## UNIVERSITI MALAYSIA PAHANG

# BORANG PENGESAHAN STATUS TESIS♦

**JUDUL**: **COMPUTER-BASED INSTRUMENTATION SYSTEM FOR TEMPERATURE MEASUREMENT USING RTD IN VISUAL BASIC APPLICATION**

**SESI PENGAJIAN**: **2007/2008**

Saya **MUHAMMAD HASBULLAH BIN RAIS ( 860709-26-5509 )**
(HURUF BESAR)

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# COMPUTER-BASED INSTRUMENTATION SYSTEM FOR TEMPERATURE MEASUREMENT USING RTD IN VISUAL BASIC APPLICATION

MUHAMMAD HASBULLAH BIN RAIS

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

Faculty of Electrical & Electronics Engineering

Universiti Malaysia Pahang

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*Specially dedicated to*

*My beloved family and those people who have guided and inspired me*

*throughout my journey of education*

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## ABSTRACT

In temperature measurement, the need to get accurate and stable reading is crucial since it play major role to what we produce. Computer-based instrumentation system for temperature measurement is one way that can be used to measure temperature where the data from measurement process can be directly use for other purpose, such as calculation and data monitoring. The purpose of this project is to study about temperature measurement as well as to develop a system to ease the process of doing experiment. The system developed is named as RTD's-Temp where it is more focus on how to save time during experiment and get more systematic result. Manual method in temperature measurement is taking the data manually before finish the other things. The system is developed as alternative to conventional way of doing experiment for subject BEE4523 – Industrial Instrumentation. From the existence of this system, hope user can get benefits from it. RTD's-Temp is developed in window-based application, which can be operated in any personal computer (PC).

# ABSTRAK

Dalam pengukuran suhu, adalah sangat penting untuk mendapat bacaan yang stabil dan tepat kerana ia memainkan peranan yang amat penting terhadap apa yang akan dihasilkan. Pengukuran suhu berasaskan sistem komputer merupakan salah satu cara yang boleh digunakan untuk mengukat suhu dimana hasilnya boleh digunakan terus samada untuk tujuan pengiraan atupun tujuan pemerhatian data. Tujuan projek ini dijalankan adalah untuk mengkaji mengenai penyukatan suhu disamping membangunkan satu sistem untuk memudahkan kerja semasa eksperimen dijalankan. Sistem yang dibangunkan ini dinamakan RTD’s-Temp dimana ianya difokuskan bagaimana untuk menjimatkan masa semasa mejalani eksperimen serta memperoleh hasil yang sistematik. Kaedah manual yang dijalankan semasa proses pengukurn suhu dimana pengguna akan merekod data secara manual dan selepas itu barulah perkara lain seperti pengiraan dapat diselesaikan. Sistem yang dibangunkan ini adalah altenatif kepada kaedah kebiasaan semasa menjalani eksperimen untuk subjek BEE4523 – Industrial Instrumentation. Diharap dengan wujudnya sistem ini akan membawa manfaat yang banyak kepada mereka yang menggunakan sistem ini. RTD’s-Temp dibangunkan berasaskan sistem windows dan boleh digunakan di mana-mana komputer peribadi.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| RTD | - | Resistance Temperature Detector |
| USB | - | Universal Serial Bus |
| DAQ or DAQ | - | Data Acquisition |
| PRT | - | Platinum Resistance Thermometer |
| °C | - | Degree Celsius |
| mA | - | miliampere |
| 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 |
| $\gamma$ | - | Degree of Freedom |

## LIST OF APPENDIXES

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

Nowadays, there are many types of measurement that we could use to measure temperature. It is important to get accurate measurement since a wrong measurement could lead to massive destruction. The sensor used depends on what the need is, for example when we need the measurement with high accuracy, we should go for platinum RTD because it gives a more accurate reading. Other popular type of sensor such as thermocouple also can be used.

This project will concentrate on the software of the system. The method that will be used in the task is to get the reading from instruments parts and transfer it directly from the hardware to the software. The reason for using the software for the given system is to minimize the time consumption for the students to do experiment in terms of calculations and study analysis. The project is based on instrumentation, and specifically for subject Industrial Instrumentation (BEE4523). It is an education purpose project which our aim is to increase the student's interest in experiments. Student can refer to the guideline given by the lecturer (lab sheet) and at the same time, they can use the system to get better understanding. The learning station will include all the necessary calculation, for example to calculate uncertainty and other things students should know about the experiment. For plotting the graph from the system, it will help student to make sure they get the right graph. Student can sketch the graph manually, but it takes time and therefore by using the system, the entire problem regarding the graph will be solved.

## 1.2 Objective Research

The objectives of the project are:

(i) To understand the concept of temperature measurement

There are various types of instrument that can be used in temperature measurement, depending on the purpose such as RTD and then we apply the concept in implementing the system.

(ii) To interface the instrument to software using hardware

Familiarize with various type of data communication to computer like USB, serial port and parallel port. Each of these has different configuration. This system will use USB as a way to connect to the computer in order to receive data from instrument.

(iii) To develop a computer-based instrumentation system used in "Temperature Instrumentation" experiment using Visual Basic application

The system will be known as "RTD's-Temp", and it will be used by student in order to save time instead of doing study analysis, which is calculation for uncertainty by their own. It takes a long time to finish the experiment, excluded the time they need to do all the necessary calculation and then finish the whole report.

## 1.3 Scope of Project

The scopes of the project are:

(i) RTD’s-Temp can plot the graph and for do calculation for study analysis

(ii) RTD’s-Temp is able to communicate to DAQ card, Advantech USB-4716 successfully via USB

User can select what mode they want to operate, either automatic or manual mode. This is a crucial part since in automatic mode; the system will automatically get the reading from the instrument with observation from user, but user still needs to initialize connection to instrument and after successful, the system will automatically receive the data according to the specification of the instrument.

(iii) Save time for doing all the calculation & plotting the graph

The main idea here is it saves a lot of time for students who are doing “Temperature Measurement” using RTD. Instead of using the conventional step, where students get all the value from experiment, do all the calculation and finally plot the graph, user can use the features of RTD’s-Temp to do all the necessary calculation and plotting the graph, and yet user can still observe what happen, so they will aware about what is happening during the experiment.

## 1.4 Problem Statement

(i) Automated system

Error in taking reading from experiment can happen if user not clearly enough about what should he/she do.

(ii) Accuracy of result

Result for calculation use in study analysis and plotting the graph need to be accurate.

(iii) Unclear about experiment procedure

Sometime user need guidance in doing experiment, thus user need to do some finding by asking lecturer, etc but if lecturer is not there, user find it difficult to complete the experiment.

### 1.4.1 Current Situation

When we talk about time, people always complain about not having enough time to do something. So, some of them came with ideas to make our life easier than before. From that kind of prospective, RTD's-Temp has been created to fulfil that needs. It will help user to reduce the time consumption by doing experiment in a shorter time.

## 1.5 Thesis Organization

This thesis consists of five chapters. This chapter discuss about overview of project, objective research, project scope, problem statement and thesis organization.

Chapter two contains a detailed description of temperature measurement process. It will explain about the concept of temperature measurement, the application of this system and the involved component in this project.

Chapter three includes the project methodology. It will explain how the project is organized and the flow of process in completing this project. Also in this topic discusses the methodology of the hardware, instruments and software design.

Chapter four will be discussing about the result obtained in this project and a discussion about the result.

Finally, the conclusions for this project are presented in chapter five. This chapter also discusses about the recommendation for the project and for the future development.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

RTD's-Temp is a computer-based instrumentation for temperature measurement using resistance temperature detector. This system consists of three main parts which are instruments, hardware and software. Each of these parts plays significant roles to make the system successfully done the job. Figure 2.1 shows overall system of RTD's-Temp.


**Figure 2.1**: Overall System of RTD's-Temp

## 2.2 Introduction to Resistance Temperature Detector

"Resistance thermometers, also called resistance temperature detectors (RTDs), are temperature sensors that exploit the predictable change in electrical resistance of some materials with changing temperature. As they are almost invariably made of platinum, they are often called platinum resistance thermometers (PRTs). They are slowly replacing the use of thermocouples in many industrial applications below 600°C." [1]

We can categorize RTD into two different categories which are film thermometer type and wire-wound thermometer type. For the first one which is film thermometer type, it has layer of platinum on its substrate and in size approximately one micrometer. The advantages of this film thermometer type are relatively low cost and fast response. For the second one which is wire-wound thermometer type, the advantage is. It has a greater accuracy especially for wide temperature ranges. RTD itself have several wiring configuration which are two-wire configuration (figure 2.2), three-wire configuration (figure 2.3), and four-wire configuration (figure 2.4). Each of the configurations has its own advantage. The simplest resistance thermometer configuration uses two wires. It is only used when high accuracy is not required as the resistance of the connecting wires is always included with that of the sensor leading to errors in the signal. 100 meters of cable can be use for this configuration. This applies equally to balanced bridge and fixed bridge system.

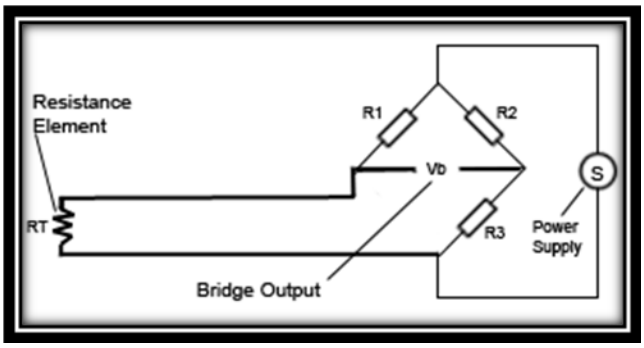

**Figure 2.2:** Two-Wire Configuration

In order to minimize the effect of lead resistance, three-wire configuration can be use. The configuration allows for up to 600 meters of cable.

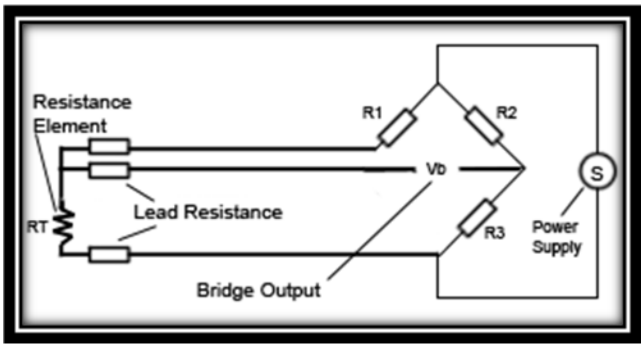


**Figure 2.3:** Three-Wire Configuration

The last configuration is four-wire configuration. It increases the accuracy and reliability of the resistance being measured.

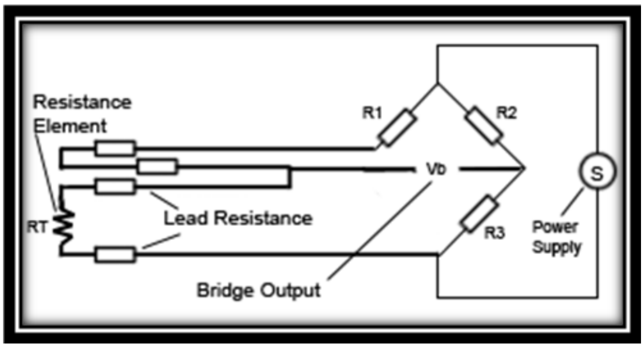


**Figure 2.4:** Four-Wire Configuration

If compared to thermocouple in certain cases, resistance thermometer offers greater stability, accuracy and repeatability than thermocouples. It uses electrical resistance and requires a small power source to operate. The resistance ideally varies linearly with temperature. Usually resistance thermometers are made from platinum since the advantage of using platinum is linear resistance-temperature relationship. Resistance thermometers require a small current to be passed through in order to determine the resistance. In most industries, they practice of using three-wire configuration. The advantages of using three-wire configuration are high accuracy, low drift, wide operating range, and suitability for precision applications. But there are some limitations when using RTD. If compare to thermistors, platinum RTD are less sensitive to small temperature changes and have a longer response time. However, thermistors have a smaller temperature range and stability. “The Resistance Temperature Detector (RTD) is an example of a sensor which can benefit greatly by smart transducer techniques that is, digital signal processing and transmission of data. The RTD is a stable sensor capable of resolving temperature changes to at least 0.001 "C over a temperature range of -200°C to 400°C continuously and over 600°C for shorter times” [1]

In the experiment, it will be concentrated only on temperature from 50°C up to 200°C. The RTD are capable to detect the temperature changes to three decimal points (0.001°C), but in the experiment, our main concern is the temperature change of one decimal point (0.1°C). After get the temperature reading, that temperature will be converted in the form of current, in range of 4mA ~ 20mA by temperature transmitter.

## 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 Temperature Transmitter

"Temperature transmitters convert the RTD resistance measurement to a current signal, eliminating the problems inherent in RTD signal transmission via lead resistance. Errors in RTD circuits (especially two and three wire RTD) are often caused by the added resistance of the lead wire between the sensor and the instrument. Transmitter input, specifications, user interfaces, features, sensor connections, and environment are all important parameters to consider when searching for temperature transmitters. Transmitter input specifications to take into consideration when selecting temperature transmitters, RTD include reference materials, reference resistance, other inputs, and sensed temperature. Choices for reference material include platinum, nickel or nickel alloys, and copper. Platinum is the most common metal used for RTD - for measurement integrity platinum is the element of choice. Nickel and nickel alloys are very commonly used metal. They are economical but not as accurate as platinum. Copper is occasionally used as an RTD element. Its low resistively forces the element to be longer than a platinum element. Good linearity and economical. Upper temperature range typically less than 150 °C. Gold and Silver are other options available for RTD probes - however their low resistively and higher costs make them fairly rare, Tungsten has high resistively but is usually reserved for high temperature work. When matching probes with instruments - the reference resistance of the RTD probe must be known. The most standard options available include 10 ohms, 100 ohms, 120 ohms, 200 ohms, 400 ohms, 500 ohms, and 1000 ohms. Other inputs include analog voltage, analog current, and resistance input. The temperature range to be sensed and transmitted is important to consider." [3]

## 2.5 Temperature Transmitter versus Direct Wiring

When making temperature measurement, there are two ways been employed to get process reading back to monitoring and control system. One method is to utilize sensor extension wires to carry the low-level signals (ohm or mV) generated by field-mounted RTD sensors (Figure 2.5). Another way is to install temperature transmitters at or near the measurement point. The transmitter amplifies and conditions the sensor signal, and transmits it over a twisted wire pair back to the control room (Figure 2.6). Direct wiring strategies have generally been considered less expensive and sometimes easier. Transmitter use, because of cost considerations, was often reserved for important loops and applications where we must hold the signal integrity.

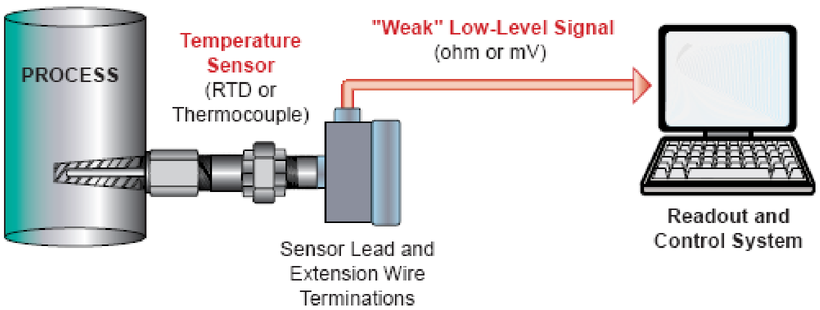

**Figure 2.5:** Sensor Extension Wires Carry Low-Level (Ohm or Mv) Signals Generated By a Field-Mounted RTD

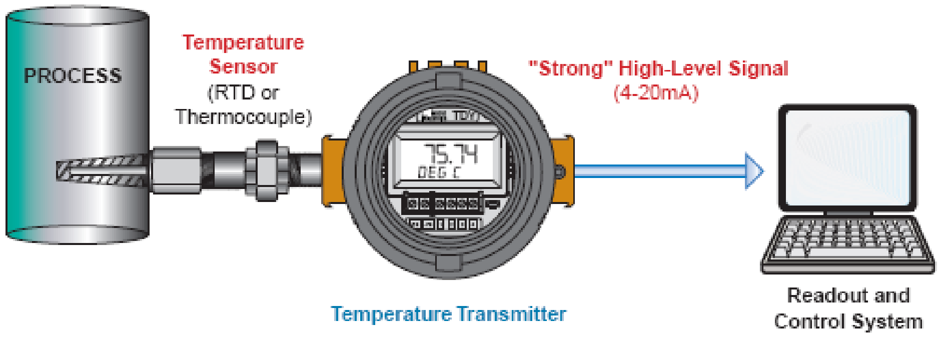


**Figure 2.6:** A Temperature Transmitter Amplifies And Conditions the Primary Sensor Signal, Then Carries It over a Twisted Pair Wire to the Control Room

Direct wiring sensor requires the use of sensor extension wires. Not only are extension wires fragile, they also cost three times more than the common shielded copper wire used for a temperature transmitters's 4 - 20mA signal. Using the less expensive wires, transmitters can pay for themselves in wire and conduit costs alone. Using temperature transmitters can substantially enhance measurement accuracy.

## 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 board 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 Process of Acquiring Data 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 Voltages 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

For methodology, the system will be integrated with combination of three main component; instruments, software and hardware. This project has utilized Visual Basic languages and its component in creating the Graphical User Interface (GUI) to interfacing the hardware and the instruments.

## 3.2 Instruments

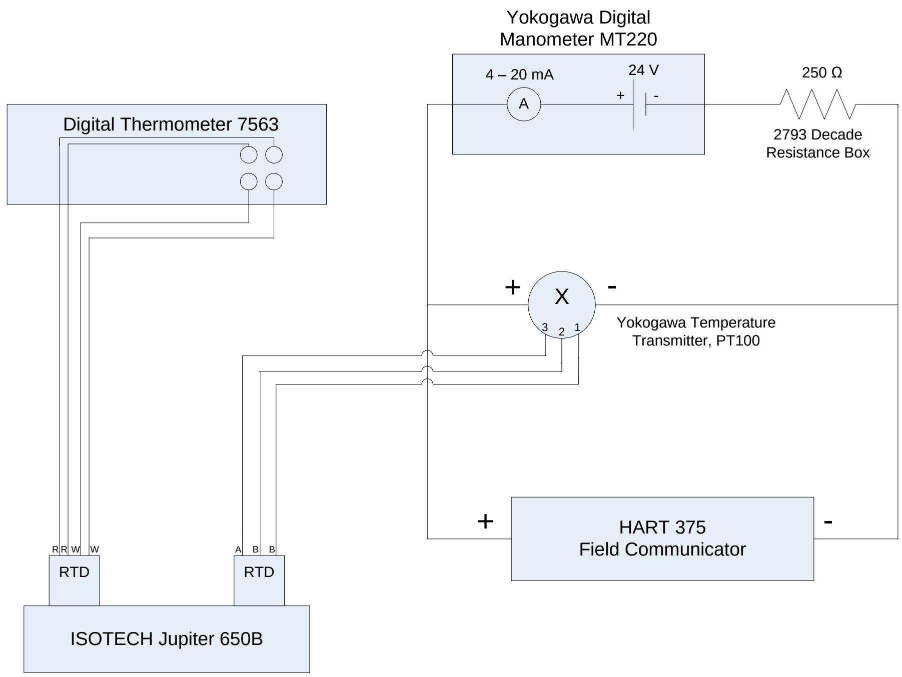


**Figure 3.1:** Block diagram for instruments

### 3.2.1 The Function for each Component in Instruments:

Resistance Temperature Detector (RTD) is a sensing element that consists of a wire coil or deposited film of pure metal. The element's resistance increases with temperature in a known and repeatable manner. RTD's exhibit excellent accuracy over a wide temperature range and represent the fastest growing segment among industrial temperature sensors Digital Thermometer. Isotech Jupiter 650B is use to provide the heat for RTD to take the reading of the temperature, for the experiment the temperature reading will be take start from 50.0°C, 87.5°C, 125.0°C, 162.5°C, and 200.0°C. HART 375 Field Communicator (Figure 3.2) is use for calibration purpose. Yokogawa Temperature Transmitter, PT100 (Figure 3.3), is use to change the temperature in form of current in the range of 4mA ~ 20mA, according to the lowest to higher range of temperature. 4mA will represent 50°C and the higher temperature, which is 200.0°C, will represent 20mA. Other temperature reading will depend on that range. Then, 2793 Decade Resistance Box (Figure 3.4) is use in order to get current, we need to use resistor to filter the voltage. Voltage Power Supply uses to supply the 24V and ammeter is for user to get the reading of the current. In the experiment, two RTD are use because the first RTD act as temperature reference. The need for using two RTD (Figure 3.5) is to ensure the temperature we get from experiment is almost the same with temperature reference. That the way we can prove that our experiment is successfully to get the correct data, in this case correct temperature reading. In the experiment, Yokogawa Manometer MT220 (Figure 3.6) replaces the function of power supply by supplying 24V and also ammeter.

