Electronic Design for a Wireless Smart Insole

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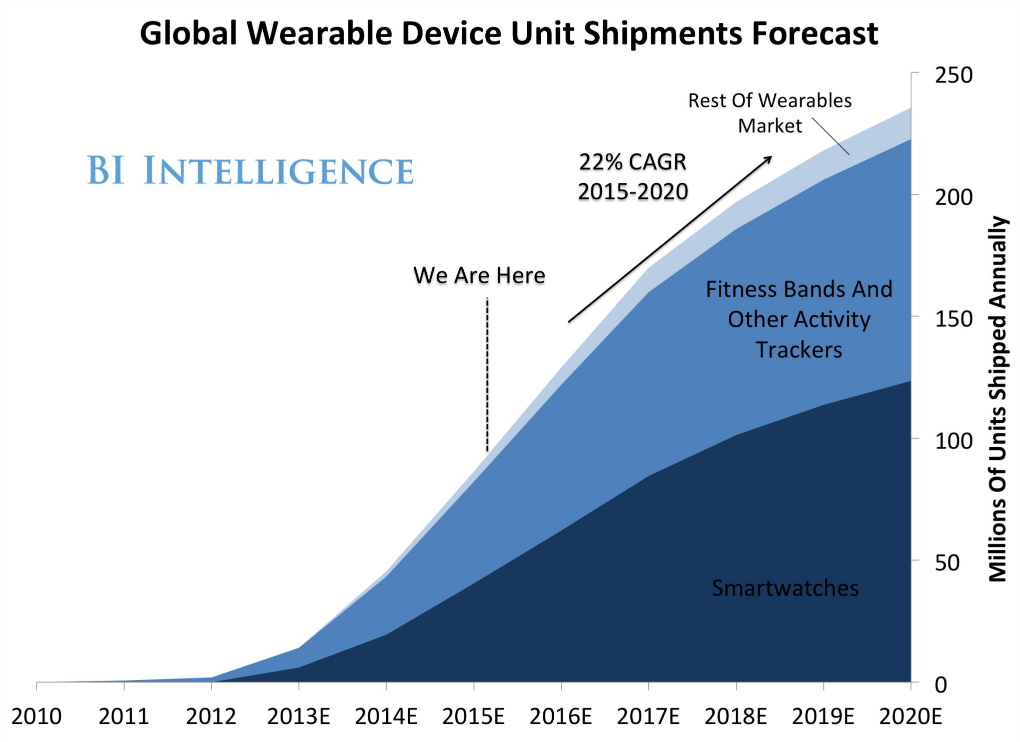
09-09-2019

