MEASURING R, L, C USING VIRTUAL INSTRUMENTATION

A THESIS

Submitted by

BANALA NARESH KUMAR
(EE11M081)

For the award of the degree

Of

MASTER OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY MADRAS

MAY 2013

THESIS CERTIFICATE

This is to certify that the thesis titled "**MEASURING R, L, C USING VIRTUAL INSTRUMENTATION"**, submitted by **BANALA NARESH KUMAR (EE11M081)**, to the Indian Institute of Technology Madras, Chennai for the award of the degree of **MASTER OF TECHNOLOGY** (Control and Instrumentation) in Electrical Engineering, is a bona fide record of the project work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

Dr. Jagadeesh Kumar V
(Project Guide)
Professor
Dept. of Electrical Engineering
IIT-Madras, 600 036

Place: Chennai

Date: 30-05-2013

ACKNOWLEDGEMENT

I would like to express my sincere thanks to my project guide Dr. Jagadeesh Kumar V Department of Electrical Engineering, IIT Madras, for his guidance, invaluable support, encouragement and attention throughout the entire period of the project work.

I am extremely grateful to Dr. Enakshi Bhattacharya, Professor and Head, Department of Electrical Engineering, IIT Madras, for her moral support and encouragement.

I thank all the teaching and non-teaching staff of the Department especially from Measurements and Instrumentation Lab, for their great help and also thank my friends Mr. Shenil P S., Mr. Noel Philip Valiyakalayil, And Ms. Induja S for their timely assistance in the completion of this work.

Last but not the least, I would like to thank my parents and family for their support and the Almighty for uncountable blessings due to which I was able to complete the project on time.

Banala Naresh Kumar

ABSTRACT

Resistors, Capacitors and Inductors are basic elements of any electronic circuit. They form an integral part of sensing elements used in sensors, elements in signal conditioning circuits, in data storage elements, in data telemetry and data processing circuits. The performance of analog or digital circuits depends on the proper functionality of these passive elements as well. Hence it becomes necessary to measure the value of resistance, capacitance and inductance accurately so as to access the parameter variations in sensors or for designing precise and highly accurate analog and digital circuits.

All the types of measuring R, L, C like Wheat Stone Bridge, Maxwell's Wien Bridge and Resonance method are designed to measuring resistance and capacitance. These methods require a demodulator and ADC to digitize the values obtained and to get the value of R, L and C. This thesis deals with measuring R, L, C using National Instruments (NI) data LabVIEW software package. In this thesis the author proposed with different test setup for measuring R, L, C. The VI reads the desired of the resistance and capacitance entered by the user on the front panel and determines its values.

Resistance(R) values have been measured using one test circuit. With another test circuit measured both Resistance(R), and capacitance(C). Measured different resistance values from 1 KΩ -473 KΩ. The error between nominal value and measure value have been calculated and found to be 16.5%.

TABLE OF CONTENTS

CHAPTER 4

CHAPTER 5

CHAPTER 6

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

LabVIEW	Laboratory Virtual Instrument Engineering Workbench
VI	Virtual Instruments
DAQ	Data Acquisition
NI	National Instruments
G-Program	Graphical Program
GPIB	General Purpose Interface Bus
RMS	Root Mean Square
RTD	Resistance Temperature Detector

SYMBOLS

V	Voltage
I	Current
P	Power
R	Resistance
C	Capacitance
L	Inductance
Z	Impedance
Y	Admittance
k	kilo
A	Ampere
m	milli
n	nano
M	Mega
F	Fared
Hz	Hertz
S	Sec
V_{p-p}	Peak to peak Voltage
Ω	Ohm
ω	Omega
ϕ	Phase shift
ω_0	Natural frequency
f_0	Central/Resonant frequency
N	Number of samples
μ	Micro

CHAPTER 1
INTRODUCTION

1.1 Need for measurement system

Resistors, Capacitors and Inductors are basic elements of any electronic circuit. They form an integral part of sensing elements used in sensors, elements in signal conditioning circuits, in data storage elements, in data telemetry and data processing circuits. The performance of analog or digital circuits depends on the proper functionality of these passive elements as well. In resistance based sensors, the variation of resistance can be used to measure temperature as in a RTD (Resistance Temperature Detector), to measure strain in strain gauges, in potentiometric sensors to sense displacement- both linear and rotary and so on. In capacitive based sensors, the variation of capacitance is used to sense displacement, for measuring acceleration, for seat occupancy detection in vehicles, for touchscreen applications, fluid level measurements and so on. In Inductance based sensors, the variation of inductance is used to measure proximity as in eddy current sensors, for measurement of linear and rotary displacements in LVDT, RVDT and differential variable reluctance sensors, for measuring the speed of motor rotor and so on.

Hence it becomes necessary to measure the value of resistance, capacitance and inductance accurately so as to access the parameter variations in sensors or for designing precise and highly accurate analog and digital circuits.

A measurement system must be capable of accurately measuring the parameter variations in any environmental conditions. For a measurement system the following must be taken into condition. The measurement setup must not load the sensor system or the parameter being measured. Hence sufficient capability to act as a buffer must be provided by the measurement system. The measurement unit must have the capability to drive the R, L or C being connected across it, so that it behaves like a stand-alone unit for measurement. The measurement system must be immune to environmental noise sources, hence this calls for the need of sufficient filtering. The measurement system must have a large bandwidth so that it can accurately measure spontaneous changes in the passive elements. The measurement system must ensure that SNR of the system is significantly high so that it has the ability to clearly distinguish the signal under consideration over noise. The measurement system must also take care of the frequency of operation, such that parasitic elements like stray capacitances are minimal at the frequency of operation.

1.2 Objective and scope of the work

There are many different methods and techniques for measuring resistance, capacitance and inductance. Those methods are Wheatstone Bridge, Maxwell Wien Bridge etc. This thesis explores a method to measure Resistance, Capacitance and Inductance using Virtual Instrumentation. In the present work the author come up with different method for measuring Resistance, Capacitance and Inductance. The author proposed one test circuit for measuring Resistance and another circuit for measuring Resistance and Capacitance.

1.3 Organization of Work

A brief introduction to measurement and need for measurement is presented in chapter1. Chapter 2 deals with the existing techniques and proposed R, L, C measurement technique. Chapter 3 provides the details of hardware description and an introduction of TINA-TI and simulation results. Chapter 4 deals with the implementation of VI concept using NI software called LabVIEW. Chapter 5 presents the design of measuring R, L, and C using LabVIEW. The LabVIEW block diagrams and experiment results. The summary of the work carried out is provided in Chapter 6.

