NANOSAT LAB

Unitary Test

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INTRODUCTION TO RESEARCH (IR)

Q2-2020/2021

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1. Description

The first step is to identify the different ICs on the PCB.

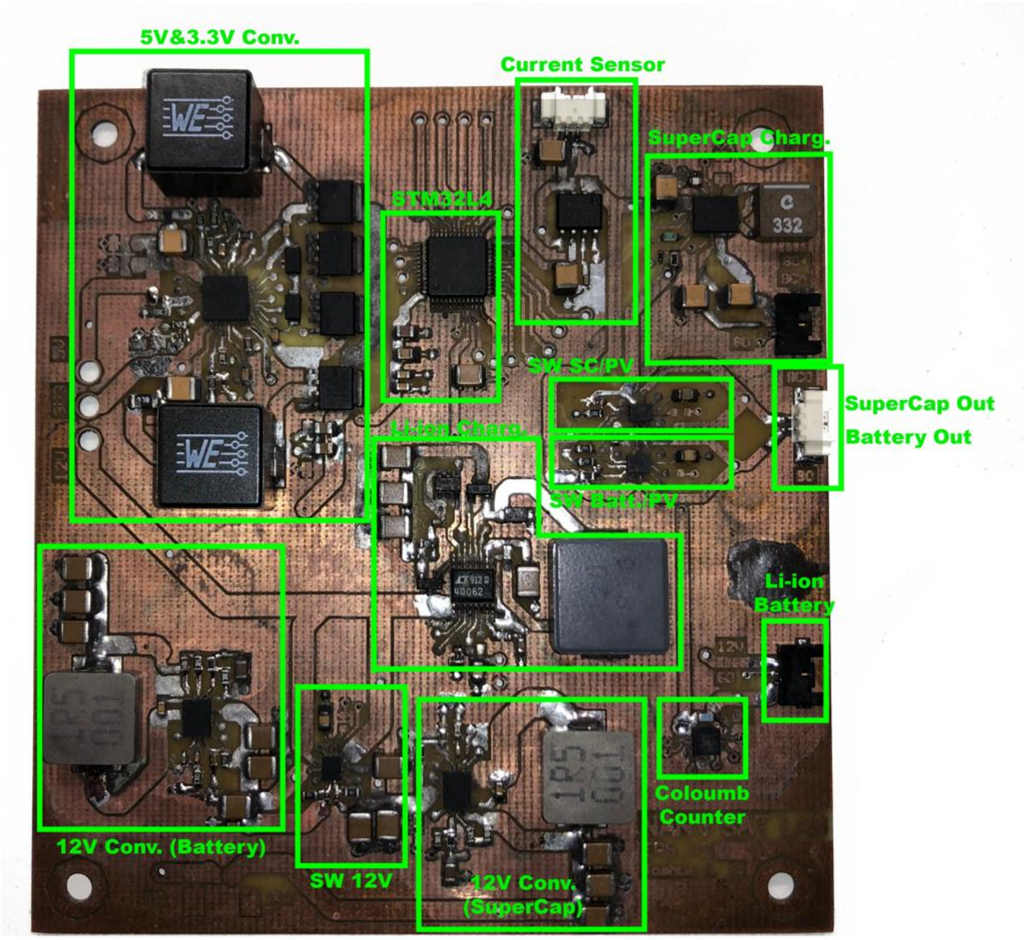
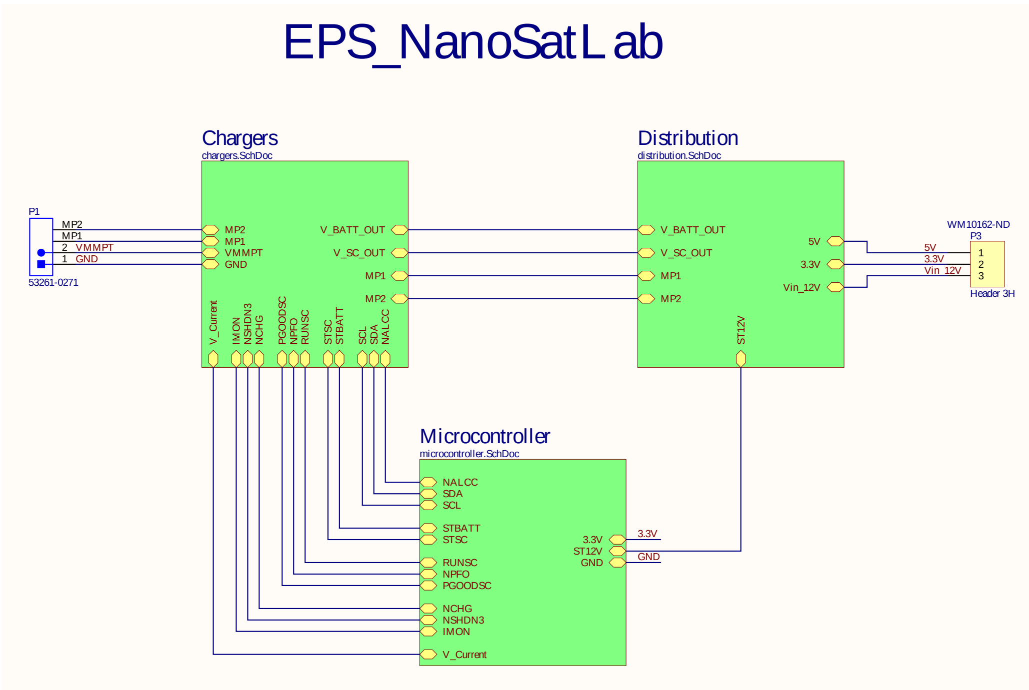
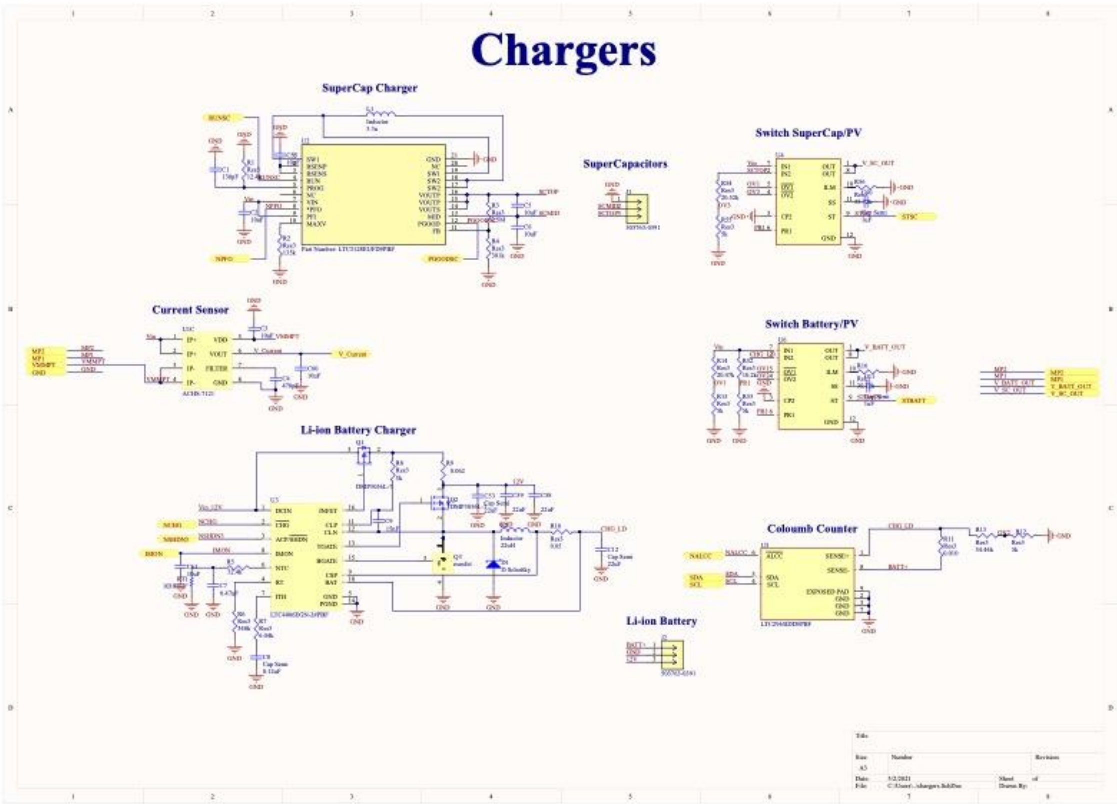
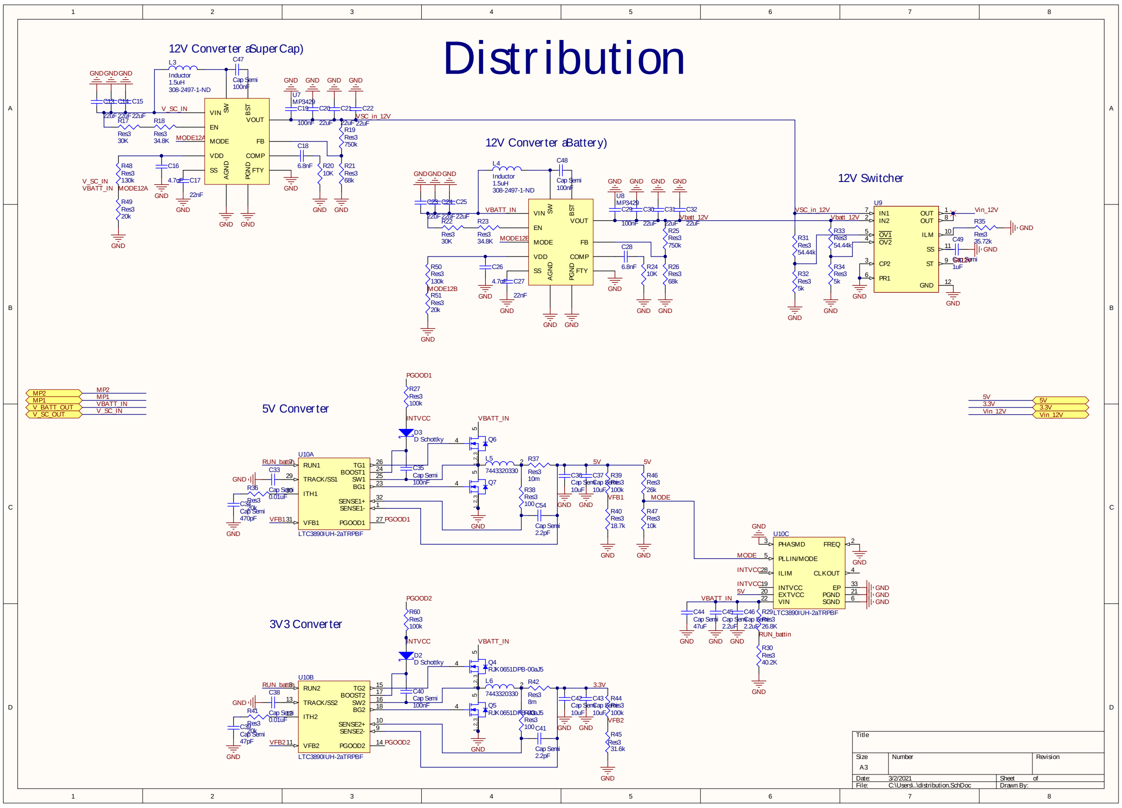


