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Computer Based Learning With LabVIEW

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كلية الهندسة والتكنولوجيا

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اسم المشروع:

Computer Based Learning With LabVIEW

أسماء الطلبة

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عبير الجعبري

بناء على نظام كلية الهندسة و التكنولوجيا و إشراف ومتابعة المشرف المباشر على المشروع و موافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الكهربائية و الحاسوب و ذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة أنظمة الحاسوب

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توقيع رئيس الدائرة

د. غاندي المناصره.....

Abstract

This project aim to use alternative and powerful way to design and implement experiments in electrical circuit lab in PPU university, using new technology to measure, acquire, manipulate and display data, as well as to generate signals through the use of a "Data Acquisition board" and use new programming language called LabVIEW which is graphical programming language that means there is no text based code compare with other programming language.

هذا المشروع يهدف إلى تصميم مختبر الدوائر الكهربائية في جامعة بوليتكنك فلسطين عن طريق استخدام تكنولوجيا جديدة، هذه التكنولوجيا تستخدم لغة جديدة تعتمد على الرسم بدلا من اعتمادها على كتابة الأوامر مقارنة باللغات الأخرى، بالإضافة إلى استخدام أداة توصيل وهي عبارة عن كرت يعمل على توصيل تجارب المختبر بجهاز الحاسوب والذي يتم التحكم بها من خلال البرنامج الذي تم تصميمه بواسطة لغة برمجة تعرف (LabVIEW).

Dedication

Acknowledgement

To our supervisor Eng. Elwan Abu Khatya for his guidance, support and
To our Parents..... Allah, Rashed and Ahmed, and Eng. Rami al-Jabri

for their help and support. Also we would like to thank our project partners for helpful
To our Families..... Also we would like to thank our family and our

girlfriend
To our Friends.....

To our supervisor.....

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	Protocol
XML	Extensible Markup Language
AD	Analog-to-Digital Converter
DA	Digital-to-Analog Converter
IO	Input-Output
PC	Personal Computer
NI	National Instruments
ADC	Analog-to-Digital Converter
PCI	Peripheral Computer Interface
MPB	Meta-Block
DC	Direct Current
AC	Alternative Current

List of Abbreviations

VI	Virtual Instrument
LabVIEW	Workbench Laboratory Virtual Instrument Engineering
DAQ	Data Acquisition
SQL	Structured Query Language
Tcp/Ip	Transfer Control Protocol /Internet Protocol
XML	Extensible Markup Language
A/D	Analog-to-Digital Converter
D/A	Digital-to- Analog Converter
I/O	Input-Output
PC	Personal Computer
NI	National Instrument
ADC	Analog-to-Digital Converter
PCI	Peripheral Computer Interface
MHz	Mega Hertz
DC	Direct Current
AC	Alternative Current

1.1 Introduction

Computer based learning has become an important part of education systems. It provides animation and interactive processes that are not possible with textbooks.

CHAPTER ONE INTRODUCTION

1.1 Introduction

1.2 Project Importance

1.3 Literature Review

1.4 Project Estimated Cost

1.5 Time Plan

1.6 Report Contents

1.1 Introduction

Computer based learning has become an important part of education systems. It provides animation and interactive processes that are not possible with textbooks.

In recent years, teaching methods have gone through a number of changes. Significant among these changes is an increased use of technology. Professors now frequently deliver instruction with the aid of computers rather than through the traditional lecture approach. Students sometimes access and complete homework over the Internet, as computers easily grade the fill-in-the-blank or multiple-choice format questions. The next logical step is to use computers to teach the lab section of a class. Students can use computers to acquire real-world signals, perform advanced analysis and present the results. However, only a limited number of instructors have made use of this technology, in part because of the perception that the use of computers will compromise the traditional hands-on focus of the lab. In reality, students will still be required to set up the experiment. They can use computers to "speed up" manual measurements made in the lab, thus allowing them to collect more real-world data than what was possible by hand. This will leave students with time to delve into a more detailed and complex analysis of the concepts addressed by the lab. The use of computers also allows students who do not have access to a physical lab to monitor and control experiments over the Internet. The networking capability of computers allows "virtual" access to a real-world lab by students at a remote location, facilitating distance learning. These students can also use a computer simulation of an experiment as a pre-lab assignment, thus allowing them to have a better understanding of the behavior of the experiment [1].

Virtual laboratory experiments are practical and effective educational tools. They may be used to allow students a more comprehensive, flexible experience and to prepare students for actual laboratory performance. The benefits include cost effectiveness and convenience. With a virtual simulation, a procedure can be repeated without cost of

لا يرفع الوقت في عمل التجارب و لا حاجة لوقت في إعداد أدوات التجارب و لا حاجة للمواد و لا حاجة للوقت في إعداد الأدوات (distance learning)

materials and labor, damage on equipment, or loss of class time. Also, multiple equipment stations are not needed, lengthy experimental setups are avoided, and one-time or remote field tests are facilitated. With a virtual laboratory, the student users control the pace, frequency, and time of the experiment. Also, distance learners can participate [2].

Computer-based measurement can reduce certain drawbacks of labs such as the need to manually record, analyze, and display data in a report. It is also important to enable students at a remote location to access to experiments that were unavailable before due to lack of laboratory resources. LabVIEW is a tool that offers all of these features today. Easy to program, LabVIEW allows both real-time connectivity to and simulation of existing labs [3].

الحاجة لتسجيل البيانات و تحليلها و عرضها في تقرير
LabVIEW

National Instruments LabVIEW:

LabVIEW is a graphical programming language based on the concept of data flow programming. Many engineers and scientists in industry and academia have adopted LabVIEW for data acquisition and instrument control applications. Functions in LabVIEW are referred to as VIs (Virtual Instruments). LabVIEW has VIs for data acquisition, data analysis, and data visualization and presentation. The data acquisition VIs allows you to acquire data from a real-world source. Consider an experimental setup in which you connect a thermocouple, measuring the temperature of the room, to one of the channels of a data acquisition board. You can use one of the data acquisitions VIs to acquire the temperature signal and then easily connect it to a graph to visualize the temperature readings. You can also perform calculations on the data using VIs such as the Mean and Standard Deviation. LabVIEW also provides tools such as the VI Server and Data Socket to allow distribution of experiments over a network of computers. The VI Server allows one machine, which runs LabVIEW and VIs for different labs, to act as the server. Students can access experiments from their home computer or any other computer connected to the network. Their computers, which need not have LabVIEW installed, will have standalone

LabVIEW
data
analysis
visualization
presentation
data acquisition
Mean
Standard Deviation
VI Server
Data Socket
distribution
network
standalone

executables that connect to the server using the TCP protocol and run the requested VI. Students can control the experimental setup from their computers and analyze the results [4].

1.2 Project Importance

This project aims to use an alternative and powerful way to design and implementing experiments in electrical circuit lab in PPU university, using new technology to measure, acquire, manipulate and display data, as well as to generate signals through the use of a "Data Acquisition board". The lab will illustrate that the integration of computers and electronics. Also, aim for expanding the learning for students in the laboratories, they will get to work in smaller work-groups, they will have additional time to access the equipment, the computerized data acquisition will eliminate slow and cumbersome methods of collecting some of the data, and the students will be able to see the basic engineering principles and phenomena displayed with less procedural details. So the students will take the result for any experiment directly from computer.

1.3 Literature Review

There are many project design under the title Computer based Learning with LabVIEW such that:

- ✦ The virtual laboratory, refer to Johns Hopkins is an example of use this type of technology. This project was designed to introduce students to experimentation, problem solving, data gathering, and scientific interpretation early in their careers--perhaps as high school seniors. They used java to implement all experiments in this project in JAVA and are fully interactive [5].
- ✦ other project refer to Jim Henry, Ph.D., P.E. who design the **Implementation of Practical Control Systems**, in University of Tennessee at Chattanooga, This project describes six computer-based systems for data acquisition and control that have been installed in an engineering laboratory used to teach classical control techniques. The engineering parameters that are the subjects of the various control stations are speed, pressure, flow, position, liquid level, and temperature. Each engineering system is a non-linear, single-input, single-output system and each system has one or more externally applied disturbance parameters. All systems have data acquisition and control programs with an operating interface which simulates a traditional analog process controller. The programs are used by students for parameter identification of the various systems and then used to tune the controller action (proportional and/or integral actions). Results of step response and frequency response experiments are used for system identification and design the systems are implemented with LabVIEW [6].
- ✦ The **Educational Laboratory Virtual Instrumentation Suite (ELVIS)** Laboratory Development project, At Iowa State University refer to FACULTY ADVISORS, PROF. Mani Mina, Prof. Diane Rover was the other example of this

title. The ELVIS system has been designed to consolidate a variety of instruments into one functionally equivalent system and to provide a means of automatic data acquisition [7].

✚ **Jim Henry**, Ph.D., P.E., Professor, Chemical and Environmental Engineering, College of Engineering and Computer Science University of Tennessee at Chattanooga, TN 37403, USA was design engineering systems laboratory at UTC has been made project The hardware consists of distributed desktop computers connected to a variety of engineering laboratory equipment. The software is all implemented with LabVIEW [8].

PC Processor (PI 240MHz, 256 MB)	112.5
RAM, 40 GB HDD	1000
Total cost	1732.5

1.4.3 Software Components Estimated Cost

Table 1.2 Software Components Estimated Cost

LabVIEW programming language	300
Windows XP	100
Total cost	1000

1.4.3 Total Estimated Cost

$$\begin{aligned} \text{Total estimated cost} &= \text{cost of Hardware components} + \text{cost of Software components} \\ &\quad + \text{Unexpected cost} \\ &= 1732.5 + 1000 + 100 = 2832.5 \end{aligned}$$

1.4 Project Estimated Cost

1.4.1 Hardware Components Estimated Cost

Table 1.1 Hardware Components Estimated Cost

Component		Estimated cost (\$)
1	DAC board	550
2	connector block	70
3	cable	112.5
4	PC Pentium (4) 2400MHz, 256 MB RAM, 40 GB HDD	1000
Total cost		1732.5

1.4.2 Software Components Estimated Cost

Table 1.2 Software Components Estimated Cost

Component		Estimated cost (\$)
1	LabVIEW programming language	900
2	Windows XP	100
Total cost		1000

1.4.3 Total Estimated Cost

Total estimated cost = cost of Hardware components + cost of Software components
+ Unexpected cost
= 1732.5 + 1000 + 100 = 2832.5\$

1.4 Project Estimated Cost

1.4.1 Hardware Components Estimated Cost

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1.4.3 Total Estimated Cost

Total estimated cost = cost of Hardware components + cost of Software components
= 1732.5 + 1000 = 2732.5\$

1.5 Time plan

1.5 Time plan

Table 1.3 Time Plan

weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Tasks																																
Data gathering																																
learn the lab view software and data analysis																																
Design																																
Implementation																																
Testing																																
Documentation																																

1.6 Project Contents

Report consists of seven chapters; the following is a brief description of the topics that are covered in each chapter.

Chapter1:

General idea about the project provides a brief introduction to LabVIEW and definitions about computer based learning and virtual lab. Also, provide the importance of the project, literature review and time plan.

Chapter2:

Introduces and illustrates the idea of the project, describes the components used in the project, software component (LabVIEW), and hardware components (DAQ card and connector).

Chapter 3:

Details the design concepts, introduces project objectives, shows the general block diagram of the system and explains how system works.

Chapter4:

Contain details about all components in our project and that is show in block diagrams, Outlines formal procedure for design, discuss design options and justify those chosen for the project.

Chapter 5:

Provides flow charts describing how the system works, and detailed of the flow charts.

Chapter 6:

Details the methods used for implementing the experiments in the electrical circuit lab, and the different procedures for testing it.

Chapter 7:

Gives the conclusions after applying the system, and suggestion for the future work.

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

2.2 Project Components

2.1 Introduction

This chapter focuses on theoretical subjects related to the main idea of the project and information about the software component "LabVIEW" and hardware component "DAQ card" used in the project.

2.2 Project components

2.2.1 Software Component

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

2.2 Project Components

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) was first released in 1986 by National Instruments. It was originally for Macintosh only, but now has versions for Windows and Linux. LabVIEW is a program used to automate testing and data acquisition.

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. The user can set up the program to manipulate and store data.

LabVIEW is a revolutionary graphical development environment with built-in functionality for data acquisition, instrument control, measurement analysis, and data presentation. LabVIEW gives the flexibility of a powerful programming language without the complexity of traditional development environments [1].

2.1 Introduction

This chapter focuses on theoretical subjects related to the main idea of the project, and information about the software component "LabVIEW" and hardware component "DAQ card" used in the project.

2.2 Project components

2.2.1 Software Component

± LabVIEW Software:

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) was first released in 1986 by National Instruments. It was originally for Macintosh only, but now has versions for Windows, and Linux. LabVIEW is a program used to automate testing and data gathering.

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. The user can set up the program to manipulate and store data.

LabVIEW is a revolutionary graphical development environment with built-in functionality for data acquisition, instrument control, measurement analysis, and data presentation. LabVIEW gives the flexibility of a powerful programming language without the complexity of traditional development environments [9].

LabVIEW has Integration with Thousands of Instruments and Measurement Devices and delivered connectivity with measurement hardware, so you can quickly configure and use virtually any measurement device, including everything from stand-alone instruments to plug-in data acquisition devices, motion controllers image, LabVIEW has open connectivity with Other Applications and furthermore.

LabVIEW can allow you to connect to other applications and share data through the Web, shared libraries, SQL, TCP/IP, XML, wireless communication and other methods.

LabVIEW has been widely used in scientific and engineering practice for a wide range of control applications, measurement at minimal cost.

Introduction to Virtual Instruments

LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Every VI uses functions that manipulate input from the user interface or other sources and display that information or move it to other files or other computers.

A VI contains the following three components:

- **Front panel:** Serves as the user interface.
- **Block diagram:** contains the graphical source code that defines the functionality of the VI.
- **Icon and connector pane:** identifies the interface to the VI so VI can use in another VI. A VI within another VI is called a subVI. A subVI corresponds to a subroutine in text-based programming languages.

- ❖ **Front panel:** is the user interface of the VI. Front panel contain two components controls and indicators, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. Controls simulate instrument input devices and supply data to the block diagram of the VI. Indicators simulate instrument output devices and display data the block diagram acquires or generates.



Figure 2.1 Digital Control

Controls = Inputs from the user = Source Terminals

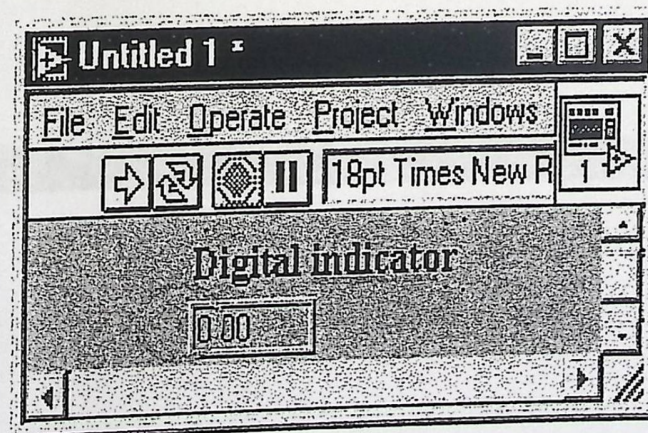


Figure 2.2 Digital Indicator

Indicators = Outputs to the user = Destination

❖ **Block diagram** :window holds the graphical source code of a LabVIEW

Where Front panel objects appear as terminals on the block diagram. Additionally, the block diagram contains functions and structures from built-in LabVIEW VI libraries. Wires connect each of the nodes on the block diagram, including control and indicator terminals, functions, and structures.

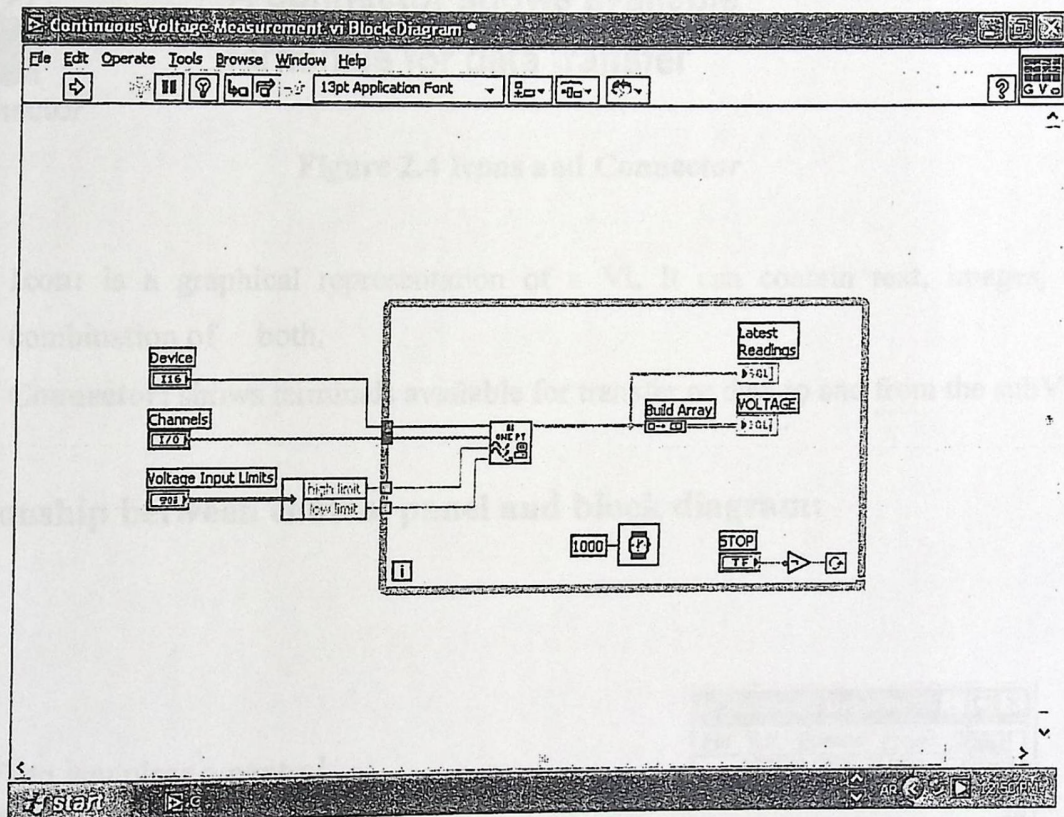
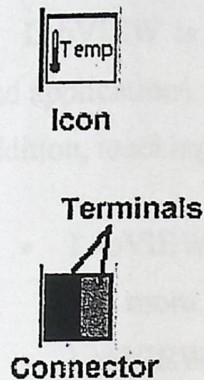


Figure 2.3 Function Source Code

❖ Icon and Connector:



- An icon represents a VI in other block diagrams

- A connector shows available terminals for data transfer

Figure 2.4 Icons and Connector

- **Icon:** is a graphical representation of a VI. It can contain text, images, or a combination of both.
- **Connector:** shows terminals available for transfer or data to and from the subVI.

Relationship between control panel and block diagram:

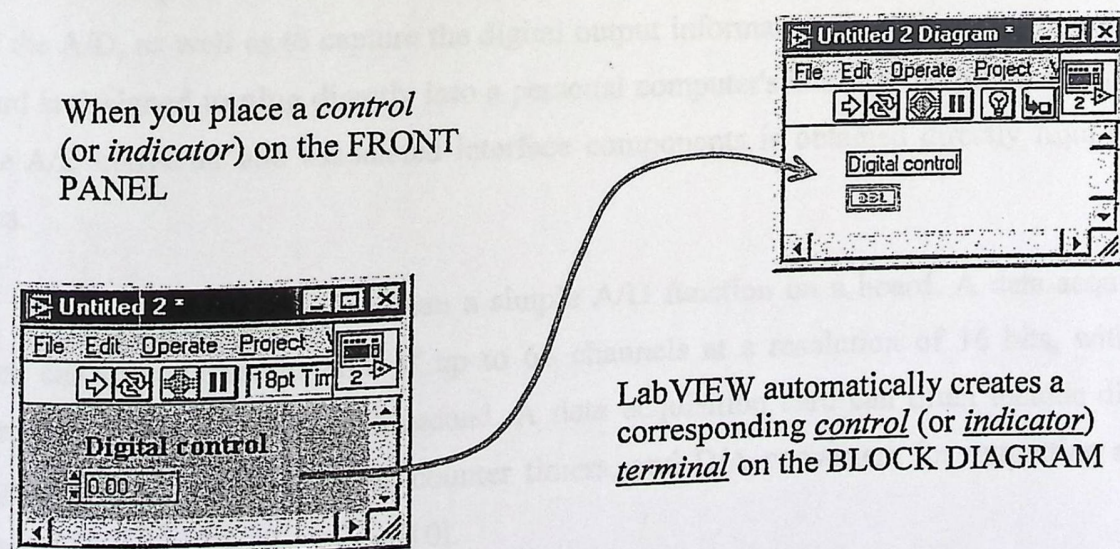


Figure 2.5 Relationships between Control Panel and Block Diagram

Why Use LabVIEW

LabVIEW is an easy-to-use, interactive, so students can write sophisticated programs and applications in a shorter amount of time without needing a computer science degree. In addition, teaching LabVIEW has the following benefits:

- LabVIEW provides open connectivity with other programs such as matlab, Excel, and more.
- LabVIEW is easy to learn and use so you can focus more of your time on teaching theory, and less on teaching programming.
- LabVIEW is widely used in industry, employable skill for students to learn.

2.2.2 Hardware Component

✦ Data Acquisition (DAQ):

DAQ is an abbreviation for data acquisition. Therefore a DAQ card is a basic A/D converter coupled with an interface that allows a personal computer to control the actions of the A/D, as well as to capture the digital output information from the converter. A DAQ card is designed to plug directly into a personal computer's bus. All the power required for the A/D converter and associated interface components is obtained directly from the PC bus.

DAQ card today is more than a simple A/D function on a board. A data acquisition card can offer measurements of up to 68 channels at a resolution of 16 bits, with data throughput rates up to 200KS/second. A data acquisition card can often include discrete digital bi-directional I/O lines, counter timers, and D/A converters for outputting analog signals for control applications [10].

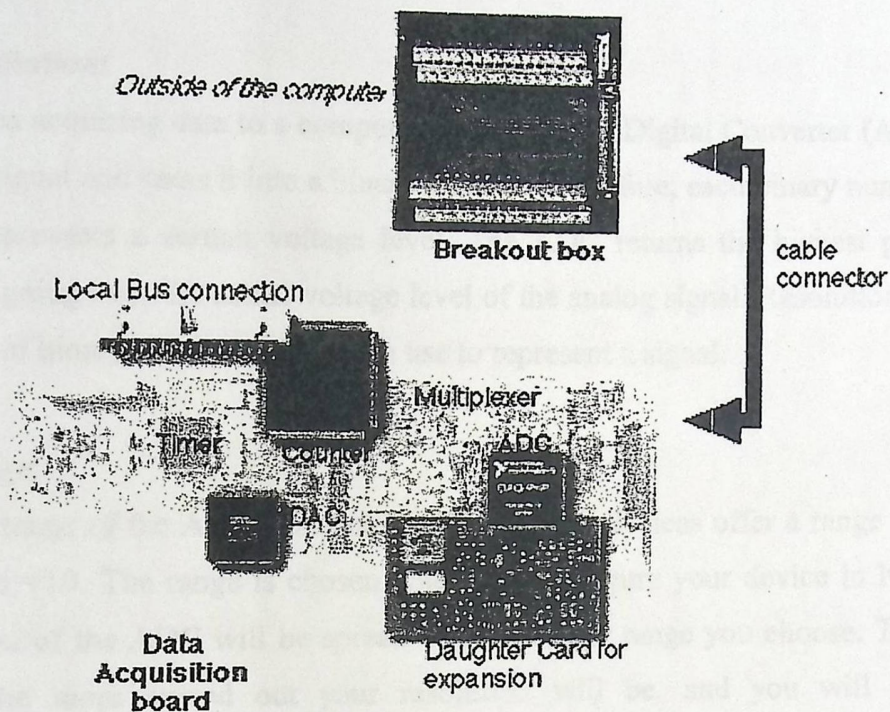


Figure 2.6 Data Acquisition (DAQ)

High-performance DAQ card will work in a very wide range of test and measurement, and control applications. Combined with powerful software, DAQ cards will turn a personal computer into powerful measurement system that may be used to automate experiments, construct product test stands, monitor and control production equipment or be embedded in products ranging from medical monitoring systems to automobile test simulators.

DAQ card converts analog signals into a digital output form, which can be manipulated with software. Using software in conjunction with a personal computer, analog data can be displayed, logged, charted, graphed, or stored in memory as needed.

Data Acquisition Terminology:

- **Resolution:**

When acquiring data to a computer, an Analog-to-Digital Converter (ADC) takes an analog signal and turns it into a binary number. Therefore, each binary number from the ADC represents a certain voltage level. The ADC returns the highest possible level without going over the actual voltage level of the analog signal. Resolution refers to the number of binary levels the ADC can use to represent a signal.

- **Range:**

The range of the ADC is selectable. Most DAQ devices offer a range from 0 - +10 or -10 to +10. The range is chosen when you configure your device in NI-DAQ. The resolution of the ADC will be spread over whatever range you choose. The larger the range, the more spread out your resolution will be, and you will get a worse representation of your signal. Thus it is important to pick your range to properly fit your input signal.

- **Gain:**

Gain refers to any amplification or attenuation of a signal. The gain setting is a scaling factor. Each voltage level on your incoming signal is multiplied by the gain setting to achieve the amplified or attenuated signal. Unlike resolution that is a fixed setting of the ADC, and range that is chosen when the DAQ device is configured, the gain is specified indirectly through a setting called input limits. Input limits refer to the minimum and maximum values of your actual analog input signal. Based on the input limits you set, the largest possible gain is applied to your signal that will keep the signal within the chosen range of the ADC. So instead of needing to calculate the best gain based on your signal and the chosen range, all you need to know is the minimum and maximum values of your signal.

NI PCI-6034E DAQ Card:

The National Instruments PCI-6034E data acquisition board is the heart of the system and is part of NI's E series of multifunction DAQ boards. It offers 16-bit resolution capability at a reasonable cost. Included with the board is the NI-DAQ software. This software is specifically designed to quickly install devices and begin data measurement. This easy-to-use software integrates the full functionality of DAQ hardware to LabVIEW, Lab Windows, and Measurement Studio for Visual Basic. Bundled with NI-DAQ is the Measurement & Automation Explorer utility program. This addition further simplifies the configuration of measurement hardware with device test panels, interactive measurements, scaled I/O channels and numerous example programs for LabVIEW and other application development environments. The NI PCI-6034E is connected to the connector Block by a shielded 2m cable. This cable is terminated with two 68-pin female D-type connectors and is specially designed to reduce crosstalk with high-speed devices [11].

Note: In this project NI PCI-6034 will be used which is available in the laboratory, and compatible with LabVIEW software.

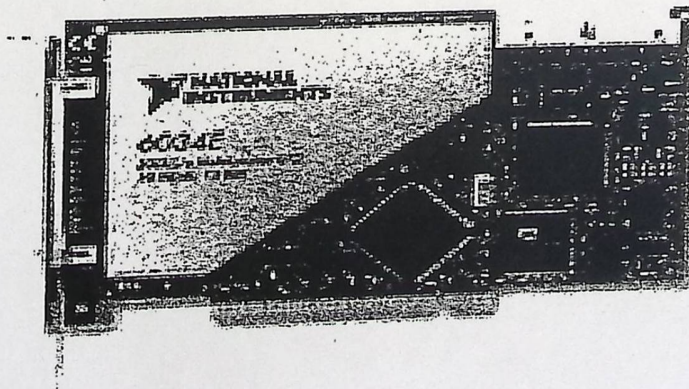


Figure 2.7 NI PCI-6034E

NI PCI-6034E DAQ Card Features:

- 8 digital I/O lines.
- 16 channels as analog signal.
- 68 pin connector.
- Sampling rate is 200kS/s.
- Two 24-bit counters.

Typically, DAQ cards are installed in a PC with high speed data bus like PCI. Depending on the speed of the motherboard of the PC, the maximum data transfers can occur between microprocessor and memory at 20 MHz to 40 MHz. To improve the data transfer rate, bus mastering (allowing DAQ board to transfer data directly) is implemented as shown in Figure 2.10(a) and 2.10(b). [12]

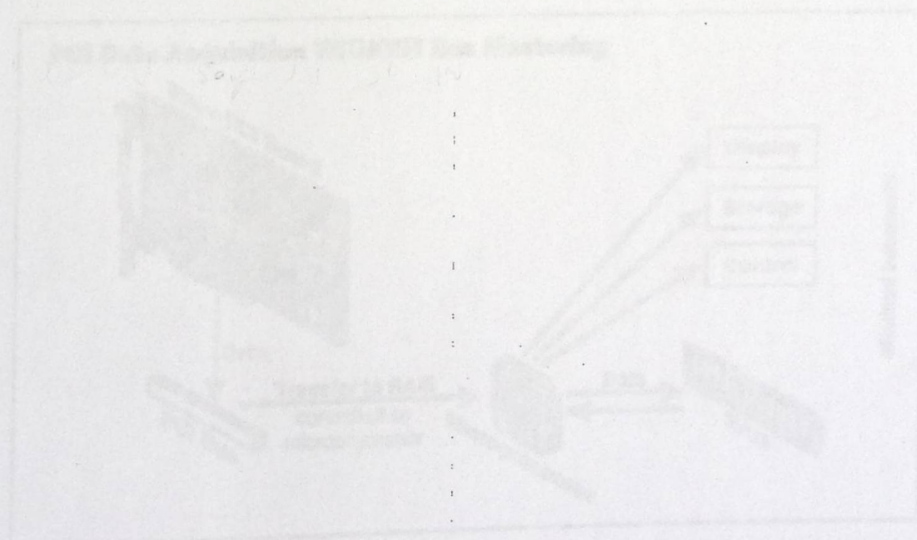


Figure 2.10(a) Data Transfer Without Bus Mastering (Conventional)

Data Transfers to the Computer

There are several ways in which the data can be exchanged between instruments and a computer.

One of this ways used to measure signals and transfer the data into a computer is by using a Data Acquisition board. A typical commercial DAQ card contains ADC and DAC that allows input and output of analog and digital signals in addition to digital input/output channels.

Typically, DAQ boards are installed in a PC with high speed data bus like PCI. Depending on the speed of the motherboard of the PC, the maximum data transfers can occur between microprocessor and memory at 20 MHz to 40 MHz. To improve the data transfers, bus mastering (allowing DAQ board to transfer data directly) is implemented as shown below in figure 2.10(a) and 2.10(b) [12].

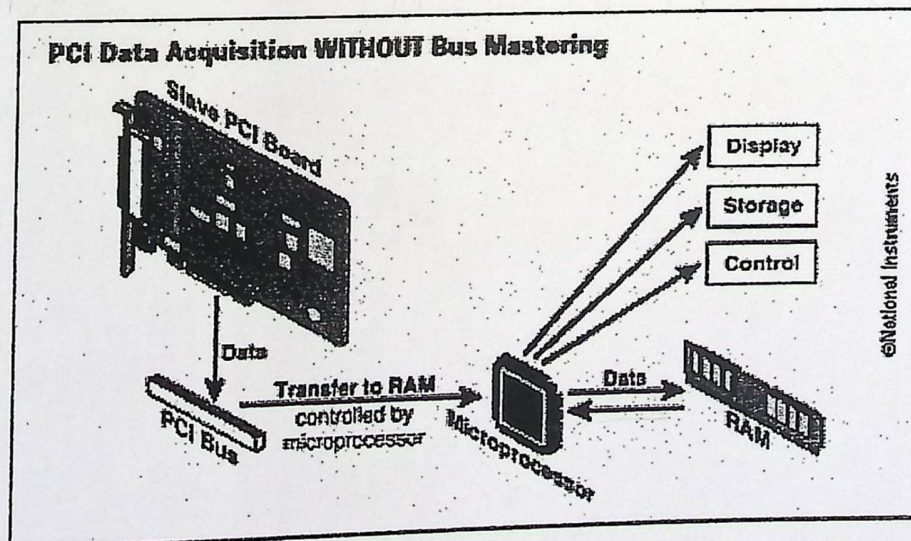


Figure 2.9(a) Data Transfer Without Bus Mastering (Conventional)

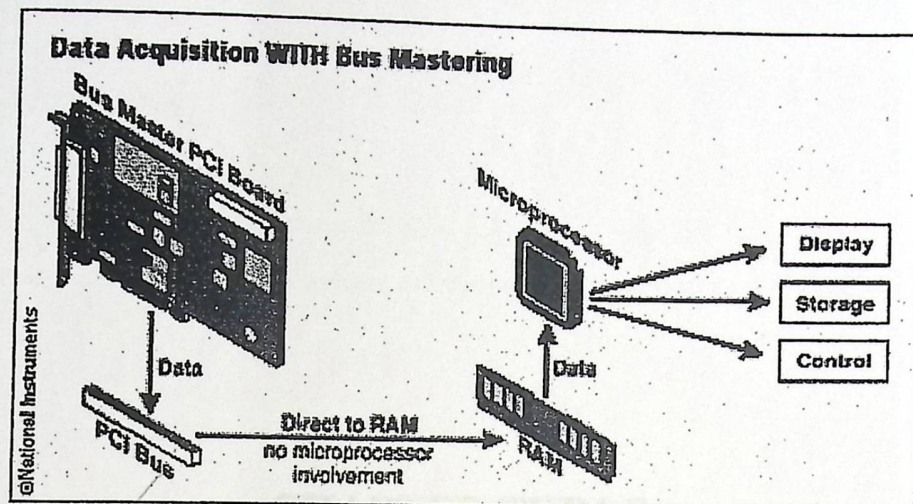


Figure 2.9(b) Data Transfer with Bus Mastering

Handwritten notes:

MP

Bus $\xrightarrow{\text{UE}}$ RAM $\xrightarrow{\text{UE}}$ MP $\xrightarrow{\text{UE}}$

3.1 Introduction

This chapter talk about main concepts of project design, it introduce project objectives and a general block diagram of the project, and it also includes who the system works.

