

COMPUTER BASED INSTRUMENTATION FOR LEVEL MEASUREMENT USING
VISUAL BASIC APPLICATION

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This thesis is submitted as partial fulfillment of the requirement for the
award of the Bachelor Degree of Electrical Engineering (Electronic)

Faculty of Electrical & Electronic Engineering
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NOVEMBER 2008

DECLARATION

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Date : 10 NOVEMBER 2008.

DEDICATION

Specially dedicate to
My beloved parents, brothers and sisters.

ACKNOWLEDGEMENT

First, I would like to express my acknowledgment and thanks to my supervisor, Miss Najidah Bt Hambali and not forget to the replacement supervisor Mr Anwar Zawawi for their guidance and co-operation during the project is develop by me

I also deeply thank to my family whose have giving me chance to continue my study at University Malaysia Pahang and full support to complete this project. Thanks for their encouragement, support, love, and their time

Finally, my great appreciation to my house mate that giving me so many opinion till I don't know which one to comprehend, especially Khuzairy, Hasbullah and Faiz thanks for their brilliant idea and my class mate whom involve directly or indirectly with this project. Thank You very Much.

ABSTRACT

Interfaces commonly used to connect computers to instruments system. It is not intended to be definitive, or very detailed, but to give the user an idea of what is readily achievable with the various systems. In this context, the study, research and system development will be focused on using GUI system as a medium to interface with the instrument part. There are several of GUI systems today but Visual Basic application will be use for this project. However, most of computer based instrumentation system widely use in industrial field compared to study field. The purpose of this project is to study the concept of computer based instrumentation system itself, redevelop the system just to make sure it's more efficient and user friendly and to find the answer whether it's suitable to be implement as a learning tools or not. As a result the system developed will be able to interface with the level measurement instrumentation and it can be a very useful learning tool for lab session of subject BEE 4523: Industrial Instrumentation. This system will reduce all the calculation hassle that might be face by the student and will reduce the calculation error because this system provide 100 % calculation made by the computer and the precision of graph should not be hesitate by the user.

ABSTRAK

Pengantaramukakan sering digunakan sebagai penyambung diantara komputer dan sistem peralatan. Ia tidak perlu bertujuan untuk didefinisikan secara mendalam, tetapi hanya memadai untuk memberi idea secara rambang kepada pengguna terhadap apa yang telah dicapai dalam pelbagai sistem yang berbeza. Dalam konteks ini, kajian dan pembinaan sistem lebih difokuskan terhadap penggunaan sistem GUI (Graphical User Interface) sebagai medium untuk mengantaramukakan komputer dengan bahagian peralatan. Terdapat pelbagai jenis sistem GUI dipasaran pada hari ini tetapi aplikasi Visual Basic akan digunakan secara menyeluruh dalam membangunkan projek ini. Bagaimanapun, kebanyakan penggunaan sistem yang berasaskan komputer dan peralatan lebih digunakan secara meluas dalam bidang pengindustrian berbanding bidang pengajian. Tujuan utama projek ini dibangunkan adalah untuk mengkaji konsep penggunaan sistem berasaskan komputer dan peralatan itu sendiri, membina kembali sistem yang sedia ada untuk memastikan ia lebih efisien dan mesra pengguna. Serta mencari jawapan, samada aplikasi sistem ini mampu diilhamkan sebagai alat bantu mengajar yang sangat berguna untuk sesi makmal bagi subjek BEE 4523: Industri Instrumentasi. Sistem ini akan mengurangkan segala kerumitan dalam pengiraan yang terdapat dalam sesi lab subjek berkenaan yang mana akan dihadapi sendiri oleh pelajar. Sistem ini juga menawarkan pengurangan peratus kesilapan yang akan dilakukan oleh pelajar kerana sistem ini menyediakan pengiraan 100 % yang akan dilakukan oleh sistem komputer dan kepersisan dan ketepatan graf yang diplot tidak perlu diragui oleh pengguna lagi.

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LIST OF SYMBOL.

USB	-	Universal Serial Bus
DAQ or DAQ	-	Data Acquisition
mA	-	miliampere
m	-	meter
A	-	Ampere
Ω	-	ohm
mV	-	milivolt
I/O	-	input/output
ADC	-	analog-to-digital converter
PC	-	Personal Computer
DAC	-	digital-to-analog converter
RAM	-	Random Access Memory
CPU	-	Central Processing Unit
MHz	-	megahertz
GUI	-	Graphical User Interface
V	-	Volt
IDE	-	Integrated Development Environment
RAD	-	Rapid Application Development
MSDN	-	Microsoft Studio Network
S/H circuit	-	Sample and Hold circuit
MUX	-	Multiplexer
UUT	-	Unit Under Test
MSU	-	Master Standard Unit
γ	-	Degree of Freedom

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

“Time best describe as a sharp sword, if you don’t try to manipulate it, it can cut you into pieces”. These words might be useful as a reminder for every human in this world. Time is priceless and it can’t be replaced with anything in this world. As a conclusion, time can be a mute enemy for lecturers in UMP. One semester which consists of six months might be enough for them, but for several reasons such as attending a workshop/seminar, absent because of private reason or on a medical leave, and a lot of public holiday will give an impact on them. As a result, they have to minimize the lab session or ignore it just because to give way to them to cover up a lot of topic before the semester end. This situation should be reconsidered back because through the lab session students might learn more compared to lectures session. They can implement the knowledge that has been taught in class on experiment they had. Besides, learning through experience (project or lab session) is better if compared to

theoretical exercise (homework or notes). For some students who are not so good at the theoretical parts they might be left behind in class.

Some lab session might be difficult if it is done manually, for an example, level instrumentation lab session for BEE4353 contains a lot of calculation that include the mean, standard deviation, uncertainties calculation and students should plotting two graphs. During the lab session, laboratory hand out might be provided by the lecturer, but to understand all those steps and all those equation that contain in it might need a lot of time. Some of the students eager to solve all those problems on their own within the two hours lab, but some of them just becoming a 'parasite' which means, they are not interested to solve the problems but they just want to copy the laboratory results from their friends. The project that will be developed in this project not can make the difficult job become easier but it can also attract and gain interest of these 'parasite' to do their lab session on their own.

Bored with the common system that need user to insert the reading value in text box? Sick of starring at the computer again and again just to confirming the reading entered is right enough? Now everything of it can be replaced with multiple clicking methods only. User just needs three single steps to do this lab session. First, user needs to set up the instrument/apparatus according to the lab sheet provided. Second, user needs to calibrate the reading of DAQ card. Third, user now can start to click the buttons appear in the system. Do not hesitate about it anymore because, every single readings that appears at the Digital Manometer will transferred automatically into the PC, thus this will reduce the typing error occur. If the user follows every single step by referring to the lab sheet, the lab session will end with the desired result. This system is readily to use and it is compatible with the Windows. User does not need to install it into their computer if they want to use it, with just a simple clicking, the system will run automatically and user ready to use it

1.2 PROBLEM STATEMENT

1.2.1 Accuracy of Calculation & Graph

How precise the last result you got compared to the real result provided is depends on how accurate the reading calculation you have made. Previously, calculation made for this kind of laboratory mostly through the manual way (use calculator). Although the calculation made by calculator is correct but the range point of decimal is limited compared to the calculation made by the pc or computers. Some students say, plotting graph might give them a problem. It is all because of; finding the accurate point to plotting graph is hard because the scale of graph paper provided is fixed and cannot be manipulate. Compared to graph plot by the computer, the accuracy of it cannot be argued anymore as long as the point you plot is correct.

1.2.2 User friendly

Manual or traditional style does not provide you a user friendly facility. Fault or error might occur if the user does not understand or not clear about the instruction in the lab sheet given. Especially for several lab session which can described as difficult or complicated.

1.3 PROBLEM SOLUTION

The software that is developed has some advantages to overcome some normal problems that will face by user as state in problem statement.

- i. This software provides a wide range of decimal point compared to a regular scientific calculator. Thus, this helps user to get a more accurate and precise result at the end of the lab session
- ii. This software has offers a user friendly facility which helps the user to work on the right path even though the user does not understand anything about the instruction in lab sheet provided. Every single step to complete the lab session will be on the right track. Thus the user does not have to worry about it.

1.4 CURRENT SITUATION

Students always complaining they need a lot of time to done this kind of experiment. Although they were aid with the lab sheet given by the lecturer, they have to take time to understand each instruction in the lab sheet. Some of them have an brilliant idea which lead the computer based instrumentation of level measurement created to fulfill their desire. It will help user reduce their time by doing experiment in shorten time

1.5 OBJECTIVE

1.5.1 INSTRUMENT

To understand about the basic measurement principle of level measurement instrumentation and to do more research about the basic measurement principle of level transmitter itself, because there are several type of measurement devices such as differential pressure transmitter that can be used.

1.5.2 HARDWARE

To interface the level measurement instrumentation with software system by using DAQ board. Familiarize with various type of data communication to computer like USB, serial port and parallel port. Each of these have different configuration. This system will use USB as a way to connect to computer in order to receive data from instrument.

1.5.3 SOFTWARE

To develop system using Visual Basic application which easy for user to plotting graph and calculate the uncertainty value. There are several version of visual basic in the market. Some researchers have been made just to make sure what is the best version that should be use to complete this project and get to know more about the real role of visual basic itself.

1.6 SCOPE

The scopes of the project are

- i. Study the basic measurement principle of level transmitter.
- ii. Searching for the suitable DAQ board model which is can be interface with the visual basic application. Several DAQ board that can be find in market mostly different in model and also can interface with different application
- iii. Build up a software that useful for study purpose, make students eager to use the software which will lead them to done their job without any calculation error occurs compare to the all fashion style which is more complicated and takes a lot of time

1.7 THESIS ORGANIZATION

This thesis been made in five chapters which discuss and talk about the overview of the project, objective research, project scope, problem statement and also thesis organization

While in chapter 2, most of this chapter contains of detailed description of literature review based on development of this project. It will explain everything on what previous project that been made by others which is quite same with this project.

In chapter 3, methodology of this project will definitely discuss in this part. It will explain about how the project is being organized and also included about the flow to completing this project. All the circuit design, software design and hardware part will be discussed completely in this chapter.

All the result regarding from this project will be included in chapter4. In this chapter also will contain with the end result and discussion about the project. And finally, the conclusion for this project will be presented in last chapter; chapter5. At this part, recommendation about the future development of this project will be discuss

CHAPTER2

LITERATURE REVIEW

2.1 INTRODUCTION

Computer based instrumentation for level measurement using visual basic application is an automatic system to completing level instrumentation lab session for subject BEE 4523 : Industrial Instrumentation. This system consists of 3 parts which is consists of instrument part, hardware part and software development. Each modules carries own functioning and special features

2.2 Theory of Pressure Measurement

2.2.1 Absolute pressure, gauge pressure, differential pressure and vacuum

Pressure is the force exerted by a gas or liquid on a surface. The SI unit of pressure measurement is the Pascal (Pa). Other common units are N/m², Torr, psi and bar. It is critical to specify the reference point of the pressure.

When we measure a pressure in a system with perfect vacuum or absolute zero as the basis then we call the value of the pressure as the *absolute pressure*. When the pressure is measured with reference to the atmospheric pressure as the basis then the measurement is called the *gauge pressure*. The relationship between absolute pressure and gauge pressure is expressed as

$$P_a = P_g + 101.3$$

Where,

P_a And P_g = absolute and gauge pressure respectively, kPa

The 101.3 in the equation is the standard atmospheric pressure at the earth's surface in kPa.

Vacuum gauges are used when the pressure being measured has a value less atmospheric pressure. Vacuum pressure may be expressed as absolute pressure or vacuum units. For example, 10 kPa vacuums signify a pressure of 10 kPa below atmosphere pressure, that is, an absolute pressure of 91.3kPa (101.3kPa – 10kPa).

Differential pressure signifies the difference in pressure between two points. Differential pressure measurement is useful for measuring flow or level.

In the case of flow, a device like orifice or venture tube is introduced into the flow path. This creates a pressure drop between the upstream and downstream points of that orifice that is related to the flow rate. Hence by measuring the pressure difference between the upstream and downstream points of the orifice we can measure the pressure drop and hence calculate the flow rate. [1]

For measuring level in tank the differential pressure between the bottom at the tank and the top of the tank is measured which is directly related to the hydrostatic head created by the liquid level which can be converted to the level using the density of the liquid.

2.2.2 Mechanical Transducers for Pressure Measurement

Pressure is measured by the force it exerts on a mechanical element and the corresponding deflection of the mechanical element. The common types of mechanical devices used are the Bourdon gauge, Bellows and Diaphragm as shown in figure 2.1.

The Bourdon gauge consists of a tube with elliptical cross section bent in the form of the arc of a circle. One end of the tube is fixed and the other is free to rotate. The free end is closed while the fixed end is connected to the pressure to be measured. When a pressure is applied inside the tube the elliptical cross section tends to become more circular. This produces a torque which tries to move the free end in a direction such that the arc becomes straighter. This small movement is converted to an electrical signal by using a suitable technique. [1]

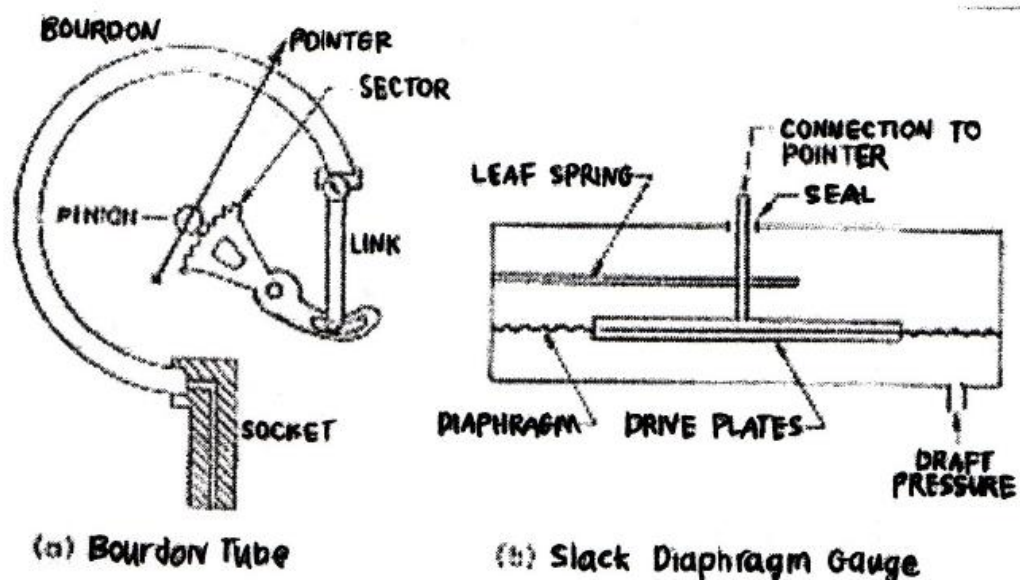


Figure 2.1

In the case of a bellows the pressure is applied to a bellows made of metal like stainless steel or phosphor bronze. One side is fixed and the other side is free to

move. The application of pressure causes a small deflection to the free end which is converted to an electrical signal using a suitable technique.

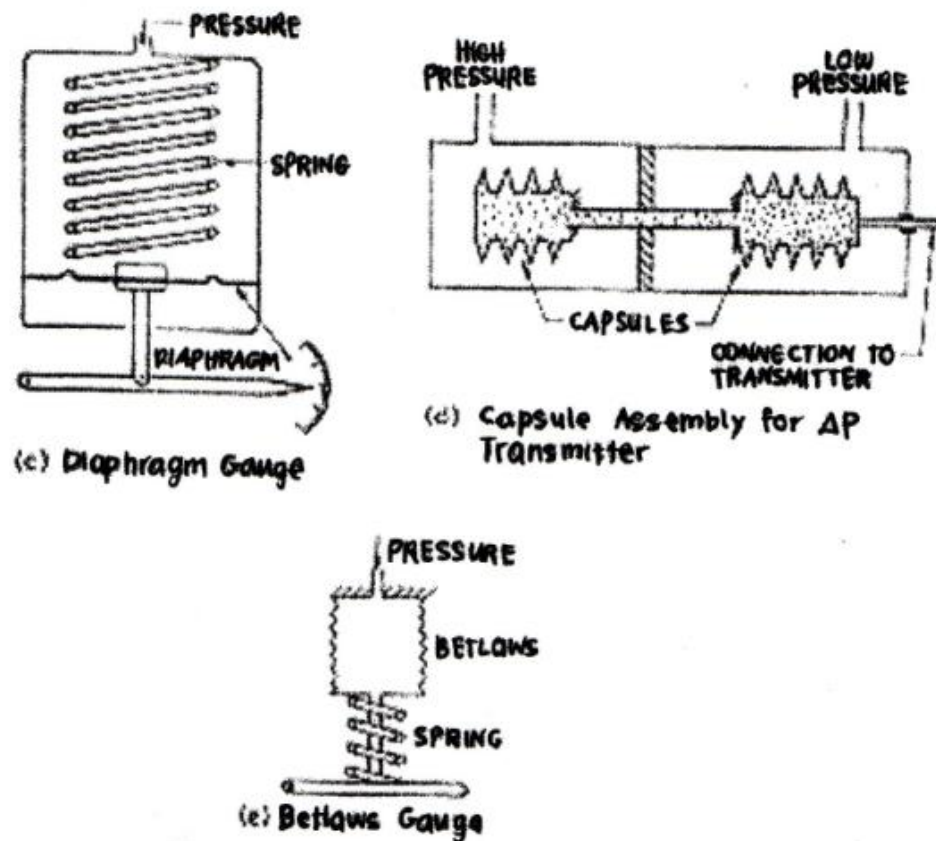


Figure 2.2

The diaphragm transducers are made of thin metallic diaphragms. They are fixed along the periphery and enclosed in a diaphragm box. When we apply the pressure to one side of the diaphragm it causes a deflection in the middle of the diaphragm which is converted to an electrical signal by appropriate methods.

2.2.3 Pressure Transmitters

The deflection of the mechanical transducers due to the action of pressure is converted to an electrical signal by a variety of methods. Linear variable differential transducers (LVDT), Potentiometric Transducers, Capacitance Transducers, Piezoresistive and Silicon Resonant Bridges are some of the more important methods used for this purpose.

Of these methods the Silicon Resonant Sensor Method is extremely accurate and stable. The Yokogawa transmitters are based on the Silicon Resonant Sensor techniques (figure 2.3a) that measures a strain-induced frequency created by the silicon resonators. [1]

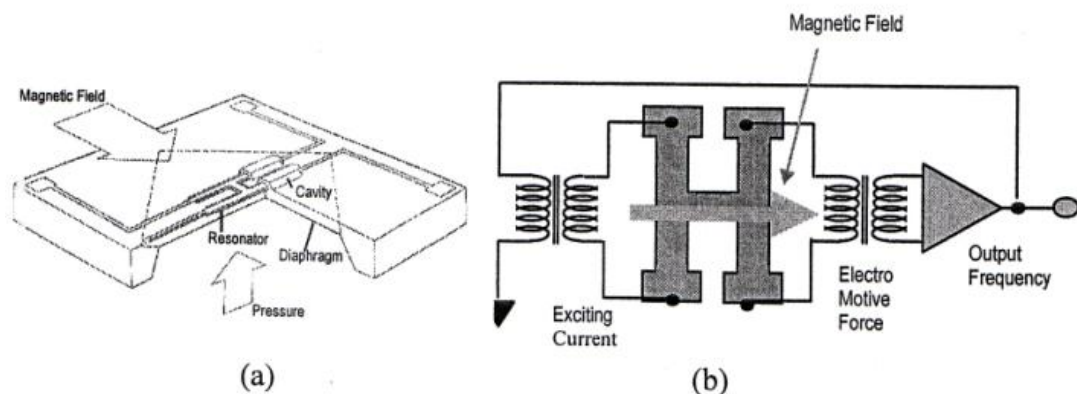


Figure 2.3

The entire sensors are made from a homogenous silicon crystal. On the silicon sensors two 'H' shaped resonators are provided. These resonators are patterned on the silicon crystal itself. One resonator is at the center of the crystal while the other is at the outer edge of the diaphragm. When no pressure is acting in the diaphragm both the bridges oscillate at a frequency of 90 kHz.

