PROJECT REPORT

End Term Evaluation, Minor Project-II

Department of Electrical Engineering

Project Title

"Development of a Low Current Measuring Device"

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Acknowledgements

Simply put, We could not have done this work without the lots of help which we received cheerfully from Advance Instrumentation lab, NIT Patna. We would specially like to thank ***Dr. Arunangshu Ghosh*** for providing us the opportunity to work upon the nice ideas. Not only did they advised about my project but having discussions was a great joy.

I am also highly indebted to Ph.D. students and M.Tech students, working in Advanced Instrumentation lab, for helping us over various challenges and their time for numerous discussions with us.

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Contents

Literature Survey

During the litertaute survey for I to V conversion, we investigated the following literatute which presented designs for I to V conversions.

- Motamed, A., Hwang, C. and Ismail, M. (1997). CMOS exponential current-to-voltage converter. *Electronics Letters*, 33(12), p.998.

- Precision, Low Power BiFET Op Amp. (2002). [ebook] Analog Devices. Available at: http://www.analog.com/media/en/technical-documentation/data-sheets/AD548.pdf

1. Project Overview

The main objective of our project is development of a low current (multi-range) measuring device with the following desired features:

- Accurate current measurement (ranging from 1nA TO 100 mA) with permissible error of 2%.
- Interfacing with LabVIEW with a user friendly interface.
- Design of a completely independent system which can be used as a part of other bigger system.

The project is based on the conversion of current to voltage using op-amp based circuit and the generated voltage is used to predict the current accurately ranging from 1nA to 50mA. Project comprises of dealing with current to voltage conversion circuits, Conversion of analog data to digital data by using data acquisition system. The device can be interfaced with computer using LabVIEW for specific applications. The block diagram of project is shown below:

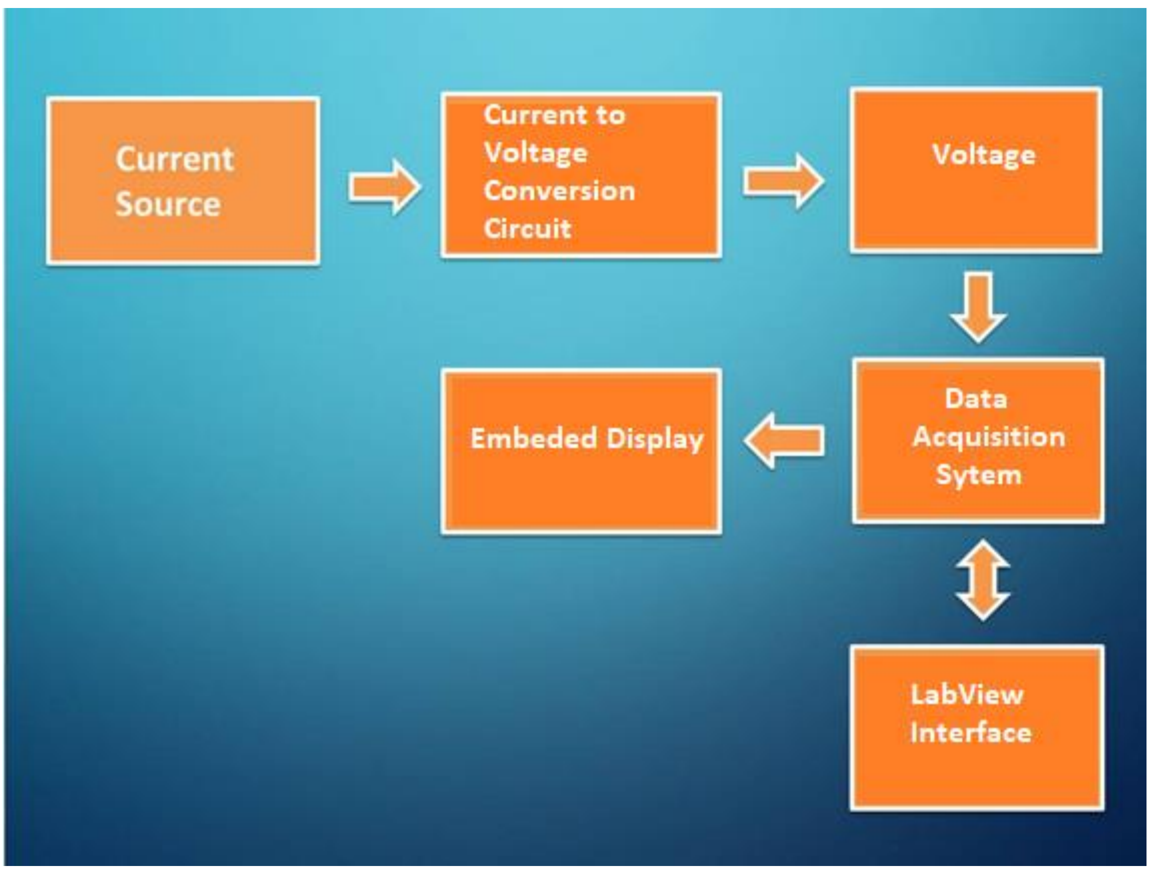


Fig.1. The block diagram of project

2. Current to Voltage Conversion Circuits

A current to voltage converter will produce a voltage proportional to the given current. In this project, we investigated the following current to voltage conversion circuits. The circuit shown in fig.1 is required for measuring voltages. The basic current to voltage conversion circuit is employed using op-amp as op-amp has very high input impedance.

