MAS.S63: Design for DIY Manufacturing
Electronics Prototyping

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MIT Media Lab
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diymanufacturing.mit.edu

Outline

- Assignment
- Prototyping
- Elements (sensing, actuation, power, etc.)
- Resources
- Advice
- Circuits

Assignment

The Larger Process

- Prototyping the electronics
- Prototyping the form
- Combining the two prototypes (mid-term)
- Designing for production (final)

Assignment

- Build a functioning (electronic) prototype of your project
- Includes essential mechanical aspects
- Not (really) worrying about production process

Goal

- Find out if what you’re doing is possible
- Experience it
- Figure out how to implement it

This is a prototype.

- Arduino board is fine
- Custom PCBs after the mid-term
- Need to test all the elements

Schedule

- Need to order parts tomorrow
- Nan-Wei and I are available tomorrow
- Arduino section? Sensor section?
- Office hours next week, too.

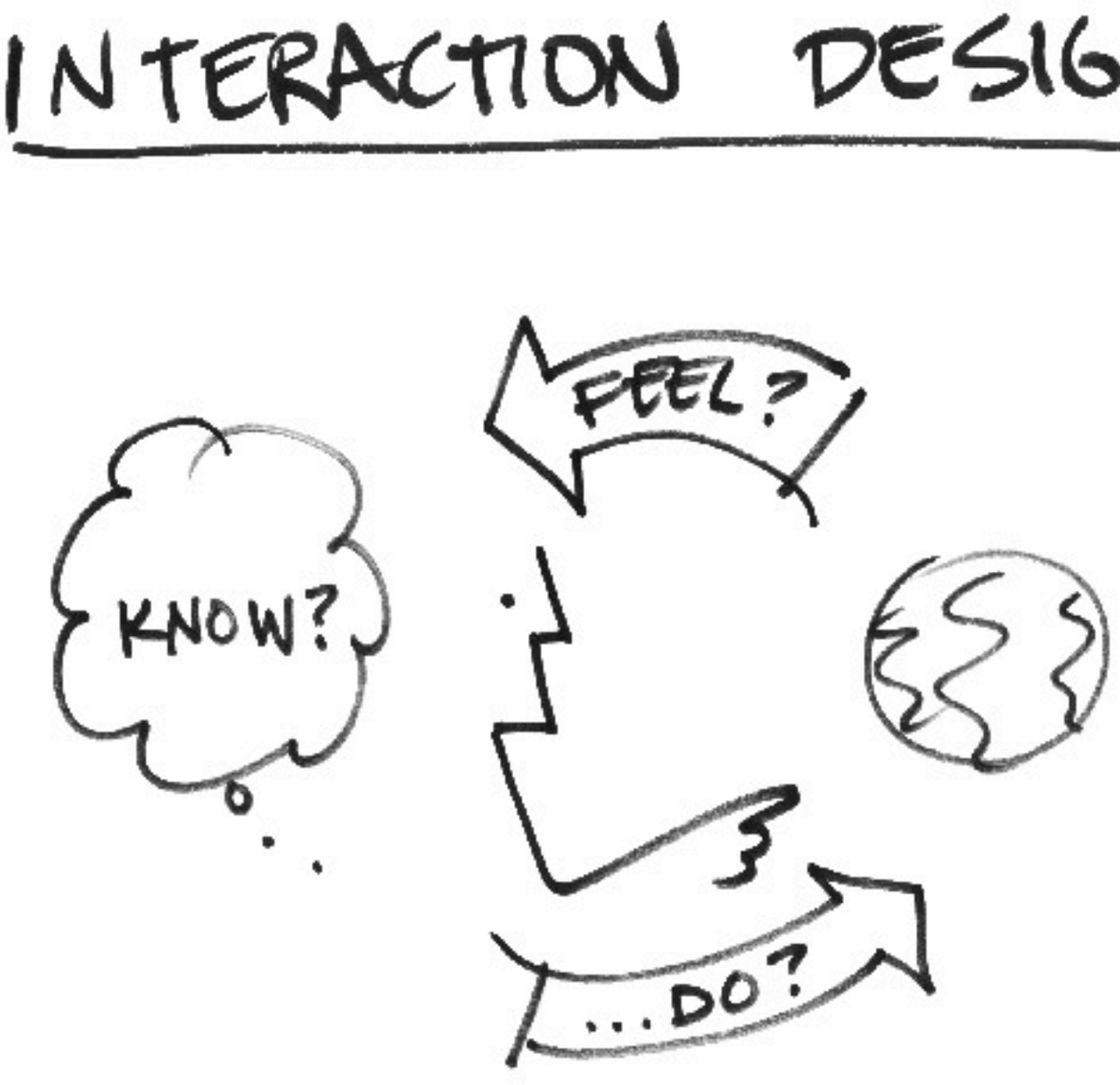
Prototyping

What do prototypes prototype?

