Executive Summary

PROFIBUS is the digital fieldbus technology with the highest distribution worldwide, providing advantages for all types of applications. The centerpiece of these applications is the PROFIBUS DP Master which controls the communication via this fieldbus.

Since the launch of PROFIBUS some 20 years ago the available hardware technology has evolved from dedicated special purpose fieldbus ASICs to new implementation approaches based on PROFIBUS IP Cores installed in general purpose FPGAs. This solution allows the integration of the required hardware and software for a PROFIBUS implementation into just one component. At the same time, the FPGA provides flexibility regarding the implementation and enables adding individual functionality.

This White Paper gives an overview of the implementation aspects of a PROFIBUS DP Master based on FPGA technology and discusses the advantages of using this solution in comparison to conventional approaches.
Implementing PROFIBUS DP Master Functionality by Using FPGAs
White Paper

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1. Introduction

Available for approximately 20 years, the PROFIBUS standard today offers a mature digital fieldbus technology. It is used in factory as well as process automation applications and can also be found in hybrid industries like food and beverages or pharmaceuticals. In addition, PROFIBUS is also applicable in other markets like building automation and railway applications. PROFIBUS is thus the only fieldbus technology serving all these different application areas.

According to the PROFIBUS & PROFINET International (PI) association more than 40 million PROFIBUS devices were sold by end of 2011 and this number is still growing rapidly. This large installed base suggests PROFIBUS as a leading fieldbus technology which definitely will be relevant for years, if not decades, to come.

Over the past 20 years the hardware market has advanced. While individual electronic components have been discontinued or are based on meanwhile outdated technology, new state-of-the-art hardware capabilities have evolved allowing to implement devices with functional advantages. This also applies to the PROFIBUS market. Whenever a re-design of existing devices becomes necessary or new devices are planned, these will be based on modern hardware platforms rather than legacy components.

One key device type of any PROFIBUS installation is the PROFIBUS DP Master, which is responsible for cyclic communication with the associated slaves as well as acyclic access to their parameters. Here one advanced implementation option is based on Field Programmable Gate Array (FPGA) technology. This approach allows combining different elements of a conventional PROFIBUS implementation into one component and supporting new PROFIBUS functionality as well.

This White Paper outlines the implementation aspects of a PROFIBUS DP Master based on FPGA technology and discusses the advantages of using this technology.
2. PROFIBUS Overview

PROFIBUS (PROcess Field BUS) is a world leading fieldbus communication standard in automation technology. It supports the digital data exchange within a network using a single bus cable, resulting in a high data transmission reliability. Based on numerous protocol extensions, it provides solutions for a wide range of application areas including manufacturing and process automation (see Figure 1).

Figure 1: Different Market Segments Supported By PROFIBUS
(Source: PROFIBUS & PROFINET International)

The history of PROFIBUS went back to 1987 when a publicly-funded collaborative project was launched by 18 companies and institutes in Germany, resulting in the PROFIBUS Fieldbus Message Specification (FMS). In 1993, the PROFIBUS Decentralized Peripherals (DP) standard was released, focusing on the simpler and much faster deterministic communication between controllers and remote I/O field devices (sensors and actuators). This communication follows the Open Systems Interconnection (OSI) Reference Model. The defined OSI layers and their PROFIBUS implementation are presented in Table 1.

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1 Today, PROFIBUS is standardized in IEC61158 Type 3.
2 This consortium commissioned Softing to develop the first PROFIBUS FMS stack implementation worldwide which has been the starting point for Softing's continuous commitment to the PROFIBUS and fieldbus technology.
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Table 1: OSI Layers and Their PROFIBUS DP Implementation
(Source: PROFIBUS & PROFINET International)

<table>
<thead>
<tr>
<th>OSI Layer</th>
<th>PROFIBUS DP Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 (Application Layer)</td>
<td>PROFIBUS DP Protocol</td>
</tr>
<tr>
<td>6 (Presentation Layer)</td>
<td>Not Used</td>
</tr>
<tr>
<td>5 (Session Layer)</td>
<td>Not Used</td>
</tr>
<tr>
<td>4 (Transport Layer)</td>
<td>Not Used</td>
</tr>
<tr>
<td>3 (Network Layer)</td>
<td>Not Used</td>
</tr>
<tr>
<td>2 (Data Link Layer)</td>
<td>Fieldbus Data Link (Including the Principles of Master/Slave Protocol and Token Protocol)</td>
</tr>
<tr>
<td>1 (Physical Layer)</td>
<td>Transmission Technology (e.g. RS485, Manchester Coded Bus Powered)</td>
</tr>
</tbody>
</table>

