Arduino

AS220 Workshop

Part I – *The Basics*

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AS220
LABS
SOUND
PIXEL GRIDS
MOVING PIXELS
FOLK ELECTRONICS

Workshop Overview

- Part I – *The Basics*
- Part II – *Interactive Design with advanced Transducers*
- Part III – *Multimedia Applications*
- Part IV – *Communication and Project Presentations*

Physical Computing

- The discipline of creating highly interactive objects using electronics and microcontrollers.
- Encourages an experimental approach.
- Values new experiences over precise theoretical foundations.
- Sometimes also called *Physical Interactive Design*

Microcontrollers

ATMega µC

- Very small computers on a single chip.
- Designed to interface efficiently with the physical world
  - Serial Comm. Ports
  - Digital IO Pins
  - A/D Converters

Interactive Applications

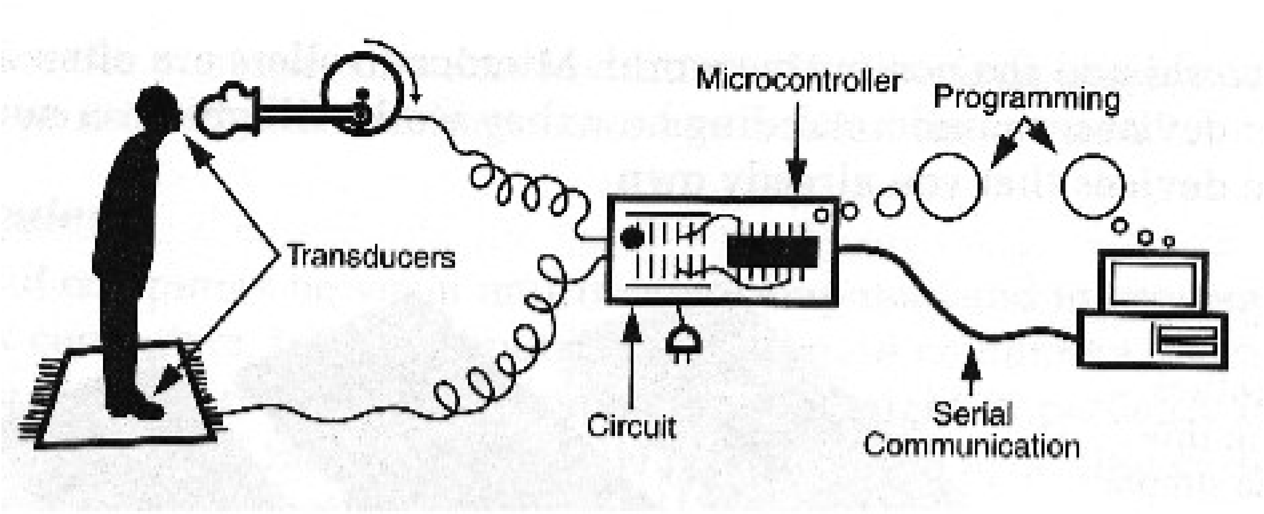
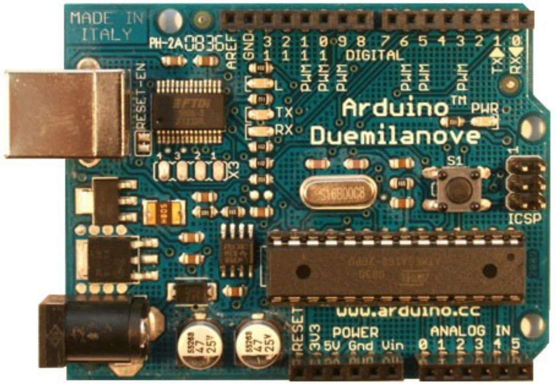


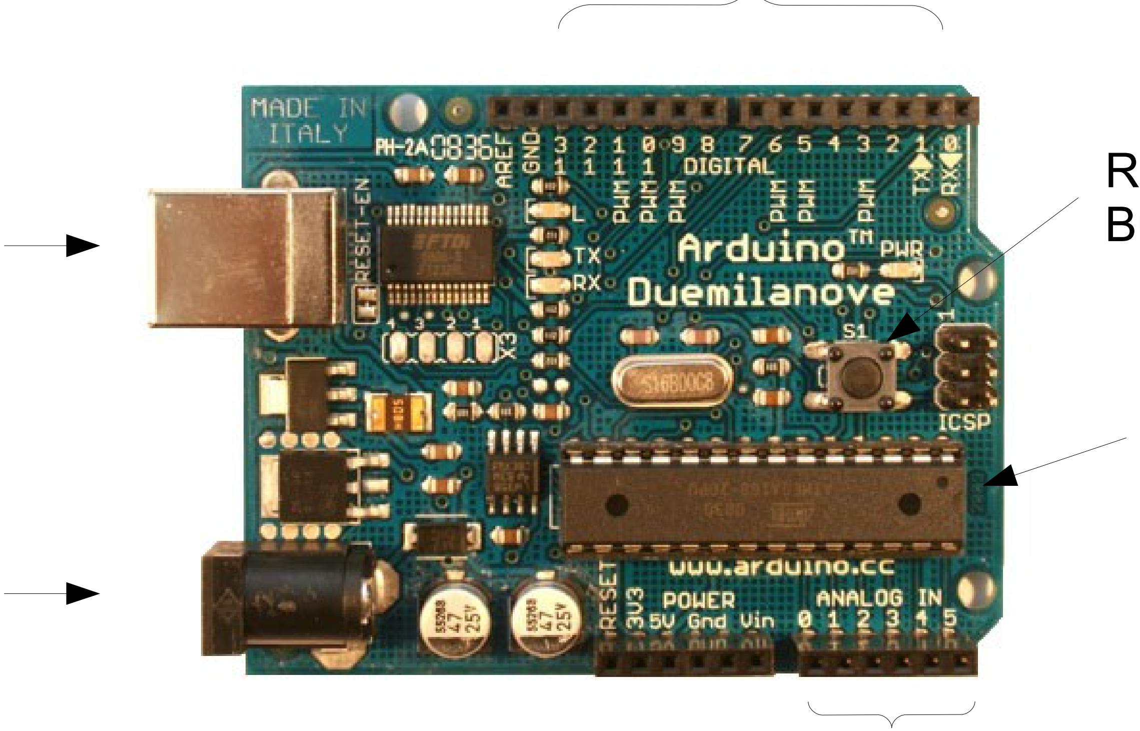
Image source: “Physical Computing”, O'Sullivan and Igoe, Thomson, 2004.

Arduino Board



- Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.
- It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.
- It includes all the electronic components to perform basic experiments.

The Board



Digital IO

USB Port

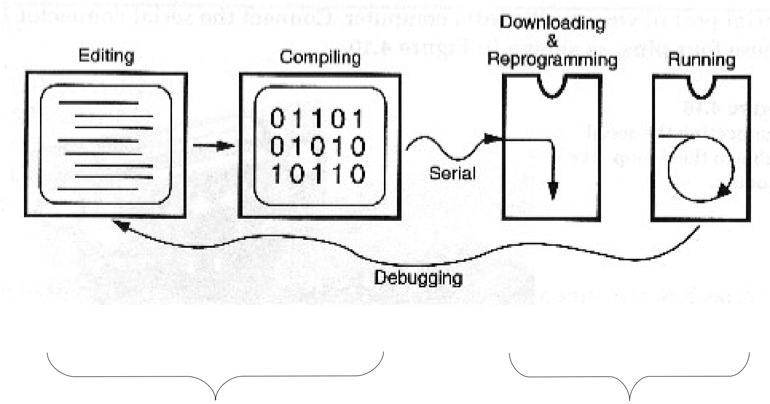
Reset Button

µC

Power Connector

Analog Input

Developing Applications



Development
Computer --
“Sketches”

μC

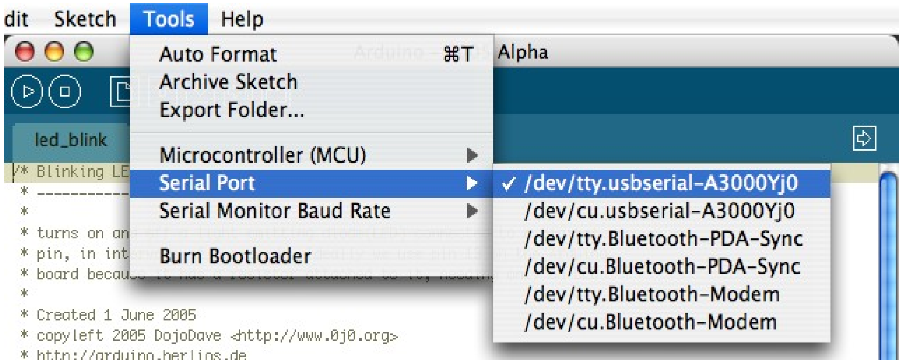
- Develop programs called “Sketches”
- The Arduino IDE compiles these programs for the μC
- The IDE has tools to load the compiled programs onto the μC

Image source: “Physical Computing”, O'Sullivan and Igoe, Thomson, 2004.

