COMPUTER-BASED INSTRUMENTATION FOR PRESSURE INSTRUMENT USING VISUAL BASIC APPLICATION

MOHD AIZAT FAIZ BIN MOHD YAZID

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **COMPUTER-BASED INSTRUMENTATION FOR PRESSURE INSTRUMENT USING VISUAL BASIC APPLICATION.**

SESI PENGAJIAN: **2008/2009**

Saya **MOHD AIZAT FAIZ BIN MOHD YAZID (850517-14-5749)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:

160, SELASAR ROKAM 14
KG. SERI AMPANG B 31350 IPOH
PAHANG

MOHD ANWAR ZAWAWI
(Nama Penyelia)

Tarikh: **12 NOVEMBER 2008**

Tarikh: : **12 NOVEMBER 2008**

CATATAN:
- * Potong yang tidak berkenaan.
- ** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
- ♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

To my beloved father, Tn. Hj Mohd Yazid bin Ibrahim and my beloved mother, Pn. Hjh. Hasnah bt Juhari,

Who always pray for me and give me courage to finish this thesis.

And also to those people who have guided and inspired me throughout my journey.

Thank you for the supports and advices that have been given.

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

Signature : ______________________________

Name : MOHD ANWAR ZAWAWI

Date : 12 NOVEMBER 2008

COMPUTER-BASED INSTRUMENTATION FOR PRESSURE INSTRUMENT
USING VISUAL BASIC APPLICATION

MOHD AIZAT FAIZ BIN MOHD YAZID

This thesis is submitted as partial fulfillment of the requirements for the award of the
Bachelor of Electrical Engineering (Hons.) (Electronics)

Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

NOVEMBER 2008

"All the trademark and copyrights use herein are property of their respective owner. References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author."

Signature : ______________________________

Author : MOHD AIZAT FAIZ BIN MOHD YAZID

Date : 10 NOVEMBER 2008

ACKNOWLEDGEMENT

Firstly, I would like to thank to my family especially to Tn. Hj. Mohd Yazid bin Ibrahim and Pn. Hjh. Hasnah bt Juhari for their fully support through all this year I have been in Universiti Malaysia Pahang (UMP). Special thanks to my very supportive supervisor, Cik Najidah Hambali and Mr. Mohd Anwar Zawawi. This thesis could not have been written without their advice and support throughout my final year project.

Also I would like to thanks to Mr. Mohamad Hamka Embong, Mr. Mohd Salmizan bin Mohd. Zain and Pn. Siti Murzalina bt Sh Murad for their patient dealing with my behavior in finishing this project.

Last but not least, I would like to thanks to all my friends especially to my classmates that helping me directly or indirectly in this project. Without their support and help, this project maybe would not ne success.

ABSTRACT

Generally, the project is about the implementation Graphical User Interface (GUI) of Visual Basic on pressure measurement. The focus on my project is to develop an interface of instrumentation systems for pressure measurement and to integrate the pressure transmitter to software system. This project can be separated into 2 parts which are software and hardware. Using Visual Basic 2008 as software, I develop the GUI so that it can be used for academic purpose especially in laboratory for BEE 4632 Industrial instrumentation subject. This software can be integrated with pressure transmitter using DAQ Board. In my case, I used Advantech USB-47I6 DAQ Boards because it used USB port as connector from instrument to computer. This DAQ Board is easy to use because it comes with installation for plug and play function, English version manual and Device Manager. For instrument, I used Differential Pressure Transmitter. User needs to key in minimum and maximum MSU applied and minimum and maximum Desired UUT in Data Page tab before further to get the actual UUT. After run 3 times of experiment and completing the table, user can calculate the average and output error. Then they can continue to get an average and output error percentage curve in Graph Page tab. Implementation of GUI to this instrumentation system can help to increase the efficiency in calculating the output data.

ABSTRAK

Secara amnya, projek ini adalah untuk menggunakan Antaramuka Grafik Pengguna dari aplikasi Visual Basic kepada pengukuran tekanan. Fokus projek ini adalah untuk membina antaramuka sistem instumentasi bagi pengukuran tekanan dan mengaplikasikan peranti tekanan ke sistem perisian. Projek ini dibahagikan kepada dua bahagian iaitu perisian dan perkakas. Menggunakan Visual Basic, Antaramuka Grafik Pengguna dibina supaya ianya boleh digunakan untuk kegunaan pelajaran terutamanya di makmal untuk subjek BEE 4632 Industrial Instrumentation. Perisian ini boleh dihubungkan kepada peranti tekanan menggunakan papan DAQ. Papan DAQ yang akan digunakan menawarkan kemudahan USB. Ini membolehkan papan DAQ ini digunakan secara Pasang dan Guna. Untuk perkakas, Peranti Perbezaan Tekanan digunakan. Pengguna perlu memasukkan minimum dan maksimum data bagi MSU dan UUT di dalam tab data sebelum boleh mendapatkan bacaan sebenar UUT dari eksperimen. Selepas 3 kali percubaan dan melengkapkan jadual, pengguna boleh mengira Ralat dan purata. Selepas kedua-dua bacaan diperolehi, langkah seterusnya adalah mendapatkan graf bagi purata dan ralat di dalam tab graf. Penggunaan Antaramuka Grafik Pengguna ini boleh meningkatkan ketepatan didalam pengiraan data keluar.

TABLES OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

CHAPTER 1

INTRODUCTION

1.1 Background

Pressure measurement is one of the syllabuses in BEE4632 Industrial Instrumentation subject in Electrical & Electronics fields. This topic can help student to understand more about the basic principles of pressure transmitter in pressure instrumentation. This will need student to demonstrate the procedure of instrument calibration and apply draft calibration of instrument.

In order to help student in studying the pressure instrumentation in more comprehensive ways, the combination of the instrument (Pressure Instrument), hardware (Data Acquisition Module), and software (Visual Basic interface) can help student to understand more compared to only using instrument.

The interface in Visual Basic can be applied in laboratory for this subject in learning process so that the time for the experiment can be reduced.

1.2 Objectives

The objective of this project is to:

i) Understands the basic measurement principles of pressure transmitter

As a requirement in BEE 4632 Industrial Instrumentation, pressure transmitter is one of the syllabuses in this subject. By understand the basic principle of pressure transmitter, it can help student to proceed on higher level of pressure instrument.

ii) Integrate the pressure transmitter to software system using DAQ Card

To archive the objective of this project, integration between hardware and software is one of important element to be done. By successfully done this, it can help student to manipulate data to get various output using software.

iii) Build interface using Visual Basic and used it to get the data such as uncertainty evaluation.

Student can used this interface to insert the data automatically from hardware but it also can be insert manually if the integration against hardware and software cannot be done.

1.3 Scope

This project actually concentrates on how to use the pressure instrumentation and use Visual Basic to get the output such as uncertainty evaluation.

i. Implementation and simulation of the pressure instrument.

Pressure instrument that will be used for this project is EJX110A Yokogawa Differential Pressure Transmitter with Ametek Hand Pump T-740, Yokogawa Digital Manometer MT220. As for reference, the HART 375 Field Communicator will be applied.

ii. Design the interface using Visual Basic and used it as software.

Visual Basic 2008 Express Edition will be used because it compatible to this project compared to Visual Basic.net, or Visual Basic 6.0

iii. Build the hardware as connection between instrument and software.

As for bridge between instrument and software, the DAQ is the best choice compared to ADC or microcontroller. This is because DAQ will show the data in real time.

iv. Programming and analyzing the software to get the data and study analysis.

Using the interface from Visual Basic, the data can be used to analyzed and calculate to get the output such as uncertainty, percentage of error in EJX110A, graph of error and other.

1.4 Problem Statement

Lack of time is the problems to student during perform the pressure instrumentation experiments in lab. This occurs because they need to get the output such as plotted graph manually before they can discuss about the curve. To help reducing the time, Graphic User Interface (GUI) using Visual Basic need to be applied to this pressure instrumentation experiment.

1.5 Methodology

In this project, there are three main parts which is;

i. Pressure Instrumentation - Differential pressure transmitter is used in this project.

ii. Visual Basic - Build interface to analyze the output and get various data.

iii. Data Acquisition Card (DAQ) - Determine the best configuration of DAQ to connect the instrument and computer.

The testing includes;

i. Connect the equipment which includes digital manometer MT220, 2793 resistance box, Differential Pressure Transmitter EJX110A, test gauge, HART 375 Field Communicator and Ametek Hand Pump T-740.

ii. Plot the average output curve for EJX110A against the MSU applied value.

iii. Plot the output error curve for EJX110A against the MSU applied value

iv. Comment the curve.

V. Calibration of EJX110A using HART 375 Field Communicator.

1.6 Thesis Outline

Chapter 1: Introduction

This chapter gives the introduction to the project, objectives, scope of works and methodology taken. It also describes briefly the hardware and software used in this project.

Chapter 2: Literature review

This chapter covers the literature review of the basic pressure theory, visual basic programming language and data acquisition module that being used in this project.

Chapter 3: System Design

This chapter explains about the system design which include hardware and software design. In hardware design, it explains about the connection of the pressure instrument and the data acquisition module. Visual basic programming explained under software design in this chapter.

Chapter 4: Result

The results are determined through the experiment of pressure calibration.

Chapter 5: Conclusion & Recommendations

This chapter will include the conclusion for this project. Some recommendations will be add in this chapter for future improvements.

CHAPTER 2

LITERATURE REVIEW

2.1 Pressure Instrument

Pressure is the force over an area applied to an object in a direction perpendicular to the surface. Gauge pressure is the pressure relative to the local atmospheric or ambient pressure. Pressure is an effect which occurs when a *force* is applied on a surface. The symbol of pressure is *p* (lower case). The upper case *P* is better reserved for power. The SI unit for pressure is the Pascal (Pa), equal to one Newton per square meter ($N\text{-}m^{-2}$ or $kg\ m^{-2}s^{-2}$**).** This special name for the unit was added in 1971; before that, pressure in SI was expressed simply as N/m2.

Several types of pressure are;

i) Sealed Pressure

- Atmosphere pressure, pressure on earth surface - Fixed (14.7 psi@ 101.36 kPa)

ii) Absolute Pressure

- Exerted by fluid
- Pressure measured with respect to the vacuum (psis) @ (kPa) use 'a' n `g' when referencing the pressure to absolute and gauge

iii) Vacuum Gauges

- Pressure below atmosphere

iv) Gauge Pressure

- Pressure measured with respect to atmosphere pressure (psig @ kPa)

v) Differential Pressure

- Pressured measured with respect to the other (one pressured is fixed, the other is measured)

For this project, the differential pressure will be use as an instrument.

2.2 Visual Basic 2008 Express Edition

Microsoft Visual Studio Express is a set of freeware integrated development environments (IDE) developed by Microsoft that are lightweight versions of the Microsoft Visual Studio 2008 product line. The idea of express editions, according to Microsoft, is to provide a streamlined, easy-to-use and easy-to-learn **IDEs** for less serious users, such as hobbyists and students. The final versions were released on November 19, 2007. In line with popular demand since the Visual Studio 2005 Express Editions, these editions will always remain free-of-charge.

Despite the fact that it is a stripped-down version of Visual Studio, some improvements were made upon Visual Basic 2008 from Visual Basic 2005. Visual Basic 2008 Express includes the following improvements over Visual Basic 2005 Express:

- Includes the visual Windows Presentation Foundation designer codenamed "Cider"
- Debugs at runtime
- Better IntelliSense support
- Fixes common spelling errors
- Corrects most invalid syntax

- Provides suggestions to class names when specified classes are not found

The Express Edition has the following limitations:

- No IDE support for databases other than SQL Server Express and Microsoft Access
- No support for Web Applications with ASP.NET (this can instead be done with Visual Web Developer Express, though the non-Express version of Visual Studio allows both web and windows applications from the same IDE)
- No support for developing for mobile devices (no templates or emulator)
- No Crystal Reports
- Fewer project templates (e.g. Windows services template, Excel Workbook template)
- Limited options for debugging and breakpoints.
- No support for creating Windows Services

2.3 Advantech USB-4716 Data Acquisition Module (DAQ)

Data acquisition is the process of gathering or generating information in an automated fashion from analog and digital measurement sources such as sensors and devices under test. Data acquisition systems (DAS) interface between the real world of physical parameters which are analog, and the artificial world of digital computation and control. With current emphasis on digital systems, the interfacing function has become an important one; digital systems are used widely because complex circuits are low cost, accurate, and relatively simple to implement. In addition, there is rapid growth in the use of microcomputers to perform difficult digital control and measurement functions.

Computerized feedback control systems are used in many different industries today in order to achieve greater productivity in our modern industrial society. Industries that presently employ such automatic systems include steel making, food processing, paper production, oil refining, chemical manufacturing, textile production, cement manufacturing, and others. The devices that perform the interfacing function between analog and digital worlds are analog-to-digital (A/D) and digital-to-analog (D/A) converters, which together are known as data converters.

CHAPTER 3

SYSTEM DESIGN

3.1 Hardware

3. 1.1 Pressure Instrument

Instrument parts as in figure below consist of Ametek Hand Pump T-740, Yokogawa Digital Manometer MT220, 2793 Decade Resistance Box, Yokogawa Differential Pressure Transmitter EJX110A, Test Gauge and HART 375 Field Communicator. The Ametek Hand Pump will give pressure as an input to Yokogawa Differential Pressure Transmitter. This transmitter will convert the input signal into current value and send to Digital Manometer. Hart 375 Field Communicator will be used as a reference to the system. This communicator also can be used to calibrate the EJX I I0A pressure transmitter.