When a pressure is applied to the diaphragm the center bridge goes into tension and the outer bridge into compression. As a result the frequencies of one resonator increase and the other decreases. This difference in frequencies is measured and converted to a frequency output. The measurement can be directly converted to digital output by pulse counters (figure 2.3b). The advantages of these techniques are the high accuracy, long term stability and the facility to directly get digital signals without having to use A/D conversion.

2.3 Description of Instrumentation

“Instrumentation is the branch of science that deals with measurement and control in order to increase efficiency and safety in the workplace. An instrument is a device placed in the field, or in the control room, to measure or manipulate flow, temperature, pressure and other variables in a process. Instruments include but are not limited to valves, transmitters, transducers, flame detectors and analyzers. Instruments send either pneumatic or electronic signals to controllers which manipulate final control elements (a valve) in order to get the process to a set point, usually decided by an operator.”[2]

These are key-point to the instrumentation:

- (i) measurement and control
- (ii) viewed in terms of a simple input-output device

These measurable variable commonly include; Pressure, Flow, Temperature, level, density, viscosity, radiation, current, voltage, inductance, capacitance and frequency.

2.4 Introduction to Visual Basic 6.0

Visual Basic is a high level programming language evolved from the earlier DOS version called BASIC which stands for Beginners' All-purpose Symbolic Instruction Code. Visual Basic is a visual and events driven programming language. These are the main divergence from the old BASIC. In Visual Basic, programming is done in a graphical environment. An important feature in Visual Basic is, its Graphical User Interface (GUI) that presents a pictorial interface to a program. A GUI control is a visual object with which the user interacts via the mouse or keyboard. Users may click on a certain object randomly; therefore each object has to be programmed independently to be able to response to certain actions. In short, Visual Basic programming is made up of many subprograms, each has its own program codes, and each can be executed independently and at the same time can be linked together.[3]

In designing Visual Basic application, firstly the appearance of the window that the user sees will be designed. Then, the events for controls button on the window will be determined. And finally, the event procedures for those events will be written.

When the program runs, Visual Basic monitors the controls in the window to detect any event that a control can recognize (mouse movements, clicks, keystrokes and so on). When Visual Basic detects an event, it examines the program to see if the users have written an event procedure for that event. If event procedure is written, Visual Basic executes the instructions that make up that event procedure and monitors the controls again. These cycles continuously until the application end. Usually, an event must happen before Visual Basic will do anything. Event-driven programs are reactive more than active and that makes them more user-friendly

2.5 Differential Pressure Transmitter

Differential pressure transmitter with an orifice has achieved great field performance and success in flow measurement as a reliable field flow meter. However, blockage in impulse line attached to transmitter is sometime caused by precipitating or solidifying liquids. The pressure signals have random fluctuation signals due to a turbulent flow in a pipeline, and in case of impulse line blockage, the fluctuation signals vary from that of normal conditions. Mean square of differential pressure fluctuation has formerly been used to evaluate the blocking state. However, mean square of differential pressure fluctuation is strongly affected by flow rate. Then we have developed a new diagnostic technique, in which a specific parameter F called 'Blockage factor' indicates the extent of each impulse line blockage. Dp transmitter EJX series is able to measure not only the differential pressure but also the static pressure at high and low pressure sides of orifice by means of Silicon resonant pressure sensor. EJX makes it possible to calculate statistical variables F by using three pressure signals. We confirmed that blockage can be detected by using statistical variables F . Thus, Impulse line blocking diagnosis of digital differential pressure transmitter contributes to predicting blockage in impulse line and saving maintenance cost. [4]

In the experiment the differential pressure transmitter is used for pressure. Thus this show that differential pressure transmitter is useable because it can measure three of the most industrial measuring objects: a flow rate, a pressure and a level. Actually the main reason of the differential pressure transmitter in this experiment is to transmit the input to the output (DAQ card)

For all the measurements described in this paper, the transmitter was connected in a conventional 4 to 20 mA current loop with the power provided by a 24 V dc stabilised supply and the output signal developed across a 250 ohm resistor. Where possible, both the test and response signals were recorded simultaneously on

digital audio tape (DAT) using a TEAC RT1 11T recorder which has an effective bandwidth of 5 kHz and a 16-bit analogue-to-digital converter. The DAT recorded signals were subsequently played back to a PC based DAS20 data acquisition system prior to analysis. The sampling rate was set at 2048 Hz and with 4096 data points per data set, the resolution of the frequency axis was maintained at 0.5 Hz. For each of the results presented, at least three data sets were analyzed.

For this project the differential pressure transmitter will be connected to the data acquisition card which uses to transmit the output value to the PC. This project seems to improve the use of the differential pressure transmitter and DAQ card (data acquisition card) with using visual Basic application which is more user friendly, well known and suitable to use as one of the learning tools.

2.6 Description of Data Acquisition

Data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, which is acquired by data acquisition hardware.

It is the processing of multiple electrical or electronic inputs from devices such as sensors, timers, relays, and solid-state circuits for the purpose of monitoring, analyzing and/or controlling systems and processes. Data acquisition instrument types include computer boards, instruments or systems, data loggers or recorders, chart recorders, input modules, output modules, and I/O modules. Computer boards are self-contained printed circuit boards with full data acquisition functionality;

typically plugs into a backplane or motherboard, or otherwise interfaces directly with a computer bus. Instruments or systems are fully packaged with input and output, user interface, communications capability. They may include integral sensors. Data loggers and data recorders are data acquisition units with instrument functionality with specific capability for data storage.

Input modules are devices (module or card) configured to accept input of sensors, timers, switches, amplifiers, transistors, etc. for use in the data acquisition system. Output modules are devices with specific functionality for output of amplified, conditioned, or digitized signal. I/O modules have both input and output functionality. Digital or discrete I/O includes on-off signals used in communication, user interface, or control.

Considering the user interfaces available is important when searching for data acquisition products. User interfaces available include no display, front panel and display, touch screens, hand-held or remote programmers, and computer programmable. The transmission rate of data is important to consider. Many products are web enabled for web addressing. Common applications for data acquisition products include general lab or industrial, environmental, vehicular, marine, aerospace or military, seismic or geotechnical, weather or meteorology, and medical or biomedical. Additional specifications to consider when searching for data acquisition products include application software, memory and storage, network specifications, filter specifications, amplifier specifications, and environmental parameters.

2.7 Data Acquired From Data Acquisition Card

Data acquisition begins with the physical phenomenon or physical property of an object (under investigation) to be measured. This physical property or phenomenon could be the temperature or temperature change of a room, the intensity or intensity change of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective data acquisition system can measure all of these different properties or phenomena.

A transducer is a device that converts a physical property or phenomenon into a corresponding measurable electrical signal, such as voltage, current, change in resistance or capacitor values. The ability of a data acquisition system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the data acquisition hardware. Transducers are synonymous with sensors in DAQ systems. There are specific transducers for many different applications, such as measuring temperature, pressure, or fluid flow. DAQ also deploy various Signal Conditioning techniques to adequately modify various different electrical signals into voltage that can then be digitized using ADCs. Signals may be digital (also called logic signals sometimes) or analogue depending on the transducer used.

Signal conditioning may be necessary if the signal from the transducer is not suitable for the DAQ hardware to be used. The signal may be amplified or deamplified, or may require filtering, or a lock-in amplifier is included to perform demodulation. Various other examples of signal conditioning might be bridge completion, providing current or voltage excitation to the sensor, isolation, linearization, etc.

Analog signals tolerate almost no cross talk and so are converted to digital data, before coming close to a PC or before travelling along long cables. For analogue data to have a high signal to noise ratio, the signal needs to be very high, and sending ± 10 Volts along a fast signal path with a 50 Ohm termination requires powerful drivers. With a slightly mismatched or no termination at all, the voltage along the cable rings multiple time until it is settled in the needed precision. Digital data can have ± 0.5 Volt.

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc) or cards connected to slots (PCI, ISA) in the mother board. Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this Box and the PC is expensive due to the many wires and the required shielding. DAQ-cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM). These are accessible via a bus by a micro controller, which can run small programs. The controller is more flexible than a hard wired logic, yet cheaper than a CPU so that it is alright to block it with simple polling loops. For example: Waiting for a trigger, starting the ADC, looking up the time, waiting for the ADC to finish, move value to RAM, switch multiplexer, get TTL input, let DAC proceed with voltage ramp. As 16 bit ADCs and DACs and OpAmps and sample and holds with equal precision as of 2007 only run at 1 MHz, even low cost digital controllers like the AVR32 have about 100 clock cycles for bookkeeping in between. Reconfigurable computing may deliver high speed for digital signals. Digital signal processors spend a lot of silicon on arithmetic and allow tight control loops or filters. The fixed connection with the PC allows for comfortable compilation and debugging. Using an external housing a modular design with slots in a bus can grow with the needs of the user. High speed binary data needs special purpose hardware called Time to digital converter and high speed 8 bit ADCs are called oscilloscope or Digital storage oscilloscope, which are typically not connected to DAQ hardware, but directly to the PC

Driver software that usually comes with the DAQ hardware or from other vendors, allows the operating system to recognize the DAQ hardware and programs to access the signals being read by the DAQ hardware.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will be discuss more about the instrument part, hardware part and software development for developing this project.

3.2 PROJECT INITIATION AND PLANNING

Through this phase, the scope and objective of the project is definitely determined as what in chapter 1. Objective is a goal defined by the project to solve any problem statement as state in chapter 1 before. While, scope of the projects means the specific purpose defined by the project. Gant Chart is use as a planner for the whole semester (PSM1 & 2). In this part every plan or schedule of the activity should be state as a main reference.

3.3 RESEARCH

From the research made to fulfill the objective of this project, there are several modification should been made. The addition of analogue to digital device will be valuable to convert the signal receive from the analogue part (differential pressure transmitter) to digital part (visual basic application). There are several device that can be use to fulfill the objective but as the result, DAQ card (data acquisition card) will be the best device to complete this project. The use of DAQ card will be discussed later in subtopic 3.4 Hardware.

The general flow of the program will be like this;

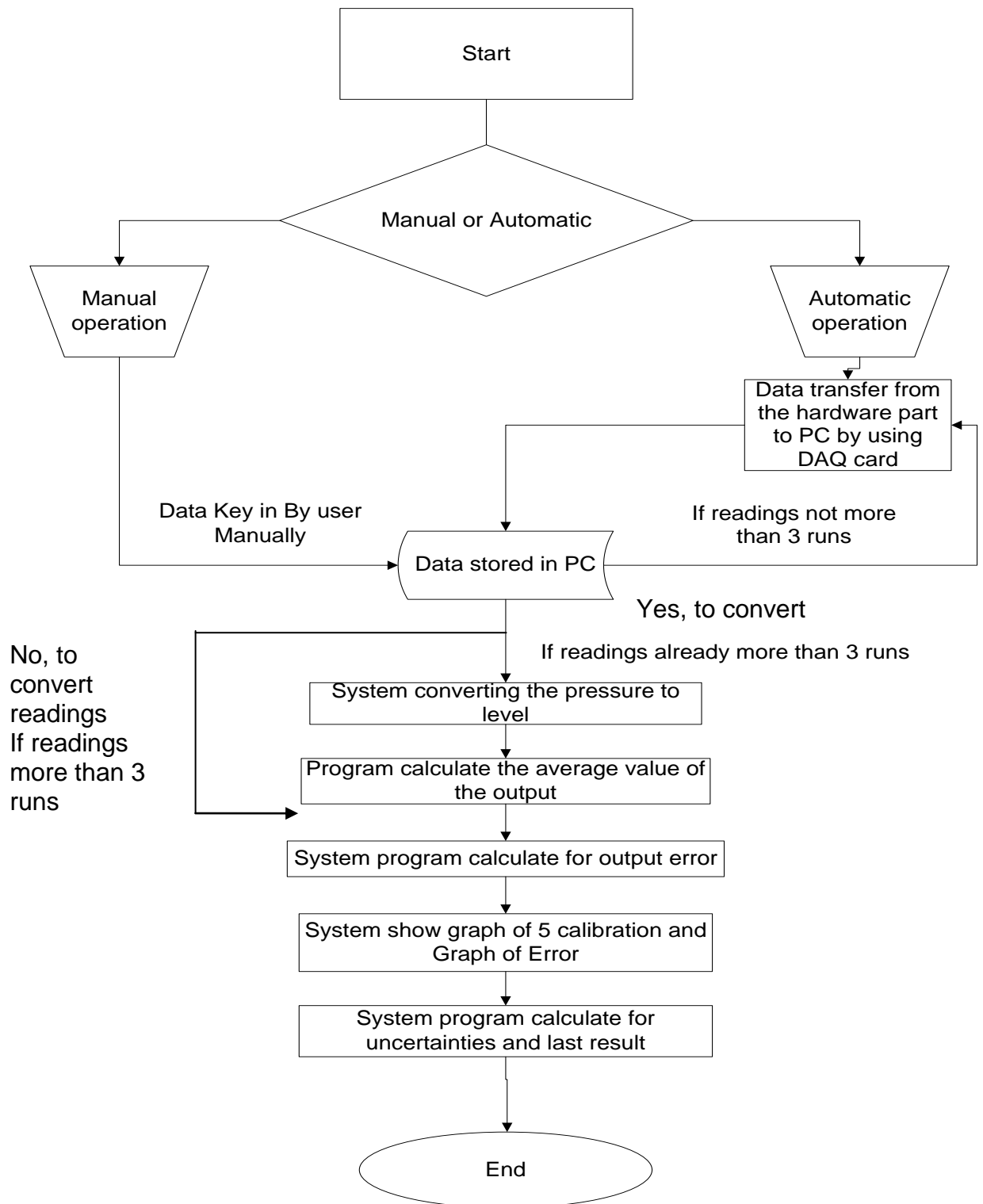


Figure 3.1

The flow of manual operation will be like this

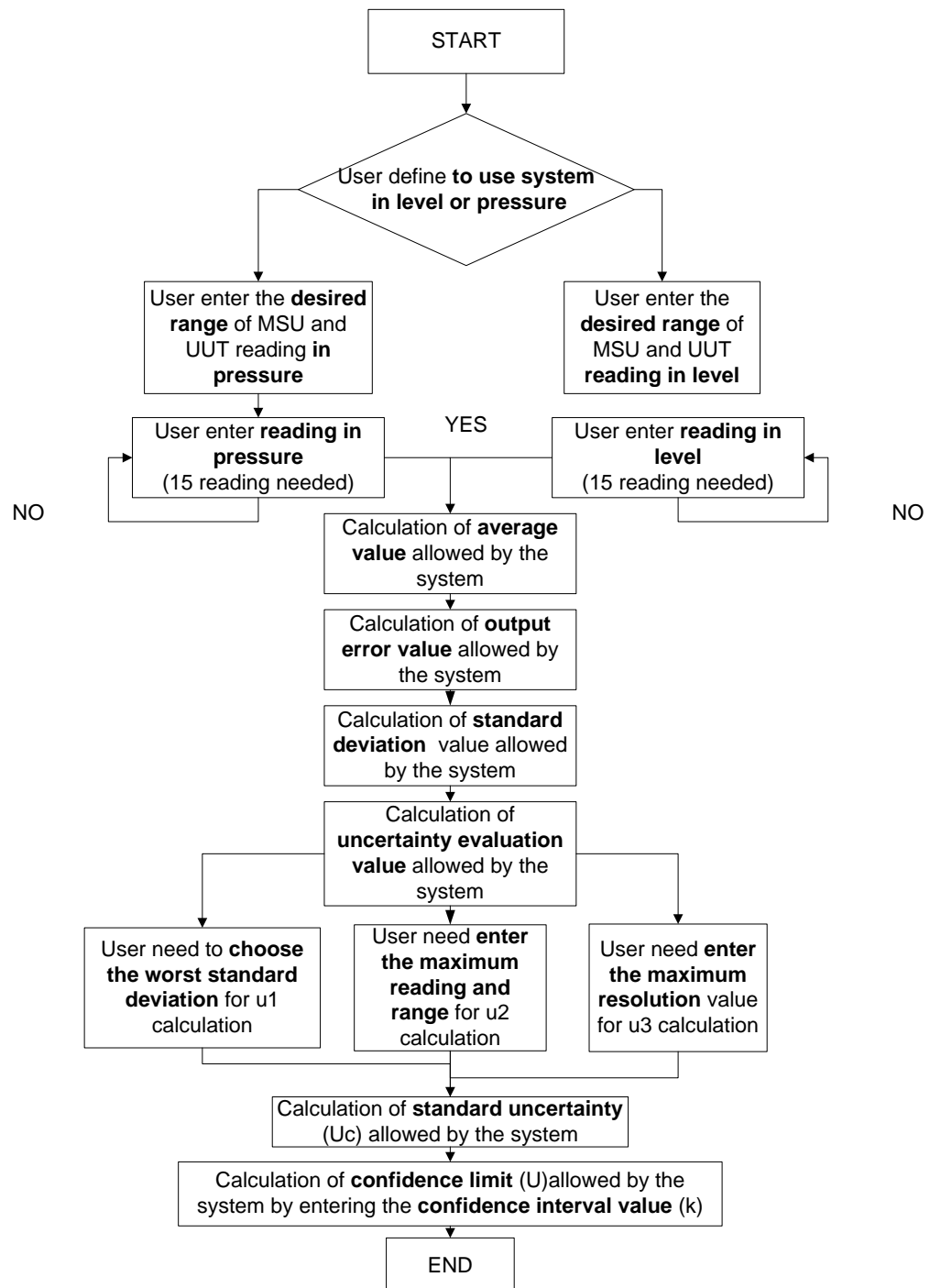


Figure 3.2

The flow of automatic operation can be like this

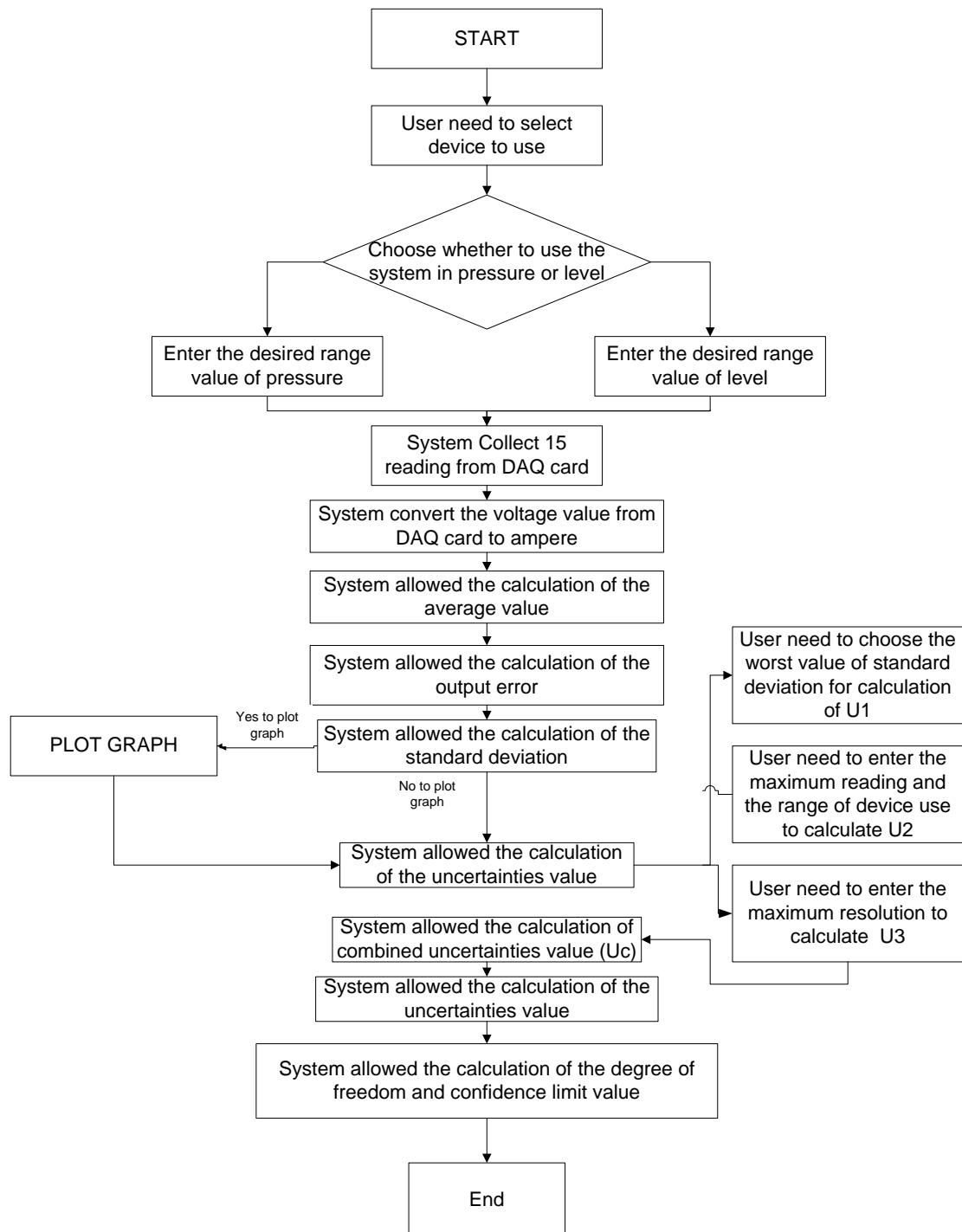


Figure 3.3

The flow chart shows the overall diagram of this software. Starting from the START case at the beginning of the programmed, the user allowed choosing their desired operation whether to proceed the use of the program manually or through automatically.

