

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

Fieldbus is an open, integrated total architecture for information integration [1]. It is an all-digital, serial, two-way communications system that serves as the base level network in a plant or factory automation environment [2]. Previous system uses a computer or expensive controller unit to control the network of devices. In recent years, some companies have developed instrument systems with more intelligence built into the devices. The drawback of these systems is that they are propriety and thus not interoperable.

The path to fieldbus technology began in the 1970s, with the introduction of the Distributed Control System (DCS), processing plants were able to distribute intelligent control throughout process facilities. During this time, most devices communicated to controllers using pneumatic or 4-20 mA analog signals [2]. These devices take input measurements and send the information to a control unit for processing. The computer then performs the necessary calculations and tells devices what their output should be. To get a device's serial number or to calibrate or test a device in the field it has to done it at the physical devices. Using Foundation Fieldbus technology these types of things can be done directly from the control room. With Foundation Fieldbus, control is brought down to the device level, after downloading the configuration, the control loop continues operating even if the monitoring computer is disconnected.

## 1.2 Problem Statement

Fieldbus is an industrial network system for real-time distributed control. Previously, computers were connected using Direct Digital Control. The integrated of this serial connection only allowed two devices to communicate. This would be the equivalent of the currently used 4-20mA communication scheme which requires that each device has its own communication point at the controller level [2]. However, the fieldbus technology is the equivalent of the current LAN-type connections, which require only one communication point at the controller level. This advantage allow multiple of analog and digital points to be connected at the same time. Hence be able to reduce both the length and the number of cable required [2]. This condition will eventually decrease the cost of wiring, cabinet space and also the analog and digital input cards.

There are many Fieldbus protocol available in the market. However, PETRONAS are now trying to use a compatible digital communication standard which provides the maximum benefits to the end user, which is Foundation Fieldbus. This project aims to enhance knowledge in the area of control of processes using Foundation Fieldbus system. The research is mainly focusing on the structure and architecture of Foundation Fieldbus and also its power system. This project is also intended to perform the Interoperability Testing of Foundation Fieldbus system by using Honeywell system. Interoperability testing is to check the ability of Foundation Fieldbus to operate multiple devices, independent of manufacture in the same system without loss of functionality [3]. The products from different manufacturers designed for one protocol cannot work with those designed for another. Thus, it is inconvenient to the end user to mix and match the devices from different vendors. Foundation Fieldbus provide standardization to make sure products from different manufacturer can interoperate with each other.

### 1.3 Objectives and Scope of Study

The main objectives of this project are:

- To perform technical verification and interoperability testing of Foundation Fieldbus devices to be used by PETRONAS, namely the basic test (focusing on validating the previous result), stress test and diagnostic test.
- To design, develop and configure on the technical design aspect of fieldbus such as to design fieldbus segment based on the requirement using the segment checker provide by Pepperl + Fuchs.
- To design a software tool that can be used to calculate the power requirement, length of cable and also the number of devices that can be connected in fieldbus system and also to do the basic research in control strategies, data communication and also power conditioners on the Foundation Fieldbus system.

This project is aims to perform the interoperability testing of Foundation Fieldbus system. During the process research has to be done to provide basic understanding about Foundation Fieldbus. The research will include on the control strategies, data communication and also power system of the Foundation Fieldbus. This understanding and knowledge will be implementing to design and configure fieldbus technical design using Segment Checker a freeware provide by Pepperl + Fuchs. The testing and calculation will determine the performance of the Foundation Fieldbus system.

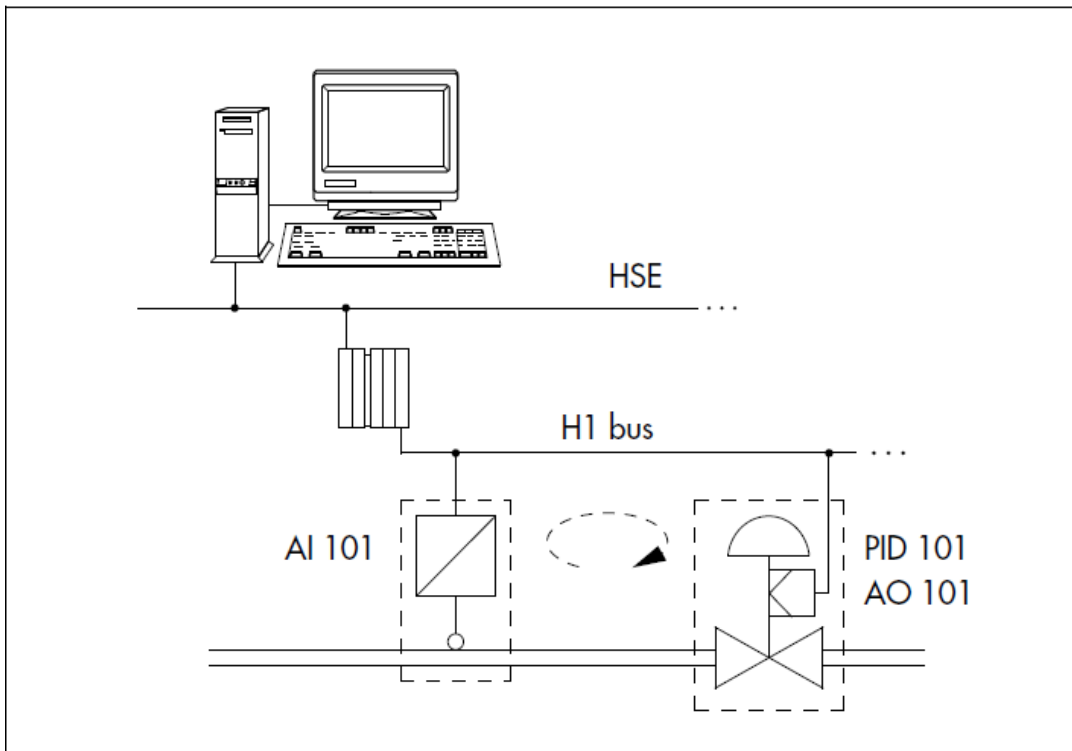
## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Foundation Fieldbus**

Foundation Fieldbus is one of the communications protocol and it is an all-digital, serial, two-way communications system. The Foundation Fieldbus is the upgraded communications protocol from the 4-20mA standard. At early stage of Foundation Fieldbus, every vendor invented its own protocol and independently used. Thus, the products can only work with other products from the same vendors. Because of this, the end user can not select the devices from different manufacturers since different vendor have a specialization in different area. The standardization had been decided by the industry experts by working on vendor independent device standard in 1985 [6].

Two related implementations of Foundation Fieldbus have been introduced to meet different needs within the process automation environment. These two implementations use different physical media and communication speeds which are H1 and HSE as shown in **Figure 1**. H1 interconnects field equipment such as sensors, actuators and I/O. HSE (High Speed Ethernet) provides integration of high speed controllers such as PLCs, H1 subsystems via a linking devices, data servers and workstations. Foundation Fieldbus is the only protocol with the built-in capability to distribute the control application across the network [1].



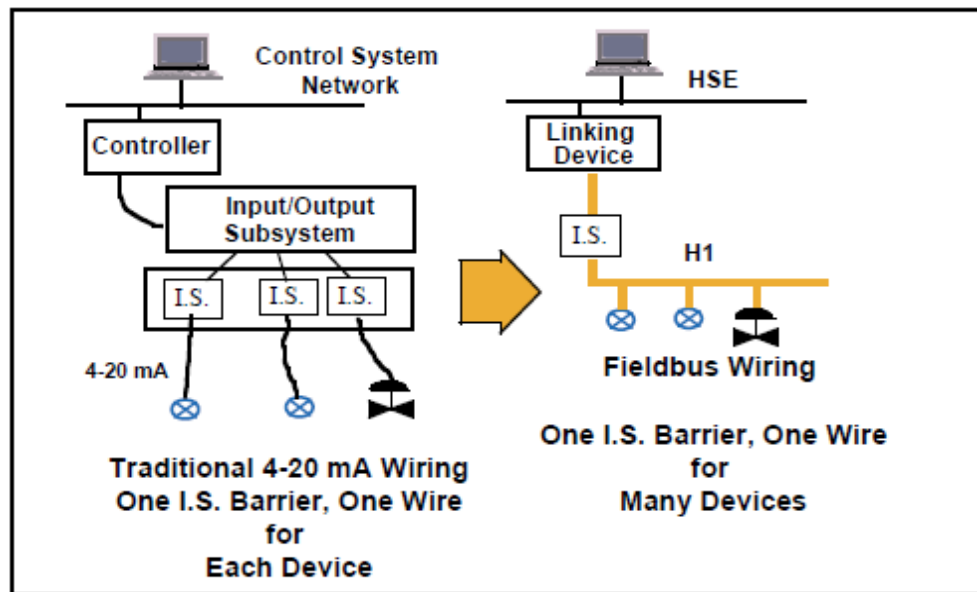
**Figure 1: Control Loop on Foundation Fieldbus**

## 2.2 Foundation Fieldbus VS Conventional Process Control

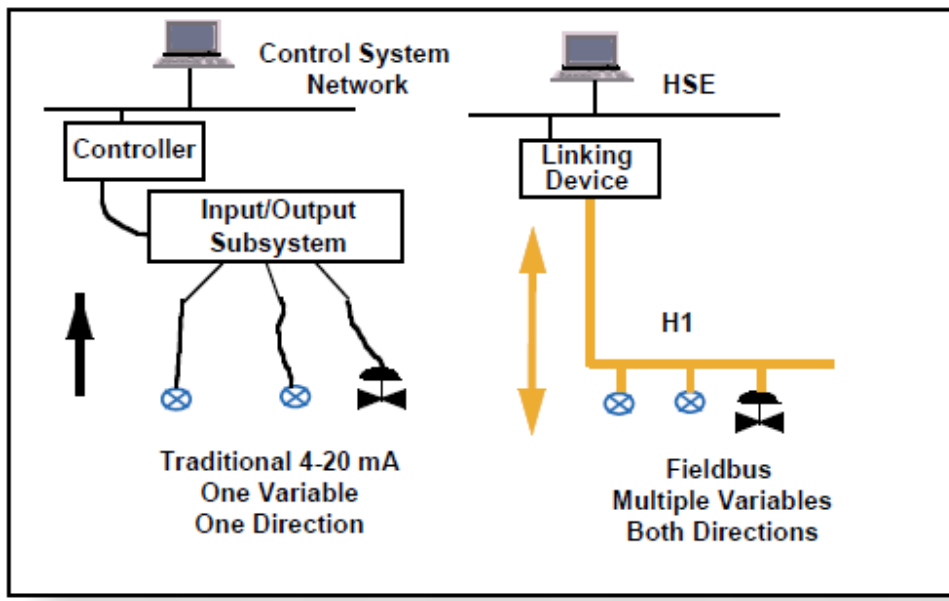
The Foundation Fieldbus provides a broad spectrum of services and functions compare to the existing conventional process control.

- Increased capabilities due to the full digital communications where a great deal of information can be communicated on a single cable. Instead of one hardwired cable for each variable, the numbers of information that can be communicated along just one network cable can be increased.
- Reduced wiring and wire terminations due to the multiple devices can be connected on one wire. This also results in fewer intrinsic safety barriers and marshalling as shown in **Figure 2**.

- Increased selection of suppliers due to the interoperability. Previously, manufactures have devices of many different protocols, and products designed for one protocol cannot work with those designed for another. Foundation Fieldbus has define a standard protocol that all devices can follow, thus making it possible for devices from different suppliers to work with each other.
- Reduces loading on control room equipment due to distribution of control and input/output functions to field devices.
- Allowed multiple variables from each device to be brought into the control system (two way communication) for archival, trend analysis, process optimization studies, report generation, predictive maintenance and asset management as shown in **Figure 3**.



**Figure 2: Comparison in the uses of I.S Barrier**



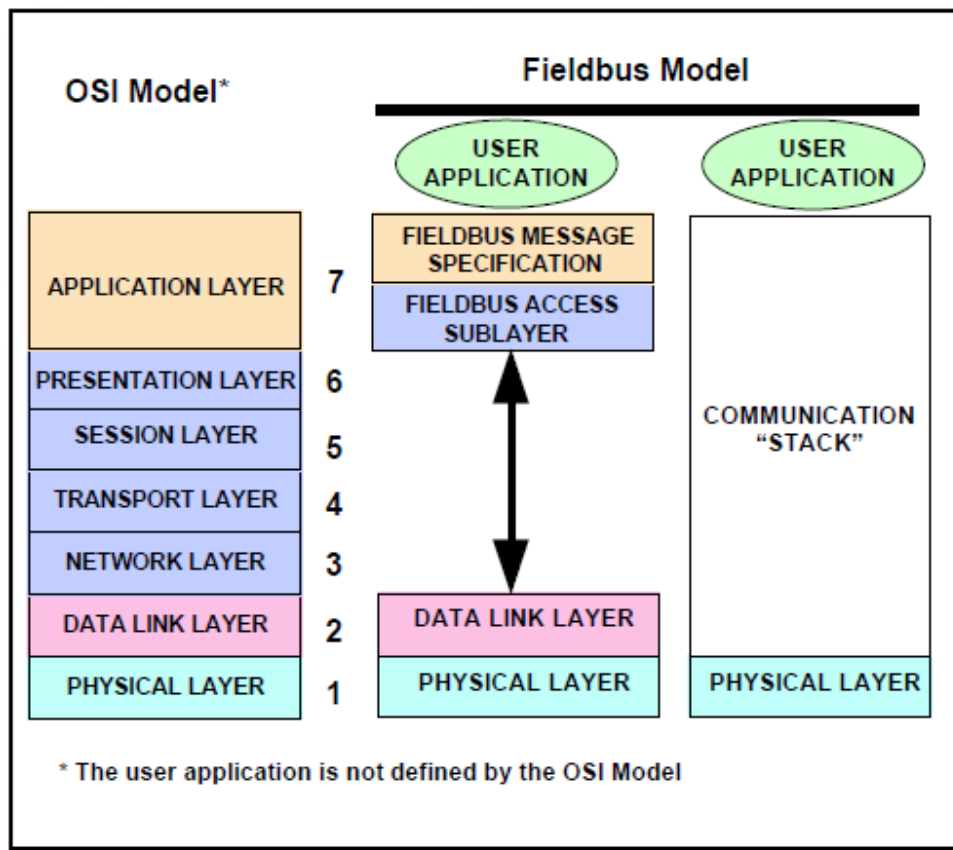
**Figure 3: Comparison on the variable and direction**

### 2.3 Foundation Fieldbus system architecture layer

The Foundation Fieldbus specification is based on the layered communications model which consists of three major elements:

- Physical Layer
- Communication Layer
- User Application

This layer was modeled using the Open Systems Interconnect (OSI) model as shown in **Figure 4**.