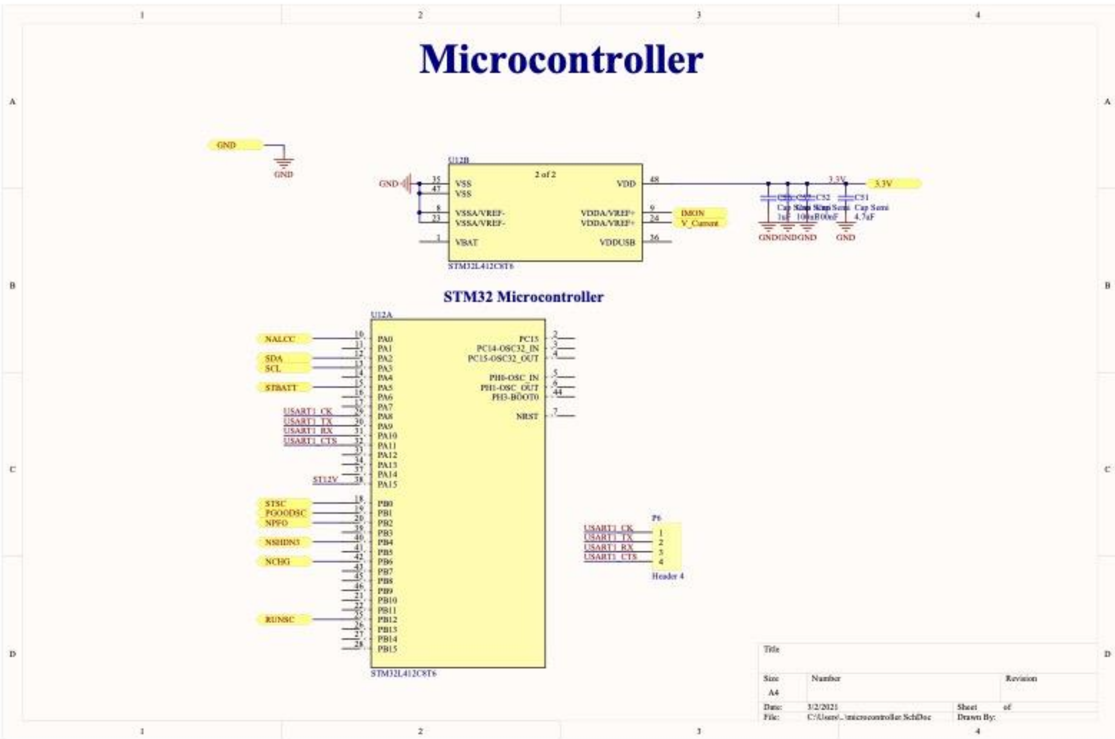
Figure 1 – PCB description

To facilitate the work and to understand better the system and its functionality, it has been organized and labeled the symbols and connections of the schematic diagram of the design.






Distribution
12V Converter (SuperCap)
12V Converter (Battery)
12V Switcher
5V Converter
3V3 Converter


Microcontroller
STM32 Microcontroller

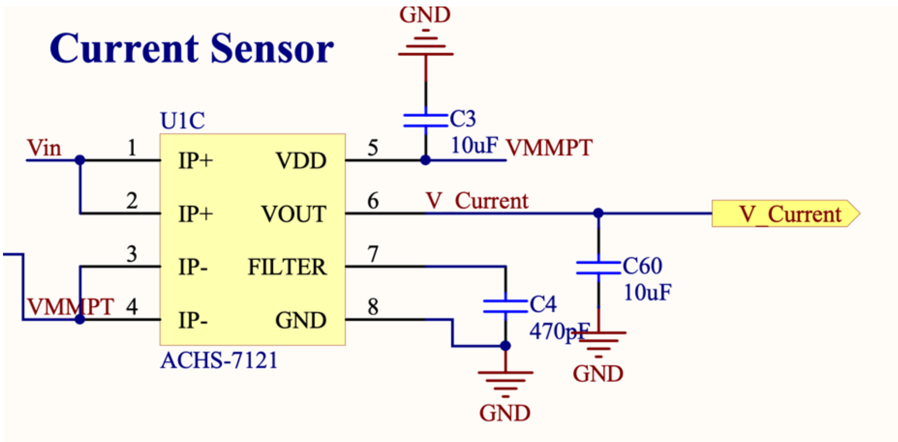
2. EPS v2 Test

2.1 U1: ACHS-7121 (Current Sensor)

2.1.1 Pinout

U1	1	IP+	Terminal for current being sampled
	2	IP+	
	3	IP-	Terminal for current being sampled
	4	IP-	
	5	GND	Output side ground
	6	FILTER	Filter pin to set bandwidth
	7	VOUT	Output Voltage
	8	VDD	Supply voltage relative to GND

2.1.2 Description



$$V_{out} = 185 \cdot I + 2600\ [mV] \quad \rightarrow \quad \pm 10A$$

$$V_{out_A} = [12\ bits\ ADC] = \frac{V_{out_D} \cdot 5200}{2^{12}} [mV]$$

$$I = \frac{V_{out_A} - 2600}{185} = \frac{\frac{V_{out_D} \cdot 5200}{4096} - 2600}{185} = \frac{V_{out_D} \cdot 5200 - 10649600}{757760} [A]$$

$$I = V_{out_D} \cdot 0{,}00686233 - 14{,}0540541\ [A]$$

2.1.3 Validation

The aim of this test is to check the current sensor detects the current as specified by their datasheet. To test it is needed to connect it to the power supply, and a Multimeter to check the voltage that indicates the current passing through the current sensor. To simulate the load, is used a 4.9Ω power resistor and a power supply to change the voltage to vary the current flowing through the resistor.

