

**DEVELOPMENT OF SENSORY-MODE INTERACTION IN
HAPTIC SYSTEM**

by

NURUL SAADAH GHAFAR

FINAL REPORT

**Submitted to the Electrical & Electronic Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons) Electrical & Electronic Engineering**

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

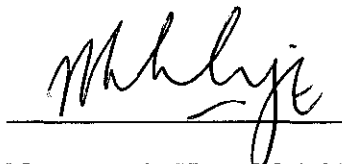
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Nurul Saadah Ghafar

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved by,



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CERTIFICATION OF ORIGINALITY

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NURUL SAADAH BINTI GHAFAR

ABSTRACT

This final report is an overview for Final Year Project titled “Development of sensory-mode interaction in haptic system”. A haptic device enables interaction between human and computer, which also give response due to the force applied by the user movements. The aim of this project is to design and develop a simple haptic device to analyze on the concept of sensory-mode interaction by using strain gauge sensor. Current application of haptic technology has been widely used in robotics, teleoperators, simulators, and video game controller. However, most of the application of existing haptic device are expensive, sophisticated, and require high level of technology. Therefore, due to the complexity of the system, a simple haptic device is designed after analyzing literature review on the related work. The device also will enable user to obtain the tactile feedback when exerting force to the interface. In order to perform the virtual measurement, a Graphical User Interface (GUI) is developed using LabView software. The hardware device will interact directly with the computer via communication board. Hence, whenever the user applies force on the device, the force value will transfer to the computer for further conversion and calculation. User can acquire data and the output value generated will be displayed on the screen of computer. The overall summary about this project is to produce a simple haptic device using the stain gauge sensor, and the amount force exerted by user can be measured and monitor via the LabView Software.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Haptics is technology that allows touch-enabled interaction with virtual objects. Haptic interface is a force reflecting device which allows a user to touch, feel, manipulate, and create the virtual environment [1]. The haptic interaction could be categorized into different types of touch sensations, which are force feedback and tactile feedback.

The force feedback device is a device that is capable to provide force, vibrations, or motions to the user meanwhile, the tactile feedback will measure the force or pressure exerted by the user to the interface. Sensory-mode interaction is one of the technologies interact using haptic technology. With the aid of haptic interface device, we can simulate and sense the touch of the material. There are several types of approaches on hardware design for haptic interface, such as finger-based system, hand-based system, exoskeleton system, and inherently passive devices.

Force feedback control is investigated for improving the quality of the haptic feedback in virtual reality applications. Advanced control design can increase the transparency of the haptic device at the haptic interface thereby increasing the realism of the simulation.[2]

1.2 Problem statement

The current application of haptic technology has been widely used in robotics, teleoperators, simulators, and video game controller. The existing haptic device such as *PHANToM* device can be used to analyze the sensory-mode interaction. The *PHANToM* is an electromechanical device that allows users to touch and manipulate virtual objects using its device. However, most of the application of haptic device nowadays are expensive, sophisticated, and require high level of technology. Therefore, due to the complexity of the system, another alternative way to render for haptic interaction can be developed by using a simple touch sensor circuit that can be used to measure on the exertion force applied by user.

1.3 Problem Identification

In order to overcome the problem, a simple haptic device will be designed after analyzing literature review on the related work of haptic devices. Besides, the device will enable user to obtain the tactile feedback when exerting force to the interface. In order to perform the virtual measurement, a Graphical User Interface (GUI) will develop using LabView software. LabView Software is a graphical programming to interface for measurement, monitoring, recording and control device. It provides integration with hardware devices such as plug in DAQ board. A DAQ device includes a set of Virtual Environment (VI) that can acquire data from, and send data to DAQ devices. DAQ devices also can perform A/D conversion, D/A conversion, digital I/O and counter/timer operations [3].

1.4 Objectives

The objectives of this project are;

1. To design and develop a simple haptic device consists of suitable equipments such as sensors, motor, and H-bridge circuits that has capability to measure force or deflection on a surface of material.
2. To build a Graphical User Interface (GUI) for ease of measuring, monitoring and database purpose using LabView Software.

1.5 Scope of Study

The aim of this project is to produce a simple haptic device that able to measure deflection on a material. Therefore, the scope of study for this project can be divided into three main parts;

- Firstly is to design on simple haptic device to enable sensory- mode interaction that can measure deflection of a material.
- Secondly, is to build and design user interface using LabView software for monitoring, recording data and perform calculation based on the forced applied by user.
- Finally, is to communicate the hardware device to the computer using Data Acquisition (DAQ) board.

CHAPTER 2

LITERATURE REVIEW

2.1 Haptic Overviews

The research on haptic has been conducted for decades. The study of haptics saw a significant boost in research during the 1980s when the concept of robotics was being developed. As the research in robotics advanced, it was felt that there was a need for manipulation of objects by touch. Development in these areas led to the invention of another sub-specialization of computer science called 'computer haptics'.

The first application of force feedback in a tele-operation system for nuclear environments has been introduced by Goertz at Argonne National Laboratories in 1954. [3] Subsequently the group led by Brooks at the University of North Carolina at Chapel Hill adapted the same electromechanical arm to provide force feedback during virtual molecular docking in 1990. Computer haptic uses a display technology through which objects can be touched. One of the major advantages in a user-haptic interaction is that the flow of information is a two way process between the user and the device. Incorporating the haptic component into virtual environments (VE) enables the tactile sensation and imparts a more realistic and tangible to the user. The 'haptic' component also enhances the user experience by offering a life-like interaction with the system. Technological advancements in haptic devices have enabled the end user to feel a range of surface textures from fine to coarse in virtual environment. [4]

Nowadays, haptic is applicable across nearly all areas of computing including video games, computer animation, virtual toys, and robot control. The discipline of education also has begun to use haptics as well. However, the applications are currently confined to the arena of higher education. For example, haptics have been widely used in undergraduate engineering curriculum, architectural layout, automotive design, and medical training.

2.2 Existing technology of haptic device

2.2.1 *Novint Falcon*

The Novint Falcon develops a 3D haptic technology and a game controller product that enables game players to experience realistic virtual touch using computer. By using the 3D haptic interface, the player can control a game in 3D and feel their shape, texture, the dynamic properties of the objects, and many other effects which are high-fidelity 3D force feedback. The Falcon controller is a 3 Degree of Freedom (DOF) force feedback device. It can moves right-left, forwards-backwards, (like a mouse) as well as up-down direction. When the user hold the Falcon's detachable Grip and move the cursor to interact with a virtual object, environment, or character, the motors in the device turn on and are updated approximately 1000 times a second, which let user feel texture, shape, weight, dimension, and dynamics [5].



Figure 1: Novint Falcon Gaming Controller Device

2.2.2 *The Personal Haptic Interface Mechanism (PHANTOM)*

PHANTOM is a haptic device that makes it possible to touch virtual objects in a computer environment. The PHANTOM is an electromechanical desktop device that can connect to a computer's I/O. The technical design of the PHANTOM includes relatively low mass, low friction, low backlash, high stiffness and good back drivability. This enable PHANTOM system to provide convincing sensation of contact, constrained motion, surface friction, texture and other mechanical attributes of virtual object. The PHANTOM allows users to touch and manipulate virtual objects by using stylus pen. The principle operation for the PHANTOM is that the stylus can track motion and position of user's fingertip whilst providing force feedback to the user. The computer that connected to the device read the position of the stylus in each millisecond. Because of that, a constant rate of force feedback is maintained at 1 kHz servo update rate to enable user to perceive a hard contact [6].



Figure 2: PHANTOM device

2.2.3 *The "Twiddler"*

The "*Twiddler*" is a device consists of electronics box and electric DC motor. The electronics box read the current rotational position of motor from the encoder and decoder and sends it to host PC through a parallel port. Then, the host

PC/software will perform haptic calculation and send feedback commands through parallel port back to electronics box. The command is converted to a motor driving signal and sends to the motor. The resulting command is sent to the hardware and is translated into a voltage that drives the motor. Finally, the motor will exert feedback force to the user. The advantages of this device are portable and low cost. The software, mechanical and electrical design are also freely available for reproduction. The disadvantage of this device is it just has a single degree rotation of haptic device.[7]

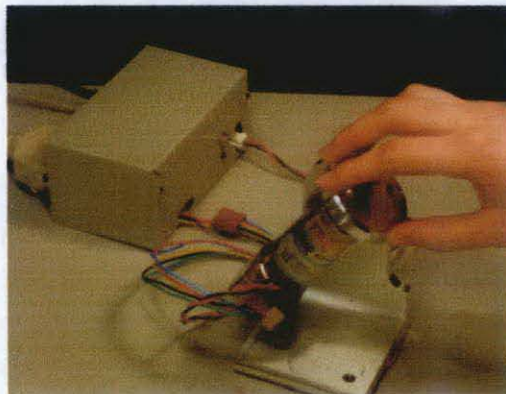


Figure 3: The Twiddler and Electronic Box Shown in Operation

2.2.4 *Haptic Texture Sensor*

The Haptic Texture sensor is a simple prototype that consist of 3 main parts; mechanical parts which include motor, communication part and also the host computer or the software that control all the system. The mechanical part used a 5V DC motor to provide vibration for human-computer interaction. Then, the DAQ board is used to allow direct connection from the motor to the host computer/ software. For the software implementation, LabView software is used to provide virtual instrument interface so that the user can key in the input on the computer and at the same time feel some sort of vibration at the hardware which connected to the computer. [8]

2.2.5 Digital Scale Strain Gauge Weight Sensor

The weighing scale is a measurement instrument for determining the weight or mass of an object by measuring the spring deflections under its load. [9]. Meanwhile, in the digital electronic scale system, the deflection of unknown object is measured using strain gauge, a sensor that is length-sensitive to the electrical resistance. The idea of this project is to make use the internal digital scale system, and wiring it to an amplifier, and then using the microcontroller to perform the measurement. The overview on the concept and working principle of strain gauge and Wheatstone bridge is also highlighted. [10]

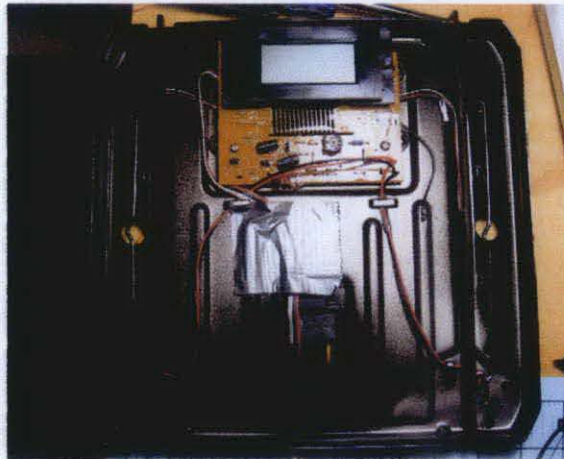


Figure 4: NerdKits product

2.3 Findings from research

There are several types or application of haptic device that used the same concept of provides the feedback force. For example, the finger based such as application in PHANTOM device, the hand based (joystick and steering wheel), and exoskeletons such as Master Arm. But all of the existing devices require a complex technology, high degree of freedom (DOF) and very expensive. The different types of interaction for haptic device also can be classified into two main categories which are the force feedback and the tactile feedback. With a force

feedback, user can feel the force on the movement of the haptic device, compared to the tactile feedback; the user can feel force that applied directly to the skin, which detected through sensors within the skin.

