Technical White Paper
Industrial Communication Protocols on AM261x and AM263Px

TEXAS INSTRUMENTS

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ABSTRACT

As industrial plants, products, and systems are becoming increasingly networked, the rapid adoption of multi-protocol Industrial Ethernet is shaping the industrial market in this new era of high-speed networking. Over a dozen communication protocols are available for industrial Ethernet and field bus, each with specific advantages and disadvantages for different industrial applications. These protocols are optimized to provide reliable operation in industrial field environments by enabling real-time data collection and the exchange of process data. This document overviews the Industrial Ethernet and Industrial IO communication protocol offering on TI's AM26x series of Arm®-based microcontrollers (MCUs). AM26x supports a wide variety of protocols. This document covers the following:

- EtherCAT®
- PROFINET®
- EtherNet/IP®
- IO-Link Master

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Trademarks

Arm® is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.
EtherCAT® is a registered trademark of Beckhoff Automation GmbH, Germany.
PROFINET® is a registered trademark of PROFIBUS Nutzerorganisation e.V. (PNO).

EtherNet/IP® is a registered trademark of ODVA, INC.
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1 Introduction

The AM26x microcontroller family comes packaged with a fully integrated networking solution and industry-leading control peripherals. This positions AM26x MCUs as an excellent solutions for Industry 4.0 enablers like Remote IO, micro PLCs, Industrial Gateways for sensors, and Industrial switches.

The AM26x System-on-Chip (SoC) family provides solutions for both industrial Ethernet connectivity and IO-Link connectivity using a real-time subsystem called the PRU-ICSSG. PRU-ICSS stands for Programmable Real-time Unit and Industrial Communication Subsystem. PRU-ICSS is a low-latency microcontroller subsystem that is included in many Texas Instruments processors and is efficient for low-latency and I/O control. It enables industrial communication protocols with 100Mbps speed. The deterministic IO is used for the IO-Link master solution with up to 8 channels simultaneously.

TI provides the industrial software kit, which consists of field bus communication protocol software stacks through the industrial communication SDK. The SDK enables real-time industrial communications for TI processors. For more info, visit the Industrial Communication Page for AM261x and AM263Px .

2 PROFINET

PROFINET is an Industrial Protocol managed by the PROFIBUS and PROFINET International group (PI). It is an application-level protocol based on Ethernet, that is a successor of the PROFIBUS protocol. PROFINET is realized on AM26x microcontrollers using the PRU ICSS switch. PROFINET supports different classes based on the cycle time requirement. Class A provides a cycle time down to 100ms. PROFINET-RT, referred to as Class B, supports a cycle time down to 1 ms. PROFINET-IRT, supported by Class C is known for isochronous real-time, supports cycle time down to 250us. TI AM26x series of microcontrollers supports all PROFINET classes. The Pre-certified PROFINET RT/IRT software solution and hardware from TI , enable faster time to production.

Figure 2-1. PROFINET on AM26x Devices

3 PROFINET Features

Feature	Details	Status/Implementation
Cycle Time	1ms(RT), 250μs(IRT)	Both RT and IRT Supported
PROFINET Specification Version	2.44	Yes
PROFINET GSDML Specification Version	2.44	Yes
Netload Class	I, II, III	Yes
PROFINET - Test Specification	2.45	Yes
Fast Start Up(FSU)	Time required to startup with prioritized start up option	460ms
PROFINET-RT (CC-A/CC-B)	Real time Cyclic/acyclic protocol	Yes
	LLDP Protocol	Yes
	PDEV records	Yes
	Extended I&M records	I&M 1,2,3,4
	SNMP and Time stamping	Yes
	MRP and system redundancy	Yes
PROFINET-IRT (CC-C)	Bandwidth reservation	250μs , 500μs and higher
	Isochronous operation	Yes

