IoT Prototyping with Arduino, Particle Photon and IFTTT

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Internet of Things (IoT)

Computers with **sensors** and **actuators** **connected** through Internet protocols

Instead of just reading and editing virtual resources, we can now measure and manipulate **physical properties**

The Internet starts pervading the real world

Topics of this workshop

Getting started
(Setup and programming of IoT hardware)

Measuring and **manipulating**
(Physical computing: sensors and actuators)

Connecting your device **to the Internet**
(IoT: monitoring sensors, controlling actuators)

Mash-ups with 3rd party services and devices

(Connecting Web-enabled devices to each other)

How the Internet works under the hood

(Some definitions and details, in case you wonder)

Questions? Just ask / Use Google / Help each other

Choosing your hardware

We use **Arduino** and Particle **Photon** hardware

Both speak the same programming language

Arduino is a **classic** and **easier** to set up

Know Arduino? Try the Photon!

Note: Check arduino.cc and particle.io to learn more

Getting started

The **IDE** (**I**ntegrated **D**evelopment **E**nvironment) allows you to **program** your board, i.e. “make it do something new”

You **edit** a program on your computer, then **upload** it to your board where it’s stored in the program memory (flash) and **executed** in RAM

Note: Once it has been programmed, your board can run on its own, without another computer

Getting started with Arduino

To install the **Arduino IDE** and connect your Arduino board to your computer via USB, see

http://arduino.cc/en/Guide/**MacOSX** or

http://arduino.cc/en/Guide/**Windows** or

http://arduino.cc/playground/Learning/**Linux**

Or install https://codebender.cc/static/plugin and use the https://codebender.cc/ online IDE

Note: Codebender is great, but has some limitations

Getting started with Photon

To install the **Particle CLI** and connect your Photon board to your computer via USB, see

https://docs.particle.io/guide/getting-started/connect/photon/

Then access the **Particle IDE** online at https://build.particle.io/

Or use the Atom IDE https://www.particle.io/dev

Note: There is an app for Photon setup, but the command line interface (CLI) is more robust

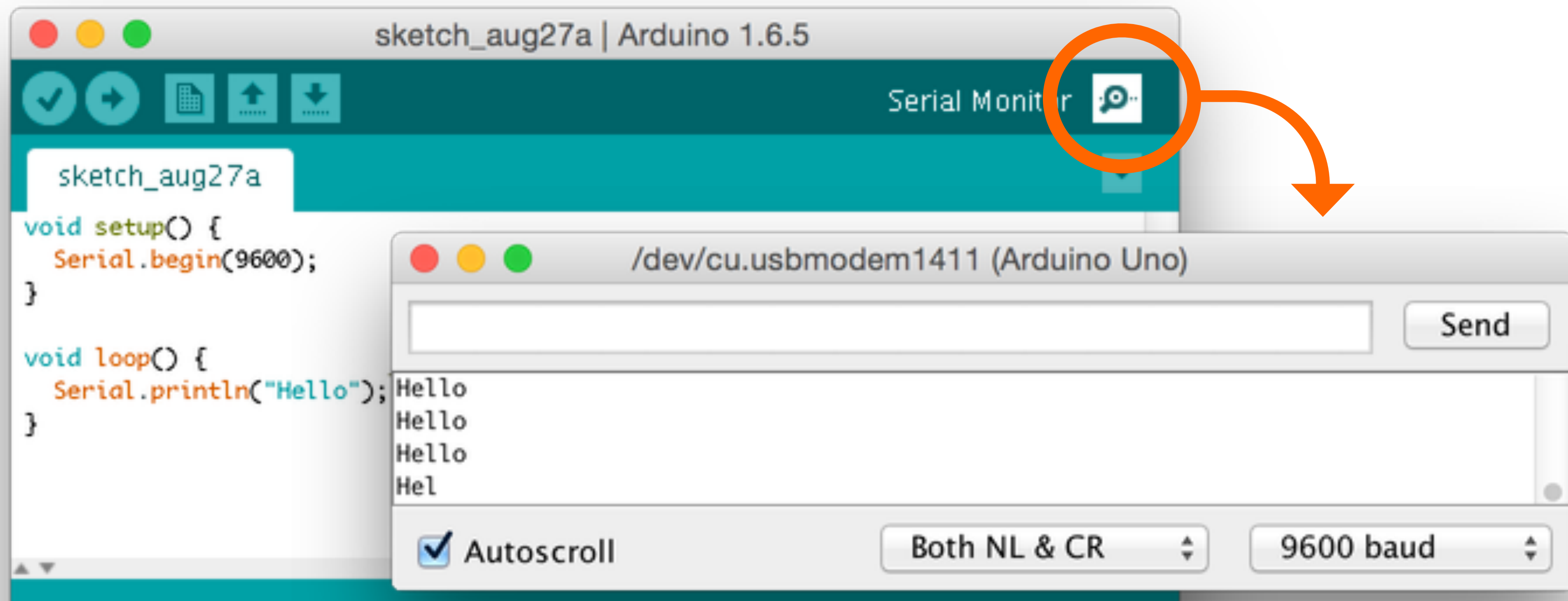
Hello (serial output)

```
void setup () { // runs once
  Serial.begin(9600); // set baud rate
}

void loop () { // runs again and again
  Serial.println("Hello"); // print Hello
}
```

Note: type this source code into your IDE and upload it to the device, then check the next slide

Serial output with Arduino

Click the *Serial Monitor* icon to see serial output, and make sure the baud rate (e.g. *9600*) matches your code



Note: Serial output is great to debug your program

Serial output with Photon on Mac

Open a **terminal**, connect the Photon to **USB**, and type

$ ***screen /dev/tty.u***

Then hit *TAB* to find the USB device name

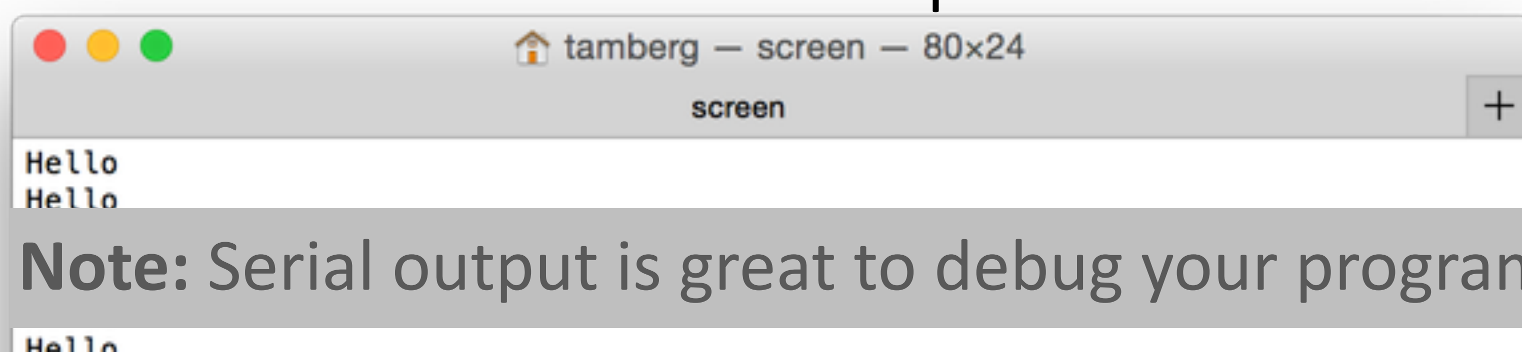
$ *screen /dev/tty.usbmodem1431*

Add the baud rate matching your source code

$ *screen /dev/tty.usbmodem1431* ***9600***

And hit RETURN to see the output

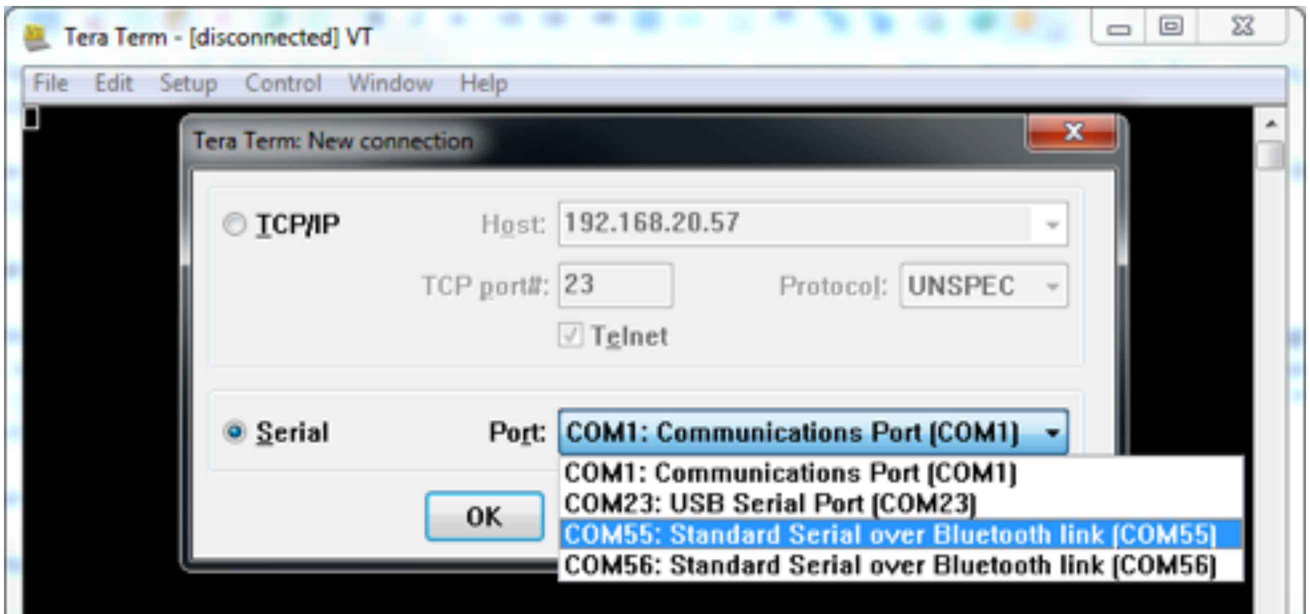
On Linux it's /dev/ttyACM



Note: Serial output is great to debug your program

Serial output with Photon on PC

Install **TeraTerm** https://en.osdn.jp/projects/ttssh2/releases/ and follow https://learn.sparkfun.com/tutorials/terminal-basics/tera-term-windows to see the output



