Intel Innovation Week

University of Johannesburg (23 – 27 Jun 2014)

Sensors

intel Galileo

What will you make?

Planning Slide Only

Equipment required (per person)

Part	Qty	Cost	Purchase / Wiki link
LDR	1	1.80 EUR	Click here
PIR motion sensor	1	5.60 EUR	Click here
Piezo element	1	1.20 EUR	Click here
Touch sensor	1	5.90 EUR	Click here
Tilt switch	1	1.95 EUR	Click here
LED	2	0.06 EUR	Click here
Resistor (330ohm)	2	0.02 EUR	Click here
Resistor (10k ohm)	2	0.02 EUR	Click here
Jumper Wires (pack)	1	3.99 EUR	Click here
Breadboard	1	4.59 EUR	Click here

Total: 25.13 EUR

Sensors – Introduction

Introduction - What are Sensors?

- A sensor is a converter that measures a physical quantity and converts it into a signal.

- For accuracy, most sensors are calibrated against known standards.

Eg calibrate temperature sensor against a thermometer (gold standard)

- Recent advances in Sensors

MEMS – Micro Electro Mechanical Sensors

Eg Accelerometers, Gyroscopes etc

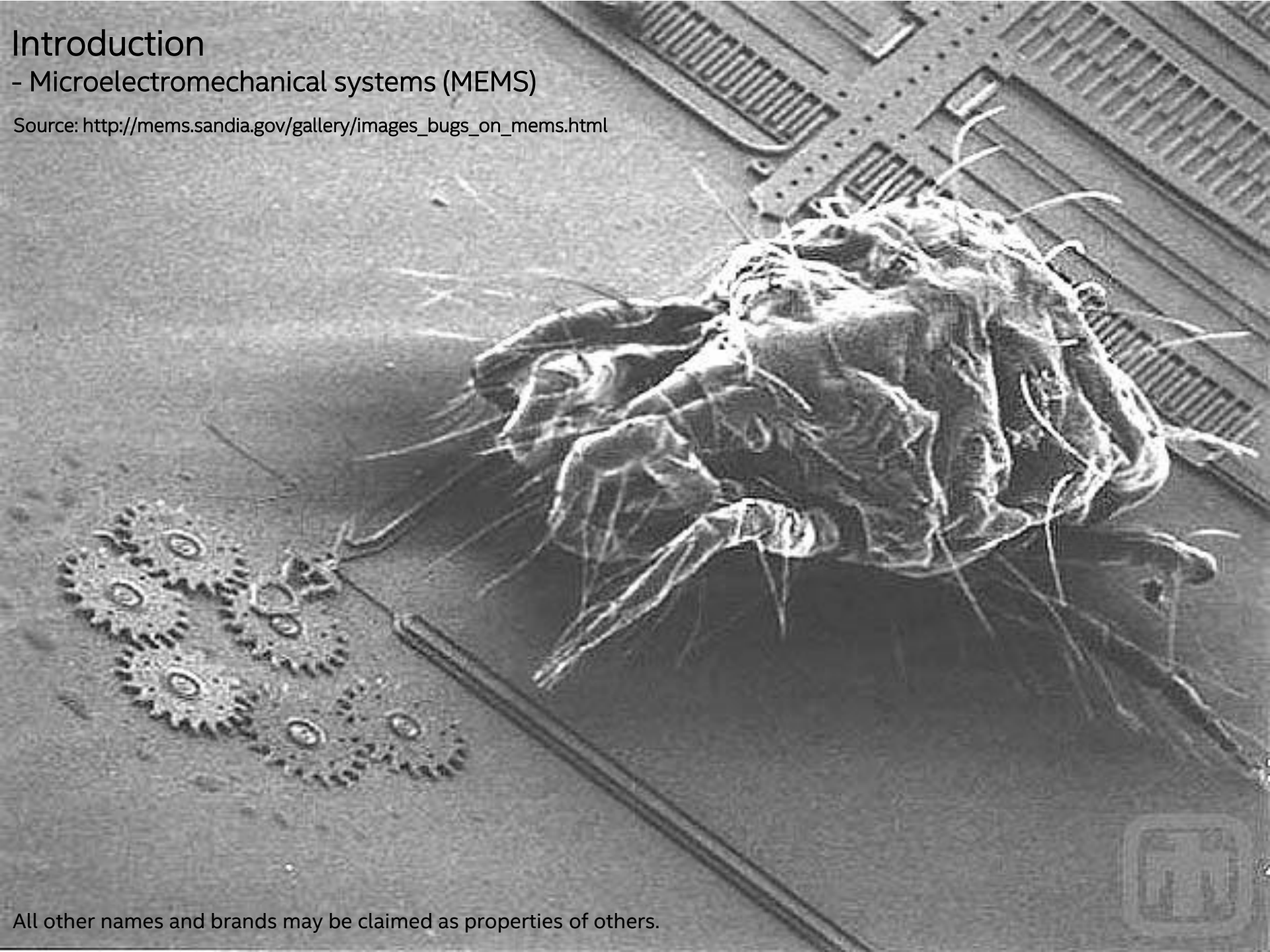
Name some sensors in a Smartphone ?

Proximity
Touch/Tap
Tilt
Accelerometer
Gyroscope
Magnetometer
GPS
Temperature
Light
Altitude/Pressure
Speech
Camera

Introduction

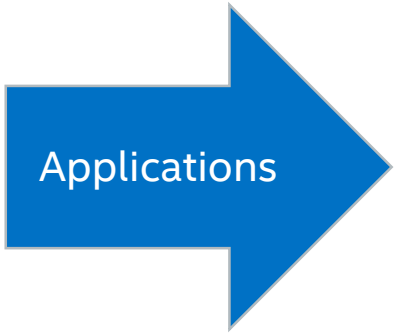
- Microelectromechanical systems (MEMS)

Source: http://mems.sandia.gov/gallery/images_bugs_on_mems.html



Introduction - What can Galileo Sense?

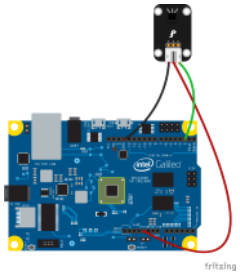
Light
Distance
Temperature
Acceleration
Vibration
Motion
Touch
Gas
Sound
Etc....

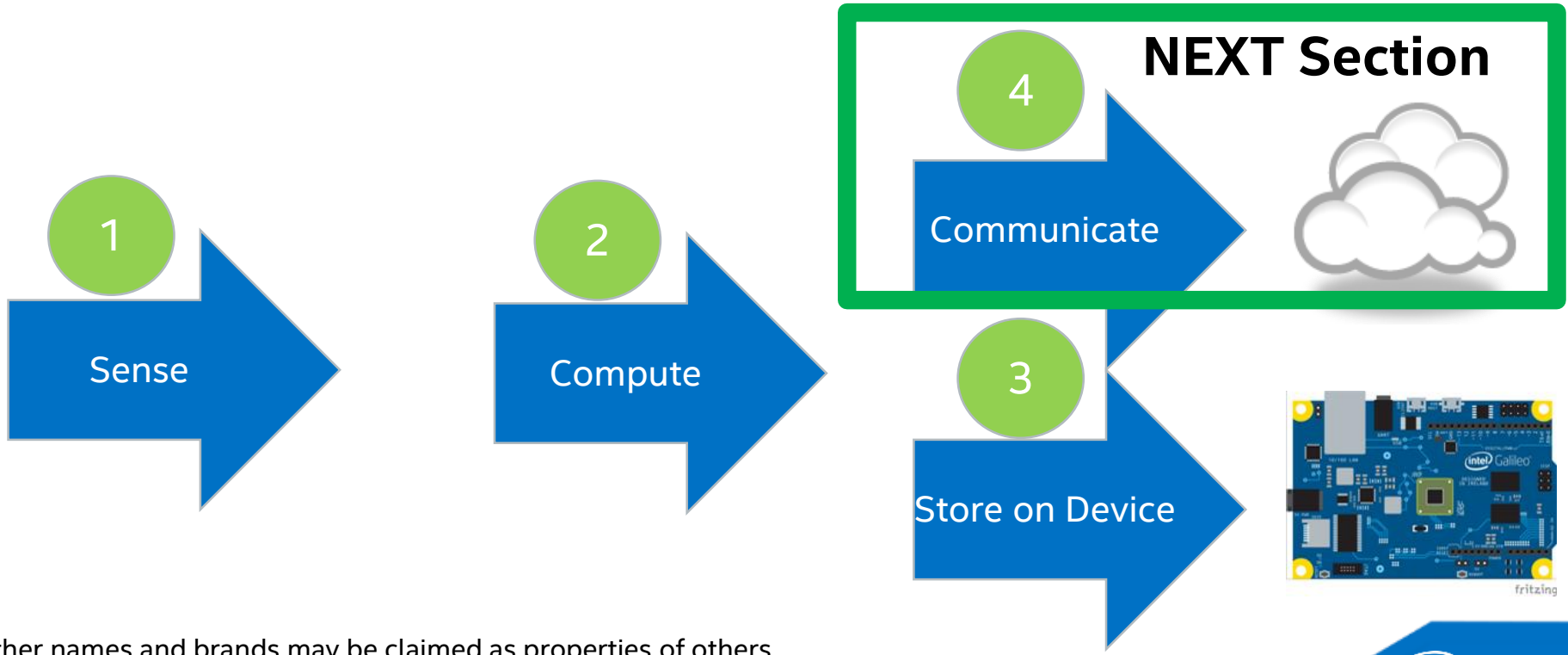


Agricultural
Automotive
Medical
Environmental
Safety
Security
Transportation/Shipping
Industrial Automation
Home Automation

Introduction – Sensor Data Flow

Sensing Motion

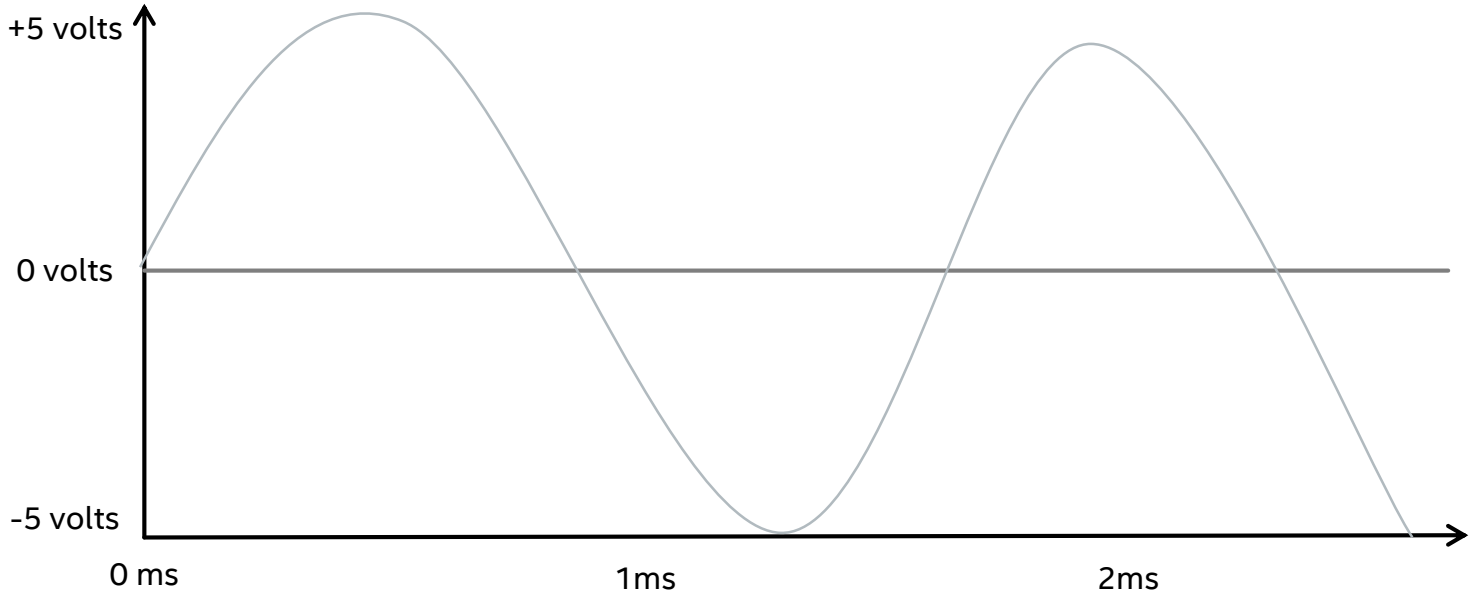




All other names and brands may be claimed as properties of others.