The aim is to check the output voltage when there is flowing 0.2A, 0.6A, 0.9A, 1.2A and 2.1A. By the Ohm's Law, the voltages that supply the resistor should be 0.98V, 2.94V, 4.41V, 5.88V and 10.29V.

After checking the output voltage with a multimeter, the performance and sensitivity will be checked by an ADC of the STM32L4 microcontroller.

2.1.4 Results

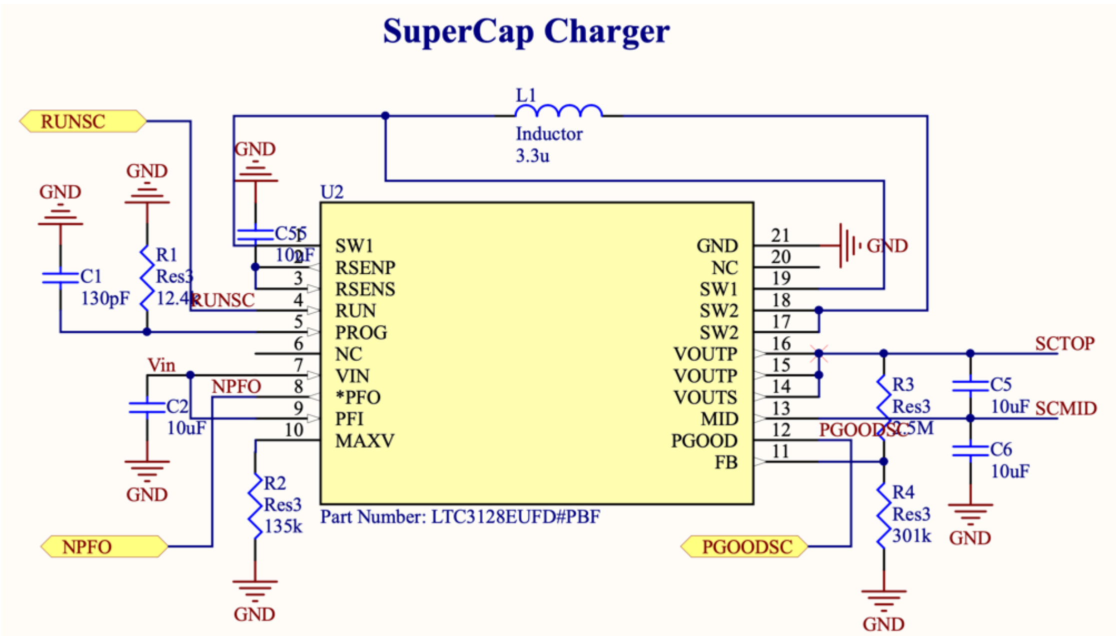
ID	Designator		Conditions	Date	Result	Judgement	Comments	Expected Value
3.1.4	**Current Sensor (Vout)**							
3.1.4.1	Sensitivity =	185 mV/A	I = 0.20 A	22/3/2021	2460 mV	OK	Vsupply = 0.98 V	2437 mV
3.1.4.2	Vdd =	4.8 V	I = 0.60 A	22/3/2021	2535 mV	OK	Vsupply = 2.94 V	2511 mV
3.1.4.3	Vout =	185*A + 2400 [mV]	I = 0.90 A	22/3/2021	2590 mV	OK	Vsupply = 4.41 V	2566.5 mV
3.1.4.4	R =	4.9 Ω	I = 1.20 A	22/3/2021	2630 mV	OK	Vsupply = 5.88 V	2622 mV
3.1.4.5			I = 2.10 A	22/3/2021	2790 mV	OK	Vsupply = 10.29 V	2788.5 mV
3.1.4.6	Real Sensor Sensitivity		STM32	22/3/2021	200 mV/A	OK		185 mV/A

2.2 U2: LTC3128EUFD#PBF (SuperCap Charger)

2.2.1 Pinout

	1	SW1	Inductor pin 1	Inductor pin
	2	RSENP	Sense Resistor Power Output	Connect other loads if necessary
	3	RSENS	Sense Resistor Power In	Connected to RSENSP
	4	RUN	Logic-Controlled Shutdown Input	Run >=1.2V Nor. Op. & <= 0.3V Shutdown
	5	PROG	Average Input Current Limit	Rprog = 11/Ilim & Cprog = 1600/Rprog
	6	NC	– – – (Tied to GND)	– – –
	7	VIN	Input Supply Pin	– – –
	8	*PFO	Power Fail Output	Sinks current when supply < Vth
	9	PFI	Power Fail Input	Supply to be monitored (Input)
	10	MAXV	Maximum voltage across supercap.	R_{MAXV}=50*V_{MAXV}
U2	11	FB	Output Voltage Feedback	Vout = 0.58*(1+R2/R1)
	12	PGOOD	Power Good Indicator	Low when Vout < Voutprog*96.75%
	13	MID	Output for active charger balancer	Tie to the junction of the two supercaps
	14	VOUTS	Output Sense Input	Tie to the Vout supercapacitor
	15	VOUTP	Output Synchronous Rectifier	Tie to the Vout supercapacitor
	16	VOUTP	Output Synchronous Rectifier	Tie to the Vout supercapacitor
	17	SW2	Inductor pin 2	Inductor pin
	18	SW2	Inductor pin 2	Inductor pin
	19	SW1	Inductor pin 1	Inductor pin
	20	NC	– – – (Tied to GND)	– – –
	21	GND	Ground	– – –

2.2.2 Description



2.2.3 Validation

The aim of this test is to check the correct functioning of the SCAP charger module. To validate it will be connecting a power supply with 5.4V and connect the SC_TOP output pin to externals resistors put in series and check the current that goes through, to check the current at which is charging the SCAP. It should be around 0.9 A, as it was limited by R1 and C1. With help of a chronometer, and a Multimeter check occasionally how long it takes to charge.