Note: Serial output is great to debug your program

Examples on Bitbucket

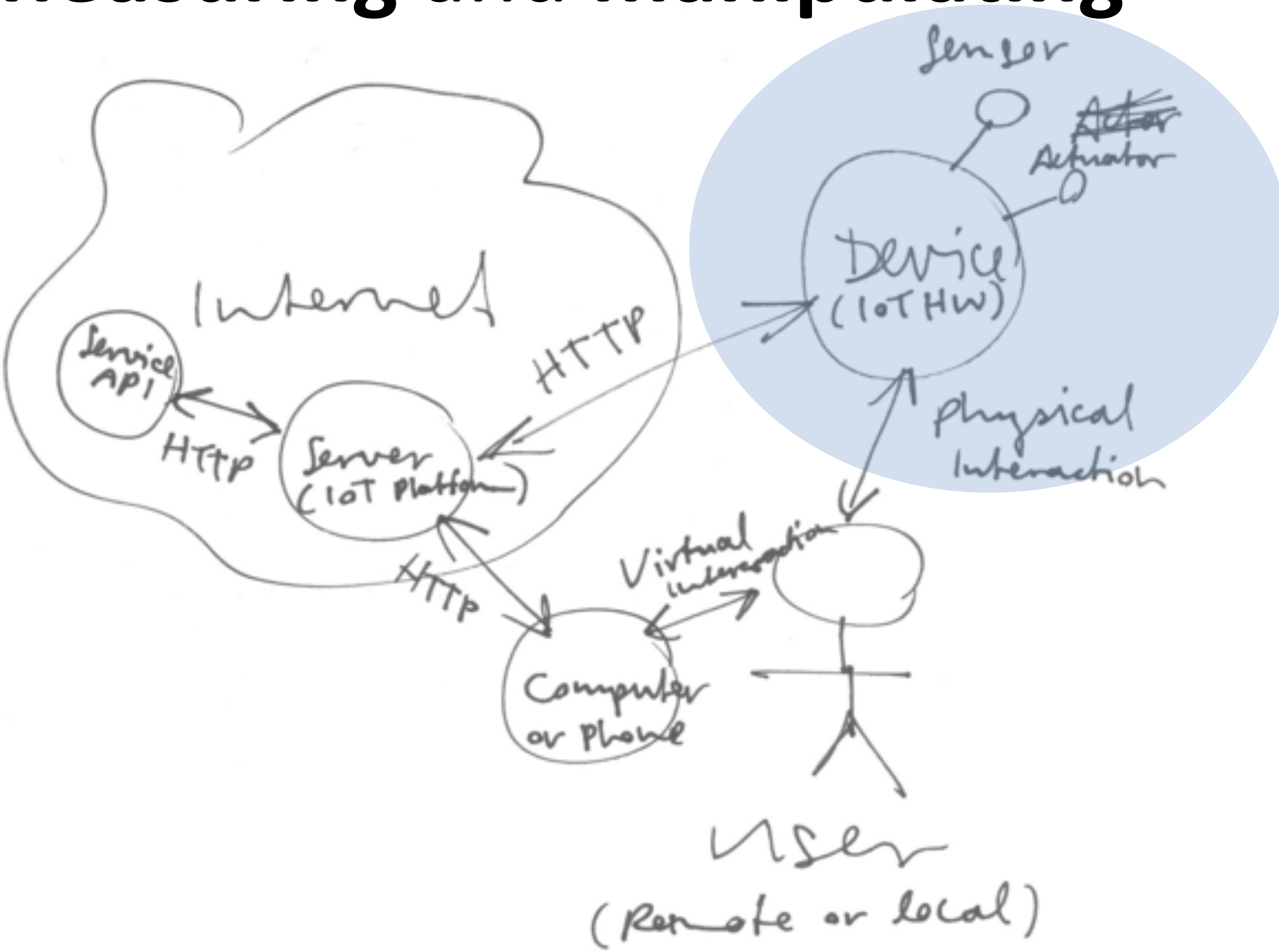
The **source code** of the following examples is available on Bitbucket, a source code repository

Download the ZIP from https://bitbucket.org/tamberg/iotworkshop/get/tip.zip

Or browse code online at https://bitbucket.org/tamberg/iotworkshop/src/tip

Note: use the *Raw* button to see files as plain text

Measuring and **manipulating**



Measuring and **manipulating**

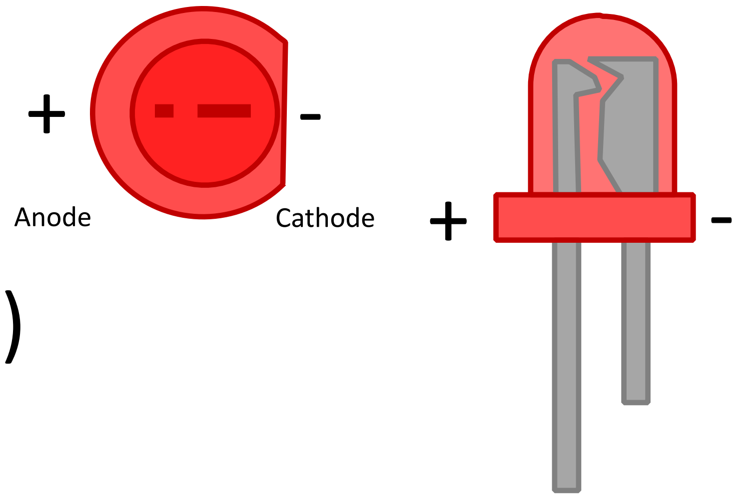
IoT hardware has an **interface to the real world**

GPIO (**G**eneral **P**urpose **I**nput/**O**utput) pins

Measure: **read** sensor value from **input** pin
Manipulate: **write** actuator value to **output** pin

Inputs and outputs can be **digital or analog**

The LED



The **LED** (**L**ight **E**mitting **D**iode)
is a simple digital **actuator**

LEDs have a **short leg** (**-**) and a **long leg** (**+**)
and it matters how they are oriented in a circuit

To prevent damage, LEDs are used together with
a 1KΩ **resistor** (or anything from 300Ω to 2KΩ)

The resistor

Resistors are the **workhorse of electronics**

Resistance is **measured in Ω** (Ohm)

A resistors orientation does not matter

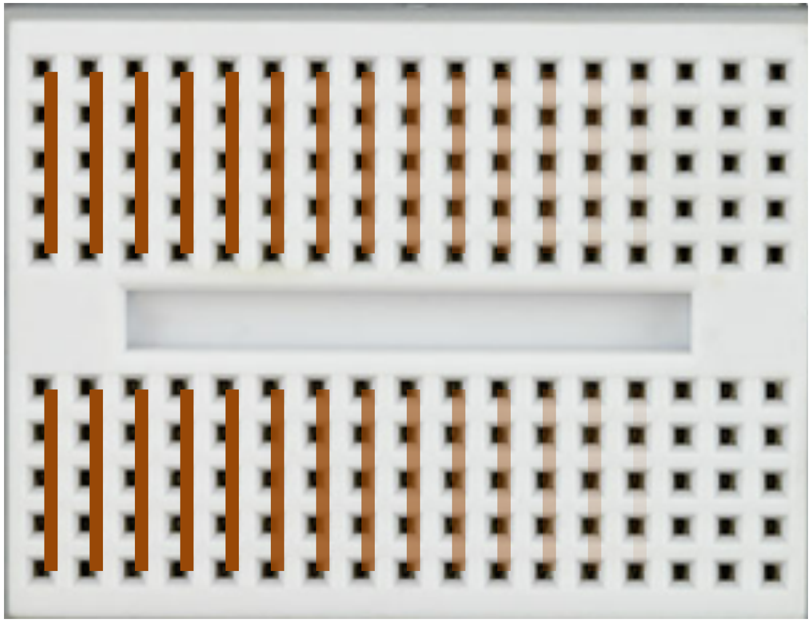
A resistors Ω value is **color-coded** right on it

Note: color codes are great, but it's easier to use a multi-meter if you've got one, and just measure Ω

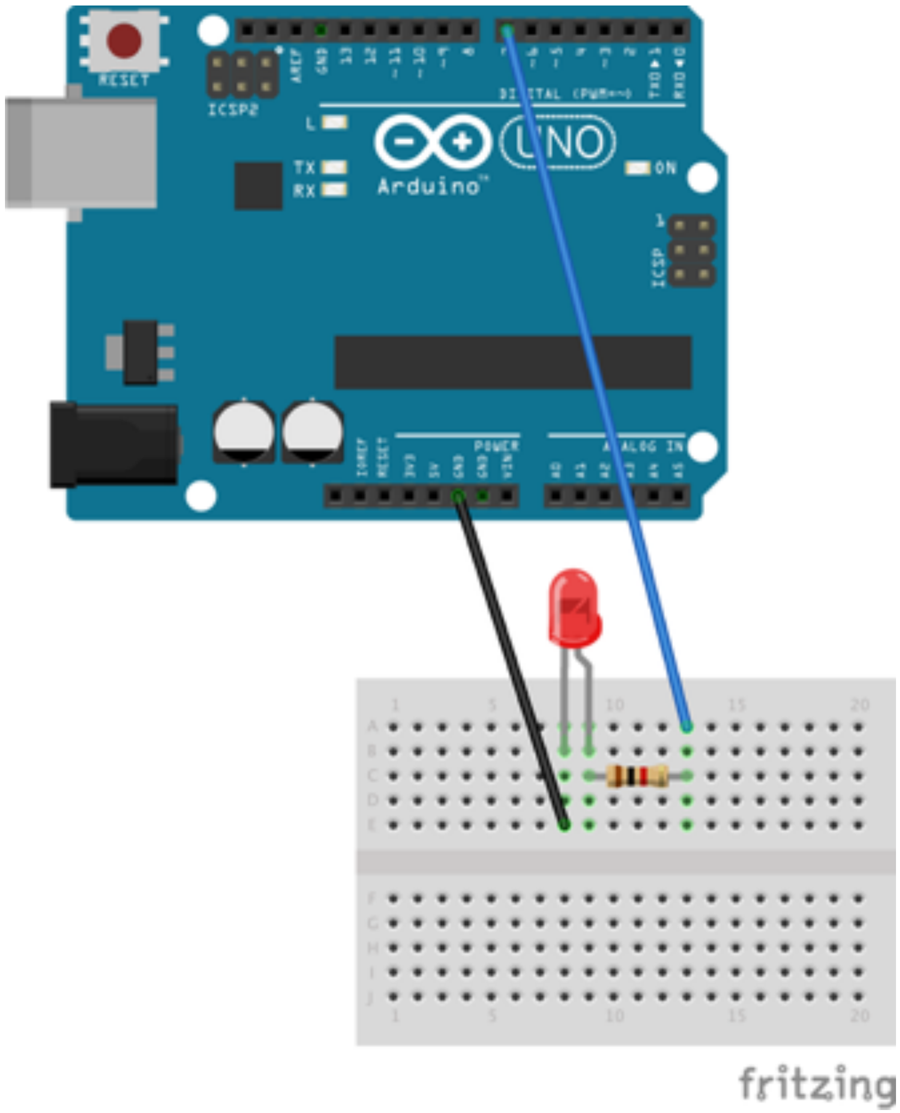
The breadboard

A breadboard lets you wire electronic components without any soldering

Its holes are connected "under the hood" as shown here



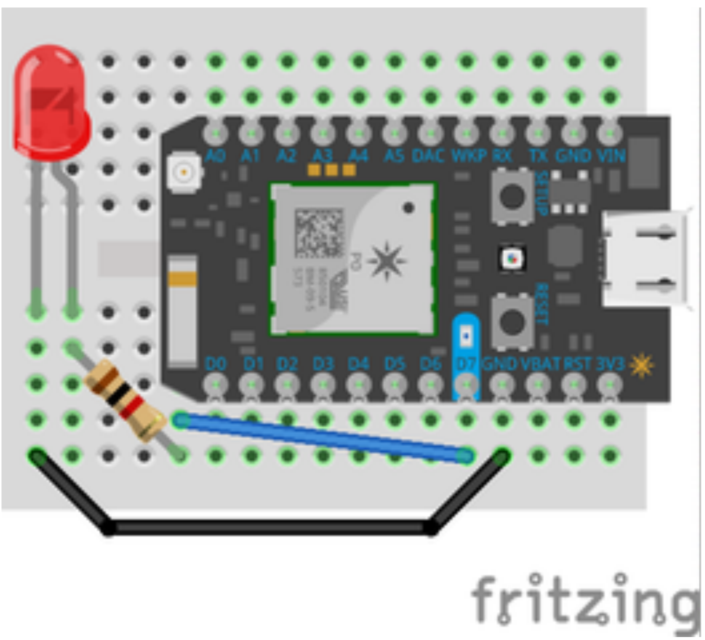
Wiring a LED with Arduino



Note: the additional **1K Ω** resistor should be used to prevent damage to the pins / LED if it's reversed

The long leg of the LED is connected to **pin D7**, the short leg to ground (**GND**)

Wiring a LED with Photon



Note: the additional **1K Ω** resistor should be used to prevent damage to the pins / LED if it’s reversed

The long leg of the LED is connected to **pin D7**, the short leg to ground (**GND**)

Controlling a LED (digital output)