**Figure 3.2:** HART 375 Field Communicator


**Figure 3.3:** Yokogawa Temperature Transmitter, PT100


**Figure 3.4:** 2793 Decade Resistance Box

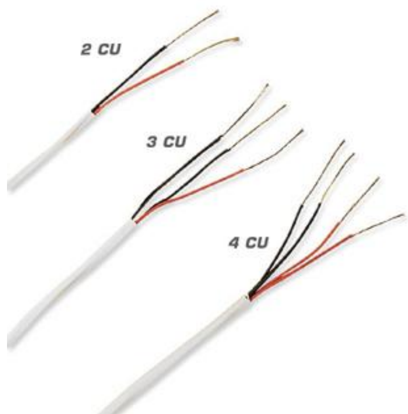


**Figure 3.5:** RTD with two, three and four wires


**Figure 3.6:** Yokogawa Digital Manometer MT220

Refer Appendix A for full specification of each instrument.

In order to get reading from DAQ card, need to place DAQ card into instruments. The connection to instruments (figure 3.7)

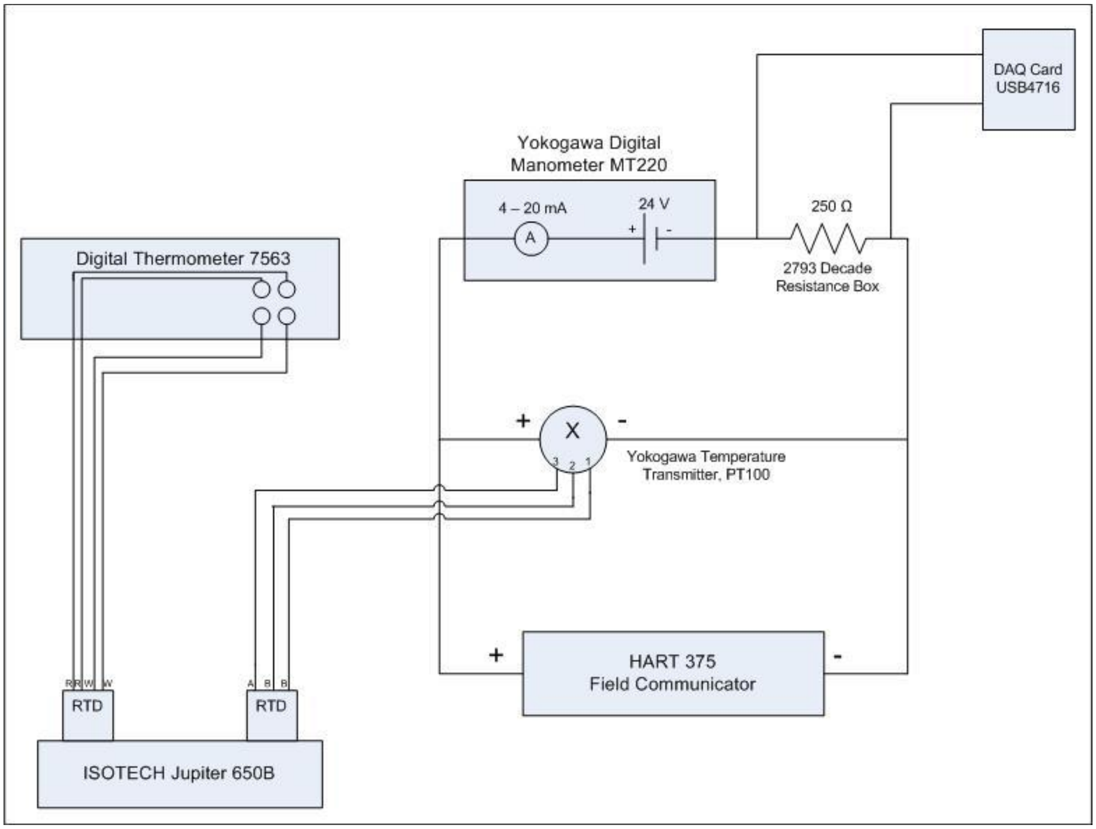


**Figure 3.7:** Block diagram for instruments with DAQ card

DAQ card are place parallel with load 250 ohm, so we can get the DAQ reading in voltage form.

## 3.3 Software

The development of the system will use Visual Basic 2008 Professional Edition. RTD's-Temp is window-based applications which can be operating in any personal computer. The advantages of using Visual Studio are easy to understand the program structure and well-documented. “Microsoft Visual Studio is the main Integrated Development Environment (IDE) from Microsoft. It can be used to develop console and Graphical user interface applications along with Windows Forms applications, web sites, web applications, and web services in both native code as well as managed code for all platforms supported by Microsoft Windows, Windows Mobile, .NET Framework, .NET Compact Framework and Microsoft Silverlight. Visual Studio includes a code editor supporting IntelliSense as well as code refactoring. The integrated debugger works both as a source-level debugger and a machine-level debugger. Visual Basic was derived from BASIC and enables the rapid application development (RAD) of graphical user interface (GUI) applications, access to databases using DAO, RDO, or ADO, and creation of ActiveX controls and objects. Scripting languages such as VBA and VBScript are syntactically similar to Visual Basic, but perform differently. 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 complex applications as well. “[4]

A few components of Microsoft Visual Basic such as SQL Server, Report Viewer, and non-microsoft component like Zedgraph that are implemented in this project has greatly improved the function of software. The other reference software is Microsoft Studio Network (MSDN) Library Visual Studio. The MSDN library is an essential recourse for developers using Microsoft tools, products and technologies. It contains a lot of technical programming information, including sample code, documentation, technical articles and reference guide.

**Figure 3.8:** Logo Microsoft Visual Studio

### 3.3.1. Control Components

Microsoft Visual Basic 2008 provides many controls to be used by programmer for various purposes. There are also many company and individual who create their own ActiveX control to enrich the Visual Basic 2008 capabilities.

There are components used in this project:

(i) SQL Server 2008
(ii) Zedgraph
(iii) Microsoft Report Viewer
(iv) Advantech ActiveDAQ Pro

#### 3.3.1.1 SQL Server 2008

SQL Server 2008 enables data to be consumed from custom applications developed using Microsoft .NET and Visual Studio. SQL Server 2008 delivers on Microsoft's Data Platform vision by helping manage data and store that data such as text and image directly to the database. SQL Server 2008 delivers a rich set of integrated services that enable you to do more with your data such as query, search, synchronize, report, and analyze.

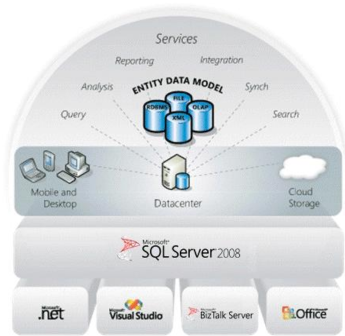


**Figure 3.9:** Microsoft Data Platform Vision

Using the *SELECT* statement

SELECT Username FROM Students2 WHERE Username = "' & Username & " ' AND ID ="' & ID & " '

To select the specific column in database named = Students2 where Username and ID is key-in by user. Afer that, the selected column will be selected and storing data will continue.

Using the *UPDATE* statement

UPDATE Students2 SET AutoDataDAQ1 = "' & AutoDataDAQ1 & "WHERE Username = "' & Username & "'"

To select the specific column in database named = Students2 where Username is key-in by user. Afer that, the selected column will be selected and storing data will contine in selected column to update data in that column.

#### 3.3.1.2 Zedgraph

"ZedGraph is a set of classes, written in C#, for creating 2D line and bar graphs of arbitrary datasets. The classes provide a high degree of flexibility -- almost every aspect of the graph can be user-modified. At the same time, usage of the classes is kept simple by providing default values for all of the graph attributes. The classes include code for choosing appropriate scale ranges and step sizes based on the range of data values being plotted. ZedGraph also includes a User Control interface, allowing drag and drop editing within the Visual Studio forms editor, plus access from other languages such as C++ and VB." [5]

#### 3.3.1.3 Microsoft Report Viewer

The Report Viewer control offers the following features:

(i) Adds visual appeal. You can specify fonts, colors, border styles, background images to make report visually appealing.
(ii) Enables interactivity in reports.
(iii) Supports conditional formatting and embed expressions in the report to change display style dynamically based on data values.
(iv) Supports printing and print preview.
(v) Supports export to Excel and PDF.

#### 3.3.1.4 Advantech ActiveDAQ Pro

ActiveDAQ Pro is a collection of ActiveX controls for performing I/O operations within any compatible ActiveX control container. Easily perform the I/O operations through properties, events and methods. Specific information about the properties, methods, and events of the individual ActiveX controls can be found in manual. ActiveX used is Advantech ActiveDAQ Pro AI Control which its function to retrieve data from ADVANTECH AI device.

To initialize connection between Advantech DAQ card and instruments, use the following coding:

*AdvAI1.SelectDevice*

AdvAI1 is a name for Advantech ActiveDAQ Pro AI Control where “SelectDevice” command to display dialog to select an AI device

### 3.3.2 Program flow

In this section, there are three types of program flow which are program flow for overall system, program flow for RTD’s-Temp operate in automatic mode and program flow for RTD’s-Temp operate in manual mode. For testing purpose, user can fill in data in username and ID field with “test” to start using the system or simply can register with own username. For RTD’s-Temp to operate in automatic mode, user needs to install first Advantech Device Manager, otherwise there is no demo device or actual DAQ card can be used.

### 3.3.2.1 Program Flow of the overall system

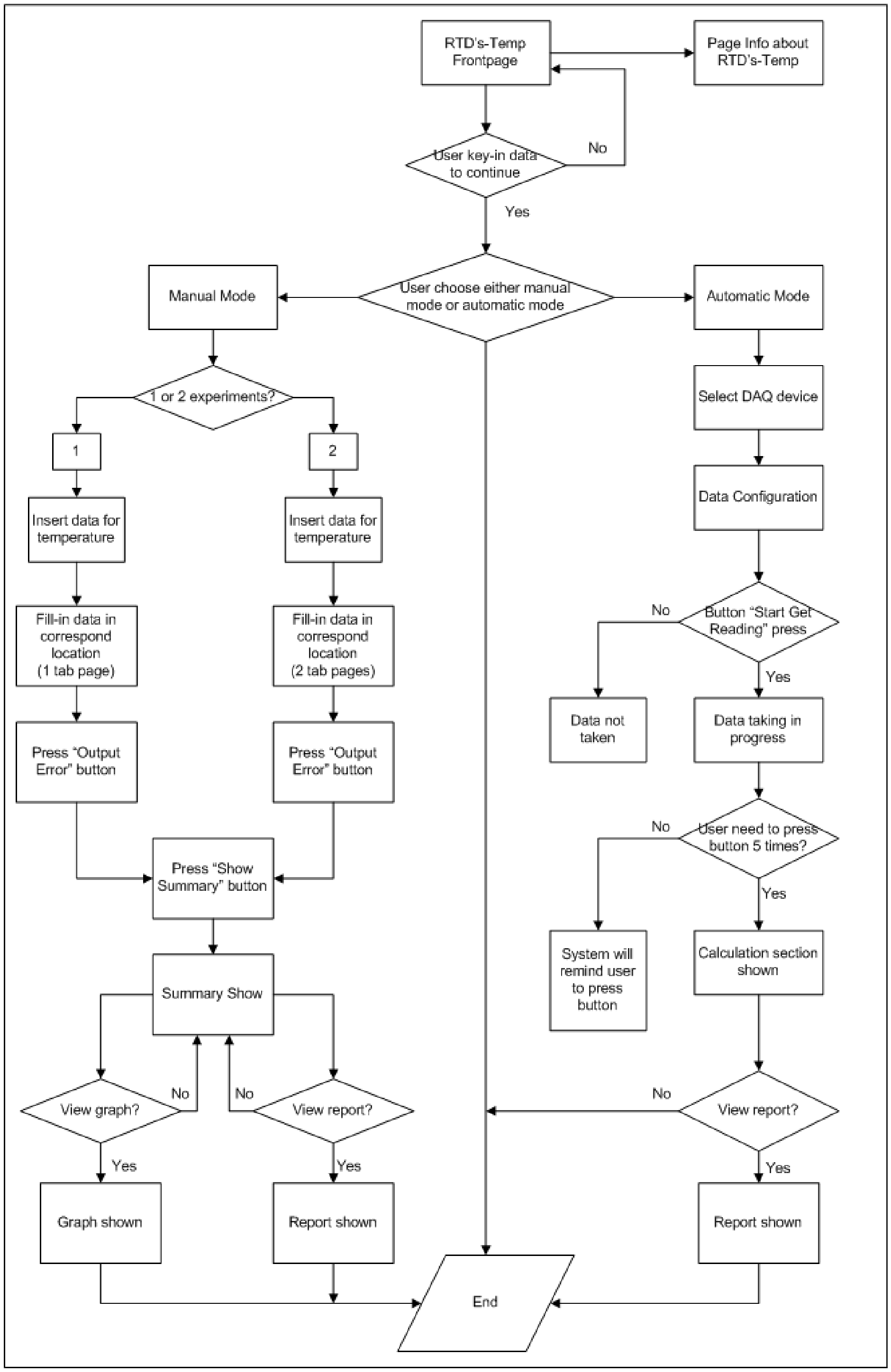


**Figure 3.10:** Overall Program Flow for RTD's-Temp

### 3.3.2.2 Program flow for RTD's-Temp operate in automatic mode

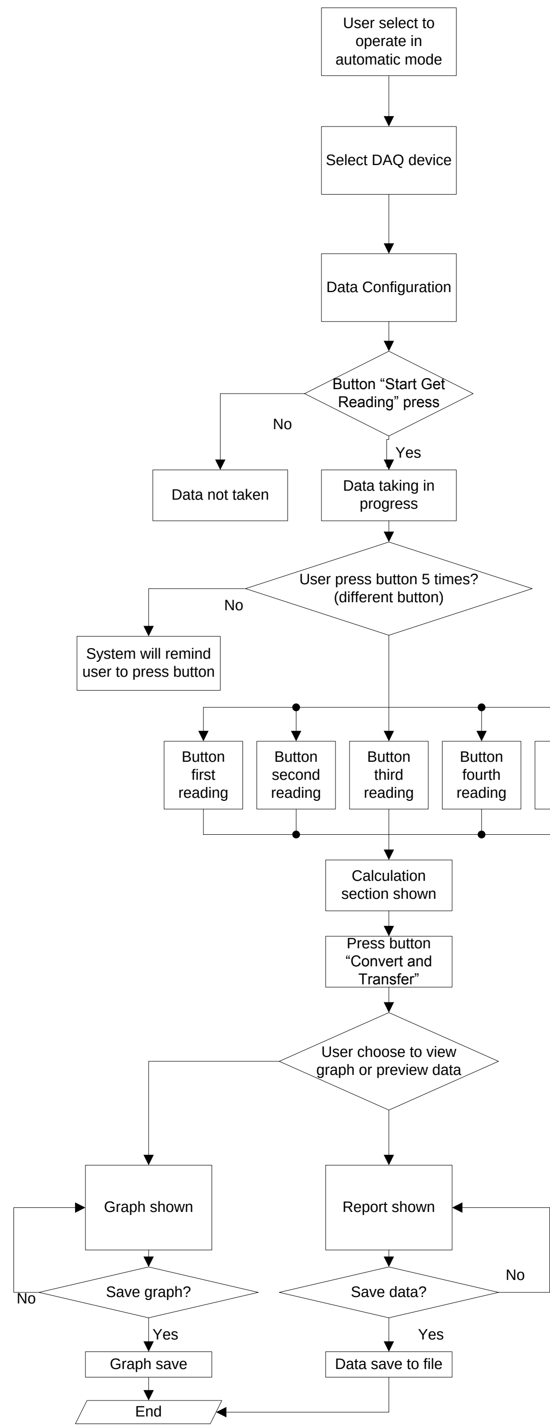


**Figure 3.11:** Program Flow for RTD's-Temp operate in automatic mode

### 3.3.2.3 Program flow for RTD's-Temp operate in manual mode

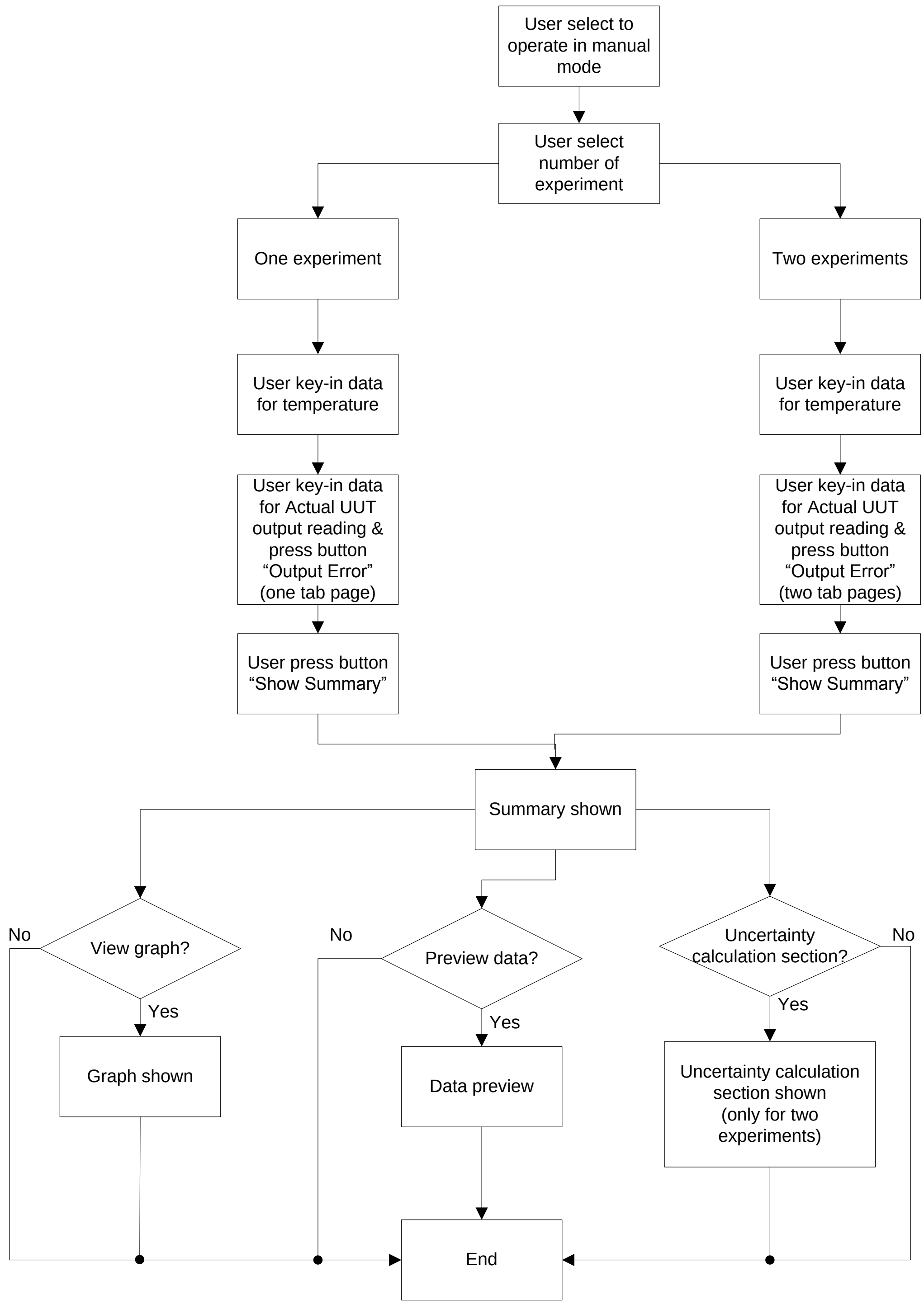


**Figure 3.12:** Program Flow for RTD's-Temp operate in manual mode

## 3.3 Hardware

RTD's-Temp use DAQ card, manufactured by Advantech to connect to the software made in visual basic. The model is USB-4716. It offers 16SE/8Diff. Inputs with 16-bit resolution, up to 200 kS/s throughput, 16 digital I/O lines and one user counter, and 16-bit analog outputs.


