Design Tradeoffs in Industrial Ethernet Hardware Implementations

Wil Florentino, Industrial Segment Marketing
Wil Florentino
– Renesas Industrial Automation Marketing Mgr

- 15 years experience in Industrial realm
  
  - International business development for a manufacturer of industrial single board computers
  
  - Worked for both FPGA leaders – Xilinx and Altera, in a strategic marketing role in the Industrial Business Unit, focused on Industrial Ethernet protocol IP implementations as well as Industrial Drives applications

- Education
  
  - BS Mechanical Eng’g and MBA
Renesas Technology & Solution Portfolio
Microcontroller and Microprocessor Line-up

2010

- **1200 DMIPS, Superscalar**
  - Automotive & Industrial, 65nm
  - 600μA/MHz, 1µA standby

- **500 DMIPS, Low Power**
  - Industrial, 90nm
  - 200μA/MHz, 1.6µA deep standby

- **25 DMIPS, Low Power**
  - Automotive & Industrial, 130nm
  - 144µA/MHz, 0.2µA standby

- **10 DMIPS, Capacitive Touch**
  - Industrial & Automotive, 130nm
  - 350μA/MHz, 1µA standby

2012

- **1200 DMIPS, Performance**
  - Automotive, 40nm
  - 100μA/MHz, 0.1µA deep standby

- **44 DMIPS, True Low Power**
  - Industrial & Automotive, 130nm
  - 144μA/MHz, 0.2µA standby

- **32-bit High Performance DSP, FPU with High Integration**
  - RX 32-bit CPU
    - 100MHz, 165 DMIPS
    - Floating Point Unit 32-bit
    - Digital Signal Processing
      - MAC 48-bit
      - RMPA 80-bit
    - Barrel Shifter 32-bit

- **1200 DMIPS, FPU, DSC**
  - Automotive, 40nm
  - 400μA/MHz, 1µA deep standby

- **Industrial Security, ASSP**
  - 90nm
  - 100mA/MHz, 100µA standby

- **600 DMIPS, True Low Power**
  - Automotive & Industrial, 90nm
  - 600μA/MHz, 1.5µA standby

- **Automotive, 65nm**
  - 600μA/MHz, 1µA standby
Renesas – Enabling The Smart Factory

- Challenge:
  “Standard enterprise TCP/IP protocol does not provide the deterministic communication required in today’s Smart Factory. Equipment OEMs are migrating to Industrial Ethernet technologies, however, selecting the right protocol is only the first consideration.”

- Solution:
  “This session will provide an overview of Industrial Ethernet implementations and highlight the considerations and tradeoffs from a system level and device requirements. You will learn how Renesas MCUs and intelligent PHYs are the ideal solution to support different protocols, and how we leverage our strong partner ecosystem”
Agenda

- How Is Industrial Ethernet Different?
- Industrial Ethernet Protocol Architectures
- Considerations In Implementing Your Industrial Ethernet Solution
- Renesas Solutions for Industrial Ethernet
- Summary
Smart Factory Devices Are Interconnected

- PLC/PACs & DCS
- Improve Efficiency
- Lower Operating Costs
- Safe Environment
- Industrial Drives & Motion Controllers
- HMIs & Operator Interfaces
- Sensors & Actuators
- I/O Modules
- Gateways & Switches

Improve Efficiency
Lower Operating Costs
Safe Environment
Industrial Networks Need Fast Cycle Times and Efficient Delivery

<table>
<thead>
<tr>
<th>Typical Cycle Time</th>
<th>Enterprise</th>
<th>Process</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>100ms</td>
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<td>10ms</td>
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<td>&lt;250 µS</td>
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</table>

Enterprise Network
- High Data Throughput
- Non-deterministic
- Fault Tolerant
- Focus is on bandwidth

vs.