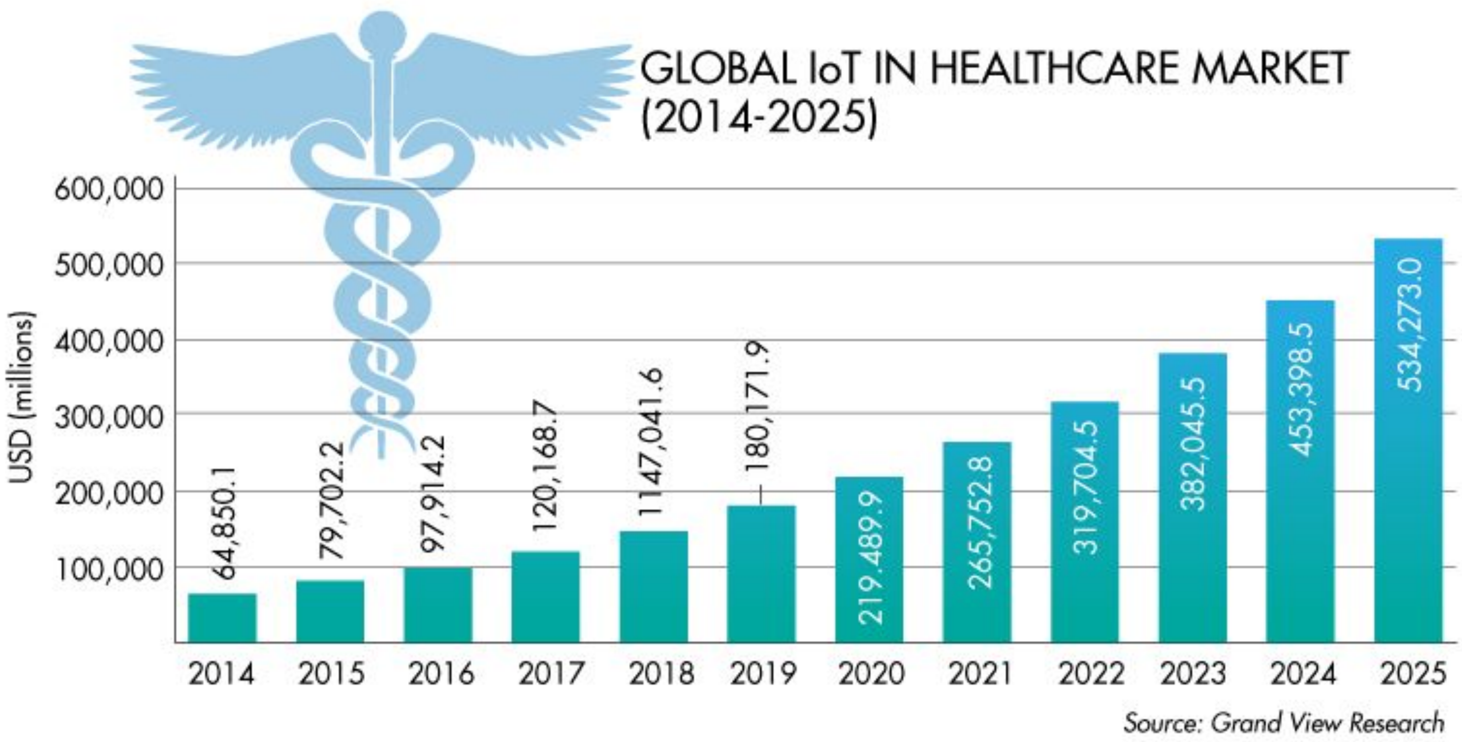
2

Introduction



Source: BI Intelligence Estimates

Introduction



Objectives & Scope of the Project

- Develop a smart insole capable to be of use to the casual user and to medical professionals

- The insole should thin enough to go unnoticed for the user and thus not creating a bias in their steps.

