HACETTEPE UNIVERSITY

Department of

Electrical and Electronics Engineering

ELE 402

Graduation Project II

Final Report

Design and Development of a Mobile Color Measurement Device

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1.INTRODUCTION

This report is written by Ahmet Deniz YILMAZ for ELE402 Senior Project 2. Before this report, I successfully finished the project and achived my first purpose which is a functional tiny mobile color measurement device. I added some necessary modules like battery, battery charger.

The last product has ability to save logs in smartphone and also rechargeable. I changed user interface in Android application for better looking for end-user and did some changes on Arduino codes for using resources like RAM and CPU to use more efficiently. With these changes, I increased communication speed between module and smart phone.

2. PROJECT DESCRIPTION

Measurement of color is a complicated and expensive measurement process.However nowadays, we have System-On-Chip(SoC) solutions that relatively cheap and easier way to measure color.

Purpose of this project will be the design and development of a mobile device capable of measuring, identifying and comparing the color of a specimen. Then data of color we measured will be transferred to and processing in smart phone.

First we need to know the basic color theory before measuring it. We should start with a definition of color. Light is made up of wavelengths of light, and each wavelength is a particular colour. The colour we see is a result of which wavelengths are reflected back to our eyes.

Without light or the illuminant, color does not exist. Therefore, several factors that influence the radiation subsequently affect the exact color that an individual perceives.

Those factors are: spectral energy

distribution of light, conditions under

which the color is viewed,

spectral characteristics of the object with respect to absorption, reflection, and transmission, sensitivity of the eye. [1]

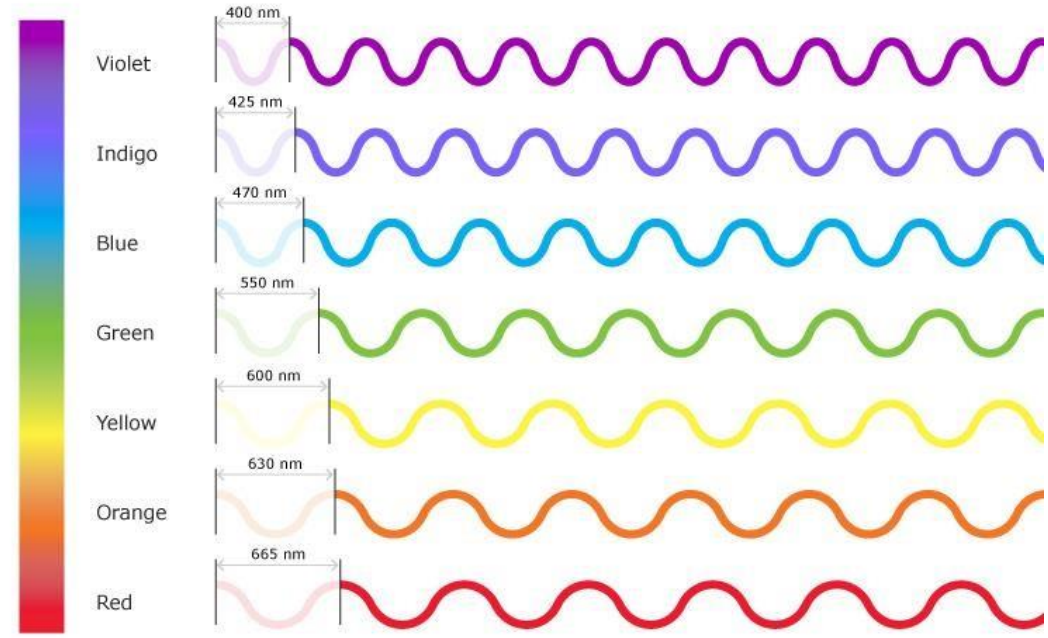


Figure 1-Color wavelenghts

The visible spectrum showing figure of the wavelengths of each of the component colors. The spectrum ranges from dark red at 700 nm to violet at 400 nm. The retina of our eyes contains two types of photoreceptors – rods and cones. The cones detect color. The rods only let us see things in black, white and grey. Our cones only work when the light is bright enough, but not when light is very dim. This is why things look grey and we cannot see colors at night when the light is dim.

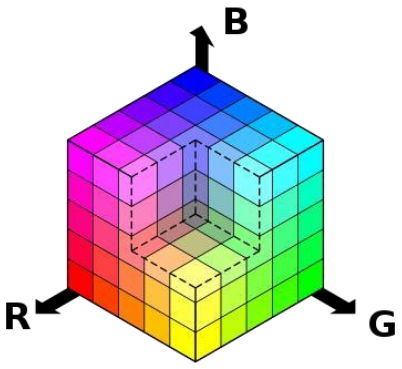


Figure 2 – RGB color model(Spitzak/Wikimedia)

RGB (Red, Green, Blue) describes what kind of light needs to be emitted to produce a given color. Light is added together to create form from darkness. RGB stores individual values for red, green and blue. RGB is not a color space, it is a color model. There are many different RGB color spaces derived from this color model. [2]

Each parameter (red, green, and blue) defines the intensity of the color as an integer between 0 and 255.

Figure 2-Hexadecimal color codes of some colors

After that I needed a device to process data to send it to a mobile device. Then I started looking market for some microcontrollers. In the market there are so many different choises for example : Raspberry PI, Arduino, PIC etc... We could use any of them but some of them are has much more ability and some of them are hard at developing proccess and I choosed Beetle BLE due to its smaller size integrated BT module and low power consumption.