Installation

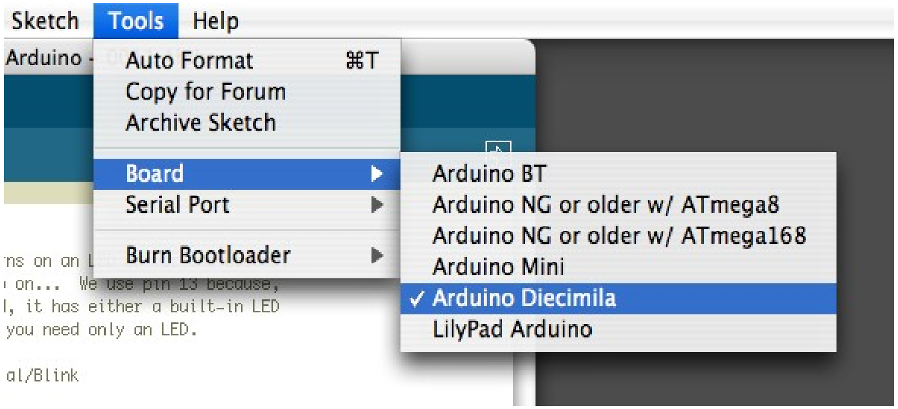
- You will need to download the Arduino IDE and drivers for your development computer
  - Windows, Mac OX, Linux are all supported
- There is nothing you need to do for the Arduino board ☺

Mac OS X Install



✓ /dev/tty.usbserial-A3000Yj0

```
/* Blinking LE
 * ----------
 *
 * turns on an
 * pin, in int
 * board becau
 *
 * Created 1 June 2005
 * copyleft 2005 DojoDave <http://www.0j0.org>
 * http://arduino.berlios.de
```



✓ Arduino Diecimila

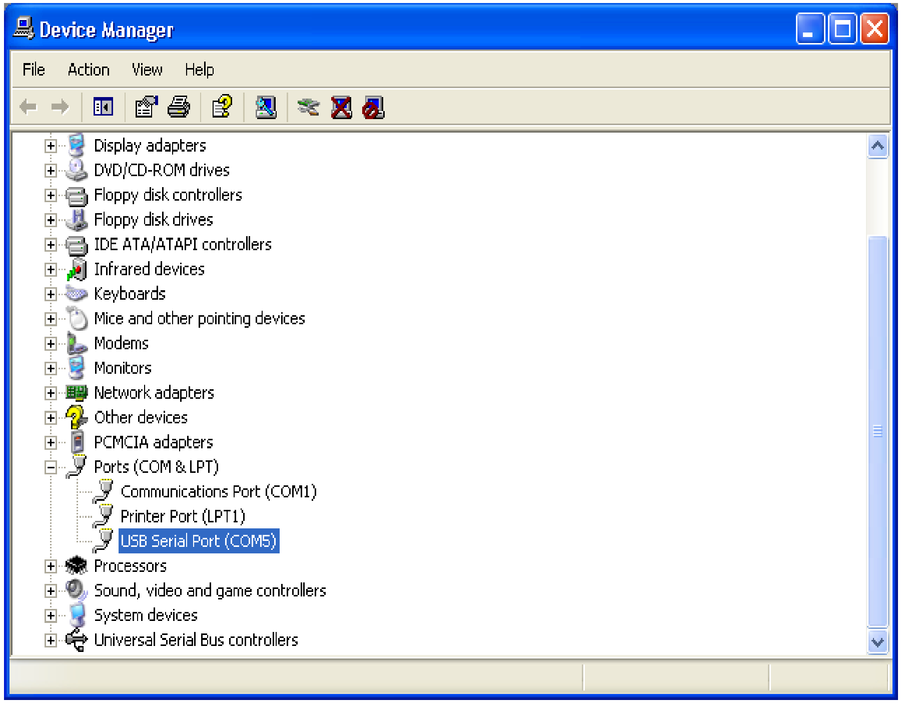
```
ns on an L
 on...  We use pin 13 because,
l, it has either a built-in LED
you need only an LED.

al/Blink
```

- Download and install the IDE
- Download and install USB drivers
- Connect Arduino board
- Start IDE and select serial port
- Select type of Arduino (Duemilanove)

Arduino

Windows Install



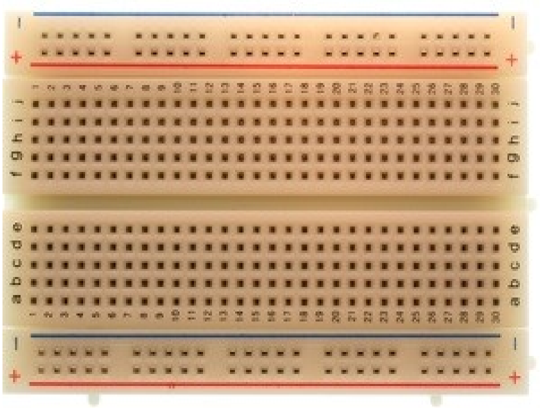
- Display adapters
- DVD/CD-ROM drives
- Floppy disk controllers
- Floppy disk drives
- IDE ATA/ATAPI controllers
- Infrared devices
- Keyboards
- Mice and other pointing devices
- Modems
- Monitors
- Network adapters
- Other devices
- PCMCIA adapters
- Ports (COM & LPT)
  - Communications Port (COM1)
  - Printer Port (LPT1)
  - USB Serial Port (COM5)
- Processors
- Sound, video and game controllers
- System devices
- Universal Serial Bus controllers

- Download and install the IDE
- Download USB drivers
- Connect Arduino board
- Use Wizard to install drivers
- Start IDE and select serial port
- Select type of Arduino (Duemilanove)

Blink – Our First Application

- Idea:
  - Connect a LED (light emitting diode) to the Arduino board
  - Write a sketch that turns the LED on and off periodically.

Blink – Our First Application



- Hardware:
  - 1 LED – Polarized, long leg (+)
  - 1 Resistor (1KΩ) – Color coded: brown, black red
  - Breadboard
  - 2 Long wires

Blink – Hardware

“The Breadboard”

NOTE: The legs of the same component should **never** be connected to the same metal strip – **short circuit!**

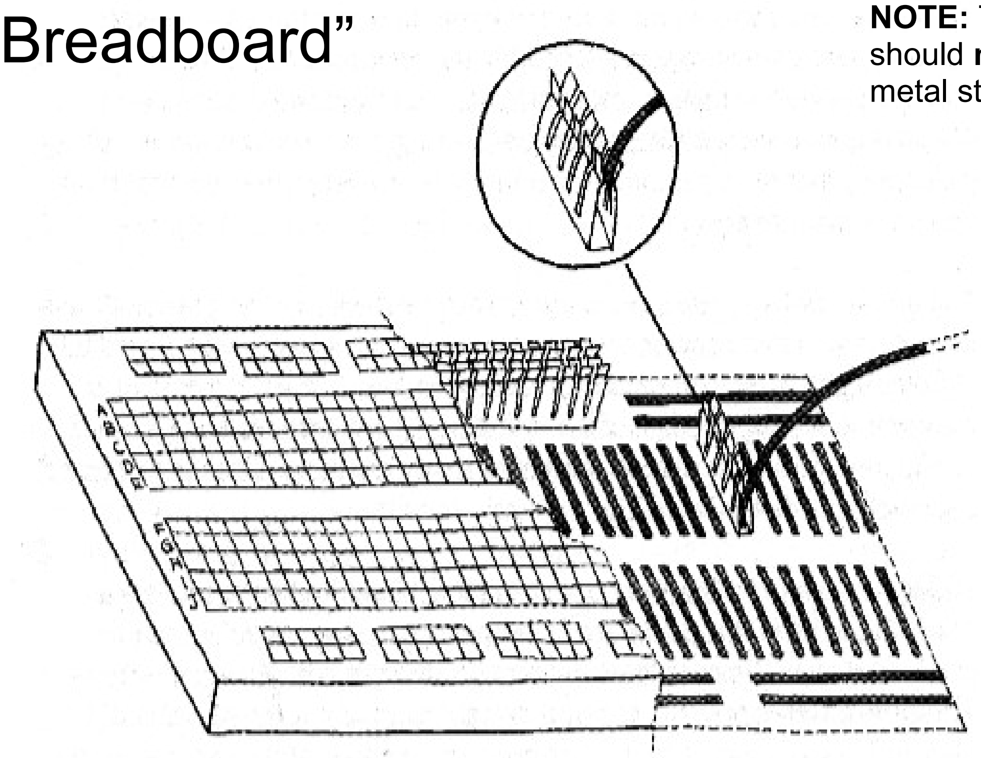
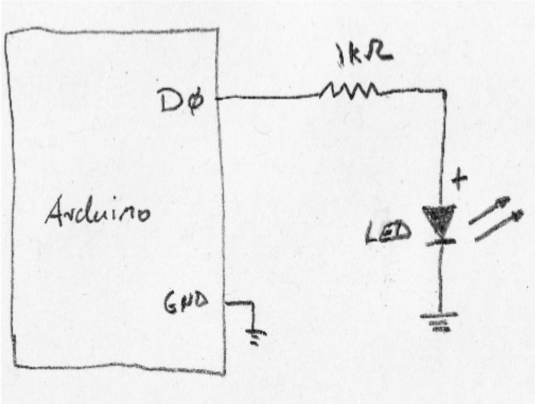


