INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Low-Tech Graphite Sensor

Features

- Low power usage (3.3V-5V)
- Low cost and low tech
- Plug-in-play
- Ergonomic and easily repairable

Applications

- Test findings of *Pencil Drawn Strain Gauges and Chemiresistors on Paper*[1]
- Applied using a transimpedance amplifier connected to the ADC of an Arduino card
- Pedagogical tool for students to design and implement their own PCB design

General Description

This innovative sensor, conceptionalized and made by students from the Applied Physics Department of INSA Toulouse, is a tool inspired by the publication *Pencil Drawn Strain Gauges and Chemiresistors on Paper*[1]. This research paper provides a simple, cost-efficient, and highly pedagogical tool for students to master their skills in Physics, Electronics, and Sensor Design. The sensor presented in the publication is a simple piece of paper with a layer of graphite on top of it, deposited with a pencil.

Due to the deposited graphite on the piece of paper, the electrons are able to move freely from particle to particle due to quantum tunnelling. This effect is extremely sensitive to the slightest movement of the paper. We observe that compressing or stretching the graphite will change the resistivity of the sensor.

[1] LIN, Cheng-Wei, ZHAO, Zhibo, KIM, Jaemyung et HUANG, Jiaxing, 2014. Pencil Drawn Strain Gauges and Chemiresistors on Paper. Scientific Reports. 22 janvier 2014. Vol.4, n°1, pp.3812. DOI 10.1038/srep03812.

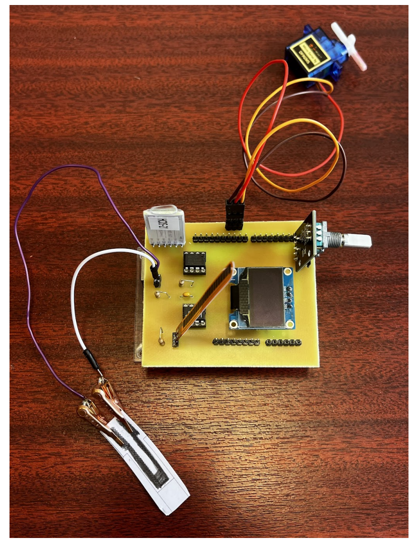

Figure 1: Graphite Sensor connected to the PCB

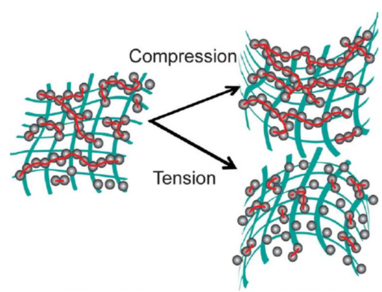

Figure 2: Compression and tension in a granular system

Electrical Diagram

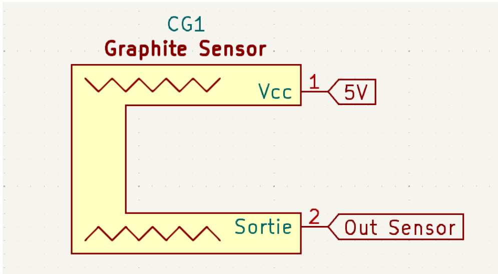

Figure 3: Schematic of the Graphite Sensor

Table 1: Specifications of the Electrical Diagram

Parameter	Pin	Symbol
Supply Voltage	V_{CC}	1
Out Sensor	V_{out}	2

Note: Both pins are invertible.

Electrical Specifications

Table 2: Values of the resistance of each type of pencil

Pencil Type	Min.	Typ.	Max.	Unit	Note
F	2.1	2.5	5	MΩ	Values highly depend on the amount of graphite deposited
HB	1.9	2.7	3.8	MΩ	
4B	0.9	1.1	1.5	MΩ	
5B	0.8	0.9	1.3	MΩ	

Absolute Maximum Ratings

Table 3: Absolute Maximum Ratings of the Graphite Sensor

Parameter	Symbol	Min.	Typ.	Max.	Unit
Supply Voltage	V_{CC}	-	5.0	-	V
Temperature	T	10.0	-	30.0	°C
Humitidy	-	30	-	60	%
Paper Thickness	-	0.15	-	0.30	mm
Pencil Tone[1]	-	4B	-	2H	-

[1] Corresponds to the US grading system.

