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Project Report

TOUCH & PLAY

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Contents

1 Project Specification

1.1 Goal of the project

The goal of the project is to the create a launchpad using Cadence EDA tool. This device is a MIDI controller device that receives in input touches, and through Bluetooth communication tells an external device which button was pressed, and the external device reproduces the music sample corresponding to pressed the button. The idea was to create a low cost launchpad to be used by amateur music producers.

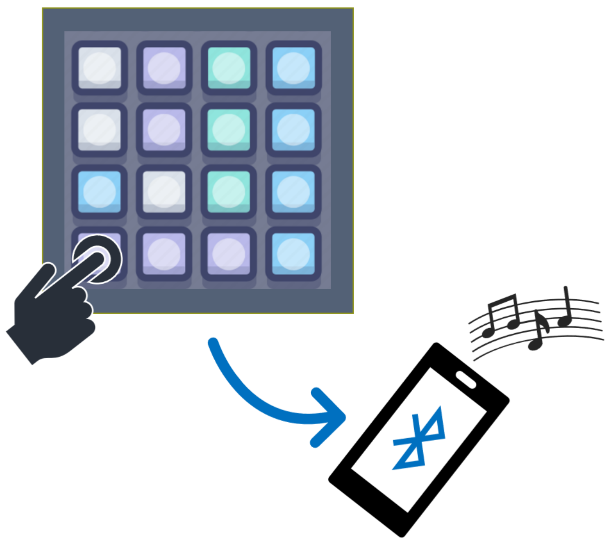


Figure 1: General idea

1.2 Features and Ratings

Here are reported the main features and non-functional specifications of our launchpad:

- Low power device
- Low cost device
- Rechargeable LiPo battery
- Bluetooth communication
- Optimized for RF performance
- Portable device

2 Design Flow

The following design flow was adopted:

- Project name and scope;
- Project specifications;
- Components selection; Develop the package;
- Design schematics in OrCad®CAPTURE CIS
- Design with OrCadtextsuperscript®PCB DESIGNER

3 Name, Logo and Block Diagram

3.1 Name and Logo

The name choose for this project is Touch&Play since the project is a launchpad with touch buttons. The letter 'O' in the word "TOUCH" is replaced by a fingerprint symbol, while the letter 'A' in the word "PLAY" is replaced by the musical play icon.

Figure 2: Touch&Play logo

3.2 Block diagram

The block diagram, which is shown in figure 3, is composed of the following parts:

- **Microcontroller**: the part contains the microcontroller, decoupling inductors and capacitors and external quartzes;
- **Touch Sensor**: the conditioning circuit of the Touch sensor (pull-up resistor and decoupling capacitor) and the sensor itself. The sensor detects touch key presses and and tells the microcontroller which button has been pressed.
- **Touch Buttons**: touch keys configured in a matrix format ;
- **LiPo Rechargeable Battery**: the power source of the system;
- **JTAG connector**: a connection to the external world, it is used to program the microcontroller using a PC;

- **USB connector**: another connection of the circuit to the external world. It is used to recharge the LiPo battery;
- **Charger Circuitry**: circuit used to charge the battery from the USB adapter source;
- **Voltage Regulator**: circuit used to provide a stable voltage to the circuit;
- **On/Off switch**: the switch used to turn on or turn off the device;
- **Bluetooth Antenna**: the 2.4GHz Patch Antenna;
- **RF Front End**: the conditioning circuit of the Antenna;
- **Led RGB** : leds that are used to show the status of the device to the user;

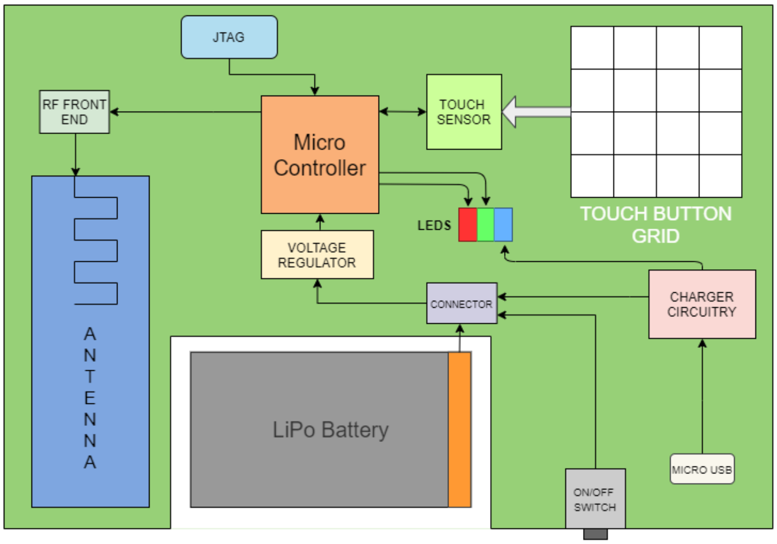


Figure 3: Touch&Play block diagram

4 Components Selection

4.1 Microcontroller

Texas Instruments Microcontroller CC2640 RGZ PACKAGE 48-PIN VQFN

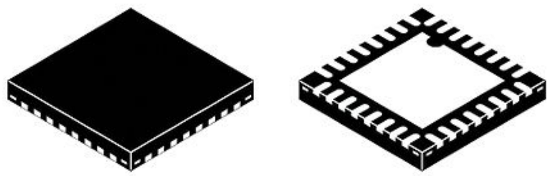


Figure 4: Microcontroller CC2640 RGZ PACKAGE 48-PIN VQFN

Features:

- Powerful ARM® Cortex®-M3
- Up to 48-MHz Clock Speed
- 128KB of In-System Programmable Flash
- 8KB of SRAM for Cache
- 20KB of Ultralow-Leakage SRAM
- RoHS-Compliant Packages
  - 4-mm × 4-mm RSM VQFN32 (10 GPIOs)
  - 5-mm × 5-mm RHB VQFN32 (15 GPIOs)
  - 7-mm × 7-mm RGZ VQFN48 (31 GPIOs)
- I2C protocol available
- Supply Voltage Range: 1.8 to 3.8 V (normal operation)
- 2.4-GHz RF Transceiver Compatible with Bluetooth Low Energy

The CC2640 device is a wireless MCU targeting Bluetooth applications. The device is a member of the CC26xx family of cost-effective, ultralow power, 2.4-GHz RF devices. Very low active RF and MCU current and low-power mode current consumption provide excellent battery lifetime. The CC2640 device contains a 32-bit ARM Cortex-M3 processor that runs at 48 MHz as the main processor and a rich peripheral feature set that includes a unique ultralow power sensor controller. This sensor controller is ideal for interfacing external sensors and for collecting analog and digital data autonomously while the rest of the system is in sleep mode.

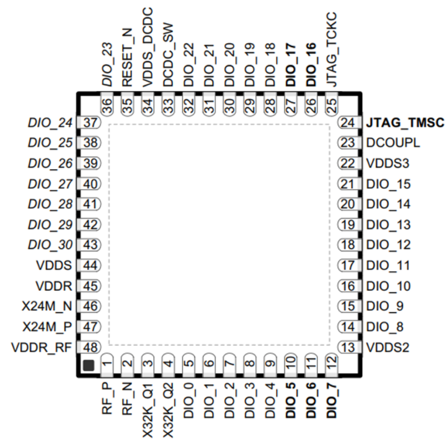


Figure 5: CC2460 RGZ package VQFN48, Pin configuration

4.2 Touch sensor

Atmel AT42QT216 16-key QMatrix Touch Sensor IC

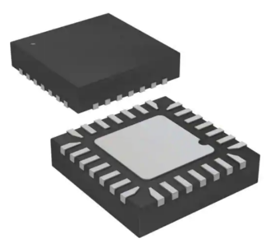


Figure 6: Atmel AT42QT216 16-key QMatrix Touch Sensor IC

Features:

- Number of keys: up to 16 keys, and one slider (constructed from 2 to 8 keys)
- Technology: patented spread-spectrum charge-transfer (transverse mode)
- I/O lines: 11 (3 dedicated-configurable for input or output, 8 shared-output only)
- Key outline sizes: 6mm × 6mm or larger; widely different sizes and shapes possible
- Key spacings: 8 mm or wider, center to center (panel thickness dependent)
- Electrode design: two-part electrode shapes (drive-receive); wide variety of possible layouts

- Interface: I^2C-compatible slave mode
- Operating Voltage: 1.8 V to 5.5 V
- Package: 28-pin 4 × 4 mm

The AT42QT2160-MMU is designed for use with up to 16 keys and a slider (constructed from 2 keys up to 8 keys). There are three dedicated General Purpose Input/Outputs (GPIOs) which can be used as inputs for mechanical switches or as driven outputs. There are eight shared General Purpose Outputs (GPOs) (X0 – X7) which are driven outputs only. There is PWM control for each GPIO/GPOs.
The QT2160 device is a digital burst mode charge-transfer sensor designed specifically for matrix layout touch controls.
The entire circuit can be built within a few square centimeters of single-sided PCB area. The PCB rear can be mounted flush on the back of a glass or plastic panel using a conventional adhesive.
The QT2160 technology employs transverse charge-transfer sensing electrode designs which can be made very compact and are easily wired. Charge is forced from an emitting electrode into the overlying panel dielectric, and then collected on a receiver electrode. This directs the charge into a sampling capacitor which is then converted directly to digital form, without the use of amplifiers. The keys are configured in a matrix format that minimizes the number of required scan lines and device pins. The key electrodes can be designed into a conventional Printed Circuit Board (PCB) or Flexible Printed conductive ink on plastic film.
The device uses an I^2C-compatible interface to allow key data to be extracted and to permit individual key parameter setup.

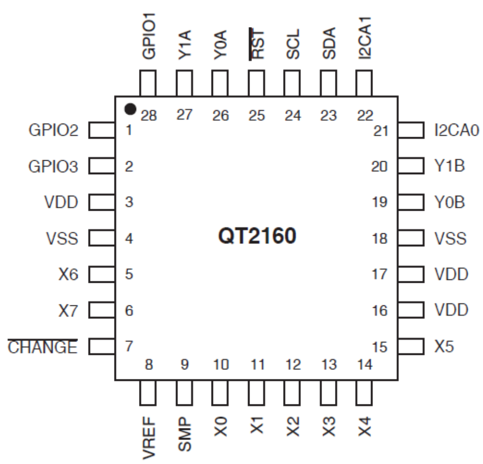


Figure 7: AT42QT216 Pin configuration

The circuit operates by scanning each key sequentially, key by key. Key scanning begins with location X = 0, Y = 0 (key 0). X axis keys are known as rows while Y axis keys are referred to as columns although this has no reflection on actual wiring.
Keys are scanned sequentially by row, for example the sequence X0Y0 X1Y0 . . . X7Y0, X0Y1, X1Y1... and so on. Keys are also numbered from 0 – 15. Key 0 is located at X0Y0.

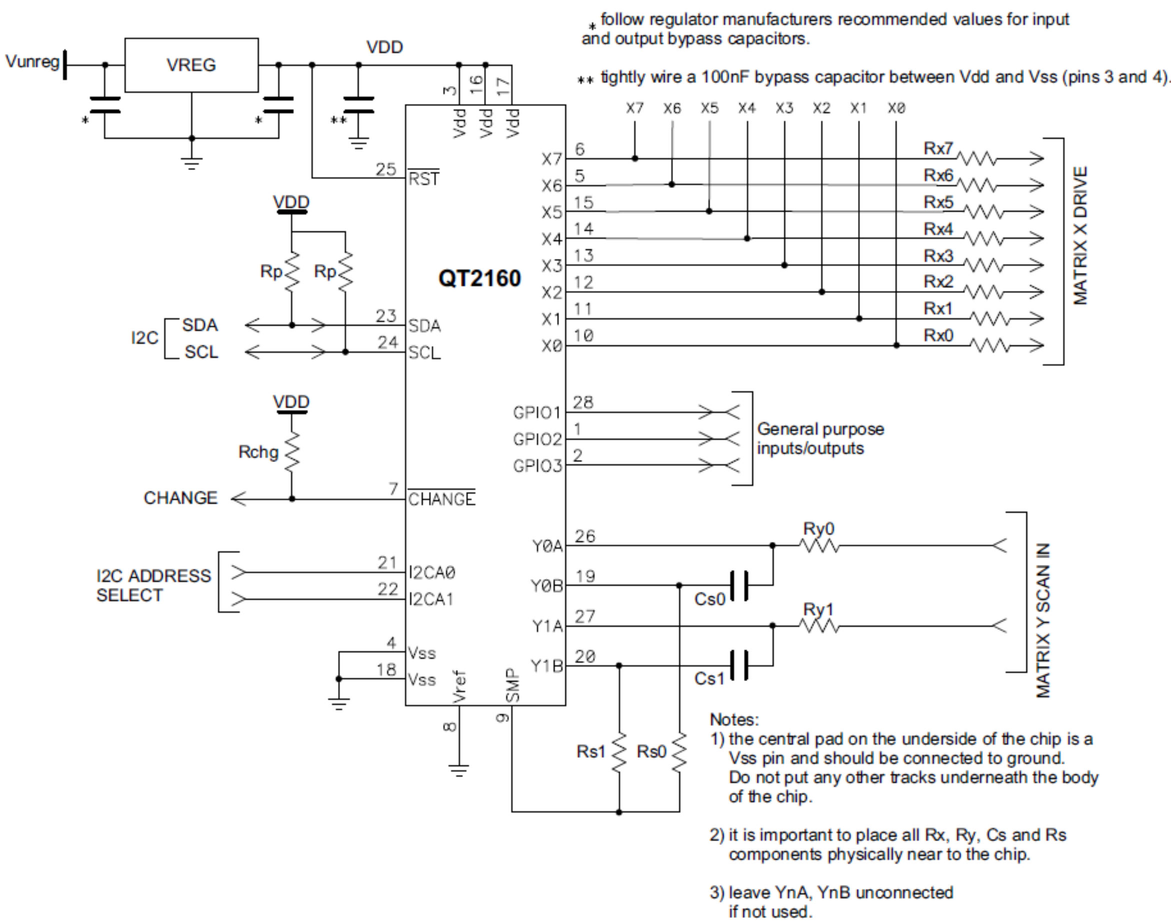


Figure 8: AT42QT2160 typical circuit

X and Y Electrodes planar construction

In planar construction field propagation relies heavily on the overlying panel as most of the coupling field flow is horizontal. The X and Y electrodes are designed to optimize the distribution of the electric field that is coupling through the overlying panel. This maximizes touch sensitivity, as the finger has the maximum opportunity to disrupt this field coupling and cause a touch to be detected. The X and Y electrodes are generally interdigitated. Typically the X electrode surrounds the Y electrode, as it helps to contain the field between the two.

