WHITE PAPER

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TEXAS INSTRUMENTS

PROFIBUS® on AM335x and AM1810 Sitara™ ARM® Microprocessors

Executive summary

PROFIBUS, one of the most used communication technologys, is installed in more than 35 million industrial nodes worldwide and is growing at a rate of approximately 10 percent each year.

Texas Instruments, Inc. (TI) first offered integrated PROFIBUS slave functionality in the Sitara AM1810 ARM9™ microprocessor. This is now enhanced to include PROFIBUS master, as well and an entirely new generation of Sitara AM335x ARM Cortex™-A8 microprocessors with integrated PROFIBUS master and slave. The PROFIBUS slave is also being released with low footprint software solution to enable further cost and system design optimizations. In both AM1810 and AM335x MPUs, the PROFIBUS Link Layer is implemented by the integrated programmable real-time unit (PRU) subsystem that makes a dedicated PROFIBUS ASIC or FPGA unnecessary. The benefits of this integration not only include lower cost but also smaller size, reduced complexity and lower power.

All software and hardware components and tools required to develop PROFIBUS applications are available from TI. With industrial-grade packaging and long-term supply, these devices are a compelling choice for PROFIBUS and other industrial communications applications. In addition, TI's PROFIBUS solution is certified for PROFIBUS compliance.

Introduction to PROFIBUS

Overview

PROFIBUS (Process Field Bus) is a standard for automation technology. It was first developed in 1989 in Germany, and today, there are over 35 million PROFIBUS nodes installed. The PROFIBUS industrial field bus is used to connect controllers to remote input/output units, sensors, actuators and inter-networking components. The applications where PROFIBUS is deployed include factory automation, drives and motion control, process automation and safety-critical applications (see Figure 1 below).

Technology

PROFIBUS increases communication efficiency in a factory by connecting a number of nodes over a single connection. This single connection not only eliminates the need for dedicated wiring for each node, it also allows reduced complexity, reduced investment and easier deployments. PROFIBUS communication technology has multiple protocols – PROFIBUS DP and PROFIBUS® PA – that are used depending upon the application requirements. PROFIBUS protocol also defines the role of master and slave nodes to manage the communication among the PROFIBUS nodes.

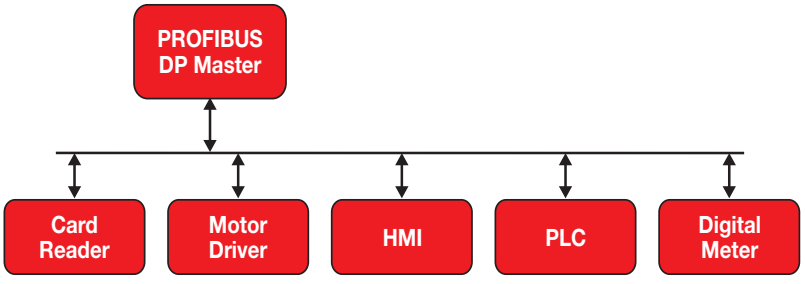

Figure 1. PROFIBUS in industrial automation

PROFIBUS Decentralized Periphery (DP)

PROFIBUS DP is the most popular PROFIBUS protocol. This protocol has three versions within the application layer – DP-V0, DP-V1 and DP-V2. DP-V0 provides cyclic data exchange and diagnostic messages. DP-V1 adds acyclic data exchange and alarm handling. DP-V2 is isochronous mode and data exchange broadcast like slave-to-slave communication.

PROFIBUS Process Automation (PA)

PROFIBUS PA is used in hazardous environments. Both data and power are transmitted on the same link, and a reduced power level is used to minimize the risk of explosion. PA has a fixed transmission rate at 31.25kBaud. Usually, the PROFIBUS DP-to-PROFIBUS PA coupler is used to create PROFIBUS network segments in a larger factory network. These couplers are also used to supply power to meet safety requirements.

PROFIBUS can be customized for end application needs by using application profiles. For some of the common applications, the PROFIBUS organization has standardized the application profiles. The PROFIsafe and PROFIdrive are two such profiles that are used in safety or in motor drives applications.