- role
- look & feel
- implementation

Stephanie Houde and Charles Hill

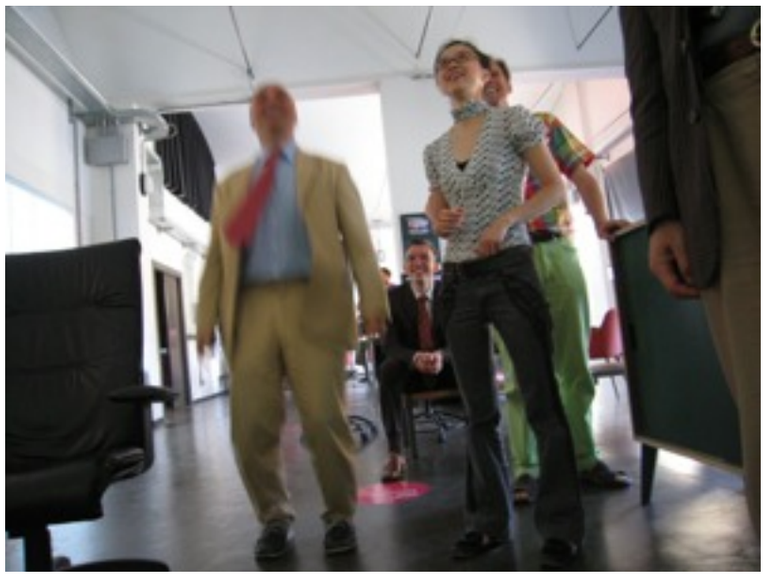
Bill Verplank

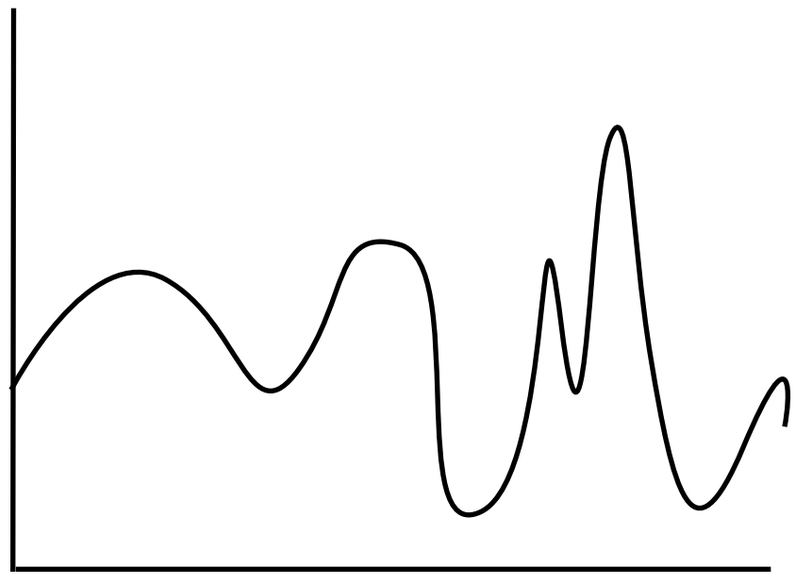


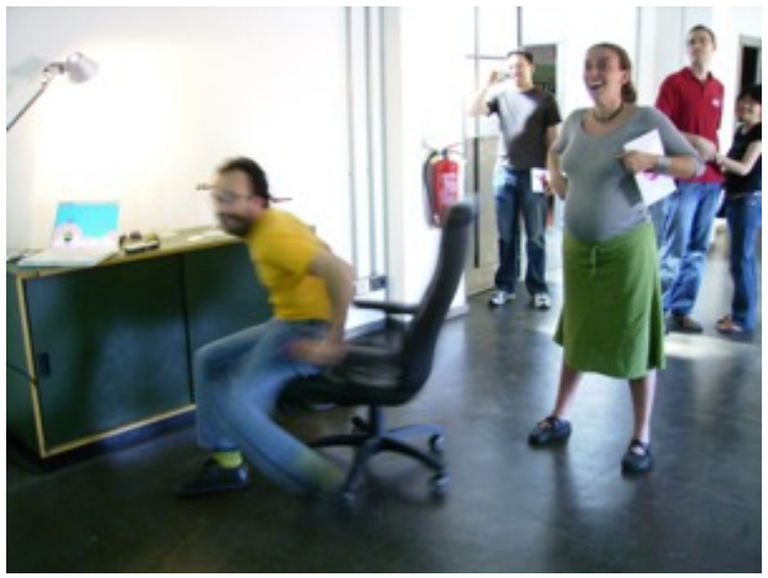
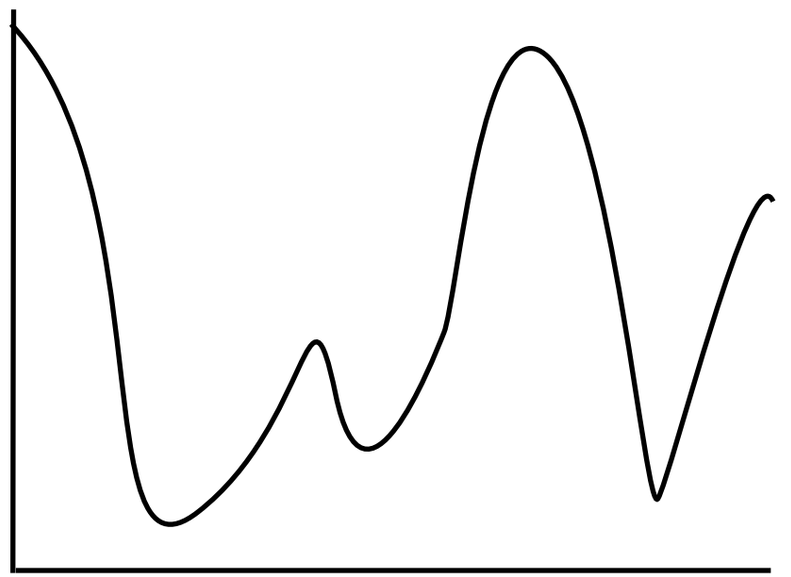
Questions

- What do you need to sense?
- What do you need to actuate?
- How are you going to power it?
- What do you need to communicate with?
- How are you going to put it together?

From Physical World to Electrical Signal

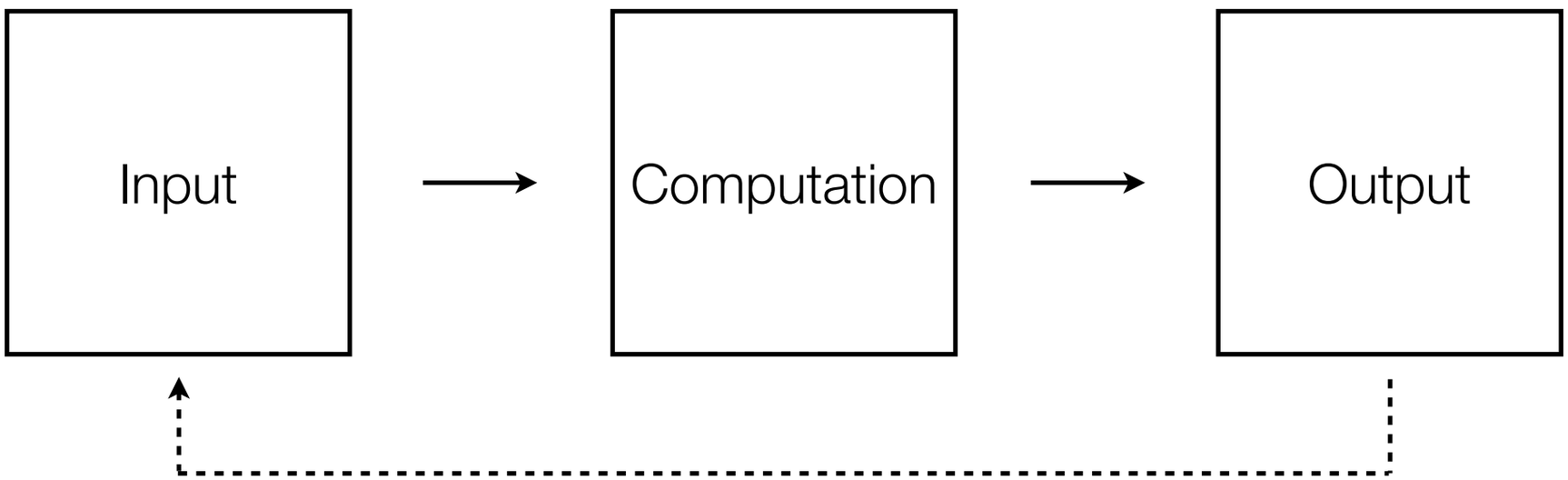




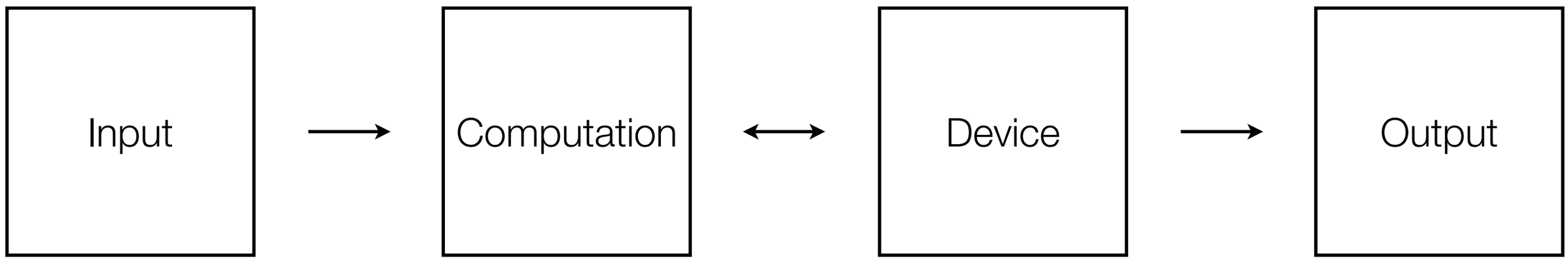



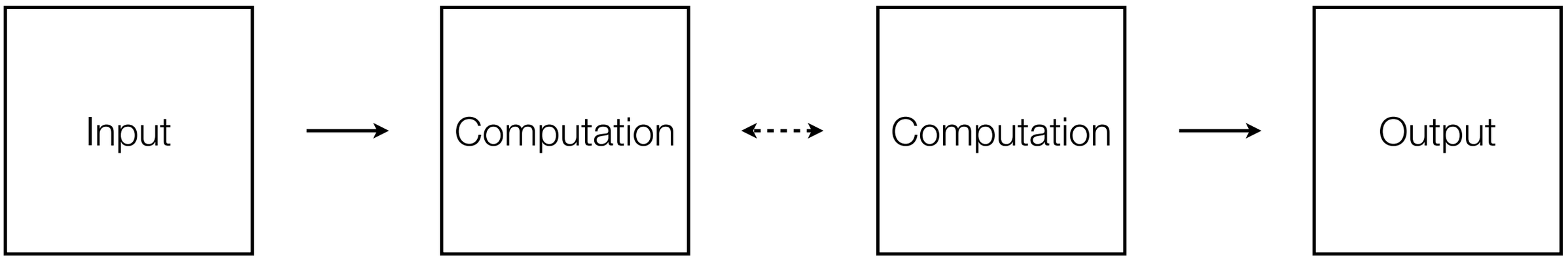
Images from Control Freaks by Haiyan Zhang, http://failedrobot.com/thesis/

Translation: Your Ideas to Electronics



Translation: Your Ideas to Electronics





Elements

Sensing

Actuation

Computation

Power

Connections

Communication

Storage

Sensing

Sensing

- interfaces
- light
- sound
- touch / contact
- motion
- proximity
- identity

Interfaces

Buttons

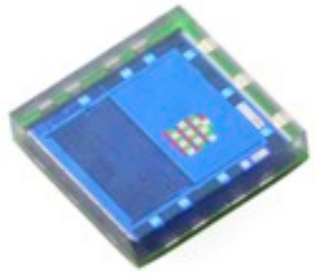
Switches

Knobs / Sliders

Light

Light-dependent resistor (LDR) / photocell ($1)

Color sensor ($5-$15)



Cameras ($10 but hard to use)

Sound

Electret Microphone ($1)

Speech Recognition Modules ($50)

