Design of a system for ambulatory measurement of peripheral temperature

Author: Antoni López

Advisor: Juan José Ramos

Abstract

- The aim of this project is:
  - Variations in human peripheral temperature as affected by stress, sleep and/or physical activity.
  - Development of the measurement system.
  - Peripheral temperature of the subject to be studied and its relation with physical activity.
  - Measurement system with a temperature sensor and an accelerometer.
  - 2-3 subject study.

Index

Introduction

Statement of purpose

- Previous scientific studies about peripheral temperature
- Develop the measurement system
- Specific hardware

Requirements

- User-friendly
- Similar to Smartwatch
- 2-3 autonomy days with data storage
- Continuous recording of Temperature and physical activity

Specifications (I)

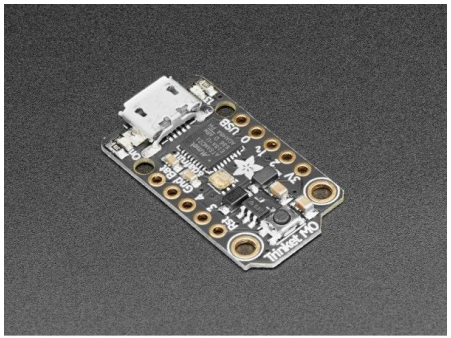
- Microcontroller
- RTC (Real Time Clock)
- EEPROM memory
- micro-USB connection
- USB charger
- LDO (Low Dropout Regulators)
- Temperature sensors (2)
- Accelerometer
- Battery
- Reset button
- In Circuit Programing interface
- Optional: three LEDS (Green, Blue and Red)

Specifications (II)

- Arduino IDE
- Short time execution
- Auto-sleep mode
- Test mode → Print Data
- Menu with sections:
  - STOP
  - START
  - SEND
  - RESET
  - READ

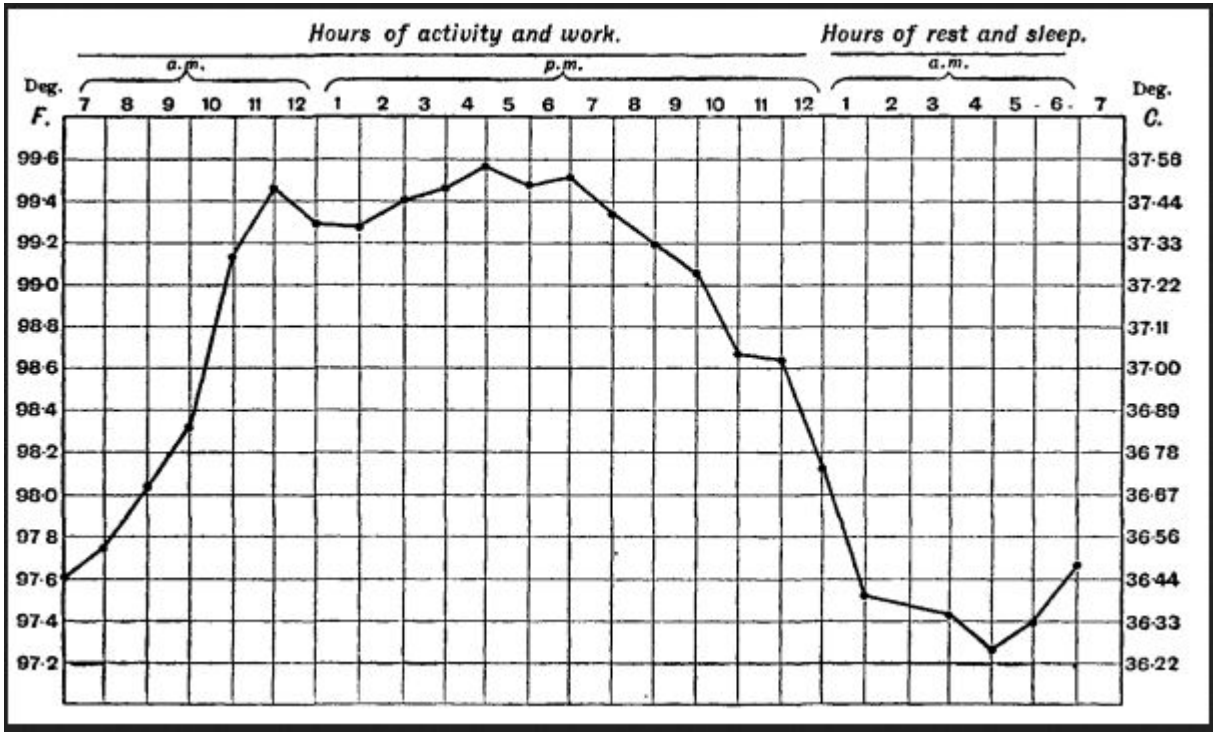
Methods and procedures

- Previous work in the lab
  - Adafruit Trinket M0
  - Own PCB
    - USB charger
    - LDO
    - EEPROM memory
    - Temperature sensors
- No physical activity measurement
- Union of the two parts
- Code and components changes