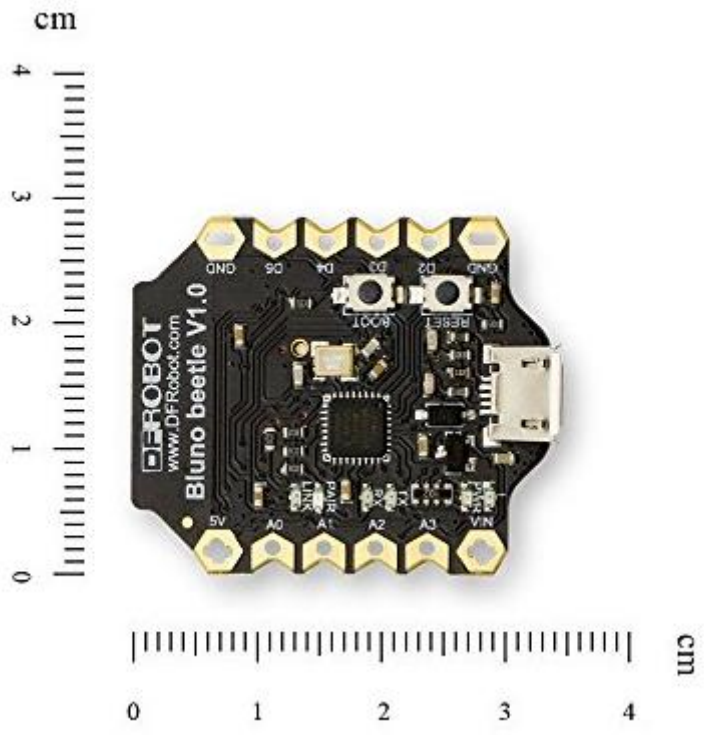


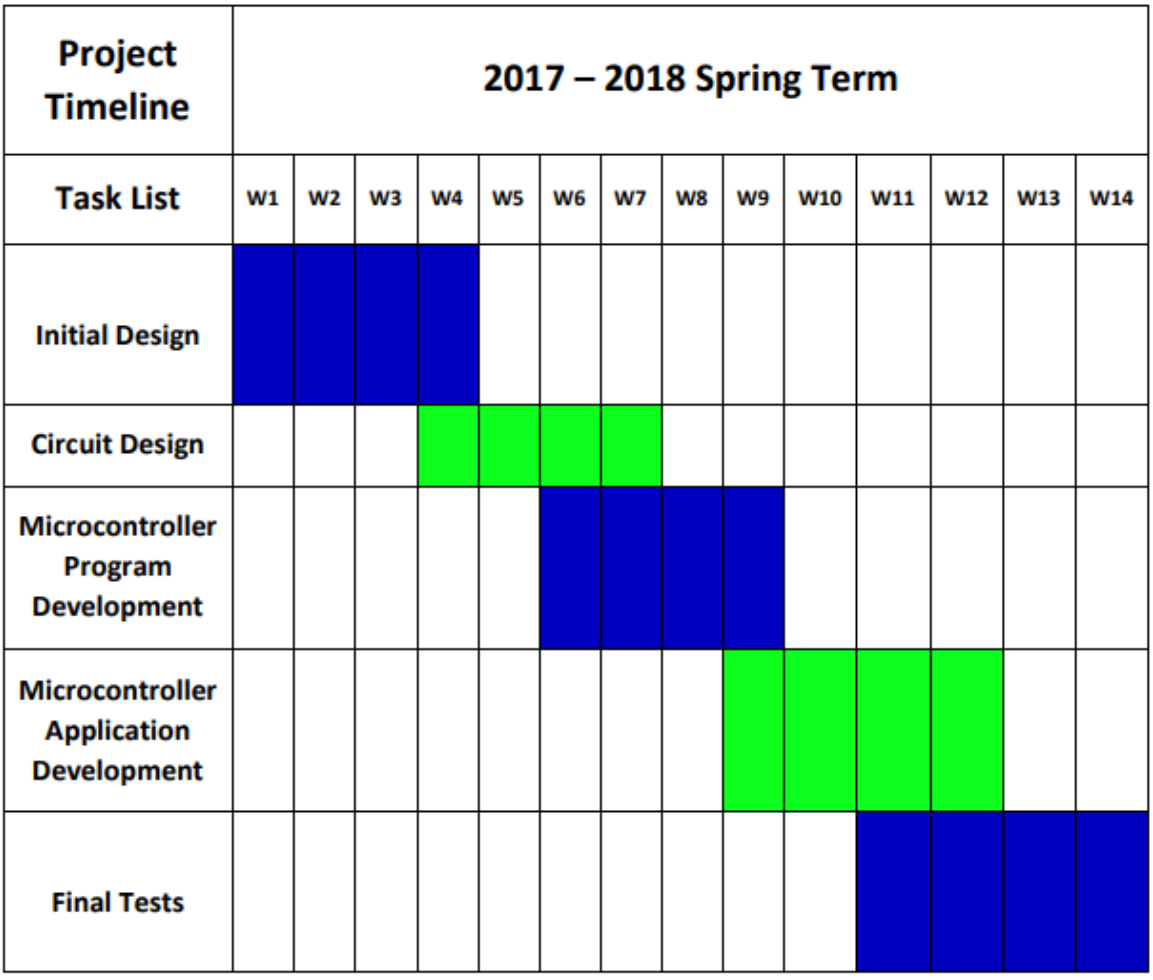
Figure 3. Beetle BLE - The smallest Arduino board w/ integrated bluetooth

The Beetle Ble (Former name as Bluno Beetle) is an Arduino Uno based board with bluetooth 4.0 (BLE). It is probably the smallest Arduino BLE board in the market. It uses standard Arduino IDE to upload codes via without any extra library and drivers. This Beetle BLE is another milestone in the Beetle line, which makes DIY users have more options in the project design. It is fully compatible with Bluno in instructions and procedures. Support Bluetooth HID and ibeacon modes.

The Beetle BLE offers a super tiny and low cost Arduino with bluetooth 4.0. The Beetle BLE can be used for disposable projects, such as DIY projects, workshops, gift projects, E-Textiles wearable and educational. For students and makers who can not afford too much on hardware purchasing, Beetle is a great solution for my project.

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 30,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics. The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks. A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device. A network of patents apply to the technology, which are licensed to individual qualifying devices. It is so common for all mobile devices and fast enough to basic sensor values. As a result, we decided to use bluetooth.

There are so many types of bluetooth modules. When we chose firstly we looked the module's price vs perfomance. Hence, HC-05 is more convenient for our project. Then, we need a mobile platform which has bluetooth module to communicate. There are 2 common choises: IOS and Android. We selected android platform because it is open-source and it is easier for programming. IOS has too much limitiation for an application. [3]



3.ENGINEERING STANDARDS AND DESIGN CONSTRAINTS

A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.

3.1.Engineering Standarts

- **FCC Declaration of Conformity** - FCC label or the FCC mark is a certification mark employed on electronic products manufactured or sold in the United States which certifies that the electro-magnetic interference from the device is under limits approved by the Federal Communications Commission. [4] (Arduino)

- **IEEE 802.11** is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands. They are created and maintained by the Institute of Electrical and Electronics Engineers (IEEE) LAN/MAN Standards Committee (IEEE 802).[5] (wi-fi)

- **IEEE 802.15.1-2005** - IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications for Wireless Personal Area Networks (WPAN)[6] (HC05) 14

3.2.Design Constraints

Size

Design shouldn't be too heavy or big to carry by hand.I will give higher priority to size than other constraints.

Economy

Modules and processor should not be too expensive but also should not be too cheap to working well. I will choose component with higher price-performance ratio.

Health and Safety

Design shouldn't affect the people health.

Manufacturability

Project's cost is really cheap so anyone who want to produce that project can buy and get the equipment easily.

Sustainability

Project's life depends on sensor, Bluetooth module and Arduino's life. It is approximately 8-10 years.[7]

Environment

Project consumes low energy because the most power using material which is Arduino is only using 5 V and we already use low power mode on that.