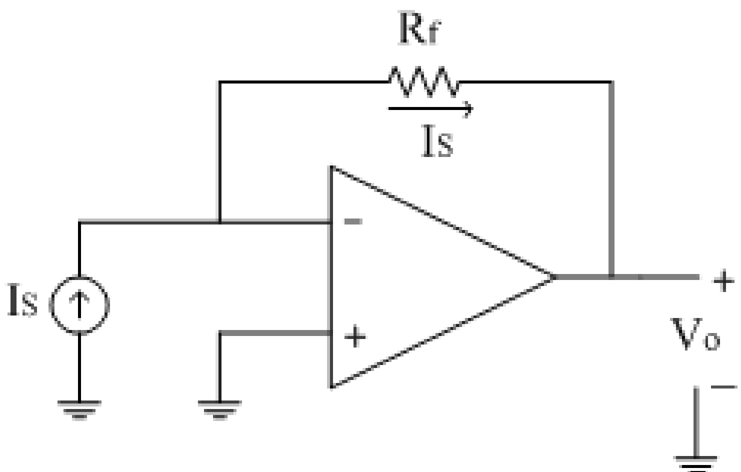


Fig.2. The basic transimpedance amplifier configuration

For circuit shown in fig.2, we have,

$$\mathbf{V_0 = I_s * R_f} \qquad (1)$$

There is another current to voltage conversion circuit shown in fig.3, in this circuit, there is presence of two additional resistances R_2 & R_4 to increase the sensitivity of circuit.

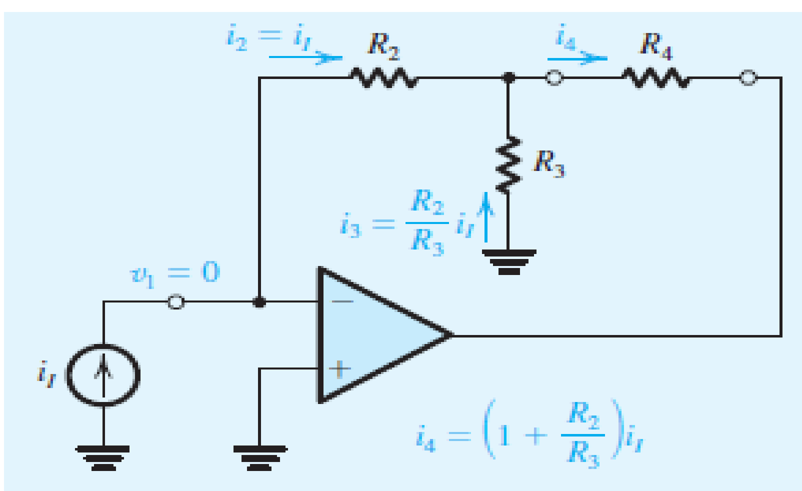


Fig.3. Improved transimpedence amplifier configuration with high sensitivity

Another popular another current to voltage conversion circuit is instrumentation amplifier which is shown in fig. 4.

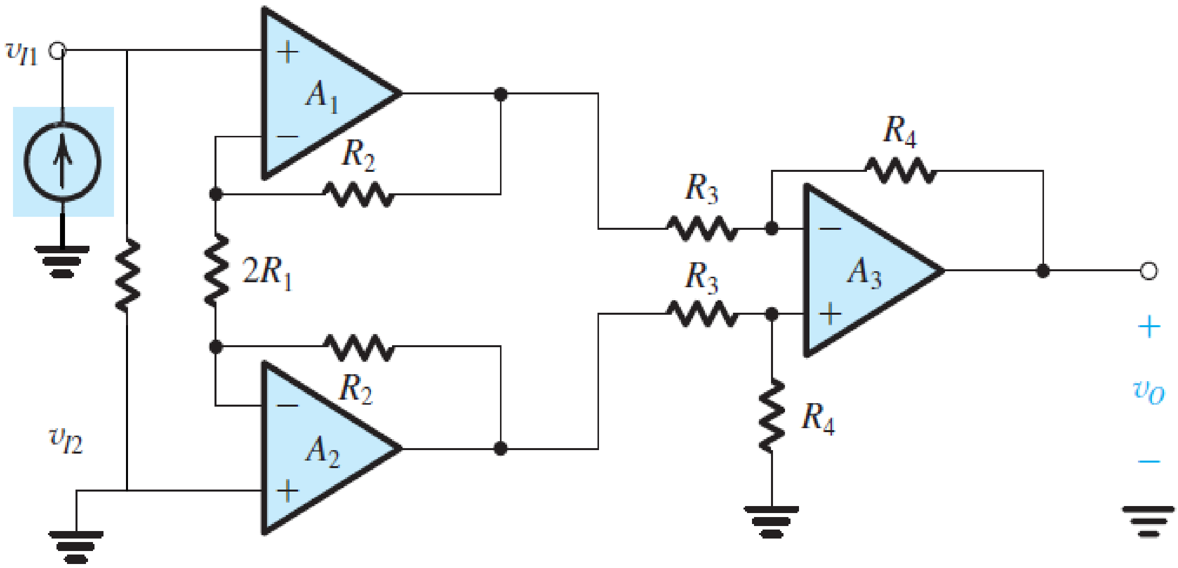


Fig.4. The instrumentation amplifier working in shunt mode

$$V_0 = ((R_4 / R_3) * [1+ (R_2 / R_1)]) * V_{Id} \tag{2}$$

3. Implementation of Current to Voltage Conversion Circuits

First circuit shown in fig.2 & fig.3 is implemented using IC AD549 for nA range and μA range. Current in nA range is difficult to detect. As a result, a very high resistance of 100MΩ is used as feedback resistance. Due to high input impedance of the op amp, the device does not take any significant portion of injected current and the current value is available to us as a proportional value of voltage. The offset and bias current of AD549 and AD548 is orders of fA and pA respectively.

