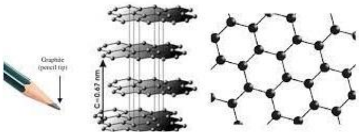


Low-cost graphite strain sensor coupled to an electronic circuit

General features

- Low power consumption
- Easy-to-use
- Simple-structured
- Small size and ultra-light
- Low Cost
- Bluetooth connexion
- OLED screen display
- Short response time

Description

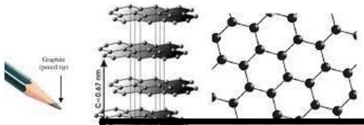
This sensor for monitoring strain constraints developed at the INSA Toulouse is based on graphite nanoparticles.
The sensor consists in a strain gauge designed on a piece of paper with a graphite pencil (graphite particles stick to the paper). Those particles create a conductive film where a current, based on the tunnel effect and proportional to the distance between particles, will flow.
So, any expansion or contraction of the distance between the particles leads to a difference of the resulting current.
The resistance is measured and displayed thanks to:

- a transimpedance circuit including an operational amplifier
- a HC-05 Bluetooth interface which allows to connect a phone to the device
- an OLED which displays the menus and the values measured
- an encoder which allows to choose the good configuration for each try

This resistance, which leads to the deformation, is different according to the pencil used because each pencil does not leave the same amount of particles on the paper: the higher the carbon content of a pencil, the darker the traces.

Specifications

Type	Deformation based sensor
Sensing principal	Tunnelling current between graphite particles
Materials	Graphite, paper
Sensor type	Passive (power supply required)



Power supply	5V
Measurand	Voltage
Deflection measure	Resistance
Response time	< 10 ms
Working time	1 sensor for each try ~ 10 minutes
Working temperature	15°C – 25°C

Electrical characteristics

Electrical characteristics of 2B Sensor:

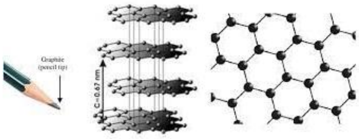
	Min	Typical	Max
Sensor resistance (MOhms)	2,00	/	4,00
Sensor voltage (V)	0	/	5
Gauge factor	3	/	7

Electrical characteristics of B Sensor:

	Min	Typical	Max
Sensor resistance (MOhms)	2,90	/	6,40
Sensor voltage (V)	0	/	5
Gauge factor	6	/	12

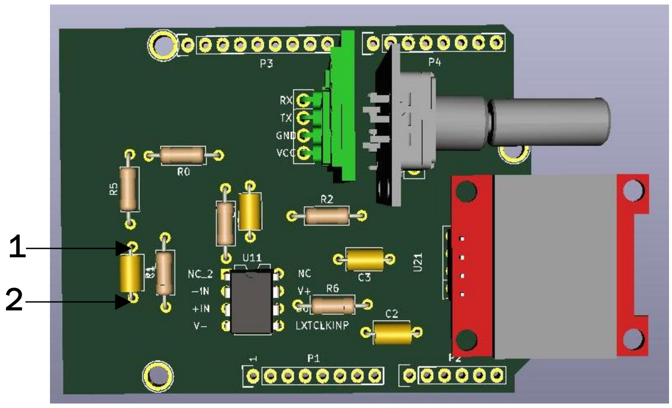
Electrical characteristics of HB Sensor:

	Min	Typical	Max
Sensor resistance (MOhms)	2,50	/	5,50
Sensor voltage (V)	0	/	5
Gauge factor	13	/	28



Pin description

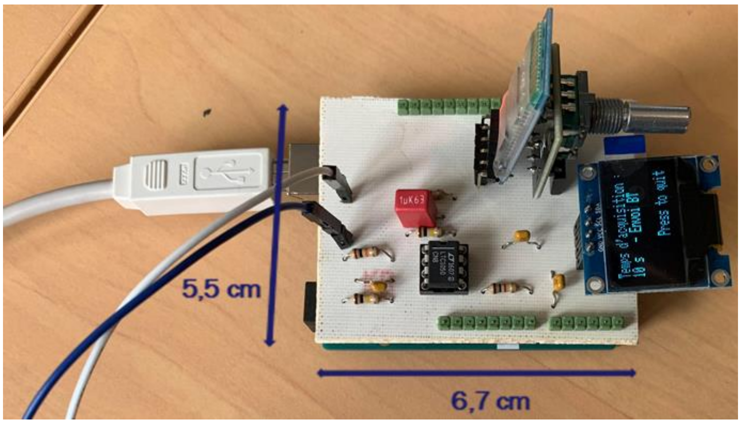
The connexion specifications of the components are listed below:



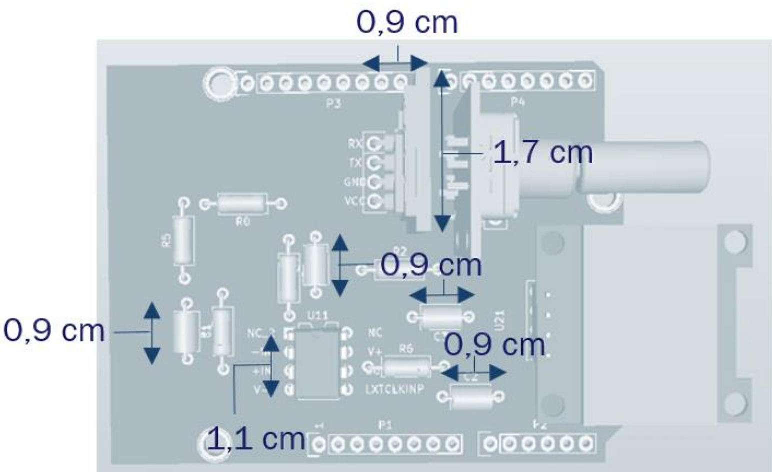
Top view of the shield represented in 3D

DEVICE	DEVICE PIN	ARDUINO PIN
Strain sensor	1	A0
	2	5V
HC-05 Bluetooth	VCC	Vin
	GND	GND
	TX	10
	RX	11
KY-040	V+	Vin
	GND	GND
	SW	2
	DT	4
	CLK	3
OLED	VCC	Vin
	GND	GND
	SCL	A5
	SDA	A4