3.2 Project Objectives

CHAPTER THREE DESIGN CONCEPTS

The main objectives of the project are:

- 1. Study the concepts of computer based learning and virtual lab.
- 2. Learn how to use the data acquisition board.
- 3. Build computer programs to collect data into the computer through DAQ card.
- 4. Gain programming skills with LabVIEW programming language.

3.1 Introduction

3.2 Project Objectives

3.3 General Block Diagram

3.4 Description of the General Block Diagram

3.5 How the System Works

3.1 Introduction

This chapter talk about main concepts of project design, it introduces project objectives and a general block diagram of the project, and it also includes who the system works.

3.2 Project Objectives

The main objectives of the project:

- ✦ Study the concepts of computer based learning and virtual lab.
- ✦ Learn how to use the data acquisition board.
- ✦ Build computer programs to collect data into the computer through DAQ card.
- ✦ Learn basic programming skills with LabVIEW programming language.
- ✦ Design and implement experiments in electrical circuit lab in PPU using LabVIEW programming language and DAQ card.
- ✦ Design and build the black box (connector) that will be used with DAQ card.

3.3 General Block Diagram

The block diagram in Figure 3.1 shows the basic components of a computer data acquisition system

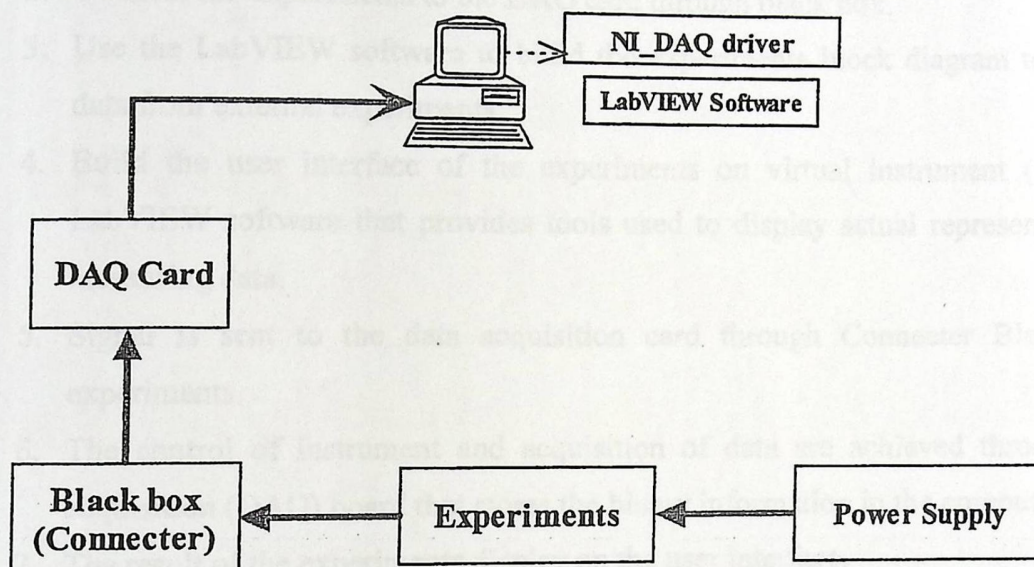


Figure 3.1 General Block Diagram

3.4 Description of the General Block Diagram

The block diagram in Figure 3.1 shows the basic components of a computer data acquisition system, the experiments will connect to the computer through Connector Block which connects with data acquisition card that is mounted internally in the computer. The data acquisition card converts the analog voltage signal to digital values. Because it only converts voltage signals, the data acquisition card has other capabilities like digital to analog conversion, counter/timer circuits, and digital I/O ports. The National Instruments NI DAQ drivers allow the data acquisition board to communicate with and store the binary information in the computer. The National Instruments LabVIEW software provides the capability to process, analysis, implement and display the data.

3.5 How the System Works

1. Design and build the black box (connector) to connect experiments with the computer.
2. Connect the experiments to the DAQ card through black box.
3. Use the LabVIEW software to build the experiments block diagram to acquire data from external experiments.
4. Build the user interface of the experiments on virtual instrument (VI) with LabVIEW software that provides tools used to display actual representation of measuring data.
5. Signal is sent to the data acquisition card through Connector Block from experiments.
6. The control of instrument and acquisition of data are achieved through data acquisition (DAQ) board that stores the binary information in the computer.
7. The result of the experiments display on the user interface.

4.1 Introduction

This project contain several experiments of electrical circuits lab, which build by LabVIEW programming language and using data acquisition card "PCI 6034E" that send signals from external connected experiments which measure the output values through connector block.

CHAPTER FOUR

HARDWARE SYSTEM DESIGN

4.2 System Design

The system has login screen that contain username, and password as shown in figure 4.1 that allow the user enter to the system and select the experiment to be executed as shown in figure 4.2.

4.1 Introduction

4.2 System Design

4.3 Experiments Design

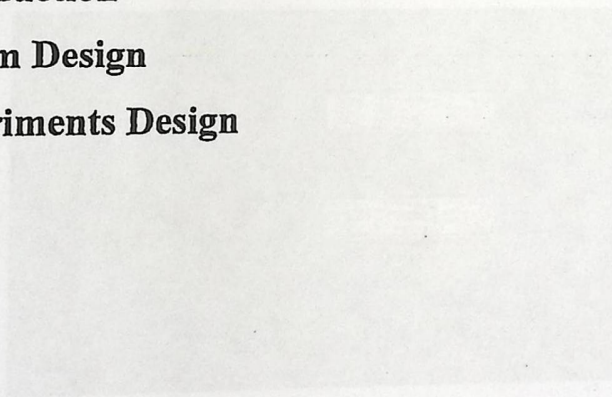


Figure 4.1 Login Screen

4.1 Introduction

This project contain several experiments of electrical circuits lab, which build by LabVIEW programming language and using data acquisition card "PCI 6034E" that enter signals from external connected experiments which measure the output values through connector block.

4.2 System Design

The system has login screen that contain username, and password as shown in figure 4.1 that allow the user enter to the system and select the experiment to be executed as shown in figure 4.2.

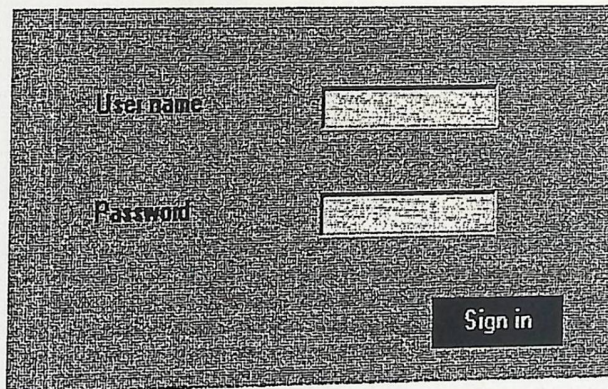


Figure 4.1 Login Screen

Electrical Circuits Lab

Choose your experiment:

AC measurement

Ohm's law

Charging and discharging capacitor

Capacitor Measurement

Oscilloscope

Maximum power transfer

Filters

Kirchhoff's laws

Help



Figure 4.2 User Manual Screens

4.3 Experiment Design:

4.3.1 Ohm's Law Experiment:

Experiment Setup:

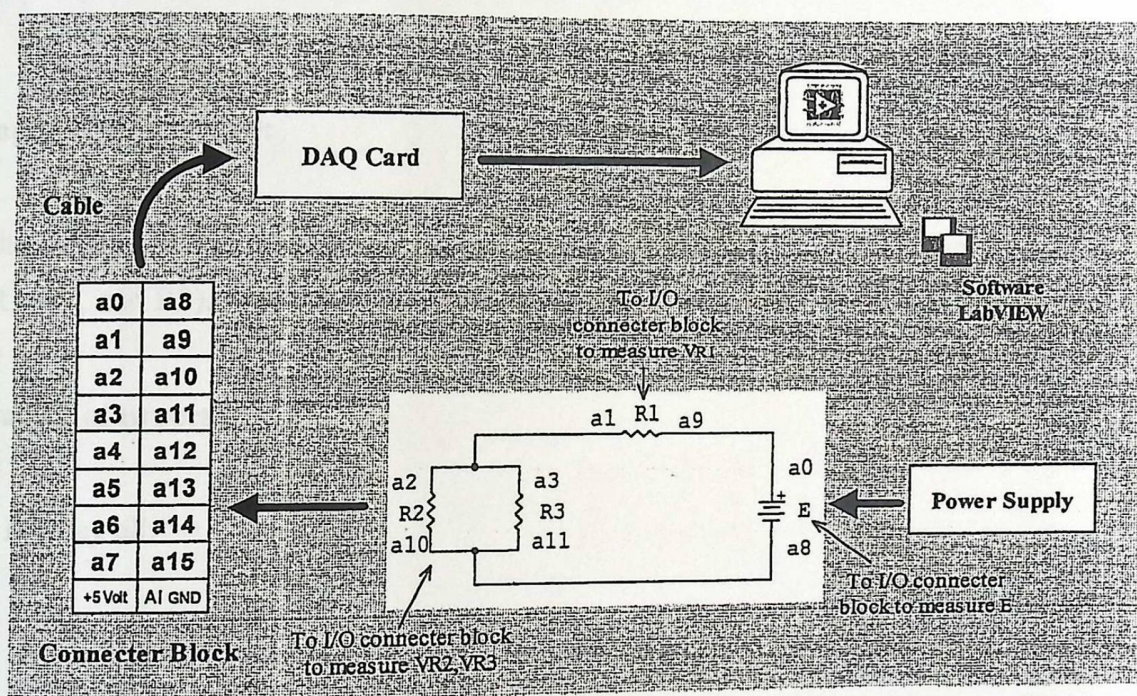


Figure 4.3 Ohm's Law Design

Procedure:

1. Select the proper components.
2. Connect ohm's law experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E) to channel a0, a8 on the connector block.
5. Connect the voltage of R1 to channel a1, a9 on the connector block.
6. Connect the voltage of R2 to channel a2, a10 on the connector block.

7. Connect the voltage of R3 to channel a3, a11 on the connector block.
8. Set DC voltage range of power supply from (0-10)V
9. Enter the value of low and high limit voltage source.
10. Enter the value of resistors (R1, R2, and R3) as connected on the breadboard.
11. Run the experiment interface.
12. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source (E) and the voltage of the resistors (R1, R2, and R3).

Output of process:

Display all:

- Voltage source(E)
- The voltage of resistors (VR1,VR2,VR3)
- The current of (R1, R2, R3).
- The power of the circuit.
- Graph of the voltage source (E).
- Total resistor (Rr).

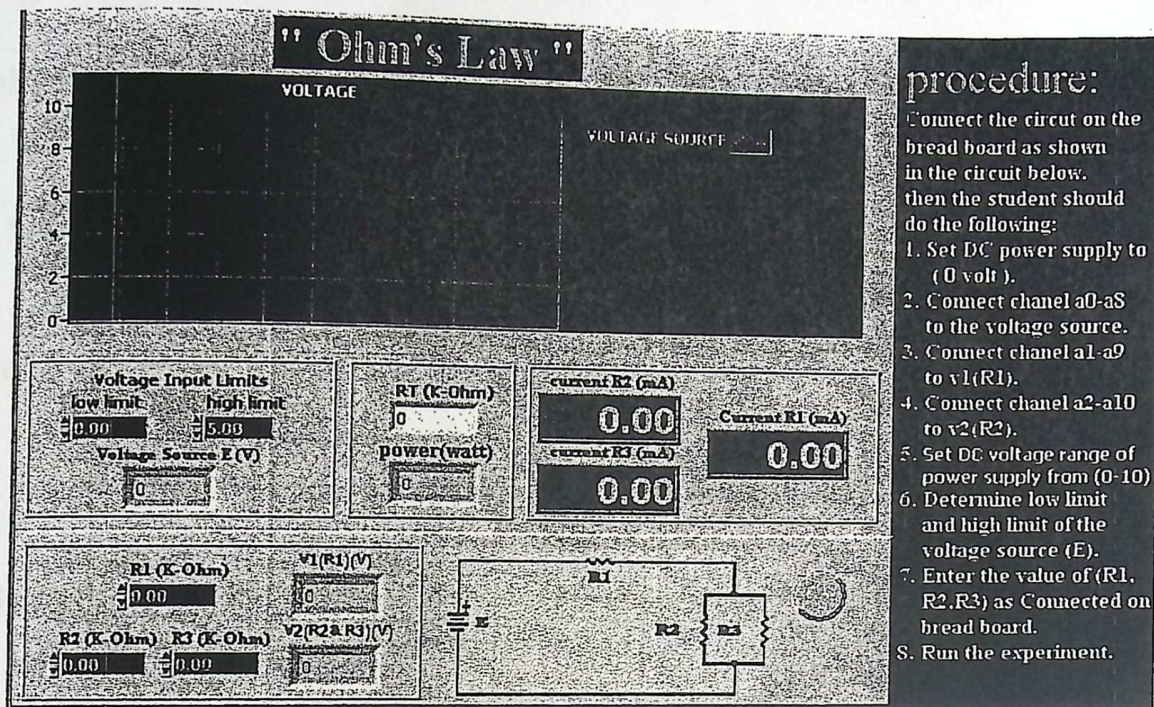


Figure 4.4 Ohm's Law Screen

Process of LabVIEW:

- Calculate the value of the current as shown in the equation:

$$I = \frac{E}{RT}$$

Where:

I: circuit current.

RT: total resistors.

E: voltage source.

- Calculate the total resistors of the circuit as shown in the equation:

$$R_T = R_1 + \left[\frac{R_2 * R_3}{R_3 + R_2} \right]$$

Where:

R_T : total resistor.

- Calculate the power of the circuit as shown in the equation:

$$P = \frac{E^2}{R_T}$$

Where:

P : circuit power.

E : voltage source.

R_T : total resistor.

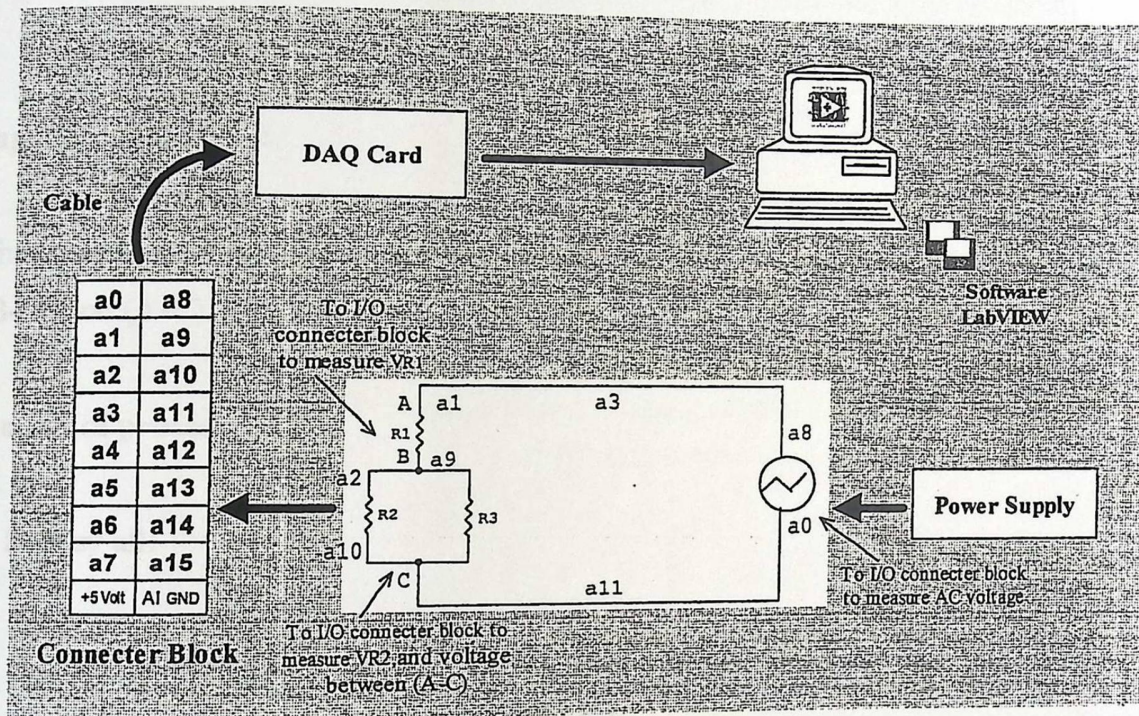
- Graph the voltage source (V).

Procedure

1. Select the proper components.
2. Connect the AC experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the voltage source AC to channel a1, a8 on the connector block.
5. Connect channel a1, a9 to V (A-C).
6. Connect channel a2, a10 to V (B-C).
7. Connect channel a3, a11 to V (A-C).

4.3.2 AC Measurement Experiment

Experiment Setup:



Procedure:

1. Select the proper components.
2. Connect the AC experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the voltage source AC to channel a0, a8 on the connector block.
5. Connect channel a1, a9 to V (A-B).
6. Connect channel a2, a10 to V (B-C).
7. Connect channel a3, a11 to V (A-C).

8. Set AC voltage range of power supply from (0-10) V.
9. Enter the value of resistors (R_1 , R_2 , and R_3) as connected on the breadboard.
10. Run the experiment interface.
11. Follow the experiment on the screen.
12. Determine peak to peak value from the graph.

Input of DAQ Card:

The DAQ card will measure the value of AC voltage source and the voltage between (A-B), (B-C), and (A-C).

Output of process:

Display all:

- AC Voltage source.
- The voltage of resistors (VR_1, VR_2, VR_3)
- The current of (R_1, R_2, R_3).
- Total resistor (R_T).
- Graph of the AC voltage.
- The value of r.m.s voltage.

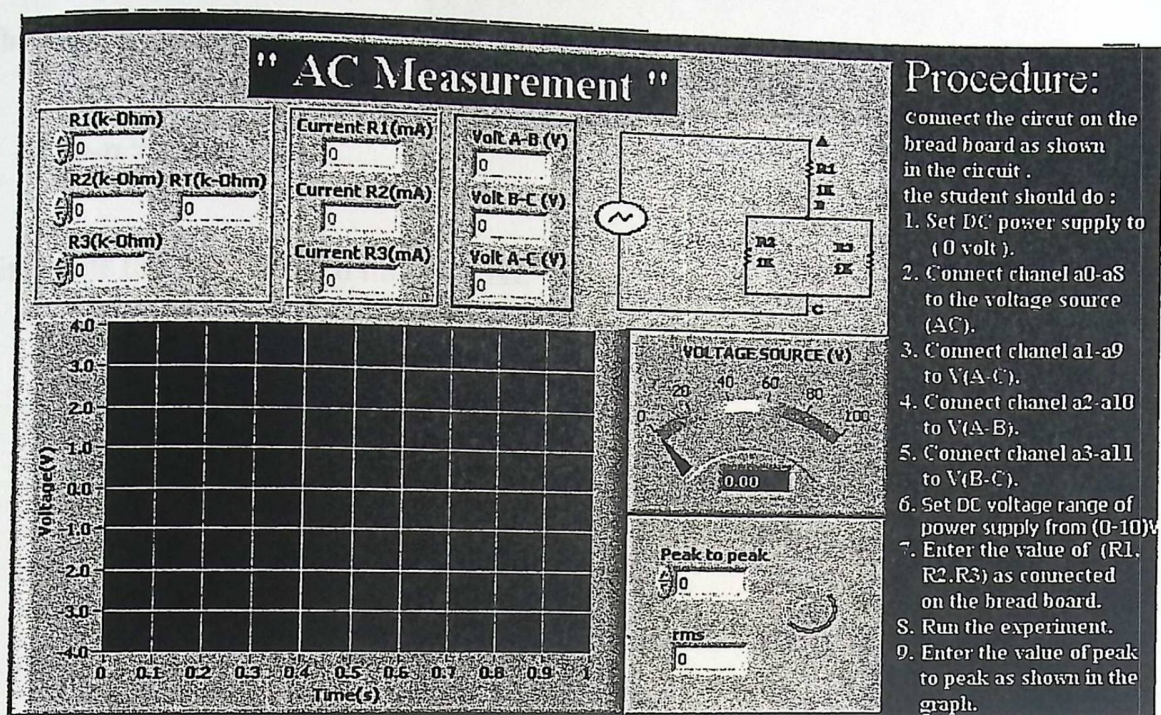


Figure 4.6 AC Measurement Screen

Process of LabVIEW:

- Calculate the value of the current through each resistor.
- Calculate the total resistors of the circuit as shown in the equation:

$$R_T = R_1 + \left[\frac{R_2 * R_3}{R_3 + R_2} \right]$$

Where:

Rr: total resistor.

R1, R2, and R3: input resistors.

- Calculate the r.m.s value as shown in the equation:

$$r.m.s = \frac{P - P}{2\sqrt{2}}$$

Where:

r.m.s: root mean square value

p-p : peak to peak.

- Graph the relation between time and AC voltage

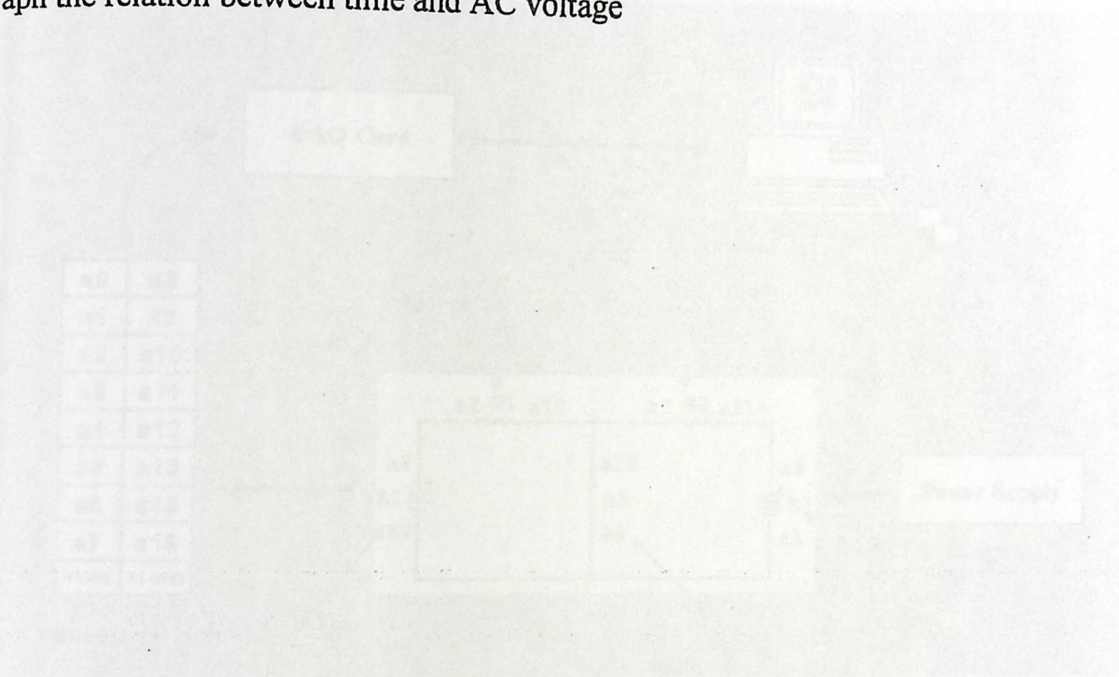


Figure 4.7 Kirchhoff's Law's Design

Procedure:

1. Select the proper components.
2. Connect Kirchhoff's laws experiment on external breadboard that supply of the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E1) to channel a0, a1 on the connector block.
5. Connect the voltage source (E2) to channel a1, a2 on the connector block.
6. Connect the voltage of R1 to channel a2, a10 on the connector block.
7. Connect the voltage of R2 to channel a3, a11 on the connector block.
8. Connect the voltage of R3 to channel a4, a12 on the connector block.

4.3.3 Kerchieff's Laws Experiment

Experiment Setup:

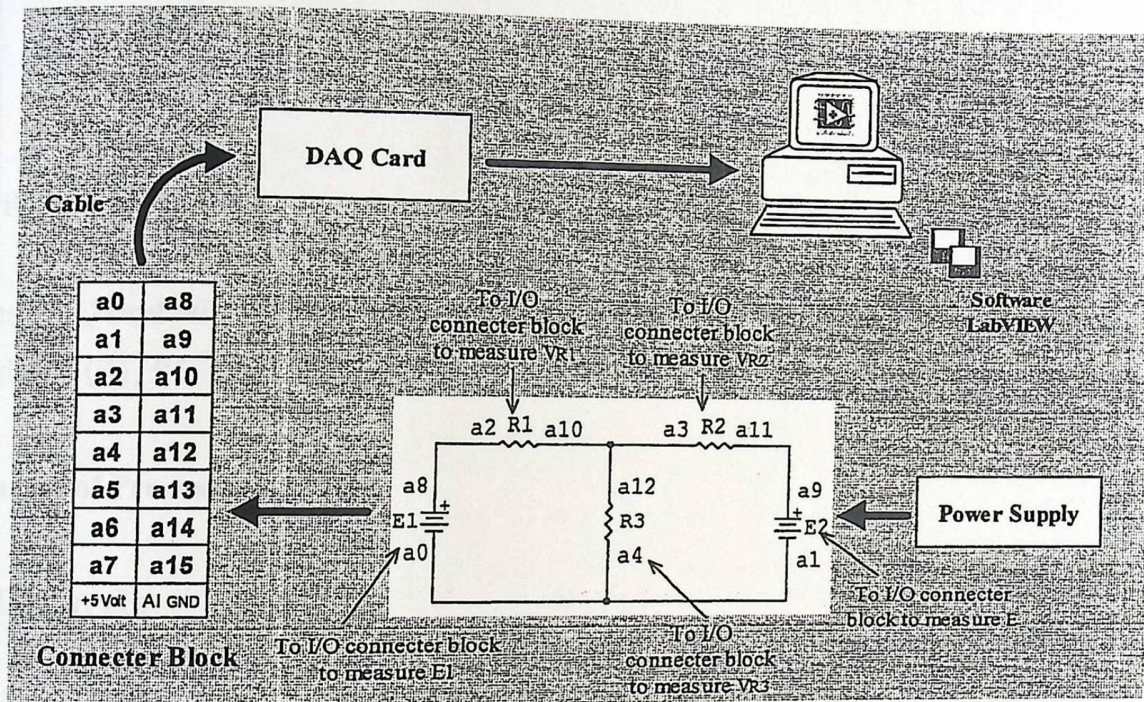


Figure 4.7 Kerchieff's Law's Design

Procedure:

1. Select the proper components.
2. Connect kerchieff's laws experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E1) to channel a0, a8 on the connector block.
5. Connect the voltage source (E2) to channel a1, a9 on the connector block.
6. Connect the voltage of R1 to channel a2, a10 on the connector block.
7. Connect the voltage of R2 to channel a3, a11 on the connector block.
8. Connect the voltage of R3 to channel a4, a12 on the connector block.

9. Set DC voltage range of power supply from (0-10) V.
10. Enter the value of low and high limit voltage source E1.
11. Enter the value of low and high limit voltage source E2.
12. Enter the value of resistors (R1, R2, and R3) as connected on the breadboard.
13. Run the experiment interface.
14. Follow the experiment on the screen.

Input of DAQ card:

The DAQ card will measure the value of voltage source (E1, E2) and the voltage of the resistors (R1, R2, and R3).

Output of Process:

Display all:

- Voltage source(E1)
- Voltage source(E2)
- The voltage of resistors (VR1,VR2,VR3)
- The current of R1.
- The current of R2.
- The current of R3.

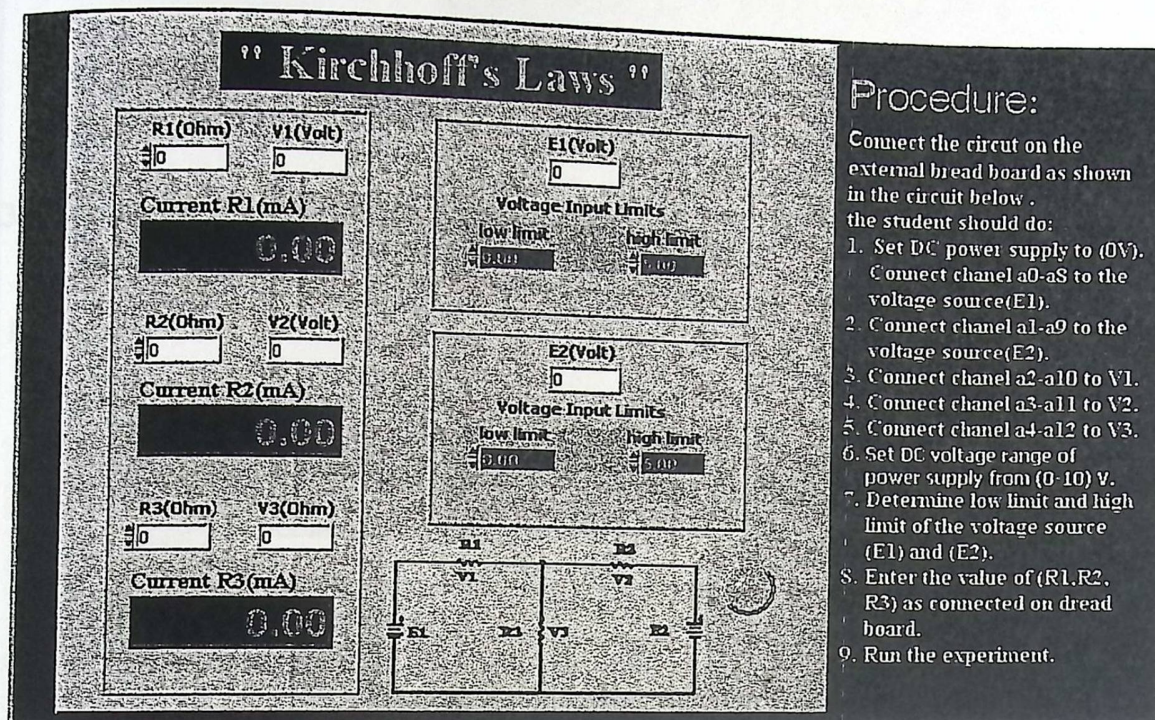


Figure 4.8 Kerchieff's Law's Screen

Process of LabVIEW:

- Calculate the value of the current for each resistor.

$$I = \frac{E}{R_T}$$

Where:

I: circuit current.

R_T: total resistors.

E: voltage source.

4.3.4 Capacitors Measurement Experiment

Experiment Setup:

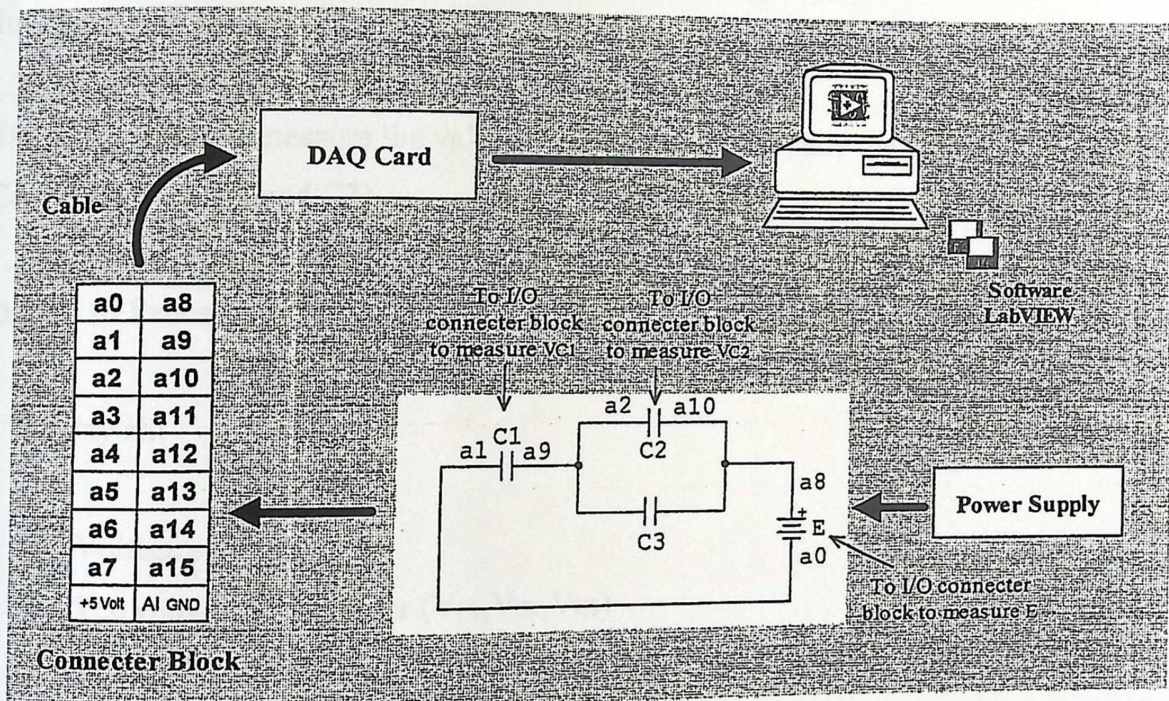


Figure 4.9 Capacitors Measurement Design

Procedure:

1. Select the proper components.
2. Connect capacitor measurement experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E) to channel a0, a8 on the connector block.
5. Connect the voltage of C1 to channel a1, a9 on the connector block.

