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DATASHEET

Pencil drawn strain gauge sensor (with Bluetooth and OLED module)

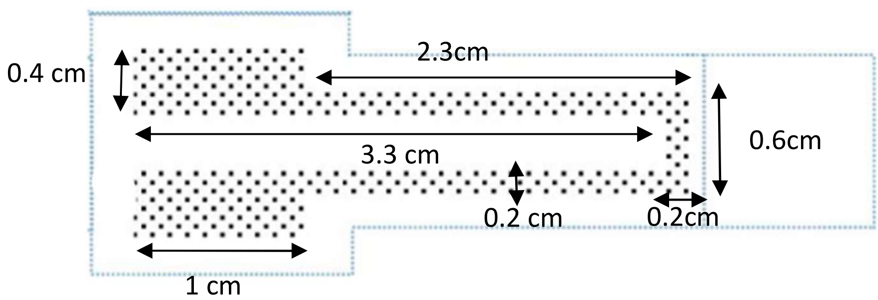
General features

- Easy-to-use
- Small size
- Low cost
- Ecological strain gauge
- Resistance sensor
- Application with resistance values sent thanks to bluetooth
- Rotary encoder included, menu on OLED screen

General description

Pencil drawn strain gauge is first described in Scientific Reports publication “Pencil Drawn Strain Gauges and Chemiresistors on Paper” written by Cheng-Wei Lin*, Zhibo Zhao*, Jaemyung Kim & Jiaxing Huang. This sensor aims at reproducing pencil drawn strain gauge in a 4th year Physical Engineering course of National Institute of Applied Sciences (INSA) Toulouse.
Pencil carbon deposited on the paper contains percolated graphite particles network where electrons move. Mechanism enabling electrons to move from grain to grain is tunnelling through potential barrier. However, tunnelling depends exponentially on the length of the barrier. When a mechanical stress is applied to the gauge, grains of percolated network spread away. Thus, when a tension is applied to gauge electrons move less. Resistance increases. When gauge is compressed, electrons move more and resistance decreases.

Strain gauge



The measured resistances are created from gauge drawings printed on paper thick enough to withstand the tensile and compression tests that will be performed. The area to be pencilled in is the dotted one. It has an area of 1.76 cm^2.The pencils tested will be HB and B. The hardness of the leads is classified as follows:

Hard Medium Light

With: **H** = Hard (or dry)

B = Bold (or oily)

HB = Hard Bold (or medium)

F = Fine point (middle of the scale)

Leads are made of clay and graphite. A soft lead, which is on the B side, contains more graphite and less clay than a hard lead, on the H side, which will contain less graphite and more clay.

As explained earlier, drawing on paper creates a thin layer of percolated graphite, which is a granular system. By compressing or pulling the pencil-covered paper, the graphite network is tightened or loosened, respectively. Thus, in compression, the electrons move more easily and the resistance decreases. On the contrary, in traction, the electrons have fewer possible paths to cross the graphite layer on the paper and the resistance increases.

Sensor specifications

Type	Strain gauge made from paper and graphite particles
Materials	• Paper gauge • Paper pencil : 2H and B
Sensor type	Strain gauge with PCB shield is passive because power supply is required
Measurand	Resistance
Measure	Voltage output
Resistance range	[11 MΩ ; 4000 MΩ]
Time response	1 resistance value sent every second

Test Bench

The test bench used is a 3D printed plastic test bench. It is composed of 7 successive half circles, with decreasing radius of curvature. Their respective diameters are as follows: 4.95, 4.45, 3.95, 3.45, 2.95, 2.45, 1.95 cm. Starting from the largest semicircle to the one with the smallest diameter, the paper is laid down by compressing or pulling it, and the resistance is waited for to stabilize before it is noted.