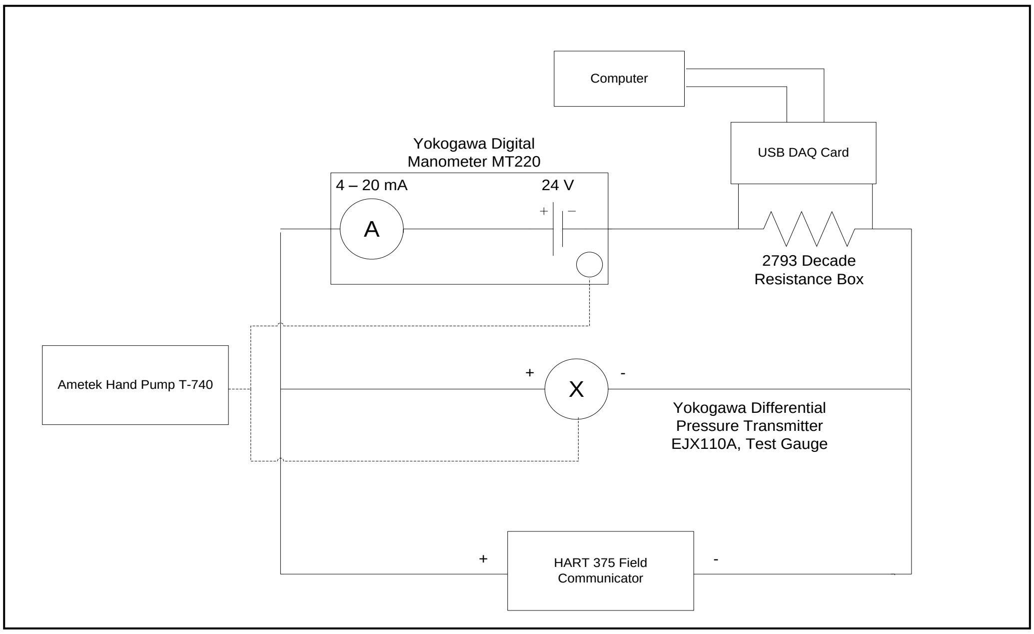


Figure 3.1: Pressure Instrument diagram

3.1.2 Advantech USB-4716 Data Acquisition Module (DAQ)

3.1.2.1 Advantech USB-471 Installation.

It is recommended to install the software driver before install the USB-4716 module into system to guarantee a smooth installation process. The 32-bit DLL driver Setup program for the USB-4716 module is included on the companion CD-ROM that is shipped with module package.

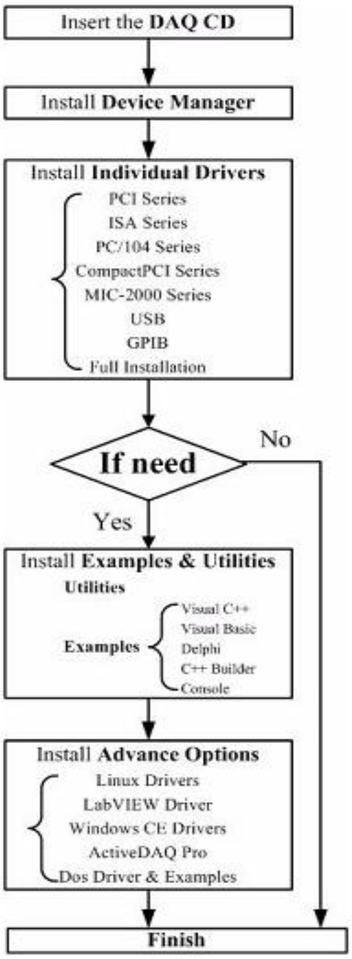


Figure 3.2: DAQ Installation Flow Graph

3.1.2.2 DAQ Pin Assignments

USB-4716 is equipped with plug-in screw-terminal connectors that facilitate connection to the module without terminal boards or cables. This DAQ Module has 10-pin I/O connectors on USB-4716.

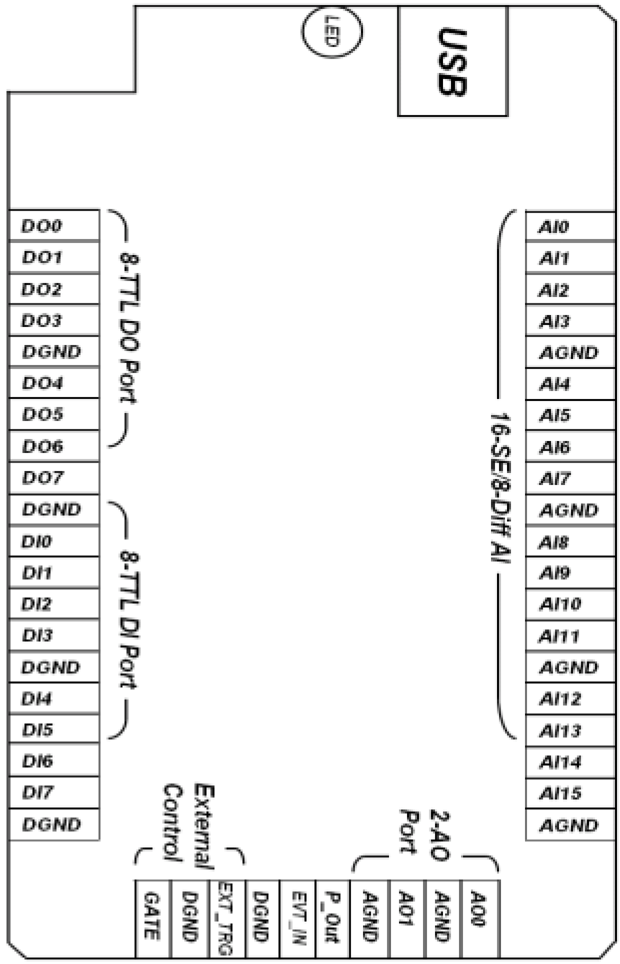


Figure 3.3: DAQ I/0 Connector Pin Assignments

**The two ground references AGND and DGND should be used separately for their designated purpose. Do not connect them together.*

Signal Name	Reference	Direction	Description
AI<0…15>	AGND	Input	Analog Input Channels 0 through 15.
AIGND	-	-	Analog Input Ground.
AO0 AO1	AGND	Output	Analog Output Channels 0/1.
AOGND	-	-	Analog Output Ground. The analog output voltages are ref-erenced to these nodes.
DI<0..7>	DGND	Input	Digital Input channels.
DO<0..7>	DGND	Output	Digital Output channels.
DGND	-	-	Digital Ground. This pin supplies the reference for the digital channels at the I/O connector.
GATE	DGND	Input	A/D External Trigger Gate. When GATE is connected to +5 V, it will disable the external trigger signal to input.
EXT_TRG	DGND	Input	A/D External Trigger. This pin is external trigger signal input for the A/D conversion. A low-to-high edge triggers A/D conver-sion to start.
EVT_IN	DGND	Input	External events input channel.
P_OUT	DGND	Output	Pulse output channel

Figure 3.4: I/0 Connector Signal Descriptions

3.2 Software

3.2.1 Visual Basic

Microsoft Visual Basic 2008 Express Edition will be use as software to develop the GUI so that it can be used with the pressure instrument application. This GUI can be connected to hardware using USB DAQ so that the data from pressure instrument can be captured directly from EJX110A Differential Pressure Transmitter.

There is one application called ActiveDAQ Pro which comes with package after buying the Advantech USB DAQ. ActiveDAQ Pro is a collection of ActiveX controls for performing I/O operations within any compatible ActiveX control container, such as Visual Basic. This application can easily perform the I/O operations through properties, events and methods. With ActiveDAQ Pro, it can perform versatile I/O operations to control Advantech devices such as USB DAQ 4716.

When using this software, user need to follow some step to make sure all the data need in this experiment can be used. Software will calculate the data automatically when user need for result from the experiment. The step that user need to follow are as Figure 3.4.

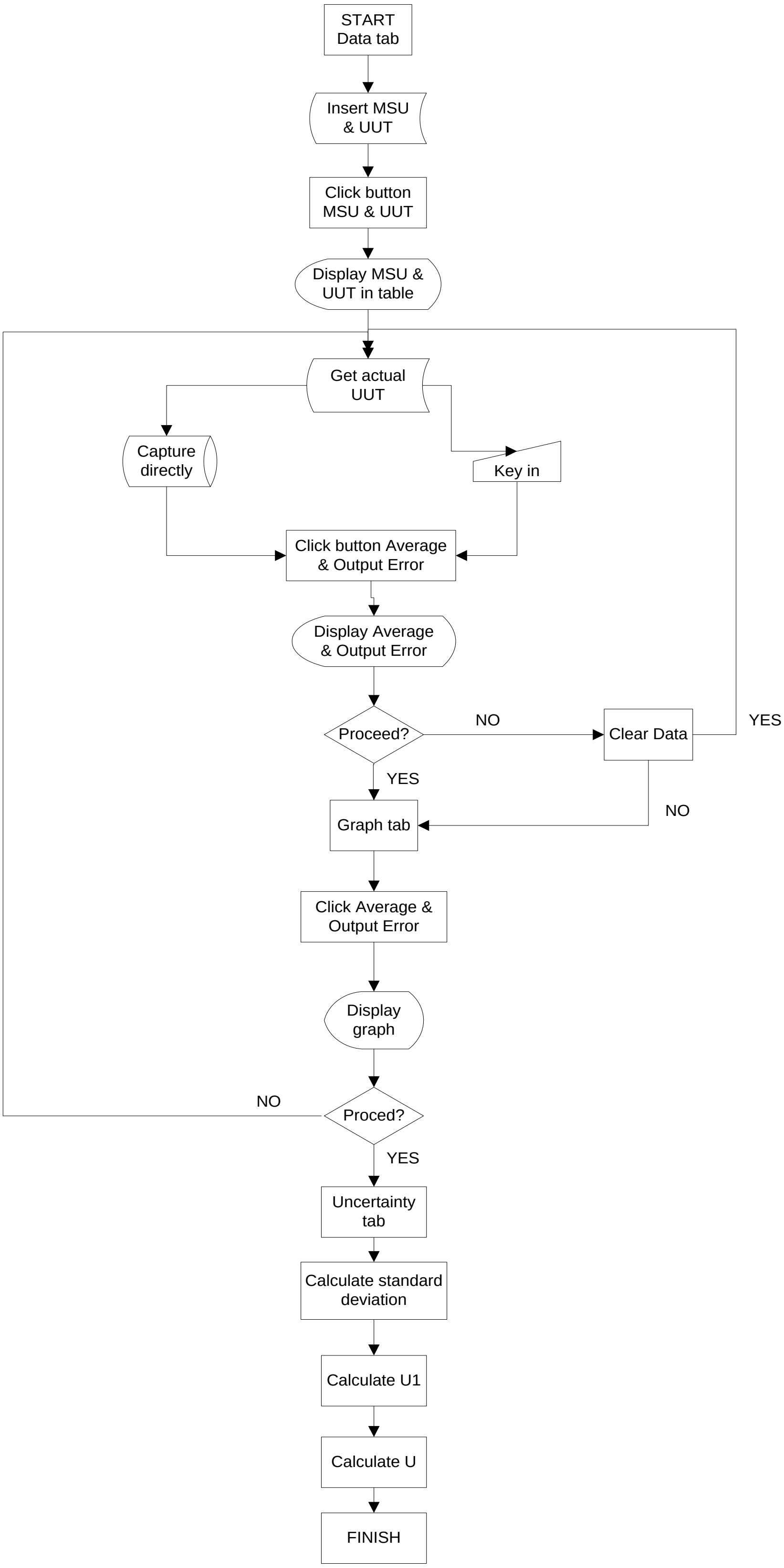


Figure 3.5: Software flowchart

CHAPTER 4

RESULTS & DISCUSSION

4.1 Pressure Instrumentation

For the Five-point calibration of the instruments, the span of the BUT is divided into five equal parts. The first point of the span is at the low range while the top point of the span as at the highest range. For an example, the pressure transmitter has the range between 0 kPa to 200 kPa. Therefore, the span is;

200 kPa — 0 kPa = 200 kPa

Dividing the span by four we get 50 kPa. Hence the five equal points are 0 kPa, 50 kPa, 100 kPa, 150 kPa and 200 kPa. The desired output for 4 mA to 20 mA range is calculated based on the 0 kPa - 200 kPa range using equation;

$$\text{Desired Output} = \frac{x}{100}(URV - LRV) + LRV$$

Where;

X	= ith point
URV	= Upper range value
LRV	= Lower range value

4.1.1 Calibration of Pressure Transmitter

There are several procedures that we need to follow to set the apparatus of pressure instrumentation such as;

1. Connect the equipment (refer block diagram of Differential Pressure Transmitter). Change the MT220 to kPa scale. (±(0.01 % of reading + 0.005% range), max reading 200 kPa and range 700 kPa.)
2. Adjust the MSU such that the UUT reads the first point. In the case of the pressure transmitter the first point on the output is 4 mA which corresponds to an input of 0 kPa. Set the required value of the MSU as in Table Result.
3. Then check the next point, that is 50 kPa and adjust the MSU so that the UUT gives this reading. Similarly proceeds till the maximum value of the fifth point that is 200 kPa is reached. This will complete 1^{St} run.
4. Repeat steps (2) to (3). This will give the 2nd run and 3^{rd} run to complete the Table Result.
5. Using the Visual Basic Graphical User Interface (GUI), plot the 5 point calibration average output curve, the output error curve, and the error percentage curve for the EJX110A pressure transmitter.

