introduction to Digital Electronics

Install the Arduino IDE on your laptop if you haven’t already!
Electronics can add interactivity!

Any sufficiently advanced technology is indistinguishable from magic
- Arthur Clark.
Electronics can add interactivity!

Any sufficiently **well executed** technology is indistinguishable from magic in the eyes of kids!
Electronics can be complex
Avoid unnecessary complexity!
Let's look at a circuit!

Battery + Light Bulb
Let’s look at a circuit!

Battery
Power Source

+ -

Light Bulb
Load
Let’s look at a circuit!
Let's look at a circuit!

\[ V = IR \]

Voltage = Current \times Resistance

\[ 5 = I \times 330 \]

Current \approx 0.015A
Let's look at a circuit!
Let's look at a circuit!
Let's look at a circuit!
Let's look at a circuit!

\[ V_1 - V_{\text{ref}} = IR \]
Let’s look at a circuit!

![Circuit Diagram](image-url)
Let's look at a circuit!

```
5V  
\|--|---
|  \  |
|   \  |
+-----+
|  \  |
|   \  |
5V  
\|--|---
|  \  |
|   \  |
0V   330Ω
```

```
5V
\|--|---
|  \  |
|   \  |
+-----+
|  \  |
|   \  |
5V
\|--|---
|  \  |
|   \  |
0V 330Ω
```
Let's look at a circuit!

5v

330Ω

0v
Time for some LIGHT!

5v

330Ω

0v

LED
Light Emitting Diode
Time for some LIGHT!

Diodes conduct current primarily in one direction.
Needs resistor!
Time for some LIGHT!

LED
Light Emitting Diode

5V
330Ω
0V

Longer is positive!
In Real Life!

5v

330Ω

0v

Power Rails
In Real Life!

5v

330Ω

0v

Power Rails
In Real Life!

5v

330Ω

0v

Power Rails
In Real Life!

5v

330Ω

0v
In Real Life!

5v

330Ω

0v
A closer look...

\[ V_{CC} (\text{also } V_{dd}, V_{high}) \]
Voltage Common Collector
(usually your power supply!)

\[ V_2 - V_{GND} = 1.4V \]

LED Forward Voltage Drop
\[ \approx 1.4V \quad \approx 0\Omega \]

Components
have rules!
A closer look...

\[ V_2 = 1.4V \]
\[ V_{CC} - V_2 = I \cdot R \]
\[ 5 - 1.4 = I \cdot 330 \]
\[ I \approx 10 \text{ mA} \]

LED Forward Voltage Drop
\[ \approx 1.4V \quad \approx 0\Omega \]

Components have rules!
A closer look...

\[ V_{CC} \]

330\( \Omega \)

\[ V_2 \]

\[ V_{GND} \]

\[ 5v \]

\[ 0v \]

\[ I \approx 10 \text{ mA} \]
A closer look...

\[ V = IR \]

LED Max Current
≈20mA

\[ I \approx 10 \text{ mA} \]

\[ I \approx \text{BIG NUMBER} \]
Digital vs Analog Circuits

**Analog Circuits**
Range of voltages
Usually requires math!

**Digital Circuits**
Usually 2 distinct voltages (high & low)
5v and 0v (roughly)

![Analog signal](image1)

![Digital signal](image2)
Using your Arduino!

A Microcontroller
.. or a small computer!
Has inputs and outputs you can control

Arduino Uno
Arduino Nano
Teensy
Using your Arduino!
Blink!
Blink!

Try making the colors alternate!
Blink!

Try making the colors alternate!
Blink!

Try making the colors alternate!

1_blink

It's your turn!

Turn the LED on for 1 seconds, and off for 2 seconds
Button Inputs

What does the Arduino sense when it’s not connected to GND?

Value is *floating*!

Pull up resistor!
Button Inputs

```
int inPin = 8;       // pushbutton connected to digital pin 8
int val = 0;         // variable to store the read value

void setup()
{
    pinMode(inPin, INPUT);       // sets the digital pin 8 as input
}

void loop()
{
    val = digitalRead(inPin);   // read the input pin
}
```
Button Inputs

Arduino

Digital Pin 8

```javascript
int inPin = 8;       // pushbutton connected to digital pin 8
int val = 0;         // variable to store the read value

void setup()
{
    pinMode(inPin, INPUT_PULLUP); // sets the digital pin 8 as input
}

void loop()
{
    val = digitalRead(inPin);    // read the input pin
}
```
Button Inputs

