Seamless Connectivity Enable Industry 4.0

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Agenda

► **Key Market Trends**

► **Factory Connectivity Overview**

► **RS-485 & M-LVDS: Enhanced for the Smart Factory**

► **IO-Link: The Intelligent Edge**

► **Industrial Ethernet: Robust, High-Bandwidth, Time-Sensitive Data**

► **10BASE-T1L: Longer Reach and Intrinsic Safety**

► **Isolated USB: Robust Peripheral Interface**

► **Conclusion**

Industry 4.0

Industry 4.0 Delivers on Increased Productivity
See where ADI is accelerating the transition to the secure connected enterprise

Flexibility
The shift to more flexible architectures allows for greater capacity and faster reconfiguration. Using universal analog I/O (input/output) brings integration, robustness, flexibility, and efficiency with significant time and cost savings. All of which create opportunities for virtualization utilizing AI and digital twin technologies.

Efficiency
Even a 1% reduction in energy use can bring tremendous savings to a factory operator. These savings can be realized through the adoption of inherently lower power solutions that are then augmented by condition-based machine monitoring analytics.
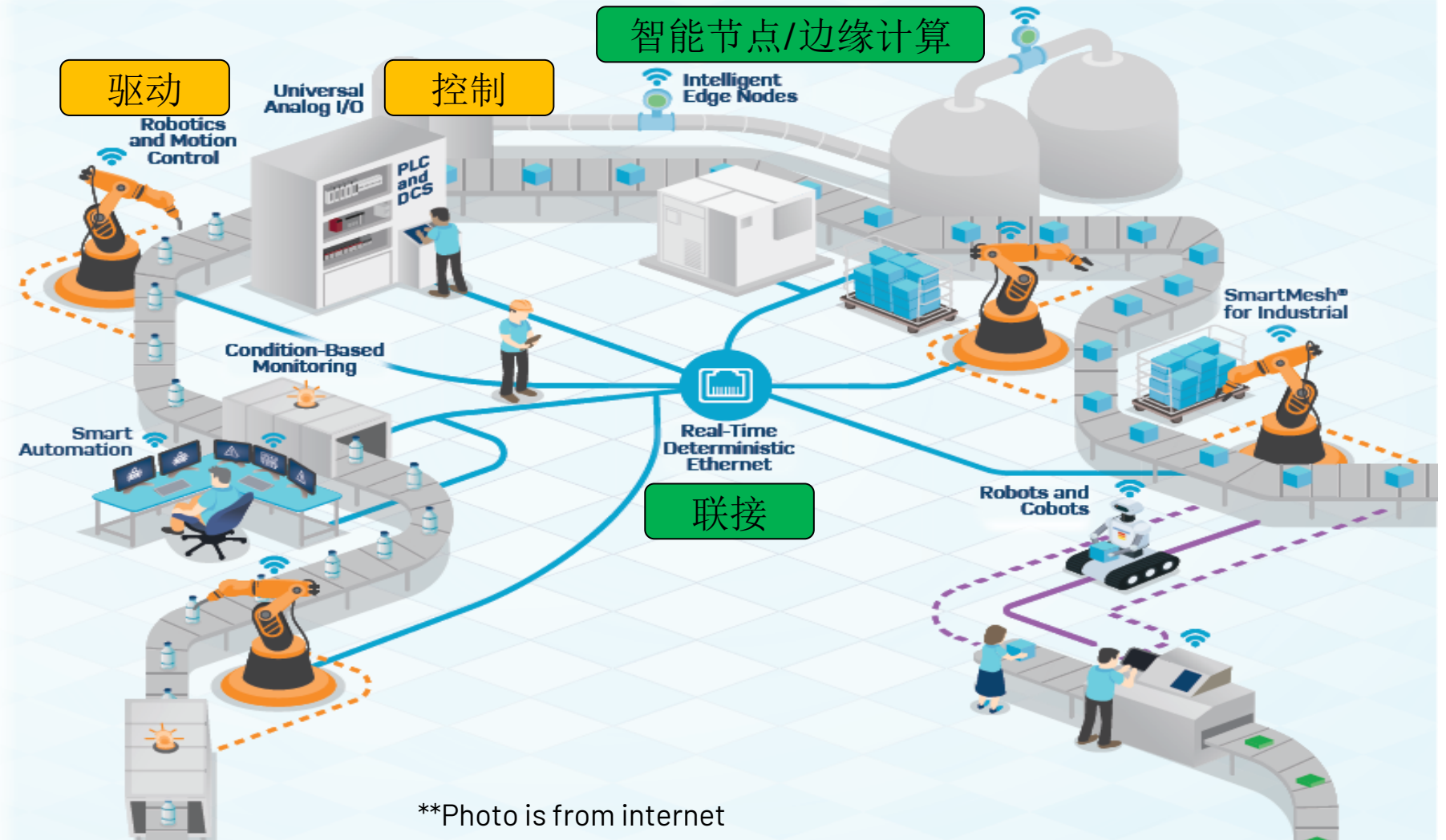
Communications
Central to the execution of Industry 4.0 is robust and secure wired and wireless communication that must support legacy standards and provide a clear path to Ethernet to the Edge and time sensitive networks (TSN).

Safety
A system is not smart if it is not safe. Functional safety is ubiquitous in automation systems with strict standardization and certifications requirements.
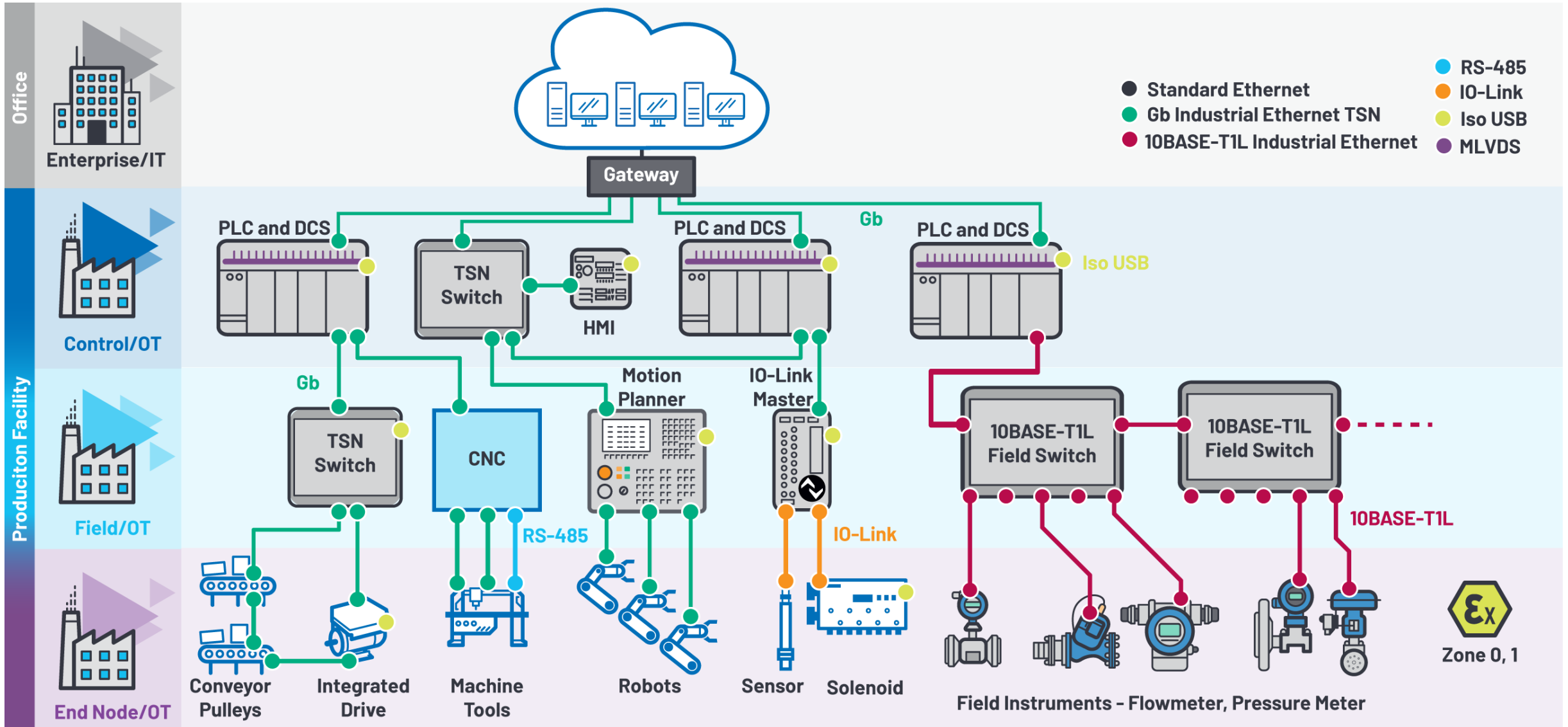
Security
Greater connectivity of smart machines with Industry 4.0 brings with it risks from cyber attacks. Factory operators and solution providers need to develop stronger cybersecurity strategies that are more vigilant and resilient to attack.

智能节点/边缘计算

驱动

控制

联接

Robotics and Motion Control

Universal Analog I/O

PLC and DCS

Intelligent Edge Nodes

Condition-Based Monitoring

Smart Automation

Real-Time Deterministic Ethernet

SmartMesh® for Industrial

Robots and Cobots

**Photo is from internet

Connected Factory

Tomorrow's Factory Connectivity Solutions

RS-485

Enhanced for the Smart Factory

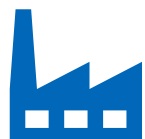# RS-485 in Industrial Connectivity
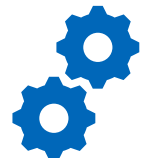
RS-485 (and RS-422) are flexible physical layer

| Application |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |

OSI Model

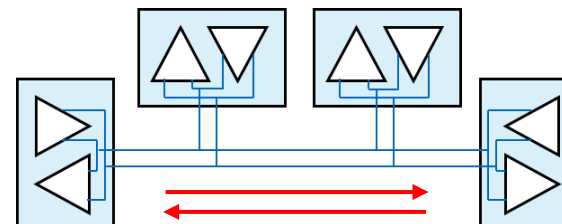**Applications**

Industrial Processing
PROFIBUS, Interbus

Motor Control
Hiperface DSL

Building Automation
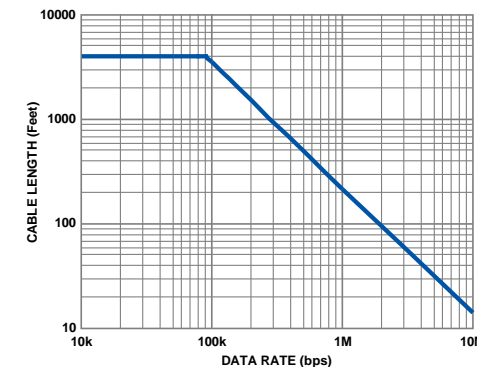Modbus RTU, BACNet

Multipoint

Reach (≥1km)

Robustness

ESD
EFT
Noise

Simplicity

ADI Advances in RS-485
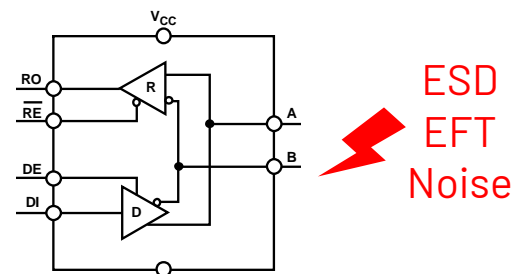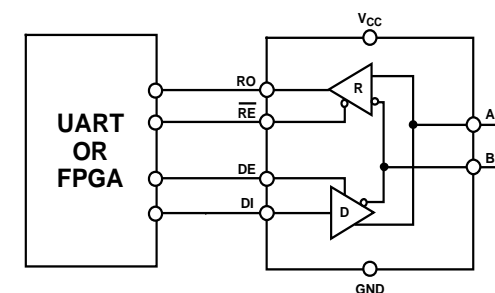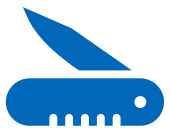

Distance & Speed
- Up to 100 Mbps
- Pre-emphasis to extend range

Pre-emphasis,预加重。与之对应的是De-emphasis去加重。是噪声整形技术在模拟信号的处理中，一项关于噪声整形技术原理的技术。所谓预加重是指在信号发送之前，先对模拟信号的高频分量进行适当的提升。在收到信号之后，再对信号进行逆处理，即去加重，对高频分量进行适当的衰减。这种预加重与去加重技术可以使信号在传输中高频损耗的影响降低，也可以使噪声的频谱发生变化，这就是模拟降噪的原理。
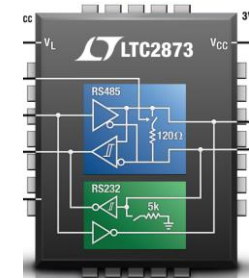
Robustness
- Fault Protection up to 80V
- ESD, EFT & Surge Immunity