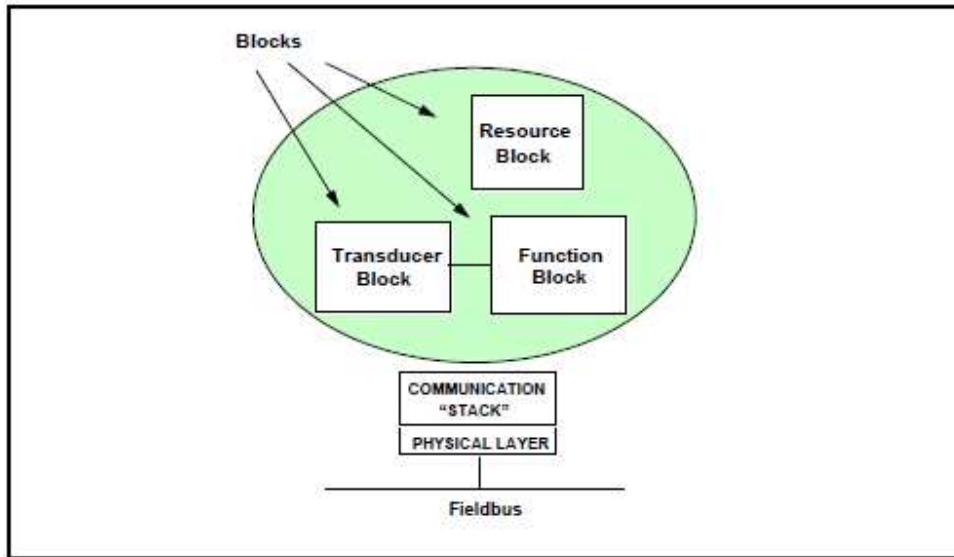
**Figure 4: Foundation Fieldbus system architecture layer compare with OSI model**

As shown in the Figure 4, the Fieldbus Model does not use OSI layers 3, 4, 5 and 6, thus the transmitting of the data for the Fieldbus Model is faster than the OSI Model. The Fieldbus Access Sublayer (FAS) maps the Fieldbus Messages Specification (FMS) onto the Data Link Layer (DLL) [1]. The Foundation Fieldbus has specified its own User Application model, significantly differentiating it from other models as the User Application Layer is not defined by the OSI model.



### 2.3.1 User Application Layer

The User Layer defines the way of accessing information within Fieldbus devices so that such information may be distributed to other devices or nodes in the Fieldbus network [4]. The Fieldbus Foundation has defined a standard User Application Layer based on Blocks. Blocks are representations of different types of application functions [1]. The types of Blocks used in User Application Layer are as shown in **Figure 5** and the assignment of all functions and device's data to the three different types of blocks is described in **Figure 6**.



**Figure 5: Types of Blocks used in User Application Layer**

## Resource Block

The Resource Block describes characteristics of the Fieldbus device such as the device name, manufacturer, and serial number. There is only one Resource Block in every device.

## Function Block

Function Blocks (FB) provides the control system behavior, where we can configure, maintain and customize the applications. Thus make this as the key concepts of the Fieldbus technology. The input and output parameters of Function Blocks can be linked over the Fieldbus. The execution of each Function Block is precisely scheduled. There can be many function blocks in single User Application. Ten standards Function Blocks for basic control are listed in **Table 1**.

**Table 1: Function Blocks**

<b>Function Block Name</b>	<b>Symbol</b>
Analog Input	AI
Analog Output	AO
Bias/Gain	BG
Discrete Input	DI
Discrete Output	DO
Manual Loader	ML
Proportional/Derivative	PD
Proportional/Integral/Derivative	PID
Ratio	RA

## Transducer Block

The Transducer Blocks are used to configure devices. These blocks decouple Function Blocks from the local input/output functions required to read sensors and command output hardware. They contain information such as calibration date and sensor type [1].

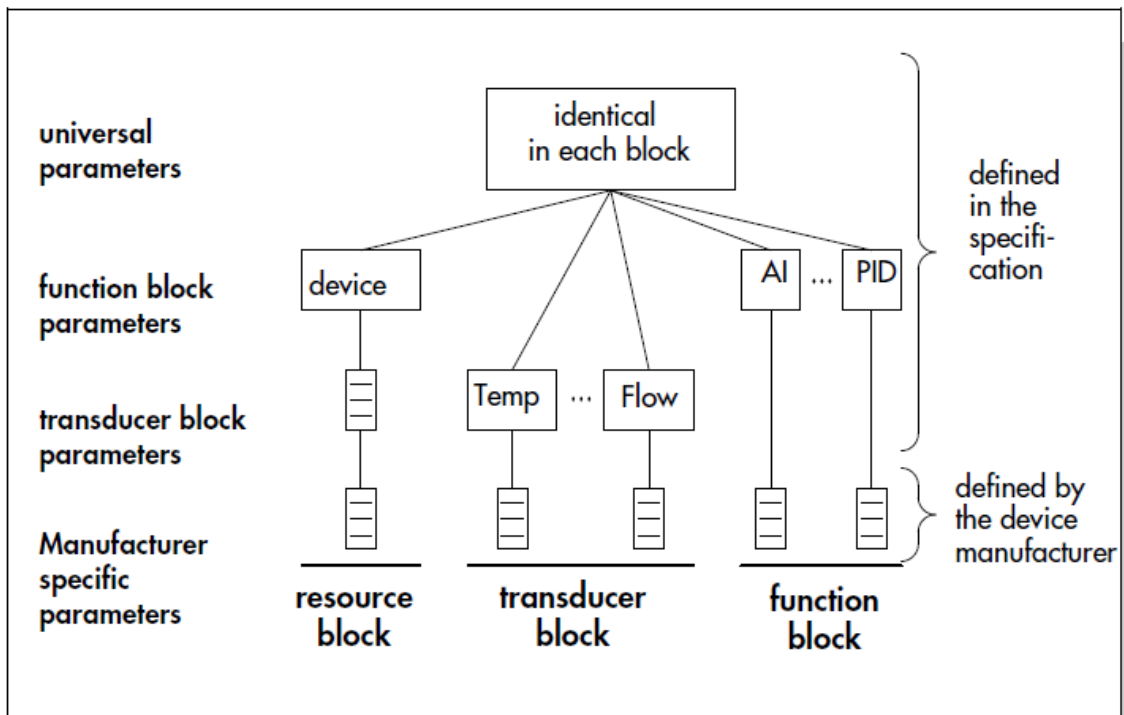


Figure 6: Division of field device data in resource, function and transducer block

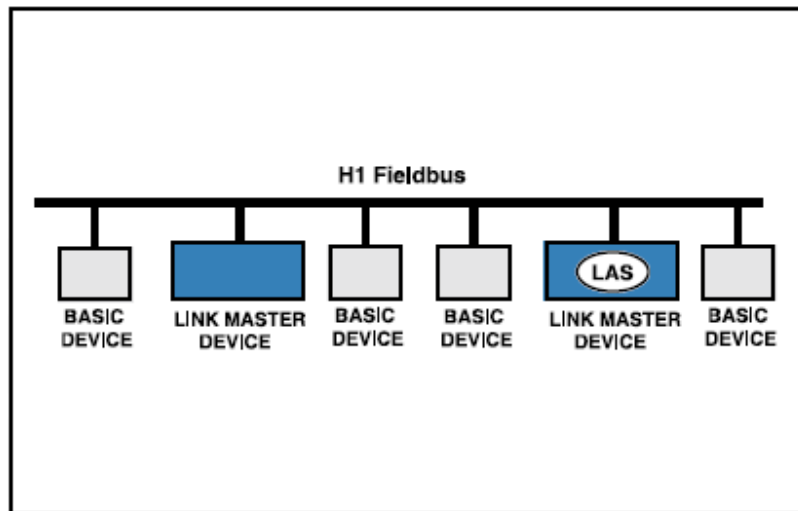
### 2.3.2 Communication Layer

The communication layer is in the form of stack called Communication Stack. This layer consists of Data Link Layer (DLL), Fieldbus Access Sublayer (FAS) and Fieldbus Message Specification (FMS).

Data link layer (DLL) controls transmission of message onto the Fieldbus. DLL manages access to the Fieldbus through a deterministic centralized bus scheduler called the Link Active Scheduler (LAS) [1].

The Link Active Schedule (LAS) controls and schedule the communication on the bus [5]. LAS will control the time for the device to communicate so that the signal will not collide during the communication. Based on the distributed communication it is important to have that two or more devices never access the bus simultaneously.

Two types of devices are defined in the DLL specifications which are Basic Device and Link Master. Link Master devices are capable of becoming the LAS if the active LAS fails. Basic Devices do not have this capability as shown in **Figure 7**.



**Figure 7: Link Master Device takes over the LAS rule**

### 2.3.3 *Physical Layer*

The function of physical layer is to receive messages from the communication layer and converts the messages into physical signals on the Fieldbus transmission and vice-versa [1]. FF used two bus systems, the slow, intrinsically safe H1 bus and the fast higher level High Speed Ethernet (HSE) as shown in the **Figure 1**.

The following summary gives a brief overview of the basic values and features of the H1 bus and HSE bus [5].

#### **H1 Bus**

- Manchester coding is used for the data transfer at the rate of 31.25kBit/s.
- Proper communication requires the field devices to have enough voltage. Minimum voltage for each device is 9volts.
- The H1 bus allows the field devices to be powered over the bus. Field devices powered by supply sources other than the bus must be connected to their own supply sources.
- The H1 bus can be designed intrinsically safe to suit application in the hazardous areas.

#### **HSE (High Speed Ethernet) Bus**

- The HSE runs at 100Mbits/s.
- The HSE bus able to respond sufficiently fast as the transmission rate is extremely high.
- The HSE bus do not support intrinsically safe.

## **2.4 Terminology of Foundation Fieldbus**

### *2.4.1 Segment*

A network may consist of one or more segments. A segment must have two terminators, one in each end. Multiple segments are connected using repeaters or other devices containing a repeater such as safety barrier. Maximum of 32 devices can be connected per segment if all the devices are separately powered. This is because the impedance of the each field device acts as a load on the communication signal. However, most fieldbus devices are bus powered thus the voltage drop along the conductors limits the number of devices to 16 for a single segment network.

### *2.4.2 Terminator*

Terminator is a simple component that does not communicate. Often the terminator is built into another device to eliminate the need for a separate terminator. The function of terminator is being the terminator function of preventing signal reflection that will lead to communication error and the second function is to convert the current change produced by a transmitting device into a voltage change across the entire network that is picked up by all devices as the means for receiving the signal.

### *2.4.3 Spurs*

Spurs are short pieces of cable that branch out from the main trunk to each individual device. By connecting the devices to trunk with spurs, it is convenient to remove the device for maintenance without disturbing the rest of the network. There should never be more than four devices connected to each spur.

## **2.5 Foundation Fieldbus Topologies**

There are several topologies may be used in the Fieldbus design. The different between these topologies is where the terminator shall be mounted.

### *2.5.1 Bus with Spurs Topology*

This topology uses a main cable called trunk runs from the marshalling cabinet out into the field until it reaches the last device, passing all the devices along the way. From the main trunk the shorter wires called spurs connected the individual devices.

### *2.5.2 Tree topology*

The trunk runs into the field where it branches out into the individual devices from a single junction box. This topology minimizes the number of connections, but the drawback is the cable length will be longer especially if the devices are not particularly close together.

### *2.5.3 Point-to-Point Topology*

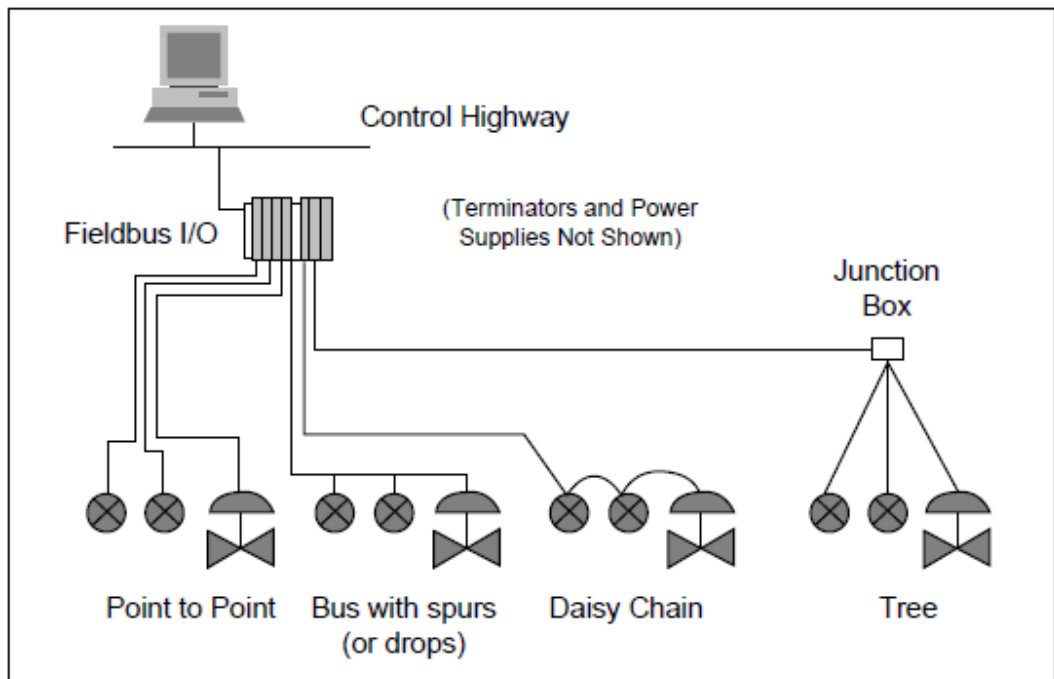
In this topology all the devices used in the application are connected in series. The Fieldbus trunk is routed from one device to the next, being interconnected to the terminals of each Fieldbus device. This type of topology is rarely used as the failure of one device will result in total network failure [4].

