ME 23N: Soft Robots for Humanity
Autumn 2019

Week 7:
Soft sensors for strain, force, contact

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Lab 5 recap:

Elastomeric robots

Stiffness

1. **Test the material properties of a silicone sample (see Section IV).** Write down the size of your sample (length, width, thickness), the weights tested, and the change in length between your measurement points.

   - Sketch out a plot of the points you tested.
   - Does the stretch seem linear?
   - What is the stiffness ($k = \frac{F}{\Delta L}$) i.e. the slope of the line?
   - What was the maximum stretch you found?

Young's Modulus

2. **Calculate the stress and the strain for each of your tested points.** To do this you'll need to know the cross-sectional area of your sample and the amount of force that the weight creates. Remember:

   stress is calculated from $\sigma = \frac{F}{A}$

   and strain is calculated from $\epsilon = \frac{L - L_o}{L_o}$

   - Find the Young's modulus of the material (slope of the stress-strain line).
   - Compare the results you found to other groups'

Functionality

3. Describe how the soft elastomeric gripper works.

- What is the pressure doing?
- What is the function of the fabric?
- What do the ridges in the mold (creating all the different chambers) do?

Functionality

4. How well does the gripper work for picking up objects?

- How much weight can it lift?
- Can it lift oddly shaped objects?
- What do you think is the best application for a gripper like this?

Your Ideas

5. **What are other potential uses for elastomers in soft robotics?** Imagine some other use cases, either using air power or using other actuation types.

6. **Any other thoughts?**

Soft Sensors

Soft Robotic Sensors

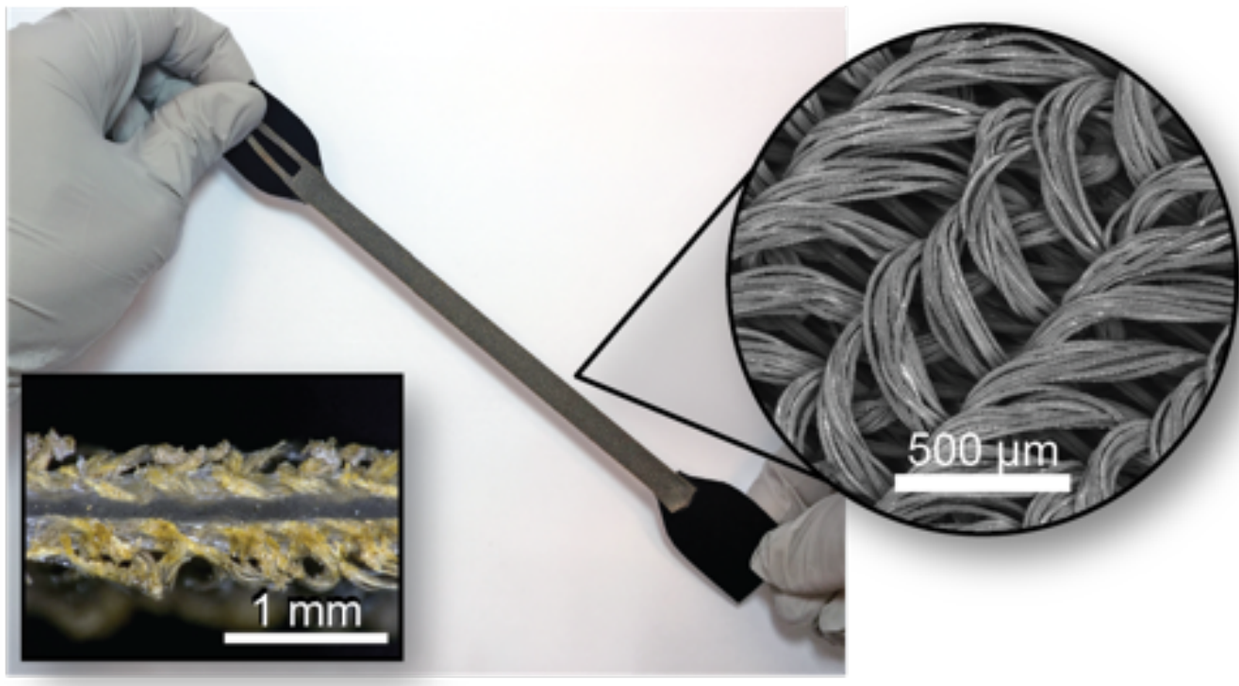
Soft robotic sensors are used on soft robots and other flexible or deformable systems to measure a wide range of properties

Sensors need to **flexible** and/or **stretchable** so that they don't interfere with the movement of the soft robot

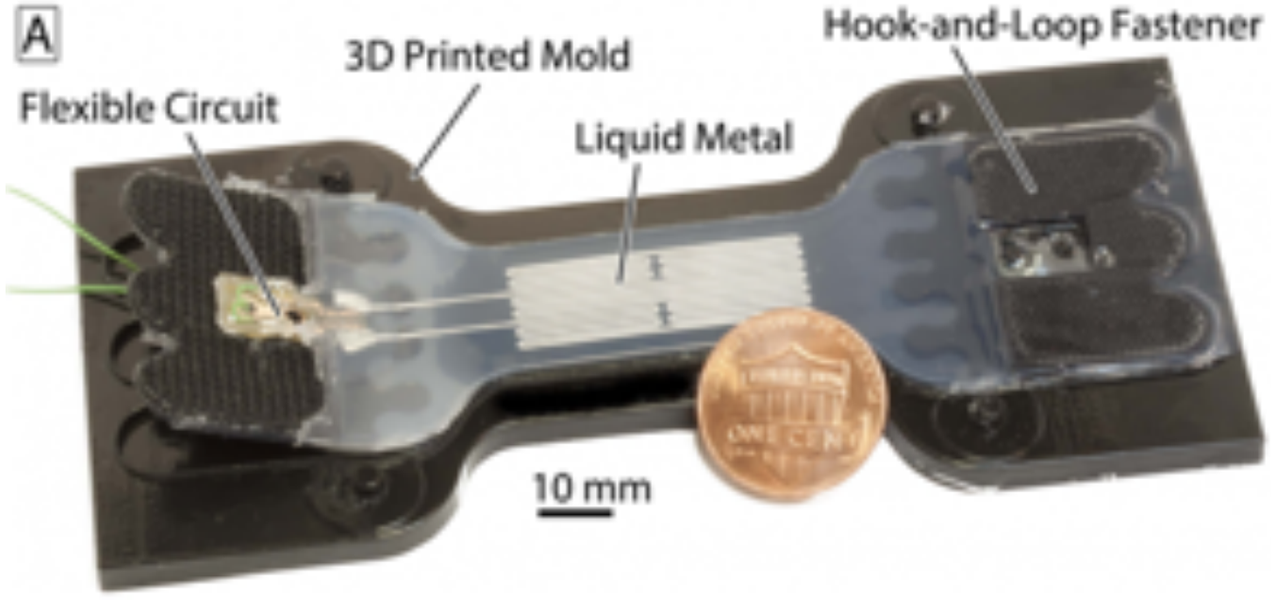
Sensors measure **bending, stretching, touch, etc.**

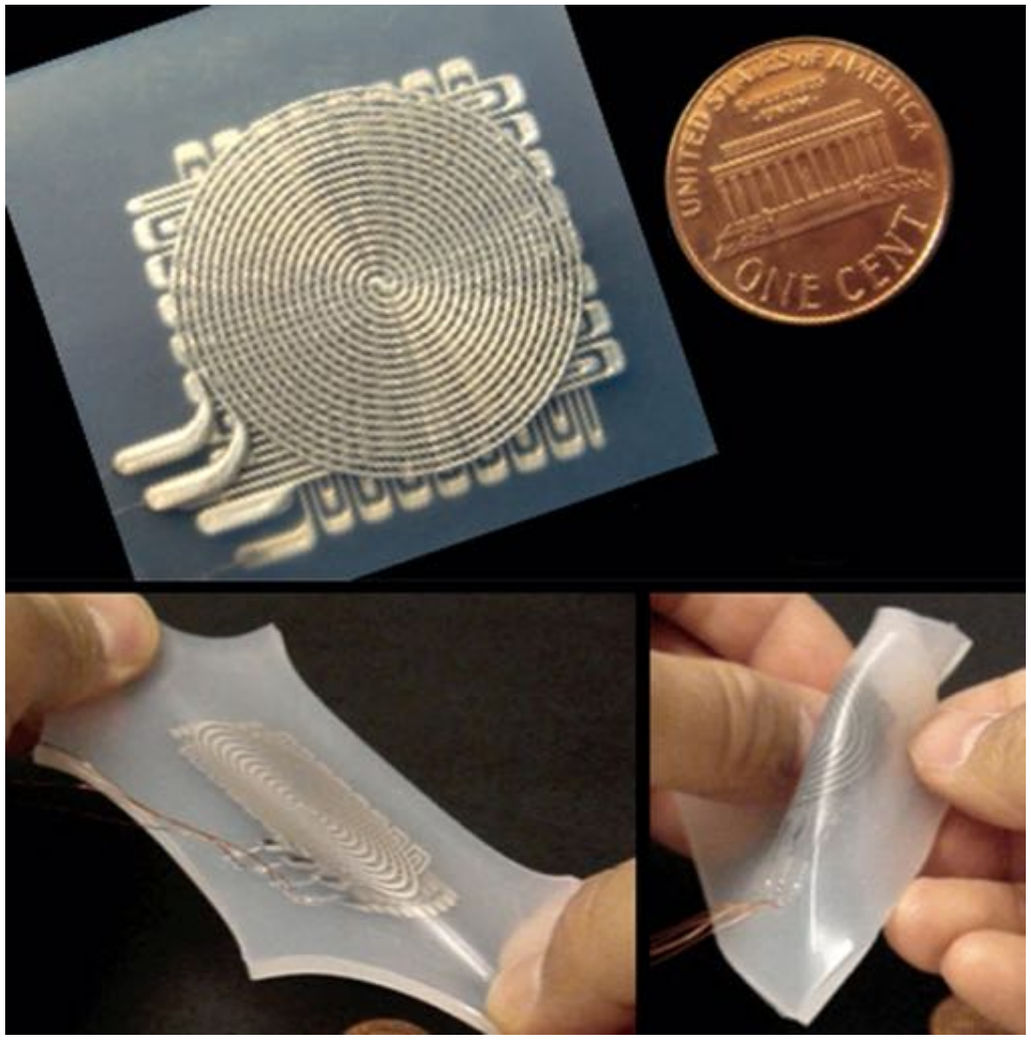
Make measurements using changes in **electric** properties (resistance, capacitance, inductance) or **optical** changes