In order to design a haptic device, there are several criteria that need to be considered to ensure the design is workable and to optimize the functionality of the prototype. Based on the literature review and research that have been done from books, journals, websites, and theses, and also some discussions with the expertise on the haptic interface and technology, there are several facts and findings that relevant to the objective of the project. The main idea of this project is based on the *Haptic Texture sensor* device and the *Digital Scale Strain Gauge Weight Sensor* product. The mechanical part consist of DC motor that provide the feedback force (vibration) to the user to sense of touching virtual environment. User can feel the force by click on the virtual object on screen. Meanwhile, the basic concept of the *Digital Scale system* is using the strain gauge sensor, that able to measure the deflection due to the changes in electrical resistance. Further studies and some modifications is done to ensure the functionality of the prototype.

2.4 Design Criteria

The basic principle for haptic device in any application are low inertia, low friction, low backlash, high stiffness, and capable to sense different level of vibration [11]. This will ensure that the design or prototype system can provide convincing sensation of contact, constrained motion, surface friction, texture and other mechanical attributes of virtual object.

Besides, haptic device have varying complexities, so that it can move in different ways. The direction of movement or known as degree of freedom (DOF) will affected the complexity of the device. Generally, the DOF types includes right-left movement (rotation about X axis), up-down movement (rotation about y axis), and forwards-backwards movement (rotation about Z axis). For a simple

haptic device that will design, the combination of two level of DOF is sufficient to keep track the position in right-left movement and forward-backward movement

Another criterion for design a simple haptic device is the size of the prototype. The design must be portable, cost-effective, simple, small and easy to use.

CHAPTER 3 METHODOLOGY

3.1 Procedure Identification

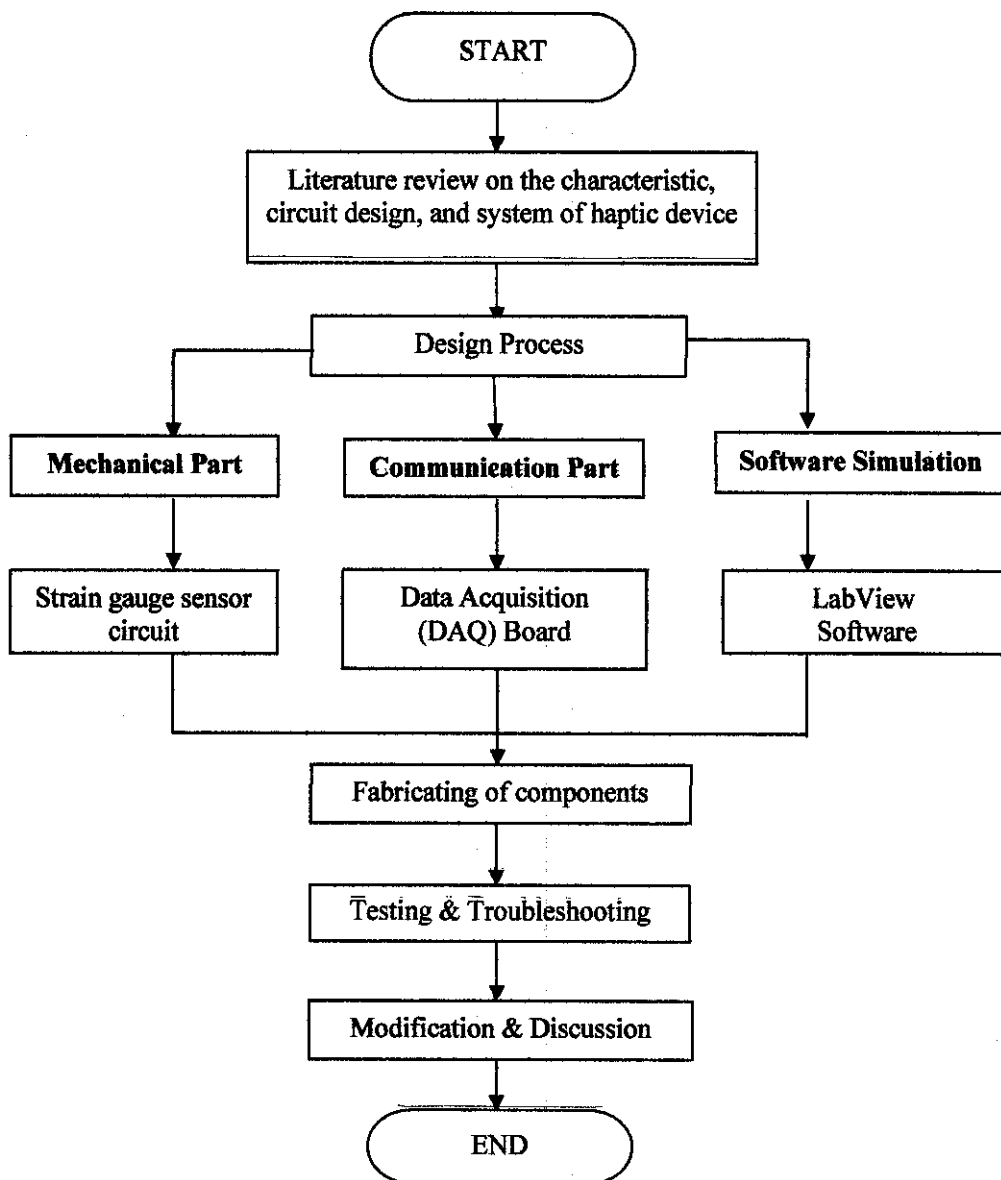


Figure 5: Flow Chart of designing Haptic System

3.2 Project Design

The design process of simple haptic device is divided into three main parts which are the mechanical part, communication part, and also host computer as the medium for software implementation design. Figure 6 shows the overall block diagram of the haptic design.

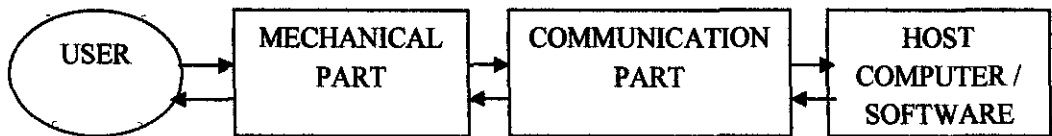


Figure 6: Block Diagram of design

The mechanical part of this hardware design allows the user to interact directly with the computer. Hence, whenever the user applies force on the device, the physical signal, which is the amount of the force apply by user will transfer to the computer via communication part for further conversion and calculation. After that, the output value generated will be displayed on the screen of computer.

3.2.1 Mechanical Part

The mechanical part consists of strain gauge sensor, which resistance changes with respect to the applied force. It can be either expansion or compression force. The value of force will converts into a change in electrical resistance which can be measured. For this project, the amount of force initially is measured in voltage. Then, it will be converted to force accordingly.

The strain gauge will be attached on a surface of metal ruler to measure the deflection of the material. Therefore, the strain experienced by the test specimen is transferred directly to the strain gage, which responds with a linear change in electrical resistance.

Strain gauge is very useful sensing element for many types of sensors, including pressure sensors, load cells, torque sensors, and position sensors. The metallic strain gage consists of a very fine wire arranged in a grid pattern. The changes in resistance can be measured between two points as illustrated in the Figure 7;

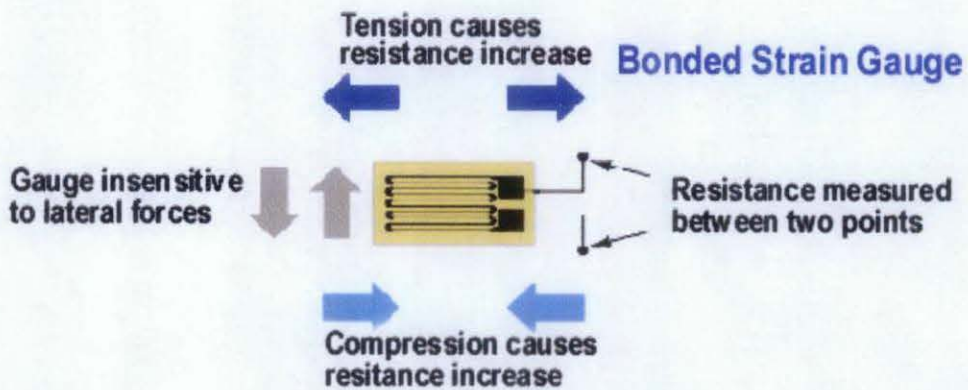


Figure 7: Grid pattern of strain gauge

Strain gauges are available commercially with nominal resistance values from 30Ω to 3000Ω . For this project, the value of the gauge used is 120Ω .

3.2.2 Communication Part

For communication part, a Low Cost NI6024E-Series Multifunction Data Acquisition Card (DAQ) is used to allow communication between the hardware device and host computer.

