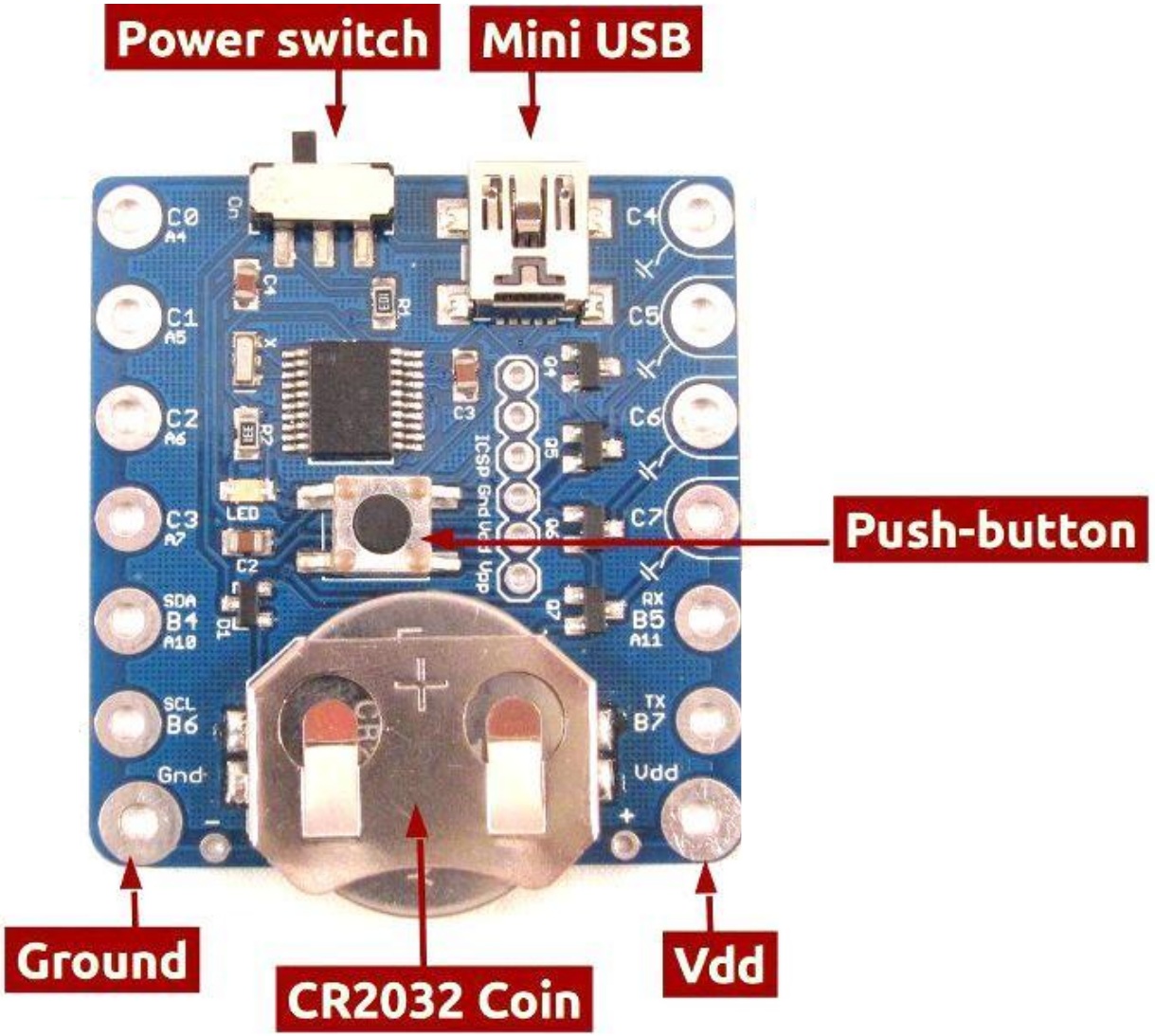
- **SquareWear**
  - A new wearable electronics controller board designed by me.
  - 12MHz CPU speed, 16KB flash, 12 digital pins
  - Can be programmed using a C style language (Microchip MPLAB X)
  - Program is uploaded using **on-board USB programmer**
  - Has on-board LED, one general-purpose pushbutton, built-in coin battery.