### *2.5.4 Daisy Chain*

With this topology, the Fieldbus cable is routed from device to device on this segment and it interconnected at the terminals of each Fieldbus device. [4].

### *2.5.5 Mixed Topology*

Mixed topology will mix the used topology connected to one another.



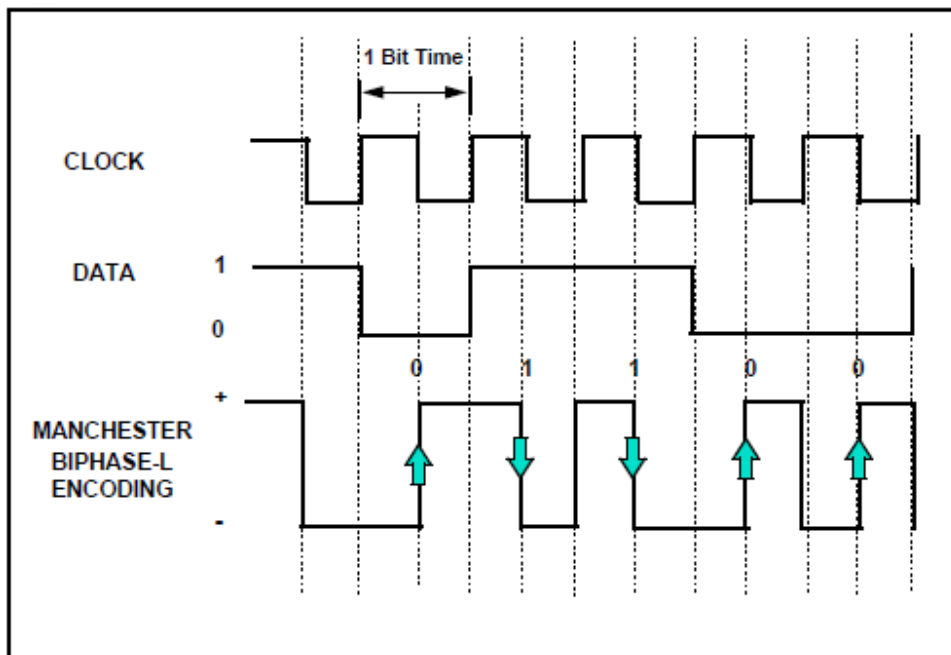
**Figure 8: Possible Fieldbus Topologies**



## 2.6 Fieldbus Data Communication

Fieldbus signals are encoded using Manchester Biphase-L technique [2]. The clock information is embedded in the serial data stream thus make the signal called 'synchronous serial'. The fieldbus signal is created by combining the data and clock signal as shown in the **Figure 9**.

The signal receiver of fieldbus signal interprets a positive transition in the middle of a bit time as a logical "0" and a negative transition as a logical "1". Special characters are defined for the preamble, start delimiter and end delimiter as shown in **Figure 10**. The preamble is used by the receiver to synchronize its internal clock with the incoming fieldbus signal [2]. Special N+ and N- are in the start delimiter and end delimiter. The receiver uses the start delimiter to find the beginning of a fieldbus message and it will accept data until the end delimiter is received.



**Figure 9: Manchester Biphase-L encoding**

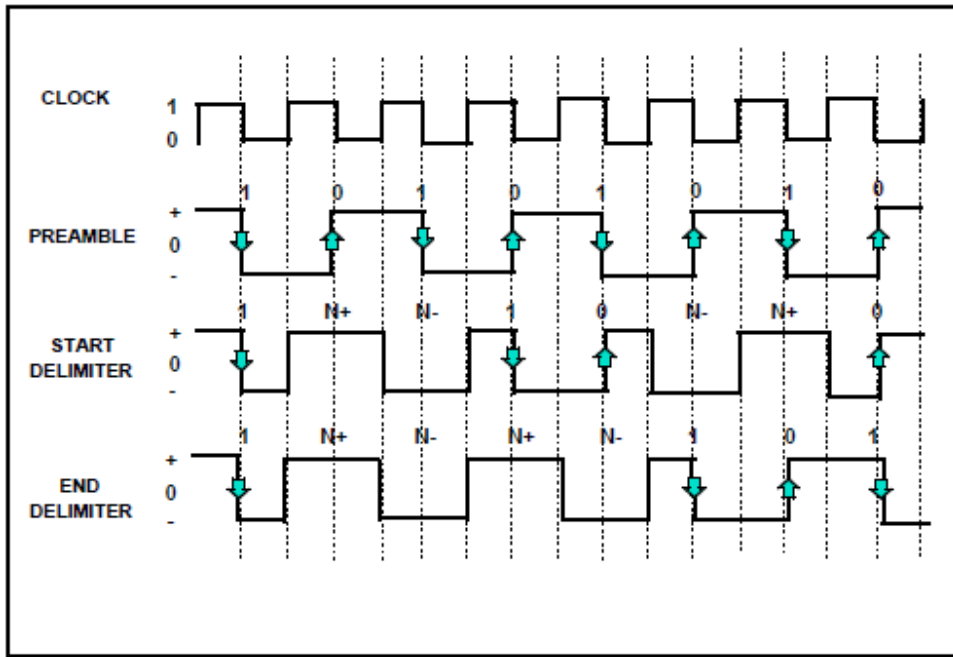
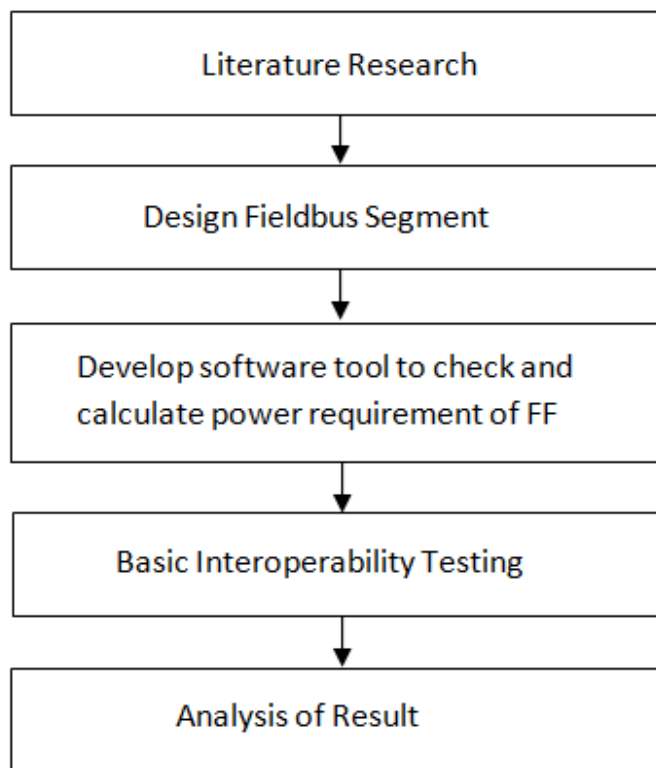


Figure 10: Preamble, Start Delimiter and End Delimiter

## CHAPTER 3

### METHODOLOGY

#### 3.1 Procedure Identification



**Figure 11: Project Work Flow**

### 3.2 Basic Interoperability Testing for Honeywell system

Basic Interoperability Testing for Honeywell systems consists of:

1. Device Commissioning
2. Device Decommissioning
3. Online Device Replacement
4. Physical Layer Diagnostic (Drop Out Test)
5. Calibration Function Check

#### 3.2.1 Test Equipment

1. Foundation Fieldbus Emerson 375 HART Communicator
2. Workstation (Honeywell Experion system)
3. Devices from different vendor (Test Bench)



**Figure 12: Foundation Fieldbus devices before upgrading**



**Figure 13: Foundation Fieldbus devices after upgrading**

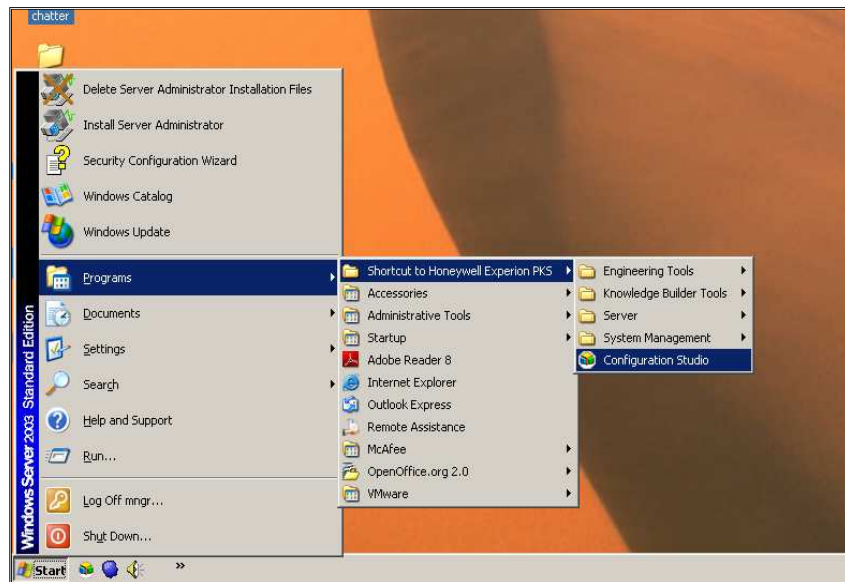


**Figure 14: Emerson 375 HART Communicator**

### 3.2.2 Procedure

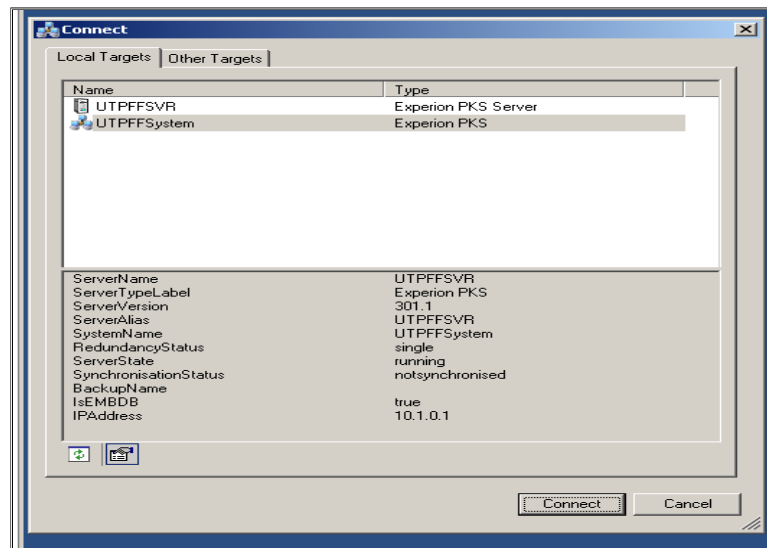
#### Test 1: Device Commissioning

- 1.1 Power up Host system at Cabinet 3.
- 1.2 Power up switch for MTL and P+F at Cabinet 2.
- 1.3 At the selector switch (front panel of Cabinet 2), select Honeywell for Segment 1 and Segment 2.
- 1.4 Click “Start”, select “Programs” then “Honeywell Experion PKS” select “Configuration Studio”.



