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High Speed Communication Using FPGAs

PROFINET IRT Implementation Based on FPGAs

PROFINET IRT convinces with short cycle times and deterministic communication behavior. Offering the ideal platform for implementing the Industrial Ethernet protocol, FPGAs open up a number of advantages. Softing combines the advantages into a full-featured solution that also supports the easy integration of additional Industrial Ethernet protocols.

It is hard to imagine modern industrial automation without communication via the Industrial Ethernet protocol. Even though its use has been discussed for many years, the technology has gained widespread acceptance among users and is employed in a wide range of applications. In the market, several competing approaches have become established. The manufacturers of automation products are now faced with the major challenge of providing products that support the different Industrial Ethernet protocols to suit individual customer needs. Manufacturers are therefore looking for an implementation solution that requires a minimum of effort while offering cost-efficiency, flexibility and a future-proof design.

Stationary network diagnostics with the PROFIBUS monitor BC-502-PB from Softing

"A lot has to happen until the bus fails and the system is standing still!" The practice shows that PROFIBUS is a rugged fieldbus. Malfunctions that happen just the same, mostly can be traced back to the bus physics. Usually, the first sign of a deterioration in bus quality go unnoticed by the "normal" bus participants. Aging, corrosion, damaged or worn cables are typical examples of the underlying causes.

To forestall a costly system failure with adequate measures, it is important to recognize the early warning signals and indicate the actual maintenance requirements: Softing's stationary **PROFIBUS Monitor BC-502-PB** "understands" the bus communication and detects problems before the network failure. The tool's open functionality allows use across all controller and PROFIBUS device types. Moreover, one PROFIBUS Monitor per bus line is all that is needed – no matter how many physical segments are to be monitored.

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A world leading provider of industrial communication products and technologies, Softing Industrial Automation supports its customers in the implementation and offers them a full-featured solution based on Field Programmable Gate Arrays (FPGA). Softing's solution allows employing the Industrial Ethernet protocols EtherCAT, PROFINET, EtherNet/IP, Ethernet POWERLINK and Modbus TCP using FPGAs from Altera and Xilinx.
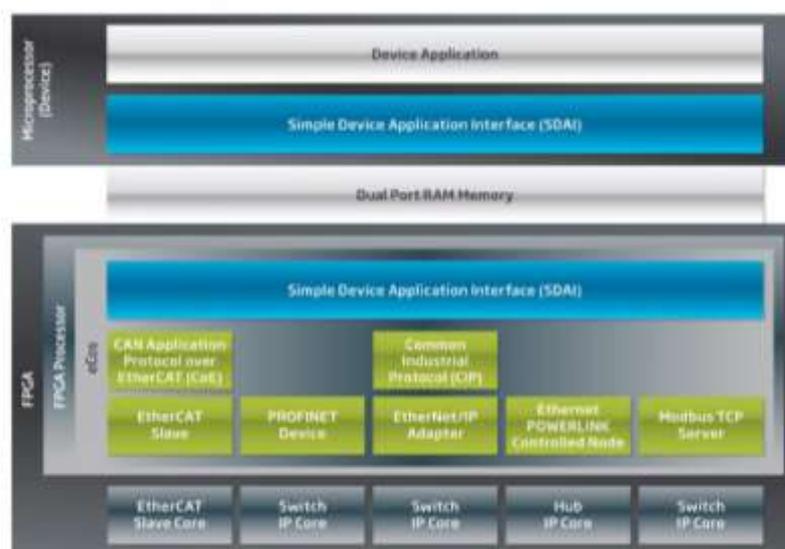
Figure 1: Cost-efficient, flexible and future-proof: FPGAs in field devices support different Industrial Ethernet protocols.

High-performance Industrial Ethernet protocols

The implementation of drive applications places stringent demands on the Industrial Ethernet protocols with regard to short cycle times and a high level of determinism. These demands could previously only be met by the EtherCAT and Ethernet POWERLINK protocols. The current specification V2.3 of PROFINET with PROFINET IRT (Isochronous Real Time) now also satisfies the requirements for this application area, achieving cycle times of less than 50µs with a maximum deviation (jitter) of less than 1µs.

Since these high-performance Industrial Ethernet protocols cannot be implemented using standard Ethernet components, other approaches need to be found. Suitable implementation options include:

- **ASIC**

  The ASIC solution covers the specific requirements of individual Industrial Ethernet protocols and is available in a wide variety of different versions (e.g. ASIC for supporting a single protocol, ASIC for supporting multiple protocols, standard processor with programmable communication peripherals). The hardware functionality is fixed and cannot be modified later.

- **FPGA**

  In the FPGA solution, IP Cores implementing specific functionality in hardware are combined with firmware that provides the remaining protocol functionality and is executed on the assigned processors within the FPGA. In this way, the specific requirements of the individual Industrial Ethernet protocols can be flexibly met. The FPGA solution offers the possibility to modify and upgrade the hardware functionality at a later stage by simply replacing the respective IP Core.

For its Industrial Ethernet solutions, Softing decided to use FPGAs. The decision was motivated by two main reasons: FPGAs offer great flexibility, and they allow the easy adaptation and integration of functionality whenever needed.

Implementation of PROFINET IRT

Softing decided to implement PROFINET IRT in three development steps. This approach was chosen to provide interoperability with other products in the market, thereby ensuring support for the functionality of future Siemens controllers and devices, which play a major role in the PROFINET environment.

