Spread the LOVE for IoT

How I created a full day IoT workshop

@Dafna_Mordechai

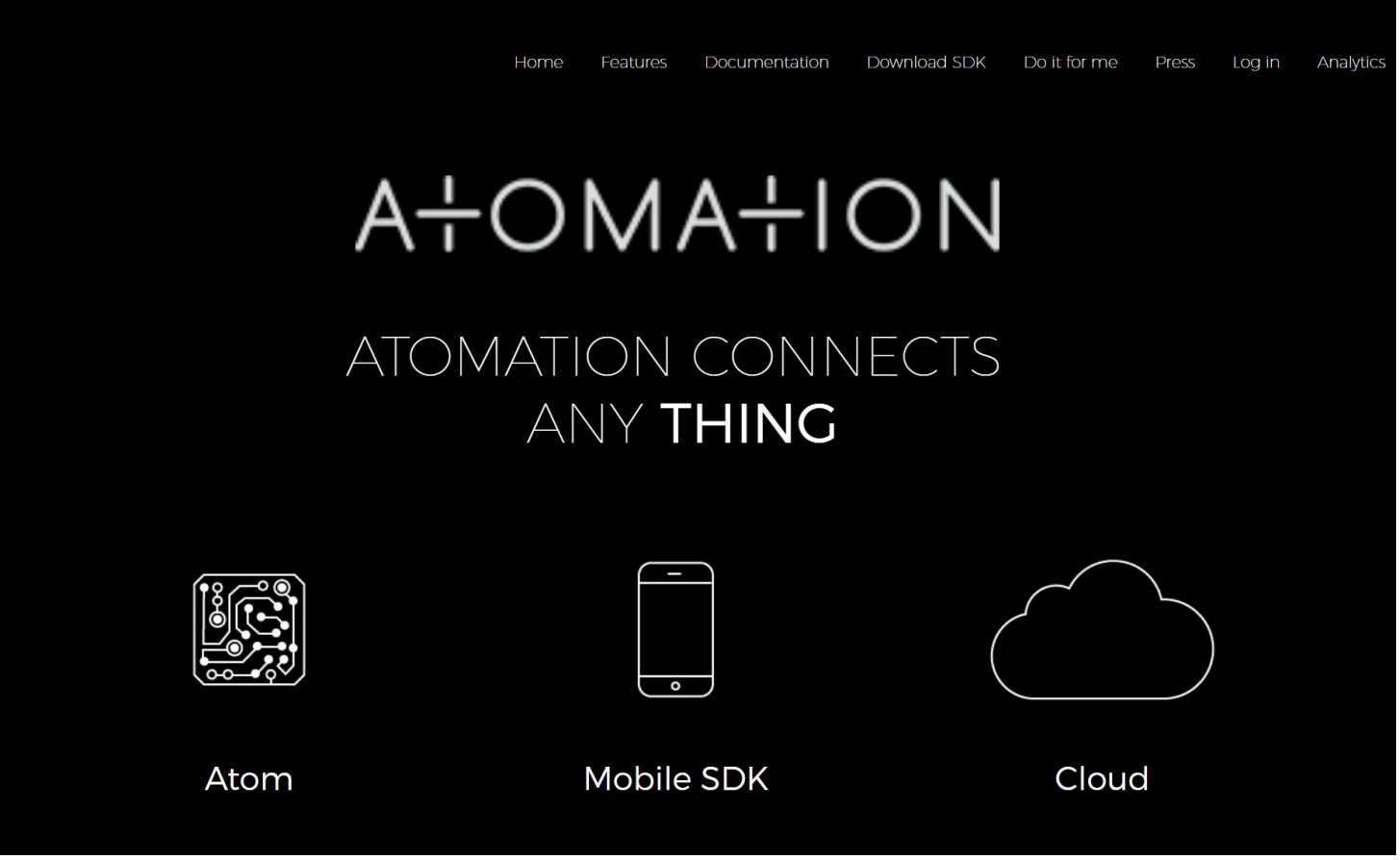
https://www.iot-workshop.online/

Hello!

- Dafna Mordechai, BSc. in Computer Science,
  The Hebrew University of Jerusalem (2008)
- RT Embedded Software Engineer
- Love technology, and love sharing it with others

@Dafna_Mordechai

https://www.iot-workshop.online/



The information presented and opinions expressed are solely the responsibility of the presenter and don't represent my employer.

Low Level & Security Celebration

Three Tracks:

- Reverse Engineering
- Virtualization Technologies
- Embedded Systems

Microsoft

Israel R&D Center

@Baot_IL

3 Preparation Assignments + 3 Theoretical Presentations

6 Hands-On Exercises

https://www.iot-workshop.online

Agenda

- **IoT overview**
- **Before the workshop**
  - What is the workshop framework?
  - Workshop's Building Blocks
  - Who are the participants?
  - What are the learning methods?
  - Hardware options for the exercises
- **The workshop**
  - Embedded systems and IoT
  - Introduction to Arduino
    - Hands on part 1
  - Bluetooth Low Energy
    - Hands on part 2

IoT – The Internet of THINGS

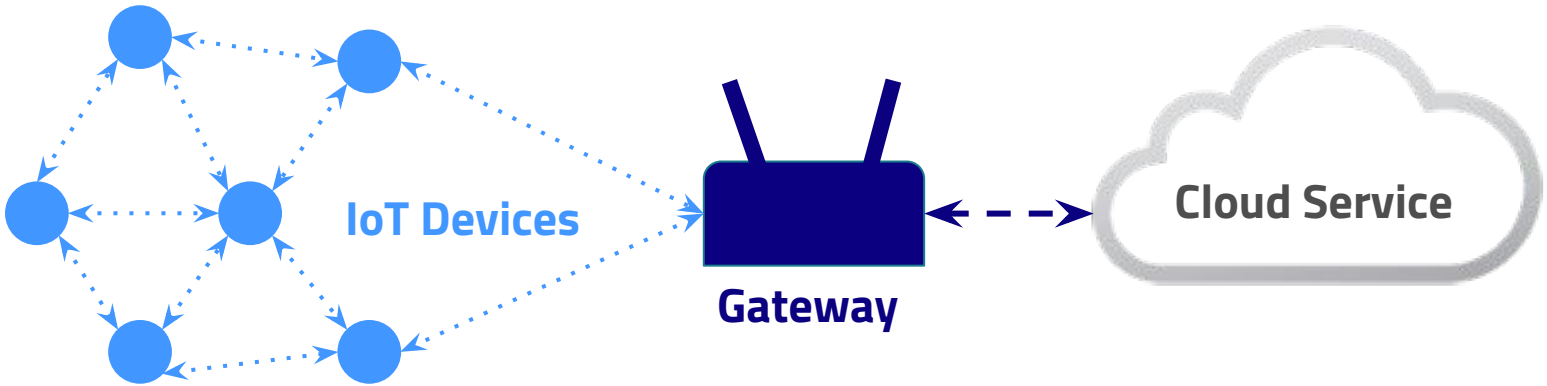
The Internet of Things refers to connecting machines and other physical objects to the internet, usually in order to gather information from sensors and to control systems from a distance.

"We project that there will be more than 55 billion IoT devices by 2025, up from about 9 billion in 2017."

