Politecnico di Torino

Basilicum Soil Moisture Sensor

Technical Report

Electronic Systems Engineering

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Group 30

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Contents

CHAPTER 1

Project Specification

1.1 Introduction

Soil moisture refers to the water content of the soil. It is defined as the amount of water per total unit volume or mass of soil.

Measuring and controlling soil water content is possible using soil moisture sensors. The measurement can be achieved using *in situ* probes or remote sensing methods. Based on periodic measures it is possible to manage irrigation systems to optimize water consumption and handle agricultural growth.

Most cheap soil moisture sensors corrode when they are in contact with the soil for long periods of time and so they can damage the soil and therefore harm the plant that is growing inside.

1.1.1 Objectives

In the light of this information, the purpose of this project was to develop a system capable of monitoring the data of the moisture of an agricultural purpose soil, which can be for a domestic or large scale agriculture application.

The expected outcomes of the project were the PCB's Gerber files and its evaluation by a manufacturer.

1.1.2 Features and Ratings

The main features of the device are:

- **Low-Cost**
- **Low-Power**
- **Digital sensor**
- **Non-damaging sensor**
- **Rechargeable Li-Po battery**
- **Low energy Bluetooth protocol**
- **No commercial purposes**

CHAPTER 2

Design Flow

The following steps were performed in the design flow of the project.

- Project name and logo development
- Project specifications
- Components selection and packages discussion
- Schematic design with Cadence
- Printed Circuit Board design with Allegro
- Gerber files generation and submission to a manufacturer
- Technical report composition

As the goal of the group was to develop only the gerber files, no future steps are planned.

CHAPTER 3

Name, Logo and Block Diagram

The name chosen for the project is **Basilicum**, which is the scientific name of the basil plant, which was the inspiration for the project. The logo of the device was designed having a basil leaf in mind, and it can be observed on Figure 3.1.

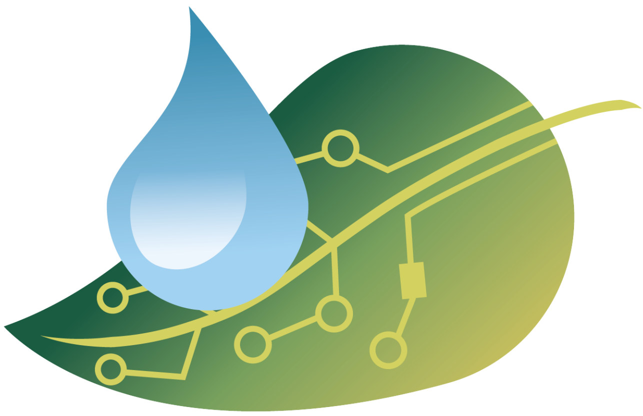


Figure 3.1: Project Logo

A block diagram of the functionality of the device can be observed on Figure 3.2.

The behaviour of the system simply a periodic data transmitter. The soil moisture data is periodically measured from the probe and it's acquired by the microcontroller. The microcontroller, in turn, transmits this acquired data via low energy Bluetooth to a receiver, which could be a smartphone. The functional schema is completed by two Quartz Oscillators, a Power Circuit which is basically composed by a rechargeable battery and some ICs used to manage the battery charging. In addition two status Led are also present, one for battery charging status and the other for microcontroller activities status. The entire circuit can be switched on and of by a three pin switch.

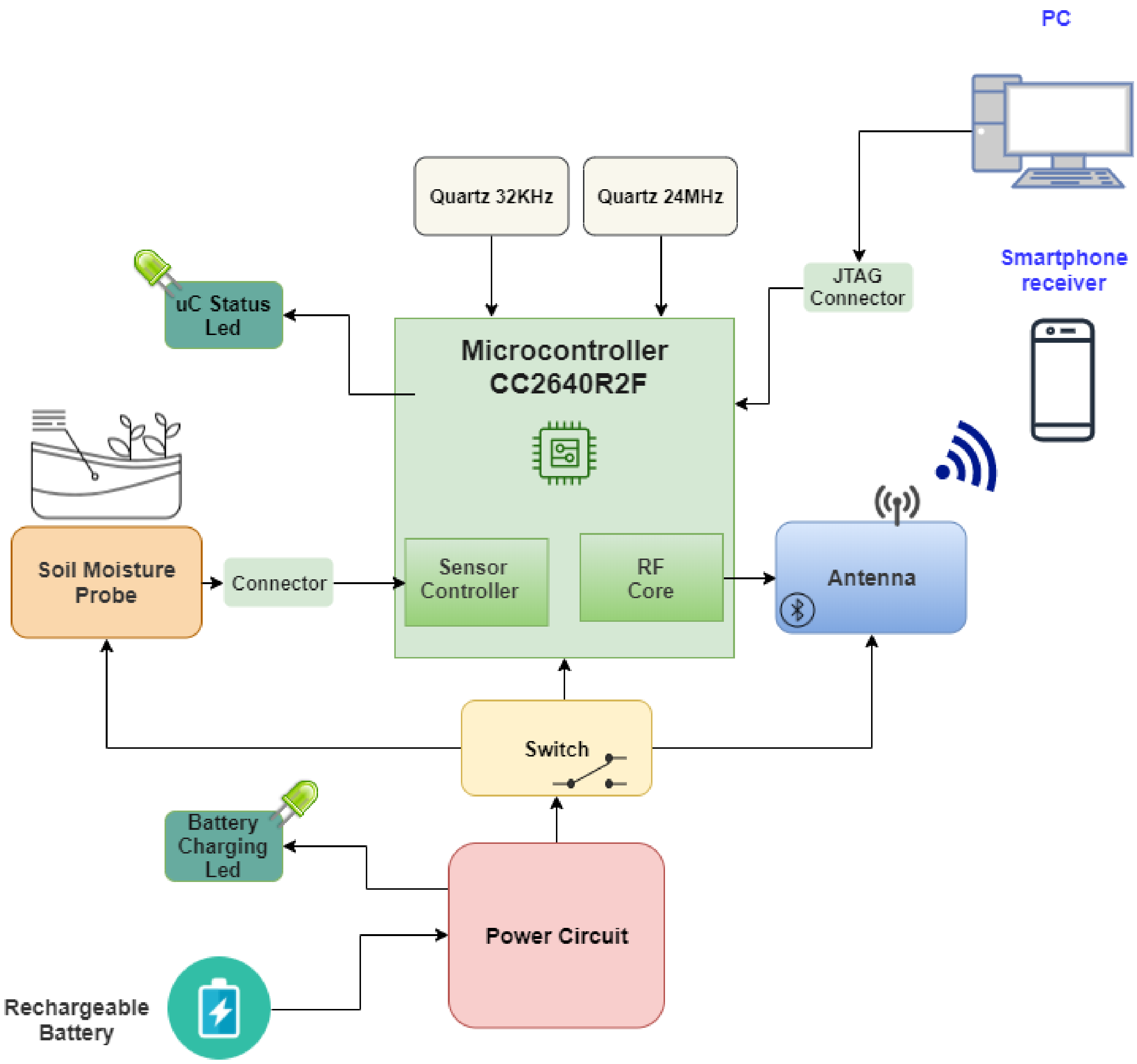


Figure 3.2: Block Diagram

CHAPTER 4

Components Selection

4.1 Soil Moisture Sensor

After a market analysis, the chosen soil moisture sensor was the **Adafruit STEMMA**. The features of the Sensor were taken from the official Adafruit website [3].