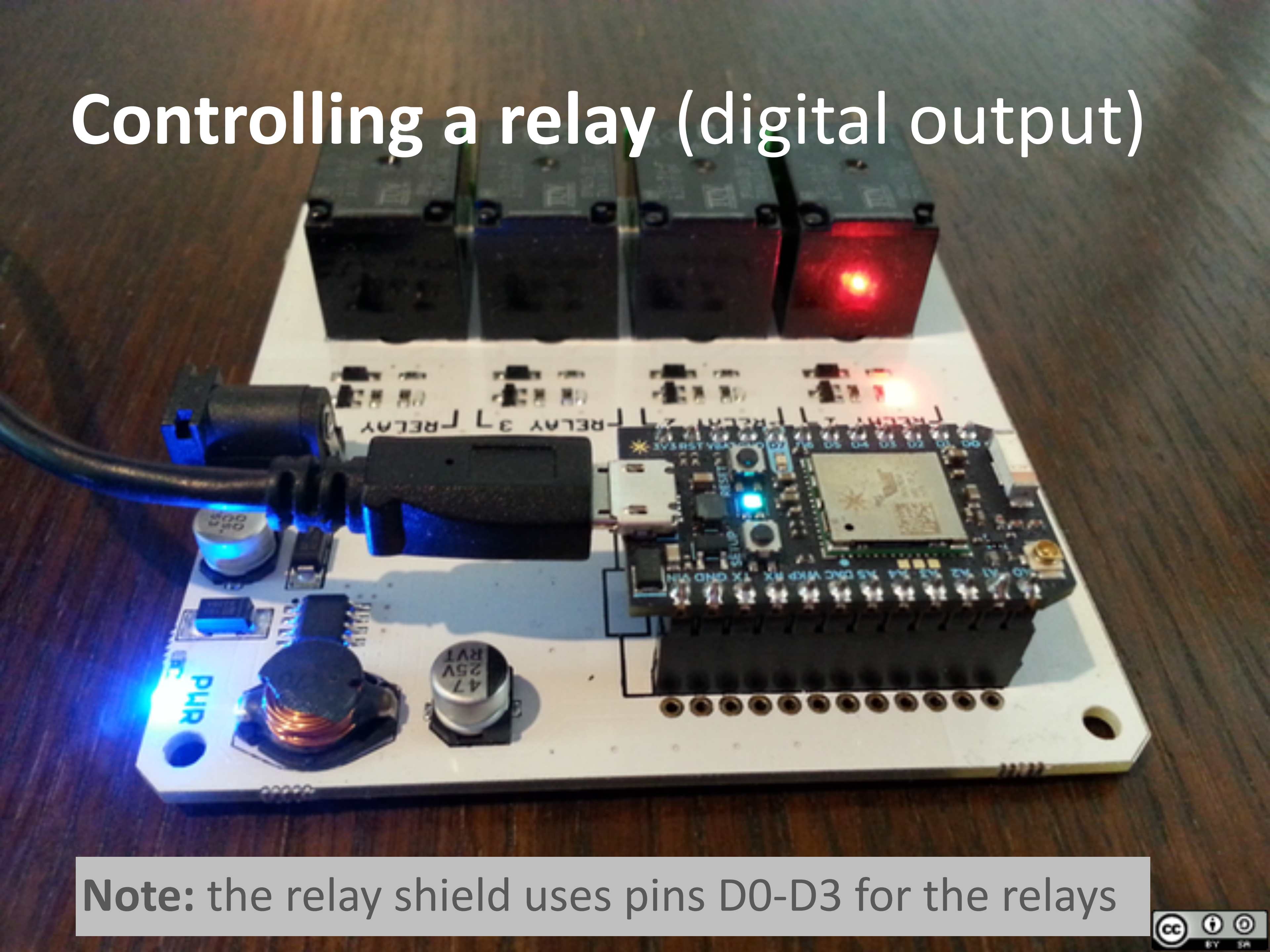
```
int ledPin = 7;

void setup () {
   pinMode(ledPin, OUTPUT);
}
void loop () {
   digitalWrite(ledPin, HIGH);
   delay(500); // wait 500ms
   digitalWrite(ledPin, LOW);
   delay(500);
}
```

Note: blinking a LED is the *Hello World* of embedded software

Set *ledPin* as wired in your LED circuit

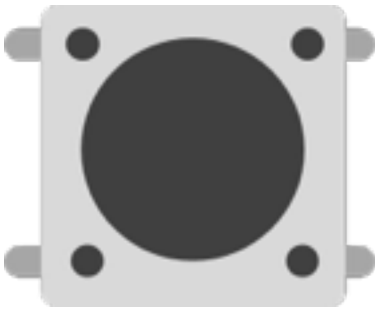
HIGH = digital 1 (5V) means LED is **on**, **LOW** = digital 0 (0V) means LED is **off**

Controlling a relay (digital output)



Note: the relay shield uses pins D0-D3 for the relays

The switch



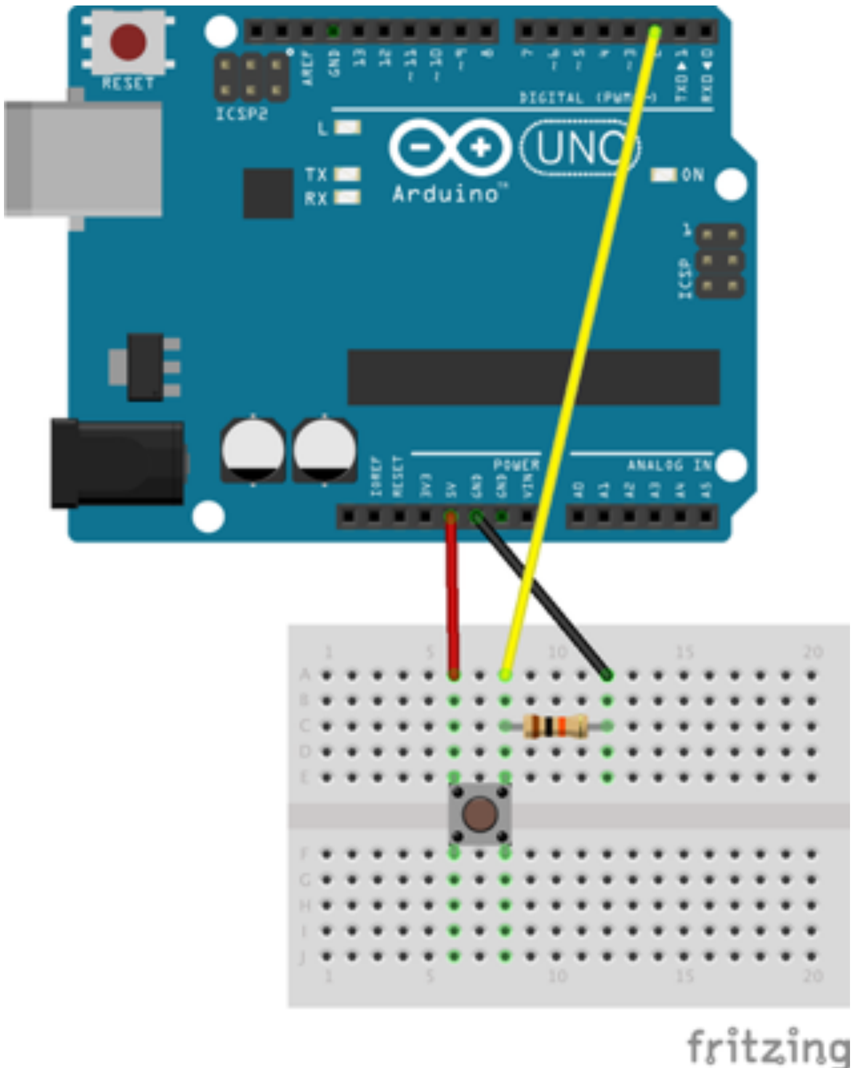
A switch is a simple, digital **sensor**

Switches come in different forms, but all of them in some way **open** or **close** a gap in a wire

The **pushbutton** switch has four legs for easier mounting, but only two of them are needed

Note: you can also easily build your own switches, for inspiration see e.g. http://vimeo.com/2286673

Wiring a switch with Arduino



Note: the resistor in this setup is called *pull-down* ‘cause it pulls the pin voltage down to GND (0V) if the switch is open

Pushbutton **switch**

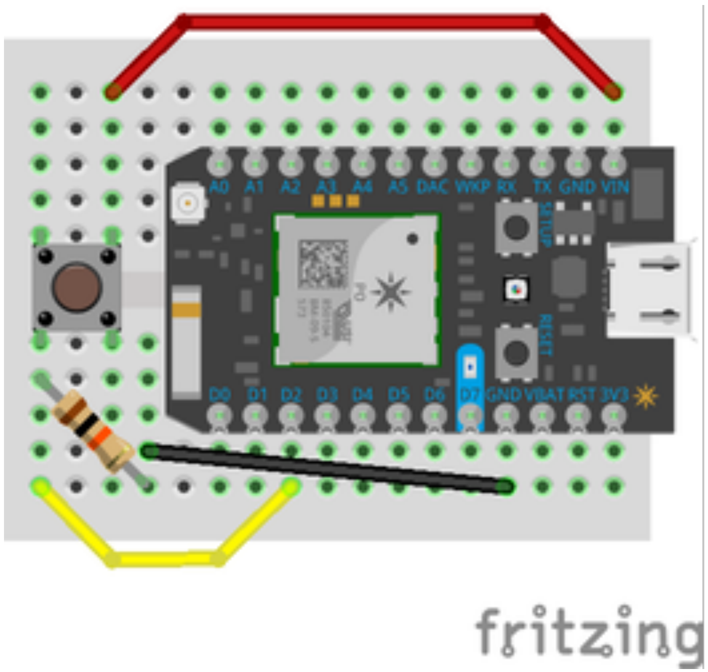
10K Ω resistor

5V

GND

D2 (max input 5V!)

Wiring a switch with Photon



Note: the resistor in this setup is called *pull-down* 'cause it pulls the pin voltage down to GND (0V) if the switch is open

Pushbutton **switch**

10K Ω resistor

VIN = 4.8V out

GND

D2 (max input 5V!)

Reading a switch (digital input)

```
int sensorPin = 2; // e.g. button switch

void setup () {
    Serial.begin(9600); // set baud rate
    pinMode(sensorPin, INPUT);
}

void loop () {
    int sensorValue = digitalRead(sensorPin);
    Serial.println(sensorValue); // print 0 or 1
}
```

Open the IDE serial monitor or terminal to see log output

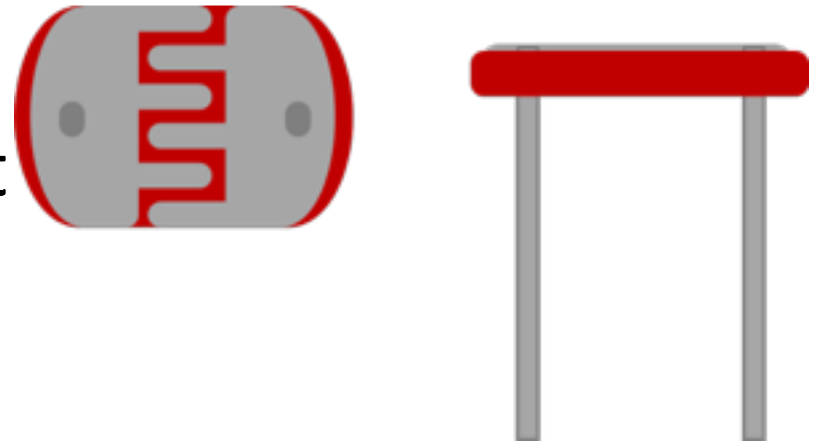
Switching a LED

```
int switchPin = 2;
int ledPin = 7; // or 13
void setup () {
   pinMode(switchPin, INPUT);
   pinMode(ledPin, OUTPUT);
}
void loop () {
   int switchValue = digitalRead(switchPin);
   if (switchValue == 0) {
      digitalWrite(ledPin, LOW);
   } else { // switchValue == 1
      digitalWrite(ledPin, HIGH);
   }
}
```

Note: figure out the wiring or just use the built-in LED, i.e. pin 13 on Arduino and D7 on Photon

The code inside an *if* statement is only executed if the con-dition is true, *else* is executed otherwise