- The insole must operate in a wide variety of environments without the risk of malfunction due to humidity or sweat.

Tools!

- Bluetooth SoCs,
- rigid-flex PCB
- u-Vias
- piezoelectric textiles and MEMS sensors
- induction charging
- magnetic switches
- full spatial position sensor
- LPWAN technologies

Methodology

Architecture

Prototyping

PCB Design

Test

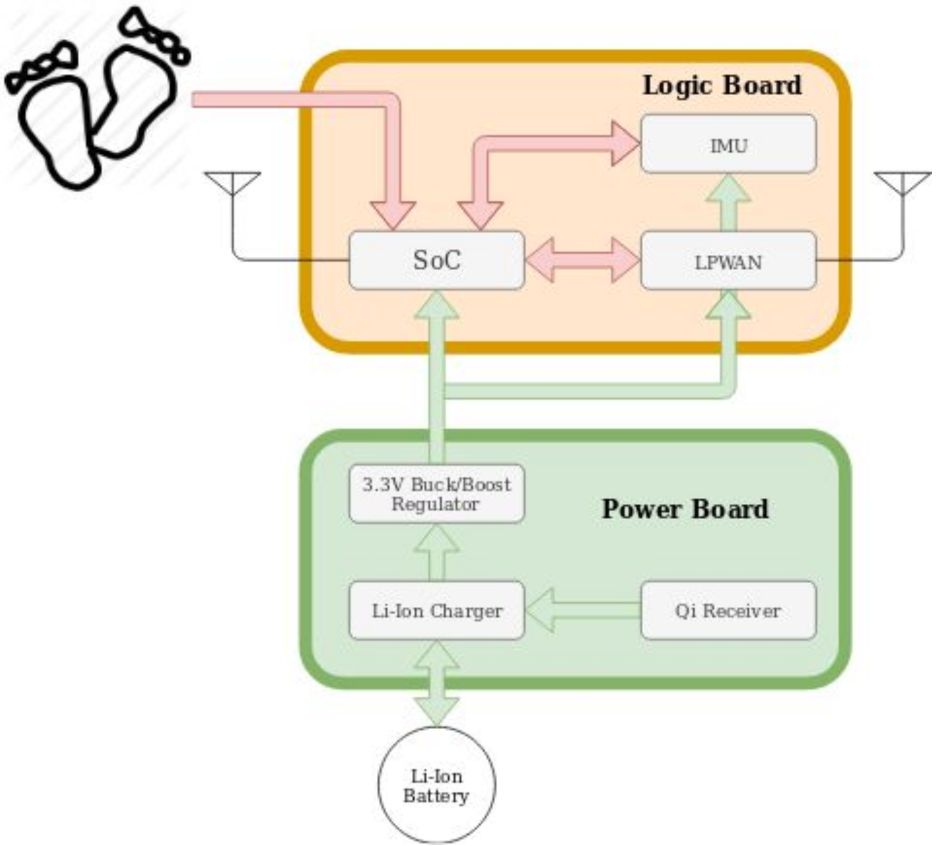
Architecture

First step:

Create a high-level abstraction schematic to define the requirements

2 sub-assemblies

- Logic Board
- Power Board



Architecture: Logic Board

- MCU SoC: STM32WB55
  - BLE 5, Ultra low power modes (50uA/MHz), up to 105°C radio temperature operation and in the SW side the, HAL libraries of ST.
- Sensors
  - <u>Pressure Sensor (STX):</u> piezoresistive material that allow for use in dynamic sensors to map and measure pressure
  - <u>IMU(BNO055):</u> 9DOF (14-bit accelerometer,16-bit gyroscope, geomagnetic sensor) With a 32-bit MCU running proprietary fusion sensor software.

Architecture: Logic Board (LPWAN)

Technology	SigFox	LoRa/LoRaWAN	NB-IoT
Range	<13Km	<11Km	<15Km
Spectrum	Unlicensed but proprietary ➔ 868 MHz ➔ 918 MHz	Unlicensed ➔ 433 MHz ➔ 868 MHz ➔ 918 MHz	Licensed 700-900Mhz
Bandwitdh	100kHZ	<500kHz	200kHz or shared
Data rate	<100kbps	<10kbps	<150kbps
Service Provider	Yes	No	Yes
Infrastructure Costs	No	“Yes”	No
Battery Life	>10 years		

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Hidden costs of certifications!

Architecture: Power Board

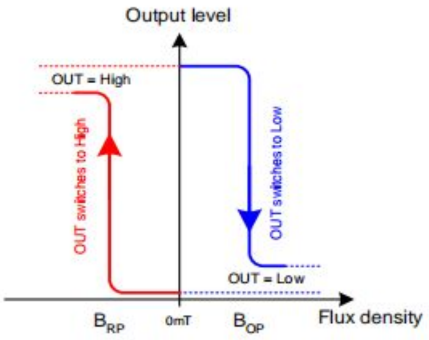
- DC/DC converter (TPS6303X):
  - Buck/ Boost topology 800mA @ 3.3v in Step-Down 500mA @ 3.3v in Step-Up Mode
  - 96% Efficiency
  - Automatic Transition Step-Down & Step-Up
  - Over-temperature Protection

- Battery Charger (MCP73831/2)
  - Li-Ion technology dedicated charger, max 500mA charger current

Architecture: Power Board II

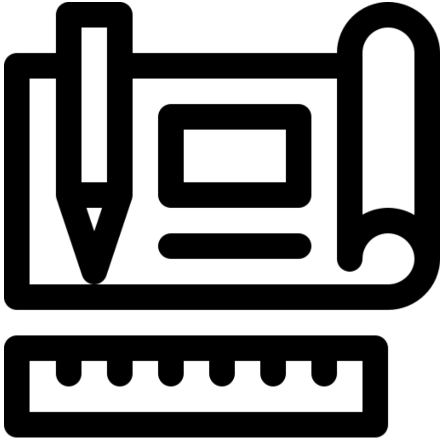
- Qi Wireless Power Receiver:
  - 15W receiver
  - BGA package (3.97 x 2.67 mm) optimized for minimal footprint

- Hall Effect Magnetic Switch (MLX92212LSE)
  - Hall effect latching circuit capable of retaining the last state
  - Advantages again Reed Switch



Prototyping Phase

Walk before run!