The RS485 transmission technology is typically used as the PROFIBUS Physical Layer in the different application areas unless it is not applicable due to specific requirements (e.g. power supply to the field devices via the bus cable, heavy interference, or long distances). RS485 is based on a shielded copper cable with a pair of twisted wires, and supports transmission rates from 9.6KBit/s to 12MBit/s. In total, up to 126 stations can be connected to one PROFIBUS DP network, supporting a linear topology. PROFIBUS DP enables the non-reactive coupling and de-coupling of stations and the incremental commissioning of the overall PROFIBUS network. In particular, this allows the subsequent expansion of the network without affecting stations already in operation.

The PROFIBUS Data Link Layer is defined by the Fieldbus Data Link (FDL) protocol. Within this protocol a Token Passing method defines the network access (see Figure 2). It differentiates between master stations (stations controlling the data exchange via the fieldbus) and slave stations (sensors and actuators responding to individual read requests or receiving data via the fieldbus) and controls the timeslots of the individual masters. Based on this master/slave technology, the fieldbus is accessed and the reliable data exchange between PROFIBUS stations is performed.

The PROFIBUS DP standard defines different versions. The PROFIBUS DP-V0 version provides the basic functionality of the communication protocol, including, in particular, cyclic communication and device-, module- and channel-specific diagnostics for quick fault

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3 A PROFIBUS network including more than 32 stations has to be structured in segments using repeaters. Each segment may contain up to 32 stations, including the repeater(s). The combination of the individual segments can be seen as one logical PROFIBUS network.

4 The timeslots of the individual masters are defined as part of the (offline) configuration process. The user has to ensure that every master receives a timeslot which is long enough to perform all its communication tasks and that all the data exchange between the individual masters and the various slaves is performed in real-time with minimal time overhead.
The PROFIBUS DP-V1 version supplements the PROFIBUS DP-V0 version with functionality for acyclic communication, i.e. supporting tasks such as parameterization, operation, monitoring, alarm handling, and maintenance. For this purpose PROFIBUS DP-V1 defines the online access to fieldbus stations via engineering tools. In comparison to PROFIBUS DP-V1, the PROFIBUS DP-V2 version provides extended functionality, including time synchronization, isochronous real-time functionality as required for drive control as well as timestamping and slave-to-slave communication.

PROFIBUS DP defines different device types which are described in Table 2.

<table>
<thead>
<tr>
<th>PROFIBUS DP Device Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROFIBUS DP Master Class 1</td>
<td>The PROFIBUS DP Master Class 1 controls the communication process for exchanging process values with individual slaves using the defined cyclic commands during the configured timeslots(^6). Typical PROFIBUS DP Master Class 1 devices include PLCs and PCs.</td>
</tr>
<tr>
<td>PROFIBUS DP Master Class 2</td>
<td>The PROFIBUS DP Master Class 2 accesses the fieldbus by using acyclic services(^7). These allow the configuration and parameterization of intelligent field devices. Engineering and operator panels typically act as PROFIBUS DP Master Class 2.</td>
</tr>
<tr>
<td>PROFIBUS DP Slave</td>
<td>The PROFIBUS DP Slave is a peripheral device that reads input information and sends output information to the periphery. The amount of supported input and output information depends on the device; a maximum of 246Bytes of input data and 244Bytes of output data is supported.</td>
</tr>
</tbody>
</table>

Table 2: PROFIBUS DP Device Types

Different network architectures are supported based on the PROFIBUS DP device types from Table 2, providing a high flexibility. These architectures include:

- **Single Master Network**
  Here only one master station (PROFIBUS DP Master Class 1) is connected to the PROFIBUS DP network during operation. While a PLC acts as the central control unit, the individual slaves are connected to the fieldbus at remote locations. The single master network provides the shortest fieldbus cycle time.

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\(^5\) For instance, PROFIBUS DP-V0 fault localization deals with faults like „Excess Temperature“ or „Short Circuit on Output“.

