PROFIBUS Design Notes

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Since the mid-1980s, the quest for a standardized, all-digital field-bus has resulted in several different and competing technologies such as PROFIBUS, DeviceNet, Foundation Fieldbus and others. Today, on each continent, at least one of these standards is widely embraced. PROFIBUS has been growing in popularity in the United States and Asia over the last several years. Although this technology was initially standardized in the late 1980s it is not easy to find any material to help design/systems engineers develop new products. This TechNote is an introductory reference for engineers with a focus on the hardware design aspect.

Industrial communication, whether in process or factory automation or motion control, is achieved through a field-bus. Field-bus networks are us at the lower levels of the industrial hierarchy (Fig. 1) referred to as the actuator/sensor level. The field-bus connects programmable logic controllers and other control devices to the actuators and sensors. An example of this lower-level field-bus is AS-Interface. One level above the actuator/sensor level, the field or cell level, the communication is about the coordination of the different steps or stages that make-up the entire automation process. An example of a field-bus that covers both layers is PROFIBUS DP, which is part of the larger field-bus family PROcess FIeldBUS, simply referred to as PROFIBUS.

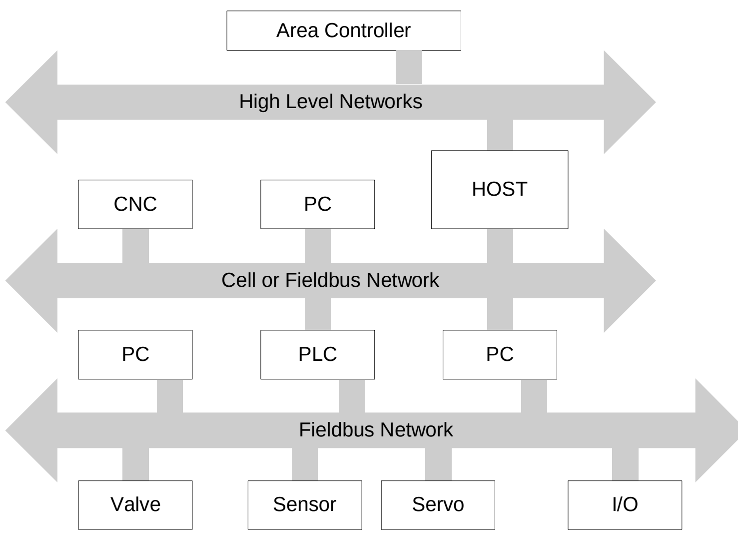

Fig. 1: Industrial Network Hierarchy

Developed in Germany, PROFIBUS was established in 1989 as a national standard (DIN 19245). In 1996, the standard was then ratified as a European Standard (EN 50170) and later was adopted internationally as IEC 61158 and IEC 61784, along with other competing field-bus standards. Over time, the term "PROFIBUS" has become a broad term encompassing many different applications. Originally, the only PROFIBUS version was PROFIBUS FMS (Field Management System). Other flavors such as PROFIBUS-DP (Factory Automation) and PROFIBUS-PA (Process Automation) have become available and have grown in popularity. These PROFIBUS protocols can be realized with TIA/EIA-485 (RS-485), fiber optic, MBP (Manchester encoding bus powered) or RS-485IS (intrinsic safety) electrical/optical layers. The PROFIBUS standard has an installed base of more than 12 million nodes globally and is being used successfully in manufacturing, process and building automation. The number of newly-installed PROFIBUS devices increased from 2 million in 2003 to 2.6 million in 2004.

As mentioned PROFIBUS comes with three different versions. The first, outdated, version is PROFIBUS-FMS, designed for general-purpose data communication in the cell and field levels. By definition the associated hardware was complex and expensive to implement. The second version is PROFIBUS-DP, which represents the majority of PROFIBUS-installed bases and features high-speed data communication required in factory and building automation. The last version is PROFIBUS-PA, which is used in applications requiring intrinsic safety.