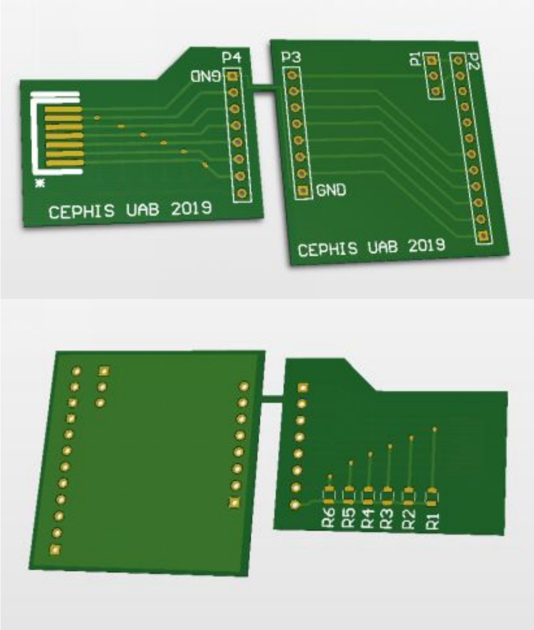


Using development boards to test code snippets and validate the hardware selection.

Example:

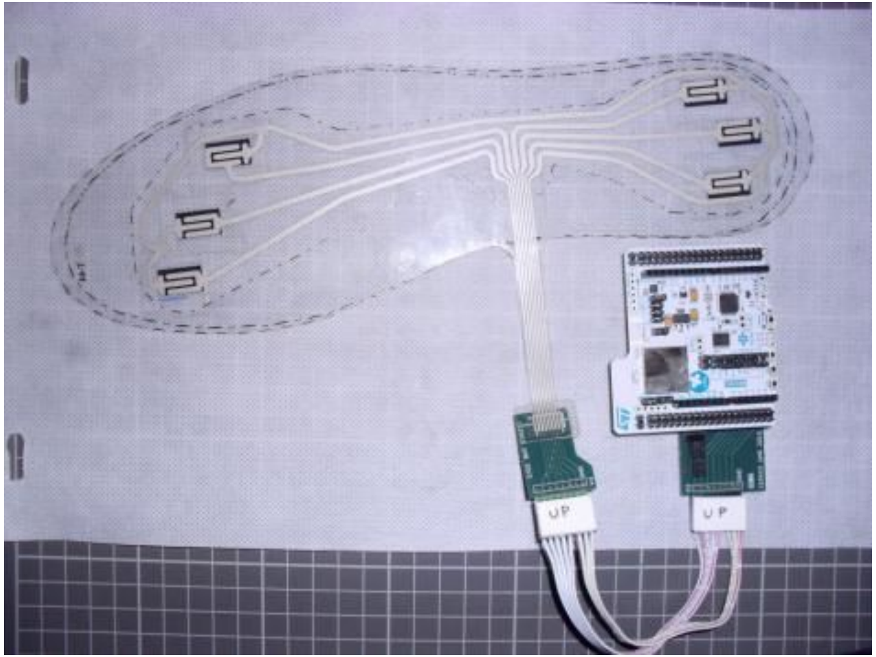
- ADC-Insole Interface
- BLE connectivity

Prototyping Phase
ADC-Insole Test



Adapter Board

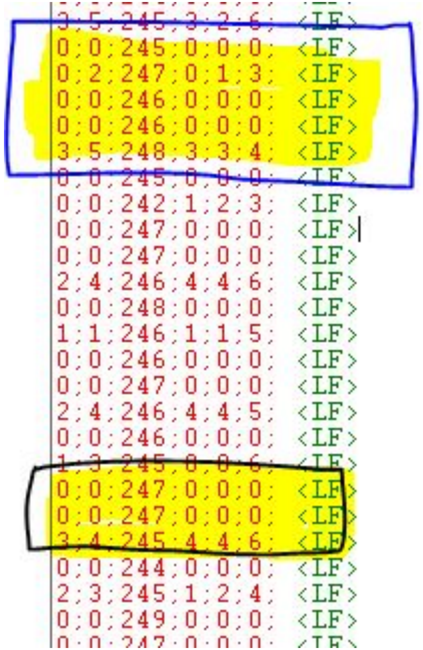
Full Test mounted with insole and MCU



Prototyping Phase
ADC-Insole Results

```
0;0;0;80;3915;0;  <LF>
0;0;0;94;3908;0;  <LF>
0;24;25;159;3928;22;  <LF>
32;74;62;180;3921;53;  <LF>
0;38;22;149;3932;35;  <LF>
34;0;2;116;3908;0;  <LF>
0;0;0;79;3908;0;  <LF>
0;0;0;112;3874;0;  <LF>
0;53;32;36;20;34;  <LF>
5;50;171;3894;47;67;  <LF>
11;18;131;3876;39;26;  <LF>
0;11;81;3890;0;0;  <LF>
0;0;63;3903;0;0;  <LF>
0;0;101;3903;0;0;  <LF>
0;13;137;3916;2;17;  <LF>
21;54;169;3927;37;55;  <LF>
14;39;124;3939;28;32;  <LF>
0;0;110;3938;0;0;  <LF>
0;0;61;3915;0;0;  <LF>
```

