EtherCAT® Industrial Ethernet Protocol

FTF-IND-F0107

Iain Davidson
Networking Business Development

Alexandra Dopplinger
Industrial Segment Manager, Robotics and Automation

June 2012

Session Overview

Session Presenters

- Alexandra Dopplinger
  - Industrial Segment Manager, Robotics and Automation
- Iain Davidson
  - Networking Business Development

Session Objectives

- Select best processors and platform solutions for applications needing EtherCAT protocol

Agenda

- EtherCAT® Protocol Introduction
  - Industrial Protocol Market Overview
  - How EtherCAT works
- Programmable Logic Controller Reference Platform
- Summary

Industrial Network Protocol Applications

Energy

Generation

Transmission

Distribution

Factory

Production

Facility
Monitoring

Switchgear

Transport

Rail Systems

Mobility and
Logistics

Industrial
Vehicles

Buildings

Control

Elevators

HVAC

Infrastructure

Water
Treatment

Oil and Gas

M2M
Communication

Industrial Control and Networking

Industrial Protocols for Different Applications

Target Applications

- Motor drives
- Motion control
- Synchronized servos

- Conveyor belts
- Picker arms
- PLCs, I/O Control
- Valves

- Sensors
- Data scanner
- Inventory management

Protocols

IRT
Deterministic
< 1 µs jitter
< 1 ms cycle time

PROFINET · EtherCAT · PROFIBUS · CIP Sync · CAN

RT
Deterministic
Jitter matters for sync
1 to 100 ms cycle time

PROFINET · EtherCAT · PROFIBUS · CIP Sync · CAN

NRT
Non-deterministic
Jitter doesn't matter
> 100 ms cycle time

PROFINET · EtherCAT · PROFIBUS · EtherNet/IP · Modbus-IDA · CAN

IEEE® 1588 Precision Time Protocol
VERY jitter sensitive; cycle time does not matter

freescale.com/IndustrialNetworking

Most Significant Industrial Protocols

Organization	Members	Protocols	Physical Interface	Installed Nodes*
EtherCAT Technology Group ethercat.org	>1975 vendors Beckhoff, Omron, ABB, NI, Schneider, Yaskawa	EtherCAT®	10/100 Ethernet	Not published
PI PROFIBUS · PROFINET PROFIBUS and PROFINET International profibus.com	>1400 vendors Siemens, GE, ABB, Schneider, Fanuc, Molex	PROFINET • PROFINET RT • PROFINET IRT	10/100/Gb Ethernet	3M 43% CAGR Dec/10
		PROFIBUS	RS-485	35M 13.4% CAGR Dec/10
ODVA Open DeviceNet Vendors Association odva.org	>250 vendors Rockwell, Schneider, Bosch Rexroth, Cisco	EtherNet/IP™ • CIP™ Sync • Device Level Ring	10/100/Gb Ethernet	3M Jan/11
		DeviceNet™	CAN	?

*Source: PTO, Oct/11

Single-processor Industrial Protocols Solutions
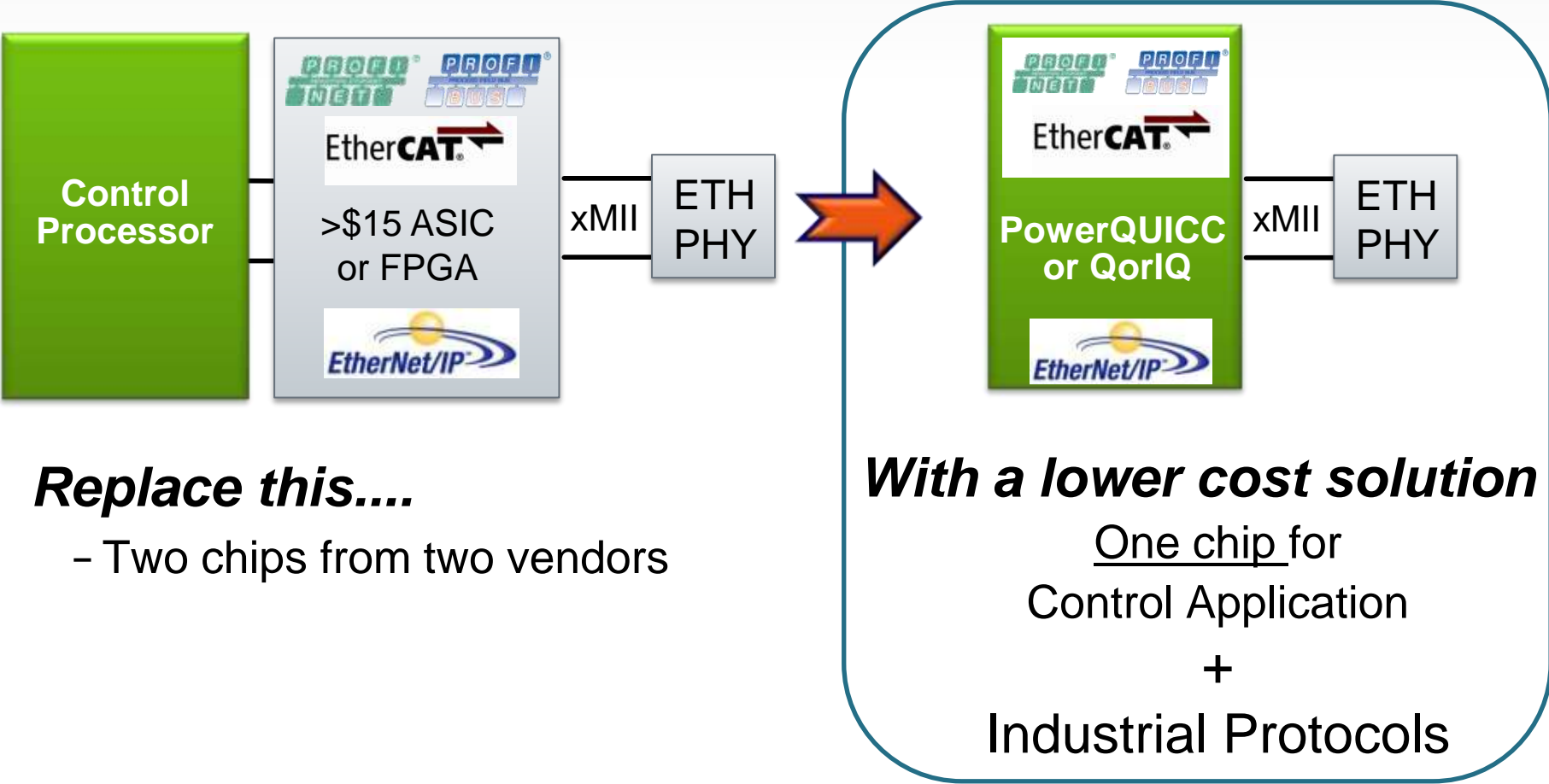
Replace this....
– Two chips from two vendors

With a lower cost solution
One chip for
Control Application
+
Industrial Protocols

freescale™

Freescale Industrial Protocol Stack Partners

	Protocol	ColdFire, ColdFire+	i.MX, Kinetis	QorIQ, PowerQUICC
Industrial Ethernet	IEEE® 1588	IXXAT	IXXAT	IXXAT
	PROFI NET	molex	molex	molex
	EtherNet/IP	RTA molex	RTA molex	RTA molex
	EtherCAT	acontis technologies	acontis technologies	.kønig acontis technologies
	Modbus-IDA	RTA IXXAT	RTA IXXAT	RTA IXXAT
	POWERLINK	IXXAT	IXXAT	IXXAT
Fieldbus	PROFI BUS			Technologie Management Gruppe DOGAV
	DeviceNet™	RTA IXXAT	RTA IXXAT	RTA IXXAT
	CAN	RTA IXXAT	RTA IXXAT	RTA IXXAT

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EtherCAT Technology Group (ETG)

Largest Fieldbus Organization	Widely-used for Synchronized Infrastructure Networks	EtherCAT is an International Standard (IEC, ISO, SEMI)

• Founded by Beckhoff in Nov/03
 	
• 1975 members in >50 countries
	• Factory and process automation
	
	• Energy generation and distribution
	
	• Transportation and traffic management
	
	• Building control
	   • Elevators, alarms, access
	
	• Entertainment
	   • Amusement rides, lighting
		• Real-time performance and flexible topology
		   • High-precision device synchronization
		   • Over 10/100 Ethernet
		• Eliminates need for switches and hubs
		   – One master can support up to 20k slaves
		• Existing application software runs over EtherCAT
		   – CANopen, SERCOS, TwinCAT

Freescale EtherCAT Status

History

- Apr/10: Freescale joined EtherCAT Technology Group
- Jun/10: First EtherCAT demo and training sessions
  - QNX / Koenig
  - Green Hills / acontis / IXXAT
- Reference platforms, webinars, training, press
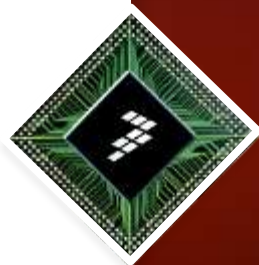
Joint Reference Platforms