Components of a PROFIBUS node

Each PROFIBUS node has three components – the electrical layer, the data link layer and an application layer. The electrical layer is implemented using RS-485, fiber-optic or Manchester Bus Power (MBP) media. The data link layer is called Fieldbus Data Link (FDL) and it implements master-slave communication. The application layer is one of DP-V0, DP-V1 and DP-V2, etc. and it supports messaging between the PROFIBUS nodes. These messages can involve data exchange, diagnosis, alarms and such. For DP-V0 and DP-V1 the PROFIBUS master is allowed to start a transmission, while the slave is only allowed to respond to a message that matches with its slave address. A maximum of 126 devices (masters and slaves) with unique addresses are permitted in a single system.

Compliance

To ensure wide interoperability among devices designed with PROFIBUS interfaces, the PROFIBUS organization has a certification program which ensures that a device is in compliance with the rules and specifications of the protocols. Each new device or already-certified device but with hardware or software change needs to pass certification to claim PROFIBUS compliance and use the official PROFIBUS logo. Certification is done by authorized certification labs that follow the test procedures defined by PNO/PI. The PNO/PI website provides a list of certification labs.

Typical PROFIBUS® solution

A typical solution in use today has architecture similar to Figure 2 below.

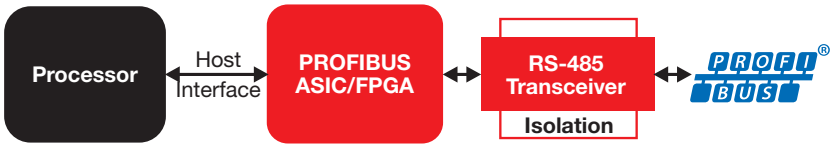

Figure 2. Typical PROFIBUS implementation

In such solutions, a microprocessor runs the PROFIBUS application level stack and implements the industrial application, a separate ASIC or FPGA implements the PROFIBUS protocol and an RS-485 transceiver provides the connection to the physical layer. The PROFIBUS device connects to the microprocessor over a parallel or a serial interface. At the physical layer, an RS-485 transceiver with galvanic isolation is used.

PROFIBUS solution from Texas Instruments

Texas Instruments Inc. (TI) has integrated PROFIBUS functionality into the Sitara™ AM1810 ARM9™ and AM335x ARM® Cortex™-A8 generations of microprocessors. These devices connect directly to the RS-485 transceiver and do not require an external PROFIBUS ASIC or FPGA.

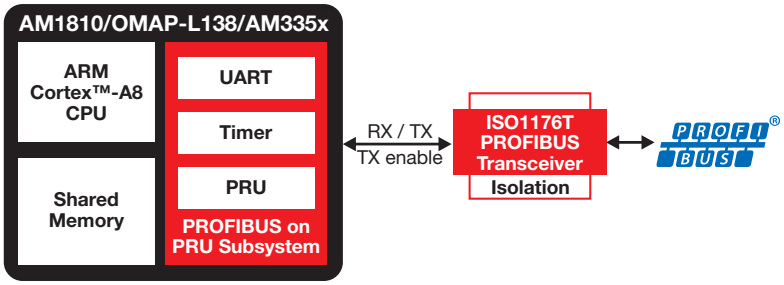

Figure 3. PROFIBUS solution from Texas Instruments

The PROFIBUS real-time frame handler (Fieldbus Data Link or FDL) is encapsulated in the programmable real-time unit (PRU) subsystem integrated on PROFIBUS-capable devices. In the Sitara AM1810 ARM9 microprocessor (MPU), the first generation of PRU subsystem was integrated while Sitara AM335x ARM Cortex-A8 MPUs integrate the second generation of PRU subsystem, which is capable of supporting industrial Ethernet standards in addition to PROFIBUS.

In each variant of the PRU subsystem, the PRUs implement real-time PROFIBUS message transmission, frame validation and communication with the ARM processor. Interrupts are used to communicate with the ARM where the PROFIBUS stack (Layer 7, DP-Protocol) and the industrial application are run. All process data handling like cyclic, acyclic and service access point (SAP) between the PROFIBUS stack on ARM and the PRU is through the internal memory. One of the PRUs controls the integrated on-chip universal asynchronous receiver/transmitter (UART) that is designated for PROFIBUS communication at up to 12Mbaud data rate. The industrial application and the PROFIBUS DP-Protocol (Layer 7) are operated on the ARM. The solution can be completed with an RS-485 transceiver suitable for harsh environments, such as TI's ISO1176T PROFIBUS transceiver.