Contact

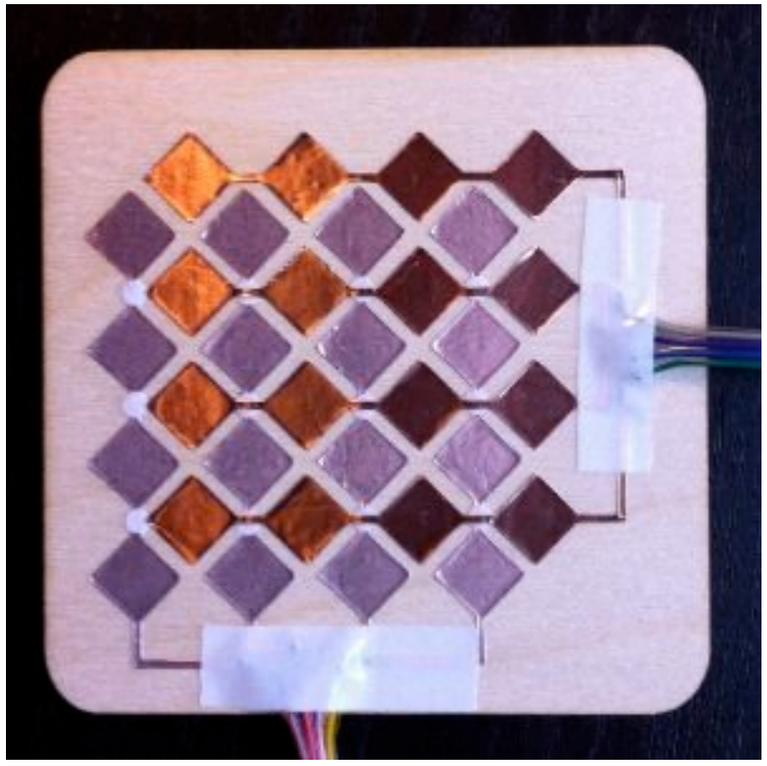
Pressure (FSR) $6

Bend / Flex Sensor $12

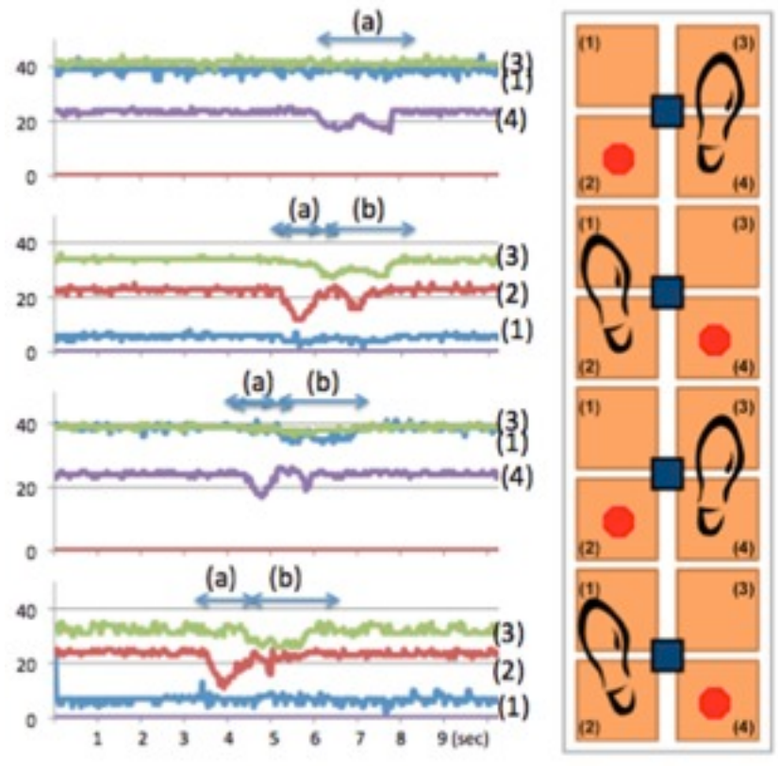
Soft Pot ($18)

Capacitive Sensing

Tayo Falase



Matt Blackshaw



Nan-Wei Gong

Motion

Tilt Sensor ($2)

Piezo Sensor ($3)

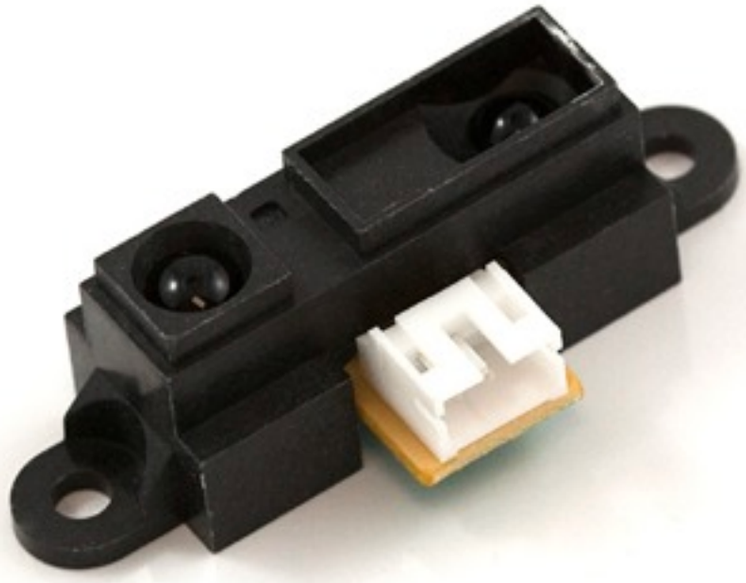
Accelerometer ($30)

Distance and Proximity Sensors

Ultrasonic

Maxbotix LV-EZ1
$25

Infrared



Sharp GP2Y0A21YK
$14

PIR

PIR
$10

Identity

RFID

Cards

Dealing w/ Noise

- Average N samples
- Running average (smoothing)
- Take lots of samples

Calibration

- Hard-coded range or threshold
- Take an average during power-up
- Look for changes

Interpretation

- Remember, you only get the data.
- *Acceleration* → *Gestures* is hard.
- Capacitive sensing can be flakey.

References

- Sensors (Joe Paradiso)
  http://resenv.media.mit.edu/classes/MAS836/

- How to Make (almost) Anything (Neil Gershenfeld)
  http://academy.cba.mit.edu/classes/input_devices/index.html

- SparkFun
  http://www.sparkfun.com/categories/23

- Nan-Wei & Mark

Actuation

Actuation

- Light
- Motion
- Sound

LEDs (through-hole, 5mm, T 1-3/4)

Red, Green, Yellow
1.7V to 2.2V

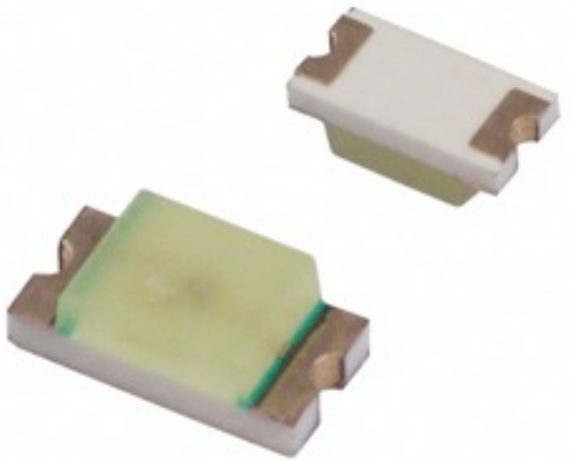
White, Blue, and
“Super-Bright”
~3V

RGB
Colors differ in voltage

Also come in infrared (IR) and ultraviolet (UV).
Also can get 3mm, 10mm.

Other Form Factors

Surface Mount (1206)



“Piranha”
7.6 x 7.6mm

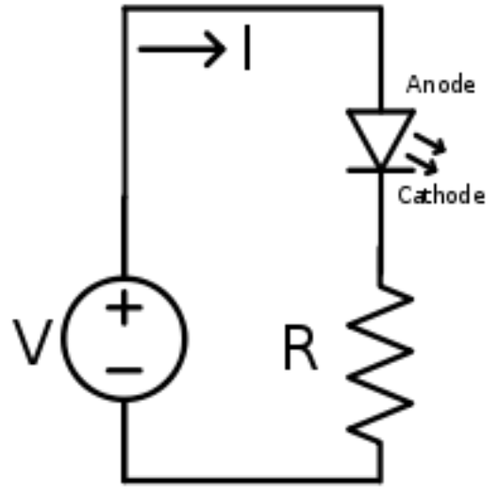
Luxeon Rebel (Philips)
Up to 1A.

Voltage, Resistance, Current (LED)

LED: 2V and 20 mA
Power Supply: 5V

What resistor do we need?

5V - 2V = 3V (across resistor)
3V / 20 mA = 3V / 0.020A = 150Ω



Motors

DC ($2)

Servo ($5-$25)
also continuous rotation

video

Stepper ($5-$50+)

