Interface application development for a Keithley 6517B electrometer using LabVIEW programming to measure resistance and temperature as functions of time

Internship report submitted in partial fulfilment of the requirements for the degree of Bachelor of Science in Applied Physics and Electronics

by
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Declaration

I, hereby, declare that the internship report titled "Interface application development for a Keithley 6517B electrometer using LabVIEW programming to measure resistance and temperature as functions of time" is based on self-derived results. This paper, has not been previously submitted for any degree.

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Abstract

This internship was set to demonstrate a basic understanding of the Keithley 6517B electrometer and LabVIEW programming. Using LabVIEW software, a Keithley 6517B Electrometer was controlled so as to supply a voltage to a 1 MΩ fixed resistor while also measuring its temperature and resistance. A resistance vs time graph and temperature vs time graph were plotted using the software. For a duration of approximately 320 seconds the temperature increased from 7.5°C to 27.5°C while during that same period of time the resistance dropped from 1.0004MΩ to 0.9816MΩ.

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Introduction

The initial plan for this internship was to go to the Atomic Energy Research Establishment (AERE) in Savar [1] and use the MJB4 Mask Aligner for photolithography and the Keithley 6517B electrometer to measure the transportation property of a conductive polymer. After a long trial and error process, it was possible to initialize the MJB4 Mask Aligner but it was still not providing the required results. Since getting the mask aligner to properly function was going to take too long to allow this paper to be finished on time, the decision was made to only use the electrometer. After BRAC University [2] purchased its own Keithley 6517B Electrometer, the visits to AERE more or less ended and the decision was made to use the electrometer to make resistance and temperature measurements.

The Keithley 6517B electrometer [3] is a $6^{1}/_{2}$-digit electrometer capable of measuring extremely high resistances in the $10^{15}\Omega$ range while measuring currents as low as 10aA. It also has an in-built voltage source (-100V to 100V at 10mA) and can measure temperatures from -25°C to 150°C.

One of the many benefits to using this electrometer is its high resistivity measurements [4]. Many test applications require measuring high levels of resistivity (surface or volume) of materials. The conventional method of making these measurements is to apply a sufficiently large voltage to a sample, measure the current that flows through the sample, then calculate the resistance using Ohm's Law (R=V/I). While high resistance materials and devices produce very small currents that are difficult to measure accurately, Keithley electrometers and picoammeters are used successfully for such measurements. Even with high quality instrumentation, inherent background currents in the material can make these measurements difficult to perform accurately. Insulating materials, polymers, and plastics typically exhibit background currents due to piezoelectric effects, capacitive elements charged by static electricity, and polarization effects. These background currents can often compare to or even exceed the current stimulated by the applied voltage. In these cases, the result is often unstable, providing inaccurate resistance or resistivity readings or even erroneous negative values.

The 6517B solves this using the Alternating Polarity Method, which greatly reduces the effect of any background currents in the sample [4]. First and second order drifts of the background currents are also cancelled out. The Alternating Polarity Method applies a voltage of positive polarity, then the current is measured after a specified delay (Measure Time). Next, the polarity is reversed and the current measured again, using the same delay. This process is repeated continuously, and the resistance is calculated based on a weighted average of the four most recent current measurements. This method typically produces a highly repeatable, accurate measurement of resistance (or resistivity) by the seventh reversal on most materials (i.e., by discarding the first three readings).

The 6517B's built-in voltage source simplifies determining the relationship between an insulator's resistivity and the level of source voltage used. It is well-suited for capacitor leakage and insulation resistance measurements, tests of the surface insulation resistance of printed circuit boards, voltage coefficient testing of resistors, and diode leakage characterization.

Two other features to consider are the humidity and temperature measurements that the device can make [4]. This is important since these parameters can influence the resistivity values of materials significantly. To help make accurate comparisons of readings acquired under varying conditions, the 6517B offers a built-in type K thermocouple and an optional 6517-RH Relative Humidity Probe. A built-in 50,000 reading data storage buffer allows recording and recalling measurements stamped with the time of the measurement, the temperature, and the relative humidity.

