Internship on KEITHLEY 6517B Electrometer

Internship Report submitted to

The Department of Mathematics and Natural Sciences, BRAC University in partial fulfilment of the requirements of the award of the degree of Bachelor of Science in Applied Physics and Electronics

By

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October, 2016

Declaration

We hereby declare that the thesis titled "KEITHLEY 6517B ELECTROMETER" submitted to the Department of Mathematics and Natural Sciences of BRAC University in partial fulfilment of the Bachelor of Science in Applied Physics and Electronics is based on our original work and has not been submitted elsewhere for the award of any other degree or publication.

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Acknowledgement

With due respect I render my heartiest gratitude to those who tried their level best to make my way through the whole internship process easier.

Firstly, I would like to thank our honorable Chairperson Professor A. A. Ziauddin Ahmad (Department of Mathematics and Natural Sciences), Muhammad Lutfor Rahman (Course Advisor and Senior Lecturer, Applied Physics and Electronics) and Mr. Mahbubul Hoq (Director, Institute of Electronics (IE)) of Atomic Energy Research Establishment (AERE), Savar, for letting me to do my Internship at their laboratories.

Last but not the least the entire staff of IE, especially the officers who belong to the VLSI laboratory are the ones to whom I would like to express my heartiest thanks since without their support and collaboration the path could be a more difficult one.

ABSTRACT

Keithley 6517B electrometer is a multifunctional electrometer which usually works with low current and high resistance. This electrometer can be controlled through interfacing. Labview software was used to interface this instrument. Using the Labview program and the electrometer electrical properties of electronic devices for example transistors, diodes, resistors etc. can be measured with more accuracy. By the end of the internship properties of several transistors, diodes and resistor were measured. In future the program that has been developed can be used further for sorting out the properties of other electronics appliances too.

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Introduction

About AERE, Savar:

AERE stands for Atomic Energy Research Establishment, Savar, which started its journey as a research set-up of Bangladesh Atomic Energy Commission (BAEC). Starting its journey in 1975 with a view to applying nuclear energy in various fields of physical, biological and engineering sciences AERE has walked a long way till now. It was established by the acquisition of 259 acrs of land at Ganakbari, Savar, 40 kms away from Dhaka City and about 4 km north of National Martyrs' Memorial at Savar.

The first phase of AERE started with the aim of establishing its four major research institutes. Starting research activities in 1981 in those four major institutes it installed in 1987 TRIGA MARK-2 research reactor at the Institute of Nuclear Science and Technology (INST).

"Strengthening of Atomic Energy Research Establishment"- a project that was initiated as the second phase of development in1997 was completed in 2007. This initiative generated potential expansion both in infrastructure development and in upgrading of laboratory and other ancillary facilities in different institutes/ units. This led to the establishment of other institutes later on and thus added new dimensions to research in the field of atomic energy and nuclear science and technology.

At present there are ten research institutes that are running to fulfil the demand of advanced research and they are:

- Institute of Nuclear Science and Technology (INST)
- Institute of Food and Radiation Biology (IFRB)

- Institute of Electronics (IE)
- Institute of Computer Science (ICS)
- Reactor Operation and Maintenance Unit (ROMU)
- Nuclear Minerals Unit (NMU)
- Tissue Banking and Biomaterial Research Unit (TBBRU)
- Energy Institute (EI)
- Central Engineering Facilities (CEF)
- Scientific Information Unit (SIU)
- Training Institute (TI)

Besides all these departments and units there is a central cafeteria to fulfil the catering demand for the whole institute and a clinic to fulfil emergency and initial medical needs. In addition to this there is a school for the education of the children of the employees especially for those who live in the residential area.

The administration of AERE is controlled by the Director General (DG). The office of the DG has two branches and those are the Central Administration Division (CAD) and the Central Finance and Accounts Division (CFAD). The Director General controls the institutes with the help of Directors and senior-most Chief Scientific Officers/ Chief Engineers/ Chief Geologists/ equivalent members of the institutes and units.

