DEVELOPMENT OF REAL-TIME ULTRASONIC SENSORING SYSTEM TO MEASURE DISTANCE USING LABVIEW

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ABSTRACT

This project involves the implementing of ultrasonic sensor for industrial related applications in real-time. Ultrasonic sensor works on the area from 40 KHz to 400 KHz. To detect the distance of the object, ultrasonic sensor measures the time from the transmission of sonic wave to reception of the sonic wave. In process industry, it present the ideal solution to level detection of non-contact level sensing of highly viscous liquids in process industry. It also used to measurement of flow, crack detection and tank level measurement. The sensor system should have DAQ capabilities using NI DAQ card USB-6009. By using the DAQ card, the data will be transfer from sensor to computer. Input and output data will be transfer through digital signals or analog signals or channels. DAQ card operate by utilizing both DAQ hardware and software. By using the LabVIEW programming language, the interface for the sensor system will be developed and LabVIEW also used to communicate with DAQ hardware. In LabVIEW, we build a block diagram contains to control the front panel objects. The developed sensor should capable of measurement in real-time. The system also capable for data storage and data retrieval for further analysis.

ABSTRAK

Projek ini melibatkan pelaksanaan sensor ultrasonik bagi aplikasi industri berkaitan dalam masa nyata. Sensor ultrasonik bekerja di kawasan dari 40 KHz hingga 400KHz. Untuk mengesan jarak objek, sensor ultrasonik mengukur masa bermula daripada penghantaran gelombang sonik hingga penerimaan gelombang sonik. Dalam industri proses, sensor ultrasonik adalah penyelesaian yang ideal untuk mengesan tahap penderiaan cecair yang sangat likat di dalam industri proses. Ia juga digunakan untuk pengukuran aliran, pengesanan retak dan pengukuran tahap tangki. Sistem sensor ini perlu mempunyai keupayaan pemerolehan data menggunakan NI DAQ USB-6009. Dengan menggunakan kad DAQ, data akan dipindahkan dari sensor ke komputer. Data input dan output akan dipindahkan melalui isyarat digital atau isyarat analog atau saluran. Kad DAQ beroperasi dengan mengunakan kedua-dua perkakasan dan perisian DAQ. Dengan menggunakan bahasa pengaturcaraan LabVIEW, antara muka untuk sistem sensor akan dibangunkan dan LabVIEW juga digunakan untuk berkomunikasi dengan perkakasan DAQ. Di LabVIEW, kita membina gambarajah blok untuk mengawal objek panel hadapan. Sistem sensor ini seharusnya mampu mengukur dalam masa nyata. Sistem ini juga mampu untuk menyimpan dan mendapatkan kembali data untuk analisis selanjutnya.

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CHAPTER 1

INTRODUCTION.

1.1 Background

This project involves the implementing of ultrasonic sensor for industrial related applications in real-time. Ultrasonic sensor works on the area from 40 KHz to 400 KHz. To determine the distance to an object, the time interval from sending and receiving echo will be calculated.

To develop interface for the sensor system, LabVIEW software will be used. Graphical User Interface (GUI) will be created to provide a user friendly system and the analysis can be performed faster and easier.

To determine the distance, the sensor will be connected to computer by using NI DAQ card. The LabVIEW program record and measure voltage from the sensor. A graph will be executed after acquiring the analog voltage from the sensor, and the voltage signal will display in time domain. By using a certain formula, we can convert this voltages to distance. The results are saved at one file.

1.2 Objective

i. To design working prototype of ultrasonic sensor system.
ii. To display result in real-time by using LabVIEW.
iii. To learn the flow of data/or data conversion/data DAQ system.
iv. To understand the operation of the circuit and applications of this system.
v. To implement working ultrasonic system for industrial based application.

1.3 Scope Project

i. Implement the real-time concept in distance monitoring system.
ii. Concentrate on measuring the distance using ultrasonic sensor
iii. Develop interface for the sensor system using LabVIEW.
iv. Saving file.

1.4 Problem Statement

In process industries, liquids is require to be pump, store in tanks, then pump to another tank and many times will be process by chemical or mixing treatment in the tanks. The basic problems are the level of fluid in a tank must always be monitored and controlled and the liquid flow between the tanks requires regulation at certain desired rate.

For future, this project, may contribute to overcome this problems. The level of fluid can be measured by using ultrasonic principle and can always be monitored in real-time by using LabVIEW programming language.

1.5 Thesis Arrangement

This thesis has 6 chapters which are Introduction, Literature Review, Hardware Design, Software Design, Result and Discussion, and Conclusion and Further Development of the project.

Chapter 1 will be discussed about the introduction of project. The contains includes basic idea of the project, the objective and overview of the project.

Chapter 2 will be discussed about the literature review. The contains includes the components that is use in this project. This chapter also contains the related methodologies from variety of sources for the development of this project.

Chapter 3 will be discussed about the design and methodology of the project. The contains includes General concept of the project like the components that have been used and also will be discussed about the simulation of the circuit. The concept idea of simulation will be discussed.

Chapter 4 will be discussed about the result and discussion. The limitation barrier in completing this project also will be discussed.

Lastly, chapter 5 will be discussed about the conclusion and further development of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For completing this project, some literature reviews from several resources have been done as the guidance to complete this project. Some applications that similar to this project also will be discussed.

2.2 Overview of Ultrasonic Sensors

Ultrasonic sensor works on the area from 40 KHz to 400 KHz. To determine the distance, sensors calculate the time interval between sending the signal and receiving the echo. [1] The term ultrasonic refers to mechanical or acoustical waves of frequency more than 20 kHz. Systems typically use a transducer which generates sound waves in the ultrasonic range, above 18,000 hertz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy which can be measured and displayed. [1] An electro acoustic transducer is a device that converts electrical energy to acoustical energy or vice versa.

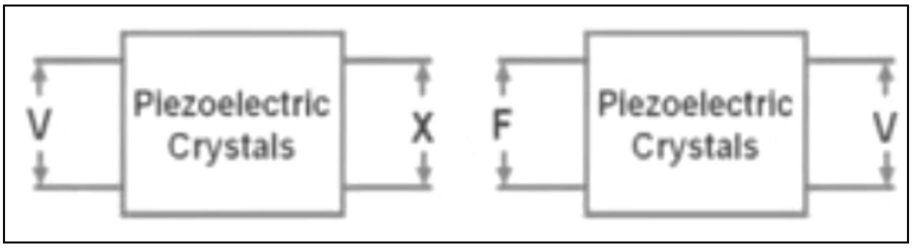
The ultrasonic distance sensor can be operated in two different modes. The first mode, referred to as continuous (or analog) mode, involves the sensor continuously sending out sound waves at a rate determined by the manufacturer. The second mode, called clock (or digital) mode, involves the sensor sending out signals at a rate determined by the user. [3] This rate can be several signals per second with the use of a timing device, or it can be triggered intermittently by an even such as the press of a button.

With respect to sensing and measurements, high frequency avoids interference from many audible, low frequency noises due to wind, machinery, pumps and vibration of large bodies. High frequency allows resolution of “the small” in both the temporal and spatial senses. The major benefit of ultrasonic distance sensor is their ability to measure difficult target; solids, liquids, powders and even transparent and highly reflective materials that would cause problems for optical sensor. In addition, analog output ultrasonic sensors offer comparatively long ranges, in many cases > 3 m. They can also be very small - some tubular models are only 12 mm in diameter, and 15 mm x 20 mm x 49 mm square-bodied versions are available for limited - space applications. [3] When used for sensing functions, the ultrasonic method has unique advantages over conventional sensors such as infrared or reverse sensor. [4] By using ultrasonic method, the discrete distances to moving objects can be detected and measured. The measurement of ultrasonic sensor also less affected by target materials and surfaces, and not affected by color. Solidstate units have virtually unlimited, maintenance free life. Ultrasonic sensors also have ability to detect small objects over long operating distances and have resistance to external disturbances such as vibration, infrared radiation, ambient noise, and EMI radiation.

The technology is limited by the shapes of surfaces and the density or consistency of the material. For example foam on the surface of a fluid in a tank could distort a reading. Turbulence, vapors, and changes in the concentration of the process material also affect the ultrasonic sensor’s response. [1] Ultrasonic sensors have limitations due to their wide beam-width, sensitivity to specular surfaces [6], and the inability to discern objects within 0.5 m [7]. Because of the typical specular nature of the ultrasonic waves reflection, only reflecting objects that are almost normal to the sensor acoustic axis may be accurately detected [8].

2.2.1 Ultrasonic Sensor Principle

The ultrasonic measurement system consists of an ultrasonic transmitter, the transmission medium, and an ultrasonic receiver. The commonly used ultrasonic sensors are the piezoelectric sensing elements.



Transmitter Receiver

Figure 2.1.: Two port network representation of piezoelectric transmitter and receiver. [21]

As we know piezoelectric effect is reversible, the ultrasonic transmitter uses the inverse piezoelectric effect i.e. if a voltage is applied to the transmitter the crystal will undergo a corresponding deformation. The vibration of the crystal is transmitted through the media from one end to the other. The particle displacement sets up an accompanying pressure which is picked up by the receiver. The receiver use the direct piezoelectric effect and converts the force into the corresponding voltage.

For the transmitter:

$$x = dV$$

For receiver:

$$q = dF$$

The performance characteristic d for both cases are same. Moreover,

$$F = Kx = Kdv$$

Where K = stiffness of the crystal.

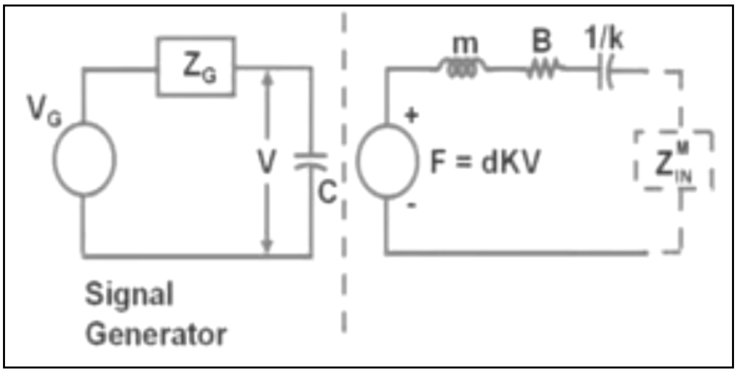


Figure 2.2: Equivalent circuit of a transmitter. [21]

Z_G = Output impedance of the signal growth.

m = Mass of the crystal.

B = Damping coefficient.

K = Spring constant.