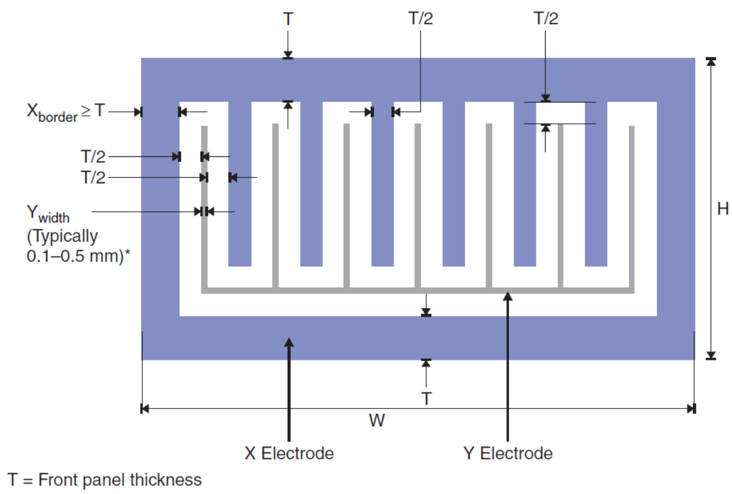


Figure 9: X and Y electrodes

The Y electrodes should use the thinnest trace possible (from 0.1 to 0.5 mm) for the Y fingers, as this minimizes the possibility of noise coupling to the sensor during touch.
For the X electrodes, wider electrodes are generally preferred as they tend to act as partial shields for the Y traces. Usually T/2 is chosen as the thickness of the fingers of the X electrode, as well as the spacing between the two electrodes.
X_{fingers} (the number of fingers of the X electrode) and X_{border} (width of the X electrode border) are calculated with the following formulas:

$$X_{fingers} = \lfloor (W - 3T - Y_{width})/(1.5T + Y_{width}) \rfloor$$

$$X_{border} = \lfloor (W - T - Y_{width} - X_{fingers}(1.5T + Y_{width}))/2 \rfloor$$

A thin overlying panel made of a material with a good dielectric constant provides good SNR and high sensitivity buttons. For this reason, a 1 mm thick glass overlying panel (T=1 mm) is chosen. Other design choices were to make the buttons 15mm X 15mm square (W=H=15 mm), and to make the Y electrode 0.5 mm thick (Y_{width}=0.5mm).
Starting from these values, all the other dimensions needed to make the electrodes are computed. In the following table all electrodes dimensions are shown:

T	1 mm
W	15 mm
H	15 mm
Y_{width}	0.5 mm
$X_{fingers}$	5
$Y_{fingers}$	6
X_{border}	1.75 mm
Spacing	0.5 mm

Table 1: X and Y electrodes dimensions

4.3 Power section

4.3.1 Rechargeable Battery

Rechargeable Battery - MIKROE-2759 HPL 402323-2C-190mAh

Figure 10: Rechargeable Battery - MIKROE-2759

Features:

- Capacity: 190 mAh
- Nominal Voltage: 3.7 V
- Charging voltage: 4.2 ± 0.03 V
- Voltage at the end of discharge: 3.0 V
- Operation temperature range: 0 °C to 45 °C (charge phase), -20 °C to 60 °C (discharge phase)
- Storage temp. range: -20 °C to 25 °C (less than 1 year), -20 °C to 40 °C (less than 3 months), -20 °C to 60 °C (1 week)
- Storage humidity range: 60 ± 25%
- Weight: 4 g
- Dimension: 24.55 mm x 23.55 mm x 4.2 mm
- Connector: JST-SHR-02V-S

4.3.2 Battery charger

MAX1555 SOT23 Dual-Input USB Adapter 1-Cell Li+ Battery Charger

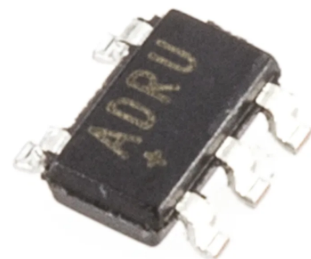


Figure 11: MAX1555

Features:

- Charge from USB;
- On-Chip Thermal Limiting simplifies Board Design;
- Charge Status Indicator;
- 5-Pin Thin SOT23 Package;

Electrical characteristics:

- DC voltage range: 3.7 V to 7.0 V
- USB voltage range: 3.7 to 6.0 V
- BAT regulation Voltage: to 4.158 V to 4.242 V
- $\overline{CHG}$ logic-low output: 300 mV

The MAX1555 charges a single-cell lithium-ion(Li+) battery from USB source. It operates with no external FETs or diodes, and accepts operating input voltages up to 7V. On-chip thermal limiting simplifies PC board layout and allows optimum charging rate without the thermal limits imposed by worst-case battery and input voltage. When the MAX1555 thermal limit is reached, the charger does not shut down, but progressively reduces charging current. The MAX1555 features a $\overline{CHG}$ output to indicate charging status. With USB connected, but without DC power, charge current is set to 100mA. This allows charging from both powered and unpowered USB hubs with no port communication required. When DC power is connected, charging current is set at 280mA. No input-blocking diodes are required to prevent battery drain. The MAX1555 is available in 5-pin thin SOT23 packages and operate over a -40°C to +85°C range.

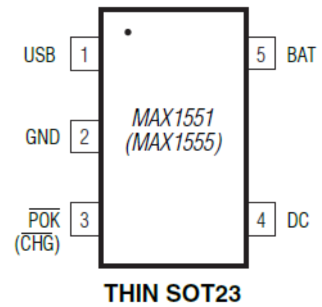


Figure 12: MAX1555 pin configuartion

4.3.3 Voltage regulator

MAX1759 Buck/Boost Regulating Charge Pump

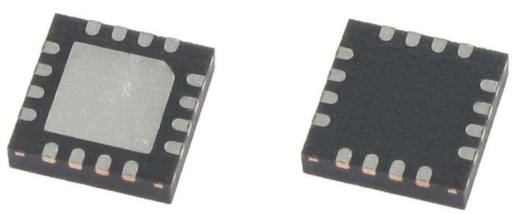


Figure 13: MAX1759

Features:

- Regulated Output Voltage (Fixed 3.3V or Adjustable 2.5V to 5.5V)
- 100mA Guaranteed Output Current
- +1.6V to +5.5V Input Voltage Range
- Low 50μA Quiescent Supply Current
- 1μA Shutdown Mode
- Load Disconnected from Input in Shutdown
- High 1.5MHz Operating Frequency
- Uses Small Ceramic Capacitors
- Short-Circuit Protection and Thermal Shutdown

The MAX1759 is a buck/boost regulating charge pump that generates a regulated output voltage from a single lithium-ion (Li+) cell. The MAX1759 operates over a wide +1.6V to +5.5V input voltage range and generates a fixed 3.3V or adjustable (2.5V to 5.5V) output. Despite its high 1.5MHz operating frequency, the MAX1759 maintains low 50μA quiescent supply current. Designed to be an extremely compact buck/boost converter, this device requires only three small ceramic capacitors to build a complete DC-DC converter capable of generating a guaranteed 100mA output current from a +2.5V input. For added flexibility, the MAX1759 also includes an open-drain power-OK (POK) output that signals when the output voltage is in regulation. The MAX1759 is available in a space-saving 10-pin μMAX package that is 1.09mm high and half the size of an 8-pin SO.

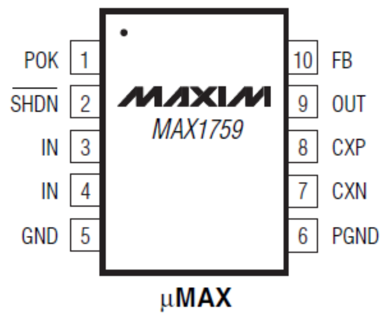


Figure 14: MAX1759 pin configuration

4.3.4 Fuel Gauge

MAX17048 3μA 1-Cell Fuel Gauge with ModelGauge

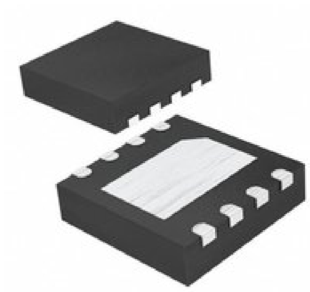


Figure 15: MAX17048

Features:

- Precision 7.5mV /Cell Voltage Measurement;
- Used for 1 Cell LiPo Battery;
- I^2C Interface;
- 8-Bit OTP ID Register;
- Programmable Reset for Battery Swap 2.28V to 3.48V Range;
- Reports Charge and Discharge Rate;
- Temperature Range: -20 C to +70 C;
- Supply Voltage: 2.5V to 4.5V ;
- Data I/O Pins: 0.3V to 5.5V ;
- SCL Clock Frequency: 100 kHz;