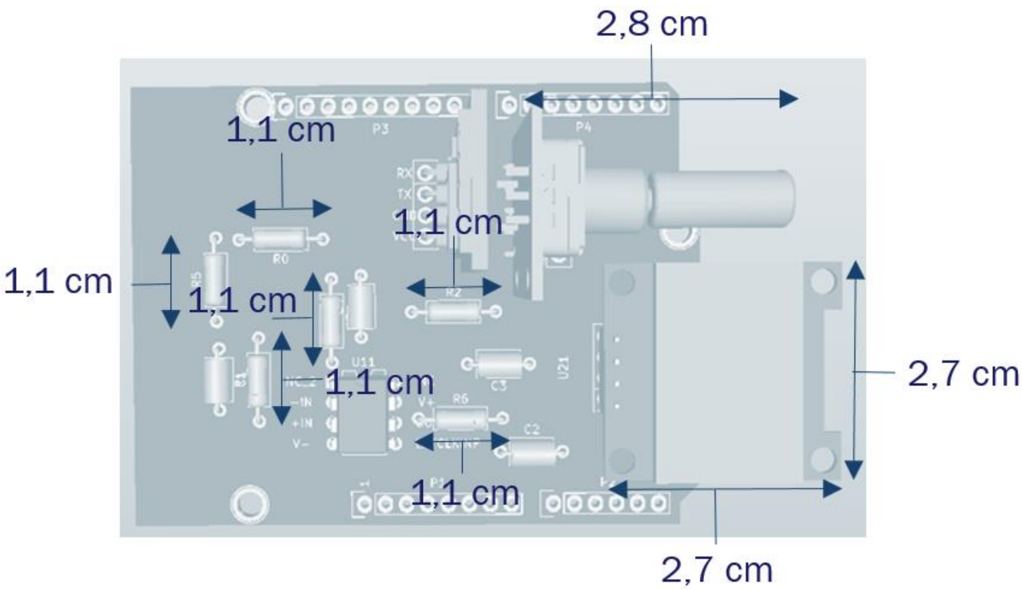
Dimensions



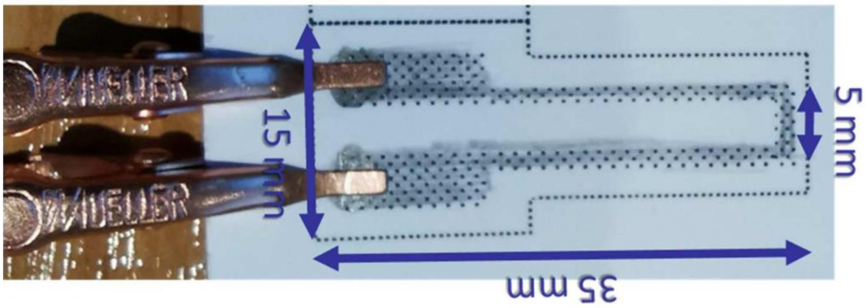
Shield - photography



Shield - 3D representation 1



Shield - 3D representation 2



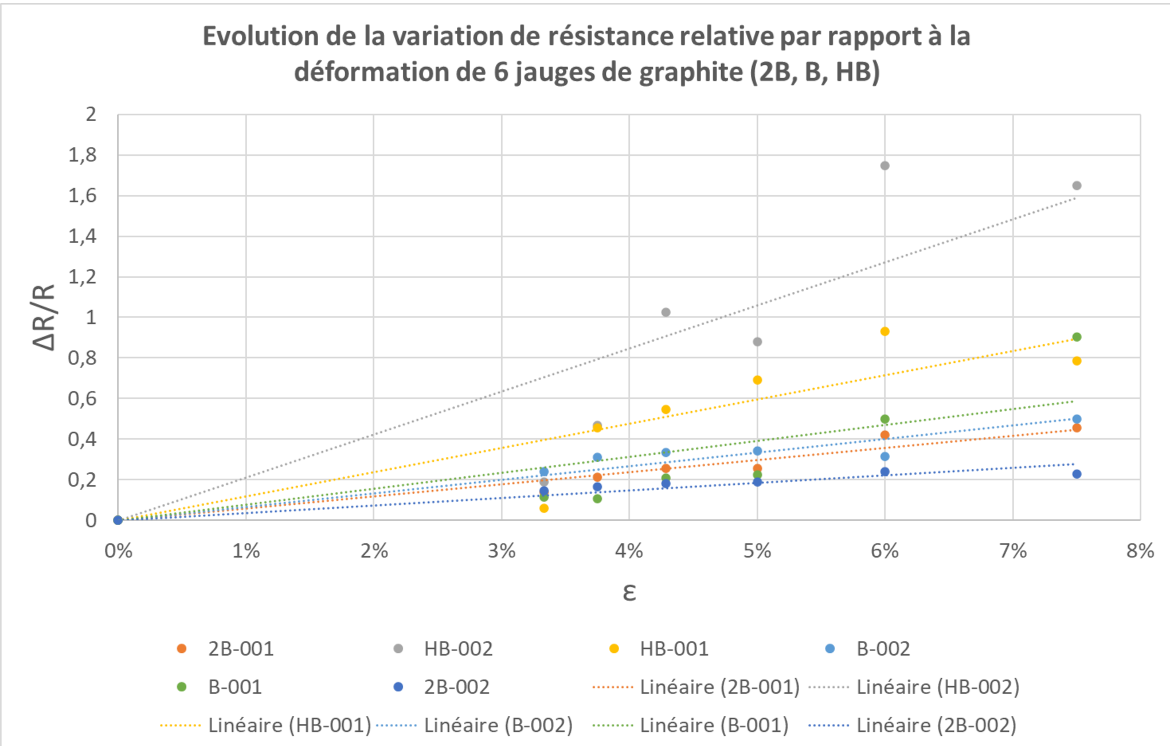
Graphite sensor

Measurement procedure and results:

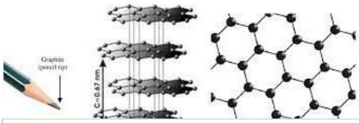
By measuring the voltage according to different deflections, we can determine the corresponding resistance. The figure below shows the evolution of ΔR/R0 in relation to the deflection, with R0 the electrical resistance of the gauge when there is no deflection applied and using a bench with constant and known rays.