**Figure 3.13:** Advantech's DAQ card model USB-4716

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 3.14) although there is variation from manufacturer to manufacturer, demonstrate the essential features of it. [6]

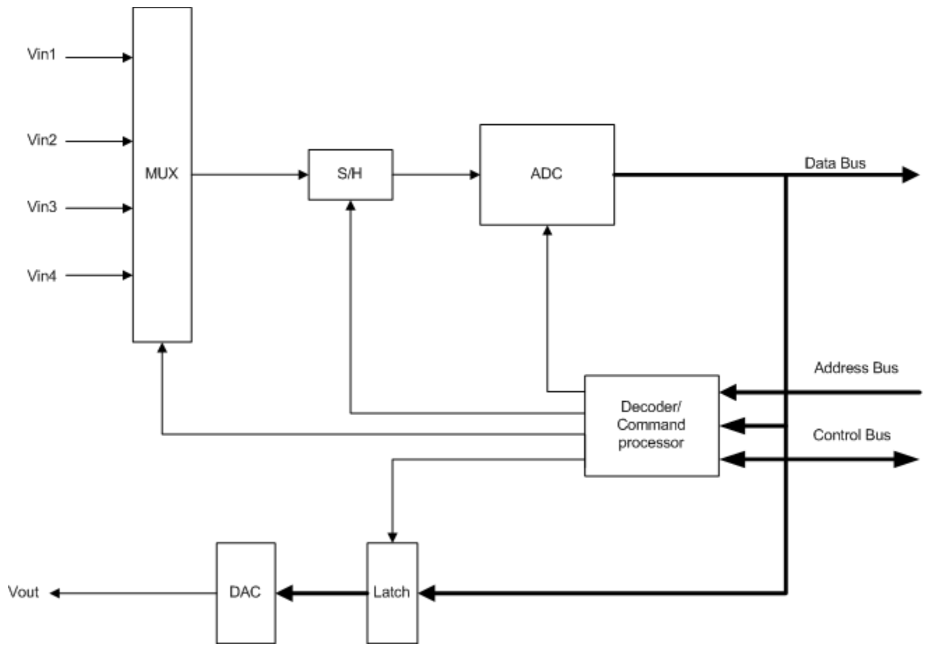


**Figure 3.14:** Typical layout of a data-acquisition board

### 3.4.1 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.

### 3.4.2 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 3.15), arranged in such a faction 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.

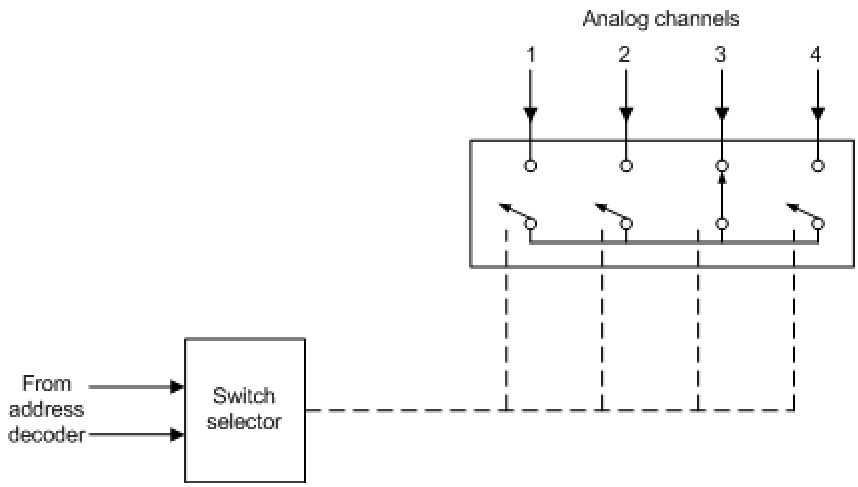


**Figure 3.15:** An analog multiplexer acts as a multiposition switch for selecting inputs to the ADC

### 3.4.3 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.

### 3.4.4 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 consists of the result and discussion about temperature measurement using RTD in Visual Basic application. All the calculations related are below.

## 4.2 Manual Mode for RTD’s-Temp

For manual mode using RTD's-Temp, all the calculation related is shown below. To get the desire output for 4 - 20mA range is calculated based on the 50°C - 200°C range using below equation:

$$\textbf{Desired output} = \frac{x}{100}(URV - LRV) + LRV$$

**Figure 4.1:** Formula to find desired output

Where: $x = i^{th}$ point

URV = Upper range value

LRV = Lower range value

Result:

**Table 4.1:** Result for one experiment

| No % | MSU applied value, °C | Desired UUT output, mA | Actual UUT output, mA | Output error, % |
|---|---|---|---|---|
| 0 | 50.0 | 4 | 3.8 | -5.26316 |
| 25 | 87.5 | 8 | 7.9 | -1.26582 |
| 50 | 125.0 | 12 | 12.0 | 0 |
| 75 | 162.5 | 16 | 15.9 | -0.62893 |
| 100 | 200.0 | 20 | 20.0 | 0 |

After calculation Table 4.1, there are two types of graph we can get. The first one is "Five Point Calibration of Temperature Transmitter for experiment number one" (Figure 4.3) and the second one is "Error Curve for Temperature Transmitter for experiment number one" (Figure 4.4).

To find calculation error, use the following formula:

$$\boldsymbol{output\ error}, \% = \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$$

**Figure 4.2:** Formula to find output error

**Table 4.2:** Calculation to find output error for experiment number one

| Reading of UUT | Output Error |
|---|---|
| 50 | $= \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$ <br> $= \frac{(\boldsymbol{3.8 - 4})}{\boldsymbol{3.8}}\ \boldsymbol{X\ 100}$ <br> $= \boldsymbol{-5.26316}$ |
| 87.5 | $= \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$ <br> $= \frac{(\boldsymbol{7.9 - 8})}{\boldsymbol{7.9}}\ \boldsymbol{X\ 100}$ <br> $= \boldsymbol{-1.26582}$ |
| 125.0 | $= \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$ <br> $= \frac{(\boldsymbol{12.0 - 12.0})}{\boldsymbol{12.0}}\ \boldsymbol{X\ 100}$ <br> $= \boldsymbol{0}$ |
| 162.5 | $= \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$ <br> $= \frac{(\boldsymbol{15.9 - 16})}{\boldsymbol{15.9}}\ \boldsymbol{X\ 100}$ <br> $= \boldsymbol{-0.62893}$ |
| 200 | $= \frac{(\boldsymbol{actual\ UUT\ output - desired\ UUT\ output})}{\boldsymbol{actual\ UUT\ output}}\ \boldsymbol{X\ 100}$ <br> $= \frac{(\boldsymbol{20.0 - 20.0})}{\boldsymbol{20.0}}\ \boldsymbol{X\ 100}$ <br> $= \boldsymbol{0}$ |

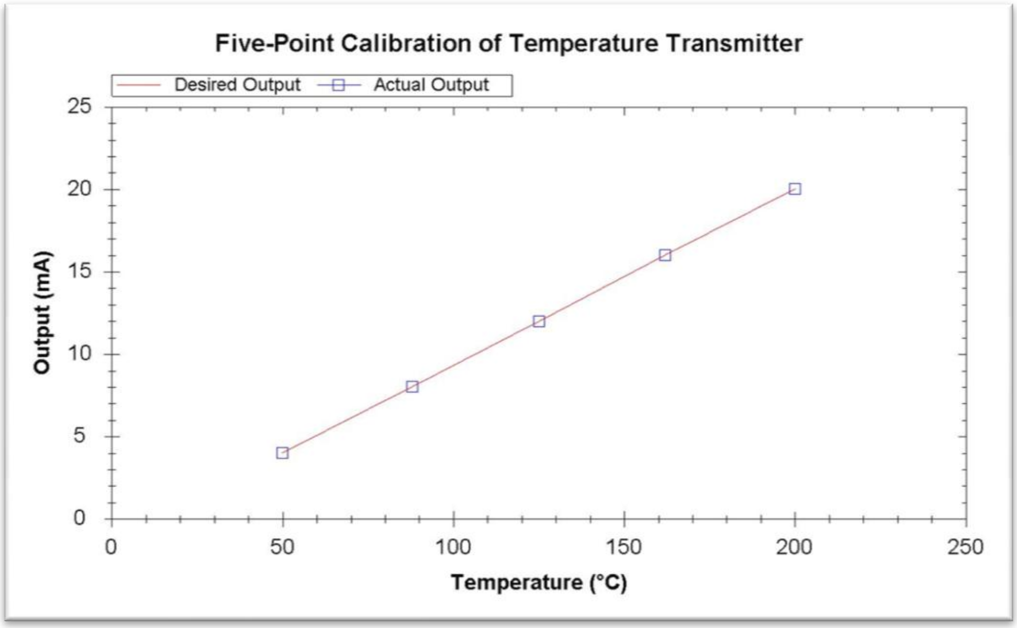


**Figure 4.3:** Graph for "Five Point Calibration of Temperature Transmitter" for experiment number one

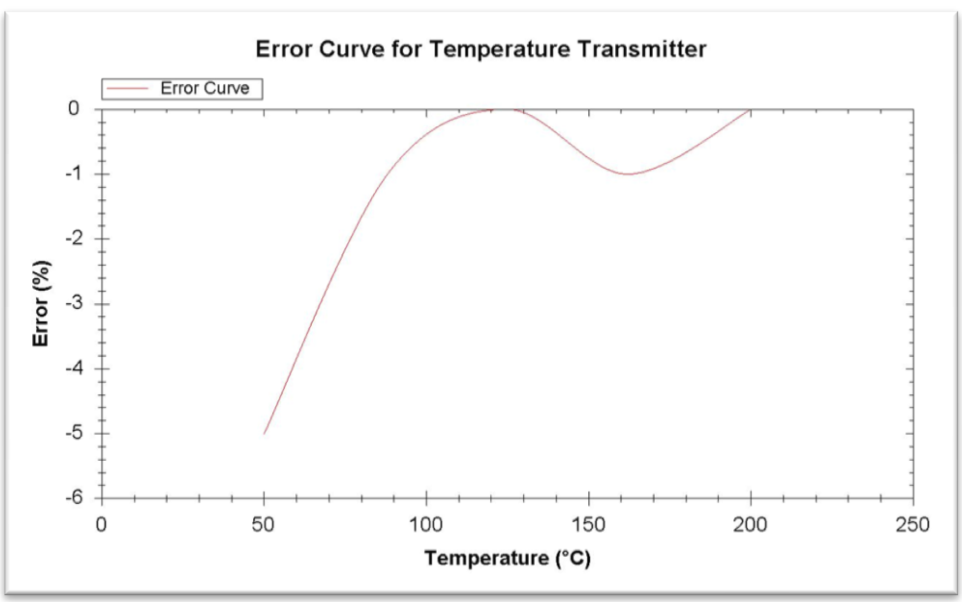


**Figure 4.4:** Graph for "Error Curve for Temperature Transmitter" for experiment number one

If user choose with two experiments, there are need to find average value of actual UUT output and standard deviation.

Result:

**Table 4.3:** Result for two experiments with average and standard deviation values

| No % | MSU applied value, °C | Desired UUT output, mA | Actual UUT output, mA | Output error, % | Second actual UUT output, mA | Average | Standard deviation |
|---|---|---|---|---|---|---|---|
| 0 | 50.0 | 4 | 3.8 | -5.26316 | 3.9 | 3.85 | 0.005 |
| 25 | 87.5 | 8 | 7.9 | -1.26582 | 8 | 7.95 | 0.005 |
| 50 | 125.0 | 12 | 12 | 0 | 11.9 | 11.95 | 0.005 |
| 75 | 162.5 | 16 | 15.9 | -0.62893 | 15.9 | 15.9 | 0 |
| 100 | 200.0 | 20 | 20 | 0 | 20 | 20 | 0 |

After calculation Table 4.3, there are four types of graph we can get. The first and second one can refer figure 4.2 and figure 4.3. The third one is “Five Point Calibration of Temperature Transmitter for experiment number two” (Figure 4.7) and the last one is “Error Curve for Temperature Transmitter for experiment number two” (Figure 4.8).

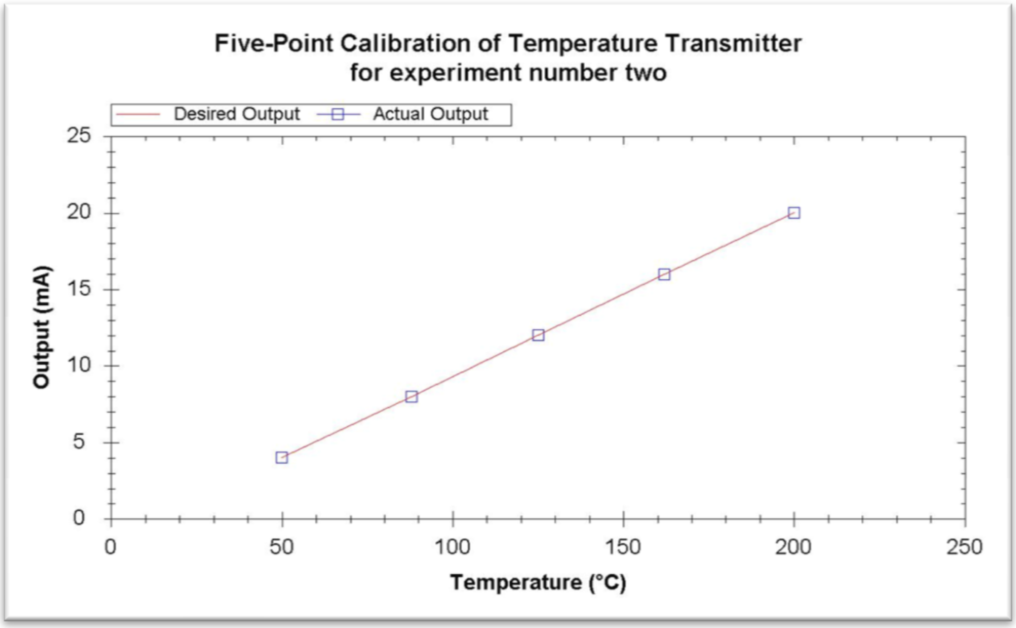


**Figure 4.5:** Graph for "Five Point Calibration of Temperature Transmitter" for experiment number two

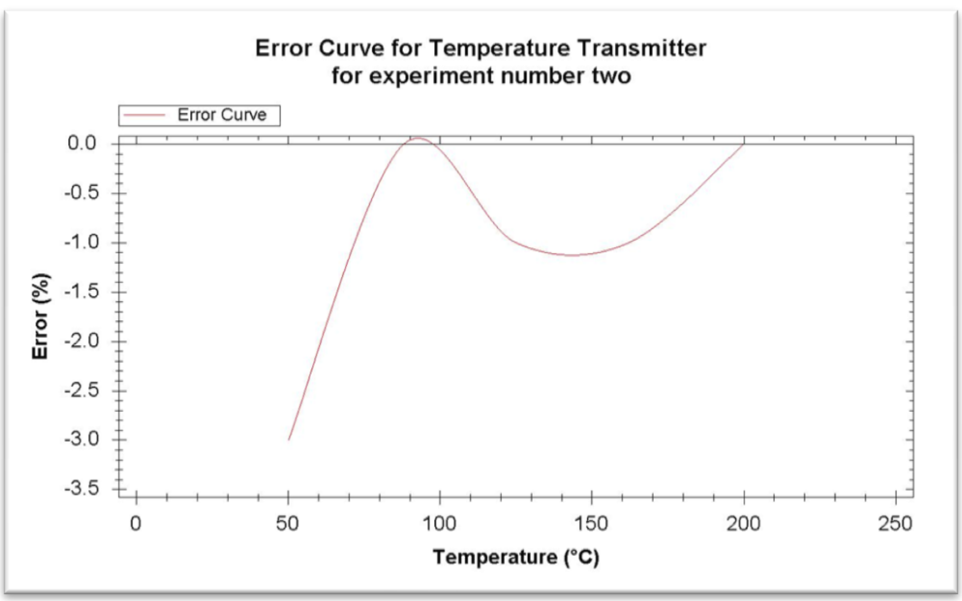


**Figure 4.6:** Graph for "Error Curve for Temperature Transmitter" for experiment number two

**Table 4.4:** Calculation to find average

| Reading of UUT | Average |
|---|---|
| 50 | $= \frac{(\boldsymbol{actual\ UUT\ output} + \boldsymbol{second\ actual\ UUT\ output})}{\mathbf{2}}$ <br> $= \frac{(\mathbf{3.8} + \mathbf{3.9})}{\mathbf{2}}$ <br> $= \mathbf{3.85}$ |
| 87.5 | $= \frac{(\boldsymbol{actual\ UUT\ output} + \boldsymbol{second\ actual\ UUT\ output})}{\mathbf{2}}$ <br> $= \frac{(\mathbf{7.9} + \mathbf{8.0})}{\mathbf{2}}$ <br> $= \mathbf{7.95}$ |
| 125.0 | $= \frac{(\boldsymbol{actual\ UUT\ output} + \boldsymbol{second\ actual\ UUT\ output})}{\mathbf{2}}$ <br> $= \frac{(\mathbf{12.0} + \mathbf{11.9})}{\mathbf{2}}$ <br> $= \mathbf{11.95}$ |
| 162.5 | $= \frac{(\boldsymbol{actual\ UUT\ output} + \boldsymbol{second\ actual\ UUT\ output})}{\mathbf{2}}$ <br> $= \frac{(\mathbf{15.9} + \mathbf{15.9})}{\mathbf{2}}$ <br> $= \mathbf{15.9}$ |
| 200 | $= \frac{(\boldsymbol{actual\ UUT\ output} + \boldsymbol{second\ actual\ UUT\ output})}{\mathbf{2}}$ <br> $= \frac{(\mathbf{20.0} + \mathbf{20.0})}{\mathbf{2}}$ <br> $= \mathbf{20.0}$ |

## 4.3 Uncertainty Calculation

### 4.3.1 Uncertainty Due To Repeatability of the Experiment

To find standard deviation value, use the following equation:

$$s(x_k) = \sqrt{\frac{1}{(n-1)}\sum_{j=1}^{k}(x_k - \bar{x})^2}$$

**Figure 4.7:** Formula to find standard deviation

**Table 4.5:** Calculation of standard deviation

| Reading of UUT | Standard Deviation |
|---|---|
| 50 | $s(x_2) = \sqrt{\frac{1}{(2-1)}\sum_{j=1}^{2}(x_2 - \bar{x})^2}$ <br> $= \left(\sqrt{\frac{1}{(2-1)}}\right)\left((x_1 - \bar{x})^2 + (x_2 - \bar{x})^2\right)$ <br> $= \left(\sqrt{\frac{1}{(2-1)}}\right)\left((3.8 - 3.85)^2 + (3.9 - 3.85)^2\right)$ <br> $= 0.005$ |
| 87.5 | $s(x_2) = \sqrt{\frac{1}{(2-1)}\sum_{j=1}^{2}(x_2 - \bar{x})^2}$ <br> $= \left(\sqrt{\frac{1}{(2-1)}}\right)\left((x_1 - \bar{x})^2 + (x_2 - \bar{x})^2\right)$ <br> $= \left(\sqrt{\frac{1}{(2-1)}}\right)\left((7.9 - 7.95)^2 + (8 - 7.95)^2\right)$ <br> $= 0.005$ |

| | |
|---|---|
| 125.0 | $s(x_2)=\sqrt{\frac{1}{(2-1)}\sum_{j=1}^{2}(x_2-\bar{x})^2}$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((x_1-\bar{x})^2+(x_2-\bar{x})^2\right)$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((12-11.95)^2+(11.9-11.95)^2\right)$ <br> $=0.005$ |
| 162.5 | $s(x_2)=\sqrt{\frac{1}{(2-1)}\sum_{j=1}^{2}(x_2-\bar{x})^2}$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((x_1-\bar{x})^2+(x_2-\bar{x})^2\right)$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((15.9-15.9)^2+(15.9-15.9)^2\right)$ <br> $=0$ |
| 200 | $s(x_2)=\sqrt{\frac{1}{(2-1)}\sum_{j=1}^{2}(x_2-\bar{x})^2}$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((x_1-\bar{x})^2+(x_2-\bar{x})^2\right)$ <br> $=\left(\sqrt{\frac{1}{(2-1)}}\right)\left((20-20)^2+(20-20)^2\right)$ <br> $=0$ |

The worst case standard deviation is 0.005. To find the value of uncertainty, we should look for experimental standard deviation of the mean s(x). s(x) is the estimation of the spread of the distribution of the mean. By using figure 4.8, we should get the value.

$$\boldsymbol{s(x)=\frac{s(x_k)}{\sqrt{2}}}$$

**Figure 4.8:** Formula to find experimental standard deviation of the mean

$$\boldsymbol{s(x)=\frac{s(x_k)}{\sqrt{2}}=\frac{0.005}{\sqrt{2}}=0.0035355}$$

We shall call this uncertainty as $u_1$ = 0.0028868 with degree of freedom $\gamma_1$ = 1

#### 4.3.2 Uncertainty Contribution Due To MSU Error

Range of the accuracy specification for this instrument provided by the manufacturer is the following:

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

**Figure 4.9:** Accuracy specification provided by manufacturer

For a maximum reading of 200V and a range of 700V, hence the error in MSU, a

$$= \pm((0.0001 \times 200) + (0.00005 \times 700))$$

$$\equiv 0.055$$

To find uncertainty contribution due to MSU error, $u_2$, as below:

$$u_2 = a/\sqrt{2}$$

$$= 0.055/\sqrt{2}$$

$$= 0.0388909$$

The degree of freedom $\gamma_2$ for this uncertainty is assumed to be $\infty$ since the manufacturer is expected to provide the error data after a large number of tests.