Feature Set
- Autodirection & polarity invert
- Selectable speed & termination

Isolation
- Reinforced digital isolation
- Low EMI isolated DCDC

ADM286xE/ADM256xE Family
3kV / 5.7kV Signal & Power Isolated RS-485

► **Transceiver**

- Half or Full duplex transceiver
- 500 kbps or 25 Mbps data rate over 192 nodes
- Level 4 IEC61000-4-2 ESD robustness on bus pins
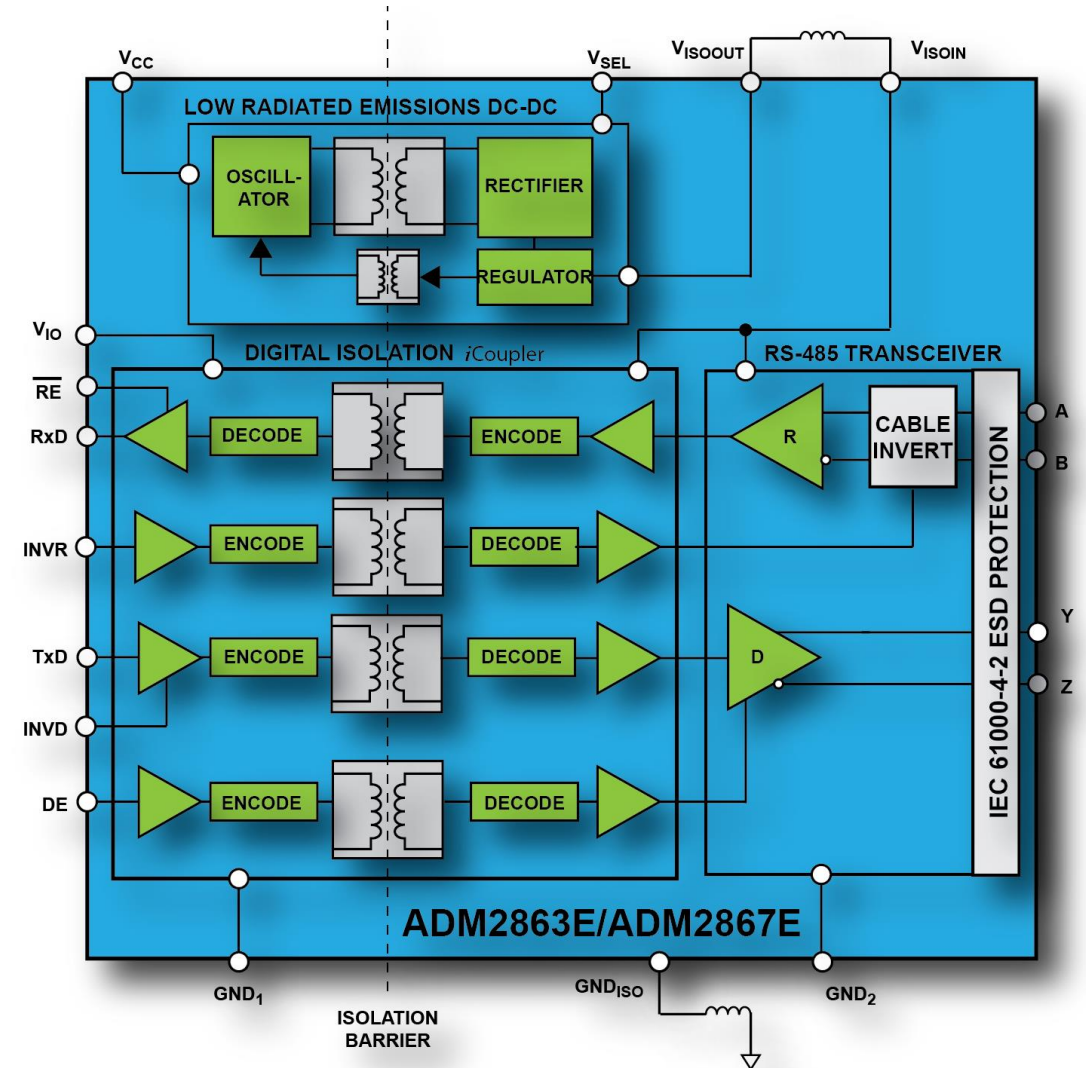- Smart cable invert feature

► **Isolated DC to DC**

- Wide 3V to 5.5V input, 3.3V or 5V output
- 5V output for PROFIBUS DP
- Meet Class B Radiated Emissions on 2-layer PCB

► **Isolator**

- Supports I/O from 1.7V – 5.5V
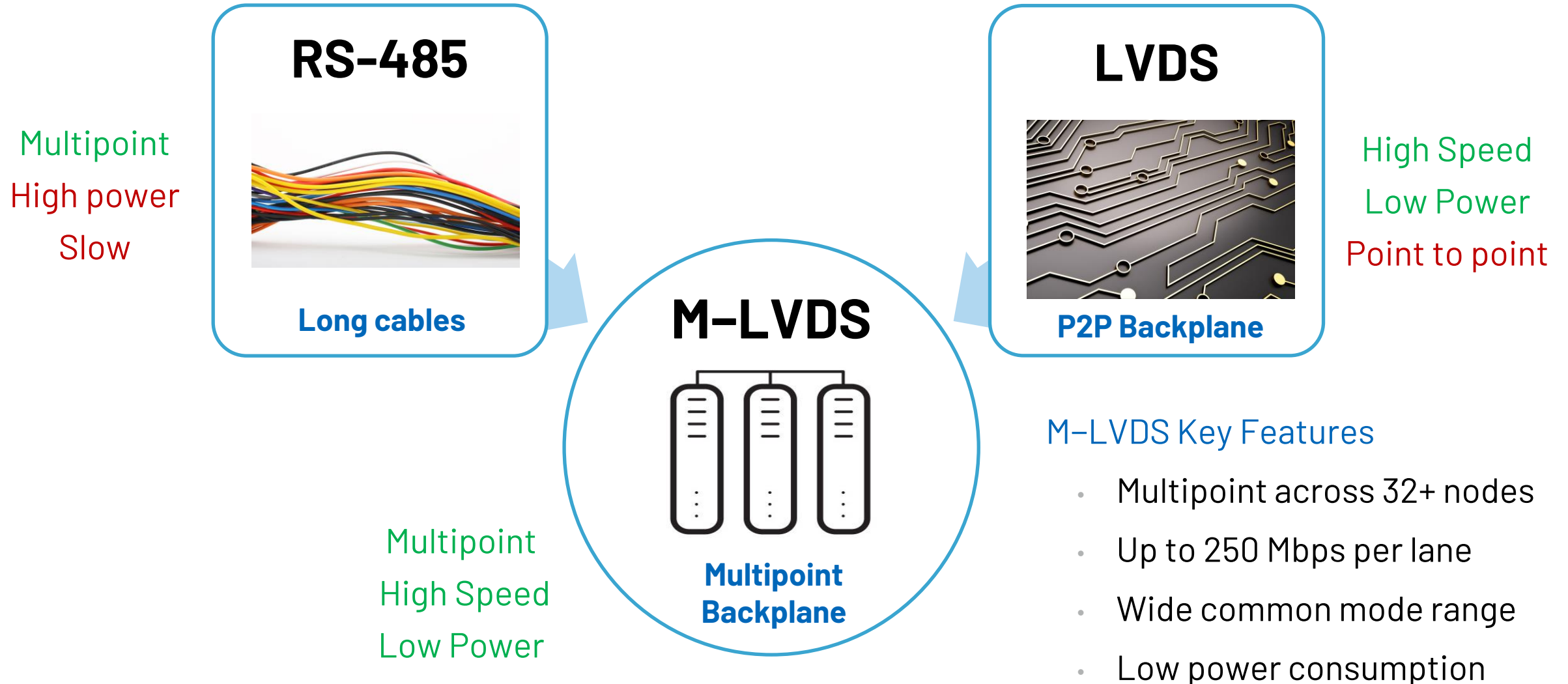- 225kV/us common-mode transient immunity.

► **Isolation / Package**

- Smallest form isoRS485 on 16L SOICW body size
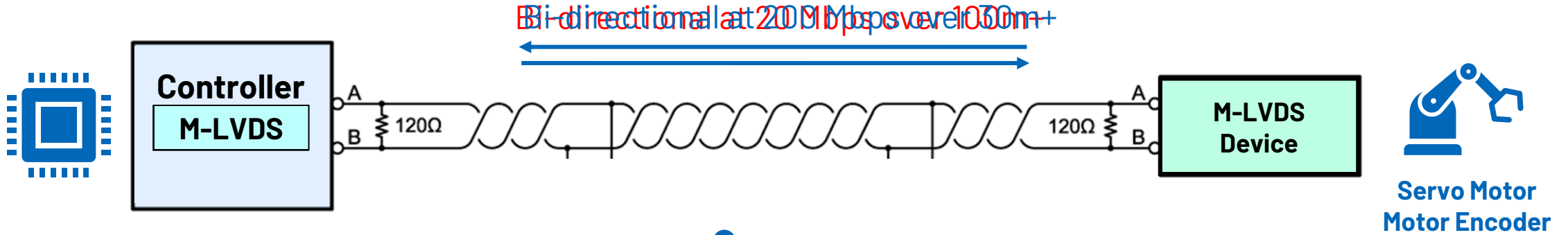- 5.7 kV, 8mm creepage, MG I for reinforced insulation

Multipoint LVDS

Enhanced Backplane Connectivity

M–LVDS : Optimised Backplane Communication

RS-485

Long cables

Multipoint

High power

Slow

LVDS

P2P Backplane

High Speed

Low Power

Point to point

M–LVDS

**Multipoint
Backplane**

Multipoint

High Speed

Low Power

M–LVDS Key Features

- Multipoint across 32+ nodes
- Up to 250 Mbps per lane
- Wide common mode range
- Low power consumption

Why M-LVDS for Motor Control

Bi-directional at 20 Mbps over 100m+
Bi-directional at 200Mbps over 30m+

Controller
M-LVDS

120Ω | 120Ω

M-LVDS Device

Servo Motor Motor Encoder

Temp Sensor

Vision Sensor

Datarate for Positional Encoder Feedback

M-LVDS

RS-485 limitation

Data rate (Hz): 100.0E+6, 90.0E+6, 80.0E+6, 70.0E+6, 60.0E+6, 50.0E+6, 40.0E+6, 30.0E+6, 20.0E+6, 10.0E+6, 000.0E+0

Timeline: 1980, 1990, 2000, 2010, 2020
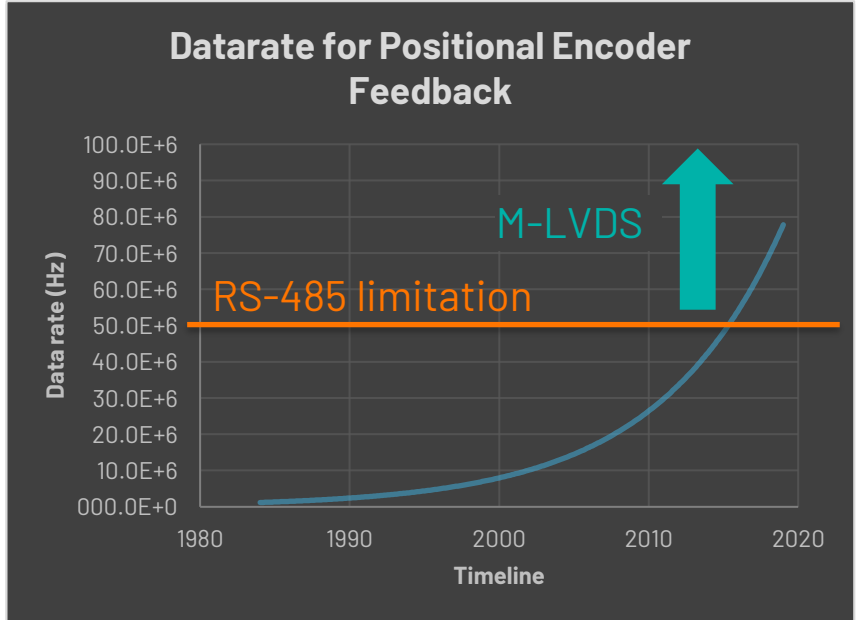
|	RS-485 / RS-422	M-LVDS
Topology	Differential, Multipoint	Differential, Multipoint
Maximum Data Rate	50 Mbps	250 Mbps
Power Consumption	High, 165mW – 425mW	Low, ~ 60mW
Min Output Voltage	1.5 V	0.48V
# of Devices, Distance	Up to 256 over 1km+	Up to 32 over 30m+