Note

Supported Functionality grouped per Conformance Class, as per: Profinet-io-conformance-classes. A detailed feature support list can be found here.
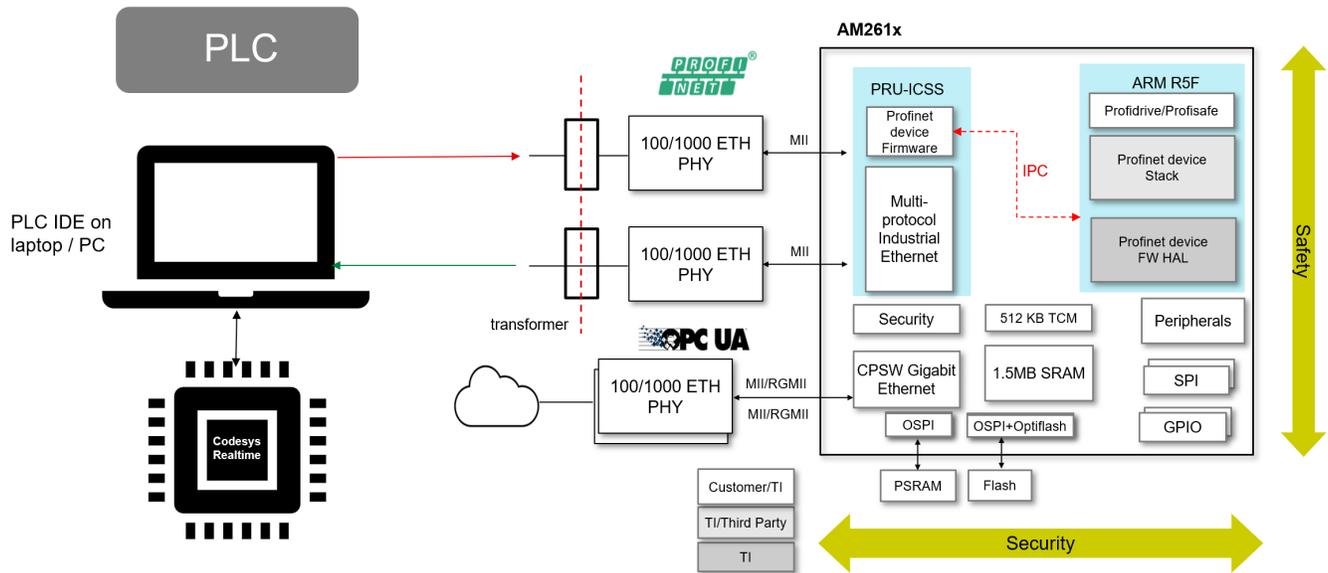

Figure 3-1. Profinet Solution Using AM261x

Table 3-1. PROFINET Application Profiles

Application Profiles	Implementation Status	Details
PROFIdrive	Supported via third party partner	PROFIdrive is a vendor-neutral application profile that is focused on drives, encoders, motors, and their applications, which range from simple to very demanding motion control tasks.
PROFIsafe	Supported via third party partner	PROFIsafe is an additional software layer that provides functional safety over the bus in PROFINET (or PROFIBUS) networks. PROFIsafe takes care of the functional safety portion of communications.
PROFINET Security	TBD	PROFINET Security enables integrity, authenticity confidentiality of messages along with authorization, with different security classes.

4 Ethernet/IP

EtherNet/IP™ is an Industrial Ethernet protocol supported by the Open Device Net Vendors Association (ODVA) standards organization and closely follows the Open Systems Interconnection (OSI) model. It is based on Ethernet standards and uses standard Ethernet physical, data link, network, and transport layers. It utilizes the Common Industrial Protocol (CIP™) for its upper layers, which provides the framework for implementing all layers of the OSI model. CIP defines a complete suite of network functionality from the physical implementation through the application or user interface layer.

Tools & Resources: Ethernet/IP on AM26 Devices

- Enabled on the AM263Px/AM261x LaunchPad
- **Target Applications**
  - Factory Automation & Control
  - Electric grid
  - Process Manufacturing Plants
  - Airports
  - Distribution Centers
- Supported by 3P Ecosystem Solutions

Figure 4-1. Ethernet/IP on AM26x Devices

Table 4-1. Ethernet/IP Features

Feature	Description	Status/Implementation
Speed and Duplexity	10/100M Half/Full/Autoneg	Yes
Conformance	ODVA Conformance test tool	ODVA CT20(latest)
Process Data Image	max. I/O assembly (size)	1480 Bytes
Supported Network FeaturesBridge Delay	Link Layer Discovery Protocol (LLDP)	All supported
	Device Level Ring (DLR)	
	Address Conflict Detection (ACD)	
	Quality of Service (QoS)	
	CIP Reset Services	

Table 4-1. Ethernet/IP Features (continued)

Feature	Description	Status/Implementation
Device Level Ring (DLR)	Beacon based/Self configuring	Both supported
	Beacon timeout / Beacon interval	400us / 200us
CIP Sync (PTP/IEEE 1588)	Supports Drives Profile : E2E clock	271KB
	Transparent/Ordinary Clock	Both supported
	Single and Two Step Clock supported	Both supported
	PTP over UDP	Yes
IP Addressing Modes	DHCP/BOOTP/Static	All supported

Note

A Detailed feature support list for EtherNET/IP can be found here.