Image source: “Getting Started with Arduino”, Banzi, O'Reilly, 2009.

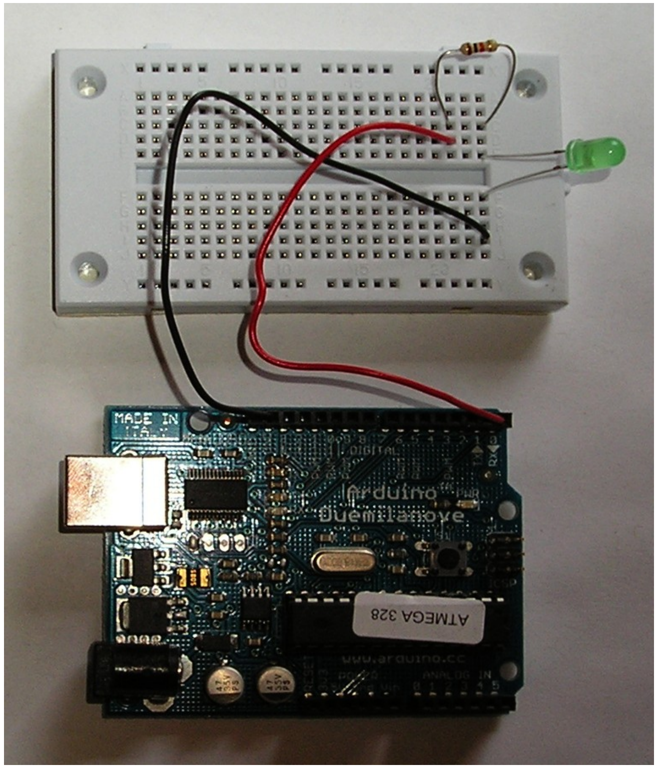
Arduino

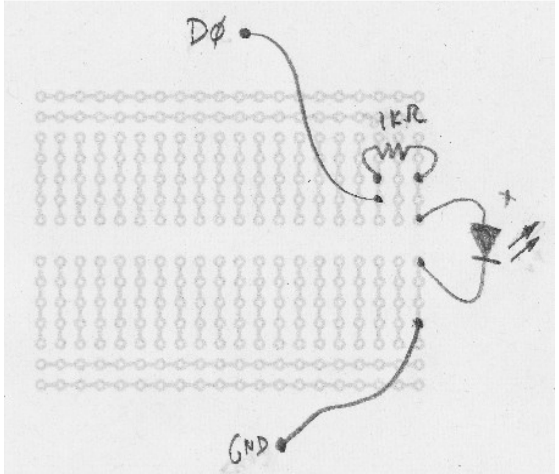
Blink – Hardware



Schematic

Complete System





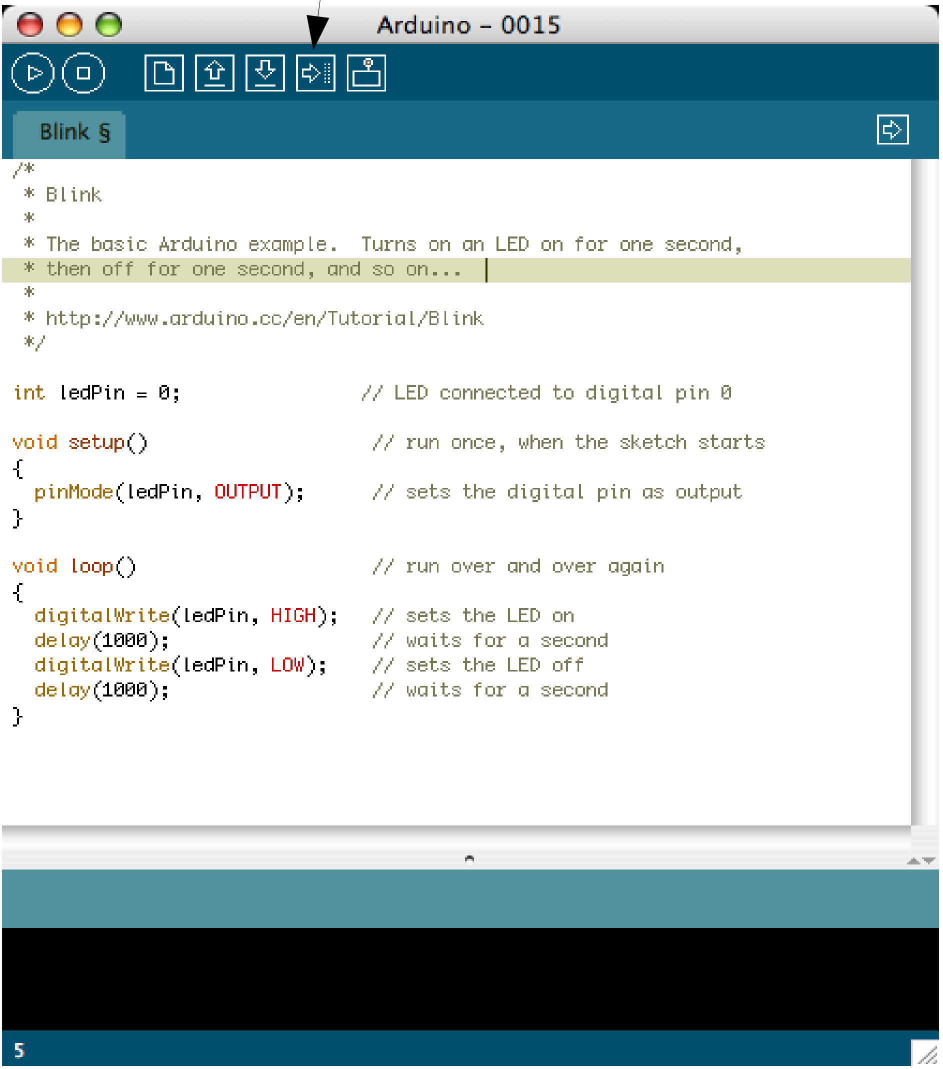
Breadboard
Layout

Blink – Software

- Sketches consist of two sections:
  - setup
    - initialize µC
    - init. IO ports
    - *etc.*
  - loop
    - this is where the processing happens.
- Once your sketch is done
  - verify it (compile it)
  - upload it (runs automatically once uploaded)