**Figure 15: Select “Configuration Studio”**

1.5 Select “UTPFFSystem”, click “Connect”.

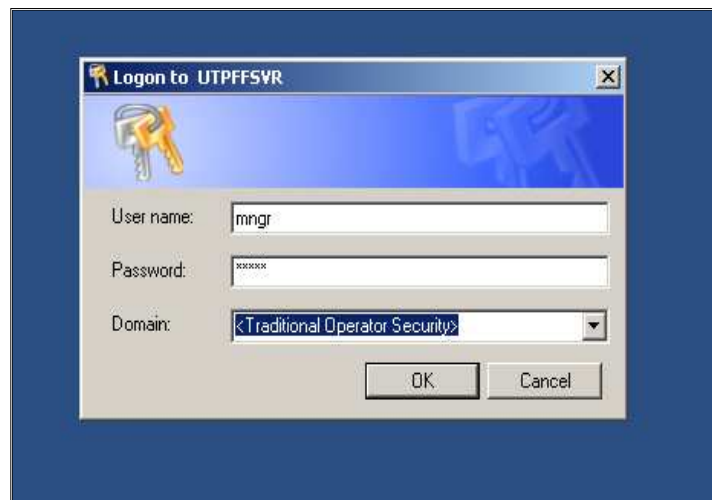


**Figure 16: Select “UTPFFSystem”**

1.6 Login to windows using following username and password:

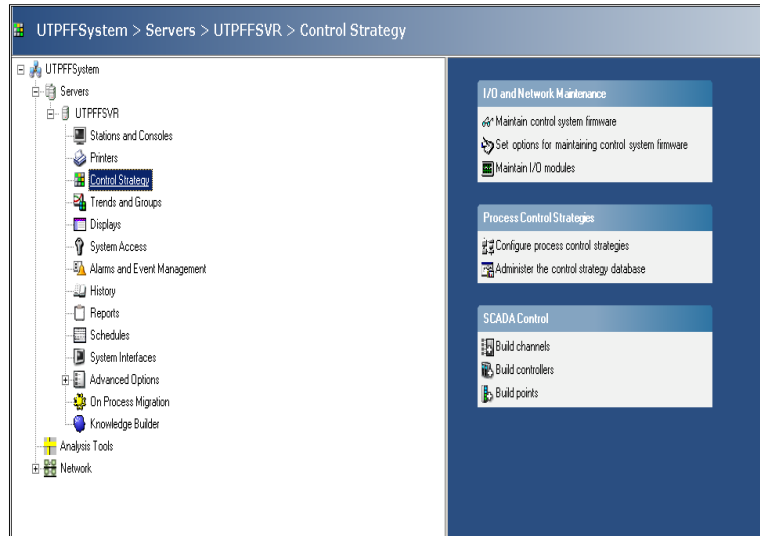
Username: mngr

Password: mngr1



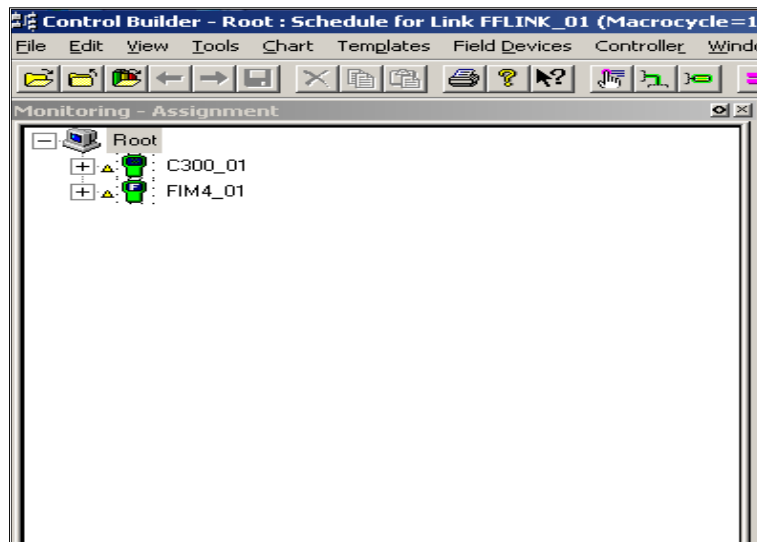
**Figure 17: Logon to UTPFFSVR**

- 1.7 Expand “UTPFSystem”, “Server”, “UTPFSSVR” and click “Control Strategy”.



**Figure 18: Select “Configure Process Control”**

- 1.8 From “Process Control Strategy”, click “Configure Process Control Strategies” And a “Control Builder” window will popup.



**Figure 19: Control Builder**



1.9 At “Monitoring –Assignment”, check the status of C300\_01 and FIM4\_01.

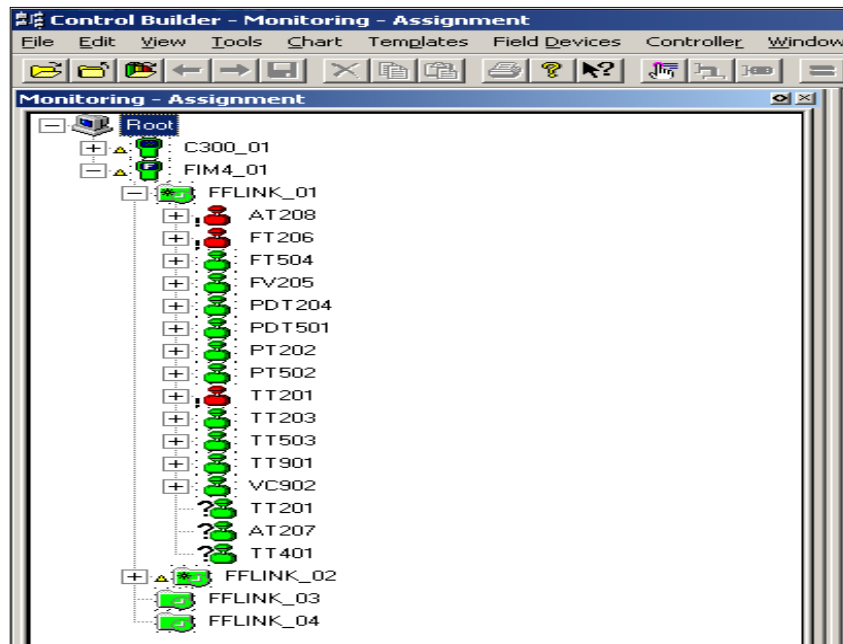
*Note: Both should be in GREEN colour. In case of Controller in offline state for more than 120hours, the program needs to be restored. The state is marked by RED colour.*

If status is in RED:

- Right Click at “C300\_01”, select “Checkpoint” and Select “Restore from Checkpoint”.
- A new window will pop up. Select the last saved checkpoint to be restored. Click “Restore”
- Start the controller by double click the controller “CEEC300\_01”.  
At “Main” tab, go to “CEE Command”, and select WARMSTART.  
Click YES. Wait until all the icons in Green.

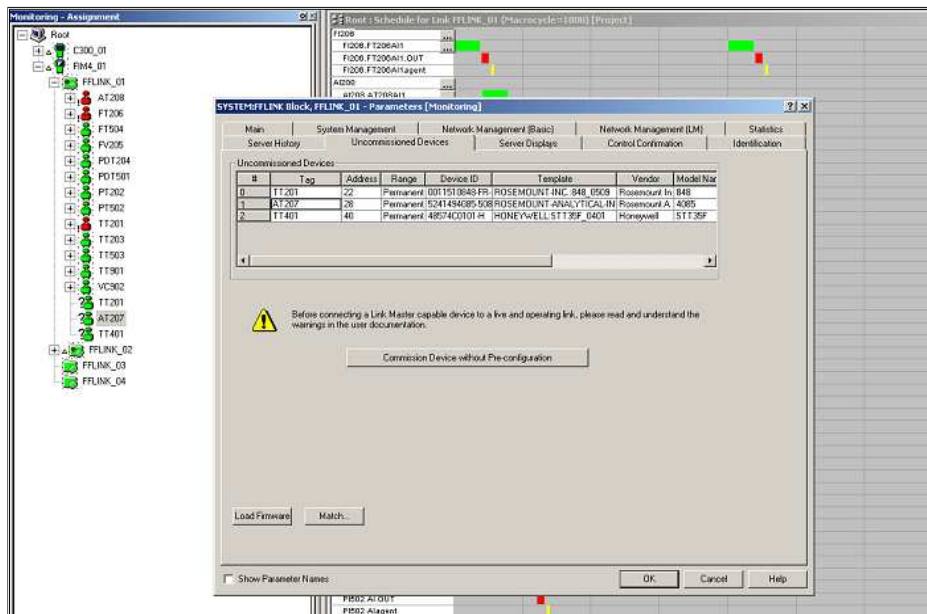
1.10 From the “Monitoring-Assignment”

- Expand “FIM4\_01”
- Expand “FFLINK\_01” (segment 1).
- Check the status of the device base on the colour/ “?” sign.
  - RED : Already in the database but the system cannot be read.
  - BLUE: Idle / Inactive
  - GREEN : Live device
  - “?” sign : Uncommissioned device



**Figure 20: Monitoring Assignment**

- 1.11 To commission a device, double click on device in RED.
- A window will be popup and select the device name. Click “Commission Device Without Pre-Configuration”. (Note: Take from devices segment), “User Authorisation” window will be popup, click “NEXT” until complete.
  - Commissioning is successful when device turn to GREEN.
  - Repeat steps for other devices.

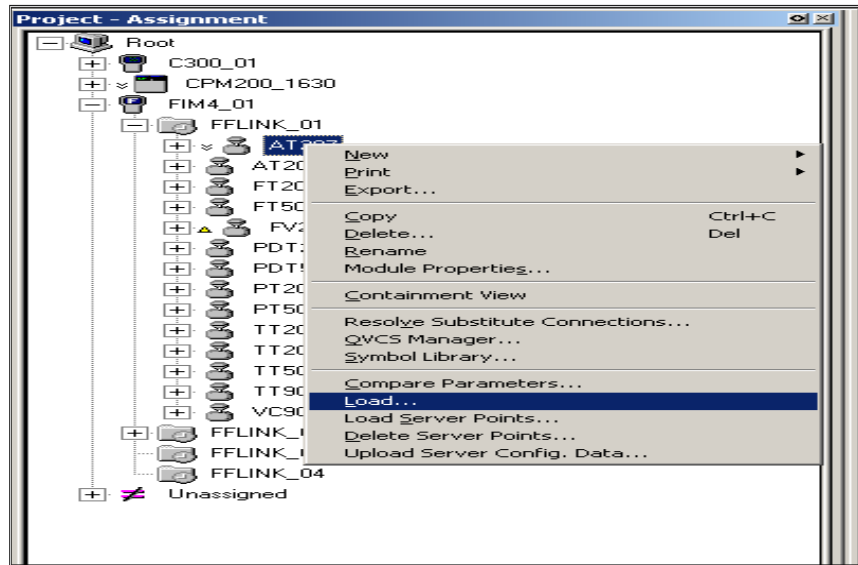


**Figure 21: Select “Commission Device Without Pre-Configuration”**

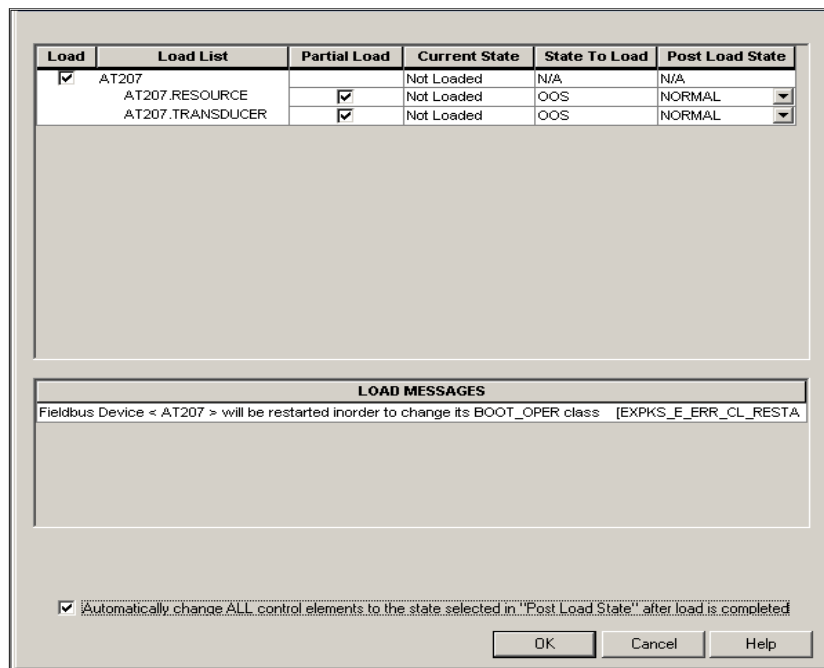
1.12 If the device unable to commission (device GREEN colour with “?” sign only), reload the project database.

- At “Project-Assignment”:
- Expand “FIM4\_01” and “FFLINK\_01”.
- Right click on the device, select “Load” and click “Continue”  
Click OK.

Note: Check the ‘Automatically change ALL control elements to the state selected in Post Load State’ after load is completed.



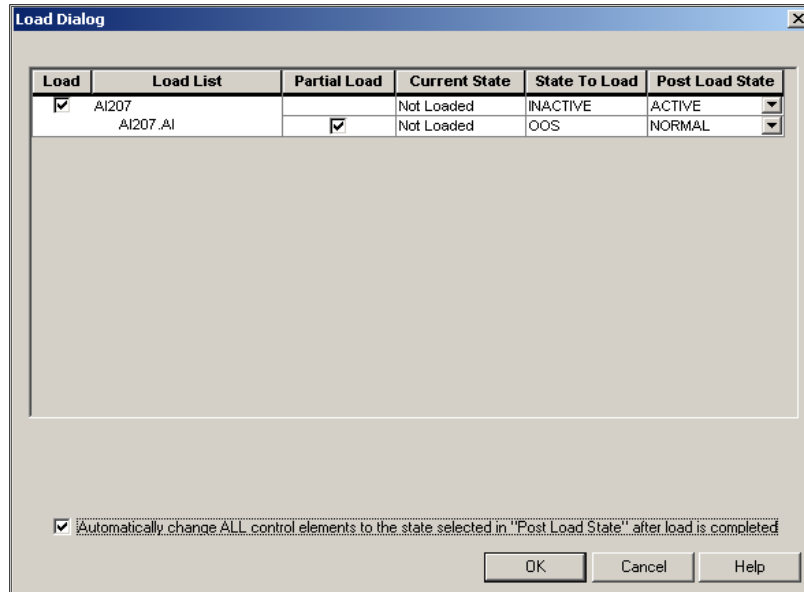
**Figure 22: Project Assignment**



**Figure 23: Reload project database**

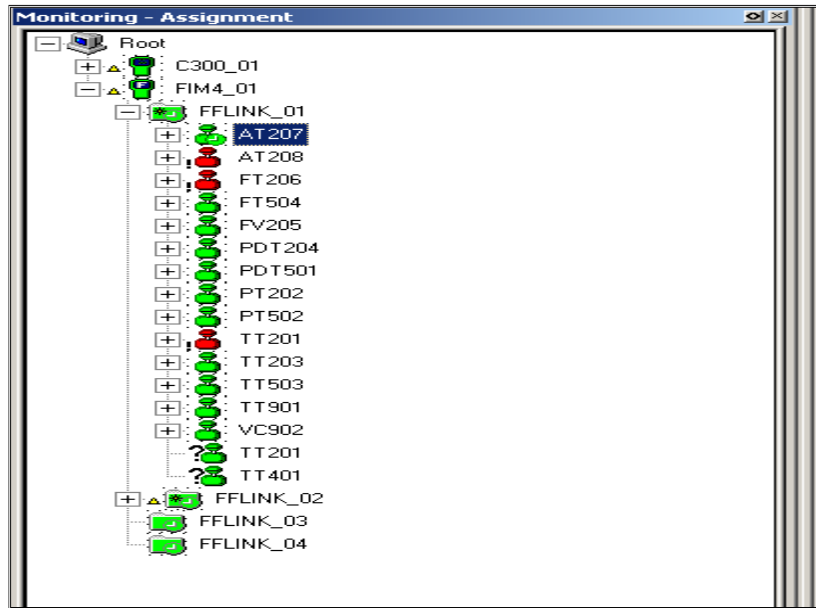
1.13 Expand “CEEC300\_01”.