Business Insider, IoT report, 2018

https://www.businessinsider.com/internet-of-things-report

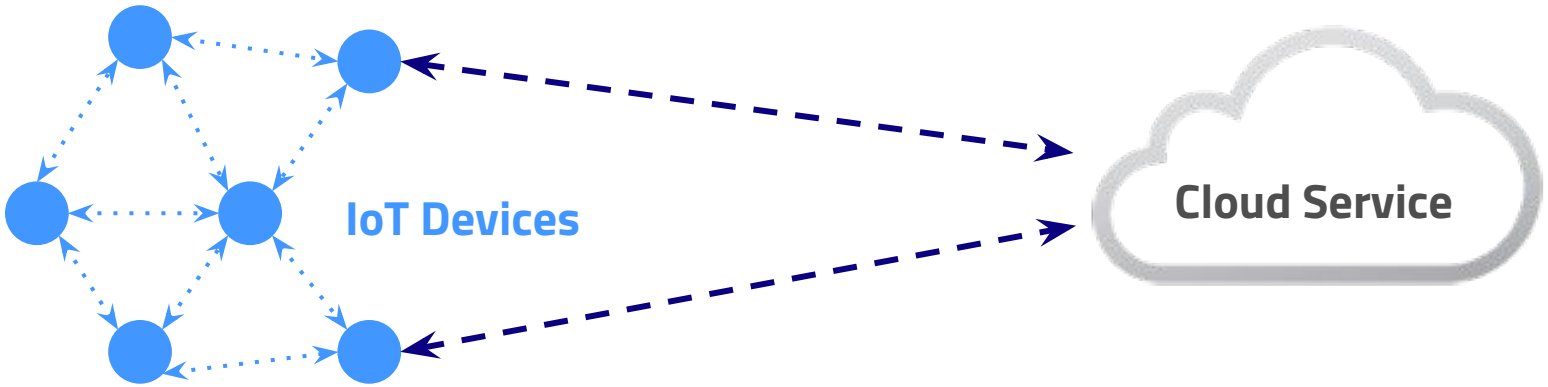
IoT – The Internet of THINGS



- Sensors / Actuators
- Wireless Communication

- Monitoring
- Analytics
- Control

IoT - The Internet of THINGS



Low-power, wide-area network (LPWAN),
e.g NB-IoT

Different THINGS have different NEEDS

Agriculture

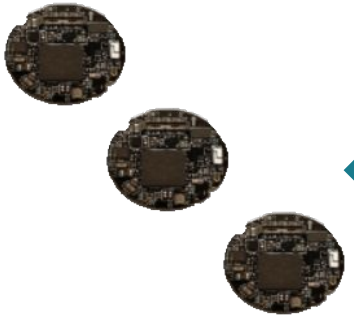
Medical

Industrial

- Resources - Computing Power / Memory / Storage / Wireless Communication
- Peripherals - Sensors / Actuators
- Power Consumption
- Cost

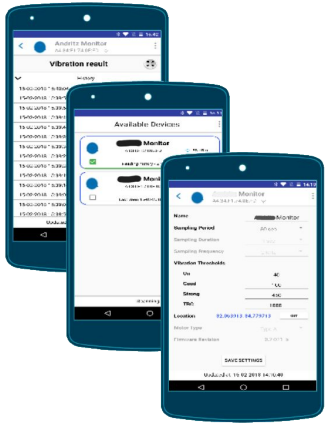
Machine Monitoring System

Sensor Unit (2€ size)



BLE

Android/iOS Gateway



4G/Wi-Fi

Cloud DB

- Vibration frequency
- Edge computing
- Data serialization
- Mobile SDK communication

- Mobile SDK
- Communication with 2E units and DB
- Gateway android/iOS app
- Data display app

- Data uploading
- FFT analytics
- Raw Data Report
- API for 3rd party systems

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What is the Workshop Framework?

- The required subject matter (Embedded Systems)
- Time (~5 learning hours)
- Budget (is never unlimited...)

Workshop's Building Blocks

What do we offer when we teach?

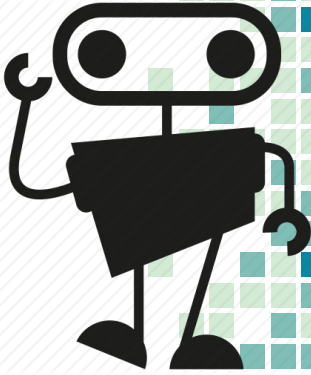
When we teach we provide structured knowledge that is suited to the participant

Who are the participants?

- Software Engineers
- Can learn a new topic quickly
- Can code C/C++

I can **not** assume:

- Any prior knowledge of embedded systems
- Any prior knowledge about specific hardware



What are the learning methods?

Before the workshop:

- **Preparation Assignments** (by email) - stretching time #1
  - Guided self-learning - learn at your own pace.
  - Different background == different understanding (and sometimes even misunderstanding).

At the workshop:

- **Frontal Instruction**
- **Hands-on exercises**

HW Option for Hands-On Exercises

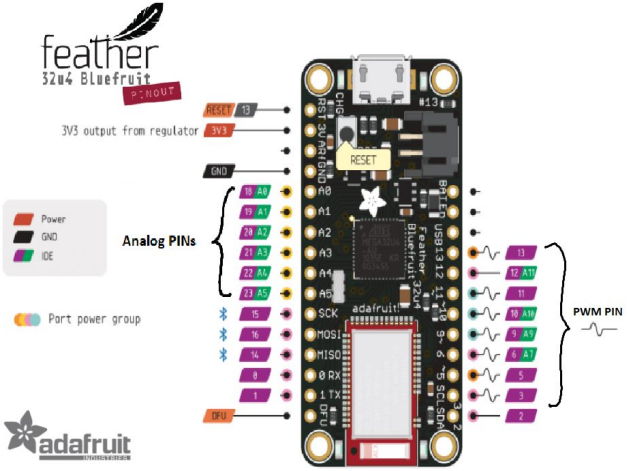
Development kit for nRF52832

SimpleLink™ CC26x2R LaunchPad™ Development Kit

Adafruit Feather 32u4 Bluefruit LE
with Headers - Assembled

- Pricing
- Ease of use with SDK and IDE

Adafruit Feather 32u4 Bluefruit LE



- Arduino-compatible board (Arduino micro)
- Arduino IDE
- Based on the nRF51822 (Nordic semiconductor), wrapped by a dedicated Arduino Library by Adafruit
- Adafruit Bluefruit LE Connect Mobile App