SquareWear

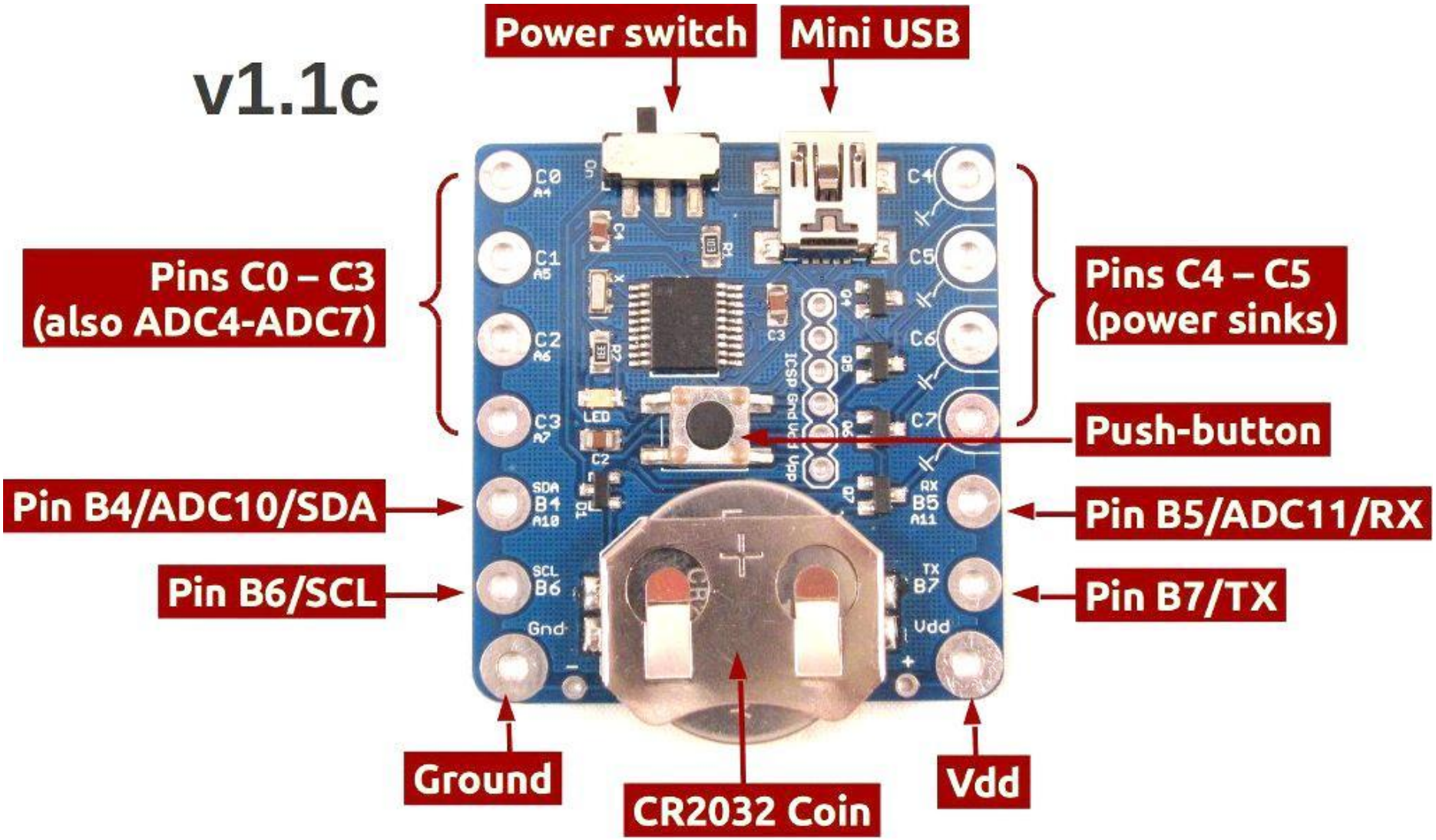

C0
A4
C1
A5
C2
A6
C3
A7
SDA
B4
A10
SCL
B6
Gnd
C4
C5
C6
C7
RX
B5
A11
TX
B7
Vdd
LED
ICSP Gnd Vdd Vpp