Aims and objectives:

The primary aims and objectives set for AERE include fundamental and applied research in:

- Nuclear and radiation chemistry, neutron activation analysis, radiation processing of natural and synthetic polymers, stress analysis, isotope hydrology, isotope production, neutron shielding, neutron scattering and radiography, electronics, computer, nuclear minerals, monitoring and processing of nuclear waste for safety, non-destructive nuclear technique, deliberation and standardization of various nucleonic electronic instrumentation and devices etc.
- Food processing and preservation, pesticide residue analysis, pest control and management, sterilization of pharmaceutical products, genetic improvement of industrial microorganisms, biotechnology, tissue banking etc.
- Reactor engineering and control, research reactor operation and maintenance, production of various radio- isotopes both for medical (diagnosis and treatment) purpose and for relevant applied research, support of reactor facilities for fundamental research and training of reactor operators etc.
- Design and development of nuclear and other sophisticated electronic appliances along with expansion and up-gradation of electronic devices, primarily required for nuclear oriented scientific activities
- Fulfilment of national goal by building paper-less and knowledge-based BAEC.
- Exploration of nuclear raw materials in the prospective areas of the country.

- Necessary engineering service to facilitate smooth functioning of laboratories and associate domains.
- Dissemination of information on the on-going research activities and achievements in the field of nuclear science and technology.
- Academic support for students and fellows of different universities/ educational institutions of the country.

Major Research Areas:

- Radiation control and waste management, nuclear and radiation chemistry, quality control and radioactive concentration of radioisotopes, technical and experimental nuclear reactor physics, isotope technique in hydrology, electronics, computer, nuclear minerals, plasma and solid state physics etc.
- Pest control and management, food technology, medical sterilization, microbiology and industrial irradiation, biotechnology and genetic engineering, agrochemical and environment, tissue banking etc.
- Engineering technology, reactor engineering and control, research reactor operation, etc.
- E-governance, software development, databases, data mining, expert system, networking, etc.

Institute of Electronics:

The Institute of Electronics was established in 1981 with a view to ensuring proper application and implementation of nuclear energy in accordance with modern electronics. A programme entitled “Atomic Energy for Peace” was BAEC’s main objective and to fulfil this objective this institute was established. Very high qualified scientists and researchers are working as the backbone of this institute so that a both nuclear and non-nuclear infrastructure for electronics is developed. Moreover, the another aspect of this institute is the development of human resource in order to materialize the vision and mission of AERE to use atomic energy for peace. The internship dealt with several operations that were performed under this institute.

Fig: Institute of Electronics

The divisions that are working under this institute are:

- GED-General Electronics Division
- MID- Medical Instrumentation Division
- NED- Nuclear Electronics Division
- PD- Production Division
- RMD- Repair and Maintenance Division
- Solar Cell Fabrication and Research Division
- Center of Excellence for VLSI Technology

VLSI Laboratory:

This is the laboratory where the internship covered most of its operations. It is said that this lab is the only one running in the country right now at this level being equipped with various sophisticated instruments for conducting high quality research regarding VLSI (Very Large system Integration) technology. The clean room is the most significant aspect of this laboratory which assures the proper use and implementation of those highly sensitive instruments. Some of these instruments are Mask Aligner that permits micro device fabrication, rapid thermal annealer (RTA) that causes the smoother annealing and the Mini Coater which is used to put thin layer of metals on semiconductor wafers.

Fig: VLSI laboratory, AERE, SAVAR

KEITHLEY 6517B ELEECTROMETER:

KEITHLEY 6517B electrometer is a very high resistance electrometer. It is generally used to measure voltage and current and very high resistance. Moreover, it can be used to measure resistivity besides being able to measure electric charge. In addition to this temperature and humidity measurement is also one of its special applications. The most important aspect of this instrument is that it can be controlled by computer interfacing. Below is a list of its special features and capabilities that it can perform.

Capabilities and features:

The Model 6517B is a 6½-digit electrometer/high-resistance test and measurement system with the following measurement capabilities:

• DC voltage measurements from 1μV to 210V

• DC current measurements from 10aA to 21mA

• Charge measurements from 10fC to 2.1μC

• Resistance measurements from 10Ω to 210PΩ

• Surface resistivity measurements

•Volume resistivity measurements

• External temperature measurements from -25°C to 150°C using the supplied Model 6517-TP thermocouple

• Relative humidity measurements (0 to 100%) using the optional Model 6517-RH probe

Some additional capabilities of the Model 6517B include:

• Built-in V-Source. The 100V range provides up to ±100V at 10mA, while the 1000V range provides up to ±1000V at 1mA

• Data storage (50,000 points)

• Single button zeroing (REL)