Introduction – Analog & Digital

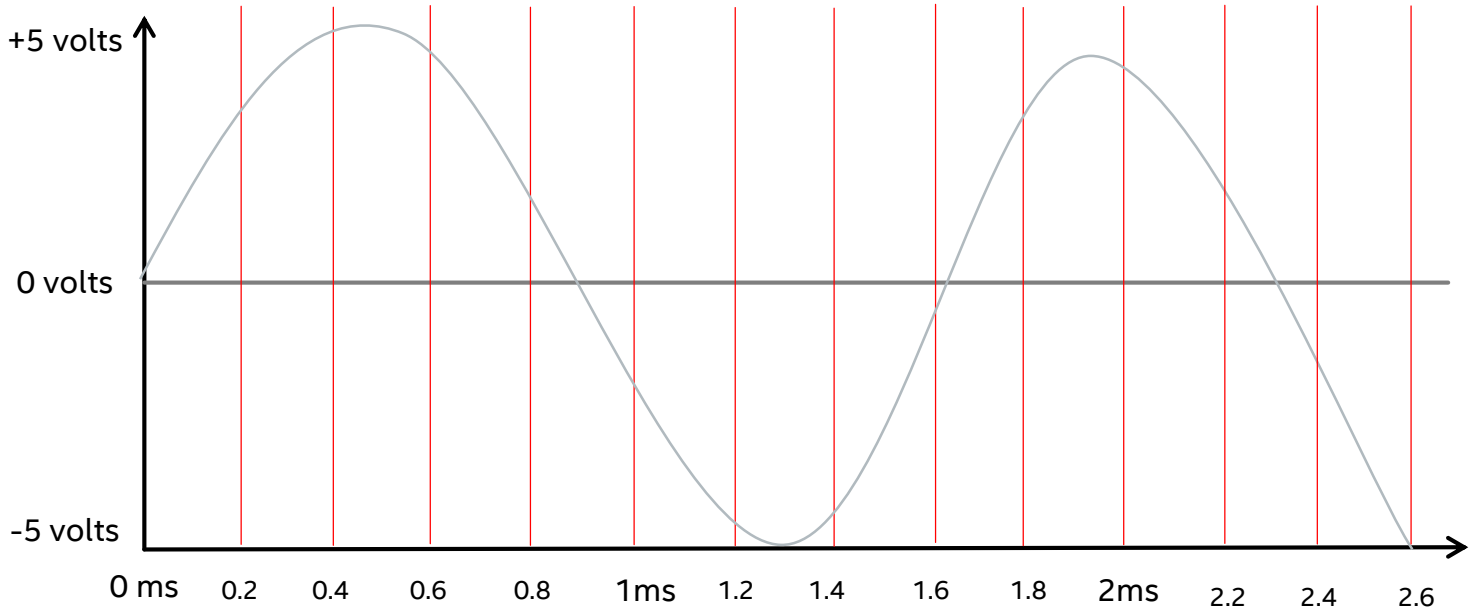
What are analog & digital signals?



Analog signal
Signal passes through infinite number of voltage levels between -5 /+5 volts.

Introduction – Analog & Digital

What are analog & digital signals?



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ADC sampling at 5kHz- take a 'snapshot' of the voltage level every 200uS

Introduction – Analog & Digital

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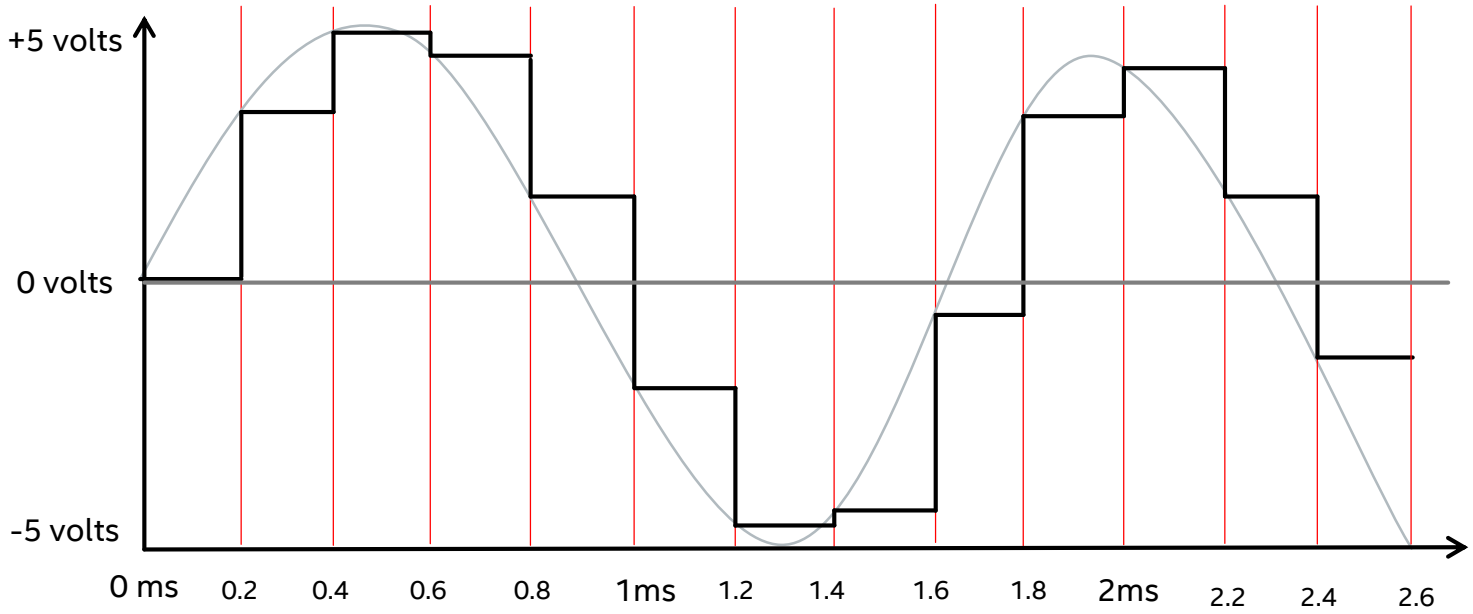


Analog signal
Signal passes through infinite number of voltage levels between -5 /+5 volts.

ADC sampling at 5kHz- take a 'snapshot' of the voltage level every 200uS

Introduction – Analog & Digital

What are analog & digital signals?

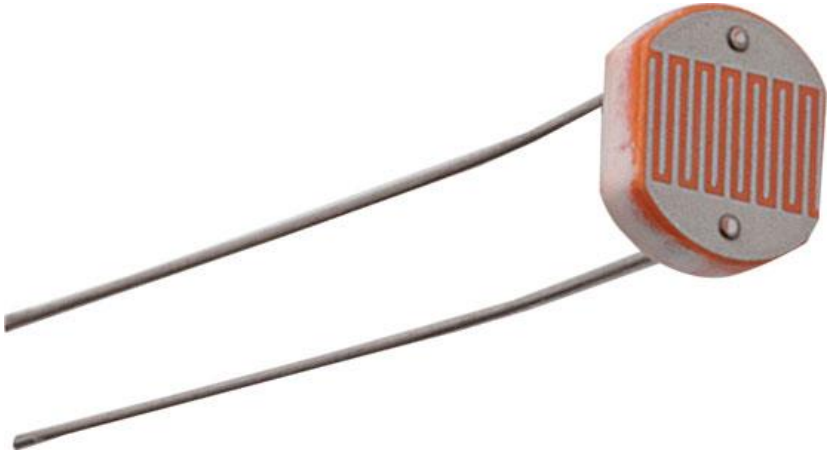
Now we have a digital signal, which contains a discrete range of values.

We can store these values in some digital storage medium, and use some tricks to approximate the analog 'curve' when we want to re-create the analog signal.

Sensors – Light

Light Sensing - Light Dependent Resistor (LDR)

- An LDR is very similar to an ordinary resistor; it is made of a semi-conductive material that will partially restrict the flow of electricity through the device.
- Variable resistor - proportional to how much light the LDR is exposed to.
- Good enough for differentiating between light & dark



DFRobot Ambient Light Sensor

Light Sensing – Basic LDR

Project Name: LDR *(Instructor Lead)*

Objective: read the value of an LDR connected to an analog pin, and print it out on the Serial port.

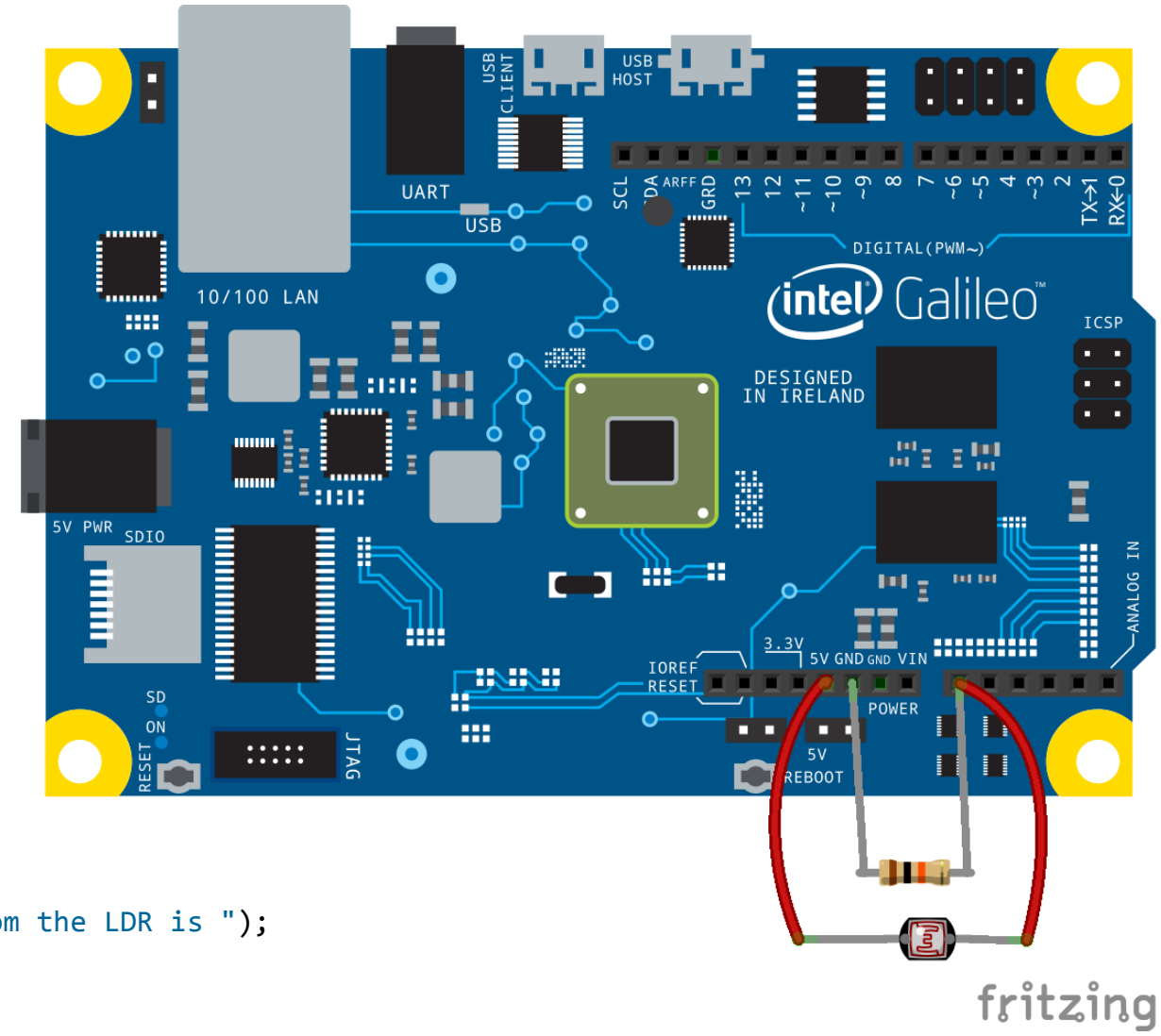
Software Elements

- analogRead()
- analogWrite()
- Serial
- delay()

Components

- Intel Galileo Board (Qty 1)
- Breadboard (QTY1)
- Jumper Wires
- 5mm LED (Qty 1)
- 220 Ohm Resistor (Qty 2)
- LDR (Qty 1)

Light Sensing – Reading the LDR




```
#define PIN 0
int value;

void setup() {
    Serial.begin(115200);
}

void loop() {
     value = analogRead(PIN);
     Serial.print("The value from the LDR is ");
     Serial.println(value);
     delay(200);
 }
```

Project Files: Lesson3-Sensing\Section1-Light\LDR_basic

Light Sensing - Engineering Challenge

Using your own circuit design and Arduino sketch, design a solution that solves the following challenges.

Use previous Lab example as needed for reference

Challenge:

Add an LED to the circuit via a PWM-enabled pin, and use values read from the LDR to control the brightness of the LED.