It consists of a multifunction I/O Card (PCI-6024E), Ribbon Cable and a connector block (CB-68LP) as shown in Figure 8;

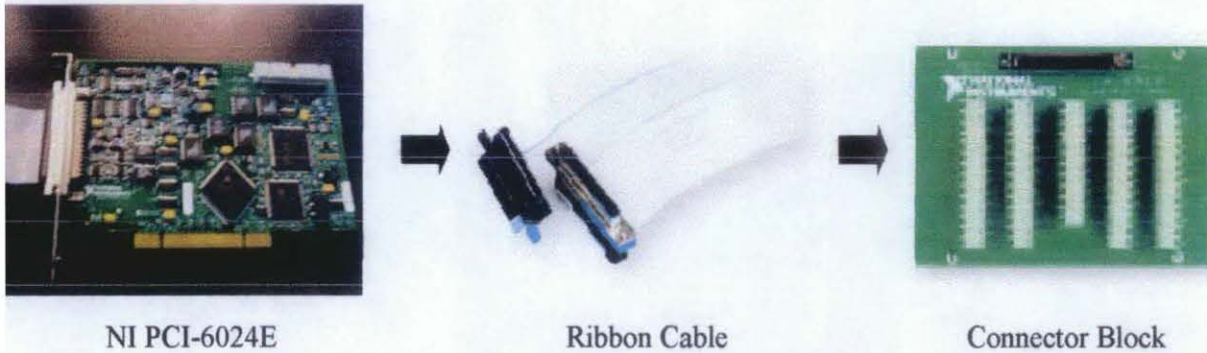


Figure 8: Communication Part connection

DAQ is the multi function, analog consisting of analog to digital converter (ADC) and digital to analog converter (DAC) that allows both digital and analog conversion [12].The system is integrated with National Instrument product, which offers direct control of all hardware on DAQ board from LabView Software.

The board used as a medium to convert the physical signal which is the force exerted by user and transfer it to the host computer for further calculation and measurement as shown in Figure 9;

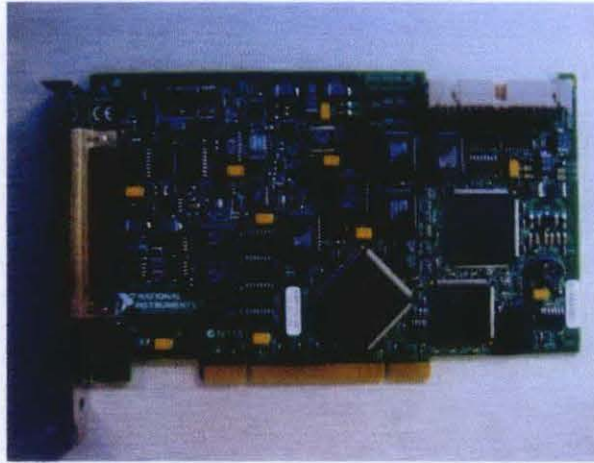


Figure 9: Data Acquisition Board (DAQ)

3.2.3 *Software/ Host Computer*

The LabView (Laboratory Virtual Instrument Engineering Workbench) software is graphical programming software used in developing program for data acquisition, control, simulation and communication applications. In the LabView environment, icons are interconnected to create a program generally referred to as a VI (Virtual Instrument), and all LabView program have an extension .vi. The VI can perform like an instrument with the advantage of flexibility of recording the data that is being measured.

All VIs must have two elements: Front Panel and the Block Diagram. The front panel is an interactive user interface of a VI because it simulates the front panel of a physical instrument. The front panel can control push buttons, graphs, knobs and many other controls and indicators as shown in Figure 10;

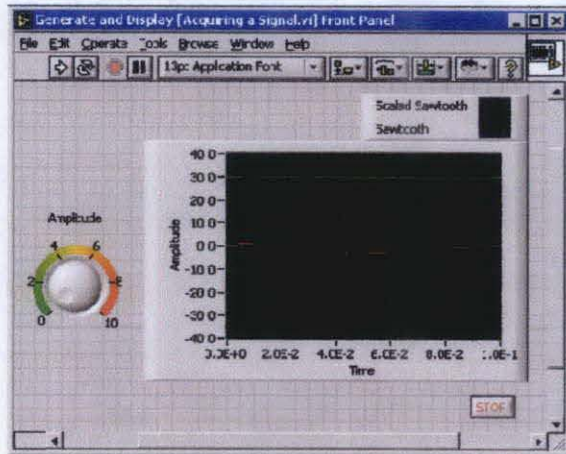


Figure 10: Example of Front Panel

Meanwhile, the block diagram is the VI's source code, constructed in LabVIEW's graphical programming language, G. The block diagram is the actual executable program follow data flow model for running VI.

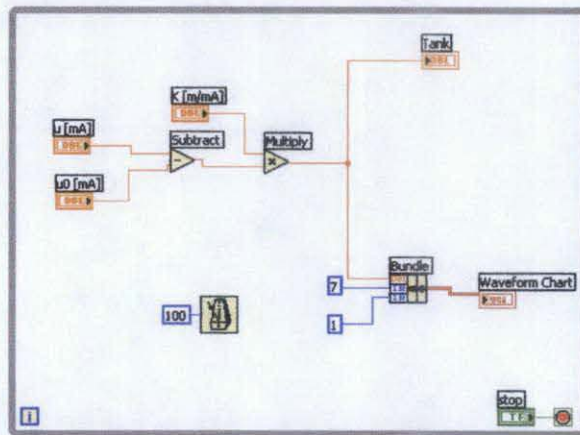


Figure 11: Example of Block Diagram

The LabView software used to design a virtual instrument interface. Therefore, when the user exerts force on the device, the computer software will measure and display the exertion force applied by the user on the material. The LabView software also will do the monitoring, recording data and perform calculation based on the deflection of the material.

3.3 Summary of Project Flow

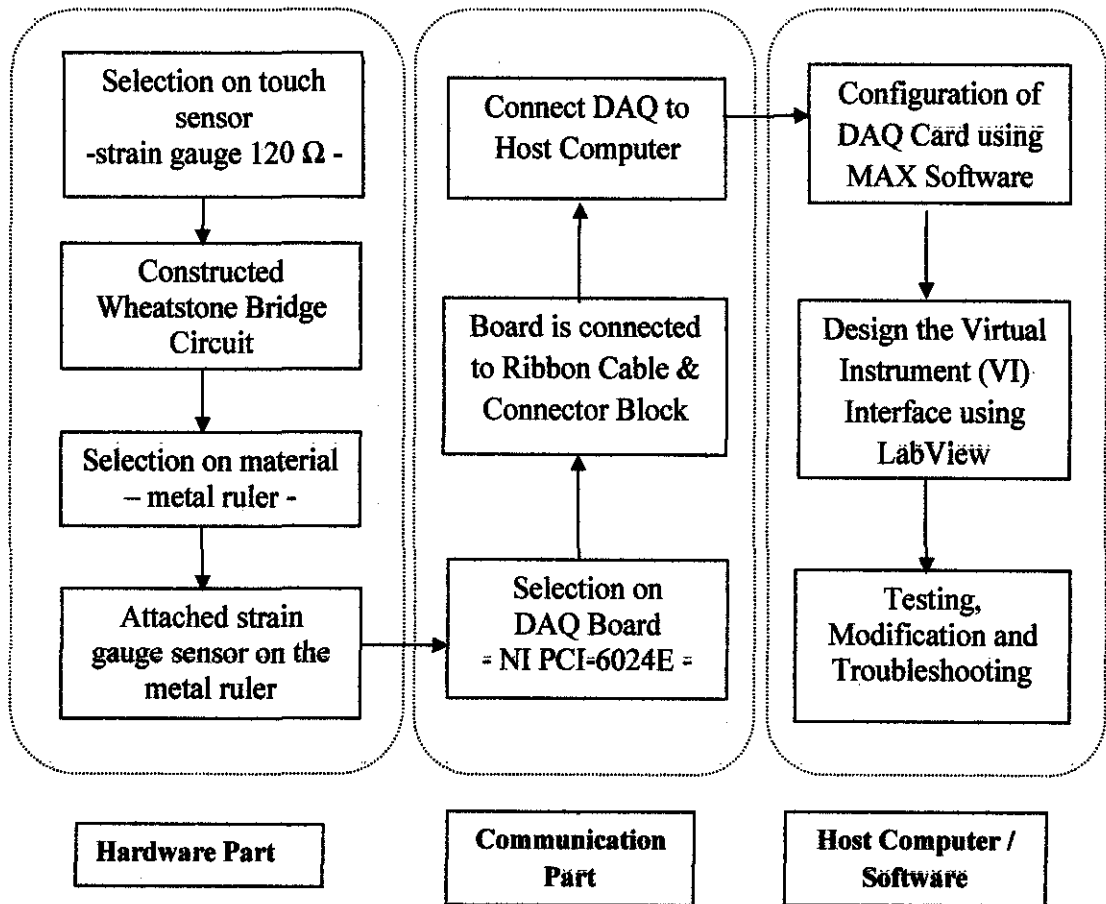


Figure 12: Process flow of the project

Flow chart in Figure 12 shows the overall design procedure for the project. The first step to design and produce the hardware device is the selection of touch sensor. After researches on several types of sensor such as force sensor, strain gauge sensor, and pressure sensor, the author found that strain gauge is the most suitable sensor to be used due to the reliability of it to measure the deflection or strain of a material. The next step is to construct Wheatstone bridge circuit, and finally the strain gauge is attached on the metal ruler that has been selected as the test specimen.

For communication part, the DAQ model PCI-6024E is chosen since it allows direct connection from hardware to the host computer. The board consist of 16 input with the input range of ± 0.05 to $\pm 10V$. Based on the datasheet specification, the output voltage, V_{out} from circuit is connected to pin 33 at Connector Block and the ground wire is connected at pin 67.

Once the hardware is connected to the connector block, the Data Acquisition board need to be configured to ensure that the board can function properly. Measurement & Automation Explorer (MAX) software will searches for the installed devices and display the related information. Figure 13 illustrated the device model PCI-6024E which has been configured.

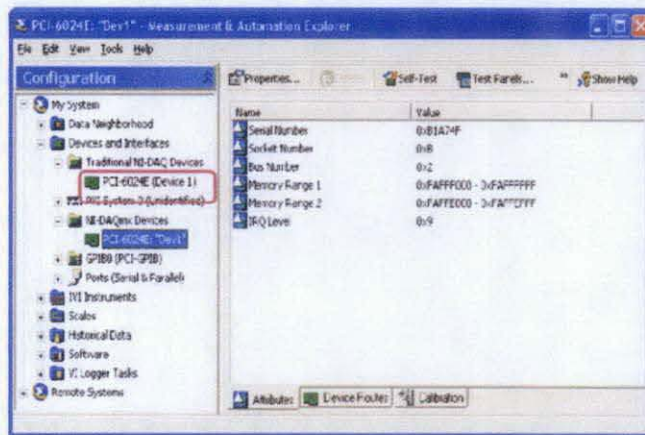


Figure 13: Configuration using MAX Software

Finally, the Virtual Instrument (VI) interface is built using LabView software before the process of testing, modification, and troubleshooting can be performed.