The 6517B has a number of internal test sequences that assists in easily setting up and performing a number of tests [4]. Device characterization sequences include diode leakage current measurement, capacitor leakage current measurement, cable insulation resistance measurement, and resistor voltage coefficient measurement. Resistivity and resistance tests include volume resistivity, surface resistivity, and surface insulation resistance testing. Parameters can be characterized as a function of voltage with the square wave and staircase test sequences. In addition to its built-in tests, the 6517B excels in low current, high impedance voltage, resistance, and charge measurements in areas of research such as physics, optics, and materials science. The electrometer's extremely low voltage burden makes it particularly valuable for use in solar cell characterization applications and its built-in voltage source and low current sensitivity make it an excellent solution for high resistance measurements of nanomaterials such as polymer-based nanowires, other nanomaterials, ceramics, dielectric films, and biomaterials. With its highly responsive measurements and DMM-like operation, the 6517B performs well in quality control, design engineering, and production test applications involving leakage current, breakdown, and resistance testing. Volume and surface resistivity measurements on non-conductive materials are particularly enhanced by the 6517B's voltage reversal method. The 6517B is also excellent for electrochemistry applications such as high impedance, ion-selective electrodes and pH measurements, conductivity cells, and potentiometry.

LabVIEW

The best way to use the electrometer is in an automated fashion so as to minimize human error and that can be done using the software LabVIEW [5]. LabVIEW codes are referred to as virtual instruments (VIs) and codes within codes are called subVIs. Execution flow is determined by the structure of a graphical block diagram (the LabVIEW-source code) on which the programmer connects different function-nodes by drawing wires. This is called graphical programming or G.

LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle [5]. Each VI has three components: a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. The front panel consists of controls and indicators. Controls act as inputs: they allow a user to supply information to the VI. Indicators are outputs: they indicate, or display, the results based on the inputs given to the VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. Additionally, the back panel contains structures and functions which perform operations on controls and supply data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Controls, indicators, structures, and functions can all be referred to as nodes. Wires connect the nodes to each other, e.g., two controls and an indicator can be wired to the multiplication function so that the indicator displays the product of the two controls. Thus a virtual instrument can be run as either a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

Even nonprogrammers can build programs using the graphical approach (G) by dragging and dropping virtual representations of lab equipment with which they are already familiar. The LabVIEW programming environment, with the included examples and documentation, simplifies the process of creating small applications. Although this is certainly advantageous, there is also a downside of underestimating the expertise needed for high-quality G programming. For complex algorithms or large-scale code, it is important that a programmer possess an extensive knowledge of the special LabVIEW syntax and the topology of its memory management. The most advanced LabVIEW development systems offer the ability to build stand-alone applications. Furthermore, it is possible to create distributed applications, which communicate by a client–server model, and are thus easier to implement due to the inherently parallel nature of G.