Z^M_{IN} = Input impedance of the medium.

$\dot{x}$ = Velocity.

Ideally,

$$Z_G = 0 \; ; \; Z^M_{IN} = 0$$

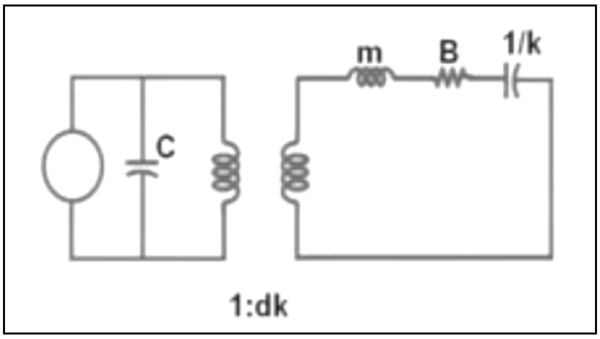


Figure 2.3: Ideal equivalent circuit of transmitter.[21]

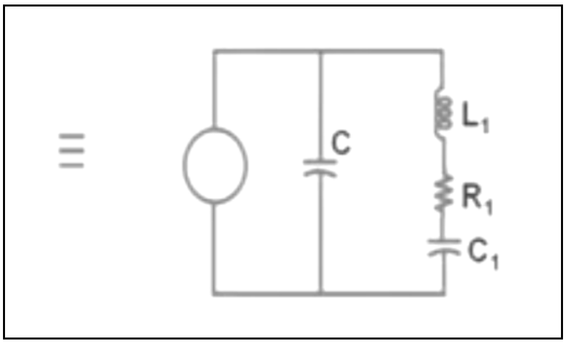


Figure 2.4: Equivalent circuit of transmitter with m, B and 1/K reflected in the primary side.[21]

Where $L_1 = m/(dk)^2$; $R_1 = B/(dk)^2$; $C_1 = d^2k$.

Overall impedance = H(s) or 1

Therefore,

$$H(j\omega) = \frac{\omega R_1 C_1 - j(1 - \omega^2 L_1\ C_1)}{\omega[(C + C_1) - \omega^2 L_1 C C_1] + j\omega^2 C C_1 R_1}$$

Thus, we have two natural frequencies:

ω_n (series natural frequency) = $\frac{1}{\sqrt{L_1 C_1}}$

ω_p (parallel resonant frequency) = $\sqrt{\frac{(C+C_1)}{L_1 C C_1}}$

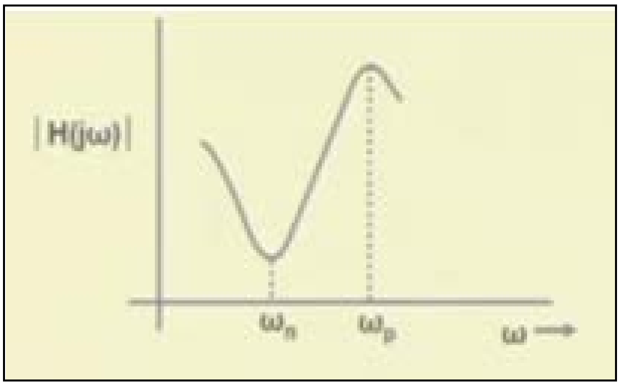


Figure 2.5: Magnitude plot of transmitter.[21]

At $\omega = \omega_n$ magnitude is minimum whereas it is maximum at $\omega = \omega_p$

Assuming $R_1 = 0$

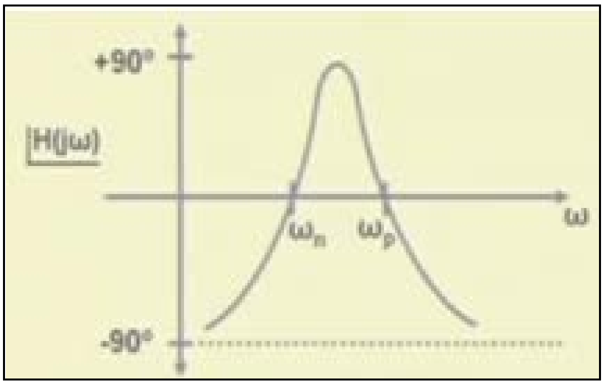


Figure 2.6: Phase plot of transmitter.[21]

At $\omega = \omega_n$ and $\omega = \omega_p$ the system is resistive. When $R_1 \neq 0$ the above diagram shifts towards the right hand side. This circuit behaves as an inductor between ω_n and ω_p.

Transmission of ultrasound:

If P = pressure or stress

$$\dot{x} = u = \text{velocity}$$

Characteristic impedance:

$$Z = P/u$$

Power intensity:

$$W = P*u$$

Average power intensity:

$$W = \frac{1}{\lambda}\int_0^{\lambda} W(z)d(z)$$

Figure 2.7: Transmission of ultrasonic signal in between two medium. [21]

Z_1 = Characteristic Impedance of medium 1

Z_2 = Characteristic Impedance of medium 2

WI = Incident power intensity

WR = Reflected power intensity

WT = Transmitted power intensity

WI is lesser than the power intensity generated by the crystal due to losses on medium 1.

α_R = Reflection Coefficient = $\frac{WR}{WI} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$

α_T = Transmission Coefficient = $\frac{WT}{WI} = \frac{4 Z_1 Z_2}{(Z_2 + Z_1)^2}$

Thus, $\alpha_R + \alpha_T = 1$

If $(Z_2 \sim Z_1)$ is large then more of the incident power intensity is reflected back.

Table 2.1: Characteristic impedance of few materials. [21]

Quartz	=	1.5×10^7
Barium Titanate	=	2.5×10^7
Polymer (PVDF)	=	0.4×10^7
Steel	=	4.7×10^7
Aluminum	=	1.7×10^7
Bone	=	0.8×10^7
Water	=	0.15×10^7
Air	=	430

α_R and α_T for different interfaces.

	α_R	α_T
Quartz / Steel	0.27	0.73
Quartz / Water	0.67	0.33
Quartz / Air	1.00	1.1×10^{-4}

Thus we can say that air is a poor choice for the transmission of ultrasound waves as the difference of the characteristic impedance of air with others is very large.

By using pulse echo technique, the ultrasound can be measured. In this technique, a piezoelectric crystal acting as a transmitter /receiver is attached to medium 1. The characteristic impedance of medium 1 and 2 must be substantially different. First the crystal acts as a transmitter and it sends out a pulse (generated by the pulse generator) of width T_w.

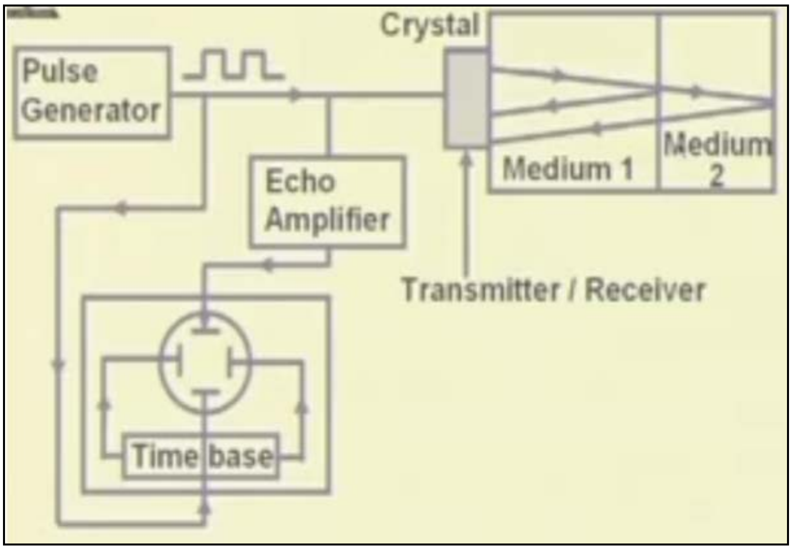


Figure 2.8 Measuring Scheme.[21]

Most of the pulse energy is reflected at the boundary of the medium 1 and 2. The crystal now acts as the receiver and receives a pulse. The time taken by a reflected pulse is

$$T_T = 2I/C$$

Where I= Distance of the interface of the two media from the crystal.

C= Velocity of sound in medium 1.

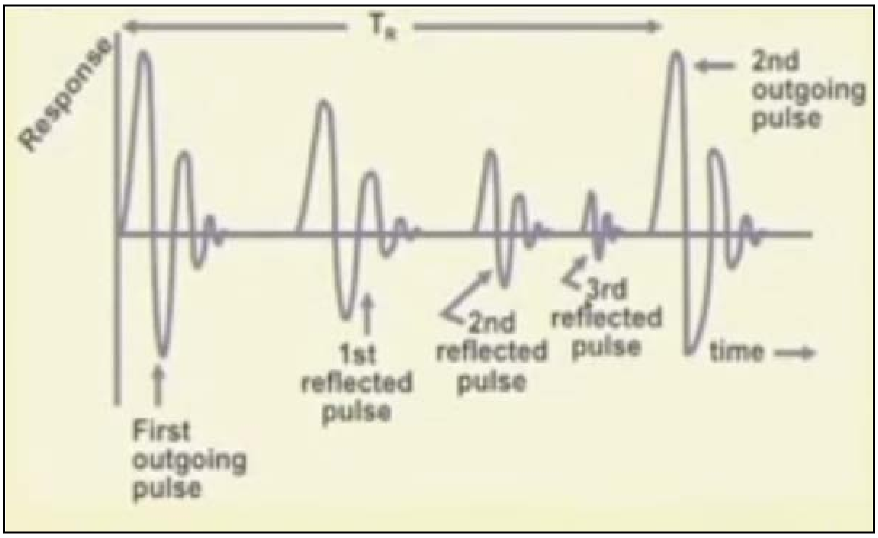


Figure 2.9: Reflected means of ultrasonic signal.[21]

The Repetition Rate T_R should be such that all the reflected pulses of interest have been observed before sending the 2nd pulse. The transmit time T_T should be large compared to the pulse width T_w to avoid interference between outgoing pulse and incoming or reflected pulse.

The advantages of ultrasonic sensor are it is easy to direct and focus a beam of ultrasound as diffraction of these waves are small due to their short wavelength and ultrasonic waves can easily pass through metals. This helps in mounting the measurement system outside the system and it will lead to the development of non-invasive sensor.