Soft Sensors: Electrical

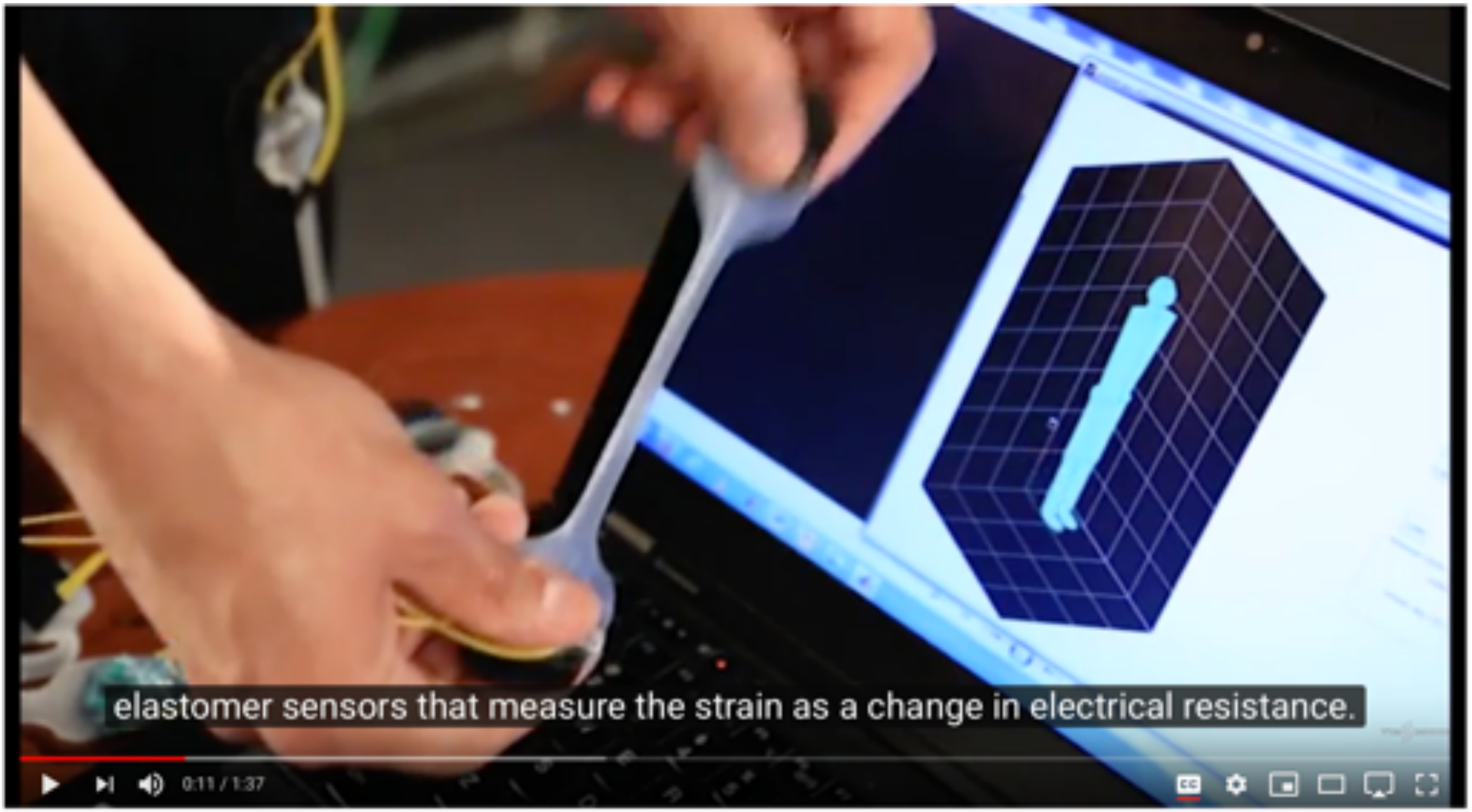


Soft Sensors: Electrical



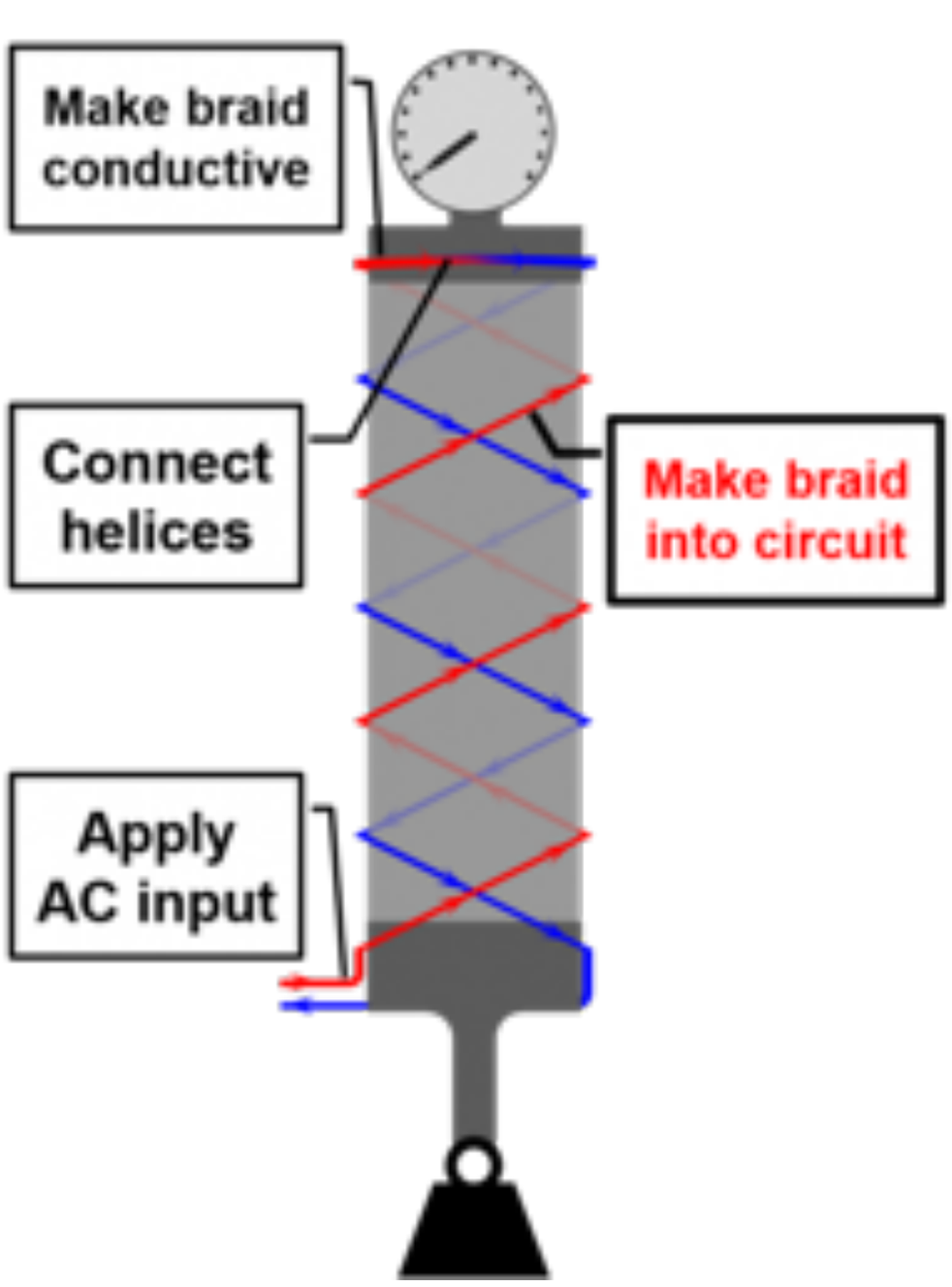


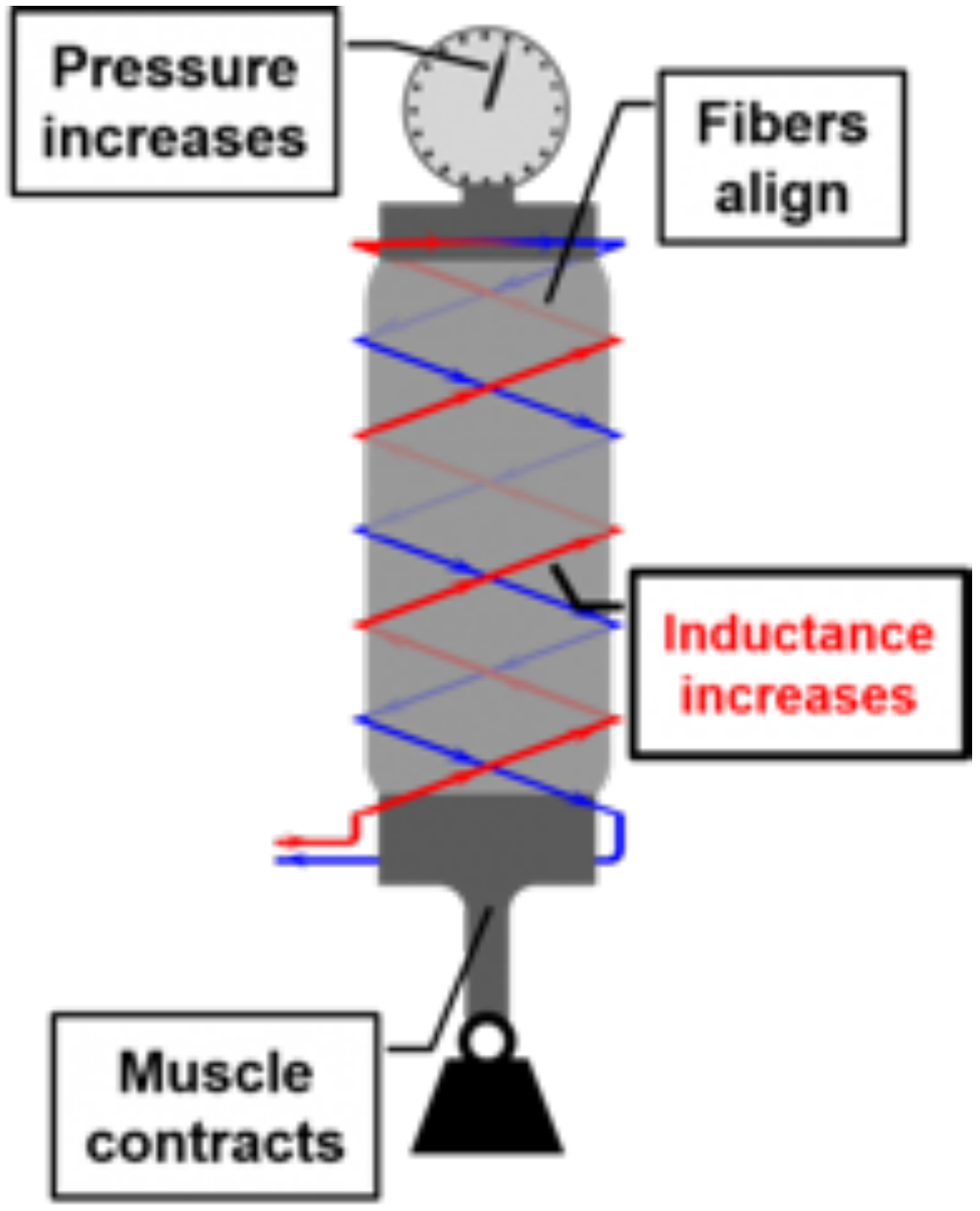
Soft Sensors: Electrical



https://www.youtube.com/watch?v=0m5koRcZ4j0&t=33s