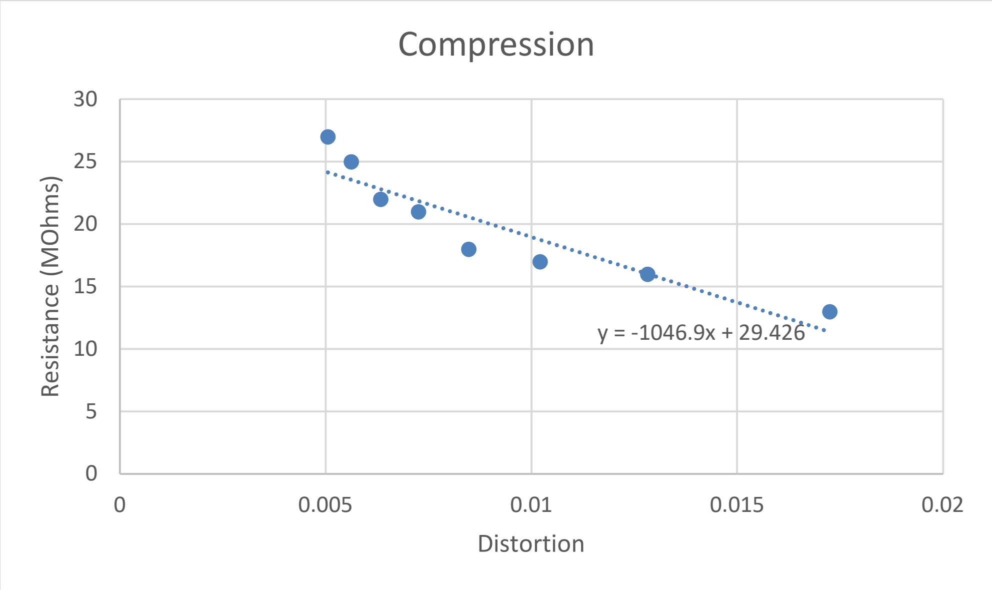
Electrical characteristics

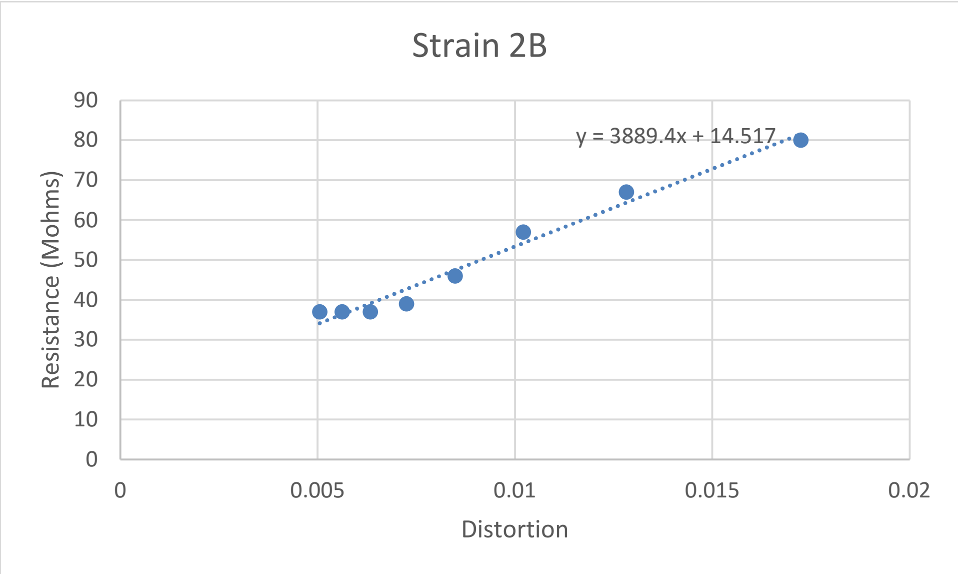
2B

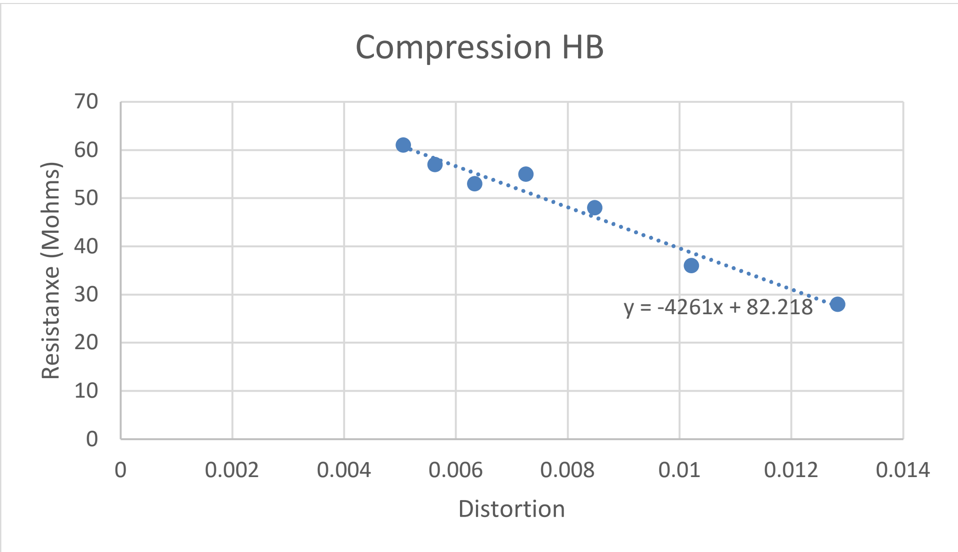
		Value		
	Unit	Typical (no distortion)	Min distortion	Max distortion
Flexion resistance	MΩ	21	37	80
Compression resistance	MΩ	30	27	13

