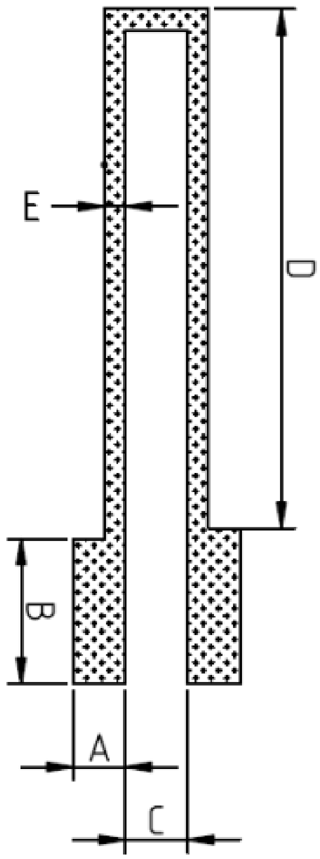
Course : Sensor

Teacher : J.Grisolia

Speciality : Applied physics

Graphite Strain Sensor



DE BARROS Alan

LEHEMBRE Lauriane

General features

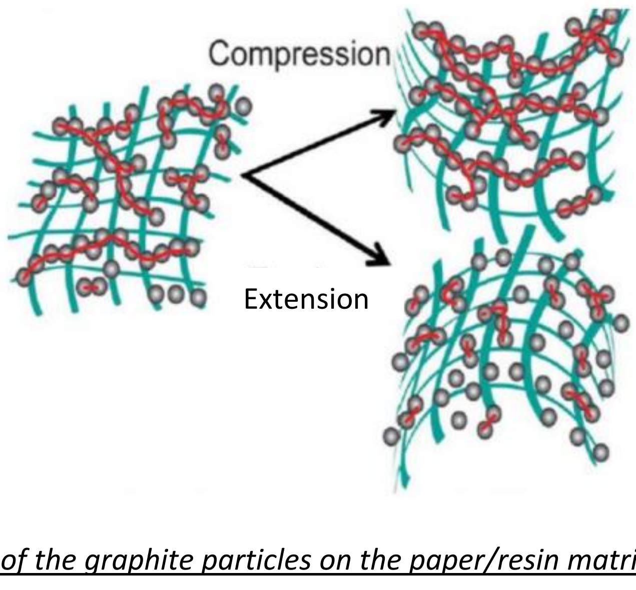
- Low-tech
- Low cost
- Open-source
- Transportable
- Easy to use
- Easy to fabricate
- Environment friendly
- Measures a deformation
- Use of graphite (HB)

General description

The sensor is a piece of paper on which graphite has been deposited (HB), its dimensions have been optimized for the analysis of resistance variations when it is subject to compression or tension, it can be used as a strain and/or deformation gauge.

The graphite particles will allow the current to pass, or not, according to their distance: the more the paper will be in compression, the closer the particles will be, and the current will be able to pass easier due to quantum tunnelling of electrons between particles (inversely for extension, the particles are further apart).

By measuring the resistance of the sensor, it is possible to determine the angle by which it is bent, expressed as a curve radius. To do this, we use an HB pencil - it can however be used with other types of pencils, but the sensitivity will be different, usually lessened.



