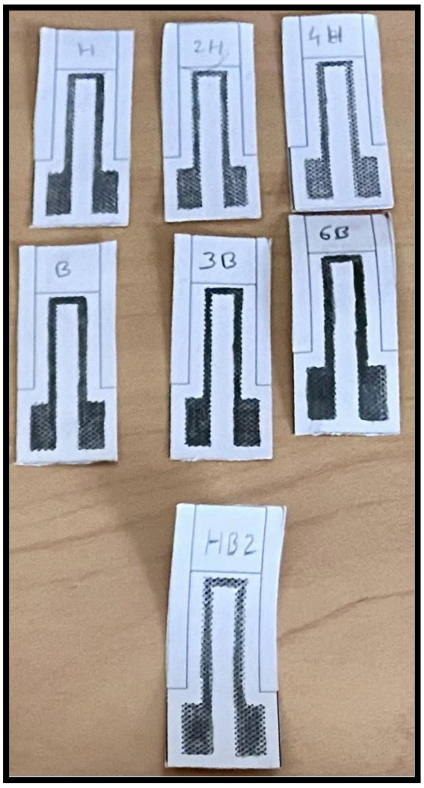
# Pencil-Drawn Strain Gauge




## Description

The pencil-drawn strain gauges represent a breakthrough in low-cost, flexible, and environmentally friendly sensor technology. These sensors are fabricated using ordinary graphite pencils on standard print paper, creating a percolated network of fine graphite particles. This network exhibits reversible resistance changes in response to mechanical deformation. The fabrication process is extremely simple, rapid, and cost-effective, making it accessible for various applications, especially in resource-limited settings. The devices are light, flexible, portable, and disposable, posing minimal environmental impact. They can be easily drawn into any shape, offering significant versatility in design. This innovative approach not only reduces the cost and complexity of sensor production but also opens up new possibilities for integrating electronics with artistic elements, such as in origami-based applications. These pencil-on-paper sensors hold potential for emergency use, educational tools, and a variety of other applications requiring flexible and disposable electronic devices. [1]

## Main features

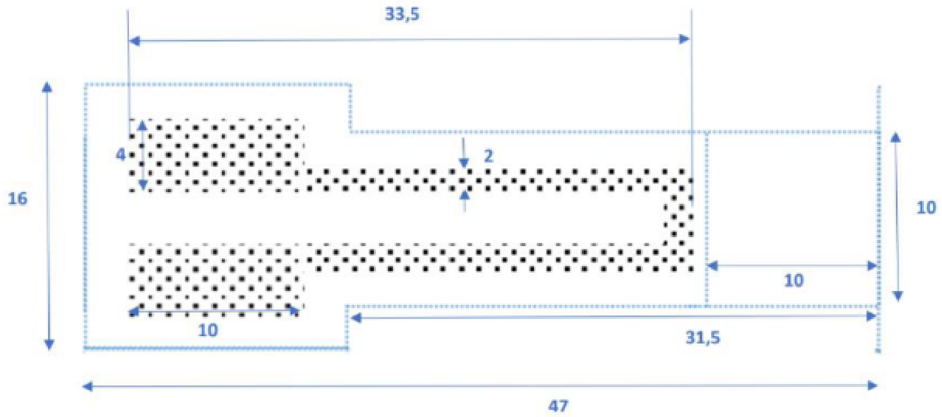
- Simple and Rapid Fabrication
- Cost-Effective
- Low Environmental Impact
- Flexibility
- Portability
- Reversibility
- Versatility

## Specifications

At ambient temperature and with an average humidity rate :
T ~ 15°C to 30°C H ~ 60% to 80 %

| | |
|---|---|
| **Type** | Strain sensor |
| **Materials** | Paper and Graphite (HB, 4B, B) |
| **Sensor type** | Passive |
| **Measurand** | Resistance/Voltage |
| **Power supply** | +5V |
| **Lifetime** | 1 to 30 uses (depending on the mechanical distortion applied) |

