Practical steps for a successful PROFIBUS Project

Presented by
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Content

⇒ Basics of PROFIBUS

⇒ Practical steps in the design and installation stages

✓ Segmentation: number of devices, length of cables
✓ Reflections and Termination
✓ Cabling, Interference and Reduction
✓ Design Documents
✓ PROFIBUS Protocol, Extensions and Profiles

⇒ Coming training courses at MMU
**PROFIBUS DP - Decentralised Periphery**

- Replacement for conventional 0-10 V voltage transmission
- Uses RS485 transmission
- High speed, Low cost, very suitable for factory automation. (e.g. Electronics, Automotive, and Metal/Mining industries)

**PROFIBUS PA - Process Automation**

- Developed specifically for the process industry to replace 4-20mA transmission. (e.g. Chemicals, Refineries, and Power Stations)
- Uses MBP transmission
- Two-wire connection carrying both power and data.
- Defined in DP-V1, the first extension to the basic protocol.
- Also defined in PA Profile.
One controller for all devices

⇒ Standard protocols and PA Profile over a single cable.
⇒ DP/PA convertor used to convert from RS485 transmission to MBP transmission.
Segmentation

⇒ On a PROFIBUS network.
  × No hubs and no switches
  × Uses Repeater, DP/PA Coupler, and OLM to expend the number of devices or cable length
PA segments can be laid out in a more flexible manner using *Tee junctions* to create *spur lines*.

Each DP segment are best laid out as a "linear bus" daisy-chaining from device to device.
When using best quality PROFIBUS RS485 (Type-A) cable:

<table>
<thead>
<tr>
<th>Baud rate</th>
<th>Maximum segment length</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.6 kbit/s</td>
<td>1 200m</td>
</tr>
<tr>
<td>19.2 kbit/s</td>
<td>1 200m</td>
</tr>
<tr>
<td>45.45 kbit/s</td>
<td>1 200m</td>
</tr>
<tr>
<td>93.75 kbit/s</td>
<td>1 200m</td>
</tr>
<tr>
<td>187.5 kbit/s</td>
<td>1 000m</td>
</tr>
<tr>
<td>500.0 kbit/s</td>
<td>400m</td>
</tr>
<tr>
<td>1.5 Mbit/s</td>
<td>200m</td>
</tr>
<tr>
<td>3.0 Mbit/s</td>
<td>100m</td>
</tr>
<tr>
<td>6.0 Mbit/s</td>
<td>100m</td>
</tr>
<tr>
<td>12.0 Mbit/s</td>
<td>100m</td>
</tr>
</tbody>
</table>

**Low speed**

**High speed**
The network runs at a certain data rate (also called the bit rate or baud rate).

PA baud rate is fixed at 31.25 kbit/s.

<table>
<thead>
<tr>
<th>DP baud rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.6 kbit/s</td>
</tr>
<tr>
<td>19.2 kbit/s</td>
</tr>
<tr>
<td>45.45 kbit/s</td>
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<tr>
<td>1.5 Mbit/s</td>
</tr>
<tr>
<td>3.0 Mbit/s</td>
</tr>
<tr>
<td>6.0 Mbit/s</td>
</tr>
<tr>
<td>12.0 Mbit/s</td>
</tr>
</tbody>
</table>
Segmentation - PA

- Total cable length of 1900m
- For intrinsic safe applications, 1000m.
- The length of the individual spur-lines depends upon the total number of spurs used:

<table>
<thead>
<tr>
<th>Number of spur-lines</th>
<th>Maximum spur length non-intrinsically safe</th>
<th>Maximum spur length intrinsically safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 to 32</td>
<td>1 m</td>
<td>1 m</td>
</tr>
<tr>
<td>19 to 24</td>
<td>60 m</td>
<td>60 m</td>
</tr>
<tr>
<td>15 to 18</td>
<td>60 m</td>
<td>60 m</td>
</tr>
<tr>
<td>13 to 14</td>
<td>90 m</td>
<td>60 m</td>
</tr>
<tr>
<td>1 to 12</td>
<td>120 m</td>
<td>60 m</td>
</tr>
</tbody>
</table>

- Example (non-intrinsic safe): 24 x 60 = 1440m spurs + 460m trunk line
PA Segmentation - Voltage Drop Calculation