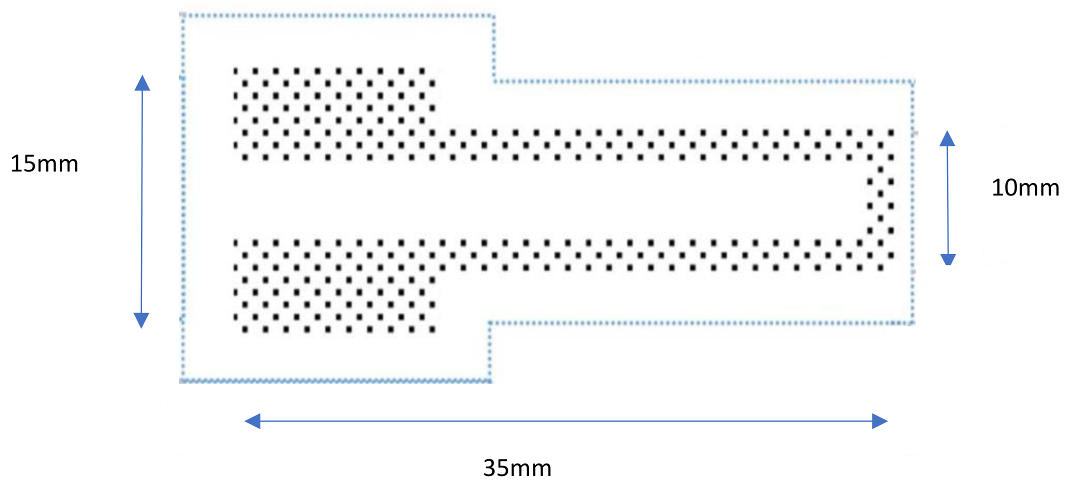
Representation of the graphite particles on the paper/resin matrix for different curvatures

In summary, a deformation of the sensor will induce a variation of the resistance (relative to the straight position resistance). We can therefore measure this resistive variation to determine the deformation undergone by the sensor.

Specifications

Type	Graphite strain sensor
Materials	Paper (thickness: 0.16mm) Graphite (carbon)
Type of sensor	Passive
Usable types of graphite	3H, 2H, H, HB, B, 2B, 3B
Measurand	Resistance
Power supply	Vin = 4,31V
Response time	Few hundred milliseconds to be stable

Dimensions



Electrical characteristics (For a diameter of 3,5cm)

	Compression				Extension			
	Min	Type	Max	Unit	Min	Type	Max	Unit
Sensor voltage	0	-	5	V	0	-	5	V
2B pencil resistance	40,1	42	43,4	MΩ	89,8	91	92	MΩ

Sensor calibration

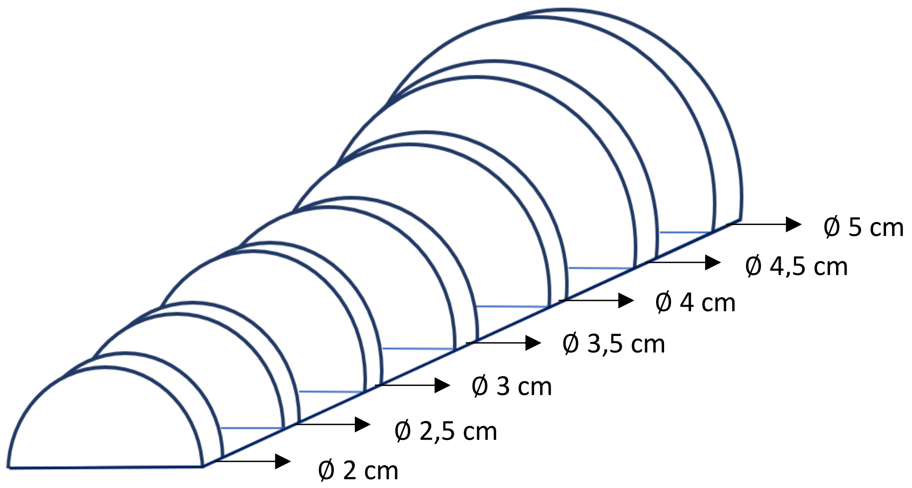
Deformation characterization

To calculate the relative variation of resistance with respect to the deformation of the sensor and thus characterize it, we use the following formula:

$$\boldsymbol{\varepsilon = \frac{e}{2R}}$$

With **e** the thickness of the paper sheet, **ε** the deformation, and **R** the radius of curvature. (e = 0,16mm)