Sitara™ AM335x ARM® MPU block diagram

The Sitara AM335x ARM MPUs are ultra-low-power devices based on the ARM Cortex™-A8 RISC core with a broad range of peripherals integrated on the device. For industrial applications, it supports two operating frequency ranges, up to 275 MHz for simple applications, such as industrial I/O devices, and up to 720 MHz for complex applications such as industrial controllers. PROFIBUS® functionality is supported in each speed grade.

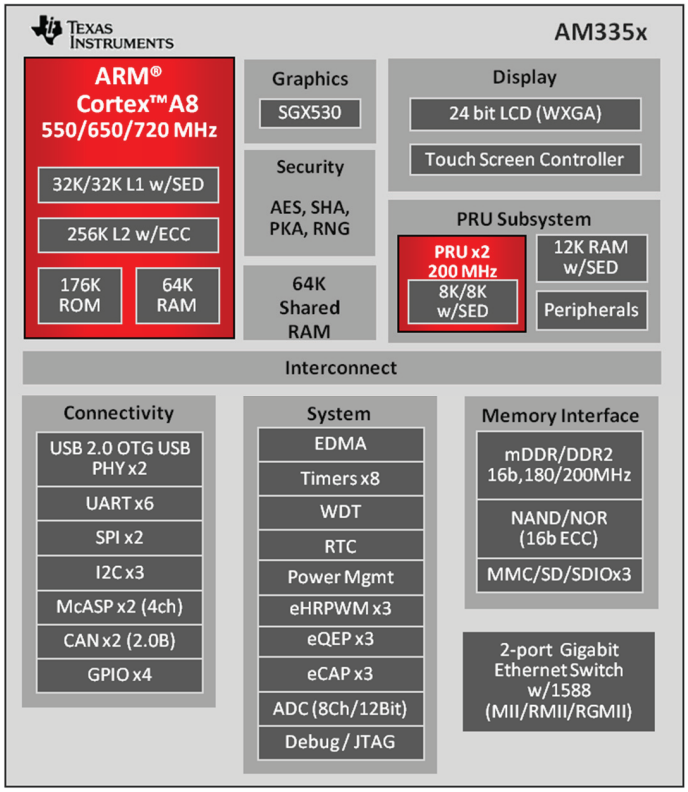

Figure 4. Sitara AM335x ARM Cortex-A8 MPU block diagram

Additional details about the Sitara AM335x ARM MPU, on-chip peripherals and their features are available in the data sheet at TI website.

Sitara AM1810 ARM9™ block diagram

The Sitara AM1810 ARM MPU is a low-power microprocessor based on the ARM926EJ-S™ RISC core with operating frequency of up to 375 MHz. This device integrates the PRU subsystem with PROFIBUS master or slave functionality and does not require any additional PROFIBUS ASIC/FPGA. As a result, AM1810-based PROFIBUS solutions significantly lower the cost of the end equipment. See Figure 5 on the following page.

Additional details about the Sitara AM1810 ARM MPU, on-chip peripherals and their features are available in the data sheet at TI website.

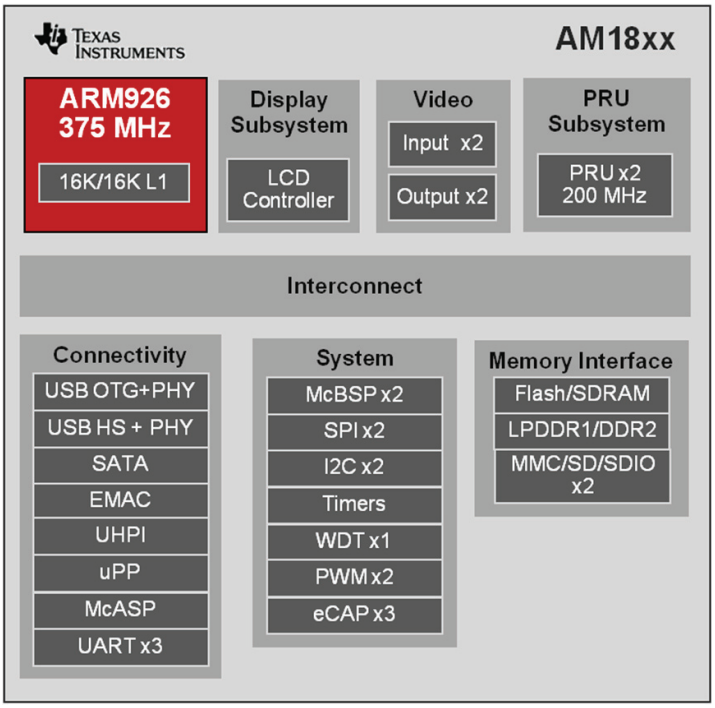

Figure 5. Sitara™ AM1810 ARM® MPU block diagram

PROFIBUS® software architecture

There are three software components in the PROFIBUS solution on TI devices. The first is the micro code that implements FDL functionality in the PRU, the second is the PROFIBUS-DP protocol that runs on the ARM MPU and third is an industrial application that is dependent on the end equipment in which this solution is used.

