PROFIBUS NETWORK IN THE INSTRUMENTATION AND CONTROL LABORATORY

A report submitted to the School of Engineering and Information Technology, Murdoch University in partial fulfillment of the requirements for the Bachelor of Engineering with Honours

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Date: 17/06/2016

Acknowledgements

For their assistance in this project, acknowledgments are given to the following individuals:

Project Supervisor: Associate Professor Graeme R Cole,

Lecturer, Murdoch University

Mr. Lafeta 'Jeff' Laava,

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Mr. Will Stirling,

Technical Officer, Murdoch University

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Declaration

I Oarabile Daniel Thema declare that except where indicated, the work I am submitting in this report is my own work and has not been submitted for assessment in another unit. This submission complies with Murdoch University's academic integrity commitments.

Abstract

The Instrumentation and Process Control Laboratory is facility that provides Engineering students a way of performing control experiments by using a combination of instrumentation hardware and LabVIEW programs. The Laboratory is based upon three components:

- The Exprimental Stations
- The Master I/O Program
- The Basic Experimental Template

The Experimrntal stations are panels where hardware components like valves and measuring devices are connected to. The Master I/O program is a LabVIEW program which acts as an interface between the Experimental Stations and the Basic Experimental Template. The Basic Experimental Template is a LabVIEW program which stundents can modify to suit their designs for process control experiments.

The main aim of this project is to integrate the PROFIBUS PA instruments into the Master Input/Output (I/O) program and to produce a guide to assist students in using these instruments. This project involves communication between instruments from different vendors, hence the use of open and vendor independent protocols.

Once completed, the project will avail more instruments to be used for process control experiments. The project also avails another infrastructure for students studying Industrial Computer Engineering to use the physical PROFIBUS network when learning about industrial communication systems. Even though PROFIBUS PA instruments are more accurate and fast, their response in controlled by the scan cycle of the Master I/O Program.

The communication protocols used in this project are PROFIBUS PA, OLE for Process Control (OPC) and Ethernet. The PROFIBUS protocol is vendor independent and based on the master and slave architecture. The SIEMENS CPU314C-2DP is used as the master, while the slaves are the Siemens DP/PA coupler, Levelflex M FMP40 and Deltbar S PMD70. Communication between the slaves and the master was via the PROFIBUS PA protocol. The configuration and programming of the SIEMENS CPU314C-2DP and PROFIBUS PA devices was done using TIA Portal V13 software.

Communication between an OPC server and CPU314C-2DP was via a serial communication port using an MPI cable. The OPC server was configured to read the required data from the

CPU314C-2DP. The Master I/O program was updated to read data from the OPC server using shared variables and calculate the measured parameters. The OPC server and Master I/O program were running on the same computer. Finally, the experimental template was updated to read data from the Master I/O program using Ethernet as the medium of communication.

The communication and programs were tested at the end of each stage to ensure functionality of each segment. In overall, the objectives of this project were achieved as the PROFIBUS PA instruments can now be used in the laboratory, and the guide on how to use them was developed.

Terminology and Acronyms

BIN – Binary Number

Bool – Boolean

CPU – Central Processing Unit

DEC – Decimal Number

DIP – Dual inline Package

DB – Data Block

FB – Function Block

Hex – Hexadecimal Number

GSD – General Station Description File

HMI – Human Machine Interface

ICE Lab– Instrumentation and process control laboratory

I/O – Input/Output

Kbps – Kilobits per second

LabVIEW – Laboratory Virtual Instrumentation Engineering Workbench

LAD – Ladder Diagram

LED – Light Emitting Diode

MBP –Manchester Bus Powered

Mbps – Megabits per second

MPI – Multi-Point Interface

OB – Organization Block

OPC – OLE for process control

PC – Personal Computer

PLC – Programmable Logic Controller

PROFIBUS – Process Fieldbus

PROFIBUS-DP – PROFIBUS Decentralized Peripherals

PROFIBUS-PA – PROFIBUS Process Automation

SCL – Structured Control Language

SIMATIC – Siemens automatic

TIA Portal – Totally Integrated Automation Porta

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1. Introduction

The integration of the PROFIBUS network in the instrumentation and control laboratory is a project aiming to fully incorporate the usage of the Profibus Instruments into the main stream experiments conducted in the ICE laboratory. The main communication methods used in the ICE laboratory are the 4-20mA analog and 24V digital communication systems. The goal of this project is to achieve a hybrid system, where the 4-20mA analog communication system and PROFIBUS PA systems can be used together. The PROFIBUS PA has the ability to measure different parameters at the same time, e.g. The Deltabar S PMD70 can measure both pressure and temperature at the same time. The use of PROFIBUS PA instruments can enhance the quality of control experiments conducted in the laboratory as they will increase the variety of instruments student can choose from. This project is building on the work done by previous thesis students and ENG454 students. The Instrumentation and Control Engineering (ICE) laboratory in Murdoch University is used to facilitate teaching and learning of both Industrial Computer System and Instrumentation and Process Control Engineering.

The proposed plan is to use the existing PROFIBUS network together with the available PROFIBUS PA instruments. PROFIBUS is an open, vendor-independent protocol which allows communication between instruments from different vendors. **[1]** This property of PROFIBUS is used in this project as the aim is to establish communication between measuring instruments from different vendors, Siemens PLC, OPC Server and LabVIEW Master I/O program.

The project gives an opportunity to students studying ICSE to research and apply the theory and skills learned in previous units to real systems.

1.1 Objective

The main objective of this project is to integrate the usage of the PROFIBUS Instruments into the main stream experiments conducted in the lab. As a build up to the main objective, the following are aims are fundamental.

- Test the wiring of the PROFIBUS network in the laboratory to locate short circuits and broken wires.
- Configure the instruments to facilitate communication
- Develop a program to facilitate communication between PROFIBUS PA measuring instruments and Siemens CPU314C-2DP, in the TIA Portal environment.
- Establish communication between the OPC server and Siemens PLC.
- Update the LabVIEW Master I/O program to read data from the OPC server.
- Update the LabVIEW Basic Experimental Template to include both the analog instruments and PROFIBUS PA instruments.
- Develop a wiring diagram and documentation to be used by students and staff for technical purposes.
- Develop a guide on how to use the PROFIBUS PA instruments within the laboratory. This includes a guide on how to add new instruments to the network and carry out the diagnosis when there is communication failure on the network.

1.2 Project Scope

The project is focused on making the PROFIBUS network in the ICE laboratory functional. The analog and digital communications in the ICE laboratory are outside the scope of this study; as such this report only gives highlights of this system. The project focuses on PROFIBUS PA devices, therefore, other PROFIBUS variants will be highlighted. The main aim is to build a step-by-step procedure on how to facilitate communication between PROFIBUS PA instruments and the client programs. The documentation produced is focused on understanding the concepts behind different communication protocols with emphasis on the PROFIBUS Protocol and OPC server.

2. Technical Review of the communication protocols

This chapter reviews the technical information of the infrastructure and protocols used in this project. The infrastructure used in this project is the Instrumentation and control laboratory (ICE Lab) and the protocols are:

- PROFIBUS PA
- Multi-Point Interface (MPI)
- OLE for process control (OPC)
- Ethernet

2.1. Instrumentation and Control Laboratory (ICE Lab)

The Instrumentation and Control Lab is located within the Physical Sciences building (PS2-026) of Murdoch University. The laboratory is used mainly by students studying Instrumentation and Process Control to conduct experiments. Students studying the Industrial Computer Systems Engineering major also use the facility to study and explore the communication systems that are used to run the lab. The Laboratory acts a research facility for both staff and students.

The hardware used in the laboratory includes valves, tanks and heat exchangers which can be connected to the analogue and digital I/O panels when performing control experiments. Figure 1 shows the structure of the ICE lab.

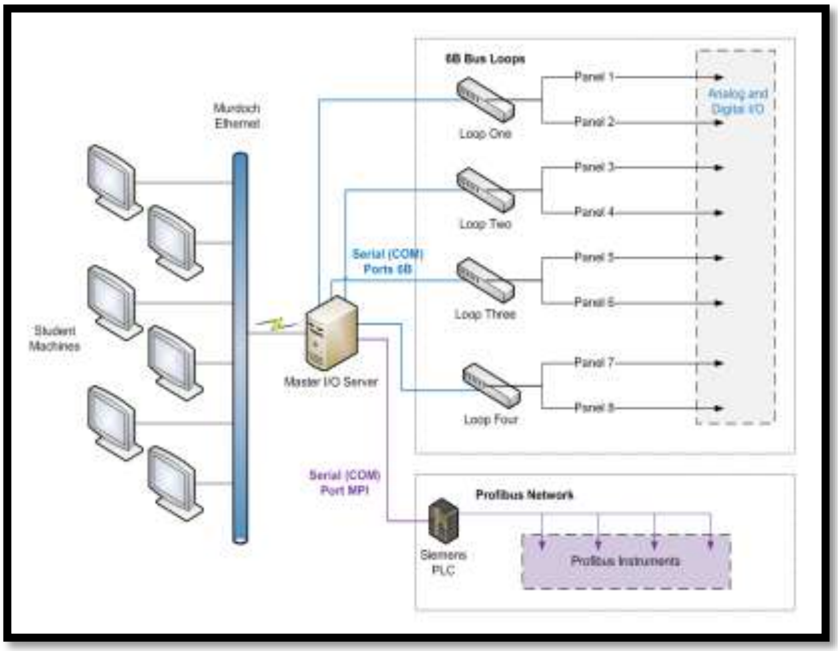


Figure 1: Layout of the ICE laboratory [2]

In Figure 1, the student machines refer to the computers that students use to run the basic experimental template. The connection between the Siemens PLC and the PC running the Master I/O program is by an MPI cable, which at present is connected when needed. Figure 2 shows an overview of the communication protocols used in the ICE laboratory.

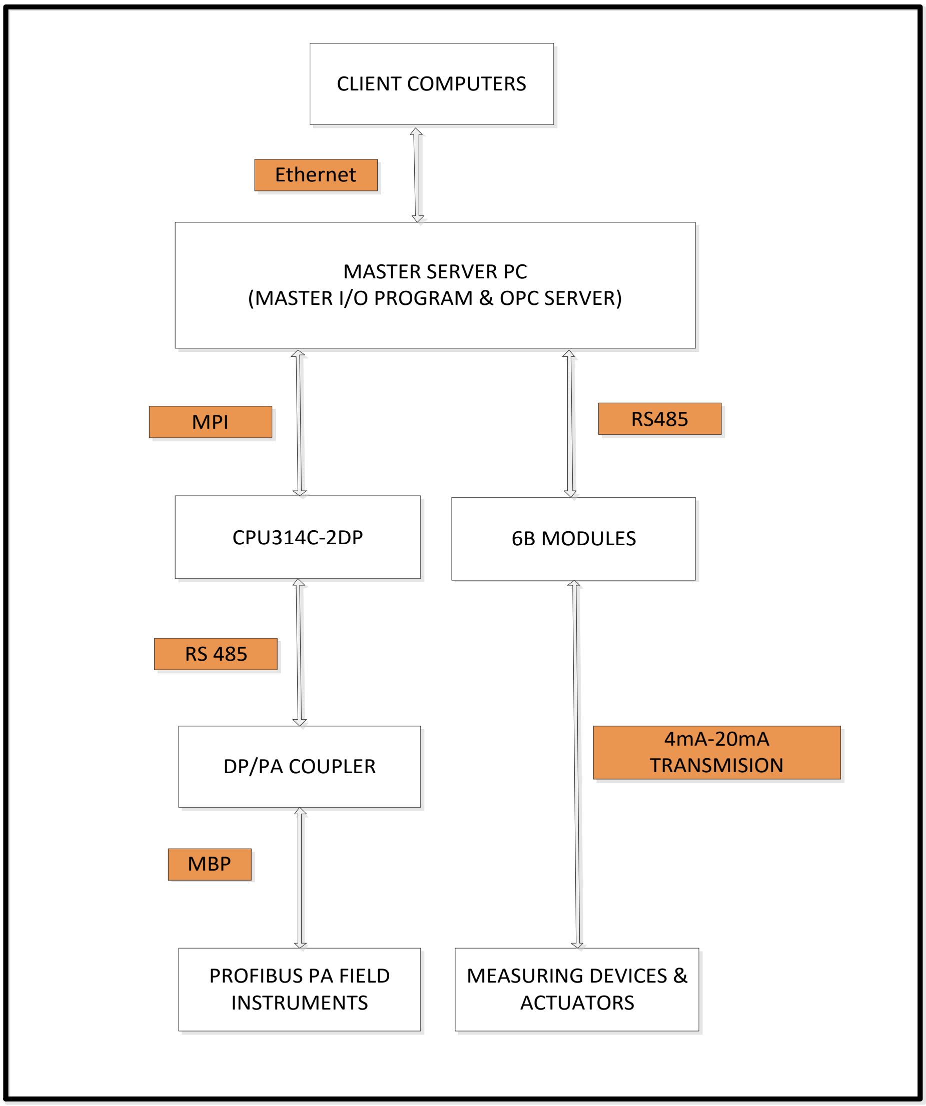


Figure 2: Overview of the communication protocols used in the laboratory

The data from the measuring devices is sent to the 6B modules which are connected to Master I/O PC by RS 485 cables. **[3]** The 6B modules provide a direct interface between the host computer and a variety of analog I/O and digital I/O applications. **[4]** The Master I/O program is a LabVIEW program which reads the inputs and writes the outputs to the 6B modules. The server is connected to the client computers by Murdoch Ethernet. Students use the basic experimental template to build control experiments in the laboratory. The communication between the Master I/O program and the basic experimental template is based on the use shared variables in LabVIEW.

2.2. PROFIBUS

"PROFIBUS is an open, vendor-independent protocol that became part of the international standard IEC 61158 in 2000." **[5]** PROFIBUS make it possible for devices of different vendors to exchange data without any special interface adjustment. PROFIBUS can be used for high-speed time critical applications and complex communication tasks. High speed communication is critical in process industry where accuracy is very important for process control. Such industries include pharmaceutical industries, water treatment plants, food process industries etc.

2.2.1. Communication Profiles

Communication Profiles define how data communication is done serially across the network **[6]**. PROFIBUS provide the following communication protocols; Field Message Specification (FMS) and Decentralized Peripherals (DP). **[7]**

2.2.1.1 Field Message Specification (FMS)

PROFIBUS FMS is the initial version of PROFIBUS and was designed to communicate between programmable controllers and PCs, sending complex messages between them. **[8]** The use of FMS is becoming less pronounced as other technologies evolve.

2.2.1.2 Decentralized Peripherals (DP)

PROFIBUS Decentralized Peripherals is commonly used for communication between automation systems and distributed peripherals. It is used for high-speed communication. The network speed can be between 9Kbs and 12Mbps depending on the medium and technology used. **[7]** "DP is suitable as a replacement for conventional, parallel signal transmission with 24 volts in manufacturing automation as well as for analog signal transmission with 4 - 20 mA current loop or Hart in process automation" **[6]**

2.2.2 Physical Profiles

The physical profile defines the transmission technology used. There are currently three transmission types existing for PROFIBUS.

- RS-485 transmission for general applications in manufacturing and automation.
- IEC 1158-2 transmission for use in process automation.
- Optical fibers for improved interference immunity and large network distances. **[6]**

Couplers or links are used to convert between PROFIBUS DP (RS-485) and PROFIBUS-PA.

2.2.3 Application Profiles

PROFIBUS Application Profiles defines the interaction of the communications protocol with the transmission technology being used. **[7]** They also identify the properties of the field devices during communication via PROFIBUS. Process Automation (PA) forms a vital part of PROFIBUS Application Profile

2.2.1.1 PROFIBUS PA

“The PROFIBUS-PA communication is based on the services provided by DPV1, and is implemented as a partial system embedded in a higher-level DP communication system.” **[9]** PROFIBUS PA is designed to have the following properties:

- Intrinsically safe transmission techniques. PROFIBUS PA can be used in explosive and hazardous areas. It can also be used for other plant application.
- Reliable data transmission. The diagnostic function of the intelligent field devices sends error messages to the master when there is a malfunction in the system.
- Interoperability. Devices from different manufacturers can operate together on the same bus line.
- Field devices are powered over the bus cable. The bus power is provided by segment couplers or links. The operating power of the bus depends on the requirements of the specific application. The sum of the individual current demands of the field devices must not exceed the maximum current output of the segment coupler.

Table 1 shows typical operating parameters of the PROFIBUS PA network

Table 1: Typical operating parameters of the PROFIBUS PA network with one segment coupler [10]

	Not Intrinsically Safe	Intrinsically Safe
Max. DC supply Voltage	≤ 32V	≤ 17.5V
Max. DC short circuit current	≤ 1 A	≤ 380 mA
Max. out power	32W	≤ 5.52 W
Max. number of devices per segment coupler	32	32 devices depending on the application

2.2.2 Characteristics of PROFIBUS

2.2.2.1 Master Slave Concept

"A PROFIBUS System comprises of a master and slaves distributed in a multi-drop fashion on a serial bus network." **[1]** A master is a controller, normally in the form of a PLC, which sends and receives messages to and from slaves. Slave devices are I/O instruments such as valves, drives and measuring devices. PROFIBUS is a bidirectional network, meaning that messages from the master to slaves and from the slaves to the master are carried on the same pair of wires. Each device on a PROFIBUS network must have a unique address. Most devices use either rotary switches (labeled in decimal or hexadecimal) or DIP switches to specify their address. The address set on the instrument must match the address used when configuring the master. For configuration of instruments in the PROFIBUS network, a General Station Description (GSD) file for each instrument is required. A GSD file defines the PROFIBUS functionality of an instrument. "It provides a way for an open configuration tool to automatically find the device properties." **[11]** GSD files can be downloaded from the Internet, normally from the manufacturer's website.

The exchange of data between a master and slave can happen in one of the two ways: cyclic and acyclic Data exchange.

2.2.2.2 Cyclic I/O Data Exchange

Data exchange takes place in a regular and repetitive manner for every slave in a master's configuration. This cyclic (repeated) I/O data exchange occurs asynchronously to the control logic scan of the master and is repeated as long as there are no interruptions occurring. "A Master transfers output data cyclically to its slaves; in return, it gets the input data. The I/O data may be accessed by the application program via the %I or %Q areas or be read or written using the function blocks GETIO and SETIO" **[12]**

2.2.2.3 Acyclic I/O Data Exchange

Acyclic I/O data exchange is an unscheduled and on-demand communication between the master and the slave. For instance, startup procedure, diagnostic massages and monitoring of field devices forms part of the acyclic communication between the master and the slave.

2.2.3 PROFIBUS Connection Technology

PROFIBUS has a wide range of applications and therefore utilize several different transmission technologies. PROFIBUS DP and FMS both can use both RS 485 (also called H2) transmission and fiber optic (FO) transmission. **[13]** On the other hand, PROFIBUS-PA uses the Manchester Bus Powered (MBP) transmission as specified in IEC 61158-2 (also called H1). **[13]**

The PROFIBUS connection technologies applied in this project are the RS 485 and Manchester Bus Powered transmission technology. The RS 485 is used between the CPU314C-2DP and the DP/PA coupler. The MBP is used between the PROFIBUS PA field instruments and the DP/PA coupler.

2.2.3.1 RS 485

PROFIBUS DP mainly uses RS 485 technology. RS 485 uses a shielded twisted pair cable connecting up to 32 devices in a single segment. **[14]** RS 485 is a differential, full duplex, multipoint serial communication protocol. Differential signaling is a technique for electrically transmitting data using two conductors carrying voltages of opposite polarity. One conductor carries a positive voltage and the other carries a negative voltage. “Information is transferred as the voltage difference between the two conductors.” **[15]**

2.2.3.2 Manchester Bus Powered (MBP) Transmission

Manchester Bus Powered (MBP) transmission is based on the IEC61158-2 transmission technique. As the name suggest, MBP provides power over the bus. “MBP works with current signals on the bus.” **[15]** The standard defines the specification to be used for PROFIBUS PA application both in hazardous areas and non-hazardous areas. Table 2 shows a summary of the differences between RS485 and MBP.

Table 2: Differences between RS485 and MBP. Adapted from [6]

	RS485	MBP
Data transmission	Digital; differential signals	Digital, bit-synchronous, Manchester coding
Transmission rate	9.6 to 12000Kbit/s	31.25Kbit/s
Power over the bus	none	yes
Intrinsic safety	yes	yes

2.2.3.2.1 Topology

The line or tree topologies can be used for MBP. The most common topology is a combination of both line and tree topology with field mounted junctions used to route cable branches to devices. The maximum length of cable to be used and the number of branches depends on the area of use. Generally, a total of up to 1900 m of cable can be used in an MBP segment, but the properties of the cable and the specifications for intrinsic safety can reduce this significantly. The limit on the number of devices connected depends on the segment power supply and intrinsic safety requirements. The sum of the input current of all devices must always be smaller than the supply current of the DP/PA coupler. "Up to 32 devices can be connected to a PA segment; however the particular characteristics of the segment power supply and/or requirements for intrinsic safety can again reduce this significantly." **[9]**

The topology used in the ICE laboratory is a combination of line and tree topology. Figure 3 shows an extract of the PROFIBUS NETWORK wiring diagram in the ICE laboratory.

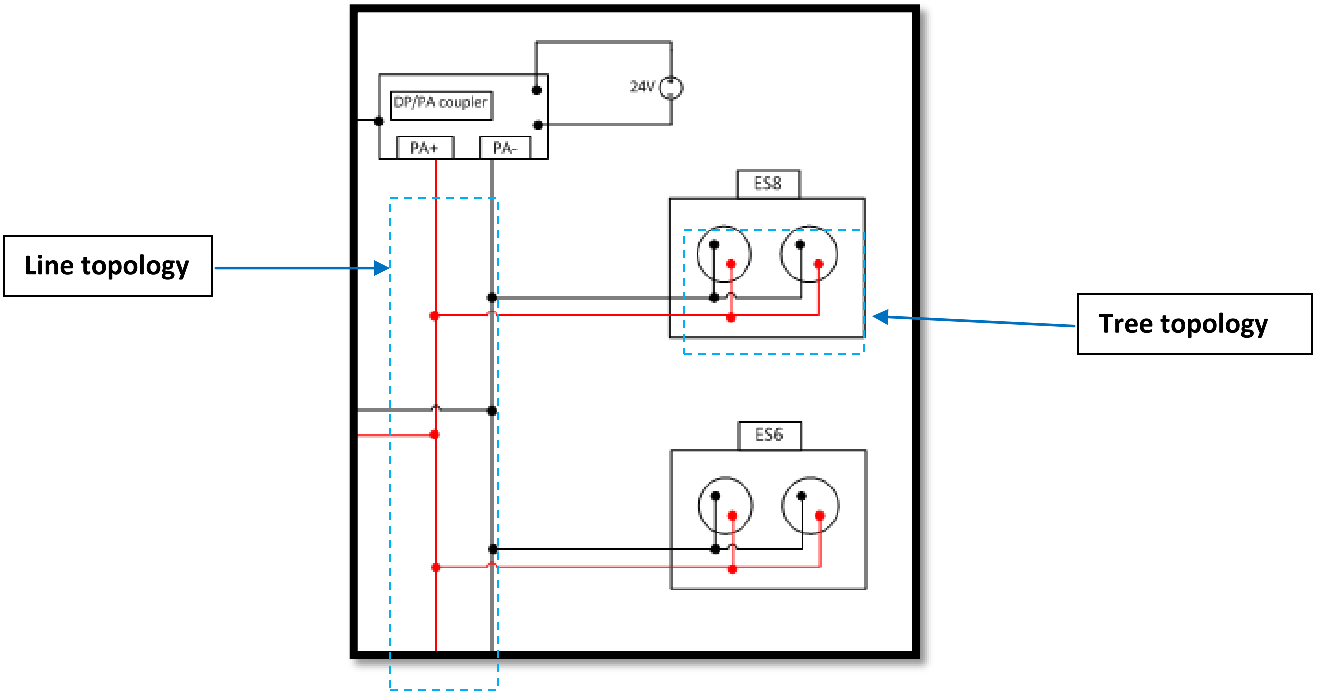


Figure 3: Line and Tree Topologies used in the ICE Laboratory

The SIEMENS DP/PA coupler FDC 157-0 provides power to the bus in the ICE laboratory. The maximum output current of the FDC 157-0 is 1 A and the operating output voltage is 31 V. **[16]** Up to 16 devices with a total power consumption of up to 31 W can be connected to the bus in the ICE laboratory.

2.2.3.2.2 Termination of PROFIBUS PA Cables

"Electrical signals travel along the length of the lines at an ultimate speed of approx. 2/3 the speed of light." **[13]** If the line is not properly terminated, the electrical energy will be reflected back along the line. The reflected signal can cause interference and distort the original signals. To minimize the effects of these reflections on transmitted signals, communication cables must be terminated properly. Figure 4 shows a properly terminated signal.

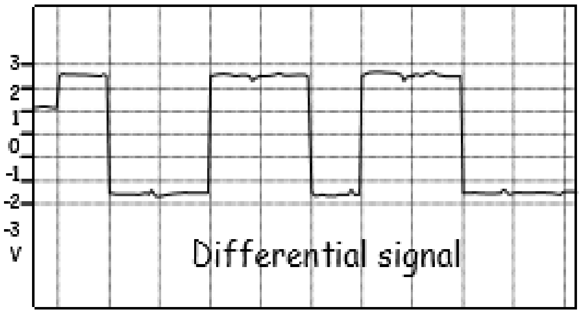


Figure 4: Properly terminated signal [13]

Figure 6 shows the effect of missing termination on a signal.

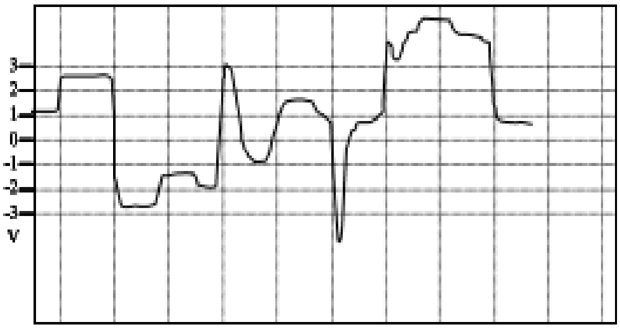


Figure 5: the effect of missing termination on a signal. [13]

The Bus terminator for PROFIBUS PA is built using a resistor and capacitor as shown in Figure 6. The main functions of the Bus terminator are to shunt the bus current and to protect the bus signal against electrical reflections. "The end of line resistor provides a normal load for communication signal and the capacitor stops DC supply draining through the resistor." **[17]**

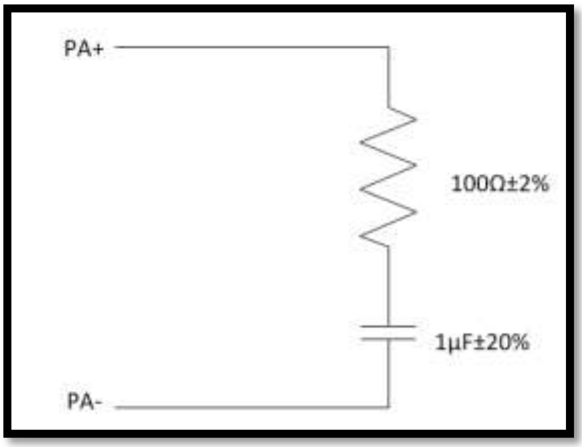


Figure 6: PROFIBUS PA termination. Adapted from [3]

Figure 7 shows a picture of the termination implemented in the ICE laboratory; a resistor of 100 Ω and capacitor of 0.5 µF are connected in series.

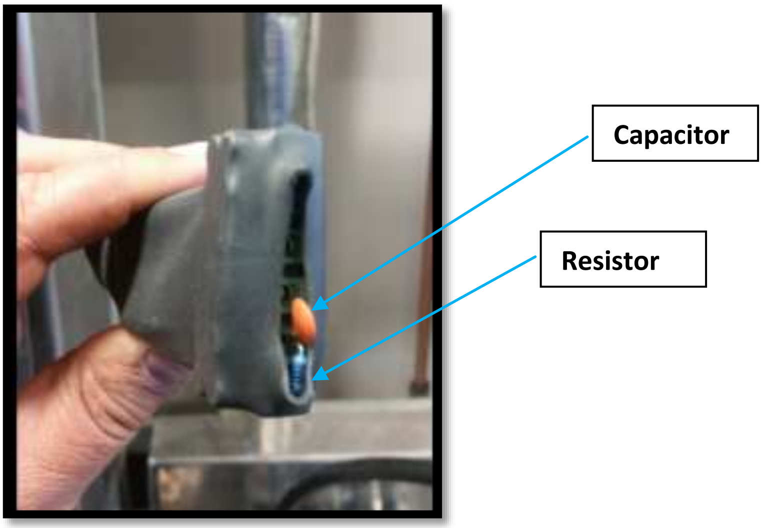


Figure 7: Picture of the termination implemented in the laboratory

2.2.3.2.3 PROFIBUS PA bus connectors

The M12 and 7/8" connectors are commonly used to connect the PROFIBUS PA devices to a bus junction. The difference between the M12 and 7/8" connectors is pin arrangement. These connectors are normally used outside control cabinets. Usually, the female connector is permanently fitted to the PROFIBUS station, and the male connector is attached to the cable connecting the field device. Figure 8 and Table 3 show the arrangement of the pins for both M12 and 7/8" connectors.

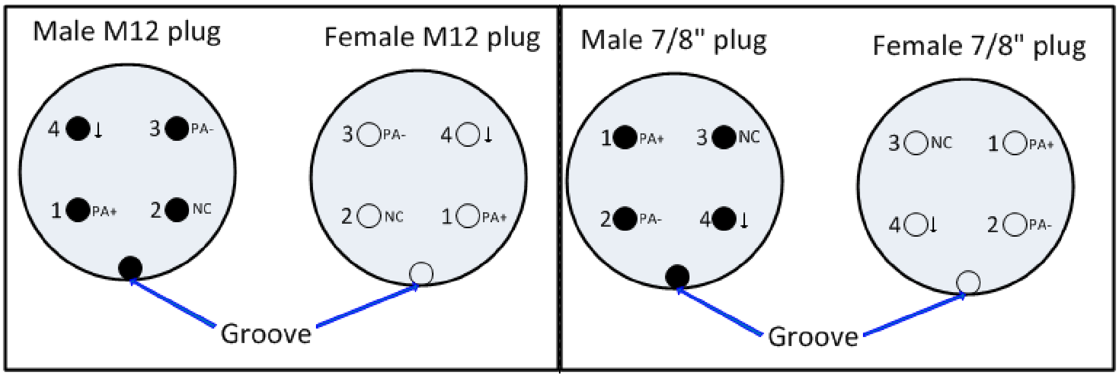


Figure 8: Arrangement of pins in an M12 and 7/8" plug. Adapted from [18]

Table 3: Arrangement of pins in an M12 and 7/8" plug. Adapted from [18]

	M12 CONNECTOR	7/8" CONNECT0R
PIN	Meaning	Meaning
1	Signal+	Signal -
2	Not Connected	Signal+
3	Signal-	Not Connected
4	Earth	Earth

Figure 9 shows a female and male 7/8" connectors used in the ICE lab to connect measuring instruments.

