Politecnico di Torino

Electronic systems engineering

PARticulate MAtter monitoring system

Technical report

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January 12, 2020

Contents

0 Project specifications

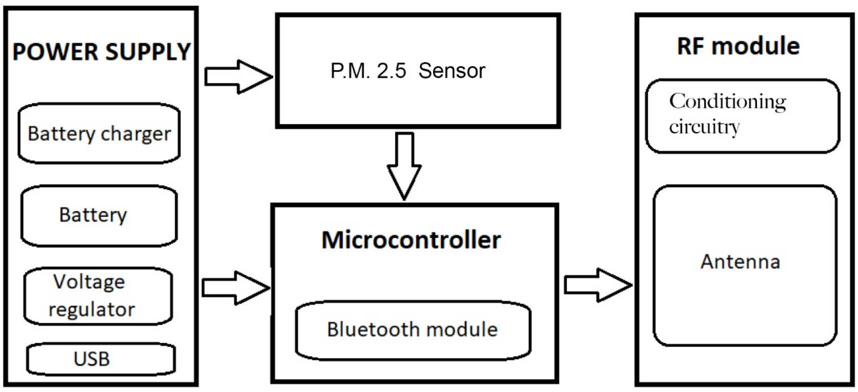
The PAR.MA. (PARticulate MAtter monitoing system) is a smart particulate matter sensor to measure the concentration of PM2.5 in the environment where it is placed and to report the measurement thanks to the bluetooth technology.
The main specifications of the system are

- PM2.5 accuracy : 10 ug/m3
- Operating temperature : -10 C to 50 C
- Portable form factor
- Rechargeable battery

The main application for this system is to measure the PM2.5 concentration of an open air environment (e.g. main street of a city center), however it can be used inside a home as well. The system is made up of four main blocks, namely

- Power supply : this block is dedicated to the power distribution of the system and the recharge process
- Microprocessor : this block is dedicated to the computational unit of the system; it reads the data coming from the sensor and start the bluetooth communication
- PM2.5 sensor : this block is dedicated to the sensing of the PM2.5 concentration; the communication with the microprocessor is achieved thanks to the UART protocol
- RF module : this block is dedicated to control the PCB antenna

The entire block diagram is shown in the following figure.



1 Design flow

The design and development of the project followed the step in the table below.

	I week	II week	III week	IV week	V week	VI week	VII week
Specification							
Component							
Schematic							
PCB & Gerber							
Report							

The following steps were followed in order to complete the system design

- At first the system specifications were defined, the choices in this stage influenced the whole design and the following steps.

- Then the components for the design were chosen according to the initial specifications.
- The schematics were created on ORCAD Capture connecting the components selected in the previous step.
- The PCB was designed according to the manufacturer constraints, the final gerber files were sent to the manufacturer for further checks.
- The technical report was written in order to explain the choices for the system design.

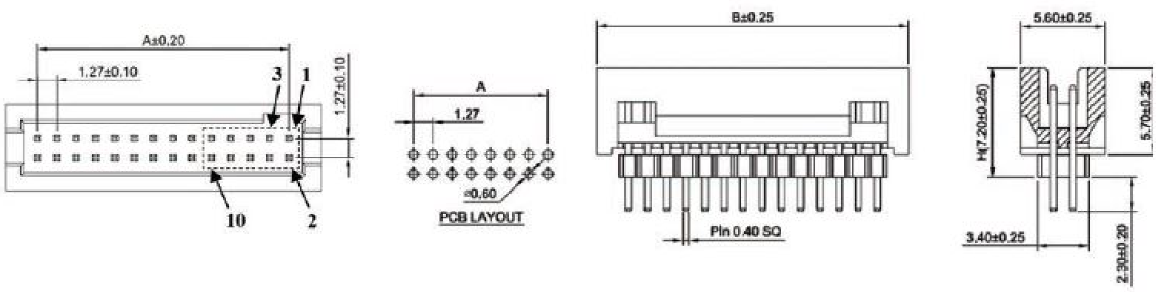
2 Component selection

In the following section the component selection process will be broken down, showing the specifications of the component selected for the final design and the reason behind the choice.

2.1 PM2.5 sensor

The Telaire SM-UART-04L sensor is a PM2.5 sensor with a digital interface for input commands/output readings. The digital interface allows a simple interface with the microprocessor, no conditioning circuitry is needed. The main specifications and features are reported below (directly taken from the datasheet).

Pin #	Pin Name	Description
1	5V	Input Supply Voltage
2	5V	Input Supply Voltage
3	GND	Ground
4	GND	Ground
5	RESET	Reset Pin @3.3V TTL, Low level reset
6	NC	—
7	RXD	UART Receiver @ 3.3V TTL
8	NC	—
9	TXD	UART Transceiver @ 3.3V TTL
10	SET/SLEEP	Working Mode Pin @ 3.3V TTL Floating or high level for normal working condition. Low level for dormancy mode.



Absolute Maximum Ratings

Absolute Maximum Ratings			
Parameter	**Symbol**	**Rating**	**Unit**
Supply Voltage	Vcc	0 to + 5.5	V
Operating Temperature	T_{opr}	-10 to 50	°C
Storage Temperature	T_{stg}	-30 to 70	°C
Operating Humidity (1)	RH_{opr}	0 to 95	%
Storage Humidity (1)	RH_{stg}	0 to 95	%