4. BACKGROUND

My previous courses helped me to during the process of project.

ELE 203-220-230-315 Circuit theory I-II, Electronics I-II;

These courses may help me for design of the implementation of project.

ELE 107 Computers and programming I;

This course helped me to know how I can use hardware components.

ELE 118-336 Computers and programming II, Microprocessor Architecture and Programming;

This course may help me about programming the software part of design.

ELE324 Telecommunication Theory I;

This course gave me brief knowledge while researching communication systems.

5. METHODS

I have two methods. In first method, I use my own Color Sensor and in the second method, I use TCS34725 Color Sensor. In these methods I will examine pros and cons of TCS34725.

TCS 34725 COLOR SENSOR

The TCS34725 device provides a digital return of red, green, blue (RGB), and clear light sensing values. An IR blocking filter, integrated on-chip and localized to the color sensing photodiodes, minimizes the IR spectral component of the incoming light and allows color measurements to be made accurately. The high sensitivity, wide dynamic range, and IR blocking filter make the TCS34725 an ideal color sensor solution for use under varying lighting conditions and through attenuating materials. The TCS34725 color sensor has a wide range of applications including RGB LED backlight control, solid-state lighting, health/fitness products, industrial process controls and medical diagnostic equipment [8]

Figure 4-TCS34725 Color sensor

In addition, the IR blocking filter enables the TCS34725 to perform ambient light sensing (ALS). Ambient light sensing is widely used in display-based products such as cell phones, notebooks, and TVs to sense the lighting environment and enable automatic display brightness for optimal viewing and power savings. The TCS34725, itself, can enter a lower-power wait state between light sensing measurements to further reduce the average power consumption.

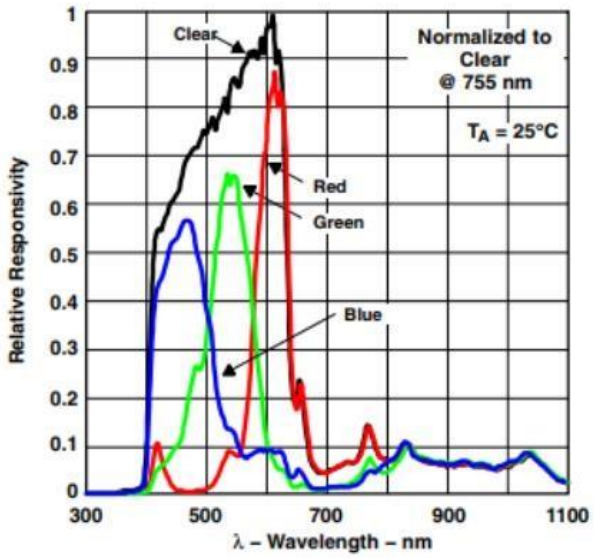


Figure 5-TCS34725 Spectral Response

The TCS3472 light-to-digital converter contains a 3 × 4 photodiode array, four analog-todigital converters (ADC) that integrate the photodiode current, data registers, a state machine, and an I2C interface. The 3 × 4 photodiode array is composed of redfiltered, green-filtered, blue-filtered, and clear (unfiltered) photodiodes. In addition, the photodiodes are coated with an IR-blocking filter.

The four integrating ADCs simultaneously convert the amplified photodiode currents to a 16bit digital value. Upon completion of a conversion cycle, the results are transferred to the data registers, which are double-buffered to ensure the integrity of the data. All of the internal timing, as well as the low-power wait state, is controlled by the state machine.

Communication of the TCS3472 data is accomplished over a fast, up to 400 kHz, two-wire I2C serial bus. The industry standard I2C bus facilitates easy, direct connection to microcontrollers and embedded processors.

Pros

+Programmable Analog Gain and Integration Time

+Very High Sensitivity — Ideally Suited for Operation Behind Dark Glass

+Programmable Upper and Lower Thresholds with Persistence Filter

+Low Power — 2.5-A Sleep State

+I2C Fast Mode Compatible Interface

+Finally, it has IR blocking filter as we refer it above. It works between nearly 755 – 1100 nm.

It means that IR filter block 750 nm and up values. It eliminates these IR lighting color error. It is appropriative value for this project. We decided to use it cause of this advantage.

6. PRELIMINARY DESIGN

For this project, I had to decide to parts as color sensor, communication system, device to connect, processor, processor programming languages and wires.

I use TCS34725 color sensor for color measurement, Bluno Beetle for both processing code and get information from sensors and send data to smart phone using internal BLE 4.0, Arduino IDE on PC for writing code about this device also I use Android Studio for creating mobile app.