4.1.2 Pressure Instrumentation results

Table 4.1: Data table of Differential Pressure Transmitter simulation.

No. %	MSU applied value	Desired UUT output (mA)	Actual UUT output (mA)				Output error %
			1st run (mA)	2nd run (mA)	3rd run (mA)	Average (mA)	
0	0.0	4.00	4.006	4.007	4.005	4.006	0.1500
25	50.0	8.00	8.038	8.038	8.035	8.037	0.4625
50	100.0	12.00	12.060	12.063	12.066	12.063	0.5250
75	150.0	16.00	16.092	16.094	16.094	16.093	0.5813
100	200.0	20.00	20.120	20.121	20.120	20.120	0.6000

Calculation

Average Output = $\frac{\mathbf{1st\ run+2nd\ run+3rd\ run}}{\mathbf{3}}$

For 0% Average = $\frac{4.006+4.007+4.005}{3}$

= 4.006 mA

For 25% Average = $\frac{8.038+8.038+8.035}{3}$

= 8.037 mA

For 50% Average = $\frac{12.060+12.063+12.066}{3}$

= 12.063 mA

For 75% Average = $\frac{16.092+16.094+16.094}{3}$

= 16.093 mA

For 100% Average = $\frac{20.120+20.121+20.120}{3}$

= 20.120 mA

$$\textbf{Output Error} = \frac{\textbf{Average Output} - \textbf{Desired Output}}{\textbf{Desired Output}} \times \mathbf{100}$$

For 0% Error % = $\frac{\mathbf{4.006 - 4.000}}{\mathbf{4.000}} \times \mathbf{100}$

= 0.1500

For 25% Error % = $\frac{\mathbf{8.037 - 8.000}}{\mathbf{8.000}} \times \mathbf{100}$

= 0.4625

For 50% Error % = $\frac{\mathbf{12.063 - 12.000}}{\mathbf{12.000}} \times \mathbf{100}$

= 0.5250

For 75% Error % = $\frac{\mathbf{16.093 - 16.000}}{\mathbf{16.000}} \times \mathbf{100}$

= 0.5813

For 100% Error % = $\frac{\mathbf{20.120 - 20.000}}{\mathbf{20.000}} \times \mathbf{100}$

= 0.6000

4.2 Visual Basic Application.

Graphical User Interface (GUI) is developing using Visual Basic application. The version that used is Microsoft Visual Basic 2008 Express Edition. The GUI will be interconnecting to hardware using DAQ Module. The GUI in this project will consist of three tab page which is;

i) Data Page tab

ii) Graph Page tab

iii) Uncertainty tab

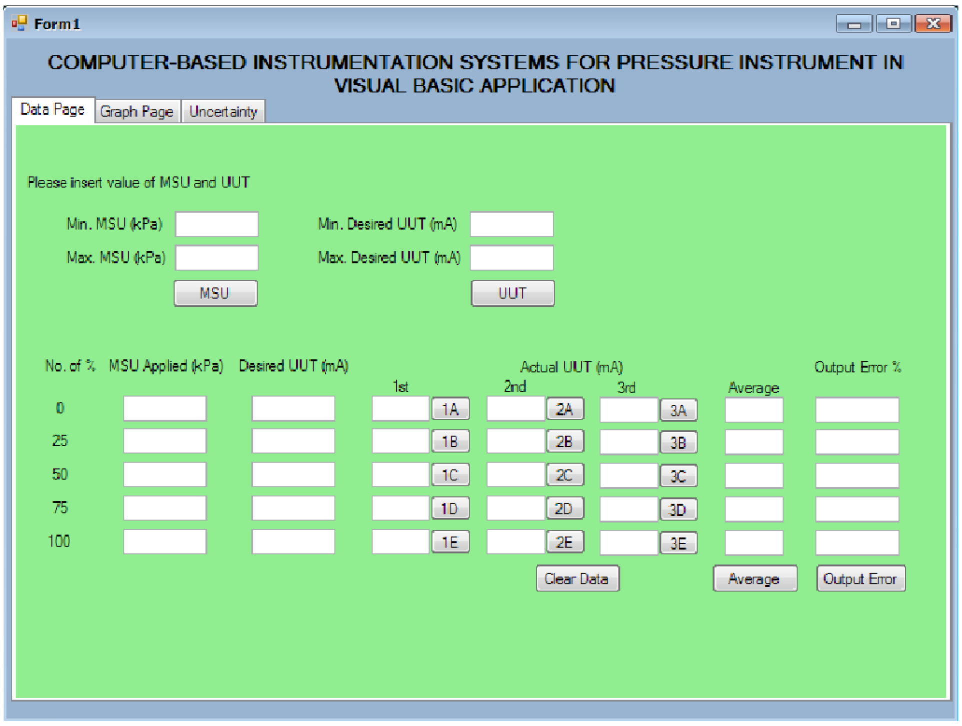


Figure 4.1: Data Page tab.

For Data Page tab, it include all the data for pressure instrumentation experiment such as the value of MSU Applied in kPa, Desired UUT in me, Actual UUT in mA, Average of Actual UUT in mA, and percentage of Output Error. User need to key in several inputs to run this start using this GUI which is;

i) Minimum MSU value (kPa)

ii) Maximum MSU value (kPa)

iii) Minimum Desired UUT value (mA)

iv) Maximum Desired UUT value (mA)

After the required data has been key in, to calculated the MSU Applied and Desired UUT, user need to click on button MSU and UUT. After it has been click, the data will display as shown below;

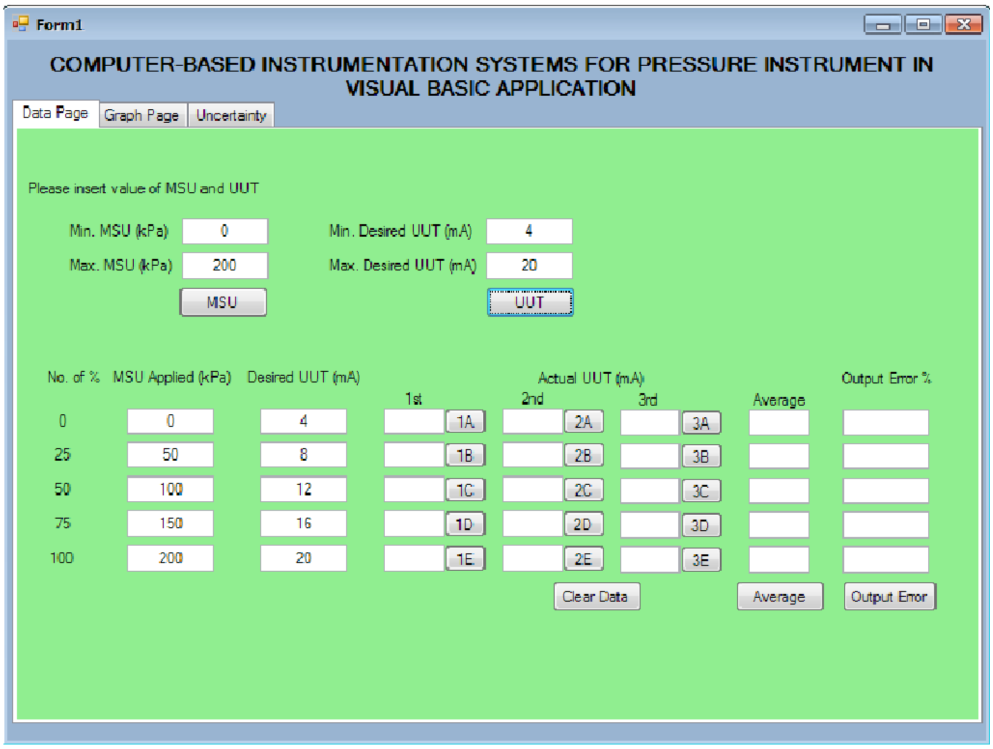


Figure 4.2: MSU and UUT value

Now user can proceed to next step. For actual UUT, we can get the data by key in it manually or captured the value from the instrument directly. If user choose to key in manually, they can just simply type the value of actual UUT. But if user chooses to capture the data from instrument, they can use the button 1A, 1B, 1C, 1D and 1E for the 1st run experiment, button 2A, 2B, 2C, 2D and 2E for 2nd experiment and button 3A, 3B, 3C, 3D and 3E for 3rd experiment. To make this button function, make sure the USB DAQ card is connect between computer and instrument.

After all the actual value has key in as shown below, we can proceed to calculate the average and output error percentage.

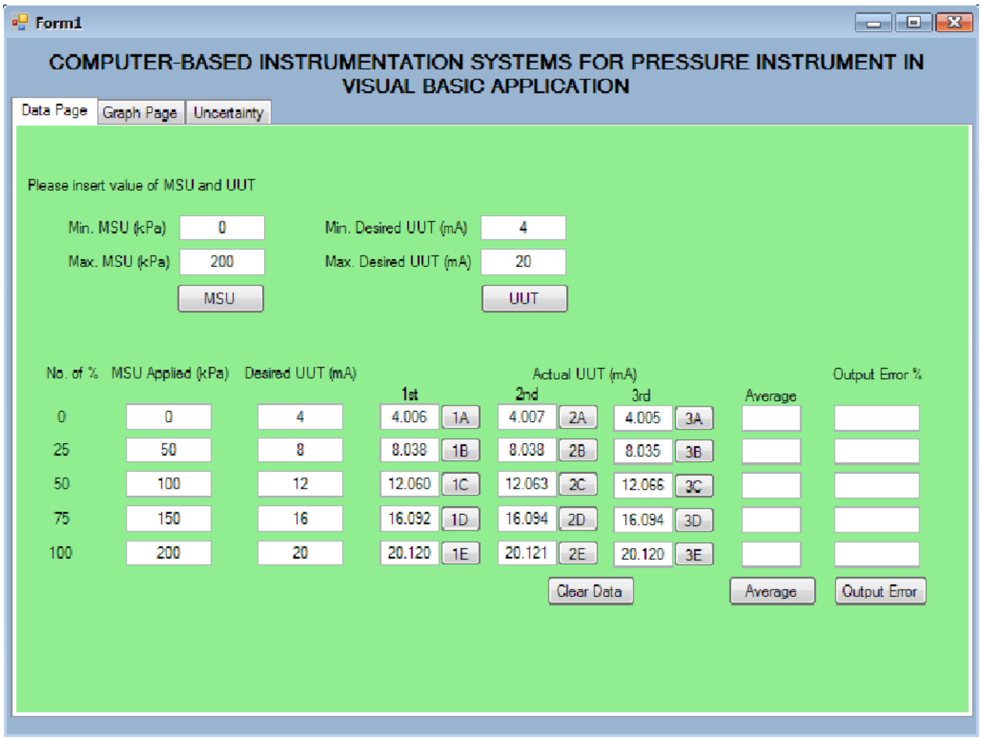


Figure 4.3: Actual UUT data has fully key in.

As show above, all the data will be displayed in 4 decimal placed and will be used in all calculation for this project. If there is any wrong data displayed, user can erase all data in the table by click at ‘Clear Data’ button. A popup window will appear for user to choose ‘Yes’ or ‘No’ to proceed.

This software provides automatic calculation for average value and output error percentage. By click Average and Output Error button, the average for the run experiment and output error percentage will be displayed.

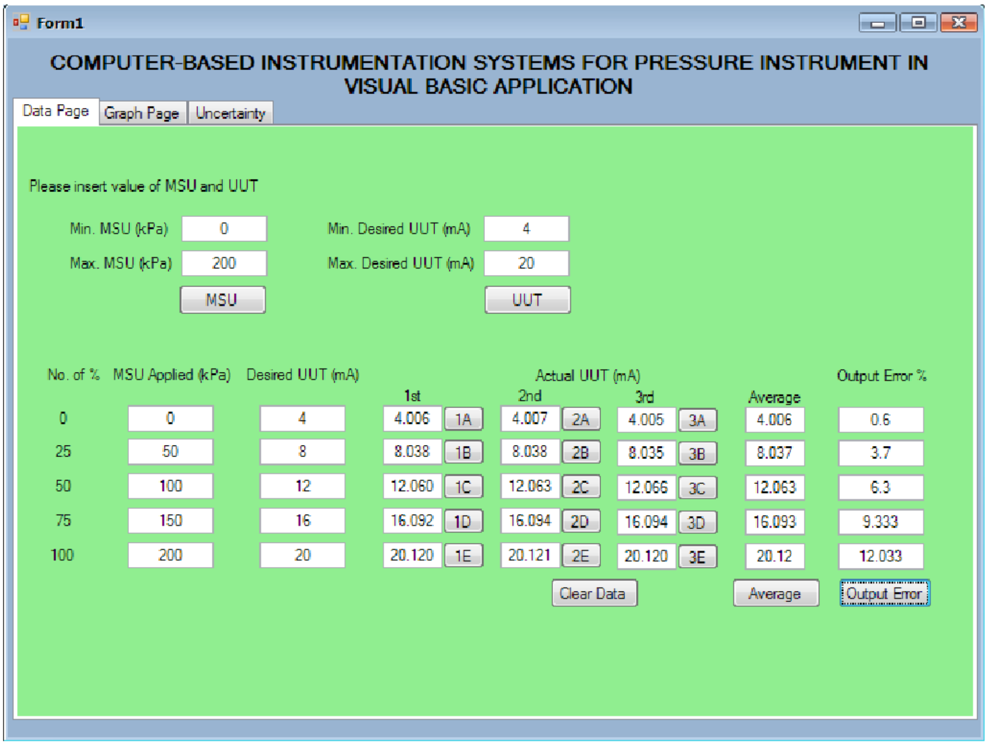


Figure 4.4: Average and Output Error Percentage value displayed.