Industrial Network
- Efficient data throughput
- Deterministic / “Real Time”
- High Reliability
- Robustness
Industrial Communications Takes Many Forms

- Backplane communication
  - In PLCs/PACs to communicate between the Master CPU card and I/O modules
- Industrial Networks
  - Industrial Ethernet that supports realtime protocols
- Safety communication
  - Dedicated channels for safe sensors and switches
- Sensor & Encoder interface
  - Slower sensor interfaces that react to condition changes
  - Motor encoders that deliver position and speed, as well as motor condition
- HMI communication
  - Serial communication for operator interface
Factories Migrating to Ethernet-Based Networks

- Enterprise Level Ethernet
  - Low Cost
  - Robust
  - Deterministic
  - Scalable
  - Open Standards

- Information Level

- Control Level

- Device Level

- FIELD BUS

- INDUSTRIAL ETHERNET
How Is Industrial Ethernet Different?

- **Real Time Protocol over Ethernet**
  - Uses UDP/IP with object identifications
  - Hard real-time: Utilizes ISO/OSI model Layer 2 – 4 to implement modified Ethernet MAC and real-time protocol

- **Deterministic Performance**
  - Assurance that data is received by the slave device

- **Synchronized**
  - Timing between packets and the process are tightly coupled

- **Redundant**
  - Measures taken so that packets can be rerouted if needed

- **Interoperability**
  - Requires that a standard protocol will work with other slave devices

---

**Diagram**

- **enterprise**
  - **process**
  - **device**

- **Non Real Time Using 802.3**
  - **TCP / UDP / IP**
  - **Ethernet**

- **Real Time Protocol over Ethernet**
  - **TCP / UDP / IP**
  - **Ethernet**
  - **Modified Ethernet**

- **Cabling** (as defined by Ethernet + rugged connectors)

- **“NRT”** Non-Real Time
- **“RT”** Real Time
- **“IRT”** Isochronous or Hardware Real Time
Protocols For Different “Real Time” Requirements

**Number of Nodes**

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

- **Non-Deterministic**
  - Jitter not important
  - 10 to 100ms Cycle Time

**Software Implemented**

- **Servo Drives**
- **Motion Controllers**
- **PLCs / PACs**
- **Gateways & Switches**
- **I/O Modules**
- **Sensors**
- **HMI**

**Hardware Assisted**

- **EtherCAT**
- **PROFINET IRT**
- **POWERLINK**
- **PROFINET RT**
- **PROFINET NRT**
- **Modbus-IDA**

**How Much “Real Time” Do I Need?**

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Industrial Ethernet Protocols
Slave Architectures Overview
Industrial Ethernet Slave Architecture

Non Real Time (NRT)

- Parameter Data and Control Data on the same channel
- Standard TCP and UDP
- Relies on object identification and prioritization to know what data is for the process or for device
- RTOS independent
- Unmodified Ethernet hardware MAC
- Known protocols

OSI Model Layers

Software

Application

Transport

Network

Data Link

Physical

Hardware

TCP/UDP

IP

Standard Ethernet MAC Controller

Automation API

Parameter Data Real-Time Data

HTTP

SNMP

DHCP

Known protocols

EtherNet/IP

PROFIBUS NRT

Modbus-IDA
Industrial Ethernet Slave Architecture

Real Time (RT)

- Dedicated Real time Data and Parameter Data run parallel to TCP/UDP
- TCP/UDP/IP controlled by timing layer
- Uses slot timing for real time performance
- Needs fast forwarding of frames
- Unmodified Ethernet hardware MAC
- Known protocols

Ingredients:
- Application
  - Data
    - IT tasks
      - HTTP
      - SNMP
      - DHCP
  - Process Data
  - Automation API
- Transport
  - TCP/UDP
  - IP
- Network
  - Timing Layer
- Data Link
- Physical

Protocols:
- PROFIBUS
- POWERLINK
- EtherCAT
- EtherCAT RT
- EtherCAT Powerlink
- EtherCAT EtherCAT
Industrial Ethernet Slave Architecture

Hardware Real Time (Isochronous Real Time)

- Dedicated Process Data and Parameter Data channels
- Embedded switch
- Custom hardware Ethernet Controller (MAC)
- RTOS dependent on protocol
- PTP (IEEE1588) precision timing may be required
- Known protocols

Supported Protocols:
- PROFINET
- EtherCAT
- POWERLINK
- SERCOS
- EtherCAT
- EtherNet/IP
# Summary of Protocol Characteristics