2.2.2 Ultrasonic Sensor Applications.

The time of flight (ToF) measurement is the most accurate method among the measurements used. This ToF is the time elapsed between the emission and subsequent collection of a ultrasonic pulse train traveling at the speed of sound, which is approximately 340 m/s, after reflection from an object. The time of flight is given by:

$$t = 2d/v$$

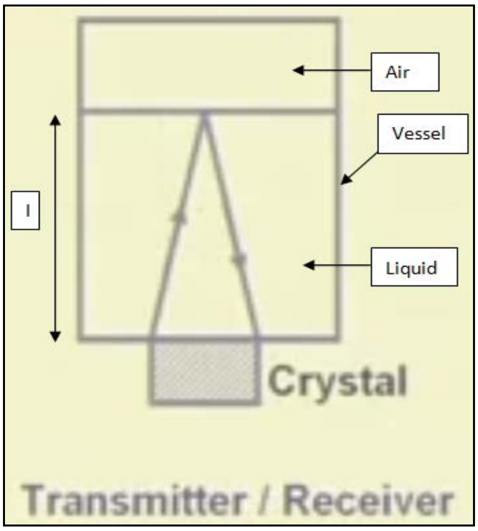
Where v is the velocity of sound in the medium above the surface. The velocity of sound in air is about $3000ms^{-1}$, so for a tank whose depth can vary from 1 to 10m, the delay will vary from about 7ms (full) to 70ms (empty). There are two methods used to measure the delay. The simplest, assume so far and mostly commonly used in industry, is a narrow pulse. The receiver will see several pulses, one almost immediately through the air, the required surface reflection and spurious reflections from sides, the bottom and rogue objects above the surface. The measuring electronics normally provides adjustable filters and upper and lower limits to reject unwanted readings. Pulse driven systems lose accuracy when the time of flight is small. For a distance below a few millimeters a swept frequency is used where a peak in the response will be observed when the path difference is a multiple of the wavelength, i.e.

$$d = v/2f$$

Where v is the velocity of propagation and f the frequency at which the peak occurs. Note that this is ambiguous as peaks will also be observed at integer multiples of the wavelength.

The method discussed above can be used for the following cases with ease.

a) Level measurement. [21]

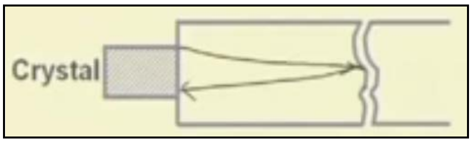


$$T = \frac{2I}{C}$$

$$I = \frac{TC}{2}$$

It is to be noted that the crystal must be placed at the bottom and not at the top. If placed at the top due to presence of air no wave will be able to propagate thus giving us erroneous measurement.

b) Crack detection. [21]



Here crack or gap acts as the second medium and thus helps us to detect where the crack has taken place.

Both methods require accurate knowledge of the velocity of propagation. The velocity of sound is $1440ms^{-1}$ in water, $3000ms^{-1}$ in air and $5000ms^{-1}$ in steel. It is also temperature dependent varying in air by 1% for a 30^0C temperature change. Pressure also has an effect. If these changes are likely to be significant they can be measured and correction factors applied. The speed of sound in air varies as a function of temperature by the relationship [11]:

$$c(T) = 13,044\sqrt{1 + \frac{T}{273}}$$

where:

c(T) = speed of sound in air as a function of temperature in inches per second
T = temperature of the air in °C

The wavelength of sound changes as a function of both the speed of sound and the frequency, as shown by the expression:

$\lambda = c/f$

where:

λ = wavelength
c = speed of light
f = frequency

As the sound travels, the amplitude of the sound pressure is reduced due to friction losses in the transmission medium. Knowing the value of this absorption loss, or attenuation, is crucial in determining the maximum range of a sensor. The attenuation of sound in air increases with the frequency, and at any given frequency the attenuation varies as a function of humidity. The value of humidity that produces the maximum attenuation is not the same for all frequencies. [12,14] Above 125 kHz, for example, the maximum attenuation occurs at 100% RH; at 40 kHz, maximum attenuation occurs at 50% RH. Since an ultrasonic sensor usually is required to operate at all possible humidities, target range calculations should use the largest value of attenuation.

In process industry, ultrasonic sensor also used as level sensor to determine the content or volume of a container. In open or closed tanks, hoppers, and ducts, the liquids, solids suspended in liquid, powdered material, and granular-solid levels are measured. The level of gasoline in the tank for an automobile is measured continuously. [2] Ultrasonic level sensing is based on the damped sensor principle or the density change principle. [2] To detect or locate a particular level, a damped sensor is used. Normally, an automatic filling operation is controlled by this sensor. Generally, to continuous operation, the density change principle is applied. This principle responds to ultrasonic waves being transmitted through materials of the same density. [2] A wave is reflected, when it reaches a pronounced change in density. This is called echo ranging. The operating principle of a damped level sensor shown in Figure 3. On the side of the storage tank, two sensors are located. The sensors respond as ultrasonic wave sources. Each piezoelectric crystal is applied with high-frequency ac, causes vibration and the emission of waves. The upper sensor is surrounded by gas or vapor from the liquid being sensed. The density of this gas is usually quite low. [2] The piezoelectric crystal vibrates with a minimum of opposition as a result.

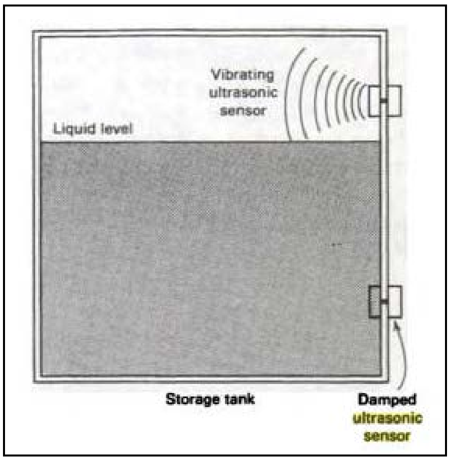


Figure 2.10: Mounted Ultrasonic Sensors.

Through materials of the same density, the density change principle deals with the transmission of ultrasonic waves. A wave is reflected away from the interface when it reaches a large enough change in density. The difference in gas or vapor and the level of material being sensed is the density change. An echo is sensed by an ultrasonic receiver. The time it takes an emitted wave to travel from its source to the material surface and back to the receiver is used to determine the level. An echo-ranging level sensor that responds to the density change principle is shown in Figure 2.11.

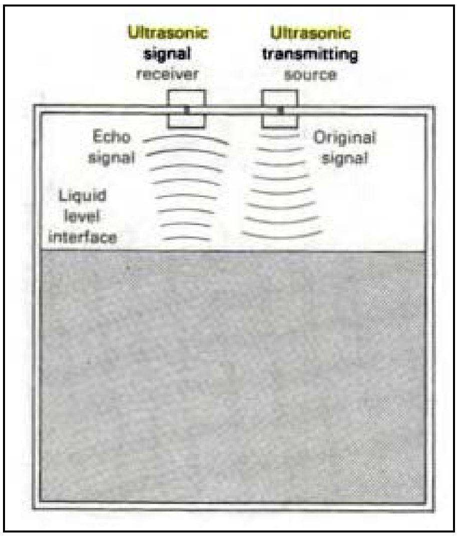


Figure 2.11: Echo-ranging level sensing.[2]

2.2.3 LV- MAXSONAR- EZ1

Figure 2.12: LV-MaxSonar-EZ1.

This sensor measure the distance by using sound and then the information will be reported through one of the three sensor outputs. This sensor has the analog voltage pin outputs to measure voltage. The distance of the object from the sensor is proportional to the output voltage. The closest detectable object will be reported by this sensor. The resolution for this sensor is one inch. In general, this sensor will be range objects from 0 to 6 inches as 6 inches, which corresponds to 58.6mV when powered at +5V DC. This sensor provides range for objects up to 254 inches away. By defining the sensor beam pattern, the closest detectable reflection from an object will be reported by this sensor. By measuring the voltage, we can calculate the range. The voltage scaling of this sensor is: (Refer to datasheet)

$$[(V_{cc} / 512) = V_i]$$

Where Vcc = Supplied Voltage

Vi = Volts per inch (Scaling)

To calculate the range:

$$[(V_m / V_i) = R_i]$$

Where Vm = Measured Voltage

Vi = Volts per inch (Scaling)

Ri = Range in inches

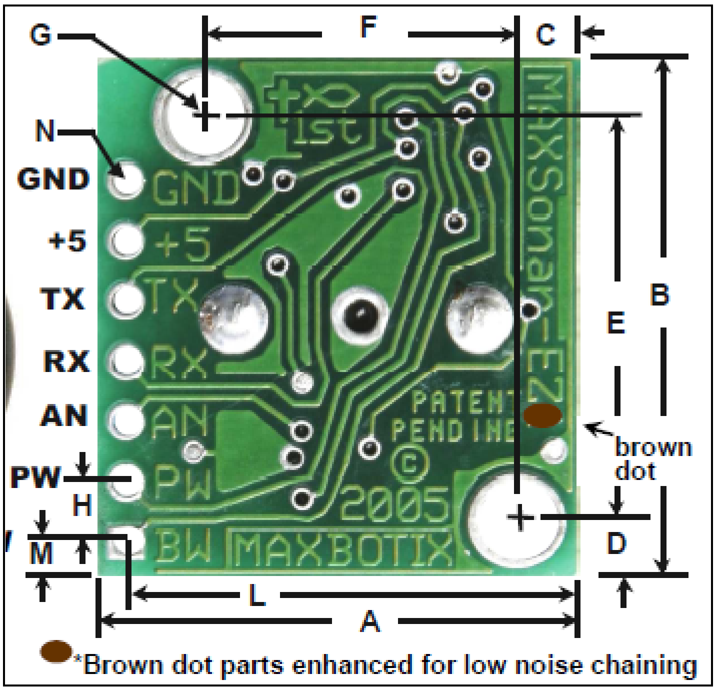


Figure 2.13: LV-MaxSonar Pin Out.

GND Circuit common and DC return.

+5 Vcc operates on 2.5V-5.5V DC. Recommended current capability of 3mA for 5V, and 2mA for 3V.

TX Delivers serial with an RS232 format when BW is set low. When BW pin is set high, it sends a single pulse, for chaining.

AN Analog voltage output. Scaling factor is (Vcc/512) per inch. A 5V supply yields~9.8mV/in.

PW Pulse width representation with a scale factor of 147µS per inch.

BW Leave open (or low) for serial output on TX. Hold high for chaining.

2.3 NI LabVIEW

LabVIEW or short for Laboratory Virtual Instrumentation Engineering Workbench is a product from National Instruments [18].

2.3.1 THE OVERVIEW OF THE LabVIEW.

Figure 2.14: LabVIEW.

