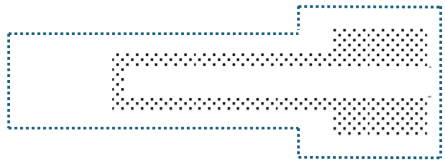
INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Graphite-based strain gauge 2024 v1.0

1 Overview

- Input signal 5V
- Low-tech strain gauge
- High resistance (Mohm)
- High sensitivity
- Easy use



2 Description

- The deformation sensor is designed to measure deformations along a single axis within the range of -3 to 3 cm.
- This sensor is ideal for educational demonstrations or science fairs, providing a hands-on showcase of strain sensing principles and graphene technology.
- It can also be seamlessly integrated into wearable devices, facilitating short-term monitoring sessions for tracking body movements or vital signs, perfect for applications like fitness tracking or rehabilitation exercises.

This strain gauge is a passive sensor crafted with pencil on paper. It epitomizes the ingenuity of low-tech solutions aimed at minimizing material consumption without resorting to metallic electrodes. The sensor is ingeniously simple: a U-shaped pattern drawn with a common household pencil. This system is granular. In essence, pencils serve as readily available sources of ultrafine graphite particles, making them an easily deployable solution.

The darker shade of the pencil indicates a higher concentration of graphite, resulting in a lower sensitivity of the sensor. To understand how this sensor works we have to view it from the atomic scale. Several grains of graphite, varying in size, are deposited on the paper sheet. When electrons pass through the sensor, their movement between the graphite grains is governed by the tunneling effect.

An easy way to understand the variation in resistivity of the strain gauge when subjected to deformation along the z-axis is to note that when the sensor is under tension, the distance between the graphite grains increases. Consequently, electrons encounter more obstacles, making it more difficult for them to pass through the sensor, resulting in higher resistance. Conversely, when the sensor is under compression, the grains are closer together, facilitating the flow of electricity through the sensor, leading to lower resistance.

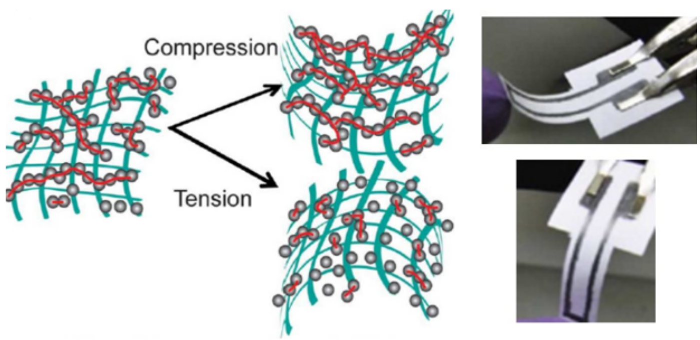


Figure 1: Strain gauge under tension and compression

3 Technical specification

	Unit	Value
Power voltage	V	5
Maximum current through SC	A	3
Dimensions	$mm * mm$	35*15
Weight	g	<1
n° of outputs	$--$	1
Voltage range signal output	V	0 - 5

4 Standard use condition

Parameter	**Unit**	**Value**
Temperature	$^\circ$C	20 ± 2
Humidity	%	50 ± 5
Bluetooth distance	m	1 ± 4

5 Pinout

Pin	Signal
1	Power 5 V
2	Vin

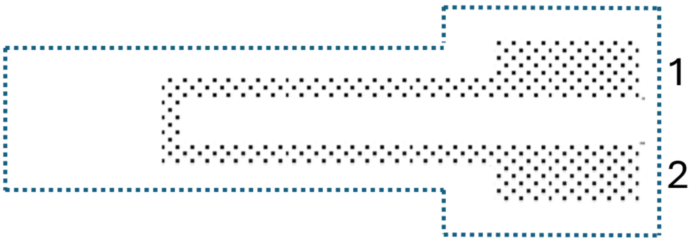


Figure 2: Pins diagram

6 Measures

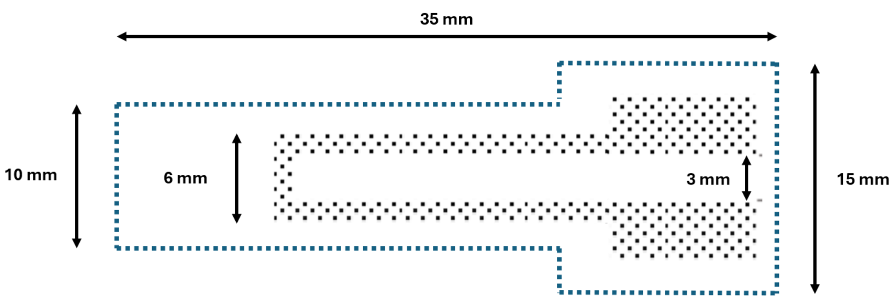


Figure 3: Dimensions of the graphite strain gauge sensor in top view

7 Characteristics

Incorporating the strain gauge sensor into the integration circuit suggested in Section 8 manifests the following characteristics. Each column denotes the sensitivity of the sensor for different pencil types: HB, 2B, 4B.