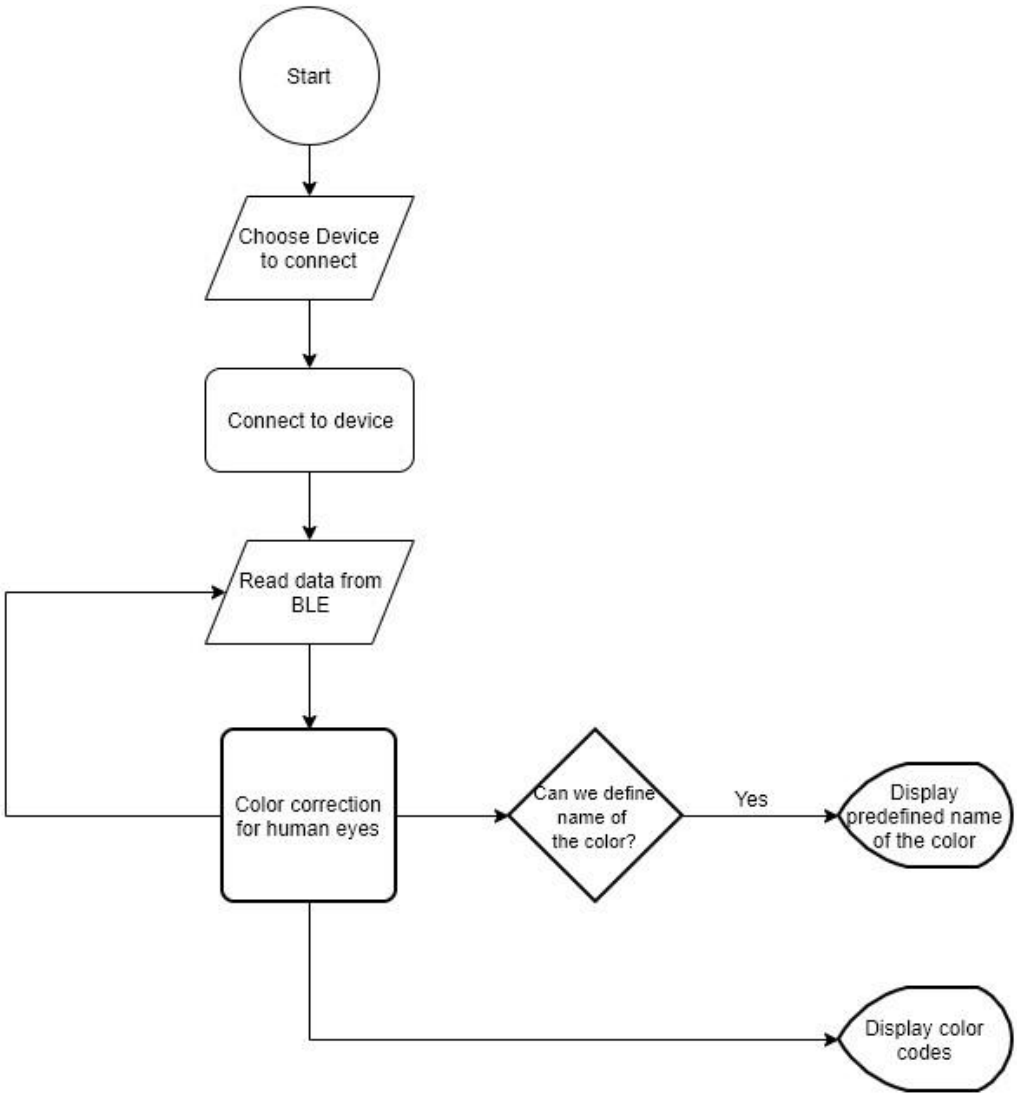


Figure 6-Android Flowchart

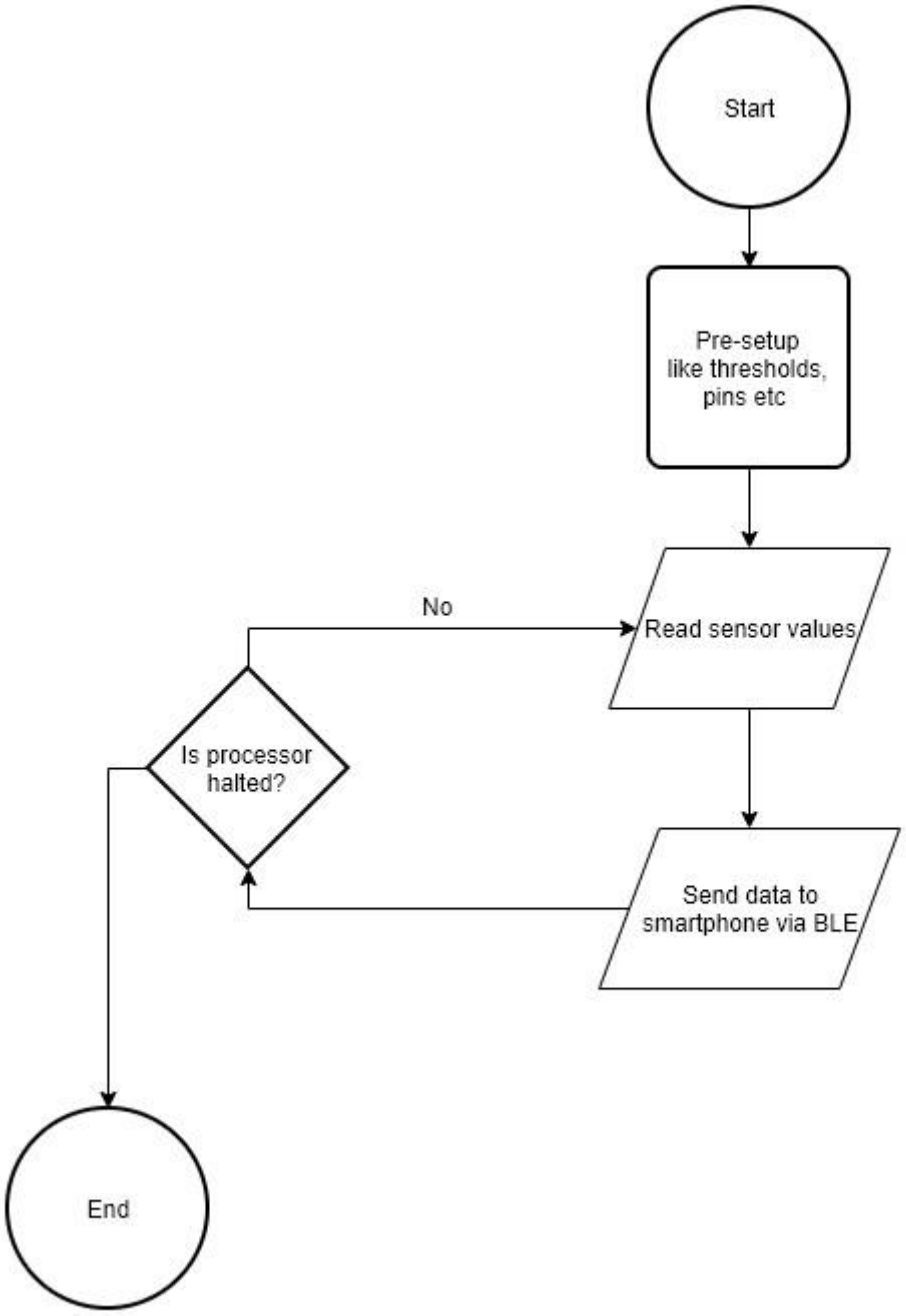


Figure 7-Processor Flowchart

7.PROTOTYPE

Main objectives of building the prototype are;

- Making sure that all the circuit parts are functional and working.
- Testing of connection between device and an android smart phone via BLE.
- Determine the exact battery I need for the device and test usage time.
- Seeing how small can the device be and decide on the box for a device.

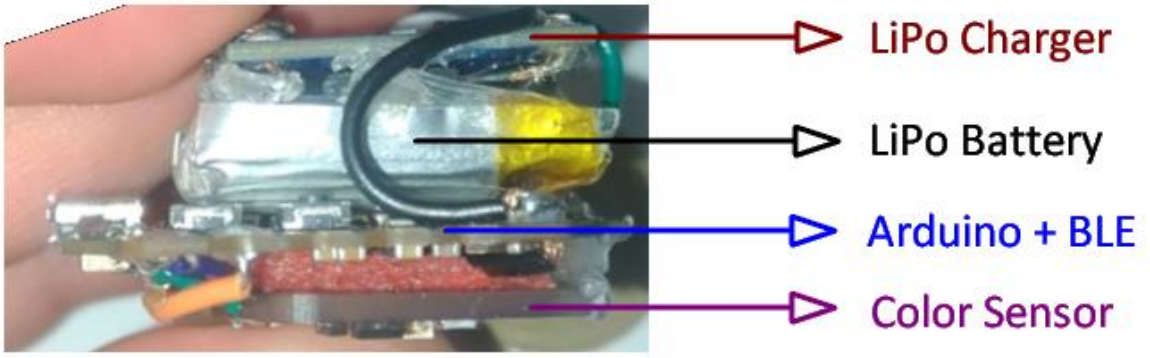


Figure 8. Device with parts

Currently prototype device can connect to the android smartphone, send and receive data from it. Also device is chargeable and have lipo battery on it.

