June 23, 2010

Industrial Network Protocols (Part 1)
FTF-IND-F0762

Alexandra Dopplinger – Industrial Segment Lead, Factory Automation & Drives
John Ralston – System Solutions Engineer, Networking Products Division
Session Introduction

► Presenters:

• **Alexandra Dopplinger, Freescale Semiconductor**
  • Global Industrial Segment Lead, Factory Automation & Drives
    • alex.dopplinger@freescale.com, +01 613-228-6825 (Ottawa, Canada)
  • Areas of expertise
    • Factory Automation & Drives market
    • Industrial protocols and industrial motor control

• **John Ralston, Freescale Semiconductor**
  • System Solutions Engineer, Networking Products Division
    • John.ralston@freescale.com, +01 613-228-6825 (East Kilbride, UK)
  • Areas of expertise
    • PowerQUICC® and QorIQ™ processors
    • Industrial and networking protocols

► Session Topics:
  • Industrial protocol support for all Freescale 32-bit processors
After completing this session you will be able to:

- Select the best Freescale processor for industrial Ethernet or Fieldbus connectivity
- Select the best Freescale partner solution for your industrial control or networking project
- Acquire software and hardware to implement industrial protocol solutions
Agenda

- Industrial protocol introduction
  - Industrial protocol overview
  - Freescale and protocol vendor support
    - PowerQUICC®, QorIQ™, i.MX, Kinetis and ColdFire® processors

- Industrial protocol description, solutions and enablement
  - Industrial Fieldbus Protocols
    - PROFIBUS, CAN® (CANOpen®, DeviceNet™), Modbus RTU
  - Industrial Ethernet Protocols
    - PROFINET, EtherNet/IP™, EtherCAT®, Modbus TCP
  - IEEE® 1588 Timestamp Protocol

- How to acquire industrial protocol software and hardware
Industrial Protocol Introduction

Industrial Protocol Overview and Support
### Most Significant Industrial Network Protocols

<table>
<thead>
<tr>
<th>Field Bus (Discrete or I/O oriented)</th>
<th>Industrial Ethernet*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROFIBUS</strong></td>
<td>Most popular fieldbus solution. 31M+ nodes installed; 24% CAGR (PTO 2010). Introduced by Siemens.</td>
</tr>
<tr>
<td><strong>DeviceNet</strong></td>
<td>CIP™ application layer on CAN. Very popular and still growing. Introduced by Rockwell.</td>
</tr>
<tr>
<td><strong>CANopen CAN</strong></td>
<td>Very popular SAE-sponsored standard but losing share in factory automation. Supported by many.</td>
</tr>
<tr>
<td><strong>Modbus-IDA</strong></td>
<td>Modbus RTU is a widely used fieldbus solution, but losing share. Introduced by Schneider.</td>
</tr>
<tr>
<td></td>
<td>2M+ PROFINET nodes installed; 40% CAGR (PTO 2010). Introduced by Siemens.</td>
</tr>
<tr>
<td></td>
<td>CIP application layer on Ethernet. Growing fast. Introduced by Rockwell.</td>
</tr>
<tr>
<td></td>
<td>May dominate due to technology and ease of use. Predict &gt;1 Mu by 2011. Introduced by Beckhoff.</td>
</tr>
<tr>
<td></td>
<td>Modbus TCP/IP is a widely used Ethernet solution, but growing less rapidly in many markets (Schneider)</td>
</tr>
</tbody>
</table>

► **Standard** Ethernet TCP/IP protocols most common of Ethernet-based nodes
  - 6.5 Mu Ethernet TCP/IP nodes installed by 2006; 24 Mu by 2011; CAGR 24.3%

► Many deterministic industrial Ethernet protocols use a form of IEEE® 1588
  - For clock synchronization through the Ethernet network

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IEEE® 1588
Industrial Network Protocol Usage

Target Applications
- Motor Drives
- Motion Control
- Synchronized Servos
- Conveyor belts
- Picker arms
- PLCs, I/O Control
- Sensors
- Data scanner
- Inventory Management

Protocols
- **IRT**
  - Deterministic
  - < 1 ms Cycle Time
  - < 1 us Jitter

- **RT**
  - Deterministic
  - 1 to 100 ms Cycle Time
  - Jitter matters for Sync

- **NRT**
  - Non-deterministic
  - > 100 ms Cycle Time
  - Jitter doesn’t matter

Number of Applications

IEEE® 1588 Precision Time Protocol
- VERY Jitter sensitive; Cycle Time does not matter
QorIQ™ multicore processors

- Evolution from PowerQUICC® family
  - Industry-leading communications and integration
- Dual core @ 800 MHz/core <5 Watts
- Eight cores @ 1.5 GHz/core <30 Watts

Hybrid software simulation environment and debug tools

- VortiQa solutions give production-ready software
- CodeWarrior multicore development environment

45nm high-performance SOI technology

Scale from 100 to 20,000+ MIPS with the best MIPS/Watt
i.MX Targets Industrial Control and HMI

► Up to 1600 MIPS with high integration <0.5W to 1W
  • Reduced system cost and complexity
  • 10/100 Ethernet, CAN, UART, SPI, SDIO, DDR2, USB PHY
  • Integrated video and graphics processors offload CPU
  • Robust on-chip security for tamper-resistance
  • Power management for increased battery life

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

► Scalability and software reuse
  • ARM9, ARM11 and Cortex-A8 core options
  • Pin-compatible migration in product families
  • WinCE and Linux OS board support packages

► Industrial qualification and long product life
  • Operation in harsh environments from -40C to +85C
  • Some products qualified for automotive use
  • Included in Product Longevity program

<0.5W to <1W

Starts <$10! (SRP)
Processors for Industrial Control, Networking and HMI

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

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

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

I/O Control
- 200 – 400 DMIPS
- < 1 W
- < $10

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

Power Architecture
- Committed
- Proposed
- ARM
- ColdFire

Pin Compatible Families
- K60 - Ethernet
- K40 + LCD + USB
- K30 + LCD
- K20 + USB
- K10 – Mixed Signal

Pin-兼容Kineto Families
- QF – Secure & Low Pwr
- QH – Low Power

Greater Flash Size
Multi-Core
Higher Performance

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## Industrial Protocol Stack Support

<table>
<thead>
<tr>
<th>Industrial Protocol</th>
<th>ColdFire, ColdFire+, Kinetis</th>
<th>i.MX</th>
<th>QorIQ and PowerQUICC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IEEE® 1588</strong></td>
<td><img src="ixxat.png" alt="Ixxat" /></td>
<td><img src="ixxat.png" alt="Ixxat" /></td>
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<tr>
<td><strong>EtherCAT</strong></td>
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<td><img src="acontis.png" alt="Acontis" /></td>
<td><img src="konig.png" alt="Konig" /></td>
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<tr>
<td><strong>Modbus-IDA</strong></td>
<td><img src="ironhorse.png" alt="Ironhorse" /></td>
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IXXAT is a German-based leading supplier for embedded communication systems for industrial and automotive applications

- Established 1987 with 20+ profitable growth years
  - 2009 sales of $16.9M worldwide
  - 80 employees (most are developers)
    - Weingarten, Germany; New Hampshire, USA
  - Represented globally in >15 countries

- Freescale products supported
  - QorIQ™ and PowerQUICC® processors
  - ColdFire® MCUs and MPUs
  - i.MX applications processors

- Contact Bill Seitz
  - seitz@ixxat.com, 603-471-0800 X102
  - 120 Bedford Center Rd., Bedford, NH 03110

- Download free evaluations from www.ixxat.com

Protocols supported:
- IEEE® 1588
- PROFINET
- EtherNet/IP™
- EtherCAT®
- Modbus
- POWERLINK
- CAN® – CANOpen®, J1939, DeviceNet™
<table>
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<tbody>
<tr>
<td><strong>IEEE® 1588</strong></td>
<td>Available</td>
<td>In development</td>
<td>Available</td>
</tr>
<tr>
<td><strong>EtherCAT®</strong></td>
<td>Master – In development</td>
<td>Master – In development</td>
<td>Master - Available</td>
</tr>
<tr>
<td><strong>EtherNet/IP</strong></td>
<td>Available</td>
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<td>In development</td>
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</tbody>
</table>
acontis technologies GmbH

acontis is a German-based leading supplier for EtherCAT Master technology
► Established 1999 with global distribution
  • Used by many Blue Chip companies
  • Located in Weingarten, Germany
► Freescale products supported
  • QorIQ™ and PowerQUICC® processors
  • ColdFire® MCUs and MPUs
  • i.MX applications processors
► Contact: Stefan Zintgraf
  • s.zintgraf@acontis.com, +49 751 56030 30
  • Haehnlehofstr. 5, D-88250 Weingarten, Germany
► Download free evaluations from

AT-EM EtherCAT Master Stack
► Full EtherCAT compliance to support all EtherCAT protocols and slaves
► Powerful feature packs
  • Hot connect, redundancy, distributed clocks
► Sophisticated diagnostic features
Koenig Prozessautomatisierungs GmbH (KPA)

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

- Established 1986 in Feucht, Germany
  - Joined EtherCAT Technology Group (ETG) 2004
  - 60+ employees
    - Feucht, Germany (near Nuremberg)
    - Associated company “Visutech” in Minsk, Belarus
  - Distribution partners
    - RADIC Technologies, Stenihoff, 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
Real-Time Automation (RTA)

RTA is a USA-based leading supplier of industrial protocols and solutions
► Established 1989 by John Rinaldi
  • 10 employees in Milwaukee WI, USA
  • Focus on networking, control & developers
  • "Media is irrelevant“

► Freescale products supported
  • QorIQ™ and PowerQUICC® processors
  • ColdFire® MCUs and MPUs
  • i.MX applications processors

► Contact John Rinaldi
  • rinaldi@rtaautomation.com, 414-453-5100
  • 150 S. Sunnyslope Road Suite 150, Brookfield, WI 53220

► Download evaluation information from
  www.rtaautomation.com

Protocols supported:
- PROFINET
- PROFIBUS
- EtherNet/IP™
- Modbus
- CAN® - CANOpen®, DeviceNet™
<table>
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<tr>
<td>PROFI®</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>EtherCAT®</td>
<td>Available - Slave</td>
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</tr>
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<td>CAN</td>
<td>Available</td>
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</table>
DoGav Systems Ltd

DoGav is an Israel-based software solution provider with more than 10 years experience developing production-ready microcode for PowerQUICC processors

► Established 1984
  • 5 employees in Petach Tikva, Israel
  • USA sales based in New York, USA

► Freescale products supported
  • QorIQ™ and PowerQUICC® processors
  • 10+ years providing microcode design services for PowerQUICC CPM and QUICC Engine™ Controller
  • 25+ years collaboration with Freescale and Motorola

► Contact David Gabbay
  • dg@dogav.net, +972-3-933-7197
  • 18 Nahum St., Petach Tikva, 49247 Israel
  • www.dogav.net

Protocols supported
  – PROFIBUS DPv1
    – Master and Slave
National Semiconductor

- National Semiconductor is a USA based supplier of industrial Ethernet PHYs
  - Represented globally
  - Contact Alex Tan, alexander.tan@nsn.com, 408-721-5561
  - www.national.com/ethernet