Upload

Verify



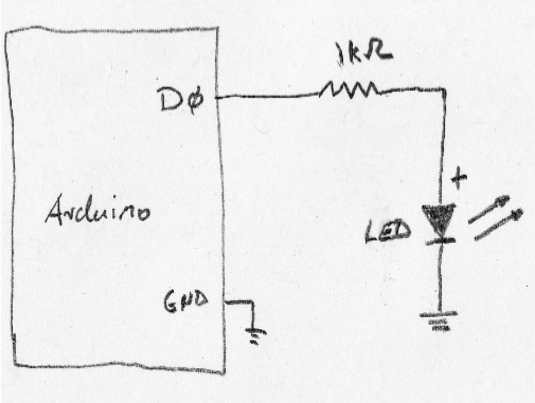
```
/*
 * Blink
 *
 * The basic Arduino example.  Turns on an LED on for one second,
 * then off for one second, and so on...
 *
 * http://www.arduino.cc/en/Tutorial/Blink
 */

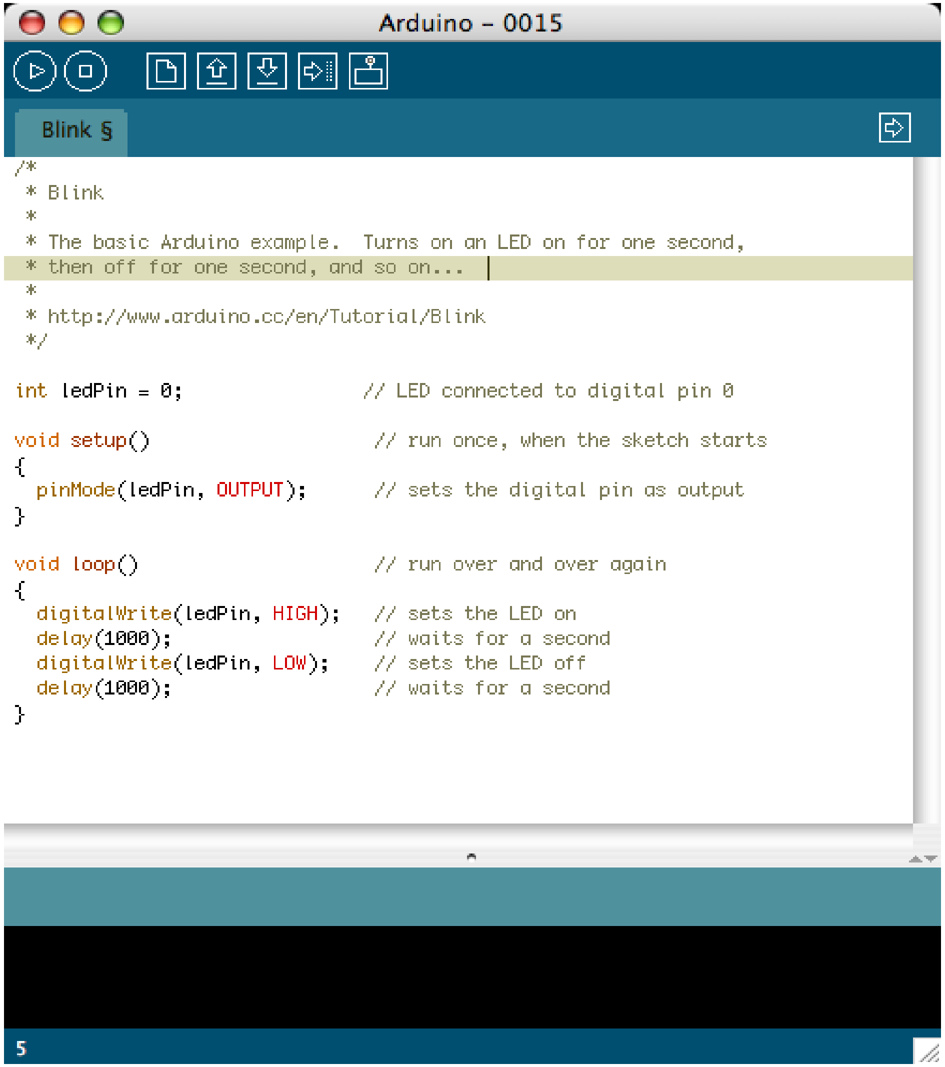
int ledPin = 0;               // LED connected to digital pin 0

void setup()                   // run once, when the sketch starts
{
  pinMode(ledPin, OUTPUT);     // sets the digital pin as output
}

void loop()                    // run over and over again
{
  digitalWrite(ledPin, HIGH);  // sets the LED on
  delay(1000);                 // waits for a second
  digitalWrite(ledPin, LOW);   // sets the LED off
  delay(1000);                 // waits for a second
}
```