Color read function not implemented yet but I have tested color sensor and got useful data which shows me that, color sensor function can easly be add to device via few lines of codes.
I will add this function soon. I focused on android code part to handle communication and color calibrate operations.

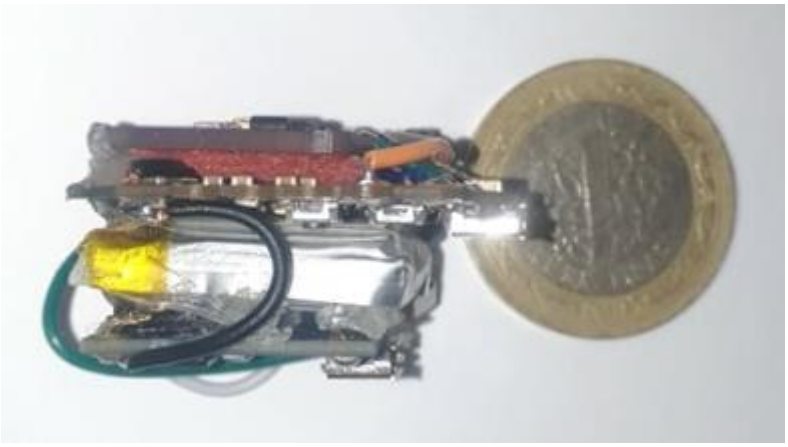


Figure 9 Side view

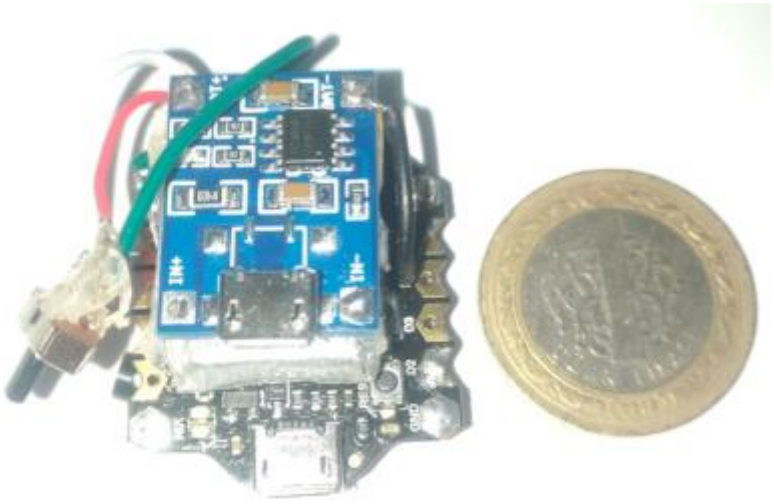


Figure 10 Upper view

8.DESIGN PROCESS

8.1. ITERATION 1- Sensor ON all the time

That was the first iteration I came up with. Merging all parts and just sending measured data to android phone seems logical to me.

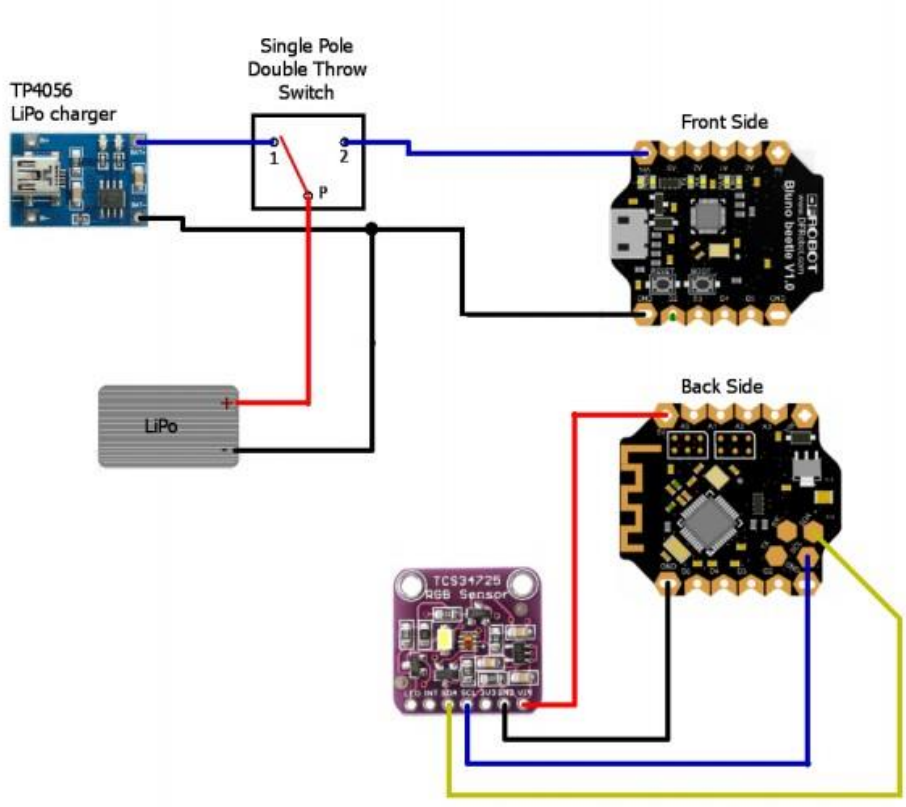


Figure 11-Iteration-1 scheme

However I realized that I need to some regulations and actions on device since it is always on and somehow consume power without anysense. So I tend more to double side communication as like 2 master devices instead of master & slave system.

8.1.1. TESTING AND RESULTS

Power consumption was extremely high because sensor led was always ON.

Controlling the sensor was impossible without android command because device alone, have no information about when to start measuring.

8.1.2. EVALUATION

I decided to add some communication codes to command from android to device. I also added transistor to cut sensor power because sensor was directly connected to power pins and it wasn't what i want.