Performance Characteristics

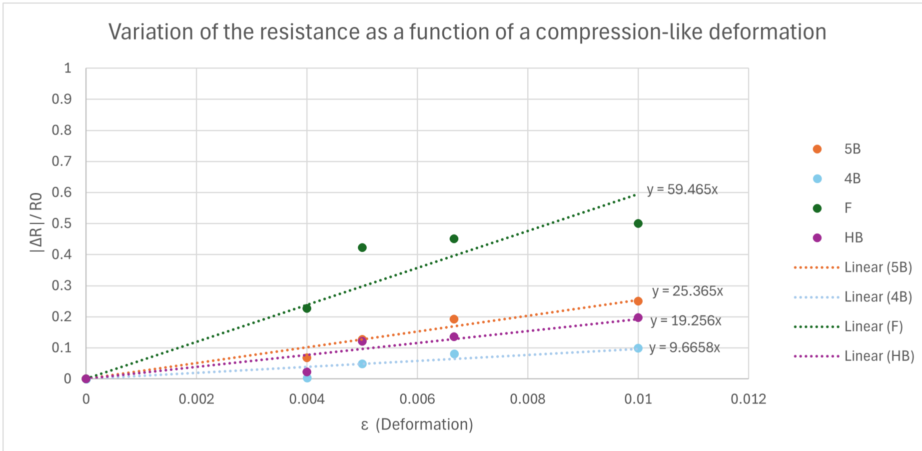

Figure 4: Characteristics of a compression-like deformation

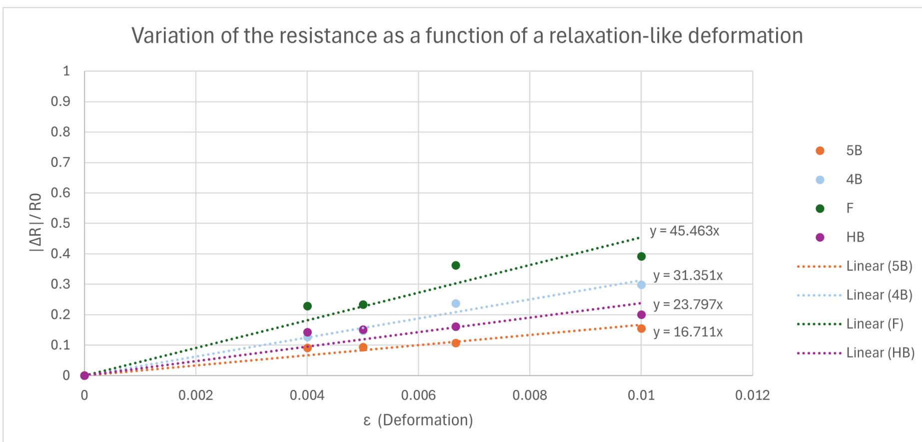

Figure 5: Characteristics of a relaxation-like deformation

Applications

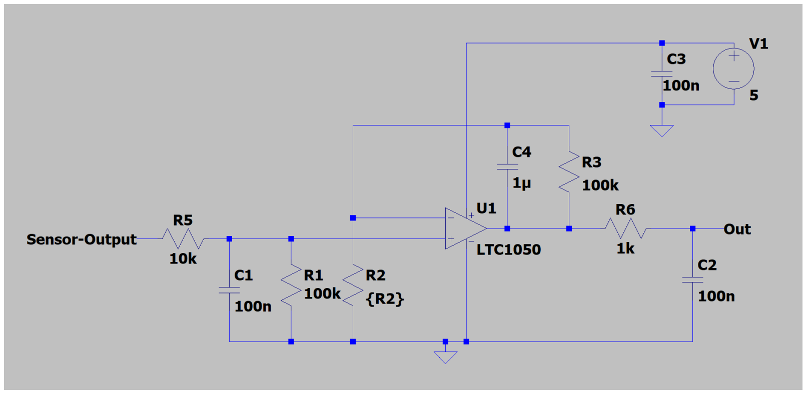

Figure 6: The transimpedance amplifier found on our board

The sensor is connected to a transimpedance amplifier circuit. The circuit is equiped with a low-pass and high-pass filters to cancel out the noise due to the 50Hz from the sector and the amplification of the signal.

The output signal of the amplifier, in our application, is transmitted to the Analog-to-digital (ADC) converter on the Arduino Uno card. We have to make sure that the signal the ADC receives does not saturate it, thus the need for this type of amplifier.

On our PCB, we have installed a digital potentiometer in lieu of the R_2 resistance in order to match the amplification of the circuit for each pencil tone. We can calculate the value of this resistance, knowing the value of the final voltage, with the following formula :

$$R_{dp} = \frac{V_{CC}}{V_{ADC}} \times R_1 \left(1 + \frac{R_3}{R_2}\right) - R_1 - R_5$$