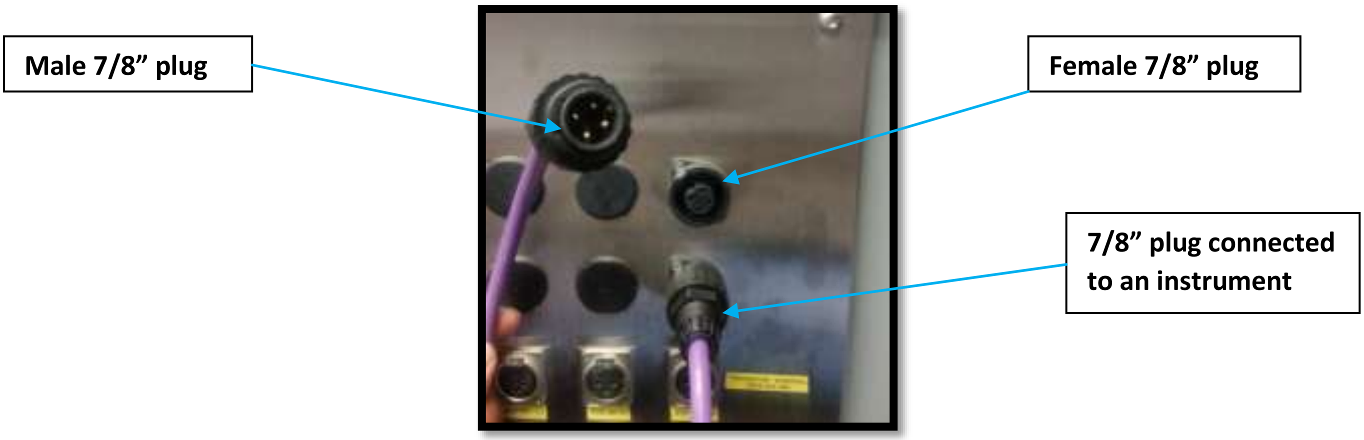


Figure 9: a picture of 7/8" connectors used in ICE laboratory

2.2.3.3 RS 485 Transmission

PROFIBUS DP normally uses RS 485 transmission which is a multi-drop communication system. The connection between SIEMENS PLC and DP/PA coupler in the ICE laboratory is using RS 485. PROFIBUS RS485 uses shielded twisted pair cable allowing communication at up to 12Mbit/s. RS485 can be used to connect up to 32 devices in a single segment (piece of cable). The bus terminator for PROFIBUS RS 485 is built using a combination of resistors. Figure 10 shows the proper way of terminating the PROFIBUS RS 485.

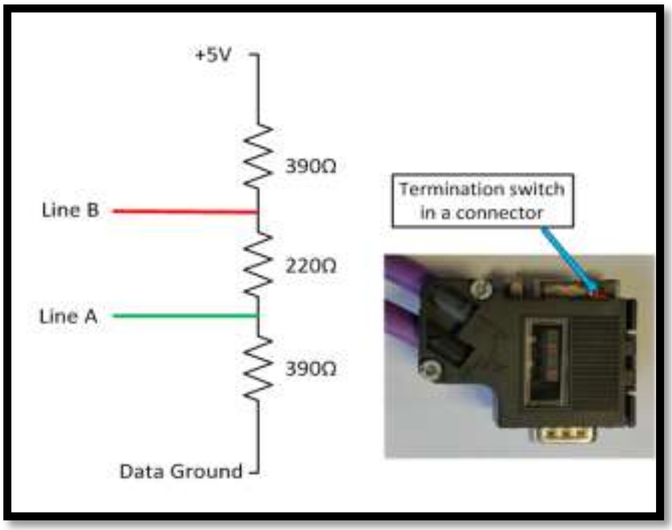


Figure 10: PROFIBUS RS 485 bus termination. Adapted from [13]

Figure 11 shows the connection between the PLC and DP/PA coupler in the ICE laboratory using the RS485.

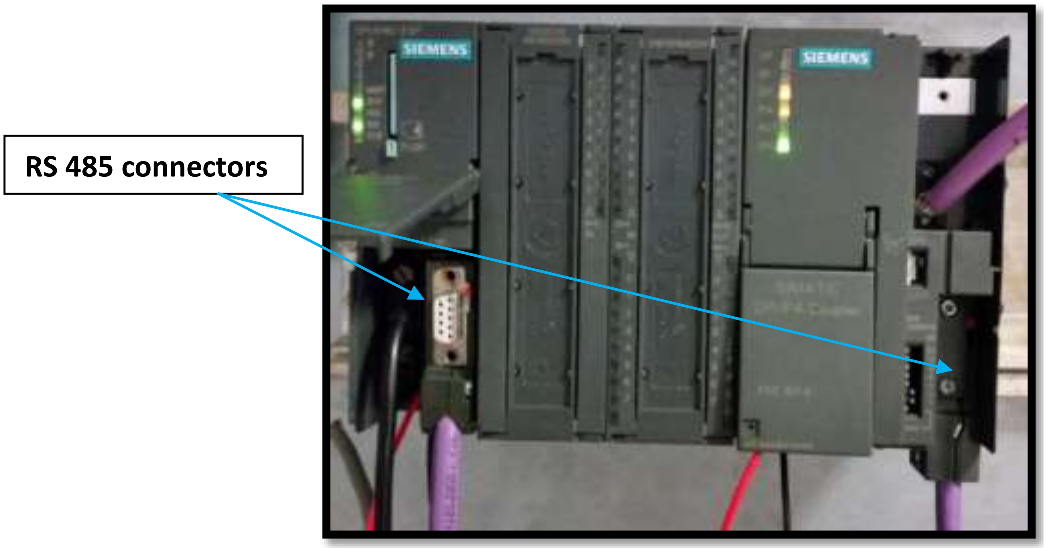


Figure 11: RS485 between CPU 314C-2DP and DP/PA coupler

2.2.4 Installation of PROFIBUS Cables

General plant or factory cables often carry high voltages and alternating currents. "Running PROFIBUS cables parallel to high voltage cables can lead to interference thus leading to data transmission errors." **[13]** Interference can be minimized by separating the PROFIBUS cable from the high voltage cables by reducing the length of any parallel runs of cables. "In general, the greater the spacing between the cables and the shorter the paths run parallel, the lower the risks of interference." **[19]** Even though it is difficult measure angles where cables cross, it is advisable that cables should cross at a 90^{o} angle as shown in Figure 12.

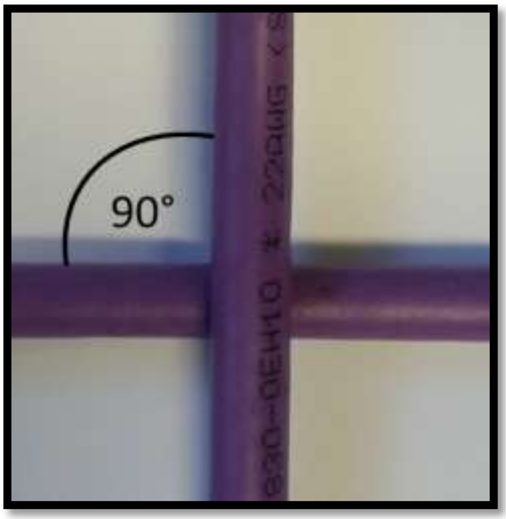


Figure 12: Cables crossing at right angle. Adapted from [14]

2.3. Multi-Point Interface (MPI)

The Multi-Point Interface commonly known as PC adapter has two variants. One is used to convert between RS232 of the PC's COM serial port c. Another variation is used to convert between USB port and RS485 (MPI port) of the SIEMENS S7-300/400 protocol. **[20]** Both the PC adapters have diagnostic LEDs to indicate the status of communication between the PLC and PC. Both of the variants are used in this project. The MPI, which converts between the USB protocol and RS485, is used during hardware configuration and programming stage. It connects the PLC to the PC when using the TIA Portal V13 software. The other MPI is used for communication between the PLC and the OPC server.

Figure 13 shows a picture of the types of MPI by SIEMENS.

Figure 13: USB MPI (Left) and Serial MPI (Right)

2.4. OLE for process control (OPC)

In this project, the OPC server is used as an interface between the Master I/O program, written using LabVIEW and the SIEMENS PLC.

"The OPC server is a software program that converts the hardware communication protocol used by a PLC to into the OPC protocol." **[21]** OPC server standard defines a way of interaction between numerous data sources and OPC clients. Data sources include devices like PLCs and HMIs while OPC clients include software like LabVIEW, which sends and receives data from data sources through an OPC server. OPC is an open standard, which means it is open to being used by devices from different manufacturers. **[22]** In a plant, only a single OPC server needs to be provided to communicate with any OPC client. Figure 14 shows a diagram of an OPC Sever used to interface between a client and PLC.

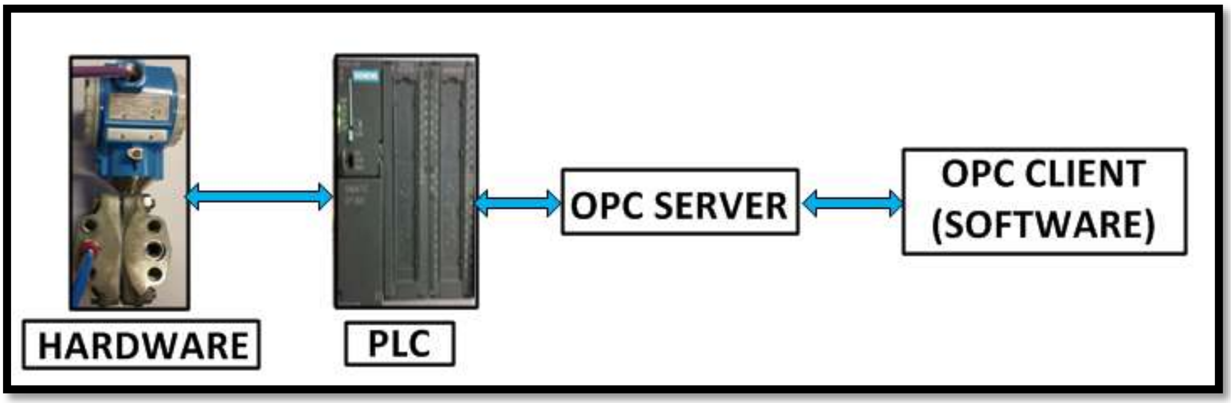


Figure 14: OPC Severs used to interface between a client and PLC. Adapted from [22]

2.5. Ethernet

Communication between the computers and the server in the ICE laboratory is by Ethernet. Ethernet is a form of networking architecture commonly based on Local Area Networks. **[23]** "A local network has been developed to ensure communication between computers, workstations, and peripherals in an area of a very limited geographical size." **[23]** The Ethernet LAN originally used coaxial cable or special grades of twisted pair wires. Recently Ethernet has evolved to include the use of wireless medium. **[23]** The type of twisted pair used in the ICE laboratory is the Unshielded Twisted Pair (UTP) CAT5, which supports transmission speed of up to 100 Mbps and full duplex communication.

3. Technical Review of the Software Packages

There were two main software packages used in this project namely, TIA Portal V13 and National Instruments LabVIEW 2016**.**

3.1 Totally Integrated Automation Portal (TIA PORTAL V13)

In this project, TIA Portal V13 is used to configure the SIEMENS CPU314C-2DP and other PROFIBUS PA devices. It is also used to program the PLC for communication with these devices.

Totally Integrated Automation **[24]** is a Siemens automation software used for configuring and programming PLCs. The TIA Portal V13 environment permits network and device configuration to be done with a single graphical editor. One of the properties of TIA portal is operability which enables it to exchange data with other systems from different vendors. TIA Portal has two main windows, the Portal View, and the Project View. Figure 15 shows network view in Project View.

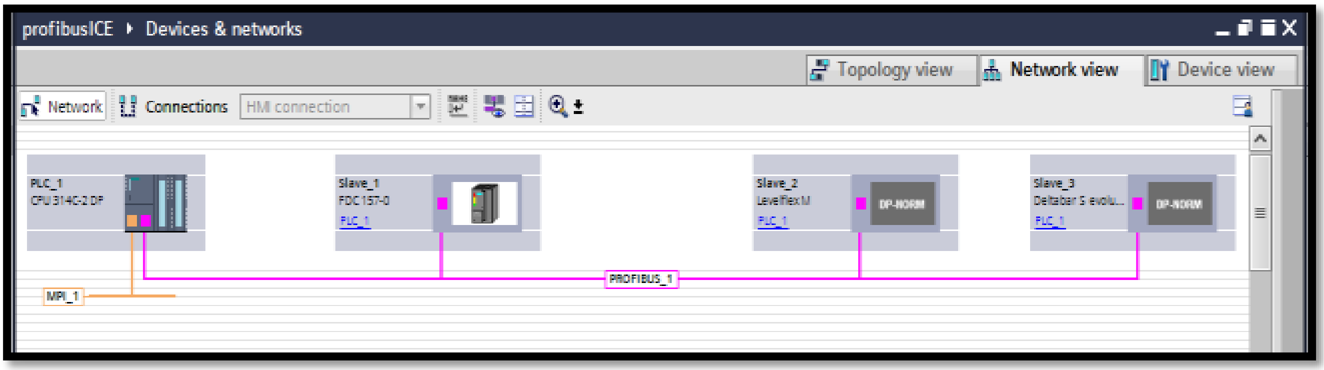


Figure 15: Network view in TIA Portal

Several languages can be used to develop programs in the TIA Portal environment. The languages include:

- Structured Control Language (SCL)
- Ladder Logic (LAD)
- Function Block Diagram (FBD)
- Statement List (STL)
- Graph

"Intuitive tools with functionalities such as drag and drop and project-wide cross-reference list are available to the user for all tasks." **[24]** The software also allows simulation without hardware. A complete program test can be carried out offline in the development office. TIA portal can communicate via the multi-Point interface (MPI), PROFIBUS DP and TCP/IP. TIA Portal V13 can be used to perform the following functions in plant automation:

- Configuration of devices and parameter assignment of the hardware;
- Defining the mode of communication to be used;
- Programming the PLCs and HMIs;
- Testing and online diagnostics;
- Real-time monitoring of the plant.

3.2 LabVIEW

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) **[25]** is a graphical programming language developed by National Instruments. LabVIEW is a dataflow programming language that means any node will only execute once all its inputs are available. LabVIEW programs have two components, a back panel, and a front panel. The block diagram (in the back panel) is an environment where the graphical code is developed. It contains structures and functions which carry out logical operations and send the results to the indicators. Structures and functions are connected using wires. An incorrect connection will appear as a broken wire, which blocks the program from running. The block diagram can also contain structures responsible for data acquisition. The front panel is mainly an HMI. It contains indicators and controls. Figure 16 shows the back panel and front panel of a LabVIEW program

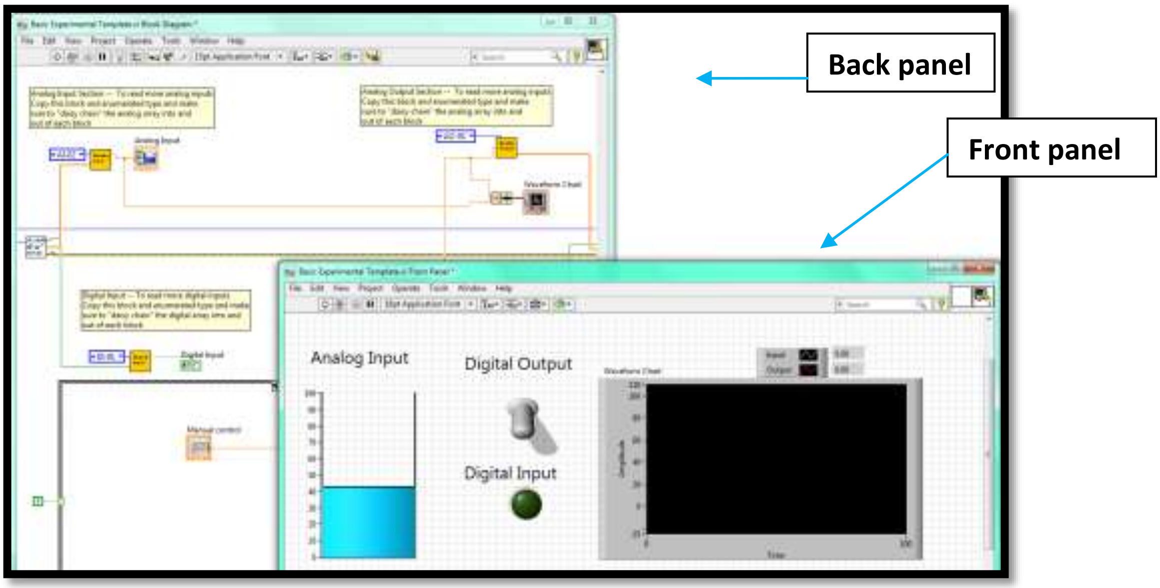


Figure 16: Back panel& Front Panel of Label [25]

The programming environment uses a drag and drop approach which makes it easy to build programs. The LabVIEW programming environment, with the incorporated examples and documentation, makes it simple to build small applications. The software also allows simulation without hardware and can also be used for real-time monitoring of a plant.

4. Technical review of the equipment

This chapter reviews the equipment used in this project. It explains the basic properties of the equipment and their relevance to the achievement of the objectives of this project.

4.1. Siemens PLC (CPU314C-2DP)

The Siemens PLC (CPU314C-2DP) is used as a Master in the PROFIBUS network in this project. The CPU314C-2DP is a Programmable Logic Controller from the S7-300 product family. **[26]** The CPU314C-2DP comes with an integrated PROFIBUS DP interface and integrated analog and digital I/O inputs. "The following PROFIBUS protocol profiles are available for the CPU 314C-2DP:

DP interface as master according to Europian fieldbus standard, EN 50170

DP interface as a slave according to EN 50170." [2]

Figure 17 shows a picture of CPU 314-2DP.

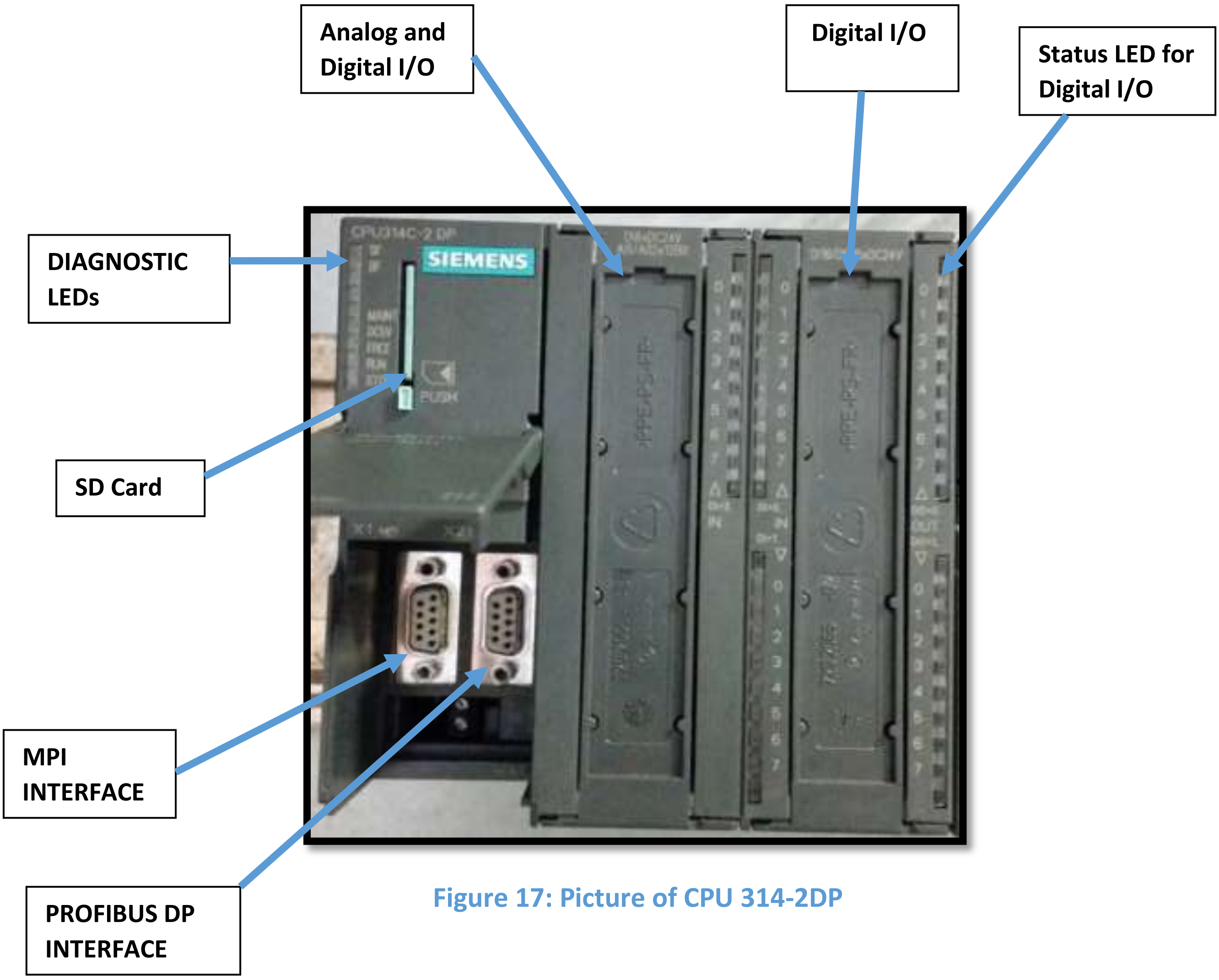


Figure 17: Picture of CPU 314-2DP

The CPU314C-2DP has the following features:

- “High processing speed in binary operations and floating point arithmetic.
- Non expandable integrated RAM of 48 KB for program and data processing.
- Load memory in the form of a micro-memory card of 64KB to 4MB.
- 8192 bytes of DI/DO
- 512 bytes AI/AO
- 256 counters, 256 timers, and 256 clock memory bytes
- 24 DIs, including 16 which can be used for integrated functions; all can be used as alarm inputs as well
- 16 DOs, integrated
- 4 AIs for current/voltage, 1 AI resistor integrated
- 2 AOs for current/voltage, integrated
- 4-channel counting and measuring with 24 V (60 kHz) incremental encoders” **[27]**

Table 4 shows the color when ON, meaning of status LED display on the CPU314C-2DP.

Table 4: Meaning of STATUS LED display. Adapted from [26]

LED designation	**Color (ON)**	**Meaning**
SF	Red	Hardware or Software error
BF	Red	PROFIBUS DP bus error
DC5V	Green	5V power for CPU and S7-300 bus is ok
FRCE	Yellow	Force job active
RUN	Green	CPU in RUN mode
STOP	Yellow	CPU in STOP or HOLD mode

The **SF LED** represents a fault in hardware or software. Examples of hardware faults include faults in the configured devices such as mismatching address and communication breakdown between devices. Examples of software faults include omission of required block in the program.

BF LED represents PROFIBUS bus faults like line breakage or when configured a instrument is not seen by the master.

4.2.SIEMENS SIMATIC DP/PA coupler FDC 157-0

The DP/PA coupler is an interface module that connects PROFIBUS-PA to PROFIBUS-DP. In this project, the DP/PA coupler is used an interface between the PROFIBUS PA field instruments and the Siemens PLC (CPU314C-2DP). The general features of DP/PA coupler include:

- Isolation between PROFIBUS-DP and PROFIBUS-PA
- Conversion between RS 485 and IEC 1158-2 transmission media
- Diagnosis using LEDs
- Integrated supply unit for PROFIBUS-PA
- Provides power to the PROFIBUS PA field devices. **[10]**

During configuration, the transmission rate on the DP side must be set to 45.45 Kbps and 31.25 Kbps on the PA side. The DP/PA coupler can be used to connect devices where intrinsic safety is a requirement. "The total current of all the field devices must not exceed the maximum output current (1 A) of the DP/PA coupler." **[16]** The DP/PA coupler must be installed outside the hazardous areas while the field devices can be connected inside. The DP/PA coupler needs a 24V DC supply. Figure 18 shows a picture of the DP/PA coupler.

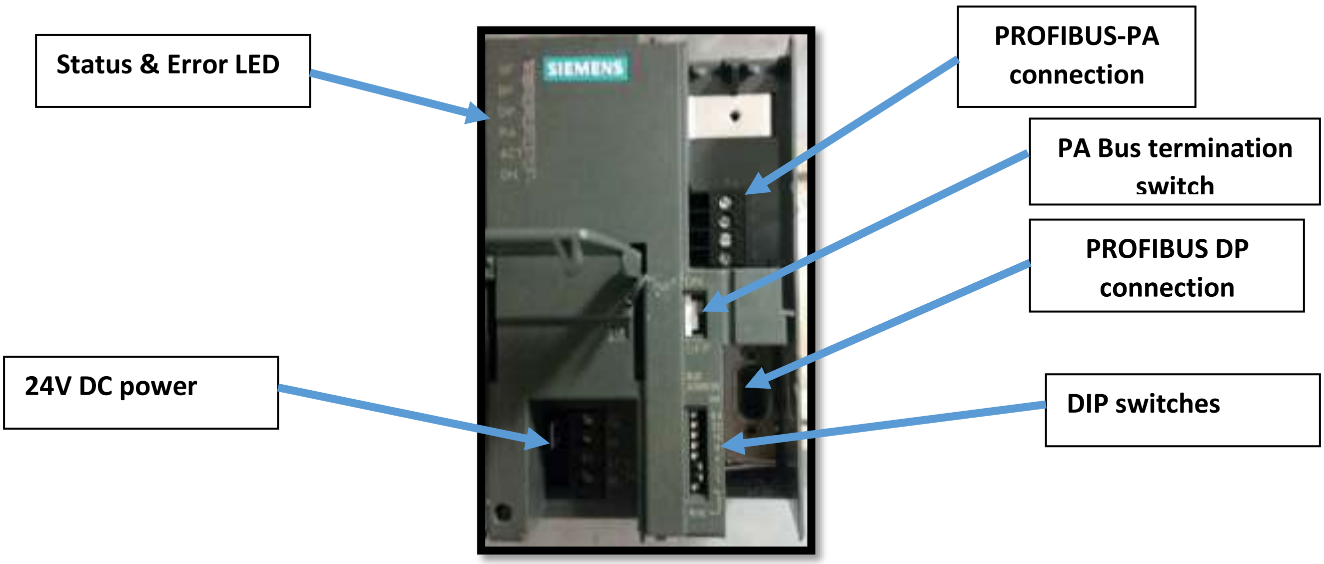


Figure 18: Picture of the DP/PA coupler

FDC 157-0 has status and error LEDs. Table 5 shows the color when ON and the meaning of status LEDs.

Table 5: Meaning of status LEDs. Adapted from [16]

LED designation		Colour	Meaning
SF	ON	Red	Hardware or Software error
BF	ON	Red	Bus error
DP	Flashing	Yellow	PROFIBUS DP data being received
DP	OFF	Yellow	Master Not in operation
PA	Flashing	Yellow	PROFIBUS PA data being received
PA	OFF	Yellow	NO response from PROFIBUS PA devices
ACT	Flashing	Yellow	Overload of the PROFIBUS-PA
ON	ON	Green	24V Power ON.

4.3. Levelflex M FMP40

In this project, the Levelflex M FMP40 is used as a PROFIBUS PA field instrument. The Levelflex M FMP40 is a compact level transmitter for measuring the level of solids and liquids constantly. **[28]** The LevelFlex M FMP40 is manufactured by Endress+Hauser. The Levelflex M FMP40 employs a Time of Flight method to measure level. High-frequency radar **[29]** pulses are introduced to a probe and move along the probe. "The pulses are reflected by the surface of the substance being measured, received by the electronic evaluation unit and changed into level information." **[28]** Figure 19 shows the LevelFlex M FMP40 installed in a tank.

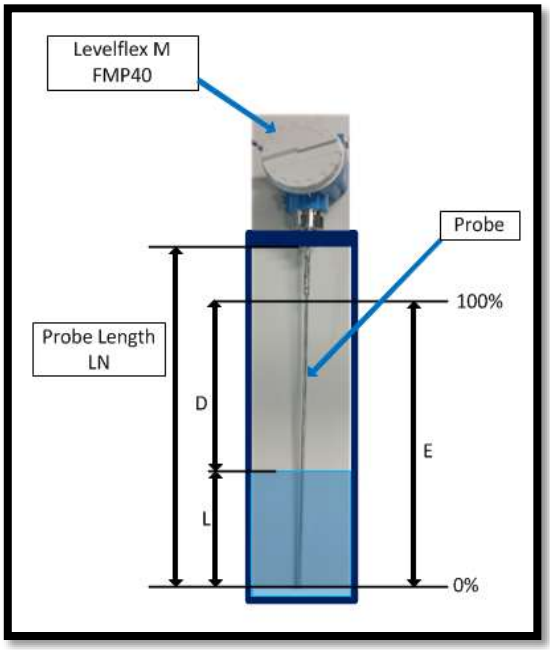


Figure 19: Levelflex M FMP40 installed in a tank. Adapted from [29]

In figure 19, D is proportional to the flight time (t) of the radar pulse. Radar pulses travel at the speed of light.

$$D = \frac{c.t}{2}$$

Where **c** is the speed of light.

The level (L) is calculated based on the knowledge of empty distance (E).

$$L = E - D \quad \textbf{[29]}$$

The Levelflex M FMP40 can be integrated into the PROFIBUS PA and connected to a bus system where the bus voltage is supplied by the DP/PA coupler. The Levelflex M FMP40 can be used in hazardous and explosive areas. In explosive areas, the Levelflex M FMP40 is designed to have an operating voltage of 17.5 V and current of 11 mA. **[29]**

Before using the Levelflex M FMP40, it has to be wired properly and connected to the bus network. Figure 20 shows how the correct way of wiring the Levelflex M FMP40.