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Through manually, the user need to key in the data's they get through the experiment they made. At this point, it shows that user need to done their lab session first just to collect the overall data. Level instrumentation experiment consists of 3 run and every run have 5 readings need to be taken. On the other words, overall readings should be 15 readings. After the user key in all the data's, user may proceed to the next stage which consists a lot of calculation such as converting the pressure value, calculate the average value, output error, graph plotting and finding the uncertainties. All of these calculations will be done automatically by clicking the command buttons provide in the software.

There are several disadvantages by using the manual mode. As a human, sometimes we might be made some mistakes, user might be key in the wrong data in the textbox provide in the software. Besides, just to make sure the data is true enough, user need to confirm the readings again and again. On the other side, maybe some of the user likes to round up the value of the data's; for an example the exact value that show through the differential pressure transmitter is 4.026784mA, but the reading taken by the user is 4.03mA. This will lead the result of the experiment not precise as the desired result needed.

For the automatic operation, there are several differences between the manual operations. Automatic operation allows users to transfer the reading taken directly to the PC, compared to the manual operation which user need to key in the whole data one by one. The action of transferring the data direct to the pc will be controlled by the user using multiple clicking methods provide through the system. All the reading taken into the system is 100 percent accurate and same as the value show from the differential pressure transmitter. Besides, for safety reasons, the system will not

allow the user to proceed to the next step until all the readings is already taken. If the readings of 3 run already in the system, the system will ask the user whether to convert the pressure value into the level value or not. When decision was made by the user, the software will let the user to enter the calculation part which is quite same as the calculation part of manual operation. This calculation parts still consist of calculation of average value, output error, plotting graph, and uncertainties value.

For user friendly reasons, this software actually fill with save and print option. Thus this help student not to sketching back the graph looks like. Users also don't need to jot down all the values appear in the software. Just using a thumb drive, all the reading and graph will be save into picture file. If user wants the result through the hard copy, they can just clicking the print button that appears at the top right side of the software.

3.4 INSTRUMENTATION

This project is consist of 5 items, the first one is Ametek hand pump which use for giving a certain pressure or level to the Yokogawa differential transmitter and Yokogawa digital manometer. In other words this hand pump is act as an input for this experiment where user has to put the desired value through this hand pump. The second item is digital manometer which is used for user to refer the value of level they want according to the level that provide from hand pump. This thing is important for this experiment because this digital manometer will show the desired value needed by the user. The third item is HART 375 field communicator, this item is use for calibrate the transmitter (YOKOGAWA differential pressure transmitter) and the system. The fourth item is use to be the 2793 decade resistance box which act as an item to detecting the current output of the system. Last but not least is YOKOGAWA differential pressure transmitter, this thing is one of the important apparatus for this experiment where this transmitter is used to transmit the input (pressure value provide from the hand pump) to the output. This transmitter also will give signals to the DAQ board (output)

3.4.1 Schematic circuit (without hardware device)

This is the connection of the instrument part

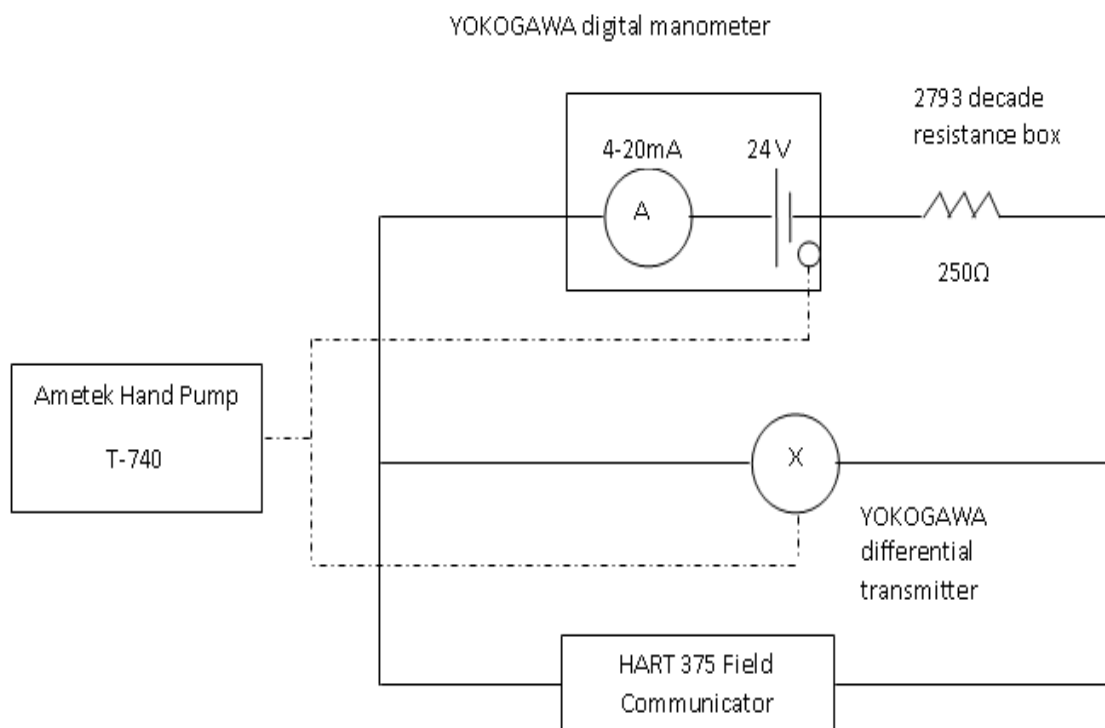


Figure 3.4

3.4.2 Schematic circuit (with hardware device)

This is the connection of instrument and hardware device (DAQ card)

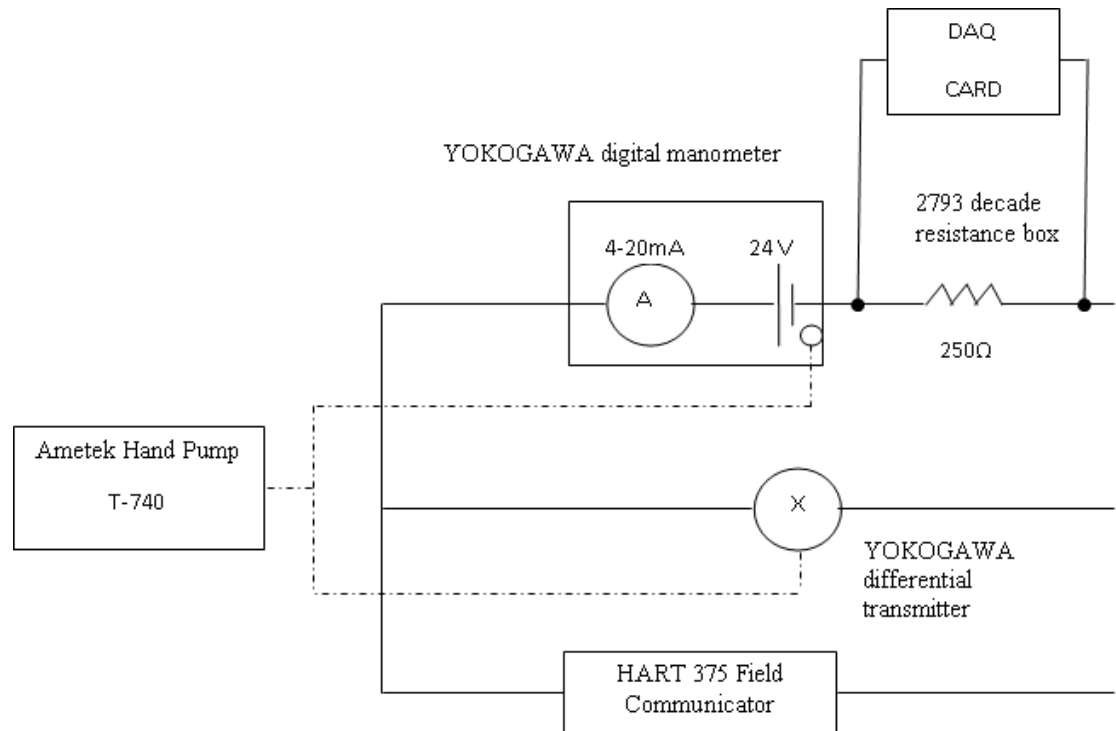


Figure 3.5

3.4.3 Function Of each Instrument

3.4.3.1 YOKOGAWA Digital manometer MT220

The MT220 can measure pressure with outstanding accuracy, high resolution, minimal tempo, and excellent stability. It offers a wealth of functions for field calibration, including transmitter output measurement (DCV/DCA functions), 24-V DC output, percent error readout, measurement data memory, and Ni-Cd battery operation. The D/A conversion output makes it simple to output data to a recorder or other equipment. And of course, data output through a GP-IB or RS-232 interface is also possible-including data output during operation on a 12 V DC power supply or Ni-Cd batteries.

In electric power, gas, nuclear power, oil refinery, petrochemical and pharmaceutical plants, numerous sensors are used to measure such variables as pressure, temperature and flow rate, and to automate the process. These sensors must be calibrated periodically to maintain product quality. However, because there are typically so many pressure and differential pressure transmitters out in the field, the transmitters are usually calibrated in-situ. This calibration accounts for much of plant maintenance work. Efficiency is therefore crucial to maintain uptime of equipment and facilities. The MT220 is a precision digital manometer for use with pressure/differential pressure transmitters and is designed to maximize the efficiency of field calibration work.[6]



Figure 3.6

Calibration involves inputting the same pressure level to both a calibrator and a transmitter and comparing the transmitter output with a value measured by the calibrator. The MT220 comes with all the functions you need for such calibration work in the plant or field. Practical functions include measuring transmitter output (1-5 V or 4-20 mA), outputting 24 V DC for driving the transmitter, and indicating the transmitter output error as a percent value. The MT220 even has a pressure range pre-adjusted to that of transmitters.

The accuracy of pressure/differential pressure transmitters has continued to improve, from $\pm 0.25\%$ to $\pm 0.1\%$, and now to $\pm 0.075\%$. That means the accuracy and stability of the manometers used to calibrate these transmitters must keep pace. The MT220 employs Yokogawa's original silicon resonant sensor-a high precision pressure sensing device. Advanced calibration environment, including a tightly-controlled traceability system. As a result, calibrators feature basic accuracy as high as $\pm 0.02\%$, and excellent stability. With the MT220, user can verify the performance of even the most accurate of pressure/differential pressure transmitters, i.e. $\pm 0.075\%$.

3.4.3.2 Ametek Hand Pump T-740

Model T-740 pneumatic pressure pump features a rugged pneumatic pump capable of generating test pressures up to 200 psi (20.6 bar). Ideal for pressure instrument calibration. This pump features an extended range vernier adjustment for precisely controlling pump pressure and comfortable pistol grip handle.



Figure 3.7

Vernier Allows Precise Adjustments. Tester is equipped with a 24-inch (60.95cm) rubber hose. The reference gauge is mounted on the body manifold with a swivel fitting for easy viewing. A vent valve is provided for quick and positive shut-off and pressure release with 0.25 inch NPT connector for connecting to the instrument under test [7]

3.4.3.3 Differential pressure transmitter

The high performance differential pressure transmitter EJX110A features single crystal silicon resonant sensor and is suitable to measure liquid, gas, or steam flow as well as liquid level, density and pressure. EJX110A outputs a 4 to 20 mA DC signal corresponding to the measured differential pressure. Its highly accurate and stable sensor can also measure the static pressure which can be shown on the

integral indicator or remotely monitored via BRAIN or HART communications. Other key features include quick response, remote set-up using communications, self diagnostics and optional status output for pressure high/low alarm. FOUNDATION Fieldbus protocol type is also available. All EJX series models in their standard configuration, with the exception of the Fieldbus type, are certified by TÜV as complying with SIL 2 for safety requirement.



Figure 3.8

Rotation in diaphragm plane has no effect. Tilting up to 90 degree will cause zero shifts up to 0.4 kPa (1.6 inH₂O) which can be corrected by the zero adjustment. Upper Range Value and Lower Range Value of the static pressure can be set in the range between 0 and Maximum Working Pressure (MWP). The upper range value must be greater than the lower range value. Minimum setting span is 0.5 MPa(73 psi). Measuring either the pressure of high pressure side or low pressure side is user-selectable. 5-digit numerical display, 6-digit unit display and bar graph. The indicator is configurable to display one or up to four of the following variables periodically. Measured differential pressure, differential pressure in %, scaled differential pressure, measured static pressure [8]

3.4.3.4 2793 Decade resistance Box

Model 2793 is high-accuracy, stable DC variable resistor with 6 dials and is available in two styles: 279301 for medium resistance from 0.1 to 1,111.210 Ω in 1 m Ω steps (best suited for calibration of resistance thermometers or bridges); 279303 for high resistance from 0 to 111.1110 M Ω in 100 Ω steps (suitable for calibration of insulation resistance testers or bridges).



Figure 3.9

The specifications of this instrument are; up to 100 M Ω in 100 Ω step. Low voltage coefficient variation of the resistance value is less than $\pm 0.1\%$ at 1 M Ω and 10 M Ω steps against 100 V applications, and less than $\pm 0.04\%$ at 100 Ω , 1 k Ω , 10 k Ω , and 100 k Ω steps against 10 V applications. Shock-and vibration-proof construction Easy-to-read in-line indication. Best suited for calibration of insulation resistance testers and bridges. High accuracy and stability, high reproducibility, simple, quick dial operation, in-line display for easy reading. The 2793 is ideal for Calibration of resistance thermometers and bridge

3.4.3.5 HART 375 Field Communicator

A portable intrinsically safe communicator that supports all their field bus devices. The result is the universal, user upgradeable, intrinsically safe, rugged and reliable 375 Field Communicator. The 375 Field Communicator is designed to support all HART® and all FOUNDATION™ field bus devices from all vendors.

Building on the experience with the proven 275 HART® Communicator, the 375 Field Communicator includes enhancements designed to simplify your work in the field. We designed the 375 Field Communicator user interface around the 275, leveraging the navigation features users told us they liked. Then we added powerful features including a much larger touch screen, HART® Revision 6 support, and the ability to upgrade your 375 Field Communicator onsite using the Internet.

See the difference. The 375 Field Communicator runs on Windows CE, a robust, real-time, operating system. The display is 70% larger than that of the 275 HART® Communicator and uses transfective technology, making it easy to read in both bright sunlight and in normal lighting. To make sure we covered all conditions, we added a multi-level backlight, allowing the display to be viewed in those areas of your plant with dim light. The touch sensitive display and large physical navigation buttons provide for efficient use both on the bench and in the field. We made sure that the weight was evenly distributed for comfortable one-handed operation in the field.



Figure 3.10

The 375 Field Communicator has a processor that is 20 times faster than the 275. It features 32MB of application memory, 64 times more than the 275 HART[®] Communicator. The Configuration Expansion Module holds hundreds of device configurations, and it is externally accessible. Enhancements in the battery pack allow a full recharge in 2 hours, 8 times faster than the 275 HART[®] Communicator.

Easy Upgrade keeps user communicator current. If that's not enough to get your attention, the 375 Field Communicator is also user upgradeable via the Internet. This means it is no longer necessary to send your communicator anywhere to have new device drivers added. A fold-away stand provides the correct viewing angle on the bench, and flips up to a locked position for secure hanging in the plant. With over 600 different HART[®] and FOUNDATION[™] field bus devices from more than 100 different vendors, having a single field communicator that works with everything is a big help. [9]

The 375 Field Communicator is designed to support all HART[®] and FOUNDATION[™] field bus devices. If you are familiar with the 275 HART[®] Communicator, used in thousands of plants worldwide for more than ten years, you will appreciate universal HART[®] support in a single intrinsically safe handheld communicator. The 375 Field Communicator can also be used to configure all the FOUNDATION[™] field bus devices in your plant. Use it to perform diagnostics for effective start-up and troubleshooting of FOUNDATION[™] field bus segments.

Create a quality segment by diagnosing the network DC voltage and average noise. Detect power supply problems by monitoring low frequency noise on a segment. Locate incorrect terminations and faulty devices by diagnosing the communications signal level. No longer do you need to drag a laptop computer out into the plant to communicate with your FOUNDATION™ field bus devices.

As new HART® and FOUNDATION™ field bus DD's become available, download them from the Internet and upgrade your 375 Field Communicator. In addition, as functional enhancements to the 375 HART® and FOUNDATION™ field bus applications become available, download software updates from the Internet and upgrade your 375 Field Communicator. No longer is it necessary to send user communicator to a service center to have new DD's or software updates added. No longer is it necessary to be without user communicator while user wait for upgrades..