\(^6\) The PROFIBUS DP Master Class 1 can also use acyclic services as defined by the Master Slave Acyclic Communication of Class 1 (MSAC_C1).

\(^7\) These services are defined by the Master Slave Acyclic Communication of Class 2 (MSAC_C2). Despite the name acyclic services can be performed by the PROFIBUS DP Master Class 2 on a regular time base, e.g. for providing data as required by a SCADA system.
• **Multi Master Network**

Here several master stations (PROFIBUS DP Master Class 1 and PROFIBUS DP Master Class 2, respectively) are connected to the PROFIBUS DP network. These either build individually independent sub-networks, each consisting of one PROFIBUS DP Master Class 1 and the appropriate slaves, or they include additional stations for development and diagnostics. While all masters can read the input and output values of the slaves, only the PROFIBUS DP Master Class 1 station configured for this slave is allowed to write the output values of a particular slave.

Figure 2 shows a PROFIBUS DP architecture example illustrating the data exchange of one PROFIBUS DP Master Class 1 station and one PROFIBUS DP Master Class 2 station based on the Token Passing method.

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**Figure 2:** Cyclic and Acyclic PROFIBUS DP Communication  
(Source: PROFIBUS & PROFINET International)

Besides the pure cyclic and acyclic data exchange, PROFIBUS DP also supports powerful diagnostic and commissioning functionality.
The capabilities of individual PROFIBUS devices are described by the General Station Description (GSD) and the Electronic Device Description (EDD) files. The GSD file contains the key data of an individual PROFIBUS device, information about its communication capabilities and, e.g. diagnostic values. It supplies all the information necessary for the cyclic exchange of measured values and manipulated variables between the field device and the PROFIBUS master, and supports the configuration of the PROFIBUS network. The EDD provides additional information describing application-specific functions and the parameters of complex field devices. It comprises a description of the device capabilities exchanged acyclically, including graphics-based options, and device information such as order data, materials, maintenance instructions, etc.\textsuperscript{8}

\textsuperscript{8} EDD files are primarily used in PROFIBUS Process Automation (PA) applications.
3. Implementing a PROFIBUS DP Master

As the PROFIBUS communication is structured in layers (see Table 1), a complete PROFIBUS DP Master implementation has to address the Physical Layer, the Data Link Layer, as well as the Application Layer. Thus, a PROFIBUS DP Master implementation consists of a hardware and a software portion.

The hardware portion of the PROFIBUS DP master implementation typically comprises a Fieldbus Controller, which is responsible for accessing the PROFIBUS DP network at the logical level, and an isolated RS485 driver. The Fieldbus Controller handles all time-critical parts of the PROFIBUS Data Link Layer like token handling and the exchange of process values. The PROFIBUS DP Master protocol stack covers the software portion of the PROFIBUS DP Master implementation, which deals with the remaining communication functionality (see Figure 3).

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9 The described distribution of time-critical and non-time-critical functionality is primarily based on a PROFIBUS DP Master implementation using the Siemens ASPC2 Fieldbus Controller (see Section 3.1.1). Other implementations like the Softing FPGA implementation (see Section 3.2) use a different distribution and, for instance, implement parts of the token handling and the process data exchange in software.
The following sections present various approaches used for implementing a PROFIBUS DP Master in the past. These approaches are then compared with a state-of-the-art PROFIBUS DP Master architecture based on an FPGA architecture.

### 3.1 Conventional PROFIBUS DP Master Implementation

The implementation of a PROFIBUS DP Master has been an important task since the release of the PROFIBUS DP standard. Over the years a number of different architectures have evolved for its implementation.
3.1.1 PROFIBUS DP Master Implementation Based on Fieldbus Controller Chip

The traditional way to implement a PROFIBUS DP Master combines a specific PROFIBUS DP Fieldbus Controller chip and the PROFIBUS DP Master protocol stack. Here, the Fieldbus Controller chip processes the time-critical parts of the Data Link Layer of the PROFIBUS DP implementation. The usage of the Fieldbus Controller chip for a PROFIBUS DP Master implementation is complemented by the PROFIBUS DP Master protocol stack that provides the software part of the PROFIBUS DP functionality with a focus on the Application Layer.

In addition to implementing the application functionality itself, the major tasks of developing a new PROFIBUS DP Master are the hardware design as well as the porting of the PROFIBUS DP Master protocol stack for execution on the target processor and operating system.