CHAPTER 2

R, L, C MEASUREMENT TECHNIQUES

2.1 EXISTING TECHNIQUES

2.1.1 Wheat Stone Bridge

Resistances can be measured by direct-current, as shown in fig 2.1

The equation 2.1 shown below

$$\frac{R_1}{R_2} = \frac{R_4}{R_3} \qquad R_1R_3 = R_2R_4 \tag{2.1}$$

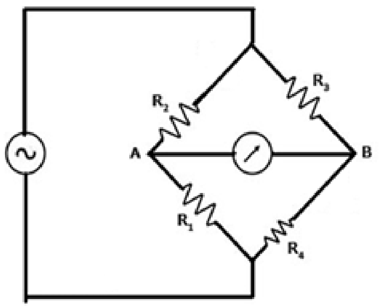


Fig 2.1 Wheat Stone Bridge

Inductance and capacitance can also be measured by a similar four-arm bridge [6], as shown in fig 2.2. In this case the alternating current source is employed by a vibration galvanometer.

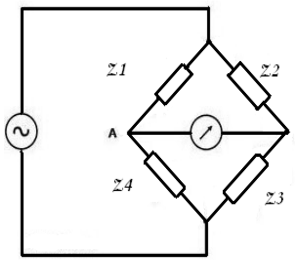


Fig 2.2 Four-arm Bridge

The equation 2.2 shown below

$$Z_1Z_3 = Z_2Z_4 \tag{2.2}$$

2.1.2 Maxwell's Wien Bridge

In the Maxwell's Wien Bridge [7] the positive phase angle of the inductance may be compensated by the negative phase angle of the capacitance impedance put in the opposite arm.

The unknown inductance then becomes known in terms of the capacitance. As shown in fig2.3

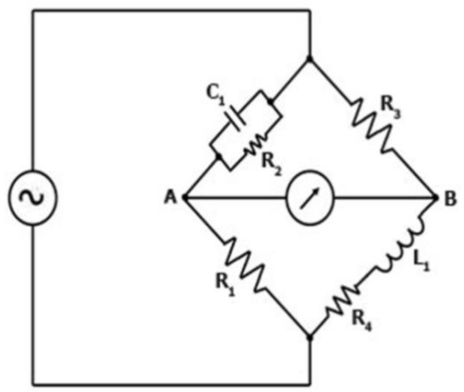


Fig 2.3 Maxwell's Wien Bridge

$$R_2R_4 + j\omega L_1R_2 = R_1R_3 + j\omega C_1R_1R_2R_3 \qquad \textbf{(2.3)}$$

2.1.3 Resonance method

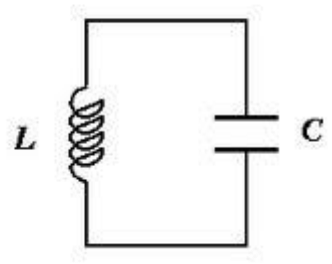


Fig 2.4 Resonance Method

The Resonance method circuit shown in fig 2.4. The resonance effect occurs when inductive and capacitive reactances are equal in magnitude. The frequency at which this equality holds for the particular circuit is called the resonant frequency. The resonant frequency of the LC circuit is

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad \textbf{(2.4)}$$

$$f = \frac{1}{2\Pi\sqrt{LC}} \qquad \textbf{(2.5)}$$

If L is varies and C is constant then f is propositional to $\frac{1}{\sqrt{L}}$

If C is varies and L is constant then f is propositional to $\frac{1}{\sqrt{C}}$

2.2 PROPOSED R, L, C MEASUREMENT TECHNIQUE

The voltage waveform is shown in fig 2.5

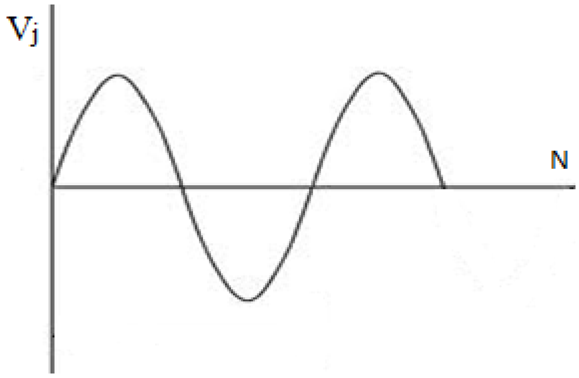


Fig 2.5 Voltage Waveform

The rms value N samples point of voltage is computed using the following expression

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{j=1}^{N} V^2{}_j} \quad \textbf{(2.6)}$$

The current waveform shown in fig 2.6

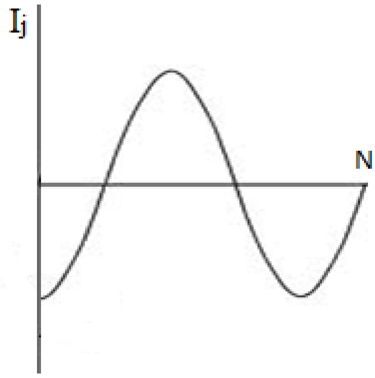


Fig 2.6 Current Waveform

The rms value N samples point of current is computed using the following expression

$$I_{rms} = \sqrt{\frac{1}{N}\sum_{j=1}^{N} I^2{}_j} \quad \textbf{(2.7)}$$

The power value N samples average for the summation of current and voltage multiplication. It is shown in equation 2.8

$$P = \frac{1}{N}\sum_{j=1}^{N} V_j I_j \quad \textbf{(2.8)}$$

The impedance Z is shown in equation 2.9

$$Z = R + j\omega L \tag{2.9}$$

The resistance R is calculated from equation 2.10

$$R = Z\cos\emptyset \tag{2.10}$$

The cos ∅ is calculated by the equation 2.11.

$$\cos\emptyset = \frac{P}{V_{rms}I_{rms}} \tag{2.11}$$

The impedance is calculated from equation 2.12

$$Z = \frac{V_{rms}}{I_{rms}} \tag{2.12}$$

The resistance R is calculating from equation 2.13

$$R = \frac{V_{rms}}{I_{rms}}\cos\emptyset \tag{2.13}$$

The admittance equation is shown in below

$$Y = G + j\omega C \tag{2.14}$$

The imaginary part is calculated by the equation shown in 2.15

$$\omega C = Y\sin\emptyset \tag{2.15}$$

The admittance is calculated from the equation 2.16

$$Y = \frac{I_{rms}}{V_{rms}} \tag{2.16}$$

The sin ∅ is calculated from equation 2.17

$$\sin\emptyset = \frac{1}{NV_{rms}I_{rms}}\left[\sum_{j=1}^{3\frac{N}{4}} V_j I_{j+\frac{N}{4}} + \sum_{j=3\frac{N}{4}+1}^{N} V_j I_{j-3\frac{N}{4}}\right] \tag{2.17}$$

The capacitance is calculated from the equation 2.18

$$C = \frac{1}{NV^2{}_{rms}\omega}\left[\sum_{j=1}^{3\frac{N}{4}} V_j I_{j+\frac{N}{4}} + \sum_{j=3\frac{N}{4}+1}^{N} V_j I_{j-3\frac{N}{4}}\right] \tag{2.18}$$

These equations are used in the LabVIEW programing for measuring the Resistance and Capacitance values.