AD549 is able to sink up to 35mA current whereas AD548 up to 25mA. The results are discussed in later section.

4. Data Acquisition System

An Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems, abbreviated by the acronyms DAS or DAQ, typically convert analog waveforms into digital values for processing.

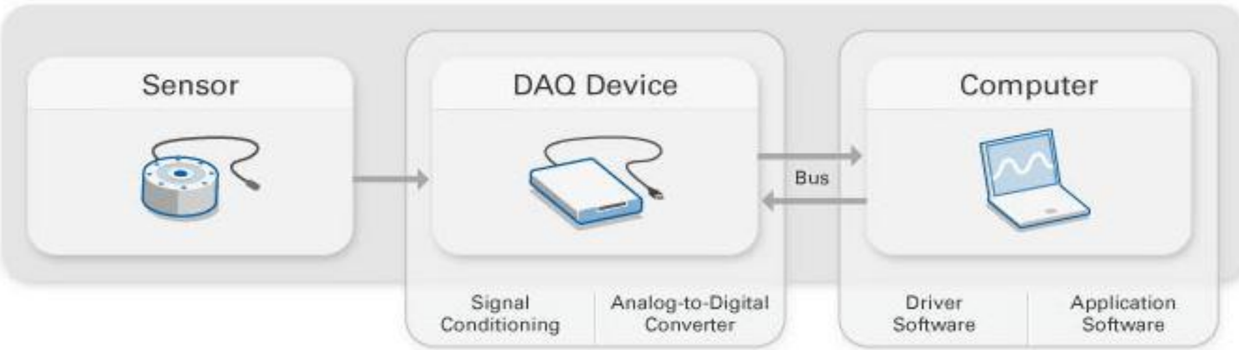


Fig.5 Functioning of Data Acquisition System

. The components of data acquisition systems include:

- Sensors, to convert physical parameters to electrical signals.
- Signal conditioning circuitry, to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, to convert conditioned sensor signals to digital values.

Key Measurement Components of a DAQ Device are:

Signal Conditioning

Signals from sensors or the outside world can be noisy or too dangerous to measure directly. Signal conditioning circuitry manipulates a signal into a form that is suitable for input into an ADC. This circuitry can include amplification, attenuation, filtering, and isolation. Some DAQ devices include built-in signal conditioning designed for measuring specific types of sensors.

Fig.6 NI ADQ 6001

Analog-to-Digital Converter (ADC)

Analog signals from sensors must be converted into digital before they are manipulated by digital equipment such as a computer. An ADC is a chip that provides a digital representation of an analog signal at an instant in time. In practice, analog signals continuously vary over time and an ADC takes periodic “samples” of the signal at a predefined rate. These samples are transferred to a computer over a computer bus where the original signal is reconstructed from the samples in software.

Computer Bus

DAQ devices connect to a computer through a slot or port. The computer bus serves as the communication interface between the DAQ device and computer for passing instructions and measured data. DAQ devices are offered on the most common computer buses including USB, and Ethernet. In this Project, we employed National Instruments DAQ-6001 as DAQ for interfacing with LabVIEW.

5. Interfacing with LabVIEW

LabVIEW is a system-design platform and development environment for a visual programming language from National Instruments. LabVIEW simplifies hardware integration so that you can rapidly acquire and visualize data sets from virtually any I/O device, whether by NI or a third-party. Combined with a graphical programming syntax that reduces programming time, LabVIEW 2017 streamlines complex system design with tools and IP at the forefront of today’s technology.

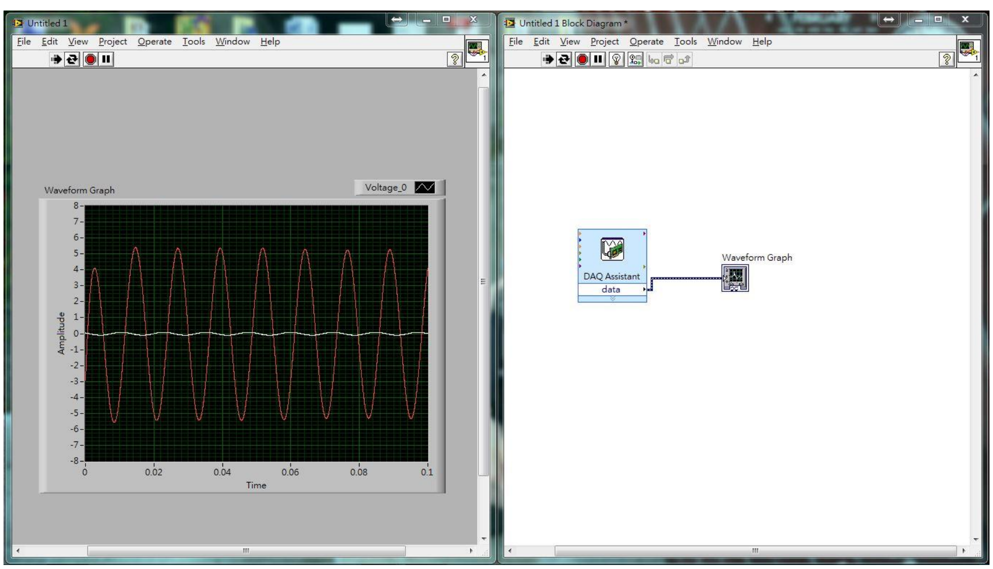


Fig.7 The Interface of LabVIEW

In this project, we used LabVIEW to generate an interface for user to operate device in a convenient way from the computer.

6. Result: Development of Low Current Measuring Device

We implemented an op amp circuit for I-V conversion to measure extremely low values of current with high accuracy. We divided the complete current range in following ranges.