SquareWear

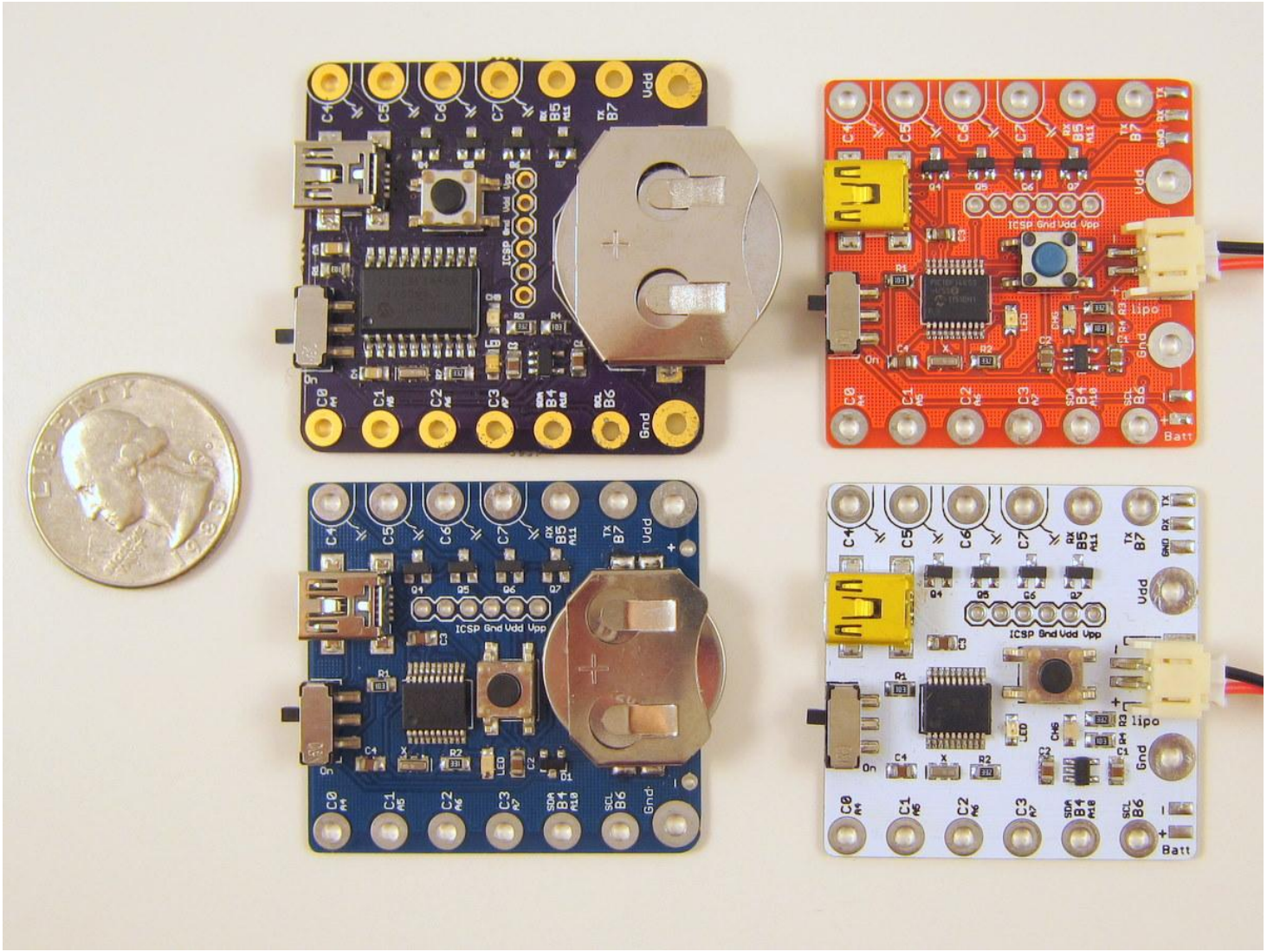
v1.1c



SquareWear

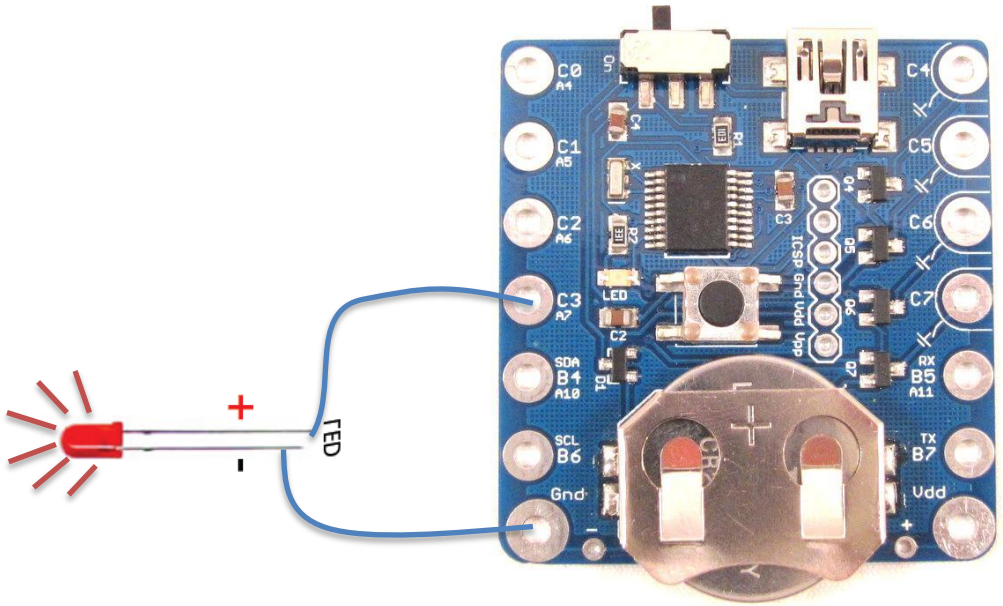

v1.1c
Power switch
Mini USB
Pins C0 – C3
(also ADC4-ADC7)
Pins C4 – C5
(power sinks)
Push-button
Pin B4/ADC10/SDA
Pin B5/ADC11/RX
Pin B6/SCL
Pin B7/TX
Ground
CR2032 Coin
Vdd

SquareWear



Microcontroller (MCU)

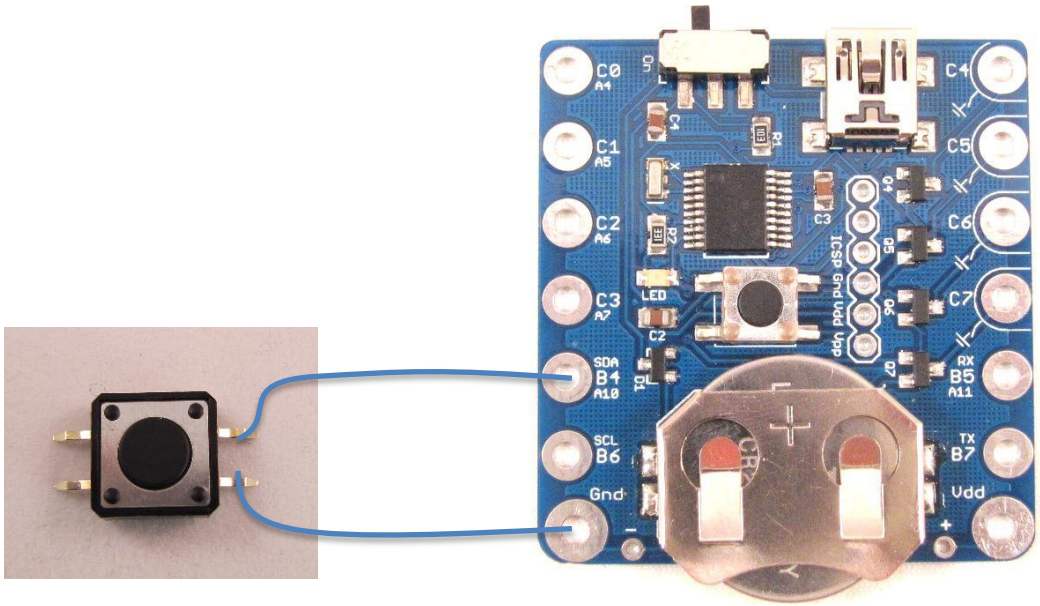
- **Digital Output**



<u>Digital Output</u> pin serves as programmable 'switch' to control the voltage supply to the LED

Microcontroller (MCU)

- **Digital Input**



<u>Digital Input</u> pin can be used to detect whether a button has been pressed. How?

Upload A Precompiled Demo Program

- Download SquareWear software package.
- **Enter Programming Mode**:
  - Insert a mini USB cable, and connect the other end of the cable to your computer's USB port.
  - **Power off** SquareWear. Then **press the push-button** while sliding the switch to 'On'. The microcontroller will now enter the programming mode. Your system should automatically detect it as a **HID class USB** device. You shouldn't need to install any driver.

Upload A Precompiled Demo Program

- **<u>Enter Programming Mode</u>**:
  - **Alternatively**, while a program is running, **press and hold** the push-button for **more than 5 seconds**. This should trigger a software reset, and then bring the device to programming mode.

Upload A Precompiled Demo Program

- **<u>Upload a Compiled Program</u>**:

  Step 1: Locate the folder named ***Uploader***, then run the uploader program corresponding to your operating system. After launching, the program should report **Device is Found** or **Device Ready**.

  - Some additional steps are needed in Linux.

Upload A Precompiled Demo Program

- **<u>Upload a Compiled Program</u>**:

  Step 2: Now click on the open folder icon to **Import a .hex file**. You can use any .hex file from folder named ***Compiled Demos***. For example, select the one in **04.BUTTON_PRESS**.

  Click on the next icon **Erase/Program/Verify**. Wait for it to finish and check if it reports success.

  Then click on the last icon to **Reset Device**. The program has now been flashed onto the microcontroller.