After done with the data, user can proceed to the next tab where it will show the Graph Page Tab. In this tab, user can generate two graphs which are;

i) Average Graph
ii) Output Error Graph

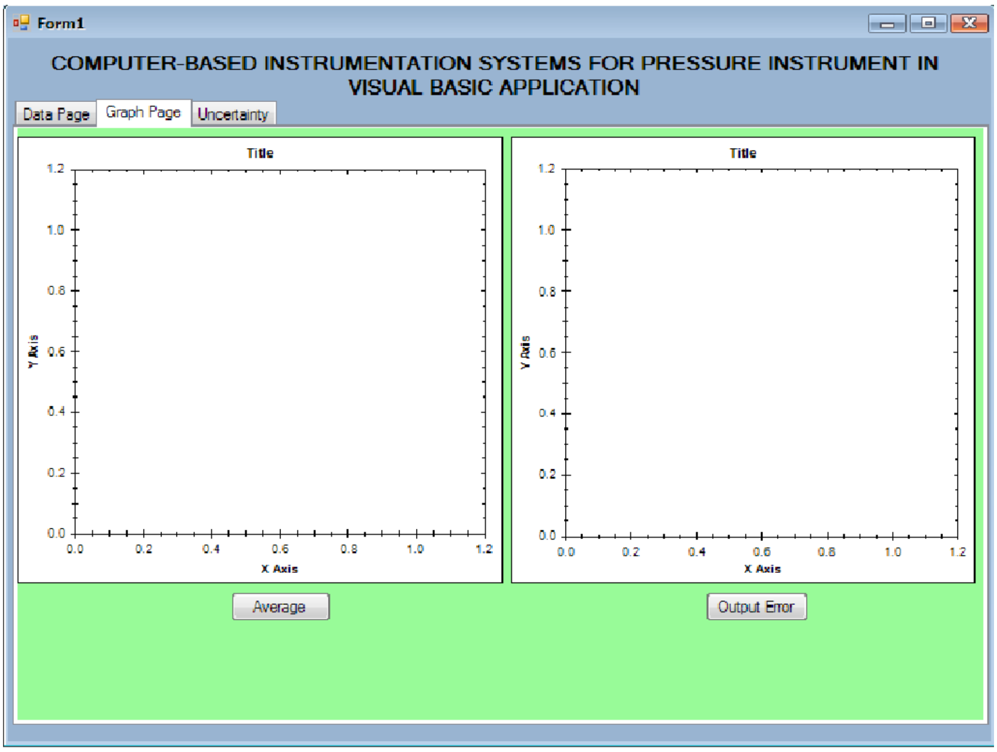


Figure 4.5: Graph Page Tab

This second tab will generate graph using the data from Data Page tab. User just need to click on the Average button and Output Error button to make the graph appear. After click on the button, user needs to click on graph and scroll mouse to zoom in and zoom out. Due to Zed graph properties, this graph can be zoom to help user identified the point more accurate.

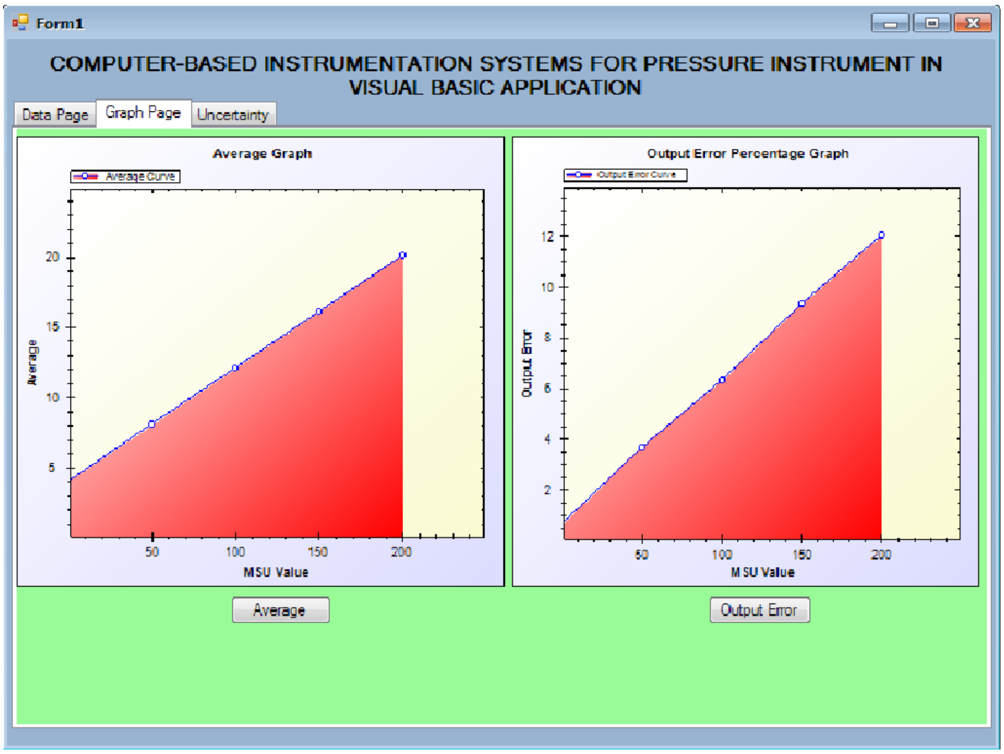


Figure 4.6: Average and Output Error Graph.

The last tab of this application is Uncertainty tab. In this tab, user can calculated the uncertainty value for the experiment. This tab will involve three type of uncertainty to determine the real uncertainty. The types of uncertainty are;

i) Uncertainty due to repeatability, U1
ii) Uncertainty due to MSU error, U2
iii) Uncertainty due to UUT/MSU resolution, U3

Users just need to click on Standard Deviation button to calculated standard deviation that will used in calculating U1. After all value of standard deviation displayed, user need to identify the worst case of standard deviation by selecting button 1, 2, 3, 4 and 5 next to the standard deviation value. By choosing the worst case standard deviation, user can proceed to button OK or NO. This will help for those who select the wrong worst case value. If correctly choose, by clicking OK, the value of U1 will be displayed.

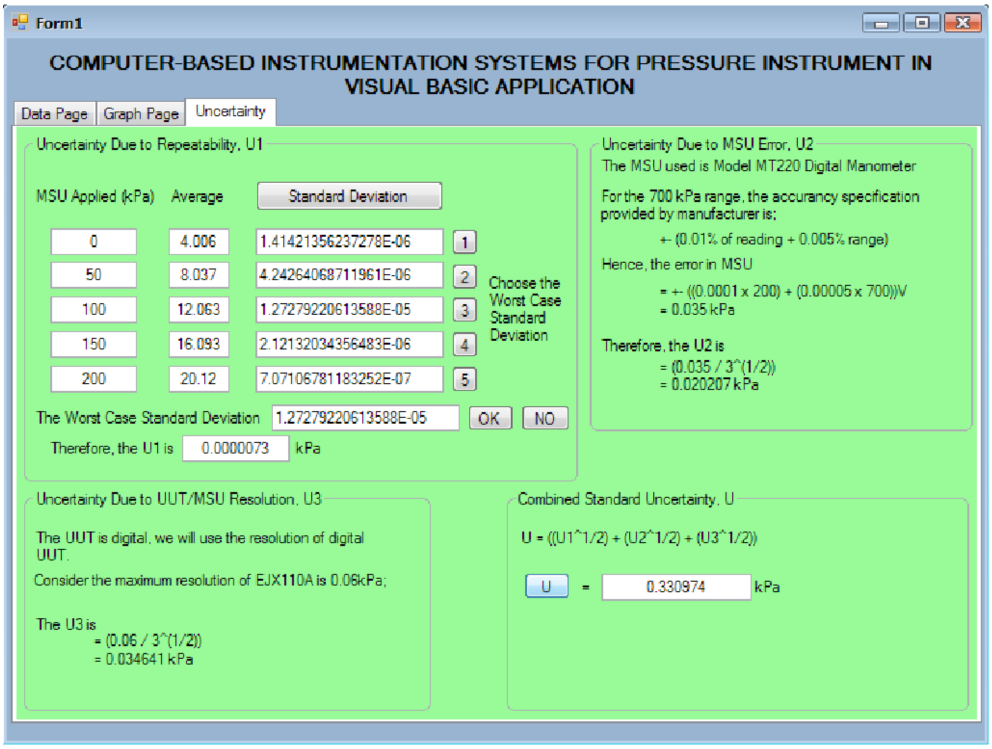


Figure 4.7: Uncertainty tab.

After value of U1 has been calculated and displayed, user can proceed directly to get the value of Combined Standard Uncertainty, U due to the fixed value of U2 and U3. The value of U2 and U3 can be change due to the changes of the instrument in experiment. If this happen, this fixed value can be change by editing the coding of the software.

From Figure 4.7, we can see that the final value of U is displayed in 6 Decimal place. This is because we need to determine the exact value of the uncertainty so that we can get the nearest value of data compared to the actual value.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The main objective of this project is to develop a graphical user interface (GUI) using Visual Basic application for pressure instrumentation.

Generally, the overall of objectives and scopes of this project have been successful achieved and the project is properly running as desired. The GUI can be use with pressure instrument which connect using DAQ Module.

Hopefully, this project can be a platform for other students to come up with more advance and efficient GUI with more users friendly. The main problem with today's GUI technology is it is too expensive for use in the lab because the GUI in market quiet expensive for large usage such as in laboratory.

5.2 Obstacles Faces

In carrying out this project, there are a few problems that have been encountered such as limited budget and limitation of freeware.

i) Limited Budget

This system is efficient using USB DAQ Module as Analog-to-Digital Converter (ADC) for connection between computer and instrument. Due to price which is so expensive, the DAQ Module provided by faculty need to be shared with other students. If we need to use this GUI for learning process in laboratory, an ADC can be used but it will cause more difficulties due to the complexity of connection compared to USB connection of DAQ Module.

ii) Limitation of Freeware

Microsoft Visual Basic 2008 Express Edition used in this project is a freeware version. This free-of-charge version give limitation to user such as it doesn't support for developing for mobile devices because no templates or emulator are provide. Therefore, if more advance GUI need to be used in mobile devices, the full version of Visual Basic application must be purchased.

5.3 Recommendations

For further upgrading, there are several recommendations to enhance and improve the system such as;

i) Use a full version of Visual Basic

The software can be upgraded to full version if more advance function need to be applied in future software upgraded.

ii) Implement the project in control laboratory

This project can be implementing on a bigger scale which required more ADC to be located at computer in control laboratory. By implement this project, it will help student to run the experiment more easily from previous way.

iii) Upgrade the GUI for more users friendly

In the future, this project can be make for more user friendly such as combining with other application like Microsoft Word or Microsoft Excel so that student can export the curve from project to this application. This will help them in submitting their laboratory report.

iv) Add more function

There are certain function can be added to make this application more fun to be used. For an example adding the save function so that the data can be store or sample using database application. Direct printing the data or export the graph to excel as example may help student done their report.

v) Make the system compatible with other type of pressure instrument

This application only can be use using Yokogawa Differential Pressure Transmitter. Maybe for future usage, the upgraded version of this application can use all type of pressure instrument.

5.4 Costing and Commercialization

For this project, all the component and devices were borrowed from faculty lab except for USB DAQ Card. The cost of this USB DAQ is around RM1500.00. There are no costs for the software because Visual Basic 2008 Express Edition is a freeware.

The benefits of this project are reducing the time to make such a complex calculation and to get the accurate reading from graph. This application can be used widely in a laboratory. This project can be commercialized for academic purpose.