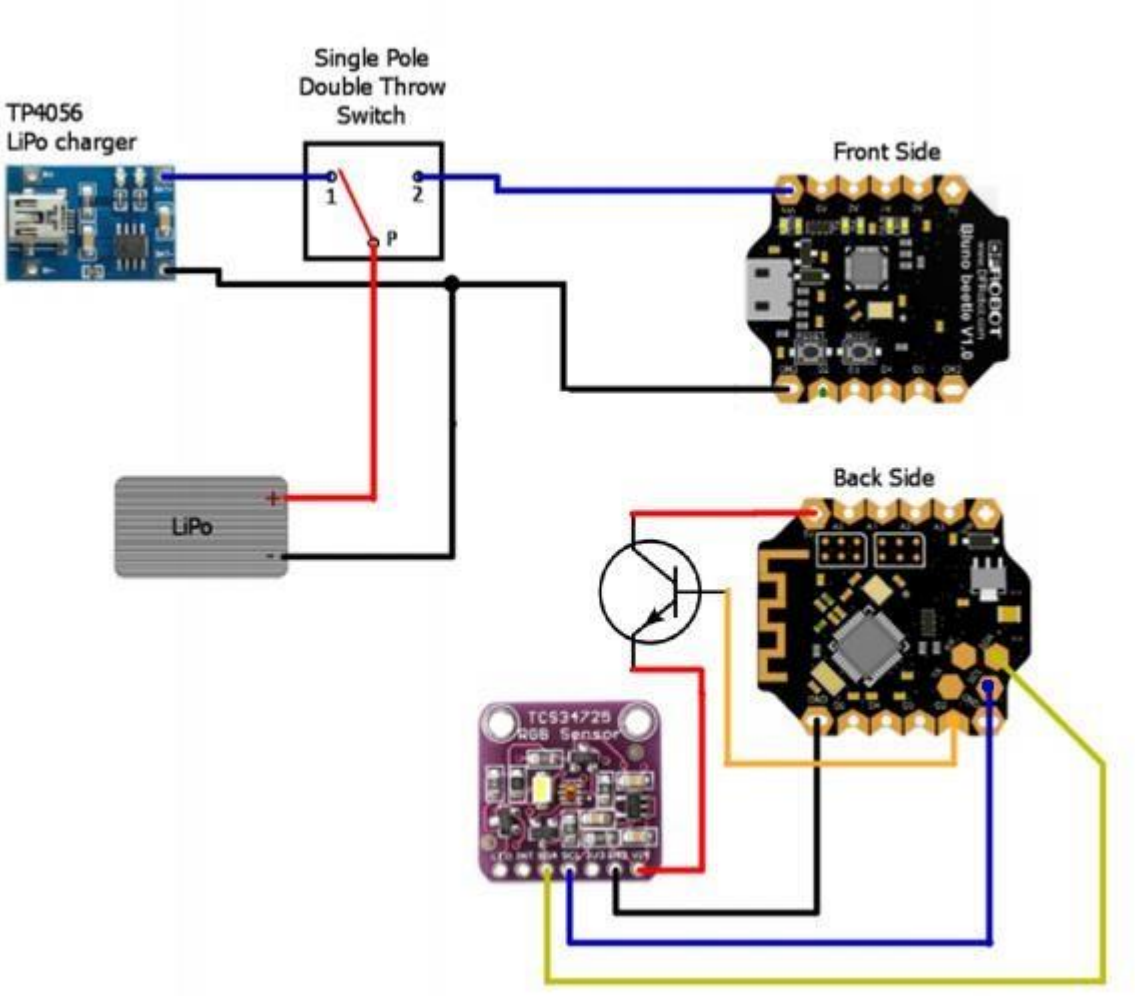


Figure 12-Solution to the problem

8.2. ITERATION 2- Reducing number of micro USB port

There is two micro usb ports on my device. One on arduino board and other one on LiPo charger. So I thought that I could somehow merge this micro usb ports and made more minimal design. However it was bit of fail to be honest.

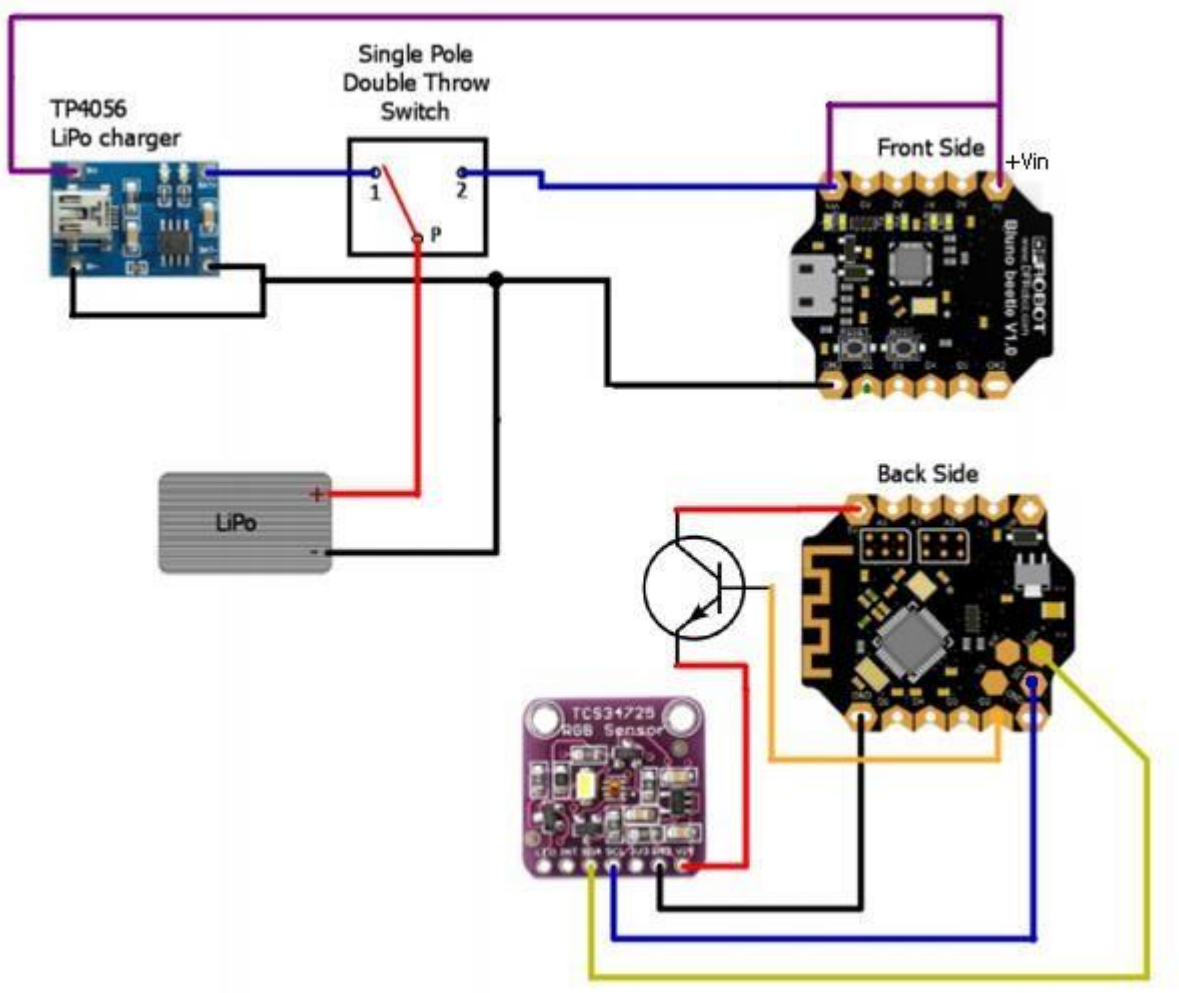


Figure 7. Iteration-2 failed scheme

This circuit diagram seems flawless but there is a critical error. When the SPDT switch at position (2)

circuit basically became a unsafe lipo charger.