“ To Build or not to Build

that is the question

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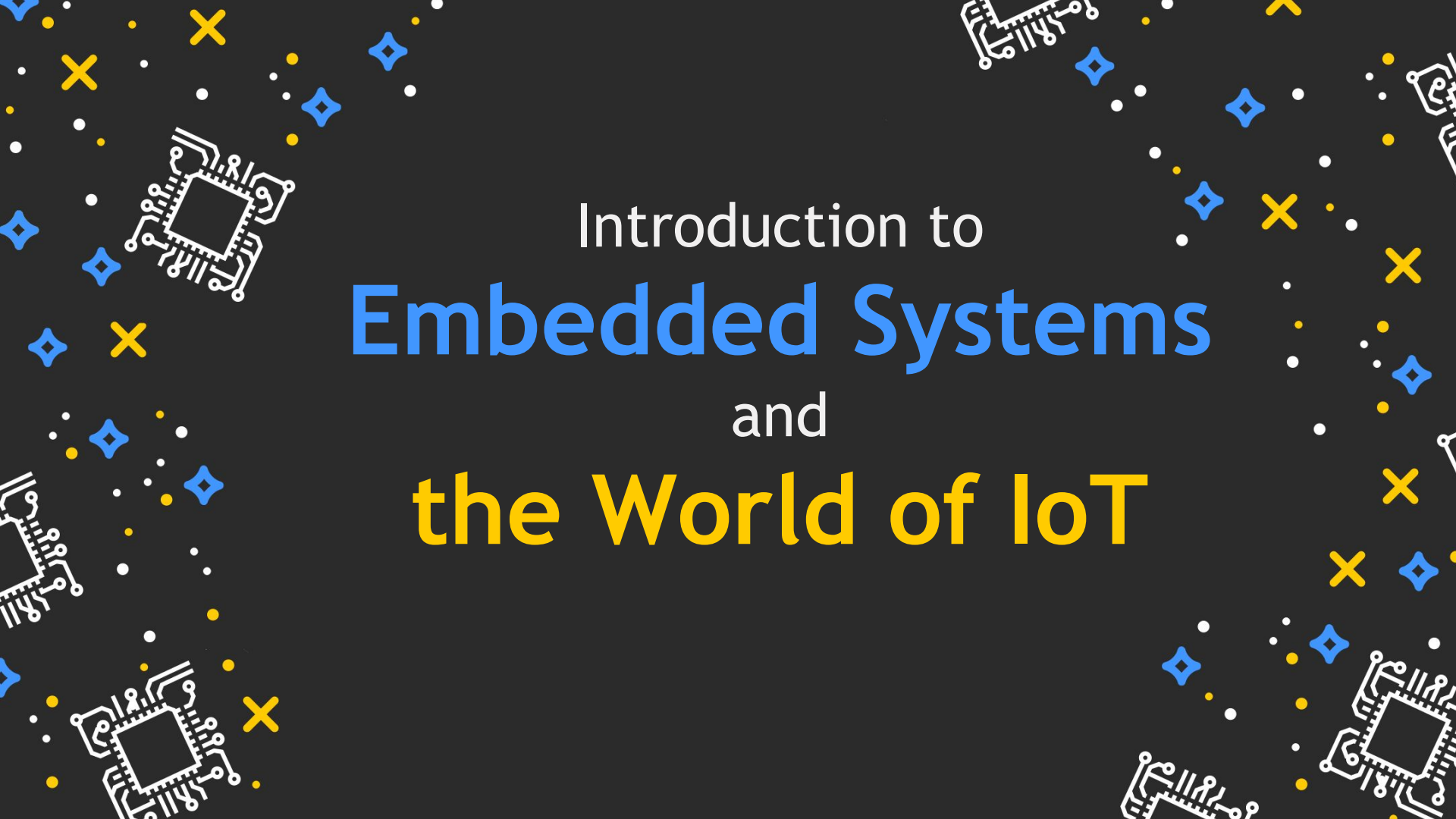
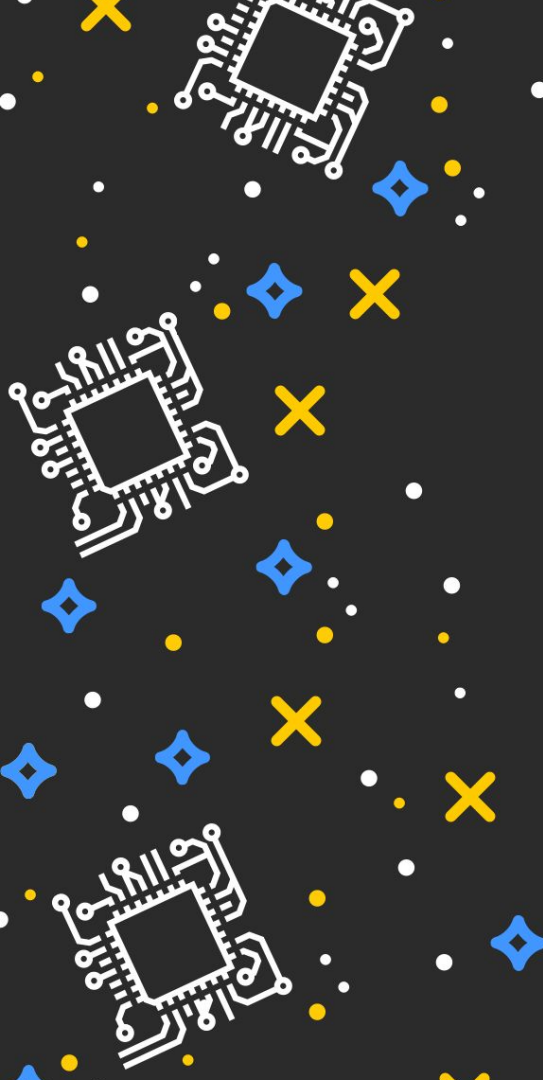
What are the learning goals?

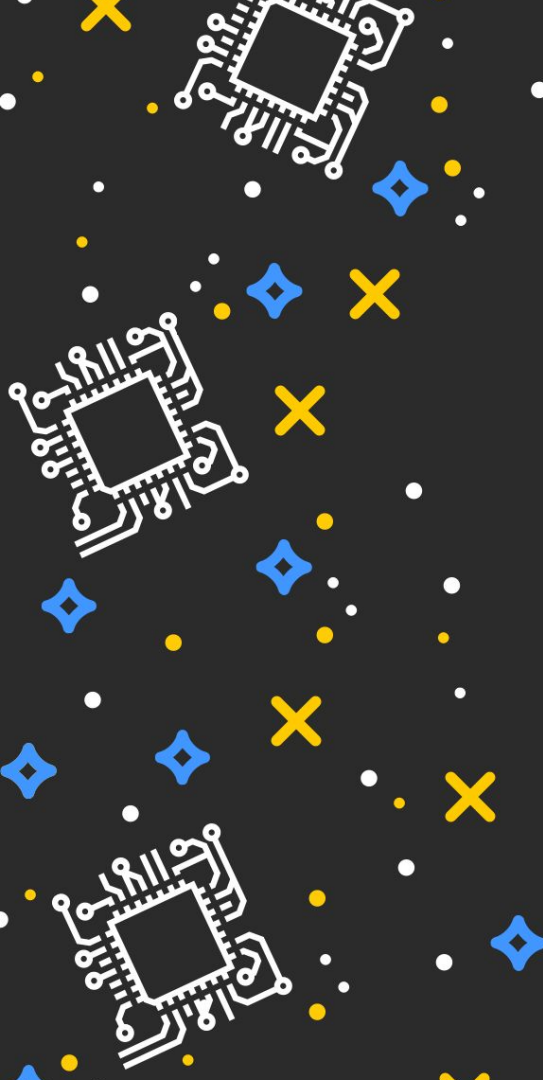
How can we organize and structure the information so it will be easily understood?


Introduction to
Embedded Systems
and
the World of IoT



Preparation Assignment #1

- Microprocessors vs. Microcontrollers
- GPIO / PWM
- Sensor / Actuator
- MSB / LSB / Little-Endian / Big-Endian
- C/C++ Rust removal



- Embedded Systems and IoT overview
- Embedded Programming
- Cross Compiling / Remote Debugging
- Microprocessors vs. Microcontrollers
- GPIO / Analog Pins / PWM
- UART / SPI / I2C
- Power Consumption Optimization
- Low Cost Devices
- CPU Properties

Just how “SMART” devices get?

Intelligence
Behaviour
Communication
Memory
Perception

Just how “SMART” devices get?

(Intelligence) Algorithms
(Behaviour) Actuators
(Communication) BLE
(Memory) RAM / FLASH
(Perception) Sensors