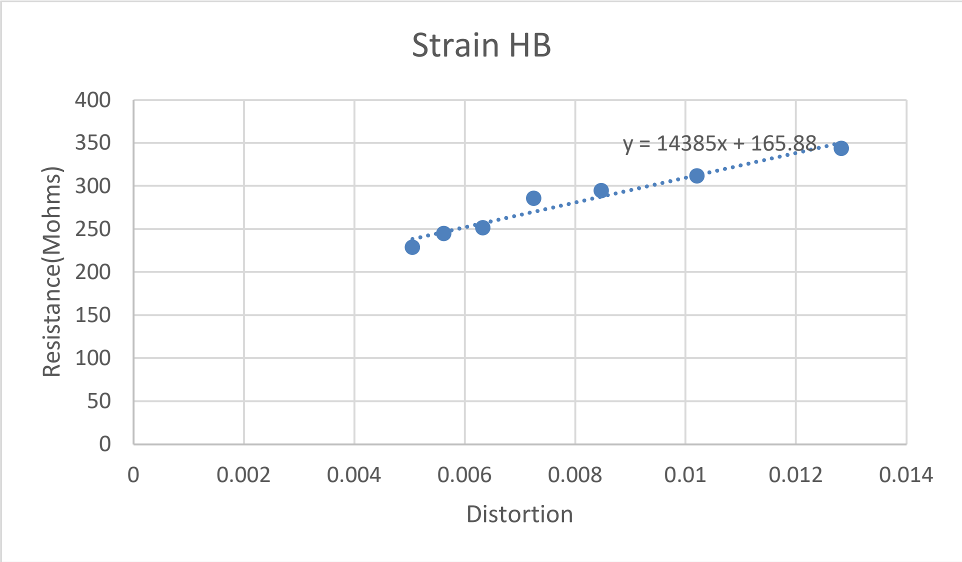
HB

		Value		
	Unit	Typical (no distortion)	Min distortion	Max distortion
Flexion resistance	MΩ	178	229	344
Compression resistance	MΩ	143	67	28


Compression
Resistance (MOhms)
30
25
20
15
10
5
0
0
0.005
0.01
0.015
0.02
Distortion
y = -1046.9x + 29.426


Strain 2B
Resistance (Mohms)
90
80
70
60
50
40
30
20
10
0
0
0.005
0.01
0.015
0.02
Distortion
y = 3889.4x + 14.517


Compression HB
Resistanxe (Mohms)
70
60
50
40
30
20
10
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Distortion
y = -4261x + 82.218