CHAPTER 3

ANALOG CIRCUIT DESIGN AND SIMULATION WITH TINA-TI

3.1 INTRODUCTION

This section describes about designing of R, L, C measurement using op-amp. The analysis of circuit simulation has done in TINA-TI. The circuit diagram is shown in figure 3.1. TINA is a Spice-based circuit simulation tool suitable for running in Microsoft Windows Operation system. TINA is able to precisely simulate analog circuits and also the switch-mode power supply circuits. It is widely applied and highly reviewed among electrical engineers, particularly analog circuits designers and application engineers. TINA is developed by Texas Instruments cooperated with Design Soft, Inc... Compare to other Spice simulation software, TINA provides the most intuitive and the easiest operating platform and view. Users usually review TINA as the fastest running Spice simulation software. This document will introduce the operation of designing process of analog circuits by TINA.

It is easy to select components from different categories as illustrated. These categories (Basic, Switches, Meters, Sources, Semiconductors, Spice Macros) also contain many of passive and active components. Click on the schematic symbol for a particular component and drag it into position in the circuit workspace. Left clicking to set the component in the desired position. Continuing with constructing the desire circuit schematic.

3.2 CIRCUIT

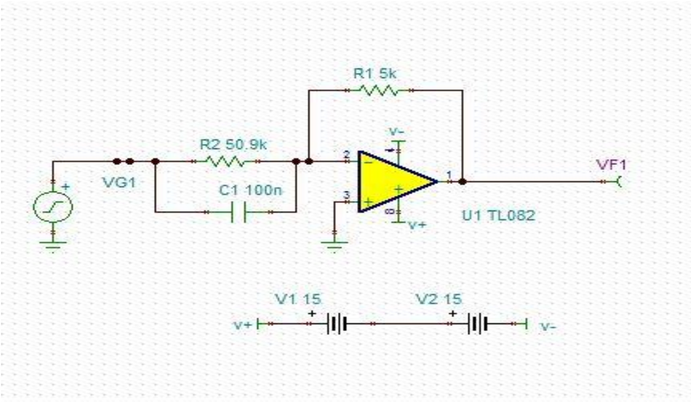
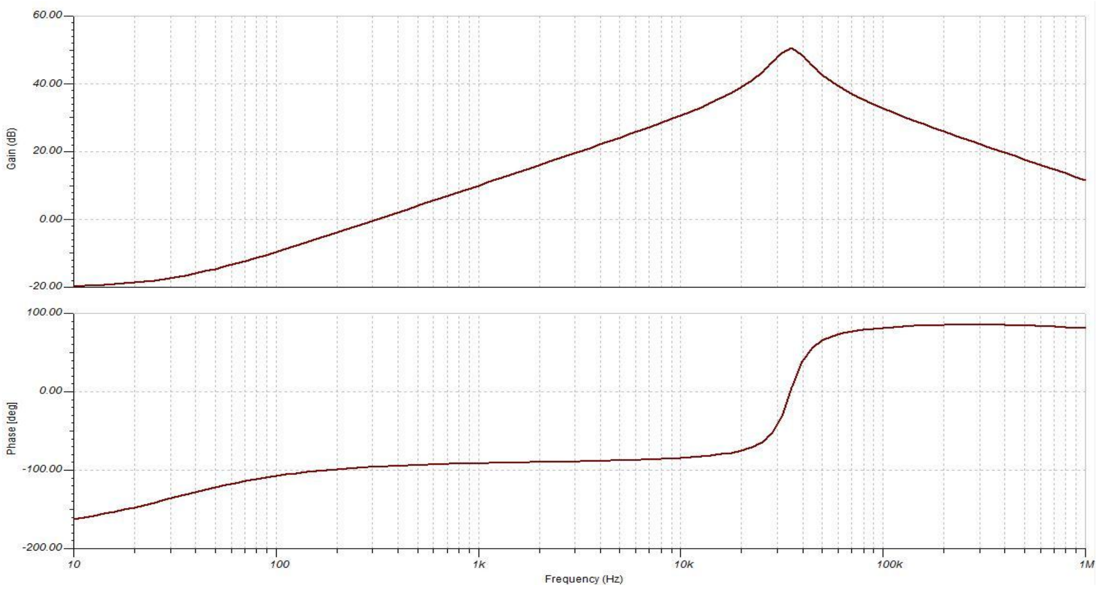