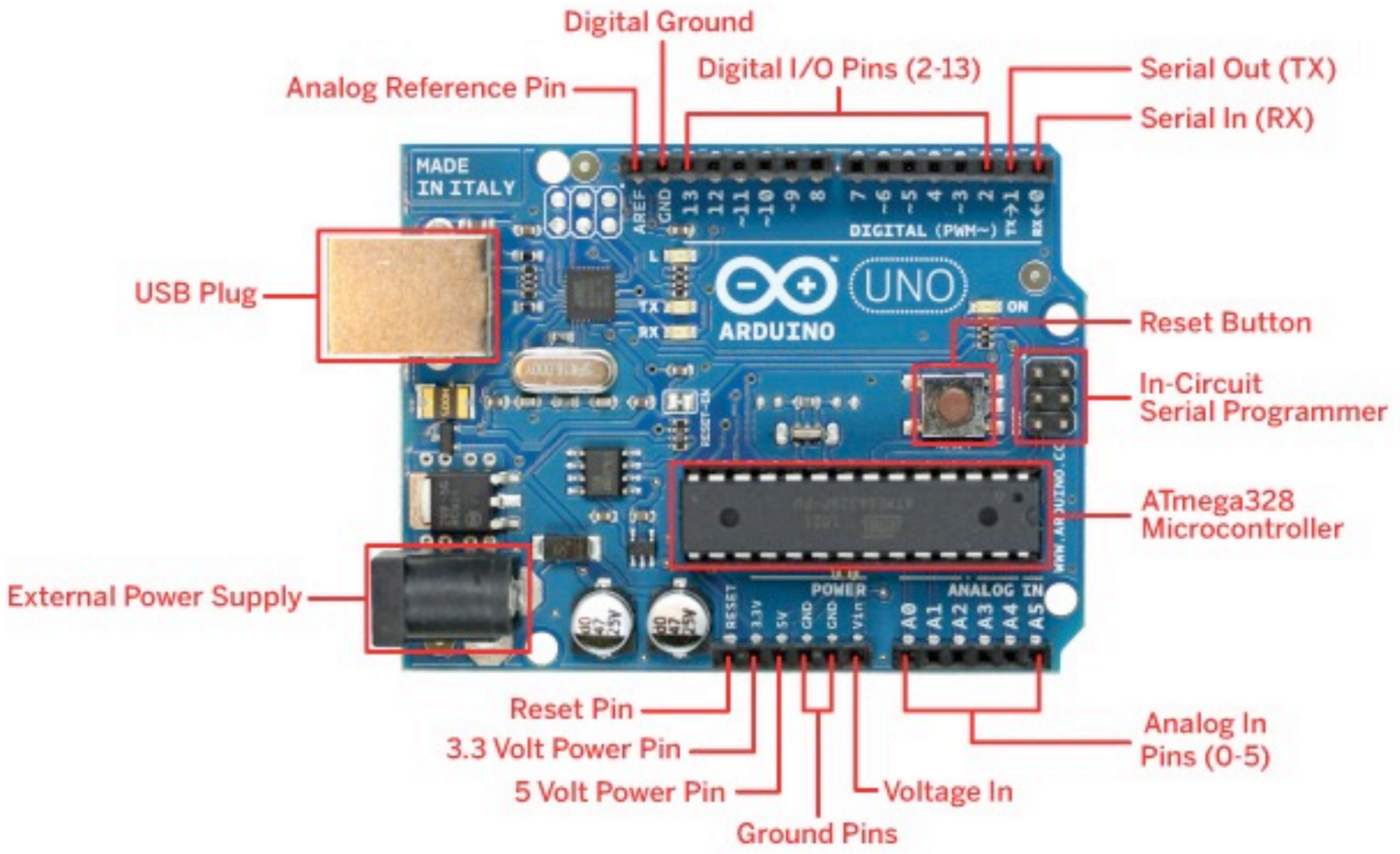
video

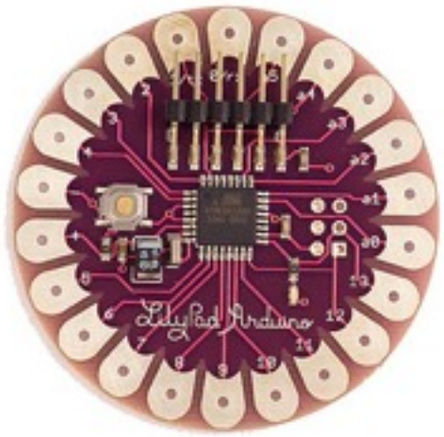
Dealing w/ High-Power

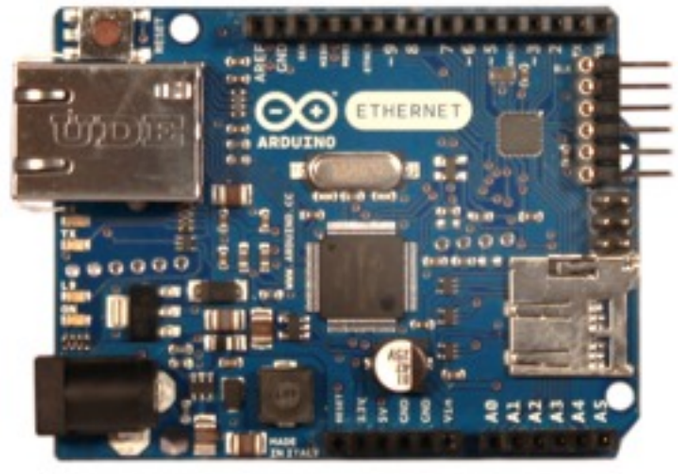
- Transistors (BJT)
- MOSFETs
- H-Bridges

Computation

Arduino







Source: Make Magazine

What can you do with an Arduino?

- 20 digital pins (input or output)
- 6 analog input pins
- 6 analog output (PWM) pins
- Various communication protocols

Analog-Digital Convertor (ADC)

By default, 0V to 5V = 0 to 1023 (resolution of ~5 mV).

Also a 1.1V reference, that is 0V to 1.1V = 0 to 1023 (resolution of ~1mV).

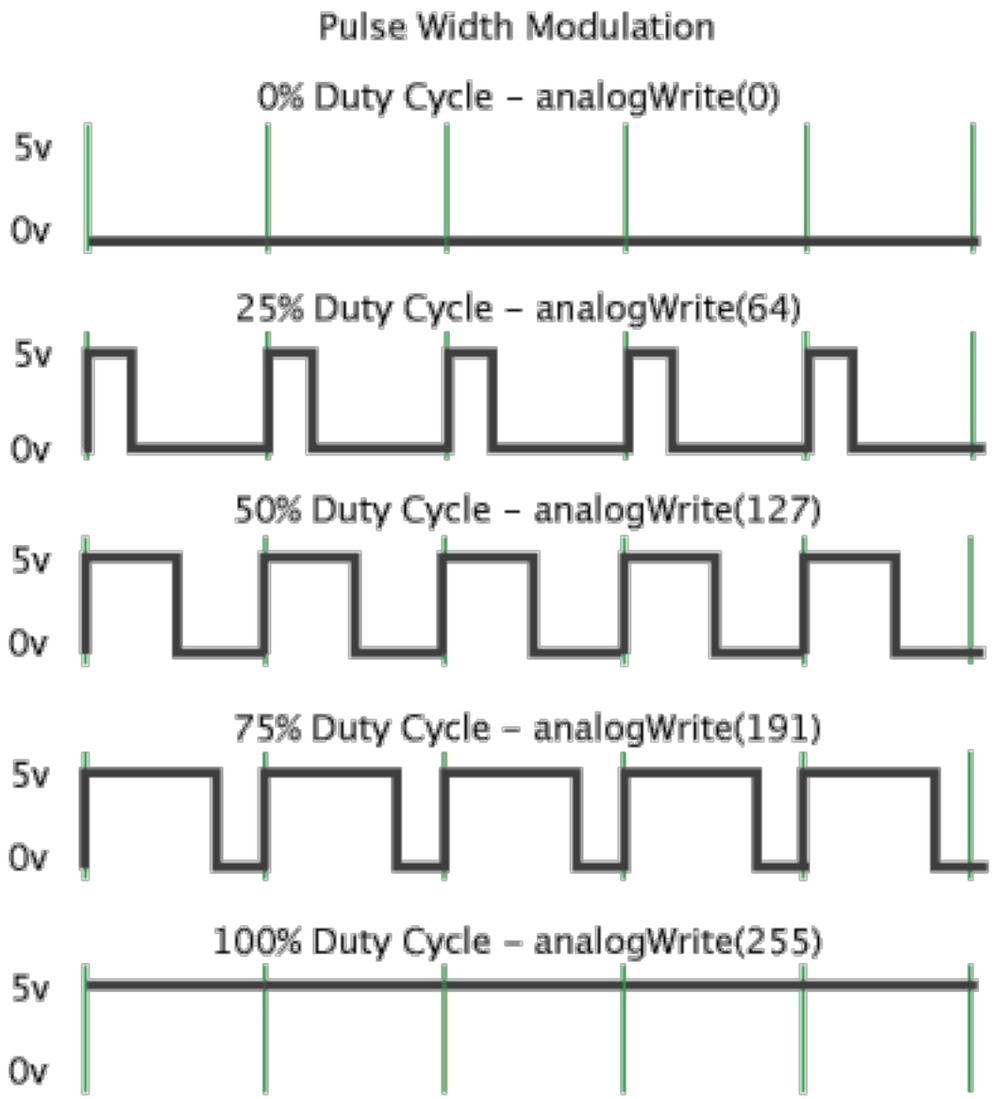
Also an external reference.

Analog input pins also work as digital pins.

Pulse-Width Modulation (PWM)

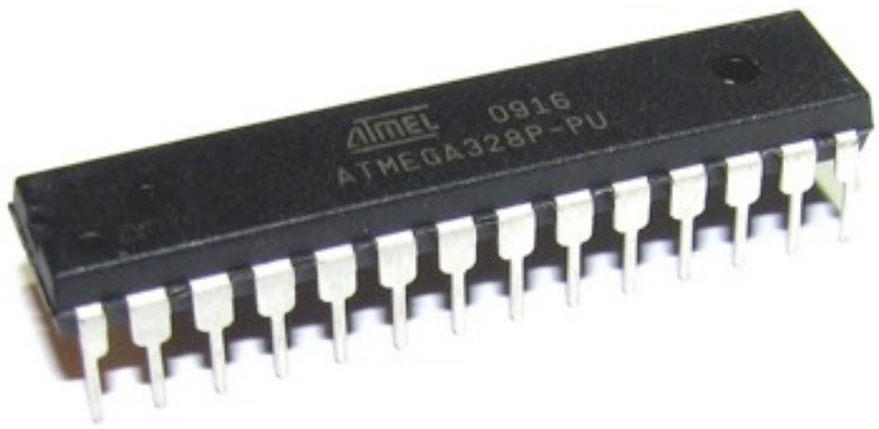
From 0 (always off) to 255 (always on).