- Current range I - **10nA to 100 nA**
- Current range II - **100nA to 1uA**
- Current range III – **1µA to 1mA**
- Current range IV – **1mA to 100mA**

During the process, the following results were obtained using the circuit shown in fig. 8. The complete circuit is further divided in two circuits: Circuit A and Circuit B.

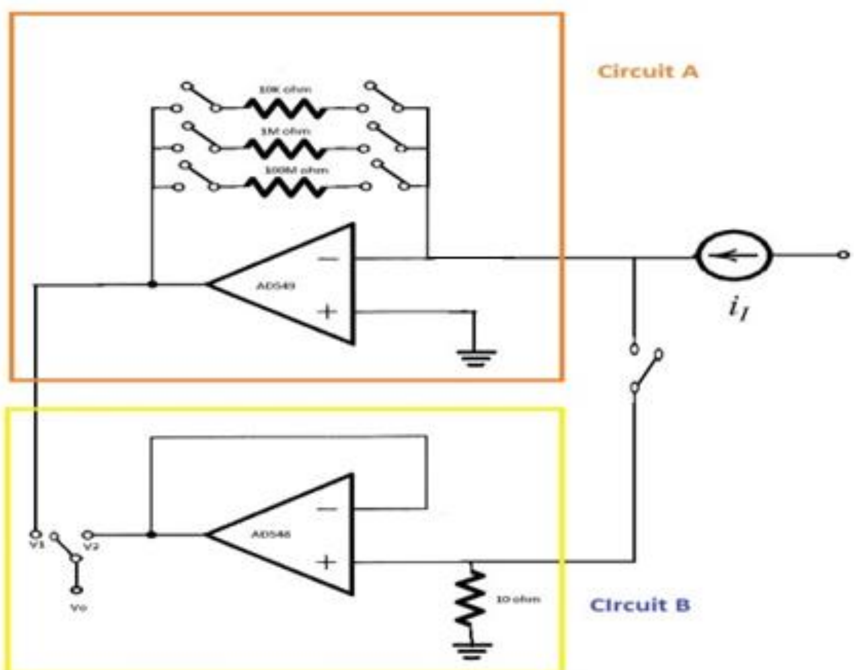
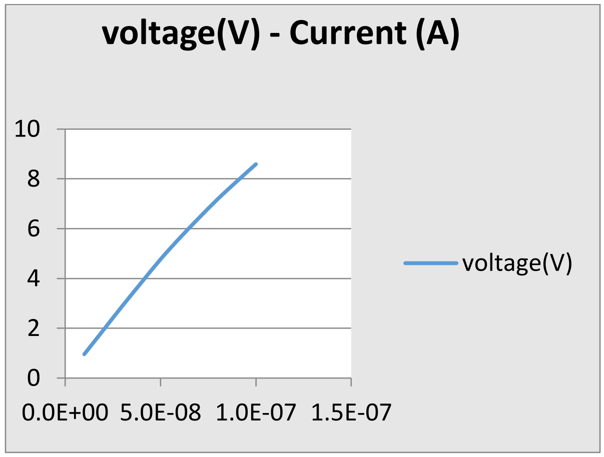


Fig.8. The implemented current to voltage Circuit

<u>**CASE 1:**</u> Current range - **10nA to 100 nA**

- **IMPLEMENTATION:**
  - Feedback resistance used is **100 MΩ employed as Circuit A of fig.8**
  - Current range measured = **10nA to 100 nA**
  - Voltage ranges from 1 V to 10 V

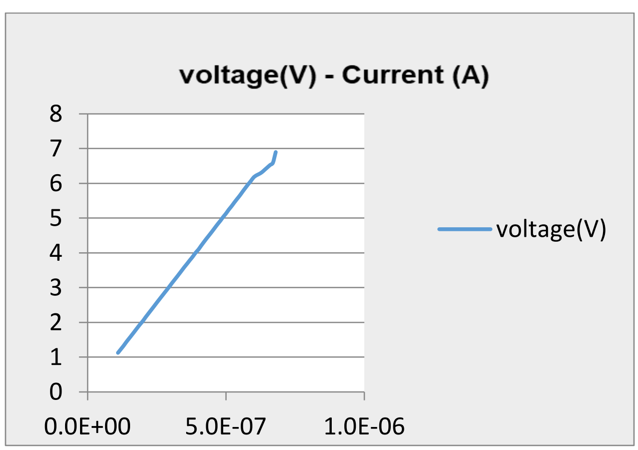
- **OBSERVATIONS:**
    - The V-I curve obtained is almost linear with an error of approximately 5%. Hence the use of resistance of **100 MΩ** is justified.



Graph 1. The Voltage vs. current characteristics for 10nA to 100nA

<u>**CASE 2:**</u> Current range - **100nA to 1uA**

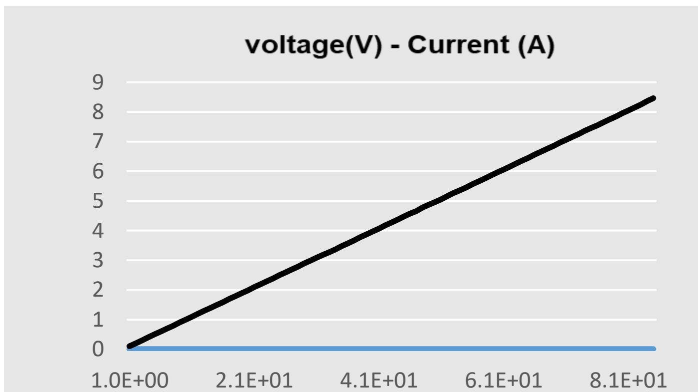
- **IMPLEMENTATION:**
    - Feedback resistance used = **1 MΩ employed as Circuit A of fig.8**
    - Current range measured = **100nA to 680nA**
    - Voltage ranges from 0.1 V to 1V
- **OBSERVATION**:
    - The V-I curve obtained is linear with an **error less than 1%.** Hence the use of resistance of **1 MΩ** is justified.