The LDR

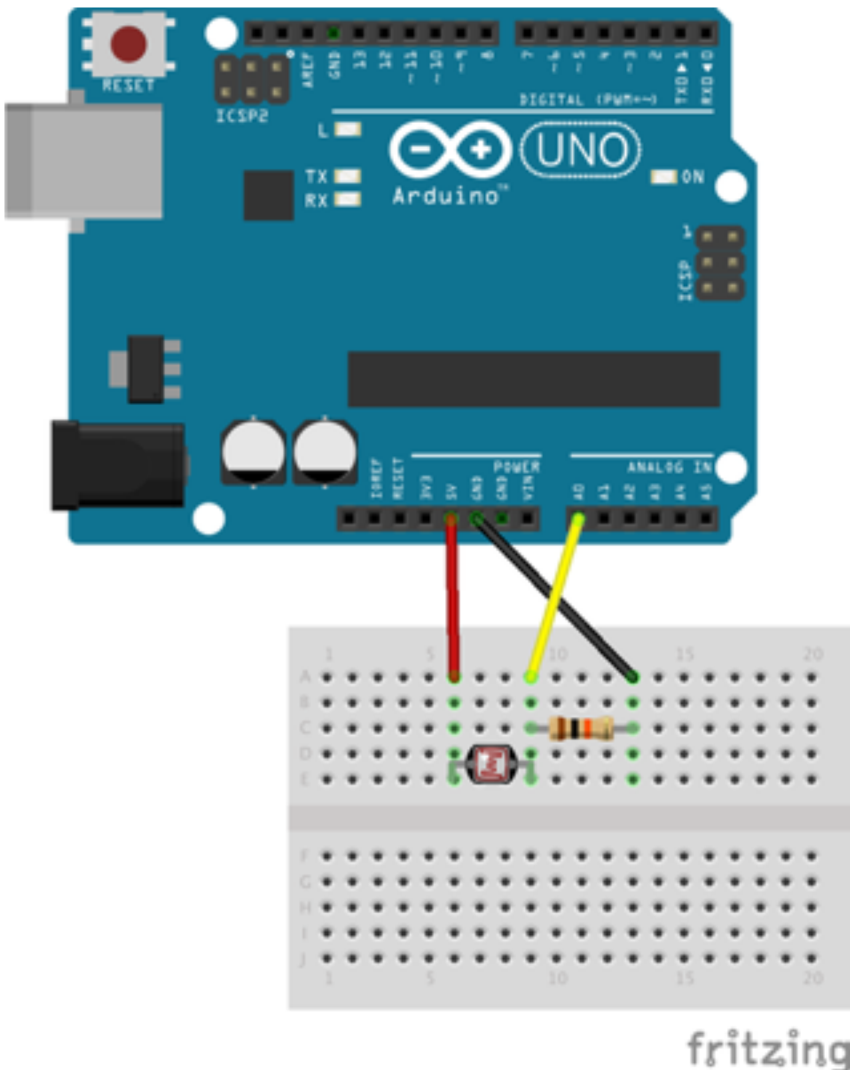


A photoresistor or **LDR** (**l**ight **d**ependent **r**esistor) is a resistor whose resistance depends on light intensity

An LDR can be used as a simple, **analog sensor**

The orientation of an LDR does not matter

Wiring an LDR with Arduino



Note: this setup is a *voltage-divider, as* the 5V total voltage is divided between LDR and resistor to keep 0V < **A0** < 2.5V

Photoresistor (LDR)

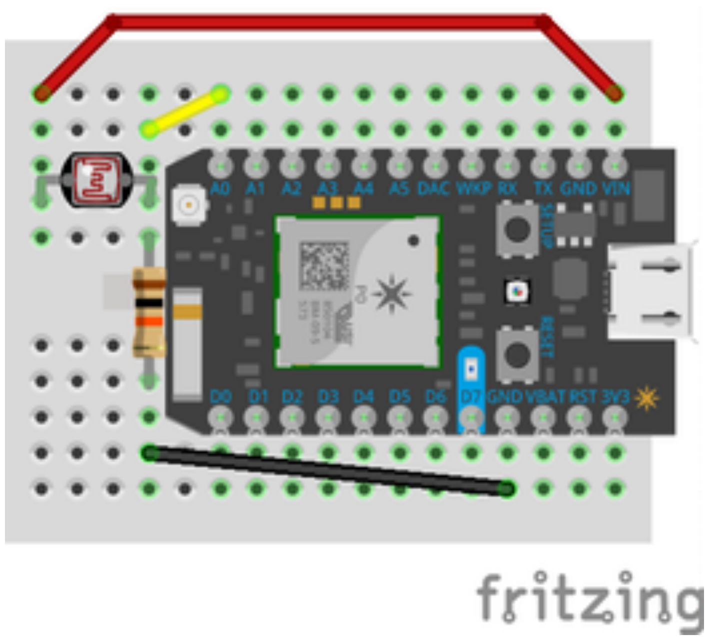
10K Ω resistor

5V

GND

A0

Wiring an LDR with Photon



Note: this setup is a *voltage-divider, as* the total voltage is divided between LDR and resistor to keep 0V < **A0** < 2.5V

Photoresistor (LDR)

10K Ω resistor

VIN = 4.8V out

GND

A0

Reading an LDR (analog input)

```
int sensorPin = A0; // LDR or other analog sensor

void setup () {
  Serial.begin(9600); // set baud rate
}

void loop () {
  int sensorValue = analogRead(sensorPin);
  Serial.println(sensorValue); // print value
}
```

Open the IDE serial monitor or terminal to see log output

Note: use e.g. Excel to visualize values over time

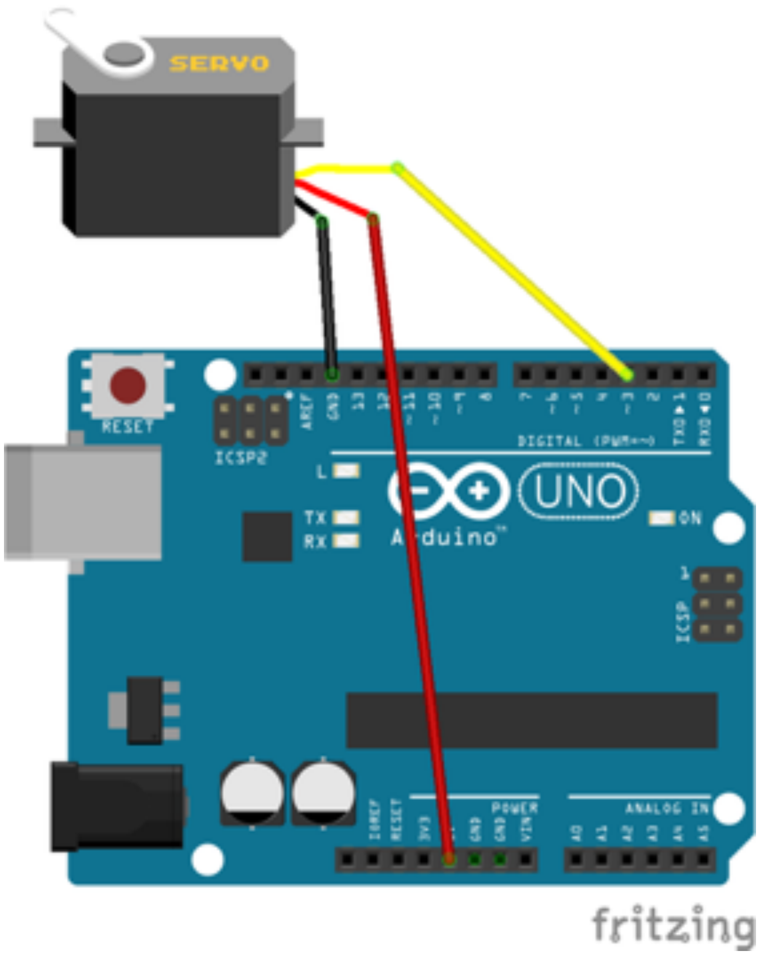
The Servo

A **servo** motor takes an input between 0 and 180 which is translated into a motor position in degrees

A servo is a **analog actuator**

To create an analog output for the servo, the device uses pulse width modulation (**PWM**)

Wiring a Servo with Arduino



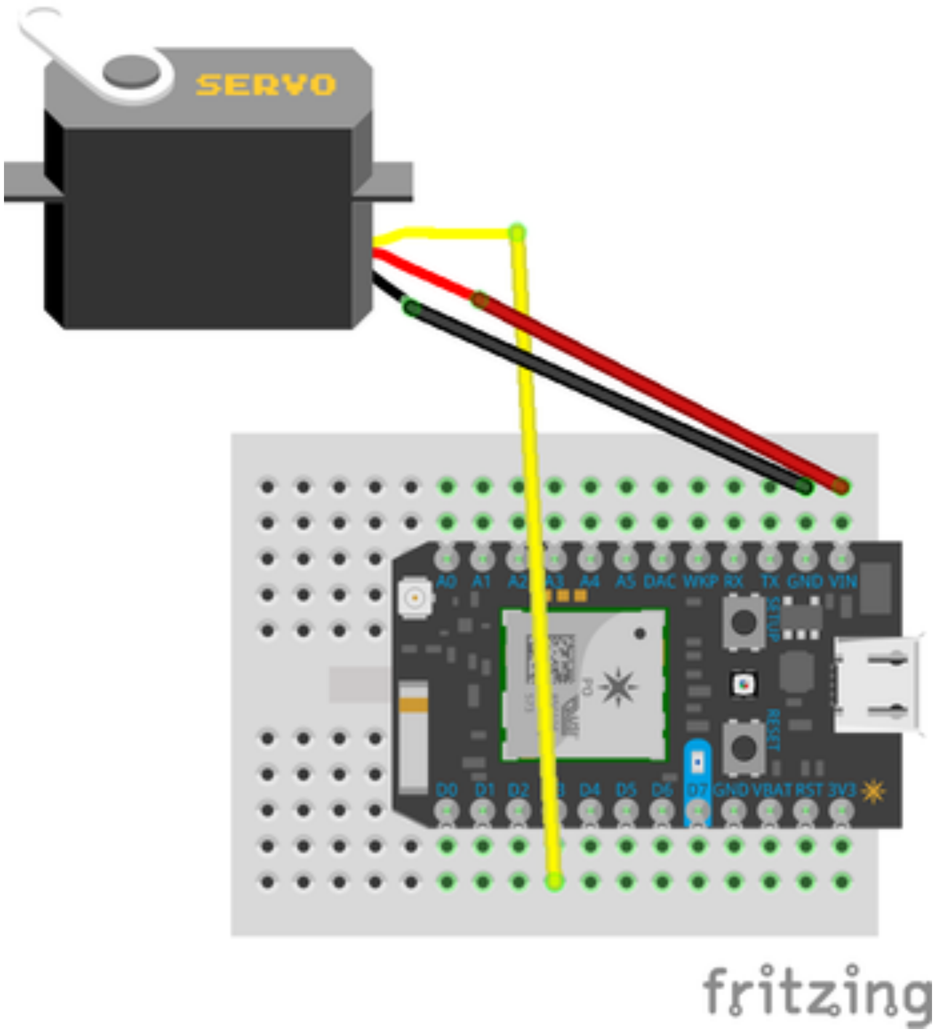
Note: PWM pins on Arduino are those with a ~ symbol

5V

GND

D3 (PWM)

Wiring a Servo with Photon



Note: PWM pins on Photon are D0 - D3, A4 and A5

VIN = 4.8V out
GND
D3 (PWM)

Controlling a Servo (PWM output)

```
#include <Servo.h> // remove this line on the Photon
Servo servo; // create a new Servo object
int servoPin = 3; // a PWM pin

void setup () {
  servo.attach(servoPin);
}

void loop () {
  for (int pos = 0; pos <= 180; pos += 10) {
    servo.write(pos);
    delay(100);
  }
}
```