• Built-in math functions

• Filtering, averaging, and median

• Built-in test sequences

• Remote operation using the IEEE-488 (GPIB) bus or the RS-232 interface

• Scan (measure) channels of an external scanner

• Scan (measure) channels of an internal scanner card

Fig: Front panel of the 6517B Electrometer

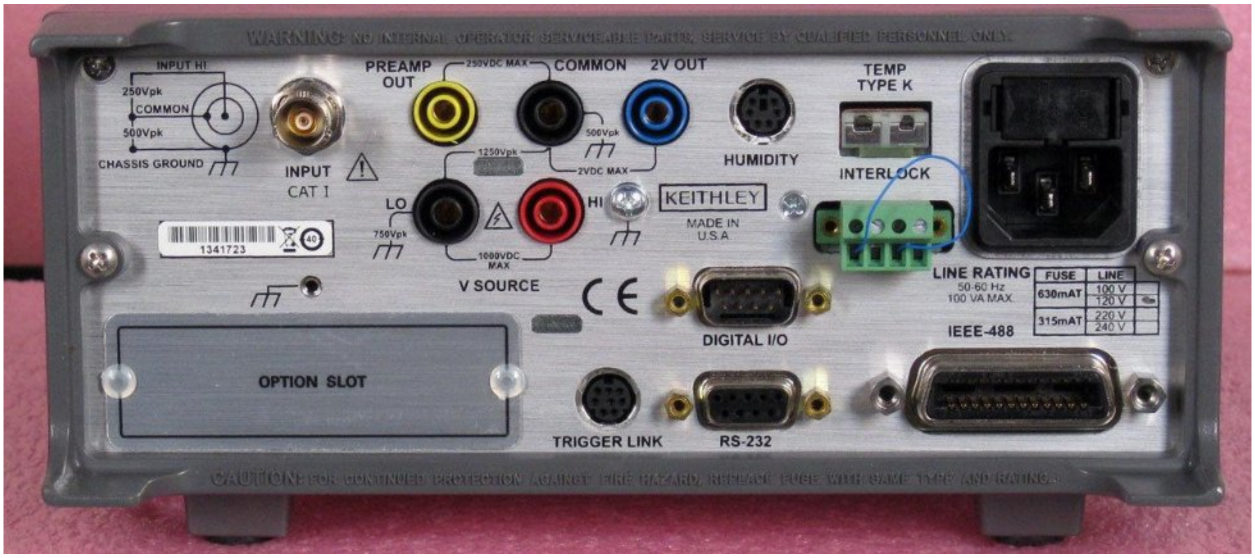

Fig: Rear panel of 6517B Electrometer

Basic measurements and safety precautions:

This electrometer is a high resistance measuring meter and that is why it has to be used with proper safety precautions. It has a special low current amplifier with an input bias current of less than 3 fA. But the peak-to-peak noise due to such low current is merely 0.75fA and the burden voltage is less than 20 microvolt. All these specifications make the instrument very accurate and most sensitive. Beside all these, it consists of a built-in 1kV voltage source that makes it capable of measuring volume and surface resistivity along with performing leakage, breakdown and high resistance testing. Since it can produce a very high amount of voltage, sometimes hazardous situation might lead to and that is why a test fixture is used for safety precautions in such case. A test fixture is stainless-steel made structure consisting of electrodes that are pre-programmed so that the manual calculations of its dimensions are not needed. It actually protects the user from direct contact with hazardous voltage. Whenever the chamber of this fixture is opened the voltage source of the electrometer is automatically turned off and thus safety is ensured. The same thing can be done with another important feature of this instrument that is the interlock in case of absence of the test fixture. The interlock automatically starts operating whenever the appropriate interlock cable is connected to the electrometer.

It has four pins as stated below:

Pin 1: Interlock safe

Pin 2: Ground

Pin 3: +5 VDC output

Pin 4: Surface/volume select (low = volume, high = surface)

Working procedure:

The task on hand to be demonstrated was to design a Labview interface to control the electrometer so that we could measure the I-V characteristics of a specific material. Before all that the electrometer has to be in working condition so that it can perform all the measurements properly. Firstly, the power cord had to be plugged in before the power button was turned on. One end of the power cord was connected to AC receptacle on the rear panel and the other end was connected to an AC outlet which was properly grounded beforehand. When the power cord is connected properly, the power button has to be switched on. After that the voltage source needed to be configured using the up and down keys on the front panel. These keys are used to set the voltage level at which the experiment is intended to be performed. Then the CONFIG button is used to configure the voltage range, voltage limit and resistive limit. The other important aspect of this button is to use the METER CONNECT option to control the internal connection between V-source LOW and the ammeter LOW. The METER CONNECT has to be always on to perform any sort of operation using this instrument. However despite having all these tasks done the electrometer cannot be operated until or unless the OPER button is pressed. The instrument will apply the voltage only when the OPER button is pressed. All these can be done through the following steps:

- Use the menu items to configure the V-source. A menu item is selected by placing the cursor on it and pressing ENTER. Parameter values are changed using the cursor keys and the RANGE keys and then pressing ENTER.
- Use the EXIT button to back out of the main menu.
- Press the “OPER” key.