User upgradeable New HART® and FOUNDATION™ field bus devices, as well as functional updates to existing devices are introduced continually by device vendors. Keeping up-to-date with the required Device Description drivers for all the devices in your plant can be a real challenge. Now, with the Easy Upgrade option, keeping your communicator updated with the most current Device Descriptions (DD's) is easy

3.5 SOFTWARE

This system will completely use visual basic application. Visual Basic was designed to be easy to learn and use. The language not only allows programmers to create simple GUI applications, but can also develop fairly complex applications as well. The system will work when the ADC give the input (reading) to the system, several readings will be taken. Then the system automatically plotting two graphs which is based on actual readings and desired readings. After the graph was plot, the system will compare these two graphs thus lead the system to plot an error graph. This system also will calculate the uncertainty value

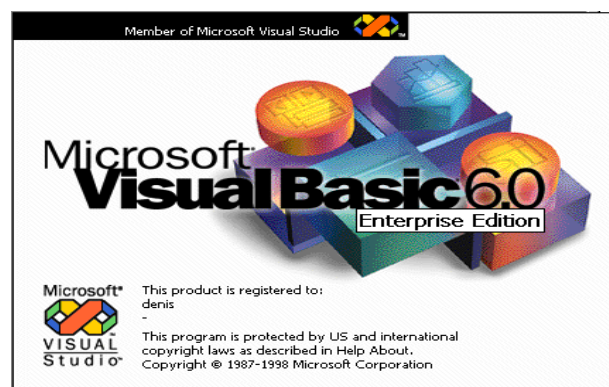


Figure 3.11

Programming in VB is a combination of visually arranging components or controls on a form, specifying attributes and actions of those components, and writing additional lines of code for more functionality. Since default attributes and actions are defined for the components, a simple program can be created without the programmer having to write many lines of code. Forms are created using drag and drop techniques. A tool is used to place controls (e.g., text boxes, buttons, etc.) on the form (window). Controls have attributes and event handlers associated with them. Default values are provided when the control is created, but may be changed by the programmer. Many attribute values can be modified during run time based on user actions or changes in the environment, providing a dynamic application. For

example, code can be inserted into the form resize event handler to reposition a control so that it remains centered on the form, expands to fill up the form, etc. By inserting code into the event handler for a key press in a text box, the program can automatically translate the case of the text being entered, or even prevent certain characters from being inserted.

3.6 HARDWARE

For the hardware part, DAQ (data acquisition board) will be use to interface the instrumentation part with the software system. We have chosen the DAQ card that produced by the ADVANTECH Corporation (ADVANTECH model USB-4716). As we know is the sampling of the real world to generate data that can be manipulated by a computer. Data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, which is acquired by data acquisition hardware



Figure 3.12

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc...) or cards connected to slots (PCI, ISA) in the mother board. Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this Box and the PC is expensive due to the many wires and the required shielding and because it is exotic. DAQ-cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM). These are accessible via a bus by a micro controller, which can run small programs. The controller is more flexible than a hard wired logic, yet cheaper than a CPU so that it is alright to block it with simple polling loops. For example: Waiting for a trigger, starting the ADC, looking up the time, waiting for the ADC to finish, move value to RAM, switch multiplexer, get TTL input, let DAC proceed with voltage ramp. As 16 bit ADCs and DACs and Op Amps and sample and holds with equal precision as of 2007 only run at 1 MHz, even low cost digital controllers like the AVR32 have about 100 clock cycles for bookkeeping in between. Reconfigurable computing may deliver high speed for digital signals. Digital signal processors spend a lot of silicon on arithmetic and allow tight control loops or filters. The fixed connection with the PC allows for comfortable compilation and debugging. Using an external housing a modular design with slots in a bus can grow with the needs of the user. High speed binary data needs special purpose hardware called Time to digital converter and high speed 8 bit ADCs are called oscilloscope, Digital storage oscilloscope, which are typically not connected to DAQ hardware, but directly to the PC.

It is usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB) or cards connected to slots (PCI, ISA) in the mother board. The hardware features of a general data-acquisition system (Figure 3.13) although there is variation from manufacturer to manufacturer, demonstrate the essential features of it. [5]

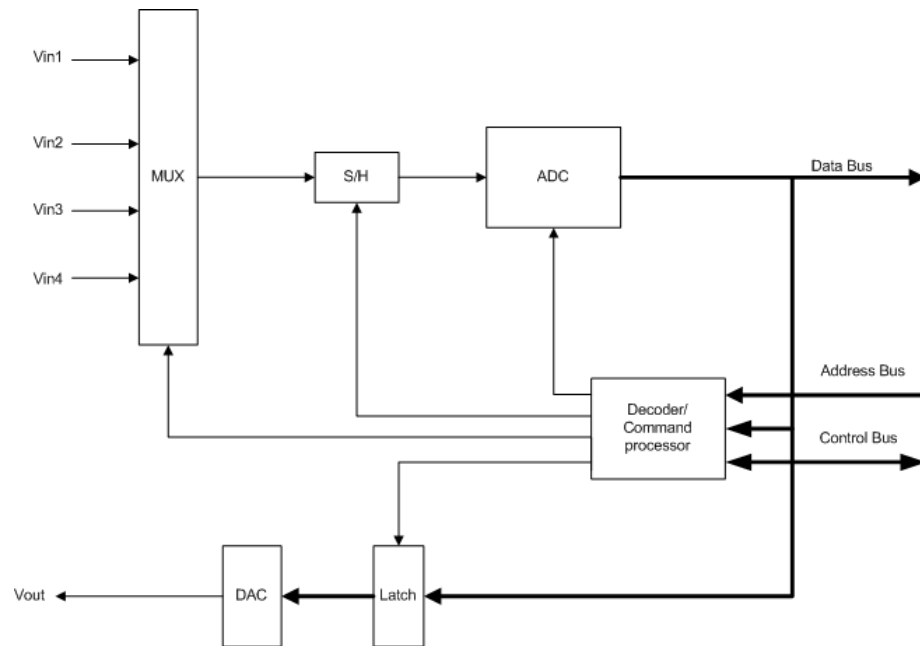


Figure 3.13: Typical layout of a data-acquisition board

3.6.1 ADC and S/H

The DAS (data acquisition system) typically has a high-speed, successive approximation-type ADC and a fast S/H circuit. Whenever the DAS is requested to obtain data sample, the S/H is automatically incorporated into a process. The ADC conversion time constitute the major part of the data sample acquisition time, but the S/H acquisition time must also be considered to establish maximum throughput.

3.6.2 Analog Multiplexer

The analog multiplexer (MUX) allows the DAS to select data from a number of different sources. The MUX has a number of input channels, each of which is connected to a different analog input voltage source. The MUX acts like a multiple

set of switches (Figure 3.14), arranged in such a fashion that any one of the input channels can be selected to provide its voltage to the S/H and ADC. In some cases, the DAS can be programmed to take channel sample sequentially.

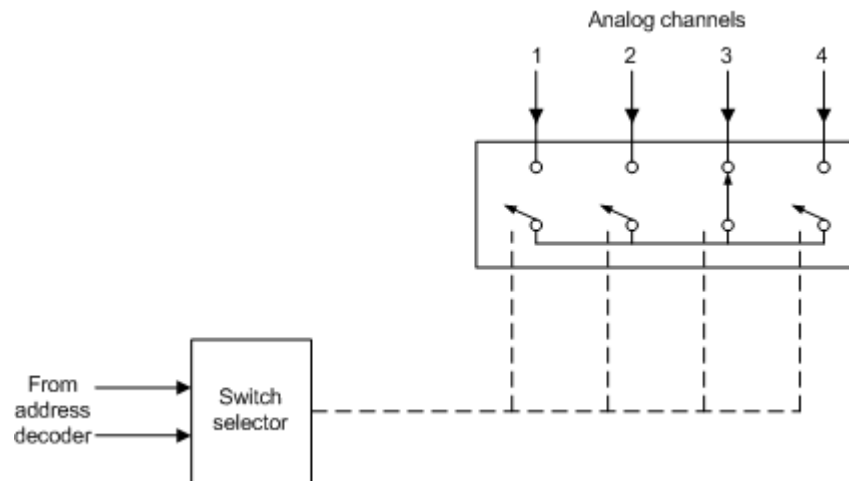


Figure 3.14: An analog multiplexer acts as a multiposition switch for selecting inputs to the ADC

3.6.3 Address Decoder / Command Processor

The computer can select to input a sample from a given channel by sending an appropriate selection on the address lines and control lines of a computer bus. These are decoded to initiate the proper sequence of command to the MUX, ADC, and S/H. Another common feature is the ability to program the DAS to take a number of samples from a channel with a specified time between samples. In this case, the computer is notified by interrupt when a sample is ready for input.

3.6.4 DAC and latch

For output purposes, the DAS often include a latch and DAC. The address decoder/command processor is used to latch data written to the DAS, which is then converted to an appropriate analog signal by the DAC.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will be focuses on the final result and calculation part that contain in this project. All devices including instrument part, hardware part, and software system are finally integrated in developing this project entitle “Computer Based Instrumentation for Level Instrumentation Using Visual Basic Application”. Everything regarding of this final result will be discus details in this chapter

4.2 CALCULATION

4.2.1 Desired Output

Throughout the experiment, there are some calculation have been made such as calculate the desired output by using this equation

$$\frac{x}{100}(URV - LRV) + LRV = \text{desired output}$$

For an example the desired value choose by the user is 4mA – 20mA. This value actually represents the value of pressure 0kPa – 200kPa. As said before there will be 5 readings need to be taken (0, 50, 100, 150, 200kPa or 0%, 25%, 50%, 75%, 100%). So the calculation step will be like this

$$\frac{0}{100}(20 - 4) + 4 = 4\text{mA}$$

$$\frac{25}{100}(20 - 4) + 4 = 8\text{mA}$$

$$\frac{50}{100}(20 - 4) + 4 = 12\text{mA}$$

$$\frac{75}{100}(20 - 4) + 4 = 16\text{mA}$$

$$\frac{100}{100}(20 - 4) + 4 = 20\text{mA}$$

4.2.2 Conversion from Pressure to Level

By using this equation, the conversion between pressures to level will be done. Pressure unit should be in Pa while the level value will be in meter

$$P = pgh$$

P= pressure (Pa)

p = density in kg/m³

h = level in meter

Thus the conversions are

$$\frac{0}{10^3 \times 9.8} = 0$$

$$\frac{50k}{10^3 \times 9.8} = 5.1m$$

$$\frac{100k}{10^3 \times 9.8} = 10.2m$$

$$\frac{150k}{10^3 \times 9.8} = 15.3m$$

$$\frac{200k}{10^3 \times 9.8} = 20.4m$$

4.2.3 Average Output

While the equation of the average output use to be like this

$$\frac{X1+X2+X3}{3} = \text{average value}$$

For an example the values of every run are

1st run	2nd run	3rd run
4.006	4.007	4.005
8.038	8.08	8.035
12.060	12.063	12.066
16.092	16.094	16.094
20.120	20.121	20.120

Table 4.0

Thus the average values are;

$$\frac{4.006+4.007+4.005}{3} = 4.006 \text{ mA}$$

$$\frac{8.038+8.08+8.035}{3} = 8.051 \text{ mA}$$

$$\frac{12.060+12.063+12.066}{3} = 12.063 \text{ mA}$$

$$\frac{16.092+16.00+16.094}{3} = 16.062 \text{ mA}$$

$$\frac{20.120+20.121+20.120}{3} = 20.120 \text{ mA}$$

4.2.4 Output Error

The equation for percent of output error is

$$\frac{\text{average value} - \text{desired value}}{\text{average value}} \times 100\% = \text{output error}$$

Thus the calculations are

$$\frac{4.006-4.00}{4.006} \times 100\% = 0.1497\%$$

$$\frac{8.051-8.00}{8.051} \times 100\% = 0.6335\%$$

$$\frac{12.063-12.00}{12.063} \times 100\% = 0.522\%$$

$$\frac{16.062-16.00}{16.062} \times 100\% = 0.386\%$$

$$\frac{20.120-20.00}{20.120} \times 100\% = 0.596\%$$

The overall value is shown in table below

No %	MSU applied (m)	Desired UTT output (mA)	1 st run	2 nd run	3 rd run	Average (mA)	Output error (%)
0	0.0	4.00	4.006	4.007	4.005	4.006	0.1497
25	5.1	8.00	8.038	8.08	8.035	8.051	0.6335
50	10.2	12.00	12.060	12.063	12.066	12.063	0.522
75	15.3	16.00	16.00	16.092	16.094	16.062	0.386
100	20.4	20.00	20.120	20.121	20.120	20.120	0.596

Table 4.1

4.2.5 Standard deviation

$$S(X_k) = \sqrt{1/(n-1) \sum_{j=1}^n (x_k - \bar{x})^2}$$

Where ;

x_k = is the value of 1st until 3rd run

\bar{x} = average

n = sample size

Thus the calculation of standard deviation will goes like this

$$\begin{aligned}
 S(X_1) &= \sqrt{1/(3-1) [(4.006 - 4.006)^2 + (4.007 - 4.006)^2 + (4.005 - 4.006)^2]} \\
 &= 1.4142 \times 10^{-6} \approx 0
 \end{aligned}$$

$$S(X2) = \sqrt{1/(3-1)} [(8.038 - 8.051)^2 + (8.08 - 8.051)^2 + (8.035 - 8.051)^2]$$

$$= 8.95 \times 10^{-4} \approx 0.0009$$

$$S(X3) = \sqrt{1/(3-1)} [(12.060-12.063)^2+(12.063 - 12.063)^2 + (12.066-12.063)^2]$$

$$= 1.273 \times 10^{-5} \approx 0.00001$$

$$S(X4) = \sqrt{1/(3-1)} [(16.00-16.062)^2 + (16.092- 16.062)^2 +$$

$$(16.094-16.062)^2]$$

$$= 4.07859 \times 10^{-3} \approx 0.0004$$

$$S(X5) = \sqrt{\frac{1}{3-1}} [(20.120 - 20.120)^2 + (20.121 - 20.120)^2 + (20.120 - 20.120)^2]$$

$$= 7.071 \times 10^{-7} \approx 0$$

The overall value is shown in table below

No %	MSU applied (m)	Desired UTT output (mA)	1 st run	2 nd run	3 rd run	Average (mA)	Output error (%)	Std deviation
0	0.0	4.00	4.006	4.007	4.005	4.006	0.1497	0
25	5.1	8.00	8.038	8.08	8.035	8.051	0.6335	0.0009
50	10.2	12.00	12.060	12.063	12.066	12.063	0.522	0.00001
75	15.3	16.00	16.00	16.092	16.094	16.062	0.386	0.0004
100	20.4	20.00	20.120	20.121	20.120	20.120	0.596	0

Table 4.2

4.2.6 Uncertainty evaluation

For determining the uncertainty contribution due to repeatability of the experiment we shall utilize the experimental results obtained from the draft UUT calibration. Choose the row having the highest deviation between the MSU values and the UTT value

We choose the worst case standard deviation the u we are looking is the experimental standard deviation of the mean $s(\bar{x})$. This $s(\bar{x})$ is the estimation of the spread of the distribution of the means. For a sample size that we have, $n = 3$. Thus the formula for the standard deviation of the mean is given by

$$s(x) = \frac{s(x_k)}{\sqrt{n}} = 0.0004 / \sqrt{3} = 0.00235$$

We shall call this uncertainty as $u_1 = 0.4082$ kPa with the degree of freedom

$$\gamma_1 = 3 - 1 = 2$$

4.2.7 Uncertainty Contribution Due to MSU error

The MSU used in this calibration is the model MT220, Digital Manometer Standard. For the 700kPa range the accuracy specification for this instrument provided by the manufacturer is the following;

$$\pm (0.01\% \text{ of reading} + 0.005 \% \text{ range})$$

For the maximum reading of 200kPa and a range of 700kPa. Hence the error in MSU = $\pm ((0.0001 \times 200) + (0.00005 \times 700))V$. Therefore the maximum error = $a = 0.055kPa$

The uncertainty contribution due to MSU error is defined as u_2 and is given by $a/\sqrt{3}$. thus the value is $0.055/\sqrt{3} = 0.031754$

Therefore $u_2 = 0.031754$ and $\gamma_2 = \infty$

4.2.8 Uncertainty Due to UUT Resolution / MSU Resolution

Generally , if the UUT is analog, we will use the resolution of the MSU. If the UUT is digital, we will use the resolution of digital UUT.

Considering the worst case scenario the maximum resolution of EJX110A is 0.06 kPa. The uncertainty u_3 is calculated as,

$$u_3 = 0.06 / \sqrt{3} = 0.034641kPa$$

Besides, we can consider the degree of freedom as ∞

4.2.9 Combined Standard Uncertainty, u_c

The combined standard uncertainty u_c is determined from the individual uncertainties u_1 , u_2 , and u_3 by the following formula

$$u_c = \sqrt{(u_1^2 + u_2^2 + u_3^2)}$$

Thus the calculation is;

$$u_c = \sqrt{(0.00235^2 + 0.031754^2 + 0.034641^2)} = 0.047051$$

The effective degree of freedom ν_e is given by,

$$\nu_e = u_c^4 / (u_1^4 \div \nu_1)$$

$$= 0.047051^4 / 1.5249 \times 10^{-11} = 321391.1985$$

Substituting the values we get $\nu_e = 321391.1985$

The total uncertainty at any confidence level is determined using the Student's Distribution (refer to table 4.0). The coverage factor k is determined from students table. Referring to the table 4.0 for a value of $\nu = 100$ and 95.45% confidence interval $k = 2.025$

The confidence limit are obtained by the formula,

$$u = u_c k$$

Therefore,

$$U = 2.025 \times 0.047051 = \pm 0.095278 \text{ kPa}$$

The confidence limit in a measurement is determined by the use of calibration techniques together with the statistical principles.