Arduino

Digital Pin 8
Button Press
Arduino Triggered
Arduino Triggered Watergun

Contact 1

Contact 2
Arduino Triggered

Relay
- Signal
- VCC
- GND

Normally Open
- NO
- COM
- NC

Watergun
- Contact 1
- Contact 2

Normally Closed
Arduino Triggered

Relay
- Signal (NO)
- VCC
- GND
- Grounded

Watergun
- Contact 1
- Contact 2

Normally Open

Normally Closed
Arduino Triggered

Relay

Watergun

Contact 1

Contact 2
Arduino Triggered

Arduino

Digital Pin 7

Relay

Signal
VCC
GND
NO
COM
NC

Watergun

Contact 1
Contact 2
Arduino Triggered

Arduino

Digital Pin 7

Relay

Watergun

Signal
VCC
GND

NO
COM
NC

Contact 1
Contact 2
Arduino Triggered

Arduino

Digital Pin 7

Relay

Signal  NO
VCC      COM
GND    NC

Watergun

Contact 1

Contact 2
Arduino Triggered

Arduino

Digital Pin 7

Relay
- Signal
- VCC
- GND
- NO
- COM
- NC

Watergun
- Contact 1
- Contact 2
Arduino Triggered

After a button press, the relay MAY or MAY NOT activate

It's your turn!

2_relay_and_button
Relays & Transistors
Relays & Transistors

Smallest transistors are 2 nanometers (IBM - 2021)
Relays & Transistors

Smallest transistors are 2 nanometers (IBM - 2021)

(Hair diameter is 65,000 nanometers)
Pulse Width Modulation

PWM!

Digital is only 0v or 5v, so how do we get values in between?

PWM to make the LED seem ‘dimmer’

50% Duty Cycle
50% of the time on, 50% of the time off

90% Duty Cycle
90% of the time on, 10% of the time off
PWM

The Fading example demonstrates the use of analog output (PWM) to fade an LED. It is available in the File->Sketchbook->Examples->Analog menu of the Arduino software.

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called the pulse width. To get varying analog values, you change, or modulate, that pulse width. If you repeat this on-off pattern fast enough with an LED for example, the result is as if the signal is a steady voltage between 0 and 5v controlling the brightness of the LED.

In the graphic below, the green lines represent a regular time period. This duration or period is the inverse of the PWM frequency. In other words, with Arduino’s PWM frequency at about 500Hz, the green lines would measure 2 milliseconds each. A call to analogWrite() is on a scale of 0 - 255, such that analogWrite(255) requests a 100% duty cycle (always on), and analogWrite(127) is a 50% duty cycle (on half the time) for example.
Servo and Moving Parts

Rotary actuator that allows for precise control of position

Arduino friendly!

Built-in Library

0 - 180 Degrees

- SIGNAL (Pin 6)
- POWER (5V)
- GND
Continuous Rotation Servo

Simple ‘motors’
Don’t allow you to specify the exact location, but can rotate CCW or CW at different speeds.

0 - 180 Degrees becomes:
CCW full speed,
stationary,
CW full speed
Continuous Rotation Servo

Simple ‘motors’
Don’t allow you to specify the exact location, but can rotate CCW or CW at different speeds.

0 - 180 Degrees becomes:
CCW full speed, stationary, CW full speed

SIGNAL (Pin 6)
POWER (5V)
GND

It’s your turn!

3_servo
Servos

Two Types!
1. Standard Servos (plenty in lab)
2. Continuous Rotation Servos (in your kits)
More Pins?

Arduinos only have a limited number of output.

There are different methods we can “get more outputs”

Method 1: **Multiplexing**

Method 2: Specific **Communication** Protocols
Multiplexing

D1

D4
Multiplexing

D1
5V

D4
5V
Multiplexing
Multiplexing

D1
5V

D4
GND

D5
5V

D6
5V
Multiplexing
Multiplexing
Multiplexing

D1
GND

D2
5V

D3
GND

D4
5V

D5
5V

D6
GND
Multiplexing
Multiplexing

LED still “on”
Multiplexing

D1  GND
D2  GND
D3  5V
D4  5V
D5  GND
D6  5V
TFT Display

Thin Film Transistor Displays

Breakout board/Arduino library handles a lot of the logic!
It's your turn!

Sketch > Include Library > Manage Libraries > Adafruit GFX Library
LED strips

A strip of LEDs
Individually Addressable LED strips!

Objectively pretty neat!

Integrated Circuit & I²C communication

**ws2812b RGB LED**

Run on 5v and can be controlled with an Arduino!

Watch out for current!
Each color ~ 15mA, total 50mA on ‘white’.

Arduino max current ~1A
Individually Addressable LED strips!

Can be individually powered (can consume a lot of power. Use rechargeable batteries!)

Connectors to help you split your LED strips into multiple lengths!
Individually Addressable LED strips!

Can be individually powered (can consume a lot of power. Use rechargeable batteries!)

Connectors to help you split your LED strips into multiple lengths!

It's your turn!

Sketch > Include Library > Manage Libraries > FastLED

5_led_party
Wrap-up!

... wrapping up wires!
Wrap-up!

All the parts today actually came from Amazon. Other places you can order electronic parts from:
- Adafruit
- Jameco
- Digikey

Take anything you’d like to keep with you (you can use these on your toys/sketch models)
introduction to Digital Electronics