by Matthieu Charnay, Alexis Briens

Low tech graphite-based strain gauge

1- General features

- Affordable
- Low electric consumption
- Easy to use
- Easily replaceable
- Eco-friendly

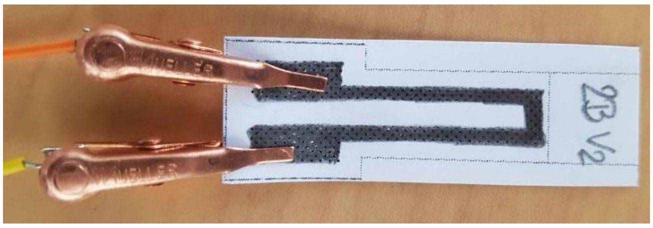


Figure 1 : Strain gauge.

2- Description

This graphite-based strain gauge is composed of a thin graphite coating on paper, acting as a flexible surface. The graphite coating's electrical conductivity depends on the paper's deformation. As such, a resistivity measurement gives access to the paper's current deformation. Its main use is to measure a given sample deformation, this may be done by attaching the sensor directly on it.

At the microscopic scale, the graphite coating is composed of a multitude of isolated carbon aggregates. The electrical conductivity of such a structure depends on the average space between those aggregates. Spreading them apart increases the resistance, while bringing them closer together lowers it. Applying a compressive force will decrease its resistivity, while applying a tensile force will increase it.

This device was developed in a low-tech spirit. Its materials are very affordable and widely accessible, and its production is effortless. It may be built in any environment by using a simple piece of paper and a pencil; the most expensive material needed is metal, used for the pins.

This strain gauge's goal is to give access to low-tech and low-price technology to individuals and organizations whose resources are strictly limited. Its fragile nature limits its use to controlled environments, and reduce its "real" usages.

3-Pins description

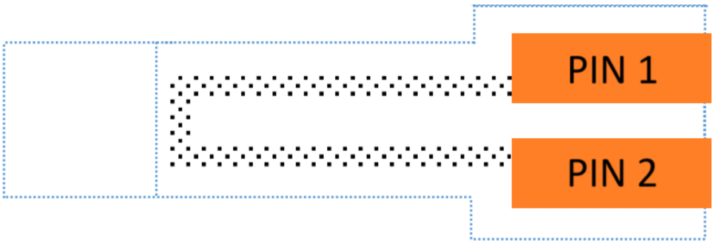


Figure 2 : Strain gauge with pins.

Pin	Signal
1	+5V
2	Analog output

Both pins are invertible.

4- Dimensions

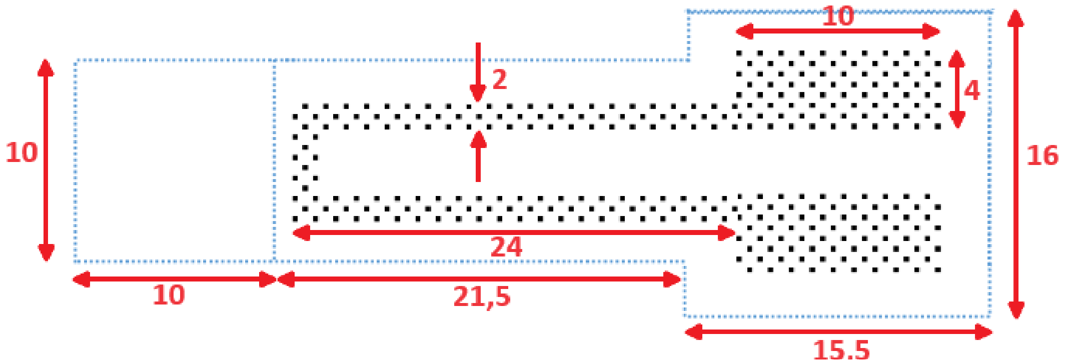


Figure 3 : Strain gauge pattern. All units are in millimeters.