IEC 61158		
General Purpose Automation PROFIBUS FMS RS-485/ Fiber Optic - Plug and play - Multi-master communication - Published in 1989	Factory/Building Automation PROFIBUS DP RS-485/ Fiber Optic - Plug and play - Efficient and cost effective - Published in 1993, 1996 & 2001	Process Automation PROFIBUS PA MBP-IS - Power over the bus - Intrinsic safety - Published in 1996
OBSOLETE	ACTIVE	ACTIVE

Table 1: IEC 61158 PROFIBUS Standard

PROFIBUS is based on the client/server architecture creating a hierarchy in a network by defining two types of stations: active (master) and passive (slave). The passive station can never initiate communication on its own only answering the master's commands. There must be at least one master present in every PROFIBUS network and, although the standard allows multiple masters on the same network, most installations use a single-master. The total number of masters and slaves on a bus cannot exceed 127 due to a 7-bit limit on addressable nodes.

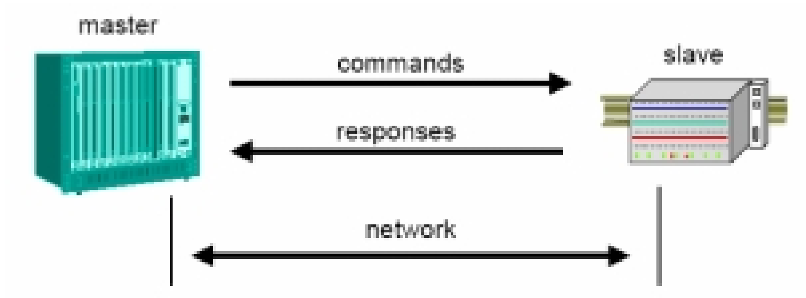

Fig. 2: Client/Server (Master/Slave) Architecture

PROFIBUS-DP is the most widely-used PROFIBUS standard in factory and building automation (estimated at 90% of PROFIBUS nodes) because the intrinsic safety provided by PROFIBUS-PA is more expensive to implement and is required in only specific applications.

For PROFIBUS-DP, either the RS-485 or fiber optic (FO) transmission medium can be used. RS-485 provides asynchronous transmission with selectable data rates within the range of 9.6 kbit/s to 12,000 kbit/s over a two-wire bus structure. (See Table 2 for maximum segment lengths -- known as bus length.)

Data rate (kbit/s)	9.6	19.2	45.45	93.75	187.5	500	1500	3000	6000	12000
Segment length (ft)	3940	3940	3940	3940	3280	1310	656	328	328	328

Table 2: Data Rates And Maximum Segment Lengths

The RS-485 medium uses a shielded twisted-pair cable that enables 32 stations per segment, and the bus reach can be extended by repeaters. The FO medium enables similar communication with extended range of up to 100 km by repeaters over mono-mode, multi-mode or plastic fibers, while providing a greater degree of electromagnetic immunity at a higher cost. For PA the physical medium must be MBP-IS, (Manchester coded and bus-powered intrinsic safety). The MBP-IS medium carries both data and powe providing synchronous transmission with a fixed data rate of 31.25 kbit/s.

Active or passive PROFIBUS-DP nodes are also referred to as controller or sensor/actuator, respectively. Since most designs are passives the remainder of this TechNote focuses on this type of node (Fig. 3).