The use of a Fieldbus Controller chip (e.g. ASPC2 from Siemens) allows implementing a PROFIBUS DP Master supporting the full set of PROFIBUS DP versions and all defined PROFIBUS DP transfer rates. However, the PROFIBUS DP Fieldbus Controller also has some disadvantages as shown in Table 3.

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-State-of-the-Art Hardware</td>
<td>Due to its age, the technology of the PROFIBUS DP Fieldbus Controller chip is outdated and thus requires additional effort for integration into modern hardware (e.g. the 5V signal level requires level shifters to meet typical low voltage architectures. In addition, the ASPC2 Fieldbus Controller chip requires a dedicated Shared RAM interface).</td>
</tr>
<tr>
<td>Single Source</td>
<td>The PROFIBUS DP Fieldbus Controller chip is only available from one manufacturer, increasing the dependency of the implemented PROFIBUS DP Master. The manufacturer may discontinue the Fieldbus Controller chip at any time, which directly jeopardizes the availability of an implemented PROFIBUS DP Master.</td>
</tr>
<tr>
<td>Fixed Hardware Functionality</td>
<td>Only software related changes can be implemented, which may be necessary for instance due to specification updates.</td>
</tr>
<tr>
<td>Difficult Interaction</td>
<td>The ASPC2 Fieldbus Controller integration into any manufacturer hardware requires in-depth know-how as the ASPC2 has to stop the processor to access the memory used by the processor via Direct Memory Access (DMA).</td>
</tr>
</tbody>
</table>

Table 3: Disadvantages of Using the Fieldbus Controller Chip for Implementing a PROFIBUS DP Master
3.1.2 PROFIBUS DP Master Implementation Based on System-on-Chip

Another PROFIBUS DP Master implementation approach makes use of a dedicated System-on-Chip (SoC). This component combines the processor with additional functionality and peripheral components. While the processor acts as the central processing unit for the PROFIBUS DP Master protocol stack, additional functionality provides memory access or timer operations, for instance, and peripheral components take care of the Fieldbus Controller functionality.

Thus, using an SoC for implementing a PROFIBUS DP Master reduces the need for additional components and results in less hardware development effort. However, there are also disadvantages associated with this approach. These are outlined in Table 4.

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed System</td>
<td>The supported functionality is defined by the SoC manufacturer. Thus, there are only limited possibilities of adapting this functionality to address specific PROFIBUS DP Master requirements. The PROFIBUS DP Master application has to be executed on a separate processor.</td>
</tr>
<tr>
<td>Single Source</td>
<td>The PROFIBUS DP Master SoC is only available from one manufacturer, increasing the dependency of the implemented PROFIBUS DP Master. The manufacturer may discontinue the SoC at any time, which directly jeopardizes the availability of an implemented PROFIBUS DP Master.</td>
</tr>
<tr>
<td>Fixed Functionality</td>
<td>The PROFIBUS hardware and software functionality is fixed within the SoC. Thus, there is no way to individually extend the provided functionality.</td>
</tr>
</tbody>
</table>

Table 4: Disadvantages of Using the System-On-Chip for Implementing a PROFIBUS DP Master

3.1.3 Software-Based PROFIBUS DP Master Implementation

The PROFIBUS DP Master can also be implemented completely in software, including the Fieldbus Controller functionality. Here the intention is to use any standard hardware providing Universal Asynchronous Receiver Transmitter (UART) circuits with RS485 output as the PROFIBUS DP Master hardware platform.

When evaluating this PROFIBUS DP Master implementation approach, however, it turns out that there are a couple of disadvantages as listed in Table 5.
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Disadvantage Description