Blink – Our First Application





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  delay(1000);                   // waits for a second
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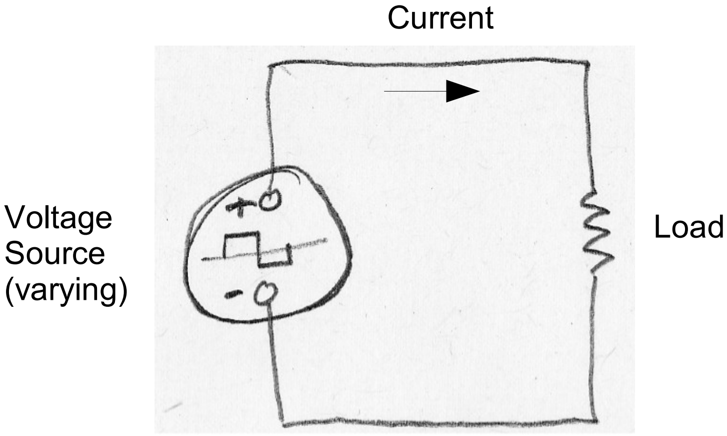
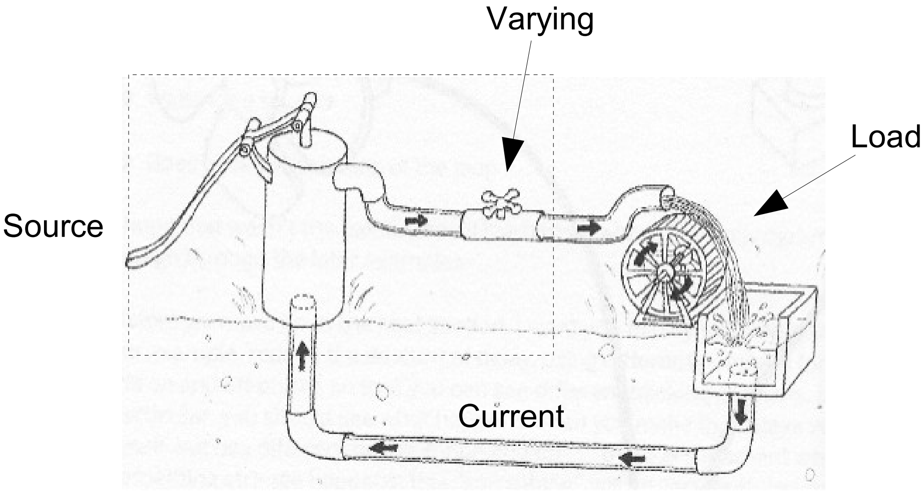
  delay(1000);                   // waits for a second
}
```

Basic Electronics



A Simple Circuit

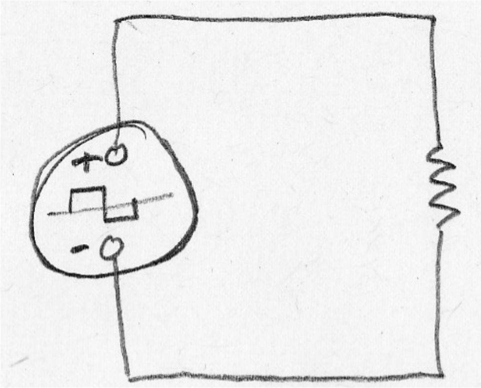
- Virtually every electronic circuit can be represented as either this simple circuit or a combination of these simple circuits.



A Physical Equivalent

Image source: “Getting Started with Arduino”, Banzi, O'Reilly, 2009.

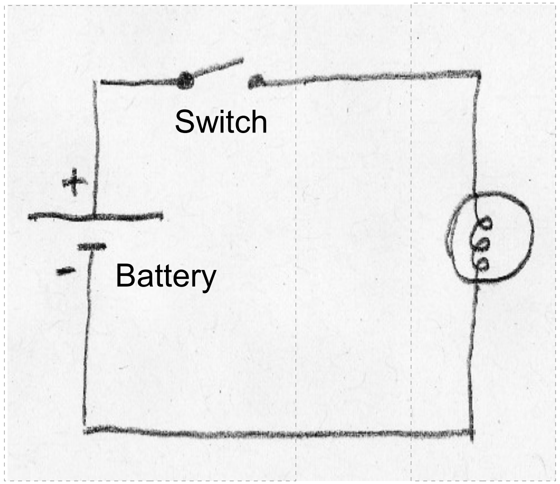
Basic Electronics



Voltage Source

Load

Flash Light



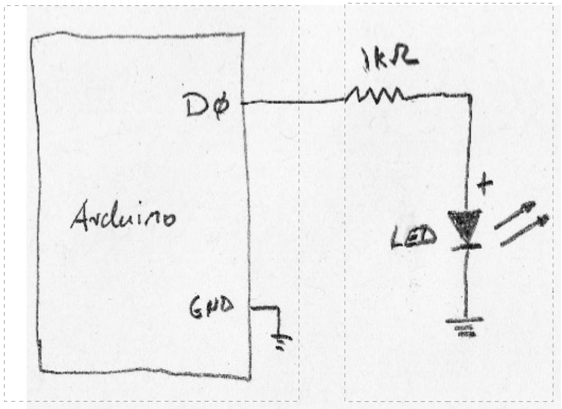
Switch

Battery

Lamp

Voltage Source

Load



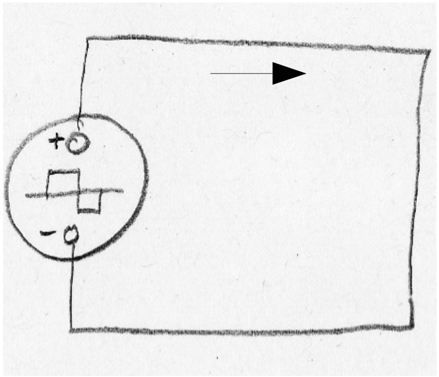
Our Blink Circuit

Voltage Source

Load

Basic Electronics

Current = ∞



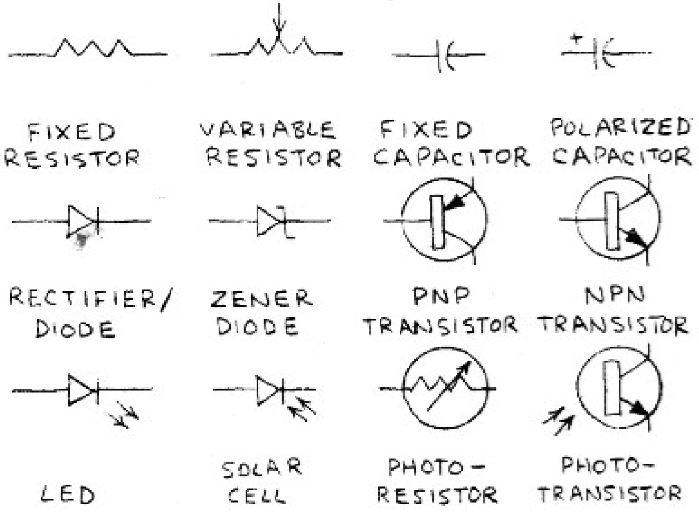
Voltage Source

Load = 0

- The dreaded *short circuit*:
  - this is a circuit with a load equal to zero
  - this allows “infinite” current to flow from the positive terminal of the voltage source to the negative terminal
  - *it will break stuff!*
- Always check your circuits carefully before applying power
- *Never* connect an Arduino output pin directly to ground, always use a *load resistor*

Arduino

Basic Electronics



Some Electronic Symbols

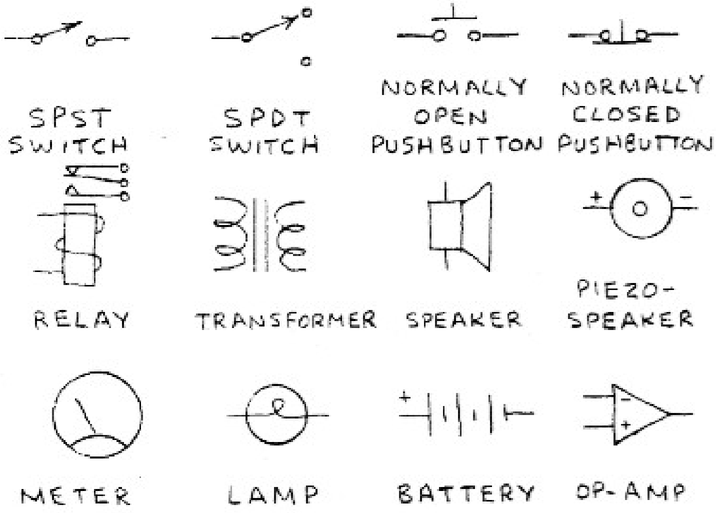


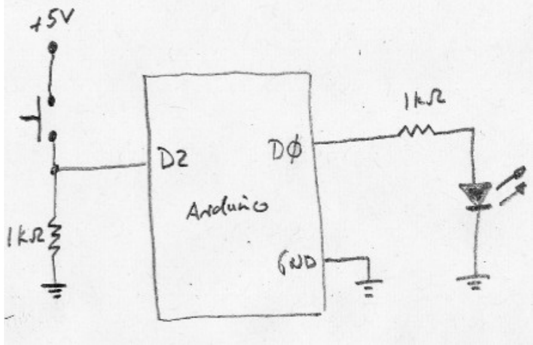
Image source: Engineer's Mini Notebook, Mims III, Master Publishining, 2007.

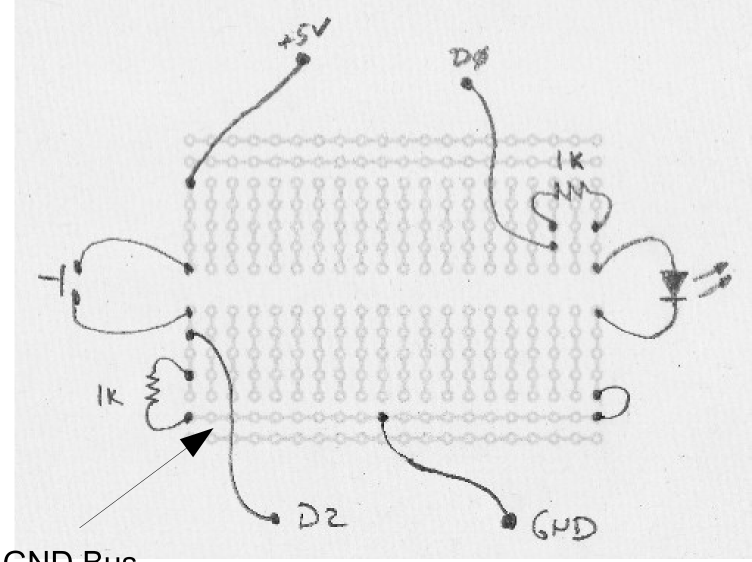
Reading Digital Input

- Idea:
  - Read the input signal produced by a *pushbutton* on a digital input pin of the Arduino board
  - Switch LED on/off on digital output pin depending on the signal on the input pin
- Specifics:
  - We tie the input pin to ground in order to generate a digital zero or LOW signal
  - We tie the input pin to +5V in order to generate a digital one or HIGH signal
  - Be careful with short circuits!

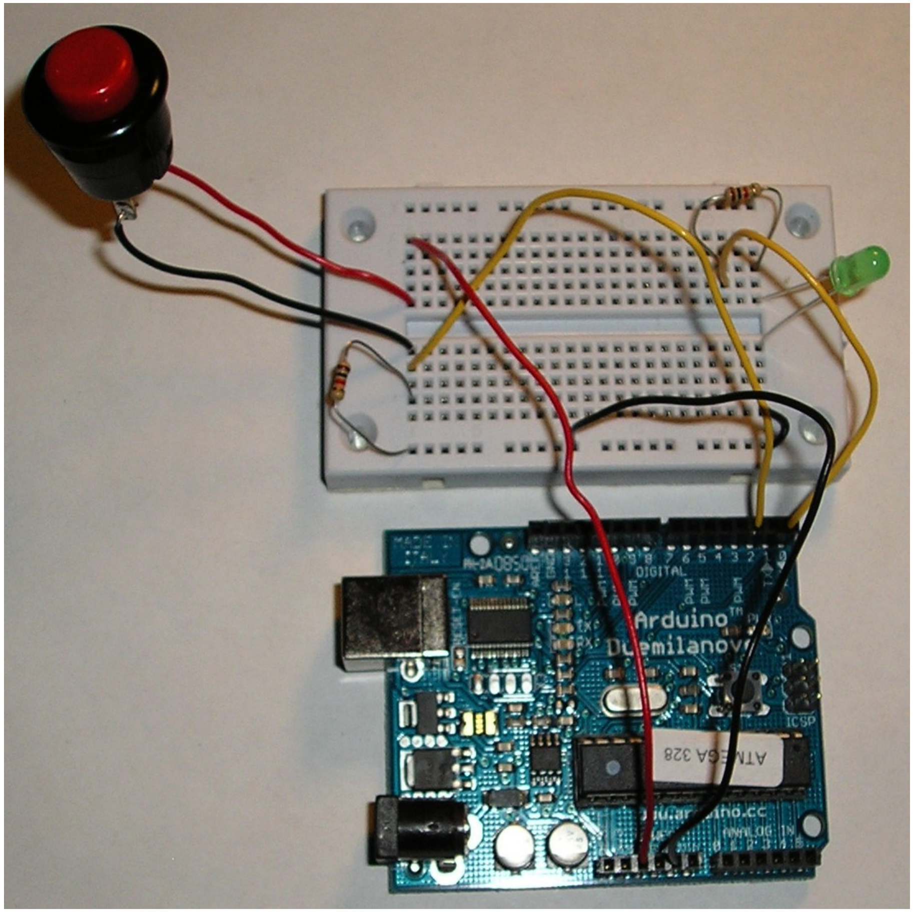
Reading Digital Input

Hardware Layout

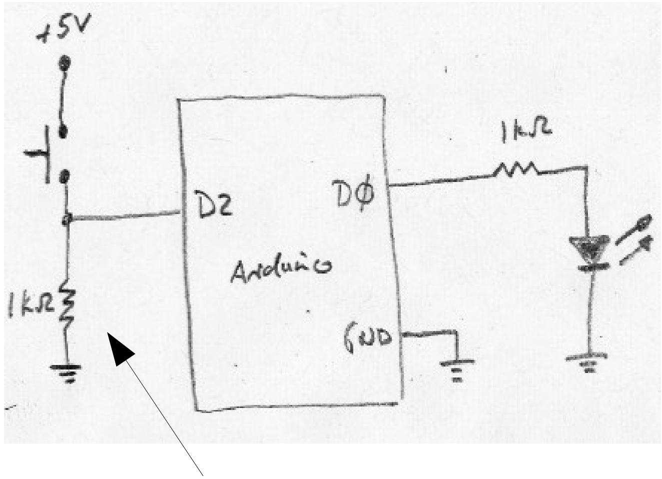




GND Bus



Reading Digital Input



Why do we need this resistor here?

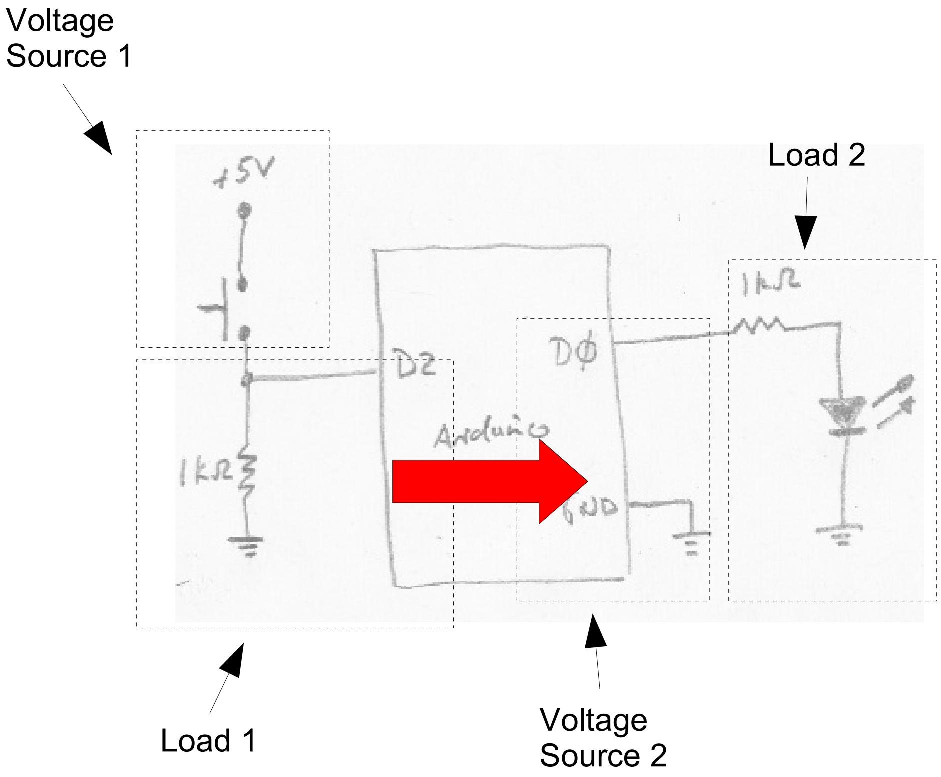
```
/*
 * Based on Button
 * by DojoDave <http://www.0j0.org>
 *
 * Turns on and off a light emitting diode(LED) connected to digital
 * pin 0, when pressing a pushbutton attached to pin 2.
 *
 * http://www.arduino.cc/en/Tutorial/Button
 */