5- Specifications

Type	Strain gauge
Sensor type	Passive
Materials	• Copper clips • Paper • Graphite coating
Power supply requirement	+5V
Nature of output signal	Analog
Measurand	Voltage
Typical application	Deformation measurement

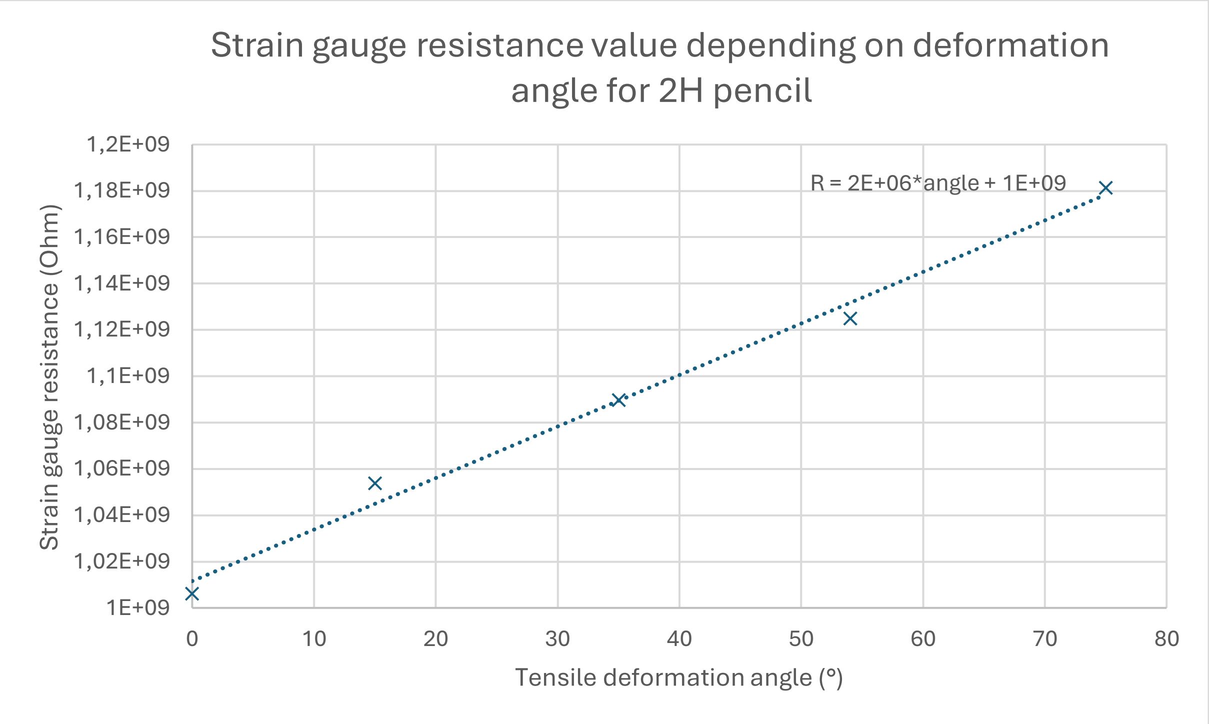
6- Standard use condition

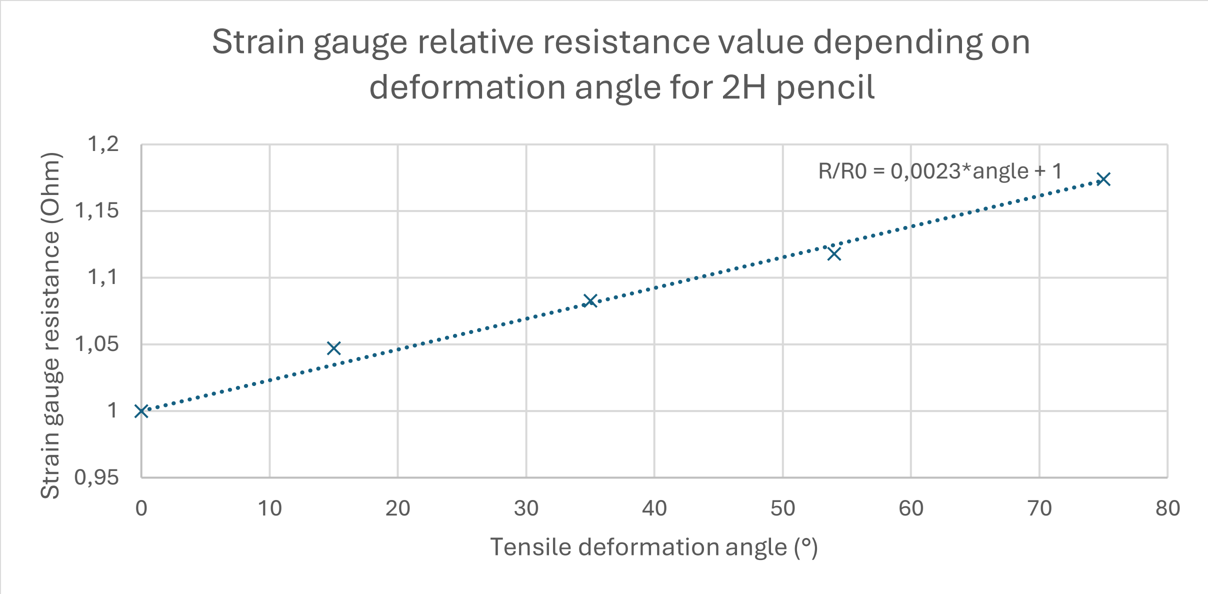
	Unit	Typical value
Temperature	°C	20±5
Humidity	%	60±5
Air quality	$\%N_2/O_2$	80/20