M–LVDS Backplane in Data Acquisition Racks

Private Server

Cloud
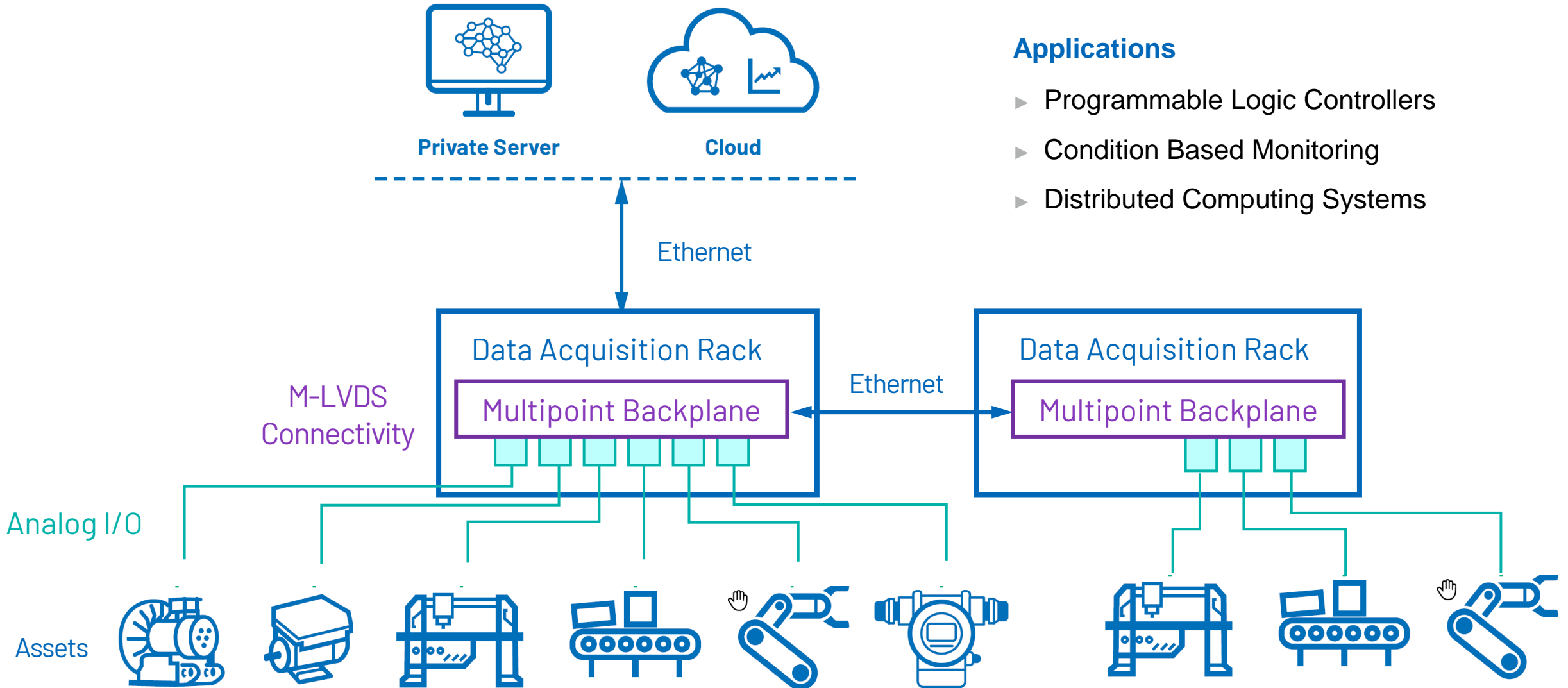
Applications

► Programmable Logic Controllers

► Condition Based Monitoring

► Distributed Computing Systems

Ethernet

Data Acquisition Rack

M-LVDS
Connectivity

Multipoint Backplane

Ethernet

Data Acquisition Rack

Multipoint Backplane

Analog I/O

Assets

M–LVDS Backplane in Data Acquisition Racks

High Performance Backplane

► High Bandwidth

► Multipoint across 32 nodes

► Aggregate lanes for more bandwidth

► Low Power Consumption
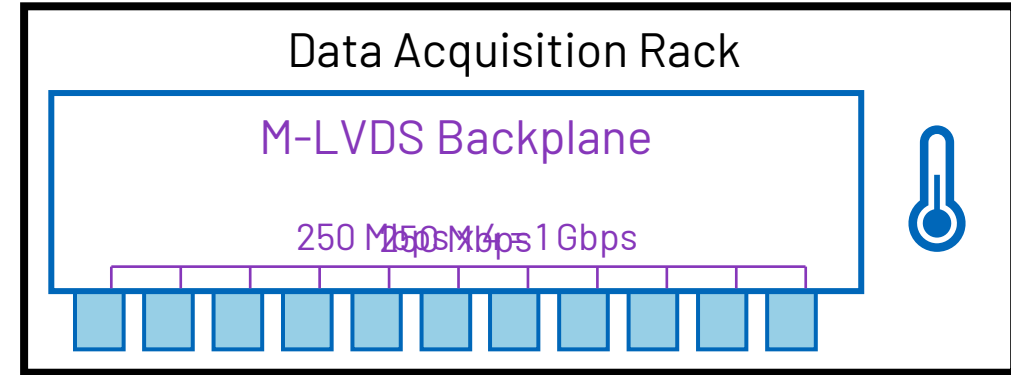
Robust Systems

► Hotswap for live insertion / removal

► Robust systems for ESD protection

► Receiver Failsafe

Data Acquisition Rack

M-LVDS Backplane

250 Mbps 1 Gbps
250 Mbps

Module Card
M-LVDS
CPU
I/O
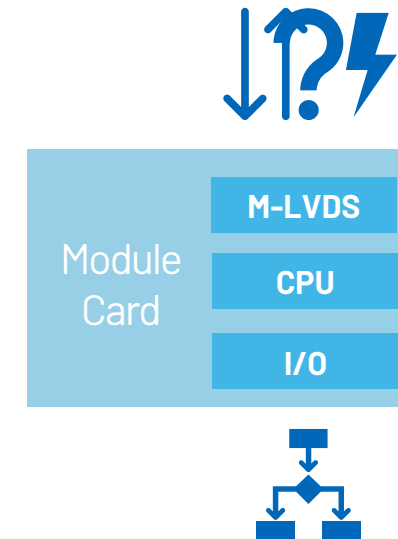
High Density M-LVDS Transceivers

## Value proposition

▶ Low power solution in a compact packages

▶ Low latency, skew and jitter performance for optimum SI
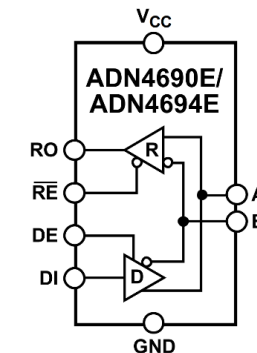
▶ Hot-swap and system level ESD for robust end systems

Key benefits

▶ Extended industrial temperature ranges

▶ Reduced dynamic power consumption

▶ Skew less than 5% of unit interval at 200 Mbps
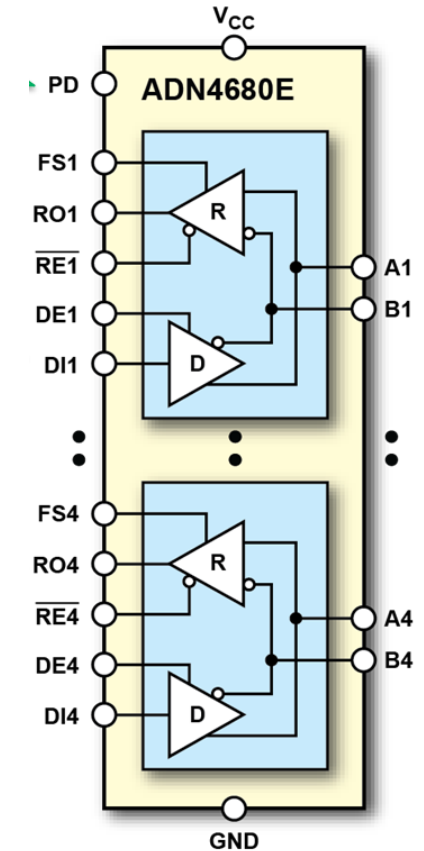
▶ Level 4 IEC 61000-4-2 ESD on M-LVDS I/O

Full duplex — ADN4693E-1

Half duplex — ADN4690E/ADN4694E
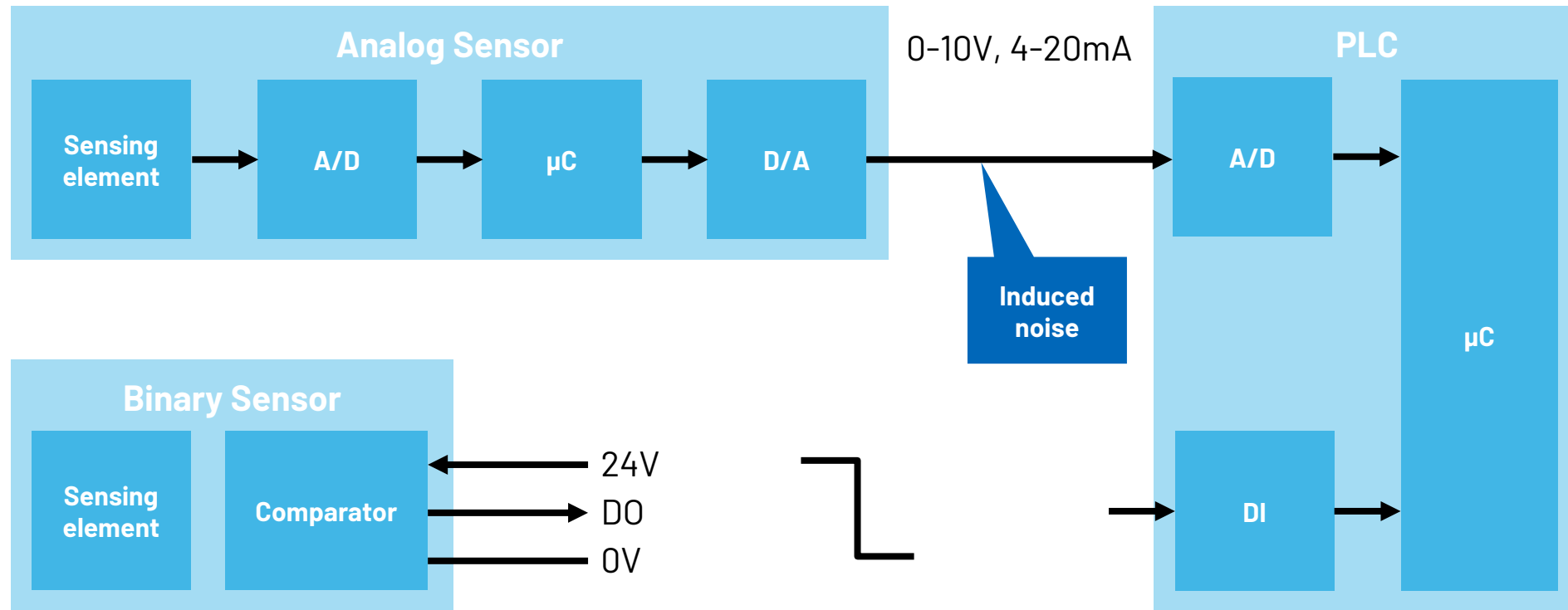
Quad half duplex — ADN4680E
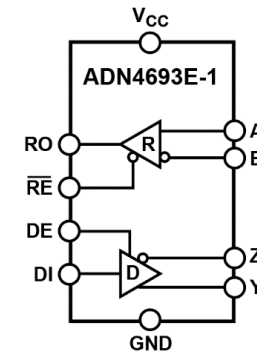
IO-Link

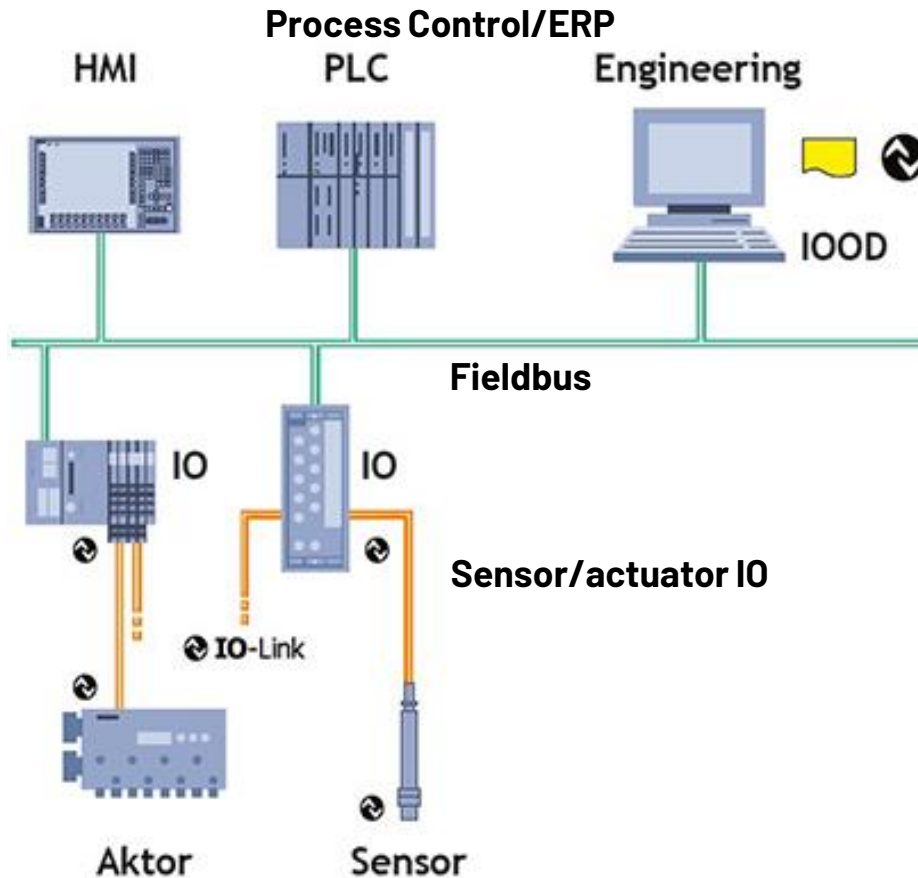The Intelligent Edge

The "Old School" Sensor

How to adjust, configure and diagnose?