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Processor Performance Required</td>
<td>A purely software based PROFIBUS DP Master implementation requires a high processor performance for supporting the full range of functionality defined by the PROFIBUS standard.</td>
</tr>
<tr>
<td>No Guarantee of Determinism</td>
<td>Depending on the processor performance and the individual tasks to be performed by the processor, the fully deterministic responses required for a PROFIBUS DP communication may not be guaranteed.</td>
</tr>
<tr>
<td>Questionable Support of 12MBit/s Transfer Rate</td>
<td>The supported PROFIBUS DP transfer rates very much depend on the performance of the processor used. PROFIBUS DP transfer rates up to 1.5MBit/s are typically supported. Thus, the support of a faster PROFIBUS DP communication is at least questionable.</td>
</tr>
<tr>
<td>Additional Processor Required</td>
<td>In order to limit the load of the processor executing the PROFIBUS DP communication, an additional processor is required to run the PROFIBUS DP Master application.</td>
</tr>
<tr>
<td>Additional Hardware Components Required</td>
<td>Even when using a processor with a high performance, the software-based PROFIBUS DP Master implementation always requires the support of additional hardware components like timers or UARTs.</td>
</tr>
</tbody>
</table>

Table 5: Disadvantages of Using the Completely Software-Based Implementation of a PROFIBUS DP Master

3.2 PROFIBUS DP Master Implementation Based on FPGA Technology

As the various conventional PROFIBUS DP Master implementations all have their disadvantages, it makes sense to look for alternatives when a re-design of an existing PROFIBUS DP Master becomes necessary or the implementation of a new PROFIBUS DP Master is planned. One option is to use FPGA technology which directly results in a number of advantages. Based on the FPGA-based PROFIBUS DP Master from Softing, this option will be discussed in more depth in the following sections.

3.2.1 FPGA Technology

The FPGA is an electronic component which can be programmed after its production. It is capable of implementing any logical function that an application-specific integrated circuit (ASIC) could perform. FPGAs are available from various manufacturers, including Altera and Xilinx. The FPGA is structured in logic elements which, on the one hand, can be used for directly implementing specific functionality and, on the other hand, also support the loading of individual IP Cores providing pre-engineered functionality. These IP Cores can be “wired together” to provide the overall functionality of an FPGA. For an individual FPGA, IP Cores are available from different sources, including FPGA manufacturers and various service providers. Plus, they also can be developed individually to meet specific needs.
One type of IP Core as provided, for instance, by FPGA manufacturers is the processor IP Core. It allows the execution of individual programs as in a standard processor. Other types of IP Cores support a specific communication technology (e.g. Fieldbus Controller IP Core for supporting PROFIBUS communication), allow connecting peripheral components like memory and I/Os, or provide a special functionality (e.g. closed loop control for drives).

A major advantage of this approach is that, based on these individually available IP Cores, a specific set of hardware and software can be loaded into an FPGA to deliver the desired functionality. As loading into the FPGA is performed at runtime, the support of re-configurability and updates in the field comes as a free added benefit. All in all, the FPGA offers a new level of flexibility unknown in other electronic components.

For implementing a fieldbus device like a PROFIBUS DP Master, a hardware part (Fieldbus Controller) as well as a software part (protocol stack) are required (see Chapter 3). These can be ideally combined into an FPGA.

### 3.2.2 Implementing the PROFIBUS DP Fieldbus Controller Based on FPGA Technology

A Fieldbus Controller implemented as an FPGA IP Core needs to provide functionality comparable to that of a Fieldbus Controller chip as described in Section 3.1.1. It is responsible for accessing the PROFIBUS DP network, for transforming the serial data stream into individual telegrams, and for observing the PROFIBUS DP timing rules.

As the available Fieldbus Controller chips were released at an early stage of the PROFIBUS life cycle, the FPGA based approach also offers the possibility to improve the Fieldbus Controller functionality as part of the FPGA implementation and to make use of a state-of-the-art hardware design. The most important of these improvements are given in Table 6.
Improvement Description

No External Parts The Fieldbus Controller is completely implemented inside the FPGA, together with additional components like memory interface, level shifters, etc. This results in reduced costs and space requirements.

Dual Port Memory Data Interface For data exchange between the Fieldbus Controller and the PROFIBUS DP Master protocol stack running on a processor IP Core, an internal Dual Port Memory is used. This replaces the costly external Shared Memory architecture.

Synchronization with Application The synchronization functionality allows synchronizing the application (e.g. the PLC cycle) with the PROFIBUS DP Master communication, resulting in a faster processing of individual field device data within the control program.

Configurable RAM Buffers The number of RAM buffers used for storing communication telegrams is configurable. Depending on the FPGA size used, it can comprise up to 32 buffers structured in data blocks of 8KB and is thus adjustable to individual requirements.