Engineering Challenge Review

Challenge 1: Add LED, use LDR value to control PWM signal

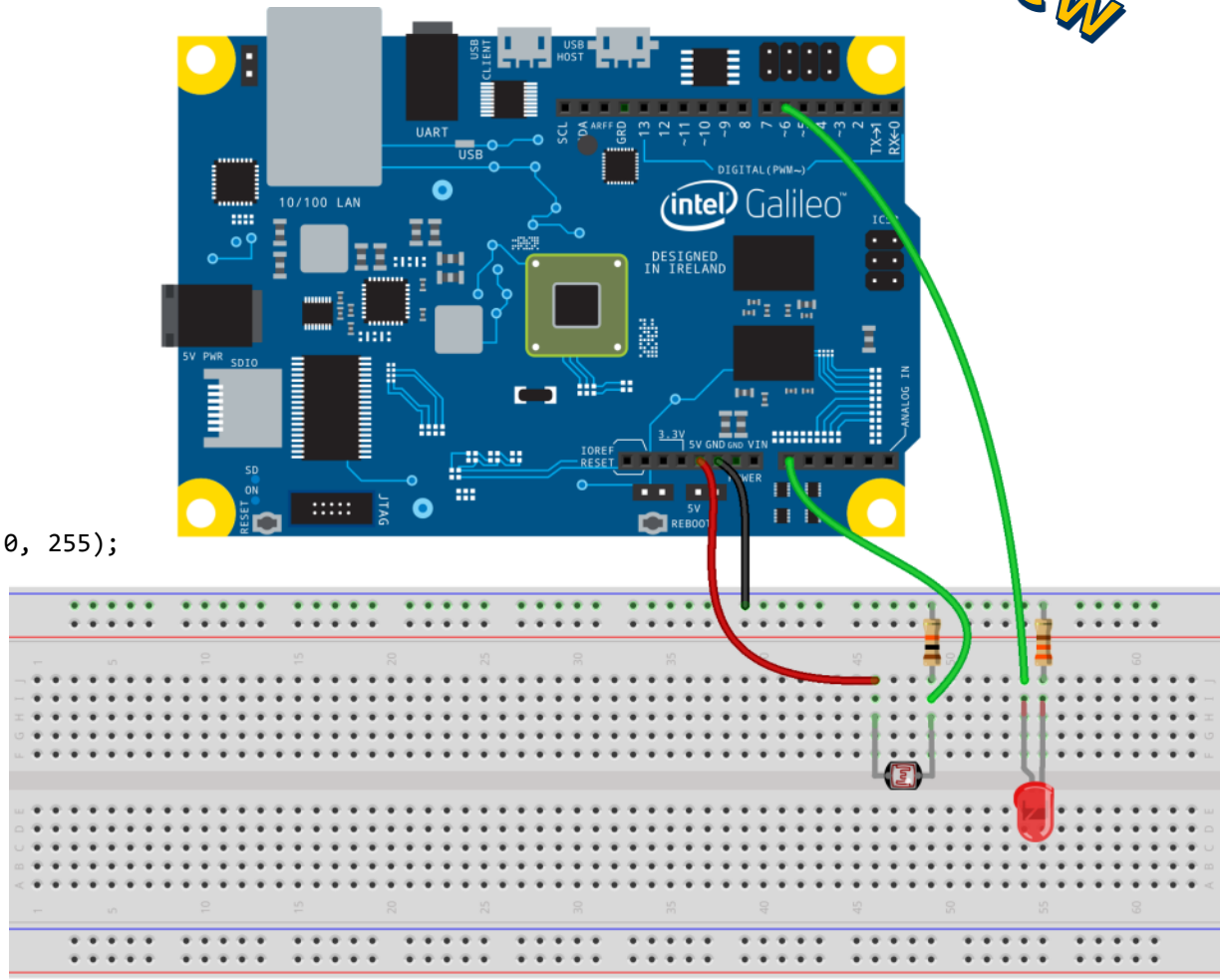
Challenge Review

```
#define A_PIN 0    //analog pin for LDR
#define D_PIN 6    //digital pin for LED

int value;

void setup() {
   pinMode(D_PIN, OUTPUT);
 }

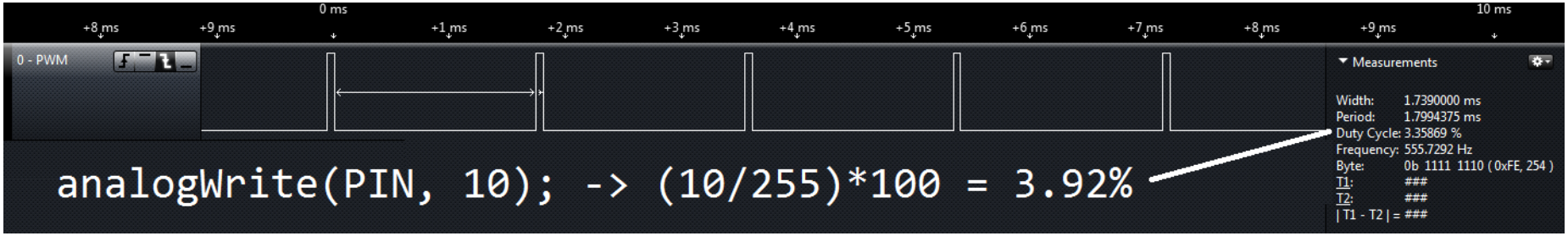
void loop() {
     value = map(analogRead(A_PIN), 0, 1023, 0, 255);
     analogWrite(D_PIN, value);
}
```



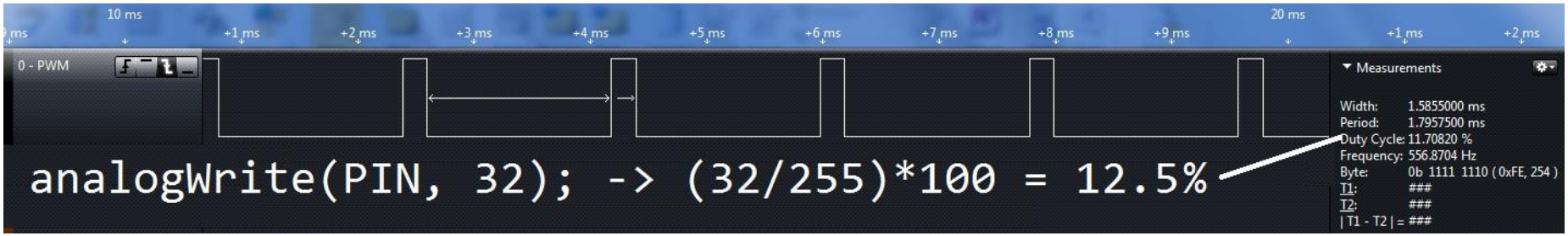
Project Files: Lesson3-Sensing\Section1-Light\LDR_challenge

PWM duty cycle on Logic Analyser

Darker – finger over LDR (PWM= ~10)



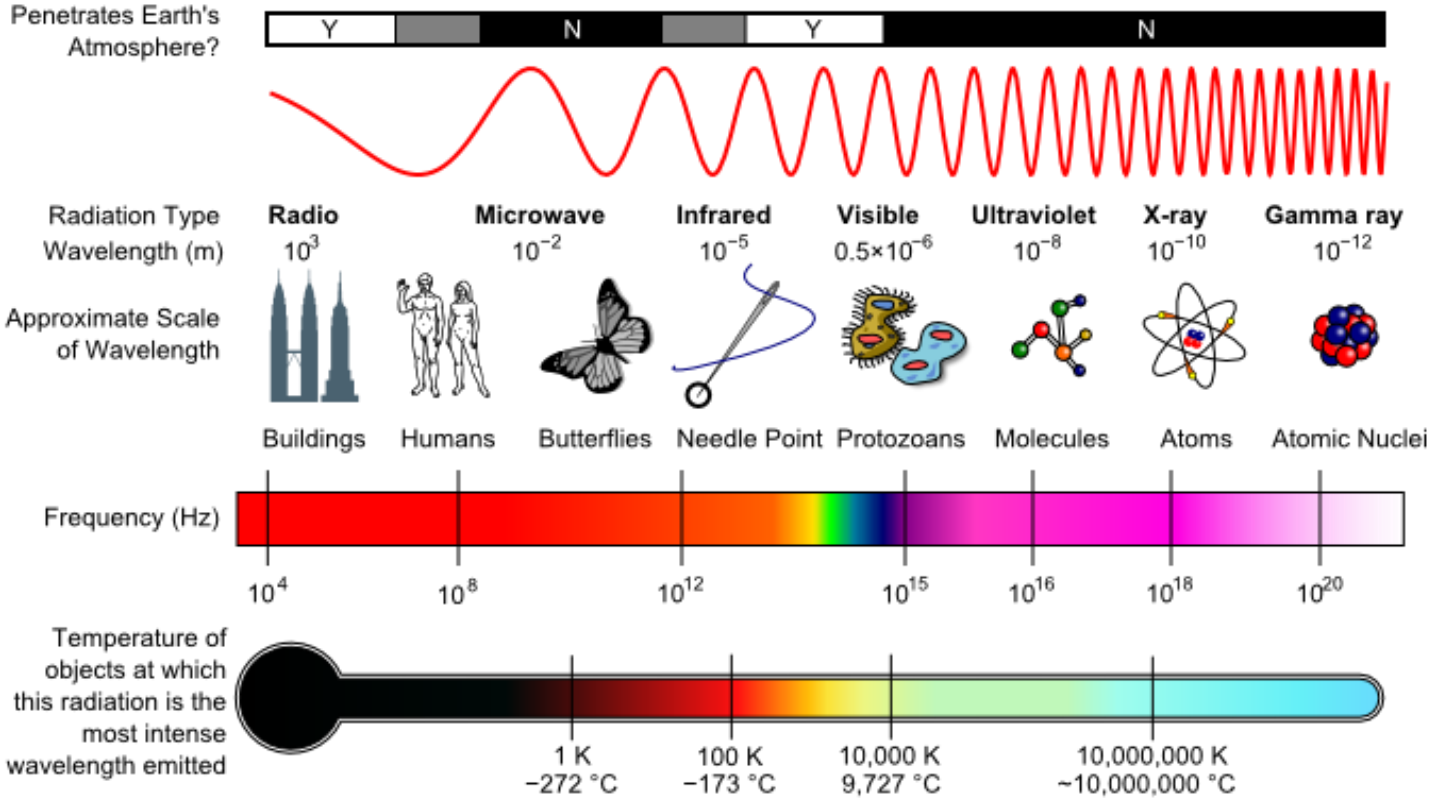
Brightness – no finger over it (PWM = ~32)



Sensors – Motion

PIR Motion Sensor

- PIR (**P**assive **I**nfra-**R**ed) motion sensors work by sensing changes in infra-red energy.
- All objects with a temperature above absolute zero (which is about -270 degrees celcius, so pretty much everything) emit heat energy in the form of infra-red radiation.



PIR Motion Sensor

A PIR sensor is not a temperature / heat sensor

Most PIR sensors are very sensitive

- Will detect movement even if the moving object has no change in temperature.
- Detects the smaller changes in the various sources of infra-red radiation around it.

The PIR sensor has a digital output; high or low.

- High = motion has been detected.
- Low = Normal and no motion is being detected.

Simple, right? Let's try an example……

PIR Motion Sensor

LAB

Project Name: PIR motion sensor

Objective: Read the value from the motion sensor, print a message when motion is detected.