1) Non-condensing

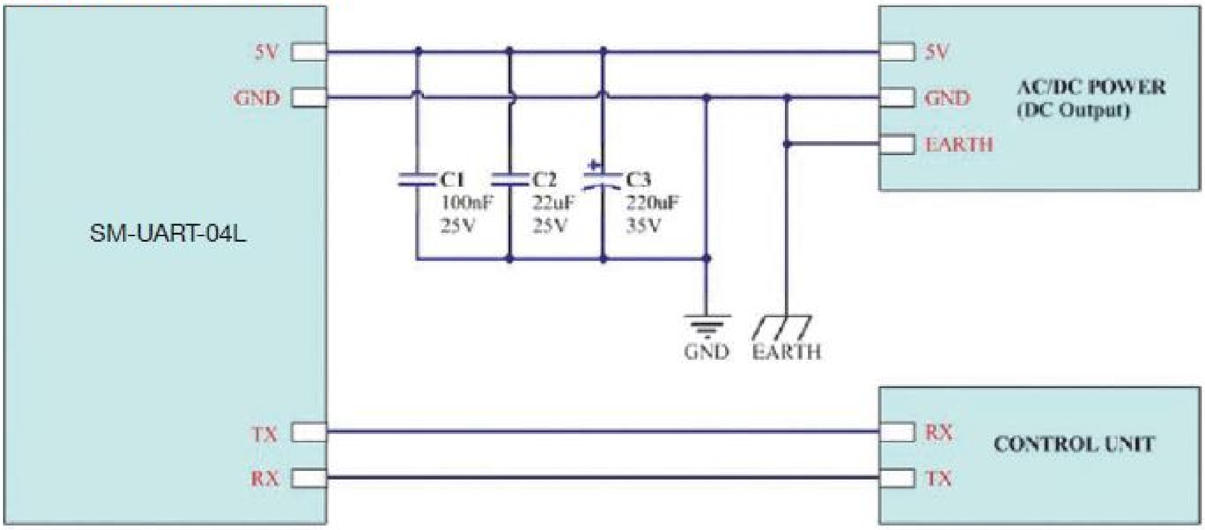
Electrical Characteristics

Parameter		Symbol	Min.	Typ.	Max.	Unit
Particle Size		D	0.3	2.5	10	um
Detection Range		D_{reg}	1	—	999	μg/m³
Resolution		R	—	1	—	μg /m³
Indication Error (2)	1 ~100 ug/m³	D_{err}	—	—	+/-10	μg /m³
	100~999 ug/m³		—	—	+/-10	%
Warm-Up Time		t_{wup} (2)	—	5	—	s
Response Time		t_{rsp} (2)	—	1	—	s
Laser Life (Average Time Before Re-Calibration)		T	—	40,000	—	hour
Supply Voltage		V_{CC}	4.8	5	5.2	V
Supply Voltage Ripple		V_{CC} Ripple	—	—	30	mV
Current Consumption		I_{CC} (2)	—	60	100	mA
Output (UART)		3.3V				

1) Non-condensing 2) Testing at T=25°C, RH=40-60%

The Telaire SM-UART-04L sensor is used only when needed, a UART transmission put the sensor in sleep mode and wakes it up for a measurement. The typical application connection is shown in the following picture.

Application Circuit



2.2 Microcontroller

The choice for the microcontroller unit (MCU) to be used in the project is a fixed requirement; the MCU used is the CC2640R2F from TI. This particular MCU offers both 4.1 and 5.0 Bluetooth connectivity for low energy applications. This particular MCU have a 32-bit ARM Cortex-M3 core, up to 128 Kbytes of flash memory, up to 20 kbytes of SRAM and supports I2C, UART and many more common interfaces. A functional diagram of the MCU is as follows

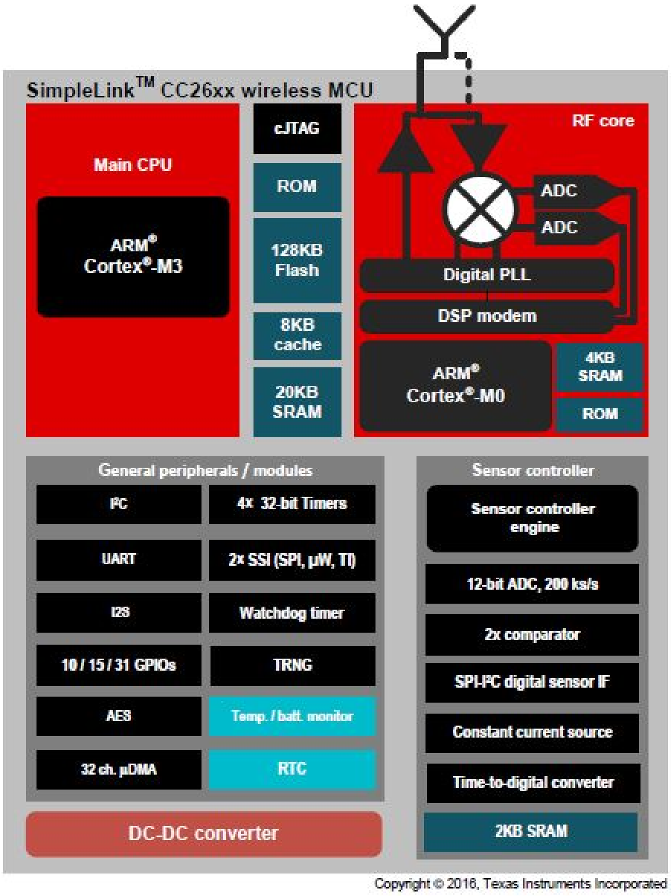


Figure 1-1. Block Diagram

This MCU is available in different packages, my choice was to employ the 7x7 mm VQFN 48 pins RGZ package for ease of use in case of potentially building the circuit at a different time. The electrical characteristics of the MCU are as follows

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)(2)]

		MIN	MAX	UNIT
Supply voltage (VDDS, VDDS2, and VDDS3)	VDDR supplied by internal DC-DC regulator or internal GLDO. VDDS_DCDC connected to VDDS on PCB.	–0.3	4.1	V
Supply voltage (VDDS[(3)] and VDDR)	External regulator mode (VDDS and VDDR pins connected on PCB)	–0.3	2.25	V
Voltage on any digital pin[(4)(5)]		–0.3	VDDSx + 0.3, max 4.1	V
Voltage on crystal oscillator pins, X32K_Q1, X32K_Q2, X24M_N and X24M_P		–0.3	VDDR + 0.3, max 2.25	V
Voltage on ADC input (V_{in})	Voltage scaling enabled	–0.3	VDDS	V
	Voltage scaling disabled, internal reference	–0.3	1.49	
	Voltage scaling disabled, VDDS as reference	–0.3	VDDS / 2.9	
Input RF level			5	dBm
T_{stg}	Storage temperature	–40	150	°C

(1) All voltage values are with respect to ground, unless otherwise noted.
(2) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(3) In external regulator mode, VDDS2 and VDDS3 must be at the same potential as VDDS.
(4) Including analog-capable DIO.
(5) Each pin is referenced to a specific VDDSx (VDDS, VDDS2 or VDDS3). For a pin-to-VDDS mapping table, see Table 6-3.

5.2 ESD Ratings

				VALUE	UNIT
V_{ESD}	Electrostatic discharge (ESD) performance	Human body model (HBM), per ANSI/ESDA/JEDEC JS001[(1)]	All pins	±2500	V
		Charged device model (CDM), per JESD22-C101[(2)]	RF pins	±750	
			Non-RF pins	±750	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Ambient temperature range		–40	85	°C
Operating supply voltage (VDDS and VDDR), external regulator mode	For operation in 1.8-V systems (VDDS and VDDR pins connected on PCB, internal DC-DC cannot be used)	1.7	1.95	V
Operating supply voltage VDDS	For operation in battery-powered and 3.3-V systems (internal DC-DC can be used to minimize power consumption)	1.8	3.8	V
Operating supply voltages VDDS2 and VDDS3		0.7 × VDDS, min 1.8	3.8	V