REFERENCES

1. Norman S. Nice (2004), *Control Systems Engineering*, Fourth Edition, John Wiley & Son Inc.

2. Curtis D. Johnson, *Process Control Instrumentation*, Eight Edition, Pearson International Edition.

3. Microsoft Visual Basic 2008 Express Edition, www.microsoft.com/MSPress/**books**/12202.aspx

4. Advantech USB-4716 Data Acquisition Card, http://www.advantech.com/products

5. 2793 Resistance Box, http://www.testequipmentdepot.com/yokogawa/precision-measuring/resistance-boxes/2793.htm

6. Yokogawa EJX110A Differential Pressure Transmitter, www.yokogawa.com/tm/

7. MT220 – Yokogawa Digital Manometer, http://www.electro-meters.com/Yokogawa/T_M_Inst/Calibrators_Meters/Pressure/MT220.htm

8. 375 HART Filed Communicator, http://www.documentation.emersonprocess.com/groups/public_assetoptprodlit/documents/data_sheets/allds0401e_375fix

9. Ametek T-740 Hand Pump, https://www.testequipmentdepot.com/ametek/pdf/t430_data

10. Microsoft Visual Basic 2008 Express Edition, www.microsoft.com/express/**vb**

APPENDICES

APPENDIX A
Visual Basic Coding

```
Imports ZedGraph

Public Class Form1

    Private Sub msu_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles msu.Click
        Dim minmsu As String
        Dim maxmsu As String

        Dim TextBoxDataminmsu As String
        Dim TextBoxDatamaxmsu As String
        Dim TextBoxDataademinmsu As String
        Dim TextBoxDataademaxmsu As String


        TextBoxDataminmsu = Trim(minmsux.Text)
        TextBoxDatamaxmsu = Trim(maxmsux.Text)
        TextBoxDataademinmsu = minmsux.Text
        TextBoxDataademaxmsu = maxmsux.Text
        minmsu = minmsux.Text
        maxmsu = maxmsux.Text


        If TextBoxDataminmsu = "" Then
            MsgBox("Please Enter your Minimum MSU Value")
        End If

        If TextBoxDatamaxmsu = "" Then
            MsgBox("Please Enter your Maximum MSU Value")


        Else

            If TextBoxDataademinmsu = minmsux.Text And
TextBoxDataademaxmsu = maxmsux.Text Then
                msu1.Text = minmsu - minmsu
                msu2.Text = (maxmsu - minmsu) * 1 / 4
                msu3.Text = (maxmsu - minmsu) * 1 / 2
                msu4.Text = (maxmsu - minmsu) * 3 / 4
                msu5.Text = (maxmsu - minmsu) * 4 / 4
                msu6.Text = minmsu - minmsu
                msu7.Text = (maxmsu - minmsu) * 1 / 4
                msu8.Text = (maxmsu - minmsu) * 1 / 2
                msu9.Text = (maxmsu - minmsu) * 3 / 4
                msu10.Text = (maxmsu - minmsu) * 4 / 4

            End If
        End If

    End Sub

    Private Sub uut_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles uut.Click
        Dim minuut As String
```

```
        Dim maxuut As String

        Dim TextBoxDataminuut As String
        Dim TextBoxDatamaxuut As String
        Dim TextBoxDataademinuut As String
        Dim TextBoxDataademaxuut As String

        TextBoxDataminuut = Trim(minuutx.Text)
        TextBoxDatamaxuut = Trim(maxuutx.Text)
        TextBoxDataademinuut = minuutx.Text
        TextBoxDataademaxuut = maxuutx.Text
        minuut = minuutx.Text
        maxuut = maxuutx.Text

        If TextBoxDataminuut = "" Then
            MsgBox("Please Enter your Minimum UUT Desired Value")
        End If

        If TextBoxDatamaxuut = "" Then
            MsgBox("Please Enter your Maximum UUT Desired Value")

        Else
            If TextBoxDataademinuut = minuutx.Text And
TextBoxDataademaxuut = maxuutx.Text Then
                uut1.Text = minuut
                uut2.Text = (maxuut - minuut) * 1 / 2
                uut3.Text = (maxuut - minuut) * 3 / 4
                uut4.Text = (maxuut - minuut)
                uut5.Text = maxuut
            End If
        End If

    End Sub

    Private Sub average_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles average.Click
        Dim a1 As Double
        Dim a2 As Double
        Dim a3 As Double
        Dim b1 As Double
        Dim b2 As Double
        Dim b3 As Double
        Dim c1 As Double
        Dim c2 As Double
        Dim c3 As Double
        Dim d1 As Double
        Dim d2 As Double
        Dim d3 As Double
        Dim e1 As Double
        Dim e2 As Double
        Dim e3 As Double

        a1 = a1x.Text
        a2 = a2x.Text
        a3 = a3x.Text
        b1 = b1x.Text
        b2 = b2x.Text
        b3 = b3x.Text
        c1 = c1x.Text
        c2 = c2x.Text
        c3 = c3x.Text
```

```
        d1 = d1x.Text
        d2 = d2x.Text
        d3 = d3x.Text
        e1 = e1x.Text
        e2 = e2x.Text
        e3 = e3x.Text

        ave1x.Text = Format((a1 + a2 + a3) / 3, "0.###")
        ave2x.Text = Format((b1 + b2 + b3) / 3, "0.###")
        ave3x.Text = Format((c1 + c2 + c3) / 3, "0.###")
        ave4x.Text = Format((d1 + d2 + d3) / 3, "0.###")
        ave5x.Text = Format((e1 + e2 + e3) / 3, "0.###")
        ave6x.Text = Format((a1 + a2 + a3) / 3, "0.###")
        ave7x.Text = Format((b1 + b2 + b3) / 3, "0.###")
        ave8x.Text = Format((c1 + c2 + c3) / 3, "0.###")
        ave9x.Text = Format((d1 + d2 + d3) / 3, "0.###")
        ave10x.Text = Format((e1 + e2 + e3) / 3, "0.###")

    End Sub

    Private Sub outputerror_Click(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles outputerror.Click
        Dim a1 As Double
        Dim a2 As Double
        Dim a3 As Double
        Dim b1 As Double
        Dim b2 As Double
        Dim b3 As Double
        Dim c1 As Double
        Dim c2 As Double
        Dim c3 As Double
        Dim d1 As Double
        Dim d2 As Double
        Dim d3 As Double
        Dim e1 As Double
        Dim e2 As Double
        Dim e3 As Double

        Dim minuut As Integer
        Dim maxuut As Integer

        minuut = minuutx.Text
        maxuut = maxuutx.Text

        a1 = a1x.Text
        a2 = a2x.Text
        a3 = a3x.Text
        b1 = b1x.Text
        b2 = b2x.Text
        b3 = b3x.Text
        c1 = c1x.Text
        c2 = c2x.Text
        c3 = c3x.Text
        d1 = d1x.Text
        d2 = d2x.Text
        d3 = d3x.Text
        e1 = e1x.Text
        e2 = e2x.Text
        e3 = e3x.Text
```

```
        error1x.Text = Format((((a1 + a2 + a3) / 3) - minuut) * 100,
"0.###")
        error2x.Text = Format((((b1 + b2 + b3) / 3) - (maxuut -
minuut) * 1 / 2) * 100, "0.###")
        error3x.Text = Format((((c1 + c2 + c3) / 3) - (maxuut -
minuut) * 3 / 4) * 100, "0.###")
        error4x.Text = Format((((d1 + d2 + d3) / 3) - (maxuut -
minuut)) * 100, "0.###")
        error5x.Text = Format((((e1 + e2 + e3) / 3) - maxuut) * 100,
"0.###")

    End Sub

    Private Sub clear_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles clear.Click
        Dim testMsg As Integer
        testMsg = MsgBox("Are You Sure To Clear Data?", vbYesNo +
vbExclamation, "Clear Data")

        If testMsg = 6 Then
            MessageBox.Show("The Data will be clear")

            a1x.Text = ""
            b1x.Text = ""
            c1x.Text = ""
            d1x.Text = ""
            e1x.Text = ""
            a2x.Text = ""
            b2x.Text = ""
            c2x.Text = ""
            d2x.Text = ""
            e2x.Text = ""
            a3x.Text = ""
            b3x.Text = ""
            c3x.Text = ""
            d3x.Text = ""
            e3x.Text = ""
            ave1x.Text = ""
            ave2x.Text = ""
            ave3x.Text = ""
            ave4x.Text = ""
            ave5x.Text = ""
            error1x.Text = ""
            error2x.Text = ""
            error3x.Text = ""
            error4x.Text = ""
            error5x.Text = ""

        ElseIf testMsg = 7 Then
            MessageBox.Show("The Data has not been clear")

        End If

    End Sub


    Private Sub graphave_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles graphave.Click
        CreateGraph1(zg1)

    End Sub
```

```
    Private Sub CreateGraph1(ByVal zgd As ZedGraphControl)
        Dim myPane As GraphPane = zgd.GraphPane

        ' Set the titles and axis labels
        myPane.Title.Text = " Average Graph"
        myPane.XAxis.Title.Text = "MSU Value"
        myPane.YAxis.Title.Text = "Average"

        ' Make up some data points from the Sine function
        Dim list = New PointPairList()


        list.Add(msu1.Text, ave1x.Text)
        list.Add(msu2.Text, ave2x.Text)
        list.Add(msu3.Text, ave3x.Text)
        list.Add(msu4.Text, ave4x.Text)
        list.Add(msu5.Text, ave5x.Text)



        ' Generate a blue curve with circle symbols, and "My Curve
2" in the legend
        Dim myCurve As LineItem = myPane.AddCurve("Average Curve",
list, Color.Blue, SymbolType.Circle)
        ' Fill the area under the curve with a white-red gradient at
45 degrees
        myCurve.Line.Fill = New Fill(Color.White, Color.Red, 45.0F)
        ' Make the symbols opaque by filling them with white
        myCurve.Symbol.Fill = New Fill(Color.White)

        ' Fill the axis background with a color gradient
        myPane.Chart.Fill = New Fill(Color.White,
Color.LightGoldenrodYellow, 45.0F)

        ' Fill the pane background with a color gradient
        myPane.Fill = New Fill(Color.White, Color.FromArgb(220, 220,
255), 45.0F)

        ' Calculate the Axis Scale Ranges
        zgd.AxisChange()
    End Sub


    Private Sub SetSize1()
        zg1.Location = New Point(5, 5)
        ' Leave a small margin around the outside of the control
        zg1.Size = New Size(ClientRectangle.Width - 5,
ClientRectangle.Height - 5)
    End Sub

    Private Sub graphouterror_Click(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles graphouterror.Click
        CreateGraph2(zg2)

    End Sub

    Private Sub CreateGraph2(ByVal zgd As ZedGraphControl)
        Dim myPane As GraphPane = zgd.GraphPane

        ' Set the titles and axis labels
```

```
        myPane.Title.Text = " Output Error Percentage Graph"
        myPane.XAxis.Title.Text = "MSU Value"
        myPane.YAxis.Title.Text = "Output Error"

        ' Make up some data points from the Sine function
        Dim list = New PointPairList()


        list.Add(msu1.Text, error1x.Text)
        list.Add(msu2.Text, error2x.Text)
        list.Add(msu3.Text, error3x.Text)
        list.Add(msu4.Text, error4x.Text)
        list.Add(msu5.Text, error5x.Text)



        ' Generate a blue curve with circle symbols, and "My Curve
2" in the legend
        Dim myCurve As LineItem = myPane.AddCurve("Output Error
Curve", list, Color.Blue, SymbolType.Circle)
        ' Fill the area under the curve with a white-red gradient at
45 degrees
        myCurve.Line.Fill = New Fill(Color.White, Color.Red, 45.0F)
        ' Make the symbols opaque by filling them with white
        myCurve.Symbol.Fill = New Fill(Color.White)

        ' Fill the axis background with a color gradient
        myPane.Chart.Fill = New Fill(Color.White,
Color.LightGoldenrodYellow, 45.0F)

        ' Fill the pane background with a color gradient
        myPane.Fill = New Fill(Color.White, Color.FromArgb(220, 220,
255), 45.0F)

        ' Calculate the Axis Scale Ranges
        zgd.AxisChange()
    End Sub

    Private Sub Form1_Resize(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles MyBase.Resize

    End Sub

    Private Sub SetSize2()
        zg2.Location = New Point(5, 5)
        ' Leave a small margin around the outside of the control
        zg2.Size = New Size(ClientRectangle.Width - 5,
ClientRectangle.Height - 5)
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles stddev.Click

        sd1.Text = (((a1x.Text - ave6x.Text) ^ 2) + ((a2x.Text -
ave6x.Text) ^ 2) + ((a3x.Text - ave6x.Text) ^ 2)) * ((1 / 2) ^ (1 /
2))
        sd2.Text = (((b1x.Text - ave7x.Text) ^ 2) + ((b2x.Text -
ave7x.Text) ^ 2) + ((b3x.Text - ave7x.Text) ^ 2)) * ((1 / 2) ^ (1 /
2))
        sd3.Text = (((c1x.Text - ave8x.Text) ^ 2) + ((c2x.Text -
ave8x.Text) ^ 2) + ((c3x.Text - ave8x.Text) ^ 2)) * ((1 / 2) ^ (1 /
```

```
2))
        sd4.Text = (((d1x.Text - ave9x.Text) ^ 2) + ((d2x.Text -
ave9x.Text) ^ 2) + ((d3x.Text - ave9x.Text) ^ 2)) * ((1 / 2) ^ (1 /
2))
        sd5.Text = (((e1x.Text - ave10x.Text) ^ 2) + ((e2x.Text -
ave10x.Text) ^ 2) + ((e3x.Text - ave10x.Text) ^ 2)) * ((1 / 2) ^ (1
/ 2))

    End Sub

    Private Sub u11_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles u11.Click

        worstcase.Text = sd1.Text

    End Sub

    Private Sub u12_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles u12.Click

        worstcase.Text = sd2.Text

    End Sub

    Private Sub u13_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles u13.Click

        worstcase.Text = sd3.Text

    End Sub

    Private Sub u14_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles u14.Click

        worstcase.Text = sd4.Text

    End Sub

    Private Sub u15_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles u15.Click

        worstcase.Text = sd5.Text

    End Sub

    Private Sub yes_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles yes.Click

        u1x.Text = Format(worstcase.Text / (3 ^ (1 / 2)),
"0.#######")

    End Sub

    Private Sub no_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles no.Click

        worstcase.Text = ""

    End Sub

    Private Sub u_Click(ByVal sender As System.Object, ByVal e As
```

```
System.EventArgs) Handles u.Click

        ux.Text = Format(((u1x.Text ^ (1 / 2)) + (0.020207 ^ (1 /
2)) + (0.034641 ^ (1 / 2))), "0.######")

    End Sub

    Private Sub a1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles a1.Click

        a1x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub b1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles b1.Click

        b1x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub c1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles c1.Click

        c1x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub d1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles d1.Click

        d1x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub e1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles e1.Click

        e1x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub a2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles a2.Click

        a2x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub b2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles b2.Click

        b2x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub c2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles c2.Click

        c2x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")
```

```
    End Sub

    Private Sub d2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles d2.Click

        d2x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub e2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles e2.Click

        e2x.Text = Format(AdvAI1.DataAnalog / 0.25, "0.####")

    End Sub

    Private Sub a3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles a3.Click

        a3x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub b3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles b3.Click

        b3x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub c3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles c3.Click

        c3x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub d3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles d3.Click

        d3x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

    Private Sub e3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles e3.Click

        e3x.Text = Format(AdvAI1.DataAnalog / 0.25, "#.####")

    End Sub

End Class
```