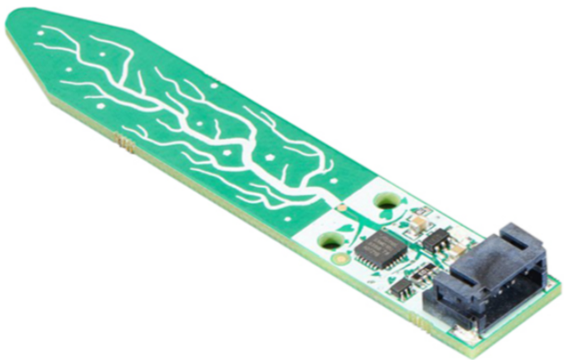


Figure 4.1: Adafruit STEMMA Soil Mosisture Sensor

Features:

- Capacitive moisture sensor
- Probe does not corrode over time.
- Digital
- I^2C interface
- Auto Calibrated
- Electical Parameters:
  - Voltage supply: 3-5 VDC
  - Active Current: 6 mA

The sensor has been chosen with the objectives to keep the cost of the system low and to be at the same time suitable for different applications. The sensor is designed to be an external sub module equipped with an external microcontroller (ATSAMD10D14) and a voltage regulator(MIC5225) as shown in the schematic in Figure 4.2.

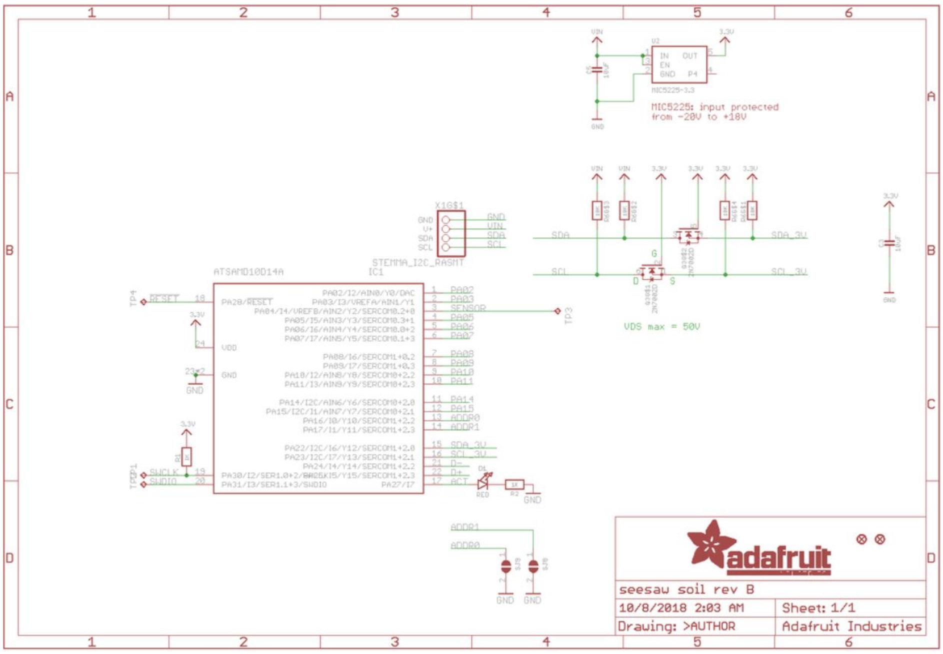


Figure 4.2: Adafruit STEMMA Soil Mosisture Sensor schematic

Pinout

- **GND:** Power and Logic Ground
- **VIN:** 3-5V DC (use the same power voltage as you would for I2C logic)
- **I2C SDA** : I2C SDA pin with a 10k pull-up resistor to VIN
- **I2C SCL** : I2C SCL pin with a 10k pull-up resistor to VIN

4.2 Microcontroller

The microcontroller used for the project was the **Texas Instruments Microcontroller CC2640R2F**. The information described in this section were found on the official datasheet [5] of the microcontroller.

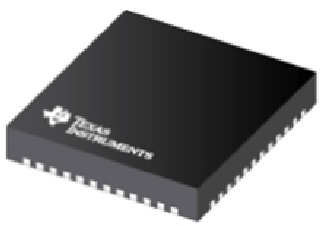


Figure 4.3: Texas Instruments Microcontroller CC2640R2F

Features:

- Package 7-mm x 7-mm RGZ VQFN48 (31 GPIOs)
- ARM Cortex-M3
- Low Power : Supply Voltage Range in Normal Operation: 1.8 to 3.8 V
- SPI,I2C compatible
- Up to 48-MHz Clock Speed
- 2.4-GHz RF Transceiver Compatible With Bluetooth low energy

In Figure 4.4 it is reported the functional schema of the Microcontroller, whereas in Figure 4.5 it is shown the Pin diagram of the CC2640R2F RGZ package used in that project (7mm x 7 mm).