Note: *Servo* objects let you use Servos without PWM skills

The *for* loop repeats from pos 0 until pos is 180, in steps of 10

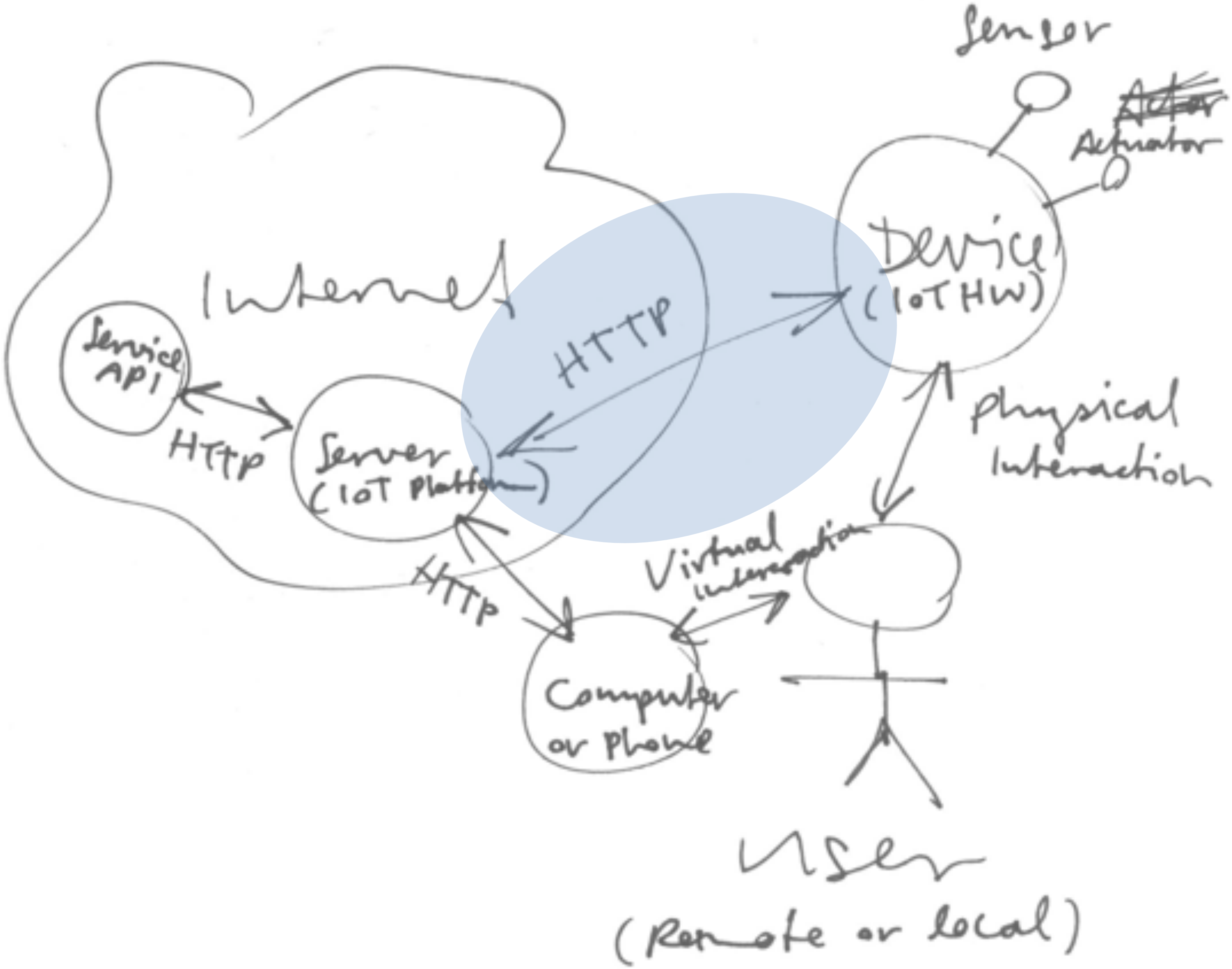
Controlling a Servo with an LDR

```
#include <Servo.h> // remove this line on the Photon
Servo servo; // create a new Servo
int servoPin = 3; // a PWM pin
int sensorPin = A0; // LDR

void setup () {
  servo.attach(servoPin);
}

void loop () {
  int val = analogRead(sensorPin);
  int pos = map(val, 0, 255, 0, 180);
  servo.write(pos);
}
```

Note: combine the wiring diagrams of both, Servo & LDR

The *map* function is useful to map one range onto another

Connecting to the Internet



Web client with Curl

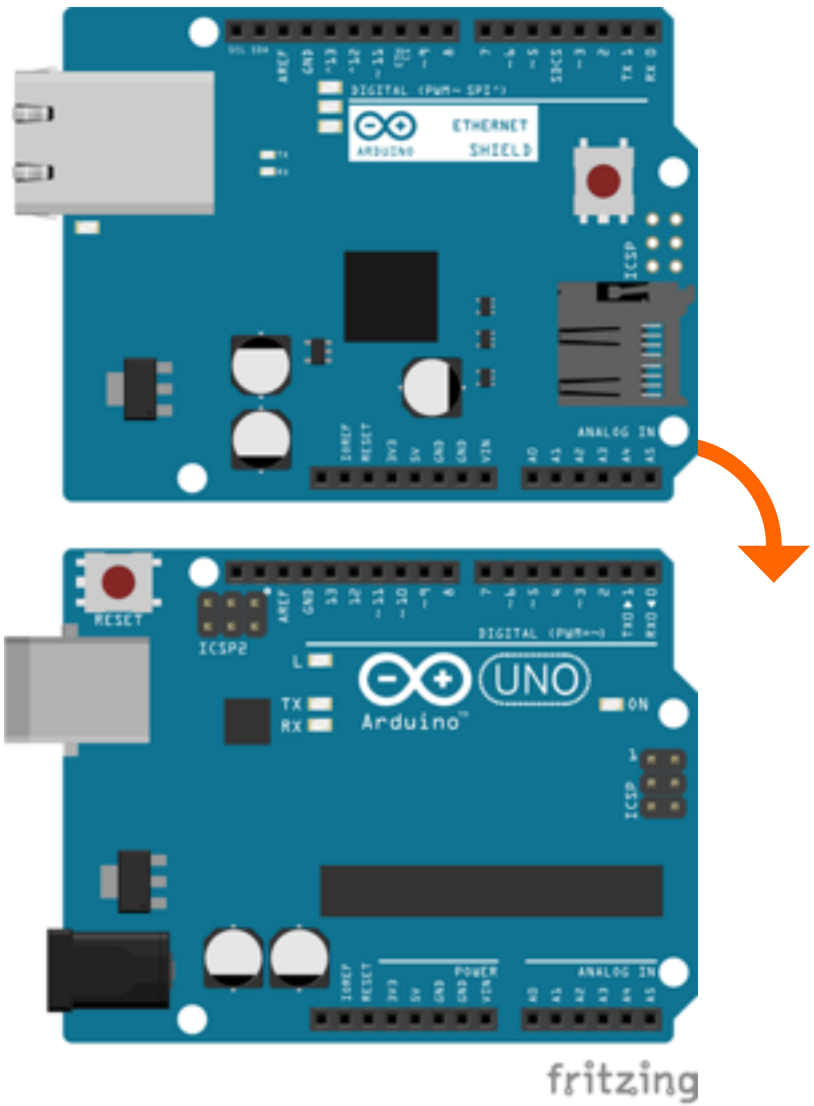
Install Curl from http://curl.haxx.se/ then open a terminal and type, e.g.

$ **curl** -vX GET http://www.oh-a-show.net/

The result is the same as opening the page http://www.oh-a-show.net/ in your browser, right-clicking it and selecting *View Page Source*

Note: browsers, curl or a device can be Web clients

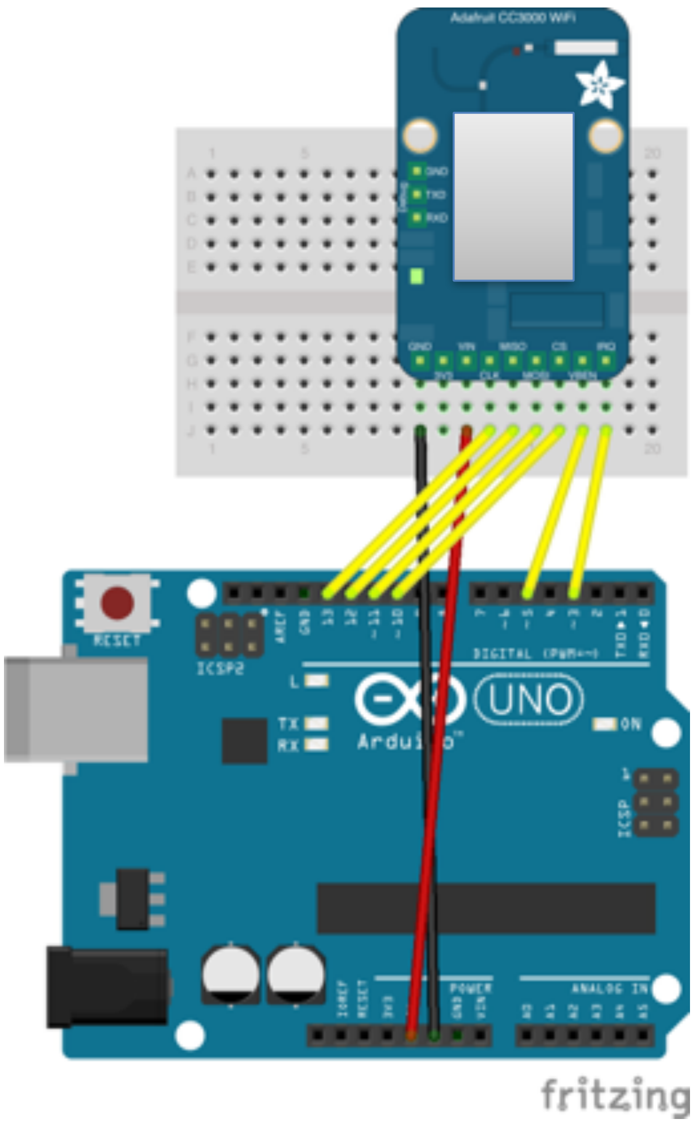
Adding Ethernet to Arduino



Note: the Ethernet shield stacks onto the Arduino - just make sure the pins line up properly

Pins 10, 11, 12 and 13 are used by the shield according to http://playground.arduino.cc/Main/ShieldPinUsage

Adding CC3000 Wi-Fi to Arduino



Note: make sure to use a reliable power source, e.g. USB, as Wi-Fi consumes lots of power

CC3000 **VIN** to **5V**

GND to **GND**

CLK to **D13**, **MISO** to **D12**, **MOSI** to **D11**, **CS** to **D10**, **VBEN** to **D5**, **IRQ** to **D3**

Web client with Arduino (Ethernet)

After adding an **Ethernet shield** to the Arduino, connect it with the Ethernet cable, then open *File > Examples > Ethernet > WebClient*

```
byte mac[] = { ... }; // MAC from sticker on shield
IPAddress ip(...); // set a unique IP or just ignore
```

If it works, change the HTTP request path and host

Note: open the serial monitor window to see output

Web client with Arduino (CC3000)

Install the library http://learn.adafruit.com/adafruit-cc3000-wifi/cc3000-library-software

then open *File > Examples > Adafruit_CC3000 > WebClient*

#define WLAN_SSID "..." // set local Wi-Fi name

#define WLAN_PASS "..." // set Wi-Fi password

If it works, change the WEBSITE and WEBPAGE

Note: open the serial monitor window to see output

Web client with Photon

The Particle Photon has **built-in** Wi-Fi. See *Getting Started with Photon*, or press SETUP for 3s and set up *SSID* and *password* of a new local network with

