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# EXPLORING THE ELECTRONIC APPLICATIONS OF GRAPHENE MIXED POLYMER FILMS USING LABVIEW

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## ABSTRACT

This work reports the possibility of using graphene based polymer film instead of solid state resistor in Wheatstone bridge circuit. Wheatstone bridge circuit containing graphene based polymer film as one of its resistor were connected to a microcontroller and interfaced with computer using LabVIEW. Output is obtained graphically to measure the voltage drop and the resistance across the graphene based polymer film. Simulated values of voltage drop and resistance across graphene based films were compared with both theoretical calculations and practical values.

**Keywords:** graphene, PVDF (Poly Vinyli Dene Fluoride), nano composites, wheatstone bridge, LabVIEW.

## 1. INTRODUCTION

19th century has seen a drastic improvement in the field of electronics and electrical engineering. Vacuum tubes were popular in those days but it occupied large area and consumes more power. In order to overcome these drawbacks, semi conducting electronics came into existence. The devices such as diode, resistors, transistors, BJT (Bipolar junction transistor), MOSFET (Metal oxide semiconductor field effect transistor) and CMOS (Complementary metal oxide semiconductor) were invented using semiconducting material which occupies less space and works more efficient when compared to vacuum tubes. These devices were used widely due to its unique advantages such as small size, low power consumption and mass production [1].

Later in 20th century integrated chips and microcontrollers were introduced for better performance and improved efficiency in electronics. Moore's law plays a major role for developing new electronic components and devices. In semiconductors, as the size of the components and devices is reduced to Nano regime there will be more losses due to factors such as leakage current. With the advent of advanced carbon materials like MWCNT's ( Multi-walled carbon Nano tubes) and graphene, researchers were able to develop novel devices which can execute operations at a faster rate and also consumes low power and dissipate less amount of heat [2]. Solid state resistors are broadly classified as fixed and variable resistors. Resistors are widely used for designing various applications in electronics.

In the present work one of the solid state resistor in Wheatstone bridge is replaced with the graphene mixed PVDF (poly vinylidene di fluoride) film based resistor. The advanced software used for hardware interface is "LabVIEW (Laboratory Virtual Instrument Engineering Workbench)". LabVIEW is mainly used for design system platforms and development environments in the visual programming language [3].

## 2. MATERIALS AND METHOD

Functionalized graphene with more than 95% purity were purchased commercially from Ad nano technologies Pvt Ltd. PVDF with 99% purity were purchased from Sigma Aldrich Pvt Ltd. Dimethyl formaldehyde and acetone were puchased commercially from kevin chemicals Pvt Ltd.

Graphene mixed PVDF (poly vinylidene di fluoride) films were prepared using solvent casting technique. The prepared films were homogeneous in nature and possess piezo resistive property [4]. Metal contacts were attached at both ends of the film and packaged into graphene mixed polymer based resistor.

## 3. SYSTEM DESIGN

A simple block diagram of Wheatstone bridge interfaced with the computer using LabVIEW software tool is shown in Figure-1. The three important tools for system design are (i) hardware, which is the external input for the system where the power is supplied to it. (ii) Software which can be useful for arranging the inputs graphically and the variations can also be represented. (iii) The interface is very important for connecting both hardware and software without any loss or damage to the circuit. All the three frames are to be maintained with caution for the better results and executions. [5]

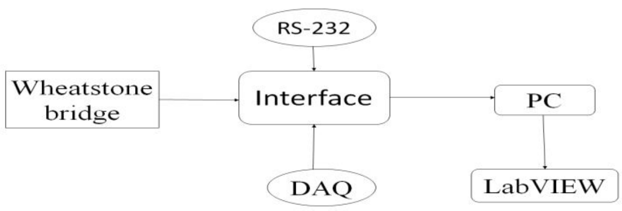


**Figure-1.** Block diagram of Wheatstone bridge circuit interfacing with LabVIEW.

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### 3.1 Hardware description

The hardware consist of the Wheatstone bridge circuit which is basically designed using four resistors namely R1, R2, R3, R4. Here circuit design is modified by replacing the fourth resistor (R4) with graphene mixed polymer film based resistor and the values are given to the A/D converter and these values are given to the microcontroller through one of the port. These values are then fetched and given to other ports such as LCD display, and RS-232. From LCD (Liquid crystal display) the values were displayed. RS-232 is a communication serial port which is used to transmit the data directly from the hardware to the computer, where a graphical outputs are displayed using software called LabVIEW [6].

