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4GP – Du capteur au banc de test

Graphite low-tech strain sensor

General features

- Open source
- Low cost
- Environmentally friendly, low-power consumption
- Easy to use and to transport
- Short response time
- Traction and compression measures
- Made of graphite layers using a pencil

Working principle

Low-tech graphite strain sensor conditioned and amplified by an analog electronic circuit that communicates data to an Android application via an Arduino microcontroller. This sensor was developed by INSA students as part of the Physics Engineering curriculum.

Graphite is deposited with a pencil on a paper in a 'U' shape: it is the sensing element. The resistance variation depends on the amount of graphite and on the type of pencil that is used (from 9B to 9H). This strain sensor is based on the percolation theory in granular system. When they are compressed, molecules bond together, decreasing the resistance. When they are stretched, they move away from each other and the resistance increases.

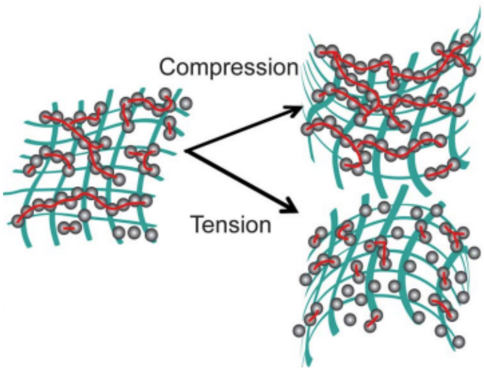

Figure 1. Variation of the number of connected graphite particle chains depending on the types of deformation

Specifications

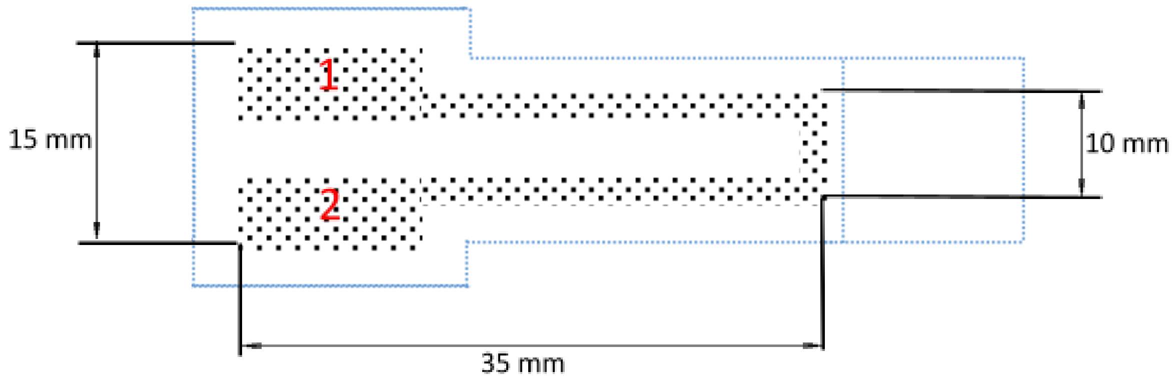

Figure 2. Sensor schematic

Dimensions	Paper thickness: 0.16 mm
Connections	1: transimpedance amplifier circuit input 2: power supply
Sensor type	Passive graphite strain gauge sensor
Materials	Graphite: carbon Paper: cellulosic plant fibres Clay ions: carbon, magnesium, aluminium, silicon
Measurand	Resistance
Output signal type	Analog
Power supply	5V
Typical response time	< 1s

Table 1. Specifications

Standard use conditions

	Unit	Typical value
Temperature	°C	20 ± 5
Humidity	%	60 ± 5

Table 2. Standard use conditions

Electrical characteristics

Pencil type	Unit	Measured R range	Typical R0 range
HB	MΩ	3.50 – 10.55	6.70 – 7.20
B		1.85 – 2.90	2.20 – 2.70

Table 3. Electrical characteristics

Values are dependant of the thickness of graphite layers.