- National Semiconductor DP83640 Precision PHYTER® Ethernet PHY
  - Adds hardware timestamp for IEEE® 1588
  - Sync to 3.5 ns with one sigma standard deviation

- Evaluate PHYTER with Freescale ColdFire® processors
  - Freescale M5234BCCKIT evaluation kit
  - Freescale M52259EVB evaluation kit
  - National Semiconductor DP83640T-EVK
  - Netburner MOD5234-1588IR
Industrial Protocol Descriptions, Solutions, and Enablement

Industrial Fieldbus Protocols
PROFIBUS, CAN (CANOpen, DeviceNet™), Modbus RTU
PROFIBUS & PROFINET International (PI)

► Oldest fieldbus organization, founded 1989
  • Open standards for factory automation, process, safety, drives, motion

► Largest fieldbus organization
  • 1400+ member companies, including all major PLC/DCS vendors
    • 500+ specialists in 50+ working groups
  • 27 Regional PROFIBUS Associations
  • 40 certified competence centers

► Largest global installed base
  • 31.4M+ installed PROFIBUS nodes
  • 2.1M+ installed PROFINET nodes

Source: PTO, June/10
World’s leading fieldbus
- 31+ million installed PROFIBUS nodes
- Open standard started by Siemens in 1989

RS485-based differential physical signaling
- PROFIBUS ASIC contains stack and MAC

Multiple PROFIBUS versions
- DP, FMS, PA

Supports up to 127 nodes at 1000 Mbps
- 244 Bytes/Message, 12 Mbps

Master/Slave “polling” type network
- UART protocol used (start+8bit+parity+stop)

Advantages
- Very fast; highly deterministic
- ASIC based with RS485 differential physical signaling
- ASIC implements communications stack
- Universal acceptance in Europe

Disadvantages
- Higher cost than other fieldbus options
- No bus power
- Traditional master/slave model

www.profibus.com
<table>
<thead>
<tr>
<th>OSI Model</th>
<th>Data Unit</th>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Layers</td>
<td>Data</td>
<td>Application</td>
<td>Communication Language</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presentation</td>
<td>Not used</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Session</td>
<td>Not used</td>
</tr>
<tr>
<td></td>
<td>Segments</td>
<td>Transport</td>
<td>Not used</td>
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<tr>
<td>Media Layers</td>
<td>Packets</td>
<td>Network</td>
<td>Not used</td>
</tr>
<tr>
<td></td>
<td>Frames</td>
<td>Data Link</td>
<td>Physical Addressing (MAC and LLC)</td>
</tr>
<tr>
<td></td>
<td>Bits</td>
<td>Physical</td>
<td>Two-wire Interface</td>
</tr>
</tbody>
</table>

PROFIBUS Uses Only OSI Layers 1-2 and 7
Two PROFIBUS Implementation Options

► QUICC Engine-based PowerQUICC MPC8569, MPC830x, QorIQ P1012/21
  • Implement L2 in on-chip programmable QUICC Engine
  • DoGav Systems provides L2 microcode
  • To achieve 12Mbps UART speed with 16x RX oversampling, UCC frequency of 192 MHz is required

► Lower cost with medium Risk
  • Customers must integrate their PROFIBUS stack with layer 2

► Any processor plus ASIC
  • Need ASIC (2 vendors)

► Higher cost
  • ASIC >$15-$20
  • Special PHY and connectors

► Low Risk
  • RTA reference schematics available
  • Customers must understand Object Model
How to Acquire PROFIBUS Solutions

► PROFIBUS applications processor: Buy from Freescale

► PROFIBUS layer 2 link-layer microcode
  • Now:
    ▪ License and support from DoGav
  • Coming soon:
    ▪ Included with Freescale evaluation board support package (BSP)
    ▪ Free download from www.freescale.com (password protected)
      – Same click-through software license as other BSPs
    ▪ Supported by Freescale (with assistance from DoGav)

► PROFIBUS Layer 7 application software options
  • Use your own, integrated with the DoGav layer 2 microcode
    ▪ Contract directly with DoGav for custom software development
  • Buy from protocol stack vendor
    ▪ Real-time Automation, IXXAT, Softing, etc.
    ▪ Contract directly with DoGav for custom software development
  • Supported by stack vendor
Processors for Single-chip PROFIBUS

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

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

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

I/O Control
200 – 400 DMIPS
< 1 W
< $10

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

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Fieldbus – CANopen and CAN

► Industrial automation protocol based on Controller-Area-Network (CAN)
  • Developed by CAN-in-Automation (CIA) user group as a standardized solution for distributed automation systems
    - SAE sponsored CAN Protocol J1939

► Master/Slave connection set
  • Cyclic/COS data transfer modes
  • Peer-to-peer messaging (not connection-based)
  • Object oriented
  • Extensive parameter group data definitions

► Advantages
  • Widely available with stacks and tools for consumer, medical and industrial apps
  • Exchangeability and interoperability of devices from different manufacturers
  • DeviceNet and CANopen share same physical signaling, MAC and bitwise arbitration collision control

► Disadvantages
  • Complex specification
  • Largely broadcast data at various rates
  • Little conformance testing available

www.can-cia.de/canopen
www.sae.org/products/j1939.htm
CANopen Reference Model

Application

Device Profile for Generic I/O Modules
CiA DS 401, V 2.1

Device Profile Drives & Motion Control
CiA DSP 402, V2.0

Interface and Device Profile for IEC 61131-3 Programmable Devices
CiA DSP 405, V2.0

CANopen Application Layer and Communication Profile (CiA DS 301, V 4.02) and Framework for CANopen Managers and Programmable CANopen Devices (CiA DSP-302, V 3.3)

CAN Data Link Layer (ISO 11898)

CAN Physical Layer (ISO 11898)

CAN Bus
CANopen Device Model

Communication Interface
- Server SDOs
- Client SDOs
- RPDOs
- TPDOs
- NMT, SYNC, Emergency, Time Stamp Messages

Object Dictionary
- Logical addressing scheme for accessing communication and application parameters, as well as data and functions

Application Process
- Device functionality
  - Functions
  - Data
  - Parameters

CAN Bus

I/O Signals
Fieldbus – DeviceNet™

- Supported by non-profit Open DeviceNet™ Vendors Association (ODVA)
- DeviceNet™ is Common Industrial Protocol (CIP) Application Layer on CAN
- Two types of messages – Explicit and I/O
  - Object-based representation
- Trunk line with drops good for conveyer line
  - Supports 64 nodes with multiple masters
  - Node removal/insertion under power

Advantages
- Standard set of services and messaging
- I/O messaging is simple data exchange
  - Both sides agree on message contents
- Explicit messaging transfers specific data
  - Packet contains message identification
  - Cable includes power and data

Disadvantages
- Controlled by ODVA

www.odva.org
DeviceNet™ Object Model

DeviceNet Network

Connection Object

Assembly Object

- ASCII Data Object
- Modbus Master Object
- Modbus Slave Object
- Analog IO Object
- Discrete IO Object
- DeviceNet Object
- Identity Object
Object Representation

<table>
<thead>
<tr>
<th>Application Layer</th>
<th>Semi Devices</th>
<th>Pneu Valve</th>
<th>AC Drives</th>
<th>Position Controllers</th>
<th>Other Profilers</th>
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Application Object Library

CIP Application Layer Explicit, I/O, Routing

Transport Data Link

<table>
<thead>
<tr>
<th>DeviceNet</th>
<th>ControlNet</th>
<th>Encapsulation</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>UPD</td>
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<td>IP</td>
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Future ?

Physical Layer

<table>
<thead>
<tr>
<th>CAN</th>
<th>ControlNet</th>
<th>Ethernet</th>
<th>Future ?</th>
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</tbody>
</table>
**CAN and DeviceNet Implementation**

- **Source code integrated with CAN Controller**
  - Organize target data as an Object Model

- **Low cost**
  - One-time source code cost
  - Minimal hardware costs (low-cost xcvr)

- **Low risk**
  - RTA reference schematics available
  - Isolation complicates design
  - Customers must understand Object Model

- **Any processor plus MCU with CAN**

- **Higher cost for higher performance**
  - Wouldn’t normally do this unless second processor needed for specific capabilities

- **Low Risk**
  - RTA reference schematics available
  - Customers must understand Object Model
CANopen and DeviceNet Support over CAN

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

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

PLC/PAC and 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

► These devices have on-chip CAN controller
  • Add CAN PHY MCZ338997
► Other devices support CAN by connecting external CAN controller

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► 1960s technology with no formal certification
► Well-defined, concise instruction set
  • Simple, concise communication strings
  • Devices modeled as Registers and Coils
► Same application layer supports both Modbus TCP and Modbus RTU
► RS232/422/485 physical layer
  • 1 Master, 254 Slaves

► Advantages
  • Clear/concise command set
  • Low-cost implementation
  • Open and widely distributed
    • Large installed base
    • Free tools on the web

► Disadvantages
  • Low speed - not real time
  • Source/destination network model
  • Difficult to troubleshoot

► Key Points
  • All devices in the system should support Modbus
  • Handy configuration tool
  • Most customers can use it
  • Easy access to gateways for other networks
Modbus RTU and TCP Implementation

- Same application layer supports both Modbus TCP and Modbus RTU
  - Source code integrated directly with Freescale OpenTCP and MQX

- Low cost
  - One-time source code cost
  - No additional hardware cost
    - RS-485 driver for Modbus RTU
    - Ethernet PHY for Modbus TCP

- Low risk
  - RTA reference schematics available
  - Customers must organize data properly as Registers & Coils
### Modbus RTU Support

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

#### PLC/PAC and HMI
300 – 800 DMIPS  
< 1.5 W  
< $10 - 20

#### I/O Control
200 – 400 DMIPS  
< 1 W  
< $10

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

<table>
<thead>
<tr>
<th>Product</th>
<th>2009 or earlier</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pin-compatible Kinetis Families</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>K60 - Ethernet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K40 + LCD + USB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K30 + LCD</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>K20 + USB</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>K10 – Mixed Signal</td>
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<tr>
<td>128-512KB Flash</td>
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<tr>
<td>≤64KB Flash</td>
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<tr>
<td>1MB Flash</td>
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<tr>
<td><strong>Pin Compatible Families</strong></td>
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<td></td>
</tr>
<tr>
<td>QF – Secure &amp; Low Pwr</td>
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<td></td>
</tr>
<tr>
<td>QH – Low Power</td>
<td></td>
<td></td>
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<tr>
<td><strong>Greater Flash Size</strong></td>
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<td></td>
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<tr>
<td><strong>Multi-Core</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Higher Performance</strong></td>
<td></td>
<td></td>
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Industrial Ethernet Protocols

PROFINET, EtherNet/IP™, Modbus TCP, EtherCAT
Common Traits of Industrial Ethernet Protocols

- **Customers love Ethernet**
  - Commercial technology
  - Globally understood
  - Common network architecture

- **IT integration**
  - IP Functionality
  - Known physical layer
  - Low installation costs*