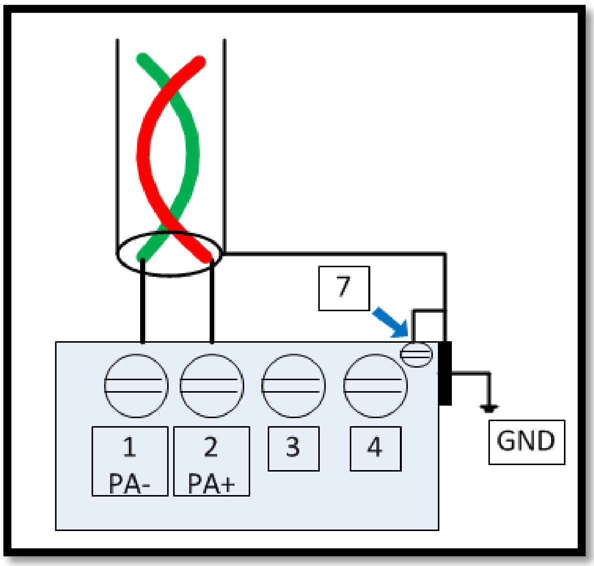


Figure 20: Wiring of the Levelflex M FMP40. Adapted [29]

In Figure 20, terminal 1 is negative and terminal 2 is positive on the PROFIBUS PA bus wire. Terminal 7 and the shield are connected to instrument ground.

4.4. Deltabar S PMD70

The Deltabar S PMD70 is used as another PROFIBUS PA field instrument The Deltabar S PMD70 **[30]** is a pressure measuring device manufactured by Endress+Hauser. The Deltabar S PMD70 can measure several parameters including flow rate and liquid level, employing the principle of differential pressure. It uses the ceramic process isolating diaphragm which employs the principle of a plate capacitor to measure differential pressure. "When one plate of a capacitor is displaced relative to the other, the capacitance between the two plates changes." **[31]** The change in capacitance can be related to the pressure applied to the plates. Figure 21 shows the ceramic measuring cell used in the Delta Bar S PMD70.

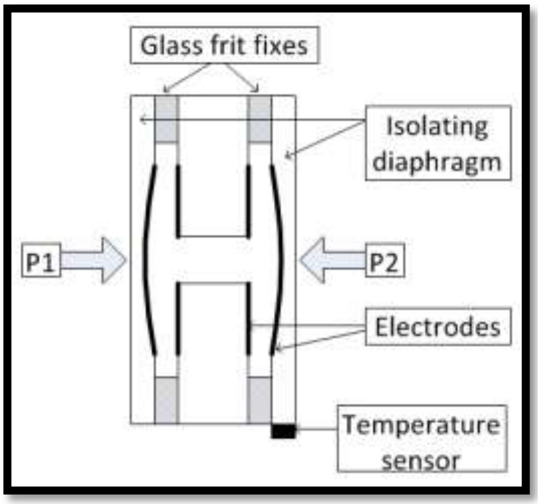


Figure 21: Ceramic measuring cell used in the Delta Bar S PMD70. Adapted from [30]

The ceramic measuring cell uses an electrode on a metal body (1) and a movable electrode on the interior of the isolating diaphragm. "A differential pressure (p1 ≠ p2) causes a corresponding deflection of both diaphragms." **[30]** The resulting capacitive values are converted and passed into the microprocessor for signal

The Deltabar S PMD70 can use the PROFIBUS PA communication protocol. It is intrinsically safe, therefore it can be used in hazardous and explosive areas. For information about the usage in hazardous areas, refer to The Deltabar S PMD 70 technical information manual page 25. The Deltabar S PMD 70 must be properly installed and wired to the bus. Figure 22 shows a proper way of wiring Deltabar S PMD70 to the PROFIBUS PA bus.

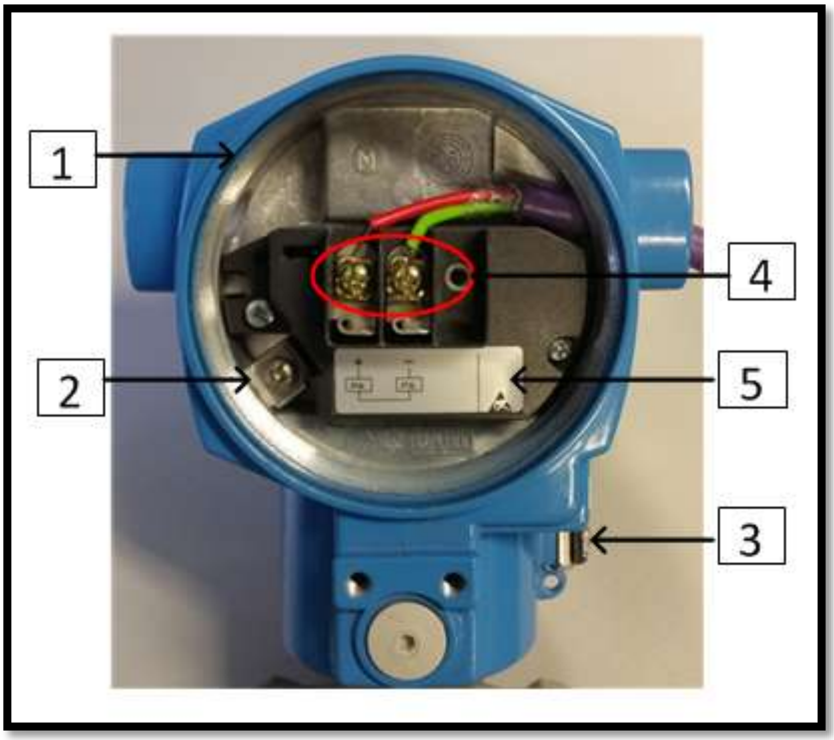


Figure 22: Electrical connection of Deltabar S PMD70 for PROFIBUS PA

In Figure 22, the positive wire of the PROFIBUS network is connected to +PA and the negative wire is connected to -PA. The meanings of the numbers in Figure 22 are shown in Table 6.

Table 6: Meaning of numbers in figure 22 [18]

Number	Meaning
1	PMD70 housing
2	Internal earth connection
3	External earth connection
4	Supply voltage and signal wires
5	Overvoltage protection label

5. Network Testing

The PROFIBUS network in the ICE laboratory was built several years ago, and several students have worked on it over the intervening years. It is common to have physical damage in the communication and electrical networks. These damages can affect proper functioning of the networks.

5.1 Purpose of Network Testing

The purpose of testing the network is to locate the faults and apply corrective measures. The common faults that can occur include.

- **Damaged cables** e.g. over bent cables

The damaged cable can distort the data transmitted. When they are located in the network, they must be replaced. Figure 23 shows an example of over bent cable.

Figure 23: Example of over bent cable

- **Short circuits in the network.**

When there is a short circuit in the network, a large current flow which can destroy the power source and the instruments in the network. A short circuit will also affect data transmission in the network. When located, the wires that created a short circuit must be separated and insulated.

- **Discontinuous wiring.**

The wires must be tested for continuity. Discontinuous wires will cut power and communication with the rest of the network. Broken lines will also introduce an unexpected end to the line and therefore termination problems. When located, broken wires must be replaced or soldered together.

Network testing in the lab was done to check short circuits and continuity of the PROFIBUS line and branches.

5.2 Instruments

There are several instruments from different manufacturers that can be used to test the PROFIBUS PA bus network. Availability of tools and objective of the test determine the appropriate instrument to be used. Some of the instruments that can be used to test the PROFIBUS PA network include:

- PROFIBUS PA Tester (BC-230-PB)
- Protek 506 Multi Meter

5.2.1 PROFIBUS PA Tester (BC-230-PB)

The PROFIBUS PA Tester **[32]** is an instrument designed to test PROFIBUS PA networks during operation. The PROFIBUS PA Tester gets power from the network and therefore does not need external power source. Once connected to the PROFIBUS PA network, the instrument automatically starts testing the segment without operator intervention. During testing, the instrument determines the following:

Segment voltage

The PROFIBUS PA Tester can be used to measure the DC voltage of the network. The DC voltage limits can be configured so that the tester can give warning when the voltage is outside the limit.

Noise

The PROFIBUS PA Tester can measure average noise and peak noise of the signal. Both average noise and peak noise are measured in three bands: frequencies in the fieldbus signaling band (Fieldbus Frequency, FF), frequencies below the fieldbus signaling band (Low Frequency, LF) and frequencies above fieldbus signaling band (High Frequency, HF). **[32]** The values are presented in milli Volts (mV). e.g. If the FF band noise level is above the allowed limit (**75 mV** by default), the Tester will display will **BAD** as shown below.

PK FF NOISE

99 mV BAD **[32]**

Short circuits between the individual signal wires

The PROFIBUS PA Tester can also be used to test the short circuits in the network. If the segment wiring is good, the PA Monitor will display

WIRING OK . [32]

The report of the test can be downloaded to the computer by USB port. The PROFIBUS PA Tester is intrinsically safe, and can be used in explosive areas. For information about use in explosive and hazardous areas refer to PROFIBUS PA DIAGONISTIC MONITOR BC-230-PB manual.

5.2.2 Protek 506 Multi Meter

When simple tests on the PROFIBUS network are required, a multimeter can be used. A multimeter has several functions which include measurement of resistance and capacitance. It can also be used to test continuity in the wires. Figure 24 shows a picture of Protek 506 Multimeter.

Limitation of the Multimeter in testing PROFIBUS Network

- Cannot measure noise in the signal.
- Cannot be configured to give warning when the measured value is outside the range.

Figure 24: A picture of Protek 506 multimeter

5.2.3 Methodology

A multimeter was used to test the wiring in the ICE laboratory because of unavailability of advanced testers and it can do the test required.

5.2.4 Testing of continuity and short circuits in the network

All devices including the DP/PA coupler were disconnected from the network. A resistor of 300Ω was connected at the end of the line as shown in Figure 25.

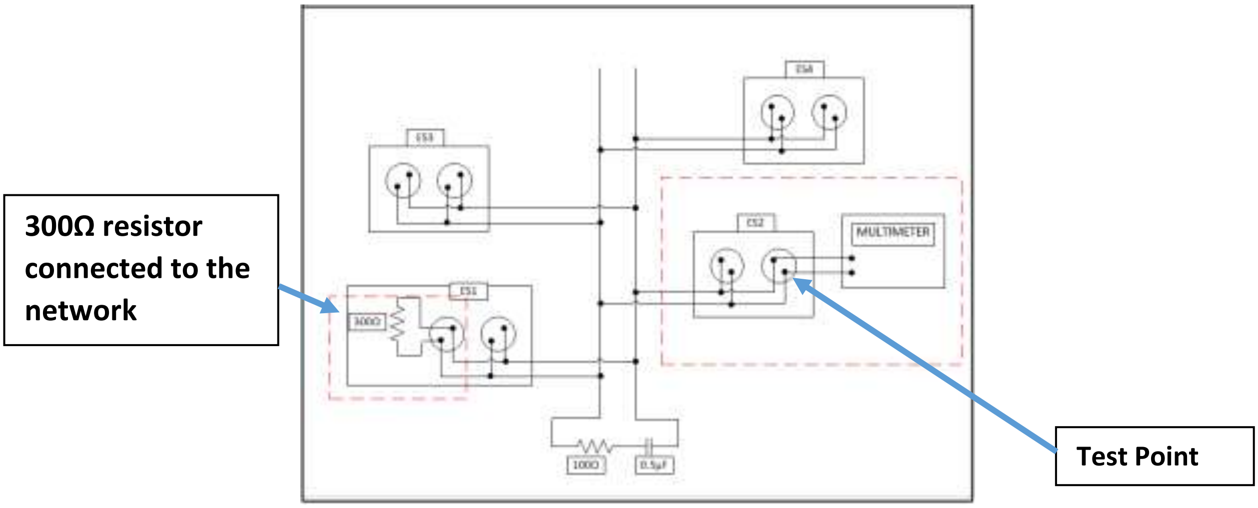


Figure 25: An extract of the wiring diagram

A multimeter was used to test the resistance at each socket. The resistor remained at the end of the line during testing. Table 7 below shows the expected multimeter reading under different faults conditions.

Table 7: Expected multimeter reading under different faults conditions.

Network Status	**Expected results**
Good	~300
Short circuit	Very low resistance
Broken lines	Very High resistance or open circuit

5.2.5 RESULTS

The results obtained from the network testing show that the network had no faults. There were no short circuits or broken lines detected in the lab. The termination mechanism was also tested and found to be in a good working condition.

From the test done, it can be concluded that the PROFIBUS network in the ICE laboratory was free of faults.

6. Configuration of the Siemens CPU 314C-2DP

For this project, the Siemens CPU314C-2DP PLC will be used as the master in the PROFIBUS network and will be programmed using STEP 7 Professional V13 (TIA Portal V13) programming software.

6.1 Project

To implement a program in a PLC, the first step is to build a project using TIA Portal. A project contains the configuration data for all the devices. It also contains the arrangement of devices in the network as well as the programs. There are two main views in TIA Portal V13: the Portal View and Project View. Portal view is the default view, so when TIA Portal V13 is started, it displays the portal view.

6.2 How to create a project in TIA Portal V13

The following steps are taken to create a project in TIA Portal, assuming TIA portal is already installed in the computer to be used.

1. Open TIA portal by clicking on the start button and then TIA Portal V13.

Start ⟶ **all programs** ⟶ **TIA portal V13.**

Or if the shortcut is on the desk, double click on the icon shown in Figure 27.

Figure 26: TIA Portal V13 shortcut icon

Once TIA portal is opened, the portal view will be displayed. In portal view click on,

Start ⟶ **Create new project.**

Figure 27 shows a window of the Portal View.

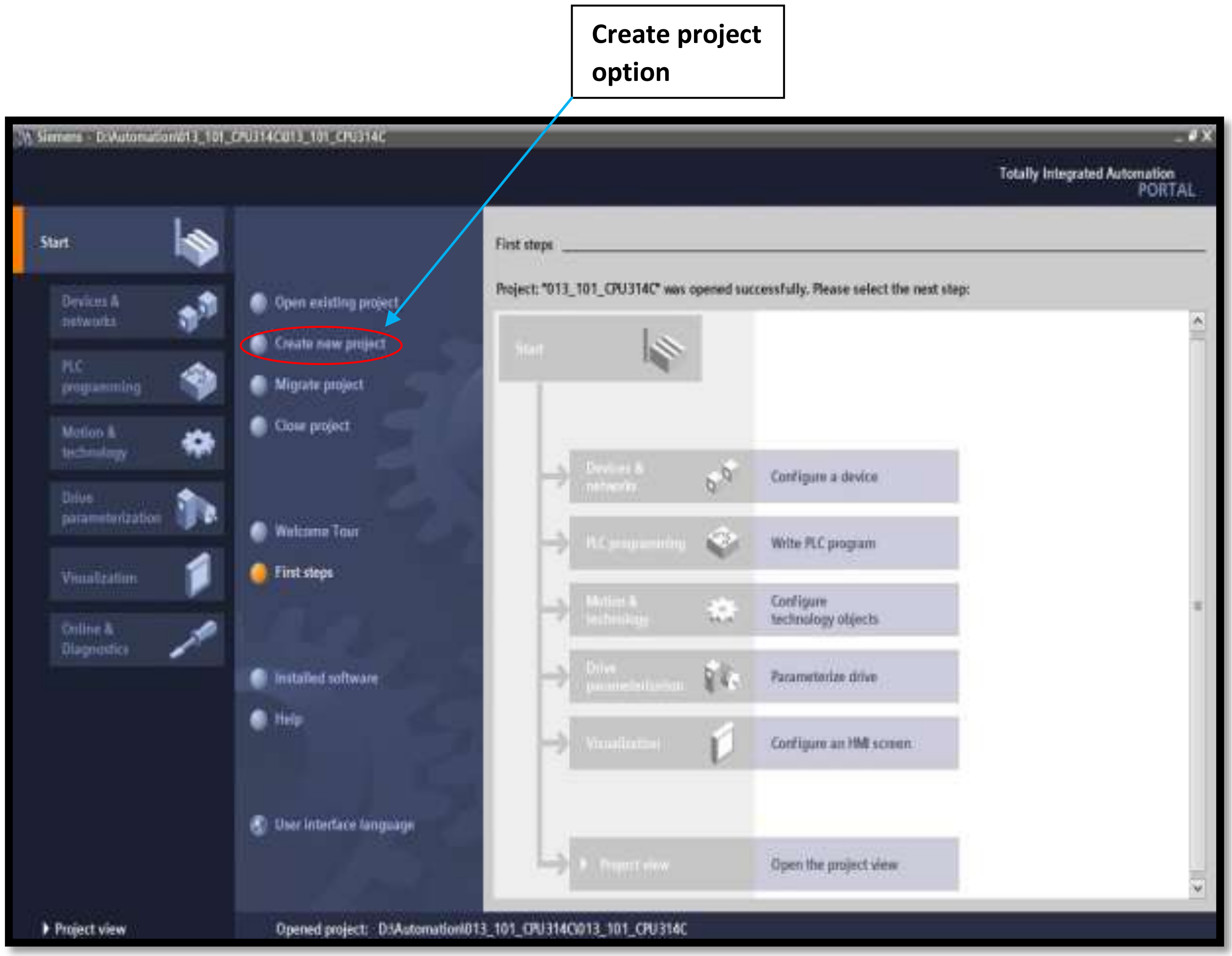


Figure 27: Portal View of TIA Portal

2. A new window will appear that comes with a default name, path and author of the project. All these parameters can be changed to suit the user's needs. Figure 28 shows the window for specifying the properties of the project.

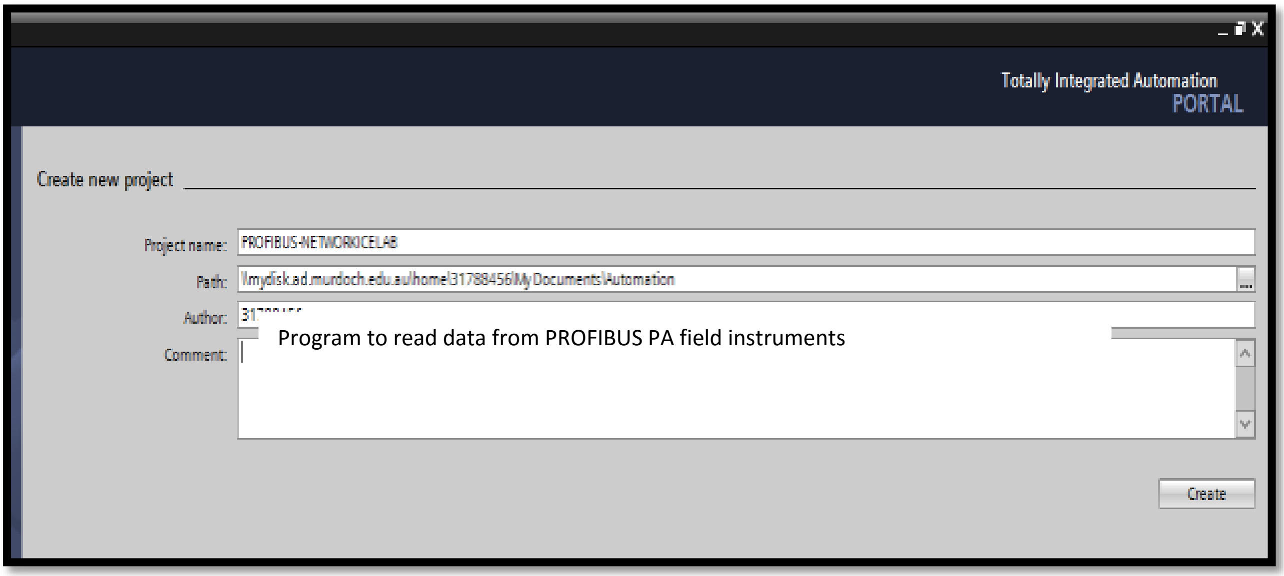


Figure 28: Window for specifying the properties of the project.

After the parameters have been modified, then click on the **Create** icon.

3. On completion of step 2, the first steps menu will be opened automatically. On the top left of the window, click on,

Devices & Networks → Add new device → SIMATIC S7-300 → CPU → CPU314C-2DP.

On the scroll down menu choose CPU314C-2DP →6ES7 314-6CH04-0AB0 and then click on the Add button. The chosen CPU must have the same properties as the physical CPU 314C-2DP to be used.

Figure 29 shows the portal view display when adding CPU 314C-2 DP to the project.

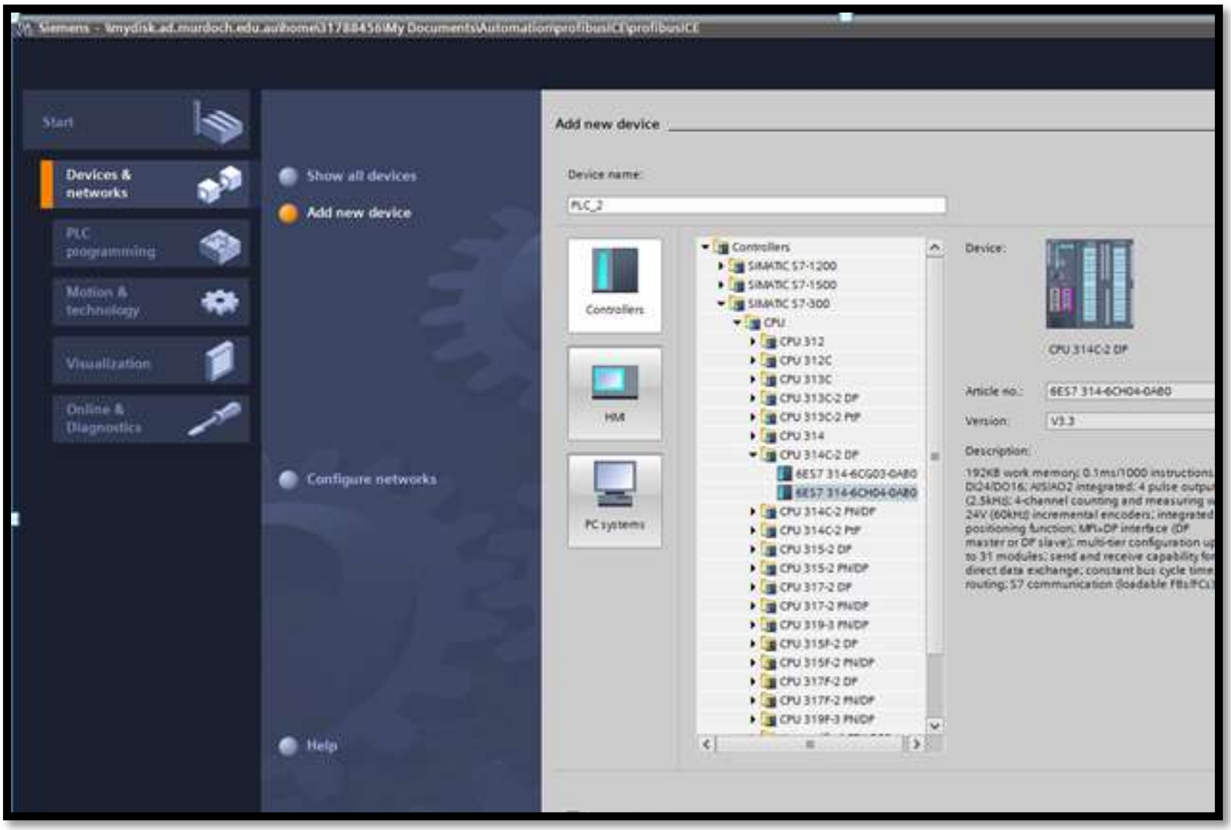


Figure 29: Window of portal view display when adding CPU 314C-2 DP to the project

Once the CPU has been added to the project, the window will automatically switch to Project View. Project View provides necessary tools for hardware configuration and creating the program. “Project View displays the menu bar with the toolbars at the top, the project tree with all components of a project on the left and the cards with instructions and libraries.” **[24]** Figure 30 shows the window of the project view.

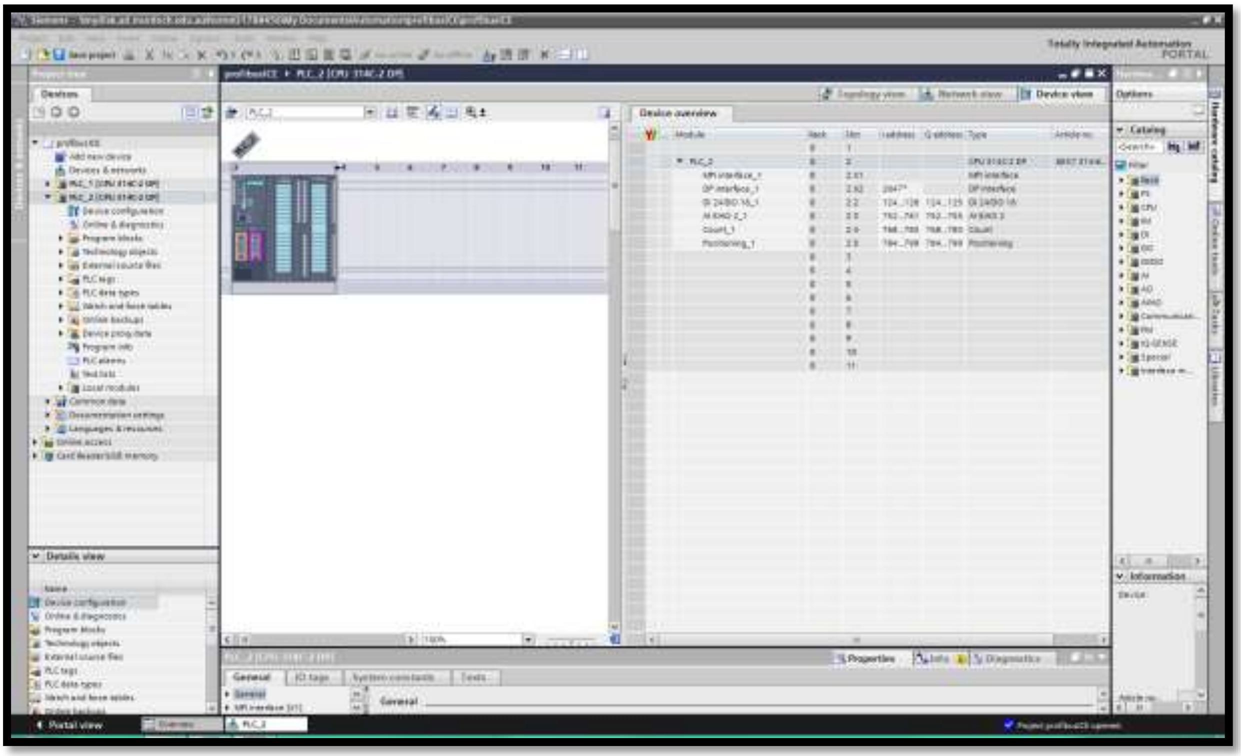


Figure 30: Window of the project view

6.3 Hardware configuration

The hardware of automation systems consists of controllers (CPUs) or PLCs, I/O modules, field sensors and actuators, interface modules and communication processors. Hardware configuration includes the initial settings and arrangement of the devices in the project. This is done by selecting hardware components from the hardware catalog, positioning them in the project and setting their properties, memory locations, addresses and operational limits. Communication between devices is defined in the network configuration.

When the CPU 314C-2 DP is added to the projected, the following modules are already configured by default:

1. Rack
2. MPI interface
3. DP interface
4. DI 24/DO 16
5. AI5/AO 2
6. Counter
7. Positioning

More capabilities can be configured when needed.

7. Configuration of the DP/PA coupler FDC 157-0

In this project, the DP/PA coupler acts as an interface between the CPU314C-2DP and the DP/PA coupler. For the DP/PA coupler to communicate with the Siemens CPU314C-2DP, it must be configured, and the configuration must be downloaded to the CPU314C-2DP.

7.1 Installing a GSD file

A General Station Description (GSD) is needed to configure and use the DP/PA coupler in the TIA Portal V13 programming software. “GSD files provide a way for an open configuration tool to automatically get the device characteristics and are provided by the vendor.” **[11]** The GSD files can also be downloaded online from the manufacturer’s website. The following steps were implemented to install a GSD file for the DP/PA coupler in the TIA V13 software.

1. In the TIA Portal V13 project view, click on options, at the top of toolbar menu, and a drop down menu will appear. Then click on Manage General Station Description file and a new window will appear.
2. Choose the source path of the file and click install.

Figure 31 shows the window that will appear when installing a GSD file.

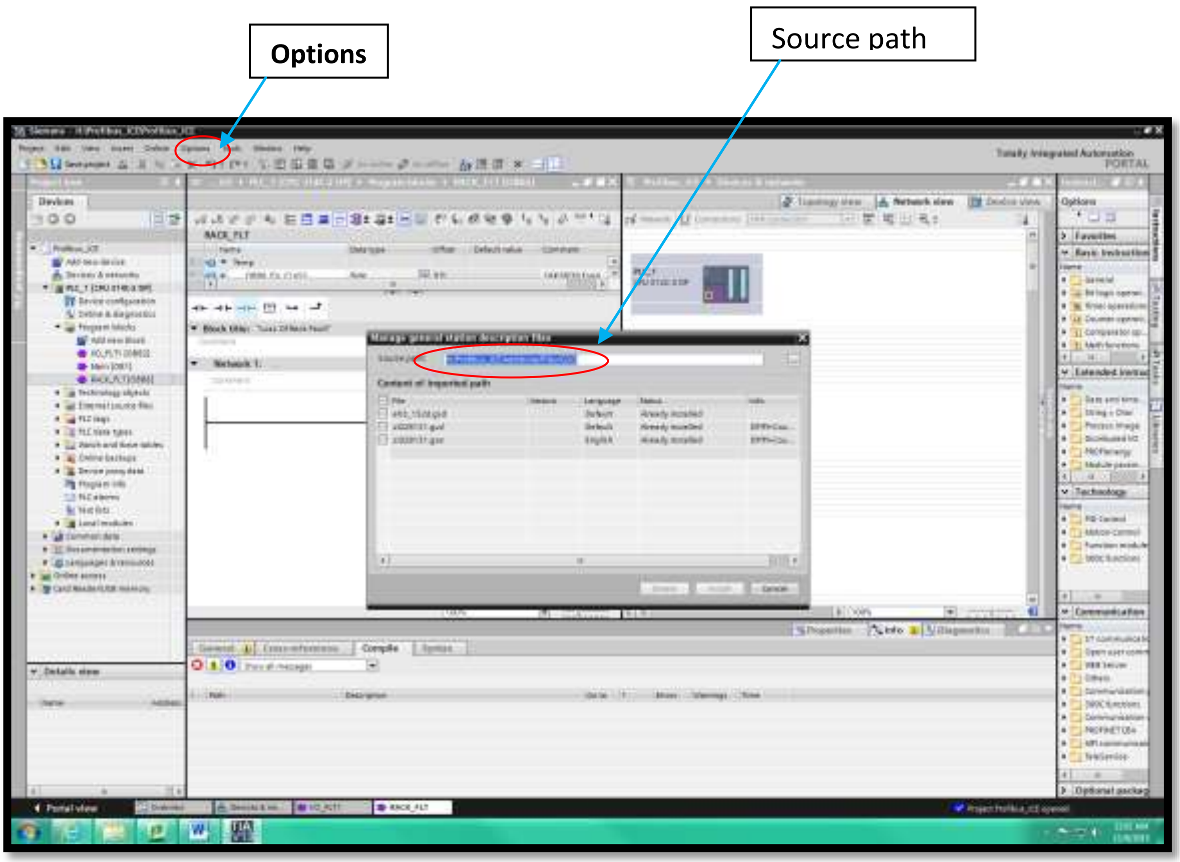


Figure 31: Window for installing GSD file

7.2 Address of DP/PA coupler

Each slave in the PROFIBUS network needs an address to identify it uniquely in the network. The address of the DP/PA coupler is set using the DIP switches. The address of the DP/PA coupler is set according to Table 8. The PA address is the addition of the switches in the ON position.