14 PA devices

Wire as a single segment

14 PA devices
### PA Segmentation – Current Calculation

<table>
<thead>
<tr>
<th>Tag</th>
<th>Address</th>
<th>Device</th>
<th>Basic current/mA</th>
<th>Fault current/mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT 003</td>
<td>3</td>
<td>Ultrasonic level</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>XV 004</td>
<td>4</td>
<td>Valve positioner</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>XV 005</td>
<td>5</td>
<td>Valve positioner</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>LT 006</td>
<td>6</td>
<td>Ultrasonic level</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>TT 007</td>
<td>7</td>
<td>Temperature</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>XV 008</td>
<td>8</td>
<td>Valve positioner</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>FT 009</td>
<td>9</td>
<td>Mass flow meter</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>TT 010</td>
<td>10</td>
<td>Temperature</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>XV 011</td>
<td>11</td>
<td>Valve positioner</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>XV 012</td>
<td>12</td>
<td>Valve positioner</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>FT 013</td>
<td>13</td>
<td>DP cell + orifice</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>XV 014</td>
<td>14</td>
<td>Valve positioner</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>LT 015</td>
<td>15</td>
<td>Ultrasonic level</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>XV 016</td>
<td>16</td>
<td>Valve positioner</td>
<td>13</td>
<td>4</td>
</tr>
</tbody>
</table>

Total current: **179**

Max fault current: **6**

Total current + max single fault current: **185** mA
PA Segmentation - Intrinsic Safe

- We must use FISCO certified coupler and field devices.
- We must not use more than 1000m of cable (total) within a segment.
- Number of devices in a segment is dependent on the current that the coupler can supply.
- Spur lines must not be longer than 60m.

Us = 12.5 V
Is = 90 mA

\[ I_{SEG} < I_s \]
\[ I_{SEG} = 55 \text{ mA} \]

\[ I_{B1} = 11 \text{ mA} \]
\[ I_{FDE} = 12 \text{ mA} \]
\[ I_{B2} = 20 \text{ mA} \]
\[ I_{B3} = 12 \text{ mA} \]

\[ 11 \text{ mA} + 20 \text{ mA} + 12 \text{ mA} + 12 \text{ mA} = 55 \text{ mA} \]

1 power supply for the bus with limited energy.

Fault

Ex
Reflections & Termination

Reflections happen when signals travel down a cable and hit the discontinuity.

Any change in resistance, capacitance or inductance causes discontinuity. In particular, the end of a wire is a major discontinuity where the resistance suddenly increases to infinity and the end becomes open circuit.
Reflections and Termination

The technique is simple - terminate the two ends of a cable with resistance that matches the cable “characteristic impedance”.

Termination must be powered to provide the characteristic impedance and it is referred to as “active termination”.

![Diagram showing device connections and terminations]
Termination

Impedance: 150 Ω

Normally built into a connector.

Can be switched in or out.
Termination

- Standalone terminator box
- Terminator on Repeaters
Termination

1 network with 2 segments.

DP/PA coupler (no address)

Power supply for PA segment

#1

#0

#10

#11

#13

#14

#15

#16

#17
Reflections - min. 1m Rule
## Reflections - Spurs!

<table>
<thead>
<tr>
<th>Baud rate</th>
<th>Total allowable spur capacitance</th>
<th>Total Spur cable length/segment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.5 Mbit/s</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>1.5 Mbit/s</td>
<td>0.2 nF</td>
<td>6.7 m</td>
</tr>
<tr>
<td>500 kbit/s</td>
<td>0.6 nF</td>
<td>20 m</td>
</tr>
<tr>
<td>187.5 kbit/s</td>
<td>1.0 nF</td>
<td>33 m</td>
</tr>
<tr>
<td>93.75 kbit/s</td>
<td>3.0 nF</td>
<td>100 m</td>
</tr>
<tr>
<td>19.2 kbit/s</td>
<td>15 nF</td>
<td>500 m</td>
</tr>
</tbody>
</table>

* Calculated for PROFIBUS cable type A at 30pF/m
M12 Connectors

M12 connector systems

- Devices often have two sockets for incoming and outgoing PROFIBUS cables - difficult to remove device without disrupting the bus.
- Special Tee connectors which can be used to connect to devices via a short spur line (one connection) to overcome this problem.
- But do not use a spur line - plug directly into device.
- Termination can be provided by special blind termination plugs.
One solution to this problem is to use a short spur line.

However this will cause reflections and we must limit the bus bit rate.
Sub-D and M12 Combined
Cabling - Cable Segregation

⇒ Recommended cable separation distances:

- **Cable Category II**: ≥20 cm, ≥10 cm, ≥10 cm, ≥50 cm, ≥50 cm, ≥50 cm
- **Cable Category I**
- **Cable Category III**
- **Cable Category IV**: ≥50 cm, ≥10 cm
Shielding and Twisting

Shielded, twisted-pair cable

Earth the screen at every device

But also ensure every device is properly earthed

Red = +
Green = -

Screw terminals

Device

Rx

Tx

Data
Earthing Issues - Optic Fibres

Cabinet 1

Cabinet 2

Local ground

OLMs

Local ground
Design - Plant Layout
Basics - Station Types

- **Master devices** (also called active stations) control the bus and initiate requests.
  - **Class 1 masters** - e.g. PLCs, controllers, some SCADA stations, etc.
  - **Class 2 masters** - e.g. engineering tools, certain diagnostic tools, etc.