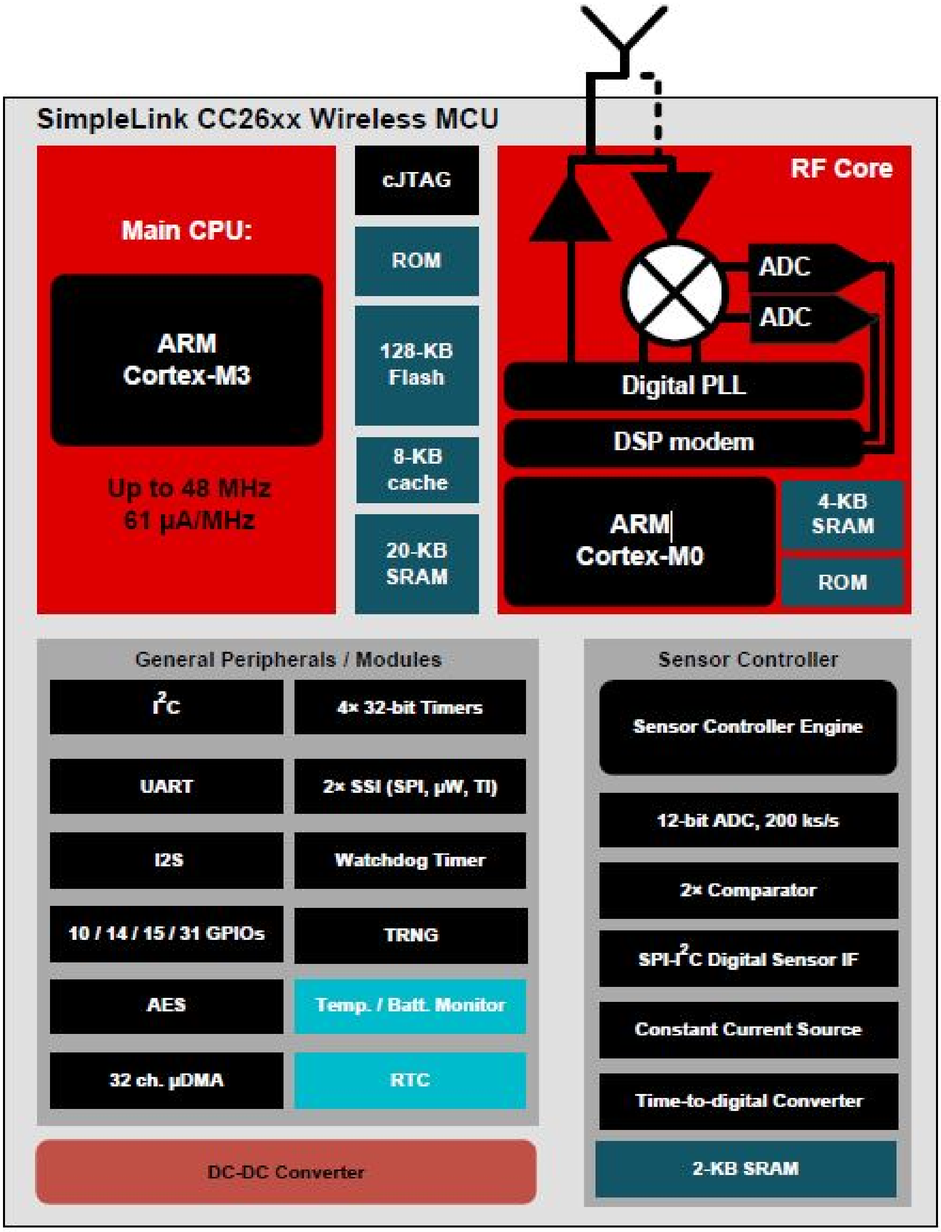


Figure 4.4: Texas Instruments Microcontroller CC2640R2F Functional Schema

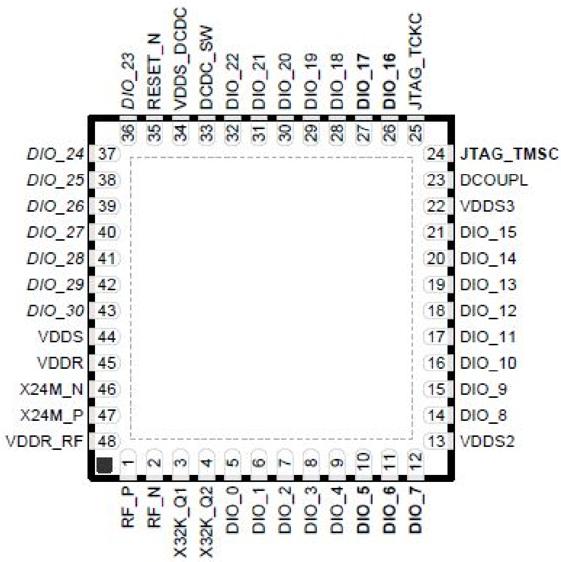


Figure 4.5: Texas Instruments Microcontroller CC2640R2F RGZ Package 48-Pin VQFN (7-mm 7-mm) Pinout, 0.5-mm Pitch

4.3 Battery Circuit

For a long operation, a rechargeable Li-Po battery was selected for the device. And therefore a circuit for the recharge of the battery is also needed to be implemented.

4.3.1 Rechargeable Battery

Figure 4.6: LP-5233345

The selected battery was the **LP-523334**. The features of the battery were taken from the official datasheet [9]. It contains a embedded protection circuit, a cable and a JST PH-2P connector. For a long duration of the system, a high capacity of 500 mAh battery was selected. In this way, the circuit can have an estimated battery cycle of approximately one week without beeing recharged.

Features:

- Lithium-polymer battery
- Nominal Voltage: 3.7V
- Voltage at end of discharge: 3V
- Charging voltage: 4.2V
- Rated Capacity: 500 mAh
- Cycles life: >500cycles

4.3.2 USB Battery Charger

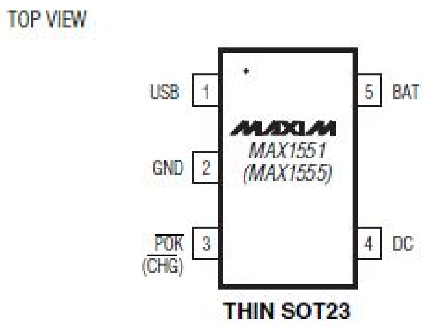


Figure 4.7: USB Battery Charger MAXIM MAX1555

The selected battery charger circuit was the **USB Battery Charger MAXIM MAX1555**. The MAX1551/MAX1555 charge a single-cell lithium-ion (Li+) battery from both USB and AC adapter sources. They operate with no external FETs or diodes, and accept operating input voltages up to 7V [7].

Pinout:

- PIN 1: USB - not used
- PIN 2: GND - Common ground to the circuit
- PIN 3: /CHG - Goes high when the battery is fully charged
- PIN 4: DC - Power input from USB port
- PIN 5: BAT - output current to the positive pin of the battery

The charger circuit does not have an enable functionality, once the power is on, the circuit will charge the battery until it is fully charged. The pin 3, /CHG, gives the opportunity to place a status led to indicate if the battery is charging or fully charged.

4.3.3 Fuel Gauge

For monitoring the battery status, the low-power Fuel Gauge **MAX17048** circuit was implemented. The circuit senses the battery State of Charge (SoC) and communicates it via an I2C interface [6].