- **High speed**
  - Moves a lot of data

- **Integrated wired/wireless**
  - Many wireless options

- **Modular automation**

<table>
<thead>
<tr>
<th>Technology</th>
<th>PROFINET</th>
<th>EtherNet/IP™</th>
<th>Modbus TCP</th>
<th>EtherCAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Largest Supplier</strong></td>
<td>Siemens</td>
<td>Rockwell Automation</td>
<td>Schneider Electric</td>
<td>Beckhoff</td>
</tr>
<tr>
<td><strong>Multi-vendor Consortium</strong></td>
<td>Profibus International</td>
<td>ODVA</td>
<td>Modbus IDA</td>
<td>ETG</td>
</tr>
<tr>
<td><strong>Factory Automation</strong></td>
<td>PROFINET IO</td>
<td>CIP™</td>
<td>RTPS</td>
<td>Shared Frame</td>
</tr>
<tr>
<td><strong>High performance Motion</strong></td>
<td>PROFINET IRT (timestamp)</td>
<td>CIP Sync™ (IEEE 1588)</td>
<td>None</td>
<td>Shared Frame</td>
</tr>
<tr>
<td><strong>Standard IEEE 802.3 PHY MAC?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Master Yes</td>
</tr>
<tr>
<td></td>
<td>IRT requires ASIC</td>
<td>IEEE 1588 for some apps</td>
<td></td>
<td>Slaves need ASIC</td>
</tr>
</tbody>
</table>
10/100/1000 Ethernet – PROFINET

- Ethernet compliant for component-based automation
  - Configure with standard office tools like SNMP
  - Or continue using legacy PROFIBUS tools
  - Browser-based monitoring
  - Remote configuration and maintenance
  - Advanced security and wireless technology
  - Supports real-time IO, peer-to-peer communication, motion control, vertical integration, safety, security

**Advantages**
- PROFINET RT (Real-time) runs on any standard Ethernet hardware
- Supports existing legacy fieldbus systems
  - No need to obsolete existing equipment
  - PROFIBUS, DeviceNet™, Interbus, Modbus, AS-Interface, Foundation Fieldbus, IEC61158-2
- Very robust

**Disadvantages**
- Typically runs on high-performance 32-bit processor
- Uses large memory
- Complex to commission
- PROFINET IRT needs custom ASIC
PROFINET Supports Different Real-Time Requirements

Standard Communication
NRT

Factory Automation
RT

Motion Control Application
IRT

100ms
10ms
<1ms

TCP/IP

Real-Time:

Slide provided by IXXAT
**PROFINET Non-Real-Time (NRT) and Real-Time (RT)**

1. **Open TCP/IP channel**
   - Device parameterization
   - Reading of diagnostics data
   - Loading of interconnections
   - Negotiation of the communication channel for user data

2. **Real-time channel (RT)**
   - High-performance transmission
   - Cyclic data Event-controlled signals

<table>
<thead>
<tr>
<th>Criteria</th>
<th>NRT</th>
<th>RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle time</td>
<td>NRT 1 msec</td>
<td>250 µsec</td>
</tr>
<tr>
<td>Jitter</td>
<td>&lt;1 µsec</td>
<td>&lt;1 µsec</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>70</td>
<td>150</td>
</tr>
<tr>
<td>Simultaneously transferable TCP/IP data</td>
<td>9 MB/sec</td>
<td>6 MB/sec</td>
</tr>
</tbody>
</table>

Slide provided by IXXAT
PROFINET Isochronous Real-time (IRT)

- Isochronous means functionality delivered by each Ethernet frame occurs precisely at the same time for each cycle
  - For applications like motion control
  - 150 axes of motion possible
    - More than any other Ethernet solution

- Time slicing makes highly efficient use of standard Ethernet telegram
  - 250 ns response

- Customer ASIC required
PROFINET Implementation

- Any processor with standard Ethernet
  - Supports only PROFINET RT

- Lower system cost
  - MPU needs high performance and memory
  - Same software cost as ASIC option

- Higher risk
  - Complex source needs to be integrated into MPU by customer
  - Customers must understand Object Model

- Any processor plus ASIC (2 vendors)
  - ASIC supports PROFINET RT and IRT

- Higher system cost
  - ASIC >$18-$25
  - High cost source code

- Lower risk
  - Complex source already integrated in ASIC
  - Customers must understand Object Model
## PROFINET RT, EtherNet/IP, Modbus TCP Support

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

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

### PLC/PAC and HMI
- **300 – 800 DMIPS**
- **< 1.5 W**
- **< $10 - 20**

### I/O Control
- **200 – 400 DMIPS**
- **< 1 W**
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### Process Control
- **50 – 200 DMIPS**
- **< 0.5 W**
- **< $1 – $5**

---

**Power Architecture**
- **MCF5445x – Ethernet + USB**
- **MCF5225x – Ethernet + USB**
- **MPC551x**
- **MPC5604P**

**ARM**
- **MPC837x**
- **MPC8360**
- **i.MX51x**
- **i.MX25x**

**ColdFire**
- **P20xx QorIQ**
- **P10xx QorIQ**
- **P1011/12 QorIQ**
- **i.MX5xx**

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10/100/1000 Ethernet – EtherNet/IP™

► Defacto standard based on Rockwell CIP™
  • Client/server scanner/adapter model (like DeviceNet)
  • Certified by Open DeviceNet™ Vendor Association (ODVA)
    • More than 280 registered ODVA members

► Based on Ethernet IEEE 802.3 datalink/physical layers
  • CIP object-based representation
  • Encapsulation layer connects EtherNet/IP to standard TCP/IP and UDP/IP
  • Messages encapsulated with unlimited data length

► Advantages
  • Supports unlimited number of nodes
  • Application runs on standard TCP/IP
    • TCP for messaging, UDP for I/O
  • Standard set of services and messaging
  • Can be used in parallel with other Internet protocols, e.g. HTTP, FTP, SMTP, etc.
  • Easy configuration
    • TCP/IP address, input and output size

► Disadvantages
  • Needs RTOS and TCP/IP stack
  • 32-bit processors (50 MHz) recommended
  • Needs 32 to 256 KB RAM (# connections)
  • Needs 64 to 128 KB ROM (CIP Profile)
  • ODVA owns all the technology

www.odva.com
Common Industrial Protocol (CIP) Overview

User Device Profiles
- I/O
- Encoders
- Valves
- Drives
- SEMI
- Others

Application
- CIP Application Layer Application Object Library

Presentation
- CIP Data Management Services Explicit Messages, I/O Messages

Session
- CIP Message Routing, Connection Management

Transport
- DeviceNet Transport
- ControlNet Transport
- Encapsulation: TCP, UDP, IP

Network
- CAN CSMA/NBA
- ControlNet CTDMA
- Ethernet CSMA/CD

Data Link
- DeviceNet Physical Layer
- ControlNet Physical Layer
- Ethernet Physical Layer

Physical Link

Future: ???

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Data Link
- DeviceNet Physical Layer
- ControlNet Physical Layer
- Ethernet Physical Layer

Physical Link

Future: ???
Frame priorities

CIP Sync Frame with priority

Ethernet frame without priority

After passing the switch

Slide provided by IXXAT
EtherNet/IP object model very similar to DeviceNet

DeviceNet Object replaced by Ethernet and TCP/IP Object

Two message types:

- I/O messaging is simple I/O data exchange
  - Both sides agree on message contents
- Explicit Messaging is transfer of specific data
  - Packet contains message ID
EtherNet/IP Implementation

▶ Source code integrated with Ethernet Controller
  • Integrates directly with Freescale OpenTCP & MQX
  • Organize target data as an Object Model

▶ Low cost
  • One-time source code cost
  • No additional hardware cost

▶ Low risk
  • RTA reference schematics available
  • Customers must understand Object Model to organize data properly
Open defacto standard developed by Modicon in 1979
- Most widely used network protocol in industrial manufacturing
  - Over seven million nodes
  - Common denominator between disparate manufacturers

Master-slave/client-server communication
- Transfers discrete/analog I/O and register data

Same application layer supports both Modbus TCP and Modbus RTU

Key Points
- Coil register representation
- Small command set is easy to implement
- Both client/server available
- Supported by almost everyone

Advantages
- Very simple to implement
- Off-the-shelf tools
- Supported by many HMIs and PLCs

Disadvantages
- Not deterministic
- No bus power
- Traditional master/slave model
Modbus TCP Structure

- Operates on TCP/IP
- Only non real-time version is available
- Does not offer determinism

Slide provided by IXXAT
Modbus RTU and TCP Implementation

► Same application layer supports both Modbus TCP and Modbus RTU
  • Source code integrated directly with Freescale OpenTCP and MQX

► Low cost
  • One-time source code cost
  • No additional hardware cost
  ▪ RS-485 driver for Modbus RTU
  ▪ Ethernet PHY for Modbus TCP

► Low risk
  • RTA reference schematics available
  • Customers must organize data properly as Registers & Coils
EtherCAT Technology Group (ETG)

- ETG founded by Beckhoff
  - Germany, Nov/03

- By Apr/10, it had 1400 members from 48 countries
  - EtherCAT slaves
    - >50 vendors offer EtherCAT drives
    - >30 vendors offer I/O devices
  - EtherCAT masters
    - >70 vendors offer controllers
      - PLCs, PC-based controls, CNC and embedded controllers
      - Using more than 15 different real-time operating systems

- EtherCAT is emerging as very important for FA&D, industrial transportation and energy segments
  - Supported by our protocol partners IXXAT, Softing, RTA, and Koenig

- EtherCAT is an international standard (IEC, ISO and SEMI)
  - Sets new standards for real-time performance and topology flexibility
    - Meets or beats legacy fieldbus cost
    - Offers high precision device synchronization
    - Includes cable redundancy options
    - Supports functional safety (SIL3)
EtherCAT Customers

Omron
- Selected EtherCAT as next Motion Bus System, Nov/08
  - Servo motors, inverters, motion controllers, etc.
- Is promoting EtherCAT to be National Japanese Standard
  - Established EtherCAT test center in Kyoto, Nov/09
- Is translating entire EtherCAT specification into Japanese language
  - Along with large amounts of supporting documentation

National Instruments
- Hosted 1st North American EtherCAT plugfest in Austin, Sep/09
  - Dr. James Truchard, President, CEO and cofounder of National Instruments, opened the event

EtherCAT is being adopted by Industrial Drives Customers with >50% market share:
- ABB
- Toshiba Schneider
- Mitsubishi
- OMRON / Yaskawa
- SEW-Eurodrive, Vacon, Fuji Electric, Lenze, Hitachi, Grundfos, Danaher Motion, Parker Hannifin, Yokogawa Electric, ...

...AND Factory Automation Customers with >25% market share:
- Schneider Electric
- Mitsubishi
- OMRON
- Honeywell
- National Instruments
- Hirschmann, MOXA, Phoenix Contact, FESTO, Hilscher, Woodhead, KUKA Roboter, ...

