INSTITUT NATIONAL
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APPLIQUÉES
TOULOUSE

Pencil Drawn Strain Gauge

General features

- Low power consumption
- Easy to use
- Environmental-friendly
- Small size
- Low cost
- Short response time
- Detection of outward deformation

Description

These pencils drawn sensors are used as graphite-based strain gauges. Equivalent to an impedance, it became possible to measure the resistance variation as a function of the deformation applied. Based on the hardness of these leads, pencils are classified on a scale from 9B to 9H. In our case, we only studied three types of pencils (H, HB and B). Sensors are made of U-shaped patterns drawn on a piece of paper and are connected to an Arduino on which is mounted an analog circuit with a transimpedance amplifier, a Bluetooth module and an OLED screen. Changes of electrical resistance were monitored using the transimpedance amplifier connected to the electrodes thanks to toothless alligator clips.

Specifications

Type	Nanoparticle based sensor
Materials	Graphite particles and clay
Sensor type	Passive
Deformation measurement	Resistive measure
Dimensions	4.7*1.6 cm
Mounting	Toothless alligator clips

Standard use condition

	Unit	Typical value
Temperature	°C	20±5

Electrical characteristics

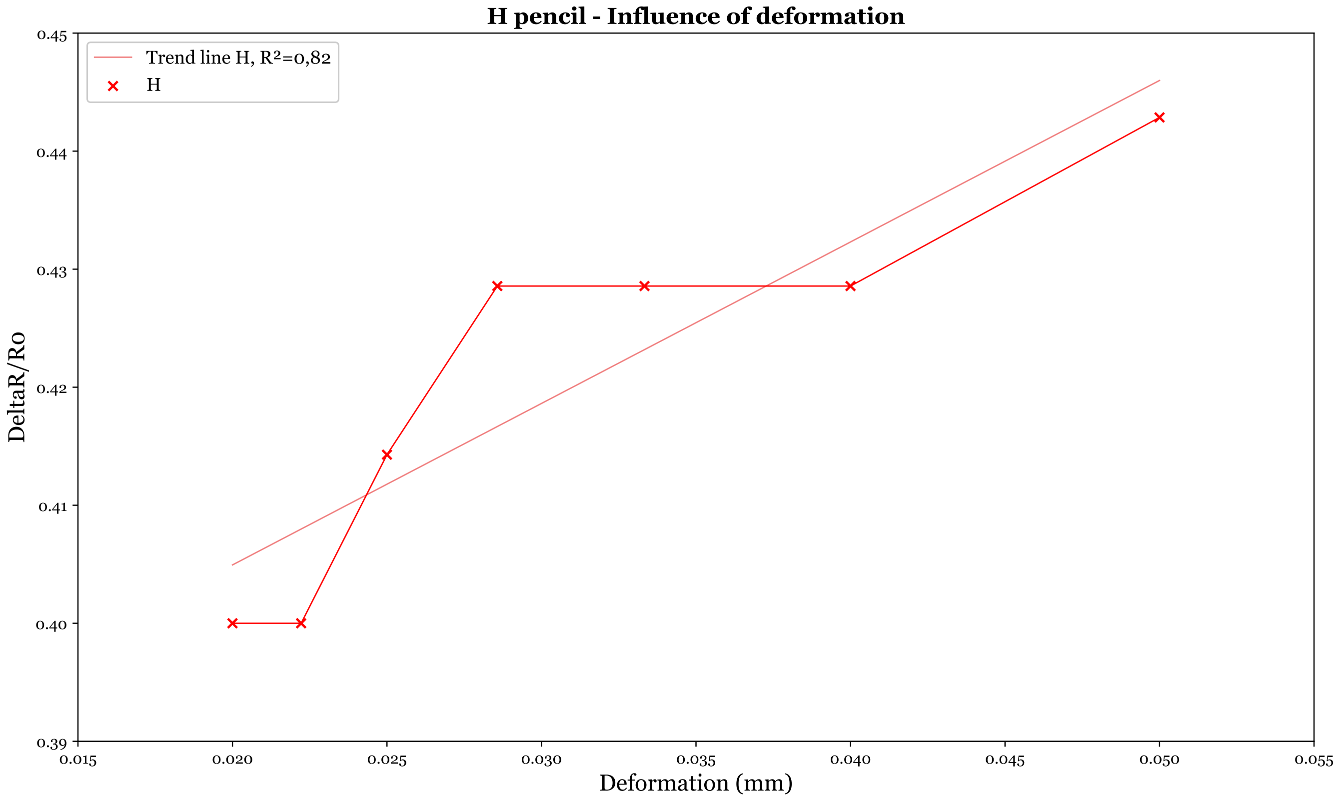
	Unit	Value		
		Min	Typical	Max
H	MΩ	70	92,9	101
HB	MΩ	41	64,9	99
B	MΩ	34	35,4	37