4.3 Graph and Result Shown By The System

Three graphs that needed in this experiment can be plot when all the calculation needed have been done. Below is a graph of five calibrations (figure 4.1), error graph (figure 4.2), and standard deviation graph (figure 4.3) that plot by using the manual operation

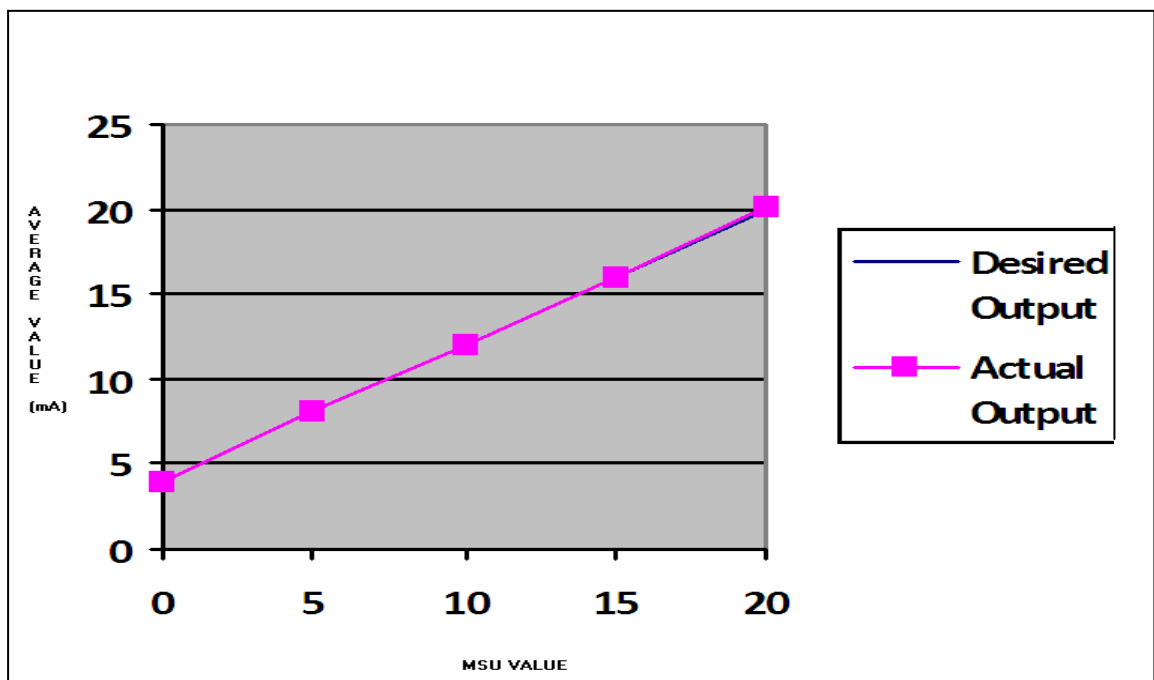


Figure 4.1

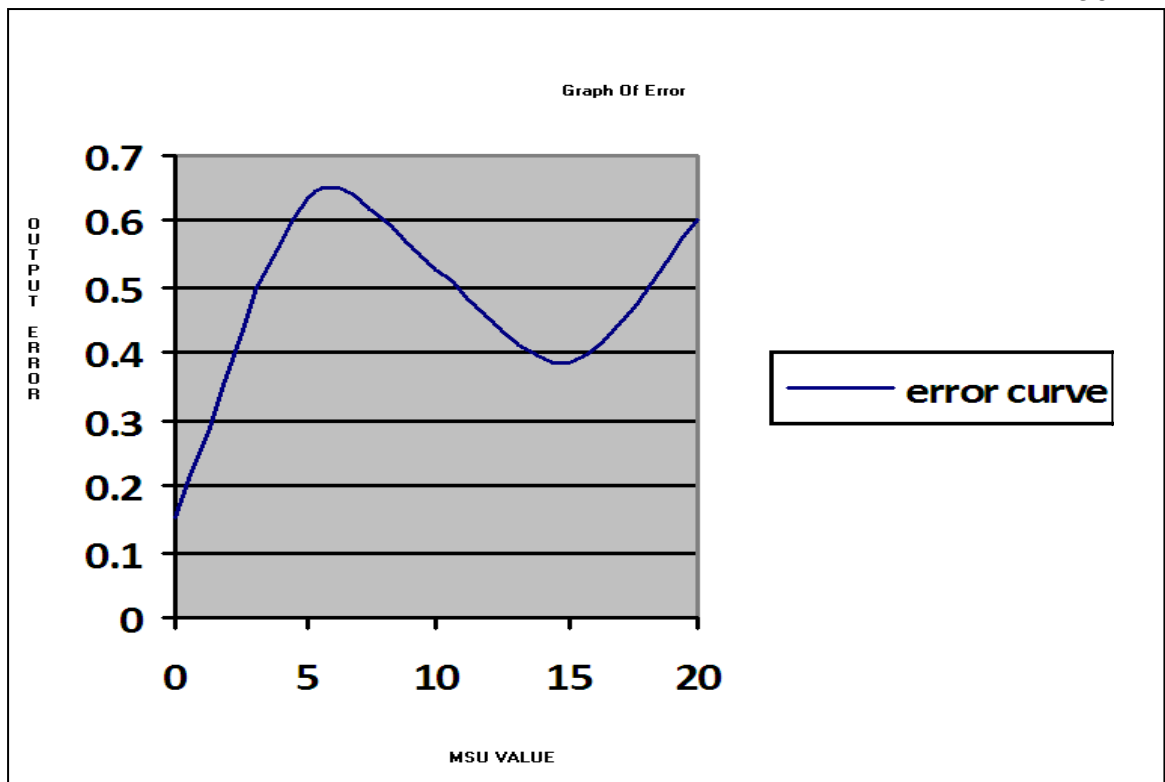


Figure 4.2

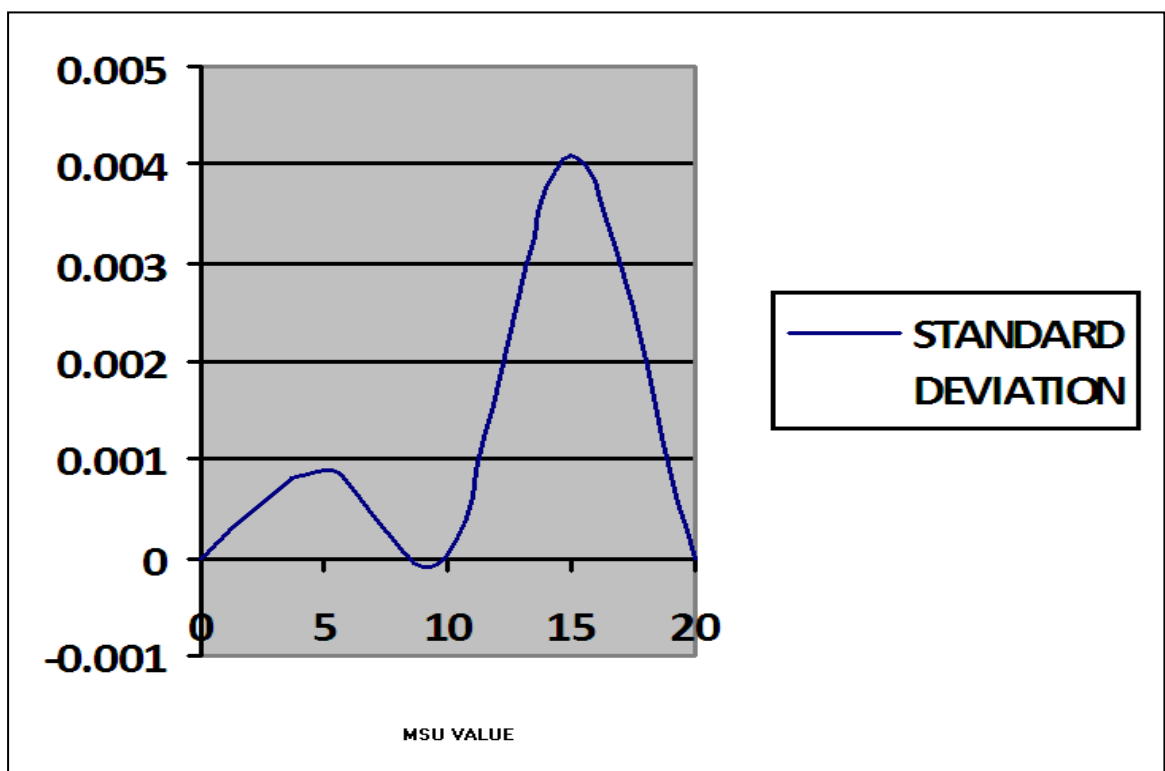


Figure 4.3

The system will show the summaries of the calculation made. For an example, below is the summary of the calculation made by the manual operation of the system

No. of Percent	MSU VALUE	UTT OUTPUT(mA)	1ST READING(mA)	2ND READING(mA)	3RD READING(mA)
0	0	4	4.006	4.007	4.005
25	5	8	8.038	8.08	8.035
50	10	12	12.060	12.063	12.066
75	15	16	16	16.092	16.094
100	20	20	20.120	20.121	20.120

AVERAGE READINGS	OUTPUT ERROR (%)	Std Deviation	Uncertainty Evaluation		Confidence Limits
4.006	0.15	0	u1= 0.002356	<input type="button" value="Click to Choose"/>	Ve= 318156.796118
8.051	0.6375	0.0009	u2= 0.031754	<input type="button" value="Calculate"/>	<input type="button" value="Calculate"/>
12.063	0.525	0.00001	u3= 0.034641	<input type="button" value="Calculate"/>	u= 0.09528
16.062	0.3675	0.00408	uC= 0.047052	<input type="button" value="Calculate"/>	<input type="button" value="Calculate u"/>
20.12033	0.60165	0			

Figure 4.4

CHAPTER 5

CONCLUSION AND FUTURE DEVELOPMENT

5.1 CONCLUSION

In general, this project have been complete the entire objective within the scope of project given. Computer based instrumentation for level measurement by using visual basic application can be implemented as a useful learning tool for student who takes BEE4523: Industrial Instrumentation subject. This project have been develop successfully with multiple functioning operate at best condition.

This kind of project should be implementing for others subject which can attract students to discover the new idea and also start to think creatively. The unique identity of interfaces gives an advantage to this project to make it more sophisticate and more users friendly. As an improvement for this project, data bases should be included in this software system just to make sure all the data that user get can be save in hard disk and user can recall the data back at any time they want it. Besides, the programming can be improved in order to gain stability for the system at any condition.

5.2 FUTURE DEVELOPMENT

Even though this project is successful, however there some addition can be made. This addition somehow can improve the performance of the system. Below are some of the suggestions for future development.

- i. The system can be use with other brand of instrument. Previously this system are only compatible with the instrument that made by Yokogawa Company
- ii. Data bases of user should be included just to make sure the right person is using the system. Outsiders are not allowed to use the system, if they still want to use it, they have to register first.
- iii. Data bases of all data can be save in hard disk. All the data that enter by the user can be stored and can be recall back on their demands.
- iv. Provide a more user friendly system which consists of help button if user find any difficulties. Through this help button all the difficulties of using the system can be solve as soon as possible

5.2.1 Costing and Commercialization

There is no cost at all to develop this kind of project because all the instrument and hardware part is provided by the FKEE laboratory. Generally at this point, it shows that this kind of project should be implemented more on other subject just because it didn't cost anything at all

Besides this kind of project has a potential to be commercialized among the universities in Malaysia. It can be a very useful learning tools for every any engineering subject that using any level measurement or pressure instrumentation in their lab session.

REFERENCES

- [1] Essential of Process Instrumentation and Control, Yokogawa Trainer Manual of Pressure Calibration
- [2] <http://www.wikipedia.org/instrumentation>
- [3] T. Knowlton, K. Barksdale and S. Collings, 2002.
- [4] <http://www.freepatentsonline.com/4559829.html>
- [5] Process Control Instrumentation Technology, Curtis D. Johnson, Pearson Education Inc
- [6] http://www.yokogawa.com/tm/mt/mt220/tm-mt220_03.htm
- [7] <http://www.calibratordepot.com/ametekt-740pneumaticcalibrationpump.aspx>
- [8] <http://www.yokogawa.com/fld/PRESSURE/EJX/fld-ejx110a-01en.htm>
- [9] http://www.emersonprocess.com/raihome/gas/products/Model_375.asp

APPENDIX A

**USER MANUAL OF COMPUTER BASED INSTRUMENTATION FOR LEVEL
MEASUREMENT USING VISUAL BASIC APPLICATION.**

COMPUTER BASED INSTRUMENTATION FOR LEVEL MEASUREMENT USING VISUAL BASIC APPLICATION

USER'S GUIDE

MOHD HAFIZ B. HASBULLAH

Step To Use the Software System

Before starting use the software, user need to choose the device that will be used. Below is an example of the Advantech Device Manager look alike. User needs to install this program first, and the manufacturer provides this program. At here user can setup the device they want to use, they can choose the desired sampling rate they want

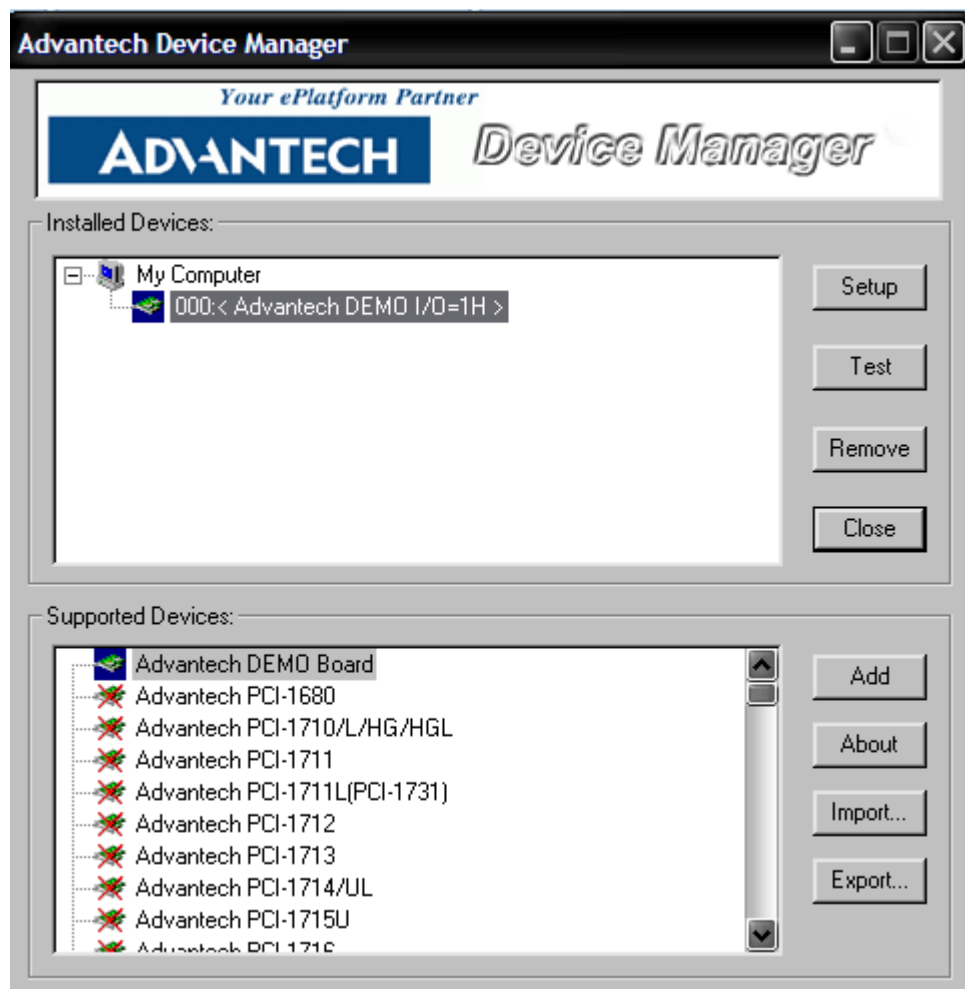


Figure 7.1

To start using the system user need to key in their name and id number. This step actually just a greeting for the user



Figure 7.2

After this step was done the popup, box will comes

Once the ok button of welcome message was click there will be another option which user has to decide whether to use the system in automatic mode or manual mode (figure 7.3). For this section, automatic mode will be the choice.

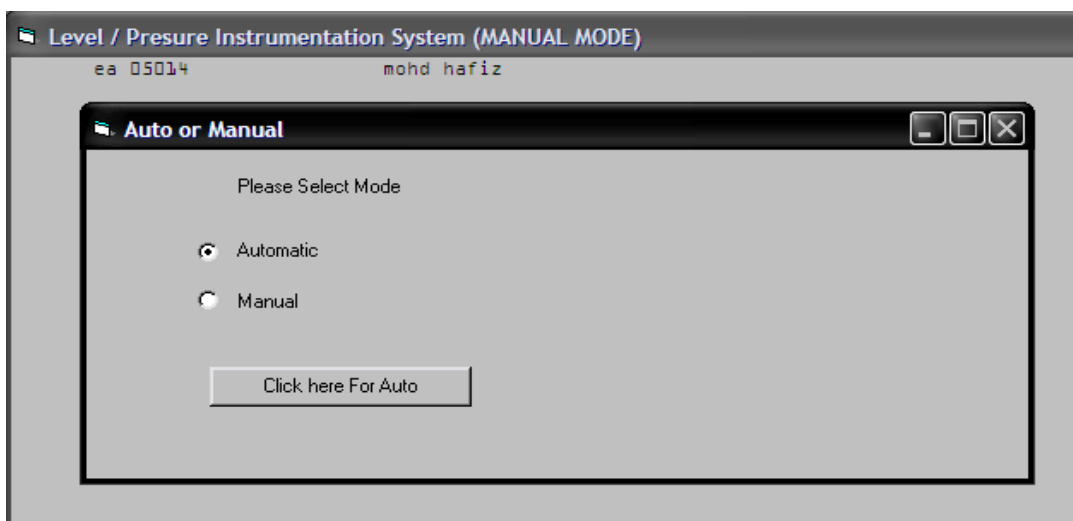


Figure 7.3

After the “click here button for auto” was click, the automatic section will pop up and look as figure 7.4.

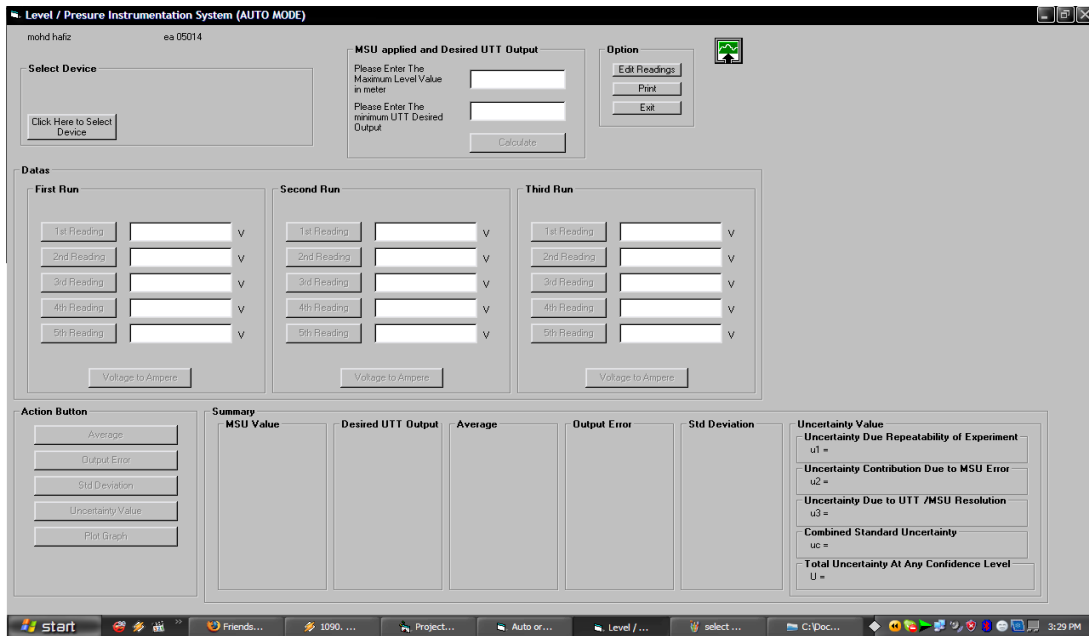


Figure 7.4

To proceed to the next step user need to choose which one device (DAQ card) that will be use. The option of choosing the device as figure 7.5

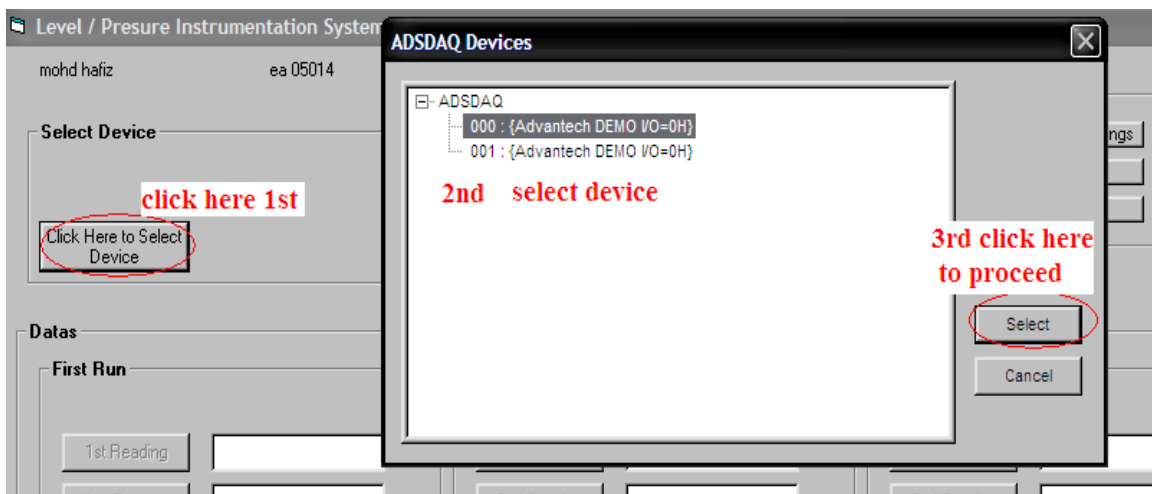


Figure 7.5

Once user has decided to select the device to use, user has to click select button to proceed to the next stage. Actually, this system support to complete the Level Instrumentation experiment and Pressure Instrumentation Experiment. At this point Level instrumentation experiment will be choosing by clicking Ok button. If user wants to proceed with Pressure instrumentation experiment, they have to click the cancel button (refer to figur

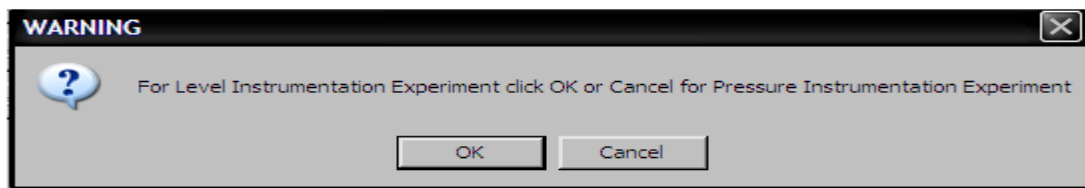


Figure 7.6

User has to insert the level value at MSU applied and UTT output section. At here, the maximum value of level needs to enter and the first desired UTT output need to enter too. After all the value needed was entering, a new section with name “Level to Pressure Conversion” will appear. This section actually is a reference to user to give a pressure input based on desired level value entered before.