Soft Sensors: Electrical

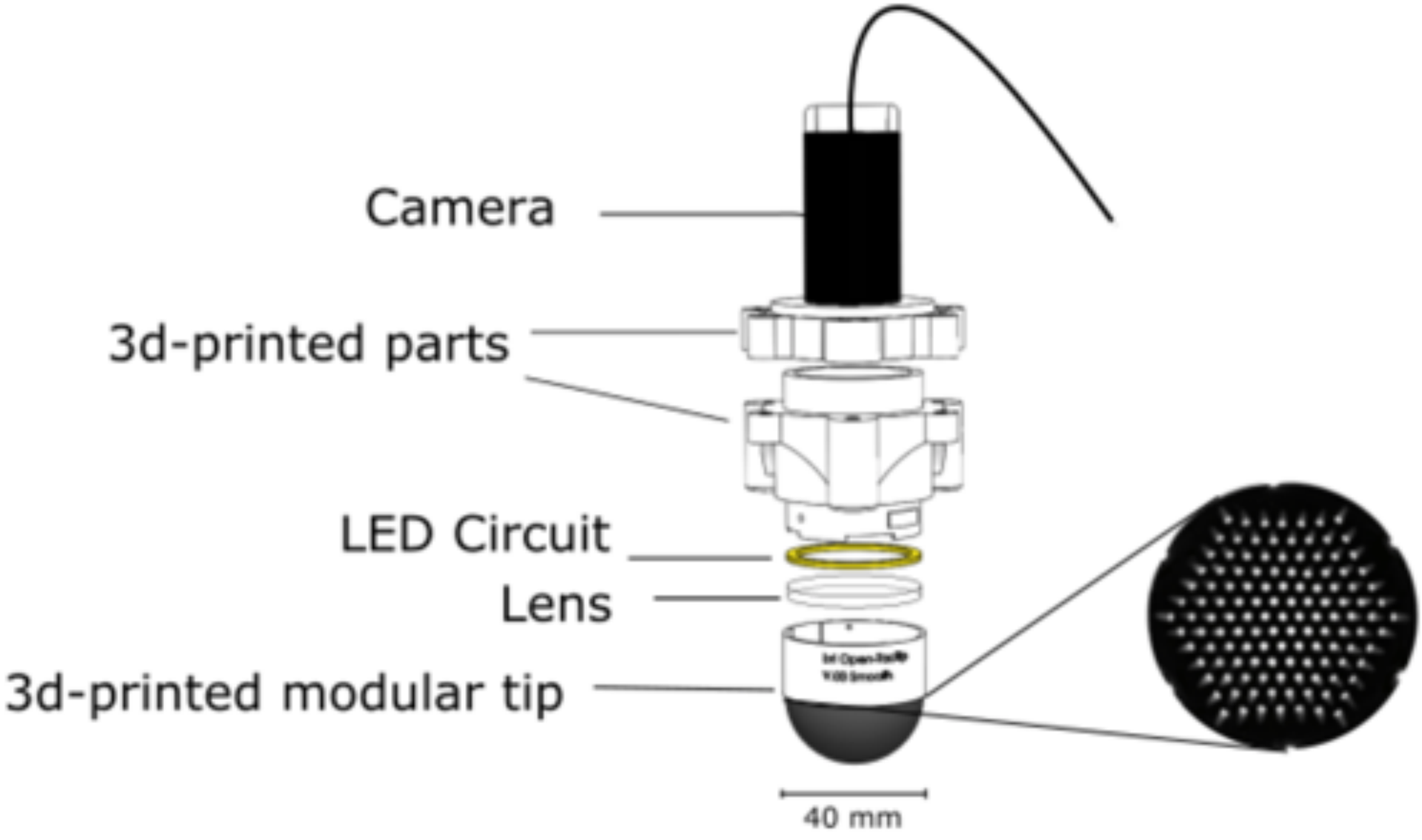




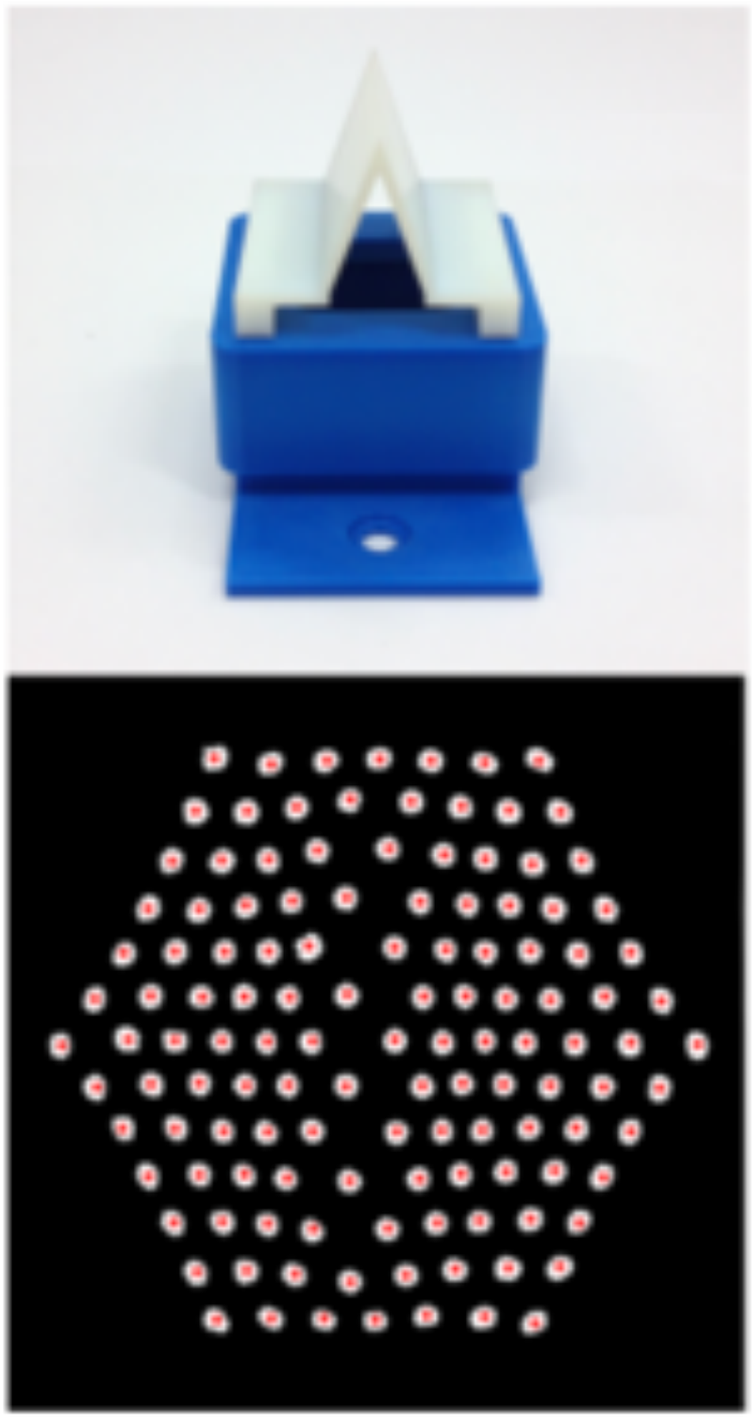
Soft Sensors: Electrical

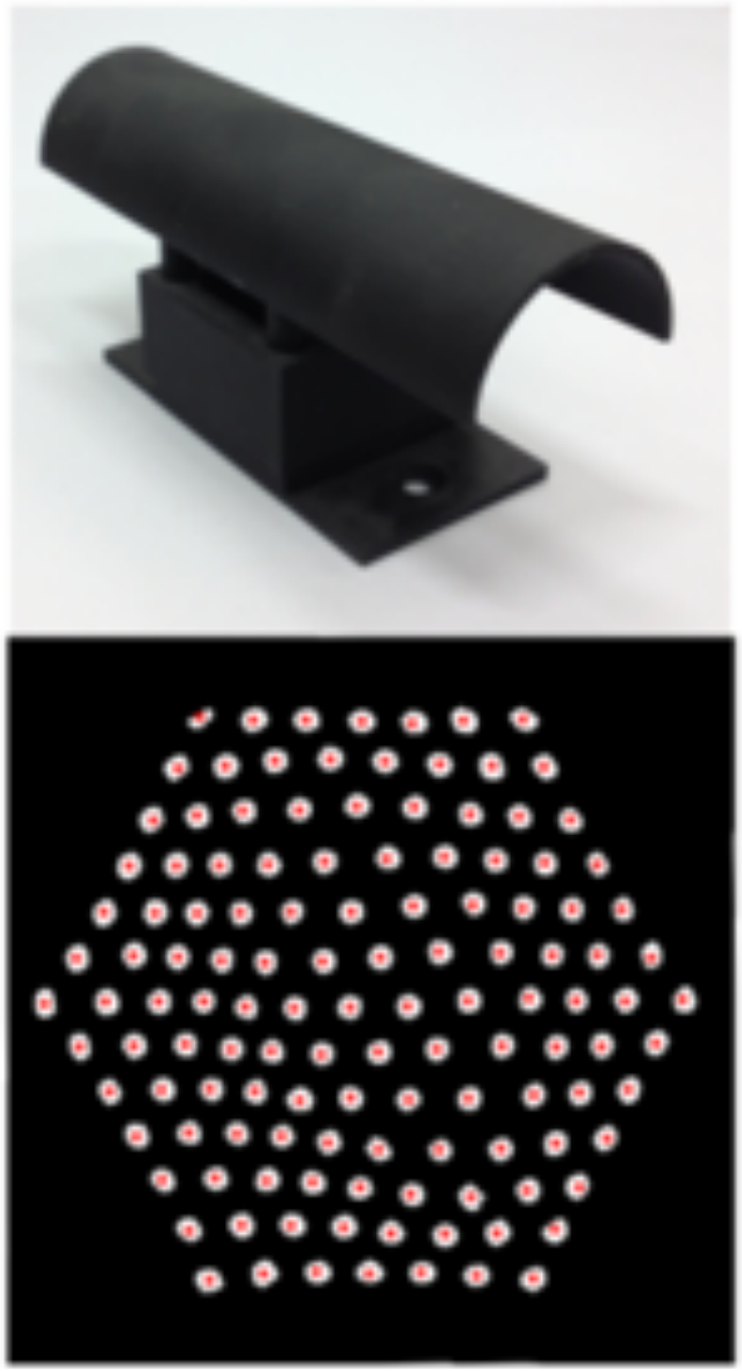
https://www.youtube.com/watch?v=XoLCroADij8