6. Connect the voltage of C2 to channel a2, a10 on the connector block.
7. Set DC voltage range of power supply from (0-10) V.
8. Enter the value of low and high limit voltage source E.
9. Enter the value of capacitor (C1, C2, and C3) as connected on the breadboard.
10. Run the experiment user interface.
11. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source (E) and the voltage of the Capacitors (C1, C2, and C3).

Output of Process:

Display all:

- Voltage source(E)
- The voltage of capacitor (V_{C1} , V_{C2} , V_{C3})
- The total capacitor.

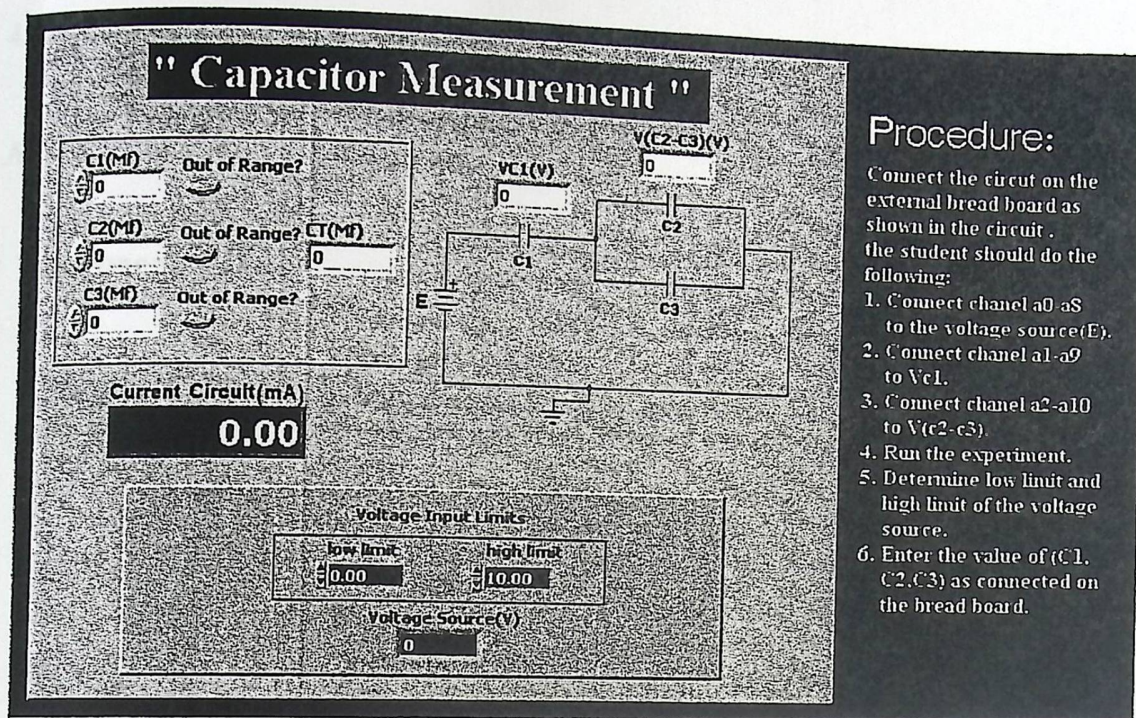


Figure 4.10 Capacitors Measurement Screen

Process of LabVIEW:

- Calculate the value of the total capacitor as shown in the equation:

$$C_T = \left[\frac{C_1 * (C_2 + C_3)}{C_1 + (C_2 + C_3)} \right]$$

Where:

C_T : total capacitor

C_1, C_2, C_3 : input capacitors

4.3.5 Charging and Discharging Capacitor Experiment

A. Charging Capacitor:

Experiment Setup:

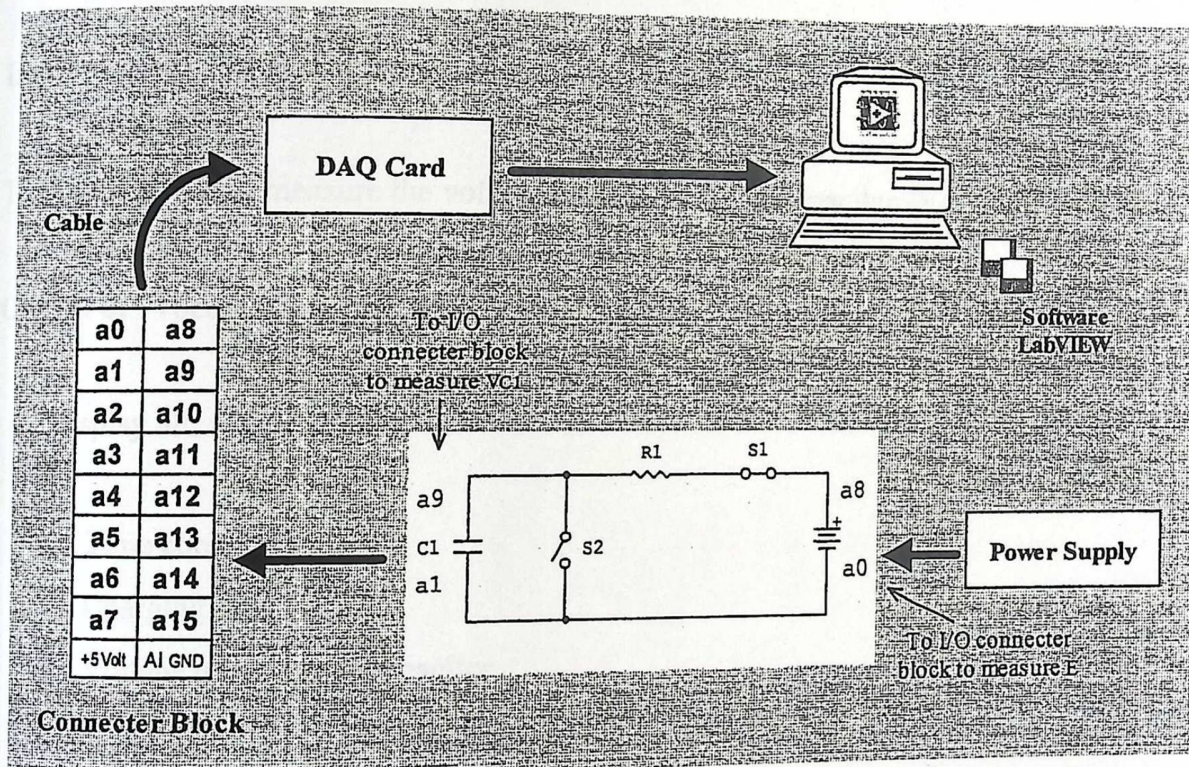


Figure 4.11 Charging Capacitor Design

Procedure:

1. Select the proper components.
2. Connect charging capacitor experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E) to channel a0, a8 on the connector block.
5. Connect the voltage of C1 to channel a1, a9 on the connector block.

6. Set DC voltage of power supply to 5 V.
7. Enter the value of capacitor ($C = 4 \text{ Mf}$), and resistor ($R = 3 \text{ K}\Omega$) as connected on the breadboard.
8. Close the switch (S1) to charge capacitor (C).
9. Run the experiment user interface.
10. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the voltage of the Charging Capacitor (V_c).

Output of Process:

Display all:

- Time constant.
- Charging time (τ).
- Voltage of charging capacitor
- Graph the relation between the capacitor voltage and the number of time constants.

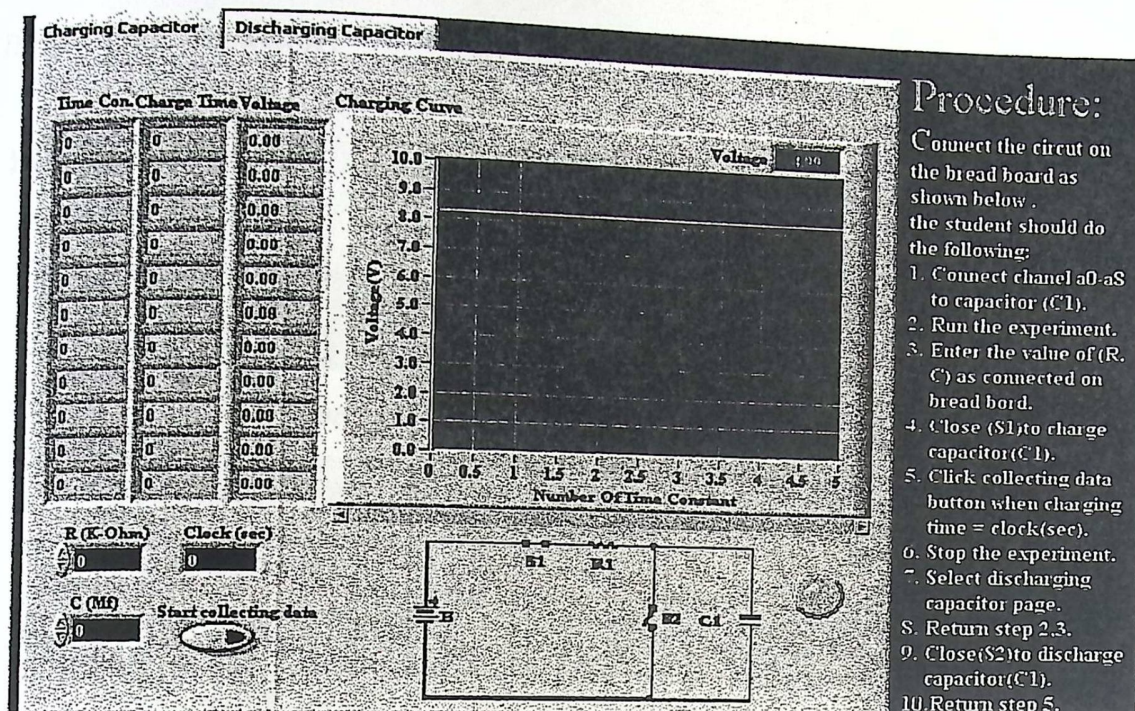


Figure 4.12 Charging Capacitor Screen

Process of LabVIEW:

- Calculate the value of the charging time by the equation:

$$\text{Charging Time} = R \cdot C \cdot t$$

R: resistor

C: capacitor

t: number of time constants.

- Graph the relation between charging capacitor voltage and number of constant time that saved in a constant array in the block diagram that programmed by the programmer.

B. Discharging Capacitor:

Experiment Setup:

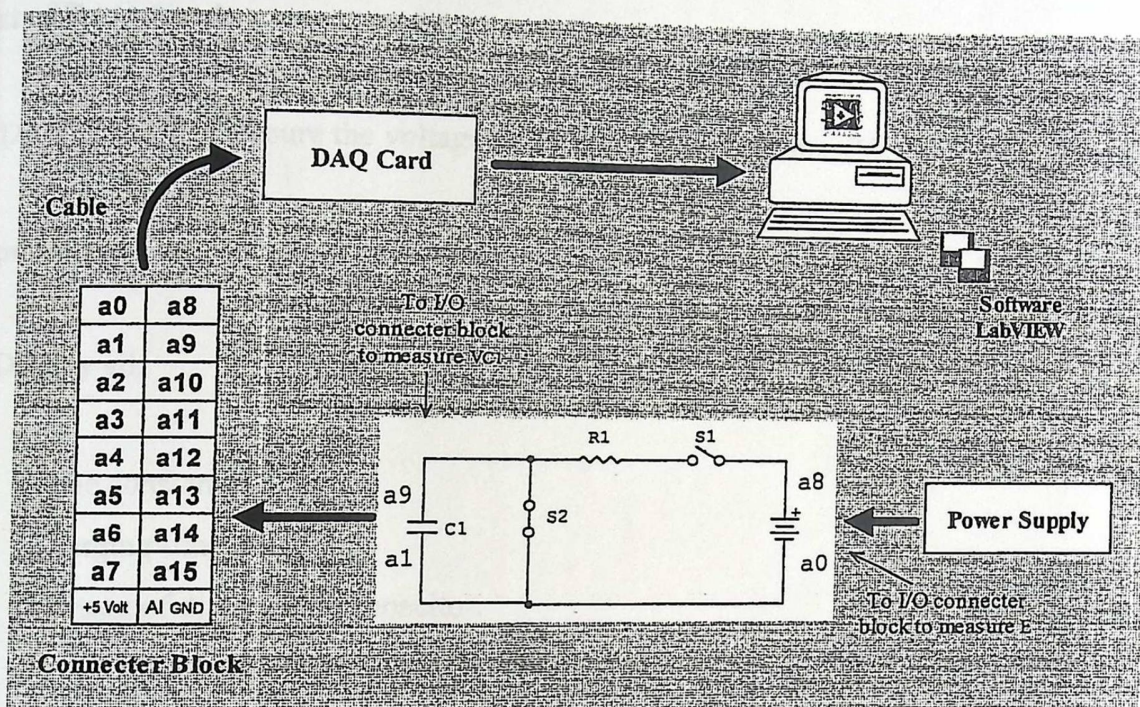


Figure 4.13 Discharging Capacitor Design

Procedure:

1. Select the proper components.
2. Connect discharging capacitor experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage source (E) to channel a0, a8 on the connector block.
5. Connect the voltage of C1 to channel a1, a9 on the connector block.
6. Set DC voltage of power supply to 5 V.
7. Enter the value of capacitor ($C = 4 \text{ Mf}$), and resistor ($R = 3 \text{ K } \Omega$) as connected on the breadboard.

8. Open the switch (S1), Close the switch (S2) to discharge capacitor (C).
9. Run the experiment user interface.
10. Follow the experiment on the screen.

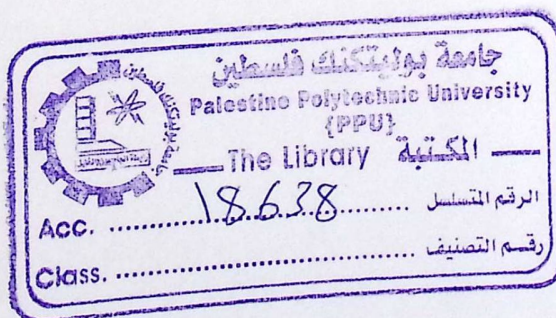
Input of DAQ Card:

The DAQ card will measure the voltage of the Charging Capacitor (V_c).

Output of Process:

Display all:

- Time constant.
- Charging time (τ).
- Voltage of discharging capacitor.
- Graph the relation between the capacitor voltage and the number of time constants.



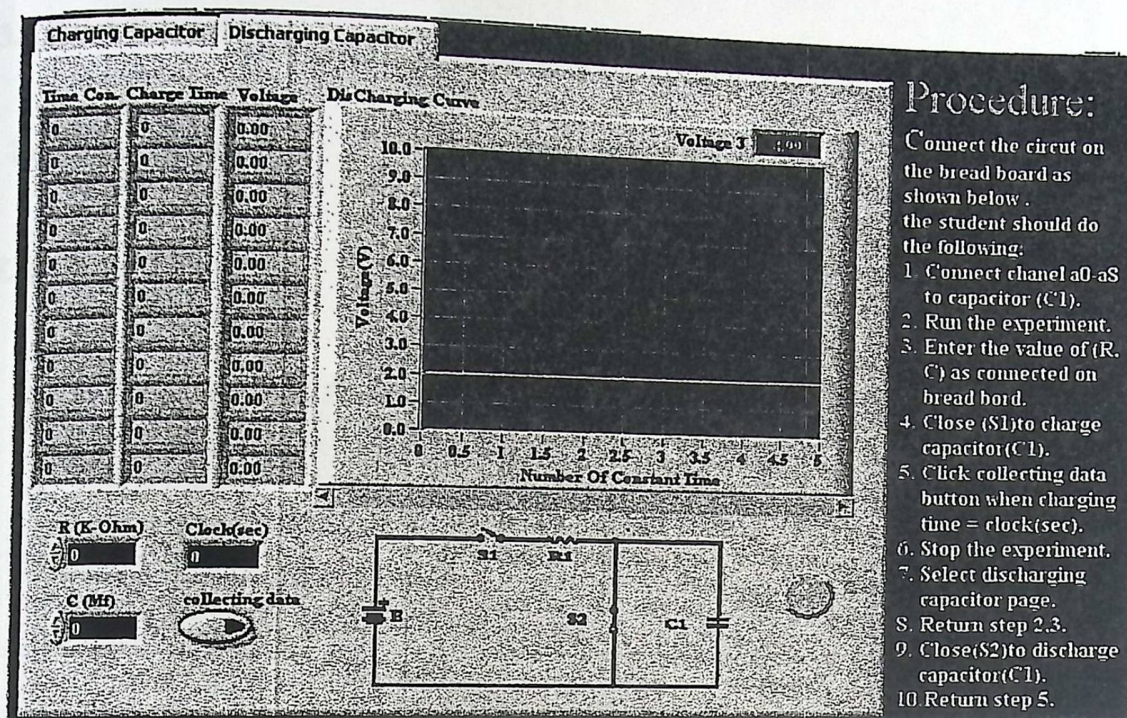


Figure 4.14 Discharging Capacitor Screen

Process of LabVIEW:

- Calculate the value of the charging time by the equation:

$$\text{Charging Time} = R * C * t$$

Where:

R: resistor.

C: capacitor.

t: number of time constants.

- Graph the relation between discharging capacitor voltage and number of constant time that saved in a constant array in the block diagram that programmed by the programmer.

4.3.6 Filter Experiment

A. Low-Pass Filter:

Experiment Setup:

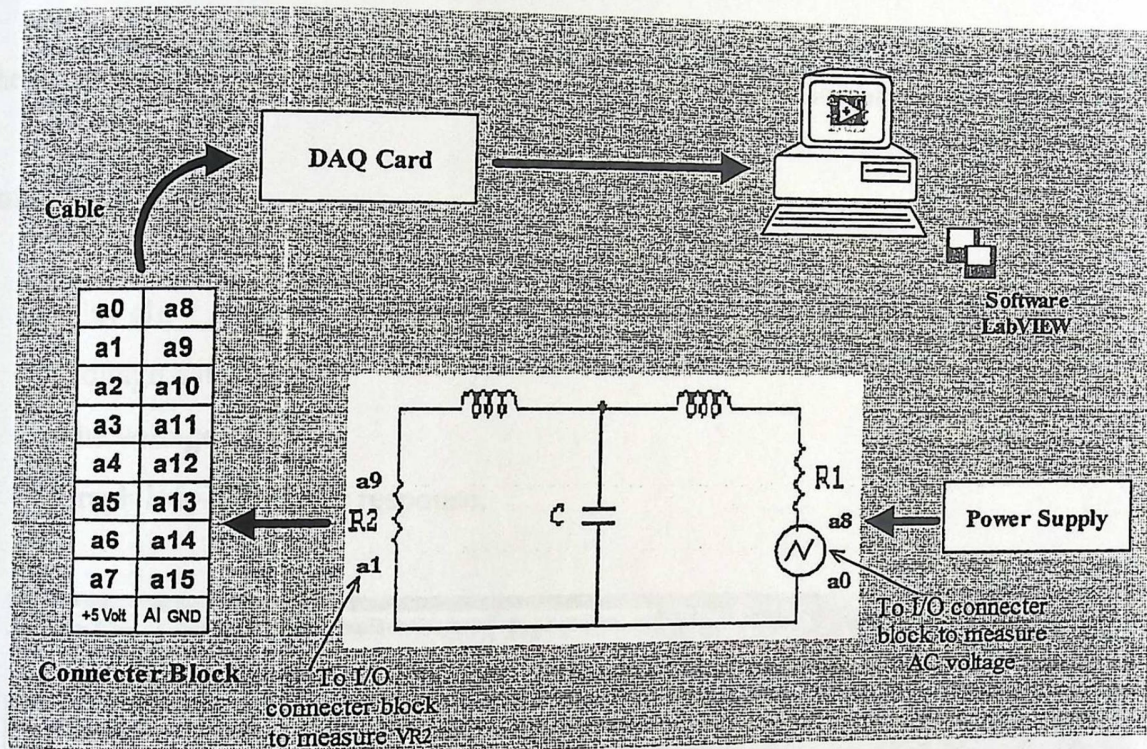


Figure 4.15 Low-Pass Filter Design

Procedure:

1. Select the proper components.
2. Connect Low-pass filter experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the AC voltage source to channel a0, a8 on the connector block.
5. Connect the voltage of R2 to channel a1, a9 on the connector block.
6. Set AC voltage range of power supply from (0-10) V.

7. Run the experiment user interface.
8. Click start collecting data button when the frequency on external generator equal the frequency on the screen by keeping AC voltage = 5volt.
9. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source and the voltage of the resistor (R2).

Output of Process:

Display all:

- Voltage source.
- The voltage of R2.
- Graph low-pass filter response.

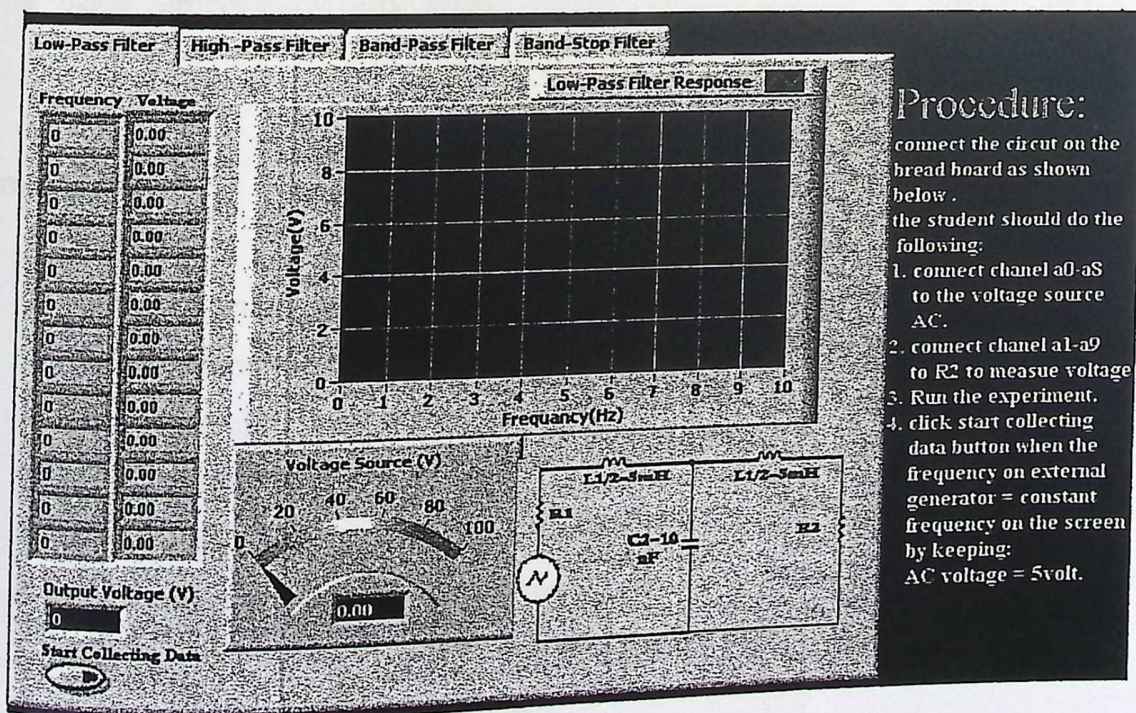


Figure 4.16 Low-Pass Filter Screen

C. Band-Pass Filter:

Experiment Setup:

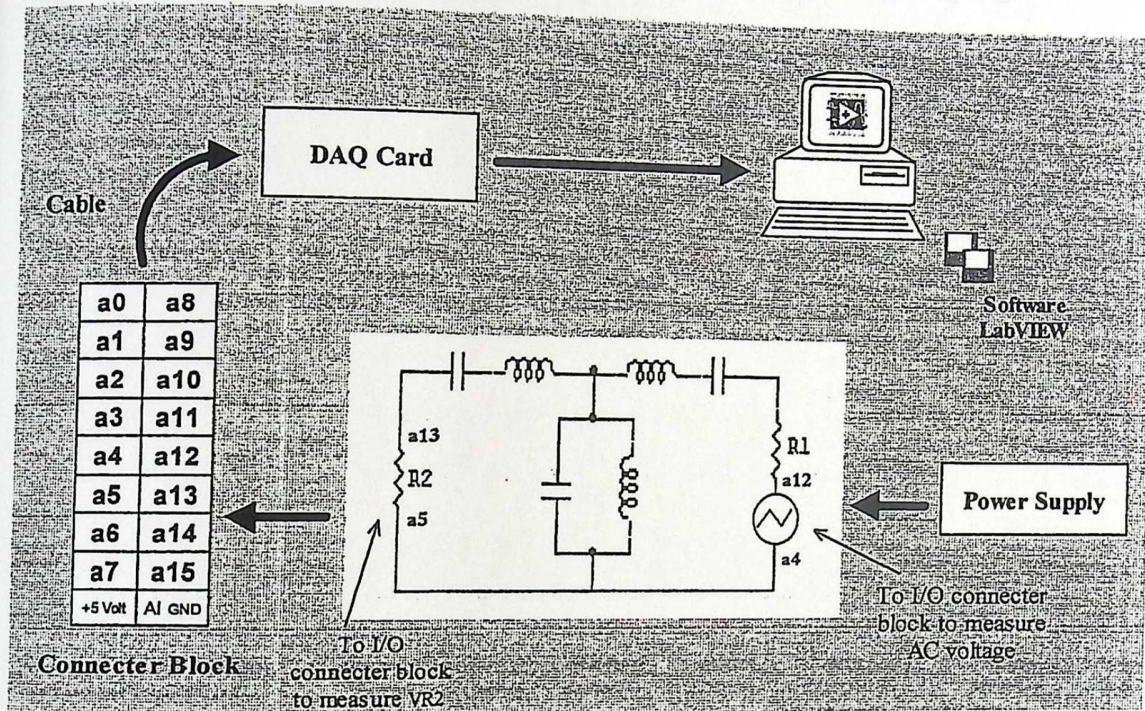


Figure 4.19 Band-Pass Filter Design

Procedure:

1. Select the proper components.
2. Connect Band-pass filter experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the AC voltage source to channel a0, a8 on the connector block.
5. Connect the voltage of R2 to channel a1, a9 on the connector block.
6. Set AC voltage range of power supply from (0-10) V.
7. Run the experiment user interface.

Process of LabVIEW:

- Graph the relation between the voltage that record by the user and the frequency that saved in a constant array in the block diagram that programmed by the programmer.

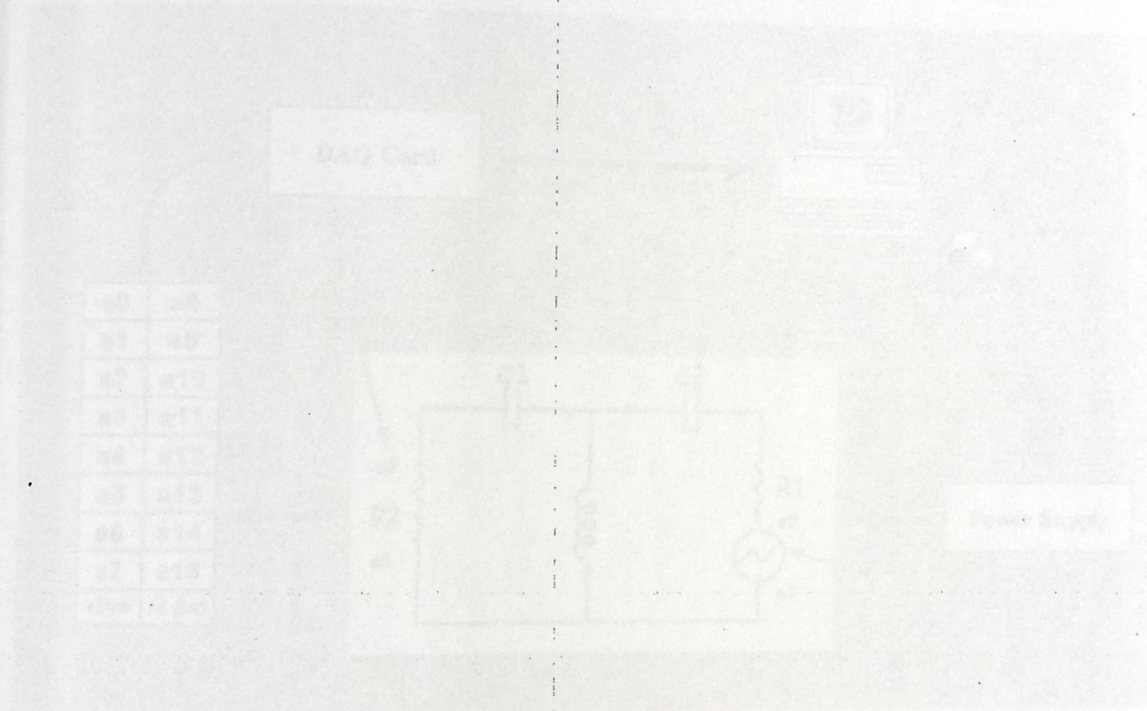


Figure 4.17 High-Pass Filter Design

Procedure:

1. Select the proper components.
2. Connect High-pass filter experiment on external bread board that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the AC voltage source to channel a0, a1 on the connector block.
5. Connect the voltage of R1 to channel a2, a3 on the connector block.
6. Set AC voltage range of power supply from (0-10) V.
7. Run the experiment user interface.

B. High-Pass Filter:

Experiment Setup:

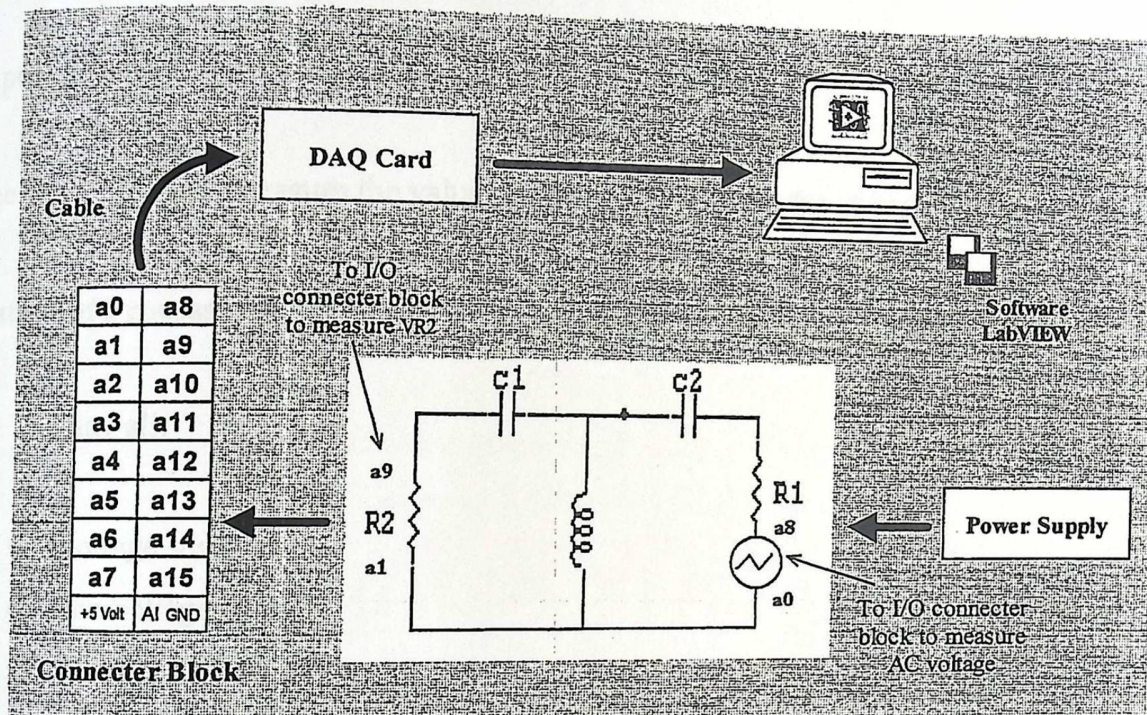


Figure 4.17 High-Pass Filter Design

Procedure:

1. Select the proper components.
2. Connect High-pass filter experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the AC voltage source to channel a0, a8 on the connector block.
5. Connect the voltage of R2 to channel a1, a9 on the connector block.
6. Set AC voltage range of power supply from (0-10) V.
7. Run the experiment user interface.

8. Click start collecting data button when the frequency on external generator equal the frequency on the screen by keeping AC voltage = 5volt.
9. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source and the voltage of the resistor (R2).

Output of Process:

Display all:

- Voltage source.
- The voltage of R2.
- Graph high-pass filter response.