In LabVIEW, a user interface or known as front panel will be developed by using a set of tools with controls and indicators Controls are knobs, push buttons, dials, and other input mechanisms. Indicators are graphs, LEDs, and other output displays.

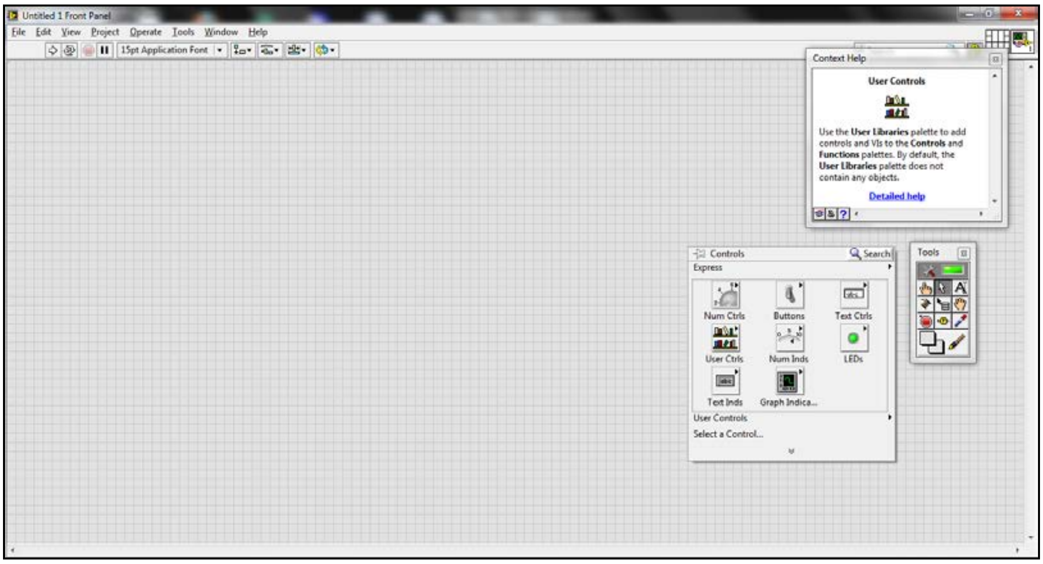


Figure 2.15: LabVIEW Front Panel.

We also build the block diagram to control the user interface using VIs and structures. To a programming problem, the block diagram supplies a pictorial solution. Front panel objects appear as icon terminals on the block diagram. Wires connect control and indicator terminals to Express VIs, VIs, and functions. Data flows through the wires in the following ways: from controls to VIs and functions, from VIs and functions to indicators, and from VIs and functions to other VIs and functions. The movement of data through the nodes on the block diagram determines the execution order of the VIs and functions. This movement of data is known as dataflow programming.

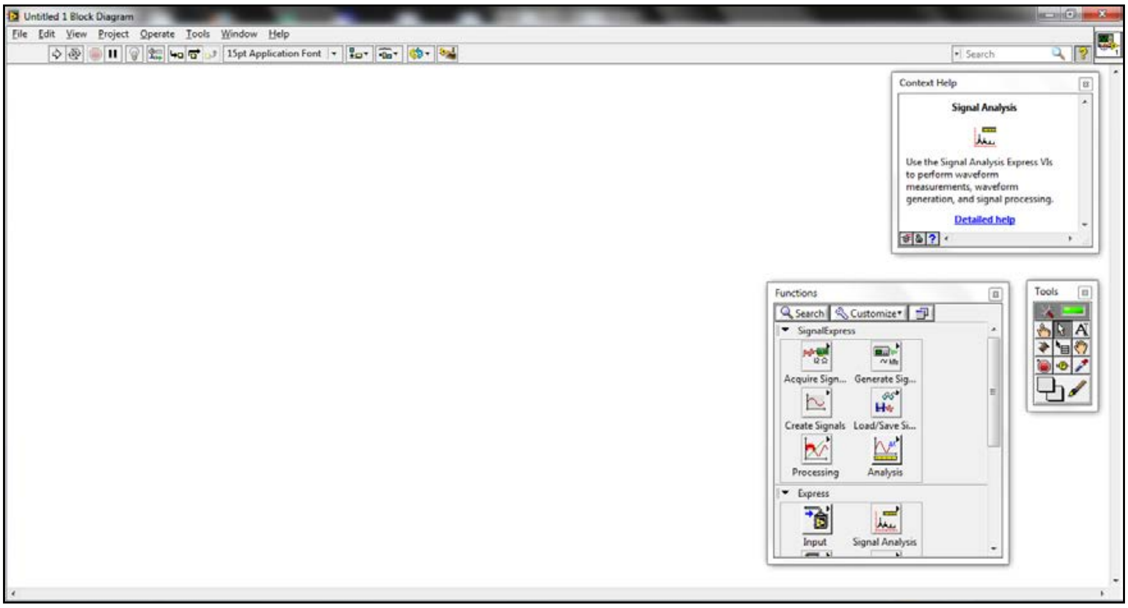


Figure 2.16: LabVIEW Block Diagram.

The application areas of LabVIEW are including to data acquisition and signal processing. LabVIEW is used to communicate with hardware such as data acquisition, motion control devices, vision, GPIB, RS-232, VXI, PXI and RS-485 instruments[18].

2.4 NI DAQ

We used data acquisition to process an electrical or voltage measurement. In data acquisition systems, we have signals, sensors, signal conditioning, DAQ hardware, and a computer with software. We used a sensor (or transducer) to converts a physical phenomenon into a voltage or current. Signal conditioning is essential when we dealing with high voltages, noisy environments, extreme high and low signals, or simultaneous signal measurement and it maximize the accuracy of a system, so that sensors can operate properly and safely. The several types of signal conditioning depend on our signal or sensor type, including amplification, attenuation, isolation, filtering, excitation, linearization, cold-junction compensation, and bridge completion. [15]We used data acquisition hardware to interface a computer and signals from the outside world. To control or drive the hardware, the data acquisition device needs software. Software is what transforms the PC and the data acquisition hardware into a complete data acquisition, analysis, and presentation tool. Without software to control or drive the hardware, the data acquisition device does not work properly. The applications of DAQ are to measure and visualize, data logging, control, test automation, monitoring and prototyping. [15]

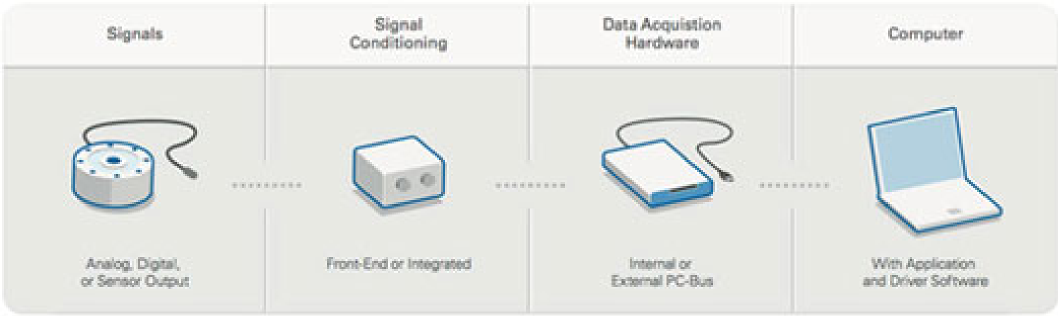


Figure 2.17: Configuration of data acquisition.

Data Acquisition board is use to measure signals and transfer the data into a computer. 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. [16]

2.4.1 NI USB-6009.

In this project, the NI USB-6009 is used to data acquisition purpose. With plug-and-play USB connectivity, it is simple enough for quick measurements and versatile enough for more complex measurement applications. [18]

Figure 2.18: NI USB-6009

It provides eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter with a full-speed USB interface [18].

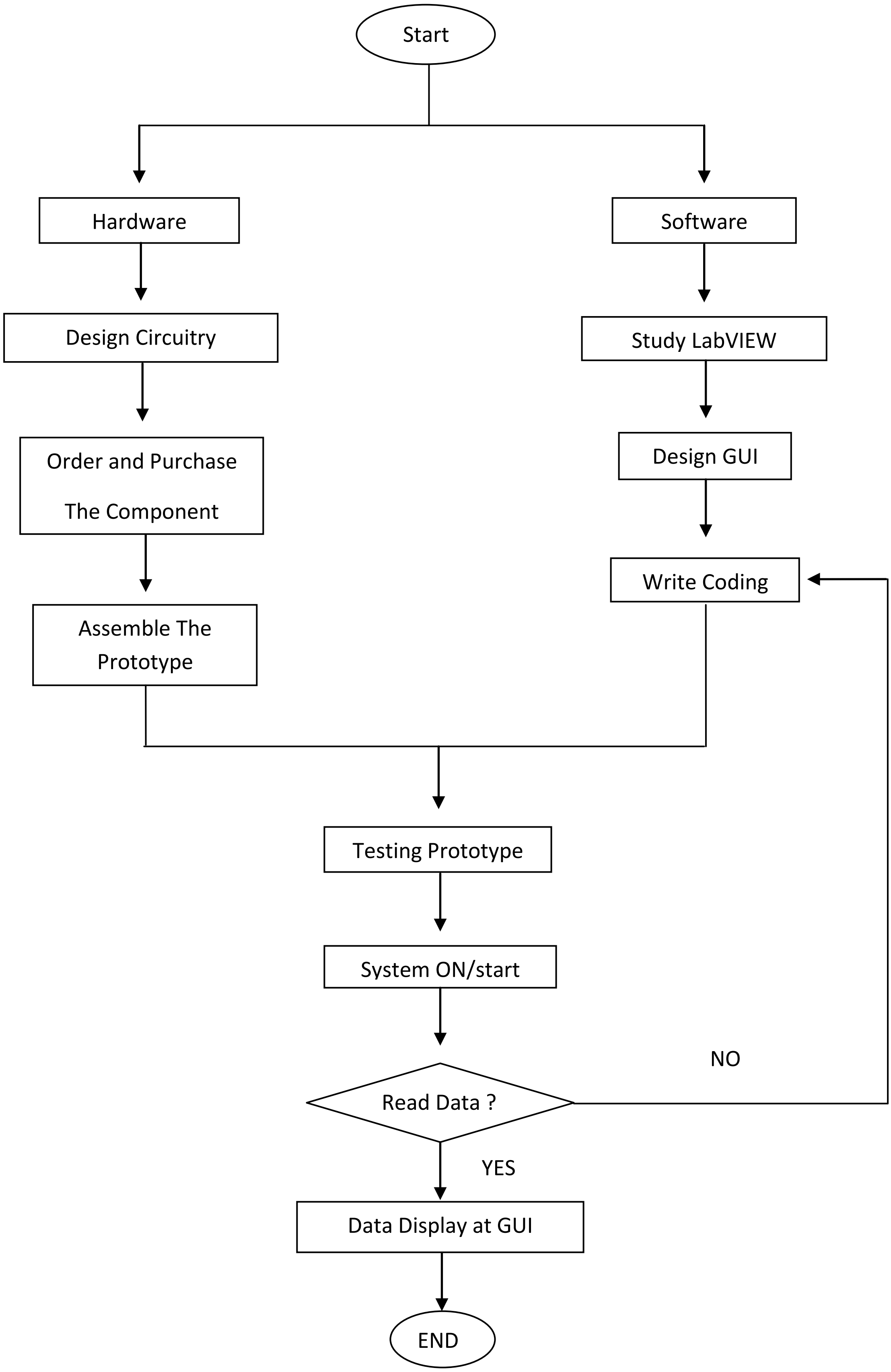
Table 2.2: Signal Descriptions.