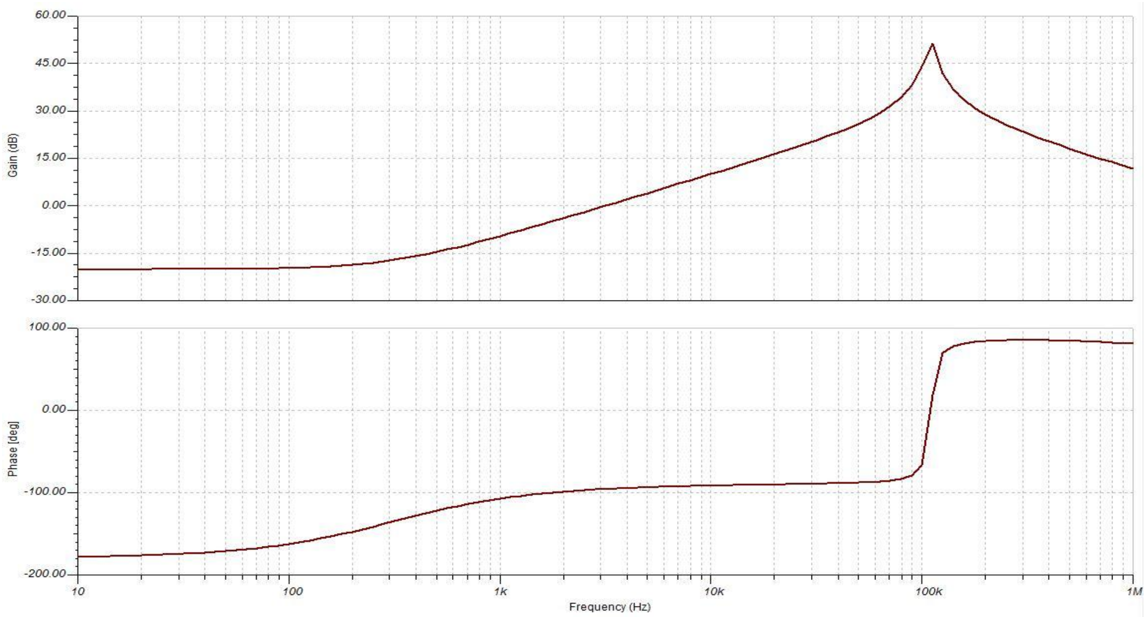
Fig.3.1 Analog Circuit Design

3.3 SIMULATION RESULTS

With the resistor value 50.9kΩ and the capacitor value 100nF, the simulation results are showing here.



.



The above simulation results using the resistor of 50.9k Ω and capacitor of 10nf.

CHAPTER 4

VIRTUAL INSTRUMENTATION

4.1 INTRODUCTION TO LABVIEW

LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. The graphical language is named "G". Originally released for the Apple Macintosh in1986, LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various flavors of UNIX, Linux, and Mac OS X.

The code files have the extension ".vi", which is an abbreviation for "Virtual Instrument". LabVIEW offers lots of additional Add-Ons and Toolkits.

4.1.1 Dataflow programming

The programming language used in LabVIEW, [2] also referred to as G, is a data flow programming language. Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, G is inherently capable of parallel execution. Multi-processing and multi-threading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

4.1.2 Graphical programming

LabVIEW ties the creation of user interfaces (called front panels) into the development cycle. LabVIEW programs/subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. However, the front panel can also serve as a programmatic interface. Thus a virtual instrument can either be run as a program, with the front panel serving as a user interface, or, when dropped as a node onto the blockdiagram, the front panel defines the inputs and outputs for the given node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program. The graphical approach also allows non-programmers to build programs simply by dragging and dropping virtual representations of lab equipment with which they are already familiar. The

LabVIEW programming environment, with the included examples and the documentation, makes it simple to create small applications. This is a benefit on one side, but there is also a certain danger of underestimating the expertise needed for good quality "G" programming. For complex algorithms or large-scale code, it is important that the programmer possess an extensive knowledge of the special LabVIEW syntax and the topology of its memory management. The most advanced LabVIEW development systems offer the possibility of building stand-alone applications. Furthermore, it is possible to create distributed applications, which communicate by a client/server scheme, and are therefore easier to implement due to the inherently parallel nature of G-code.

4.1.3 Benefits

One benefit of LabVIEW over other development environments is the extensive support for accessing instrumentation hardware. Drivers and abstraction layers for many different types of instruments and buses are included or are available for inclusion. These present themselves as graphical nodes. The abstraction layers offer standard software interfaces to communicate with hardware devices. The provided driver interfaces save program development time. The sales pitch of National Instruments is, therefore, that even people with limited coding experience canwrite programs and deploy test solutions in a reduced time frame when compared to more conventional or competing systems. A new hardware driver topology (DAQmxBase), which consists mainly of G-coded components with only a few register calls through NI Measurement Hardware DDK (Driver Development Kit) functions, provides platform independent hardware access to numerous data acquisition and instrumentation devices. The DAQmxBase driver is available for LabVIEW on Windows, Mac OS X and Linux platforms.

4.2 INTRODUCTION TO DAQ - DATA ACQUISITION

The purpose of data acquisition is to measure an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. While each data acquisition system is defined by its application requirements, every system shares a common goal of acquiring, analyzing, and presenting information. Data acquisition systems incorporate signals, sensors, actuators, signal conditioning, data acquisition devices, and application software. So summing up, [3] Data Acquisition is the process of:

- Acquiring signals from real-world phenomena
- Digitizing the signals
- Analyzing, presenting and saving the data

4.2.1 Physical input/output signals

- A physical input/output signal is typically a voltage or current signal.
- A voltage signal can typically be a 0-5V signal, while a current signal can typically be a 4-20mA signal.

4.2.2 DAQ device/hardware

DAQ hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them A DAQ device (Data Acquisition Hardware) usually has these functions:

- Analog input
- Analog output
- Digital I/O
- Counter/timers

We have different DAQ devices, such as:

- “Desktop DAQ devices” where you need to plug a PCI DAQ board into your computer. The software is running on a computer.
- “Portable DAQ devices” for connection to the USB port, Wi-Fi connections, etc. The software is running on a computer.

“Distributed DAQ devices” where the software is developed on your computer and then later downloaded to the distributed DAQ device.

CHAPTER 5

PROTOTYPE DEVELOPMENT

5.1 METHODOLOGY

The methodology used for the measurement is represented in fig 5.1. The block diagram can be represented by circuit, DAQ assistant and LabView.

Fig.5.1 Block Diagram

5.1.1 Circuit

The circuit components are resistor, capacitor and op amp (TL082). The resistor and capacitor are connected in parallel.

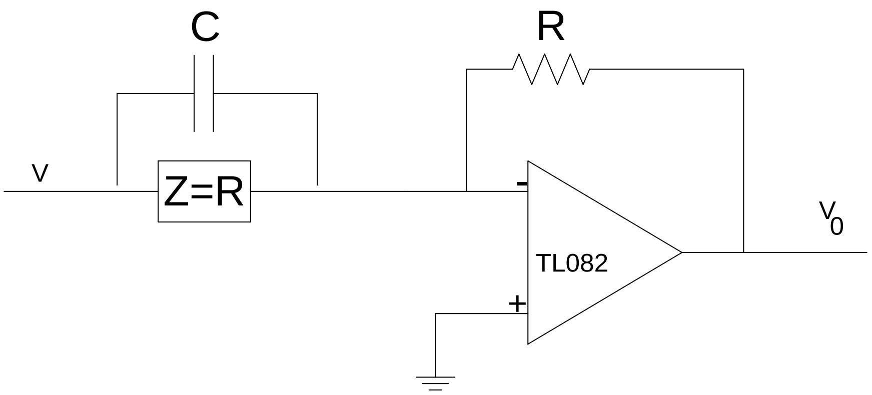


Fig 5.2 circuit diagram

Op amp (TL082):

These devices are low cost, high speed, dual JFET input operational amplifiers with an internally trimmed input offset voltage. They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The TL082 is pin compatible with the standard LM1558 allowing designers to immediately upgrade the overall performance of existing LM1558 and most LM358 designs. These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset volt-age, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices also exhibit low noise and offset voltage drift.