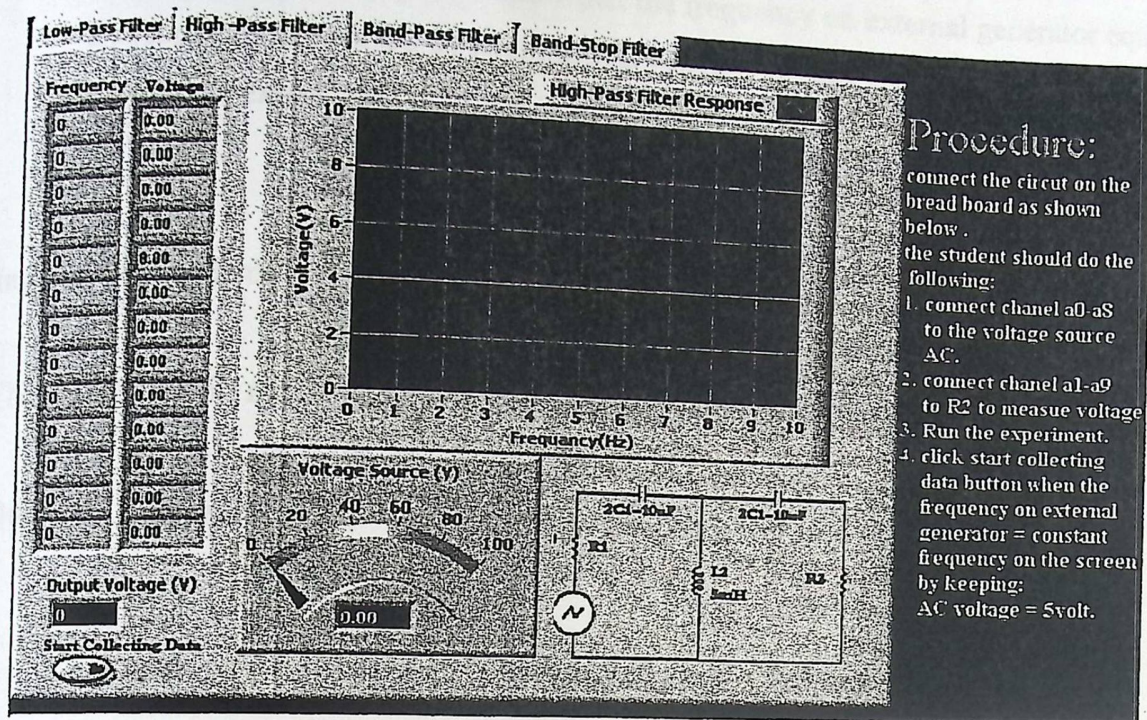


Figure 4.18 High-Pass Filter Screen

Process of LabVIEW:

- Graph the relation between the voltage that record by the user and the frequency that saved in a constant array in the block diagram that programmed by the programmer.

8. Click start collecting data button when the frequency on external generator equal the frequency on the screen by keeping AC voltage = 5volt.
9. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source and the voltage of the resistor (R2).

Output of Process:

Display all:

- Voltage source.
- The voltage of R2.
- Graph high-pass filter response.

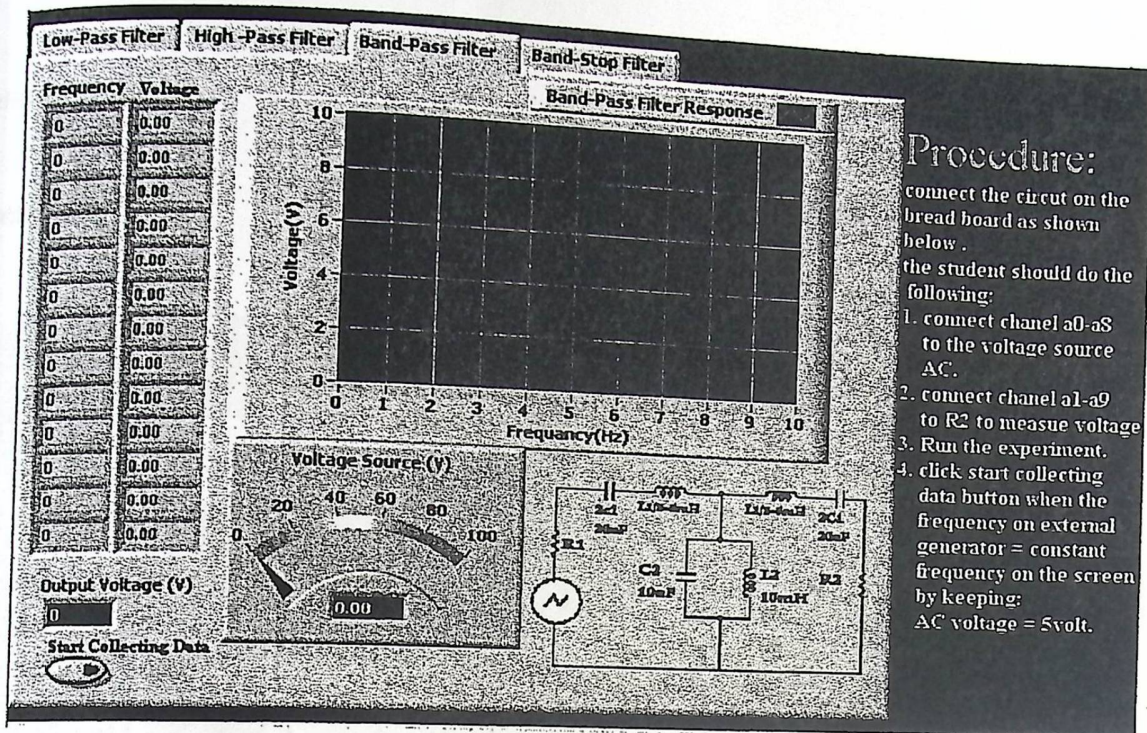


Figure 4.20 Band-Pass Filter Screen

Process of LabVIEW:

- Graph the relation between the voltage that record by the user and the frequency that saved in a constant array in the block diagram that programmed by the programmer.

C. Band-Stop Filter

Experiment setup:

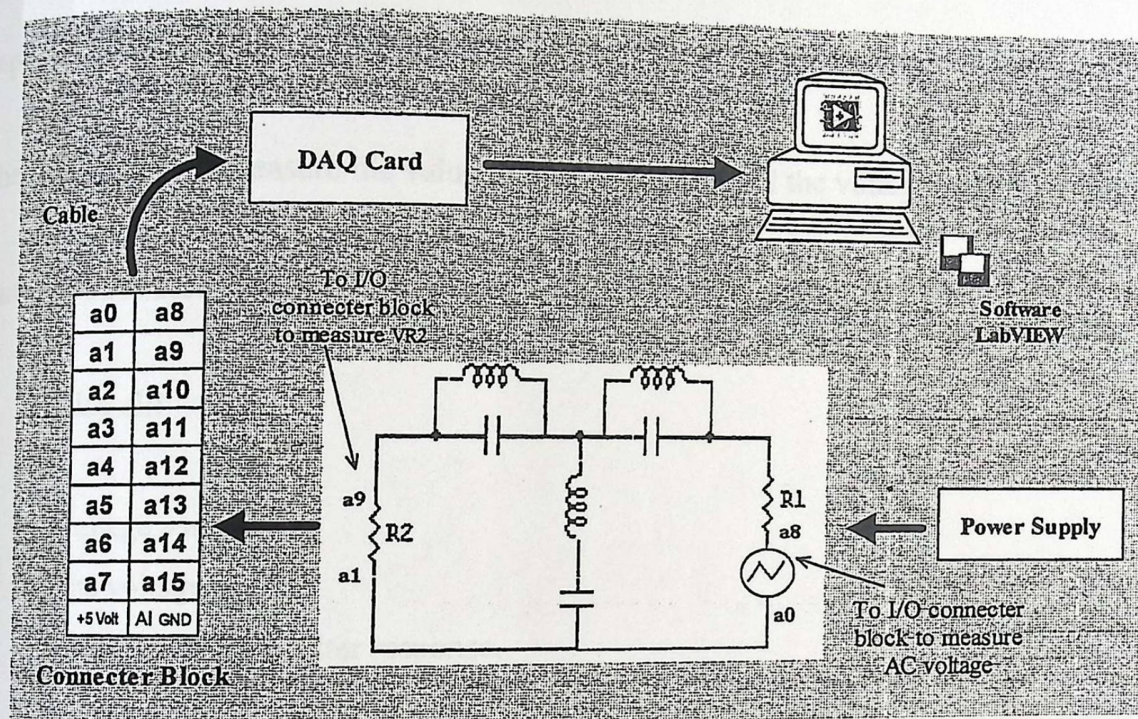


Figure 4.21 Band-Stop Filter Design

Procedure:

1. Select the proper components.
2. Connect Band-stop filter experiment on external breadboard that supplied the circuit from external AC power supply.
3. Set AC power supply to 0 volt.
4. Connect the AC voltage source to channel a0, a8 on the connector block.
5. Connect the voltage of R2 to channel a1, a9 on the connector block.
6. Set AC voltage range of power supply from (0-10) V.
7. Run the experiment user interface.

9. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of voltage source and the voltage of the resistor (R2).

Output of Process:

Display all:

- Voltage source.
- The voltage of R2.
- Graph Band-Stop filter response.

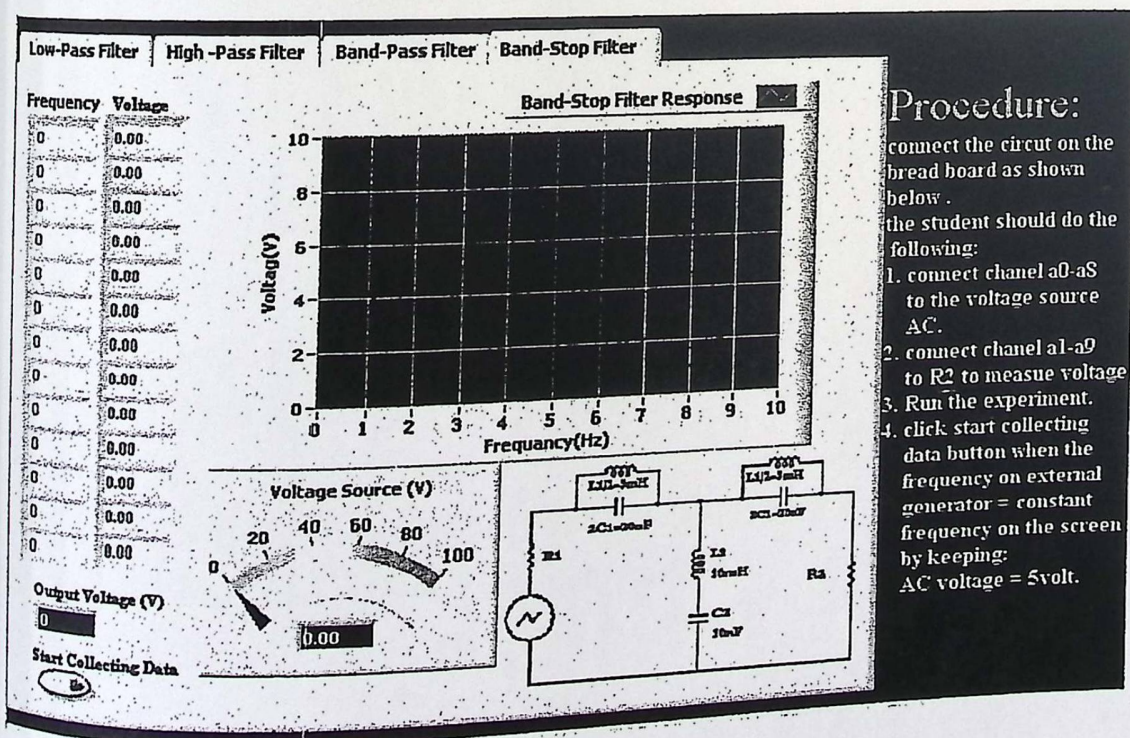


Figure 4.22 Band-Stop Filter Design

Maximum Power Transfer Experiment

Experiment Setup:

Process of LabVIEW:

- Graph the relation between the voltage that record by the user and the frequency that saved in a constant array in the block diagram that programmed by the programmer.

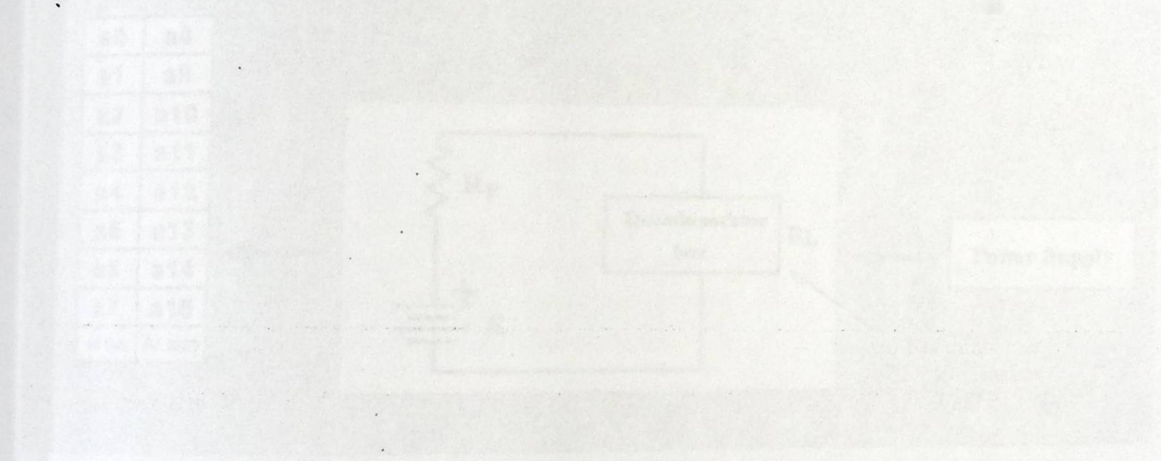


Figure 4.33 Maximum Power Transfer Design

Procedure:

1. Select the proper components.
2. Connect maximum power transfer experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage of RL to channel x0, x1 on the connector block.
5. Set DC voltage range of power supply from (0-10) V.
6. Run the experiment user interface.
7. Click start collecting data button when the resistor load on resistor box equal resistor on the circuit.

4.3.7 Maximum Power Transfer Experiment

Experiment Setup:

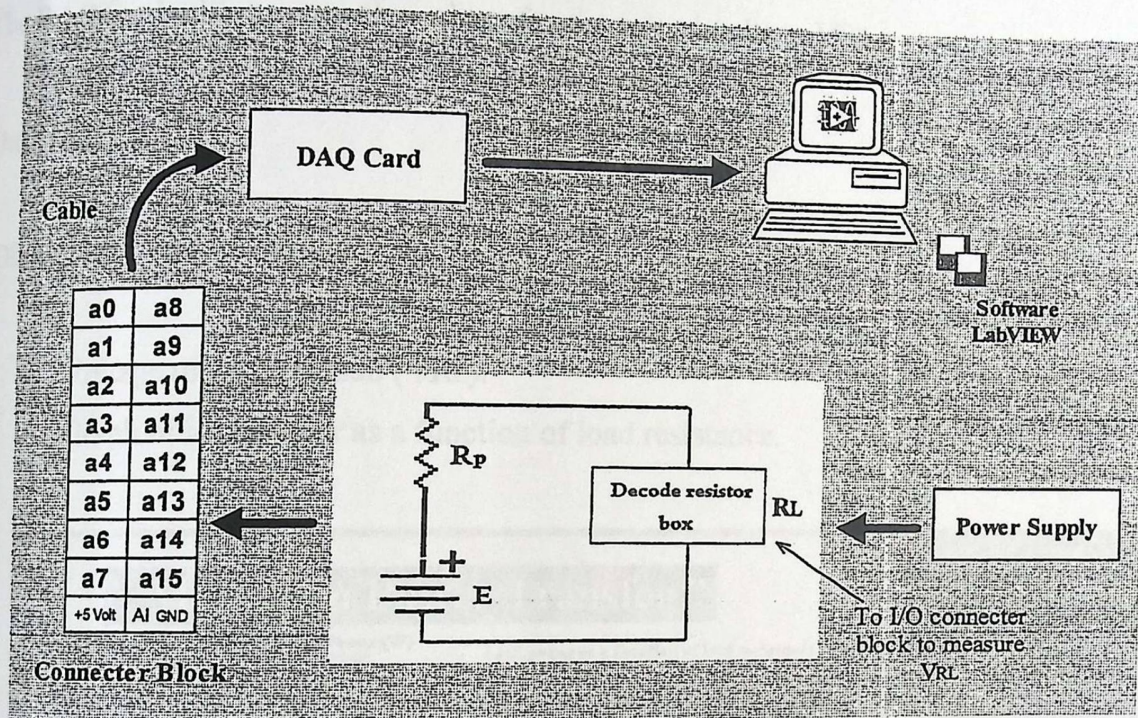


Figure 4.23 Maximum Power Transfer Design

Procedure:

1. Select the proper components.
2. Connect maximum power transfer experiment on external breadboard that supplied the circuit from external DC power supply.
3. Set DC power supply to 0 volt.
4. Connect the voltage of R_L to channel a0, a8 on the connector block.
5. Set DC voltage range of power supply from (0-10) V.
6. Run the experiment user interface.
7. Click start collecting data button when the resistor load on resistor box equal resistor on the screen.

8. Follow the experiment on the screen.

Input of DAQ Card:

The DAQ card will measure the value of resistor load voltage V_{RL} .

Output of Process:

Display all:

- Voltage of resistor load (V_{RL}).
- Graph of load power as a function of load resistance.

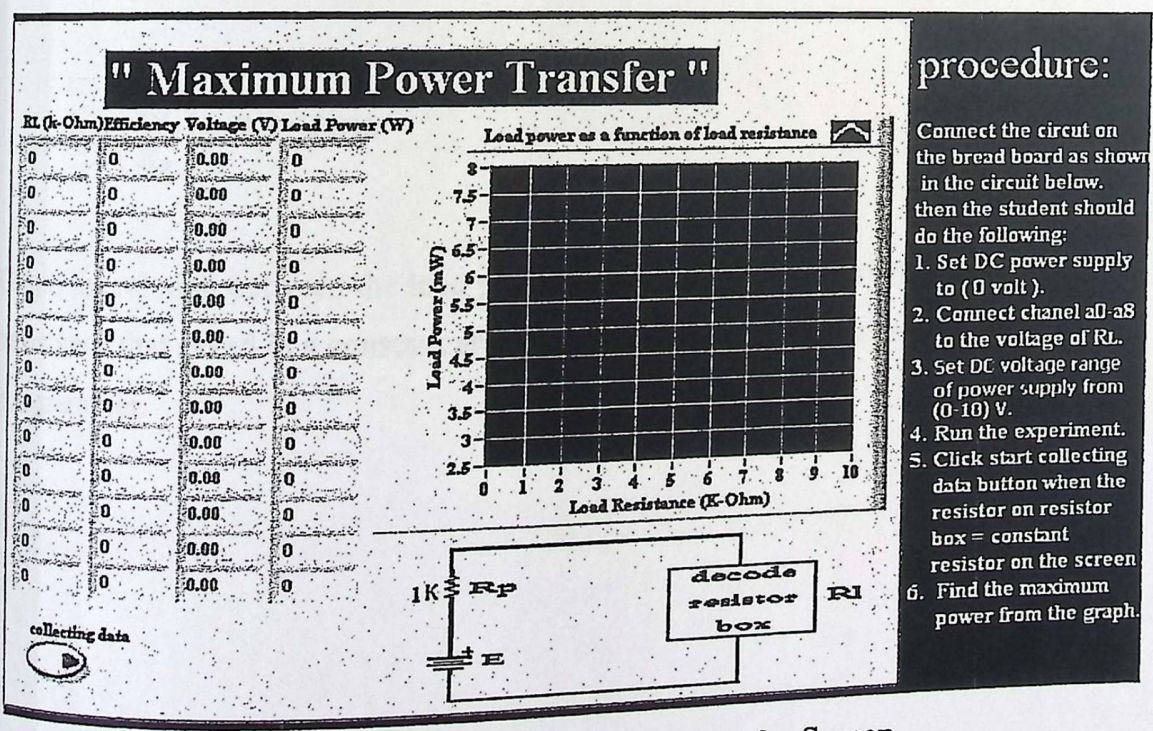


Figure 4.23 Maximum Power transfer Screen

Process of LabVIEW:

- Calculate the value of load power as shown in the equation:

$$P = \frac{V_L^2}{R_L}$$

Where:

P: load power

R_L: load resistor

V_L: voltage of R_L

- Calculate the value of efficiency as shown in the equation:

$$\eta = \left(\frac{R_L}{R_p} \right) + R_L * 100\%$$

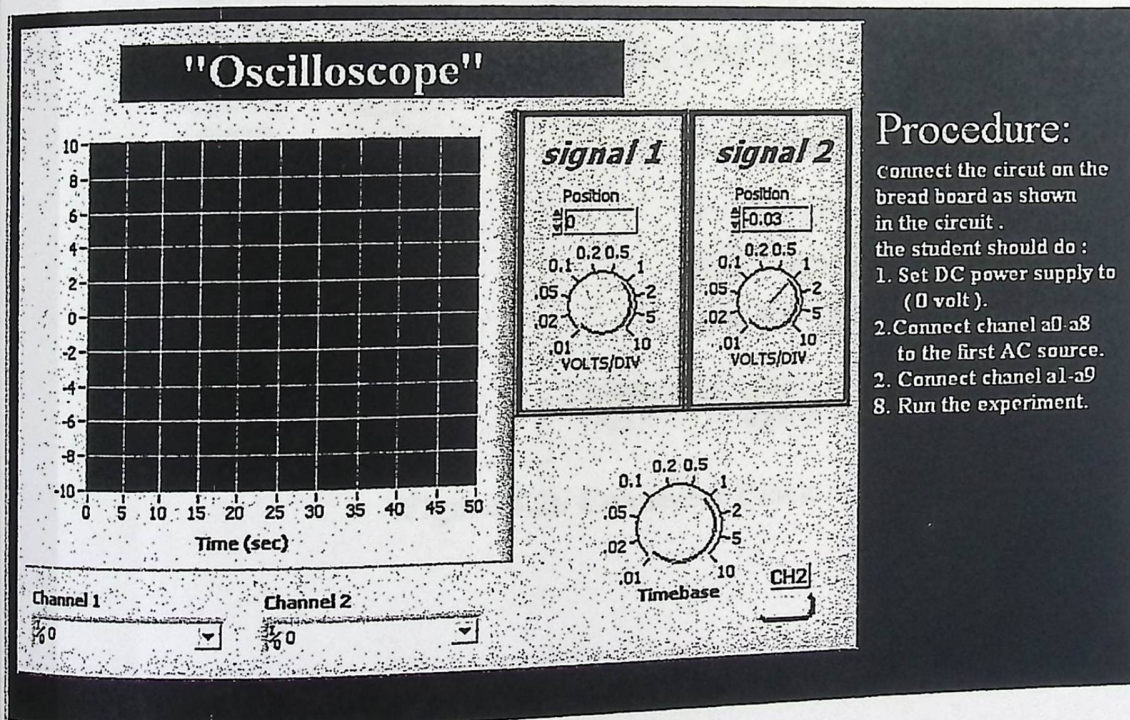
- Graph the relation between the load power that calculated by LabVIEW and the load resistance that saved in a constant array in the block diagram that programmed by the programmer.

Input of DAQ Card:

The DAQ card will measure the value of AC voltage source for each signal.

Output of Process:

- Display the graph of two signals.



Procedure:

- Connect the circuit on the bread board as shown in the circuit. the student should do :
1. Set DC power supply to (0 volt).
 2. Connect channel a0-a8 to the first AC source.
 2. Connect channel a1-a9
 8. Run the experiment.

Figure 4.25 Oscilloscope Screen

4.3.9 Connector Block Design:

This board is the interface between the external experiment and the DAQ card, It's including eight analog input pair of channels; each pair is used to measure the voltage across one of the component (capacitor, resistor, coil ...).

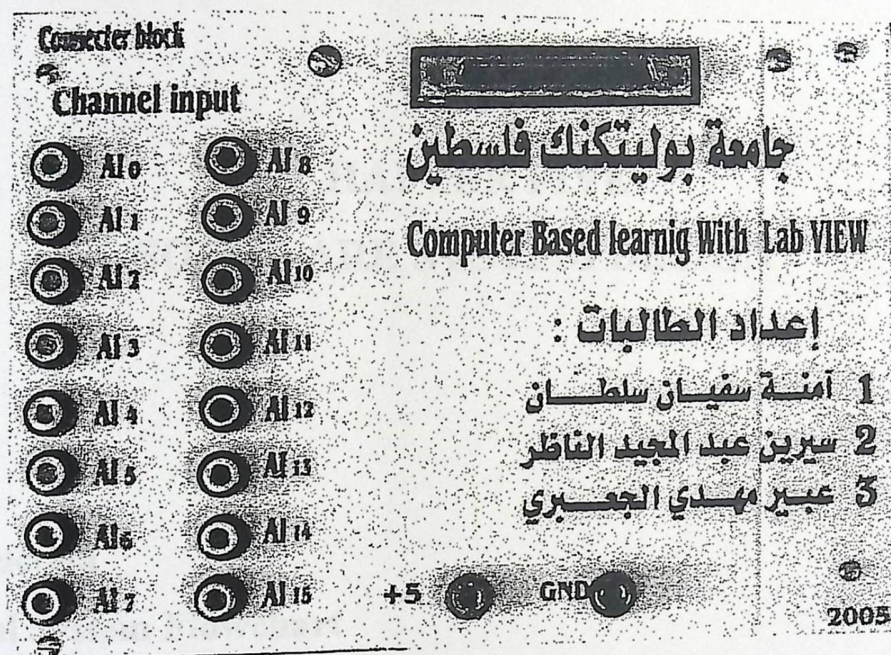


Figure 4.26 Connector Block

5.1 Introduction

In this chapter, the software subroutines and their functionality are going to be explained in details.

5.2 General System Flowchart

CHAPTER FIVE SOFTWARE SYSTEM DESIGN

5.1 Introduction

5.2 General System Flowchart

5.3 System experiments Flow Charts

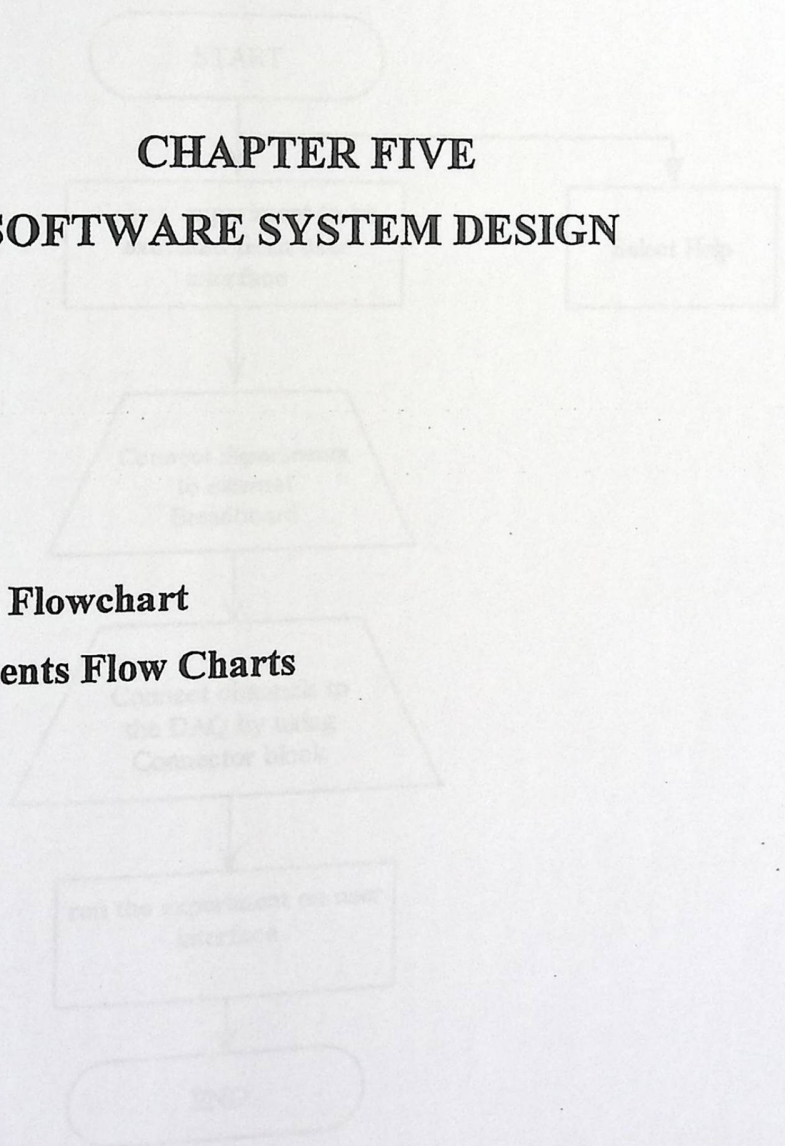


Figure 5.1 General System Flow Chart

5.1 Introduction

In this chapter, the software subroutines and their functionality are going to be explained in details.