5.4 Power Consumption Summary

Measured on the TI CC2650EM-5XD reference design with T_c = 25°C, V_{DDS} = 3.0 V with internal DC-DC converter, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{core}	Core current consumption	Reset. RESET_N pin asserted or VDDS below Power-on-Reset threshold		100		nA
		Shutdown. No clocks running, no retention		150		nA
		Standby. With RTC, CPU, RAM and (partial) register retention. RCOSC_LF		1		µA
		Standby. With RTC, CPU, RAM and (partial) register retention. XOSC_LF		1.2		µA
		Standby. With Cache, RTC, CPU, RAM and (partial) register retention. RCOSC_LF		2.5		µA
		Standby. With Cache, RTC, CPU, RAM and (partial) register retention. XOSC_LF		2.7		µA
		Idle. Supply Systems and RAM powered.		550		µA
		Active. Core running CoreMark		1.45 mA + 31 µA/MHz		
		Radio RX [1]		5.9		mA
		Radio RX[2]		6.1		mA
		Radio TX, 0-dBm output power[1]		6.1		mA
		Radio TX, 5-dBm output power[2]		9.1		mA
Peripheral Current Consumption (Adds to core current I_{core} for each peripheral unit activated)[3]						
I_{peri}	Peripheral power domain	Delta current with domain enabled		20		µA
	Serial power domain	Delta current with domain enabled		13		µA
	RF Core	Delta current with power domain enabled, clock enabled, RF core idle		237		µA
	µDMA	Delta current with clock enabled, module idle		130		µA
	Timers	Delta current with clock enabled, module idle		113		µA
	I^2C	Delta current with clock enabled, module idle		12		µA
	I2S	Delta current with clock enabled, module idle		36		µA
	SSI	Delta current with clock enabled, module idle		93		µA
	UART	Delta current with clock enabled, module idle		164		µA

(1) Single-ended RF mode is optimized for size and power consumption. Measured on CC2650EM-4XS.
(2) Differential RF mode is optimized for RF performance. Measured on CC2650EM-5XD.
(3) I_{peri} is not supported in Standby or Shutdown.

2.3 Power block

2.3.1 Rechargeable battery

The Mikroelektronika HPL402323-2C-190mAh battery is a small footprint Li-Po battery. With a capacity of 190 mAh and a possibility of discharging a continuous current of 380 mA it is a suitable battery to deliver the 100 mA max. peak current to the PM2.5 sensor. It is charged at 4.2 V and is 3 V when completely discharged.

The battery includes protection circuitry to protect the battery from over charge and over discharge. The main specifications are as follows

4.Product Specification

4.1 Specification Table 1

No.	Item	Rated Performance	Remark
1	Rated Capacity	Typical 190mAh Minimum 190mAh	Discharge at $0.2C_5A$ after standard charge fully.
2	Nominal Voltage	3.7V	Mean operation voltage during standard discharge.
3	Voltage at end of Discharge	3.0V	Discharge cut-off voltage.
4	Charging Voltage	4.2±0.03V	
5	AC (1KHz) Impedance New Cell Max.(mΩ)	≤250mΩ	
6	Standard Charge	Constant Current $0.5C_5A$ Constant Voltage 4.2V $0.01\ C_5A$ cut-off	Charge time: Approx 4.0h.
7	Standard Discharge	Constant current $0.2\ C_5A$ end voltage 3.0V	Discharge time: Approx 6.0h.
8	Fast Charge	Constant Current $1C_5A$ Constant Voltage 4.2V $0.01\ C_5A$ cut-off	Charge time: Approx 2.5h.
9	Fast Discharge	Constant current $2C_5A$ end voltage 3.0V	
10	Maximum Continuous Charge Current	$1.0C_5A$	
11	Maximum Continuous Discharge Current	$2.0C_5A$	
12	Operation Temperature Range	Charge: 0~45°C Discharge: -20~60°C	60±25%RH.
13	Storage Temperature Range	Less than 1 year: -20~25°C Less than 3 months: -20~40°C 1 Week: -20~60°C	60±25%RH.
14	Storage Humidity Range	60±25%RH.	
15	Weight	Approx: 4.5 g	Whole product
16	Product Dimension	Thickness: Max. 4.2mm Width: Max.23.5mm Length:Max.24.5mm	Initial dimension

2.3.2 Battery charger

The MAX1555 by MAXIM charges a single-cell lithium-ion (Li+) battery from both USB and AC adapter sources. My choice was to employ a micro-usb connector and exploit the USB capabilities of the MAX1555. The main specifications for the battery charger are as follows

ELECTRICAL CHARACTERISTICS

(V_{DC} = 5V, V_{USB} = 0, I_{BAT} = 0, C_{BAT} = 1µF, **T_A = 0°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC					
DC Voltage Range	(Note 1)	3.7		7.0	V
DC to BAT Voltage Range		0.1		6.0	V
DC Undervoltage Lockout Threshold	Input rising, 430mV hysteresis, V_{BAT} = 3V (Note 1)	3.75	3.95	4.15	V
DC Supply Current			1.75	3	mA
DC to BAT On-Resistance	V_{DC} = 3.7V, V_{BAT} = 3.6V		1	2	Ω
DC to BAT Dropout Voltage	When charging stops, V_{BAT} = 4V, DC falling, 200mV hysteresis	30	60	90	mV
USB					
USB Voltage Range	(Note 1)	3.7		6.0	V
USB Undervoltage Threshold	Input rising, 430mV hysteresis, V_{DC} = 0, V_{BAT} = 3V (Note 1)	3.75	3.95	4.15	V
USB Supply Current	V_{USB} = 5V, V_{DC} = 0		1.65	3	mA
USB to BAT On-Resistance	V_{USB} = 3.7V, V_{BAT} = 3.6V, V_{DC} = 0		2	4	Ω
USB to BAT Dropout Voltage	When charging stops, V_{BAT} = 4V, USB falling, 200mV hysteresis, V_{DC} = 0	30	60	90	mV
BAT					
BAT Regulation Voltage	V_{DC} or V_{USB} = 5V	4.158	4.2	4.242	V
DC Charging Current	V_{BAT} = 3.3V, V_{USB} = 0, V_{DC} = 5V	220	280	340	mA
USB Charging Current	V_{BAT} = 3.3V, V_{DC} = 0, V_{USB} = 5V	80	90	100	mA
BAT Prequal Threshold	V_{BAT} rising, 100mV hysteresis	2.9	3	3.1	V
Prequalification Charging Current	V_{BAT} = 2.8V	20	40	80	mA
BAT Leakage Current	V_{DC} = V_{USB} = 0, V_{BAT} = 4.2V			5	µA
$\overline{POK}$, $\overline{CHG}$, AND THERMAL LIMIT					
$\overline{CHG}$ Threshold	Charge current where $\overline{CHG}$ goes high, I_{BAT} falling, 50mA hysteresis	25	50	100	mA
$\overline{CHG}$, $\overline{POK}$ Logic-Low Output	$I_{\overline{CHG}}$, $I_{\overline{POK}}$ = 10mA		150	300	mV
$\overline{CHG}$, $\overline{POK}$ Leakage Current	$V_{\overline{CHG}}$, $V_{\overline{POK}}$ = 6V, T_A = +25°C		0.001	1	µA
Thermal-Limit Temperature	Charge current reduced by 17mA/°C above this temperature		+110		°C