- MPC8536 PowerQUICC processor
  - QNX Neutrino® RTOS
  - Koenig EtherCAT software
  - Koenig PCI card with Beckhoff ASIC
    - EtherCAT Layer 2 ASIC for slave
- P2020 QorIQ dual-core processor
  - Green Hills Integrity® RTOS
  - acontis EtherCAT master software
- i.MX28 applications processors
  - Green Hills Integrity RTOS
  - acontis EtherCAT master software

freescale.com/ethercat

How EtherCAT Works

June 2012

EtherCAT Industrial Ethernet
www.ethercat.org

Characteristics

- One version for all applications
  - TwinCAT, CANopen and SERCOS application layers
- Master with many slave devices
  - Full duplex data
 - 10/100 Ethernet with standard IEEE® 802.3 frames

Advantages

- Highly deterministic
  - Cycle time <50 µs
- Flexible topology
  - 100BaseT has good robustness/EMC
  - LVDS/E-Bus has low robustness/EMC
- Simple to implement and maintain

Disadvantages

- Slaves need high-cost ASIC or FPGA
  - Standard Ethernet interface latency too high
- No gigabit Ethernet
- Technology defined and controlled by Beckhoff

EtherCAT Structure

Master

Slaves

Tx

Rx
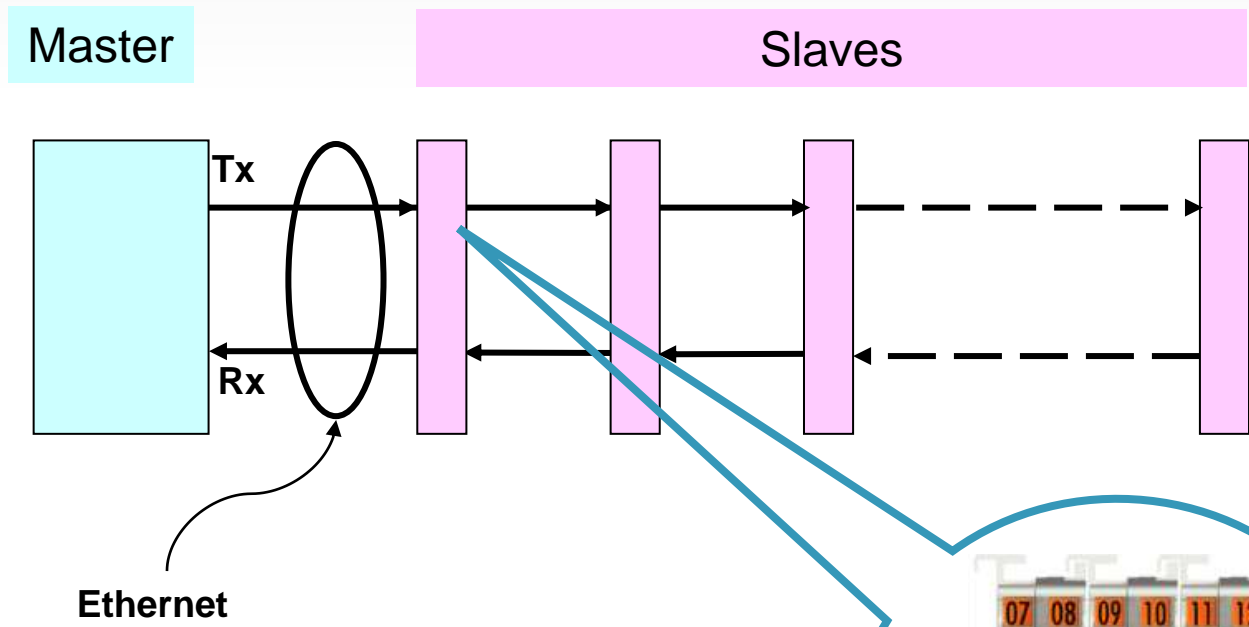
Ethernet

- Slave devices network with a master in line or ring topology
  - Data from each device extracted and packed into Ethernet data packet that traverses the entire ring
  - Devices pass messages through master before sending to another device
  - Separate "e-bus" eliminates 1 µs delays in each slave

07 08 09 10 11 12

E1 E2

From the master

To the master
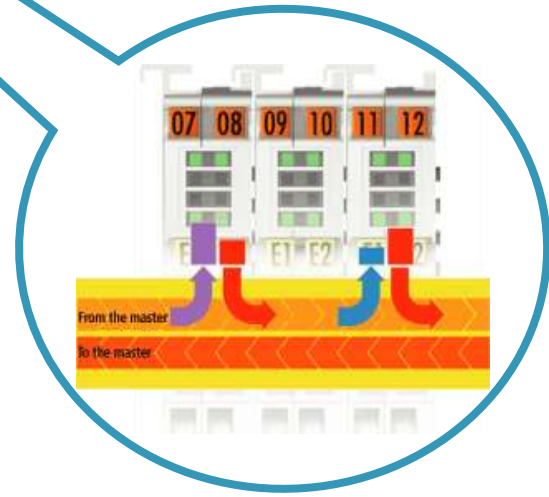
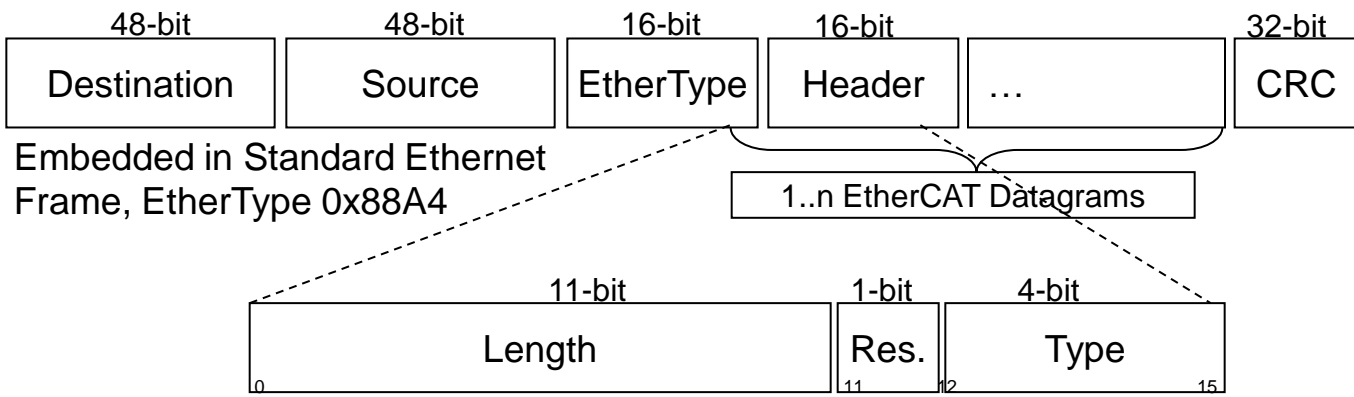# Functional Principle is Ethernet On-The-Fly
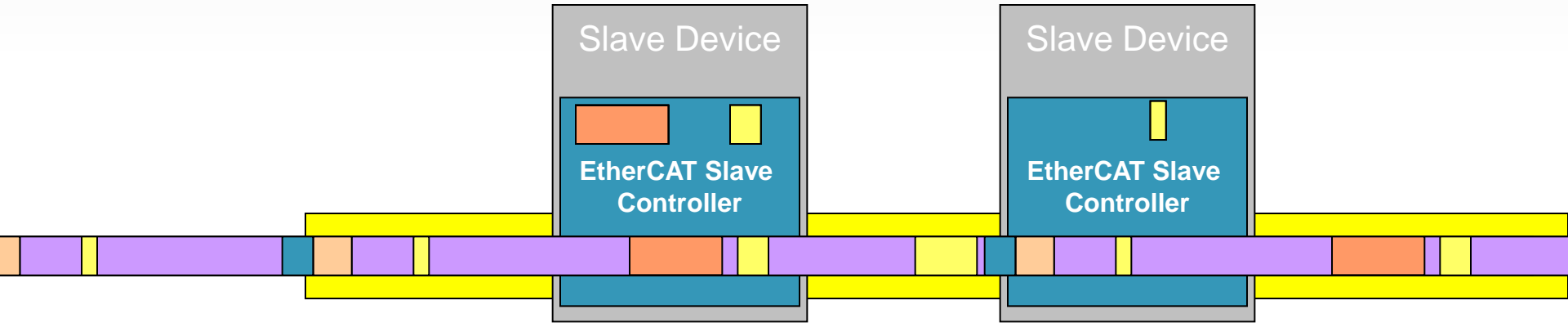
- Process data extracted and inserted on-the-fly
- Process data size per slave almost unlimited
  - 1 bit…60 Kbyte, if needed using several frames
- Compilation of process data can change in each cycle
  - e.g. ultra short cycle time for axis, and longer cycles for I/O update are possible
- In addition asynchronous, event-triggered communication