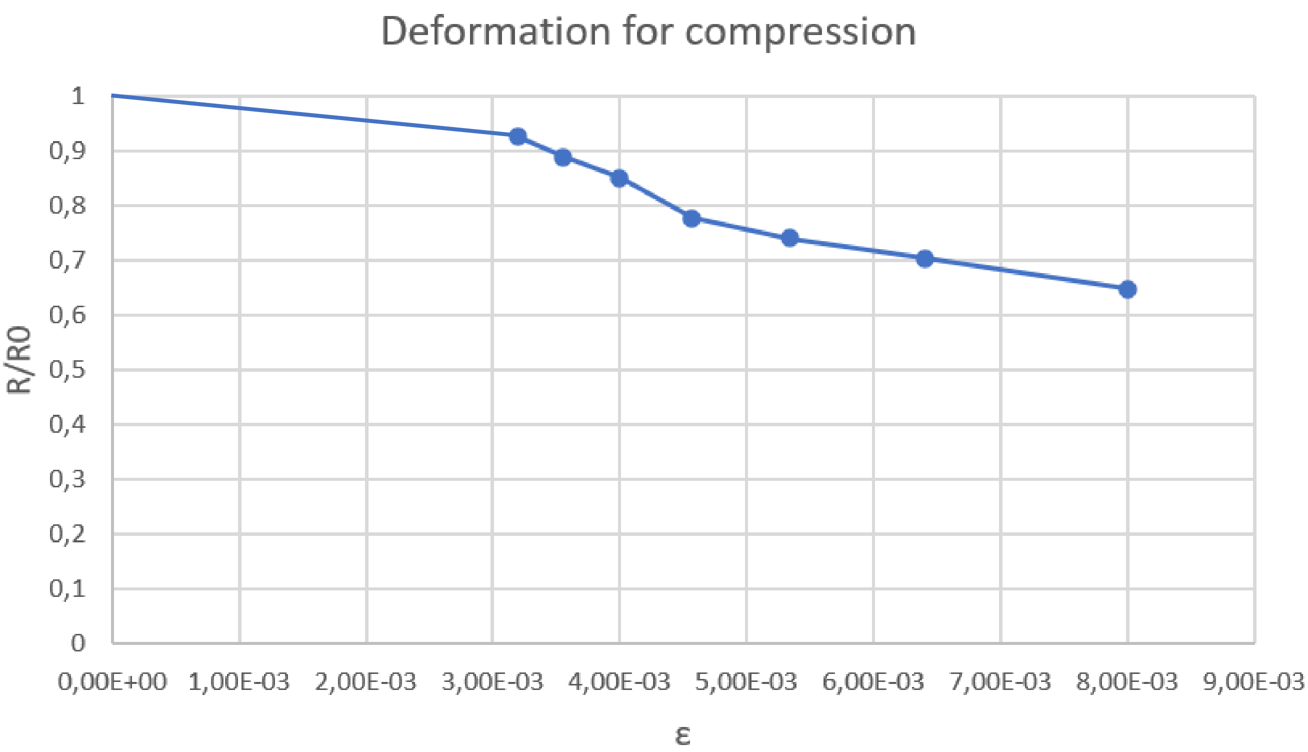
To calculate the deformation induced by the curvature of our test bench, we used different radii and reported the resulting changes of resistance value:



R/R_0 is calculated for a R_0 = 54 MΩ.

- Tension:

- Compression:



Sensor sensitivity:

On the linear part of the resistance curves we obtain a sensitivity of:

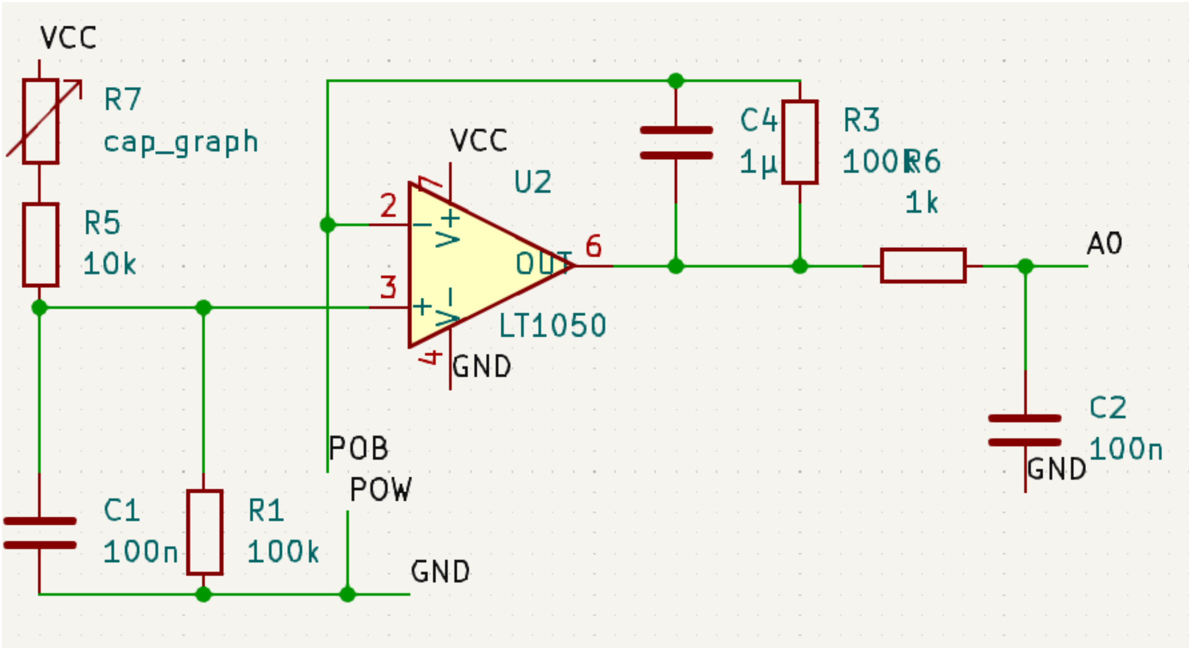
- Approximately <u>0.675 GΩ/%</u> during compression (% is percentage of relative length change = ε/100)
- Approx. <u>0.2 GΩ/%</u> during extension

Keep in mind the relative length change is very low during normal use of the sensor, the corresponding radius can be calculated using the equation. $\varepsilon = \frac{e}{2R}$

These values are for comparative use only to get orders of magnitude, they are very unstable until the sensor is stabilized in a specialized housing.

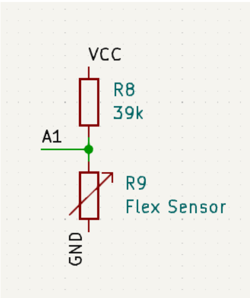
Circuit specifications on KiCAD 7.0

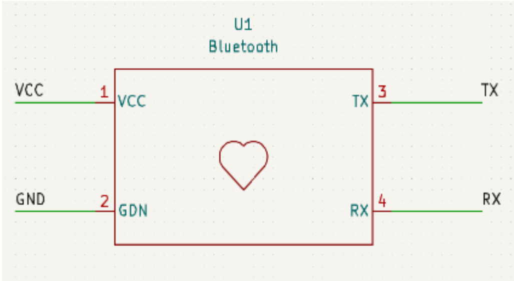
<u>Schematic of the signal amplification circuit:</u>

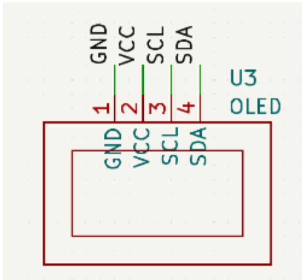


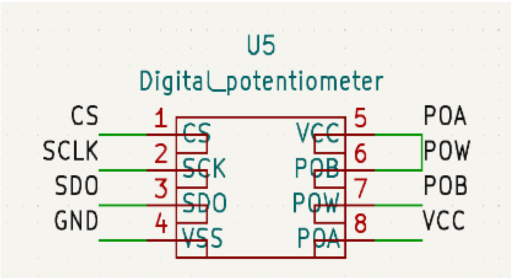
The R2 resistance is between the POB and POW pins and allows the calibration of the amplifier with the use of an MCP41050 SPI Digital Potentiometer.