	Unit	HB	2B	4B
Sensitivity in compression	$\mathrm{mV\,cm^{-1}}$	59.5	50.4	42.5
Sensitivity in tension	$\mathrm{mV\,cm^{-1}}$	117.0	75.6	12.3

Curves obtained by deforming the strain gauge sensor and applying power and compression :

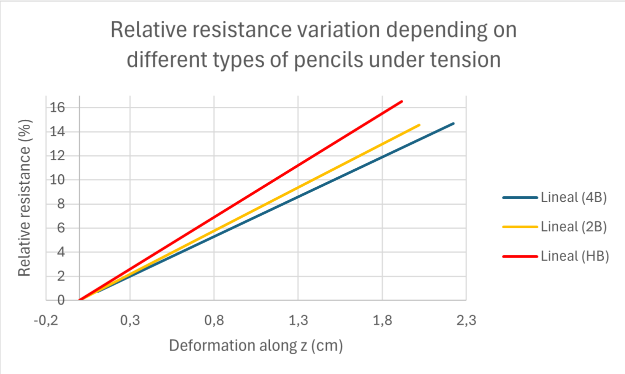


Figure 4: Variation in relative resistance as a function of deformation along the z-axis under tension

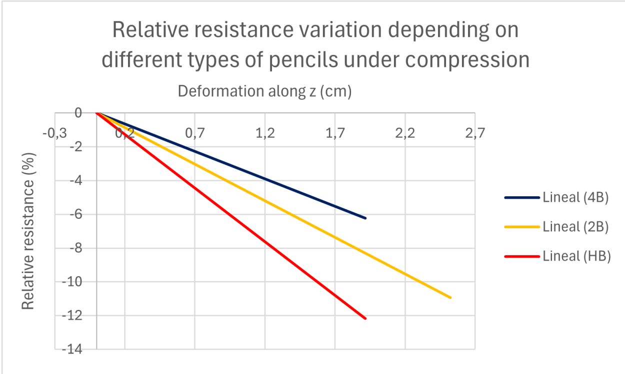


Figure 5: Variation in relative resistance as a function of deformation along the z-axis under compression

8 Example of integration circuit

Due to the significant variation in resistance values among different types of pencils, we have designed a transimpedance amplifier circuit capable of measuring a wide range of resistance values of the graphite strain gauge. This is achieved by simply adjusting the value of resistor R2. The circuit can be divided into three main sections:

- **Input Filtering:** Resistor R1 and capacitor C1 form a low-pass filter at the input of the circuit, ensuring that only the desired signal frequencies are passed through.
- **Signal Amplification:** The operational amplifier, along with resistors R2, R3, and R4, serves to amplify the signal received from the strain gauge. This amplification stage ensures that even small variations in resistance are accurately detected and measured.
- **Output Filtering:** Resistor R6 and capacitor C3 are utilized as a low-pass filter at the output of the circuit, further refining the amplified signal and reducing high-frequency noise.

Both low-pass filters will effectively allow the passage of the desired signal, given that the sensor is designed to detect low frequencies. Additionally, capacitor C4 is included in the design to mitigate undesirable oscillations in the power supply, enhancing the stability and reliability of the circuit.

This carefully crafted circuit design enables precise and reliable measurement of the resistance variations in the graphite strain gauge, making it suitable for a wide range of applications requiring accurate strain sensing.