Pencil drawn strain gauges characteristics

The following resistance variation measurements are obtained using a series of semicircles of radii from 1 cm to 2.5 cm. By imposing a certain curvature on the sensor, a resistance value is obtained which depends on the deformation ε applied.
R_0 is the resistance a gauge has without any deformation applied.

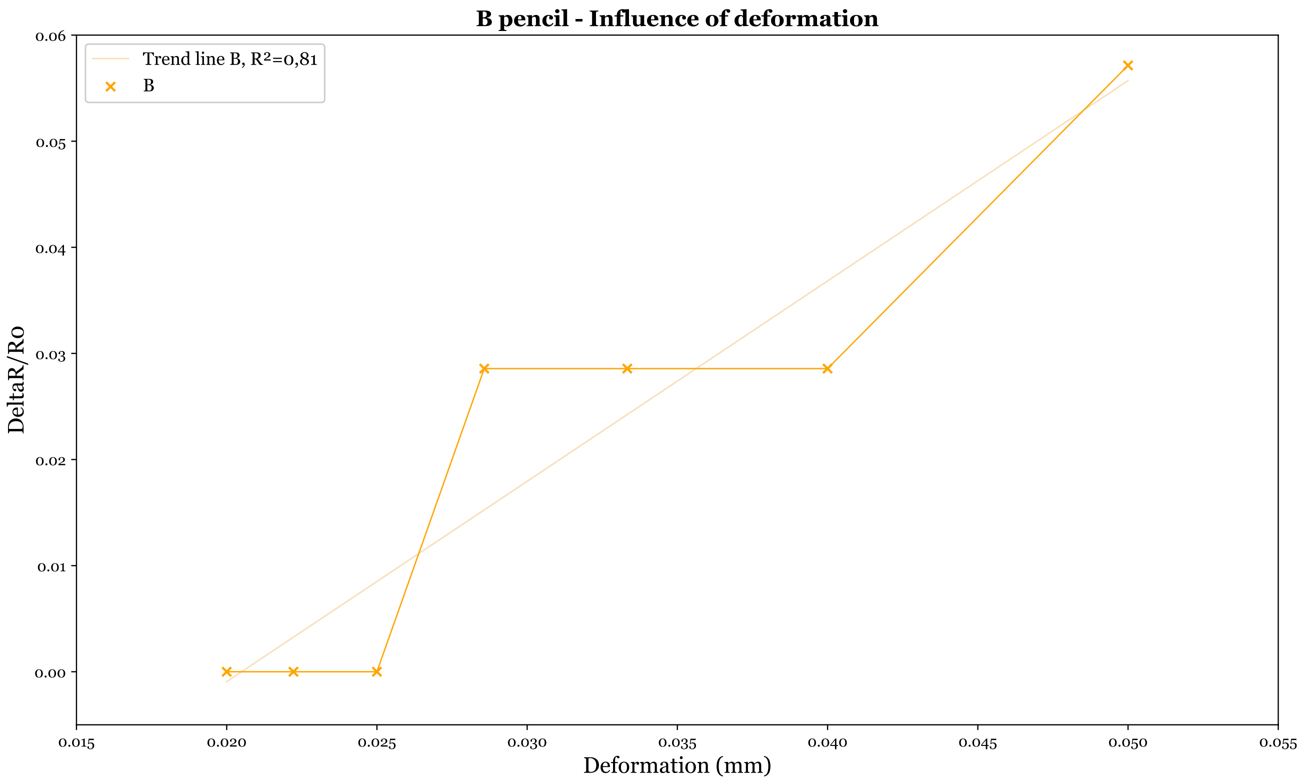
Figure 1 : Test bench used for carrying out measurements

It can easily be shown that $\boldsymbol{\varepsilon} = \frac{\boldsymbol{e}}{\boldsymbol{2R}}$, ε being the deformation, e the thickness of the paper equal to 1 mm and R the radius of the semi-circle.
All the following deformation values have been calculated with this formula.