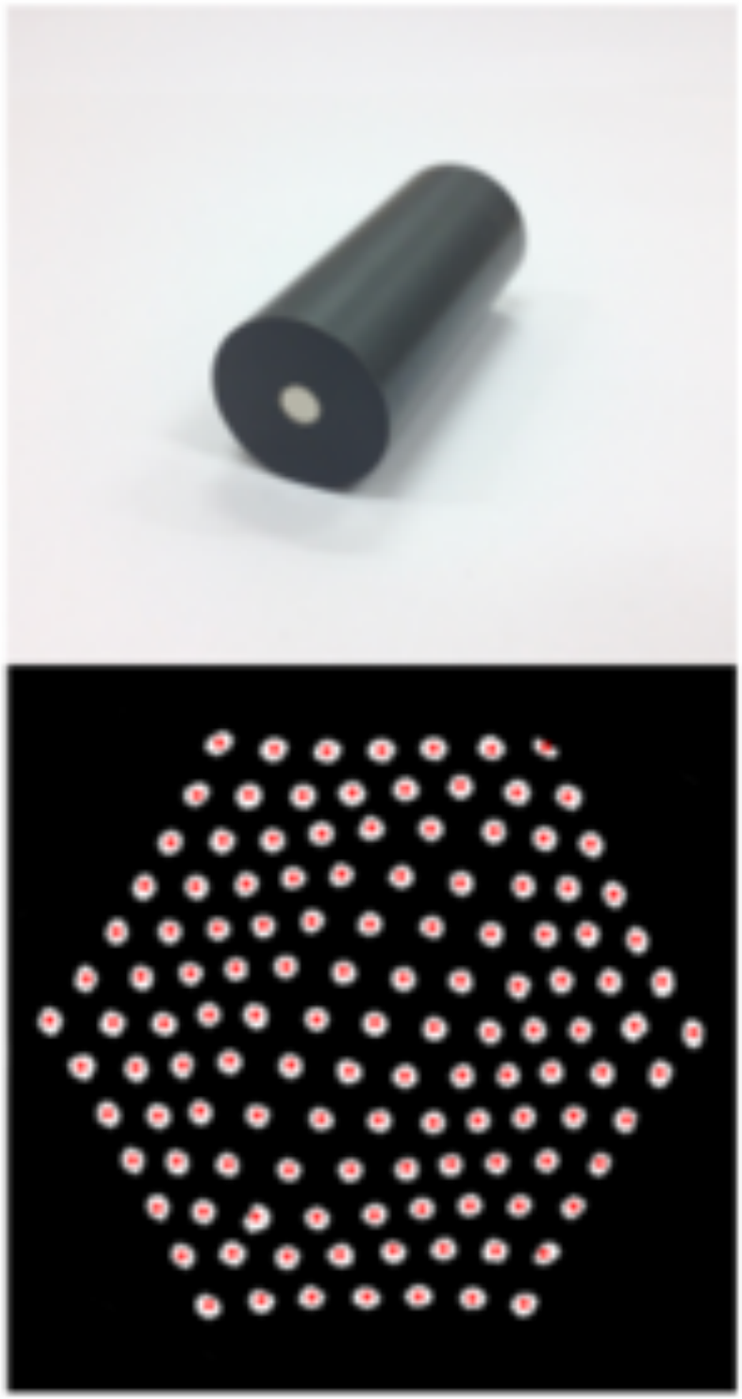
Soft Sensors: Optical



Soft Sensors: Optical







Hapkit Board

The Hapkit Board is a single-board microcontroller based on the Arduino, with some bells and whistles added.

It is primarily used for the Hapkit, an open-source haptic device (http://hapkit.stanford.edu) that is part of Allison's *other* Freshman IntroSem,
ME 20N: Haptics: Engineering Touch

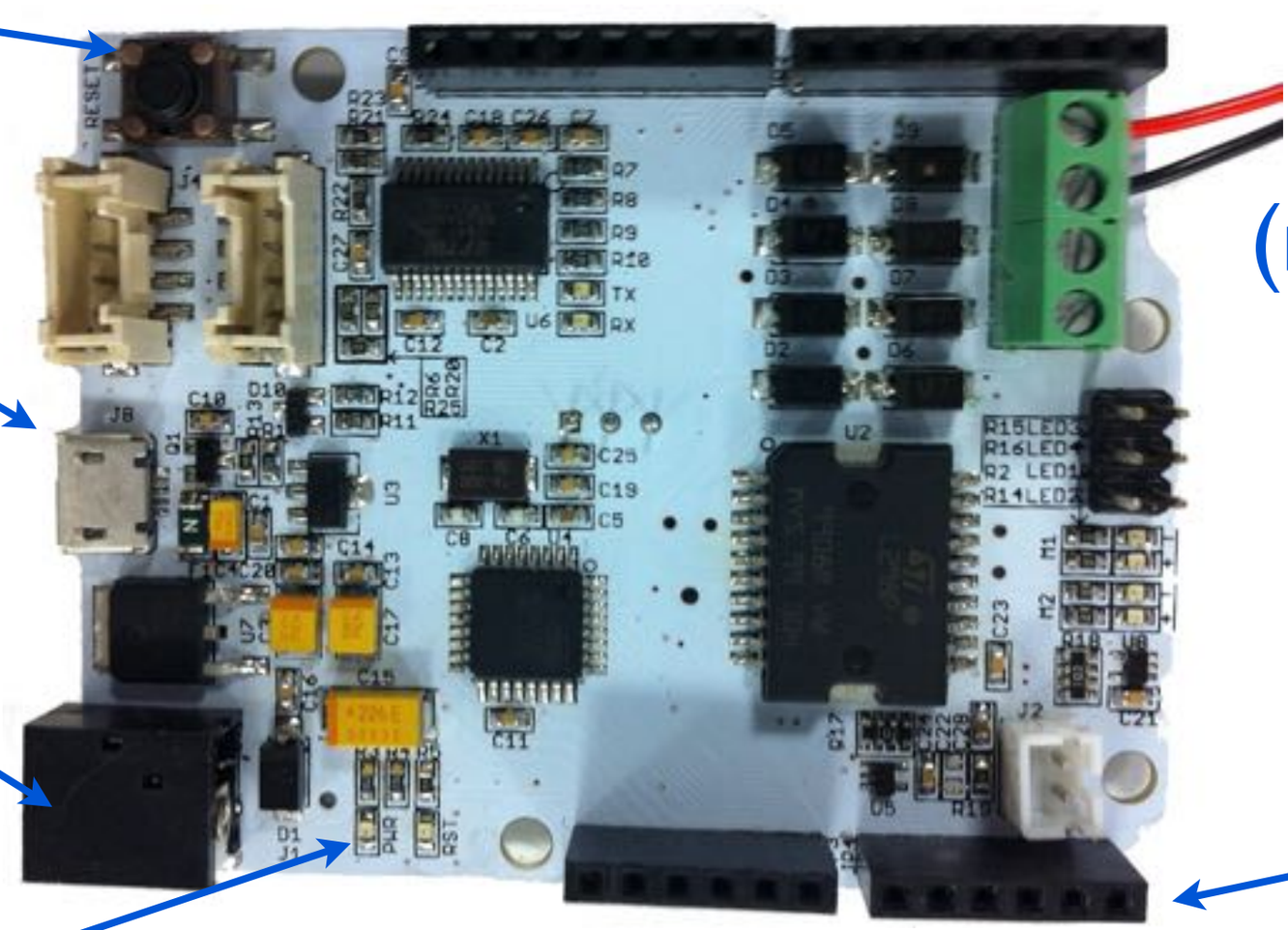
Hapkit board "front"

reset button

Micro USB connector

connector for power adaptor (for motor)

power LED



motor leads (not applicable for this lab)