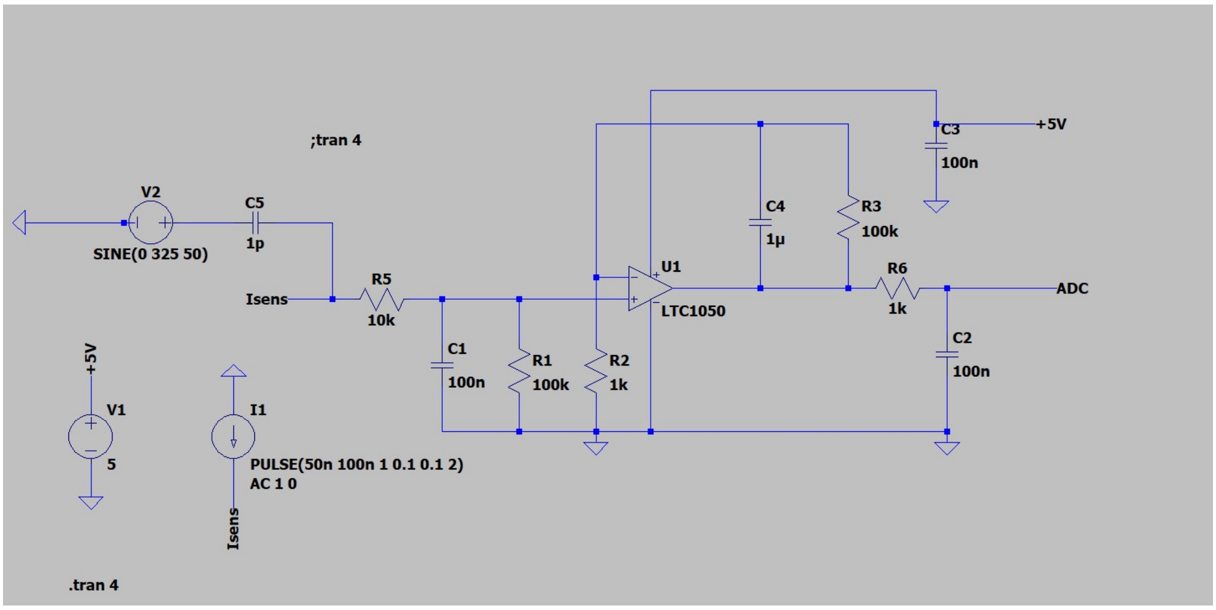


The affine trend line for these curves shows the typical resistance value (without deformation) as the intercept, i.e. epsilon =0.