Therefore,

$$u_2 = 0.0388909$$

$$\gamma_2 = \infty$$

### 4.3.3 Uncertainty Due To UUT Resolution/MSU Resolution

The resolution of the UUT model UR1000 Universal Recorder = 0.1

$u_3$ = The resolution of the UUT model UR1000 Universal Recorder / √2

= 0.1 / √2

= 0.0707107

We can consider the degree of freedom as $\infty$

Therefore,

$u_3$ = 0.0707107

$\gamma_3 = \infty$

### 4.3.4 Combined Standard Uncertainty

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

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

**Figure 4.10**: Combined standard uncertainty

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

$$= \sqrt{(0.0035355^2) + (0.0388909^2) + (0.0707107^2)}$$

$$= 0.0807775$$

The effective degrees of freedom $v_e$ is given by,

$$v_e = \frac{\mu_c^4}{\left(\frac{u_1^4}{v_1}\right)}$$

Figure 4.11: Formula to find effective degrees of freedom

$$v_e = \frac{\mu_c^4}{\left(\frac{u_1^4}{v_1}\right)}$$

$$= \frac{0.0472581^4}{\left(\frac{0.005^4}{1}\right)}$$

= 7980.41

Since we get large value of $v_e$, we should refer T-Distribution Table (Appendix D) to proceed and choose value from there.

The total uncertainty at any confidence level is determined using the Student's t distribution. The coverage factor k is determined from student table.

Referring to Appendix D for a value of v = 7980 and 95.45% confidence interval k = 2.025

The confidence limit is obtained by the formula:

$U = u_c k = (0.0807775)(2.000)$

$= (0.0807775)(2.000)$

$= \pm\ 0.161555$

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

**Table 4.6:** Summary of all uncertainty values and degree of freedom

| Type of Uncertainty | Symbol | Degree of freedom $(\gamma)$ | Uncertainty Value |
|---|---|---|---|
| Uncertainty Due To Repeatability of the Experiment | $u_1$ | 1 | 0.0035355 |
| Uncertainty Contribution Due To MSU Error | $u_2$ | $\infty$ | 0.0388909 |
| Uncertainty Due To UUT Resolution/MSU Resolution | $u_3$ | $\infty$ | 0.0707107 |
| Combined Standard Uncertainty | $u_c$ | $v_e =$ 272494.8291635 | ± 0.161555 |

## 4.4 Automatic Mode for RTD's-Temp

The calculations for automatic mode are typically the same with manual mode but there is some limitation such as there is no section for uncertainty calculation since to do uncertainty calculation, we need two or more reading. For automatic mode using RTD's-Temp, all the calculation related is shown below. To get the desire output for 4 - 20mA range is calculated based on the 50°C - 200°C range using figure 4.1.

Result:

**Table 4.7:** Result for Desired UUT output and MSU applied value

| No % | MSU applied value, °C | Desired UUT output, mA |
|---|---|---|
| 0 | 50.0 | 4 |
| 25 | 87.5 | 8 |
| 50 | 125.0 | 12 |
| 75 | 162.5 | 16 |
| 100 | 200.0 | 20 |

We develop linear equation between temperature and current. We can define the equation (figure 4.12).

$$I = mT + I_o$$

**Figure 4.12**: Formula for linear equation

Where T = temperature, I = current

From figure 4.12, we have two equations in two unknown:

$$Eqn. 1 : 4\ mA = (50°\text{C})m + I_o$$

$$Eqn. 2 : 20\ mA = (200°\text{C})m + I_o$$

Eqn. 1 – Eqn. 2:

$$16\ mA = (150°\text{C})m$$

We need to find value of m:

$$m = 1.06667\ x\ 10^{-4}$$

We insert m in Eqn. 1:

$$I_o = -1.33335\ x\ 10^{-3}$$

From Eqn. 1:

$$I = T(1.06667\ x\ 10^{-4}) - 1.33335\ x\ 10^{-3}$$

From figure 4.13, DAQ card is placed parallel with load of 250 ohm.

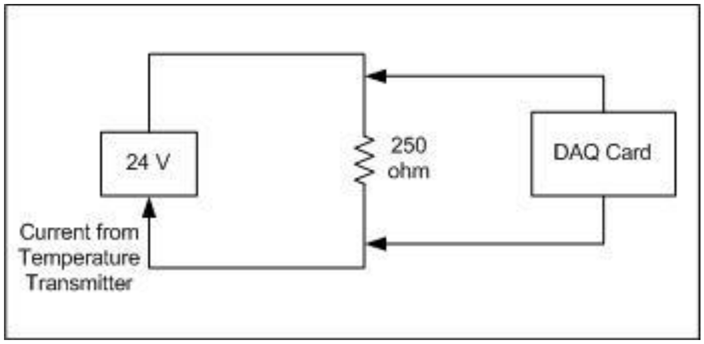


**Figure 4.13:** DAQ card connected parallel to load

**Table 4.8:** Result for data from DAQ card

| Current from temperature transmitter, mA | DAQ card reading, V |
|---|---|
| 4.01024 | 4.01024 x 250 = 1.00256 |
| 8.0026 | 8.0026 x 250 = 2.00065 |
| 11.95044 | 11.95044 x 250 = 2.98761 |
| 16.40392 | 16.40392 x 250 = 4.10098 |
| 19.58636 | 19.58636 x 250 = 4.89659 |

After five times user clicks the necessary button to capture data from DAQ to RTD's-Temp, the results are below.

Result:

**Table 4.9:** Result for data from DAQ card

| Reading | Data from DAQ, V | Actual UUT output, mA |
|---|---|---|

| | | |
|---|---|---|
| 1 | 1.00256 | 4.01024 |
| 2 | 2.00065 | 8.0026 |
| 3 | 2.98761 | 11.95044 |
| 4 | 4.10098 | 16.40392 |
| 5 | 4.89659 | 19.58636 |

**Table 4.10:** Calculation to find output error for automatic mode

| Reading of UUT | Output Error |
|---|---|
| 50 | $= \frac{(actual\ UUT\ output - desired\ UUT\ output)}{actual\ UUT\ output}\ X\ 100$ <br> $= \frac{(4.01024 - 4)}{4.01024}\ X\ 100$ <br> $= 0.25535$ |
| 87.5 | $= \frac{(actual\ UUT\ output - desired\ UUT\ output)}{actual\ UUT\ output}\ X\ 100$ <br> $= \frac{(8.0026 - 8)}{8.0026}\ X\ 100$ <br> $= 0.03249$ |
| 125.0 | $= \frac{(actual\ UUT\ output - desired\ UUT\ output)}{actual\ UUT\ output}\ X\ 100$ <br> $= \frac{(11.95044 - 12.0)}{11.95044}\ X\ 100$ <br> $= -0.41471$ |
| 162.5 | $= \frac{(actual\ UUT\ output - desired\ UUT\ output)}{actual\ UUT\ output}\ X\ 100$ <br> $= \frac{(16.40392 - 16)}{16.40392}\ X\ 100$ <br> $= 2.46234$ |
| 200 | $= \frac{(actual\ UUT\ output - desired\ UUT\ output)}{actual\ UUT\ output}\ X\ 100$ <br> $= \frac{(19.58636 - 20.0)}{19.58636}\ X\ 100$ <br> $= -2.11188$ |

Result:

**Table 4.11:** Summary for automatic mode in RTD's-Temp

| No % | MSU applied value, °C | Desired UUT output, mA | Actual UUT output, mA | Output error, % |
|---|---|---|---|---|
| 0 | 50.0 | 4 | 4.01024 | 0.25535 |
| 25 | 87.5 | 8 | 8.0026 | 0.03249 |
| 50 | 125.0 | 12 | 12.09424 | -0.41471 |
| 75 | 162.5 | 16 | 16.40392 | 2.46234 |
| 100 | 200.0 | 20 | 19.58636 | -2.11188 |

There are two types of graph can be produce from this experiment which is Five Point Calibration of Temperature Transmitter and Error Curve of Temperature Transmitter

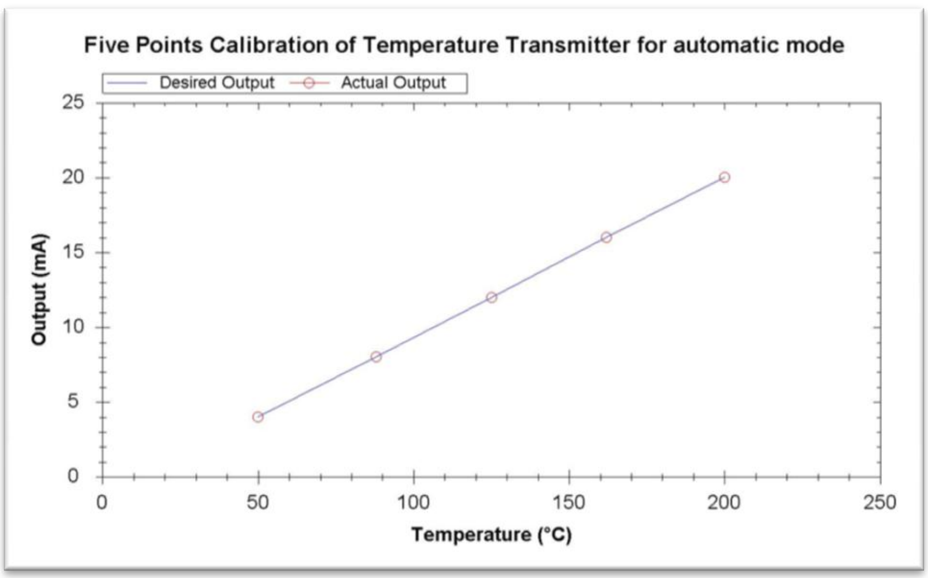


**Figure 4.14:** Graph for "Five Point Calibration of Temperature Transmitter for automatic mode"

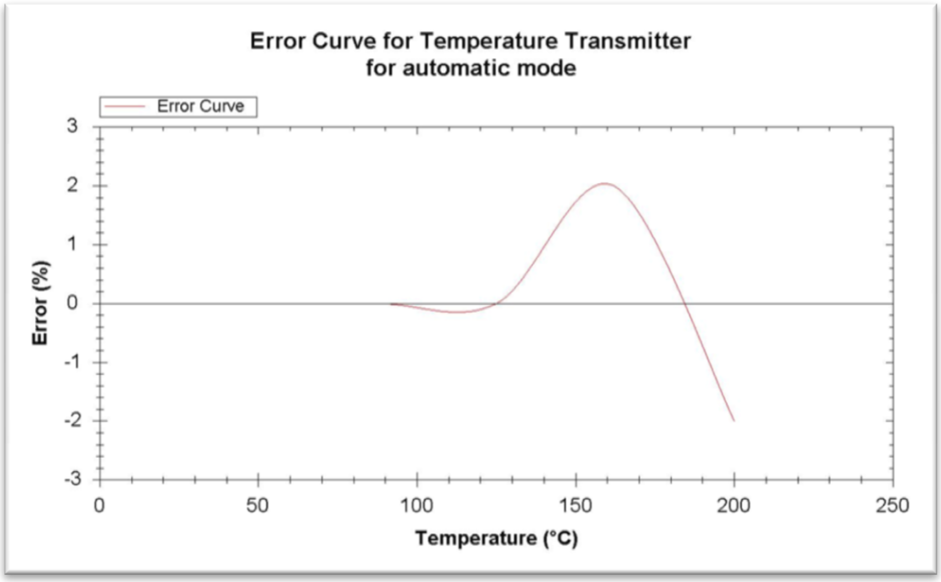


**Figure 4.15:** Graph for “Error Curve for Temperature Transmitter for automatic mode”

## 4.5 Result of entire program

There are two ways to operate RTD’s-Temp. First one is by manual mode and second one is by automatic mode. The reason by having both of them is because sometime user does the experiment by automatic mode. In order to get to uncertainty calculation, user needs two or more reading to proceed. By having this manual mode, user can do the experiment, maybe two times under same the condition. After get two or more reading, user can proceed with uncertainty calculation section. Data from the calculation is automatically saved to the database, and user can get preview of that data then save it to file. But there is some limitation for the data to be displayed in the report. After finish using RTD’s-Temp, in order to get report for the latest data recorded to the database, user need to close RTD’s-Temp and then open it again. After that, all the latest data can be view.

# CHAPTER 5

# CONCLUSION AND FUTURE DEVELOPMENT

## 1.1 Introduction

This thesis has discussed on development of RTD’s-Temp. This project is implemented using resistance temperature detector (RTD) and interface between the hardware and instruments through universal serial bus (USB) port with a development program using Microsoft Visual Basic 2008.

This project has been able to achieve its objectives. RTD’s-Temp is produced. This chapter will discuss about the problem faced during development of this project. Then, conclusion will be made. Lastly, planning for future work will be discussed.

## 1.2 Problem And Solution

Some of the problem encountered during development of the system:

(i) Difficult to interface between RTD's-Temp and instrument using DAQ card
- Solution

  Refer guideline given by manufacturer

(ii) Reading from instrument easily disturbed in slight movement
- Solution:

  Properly place the instruments and try to avoid making movement to the wires connected to instruments

(iii) Some of the instrument are not in good condition
- Solution:

  Need to do calibration process in order to make sure the data is valid

(iv) Data from DAQ card are not the same with data in RTD's-Temp
- Solution:

  Make sure time samplings in both DAQ card and software are the same

(v) Reading data not accurate
- Solution:

  In RTD's-Temp, most of the calculations are using five decimal places

(vi) To verify the temperature reading
- Solution:

  Get reference temperature by connecting RTD directly to Digital Thermometer form heater (ISOTECH Jupiter)

## 1.3 Conclusion

The development of RTD’s-Temp with RTD has been presented in this project. This project achieved all the objectives and the results of the output are similar to the one stated in reference studied. RTD’s-Temp can be use in laboratory session for temperature measurement for Industrial Instrumentation (BEE4523) subject. Data for temperature measurement laboratory session can be obtained by connecting DAQ card with instrument but user still need to carefully connect the instrument in order to get reasonable result.

## 1.4 Future Recommendation

Even though this project is successful, however there are some enhancements can be applied to the system. These suggested steps can be implemented to improve performance of the system. Below are some suggestions for the future development:

(i) RTD’s-Temp can be operated in other types of temperature reading such as Kelvin and Fahrenheit, so that the system can handle more than one type of temperature reading.

(ii) RTD’s-Temp can be used for other type of temperature sensor such as thermocouple. This addition can make this system compatible when using with other type of temperature sensor.

(iii) Produce more users friendly GUI, so user does not face difficulties when handling the system and yet user can still refers to user manual if he faces any problem.

(iv) More feature available for RTD’s-Temp such as save and load options, user can retrieve data from internet, and complete report for the experiment. This addition has been suggested since there is no time to make that feature possible.

### 1.4.1 Costing and Commercialization

RTD’s-Temp has been produced with no cost at all since this is educational purpose project where the instrument and hardware are available at university’s laboratory. For Microsoft Visual Basic 2008 Express Edition software, the software is available and can be downloaded as express edition at www.microsoft.com/express/**vb**/

RTD’s-Temp can be commercialized among other educational institution in Malaysia like universities and polytechnic if there is laboratory session for temperature measurement using RTD, with using the same types of instrument and hardware since the system developed based on that.

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# APPENDIX A

## *DATASHEETS*

***Digital Thermometer 7563***

***Yokogawa Digital Manometer MT220***

***Advantech USB-4716***

***Yokogawa Temperature Transmitter, YTA 110***

***HART 375 Field Communicator***

# Digital Thermometer 7563 – page one (1)

## 7563

### SPECIFICATIONS

#### ■ DC VOLTAGE (DC V)

● **Ranges:**

* 16.7 ms shows 16.66 ....

| | Integrating Time (500/200 ms) | | Integrating Time (100/20/16.7 ms)* | | Integrating Time (2.5 ms) | | Input Resistance | Max. Input |
|---|---|---|---|---|---|---|---|---|
| | Max. Reading | Resolution | Max. Reading | Resolution | Max. Reading | Resolution | | |
| 200 mV | 199.9999 | 100 nV | 199.999 | 1 µV | 199.99 | 10 µV | > 1 GΩ | ±200 V peak between Hi and Lo. ±42 V peak between Lo and guard. ±500 V peak between guard and case. |
| 2,000 mV | 1,999.999 | 1 µV | 1,999.99 | 10 µV | 1,999.9 | 100 µV | | |
| 20 V | 19.99999 | 10 µV | 19.9999 | 100 µV | 19.999 | 1 mV | | |
| 200 V | 199.9999 | 100 µV | 199.999 | 1 mV | 199.99 | 10 mV | 10 MΩ±1% | |

● **Accuracy (Integrating Time 500 ms):** ±(% of reading+digits)

| Range | 24 h, 23±1°C | 90 days, 23±5°C | 1 year, 23±5°C | Temperature Coefficient (/°C*) |
|---|---|---|---|---|
| 200 mV | 0.004+20(3) {4} | 0.006+25(4) {4} | 0.01+25(4) {4} | 0.0007+5(.6) {.2} |
| 2,000 mV | 0.0025+ 8(2) {3} | 0.0045+10(2) {3} | 0.0075+10(2) {3} | 0.00055+1(.2) {.1} |
| 20 V | 0.003+ 8(2) {3} | 0.005+10(2) {3} | 0.009+10(2) {3} | 0.00065+1(.2) {.1} |
| 200 V | 0.0045+10(2) {3} | 0.009+15(2) {3} | 0.016+15(2) {3} | 0.00075+1(.2) {.1} |

* Temperature range: 5 to 18, 28 to 40°C.

- Accuracy at 24 hours, 23±1°C is the value for the calibration standard.
- Auto Zero ON, Null.
- **Integrating time:** At 200 ms, 2 is added to the value (digits) in integrating time 500 ms.
- ( ) indicates the value (digits) in integrating time 100 ms. At 20/16.7 ms, 2 is added to the value (digits) in integrating time of ( ).
- { } indicates the value (digits) integrating time 2.5 ms.
- At Auto Zero OFF, temperature coefficient of ±(0.0015% of range ±25 µV)/°C is added (at 5 to 40°C).
- **Common Mode Rejection:** 120 dB or more. Integrating time: 500/200/100/20/16.7 ms. Rs = 1 kΩ, 50/60 Hz ±0.1% (Rs: signal source resistance.)
- **Normal Mode Rejection:** 60 dB or more. Integrating time: 500/200/100/20/16.7 ms, 50/60 Hz ±0.1%.

#### ■ RESISTANCE (OHM)

● **Ranges:**

| Range | Integrating Time (500/200 ms) | | Integrating Time (100/20/16.7 ms) | | Integrating Time (2.5 ms) | | Current through Unknown |
|---|---|---|---|---|---|---|---|
| | Max. Reading | Resolution | Max. Reading | Resolution | Max. Reading | Resolution | |
| 200 Ω | 199.9999 | 100 µΩ | 199.999 | 1 mΩ | 199.99 | 10 mΩ | 1 mA |
| 2,000 Ω | 1,999.999 | 1 mΩ | 1,999.99 | 10 mΩ | 1,999.9 | 100 mΩ | 1 mA |
| 20 kΩ | 19.99999 | 10 mΩ | 19.9999 | 100 mΩ | 19.999 | 1 Ω | 100 µA |
| 200 kΩ | 199.9999 | 100 mΩ | 199.999 | 1 Ω | 199.99 | 10 Ω | 10 µA |
| 2,000 kΩ | 1,999.999 | 1 Ω | 1,999.99 | 10 Ω | 1999.9 | 100 Ω | 1 µA |
| 20 MΩ | 19.9999 | 100 Ω | 19.9999 | 100 Ω | 19.999 | 1 kΩ | 100 nA |

● **Accuracy (4-wire, Integrating Time 500 ms):** ±(% of reading+digits)

| Range | 24 h, 23±1°C | 90 days, 23±5°C | 1 year, 23±5°C | Temperature Coefficient (/°C*) |
|---|---|---|---|---|
| 200 Ω | 0.004+25(4) {4} | 0.008+30(5) {4} | 0.012+30(6) {4} | 0.001+10(2) {0.5} |
| 2,000 Ω | 0.003+15(3) {3} | 0.006+25(4) {3} | 0.01+25(5) {3} | 0.00075+2(0.5) {0.1} |
| 20 kΩ | 0.003+15(3) {3} | 0.006+25(5) {3} | 0.01+25(5) {3} | 0.00075+2(0.5) {0.1} |
| 200 kΩ | 0.005+20(3) {3} | 0.008+30(5) {3} | 0.012+30(5) {3} | 0.00075+1(0.5) {0.1} |
| 2,000 kΩ | 0.02+135(15) {20} | 0.03+150(20) {30} | 0.05+150(20) {30} | 0.003+2(0.5) {0.1} |
| 20 MΩ | 0.2+30(30) | 0.2+30(30) | 0.02+30(30) | 0.02+1(1) |

* Temperature range: 5 to 18, 28 to 40°C.

- Accuracy at 24 hours, 23±1°C is the value for the calibration standard.
- Auto Zero ON, Null.
- **Integrating Time:** At 200 ms, 2 is added to the value (digits) in integrating time 500ms.
- ( ) indicates the value (digits) in integrating time 100 ms. For integrating time 20/16.7 ms, 2 is added to the value (digits) enclosed in the parentheses.
- { } indicates the value (digits) in integrating time 2.5 ms.
- For 20 MΩ at sampling interval 400 ms or more. Accuracy is not prescribed in integrating time 2.5 ms.
- At Auto Zero OFF, temperature coefficient on 200 Ω range is ±(0.013% of range)°C, on other ranges ±(0.003% of range/°C is added (at 5 to 40°C).
- For 2-wire system, 2 mΩ/°C is added.
- Excluding the influence of leadwires.
- **Open Circuit Voltage:** Max. 10 V.
- **Maximum Input Voltage:** ±200 V peak or 200 V rms (between Hi and Lo).
- **Response Time:** 0.4 s or less on 2,000 kΩ/20 MΩ ranges (to final value).