Table 8: Value of address for DIP switches in the ON position. Adapted from [10]

DIP Switch Number	0	1	2	4	8	32	64
Address value	RING	+1	+2	+4	+8	+32	+64

Example

Figure 32 shows DIP switches configured for address 3. DIP switches 1 and 2 are in the ON position and the rest of the DIP switches are in off position.

PROFIBUS PA ADDRESS = 1+2=3

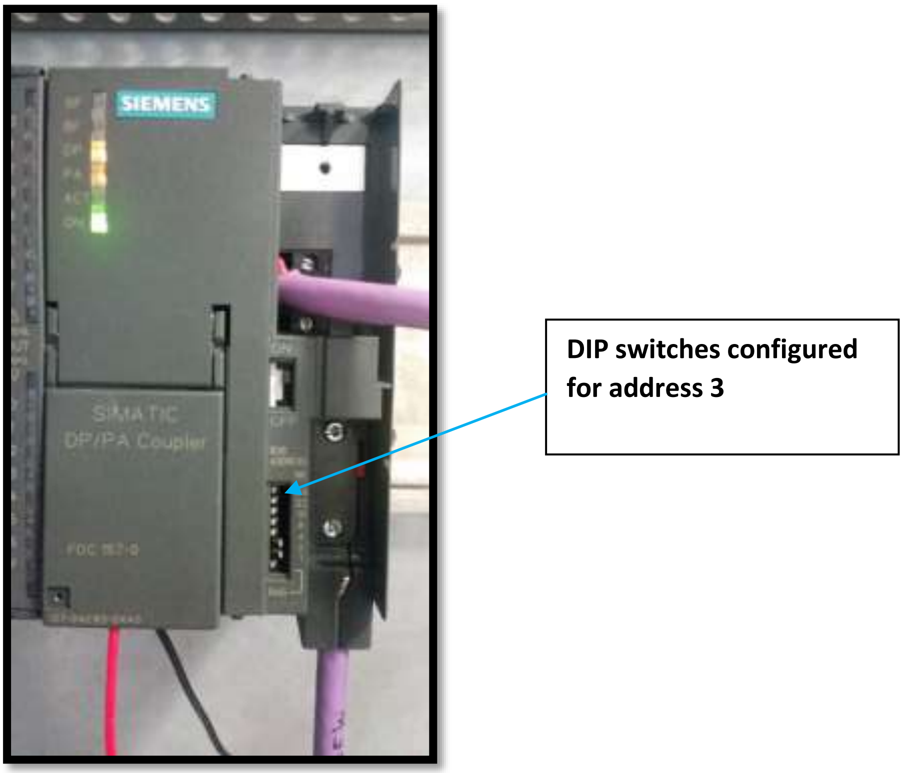


Figure 32: DP/PA Coupler DIP switches configured for address 3

For PROFIBUS PA ADDRESS 10, DIP switches 2 and 8 must be in the ON position and the rest OFF.

7.3 Adding DP/PA Coupler to the network

In the TIA portal project view, click on the

Hardware catalog → Other field devices → PROFIBUS DP→ PROFIBUS PA profile → SIEMENS AG → DP/PA-LINK → FDC157-0 → 6ES7 157-OAC83-OXAO

Drag the FDC 157-0 6ES7 157-OAC83-OXAO to the network view and connect it to the PLC. Figure 33 shows the drop down menu and the PLC connected to DP/PA coupler in DP Master System network.

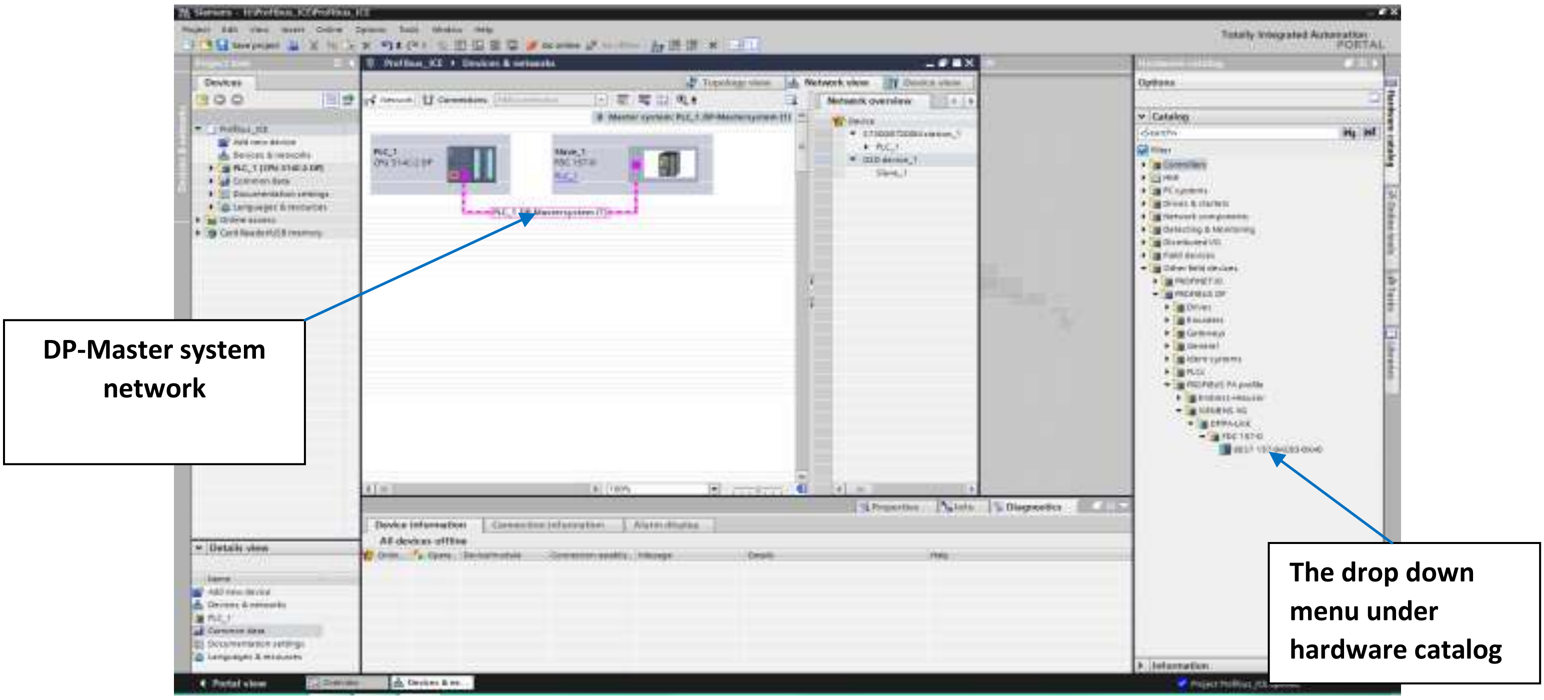


Figure 33: Window for configuring DP/PA coupler in the PROFIBUS Network

7.4 Setting the parameters of the DP/PA Coupler

The DP/PA coupler is used to convert from PROFIBUS PA to PROFIBUS DP. It converts from 45.45 Kbps on the PROFIBUS DP side to 31.25Kbps on the PROFIBUS PA side. The transmission speed is set by clicking on the PLC_1 DP-Master system line connecting the PLC and DP/PA coupler, and a window will appear at the bottom of the screen. Click on

General →PROFIBUS.

Change the transmission speed to 45.45(31.25) Kbps. To set the parameters of the DP/PA coupler, double click on its icon in the network and a window will appear at the bottom of the screen. Modify the address to the one set on the DP/PA coupler using the DIP switches and change the transmission speed to 45.45(31.25) Kbps. Figure 34 shows the window that will appear when the above steps are implemented.

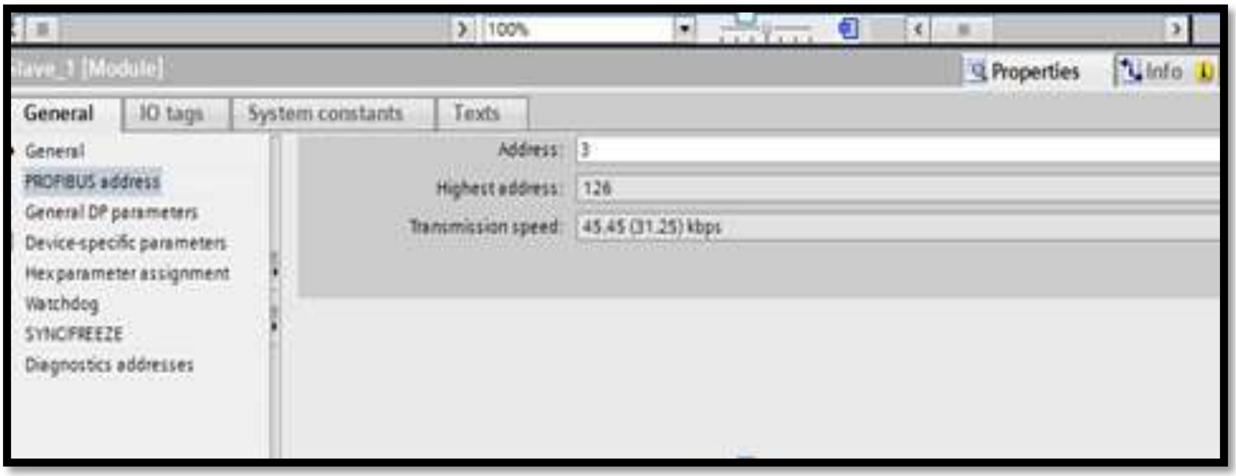


Figure 34: Window for modifying the parameters of DP/PA Coupler

Physically connect the PLC and the DP/PA coupler with an RS 485 cable and terminate the signal at both sides of the cable. Ensure that the power supply of the CPU314C-2DP is separate from the power supply of the DP/PA coupler. The DP/PA coupler is designed to have electrical isolation between PROFIBUS DP and PROFIBUS PA. **[10]** Confirm that the address set in the hardware configuration matches the one set using DIP switches on the DP/PA coupler.

8. Configuration of the Levelflex M FMP 40

8.1 Installing the GSD File

The Levelflex M FMP40 uses the PROFIBUS PA protocol to communicate on the PROFIBUS network. As with all PROFIBUS instruments, a GSD file must be installed in the TIA portal software for the Level Flex FMP 40 to be recognized by the Siemens PLC. Once the GSD file has been installed, the device can be configured to communicate on the PROFIBUS network.

- Installation of the GSD file for Levelflex M FMP 40 is done by following the same steps discussed in section 7.1.

8.2 Address of Levelflex M FMP40

The address of the Levelflex M FMP 40 is set using the DIP switches. Table 9 is used to determine the value of the address depending on the arrangement of the switches.

Table 9: Value of address for DIP switches in the ON position. Adapted from [28]

Switch number	1	2	3	4	5	6	7
Value in “off” position	0	0	0	0	0	0	0
Value in “on” position	1	2	4	8	16	32	64

To set the address, open the cover of the Levelflex M FMP 40 and arrange the PID switches to the desired address value.

Example

Figure 35 shows the DIP switches for the Levelflex M FMP 40 configured for address 4. DIP switch 3 is in the on position and according to Table 2, the PROFIBUS address is be 4.

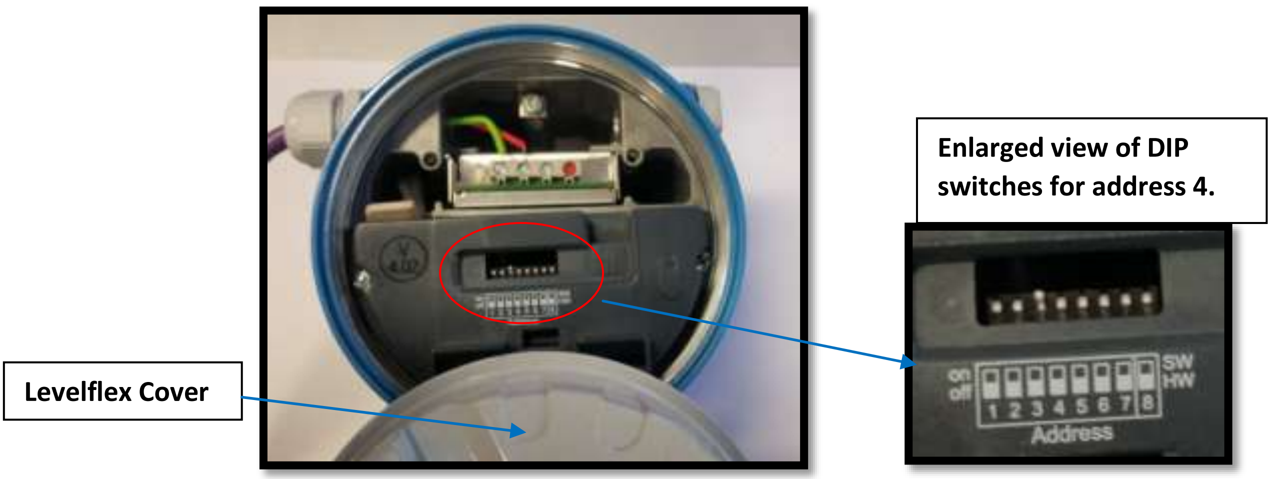


Figure 35: DIP switches for the Levelflex M FMP 40 configured for address 4

8.3 Adding Levelflex M FMP40 to the network

To add the Levelflex M FMP40 to the PLC_1 DP-Master system the following steps were implemented.

Click on,

Hardware catalog→ PROFIBUS PA profile → Endress+Hauser → Level → Echo → LevelflexM.

Then drag the Levelflex M FMP40 icon into the network and connect it to the DP/PA coupler in the network.

Figure 36 shows a window for adding the Levelflex M FMP 40 to the PLC_1 DP-Master system.

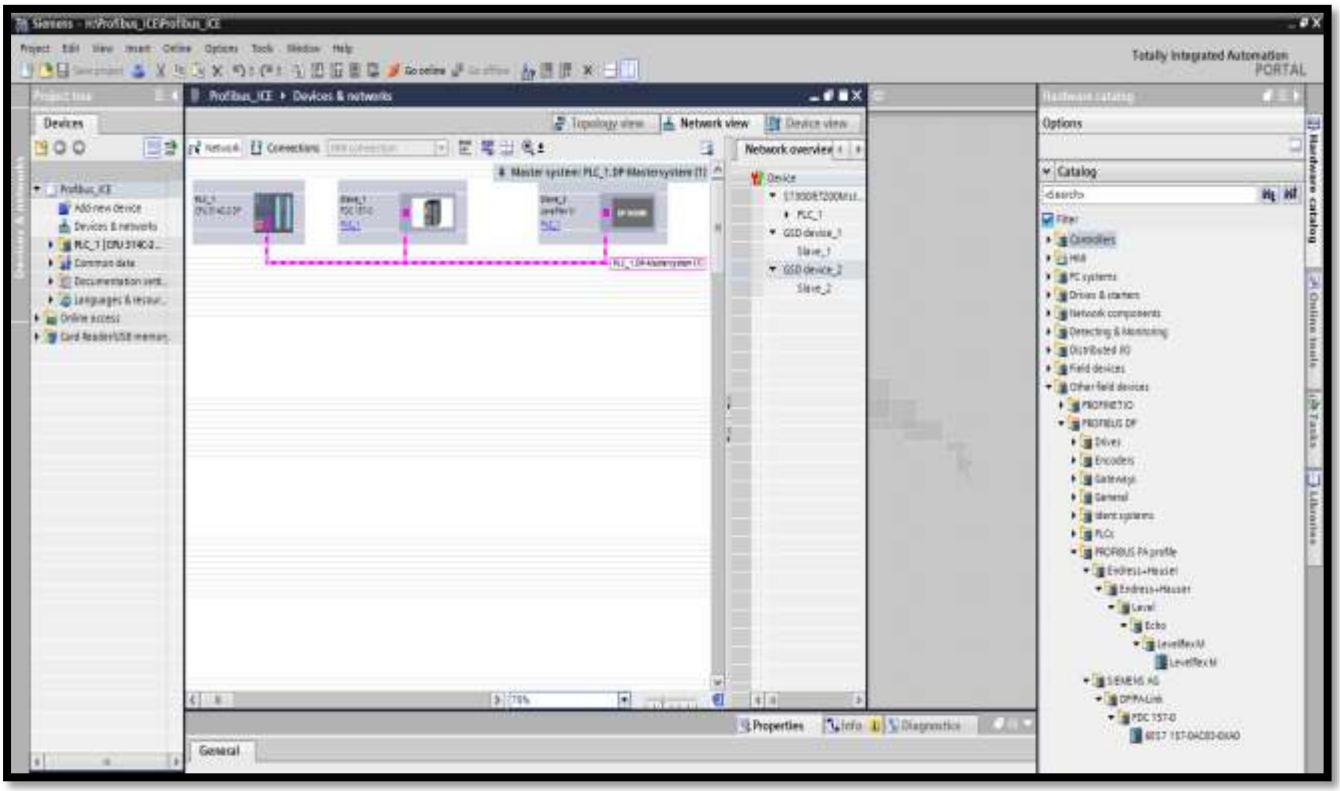


Figure 36: Window for adding the Levelflex M FMP 40 to the PLC_1 DP-Master system.

To set the parameters of the of the Levelflex M FMP40, double click on its icon in the network, and the window shown in Figure 37 will appear. The address must be changed to be the same as the address set using the DIP switches, in this case, address 4. The transmission speed must be set to 45.45(31.25) Kbps.

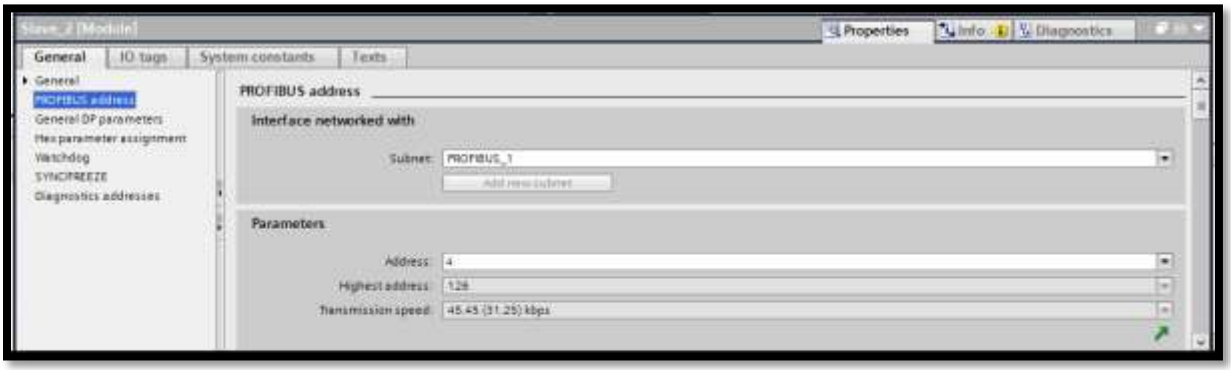


Figure 37: Window for setting the parameters of the Levelflex M FMP40

The hard configuration can be saved and downloaded to the CPU314C-2DP. The communication protocol used between the CPU314C-2DP and the PC is Multipoint Interface (MPI). If the Hardware configuration is **NOT** set properly, the PLC will display an SF fault in the diagnostic LEDs.

Common faults include:

1. Address mismatch e.g. when the set address using DIP switches is different from the one configured in TIA Portal.
2. Configured Slave not found in the network. If the configured slave is not physically connected to PROFIBUS network, or there is communication breakdown, the CPU314C-2DP will display a BF fault status.

The configuration of the Deltabar S PMD70 pressure sensor is done in the same way as the Levelflex M FMP40, so it is shown in Appendix C.

9. Programming CPU314C-2DP for data exchange

"The complete program of a CPU comprises the operating system and the user program (control program)." **[33]** The operating system of the CPU cannot be modified. Siemens periodically provide firmware updates of the operating system of the CPU. The user program contains programs blocks which are executed by the CPU for defined events. A sequence of program execution is defined by interrupt capability of the CPU. The CPU runs the main program cyclically. The main program has the lowest execution priority. When there is an interrupt, the operating system interrupts the running of the main program and runs a relevant interrupt block or fault program. The execution of the main the program will resume after the all faults have been processed.

Organization Blocks (OBs) are the link between the operating system of the CPU and the user program. The organization blocks are classified according to priority classes.

The organization blocks used in this project are OB 82, OB 86 and OB 1, the role of each is describe below:

9.1 Diagnostic Interrupt Organization Block (OB82)

Diagnostic Interrupt Organization Block (OB82), is the organization block that the operating system calls if a fault occurs in the module with diagnostic capabilities that have been configured and programmed. If OB82 in not included in the program and the module with diagnostic capability outputs a fault, the CPU 314C-2DP changes to stop mode. **[34]**

The OB 82 and can be used in several ways:

- Recover from the fault.
- Save the data before fault condition and during the fault.
- Turn the equipment off.
- Set alarm.

9.2 Rack Failure Organization Block (OB86)

"The operating system of the CPU314C-2DP calls OB86 whenever a fault occurs in the central I/O modules." **[34]** The OB 86 is also called when DP master system or a station is detected in the distributed I/O (PROFIBUS DP or PROFINET IO) and is not configured. The CPU314C-2DP goes to stop when these faults occur without OB 86 being programmed.

The OB 86 and can be used in several ways:

- Recover from the fault.
- Save the data before fault condition and during the fault.
- Set alarm.

In this project, the both OB 82 and OB 86 were used to set alarms.

9.3 How to add OB 82 and OB 86 to the project

Under the project tree menu, click on the programs blocks, then double click on **Add new block**. A new window will appear, then click on Fault interrupts/O_FLT1 [OB 82] and then OK. Figure 38 shows the window for adding Organizational Blocks.

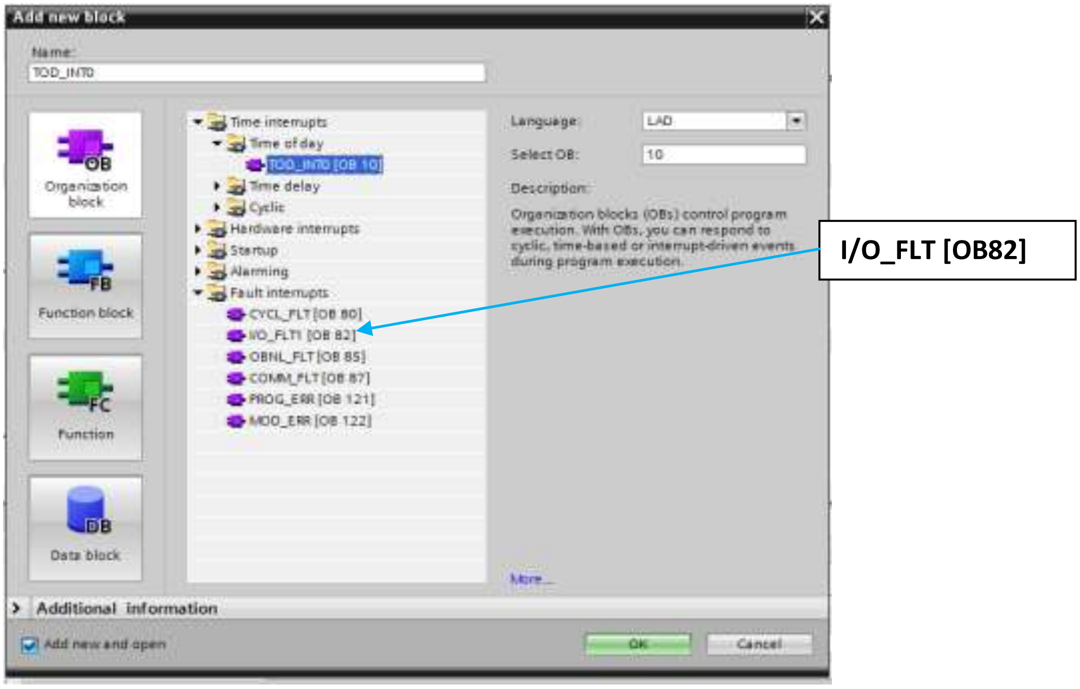


Figure 38: Window for adding organization blocks

9.4 Program Cycle Organization Block (OB1)

OB1 is where the main program is built. It is executed cyclically by the operating system. "Cyclic execution of OB1 is started after the startup has been completed." **[33]** OB1 can call functions and function blocks during its execution.

9.5 Reading Data from the PROFIBUS PA slaves

In this project, a SIEMENS PLC CPU314C-2DP is used as a class-1 master which exchanges data with field devices. PROFIBUS PA devices are classified under DPV-1 services, which enable the class-1 master to have cyclic access to field devices data. The communication function blocks for DP-Master (Class-1) are defined in the IEC 61131-3 standard. This project is only concerned with reading data from the PROFIBUS PA devices, therefore writing data to PROFIBUS PA devices will not be discussed.

GETIO

GETIO is a function block. Function Blocks are predefined programs contained within a single block. Function blocks are part of the user programs while organisation blocks are the interface between operating system and user program. **[33]** GETIO is used in this project to continuously read data from the field device. **"**The GETIO function block gets the input data of the addressed slot of a DP-Slave from the DP-Master interface out of the cyclically read input data of the DP-Slave." **[12]** Figure 39 shows the GETIO function block.

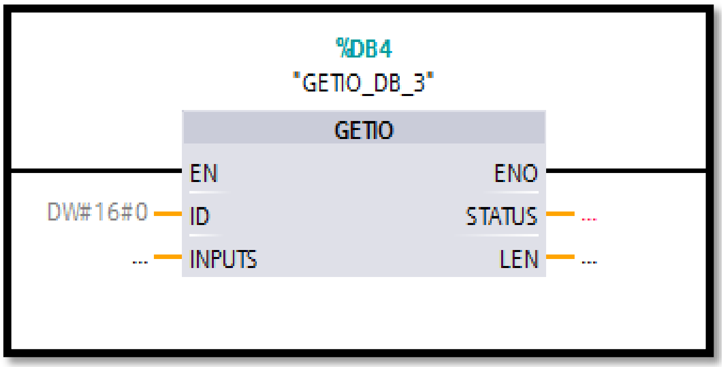


Figure 39: GETIO Block

Table 10 shows the parameters of the GETIO Function Block

Table 10: Parameters of the GETIO Function Block [12]

Parameter	Declaration	Data type	Description
ID	Input	DWORD	Logical address of the DP slave
STATUS	output	DWORD	Contains the error information of form DW#16#40xxxx00
LEN	output	INT	Amount of data read in bytes
INPUTS	Input	any	Destination area for the read data. It must have the same length as the area that you configured for the selected DP slave. Only the BYTE data type is permitted.

9.5.1 Reading data from the Levelflex M FMP40

Figure 40 shows the program used to read data from the Levelflex M FMP40.

The communication function blocks for DP-Master (Class-1) are defined in the IEC 61131-3 standard

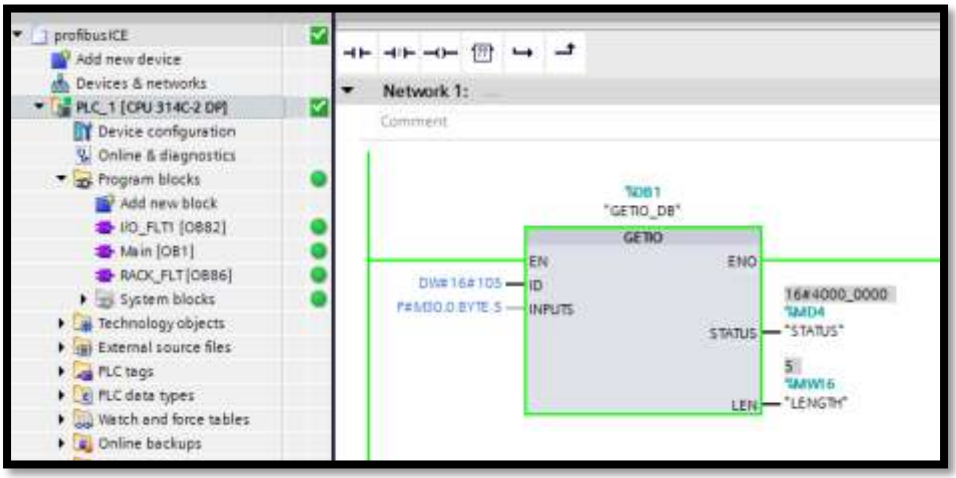


Figure 40: Program used to read data from the Levelflex M FMP40

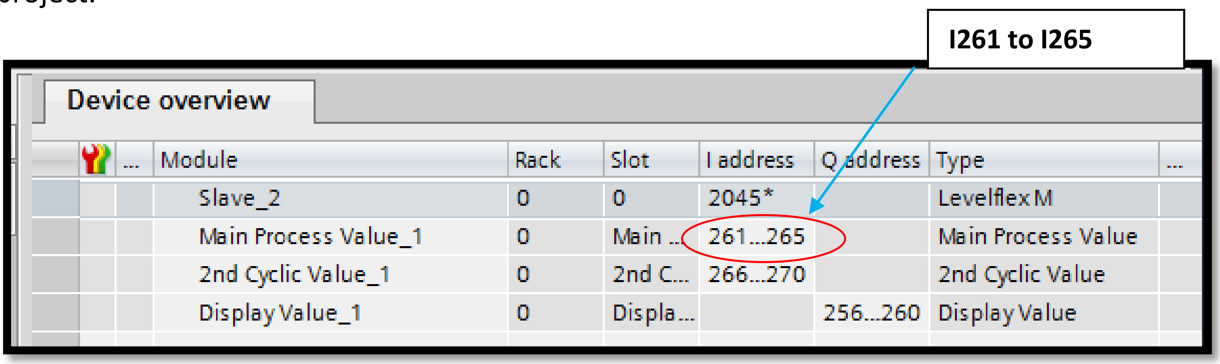
An explanation of how to get and use the parameters in Figure 41 is given below.