Features:

- Monitors one Lithium-polymer battery
- Precision 7.5mV
- Reports Charge and Discharge Rate
- Configurable Alert Indicator
- I2C Interface
- Supply Voltage: 2.5 - 4.5 V

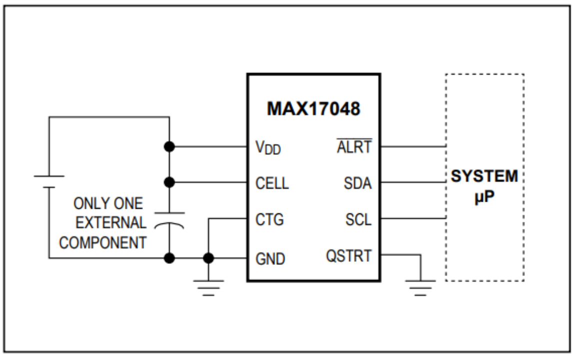


Figure 4.8: Fuel Gauge MAXIM MAX17048 example circuit

PIN-OUT:

- PIN 1: CTG - Connect to Ground
- PIN 2: CELL - Connect to the Positive Battery Terminal.
- PIN 3: VDD - Power-Supply Input. Bypass with 0.1F to GND
- PIN 4: GND - Ground. Connect to negative battery terminal.
- PIN 5: /ALERT - Open-Drain, Active-Low Alert Output. Optionally connect to interrupt input of the system microcontroller
- PIN 6: QSTRT - Quick-Start Input. Allows reset of the device through hardware. Connect to GND if not used.
- PIN 7: SCL - I2C Clock Input. SCL has an internal pulldown (IPD) for sensing disconnection
- PIN 8: SDA - Open-Drain I2C Data Input/Output. SDA has an internal pulldown (IPD) for sensing disconnection

4.4 Connectors

4.4.1 Micro USB

The **Micro USB MOLEX 1051640001** has been chosen simply as a connector for battery charging. In the Figure 4.11 are reported some basic information.

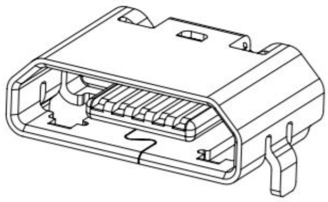


Figure 4.9: Micro USB MOLEX 1051640001

Physical	
Boot Color	N/A
Circuits (Loaded)	5
Circuits (maximum)	5
Color - Resin	Black
Durability (mating cycles max)	10000
Flammability	94V-0
Gender	Female
Keying to Mating Part	Yes
Lock to Mating Part	No
Material - Metal	Copper Alloy
Material - Plating Mating	Gold
Material - Plating Termination	Gold
Material - Resin	High Temperature Thermoplastic
Net Weight	0.234/g
Number of Rows	1
Orientation	Right Angle
PCB Retention	None
Packaging Type	Embossed Tape on Reel
Panel Mount	No
Pitch - Mating Interface	0.65mm
Pitch - Termination Interface	0.65mm
Polarized to Mating Part	Yes
Ports	1
Surface Mount Compatible (SMC)	Yes
Temperature Range - Operating	-30° to +85°C
Termination Interface: Style	Surface Mount
Waterproof / Dustproof	No
Electrical	
Current - Maximum per Contact	1.8A, 1.0A
Grounding to Panel	Yes
Shield Type	Full Shield
Shielded	Yes
Voltage - Maximum	30V AC (RMS)

Figure 4.10: Micro USB MOLEX 1051640001 DataSheet

4.4.2 JTAG

The **JTAG Connector Samtec FTSH-105-01-L-D-K** is to connect the microcontroller to a pc.

Figure 4.11: JTAG Connector Samtec FTSH-105-01-L-D-K

4.4.3 Other Connectors

The other connectors used are the **Battery connector JST SM02B-SRSS-TB(LF)(SN)** for battery connection and the **Male JST 4-Pin Connectors** for Sensor sub module connection.

4.5 Others

4.5.1 Slide Switch

Figure 4.12: Slide Switches JS102011SAQN SPDT

The chosen switch is the **ON-OFF Sub-Miniature Slide Switches JS102011SAQN SPDT**. It presents two holes as reported in [1] in order to guarantee a better mechanical stability with respect to the common surface mount switches.

4.5.2 Status LED

Figure 4.13: Led 0603 SMLD12EN1WT86

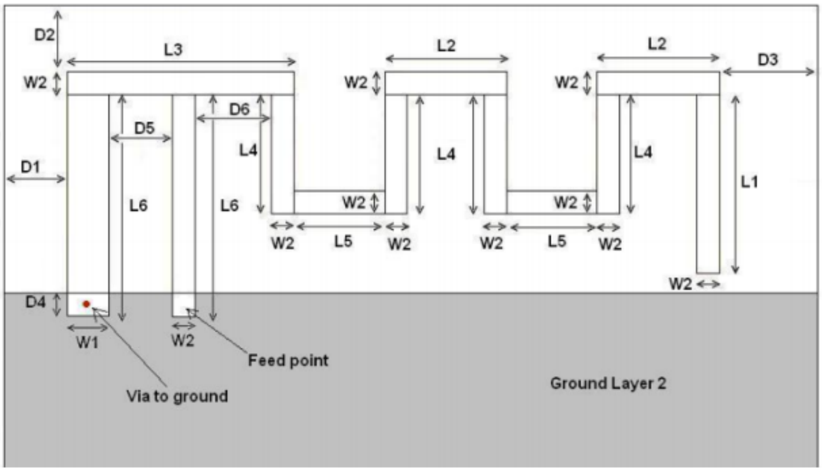
The led chosen for that system to work as a Status indicator is the **Led 0603 SMLD12EN1WT86** as reported in the datasheet [8] it requires an Active Current of 5mA.

4.5.3 Passive Components

The passive components used are resistors, inductors and capacitors SMD 0603.

4.5.4 Patch Antenna

For a Bluetooth communication, an antenna is needed in order to achieve a good communication distance. In this way, a PCB patch antenna was implemented following the Texas Instruments recommendations. The antenna must be connected to the ground and to a feed point. A decoupling circuit is also needed from the RF pin of the microcontroller to the feed point of the antenna.



L1	3.94 mm
L2	2.70 mm
L3	5.00 mm
L4	2.64 mm
L5	2.00 mm
L6	4.90 mm
W1	0.90 mm
W2	0.50 mm
D1	0.50 mm
D2	0.30 mm
D3	0.30 mm
D4	0.50 mm
D5	1.40mm
D6	1.70 mm

Figure 4.14: PCB antenna dimensions description

4.5.5 Crystals

The Quartz inserted in the PCB are **Quartz 24MHz TSX-3225 24.0000MF15X-AC3**[2] and **Seiko SC-20S 7pF**[4].