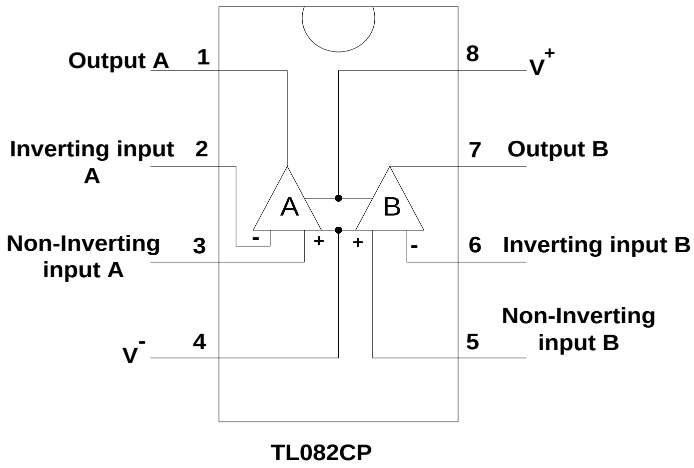


Fig.5.3 OP Amp

Features

- Internally trimmed offset voltage: 15 mV
- Low input bias current: 50 pA
- Low input noise voltage: 16nV/√Hz
- Low input noise current: 0.01 pA/√Hz
- Wide gain bandwidth: 4 MHz
- High slew rate: 13 V/µs
- Low supply current: 3.6 mA
- High input impedance: $10^{12}\Omega$
- Low total harmonic distortion AV=10,: <0.02%
  RL=10k, VO=20 Vp − p, BW=20 Hz−20 kHz
- Low 1/f noise corner: 50 Hz
- Fast settling time to 0.01%:2µs

5.1.2 Resistor

When electrons flow through a bulb or another conductor, the conductor does offers some obstruction to the current. This obstruction is called electrical resistance.

The longer the conductor higher the resistance

The smaller its area the higher its resistance

Every material has an electrical resistance and it is the reason that the conductor give out heat when the current passes through it.

Resistance is a measure of how much an object opposes the passage of electrons. The unit of electrical resistance is the ohm and it is represented by Ω

5.1.3 Capacitor

Capacitor is an electronic component that stores electric charge. The capacitor is made of 2 close conductors (usually plates) that are separated by a dielectric material. The plates accumulate electric charge when connected to power source. One plate accumulates positive charge and the other plate accumulates negative charge.
The capacitance is the amount of electric charge that is stored in the capacitor at voltage of 1 Volt. The capacitance is measured in units of Farad (F).
The capacitor disconnects current in direct current (DC) circuits and short circuit in alternating current (AC) circuits.

5.2 DAQ ASSISTANT

The DAQ boards (made by National Instruments) [3] are multi-function plug-n-play, analog and digital input/output boards consisting of a onboard timer, 12 bit analog to digital converter (ADC) with 8 channel input, 2 digital to analog converters (DAC) and 24 TTL level logic inputs.
Since the system is integrated with National Instruments products, it offers direct control of all hardware on the DAQ board from the LabVIEW software. LabVIEW is the emerging standard in visual programming based instrumentation control systems. LabVIEW is programmed with a set of graphical icons (called "G") which are connected with "wires". The combination of a DAQ board and LabVIEW software makes a virtual instrument or a VI. A VI can perform like an instrument and is programmable by the software with the advantage of flexibility of logging the data that is being measured.

5.2.1 Sampling Rate

Sampling rate determines the sound frequency range (corresponding to pitch) which can be represented in the digital waveform. The range of frequencies represented in a waveform is often

called its *band width.* Waveforms sampled at a high sampling rate can represent a broad range of frequencies and hence have broad bandwidth. In fact, the maximum bandwidth of a sampled waveform is determined exactly by its sampling rate; the maximum frequency representable in a sampled waveform is termed its *Nyquist* frequency, and is equal to one half the sampling rate.

The sampling rate in this taking is high frequency. Then the number of samples is less than the sampling rate. The frequency is also is less it is depends on the sampling rate and the number of samples.

5.3 LABVIEW PROGRAMMING FOR R, L, C MEASUREMENT

In the LabVIEW programing used palettes are waveform graph, array subset, array size, numeric, and Basic Averaged DC-RMS and tone measurements.

Waveform graph: A *Waveform Graph* accepts arrays of data in various forms, e.g. array, waveform, or dynamic data. It then plots all the received points at once. It does not accept single point values. When an array of points is wired to a waveform graph, it assumes the points are equally spaced out. By default, the starting X value and step size are 0 and 1 respectively. This can be changed in the properties of the graph or using property nodes.

Array subset: Returns a portion of array starting at index and containing length elements.

Array size: Returns the number of elements in each dimension of array.

Basic Averaged DC-RMS: Calculates the DC and RMS values of an input waveform or array of waveforms. This VI is similar to the Basic Averaged DC-RMS VI, but this VI gives more precise control over the individual DC and RMS calculations. In that using only some points reset, DC value waveform and RMS value waveform.

Reset resets the history of your time signal. You typically use **reset** to reset the exponentially averaged measurement.

DC value waveforms are an array of waveforms containing DC values.

RMS value waveforms are an array of waveforms containing RMS values.

Numeric: Use the numeric constant to pass a numeric value to the block diagram.

5.4 MEASURING RESISTANCE AND CAPACITANCE

The below figure 5.4 is a Resistance measurement setup in LabVIEW.