Procedure

Physical Configuration of electrometer

Figure 2.1 Keithley 6517B front panel

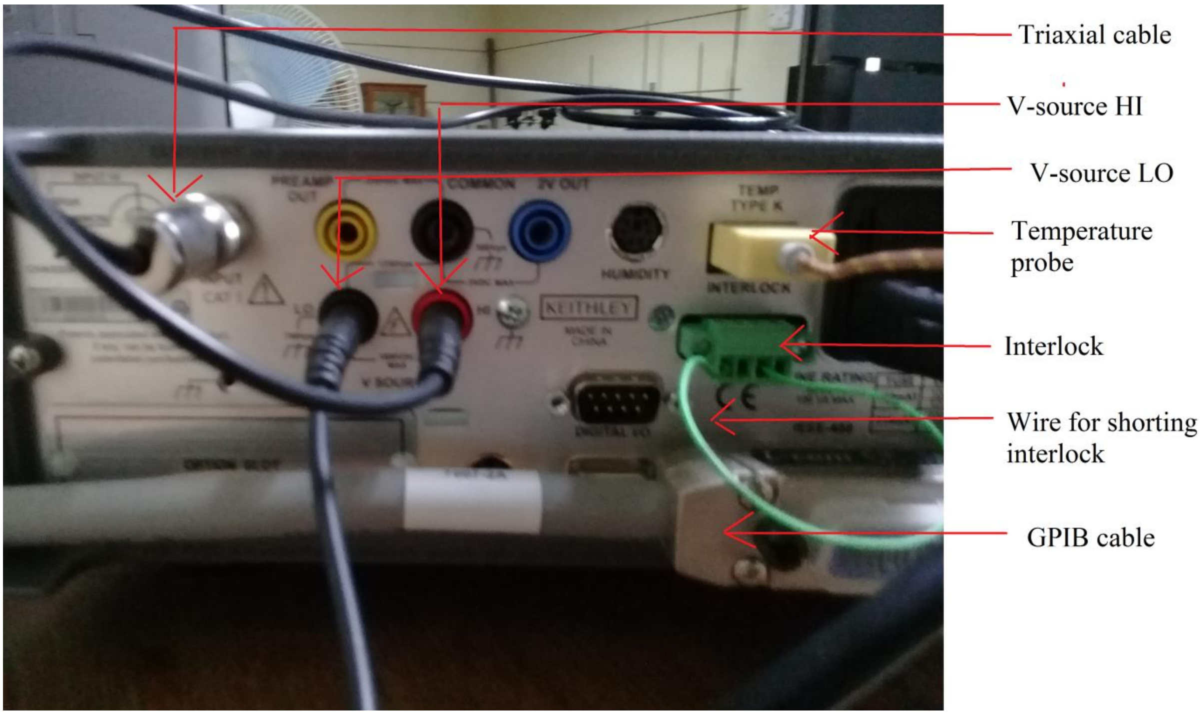

Figure 2.2 Keithley 6517B back panel connections

Before measuring temperature or resistance, some preparatory steps must be taken which are:

1. Shorting the interlock- Since the Keithley 6517B is capable of releasing some very high voltage values, a common precautionary measure is to use a test fixture which is a box with a wire running through it such that one end attaches to pin 1 of the interlock and the other end attaches to pin 3 and the circuit can only be completed if the lid is closed. Since a test fixture was not available, a wire had to be attached from pin 1 to pin 3of the interlock as shown in figure 2.2 to allow current flow. To ensure safety, low voltage values were used throughout the experiment.

2. Attaching one end of the GPIB cable to the appropriate area at the back of the device and the other end to a CPU. This will allow communication between the computer and the electrometer.

3. Installing the device drivers from the CD supplied with the electrometer.

4. Installing LabVIEW and its appropriate drivers.

Temperature measurement configuration

In order to enable temperature readings, we must press the menu button on the front panel (shown in figure 2.1) then using the horizontal arrows go the ‘General’ then ‘A/D Controls’ and then ‘Data Stamp’ where we can change the ON/OFF status of the ‘Temperature’ using the vertical arrows. After selecting ON then pressing Enter, we have enabled temperature readings. This configuration can be saved by going to ‘Menu’>’Savesetup’>’Save’. Of course none of these steps will lead to temperature readings unless the Keithley 6517-TP thermocouple bead probe is attached to the electrometer (shown in figure 2.2).

Resistance measurement configuration

A wire must be connected to V-source HI, another one to V-source LO and a triaxial cable must be connected all as shown in figure 2.2. The connections to the resistance being measured are shown in figure 2.3.