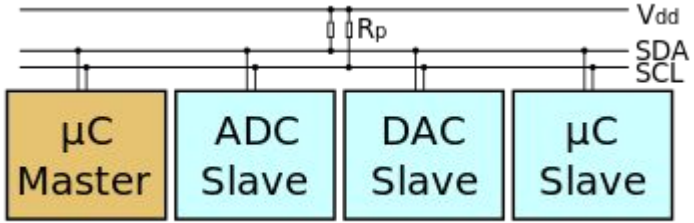
State of the art

Why peripheral temperature?



Specific components and I2C bus

- Components compatible with I2C bus
- ¿Why I2C bus?
- ¿How works I2C bus?

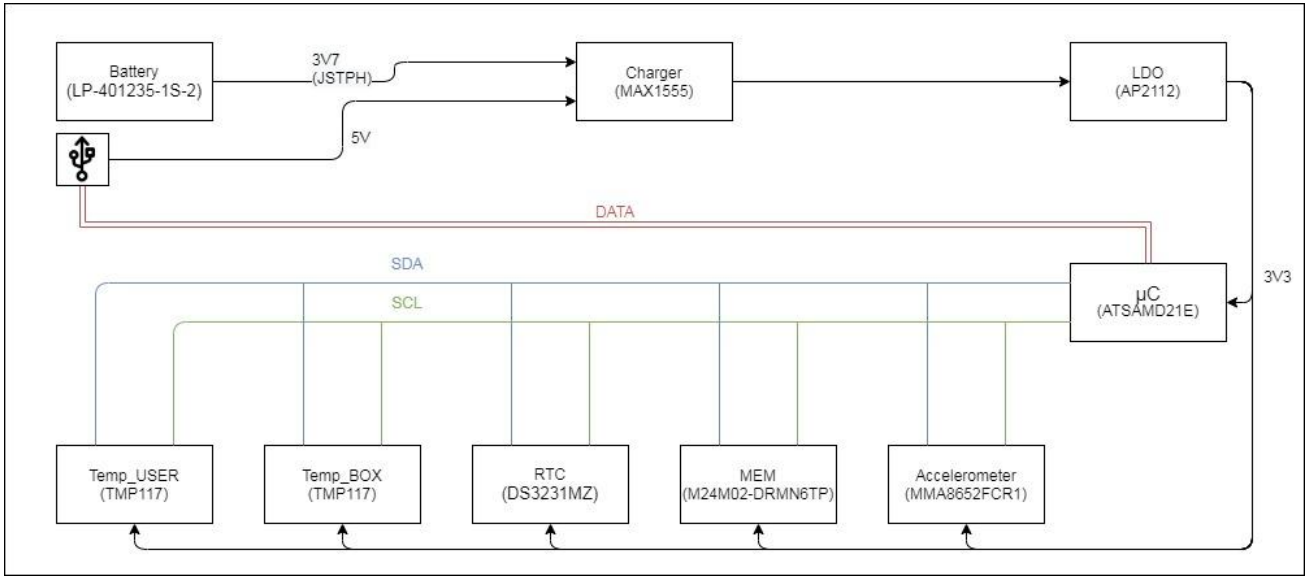


Software tools

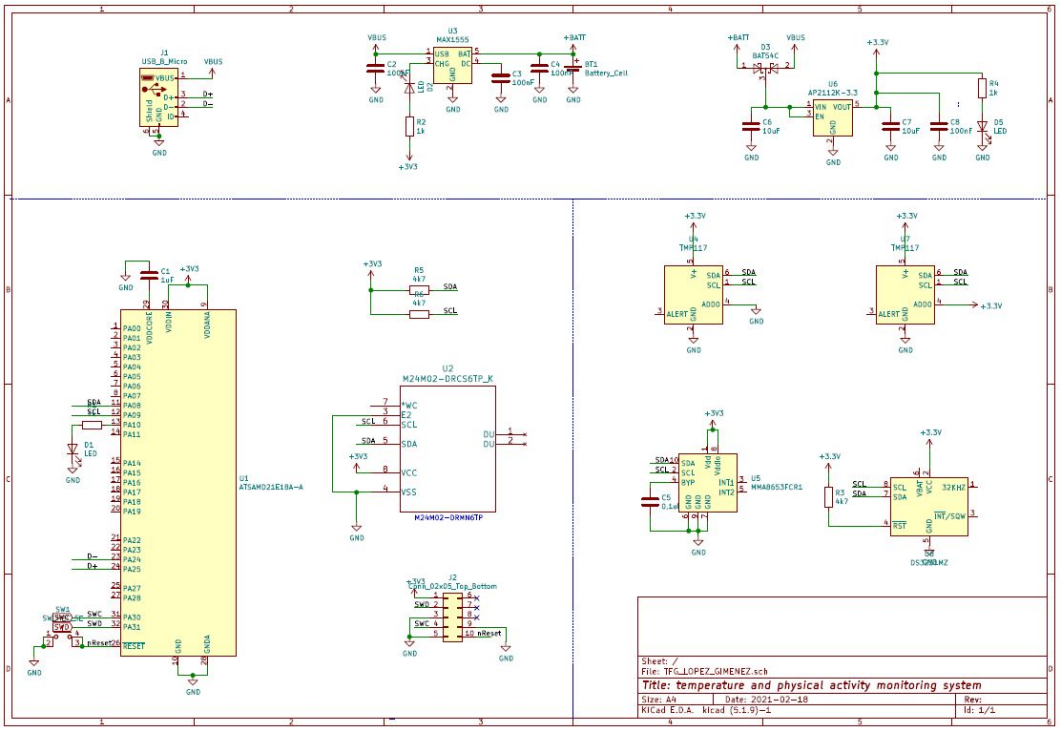
- KiCad EDA → PCB design
- Arduino IDE → Microcontroller programming
- Microchip Studio → Upload Arduino bootloader
- CoolTermWin → Terminal to store data
- Freedom Sensor Toolbox → Accelerometer Software
- Matlab → Convert Data
- Fusion 360 → Box design