What is IO-Link?

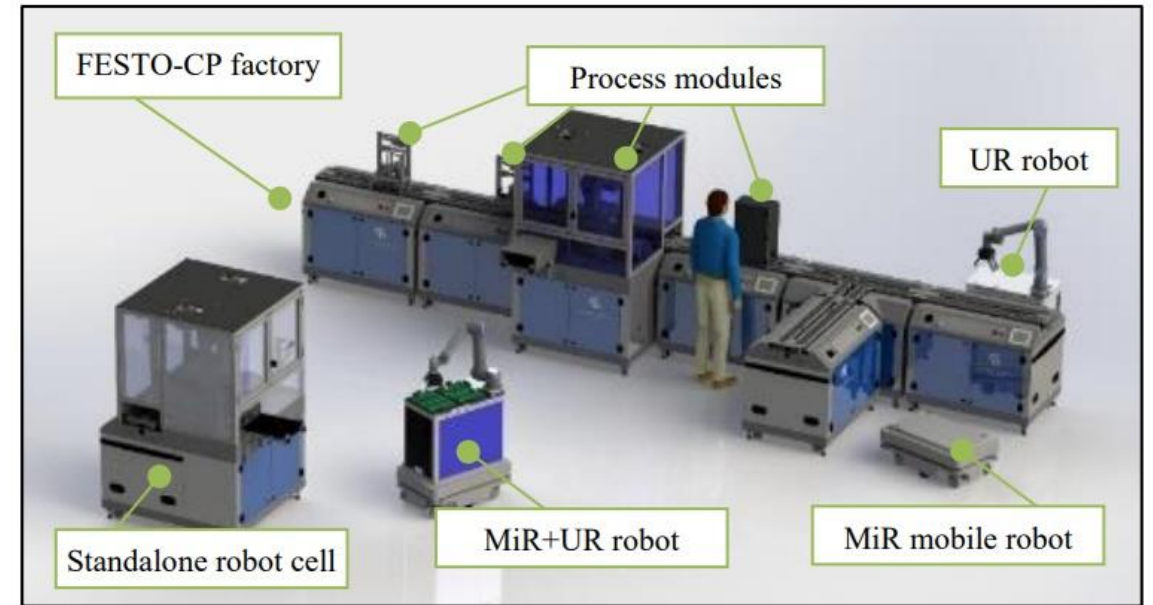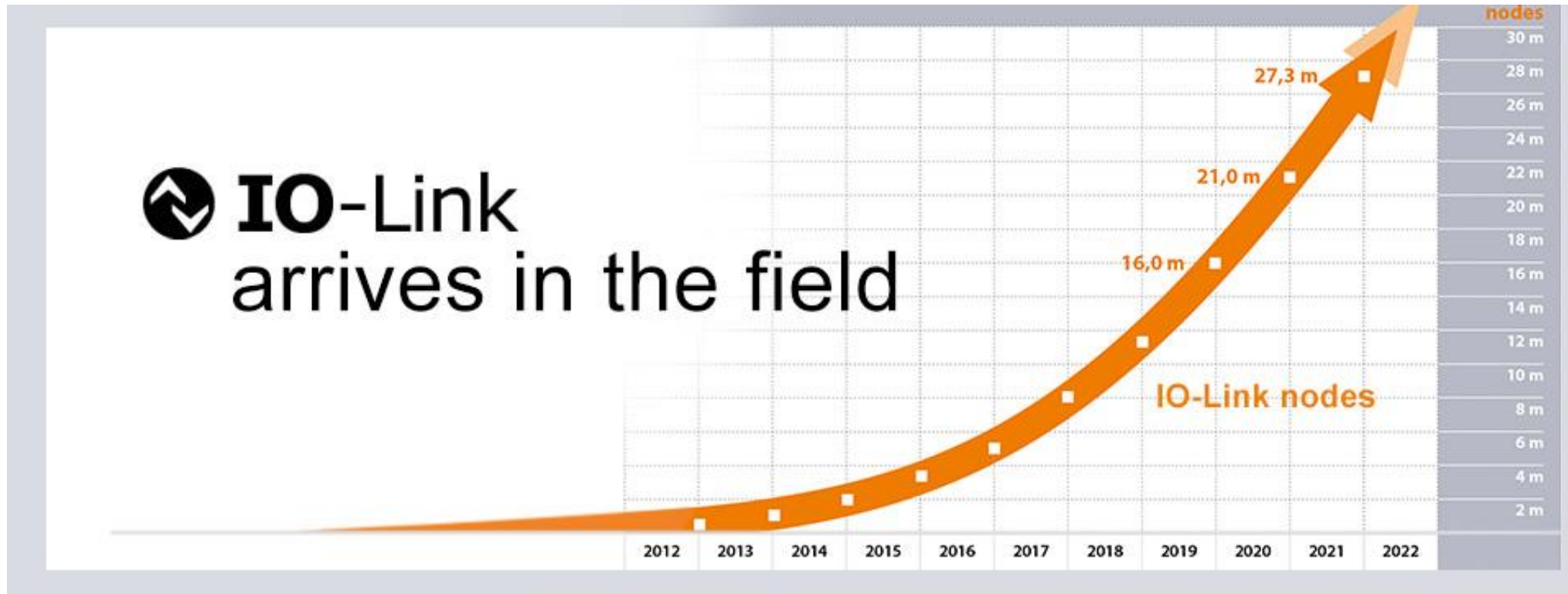**System architecture example**

Source: IO-Link.com

- ▶ IO technology for sensors and actuators
  - NOT a Fieldbus

- ▶ Based on long established 3-wire sensor and actuator connection using unshielded cables/M12 connectors

- ▶ Fieldbus independent; universal solution

- ▶ Simplifies Installation
  - Standardized interface and cable
  - Replace parallel wires, analog signals, upgrade binary sensors ....

- ▶ Automated parameter setting
  - IODD assists parameter setting remotely
  - Simplifies remote configuration

- ▶ Expanded diagnostics
  - Remote diagnostics down to field device level
  - Simplifies maintenance

Where is IO-Link Technology ?

- ► **Industries which require frequent changeovers or suffer from long down times**
  - Automotive
  - Material handling/packaging
  - Food & beverage
  - And many more ....

- ► **Industries with small batch sizes**
  - Cost effective at sample-size one

- ► **Industry 4.0 .....**
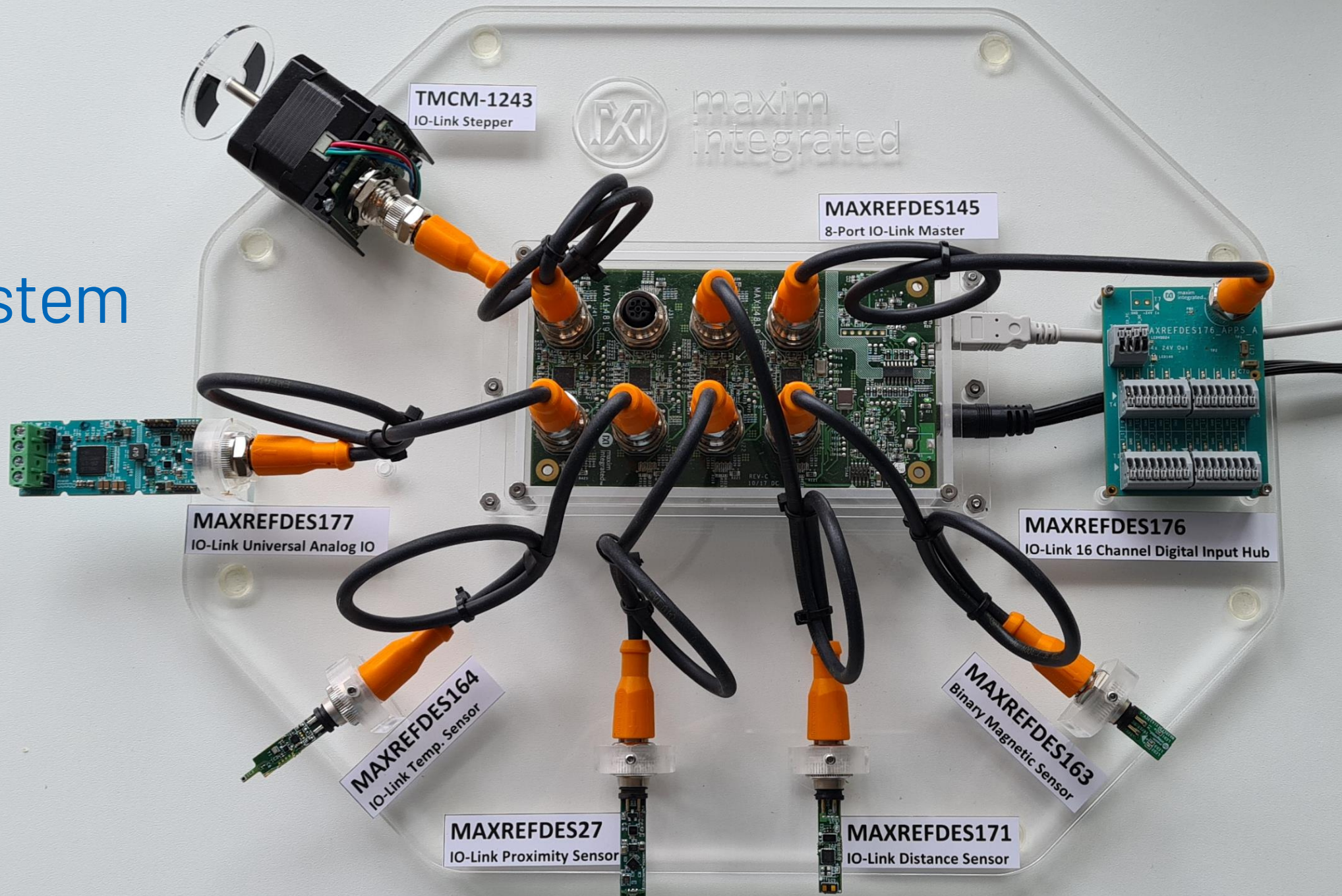 - Smart manufacturing

Source – http://ceur-ws.org/Vol-1898/paper4.pdf

IO-Link Market Growth

Source: IO-Link.com

IO-Link
Demo System

TMCM-1243
IO-Link Stepper

MAXREFDES145
8-Port IO-Link Master

MAXREFDES176_APPS_A

MAXREFDES176
IO-Link 16 Channel Digital Input Hub

MAXREFDES177
IO-Link Universal Analog IO

MAXREFDES164
IO-Link Temp. Sensor

MAXREFDES163
Binary Magnetic Sensor

MAXREFDES27
IO-Link Proximity Sensor

MAXREFDES171
IO-Link Distance Sensor

maxim integrated

Design Challenges with Sensors

Heat

► Sensors often come in tiny housings and warm up very quickly when dissipating power
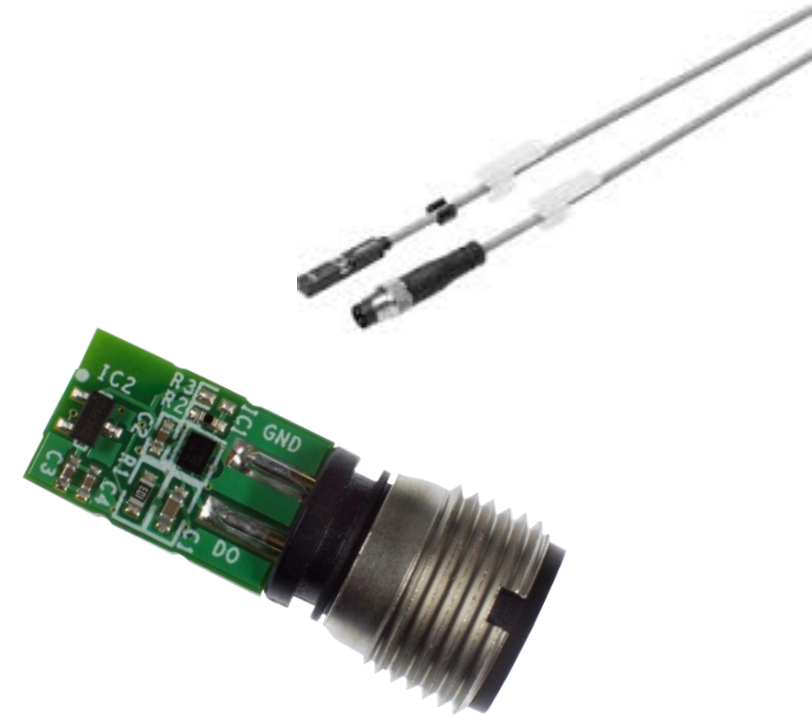
Size