5.2 General System Flowchart

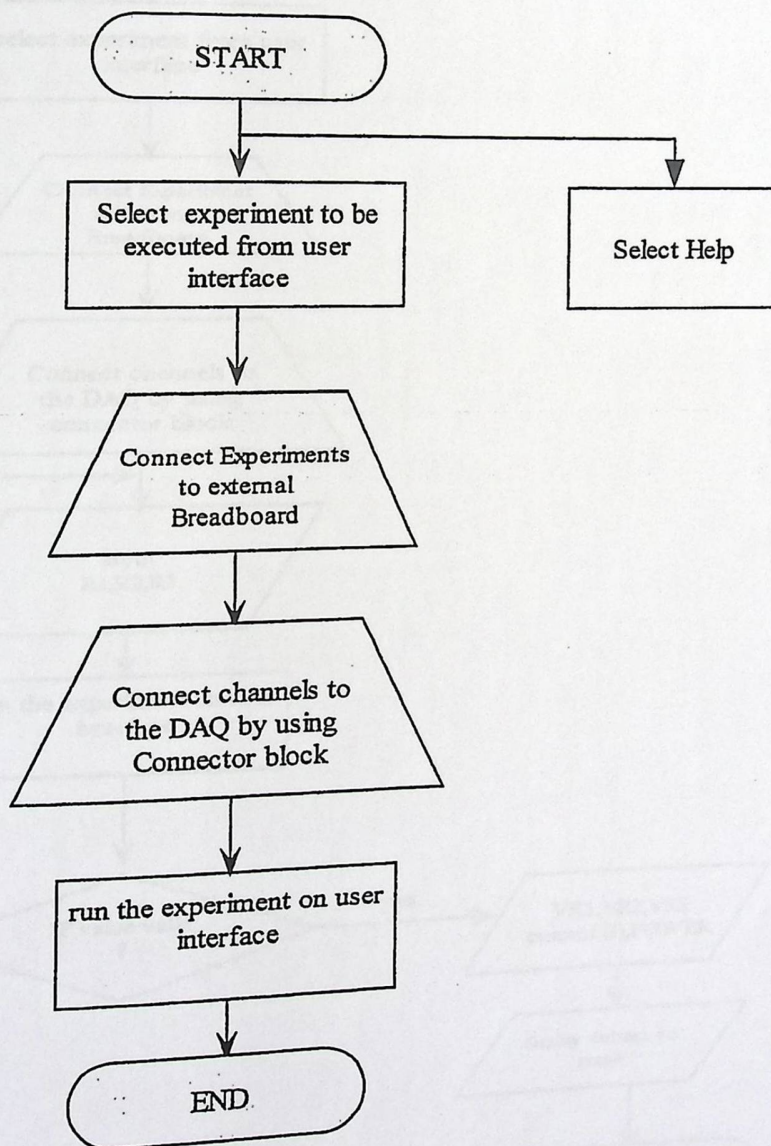


Figure 5.1 General System Flow Chart

5.3 Experiments Flow Charts:

This section describes how experiments work and describe the inputs and outputs for each experiment:

5.3.1 Ohm's Law:

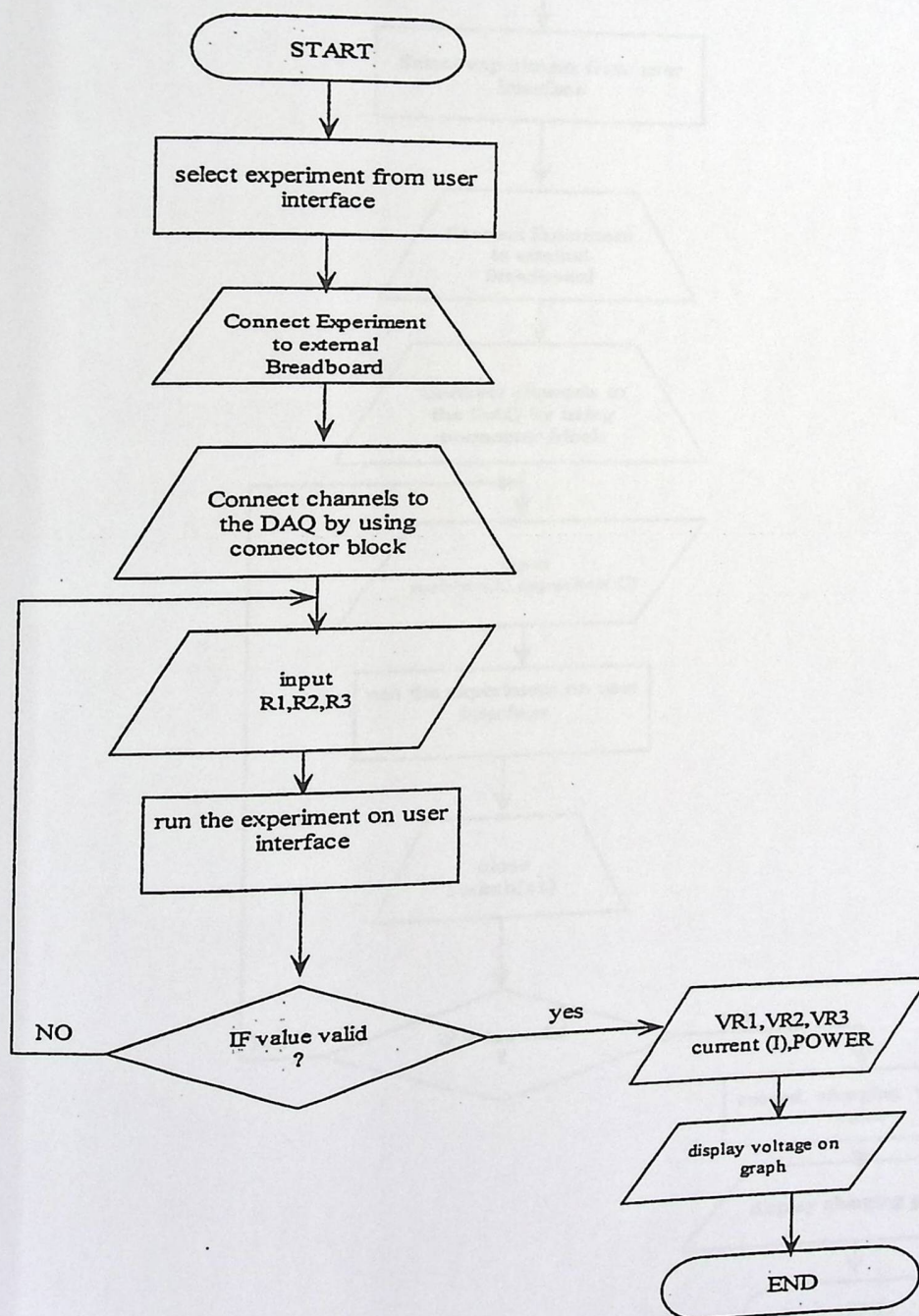


Figure 5.2: Ohm's Law Flow Chart

5.3.2 Charging Capacitor:

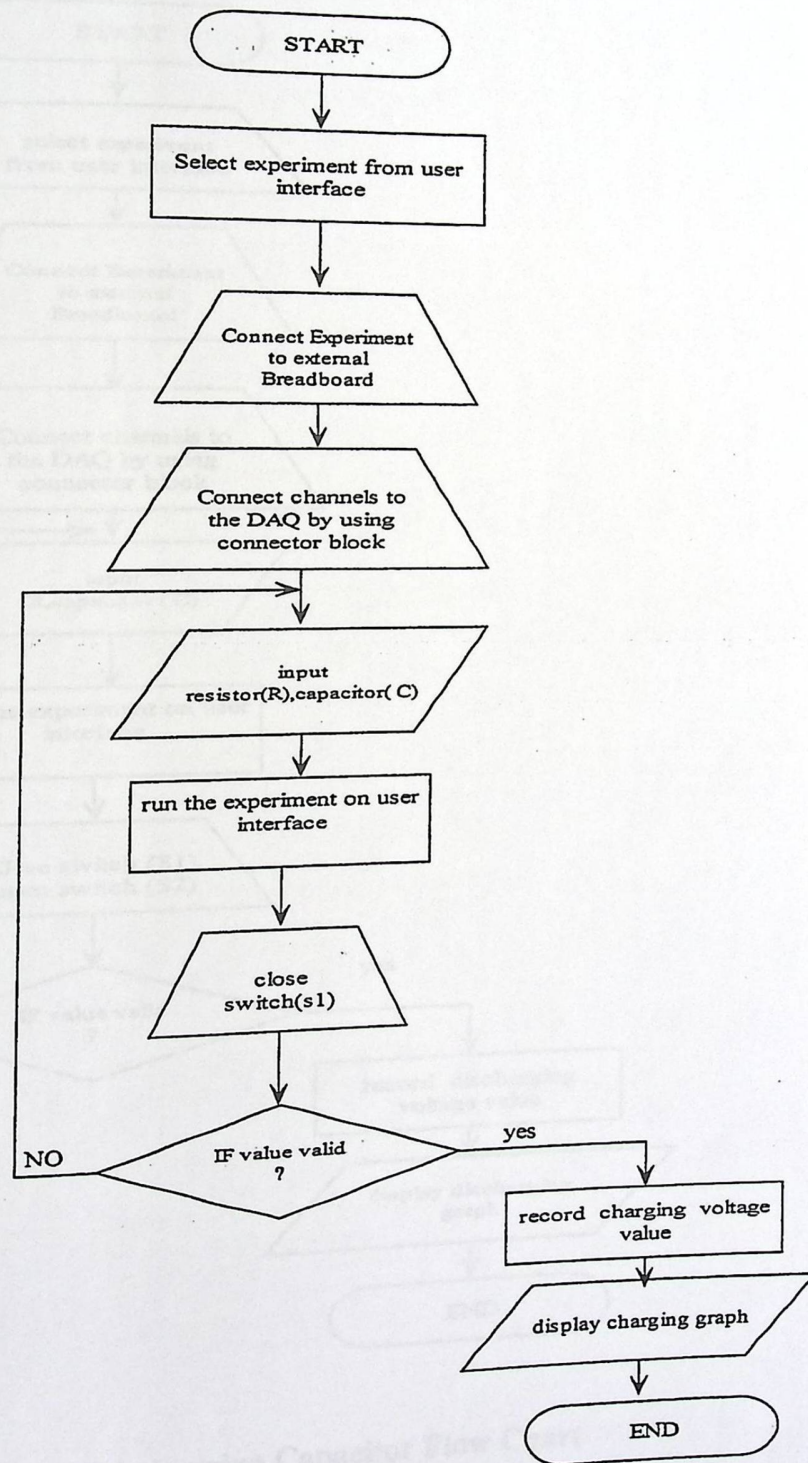


Figure 5.3 Charging Capacitor Flow Chart

5.3.3 Discharging Capacitor:

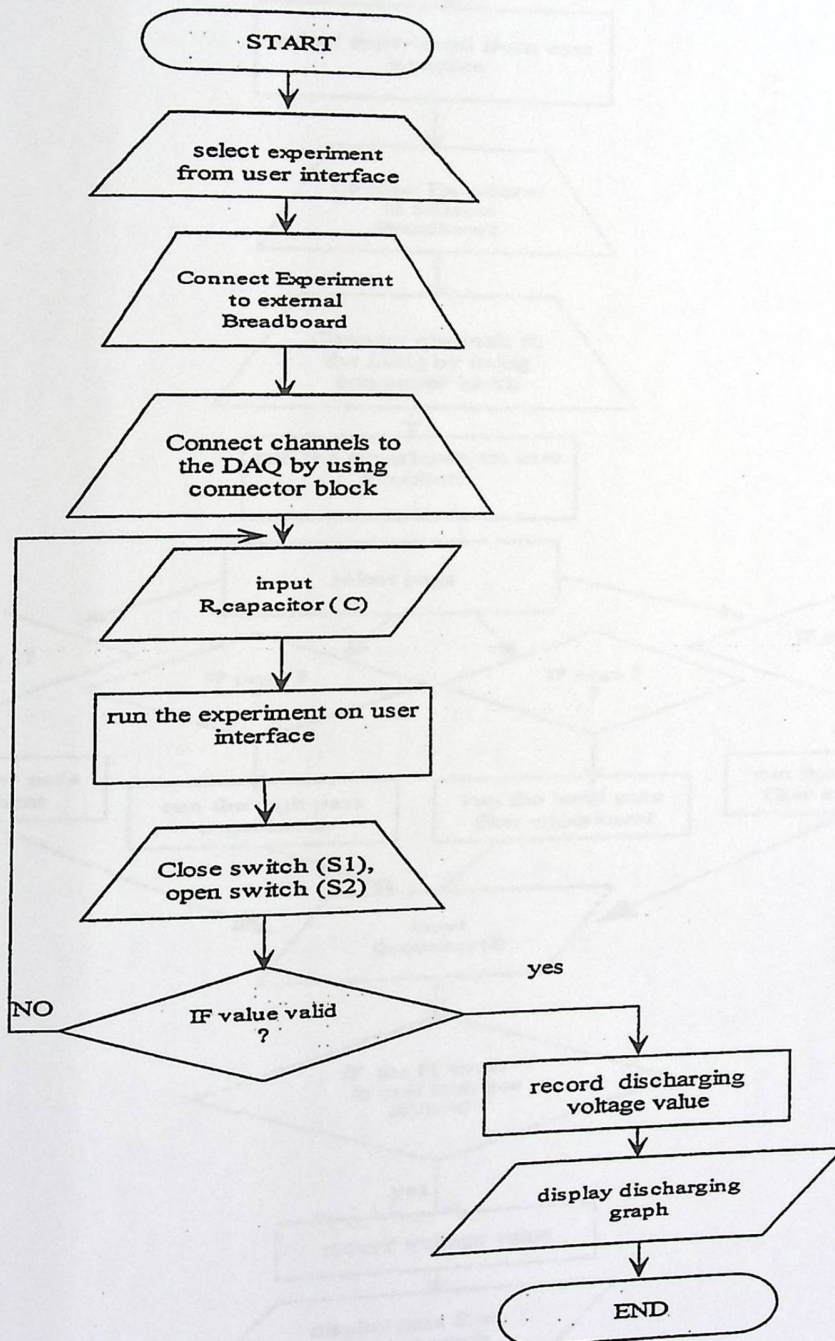


Figure 5.4 Discharging Capacitor Flow Chart

5.3.4 Filter Response:

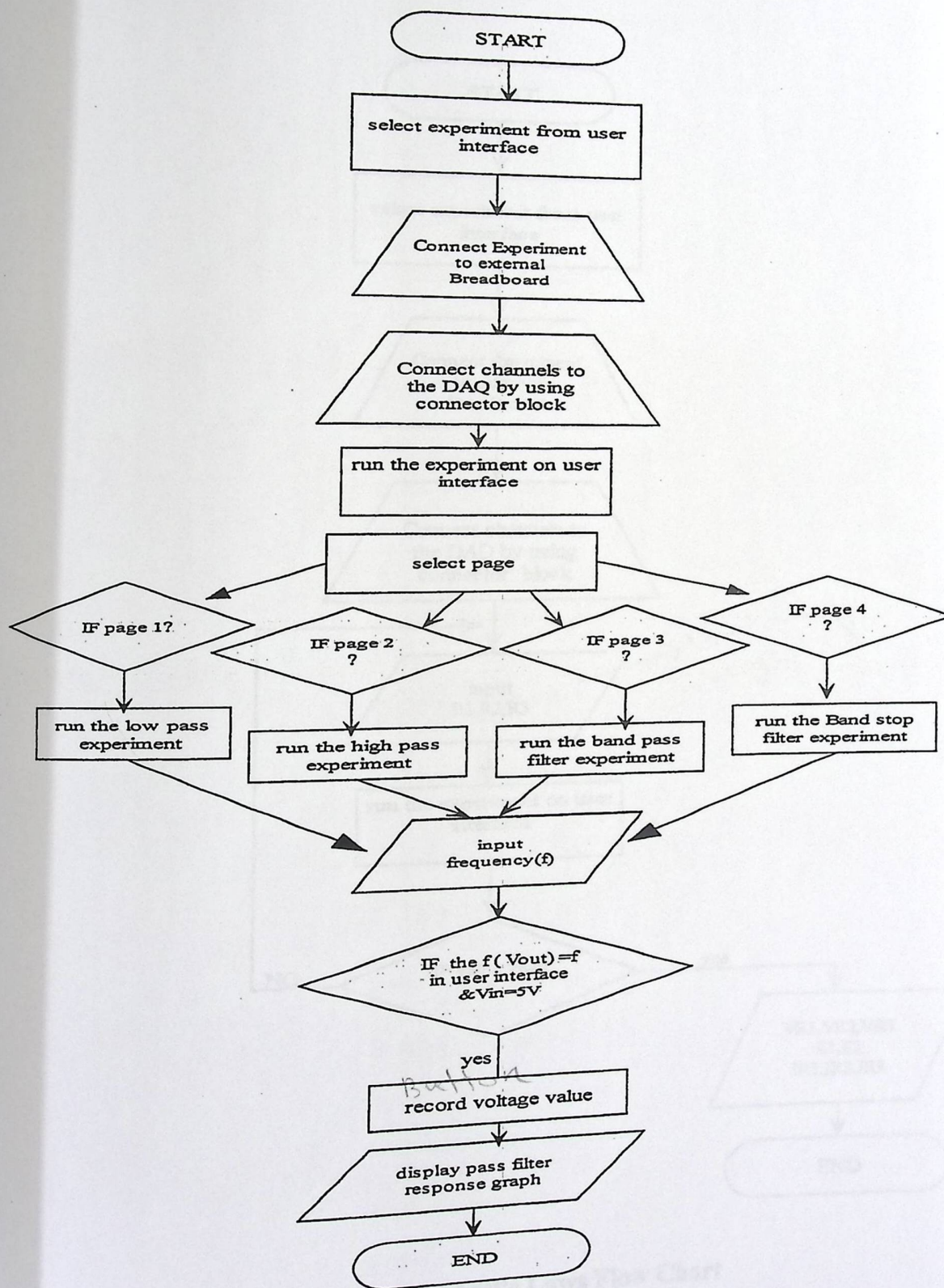


Figure 5.5 Filter Response Flow Chart

3.4 Filter Response:

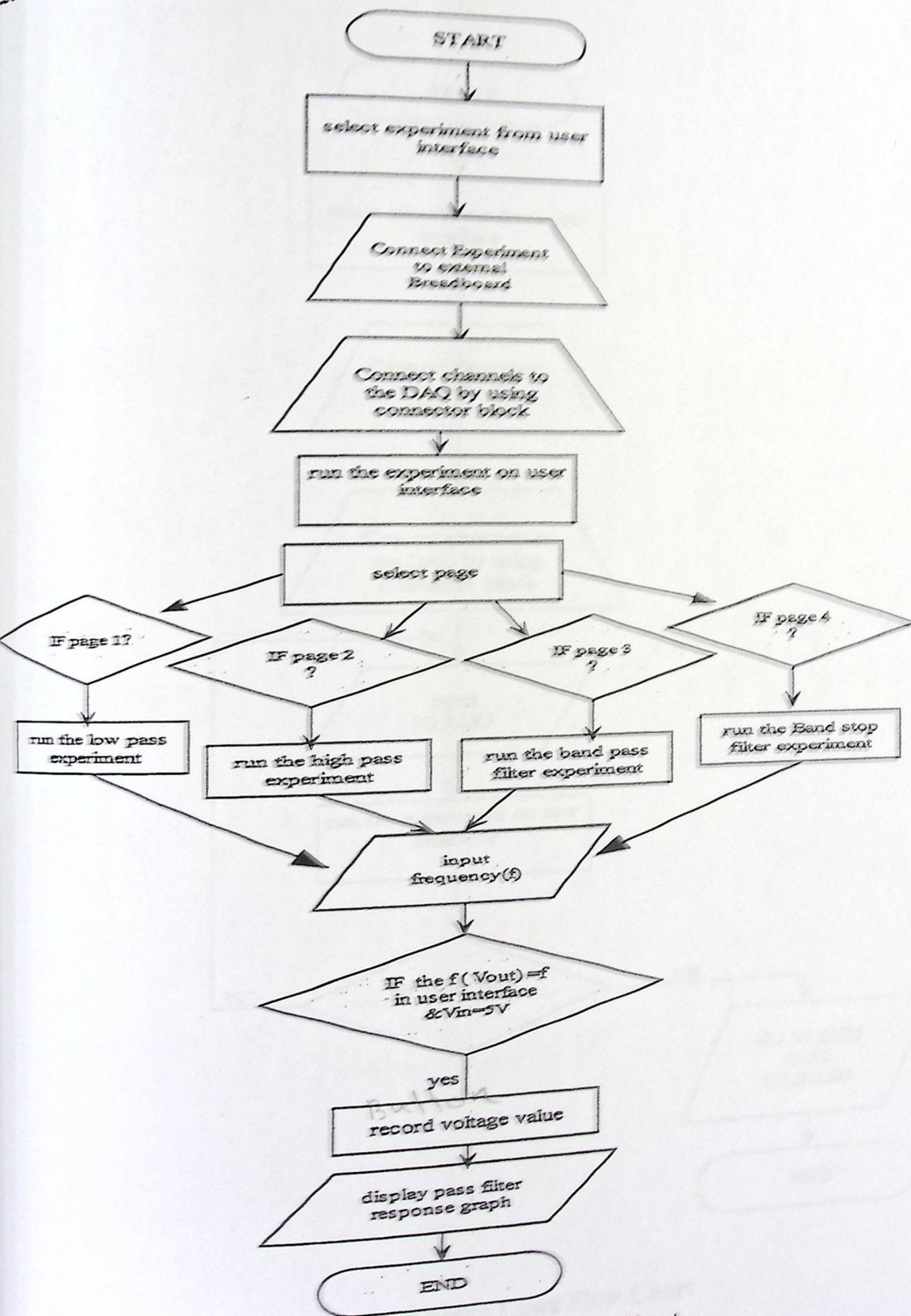


Figure 5.5 Filter Response Flow Chart

5.3.5 Kirchhoff's Laws:

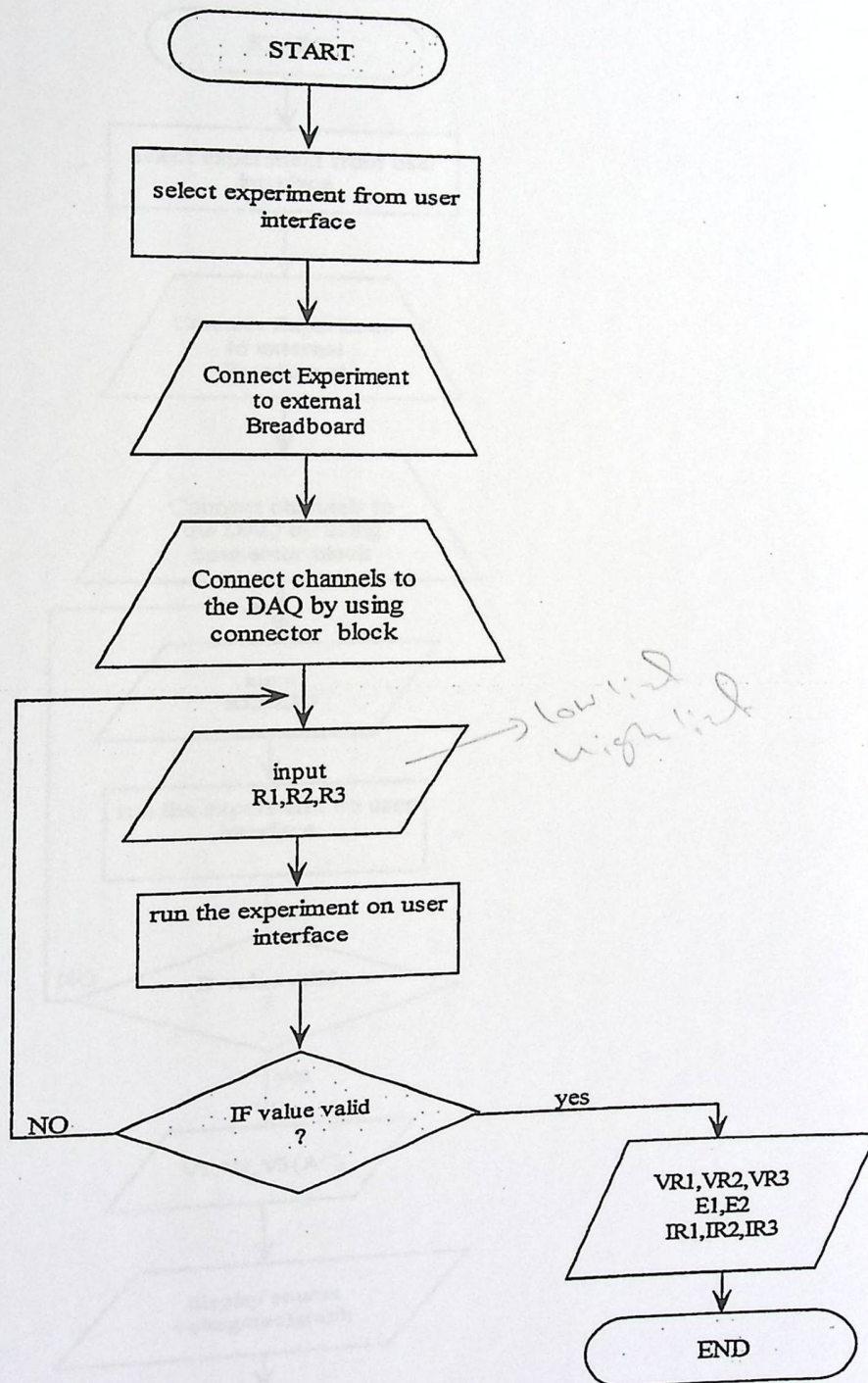


Figure 5.6 Kirchhoff's Laws Flow Chart

5.3.6 AC Measurement:

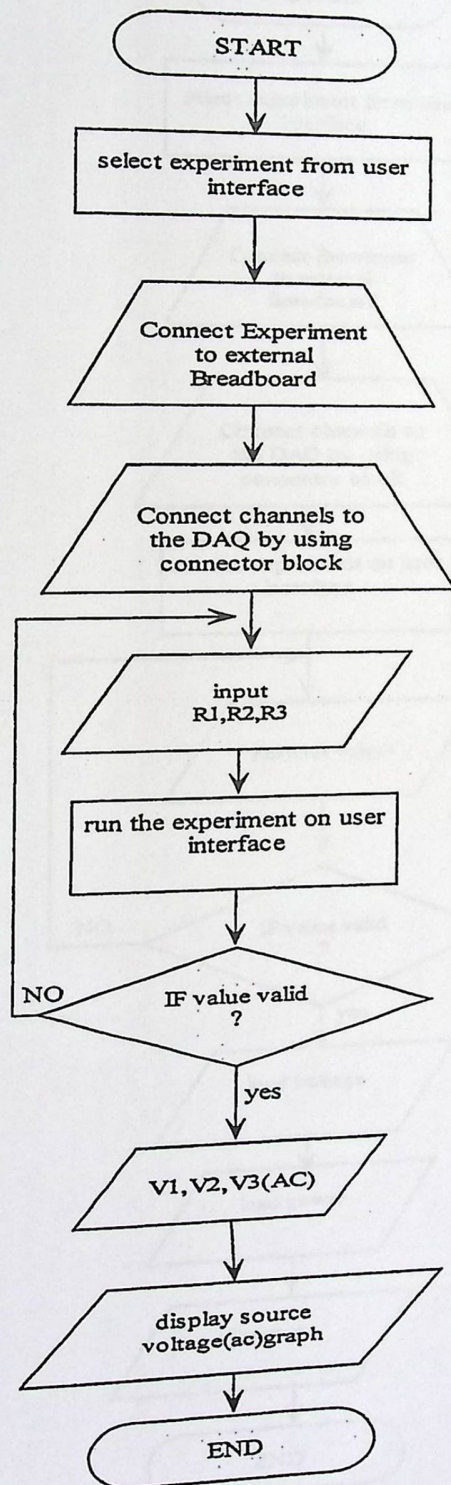


Figure 5.7 AC Measurement Flow Char

5.3.7 Maximum Power:

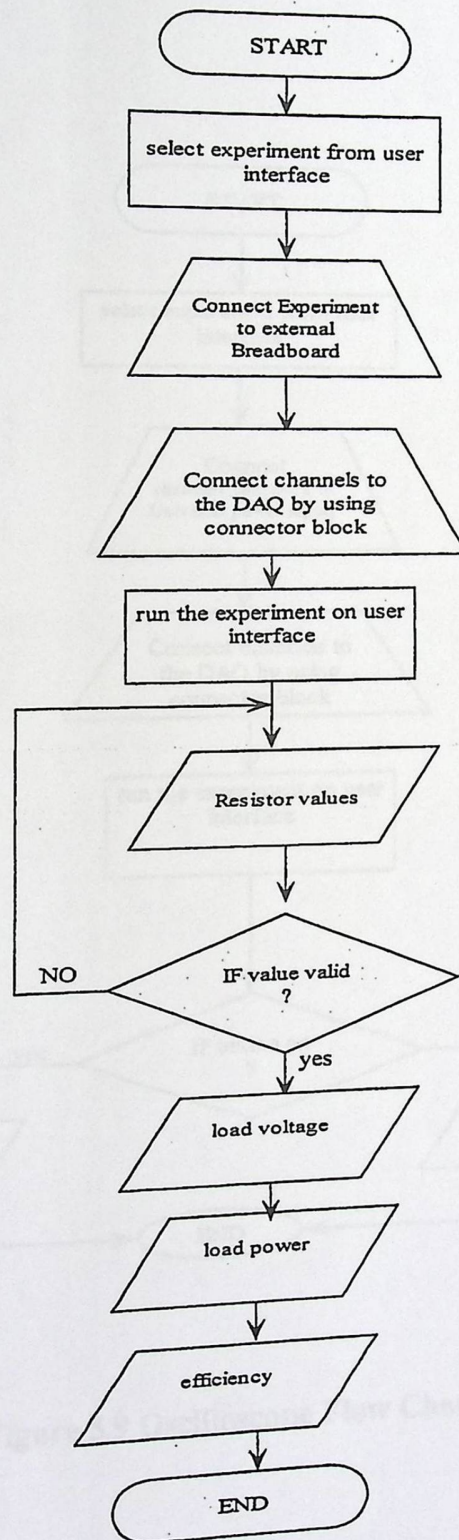


Figure 5.8 Maximum Power Transfer Flow Chart

5.3.8 Oscilloscope:

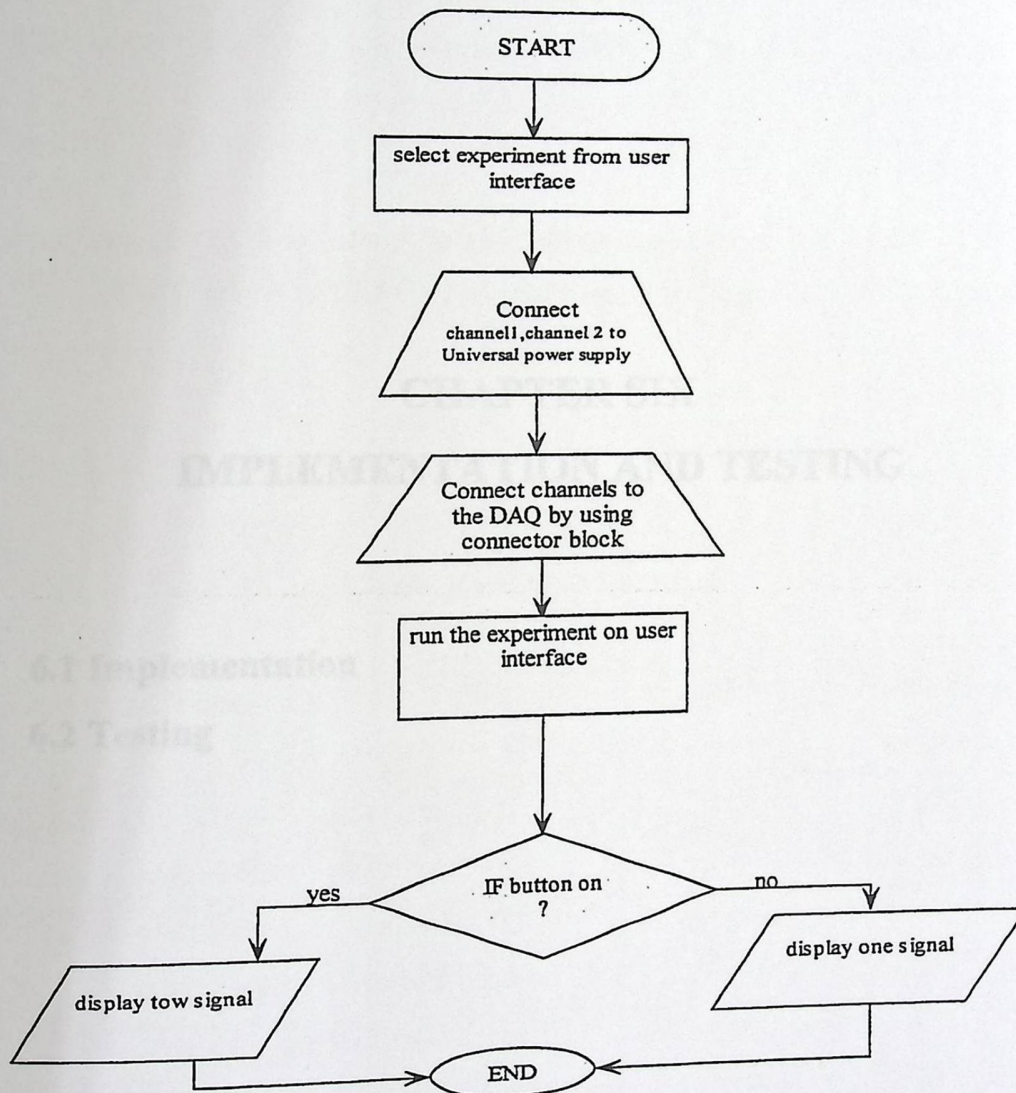


Figure 5.9 Oscilloscope Flow Chart

6.1 Implementation

Implementation the system was done through connect the experiments signal board board and enter signal data external device then run each experiment LabVIEW user interface.

6.2 Testing

Testing the system was done through storing each experiment as LabVIEW and the value on the graph. Also test the connector block through check each channel by each input external experiment.

CHAPTER SIX IMPLEMENTATION AND TESTING

Table 6.1 Ohm's Law Test

6.1 Implementation

6.2 Testing

Test Case	Input	Value	Expected output	Actual output	Screen
Ohm's Law	Voltage	Low limit=0	Valid	Valid	Figure 6.1
	Input limit	High limit=5			
Ohm's Law	Voltage	Low limit=-1	Invalid	Invalid	Figure 6.2
	Input limit	High limit=12...			
Ohm's Law	Input resistance	R1= +(1K Ohm) R2= +(2K Ohm) R3= +(3K Ohm)	Valid	Valid	Figure 6.1
Ohm's Law	Input resistance	R1= -(1K Ohm) R2= +(2K Ohm) R3= -(3K Ohm)	Invalid	Invalid	Figure 6.2

6.1 Implementation

Implementation the system was done through connect the experiments on the external bread board and enter signal from external device then run each experiment on LabVIEW user interface.

6.2 Testing

Testing the system was done through execute each experiment on LabVIEW and plot the values on the graph. Also test the connector block through check each channel by enter signal from external experiment.