ID: is the starting address of the memory allocated for the data from the Levelflex M FMP40. The address is represented as hexadecimal. The memory address is obtained by clicking;

Project tree → Devices & network → Device view.

Select the slave from the drop down menu.

Figure 41 shows the memory address for the Levelflex M FMP40 as configured in this project.



Module	Rack	Slot	I address	Q address	Type
Slave_2	0	0	2045*		Levelflex M
Main Process Value_1	0	Main ...	261...265		Main Process Value
2nd Cyclic Value_1	0	2nd C...	266...270		2nd Cyclic Value
Display Value_1	0	Displa...		256...260	Display Value

Figure 41: Window for Levelflex M FMP40 properties

The transferred data from the Levelflex M FMP40 is contained in the memory address I261 to I265 of the CPU314C-2DP. The starting address is I261, which is 105 in HEX hence, in the program the ID is written as **DW#16#105**.

INPUTS: is the destination area of the read data. The measured value from the Levelflex M FMP40 is transmitted as a 32 bit number and the status as an 8 bit number; hence, the total data transmitted is 5 bytes long. The input data will be stored in memory bytes M30.0 to M34.0 of the CPU314C-2DP.

Status: Error information from the Levelflex M FMP40. A value of 40000000 in HEX means no error. The table which shows the status code is shown in Appendix A.

LEN: is the length of the read data, which is stated as 5 in this project.

9.6 Program Testing

After downloading the program to the PLC, the input data from the Levelflex M FMP40 can be observed in the watch tables. Figure 42 shows an extract from the watch table obtained during the testing of the program.

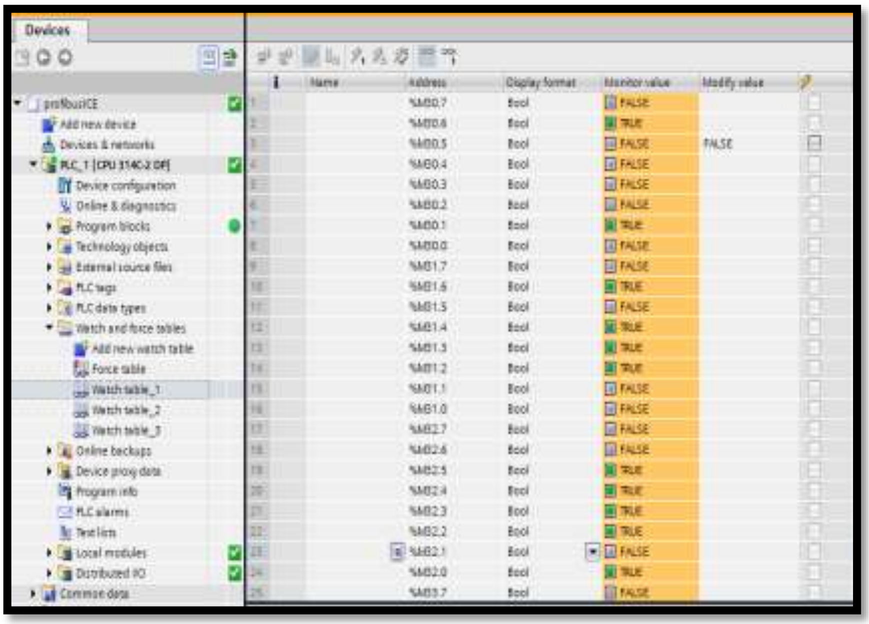


Figure 42: Extract from the watch table obtained during the testing of the program

Figure 42 shows the data contained in memory Byte M30, M31, and M32 of the CPU314C-2DP. The data is of Boolean type.

The program to read data from the Deltabar S FMD70 pressure sensor is provided in Appendix C.

10. Communication between CPU 314C-2DP and the OPC server

The main aim of this chapter is to explain how to set up communication between the OPC server and the Siemens PLC. This includes a detailed description of how to configure the OPC server and facilitate data exchange between the server and the SIEMENS CPU314C-2DP PLC. Diagnosis of communication breakdown is also included.

OLE for process control (OPC) is a standard mechanism for communicating with numerous data sources and databases. In this project, the OPC server is used as an interface between Siemens CPU 314C-2DP and LabVIEW Master I/O program.

10.1 Configuration of the OPC server

To communicate with CPU314C-2DP, the OPC server must be configured. The following steps were implemented to configure the OPC server.

1. Click on

   Start → All Programs → National Instruments → OPC Servers 2013 → OPC Servers Administration.

Then an icon for the OPC server will appear in the pull-up menu on the bottom right corner of the screen as shown in Figure 43.

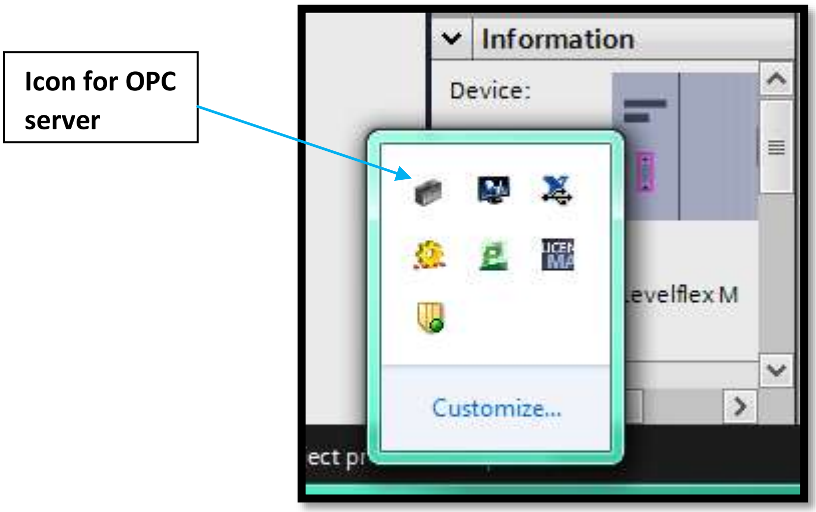


Figure 43: Icon for the OPC Server

2. Double Click on the icon or left click and select configuration and a new window for configuration will appear. Figure 44 shows the OPC server configuration window. Add a Channel by clicking on the **Add new channel** icon as shown in Figure 44.

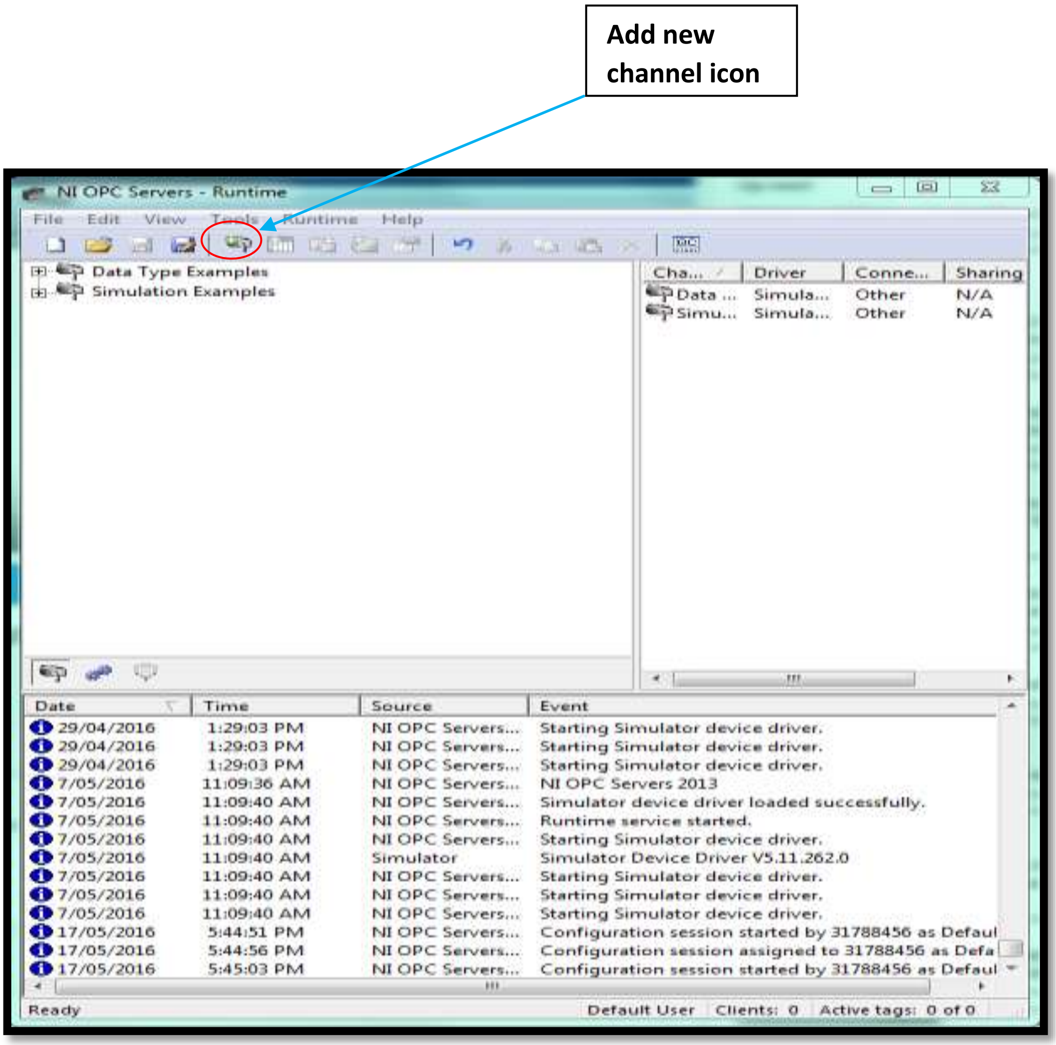


Figure 44: Configuration window for OPC Server

3. When step 2 is implemented, a window shown in Figure 45 will appear. Modify the channel name and click on next.

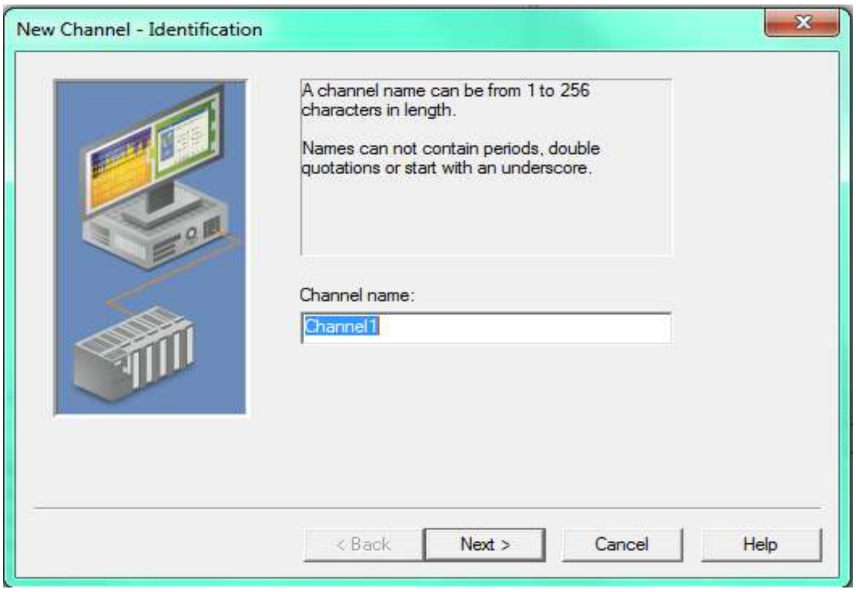


Figure 45: Channel identification for OPC server configuration

4. The next step will be to select the device driver from the drop down list. Select SIEMENS S7 MPI and click on Next, then the window for communication settings will be displayed as shown in Figure 46.

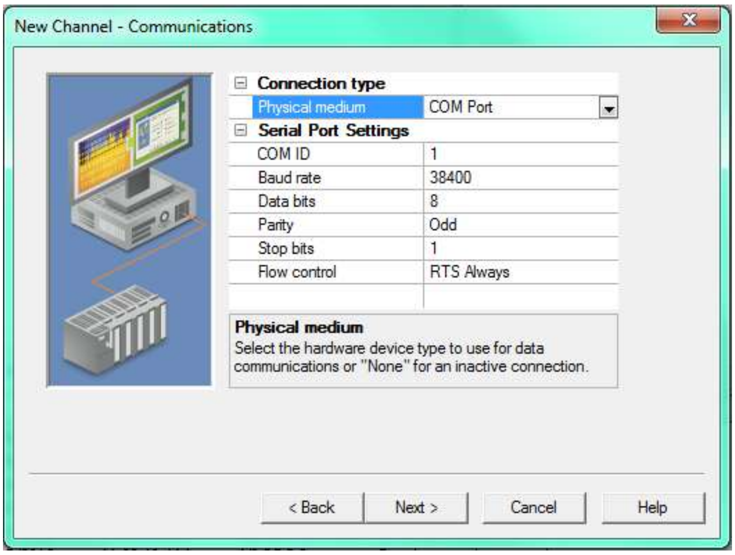


Figure 46: Communication settings for the OPC server

For SIEMENS CPU 314C-2DP, select a **COM port** as the physical medium, and make sure the **COM ID** in the same as **COM port** connected to the PLC. Confirm that the properties are correct and click on Next.

5. The next step is to select if the server should report communication errors and how long to close the connection when idle. It is up to the designer to choose the parameters that meet the specification of the project at hand. Once these modifications are completed, click on Next.
6. In the window that will appear, under the Optimization method, select the desired method which the server must use to write to the channel modify, select the duty cycle and click on next.
7. Modify how the driver handles non-normalized floating point values and click on next. The default setting is; non-normalized values should be unmodified. Another option is to replace non-normalized values with zeroes.
8. Select the MPI bus address used by this driver on the network and click on Next. A window that displays the summary of the settings done will appear. If the settings are correct, then click on Finish, if not then click on Back. Make corrections to the

settings, and click on Next until the last window then click on Finish. A new channel will be added as shown in Figure 47.

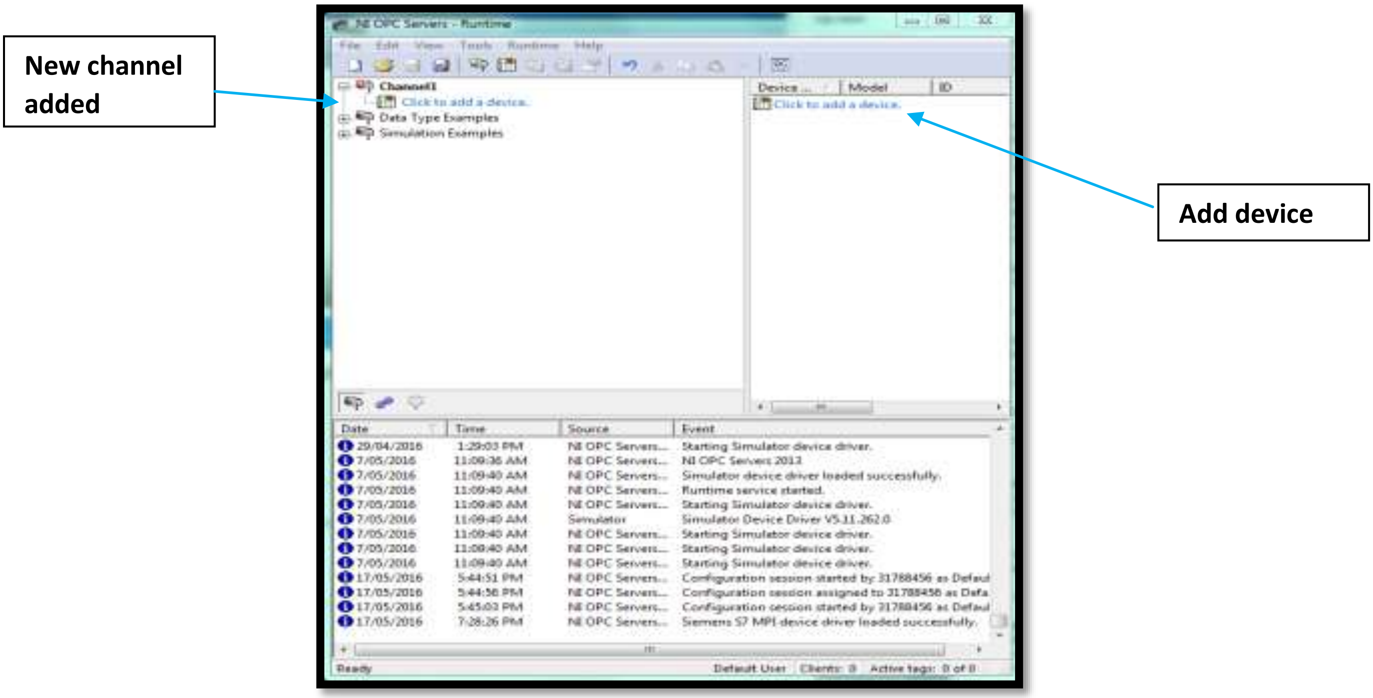


Figure 47: Display of new channel added

The next step is to define a device that will communicate with the added channel. The following steps were implemented.

9. Click on **add device** as shown in Figure 47 and the window in Figure 48 will be displayed.

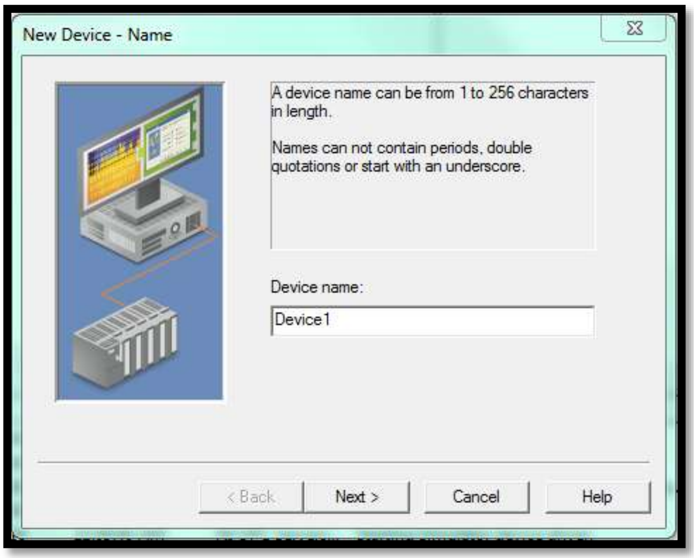


Figure 48: Device Identification window

10. Modify the Device name and click on next.
11. In the next window, select **device ID** then click on Next.
12. Select the preferred scan mode from the drop down menu and click on Next.
13. Select the communication timing parameters and click Next. A window showing the summary of settings will appear, click Finish if the information is correct. At this stage, the configuration window must be as shown in Figure 49.

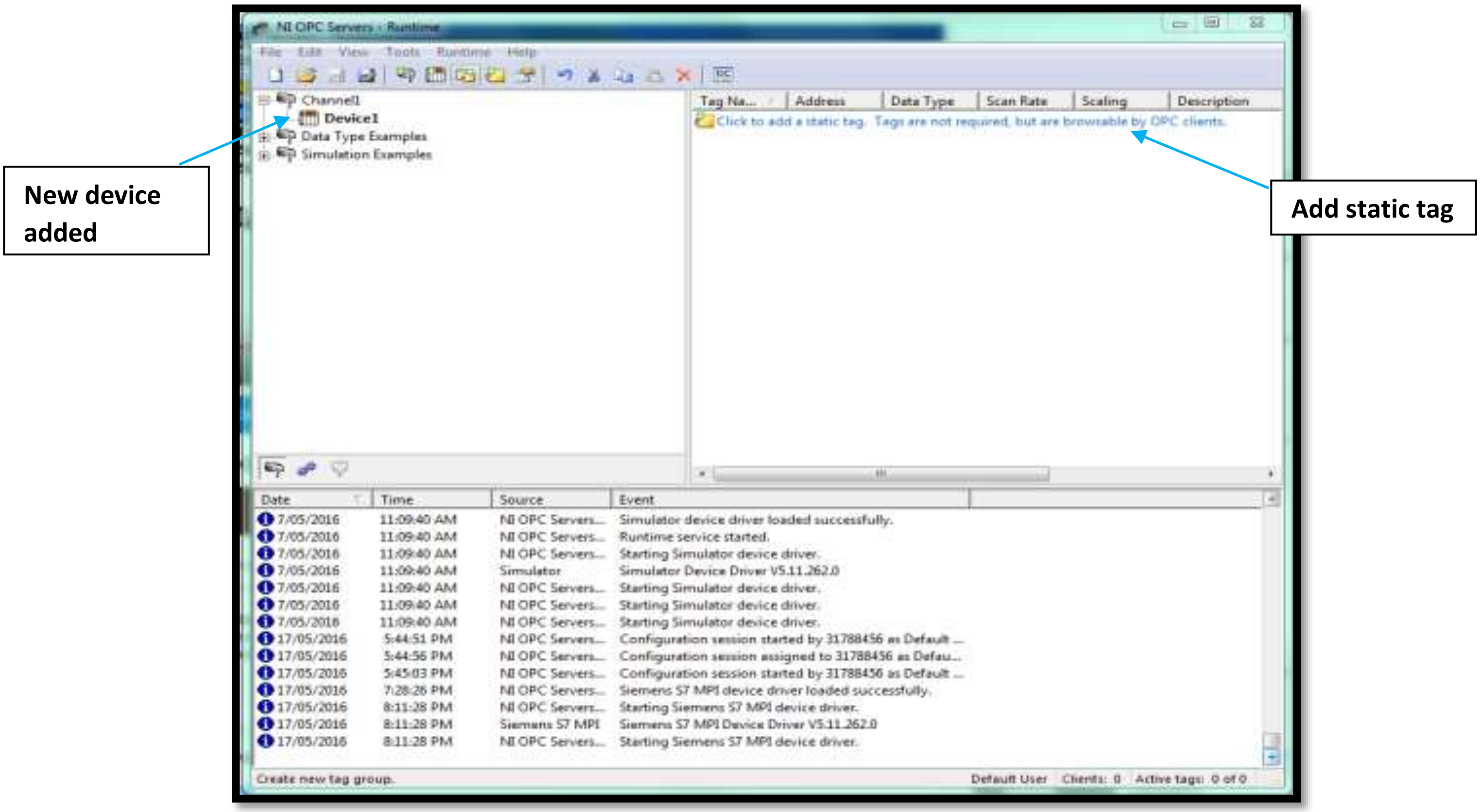


Figure 49: New device added

The next step is to specify the memory location and data to be read from the CPU314C-2DP. The following steps were implemented.

14. Click on the **add static tag** icon as shown in Figure 49. A window where tag properties should be specified will be displayed as shown in Figure 50. Enter the properties of the data that is to be transmitted and click on **Apply** → **OK**.

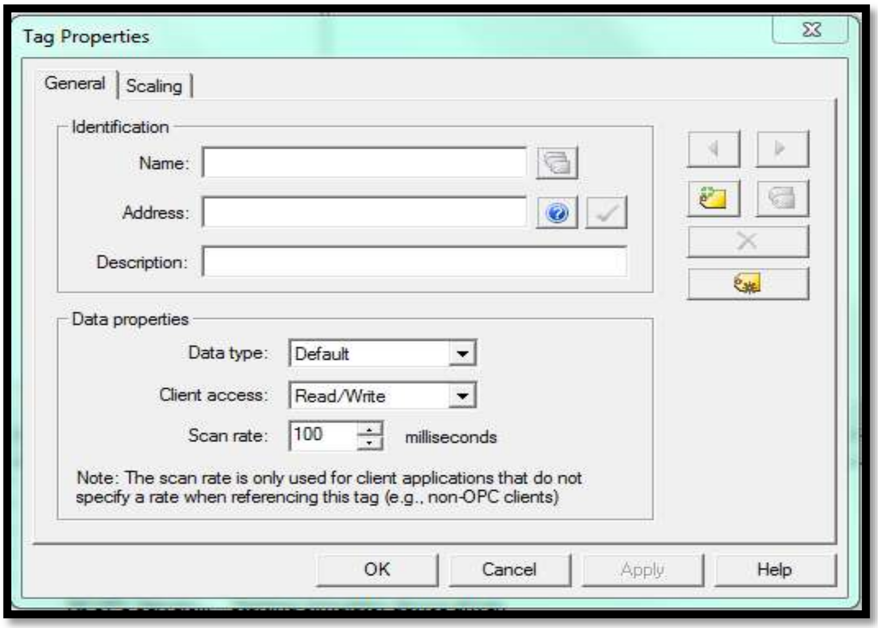


Figure 50: Tag properties

15. To communicate with the PLC, connect the serial MPI cable to the **COM port** specified in the OPC server configuration
16. On the bottom right corner, click on the pull-up menu and right click on the icon of the **OPC server → Start Runtime Service.**
17. On the OPC server configuration window, click on **runtime → connect**.

10.2 Testing communication between OPC server and PLC

To test the communication between the CPU314C-2DP and the OPC server, the following steps were implemented. In the OPC server window;

Click on the Quick Client icon → channel name → Select the device name.

The window shown in Figure 51 will be displayed. If communication between the server and PLC is OK, then the **quality** of the channel will be read as **Good**. If there is a communication breakdown, the **quality** will be displayed as **Bad.** Some causes of communication breakdown are:

1. The server runtime has expired
2. The MPI cable is disconnected
3. The CPU314C-2DP is in STOP MODE.

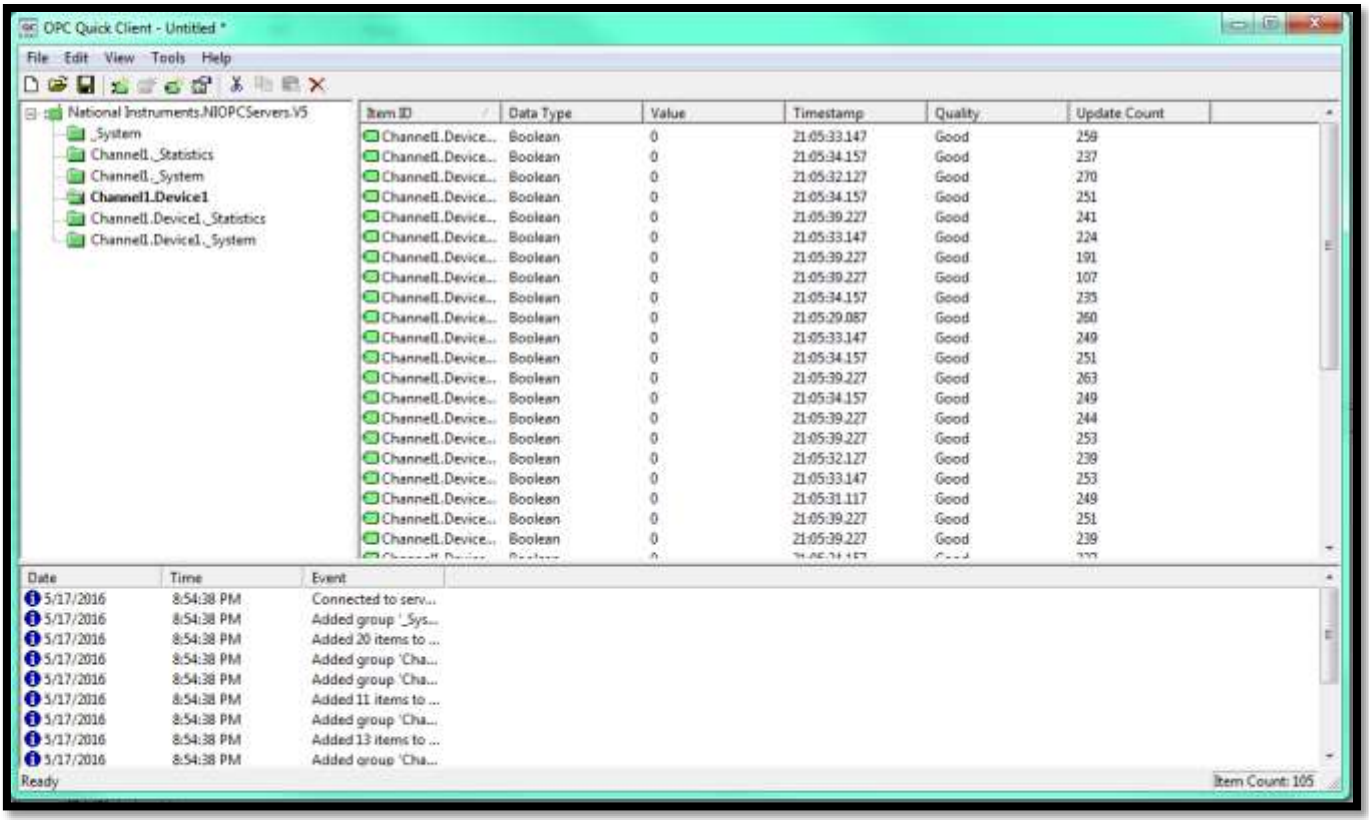


Figure 51: Quick Client window

In Figure 51, **Item ID** is the specified memory to be read from the CPU314C-2DP. Item ID states the channel name, device name, and tag name.

Data type is the data type as specified in tag properties.

Value is the value of the tag as read from the CPU314C-2DP.

11. Modification of the Master I/O program

The main objective of this chapter is to modify the Master I/O program to read data from the OPC server and make it available to the client computers in the lab. The client computers use the Basic Experimental Template to communicate with the Master I/O program. Both the Master I/O program and the Basic Experimental Template are LabVIEW programs. The communication protocol used between the client computers and the master server is Ethernet. The focus of this chapter is to explain:

1. How to setup the communication between the OPC server and the Master I/O program.
2. How to use the data from the OPC server to calculate the measured value by PROFIBUS PA instruments using Levelflex M FMP40 as an example.
3. Modification of the Basic Experimental Template to read the calculated level from the Master program.

11.1 Networked published Shared Variables

Communication between OPC server and the master program is facilitated through the use of network-published shared variables. Network-published shared variables publish data over the network so that LabVIEW clients in the same network can use it **[25]**. Modification of the Master I/O program was achieved by implementing the following step.

The latest I/O server program is found in the folder called Master I/O V7.5 on the desktop of the server computer in the ICE laboratory and the eng-shared folder under the ICElab project.

NB: Make a copy of this file and use a copy for any modification planned. Ensure that the OPC server is already configured and communicating with the SIEMENS CPU314C-2DP.