► Sensors must be small to fit into the small space at the edge

  ▪ This can also cause issues when there is a lot of heat

Robustness

► Sensors must survive ESD and EFT bursts in harsh industrial environments

► Most customers also require some level of surge protection

Capability

► IO-link devices must be able to drive 200ma per channel, keeping power dissipation and heat at a minimum

**Photo is from internet

Surge Protected IO-Link Device Transceivers

MAX22513 / MAX22514 / MAX22515

- ► Low power dissipation
  - ▪ 2.3Ω/2.1Ω (typ.) driver on resistance

- ► Integrated high-efficiency DC-DC buck regulator
  - ▪ 2.5V-12V, 300mA (max)

- ► Small package size: 2.5 x 2.0mm WLP

- ► Integrated ±1kV / 500Ω surge protection

- ► High configurability
  - ▪ Integrated LDOs and oscillator
  - ▪ Auxiliary 24V DO/DI
  - ▪ SPI/I^2C interface options

- ► MAX22513 – Dual driver with integrated DC-DC

- ► MAX22514 – Single driver with integrated DC-DC

- ► MAX22515 – Dual driver (no DC-DC)
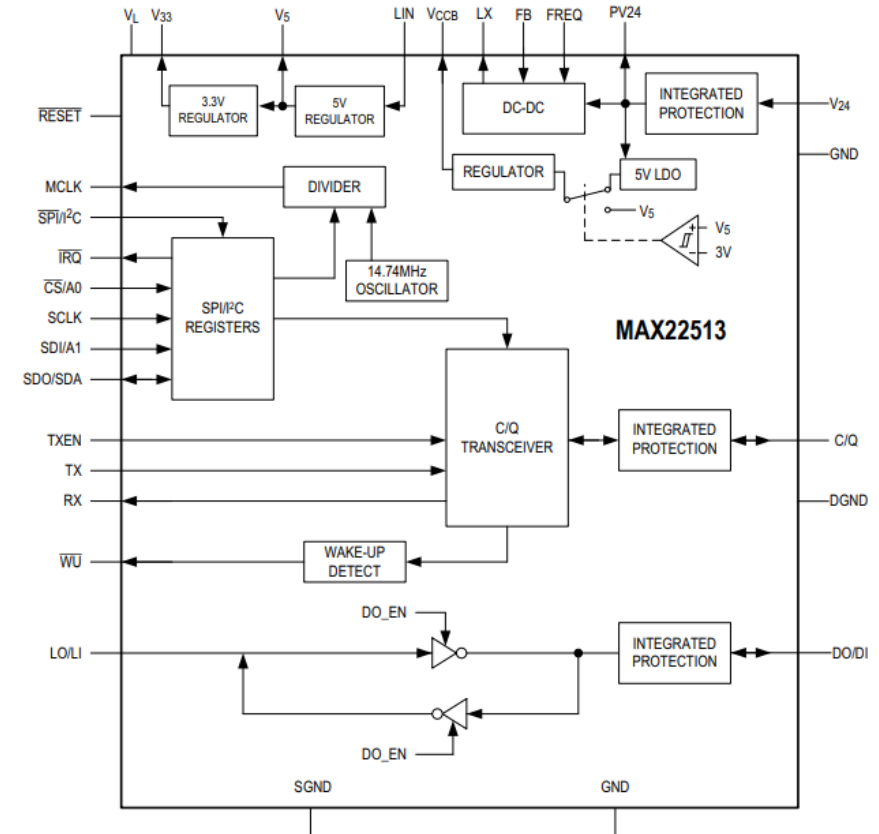
Dual IO-Link Master

MAX14819 / MAX14819A

▶ **Dual channel master with additional industrial digital inputs**

▶ **Low power architecture**
- 1Ω (typ.) driver on-resistance
- 1.9mA (typ.) total supply current for 2 channels

▶ **Integrated IO-Link framer eliminates need for external UARTs**

▶ **Two auxiliary Type 1/Type 3 digital inputs**

▶ **Integrated protection enables robust systems**
- C/Q and DI fully compliant with IEC 61131-2
- C/Q compliant with IO-Link 1.1.2
- Reverse current blocking on L+
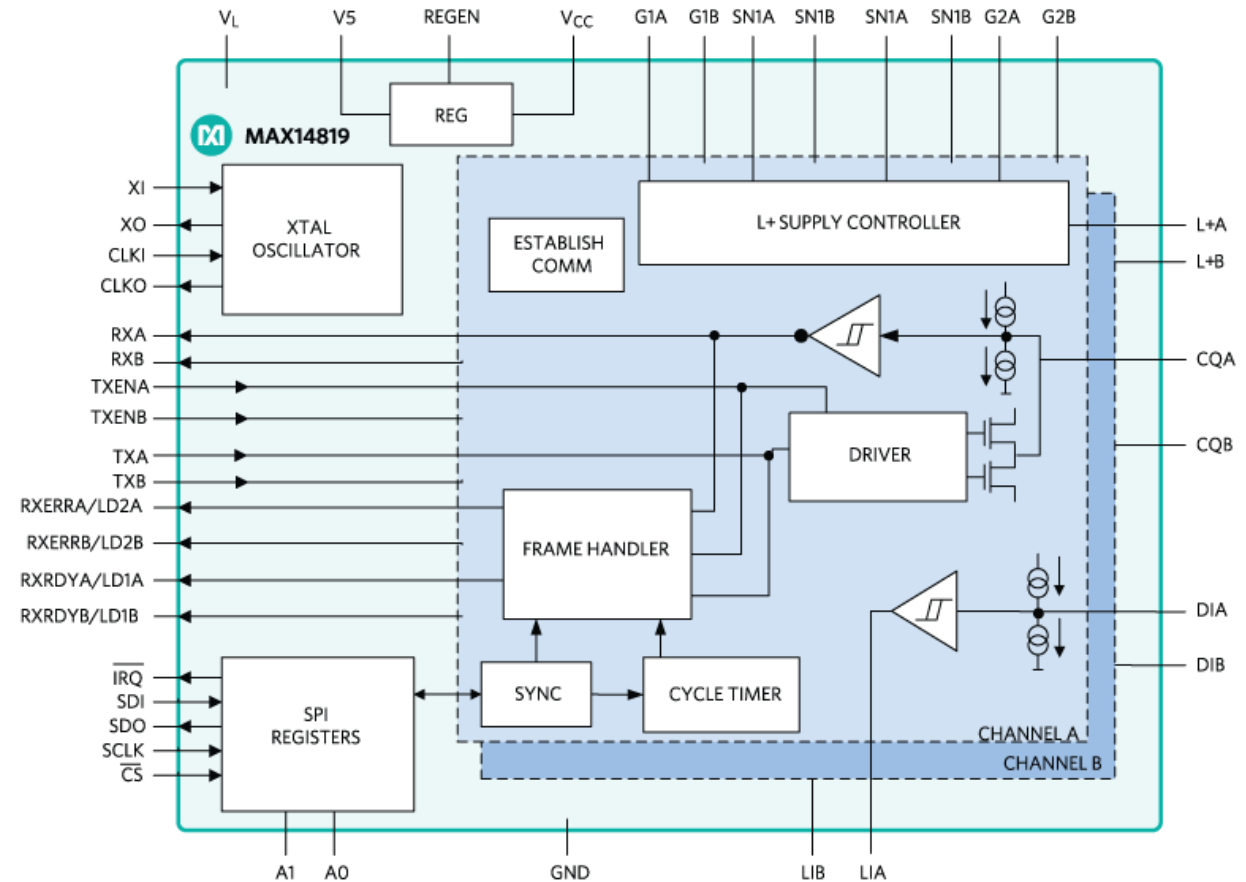
Industrial Ethernet

Robust, High-Bandwidth, Time-Sensitive Data
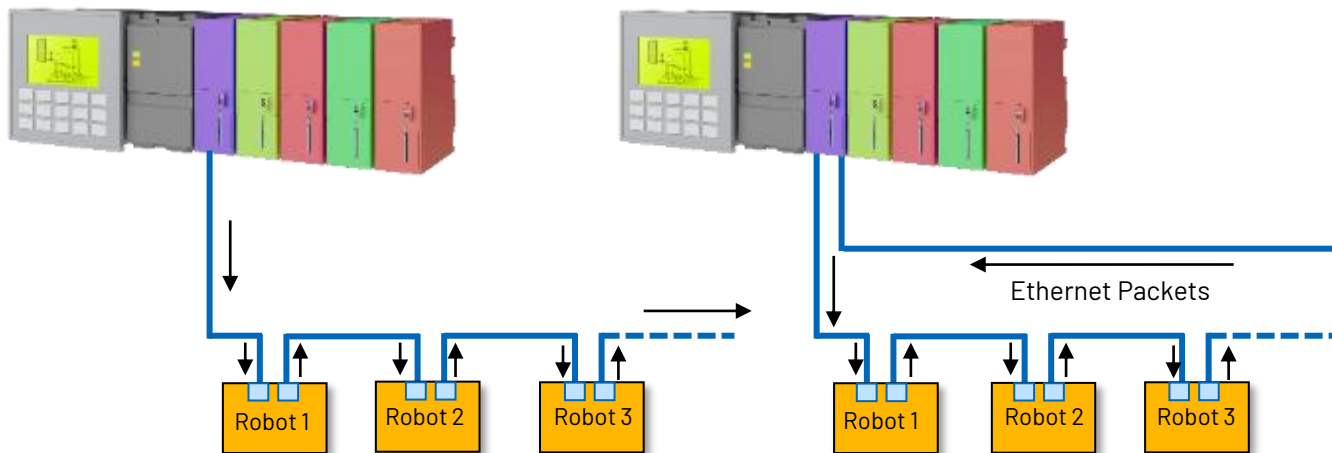
Why Industrial Ethernet

LINE and RING industrial ethernet network topologies

Low PHY latency/network cycle time

▶ Collect and update the data of all devices

▶ Achieve higher application performance in time-critical communications

▶ Connect more devices to the network

Low power consumption

▶ More of the power budget available for FPGA/processor and ethernet switch in device

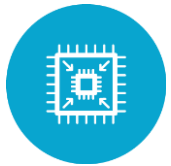▶ Less power dissipation. Important for 105°C Ambient temperature operation

Ethernet Packets

Robot 1   Robot 2   Robot 3   Robot 1   Robot 2   Robot 3

**Photo is from internet

Introducing

Industrial Ethernet Solutions

- **Physical layer devices**

- **Embedded switches**

- **Platform solutions**

**Photo is from internet
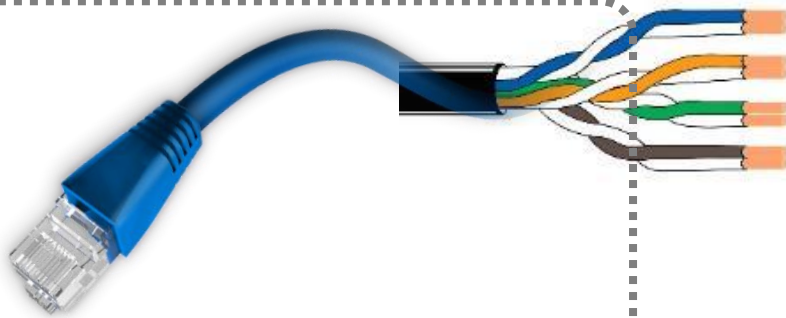
10BASE-T1L

Longer Reach and Intrinsic Safety

10BASE-T1L

Ethernet Physical Layer, IEEE 802.3cg-2019

Robust Physical Layer

- ► 1000BASE-T
- ► 100BASE-TX
- ► 10BASE-T

- ► 10BASE-T1L

PHY Key Features	10/100/1000 BASE-TX	10BASE-T1L
Cabling		
	2 or 4 pair Ethernet	Single Pair Ethernet
Distance	100m	Up to 1km
Speed	10Mb, 100Mb, Gb	10Mb
Connector	RJ45	Two Pin Connector
Intrinsic Safety Compatibility (Ex)	No	Yes (Ex)
Power	PoE	PoDL or Engineered Power (Ex)

**Photo is from internet

Simple, Seamless Edge-to-Cloud Connectivity
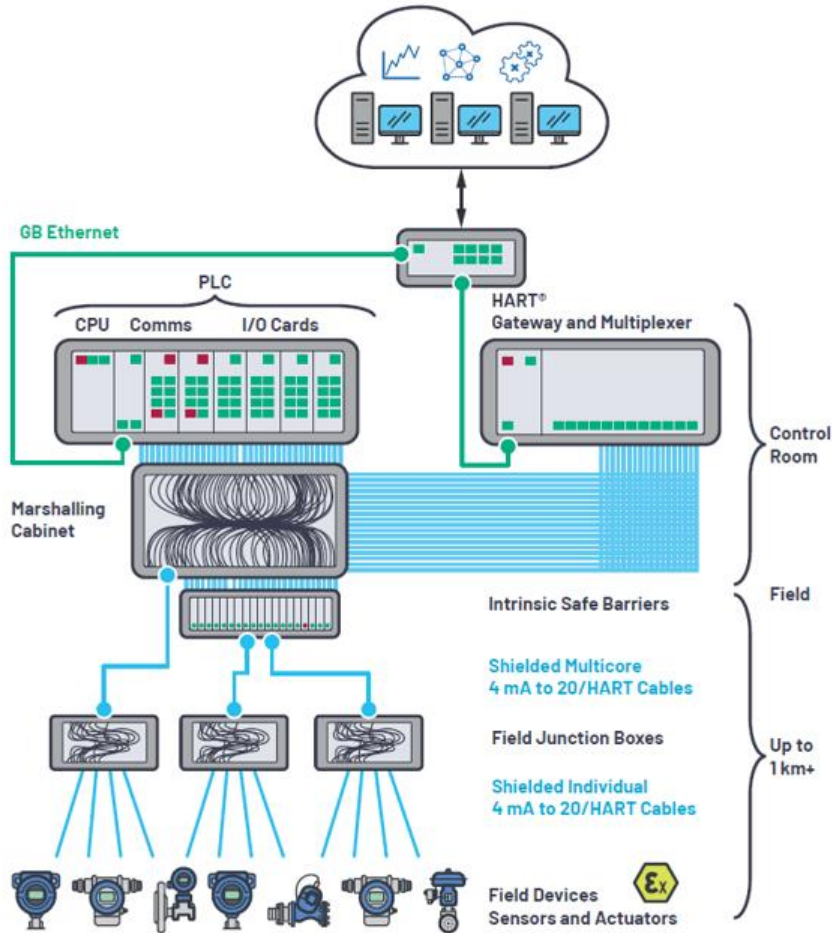
4-20mA/HART