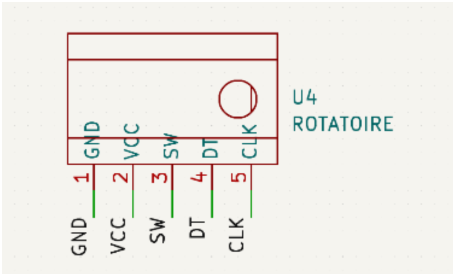
Additional modules and their connexions:



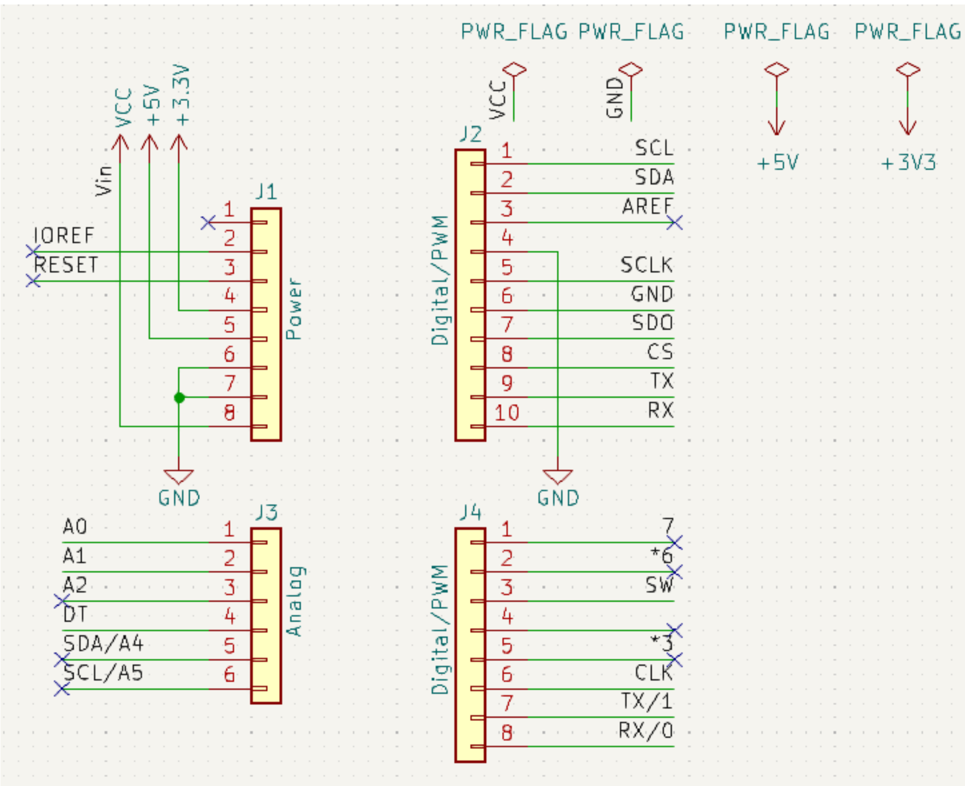








Pin setup for Arduino connection



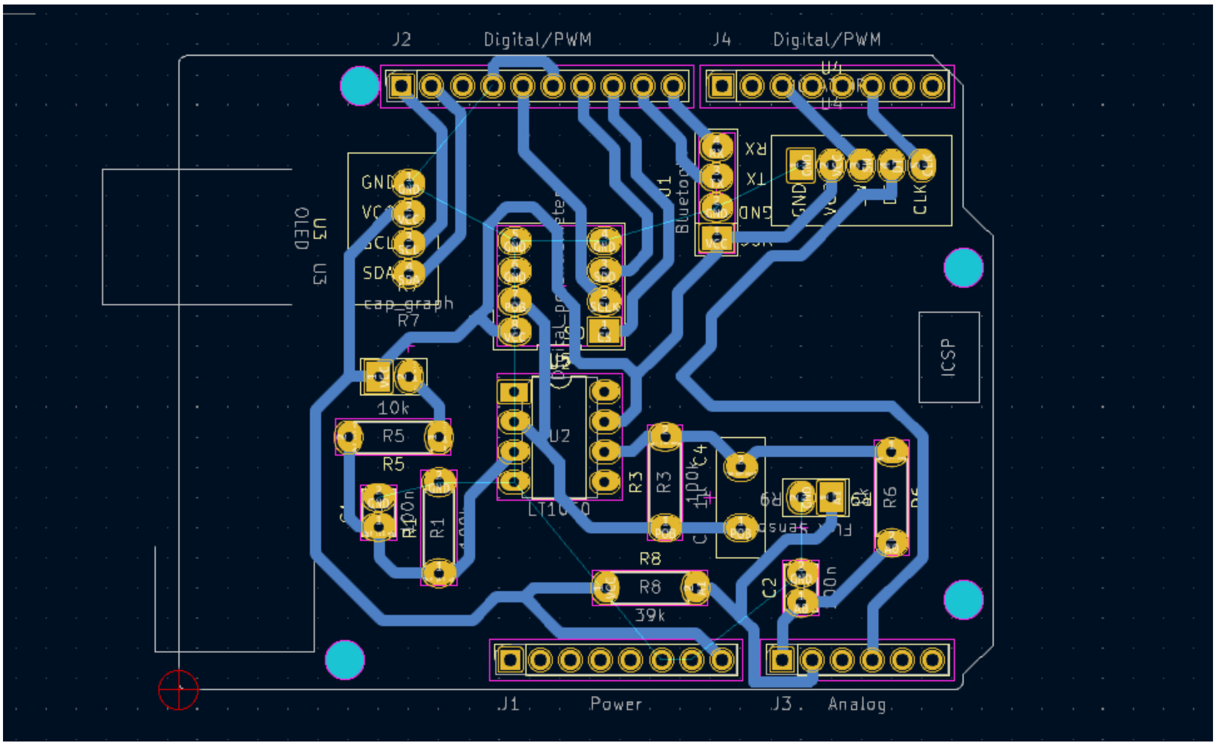
<u>Components needed:</u>

- Arduino Uno
- Bluetooth module HC05
- LTC1050 Amplifier
- I2C OLED screen Joy-it SBC-OLED01
- Rotatory encoder with push button (Joy-it KY-040)
- Spectrasymbol 005 21 Flex Sensor
- MCP41050 SPI Digital potentiometer