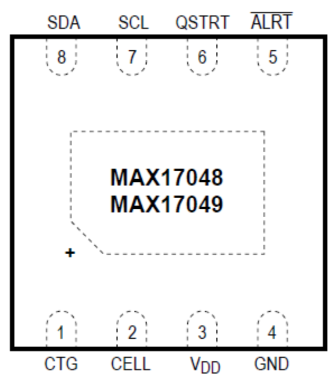
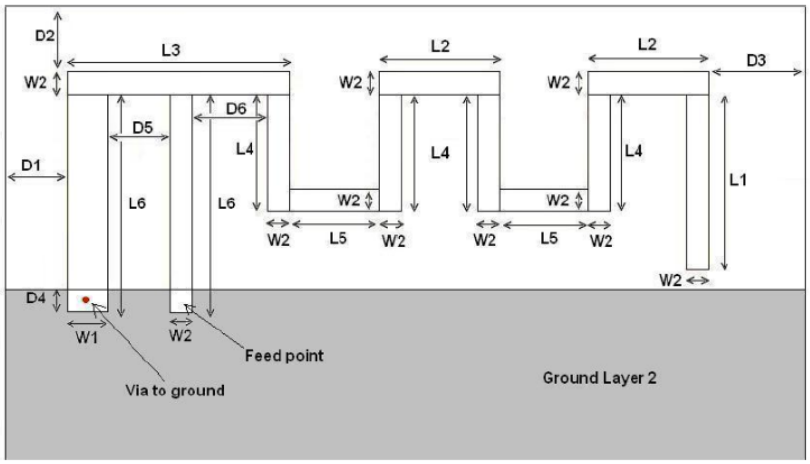


Figure 16: MAX17048 pin configuration - TDFN package (2mm x 2mm)

The MAX17048 Is is a tiny, micropower current fuel gauge for lithium-ion (Li+) batteries in handheld and portable equipment. The MAX17048 operates with a single lithium cell. The IC uses the sophisticated Li+ battery-modeling algorithm ModelGauge™ to track the battery relative state-of charge. The ModelGauge algorithm eliminates current-sense resistor and battery-learn cycles required in traditional fuel gauges. Temperature compensation is implemented using the system microcontroller. The IC automatically detects when the battery enters a low-current state and enters low-power 3μA hibernate mode, while still providing accurate fuel gauging. The IC automatically exits hibernate mode when the system returns to active state. On battery insertion, the IC debounce initial voltage measurements to improve the initial SOC estimate, thus allowing them to be located on system side. SOC, voltage, and rate information is accessed using the I^2C interface.

4.4 Antenna

The PCB antennais a meandered inverted F antenna (IFA). The IFA was designed to match an impedance of 50 ohm at 2.45 GHz.



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 17: Antenna AN043 dimensions

4.5 Other components

4.5.1 USB connector

The USB connector is a connection with the external word, it is used to recharge the LiPo battery.

MOLEX 1051640001 USB Connector

Figure 18: MOLEX 1051640001 USB Connector

4.5.2 JTAG connector

The JTAG connector is used to connect the microcontroller to a pc in order to program it.

FTSH-105-01-L-D-K JTAG Connector

Figure 19: FTSH-105-01-L-D-K JTAG Connector

4.5.3 LED

The RGB led id used to show the user the status of the device:

- Blue LED: is on when the battery is charging.
- Green LED: is on during normal operation.
- Red LED: is on when the charge level of the battery is low.

SMLP36-RGB LED

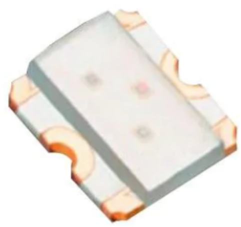


Figure 20: SMLP36-RGB LED

Electrical characteristics:

Part No.	Chip Structure	Emitting Color	Absolute Maximum Ratings (Ta=25ºC)						Electrical and Optical Characteristics (Ta=25ºC)											
			Power Dissipation P_D(mW)	Forward Current I_F(mA)	Peak Forward Current I_{FP}(mA)	Reverse Voltage V_R(V)	Operating Temp. T_{opr}(ºC)	Storage Temp. T_{stg}(ºC)	Forward Voltage V_F Typ. (V)	Forward Voltage V_F I_F (mA)	Reverse Current I_R Max. (μA)	Reverse Current I_R V_R (V)	Dominant Wavelength λ_D Min.*2 (nm)	Dominant Wavelength λ_D Typ. (nm)	Dominant Wavelength λ_D Max.*2 (nm)	Dominant Wavelength λ_D I_F (mA)	Luminous Intensity I_V Min. (mcd)	Luminous Intensity I_V Typ. (mcd)	Luminous Intensity I_V I_F (mA)
	AlGaInP	Red							2.1				619	624	629		14	35	
SMLP36RGB2W (R)	InGaN	Green	26	10	50*1	5	-40～ +85	-40～+100	3.1	5	10	5	520	527	535	5	56	110	5
		Blue							3.0				465	470	475		14	35	

*1 : Duty ≦1/20, Pulse width≦ 1ms *2 : Measurement tolerance:±2nm

Figure 21: LED electrical characteristics

4.5.4 Switch

This switch is used to turn on or turn off the device.

Switch PCM12SMTR

Figure 22: PCM12SMTR Surface Mount Slide Switch

5 OrCAD

5.1 Schematic Block Diagram

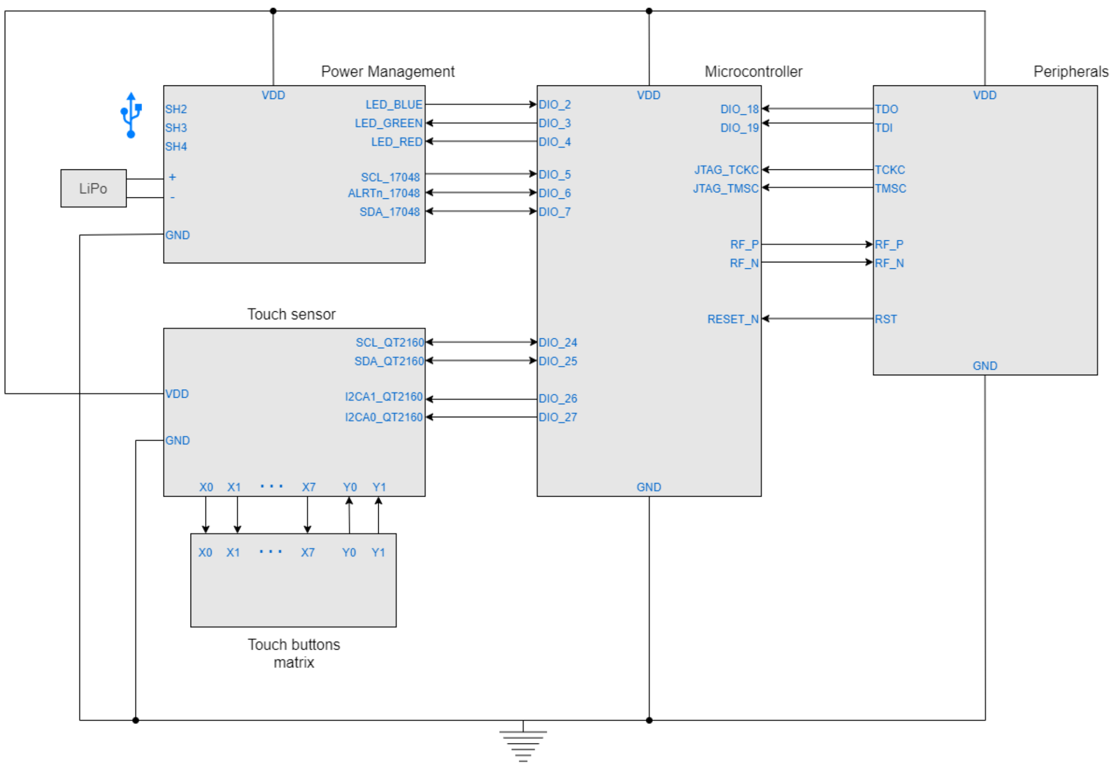


Figure 23: Schematic Block Diagram

In the figure 23 the five blocks that compose the schematic can be seen:

- **Microcontroller:** elaborates the received data and acts as interface with the peripherals;
- **Touch-Sensor:** detects touch button presses. It communicates with the microcontroller through an I^2 interface.
- **Touch buttons matrix:** square touch buttons, configured in a 4 X 4 matrix format. Each button is realized through two interdigitated electrodes.
- **Power Management**: provides a stable voltage (V_{dd}=3.3V) to all the circuit, and manage the charge of the battery;
- **Peripherals:** allow the user to interact with the device;

5.2 Power Management

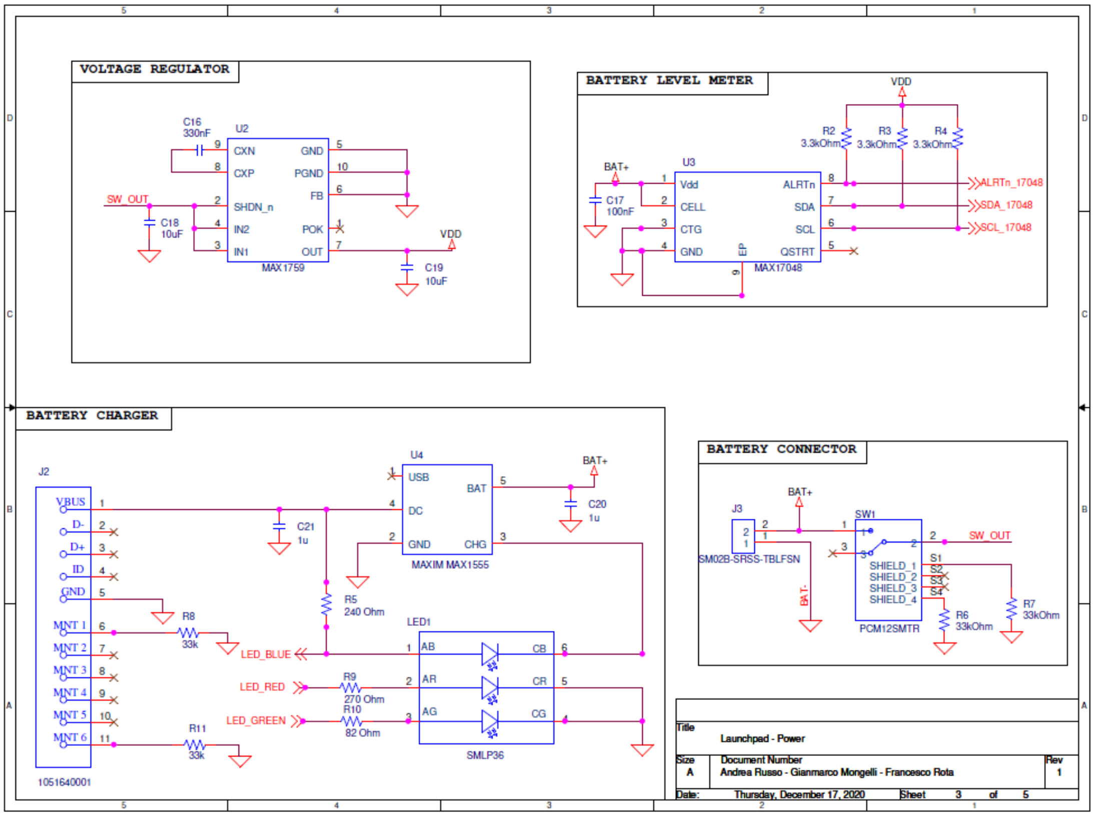


Figure 24: Power Management

This section consists of the following components:

- Battery charger MAX1555 as interface with the USB connector;
- Voltage regulator MAX1759 to provide a stable voltage to the circuit;
- Battery level meter MAX17048 used to check the charge level of the battery;
- LED SMLP36-RGB used to show the status of the device;
- PCM12SMTR switch used to turn on or turn off the device;

5.2.1 Resistor R5 value computation

The blue Led is connected between external voltage given by the USB and the CHG pin of MAX1555. This led is used to signal the user that the battery is charging. The USB connector provides a typical

voltage V_{typ} of 5V, a maximum voltage $V_{USB\ MAX}$ of 5.25V and a minimum voltage $V_{USB\ MIN}$ of 4.40V. The blue led has a typical forward voltage $V_{F\ BLUE}$ of 3V and it needs a minimum forward current I_F of 5mA to be on and it can tolerate a maximum forward current $I_{F\ MAX}$ of 10 mA.
The value of R5 can be obtained in the following way:

$$I_F = \frac{V_{USB_{MIN}} - V_{F_{BLUE}}}{R5} = \frac{4.4V - 3V}{R5} > 5mA \Longrightarrow R5 < 280\Omega$$

$$I_F = \frac{V_{USB_{MAX}} - V_{F_{BLUE}}}{R5} = \frac{5.25V - 3V}{R5} < 10mA \Longrightarrow R5 > 225\Omega$$

So it has been chosen a resistor R5 of 270 Ω.

5.2.2 Resistor R9 value computation

The red led is driven by the microcontroller and it is used to signal the user that he charge level of the battery is low. The output voltage on a digital pin of the micro V_{MICRO} is 3.6V (V_{MICRO}=V_{DDS} + 0.3V = 3.3V + 0.3V) while the typical forward voltage $V_{F\ RED}$ of the red led is 2.1V.
The value of R9 can be obtained in the following way:

$$I_F = \frac{V_{MICRO} - V_{F_{RED}}}{R9} = \frac{3.6V - 2.1V}{R9} > 5mA \Longrightarrow R9 < 300\Omega$$

$$I_F = \frac{V_{MICRO} - V_{F_{RED}}}{R9} = \frac{3.6 - 2.1V}{R9} < 10mA \Longrightarrow R9 > 150\Omega$$

So it has been chosen a resistor R9 of 270 Ω.

5.2.3 Resistor R10 value computation

The green led is driven by the microcontroller and it is on during normal operation. The output voltage on a digital pin of the micro V_{MICRO} 3.6V while the typical forward voltage $V_{F\ GREEN}$ of the green led is 3.1 V.
The value of R10 can be obtained in the following way:

$$I_F = \frac{V_{MICRO} - V_{F_{GREEN}}}{R10} = \frac{3.6V - 3.1V}{R10} > 5mA \Longrightarrow R10 < 100\Omega$$

$$I_F = \frac{V_{MICRO} - V_{F_{GREEN}}}{R10} = \frac{3.6 - 3.1V}{R10} < 10mA \Longrightarrow R10 > 50\Omega$$

So it has been chosen a resistor R10 of 82 Ω.