EtherCAT Format

- EtherCAT uses standard Ethernet frames (IEEE 802.3)
- Master is Ethernet MAC without co-processor or special hardware
  - Fully transparent for other Ethernet protocols
- Internet technologies (TCP/IP, FTP, Web server, etc.)
  - Does not restrict real-time capabilities, even with 100 µs cycle time
  - No large time gaps for rare traffic needed
- Full tool access to devices at real-time operation – with and without TCP/IP

48-bit	48-bit	16-bit	16-bit		32-bit
Destination	Source	EtherType	Header	…	CRC

Embedded in Standard Ethernet
Frame, EtherType 0x88A4

1..n EtherCAT Datagrams

11-bit	1-bit	4-bit
Length	Res.	Type

0 · · · 11 · 12 · · · 15

EtherCAT Development Steps

1. Select device @ freescale.com/EtherCAT
2. Engage with stack vendor to port stack (possibly to port your application)

    3. Stack vendor port EtherCAT to device and OS (2-5 days)
    4. Stack vendor training to port your application (2-5 days)
    5. You or stack vendor to port your application (5-8 weeks typical)

        5. Pre-test and debug at stack vendor lab (1-2 weeks)
        6. Test at Beckhoff lab and receive test report (1-2 days)

            7. EtherCAT certificate

Evaluate ½ month	Develop 2 months	Test ½ month	Certify (optional) 1 month

Programmable Logic Controller Reference Platform

Programmable Logic Controller Reference Platform with EtherCAT® Master

Designs ← → Run Time

Development Environment

- IEC 61131 / IEC 61499 — ISaGRAF
- EtherCAT Configure — .konig

Port

Programmable Logic Controller
- User Application
- PLC Run Time — ISaGRAF
- EtherCAT Stack — .konig
- Neutrino RTOS — QNX
- QorIQ Hardware — freescale™

Ethernet

Port · Port · Port

DEVICE (Slave) — Port · Port
DEVICE (Slave) — Port · Port

EtherCAT.

PLC – EtherCAT Demo

Windows PC | **TWR-1025** | **Beckhoff** | **A another**

Development Environment
- Off Line Tools
  - App Code
  - Libraries
  - GUI / Compiler Configure
- Windows OS

PLC
- PLC Application
- PLC Run Time
- Protocol Stack
- OS
- Drivers
- Port | Port

Ethernet

DEVICE
- DEVICE Application
- Application Interface
- Protocol Stack
- Service Framework
- Drivers
- Port | Port

EtherCAT.

DEVICE
- DEVICE Application
- Application Interface
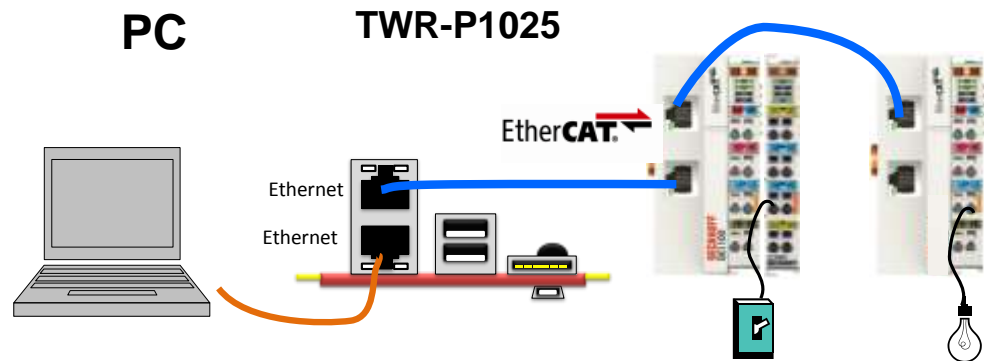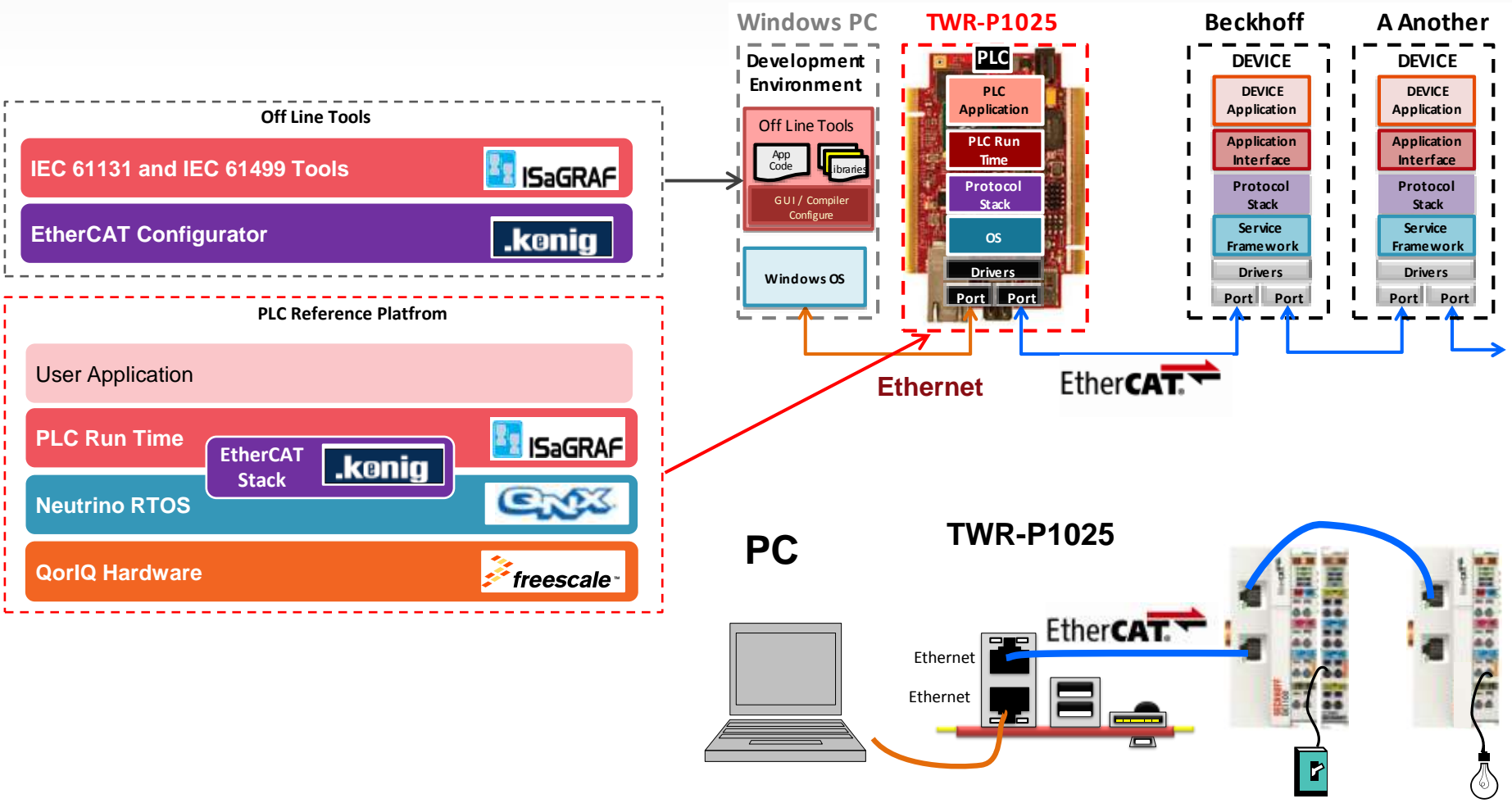- Protocol Stack
- Service Framework
- Drivers
- Port | Port

Allows a user to:

1. Build a simple application
2. Configure the network
3. Run the application
4. **In a time frame of ~10 to 15 minutes**

PC   **TWR-P1025**

EtherCAT.

Ethernet
Ethernet

Programmable Logic Controller Reference Platform

PLC EtherCAT Solution Partners

Pre-integrated, certifiable
EtherCAT Master solution

- Koenig-KPA www.koenig-pa.de
  - EtherCAT Master and Slave stack
  - EtherCAT services and tools

- QNX Software Systems www.qnx.com
  - IEC 61508 SIL 3 certified Neutrino® RTOS
  - Operating system development tools

- Freescale www.freescale.com/ethercat
  - QorIQ and PowerQUICC processors
  - Evaluation and development tools and hardware with Linux OS or MQX RTOS

freescale.com/ethercat

QNX Software Systems

QNX Software Systems is a leading supplier of middleware, development tools, real-time operating system software and services for both general embedded and life-critical systems

- More than 30 years of service
- Headquarters in Ottawa, Canada
- Global supplier to Cisco, Delphi, General Electric, Siemens, Thales and many other leaders
- Technical support centers: USA, Europe, Japan
- Freescale products supported
  - QorIQ, PowerQUICC and i.MX processors
- Contact Romain Saha
  - rsaha@qnx.com, +01 613-271-9217
- More info at www.qnx.com

Technology provider for:
- IEC 61508 SIL 3 certified Neutrino® RTOS
- Extensive middleware support includes EtherCAT Master, PROFINET (planned)
- Full development lifecycle support with highly-integrated Momentics® development suite

QNX: 32+ Years of Industrial Automation Leadership: 100s of Industrial OEM Customers Globally

The Market for QNX RTOS was built on Industrial Automation

- Safe, secure architecture field proven in many segments
- Intuitive POSIX API model, stable, compact, clean IP
- Extensive Eclipse-based Multi-core aware Development Tools
- Unmatched HMI Framework
- IEC 61508 SIL3 Safety Certification, Support & Services
- Extensive ecosystem of value-add 3rd Party products

Industrial Customer Base

QNX roots are in industrial built over 30 years for 100's of customers, and have been used in applications ranging from factory automation, to power, to transportation.