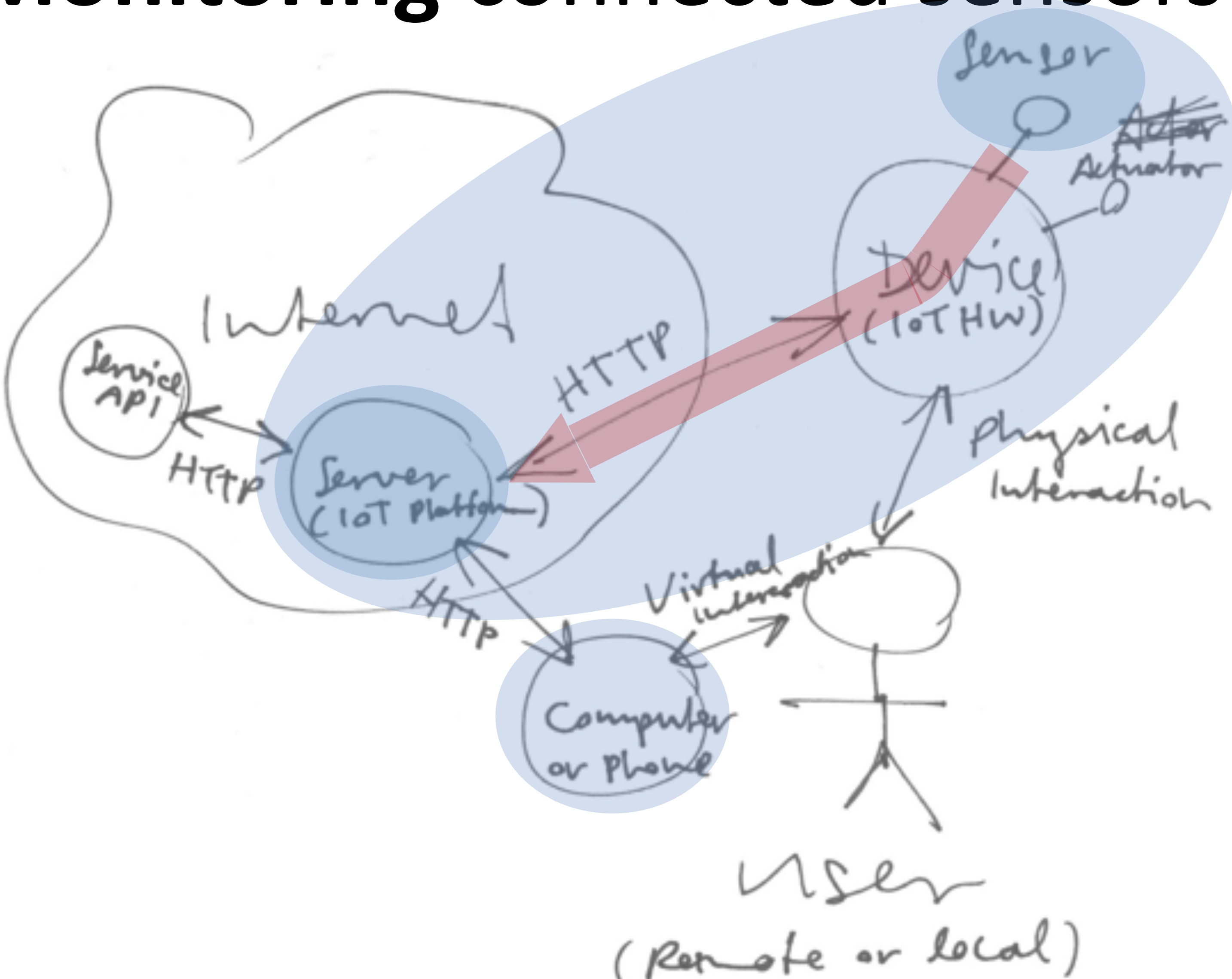
$ **particle** setup wifi

In the Particle IDE, go to *Libraries > Community Libraries > HttpClient* and click *Use This Example*

If it works, change request hostname and path

Note: open the serial monitor window to see output

Monitoring connected sensors



ThingSpeak with Curl

The ThingSpeak service lets you store, **monitor** and share **sensor data** in open formats. Sign up at https://thingspeak.com/ to create a channel and get API keys, then try the following:

$ **curl** -vX **POST** http://api.thingspeak.com/
update?key=*WRITE_API_KEY*&field1=42

$ **curl** -v http://api.thingspeak.com/channels/
CHANNEL_ID/**feed.json**?key=*READ_API_KEY*

ThingSpeak with Arduino (Ethernet)

Copy & paste the code https://github.com/iobridge/ThingSpeak-Arduino-Examples/blob/master/Ethernet/Arduino_to_ThingSpeak.ino

Note: use *Raw* to get text

```
byte mac[] = { ... }; // MAC from sticker on shield
String writeApiKey = "..." // from channel API keys
```

Analog input expected on pin **A0**, e.g. from an **LDR**

See https://thingspeak.com/channels/*CHANNEL_ID*

ThingSpeak with Arduino (CC3000)

Open *File > Examples > Adafruit_CC3000 > WebClient* and set *WLAN_SSID* and *WLAN_PASS* as before, then change web site and page to

*#define WEBSITE "**api.thingspeak.com**"*

*#define WEBPAGE "**/update?key=**WRITE_API_KEY**&field1=42**"*

If it works, replace *42* with analog input, e.g. from an **LDR** using something like + String(analogRead(A0))

See https://thingspeak.com/channels/*CHANNEL_ID*

Note: this example requires a bit of programming

ThingSpeak with Photon

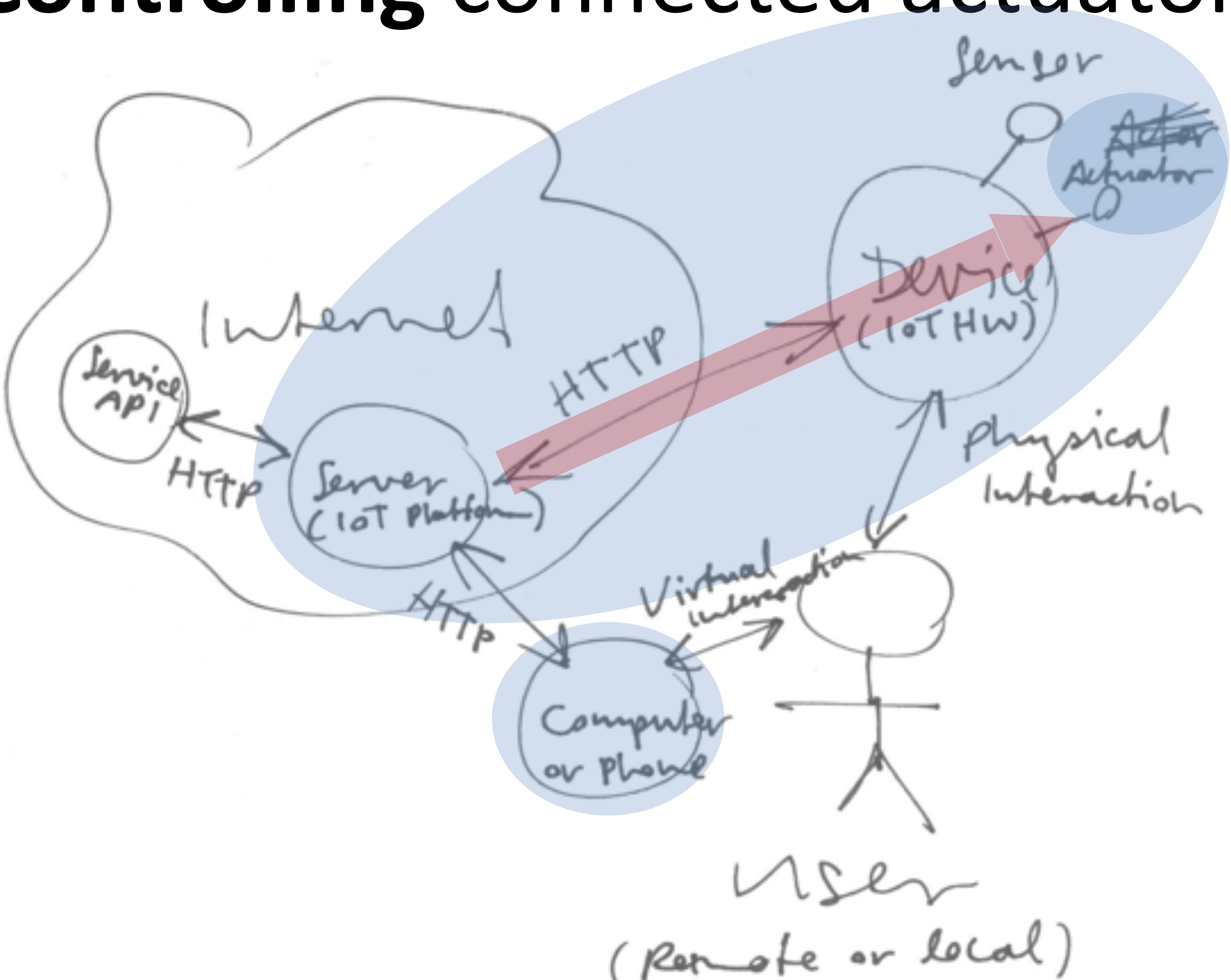
In the Particle IDE, go to *Libraries > Community Libraries > ThingSpeak* and click *Use This Example*

Replace *YOUR-CHANNEL-KEY* with a write API key

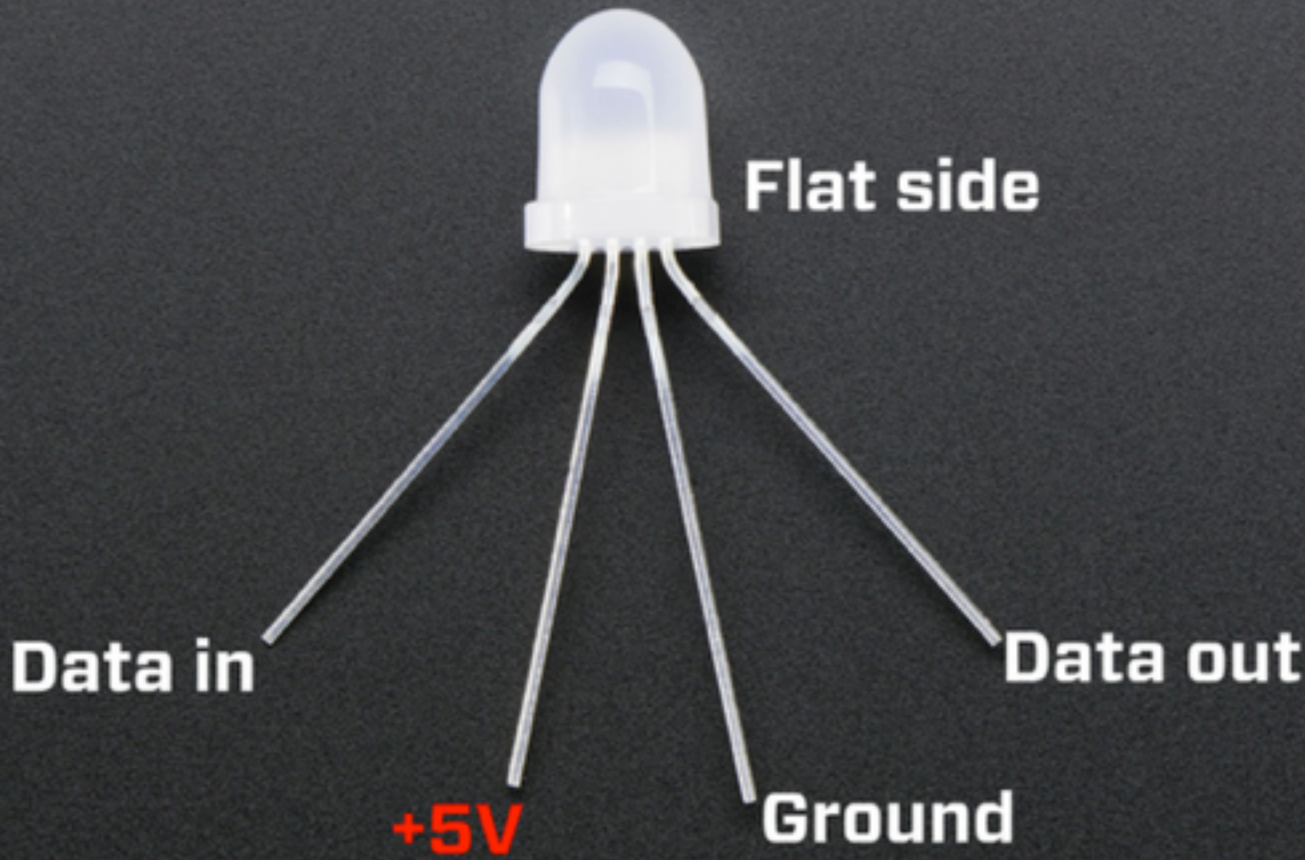
If it works, replace *int rand = ...* with analog input, e.g. from an **LDR** on pin **A0**