Software Elements

- analogRead()
- Serial
- delay()

Components

- Intel Galileo Board (Qty 1)
- Breadboard (QTY1)
- Jumper Wires
- PIR motion sensor

PIR Motion Sensor

LAB

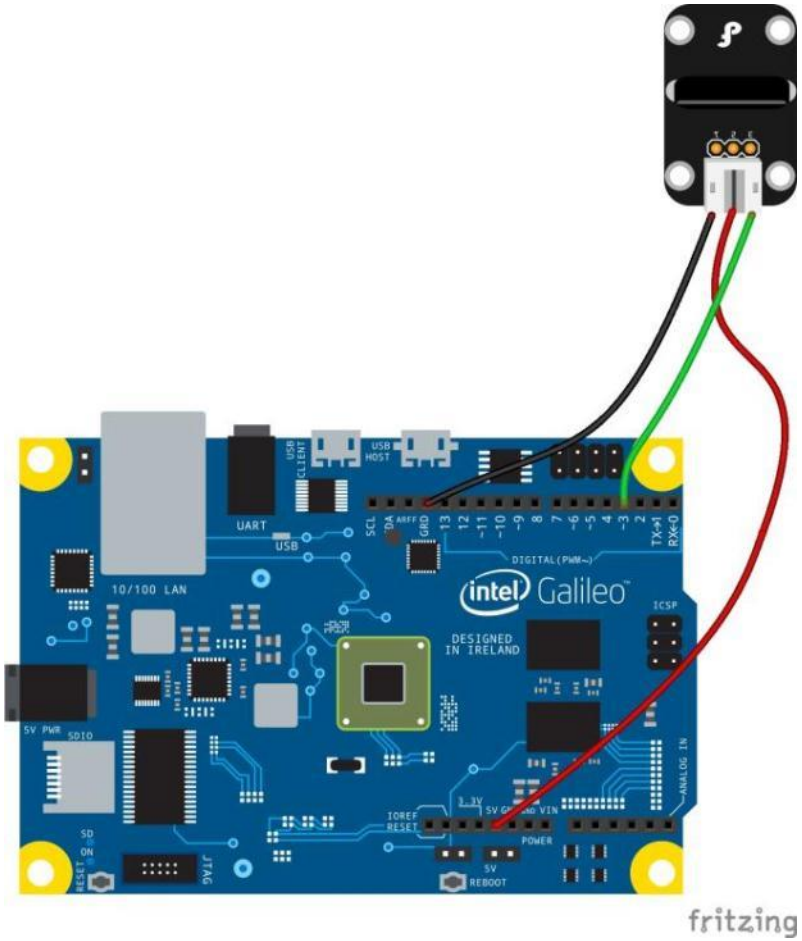
Sensor Reference Page:

http://www.dfrobot.com/wiki/index.php/Digital_Infrared_motion_sensor_(SKU:SEN0018)

```
short pin = 3;

void setup()
{
   Serial.begin(115200);
   pinMode(pin, INPUT);
}

void loop() {
     if (digitalRead(pin) == 1)
     {
         Serial.println("Motion detected!");
     }
}
```



Project Files: Lesson3-Sensing\Section2-Motion\PIR_motion_sensor_basic

PIR Motion Sensor

Well, it sort of works, but there's one problem...

PIR Motion Sensor

Well, it sort of works, but there's one problem...

```
Motion detected!
Motion detected!
Motion detected!
Motion detected!
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Motion detected!
Motion detected!
Motion detected!
Motion detected!
Motion detected!
Motion detected!
Motion detected!
Motion detected!
Motion detected!
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Motion detected!
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Motion detected!
```

PIR Motion Sensor

LAB

```
#define MOTION 1
#define NOMOTION 0

short state = NOMOTION;
short pin = 3;
short value;

void setup()
{
   Serial.begin(115200);
   pinMode(pin, INPUT);
}

void loop() {
      value = digitalRead(pin);
      if (value == MOTION && state == NOMOTION)
      {
           state = MOTION;
           Serial.println("Motion detected!");
      }

      else if (value == NOMOTION && state == MOTION)
      {
          state = NOMOTION;
          Serial.println("No more motion.");
      }
}
```

To stop the message printing continuously while motion is detected, we'll add an extra variable called `state`, to keep track of the state of the pin we are reading.

Initially, `state` will contain a value of `0`. After we take a reading from the motion sensor, inside the condition portion of the `if` statement, we check if the motion sensor's pin is high **and** if the state variable is equal to `0`. If both of these are true, then set state to `1` and do the `Serial.print()`.

Now, we also have to add a second `if` statement – if the signal from the motion sensor goes low and `state` is still equal to `1`, we must set it back to `0` to the next high signal can be detected.

Project Files: Lesson3-Sensing\Section2-Motion\PIR_motion_sensor_basic

PIR Motion Sensor - Engineering Challenge

Using your own circuit design and sketch, design a solution that solves the following challenges.

Use previous Lab example as needed for reference

Challenge:

Add an LED to the previous circuit. When motion is detected, fade the LED from dark up to full brightness. Keep the LED lit until motion is not detected, at which point the LED should fade down, and remain off until motion is detected again.

Challenge 1:

PIR Motion sensor with LED

Challenge Review

```
#define MOTION 1
#define NOMOTION 0
#define INPIN 3
#define OUTPIN 5

short state = NOMOTION;
short value;

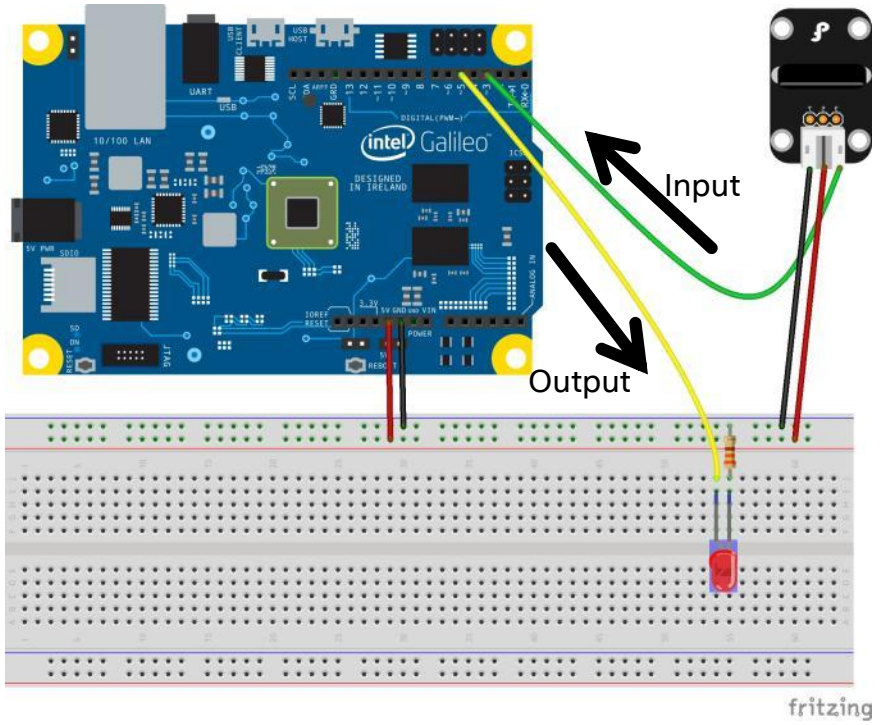
void setup()
{
   Serial.begin(115200);
   pinMode(INPIN, INPUT);
}

void fadeUp(int pin)
{
    for (int i = 0; i <= 255; i++)
    {
        analogWrite(pin, i);
    }
}

void fadeDown(int pin)
{
    for (int i = 255; i >= 0; i--)
    {
        analogWrite(pin, i);
    }
}

void loop()
{
      value = digitalRead(INPIN);
      if (value == MOTION && state == NOMOTION)
      {
          state = MOTION;
          fadeUp(OUTPIN);
      }

      else if (value == NOMOTION && state == MOTION)
      {
          state = NOMOTION;
          fadeDown(OUTPIN);
      }
}
```



Project Files: Lesson3-Sensing\Section2-Motion\PIR_motion_sensor_challenge

Break Time ☺

Sensors – Vibration

Vibration sensor

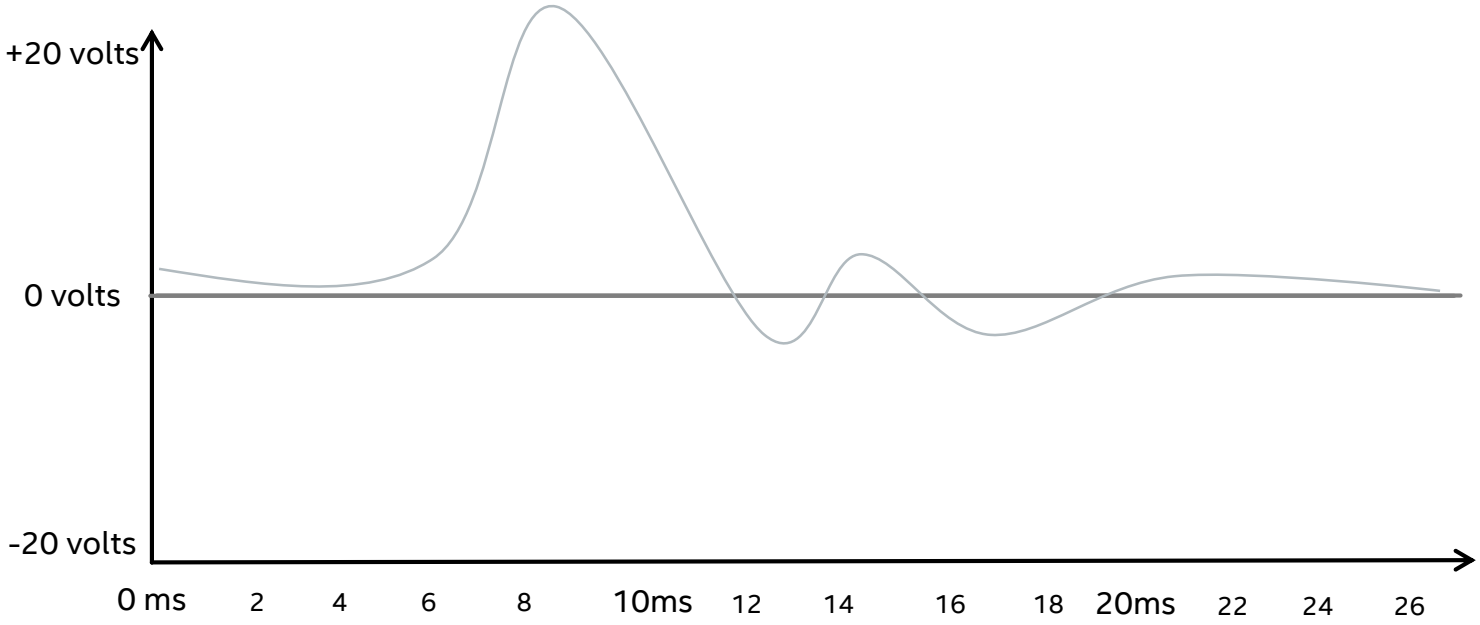
Commonly known as a '**piezo element**', '**piezo transducer**' or simply '**piezo disc**'.

- It consists of a small slice of piezo crystal, coupled with thin copper disc.
- Voltage Spike across the copper disc and piezo element occurs when something impact the disc (i.e. if you drop it, tap it, slap it etc),
- This sensor is **passive**, meaning no power source is required for it to operate.

Now, let's look at some of the problems we'll meet in trying to read this sensor, and how we can work around them....

Vibration sensor

here's an approximation of what the voltage spike looks like when you give the piezo a single tap.



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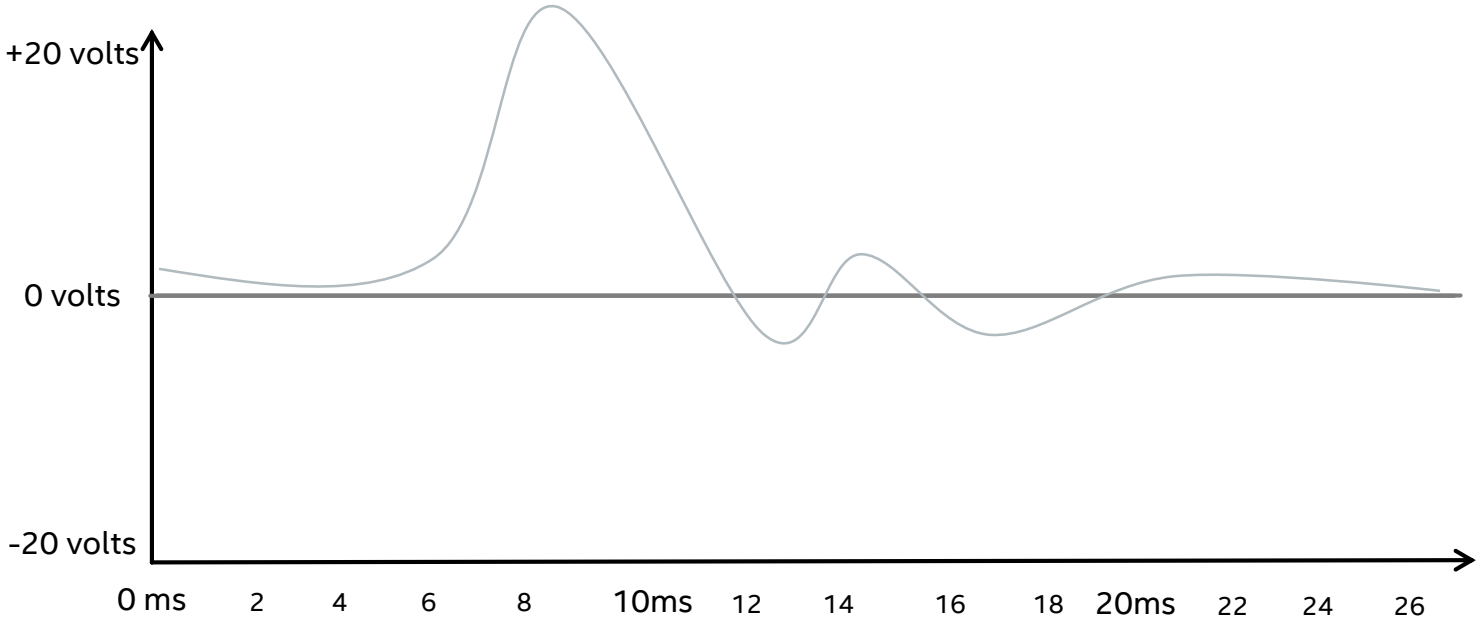