QNX microkernel architecture

- Microkernel has the fewest possible components within it

- BSP, networks stacks, drivers ... are not bound into microkernel

- Faults are contained so that it affects only the faulty component – networks stacks, drivers ...

- Failed components can be dynamically and gracefully recovered while the system continues to operate

- Same version of microkernel for both certified and non-certified applications
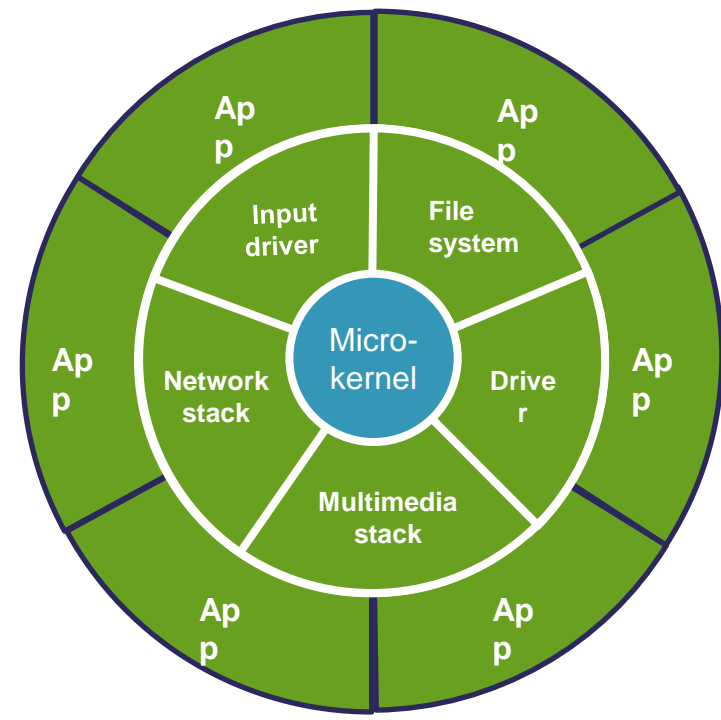
The QNX Microkernel Advantage ?

1. Provides protection and isolation for safety-critical components resulting in highest reliability

2. Facilitates co-existence of components with different Safety Integrity Levels, reducing R&D costs

3. Simplifies and reduces the costs related to the construction of the safety case.

4. QNX's Adaptive Partitioning Solution (APS) technology guarantees system integrity

5. Reduces development and certification costs as one version of OS and BSP supports both certified and non-certified products

6. Reduces development and certification costs and future proofs platform decisions as same version of IEC 61508 SIL3 certified OS and BSP also provides **Multicore** support

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Koenig Prozessautomatisierungs GmbH (KPA)

Koenig-KPA is a German-based provider of EtherCAT protocol stacks, configuration tools and services

- Established 1986 in Feucht, Germany
  - Joined ETG 2004
  - 60+ employees
    - Feucht, Germany (near Nuremberg)
    - Associated company "Visutech" in Minsk, Belarus
  - Distribution partners: RADIC Technologies, Steinhoff, easiTEC S.r.l., Micronet
- Freescale products supported
  - QorIQ and PowerQUICC processors
- Contact Gerhard Spiegel
  - gerhard.spiegel@koenig-pa.com
  - Phone: +49 (9128) 725 652 www.koenig-pa.de

EtherCAT Specialties
- KPA Studio EtherCAT
  - configuration & diagnostics tool
- KPA Master EtherCAT
  - master stack for various OS
- KPA Slave EtherCAT
  - slave stack for various OS
- KPA Slave Tester EtherCAT
  - slave tester tool
- KPA EtherCAT Boards
  - PCI & PC104 slave boards

KPA EtherCAT Solutions

- **KPA Studio EtherCAT**

  A Windows-based configuration & diagnostics tool based on .NTE Technology

- **KPA Master EtherCAT**

  Master stack for various operating systems

- **KPA Slave EtherCAT**

  Slave stack for use with or without an OS
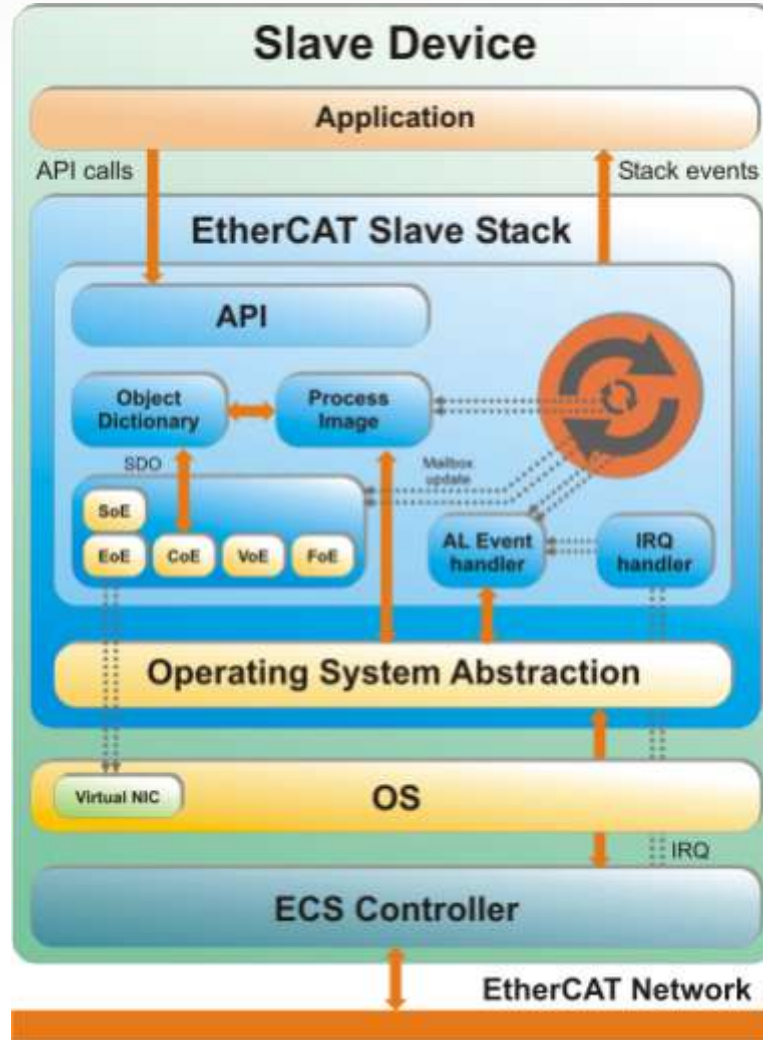
- **KPA Slave Tester EtherCAT**