The other two important keys to be configured of the electrometer are the REL and Z-CHK. The REL lets the instrument to subtract a reference value from actual readings and thus lead the subsequent readings to be the difference between the actual input value and the REL value. The zero check option enables the input signal to get connected to a low through a high impedance shunt. This option has to be always able for measuring current, voltage and resistance. Finally the REL and Z-CHK work together to cancel any internal offsets that may lead to any unwanted inaccuracy. Z-CHK and REL can be configured as follows:

1. Select the **V** or **I** function.

2. Enable zero check.

3. Select the range that will be used for the measurement, or select the lowest range.

4. Press **REL** to zero correct the instrument. The REL indicator turns on and the “ZCor” message is displayed. For the volts function, the “ZCor” message will not be displayed if guard is already enabled.

5. Press **Z-CHK** to disable zero check.

6. Readings can now be taken in the normal manner. The instrument will remain zeroed even if the instrument is upranged. If downranged, re-zero the instrument.

7. To disable zero correct, first enable zero check and then press **REL**.

Remote interfacing:

As mentioned before that the most important aspect of this instrument is that it can be controlled remotely. For this purpose either IEEE-488 GPIB interface or RS-232 interface can be used. I used IEEE-488 GPIB for interfacing. The IEEE-488 GPIB (General Purpose Interface Bus) connects the 6517B electrometer to the computer using standard IEEE-488 connectors. When all the connections are set up, the GPIB needs to be configured using the electrometer as follows:

1. Press **MENU** to display the MAIN MENU

2. Place the cursor on **COMMUNICATION** and press **ENTER**. The interface options (GPIB

and RS-232) are displayed

3. Place the cursor on **GPIB** and press **ENTER** to select the IEEE-488 bus interface. If the RS-232 interface was previously selected; the unit will exit from the MAIN MENU when GPIB is selected. In that event, repeat steps 1, 2, and 3 to continue in the menu structure.

4. Following steps have to be performed in order to check and change the primary address:

   - Place the cursor on **ADDRESSABLE** and press **ENTER** to display the addressable Menu items (ADDRESS and LANGUAGE)
   - Place the cursor on **ADDRESS** and press **ENTER** to display the primary address.
   - To change the address, use the cursor keys (and) and the **RANGE** keys to display the desired address, then press **ENTER**. Each device on the bus must have a unique address. Typically, the computer uses address *0 or 21.*

5. Perform the following steps to check and change the language mode:

   - Place the cursor on **LANGUAGE** and press **ENTER** to display the language options (SCPI or DDC). Cursor position indicates the present language mode.
   - Place the cursor on the desired language and press **ENTER**. Changing the language mode causes the unit to exit from the MAIN MENU. If the language is unchanged, then use the **EXIT** key to back out of the menu structure.

Once all these aforementioned steps are taken, the machine is ready to take measurements.

A device has been designed that consists of two electrodes by depositing materials (e.g. aluminium, copper) on very thin glass slides using TECTRA MINI-COATER Evaporator. This is going to be discussed next.

Current-Voltage tests –

Resistor:

When the electrometer was ready, it was used to take some measurements. Connections were made, and the electrometer was then configured to take input as current for varying levels of voltage steadily increasing. The results are given below:

Voltage (V)	**Current (A)**	**Resistance (Ohm)**
0.0	0.000000	0.000000
1.0	0.000374	2675.241708
2.0	0.000744	2689.386605
3.0	0.001114	2693.871174
4.0	0.001483	2696.333526
5.0	0.001855	2696.119798
6.0	0.002224	2697.562752
7.0	0.002594	2698.691135
8.0	0.002964	2699.273895
9.0	0.003334	2699.848808
10.0	0.003705	2699.281181

Fig: Current-Voltage characteristics of a 2.5k ohm resistor

As mentioned above, the resistor chosen arbitrarily was a 2.5k ohm (rated) resistor. Measurements were recorded after connecting the electrometer's HI cable to one end and the LOW to the other, and thus completing a circuit. The resistance for a potential difference of 0 V is obviously dubious, since the resistance cannot be recorded without the current due to voltage source. A graph was also taken for the tabulated data, and the actual resistance was approximated through the mean value. The straight line shown in the current-voltage graph is also an indicator of the specimen being a resistor.