# Digital Thermometer 7563 – page two (2)

## 7563

### TEMPERATURE (TC)

| Range[*1] | Measurement Range | | Resolution (500/200 ms) | Accuracy[*2] (Inegrating Time 500/200/100/20/16.7 ms): ± (% of rdg + °C) | | | Temperature Coefficient (common to Each Integrating Time) [*5] |
|---|---|---|---|---|---|---|---|
| | | | | 24 hours, 23±1°C [*4] | 90 days, 23±5°C [*4] | 1 year, 23±5°C [*4] | Temperature Coefficient [*4] (% of rdg + °C)/°C |
| R | – 50.0 to 0°C | – 58.0 to 32.0°F | 0.1°C (0.1°F) | 0.005 + 0.5 {0.7} | 0.007 + 0.5 {0.7} | 0.01 + 0.5 {0.7} | 0.001 + 0.07 |
| | 0.0 to 100.0°C | 32.0 to 212.0°F | 0.1°C (0.1°F) | 0.005 + 0.4 {0.5} | 0.007 + 0.4 {0.5} | 0.01 + 0.4 {0.5} | |
| | 100.0 to 600.0°C | 212.0 to 1,112.0°F | 0.1°C (0.1°F) | 0.005 + 0.3 {0.4} | 0.007 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | |
| | 600.0 to 1,760°C | 1,112.0 to 3,200.0°F | 0.1·C (0.1°F) | 0.005 + 0.2 {0.3} | 0.007 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| S | – 50.0 to 0°C | – 58.0 to 32.0°F | 0.1°C (0.1°F) | 0.005 + 0.6 {0.7} | 0.007 + 0.6 {0.7} | 0.01 + 0.6 {0.7} | 0.001 + 0.07 |
| | 0.0 to 100.0°C | 32.0 to 212.0°F | 0.1°C (0.1°F) | 0.005 + 0.4 {0.5} | 0.007 + 0.4 {0.5} | 0.01 + 0.4 {0.5} | |
| | 100.0 to 600.0°C | 212.0 to 1,112.0°F | 0.1°C (0.1°F) | 0.005 + 0.3 {0.4} | 0.007 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | |
| | 600.0 to 1,760.0°C | 1,112.0 to 3,200.0°F | 0.1°C (0.1°F) | 0.005 + 0.2 {0.3} | 0.007 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| B | 0.0 to 42°C | 32.0 to 107.6°F | — | — | — | — | 0.001 + 0.02 |
| | 42.0 to 100.0°C | 107.6 to 212.0°F | 0.1°C (0.1°F) | 0.005 + 7.0 {9.0} | 0.007 + 7.0 {9.0} | 0.01 + 7.0 {9.0} | |
| | 100.0 to 200.0°C | 212.0 to 392.0°F | 0.1°C (0.1°F) | 0.005 + 1.5 {2.0} | 0.007 + 1.5 {2.0} | 0.01 + 1.5 {2.0} | |
| | 200.0 to 300.0°C | 392.0 to 572.0°F | 0.1°C (0.1°F) | 0.005 + 1.0 {1.2} | 0.007 + 1.0 {1.2} | 0.01 + 1.0 {1.2} | |
| | 300.0 to 400.0°C | 572.0 to 752.0°F | 0.1·C (0.1°F) | 0.005 + 0.7 {0.9} | 0.007 + 0.7 {0.9} | 0.01 + 0.7 {0.9} | |
| | 400.0 to 1,820.0°C | 752.0 to 3,308.0°F | 0.1°C (0.1°F) | 0.005 + 0.3 {0.4} | 0.007 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | |
| K | – 270.0 to – 250.0°C | – 454.0 to – 418.0°F | 0.1°C (0.1°F) | 0.004 + 1.3 {2.5} | 0.006 + 1.3 {2.5} | 0.01 + 1.3 {2.5} | 0.0007 + 0.02 |
| | – 250.0 to – 200.0°C | – 418.0 to – 328.0°F | 0.1°C (0.1°F) | 0.004 + 0.5 {0.9} | 0.006 + 0.5 {0.9} | 0.01 + 0.5 {0.9} | |
| | – 200.0 to 0.0°C | – 328.0 to 32.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.4} | 0.006 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | |
| | 0.0 to 1,370.0°C | 32.0 to 2,498.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| J | – 210.0 to – 200.0°C | – 346.0 to –328.0°F | 0.1°C {0.1°F) | 0.004 + 0.4 {0.6} | 0.006 + 0.4 {0.6} | 0.01 + 0.4 {0.6} | 0.0007 + 0.01 |
| | – 200.0 to –150.0°C | – 328.0 to –238.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.5} | 0.006 + 0.3 {0.5} | 0.01 + 0.3 {0.5} | |
| | – 150.0 to 0.0°C | – 238.0 to 32.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.4} | 0.006 + 0.2 {0.4} | 0.01 + 0.2 {0.4} | |
| | 0.0 to 1,200.0°C | 32.0 to 2,192.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| E | – 270.0 to – 250.0°C | – 454.0 to – 418.0°F | 0.1°C (0.1°F) | 0.004 + 0.8 {1.5} | 0.006 + 0.8 {1.5} | 0.01 + 0.8 {1.5} | 0.0007 + 0.01 |
| | – 250.0 to – 200.0°C | – 418.0 to – 328.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.6} | 0.006 + 0.3 (0.6) | 0.01 + 0.3 {0.6} | |
| | – 200.0 to 0.0°C | – 328.0 to 32.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.4} | 0.006 + 0.2 {0.4} | 0.01 + 0.2 {0.4} | |
| | 0.0 to 1,000.0°C | 32.0 to 1,832.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| T | – 270.0 to – 250.0°C | – 454.0 to – 418.0°F | 0.1°C (0.1°F) | 0.004 + 1.0 {1.5} | 0.006 + 1.0 {1.5} | 0.01 + 1.0 {1.5} | 0.0007 + 0.02 |
| | – 250.0 to – 200.0°C | – 418.0 to – 328.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.5} | 0.006 + 0.3 (0.5) | 0.01 + 0.3 {0.5} | |
| | – 200.0 to 400.0°C | – 328.0 to 752.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| U | – 200.0 to – 100.0°C | – 328.0 to –148.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.4} | 0.006 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | 0.0007 + 0.01 |
| | – 100.0 to 0.0°C | – 148.0 to 32.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.4} | 0.006 + 0.3 {0.3} | 0.01 + 0.3 {0.4} | |
| | 0.0 to 600.0°C | 32.0 to 1,112.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.2} | 0.01 + 0.2 {0.4} | |
| L | – 200.0 to – 100.0°C | – 328.0 to – 148.0°F | 0.1°C (0.1°F) | 0.004 + 0.3 {0.4} | 0.006 + 0.3 {0.4} | 0.01 + 0.3 {0.4} | 0.0007 + 0.01 |
| | – 100.0 to 900.0°C | – 148.0 to 1,652.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | |
| N | 0.0 to 1,300.0°C | 32.0 to 2,372.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.3} | 0.006 + 0.2 {0.3} | 0.01 + 0.2 {0.3} | 0.0007 + 0.02 |
| W | 0.0 to 2,315.0°C | 32.0 to 4,199.0°F | 0.1°C (0.1°F) | 0.004 + 0.2 {0.4} | 0.006 + 0.2 {0.4} | 0.01 + 0.2 {0.4} | 0.001 + 0.03 |
| KPvsAu7Fe | 0.0 tp 20.0 K | — | 0.1K | *2 0.005 + 1.3 {0.4} | *2 0.007 + 0.3 {0.3} | *2 0.011 + 0.3 {0.3} | *3 0.001 + 0.05 |
| | 20.0 to 70.0K | | 0.1K | 0.005 + 0.2 {0.3} | 0.007 + 0.2 {0.2} | 0.011 + 0.2 {0.2} | |
| | 70.0 to 300.0K | | 0.1K | 0.005 + 0.2 {0.2} | 0.007 + 0.2 {0.2} | 0.011 + 0.2 {0.2} | |

*1 As to the R, S, B, K, J, E, T and N, the provisions of IEC584-1 apply.
As to the U and L, those of DIN 43710 apply.
As to the W, those of Hoskins Mfg Co. (USA) apply.
As to the KPvsAu7Fe, those of NSB Vol. 76A apply.

*2 KPvsAu7Fe: ± (% of rdg + K)

*3 KPvsAu7Fe: ± (% of rdg + K)/°C

*4 In case of accuracy and temperature coefficient of °F, multiply 1.8 × °C.

*5 Condition: At ambient temperature of 5 to 18°C (41 to 64°F) and 28 to 40°C (82 to 104°F)

### ● Accuracy of reference junction compensation

| Range | Accuracy of Reference Junction Compensation (°C) | Description |
|---|---|---|
| R, S, B, W, KPvsAu7Fe | ±0.3°C (±0.6°F) | At the ambient temperature of 5 to 40°C |
| K, J, E, U, L, N, T | ±0.2°C (±0.4°F) | |

- In case of internal compensation, the above accuracy of reference junction compensation should be added to measuring accuracy.
- The accuracy of Type B at 0 to 42°C is not prescribed.

■ **Temperature unit:** Changeable among °C, °F, and K. Provided, however, that only K applies as to KPvsAu7Fe.

### ■ Accuracy

- The accuracy is in the case of REAR input, external RJC (reference junction temperature = 0°C.)
- In case of FRONT input, 0.2°C should be added.
- { } indicates the values in integrating time of 2.5 ms.
- Auto Zero ON.
- Accuracy of RJC is excluded.
- The accuracy for Type B at 0 to 42°C is not prescribed.
- **Common mode rejection:** 120dB or more. Integrating time: 500, 200, 100, 20 and 16.7 ms, Rs=1 kΩ, 50/60 Hz ± 0.1%
- **Normal mode rejection:** 60 dB or more. Integrating time: 500, 200, 100, 20, and 16.7 ms, 50/60 Hz + 0.1%
- In case of integrating time 200 or 500 ms at measuring temperature, the response time is 100 ms by setting FILTER.

# Digital Thermometer 7563 – page three (3)

## 7563

### ■ TEMPERATURE (RTD)

| *1 Range | Measurement Range | Resolution 500/200/100 ms | Current through Unknown | *2 Accuracy (Integrating Time 500/200 ms): ±(% of rdg+°C) 24 hours, 23±1°C*4 | 90 days, 23±5°C*4 | 1 year, 23±5°C*4 | Temperature Coefficient (Common to Each Integrating Time)*5 Temperature Coefficient (% of rdg+°C)/°C*4 |
|---|---|---|---|---|---|---|---|
| Pt100 | –200.00 to 650.00°C (–328.00 to 1,202.00°F) | 0.01°C (0.01°F) | 1 mA | 0.005+0.07 (0.1) {0.3} | 0.01+0.07 (0.1) {0.3} | 0.014+0.07 (0.1) {0.3} | 0.001+0.006 |
| JPt100 | –200.00 to 510.00°F (–328.00 to 950.00°F) | 0.01°C (0.01°F) | 1 mA | 0.005+0.07 (0.1) {0.3} | 0.01+0.07 (0.1) {0.3} | 0.014+0.07 (0.1) {0.3} | 0.001+0.004 |
| Pt1000 | –200.00 to 650.00°C (–328.00 to 1,202.00°F) | 0.01°C (0.01°F) | 0.1 mA | 0.005+0.05 (0.07) {0.2} | 0.01+0.05 (0.07) {0.2} | 0.014+0.05 (0.07) {0.2} | 0.001+0.003 |
| J263*B | 2.0 to 300.0K | 0.1K | 1 mA | *2 [0.005+0.1 (0.1) {0.2} | *2 [0.012+0.1 (0.1) {0.2} | *2 [0.016+0.01 (0.1) {0.2} | *3 0.001+0.003 |

*1 As to Pt100, IEC751-1995 apply. As to JPt100, JIS1604-1989 apply. As to Pt1000, the prescription for Pt100 of IEC751-1995 applies.
*2 J263*B: ±(% of rdg+K)
*3 J263*B: ±(% of rdg+K)/°C.
*4 In case of accuracy and temperature coefficient of °F, multiply 1.8 × °C.
*5 Conditions: Ambient temperature 5 to 18°C (41 to 64°F), 28 to 40°C (82 to 104°F).

### ■ TEMPERATURE UNIT

Changeable among °C, °F and K, but as to J263*B only K applies.

### ■ ACCURACY

- Same accuracy for both FRONT and REAR input.
- Allowable conductor resistance: Less than 10 Ω.
- ( ) indicates the accuracy in integrating time of 100, 20, 16.7 ms.
- { } indicates the accuracy in integrating time of 2.5 ms.

### ■ TEMPERATURE COEFFICIENT

- For 3-wire Pt100, J263 ... 0.003°C/°C
  JPt100, Pt1000 ... 0.002°C/°C is added.

### ■ SAMPLING INTERVAL

10 ms to 60 min. (Resolution: 1 ms, 1 s at 3 s or more)

### ■ MINIMUM TIME OF THE FOLLOWING CONDITIONS

**● DC V,OHM, RTD (2- or 4-wire), TC (reference junction compensation)**

| Integrating Time | Measuring Interval (Auto Zero OFF) | Measuring Interval (Auto Zero ON) |
|---|---|---|
| 2.5 ms | 10 ms | 15 ms |
| 16.7 ms | 25 ms | 45 ms |
| 20 ms | 35 ms | 55 ms |
| 100 ms | 110 ms | 215 ms |
| 200 ms | 210 ms | 415 ms |
| 500 ms | 510 ms | 1015 ms |

**● RTD (3-wire)**

| Integrating Time | Measuring Interval |
|---|---|
| 2.5 ms | 95 ms |
| 16.7 ms | 145 ms |
| 20 ms | 155 ms |
| 100 ms | 395 ms |
| 200 ms | 695 ms |
| 500 ms | 1595 ms |

**● TC**

| Integrating Time | | |
|---|---|---|
| 2.5 ms | 70 ms | 150 ms |
| 16.7 ms | 135 ms | 215 ms |
| 20 ms | 150 ms | 230 ms |
| 100 ms | 470 ms | 550 ms |
| 200 ms | 870 ms | 950 ms |
| 500 ms | 2070 ms | 2150 ms |

### ■ GENERAL SPECIFICATIONS

**Operating Principle:** Feedback pulse width modulation method.
**Sample Mode:** Auto/Single/N reading.
**Maximum Reading:** 1999999
**Overrange Information:** -oL- sign display.
**Data Memory:** 1,000 data, measured data can be stored and recalled: (STORE/RECALL).
**Ranging:** AUTO, MANUAL, (remote control and programming possible).
**Analog Output (D/A converter):** Optional.
**Burnout:** TC burnout (defective connection or disconnection etc.) is automatically checked and indicated by alarm display (ON or OFF selectable).
2 kΩ or less (normal), if the value is higher than 30 kΩ, the connection is cut down. Current 2.2 μA or so. Pulse width detection; 2.4 ms or so.
**Operating Temperature Range:** 5 to 40°C (41 to 104°F).
**Humidity Range:** 20 to 80% relative humidity.
**Warmup Time:** Approx. 60 minutes to rated accuracy.
**Power Requirements:** 100/115 V AC±10% (100/115 V: selectable by switch), 50 or 60 Hz (200/230 V must be specified, selectable)
**Power Consumption:** 20 VA max.
**Dimensions (Approx.):** 213(W) × 88(H) × 350(D) mm, (8-3/8 × 3-1/2 × 13-15/16")
**Weight (Approx.):** 3 kg (6.6 lbs)

**● GP-IB Interface (756301)**

**Electrical & Mechanical Specifications:** Conforms to IEEE St'd 488-1978.
**Interface Function & Identification:** SH1, AH1, L4, SR1, RL1, PP0, DC1, DT1, C0. Address mode, address and header ON/OFF are settable.

**● RS-232-C Interface (756302)**

**Transmission Systems:** Start-stop system.
**Data Transfer Rates:** 75, 150, 300, 600, 1,200 2,400, 4,800, 9,600 bps. Hand Shake mode, bps rate, No. of bits and header ON/OFF are settable.

**Yokogawa Digital Manometer MT220 – page one (1)**

# 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<br>Negative pressure: -10 to 0 kPa | Positive pressure: 0 to 130 kPa<br>Negative pressure: -80 to 0 kPa | Positive pressure: 0 to 700 kPa<br>Negative pressure: -80 to 0 kPa | Positive pressure: 0 to 3000 kPa<br>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)<br>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<br>Negative pressure: ±(0.2% of reading +0.1% of full scale) | Positive pressure: ±(0.01% of reading +0.005% of full scale)<br>Negative pressure: ±(0.2% of reading +0.1% of full scale) | Positive pressure: ±(0.01% of reading +0.005% of full scale)<br>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<br>Span: ±0.001% of full scale/°C | Zero point: ±0.001% of full scale/°C<br>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<br>Span: ±2.5% of full scale | Zero point: ±0.01% of full scale<br>Span: ±0.2% of full scale | Zero point: ±0.01% of full scale<br>Span: ±0.05% of full scale | Zero point: ±0.01% of full scale<br>Span: ±0.01% of full scale | Zero point: ±0.01% of full scale<br>Span: ±0.2% of full scale |
| Leak rate | $10^{-5} cm^3/sec$ | | | | |
| 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 | $5 \times 10^{-6}$ $m^2/sec$ 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 $mmH_2O$ or a group consisting of kPa, psi, inHg, $inH_2O$, $kgf/cm^2$, 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) | | | | |

## ■ Pressure Unit Conversion Table

| Pa | bar | $kgf/cm^2$ | atm | $mmH_2O$ or mmAq | mmHg or Torr |
|---|---|---|---|---|---|
| **1** | $1 \times 10^{-5}$ | $1.019\,72 \times 10^{-5}$ | $9.869\,23 \times 10^{-6}$ | $1.019\,72 \times 10^{-1}$ | $7.500\,62 \times 10^{-3}$ |
| **$1 \times 10^5$** | 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 | $9.678\,41 \times 10^{-1}$ | $1 \times 10^4$ | $7.355\,59 \times 10^2$ |
| **$1.013\,25 \times 10^5$** | 1.013 25 | 1.033 23 | 1 | $1.033\,23 \times 10^4$ | $7.600\,00 \times 10^2$ |
| **9.806 65** | $9.806\,65 \times 10^{-5}$ | $1 \times 10^{-4}$ | $9.678\,41 \times 10^{-5}$ | 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 |

# Yokogawa Digital Manometer MT220 – page two (2)

## ■ 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.<br>(50/60 Hz; Rs = 1 kΩ) | —<br>— |
| NMRR | 60 dB min.<br>(50/60 Hz) | —<br>— |
| 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<br>Example of corresponding output voltages when measured with a 130-kPa gauge-pressure model set to the ±2 V range:<br>0 kPa = 0 V<br>65 kPa = 1 V<br>130 kPa = 2 V<br>156 kPa = 2.4 V<br>-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<br>IN = 1, if upper limit ≥ measured value ≥ lower limit<br>LOW = 1, if measured value < lower limit<br>BUSY = 1, if there is a transition in the output signal<br>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. |

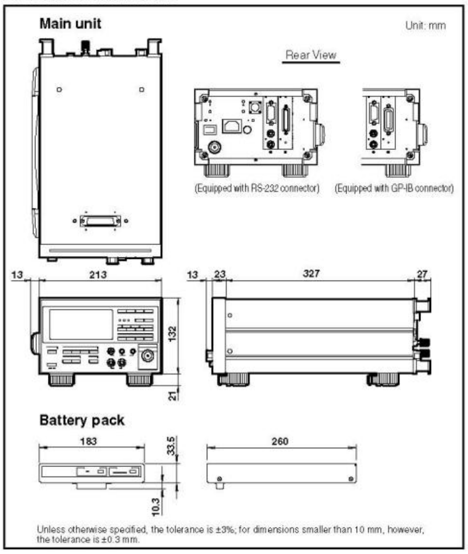
## ■ Common Specifications

| | |
|---|---|
| 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<br>Allowable supply voltage range<br>Allowable supply frequency range | 100 to 120/200 to 240 V AC, at 50/60 Hz<br>90 to 132 V/180 to 264 V AC<br>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).<br>Battery charger: Built into the MT220 main unit<br>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<br>When in recharge mode: 45 VA max. for 100-V power line; 65 VA max. for 200-V power line<br>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:<br>Approx. 132 mm × 213 mm × 350 mm, excluding protrusions<br>Battery pack (optional):<br>Approx. 33 mm × 182 mm × 260 mm, excluding protrusions |
| Weight | Main unit: See the Pressure-measurement Specifications section.<br>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



## Advantech USB-4716

# USB-4716

**200 kS/s, 16-bit, 16-ch 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
- Wiring terminal on modules
- Suitable for DIN-rail mounting
- Lockable USB cable for rigid connection

CE FCC

### 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/ 8differential (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

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# Yokogawa Temperature Transmitter, YTA 110 – page one (1)

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## General Specifications

Model YTA110
Temperature Transmitter

YTA SERIES

GS 01C50B01-00E [Style: S3]

The YTA110 is the high performance temperature transmitter that accepts Thermocouple, RTD, ohms or DC milivolts inputs and converts it to a 4 to 20 mA DC signal for transmission. The YTA110 supports either BRAIN or HART communication protocol.