6.2.1 Ohm's Law Test

Table 6.1 Ohm's Law Test

Experiment	Data	Values	Expected output	Actual output	Screen
Ohm's Law	Voltage input limit	Low limit= 0 High limit= 5	Valid	Valid	Figure 6.1
Ohm's Law	Voltage input limit	Low limit= -1 High limit=12...	Invalid	Invalid	Figure 6.2
Ohm's Law	Input resistance	R1= +(1k Ohm) R2= +(2k Ohm) R3= +(3K Ohm)	Valid	Valid	Figure 6.1
Ohm's Law	Input resistance	R1= -(1k Ohm) R2= +(2k Ohm) R3= +(3K Ohm)	Invalid	Invalid	Figure 6.2

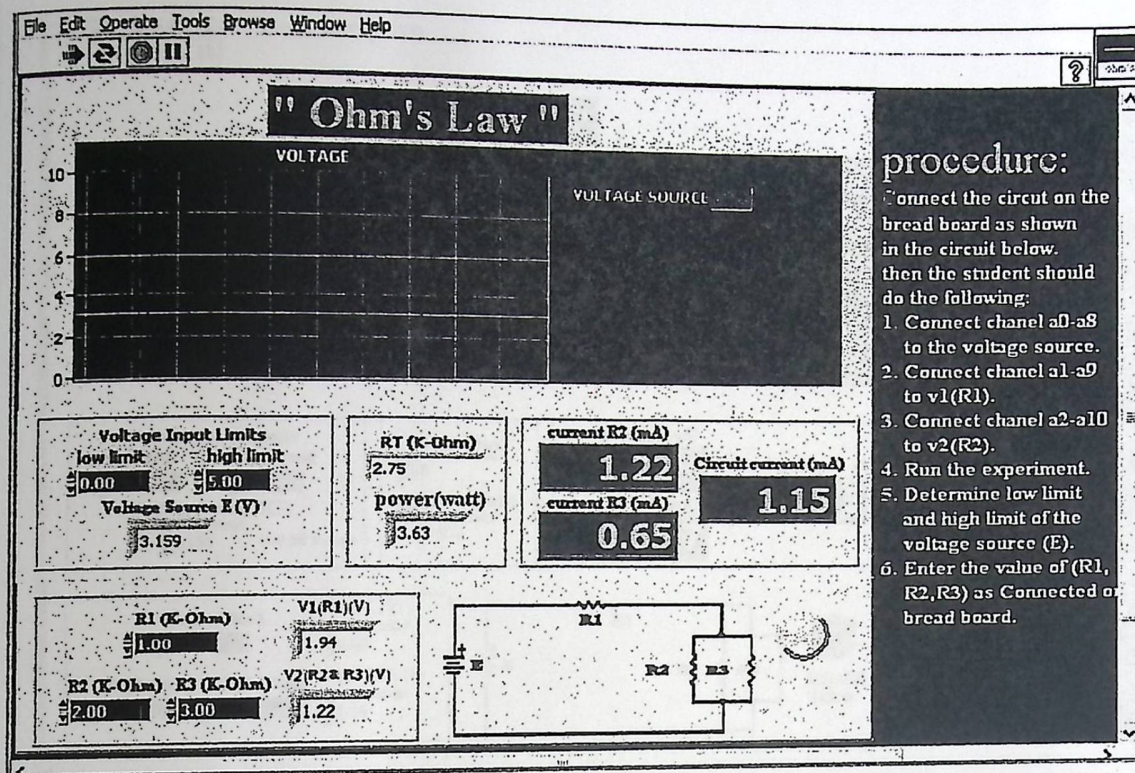


Figure 6.1 Valid Ohm's Law Test

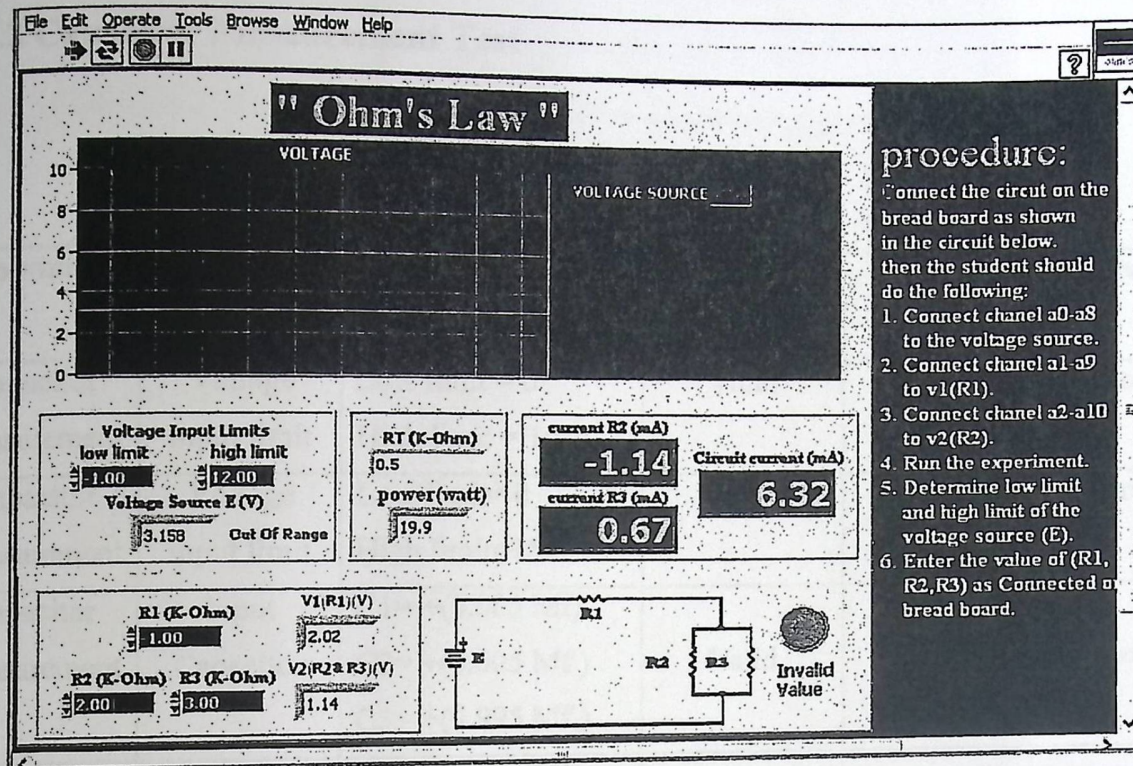


Figure 6.2 Invalid Ohm's Law Test

6.2.2 Capacitor Measurement Test

Table 6.2 Capacitor Measurement Test

Experiment	Data	Values	Expected output	Actual output	Screen
Capacitor Measurement	Voltage input limit	Low limit = 0 High limit = 10	Valid	Valid	Figure 6.3
Capacitor Measurement	Voltage input limit	Low limit= 0 High limit=15	Invalid	Invalid	Figure 6.4
Capacitor Measurement	Input Capacitor	C1= +(0.005 Mf) C2= +(0.005 Mf) C3= +(0.995 Mf)	Valid	Valid	Figure 6.3
Capacitor Measurement	Input Capacitor	C1= -(0.005 Mf) C2= -(1.005 Mf) C3= -(0.995 Mf)	Invalid	Invalid	Figure 6.4

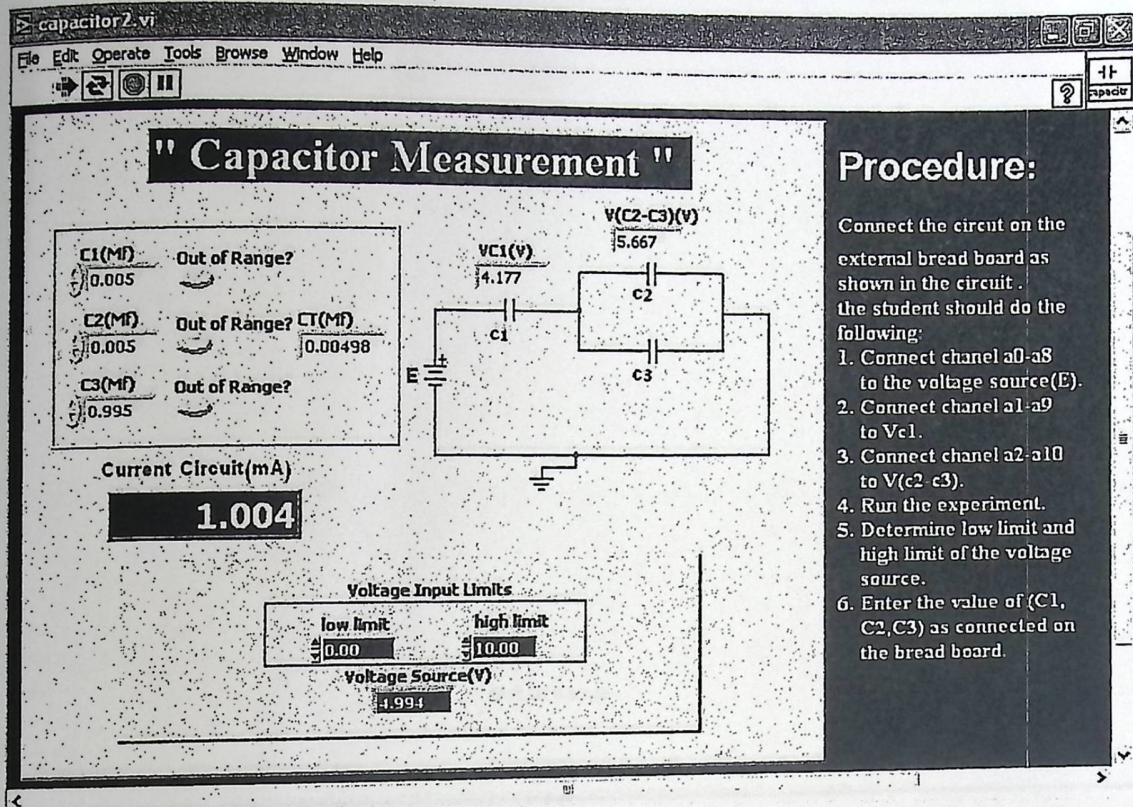


Figure 6.3 Valid Capacitor Measurement Test

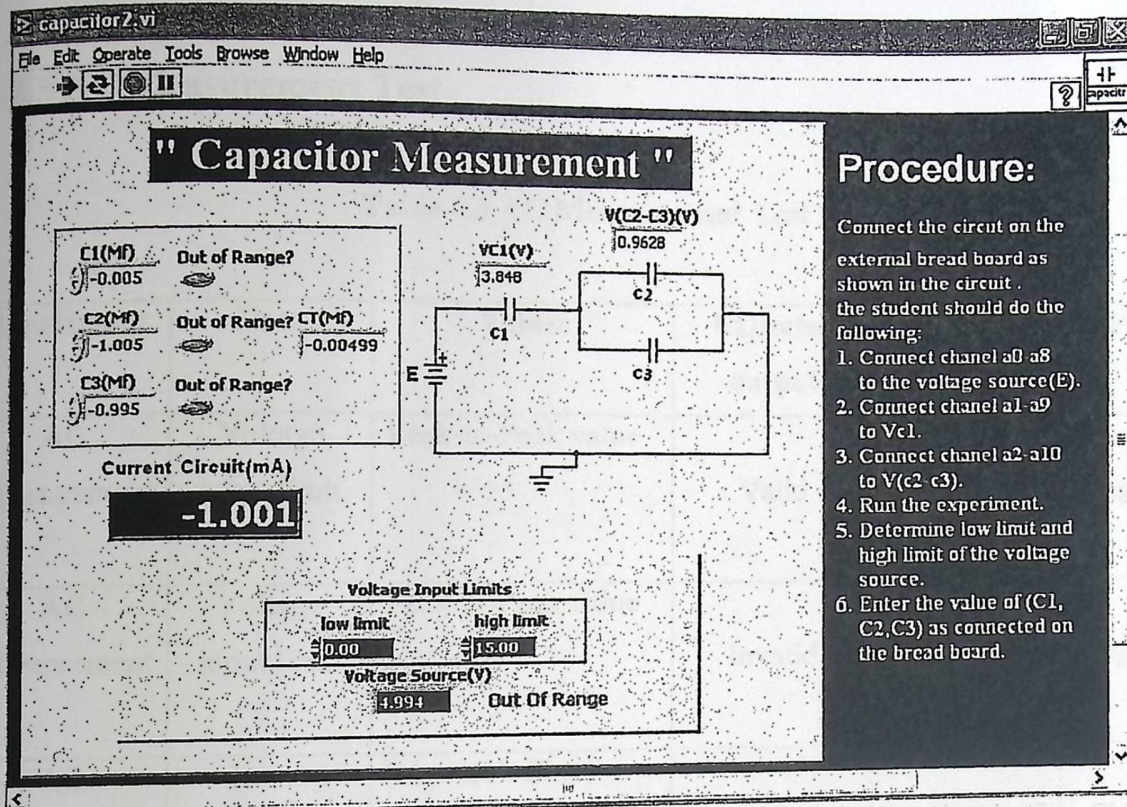


Figure 6.4 Invalid Capacitor Measurement Test

6.2.3 AC Measurement Test

Table 6.3 AC Measurement Test

Experiment	Data	Values	Expected output	Actual output	Screen
AC Measurement	Voltage input limit	Peak-to-Peak value = +5	Valid	Valid	Figure 6.5
AC Measurement	Voltage input limit	Peak-to-Peak value = -5	Invalid	Invalid	Figure 6.6
AC Measurement	Input resistance	R1= +(1k Ohm) R2= +(1k Ohm) R3= +(1K Ohm)	Valid	Valid	Figure 6.5
AC Measurement	Input resistance	R1= +(1k Ohm) R2= -(4k Ohm) R3= +(1K Ohm)	Invalid	Invalid	Figure 6.6

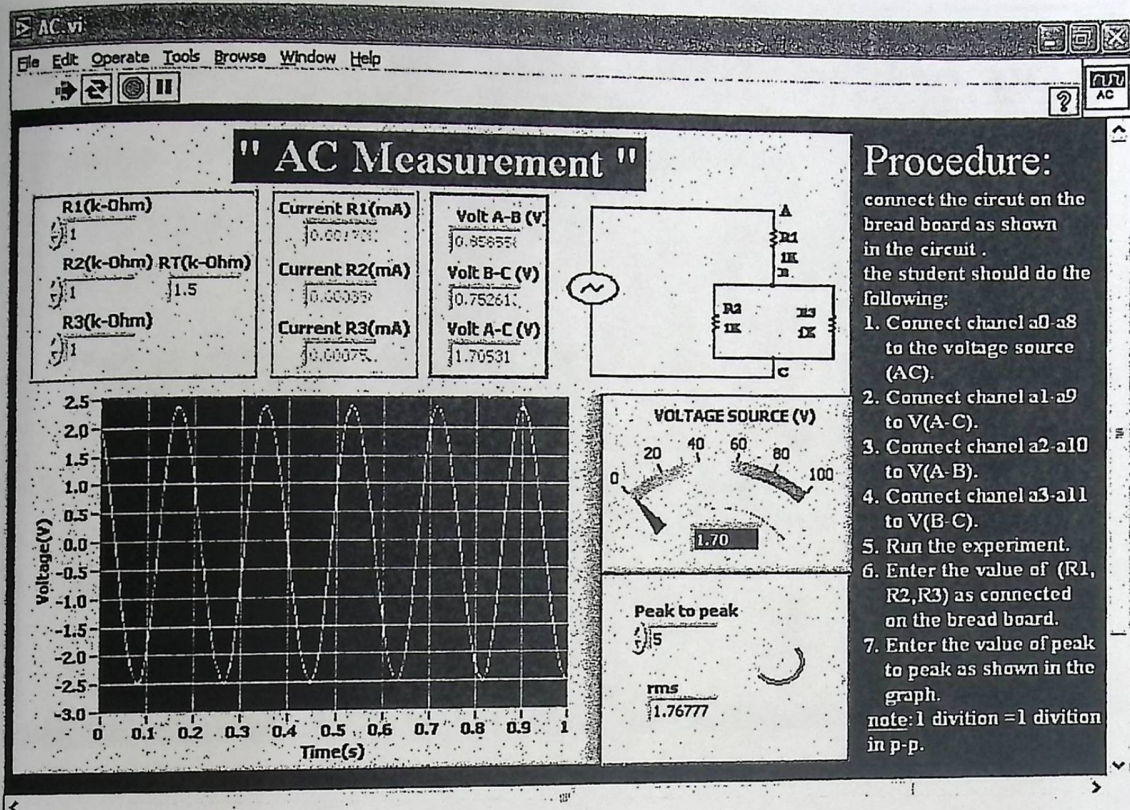


Figure 6.5 Valid AC Measurement Test

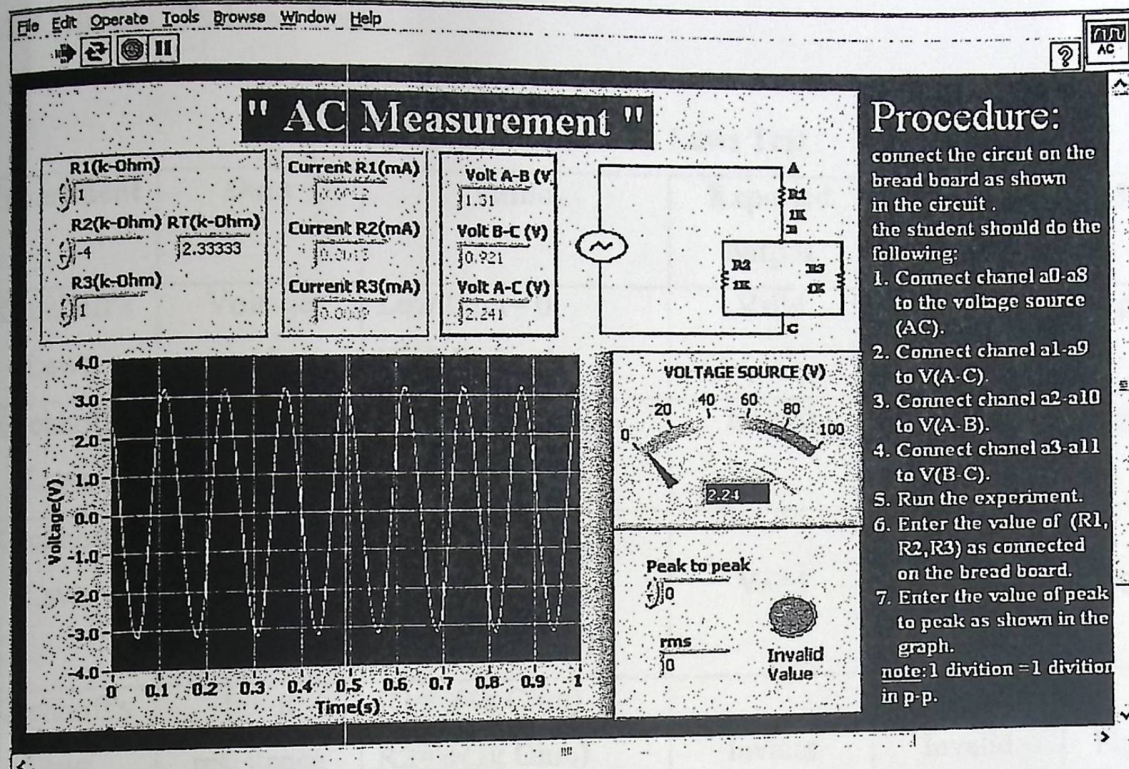


Figure 6.6 Invalid AC Measurement Test

6.2.4 Kirchhoff's Laws Test

Table 6.4 Kirchhoff's Laws Test

Experiment	Data	Values	Expected output	Actual output	Screen
Kirchhoff's Laws	Voltage input limit	Low limit= 0 High limit= 5	Valid	Valid	Figure 6.7
Kirchhoff's Laws	Voltage input limit	Low limit= 0 ,-2 High limit=11,5	Invalid	Invalid	Figure 6.8
Kirchhoff's Laws	Input resistance	R1= +(1k Ohm) R2= +(1k Ohm) R3= +(2K Ohm)	Valid	Valid	Figure 6.7
Kirchhoff's Laws	Input resistance	R1= -(4k Ohm) R2= +(1k Ohm) R3= -(2K Ohm)	Invalid	Invalid	Figure 6.8

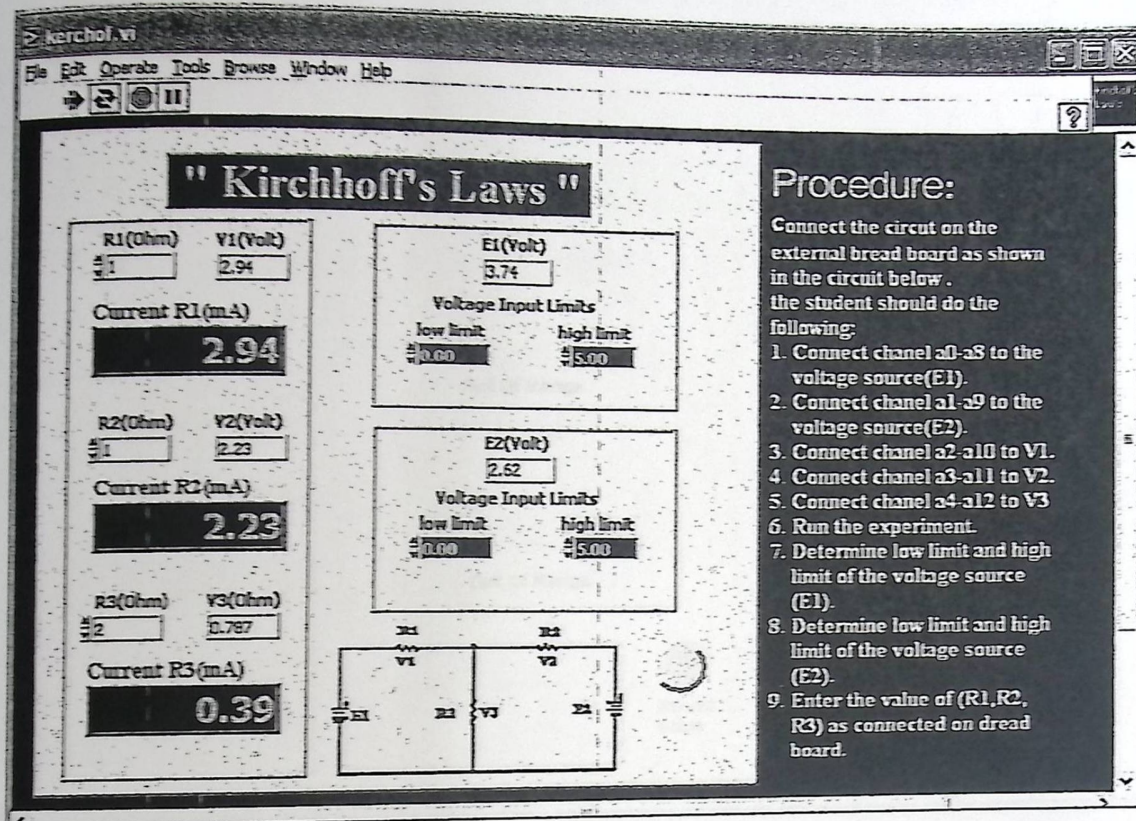


Figure 6.7 Valid Kirchhoff's Laws Test

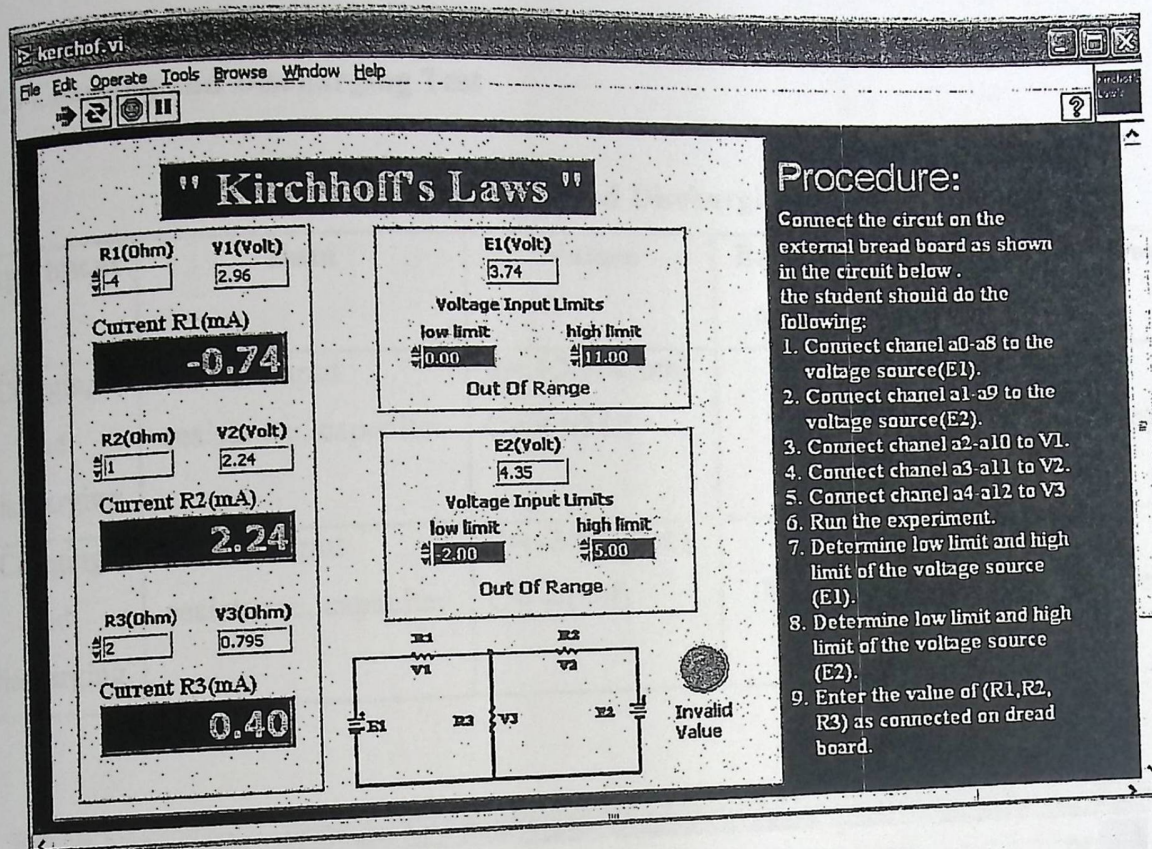


Figure 6.8 Invalid Kirchhoff's Laws Test

6.2.5 Charging and Discharging Test

Table 6.5 Charging and Discharging Test

Experiment	Data	Values	Expected output	Actual output	Screen
Charging and Discharging	Input resistance, capacitor	$R = +3(K\text{-Ohm})$ $C = +4(Mf)$	Valid	Valid	Figure 6.9
Charging and Discharging	Input resistance, capacitor	$R = -3(K\text{-Ohm})$ $C = -4(Mf)$	Invalid	Invalid	Figure 6.10

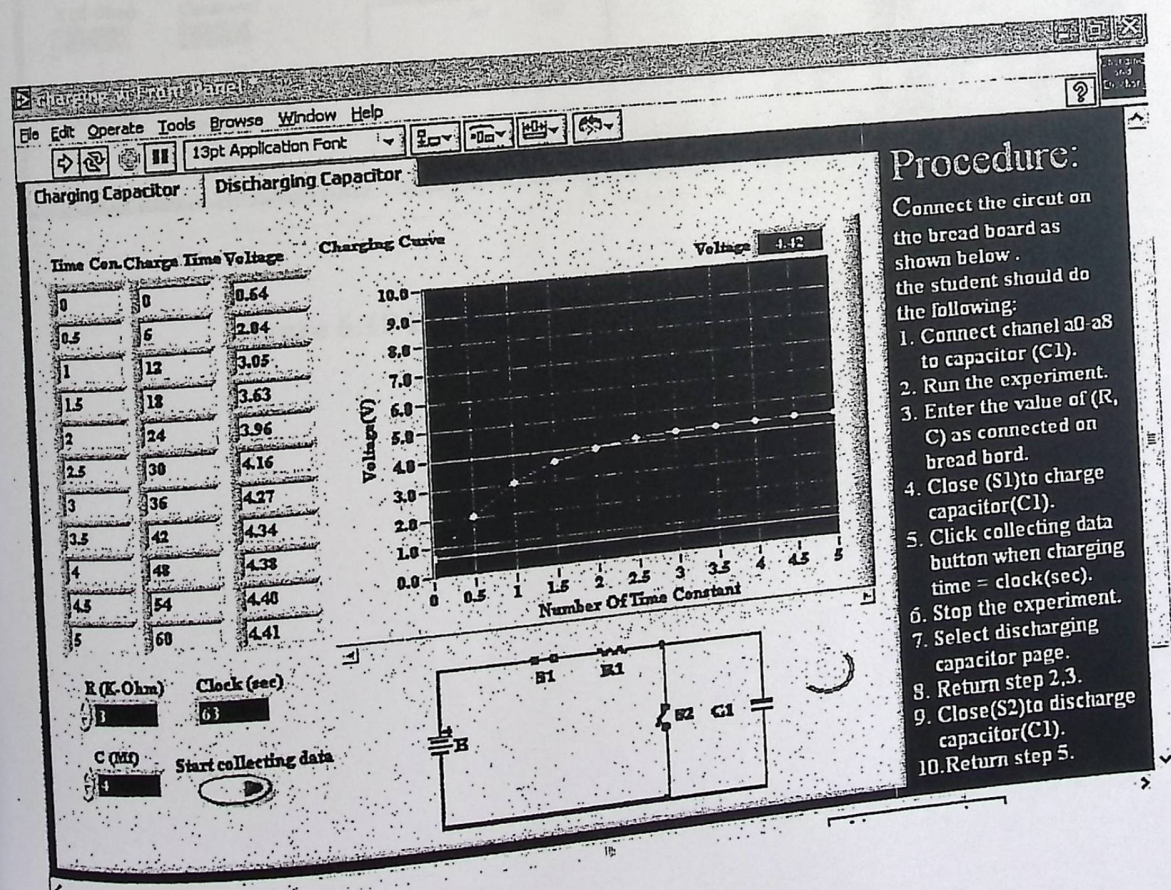


Figure 6.9 Valid Charging and Discharging Test

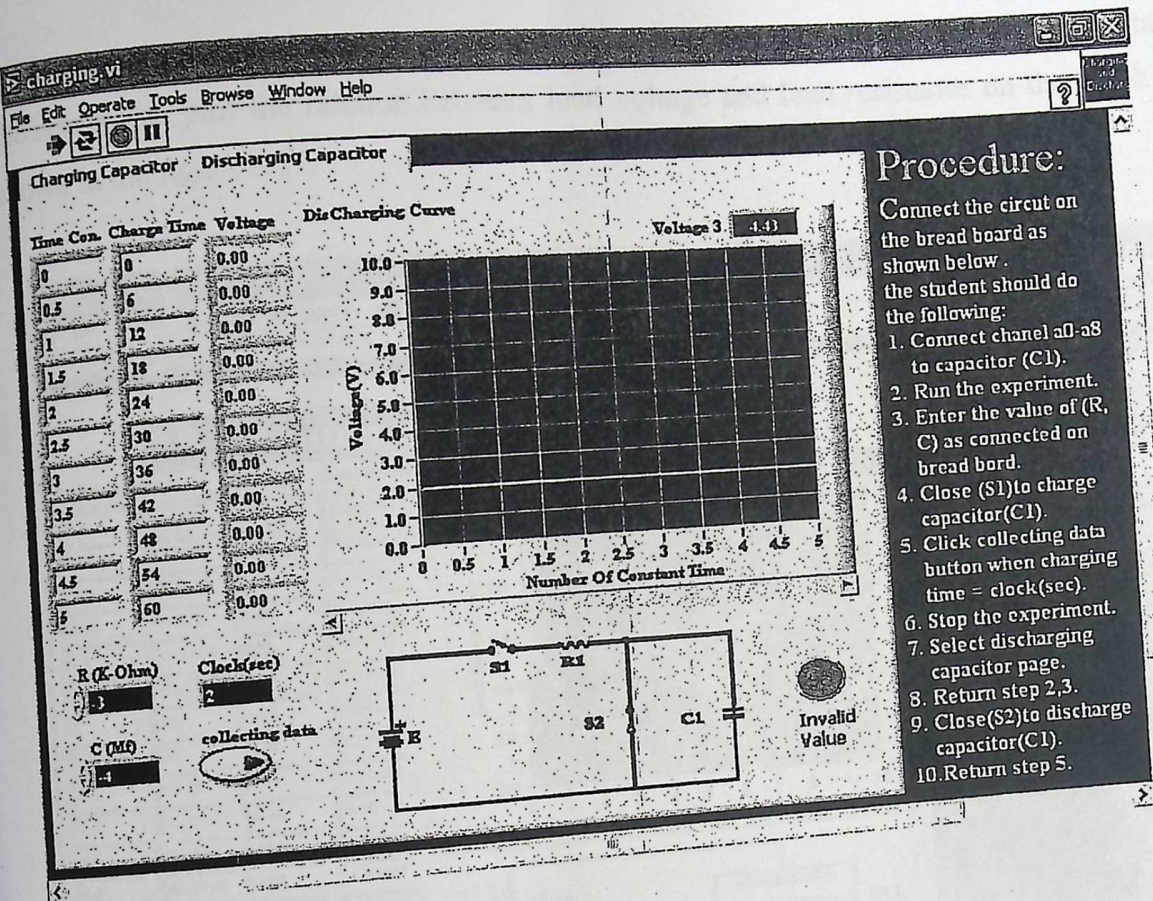


Figure 6.10 Invalid Charging and Discharging Test

6.2.6 Maximum Power Transfer Test

Testing the Maximum Power Transfer was done through excite the experiment and take the result also plot the relation between load voltage and load resistance on the graph as shown in the figure 6.11.