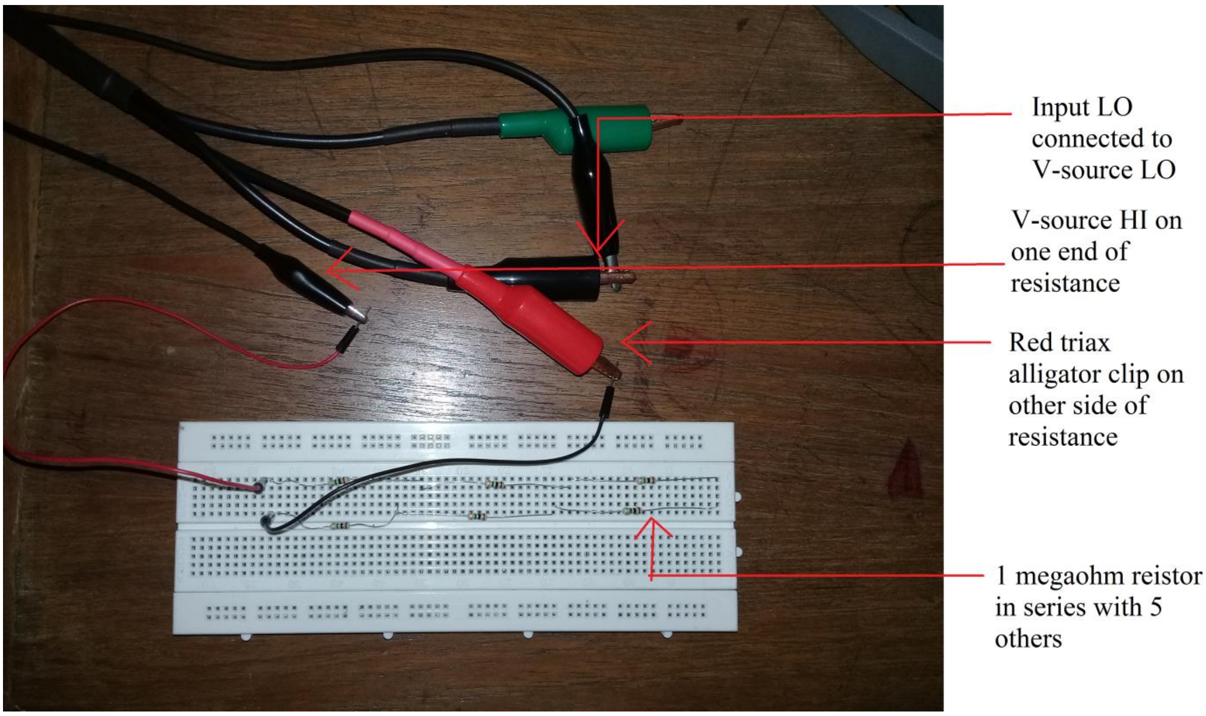

Figure 2.3 Resistance connections with electrometer

While the connections are being made according to the diagram i.e. V-source HI on one side of the resistance while Input HI on the other and Input LO and V-source LO connected to each other, the electrometer should be kept off for safety purposes.

LabVIEW programming

The block diagram of the LabVIEW program is shown in figure 2.4.

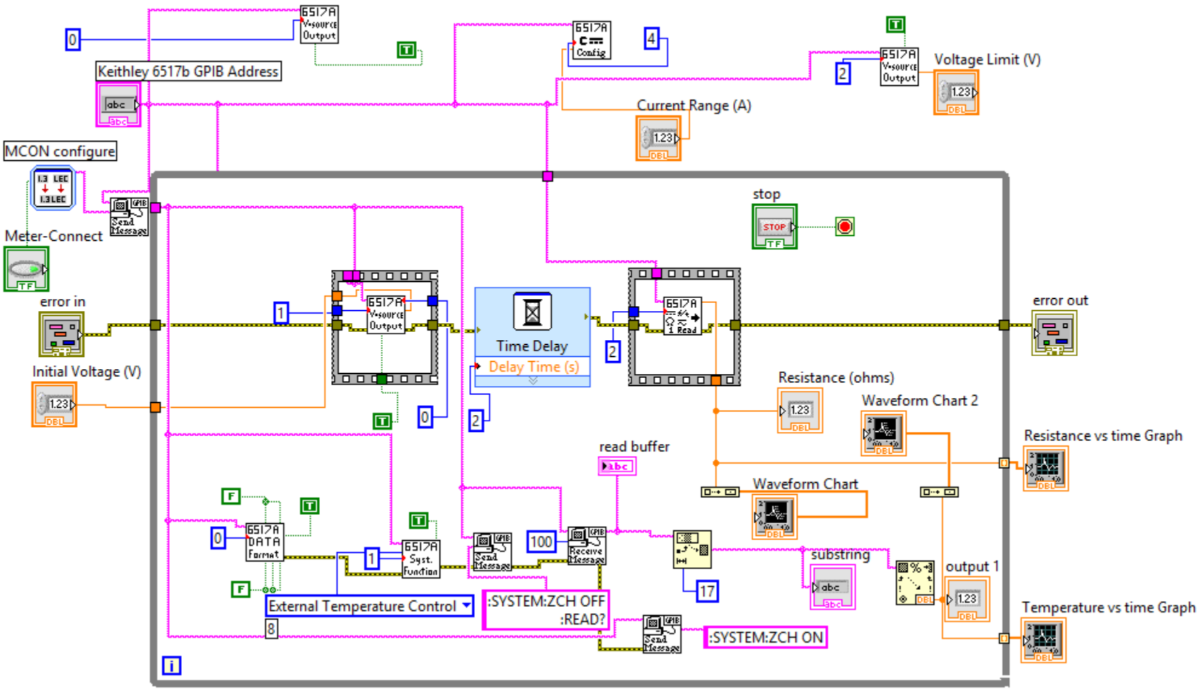

Figure 2.4 LabVIEW block diagram for temperature and resistance measurement as functions of time

The upper portion of the block diagram outside of the while loop (large grey perimeter) mainly consists of configurations for the voltage source as well as a place to input the GPIB address. The upper portion within the loop provides the value of the voltage source and also configures the resistance measurement. The lower portion within the loop configures the temperature measurement.