Graph 2. The Voltage vs. Current characteristics for 100nA to 680nA

<u>CASE 3</u>: Current range – **1μA to 1mA**

- **IMPLEMENTATION:**
  - Feedback resistance used = **10 kΩ employed as Circuit A of fig.8**
  - Current range measured = **1 μA to 850 μA**
- **OBSERVATION**:
  - The V-I curve obtained is linear with an **error of approximately 1%**. Hence the use of resistance of **10 KΩ** is justified.



Graph 3. The Voltage vs. Current characteristics for 1 μA to 850 μA

7. Pin Diagram of Op-Amp AD 548 and AD549

The pin configuration of op-amps (AD548 and AD 549) used in project are shown below:

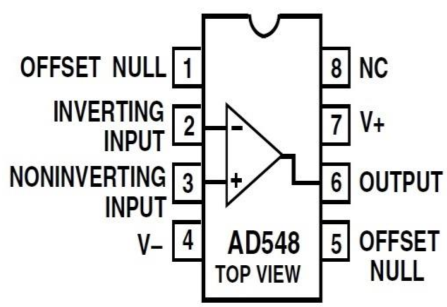


Fig. 9 The Pin configuration of AD 548

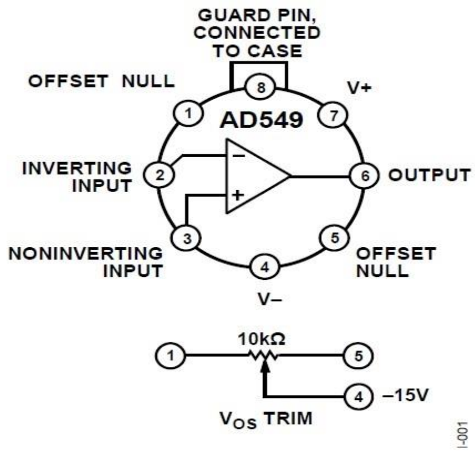


Fig. 10 The Pin configuration of AD 549

8. Implementation of Switches Mentioned in Circuit shown in fig. 8

Miniature relay EA2-5TNJ miniature signal relays offer a compact case size in a flat package. Minimal board space is consumed with either a through-hole or surface mount configuration. All the switches are implemented using this relay.

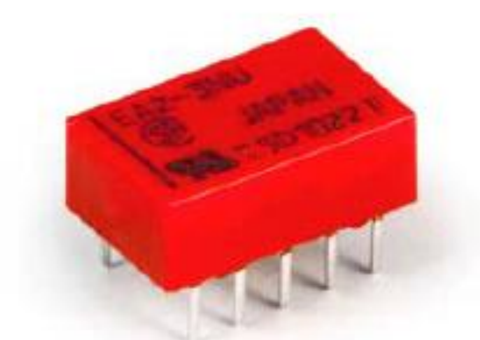


Fig. 11 EA2-5TNJ Package

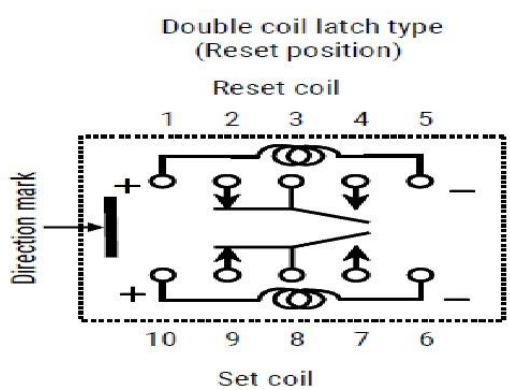
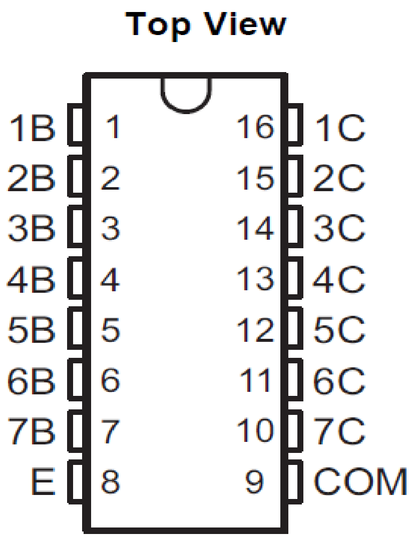


Fig. 12 Pin Configuration of EA2-5TNJ

Relay driver IC ULN 2003 is used to drive the inputs to the EA2-5TNJ relay package. The ULx200xA devices are high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs can be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers. The pin configuration of ULN 2003 is shown below.



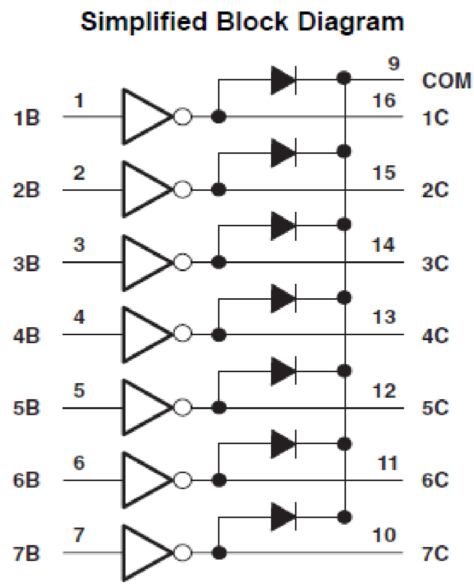


Fig. 13 The Pin diagram of ULN2003

Fig. 14 The Internal connections of ULN 2003

9. Implementation of Interfacing of device with LabVIEW

The output voltage of current to voltage converting circuit is sent as input to NI-DAQ. The input is processed there in order to predict the correct value of current with in permissible error limits. An interface is designed for the user to operate the device efficiently and with ease. The interface is mplemented by graphical programming in LabVIEW. A section of the schematic of graphical program is mentioned below.