The YTA110 in it standard configuration is certified by TÜV as complying with SIL2 for safety requirement.

### ■ FEATURES

**High performance**

Microprocesser-based sensing technology ensures long-term accuracy and high reliability.

**High reliability**

Dual-compartment housing realizes high resistance capability to harsh environments, and YTA110 has SIL2 capability for safety requirement.

**Variety of sensor inputs**

The type of sensor input is user-selectable from thermocouples (T/C), RTDs, ohms, or DC milivolts.

**Digital communication**

BRAIN or HART® communication protocol is available. The insturment configuration can be changed by the user with using the BT200 or HART communicator.

**Self-diagnostics function**

Continuous self-diagnostics capability ensures long-term performance and lower cost of ownership.

**LCD display with bargraph**

The LCD display provides both a digital readout and percent bargraph simultaneously.

### ■ STANDARD SPECIFICATIONS

#### □ PERFORMANCE SPECIFICATIONS

**Accuracy**
(A/D accuracy/span + D/A accuracy) or ± 0.1 % of calibrated span, whichever is greater.
See Table 1. on page 3.

**Cold Junction Compensation Accuracy**
(For T/C only)
± 0.5°C (± 0.9 °F)

**Ambient Temperature Effect (per 10 °C change)**
± 0.1 % or ± (Temperature Coefficient /span), whichever is greater. See Table 2. for Temperature Coefficient.

**Stability**
RTD:
±0.1% of reading or ±0.1°C per 2 years, whichever is greater at 23±2°C.


T/C:
±0.1% of reading or ±0.1°C per year, whichever is greater at 23±2°C.

**5 Year Stability**
RTD:
±0.2% of reading or ±0.2°C, whichever is greater at 23±2°C.
T/sC:
±0.4% of reading or ±0.4°C, whichever is greater at 23±2°C.

**RFI Effect**
Tested per EN 50082-2, field intensity up to 10 V/m.

**Power Supply Effect**
±0.005 % of calibration span per volt

**Vibration Effect**
10 to 60 Hz 0.21 mm peak displacement
60 to 2000 Hz 3G

**Position Effect**
None

#### □ FUNCTIONAL SPECIFICATIONS

**Input**
Input type is selectable: Thermocouples, 2-, 3-, and 4-wire RTDs, ohms and DC milivolts. See Table 1. on page 3.

**Span & Range Limits**
See Table 1. on page 3.

**Input signal source resistance (for T/C, mV)**
1 kΩ or lower

**Input lead wire resistance (for RTD, ohm)**
10 Ω per wire or lower

**Output**
Two wire 4 to 20 mA DC. Output range: 3.68 mA to 20.8 mA
BRAIN or HART ® protocol is superimposed on the 4 to 20 mA signal.
Any single value from the followings can be selected as the analog output signal.
Sensor 1, Terminal Temperature.
Also, up to three of the above values can be displayed on LCD display or read via communication.

**Isolation**
Input/Output/GND isolated to 500 V DC

YOKOGAWA ◆

Yokogawa Electric Corporation
2-9-32 Nakacho, Musashino-shi, Tokyo, 180-8750 Japan
Phone: 81-422-52-5690 Fax.: 81-422-52-2018

## Yokogawa Temperature Transmitter, YTA 110 – page two (2)



**Sensor Burnout**
High (21.6 mA DC) or Low (3.6 mA DC), userselectable.

**Output in Transmitter Failure**
Up-scale: 110%, 21.6 mA DC or more (Standard or Optional code /C3)
Down-scale: –5%, 3.2 mA DC or less (Optional code /C1 or /C2)

**Update Time**
Approximately 0.5 seconds

**Turn-on Time**
Approximately 5 seconds

**Damping Time Constant**
Selectable from 0 to 99 seconds

**Ambient Temperature Limits**
Option code may affect limits.
-40 to 85 °C (-40 to 185 °F)
-30 to 80 °C (-22 to 176 °F) with Integral Indicator

**Ambient Humidity Limits**
5 to 100 % RH at 40 °C (104 °F)

**EMC Conformity Standards** CE , N200
EN61326, AS/NZS CISPR11

**SIL Certification**
YTA110 temperature transmitter is certified by TÜV NORD CERT GmbH in compliance with the following standards;
IEC 61508: 2000; Part1 to Part 7 Functional Safety of Electrical/electronic/programmable electronic related systems;
SIL 2 capability for single transmitter use, SIL 3 capability for dual transmitter use.

**Self-calibration**
The analog-to-digital measurement circuitry automatically self-calibrates for temperature update by comparing the dynamic measurement to extremely stable and accurate internal reference elements.

**Self-diagnostics**
Loss of input error, ambient temperature error, EEPROM error, and CPU error. Up to four error history can be stored in the memory.

**Manual Output Function**
The output value can be set manually.

**Supply & Load Requirements**

**Supply Voltage**
10.5 to 42 V DC for general use and flameproof type
10.5 to 32 CV DC for lightning protector (Optional code /A)
10.5 to 30 V DC for intrinsically safe, Type n, nonincendive, or non-sparking type
Minimum voltage limited at 16.4 V DC for digital communications, BRAIN and HART® protocols

**Load**
0 to 1335 Ω for operation
250 to 600 Ω for digital communication
See Figure 1. on page 4.

**Communication Requirements**

**BRAIN:**

**Communication Distance**
Up to 2 km (1.25 miles) when using CEV polyethylene-insulated PVC-sheathed cables. Communication distance varies depending on type of cable used.

**Load Capacitance**
0.22 μF or less

**Load Inductance**
3.3 mH or less

**Input Impedance of communicating device**
10 kΩ or more at 2.4 kHz.

### ☐ PHYSICAL SPECIFICATIONS

**Enclosure**

**Material**
Low copper cast-aluminum alloy

**Coating**
Polyurethan resin baked finish
Color: Deep-sea moss green (Munsell 0.6GY3.1/2.0)

**Degrees of Protection**
IP67, NEMA4X, JIS C0920 immersion proof

**Data and tag plate**
SUS304 Stainless steel

**Mounting**
Optional mounting brackets can be used either for two-inch pipe or flat panel mounting.

**Terminal Screws**
M4 screws

**Integral Indicator**
Optional LCD digital indicator includes 5-digit numerical dispaly with °C, K, °F,°R, % and mV, 0 to 100 % bargraph and dot-matrix display.

**Weight**
1.2 kg(2.6 lb) without Integral indicator and Mounting bracket. Integral indicator weights 0.2 kg(0.4 lb).

**Electrical Connections**
Refer to '**MODEL AND SUFFIX CODES**' on page 5.

# Yokogawa Temperature Transmitter, YTA 110 – page three (3)



**Table 1. Sensor type, measurement range, and accuracy.**

| Sensor Type | | Reference Standard | Measurement Range °C | Measurement Range °F | Minimum Span (Recommended) | Accuracy: Input range °C | Input range °F | A/D Accuracy °C | A/D Accuracy °F | D/A Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|
| T/C | B | IEC584 | 100 to 1820 | 212 to 3308 | 25 °C (45 °F) | 100 to 300 | 212 to 572 | ± 3.0 | ± 5.4 | ± 0.02% of span |
| | | | | | | 300 to 400 | 572 to 752 | ± 1.0 | ± 1.8 | |
| | | | | | | 400 to 1820 | 752 to 3308 | ± 0.75 | ± 1.35 | |
| | E | | -200 to 1000 | -328 to 1832 | | -200 to -50 | -328 to -58 | ± 0.35 | ± 0.63 | |
| | | | | | | -50 to 1000 | -58 to 1832 | ± 0.16 | ± 0.29 | |
| | J | | -200 to 1200 | -328 to 2192 | | -200 to -50 | -328 to -58 | ± 0.40 | ± 0.72 | |
| | | | | | | -50 to 1200 | -58 to 2192 | ± 0.20 | ± 0.36 | |
| | K | | -200 to 1372 | -328 to 2502 | | -200 to -50 | -328 to -58 | ± 0.50 | ± 0.90 | |
| | | | | | | -50 to 1372 | -58 to 2502 | ± 0.25 | ± 0.45 | |
| | N | | -200 to 1300 | -328 to 2372 | | -200 to -50 | -328 to -58 | ± 0.80 | ± 1.44 | |
| | | | | | | -50 to 1300 | -58 to 2372 | ± 0.35 | ± 0.63 | |
| | R | | -50 to 1768 | -58 to 3214 | | -50 to 0 | -58 to 32 | ± 1.0 | ± 1.8 | |
| | | | | | | 0 to 100 | 32 to 212 | ± 0.80 | ± 1.44 | |
| | | | | | | 100 to 600 | 212 to 1112 | ± 0.60 | ± 1.08 | |
| | | | | | | 600 to 1768 | 1112 to 3214 | ± 0.40 | ± 0.72 | |
| | S | | -50 to 1768 | -58 to 3214 | | -50 to 0 | -58 to 32 | ± 1.0 | ± 1.8 | |
| | | | | | | 0 to 100 | 32 to 212 | ± 0.80 | ± 1.44 | |
| | | | | | | 100 to 600 | 212 to 1112 | ± 0.60 | ± 1.08 | |
| | | | | | | 600 to 1768 | 1112 to 3214 | ± 0.40 | ± 0.72 | |
| | T | | -200 to 400 | -328 to 752 | | -200 to -50 | -328 to -58 | ± 0.25 | ± 0.45 | |
| | | | | | | -50 to 400 | -58 to 752 | ± 0.14 | ± 0.25 | |
| | W3 | ASTM E988 | 0 to 2300 | 32 to 4172 | | 0 to 400 | 32 to 752 | ± 0.80 | ± 1.44 | |
| | | | | | | 400 to 1400 | 752 to 2552 | ± 0.50 | ± 0.90 | |
| | | | | | | 1400 to 2000 | 2552 to 3632 | ± 0.60 | ± 1.08 | |
| | | | | | | 2000 to 2300 | 3632 to 4172 | ± 0.90 | ± 1.62 | |
| | W5 | | 0 to 2300 | 32 to 4172 | | 0 to 400 | 32 to 752 | ± 0.70 | ± 1.26 | |
| | | | | | | 400 to 1400 | 752 to 2552 | ± 0.50 | ± 0.90 | |
| | | | | | | 1400 to 2000 | 2552 to 3632 | ± 0.70 | ± 1.26 | |
| | | | | | | 2000 to 2300 | 3632 to 4172 | ± 0.90 | ± 1.62 | |
| | L | DIN43710 | -200 to 900 | -328 to 1652 | | -200 to -50 | -328 to -58 | ± 0.30 | ± 0.54 | |
| | | | | | | -50 to 900 | -58 to 1652 | ± 0.20 | ± 0.36 | |
| | U | | -200 to 600 | -328 to 1112 | | -200 to -50 | -328 to -58 | ± 0.50 | ± 0.90 | |
| | | | | | | -50 to 600 | -58 to 1112 | ± 0.25 | ± 0.45 | |
| RTD | Pt100 | IEC751 | -200 to 850 | -328 to 1562 | 10 °C (18 °F) | -200 to 850 | -328 to 1562 | ± 0.14 | ± 0.25 | |
| | Pt200 | | -200 to 850 | -328 to 1562 | | -200 to 850 | -328 to 1562 | ± 0.30 | ± 0.54 | |
| | Pt500 | | -200 to 850 | -328 to 1562 | | -200 to 850 | -328 to 1562 | ± 0.20 | ± 0.36 | |
| | JPt100 | JIS C1604 | -200 to 500 | -328 to 932 | | -200 to 500 | -328 to 932 | ± 0.16 | ± 0.29 | |
| | Cu | SAMA RC21-4 | -70 to 150 | -94 to 302 | | -70 to -40 | -94 to -40 | ± 1.35 | ± 2.43 | |
| | | | | | | -40 to 150 | -40 to 302 | ± 1.0 | ± 1.8 | |
| | Ni120 | — | -70 to 320 | -94 to 608 | | -70 to 320 | -94 to 608 | ± 0.11 | ± 0.19 | |
| mV | | — | -10 to 100 [mV] | | 3 [mV] | — | | ± 12 [μV] | | |
| ohm | | | 0 to 2000 [Ω] | | 20 [Ω] | | | ± 0.35 [Ω] | | |

T01E.EPS

Total Accuracy = (A/D Accuracy / Span + D/A Accuracy) or (± 0.1% of calibrated span), whichever is greater.

For T/C input, add Cold Junction Compensation Accuracy (± 0.5 °C) to the total accuracy.

Example; when selecting Pt100 with measurement range of 0 to 200 °C.

$$\frac{0.14^\circ C}{200^\circ C} \times 100\% \text{ of span} + 0.02\% \text{ of span} = 0.09\% \text{ of span}$$

Since the value is smaller than ± 0.1% of span, the total accuracy is ± 0.1%.

 

## Yokogawa Temperature Transmitter, YTA 110 – page four (4)



**Table 2. Temperature Coefficient**

| Sensor Type | | Temperature Coefficient |
|---|---|---|
| Thermocouples E,J,K,N,T,L,U | | 0.08°C + 0.02% of abs.reading |
| Thermocouples R,S,W3,W5 | | 0.25°C + 0.02% of abs.reading |
| T/C B | 100°C ≦ Reading < 300°C | 1°C + 0.02% of abs.reading |
| | 300°C ≦ Reading | 0.5°C + 0.02% of abs.reading |
| RTD | | 0.08°C + 0.02% of abs.reading |
| mV | | 0.002 mV + 0.02% of abs.reading |
| ohm | | 0.1 Ω + 0.02% of abs.reading |

T02E.EPS

Note1: Ambient Temperature Effect per 10°C change is ±0.1% or ±(temperature coefficient/span), whichever is greater.
Note2: The "abs.reading" on Table2 means the absolute value of the reading in °C.
Example of abs reading;
When the temperature value is 250 Kelvin, abs reading is 23.15, absolute (250−273.15).
Example of Ambient Temperature Effect;
Conditions;
1) Input Sensor: Pt100
2) Calibration Range: −100 to 100°C
3) Reading value: −50°C
Ambient Temperature Effect per 10°C;
Temperature Coefficient/Span=(0.08°C+0.02/100×|−50°C|)/{100°C−(−100°C)}= 0.00045
→ 0.045%
Therefore, Ambient Temperature Effect is ±0.1%/10°C

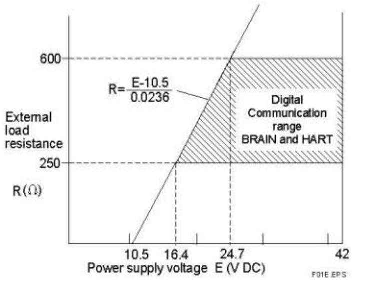


**Figure 1. Relationship Between Power Supply Voltage and External Load Resistance.**

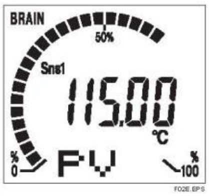


**Figure 2. Integral Indicator Display Example.**

# Yokogawa Temperature Transmitter, YTA 110 – page five (5)



## ■ MODEL AND SUFFIX CODES

| Model | Suffix Codes | Descriptions |
|---|---|---|
| YTA110 | ························ | Temperature Transmitter |
| Output Signal | -D ······················ | 4 to 20mA DC with digital commnuication (BRAIN protocol) |
| | -E ······················ | 4 to 20mA DC with digital communication (HART protocol, refer to GS 01C50T01-00E) |
| — | A ················ | Always A |
| Electrical Connection | 0 ············ | G1/2 female |
| | 2 ············ | 1/2 NPT female |
| | 3 ············ | Pg 13.5 female |
| | 4 ············ | M20 female |
| Integral Indicator | D ········ | with digital indicator |
| | N ········ | None |
| Mounting Bracket | B ···· | SUS304 Stainless steel 2-inch horizontal pipe mounting *1 |
| | D ···· | SUS304 Stainless steel 2-inch vertical pipe mounting *1 |
| | N ···· | None |
| Optional Codes | /□ | Optional Specifications |

*1: For flat-panel mounting, please prepare bolts and nuts.

T03E.EPS

## ■ OPTIONAL SPECIFICATIONS

| Item | | Descriptions | | Code |
|---|---|---|---|---|
| Lightning protector | | Power supply voltage: 10.5 to 32 V DC<br>Allowable current: Max. 6000A(1×40μs), repeating 1000A(1×40μs) 100 times | | A |
| Painting | Coating change | Epoxy resin coating | | X1 |
| | Color change | Amplifier cover only | Munsell code: N1.5 Black | P1 |
| | | | Munsell code: 7.5BG4/1.5, Jade green | P2 |
| | | | Metallic silver | P7 |
| | | Amplifier and terminal Covers | Munsell code: 7.5 R4/14 Red | PR |
| Calibration Unit | | Degree F/Degree R unit | | D2 |
| Output signal low-side in Transmitter failure | | Output signal low-side: -5%, 3.2 mA DC or less.<br>Sensor burnout is also set to 'LOW': -2.5%, 3.6 mA DC. | | C1 |
| NAMUR NE43 Compliant | | Output signal limits: 3.8 mA to 20.5 mA | Failure alarm down-scale: output status at CPU failure and hardware error is -5%, 3.2 mA or less.<br>Sensor burnout is also set to LOW: -2.5%, 3.6 mA DC. | C2 |
| | | | Failure alarm up-scale: output status at CPU failure and hardware error is 110%, 21.6 mA or more.<br>In this case Sensor burnout is High: 110%, 21.6 mA DC. | C3 |
| Data Configuration | | Description into "Descriptor" parameter of HART protocol<br>(max. 16 characters) | | CA |
| Stainless steel housing *1 | | Housing Material: SCS14A stainless steel (equivalent to SUS316 cast stainless steel and ASTM CF-8M) | | E1 |

*1: Not applicable for optional code JF3, G11, G12, P1, P2, P7, PR, and X1.

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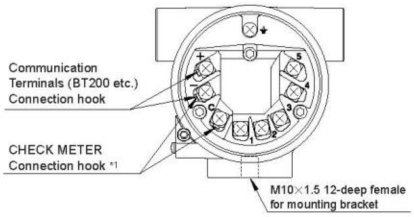
# Yokogawa Temperature Transmitter, YTA 110 – page six (6)



## Terminals




Terminal Configuration

| | |
|---|---|
| + − | Power Supply and output terminal |
| − C | External Indicator (ammeter) terminal *1 |
| ⏚ | Ground terminal |

*1: When using an external indicator or check meter, the internal resistance must be 10Ω or less. This hook is not available for Fieldbus communication type(output signal code F).

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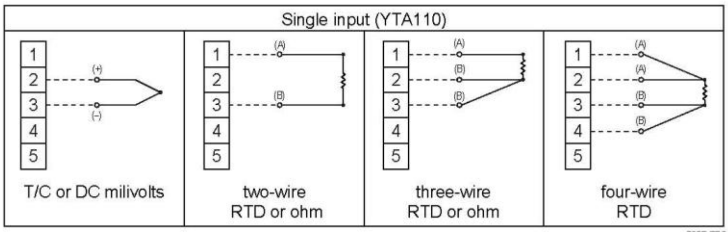
## Input Wiring




F05E.EPS

**< Ordering Information >**

Specify the following when ordering

Model, suffix codes, and optional codes

The instrument is shipped with the settings shown in Table A. Specify the following when necessary.

1. Sensor type.
   For RTD and resistance input, specify the number of wire as well.
   (Example; Pt200 3-wire system)
2. Calibration range and unit
   1) Calibration range can be specified within the measurement range shown in Table 1. on page 3.
   2) Specify one range from °C, K, °F or °R for temperature input. °F and °R are available when Optional code D2 is specified. It is not necessary to specify the unit of mV and ohm inputs, for these units automatically will be mV or Ω.
3. Tag Number
4. Other Items related with options
   /CA option allows specifying the setting Descriptor for HART protocol type at factory.
   Specify upto 16 characters to be entered in the Descriptor parameter.

**Table A. Settings upon shipment.**

| | |
|---|---|
| Input sensor type | Pt100 three-wire system, or as specified |
| Calibration range lower limit | "0" or as specified |
| Calibration range upper limit | "100" or as specified |
| Calibration unit | "°C" or as specified |
| Damping time constant | 2 seconds |
| Sensor burnout *1 | High (110%, 21.6 mA DC) |
| Output in Transmitter failure *1 | High (110%, 21.6 mA DC or more) |
| Integral Indicator *2 | PV |
| Output type | Sensor 1 |
| Tag number | As specified in order |

*1: Except when Optional code C1 or C2 is specified.
*2: When Integral indicator is specified.