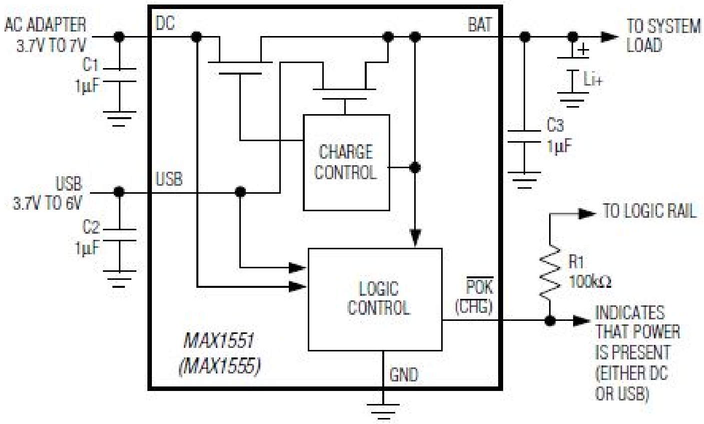
ELECTRICAL CHARACTERISTICS

(V_{DC} = 5V, V_{USB} = 0, I_{BAT} = 0, C_{BAT} = 1µF, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 2)

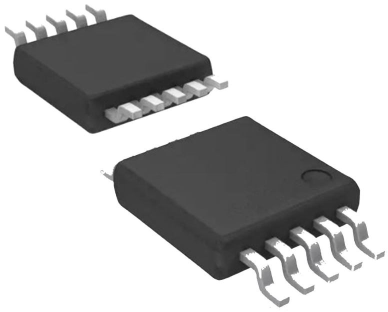
PARAMETER	CONDITIONS	MIN	MAX	UNITS
DC				
DC Voltage Range	(Note 1)	3.7	7.0	V
DC to BAT Voltage Range		0.1	6.0	V
DC Undervoltage Lockout Threshold	Input rising, 430mV hysteresis, V_{BAT} = 3V (Note 1)	3.75	4.15	V
DC Supply Current			3	mA
DC to BAT On-Resistance	V_{DC} = 3.7V, V_{BAT} = 3.6V		2	Ω
DC to BAT Dropout Voltage	When charging stops, V_{BAT} = 4V, DC falling, 200mV hysteresis	30	95	mV
USB				
USB Voltage Range	(Note 1)	3.7	6.0	V
USB Undervoltage Lockout Threshold	Input rising, 430mV hysteresis, V_{DC} = 0, V_{BAT} = 3V (Note 1)	3.75	4.15	V
USB Supply Current	V_{USB} = 5V, V_{DC} = 0		3	mA
USB to BAT On-Resistance	V_{USB} = 3.7V, V_{BAT} = 3.6V, V_{DC} = 0		4	Ω
USB to BAT Dropout Voltage	When charging stops, V_{BAT} = 4V, USB falling, 200mV hysteresis, V_{DC} = 0	30	95	mV
BAT				
BAT Regulation Voltage	V_{DC} or V_{USB} = 5V	4.141	4.259	V
DC Charging Current	V_{BAT} = 3.3V, V_{USB} = 0, V_{DC} = 5V	220	340	mA
USB Charging Current	V_{BAT} = 3.3V, V_{DC} = 0, V_{USB} = 5V	80	100	mA
BAT Prequal Threshold	V_{BAT} rising, 100mV hysteresis	2.9	3.1	V
Prequalification Charging Current	V_{BAT} = 2.8V	20	80	mA
BAT Leakage Current	V_{DC} = V_{USB} = 0, V_{BAT} = 4.2V		5	µA
$\overline{POK}$, $\overline{CHG}$				
$\overline{CHG}$ Threshold	Charge current where $\overline{CHG}$ goes high, I_{BAT} falling, 50mA hysteresis	25	100	mA
$\overline{CHG}$, $\overline{POK}$ Logic-Low Output	$I_{\overline{CHG}}$, $I_{\overline{POK}}$ = 10mA		300	mV
$\overline{CHG}$, $\overline{POK}$ Leakage Current	$V_{\overline{CHG}}$, $V_{\overline{POK}}$ = 6V, T_A = +25°C		1	µA

PIN	NAME	FUNCTION
1	USB	USB Port Charger Supply Input. USB draws up to 100mA to charge the battery. Decouple USB with a 1µF ceramic capacitor to GND.
2	GND	Ground
3	$\overline{POK}$	Power-OK Active-Low Open-Drain Charger Status Indicator. $\overline{POK}$ pulls low when either charger source is present (MAX1551 only).
	$\overline{CHG}$	Active-Low Open-Drain Charge Status Indicator. $\overline{CHG}$ pulls low when the battery is charging. $\overline{CHG}$ goes to a high-impedance state, indicating the battery is fully charged, when the charger is in voltage mode and charge current falls below 50mA. $\overline{CHG}$ is high impedance when both input sources are low (MAX1555 only).
4	DC	DC Charger Supply Input for an AC Adapter. DC draws 280mA to charge the battery. Decouple DC with a 1µF ceramic capacitor to GND.
5	BAT	Battery Connection. Decouple BAT with a 1µF ceramic capacitor to GND.

The MAX1555 does not have an enable pin, so as soon as power is connected the battery is charged. A typical application circuit, which can be found in the datasheet, is as follows



2.3.3 Voltage regulator



The MAX1759 by MAXIM is a buck/boost regulating charge pump that generates a regulated output voltage from a single lithium-ion (Li+) cell. The main features for the voltage regulator are as follows