...AND other significant Industrial Customers:
- Bosch, John Deere, Otis Elevator, Philips Healthcare, Samsung, ThyssenKrupp, ...
**ETHERnet for Control Automation Technology**
- Standard Ethernet IEEE 802.3 frames with real-time features
- Full duplex data transmission

**Slave devices network with a master in 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

**Advantages**
- Very simple to implement and use
- Supports daisy chain (line) topology
- Two different Ethernet PHYs may be used
  - 100BaseT has good robustness/EMC
  - LVDS/E-Bus has low robustness/EMC

**Disadvantages**
- Slaves must use ASIC or FPGA
  - Standard Ethernet interface latency too high
- No gigabit Ethernet support
- Technology defined/controlled by Beckhoff

**TwinCAT, CANopen, SERCOS application layers**
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

Slide provided by IXXAT
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

![EtherCAT Format Diagram]

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

Embedded in Standard Ethernet Frame, EtherType 0x88A4

1..n EtherCAT Datagrams

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

Type

Res.
EtherCAT Implementation

► EtherCAT master
  • Any processor with standard Ethernet

► Lower system cost
  • MPU needs high performance and memory
  • Same software cost as ASIC option

► Mild risk
  • Complicated source already integrated into MPU (but already done by partners!)

► EtherCAT slave
  • Any processor plus ASIC or FPGA
    • 2 vendors
    • ASIC supports EtherCAT layer 2

► Higher system cost
  • ASIC adds $5 - $15 to system cost

► Lower risk
  • Complicated source already integrated into ASIC
How to Acquire EtherCAT Solution

► EtherCAT applications processor: Buy from Freescale
  • Evaluation board and board support package available for Linux

► EtherCAT Master protocol software integrated with OS
  • Buy from protocol stack vendor and OS vendor
    ▪ Acontis or IXXAT with Green Hills INTEGRITY OS
    ▪ KPA with QNX Neutrino RTOS
  • Joint support by protocol and OS vendor
    ▪ OS vendors to offer board support package for selected Freescale evaluation platforms – P2020 is first one
      – Integration source code available for license from each vendor
    ▪ Contract custom software development from protocol vendor

Software integrated already
IEEE® 1588 Synchronizes Networked Clocks Over Ethernet

**NETWORK**

- **Grandmaster Clock**
  - Time = 9:04
  - Serves as timebase for the system

- **Slave Clock**
  - Time = 9:04

- **Slave Clock**
  - Time = 9:04
IEEE® 1588 Target Applications

► Factory automation
  • Sync sensors and actuators over single-wire distributed network to control automated assembly processes
    • CIP SYNC™ uses IEEE 1588

► Aerospace
  • Sync vehicle controls

► Test and measurement
  • Maintain accurate time sync with devices under test in many different operating environments
    • LXI consortium uses IEEE 1588

► Power line management
  • Sync across large-scale distributed power grid for smooth power transfer

► Networking and telecom
  • Precision time sync between communicating nodes

► FEMTO home base station
  • Lower cost time sync between communicating nodes

► Audio-video bridging (AVB)
  • Ensure customers don’t hear or see effects of packet delay or loss from Ethernet-connected speakers and monitors
    • IEEE 802.1AS AVB uses IEEE 1588
Why Timestamp Ethernet Packets?

► Everyone wants to use Ethernet for network communication
  • Globally well known and relatively cost-effective

► Ethernet was not designed for deterministic real-time applications
  • Test and measurement
  • Factory and process automation
  • Telecommunications networks
  • Streaming audio and video

► Step 1: Add timestamps to packets
  • Synchronize clocks on every network node

► Step 2: Overlay Ethernet with real-time deterministic protocols
  • Ensure/confirm data arrives on time
IEEE® 1588 Differentiators

- High clock sync accuracy
  - <1 microsecond

- Fast synchronization of networked clocks
  - <1 minute; typically <20 packets

- Minimal compute and network footprint
  - <1% CPU utilization

- Supports heterogeneous systems of clocks
  - Clocks with varying accuracy, resolution, drift, stability

- Easy configuration and operation by non-expert users
  - Low cost
IEEE® 1588 Synchronizing Clocks Across a Network

Master Clock

Slave Clock

Local Counter

SYNC

PTP Software

Local Counter

Clock Phase/Freq. Adjust

Clock Phase/Freq. Compare
Step 1: IEEE® 1588 Offset + Delay Measurement

For IEEE 1588 version 1:
- Sync and follow-up sent as multicast
- Sync intervals 1, 2, 8, 16 or 64 seconds
- Dedicates UDP port 319, 320 for messages

IEEE 1588 version 2 adds:
- Sync and follow-up sent as unicast
- Sync intervals <<1 second
- Additional message format/types

Equation 1:
\[ t_1 - t_0 = \text{offset} + \text{delay} \]
Step 2: IEEE® 1588 Offset + Delay Measurement

System A (Master)  
System B (Slave)

t3 = timestamp of delay_req msg received

delay_req msg

delay_resp msg (includes t3)

Equation 2:
\[ t_3 - t_2 = \text{delay - offset} \]

-> Action: PTP software adjusts slave clock offset

\[ t_2 = \text{timestamp of delay_req msg sent} \]
IEEE® 1588-2008 Version 2.2 Changes

- IEEE 1588-2008 released Jun/08
  - IEEE/IEC 61588-2008 later 2008

- Supports sub-nanosecond accuracy
  - Critical for some applications

- Supports shorter messages, unicast messaging, new messages (delay request) and message fields
  - Critical for control, telecom, and residential Ethernet

- Supports faster SYNC message rates (up to 1000 per second)
  - Requires “in-band” TX/RX timestamp to offload CPU
  - Critical for telecom, residential Ethernet, and many control applications

- Requires phase-aligned output pulse per second (PPS)
  - Enables relative accuracy measurements
  - Critical for all applications

- Supports Transparent Clocks
  - Used in residential Ethernet and telecom to correct timestamps, sometimes on the fly

- Optionally supports SHA-1/2 authentication of PTP messages
  - Critical for telecom and other applications where messaging occurs over public networks
Hardware Timestamp is Better than Software Timestamp

**Master Clock**
- PTP
- UDP
- IP
- MAC
- PHY

**Slave Clock**
- PTP
- UDP
- IP
- MAC
- PHY

**Network**

- IEEE® 1588 PTP Code
- Network protocol stack and OS
- Timestamp generation / message detection
- MII / GMII
- PHY

Hardware TS removes milliseconds of variation introduced by protocol stack jitter

Now, it's ...

... 9:25 !

Minimize impact of protocol stack jitter by generating timestamps as close to the physical interface boundary as possible

Hundreds of nanoseconds to microseconds of variation introduced by repeater and switch jitter

Milliseconds introduced by router jitter

– Other techniques must be used to reduce this effect

OK, thanks 9:25 !

Hardware TS removes milliseconds of variation introduced by protocol stack jitter
IEEE® 1588 Hardware Timestamp in Ethernet MAC

- **Nanosecond accuracy**
- **HW timestamp available on PowerQUICC® and QorIQ™ processors**
  - Planned for future products
- **Supports 10/100 and Gigabit Ethernet**
- **1st demo at Embedded Systems Conf Apr/07**
  - < +/- 40 ns between two MPC8360 connected back-to-back
IEEE® 1588 Hardware Timestamp in Ethernet PHY

- **Nanosecond accuracy**
- **Supports any processor with Ethernet interface**
  - PowerQUICC® processor
  - QorIQ™ processor
  - ColdFire® MCU
  - mobileGT® platform
  - i.MX processor
- **National Semiconductor PHYTER® supports only 10/100 Ethernet**
  - No Gigabit Ethernet yet
- **1st demo at Embedded World Feb/08**
  - < +/- 40 ns between two MCF5234 with PHYTER connected back-to-back
Hardware Timestamps Much Better than Software Timestamps

► MAC and PHY hardware timestamps reduce stack jitter

► MAC and PHY hardware timestamps give good performance
  • Sub-microsecond clock synchronization accuracy
    • Theoretical sub-nanosecond for PHY timestamp
  • Measured less than +/- 40 ns between
    • Two MPC8360 connected back-to-back
    • Two MCF5234 + NS Precision PHYTER® connected back-to-back

► MAC hardware timestamp support:
  • All existing and future QorIQ™ processors
    • P1020/12, P2020/10, P4080
  • Some PowerQUICC® processors
    • MPC8360, MPC8313/14/15, MPC837x
    • MPC8572, MPC8536, MPC8569
  • Planned for new Ethernet-based products to be announced

► Software timestamps on core have highest jitter

► Software timestamps on CPU reduce performance
  • Sub-millisecond clock synchronization accuracy
  • Measured less than +/- 15 us between two MPC8349 connected back-to-back

► Software and PHY hardware timestamps supported on all processors with Ethernet
  • PowerQUICC processor (MPC8xxx)
  • QorIQ processor (Pxxx)
  • ColdFire® processor (MCFxxx)
  • mobileGT platform (MPC5xxx)
  • i.MX processor
## Support for Processors with Hardware Timestamp in MAC

<table>
<thead>
<tr>
<th>Processor</th>
<th>Development Kit</th>
<th>Freescale IEEE 1588 BSP Driver</th>
<th>IXXAT IEEE 1588 Application Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC8313</td>
<td>MPC8313E-RDB</td>
<td>V1/V2 available from linux.freescale.net. Contact David Rosado</td>
<td>V1 or V2 contact Bill Seitz. Not on IXXAT web yet.</td>
</tr>
<tr>
<td>MPC8314</td>
<td>MPC8315E-RDB</td>
<td>V1 available. Contact David Rosado</td>
<td>V1 or V2 contact Bill Seitz. Not on IXXAT web yet.</td>
</tr>
<tr>
<td>MPC8315</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPC8360</td>
<td>MPC8360E-RDK</td>
<td>V1/V2 available from linux.freescale.net</td>
<td>V1 on IXXAT web</td>
</tr>
<tr>
<td>MPC8358</td>
<td></td>
<td></td>
<td>V2 contact Bill Seitz</td>
</tr>
<tr>
<td>MPC837x</td>
<td>MPC837xE-xxx</td>
<td>Not started yet</td>
<td>Contact Bill Seitz</td>
</tr>
<tr>
<td>MPC8536</td>
<td>MPC8536E-xxx</td>
<td>V2 driver planned. Contact Don Shin.</td>
<td>Contact Bill Seitz</td>
</tr>
<tr>
<td>MPC8572</td>
<td>MPC8572E-ADS</td>
<td>Not started yet</td>
<td>Contact Bill Seitz</td>
</tr>
<tr>
<td>QorIQ™ Platform, e.g. P2020</td>
<td></td>
<td>Planned. Contact factory</td>
<td>Contact Bill Seitz</td>
</tr>
<tr>
<td>ColdFire® V4 &amp; mobileGT</td>
<td>New devices planned</td>
<td>Planned. Contact factory</td>
<td>Contact Bill Seitz</td>
</tr>
</tbody>
</table>
## Support for Processors with No Hardware Timestamp