Strain sensor characteristics

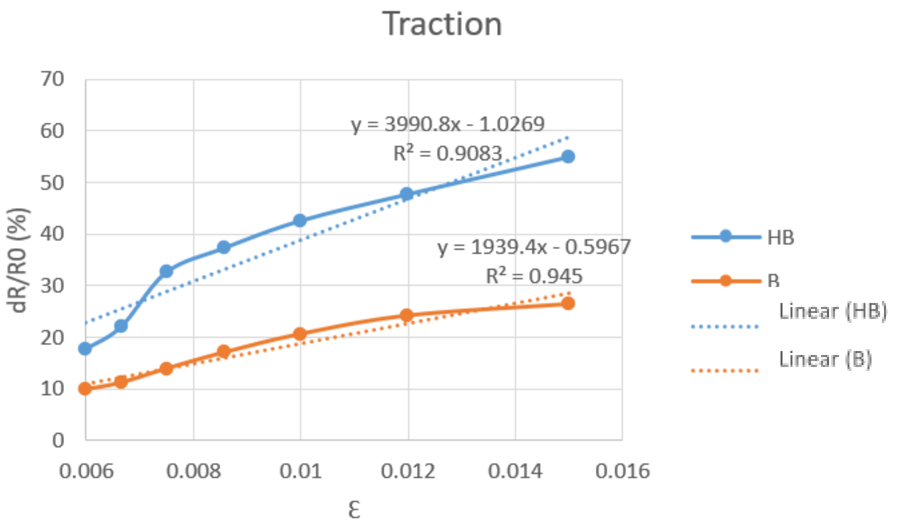

Figure 3. Sensor response to tensile tests

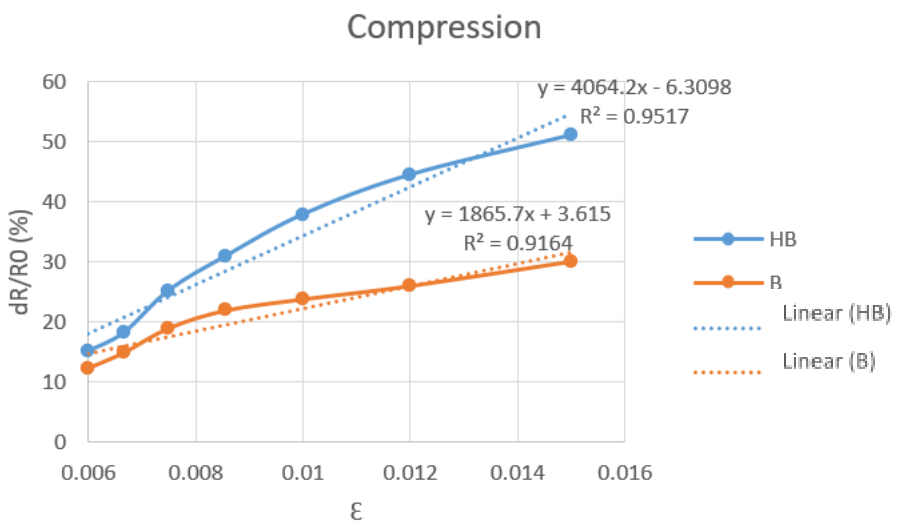

Figure 4. Sensor response to compressive tests

Proper functioning of the sensor can only be guaranteed in the linear range of its characteristic curve.

Sensor calibration

To characterize the deformation of the sensor, we use the following test bench:

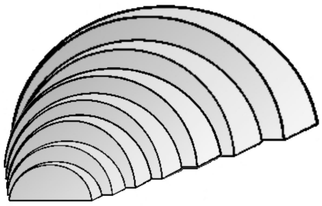

Figure 5. Test bench schematic

It is made of seven half-spheres with a radius between 1 to 2.5 cm, with a step of 0.25 cm.

We can determine the curvature of the sensor for each radius, and then use the following formula to calculate the relative variation of resistance with respect to the deformation:

$$\varepsilon = \frac{\sigma}{E} = \frac{e}{2r} = \frac{0.16\,mm}{2r}$$

where ε is the deformation,
e is the thickness of the paper sheet,
r is the radius.

Typical application

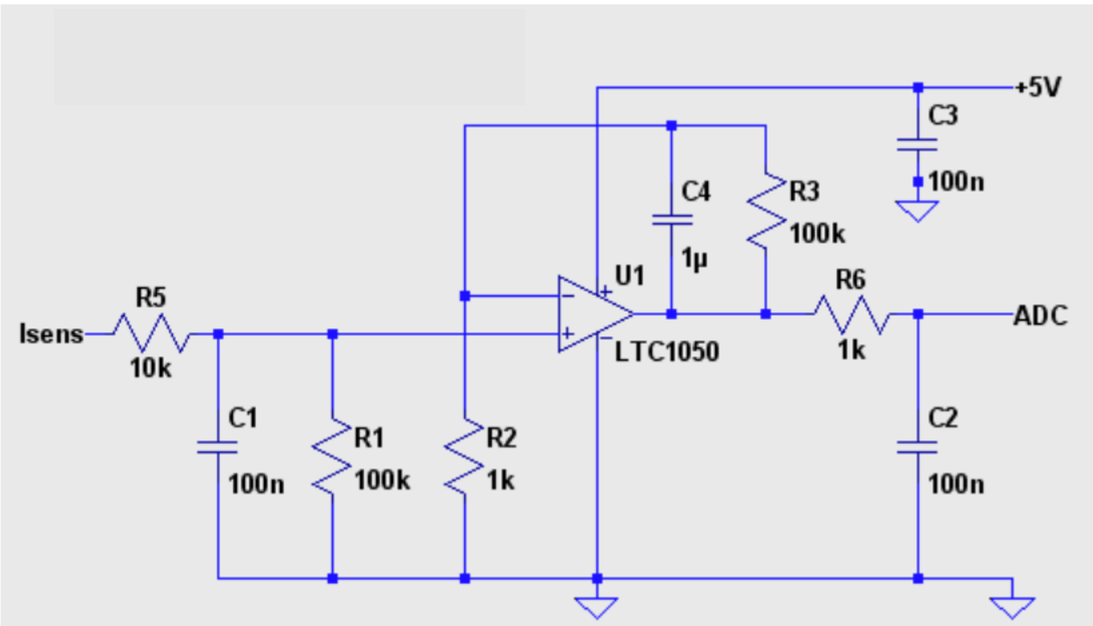

Figure 6. SPICE model

Above is a typical application of the sensor in an analogic circuit. The strain sensor is connected in series with the resistor R5 to avoid electrostatic discharges in the amplifier. R5, C1 and R1 form filters to reduce both voltage and current noises. The outcoming tension is amplified by a LTC1050 operational amplifier before being filtered by a RC filter (low pass).