5 Ethernet/IP Application Profiles

Table 5-1. Ethernet/IP Application Profiles

| Application Profiles	Implementation Status	Details
CIP Sync	Supported	Encapsulates the IEEE-1588 services which measure network transmission latencies and correct for infrastructure delays
CIP Motion	Supported via third party partner	Extension to EtherNet/IP that allows integration of field devices and motion drives on the same network.
CIP Safety	Supported via third party partner HMS Safety Target EIP	CIP safety protocol provides fail-safe communication between nodes and safety PLCs in safety applications up to Safety Integrity Level (SIL) 3 according to IEC 61508 standards
CIP Security	Supported via third party partner HMS	CIP Security enables securely transmitting data at a protocol layer, facilitating secure communication between I/O devices on the production floors with the goal to create a safe and secure transport of information over EtherNet/IP networks.
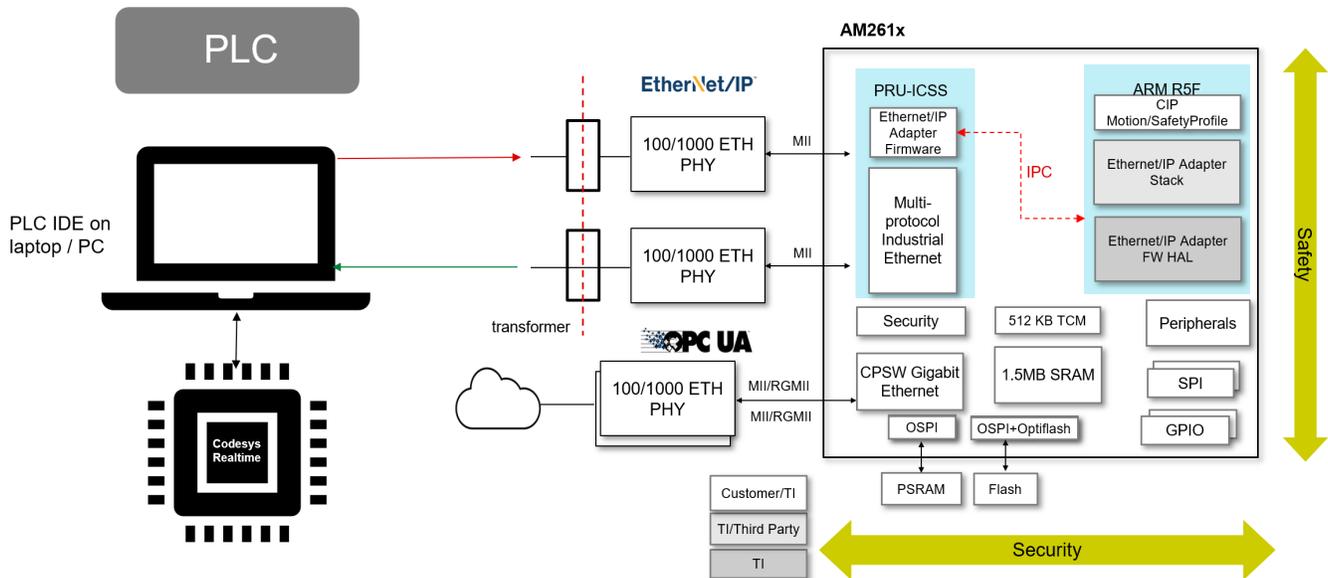
Figure 5-1. Ethernet/IP Solution Using AM261x