Embedded Workshop

With Arduino

ARDUINO for Engineers

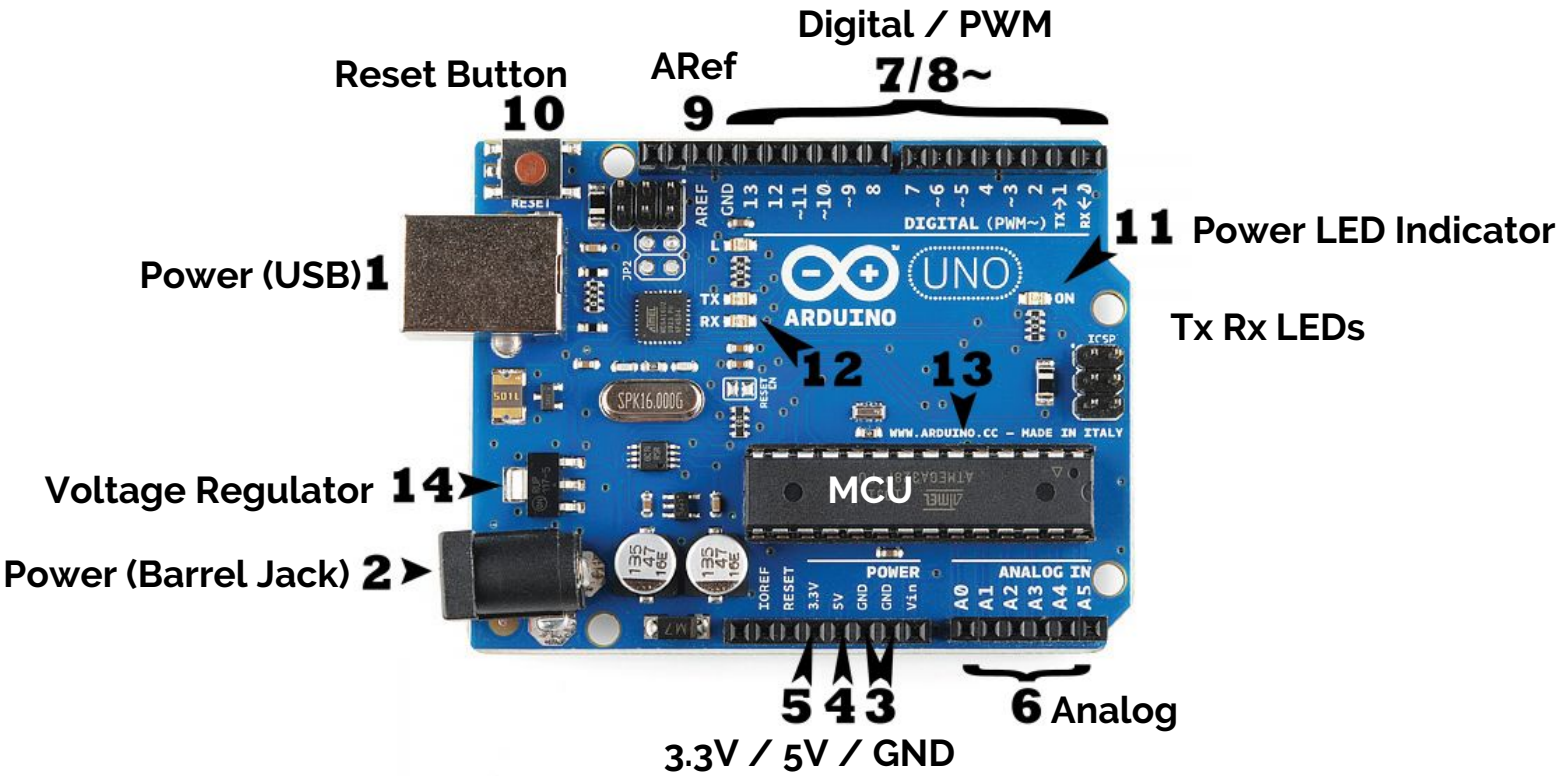
Preparation Assignment #2

- *.ino / setup() / loop()
- Libraries
- Hex file format
- Installations:
  - Arduino IDE
  - Bluefruit-LE board
  - Bluefruit Library

ARDUINO for Engineers

- Single Board Computer
- Open software / Open hardware
- Compilation process
- Boards manager
- Arduino shields

What's on the board?



Picture credit: https://learn.sparkfun.com/tutorials/what-is-an-arduino

Arduino for Engineers

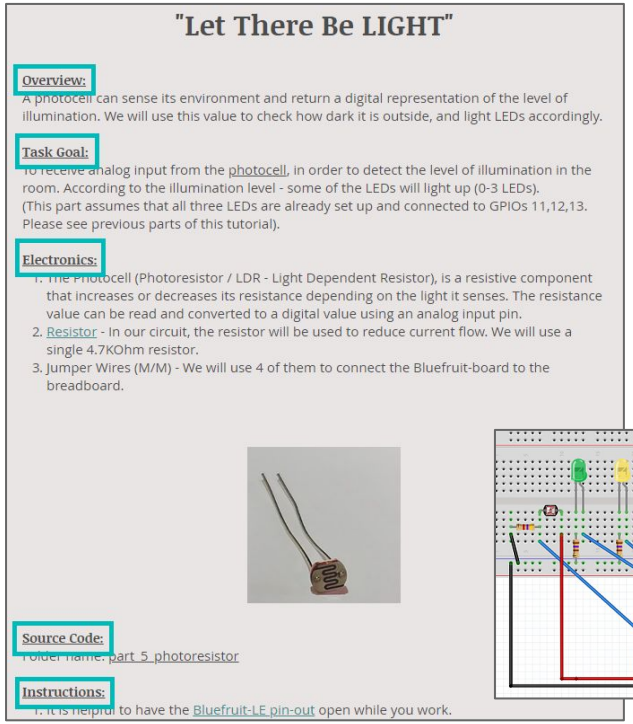
Documents › ArduinoData › packages › arduino › hardware › avr › 1.6.21 › cores › arduino

Name	Type
WString.h	H File
WString.cpp	CPP File
WMath.cpp	CPP File
wiring_shift.c	C File
wiring_pulse.S	S File
wiring_pulse.c	C File
wiring_private.h	H File
wiring_digital.c	C File
wiring_analog.c	C File
wiring.c	C File
WInterrupts.c	C File
WCharacter.h	H File
USBDesc.h	H File
USBCore.h	H File
USBCore.cpp	CPP File
USBAPI.h	H File
Udp.h	H File
Tone.cpp	CPP File
Stream.h	H File
Stream.cpp	CPP File
Server.h	H File
Printable.h	H File
Print.h	H File
Print.cpp	CPP File
PluggableUSB.h	H File

```
// frequency (in hertz) and duration (in milliseconds).

void tone(uint8_t _pin, unsigned int frequency, unsigned long duration)
{
  uint8_t prescalarbits = 0b001;
  long toggle_count = 0;
  uint32_t ocr = 0;
  int8_t _timer;

  _timer = toneBegin(_pin);

  if (_timer >= 0)
  {
    // Set the pinMode as OUTPUT
    pinMode(_pin, OUTPUT);

    // if we are using an 8 bit timer, scan through prescalars to f
    if (_timer == 0 || _timer == 2)
    {
      ocr = F_CPU / frequency / 2 - 1;
      prescalarbits = 0b001;  // ck/1: same for both timers
      if (ocr > 255)
      {
        ocr = F_CPU / frequency / 2 / 8 - 1;
        prescalarbits = 0b010;  // ck/8: same for both timers

        if (_timer == 2 && ocr > 255)
        {
          ocr = F_CPU / frequency / 2 / 32 - 1;
          prescalarbits = 0b011;
        }

        if (ocr > 255)
        {
          ocr = F_CPU / frequency / 2 / 64 - 1;
          prescalarbits = _timer == 0 ? 0b011 : 0b100;

          if (_timer == 2 && ocr > 255)
          {
            ocr = F_CPU / frequency / 2 / 128 - 1;
```

BEHIND THE SCENES

Tutorials - Stretching Time #2

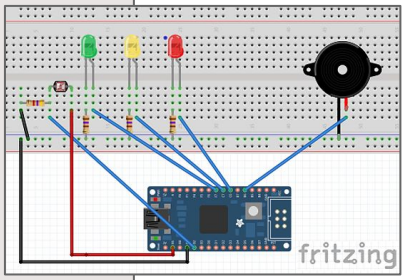


"Let There Be LIGHT"

Overview:
A photocell can sense its environment and return a digital representation of the level of illumination. We will use this value to check how dark it is outside, and light LEDs accordingly.

Task Goal:
To receive analog input from the photocell, in order to detect the level of illumination in the room. According to the illumination level - some of the LEDs will light up (0-3 LEDs).
(This part assumes that all three LEDs are already set up and connected to GPIOs 11,12,13. Please see previous parts of this tutorial).

Electronics:
1. The Photocell (Photoresistor / LDR - Light Dependent Resistor), is a resistive component that increases or decreases its resistance depending on the light it senses. The resistance value can be read and converted to a digital value using an analog input pin.
2. Resistor - In our circuit, the resistor will be used to reduce current flow. We will use a single 4.7KOhm resistor.
3. Jumper Wires (M/M) - We will use 4 of them to connect the Bluefruit-board to the breadboard.