- **Slave devices** (also called passive stations) respond to Master requests.
  - e.g. I/O devices, transmitters, sensors, actuators, valves, and drives, etc.
Basics - Addressing

⇒ Within a network, every PROFIBUS device or station is given an *address* through which communication is directed.

⇒ The address must not overlap. Every station must have a unique address.

⇒ Station addresses can be set in several ways:

  ▪ A local switch on the device (binary dip switch or rotary switch).

  ▪ Software setting of device address over the PROFIBUS network using a configuration tool (called a *class 2 master*, change from #126 to #21).

  ▪ Finally, some devices may use special software and a serial link or hand-held tool to set the device address (e.g. some PLCs, drives or HMI devices.)
Basics - GSD Files

- Every PROFIBUS device must have a GSD file (General Station Description).
- A GSD file contains a unique Identification Number, which defines a type of device and issued by PI.
- The ID is expressed as a four digit hexadecimal number using the digits 0 to 9 and A to F. (e.g. 802D).
- The GSD is a text file and filename is in the format of manufacturer’s short name and the hex. ID number, e.g. SIEM802D and WAGOD730.
- If you know the ID or GSD filename, you can search for the GSD file on the Internet and then be able to configure the device.
Basics - Cyclic Communication

Token passing and Master-slave communication

Cyclic operation:
M1 → S1, S1 → M1
M1 → S2, S2 → M1
M1 → S4, S4 → M1
M1 → token → M2
M2 → S3, S3 → M2
M2 → S5, S5 → M2
M2 → token → M1
M1 → S1, S1 → M1
M1 → S2, S2 → M1
etc.
 Basics - Timing

- PLC cycle time.
- Bus cycle time.

Diagram:
- Controller
- Bus
Documentation - Network Drawings
Design - An Example

- Multiple DP Master cards to create multiple networks
- DP/PA couplers to create PA segments
Should the cable be damaged anywhere in the field, a quick repair can be made using the layout.

Terminating the cable either sides of the damage, and

Connecting the end of the cable from the AT to the master and removing the terminator at the master.
⇒ FA and PA

- Manufacturing Automation
  - Car manufacturing
  - Bottling systems
  - Storage systems

- Building Automation
  - Traffic automation
  - Heating, air-conditioning

- Process Automation
  - Purification plants
  - Chemical and petrochemical plants
  - Paper and textile plants

- Power Generation and Power Distribution
  - Power plants
  - Switch Gear

Car manufacturing, at General Motors, BMW, Ford, FIAT....

Waste Water Purification

Bottling Plants

Lime Production

Breweries

Glue Production

Food Production

Polymer Storage

Building Automation
The PROFIBUS Family

There are variant solutions to meet different requirements in automation applications.

➢ **PROFIBUS DP – Decentralised Periphery**
  - General factory automation
  - Low cost, fast speed, replacement for 0 - 10 V voltage transmission

➢ **PROFIBUS PA – Process Automation**
  - Designed for replacement of 4 - 20 mA transmission
  - Carries power over the cable, also applied in Ex areas

➢ **PROFI SAFE – for functional safety**
  - Safeguarding, interlocking, emergency stopping, SIL 3
  - When used in drives, provides significant benefits through controlled stop functions compared to switch off power

➢ **PROFI drive – for motion controls**
  - High speed, synchronised drive & motion controls
One controller for all devices

- Standard Protocol and failsafe functions over a single cable.
- Cost cutting - no need for special bus; only one engineering environment.
One controller for all devices

- Standard Protocol and Drive Profile over a single cable.
- Exact synchronization of different drives.
Applications and Communication Protocol Versions

- DP devices or PA devices?
- Safety systems?
- High speed drives and synchronised motions?
- PROFIBUS Versions, DP-V0, DP-V1, or DP-V2?
- Latest Profile versions
  - PA Profile 3.02
  - PROFIsafe Profile 2.4
  - PROFIdrive Profile 4.1.
- Newer versions are backwards compatible with older versions!
Conclusion

⇒ For a successful PROFIBUS project:

✓ Good design with proper segments and detailed network drawings

✓ Good installation with reflections eliminated and interference reduced to minimum.

⇒ To achieve this:

✓ Training!
Training Courses at MMU

- Certified PROFIBUS Installer
  - Installation guidelines, PROFIBUS basics. 8th Nov.

- PROFIBUS Commissioning and Maintenance
  - Troubleshooting, health checking, use of ProfiTrace. 9th Nov.

- Certified PROFIBUS Engineer
  - Details of PROFIBUS DP and PA operation
    - 10th – 12th Nov.

- Certified PROFINET Engineer
  - Details of PROFINET operation. 12th – 14th Oct.

- Open PLC programming Course
  - Basic and certified Open PLC Courses, 22nd – 26th Nov.

Thank you!

Ann Squirrell, admin@uk.profibus.com