Let's write a quick sketch to read this sensor and detect an impact:

```
void setup()
{
   Serial.begin(115200);
}

void loop()
{
   if (analogRead(0) > 600)
   {
      Serial.println("Impact!");
   }
}
```

Vibration sensor

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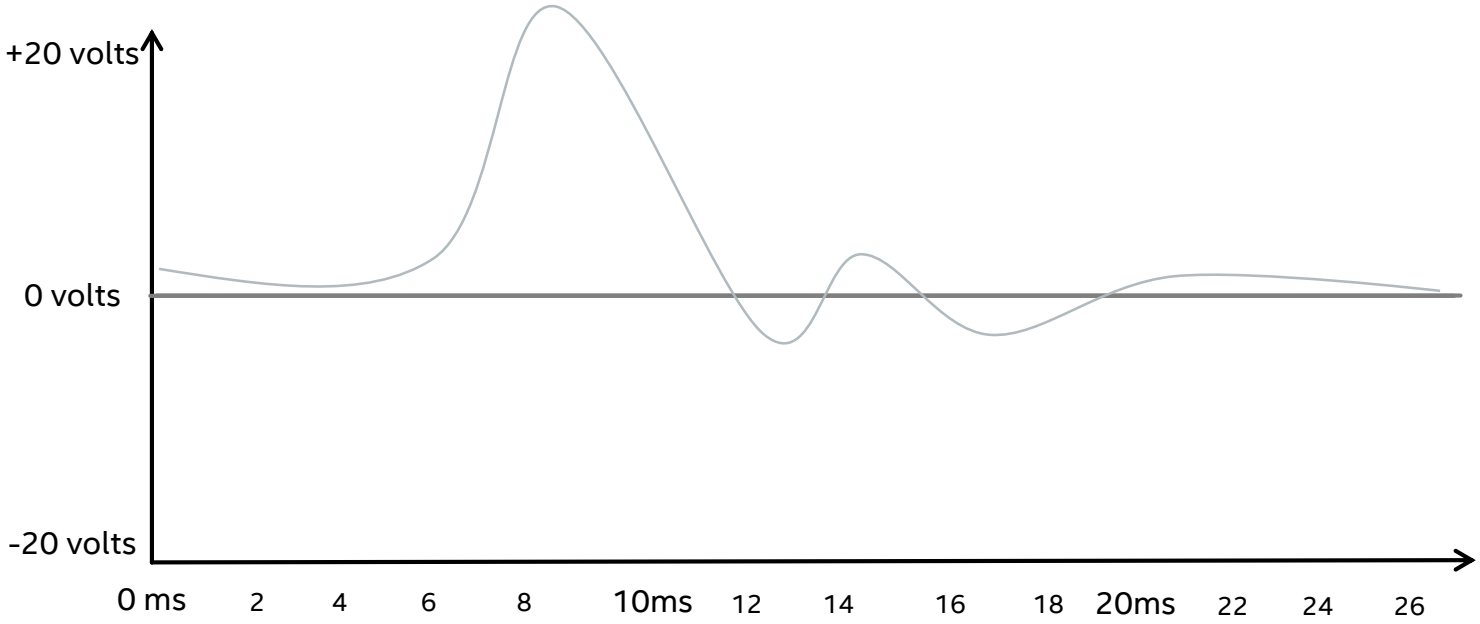

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Can anyone see a problem with this program?!

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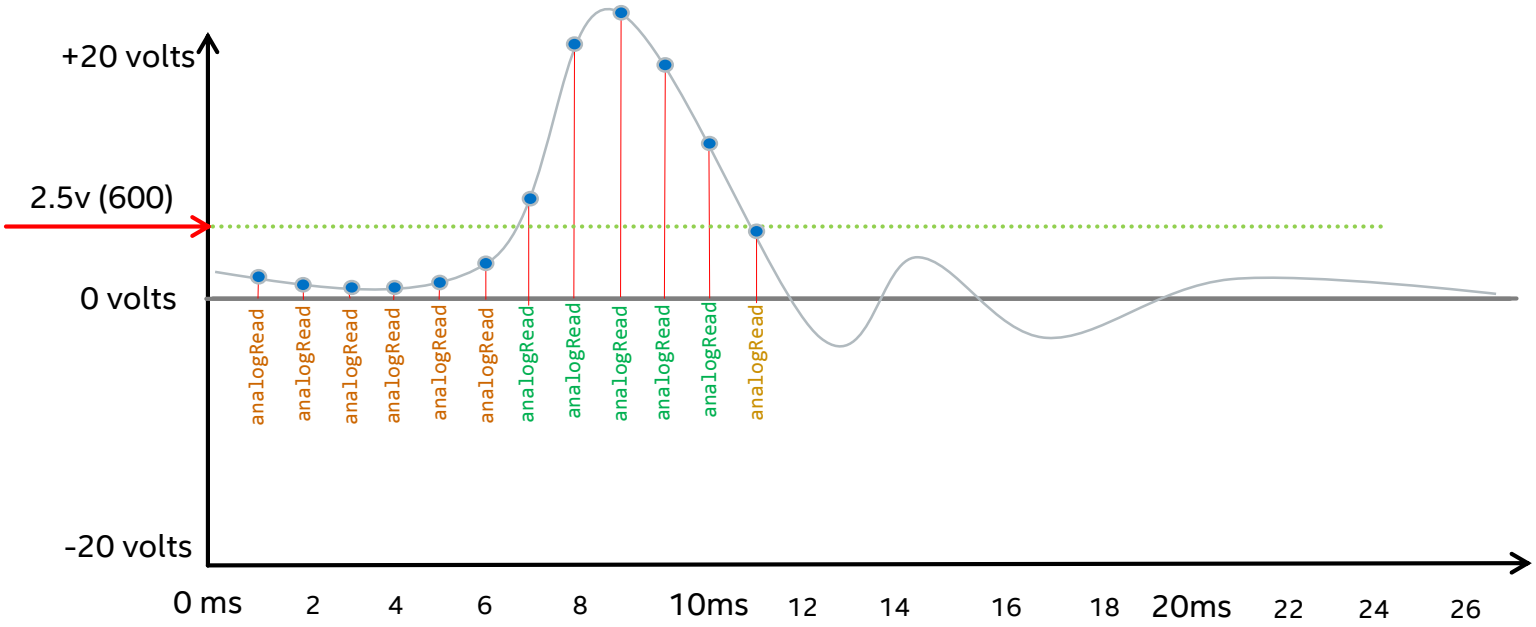

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Output:

```
Impact!
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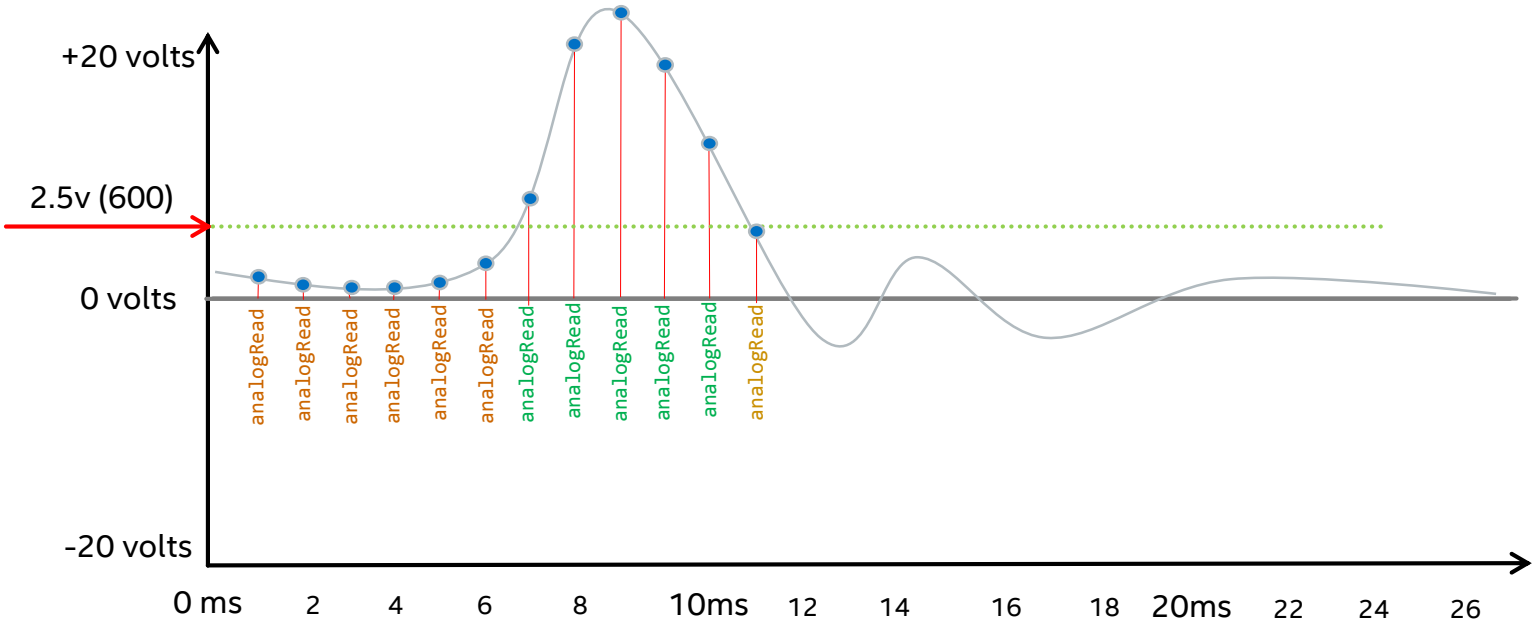

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}

void loop()
{
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   {
      Serial.println("Impact!");
   }
}
```

Output:

```
Impact!
Impact!
Impact!
Impact!
Impact!
```

After the initial impact, the piezo signal takes some time to decay- only a few milliseconds. But the Galileo's ADC is taking readings fast enough that, by the time it comes around for the next reading, the signal is still decaying and it registers **another** impact (even though it's still decaying from the **first** impact)

Vibration sensor

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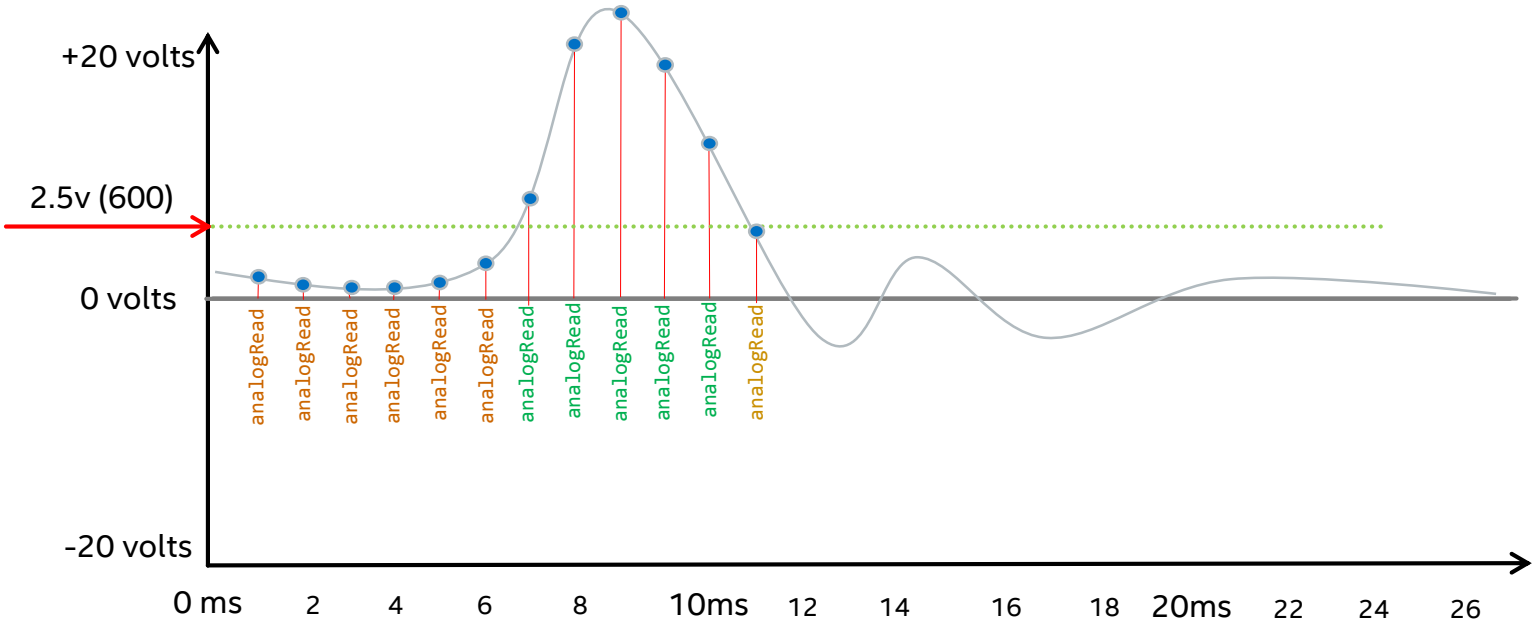