5.3 Microcontroller

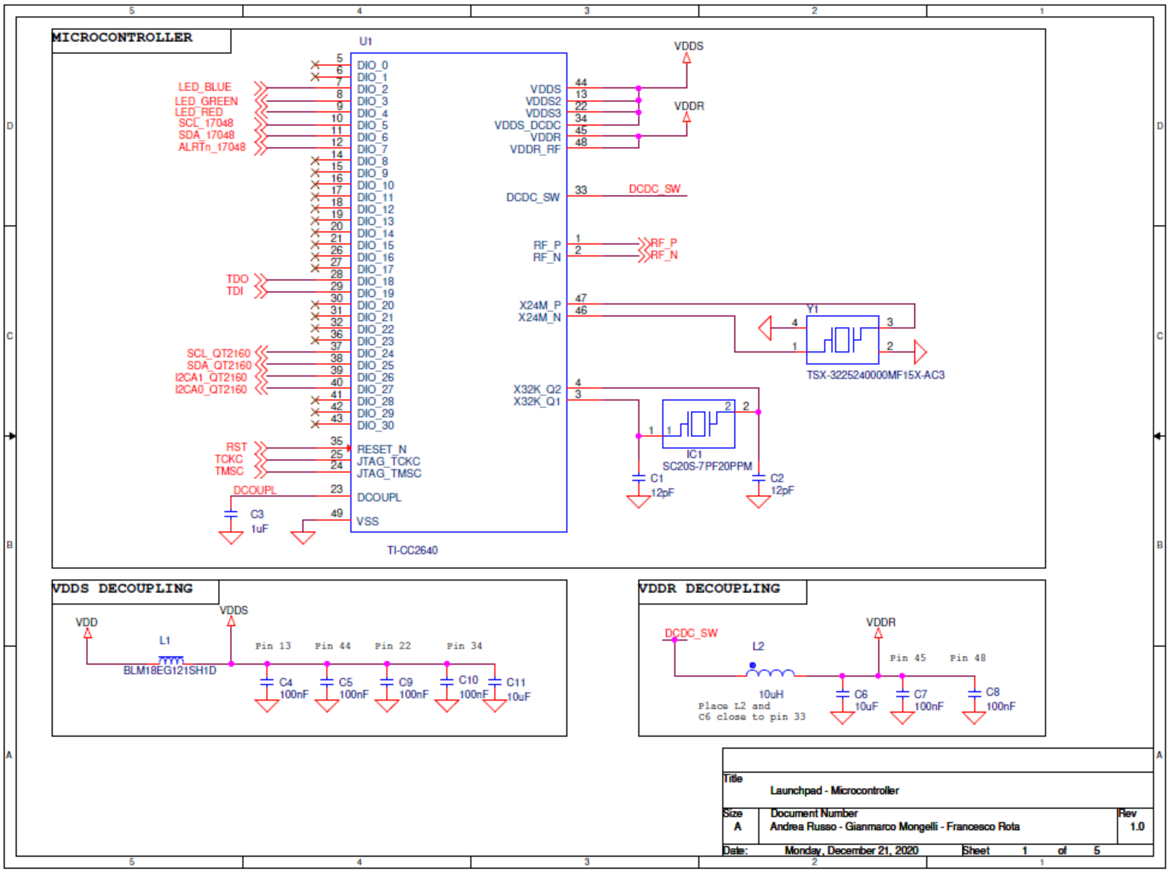


Figure 25: Microcontroller schematic

RF_N and RF_P pins are connected to the RF front-end circuit in order to send data from the internal Bluetooth module to the antenna.
The DIO_10, DIO_11, DIO_13, DIO_14 pins are used to communicate with the Touch Sensor.
The pins DIO_2, DIO_3, DIO_4 are used to interact with the RGB LED in the power section, in order to highlight different condition of the circuit, while the pins ALRT_17048, SDA_17048, SCL_17048 are used to send an interrupt to report a low battery level.
JTAG_TMSC,JTAG_TCKC, DIO_18,DIO_19 are used to connect the microcontroller to the JTAG connector.
Different capacitors are used to decouple the pins of the microcontroller.
Two external clock sources are used: in detail, the 24MHz crystal, required as the frequency reference for the radio, does not require decoupling capacitors.

5.4 Touch-Sensor

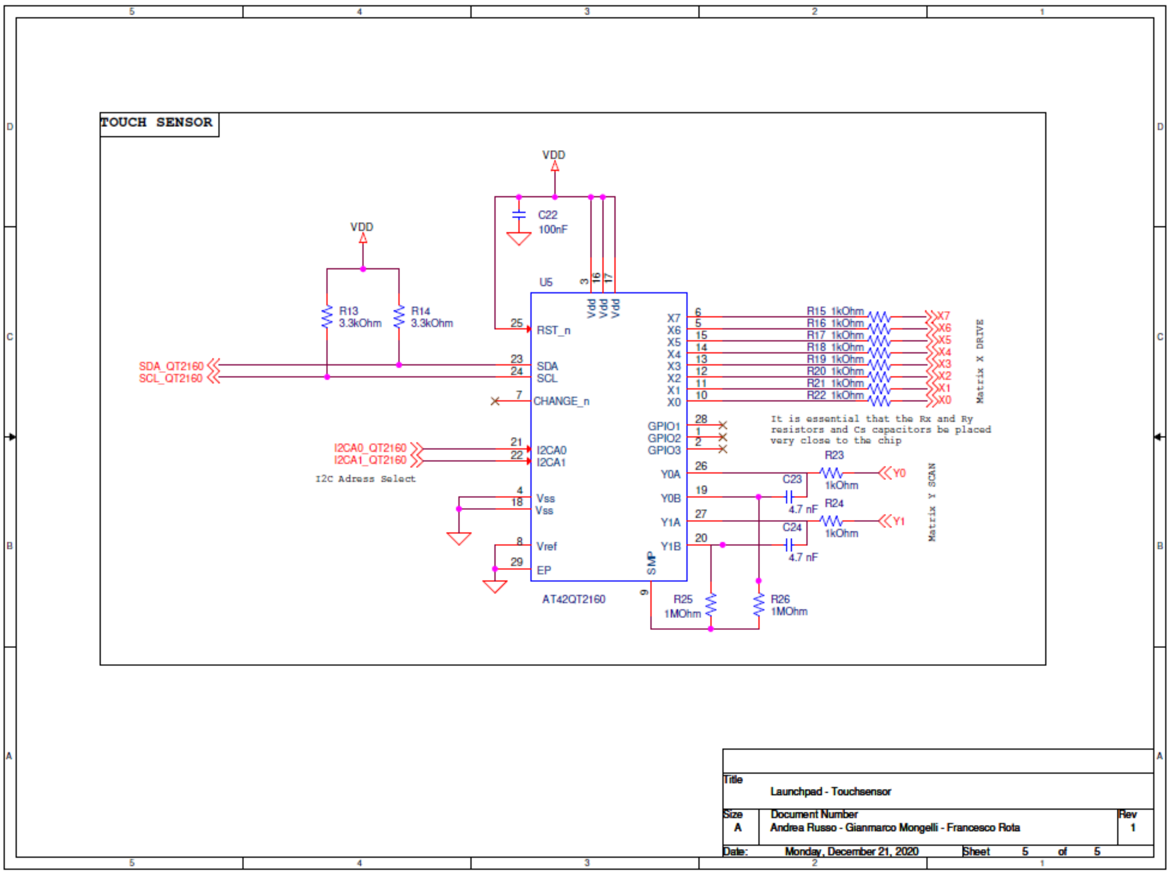


Figure 26: Touch Sensor schematic

The circuit includes two pull-up resistor on data wires and a bypass capacitor between the power supply and ground, as close as possible to the sensor.
The communication with the microcontroller is carried out according the I_2C Protocol.
The X0-X7 pins are used to drive the emitting electrodes (X electrodes), while the Y0 - Y1 lines are used to scan the riceiving electrodes.
Cs capacitors ($Cs0 - Cs1$) absorb charge from the key electrodes.
The sample resistors ($Rs0 - Rs1$) are used to perform ADC conversion of the acquired charge on each Cs capacitor.
The X and Y matrix scan lines can use series resistors ($Rx0 - Rx7$ and $Ry0 - Ry1$ respectively)for improved EMC performance (Rx resistors are used to reduce RF emissions, while Ry resistors areused to reduce EMC susceptibilty problems).