APPENDIX B
DAQ Card Module Data Sheet

USB-4716

200 kS/s, 16-bit Multifunction USB Module

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 (USB-4716L w/o AO)
- 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** Off: 100 MΩ/10 pF, On: 100 MΩ/100 pF
- **Sampling Modes** Software, onboard programmable pacer, or external
- **Input Range** (V, software programmable)

Bipolar	±10	±5	±2.5	±1.25	±0.625
Accuracy (% of FSR ±1LSB)	0.15	0.03	0.03	0.05	0.1

*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: 4 mA (sink)
  Source: 4 mA (source)

Event Counter

- **Channels** 1
- **Compatibility** 3.3 V/5 V/TTL
- **Max. Input Frequency** 0.1–1K while using FAI; 0.1–10K while using SWAI

General

- **Bus Type** USB V2.0
- **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** 200kS/s, 16-bit Multifunction USB Module, one 1.8 m USB 2.0 cable included

ADVANTECH USB I/O Modules

APPENDIX C
How to use ActiveDAQ Data Sheet

1.0	Description 主旨說明	This Demo video shows how to control Advantech DA&C cards with Microsoft Visual Basic using ActiveQAQ OCX component.	
2.0	Product(s) 適用對象	All Advantech DA&C cards. PCI-1710/ 1710L/1710HG/1710HGL, PCI-1711/1711L, PCI-1712/1712L, PCI-1716/1716L, PCI-1718HDU, PCI-1718HGU, PCL-1718HD/HG, PCI-1714U, PCI-1742U, PCL-711B, PCL-812PG, PCL-818L, PCI-1713, PCI-1714, PCI-1714UL, PCI-1747U, PCI-1715U, PCL-813B, PCI-1720U, PCI-1721, PCI-1723, PCI-1724U, PCI-1727U, PCL-727, PCL-726, PCL-728, PCI-1751U, PCI-1753, PCI-1753E, PCI-1755, PCI-1735U, PCL-720+, PCI-1737U, PCL-724, PCI-1739U, PCL-731, PCI-1757UP, PCL-722, PCI-1730, PCL-730, PCI-1733, PCL-733, PCI-1734, PCL-734, PCI-1750, PCI-1752, PCI-1754, PCI-1756, PCI-1758UDI, PCI-1758UDO, PCI-1758UDIO, PCI-1736UP, PCI-1763UP, PCI-1761, PCL-725, PCI-1760U, PCI-1762, PCL-735, PCL-836, PCI-1780, PCM-3712, PCM-3718H/HG/HO, PCM-3724, PCM-3725, PCM-3730, PCM-3780, USB-4711, USB-4716, USB-4718, USB-4751, USB-4761, USB-4671	
3.0	System requirement 系統需求	OS	Windows XP/ 2000/ 98/ 95/ NT
		Hardware	Host PC, DA&C card
		Software	Microsoft Visual Basic 6.0 or above, Advantech Device Manager, DLL driver, ActiveDAQ driver
4.0	System architecture and configuration 系統架構與設定	DA&C cards Install Microsoft Visual Basic 6.0 or above Install Advantech Device Manager Install DLL driver for DA&C cards Install ActiveDAQ driver	
5.0	Preventive Action 操作步驟	1. Open Visual Basic software. 2. Add ActiveDAQ component by right-clicking the tool box. 3. Double-click the added ActiveDAQ icon for applying it to the form. 4. Develop VB program with ActiveDAQ OCX component. (please refer to ActiveDAQ User Manual in C:\Program Files\ADVANTECH\ActiveDAQ) 5. Run the program to test the results.	

APPENDIX D
2793 Decade Resistance Box Data Sheet

[<< Yokogawa Decade Resistance Boxes Index]

Yokogawa 279301 and 297303 Decade Resistance Boxes

High Accuracy and Stability
High Reproducibility
Simple, quick dial operation
In-line display for easy reading
The 297301 is ideal for Calibration of resistance thermometers and bridges
The 297303 is best suited for calibration of insulation resistance testers and bridges.
Excellent Anti-shock and anti-vibration properties

Yokogawa 2793 Shown

The Yokogawa 2793 Decade Resistor Box series is a high-accuracy, stable DC variable resistor with 6 dials and is available in two styles: 279301 for medium resistance from 0.1 to 1,111.210Ω in 1mΩ steps. The 279303 is made for high-resistances from 0 to 111.1110MΩ in 100Ω steps.

Specifications		2793-01	2793-03	
Resistance Range		0.1mΩ to 1,111.2100Ω (minimum resistance is 0.1Ω)	0 to 1,111.110Ω	
Dial Composition		0.001Ω x 10 + 0.01Ω x 10 + 0.1Ω x 11 + 1Ω x 10 + 10Ω x 10 + 100Ω x 10	100Ω x 10 + 1kΩ x 10 + 10kΩ x 10 + 100kΩ x 10 + 1MΩ x 10 + 10MΩ x 10	
Resolution		1mΩ	-	
Maximum Allowed Input	**0.1Ω**	1.5mA		
	1Ω	500		
	10Ω	150mA		
	100Ω	50mA	100mA	
	1kΩ	-	30mA	
	10kΩ		10mA	
	100kΩ		3mA	
	1MΩ		2000V	
	10MΩ			
Accuracy		±(0.01Ω + 2mΩ)at temperature of 23±2°C, humidity of 45 to 85%, and 0.1W Power Application	**100Ω, 1kΩ, 10kΩ, 100kΩ Steps**	±(0.05Ω + 0.05mΩ)
			1 MΩ and 10MΩ Steps	±0.2%
Insulation Resistance		More than 500MΩ at 500V DC between panel and circuit	More then 10^{11}Ω at 1,000V DC between panel and circuit	
Dielectric Strength		1,000 V AC for one minute between Panel and Circuit	2,500 AC for one minute between Panel and Circuit	
Dimensions		110 x 491 x 140mm (4 3/8 x 19 3/8 x 5 1/2")		
Weight		10.6lbs (4.8kg)		

APPENDIX E
EJX110A Differential Pressure Transmitter Data Sheet

<<Contents>> <<Index>>

General Specifications

EJX Series
FOUNDATION
Fieldbus Communication

GS 01C25T02-01E

FOUNDATION Fieldbus is the digital communication line for the field instruments, whose signal is internationally standardized by Fieldbus Foundation.

The Fieldbus bi-directional digital communication performance makes possible for the field instruments and the control devices to be a complete on-line system, superseding the existing analog transmission lines. EJX series differential pressure transmitters can also measure and transmit the static pressure value. Thus, based on FOUNDATION Fieldbus specifications, EJX Fieldbus models offer more flexible instrumentation through a higher level communication capability and propose the cost reduction by multi-drop wirings with less cables.

■ FEATURES

● Interoperability
FOUNDATION Fieldbus specifications grant the interoperability of the field instruments without preparing designated softwares for the instrument.

● Multi-sensing function
EJX110A Fieldbus model, for example, has three independent AI function blocks for differential pressure and static pressure.

● Function blocks
Arithmetic (AR), Integrator (IT) , Signal Characterizer (SC), and Input Selector (IS) function blocks are available as standard function besides three AI function blocks. PID function block is also supported as an option.

● Multi-signal display (Applicable when digital indicator is specified)
Up to four I/O signals can be alternatively displayed on the digital indicator. The block tags, the parameter names, the process units and the statuses are also displayed in order to show what the displayed signals are.

● Link master function
EJX Fieldbus models support the Link Master function. This function enables backup of network manager and local control only by field devices.

● Alarm function
EJX Fieldbus models securely support various alarm functions, such as high/low alarm, notice of block error, etc. based on FOUNDATION Fieldbus specifications.

● Self-diagnostic function
The reliable self-diagnostic function detects the measuring range failure, the temperature-static pressure failure, and the hardware failure, such as pressure sensor, temperature sensor or amplifier assembly, etc.

● Software download function(option)
Software download function permits to update EJX software via a FOUNDATION Fieldbus.
Typical use of this function is to add new features such as function blocks and diagnostics to existing devices.

4th Edition Apr. 2005

■ STANDARD SPECIFICATIONS

For items other than those described below, refer to each General Specification sheet.

Applicable Model:
All DPharp EJX series.

Output:
Digital communication signal based on FOUNDATION Fieldbus protocol.

Supply Voltage:
9 to 32 V DC for general use, flameproof type, Type n, or nonincendive.
9 to 24 V DC for intrinsically safe type Entity model
9 to 17.5 V DC for intrinsically safe type FISCO model

Communication Requirements:
Supply Voltage: 9 to 32 V DC
Current Draw:
Steady state: 15 mA (max)
Software download state: 24 mA (max)

Response Time (for Primary Value)
L capsule: 185 msec
M, H, A, B, C, D capsule: 150 msec
When amplifier damping is set to zero, and including dead time.

Update Period:
Differential Pressure: 100 msec
Static Pressure: 100 msec
Capsule Temperature: 1 sec
Amplifier Temperature: 1 sec

Integral Indicator (LCD display)
5-digit Numerical Display, 6-digit Unit Display and Bar graph. The indicator is configurable to display one or up to four of the I/O signals periodically.

Functional Specifications:
Functional specifications for Fieldbus communication conform to the standard specifications (H1) of FOUNDATION Fieldbus.

Function Block:

Block name	Number	Execution time	Note
AI	3	30 mS	For differential pressure, static pressure and temperature
SC	1	30 mS	An output of Signal Characterizer block is a non-linear function of the respective input. The function is determined by a table
IT	1	30 mS	Integrator block integrates a variable as a function of the time or accumulates the counts
IS	1	30 mS	Input Selector block provides selection of up to eight inputs and generate an output based on the configured action
AR	1	30 mS	Arithmetic block permits simple use of popular measurement math functions
PID	1	45 mS	Applicable when LC1 option is specified

T01.EPS

LM Function:
LM function is supported.

■ MODEL AND SUFFIX CODE

EJX□□□(□)-F□□□□-□□□□□/□
└─ Output signal ... Digital communication (FOUNDATION Fieldbus protocol)

■ OPTIONAL SPECIFICATIONS

For items other than those described below, refer to each General Specification sheet.