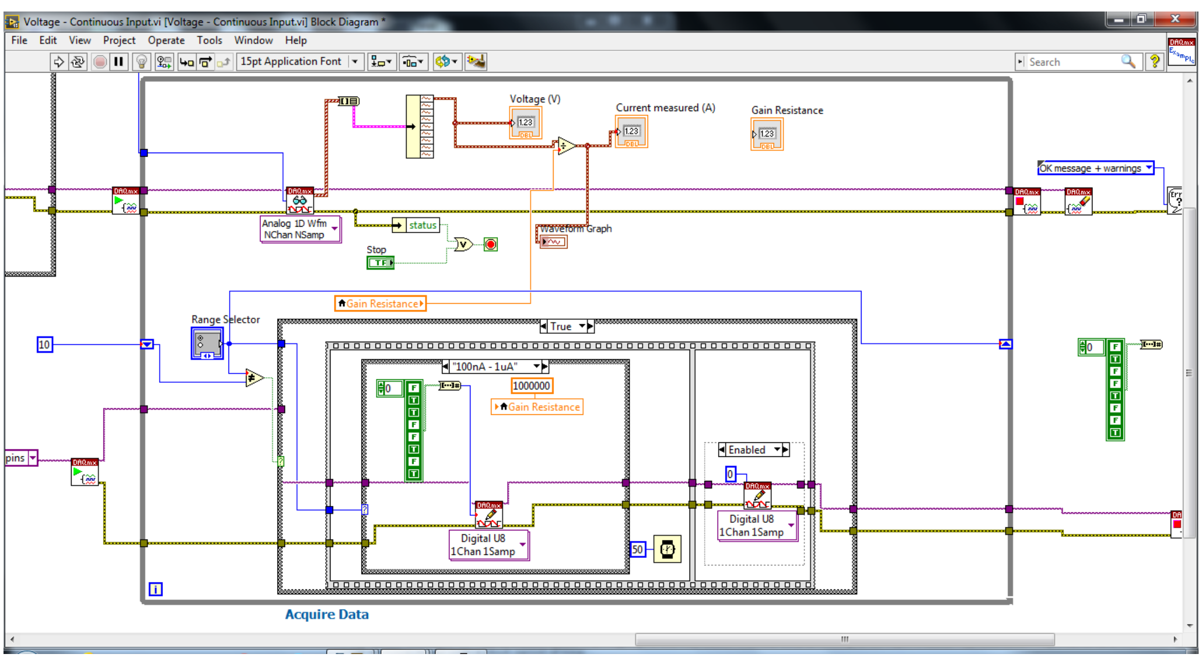


Fig. 15 The graphical program for developing the LabVIEW interface for user

The final LabVIEW user interface for operating the device appears as follows:

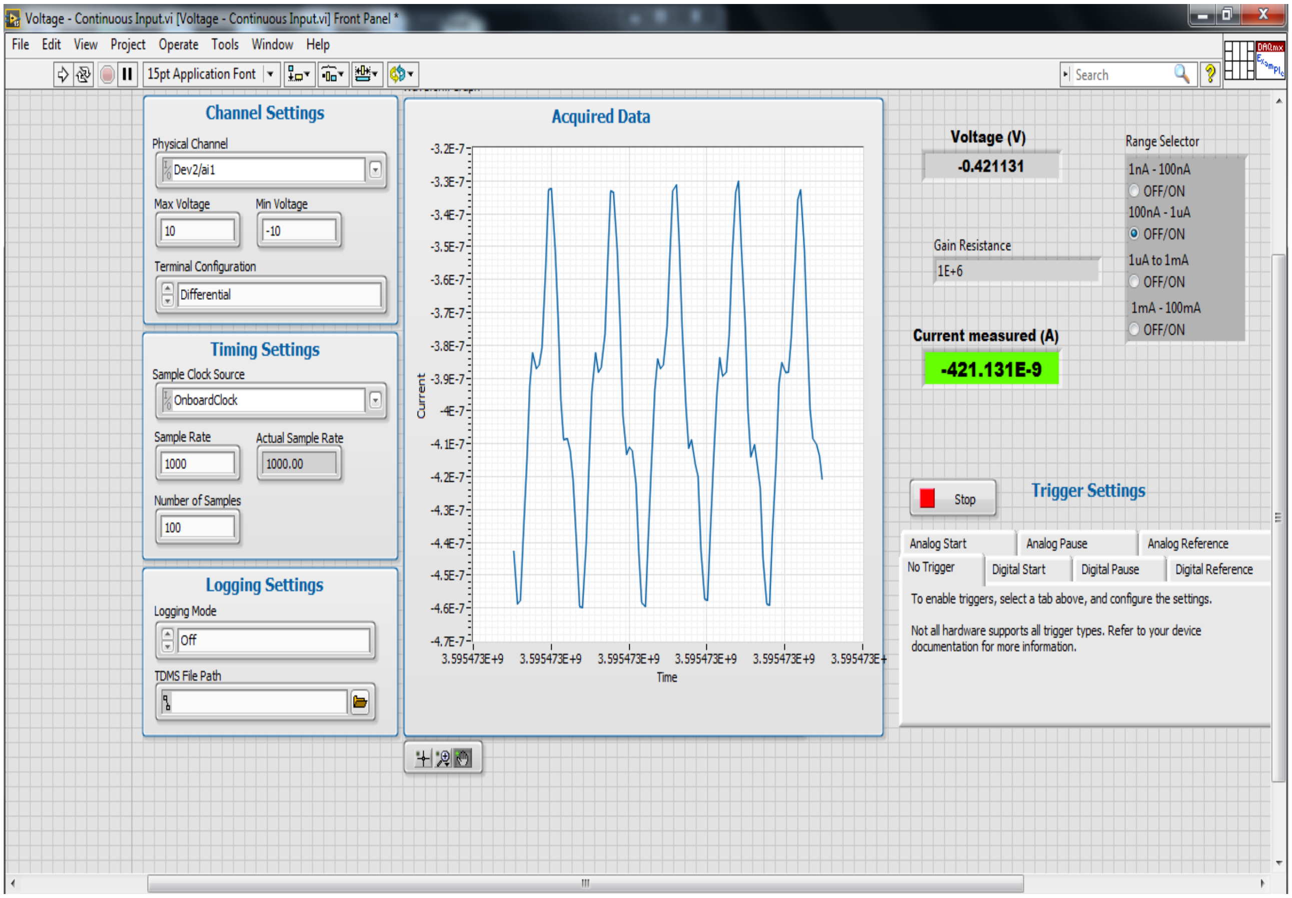


Fig. 16 LabVIEW Interface for device

10. Final Completed Circuit

The final completed circuit consists of 4 active relays (with one relay in backup on board), two op-amp Ad548 and AD549 and 4 resistors for covering four ranges of current. The idea of device is to measure the output voltage by using appropriate resistance in feedback path of op-amp. The relays are used to switch the resistances according to the current range. The obtained value of voltage is fed to DAQ and processed in LabVIEW in order to derive the value of current. An interface is designed for user to operate the device. Radio buttons are provided to switch the current ranges according to the range of current in which user want to measure the current as shown in fig. 16.