Project Development

Hardware part (Block Diagram)



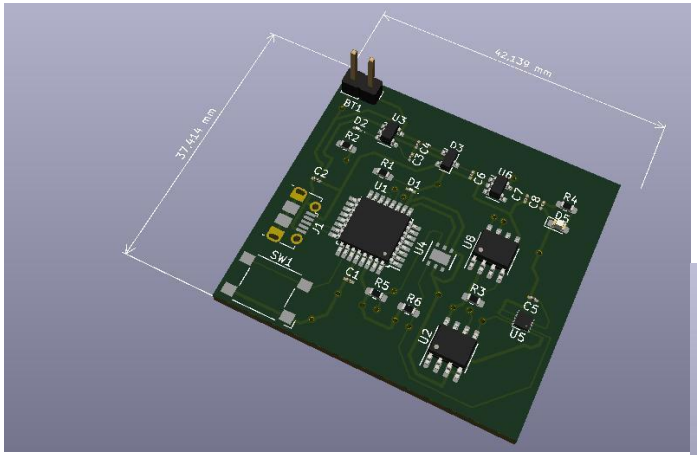
Hardware part (Schematic)

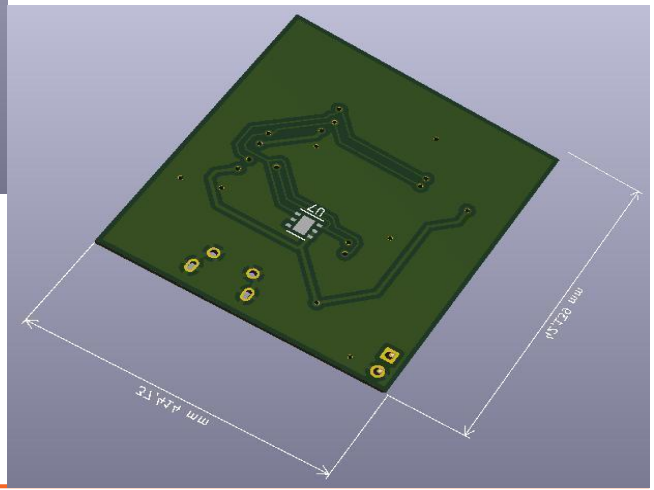


Hardware Part

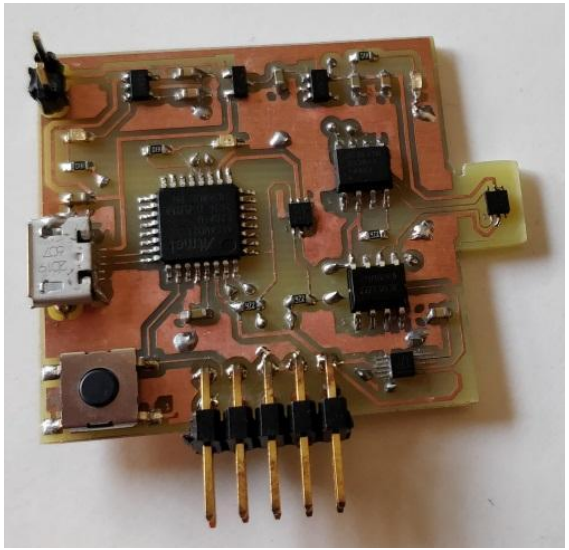
- Temperature:
  - Accuracy: ±0.2°C (–10°C to +85°C)
  - Resolution: 0.0078°C
  - Sensor type: Diode temperature sensor?
- Physical activity → accelerometer:
  - Type of sensor: capacitive micromachined accelerometer
  - How it works? Integrated embedded functions + 3 capacitance transducers
- Saving information → EEPROM memory