### 3.2 Interfacing

Circuit interfacing is possible using serial cable RS-232 as communication port to the software. For any type of the devices the specific drivers have to be installed for the functioning of the hardware[7].

### 3.3 Software description

LabVIEW is the user interface (front panel) development system, as the programs / subroutines known as Virtual Instruments (VIs). Every VI consist of three main components namely block diagram that represents the blocks, front panel which is used for indicators and controllers (including connector panel) are used to interlink the other VI blocks.

The front panel consists of controls as inputs and indicators as outputs, these results are based on the inputs provided. All the object in the front panel will appear on the back panel as outputs. Benefits of using LabVIEW is to do interface with any type of the hardware devices [8].

Figure-2 (a) shows the normal Wheatstone bridge circuit and Figure-2 (b) shows the same circuit with one of the resistor being replaced with the graphene based polymer film[9]. Figure-3 shows the virtual blocks in the LabVIEW and gives the details of how the data is converted graphically and Figure-4 represents the graphical output of voltage drop and resistance value of graphene mixed polymer film based resistor in LabVIEW [10].

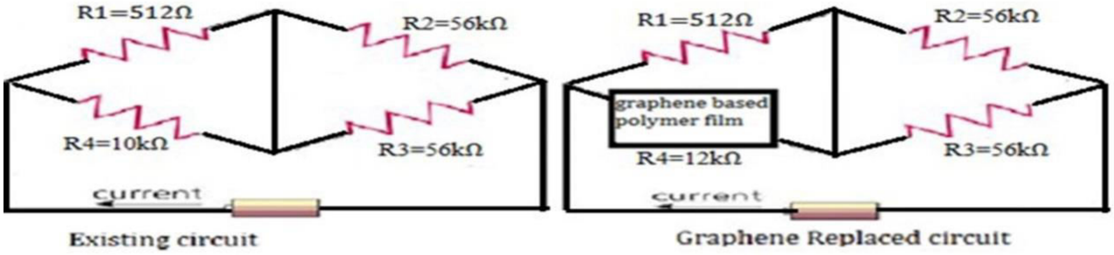


**Figure-2.** Wheatstone bridge diagram (a) with resistor and (b) with graphene based film.

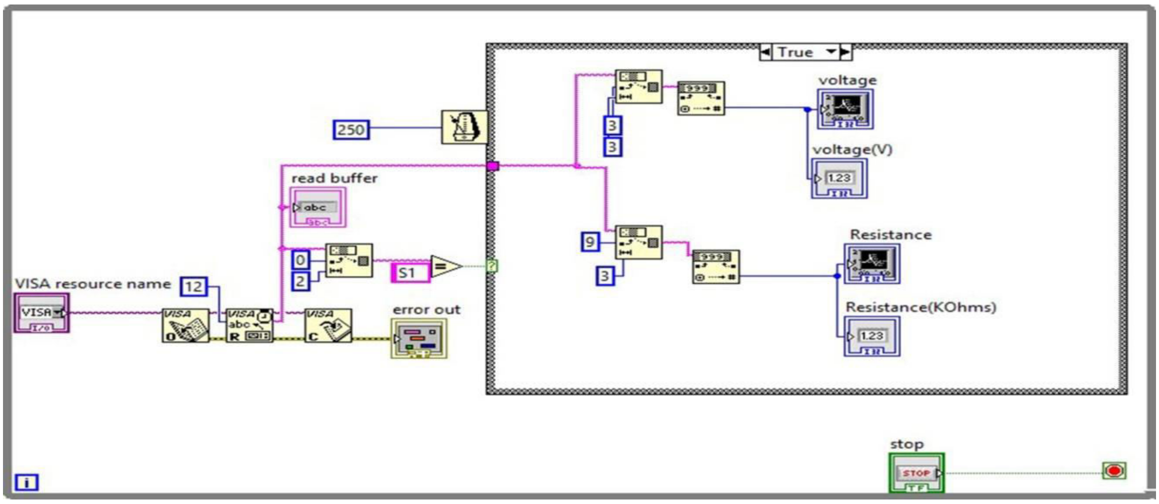


**Figure-3.** Front panel block of LabVIEW showing various basic blocks.

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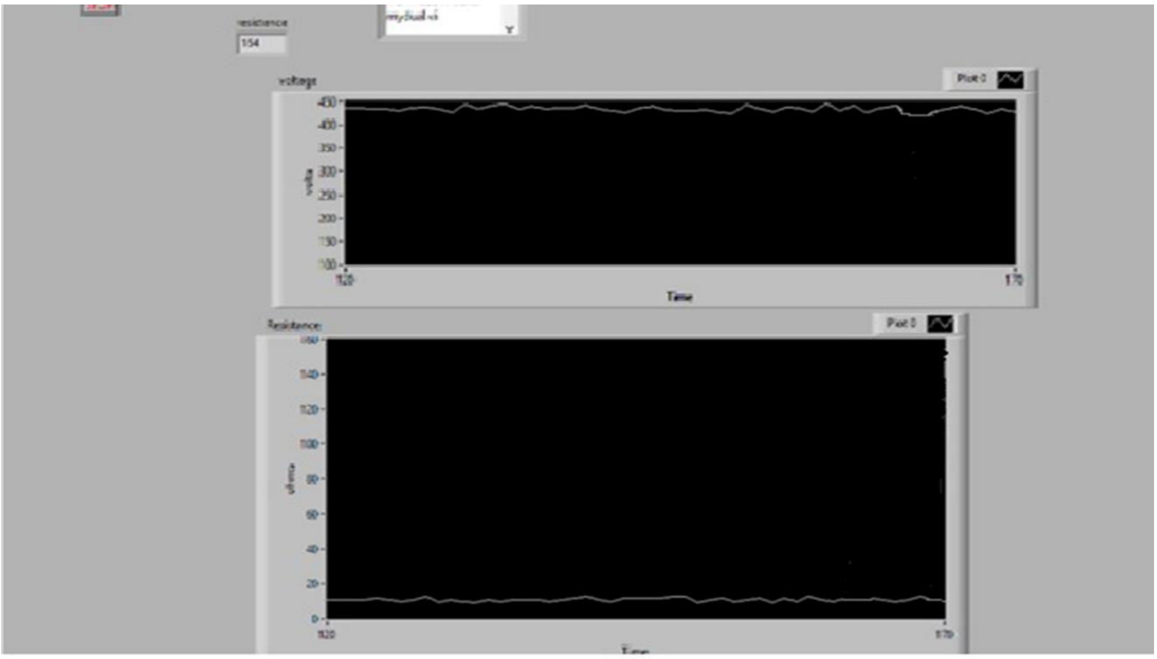


**Figure-4.** Resistance and output voltages were shown graphically in LabVIEW.

## 4. RESULTS AND DISCUSSIONS

Figure-5 shows the circuit consist of the solid state resistor where resistance and output voltage is plotted graphically using LabVIEW and displayed in the screen. In Figure-6 the solid state resistor is replaced with the graphene based polymer film and output is measured by noting down the value displayed in LCD. Output obtained from LCD display, simulated value using LabVIEW tool and theoretical output were compared and tabulated as shown in Table 1, 2 and 3.