<table>
<thead>
<tr>
<th>Processor</th>
<th>Development Kit</th>
<th>Freescale IEEE 1588 BSP Driver</th>
<th>IXXAT IEEE 1588 Application Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCF5234</td>
<td>M5234BCCKIT with National Semiconductor Precision PHYTER® (IEEE 1588 in PHY)</td>
<td>V1 and V2 ship with the kit</td>
<td>V1 and V2 ship with the kit</td>
</tr>
<tr>
<td>MCF5225x</td>
<td>M52259EVB kit to be soon released</td>
<td>V1 and V2 will soon ship with the kit</td>
<td>Contact Bill Seitz</td>
</tr>
<tr>
<td>Other Ethernet-enabled processors</td>
<td>?? With National Semi PHYTER</td>
<td>Contact factory</td>
<td>Contact Bill Seitz</td>
</tr>
</tbody>
</table>
IEEE 1588 Resources

Available from Partners:
- IXXAT [www.ixxat.com](http://www.ixxat.com)
- Symmetricom [www.symmetricom.com](http://www.symmetricom.com)

Available from Freescale:
- [www.freescale.com/connectivity](http://www.freescale.com/connectivity)
- [www.freescale.com/ieee1588](http://www.freescale.com/ieee1588)
  - Download demo M5234BCKIT, which includes IXXAT evaluation software
  - Application Note AN3625, “IEEE 1588 Implementation on a ColdFire Processor”
- [www.freescale.com/mqx](http://www.freescale.com/mqx)
  - Freescale MQXTM Real-Time Operating System User's Guide
  - Freescale MQX™ RTOS 3.3.0 Release Notes
  - Freescale MQX IEEE1588 Communication Library User’s Guide
  - AN3910 - Freescale MQX IEEE 1588 Communication Library based Implementation of IEEE 1588 v2 Node on the ColdFire M52259
  - Freescale MQX IEEE 1588 Communication Library based IEEE®1588v2 Demo for M52259EVB - Quick Start Guide
Ethernet Hardware Timestamp Summary

► Hardware timestamp protocols are used in many applications
  • Automation, test, telecom, networking, aerospace, power, multimedia, financial, automotive

► MAC-layer hardware timestamps give nanosecond-level clock sync accuracy
  • 10/100/Gigabit Ethernet, multiple clock options, flexible frame detection, trigger inputs/outputs
  • In many PowerQUICC® and all QorIQ™ processors
    ▪ MPC8360, MPC8313/14/15, MPC837x, MPC8572, MPC8536, MPC8569
    ▪ All QorIQ Platform, including P1011/12, P2020/10, P4080
  • Planned for other new Ethernet-based products to be announced

► Use National Semiconductor Precision PHYTER® if no MAC hardware timestamp
  • This option only supports 10/100 Ethernet

► IXXAT IEEE 1588 protocol stack supports QorIQ, PowerQUICC and ColdFire platforms with or without hardware timestamp PHY
  • Freescale solutions [www.freescale.com/ieee1588](http://www.freescale.com/ieee1588)
  • FREE evaluation software [www.ixxat.com](http://www.ixxat.com)
Freescale:

- Industrial applications – www.freescale.com/industrial
- Industrial protocols – www.freescale.com/connectivity
- IEEE® 1588 – www.freescale.com/IEEE1588
- Motor Control – www.freescale.com/motorcontrol
- MQX solutions – www.freescale.com/mqx
- 8-bit microcontrollers – www.freescale.com/8bit
- 32-bit ColdFire microcontrollers – www.freescale.com/coldfire
- Analog products – www.freescale.com/analog

Protocol Partners:

- Acontis Technologies GmbH – http://www.acontis.com
- DoGav Systems Limited – www.dogav.net
- IXXAT Automation GmbH – www.ixxat.com
- Koenig Prozessautomatisierungs GmbH – www.koenig-pa.de
- Real-time Automation (RTA) – www.rtautomation.com
Freescale meets industrial control requirements

- Scalable system performance from 50 to 20,000+ MIPS
  - High-performance Integrated processors starting <$10
  - Target mobile battery-operated applications <0.5 to 1W
- Industrial or automotive qualification for -40C to +85C ambient
  - Stability of 10+ or 15+ year product longevity statement

Support legacy fieldbus and industrial Ethernet

- PowerQUICC®, QorIQ™, mobileGT®, i.MX & ColdFire® processors
- Solutions, enablement and 3rd party protocol stacks
  - PROFIBUS, CANopen, DeviceNet™, Modbus RTU
  - PROFINET, EtherNet/IP™, Modbus TCP, EtherCAT, IEEE 1588
## Related Session Resources

### Sessions

<table>
<thead>
<tr>
<th>Session ID</th>
<th>Title</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IND-F0762</td>
<td>Industrial Network Protocols (Part 1)</td>
<td></td>
</tr>
<tr>
<td>IND-F0751</td>
<td>Industrial Network Protocols (Part 2)</td>
<td></td>
</tr>
<tr>
<td>IND-F0760</td>
<td>Industrial Control and Networking Trends and Roadmap</td>
<td></td>
</tr>
</tbody>
</table>

### Demos

<table>
<thead>
<tr>
<th>Demo ID</th>
<th>Demo title</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Z9</td>
<td>EtherCAT on Safety-certified Neutrino RTOS</td>
<td></td>
</tr>
<tr>
<td>Z10</td>
<td>EtherCAT on Safety-certified INTEGRITY OS</td>
<td></td>
</tr>
<tr>
<td>Z11</td>
<td>PROFIBUS for QorIQ and PowerQUICC Processors</td>
<td></td>
</tr>
</tbody>
</table>
Thank you!
Backup Slides
## Industrial Control Processor Examples

<table>
<thead>
<tr>
<th>Device Family</th>
<th>MCF5225x ColdFire</th>
<th>MCF54453 ColdFire</th>
<th>i.MX35x i.MX</th>
<th>MPC8314/15 PowerQUICC</th>
<th>MPC837x PowerQUICC</th>
<th>P2010/20 QorIQ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Application</strong></td>
<td>PLC, IO, Process, Temperature</td>
<td>PLC, IO, Process</td>
<td>PLC, IO, Process</td>
<td>PLC, IO, Process</td>
<td>PLC, PAC, Motion</td>
<td>PLC, PAC, Motion</td>
</tr>
<tr>
<td><strong>Core Type</strong></td>
<td>ColdFire V2 76 DMIPS 80 MHz</td>
<td>ColdFire V4 410 DMIPS 266 MHz</td>
<td>ARM11 532 DMIPS 532 MHz</td>
<td>e300 Power 760 DMIPS 266 to 400 MHz</td>
<td>e300 Power 1267 DMIPS 400 to 667 MHz</td>
<td>e500 Power Up to 2760 DMIPS 533 to 1200 MHz</td>
</tr>
<tr>
<td><strong>Core Frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethernet MAC</strong></td>
<td>1 x 10/100</td>
<td>2 x 10/100</td>
<td>1 x 10/100</td>
<td>2 x 10/100/GbE</td>
<td>2 x 10/100/GbE</td>
<td>3 x 10/100/GbE</td>
</tr>
<tr>
<td><strong>MAC H/W timestamp</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>IEEE 1588</td>
<td>IEEE 1588</td>
<td>IEEE 1588</td>
</tr>
<tr>
<td><strong>PCI or PCI Express</strong></td>
<td>1 PCI</td>
<td>1 PCI</td>
<td>No</td>
<td>1 PCI, 2 PCI-Express</td>
<td>1 PCI, 2 PCI-Express (8377/78)</td>
<td>3 PCI-Express</td>
</tr>
<tr>
<td><strong>SPI</strong></td>
<td>1 DSPI</td>
<td>1 DSPI</td>
<td>3 SPI</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>USB</strong></td>
<td>Full-speed Host/Device OTG</td>
<td>High Speed HS Host, HS OTG with 2 x PHY</td>
<td>High Speed Host, Device, or OTG with PHY</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Other interfaces</strong></td>
<td>CAN, 3 x UART, I2C, SSI</td>
<td>3 x UART, I2C, SSI</td>
<td>2 x CAN, 3 x UART, 3 x I2C, 2 x SDIO, 2 x SSI</td>
<td>2 x UART, 1 x I2C</td>
<td>2 x UART, 2 x I2C</td>
<td>2 x UART, 2 x I2C</td>
</tr>
<tr>
<td><strong>Max power @ 85°C</strong></td>
<td>1.5 W</td>
<td>1.5 W</td>
<td>&lt;1 W</td>
<td>2 W</td>
<td>4.1 W</td>
<td>8 W (est)</td>
</tr>
<tr>
<td><strong>Security Hardware</strong></td>
<td>Encryption CAU</td>
<td>Network crypto</td>
<td>IP clone protection</td>
<td>Network crypto (opt)</td>
<td>Network crypto (opt)</td>
<td>Network crypto (opt)</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>512K bytes Flash, PWM</td>
<td>LCD control, touchscreen, 12-bit ADC, ATA, OpenVG</td>
<td>SATA on MPC8315, Power management, boot from NOR/NAND</td>
<td>SATA on MPC8377 and MPC8379</td>
<td></td>
<td>Dual core on P2020</td>
</tr>
</tbody>
</table>

Extended Temperature -40° to 85°C ambient
# Industrial Networking Processors Examples

<table>
<thead>
<tr>
<th>Device Family</th>
<th>i.MX25x i.MX</th>
<th>MCF54453 ColdFire</th>
<th>MPC8313 PowerQUICC</th>
<th>MPC8360/58 PowerQUICC</th>
<th>MPC837x PowerQUICC</th>
<th>P2010/20 QorIQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Application</td>
<td>Simple converters</td>
<td>Simple hubs, converters</td>
<td>Hubs, converters, switches, gateways</td>
<td>Hubs, converters, switches, gateways</td>
<td>Hubs, switches, gateways</td>
<td>Gateways, routers, switches</td>
</tr>
<tr>
<td>Core Type Dhrystone 2.1 MIPS</td>
<td>ARM9 400 DMIPS 400 MHz</td>
<td>ColdFire V4 410 DMIPS 266 MHz</td>
<td>e300 Power 760 DMIPS 266 to 400 MHz</td>
<td>e300 Power 760 DMIPS 266 to 400 MHz</td>
<td>e300 Power 1267 DMIPS 400 to 667 MHz</td>
<td>e500 Power 2760 DMIPS 533 to 1200 MHz</td>
</tr>
<tr>
<td>Core Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethernet MAC</td>
<td>1 x 10/100</td>
<td>2 x 10/100</td>
<td>2 x 10/100/GbE or up to 8 x 10/100</td>
<td>2 x 10/100/GbE</td>
<td>2 x 10/100/GbE</td>
<td>3 x 10/100/GbE</td>
</tr>
<tr>
<td>MAC/H/W timestamp</td>
<td>No</td>
<td>No</td>
<td>IEEE 1588</td>
<td>IEEE 1588</td>
<td>IEEE 1588</td>
<td>IEEE 1588</td>
</tr>
<tr>
<td>PCI or PCI Express</td>
<td>No</td>
<td>1 PCI</td>
<td>1 PCI</td>
<td>1 PCI</td>
<td>1 PCI, 2 PCI-Express (8377/78)</td>
<td>3 PCI-Express</td>
</tr>
<tr>
<td>SPI</td>
<td>3</td>
<td>1 DSPI</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>USB</td>
<td>High speed, OTG, with 2 PHY</td>
<td>High Speed OTG</td>
<td>High Speed host/device OTG with HS PHY</td>
<td>Low/Full Speed</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Other interfaces</td>
<td>5 x UART, 3 x I^2C, 2 x CAN, 2 x SDIO, 2 x SSI</td>
<td>3 x UART, I^2C, SSI</td>
<td>2 x UART, 1 x I^2C</td>
<td>2 x UART, 2 x I^2C</td>
<td>2 x UART, 2 x I^2C</td>
<td>2 x UART, 2 x I^2C</td>
</tr>
<tr>
<td>Max power @ 85°C</td>
<td>&lt;1 W</td>
<td>1.5 W</td>
<td>2 W</td>
<td>6.8 W for MPC8360 5.0 W for MPC8358</td>
<td>4.1 W</td>
<td>8 W (est)</td>
</tr>
<tr>
<td>Security Hardware</td>
<td>IP cloning protection</td>
<td>Network crypto</td>
<td>Optional network crypto</td>
<td>Optional network crypto</td>
<td>Optional network crypto</td>
<td>Optional network crypto</td>
</tr>
<tr>
<td>Other</td>
<td>LCD controller, 12-bit ADC</td>
<td>Power management controller, boot from NOR/NAND</td>
<td>PROFIBUS support by QUICC Engine</td>
<td>SATA on MPC8377 and MPC8379</td>
<td></td>
<td>Dual core on P2020</td>
</tr>
</tbody>
</table>