Item	Description	Code
PID function	PID control function	**LC1**
Data configuration at factory *1	Software damping	CC
Software download function	Based on Fieldbus Foundation Specification(FF-883) Download class: Class1	EE

T03.EPS

*1: Also see 'Ordering Information'

■ OPTIONAL SPECIFICATIONS (For Explosion Protected type)

Item	Description	Code
Factory Mutual (FM)	FM Explosionproof Approval *1 Explosionproof for Class I, Division 1, Groups B, C and D Dust-ignitionproof for Class II/III, Division 1, Groups E, F and G in Hazardous locations, indoors and outdoors (NEMA 4X) Temperature class: T6 Amb. Temp.:–40 to 60°C (–40 to 140°F)	**FF1**
	FM intrinsically safe Approval *1	—
CENELEC ATEX	ATEX (KEMA) Flameproof Approval *1 II 2G, 1D EExd IIC T4, T5, T6 Amb. Temp. (Tamb) for gas-proof: T4; –50 to 75°C (–58 to 167°F), T5; –50 to 80°C (–58 to 176°F), T6; –50 to 70°C (–58 to 158°F) Max. process Temp. (Tp): T4; 120°C (248°F), T5; 100°C (212°F), T6; 85°C (185°F) Max. surface Temp. for dust-proof: T80°C (Tamb: –40 to 40°C, Tp: 80°C), T100°C (Tamb: –40 to 60°C, Tp: 100°C), T120°C (Tamb: –40 to 80°C, Tp: 120°C)	**KF2**
	CENELEC ATEX (KEMA) Intrinsically safe Approval *1 II 1GD EEx ia IIB/IIC T4 Amb. Temp. : –40 to 60°C (–40 to 140°F) Max. Process Temp. (Tp) : 120°C (248°F) Max. Surface Temp. for dust-proof: T85°C (Tp:80°C), T100°C (Tp:100°C), T120°C (Tp:120°C) Enclosure : IP66 and IP67 [FISCO (IIC)] Ui=17.5V, Ii=380mA, Pi=5.32W, Ci=1.76nF, Li=0μH [FISCO (IIB)] Ui=17.5V, Ii=460mA, Pi=5.32W, Ci=1.76nF, Li=0μH [Entity] Ui=24V, Ii=250mA, Pi=1.2W, Ci=1.76nF, Li=0μH	**KS25**
	CENELEC ATEX Type n Approval *1 EEx nL IIC T4 Amb. Temp. : –40 to 60°C (–40 to 140°F), Enclosure : IP66 and IP67 Ui=32V, Ci=1.76nF, Li=0	**KN25**
Canadian Standards Association (CSA)	CSA Explosionproof Approval *2 [For CSA C22.2] Explosion-Proof for Class I, Groups B, C and D. Dust-ignitionproof for Class II/III, Groups E, F and G. When installed in Division 2, "SEAL NOT REQUIRED" Enclosure: TYPE 4X, Temp. Code: T6...T4 Max.Process Temp.: T4;135°C (275°F), T5;100°C (212°F), T6; 85°C (185°F) Amb.Temp.: –50 to 80°C (–58 to 176°F) for T5 & T4, –50 to 75 °C (–58 to 167°F) for T6 [For CSA E60079] Flameproof for Zone 1, Ex d IIC T6...T4 Enclosure: IP66 and IP67 Max.Process Temp.: T4;120°C (248°F), T5;100°C (212°F), T6; 85°C (185°F) Amb.Temp.: –50 to 75°C (–58 to 167°F) for T4, –50 to 80 °C (–58 to 176°F) for T5, –50 to 70°C (–58 to 158°F) for T6	**CF1**

T02.EPS

Contact Yokogawa representative for the codes indicated as '-'.
*1: Applicable for Electrical connection code 2, 4, 7 and 9.
*2: Applicable for Electrical connection code 2 and 7.

<Ordering Information>

Specify the following when ordering
1. Model, suffix codes, and optional codes
2. Calibration range and unit (XD_SCALE of AI1);
   1) Calibration range can be specified with range value specifications up to 5 digits (excluding any decimal point) for low or high range limits within the range of –32000 to 32000.
   2) Specify only one unit from the table, 'Factory Setting'.
3. Output mode (L_TYPE of AI1);
   Select 'Direct', 'Indirect Linear' or 'Indirect SQRT'.
4. Output scale and unit (OUT_SCALE of AI1);
   When digital indicator is required, the scale range can be specified with range limit specifications up to 5 digits (excluding any decimal point) for low or high range limits within the range of –32000 to 32000. Unit display consists of 6-digit, therefore, if the specified scaling unit excluding '/' is longer than 6-characters, the first 6 characters will be displayed on the unit display. When L_TYPE is Direct, these setting does not affect the output of the AI block
5. Tag Number;
   Specify software tag (up to 30 letters) to be written on the amplifier memory and Tag number (up to 18 letters) to be engraved on the tag plate separately.
6. Node Address

[When /CC option is specified]

7. Operation Functional Class
   Select 'BASIC' or 'LINK MASTER'
8. Software damping (PRIMARY_VALVE_FTIME of TB);
   Specify software damping : 0.00 to 100.00 (sec)

Example; When 50 to 1000 mmH_2O for calibration range and 0 to 100% output range is required, specify the values as follows:

Calibration range:		
	Higher value	1000
	Lower value	50
Calibration unit:		mmH_2O
Output range:		
	Higher value	100
	Lower value	0
Unit of output range:		%
Output mode:		Indirect Linear

Explanation of Fieldbus parameters:

(1) XD_SCALE: Set the input value from Transducer block (input range of sensor) which corresponds to 0% value and 100% value of the calculation in the AI function block. In the case of EJX series, the value set as calibration range should be entered to this parameter.

(2) OUT_SCALE: Output scaling parameter. Set the output value which corresponds to 0% value and 100% value of the calculation in the AI function block. In the case of EJXseries, the value set as output scale should be entered to this parameter. When integral indicator is required, this output is shown on LCD.

(3) L_TYPE: Determines if the values passed by the tranducer block to the AI block may be used directly (Direct) or if the value is in different units and must be converted linearly (Indirect Linear) or with square root (Indirect SQRT), using the input range defined by XD_SCALE and the associated output range (OUT_SCALE).

< Factory Setting >

Tag Number (Tag plate)		As specified in order
Software Tag (PD_TAG)		'PT2001' unless otherwise both Tag Number and Software Tag specified in order
Node Address		'0xF5' unless otherwise specified in order
Operation Functional Class		'BASIC' or as specified
Primary value *1	Output Mode (L_TYPE)	'Direct' unless otherwise specified in order
	Calibration Range (XD_SCALE) Lower/Higher Range Value	As specified in order
	Calibration Range Unit	Selected from mmH_2O, mmH_2O(68°F), mmHg, Pa, hPa, kPa, MPa, mbar, bar, gf/cm^2, kgf/cm^2, inH_2O, inH_2O(68°F), inHg, ftH_2O, ftH_2O(68°F) or psi. (Only one unit can be specified)
	Output Scale (OUT_SCALE) Lower/Higher Range Value	'0 to 100%' unless otherwise specified.
	Software Damping *2	'2 seconds' or as specified in order
Static pressur display range		'0 to 25 MPa' for M and H capsule and '0 to 16 MPa' for L capsule, absolute value. Measuring high pressure side.

T04.EPS

*1: Primary means differential pressure in case of differential presser transmitters and pressure in case of pressure transmitters.
*2: To specify this item, /CC option is required.

< Related Instruments >

The customer should prepare instrument maintenance tool, terminator, fieldbus power supply etc.

<Reference>

FOUNDATION; Trademark of Fieldbus Foundation.

APPENDIX F
MT220 Digital Manometer Data Sheet

High-Performance, High-Efficiency Field Calibration

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.

Functions Tailored to Your Calibration Work

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.

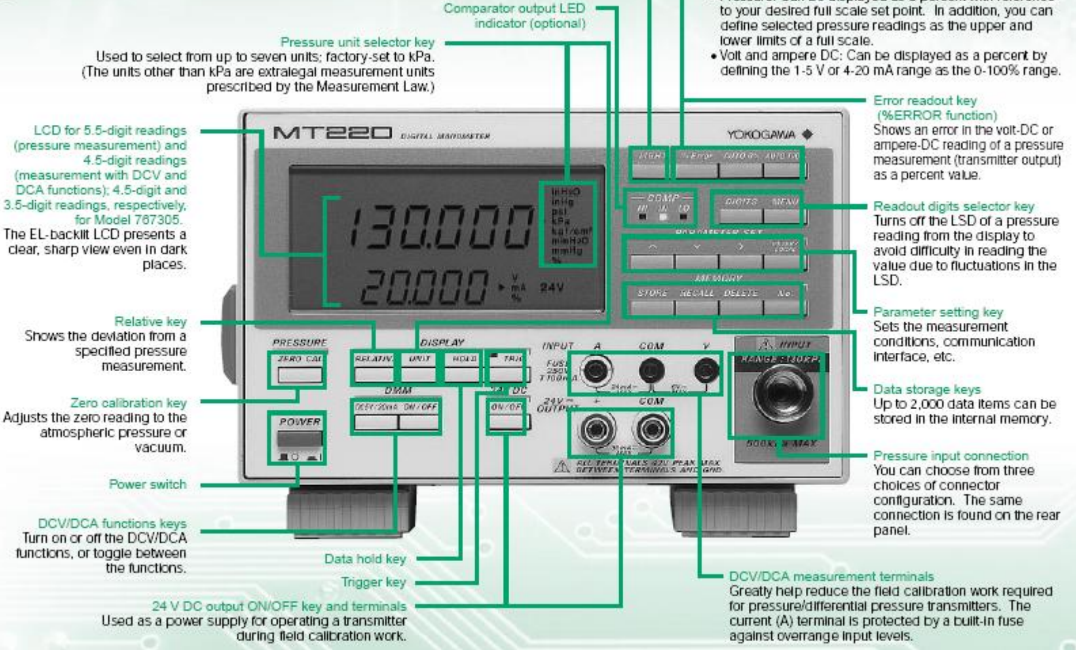
Assured Compatibility with Earlier Models

The specifications of the MT220 are based on the earlier series of MT120 manometers to ensure compatibility; both series also share the same communications commands.

Other Major Functions

Many other handy functions found on the front and rear panels help you implement your specific applications successfully.

● Front Panel



Full Support for Higher Accuracy of Pressure/Differential Pressure Transmitters

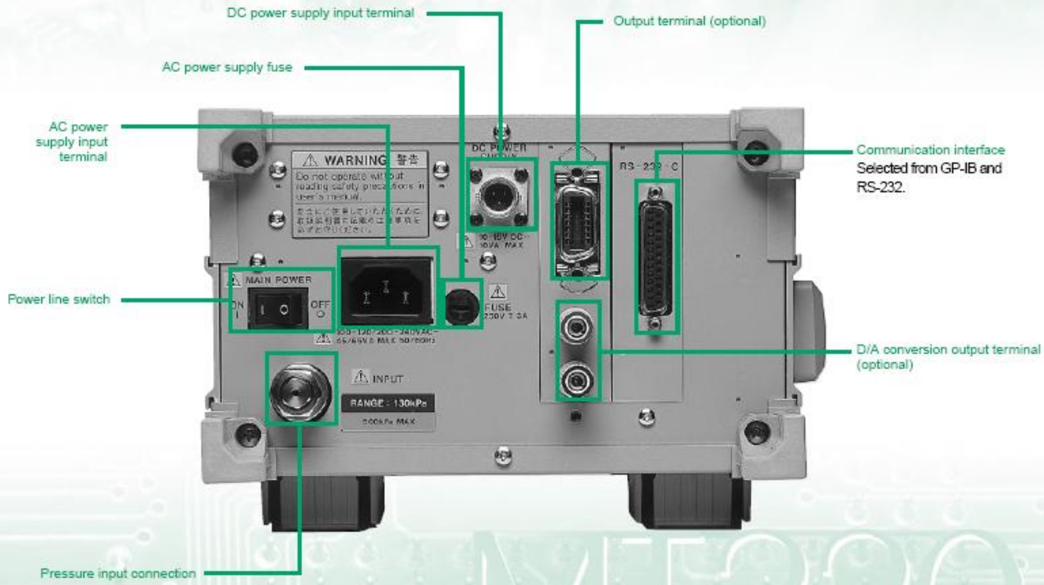
The accuracy of pressure/differential pressure transmitters has continued to improve, from ±0.25% to ±0.1%, and now to ±0.075%. That means the accuracy and stability of the manometers used to calibrate these transmitters must keep pace.

The MT220 employs Yokogawa's original silicon resonant sensor—a high precision pressure sensing device. We've also set up an advanced calibration environment, including a tightly-controlled traceability system. As a result, our calibrators feature basic accuracy as high as ±0.02%, and excellent stability. With the MT220, you can verify the performance of even the most accurate of pressure/differential pressure transmitters, i.e. ±0.075%.

Years of Experience in Precision Pressure Measuring Instruments

Yokogawa, a leading company with a proven track record in the field of industrial instruments and instrumentation, also has decades of experience in pressure measurement. We've been developing digital manometers for more than 20 years and have won a great many loyal customers. Our wide range of pressure measuring instruments offer unrivalled functionality and performance.

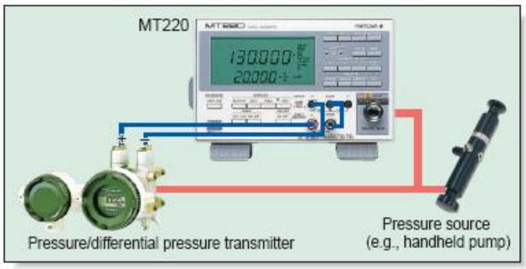
● Rear Panel



Field Calibration of Pressure/Differential Pressure Transmitters

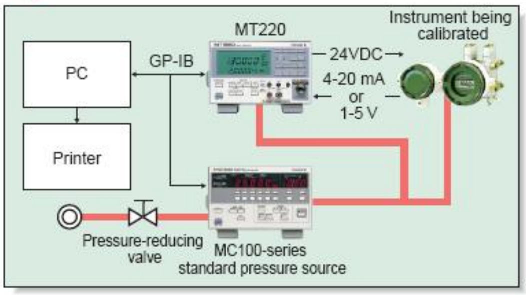
Example of Calibration Work

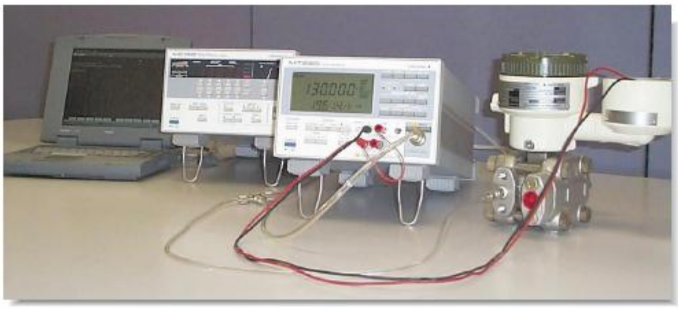
The MT220 can measure pressure with outstanding accuracy, high resolution, minimal tempco, and excellent stability. It offers a wealth of functions for field calibration, including transmitter output measurement (DCV/DCA functions), 24-V DC output, percent error readout, measurement data memory, and 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.