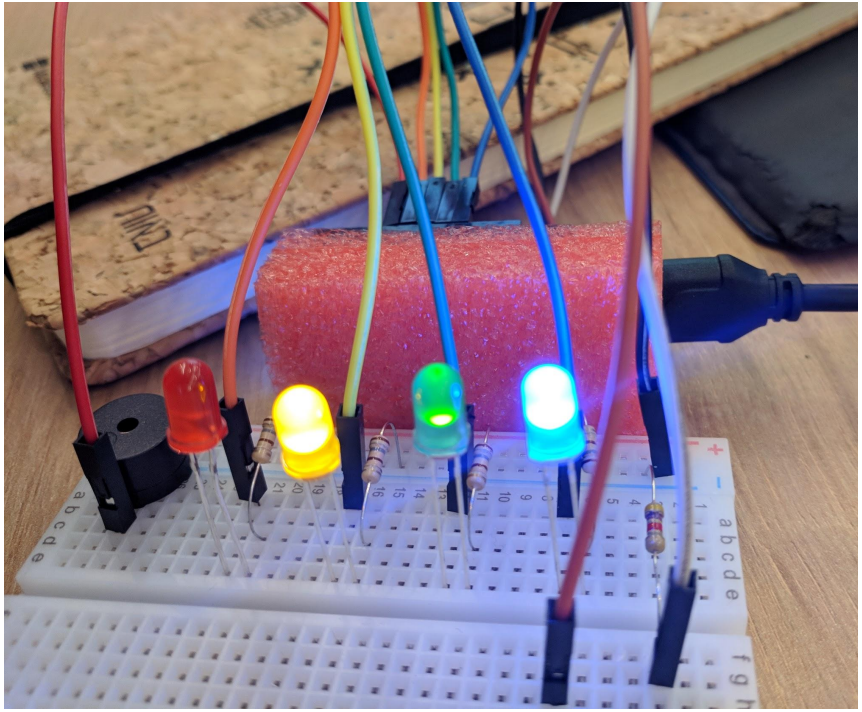
Source Code:
Folder name: part_5_photoresistor

Instructions:
1. It is helpful to have the Bluefruit-LE pin-out open while you work.

- Self-learning tutorials for hands-on exercises .
- Mentors assist participants as required
- Source code is provided -

  coding in C/C++ was **NOT** a learning goal.

Hands On #1 - Blinking LEDs



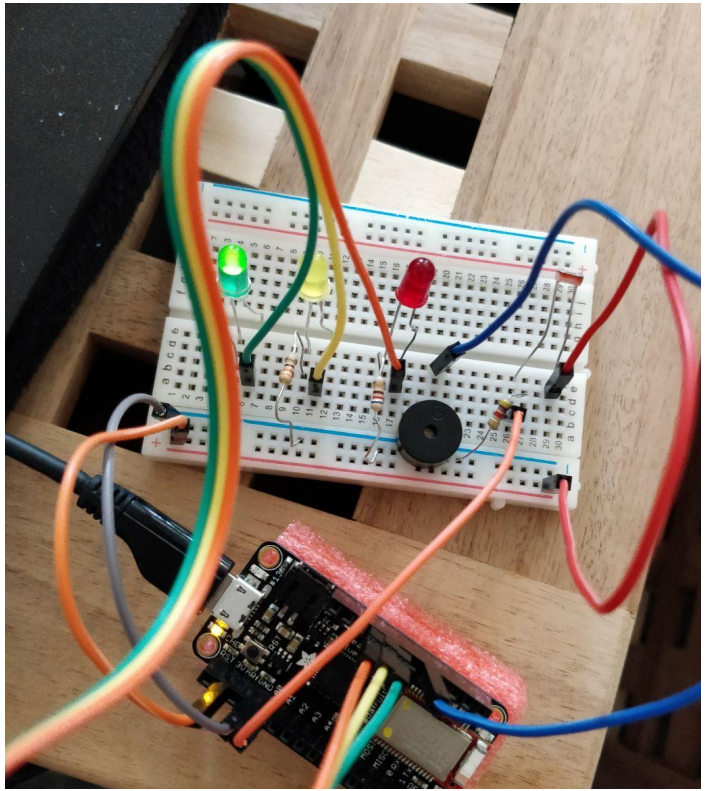
Task Goal:

Blinking three LEDs

Learning Goal:

- Understanding the board's pinout
- Working with GPIOs

Hands On #2 - Making Music



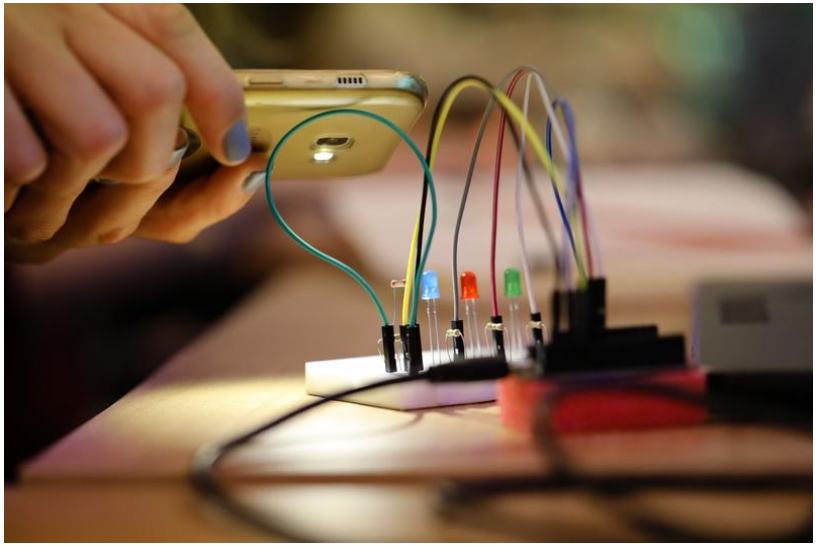
Task Goal:

To play a song with the buzzer, and for every time a note is played, a different LED will blink.

Learning Goal:

Working with PWM

Hands On #3 - Photocell



Task Goal:

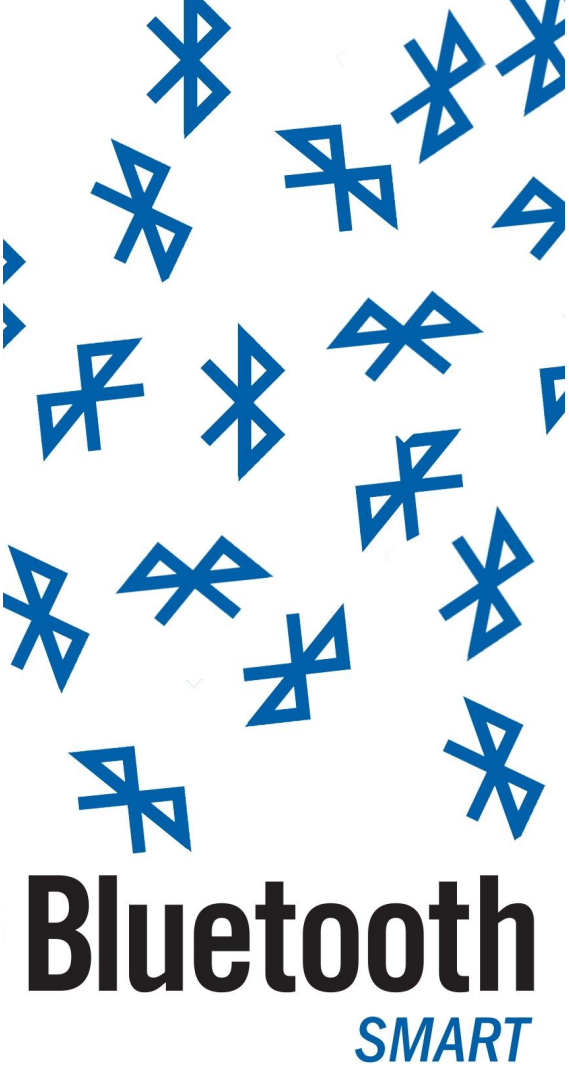
To receive analog input from the photocell, in order to detect the level of illumination in the room. Based on the illumination level - some of the LEDs will light up (0-3 LEDs).