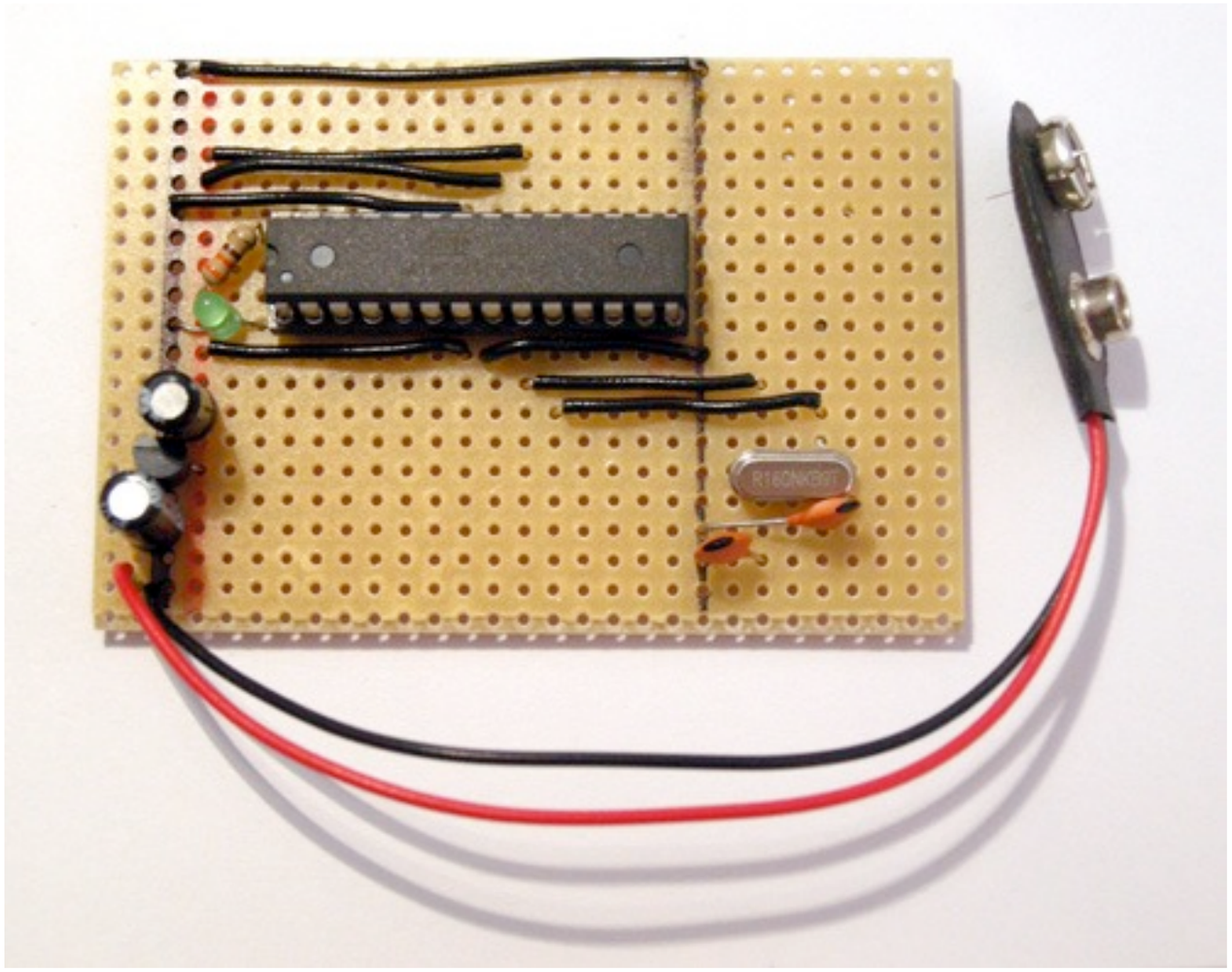
Sometimes smoothed automatically.



ATmega328 (AVR)

- 16 MHz
- 32 KB flash
- 2 KB RAM





Other Microcontrollers

- ATtiny
- Other ATmega's
- PIC
- ARM
- Propeller

Other Development Boards

- Teensy
- Maple
- NETduino
- Microsoft Gadgeteer

Programming

- Assembly
- C
- Arduino

Resources

- Arduino website
  http://arduino.cc/

- Make | Arduino
  http://blog.makezine.com/arduino/

- LadyAda
  http://www.ladyada.net/learn/arduino/index.html

- Google!

Power

Power

- Batteries
- Wall power (“mains”)
- USB power
- Other

Batteries

- AA, AAA (often 2, 3, or 4)
- 9V
- Coin Cell (e.g. the 3V CR2032, 20mm x 3.2mm)
- Rechargeable LiPo (3.7V)

Power Supplies

Wall Power Supplies
5V, 9V, 12V / 0.5-1A
$5-$10

Power Supplies
5V, 12V, 24V / 1-20A
$25-$50

Bench Power Supplies
Adjustable
$200-$500

Other Power Sources

Constant Current
LED Driver
e.g. MicroPuck
(350 mA from 3V)
or BuckToot
(350 mA from 5-28V)