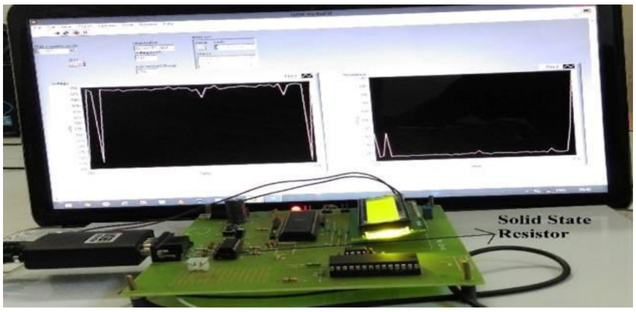


**Figure-5.** System design circuit board consist of the solid state resistor.

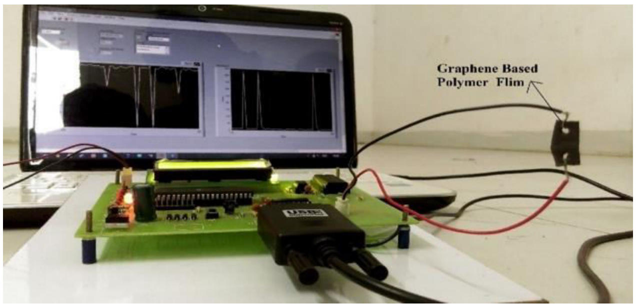


**Figure-6.** System design circuit board containing Graphene mixed polymer based resistor instead of solid state resistor.

In Table-1 first column gives the measured resistance values of the solid state resistor using colour code technique and second column gives the resistance value of the solid state resistance displayed using LCD (Liquid crystal display). The last column gives the measured values of the voltages across the resistor using voltmeter. In Table-2 first column gives the simulated values of the resistance and second column gives the obtained resistance value of the solid state resistance displayed using LabVIEW. The last column gives the obtained voltages across the resistor using LabVIEW tool. Table-3 gives the theoretical values of the resistance which is replaced with graphene mixed film in Wheatstone bridge circuit was calculated using the standard formula of circuit equivalent.

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**Table-1.** Represent the practical values of the resistance.

| **Practical values** (LCD) | | |
|---|---|---|
| **Resistance** (kΩ) **Using colour code technique** | **Obtained resistance** (kΩ) **using LCD** | **Obtained voltage** (v) **using LCD** |
| 1.5 | 0.8 | 4.48±0.05 |
| 5 | 9 | 4.42±0.05 |
| 10 | 13 | 4.23±0.05 |
| 21 | 25 | 3.6±0.05 |
| 50 | 43 | 2.62±0.05 |
| Graphene mixed Polymer (around 12kΩ) | 15 | 4.15±0.05 |

**Table-2.** Simulated values of the resistance using LabVIEW.

| **Simulated values** (LabVIEW) | | |
|---|---|---|
| **Resistance** (kΩ) | **Obtained resistance** (kΩ) | **Obtained voltage** (v) |
| 1.5 | 0.8 | 4.48±0.05 |
| 5 | 9 | 4.42±0.05 |
| 10 | 13 | 4.23±0.05 |
| 21 | 25 | 3.6±0.05 |
| 50 | 43 | 2.62±0.05 |
| Graphene mixed Polymer based film (around 12kΩ) | 15 | 4.15±0.05 |

**Table-3.** Theoretical values of the resistance (using theoretical calculation).

| **Theoretical values** (calculated) | | |
|---|---|---|
| **Resistance** (kΩ) | **Obtained resistance** (kΩ) | **Obtained voltage** (v) |
| 1.5 | 0.8 | 4.48 |
| 5 | 9 | 4.42 |
| 10 | 13 | 4.23 |
| 21 | 25 | 3.54 |
| 50 | 43 | 2.59 |
| Graphene mixed Polymer based film (around 12kΩ) | 15 | 4.15 |

Figure-7(a) shows the Wheatstone bridge circuit with 5v power supply in which one of the resistor R4 used is made up of graphene based polymer film and Figure-7 (b) shows the simplified circuit of the Wheatstone bridge. From the Figure-8(a) the equivalent resistance $(\mathrm{R}) = (\mathrm{R5} * \mathrm{R6}) / (\mathrm{R5} + \mathrm{R6})$ by substituting the values of resistance the equivalent resistance (R) is calculated as $R = 30.86K\Omega$.