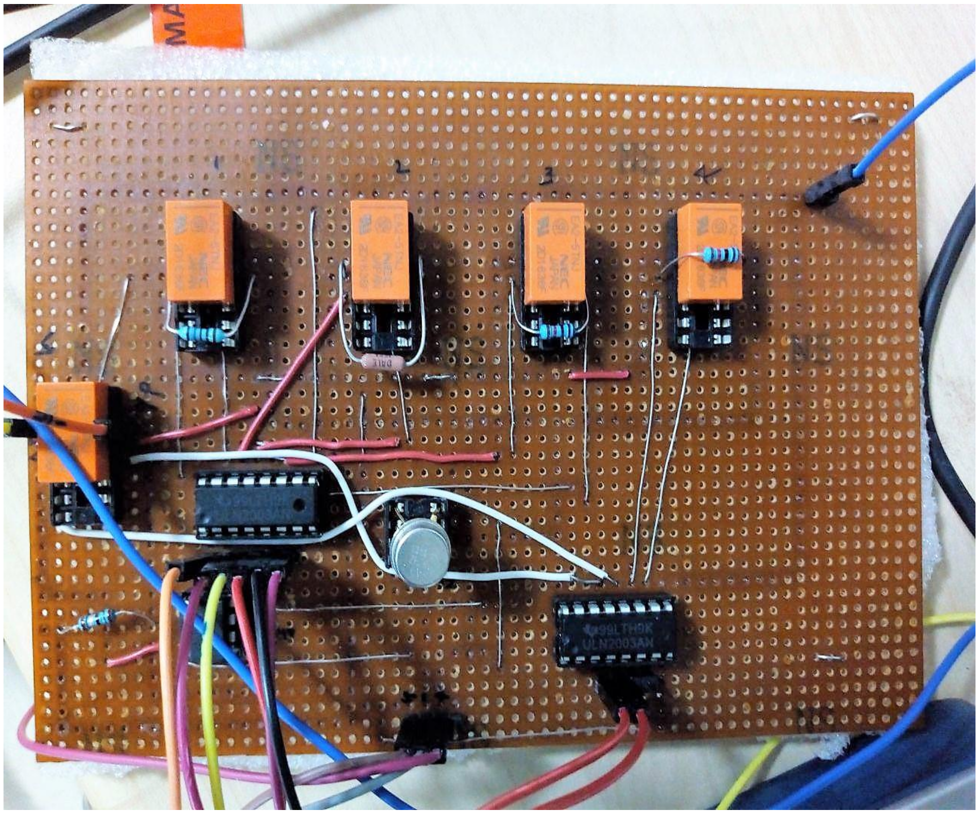


Fig. 17 The Top View of Implemented Circuit

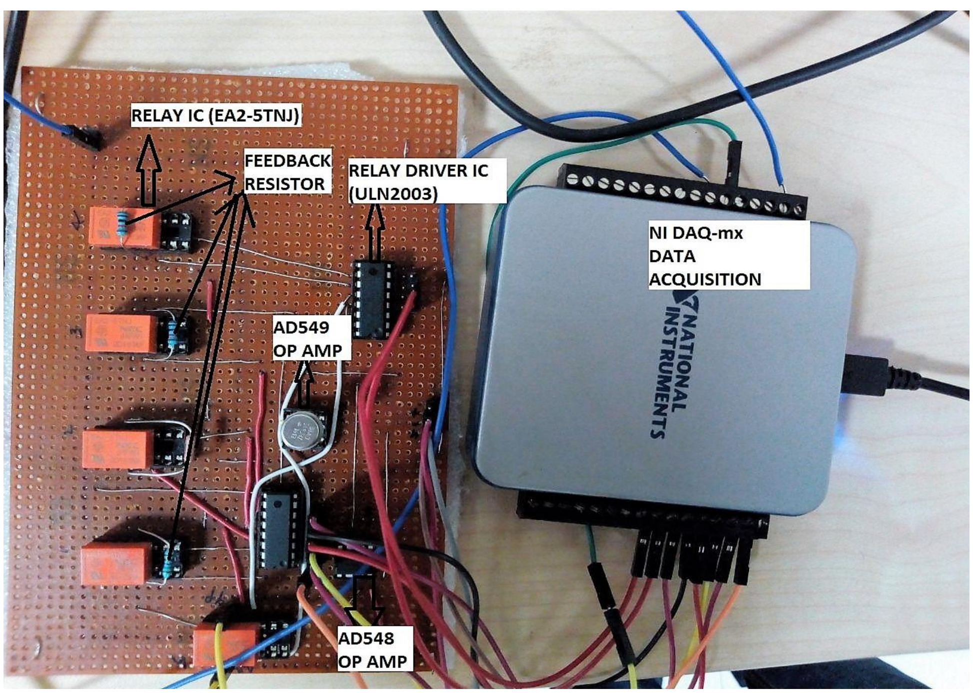


Fig. 18 View of Implemented I to V Converter Circuit with DAQ

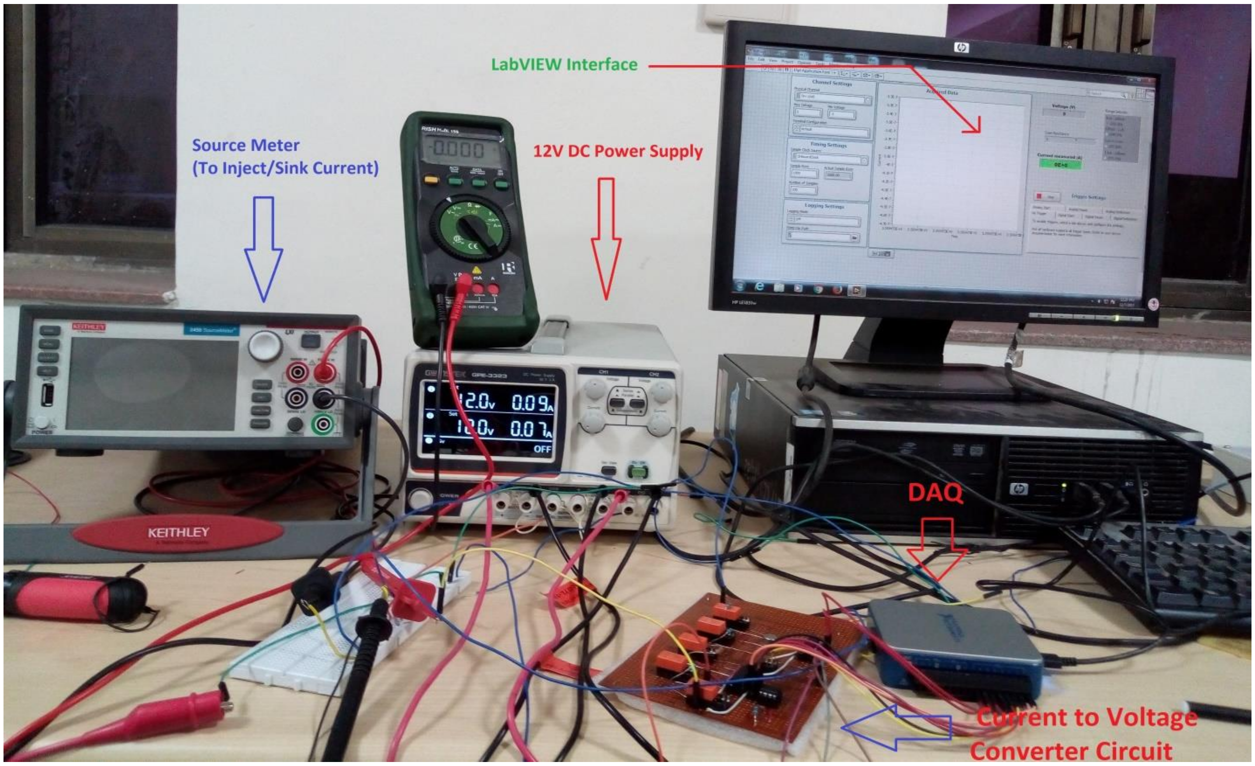


Fig. 19 Complete Setup of Low Current Measuring Device

The complete setup of low current measuring device is installed at advanced instrumentation lab of electrical engineering department.

11. Application of this Project

For measuring low level current and currents in wide range for electronics and biomedical purposes are in great need. There may be following possible applications of this project.

- Bio medical applications
- Electrochemical applications
- Current emitted from a photodiode can be measured accurately
- The device has multiple range, i.e, it can measure current from nano amps to mili amps thus finding a large field of application

12. References:

- Sedra, A., Smith, K. and Chandorkar, A. (2013). *Microelectronic circuits*. New Delhi, India: Oxford University Press.

- Motamed, A., Hwang, C. and Ismail, M. (1997). CMOS exponential current-to-voltage converter. *Electronics Letters*, 33(12), p.998.
- Precision, Low Power BiFET Op Amp. (2002). [ebook] Analog Devices. Available at: http://www.analog.com/media/en/technical-documentation/data-sheets/AD548.pdf
- En.wikipedia.org. (2017). *Analog-to-digital converter*. [online] Available at: https://en.wikipedia.org/wiki/Analog-to-digital_converter