1. Open the Master I/O V7.5 file then Double Click on the MasterIO-V7.5 LabVIEW project as highlighted in Figure 52.

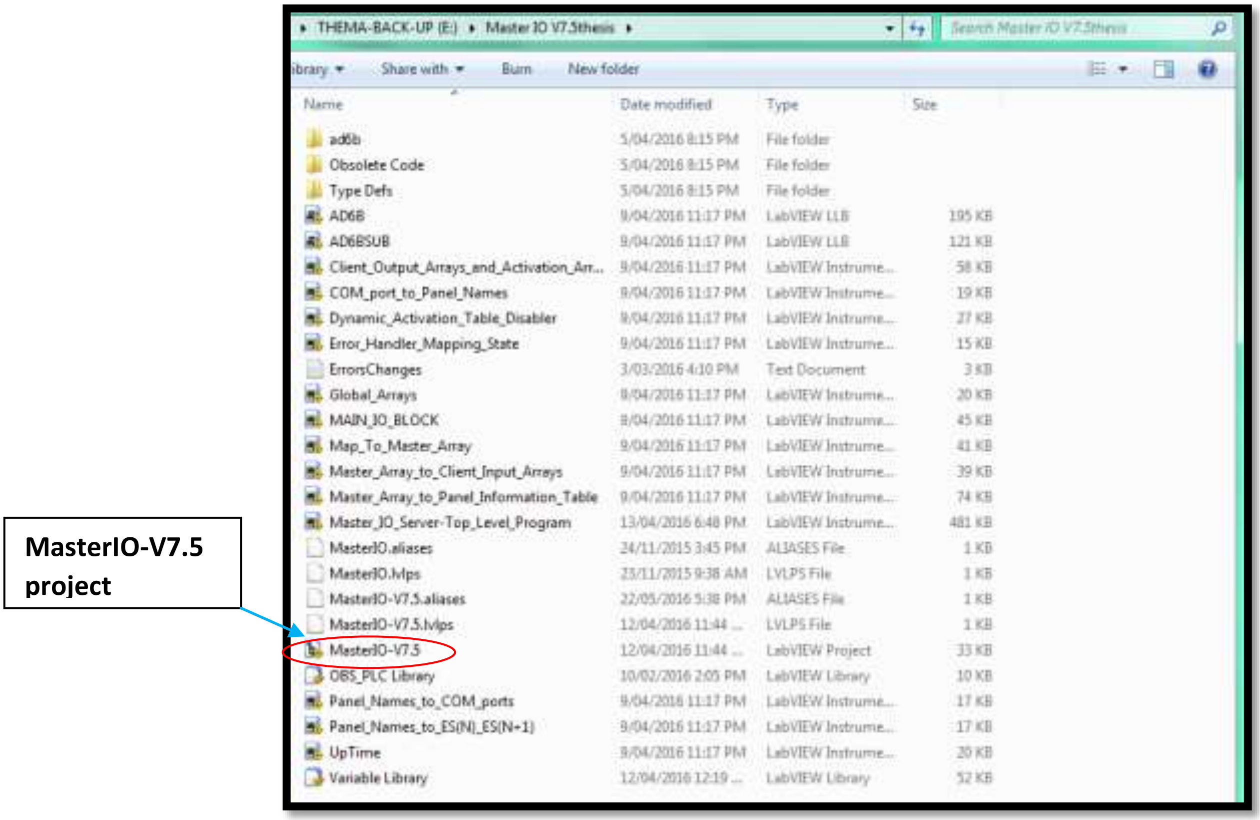


Figure 52: Window for opening the Master I/O project

On the Master I/O V7.5 project explorer window, right click on:

My Computer → New → I/O server.

A configuration window shown in Figure 53 will appear.

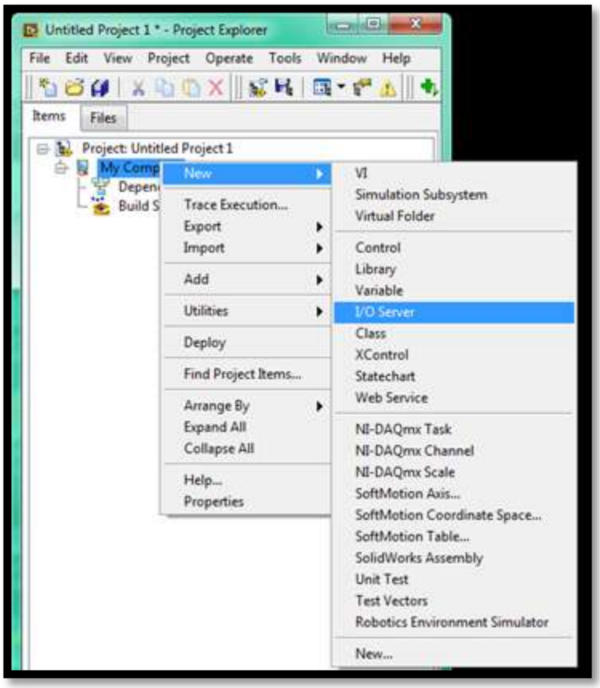


Figure 53: Window for adding I/O server

Under its settings option, select machine localhost, modify the update rate to suit the design specification and under registered OPC servers, select National Instruments.NIOPCServers.V5 as shown in Figure 54 and click on **OK**.

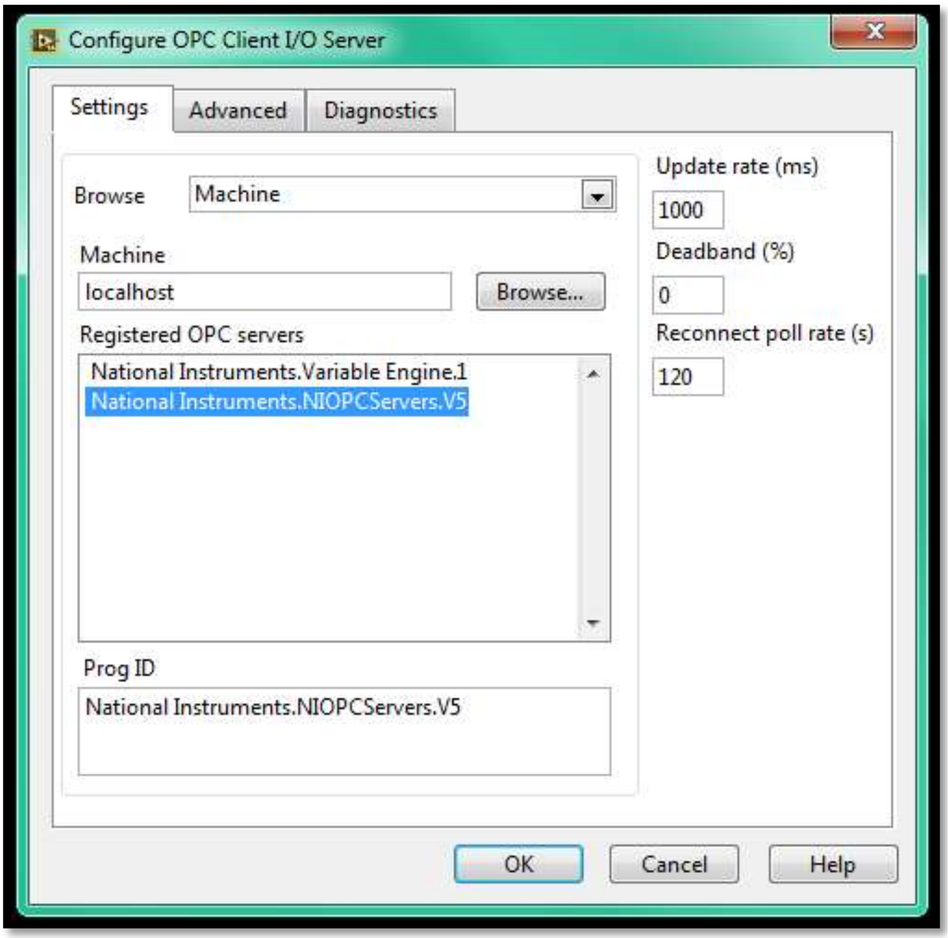


Figure 54: OPC server configuration window

A new untitled library will be added to the project. The OPC server will be contained in this new library. Modify the name of the new library and save it.

The next step is to create shared variables in the variable library and bind them to the tags in the OPC server. The shared variables created will take the value of the tags in the OPC server. e.g if the shared variable is aliased with a memory bit which has a value of one '**1**', the shared variable will also have a value of '**1**'.

The following steps were implemented to create shared variables and bind them to the tags in the OPC server.

1. Click on

   Variable library icon → New → Variable

   A window with shared variable properties will appear.

2. Give the new variable a name, under variable Types, select Network published and click on the box to enable Aliasing.

Click on browse select the path of the variable to aliased with the new variable.

My computer → OPCServer.lvlib → OPC1 → SIEMENS PLC→CPU314_2DP → Tag Name

Then the path will be shown as highlighted in Figure 55

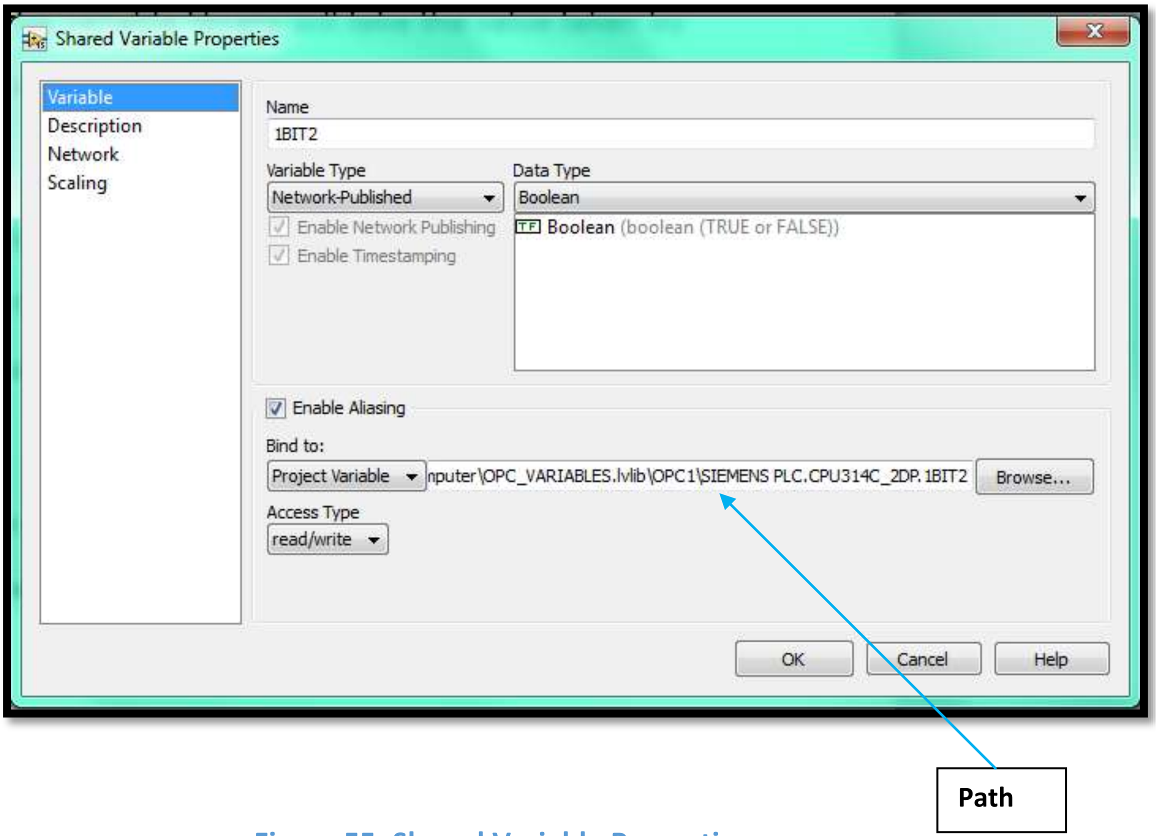


Figure 55: Shared Variable Properties

The new variable will appear under the variable library and can be used in the in LabVIEW program.

11.2 Calculating the level read by Levelflex M FMP40 in the Master I/O program

The input data from the Levelflex M FMP40 is transmitted as a 32-bit floating point number. Table 11 shows the structure of the transmitted data.

Table 11: Structure of the transmitted data. [28]

Index Input Data	Data	Access	Format/ Remarks
0,1,2,3	Main Value	read	32 bit floating point number (IEEE-754)
4	Status code for main value	read	See "Status codes."

The Table, which shows the status code of the Levelflex M FMP70 is shown in Appendix A.

The measured value is transmitted as an IEEE 754 floating point number, whereby

$$\boldsymbol{Measure\ value} = (-\mathbf{1}^{VZ}) \times \mathbf{2}^{(E-127)} \times (\mathbf{1} + \mathbf{F}) \quad \textbf{..........Equation 1}$$

E is the sum of each individual contribution made by Bit0 to Bit6 of Byte 1 and Bit 7 0f Byte 2. This sum is referred to as the Exponent.

F is the sum of each individual contribution of Byte 2, Byte 3, and Byte 4.

Table 12: Table used to calculate level from Levelflex M FMP40. Adapted from [28]

Byte 1								Byte 2							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit 0	Bit7	Bit 6	Bit 5	Bit 4	Bit3	Bit2	Bit1	Bit0
VZ	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}
	Exponent (E)								Mantissa(F)						

Byte 3								Byte 4							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit 1	Bit 0	Bit7	Bit6	Bit 5	Bit 4	Bit3	Bit2	Bit1	Bit0
2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}	2^{-13}	2^{-14}	2^{-15}	2^{-16}	2^{-17}	2^{-18}	2^{-19}	2^{-20}	2^{-21}	2^{-22}	2^{-23}
Mantissa(F)															

The shared variables created in section 11.1 above are used to create a program to calculate the level read from the Levelflex M FMP40. In this project, the tags in the OPC server are configured as Boolean type of data. A LabVIEW program is built to convert Boolean data into a floating point number using Table 12.

Illustration

From Figure 41, (reading data from the Levelflex meter) the data from the CPU314-2CP is stored in memory locations M30 to M34. Byte 1 is stored in M30.0, therefore Bit 7 of this byte is stored in M30.7

Example

In Figure 56, the shared variable "BIT6" is aliased with the tag in the OPC server which reads bit M30.0 from the CPU314C-2DP. According to Table 10, the BIT6 is multiplied by 2^7. The selector is used to output 1 when the BIT6 is high and 0 when BIT6 is low. The output of the selector which represents the value taken by BIT6 is multiplied by 2^7. After calculating the contribution of each byte according to Table 10, equation 1 is used to calculate the measured value.

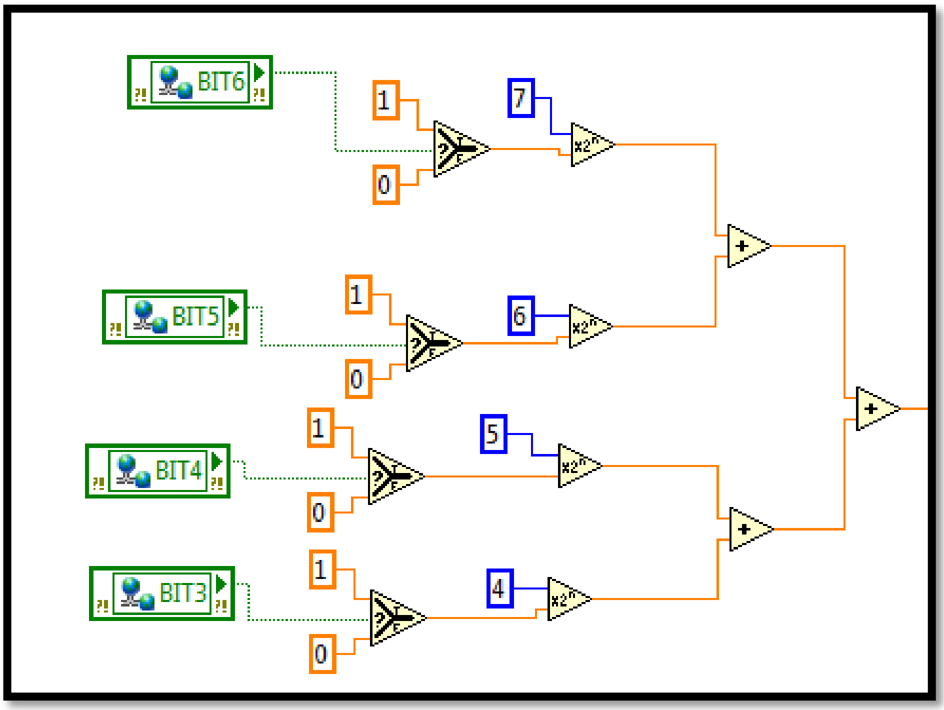


Figure 56: Extract of the LabVIEW program used to calculate the measured value

The measured level calculated is stored in shared variables and can be read by the Basic experimental template program. The name of the shared variable used for the measured value of Levelflex M FMP40 in this project is **PB_TANK_LEVEL.** The variable to indicate the status of the Levelflex M FMP40 is also included and is called **PB_TANK_STATUS.**

Complete LabVIEW program to calculate the level read from Levelflex M FMP40 is discussed in Appendix B.

11.3 Modification of the Basic Experimental Template

The Basic Experimental Template is a LabVIEW program that students use to conduct experiments in the ICE laboratory. The Basic Experimental Template is run on the computers in the ICE laboratory which act as clients to the Master I/O program. The communication medium between the client computers and Master I/O program is through Ethernet. To read the level of the Levelflex M FMP40 from Master I/O program, the Basic Experimental Template needs to be modified. The following steps were implemented to facilitate this modification.

1. In the client computer, click on

Start → All Programs → National Instruments → NI Distribution System Manager

A new window shown in Figure 57 will be displayed.

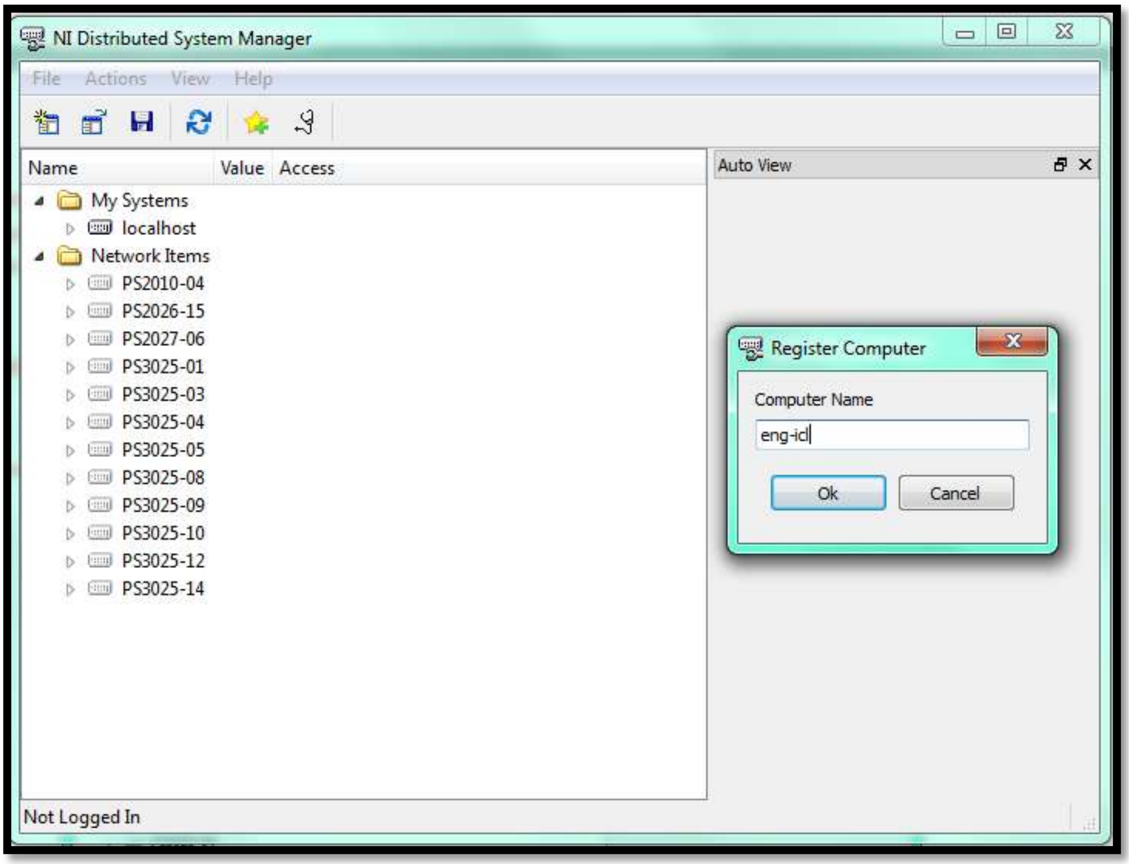


Figure 57: A window for registering a server in the client computer

1. Check under Network Items that eng-icl is available. If it is not, click on

   Actions → register computer

   Enter **eng-icl** as the Computer Name and click on enter.

The **eng-icl** will be added to the Network Items.

eng-icl is the name given the computer running the Master I/O program in ICE laboratory.

2. Copy the Experimental Template V5.2 from the eng-shared folder. Open the Experimental template V5.2 folder and double click on the client project.
3. Click on the variable library **icon → New → Variable**

   A window with shared variable properties will appear.
4. Give new variable a name, under variable Types, select Network published and click on the box to enable Aliasing.
5. Click on browse select the path of the variable to aliased with the new variable.

   eng-icl → Variable Library → PB_TANKLEVEL

   and click **OK**.

The window for defining the properties of the shared variable is shown in Figure 55.

Then this variable will be aliased with the variable that indicates the level read by Levelflex M FMP40 in the Master I/O program. In the client program, it can be connected to the indicator which will show its value.

11.4 Testing of the PROFIBUS Network

The purpose of this experiment is to test the transfer of data from the PROFIBUS PA instruments to the Basic Experimental Template and demonstration the integration of PROFIBUS PA instruments into the master I/O program in the ICE lab.

Instruments

Levelflex M FMP40

Deltabar S PMD70

Valve

Tank

11.4.1 Levelflex M FMP40

The Levelflex M FMP40 comes with a default setting to measure the level of the fluid in the tank. The default scale is in percentage with 0% representing a level of 0 cm and 100% representing 120 cm as shown in Figure 58.

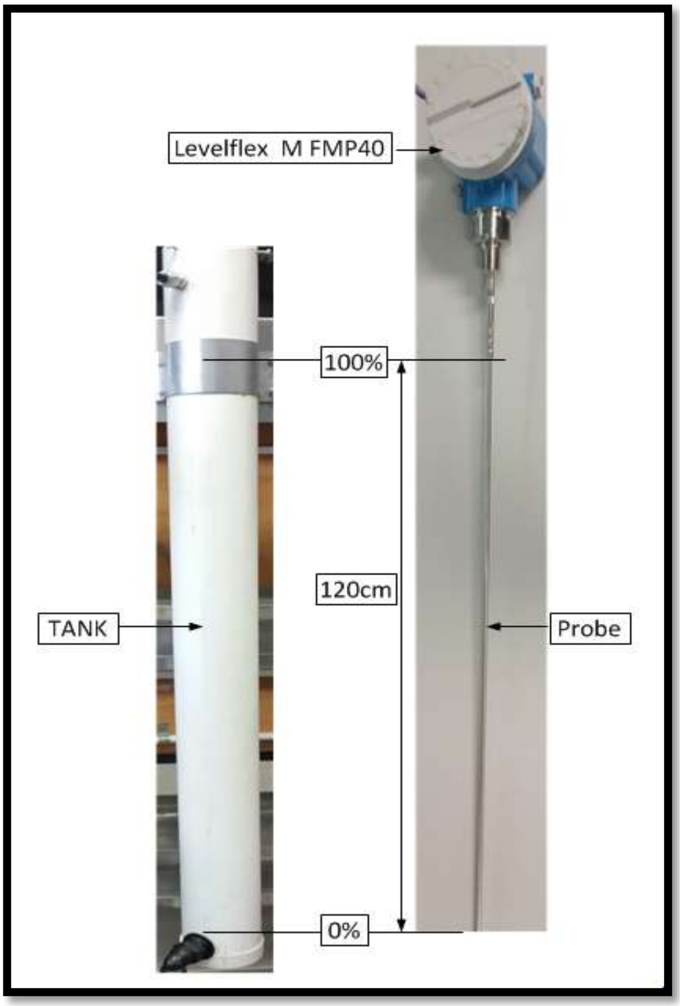


Figure 58: Levelflex M FMP40 scale range representation

The Levelflex M FMP40 was put into the tank and a valve was connected to the tank as shown in Figure 59. The valve is communicating by the 4-20mA analog 6B modules. The valve was open to 50% and the data was collected as water flowed in the tank.

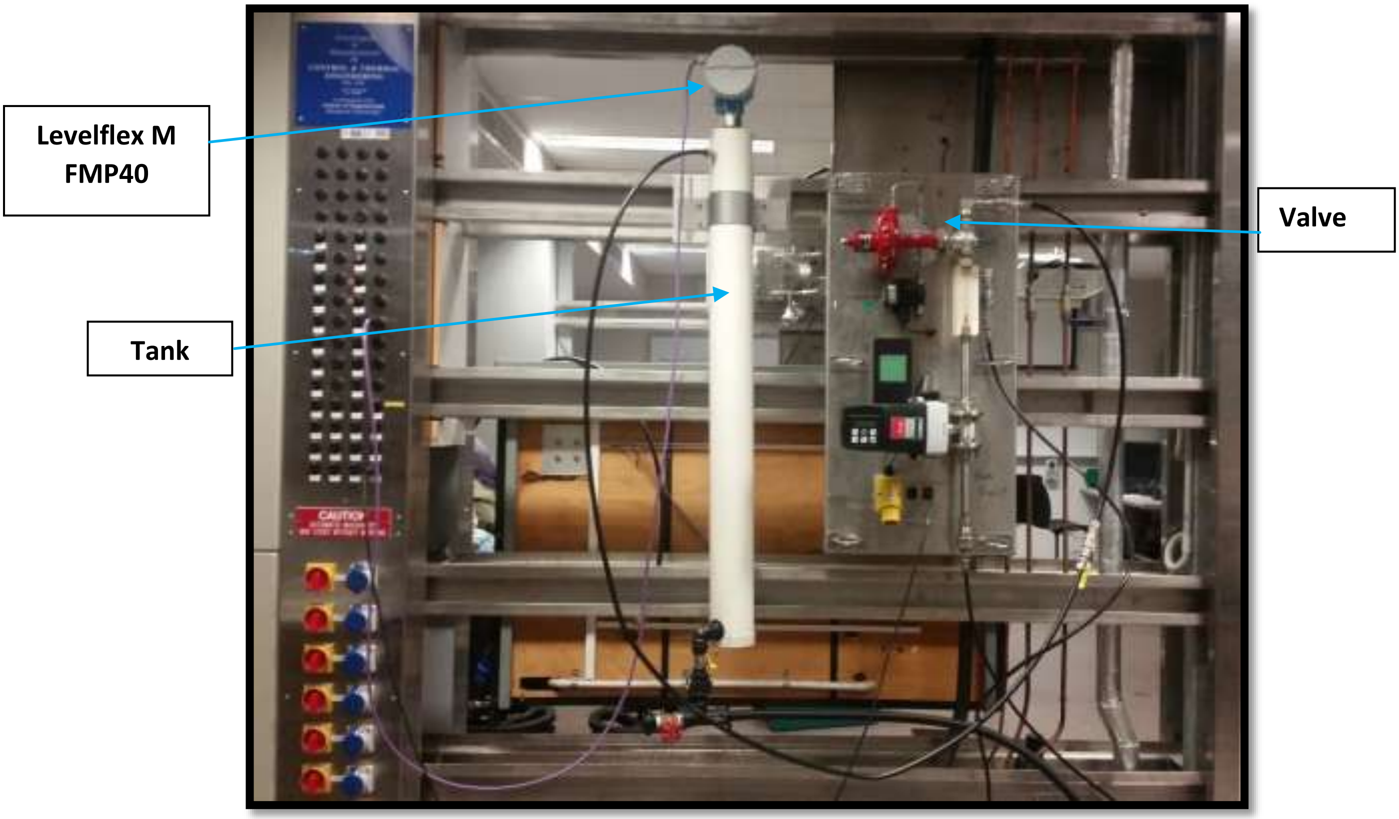


Figure 59: a picture of experimental setup

Figure 60 shows the increase in the level of water in the tank from the time the valve was opened to 50% until the tank is full. The data read from the Levelflex M FMP40 has a 5s delay. The valve position was changed when the time was 5s and the change in the level was realised 5s later.

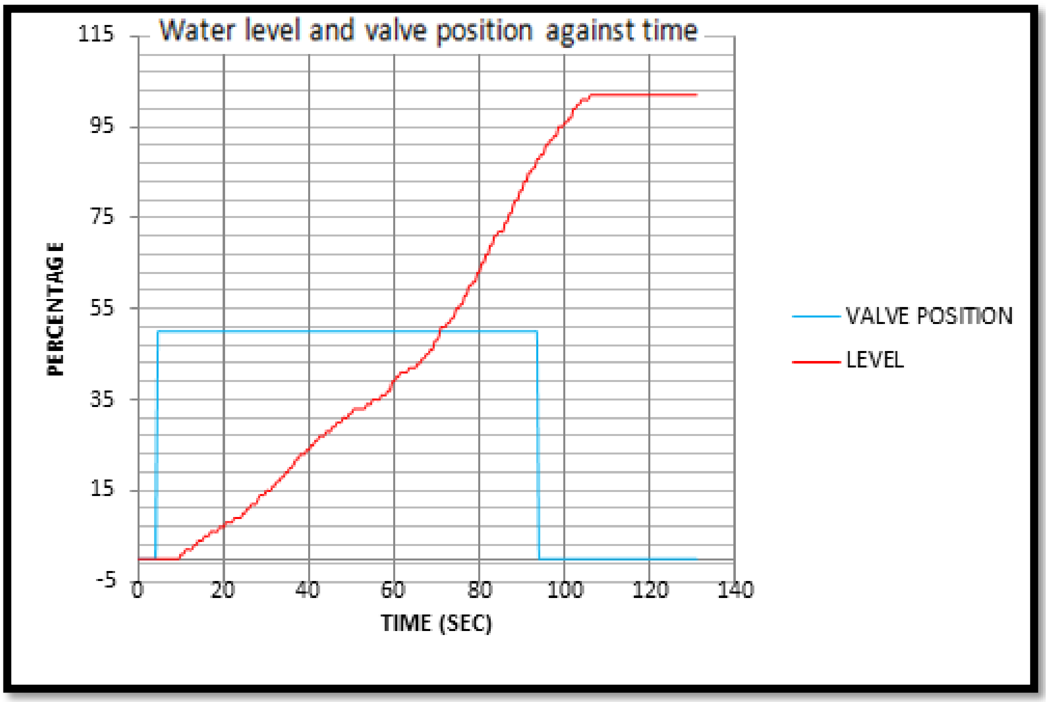


Figure 60: Water level and valve position against time

CONTROL

This part of the experiment was done to demonstrate that the data from Levelflex M FMP40 can be used to control the level of water in the tank. A PID controller was implemented to try to control the level of the water in the tank. In this experiment the manipulated variable is the flow rate of water using valve position and process variable is the level of water in the tank. The controller was not optimally tuned as it is only used to demonstrate the integration of the PROFIBUS instruments in the ICE laboratory. Figure 61 shows the modified part of the Basic Experimental Template. The modification was put in a while loop so that it will execute when selector is **TRUE**, when selector is **FALSE** the valve position can be controlled manually. This modification was done to demonstrate the integration of PROFIBUS PA instruments in the ICE laboratory. Students can modify the Basic Experimental Template to suit their design specification.