ELECTRICAL CHARACTERISTICS

(Circuit of Figure 1, $V_{IN} = V_{\overline{SHDN}}$ = 2V, FB = PGND = GND, C_{IN} = 10µF, C_X = 0.33µF, C_{OUT} = 10µF, **T_A = 0°C to +85°C**, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		1.6		5.5	V
Input Undervoltage Lockout Voltage	V_{UVLO}		0.6	1.0	1.4	V
Output Voltage Adjustment Range		1.6V ≤ V_{IN} ≤ 5.5V	2.5		5.5	V
Output Voltage	V_{OUT}	2V ≤ V_{IN} ≤ 5.5V, 1mA ≤ I_{LOAD} ≤ 50mA	3.17	3.3	3.43	V
		2.5V ≤ V_{IN} ≤ 5.5V, 1mA ≤ I_{LOAD} ≤ 100mA	3.17	3.3	3.43	
Maximum Output Current	$I_{LOAD,MAX}$	2.5V ≤ V_{IN} ≤ 5.5V	100			mA
Transient Load Current		I_{LOAD} ≤ 100mA (RMS)		200		mA
Quiescent Supply Current	I_Q	$V_{IN} = V_{\overline{SHDN}}$ = 4V, V_{FB} = 0, stepping down		50	90	µA
		$V_{IN} = V_{\overline{SHDN}}$ = 2V, V_{FB} = 0, stepping up		85	180	
Shutdown Supply Current	$I_{Q,\overline{SHDN}}$	1.6V ≤ V_{IN} ≤ 5.5V, $V_{\overline{SHDN}}$ = 0		1	5	µA
Leakage Current into OUT in Shutdown		V_{IN} = 2V, V_{OUT} = 3.3V, $V_{\overline{SHDN}}$ = 0		1	5	µA
$\overline{SHDN}$ Logic Input Voltage	V_{IL}	1.6V ≤ V_{IN} ≤ 5.5V			0.25 • V_{IN}	V
	V_{IH}	1.6V ≤ V_{IN} ≤ 5.5V	0.7 • V_{IN}			
$\overline{SHDN}$ Input Leakage Current	$I_{\overline{SHDN}}$	$V_{\overline{SHDN}}$ = 5.5V	-1		1	µA
FB Regulation Voltage	V_{FB}	V_{IN} = 1.65V, V_{OUT} = 3.3V	1.205	1.235	1.265	V
FB Input Current		V_{FB} = 1.27V		25	200	nA
FB Dual-Mode Threshold		Internal feedback		100	50	mV
		External feedback	200	100		mV
POK Trip Voltage		Falling edge at FB	1.0	1.1	1.2	V
POK Output Low Voltage	V_{OL}	I_{SINK} = 0.5mA, V_{IN} = 2V		5	100	mV
POK Leakage Current		V_{POK} = 5.5V, V_{FB} = 1.27V		0.01	0.2	µA
Switching Frequency	f_{OSC}	1.6V ≤ V_{IN} ≤ 5.5V, V_{FB} = 1V	1.2	1.5	1.8	MHz
Output Short-Circuit Current		V_{OUT} = 0, 2.5V ≤ V_{IN} ≤5.5V, foldback current limit		110		mA
Thermal Shutdown Temperature		Rising temperature		160		°C
Thermal Shutdown Hysteresis				20		°C
Efficiency		V_{IN} = 3.6V, I_{LOAD} = 10mA		90		%

ELECTRICAL CHARACTERISTICS

(Circuit of Figure 1, $V_{IN} = V_{\overline{SHDN}} = 2V$, FB = PGND = GND, $C_{IN} = 10\mu F$, $C_X = 0.33\mu F$, $C_{OUT} = 10\mu F$, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
Input Voltage Range	V_{IN}		1.6	5.5	V
Input Undervoltage Lockout Voltage	V_{UVLO}		0.6	1.4	V
Output Voltage	V_{OUT}	$2V \le V_{IN} \le 5.5V$, $0 \le I_{LOAD} \le 50mA$	3.15	3.45	V
		$2.5V \le V_{IN} \le 5.5V$, $0 \le I_{LOAD} \le 100mA$	3.15	3.45	V
Output Voltage Adjustment Range		$1.6V \le V_{IN} \le 5.5V$	2.5	5.5	V
Maximum Output Current	$I_{LOAD,MAX}$	$2.5V \le V_{IN} \le 5.5V$	100		mA
Quiescent Supply Current	I_Q	$V_{IN} = V_{\overline{SHDN}} = 4V$, $V_{FB} = 0$		90	µA
		$V_{IN} = V_{\overline{SHDN}} = 2.5V$, $V_{FB} = 0$		180	
Shutdown Supply Current	$I_{Q,\overline{SHDN}}$	$1.6V \le V_{IN} \le 5.5V$, $V_{\overline{SHDN}} = 0$		6	µA
Leakage Current into OUT in Shutdown		$V_{IN} = 2V$, $V_{OUT} = 3.3V$, $V_{\overline{SHDN}} = 0$		5	µA
$\overline{SHDN}$ Input Logic Voltage	V_{IL}	$1.6V \le V_{IN} \le 5.5V$		$0.2 \cdot V_{IN}$	V
	V_{IH}	$1.6V \le V_{IN} \le 5.5V$	$0.7 \cdot V_{IN}$		V
$\overline{SHDN}$ Input Leakage Current	$I_{\overline{SHDN}}$	$V_{\overline{SHDN}} = 5.5V$	-1	1	µA
FB Regulation Voltage	V_{FB}	$V_{IN} = 1.65V$, $V_{OUT} = 3.3V$	1.205	1.265	V
FB Input Bias Current		$V_{FB} = 1.27V$		200	nA
FB Dual Mode Threshold		Internal feedback		40	mV
		External feedback	200		mV
POK Trip Voltage		Falling edge at FB	1.0	1.2	V
POK Output Low Voltage	V_{OL}	$I_{SINK} = 0.5mA$, $V_{IN} = 2V$		100	mV
POK Leakage Current		$V_{POK} = 5.5V$		0.2	µA
Switching Frequency	f_{OSC}	$1.6V \le V_{IN} \le 5.5V$, $V_{FB} = 1V$	1.1	1.9	MHz

A typical application circuit for step-up, step-down and 3.3V output functionalities are as follows

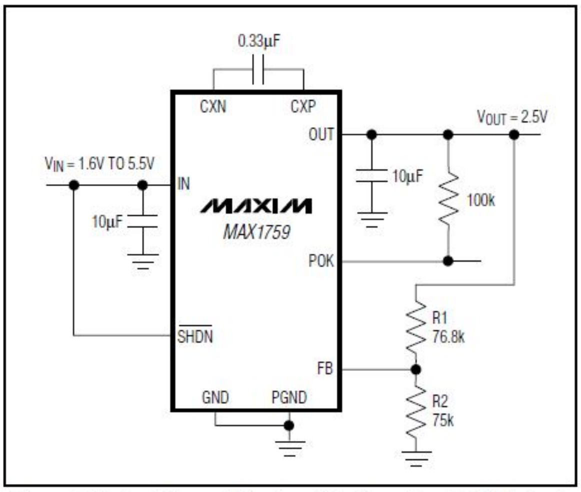


Figure 3. Using External Feedback for Regulated 2.5V Output

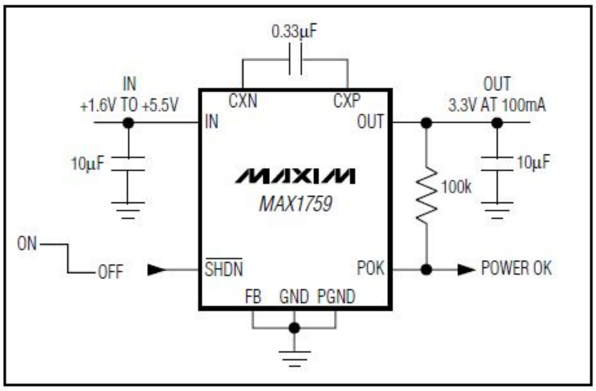


Figure 1. Typical Application Circuit

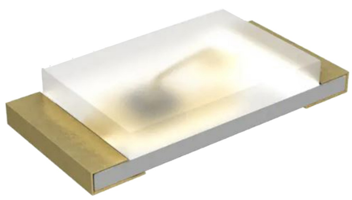
2.4 Switch

The JS202011SCQN-DPDT switch has been used. The switch is used to cut off the Li-Po battery from the circuit. The main specifications for the JS202011SCQN-DPDT switch are as follows