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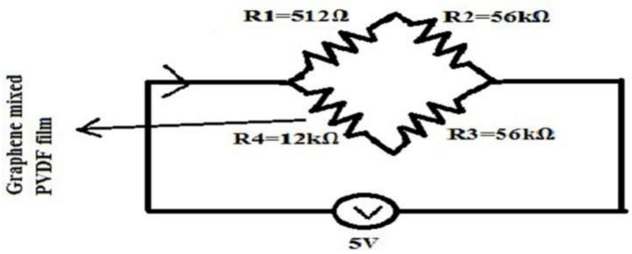


**Figure-7(a).** Wheatstone bridge circuit.

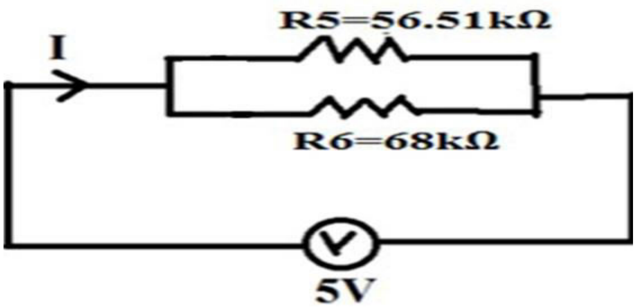


**Figure-7(b).** Simplified circuit.

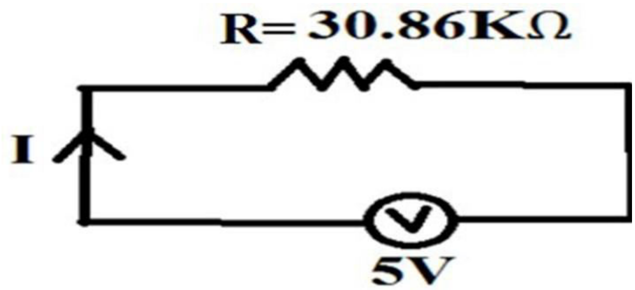


**Figure-8(a).** Circuit to calculate the current (in amperes).

From Figure-8(b), the ohm's law for the total current is calculated by using the current (I) $= V/R$ then current is equal to $I = 0.16A$.From the Figure-8 (b) the current through the resistance R5 is given by the formula $I1 = (I * R6)/(R5 + R6)$ by substituting the values the current across the resistor R5, $I1 = 0.073A$. From this current through the R6 resistor is given as follows, $I2 = I - I1$. Hence $I2 = 0.16 - 0.0725$ thus current $(I2) = 0.088A$.The voltage across the each resistor is calculated $V1 = I1 * R5$ by substituting the values, voltage obtained $V1 = 4.964V$. Then voltage across the other resistor (R6) can be calculated by$V2 = I2 * R6$. Hence the voltage is$V2 = 4.972V$.

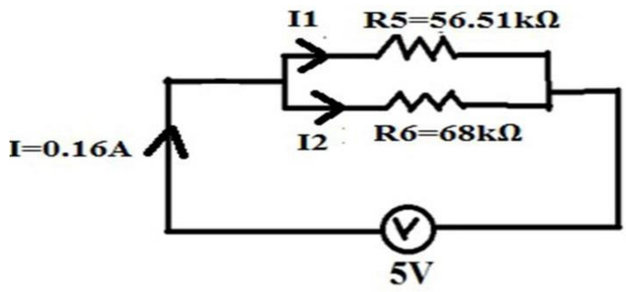


**Figure-8(b).** Circuit to find the internal currents I1, I2 (in Amperes).

From the Figure-8(c) voltage $V11$ is calculated by using the formula $V11 = (V1 * R4)/(R4 + R3)$ hence by substituting the value$V11 = (4.96)(12)/68$. The final voltage across graphene PVDF film based resistor is $V11 = 0.87V$ (voltage across graphene mixed PVDF polymer film).The remaining voltage after voltage drop at graphene =4.13V.

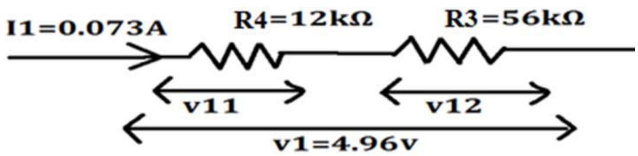


**Figure-8(c).** The voltages V11=0.87V and V12=4.09V (approx.)

Table-4 gives the details of current and voltage across the two resistors R3 and R4 in a Wheatstone bridge circuit which is shown in Figure-7(b) in which one of the resistor is graphene based polymer film. From the three Tables (1-3) the value of the voltage and resistance of the resistance are calculated as equal (0.87V). Theoretical calculations also matches with practical and simulated results.