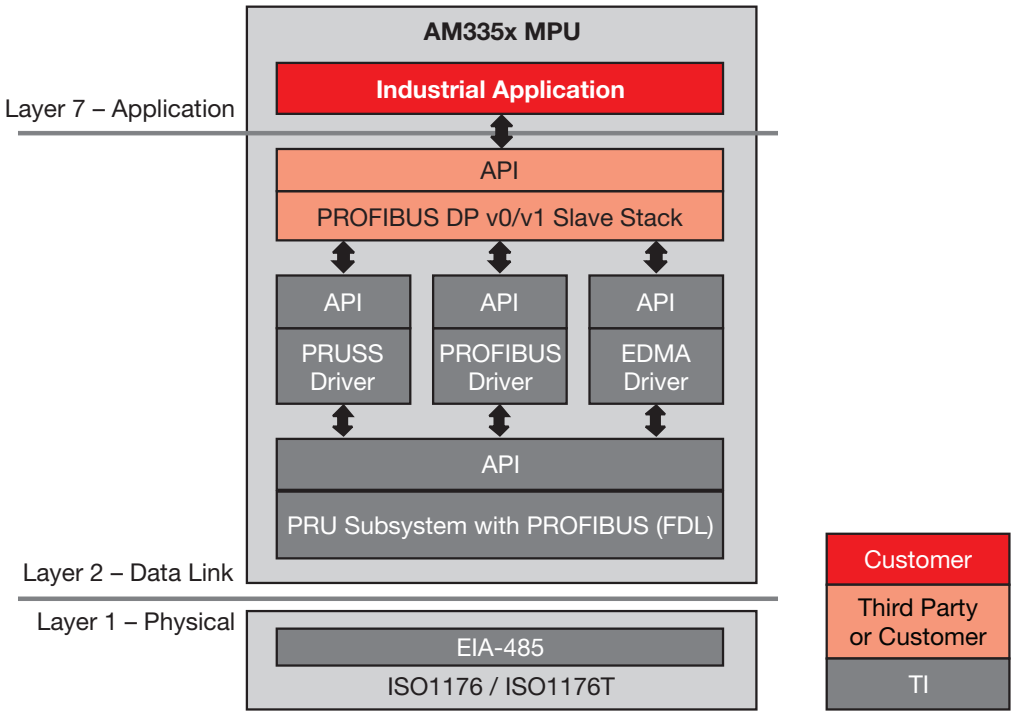

Figure 6. Software architecture for PROFIBUS-DP

The PROFIBUS® solutions from TI support both high-level operating systems (OS) such as Linux™ as well as applications with no operating system. In either architecture, the software structure is consistent.

Note that this PROFIBUS solution is agnostic to the OS and the PROFIBUS DP stack and increases flexibility in choosing the OS and PROFIBUS-DP protocol stack.

Key PROFIBUS parameters

The key parameters for the PROFIBUS solutions are tabulated below.

PROFIBUS slave

Feature	AM1810 ARM9 MPU/OMAP-L138 ARM9™ + DSP processor	AM335x ARM Cortex-A8 MPU
ARM frequency	Up to 375 MHz	1. Up to 275 MHz 2. Up to 720 MHz
Data rates (baud)	12M, 6M, 3M, 1.5M, 500k, 187.5k, 93.75k, 45.45k 19.2k, 9.6k	
Telegram size	Up to 244 bytes	
DPv0 support	Cyclic exchange of data and diagnosis	
DPv1 support	Acyclic/cyclic data exchange and alarm handling	
DPv2 support	Available upon request. Please contact TI for additional information.	
Response time	11-bit minimum TSDR response time	
Watchdog	10ms time base	
Operating system	1. Linux 2. No operating system	1. Linux 2. No operating system 3. SYS/BIOS™ real-time kernel