pins available for read/ write

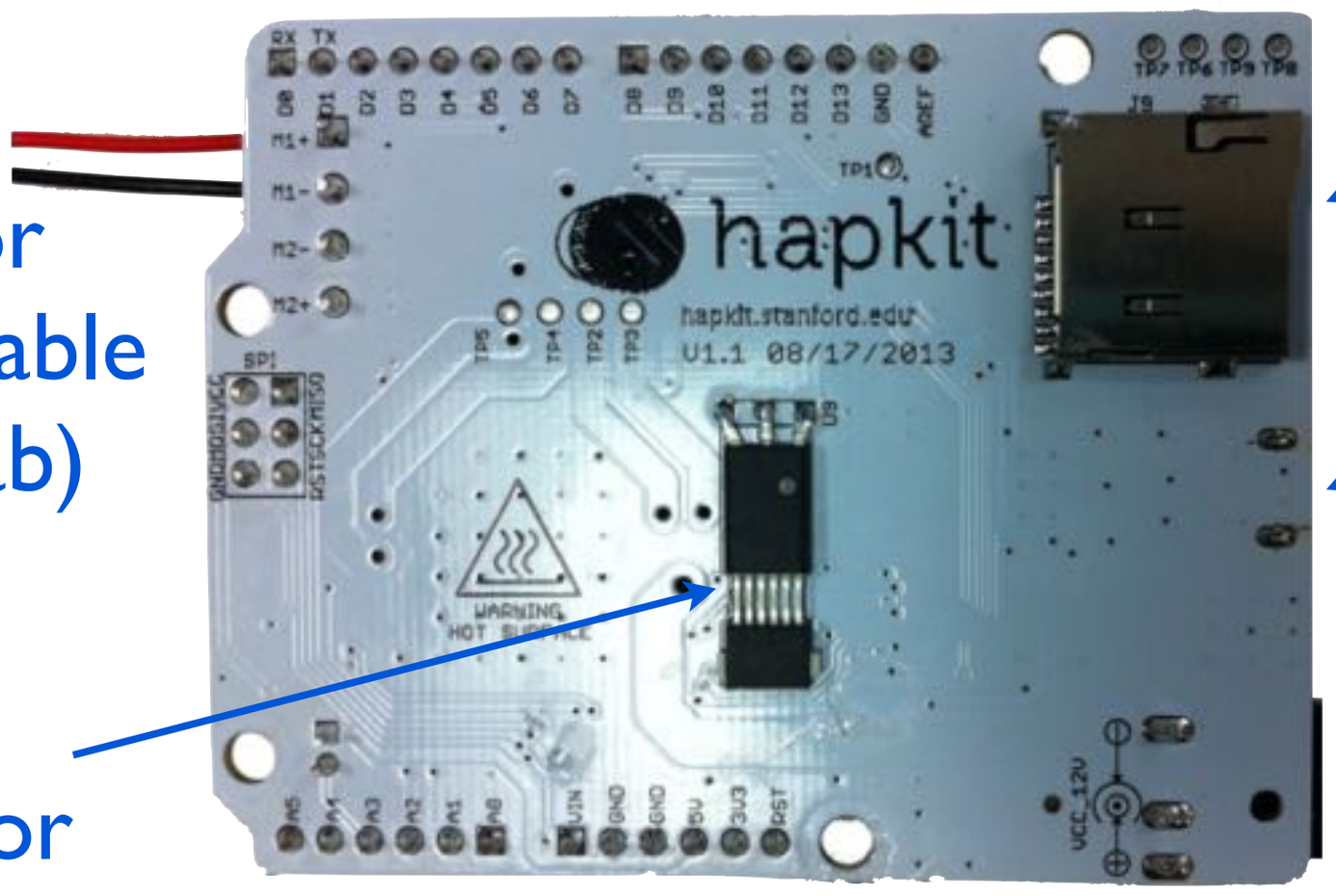
Hapkit board "back"

digital input/output pins

Micro SD card port

to motor (not applicable for this lab)

Micro USB connector



MR sensor (not applicable for this lab)

connector for power adaptor (for motor)

analog input pins

Circuit basics

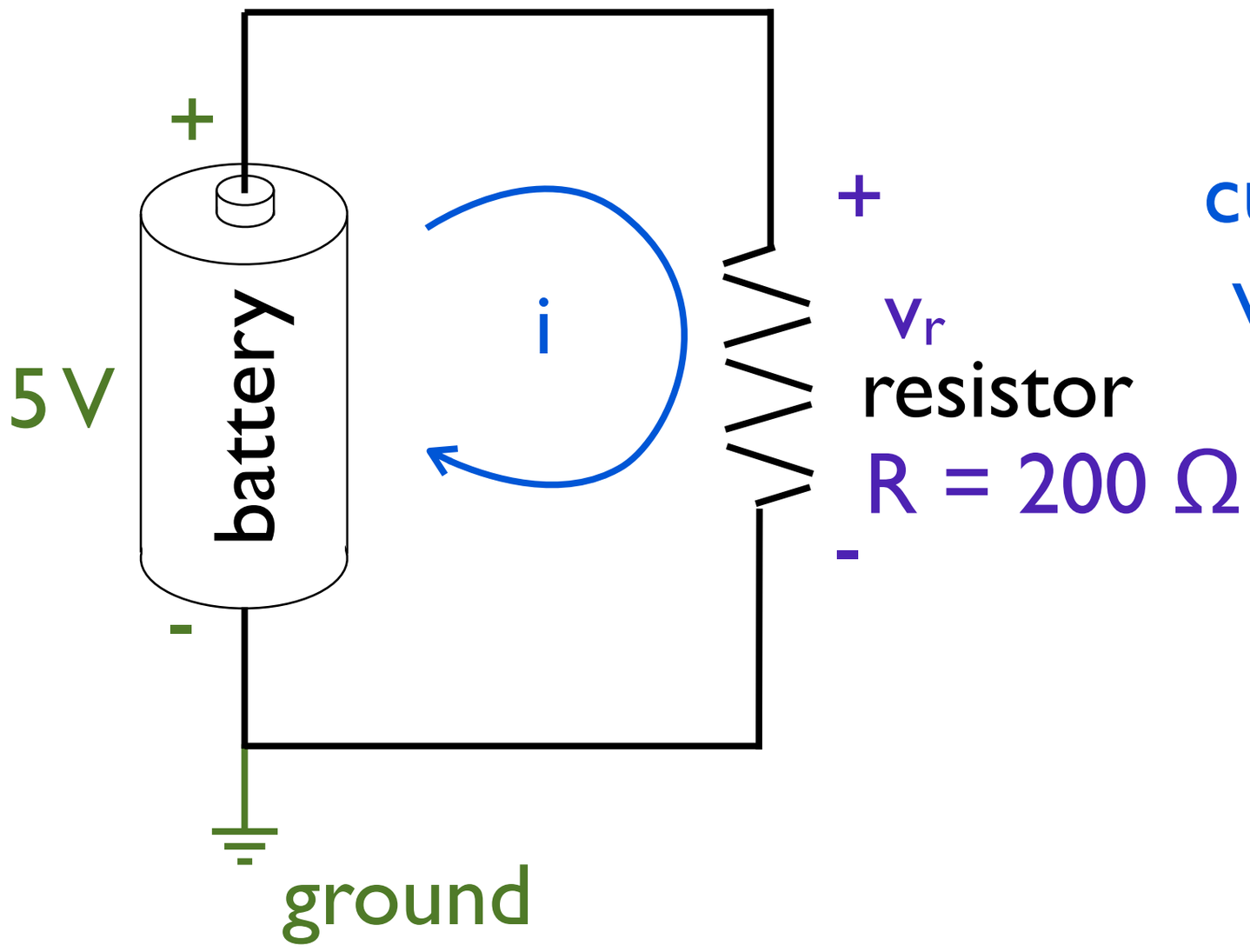
Electric current is a movement or flow of electrically charged particles, typically measured in amperes (A).

Voltage is the electric potential difference between two points, typically measures in volts (V)

Circuit elements such as resistors, capacitors, inductors, and diodes determine the relationship between current and voltage

A circuit needs a **power source** and a **ground** to generate a voltage and induce current.

Example circuit



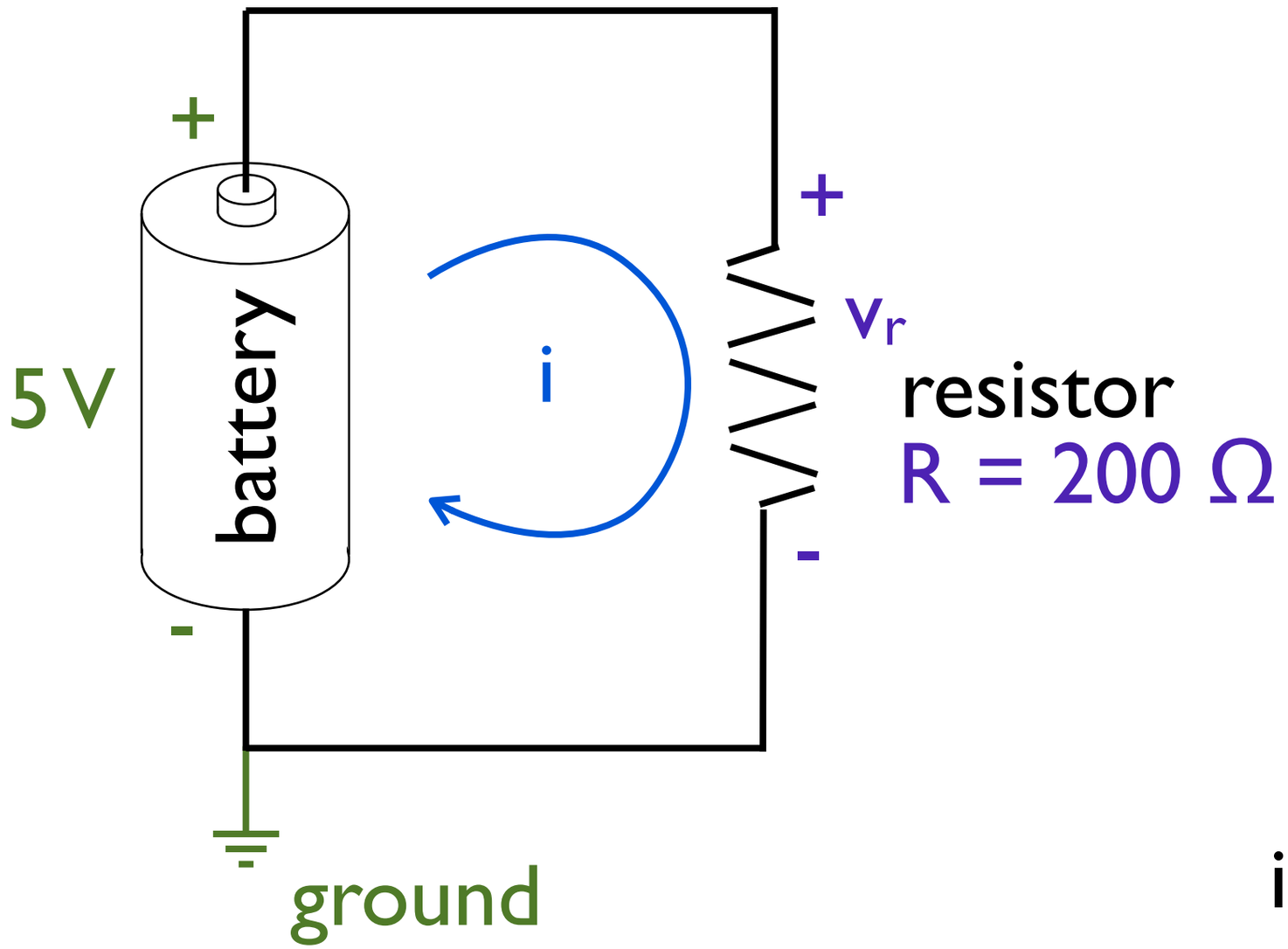
say the battery is a 5 V source

current flows from high voltage to low voltage

the voltage drop across the resistor is computed from Ohm's law:

$v_r = i\,R$

Example circuit



$v_r = i\,R$

$i = v_r / R$

$v_r = 5\,\text{V}$

$i = 5\,\text{V} / 200\,\Omega$

$i = 0.025\,\text{A} = 25\,\text{mA}$

Resistor values

resistors are usually conveniently marked with colored bands that represent the resistance