Learning Goal:

Read analog input. React if input value crosses a threshold

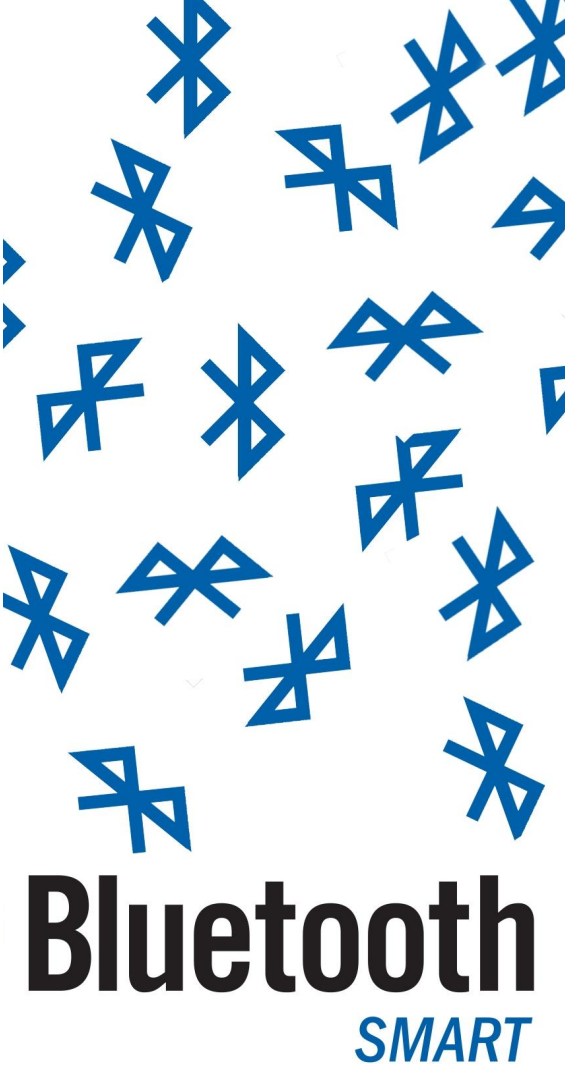
Introduction to

Bluetooth Low Energy



Preparation Assignment #3

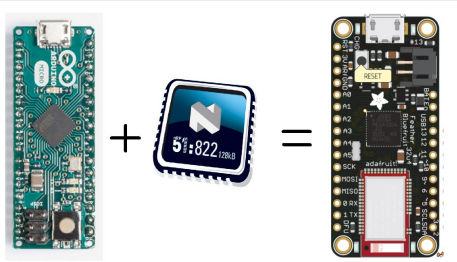
- The Electromagnetic Spectrum
- Network Topologies (Point-to-Point, Star, Mesh, Scatternet).
- Master / Slave Architecture.
- RSSI
- BLE Overview
- Exercise with nRF-Connect App



Bluetooth Low Energy

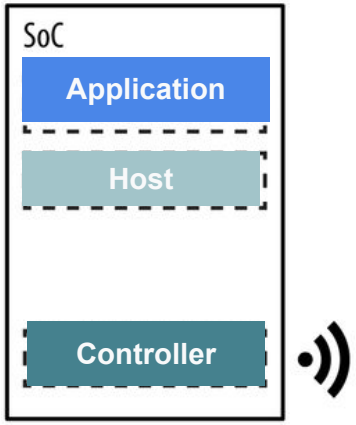
- Wireless communications:
  - Range
  - Data Rate
  - Network Topology
  - Power Consumption
- Advertising and Connection
- Data Module (Services/Characteristics)
- BLE Stack
- Development Tools

Android 4.3 (API level 18)
MAC OS
Linux BlueZ

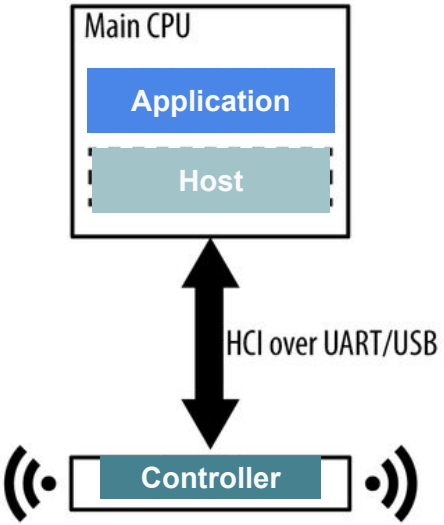


BLE Stack

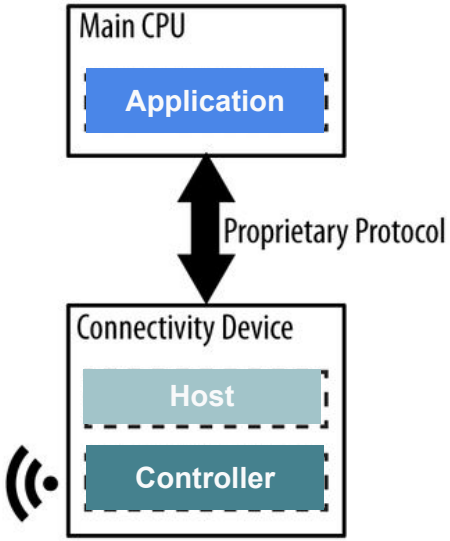
System on Chip



Dual IC over HCI



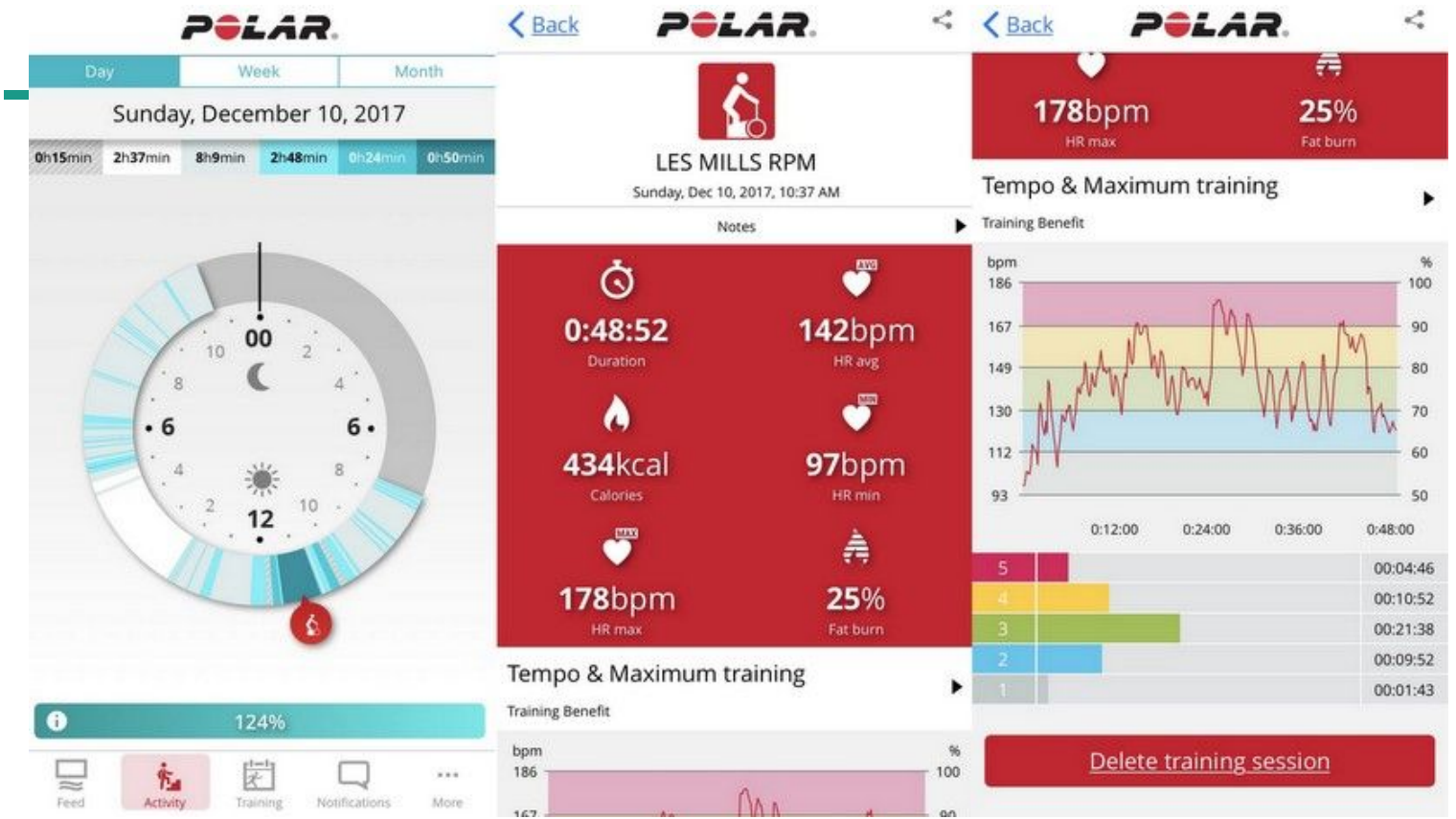
Dual IC (Connectivity Device)