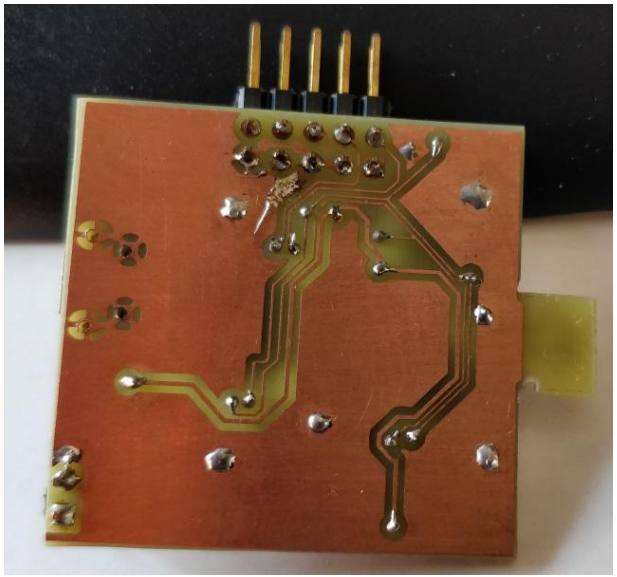
Hardware part (Prototype board)



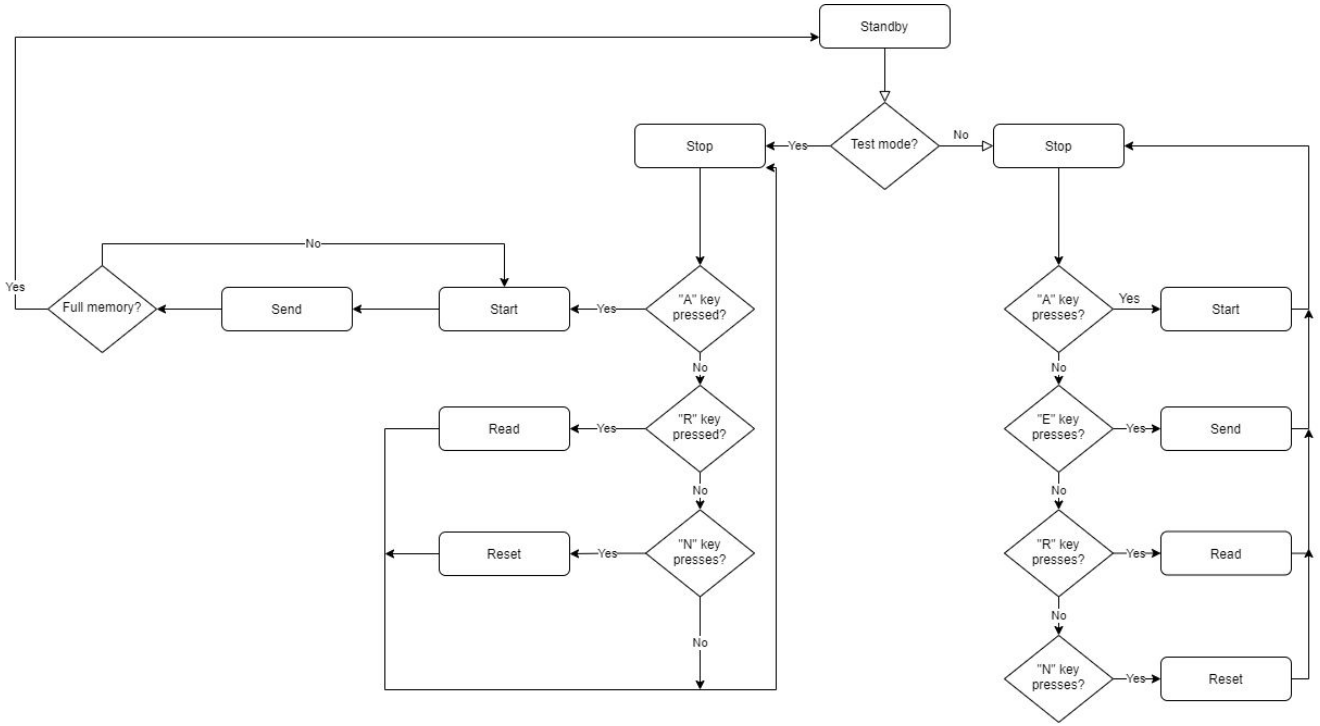


Hardware part (Final board)