MSU applied and Desired UTT Output

Please Enter The Maximum Level Value in meter:

Please Enter The minimum UTT Desired Output:

Option

Level To Pressure Conversion

$P = \rho gh$

P = pressure in Pa
 ρ = density in kg / m^3
 g = acceleration due to gravity
 h = level value in m

***density that will use for this conversion is water density which is equal to 1000 kg/m^3*
***acceleration due to gravity will be 9.8 m/s^2*

Level Value (m)	Pressure Value (Pa)
0	0
5	49000
10	98000
15	147000
20	196000

Third Run

1st Reading: V

2nd Reading: V

3rd Reading: V

4th Reading: V

5th Reading: V

Figure 7.7

This software also was set up with safety requirement, to avoid the system running into error just because the user forgets to key in the data. The pop up box will appear automatically when the system discover the error like figure 7.8

MSU applied and Desired UTT Output

Please Enter The Maximum Level Value in meter:

Please Enter The minimum UTT Desired Output:

Option

ERROR

There must be one or more textbox reading is empty, please check!

Figure 7.8

Data's section will be enabled once the calculate button of MSU applied and Desired UTT output section was clicked. User need to click several button appeared to read the value from the DAQ card. The value appeared will be in voltage reading, thus user need to click the "Voltage to Ampere" button to convert those values into Ampere. This section also provide safety requirement especially the reading of voltage not entered yet. The safety pop out box definitely same as figure 7.8

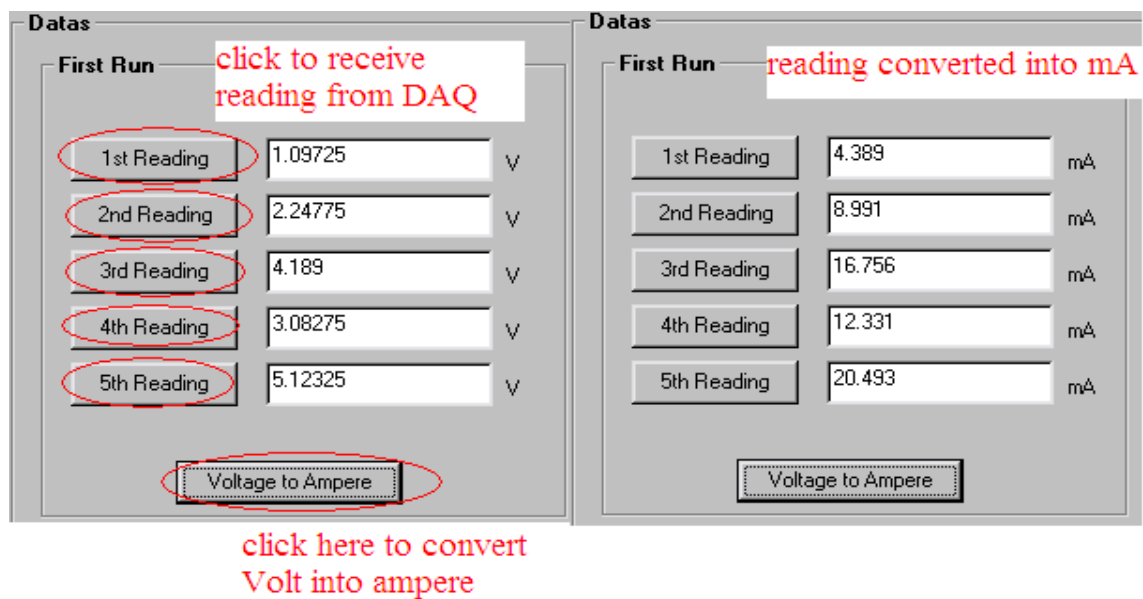


Figure 7.9

After all the reading was entered, several button in "Action Button" section will be enabled. The first button that will be enabled when all the data key in step was done is "Average Button"

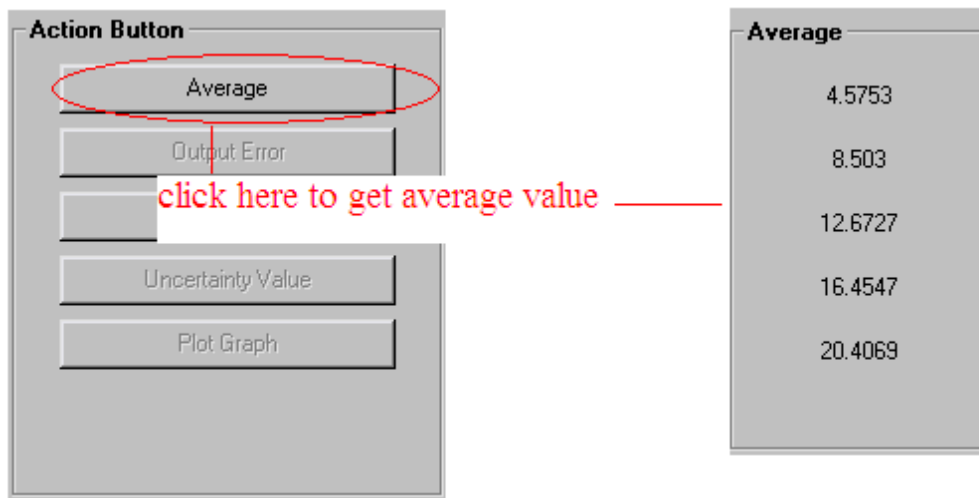


Figure 7.10

After the average button was click, the “Output Error” button will enable. This process is keep on going step by step, it means that after the “output Error” was clicked the “Uncertainty Value” button will enabled. This process is keeping going until the “Plot Graph” button is enabling. Below is all the value needed was calculated once the entire button in “Action Button” section was clicked.

Action Button	Summary				
<div>Average</div> <div>Output Error</div> <div>Std Deviation</div> <div>Uncertainty Value</div> <div>Plot Graph</div>	MSU Value	Desired UTT Output	Average	Output Error	Std Deviation
	0	4	4.5753	14.3825	0.1803
	5	8	8.503	6.2875	0.258
	10	12	12.6727	5.6058	0.1285
	15	16	16.4547	2.8419	0.1949
	20	20	20.4069	2.0345	0.0468

Figure 7.11

Once all the calculation of average, standard deviation, and output error was done. The “Plot Graph” button will enable, to plot graph just click the button and a new window will come out.

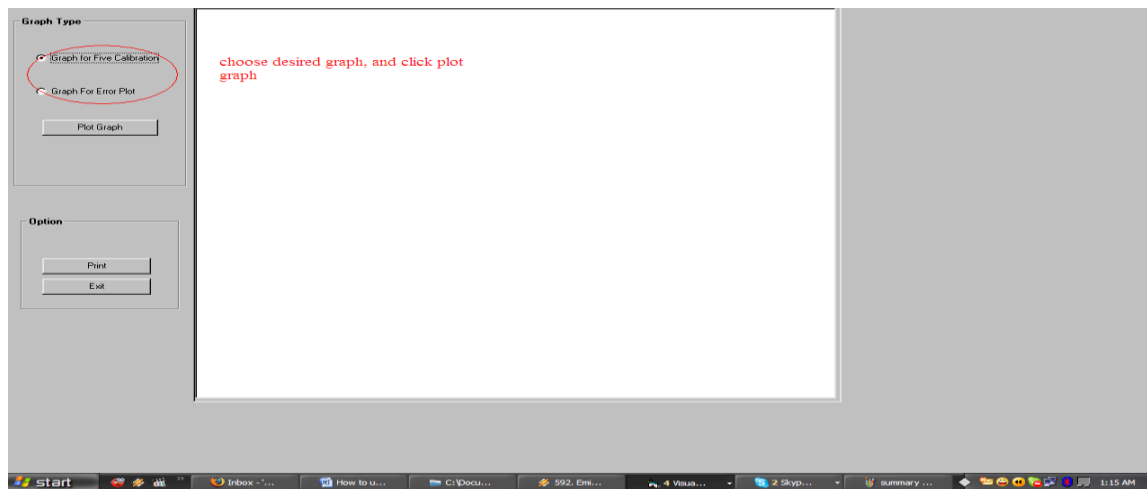


Figure 7.12

The graph part is blank, user need to choose which graph want to plot by using radio button appear in this section and click plot graph. The graph is like figure 7.13.

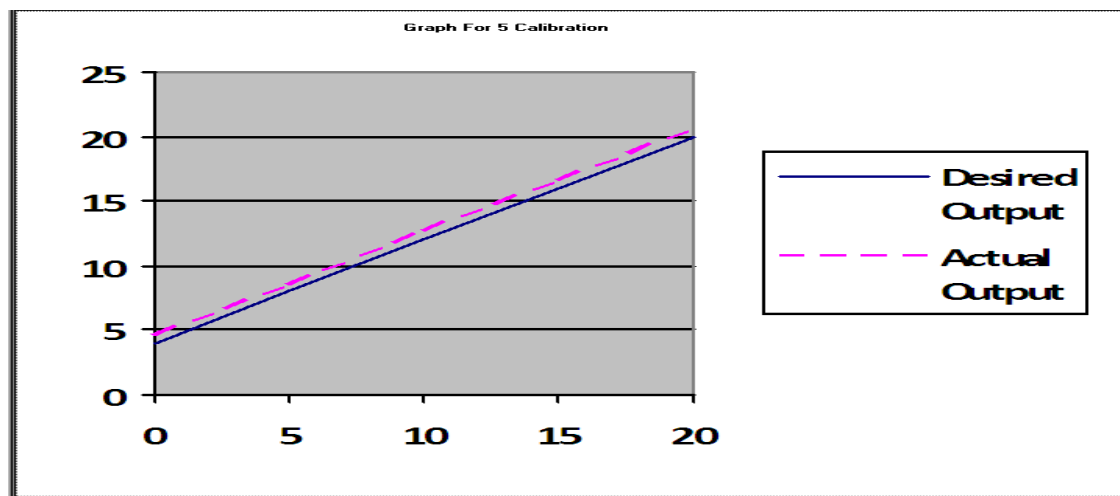


Figure 7.13

While for error graph, click the “error graph” option and click plot graph. Thus the graph will look like this.

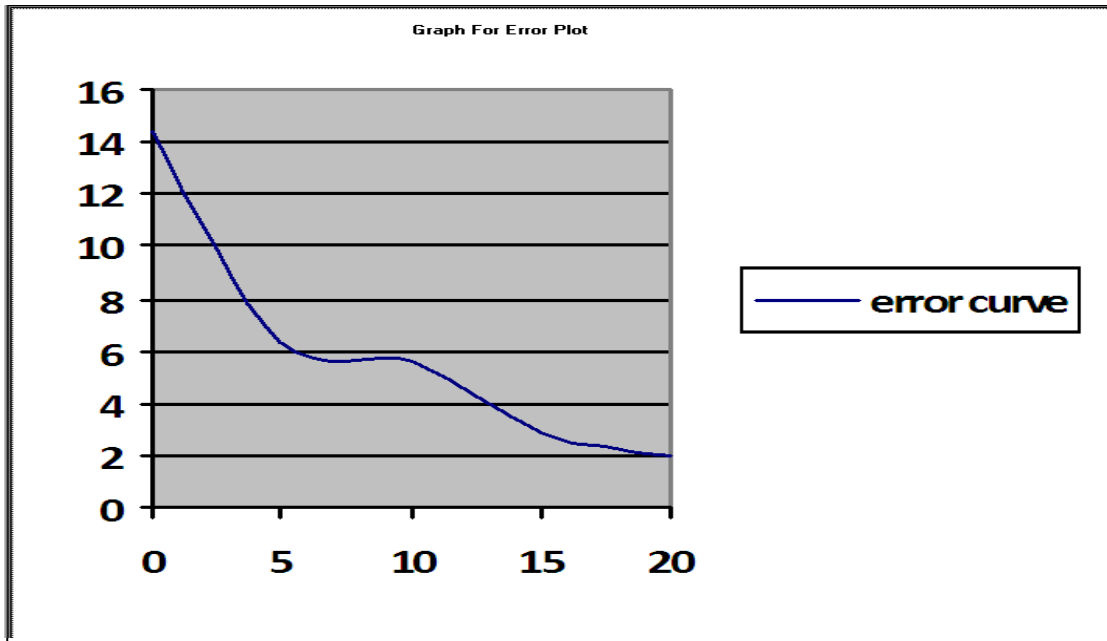


Figure 7.14

This software also provides the user with save option, which the system will save the graph into bitmap image. Besides, print button also can be finding at the option section, which appear in this graph window. To close the graph window, just click exit

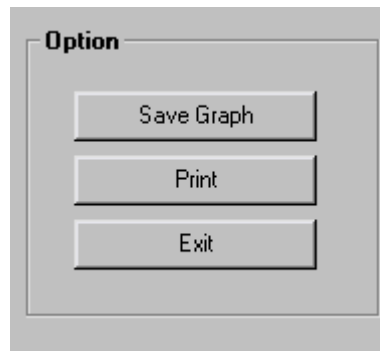


Figure 7.15

To calculate the uncertainty, just click the uncertainty value button appears in action button section. At this part, some of the value needed is based on instrument part, for example to calculate the u_2 , user need to confirm the maximum reading and range of the instrument that they use. Same goes to calculate u_3 which this part need the resolution of the differential pressure transmitter

Figure 7.16

When all the value enter by the user, the summary section will filled up with the value needed

Summary					Uncertainty Value	
MSU Value	Desired UTT Output	Average	Output Error	Std Deviation	Uncertainty Due Repeatability of Experiment	
0	4	4.5753	14.3825	0.1803	u1 = 0.112526	
5	8	8.503	6.2875	0.258	Uncertainty Contribution Due to MSU Error	
10	12	12.6727	5.6058	0.1285	u2 = 0.031754	
15	16	16.4547	2.8419	0.1949	Uncertainty Due to UTT /MSU Resolution	
20	20	20.4069	2.0345	0.0468	u3 = 0.034641	
					Combined Standard Uncertainty	
					uc = 0.121944	
					Total Uncertainty At Any Confidence Level	
					U = 0.24389	

Figure 7.17

APPENDIX B**YOKOGAWA DIFFERENTIAL PRESSURE TRANSMITTER EJX110****YOKOGAWA DIGITAL MANOMETER, MT220****ADVANTECH USB4716****AMETEK HAND PUMP T-740****HART 375 FIELD COMMUNICATOR**

Drawings

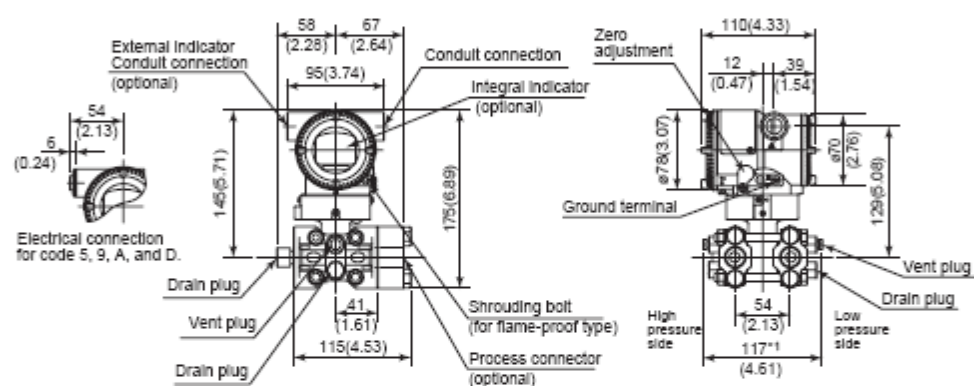
EJX110A Differential Pressure Transmitter Universal Flange

DPharp EJX™

[Style: S3]

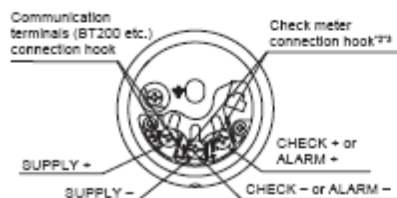
Unit: mm(approx. inch)

● Universal Flange (Installation code U)



*1: When Option code K1, K2, K5, or K6 is selected, add 30 mm (1.18 inch) to the value.

● Terminal Configuration



● Terminal Wiring

SUPPLY +	Power supply and output terminal
CHECK + or ALARM +	External indicator (ammeter) terminal ^{*2} or Status contact output terminal ^{*3} (when /AL is specified)
—	Ground terminal

*2: When using an external indicator or check meter, the internal resistance must be 10 Ω or less. A check meter or indicator cannot be connected when /AL option is specified.

*3: Not available for fieldbus communication type.

Drawings

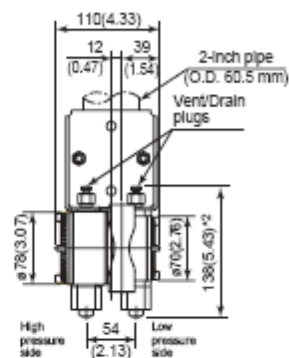
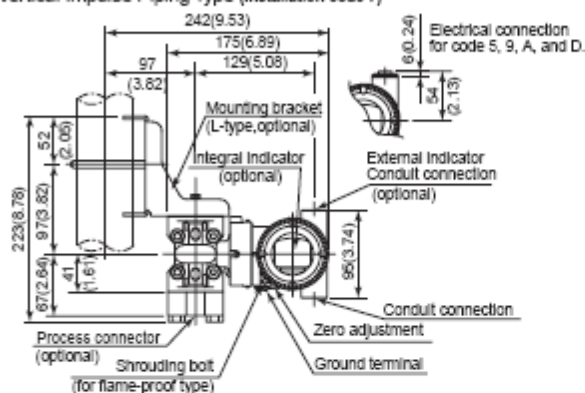
EJX110A
Differential Pressure Transmitter
Wetted Parts Material Code: S

DPharp EJX™

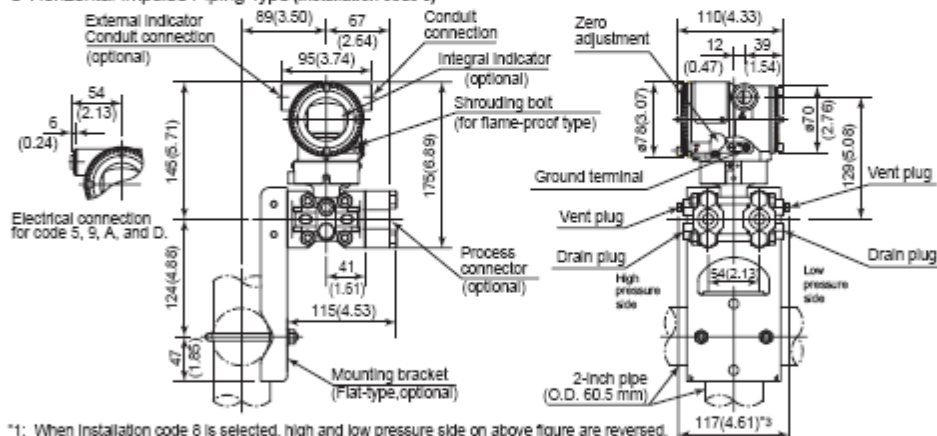
[Style: S3]

Unit: mm(approx. inch)

● Vertical Impulse Piping Type (Installation code 7)



● Horizontal Impulse Piping Type (Installation code 9)

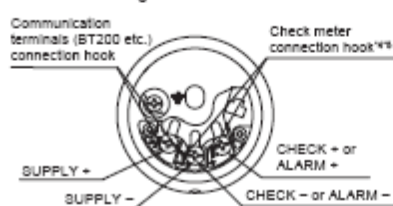


*1: When Installation code 8 is selected, high and low pressure side on above figure are reversed.
(i.e. High pressure side is on the right side.)