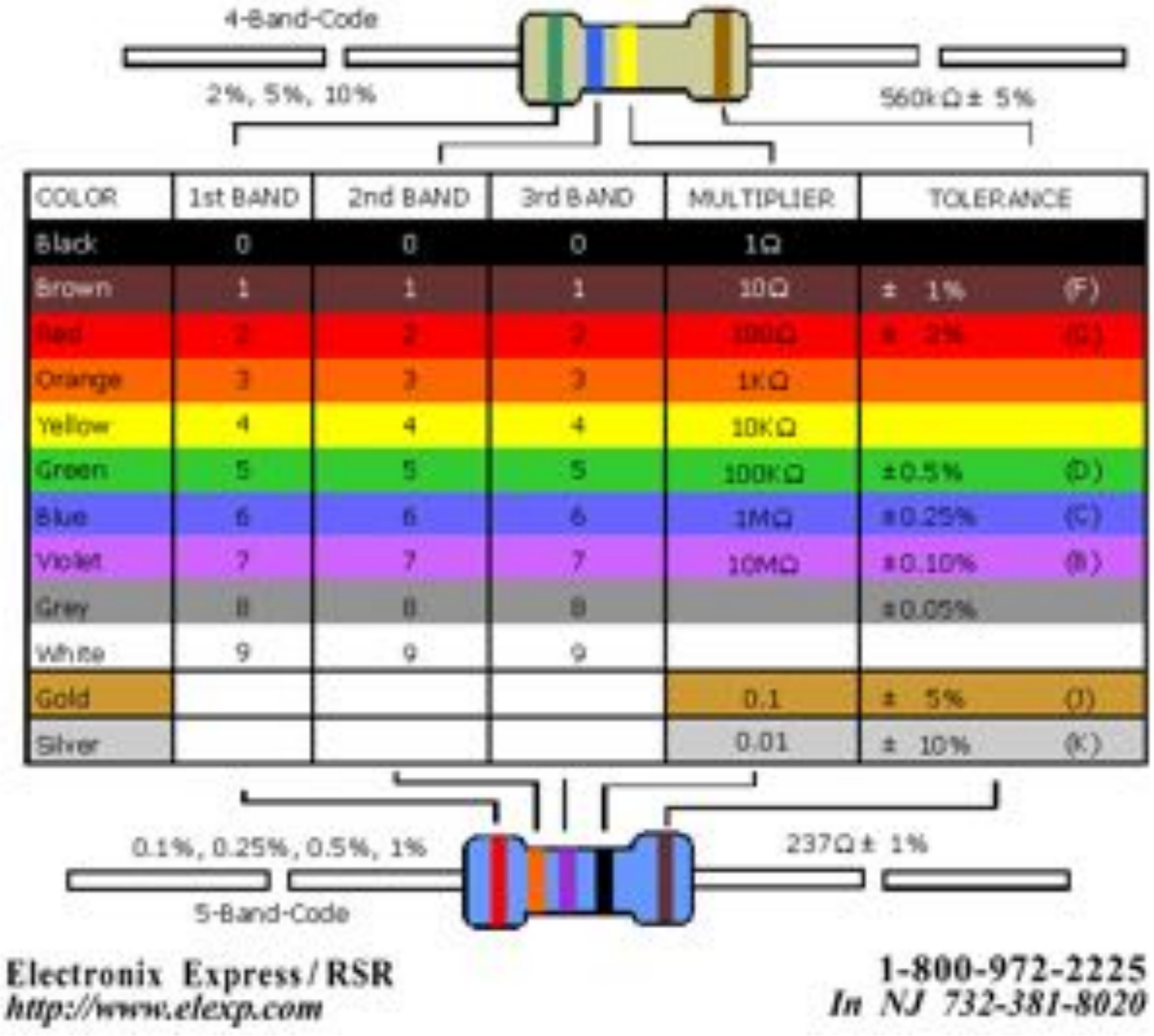
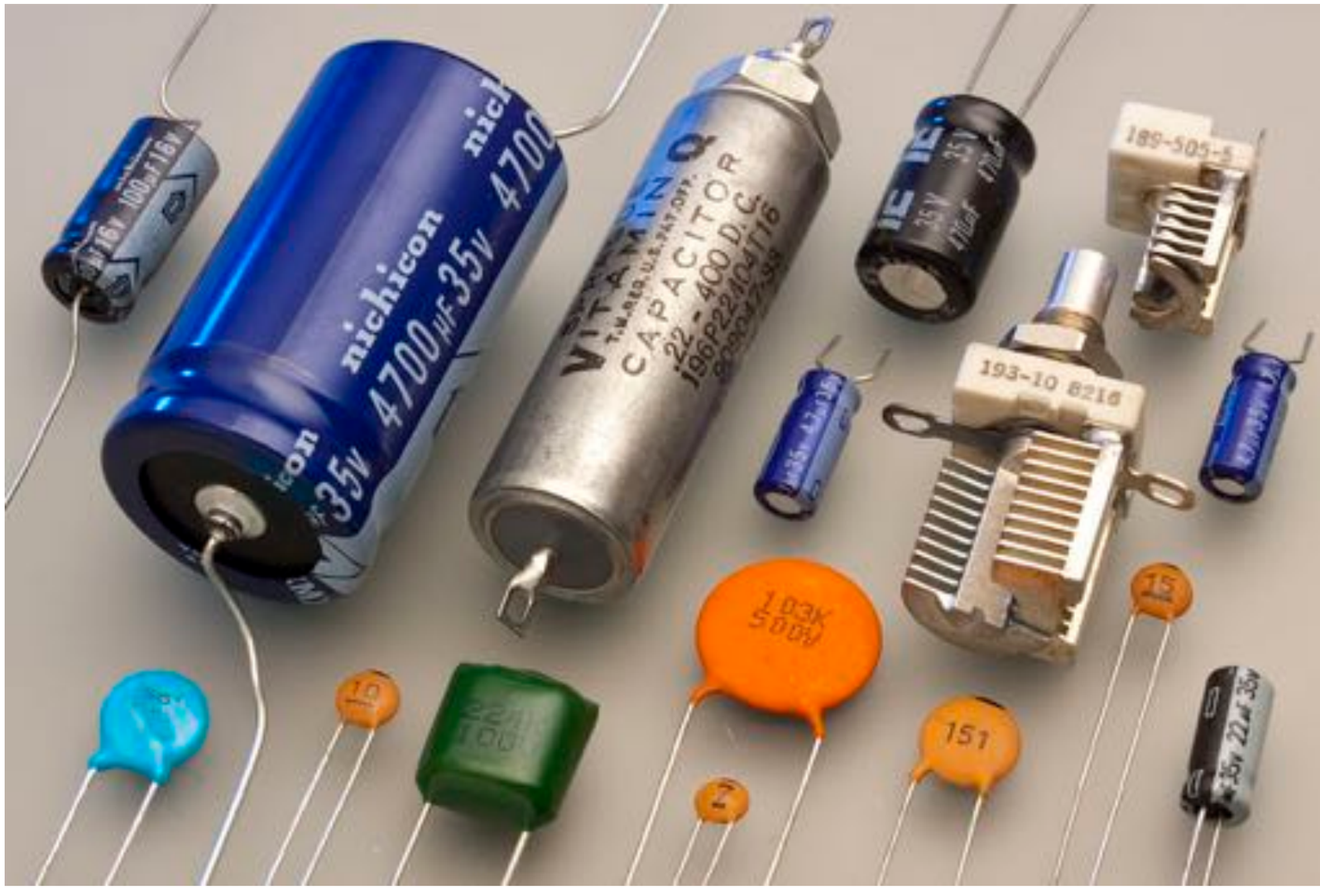


image credit: superbrightleds.com

Capacitor values

Capacitors are measured in farads (F), with typical values often in the range of picoFarads (pF) to microFarads (μF)

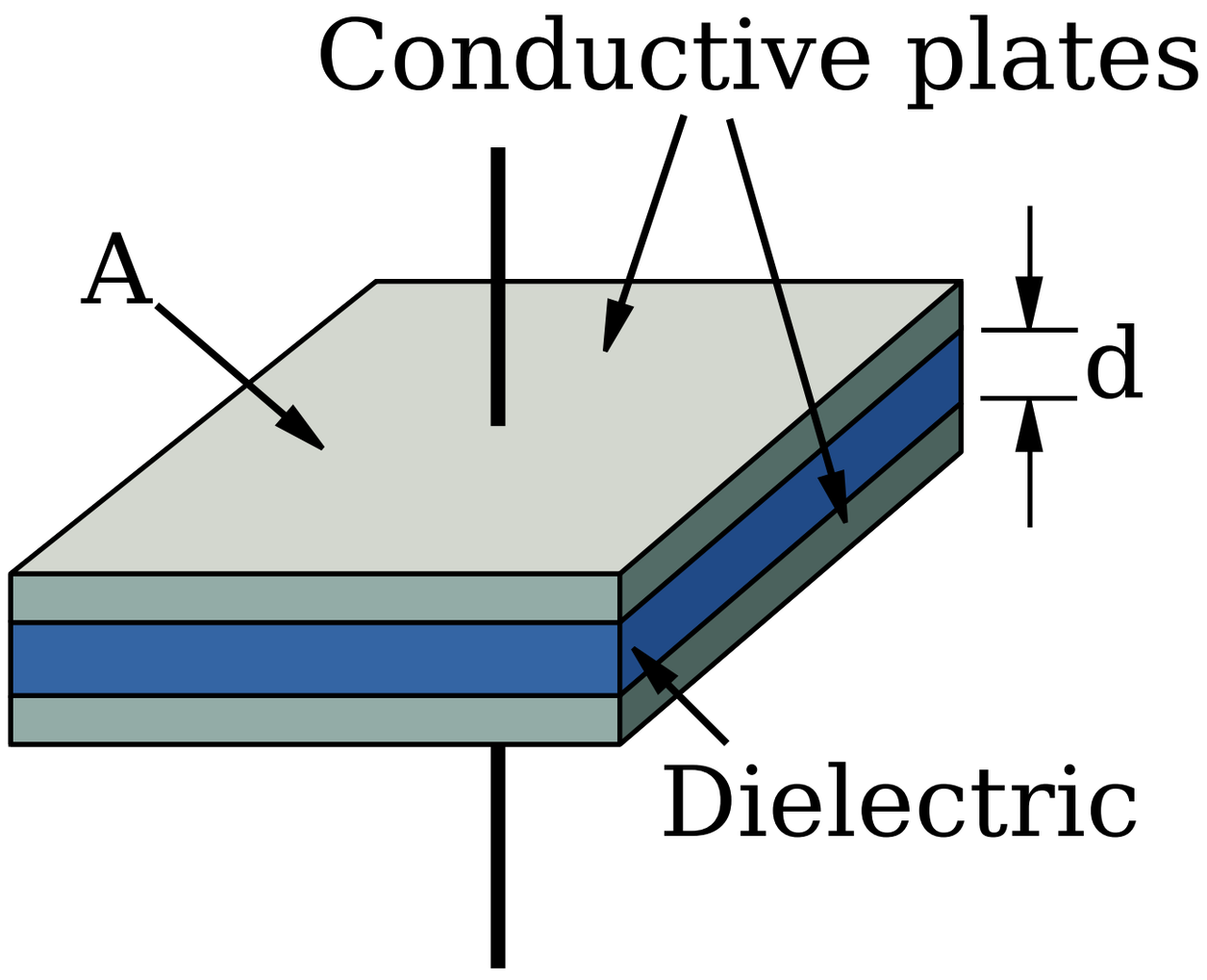
Usually values are written straight on the component