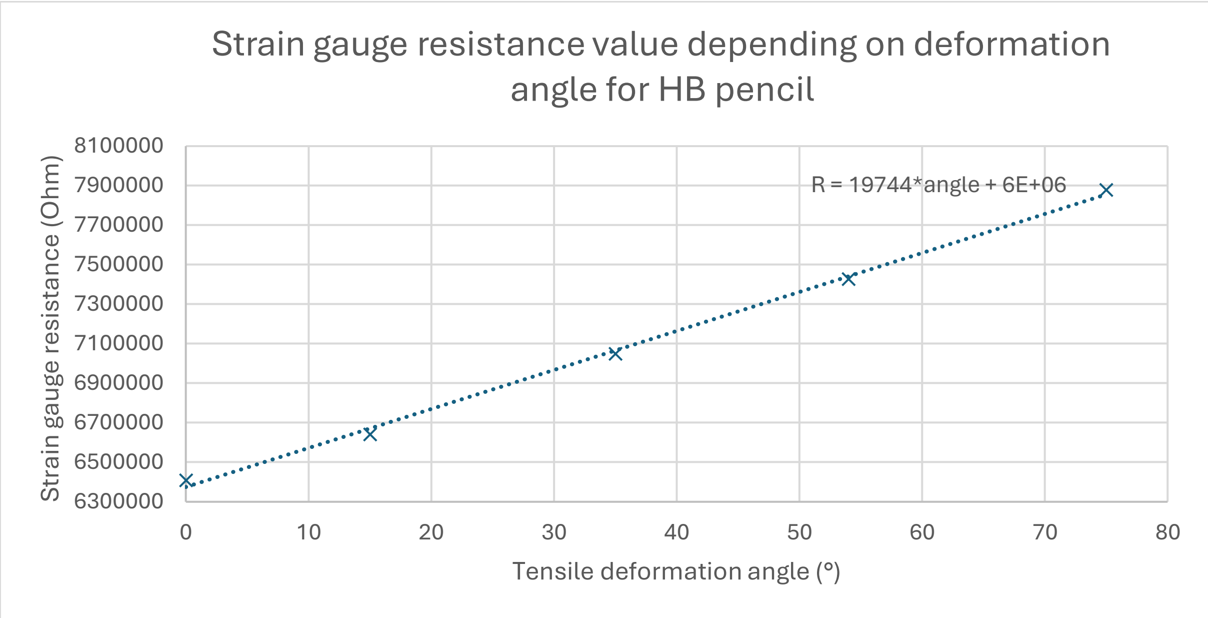
7- Electrical characteristics

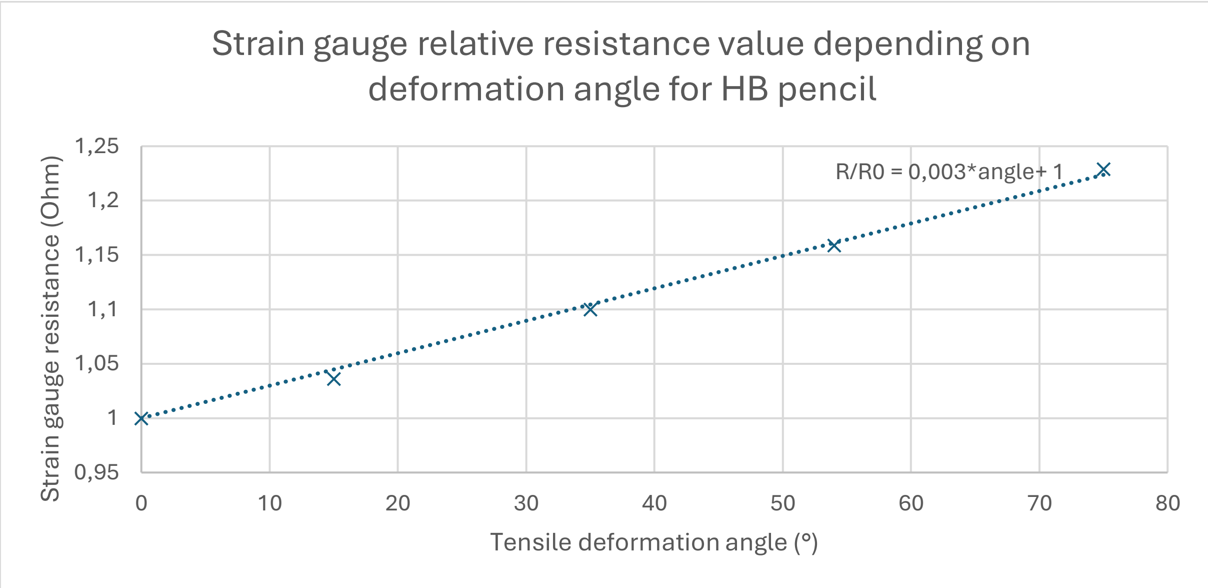
Tensile deformation electrical characteristics