*2: When Option code K1, K2, K5, or K6 is selected, add 15 mm(0.59 inch) to the value in the figure.

*3: When Option code K1, K2, K5, or K6 is selected, add 30 mm(1.18 inch) to the value in the figure.

● Terminal Configuration



● Terminal Wiring

SUPPLY +	Power supply and output terminal
CHECK + or ALARM +	External indicator (ammeter) terminal ^{*4} or Status contact output terminal ^{*5} (when IAL is specified)
SUPPLY -	Ground terminal

*4: When using an external indicator or check meter, the internal resistance must be 10 Ω or less. A check meter or indicator cannot be connected when IAL option is specified.

*5: Not available for fieldbus communication type.

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P -

SD 01C25B01-01E
1st Edition: Feb. 27, 2004
7th Edition: June 30, 2008

Drawings

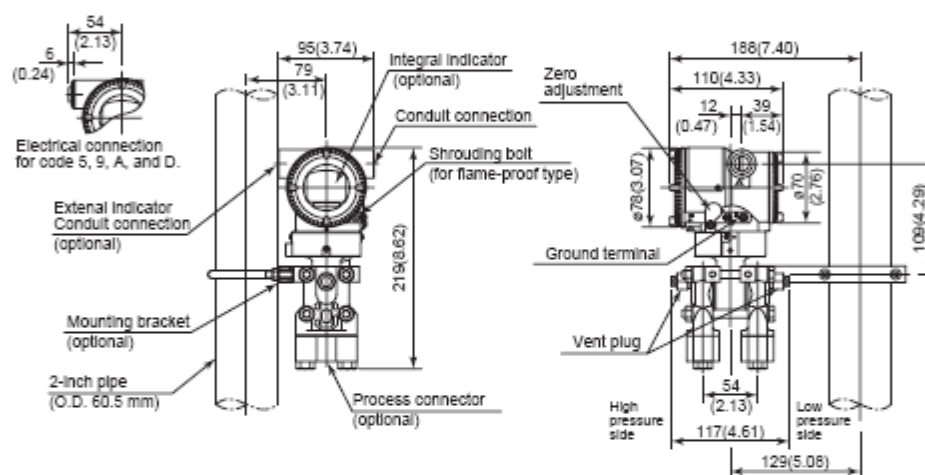
EJX110A Differential Pressure Transmitter Bottom Process Connection

DP *sharp* **EJX™**

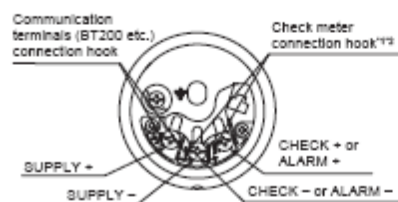
[Style: S3]

Unit: mm(approx. inch)

● Bottom Process Connection (Installation code B)



● Terminal Configuration



● Terminal Wiring

SUPPLY +	Power supply and output terminal
CHECK +	External indicator (ammeter) terminal ^{1,2}
or	or
ALARM +	Status contact output terminal ²
	(when /AL is specified)
Ground terminal	Ground terminal

¹: When using an external indicator or check meter, the internal resistance must be 10 Ω or less. A check meter or indicator cannot be connected when /AL option is specified.

²: Not available for fieldbus communication type.

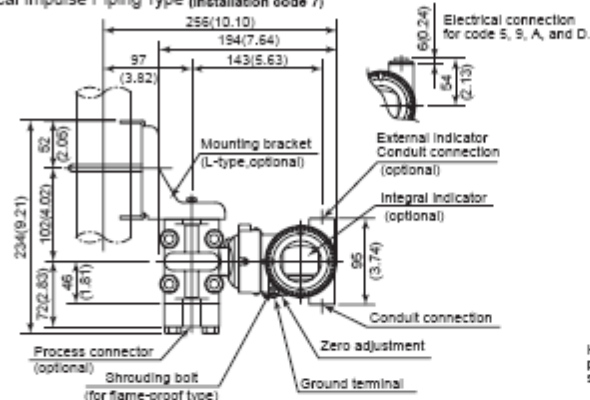
Drawings

EJX110A Differential Pressure Transmitter Wetted Parts Material Code: H, M, T, A, B, D

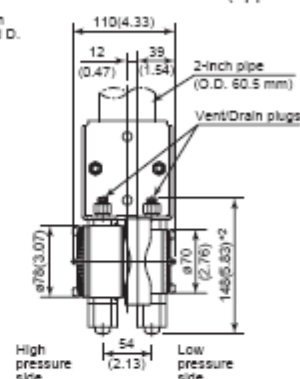
DPharp EJX™

[Style: S3]

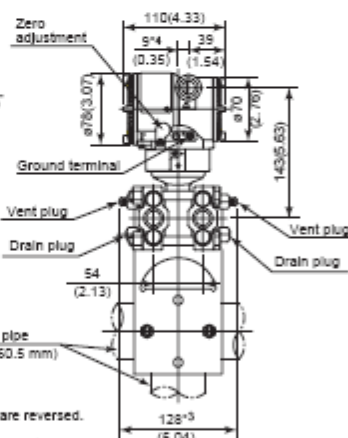
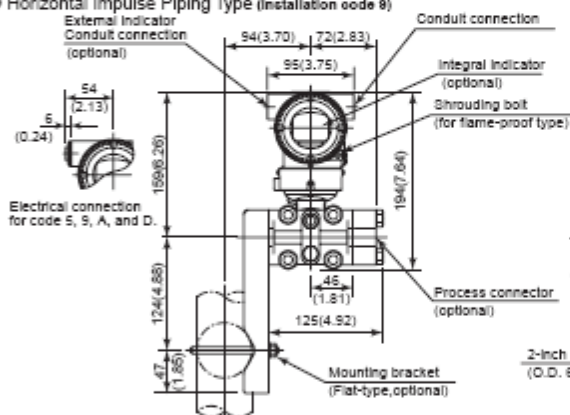
● Vertical Impulse Piping Type (Installation code 7)



Unit: mm(approx. inch)



● Horizontal Impulse Piping Type (Installation code 8)



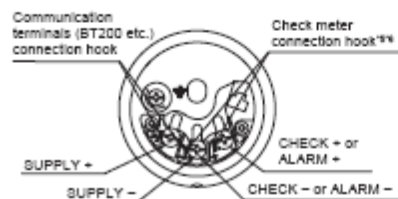
*1: When installation code 8 is selected, high and low pressure side on above figure are reversed.
(i.e. High pressure side is on the right side.)

*2: When Option code K1, K2, K5, or K6 is selected, add 15 mm(0.59 inch) to the value in the figure.

*3: When Option code K1, K2, K5, or K6 is selected, add 30 mm(1.18 inch) to the value in the figure.

*4: 15 mm(0.59 inch) for right side high pressure.

● Terminal Configuration



● Terminal Wiring

SUPPLY +	Power supply and output terminal
CHECK +	External indicator (ammeter) terminal*5
or	or
ALARM +	Status contact output terminal*5 (when /AL is specified)
Ground symbol	Ground terminal

*5: When using an external indicator or check meter, the internal resistance must be 10 Ω or less. A check meter or indicator cannot be connected when /AL option is specified.

*6: Not available for fieldbus communication type.

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SD 01C25B01-06E
1st Edition: May 23, 2008

General Specifications

EJX110A Differential Pressure Transmitter

DPharp EJX™

GS 01C25B01-01E

[Style: S3]

The high performance differential pressure transmitter EJX110A features single crystal silicon resonant sensor and is suitable to measure liquid, gas, or steam flow as well as liquid level, density and pressure. EJX110A outputs a 4 to 20 mA DC signal corresponding to the measured differential pressure. Its highly accurate and stable sensor can also measure the static pressure which can be shown on the integral indicator or remotely monitored via BRAIN or HART communications. Other key features include quick response, remote set-up using communications, self-diagnostics and optional status output for pressure high/low alarm. FOUNDATION Fieldbus protocol type is also available. All EJX series models in their standard configuration, with the exception of the Fieldbus type, are certified by TÜV as complying with SIL 2 for safety requirement.



■ STANDARD SPECIFICATIONS

Refer to GS 01C25T02-01E for Fieldbus communication type marked with "◇."

□ SPAN AND RANGE LIMITS

Measurement Span/Range	kPa	inH ₂ O/(D1)	mbar/(D3)	mmH ₂ O/(D4)
L				
Span	0.1 to 10	0.4 to 40	1 to 100	10 to 1000
Range	-10 to 10	-40 to 40	-100 to 100	-1000 to 1000
M				
Span	0.5 to 100	2 to 400	5 to 1000	50 to 10000
Range	-100 to 100	-400 to 400	-1000 to 1000	-10000 to 10000
H				
Span	2.5 to 500	10 to 2000	25 to 5000	0.025 to 5 kgf/cm ²
Range	-500 to 500	-2000 to 2000	-5000 to 5000	-5 to 5 kgf/cm ²
V				
Span	0.07 to 14 MPa	10 to 2000 psi	0.7 to 140 bar	0.7 to 140 kgf/cm ²
Range	-0.5 to 14 MPa	-71 to 2000 psi	-5 to 140 bar	-5 to 140 kgf/cm ²

T01E.EPS

□ PERFORMANCE SPECIFICATIONS

Zero-based calibrated span, linear output, wetted parts material code S and silicone oil, unless otherwise mentioned.

For Fieldbus communication type, use calibrated range instead of span in the following specifications.

Specification Conformance

EJX series ensures specification conformance to at least $\pm 3\sigma$.

Reference Accuracy of Calibrated Span

(includes terminal-based linearity, hysteresis, and repeatability)

Measurement span	M
Reference accuracy	
X ≤ span	±0.04% of Span
X > span	±(0.005+0.0035 URL/span)% of Span
X	10 kPa (40 inH ₂ O)
URL (upper range limit)	100 kPa (400 inH ₂ O)

T02E.EPS

Measurement span	H
Reference accuracy	
X ≤ span	±0.04% of Span
X > span	±(0.005+0.0049 URL/span)% of Span
X	70 kPa (280 inH ₂ O)
URL (upper range limit)	500 kPa (2000 inH ₂ O)

T06E.EPS

Measurement span	V
Reference accuracy	
X ≤ span	±0.04% of Span
X > span	±(0.005+0.00125 URL/span)% of Span
X	500 kPa (2000 inH ₂ O)
URL (upper range limit)	14 MPa (2000 psi)

T09E.EPS

Measurement span	L
Reference accuracy	
X ≤ span	±0.04% of Span
X > span	±(0.015+0.005 URL/span)% of Span
X	2 kPa (8 inH ₂ O)
URL (upper range limit)	10 kPa (40 inH ₂ O)

T03E.EPS

Square Root Output Accuracy

The square root accuracy is a percent of flow span.

Output	Accuracy
50% or Greater	Same as reference accuracy
50% to Dropout point	Reference accuracy × 50 Square root output (%)

T03E.EPS

Ambient Temperature Effects per 28°C (50°F) Change

Capsule	Effect
M	±(0.04% Span+0.009% URL)
H, V	±(0.04% Span+0.0125% URL)
L	±(0.055% Span+0.09% URL)

Technical Data

■ Pressure-Measurement Specifications

Model	767351	767353	767355	767356	767357
Pressure type	Gauge				Absolute
Measurement range (with guaranteed accuracy)	Positive pressure: 0 to 10 kPa Negative pressure: -10 to 0 kPa	Positive pressure: 0 to 130 kPa Negative pressure: -80 to 0 kPa	Positive pressure: 0 to 700 kPa Negative pressure: -80 to 0 kPa	Positive pressure: 0 to 3000 kPa Negative pressure: -80 to 0 kPa	0 to 130 kPa abs
Readout range	-12.0000 to 12.0000 kPa	Up to 156.000 kPa	Up to 840.000 kPa	Up to 3600.00 kPa	Up to 156.000 kPa abs
Accuracy six months after calibration (Tested at 23 ±3°C, after zero calibration)	Positive pressure: ±(0.01% of reading +0.015% of full scale) Negative pressure: ±(0.2% of reading +0.1% of full scale)	Positive pressure: ±(0.01% of reading+3 digits) for 20 to 130 kPa ±5digits for 0 to 20 kPa Negative pressure: ±(0.2% of reading +0.1% of full scale)	Positive pressure: ±(0.01% of reading +0.009% of full scale) Negative pressure: ±(0.2% of reading +0.1% of full scale)	Positive pressure: ±(0.01% of reading +0.005% of full scale) Negative pressure: ±(0.2% of reading +0.1% of full scale)	±(0.01% of reading+0.005% of full scale)
Measurement accuracy one year after calibration (add each value to the accuracy six months after calibration) (Tested at 23 ±3°C, after zero calibration)	±(0.01% of full scale)	±(0.005% of full scale)			
Readout update interval ¹⁾	250msec				
Response time ²⁾	2.5 sec max.				
Resolution	0.0001 kPa	0.001 kPa	0.01 kPa	0.01 kPa	0.001 kPa
Allowable input	2.7 kPa abs to 500 kPa gaug	2.7 kPa abs to 500 kPa gauge	2.7 kPa abs to 3000 kPa gauge	2.7 kPa abs to 4500 kPa gauge	1 Pa abs to 500 kPa abs
Internal volume	Approx. 10 cm ³				
Temperature effect	Zero point: ±0.0015% of full scale/°C Span: ±0.001% of full scale/°C	Zero point: ±0.001% of full scale/°C Span: ±0.001% of full scale/°C			
Effect of attitude • 90° tilt, forward or backward • 30° tilt, right or left	Zero point: ±0.1% of full scale Span: ±2.5% of full scale	Zero point: ±0.01% of full scale Span: ±0.2% of full scale	Zero point: ±0.01% of full scale Span: ±0.05% of full scale	Zero point: ±0.01% of full scale Span: ±0.01% of full scale	Zero point: ±0.01% of full scale Span: ±0.2% of full scale
Leak rate	10 ⁻⁶ cm ³ /sec				
Weight (main unit)	Approx. 8.5 kg	Approx. 7.0 kg	Approx. 8.5 kg	Approx. 7.0 kg	Approx. 7.0 kg
Applicable fluids	Gases and liquids (non-flammable, non-explosive, non-toxic and non-corrosive fluids)				
Fluid temperature	5 to 50°C				
Liquid viscosity	5 × 10 ⁻⁶ m ² /sec max.				
Pressure sensor	Silicon resonant sensor				
Pressure sensing element	Diaphragm				
Readout unit	kPa only, or selection from a group consisting of kPa, kgf/cm ² , mmHg and mmH ₂ O or a group consisting of kPa, psi, inHg, inH ₂ O, kgf/cm ² , mmHg and mmH ₂ O; specify when ordering ³⁾				
Pressure input connector	Rc1/4 or NPT1/4 female-threaded or VCO1/4" (specify when ordering), located on both front and rear panels; however, simultaneous input to connections on both sides is prohibited)				
Material of measurement section	Diaphragm: Hastelloy C276; flange of measurement chamber: stainless steel (JIS SUS316), Internal piping: stainless steel (JIS SUS316); O-ring: fluororubber; input connector: stainless steel (JIS SUS316)				

■ Pressure Unit Conversion Table

Pa	bar	kgf/cm ²	atm	mmH ₂ O or mmAq	mmHg or Torr
1	1 × 10 ⁻⁵	1.019 72 × 10 ⁻⁵	9.869 23 × 10 ⁻⁶	1.019 72 × 10 ⁻¹	7.500 62 × 10 ⁻³
1 × 10 ⁵	1	1.019 72	9.869 23 × 10 ⁻¹	1.019 72 × 10 ⁴	7.500 62 × 10 ²
9.806 65 × 10 ⁴	9.806 65 × 10 ⁻¹	1	9.678 41 × 10 ⁻¹	1 × 10 ⁴	7.355 59 × 10 ²
1.013 25 × 10 ⁵	1.013 25	1.033 23	1	1.033 23 × 10 ⁴	7.600 00 × 10 ²
9.806 65	9.806 65 × 10 ⁻⁶	1 × 10 ⁻⁶	9.678 41 × 10 ⁻⁶	1	7.355 59 × 10 ⁻²
1.333 22 × 10 ²	1.333 22 × 10 ⁻³	1.359 51 × 10 ⁻³	1.315 79 × 10 ⁻³	1.359 51 × 10	1

■ DCV/DCA Function Specifications

	Voltage	Current
Measurement range (with guaranteed accuracy)	0 to ± 5.25 V	0 to ± 21 mA
Accuracy (Tested at 23 $\pm 3^\circ\text{C}$)	$\pm(0.01\%$ of reading + 2 digits) 30 days after calibration	
	$\pm(0.03\%$ of reading + 2 digits) 90 days after calibration	
	$\pm(0.05\%$ of reading + 3 digits) 6 months after calibration	
	$\pm(0.07\%$ of reading + 3 digits) 1 year after calibration	
Readout range	0 to ± 5.0000 V	0 to ± 24.000 mA
Maximum allowable input	30VDC	100mA
Readout unit	V	mA
Input impedance	Approx. 10 M Ω	Approx. 20 M Ω
CMRR	120 dB min. (50/60 Hz; $R_s = 1$ k Ω)	—
NMRR	60 dB min. (50/60 Hz)	—
Temperature effect	$\pm(0.01\%$ of reading + 2 digits) / 10°C	

Note: The maximum allowable potential difference between any measuring terminal and the grounding terminal is 42 Vpeak.

■ 24 V DC Output Specifications

Output voltage	24 ± 1 V DC (fixed)
Output current	30 mA max. (with limiter)

Note: The maximum allowable potential difference between any measuring terminal and the grounding terminal is 42 Vpeak.