Specifications

CONTACT RATING: 6 VDC @ 0.3A
ELECTRICAL LIFE: 5,000 make-and-break cycles
CONTACT RESISTANCE: 70 m Ω max.
INSULATION RESISTANCE: 100 M Ω min. @ 500V.
DIELECTRIC STRENGTH: 500 VAC min. @ sea level.
OPERATING TEMPERATURE: -40°C to +85°C
STORAGE TEMPERATURE: -40°C to +85°C

2.5 LED



The APG1608ZGC from Kingbright LED's are used for the design. Typical applications for this component are status indicator, backlight and wearable and portable devices as stated in the datasheet. The main characteristics for this component are as follows

FEATURES

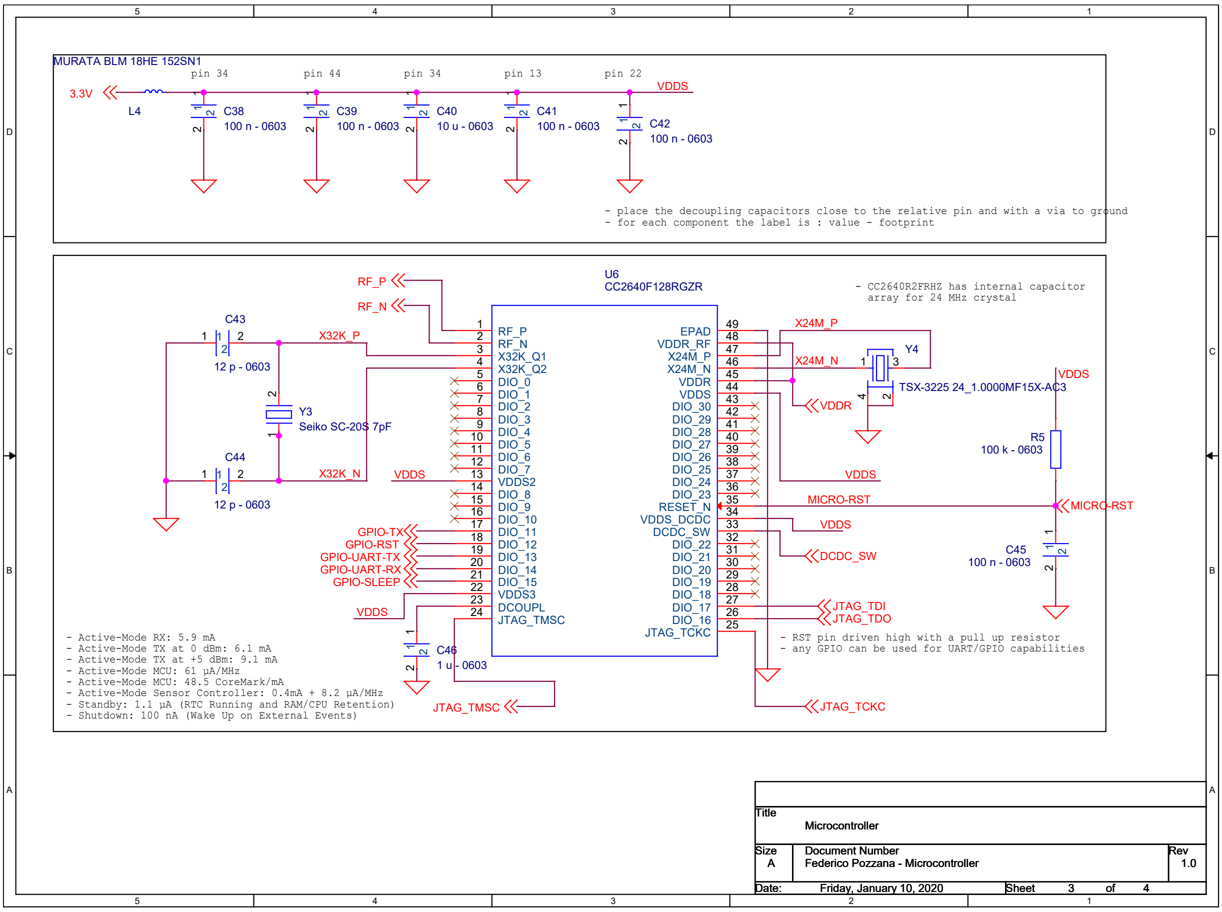
- 1.6 mm x 0.8 mm SMD LED, 0.25 mm thickness
- Low power consumption
- Wide viewing angle
- Compatible with automatic placement equipment
- Ideal for backlight and indicator
- Package: 4000 pcs / reel
- Moisture sensitivity level: 3
- RoHS compliant

3 Schematics

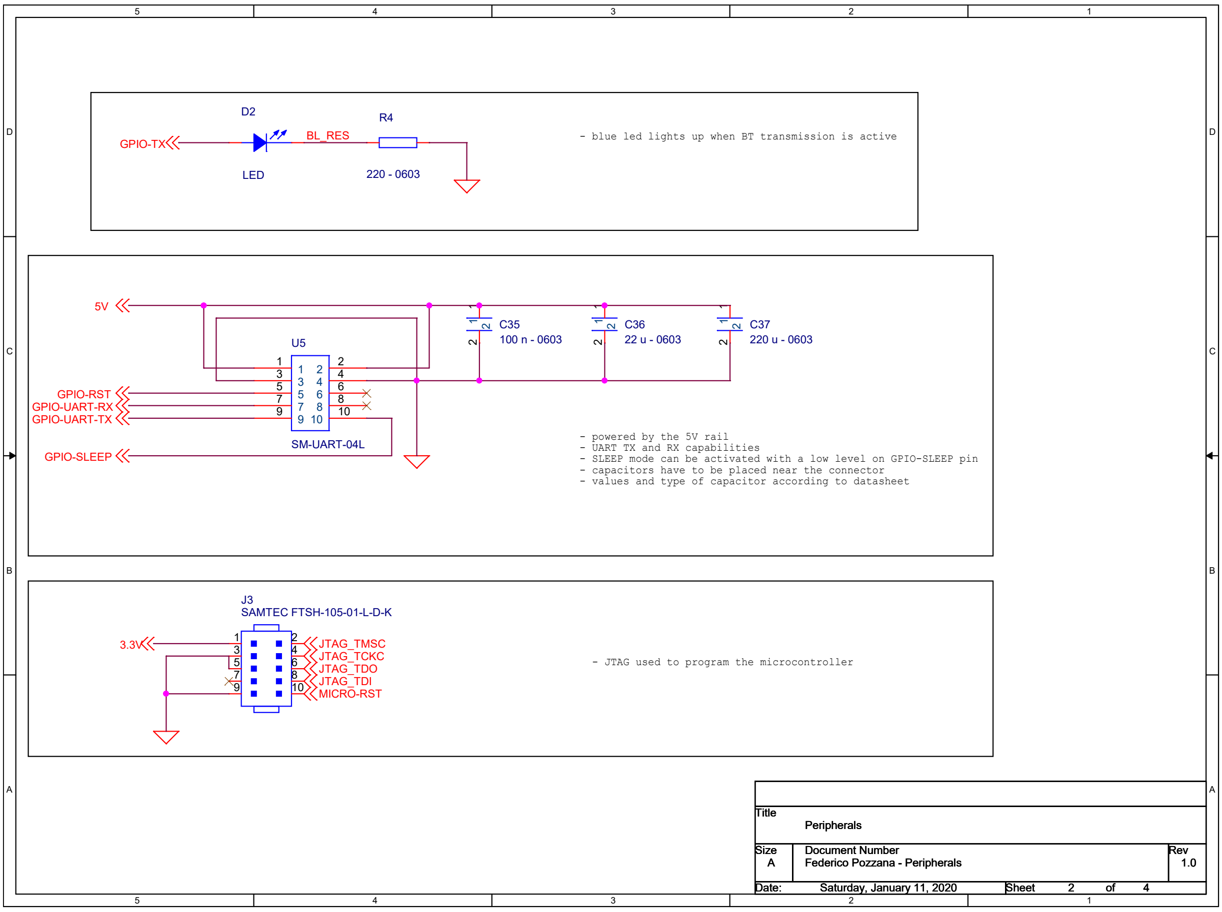
The schematics for this project are designed using ORCAD Capture. It is possible to identify four possible sections for the PAR.MA. project