Full experimental setup

A 1MΩ resistor with one end connected to the V-source HI and the other end to the Input HI was placed on some ice covered in aluminium foil (shown in figure 2.5). The ice would cool it down while the foil would make sure that the wires do not come into contact with liquid water. The measuring end of the thermal probe was placed next to the resistor in order to get temperature readings.

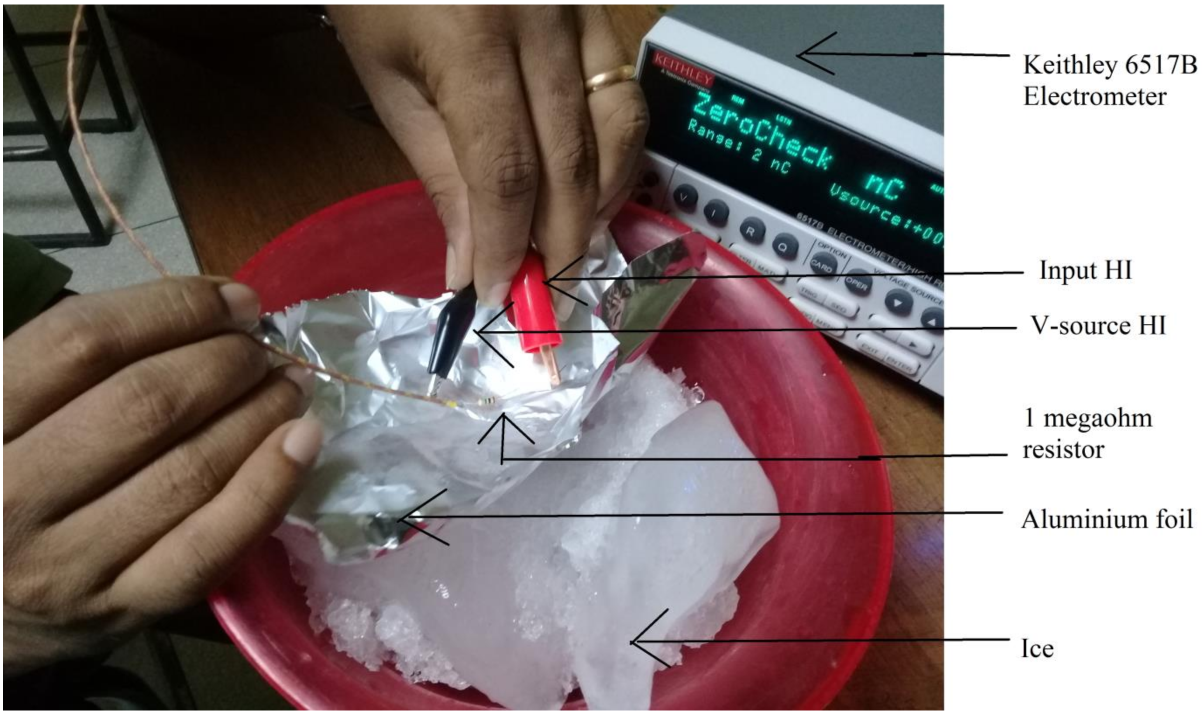

Figure 2.5 Full experimental setup

After everything is placed as shown in the figure, the LabVIEW program is run. The Input HI and V-source HI provide resistance data to the electrometer which then sends it to the LabVIEW program. At the same time the thermal probe provides the temperature data. In this way simultaneous resistance and temperature data is sent to the program until it is manually stopped. LabVIEW then uses this data to form a resistance vs time graph and a temperature vs time graph. Slowly, the resistor is moved away from the ice which allows the temperature to rise and using the corresponding resistance values, we can see the effect of temperature on resistance.