USB Power
500 mA at 5V

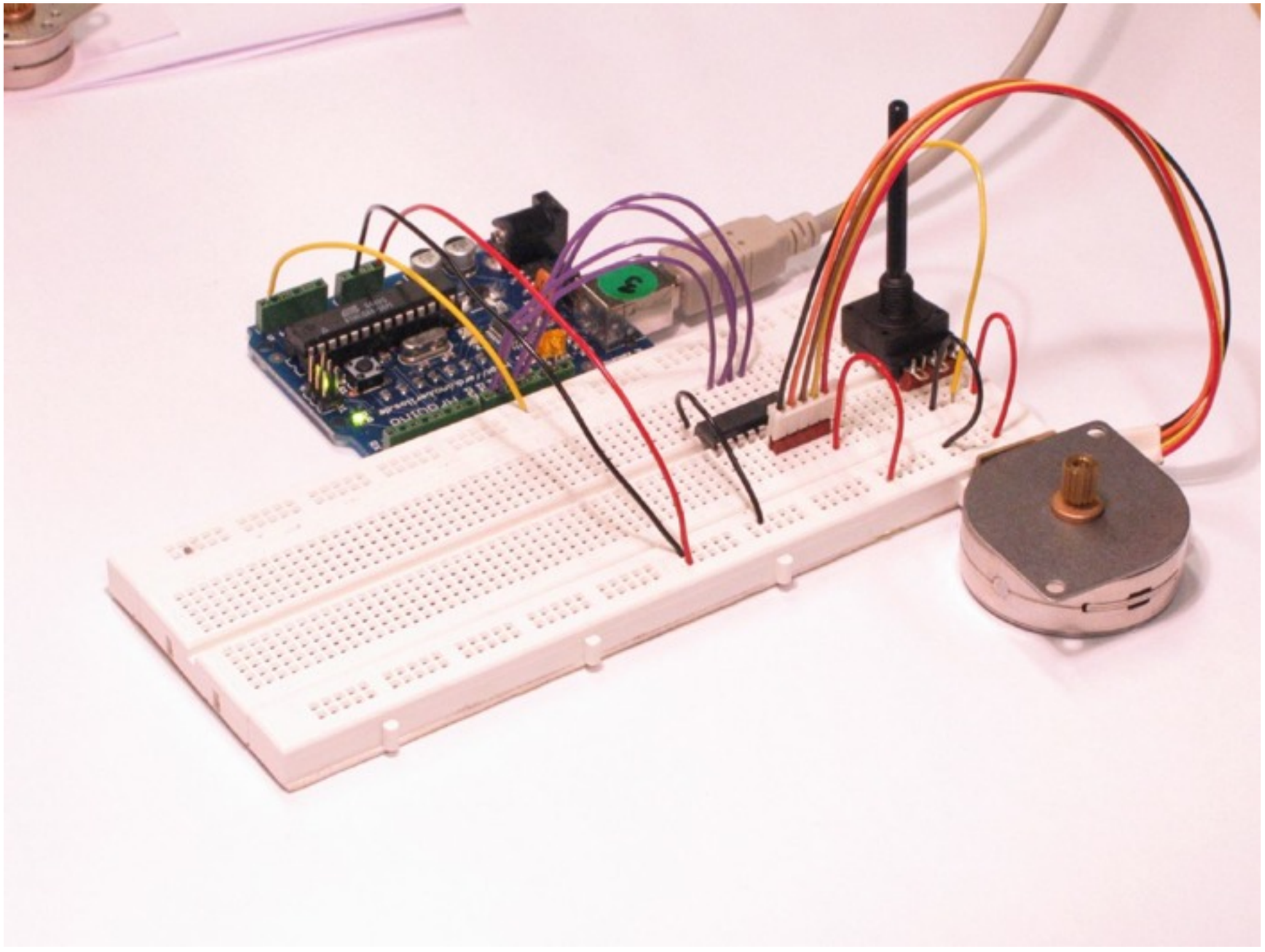
ATX Power Supply
5V and 12V

Other Power Sources

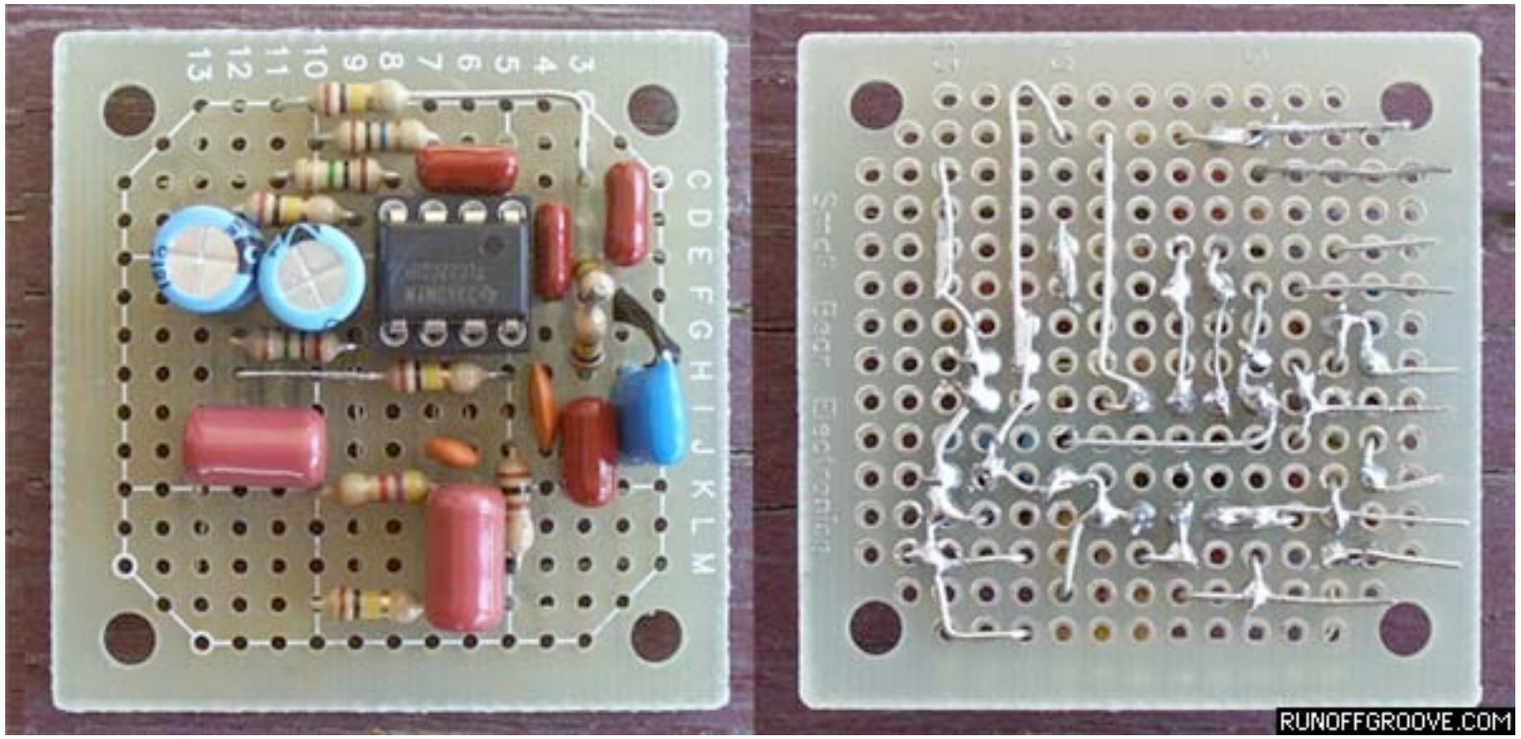
- Solar
- Piezo
- Generators
- Non-Electrical Activation (e.g. temperature, movement)