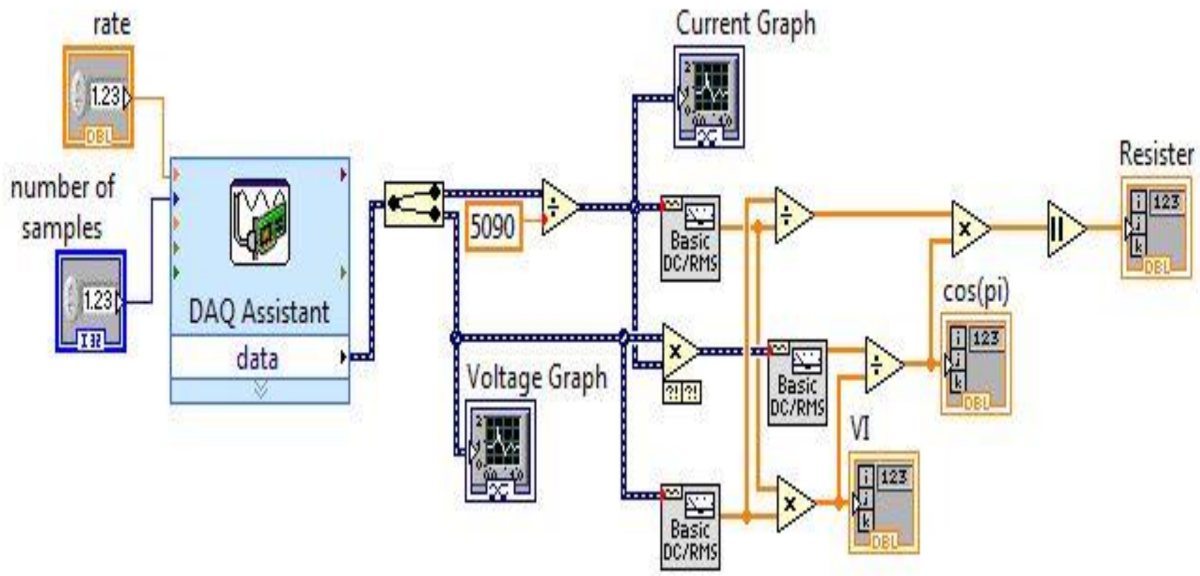


Figure: 5.4 Measuring Resistor-Block Diagram Image

The fig 5.5 shown in measuring resistance and capacitance setup in LabVIEW.