POLAR
Bluetooth
SMART


POLAR
138
00:29 34
A300


POLAR
Activity
TODAY FRI 22 AUG
12
P.M.
6
6
A.M.
12
7h 32
1h 40
58min
21min
94%
9:41 AM
100%
POLAR
Analysis
VERY GOOD
RUNNING INDEX
44
TRAINING BENEFIT
STEADY STATE & TEMPO TRAINING
HEART RATE
[bpm]
[%]
174
154
135
116
97
90
80
70
60
50
00:10
00:20
00:30
00:40
00:50
5
00:00:00
00:21:23
00:28:15
00:02:10

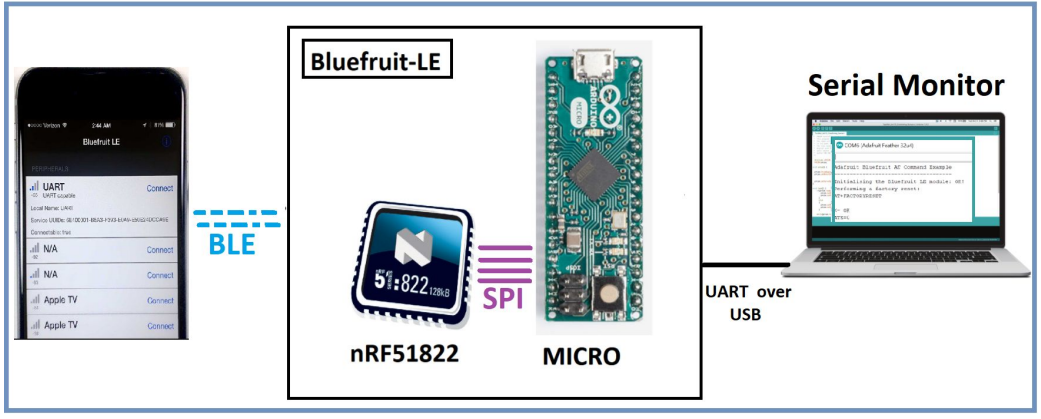

POLAR
Day
Week
Month
Sunday, December 10, 2017
0h15min
2h37min
8h9min
2h48min
0h24min
0h50min
124%
Feed
Activity
Training
Notifications
More
Back
POLAR
LES MILLS RPM
Sunday, Dec 10, 2017, 10:37 AM
Notes
0:48:52
Duration
142bpm
HR avg
434kcal
Calories
97bpm
HR min
178bpm
HR max
25%
Fat burn
Tempo & Maximum training
Training Benefit
bpm
%
186
167
149
130
112
93
100
90
80
70
60
50
0:12:00
0:24:00
0:36:00
0:48:00
5
4
3
2
1
00:04:46
00:10:52
00:21:38
00:09:52
00:01:43
Delete training session

Hands On #4 - BLE Warm Up 1

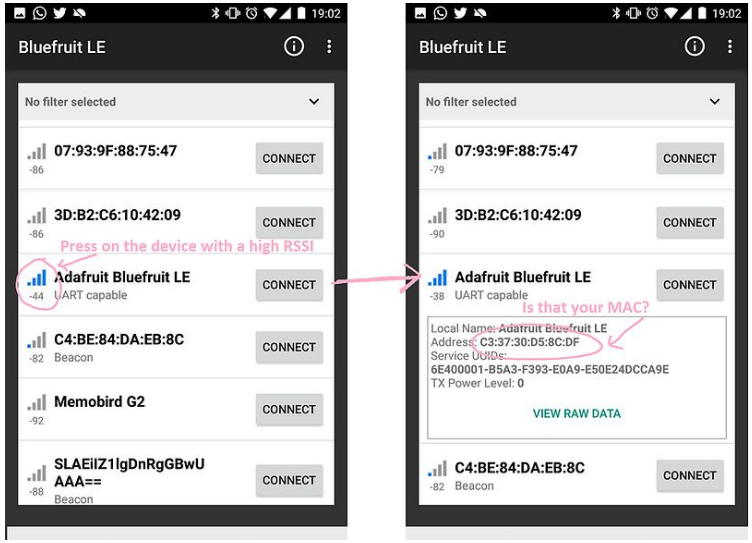
Task Goal: To transfer strings back and forth between the BLE app on mobile phone and a laptop, through the Feather Bluefruit-LE board.

Learning Goal:

BLE - Advertising / Connection / The Nordic UART Service (NUS)



Hands On #5 - BLE Warm Up 2 (Optional)



Task Goal:

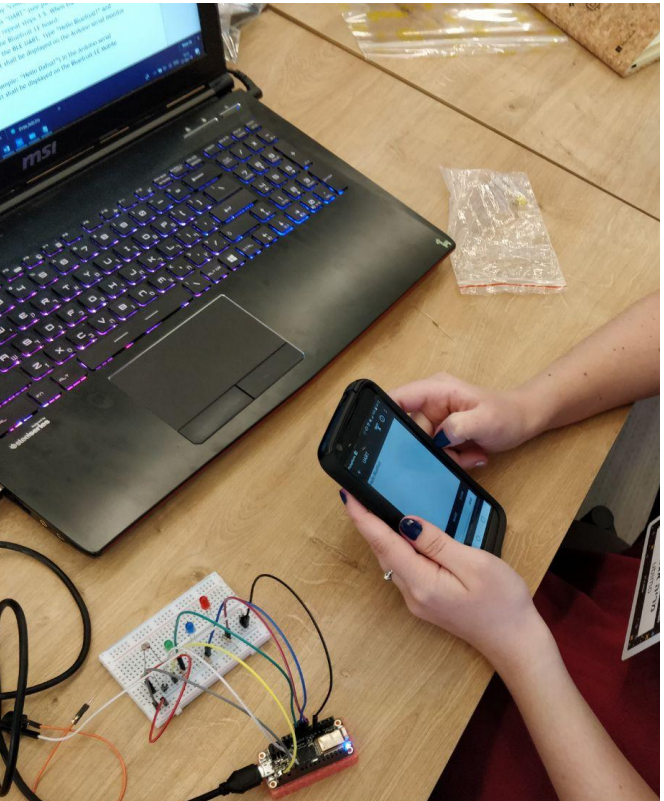
Find the MAC address of your BLE device.

Learning Goal:

Get familiar with:

- AT commands
- BLE Advertising
  RSSI
- MAC Address

Hands On #6 - BLE Magic

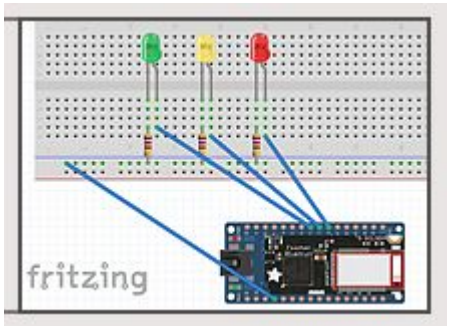


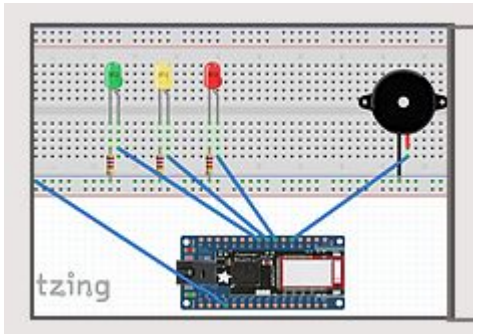
Task Goal:

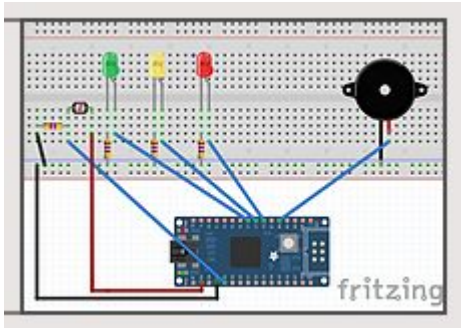
To control three LEDs from a mobile phone (turn them on or off as we wish).