APL / 10BASE-T1L

Transition
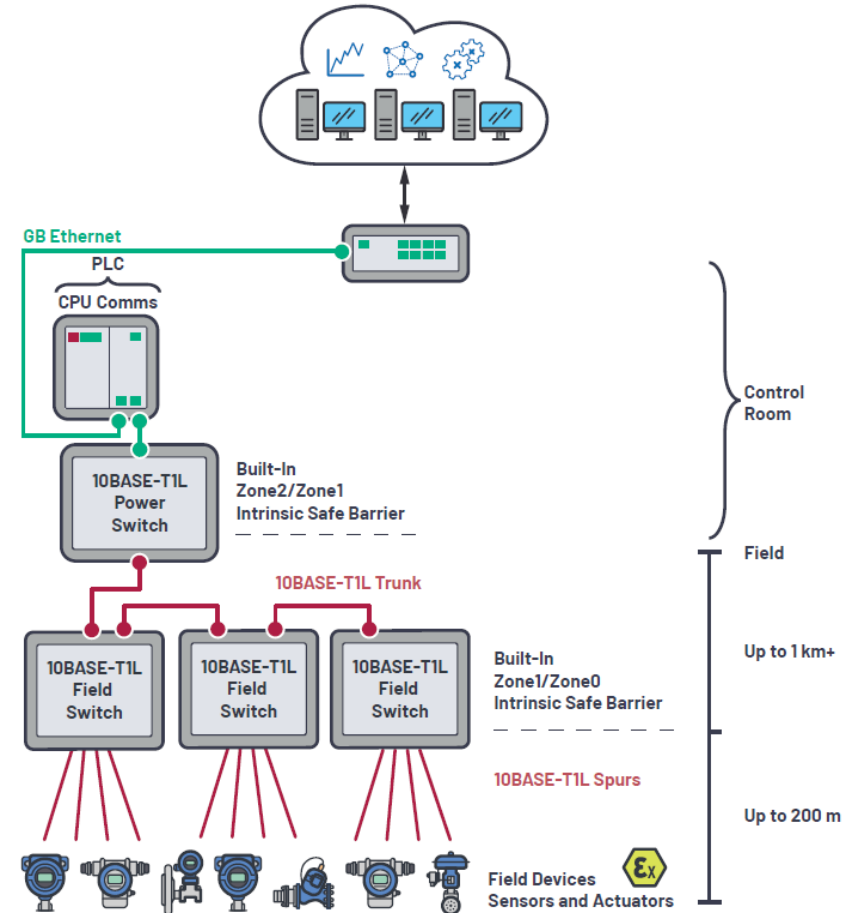
2.4 Vpp Tx

1.0 Vpp Tx

Process Automation

ADI solutions in system context
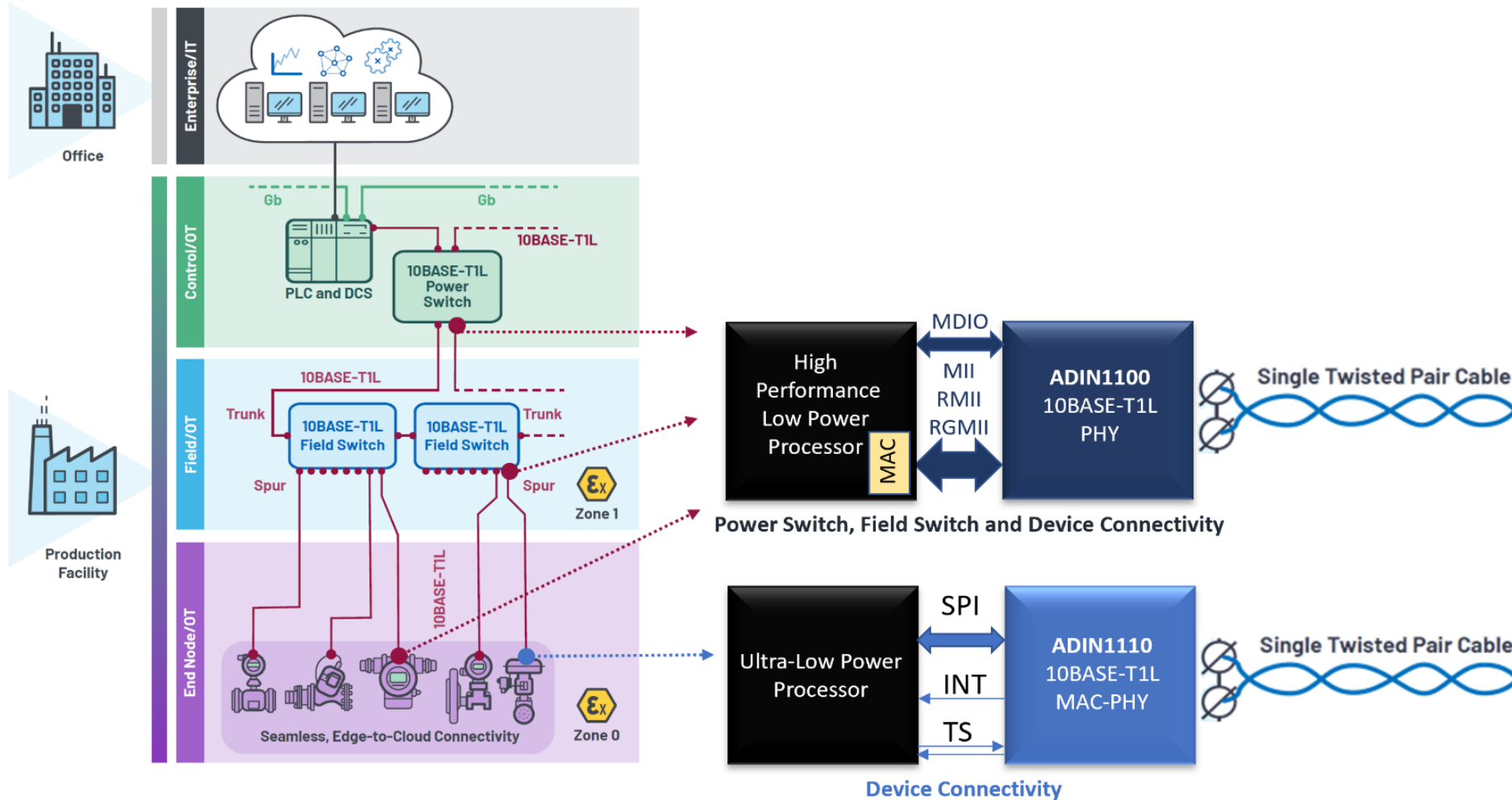
Optimise System Performance & Power Consumption

Highest performance solution

▶ MAC interface drivers (MII, RMII, RGMII)

▶ Scale up to higher performance processors

▶ Supports ethernet switches and FPGA
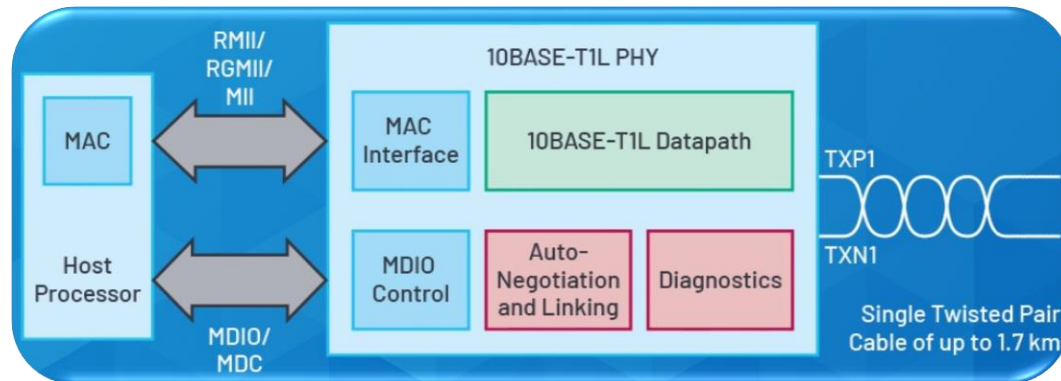
Lowest system power

▶ Wider selection of processors

▶ Architecture & software reuse from existing solution

▶ IEEE1588 time synchronization

▶ Advanced packet filtering

ADIN1100 – PHY
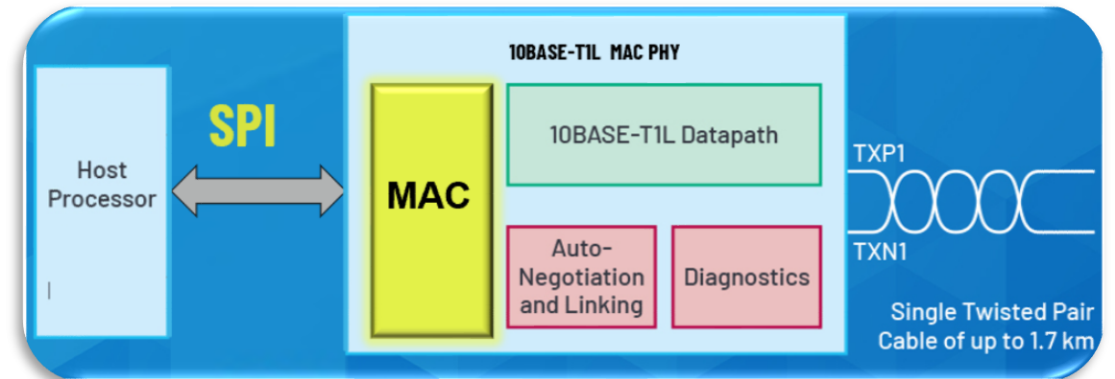
ADIN1110 – MAC PHY
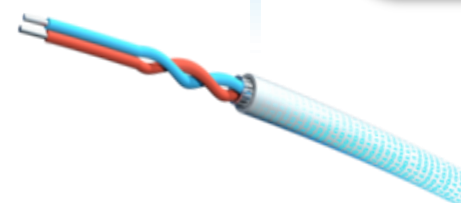
10BASE-T1L 2-Port Low Complexity Switch

ADIN2111

► Low complexity ethernet switch
  - Cut-through or store & forward operation

► SPI host interface
  - 10Mb/sec full duplex
  - Generic/Open Alliance SPI

► Low power: 118 mw typ. (Dual supply,1V p-p)