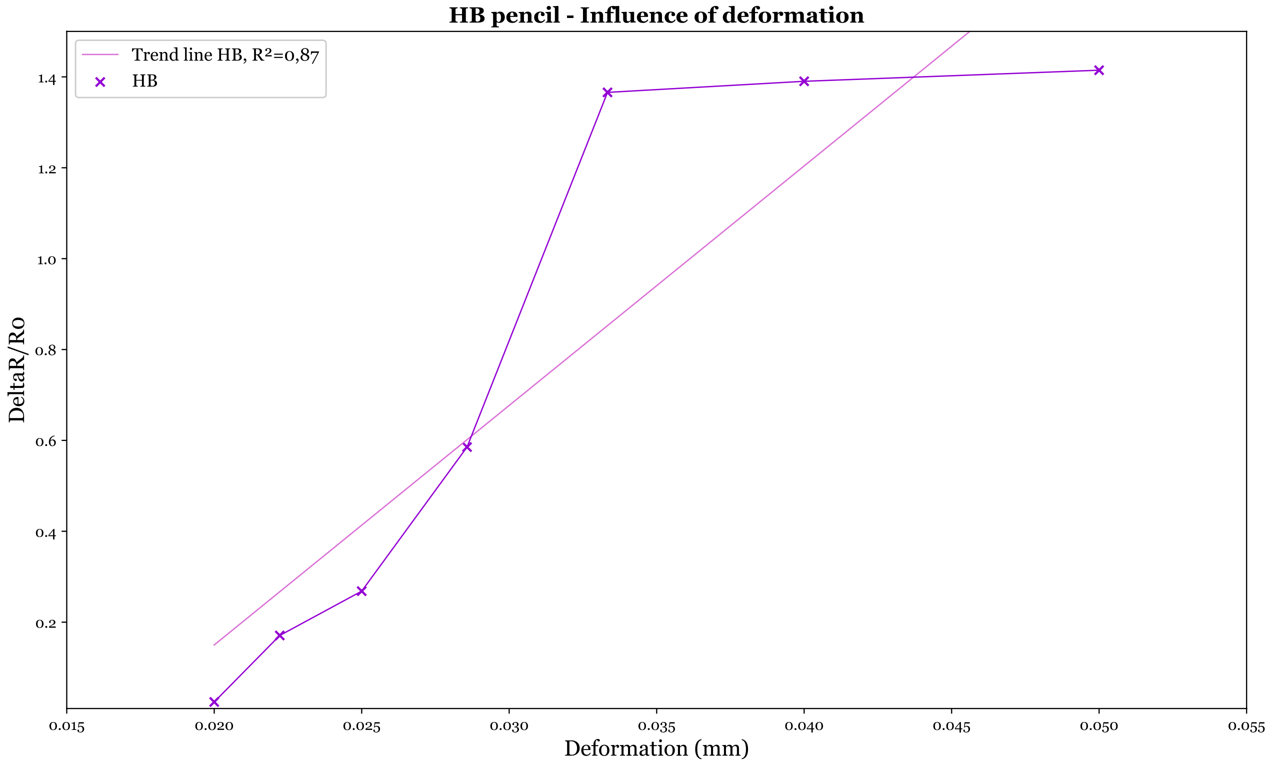

```
>>> (executing lines 1 to 38 of "Carac deformation crayon H.py")
Coefficient R² : 0.8165391778200985
Slope : [1.36817115]
Intercept : 0.3775791322673512
```

Figure 2: Characteristic [Variation of resistance/Deformation] of the H pencil and trend line equation




```
>>> (executing lines 1 to 36 of "Carac deformation crayon B.py")
Coefficients R²: 0.8748326704339843
Slope : [1.8882224]
Intercept : -0.038700476505957772
```