3.4 Integration Process

The integration process is a process to assemble each of single components in order to develop the complete haptic system. The hardware part that consists of the haptic device is connected to the host computer via the Data Acquisition board as shown in Figure 14;

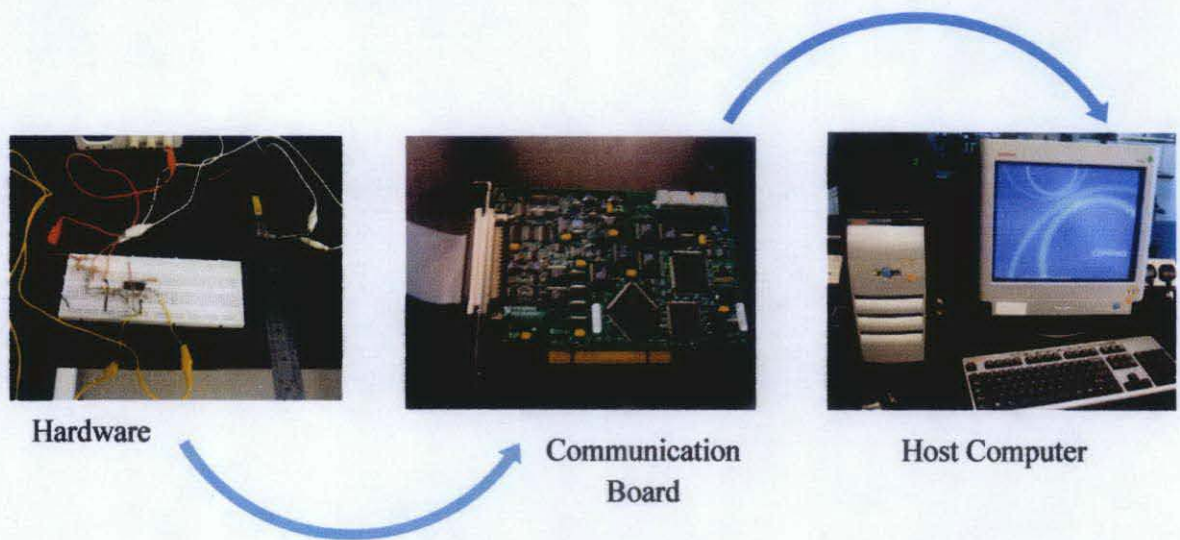


Figure 14: The haptic system

CHAPTER 4

RESULT & DISCUSSION

4.1 General Block Diagram

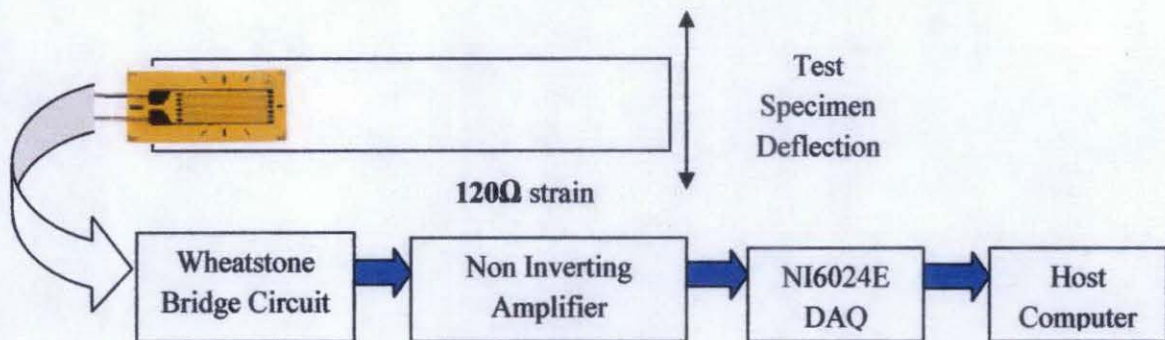


Figure 15: Block Diagram of overall system

Figure 15 illustrated block diagram of the strain gauge sensor measurement. A strain gauge sensor which attached on a metal ruler is then connected to a Wheatstone bridge circuit, consist of three identical resistors. The Wheatstone bridge circuit is built to enable the use of strain gauge to measure amount of deflection of the material based on the force applied by user. Traditionally, the amount of deflection in form of voltage is measured by using digital multi meter (DMM). The continuous generated signal while the metal ruler is deflected upward and downward also can be observed from the oscilloscope [13]. However, the process of record the measurement and collecting data has to perform manually.

Instead of using the traditional measurement, the Virtual Instrument (VI) offer higher accuracy and flexibility for measurement. Therefore, the amplified voltage output from the Wheatstone bridge circuit can be measure, display, record, and monitor using the LabView Software. The sensor will be attached to the DAQ board. For this project, PCI-6024E DAQ Board is used since it is available from EE Store. The DAQ Board is then connected to host computer. LabView Software Version 6.0 is used to design virtual instrument interface for acquire data.

4.2 Schematic Design

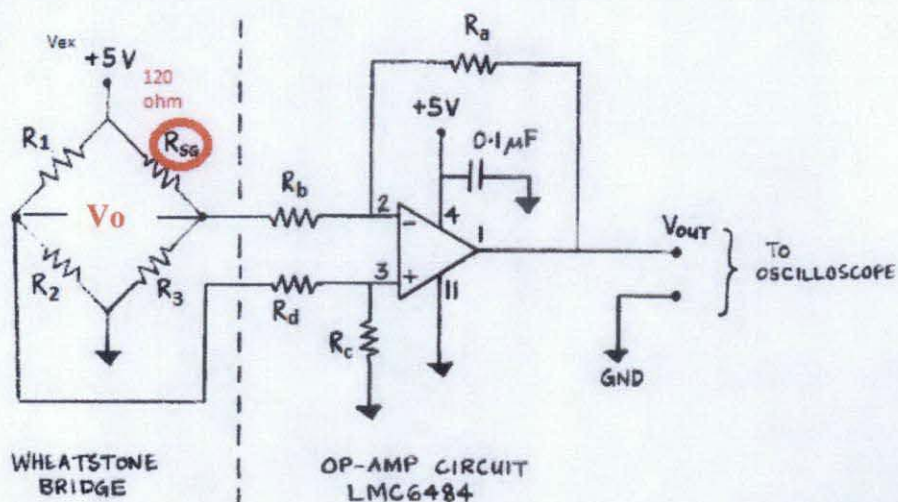


Figure 16: Schematic Circuit for Wheatstone Bridge and Operational Amplifier [14]

The Wheatstone bridge circuit is constructed as shown in Figure 16. The value of strain gauge sensor used, R_{SG} is 120Ω . It is attached on a metal ruler, which can be deflected upward and downward easily. In order to make the bridge circuit balanced, the remaining resistance at the three arms of the Wheatstone bridge should have the same value as R_{SG} . Therefore,

$$R_1 = R_2 = R_3 = 120\Omega.$$

The output voltage (V_o) of the Wheatstone bridge circuit is expressed in millivolt output as shows in Figure 13. Then, from the Wheatstone bridge, the output is amplified using operation amplifier model LMC6484 [15]. This CMOS Quad Rail-to-Rail Input and Output Operational Amplifier is most suitable to be due to the common mode range that extends to both supply rails. Thus, with the high accuracy and reliability of this amplifier makes it an ideal system for data acquisition board that requires a large input signal range. The actual circuit connection is illustrated in Figure 17.

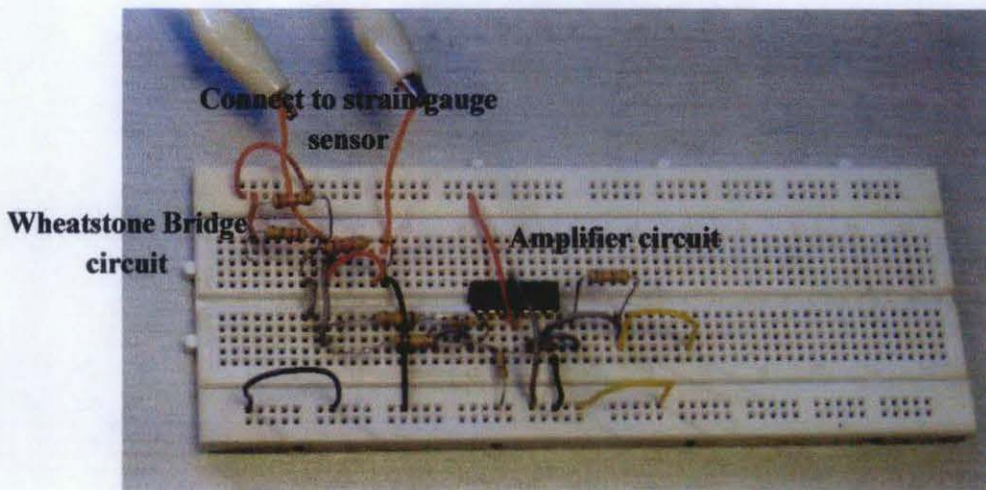


Figure 17: Wheatstone bridge circuit with amplifier

The diagram on Figure 18 demonstrated the overall mechanical part of the prototype, after the circuit is connected to the strain gauge sensor. The strain gauge sensor should be attached on the metal ruler carefully during the process of fabrication in order to avoid the metal foil of the sensor get damage.