Also, it will be checked the monitoring pins of the charging state with the microcontroller.

2.2.4 Results

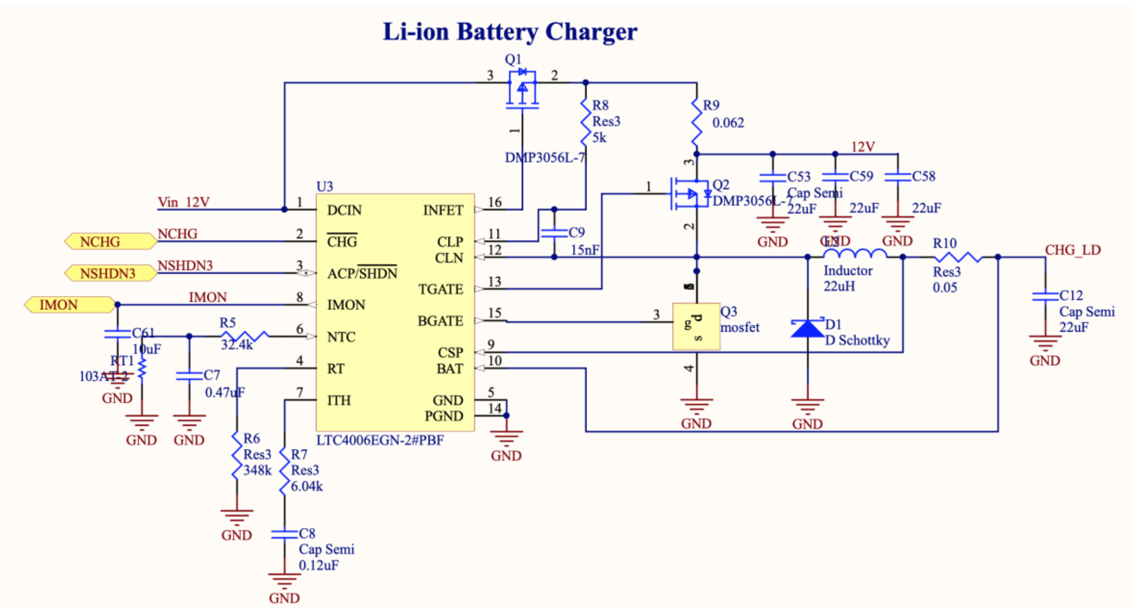
ID	Designator	Conditions	Date	Result	Judgement	Comments	Expected Value
3.2.4	**Super Capacitor Charger**						
3.2.4.1	Check charging state	Vin = 12 V	3/3/2021				12 V
3.2.4.2	NCHG Pin State Check	Vnchg = 2V	3/3/2021				0 V
3.2.4.3	Imax = 2	I = 0.50 A	3/3/2021				0.52925 V
3.2.4.4	Sensitivity = 0.4405	I = 1.20 A	3/3/2021				0.8376 V

2.3 U3: LTC4006EGN-2#PBF (Li-ion Battery Charger)

2.3.1 Pinout

	1	DCIN	External DC Power Input	– – –
	2	*CHG	Charge Status Output	Low when the battery is being charged
	3	*SHDN	AC Adapter indicator	High if the AC adapter voltage is adequate
	4	RT	Timer Resistor	Timer = 1h*RT/154k
	5	GND	Ground	– – –
	6	NTC	Thermistor network	Indicates if battery temp. is safe
	7	ITH	Current Mode PWM Control	Higher ITH volt. -> higher charg. current
U3	8	IMON	Current Monitoring Output	Liniear indication of charg. current
	9	CSP	Current Amp. CA1 Input	Supply to be monitored (Input)
	10	BAT	Battery Sense Input	Battery pin and shunt resistor
	11	CLP	In+ Sup. Curr. Lim. Amp. CL1	Vout = 0.58*(1+R2/R1)
	12	CLN	In- Sup. Curr. Lim. Amp. CL1	Low when Vout < Voutprog*96.75%
	13	TGATE	Drives Top PMOS	For the battery charger buck converter
	14	PGND	Ground Return BGATE Driver	Tie to the Vout supercapacitor
	15	BGATE	Drives Bottom NMOS	For the battery charger buck converter
	16	INFET	Drives Gate Input PFET	For the battery charger buck converter

2.3.2 Description



$$V_{I_{MON}} = \frac{0,881}{I_{MAX}} \cdot I + 0,309\ [V] \qquad I = \frac{V_{I_{MON}} - 0,309}{0,881} \cdot I_{MAX}\ [A]$$

2.3.3 Validation

The aim of this test is to check the correct functioning of the battery charger module. The design is implemented for 2A Li-Ion Batteries, as the typical application of the charger datasheet.

Power supply the DCIN pin by 12V and check the charge state of the batteries by measuring their voltage referred to GND and the state of the *CHG pin, high when charging.

Check the current monitoring by measuring the voltage of IMON pin and the voltage drop on the shunt resistor and finally apply the correspondent conversion. And likewise calculate its sensitivity by changing the current.

Check the time of charging and discharging by a help of a chronometer.