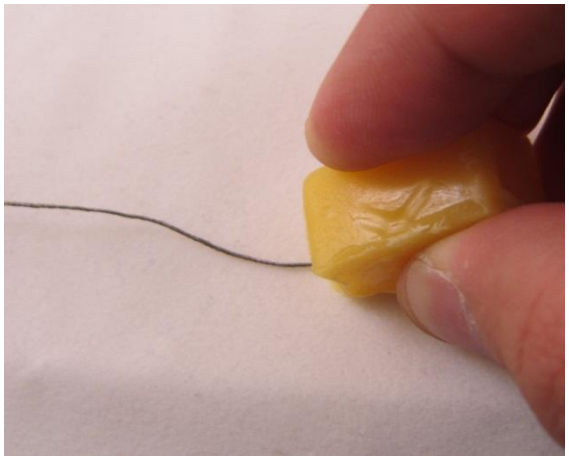
Upload A Precompiled Demo Program

- **<u>Upload a Compiled Program</u>**:

  Step 3: You don't need to close the uploader. You can keep it running, and the next time you enter the programming mode again, the uploader will automatically become ready.

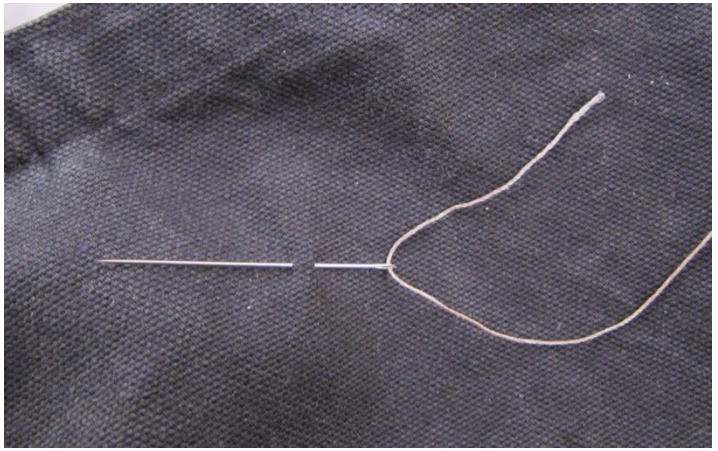
Basic Sewing Skills

- **Sewing 101 (**demonstration**)**
  1. Pick up a needle (with a large needle hole)
  2. Pick up a **conductive thread (what is this?)**
  3. Threading (use *beeswax* or *threader* to help you)
  4. Make a knot (we use single thread)



Basic Sewing Skills

- **Sewing 101**
  1. Pick up a needle (with a large needle hole)
  2. Pick up a conductive thread
  3. Threading (use *beeswax* or *threader* to help you)
  4. Make a knot (we use single thread)
  5. March the needle in small steps
  6. Finishing up



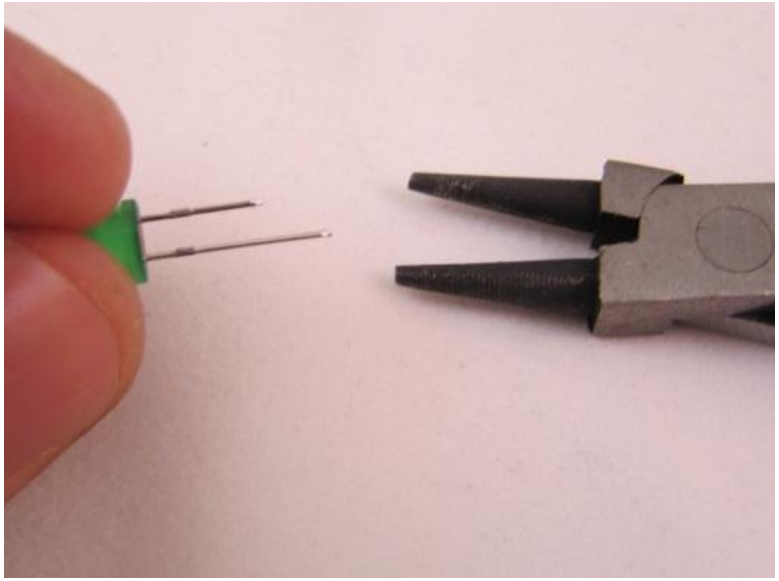
Basic Sewing Skills

-  **<u>Safety</u>:**
  - **Be careful to protect your fingers.**
  - **After you are done, insert the needle into a needle cushion**
  - **Avoid crossing conductive threads. Why?**
  - **When sewing, watch where the thread goes. At the beginning, go slowly.**

Sewing Electronics Components

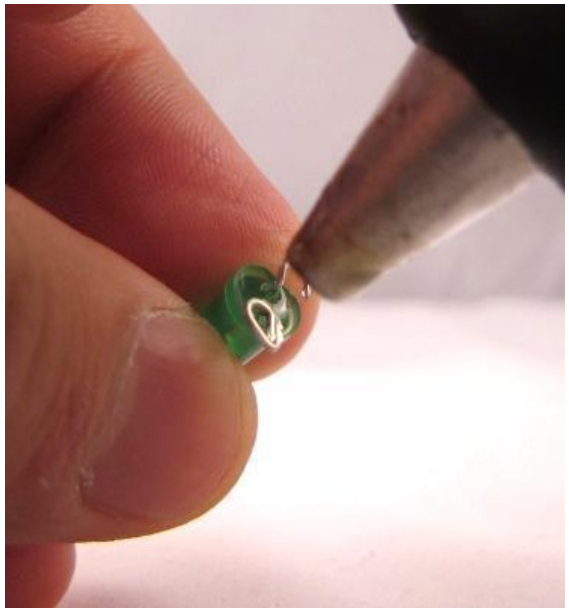
- **General steps:**
  1. **Curl leads into circles** (use *needle nose pliers*)

Make sure you can find the positive lead! (mark the positive side, or curl it differently)



Sewing Electronics Components

- **General steps:**
  1. **Curl leads into circles** (use *needle nose pliers*)
  2. Use a **tape** or small amount of **hot glue** to fix the component onto textile