Deeply Integrated Line Redundancy The line redundancy facilitates the connection of two separate PROFIBUS networks to the PROFIBUS DP Master via two redundant bus connections. Each telegram is sent to both networks in parallel. For processing the received telegrams, only the telegram with the better quality of the two is used.
As opposed to using external redundancy modules, the bus signal does not have to be repeated. It is only available when needed.

Possibility to Provide Additional Functionality The FPGA can be used for implementing any other application specific requirements in parallel. Thus, there is no need for additional components. This results in a highly integrated solution, supporting a small footprint.

Table 6: Improvements When Implementing a PROFIBUS DP Master Based on FPGA Technology

The topology of a PROFIBUS DP network supporting line redundancy is shown in Figure 4.

10 While the figures given reflect the Softing implementation, different sizes may also apply.
In summary, the PROFIBUS DP Fieldbus Controller implementation based on FPGA technology uses an IP Core, which supports an extensive set of functionality while focusing on the time-critical part of the PROFIBUS FDL protocol stack. This implementation is 100% compliant with the PROFIBUS standard and supports all defined transfer rates. The less time-critical part of the PROFIBUS FDL protocol stack, like the handling of the Live List or the general communication management, is implemented in software as part of the PROFIBUS DP Master protocol stack.

The Fieldbus Controller implementation is typically available to the manufacturers of PROFIBUS DP Master applications (e.g. PLC or DCS manufacturers) in an encrypted format which allows them to include this IP Core in their own FPGA design.

### 3.2.3 Implementing the PROFIBUS DP Master Protocol Stack Based on FPGA Technology

The PROFIBUS DP Master protocol stack is available in binary format for direct execution on a processor IP Core in an FPGA. As opposed to the classical approach, the stack does not need to be ported to the target processor and operating system. It is designed from the outset for use with the IP Core and uses a royalty-free operating system\(^\text{11}\). The stack comprises the complete PROFIBUS Application Layer as well as the non-time-critical parts of the PROFIBUS FDL protocol.

While a standard application uses just one instance of the PROFIBUS DP Master implementation, the FPGA technology also supports multiple independent PROFIBUS DP channels. All that is required in this case is a bigger FPGA with more capacity to include the appropriate number of instances of the PROFIBUS DP Master IP Cores.

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\(^{11}\) The Softing approach uses the eCos operating system.
From the user’s point of view, the complete PROFIBUS DP Master implementation is encapsulated and provides an application interface, typically based on a Dual Port Memory, for exchanging data with an additional application. This application, for instance, can manage the communication via the backplane bus or even perform PLC functionality. Due to the supported FPGA capabilities this application can either be processed within the same FPGA or by an external processor. Two possible architectures are shown in Figure 5.

Figure 5: Flexibility Regarding PROFIBUS DP Master Architecture When Using an FPGA-Based Implementation
3.2.4 PROFIBUS DP Master Implementation Aspects

The FPGA size required for implementing a PROFIBUS DP Master is driven by the specific functionality supported in the individual case. Based on the implemented features the resources can be determined and the appropriate FPGA size can be chosen. Typical FPGA resource requirements for implementing various aspects of a PROFIBUS DP Master are given in Table 7.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Logic Elements</th>
<th>M9K Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROFIBUS DP Fieldbus Controller IP Core, Processor Running PROFIBUS DP Master Protocol Stack, Dual Port Memory Interface, DDR2 RAM Controller</td>
<td>12,200</td>
<td>114(^{14})</td>
</tr>
<tr>
<td>PROFIBUS DP Fieldbus Controller IP Core</td>
<td>3,050</td>
<td>12</td>
</tr>
<tr>
<td>PROFIBUS DP Master Line Redundancy Implementation (in Addition)</td>
<td>1,300</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7: Required FPGA Resources for PROFIBUS DP Master Implementation\(^{15}\) (Rough Range Based on Altera Cyclone III Implementation)

Device manufacturers can choose from different hardware options for implementing the PROFIBUS DP Master functionality based on FPGA technology. One is to use an embedded communication module that comprises all the required PROFIBUS DP hardware and software, and is integrated into the target hardware as a piggy-back board. Another option is a custom FPGA hardware development, including the PROFIBUS DP Master functionality and all manufacturer-specific functions in a cost-optimized manner.