Connections

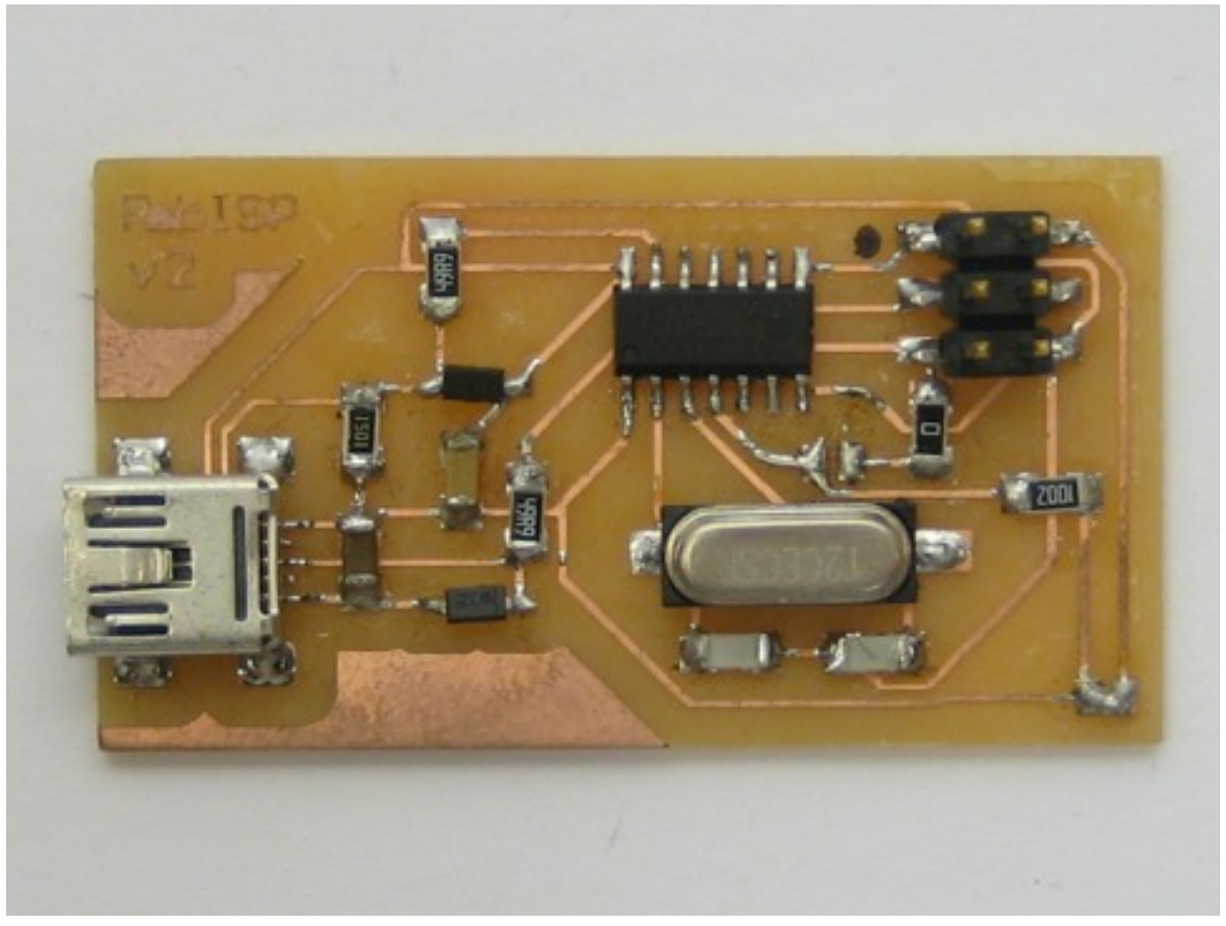
Breadboard

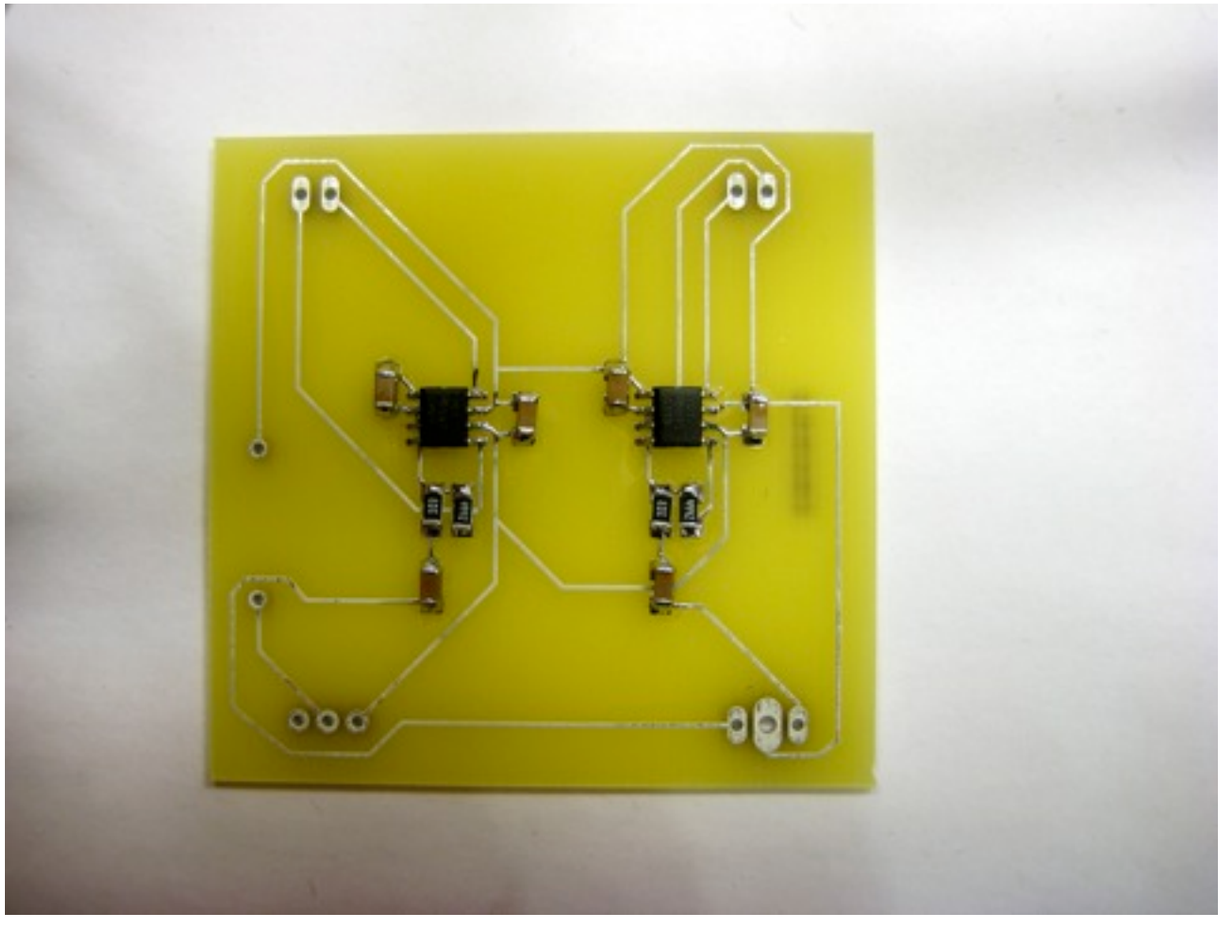


Perfboard / Protoboard / Stripboard / Millefori

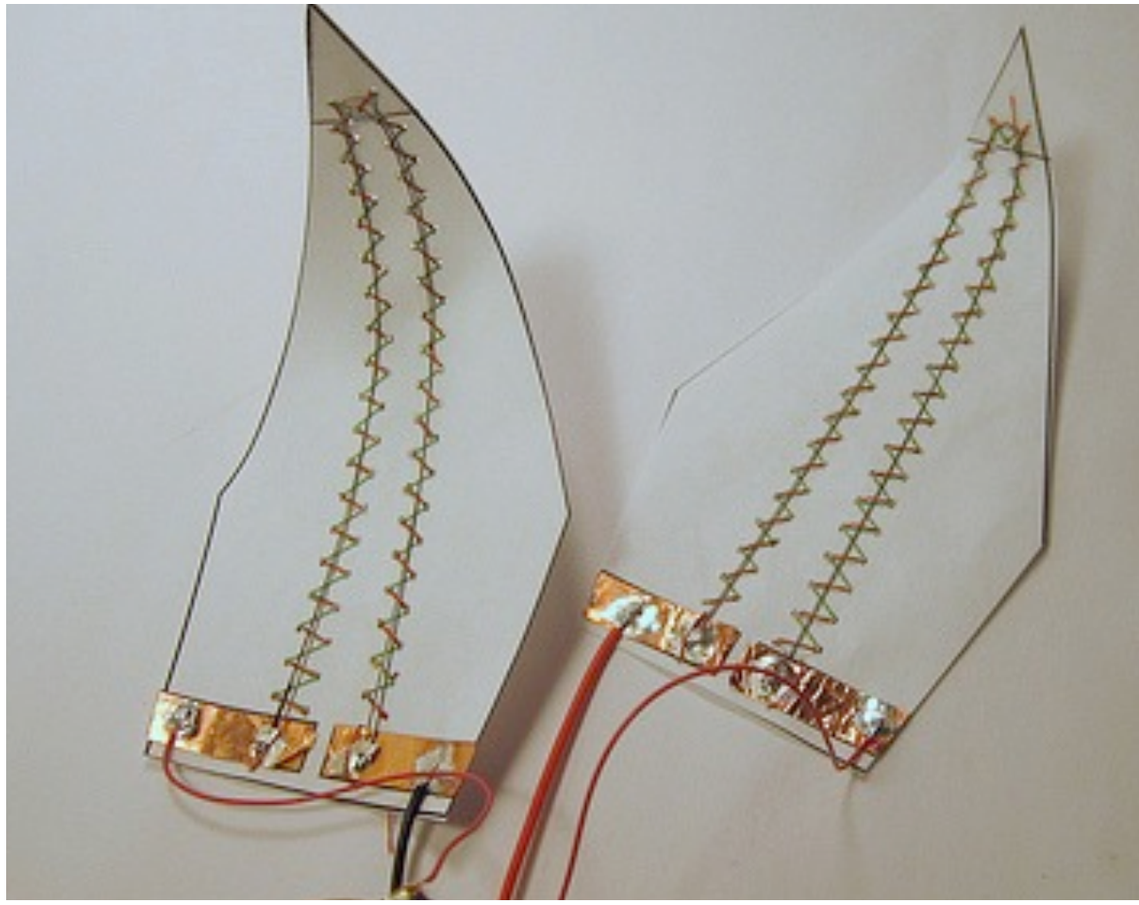


Milling & Ordering





Soft Circuits



See: “How To Get What You Want” at http://www.kobakant.at/DIY/

Connectors

- Headers (female / male)
- Screw & spring terminals
- Phone / Ethernet: RJ9 (4p4c), RJ11 (6p6c, 6p4c, 6p2c), RJ45 (8p8c)
- Audio
- DC power jack (2.1 x 5.5 mm)

Communication

Wired

- Serial
- SPI
- I^2C
- USB
- Ethernet

Wireless

- XBee
- Bluetooth
- WiFi
- IR

Resources

- *Making Things Talk*, Tom Igoe

- *Building Wireless Sensor Networks,* Rob Faludi

Storage

Storage

- On-chip flash (32KB), EEPROM (1KB)
- Flash chips (MBs)
- SD cards (GBs)

Resources

Suppliers

- SparkFun
- Digi-Key
- Mouser
- Jameco
- McMaster Carr

Parts Lists

- Fab Labs
  http://fab.cba.mit.edu/about/fab/inv.html

- High-Low Tech
  http://hlt.media.mit.edu/?p=1300

- Adafruit Parts Wiki
  http://www.ladyada.net/wiki/partselector

- Octopart
  http://www.octopart.com/

Resources

- *Physical Computing*, Dan O'Sullivan & Tom Igoe

- ITP Physical Computing
  http://itp.nyu.edu/physcomp/

- Make Magazine
  http://makezine.com/

- Bildr
  http://bildr.org/

Advice

Keep building on a single prototype.

Don’t take apart anything that works.

Making sense of sensor data is hard.

If it’s flakey, add more capacitors.

Sometimes it’s easier to fix everything that looks wrong (rather than actually finding the failure).

Keep it neat (e.g. use red wires for power, black wires for ground).

Sort by price!

Circuits

Basic Concepts

- Voltage (V), measured in volts (V)
- Resistance (R), measured in ohms (Ω)
- Current (I), measured in amperes (A)

kilo- = 1,000 (kΩ, kV), mega- = 1,000,000 (MΩ), milli = 1/1000 (mA, mV)

Ohm's Law

$$V = IR$$

Battery (Alkaline, 1.5V)