Sewing Electronics Components

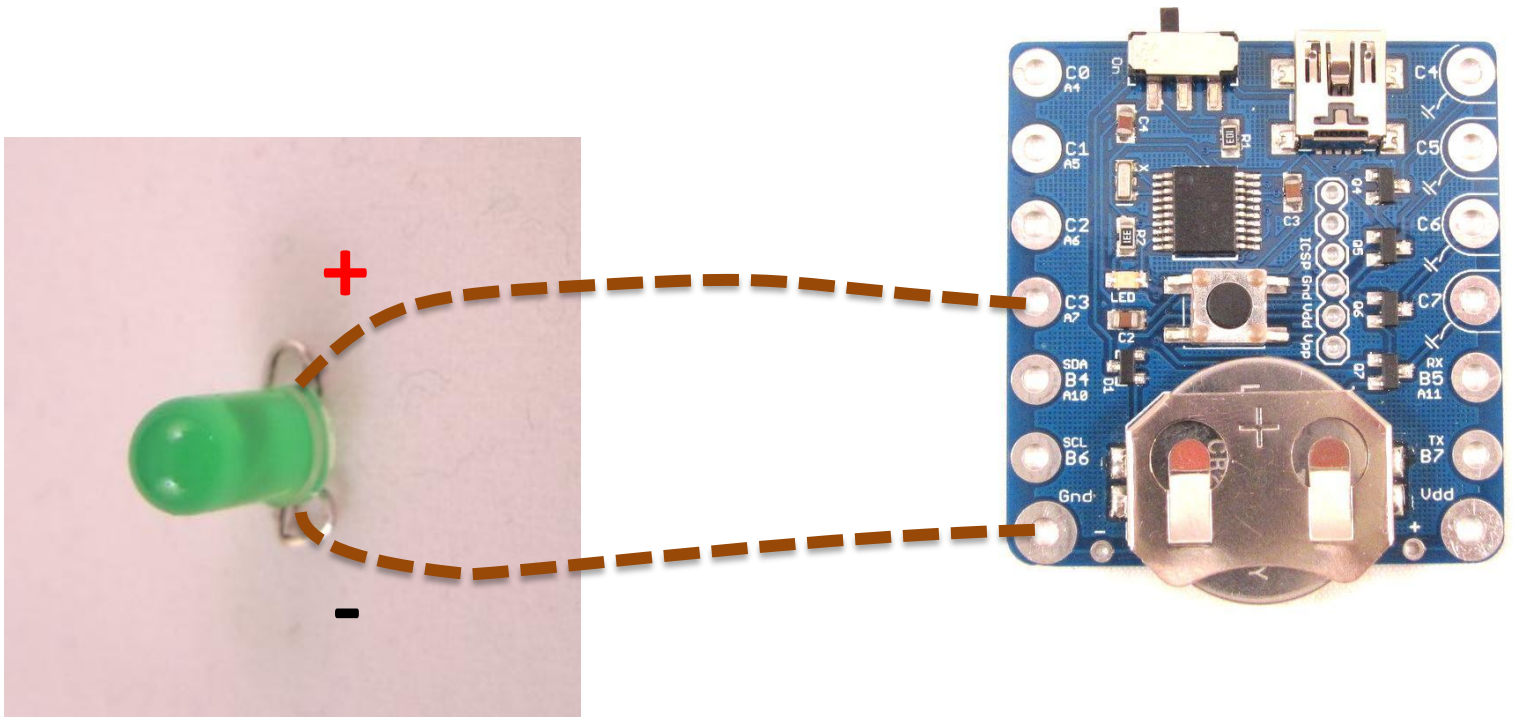
- **General steps:**
  1. **Curl leads into circles** (use *needle nose pliers*)
  2. Use a **tape** or small amount of **hot glue** to fix the component onto textile
  3. Sewing with conductive thread. Use **at least 3-4 stiches** on each lead, make the stiches tight so that the contact is reliable.
     - If necessary, use hot glue

Sewing Electronics Components

- **Example:**

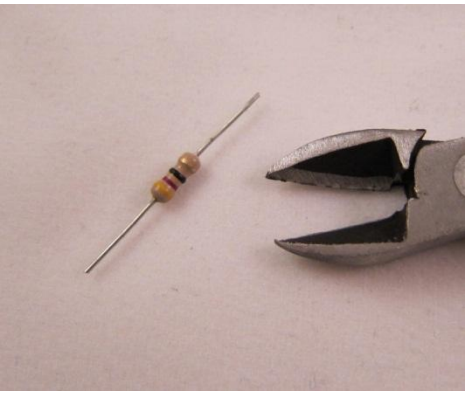
Sewing Electronics Components

- **Exercise: use conductive thread**
  - Conductive thread has a considerable amount of resistance. Keep them short.



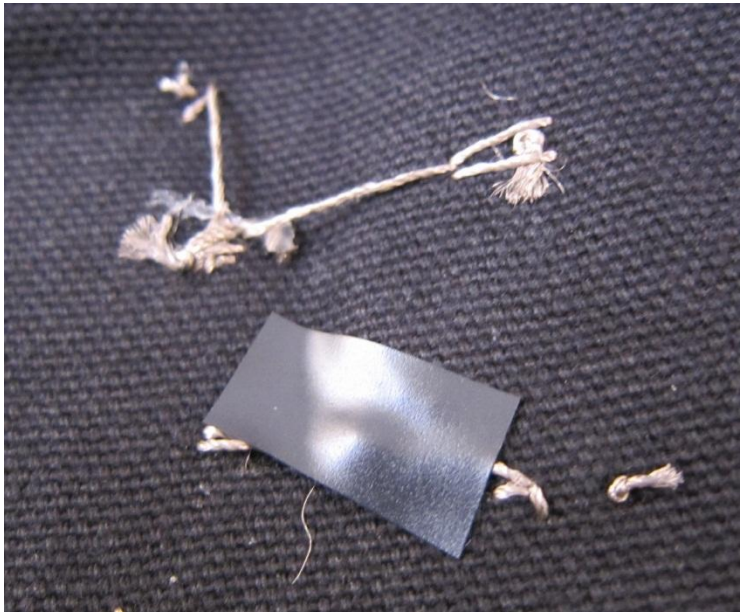
Sewing Electronics Components

- **Sewing Other Components:**
  - Unpolarized, so no need to distinguish between positive and negative