## Dimensions (in mm)

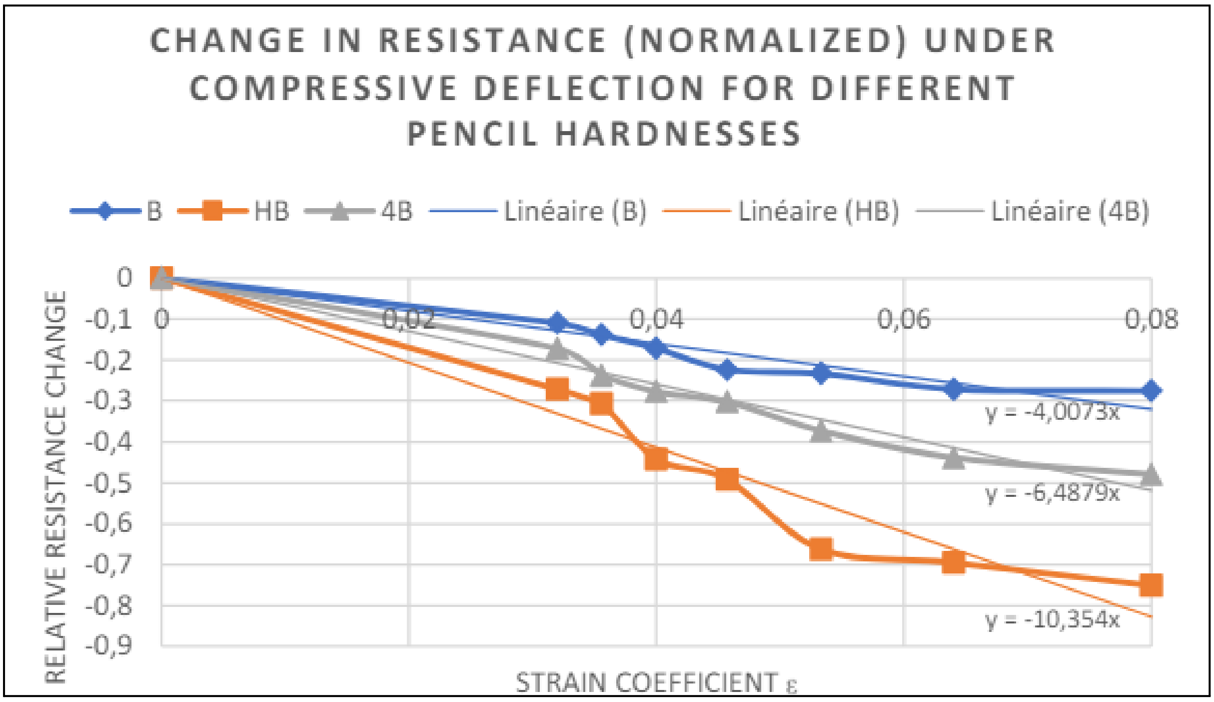



*Thickness = 0.16 mm*

## Pin connexion

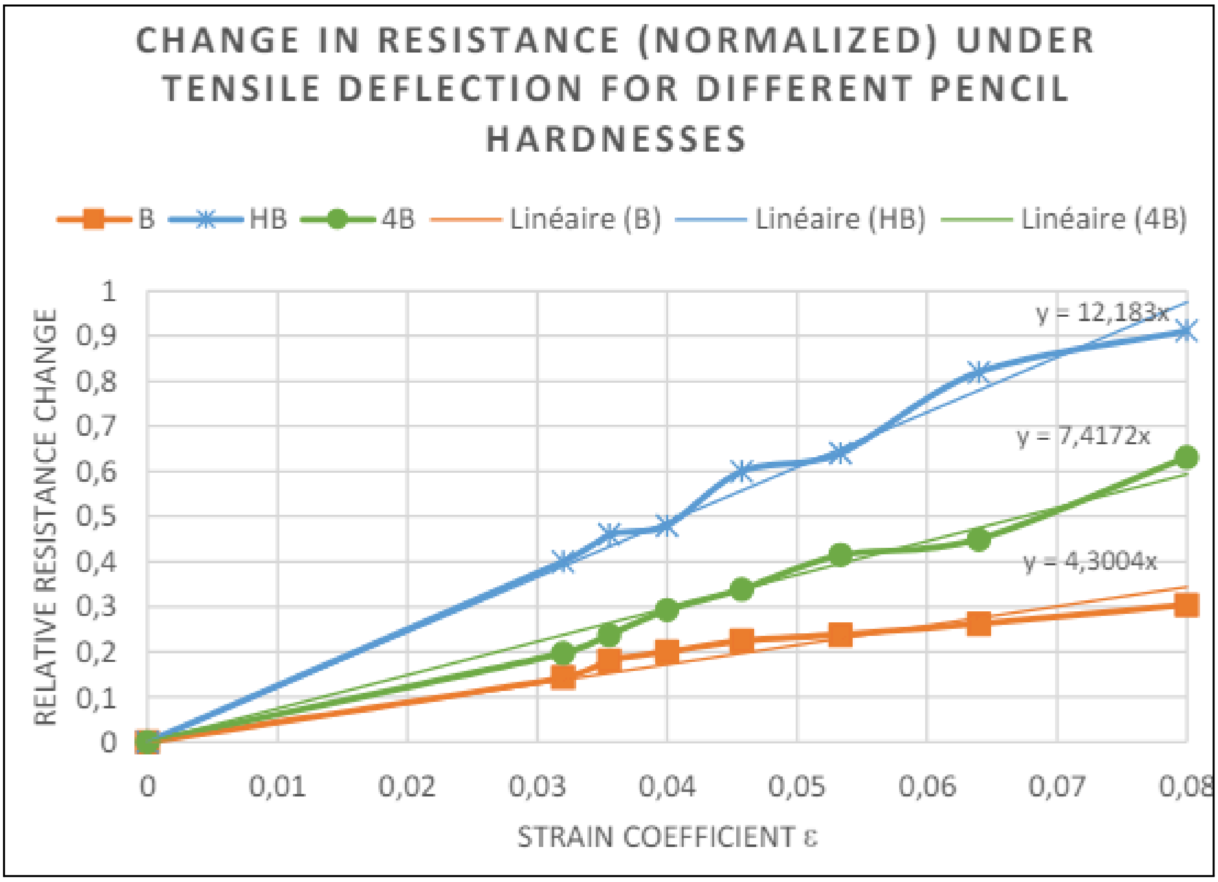

→ pin 1 : Connected to $V_{CC}$ = +5V
→ pin 2 : $V_{OUT}$ (analog output)

## Electrical characteristics

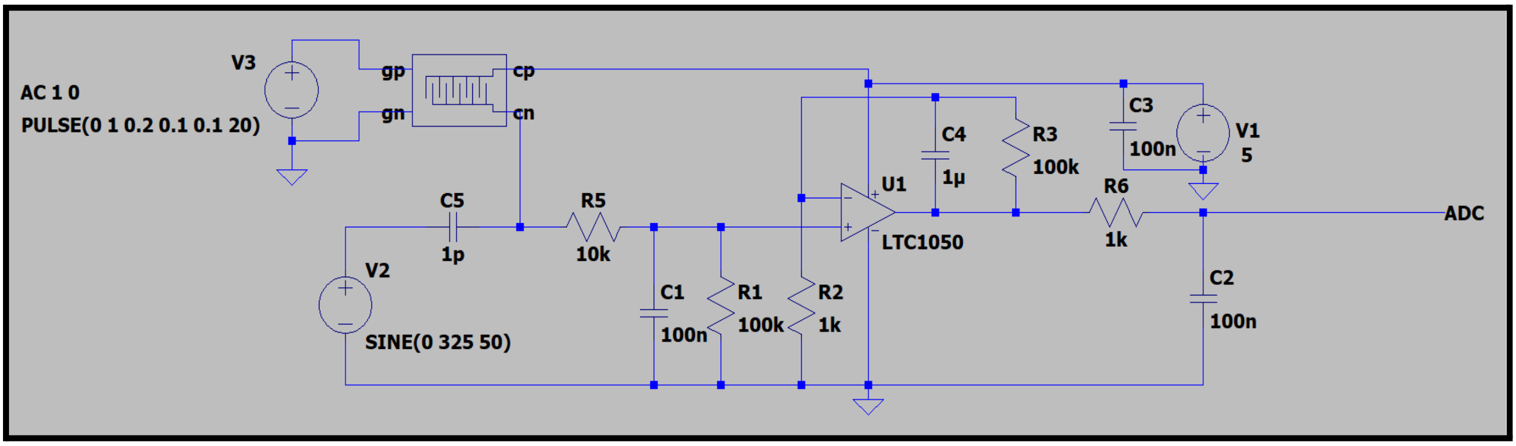



with :

- $\varepsilon = \frac{e}{2r}$ , e = paper thickness ; r = radius of curvature of the disc used to test the sensors
- Relative resistance : $\Delta R = \frac{R-R_0}{R_0}$ , R = resistance measured ; $R_0$ = resistance when the sensor is flat.



## Application Example




Here is an application example for measuring the strain of a graphite sensor. It consists of an electrical circuit shaped to filter and amplify the $V_{OUT}$ signal sent by the sensor. These two functions are carried out by :

- **3 low-pass filters** :
  - The 1st one, formed by $R_5$, $C_1$, and $R_1$, filters out the current noise in the input signal caused by the 5V power supply (symbolized by the 'SINE' and $C_3$)
  - The 2nd filter, formed by $C_4$ and $R_3$, is designed to reduce the 50 Hz noise component induced by the ambient electrical network.
  - The 3rd filter is formed by $R_6$ and $C_2$, placed at the output of the amplifier, which attenuates the intrinsic noise of the circuit.
- **1 LTC-1050 operational amplifier**

This circuit demonstrates an efficient way to measure mechanical strain using a graphite strain sensor. The combination of passive components (resistors and capacitors) with an operational amplifier provides a stable and amplified signal suitable for digital measurement potentially handled by a microcontroller board like an Arduino UNO.

The sensor resistance is calculated thanks to the following formula :

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

with $R_{potentio}$ corresponding to $R_2$ in our example.

## Bibliography

[1] : Cheng-Wei Lin and al. (2014) - Pencil Drawn Strain Gauges and Chemiresistors on Paper