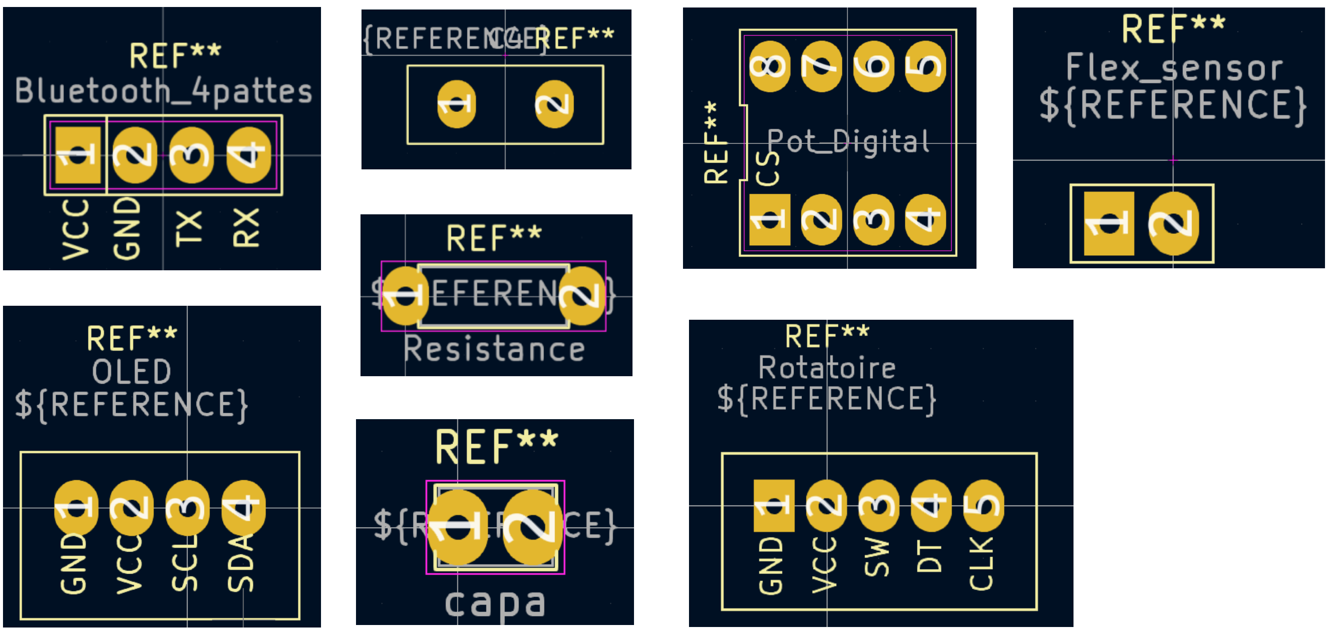
To filter noise, the sensor is connected via a low-pass filter tuned appropriately.

To amplify the signal, it is also connected to a trans-impedance amplifier.

KiCAD PCB:



Footprints of the components (2.54mm grid):



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1    C1 -                 100n : Empreinte_Capteur:capa
2    C2 -                 100n : Empreinte_Capteur:capa
3    C4 -                   1µ : Empreinte_Capteur:C4
4    J1 -                Power : Connector_PinSocket_2.54mm:PinSocket_1x08_P2.54mm_Vertical
5    J2 -          Digital/PWM : Connector_PinSocket_2.54mm:PinSocket_1x10_P2.54mm_Vertical
6    J3 -               Analog : Connector_PinSocket_2.54mm:PinSocket_1x06_P2.54mm_Vertical
7    J4 -          Digital/PWM : Connector_PinSocket_2.54mm:PinSocket_1x08_P2.54mm_Vertical
8    R1 -                 100k : Empreinte_Capteur:Resistance
9    R3 -                 100k : Empreinte_Capteur:Resistance
10   R5 -                  10k : Empreinte_Capteur:Resistance
11   R6 -                   1k : Empreinte_Capteur:Resistance
12   R7 -            cap_graph : Empreinte_Capteur:Flex_sensor
13   R8 -                  39k : Empreinte_Capteur:Resistance
14   R9 -          Flex Sensor : Empreinte_Capteur:Flex_sensor
15   U1 -            Bluetooth : Empreinte_Capteur:Bluetooth_4pattes
16   U2 -               LT1050 : Package_DIP:DIP-8_W7.62mm_LongPads
17   U3 -                 OLED : Empreinte_Capteur:OLED
18   U4 -            ROTATOIRE : Empreinte_Capteur:Rotatoire
19   U5 - Digital_potentiometer : Empreinte_Capteur:Pot_Digital
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In this table, you can retrieve the components we used and the library in which you can find their respective footprints. Certain components were custom-made for the purposes of this sensor, others come from native KiCad 7.0 libraries. You can find the files in our GitHub repository.