- Right click on the function block of device, select “Load” and click “Continue”, Click OK.



**Figure 24: Check the ‘Automatically change ALL control elements to the state selected in Post Load State after load is complete’.**

- At “Monitoring-Assignment” device should turn to GREEN without “?” sign.



**Figure 25: Device turn to green color**

## Test 2: Device Decommissioning

### 2.1 From 'Monitoring-Assignment'

- Expand "FIM4\_01"
- Expand "FFLINK\_01" (segment 1).
- Check the status of the device base on the colour/ "?" sign.  
 RED : Already in the database but the system cannot be read  
 BLUE: Idle / Inactive  
 GREEN : Live device  
 "?" sign : Uncommissioned device

### 2.2 Expand "CEEC300\_01"

- Right click the function block of the device and select "Inactivate".
- Select "Selected item(s)" and click YES. Device will turn BLUE.
- Right click at the BLUE function block and select "Delete". A window will popup. Click "Continue".
- Click "Delete Selected Object(s)". Function block will be deleted.

- 2.3 Expand “FIM4\_01”. Expand “FFLINK\_01”.
- Right click device tag and select “Force Delete”. “Force Delete” window will popup, click “Continue”. Click “Force Delete”
  - Device will turn GREEN with “?” sign. It shows device decommission is successful.

### Test 3: Online Device Replacement

- 3.1 At “Monitoring-Assignment”, select the device that need to be replaced.

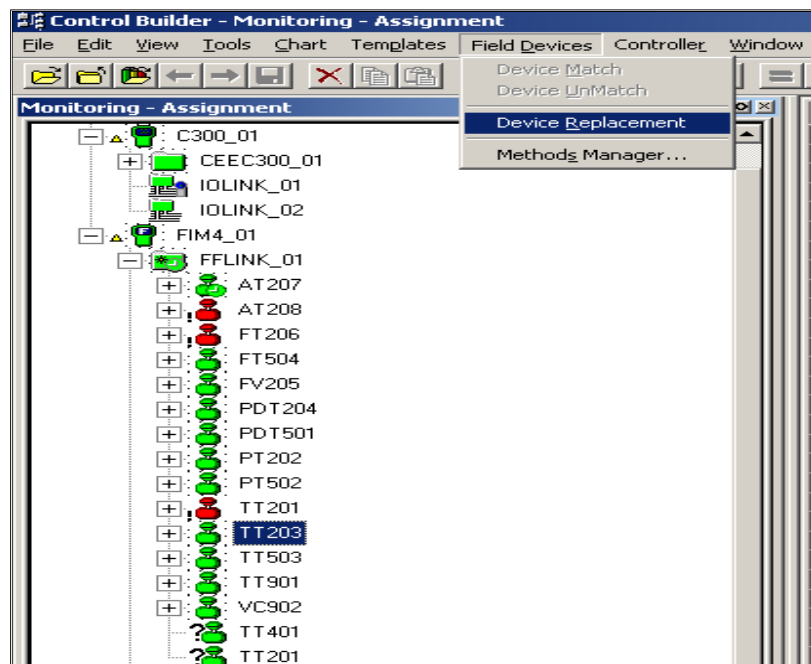
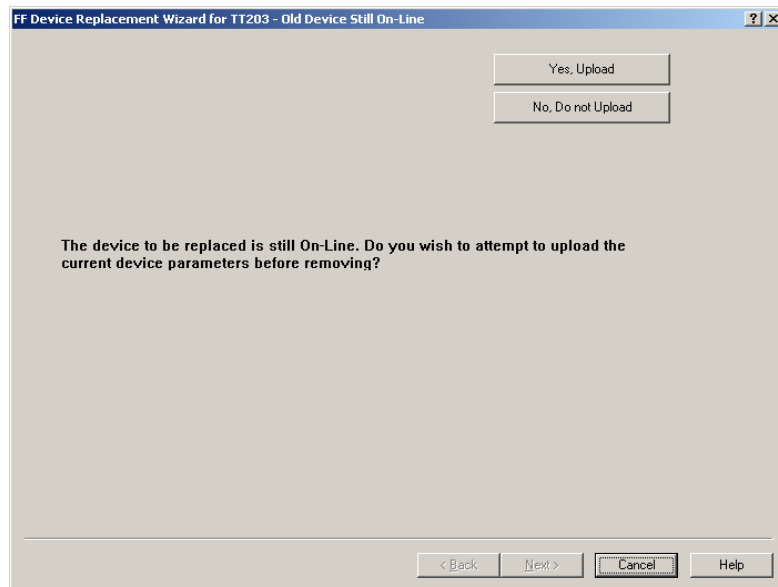


Figure 26: Select the device that needs to be replaced

- 3.2 Click “Field Devices” (located at top of the window).
- Select “Device Replacement”. Device Replacement Wizard Window will popup.
  - Click NEXT and click “Yes, Upload”. FF Device Replacement Wizard window will popup.
  - Wait for the device that need to be replaced been detected by the system.



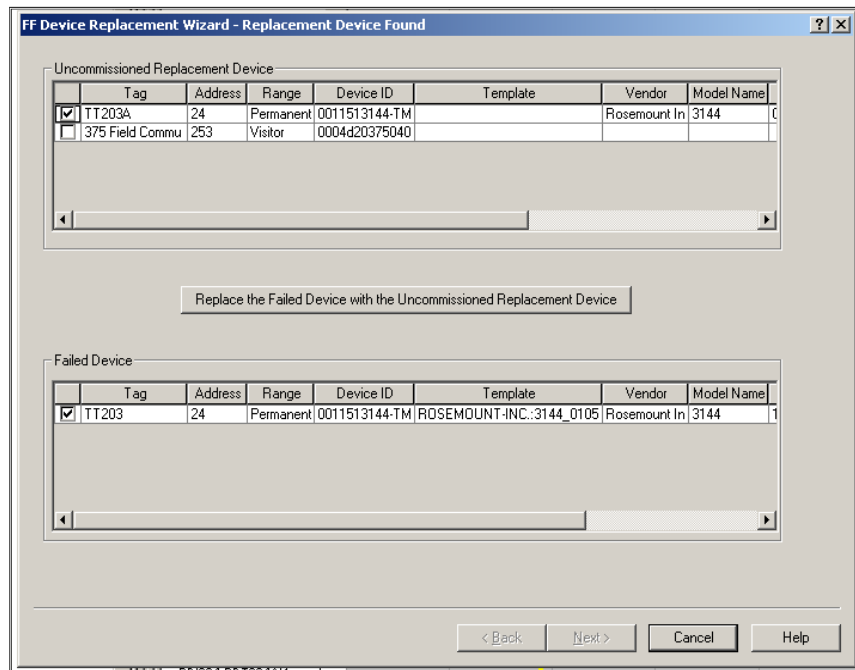
**Figure 27: Click “Yes, Upload”**

- 3.3 At field site, the old device need to be disconnect and replace with the new device. (For the testing: replaced with the same device but with the new tag name and new address using 375 Field Communicator Device.
- 3.4 Using 375 Field Communicator Device, connect the cable to the Fieldbus Port and Press ‘On’ button.
- Select “Fieldbus Application”
  - Select “Online”. (Note: The communicator will upload information on all devices connected to the segment).



- Double click at the device. Select “Details”. Select “Physical Device Tag”.
- Change the tag name of the device. Click OK.
- Click “Send” and wait for the changes to be completed.

3.5 At “Uncommissioned Replacement Device”, tick (✓) at the new device that will be replace. Uncheck and check again in order for a box will be popup at the bottom of the box. Click “Replaced the Failed Device with the Uncommissioned Replacement Device”.

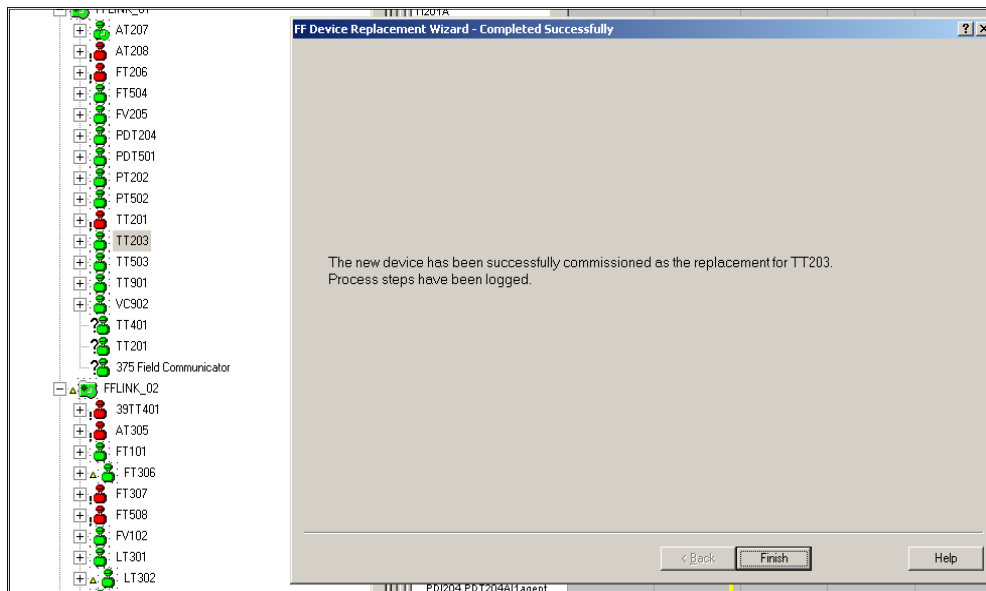


**Figure 28: Replace the Fail Device**

3.6 “FF Device Replacement Wizard- Verifying Replacement Device”. window will popup. Click “Continue”. Click OK.

*Note: Check for “Automatically change ALL highlighted control elements to INACTIVE/OUT\_OF\_SERVICE before load” and “Automatically change ALL control elements to the state selected in “Post Load State” after load is completed.*

3.7 Click “Continue” and wait for the process. Click “Finish”. Device will turn to green and commission as new.



**Figure 29: Device successfully commissioned and replaced**

## **CHAPTER 4**

### **RESULT AND DISCUSSION**

#### **4.1 Design Fieldbus Segment using Segment Checker by Pepperl +Funchs**

Fieldbus Segment has been designed in order to develop and configure on the technical design aspect of fieldbus system using the segment checker provide by Pepperl + Fuchs. Segment Checker is the complete tool for planning, validation and documentation of FOUNDATION Fieldbus and PROFIBUS PA Fieldbus installations according to the international Fieldbus standard IEC 61158-2.

This Segment Checker feature is based on easily per Drag & Drop, it considers all relevant device data as well as all cable parameters. The Segment Checker software shows Fieldbus installation in form of stylized topologies. Segment Checker calculates all relevant parameters e. g. necessary supply voltage, supply current, input voltages of the field devices as well as the output voltages at the spurs.

This Segment Checker will come out with a summary of the project and all integrated devices on the segment designed. By using this tool the user can check the functionality of the segment before proceeding with the real segment at the field.

Plant and Instrument Diagram (P&ID) of Produced Water Reinjection plant was choose as a case study to design this Fieldbus segment. Basically this project is one of the Brunei Shell Petroleum (BSP) project. This project is a FFDCS for monitoring and control of onshore Produced Water Re-Injection (PWRI) and Effluent Water Treatment Plant (EWTP) Process.

#### *4.1.1 Operation of process*

Based on the Process Graphic in **Figure 30**, the operation of the process is described. In this process, the tank 60 is the filtered water buffer tank before produced water is injected to the Seria North Flank water injection wells. The tank 60 is monitored in terms of the low level and high level alarm, low and high pressure alarm and also pump in running/stop mode. It also monitors the recycle flow control valve in terms of its percentage of valve opening position.

Pump P-1300/1310 is using water from Tank 60 which one unit running & one unit standby. The tag 62FICSA-130L/131L is the recycle control valve, if pump P1300/1310 reaches minimum flow, this recycle control valve will opens automatically via given set point & water shall flow back to Tank 60 to maintain the tank level as well to prevent pump P-1300/1310 from running low flow which can cause damage to the mechanical seal of the pump. All alarm will be activated in the control room when the system reaches the set point thus process controller shall intervene to normalise or shutdown the process if abnormal happened.

The fuel gas line which is yellow line supplied to Tank 60 to the surface of the tank is for gas blanketing which means to minimize oxygen content in water. The regulator installed above the tank (74-PCV-600/601) is to reduce pressure supply to Tank 60 as the main gas supply is 560 kpa regulated to below 10 kpa for internal tank gas blanketing system. The ESD valve (Emergency Shutdown valve) (74-USV-600) is to close gas supply if the gas is exceeding the set point to Tank 60.

This serves for safeguarding system to prevent Tank 60 operating over pressure thus alarm will activate from 74-PISA600HH sending signal to the control room. For the Tank 60 water high level & low level, the tag 62LISAHH/LL will activate alarm to the control room if water level reaches 3.0 meters (for low level setting) thus shutting down the pump P-1300/1310 OR P-1400/1410 respectively. Pump will not

able to be restarted if Tank 60 level is not above 3.0 meters as to prevent low suction or low flow that can damage pump mechanical seal.