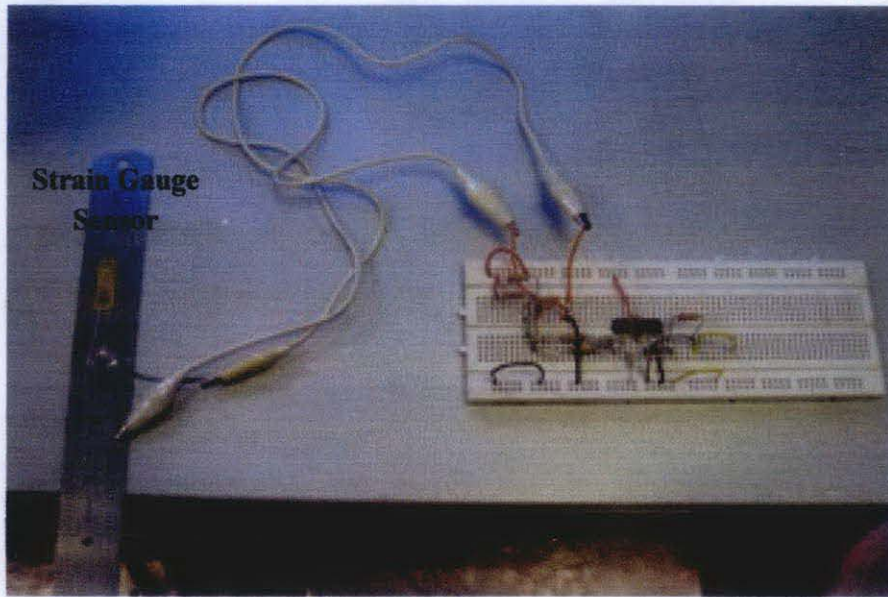


Figure 18: Mechanical part of the prototype

4.3 Principle of Strain Gauge Sensor

Since the strain-initiated resistance change is extremely small, a Wheatstone bridge is constructed to convert the resistance change to a voltage changes for a measurement. Initially, the resistance values are identical for R1, R2, R3 and RSG. Then, the calculated output voltage, Vo is obtained using the following general equation:

$$V_o = \left(\frac{R_2 R_4 - R_1 R_3}{(R_1 + R_2)(R_3 + R_4)} \right) \times V_{EX} \quad \dots\dots\dots (1)$$

Where;

V_{EX} = the supply voltage (5V)

V_o = the output voltage from Wheatstone bridge

$R_4 = R_{SG}$

$R_1 = R_2 = R_3 = 120 \Omega$.

Ideally, when no force applied to the sensor, the bridge will symmetrically balance, therefore zero output is produced. It shows that the Wheatstone bridge circuit is in balance condition with no deflection. Meanwhile, when the metal ruler is deflected, the strain gauge is changes by ΔR due to strain. Then, the output voltage can be computed using this equation;

$$V_o = \left(\frac{(R2 + \Delta R)R4 - R1R3}{(R1 + R2)(R3 + R4 + \Delta R)} \right) \times V_{EX} \quad \dots\dots\dots (2)$$

Where;

ΔR = changes in strain gauge resistance

Several measurements are taken when the metal ruler is being deflected. The measurement is made using Digital Multimeter (DMM).The calculated value is computed using Equation 1 and 2, and the output comparison between calculated and measured output voltage before the output is amplified illustrated in Table 1;

Table 1: Comparison between Measured & Calculated Values

Changes in Rsg, ΔR	CALCULATED VALUE (V)	MEASURED VALUE (V)	ERROR (%)
0	0	0.0015	0.001
1.5	0.016	0.001	15
3.0	0.03	0.025	20
4.5	0.047	0.04	15

Error of percentage can be calculated from equation 3;

$$\text{Error}(\%) = \frac{\text{Calculated Value} - \text{Measured Value}}{\text{Calculated Value}} \times 100\% \quad \dots\dots\dots (3)$$

4.4 Display Output Value from Measurement

The author had conducted two types of measuring output value which are measurement using Digital Multimeter (DMM) and measurement from LabView. However, those measurements were conducted simultaneously while the metal ruler is being deflected. The measured output from DMM is recorded manually, meanwhile the output generated from LabView can be observed from host computer. By having two values of different types of measurement, the author can verify the functionality and reliability of the hardware device. Hence, it is easier to make comparison between the measured values. Figure 19 demonstrated the experimental setup to measure the deflection of metal ruler using DMM.

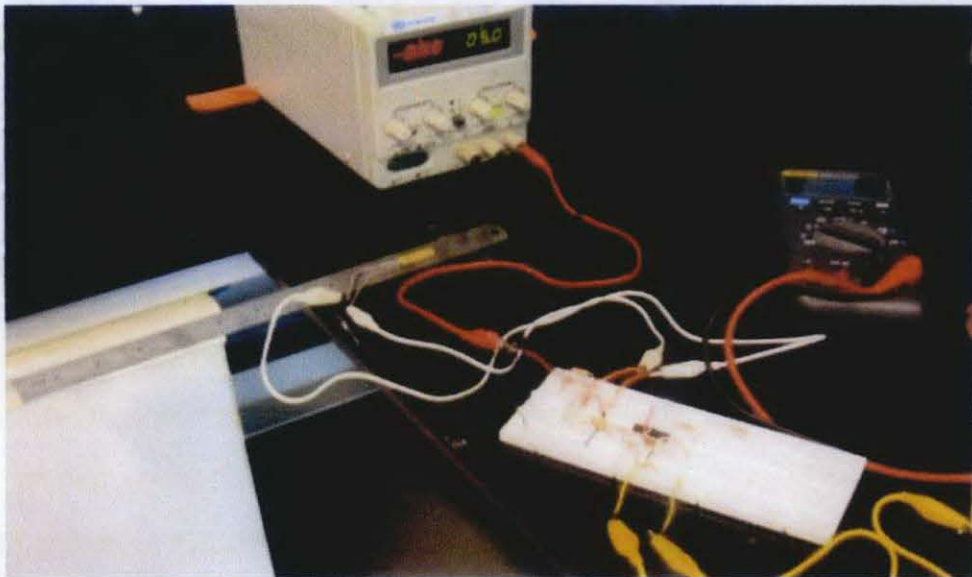


Figure 19: Experimental setup for measuring deflection of metal ruler

Several measurements are taken to obtain the deflection of the metal ruler when user applying force to it. The output measured from DMM is recorded as illustrated in Table 2.

Table 2: Measured Value from Digital Multimeter (DMM)

No of reading	Measured Voltage (V)
1	2.20
2	2.49
3	2.28
4	2.60
5	2.05
6	2.88
7	2.90
8	2.49
9	2.55
10	2.73

Previously, an experiment also had conducted to observed output waveform using oscilloscope when the ruler is deflected. The values are keep on changing as the force applied to the ruler is varying as illustrated in Figure 20:

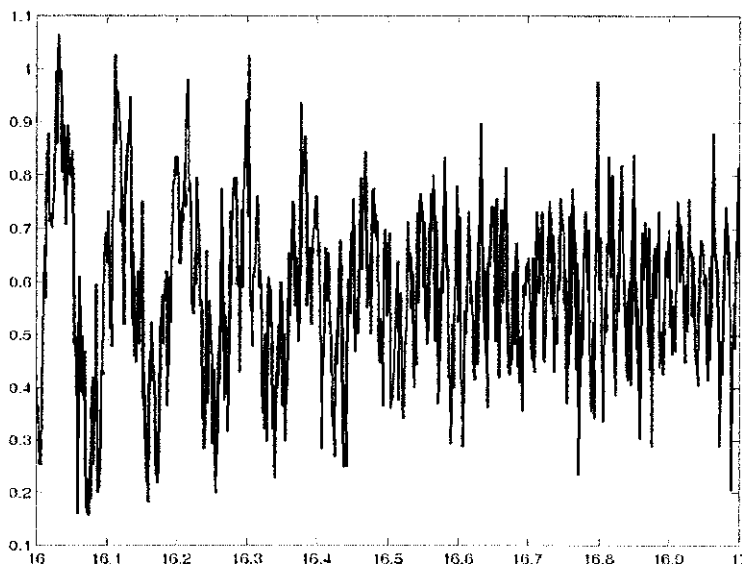


Figure 20: Deflection output

4.5 Problem Identification

The process of developing the simple haptic device has been divided into three main tasks consists of mechanical part, communication part, and host computer/software. After each of the tasks is done, the hardware device is integrated with the host computer via communication DAQ Board. However, few problems encountered to assemble the hardware to the computer. During the test and measurement, the main problem occurred is during the conversion of Analog to Digital Signal by DAQ Board due to insufficient output from the device. The problem is overcome by adding non-inverting amplifier circuit to the device. The prototype was tested several times; corrective actions and upgrading are done to ensure the device work efficiently.

4.6 Acquire data using LabView Software

The graphical LabView program is designed before the circuit (strain gauge sensor) is being connected to the computer via connector block [17]. The DAQ Board is functional for converting both Analog to Digital Signal (ADC), and Digital to Analog Signal (DAC). Therefore, it allows direct connection from the sensor attached on metal ruler to the virtual instrument interface in LabView Software. When the force is applied or whenever there is deflection upon the metal ruler, the output voltage generated can be observed from the computer screen in the form of waveform graph. Several measurements have taken when the force applied to the surface of material. The results are shows on the next sections.

4.6.1 Output Voltage Value

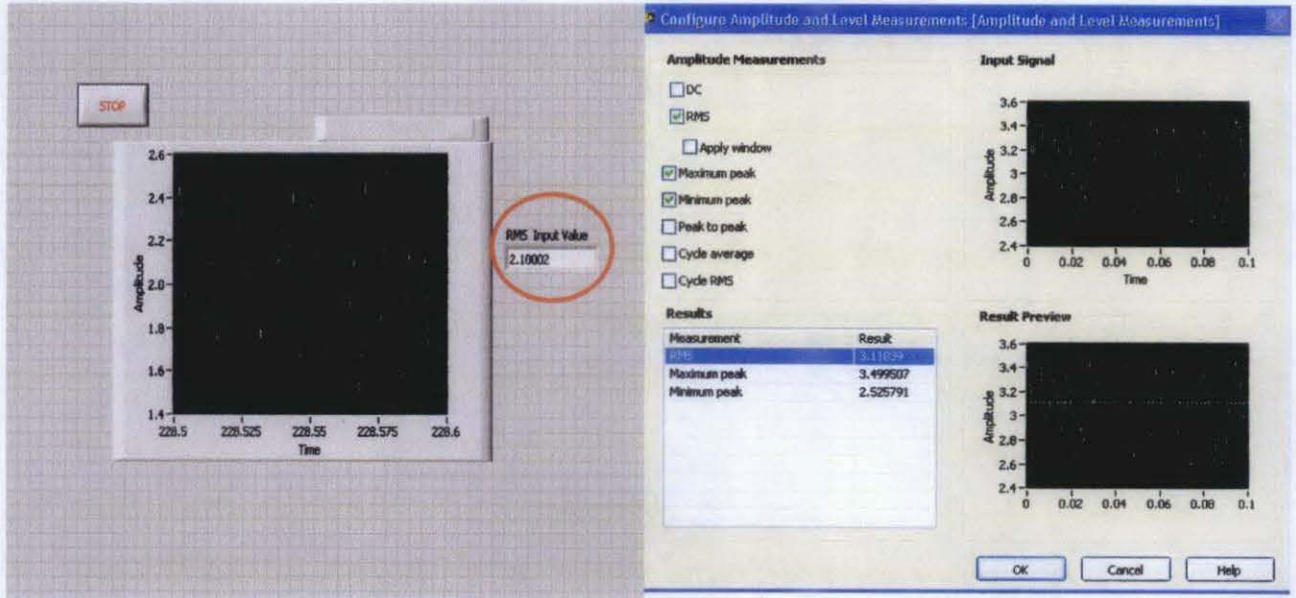


Figure 21: Front Panel of Output Voltage

The waveform chart on Figure 21 shows the output voltage when the ruler is being deflected upwards and downwards. Based on the program build in LabView software, the RMS value, maximum and minimum output value also can be obtained. The summary of the measurements is recorded in Table 3;