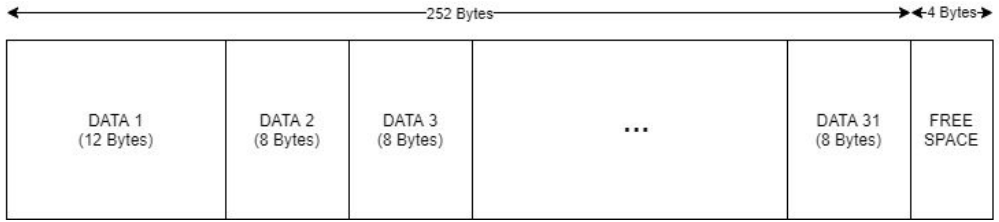


Software part

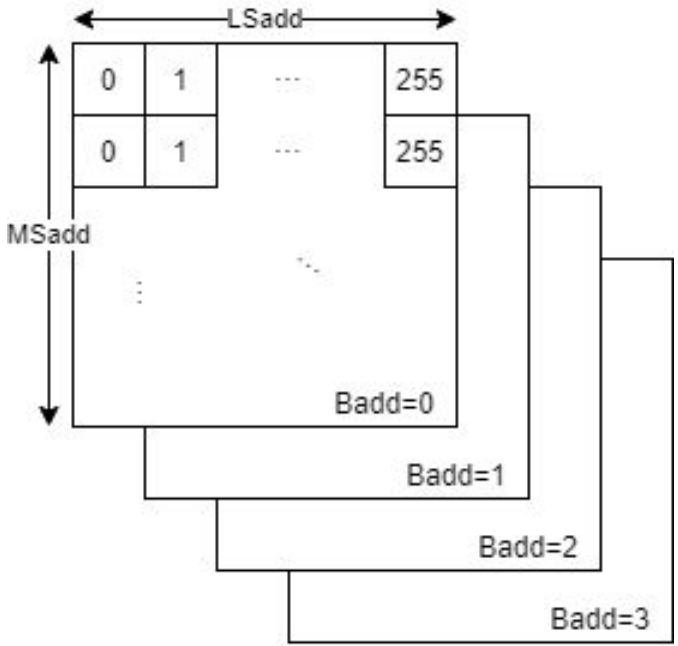


Software Part

- Struct Data:
  - [Byte] day
  - [Byte] month
  - [Int] year
  - [Byte] hour
  - [Byte] min
  - [Byte] sec
  - [Float] int_temp
  - [Float] pat_temp
  - [Bool] phy_act