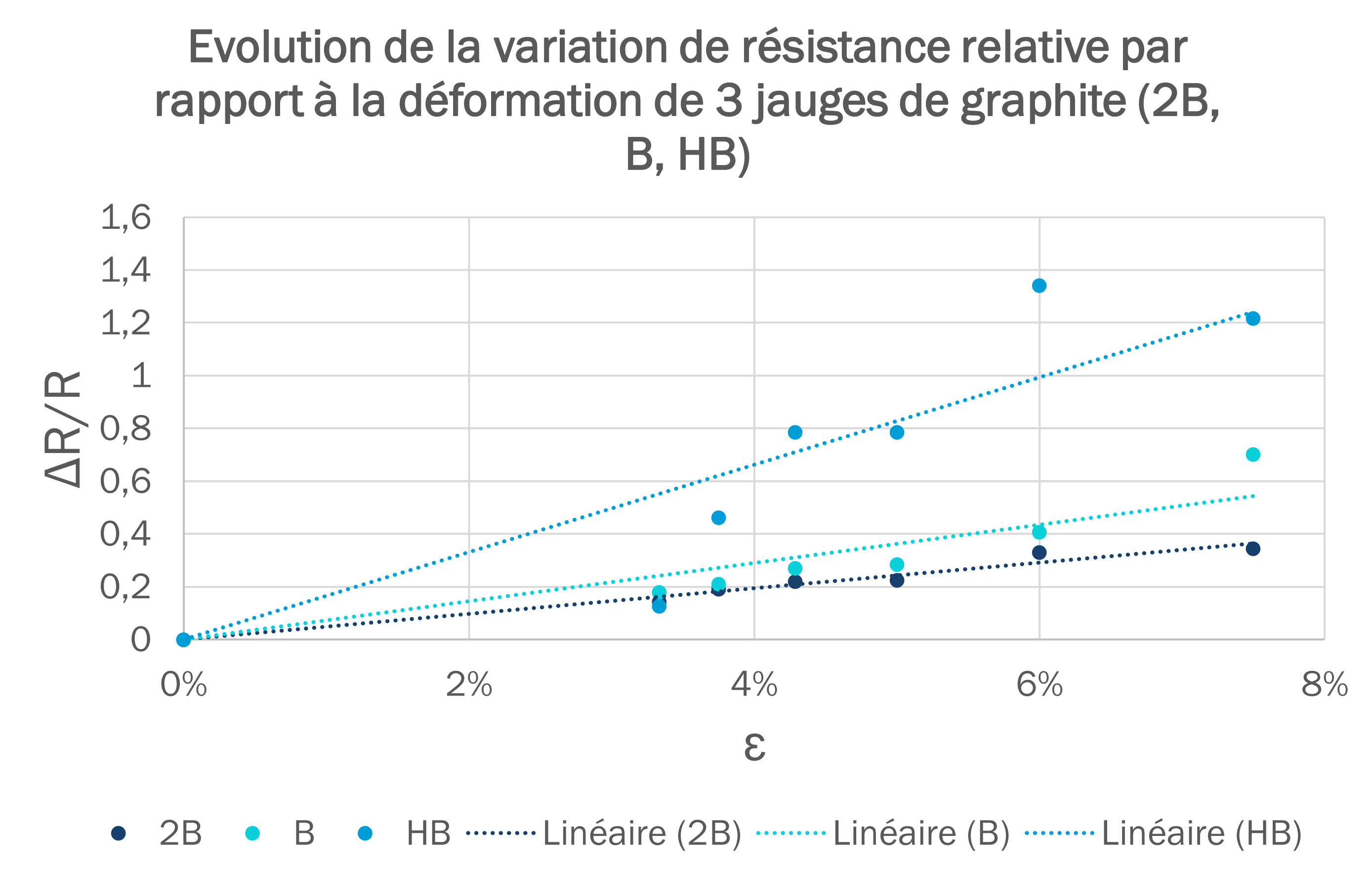
To improve the characterisation of the sensor, another bench with a servomotor was used: so, the deflection is represented in relation to time.

> **Warning:** It is difficult to have a repeatable experiment: the amount of graphite decreases over time because of the alligator clips friction with the paper, the extreme deflections applied or the contact with fingers.



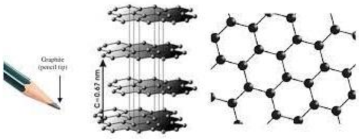
Evolution of the relative resistance variation in function of the deflection of 6 graphite sensors (2B, B, HB)