Table 3: Output Voltage from LabView

Vrms	2.01 V
Vmax	2.59 V
Vmin	1.46 V

4.6.2 Tabulate Digital Output Value

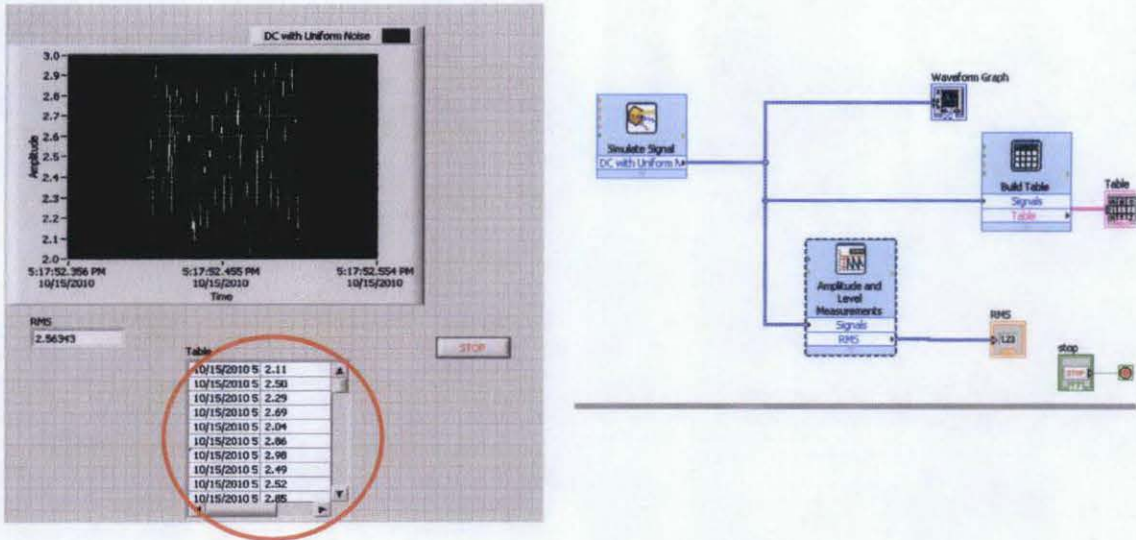


Figure 22: Front Panel & Block Diagram after adding Table to display digital value

Based on the result obtained, the output voltage is fluctuating rapidly with respect to the changes in force applied by the user to the surface material. Therefore, by adding the Table function in the LabView program, the digital output value is calculated by the program and displayed at the front panel. The table generated from Figure 22 displays the mean value during the measurements. From the result obtained, the measured voltage is tabulated in Table 4, and the range of the output is varies between 2.11V to 2.98V based on the force applied by the user.

Table 4: Measured value from LabView Software

No of reading	Measured Voltage (V)
1	2.11
2	2.50
3	2.29
4	2.69
5	2.04
6	2.86
7	2.98
8	2.49
9	2.52
10	2.85

Based on the measured voltage obtained from Table 4, a comparison output between the DMM Measurement and Virtual Instrument (LabView) are demonstrated in Table 5. Hence, based on the calculation for difference in both measurements, the author identified that the deviations for these output values are relatively small, which is between 0V to 0.12V.

Table 5: Comparison between DMM Measurement and Virtual Instrument

No of reading	Measured Voltage from DMM (V)	Measured Voltage from LabView (V)	Difference in measurements (V)
1	2.20	2.11	0.09
2	2.49	2.50	0.01
3	2.28	2.29	0.01
4	2.60	2.69	0.09
5	2.05	2.04	0.01
6	2.88	2.86	0.02
7	2.90	2.98	0.08
8	2.49	2.49	0.0
9	2.55	2.52	0.03
10	2.73	2.85	0.12

Thus, to see the difference clearly, a graph chart contain data from both measurement is plotted and the result illustrated in Figure 23.

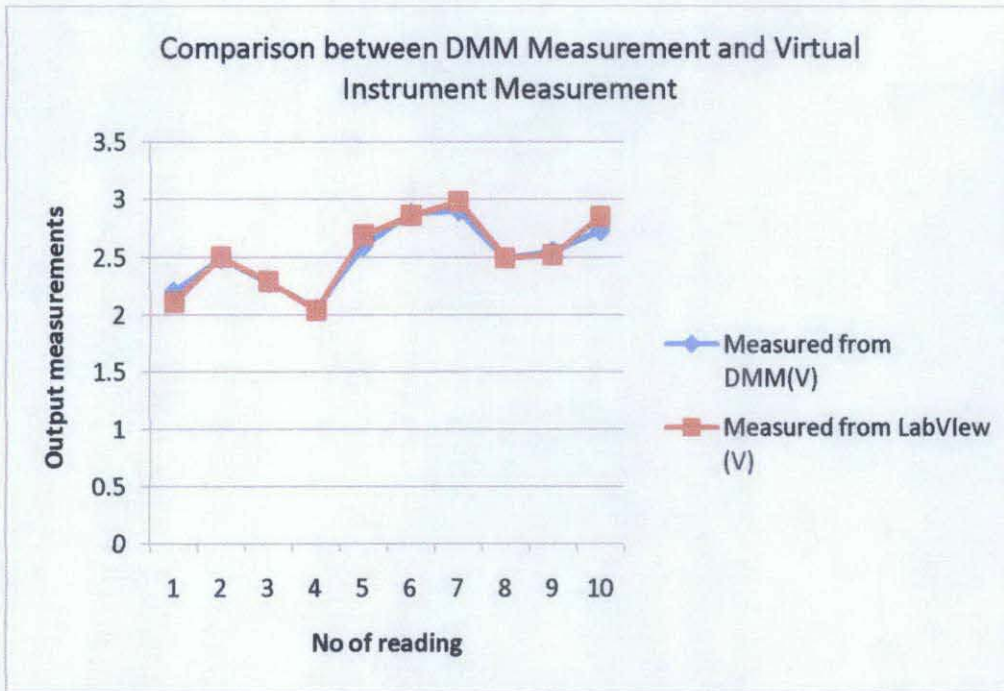


Figure 23: Comparison Chart between Measurements

4.6.3 Save Data to File

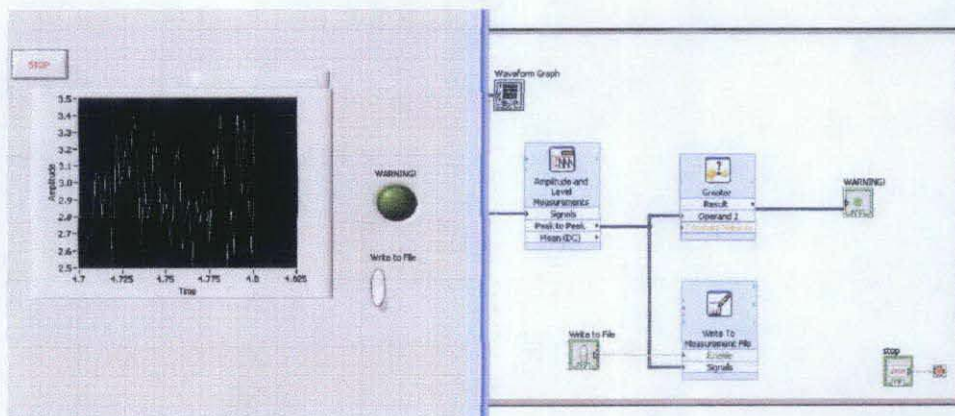


Figure 24: Front Panel & Block Diagram for the Save Data

The button “*Write to File*” is added in order to ease for monitoring and recording data as prompted by the user. The user can store sampling data at certain time by configuring the Write LabView Measurement File Express VI. The data stored can be retrieved later using spreadsheet application.

4.7 Relationship between Voltage Output and Force

The experiment conducted from this project demonstrated that the amount of strain due to the changes in electrical resistance can be measured directly. The force applied by the user will determine the deflection of the metal ruler which is measured in form of voltage. The relationship between output voltage and force can be generated using Hooke’s Law [18]. According to Hooke’s Law, the force applied from the experiment conducted can be calculated from Equation 4;

$$F = kx \quad \dots\dots\dots (4)$$

Where k = coefficient density of the metal ruler

x = the deflection of metal ruler (V)

Therefore, from this equation, in ideal case, the amount of deflection should have linear response with respect to force applied. Thus, for this project, the amount of force is determined by monitoring the output voltage. The force value can be computed using Equation 4 with the specific coefficient density for the metal used is 8.97[18]. The importance of getting the force value for the system is to identify the maximum force that can be applied before the material damaged or get into permanent deformation state.