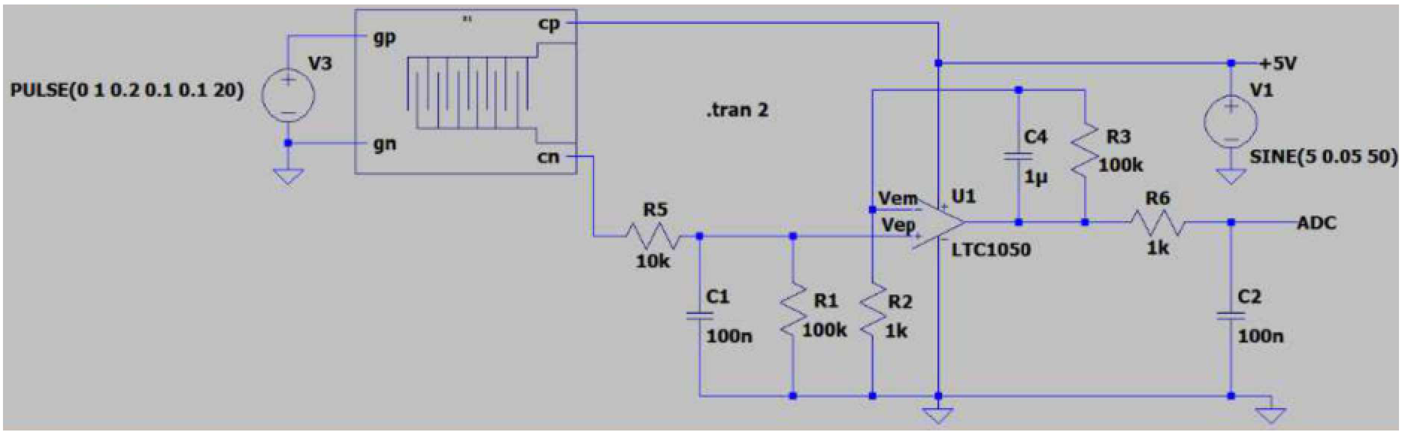


Figure 6: Transimpedance amplifier circuit

9 Schematic

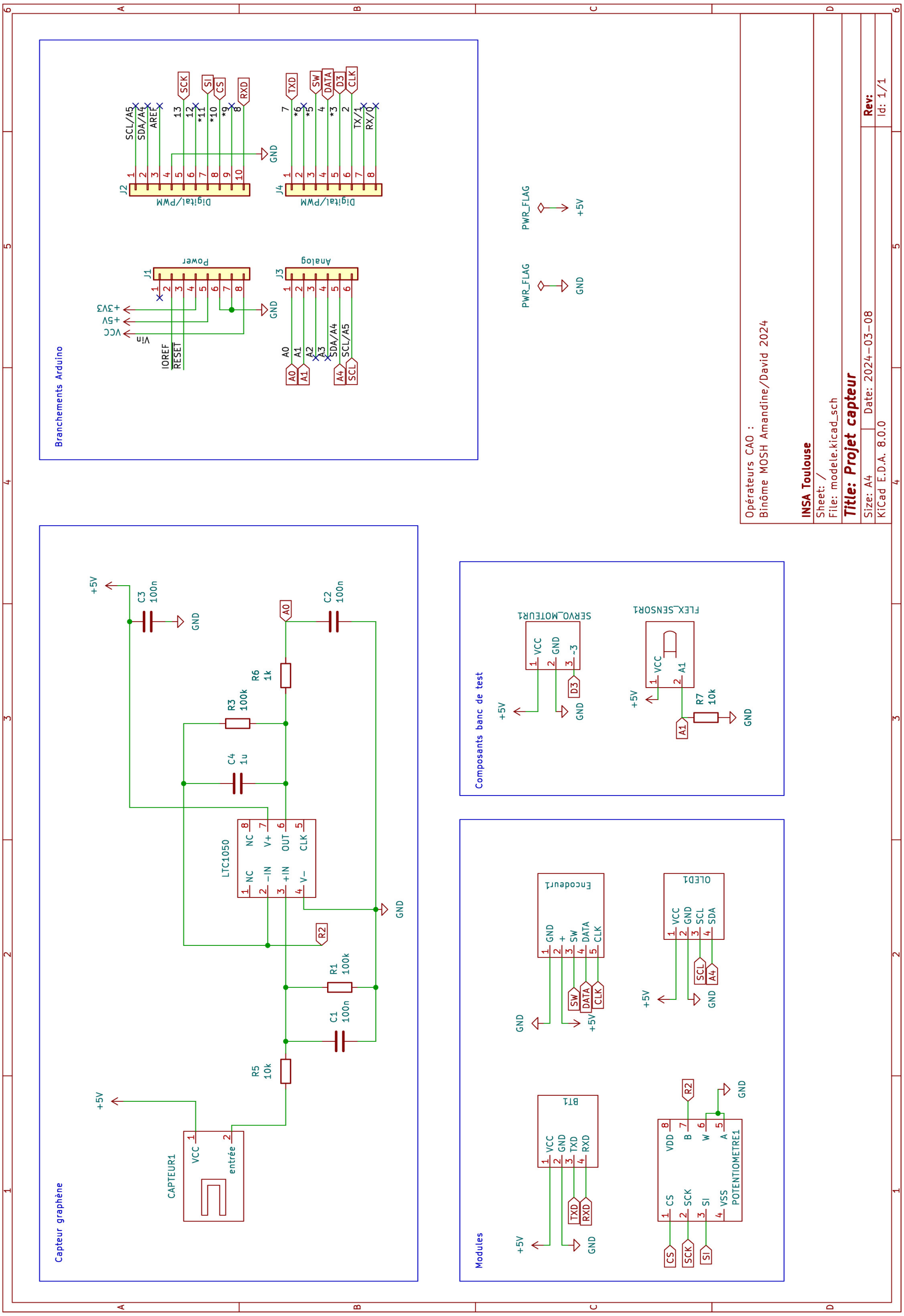


Figure 7: Schematic of all the components used