Figure 3: Characteristic [Variation of resistance/Deformation] of the B pencil and trend line equation




```
>>> (executing lines 1 to 36 of "Carac deformation crayon HB.py")
Coefficient R²: 0.8109889482622271
Slope : [52.7021513]
Intercept : -0.9041358956870035
```

Figure 4: Characteristic [Variation of resistance/Deformation] of the HB pencil and trend line equation

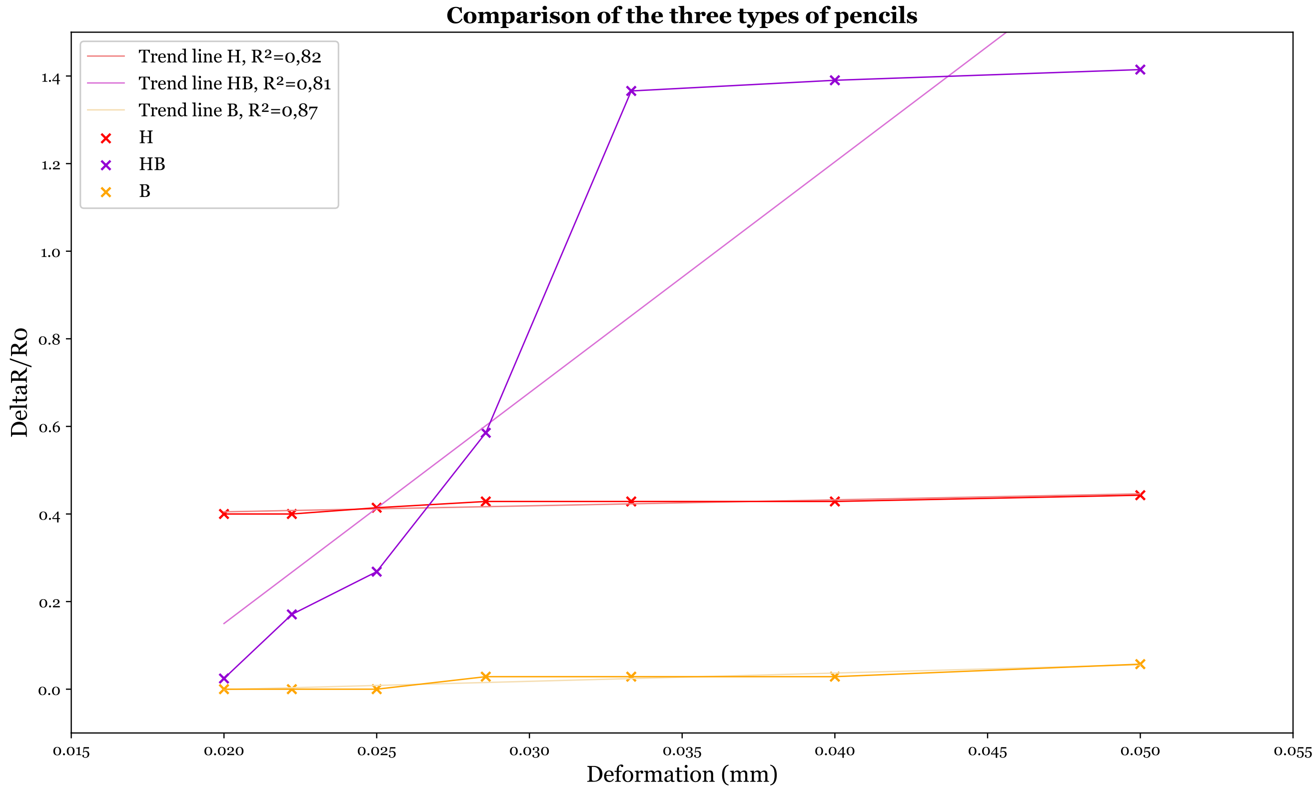
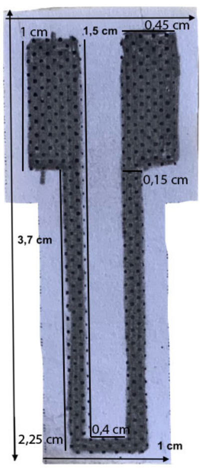


Figure 5: Relative change in resistance versus deformations for three types of pencils

Dimensions



The grey area represents the area to be colored by the pencil.