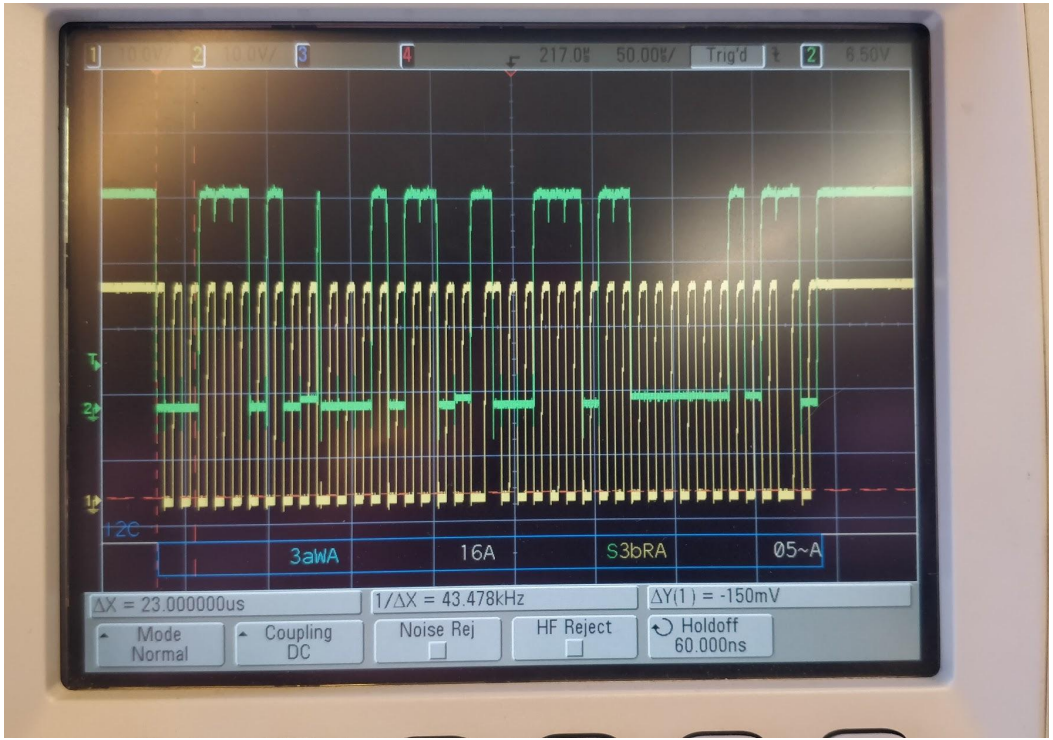


Software Part

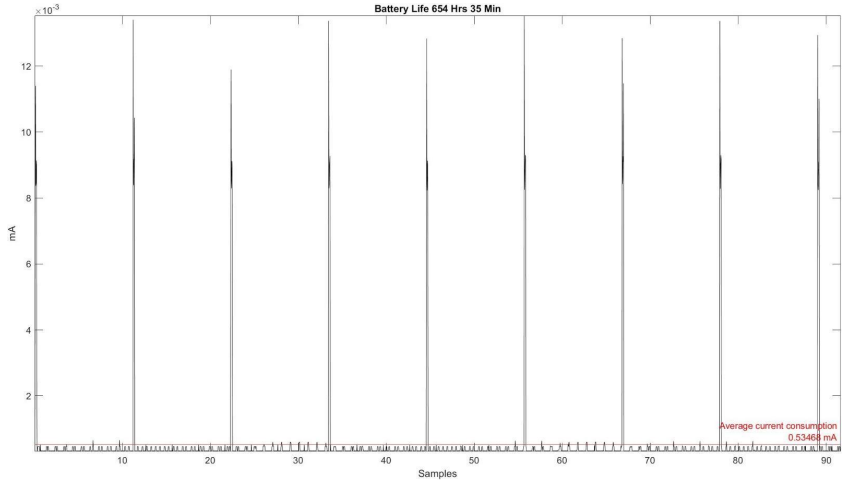


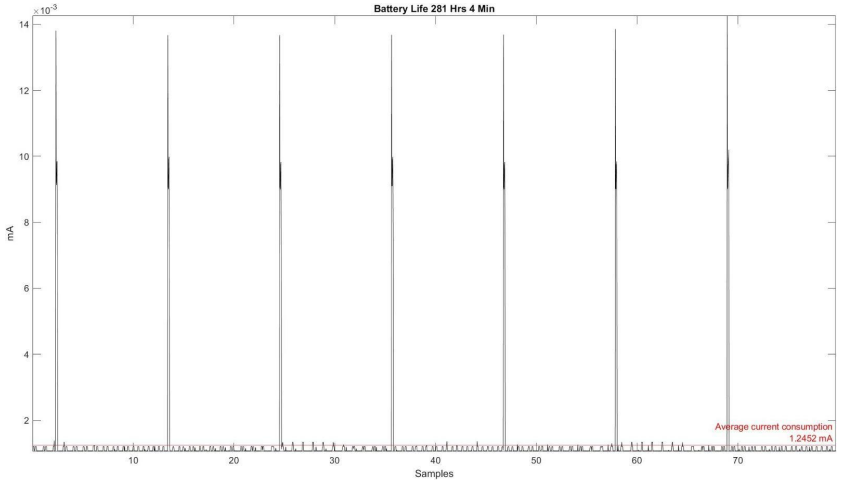
Results

Accelerometer communication



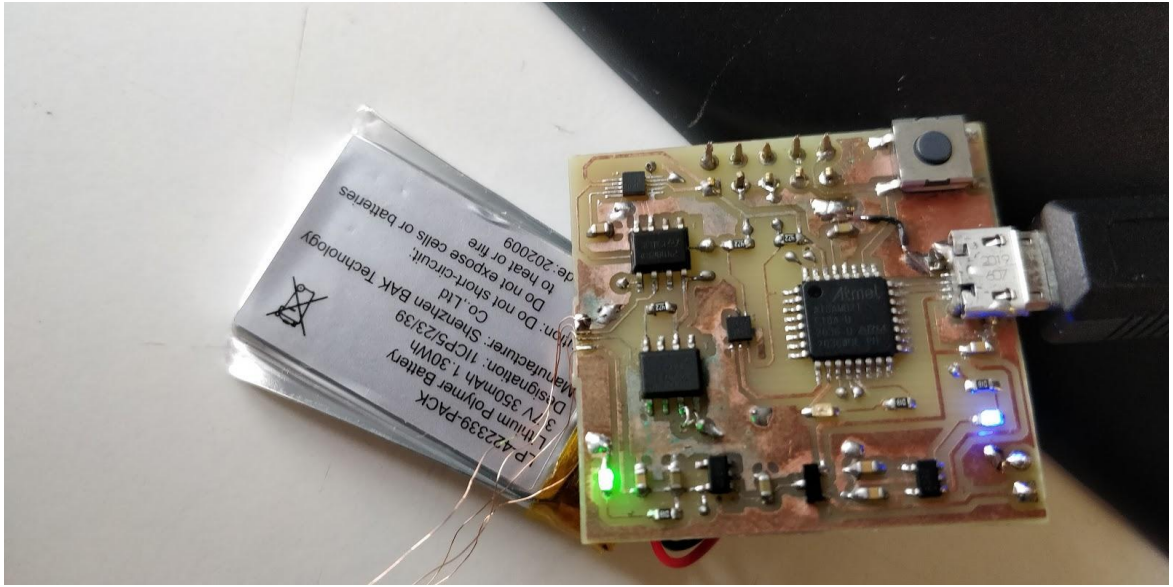