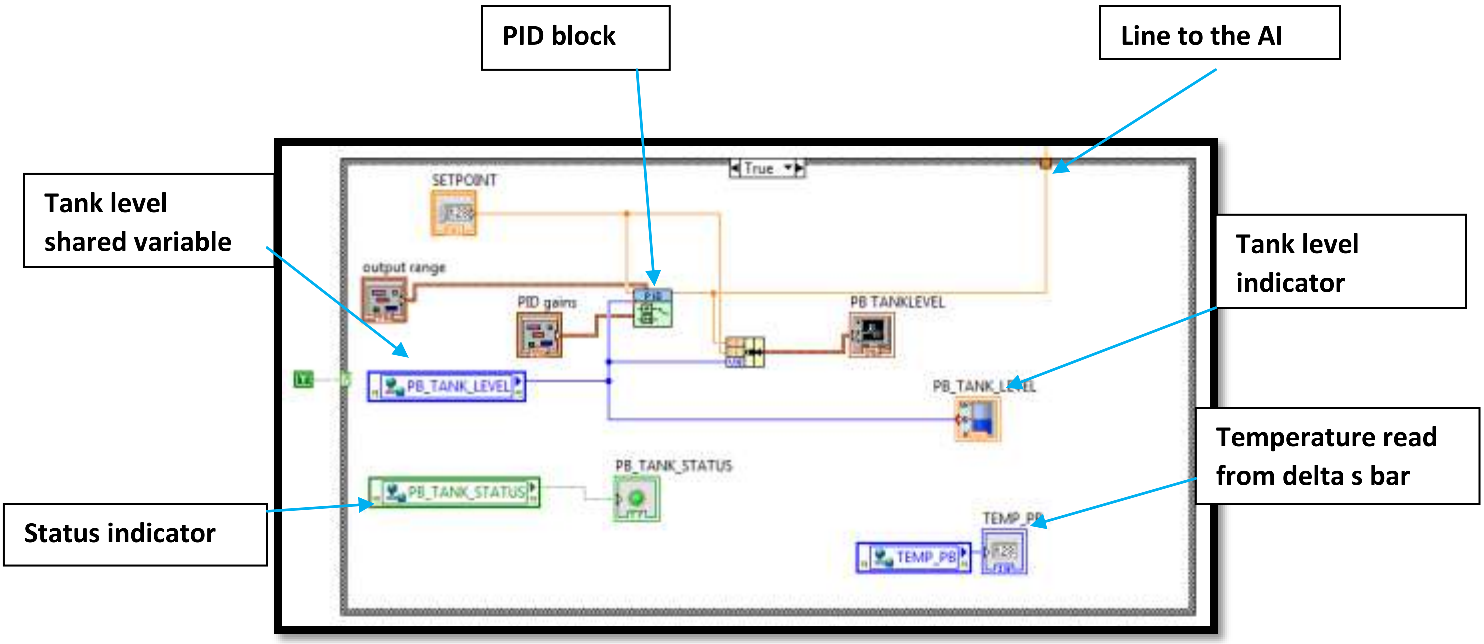


Figure 61: Modification made to the Basic Experimental Template

Figure 62 shows the response of the system under PI control.

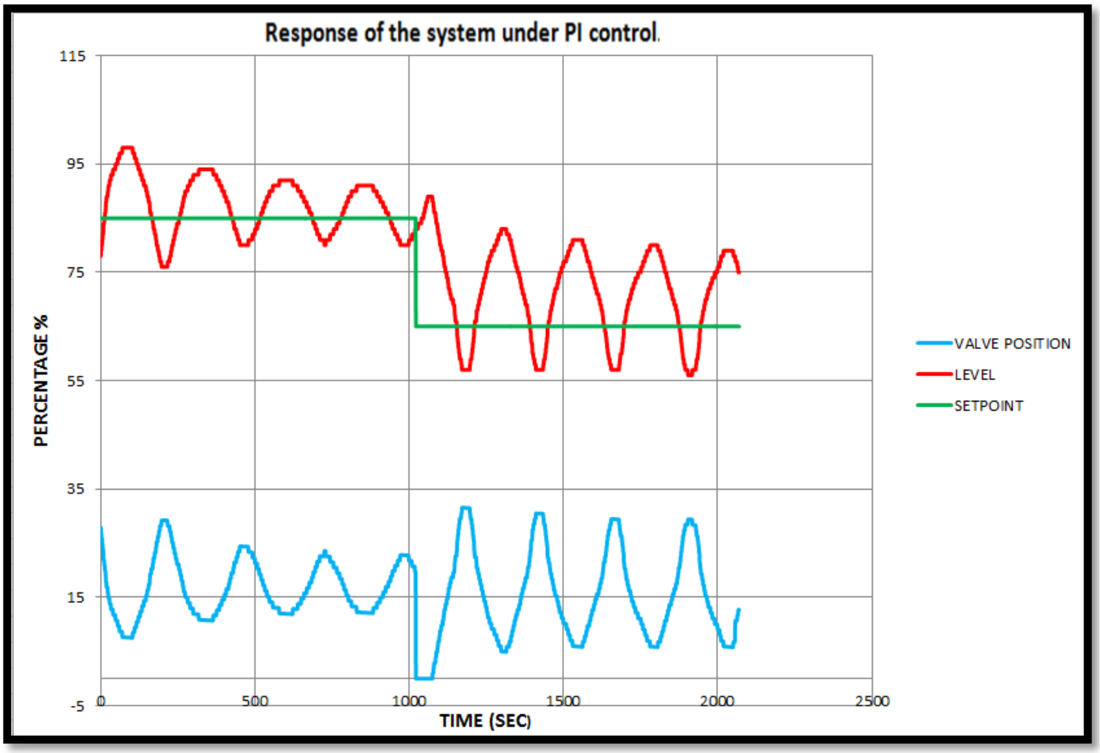


Figure 62: Response of the system under PI control

In Figure 62, it was observed that the level of the tank is oscillating around the set point. From 0s to around 1000s, the set point was 85% and the level was oscillating between 80% and 91%. At around 1000s the set point was changed to 65% and the started oscillating between 57% and 81%. As stated earlier, the controller was not optimally tuned. Figure 63 shows a front panel screen shot taken during testing.

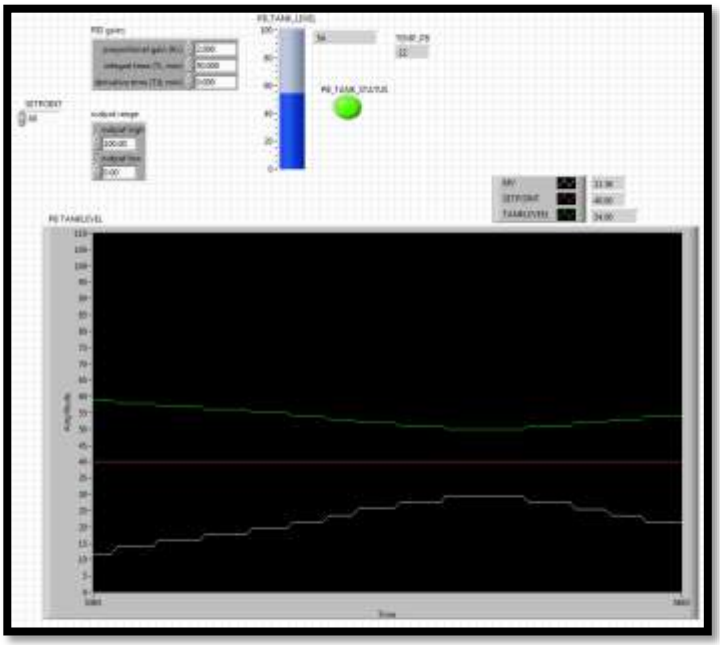


Figure 63: Front panel of the experimental template during testing.

In Figure 63 the:

- the green line is the measured level of the tank;
- the white line is the valve opening;
- The red line is the set point of 40%.

11.4.2 Deltabar S PMD70

Pressure

The Deltabar S PMD70 was connected at the bottom of the tank to measure the pressure of water at the bottom of the tank and the temperature of the water. This pressure can be used to measure the level of water in the tank. Figure 64 shows a picture of Deltabar S PMD70 connected to the tank.

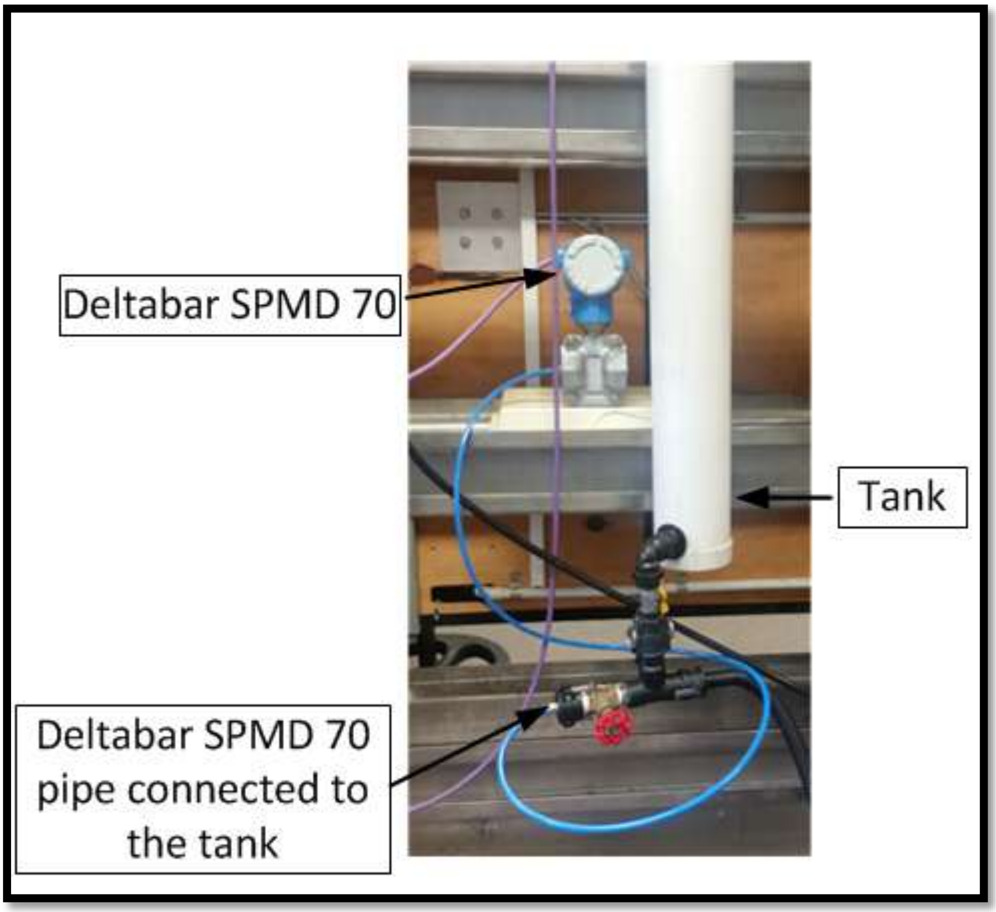


Figure 64: Deltabar S PMD70 connected to the tank

Water was pumped in to the tank, and Figure 65 shows a comparison of the level recorded by Levelflex M FMP40 and the pressure recorded by the Deltabar S PMD70. The level is measured as a percentage of the tank and the units of pressure are mbar.

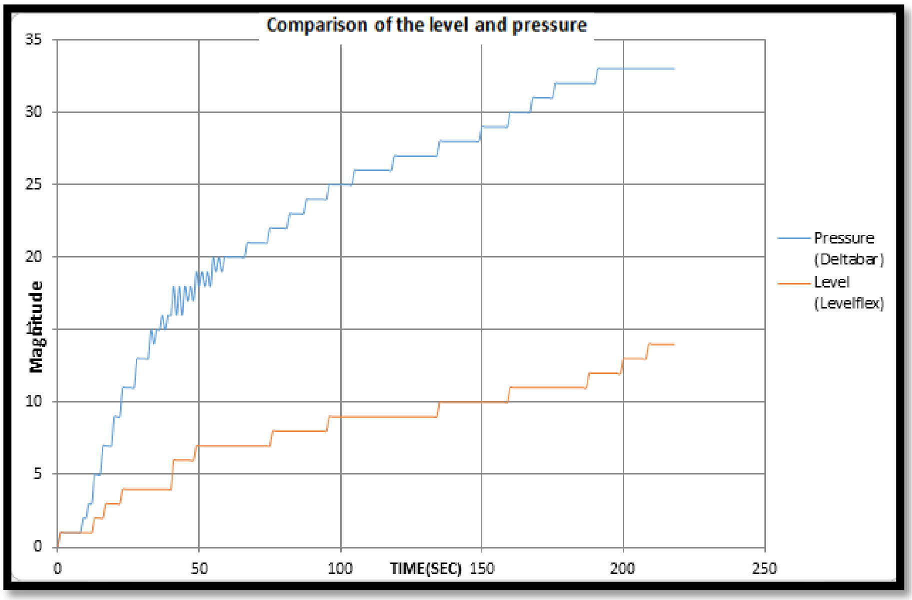


Figure 65: Comparison of the level and pressure

It was observed that the Deltabar S PMD70 returns an over limit fault when the pressure reaches 25 mbar and at 33 mbar it stops reading even if the level is increased. The settings on the Deltabar S PMD70 need to be changed to suit its usage in the ICE laboratory.

Temperature

The Deltabar S PMD70 can also be used to measure the temperature of water. The water in the tank was heated and Figure 66 shows the change in temperature recorded by the Deltabar S PMD70. Even though the temperature measurement was tested over a small range, there were no problems observed with it.

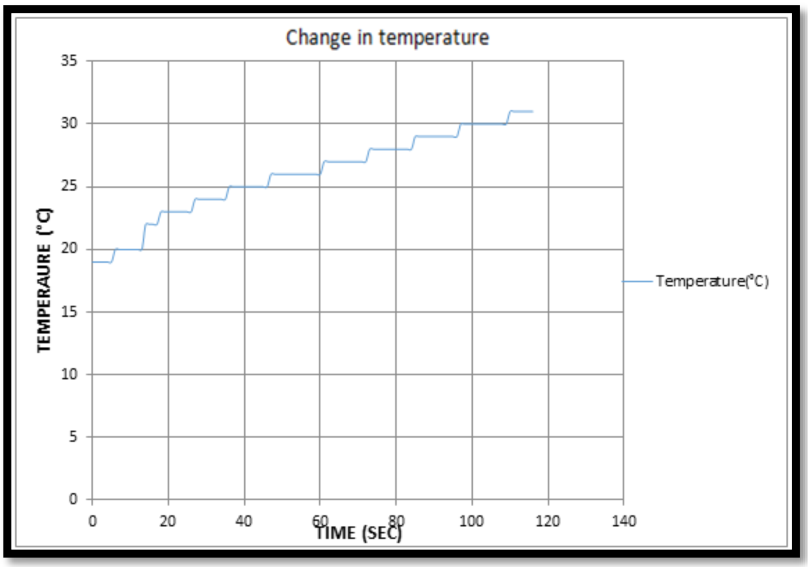


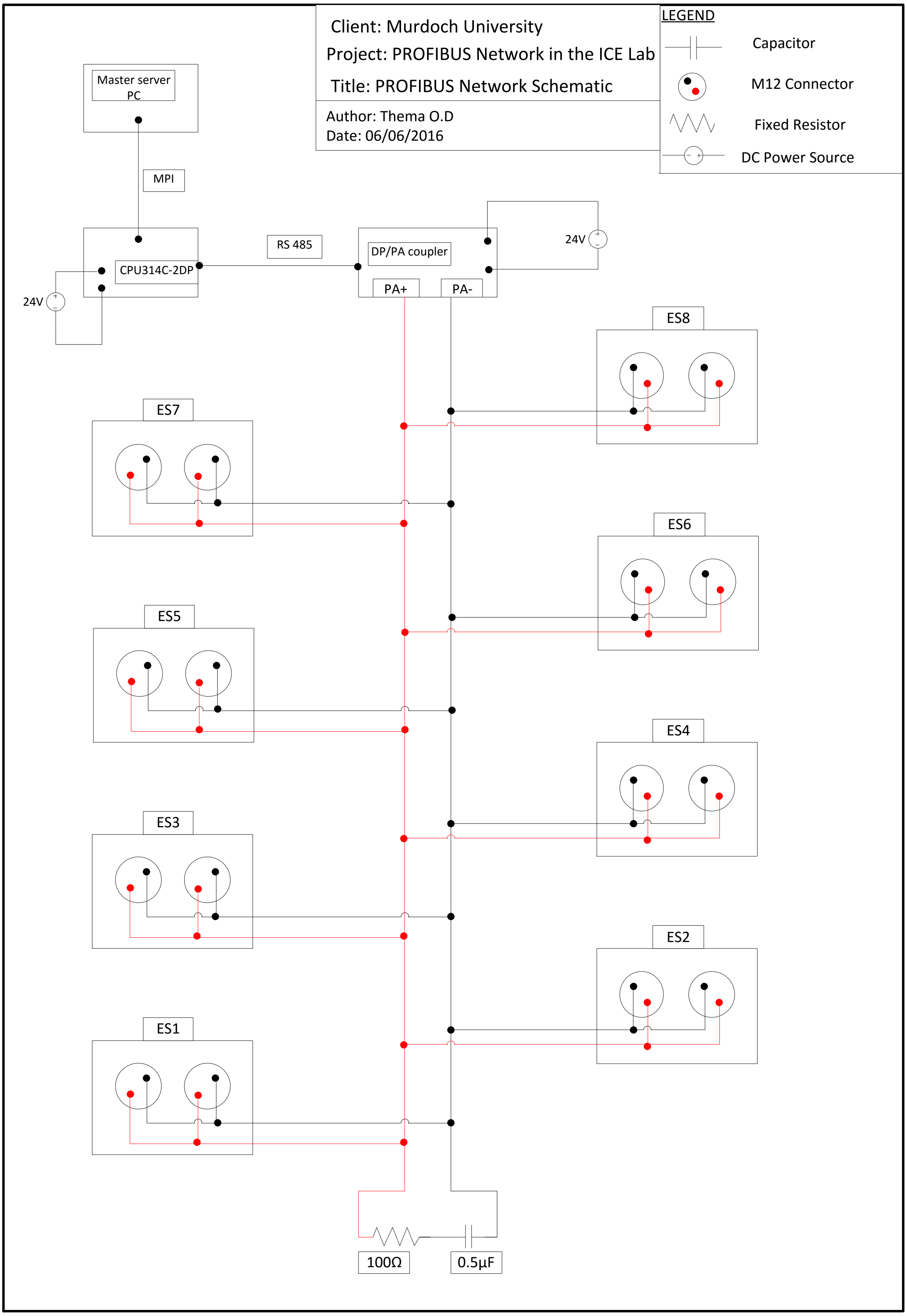
Figure 66: Change in Temperature

12. Future Work

- The Deltabar S PMD70 pressure sensor needs to be investigated as it returns an over limit fault message when the pressure goes over 25 mbar. The calibration and settings must be investigated.
- Both the Levelflex M FMP40 and Deltabar S PMD70 pressure were operated using the default settings from the manufacturer. How to fully utilize the capability of these devices should be investigated.
- The change in the level is observed in the Basic Experimental Template after 5 seconds from the time the valve position was changed. The delay in communication between PROFIBUS PA devices and CPU 314C-2DP needs to be investigated.
- The MPI connection between the CPU314C-2DP and PC was connected when doing the test. The connection needs to be made permanent.

13. Wiring Diagram

This is a wiring diagram for the PROFIBUS PA network in the ICE laboratory. The red line is the positive voltage wire and the black line is the negative voltage wire.



14. Conclusion

PROFIBUS is an open, vendor-independent communication protocol that is mainly used for industrial automation. The main aim of this project was to integrate the usage of PROFIBUS PA instruments into the ICE laboratory and develop a guide to assist students to develop LabVIEW programs to use these instruments. The project included a review of the communication protocols used and the instruments used. PROFIBUS is based on the idea of Master and Slave, where the master, normally in the form of a PLC sends a request to the slaves and the slaves responds by sending information to the master. A SIEMENS CPU314C-2DP was used as the master while the SIEMENS DP/PA coupler, the Levelflex M FMP40, and Deltabar S PMD70 were used as slaves. The GSD files of the SIEMENS DP/PA coupler, the Levelflex M FMP40, and Deltabar S PMD700 were installed in TIA Portal V13. A program to read data from the PROFIBUS PA instruments was created using GETIO blocks in ladder logic and downloaded to the CPU314C-2DP. As an intermediate check, communication between the PROFIBUS PA instruments and CPU314C-2DP was checked using watch tables in TIA Portal V13. OPC server was configured on the PC that is running the Master I/O program in the ICE laboratory. Communication between the CPU314C-2DP and the OPC server was checked by using the Quick Client tool in the OPC server. Communication between the OPC server and the Master I/O program (LabVIEW) was established by the use shared variables. The Master I/O Program was modified to include a program which calculates the measured parameters by PROFIBUS PA instruments. Finally, the Basic Experimental Template was modified to read measured parameters by PROFIBUS PA from the Master I/O program.

The deliverables of this project have been achieved, as the integration of PROFIBUS PA instruments into the ICE laboratory was successfully completed. A wiring diagram and guide on how to use PROFIBUS PA instruments was also developed. A TIA portal program and LabVIEW program developed in the project are included in the handover documents.

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15. Appendices

Appendix A

Status Code of the Levelflex M FMP40.

The data from the Levelflex M FMP40 is transmitted as a 32-bit floating number. The first 4 bytes contain the measured value while the 5th byte contains the status of the Levelflex M FMP40. The value of the status of the Levelflex M FMP40 can also be direct from the GETIO block. Table 13 shows the status code of the Levelflex M FMP40.

Table 13: Status code for the Levelflex M FMP40 [28]

Status code	Device Status	Significance
0C Hex	BAD	Device error
OF Hex	BAD	Device error
1 F Hex	BAD	Out –of service (target mode)
40 Hex	UNCERTAIN	Non-specific (simulation)
47 Hex	UNCERTAIN	Last usable value (Fail safe mode active)
4B Hex	UNCERTAIN	Substitute set (Fail safe mode active)
4F Hex	UNCERTAIN	Initial value (Fail safe mode active)
5C Hex	UNCERTAIN	Configuration error
80 Hex	GOOD	OK
84 Hex	GOOD	Active block alarm(static revision counter incremented)
89 Hex	GOOD	LOW_LIM(alarm active)
8A Hex	GOOD	HI_LIM (alarm active)
8D Hex	GOOD	LOW_LOW_LIM (alarm active)
8E Hex	GOOD	HI_HI_LIM (alarm active)

Appendix B

LabView Program to calculate Measured Level

Figure 67 shows an extract of the LabVIEW program used to calculate the measured. This section of the program is used to calculate the value of the Exponent based on Table 12 and the value is to be used in equation 1.

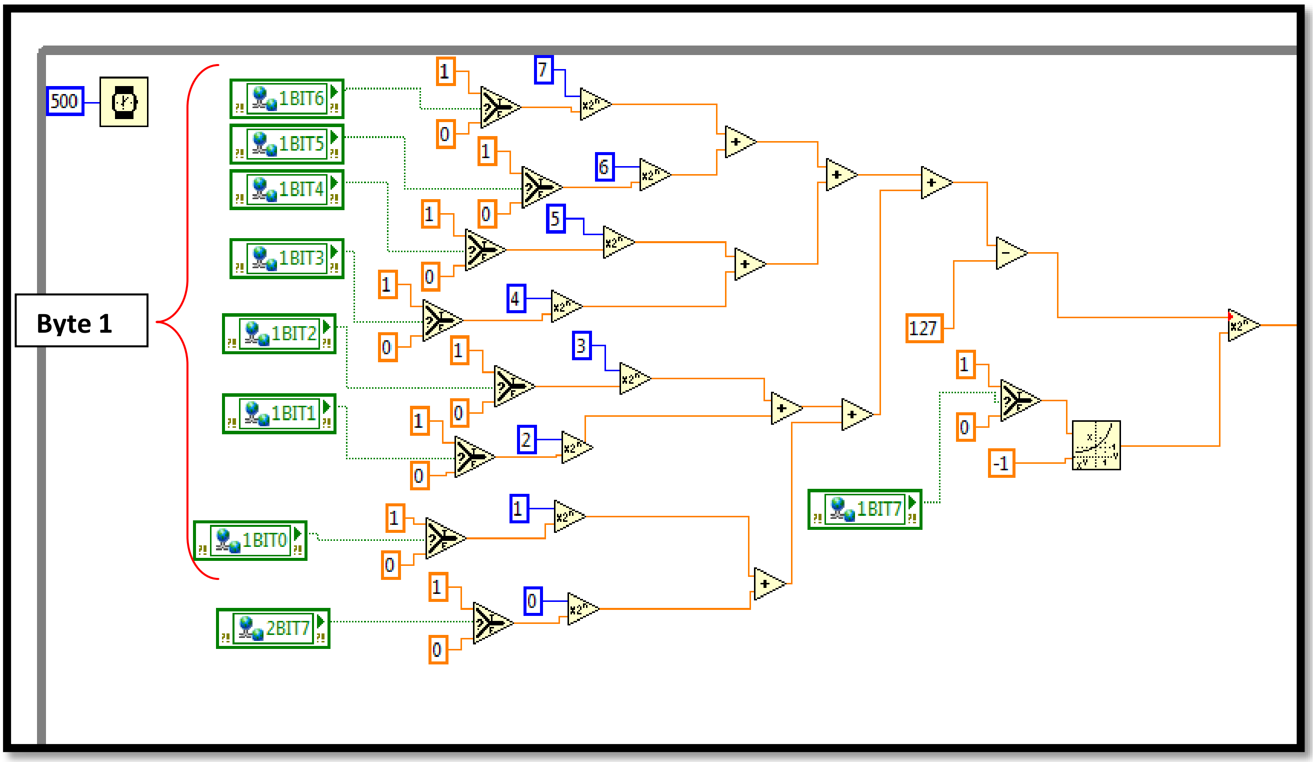

Figure 67: Extract of the LabVIEW program used to calculate Exponent (E) according to Table 12

Figure 68 is a continuation of the LabVIEW program shown in Figure 62. It shows the contribution of bytes 2 and 3 in the calculation of the measured level by the Levelflex M FMP40

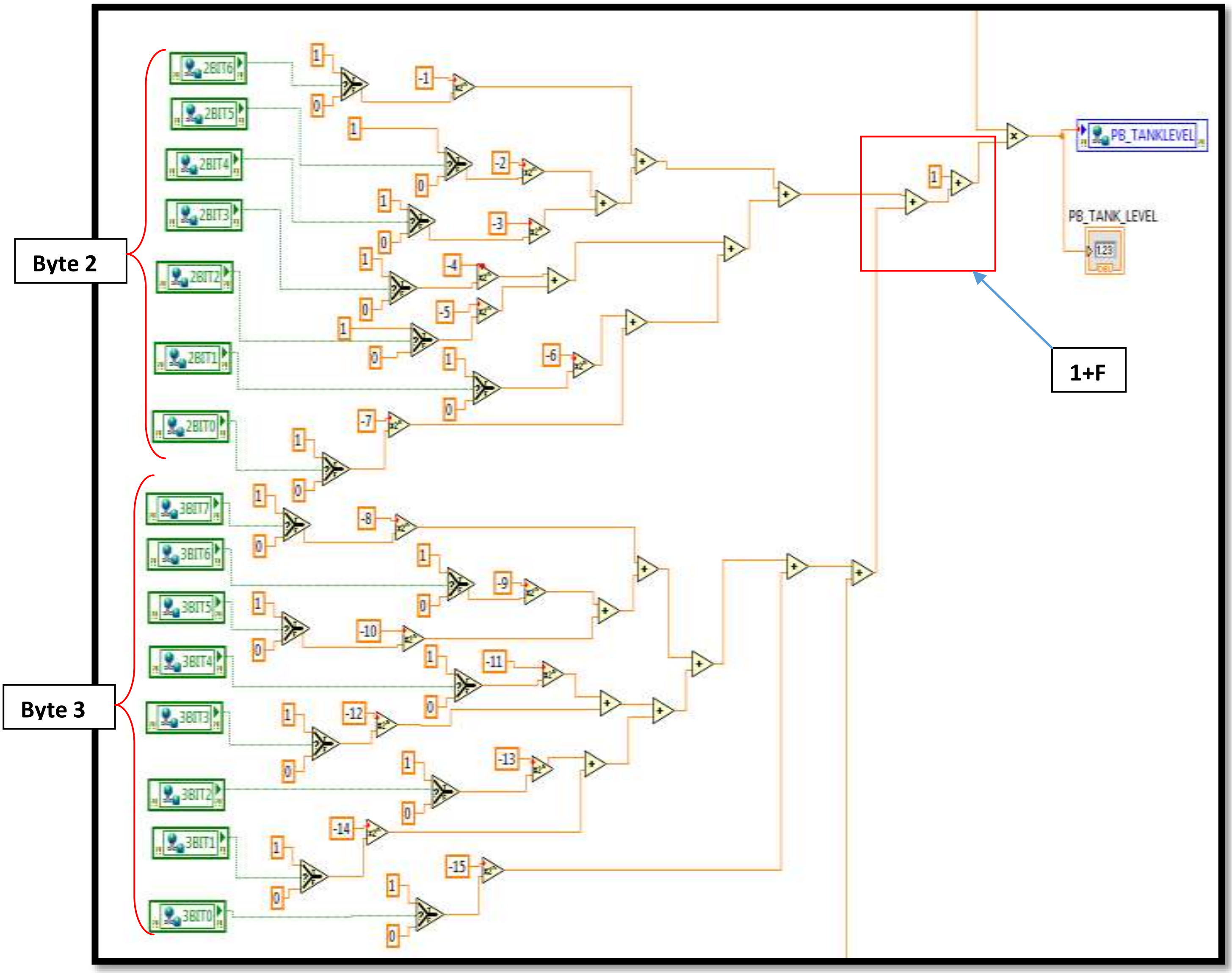

Figure 68: Continuation of the LabVIEW program

Figure 69 is the last part of the LabVIEW program built to calculate the measured level by the Levelflex M FMP40. It shows the contribution of the Byte 4 to the calculation. According to Table 12, the contribution of Byte2, Byte3 and Byte4 are called Mantissa(F) which is used in equation 1.