► Small package 48-lead (7 x 7 mm) LFCSP

► 2x 10BASE-T1L PHYs
  - Features as on ADIN1100
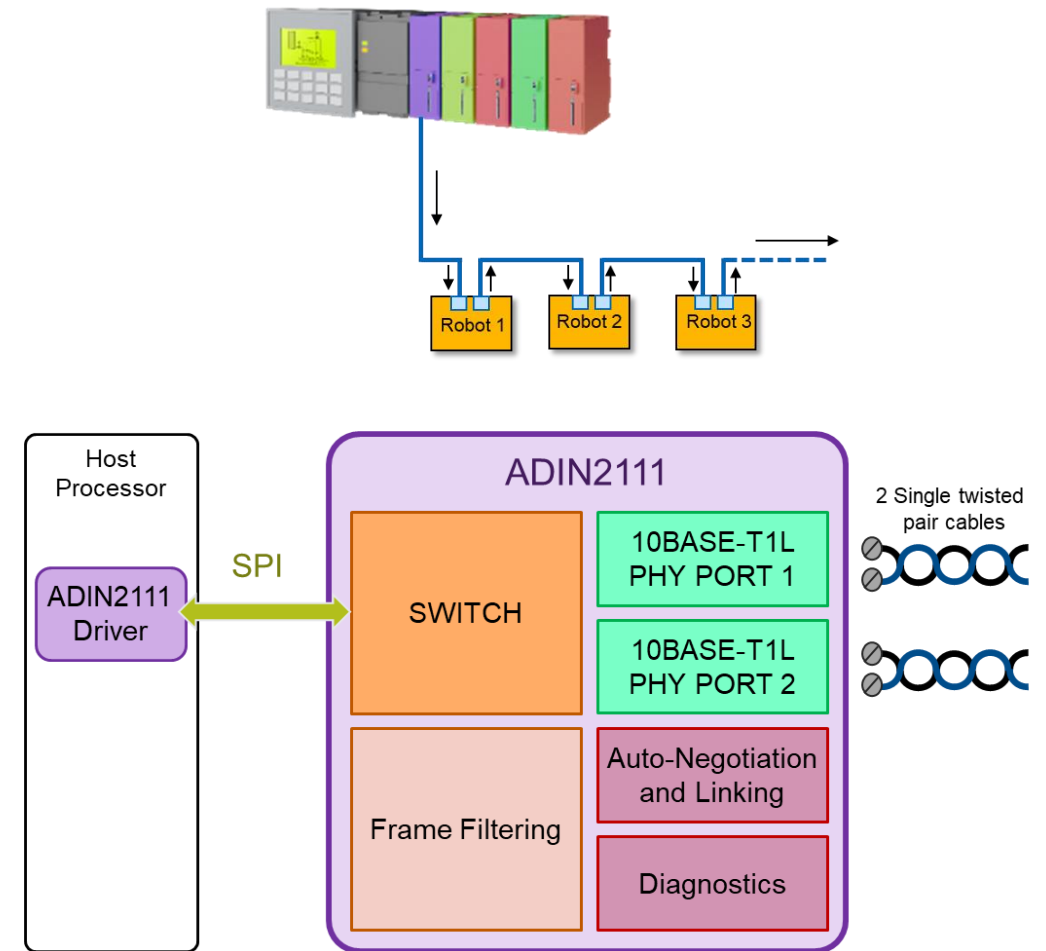
Cable Types and Diagnostics

IEEE cable characteristics

- ▶ 100 Ohm impedance
- ▶ Insertion loss limit
- ▶ Return loss limit
- ▶ Maximum link delay
- ▶ Conversion mode
- ▶ Up to 10 inline connectors

IEEE 802.3cg Cable Specifications - Insertion Loss

— Insertion Loss 1.0Vpp   — Insertion Loss 2.4Vpp
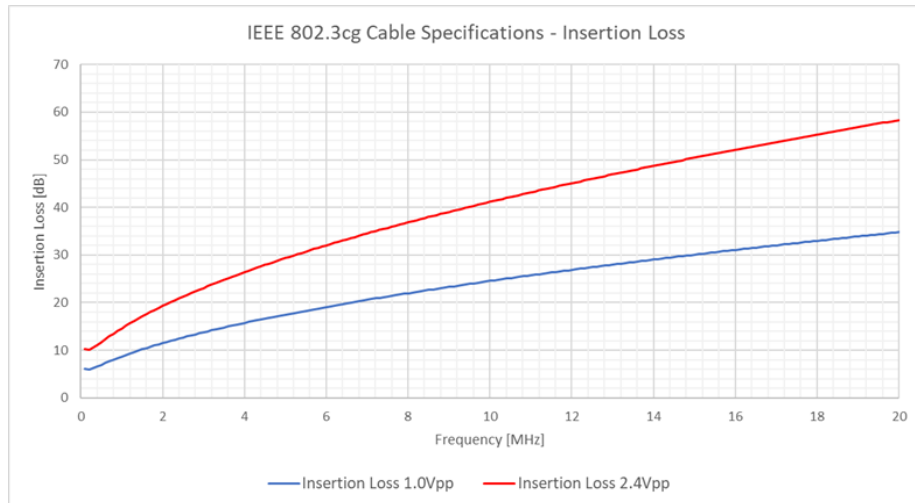
ADI's 10BASE-T1L diagnostic capabilities

- ▶ Transmitter PMA test modes
- ▶ Signal quality monitoring through MSE
- ▶ Loopback modes
- ▶ Frame generator & frame checker
- ▶ On-chip Time Domain Reflectometry engine

Distance to Fault (Error < 2%)
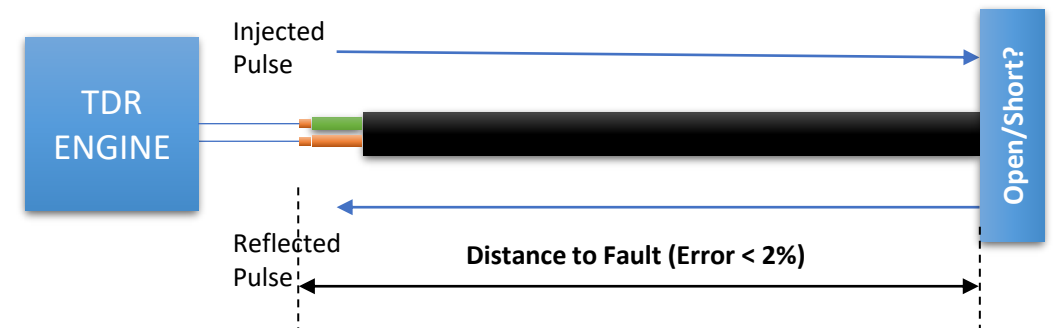
**Photo is from internet

Analog Devices 10BASE-T1L

Solutions for flexible system design

Maximize your system power budget

► Ultra-low power consumption
  ▪ 39 mW ADIN1100
  ▪ 43mW MAC PHY ADIN1110

Leverage a proven solution

► Full compliant to 10BASE-T1L IEEE® Std 802.3cg™

► Auto-negotiation with cable reach up to **1.7km**

Increase design flexibility

► PHY only with MII, RMII, RGMII interface or MAC-PHY directly with SPI interface

► Easily implement line and ring topologies with low complexity 2 port switch

Reduce debug work and effort

► Full suite of debugging capabilities such as TDR, frame generator & Checker,

10/100/1000BASE-T
Ethernet

ADIN1300: 10/100/1000 Robust Industrial Ethernet PHY

ADIN1300 10/100/1000 gigabit PHY

- ► Small footprint: 6 x 6mm 40-LFCSP
- ► Low power: 330mW
- ► Low latency: 290ns Tx & Rx (RGMII)

ADIN1200 10/100 fast ethernet PHY

- ► Small footprint: 5 x 5mm 32-LFCSP
- ► Low power: 139mW
- ► Low latency: 300ns Tx & Rx (MII)
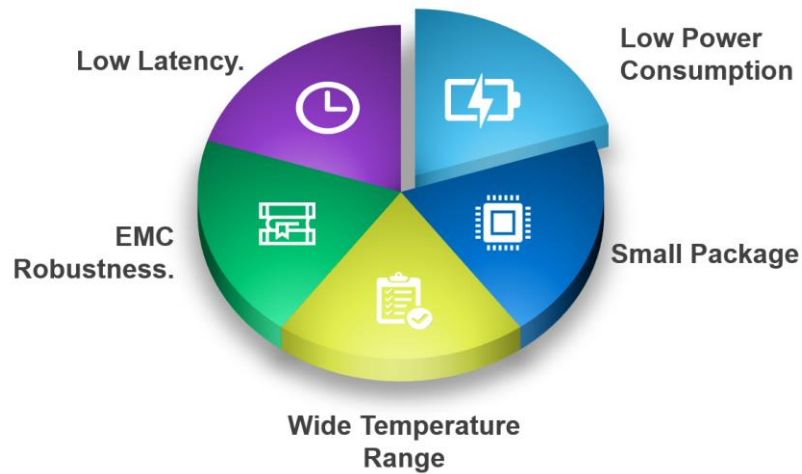
Extensive EMC/ robustness testing

- ► IEC 61000-4-5 surge (±4 kV)
- ► IEC 61000-4-4 electrical fast transient (EFT) (±4 kV)
- ► IEC 61000-4-2 ESD (±6 kV contact discharge)
- ► IEC 61000-4-6 conducted immunity (10 V)
- ► EN55032 radiated emissions (Class A)
- ► EN55032 conducted emissions (Class A)

Low Latency.

Low Power Consumption

EMC Robustness.

Small Package

Wide Temperature Range

RapID Platform Generation 2 (RPG2) – 100BASE-Tx

- ▶ 2-Port multiprotocol platform

- ▶ Network software for each protocol
  - ▪ A module comes pre-installed with network software (PROFINET is shown here in RED)

- ▶ Driver provided for the host-side software to communicate with the network software

- ▶ Unified interface in the network software
  - ▪ Host application software does not have to change when the protocol changes
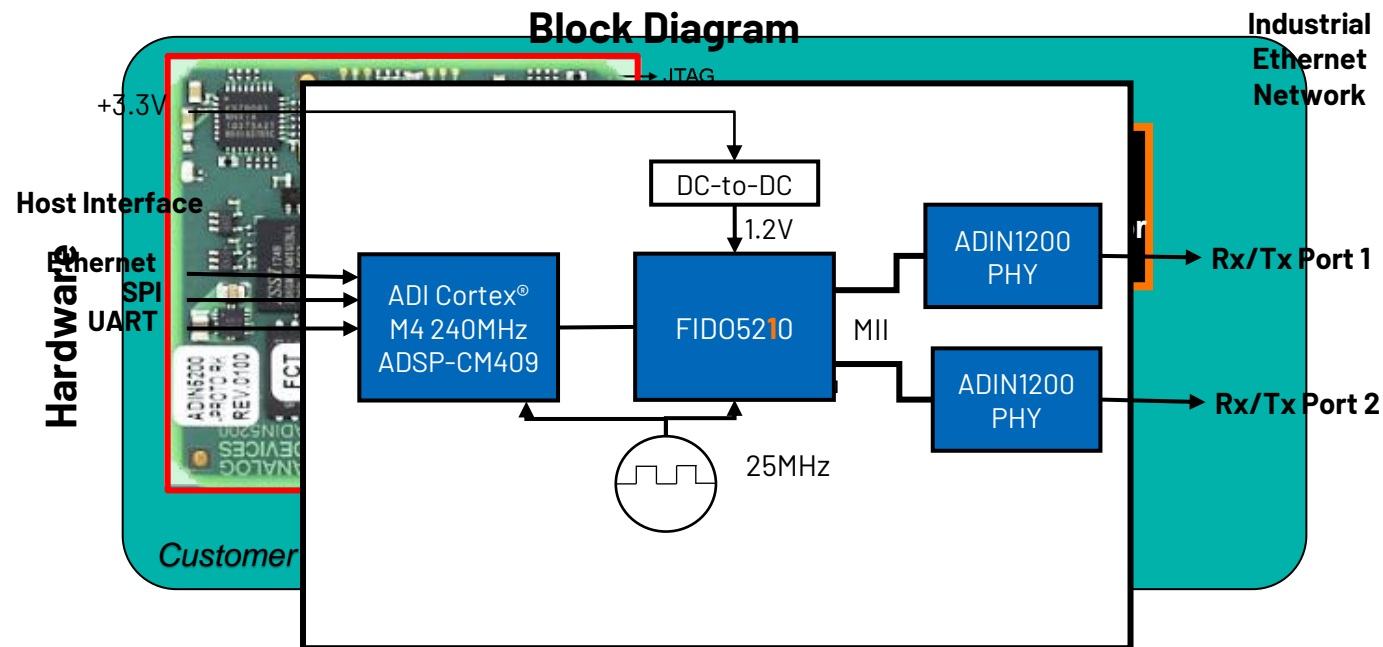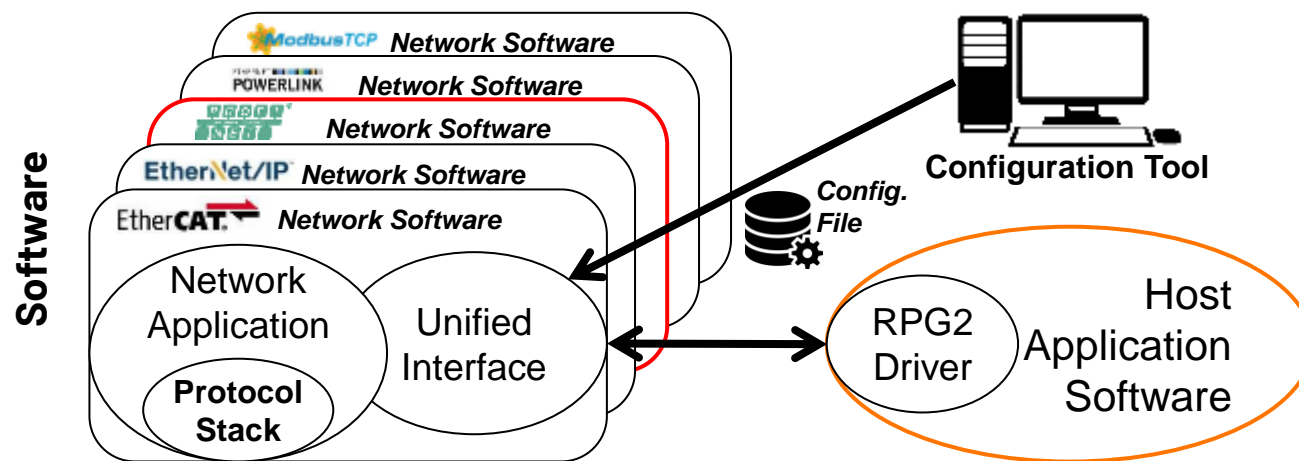
Network Interface Solutions: Two Options