The first step was to implement the basic functionality of PROFINET IRT, including time synchronization based on the Precision Time Control Protocols (PTCP) and the fast forwarding of frames based on the address information. With the implementation of Step 1, minimum cycle times of up to 250µs can be achieved.
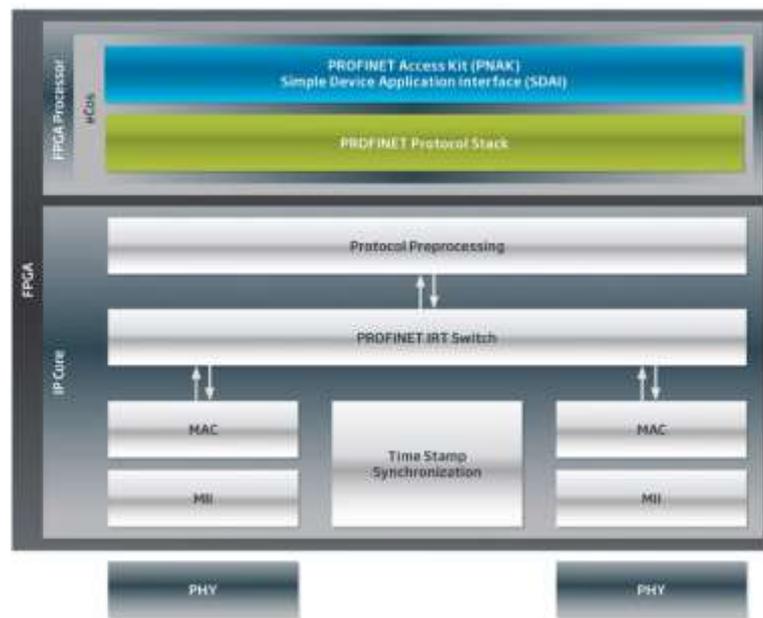

Figure 2: Structure of the FPGA-based PROFINET IRT implementation.

An essential part of the first development step is the implementation of the PROFINET IRT IP Core with the appropriate Function Blocks (see Figure 2). In addition to the two Media Access Control (MAC) components, the unit comprises the time synchronization, the (IRT) switch and part of the protocol pre-processing. The IP Core has a modular structure and can support a maximum of five ports, including up to two ports with IRT functionality. The use of the physical interfaces (PHY) from Renesas (µPD606xx) and National (DP83640) has also been implemented.

The remaining protocol functionality is executed in software on the assigned FPGA processor using the royalty-free eCos operating system. A software interface is provided for the application, which can

either run on an additional processor in the FPGA or on an external processor. The user can choose between the special PROFINET Access Kit (PNAK) interface or the Simple Device Application Interface (SDAI). The use of the SDAI interface is recommended because it also supports additional Industrial Ethernet protocols and provides access to important functionality.

Table 1 shows the memory sizes used in Softing's PROFINET IRT implementation. Using the data memory size given, up to four application relations can be supported. The comprehensive support of the Management Information Base (MIB) allows excellent diagnosability, as background information is available for troubleshooting.

Switch IP Core	Logic Elements	15,000
	M9K Blocks	48
Firmware (Stack, eCos Operating System)	Code	500KB
	Data	2.6MB
	RAM	3.2MB
	Flash	570KB

Table 1: Memory sizes of the FPGA-based PROFINET IRT implementation.

As part of the PROFINET IRT implementation, Softing performed extensive conformity and interoperability tests with available PROFINET RT and PROFINET IRT devices. The resulting solution is thus tried-and-tested, functional, and ensures seamless interoperability with other devices. The suitability for use in real-world environments is proven in field tests conducted at various customer locations.

In the next development step (Step 2), the Dynamic Frame Packing function will been added. Using this feature, cycle times of 32µs can be achieved. As a parallel transmission of standard Ethernet frames is not possible with these short cycle times, the disassembly and reassembly of packets will also be implemented in this phase. The second

development step will be completed by this year's SPS/IPC/DRIVES trade show, which will take place in Nuremberg in November.

The media redundancy functionality will then be implemented by the end of Q1/2014.

Wide range of applications

To exchange data with applications on an additional processor within the FPGA or on an external processor, Softing's PROFINET IRT solution utilizes Dual Port RAM. It is also possible to run an application on the same processor that is used for the communication. This approach, for example, allows the exchange of data with an external processor that does not support Dual Port RAM. A Serial Protocol Interface (SPI) is employed in this case.

The new FPGA families from Altera and Xilinx featuring two ARM processors will also be supported by Softing's PROFINET IRT solution. The easiest option here is to use the freely programmable part of the respective FPGA for the PROFINET IRT implementation and to run the application on an ARM processor. Another possibility would be to execute the PROFINET IRT stack on the second ARM processor.

Demo packages available

There are various demonstration packages to suit different development boards. The following are available:

- Evaluation Kit for RTE Device Stacks from Softing

- Industrial Networking Kit from Altera with Cyclone IV FPGA

- Industrial Ethernet Kit from Xilinx with Spartan 6 FPGA

Each demonstration package includes a full-featured version of the IP Core and PROFINET stack, which are ready-to-use out of the box. This

way, anyone interested in Softing's solution can quickly and easily
evaluate its functionality, performance and interoperability capabilities.

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