Learning Goal:

- Work with AT commands (Hayes command set)
- Blinking LEDs via BLE
- The Nordic UART Service (NUS)

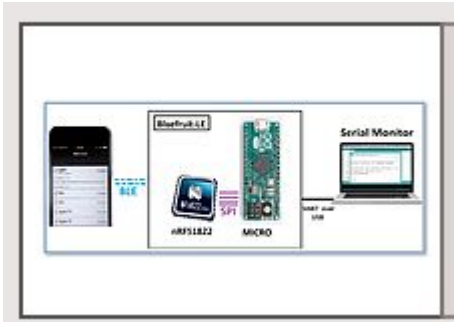


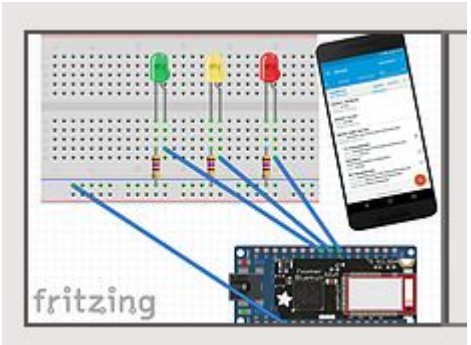




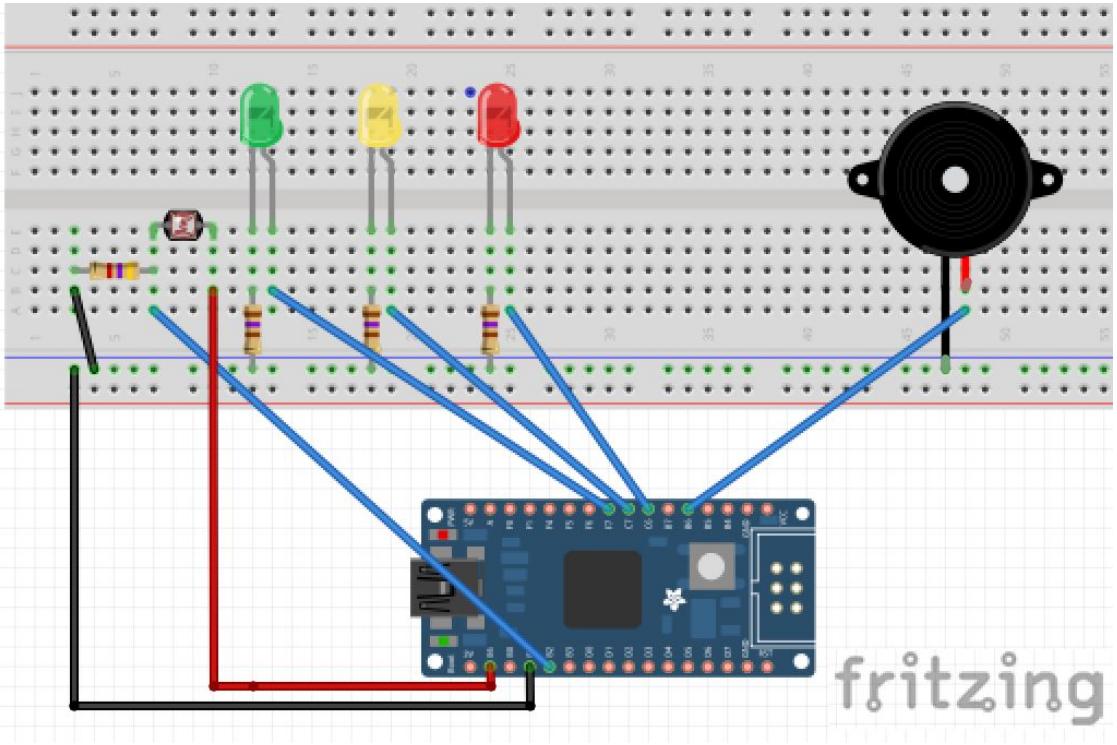
Hands On!

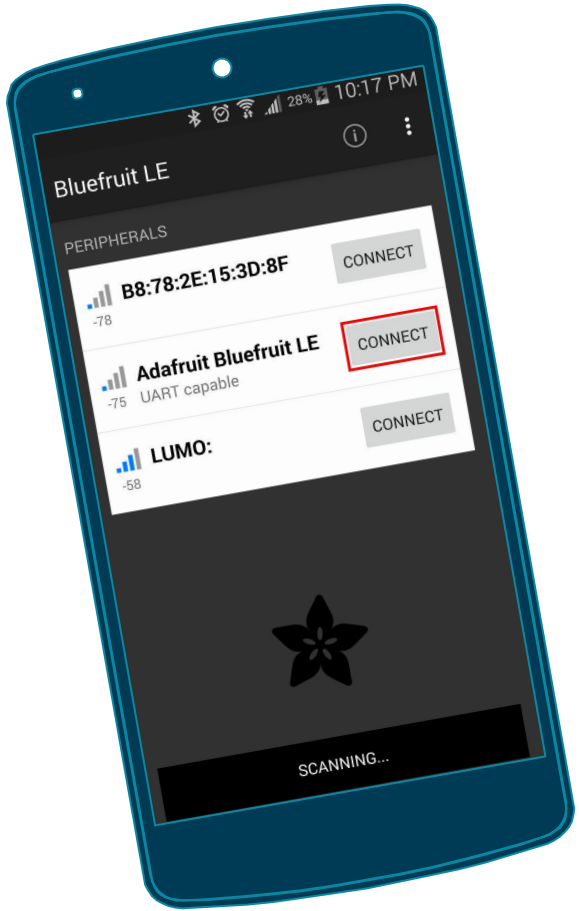
- Basic Electronics
- GPIO output
- PWM output
- Analog input
- RSSI
- MAC Address
- AT commands
- BLE - Advertising / Connection
- The Nordic UART Service (NUS)





Today's Project:

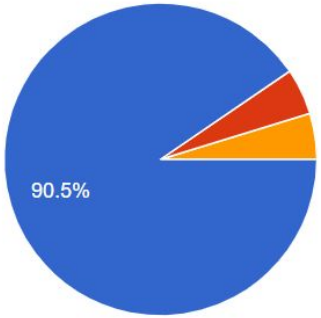




Feedback

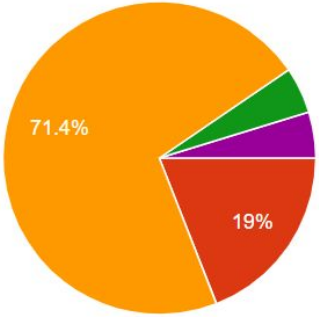
"The workshop was extremely interesting, It could have been nice if we could code more, but with the time limitations I can understand why we couldn't..."

Feedback



Before the workshop my background was:

- I never worked with Arduino
- I worked with Arduino once or twice
- I worked with Arduino Three times or more



After the workshop, my ability to work with Arduino is:

- Poor, I am able to understand the concept, but not to work with the system.
- Fair, I am able to program an existing project, if I will have some guidance
- Good, I am able to choose an existing project from the web and learn it on my own
- Very good, I am able to design a project on my own
- Great, I am able to design a project on my own with a board and parts I will choose and even instruct others to do so.

What is the Workshop Framework?

Who are the participants?

What are the learning methods?

What are the learning goals?

How can we organize and structure the information so it will be easily understood?

Go on!
Spread the LOVE!

Thank You!

@Dafna_Mordechai

https://www.iot-workshop.online/