See https://thingspeak.com/channels/*CHANNEL_ID*

Controlling connected actuators

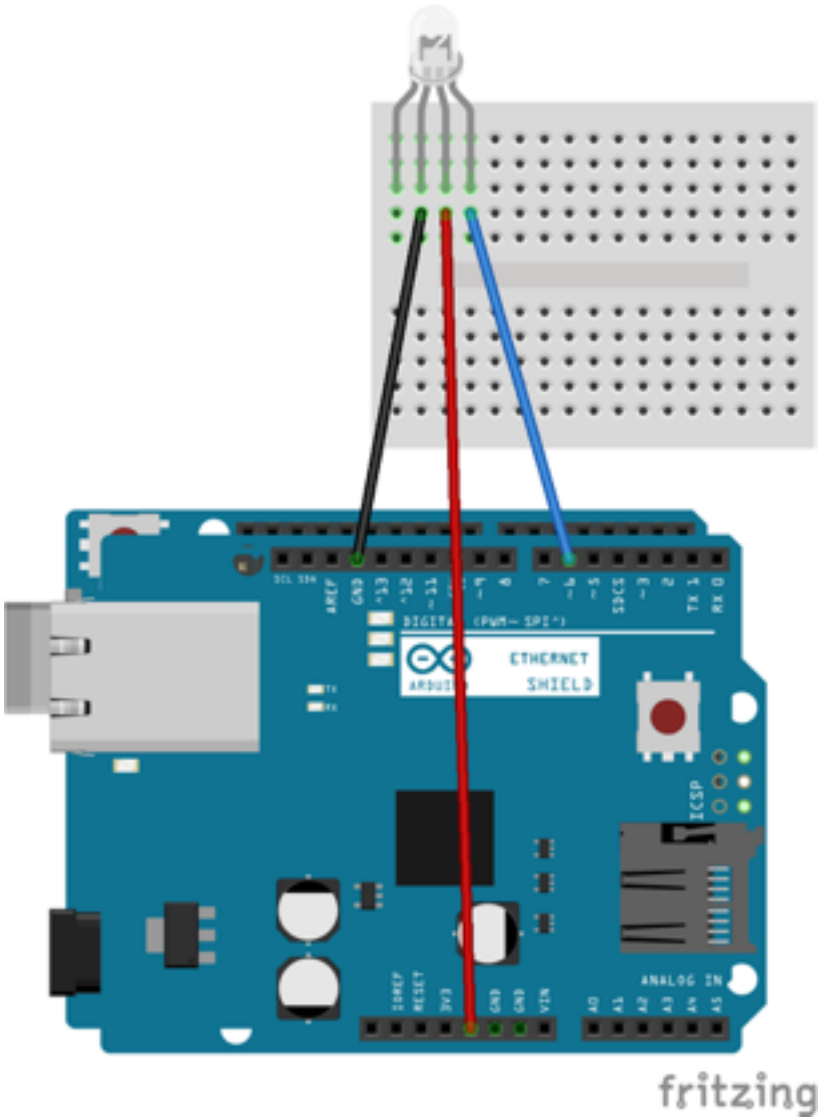


The NeoPixel



A **multi-color LED** with a chip in each pixel that can be controlled with a (PWM-based) library

Wiring a NeoPixel with Arduino

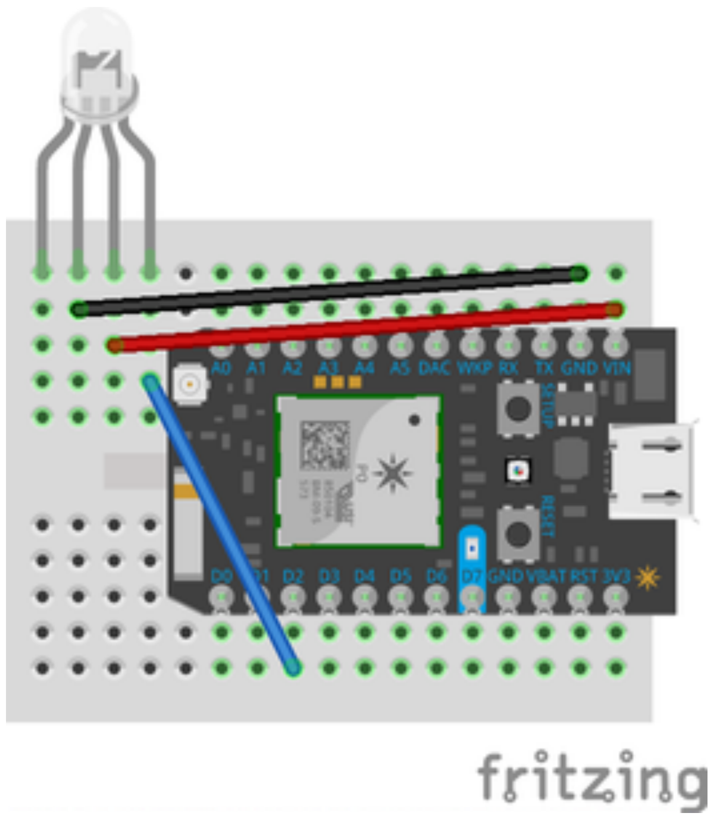


Note: PWM pins on Arduino are those with a ~ symbol

Flat side of the LED is left on this picture

5V
GND
D6 (PWM)

Wiring a NeoPixel with Photon



Note: PWM pins on Photon are D0 - D3, A4 and A5

Flat side of the LED is left on this picture

VIN = 4.8V out
GND
D2 (PWM)

Testing a NeoPixel with Arduino

Install the library https://github.com/adafruit/Adafruit_NeoPixel then open *File > Examples > Adafruit_Neopixel > strandtest*

*Adafruit_NeoPixel strip = Adafruit_NeoPixel(**1**, PIN, NEO_GRB + **NEO_KHZ400**);*

If it works, replace *loop* content with *strip.setPixel Color(0, strip.Color(0, 255, 0)); strip.show();*

Note: the rapid blinking is intended for LED strands

Testing a NeoPixel with Photon

In the Particle IDE, go to *Libraries > Community Libraries > NeoPixel* and click *Use This Example*

```
#define PIXEL_COUNT 1 // 10
#define PIXEL_TYPE WS2811 // WS2812B
```

If it works, remove the *for* loops and try *strip.setPixelColor(0, strip.Color(0, 255, 0));*

Note: the pixel is set green, red, blue (GRB), not RGB

Connected LED with Arduino (Ethernet)

Sign up at https://yaler.net/ to get a relay domain

https://bitbucket.org/tamberg/iotworkshop/src/tip/Arduino/NeoPixelWebService/NeoPixelWebService.ino

$ **curl** –vX PUT http://*RELAY_DOMAIN*.try.yaler.net/led/color/ee6600

Note: replace RELAY_DOMAIN with your relay domain

Connected LED with Arduino (CC3000)

Sign up at https://yaler.net/ to get a relay domain

https://bitbucket.org/tamberg/iotworkshop/src/tip/Arduino/NeoPixelWebServiceCc3k/NeoPixelWebServiceCc3k.ino

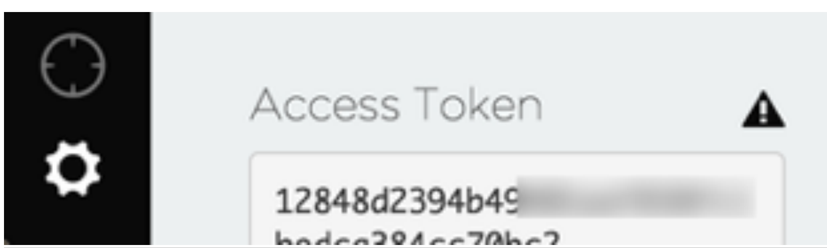
$ **curl** –vX PUT http://*RELAY_DOMAIN*.try.yaler.net/led/color/ee6600

Note: replace RELAY_DOMAIN with your relay domain

Connected LED with Photon

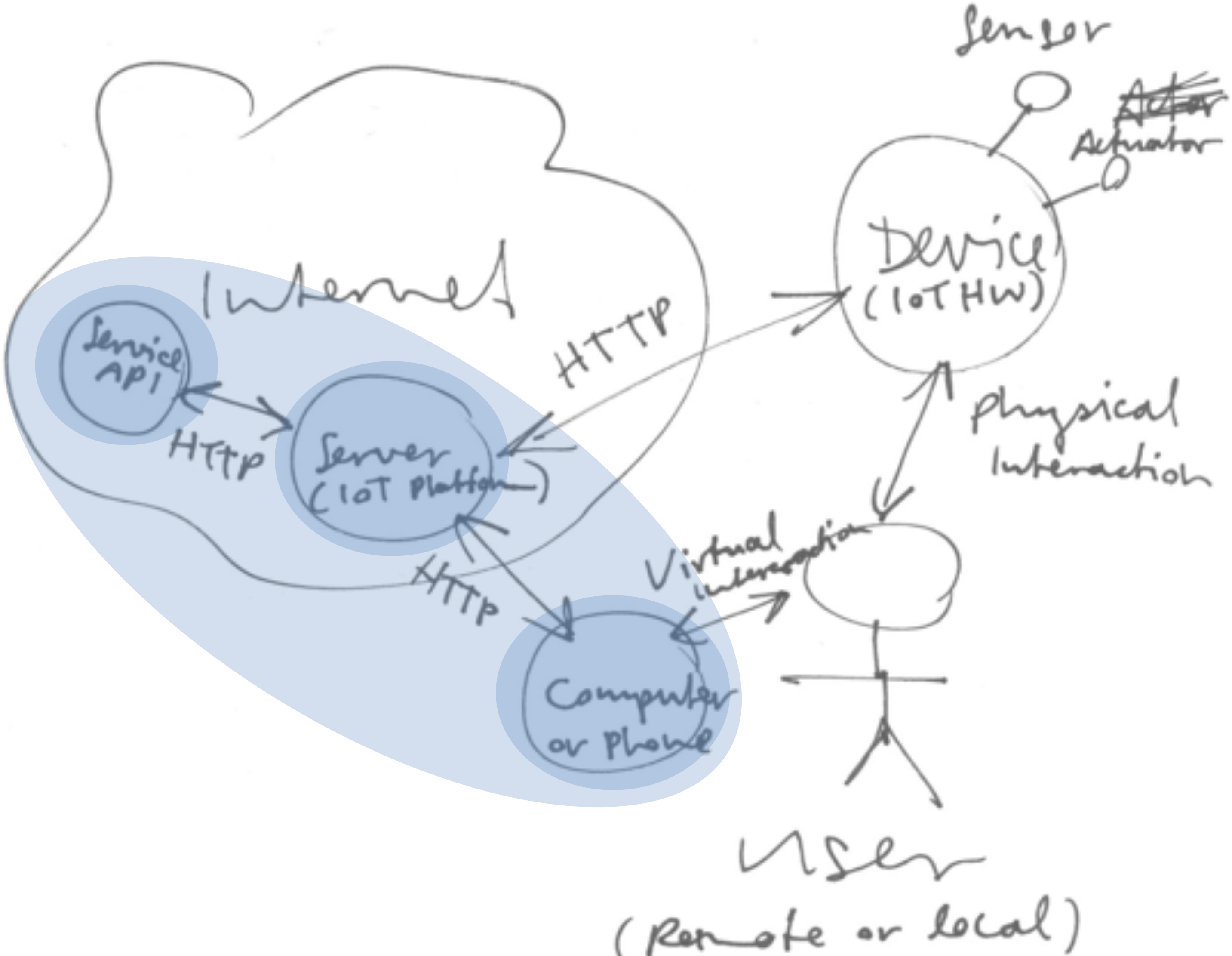
https://bitbucket.org/tamberg/iotworkshop/src/tip/ParticlePhoton/NeoPixelWebService/NeoPixelWebService.ino (include NeoPixel library)

$ **curl** -vX POST https://api.particle.io/v1/devices/*DEVICE_ID*/led -d access_token=*ACCESS_TOKEN* -d args=330033



Note: the Particle Cloud API simplifies Web services

Mash-ups


Sensor
Actuator
Device
(IoT HW)
Internet
Service API
HTTP
Server
(IoT Platform)
HTTP
HTTP
Physical Interaction
Virtual interaction
Computer or Phone
User
(Remote or local)