Capacitor values

Capacitors are made of two conductive plates separated by a thin dielectric (non-conductive) material.

$$C = \frac{\epsilon A}{d}$$



Light-emitting diodes (LEDs)

electroluminescent light source
that is easily integrated into circuits

circuit symbol:

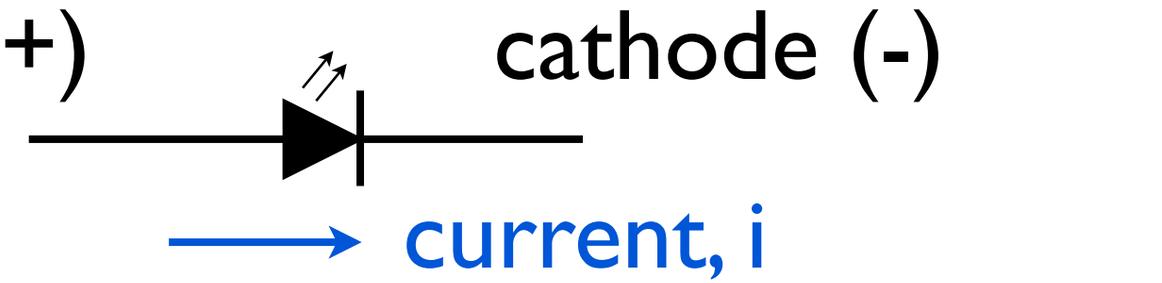
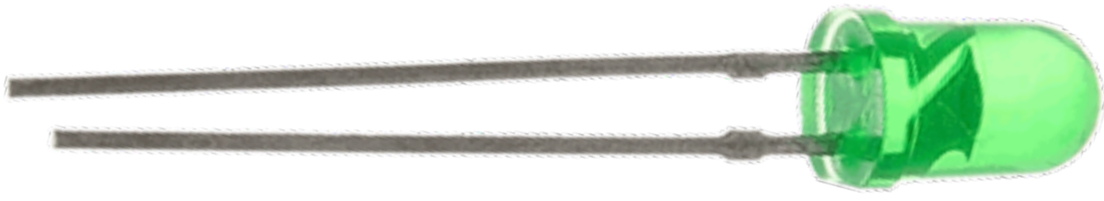


image:

anode (+)

cathode (-)



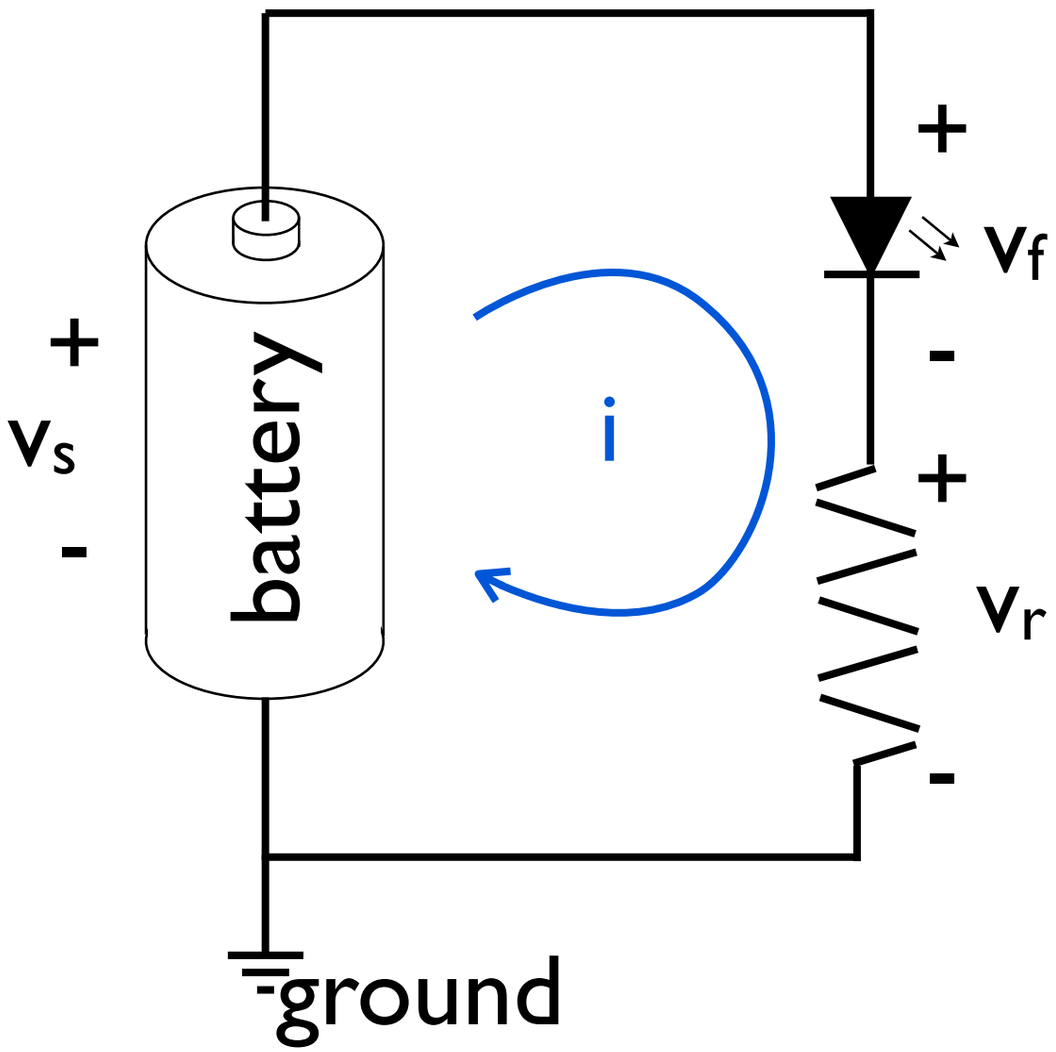
Light-emitting diodes (LEDs)

Every LED has a **forward voltage**, v_f, which defines how much voltage *drops* as the current passes through the LED

Also, an LED has a recommended **current rating**, which states how much current can safely go through the LED without burning it out

The higher the current, the brighter the LEDS shines.
But you **must limit this current**!

Light-emitting diodes (LEDs)

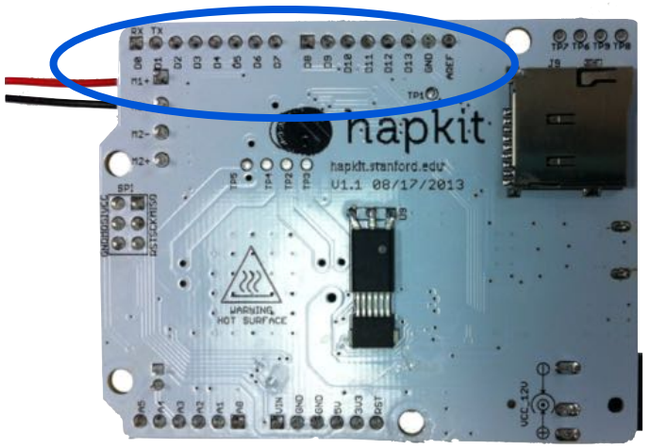


Problem:
Given a desired current **i** (due to LED current rating) supply voltage $\mathbf{v_s}$, and forward voltage of the LED $\mathbf{v_f}$, what size resistor should I use?