2.3.4 Validation

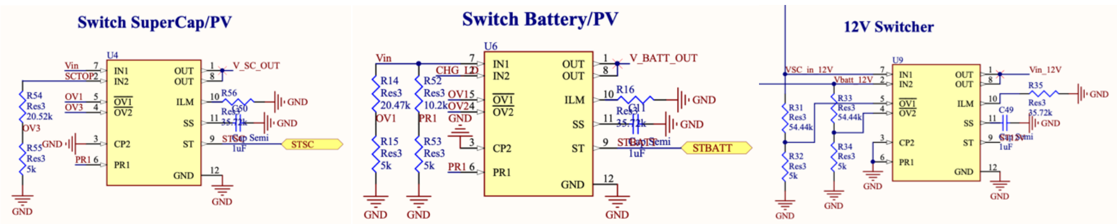
ID	Designator		Conditions	Date	Result	Judgement	Comments	Expected Value
3.3.4	**Battery Charger**							
3.3.4.1	Check charging state		Vin = 12 V	3/3/2021				12 V
3.3.4.2	NCHG Pin State Check		Vnchg = 2V	3/3/2021				0 V
3.3.4.3	Imax =	2	I = 0.50 A	3/3/2021				0.52925 V
3.3.4.4	Sensitivity =	0.4405	I = 1.20 A	3/3/2021				0.8376 V
3.3.4.5	V_Imon =	0.4405*I + 0.309 [V]	I = 2.00 A	3/3/2021				1.19 V
3.3.4.6	Charging time		I = 0.00 A	3/3/2021				60 s

2.4 U4/U6/U9: TPS2121 (Power Multiplexer/Switch)

2.4.1 Pinout

Ux	1	OUT	Power Output
	2	IN2	Power Input Source 2
	3	CP2	Enables Comparator Operation
	4	OV2	Enables IN2 Overvoltage Protection
	5	OV1	Enables IN2 Overvoltage Protection
	6	PR1	Enables Priority Operation
	7	IN1	Power Input Source 1
	8	OUT	Power Output
	9	ST	Status Output
	10	ILM	Output Current Limiting
	11	SS	Adjusts Input Setting Delay Time and Output Soft Start Time
	12	GND	Ground

2.4.2 Description



$$I_{LM} = \frac{65,2}{R_{ILM}^{\ 0,861}} \;\rightarrow\; R_{ILM}[k\Omega]$$

2.4.3 Validation

The aim of this test is to measure the time it takes to change paths of this component by applying the corresponding conditions.

Supply both inputs with two different power supplies and force the change of input selection and by a help of an oscilloscope trigger the instant of changing and measure the time and check the ST pin for the output status.

2.4.4 Results

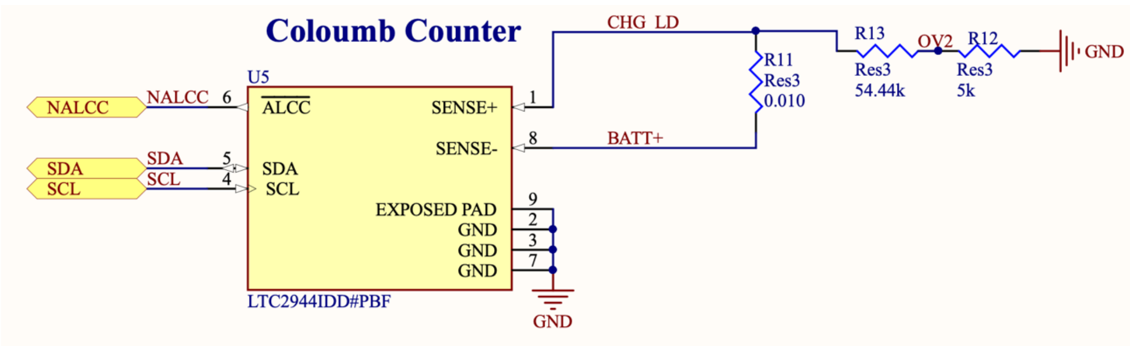
Unable to test operation due to a design problem, see section 3.2 for details.

2.5 U5: LTC2944IDD#PBF (Coulomb Counter)

2.5.1 Pinout

U5	1	SENSE+	Positive Current Sense Input and Power Supply (3,6V – 60V)
	2	GND	Ground
	3	GND	Ground
	4	SCL	Serial Bus Clock I2C Input
	5	SDA	Serial Bus Data I2C Input
	6	*ALCC	Alert Output and Charge Complete Input
	7	GND	Ground
	8	SENSE-	Negative Current Sense Input (Negative Side Shunt Resistor) +-50mV
	9	GND	Ground

2.5.2 Description



$$R_{SENSE} \leq \frac{50mV}{I_{MAX}}$$

$$q_{LSB} = 0{,}34\ mAh \cdot \frac{50m\Omega}{R_{SENSE}} \cdot \frac{M}{4096} \qquad M: Prescaler\ Coulomb\ Counter \qquad 1mAh = 3{,}6C$$

$$\text{If } Q_{BAT} > I_{MAX} \cdot 22h \quad \rightarrow \quad R_{SENSE} \leq \frac{0{,}34mAh \cdot 2^{16}}{Q_{BAT}} \cdot 50m\Omega$$

2.5.3 Validation

The aim of this test is to test the I2C bus data. Connect the Li-Ion batteries with a known load and check the voltage drop on the shunt resistor and compare with the I2C bus data by a help of an oscilloscope in decoder mode.