T07E.EPS

**< Related Instruments >**

Power Distributor: Refer to GS 01B04T01-02E or GS 01B04T02-00E
BRAIN TERMINAL: Refer to GS 01C00A11-00E

**< Reference >**

HART; Trademark of The HART Communiation Foundation. (USA)

**Material Cross Reference Table**

| | |
|---|---|
| SUS304 | AISI 304 |

T08E.EPS

**HART 375 Field Communicator**

# 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) transflective 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)

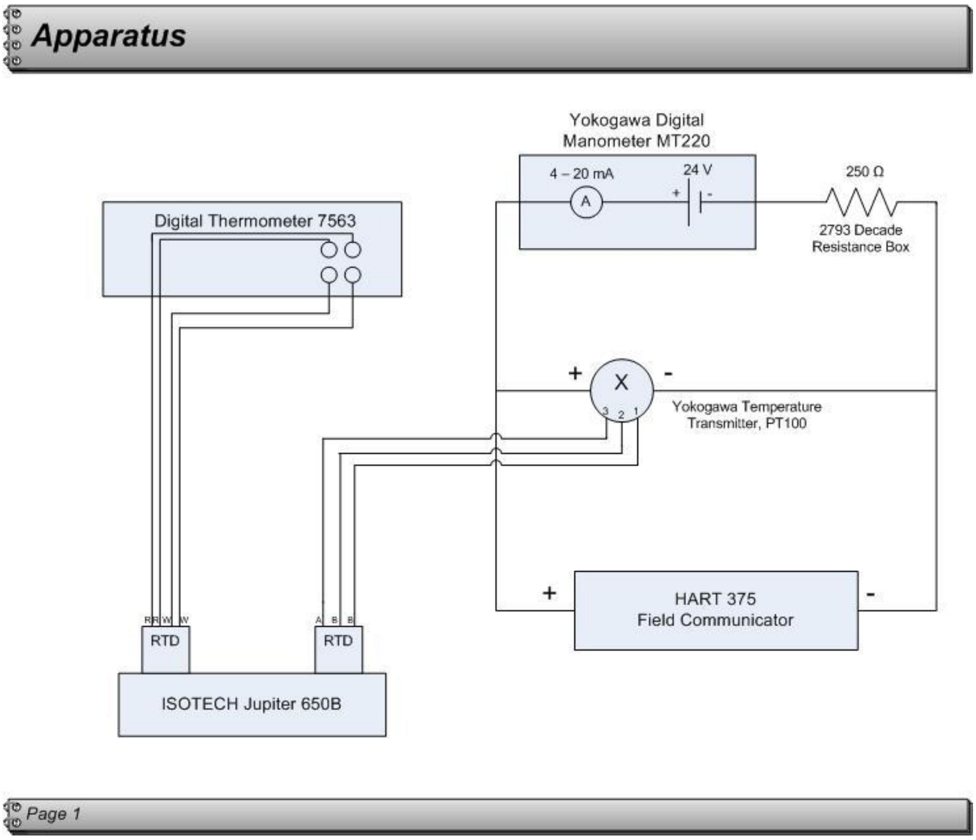
**Shock**
- Tested to survive a 1-meter drop test onto concrete

## *EASY UPGRADE* REQUIREMENTS

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

# APPENDIX B

## *INSTRUMENTS CONNECTION*



## APPENDIX C

***Student's T-Distribution Table***

| Degree of Freedom v | **Fraction ρ in percent** | | | | | |
|---|---|---|---|---|---|---|
| | **68.27*** | **90.00** | **95.00** | **95.45** | **99.00** | **99.73*** |
| 1 | 1.84 | 6.31 | 12.71 | 13.97 | 63.66 | 235.8 |
| 2 | 1.32 | 2.92 | 4.30 | 4.53 | 9.92 | 19.21 |
| 3 | 1.20 | 2.35 | 3.18 | 3.31 | 5.84 | 9.92 |
| 4 | 1.14 | 2.13 | 2.78 | 2.87 | 4.60 | 6.62 |
| 5 | 1.11 | 2.02 | 2.57 | 2.65 | 4.03 | 5.51 |
| 6 | 1.09 | 1.94 | 2.45 | 2.52 | 3.71 | 4.90 |
| 7 | 1.08 | 1.89 | 2.36 | 2.43 | 3.50 | 4.53 |
| 8 | 1.07 | 1.86 | 2.31 | 2.37 | 3.36 | 4.28 |
| 9 | 1.06 | 1.83 | 2.26 | 2.32 | 3.25 | 4.09 |
| 10 | 1.05 | 1.81 | 2.23 | 2.28 | 3.17 | 3.96 |
| | | | | | | |
| 11 | 1.05 | 1.80 | 2.20 | 2.25 | 3.11 | 3.85 |
| 12 | 1.04 | 1.78 | 2.18 | 2.23 | 3.05 | 3.76 |
| 13 | 1.04 | 1.77 | 2.16 | 2.21 | 3.01 | 3.69 |
| 14 | 1.04 | 1.76 | 2.14 | 2.20 | 2.98 | 3.64 |
| 15 | 1.03 | 1.75 | 2.13 | 2.18 | 2.95 | 3.59 |
| | | | | | | |
| 16 | 1.03 | 1.75 | 2.12 | 2.17 | 2.92 | 3.54 |
| 17 | 1.03 | 1.74 | 2.11 | 2.16 | 2.90 | 3.51 |
| 18 | 1.03 | 1.73 | 2.10 | 2.15 | 2.88 | 3.48 |
| 19 | 1.03 | 1.73 | 2.09 | 2.14 | 2.86 | 3.45 |
| 20 | 1.03 | 1.72 | 2.09 | 2.13 | 2.85 | 3.42 |
| | | | | | | |
| 25 | 1.02 | 1.71 | 2.06 | 2.11 | 2.79 | 3.33 |
| 30 | 1.02 | 1.70 | 2.04 | 2.09 | 2.75 | 3.27 |
| 35 | 1.01 | 1.70 | 2.03 | 2.07 | 2.72 | 3.23 |
| 40 | 1.01 | 1.68 | 2.02 | 2.06 | 2.70 | 3.20 |
| 45 | 1.01 | 1.68 | 2.01 | 2.06 | 2.69 | 3.18 |
| | | | | | | |
| 50 | 1.01 | 1.68 | 2.01 | 2.05 | 2.68 | 3.16 |
| 100 | 1.005 | 1.660 | 1.984 | 2.025 | 2.262 | 3.077 |
| | 1.000 | 1.645 | 1.960 | 2.000 | 2.576 | 3.000 |

*For a quality Z described by a normal distribution with expectation $\mu z$ and standard deviation $\sigma$, the interval $\upsilon z \pm k\sigma$ encompasses $\rho$ = 68.27, 95.45 AND 99.73 percent of the distribution for k = 1, 2 and 3 respectively.

**APPENDIX D**

***RTD's-Temp User Manual***

---

# RTD's-Temp User Manual

**Author: Muhammad Hasbullah Bin Rais**

**Version: 1.0.0.1**

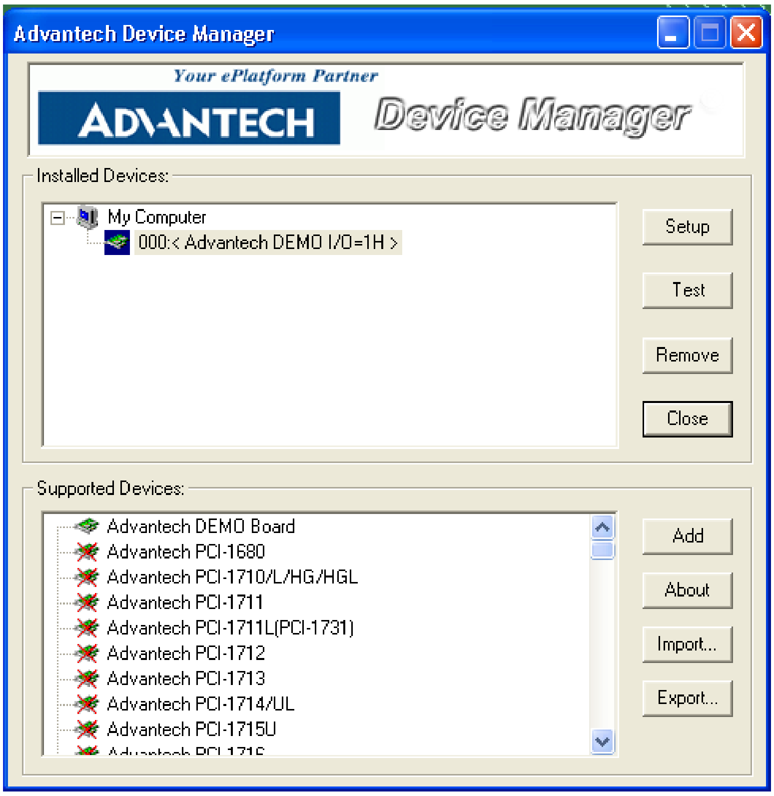
# Table of Contents

# 1. Basic Connection and Setup Guide

## 1.1 Connection to Advantech Device Manager

In order to communicate with DAQ card, we need to initialize connection to DAQ itself via Advantech Device Manager.

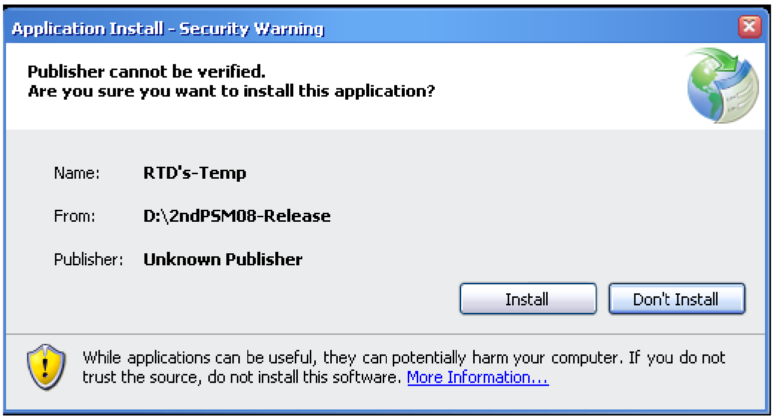
**Start** > **All Programs** > **Advantech Automation** > **Device Manager** > **Advantech Device Manager**




After plug-in the DAQ card into USB module located at computer, in "Installed Devices:" section will have the type of DAQ card inserted.

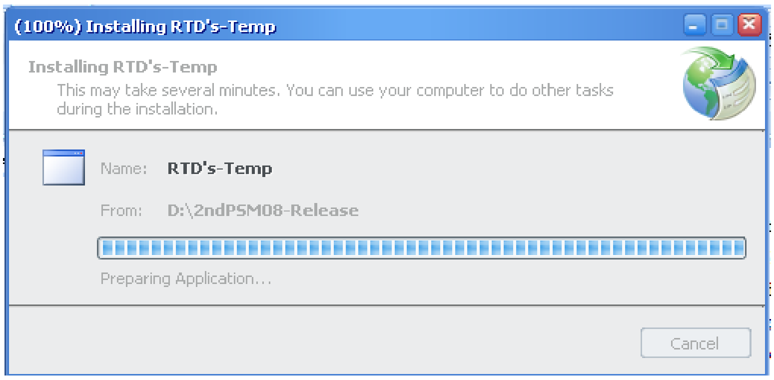
## 1.2 Installing RTD's-Temp

Installer of this program has been publishing under Microsoft Visual Basic (ClickOnce deployment). To install RTD's-Temp, double-click **setup.exe** from installation folder. If there is any component which is not available at computer, prerequisite page will appear. To proceed, just follow instruction. After double-click **setup.exe**, following page appear.

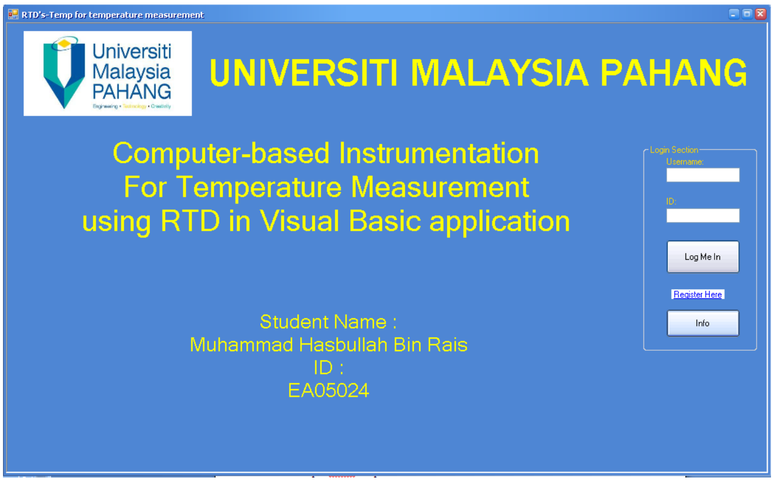



To continue installing RTD’s-Temp, click “Install” button. To cancel the installation, click “Don’t Install” button.

Installation page:




After installation process finish, the following page appears. It means you are successful install RTD’s-Temp.




## 1.3 Opening RTD’s-Temp

RTD’s-Temp now is successfully installed, which mean it can be launch from your computer. To open RTD’s-Temp:

**Start > All Programs > Temperature Measurement using RTD > RTD’s-Temp**

## 1.4 Uninstalling RTD’s-Temp

RTD’s-Temp can be uninstalled from computer by following this instruction:

(i) Go to **Control Panel**

**Start > Control Panel**

(ii) Double-click **Add or Remove Program**

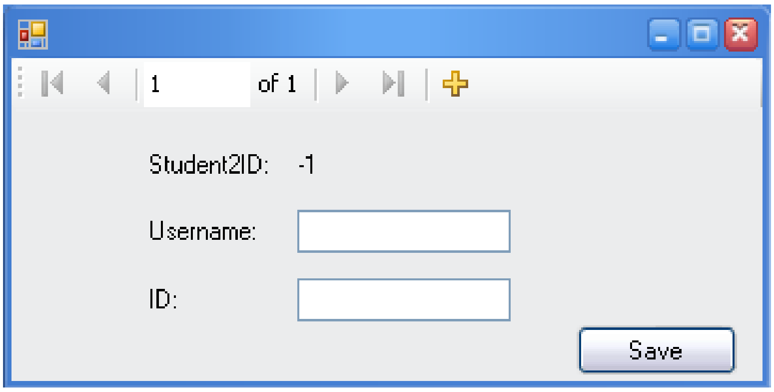
(iii) Find **RTD’s-Temp,** click **Change/Remove** button

(iv) RTD’s-Temp successfully uninstalled

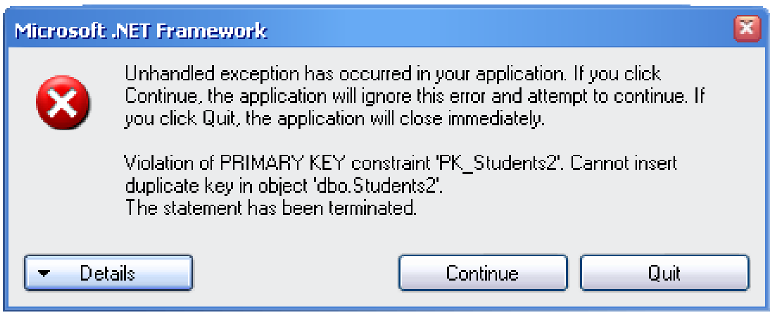
## 1.5 Register User

In order to use RTD's-Temp, user needs to register username or can use "test" in username and ID field to proceed.

To register a new username, click **Register Here**. To proceed, key-in data to username and ID field.



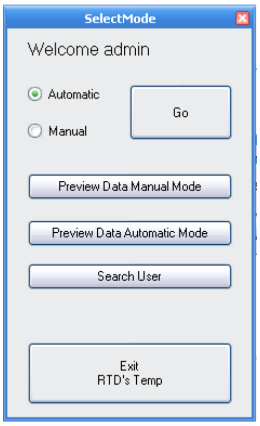

**this program is still in beta stage. If user entered the same username which already in database, the following message will appear. To proceed, just click **continue** button and key-in another username.*




After key-in another data in username and ID field, the conformation about data has been saved appear.


### 1.6 Select Operating Mode

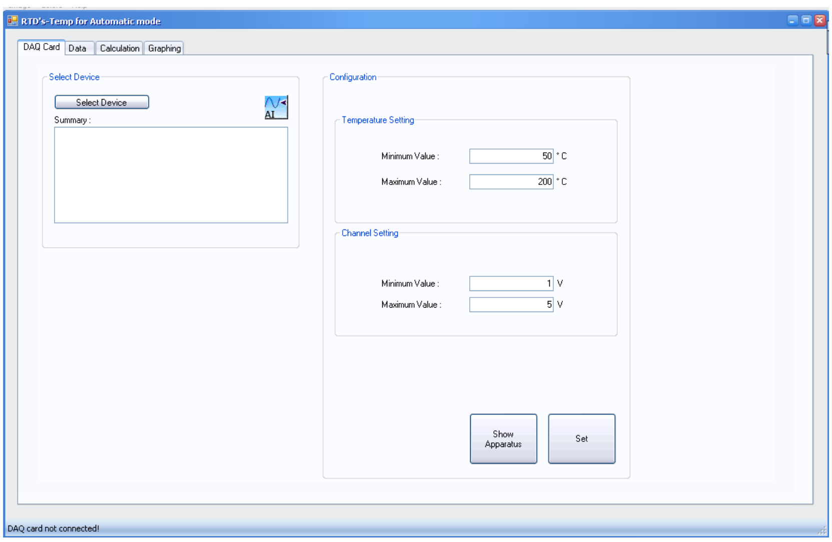
There are two types of operating RTD's-Temp.




(i) Automatic Mode

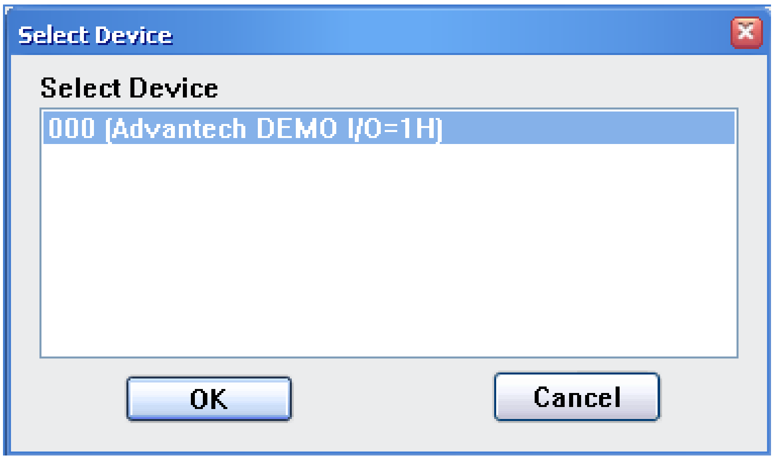
(ii) Manual Mode

## 2 Automatic Mode

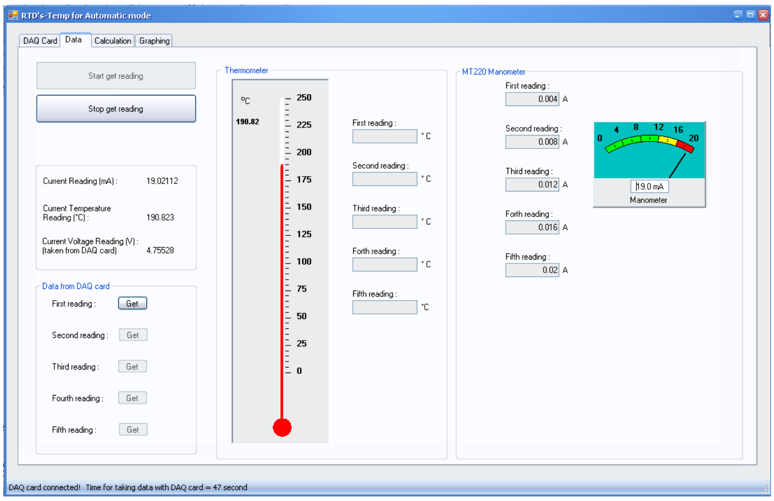


The interfaced for automatic mode. There are four categories tab pages; **DAQ Card, Data, Calculation, Graphing**

To start, click **Select Device** button to select device.




After that, key-in data for minimum and maximum temperature reading in degree Celsius (°C). The default values are 50°C for minimum value and 200°C for maximum value. Click **set** button to proceed. To start get data from DAQ card, click **Start get reading** button. By using demo device provided by Advantech, the following data has been capture by pressing button **Get** at **Data from DAQ Card** section.