int ledPin = 0;                  // pin for the LED
int inputPin = 2;                // input pin (for a pushbutton)
int val = 0;                     // variable for input pin status

void setup() {
  pinMode(ledPin, OUTPUT);       // declare LED as output
  pinMode(inputPin, INPUT);      // declare pushbutton as input
}

void loop(){
  val = digitalRead(inputPin);   // read input value
  if (val == HIGH) {             // check if the input is HIGH
    digitalWrite(ledPin, HIGH);  // turn LED ON
  } else {
    digitalWrite(ledPin, LOW);   // turn LED OFF
  }
}
```

Reading Digital Input



Voltage Source 1

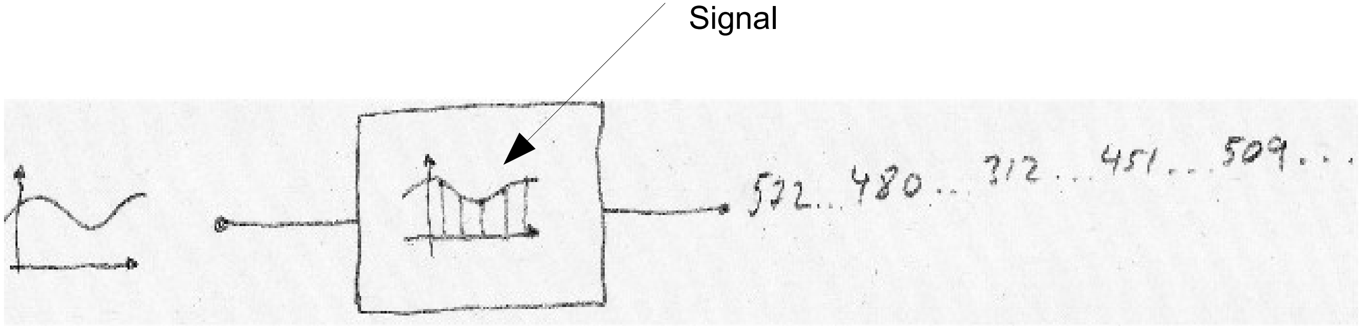
Load 2

Load 1

Voltage Source 2

- Our circuit consists of two “simple circuits”
- The load of the first circuit controls the voltage source of the second circuit (indicated by red arrow)
- Notice that if we had tied D2 in the first circuit directly to ground then the load would have had a short circuit

Reading Analog Input



Sampled Signal

Analog Signal

A/D Converter (Analog/Digital)

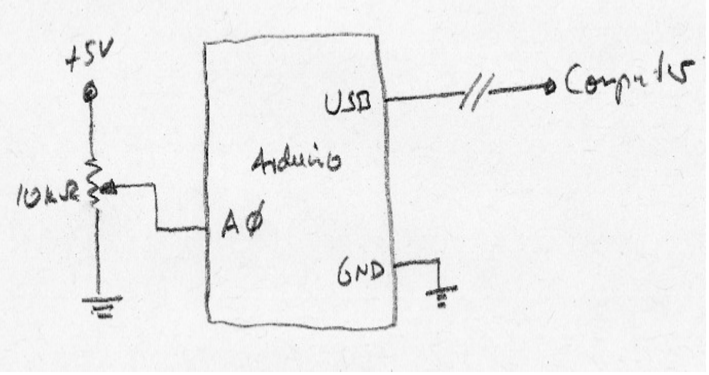
Digital Signal

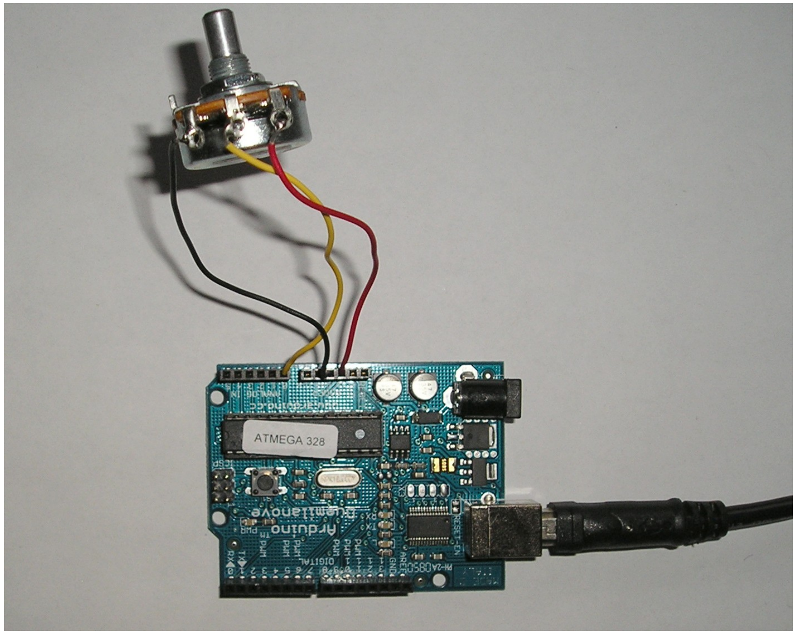
- A/D converters take analog signals and convert them into sequences of numbers.
- The Arduino has six onboard A/D converters.
- Each A/D converter converts voltages between 0V and 5V into numbers between 0 and 1023.

Reading Analog Input

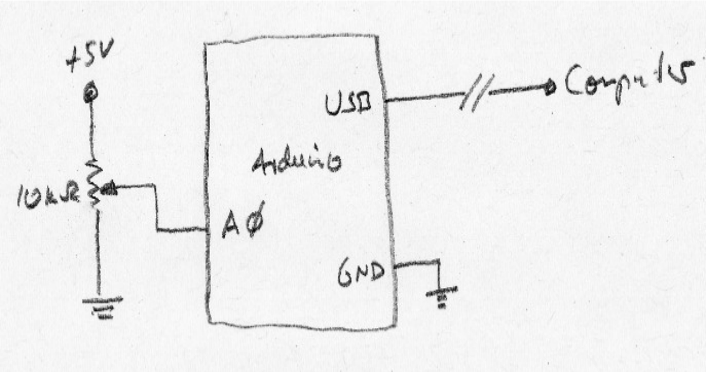
- Idea:
  - Use a *potentiometer* to generate an analog signal
  - Use a A/D converter to convert it to a digital signal
  - Display the digital signal on the serial monitor in the Arduino IDE
  - Our sampling frequency is one sample per second

Reading Analog Input





Reading Analog Input