  Slave testing tool

- **KPA EtherCAT Boards**
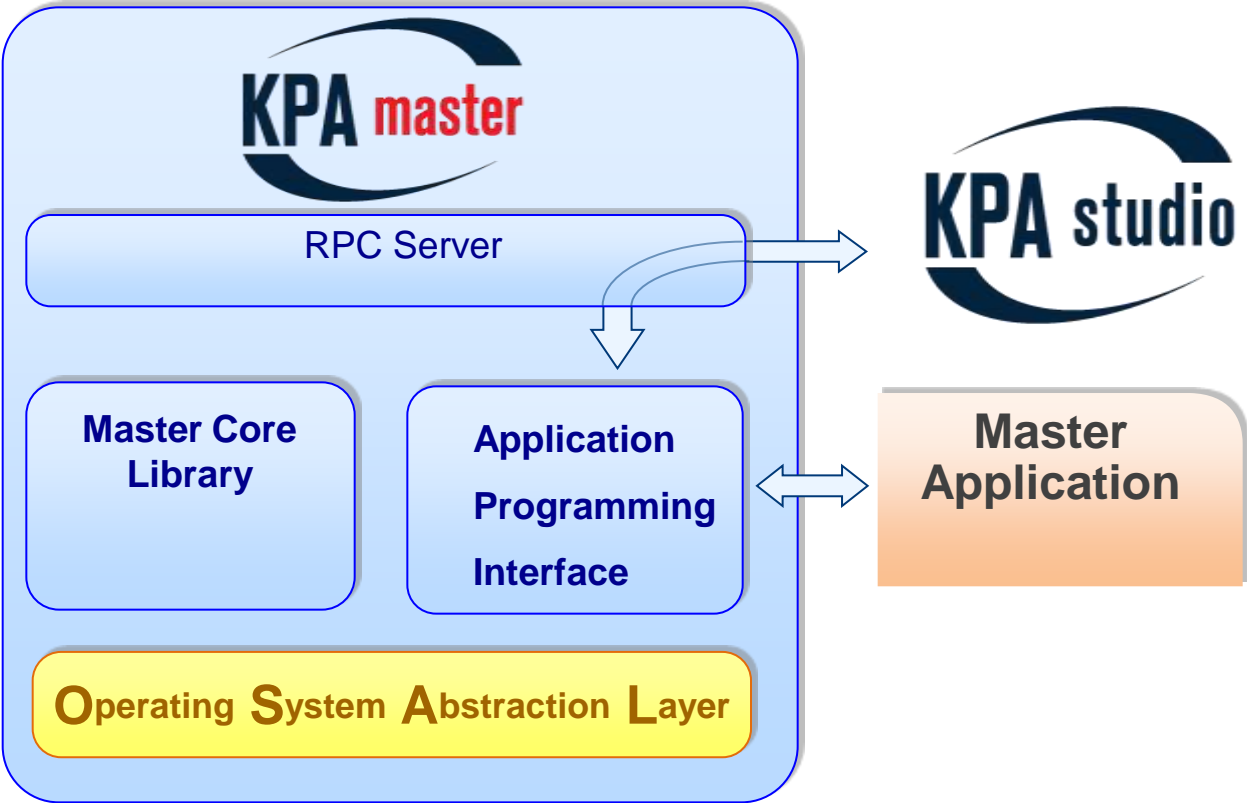
  PCI & PC104 slave boards

KPA Slave EtherCAT Architecture

Supporting various OS and RTOSs including **QNX Neutrino**

KPA Master Architecture

Same API for Studio and Application

KPA master

RPC Server → KPA studio

Master Core Library

Application Programming Interface ⟷ Master Application

Operating System Abstraction Layer

KPA master

freescale™

ISaGRAF Technology

ISaGRAF Workbench
IEC 61131 and IEC 61499
Development environment

Controller Firmware

"C" Code compiled to native code for the P1025 controller and the QNX OS

TIC Code

Process Automation Controller

User application compiled by the WB and downloaded as binary code

ISaGRAF Integration

There are two main parts for the ISaGRAF integration

ISaGRAF Firmware integration
- Adapt ISaGRAF Firmware to QNX
- Realise communication between ISaGRAF firmware and EtherCAT master stack

QNX 6.5

KPA master

ISaGRAF Workbench
- Integrate the KPA configuration tool inside the ISaGRAF Workbench

KPA studio

KPA Studio Integration into ISaGRAF 6 Workbench

- Permits users to configure an EtherCAT network
- Allows users to discover an existing EtherCAT network
- Has the capability to go online and manage the EtherCAT master
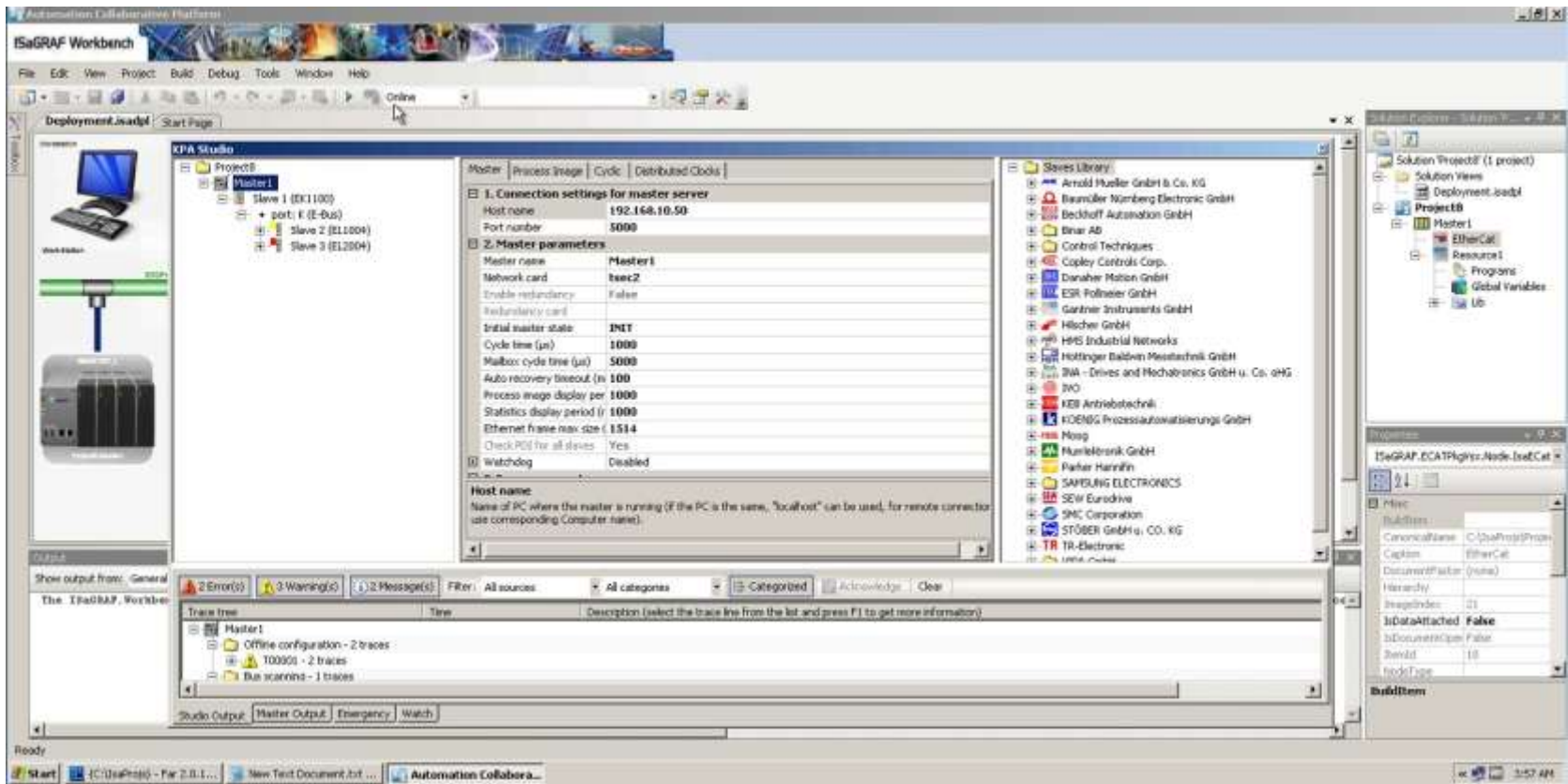
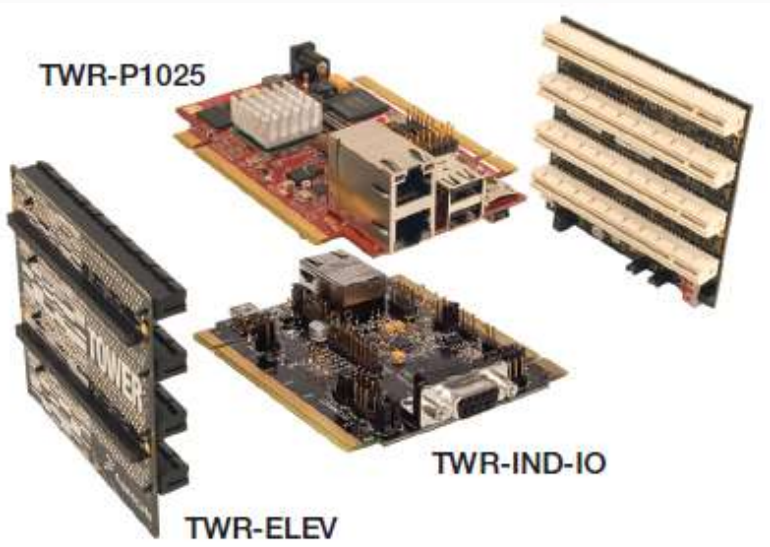# Rapid Prototype Tower System TWR-P1025-KIT

freescale.com/TWR-P1025

TWR-P1025-KIT, $299

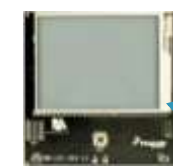**TWR-P1025**

TWR-IND-IO

RS485

TWR-ELEV

TWR-P1025-KIT includes
schematics and gerber files

optional, not in TWR-P1025-KIT

TWR-LCD

HMI

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Controller Module: TWR-P1025
QorIQ P1025 Controller Module

TWR-P1025

QorIQ P1025 Processor
- Dual e500 core processors running 533 MHz, 2558 DMIPS
- 266 MHz protocol engine
- DDR2/3 (32-bit w/ ECC)
- 3x 10/100/1000 Ethernet controllers
- Dual PCI Express® 1.0a controllers
- USB 2.0 OTG
- SD/SDIO/MMC