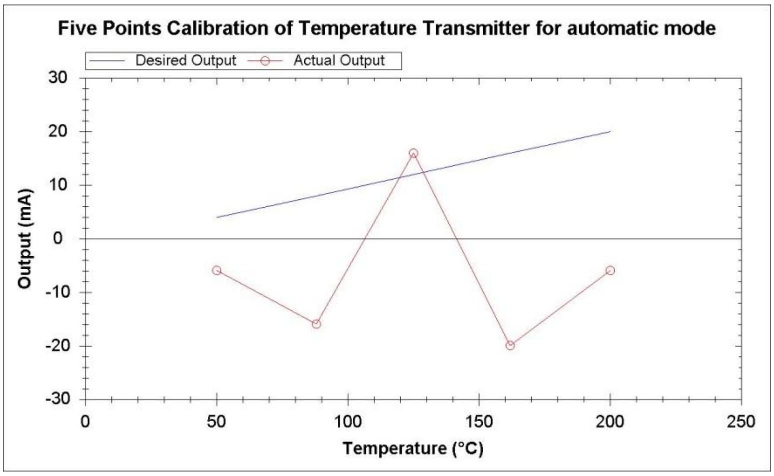


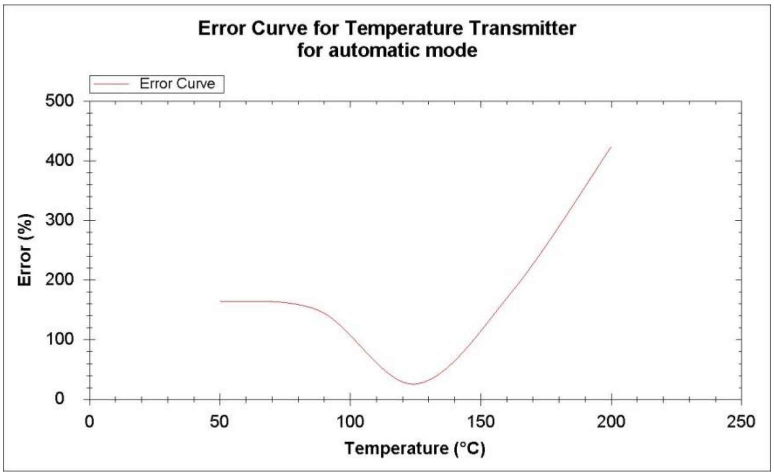

After finished taking data, go to **Calculation** tab page. Press **Convert & Transfer** button to continue. The data will be transferred to summary table and press **Calculate Output Error** to finish.

| No % | MSU applied value C | Desired UUT output mA | Actual UUT output mA | Output Error % |
|---|---|---|---|---|
| 0 | 50 | 4 | -6.18034 | 164.72136 |
| 25 | 87.5 | 8 | -16.18034 | 149.44272 |
| 50 | 125 | 12 | 16.18034 | 25.83592 |
| 75 | 162.5 | 16 | -19.7537592 | 180.99724 |
| 100 | 200 | 20 | -6.18034 | 423.60679 |

Calculate Output Error

To save data to database, click **Save Data** button. To view graph of "5 Point calibration", press **Show Graph "5 Point Calibration".** To view graph of "Error Curve", press **Show Graph "Error Curve".**



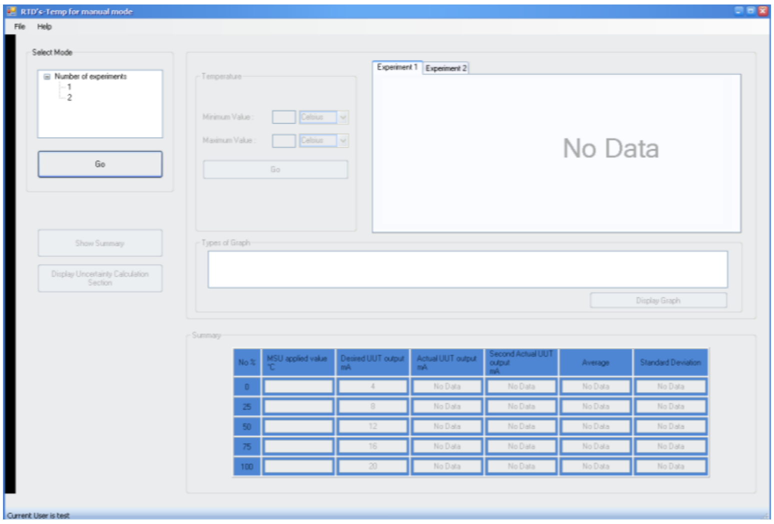




## 3. Manual Mode

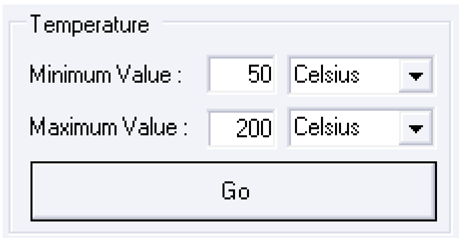
Open RTD’s Temp software

**Start > All Programs > Temperature Measurement using RTD > RTD’s-Temp**

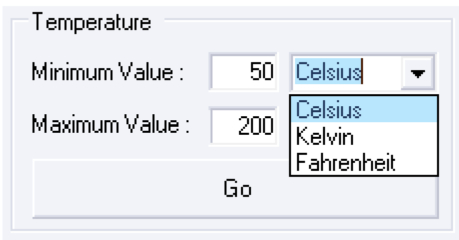
For manual mode, user needs to tick “Manual” in select mode section and select number of experiments before press button “Go” to proceed.

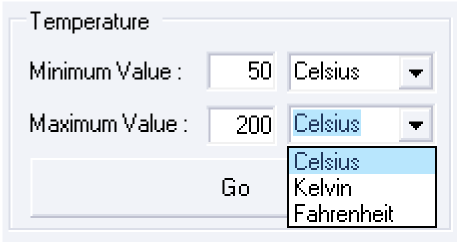



After that, user needs to fill in the transmitter temperature range in correspond location and press button “Go”. E.g. temperature transmitter has range 50°C – 200°

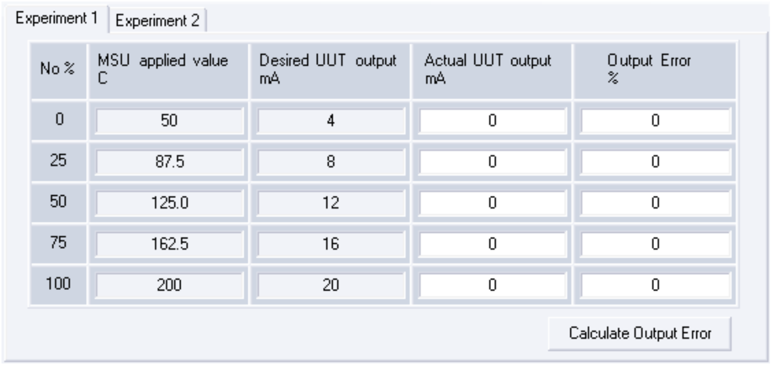



User has choices to key in data in three different kind of temperature reading, Celsius, Kelvin and Fahrenheit. By default, choice for Celsius is selected.



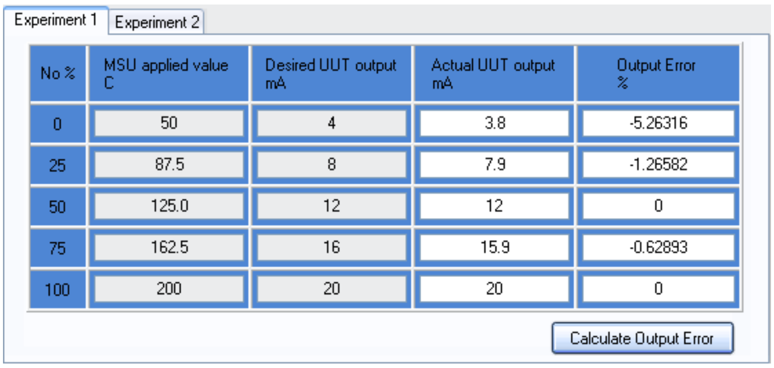



After that, the section that contains all the necessary information about experiment is appear, user need to key in data to the correspond location.




| No % | MSU applied value C | Desired UUT output mA | Actual UUT output mA | Output Error % |
|---|---|---|---|---|
| 0 | 50 | 4 | 0 | 0 |
| 25 | 87.5 | 8 | 0 | 0 |
| 50 | 125.0 | 12 | 0 | 0 |
| 75 | 162.5 | 16 | 0 | 0 |
| 100 | 200 | 20 | 0 | 0 |

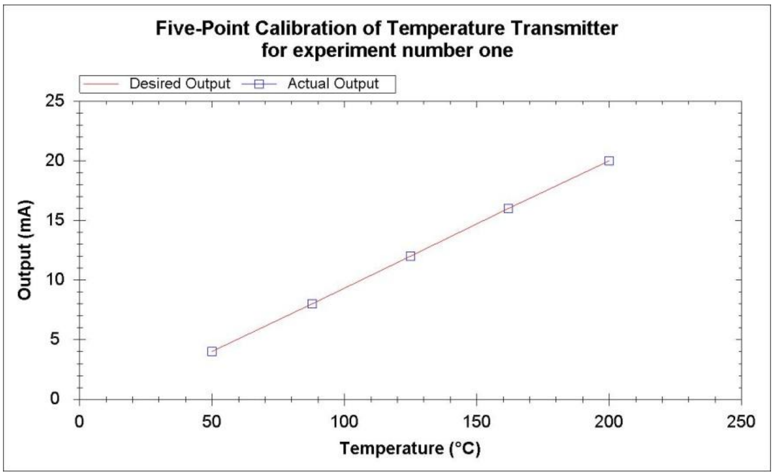
E.g. user need to key in data to “Actual UUT output” field, and press button “Calculate Output Error” to get result



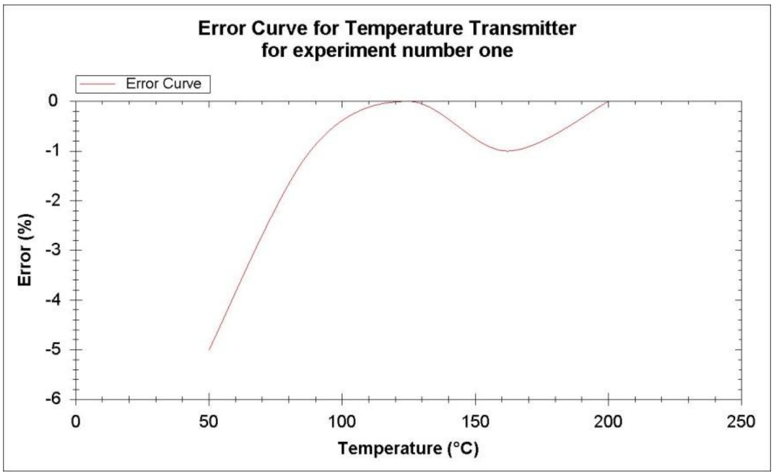

| No % | MSU applied value C | Desired UUT output mA | Actual UUT output mA | Output Error % |
|---|---|---|---|---|
| 0 | 50 | 4 | 3.8 | -5.26316 |
| 25 | 87.5 | 8 | 7.9 | -1.26582 |
| 50 | 125.0 | 12 | 12 | 0 |
| 75 | 162.5 | 16 | 15.9 | -0.62893 |
| 100 | 200 | 20 | 20 | 0 |

If user chooses with two experiments, user needs to follow step above because it contains the same step.

To display graph, user has choice to display either graph for “5 Point Calibration of PT100 for experiment number one” or graph for “Error Curve for PT100 for experiment number one”. To continue, select type of graph in types of graph section and press button “Display Graph”. If user selects to display graph for “5 Point Calibration of PT100 for experiment number one”, the graph will show as below:

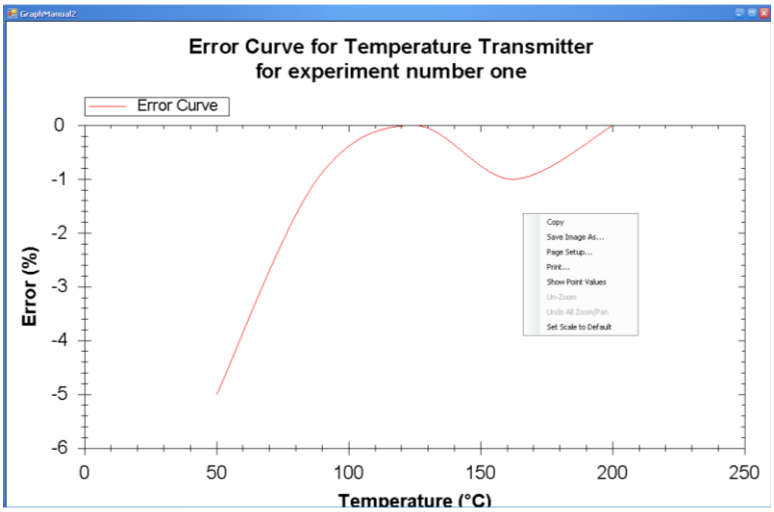



If user selects to display graph for "Error Curve for PT100 for experiment number one", the graph will show as below:




The graphs above only valid with one experiment, since with two experiments, the result will look quite same with one experiment.

User can save image, print, show point values by mouse right-click on graph and select desired action.




To proceed for uncertainty calculation, press button "Show Summary" and table of summary will display. This applied only with two experiments since need to find average values of actual UUT output and standard deviation.

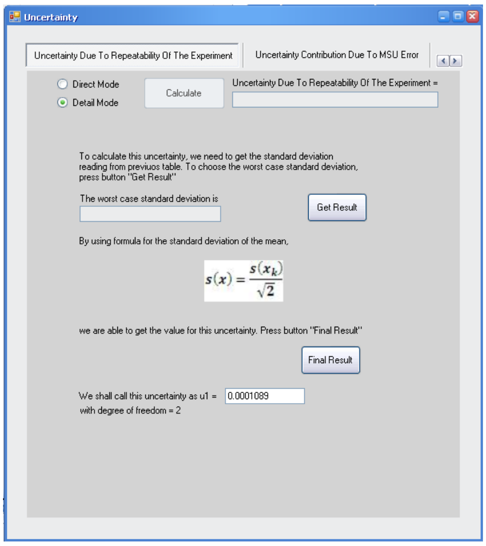
Summary

| No % | MSU applied value °C | Desired UUT output mA | Actual UUT output mA | Second Actual UUT output mA | Average | Standard Deviation |
|---|---|---|---|---|---|---|
| 0 | 50 | 4 | 3.8 | 3.9 | 3.85 | 0.005 |
| 25 | 87.5 | 8 | 7.9 | 8 | 7.95 | 0.005 |
| 50 | 125.0 | 12 | 12 | 11.9 | 11.95 | 0.005 |
| 75 | 162.5 | 16 | 15.9 | 15.9 | 15.9 | 0 |
| 100 | 200 | 20 | 20 | 20 | 20 | 0 |

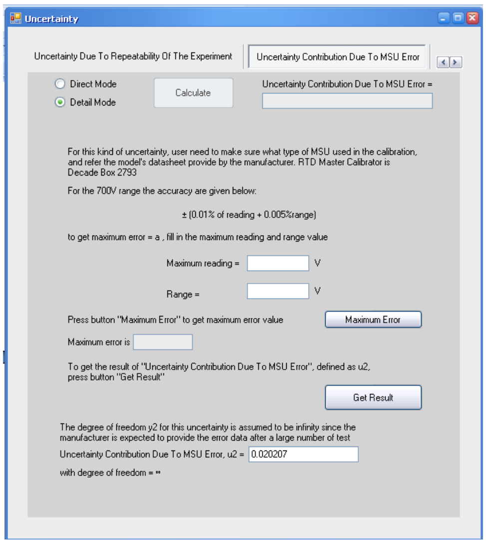
For uncertainty calculation section, user need to press button "Display Uncertainty Calculation Section" and new window will appear.

There are four element of uncertainty that need to calculate, that is Uncertainty Due To Repeatability of the Experiment, Uncertainty Contribution Due To MSU Error, Uncertainty Due To UUT Resolution/MSU Resolution, and Combined Standard Uncertainty. In this section, user can choose either want to use Direct Mode or Detail Mode. In direct mode, user just needs to press some button in order to get uncertainty values. But in detail mode, user needs to key-in data to correspond textbox.

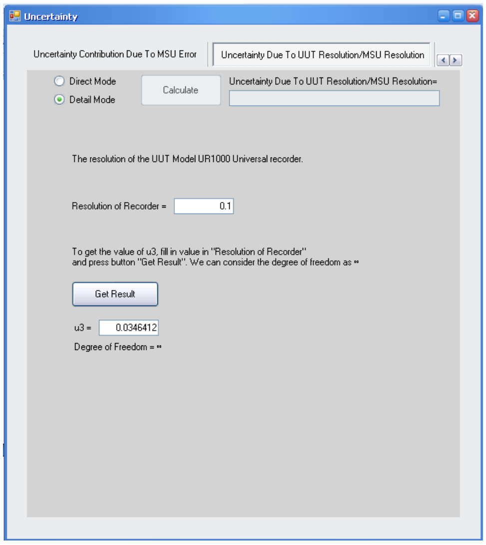
### 3.1.1 Uncertainty Due To Repeatability of the Experiment



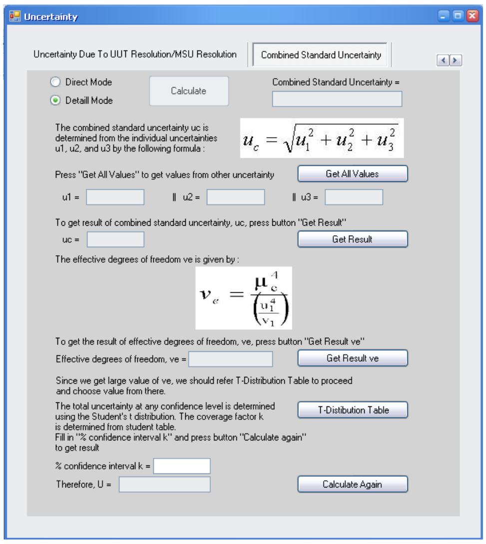

### 3.1.2 Uncertainty Contribution Due To MSU Error




### 3.1.3 Uncertainty Due To UUT Resolution/MSU Resolution



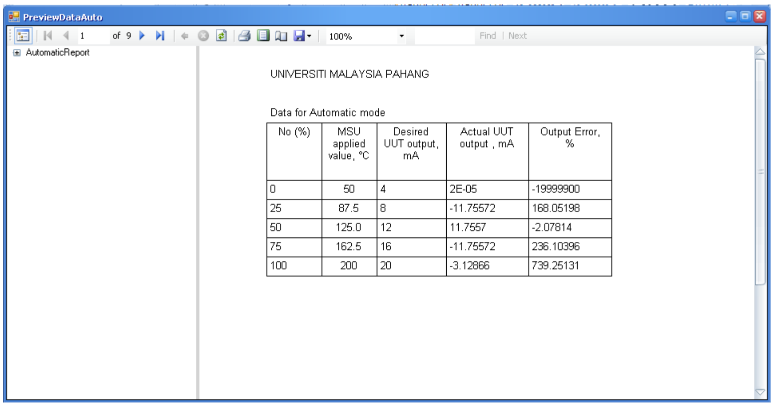

### 3.1.4 Combined Standard Uncertainty




# 4 Report Viewer

User can use report viewer to preview data or save the data to the file. Data can be save in form of excel (.xls) format and acrobat file (.pdf) format. User also can search text within the document and print it.

## 4.1 For Automatic Mode

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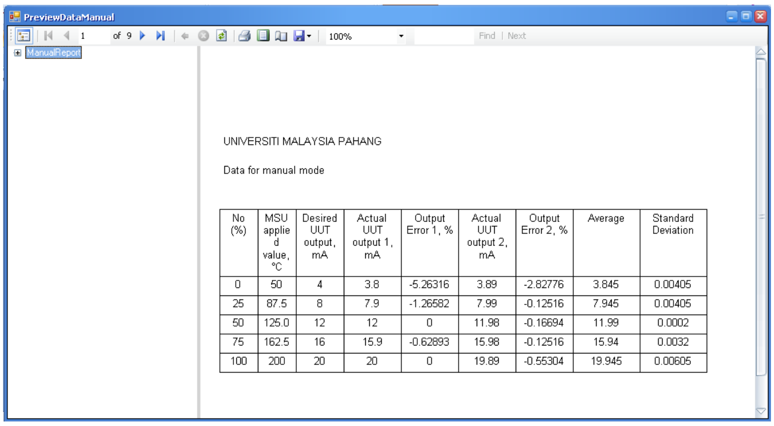
Data for Automatic mode

| No (%) | MSU applied value, °C | Desired UUT output, mA | Actual UUT output , mA | Output Error, % |
|---|---|---|---|---|
| 0 | 50 | 4 | 2E-05 | -19999900 |
| 25 | 87.5 | 8 | -11.75572 | 168.05198 |
| 50 | 125.0 | 12 | 11.7557 | -2.07814 |
| 75 | 162.5 | 16 | -11.75572 | 236.10396 |
| 100 | 200 | 20 | -3.12866 | 739.25131 |

## 4.2 For Manual Mode

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Data for manual mode

| No (%) | MSU applied value, °C | Desired UUT output, mA | Actual UUT output 1, mA | Output Error 1, % | Actual UUT output 2, mA | Output Error 2, % | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| 0 | 50 | 4 | 3.8 | -5.26316 | 3.89 | -2.82776 | 3.845 | 0.00405 |
| 25 | 87.5 | 8 | 7.9 | -1.26582 | 7.99 | -0.12516 | 7.945 | 0.00405 |
| 50 | 125.0 | 12 | 12 | 0 | 11.98 | -0.16694 | 11.99 | 0.0002 |
| 75 | 162.5 | 16 | 15.9 | -0.62893 | 15.98 | -0.12516 | 15.94 | 0.0032 |
| 100 | 200 | 20 | 20 | 0 | 19.89 | -0.55304 | 19.945 | 0.00605 |