The other tag 62LISAHH/LL is for high level sending alarm to control room to prevent water overflowing from the tank. If alarm is activated inlet flow to Tank 60 will be reduced by process controller who is monitoring the DCS.

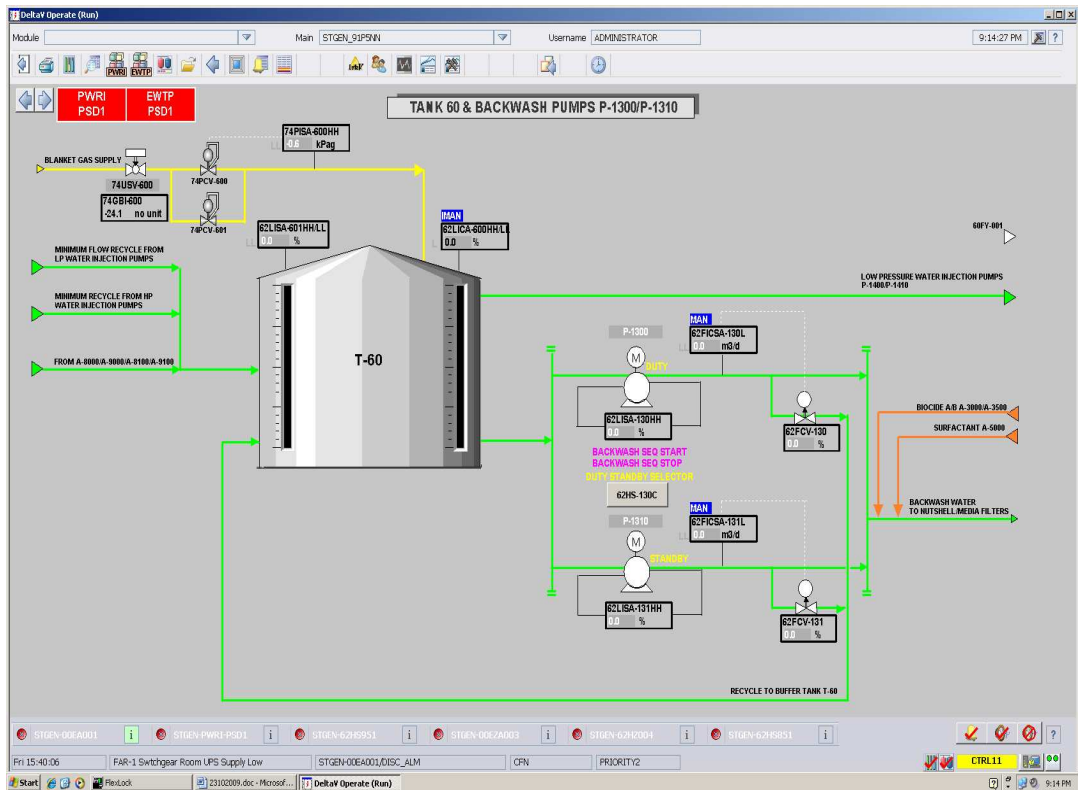


Figure 30: Tank 60 & Backwash Pumps

#### *4.1.2 Devices used in the plant*

All the devices that involved in the process plant will be used to design the fieldbus segment.

1. 74 USV-600 – Emergency shutdown valve
2. 74 PCV-600 – Pressure control valve
3. 74 PSV-601 – Pressure control valve
4. 62 FCV-130 – Flow control valve
5. 62 FCV-131 – Flow control valve
6. 62 FICSA-130L – Flow indicator control safety alarm
7. 62 FICSA-131L – Flow indicator control safety alarm
8. 62 LISA-130HH – Level indicator safety alarm
9. 62 LISA-131HH – Level indicator safety alarm
10. 74 GBI-600 – Positioner feedback signal
11. 62 LICA-600HH/LL – Level indicator control alarm
12. 62 LISA-601HH/LL – Level indicator safety alarm
13. 74 PISA-600HH – Pressure indicator safety alarm
14. P-1300 – Pump
15. P-1310 – Pump

#### *4.1.3 Segment description*

All the 15 devices are connected in one segment as the number of devices still not exceeds the maximum number of devices that can be connected to a segment. However in real life applications it is better to put pump P-1300 and pump P-1310 in different segment. This is because if one segment got faulty the standby pump will still be able to take over the faulty pump.

Various types of cable are usable for Foundation Fieldbus. Type A cable which is shielded twisted pair is used as it is recommended as preferred fieldbus cable. Besides, only this type of cable is specified for the maximum bus length which is 1900 m per segment.

Cable length calculation for the network in **Figure 31** is as followed. Based on the calculation below, the total of the cable length including the length of spurs and trunk must be less than 1893m for this network. As defined in the standard, a fieldbus device needs a minimum of 9V to operate. For nonintrinsically safe networks the power supply voltage typically is 24V. The current consumption for each device is assumed as 12mA. Type A cable has resistance of 22 ohm/km in each of the two conductors. So for a network that populated with 15 devices, the maximum cable length that can be connected is calculated as 1893m.

$$L = U / (I \times n \times 2 \times R_c) \quad (1)$$

$$= (24V - 9V) / (12mA \times 15 \times 2 \times 22)$$

$$= 1.893 \text{ km}$$

Where:

L = Maximum length of cable, km

U = Voltage drop of the network

I = Current consumption of each device

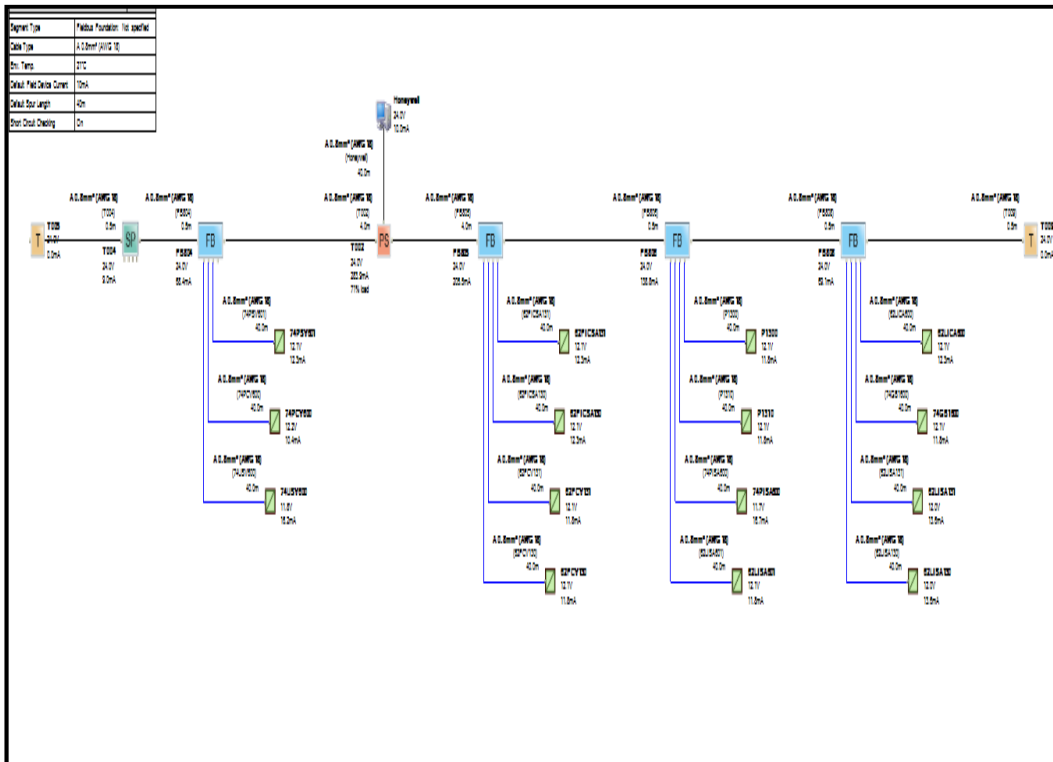
n = Number of devices

R<sub>c</sub> = Manufacturer specified resistance cable, ohm/km

The topology used for this connection is tree topology. The advantage of using tree topology is the devices can be installed or remove from the system under power and it will not affect the system and other devices.

From the designed segment in **Figure 31**, we can see that the power supply is not connected directly to the Foundation Fieldbus Cable. The power from the power supply needs to be conditioned first before supplying through the cable using power conditioner. This is because the power supply will absorb the communication signal on the cable in order to maintain the constant voltage level on the cable.

The total cable length of design segment in **Figure 31** and all the calculated relevant parameter is shown in **Appendix B**.



**Figure 31: Segment Designed**



## 4.2 Develop Software Tool

### 4.2.1 Software Tool to calculate maximum cable length

In order to check and calculate the power requirement for a segment in the fieldbus, a software tool is designed using Microsoft Excel. By using this software, the user can input the number of devices that need to be connected in a segment and the maximum cable length that allows will be calculated according to the type of cable used.

In order to come to this result, the user has to key in the voltage power supply used by the system and also the current consumption of device. The current consumption of each device is assumed to be the same while using this software tool.

For the calculation below, the current consumption of each device is input as 12mA. The total of 15V is input as the voltage drop of the system. Power supply voltage is 24V, and as defined in the standard, each fieldbus device needs a minimum of 9V to operate. The  $R_c$  value is calculated based on the resistive of the cable, and the value varies as the type of cable used varied. This software tool is designed using the following formula:

$$L = U / (I \times n \times 2 \times R_c) \quad (1)$$

Where:

$L$  = Maximum length of cable, km

$U$  = Voltage drop of the network

$I$  = Current consumption of each device

$n$  = Number of devices

$R_c$  = Manufacturer specified resistance cable, ohm/km

68						
69	<b>Cable type A</b>					
70		Quantity	Voltage drop (24V-9V I (A)	r		
71	Number of devices	15	15	0.012	660	
72						
73	Total cable length (km)	1.89				
74	Max length according to cable type specification (km)	1.9				
75						
76						
77	<b>Cable type B</b>					
78		Quantity	Voltage drop (24V-9V I (A)	r		
79	Number of devices	12	15	0.012	1344	
80						
81	Total cable length (km)	0.93				
82	Max length according to cable type specification (km)	1.2				
83						
84						
85	<b>Cable type C</b>					
86		Quantity	Voltage drop (24V-9V I (A)	r		
87	Number of devices	16	15	0.012	4224	
88						
89	Total cable length (km)	0.30				
90	Max length according to cable type specification (km)	0.4				
91						
92						
93	<b>Cable type D</b>					
94		Quantity	Voltage drop (24V-9V I (A)	r		
95	Number of devices	16	15	0.012	640	
96						
97	Total cable length (km)	1.95				
98	Max length according to cable type specification (km)	0.2				
99						

**Figure 32: Software to calculate total cable length**

The overall result of total cable length for different type of cable according to number of devices connected in the segment by using equation 1 is shown in **Table 2** below.

**Table 2: Overall result for total cable length**

<b>n</b>	<b>Length of Cable Type A, km</b>	<b>Length of Cable Type B, km</b>	<b>Length of Cable Type C, km</b>	<b>Length of Cable Type D, km</b>
1	28.41	11.6	4.73	31.25
2	14.20	5.58	2.37	15.63
3	9.47	3.72	1.58	10.42
4	7.10	2.79	1.18	7.81
5	5.68	2.23	0.95	6.25
6	4.73	1.86	0.79	5.21
7	4.06	1.59	0.68	4.46
8	3.55	1.40	0.59	3.91
9	3.16	1.24	0.53	3.47
10	2.84	1.12	0.47	3.13
11	2.58	1.01	0.43	2.84
12	2.37	0.93	0.39	2.60
13	2.19	0.86	0.36	2.40
14	2.03	0.80	0.34	2.23
15	1.89	0.74	0.32	2.08
16	1.78	0.70	0.30	1.95

4.2.2 *Software Tool to calculate maximum length of trunk cable and voltage available at each device*

A trunk is the longest cable run in fieldbus network. In addition to the calculating the maximum cable length that can be used earlier, a software tool of calculating the maximum length of trunk cable is designed.

The calculation on the maximum trunk length and the voltage available at each field device can be used on a system with approximately equal spur length and devices with nearly equivalent current, voltage and capacitance needs. This software tool is designed based on this equation:

$$L_{TMAX} < [(V_{PS} - V_{Min}) \times 10^6 - I_D \times 2 \times R_s \times L_s] / \sum I_D \times 2 \times R_T \quad (2)$$

Where:

$L_{TMAX}$  = Maximum of trunk cable, meters

$V_{PS}$  = Power supply voltage, volts

$V_{Min}$  = Largest minimum voltage of all the field devices, volts

$I_D$  = DC current draw of the field device with the largest minimum voltage, mA

$R_s$  = Manufacturer specific resistance of spur cable, ohm/km

$L_s$  = Length of spur cable, meters

$\sum I_D$  = Total sum of DC current draw of all field devices, mA

$R_T$  = Manufacturer specified resistance of trunk cable, ohm/km

21	Maximun trunk length on system with					
22	approximately equal spur					
23		Quantity	Vps-Vmin (24V-9V)	I (mA)	Rs(ohm/km)	Ls (m)
24	Number of devices	15	15	12	44	40
25						
26						
27						
28						
29						
30	Max length of trunk cable (m) <	1891.27				
31						
32						
33		Voltage supply(V)	Length of trunk cable (m)			
34		24	1891.27			
35						
36	Voltage available at field device (V)	9.00				
37	Min voltage required by each device	9				
38						

**Figure 33: Software to calculate max trunk cable and voltage at field device**

As shown in **Figure 33**, the details of calculation to calculate maximum length of trunk cable for 15 devices connected to a segment is as followed:

Number of devices = 15 devices

Power supply voltage = 24 V

Current draw of field device = 12 mA

Length of spur cable = 40 m

Cable resistance = 44 ohm/km

As defined in the standard, each fieldbus device needs a minimum of 9V to operate. In the case of, if each of the field devices has very different minimum voltages, the voltage available at each device on the segment can be calculated using the following formula:

$$V_D = V_{PS} - (\sum I_D \times 2 \times R_T \times L_T + \sum I_D \times 2 \times R_S \times L_S) \times 10^{-6} > V_{Min} \quad (3)$$

Where:

$V_{Min}$  = Minimum voltage of the field devices, volts

$V_D$  = DC voltage available at the field device, volts

$V_{PS}$  = Power supply voltage, volts

$\sum I_D$  = Total sum of DC current draw of all field devices, mA

$R_T$  = Manufacturer specified resistance of trunk cable, ohm/km

$L_T$  = Length of trunk cable, meters

$I_D$  = DC current draw of the field device, mA

$R_S$  = Manufacturer specific resistance of spur cable, ohm/km

$L_S$  = Length of spur cable, meters

### **4.3 Basic Test**

The result for the fieldbus testing is focused on the five tests that have been conducted in the basic test, which are Device Commissioning, Device Decommissioning, Online Device Replacement, Physical Layer Inspection/Device Drop Out and Calibration Function Check. However, for this time being the author only managed to complete Device Commissioning, Device Decommissioning, and Online Device Replacement due to fieldbus plant at the lab is not available for usage due to the construction work that has been conducted. The author also encounters some problem while conducting the test and some of the testing needed to be repeated several times before the author obtained the result. The following results are based on the result for field devices in Segment 1 as the segment 2 is reserved for other purpose.