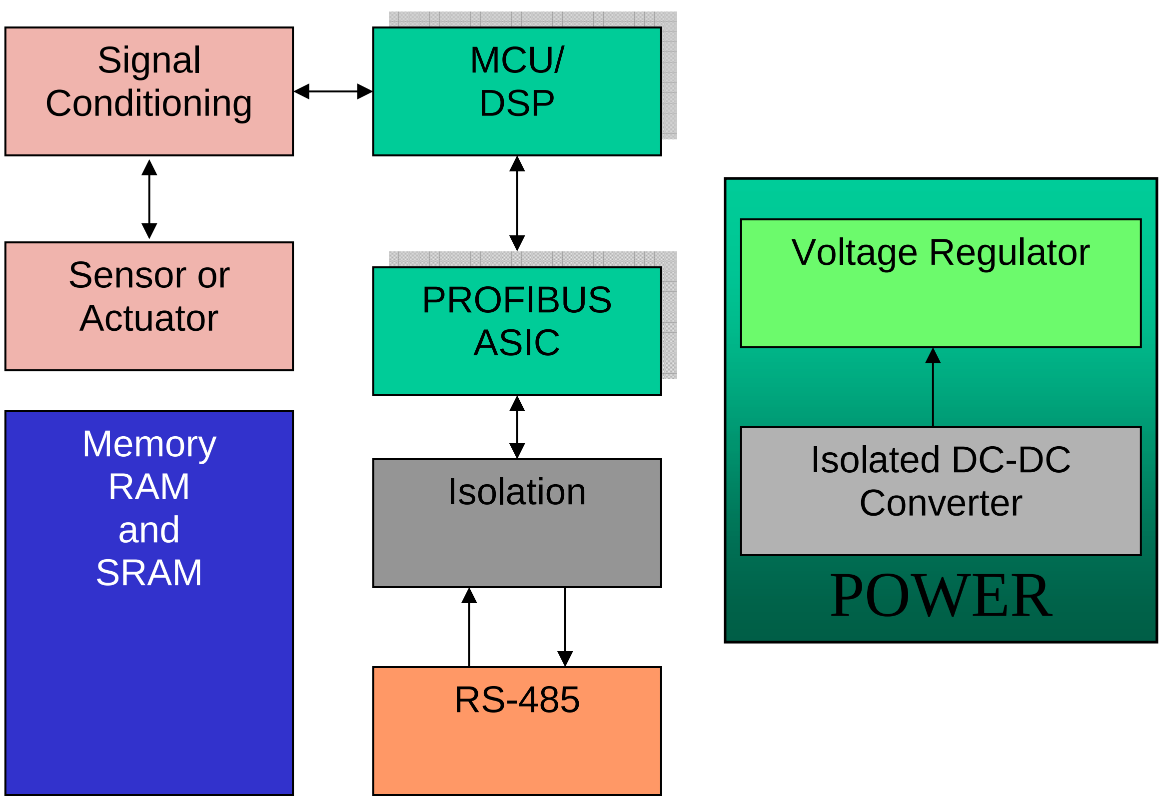

Fig. 3: Major Blocks Of A Typical PROFIBUS Node

PROFIBUS ASIC

The PROFIBUS ASIC is the heart of any PROFIBUS system. PROFIBUS ASICs are available from several sources. The first and most commonly-used supplier is Siemens, which provides the following commonly-used devices:

ASIC Name	Node Type	DP	MBP
ASPC2	Master	Yes	No
SPC3	Intelligent Slave	Yes	No
DPC31	Intelligent Slave	Yes	Yes
SIM11	Intelligent Slave	No	Yes
LSPM2	Simple Slave	Yes	No
SPM2	Simple Slave	Yes	No

For non-intelligent slave designs either LSPM2 or SPM2 is recommended. For intelligent slave designs SPC3 is recommended.

For designs that will act as masters on the bus it is strongly recommended to use ASPC2. While it is possible to use high-performance microcontrollers (MCU) or digital signal processors (DSP) instead of ASICs, very few companies do so because of expensive development costs and the hard timing requirements of PROFIBUS' cyclic communication. Instead, most companies design with ASICs and their choice of MCUs/DSPs to provide maximum flexibility in offloading time-critical functions to the ASIC.

Due to stringent timing requirements most designs use quality oscillators (not shown in Fig. 3) and while they make excellent clocks their power consumption may not be acceptable for satellite nodes. For low-power designs a carefully designed 48-kHz crystal oscillator with a series of inverters provides adequate timing references -- but EMC performance should be carefully monitored.

From a power perspective DPC31 provides the best performance based on an 8031 core. However, most passive designs use a SPC3 ASIC due to simplicity, though this chip consumes more power compared to the DPC31. A more comprehensive list can be found below although it is recommended to check with a non-profit PROFIBUS organization for more up-to-date lists.