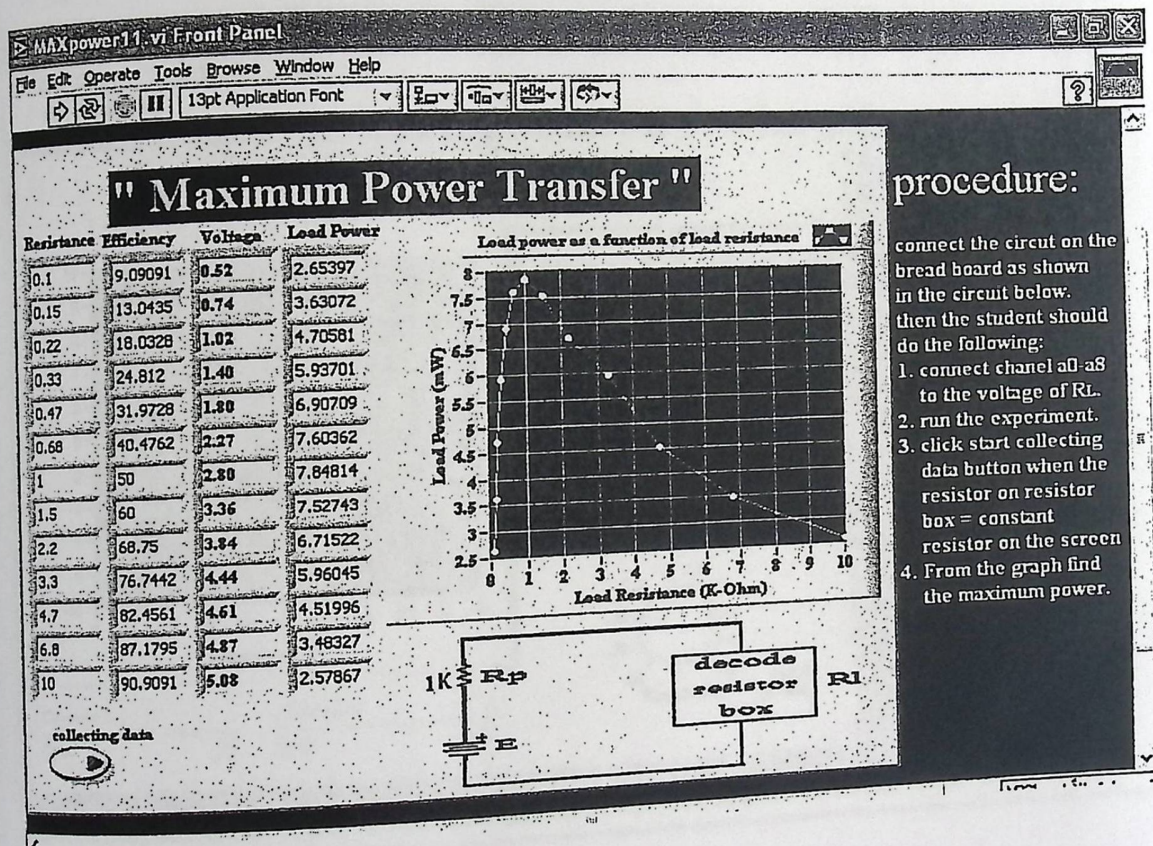


Figure 6.11 Valid Maximum Power Transfer Test

6.2.7 Oscilloscope Test

Testing the Oscilloscope was done through enter two signal from external power supply through connector block that controlled from LabVIEW as shown in the figure 6.12.

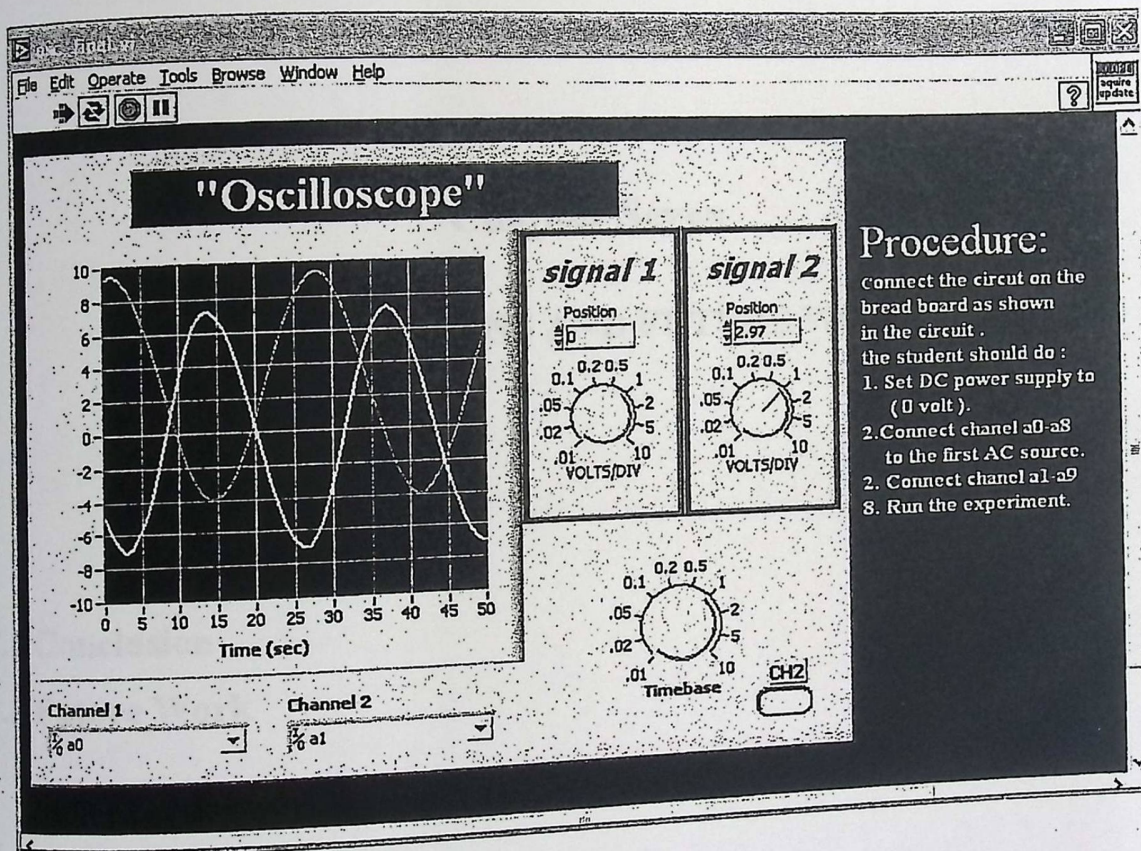


Figure 6.12 Valid Oscilloscope Test

6.2.8 Filter Test:

After execute this experiment the value of the r.m.s voltage was not accuracy so the graph of filter response not accuracy.

7.1 Conclusions

There are many conclusions that are reached after working with this project and in the next section a description of the results and conclusions will be presented.

- Working with this project increases the knowledge of virtual lab, and its features and advantages over lab.
- With the Virtual Laboratory you can do an experiment and take result and conclusions in less time.

Chapter Seven

CONCLUSIONS AND FUTURE WORK

7.1 Conclusion

7.2 Future Work

7.2.1 Future Work

The following point can be implemented as future work:

- This project is done for student in PFU electrical laboratory. This project may be developed in future on internet and the student can use it as distance learning. That means any student could be executed any experiment from your house on internet and take result.

7.1 Conclusions

There are many conclusions that are concluded after working with this project and in this section a description of the resulted conclusions will be pointed

- Working with this project increases the knowledge of virtual lab, and its features and advantages over lab
- With the Virtual Laboratory you can do an experiment and take result and conclusions in few time
- Working with this project increases the knowledge of labVIEW programming language and its advantage
- Virtual Electrical Circuit Lab has approximately 8 interactive experiments which have been used successfully in the classroom by teachers as well as by pupils individually
- The LabVIEW environment is useful since it can be programmed with a variety of display options and interactivity

7.2 Future Work

The following point can be implemented as future work

- This project is done for student in PPU electrical laboratory ,this project may be developed in future on internet and the student can use it as distance learning; that mean any student could be executed any experiment from yours home on internet and take result.

Reference

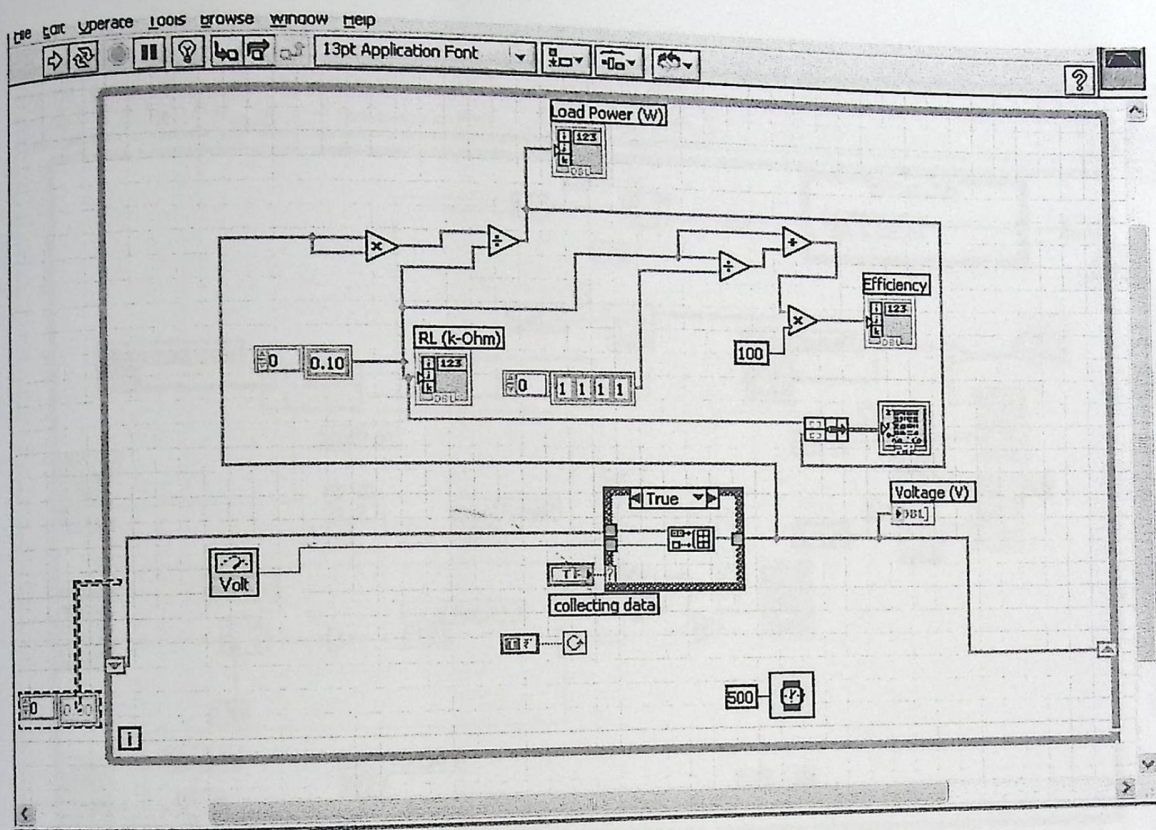
- [1]: <http://www.westga.edu/~distance/jmain11.html>.
- [2]: <http://ir.chem.cmu.edu/irproject/applets/virtuallab/>.
- [3]: <http://www.health.state.mn.us/divs/hrm/dl/compbased.html>.
- [4]: http://hannahsmac.magnet.fsu.edu/labview/basic_labviewbooks.html.
- [5]: <http://www.math.uah.edu/stat/>.
- [6]: <http://www.highvelocitysystems.com/computer-based-information-system.shtml>.
- [7]: <http://www.hhmi.org/biointeractive/vlabs/>.
- [8]: <http://www.microsoft.com/technet/traincert/virtuallab/default.mspx>.
- [9]: <http://adtest.co.za/NI%20Software%20Labview.htm>.
- [10]: <http://www.ni.com/dataacquisition/>.
- [11]: <http://www.pevatech.com/downloads/daq.pdf#search='DAQ%20card'>.
- [12]: <http://www.labviewexpert.com/>.

Max Power Transfer Block Diagram

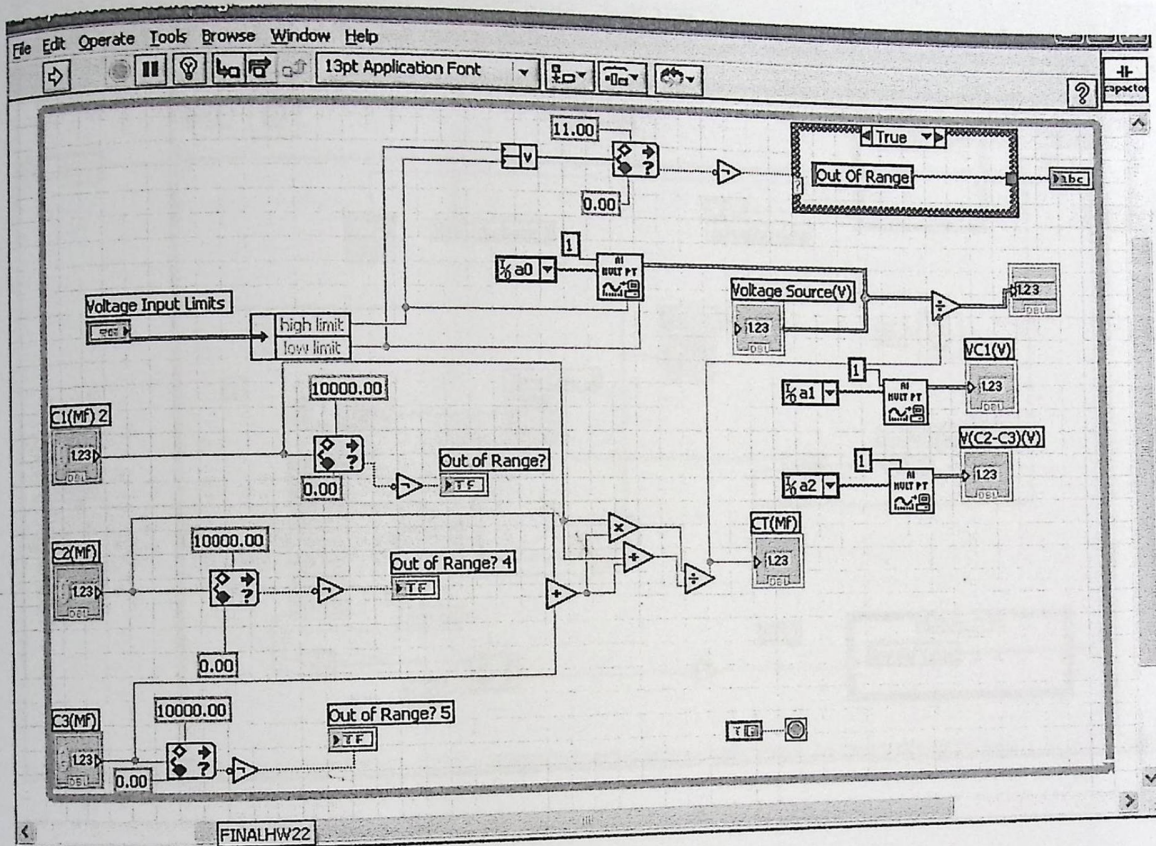
Appendix A

Block Diagram

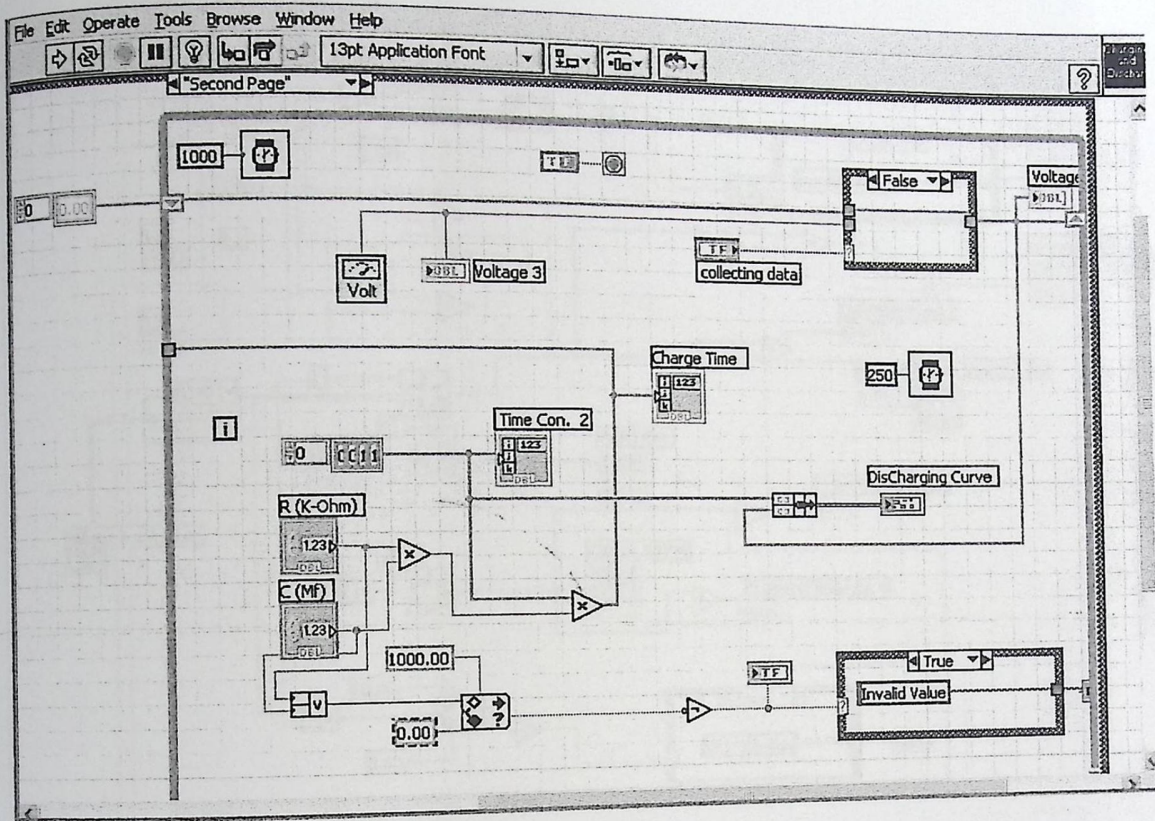
- Max Power Transfer Block Diagram



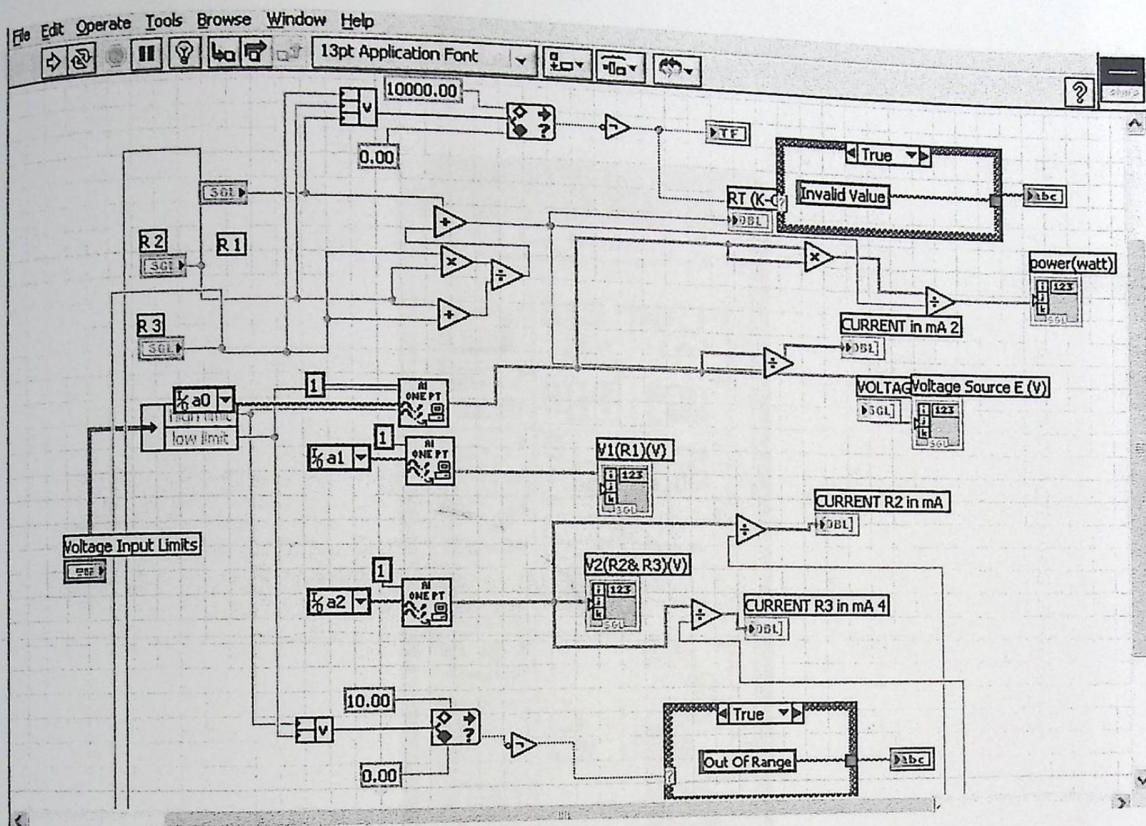
- Capacitor Measurement Block Diagram



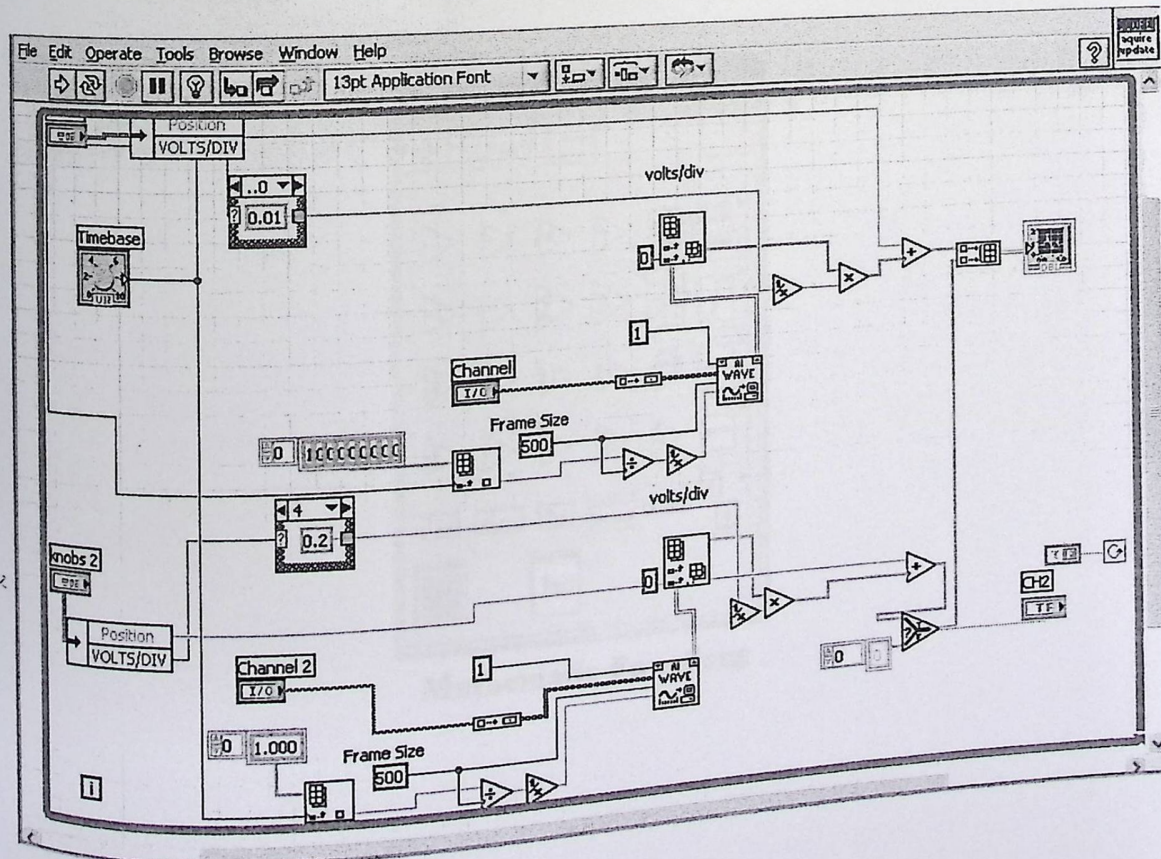
• Charging Capacitor Block Diagram



• Ohm's Law Block Diagram

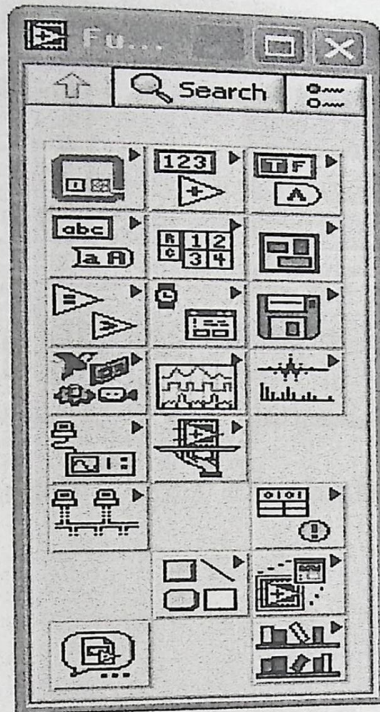


- **Oscilloscope Block Diagram**

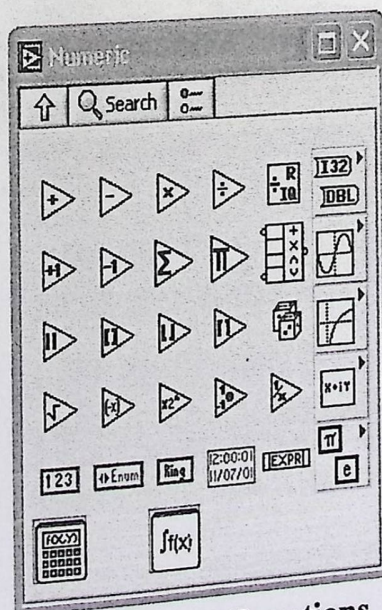


Function Palette:

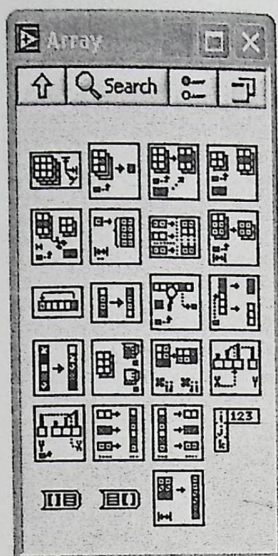
The most common functions used in LabVIEW



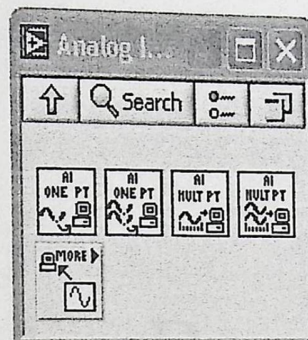
Functions



Mathematic Functions



Arrays Function



Analog Input Channel

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

Appendix B

Data Sheet

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

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 simplifies configuration and measurements

Families

- 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

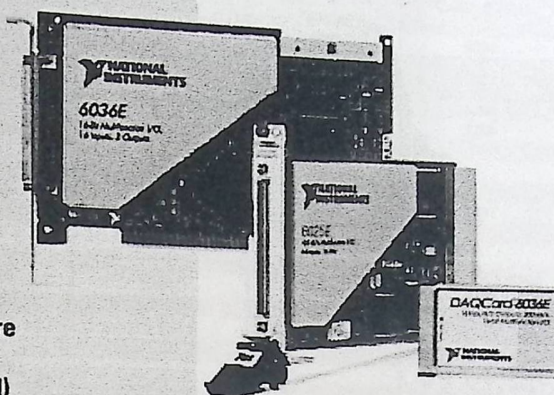
Other Compatible Software

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

Driver Software (included)

- NI-DAQ 7

Calibration Certificate Included



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 out put. 1kS/s maximum when using the single DMA channel for either analog input or counter/timer operations. 1 kS/s maximum for PCMCIA DAQCards in all cases.

Table 1. NI Low-Cost E Series Model Guide

Overview and Applications

NI 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 per °C.

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

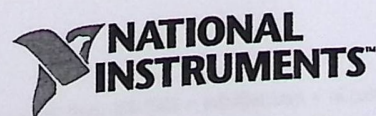
Onboard Self-Calibration – Precise voltage reference included for calibration and measurement accuracy. Self-calibration is completely software controlled, with no potentiometers to adjust.

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 can be used for software-controlled routing of interboard and intraboard digital and timing signals.



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

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

Note: Accuracies 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. *Smallest detectable voltage change in the input signal at the smallest input range.

Table 2. Low-Cost E Series Analog Input Absolute Accuracy Specifications

		Full-Featured E Series				Low-Cost E Series		Basic
Models		NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	PCI-6036E	PCI-6024E, NI 6025E	NI 6013, NI 6014
Nominal Range (V)								
Positive FS	Negative FS	Absolute Accuracy (mV)						
10	-10	1.43	1.405	8.127	8.127	2.417	8.127	3.835
10	0	1.201	1.176	5.685	5.685	—	—	—

Table 3. Low-Cost E Series Analog Output Absolute Accuracy Specifications

RTSI or PXI Trigger Bus – Used to share timing and control signals between multiple devices to synchronize operations.

RSE Mode – In addition to differential and nonreferenced single-ended modes, NI low-cost E Series devices offer 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.

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 beginning or advanced user. Helpful features include:

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

Cleaner 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 device support in NI-DAQ 7,
visit ni.com/dataacquisition

Visit ni.com/oem for quantity discount information.

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

Worldwide Support and Services

NI provides you with a wealth of resources to help you get your application up and running more quickly, including:

Technical Support – Purchase of NI hardware or software gives you access to application engineers all over the world as well as Web resources with more than 3,000 measurement examples and more than 9,000 KnowledgeBase entries. – ni.com/support

NI Factory Installation Services (FIS) – Software and hardware installed in PXI and PXI/SCXI systems, tested and ready to use – ni.com/advisor

Calibration – Includes NIST-traceable basic calibration certificates, services for ANSI/NCSL-Z540 and periodic calibration – ni.com/calibration

Extended Warranty – Meet project life-cycle requirements and maintain optimal performance in a cost-effective way – ni.com/services

Data Acquisition Training – Instructor-led courses – ni.com/training

Professional Services – Feasibility, consulting, and integration through our Alliance Partners – ni.com/alliance

For more information on NI services and support, please visit ni.com/services

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 10X more accurate than terminal blocks (please visit ni.com/signcon for more details). Refer to the table below for more information:

Sensor/Signals (>10 V)			
System Description	DAQ Device	Signal Conditioning	Page
High performance	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCXI	270
Low-cost, portable	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCC	251

Signals (<10 V) ¹				
System Description	DAQ Device	Terminal Block	Cable	Page
Shielded	PCI-60xxE	SCB-68	SH6868-EP	214
Shielded	PXI-60xxE	TB-2705	SH6868-EP	214
Shielded	DAQCard-60xxE	SCB-68	SHC6868-EP	214
Low-cost	PCI-6025E/PXI-6025E	Two TBX-68s	SH1006868	214
Low-cost	PCI-60xxE/PXI-60xxE	CB-68LP	R6868	214
Low-Cost	DAQCard-60xxE	CB-68LP	RC6868	214

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

Table 4. Recommended Accessories

Ordering Information

NI PCI-6036E	778465-01
NI DAQCard-6036E	778561-01
NI PCI-6034E	778075-01
NI PXI-6025E	777798-01
NI PCI-6025E	777744-01
NI DAQCard-6024E	778269-01
NI PCI-6024E	777743-01
NI PCI-6023E	777742-01

Includes NI-DAQ driver software and calibration certificate.

BUY ONLINE!

Visit ni.com/dataacquisition

Multifunction DAQ Overview

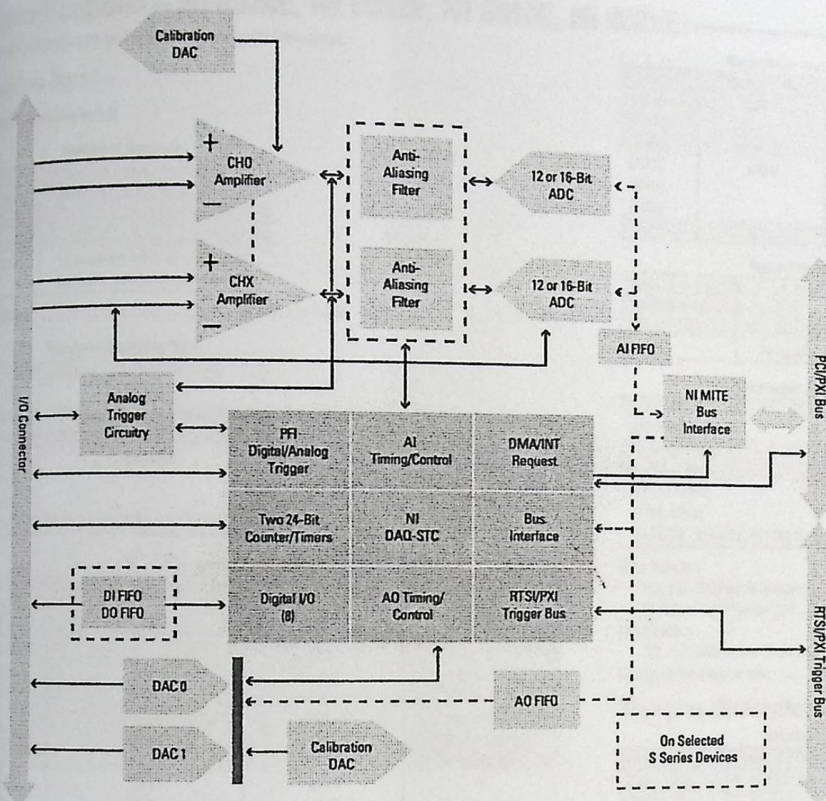


Figure 1. S Series Hardware Block Diagram

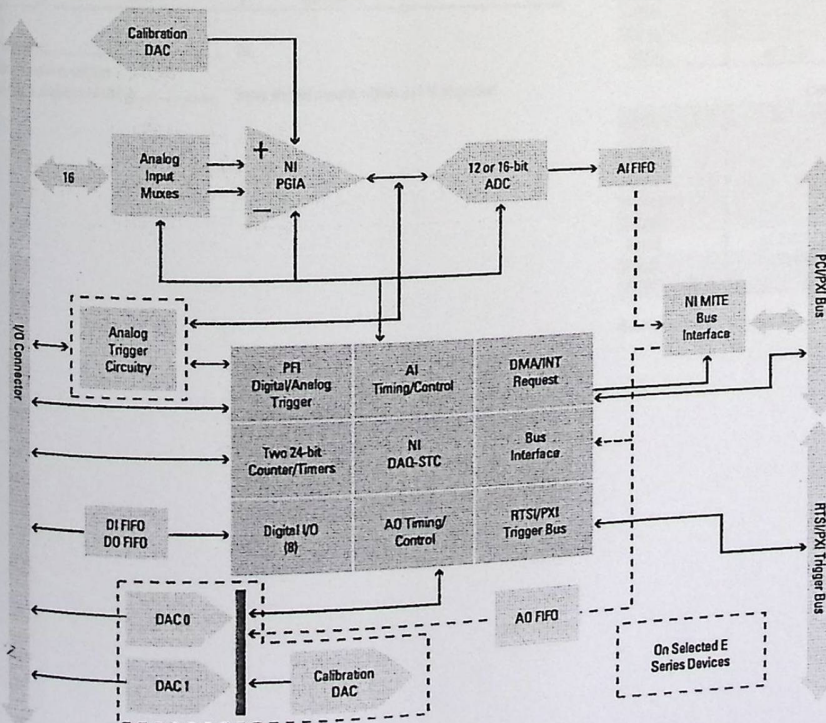


Figure 2. E Series Hardware Block Diagram

12-Bit E Series Multifunction DAQ Specifications

Specifications – NI 607xE, NI 6062E, NI 6040E, NI 602xE

These specifications are typical for 25 °C unless otherwise noted.