2.5.4 Results

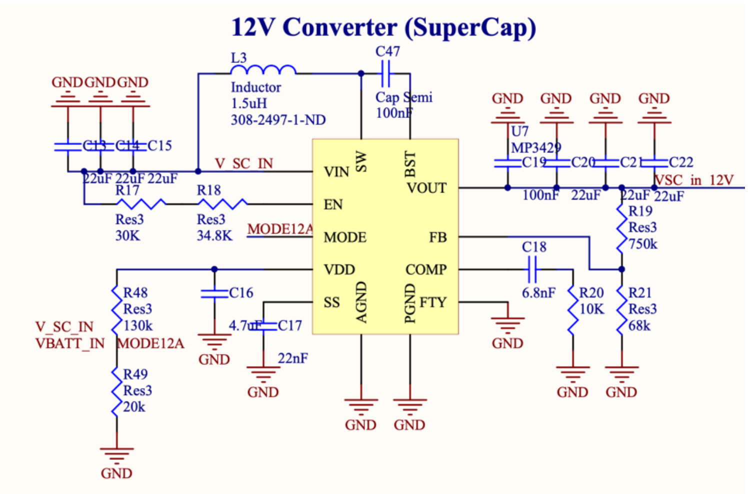
ID	Designator	Conditions	Date	Result	Judgement	Comments	Expected Value
3.5.4	**Coulomb Counter**						
3.5.4.1	Voltage Drop	Vbat = 3.2V	3/3/2021				0 V
3.5.4.2	SDA Current	Iload = 2A	3/3/2021				0 V

2.6 U7/U8: TPS2121 (Boost Converter 12V)

2.6.1 Pinout

Ux	1	SW	Converter Switch, connected to power inductor
	2	VDD	Internal bias supply. If VIN > 3.4V, IC is powered by VIN
	3	SS	Soft-Start Programming
	4	COMP	Internal Error Amplifier Output
	5	FB	Feedback input, connected a resistor divider.
	6	AGND	Analog Ground
	7	PGND	Power Ground
	8	VOUT	Output
	9	FTY	Connected to GND
	10	MODE	Mode selection. Floating:USM, High:FCCM and Low: PSM
	11	EN	Chip Enable Control. For auto start-up, connect to Vin
	12	VIN	Input Supply
	13	BST	Bootstrap. Cap beetwen BST and SW, power the sync. HS-FET

2.6.2 Description



2.6.3 Validation

The aim of this test is to check that the converters are working appropriately. Connect a power supply with 5.4 V and 2.7V and check the output voltage of the converter is 12V.

2.6.4 Results

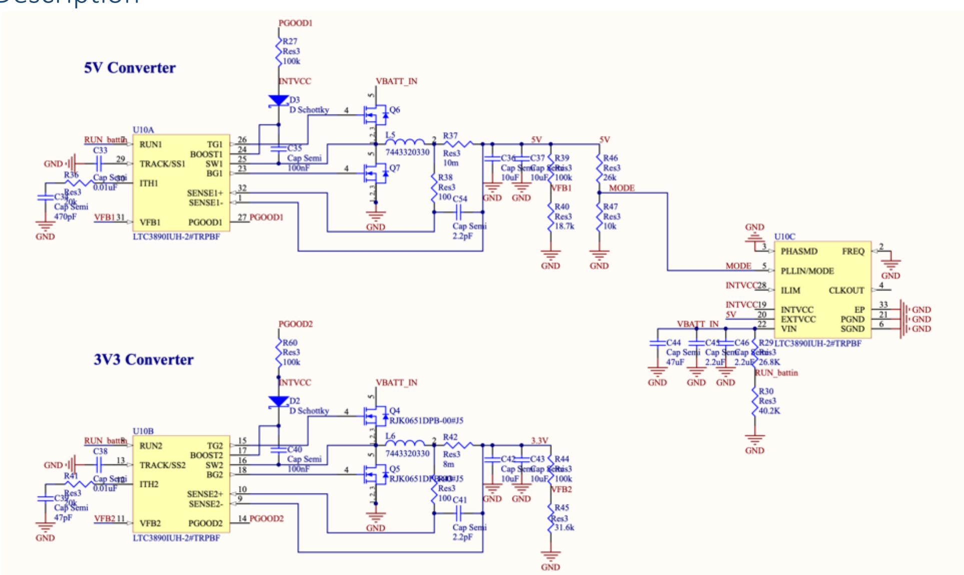
ID	Designator	Conditions	Date	Result	Judgement	Comments	Expected Value
3.6.4		**12V Converter**					
3.6.4.1	V_SC	Vin = 5.4 V	23/3/2021	12.14 V	OK		12 V
3.6.4.2	V_SC	Vin = 2.7 V	23/3/2021	11.91 V	OK		12 V
3.6.4.3	V_Batt	Vin = 5.4 V	23/3/2021	12.16 V	OK		12 V
3.6.4.4	V_Batt	Vin = 2.7 V	23/3/2021	11.95 V	OK		12 V