\(^{12}\) The number of logic elements describes the amount of programmable logic components used within an FPGA. Depending on the configuration, logic elements may perform complex combinational functions, or merely simple logic gates like AND and XOR.

\(^{13}\) The number of M9KBlocks refers to Altera FPGAs and describes the size of embedded memory used within the FPGA. Here, each memory block has a size of 9,216Bits (including parity bits). The FPGAs of other manufacturers may use embedded memory blocks of a different size.

\(^{14}\) The amount of 114 M9K blocks refers to the Softing reference implementation and is based on using a code and data cache of 16KB each. Using a minimum size for the code and data cache of 4KB each and a Dual Port Memory of 64KB would result in about 85 M9K blocks. Implementing a PROFIBUS DP Master Class 2 can be done with significantly less memory.

\(^{15}\) The figures presented in this table give a rough range of the size of programmable logic and embedded memory required for implementing a PROFIBUS DP Master on an Altera Cyclone III FPGA.
4. Advantages of Using FPGA Technology for PROFIBUS DP Master Implementation

There are a number of advantages to be gained from using the FPGA technology for implementing a PROFIBUS DP Master. These advantages are discussed in this chapter.

4.1 Flexibility for Implementing a PROFIBUS DP Master

A main advantage of FPGA technology is that it provides a high level of flexibility for implementing a PROFIBUS DP Master. Different aspects resulting from the provided flexibility are discussed in Table 8.
**Flexibility Aspect** | **Description**
--- | ---
Supported Architecture | The FPGA is structured by individual IP Cores which can be combined into one FPGA as long as the FPGA provides the required resources. Thus, different PROFIBUS DP Master architectures can be implemented, including a pure PROFIBUS DP Master and the additional implementation of the application processor within the same FPGA and IP Core processor, respectively (see Figure 5).

Number of Supported PROFIBUS DP Channels | A PROFIBUS DP Master supporting more than one PROFIBUS DP channel can be implemented simply by loading the appropriate number of instances of the respective IP Cores into the FPGA. The FPGA used only has to provide the required resources.

Scope of Implemented Functionality | The FPGA allows manufacturers to not only implement the PROFIBUS DP Master functionality, but also add individual capabilities (e.g. access to the backplane bus) according to their specific requirements. This is done by simply adding the appropriate IP Cores.

Scalability | As FPGAs are available in different sizes, the required size can be determined based on the functionality supported by the individual manufacturer.

Integration of Interfaces | IP Cores supporting different types of memory interfaces (e.g. SDRAM, DDR2RAM, etc.) and interfaces for application integration (e.g. Dual Port Memory, Serial Peripheral Interface, etc.) are available and can be integrated directly into the FPGA of the PROFIBUS DP Master implementation.

Reduced Number of Hardware Variants | Using FPGA technology, a set of different PROFIBUS DP Master implementation variants can be supported by a single hardware platform (only the individual IP Cores loaded into the FPGA differ).

Support of Specification Updates | The functionality provided by an FPGA is not fixed, but can be updated as required by simply loading the individual IP Core into the FPGA. This way, for instance, a future specification update can be implemented and used within an existing FPGA hardware.

Upgrade to Next Technology Level | Device manufacturers are free to decide on a new hardware generation on the basis of their own individual considerations and not driven by external factors like the discontinuation of an individual electronic component. Existing IP Cores can be re-used with next-generation FPGAs, and new IP Cores (e.g. supporting a new memory technology) can easily be added.

---

**Table 8:** Flexibility Provided by Using FPGA Technology for PROFIBUS DP Master Implementation
4.2 Further Advantages

Besides flexibility there are other benefits in using FPGA technology for implementing a PROFIBUS DP Master.

One is that with FPGAs, the investment in the PROFIBUS DP Master implementation is guaranteed for the future: A specific Fieldbus Controller as well as a PROFIBUS DP Master SoC are specialized components which are typically only available from a single manufacturer. Some of these niche products have already been on the market for several years, which increases the probability of supply bottlenecks and product discontinuation in the near future, and thus directly impacts the product availability of the PROFIBUS DP Master implemented based on these components.

FPGAs in contrast are universal mainstream products which are produced and distributed in large amounts. Their product maintenance is thus of vital interest to FPGA manufacturers. Improvements in semiconductor technology can be implemented very quickly and additional IP Cores, for instance supporting new memory technologies, continuously become available. Therefore, basing a PROFIBUS DP Master implementation on FPGA technology ensures its continued availability in the future.