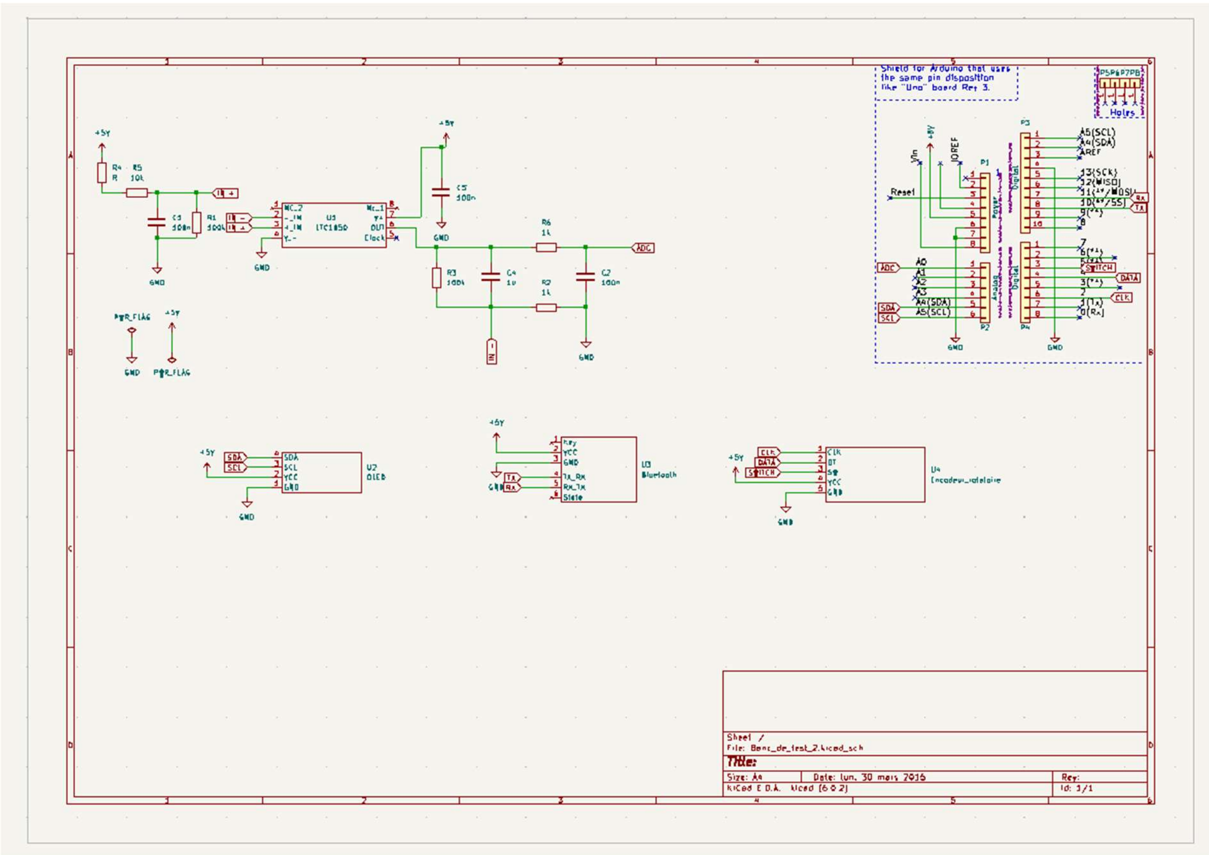
Electronic integration circuit

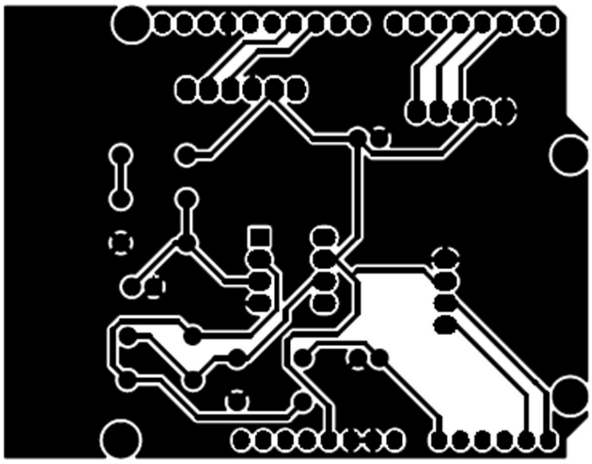
In order to effectively measure the resistance of this strain sensor, we have integrated it into an electrical circuit consisting of a transimpedance operational amplifier