Extended Temperature -40° to 85°C ambient
<table>
<thead>
<tr>
<th></th>
<th>PowerQUICC I (MPC8xx)</th>
<th>PowerQUICC II (MPC82xx)</th>
<th>PowerQUICC II Pro (MPC83xx)</th>
<th>QorIQ (P1 Series)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>50-133MHz</td>
<td>166-450MHz</td>
<td>266-667MHz</td>
<td>400-800MHz</td>
</tr>
<tr>
<td>DMIPS</td>
<td>66-175</td>
<td>318-864</td>
<td>505-1280</td>
<td>920-3680</td>
</tr>
<tr>
<td>Floating Point Support</td>
<td>All-handled in SW using exception mechanism</td>
<td>All</td>
<td>All (8323/21 FPU handled in SW using exception mechanism)</td>
<td>Single precision embedded floating point, SPE</td>
</tr>
<tr>
<td>Caches</td>
<td>Up to 16KB/8KB</td>
<td>16K/16K</td>
<td>Up to 32K/32K</td>
<td>I/D 32K/32K L1, 256K L2</td>
</tr>
<tr>
<td>Memory</td>
<td>SDRAM</td>
<td>SDRAM</td>
<td>DDR1/2</td>
<td>DDR2/3</td>
</tr>
<tr>
<td>Local Bus</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes (enhanced Local Bus)</td>
</tr>
<tr>
<td>PCI Bus Options</td>
<td>-</td>
<td>PCI-All (Hip4 process)</td>
<td>PCI-All, PCI Express 8315/14, 837x</td>
<td>PCI Express</td>
</tr>
<tr>
<td>Security Engine</td>
<td>885, 875</td>
<td>8248, 8272</td>
<td>All E Versions</td>
<td>All E Versions</td>
</tr>
<tr>
<td>Communications Processor</td>
<td>All</td>
<td>All, except 8241/45/40</td>
<td>832x, 836x Only QE</td>
<td>P1023 / P1013</td>
</tr>
<tr>
<td>Ethernet</td>
<td>10/100 All (10 Mbps on 850/823/860)</td>
<td>10/100</td>
<td>10/100/1000 (10/100 on 832x)</td>
<td>10/100/1000</td>
</tr>
<tr>
<td>SATA</td>
<td>-</td>
<td>-</td>
<td>8315, 8379, 8377</td>
<td>-</td>
</tr>
<tr>
<td>ATM</td>
<td>88x/862/859/857/855/850</td>
<td>All except 8250/8248/8247/8270</td>
<td>8323/836x</td>
<td></td>
</tr>
<tr>
<td>USB</td>
<td>885/880/875/870/850</td>
<td>8248/47, 827x</td>
<td>High Speed (except 832X, 836x)</td>
<td>High Speed USB 2.0</td>
</tr>
<tr>
<td>Packaging</td>
<td>256/357 PBGA</td>
<td>352/480 TBGA, 357/516 PBGA</td>
<td>516/620/668/689 PBGA, 672/740 TBGA</td>
<td>689 TePBGAII</td>
</tr>
</tbody>
</table>
# QorIQ™ P2 and PowerQUICC III

<table>
<thead>
<tr>
<th></th>
<th>MPC8544</th>
<th>P2010</th>
<th>MPC8548</th>
<th>P2020</th>
<th>MPC8572</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPU</strong></td>
<td>e500 667 – 1067MHz 32K I/D</td>
<td>e500 800 - 1200MHz 32K I/D</td>
<td>e500 1000 - 1333MHz 32K I/D</td>
<td>Dual e500 800 to 1200MHz 32K I/D</td>
<td>Dual e500 1200 to 1500MHz 32K I/D</td>
</tr>
<tr>
<td><strong>L2 Cache</strong></td>
<td>256kB</td>
<td>512KB</td>
<td>512kB</td>
<td>512KB</td>
<td>1MB</td>
</tr>
<tr>
<td><strong>DDR I/F Type/Width</strong></td>
<td>DDR1/2, 64b</td>
<td>DDR2/3, 64-bit</td>
<td>DDR1/2, 64b</td>
<td>DDR2/3, 32/64-bit</td>
<td>Dual DDR2/3, 64b</td>
</tr>
<tr>
<td><strong>10/100/1000 Ethernet</strong></td>
<td>2 w/ all SGMII</td>
<td>3 w/ 2 SGMII</td>
<td>4</td>
<td>3 w/ 2 SGMII</td>
<td>4 w/ all SGMII + 10/100</td>
</tr>
<tr>
<td><strong>PCI</strong></td>
<td>32b PCI + 3 PCIe controllers w/ 9 SerDes</td>
<td>3 PCIe controllers w/ 4 SerDes</td>
<td>64b PCI-X and PCIe w/ 8 SerDes</td>
<td>3 PCIe controllers w/ 4 SerDes</td>
<td>2 PCIe controllers w/ 8 SerDes</td>
</tr>
<tr>
<td><strong>sRIO 1.2</strong></td>
<td>-</td>
<td>2 x 1 or 1 x 4</td>
<td>1 x 4</td>
<td>2 x 1 or 1 x 4</td>
<td>1 x 4 or 1 x 1</td>
</tr>
<tr>
<td><strong>USB2.0</strong></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Local bus controller</strong></td>
<td>32b</td>
<td>16b</td>
<td>32b</td>
<td>16b</td>
<td>32b</td>
</tr>
<tr>
<td><strong>Memory Card</strong></td>
<td>-</td>
<td>SD/MMC</td>
<td>-</td>
<td>SD/MMC</td>
<td>-</td>
</tr>
<tr>
<td><strong>Other interfaces</strong></td>
<td>DUART, 2xI2C</td>
<td>DUART, 2xI2C, SPI</td>
<td>DUART, 2xI2C</td>
<td>DUART, 2xI2C, SPI</td>
<td>DUART, 2xI2C</td>
</tr>
<tr>
<td><strong>Accelerators</strong></td>
<td>SEC2.1</td>
<td>SEC3.1</td>
<td>SEC 3.0</td>
<td>SEC3.1</td>
<td>SEC 3.0, PME, TLU</td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td>783 FC-PBGA</td>
<td>689 Te PBGAII</td>
<td>783 FC-CBGA and FC-PBGA</td>
<td>689 Te PBGAII</td>
<td>1023 FC-PBGA</td>
</tr>
<tr>
<td></td>
<td>P1011</td>
<td>P1020</td>
<td>P2010</td>
<td>P2020</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td><strong>CPU</strong></td>
<td>e500</td>
<td>Dual e500</td>
<td>e500</td>
<td>Dual e500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 800MHz</td>
<td>Up to 800MHz</td>
<td>Up to 1200MHz</td>
<td>Up to 1200MHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32K I/D</td>
<td>32K I/D</td>
<td>32K I/D</td>
<td>32K I/D</td>
<td></td>
</tr>
<tr>
<td><strong>L2 Cache</strong></td>
<td>256KB</td>
<td>256KB</td>
<td>512KB</td>
<td>512KB</td>
<td></td>
</tr>
<tr>
<td><strong>DDR I/F Type/Width</strong></td>
<td>DDR2/3 32-bit</td>
<td>DDR2/3 32-bit</td>
<td>DDR2/3 32/64-bit</td>
<td>DDR2/3 32/64-bit</td>
<td></td>
</tr>
<tr>
<td><strong>10/100/1000 Ethernet</strong></td>
<td>3 w/(2) SGMII</td>
<td>3 w/(2) SGMII</td>
<td>3 w/(2) SGMII</td>
<td>3 w/(2) SGMII</td>
<td></td>
</tr>
<tr>
<td>(with IEEE1588v2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TDM</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>PCI-Exp 1.0a</strong></td>
<td>2 controllers w/ 4 SERDES</td>
<td>2 controllers w/ 4 SERDES</td>
<td>3 controllers w/ 4 SERDES</td>
<td>3 controllers w/ 4 SERDES</td>
<td></td>
</tr>
<tr>
<td><strong>sRIO 1.2</strong></td>
<td>-</td>
<td>-</td>
<td>2 x1 or 1 x4</td>
<td>2 x1 or 1 x4</td>
<td></td>
</tr>
<tr>
<td><strong>USB2.0</strong></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td><strong>Memory Card</strong></td>
<td>SD/MMC</td>
<td>SD/MMC</td>
<td>SD/MMC</td>
<td>SD/MMC</td>
<td></td>
</tr>
<tr>
<td><strong>Other interfaces</strong></td>
<td>SPI, 2xI2C, DUART</td>
<td>SPI, 2xI2C, DUART</td>
<td>SPI, 2xI2C, DUART</td>
<td>SPI, 2xI2C, DUART</td>
<td></td>
</tr>
<tr>
<td><strong>Accelerators</strong></td>
<td>SEC3.1</td>
<td>SEC3.1</td>
<td>SEC3.1</td>
<td>SEC3.1</td>
<td></td>
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<tr>
<td><strong>Package</strong></td>
<td>689 Te PBGAII</td>
<td>689 Te PBGAII</td>
<td>689 Te PBGAII</td>
<td>689 Te PBGAII</td>
<td></td>
</tr>
</tbody>
</table>
P1012/P1021 QorIQ™ Processor

- **Single or Dual e500 Power Architecture™ core**
  - 533 – 800 MHz
  - 256KB frontside L2 cache with ECC, HW cache coherent
  - 36 bit physical addressing, DP-FPU