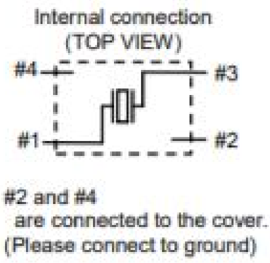


Figure 4.15: Quartz 24MHz TSX-3225 24.0000MF15X-AC3 top view

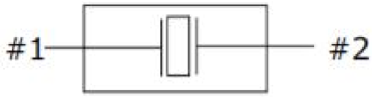


Figure 4.16: Seiko SC-20S 7pF

Item	Symbol	Specifications	Conditions Note
Nominal Frequency	f_nom	32.768kHz	
Frequency Tolerance	f_tol	$\pm 20\times 10^{-6}$	Please specify
Turnover Temperature	Ti	+25±5℃	
Parabolic Coefficient	B	$(-0.030\pm 10\%)\times 10^{-6}/℃^{2}$	
Load Capacitance	CL	6pF～12.5pF	
Motional Resistance (ESR)	R1	70kΩ max.	
Absolute Max. Drive Level	Dlmax.	1.0μW max.	
Drive Level	DL	0.1μW typ.	
Shunt Capacitance	C0	1.3pF typ.	
Frequency Ageing	f_age	$\pm 3\times 10^{-6}$	+25±3℃, First Year
Operating Temperature	T_use	-40～+85℃	
Storage Temperature	T_stg	-55～+125℃	Piece part basis

Figure 4.17: Seiko SC-20S 7pF general information

CHAPTER 5

Orcad

Once the components were selected, a schematic design using Cadence Orcad was performed. The design was divided into three different schematics: One for the microcontroller, one for the peripherals and one for the power circuit.

5.1 Microcontroller

In the Microcontroller schematic shown in Figure 5.1 , it can be seen that there are three main circuits that interact with the microcontroller in a closer level: the decoupling circuits, the antenna and the crystals.

The decoupling capacitors are placed near every power pin of the microcontroller, in order to stabilize the power supply when more current is drawn or in the case when the supply voltage from the battery oscillates or ripples. The capacitors are placed near the pins 44,13,22 and 34 for power, and 45 and 48 for a RF decoupling.

The antenna circuit is the one given by the datasheet of the microcontroller. The inductors and capacitors are placed in order to optimize the Bluetooth transmission performed by the microcontroller.

The two crystals present in the circuit are the 24 MHz crystal used by the microcontroller to create it's clock and the 32.768 kHz used for the Bluetooth transmission.

The microcontroller itself interacts with the rest of the circuit via the Digital Input Output (DIO) pins from DIO-18 to DIO-22. It communicates with the sensor trough the connector (I2C) and the battery monitor, as well as the status LED.

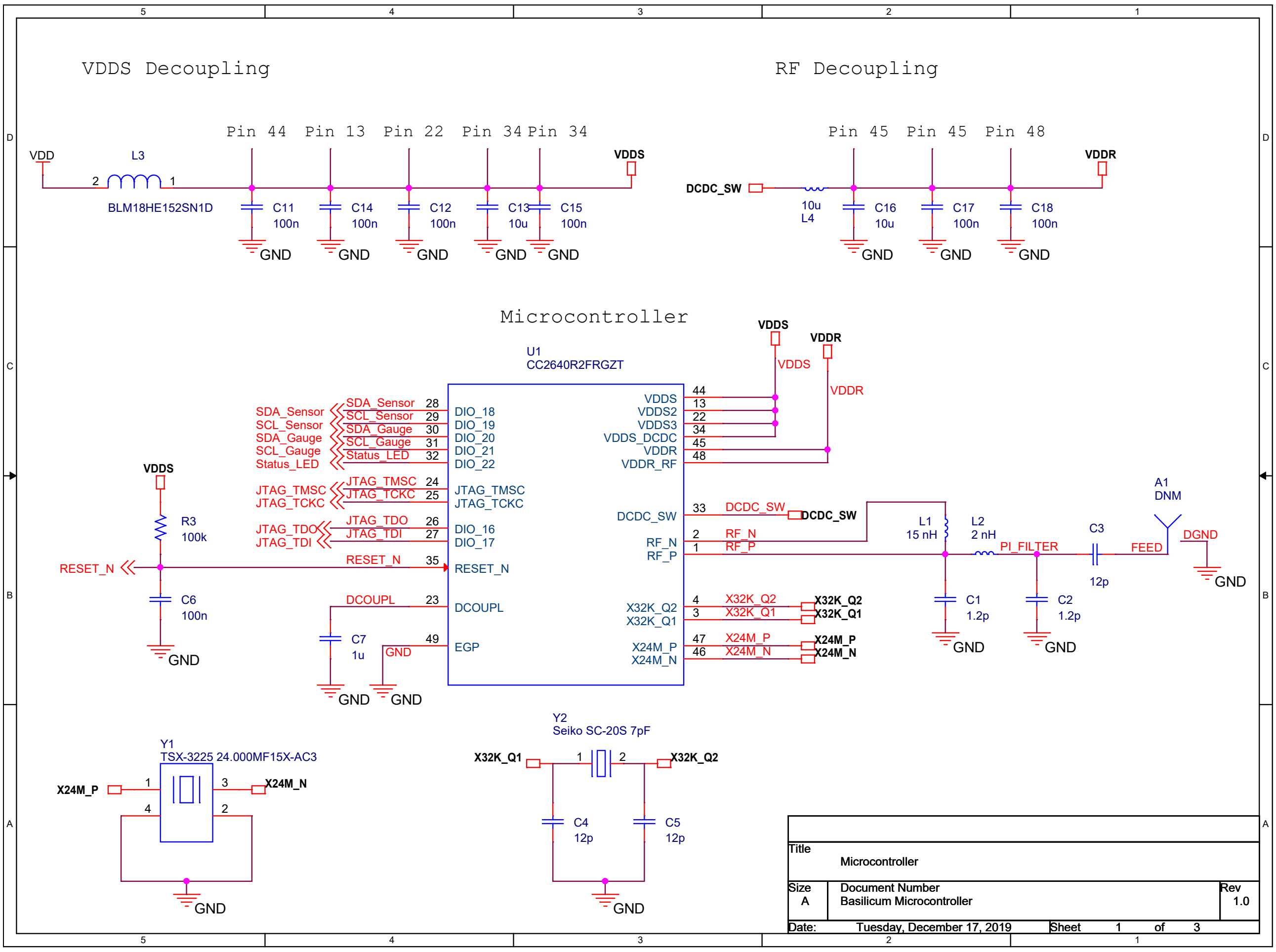


Figure 5.1: Schematic 1: Microcontroller

5.2 Peripherals

In the Peripherals schematic shown in Figure 5.2 , it can be observed the JTAG connector, the Sensor Connector and the Status LED.