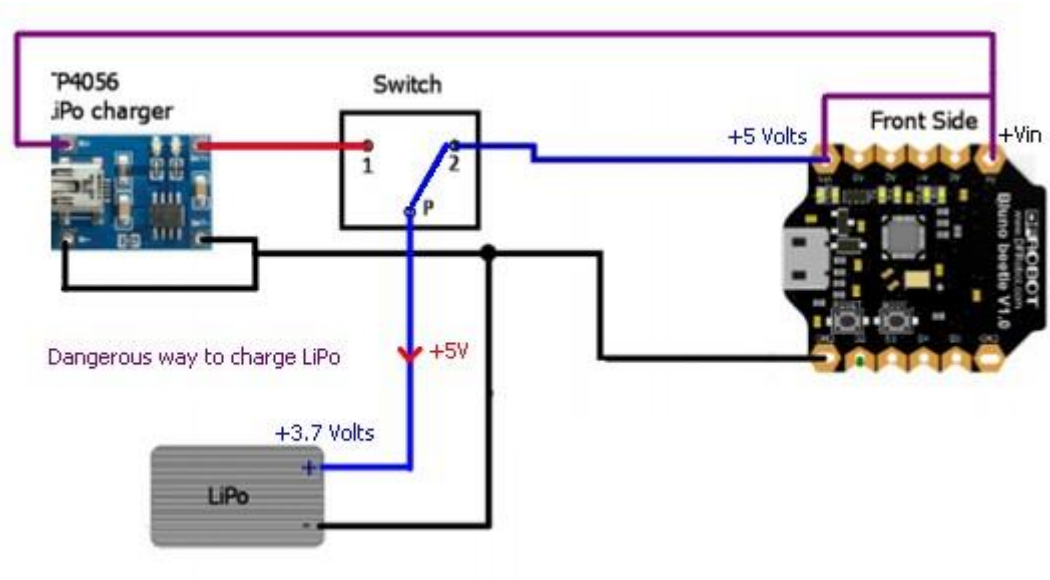


Figure 8. Circuit diagram at switch position 2

8.3. ITERATION 3- Reducing number of micro USB port part2

I tried to solve previous iteration's problem with a little add-on. I added diode to prevent current leakage from device to LiPo.

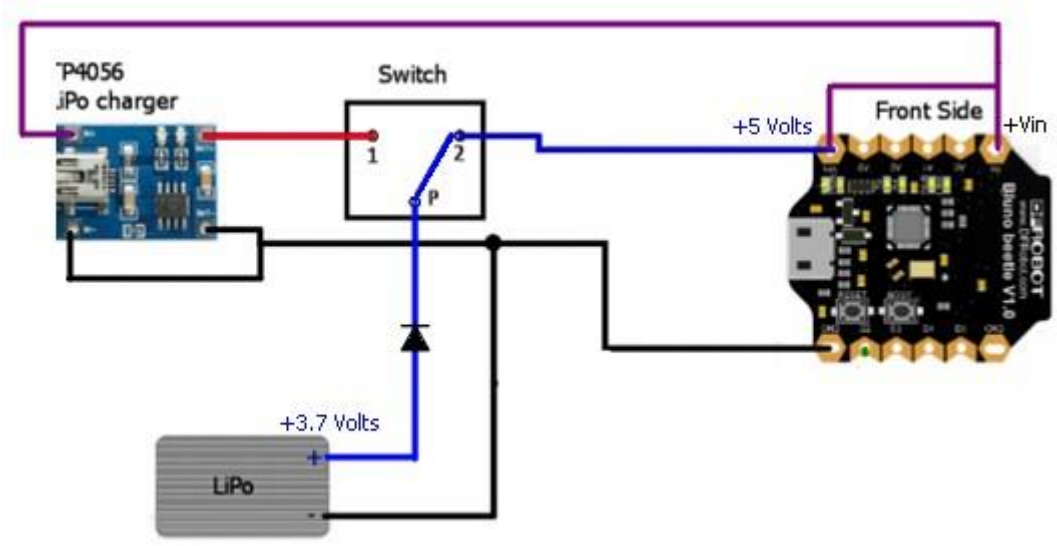


Figure 9.Diode added circuit

Circuit looks perfect after added diode but when device working without charging this diode reduce working voltage by 0.7 so LiPo voltage reduced to 2.0(min) – 3.0(max) Volts from 2.7(min) - 3.7(max) Volts and became unstable below 2.5 Volts.

8.3.1. EVALUATION

After a few research, I decided to remove the diode and choose stability over minimality.