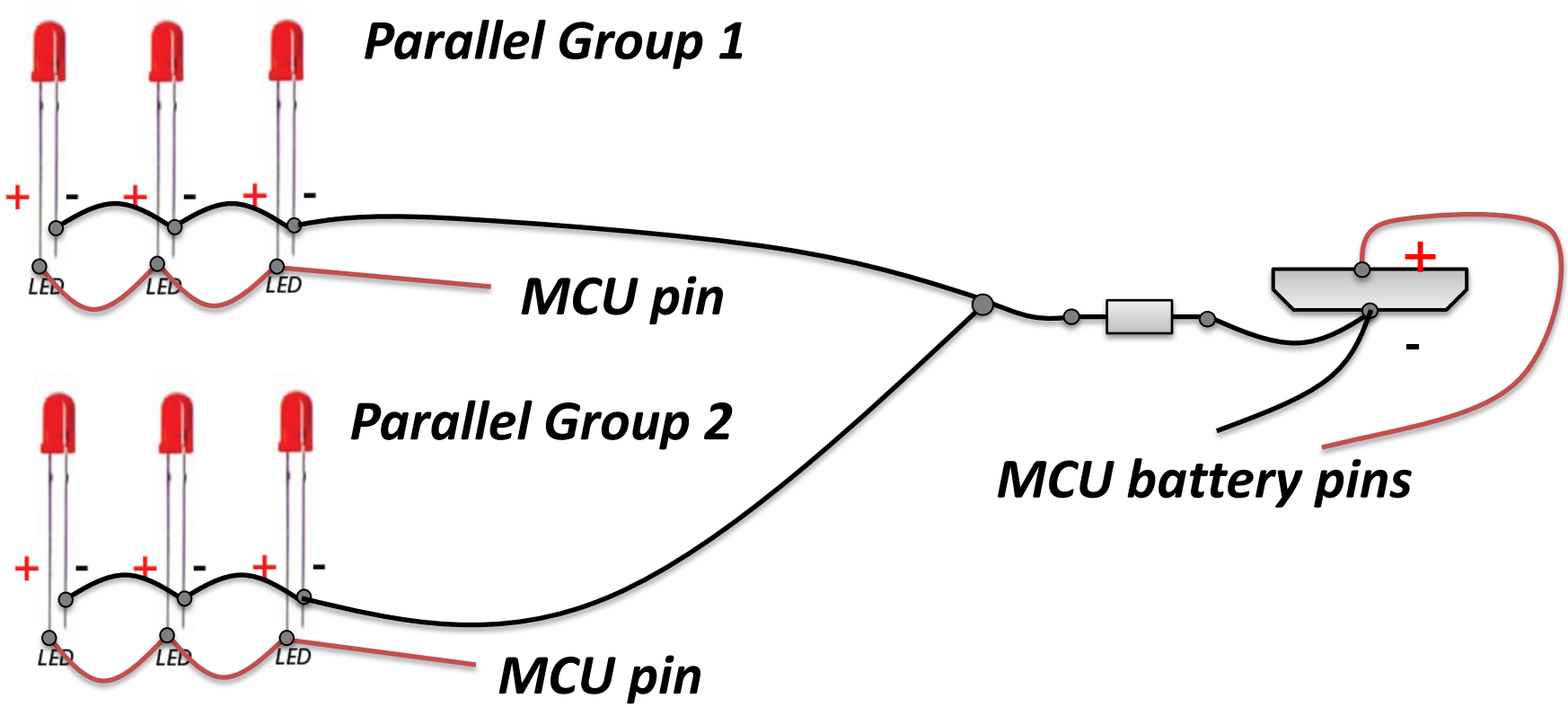

Sewing Electronics Components

- **<u>Important</u>: watch out flying threads. They are conductive! Cut excessive threads to avoid shorting. Use glue if necessary.**



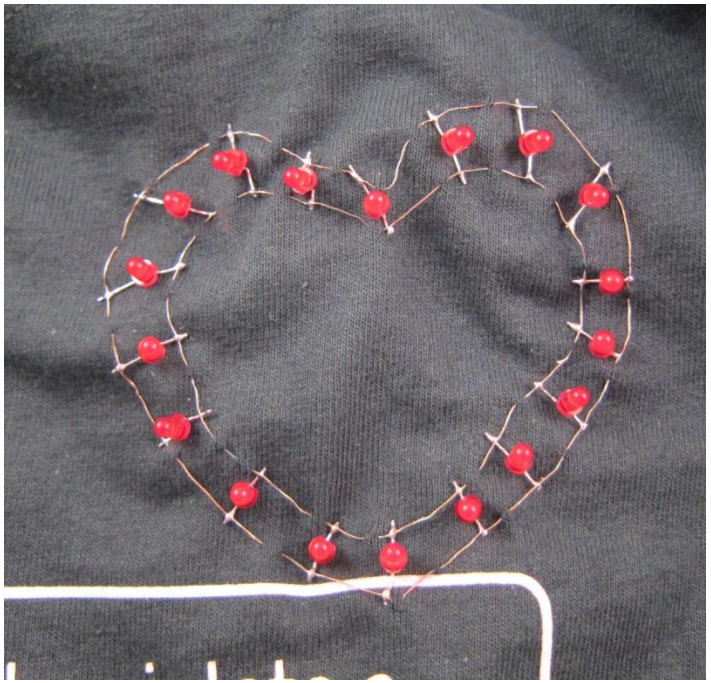
Sewing Electronics Components

- **Pattern Planning:**



Sewing Electronics Components

- **Pattern Planning:**



Putting Everything Together

- **Step 1: make a design**
  - Decide the pattern
    - How many LEDs? What colors? Number of pins to use (which determines the number of parallel groups).
  - **Don't be too ambitious!**
    - Sewing is time consuming. Do <u>not</u> plan more than 12 LEDs this time.
  - **Ask for help if you are not sure.**

Putting Everything Together

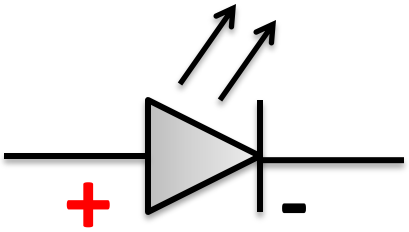
- **Step 2: sewing LEDs according to pattern**
  - Make sure you can still **distinguish between positive and negative leads after curling.**
  - Use **hot glue or electric tape** to help fixing components.
  - Watch out for where the conductive threads go. **Avoid unintentional crossing of threads**!