5.5 Touch-Matrix

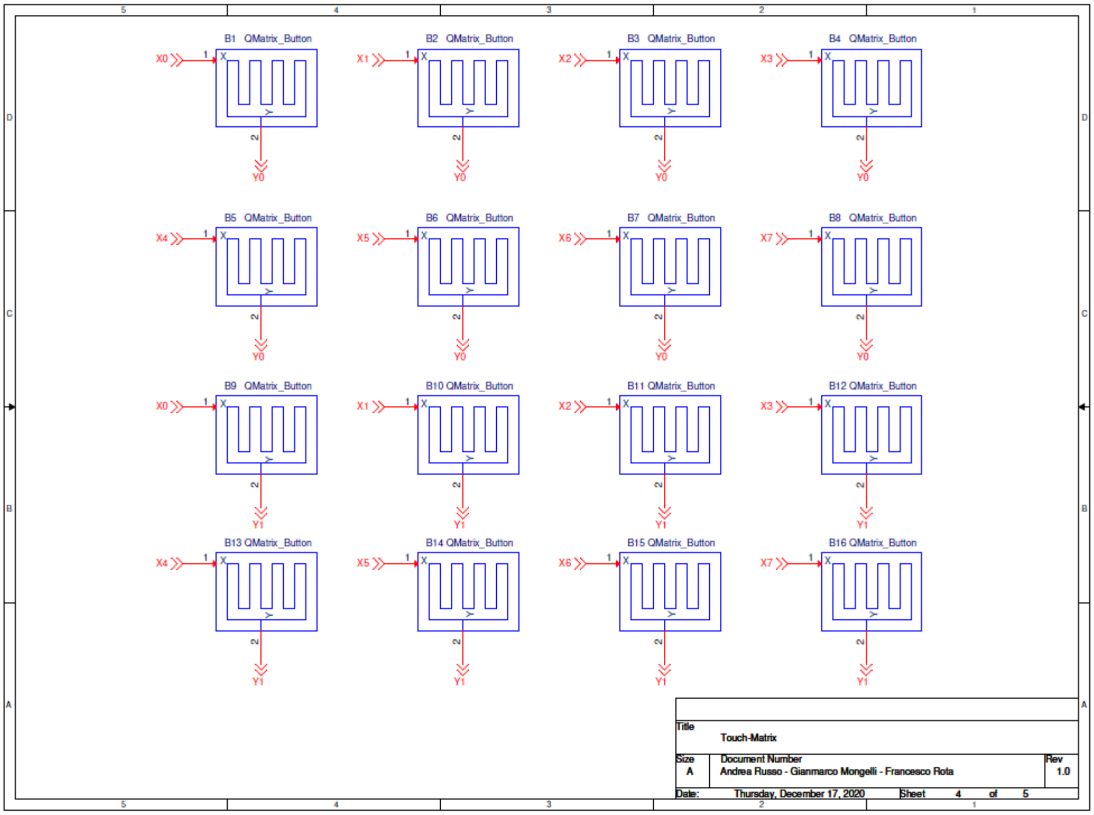


Figure 27: Touch buttons matrix

5.6 Peripherals

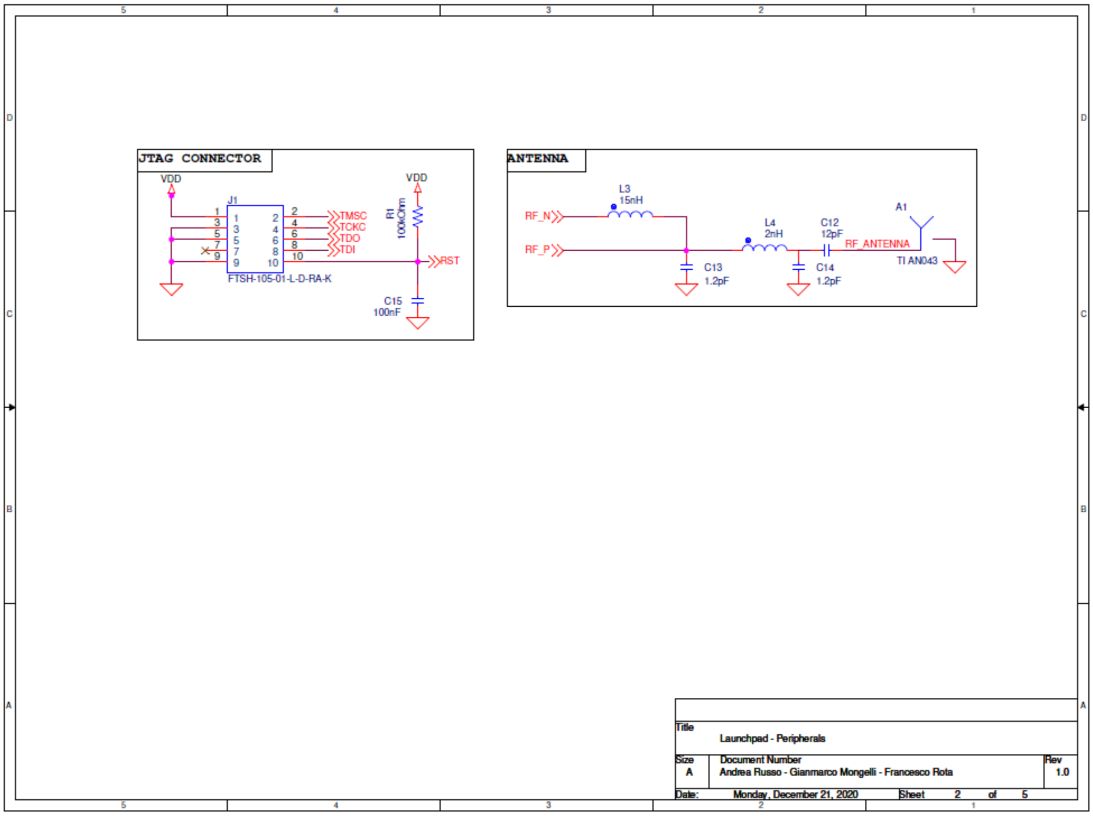


Figure 28: Peripherals schematic

In this section some communication elements, that are directly connected to the microntroller, are included:

- JTAG connector to program and debug the circuit through a PC;
- single ended Antenna AN043 and RF front-end circuit;

5.7 Bill of Materials

From OrCAD it is possible to extract the Bill of Materials of the entire circuit.

Item	Quantity	Reference	Part
1	1	A1	TI AN043
2	16	B1,B2,B3,B4,B5,B6,B7,B8,B9, B10,B11,B12,B13,B14,B5,B16	QMatrix_Button
3	3	C1,C2,C12	12pF
4	1	C3	1uF
5	9	C4,C5,C7,C8,C9,C10,C15,C17,C22	100nF
6	4	C6,C11,C18,C19	10uF
7	2	C13,C14	1.2pF
8	1	C16	330nF
9	2	C20,C21	1uF
10	2	C23,C24	4.7 nF
11	1	IC1	SC20S-7PF20PPM
12	1	J1	FTSH-105-01-L-D-RA-K
13	1	J2	1051640001
14	1	J3	SM02B-SRSS-TBLFSN
15	1	LED1	SMLP36
16	1	L1	BLM18EG121SH1D
17	1	L2	10uH
18	1	L3	15nH
19	1	L4	2nH
20	1	R1	100kOhm
21	5	R2,R3,R4,R13,R14	3.3kOhm
22	1	R5	240 Ohm
23	2	R6,R7	33kOhm
24	2	R8,R11	33kOhm
25	1	R9	270 Ohm
26	1	R10	82 Ohm
27	10	R15,R16,R17,R18,R19,R20,R21,R22,R23,R24	1kOhm
28	2	R25,R26	1MOhm
29	1	SW1	PCM12SMTR
30	1	U1	TI-CC2640
31	1	U2	MAX1759
32	1	U3	MAX17048
33	1	U4	MAXIM MAX1555
34	1	U5	AT42QT2160
35	1	Y1	TSX-3225240000MF15X-AC3

Table 2: Bill of Materials

6 Allegro

We started the PCB design with the antenna positioning since it is the most critical component. It has been put on the right side of the circuit as close as possible to the microcontroller to avoid parasitics. No Ground plane was placed below the antenna and no components were placed under it. After placing the microcontroller all the related decoupling capacitors were positioned near the IC. After this we placed all the touch electrode buttons building a 4 x 4 matrix in the bottom part of the board. The touch sensor was placed in a position in between both the touch matrix and the microcontroller to simplify the routing. The top left part of the board was dedicated to the peripherals connecting to the external world, here we placed the USB connector, the battery connector and the switch. The JTAG connector was placed in the top part of the board but still near the microcontroller. After routing all the possible connections on the etch top layer the bottom layer was used for the ground plane and for routing the missing connections. Only the unavoidable connections were made in the bottom layer to avoid as much as possible the creation of high current density points. In order to make a good design, big traces were used for the power connections and smaller ones were used for the signal connections. Whenever it was possible we used multiple vias for the ground routing of ICs.