- Microcontroller
- Peripherals
- Power
- RF

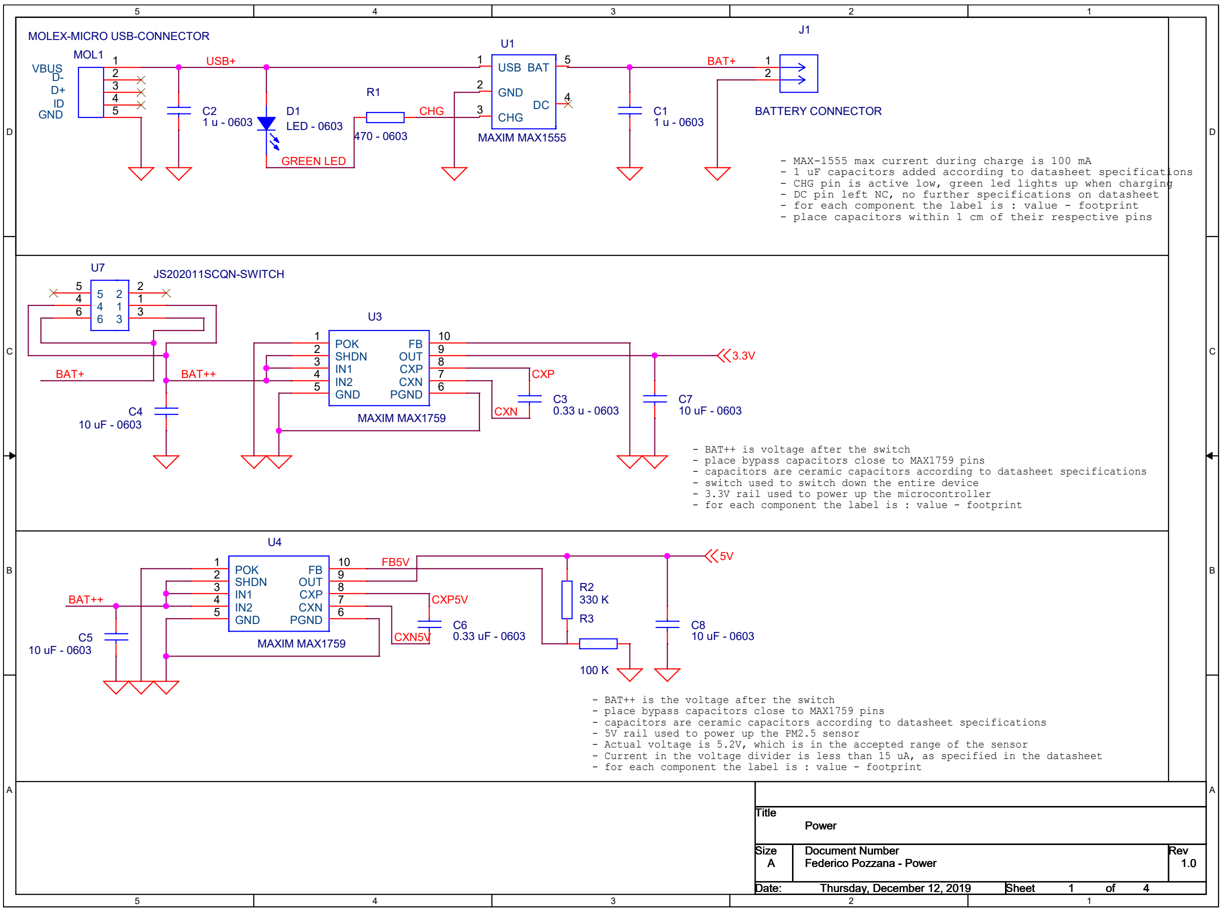
3.1 Microcontroller



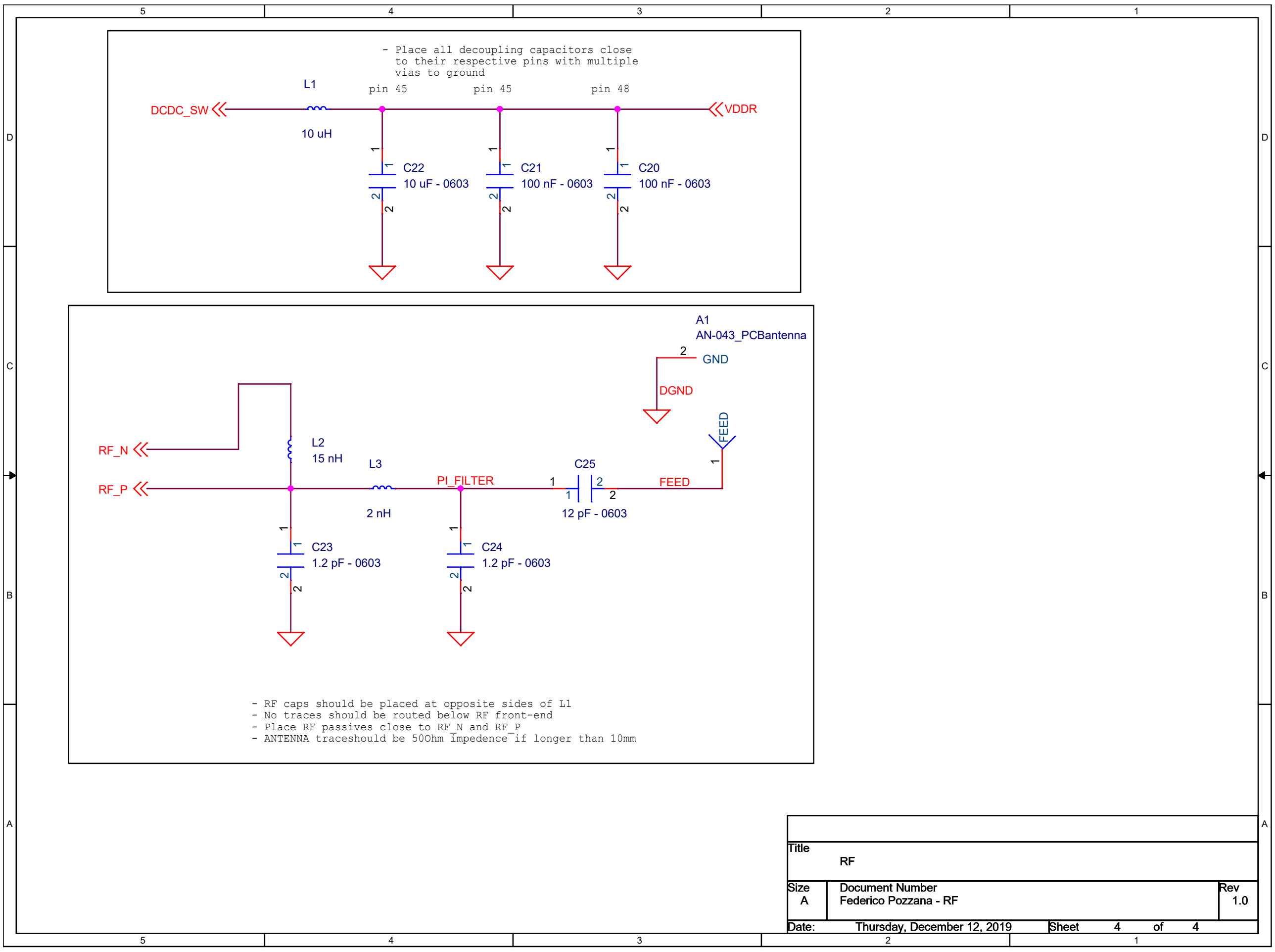
3.2 Peripherals



3.3 Power


MOLEX-MICRO USB-CONNECTOR
MOL1
VBUS
D-
D+
ID
GND
USB+
C2
1 u - 0603
D1
LED - 0603
GREEN LED
R1
470 - 0603
CHG
U1
USB BAT
GND
DC
CHG
MAXIM MAX1555
C1
1 u - 0603
BAT+
J1
BATTERY CONNECTOR
- MAX-1555 max current during charge is 100 mA
- 1 uF capacitors added according to datasheet specifications
- CHG pin is active low, green led lights up when charging
- DC pin left NC, no further specifications on datasheet
- for each component the label is : value - footprint
- place capacitors within 1 cm of their respective pins
U7
JS202011SCQN-SWITCH
U3
POK FB
SHDN OUT
IN1 CXP
IN2 CXN
GND PGND
MAXIM MAX1759
BAT+
BAT++
C4
10 uF - 0603
CXP
CXN
C3
0.33 u - 0603
C7
10 uF - 0603
3.3V
- BAT++ is voltage after the switch
- place bypass capacitors close to MAX1759 pins
- capacitors are ceramic capacitors according to datasheet specifications
- switch used to switch down the entire device
- 3.3V rail used to power up the microcontroller
- for each component the label is : value - footprint
U4
MAXIM MAX1759
BAT++
C5
10 uF - 0603
FB5V
CXP5V
CXN5V
C6
0.33 uF - 0603
R2
330 K
R3
100 K
C8
10 uF - 0603
5V
- BAT++ is the voltage after the switch
- place bypass capacitors close to MAX1759 pins
- capacitors are ceramic capacitors according to datasheet specifications
- 5V rail used to power up the PM2.5 sensor
- Actual voltage is 5.2V, which is in the accepted range of the sensor
- Current in the voltage divider is less than 15 uA, as specified in the datasheet
- for each component the label is : value - footprint
Title
Power
Size
A
Document Number
Federico Pozzana - Power
Rev
1.0
Date: Thursday, December 12, 2019
Sheet 1 of 4

3.4 RF


- Place all decoupling capacitors close to their respective pins with multiple vias to ground
L1
10 uH
DCDC_SW
VDDR
pin 45
pin 45
pin 48
C22
10 uF - 0603
C21
100 nF - 0603
C20