Signal Name	Reference	Direction	Description
GND	—	—	**Ground**—The reference point for the single-ended AI measurements, bias current return point for differential mode measurements, AO voltages, digital signals at the I/O connector, +5 VDC supply, and the +2.5 VDC reference.
AI <0..7>	Varies	Input	**Analog Input Channels 0 to 7**—For single-ended measurements, each signal is an analog input voltage channel. For differential measurements, AI 0 and AI 4 are the positive and negative inputs of differential analog input channel 0. The following signal pairs also form differential input channels: <AI 1, AI 5>, <AI 2, AI 6>, and <AI 3, AI 7>.
AO 0	GND	Output	**Analog Channel 0 Output**—Supplies the voltage output of AO channel 0.
AO 1	GND	Output	**Analog Channel 1 Output**—Supplies the voltage output of AO channel 1.
P1.<0..3> P0.<0..7>	GND	Input or Output	**Digital I/O Signals**—You can individually configure each signal as an input or output.
+2.5 V	GND	Output	**+2.5 V External Reference**—Provides a reference for wrap-back testing.
+5 V	GND	Output	**+5 V Power Source**—Provides +5 V power up to 200 mA.
PFI 0	GND	Input	**PFI 0**—This pin is configurable as either a digital trigger or an event counter input.

CHAPTER 3

METHODOLOGY

3.0 FLOW CHART.



3.1 Hardware Development.

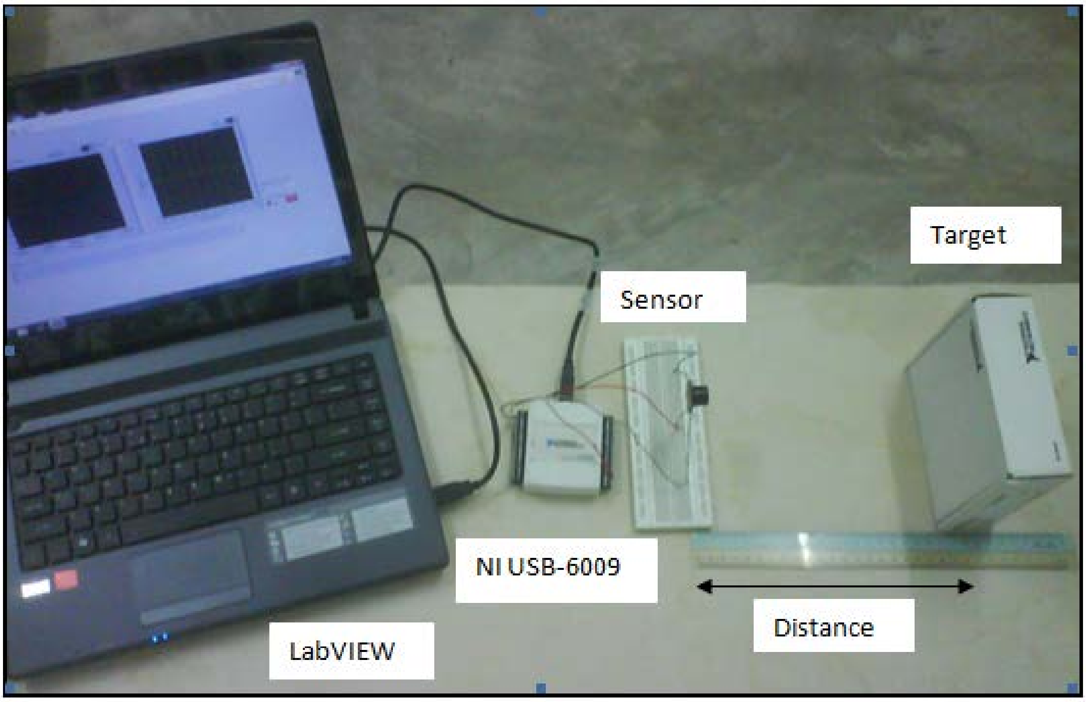


Figure 3.1: Configuration of project circuit.

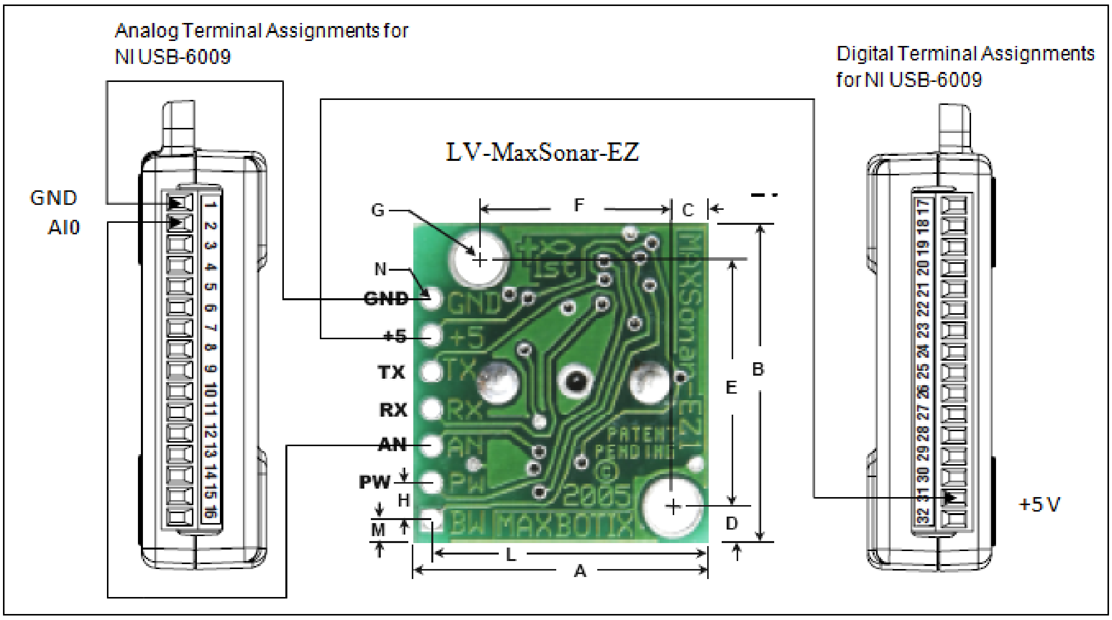


Figure 3.2: Connection between LV-MaxSonar-EZ and NI USB-6009.

In this system, the +5V pin, GND pin and AN pin of the ultrasonic sensor will be connected to +5V pin, GND pin and AI0 pin of NI USB-6009. Then, the NI USB-6009 will be connected to computer. The voltage measurement from the sensor will be displayed by LabVIEW in real-time. After that, we convert the measured voltage to distance by using a formula. Then, the graph of voltage versus distance will be display. The data of result will be stored in a LVM file.

3.2 Software Development.

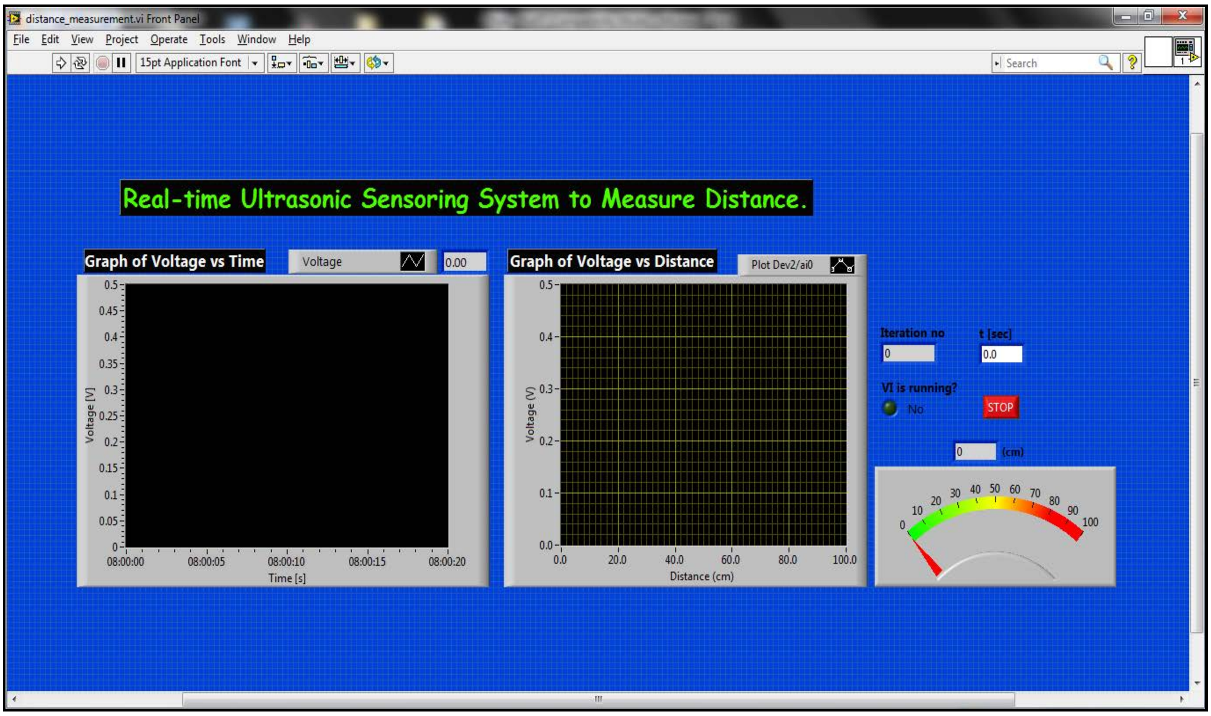
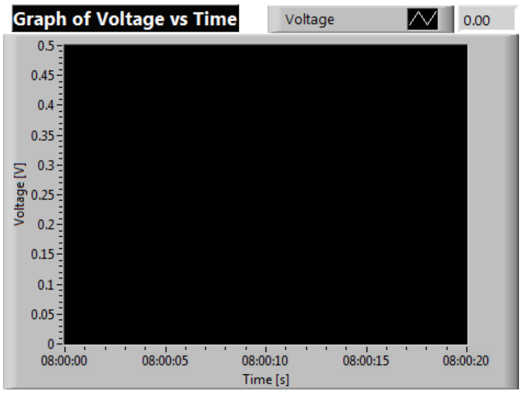
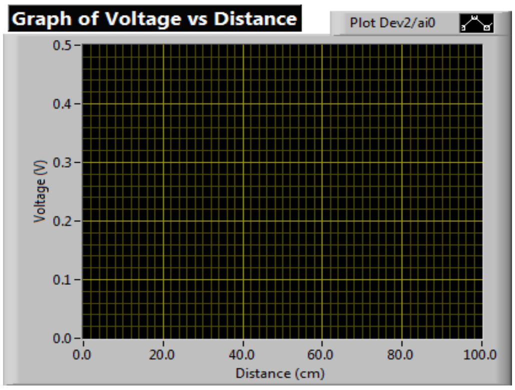
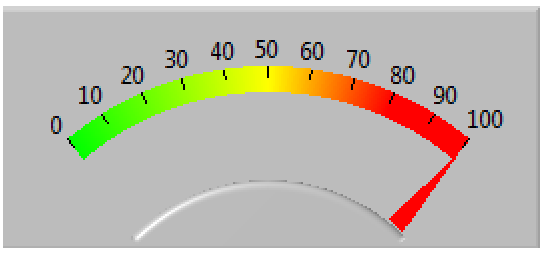
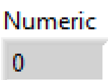