Result ADC 12-Bits conversion (4th row)



```
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0;0;245;0;0;0;  <LF>
0;2;247;0;1;3;  <LF>
0;0;246;0;0;0;  <LF>
0;0;246;0;0;0;  <LF>
3;5;248;3;3;4;  <LF>
0;0;245;0;0;0;  <LF>
0;0;242;1;2;3;  <LF>
0;0;247;0;0;0;  <LF>
0;0;247;0;0;0;  <LF>
2;4;246;4;4;6;  <LF>
0;0;248;0;0;0;  <LF>
1;1;246;1;1;5;  <LF>
0;0;246;0;0;0;  <LF>
0;0;247;0;0;0;  <LF>
2;4;246;4;4;5;  <LF>
0;0;246;0;0;0;  <LF>
1;3;245;0;0;6;  <LF>
0;0;247;0;0;0;  <LF>
0;0;247;0;0;0;  <LF>
3;4;245;4;4;6;  <LF>
0;0;244;0;0;0;  <LF>
2;3;245;1;2;4;  <LF>
0;0;249;0;0;0;  <LF>
```
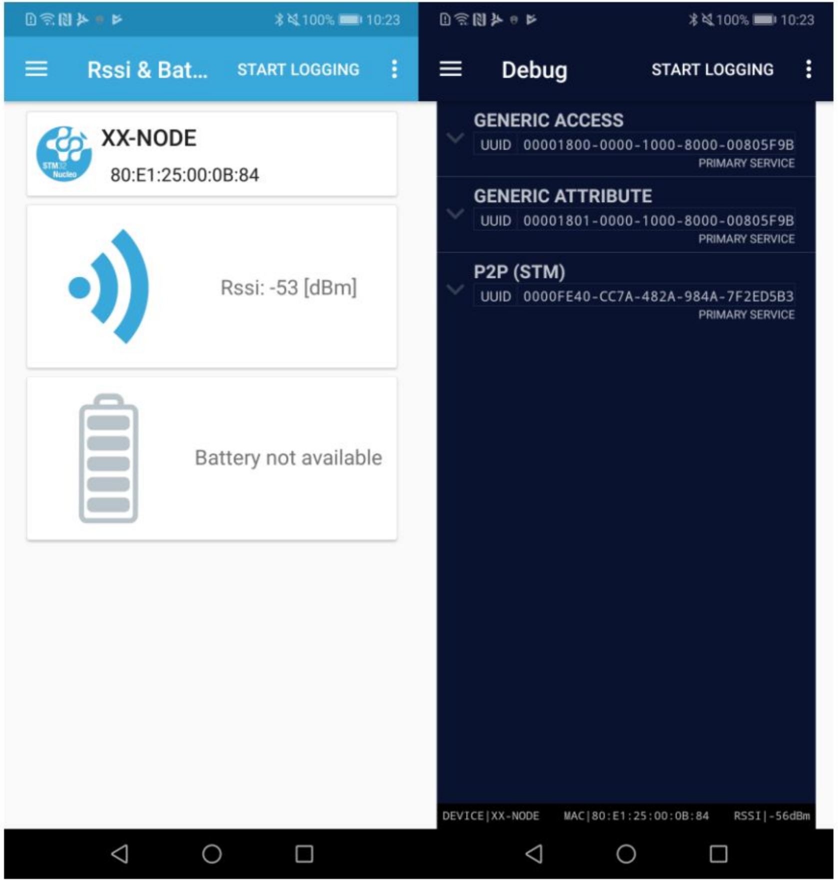
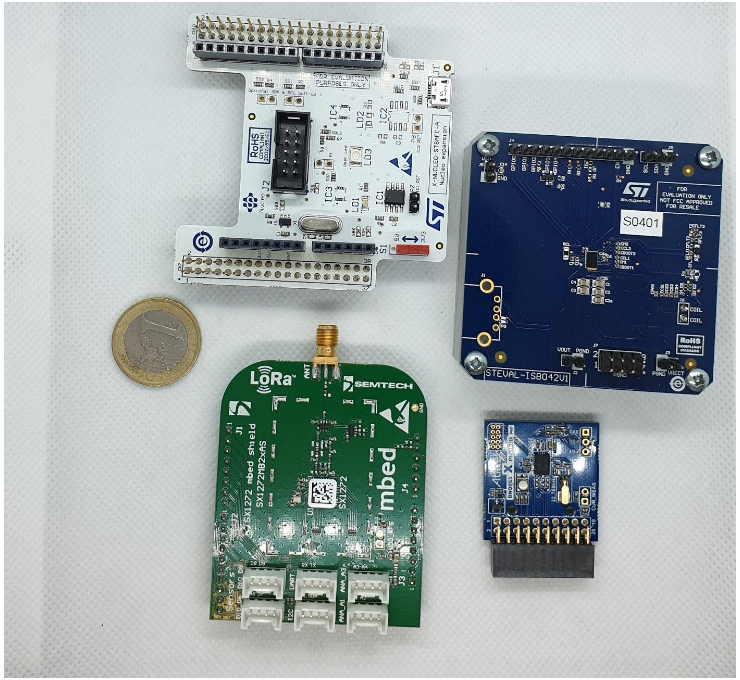