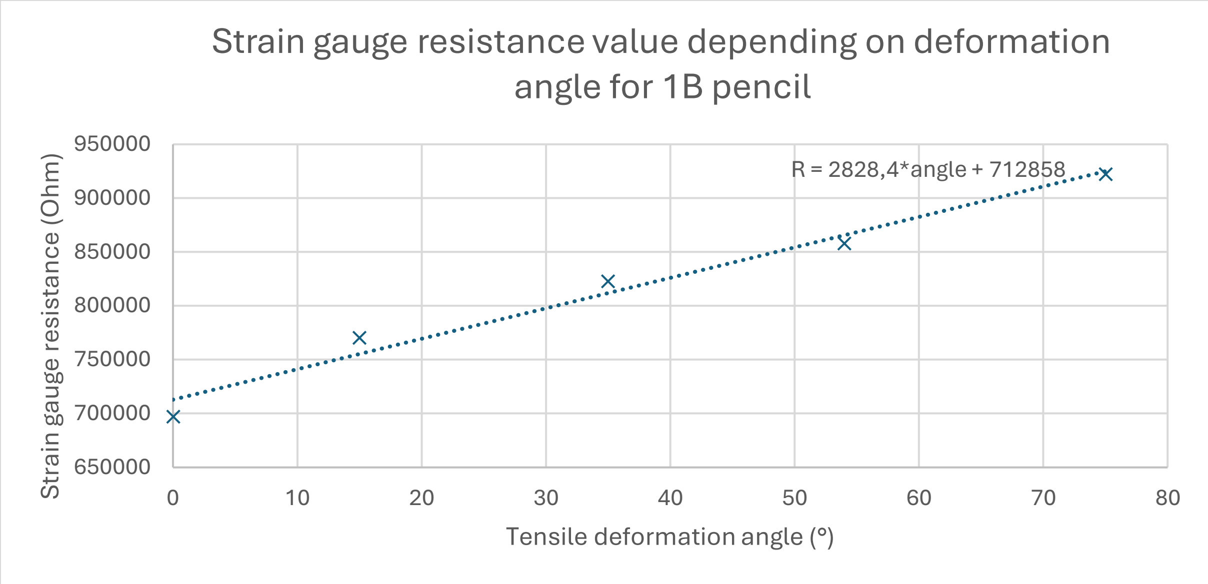
Graphite coating	Unit	Value		
		Min	Typical	Max
2H	GΩ	1	1.1	1.2
HB	MΩ	6.4	7.2	8
1B	MΩ	0.65	0.8	0.95
2B	MΩ	0.95	1.1	1.2