2.7 U10: LTC3890IUH-2#TRPBF (5V/3V3 Converter)

2.7.1 Pinout

U10	1	SENSE1-	In- Differential Current Comp.1
	2	FREQ	Freq. Control internal VCO
	3	PHASMD	Control Input to Phase Selector
	4	CLKOUT	Output Clock Signal
	5	PLLIN/MODE	External Synch. Input to Phase Detector and Forced Cont. Mode Input
	6	SGND	Small-signal Ground
	7	RUN1	Digital Run Control Input Controller 1
	8	RUN2	Digital Run Control Input Controller 2
	9	SENSE2-	In- Differential Current Comp.2
	10	SENSE2+	In+ Differential Current Comp.2
	11	VFB2	Receives the remotely sensed feedback voltage from Controller 2
	12	ITH2	Error Amplifier Outputs and Switching Regulator Compensation Points
	13	TRACK/SS2	External Tracking and Soft-Start Input
	14	PGOOD2	Open-Drain Logic Output. Low when VFB2 < ±10% of its set point.
	15	TG2	High Current Gate Drives for Top NMOSFET
	16	SW2	Switch Node Connections to Inductors
	17	BOOST2	Bootstrapped Supplies to the Topside Floating Drivers
	18	BG2	High Current Gate Drives for Bottom (Synchronous) NMOSFET
	19	INTVCC	Output of the Internal Linear Low Dropout Regulator
	20	EXTVCC	External Power Input to an Internal LDO Connected to INTVCC
	21	PGND	Driver Power Ground
	22	VIN	Main Supply Pin
	23	BG1	High Current Gate Drives for Bottom (Synchronous) NMOSFET
	24	BOOST1	Bootstrapped Supplies to the Topside Floating Drivers
	25	SW1	Switch Node Connections to Inductors
	26	TG1	High Current Gate Drives for Top NMOSFET
	27	PGOOD1	Open-Drain Logic Output. Low when VFB1 < ±10% of its set point.
	28	ILIM	Current Comparator Sense Voltage Range Inputs
	29	TRACK/SS1	External Tracking and Soft-Start Input
	30	ITH1	Error Amplifier Outputs and Switching Regulator Compensation Points
	31	VFB1	Receives the remotely sensed feedback voltage from Controller 1
	32	SENSE1+	In+ Differential Current Comp.1

2.7.2 Description



2.7.3 Validation

The aim of this test is to check that the converter is working appropriately. Connect a power supply with 5.4 V and 2.7V and check both output voltages of the converter are 5V and 3.3V.

2.7.4 Results

ID	Designator	Conditions	Date	Result	Judgement	Comments	Expected Value
3.7.4	**5V and 3,3V Converter**						
3.7.4.1	V_5V	Vin = 5.4 V	23/3/2021	0.06 V	NOK		5 V
3.7.4.2	V_5V	Vin = 2.7 V	23/3/2021	0 V	NOK		5 V
3.7.4.3	V_3V3	Vin = 5.4 V	23/3/2021	0.09 V	NOK		3.3 V
3.7.4.4	V_3V3	Vin = 2.7 V	23/3/2021	0 V	NOK		3.3 V

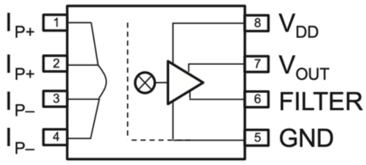
3. Issues

3.1 Pinout U1: ACHS-7121 (Current Sensor)

The pinout in the design do not corresponds to the datasheet pinout.

U1:Pin5	VDD
U1:Pin6	VOUT
U1:Pin7	FILTER
U1:Pin8	GND

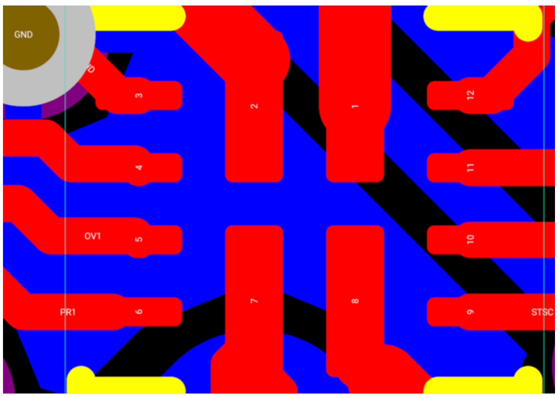
The correct pinout is as the following figure extracted from the sensor datasheet:

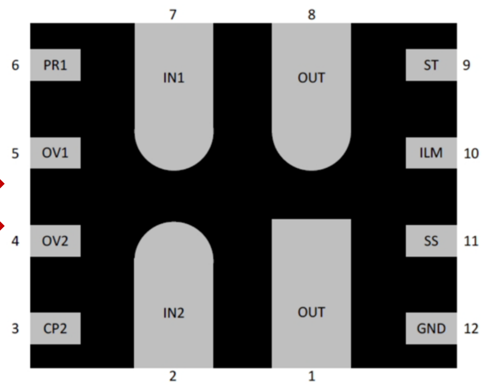


Solution:
Cut the traces and rework the connections with the correct pins.

3.2 Pinout U4/U6/U9: TPS2121 (Multiplexer/Switch)

The pinout in the design footprint do not corresponds to the datasheet pinout.





The footprint is flipped horitzontally.

Solution:
???

3.3 V_BATT Line

U6-Pin1 [Switch BAT-Out] should be connected to U8-Vin, Q6-Pin5, Q4-Pin5 and U10-Pin22.

U6-Pin1	U8 - Vin
	U10 - Pin22
	Q4 - Pin5
	Q6 - Pin5

The U6-Pin1 corresponds to the output of the switcher that select the supply from PV or the battery, this switch-output feeds the power converters (3.3V, 5V and 12V).

Solution:
Solder a cable between both traces (VBATT_IN and V_BATT_OUT).

3.4 V_SC Line

U4-Pin1 [Switch SC-Out] should be connected to U7-Vin.

U4-Pin1	U7 - Vin

The U4-Pin1 corresponds to the output of the switcher that select the supply from PV or the SuperCapacitor, this switch-output feeds the power converter of 12V.

Solution:
Solder a cable between both traces (VBATT_IN and V_BATT_OUT).

3.5 Serial Wire Debugger (SWD) for STM32-MCU

Missing the traces and connector to program the STM32L4 by the SWD pins.

STM32	STLINK (Programmer)
VDD	3V3
VSS	GND
PA13 (Pin34)	SWDIO
PA14 (Pin37)	SWCLK

Solution:
Solder wires directly from the STM32 pins to a connector used to plug-in to the STLINK of a NUCLEO board.