MSRP: $199 USD
Available Now

- **Hardware:**
  - QorIQ P1025 dual-core processor
  - JTAG 14-pin debug header
  - 512 MB of DDR3 memory
  - Boot from NOR flash
  - Two RGMII GbE interfaces
  - One PCIe interface x1 (mini-PCIe+USB)
  - Two USB 2.0 interfaces
  - Two UART interfaces (via mini-USB)
  - One accelerometer (on I^{2}C)
  - QE UART header (provides RS485 connectivity via interface card)

- **Software:**
  - Linux OS
  - MQX RTOS
  - CodeWarrior IDE
  - Support for 5x end applications out of the box
  - 100% compliant with Tower infrastructure

- **freescale.com/TWR-P1025**

TWR-P1025 Memory and Interfaces

P1025 Memory
- – DDR3 512MByte
- – NOR Flash 64MByte

Connectors
- – 1 x USB (2x) UART to USB
- – 2 x RJ45 10/100/1000 Ethernet
- – 2 x USB 2.0 (Hub)
- – 1 x Micro PCIe
- – 1 x IEEE1588 Header
- – 1 x +5V Barrel connector

Elevator Connections
- – 1 x MII 10/100 Ethernet
- – 1 x RMII 10/100 Ethernet
- – 2 x Serial
- – 1 x SPI (2 x Chip selects)
- – 2 x I²C
- – 1 x Parallel Bus (LB/LCD)
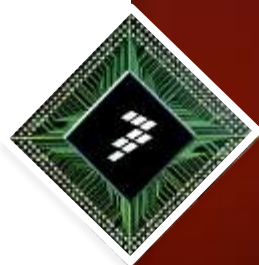- – 1x PCIe (x1)
- – 1 x SGMII 10/100/1000 Ethernet
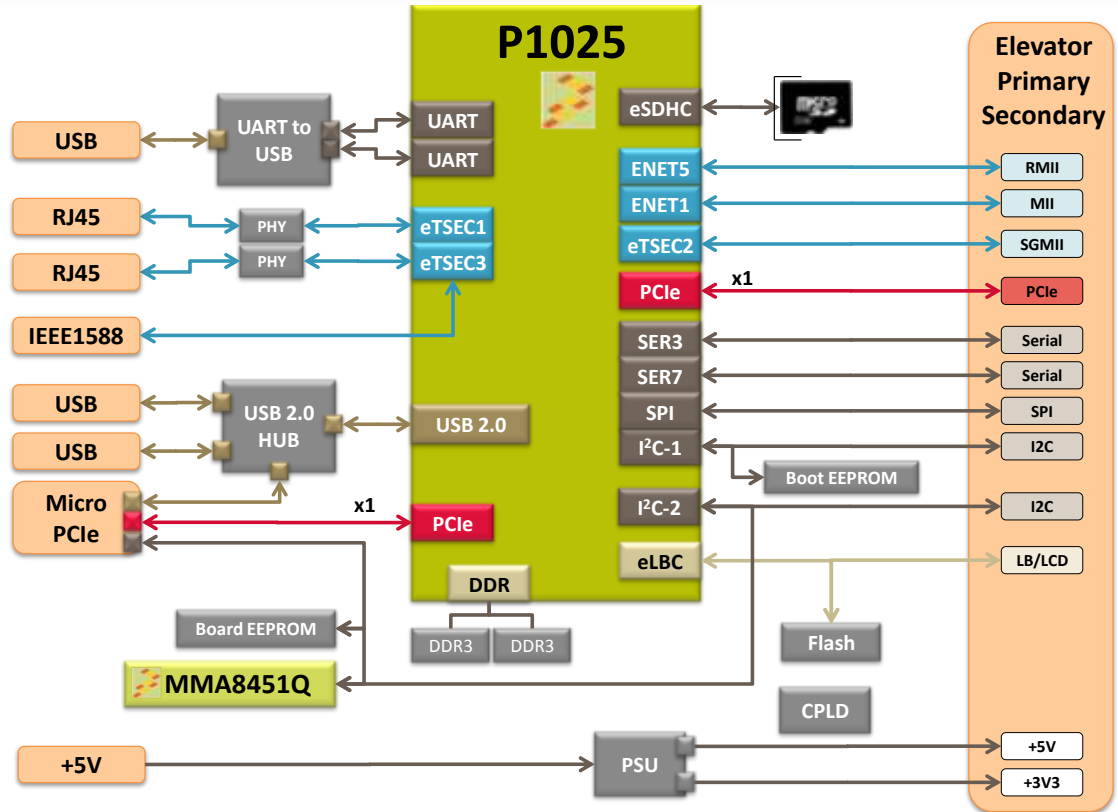
PCIe and SGMII on Edge Connectors requires Elevators that support SERDES

FTF | **FREESCALE** TECHNOLOGY **FORUM**
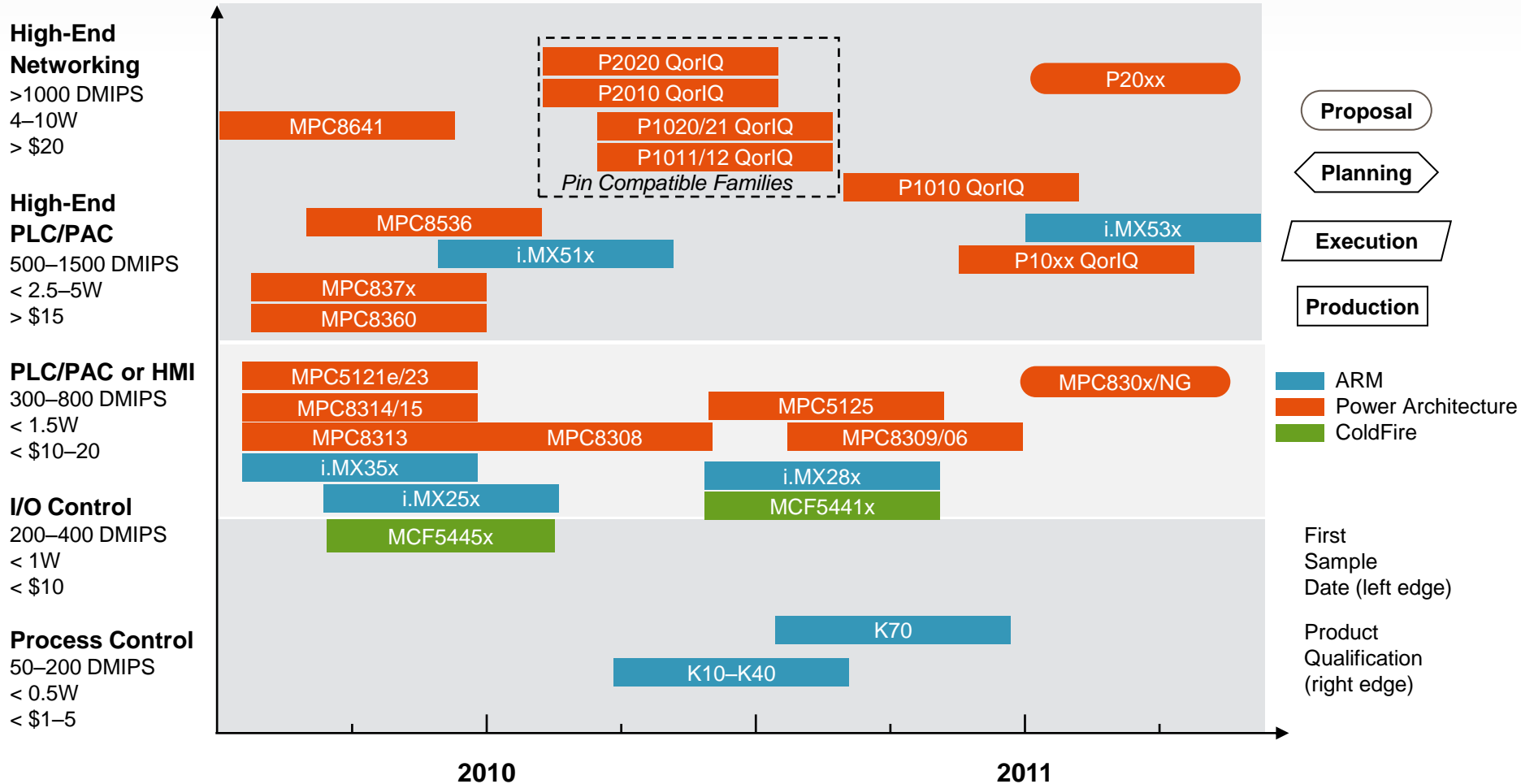POWERING INNOVATION

Other EtherCAT Solutions

June 2012

Single-Processor Protocol Solutions for PROFINET, EtherNet/IP™ and EtherCAT® Master