IFTTT

If This Then That (IFTTT) is a **mash-up** platform

An IFTTT Recipe connects two Web services (or a service and a device) using their Web **API**s

The IFTTT **Maker Channel** uses **Webhooks** (outgoing HTTP requests) to call your device, and you can use **Web requests** to trigger IFTTT, the **Particle Channel** (for Photon) explains itself

IFTTT Do Button with Arduino

Connect the Maker Channel at https://ifttt.com/maker

Get the **Do Button App**, tap *'+' > Channels > Maker > Create a new recipe > Make a Web request >* ... then go to https://ifttt.com/myrecipes/do for convenience

URL: http://RELAY_DOMAIN.try.yaler.net/led?color=330033

Method: POST

Content Type: application/x-www-form-urlencoded

IFTTT Do Button with Photon

Connect the Particle channel at https://ifttt.com/particle

Get the **Do Button App**, tap *'**+**' > Channels > Particle > Create a New Recipe > Call a function* and select, e.g. *led on DEVICE_NAME*

Set the *with input* field to a color value, e.g. 330033

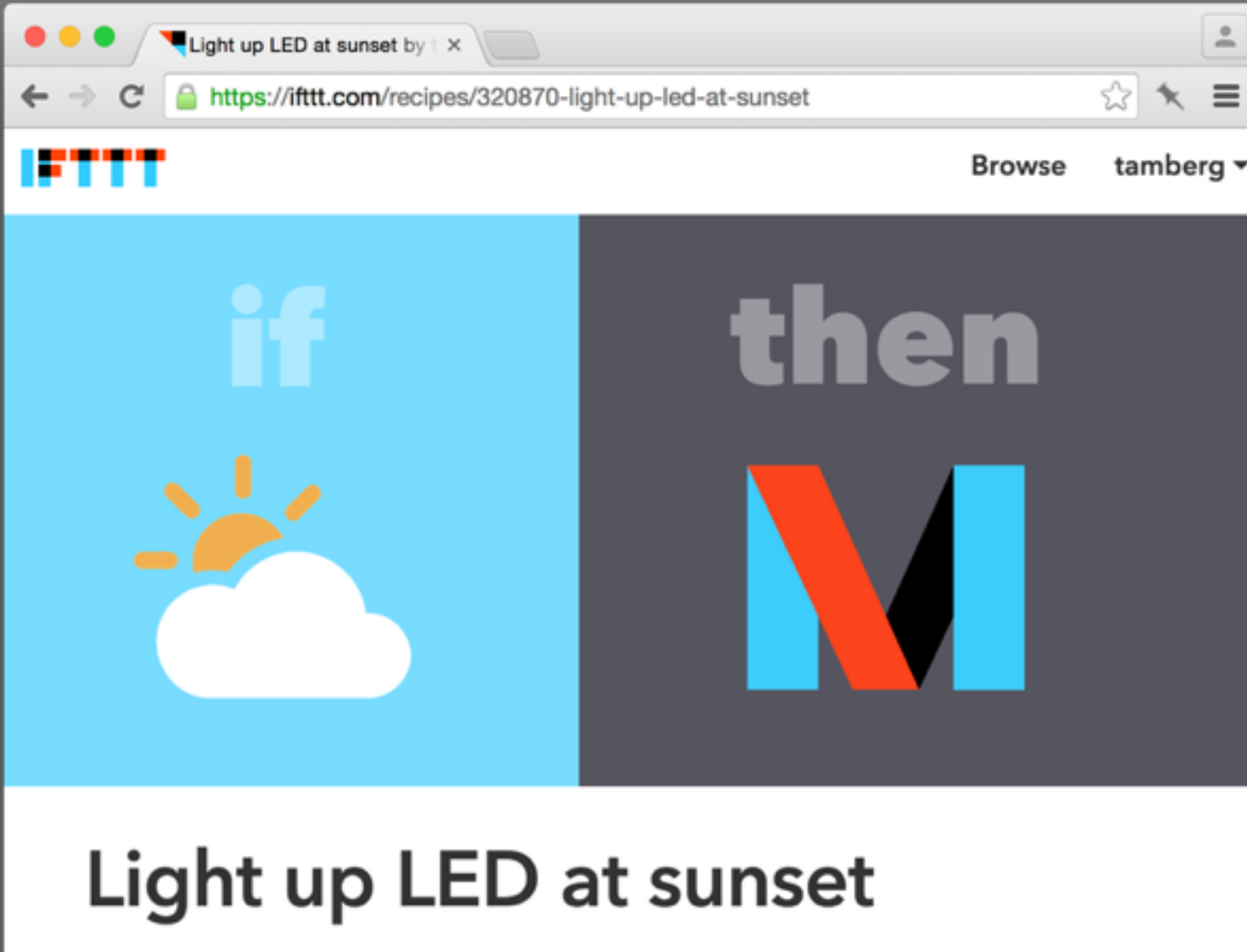
IFTTT Recipes

Once a recipe works, you can publish it (hiding unneeded fields) for everybody to clone, e.g.

https://ifttt.com/recipes/320868-light-up-arduino-led-at-sunset

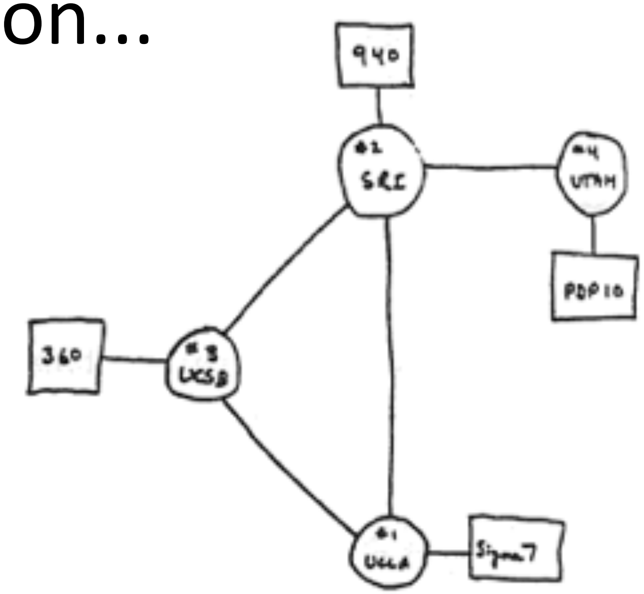
https://ifttt.com/recipes/320870-light-up-photon-led-at-sunset

Note: "Do" recipes cannot be published for now


Light up LED at sunset by
https://ifttt.com/recipes/320870-light-up-led-at-sunset
Browse
tamberg
if
then
Light up LED at sunset

How the Internet works in detail

If you wonder what TCP/IP, HTTP or DNS means - or care about the difference between protocol, data format and API, read on...



THE ARPA NETWORK

DEC 1969

Protocols

Parties need to agree on **how to exchange** data

(communicating = exchanging data according to a protocol)

e.g. **Ethernet** links local computers physically,

TCP/IP is the foundation of the **Internet**, and

HTTP is the protocol that enables the **Web**

Note: protocols are layered, e.g. HTTP messages transported in TCP/IP packets sent over Ethernet

TCP/IP

IP (**I**nternet **P**rotocol) deals with host addressing (each host has an **IP address**) and packet routing

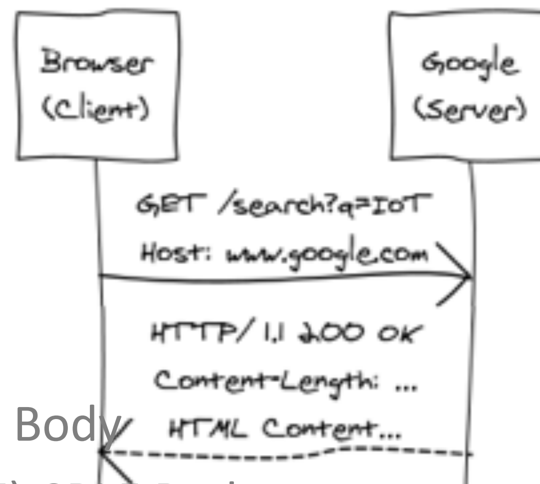
TCP (**T**ransmission **C**ontrol **P**rotocol): connection oriented, reliable data stream (**packets** in-order, errors corrected, duplicates removed, discarded or lost packets resent) from client to server

Note: *DHCP* assigns an *IP address* to your device which is mapped to the device's *MAC address*

HTTP

HTTP (**H**yper**t**ext **T**ransfer **P**rotocol) enables the distributed, collaborative system we call the **Web**

The **client** sends an HTTP **request**, the **server** replies with a **response**



HTTP Message = Request|Response

Request = (GET|POST|…) Path CRLF *(Header CRLF) CRLF Body

Response = "HTTP/1.1" (200|404|…) CRLF *(Header CRLF) CRLF Body

CRLF = "\r\n"

(Read the spec: http://tools.ietf.org/html/rfc2616)

Note: HTTP is human readable, i.e. it’s easy to debug

URIs

The **URI** (**U**niform **R**esource **I**dentifier) is a string of characters used to identify a resource

http://blog.tamberg.org/2011-10-17/side-projects.html

scheme	authority = host [‘:’ port]	path

(Read the spec: http://tools.ietf.org/html/rfc3986)

QR codes, ***NFC tags*** can contain a machine readable URI

IoT: URIs can refer to things or their physical properties

Note: good URIs can be hand-written on a napkin and re-typed elsewhere, without any ambiguity

DNS

DNS (**D**omain **N**ame **S**ystem) maps Internet domain names to one or more IP addresses

Try it in your desktop computer terminal, e.g.

$ nslookup ***google.com***

173.194.35.6 …

Note: if your device doesn't support DNS you can connect to the server's IP, but beware of changes

Data formats

Parties need to agree on **what is valid** content
(parsing = reading individual content tokens)

CSV: easy to parse, suited for tables, old school
JSON: easy to parse, de facto standard
XML: used by many services, W3C standard
Semi-structured text, e.g. Twitter's @user, #tag
Binary formats, e.g. PNG, MP3, …

RSS

In addition to generic data formats like CSV, JSON, XML there are refinements that **add semantics** to the document

RSS (or **Atom**) is a data format for **lists** of **items**

Invented for blogs, RSS is great for **data feeds**

Note: RSS documents are also XML documents, but not all XML documents contain valid RSS

HTML

HTML (**H**yper**t**ext **M**arkup **L**anguage) is a data format describing how a Web page should be structured and displayed

Look at the HTML (and Javascript) code of any Web page with "**view source**" in your browser

Note: HTML documents are not always valid XML documents, but Web browsers are very forgiving

APIs

An **API** (**A**pplication **P**rogramming **I**nterface), is an agreement between clients and providers of a service on **how to access a service**, how to **get data out** of it or **put data into it**

The **UI** (User Interface) of a service is made **for humans**, the **API** is made **for other computers**

Note: good APIs are documented or self-explanatory

REST

REST (**Re**presentational **S**tate **T**ransfer) is a style of designing an API so that it is easy to use

REST APIs use **HTTP methods** (GET, PUT, POST, DELETE) to let you perform actions on **resources**

REST APIs can be explored by following links

Note: good Web UIs are often built following the same principles, therefore REST APIs feel natural

Learning more

Electronics: Ohm's law, Kirchhoff's current and voltage law (KCL & KVL), *Make: Electronics* by Charles Platt

Interaction Design: *Smart Things* by Mike Kuniavsky, *Designing Connected Products* by Claire Rowland et al.

Physical Computing: *Making Things Talk* by Tom Igoe

REST: *RESTful Web Services* by Leonard Richardson

Programming: read other people's code, e.g. on GitHub

IoT: *Designing the Internet of Things* by Adrian McEwen and Hakim Cassimally, Postscapes.com, IoTList.co

Note: MechArtLab Zürich has an OpenLab on Tuesdays

Reducing E-waste

Tired of hacking?

Donate your hardware…

e.g. MechArtLab

Hohlstrasse 52

8004 Zürich

Thank you

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twitter.com/tamberg

tamberg.org

Slides online at http://**goo.gl/n3hCbK**