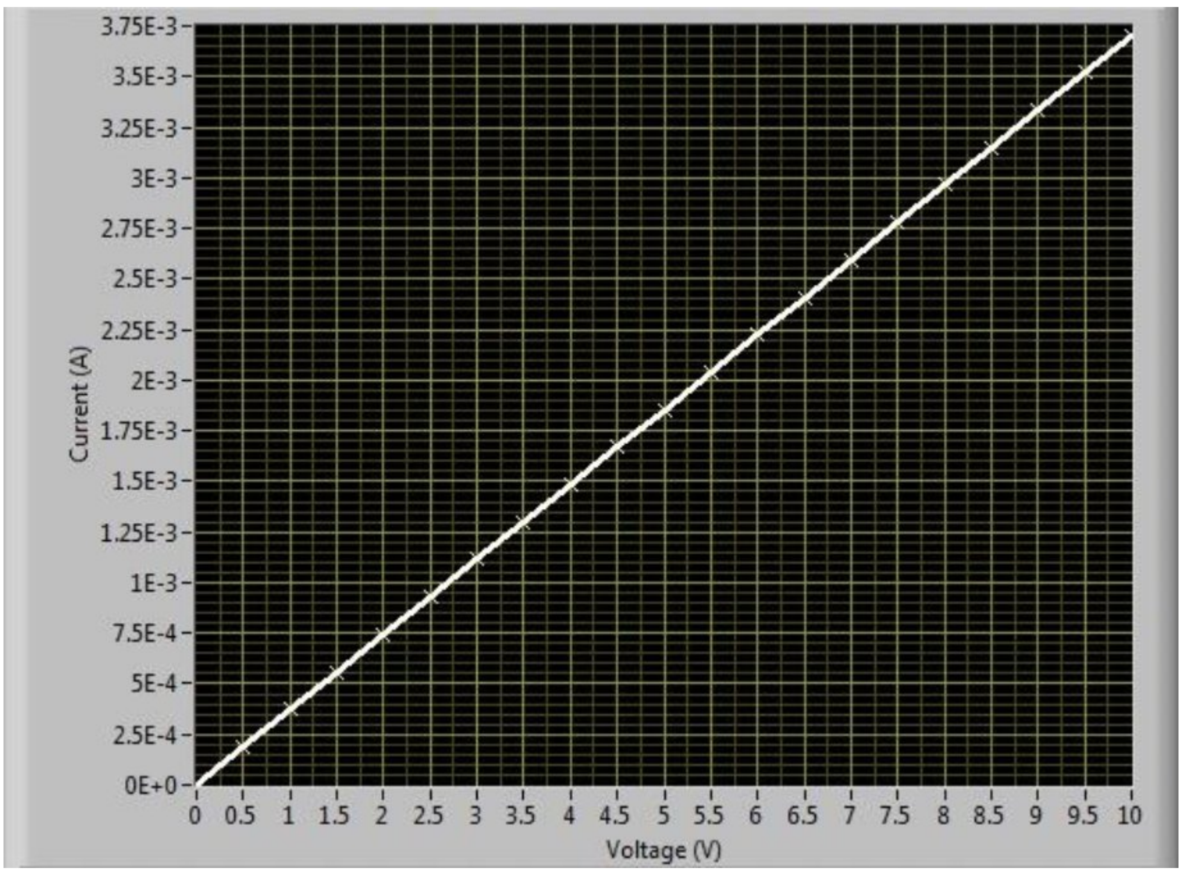

Fig: A graph showing the I-V curve of the measured 2.5k ohm resistor

The mean value of the resistance is calculated to be 2694.5610582 ohm, taking into account all the usable data recorded. This puts the actual resistance of the 2.5k ohm rated resistor to be about 2.7k ohm.