Analog Input

Input Characteristics

Number of Channels	
607xE	16 single-ended or 8 differential (software selectable per channel)
6062E	
6040E	
602xE	
6071E	64 single-ended or 32 differential (software selectable per channel)

Resolution 12 bits, 1 in 4,096

Maximum Sampling Rate	
607xE	1.25 MS/s
6062E	500 kS/s
6040E	500 kS/s single-channel scanning 250 kS/s multichannel scanning
6023E	200 kS/s
6024E	
6025E	
6020E	100 kS/s

Input Signal Ranges

Device	Range (Software Selectable)	Bipolar Input Range	Unipolar Input Range
607xE	20 V	±10 V	—
6062E	10 V	±5 V	0 to 10 V
6040E	5 V	±2.5 V	0 to 5 V
6020E	2 V	±1 V	0 to 2 V
	1 V	±500 mV	0 to 1 V
	500 mV	±250 mV	0 to 500 mV
	200 mV	±100 mV	0 to 200 mV
	100 mV	±50 mV	0 to 100 mV
6023E	20 V	±10 V	—
6024E	10 V	±5 V	—
6025E	1 V	±500 mV	—
	100 mV	±50 mV	—

Input coupling DC

Maximum working voltage (signal + common mode) Input should remain within ±11 V of ground

Overvoltage Protection		
Device	Powered On	Powered Off
607xE	±25 V	±15 V
6062E		
6040E		
6023E	±40 V	±25 V
6024E		
6025E		
6020E	±35 V	±25 V

Inputs Protected	
6070E	AI <0..15>, AI SENSE
6062E, 6040E	
602xE	
6071E	AI <0..63>, AI SENSE, AI SENSE2

FIFO Buffer Size	
DAQCard-6062E	8,192 samples
DAQPad-6020E	4,096 samples
DAQPad-6070E	2,048 samples
DAQCard-6024E	
PCI/PXI-6070E	512 samples
6071E, 6040E	
PCI-6023E, NI 6025E, PCI-6024E	

Data transfers

PCI, PXI, DAQPad for FireWire DMA, interrupts, programmed I/O
DAQCard, DAQPad for USB Interrupts, programmed I/O

DMA modes

PCI, PXI, DAQPad for FireWire Scatter-gather (single-transfer, demand transfer)

Configuration memory size 512 words

Transfer Characteristics

Relative Accuracy		
Device	Typical Dithered	Maximum Undithered
607xE	±0.5 LSB	±1.5 LSB
6062E		
6040E		
6023E		
6024E		
6025E		
6020E	±0.2 LSB	±1.5 LSB

DNL		
Device	Typical	Maximum
607xE	±0.5 LSB	±1.0 LSB
6040E		
6023E		
PCI-6024E		
6025E		
6020E	±0.2 LSB	±1.0 LSB
6062E	±0.75 LSB	-0.9, +1.5 LSB
DAQCard-6024E		

No missing codes 12 bits, guaranteed

12-Bit E Series Multifunction DAQ Specifications

Specifications — NI 607xE, NI 606xE, NI 6040E, NI 602xE (continued)

Amplifier Characteristics

Device	Input Impedance		
	Normal Powered On	Powered Off	Overload
6070E 6062E 6040E PCI-6071E PXI-6071E 6023E, 6024E 6025E 6020E	100 G Ω in parallel with 100 pF	820 Ω	820 Ω
	100 G Ω in parallel with 100 pF	4.7 k Ω	4.7 k Ω
	100 G Ω in parallel with 50 pF	3 k Ω	3 k Ω

Input bias current ± 200 pA
Input offset current ± 100 pA

CMRR, DC to 60 Hz

Device	Range	CMRR (dB)
607xE	20 V	95
	10 V	100
	100 mV to 5 V	106
6040E	10 to 20 V	85
	5 V	95
6062E	100 mV to 2 V	100
6023E	10 to 20 V	85
6024E	100 mV to 1 V	90
6025E	100 mV to 20 V	90

Dynamic Characteristics

Bandwidth

Device	Small Signal (-3 dB)	Large Signal (1% THD)
607xE	1.6 MHz	1 MHz
6062E	1.3 MHz	250 kHz
6040E	600 kHz	350 kHz
6023E	500 kHz	225 kHz
PCI-6024E 6025E		
DAQCard-6024E	500 kHz	265 kHz
DAQPad-6020E	150 kHz	200 kHz

Settling Time to Full-Scale Step

Device	Range	Accuracy		
		$\pm 0.012\%$ (± 0.5 LSB)	$\pm 0.024\%$ (± 1 LSB)	$\pm 0.050\%$ (± 1 LSB)
6070E	20 V	2 μ s typical 3 μ s maximum	1.5 μ s typical 2 μ s maximum	1.5 μ s typical 2 μ s maximum
	10 V	2 μ s typical 3 μ s maximum	1.5 μ s typical 2 μ s maximum	1.3 μ s typical 1.5 μ s maximum
	200 mV to 5 V	2 μ s typical 3 μ s maximum	1.5 μ s typical 2 μ s maximum	0.9 μ s typical 1 μ s maximum
	100 mV	2 μ s typical 3 μ s maximum	1.5 μ s typical 2 μ s maximum	1 μ s typical 1.5 μ s maximum
	20 V	3 μ s typical 5 μ s max	1.9 μ s typical 2.5 μ s maximum	1.5 μ s typical 2 μ s maximum
	10 V	3 μ s typical 5 μ s maximum	1.9 μ s typical 2.5 μ s maximum	1.2 μ s typical 1.5 μ s maximum
6071E	20 V	3 μ s typical 5 μ s max	1.9 μ s typical 2.5 μ s maximum	1.5 μ s typical 2 μ s maximum
	10 V	3 μ s typical 5 μ s maximum	1.9 μ s typical 2.5 μ s maximum	1.2 μ s typical 1.5 μ s maximum
	200 mV to 5 V	3 μ s typical 5 μ s maximum	1.9 μ s typical 2.5 μ s maximum	1.2 μ s typical 1.5 μ s maximum
	100 mV	3 μ s typical 5 μ s maximum	1.9 μ s typical 2.5 μ s maximum	1.2 μ s typical 1.5 μ s maximum
	All	4 μ s typical 8 μ s maximum	4 μ s typical 5 μ s maximum	4 μ s typical 5 μ s maximum
	All	5 μ s typical	5 μ s maximum	5 μ s maximum
6062E	All	10 μ s maximum	10 μ s maximum	10 μ s maximum

System Noise (LSB_{rms}, Not Including Quantization)

Device	Range	Dither Off	Dither On
6070E	1 to 20 V	0.25	0.5
	500 mV	0.4	0.6
	200 mV	0.5	0.7
	100 mV	0.8	0.9
6062E	1 to 20 V	0.25	0.6
	500 mV	0.4	0.75
	200 mV	0.5	0.8
	100 mV	0.8	1.0
6040E	1 to 20 V	0.2	0.5
	500 mV	0.25	0.5
	200 mV	0.5	0.7
	100 mV	0.9	1.0
6023E	1 to 20 V	0.1	0.6
	100 mV	0.7	0.8
PCI-6024E, 6025E	10 to 20 V	0.1	0.65
	1 V	0.45	0.65
	100 mV	0.70	0.90
	100 mV	0.07	0.5
6020E	1 to 20 V	0.12	0.5
	500 mV	0.25	0.6
	200 mV	0.5	0.7
	100 mV	0.5	0.7

Crosstalk, DC to 100 KHz

Device	Adjacent Channels	All Other Channels
607xE, 6062E, 6040E	-75 dB	-90 dB
602xE	-60 dB	-80 dB

12-Bit E Series Multifunction DAQ Specifications

Specifications – NI 607xE, NI 606xE, NI 6040E, NI 602xE (continued)

Analog Output

Output Characteristics

Number of Channels	
607xE	2 voltage outputs
606xE	
6040E	
602xE	
6020E	
6022E	None

Resolution 12 bits, 1 in 4,096
Maximum update rate

Waveform Generation

Device	FIFO Mode		Non-FIFO Mode	
	Internally Timed	Externally Timed	1 Channel	2 Channels
607xE	1 MS/s	950 kS/s	800 kS/s, system dependent	400 kS/s, system dependent
6040E				
6062E	850 kS/s	850 kS/s	800 kS/s, system dependent	400 kS/s, system dependent
6023E	N/A	N/A	10 kS/s with DMA	10 kS/s with DMA
PCI-6024E			1 kS/s with interrupts	1 kS/s with interrupts
6025E			system dependent	system dependent
DAQCard-6024E	N/A	N/A	1 kS/s with interrupts	1 kS/s with interrupts
DAQPad-6020E	N/A	N/A	20 S/s, system dependent	20 S/s, system dependent

FIFO Buffer Size

607xE, 6062E	2,048 samples
6040E	512 samples
602xE	None

Data transfers

PCI, PXI, DAQPad for IEEE 1394 DMA, interrupts, programmed I/O
DAQCard, DAQPad for USB Interrupts, programmed I/O
DMA modes
PCI, PXI, DAQPad Scatter-gather (single transfer, demand transfer)

Transfer Characteristics

Relative accuracy
After calibration
6062E, DAQCard-6024E ± 0.5 LSB typical, ± 1.0 LSB maximum
All others ± 0.3 LSB typical, ± 0.5 LSB maximum
Before calibration ± 4 LSB maximum
DNL
After calibration
6062E, DAQCard-6024E ± 0.5 LSB typical, ± 1.0 LSB maximum
All others ± 0.3 LSB typical, ± 1.0 LSB maximum
Before calibration ± 3 LSB maximum
Monotonicity 12 bits, guaranteed after calibration
Gain error (relative to external reference)
6062E, 6020E $\pm 0.5\%$ of output maximum, not adjustable
607xE, 6040E 0 to 0.67% of output maximum, not adjustable

Voltage Output

Output coupling DC
Output impedance 0.1 Ω maximum

Ranges	
607xE, 6040E, 6020E	± 10 V, 0 to 10 V, $\pm$ EXT REF, 0 to EXT REF, software selectable
6062E	± 10 V, $\pm$ EXT REF, software selectable
6024E, 6025E	± 10 V

Current drive ± 5 mA maximum
Protection Short-circuit to ground
Power-on state 0 V (± 200 mV)

External Reference Input

Range 11 V
Overvoltage protection
607xE, 6062E, 6040E ± 25 V powered on, ± 15 V powered off
6020E ± 35 V powered on, ± 25 V powered off
Input impedance 10 k Ω
Bandwidth (-3 dB)
607xE, 6040E 1 MHz
6062E 50 kHz
6020E 300 kHz

Dynamic Characteristics

Device	Settling Time for Full-Scale Step	Slew Rate
607xE	3 μ s to ± 0.5 LSB accuracy	20 V/ μ s
6062E		
6040E		
602xE	10 μ s to ± 0.5 LSB accuracy	10 V/ μ s

Device	Reglitching Disabled	Reglitching Enabled
607xE, 604xE	± 20 mV	± 4 mV
PCI-6024E	± 42 mV	N/A
6025E		
DAQCard-6024E	± 13 mV	N/A
6020E	± 100 mV	N/A
6062E	± 80 mV	± 30 mV

Glitch Duration (At Mid-Scale Transition)

607xE	1.5 μ s
6040E	
6024E	2 μ s
6025E	
6020E	3 μ s
6062E	

Noise 200 μ V_{rms}, DC to 1 MHz
Glitch energy magnitude (at mid-scale transition)

Stability

Gain temperature coefficient (except 6024E, 6025E)
External reference ± 25 ppm/ $^{\circ}$ C

12-Bit E Series Multifunction DAQ Specifications

Specifications – NI 607xE, NI 606xE, NI 6040E, NI 602xE (continued)

Analog Output

Output Characteristics

Number of Channels	
607xE	2 voltage outputs
606xE	
6040E	
6020E	
602xE	
6022E	None
6024E	

Resolution 12 bits, 1 in 4,096

Maximum update rate

Waveform Generation

Device	FIFO Mode		Non-FIFO Mode	
	Internally Timed	Externally Timed	1 Channel	2 Channels
607xE	1 MS/s	950 kS/s	800 kS/s	400 kS/s
6040E			system dependent	system dependent
6062E	850 kS/s	850 kS/s	800 kS/s	400 kS/s
6020E	N/A	N/A	system dependent	system dependent
PCI-6024E			10 kS/s with DMA	10 kS/s with DMA
6025E			1 kS/s with interrupts	1 kS/s with interrupts
DAQCard-6024E	N/A	N/A	system dependent	system dependent
			1 kS/s with interrupts	1 kS/s with interrupts
DAQPad-6020E	N/A	N/A	system dependent	system dependent
			20 S/s	20 S/s
			system dependent	system dependent

FIFO Buffer Size

607xE, 6062E	2,048 samples
6040E	512 samples
602xE	None

Data transfers

PCI, PXI, DAQPad for IEEE 1394 DMA, interrupts, programmed I/O

DAQCard, DAQPad for USB Interrupts, programmed I/O

DMA modes

PCI, PXI, DAQPad Scatter-gather (single transfer, demand transfer)

Transfer Characteristics

Relative accuracy

After calibration

6062E, DAQCard-6024E ± 0.5 LSB typical, ± 1.0 LSB maximum

All others ± 0.3 LSB typical, ± 0.5 LSB maximum

Before calibration

..... ± 4 LSB maximum

DNL

After calibration

6062E, DAQCard-6024E ± 0.5 LSB typical, ± 1.0 LSB maximum

All others ± 0.3 LSB typical, ± 1.0 LSB maximum

Before calibration

..... ± 3 LSB maximum

Monotonicity

..... 12 bits, guaranteed after calibration

Gain error (relative to external reference)

6062E, 6020E $\pm 0.5\%$ of output maximum, not adjustable

607xE, 6040E 0 to 0.67% of output maximum, not adjustable

Voltage Output

Output coupling

..... DC

Output impedance

..... 0.1 Ω maximum

Ranges

607xE, 6040E, 6020E	± 10 V, 0 to 10 V, $\pm$ EXT REF, 0 to EXT REF, software selectable
6062E	± 10 V, $\pm$ EXT REF, software selectable
6024E, 6025E	± 10 V

Current drive

..... ± 5 mA maximum

Protection

..... Short-circuit to ground

Power-on state

..... 0 V (± 200 mV)

External Reference Input

Range

..... 11 V

Overvoltage protection

607xE, 6062E, 6040E ± 25 V powered on, ± 15 V powered off

6020E ± 35 V powered on, ± 25 V powered off

Input impedance

..... 10 k Ω

Bandwidth (-3 dB)

607xE, 6040E 1 MHz

6062E 50 kHz

6020E 300 kHz

Dynamic Characteristics

Device	Settling Time for Full-Scale Step	Slew Rate
607xE	3 μ s to ± 0.5 LSB accuracy	20 V/ μ s
6062E		
6040E		
602xE	10 μ s to ± 0.5 LSB accuracy	10 V/ μ s

Device	Reglitching Disabled	Reglitching Enabled
607xE, 604xE	± 20 mV	± 4 mV
PCI-6024E	± 42 mV	N/A
6025E		
DAQCard-6024E	± 13 mV	N/A
6020E	± 100 mV	N/A
6062E	± 80 mV	± 30 mV

Glitch Duration (At Mid-Scale Transition)

607xE	1.5 μ s
6040E	
6024E	2 μ s
6025E	
6020E	3 μ s
6062E	

Noise 200 μ V_{rms}, DC to 1 MHz

Glitch energy magnitude (at mid-scale transition)

Stability

Gain temperature coefficient (except 6024E, 6025E)

External reference ± 25 ppm/ $^{\circ}$ C

12-Bit E Series Multifunction DAQ Specifications

Specifications – NI 607xE, NI 606xE, NI 6040E, NI 602xE (continued)
Digital I/O

Number of Channels	
602xE	32 input/output
All others	8 input/output

Compatibility	5 V TTL
Power-on state	Input (high-impedance)
Digital logic levels	
P0<0..7>	

Level	Minimum (V)	Maximum (V)
Input low voltage	0	0.8
Input high voltage	2.0	5.0
Output low voltage ($I_{OL} = 24$ mA)	—	0.4
Output high voltage ($I_{OH} = -13$ mA)	4.35	—

P1<0..7>, P2<0..7>, P3<0..7>

Level	Minimum (V)	Maximum (V)
Input low voltage	0	0.8
Input high voltage	2.2	5.0
Output low voltage ($I_{OL} = 2.5$ mA)	—	0.4
Output high voltage ($I_{OH} = -2.5$ mA)	3.7	—

Data Transfers	
602xE	Interrupts, programmed I/O
All others	Programmed I/O

Transfer rate (1 word = 8 bits)
Maximum with NI-DAQ, system dependent

Transfer Rate	
DAQPad-6070E	5 kwords/s
All others	50 kwords/s

Constant sustainable rate..... 1 to 10 kwords/s, system dependent

Timing I/O

Number of channels

Up/down counter/timers	2
Frequency scaler	1

Resolution

Up/down counter/timers	24 bits
Frequency scaler	4 bits

Compatibility..... 5 V/TTL

Base clocks available

Up/down counter/timers	20 MHz and 100 kHz
Frequency scaler	10 MHz and 100 kHz

Base clock accuracy..... $\pm 0.01\%$

Maximum source frequency

Up/down counter/timers	20 MHz
------------------------	--------

Minimum source pulse duration..... 10 ns, edge-detect mode

Minimum gate pulse duration..... 10 ns, edge-detect mode

Data transfers..... DMA*, interrupts, programmed I/O

*Except DAQCard and USB DAQPad

Triggers

Analog Triggers

Number of Triggers	
607xE	1
6062E	
6040E	
602xE	None

Purpose

Analog input	Start and stop trigger, gate, clock
Analog output	Start trigger, gate, clock
General-purpose counter/timers	Source, gate

Source..... All analog input channels, PFI 0/AI START TRIG

Level

Internal source, AI<0..15/63>	$\pm$ Full-scale
External source, PFI 0/AI START TRIG	± 10 V

Slope..... Positive or negative; software selectable

Resolution..... 8 bits, 1 in 256

Bandwidth (-3 dB)

Device	Internal Source	External Source
607xE	2 MHz	7 MHz
6062E	500 kHz	2.5 MHz
6040E	650 kHz	3 MHz

Hysteresis..... Programmable

Digital Triggers (All Devices)

Purpose

Analog input	Start and stop trigger, gate, clock
Analog output	Start trigger, gate, clock
General-purpose counter/timers	Source, gate

Source..... PFI <0..9>, RTSI <0..6>

Compatibility..... 5 V/TTL

Response..... Rising or falling edge

Pulse width..... 10 ns minimum

External Input For Digital Or Analog Trigger (PFI0/TRIG1)

Impedance

6062E	12 k Ω
607xE, 6040E	10 k Ω

Coupling..... DC

Protection

Digital trigger..... -0.5 to $V_{CC} + 0.5$ V

Calibration

Recommended warm-up time..... 15 minutes; 30 minutes for DAQCard and DAQPad

Calibration interval..... 1 year

Onboard calibration reference

DC level..... 5.000 V (± 3.5 mV) over full operating temperature, actual value stored in EEPROM

Temperature coefficient..... ± 5 ppm/ $^{\circ}$ C maximum

Long-term stability..... ± 15 ppm/ $\sqrt{1000}$ h

12-Bit E Series Multifunction DAQ Specifications

Specifications – NI 607xE, NI 606xE, NI 6040E, NI 602xE (continued)

RTSI Bus (PCI and FireWire only)

Trigger lines ¹	
PCI	7
FireWire (DAQPad)	4

PXI Trigger Bus (PXI only)

Trigger lines	6
Star trigger	1

Bus Interface

PCI, PXI, FireWire (DAQPad)	Master, slave
USB (DAQPad)	Slave
PCMCIA (DAQCard)	Slave

Power Requirements²

Device	+5 VDC (±5%) ^a	Power Available at I/O Connector
PCI-607xE, PXI-607xE	1.1 A	+4.65 to +5.25 VDC, 1 A
6040E	1.0 A	+4.65 to +5.25 VDC, 1 A
DAQCard-6062E	340 mA typical 750 mA maximum	+4.65 to +5.25 VDC, 250 mA
DAQCard-6024E	270 mA typical 750 mA maximum	+4.65 to +5.25 VDC, 250 mA
6023E, 6025E, PCI-6024E	0.7 A	+4.65 to +5.25 VDC, 1 A

Device	Power ^a	Power Available at I/O Connector
DAQPad-6020E	15 W, +9 to +30 VDC	+4.65 to +5.25 VDC, 1 A
DAQPad-6070E	17 W, +9 to +25 VDC	+4.65 to +5.25 VDC, 1 A

^aExcludes power consumed through I/O connector

Discharge time with BP-1 battery pack

FireWire (DAQPad)	2.5 hours, typical
USB (DAQPad)	3 hours, typical

Physical²

Dimensions (Not Including Connectors)

PCI	17.5 by 10.7 cm (6.9 by 4.2 in.)
PXI	18.0 by 10.0 cm (6.3 by 3.9 in.)

DAQPad (30 cm enclosure)	25.4 by 30.7 by 4.3 cm (10 by 12.1 by 1.7 in.)
DAQPad (15 cm enclosure)	14.6 by 21.3 by 3.8 cm (5.8 by 8.4 by 1.5 in.)
DAQCard	Type II PC Card

I/O Connector

6070E	68-pin male 0.050 D-type
6040E	
6020E	
6023E	
PCI-6024E	68-pin female VHDCI
DAQCard-6062E, DAQCard-6024E	
6071E	100-pin female 0.050 D-type
6025E	

Environment

Operating temperature	0 to 55 °C 0 to 40 °C for DAQCard-6062E and DAQCard-6024E with a maximum internal temperature of 70 °C as measured by onboard temperature sensor; case temperature should not exceed 55 °C for any DAQCard
Storage temperature	-20 to 70 °C
Relative humidity	10 to 90%, noncondensing

Certifications and Compliances

CE Mark Compliance

¹Refer to RTSI specifications for available RTSI trigger lines. RTSI not available on DAQCards.

²See page 134 for RT Series devices, power requirements and physical parameters.

NI Cable Design Advantages

Figure 2. NI off-the-shelf cable and adapter such as the SH-2000 and the BNC-2000.

Platform	Shielding	Connect to ...	Cable	Adapter	Accessory
PC/PXI/USB/FireWire					
	Shielded	SCC portable signal conditioning per channel	SH68-68-EP	—	SC-2345 and modules, page 251
	Shielded	SCXI high-performance signal conditioning	SCXI-1349	—	SCXI Chassis and Modules, page 270
	Shielded	Screw terminals ¹	SH68-68-EP or SH68-68R1-EP	—	SCB-68
	Shielded	BNC terminal block	SH68-68-EP	—	BNC-2110, BNC-2120, BNC-2090
	Shielded	50-pin connector	SH6850	—	CB50, custom or 3rd party
	Shielded	Configurable connectivity box	SH68-68-EP	—	CA-1000, page 351
	Unshielded	Screw terminals ¹	R6868	—	TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory
	Unshielded	50-pin connector	R6850	—	CB50, custom or 3rd party
PXI only					
	Shielded	Front-mounted screw terminals	N/A	—	TB-2705
PCMCIA					
	Shielded	Screw terminals ¹	SHC68-68-EP or SHC68U-68-EP ²	—	SCB-68, CA-1000
	Shielded	50-pin connector	SHC68-68-EP or SHC68U-68-EP ²	68M-50F MID	CB50, custom or 3rd party
	Unshielded	Screw terminals ¹	RC68-68	—	TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory
	Unshielded	50-pin connector	RC68-68	68M-50F MID	CB50, custom or 3rd party

Unshielded	50-pin connector	
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¹Unshielded cables can connect to shielded accessories and vice-versa. ²In adjacent PCMCIA slots, both cables types are required because the same cable would cause mechanical hindrance.

¹Unshielded cables can connect to shielded accessories and vice-versa. ²In adjacent PDMCIA slots, both cables types are required because the cables are not interchangeable.

Multifunction DAQ Cable and Accessory Selection Guides

AI 0-	34	68	AI 0+
AI 1+	33	67	AI 0 GND
AI 1 GND	32	66	AI 1-
AI 2-	31	65	AI 2+
AI 3+	30	64	AI 2 GND
AI 3 GND	29	63	AI 3-
NC	28	62	NC
NC	27	61	NC
NC	26	60	NC
NC	25	59	NC
NC	24	58	NC
NC	23	57	NC
AO 0	22	56	NC
AO 0	21	55	AO GND
EXT REF	20	54	AO GND
P0.4	19	53	D GND
D GND	18	52	P0.0
P0.1	17	51	P0.5
P0.6	16	50	D GND
D GND	15	49	P0.2
+5V	14	48	P0.7
D GND	13	47	P0.3
D GND	12	46	AI HOLD
PR 0/AI START	11	45	EXT STROBE
PR 1/REF TRIG	10	44	D GND
D GND	9	43	PR 2/AI CONV
+5V	8	42	PR 3/CTR 1 SRC
D GND	7	41	PR 4/CTR 1 GATE
PR 5/AO SAMP	6	40	CTR 1 OUT
PR 6/AO START	5	39	D GND
D GND	4	38	PR 7/AI SAMP
PR 8/CTR 0 GATE	3	37	PR 8/CTR 0 SRC
CTR 0 OUT	2	36	D GND
F OUT	1	35	D GND

Figure 3. S Series Devices Connector

*No connects for boards that do not support AO or use an external reference with the SH1006868 cable.

AI 8	34	68	AI 0
AI 1	33	67	AI GND
AI GND	32	66	AI 9
AI 10	31	65	AI 2
AI 3	30	64	AI GND
AI GND	29	63	AI 11
AI 4	28	62	AI SENSE
AI GND	27	61	AI 12
ACH13	26	60	AI 5
ACH8	25	59	AI GND
AI GND	24	58	AI 14
ACH15	23	57	AI 7
AO 0 ¹	22	56	AI GND
AO 1 ¹	21	55	AO GND
EXT REF ¹	20	54	AO GND
P0.4	19	53	D GND
D GND	18	52	P0.0
P0.1	17	51	P0.5
P0.6	16	50	D GND
D GND	15	49	P0.2
+5V	14	48	P0.7
D GND	13	47	P0.3
D GND	12	46	AI HOLD
PR 0/AI START	11	45	EXT STROBE
PR 1/REF TRIG	10	44	D GND
D GND	9	43	PR 2/AI CONV
+5V	8	42	PR 3/AI CTR 1 SRC
D GND	7	41	PR 4/AI CTR 1 GATE
PR 5/AO SAMP	6	40	CTR 1 OUT
PR 6/AO START	5	39	D GND
D GND	4	38	PR 7/AI SAMP
PR 8/CTR 0 GATE	3	37	PR 8/CTR 0 SRC
CTR 0 OUT	2	36	D GND
F OUT	1	35	D GND

Figure 4. I/O Connector for 16-Channel E Series and Basic Multifunction DAQ Devices, except NI 6025E

AI GND	1	51	AI 16
AI GND	2	52	AI 24
AI 0	3	53	AI 17
AI 8	4	54	AI 25
AI 1	5	55	AI 18
AI 9	6	56	AI 26
AI 2	7	57	AI 19
AI 10	8	58	AI 27
AI 3	9	59	AI 20
AI 11	10	60	AI 28
AI 4	11	61	AI 21
AI 12	12	62	AI 29
AI 5	13	63	AI 22
AI 13	14	64	AI 30
AI 6	15	65	AI 23
AI 14	16	66	AI 31
AI 17	17	67	AI 32
AI 15	18	68	AI 40
AI SENSE	19	69	AI 33
AO 0	20	70	AI 41
AO 1	21	71	AI 34
EXT REF	22	72	AI 42
AO GND	23	73	AI 35
D GND	24	74	AI 43
P0.0	25	75	AI SENSE 2
P0.4	26	76	AI GND
P0.1	27	77	AI 36
P0.5	28	78	AI 44
P0.2	29	79	AI 37
P0.6	30	80	AI 45
P0.3	31	81	AI 38
P0.7	32	82	AI 46
D GND	33	83	AI 39
+5V	34	84	AI 47
+5V	35	85	AI 48
AI HOLD	36	86	AI 56
EXT STROBE	37	87	AI 49
PR 0/AI START	38	88	AI 57
PR 1/REF TRIG	39	89	AI 50
PR 2/AI CONV	40	90	AI 58
PR 3/CTR 1 SRC	41	91	AI 51
PR 4/CTR 1 GATE	42	92	AI 59
CTR 1 OUT	43	93	AI 52
PR 5/AO SAMP	44	94	AI 60
PR 6/AO START	45	95	AI 61
PR 7/AI SAMP	46	96	AI 62
PR 8/CTR 0 SRC	47	97	AI 63
PR 9/CTR 0 GATE	48	98	AI 64
CTR 0 OUT	49	99	AI 65
F OUT	50	100	AI 63

Figure 5. I/O Connector for 64-Channel E Series Devices

AI GND	1	51	P1.7
AI GND	2	52	GND
AI 0	3	53	P3.8
AI 8	4	54	GND
AI 1	5	55	P3.5
AI 9	6	56	GND
AI 2	7	57	P2.4
AI 10	8	58	GND
AI 3	9	59	P2.3
AI 11	10	60	GND
AI 4	11	61	P2.2
AI 12	12	62	GND
AI 5	13	63	P1.1
AI 13	14	64	GND
AI 6	15	65	P1.0
AI 14	16	66	GND
AI 17	17	67	P2.7
AI 15	18	68	GND
AI SENSE	19	69	P2.6
AO 0	20	70	GND
AO 1	21	71	P2.5
EXT REF	22	72	GND
AO GND	23	73	P2.4
D GND	24	74	GND
P1.0	25	75	P2.3
P1.4	26	76	GND
P1.1	27	77	P2.2
P1.5	28	78	GND
P1.2	29	79	P2.1
P1.6	30	80	GND
P1.3	31	81	P2.0
P1.7	32	82	GND
D GND	33	83	P1.7
+5V	34	84	GND
+5V	35	85	P1.6
AI HOLD	36	86	GND
EXT STROBE	37	87	P1.5
PR 0/AI START	38	88	GND
PR 1/REF TRIG	39	89	P1.4
PR 2/AI CONV	40	90	GND
PR 3/CTR 1 SRC	41	91	P1.3
PR 4/CTR 1 GATE	42	92	GND
CTR 1 OUT	43	93	P1.2
PR 5/AO SAMP	44	94	GND
PR 6/AO START	45	95	P1.1
PR 7/AI SAMP	46	96	GND
PR 8/CTR 0 SRC	47	97	P1.0
PR 9/CTR 0 GATE	48	98	GND
CTR 0 OUT	49	99	+5V
F OUT	50	100	GND

Figure 6. I/O Connector for the NI 6025E Device

E Series Devices (NI 6031E, NI 6033E, NI 6071E, NI 6025E)

Platform	Shielding	Connect to	Cable	Cable Leg	Adaptor	Accessory
PCL PXI						SCB-100
	Shielded	Screw terminals	SH100100	—	—	SCB-68
	Shielded	Screw terminals	SH1006868	MIO:	—	SCB-68
	Shielded		SH1006868	Extended:	—	TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory
	Shielded	Screw terminals ¹	SH1006868	MIO:	—	TBX-68, CB-68LP, CB-68LPR
	Shielded			Extended:	—	BNC-2110, BNC-2120, BNC-2090
	Shielded	Screw terminals ¹	SH1006868	MIO:	—	BNC-2115
	Shielded	BNC terminal block	SH1006868	Extended:	—	Custom or 3rd party
	Shielded		SH1006868	MIO:	68M-50F MIO	Custom or 3rd party
	Shielded	50-pin connectors	SH1006868	Extended:	68M-50F Extended	Custom or 3rd party
	Shielded		SH1006868	MIO:	—	Custom or 3rd party
	Unshielded	50-pin connector	R1005050	Extended:	—	Custom or 3rd party
	Unshielded		R1005050	Extended:	—	

¹Shielded cable with unshielded accessories

Table 2. Cable Connection Specifications for 64-Channel E Series Devices and the NI 6025E