PROFIBUS master

Feature	AM1810 ARM9 MPU/OMAP-L138 ARM9 + DSP processor	AM335x ARM Cortex-A8 MPU
ARM frequency	Up to 375 MHz	1. Up to 275 MHz 2. Up to 720 MHz
Data rates (baud)	12M, 6M, 3M, 1.5M, 500k, 187.5k, 93.75k, 45.45k 19.2k, 9.6k	
Telegram size	Up to 244 bytes	
Modes of operation	Class 1 and Class 2	
Multi-master mode	Supported	
DPv0 support	Cyclic exchange of data and diagnosis	
DPv1 support	Acyclic/cyclic data exchange and alarm handling	
DPv2 support	Available upon request. Please contact TI for additional information.	
Operating system	Linux	

Easy PROFIBUS integration

TI has made the process of integrating PROFIBUS straightforward and simple. All the tools and software code required to integrate PROFIBUS is available as part of the software development kits (SDKs) for supported devices

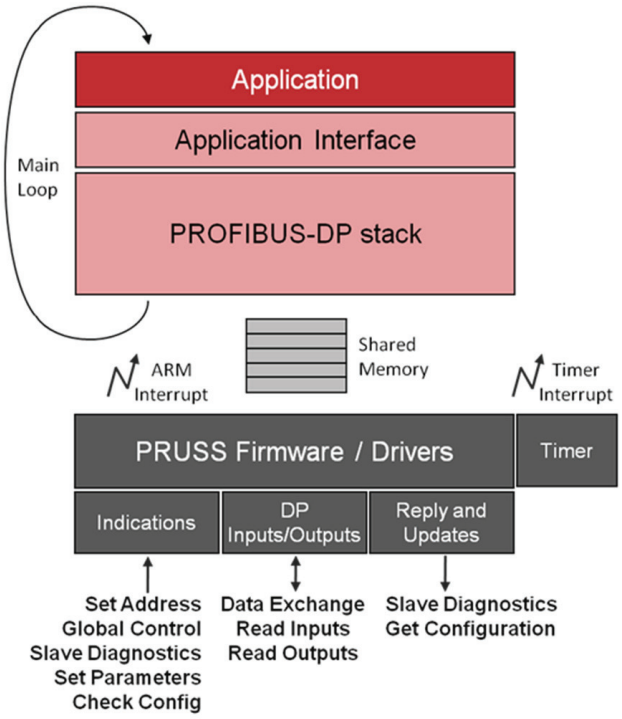

Figure 7. PROFIBUS® software integration

For a typical use case, the PROFIBUS firmware, the stack, the drivers and the high-level operating system (if needed) are all reused from the respective software development kit. There is usually only one file to be modified by the user.

Power consumption

The PROFIBUS slave implementation benefits from the low-power architecture of TI's ARM MPU platform, which eliminates the need for fan or heat sink. For a typical use case, TI devices with PROFIBUS consume less than 1mW per MHz of ARM CPU speed.

Device	ARM frequency	Active power consumption (approx.)
AM1810	375 MHz	330 mW
AM335x	275 MHz	300 mW
AM335x	720 MHz	650 mW

Integrating PROFIBUS solution on end products

The PROFIBUS solution can be integrated into industrial applications in need for PROFIBUS master or slave interface. For slave devices, customers can directly use TI's PROFIBUS implementation and complete their design process using the evaluation copy of the PROFIBUS slave stack that is provided by TI. The slave stack is owned by TMG and it can be licensed by customers for a one-time licensing fee. If so desired, customers can also use a slave stack from a different vendor or develop their own. Once the development is complete,

the customer can take their product to the PROFIBUS® test labs for certification. For certification for PROFIBUS master, please visit **www.ti.com/e2e_sitara** for further information.

Devices for PROFIBUS implementation

TI provides the applications processor for PROFIBUS implementation, as well as analog signal chain and power management products for interface to the physical layer. A brief description of these products is provided in the table below. These products are available in industrial grade temperature range and have long term availability.

Product	Description
AM335x	ARM® Cortex™-A8 32-bit microprocessor available in two speed grades Integrated PROFIBUS and multiple industrial Ethernet standards
AM1810	ARM9 32-bit microprocessor Integrated PROFIBUS Fieldbus Data Link Layer
OMAP-L138	ARM9 32-bit microprocessor with TI C674x floating-point DSP Integrated PROFIBUS Fieldbus Data Link Layer
ISO1176T	Isolated differential line transceiver with integrated oscillator outputs that provide the input signal required by an isolation transformer

Development tools for PROFIBUS implementation

TI provides AM1810 and AM335x Evaluation Modules (EVMs) with comprehensive design data to assist customers with their implementation. All design data for these EVMs such as schematics and layout is available for accelerating development of customer designs. In addition, TI also collaborates with external vendors for an additional development platform targeted for industrial applications.