The JTAG connector is used for debugging and programming the microcontroller trough a proper firmware.

The sensor connector interfaces with the two I2C inputs from the sensor and also the sensor's power supply.

The status LED is a peripheral inserted to indicate when the device is ON or OFF.

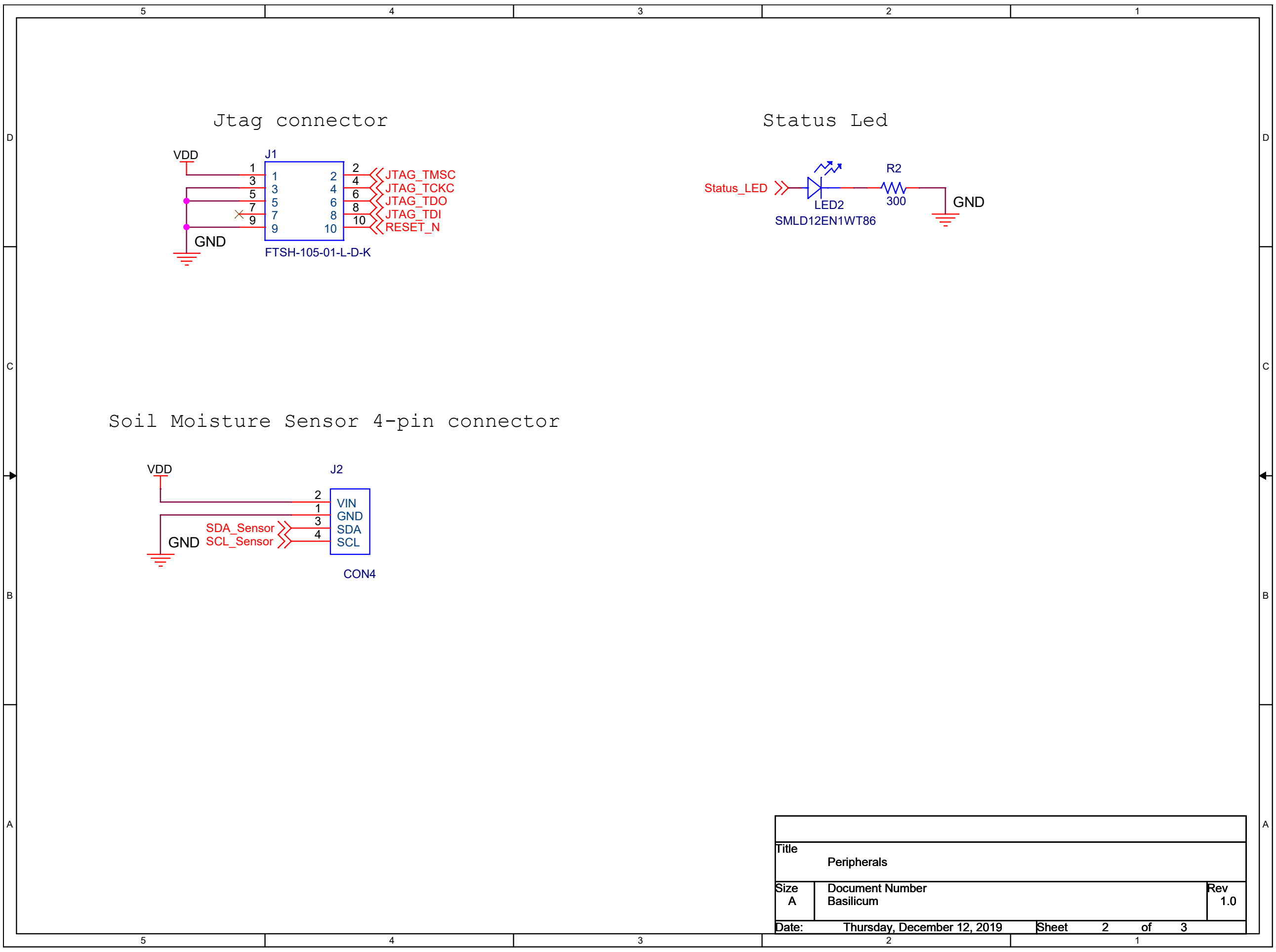


Figure 5.2: Schematic 2: Peripherals

5.3 Power Circuit

In the Power circuit, shown in Figure 5.3, the interface of the power supply and the circuit can be observed. With the micro USB connector, the power input passes through the charging circuit and goes to the battery connector, which by it's time passes through the slide switch and goes to the rest of the circuit. The charging circuit contains a status indicator LED, that is on when the circuit is charging and OFF when it is not, or when the battery charge is complete.

It can also be observed the Fuel Gauge, the battery monitor, which communicates with the micro-controller via a I2C interface.