Results and Discussion

Temperature vs time data

Time/s	Temperature/ degrees celsius
0	0
10	10.1
20	7.8
30	7.9
40	7.6

50	8.3
60	7.7
70	7.6
80	8
90	13.8
100	17.6
110	20.6
120	22.3
130	23.1
140	23.7
150	24.4
160	25
170	25.5
180	25.7
190	26
200	25.9
210	26
220	26.3
230	26.7
240	26.7
250	27.1
260	27.1
270	26.9
280	26.9
290	29.3
300	27.5
310	27.4
320	27.1

Resistance vs time data

Time/s	Resistance/ohms
0	1.00E+06
10	1.00E+06
20	1.00E+06
30	1.00E+06
40	999052
50	996838
60	999382
70	999572
80	996975
90	991998
100	988866
110	986730

120	985927
130	985198
140	984428
150	983599
160	983081
170	982443
180	982828
190	983058
200	982922
210	982452
220	982192
230	982150
240	981898
250	981856
260	981800
270	982201
280	981817
290	981272
300	981750
310	981168
320	981729

Graphical comparison

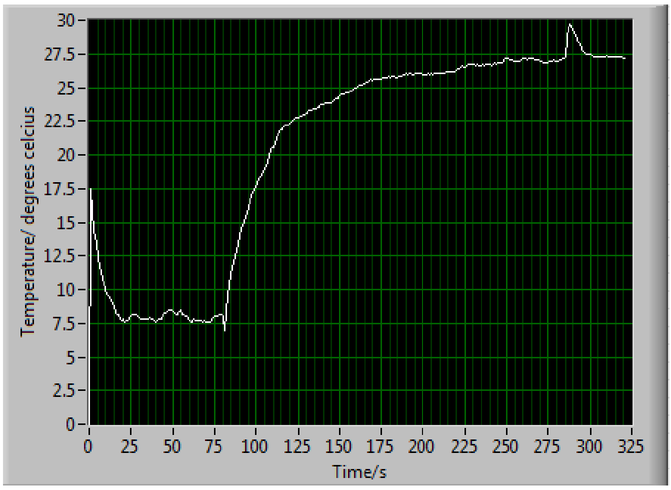

Figure 3.1 Temperature vs time

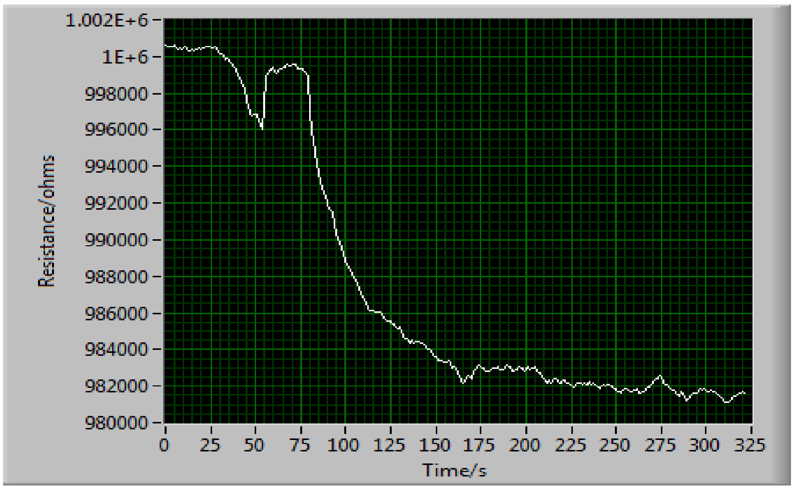

Figure 3.2 Resistance vs time

The overall change in temperature over 320 seconds is an increase from 7.5°C to 27.5°C while the corresponding change in resistance is a decrease from 1.0004MΩ to 0.9816MΩ. This could be explained by the fact that the resistor is probably a carbon film resistor as it has only 4 colour bands and its casing is tan in colour. Carbon film resistors have a slight negative temperature coefficient [6] i.e. as temperature rises, resistance decreases.

Conclusion

This internship was a great learning experience as this was the first time that I had used the LabVIEW program to control a technically advanced device and have an experiment be run fully automatically. The final version of the VI did not show any errors and the device did not malfunction in any way either. Both the temperature vs time and resistance vs time plots showed values that matched with that of expectations. After finishing this internship, I have gained at least a basic understanding of LabVIEW programming and Keithley 6517B electrometer configurations.

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