Weird Cyclic Error

BLE connectivity

- Tested:
  - SoC SWD Programming/Debugging
  - BLE paring
  - BLE range
  - BLE interaction with phone



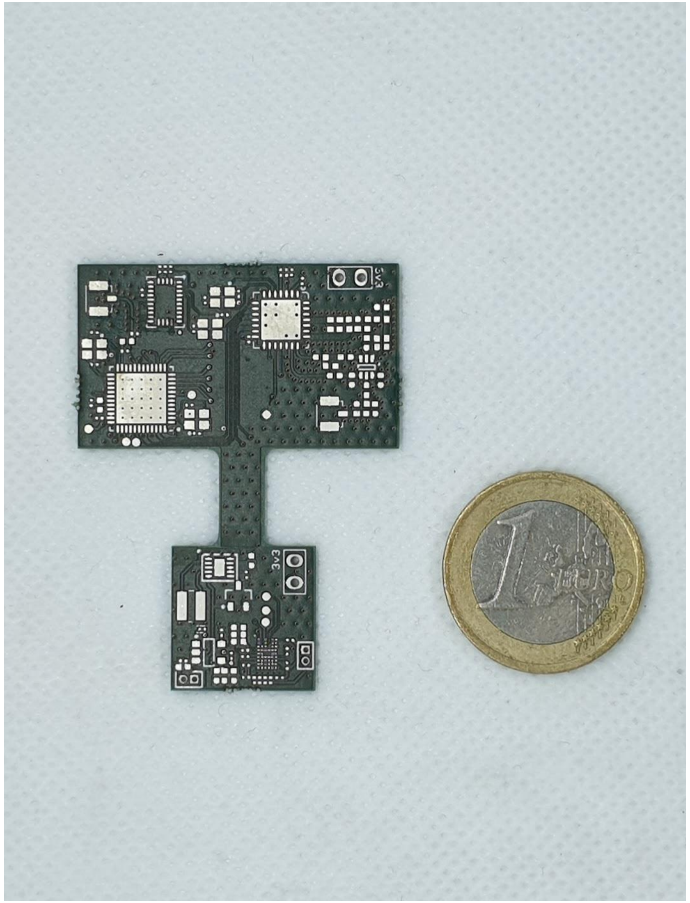
Miniaturization

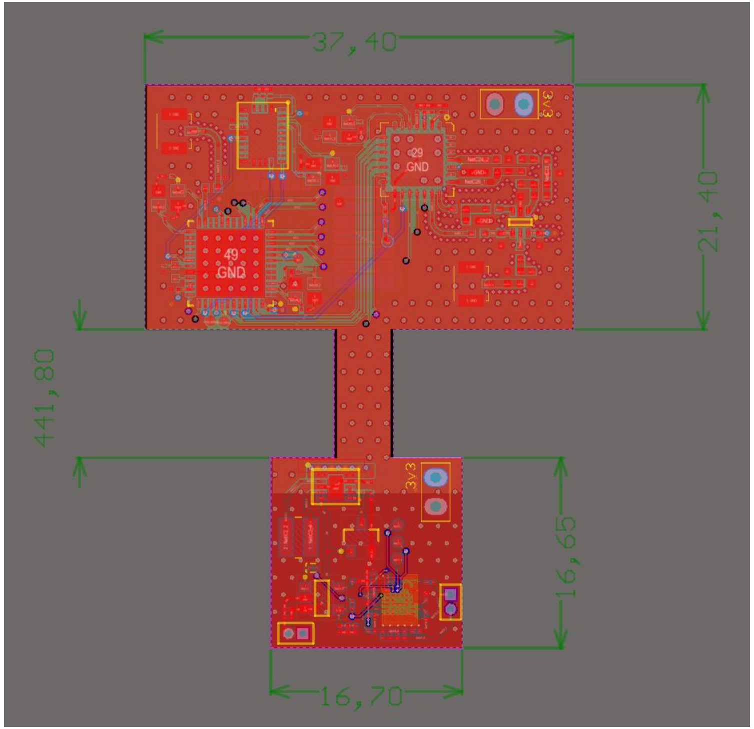


Shrink all this development board into a functional prototype, capable of operate in a minimal space

17

Miniaturization





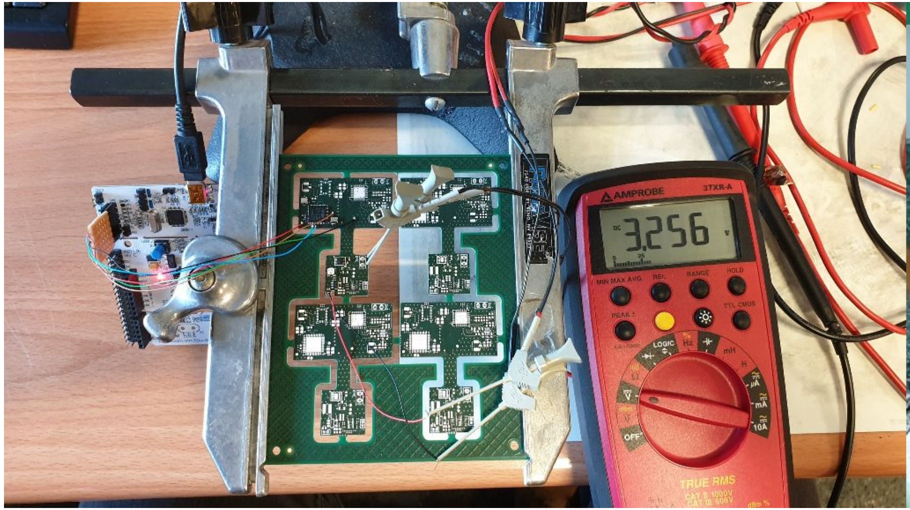
Finishing the prototype

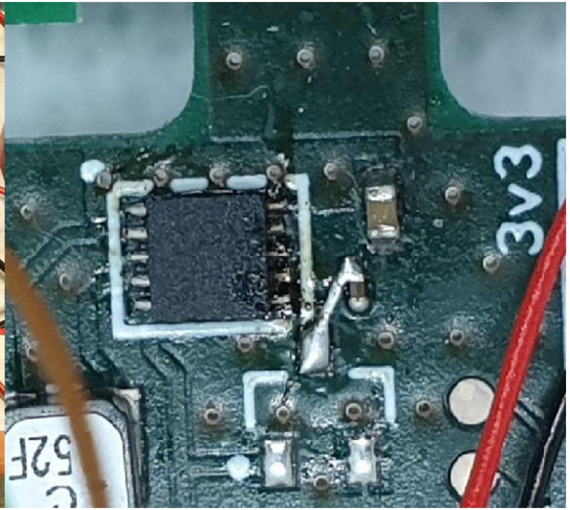
In order to validate the design, it is necessary to solder the components and carry out a test plan.