```
// Reading analog input
// sample an analog signal on analogPin
// write the digitized signal to the USB
// serial line
int analogPin = 0;
int val = 0;

void setup() {
  // initialize the USB serial line
  Serial.begin(9600);
}

void loop() {
  // get a sample from the A/D converter
  val = analogRead(analogPin);
  // write the value to the serial line
  Serial.print(val);
  Serial.print(“ “);
  // wait a second until our next sample
  delay(1000);
}
```

PWM Signals

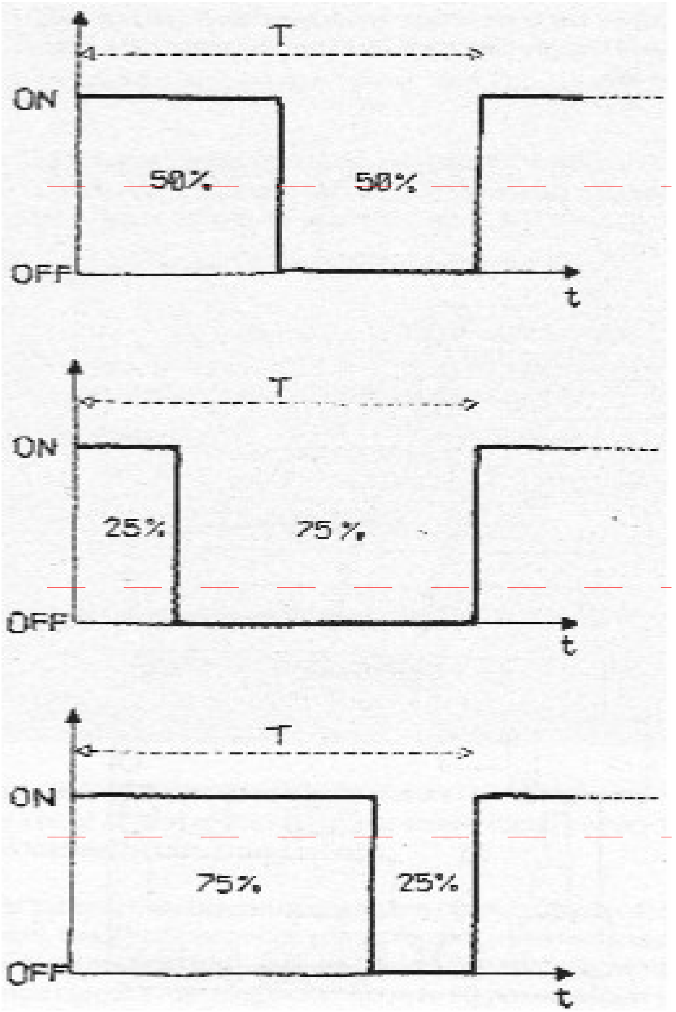
- Pulse Width Modulated (PWM) Signals
- µCs cannot generate analog output, but we can fake it by creating digital signals with different “duty cycles” - signals with different *pulse widths.*
- To the analog world the different duty cycles create different effective voltages

PWM Signals

50% Duty Cycle

25% Duty Cycle

75% Duty Cycle



Effective Voltage

Effective Voltage

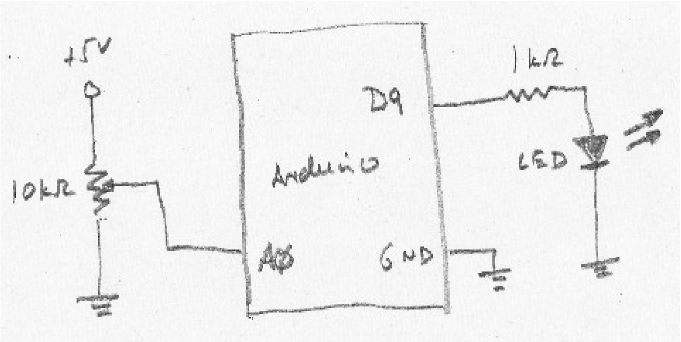
Effective Voltage

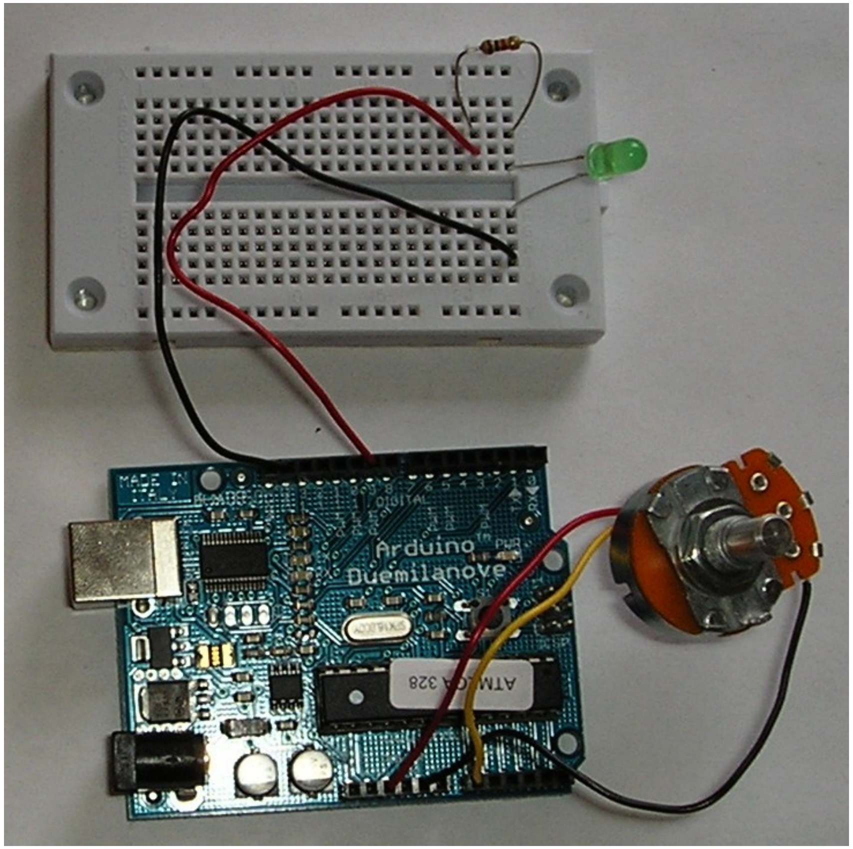
Image source: “Getting Started with Arduino”, Banzi, O'Reilly, 2009.

Dimmer

- Idea:
  - Read an analog signal from an analog input
  - Use this input to set the brightness of a LED
- NOTE: the LED needs to be connected to a PWM capable digital output (Duemilanove: 3,5,6,9,10, or 11)

Dimmer


+5V
10kΩ
Arduino
A0
D9
GND
1kΩ
LED


MADE IN ITALY
DIGITAL
Arduino
Duemilanove
ATMEGA 328

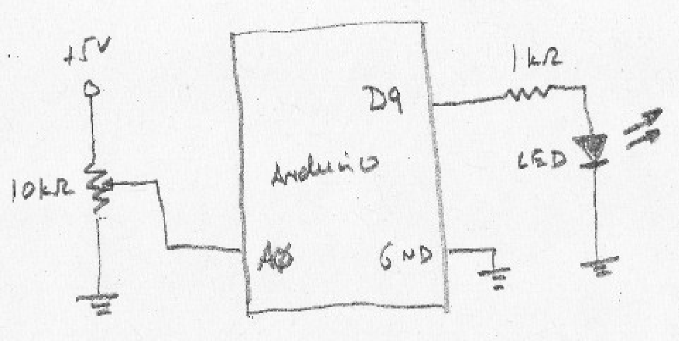
Dimmer