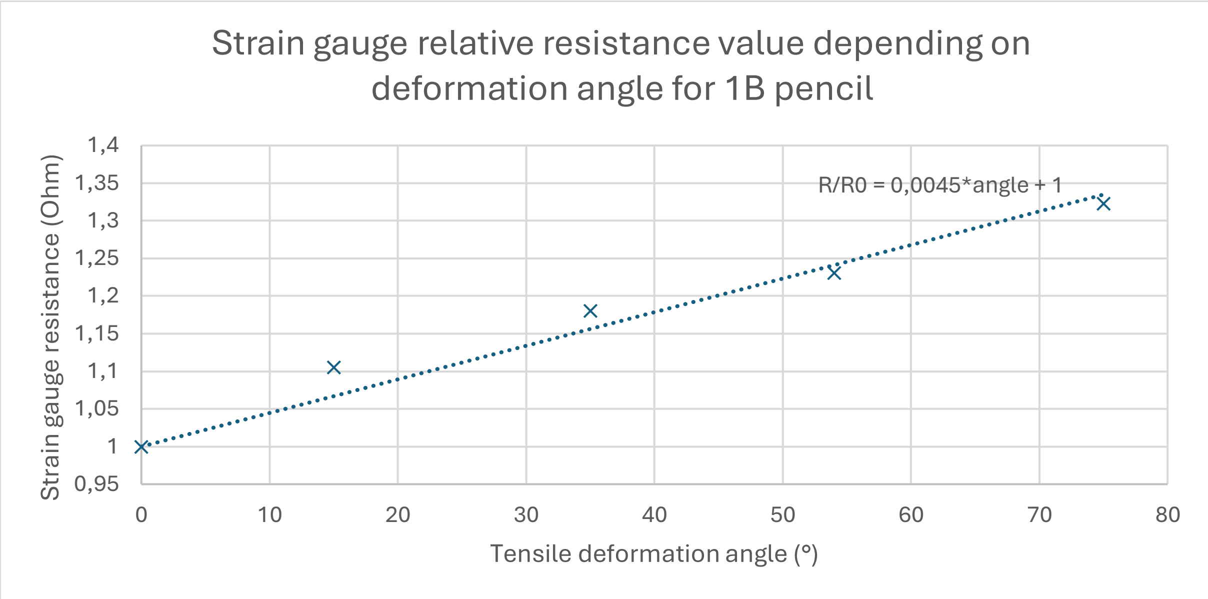


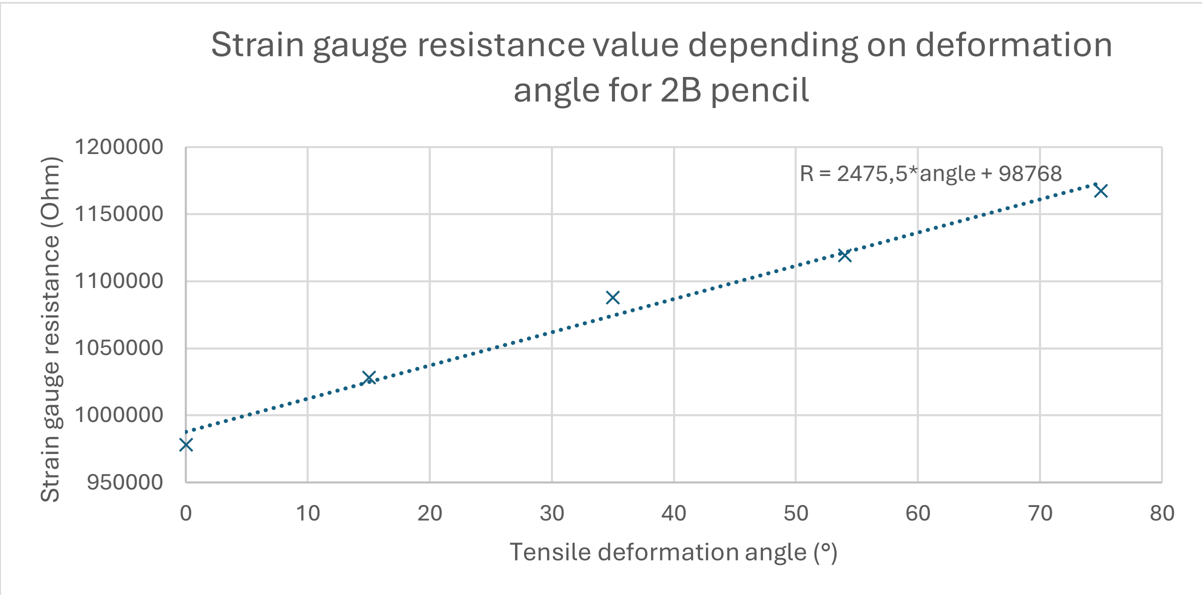

Strain gauge relative resistance value depending on deformation angle for 2H pencil
R/R0 = 0,0023*angle + 1
Strain gauge resistance (Ohm)
1,2
1,15
1,1
1,05
1
0,95
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)