Diode (Silicon):

Next we wanted to see diode characteristics, mainly to observe its electrical characteristics in and around its breakdown voltage. As silicon diode was taken, proper connections were made to the electrometer, and then the current values were recorded for the corresponding voltage levels applied by the electrometer's DC voltage source. The data obtained are given below:

Voltage (V)	**Current (A)**	**Resistance (ohm)**
0.0	0.000000	0.000000
0.1	$9.911010*10^{-9}$	$1.008979*10^{7}$
0.2	$1.127554*10^{-7}$	1773750.968911
0.3	$1.356568*10^{-6}$	221146.304498
0.4	$1.731087*10^{-5}$	23106.868690
0.5	0.000193	2595.594446
0.6	0.001419	422.741223
0.7	0.004218	165.965266
0.8	0.008889	89.999685
0.9	0.011131	80.852872
1.0	0.011192	89.346901

1.1	0.011232	97.933427

Fig: Current-Voltage characteristics of a Si diode

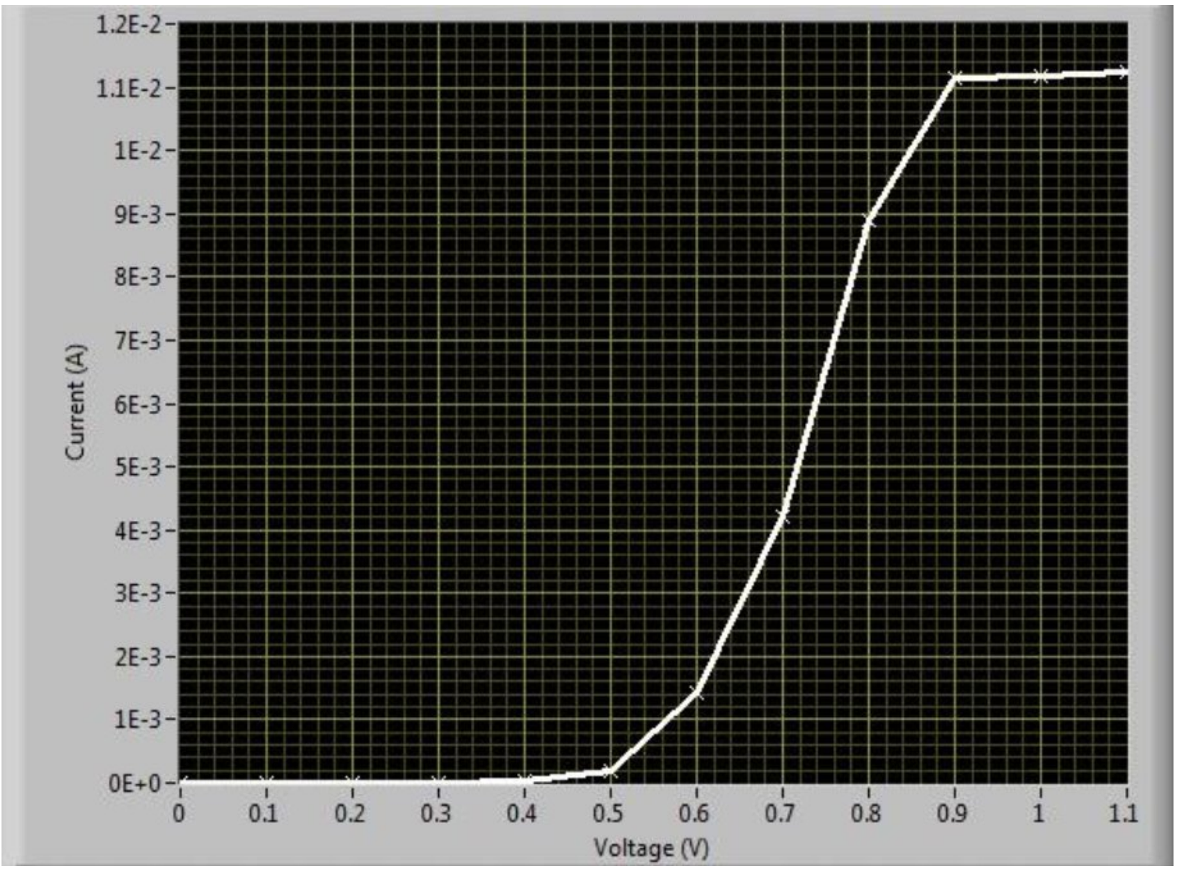

Fig: A graph showing the I-V curve of the measured Si diode

As we can see from the current-voltage graph, the sudden jump is at around 0.7 V. This is characterized by the breakdown voltage in the forward bias for a silicon diode. For a source voltage less than 0.7 V, hardly any current passes through the diode. Exceeding this voltage of 0.7 V will finally allow the passage of current.

Conclusion:

The data and results that I got from my internship were near about same as ideal results which refers to the fact that the electrometer as well as the Labview program worked correctly. Moreover, finishing my internship in AERE really added new dimensions to the ability to work with high ended modern instruments especially electrometer and evaporator. I hope the experience that I gathered here will help me a lot in future in applying the knowledge and develop further in both scientific and professional aspect.

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