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6 IO-Link

IO-Link is an open standard protocol addressing the need for intelligent control of small devices such as sensors and actuators, allowing a seamless data flow from the sensor to the control level. This standard provides low-speed point-to-point serial communication between a device and a master that normally serves as a gateway to a field bus and PLC. The intelligent link established enables ease of communication for process data exchange, configuration, and diagnostics. Data rates range up to 230,4kbps with a minimum cycle time of 400µs. An IO-Link port can be used with all the benefits of IO-Link or an alternative in Fallback Mode as Digital I/O. The capabilities of a device are described in the IO Device Description (IODD). There is the possibility to exchange cyclic process-data, device parameters, and diagnostic data. The many advantages of an IO-Link system include standardized wiring, increased data availability, remote monitoring and configuration, simple replacement of devices, and advanced diagnostics.
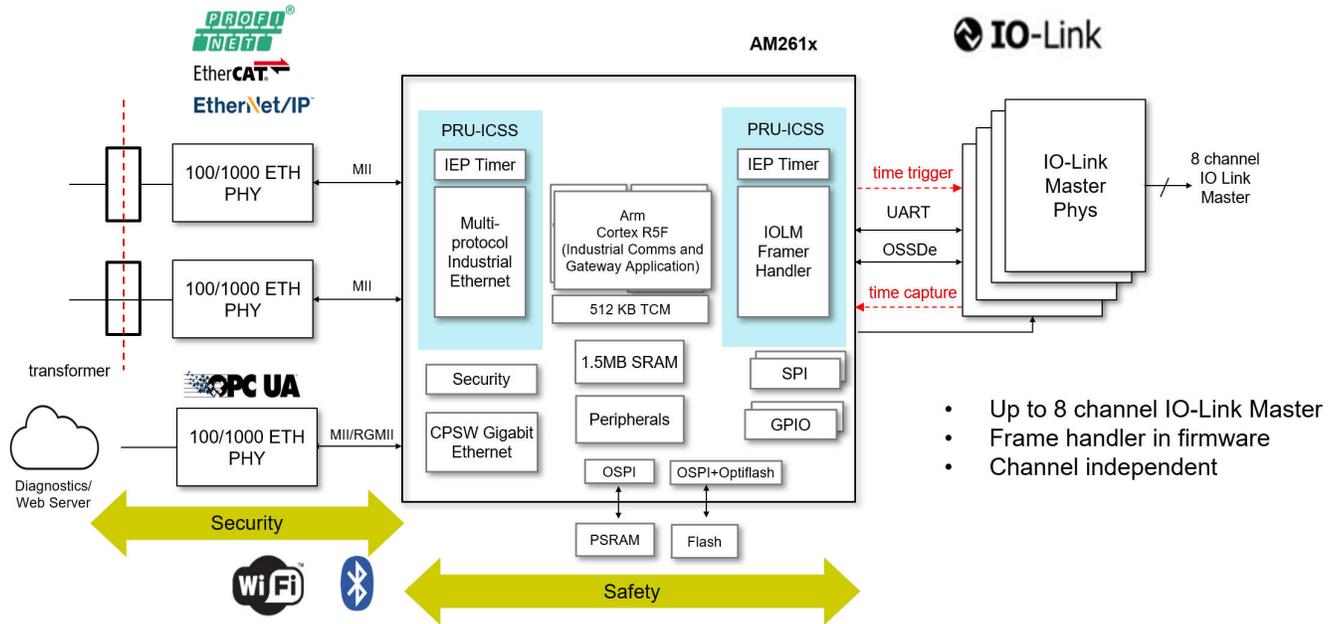

Figure 6-1. IO-LINK Solution Using AM261x

Table 6-1. IO-Link Features

Feature	Description	Status/Implementation
IO-Link Type	PRU_ICSS based IO-Link Master	Supported
IO-Link Standards	IO-Link Specification IEC 61131-9	V1.1.2 (V1.0 backwards compatible) and V1.1.3
Communication Classes	Com ports and baud rate	Com1, Com 2, Com 3 (4.8, 38.4, 230.4 Kbit/s)
IO-Link Stack	Hardware interface (BSP, HW control)	All supported
	Message handler	
	Application layer (on-request data objects, process data objects)	
	Standard Master Interface via UART	
	Standard Master Interface via API	
PRU FW Features	No. of Channels	8
	Cycle time(8 Ports)	400µs
	Checksum calculation and verification	Both supported
	Time control and monitoring per port	Yes
Device Configuration	IO-Link Master Configuration Tool	Available

> **Note**
> A detailed feature support list for IO-Link Master can be found here.

7 EtherCAT

EtherCAT is an Industrial Ethernet protocol that offers real-time communication by using the concept of on-the-fly communication to ensure short cycle time and low jitter for accurate synchronization. In a network, the EtherCAT main device (formerly known as EtherCAT Master) sends a telegram, and each Sub Device (formerly known as EtherCAT Slave) reads the data addressed to it and, based on the commands, write. It supports the data in the frame when the frame is propagating downstream. EtherCAT subdevice processes frames on the fly and in hardware. Thus, frames are delayed only by hardware propagation delay, making network performance predictable. It supports the DC clock feature for synchronization with high accuracy. It supports connectivity to standard Ethernet networks by using special switch ports that allow the tunneling of TCP/IP packets using Ethernet over EtherCAT (EoE) protocol. It can support 65,535 devices in an EtherCAT segment.