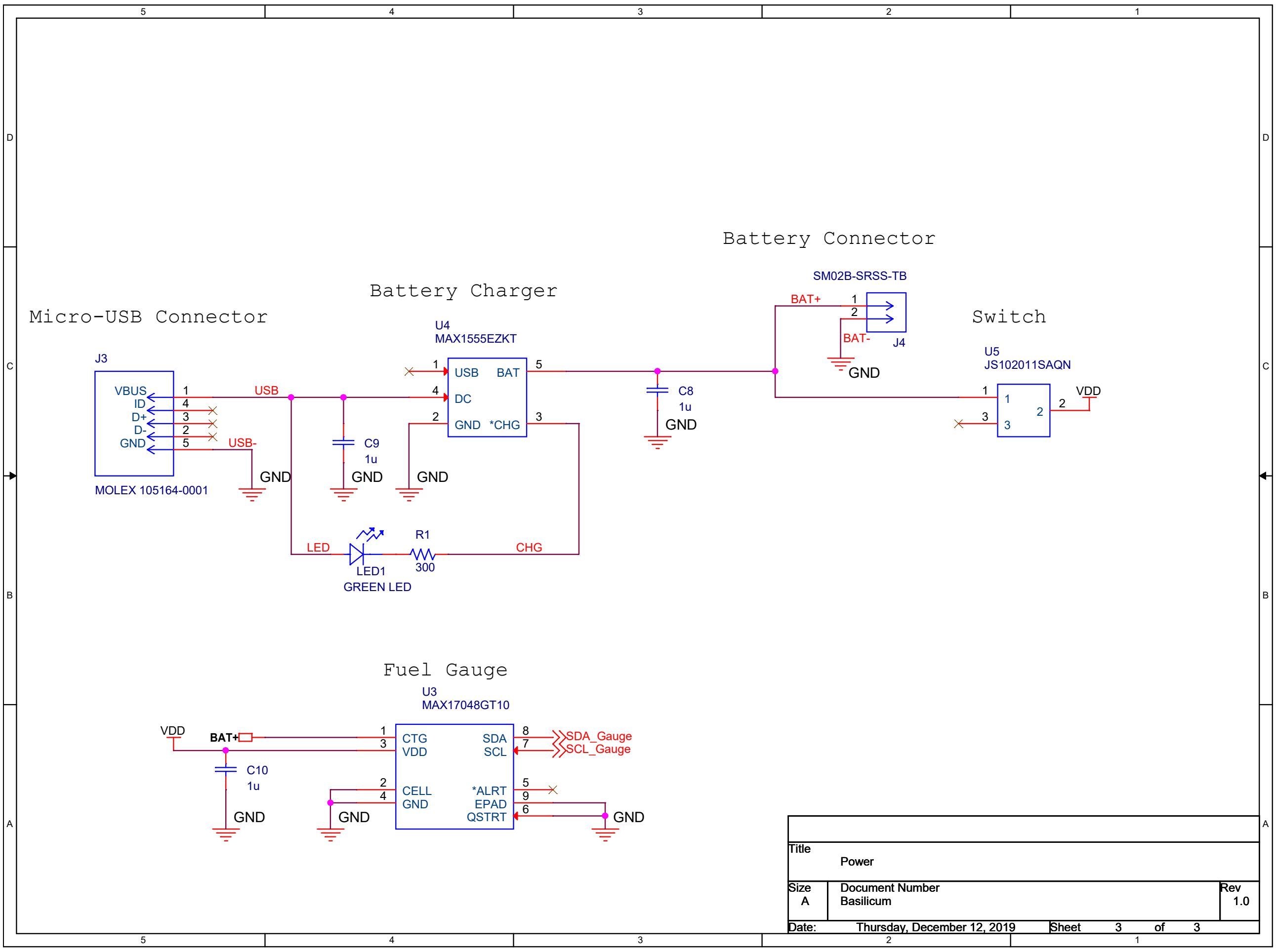


Figure 5.3: Schematic 3: Power

CHAPTER 6

Allegro

After the schematic design was finished, the last step was to draw the PCB of the circuit using Allegro. The main considerations in this phase were: to leave the path to the patch antenna the shortest as possible to avoid parasitic capacitors with the microcontroller and to put decoupling capacitors as close as possible the related pins. The path from the decoupling capacitors to the power supply pins of the integrated circuits was made the shortest as possible as well.

A ground plane was inserted in the bottom layer of the PCB, apart from the patch antenna region to avoid interference.

The JTAG connector, the sensor connector and the slide switch were positioned having in mind the easiest possible utilization of the device.

The obtained PCB is a double layer PCB and it it shown in it's Allegro Top Etch Silk View and Allegro Bottom Etch Silk View, respectively in Figure 6.1 and 6.2

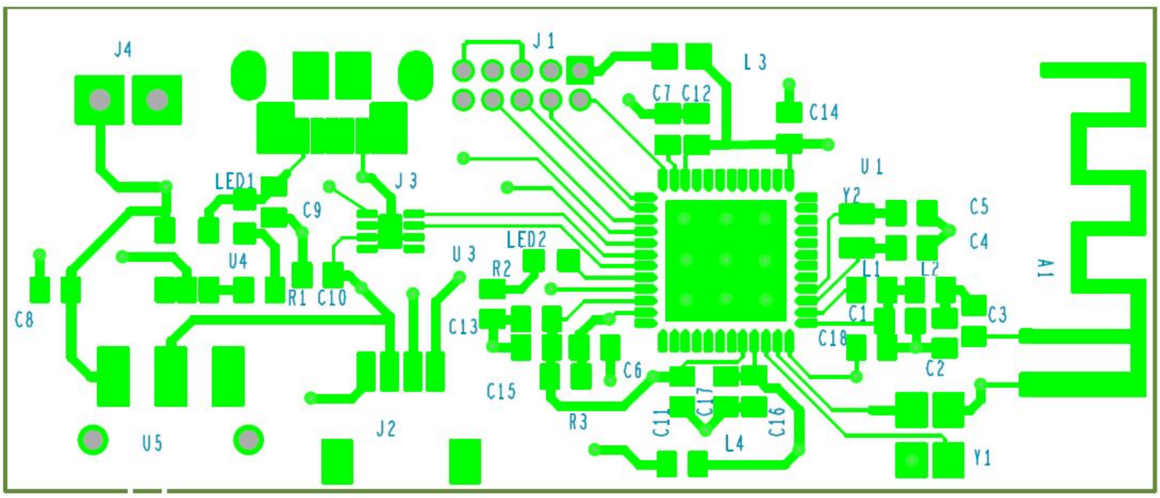


Figure 6.1: Allegro Top Etch Silk View

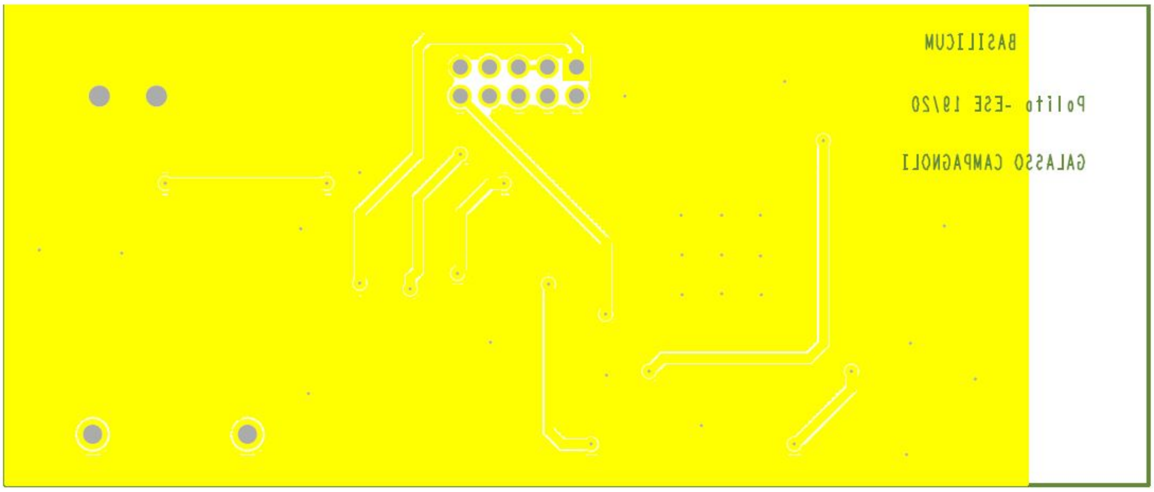


Figure 6.2: Allegro Bottom Etch Silk View

After the design phase the Gerber files were generated and sent to the manufacturer EURO Circuits. The class obtained was 6C and the final fabrication cost without VAT obtained is 35.53 EUR. In Figure 6.3 there are reported the final PCB Technology & options EURO Circuits report. Finally in Figure 6.4 and 6.5 are reported the Top and Bottom View of the manufactured board.