100 nF - 0603
A1
AN-043_PCBantenna
GND
DGND
FEED
RF_N
RF_P
L2
15 nH
L3
2 nH
PI_FILTER
C25
12 pF - 0603
C23
1.2 pF - 0603
C24
1.2 pF - 0603
- RF caps should be placed at opposite sides of L1
- No traces should be routed below RF front-end
- Place RF passives close to RF_N and RF_P
- ANTENNA traceshould be 50Ohm Impedence if longer than 10mm
Title
RF
Size
A
Document Number
Federico Pozzana - RF
Rev
1.0
Date: Thursday, December 12, 2019
Sheet 4 of 4

3.5 Bill of materials

The output below reports the bill of material extracted from the schematic.

Bill Of Materials January 10,2020 17:37:56 Page1

Item	Quantity	Reference	Part
1	1	A1	AN-043_PCBantenna
2	3	C27,C28,C46	1 u - 0603
3	6	C29,C30,C33,C34,C40,C50	10 u - 0603
4	2	C31,C32	0.33 u - 0603
5	8	C35,C38,C39,C41,C42,C45,C51,C52	100 n - 0603
6	1	C36	22 u - 0603
7	1	C37	220 u - 0603
8	3	C43,C44,C49	12 p - 0603
9	2	C47,C48	1.2 p - 0603
10	1	D1	LED - 0603
11	1	D2	LED
12	1	J1	BATTERY CONNECTOR
13	1	J3	SAMTEC FTSH-105-01-L-D-K
14	1	L1	10 uH
15	1	L2	15 nH
16	1	L3	2 nH
17	1	L4	MURATA BLM 18HE 152SN1
18	1	MOL1	MOLEX-MICRO USB-CONNECTOR
19	1	R1	470 - 0603
20	1	R2	330 K
21	1	R3	100 K
22	1	R4	220 - 0603
23	1	R5	100 k - 0603
24	2	U3,U4	MAXIM MAX1759
25	1	U5	SM-UART-04L
26	1	U6	CC2640F128RGZR
27	1	U8	MAXIM MAX1555
28	1	U9	JS202011SCQN-DPDT-SWITCH
29	1	Y3	Seiko SC-20S 7pF
30	1	Y4	TSX-3225 24_1.0000MF15X-AC3

4 Allegro

The top and bottom layer of the PCB are reported in the PCBPROTO.pdf file.
The ground plane is absent below the antenna in order to avoid interferences during transmission and reception in that particular direction. All the decoupling and bypass capacitors were placed as close as possible to the respective pins.The bottom layer is reserved to the ground plane and some traces that couldn't be routed in the top layer.

5 Conclusion

The project is ready to be manufactured, however the goal for this project is to deliver the gerber files without building it. For this reason no app and firmware are going to be developed.