and several RC filters to filter out noise. Below is a schematic of the electrical circuit :

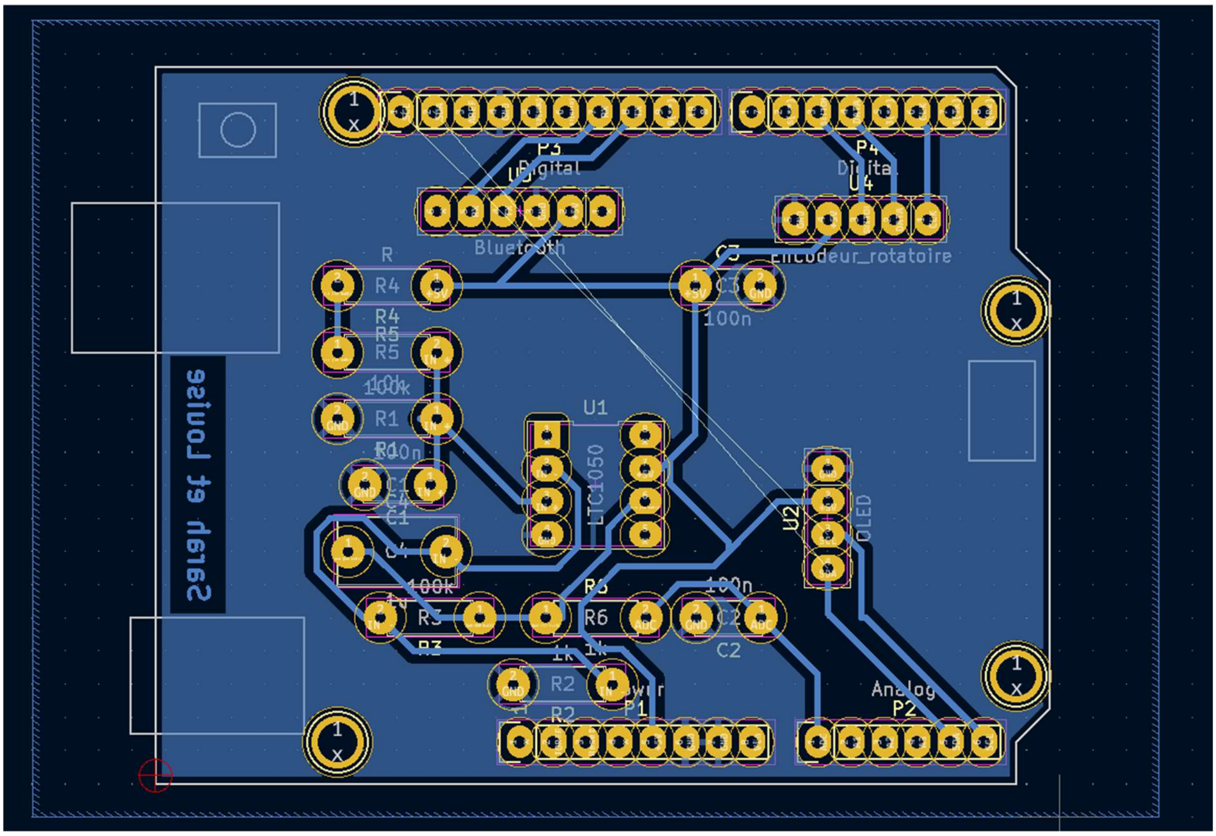
- 2 resistances 1 kΩ
- 2 resistances 100 kΩ
- 1 resistance 10 kΩ
- 3 capacitances 100 nF
- 1 capacitance 1 µFs
- 1 operational amplifier LTC1050