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Before we move on to the lab, see if you can fix this sketch by adding **one more line**

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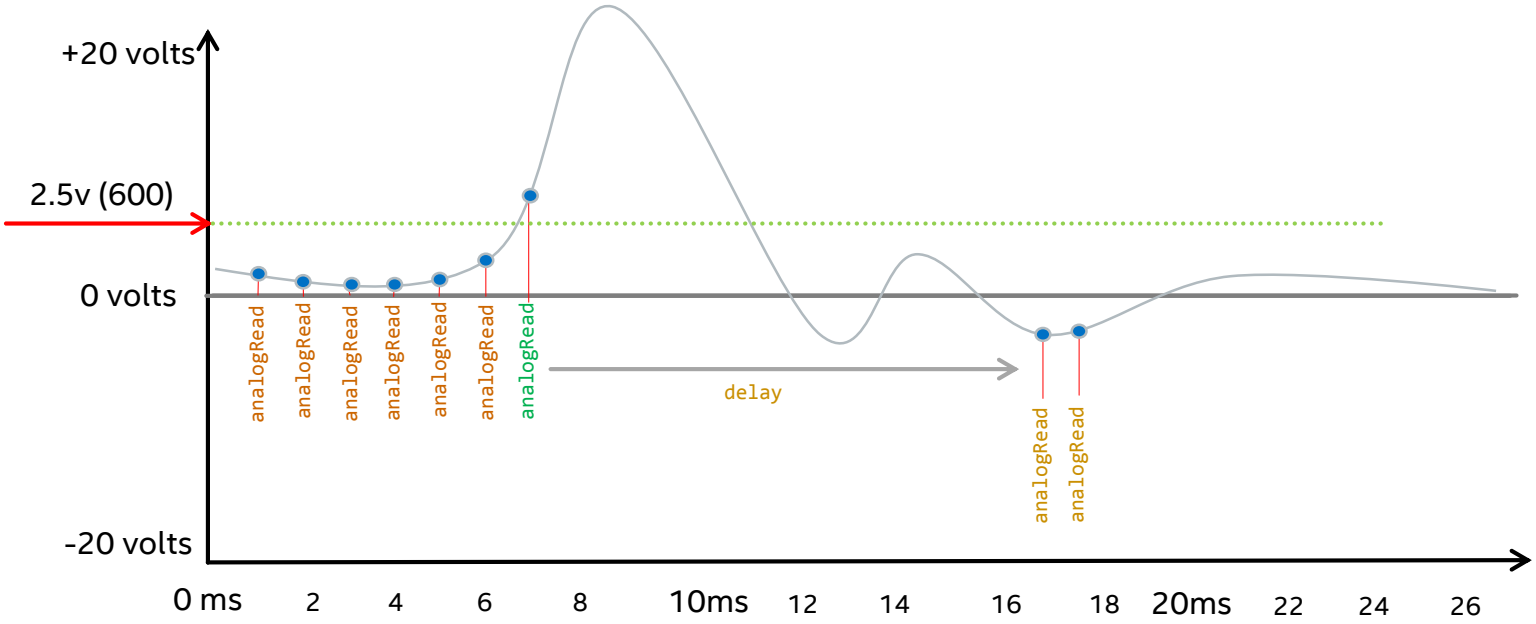

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```
void setup()
{
   Serial.begin(115200);
}

void loop()
{
   if (analogRead(0) > 600)
   {
      Serial.println("Impact!");
      delay(10);
   }
}
```

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Vibration sensor

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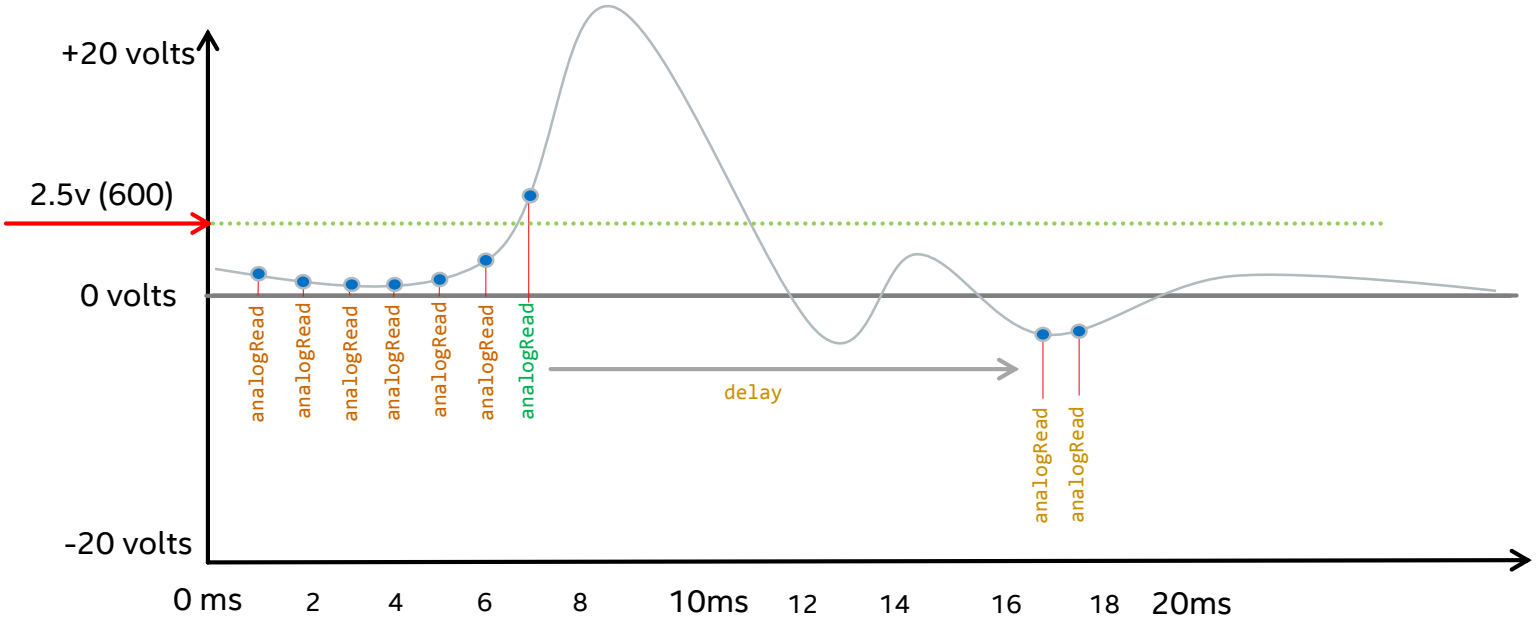

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{
   Serial.begin(115200);
}

void loop()
{
   if (analogRead(0) > 600)
   {
      Serial.println("Impact!");
      delay(10);
   }
}
```

Before we move on to the lab, see if you can fix this program by adding **one more line**

NOTE: This technique works in our simple case, but it's not the best option since **delay()** blocks execution (program will wait for 10 ms before continuing)

Sensors - Piezo element

LAB

Project Name: piezo debouncing *(Instructor Lead)*

Objective: read the analog voltage from a piezo element, and use **non-blocking** debouncing techniques to determine if there has been a 'hit'

Software Elements

- analogRead()
- millis()
- Serial
- delay()

Components

- Intel Galileo Board (Qty 1)
- Breadboard (QTY1)
- Jumper Wires
- 1 Mega Ohm Resistor (Qty 1)

Piezo debouncing

LAB

Sensor Reference Page:

http://ie.farnell.com/multicomp/abt-448-90-rc/piezo-element-35mm-2-900hz-leaded/dp/1675549

Or you can use this one this one if you have a sensor kit. I found threshold of dfrobot sensor to be ~110
http://www.dfrobot.com/wiki/index.php?title=Analog_Piezo_Disk_Vibration_Sensor_(SKU:DFR0052)

```
#define THRESH 300
//values higher than this value register a 'hit'

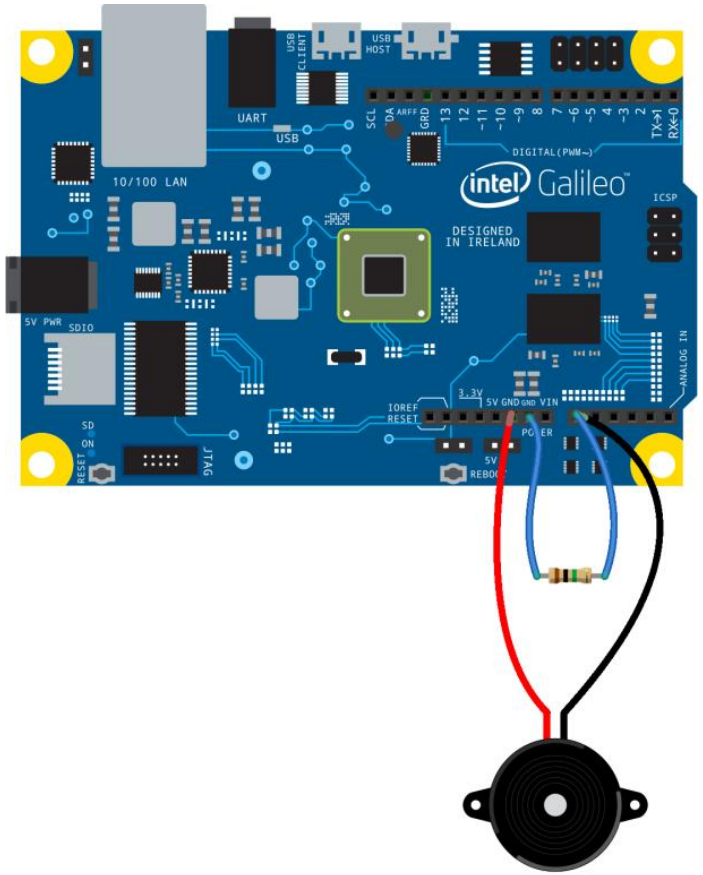
#define WAIT 150
 //how long we wait before reading again

#define PIN 0
int value;
long timer = 0;

void setup() {
     Serial.begin(115200);
 }

void loop() {
    value = analogRead(PIN);
    if (value > THRESH && timer == 0) {
        timer = millis();
        Serial.println("That's a hit!");
    }

    else if ((millis() - timer) >= WAIT && value < THRESH) {
        timer = 0;
    }
 }
```



Project Files: Lesson3-Sensing\Section3-Vibration\vibration_sensor_basic

Sensors – Touch

Touch sensor

- This capacitive touch sensor works kind of like a capacitor, except your body acts as one half of the capacitor.
- So when you touch your finger (or any other body part) to the metal surface, the significant change in capacitance indicates that a touch has occurred.
- This underlying concept is the basis for touch screens on phones and tablets.

Image source: http://www.dfrobot.com

Before we move on to the lab, take 10 minutes and see if you can adapt the code from the 'PIR motion sensor' lesson to work for this sensor.

Touch Sensor

Project Name: Touch sensor *(Instructor Lead)*

Objective: Read the touch sensor and detect when somebody is touching it.