Calibration System Configuration Using a Combination of MT220 and Standard Pressure Source

Calibrating transmitters, pressure sensors and manometers is easy. Simply combine the MT220 with a standard pressure source (e.g., MC100 series) or a handheld pump (e.g., Model BA-11). You can also automate your calibration system by integrating your PC and relevant equipment with the system, making it ideal for a calibration laboratory, for example.





Example of System Configuration

Major Users of Yokogawa Digital Manometers (for Reference Only)

National standards institutions in Japan and abroad; institutions related to nuclear power generation; national and public research institutions; electric-power companies; automakers and their affiliates; electric home appliances manufacturers; precision instruments manufacturers; semiconductor and electronic components manufacturers; pharmaceutical manufacturers; heavy electrical machinery builders; oil refinery companies and chemical and petrochemical companies; and engineering companies.

Technical Data

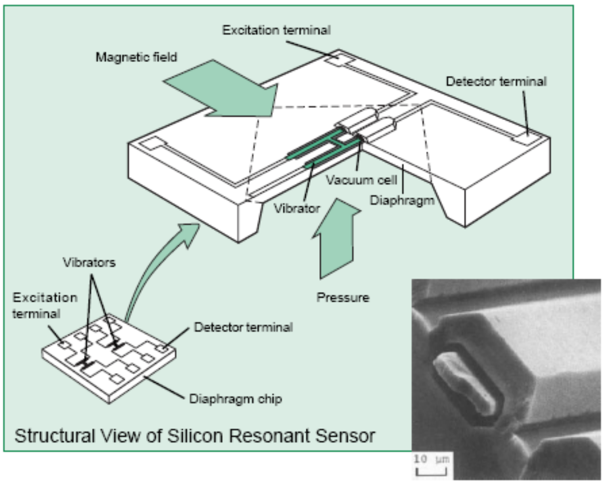
■ Pressure-Measurement Specifications

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 +0.005% 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 cm³				
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}cm³/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} m²/sec max.				
Pressure sensor	Silicon resonant sensor				
Pressure sensing element	Diaphragm				
Readout unit	kPa only, or selection from a group consisting of kPa, kgf/cm², mmHg and mmH_2O or a group consisting of kPa, psi, inHg, inH_2O, kgf/cm², mmHg and mmH_2O; specify when ordering[*3])				
Pressure input connector	Rc1/4 or NPT1/4 female-threaded or VCO1/4[*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)				

■ Reference Information

Yokogawa's Original Silicon Resonant Sensor (Winner of the Ohkochi Grand Technology Prize and the Chairman's Award of the Japan Federation of Economic Organizations (Keidanren))

Thanks to Yokogawa's award-winning sensor, the MT220 boasts a basic accuracy as high as ±0.02%, and high resolution. The silicon resonant sensor is also practically immune to external effects such as temperature variations.



Structural View of Silicon Resonant Sensor

■ Pressure Unit Conversion Table

Pa	bar	kgf/cm²	atm	mmH_2O or mmAq	mmHg or Torr
1	1×10^{-5}	$1.019\,72 \times 10^{-5}$	$9.869\,23 \times 10^{-6}$	$1.019\,72 \times 10^{-1}$	$7.500\,62 \times 10^{-3}$
1×10^{5}	1	1.019 72	$9.869\,23 \times 10^{-1}$	$1.019\,72 \times 10^{4}$	$7.500\,62 \times 10^{2}$
$9.806\,65 \times 10^{4}$	$9.806\,65 \times 10^{-1}$	1	$9.678\,41 \times 10^{-1}$	1×10^{4}	$7.355\,59 \times 10^{2}$
$1.013\,25 \times 10^{5}$	1.013 25	1.033 23	1	$1.033\,23 \times 10^{4}$	$7.600\,00 \times 10^{2}$
9.806 65	$9.806\,65 \times 10^{-5}$	1×10^{-4}	$9.678\,41 \times 10^{-5}$	1	$7.355\,59 \times 10^{-2}$
$1.333\,22 \times 10^{2}$	$1.333\,22 \times 10^{-3}$	$1.359\,51 \times 10^{-3}$	$1.315\,79 \times 10^{-3}$	$1.359\,51 \times 10$	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 ±3°C)	±(0.01% of reading + 2 digits) 30 days after calibration	
	±(0.03% of reading + 2 digits) 90 days after calibration	
	±(0.05% of reading + 3 digits) 6 months after calibration	
	±(0.07% of reading + 3 digits) 1 year after calibration	
Readout range	0 to ±6.0000 V	0 to ±24.000 mA
Maximum allowable input	30VDC	100mA
Readout unit	V	mA
Input impedance	Approx. 10 MΩ	Approx. 20 MΩ
CMRR	120 dB min. (50/60 Hz; Rs = 1 kΩ)	— —
NMRR	60 dB min. (50/60 Hz)	— —
Temperature effect	±(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 ratea	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 156 kPa = 2.4 V -80 kPa = -1.230 V
Output resolution	16 bits, where full scale is approximately ±125% of range
Output accuracy (Tested at 23 ±3°C, after zero calibration, using the D/A conversion output terminal)	Add ±0.05% of full scale to accuracy in the Pressure-measurement Specifications section.
Temperature effect	±(0.005% of full scale)/°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 kΩ min.

Comparator Output

Output signal	HIGH, IN, LOW, BUSY
Operation	HIGH = 1, if measured value > upper limit IN = 1, if upper limit ≥ measured value ≥ 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.

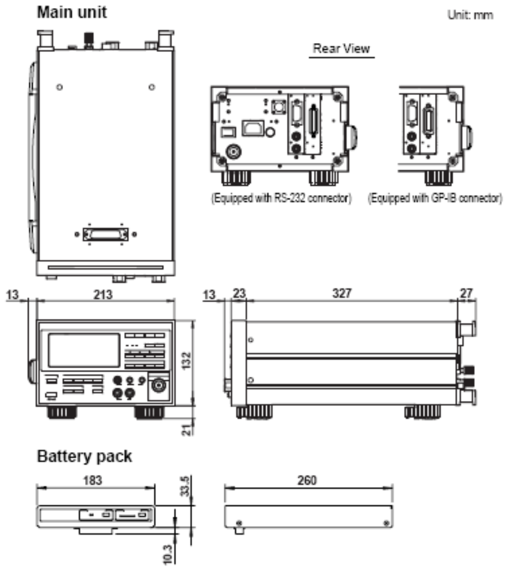
■ Common Specifications

Display	LCD (with backlight); number of readout digits: 5.5 or 4.5[*5] digits for pressure measurement and 4.5 digits for measurement with DCV/DCA functions
Warm-up time	Approx. 5 minutes
Operating temperature/humidity ranges	5 to 40°C/20 to 80% RH (no condensation)
Altitude of operation	2000 m max.
Storage temperature range	-20°C to 60°C
Power Supply	Three-way power (AC or DC supply, or optional Ni-Cd batteries)
AC power rating Allowable supply voltage range Allowable supply frequency range	100 to 120/200 to 240 V AC, at 50/60 Hz 90 to 132 V/180 to 264 V AC 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 MΩ 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 × 213 mm × 350 mm, excluding protrusions Battery pack (optional): Approx. 33 mm × 182 mm × 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 ±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 VCO is a registered trademark of Swagelok Company.
*5 4.5/3.5 digits for Model 767355.

■ External Dimensions



Unless otherwise specified, the tolerance is ±3%; for dimensions smaller than 10 mm, however, the tolerance is ±0.3 mm.

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_2O
		–U3	kPa, switchable to psi, inHg, inH_2O, kgf/cm_2, mmHg or mmH_2O
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 ϕ4 × ϕ6 PVC tubing
Simplified connector assembly kit	B9310ZH	——	For use with ϕ4 × ϕ6 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

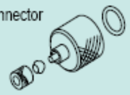
■ Carrying Case

Picture of B9320ND carrying case

■ Adapting Connectors for Input Section

Connector assembly kit
B9310RR

Simplified connector assembly kit
B9310ZH



Adapting connector (JIS)
G9612BG

Adapting connector (ANSI)
G9612BJ

Adapting connector (ANSI)
G9612BW

■ 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.

Related Products

MT210/210F Digital Manometers

- High accuracy: ±0.02% of reading
- Maximum allowable input: 500 kPa (130 kPa-range model)
- A wide range of pressures, from low differential pressure of 1 kPa to high gauge pressure of 3000 kPa
- Selection from three measurement modes: normal speed, medium speed and high speed (MT210F series)
- D/A conversion output, comparator output, and external trigger input (optional)
- GP-IB and RS-232 interfaces
- 12-V DC power supply
- Battery operation (optional)

MT10 Mini-manometer

- Highly reliable design based on silicon resonant sensor
- Compact
- High accuracy: ±(0.04% of reading + 0.03% of full scale) for 130 kPa-range model
- Three choices of pressure range: 130, 700 and 3000 kPa
- Simple operation
- Data hold function
- RS-232 interface

CA100 "Compact CAL" Calibrator

- High accuracy: ±0.02 of setting for DC voltage generation function
- Resistance generation function, in addition to DC voltage/current, thermocouple/RTD output, and frequency generation functions
- Separate generation and measurement functions
- Compact (A5-size footprint)
- 24-V DC power supply convenient for providing maintenance services to transmitters, etc.
- SINK/SOURCE functions for providing sink/source currents

MC100 Pressure Standard

- High accuracy: ±(0.05% of full scale)
- Excellent stability of operation based on silicon resonant sensor
- Two choices of pressure ranges: 25 and 200 kPa
- Output divider function for generating fractions of a pressure setpoint, to a maximum resolution of 1/20
- Output autostep function
- Output sweep function
- Offset monitor function

BA-11 Handheld Pump

- Maximum available pressure: 700 kPa
- External dimensions: Approx. 55 mm × 200 mm
- Weight: 400 g
- Accessories: 2-m long, ϕ4 × ϕ6 PVC tube; T-shaped fitting (1); carrying case (1)
- Sales representative:
  Yokogawa Trading Corporation
  Phone: +81-422-52-5560

NOTICE

- Before operating the product, read the instruction manual thoroughly for proper and safe operation.
- If this product is for use with a system requiring safeguards that directly involve personnel safety, please contact the Yokogawa sales offices.

YOKOGAWA

YOKOGAWA ELECTRIC CORPORATION
Measurement Sales Dept./Phone: 81-422-52-6614, Fax: 81-422-52-6624
Network Solutions Sales Dept./Phone : 81-422-52-6765, Fax : 81-422-52-6793

YOKOGAWA CORPORATION OF AMERICA Phone: 1-770-253-7000, Fax: 1-770-251-2088
YOKOGAWA EUROPE B.V. Phone: 31-33-4622142, Fax: 31-33-4641616
YOKOGAWA ENGINEERING ASIA PTE. LTD Phone: 65-2419933, Fax: 65-2412606

APPENDIX G
Ametek T-430 Hand Pump Data Sheet

Model T-740 pneumatic pressure pump is similar to the T-730, except that it can generate pressures up to 300 psi (20.6 bar).

Model T-750 vacuum pump is ideal for testing and calibrating vacuum instruments in ranges up to 25-inches Hg vacuum.

Functional specifications - Model T-730

Operating Pressure (Maximum)........................... 2 bar / 30 psi
Wetted Parts........................ Aluminum, brass, stainless steel,
.... steel, nylon and Nylantron®
"O" Rings..Buna-N
Test medium..Air
Test Connections .... 0.6 m / 24 in hose with 1/4" BSP
....and NPT female terminations
Net weight .... 1.11 kg / 2.452 lb

Functional specifications - Model T-740

Operating Pressure (Maximum)...................... 15 bar / 200 psi
Wetted Parts........................ Aluminum, brass, stainless steel,
.... steel, nylon and Nylantron®
"O" Rings..Buna-N
Test medium..Air
Test Connections .... 0.6 m / 24 in hose with 1/4" BSP
....and NPT female terminations
Net weight .... 1.04 kg / 2.30 lb

Functional specifications - Model T-750

Operating Pressure (Maximum)................-0.850 bar / 25 inHg
Wetted Parts........................ Aluminum, brass, stainless steel,
.... steel, nylon and Nylantron®
"O" Rings..Buna-N
Test medium..Air
Test Connections .... 0.6 m / 24 in hose with 1/4" BSP
....and NPT female terminations
Net weight .... 1.08 kg / 2.38 lb

Ordering code - Model T-730 / T-740 / T-750

T-730	Pneumatic pump, 0 to 2 bar (30 psi)
T-740	Pneumatic pump, 0 to 15 bar (200 psi)
T-750	Vacuum pump, -0,850 to 0 bar (-25 to 0 inHg)