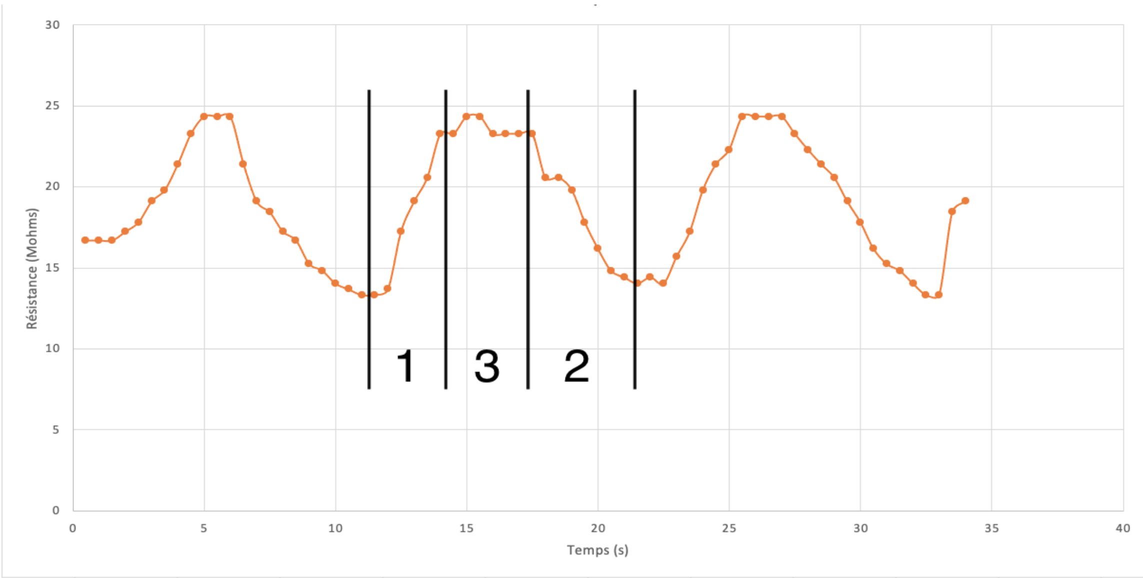




Average evolution of the relative resistance variation in function of the deflection of 3 type of graphite sensors (2B, B, HB)

The graphic above shows us the possibility to make different strain sensors with different pencils. We observe that for a harder pencil we have a better sensibility. Indeed, the sensor sensibility depends on the quantity of graphite that you put on your paper. We can see that the HB make much more efficient sensors than 2B, but with not enough graphite we risk the non-electrical continuity and the impossibility to use the sensor.





Evolution of the sensor's resistance in function of time during a periodic deflection application.

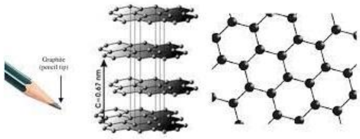
Thanks to the graphic above, we observe the periodic response of the sensor. On the dynamic bench the sensor is folded instead of stretched. We can see three different zone on this response.

The first zone is the one corresponding to the diminution of the deflection. Indeed, the sensor is recovering the value of R0 which is its maximum value in this experiment.

The second zone is the one corresponding to the augmentation of the deflection. The sensor is folded, and the resistance diminish.

The third zone is corresponding to the moment of non-contact of the sensor with the bench. The response is almost R0.

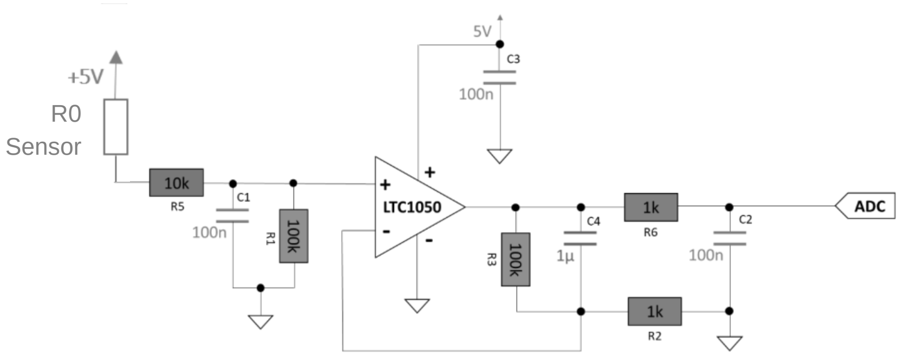
This diagram aims to show the tiredness of the sensor in time evolution with a periodic deflection. At this point no tiredness can be observed, but with longer tests we should find the limit of utilisation cause by the use of the sensor.



Typical applications

The following diagram is a typical application of the graphite strain gauge. The sensor is connected to a transimpedance amplifier with a low-pass filter to limit the noise and recover only the information of interest. The resulting voltage can be recovered on a 5V ADC and converted into a measure of resistance thanks to the relation:

$$\boldsymbol{R_{sensor} = \left(1 + \frac{R_3}{R_2}\right) \frac{R_1 V_{cc}}{\frac{5}{1024} V_{measured}} - R_1 - R_5}$$



Typical application of the sensor