Figure 3.3: LabVIEW Front Panel.

Types of Indicator	Description
Waveform Charts.  	The waveform chart is a special type of numeric indicator that displays one or more plots of data typically acquired at a constant rate. The waveform chart maintains a history of data, or buffer, from previous updates. The frequency at which you send data to the chart determines how often the chart redraws. This chart displays the value of the level according to measurement signal.
XY Graph  	The XY graph displays any set of points, evenly sampled or not. The XY graph can display plots containing any number of points. The XY graph also accepts several data types, which minimizes the extent to which you must manipulate data before you display it. In this graph, the X-input is distance and the Y-input is voltage.
Rotary indicator  	A numeric objects with a scale. We used this indicator to display the distance from the results of formula.
Numeric indicator  	Display numeric data

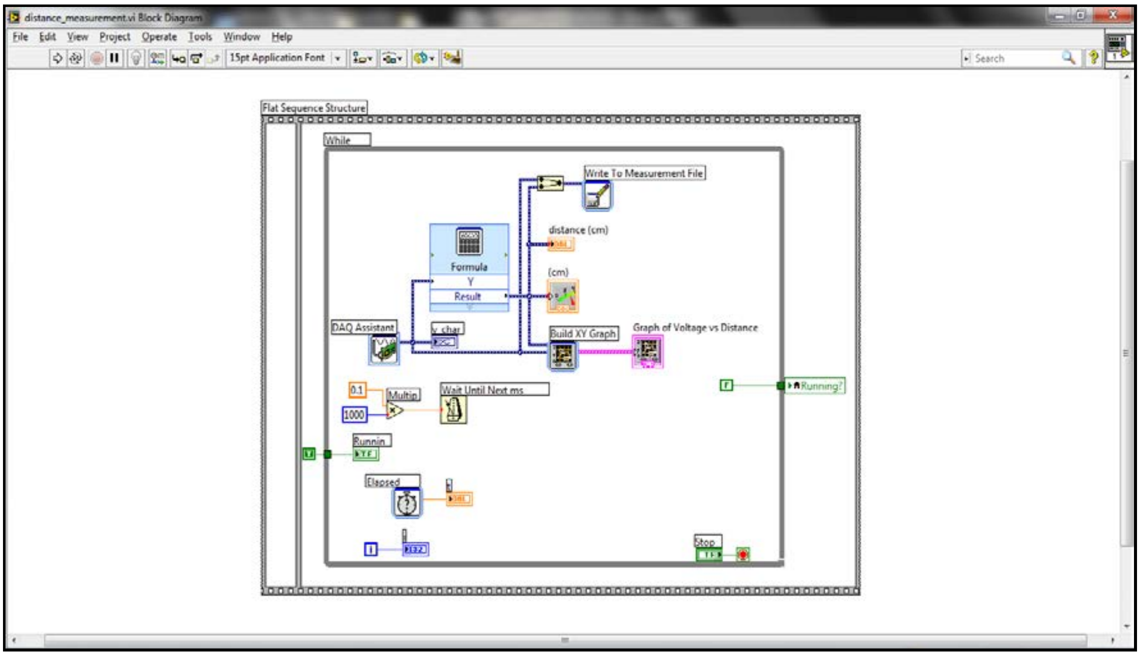
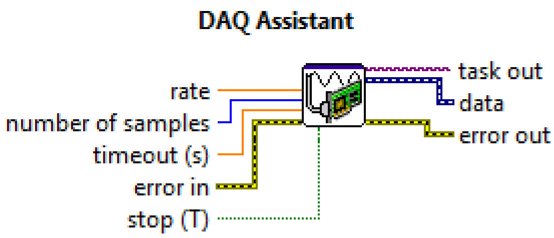
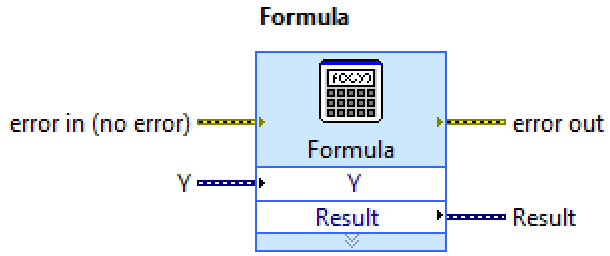
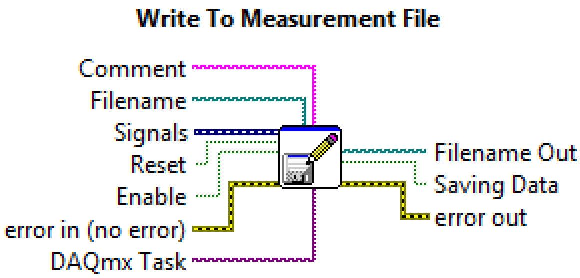
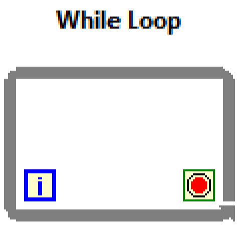
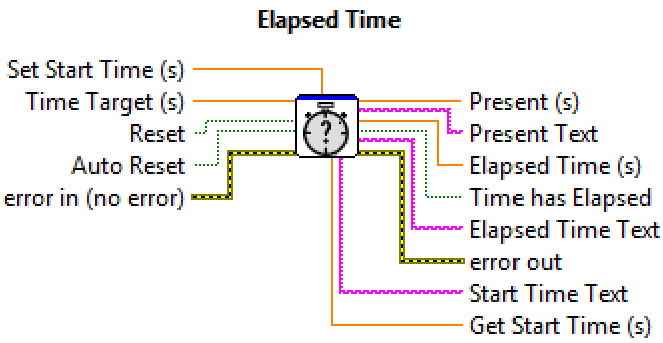


Figure 3.4: LabVIEW Block Diagram.

Symbol	Description
	**data** contains samples to write to the task. **data** is an output for measurement tasks and an input for analog. In this project data is analog input voltage. **number of samples** specifies the number of samples to acquire or generate for each channel in a finite task. For finite tasks, this VI ignores all settings for this input other than the initial input. **rate** specifies the sampling rate in samples per channel per second. **timeout(s)** specifies

	the amount of time in seconds to wait for the VI to read or write all samples. This VI returns an error if the time elapses. The default timeout is 10 seconds.
	Uses a calculator interface to create mathematical formulas. In this project, the Y-input is voltage and the result is distance.
	Writes data to text-based measurement files (.lvm)
	Repeats the subdiagram inside it until the conditional terminal, an input terminal, receives a particular Boolean value. The Boolean value depends on the continuation behavior of the While Loop.
	Keeps track of time by indicating when a certain amount of time has elapsed. The elapsed time is the present time minus the start time that we specify.

CHAPTER 4

RESULTS AND DISCUSSIONS.

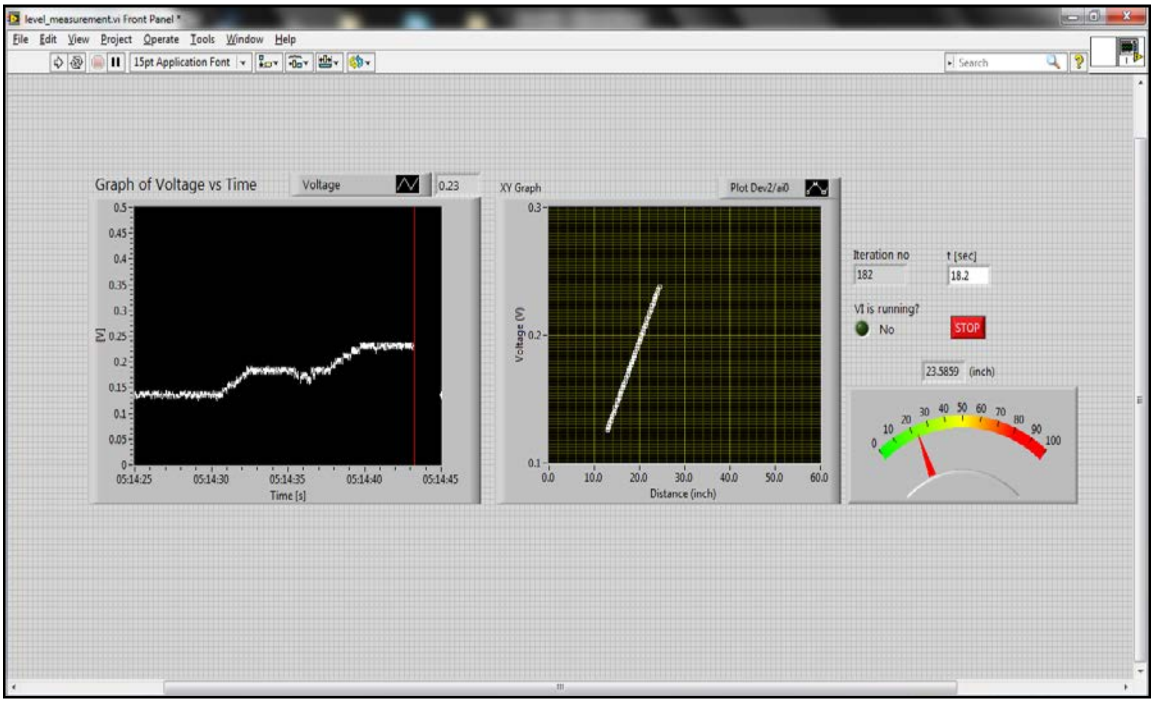


Figure 4.1: Graph of voltage and distance measurement.