Figure 6: Sensor's dimensions

Typical Applications

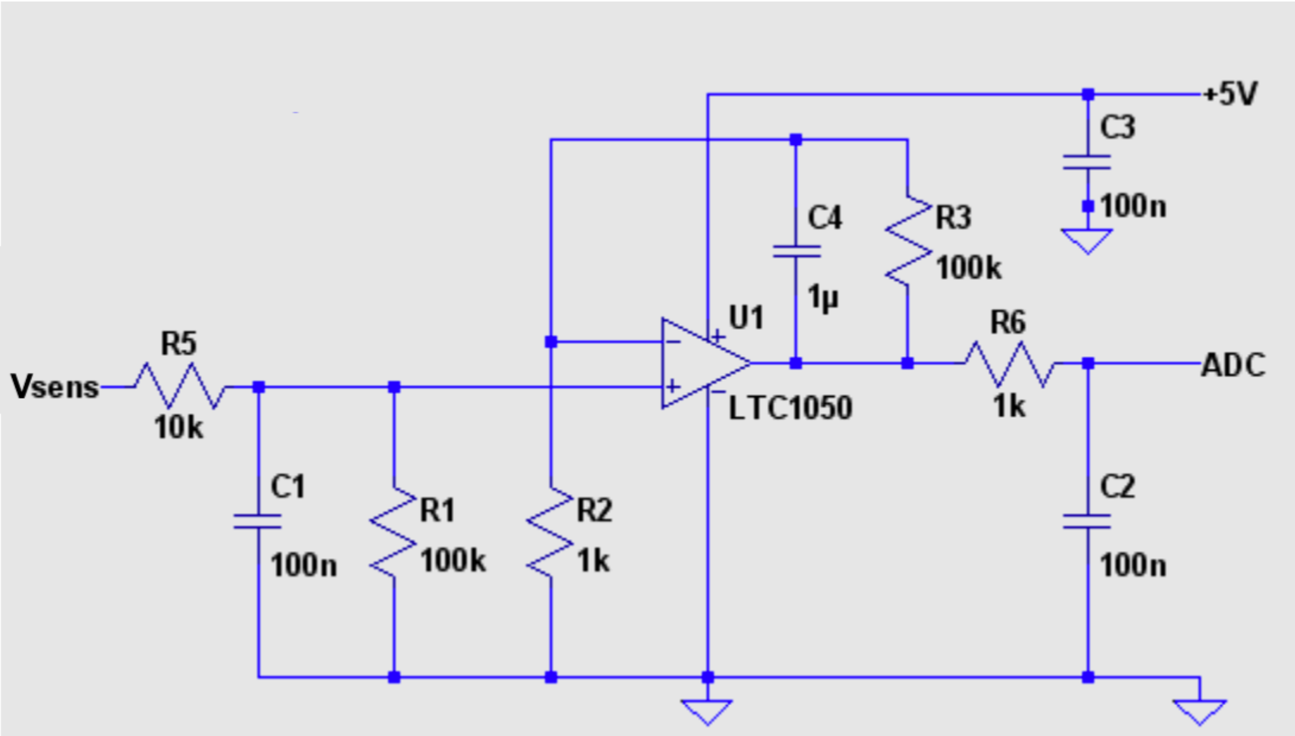


Figure 7: Electrical scheme of the sensor connections

The sensor can be used in an analog circuit transimpedance amplifier. The sensor is connected in series to two resistances of a dividing bridge. The tension is then amplified by a LTC1050 before being filtered by a low pass filter (RC circuit). The resulting voltage can be read on an ADC. An Arduino board can be used for this. We can then go back to the resistance of the sensor R_{sensor} from the voltage measured V_{read} on a 10-bit 5V ADC.

At low frequency, we have the following relation : $R_{sensor} = \left(1 + \frac{R_3}{R_2}\right) \frac{R_1 V_{cc}}{\frac{5}{1024} V_{read}} - R_1 - R_5$

with V_{cc}=5V