Tools & Resources: EtherCAT on AM26 Devices

Ethernet for **C**ontrol **A**utomation **T**echnology
- Technology based on Ethernet
- Developed by Beckhoff Automation specifically for Industrial Applications
- Evaluate EtherCAT with an AM261x LaunchPad EVM
- Production-ready hardware and Software solutions to reduce production time
- **Target Applications:**
  - Factory Automation
  - Servo Drives

Figure 7-1. Protocols in an EtherCAT Network

Table 7-1. EtherCAT Features

Feature	Detail	Value
Fieldbus Memory Management Units (FMMU)	Convert logical addresses into physical addresses by means of internal address mapping	4
SYNC Manager	Ensure consistent and secure data exchange between EtherCAT master and local application of slave device	4
Process Data	Maximum Input	1024 Bytes
	Maximum Output	1024 Bytes
Cycle Time	Free run	31.25us
	DC mode	50us
Distributed Clocks	Accuracy	64-bit
	SYNC0	Generation single-shot and cyclic mode support
	SYNC1	SYNC1 cycle time multiple of SYNC0 cycle time

> **Note**
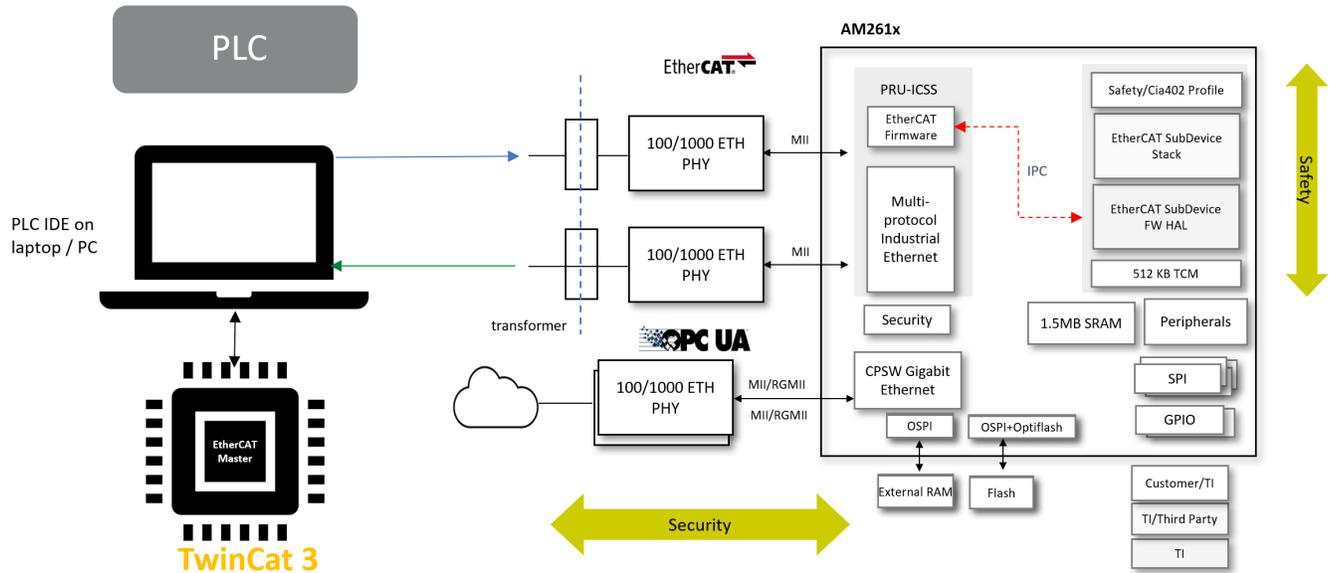> A detailed feature support list for EtherCAT Sub-device can be found here.

Figure 7-2. EtherCAT Solution

Table 7-2. EtherCAT Profiles

Application Profiles	Implementation Status	Details
Cia402 Profile	Supported	This profile is provided by TI via application in Industrial Communication SDK
FSoE	Supported via third party partner ISIT, Neuron-automation	FSoE protocol provides control and safety functions by differentiating between regular data and safety-critical data.
FoE/EoE/CoE	Supported	These profiles are provided by TI via application in Industrial Communication SDK