Software Elements

- digitalRead()
- millis()
- Serial
- delay()

Components

- Intel Galileo Board (Qty 1)
- Breadboard (QTY1)
- Jumper Wires
- 1 Mega Ohm Resistor (Qty 1)

Touch Sensor

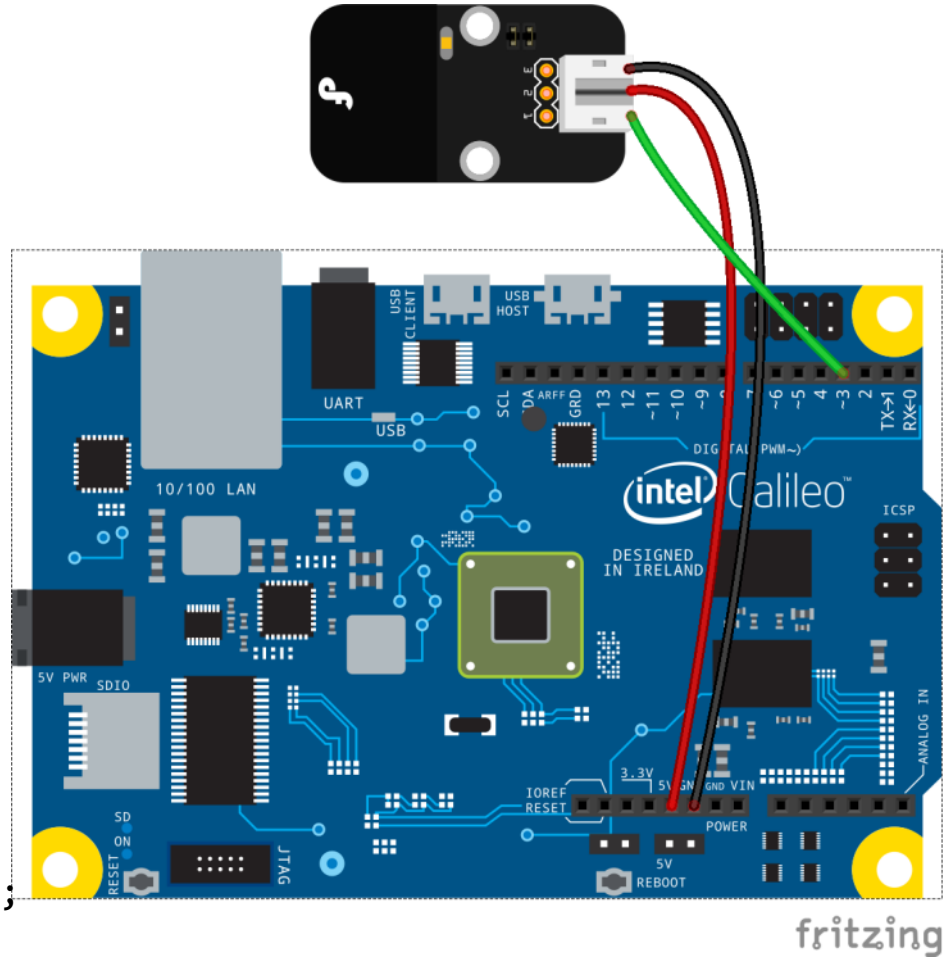
LAB

Sensor Reference Page:

http://www.dfrobot.com/index.php?route=product/product&product_id=78#.U5nw7vk7uSp

```
#define PIN 3
short state = 0;
short value;
void setup()
{
    Serial.begin(115200);
    pinMode(PIN, INPUT);
}

void loop()
{
    value = digitalRead(PIN);
    if (value == 1 && state == 0)
    {
        state = 1;
        Serial.println("Touch");
    }
    else if (value == 0 && state == 1)
    {
        state = 0;
        Serial.println("Finger lifted");
    }
}
```



Project Files: Lesson3-Sensing\Section3-Touch\touch_sensor_basic

Touch Sensor- Engineering Challenge

Using your own circuit design and Arduino sketch, design a solution that solves the following challenges.

Use previous Lab example as needed for reference

Challenge:

Add an LED to your circuit, and use the touch sensor to control the brightness of the LED in steps. Use 4 steps, with each step brighter than the last. When the highest step is reached, the next touch will send it back to the first step.

Engineering Challenge Review

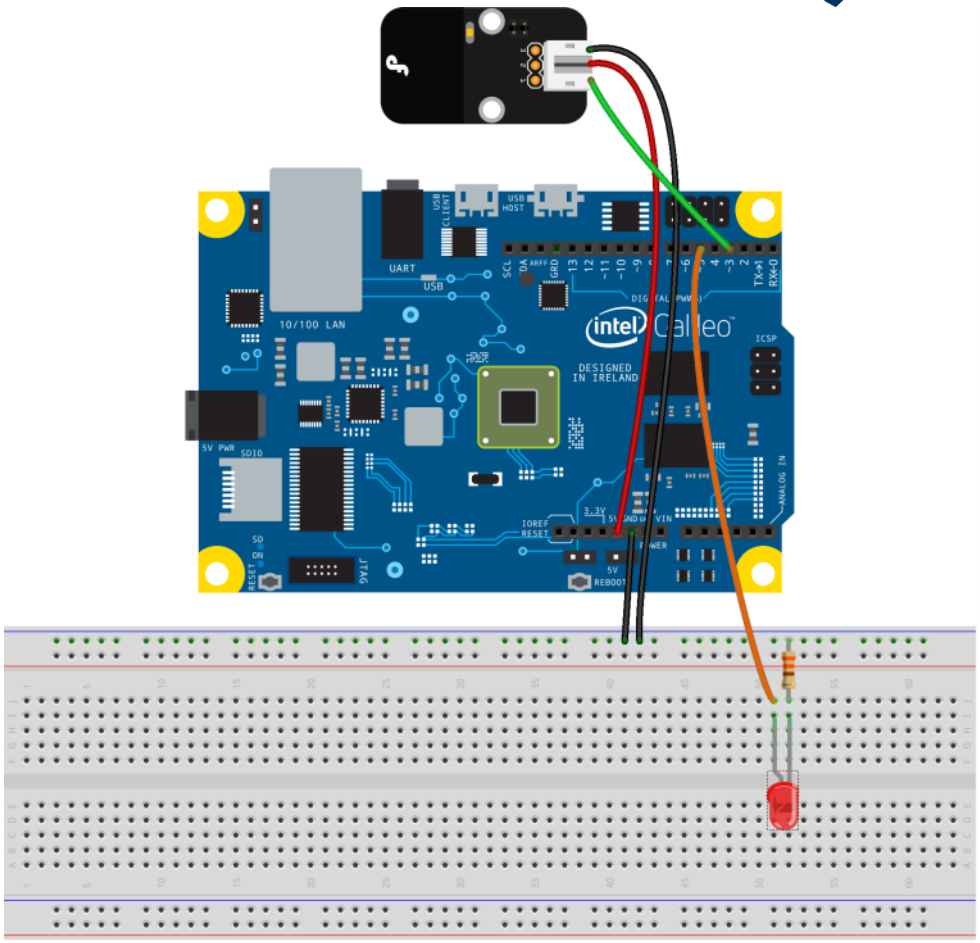
Challenge Review

Challenge 1: Cycle through LED brightness levels

```
#define TOUCH 3
#define LED 5
short state = 0;
short value;
const int step = 80;
const int PWM_MAX = 255;
short brightness = 0;

void setup()
{
    Serial.begin(115200);
    pinMode(TOUCH, INPUT);
}
void loop()
{
    value = digitalRead(TOUCH);
    if (value == 1 && state == 0)
    {
        state = 1;
        if (brightness >= PWM_MAX)
            brightness = 0;
        else
            brightness += step;

        analogWrite(LED, brightness);
    }
    else if (value == 0 && state == 1)
    {
        state = 0;
    }
}
```



Project Files: Lesson3-Sensing\Section4-Touch\touch_sensor_challenge

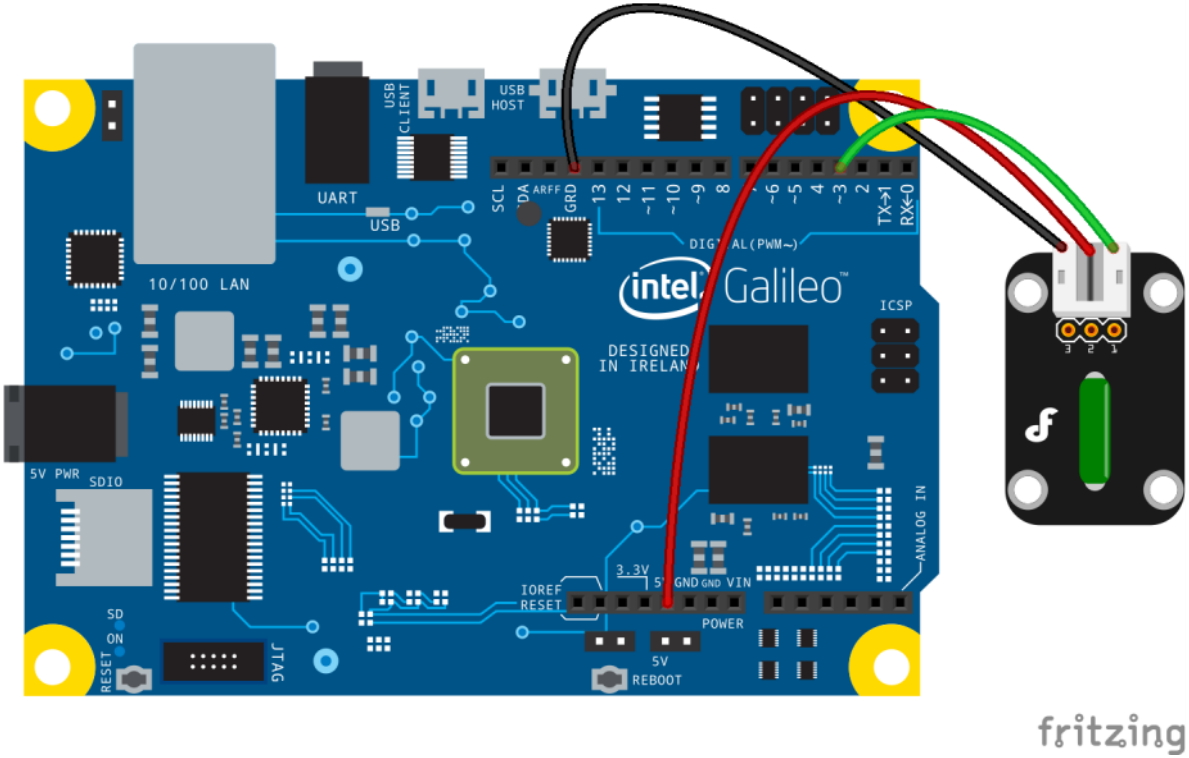
Sensors – Tilt

Tilt sensor

- For this last sensor, you're going to be completely on your own. No code or explanation is provided for this sensor- see if you can figure out what it does and how to use it!

Sensor Reference Page:

http://www.dfrobot.com/index.php?route=product/product&product_id=77#.U5n10fk7uSo



Break Time ☺

Sensors – Sensor Logger

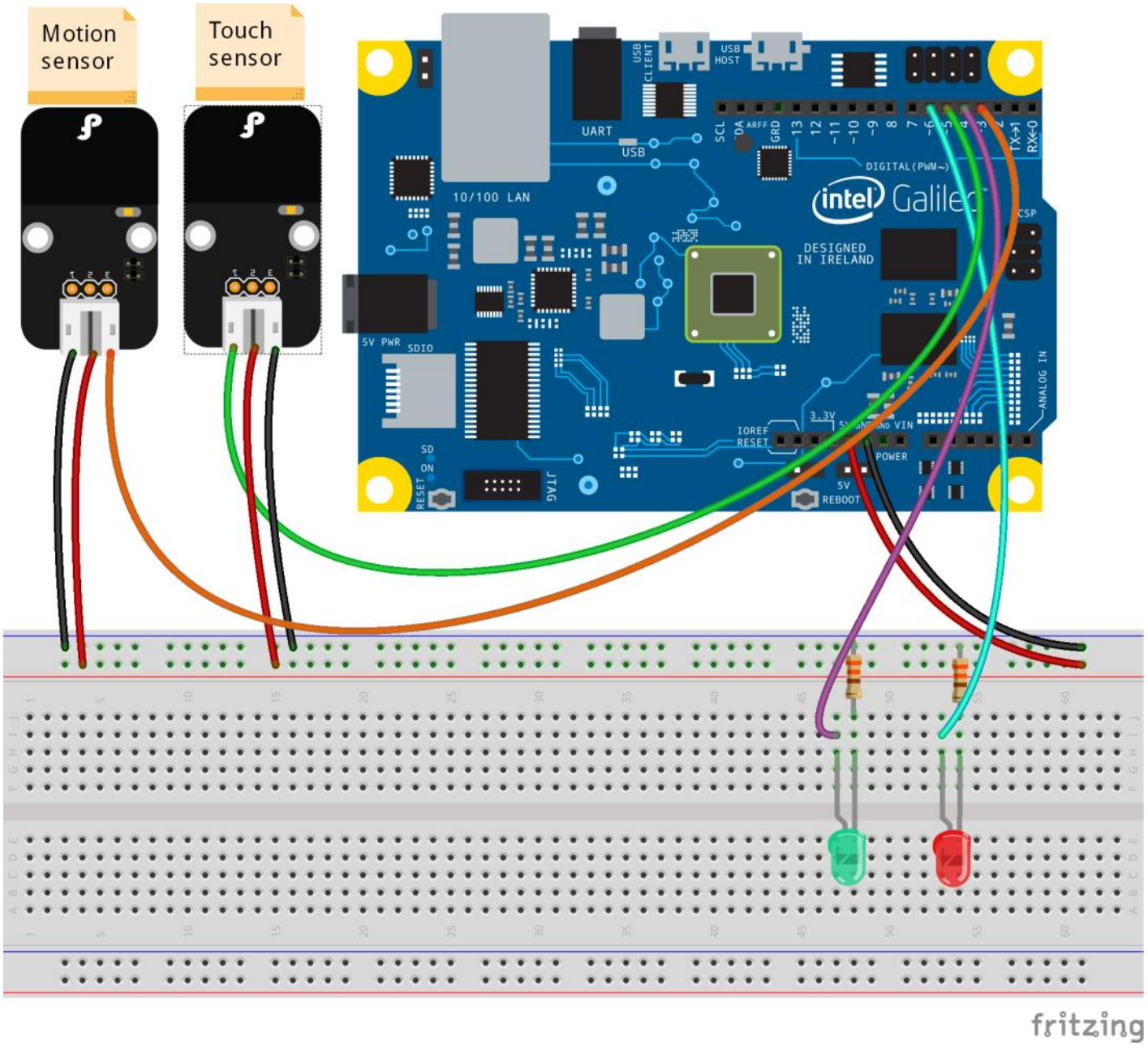
Sensor Logger – Touch enabled

Using your own circuit design and Arduino sketch, design a solution that solves the following challenges.