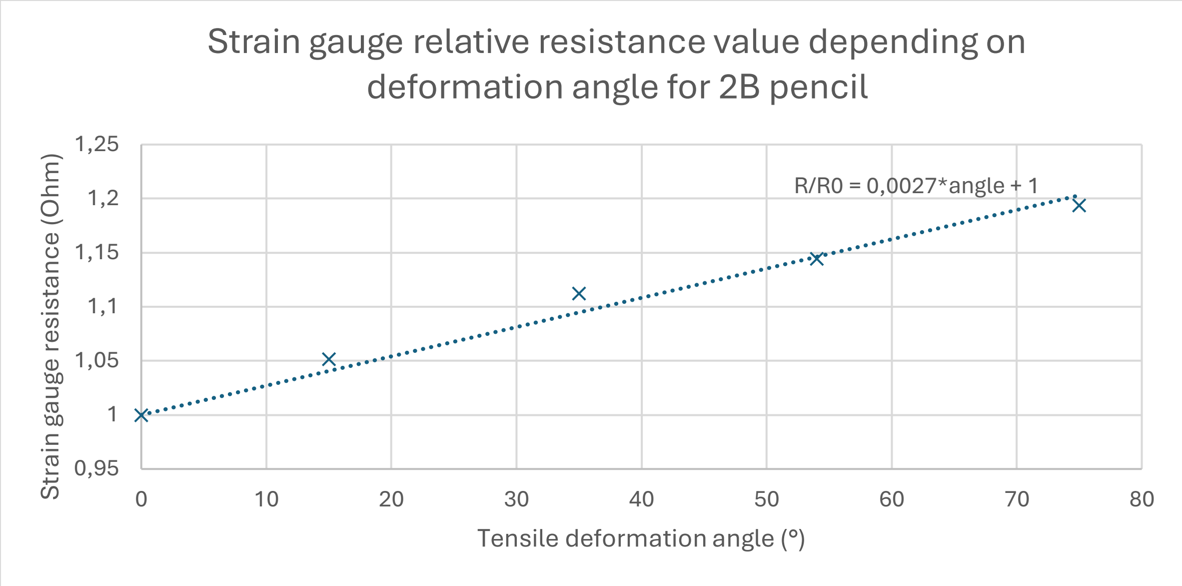

Strain gauge resistance value depending on deformation angle for HB pencil
R = 19744*angle + 6E+06
Strain gauge resistance (Ohm)
8100000
7900000
7700000
7500000
7300000
7100000
6900000
6700000
6500000
6300000
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)