Consumption



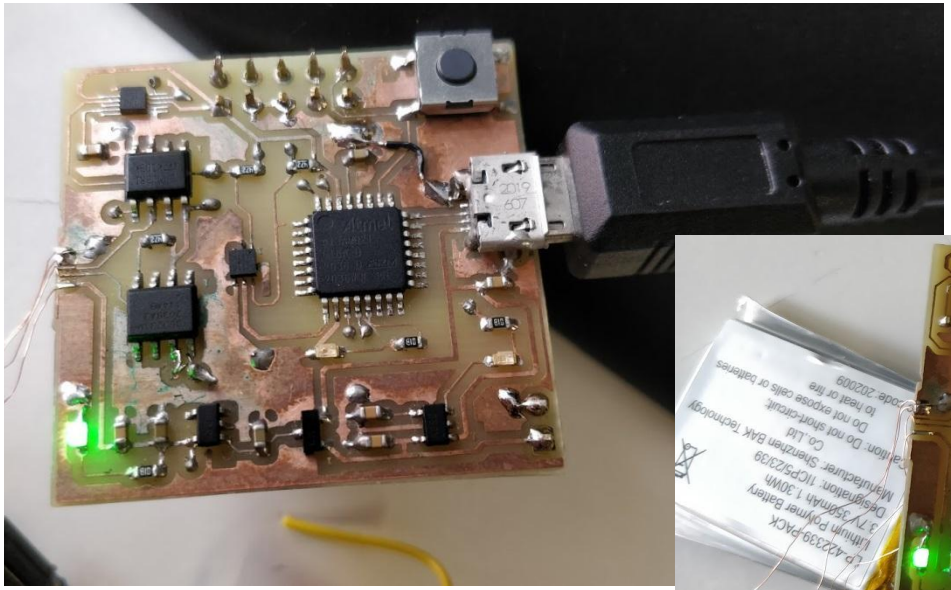


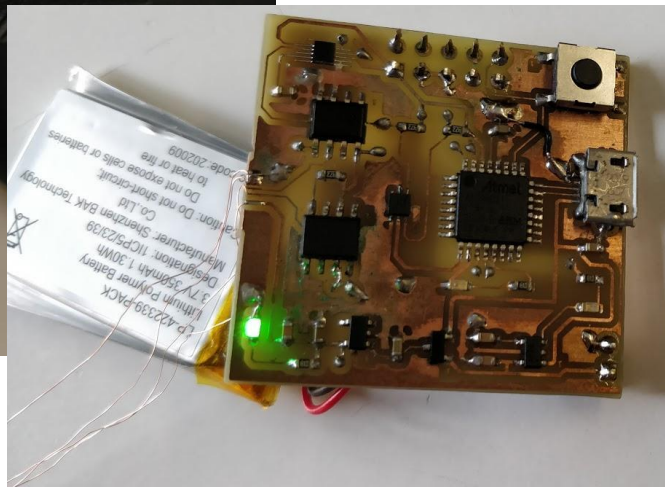
Conditions	Average current (mA)	Peak current (mA)	Battery life (Hours)
With LED	1.24	14	281 (12 days)
W/o LED	0.53	12	654 (28 days)