#### 4.4 Result for Basic Testing using Honeywell system

##### 4.4.1 Device Commissioning

**Table 3: Result for Device Commissioning**

<b>Tag Name</b>	<b>Device Vendor</b>	<b>Successful Commission</b>
AT 207	Rosemount	√
AT 208	Rosemount	×
FV 205	Rosemount	√
PDT 204	Rosemount	√
PT 202	Rosemount	√
TT 203	Rosemount	√
TT 201	Rosemount	×
FT 504	Yokogawa	√
PDT 501	Yokogawa	√
PT 502	Yokogawa	√
TT 503	Yokogawa	√
TT 901	Pepperl Fuchs	√
VC 902	Pepperl Fuchs	√
FT 206	Micro Motion	×

Table above shows the result of the device commissioning for segment 1. The host is able to read data from all the devices without any problem except for devices AT 208, TT 201 and FT 206. For the devices, that were successfully commissioned, there are “?” sign at the device icon in the host and the sign gone when the devices successfully commissioned.



The objectives of this test are:

- To check whether the host is able to read data from the fieldbus device.
- To test how well the FF startup Procedure of a completely new system works.

#### 4.4.2 Device Decommissioning

**Table 4: Result for Device Decommissioning**

<b>Tag Name</b>	<b>Device Vendor</b>	<b>Successful Decommissioning</b>
AT 207	Rosemount	√
AT 208	Rosemount	×
FV 205	Rosemount	√
PDT 204	Rosemount	√
PT 202	Rosemount	√
TT 203	Rosemount	√
TT 201	Rosemount	×
FT 504	Yokogawa	√
PDT 501	Yokogawa	√
PT 502	Yokogawa	√
TT 503	Yokogawa	√
TT 901	Pepperl Fuchs	√
VC 902	Pepperl Fuchs	√
FT 206	Micro Motion	×

Table above shows the result of the device decommissioning for segment 1. Decommission is performed when to remove the device either for maintenance or to change with other device. All the devices successfully decommissioned without any problem except AT 208, TT 201 and FT 206. After decommission the devices, there are “?” sign at the device icon in the host. The purpose of this testing is to note the proper method of putting device in offline mode and to make sure that the host does not scan the detached device as error.

#### 4.4.3 Online Device Replacement

**Table 5: Result for Online Device Replacement**

<b>Tag Name</b>	<b>Device Vendor</b>	<b>Time Taken</b>	<b>Successful Replace</b>
AT 207	Rosemount	9 min 13 sec	√
AT 208	Rosemount		×
FV 205	Rosemount	9 min 14 sec	√
PDT 204	Rosemount	7 min 45 sec	√
PT 202	Rosemount	12 min 49 sec	√
TT 203	Rosemount	8 min 23 sec	√
TT 201	Rosemount		×
FT 504	Yokogawa	8 min 35 sec	√
PDT 501	Yokogawa	13 min 15 sec	√
PT 502	Yokogawa	9 min 36 sec	√
TT 503	Yokogawa	7 min 24 sec	√
TT 901	Pepperl Fuchs	6 min 30 sec	√
VC 902	Pepperl Fuchs	9 min 13 sec	√
FT 206	Micro Motion		×

Table above shows the result for online device replacement. All devices at segment 1 successfully replaced except for AT208, TT201, and FT206. 375 Field Communicator Device was used in order to replace the same device but with new tag name and new address during online device replacement. The purpose of this test is to ensure that there is no major interruption and also to test the effects of an unknown device being introduced into a FF system. At Control Builder (monitoring), the device will turn to red colour when the device was disconnected at the field. The devices then turn back to green in colour when the device had been displaced.

#### *4.4.4 Discussion*

The Basic Interoperability Testing for Honeywell system was done with some errors due to the certain devices that cannot be commission, decommissioned and replaced during the online replacement. This error may encounter during the host being switched with the other system before the testing can be done. Due to some error the DD (Device Description) file that containing information of the device are missing in the system. The system or host need to upload the DD file for each of the device to make sure that the system can recognize that particular device. For online replacement testing, the author also encountered the same problem with the same devices that cannot be commission and decommissioned which are AT208, TT201, and FT206. The author has concluded that in order to successfully do the online device replacement, all the errors need to be compensated.

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATION**

#### **5.1 Conclusion**

At the end of this project, the author had managed to perform technical verification and interoperability testing of Foundation Fieldbus devices to be used by PETRONAS. The author also managed to design, develop and configure on the technical design aspect of fieldbus such as to design fieldbus segment by using segment checker and also to design a software tool that can be used to calculate the power requirement, length of cable and also the number of devices that can be connected in fieldbus segment. The Foundation Fieldbus Interoperability Testing is very important for PETRONAS to get the procedure and the results to be used as references on Foundation Fieldbus System. Due to the current upgrading work in the UTP Fieldbus lab, the author managed to complete three of the basic test and not be able to proceed with the stress test. From the result of the Basic Interoperability Testing for Honeywell system, the devices can interoperate with each other and the host can communicate with all the devices from difference manufacturer. Toward better understanding of fieldbus system, study on the important fieldbus technical design aspect has also been done. The design of fieldbus segment has been carried out using the Segment Checker provides by Pepperl + Fuchs. This understanding and knowledge has been implemented throughout this project.

## **5.2 Recommendation**

The Fieldbus Interoperability Test is still ongoing in the future to proceed with the stress test. This project can be expanded and obtain an efficient result if the delay in performing the test would not be too long and each vendor that involved in this project should provide more training to the students involved in terms of hardware and software in order to provide them with enough knowledge on the system.

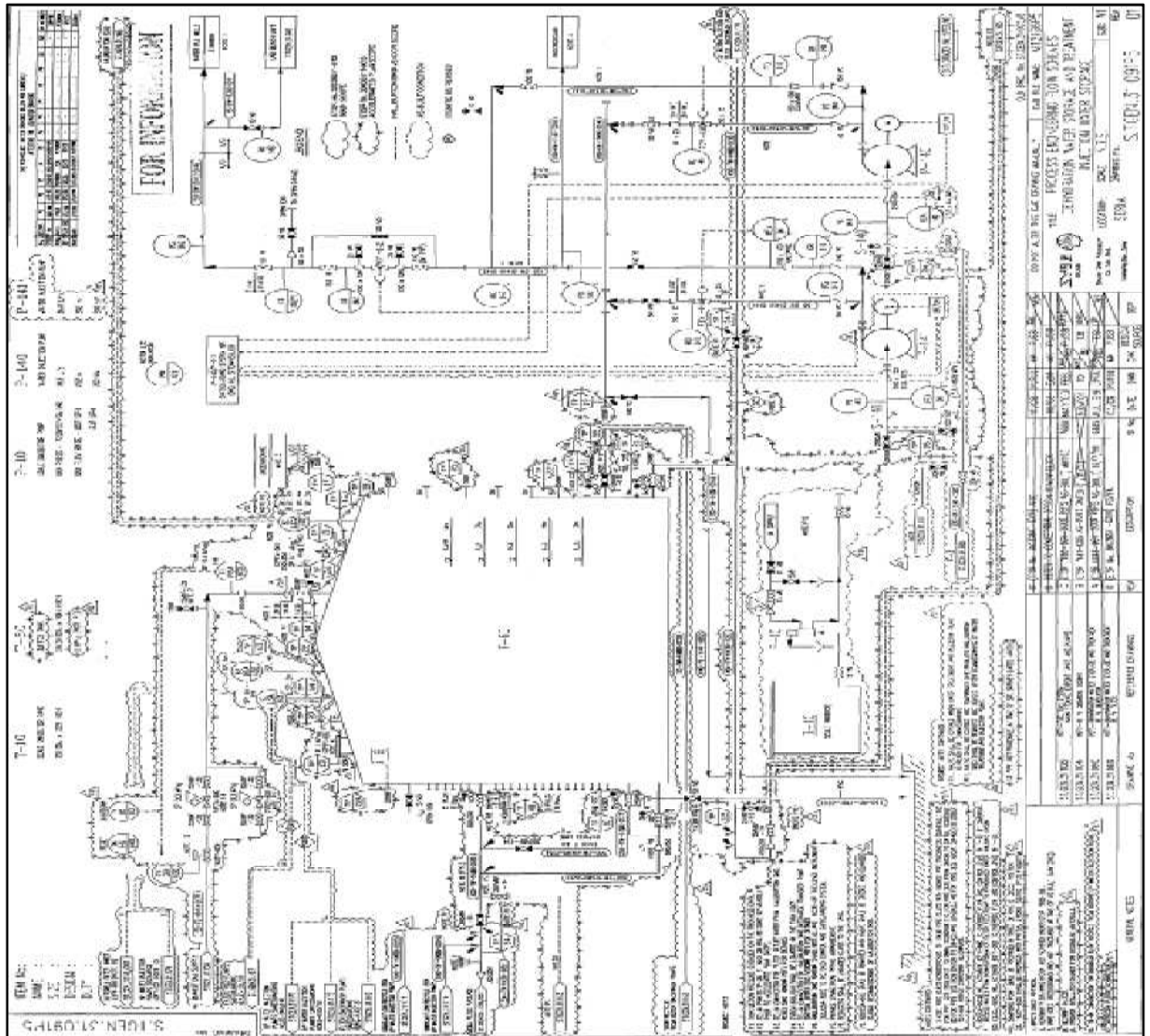
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## **APPENDICES**

# Appendix A

## Dehydration Water Storage and Treatment Injection Water Storage





## Appendix B

### Report of Segment Checker

#### Project Parameters

---

Segment Type	= Fieldbus Foundation: Not specified
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Env. Temp.	= 21°C
Default Field Device Current	= 12mA
Default Spur Length	= 40m
Short Circuit Checking	= On

#### Checker Results

---

Checker Summary	
Topology Check	success
Power Distribution Check	success
Short Circuit Check	success

#### Device Summary

---

Devices	
F2D0-FB-EX4.xx	4
Gen. Field Device	15
Gen. Host	1
Gen. Power Supply	1
Gen. Terminator	2
R2-SP-N4	1

Cables	
A 0.8mm <sup>2</sup> (AWG 18)	650.5m

#### Device List

---

<b>Device Type:</b> Gen. Host	<b>Tag:</b> Honeywell
-------------------------------	-----------------------

##### Device Parameters

Input Current	= 10mA
Min. Input Voltage	= 9V

##### Connections

Input	⇒T002
-------	-------

<b>Device Type:</b> Gen. Terminator	<b>Tag:</b> T005
-------------------------------------	------------------

##### Device Parameters

##### Connections

Input	⇒T004
-------	-------

<b>Device Type:</b> R2-SP-N4	<b>Tag:</b> T004
------------------------------	------------------

##### Device Parameters

Number of Spurs	= 4
Max. Current/Spur	= 41mA
Short circuit current limit per Spur	= 57mA
Terminator	= Off
<b>Connections</b>	
Input	⇒FB804
Output	⇒T005

<b>Device Type:</b> F2D0-FB-EX4.xx	<b>Tag:</b> FB804
------------------------------------	-------------------

<b>Device Parameters</b>	
Number of Spurs	= 4
Min. Input Voltage	= 16V
Max. Voltage/Spur	= 13V
Max. Current/Spur	= 40mA
Short circuit current limit per Spur	= 47mA
Terminator	= Off
<b>Connections</b>	
Input	⇒T002
Output	⇒T004
Spur 1	⇒74USV600
Spur 2	⇒74PCV600
Spur 3	⇒74PSV601

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 74USV600
---------------------------------------	----------------------

<b>Device Parameters</b>	
Input Current	= 12mA
Min. Input Voltage	= 9V
<b>Connections</b>	
Input	⇒FB804

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 74PCV600
---------------------------------------	----------------------

<b>Device Parameters</b>	
Input Current	= 12mA
Min. Input Voltage	= 9V
<b>Connections</b>	
Input	⇒FB804

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 74PSV601
---------------------------------------	----------------------

<b>Device Parameters</b>	
Input Current	= 12mA
Min. Input Voltage	= 9V
<b>Connections</b>	
Input	⇒FB804

<b>Device Type:</b> Gen. Power Supply	<b>Tag:</b> T002
---------------------------------------	------------------

<b>Device Parameters</b>	
Open-circuit Voltage	= 24V
Rated current	= 0.4A
Terminator	= Off
Integrated Master/Host	= Off
<b>Connections</b>	
Output	⇒FB804
Output	⇒FB805
Master Con.	⇒Honeywell