- **System Unit**
  - 32-bit DDR2/DDR3, 667 MHz data rate with ECC
  - Integrated SEC 3.3 Security Engine
  - Open-PIC Interrupt Controller, Performance Monitor
  - 2x I²C, Timers, 16 GPIO, DUART
  - USB 2.0 Controller Host/Device
  - 16-bit Enhanced Local Bus supports boot from NAND Flash
  - SPI controller supports boot from SPI serial Flash
  - SD/MMC card controller supports boot from Flash cards
  - Three 10/100/1000 Ethernet Controllers (eTSEC) with Jumbo Frame support, SGMII interface
    - IEEE® 1588v2 Support
    - QUICC Engine® for protocol off load and legacy interfaces
      - 4 x TDM interfaces with HDLC support
      - 4 x UCC for Serial Protocols
    - Two PCI Express 1.0a Controllers operating up to 2.5Gbps
    - Power Management

- **Process & Package**
  - 45nm SOI, 0.95V+/−50mV, -40C to 125C Tj
  - 689-pin TePBGAII

Supports Industrial Ethernet and PROFIBUS, low power consumption
MPC8308 PowerQUICC Processor

Features

- Power Architecture e300, 400 MHz
  - FPU + Dual IU
- DDR2 @ 266MHz
  - 16/32-bit with ECC protection
  - 32-bit Local Bus
  - Boot from NAND Flash
- Two 10/100/1000 Ethernet MACs
  - MII / RGMII
  - IEEE1588 hardware timestamp
- PCI Express v1.0a
- USB 2.0 – Host / Device / OTG
- SDHC (host controller)
- Multi-channel DMA controller
- DUART, I²C, SPI, GTM, RTC
- Three dedicated GPIO
  - Plus 21 multiplexed with peripherals

Package and Power

- 473pin MAPBGA
  - 0.8 mm pitch, 19 mm x 19 mm
  - ~1.2W typical @ 333 MHz, Tj 25C

Production: Q1 2010

Low cost embedded controller with high speed peripherals
Industrial and Multi-Market 32-bit MCU Roadmap

<New Brand>
Scalable, Mixed-signal, Microcontrollers based on ARM Cortex-M4

ColdFire
Application-oriented solutions for Consumer & Industrial vertical markets

ColdFire+

Pin-compatible Families

K50 - Medical

NEW! 90nm

K70

K60 - Ethernet

K40 + LCD + USB

K30 + LCD

K20 + USB

K10 – Mixed Signal

128-512KB Flash

<64KB Flash

1MB Flash

Committed

Proposed

General Purpose

Application-Focused

2009 or earlier

2010

2011

NEW! 90nm

MCF5225x – Ethernet + USB

V1 CN - Ethernet

V1 Flexis QE – Low Power

V1 Flexis JM - USB

V1 Flexis AC - Appliaqne

V1 AG - Appliance

V1 Flexis EM - Metering

V1 Flexis MM - Medical

V1 Flexis JE - Medical

Pin Compatible Families

JF – Secure Consumer

QF – Secure & Low Pwr

QC – Low Power

QH – Low Power

Appliance

Metering

Greater Flash Size

Multi-Core

Higher Performance

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i.MX-based Solutions for HMI and Control

Cortex A8
- i.MX357
  - Open VG 1.1
- i.MX353
  - ARM1136, 532 MHz
  - Ethernet, DDR2
  - USB Phy x 2, CAN x 2
- Associated PMIC: MC13892
- Next Gen

ARM11
- i.MX258
  - Security
- i.MX257
  - Touchscreen
  - CAN x 2
- i.MX253
  - ARM926, 400MHz
  - Ethernet, DDR2
  - USB Phy x 2
- Associated PMIC: MC34704B
- In Development

ARM9
- i.MX515
  - Open VG 1.1
  - OpenGL ES 2.0
  - Security
- i.MX513
  - HD720p Video Decode
  - D1 Video Encode
- i.MX512
  - Cortex A8, 800MHz
  - Ethernet, DDR2, USB Phy
- Associated PMIC: MC13892

i.MX515

i.MX2x
  - Next gen
- Associated PMIC: MC13892
- Embedded PMIC
  - ARM926, 450MHz
  - Integrated PM
  - Ethernet, CAN, USB PHY
  - Touchscreen

2009
2010
2011

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## i.MX ARM9 for General Embedded Market

<table>
<thead>
<tr>
<th>Feature</th>
<th>i.MX27(L)</th>
<th>i.MX233</th>
<th>i.MX253</th>
<th>i.MX257</th>
<th>i.MX258</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Markets</strong></td>
<td>Consumer, Industrial</td>
<td>Consumer &amp; Industrial</td>
<td>Industrial &amp; Consumer</td>
<td>Industrial &amp; Consumer</td>
<td>Industrial</td>
</tr>
<tr>
<td><strong>Target Segments</strong></td>
<td>▶ IP Camera</td>
<td>▶ PMP, PND Audio Accessories</td>
<td>▶ HMI</td>
<td>▶ “Smart Touch” HMI</td>
<td>▶ Secure Residential Gateway (Smart Meters)</td>
</tr>
<tr>
<td></td>
<td>▶ Media Phones</td>
<td>▶ VoIP</td>
<td>▶ Portable/Tethered Printers</td>
<td>▶ Factory Automation (CAN)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ Digital Signage</td>
<td>▶ Smart remotes</td>
<td>▶ Medical</td>
<td>▶ Barcode Scanners</td>
<td>▶ Point-of-sale Biometrics Secure Devices</td>
</tr>
<tr>
<td></td>
<td>▶ Medical (Video)</td>
<td>▶ HMI (home appliances, etc)</td>
<td>▶ Factory Automation (Ethernet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td>ARM926EJ-S™</td>
<td>ARM926EJ-S™</td>
<td>ARM926EJ-S™</td>
<td>ARM926EJ-S™</td>
<td>ARM926EJ-S™</td>
</tr>
<tr>
<td><strong>CPU Speed</strong></td>
<td>400 MHz</td>
<td>454 MHz</td>
<td>400 MHz</td>
<td>400 MHz</td>
<td>400 MHz</td>
</tr>
<tr>
<td><strong>Key Differences</strong></td>
<td>▶ MPEG-4/H.264 Video Encode / Decode</td>
<td>▶ Integrated power management</td>
<td>▶ DDR2 Integrated Ethernet</td>
<td>▶ i.MX253 + CAN, Smartcard</td>
<td>▶ i.MX257 + Secure key/data storage</td>
</tr>
<tr>
<td></td>
<td>▶ CMOS Sensor I/F</td>
<td>▶ Analog Audio</td>
<td>▶ Integrated USB Phy's</td>
<td>▶ CMOS Sensor I/F Touchscreen controller</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ 32-bit mDDR bus</td>
<td>▶ Small packages</td>
<td>▶ NOR Flash</td>
<td></td>
<td>▶ Tamper detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>▶ Secure boot</td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td>0.8mm 473BGA</td>
<td>128LQFP</td>
<td>0.8mm 400BGA</td>
<td>0.8mm 400BGA</td>
<td>0.8mm 400 BGA</td>
</tr>
<tr>
<td></td>
<td>0.65mm 404BGA</td>
<td>0.8mm 169BGA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Positioning</strong></td>
<td>Video acceleration</td>
<td>Integrated power management and analog audio</td>
<td>Ethernet, DDR2</td>
<td>Ethernet, CAN, DDR2, Touchscreen controller</td>
<td>Security</td>
</tr>
<tr>
<td><strong>10KU Suggested Disty Resale</strong></td>
<td>$8.10 - $11.42</td>
<td>QFP $4.60-$5.29 BGA $5.42-$6.11</td>
<td>$6.26-$6.48</td>
<td>$7.00-$7.53</td>
<td>$8.11</td>
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<tr>
<td><strong>OS</strong></td>
<td>Linux, WinCE RTOS</td>
<td>Linux, WinCE</td>
<td>Linux, WinCE, RTOS</td>
<td>Linux, WinCE, RTOS</td>
<td>Linux, WinCE, RTOS</td>
</tr>
<tr>
<td><strong>General Availability</strong></td>
<td>Mass Production</td>
<td>Mass Production</td>
<td>Mass Production</td>
<td>Mass Production</td>
<td>Mass Production</td>
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### i.MX ARM11 for General Embedded Market

<table>
<thead>
<tr>
<th>Feature</th>
<th>i.MX31</th>
<th>i.MX353</th>
<th>i.MX357</th>
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<tbody>
<tr>
<td><strong>Target Markets</strong></td>
<td>Consumer, Industrial</td>
<td>Consumer &amp; Industrial</td>
<td>Industrial &amp; Consumer</td>
</tr>
<tr>
<td><strong>Target Segments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Smartphones</td>
<td>• HMI (home appliances, etc)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Medical</td>
<td></td>
<td>• HMI (factory automation, building control)</td>
</tr>
<tr>
<td></td>
<td>• Photo frames</td>
<td></td>
<td>• PND</td>
</tr>
<tr>
<td></td>
<td>• Web tablets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Scanners</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td>ARM1136™</td>
<td>ARM1136™</td>
<td>ARM1136™</td>
</tr>
<tr>
<td><strong>CPU Speed</strong></td>
<td>532 MHz</td>
<td>532 MHz</td>
<td>532 MHz</td>
</tr>
<tr>
<td><strong>Key Differences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Video Encode</td>
<td>• Integrated Ethernet, CAN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 3D graphics</td>
<td>• DDR2 support</td>
<td>• OpenVG 1.1</td>
</tr>
<tr>
<td></td>
<td>• acceleration</td>
<td>• 3.3V I/O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fast IrDa</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 5 UARTs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td>0.8 mm BGA 0.65mm BGA</td>
<td>0.8mm 400BGA</td>
<td>0.8mm 400BGA</td>
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<tr>
<td><strong>Positioning</strong></td>
<td>3D acceleration</td>
<td>Integrated CAN, Ethernet, and USB+PHYs</td>
<td>2D acceleration</td>
</tr>
<tr>
<td><strong>10KU Suggested Resale</strong></td>
<td>$15.35</td>
<td>$11.98</td>
<td>$13.18</td>
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<td><strong>OS</strong></td>
<td>Linux, WinCE, RTOS</td>
<td>Linux, WinCE, RTOS</td>
<td>Linux, WinCE, RTOS</td>
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<td><strong>General Availability</strong></td>
<td>Production</td>
<td>Production</td>
<td>Production</td>
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</table>
## i.MX51 Family: 3-Digit Part Numbering