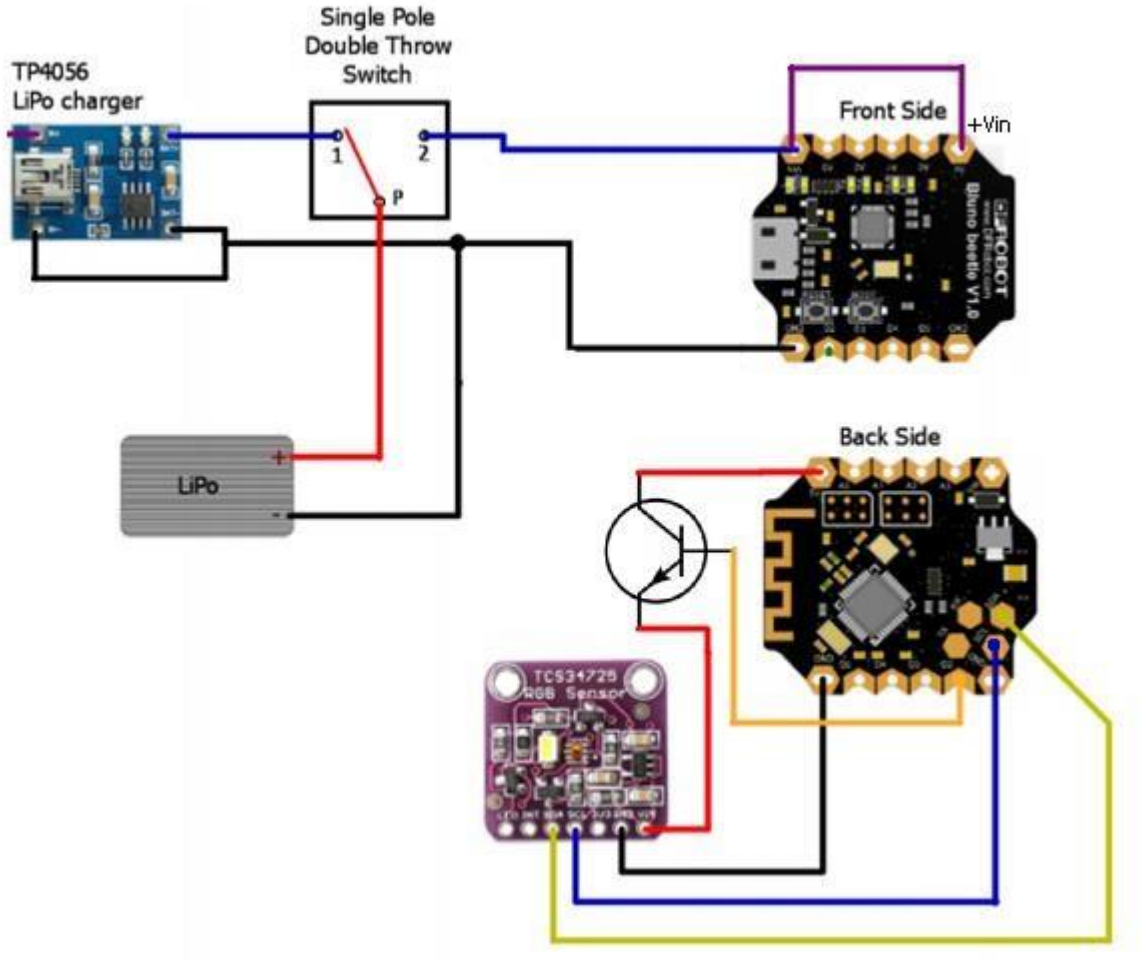


Figure 10. Last Version of circuit diagram

9. FINAL DESIGN

Final design of device succesfully measured color with a little error. Android and device working flowchart not changed since algorithms were good for the color measuring and communication.

My main objective was able to create the small, mobile, and accurate measuring device and I achieved to all.

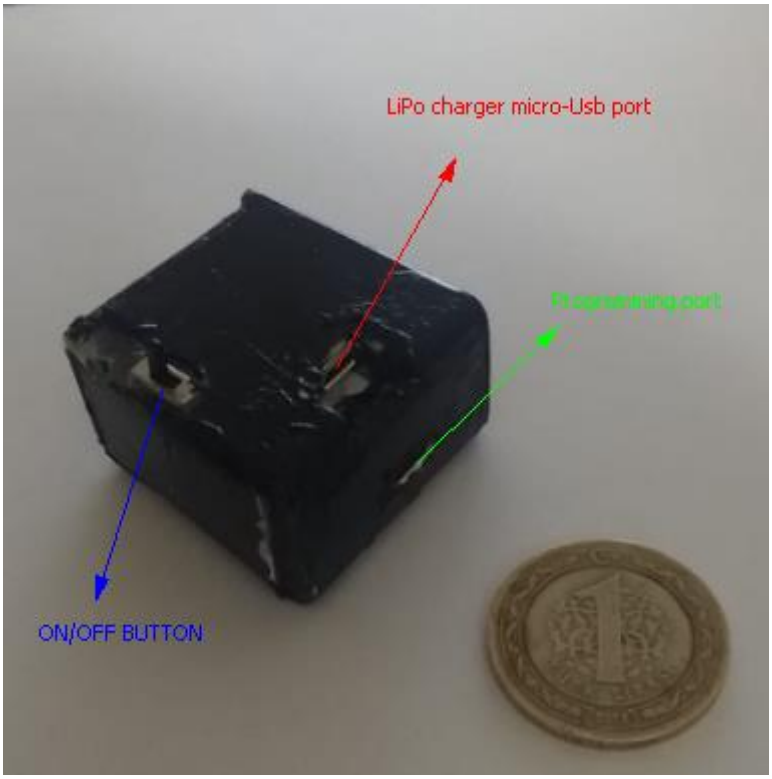


Figure 13-Final device

9.1.TESTING

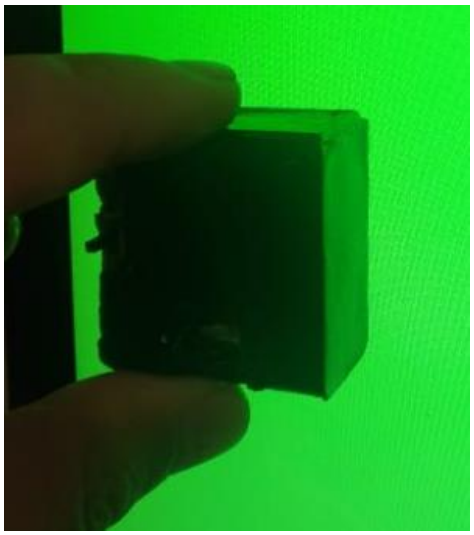


Figure 14-Testing color measurement

Color value for testing was a random bright color #39fb2a. Its almost full green with a little bit red and blue.

Figure 15-#39fb2a color

Measured color was #42FD2D close enough to detect color.

Figure 16-Screenshot of measurement

9.2.MEETING THE CONSTRAINTS AND ENGINEERING STANDARDS

When I create this project always searched engineering standards availability. My dedicated modules which are color sensors, microprocessor and other basic devices has get approval from engineering standards. They all have engineering standards. I checked this device about engineering standards, this device with all its packet can get a new engineering standards and it can get approval.

9.3.COST ANALYSIS

Prices of Sensors;

-TCS3200	26.98 TL	(chinese price $2.94 = 17.89 TL + shipping)
- TCS34725	63.82 TL	(chinese price $4.64 = 27.27 TL + shipping)
Processors		
-Arduino nano	18.00 TL	(chinese price $1.58 = 9.29 TL + shipping)
-Bluno Beetle BLE	106,63 TL	(DF robot price $14.90 = 86.75 TL + shipping)
150 mAh LiPo battery	17.50 TL	
Total cost of project	232.95 TL	

10. TEAM WORK

I worked alone in this project. It was bit difficult to working alone on both android and hardware part but I saw that It’s possible with good time planning.

11. COMMENTS AND CONCLUSIONS

I have gained experience from this project. First, I learned read the datasheet when design a project and increased my experiences. I learned to be able to make fast decisions under difficult conditions. This project has made a lot of contribution to our engineering development. I learned the market research and find proper and cheap components. I will continue to developing and improving to android application and merge with a android camera and machine learning.

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