**Table-4.** Resistance, current and voltage values of the Wheatstone bridge circuit.

| **Resistance** (Kohms) | **Current** (Amp) | **Voltage** (volts) |
|---|---|---|
| R4=12kΩ | 0.07A | V11=0.87V |
| R3=56kΩ | 0.07A | V12=4.09V |

Graphene mixed PVDF based resistor films are piezoresistve in nature. Tensile test is carried out by applying stress across the graphene mixed PVDF film based resistor in the Wheatstone bridge circuit manually and its resistance and voltage variations is obtained graphically as shown in Figure-9. Since resistance value varies with respect to stress applied, it can also be used as the variable resistor in electronics.

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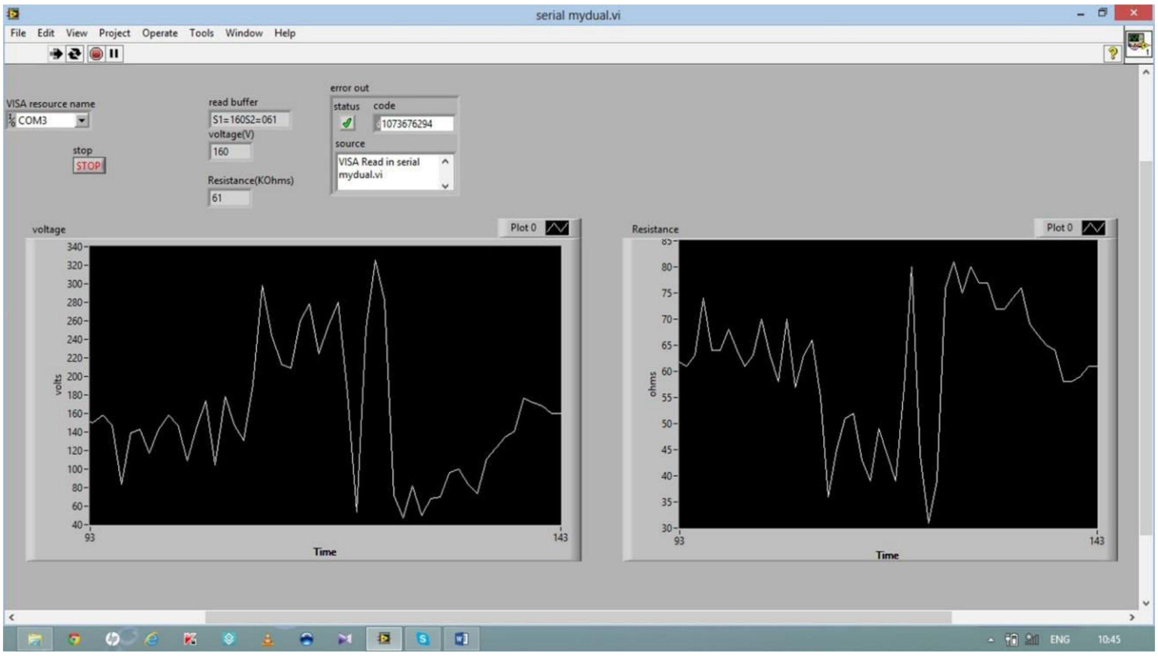


**Figure-9.** Variation of resistance and voltage across graphene mixed PVDF film based resistor undergoing tensile test.

## 5. CONCLUSIONS

The possibility of replacing solid state resistors with the graphene mixed polymer film based resistor in any of the electrical and electronic devices is explored. Graphene mixed polymer film based resistor is used successfully instead of solid state resistor. Practical output obtained is verified theoretically and confirmed with the simulated values obtained using LabVIEW. By altering the size, thickness and filler content used in the preparation of graphene mixed PVDF film the resistance value can be varied. It can also be used as potentiometers in all electronic circuits.

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