Putting Everything Together

- **Step 3: sewing SquareWear**
  - Connect LEDs with planned SquareWear pins.
- **Step 4: program SquareWear**
  - Plug in mini USB cable and upload program.
  - Check if all LEDs function as desired.
  - If LEDs do not light up, check your connection. Use a multimeter to see if there is any shorting.
- **Voila, you are done!**

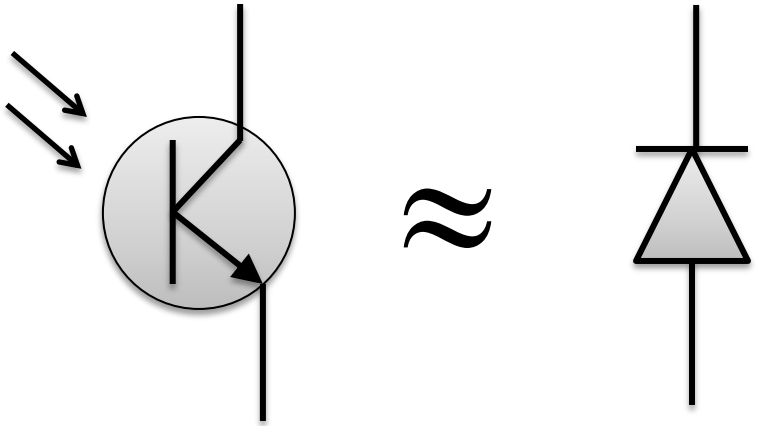
Other Electronic Components

- **Infrared LEDs**
  - Similar to standard LEDs but emit light in the IR range (about 940nm wavelength)
  - You can't see IR light, but camera sensors can!
  - Where can you find infrared LEDs in your home?