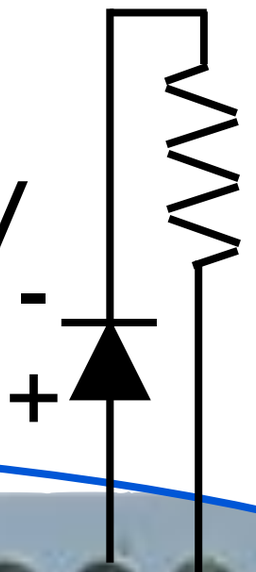
$$v_s = v_f + v_r$$

$$i = v_r / R$$

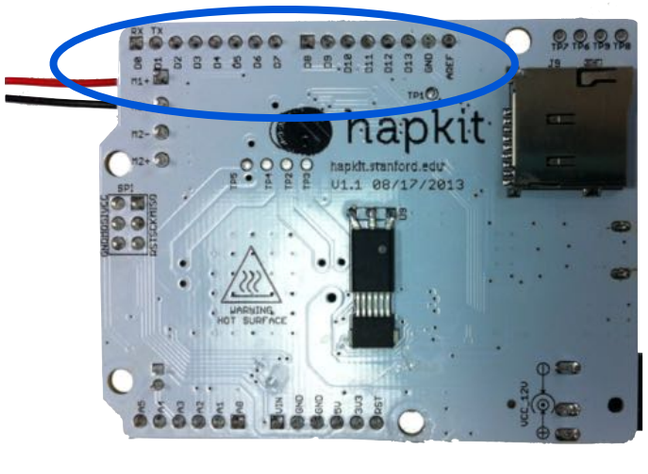
LED connection



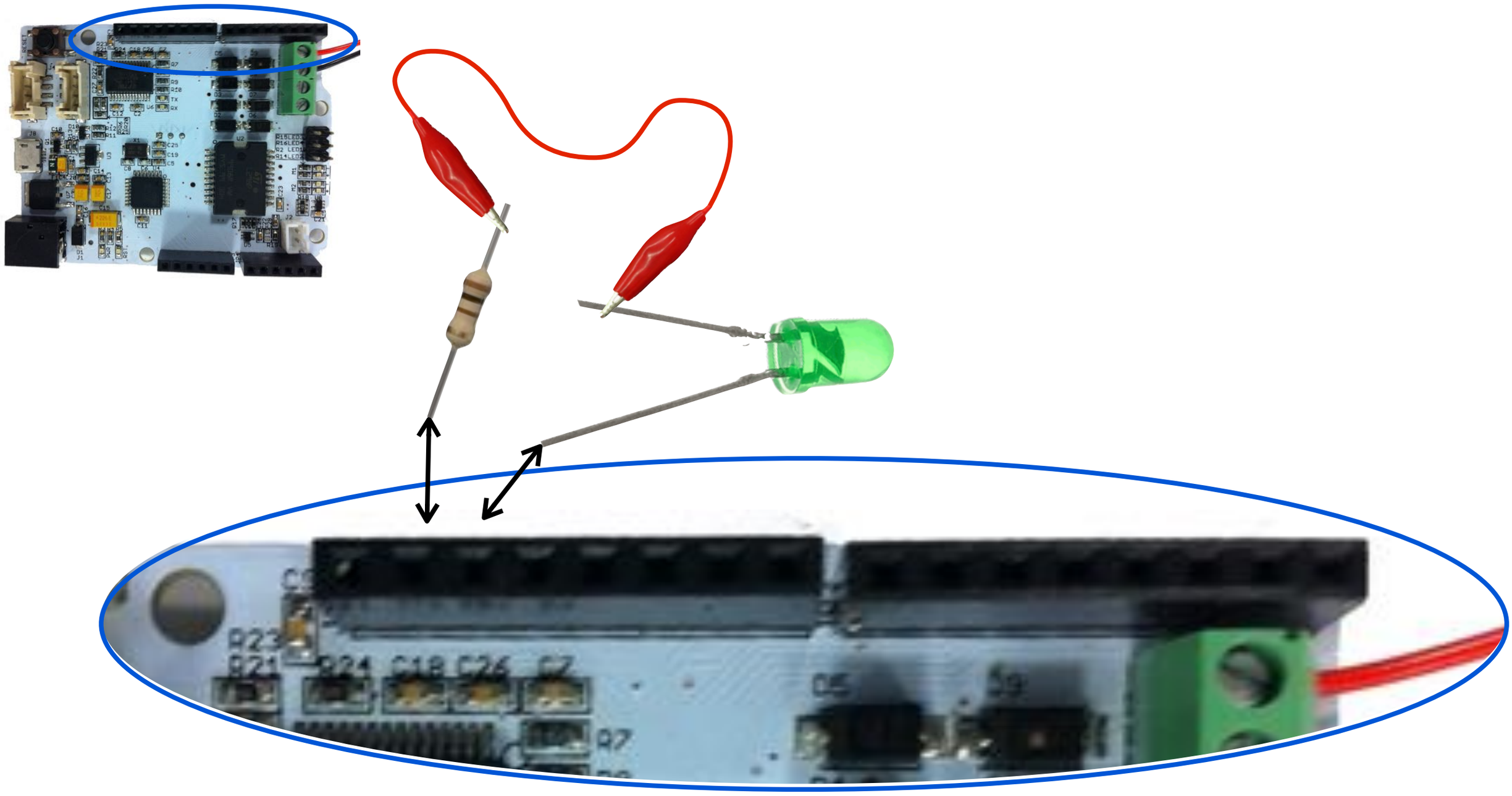
When commanded to go HIGH, pin 13 will output approximately 5 V



LED connection



LED connection



Programming Hapkit

Arduino is a single-board microcontroller that makes using electronics in multidisciplinary projects relatively easy

The Hapkit board is based on the Arduino design, with some added features

The Hapkit board can be programmed using the same Arduino integrated development environment (IDE) as an Arduino board

Follow the instructions in the handout to download, install, and test the Arduino software

Example Hapkit Program

Programming Area

The Arduino programming language is similar to C and java

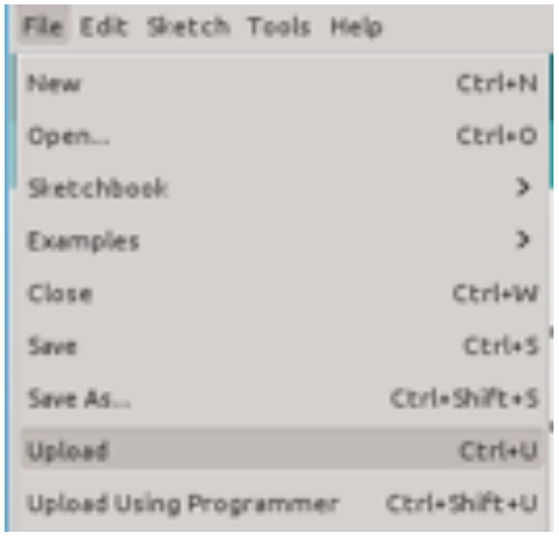
Code:

```
// Blink the pin 13 LED
void setup() {
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);
  delay(1000);
  digitalWrite(13, LOW);
  delay(1000);
}
```

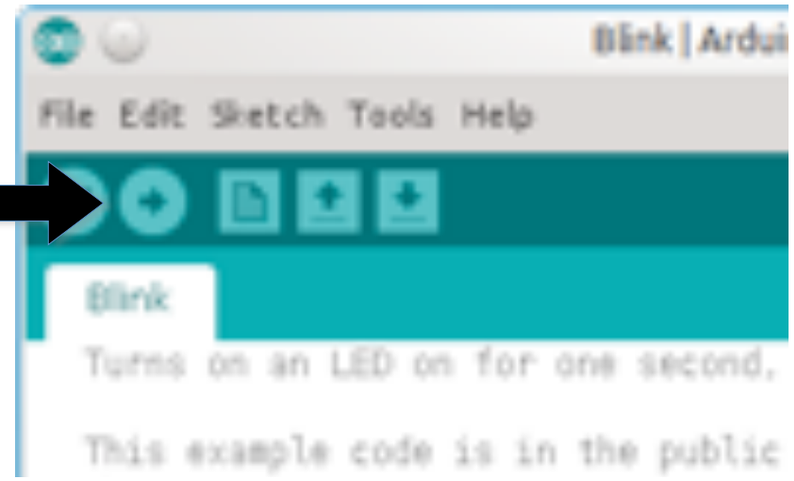
material courtesy Paulo Blikstein

Running a Hapkit Program



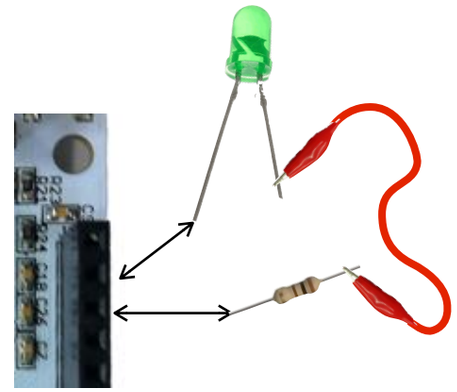
Click
File > Upload

or click the Upload button



Clicking Upload
sends the code
from the computer
to the Hapkit board

Your code is now running on the Hapkit Board! What is the LED doing?



material courtesy Paulo Blikstein

Understanding the code

```
// Blink the pin 13
LED
void setup() {
  pinMode(13,
OUTPUT);
}

void loop() {
  digitalWrite(13,
HIGH);
  delay(1000);
  digitalWrite(13,
LOW);
  delay(1000);
}
```

void setup() { … }

Any code inside the setup function runs *once* to setup the Arduino

void loop() { … }

Any code inside the loop function loops over and over again

material courtesy Paulo Blikstein

Understanding the code

```
// Blink the pin 13
LED
void setup() {
  pinMode(13,
OUTPUT);
}

void loop() {
  digitalWrite(13,
HIGH);
  delay(1000);
  digitalWrite(13,
LOW);
  delay(1000);
}
```

pinMode(Pin Number, INPUT or OUTPUT)

This tells the Arduino whether the pin is an input (ie. sensor, switch) or an output (ie. LED, motor). Pin 13 is connected to an LED on the board. The other pins can be externally connected to whatever you want!

material courtesy Paulo Blikstein

Understanding the code

```
// Blink the pin 13 LED
void setup() {
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);
  delay(1000);
  digitalWrite(13, LOW);
  delay(1000);
}
```

digitalWrite(Pin Number, HIGH or LOW)

This makes the specified pin HIGH (a digital 1) or LOW (a digital 0). The LED is on if it is HIGH and off if it is LOW. We first make the LED turn on by making pin 13 HIGH, then we make it turn off by making pin 13 LOW.

Digital 0 = 0 Volts = LOW

Digital 1 = +5 Volts = HIGH

delay(Milliseconds)

This makes the Arduino wait for the specified number of milliseconds. Without the delay, the LED would blink so fast, you wouldn't notice!

material courtesy Paulo Blikstein

The Serial Monitor

- The Arduino environment's built-in serial monitor can be used to communicate with your Hapkit board
- In the menu, click on **Tools > Serial Monitor** to view
- You can use the following code to interact with the serial monitor:

```
void setup() {
  Serial.begin(9600); // open the serial port at 9600 bps
}
```

to print to the serial monitor:

```
Serial.println("Hello World!");

int my_variable = 0;
Serial.println(my_variable);
```

to read from the serial monitor:

```
if (Serial.available() > 0)
{
  char inByte = Serial.read();
}
```

Programming syntax/hints

- Use // before any text you want to have as a comment (and comment well!)
- Each statement must end with a ; (semicolon)
- You must declare variables before you use them
- Call built-in Arduino functions to perform I/O (input/output)
- See http://arduino.cc/en/Reference/HomePage for a language reference that describes structure, variables, and functions
- If you have never programmed before, the easiest way to learn is by looking at and modifying example programs. Don't modify too many things at once before testing your code. Many examples under File > Examples

Lab 6:

Soft strain sensors

In this lab, you will…

- Set up a Hapkit Board and test on your computer
- Create a soft strain sensor using fabric with embedded metallic threads
- Create and test a circuit that measures capacitance change due to strain
- Use an Arduino program to display the stretch of your sensor

To Do

- Keep your lab notebook, Allison will check them next week!
- Take over a lab bench with your partner (next slide).
- Read the lab handout
- Work on the lab for the remainder of today, and you'll finish the lab on Thursday.
- Answer the questions in your lab notebook (clearly label it with the date and "Lab 6"). Turn in the lab notebook by the end of class on Thursday, or let us know if you need more time/help.

Groups of two for Lab 6

1	Leena	Alana
2	Caroline	Huy
3	Brian	Emma
4	Tomas	Josue
5	Sochima	Ellie
6	Cherié	Nadin
7	Nick	Youngju
8	Senkai	Angelo