► Pre-certified hardware with multiprotocol software

► Reduces development effort

► Speeds time to market

Module

ADIN2299

Complete off-the-shelf,
ready-to-use solution

Fully tested reducing
development risk

Embedded reference design

Pre-certified

Enables optimisation
of board design

Cost effective solution for
high volume applications

Isolated USB

Robust Peripheral Interface

Isolated USB in Industrial Systems
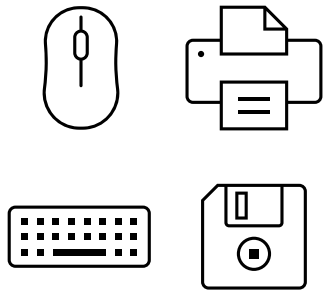
▶ Debug Ports (RS-232 Replacement)

▶ Noise Immunity

▶ Electrical Safety for Operators

**Photo is from internet

Gen 1 Isolator (USB 1.X)
Low Speed (0.5 Mbps)
Full Speed (12 Mbps)

Gen 2 Isolator (USB 2.0)
Low & Full Speed
High Speed (480 Mbps)
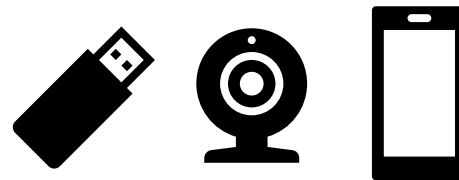
ADI 2nd Gen Isolated USB
- Faster Firmware Updates
- Supports video streams
- More flexible systems
- Enhanced robustness

Isolated USB Gen 2 Product Highlights

ADuM3165/ADuM3166/ADuM4165/ADuM4166

IEC61000-4-2 ESD ± 8kV Contact across isolation barrier

Market first medical grade 20kv surge protection

-55°C to +125°C Extended temp range

Re-timing for USB compliance

Low power mode supports battery-powered peripherals

Upstream short circuit protection

Downstream P_{GOOD} indicator

480Mbps data rate for faster software downloads and video streaming apps

Pass CISPR32 Class B EMI emissions

Host mode auto-detects peripheral connections for all 3 USB 2.0 speeds 1.5/12/480Mbps

Isolated USB 2.0 High Speed Operation
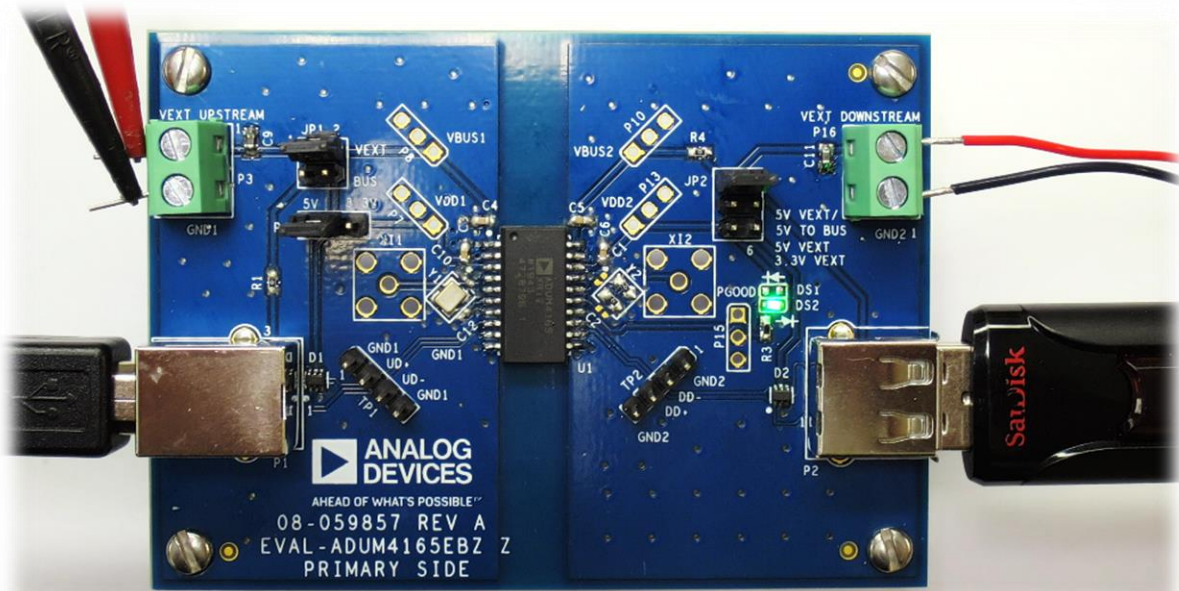
EVAL-ADuM4165EBZ Evaluation Board

High Speed 480 Mbps
10 ns / div
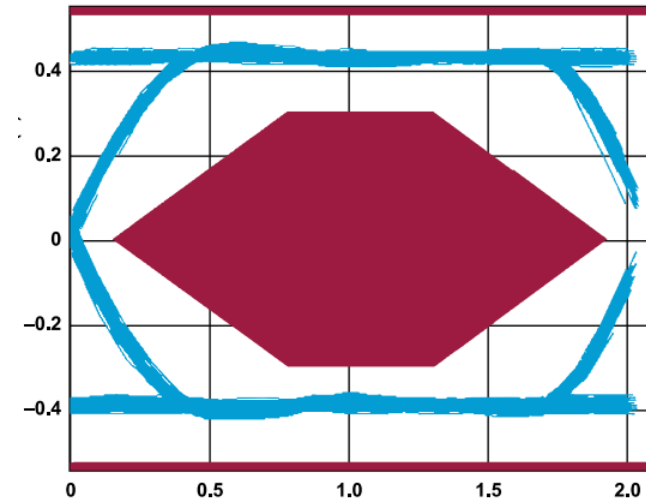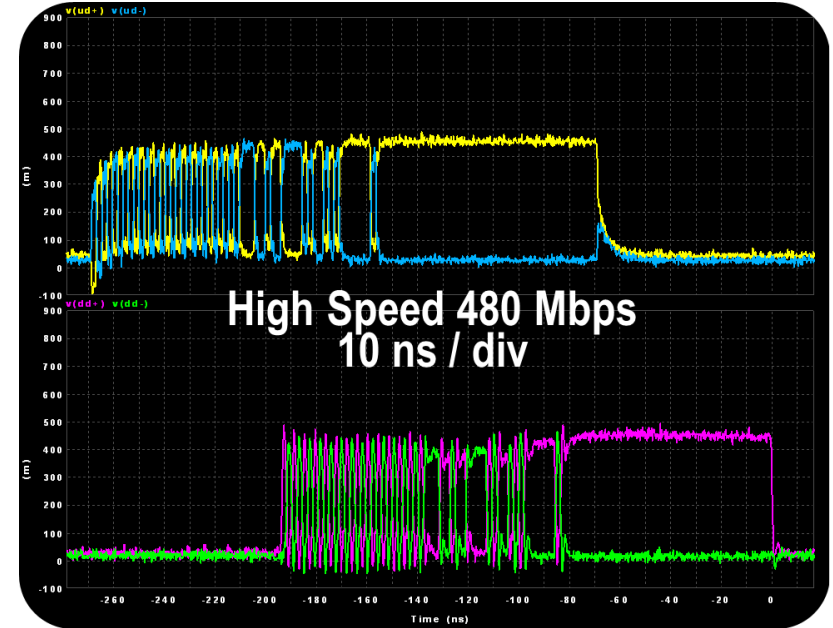
High-Speed Isolated USB Part Selection

Isolation/package & clock/retiming host vs. peripheral

		Host	Peripheral
		ADuM4165	ADuM4166
20-Lead SOIC-IC 5kV$_{RMS}$	8mm C&C		
SSOP 20 3.75kV$_{RMS}$	5.3mm C&C	ADuM3165	ADuM3166

All models released

Comparison approx. to scale
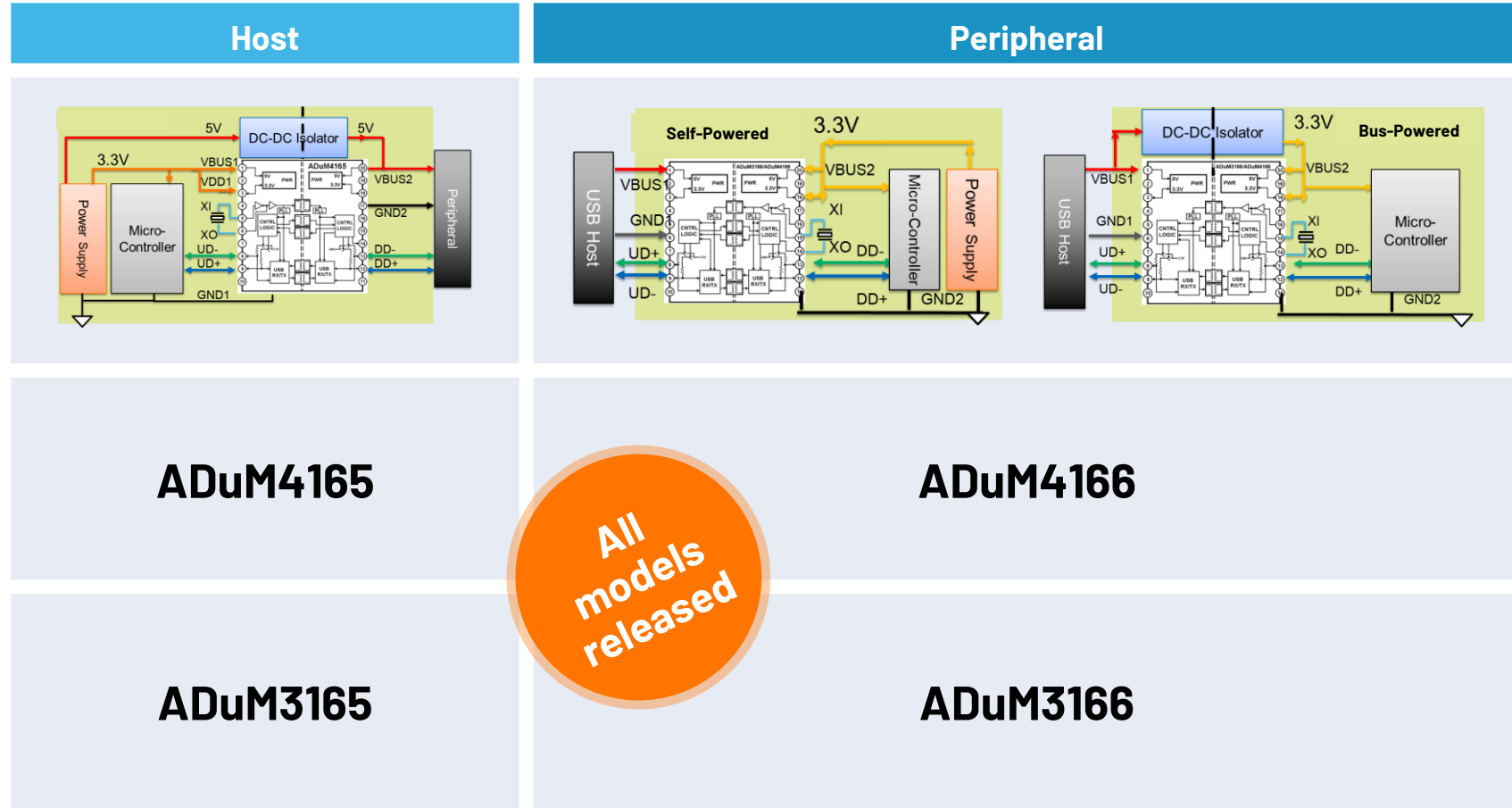
Factory Automation – A Quick Review

Information level
Top level of plant or automation system

Control level
MLVDS

Cell sublevel
RPG2, ADIN2299

Field level
IO Link, 10BASE-T1L

Office — Enterprise/IT

Production Facility — Control/OT, Field/OT, End Node/OT

Gateway

Legend:
- Standard Ethernet
- Gb Industrial Ethernet TSN
- 10BASE-T1L Industrial Ethernet
- RS-485
- IO-Link
- Iso USB
- MLVDS

PLC and DCS — TSN Switch — HMI — PLC and DCS — PLC and DCS — Iso USB — Gb

TSN Switch — CNC — Motion Planner — IO-Link Master — 10BASE-T1L Field Switch — 10BASE-T1L Field Switch — 10BASE-T1L

Gb — RS-485 — IO-Link

Conveyor Pulleys — Integrated Drive — Machine Tools — Robots — Sensor — Solenoid — Field Instruments - Flowmeter, Pressure Meter — Zone 0, 1

Tomorrow's Factory Connectivity Solutions

- RS-485
- Standard Ethernet
- 100 Mb Industrial Ethernet
- Gb Industrial Ethernet TSN

Take the Next Step

► ADI has you covered for industrial connectivity solutions

► Learn more about today's topics by visiting these links

► Isolated RS-485
  ▪ Link

► IO-Link
  ▪ https://www.maximintegrated.com/en/products/interface/io-link-transceivers.html

► Industrial Ethernet and 10BASE-T1L
  ▪ http://www.analog.com/chronous

► M-LVDS
  ▪ Link

Thank You

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