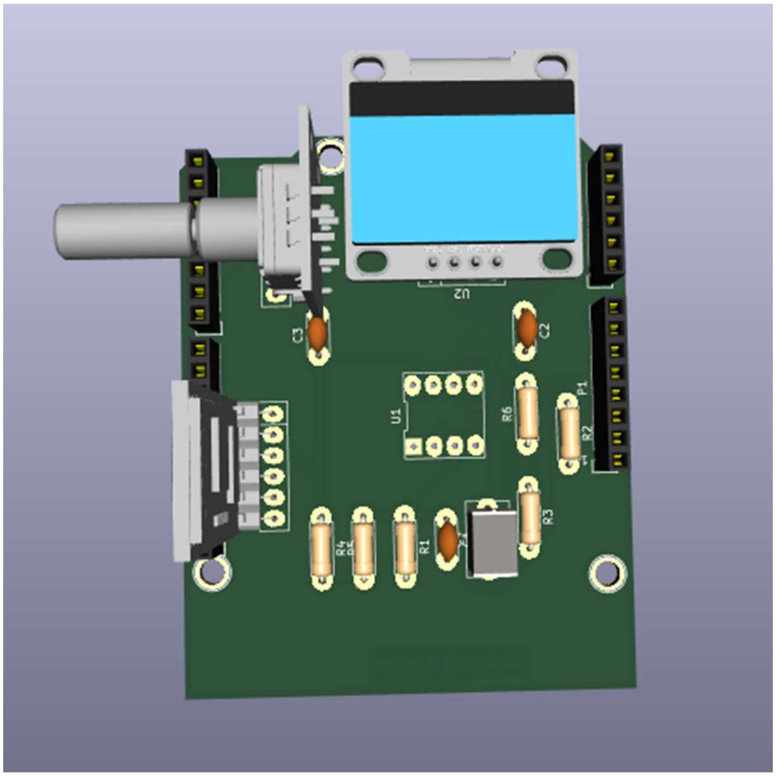


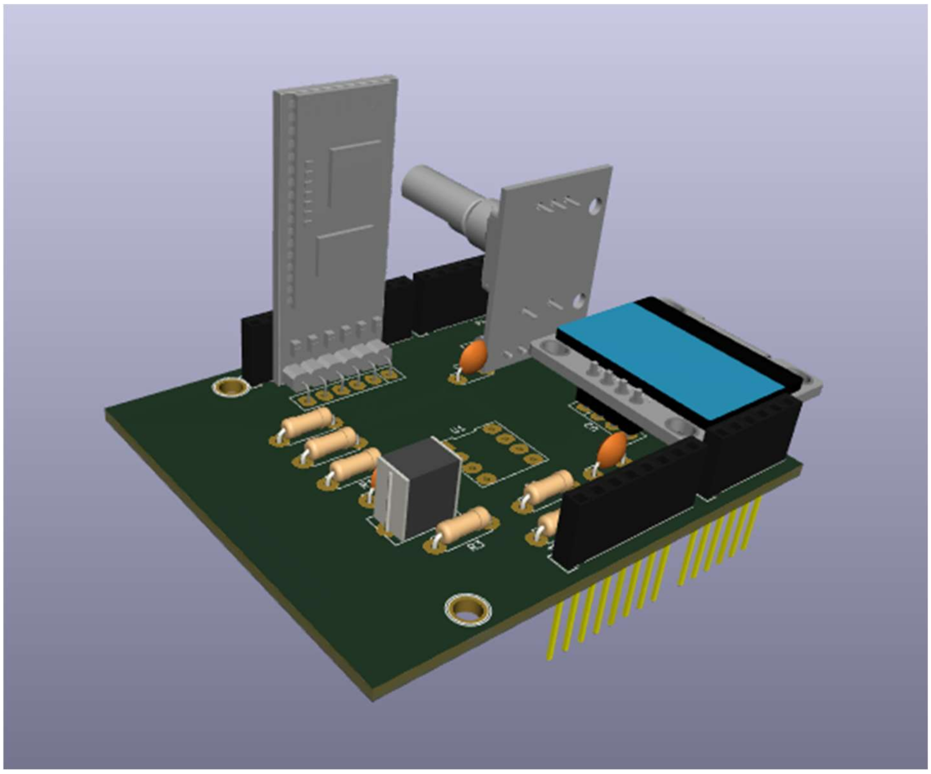
We then designed this electrical circuit as a shield PCB using KiCad 6.0 software, in order to make it more ergonomic. We incorporated an OLED screen and a rotary encoder which allow to create a menu on which the user can choose the data to display, as well as a bluetooth module which allows to send the data to a mobile phone. Below are the schematics of the shield PCB, as well as a 3D view of the components soldered on it:



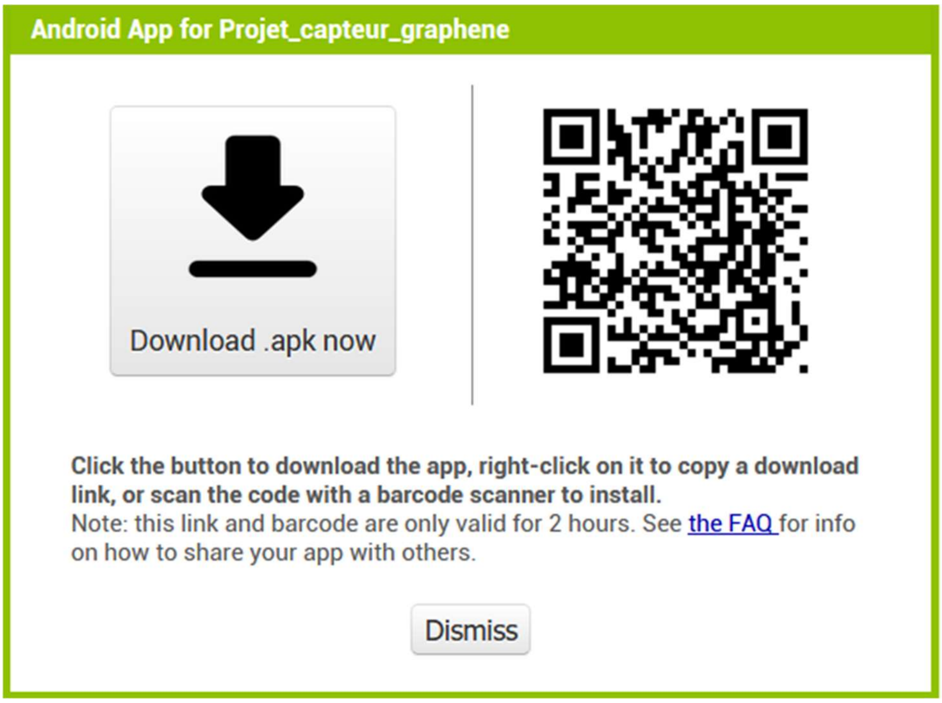



P3
Digital
Bluetooth
P4
Digital
U4
encodeur_rotatoire
C3
100n
R4
R5
100k
R1
U1
LTC1050
U2
OLED
R3
R6
1k
C2
R2
P1
Analog
P2





Finally, here is the flashcode to download the mobile application that receives the resistance values sent by the bluetooth module.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Dismiss