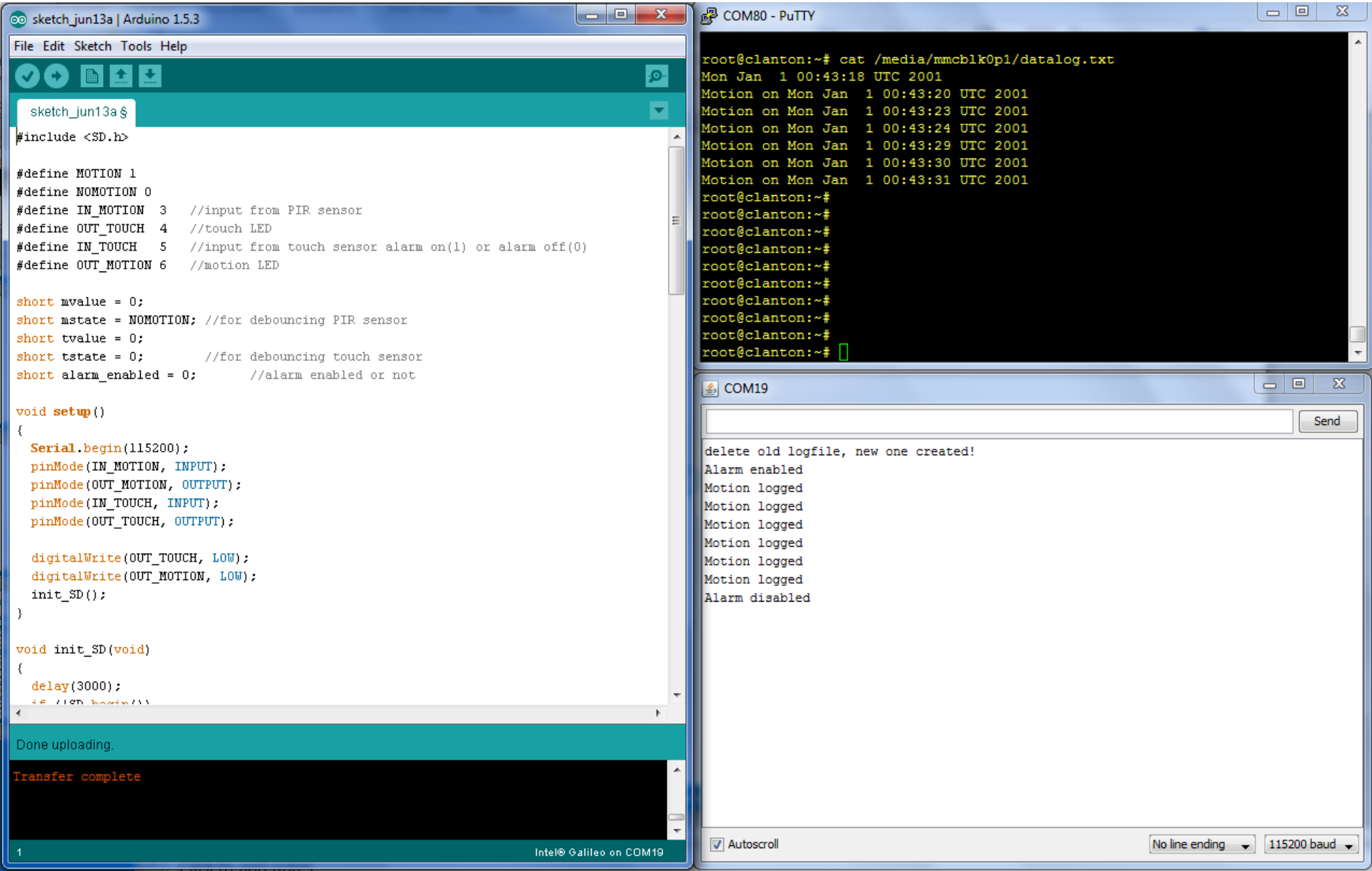
Use previous Lab example as needed for reference

Challenge:

Build a motion detection system that is enabled/disabled through touch. When enabled it will log (record) all motion events to the SD card on your Galileo.

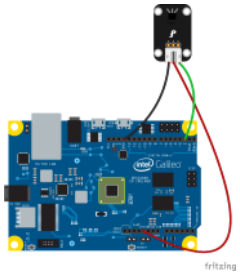

Motion sensor
Touch sensor
10/100 LAN
UART
USB
USB CLIENT
USB HOST
DIGITAL(PWM~)
DESIGNED IN IRELAND
5V PWR
SDIO
IOREF
RESET
POWER
ANALOG IN
JTAG
fritzing

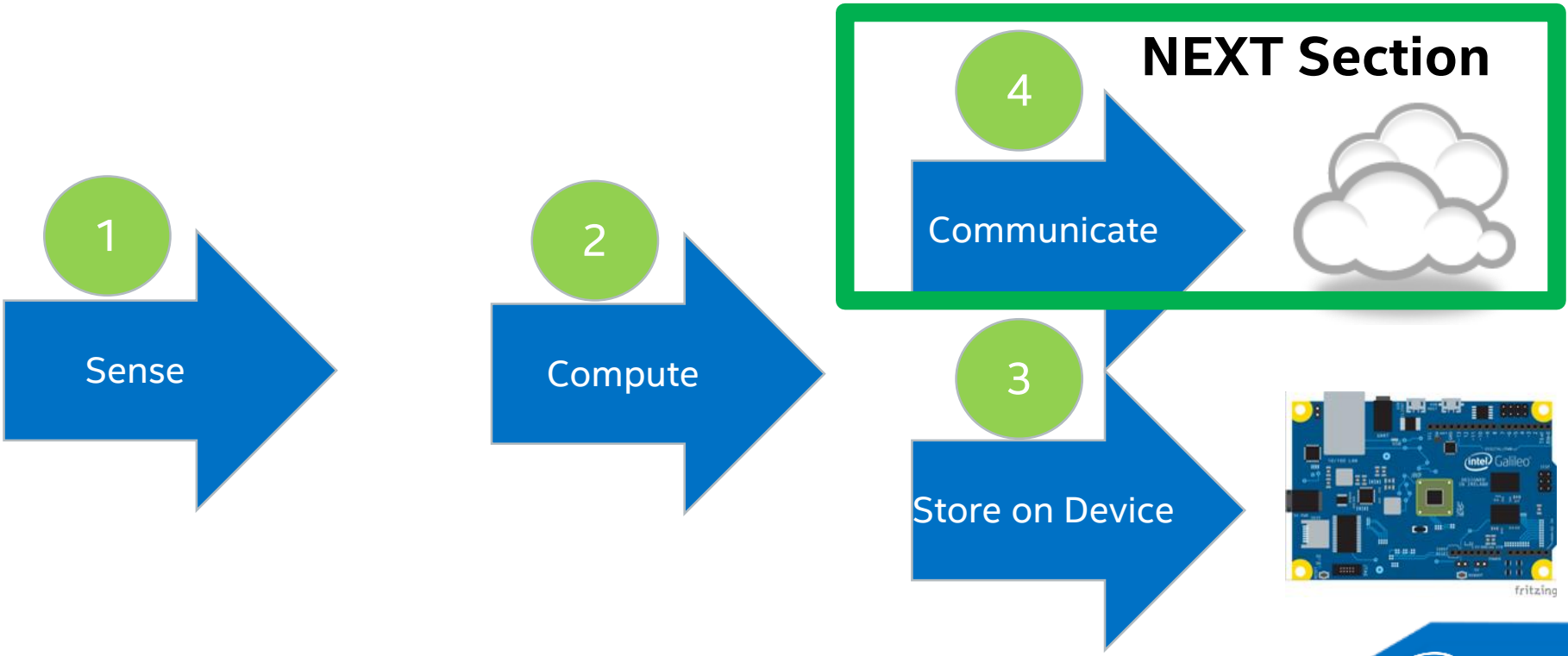
Motion data logged to Galileo SD card



Conclusion – We have covered 1, 2 and 3

Sensing Motion





Congratulations ☺

Legal Disclaimer


intel

Backup Section

Piezo debouncing- Engineering Challenge

Using your own circuit design and Arduino sketch, design a solution that solves the following challenges.

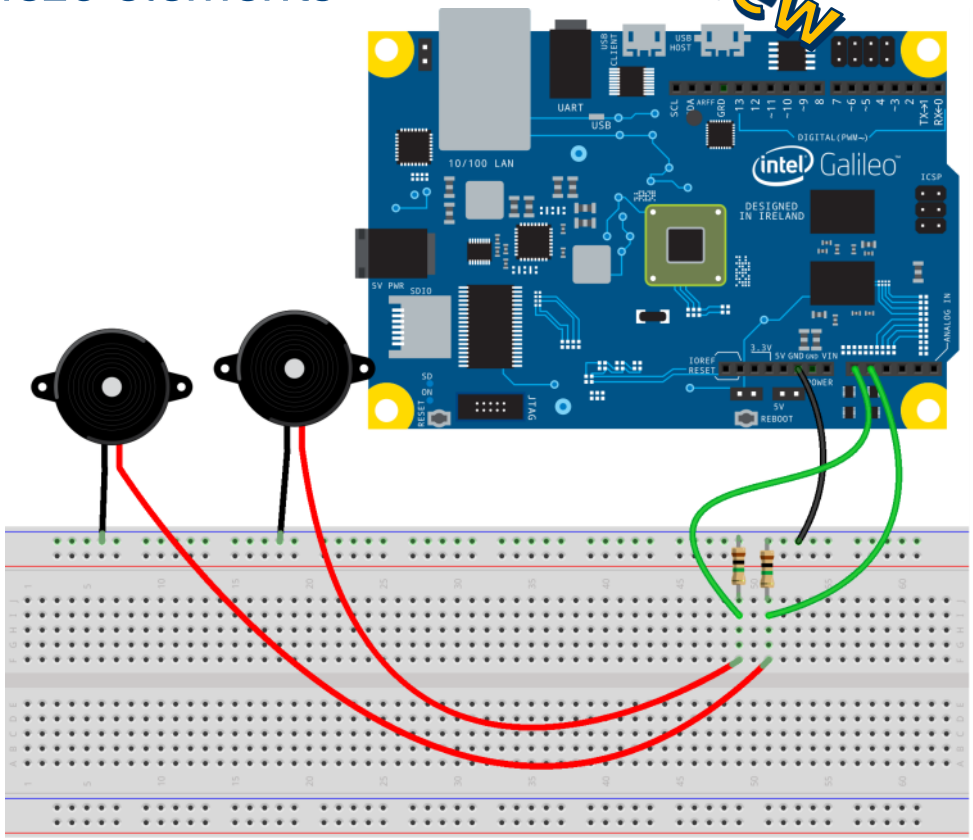
Use previous Lab example as needed for reference

Challenge:

Build a circuit with **two** piezo sensors, and maintain **two** timers to keep track of hits.

Engineering Challenge Review

Challenge 1: detect hits from two piezo elements




```
#define THRESH 300
//values higher than this value register a 'hit'

#define WAIT 150
 //how long we wait before reading again

int value;
long timer[2] = {0, 0};

void setup() {
    Serial.begin(115200);
}

void loop() {
    for (int i = 0; i < 2; i++)
    {
        value = analogRead(i);

        if (value > THRESH && timer[i] == 0)
        {
            timer[i] = millis();
            Serial.println(i);
        }
        else if ((millis() - timer[i]) >= WAIT && value < THRESH)
        {
            timer[i] = 0;
        }
    }
}
```

Project Files: Lesson3-Sensing\Section3-Vibration\vibration_sensor_challenge