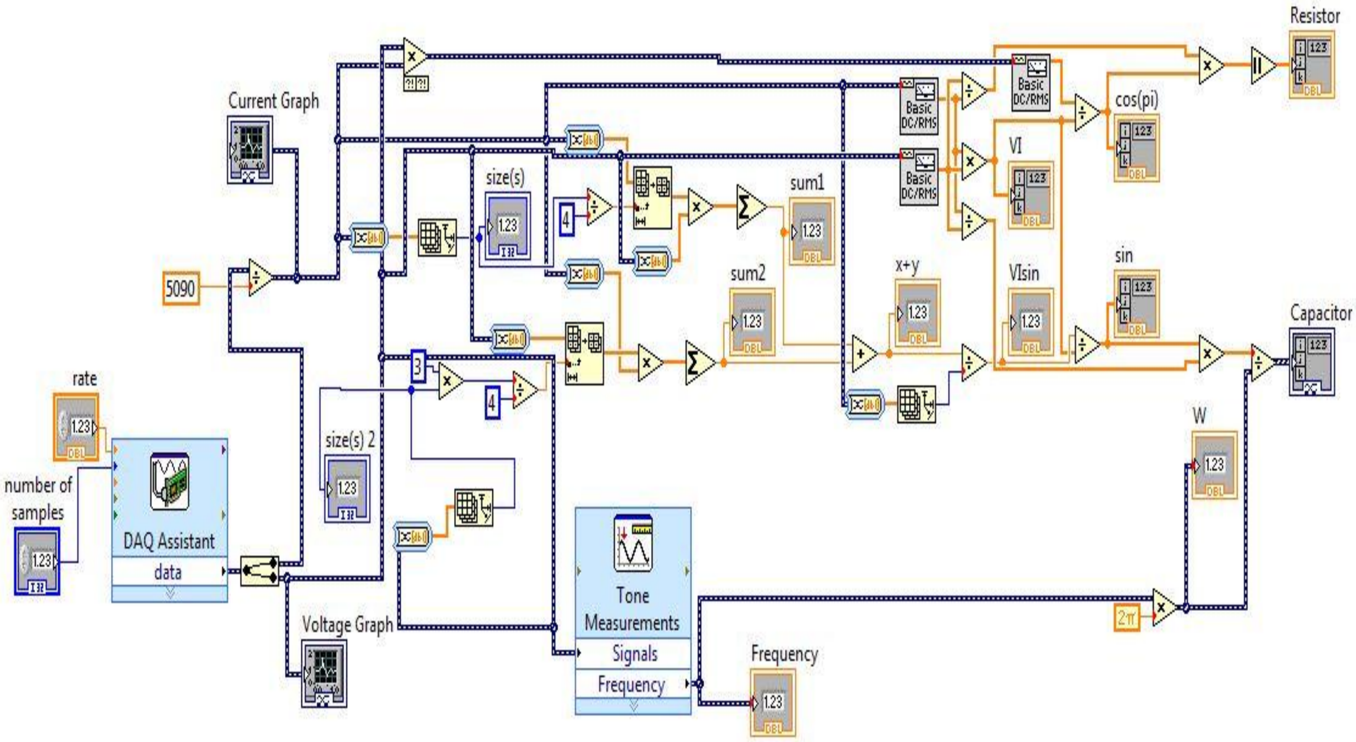


Figure: 5.5 Measuring Resistor and Capacitor-Block Diagram Image

5.5 EXPERIMENT RESULTS

5.5.1 Measuring Resistance

The measured resistance value is shown in figure 5.6

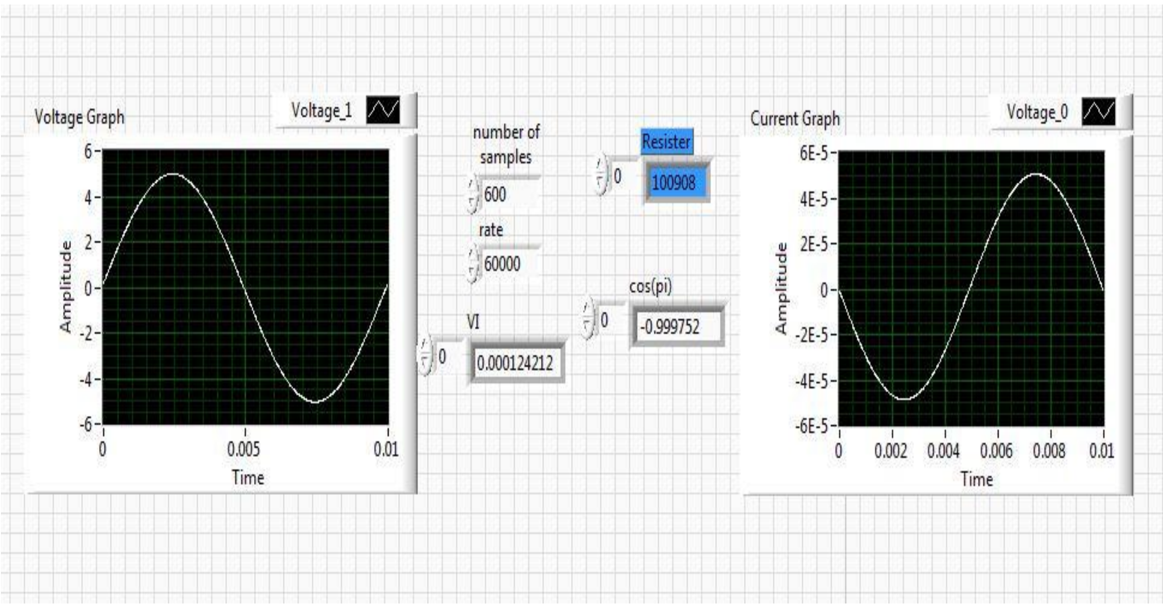


Figure: 5.6 Measuring Resistor-Front Panel Results

The specifications for this circuit are given below:

Actual Resistor - 100.9kΩ Measured Resistor – 100.9 kΩ

Frequency of signal - 100Hz

Sample rate - 60000Hz

Number of samples - 600

Amplitude - 10

Start frequency - 20Hz

Stop frequency – 1 kHz

5.5.2 Measuring Resistance and Capacitance

The resistance and capacitance values at 100.8nF are shown in below figure 5.7

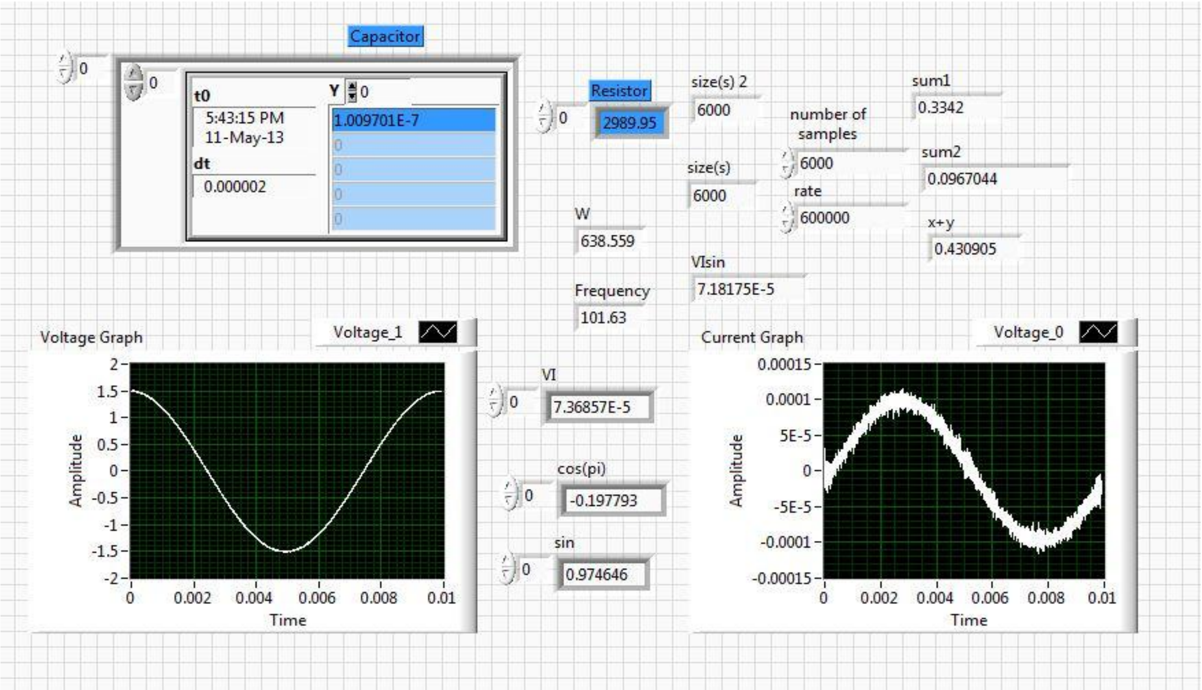


Figure: 5.7 Measuring Resistance and Capacitance-Front Panel Results

The specifications for this circuit are given as:

Actual Resistor - 100.9kΩ   Measured Resistor – 2.98 kΩ

Actual Capacitor - 100.8nF   Measured Capacitor - 100.9nF

Frequency of signal - 100Hz

Sample rate - 600000Hz

Number of samples - 6000

Amplitude - 3

Start frequency - 20Hz

Stop frequency – 1 kHz

The resistance and capacitance values at 10.1nF are shown in below figure 5.8

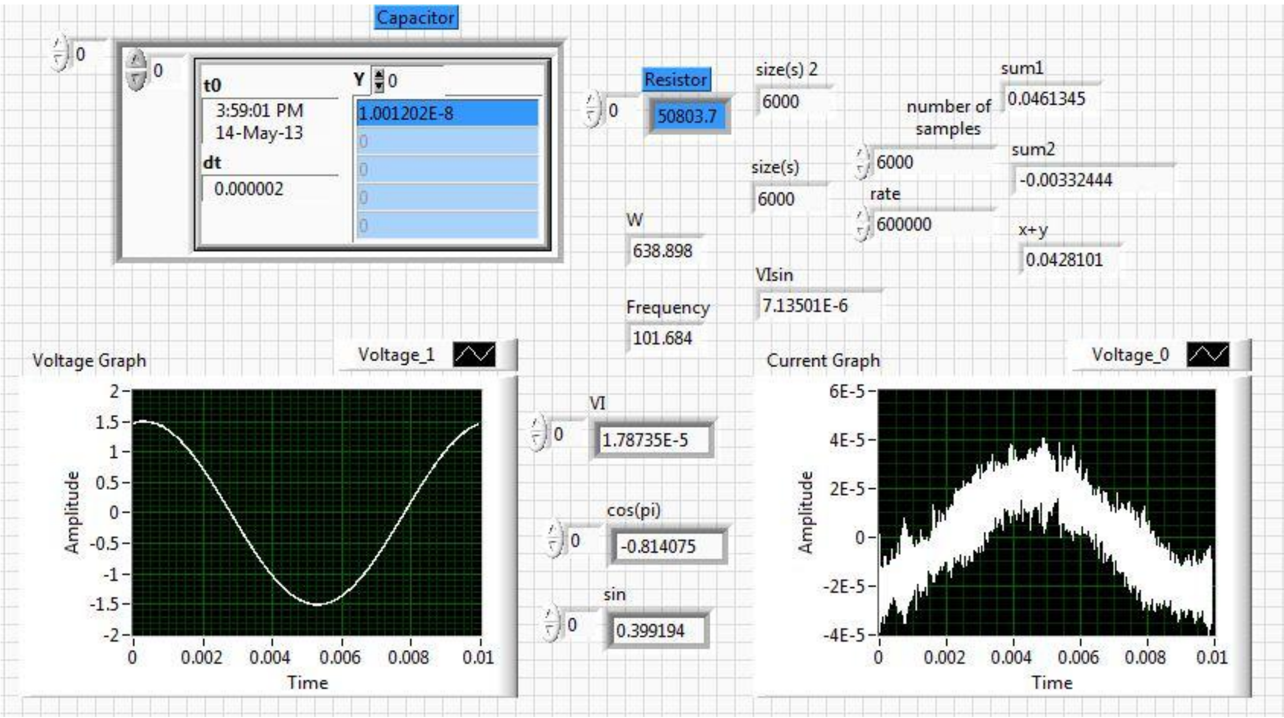


Figure: 5.8 Measuring Resistance and Capacitance-Front Panel Results

The specifications for this circuit are given as:

Actual Resistor - 100.9kΩ Measured Resistor – 50.8 kΩ

Actual Capacitor - 10.1nF Measured Capacitor – 10.01nF

Frequency of signal - 100Hz

Sample rate - 600000Hz

Number of samples - 6000

Amplitude - 3

Start frequency - 20Hz

Stop frequency – 1 kHz

The Table 5.1 shows the originals resistance, measured resistance and the error

Resistance (kΩ)	Measured Resistance (kΩ)	Error (%)
1.09	1.09	0
2	2	0
3	2.998	0.06
5.08	5.08	0
6.19	6.188	0.03
7.47	7.469	0.01
8.18	8.18	0
9.14	9.135	0.05
9.95	9.943	0.07
15	14.994	0.04
20	20	0
23.9	23.894	0.02
30	29.99	0.03
50.8	50.787	0.02
55.9	55.89	0.01
61.9	61.89	0.01
75.2	75.189	0.01
82	81.99	0.01
90.8	90.759	0.04
100.9	100.852	0.04
131	130.88	0.09
180.1	179.8	0.16
200	199.89	0.05
221	220.967	0.01
242	241.76	0.09
270	269.61	0.14
300	298.87	0.3
336	332.84	0.9
394	390.8	0.8
441	436.89	0.93
473	466.97	1.2

Table: 5.1 Resistance Values

The capacitance value is taken as 10.1nF and by varying the resistance value, measured resistance and capacitance. These measured values are shown in Table 5.2

Resistance (kΩ)	Measured Capacitance (nF)	Measured Resistance (kΩ)
2	8.8	2.1
3	9.5	2.9
5	9.5	4.9
6.1	9.5	5.9
7.4	9.6	7.1
8.1	9.7	7.8
9.1	9.7	8.7
9.9	9.8	9.3
15	9.8	13.9
20	9.8	18.1
23.9	9.8	21.1
30	9.8	25.5
50.8	9.9	37.4
55.9	9.9	39.5
61.9	10	41.6
75.2	10	45.8
82	10	47.7
90.8	10.1	48.9
100.9	10.1	50.8
149	10.1	54.1
200	10.1	53.5
242	10.1	51.9
300	10.1	50.2
394	10.1	48.1
441	10	48.1
473	10	45.2

Table: 5.2 Capacitance and Resistance Measurements at 10.1nF

The capacitance value is taken as 100.8nF and by varying the resistance value, measured resistance and capacitance. These measured values are shown in Table 5.3

Resistance (kΩ)	Measured Capacitance (nF)	Measured Resistance (kΩ)
2	89.5	2.1
3	97.9	2.8
5	98.4	4.48
6.1	98.5	5.20
7.4	98.6	5.93
8.1	98.9	6.66
9.1	99.1	6.87
9.9	99.7	7.74
15	99.7	7.74
20	100	7.63
23.9	100.3	7.30
30	100.4	6.69
50.8	100.6	4.90
55.9	100.8	4.55
61.9	100.8	4.24
75.2	100.8	3.69
82	100.8	3.47
90.8	100.9	3.19
100.9	100.9	2.98
149	100.9	2.24
200	100.9	1.85
242	100.9	1.64
300	100.9	1.45
394	100.9	1.27
441	100.9	1.21
473	100.9	1.17

Table: 5.3 Capacitance and Resistance Measurements at 100.8nF

CHAPTER 6

CONCLUSION

6.1 Summary of work

This work provides a means to measure equivalent Resistance(Req) and equivalent Reactive Impedance (Xeq) using LabVIEW and a Current-to-Voltage converter. The error between nominal and measured resistance error is less when a resistor alone is measured. For measurement of capacitance, it is necessary to operate at higher frequencies such that the resistance of the capacitor is negligible when compared to the impedance of the capacitive network. Hence a high sampling rate provides an accurate measurement of capacitor. For a circuit which has R and C in parallel, the proposed measurement scheme is only able to compute the value of equivalent real part (Req) of the network and the equivalent reactance part (Xeq) of the network. Hence to measure the actual value of R and C accurately it becomes necessary to modify the front end circuit or to provide additional logic in LabVIEW.

The proposed measuring technique is capable of providing accurate results for R and L in series and for R and C in series.

REFERENCES

[1] "LabVIEW - Graphical Programming for Instruments, User Manual", National Instruments, 1996.

[2] L.K. Wells, "LabVIEW Student Edition User's Guide", National Instruments, 1995.

[3] "Data Acquisition Basics Manual", National Instruments, 1996.

[4] J. P. Bentley, Principles of Measurement Systems, 3rd ed. Singapore: Longman Singapore Publisher Ltd., 1995.

[5] S. Fericean and R. Droxler, “Proximity and inductive linear displacement sensors for industrial automation,”IEEE Sensors J., vol. 7, no. 11, pp. 1538–1545, Nov. 2007.

[6] E. Takagishi, “On the balance of an AC Wheatstone bridge,”IEEE Trans. Instrum. Meas., vol. IM-29, no. 2, pp. 131–140, Jun. 1980.

[7] T. L. Zapf, “Calibration of inductance standards in the Maxwell–Wien bridge circuit,” J. Res. NBS, vol. 65C, pp. 183–188, Sep. 1961.