Technology & options

Board definition			
Number of layers	2	Delivery format	No
PCB width (X)	50.14 mm	PCB height (Y)	21.07 mm
eC-registration compatible	No		
Board definition			
Top soldermask	Verde	Bottom soldermask	Verde
Top legend	Bianco	Bottom legend	Bianco
Surface finish	Qualunque finitura leadfree		
Bare board testing	Yes		
Board technology			
Pattern class	6	Drill class	Drill C
Outer layer trackwidth (OL-TW)	0.150 mm	Hole density	<1000/dm2
Outer layer isolation distance (OL-TT-TP-PP)	0.150 mm	Holes <= may be reduced	0.45 mm
Outer layer annular ring (OAR)	0.125 mm		

Figure 6.3: PCB Technology & options EURO Circuits

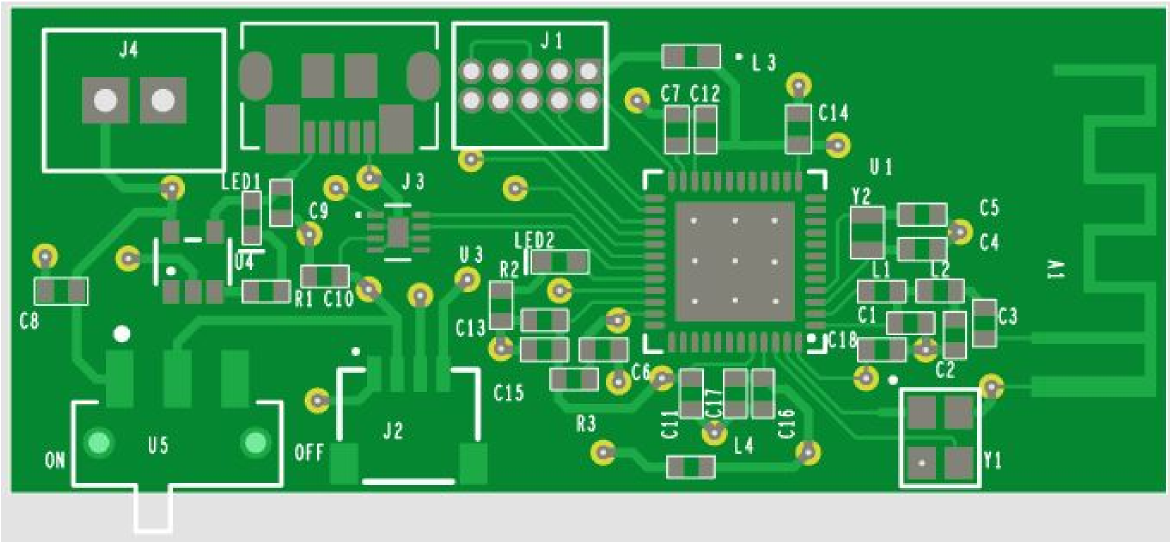


Figure 6.4: Top View

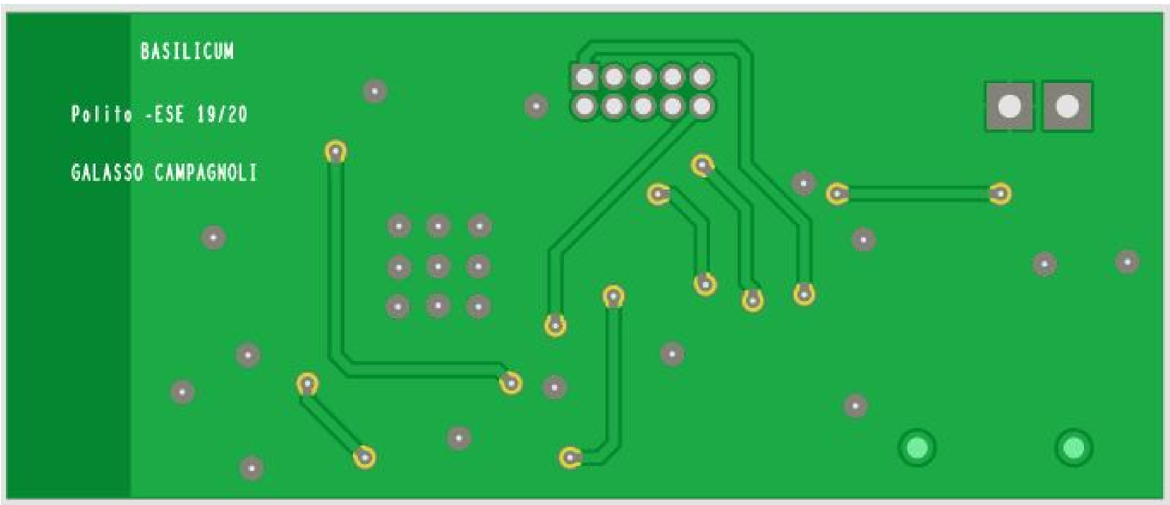


Figure 6.5: Bottom View

CHAPTER 7

History of the project

The Board realization started from the choice of the sensor to use. After that in about two weeks, during which the datasheets of the components were studied, an initial project presentation was realized taking into account four possible sensors; three of them was analog and the last was digital. After studying the various possible applications and the design choices in dependence of the type of sensor to choose; the digital Sensor was chosen. In the following two weeks the effective design was performed. Initially the Capture schematic was realized with few difficulties. The Capture design phase ended generating the Bill Of Materials(BOM) file. Then in the Allegro environment the placement and routing was carried out following hints and rules displayed during the Electronic Systems Engineering course lectures and laboratories. First the top and bottom layer were realized. Then, in the last days, the silkscreen was completed and the Gerber files could be generate. The files were then sent to the manufacturer EURO Circuits. Some minor modifications were performed in the board in order to reduce the Board Technology pattern and drill classes. During the entire second part of the board development this report was written.

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