Other Electronic Components

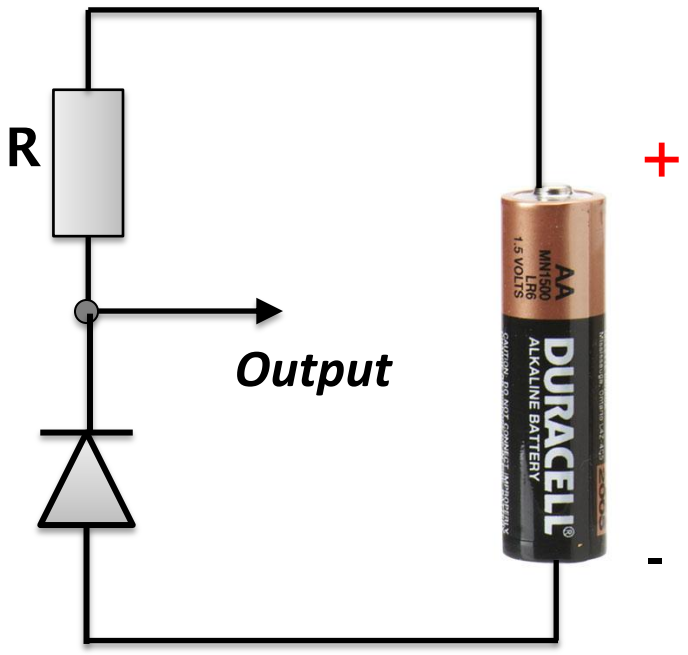
- **Infrared Photo-Transistors**

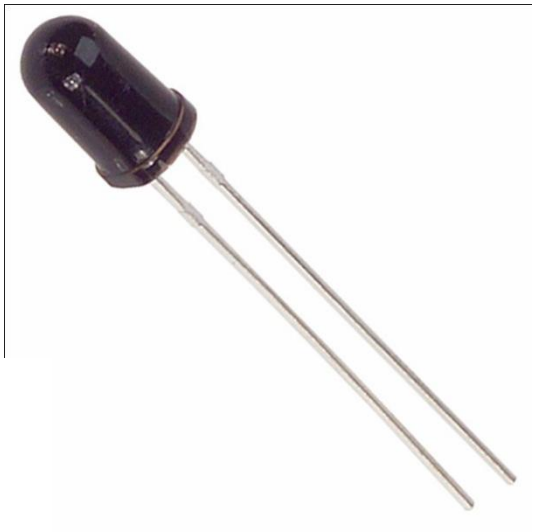


Think of it as **a photo-sensitive resistor**

Photo-Transistors

- **Infrared Photo-Transistors**

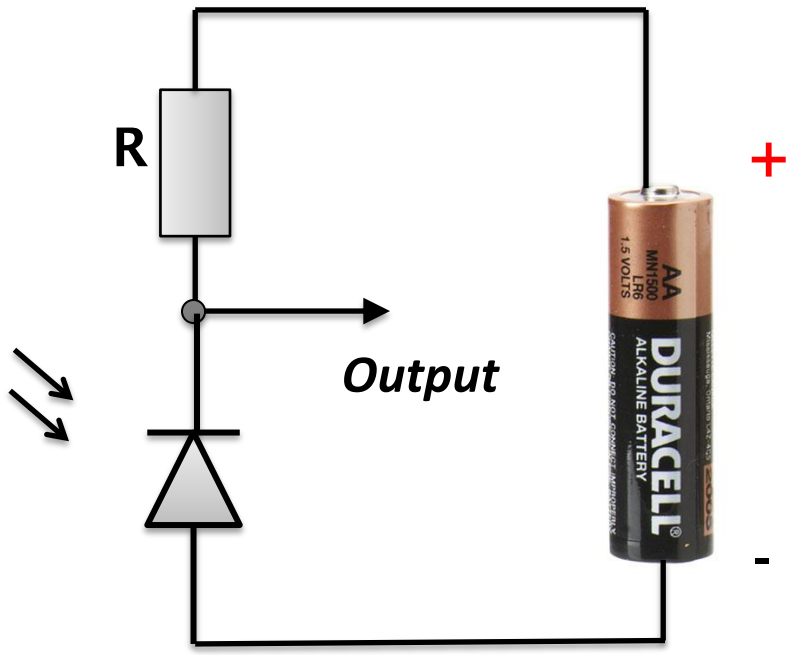


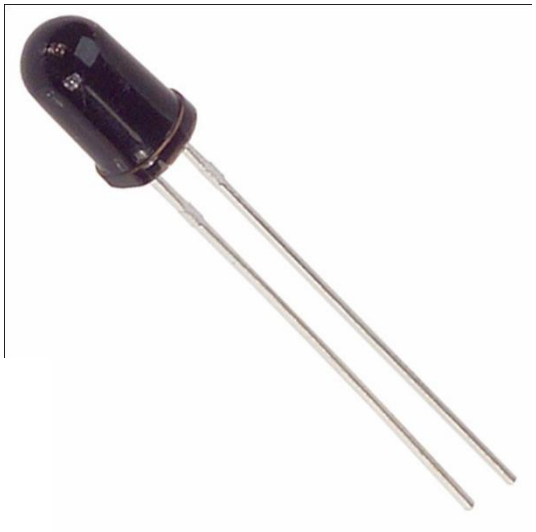


No light → Photo-transistor high resistance → High output value

Photo-Transistors

- **Infrared Photo-Transistors**

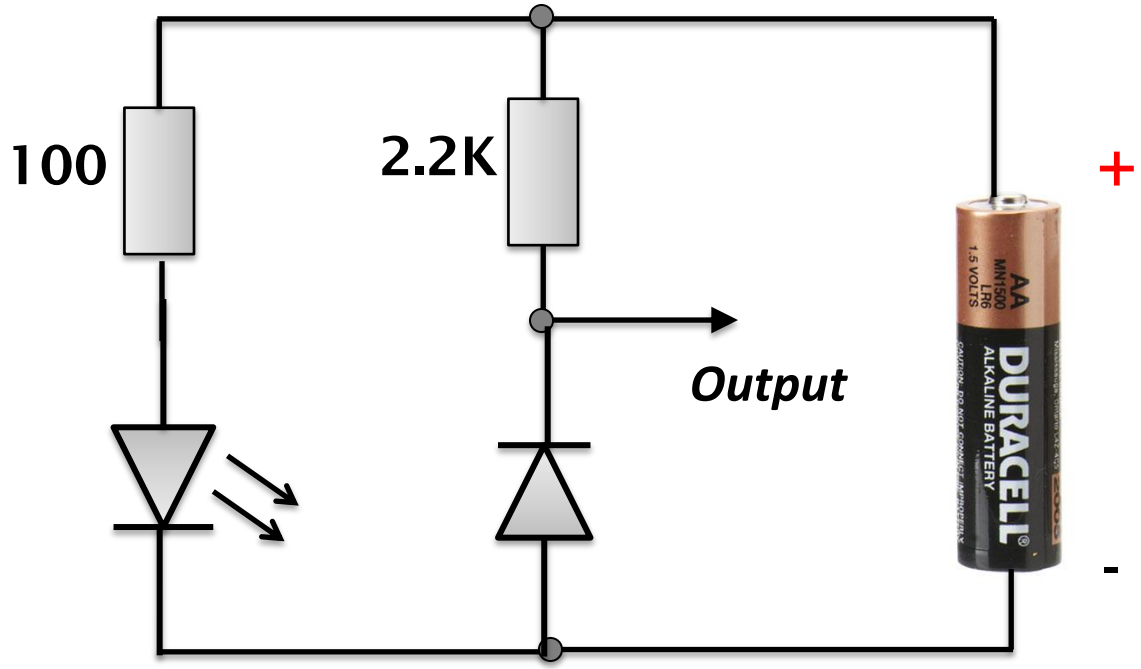


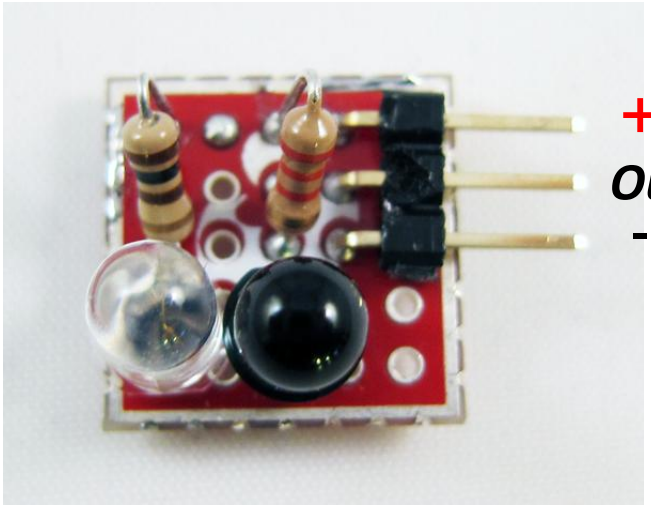


Strong light → Photo-transistor low resistance → Low output value

Pulse Sensor

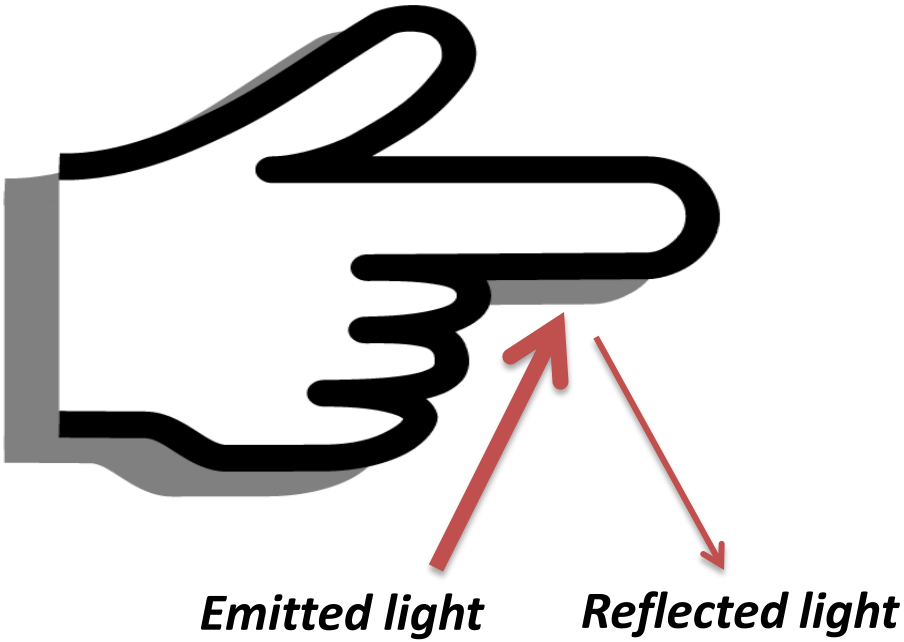
- **Schematic**





Pulse Sensor

- **What is it?**
  - A sensor that can detect your heart beat.
- **How does it work?**



Pulse Sensor

- **What is it?**
  - A sensor that can detect your heart beat.
- **How does it work?**