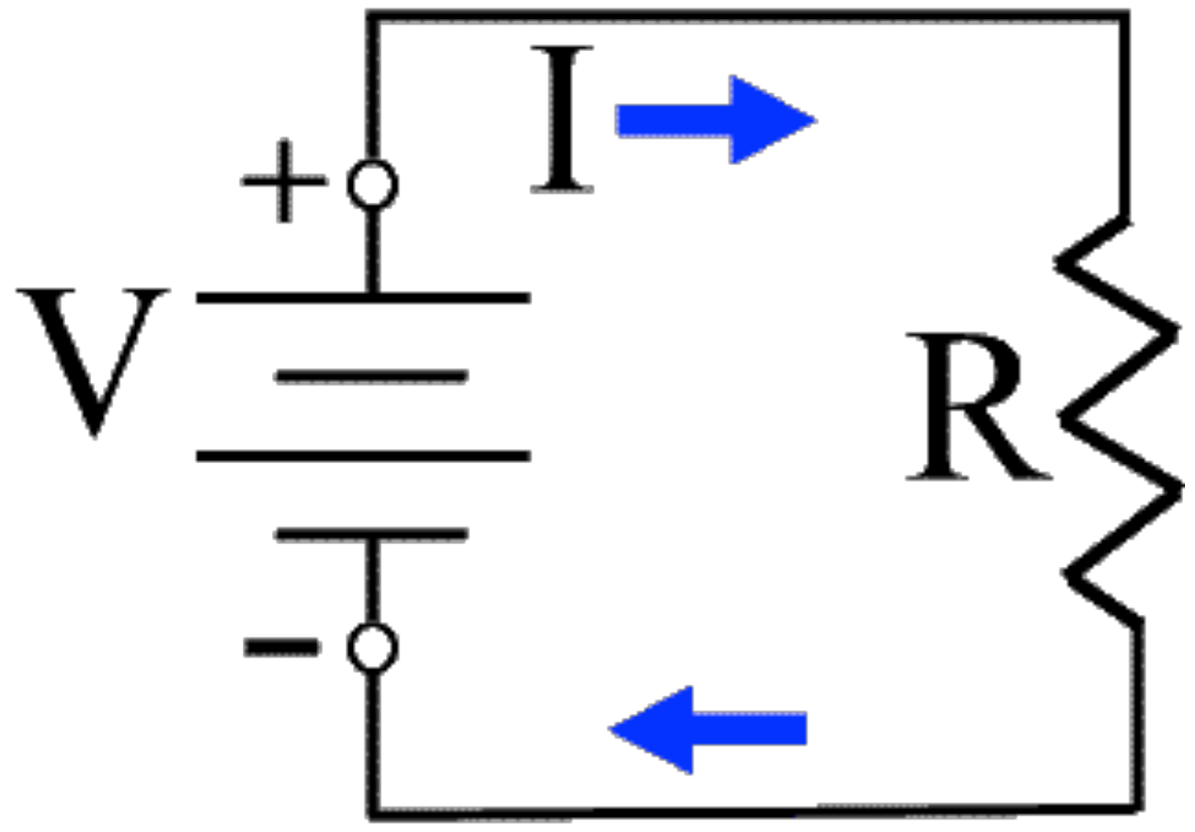
Resistor (10KΩ)

Circuit

V=IR

V/R=I

I = 1.5V / 10kΩ = 0.15 mA



Battery Charge

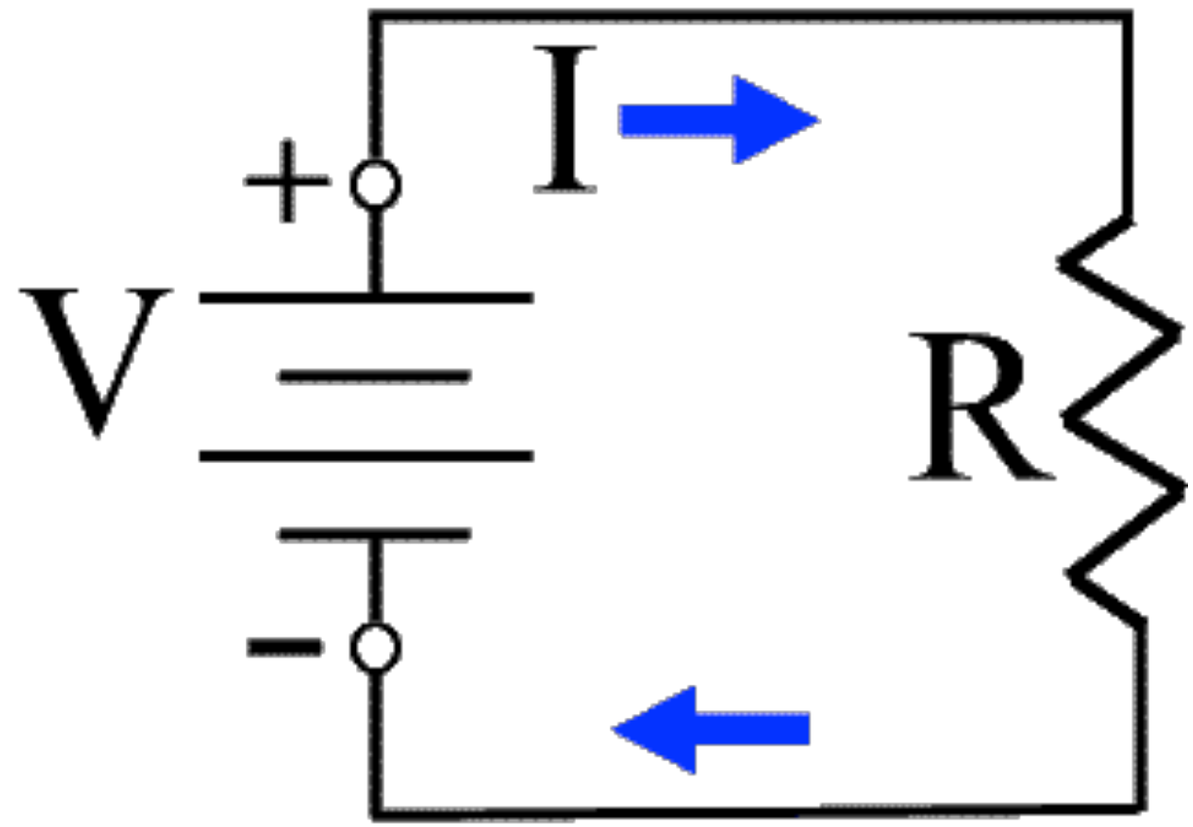
- Typically measured in milliamp hours (mAh)
- AAA: 1,200 mAh
- AA: 2,700 mAh
- C: 8,000 mAh
- D: 12,000 mAh
- 9V: 565 mAh

Circuit

I = 1.5V / 10kΩ = 0.15 mA

AAA: 1,200 mAh

1,200 mAh / 0.15 mA = 8000 h



One more equation...

Power, measured in watts (W).

$P=VI$

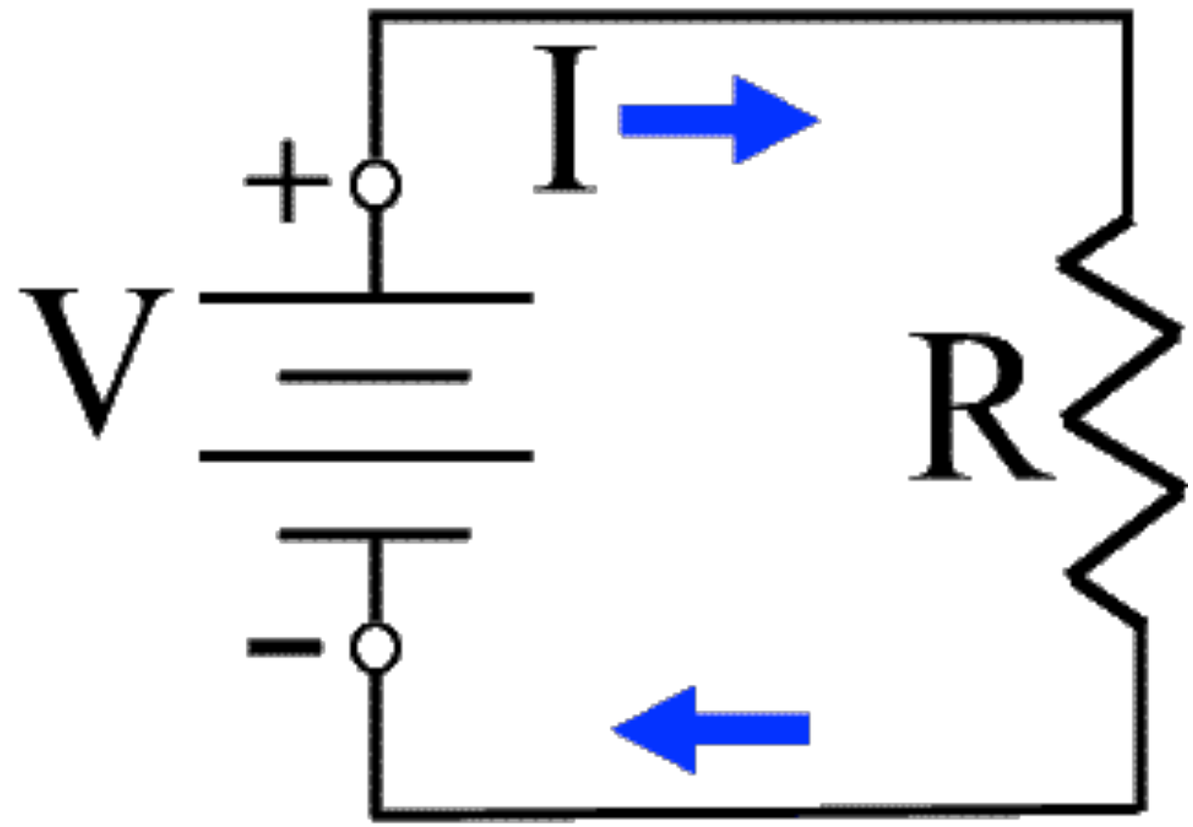
$P=I^2R$ (remember, $V=IR$)

Circuit

I = 1.5V / 10kΩ = 0.15 mA

P=VI

1.5V x 0.15mA = 0.225 mW



Resistor (1/4W)

Another Example

9V battery and 10Ω resistor

I = V / R = 9V / 10Ω = 0.9 A

P = IV = 0.9A x 9V = 8.1W

Bad!

565 mAh / 0.9A = ~0.62 hours = ~38 minutes

Series and Parallel