<table>
<thead>
<tr>
<th>Feature</th>
<th>i.MX512</th>
<th>i.MX513</th>
<th>i.MX514</th>
<th>i.MX515</th>
<th>i.MX516</th>
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</thead>
<tbody>
<tr>
<td><strong>Target Markets</strong></td>
<td>Consumer, Industrial</td>
<td>Consumer &amp; Industrial</td>
<td>Automotive</td>
<td>Industrial &amp; Consumer</td>
<td>Automotive</td>
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<tr>
<td><strong>Target Segments</strong></td>
<td>▶ Factory Automation (Ethernet)</td>
<td>▶ IP Camera</td>
<td>▶ Navigation</td>
<td>▶ Smartbook</td>
<td>▶ Infotainment</td>
</tr>
<tr>
<td></td>
<td>▶ HDMI</td>
<td>▶ Media Phones</td>
<td>▶ Advanced HMI</td>
<td>▶ Mobile internet devices</td>
<td>Rear Seat</td>
</tr>
<tr>
<td></td>
<td>▶ Portable/Tethered Printers</td>
<td>▶ Digital Signage</td>
<td>▶ Instrument Cluster</td>
<td>▶ PMPs</td>
<td>Entertainment</td>
</tr>
<tr>
<td></td>
<td>▶ Medical devices</td>
<td>▶ HMI (home appliances, etc)</td>
<td>▶ Telematics</td>
<td>▶ Secure Devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ Ebooks</td>
<td></td>
<td></td>
<td>▶ Advanced HMI</td>
<td></td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td>Cortex™-A8</td>
<td>Cortex™-A8</td>
<td>Cortex™-A8</td>
<td>Cortex™-A8</td>
<td>Cortex™-A8</td>
</tr>
<tr>
<td><strong>CPU Speed</strong></td>
<td>Consumer: up to 800 MHz</td>
<td>Consumer: up to 800 MHz</td>
<td>Up to 600 MHz</td>
<td>Consumer: up to 800 MHz</td>
<td>Up to 600 MHz</td>
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<tr>
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<td>Industrial: up to 600 MHz</td>
<td>Industrial: up to 600 MHz</td>
<td></td>
<td>Industrial: up to 600 MHz</td>
<td></td>
</tr>
<tr>
<td><strong>Key Differences</strong></td>
<td>▶ DDR2</td>
<td>▶ i.MX512 + HW Video Codec: Multi-format D1 video encode &amp; multi-format HD720 decode</td>
<td>▶ i.MX512 + OpenGL ES 2.0 3D accelerator &amp; OpenVG 1.1 graphics accelerator</td>
<td>▶ Security: Sahara v4 &amp; Trust Zone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ Integrated USB Phy’s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ Integrated Ethernet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ Vector Floating Point</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ HD 720 TV-Out</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>▶ i.MX512 + HW Video Codec: Multi-format D1 video encode &amp; multi-format HD720 decode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶ OpenGL ES 2.0 3D accelerator &amp; OpenVG 1.1 graphics accelerator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶ Security: Sahara v4 &amp; Trust Zone</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td>0.8mm 529BGA 0.5mm 527BGA</td>
<td>0.8mm 529BGA 0.5mm 527BGA</td>
<td>0.8mm 529BGA 0.5mm 527BGA</td>
<td>0.8mm 529BGA 0.5mm 527BGA</td>
<td>0.8mm 529BGA 0.5mm 527BGA</td>
</tr>
<tr>
<td><strong>Positioning</strong></td>
<td>High end processor</td>
<td>Video supported</td>
<td>Automotive support for graphics and security</td>
<td>Full featured: Video, graphics and security</td>
<td>Full featured: Video, graphics and security</td>
</tr>
<tr>
<td><strong>10KU Suggested Disty Resale 2010</strong></td>
<td>$18.96 - $22.11</td>
<td>$19.40 - $22.29</td>
<td>Contact FSL Sales</td>
<td>$21.63 - $25.59</td>
<td>Contact FSL Sales</td>
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<tr>
<td><strong>General Availability</strong></td>
<td>Production</td>
<td>Production</td>
<td>Production</td>
<td>Production</td>
<td>Production</td>
</tr>
</tbody>
</table>
## i.MX ARM Cortex A8 Third Party Development Boards

<table>
<thead>
<tr>
<th>Device</th>
<th>Partner</th>
<th>Focus</th>
<th>URL</th>
<th>Key Board Features</th>
<th>Other Info</th>
</tr>
</thead>
</table>
| i.MX51 | Digi    | ► Design capabilities  
► BSPs: WinCE | www.digi.com | Integrated 802.11a/b/g/n |          |
| i.MX51 | Karo    | ► BSPs: WinCE & Linux  
► Development services | www.karo-electronics.de |          | SoM only 26mm |
| i.MX51 | Eukrea  | ► Designs hardware and software solutions optimized for embedded Linux | www.eukrea.com |          | SoM + dev board |
| i.MX51 | Bluetechnix | ► High-quality, easy-to-use Linux distribution (Ubuntu) | www.bluetechnix.com |          | Single board computer |
| i.MX51 | Boundary Devices | ► Maximizing multimedia performance while minimizing the power consumption. | www.boundarydevices.com |          | Single board computer |
i.MX25 On-chip Security Features

► High Assurance Boot
  • Protection against rogue software; only authenticated software can run on device
  • Needed for secure residential gateways, biometric devices, point-of-sale

► Tamper detection, key storage
  • Voltage, frequency, temperature monitors
  • Fast key erasure upon threat detection
  • Secure 47-bit time counter
  • Secure 32-bit monotonic counter
  • Volatile key storage

► True Random Number Generator

► User Programmable e-Fuses
Freescale i.MX25 Product Development Kit (PDK)

**CPU Module**
- i.MX25 ARM926EJ-S™ Processor
- Freescale MC34704B PMIC
- Freescale SGTL5000 Audio Codec
- 512Mb DDR2
- 2GB NAND Flash

**Personality Module**
- 5.7” VGA LCD with Touchscreen
- USB 2.0 OTG, USB 2.0 Host, 10/100 Ethernet
- SD/MMC Connector
- Smartcard and CAN Connectors
- CMOS Image Sensor

**Software**
- Windows Embedded 6.0 r2 BSP
- Linux 2.6.26 BSP
- ATK Flash Utility

**Debug Module**
- Debug Ethernet, Serial, JTAG
- Reset, Interrupt, Boot Switches
- Debug Display/LED’s
- Current/Power Monitoring
Factory Automation and Drives
Analog, Sensor and Wireless Processors

Sensors
- MPX5050D
- MPX5999D
- MP3V5004
- MPR084
- MPR031

Proximity
- MPR121
  More inputs

Inertial
- MMA736xL
- MMA745xL

Pressure
- MMA7660
- MMA6700
  High-end
  2-axis

Wireless
- MC3394x
- MC33926, 32
- MC33910, 11, 12
- MC33742

RF (2.4 GHz, UHF)
- MC1320x
- MC1319x
- MC13213
- MC13224

Analog
- MC34670 (PoE)
- H-bridges
- MC33972, 75
- Power Supply
- MC34727, 26
- Linear Regulator
- MC33742
- MC33937
- MC33901, 11, 12
- LED backlight
- MC34844, 45

CAN PHY
- MCZ33897

Signal Conditioning
- MC33972, 75

2009 and earlier

2010

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Backup - IEEE® 1588 Hardware Timestamp

PowerQUICC Enhanced Triple Speed Ethernet (eTSEC) Controller
IEEE 1588 Hardware Assist Input Clock Options

Lower Cost and Accuracy

Higher Cost and Accuracy

System Cost for Timestamp Clock

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Enhanced Triple-Speed Ethernet Controller

- Code compatible with PowerQUICC III TSEC
- Support for weighted round robin and strict priority queueing
- TCP/IP checksum offload for RX and TX
- IPv6 and Magic Packet support
- FIFO I/F to ASICs – 8-/16-bits at OC-48 rates and above
- RMII Interface Support added

- QoS support for 8 Rx and 8 Tx hardware queues
- Programmable IP header alignment
- Customizable per-packet rejection
- Customizable per-packet filtering/filing to 64 logical receive queues. Examples: 802.1p, IP TOS, Diffserv classification, TCP/UDP ports, etc.

Layer 2 features:
- VLAN insertion and deletion per frame
- 16 exact-match MAC addresses
- Increased hash table address matching

SGMII Interface Support
IEEE1588 Hardware Support
Backup - IEEE® 1588 Hardware Timestamp
PowerQUICC QUICC Engine Controller
IEEE 1588 in the QUICC Engine

PTP1 Register Space

UCC1  UCC3  UCC5  UCC7
Ethernet  Ethernet  Ethernet  Ethernet
Mac     Mac     Mac     Mac

GMII/ RGMII  GMII/ RGMII  MII/ RMII  MII/ RMII
Time- Time- Time- Time-
stamp  stamp  stamp  stamp
Unit    Unit    Unit    Unit

PTP2 Register Space

UCC2  UCC4  UCC6  UCC8
Ethernet  Ethernet  Ethernet  Ethernet
Mac     Mac     Mac     Mac

MII/ RMII  MII/ RMII  MII/ RMII  MII/ RMII
Time- Time- Time- Time-
stamp  stamp  stamp  stamp
Unit    Unit    Unit    Unit

RTC Register Space

1588 Real Time Clock
IEEE 1588 Hardware-Assist Implementation (QUICC Engine)

Optional In-band mode uses the timestamp registers

External Event Trigger Inputs

External Clock Ref

Platform Clock Ref

1588 Clock

Bypass Enable

Carry

64-bit Offset Register

64-bit Current System Time

Interrupt and Output Logic

Output Clock

System Interrupts

Trigger Outputs

PPS Output

64-bit TX Timestamp

64-bit RX Timestamp

Alarm Register

64-bit Event Time

≥

Timestamp Enables

Edge Detector

32-bit Accum + Counter

64-bit Counter

64-bit Accum + Counter

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Insert Hardware Timestamps with Ethernet MAC

1. Real-time clock
2. Ethernet frame
3. Timestamp
   - 62665....
4. Interrupt
5. Read Data
6. Detect received PTP frame status in RxBD (e.g. DELAY_Req frame)

Ethernet MAC (QE)
- Timestamp
  - Timestamp_n
  - Timestamp_n+1
  - Timestamp_n+2
- FrameData
  - FrameData_n
  - FrameData_n+1
  - FrameData_n+2

Rx PTP
- Last
- PTP bit set; Close RxBD

RxBD

CPU

Timestamp Unit
- 1588 HW assist

MII/GMII
Out-of-Band Receive Data Flow (QUICC Engine RX Mode1)

1. Real time clock
2. Ethernet frame
3. Set PTP bit in RxBD
4. Interrupt
5. Detect received PTP frame status in RxBD (e.g. DELAY_Req frame)
6. Read Timestamp

CPU

RxBD

PTP FRAME

Rx Buffer

Ethernet MAC (QE)

Timestamp Unit
1588 HW Assist (parser)

62665….
In-Band Receive Data Flow (QUICC Engine RX Mode2)

1. Ethernet frame
2. Timestamp Unit 1588 HW assist
3. Detect received PTP frame status in RxBD (e.g. DELAY_Req frame)
4. CPU
5. Read Data
6. PTP FRAME

- Timestamp_n
- FrameData_n
- Timestamp_n+1
- FrameData_n+1
- Timestamp_n+2
- FrameData_n+2

Real time clock

- MII/GMII

Ethernet MAC (QE)

Interrupt
1. Set PTP bit in TxBD when timestamp required (e.g. SYNC frame)

2. Ethernet frame

3. MII/GMII

4. Close TxBD

5. Interrupt

6. Read Timestamp
In-Band Transmit Data Flow (QUICC Engine TX Mode2)

1. Set PTP bit in TxBD when timestamp required (e.g. SYNC frame)
2. Close TxBD
3. Read Timestamp Data
4. Ethernet frame
5. Interrupt and Timestamp
6. Real time clock

CPU

Tx PTP

PTP FRAME

Ethernet MAC (QE)

QE RISC Core

Tx Buffer

MII/GMII

62665...