Development platform	Supported PROFIBUS modes
AM3359 Industrial Development Kit (IDK)	PROFIBUS slave/master
AM3359 Industrial Communications Engine (ICE)	PROFIBUS slave/master
AM1810 EVM	PROFIBUS slave/master
MityARM AM1810	PROFIBUS slave

AM3359 Industrial Development Kit

The AM3359 Industrial Development Kit (IDK) is designed for industrial applications such as industrial communication input/output (I/O) devices, programmable logic controllers (PLCs) and motor control. The software supplied with the IDK includes TI's SYS/BIOS™ real-time kernel, PROFIBUS firmware for PRU and an evaluation version of PROFIBUS application level stack. See Figure 8 on the following page.

The board includes a PROFIBUS transceiver, PROFIBUS connector, debug hardware, SD/MMC, Ethernet, UART and more. For motor-control applications, the IDK includes multiple pulse width modulation (PWM)

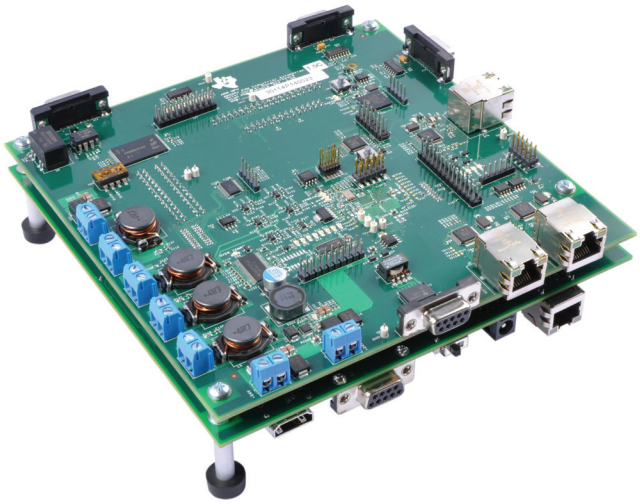

Figure 8. AM3359 Industrial Development Kit (IDK)

drivers and motor feedback hardware, such as analog-to-digital converters (ADCs). The IDK supports development of practically all types of industrial equipment that incorporate PROFIBUS®.

Detailed hardware and software information is available at **www.ti.com/tool/tmdxidk3359**.

AM3359 Industrial Communications Engine

The AM3359 Industrial Communications Engine (ICE) is a cost and form-factor optimized platform for industrial communication applications such as communication modules, I/O devices, sensors and more where the key is simple design and minimum cost. Only those peripherals essential for communication standards such as PROFIBUS are retained, and the included software is designed to keep the memory footprint small enough to ensure small capacity flash devices can be used for code storage. The SDK includes a SYS/BIOS™-based real-time kernel with application level communication stack and device drivers. The development and debug tools are also included with this platform. Details on hardware, software and pricing are available at **www.ti.com/tool/tmdxice3359**.

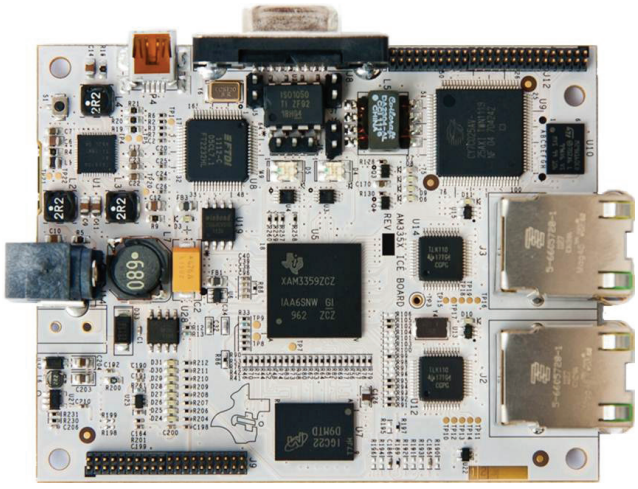

Figure 9. AM3359 Industrial Communications Engine (ICE)

AM1810 ARM MPU EVM

The AM1810 EVM is the primary platform for developing PROFIBUS®-based applications on the Sitara™ AM1810 ARM9™ MPU. It includes real-time enabled distribution of Linux™ and device driver packages developed by TI. The software development kit provided with the EVM includes a working copy of the PROFIBUS slave implementation.