Strain gauge relative resistance value depending on deformation angle for HB pencil
R/R0 = 0,003*angle+ 1
Strain gauge resistance (Ohm)
1,25
1,2
1,15
1,1
1,05
1
0,95
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)


Strain gauge resistance value depending on deformation angle for 1B pencil
R = 2828,4*angle + 712858
Strain gauge resistance (Ohm)
950000
900000
850000
800000
750000
700000
650000
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)


Strain gauge relative resistance value depending on deformation angle for 1B pencil
R/R0 = 0,0045*angle + 1
Strain gauge resistance (Ohm)
1,4
1,35
1,3
1,25
1,2
1,15
1,1
1,05
1
0,95
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)


Strain gauge resistance value depending on deformation angle for 2B pencil
R = 2475,5*angle + 98768
Strain gauge resistance (Ohm)
1200000
1150000
1100000
1050000
1000000
950000
0
10
20
30
40
50
60
70
80
Tensile deformation angle (°)



8-Typical application

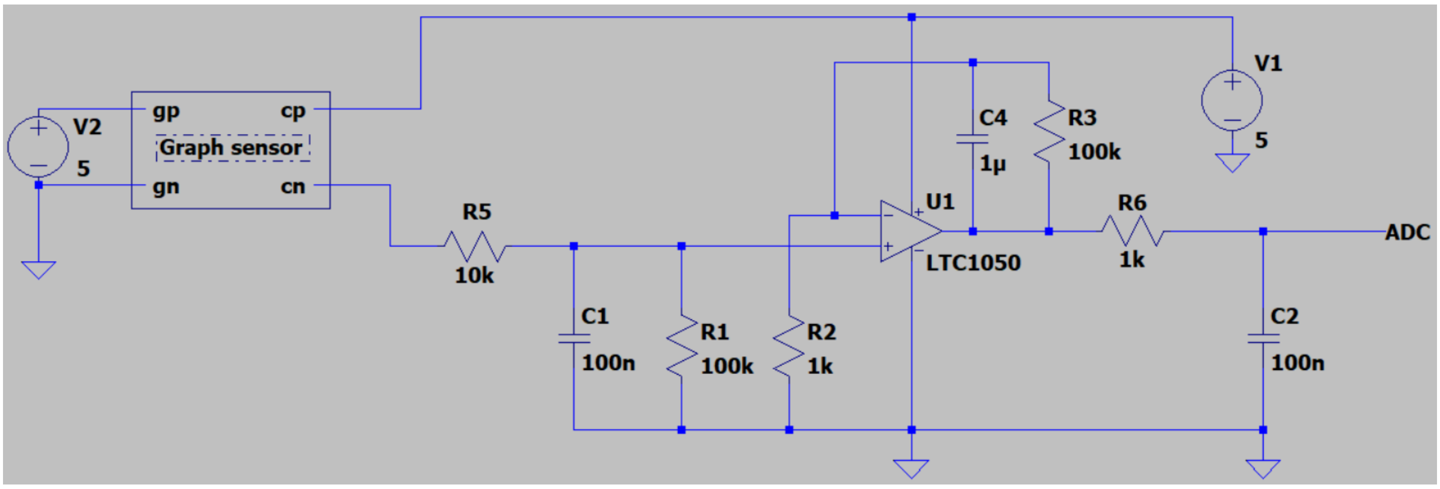


Figure 4 : Transimpedance amplifier circuit.

Above is a typical application of the sensor in a transimpedance amplifier circuit with filter stages. The output tension is amplified by a LTC1050 operational amplifier. The tension may then be connected to a 5V ADC reader such as in an Arduino input. At low frequencies, we may convert the voltage value into the resistance of the graphite sensor with the following formula:

$$R_c = (1 + \frac{R_3}{R_2}) \times R_1 \times \frac{V_{cc}}{V_{ADC}} - R_6 - R_{10}$$