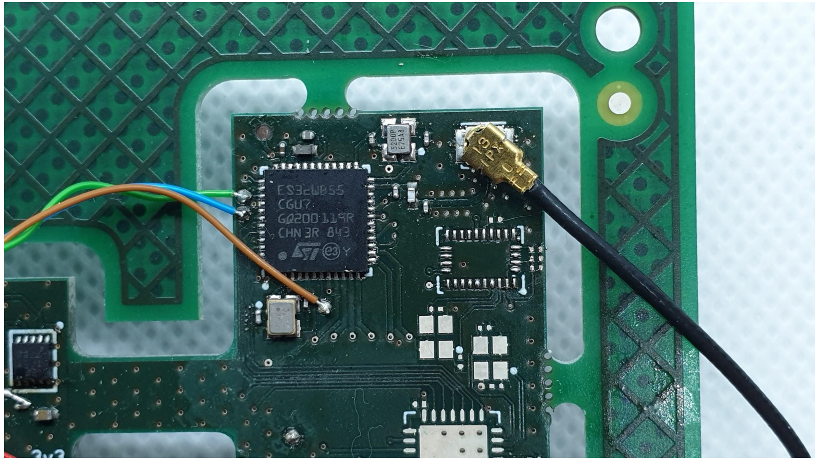
Task	Method
Soldering of the Buck/boost (with passive) and the battery charger.	Apply voltage in the range (2.7, 4.6v) at the battery connector. 3.3v regulated are expected
Soldering of the MCU (with passives).	Visual inspection to check for faulty connections/ tombstone (0201)
Program the MCU (soldering cables to SWD pads)	Download FW elementary code (hello world)
Load software into MCU to test BLE coms	Add 2.4GHz Antenna, download Stdemo code, check with APP
Soldering IMU sensor, and passives	Visual inspection to check for faulty connections/ tombstone (0201)
Test the MCU SW for the IMU	Read IME values changing the board orientation (gravity vector, motion angles, magnetic pole)
Test the MCU SW for the IMU cortexM0	Read trajectory (or quaternions or Euler angles) to veryfy the M0 compuation
Test the MCU SW for the IMU ranges	Configuraion capabilities & range scale
Soldering LoRa transceiver, and passives for the line transmission	Visual inspection to check for faulty connections/ tombstone (0201)
Test the software of the LoRa sending frames to our getway to test the correct functionality	Add 868MHz Antenna, download demo code, check with Lora server
Test the insole pressure sensors	Add insole sanple data, sent by bluetooth, check with the apps (and tailored weights)
Soldering Qi RX and passives for wireless charging	Visual inspection to check for faulty connections/ tombstone (0201)
Test the Qi wireless charging	Check the St component, antenna. Use the ST Qi kit

19

Finishing the prototype







Finishing the prototype: Results

Task	Method	Result	Comment	Action	Files
Soldering of the Buck/boost (with passive) and the battery charger.	Apply voltage in the range (2.7, 4.6v) at the battery connector. 3.3v regulated are expected	FAIL	Hall switch, wrong footprint, solder cable from enable to C5 to create a enable state in the regulator	Change at the PCB design	No
Soldering of the MCU (with passives).	Visual inspection to check for faulty connections/ tombstone (0201)	OK	None	None	No
Program the MCU (soldering cables to SWD pads)	Download FW elementary code (hello world)	OK	Complex programming with probes	Create a PCB with pogo pins to provide 3.3v and SWD	filename, app
Load software into MCU to test BLE coms	Add 2.4GHz Antenna, download Stdemo code, check with APP	Not Tested	pairing, STM32_2_APP (fixed sensor values), APP_2_STM32 (toggle output)		
Soldering IMU sensor, and passives	Visual inspection to check for faulty connections/ tombstone (0201)	Not Tested			
Test the MCU SW for the IMU	Read IME values changing the board orientation (gravity vector, motion angles, magnetic pole)	Not Tested	Acceleration, gyro, magnetic sensors		
Test the MCU SW for the IMU cortexM0	Read trajectory (or quaternions or Euler angles) to veryfy the M0 compuation	Not Tested	motion parameters		
Test the MCU SW for the IMU ranges	Configuraion capabilities & range scale	Not Tested	configuration capabilities		
Soldering LoRa transceiver, and passives for the line transmission	Visual inspection to check for faulty connections/ tombstone (0201)	Not Tested			
Test the software of the LoRa sending frames to our getway to test the correct functionality	Add 868MHz Antenna, download demo code, check with Lora server	Not Tested			
Test the insole pressure sensors	Add insole sanple data, sent by bluetooth, check with the apps (and tailored weights)	Not Tested			
Soldering Qi RX and passives for wireless charging	Visual inspection to check for faulty connections/ tombstone (0201)	Not Tested			
Test the Qi wireless charging	Check the St component, antenna. Use the ST Qi kit	Not Apply			

Conclusions

- The design of a PCB has been achieved and the testing phase with development boards has also been passed, so this part is a success. The test with the fully functional PCB is still in progress.
- Smaller is not Better. The smaller component should be 0402
- Search for alternative Qi Wireless Power Receiver
- Use the Qi market discontinuation to propose a further miniaturization and cost reduction of the Power Board.
- Some error identified in the PCB design must be corrected in the rigid-flex prototype.

Thank you!

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