Vendor	ASIC Name	Type	Description	FMS	DP	Integrated CPU	Software	Maximum Baud Rate
AGE	Agent-PB	Master/Slave	FGPA-based, universal protocol chip	Yes	Yes	Yes	Yes	up to 12 Mbps
IAM	PBM	Master	Peripheral protocol chip	Yes	Yes	Yes	Yes	up to 3 Mbps
M2C	IX1	Master/Slave	Single chip or peripheral protocol chip	Yes	Yes	No/Yes	No/Yes	up to 3 Mbps
Siemens	SPC4	Slave	Peripheral protocol chip	Yes	Yes	Yes	Yes	up to 12 Mbps
Siemens	SPC3	Slave	Peripheral protocol chip	No	Yes	Yes	Yes	up to 12 Mbps
Siemens	DPC31	Slave	Protocol chip with integrated microcontroler	No	Yes	No/Yes	Yes	up to 12 Mbps
Siemens	ASPC2	Master	Peripheral protocol chip	Yes	Yes	Yes	Yes	up to 12 Mbps
Siemens	SPM2	Slave	Single chip, 64 I/O bits	No	Yes	No	No	up to 12 Mbps
Siemens	LSPM2	Slave	Low cost, Single chip, 32 I/O bits	No	Yes	No	No	up to 12 Mbps
PROFICHIP	VPC3+	Slave	Peripheral protocol chip	No	Yes	Yes	Yes	up to 12 Mbps
PROFICHIP	VPC LS	Slave	Low cost, Single chip, 32 I/O bits	No	Yes	No	No	up to 12 Mbps

Other important components in PROFIBUS systems are MCUs/DSPs, signal conditioning, power management, galvanic isolation and transceiver ICs.

For MCUs/DSPs: such as MSP430 or TMS320x2000 series DSPs from Texas Instruments, many designs use current solutions due to backward compatibility and existing code.

For power management: an isolated dc-dc converter is required and it is strongly recommended to have regulation functionality that can be either discrete or incorporated with the isolated dc-dc converters.

For galvanic isolation: opto-couplers (optical-isolators), magnetic-based or capacitive-based isolators can be used.

For transceivers: PROFIBUS-DP refers to either RS-485 (TIA/EIA-485) or FO media. For designs using copper media, standard RS-485 transceivers can be used. However, new generation systems demand enhanced capabilities in terms of differential output voltage, bus-capacitance, electrostatic discharge (ESD) protection and switching performance. Several new-generation products such as the SN65HVD1176 can be used and these new-generation products are optimized for PROFIBUS applications.

Although protection devices and filters are not required by PROFIBUS these devices are recommended to remove high voltages and currents. Depending on the environment any combination of these methods can be used. The first way to protect your design is by adding parallel components such as Zener diodes or tranzorbs, but additional capacitance from these elements can be an issue. When the number of diodes is increased any glitch during a transition from logic 1 to logic 0 state can be misinterpreted, so it is strongly recommended to check the capacitance of these elements in the light of connector type, cable characteristic and length. The second way to protect the design is through serial elements, such as PTCs (positive temperature coeffiecient), that provide over-current protection, but these tend to attenuate the signal due to inherent small dc resistance.

Software for development: In factory automation, for historic reasons, the GSD (generic station description) files are preferably used, but the use of FDT (field device tool) increases as well. In process automation, depending on the requirements, EDD (electronic device description) and FDT are used. For simple designs, communication features of a PROFIBUS device are described in a communication features list (GSD) in a defined data format. A GSD file is a readable ASCII text file and contains both general and device-specific specifications for communication. Each of these entries describes a feature that is supported by a device. By means of keywords a configuration tool reads the device's identification, the adjustable parameters, the corresponding data type and the permitted limit values for the configuration. Some of the keywords are mandatory such as "Vendor Name." Others are optional, such as "Sync Mode supported." The GSD files are structured in three different sections: General Specification, Master Specification and Slave Specification.

For development tools: a PROFIBUS-to-PC interface (PCI, USB or some other interface), a PLC and software for testing your designs is recommended. There is a handful of solutions available, some of which are Amprolyzer CP5611 from SanHammer (PCI based) and CP55M Bus Monitor from Trebing & Himstedt: Bus Monitor (PCMCIA based) and PROFItrace (USB based) from the PROFIBUS Technical Center in The Netherlands: http://www.PROFIBUScenter.nl/.

Today there are many field-bus technologies available to choose from, and PROFIBUS is a leading candidate deserving serious consideration. According to PROFIBUS Trade Organization, PROFIBUS grew 30% year-on-year in 2004, and the installed base is expected to double by 2008. In addition PROFIBUS is complemented by PROFINET and therefore well-positioned as some industrial applications become Ethernet-based.

About The Author

Burak Ilhan is currently World Wide Marketing Manager for CAN, RS-485 & Isolation Interface Products at Texas Instruments Incorporated. He earned his BS from Lamar University and an MS in Electrical Engineering from Southern Methodist University (SMU). Burak has also earned an MBA from The University of Texas at Austin.

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