The voltage measurement was testing by ranging the distance. The result shows that when the range increases, the voltage also increases. But, this ultrasonic sensor will be range objects from 0 to 6 inches as 6 inches, which corresponds to 58.6mV when powered at +5V DC. The result of measurement is displayed in real-time. In this measurement, the supplied voltage, Vcc is +5V DC.

So that, The voltage scaling of this sensor is:

[(Vcc / 512) = Vi]

[(5V / 512)] = 9.765625mV

Where Vcc = Supplied Voltage

Vi = Volts per inch (Scaling)

To calculate the range:

[(Vm / Vi) = Ri]

Where Vm = Measured Voltage

Vi = Volts per inch (Scaling)

Ri = Range in inches

In this project, two experiments were conducted. For the first case, the voltage was measured at ten different distances for three sets of reading. Then, the average voltages were calculated to plot the linear graph of voltage versus distance. After that, the slope of graph was obtained to find the linear relationship between the voltage and distance. From the measurement results that was done, the accuracy of measurement of this ultrasonic sensor can be determined. For the second case, we measure the voltage of three different materials at ten different distances to investigate the effects of type of materials to voltage measurement.

Case 1.

Table 4.1: Voltage output of ultrasonic sensor versus distance.

Distance, x (cm)	y_1 (V)	y_2 (V)	y_3 (V)	Average, y (V)
15	0.10	0.11	0.10	0.10
20	0.11	0.11	0.10	0.11
25	0.12	0.13	0.12	0.12
30	0.14	0.14	0.14	0.14
35	0.16	0.16	0.16	0.16
40	0.18	0.18	0.18	0.18
45	0.20	0.20	0.20	0.20
50	0.22	0.22	0.22	0.22
55	0.24	0.24	0.24	0.24
60	0.26	0.26	0.26	0.26

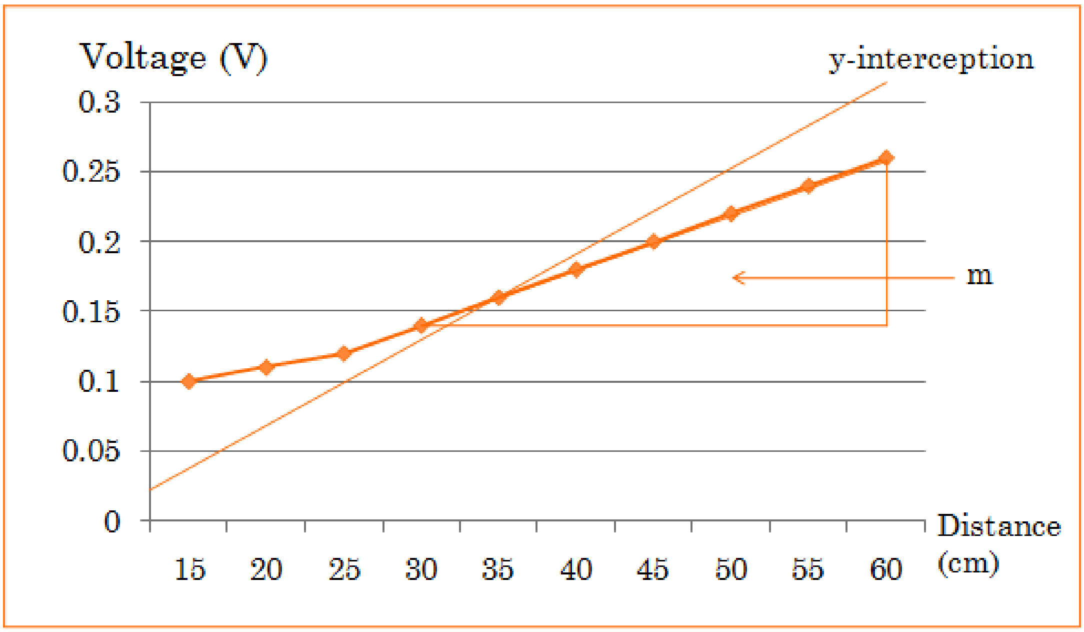


Figure 4.2: Graph of average voltage versus distance.

Based on graph above,

y = mx + c

y = Voltage (V)

x = Distance (cm)

m = Gradient of graph

c = Interception of y

m = (y2 - y1) / (x2 - x1)

m = (0.26 – 0.14) / (60 – 30)

m = 0.004

c = 0.02

Therefore, the equation for the linear relationship between voltage and distance is

y = 0.004x + 0.02

This means the voltage output goes up 0.004 for each cm an object moves away.

From the measurement results that was done, the accuracy of measurement of this ultrasonic sensor can be determined.

At 0.10 V,

$$\text{Relative Error} = \left| [(\text{Experimental} - \text{Theoretical}) / \text{Theoretical}] \times 100\% \right|$$

$$= \left| [(20cm - 26cm) / 26cm] \times 100\% \right|$$

$$= 23.08\%$$

At 0.12 V,

$$\text{Relative Error} = \left| [(25cm - 31.21cm) / 31.21cm] \times 100\% \right|$$

$$= 19.9\%$$

At 0.14 V,

$$\text{Relative Error} = \left| [(30cm - 36.41cm) / 36.41cm] \times 100\% \right|$$

$$= 17.61\%$$

At 0.16 V,

$$\text{Relative Error} = \left| [(35cm - 41.62cm) / 41.62cm] \times 100\% \right|$$

$$= 15.91\%$$

At 0.18 V,

$$\text{Relative Error} = \left| [(40cm - 46.82cm) / 46.82cm] \times 100\% \right|$$

$$= 14.57\%$$

At 0.20 V,

Relative Error = $\left|[(45cm – 52.02cm) / 52.02cm] \times 100\%\right|$

= 13.5%

At 0.22 V,

Relative Error = $\left|[(50cm – 57.22cm) / 57.22cm] \times 100\%\right|$

= 12.62%

At 0.24 V,

Relative Error = $\left|[(55cm – 62.42cm) / 62.42cm] \times 100\%\right|$

= 11.89%

At 0.26 V,

Relative Error = $\left|[(60cm – 67.62cm) / 67.62cm] \times 100\%\right|$

= 11.27%

The average of relative error = (23.08% + 19.9% + 17.61% + 15.91% + 14.57% +

13.5% + 12.62% + 11.89% + 11.27%) / 9

= 15.59%

The efficiency of measurement can be influenced by air. Air is a poor choice for the transmission of ultrasound waves as the difference of the characteristic impedance of air with other materials is very large. Another variables which can effect the operation of ultrasonic sensing can be include: target surface angle, reflective surface roughness or changes in temperature or humidity. Temperature of air between the sensor and the target can effect measurement accuracy since the speed of sound varies with temperature. At room temperature, the speed of sound changes approximately 0.175% / C^0 or 1% for every $5.7C^0$. As temperature increases, target will measure closer and vice versa. The value of humidity that produces the maximum attenuation is not the same for all frequencies. At 40kHz maximum attenuation occurs after 50% RH. Since an ultrasonic sensor usually is required to operate possible humidities, target range should be use the largest value of attenuation.

Case 2.

Table 4.2: Voltage output of ultrasonic sensor versus distance for different materials.

Distance, x (cm)	Types of material		
	Paper	Aluminium	Plastic
15	0.10 V	0.10 V	0.10
20	0.11 V	0.11 V	0.11
25	0.12 V	0.13 V	0.13
30	0.14 V	0.15 V	0.15
35	0.16 V	0.18 V	0.17
40	0.18 V	0.19 V	0.19
45	0.20 V	0.21 V	0.20
50	0.22 V	0.22 V	0.23
55	0.24 V	0.25 V	0.24
60	0.26 V	0.27 V	0.27

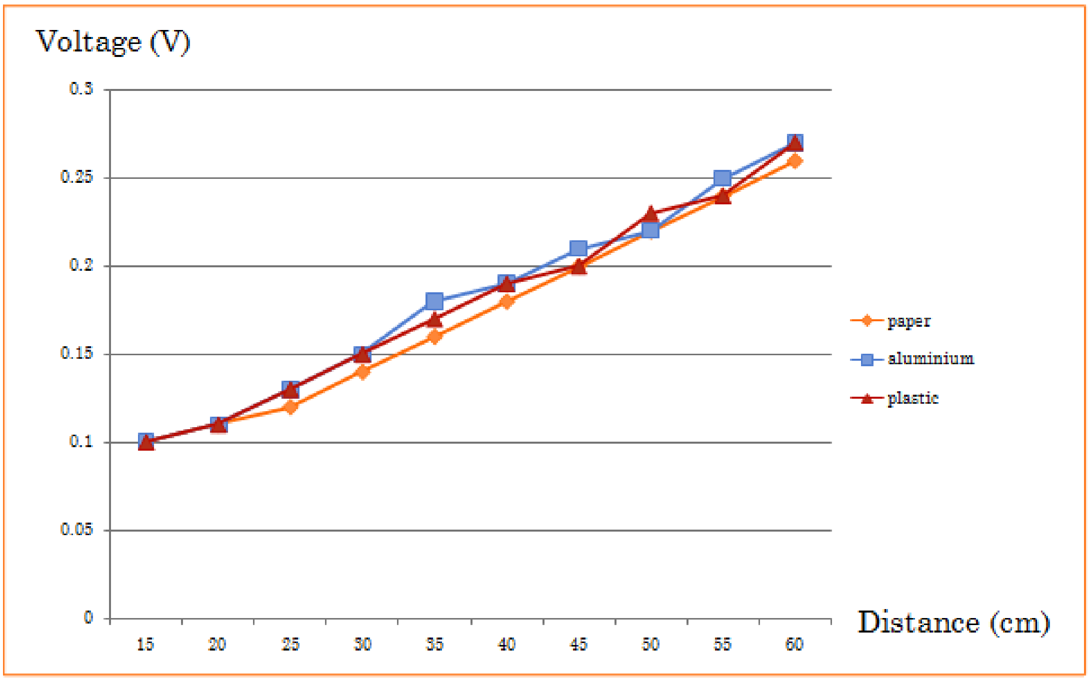


Figure 4.3: Graph of voltage versus distance for different materials.