■ Data Memory Specifications

Memory capacity	2000 data items
-----------------	-----------------

■ Specifications of Communication Interfaces (choose one)

GP-IB Interface	
Electrical and mechanical specifications	Conforms to IEEE Standard 488-1978
Functional specifications	SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT1, C0
RS-232 Interface	
Transmission method	Start-stop synchronization
Transfer rates	1200, 2400, 4800, 9600 bits/sec

■ Specifications of "/DA" Option

D/A Conversion Output

Output voltage	Switchable between 0 to ± 2 V and 0 to ± 5 V to reflect the readout of pressure measurement. Example of corresponding output voltages when measured with a 130-kPa gauge-pressure model set to the ± 2 V range: 0 kPa = 0 V 65 kPa = 1 V 130 kPa = 2 V 165 kPa = 2.4 V -80 kPa = -1.230 V
Output resolution	16 bits, where full scale is approximately $\pm 125\%$ of range
Output accuracy (Tested at 23 $\pm 3^\circ\text{C}$, after zero calibration, using the D/A conversion output terminal)	Add $\pm 0.06\%$ of full scale to accuracy in the Pressure-measurement Specifications section.
Temperature effect	$\pm 0.005\%$ of full scale/ $^\circ\text{C}$
Output update interval	Approx. 2 msec
Response time	Same as the response time specified in the Pressure-measurement Specifications section.
Output resistance	0.1 Ω max.
Load resistance	1 k Ω min.

Comparator Output

Output signal	HIGH, IN, LOW, BUSY
Operation	HIGH = 1, if measured value > upper limit IN = 1, if upper limit \geq measured value \geq lower limit LOW = 1, if measured value < lower limit BUSY = 1, if there is a transition in the output signal An LED lamp on the display corresponding to HIGH, LOW or IN comes on.
Signal level	TTL

External Trigger

Input level	TTL
Operation	A start-of-measurement trigger is applied at a falling edge when the high-state level of an external signal is input with the HOLD function enabled. At the moment of triggering, the LED lamp on the front panel comes on.

■ Common Specifications

Display	LCD (with backlight); number of readout digits: 5.5 or 4.5 ⁴ digits for pressure measurement and 4.5 digits for measurement with DCV/DCA functions
Warm-up time	Approx. 5 minutes
Operating temperature/humidity range	5 to 40 $^\circ\text{C}$ /20 to 80% RH (no condensation)
Altitude of operation	2000 m max.
Storage temperature range	-20 $^\circ\text{C}$ to 60 $^\circ\text{C}$
Power Supply	Three-way power (AC or DC supply, or optional Ni-Cd batteries)
AC power rating	100 to 120/200 to 240 V AC, at 50/60 Hz
Allowable supply voltage range	90 to 132 V/180 to 264 V AC
Allowable supply frequency range	47 to 63 Hz
DC power rating	10 to 15 V DC
Battery pack (optional)	Ni-Cd batteries: Last approximately 6 hours in continuous operation mode when fully charged (tested with the backlight, DCV/DCA functions and 24-V DC output turned on). Battery charger: Built into the MT220 main unit. Recharge time: Approx. 12 hours
Power consumption	When in pressure measurement mode: 25 VA max. for 100-V power line; 40 VA max. for 200-V power line When in recharge mode: 45 VA max. for 100-V power line; 65 VA max. for 200-V power line When in DC-powered operation: 10 VA max.
Insulation resistance	20 M Ω min. at 500 V DC, between AC power supply and casing
Withstanding voltage	1500 V AC (50/60 Hz) for 1 minute, between AC power supply and casing
External dimensions	Main unit: Approx. 132 mm \times 213 mm \times 350 mm, excluding protrusions Battery pack (optional): Approx. 33 mm \times 182 mm \times 260 mm, excluding protrusions
Weight	Main unit: See the Pressure-measurement Specifications section. Battery pack: Approx. 2.7 kg
Accessories	Connector for DC power supply (1), rubber pads for rear foot (2), labels for indicating measurement object, test lead (1), power cord (1), and user's manual (1)

¹ The interval of outputting data via communication is the same as the readout update interval.

² Conditions of response time measurement

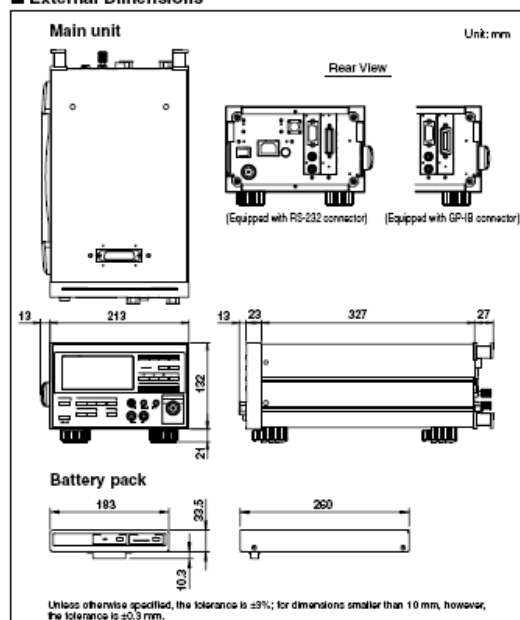
- The response time is defined as the interval from the start of change to the time the readout settles to within $\pm 1\%$ of its final value.
- The manometer under test is made open to the atmospheric pressure when it is at its full-scale value, where the input section is under no load. In the case of absolute-pressure models, the manometer under test is made open to the atmospheric pressure at a scale value of 0.
- Measurement is performed using the D/A conversion output.

³ All models are factory-set to kPa.

⁴ VDO is a registered trademark of Swagelok Company.

⁵ 4.5/5.5 digits for Model 767955.

■ External Dimensions



Models and Suffix Codes

■ Main Units

Product	Model	Suffix Code	Remarks
MT220 series of digital manometers	767351	—	10 kPa-range, gauge-pressure model
	767353	—	130 kPa-range, gauge-pressure model
	767355	—	700 kPa-range, gauge-pressure model
	767356	—	3000 kPa-range, gauge-pressure model
	767357	—	130 kPa-range, absolute-pressure model
Pressure unit	—U1	—	kPa
	—U2	—	kPa, switchable to kgf/cm ² , mmHg or mmH ₂ O
	—U3	—	kPa, switchable to psi, inHg, inH ₂ O, kgf/cm ² , mmHg or mmH ₂ O
Communication interface	—C1	—	GP-IB
	—C2	—	RS-232
Pressure I/O connection	—P1	—	Rc 1/4
	—P2	—	NPT1/4 female-threaded
	—P3	—	VCO 1/4*
Power cord	—D	—	UL standard
	—F	—	VDE standard
	—R	—	SAA standard
	—Q	—	BS standard
Option	—DA	—	D/A conversion output, comparator output and external trigger input

* VCO is a registered trademark of Swagelok Company.

■ Optional Accessories

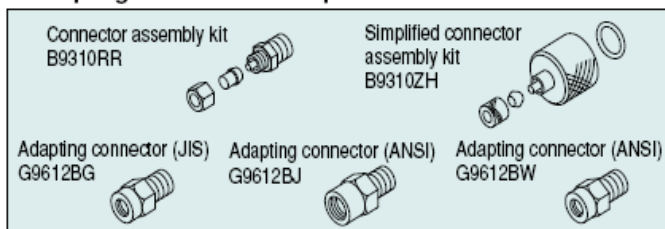
Product	Model	Suffix Code	Remarks
Battery pack	269913	—	Ni-Cd batteries for MT210/220 series
Ni-Cd batteries	269914	—	A kit of three Ni-Cd batteries for the 269913 battery pack
Carrying case	B9320ND	—	For use with MT210/220 series
Connector assembly kit	B9310RR	—	For use with $\phi 4 \times \phi 6$ PVC tubing
Simplified connector assembly kit	B9310ZH	—	For use with $\phi 4 \times \phi 6$ PVC tubing
Adapting connector	G9612BG	—	JIS; R1/4-to-Rc1/8
Adapting connector	G9612BJ	—	ANSI; R1/4-to-NPT1/4 female thread
Adapting connector	G9612BW	—	ANSI; R1/4-to-NPT1/8 female thread

■ Carrying Case



Picture of B9320ND carrying case

■ Adapting Connectors for Input Section



■ Optional Documentation

Item	Document Code	Available No. of Copies
Test certificate	DOC TC	—
User's manual	DOC IM	One per order
Drawings for approval	3984 03	Five max.

USB-4716

200 kS/s, 16-bit, 16-ch Multifunction USB Module



CE FCC

Features

- Supports USB 2.0
- Portable
- Bus-powered
- 16 analog input channels
- 16-bit resolution AI
- Sampling rate up to 200 kS/s
- 8DI/8DO, 2 AO and 1 32-bit counter
- Wiring terminal on modules
- Suitable for DIN-rail mounting
- Lockable USB cable for rigid connection

Introduction

The USB-4700 series consists of true Plug & Play data acquisition devices. No more opening up your computer chassis to install boards—just plug in the module, then get the data. It's easy and efficient. USB-4716 offers 16SE/8Diff. inputs with 16-bit resolution, up to 200 kS/s throughput, 16 digital I/O lines and 1 user counter, and 16-bit analog outputs.

Reliable and rugged enough for industrial applications, yet inexpensive enough for home projects, the USB-4716 is the perfect way to add measurement and control capability to any USB capable computer. The USB-4716 is fully USB Plug & Play and easy to use. It obtains all required power from the USB port, so no external power connection is ever required.

Specifications

Analog Input

- Channels 16 single-ended/ 8 differential (SW programmable)
- Resolution 16 bits
- Max. Sampling Rate* 200 kS/s max. (For USB 2.0)
- FIFO Size 1024 samples
- Overvoltage Protection 30 Vp-p
- Input Impedance 1 GΩ
- Sampling Modes Software, onboard programmable pacer, or external
- Input Range (V, software programmable)

Gain Code		4	0	1	2	3
Gain		0.5	1	2	4	8
Input Range	Bipolar	+/-10V	+/-5V	+/-2.5V	+/-1.25V	+/-0.625V
	Uni-Polar	N/A	0 ~ 10V	0 ~ 5V	0 ~ 2.5V	0 ~ 1.25V

*Note: The sampling rate and throughput depends on the computer hardware architecture and software environment. The rates may vary due to programming language, code efficiency, CPU utilization and other factors.

Analog Output

- Channels 2
- Resolution 16 bits
- Output Rate Static update
- Output Range (V, software programmable)

Internal Reference	Unipolar	0 ~ 5, 0 ~ 10
	Bipolar	±5 V, ±10 V

- Slew Rate 0.125 V/μs
- Driving Capability 5 mA
- Output Impedance 0.1 Ω max.
- Operation Mode Single output
- Accuracy Relative: ±1 LSB

Digital Input

- Channels 8
- Compatibility 3.3 V/5 V/TTL
- Input Voltage Logic 0: 0.8 V max.
Logic 1: 2.0 V min.

Digital Output

- Channels 8
- Compatibility 3.3 V/TTL
- Output Voltage Logic 0: 0.4 V max.
Logic 1: 2.4 V min.
- Output Capability Sink: 2 mA (sink)
Source: 2 mA (source)

Event Counter

- Channels 1
- Compatibility 3.3V/TTL
- Max. Input Frequency 0.1 ~ 1K while using FAI; 0.1 ~ 10K while using SWAI

General

- Bus Type USB 2.0
- I/O Connector On board screw terminal
- Dimensions (L x W x H) 132 x 80 x 32 mm
- Power Consumption Typical: +5 V @ 340 mA
Max: +5 V @ 440 mA
- Operating Temperature 0 ~ 60° C (32 ~ 158° F) (refer to IEC 68-2-1, 2)
- Storing Temperature -20 ~ 85° C (-4 ~ 158° F)
- Operating Humidity 5 ~ 85% RH non-condensing (refer to IEC 68-1, -2, -3)
- Storage Humidity 5 ~ 95% RH non-condensing (refer to IEC 68-1, -2, -3)

Ordering Information

- USB-4716 200 kS/s, 16-bit Multifunction USB Module, one 1.8 m USB 2.0 cable included
- 1960004544 Wallmount Bracket
- 1960005788 VESA Mount Bracket

FUNCTIONAL SPECIFICATIONS



Model T-620 Hydraulic Pressure Tester

Model T-620 Hydraulic Pressure Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
Model T-620 3000 PSIG
Model T-620H 5000 PSIG

Wetted Parts
Aluminum, Brass, Stainless Steel, and LEXAN®

"O" Rings
Buna-N

Reservoir Capacity
0.5 pint

Test Connections
0.25-inch NPT, 24-inch (60.95cm) long hose

Weight (Approximate)
3.0 lbs (1.36 kg)

Model T-730 Pneumatic Pressure Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
30 PSIG

Wetted Parts
Aluminum, Brass, Stainless Steel, NYLON® and NYLATRON GS®

"O" Rings
Buna-N

Test Connections
0.25-inch NPT, 24-inch (60.95cm) long hose

Weight (Approximate)
3.0 lbs (1.36 kg)



Model T-730 Pneumatic Pressure Tester

Model T-740 Pneumatic Pressure Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
200 PSIG

Wetted Parts
Aluminum, Brass, Stainless Steel, NYLON® and NYLATRON GS®

"O" Rings
Buna-N

Test Connections
0.25-inch NPT, 24-inch (60.95cm) long hose

Weight (Approximate)
3.0 lbs (1.36 kg)

Model T-750 Vacuum Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
25" Hg

Wetted Parts
Aluminum, Brass, Stainless Steel, NYLON® and NYLATRON GS®

"O" Rings
Buna-N

Test Connections
0.25-inch NPT, 24-inch (60.95cm) long hose

Weight (Approximate)
3.0 lbs (1.36 kg)



Model T-810 Pneumatic Pressure Tester

Model T-810 Pneumatic Pressure Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
200 PSIG

Wetted Parts
DELTRIN, Stainless Steel and Buna-N

Test Connections
0.125-inch FNPT (T-810)
0.125-inch FBSPT (T-810-M)

Weight (Approximate)
0.7 lbs (0.32 kg)

Model T-811 Vacuum Pressure Tester

Accuracy
±0.5% of Gauge Span

Operating Pressure (Maximum)
600mm Hg vacuum

Wetted Parts
DELTRIN, Stainless Steel and Buna-N

Test Connections
0.25-inch NPT, 24-inch (60.95cm) long hose

Weight (Approximate)
0.7 lbs (0.32 kg)

ORDERING INFORMATION

MODEL T-730 PNEUMATIC PRESSURE TESTER

Order Number	Description
Base Number	
T-730	Hand-held Pneumatic Tester, 0 to 30 PSIG Range, No Test Gauge
T-731	Hand-held Pneumatic Tester, 0 to 30 PSIG Range, 0 to 300" H ₂ O Integral Gauge
T-732	Hand-held Pneumatic Tester, 0 to 30 PSIG Range, 0 to 30 PSIG Integral Gauge
Calibration Certification Option	
/C	NIST Certification and Data
T-732/C	Sample Order Number Model T-730 Pneumatic Tester, 0 to 30 PSIG Range, with integral 0 to 30 PSIG Gauge

MODEL T-740 PNEUMATIC PRESSURE TESTER

Order Number	Description
Base Number	
T-740	Hand-held Pneumatic Tester, 0 to 200 PSIG Range, No Test Gauge
T-741	Hand-held Pneumatic Tester, 0 to 200 PSIG Range, 0 to 60 PSIG Integral Gauge
T-742	Hand-held Pneumatic Tester, 0 to 200 PSIG Range, 0 to 100 PSIG Integral Gauge
T-743	Hand-held Pneumatic Tester, 0 to 200 PSIG Range, 0 to 200 PSIG Integral Gauge
T-744	Hand-held Pneumatic Tester, 0 to 200 PSIG Range, 0 to 300 PSIG Integral Gauge
Calibration Certification Option	
/C	NIST Certification and Data
T-742	Sample Order Number Model T-740 Pneumatic Tester, 0 to 200 PSIG Range, with integral 0 to 100 PSIG Gauge

MODEL T-620 HYDRAULIC PRESSURE TESTER

Order Number	Description
Base Number	
T-620	Hand-held Hydraulic Tester, Pump Only, No Test Gauge
T-621	Hand-held Hydraulic Tester, 0 to 1000 PSIG Range Test Gauge
T-622	Hand-held Hydraulic Tester, 0 to 2000 PSIG Range Test Gauge
T-623	Hand-held Hydraulic Tester, 0 to 3000 PSIG Range Test Gauge
T-620H	Hand-held Hydraulic Tester, 0 to 5000 PSIG Range Test Gauge
Calibration Certification Option	
/C	NIST Certification and Data
T-622/C	Sample Order Number Model T-622 Hydraulic Tester, with 0 to 2000 PSIG Range Test Gauge

MODEL T-750 VACUUM TESTER

Order Number	Description
Base Number	
T-750	Hand-held Vacuum Tester, Pump Only, No Test Gauge
T-751	Hand-held Vacuum Tester, 0 to 30" Hg Vacuum Range Test Gauge
T-750	Sample Order Number Model T-750 Vacuum Tester, Pump Only

Product Data Sheet

December 2003

375 Field Communicator

■ Intrinsically Safe.

The 375 Field Communicator meets the Intrinsic Safety requirements of the listed regulatory agencies and standards. All of the available Hazardous Locations approvals are provided in a single model option (see Ordering Information).

- CENELEC/ATEX
- Factory Mutual (FM)
- Canadian Standards Association (CSA)
- FISCO



Even the battery pack is approved for installation in hazardous areas. The 375 Field Communicator is designed for use in areas where laptops shouldn't go.

■ Rugged and Reliable.

It's called 'Field Communicator' for a reason. Some tasks just have to be performed at the device. The 375 Field Communicator is designed for tough use in your plant or mill.

Its large keys and physical navigation buttons allow for one-handed operation, even with your work gloves on. The rugged display is designed to take the knocks and shocks from normal use in the plant.

As for reliable, when was the last time you had to send your 275 HART Communicator in for repair? That's exactly the kind of reliability we've built into the 375. The 375 Field Communicator is designed, manufactured and tested to specifications that are even more demanding. The 375 Field Communicator is designed to go wherever you have to go to get the job done.

Specifications

Processor and Memory Specifications

- Microprocessor**
 - 80 MHz Hitachi® SH3
- Memory Internal Flash**
 - 32 MB
- System Card**
 - 128 MB or higher secure digital card
- RAM**
 - 32 MB
- Expansion Module**
 - 32 MB or higher secure digital card

PHYSICAL Specifications

- Weight**
 - Approximately 2 lb. (0.9kg) with battery
- Display**
 - 1/4 VGA (240 by 320 pixels) monochrome 3.8" (9.6 cm) transreflective display with touch screen
 - Anti-glare coated
- Keypad**
 - 25 keys including 4 action keys, 12 alphanumeric keys, 4 programmable function keys, on/off and 4 cursor-control (arrow) keys; membrane design with tactile feedback

POWER SUPPLY Specifications

- Battery Pack**
 - Rechargeable NiMH batteries
- Battery Operating Time**
 - Up to ten hours depending on usage
- Battery Charger Options**
 - Input voltage 85-240 VAC, 50/60 Hz
 - Cables included with U.S., European and U.K. plugs

CONNECTION Specifications

- Battery Charger**
 - Mini DIN 4-pin jack
- HART and Fieldbus**
 - Three 4mm banana plugs (one common to HART and Foundation fieldbus)
- IrDA Port**
 - IrDA (Infrared Data Access) port supporting up to 115 Kbps
 - ±15 degrees recommended maximum angle from center line
 - Approximately 12" (30 cm) recommended maximum distance

ENVIRONMENTAL Specifications

- Usage**
 - -10° C (14° F) to +50° C (122° F)
 - 0% to 95% RH (non-condensing) for 0° C (32° F) to +50° C (122° F)
- Charge**
 - 0° C (32° F) to +40° C (104° F)
- Storage**
 - -20° C (-4° F) to +55° C (131° F) with batteries
- Storage Without Batteries**
 - -20° C (-4° F) to +60° C (140° F)
- Enclosure Rating**
 - IP51 (from front)
- Shock**
 - Tested to survive a 1-meter drop test onto concrete

EASY UPGRADE REQUIREMENTS

- Usage**
 - PC with internet access
 - CD Rom drive
 - IrDA port (or adapter)
 - Windows 2000 or XP