High-End Networking
>1000 DMIPS
4–10W
> $20

High-End PLC/PAC
500–1500 DMIPS
< 2.5–5W
> $15

PLC/PAC or HMI
300–800 DMIPS
< 1.5W
< $10–20

I/O Control
200–400 DMIPS
< 1W
< $10

Process Control
50–200 DMIPS
< 0.5W
< $1–5

P2020 QorIQ
P2010 QorIQ
P1020/21 QorIQ
P1011/12 QorIQ
Pin Compatible Families

P20xx

MPC8641

P1010 QorIQ

MPC8536

i.MX53x

i.MX51x

P10xx QorIQ

MPC837x

MPC8360

MPC5121e/23

MPC830x/NG

MPC8314/15

MPC5125

MPC8313   MPC8308   MPC8309/06

i.MX35x

i.MX28x

i.MX25x

MCF5441x

MCF5445x

K70

K10–K40

Proposal

Planning

Execution

Production

■ ARM
■ Power Architecture
■ ColdFire

First Sample Date (left edge)

Product Qualification (right edge)

2010   **2011**

QorIQ and PowerQUICC Network Processors

- Industry-leading integrated control and network processors
  - Single core @ 800 MHz <3 Watts
  - Eight cores @ 1.5 GHz/core <30 Watts
  - Twelve 64-bit cores @ 2.0 GHz/core 50 Watts
    - 10/100/1000 Ethernet, CAN, UART, PCI, PCI Express®, USB, SPI, GPIO
   - Integrated security, secure boot, anti-tamper

- Industrial qualification and long product life
  - Operates in harsh environments from -40°C to +85°C
  - Included in product longevity program

Starts <US$8! (SRP)

BUILT ON 7 Power

P1012

PowerQUICC I

PowerQUICC II PRO

PowerQUICC II

Pin-compatible solutions up to 50,000+ MIPS with leading MIPS/Watt

freescale ™

Dual-core P2020 QorIQ Control Processor
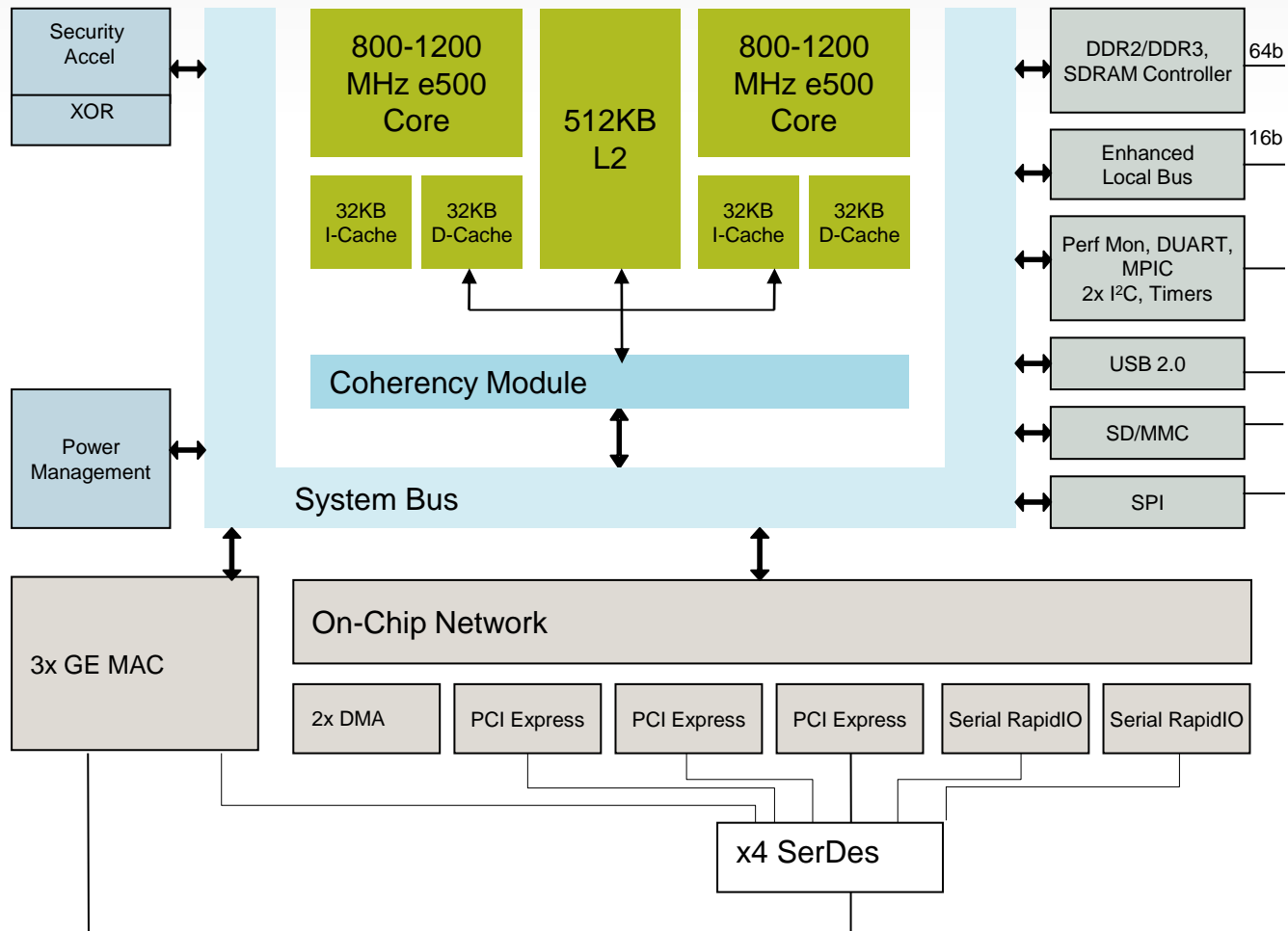
One chip runs PROFINET + Control Application <3W @ 800 MHz

MPC8309 Industrial Network Processor

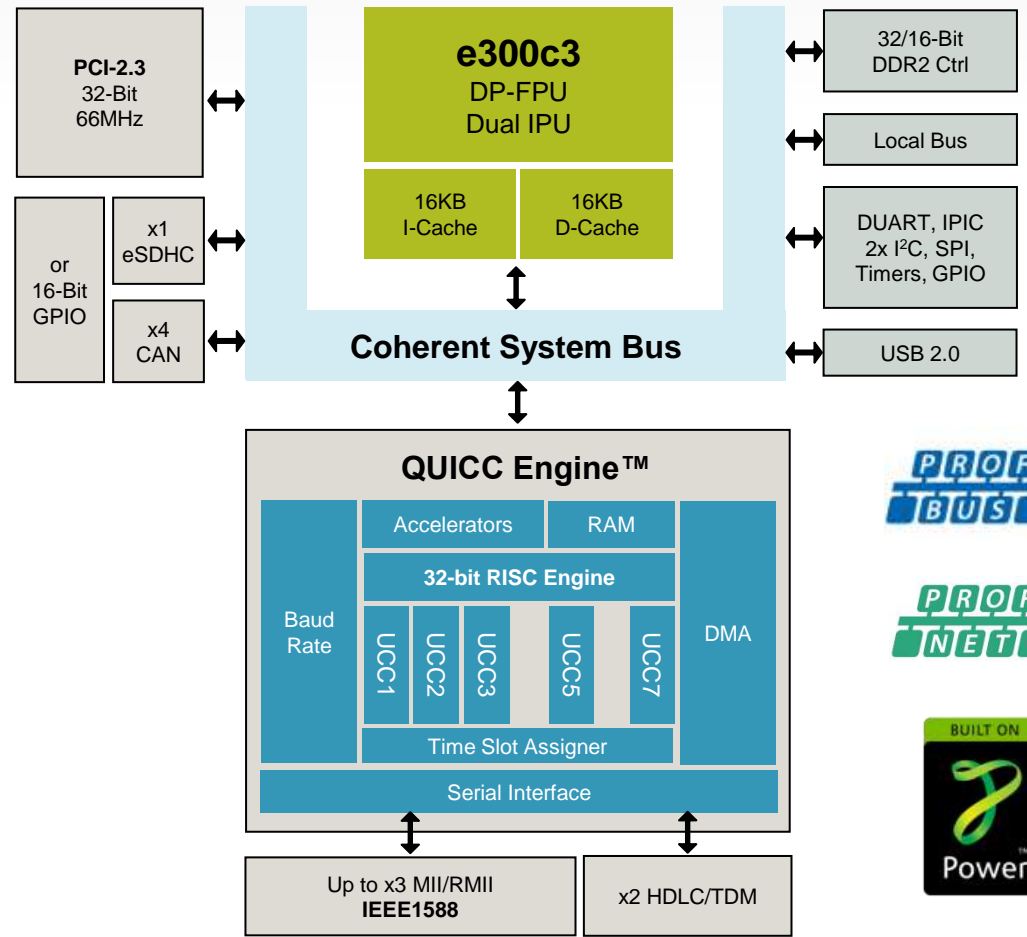**Performance and Power Consumption:**

- 835 DMIPS @ 417 MHz Below 1.6 watts

Price:

- Starts at $7.87
- SRP @ 10K units

Package:

- 489 MAPBGA
- 19 mm x19 mm
- 0.8 mm pitch

835 MIPS, DP FP, 3x Ethernet, 4x CAN, 2x PROFIBUS, 4x UART, PCI

i.MX Processors for Industrial Control and HMI

- Evolved from handheld battery-operated devices
  - Single core @ 800 MHz <1 Watt
  - 10/100 Ethernet, CAN, UART, SPI, SDIO, USB
  - On-chip power management to increase battery life

- Market-leading human machine interface
  - High resolution color LCD controller with touch screen
  - Hardware accelerated video processing and graphics rendering
  - Camera interface

- Industrial qualification and long product life
  - Operation in harsh environments from -40°C to +85°C
  - Included in product longevity program

ARM®

PROFI® NET

Starts <$10! (SRP)

Pin-compatible solutions up to 1600 MIPS <1W

freescale™

Kinetis Microcontrollers for Industrial Control

MCU Family	USB OTG (FS & HS)	Dual CAN	Ethernet (IEEE 1588)	Encryption (CAU+RNG)	LCD (Segment/Graphics)	NAND Flash Controller (120MHz, 150MHz, only)	Floating Point Unit (120MHz, 150MHz, only)	Hardware Tamper Detect	DRAM Controller (256 pin MAPBGA only)
K70 Family 512KB-1MB, 196-256pin	●	●	●	●	●	●	●	●	●
K60 Family 256KB-1MB, 100-256pin	●	●	●	●		●	●	●	●
K50 Family 128-512KB, 64-144pin	●		●	●	●				
K40 Family 64-512KB, 64-144pin	●	●			●				
K30 Family 64-512KB, 64-144pin		●			●				
K20 Family 32KB-1MB, 32-144pin	●	●				●	●		
K10 Family 32KB-1MB, 32-144pin		●				●	●		

PROFI NET®

First available broad-market MCU samples based on ARM® Cortex™-M4!

Solutions @ freescale.com/IndustrialNetworking

Freescale ▶ Industrial Network and Field Bus Protocols

Industrial Network and Field Bus Protocols

Factory automation controllers, industrial drives, power grid management, health care facilities, and transportation systems demand reliable, real-time, and deterministic network connections. These may use traditional field bus protocols, such as PROFIBUS®, DeviceNet™, CAN®, InterBus and Foundation Field Bus, or newer industrial Ethernet protocols, which include PROFINET®, EtherNet/IP™, Powerlink, EtherCAT®, Modbus® TCP and SERCOS III. Many Freescale processors can bridge between different industrial protocols.

Featured Protocols

- Controller Area Network
- EtherCAT
- EtherNet/IP™
- IEEE 1588®
- ETHERNET Powerlink
- PROFIBUS
- PROFINET®

Design Resources

- Getting Started
  - Industrial Control and Networking Trends and Roadmap
  - Industrial Network Protocols (Part 1)
  - PROFINET, EtherCAT® and EtherNet/IP™ Panel Discussion
- Technologies, Standards & Protocols
  - Product Longevity
- Design Partners
  - acontis technologies GmbH
  - DeCay Systems

(KPA)

Featured Products

▶ P1021 and P1012
QorIQ Multiprotocol Communications Processors

▶ i.MX28
ARM9™ Based solutions for industrial

Train...

Indus...
- Ele... Fre...
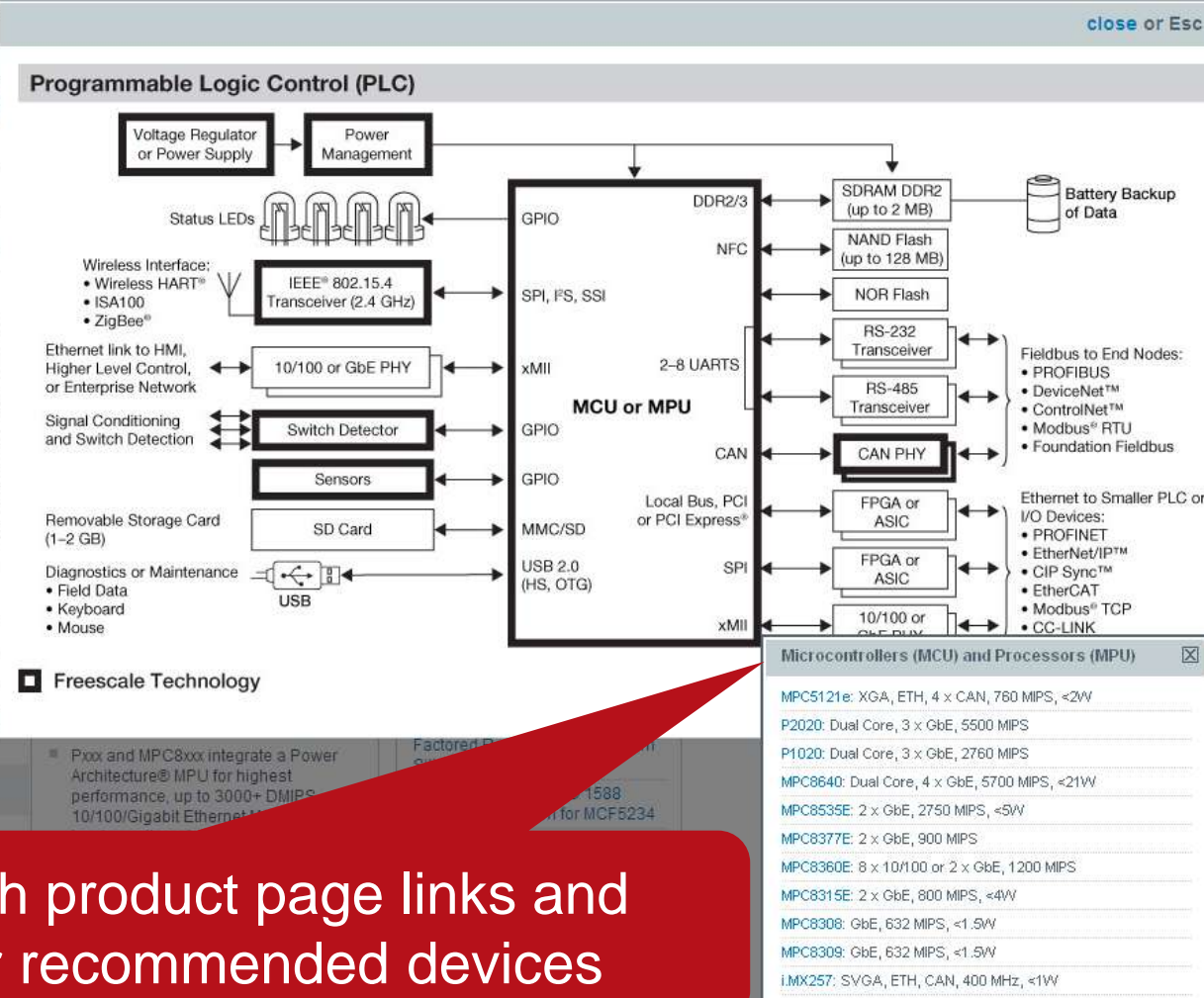- SP... an...
- Ha... ETG...

Read More

Why so many industrial protocols?

freescale.com/CAN
freescale.com/EtherCAT
freescale.com/EtherNetIP
freescale.com/IEEE1588
freescale.com/PROFIBUS
freescale.com/PROFINET

Today's session will link here

Solutions @ freescale.com/IndustrialNetworking

Block diagram with product page links and differentiators for recommended devices

Related Sessions and Demos

Sessions

- IND-F0103 Industrial Control and Networking Trends and Roadmap
- Industrial Network Protocols:
  - SEG-F0135 Part 2: Smart Energy and Factory Automation Solutions on QorIQ Processors
  - SEG-F0101 Part 3: IEEE® 1588 Power Profile
  - IND-F0070 Part 4: PROFIBUS and PROFINET on the Industrial Tower System
  - NET-F0102 IEEE® 1588 Precision Time Protocol for Telecom and Networking Applications
  - SEG-F0198 Smart Energy 2.0: Protocols and Their Applications

Tech Lab Demos

Partners

- QNX: Programmable Logic Controller Reference Platform
- Oracle: JAVA Technology Enables Reliable Industrial Automation

Freescale

- PROFIBUS Certified on QorIQ and PowerQUICC Processors
- Metropolitan Area Network: Enabling Smart Cities
- IEEE 802.15.4 Wireless Reference Platforms

Session Closing

- **Freescale meets EtherCAT master requirements**
  - Scalable system performance from 200 to 50,000+ MIPS
  - Reduced system cost with integrated processors starting <$10
  - Fanless operation at 85°C: 1600 MIPS <1W, 3500 MIPS <5W
- **Strong EtherCAT partner solutions and tools**
  - Protocol support from KPA and acontis
  - Industrial-grade safety-certified OS from QNX and Green Hills
- **Rugged devices with long life and reliability**
  - Industrial or automotive qualification for -40°C to +85°C ambient
  - Offer stability of 10 or 15 year product longevity statement

Thank-you for considering Freescale industrial solutions!

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