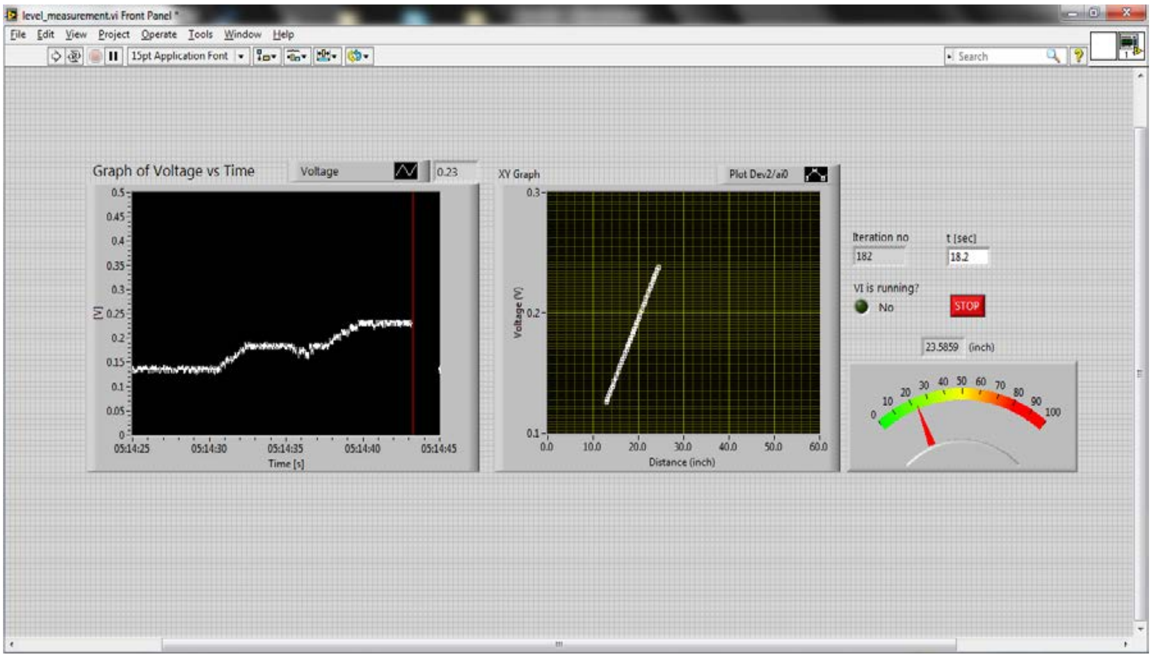


Figure 4.4: Results measurement for box.

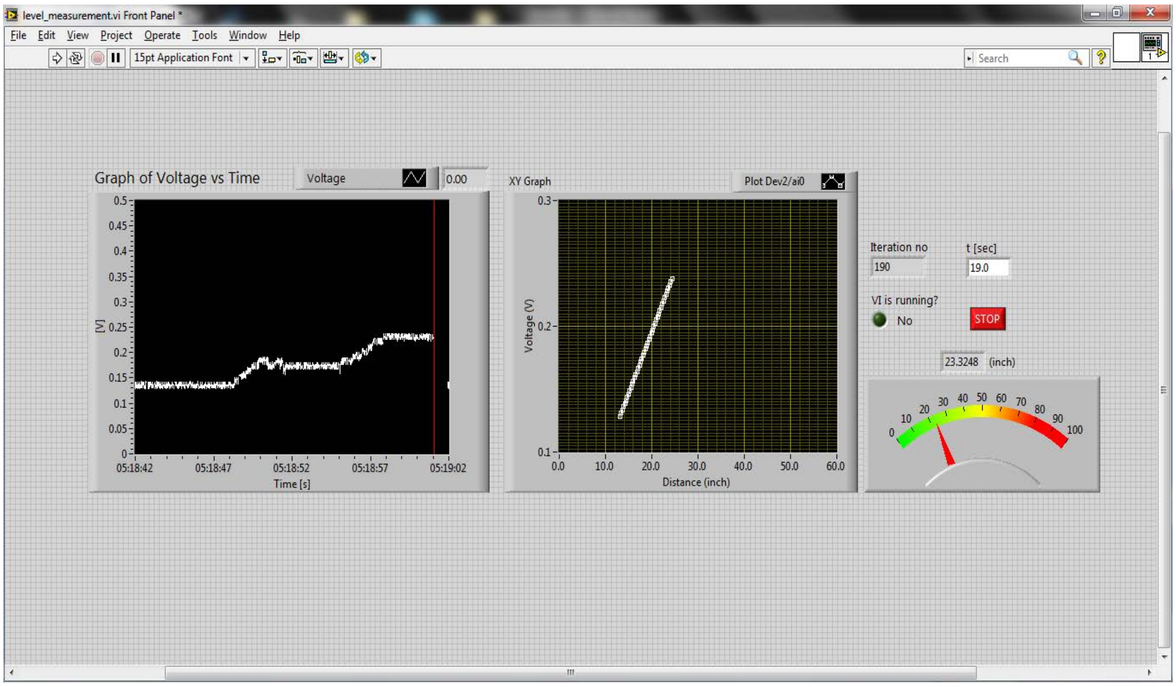


Figure 4.5: Results measurement for aluminium.

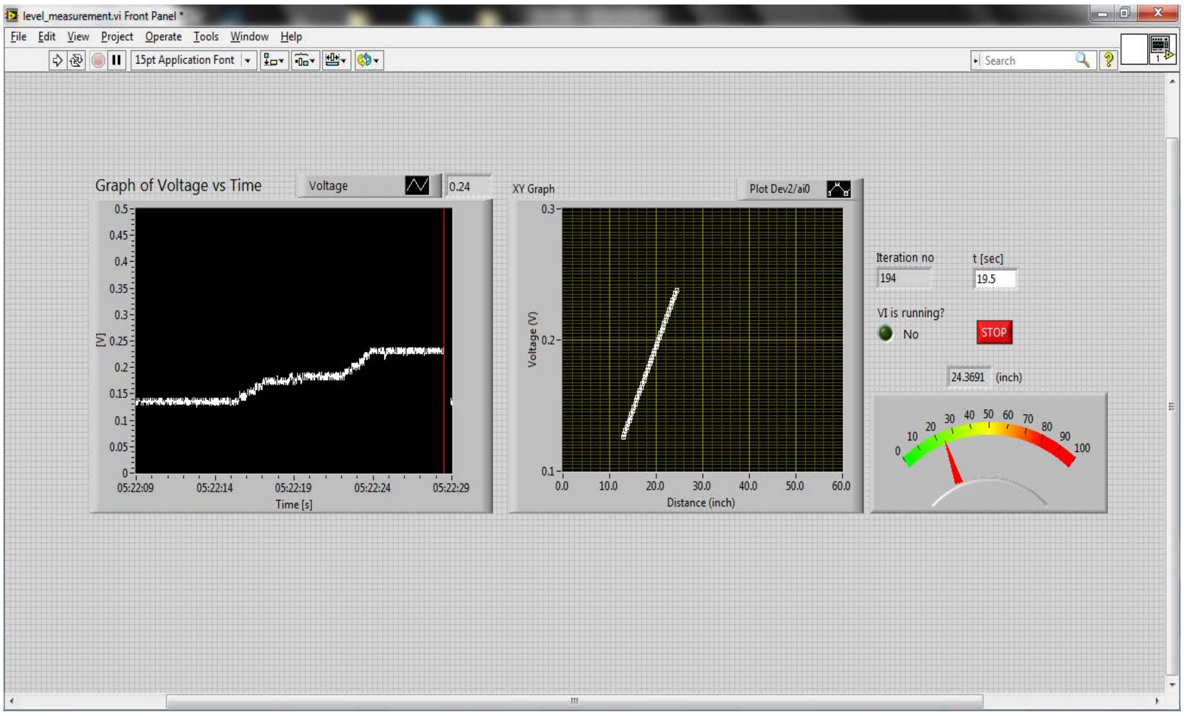


Figure 4.6: Results measurement for white plastic surfaces.

In case 2, we measure the voltage of three different materials at ten different distances to investigate the effects of type of materials to voltage measurement. We can see that the results for all the three type of materials are almost same. These results show that the ultrasonic measurements are less affected by target materials, surfaces and color because the output signal from the ultrasonic sensor does not depend on surface color and smoothness. As we know, ultrasonic sensors use sound instead of light for ranging. The high frequency of ultrasound avoids interference from many audible, low frequency noises due to wind, machinery pumps and vibration of large bodies.

4.2 Problems of project.

The measurement of ultrasonic sensor limited by the shapes of surfaces, the density or consistency of the material and limitations due to their wide beam width and sensitivity to specular surfaces. The efficiency of measurement also can be influenced by air. Air is a poor choice for the transmission of ultrasound waves. To overcome these problems, the shape of surfaces must be flat. Reflecting objects that are almost normal to the sensor acoustic axis may be accurately detected. To improve the accuracy of measurement, we can choose the water or aluminium for the transmission of ultrasound waves because the difference of the characteristic impedance of these mediums with air are smaller.

CHAPTER 5

CONCLUSIONS AND FUTURE RECOMMENDATIONS.

5.1 CONCLUSIONS.

As the conclusion, the working prototype of ultrasonic sensor system was designed. In this project, we focused on the ability of the sensors to detect the range of objects of flat surfaces and of different materials and the result shows that when the distance increases the voltage also increases. Based on case1 and case 2, we can see that the voltage output goes up 0.004 for each cm an object moves away and the ultrasonic measurements are less affected by target materials, surfaces and color. Since we used flat surfaces in this experiment, we achieved good results. The results of measurement was displayed in real-time by using LabVIEW.

5.2 FUTURE RECOMMENDATIONS.

For future, this project can be implementing to control the range by providing trigger or alarm. Since ultrasonic sound waves reflect off the target object, target angles indicate acceptable amounts of tilt for the sensor. If an application requires a target angle beyond the capabilities of a single sensor, two sensors can be teamed up to provide an even broader angle of tilt.

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