```
// LED dimmer

int ledPin = 9;        // LED connected to digital pin 9, this is a PWM
                       // capable output port
int analogPin = 0;     // potentiometer connected to analog pin 0
int val = 0;           // variable to store the read value

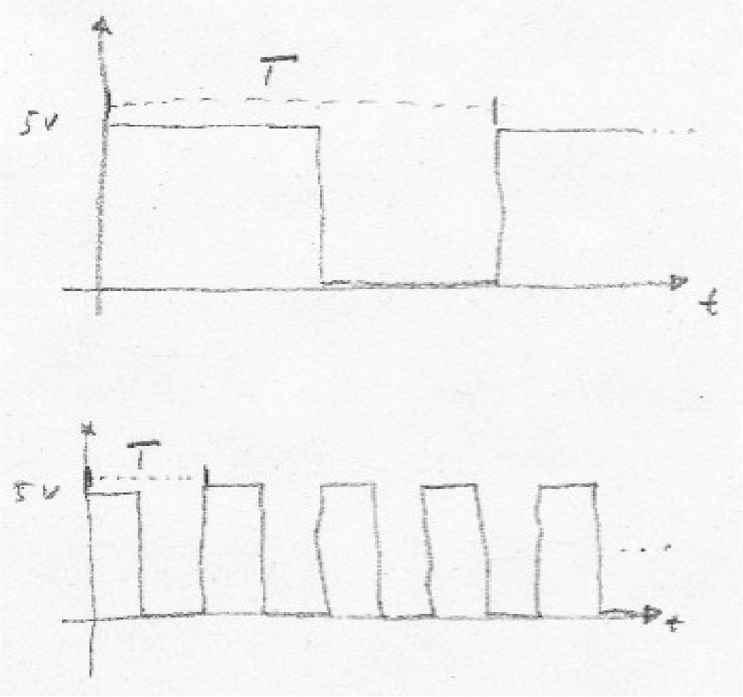
void setup()
{
  pinMode(ledPin, OUTPUT);    // sets the pin as output
}

void loop()
{
  val = analogRead(analogPin);    // read the input pin
  analogWrite(ledPin, val / 4);   // analogRead values go from 0 to 1023,
                                  // analogWrite values from 0 to 255
}
```



Arduino

Simulating Soundwaves



Low pitched tone – long period T

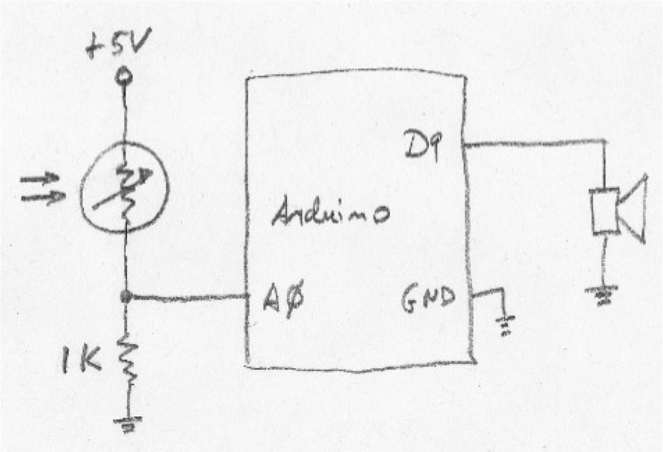
High pitched tone – short period T

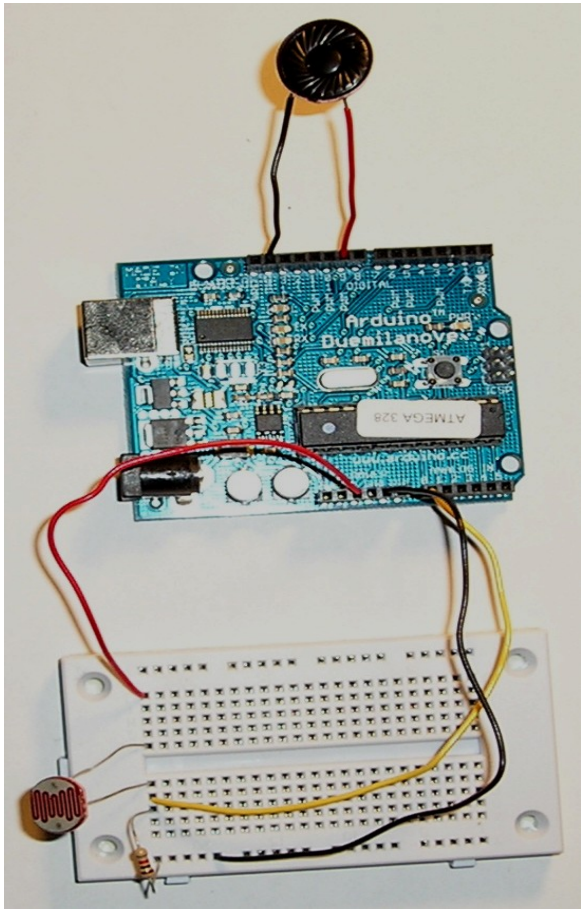
Note: For a 20Hz sound wave we have T = 50ms, for a 200Hz sound wave we have T = 5ms.

Optical Theremin

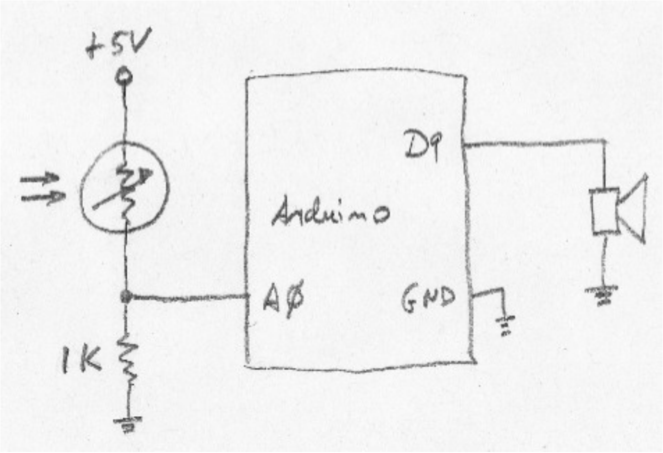
- Idea:
  - Read an analog signal generated through a *photoresistor*
  - We interpret the digitized value from the A/D conversion as the period of the sound wave we want to generate
  - Generate one period of the sound wave, output it to the *speaker* and then sample the input again

Optical Theremin





Optical Theremin



```
// Optical Theremin
// It will generate square wave on soundPin.
// The period/frequency of the wave is governed by
// the value read from the pot.  It will generate a
// wave from roughly 20Hz to 200Hz

int soundPin = 9;    // output on digital pin 9
int freqPin = 0;     // photoresistor connected to analog pin 0
int interval = 0;    // variable to store the read value

void setup()
{
  pinMode(soundPin, OUTPUT);   // sets the pin as output
}

void loop()
{
  // read the interval value - an interval value is
  // half a period of the sound wave
  interval = (analogRead(freqPin)/25 + 5)/2;

  // generate one whole period of the wave
  digitalWrite(soundPin, HIGH);
  delay(interval);
  digitalWrite(soundPin, LOW);
  delay(interval);
}
```

Things to do for Next Time

- Design a concept for an interactive object
  - for inspiration check out:
    http://www.arduino.cc/playground/Projects/ArduinoUsers
    http://www.instructables.com/tag/?q=arduino
  - Notice how many interactive objects there are in your everyday environment
- individual or group projects
- Read “Getting Started with Arduino”, Chapters 1 through 4, and the Appendices