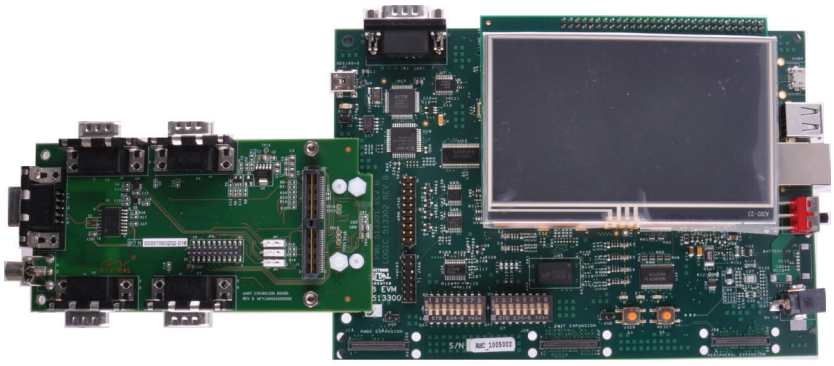

Figure 10. TI Sitara AM1810 EVM

The board has a built-in Ethernet, RS-232, SD card, USB, audio outputs, power management and LCD panel with touch-screen. Not all peripherals available on the EVM are necessary for PROFIBUS application, but the EVM allows for development of systems ranging from simple I/O modules and sensors to complex systems such as PLCs with human machine interfaces (HMIs) and PROFIBUS interface.

Critical Link's MityARM AM1810 Module with Industrial Applications Board

Critical Link has developed an industrial applications board with SODIMM slot for various CPU modules. The board accepts both OMAP-L138 DSP+ARM processor and AM1810 ARM MPU and enables industrial protocols over the RS-485, controller area network (CAN) and 10/100 Ethernet interfaces. The PROFIBUS

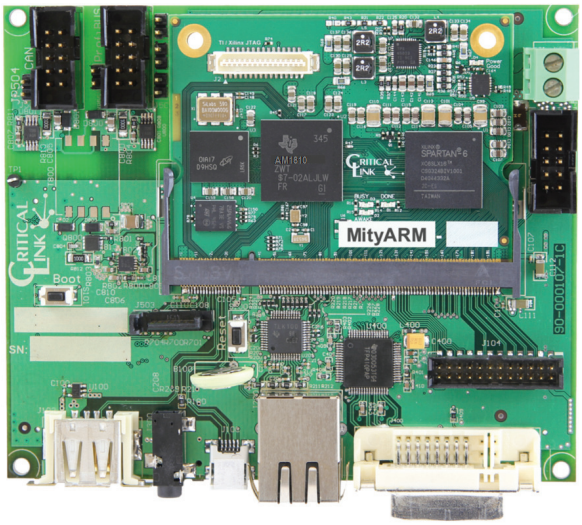

Figure 11. Critical Link industrial IO board with AM1810 Sitara ARM MPU SOM

slave implementation from TI is supported on this platform. Other industrial protocols such as PROFINET®, CANopen and EtherCAT® Master can also be implemented. The board features isolated power supplies, connectors for display and touch-screen, SATA, SD card, Ethernet, RS-232, USB and audio output ports on an ETX form-factor board. If required, a wireless LAN interface can also be integrated to the board. See Figure 11 on the previous page.

The CPU module is available with or without an FPGA on it. For applications that require custom logic, the on-board FPGA can be used. The board is available directly from Critical Link and supports the Linux® operating system and application development.

Summary

TI offers integrated PROFIBUS® master and slave solutions on Sitara™ AM1810 ARM9 and AM335x ARM® Cortex™-A8 devices targeted for industrial I/O devices, sensors, PLCs and HMIs. The integration of PROFIBUS with powerful yet low-power ARM cores results in lower cost end products without compromising the functional or operational requirements. TI also offers the ISO1176T PROFIBUS transceiver with built-in isolation. With comprehensive software and hardware development tools and worldwide support, customers can look forward to greatly simplified PROFIBUS integration with an added benefit of significant cost savings.

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DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
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