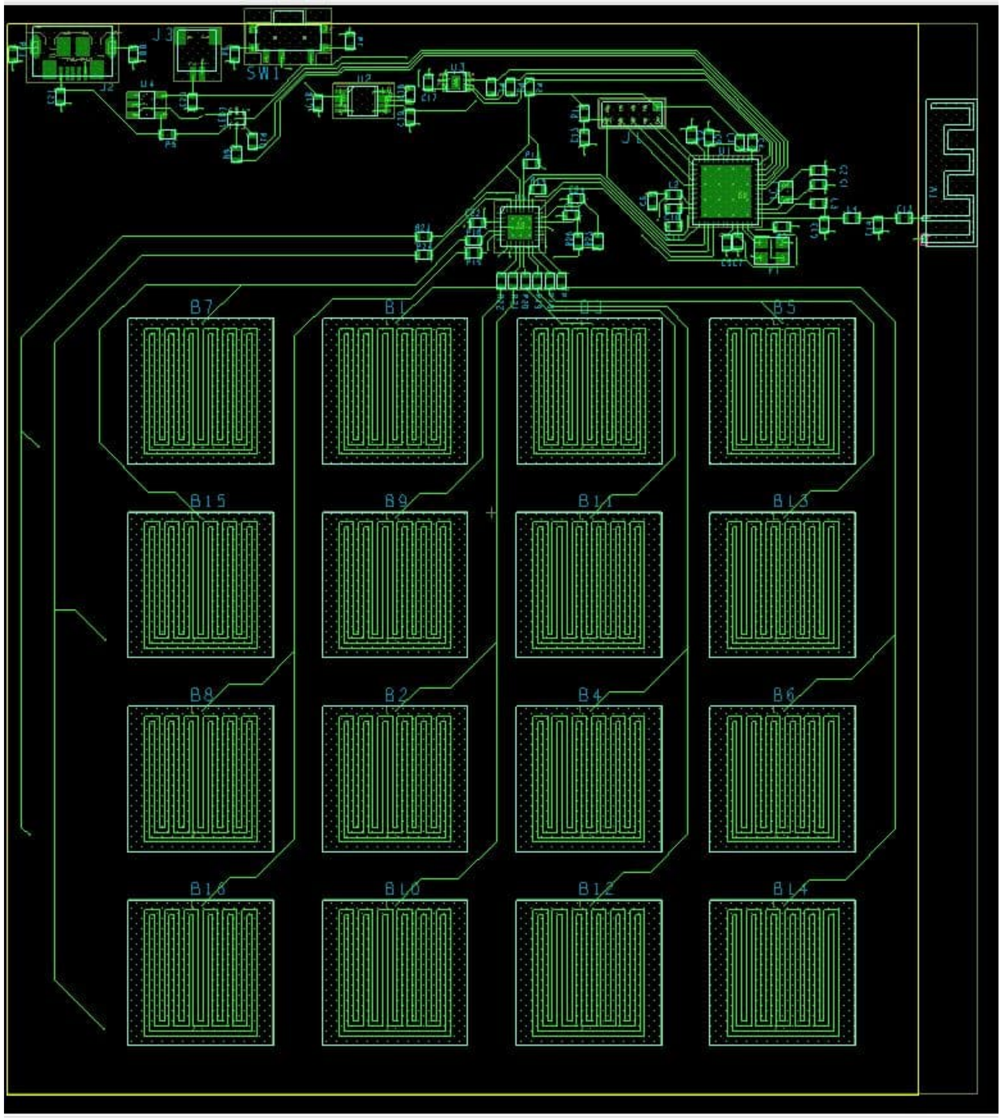


Figure 29: PCB Top view

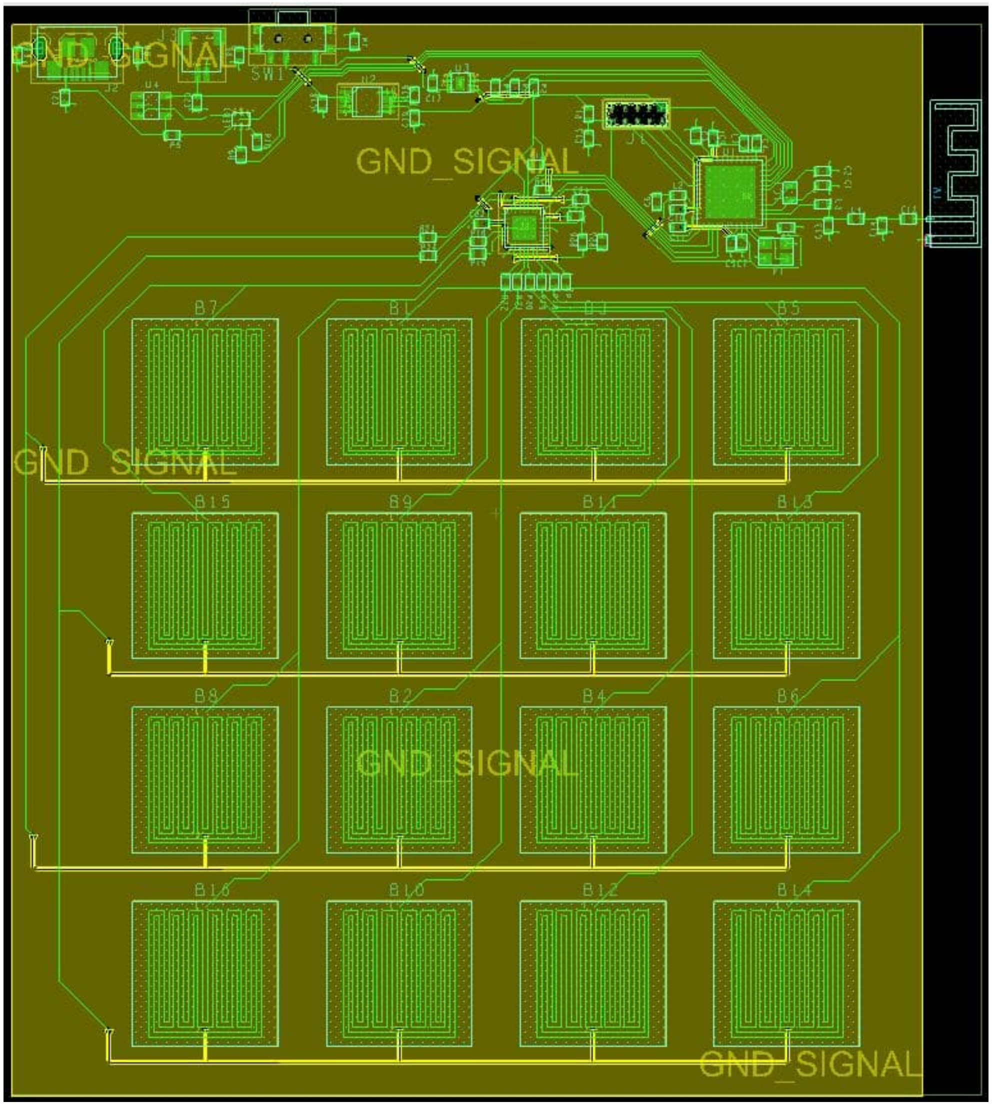


Figure 30: PCB Bottom view