Table 6: Calculation of Force value

No of reading	Measured Voltage from LAbView(V)	Force applied by user (Nm)
1	2.11	18.93
2	2.50	22.43
3	2.29	20.54
4	2.69	24.13
5	2.04	18.30
6	2.86	25.65
7	2.98	26.73
8	2.49	22.34
9	2.52	22.60
10	2.85	25.56

Table 6 illustrated the computed amount of force based on the deflection of the material. Hence, a graph is plotted to see the relationship between the output voltage and force applied by user as shown in Figure 25;

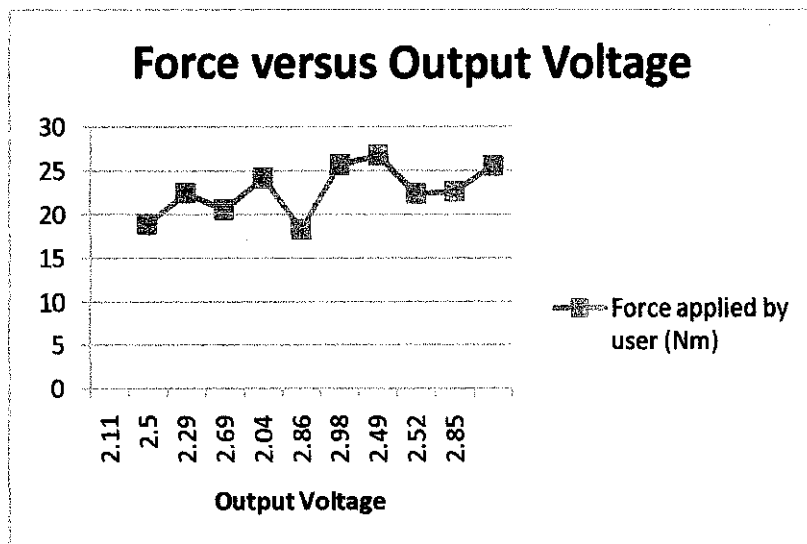


Figure 25: The relationship between output and force

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

Haptic device technology allows human-computer interaction. It has been widely used in various applications especially in the education system which has not been commercialized yet. The aim of this project to design and build a simple haptic device has achieved. It can be used to measure the deflection of material while the force is being applied on it. The measured force also will determine the maximum deflection can be applied by the user before the material gets deformed.

The device is developed by considering the design criteria that has been explained throughout this report to optimize the functionality of the prototype. The basic concept utilize three main components which the mechanical, communication and software parts does not require a complex and specialized technology. This project also is very helpful in providing a simpler design for haptic device as well as to understand the concept of haptic technology.

5.2 Recommendation

Future work can be performed to ensure reliability of the device so that it can increase the accuracy during the measurement. Based on the result obtained, there are few recommendations that could help in future to enhance the project. Those recommendations are:

1. The deflection measurement should be tested on different types of bendable materials. The sensitivity of each material also should be analyzed. Therefore, the workability and functionality of the circuit design is verified. The comparison between the maximum force of different materials also can be obtained.
2. Besides, voltage fluctuation from the measurement also can be reduced by adding analog Low Pass Filter. The voltage fluctuation due to noise should be significantly less after filtering. Therefore, the author is recommending having further research on the haptic device technology to make improvement on the prototype.
3. The author and other students who are working with LabView software also should be given the opportunity to get a proper training from any LabView expertise user so that the students will be able to fully utilize the software and would not spend a lot of time learning the software by themselves.

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APPENDICES

APPENDIX A

GANTT CHART FOR FYP 1

No.	Task Name	Duration	JAN	FEB					MAC			APRIL					MAY - JUNE				
			1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	16-18	19-20	
1	Selection & Confirmation on Project Topic	2 days																			
2	Research and Literature Review on Haptic System	20 days																			
3	Preparation for Preliminary Report	3 days																			
4	Submission of Preliminary Report	1 day		●																	
5	Assemble data & study on Haptic Device Design Criteria	18 days																			
6	Hardware design	18 days																			
7	Submission Progress Report	1 day																			
9	Selection on suitable sensor and material	3 days																			
10	Construct and fabricating circuit design	14 days																			
11	Seminar	3 days																			
12	Testing Device, Analyze & Modification	10 days																			
13	Preparation for Interim Final Report	7 days																			
14	Submission of Interim Final report	1 day																			
15	Oral Presentation	1 day																			

- Suggested milestone
- Process

APPENDIX B
MULTIFUNCTION I/O DATASHEET

Low-Cost E Series Multifunction DAQ – 2 or 16-Bit, 200 kS/s, 16 Analog Inputs

II E Series – Low-Cost

16 analog inputs at up to 200 kS/s,
12 or 16-bit resolution
Up to 2 analog outputs at 10 kS/s,
12 or 16-bit resolution
8 digital I/O lines (TTL/CMOS);
two 24-bit counter/timers
Digital triggering
4 analog input signal ranges
NI-DAQ driver that simplifies
configuration and measurements

Models

NI 6036E
NI 6034E
NI 6025E
NI 6024E
NI 6023E

Operating Systems

- Windows 2000/NT/XP
- Real-time performance with LabVIEW
- Others such as Linux® and Mac OS X

Recommended Software

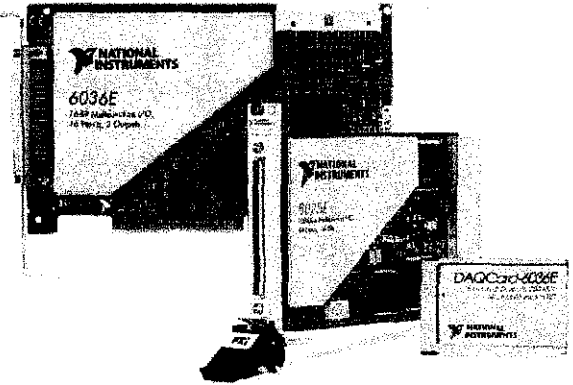
- LabVIEW
- LabWindows/CVI
- Measurement Studio
- VI Logger

Other Compatible Software

- Visual Basic, C/C++, and C#

Driver Software (included)

- NI-DAQ 7



Family	Bus	Analog Inputs	Input Resolution	Max Sampling Rate	Input Range	Analog Outputs	Output Resolution	Output Rate	Output Range	Digital I/O	Counter/Timers	Triggers
NI 6036E	PCI, PCMCIA	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	2	16 bits	10 kS/s ¹	±10 V	8	2, 24-bit	Digital
NI 6034E	PCI	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	0	—	—	—	8	2, 24-bit	Digital
NI 6025E	PCI, PXI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s ¹	±10 V	8	2, 24-bit	Digital
NI 6024E	PCI, PCMCIA	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s ¹	±10 V	8	2, 24-bit	Digital
NI 6023E	PCI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	0	—	—	—	8	2, 24-bit	Digital

¹10 kS/s typical when using the single DMA channel for analog output. 1 kS/s maximum when using the single DMA channel for either analog input or counter/timer operations. 1 kS/s maximum for PCMCIA DAQCard devices in all cases.

Table 1. Low-Cost E Series Model Guide

Overview and Applications

National Instruments low-cost E Series multifunction data acquisition devices provide full functionality at a price to meet the needs of the budget-conscious user. They are ideal for applications ranging from continuous high-speed data logging to control applications to high-voltage signal or sensor measurements when used with NI signal conditioning. Synchronize the operations of multiple devices using the RTSI bus or PXI trigger bus to easily integrate other hardware such as motion control and machine vision to create an entire measurement and control system.

Highly Accurate Hardware Design

NI low-cost E Series DAQ devices include the following features and technologies:

Temperature Drift Protection Circuitry – Designed with components that minimize the effect of temperature changes on measurements to less than 0.0010% of reading/°C.

Resolution-Improvement Technologies – Carefully designed noise floor maximizes the resolution.

Onboard Self-Calibration – Precise voltage reference included for calibration and measurement accuracy. Self-calibration is completely software controlled, with no potentiometers to adjust.

NI DAQ-STC – Timing and control ASIC designed to provide more flexibility, lower power consumption, and a higher immunity to noise and jitter than off-the-shelf counter/timer chips.

NI MITE – ASIC designed to optimize data transfer for multiple simultaneous operations using bus mastering with one DMA channel, interrupts, or programmed I/O.

NI PGIA – Measurement and instrument class amplifier that guarantees settling times at all gains. Typical commercial off-the-shelf amplifier components do not meet the settling time requirements for high-gain measurement applications.

PFI Lines – Eight programmable function input (PFI) lines that you can use for software-controlled routing of interboard and intraboard digital and timing signals.

RTSI or PXI Trigger Bus – Bus used to share timing and control signals between two or more PCI or PXI devices to synchronize operations.

RSE Mode – In addition to differential and nonreferenced single-ended modes, NI low-cost E Series devices offer the referenced single-ended (RSE) mode for use with floating-signal sources in applications with channel counts higher than eight.

Onboard Temperature Sensor – Included for monitoring the operating temperature of the device to ensure that it is operating within the specified range.



Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

Recommended Accessories

Signal conditioning is required for sensor measurements or voltage inputs greater than 10 V. National Instruments SCXI is a versatile, high-performance signal conditioning platform, intended for high-channel-count applications. NI SCC products provide portable, flexible signal conditioning options on a per-channel basis. Both signal conditioning platforms are designed to increase the performance and reliability of your DAQ system, and are up to 10 times more accurate than terminal blocks (please visit ni.com/sigcon for more details). Refer to the table below for more information:

Sensor/Signals (>10 V)		
System Description	DAQ Device	Signal Conditioning
High-performance	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCXI
Low-cost, portable	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCC

Signals (<10 V)			
System Description	DAQ Device	Terminal Block	Cable
Shielded	PCI-60xxE	SCB-68	SH6868-EP
Shielded	PXI-60xxE	TB-2705	SH6868-EP
Shielded	DAQCard-60xxE	SCB-68	SHC6868-EP
Low-cost	PCI-6025E/PXI-6025E	Two TBX-68s	SH1006868
Low-cost	PCI-60xxE/PXI-60xxE	CB-68LP	R6868
Low-cost	DAQCard-60xxE	CB-68LP	RC6868

¹Terminal blocks do not provide signal conditioning (i.e., filtering, amplification, isolation, and so on), which may be necessary to increase the accuracy of your measurements.

Table 4. Recommended Accessories

Ordering Information

PCI

NI PCI-6036E.....	778465-01
NI PCI-6034E.....	778075-01
NI PCI-6025E.....	777744-01
NI PCI-6024E.....	777743-01
NI PCI-6023E.....	777742-01

PCMCIA

NI DAQCard-6036E.....	778561-01
NI DAQCard-6024E.....	778269-01

PXI

NI PXI-6025E.....	777798-01
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Includes NI-DAQ driver software.

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For complete product specifications, pricing, and accessory information, call (800) 813 3693 (U.S.) or go to ni.com/dataacquisition.

BUY ONLINE at ni.com or CALL (800) 813 3693 (U.S.)

Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

Models	Full-Featured E Series				Low-Cost E Series			Basic
	NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6036E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014	
Measurement Sensitivity ¹ (mV)	0.0023	0.0025	0.009	0.008	0.0036	0.008	0.004	
Nominal Range (V)								
Positive FS				Absolute Accuracy (mV)				
10	-10	1.147	4.747	14.369	15.373	7.560	16.504	8.984
	-5	2.077	0.876	5.193	5.697	1.790	5.263	2.003
5	-2.5	–	1.190	3.605	3.859	–	–	–
	-2	0.836	–	–	–	–	–	–
	-1	0.422	0.479	1.452	1.556	–	–	–
5	-0.5	0.215	0.243	0.735	0.789	0.399	0.846	0.471
25	-0.25	–	0.137	0.379	0.405	–	–	–
2	-0.2	0.102	–	–	–	–	–	–
1	-0.1	0.061	0.064	0.163	0.176	–	–	–
05	-0.05	–	0.035	0.091	0.100	0.0611	0.106	0.069
0	0	0.976	1.232	6.765	7.269	–	–	–
	0	1.992	2.119	5.391	5.645	–	–	–
	0	0.802	0.850	2.167	2.271	–	–	–
	0	0.405	0.428	1.092	1.146	–	–	–
5	0	0.207	0.242	0.558	0.583	–	–	–
2	0	0.098	0.111	0.235	0.247	–	–	–
1	0	0.059	0.059	0.127	0.135	–	–	–

¹Accuracies are valid for measurements following an internal calibration. Measurement accuracies are listed for operational temperatures within $\pm 1^\circ\text{C}$ of internal calibration temperature and $\pm 10^\circ\text{C}$ of external or factory calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ± 10 V range) after one year, assuming 100 pt averaging of data.

²Smallest detectable voltage change in the input signal at the smallest input range.

Table 2. E Series Analog Input Absolute Accuracy Specifications

Models	Full-Featured E Series				Low-Cost E Series			Basic
	NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6036E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014	
Nominal Range (V)								
Positive FS				Absolute Accuracy (mV)				
10	-10	1.430	1.405	8.127	8.127	2.417	8.127	3.835
0	0	1.201	1.176	5.685	5.685	–	–	–

Table 3. E Series Analog Output Absolute Accuracy Specifications

High-Performance, Easy-to-Use Driver Software

NI-DAQ is the robust driver software that makes it easy to access the functionality of your data acquisition hardware, whether you are a beginner or advanced user. Helpful features include:

Automatic Code Generation – DAQ Assistant is an interactive guide that steps you through configuring, testing, and programming measurement tasks and generates the necessary code automatically for NI LabVIEW, LabWindows/CVI, or Measurement Studio.

Easier Code Development – Basic and advanced software functions have been combined into one easy-to-use yet powerful set to help you build cleaner code and move from basic to advanced applications without replacing functions.

High-Performance Driver Engine – Software-timed single-point input (typically used in control loops) with NI-DAQ achieves rates of up to 50 kHz. NI-DAQ also delivers maximum I/O system throughput with a multithreaded driver.

Test Panels – With NI-DAQ, you can test all of your device functionality before you begin development.

Scaled Channels – Easily scale your voltage data into the proper engineering units using the NI-DAQ Measurement Ready virtual channels by choosing from a list of common sensors and signals or creating your own custom scale.

LabVIEW Integration – All NI-DAQ functions create the waveform data type, which carries acquired data and timing information directly into more than 400 LabVIEW built-in analysis routines for display of results in engineering units on a graph.

For information on applicable hardware for NI-DAQ 7, visit ni.com/dataacquisition.

Visit ni.com/oem for quantity discount information.

NI Services and Support



NI has the services and support to meet your needs around the globe and through the application life cycle – from planning and development through deployment and ongoing maintenance. We offer services and service levels to meet customer requirements in research, design, validation, and manufacturing. Visit ni.com/services.

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Training is the fastest, most certain route to productivity with our products. NI training can shorten your learning curve, save development time, and reduce maintenance costs over the application life cycle. We schedule instructor-led courses in cities worldwide, or we can hold a course at your facility. We also offer a professional certification program that identifies individuals who have high levels of skill and knowledge on using NI products. Visit ni.com/training.

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NI Factory Installation Services

NI Factory Installation Services (FIS) is the fastest and easiest way to use your PXI or PXI/SCXI combination systems right out of the box. Trained NI technicians install the software and hardware and configure the system to your specifications. NI extends the standard warranty by one year on hardware components (controllers, chassis, modules) purchased with FIS. To use FIS, simply configure your system online with ni.com/pxiadvisor.

Calibration Services

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APENDIX C
OPERATIONAL AMPLIFIER LMC 6484

LMC6484 CMOS Quad Rail-to-Rail Input and Output Operational Amplifier

General Description

The LMC6484 provides a common-mode range that extends to both supply rails. This rail-to-rail performance combined with excellent accuracy, due to a high CMRR, makes it unique among rail-to-rail input amplifiers.

It is ideal for systems, such as data acquisition, that require a large input signal range. The LMC6484 is also an excellent upgrade for circuits using limited common-mode range amplifiers such as the TLC274 and TLC279.

Maximum dynamic signal range is assured in low voltage and single supply systems by the LMC6484's rail-to-rail output swing. The LMC6484's rail-to-rail output swing is guaranteed for loads down to 600Ω.

Guaranteed low voltage characteristics and low power dissipation make the LMC6484 especially well-suited for battery-operated systems.

See the LMC6482 data sheet for a Dual CMOS operational amplifier with these same features.

Features

(Typical unless otherwise noted)

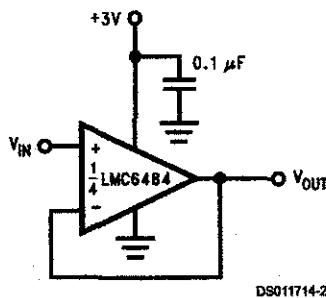
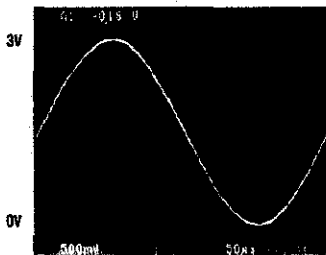
- Rail-to-Rail Input Common-Mode Voltage Range (Guaranteed Over Temperature)
- Rail-to-Rail Output Swing (within 20 mV of supply rail, 100 kΩ load)
- Guaranteed 3V, 5V and 15V Performance
- Excellent CMRR and PSRR: 82 dB
- Ultra Low Input Current: 20 fA
- High Voltage Gain ($R_L = 500\text{ k}\Omega$): 130 dB
- Specified for 2 kΩ and 600Ω loads

Applications

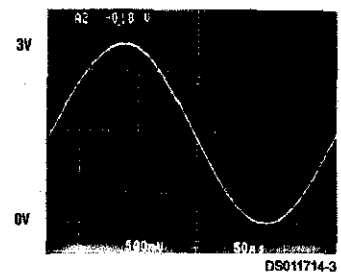
- Data Acquisition Systems
- Transducer Amplifiers
- Hand-held Analytic Instruments
- Medical Instrumentation
- Active Filter, Peak Detector, Sample and Hold, pH Meter, Current Source
- Improved Replacement for TLC274, TLC279

3V Single Supply Buffer Circuit

Rail-to-Rail Input



Rail-to-Rail Output



Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

ESD Tolerance (Note 2)	2.0 kV
Differential Input Voltage	\pm Supply Voltage
Voltage at Input/Output Pin	$(V^+) + 0.3V, (V^-) - 0.3V$
Supply Voltage ($V^+ - V^-$)	16V
Current at Input Pin (Note 12)	± 5 mA
Current at Output Pin (Notes 3, 8)	± 30 mA
Current at Power Supply Pin	40 mA
Lead Temp. (Soldering, 10 sec.)	260°C

Storage Temperature Range	-65°C to +150°C
Junction Temperature (Note 4)	150°C

Operating Ratings (Note 1)

Supply Voltage	$3.0V \leq V^+ \leq 15.5V$
Junction Temperature Range	
LMC6484AM	$-55^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$
LMC6484AI, LMC6484I	$-40^\circ\text{C} \leq T_J \leq +85^\circ\text{C}$
Thermal Resistance (θ_{JA})	
N Package, 14-Pin Molded DIP	70°C/W
M Package, 14-Pin Surface Mount	110°C/W

DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25^\circ\text{C}$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$ and $R_L > 1M$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LMC6484AI Limit (Note 6)	LMC6484I Limit (Note 6)	LMC6484M Limit (Note 6)	Units	
V_{OS}	Input Offset Voltage		0.110	0.750 1.35	3.0 3.7	3.0 3.8	mV max	
TCV_{OS}	Input Offset Voltage Average Drift		1.0				$\mu\text{V}/^\circ\text{C}$	
I_B	Input Current	(Note 13)	0.02	4.0	4.0	100	pA max	
I_{OS}	Input Offset Current	(Note 13)	0.01	2.0	2.0	50	pA max	
C_{IN}	Common-Mode Input Capacitance		3				pF	
R_{IN}	Input Resistance		>10				Tera Ω	
CMRR	Common Mode Rejection Ratio	$0V \leq V_{CM} \leq 15.0V$, $V^+ = 15V$	82	70 67	65 62	65 60	dB min	
		$0V \leq V_{CM} \leq 5.0V$, $V^+ = 5V$	82	70 67	65 62	65 60	dB min	
+PSRR	Positive Power Supply Rejection Ratio	$5V \leq V^+ \leq 15V$, $V^- = 0V, V_O = 2.5V$	82	70 67	65 62	65 60	dB min	
-PSRR	Negative Power Supply Rejection Ratio	$-5V \leq V^- \leq -15V$, $V^+ = 0V, V_O = -2.5V$	82	70 67	65 62	65 60	dB min	
V_{CM}	Input Common-Mode Voltage Range	$V^+ = 5V$ and $15V$ For CMRR ≥ 50 dB	$V^- - 0.3$	-0.25 0	-0.25 0	-0.25 0	V max	
			$V^+ + 0.3$	$V^+ + 0.25$ V^+	$V^+ + 0.25$ V^+	$V^+ + 0.25$ V^+	V min	
A_V	Large Signal Voltage Gain	$R_L = 2k\Omega$ (Notes 7, 13)	Sourcing	666	140 84	120 72	120 60	V/mV min
			Sinking	75	35 20	35 20	35 18	V/mV min
		$R_L = 600\Omega$ (Notes 7, 13)	Sourcing	300	80 48	50 30	50 25	V/mV min
			Sinking	35	20 13	15 10	15 8	V/mV min