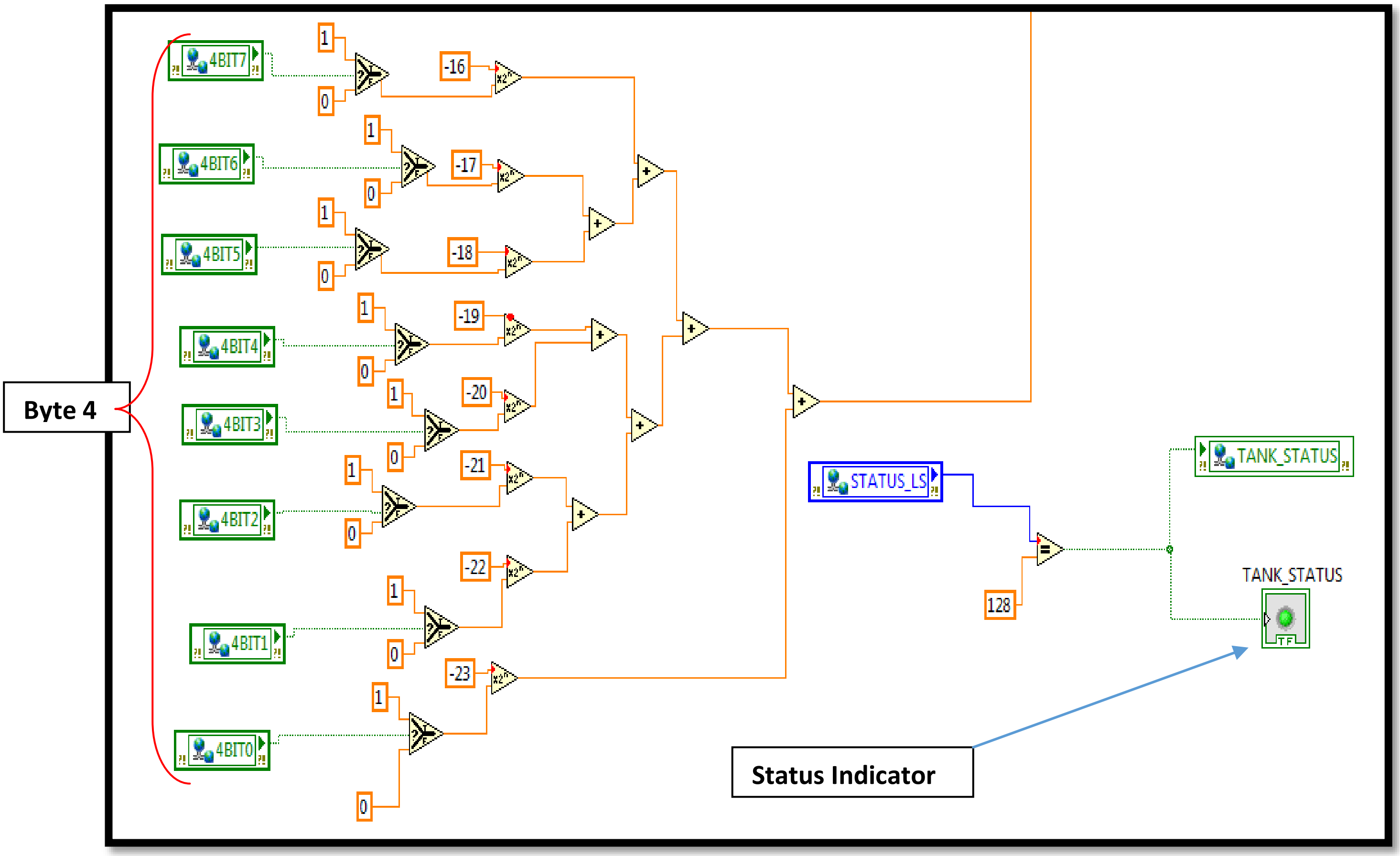

Figure 69: The contribution of Byte 4 in the calculation of the measured level by Levelflex M FMP40

In Figure 69, the value of byte 5 is aliased with the shared variable "STATUS_LS". If STATUS_LS is equal to 128, then the indicator LED will be GREEN, else it will be RED. **128DEC** is **80 Hex**, and according to Table 11, the status code of **80 HEX** means the device is good.

Appendix C

Configuration of the Deltabar S PMD70

GSD File

The Deltabar S PMD70 uses the PROFIBUS PA protocol and as with other PROFIBUS instruments, a GSD file must be installed in the TIA portal software for the Deltabar S PMD70 to be recognized by the Siemens PLC. The following steps were implemented to configure the Deltabar S PMD70.

- Install a GSD file for Level Deltabar S PMD70 by following the same steps discussed in Section 7.1

Address

The address of the Deltabar S PMD70 is set using the DIP switches. Table 14 is used the value of the address.

Table 14: Value of DIP switches in ON position for Deltabar S FMP70 [18]

Switch number	1	2	3	4	5	6	7
Value in “off” position	0	0	0	0	0	0	0
Value in “on” position	1	2	4	8	16	32	64

To set the address, open the cover of the Deltabar S PMD70 and arrange the PID switches to the desired address value as shown in Figure 70.

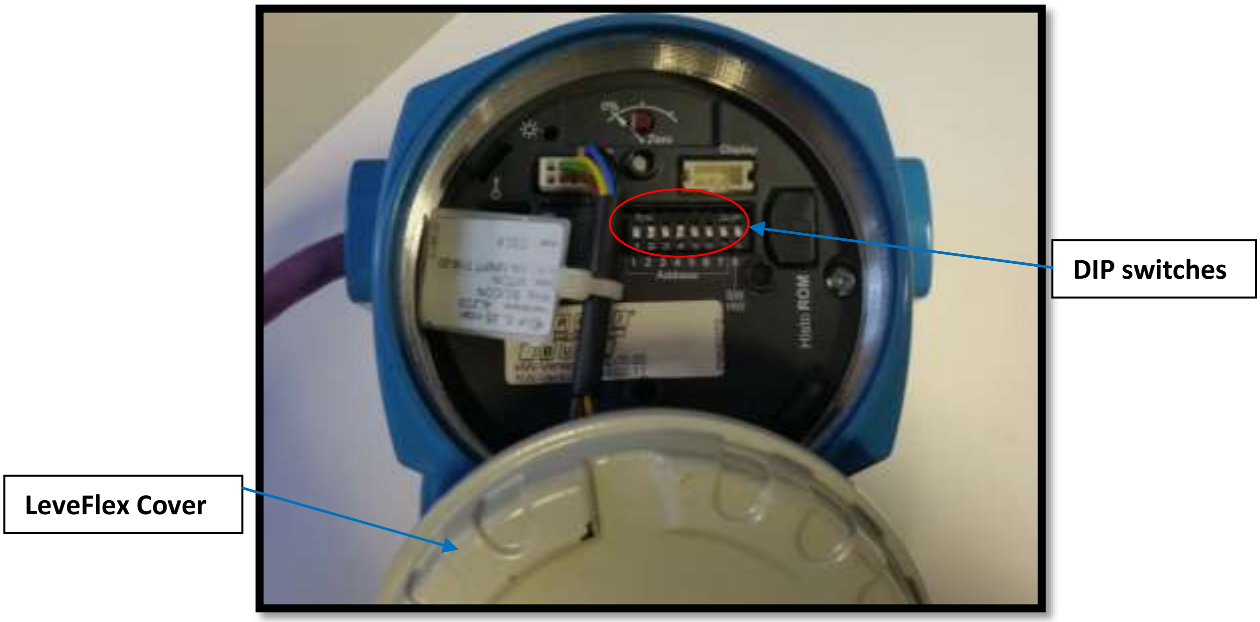

Figure 70: Picture of the address setting for the Deltabar S PMD70

Adding Deltabar S PMD70 to the network

Add the Deltabar S PMD70 to the PROFIBUS Network by the following the path below

Hardware catalog→ PROFIBUS PA profile → Endress+Hauser → Level → Echo → Deltabar S PMD70

Then drag the Deltabar S PMD70 icon into the network and connect it to the Levelflex MFMP40 network.

Figure 71 is a window showing the Deltabar S PMD70 on the network.

Figure 71: Deltabar S PMD added to the network

To set the parameters of the of the Deltabar S PMD70**,** double click on its icon in the network view, and the window shown in Figure 72 will appear. The address must be changed to be the same as the address set using the DIP switches, in this case, address 10. The transmission speed must be set to 45.45(31.25) Kbps. Figure 72 shows the settings for the Deltabar S PMD70. The value entered for the address is set using DIP switches.

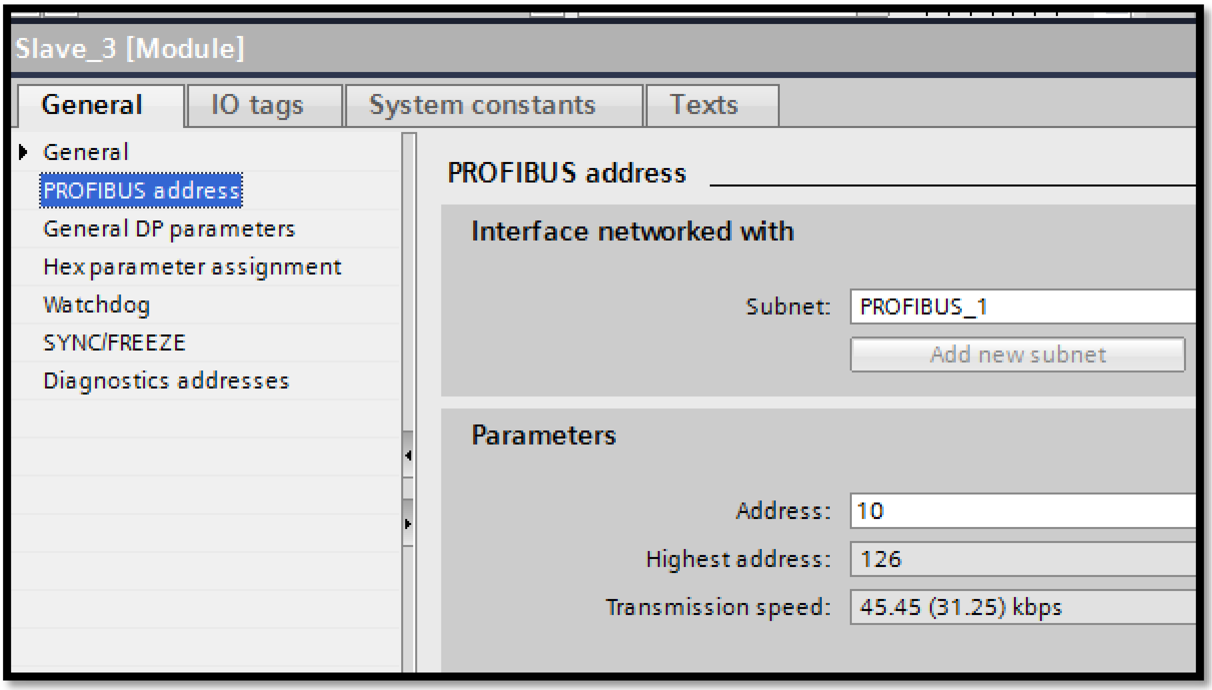

Figure 72: Window for setting properties of Delabar S PMD70

Reading Data from the Deltabar S PMD70

Figure 73 shows two GETIO blocks used to read data from Deltabar S PMD70. One block is used to get data for pressure measurement and the other is used for temperature measurement.

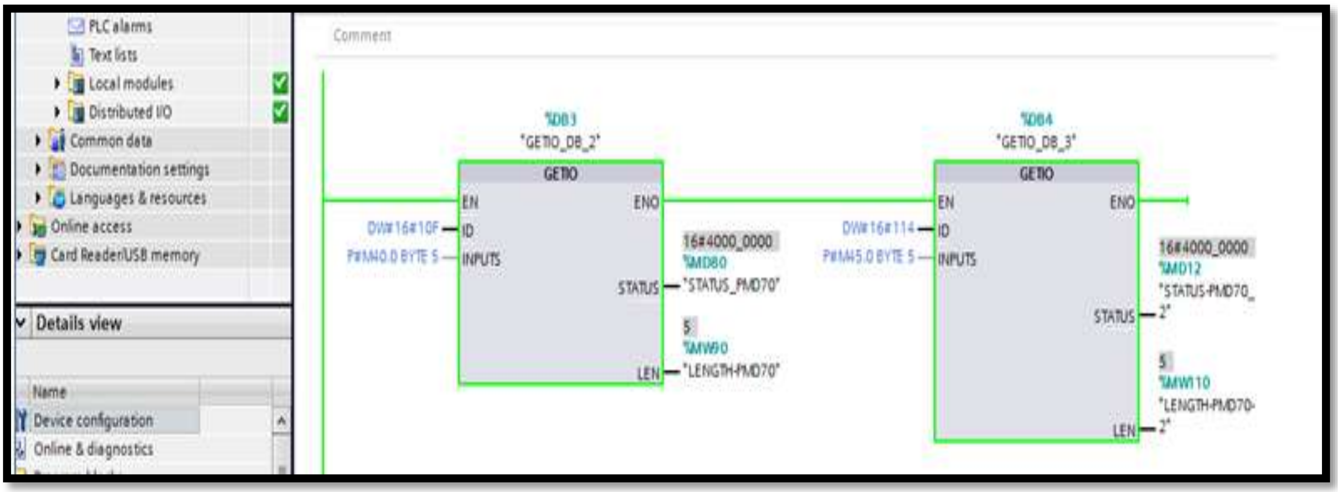

Figure 73: Program to read data from Deltabar S PMD70

The parameters of the blocks are obtained in the same way as in section 9.5.1.

Testing of the communication is between the Deltabar S PMD70 and CPU314C-2DP is also done through the use watch tables.

Appendix D

Calculation of pressure and temperature for the Deltabar S PMD70

The input data from the Deltabar S PMD70 is transmitted as a 32-bit floating point number. Table 15 shows the format of the transmitted data.

Table 15: Format of Transmitted Data from the Deltabar S PMD70 [18]

Byte 1	Byte 2	Byte 3	Byte 4	Byte5
Measured value as IEEE 754 floating point number				Status

The measured value is transmitted as an IEEE 754 floating point number, whereby

Measured value = $(-1)^{sign}$ X $2^{(E-127)}$ X (1+F)

Table 16 is used to calculate the measured value by Deltabar S PMD70 for both pressure and temperature.

Table 16: Structure of Data transmitted by Deltabar S FMP70 [18]

Byte 1								Byte 2							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit 0	Bit7	Bit 6	Bit 5	Bit 4	Bit3	Bit2	Bit1	Bit0
sign	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}
	Exponent (E)								Mantissa(F)						
Byte 3								Byte 4							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit 1	Bit 0	Bit7	Bit6	Bit 5	Bit 4	Bit3	Bit2	Bit1	Bit0
2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}	2^{-13}	2^{-14}	2^{-15}	2^{-16}	2^{-17}	2^{-18}	2^{-19}	2^{-20}	2^{-21}	2^{-22}	2^{-23}
Mantissa(F)															

Table 17 shows the status code of the Deltabar S PMD70

Table 17: Status Code for the Deltabar S PMD70 [18]

Status code[1)]	Device status	Meaning	Main process value	2nd cyclic value	3rd cyclic value
0000 0000	BAD	Not specific (FSAFE_TYPE = 2)	X	X [2)]	X [2]
0000 01xx	BAD	Configuration error (e.g. calibration not performed correctly) (FASFE_TYPE =2)	X	X [2]	X [2]
0000 11xx	BAD	Device error (FASFE_TYPE =2)	X	X [2]	X [2]
0001 00xx	BAD	Sensor error (FASFE_TYPE =2)	X	X [2]	X [2]
0001 1111	BAD	Out of service (target mode)	X		
0100 00xx	UNCERTAIN	Not-specific	X	X [2]	X [2]
0100 0100	UNCERTAIN	Last valid value (FSAFE_TYPE =1)	X		
0100 1000	UNCERTAIN	Substitute value (FSAFE_TYPE = 0)	X		
0100 1100	UNCERTAIN	Initial value (FSAFE_TYPE = 1)	X		
0101 11xx	UNCERTAIN	Configuration error (e.g. linearisation table not monotonic increasing)	X	X [2]	X [2]
0110 00xx	UNCERTAIN	Simulation in progress	X	X [2]	X [2]
1000 0000	GOOD	OK	X	X	X
1000 0100	GOOD	Active block alarm (static revision was increased)	X		
1000 1001	GOOD	LOW_LIM (alarm active)	X		
1000 1010	GOOD	HI_LIM (alarm active)	X		
1000 1101	GOOD	LOW_LOW_LIM (alarm active)	X		
1000 1110	GOOD	HI_HI_LIM (alarm active)	X		

Appendix E

LabVIEW Program to calculate Measured Pressure and Temperature

The shared variables are used to create a program to calculate pressure measured by Deltabar S PMD70. From Figure 73, the data from the CPU314-2CP is stored in memory locations M35 to M39. Byte 1 is stored in M35.0 therefore, Bit 7 of byte 1 is stored in M35.7 for the measured pressure. For the measured temperature, the data is stored in memory locations M40.0 to M44 of the CPU314C-2DP. The Labview program is the same as that built to calculate measured value for Levelflex M FMP40 with the shared variables aliased to the tags for reading data from Deltabar S PMD70.

Appendix F

A guide of how to use PROFIBUS PA instruments in the ICE Lab

This guide is focused on using the instruments that are already configured and integrated to the Master I/O program. The addition of new instruments to the network is done as discussed in the report from Section 8 to Section 11.

NB:The names of the shared variables are as used in this project.

To read data from the PROFIBUS PA instruments the following steps must be implemented.

1. In the client computer, click on

Start → All Programs → National Instruments → NI Distribution System Manager

A new window shown in Figure 74 will appear.

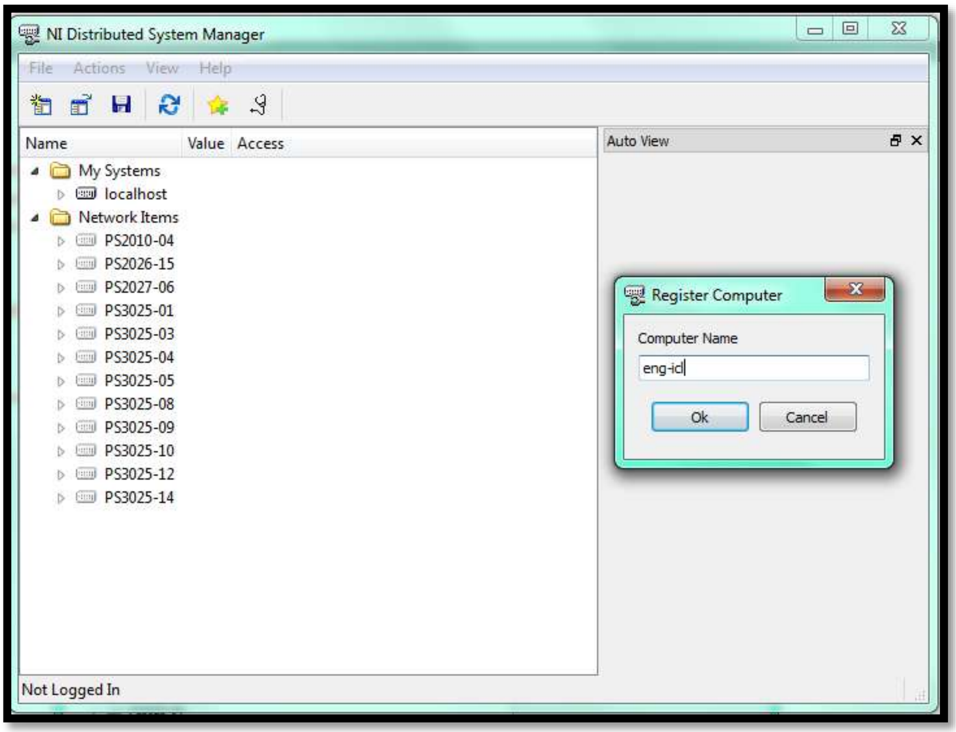

Figure 74: Registering a server in the client computer

6. Check under network items that **eng-icl** is available. If it is not, click on

   Actions → Register computer

   Enter eng-icl in the Computer Name and click on enter.

   The eng-icl will be added to the Network Items.

   Open the Basic Experimental Template Project

7. Click on the **variable library icon → New → Variable**

A window with shared variable properties will appear.

8. Give new variable a name, under variable Types, select Network published and click on the box to enable Aliasing.
9. Click on browse select the path of the variable to aliased with the new variable.

   eng-icl → Variable Library → PB_TANKLEVEL

   and click OK.

   The other variables can be read from the Master I/O are

   1. PB_TANK_STATUS, which display the status of the Levelflex M FMP40
   2. TEMP_PB, which shows the temperature measured by the Deltabar S FMP70.

Figure 75 shows the window that will appear when creating a shared variable

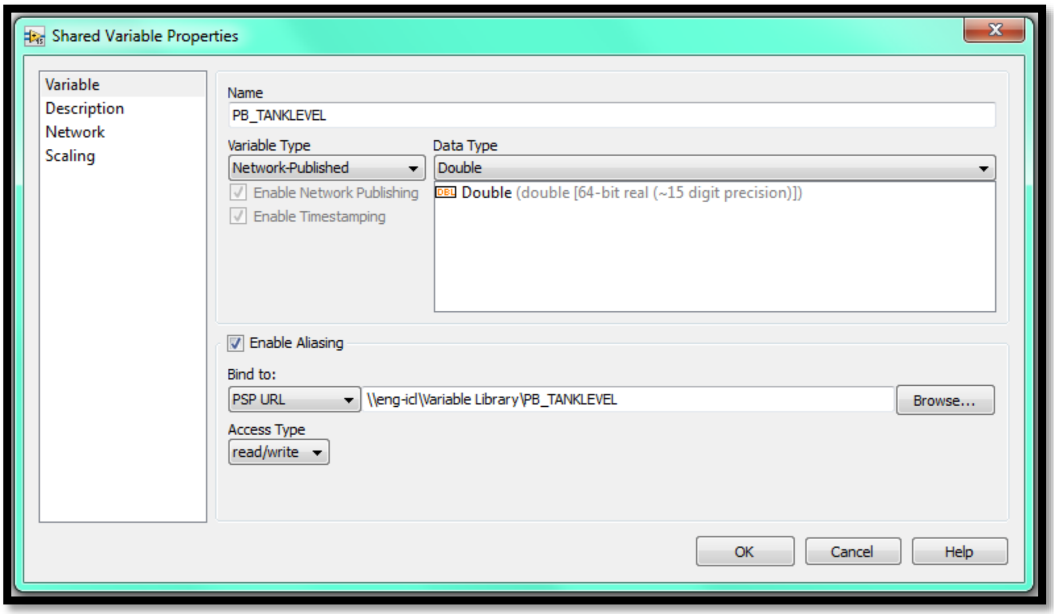

Figure 75: window for defining the properties of shared variable

The newly created variable will be aliased with the variable that indicates the level read by Levelflex M FMP40 in the Master I/O program. In the client program, it can be connected to the indicator which will show its value.

Before running the program, ensure the following checklist is satisfied.

CHECKLIST

1. CPU314C-2DP is running without faults
2. The serial MPI cable is connected between the CPU314C-2DP and PC running the Master I/O program.

3. Ensure that communication between the CPU314C-2DP and the OPC server is established. Check by using the Quick Client tool of the OPC server and ensuring that the quality is good. Figure 76 shows the Quick Client window.

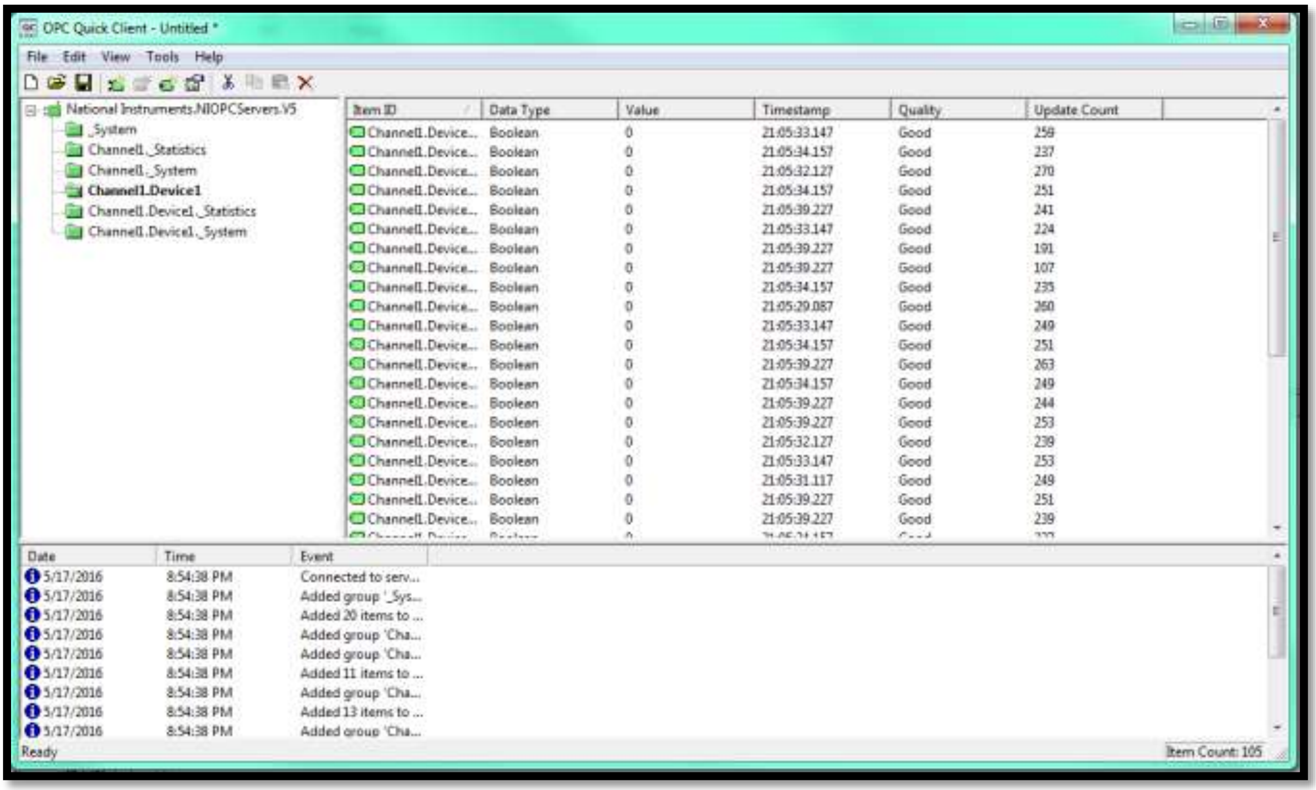

Figure 76: Window for quick client tool

4. If the quality is bad and the 1 and 2 in the checklist are satisfied then reinitialize the OPC server by implementing the following instructions

   - Right click on the arrow for the pull-up menu on the bottom right corner of the screen, then left click on the OPC server icon and select “**Stop Runtime Service**” as shown in Figure 77.

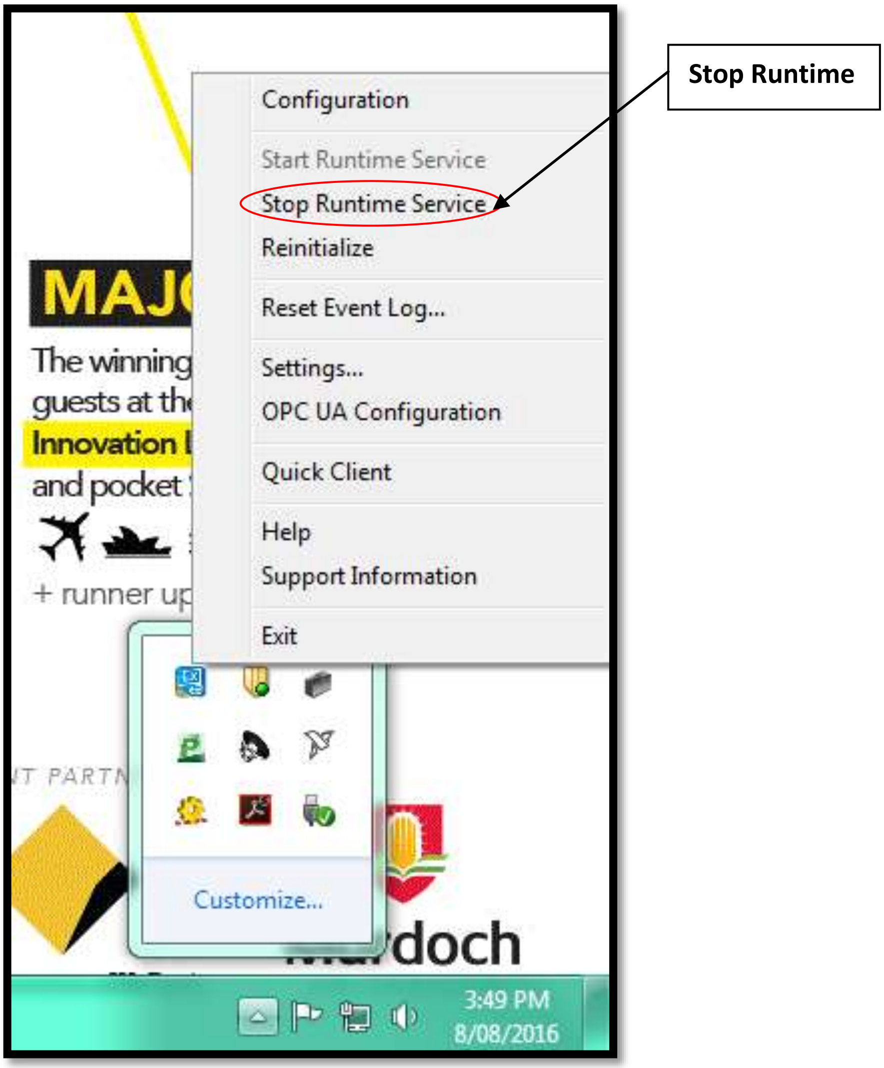

Figure 77: Reinitialization of the OPC server

Repeat the above step, but this time, select **Start Runtime Service.**

Check the quality of the communication again through Quick Client

If the communication is good, then run the Master I/O program and proceed to run the Basic Experimental Template.