The easy integration of the PROFIBUS DP Master protocol stack is another advantage of using FPGA technology. As the environment (i.e. processor IP Core, operating system, and memory access) is fully defined, the executable format of the PROFIBUS DP Master protocol stack can be prepared in advance. This eliminates the need to port this protocol stack to the target platform. All that has to be implemented is the access to the planned application interface, resulting in significantly less effort.

Within an existing PROFIBUS DP Master implementation, an application like the communication via the backplane bus is often already provided using FPGA technology. Thus, the decision to use an FPGA for implementing the PROFIBUS DP Master does not require additional hardware components. Instead, this functionality can be merged into an existing FPGA.

4.3 Support of Additional Communication Capabilities

Using FPGA technology for implementing the PROFIBUS DP Master opens the door to supporting additional functionality on the same hardware platform. For instance, this approach allows the parallel implementation of additional communication protocols like other fieldbuses and Industrial Ethernet (e.g. PROFINET Controller). In this case, the appropriate IP Core just needs to be loaded into the FPGA, while the application interface remains unchanged. Only the communication interface has to be adapted (e.g. from RS485 to RJ45).

This approach provides additional freedom to hardware manufacturers. It allows using a universal hardware and application platform to support multiple protocols within several product families. All in all this results in the effective use of the implementation effort invested and minimizes the required amount of stock held by the manufacturer.
5. Summary

FPGA technology allows implementing a PROFIBUS DP Master which provides the full PROFIBUS DP functionality while offering advantages over a conventional closed implementation.

To sum up the FPGA advantages, a comparison regarding various aspects of a PROFIBUS DP Master implementation is given in Table 9. This comparison addresses the usage of an FPGA vs. an SoC or a standard processor (with or without the use of a Fieldbus Controller). (As the available SoCs and standard processors support different PROFIBUS DP Master functionality, the best known SoC and standard processor are used for this comparison.)

<table>
<thead>
<tr>
<th>Topic</th>
<th>FPGA (see Section 3.2)</th>
<th>Standard Processor Plus Fieldbus Controller (see Section 3.1.1)</th>
<th>SoC (see Section 3.1.2)</th>
<th>Standard Processor (Pure Software Solution) (see Section 3.1.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Support of PROFIBUS DP Master Functionality (Including Fieldbus Controller Functionality)</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Integration of Application</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scalability</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Long-Term Availability of Technology (Including Successor Products)</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flexibility Regarding Support of Add-On Functionality</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Price of PROFIBUS DP Master</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Price of Complete Hardware</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 9: Advantages of FPGA Usage in Comparison With Conventional Implementation Approaches
(Coverage of Topic: +: Good, O: Neutral, -: Bad)

The FPGA hardware platform which has been developed as part of a PROFIBUS DP Master implementation also provides additional capabilities. It makes use of a universal hardware architecture which results in a general platform supporting multiple communication protocols.
6. About Softing

The Softing Industrial Automation segment is part of the Softing group founded in 1979.

Softing Industrial Automation is a global specialist in industrial communication technologies such as fieldbuses and Industrial Ethernet. With over 30 years of experience, Softing’s Industrial Automation business units deliver connectivity, diagnostic products, and services to customers in the factory and process automation industry.

Softing has been working on the PROFIBUS technology since the start of the initial PROFIBUS project launched in 1987. Since then Softing has been deeply involved in the development of various kinds of PROFIBUS products. Today, the Softing PROFIBUS offering is proven-in-use in a wide variety of applications by a large number of manufacturers and users around the world.

The options offered by Softing for implementing a PROFIBUS DP Master are based on the great technical experience and the high quality resulting from implementing a vast number of field-proven products and successful customer-specific projects. Thus, for an individual PROFIBUS DP Master implementation a unique combination of perfectly matched high-quality products and professional services is available from a single source. Softing’s relationship with its customers is shaped by a high degree of flexibility for adaptations to individual requirements as well as by a long-term partnership. A network of sales offices and distribution partners around the world enable Softing to address individual customer needs in a quick and appropriate way.

The Softing products are tailored to the requirements of system integrators, device vendors, machine and equipment manufacturers, or end users and are known for their ease of use and functional advantages.

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