<b>Device Type:</b> F2D0-FB-EX4.xx	<b>Tag:</b> FB805
------------------------------------	-------------------

**Device Parameters**

Number of Spurs = 4  
 Min. Input Voltage = 16V  
 Max. Voltage/Spur = 13V  
 Max. Current/Spur = 40mA  
 Short circuit current limit per Spur = 47mA  
 Terminator = Off

**Connections**

Input ⇒T002  
 Output ⇒FB806  
 Spur 1 ⇒62FCV130  
 Spur 2 ⇒62FCV131  
 Spur 3 ⇒62FICSA130  
 Spur 4 ⇒62FICSA131

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 62FCV130
---------------------------------------	----------------------

**Device Parameters**

Input Current = 12mA  
 Min. Input Voltage = 9V

**Connections**

Input ⇒FB805

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 62FCV131
---------------------------------------	----------------------

**Device Parameters**

Input Current = 12mA  
 Min. Input Voltage = 9V

**Connections**

Input ⇒FB805

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 62FICSA130
---------------------------------------	------------------------

**Device Parameters**

Input Current = 12mA  
 Min. Input Voltage = 9V

**Connections**

Input ⇒FB805

<b>Device Type:</b> Gen. Field Device	<b>Tag:</b> 62FICSA131
---------------------------------------	------------------------

**Device Parameters**

Input Current = 12mA  
 Min. Input Voltage = 9V

**Connections**

Input ⇒FB805

<b>Device Type:</b> F2D0-FB-EX4.xx	<b>Tag:</b> FB806
------------------------------------	-------------------

**Device Parameters**

Number of Spurs = 4  
 Min. Input Voltage = 16V  
 Max. Voltage/Spur = 13V  
 Max. Current/Spur = 40mA  
 Short circuit current limit per Spur = 47mA  
 Terminator = Off

**Connections**

Input ⇒FB805  
 Output ⇒FB808  
 Spur 1 ⇒62LISA601  
 Spur 2 ⇒74PISA600

Spur 3 ⇒P1310  
Spur 4 ⇒P1300

**Device Type:** Gen. Field Device | **Tag:** 62LISA601

**Device Parameters**

Input Current = 12mA  
Min. Input Voltage = 9V

**Connections**

Input ⇒FB806

**Device Type:** Gen. Field Device | **Tag:** 74PISA600

**Device Parameters**

Input Current = 12mA  
Min. Input Voltage = 9V

**Connections**

Input ⇒FB806

**Device Type:** Gen. Field Device | **Tag:** P1310

**Device Parameters**

Input Current = 12mA  
Min. Input Voltage = 9V

**Connections**

Input ⇒FB806

**Device Type:** Gen. Field Device | **Tag:** P1300

**Device Parameters**

Input Current = 12mA  
Min. Input Voltage = 9V

**Connections**

Input ⇒FB806

**Device Type:** F2D0-FB-EX4.xx | **Tag:** FB808

**Device Parameters**

Number of Spurs = 4  
Min. Input Voltage = 16V  
Max. Voltage/Spur = 13V  
Max. Current/Spur = 40mA  
Short circuit current limit per Spur = 47mA  
Terminator = Off

**Connections**

Input ⇒FB806  
Output ⇒T009  
Spur 1 ⇒62LISA130  
Spur 2 ⇒62LISA131  
Spur 3 ⇒74GB1600  
Spur 4 ⇒62LICA600

**Device Type:** Gen. Field Device | **Tag:** 62LISA130

**Device Parameters**

Input Current = 12mA  
Min. Input Voltage = 9V

**Connections**

Input ⇒FB808

**Device Type:** Gen. Field Device | **Tag:** 62LISA131

**Device Parameters**

Input Current = 12mA

Min. Input Voltage = 9V

**Connections**

Input ⇒FB808

**Device Type:** Gen. Field Device **Tag:** 74GB1600**Device Parameters**

Input Current = 12mA

Min. Input Voltage = 9V

**Connections**

Input ⇒FB808

**Device Type:** Gen. Field Device **Tag:** 62LICA600**Device Parameters**

Input Current = 12mA

Min. Input Voltage = 9V

**Connections**

Input ⇒FB808

**Device Type:** Gen. Terminator **Tag:** T009**Device Parameters****Connections**

Input ⇒FB808

**Connection List****Cable Parameters: T002-Honeywell**Cable Type = A 0.8mm<sup>2</sup> (AWG 18)Cross Wire Section = 0.8mm<sup>2</sup>

Wire Resistance = 44Ohm/km

Wire Length = 40.0m

Temp. Coefficient = 0.00391/K

**Cable Parameters: T004-T005**Cable Type = A 0.8mm<sup>2</sup> (AWG 18)Cross Wire Section = 0.8mm<sup>2</sup>

Wire Resistance = 44Ohm/km

Wire Length = 0.5m

Temp. Coefficient = 0.00391/K

**Cable Parameters: FB804-T004**Cable Type = A 0.8mm<sup>2</sup> (AWG 18)Cross Wire Section = 0.8mm<sup>2</sup>

Wire Resistance = 44Ohm/km

Wire Length = 0.5m

Temp. Coefficient = 0.00391/K

**Cable Parameters: T002-FB804**Cable Type = A 0.8mm<sup>2</sup> (AWG 18)Cross Wire Section = 0.8mm<sup>2</sup>

Wire Resistance = 44Ohm/km

Wire Length = 4.0m

Temp. Coefficient = 0.00391/K

**Cable Parameters: FB804-74USV600**Cable Type = A 0.8mm<sup>2</sup> (AWG 18)Cross Wire Section = 0.8mm<sup>2</sup>

Wire Resistance = 44Ohm/km

Wire Length = 40.0m

Temp. Coefficient = 0.00391/K

**Cable Parameters: FB804-74PCV600**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB804-74PSV601**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: T002-FB805**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 4.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB805-62FCV130**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB805-62FCV131**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB805-62FICSA130**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB805-62FICSA131**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB805-FB806**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 0.5m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB806-62LISA601**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km  
 Wire Length = 40.0m  
 Temp. Coefficient = 0.00391/K

**Cable Parameters: FB806-74PISA600**

Cable Type = A 0.8mm<sup>2</sup> (AWG 18)  
 Cross Wire Section = 0.8mm<sup>2</sup>  
 Wire Resistance = 44Ohm/km

Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB806-P1310</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB806-P1300</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB806-FB808</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 0.5m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB808-62LISA130</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB808-62LISA131</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB808-74GB1600</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB808-62LICA600</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 40.0m
Temp. Coefficient	= 0.00391/K
<b>Cable Parameters: FB808-T009</b>	
Cable Type	= A 0.8mm <sup>2</sup> (AWG 18)
Cross Wire Section	= 0.8mm <sup>2</sup>
Wire Resistance	= 44Ohm/km
Wire Length	= 0.5m
Temp. Coefficient	= 0.00391/K

## Checker Details

Power Distribution Check					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.988	success
T004	9.0	9.0	9.000	23.988	success
T004:Output	0.0	0.0	0.000	23.988	
FB804	45.0	66.3	16.000	23.988	success
FB804:Output	9.0	9.0	9.000	23.988	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	275.9	16.029	24.000	success
T002:Output	45.0	66.3	16.008	24.000	
T002:Output	144.0	199.5	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	199.5	16.003	23.965	success
FB805:Output	96.0	133.0	16.003	23.965	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	133.0	16.001	23.962	success
FB806:Output	48.0	66.5	16.001	23.962	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	66.5	16.000	23.960	success
FB808:Output	0.0	0.0	0.000	23.960	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.960	success

Result reached after 2 iterations with an accuracy of 0.043mA.

### Summary:

Minimum applied voltage level for a device: 12.079V



<b>Short Circuit Check</b>					
FB804 - Short Circuit Check:					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.982	success
T004	9.0	9.0	9.000	23.982	success
T004:Output	0.0	0.0	0.000	23.982	
FB804	45.0	99.8	16.000	23.982	success
FB804:Output	9.0	9.0	9.000	23.982	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	309.3	16.029	24.000	success
T002:Output	45.0	99.8	16.008	24.000	
T002:Output	144.0	199.5	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	199.5	16.003	23.965	success
FB805:Output	96.0	133.0	16.003	23.965	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	133.0	16.001	23.962	success
FB806:Output	48.0	66.5	16.001	23.962	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	66.5	16.000	23.960	success
FB808:Output	0.0	0.0	0.000	23.960	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.960	success

Result reached after 2 iterations with an accuracy of 0.062mA.

<b>Short Circuit Check</b>					
T004 - Short Circuit Check:					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.977	success
T004	9.0	66.0	9.000	23.977	success
T004:Output	0.0	0.0	0.000	23.977	
FB804	45.0	123.4	16.000	23.978	success
FB804:Output	9.0	66.0	9.000	23.978	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	332.9	16.029	24.000	success
T002:Output	45.0	123.4	16.008	24.000	
T002:Output	144.0	199.5	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	199.5	16.003	23.965	success
FB805:Output	96.0	133.0	16.003	23.965	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	133.0	16.001	23.962	success
FB806:Output	48.0	66.5	16.001	23.962	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	66.5	16.000	23.960	success
FB808:Output	0.0	0.0	0.000	23.960	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.960	success

Result reached after 2 iterations with an accuracy of 0.004mA.

<b>Short Circuit Check</b>					
FB805 - Short Circuit Check:					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.988	success
T004	9.0	9.0	9.000	23.988	success
T004:Output	0.0	0.0	0.000	23.988	
FB804	45.0	66.3	16.000	23.988	success
FB804:Output	9.0	9.0	9.000	23.988	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	300.2	16.029	24.000	success
T002:Output	45.0	66.3	16.008	24.000	
T002:Output	144.0	223.8	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	223.8	16.003	23.960	success
FB805:Output	96.0	133.0	16.003	23.960	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	133.0	16.001	23.958	success
FB806:Output	48.0	66.5	16.001	23.958	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	66.5	16.000	23.956	success
FB808:Output	0.0	0.0	0.000	23.956	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.956	success

Result reached after 2 iterations with an accuracy of 0.021mA.

<b>Short Circuit Check</b>					
FB806 - Short Circuit Check:					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.988	success
T004	9.0	9.0	9.000	23.988	success
T004:Output	0.0	0.0	0.000	23.988	
FB804	45.0	66.3	16.000	23.988	success
FB804:Output	9.0	9.0	9.000	23.988	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	300.2	16.029	24.000	success
T002:Output	45.0	66.3	16.008	24.000	
T002:Output	144.0	223.8	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	223.8	16.003	23.960	success
FB805:Output	96.0	157.3	16.003	23.960	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	157.3	16.001	23.957	success
FB806:Output	48.0	66.5	16.001	23.957	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	66.5	16.000	23.956	success
FB808:Output	0.0	0.0	0.000	23.956	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.956	success

Result reached after 2 iterations with an accuracy of 0.002mA.

<b>Short Circuit Check</b>					
FB808 - Short Circuit Check:					
Tag	Current [mA]		Voltage [V]		Result
	must	is	must	is	
Honeywell	10.0	10.0	9.000	23.982	success
T005	0.0	0.0	0.000	23.988	success
T004	9.0	9.0	9.000	23.988	success
T004:Output	0.0	0.0	0.000	23.988	
FB804	45.0	66.3	16.000	23.988	success
FB804:Output	9.0	9.0	9.000	23.988	
FB804:Spur 1	12.0	12.0	9.021	12.100	
FB804:Spur 2	12.0	12.0	9.021	12.100	
FB804:Spur 3	12.0	12.0	9.021	12.100	
74USV600	12.0	12.0	9.000	12.079	success
74PCV600	12.0	12.0	9.000	12.079	success
74PSV601	12.0	12.0	9.000	12.079	success
T002	189.0	300.2	16.029	24.000	success
T002:Output	45.0	66.3	16.008	24.000	
T002:Output	144.0	223.9	16.029	24.000	
T002:Master Con.	10.0	10.0	9.018	24.000	
FB805	144.0	223.9	16.003	23.960	success
FB805:Output	96.0	157.3	16.003	23.960	
FB805:Spur 1	12.0	12.0	9.021	12.100	
FB805:Spur 2	12.0	12.0	9.021	12.100	
FB805:Spur 3	12.0	12.0	9.021	12.100	
FB805:Spur 4	12.0	12.0	9.021	12.100	
62FCV130	12.0	12.0	9.000	12.079	success
62FCV131	12.0	12.0	9.000	12.079	success
62FICSA130	12.0	12.0	9.000	12.079	success
62FICSA131	12.0	12.0	9.000	12.079	success
FB806	96.0	157.3	16.001	23.957	success
FB806:Output	48.0	90.8	16.001	23.957	
FB806:Spur 1	12.0	12.0	9.021	12.100	
FB806:Spur 2	12.0	12.0	9.021	12.100	
FB806:Spur 3	12.0	12.0	9.021	12.100	
FB806:Spur 4	12.0	12.0	9.021	12.100	
62LISA601	12.0	12.0	9.000	12.079	success
74PISA600	12.0	12.0	9.000	12.079	success
P1310	12.0	12.0	9.000	12.079	success
P1300	12.0	12.0	9.000	12.079	success
FB808	48.0	90.8	16.000	23.955	success
FB808:Output	0.0	0.0	0.000	23.955	
FB808:Spur 1	12.0	12.0	9.021	12.100	
FB808:Spur 2	12.0	12.0	9.021	12.100	
FB808:Spur 3	12.0	12.0	9.021	12.100	
FB808:Spur 4	12.0	12.0	9.021	12.100	
62LISA130	12.0	12.0	9.000	12.079	success
62LISA131	12.0	12.0	9.000	12.079	success
74GB1600	12.0	12.0	9.000	12.079	success
62LICA600	12.0	12.0	9.000	12.079	success
T009	0.0	0.0	0.000	23.955	success

Result reached after 2 iterations with an accuracy of 0.001mA.