Charging mode



Acquisition mode

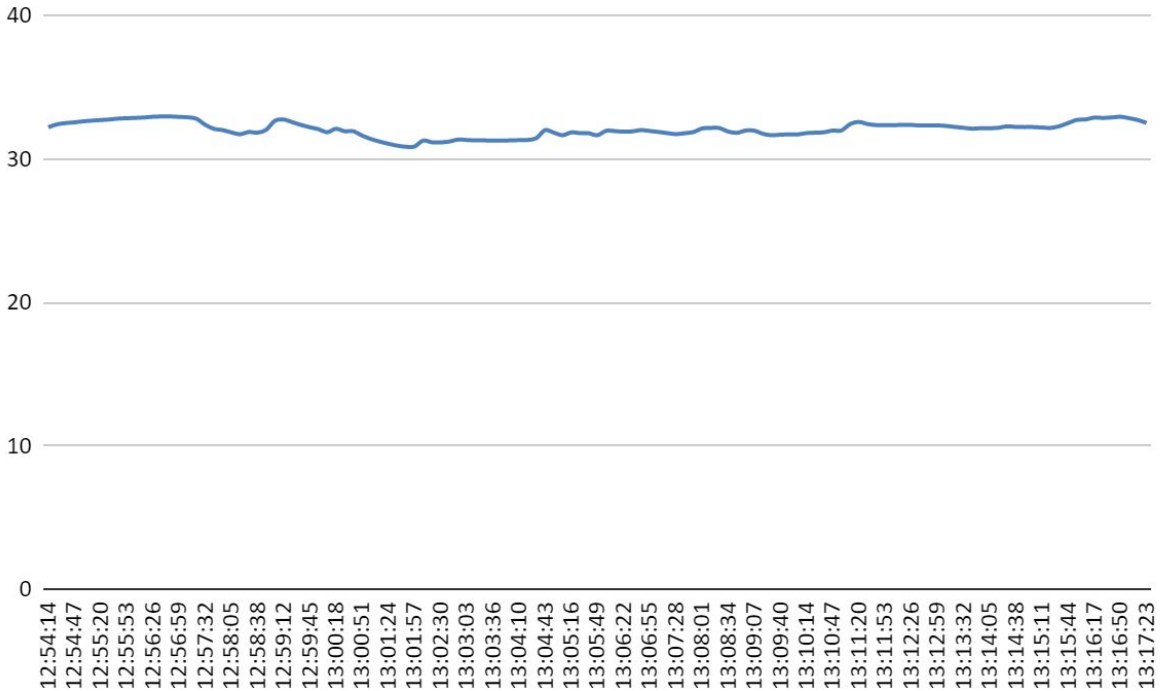




Acquisition mode (I)

	1 Date	2 Time	3 Pheripherical_temperature	4 Internal_temperature	5 Physical_Activity
1	"30/4/2021"	"17:43:52"	"0"	"28.79"	"NO"
2	"30/4/2021"	"17:43:55"	"0"	"28.76"	"NO"
3	"30/4/2021"	"17:43:58"	"0"	"28.67"	"NO"
4	"30/4/2021"	"17:44:01"	"0"	"28.58"	"NO"
5	"30/4/2021"	"17:44:04"	"0"	"28.5"	"NO"
6	"30/4/2021"	"17:44:07"	"0"	"28.42"	"NO"
7	"30/4/2021"	"17:44:10"	"0"	"28.36"	"NO"
8	"30/4/2021"	"17:44:13"	"0"	"28.3"	"NO"
9	"30/4/2021"	"17:44:16"	"0"	"28.26"	"NO"
10	"30/4/2021"	"17:44:19"	"0"	"28.21"	"NO"
11	"30/4/2021"	"17:44:22"	"0"	"28.18"	"NO"
12	"30/4/2021"	"17:44:25"	"0"	"28.14"	"NO"
13	"30/4/2021"	"17:44:28"	"0"	"28.11"	"NO"
14	"30/4/2021"	"17:44:31"	"0"	"28.09"	"NO"
15	"30/4/2021"	"17:44:34"	"0"	"28.06"	"NO"
16	"30/4/2021"	"17:44:37"	"0"	"28.04"	"NO"

Acquisition mode (II)



Budget

Components Budget

Component	Commercial Price (€)	Quantity	Subtotal(€)
ATSAMD21E18A-AU	3.3	2	6.6
AP2112K-3.3TRG1	0.655	2	1.31
DS3231MZ+	6.24	2	12.48
TMP116AIDRVR	4.1	3	12.3
M24M02-DRMN6TP	2.93	2	5.86
MMA8652FCR1	1.96	2	3.92
MAX1555EZK+T	1.61	2	3.22
B3FS-1000	0.18	2	0.36
MOLEX105017-0001	0.724	2	1.45
BAT54C,215	0.144	2	0.288
YOBLP422339PACK	19.96	2	39.92
		TOTAL	87.71

Personal Budget

Workers	Salary/Hour (€)	Total Hours	Cost (without taxes)
Junior Engineer	9	430	3870
Laboratory Technician	35	20	700
		TOTAL	5570

With that the total budget of the project is 4657,71€.

Conclusions

Project Conclusions

- Friendly and easily microcontroller IDE programming
- It needed extra time
- Delay in deadline
  - PCB desgin
  - SMD soldering
- Improvement in battery autonomy (12 days vs 2-3 theoretical days)
- Accelerometer soldering and programming problems

Own conclusions

- Too optimistic
- My injury didn’t helps me
- Lack of experience
- A lot of learning and experience

Incidents

- No time for scientific survey
- Find the correct box design
- Problems with Read and Write EEPROM memory
- Lack of experience in SMD components soldering
- Lack of guaranties with accelerometer soldering

Future Development

Improvements

- Components Packaging changes
- Exercise algorithm
- LEDs remove
- Box changes

Dedication

I want to dedicate this thesis to my mother because she helped and supported me every day during my bachelor’s degree and also for being mother and father at the same time. Without her advice and support, maybe I would not have finished my bachelor’s degree.

Thanks mum.

Thanks for listening!