<table>
<thead>
<tr>
<th>Consortia</th>
<th><a href="www.modbus.org">Modbus-IDA</a></th>
<th><a href="www.odva.org">EtherNet/IP</a></th>
<th><a href="www.ethernet-powerlink.org">EtherCAT</a></th>
<th><a href="www.profinet.com">Profinet</a></th>
<th><a href="www.ethercat.org">EtherCAT</a></th>
<th><a href="www.sercos.org">Sercos</a></th>
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<tbody>
<tr>
<td>Key Supplier</td>
<td>Schneider Electric</td>
<td>Rockwell Automation</td>
<td>B&amp;R</td>
<td>Siemens</td>
<td>Beckhoff</td>
<td>Bosch Rexroth</td>
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<td>Ethertype</td>
<td>0x0800 (IPv4)</td>
<td>0x88AB</td>
<td>0x8892</td>
<td>0x88A4</td>
<td>0x88CD</td>
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<td>Ethernet</td>
<td>Standard Ethernet Controller (MAC)</td>
<td>Custom Hardware Ethernet Controller (MAC)</td>
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<td>Process Data</td>
<td>TCP/IP</td>
<td>UDP/IP</td>
<td>Protocol Specific</td>
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<td></td>
<td></td>
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<tr>
<td>Real Time</td>
<td>None</td>
<td>Prioritizing</td>
<td>Scheduling</td>
<td>Prioritizing</td>
<td>Summation Frame</td>
<td></td>
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<td>Service Data</td>
<td>TCP/IP</td>
<td>UDP/IP</td>
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<td>Hardware Configurations</td>
<td>MCU</td>
<td>MCU</td>
<td>MCU + FPGA</td>
<td>MCU + ASIC</td>
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<tr>
<td>Protocol Implementation</td>
<td>Software Stack</td>
<td></td>
<td>MCU + FPGA + FPGA</td>
<td>MCU + ASSP</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MCU + FPGA + ASSP + System On Chip</td>
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<td></td>
<td></td>
<td></td>
<td>MCU + ASIC + FPGA + ASSP</td>
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</tbody>
</table>
Industrial Ethernet Development Considerations
Typical Multi-Chip Industrial Control System With Networking

- Microcontroller/MPU/DSP
  - Manages the application
  - Algorithm processing
  - Analog input/output
  - Backplane/Bus interface

- FPGA extension
  - Processor offload
  - I/O extension
  - Glue Logic
  - High speed interface

- Communications processor
  - Software stack
  - Multi-port switch
  - Ethernet MAC
  - Fieldbus and serial comms

What Architecture Works Best For My Application?
Considerations To Implementing Industrial Ethernet Solutions

- Selecting the right protocol
  - What level of ‘real time’ do I need?
  - What nuances in the protocol may provide a technical challenge?

- Flexibility, scalability and costs
  - How flexible is my solution for different protocol implementations?
  - Will my architecture scale based on my customer needs?
  - What is the impact on size or power?
  - What are the cost impacts to the solution?
  - MCU device considerations?
  - What about Functional Safety considerations?

- Completeness of solution
  - HW solutions: MCU, ASIC, ASSP, even Ethernet PHYs
  - Software solutions: Protocol stacks TCP/IP, Industrial Ethernet
  - Business model fit
  - Reference solutions – how do I get started?
### Industrial Ethernet Implementation Differences

<table>
<thead>
<tr>
<th>Configuration</th>
<th>MCU</th>
<th>MCU + ASIC</th>
<th>MCU + FPGA</th>
<th>MCU + ASSP</th>
<th>System On Chip</th>
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<tr>
<td>Low Cost</td>
<td>MCU</td>
<td>MCU</td>
<td>MCU</td>
<td>MCU</td>
<td>MCU</td>
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<tr>
<td>Fits Many IE</td>
<td>PHY</td>
<td>ASIC</td>
<td>FPGA</td>
<td>ASSP</td>
<td>ASSP</td>
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<tr>
<td>Implementations</td>
<td></td>
<td></td>
<td>Memory</td>
<td></td>
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</tr>
</tbody>
</table>

**Benefits:**
- **Low Cost**
- Fits Many IE Implementations
- Dedicated ASIC supported by protocol consortia
- Flexibility in implementing different protocols
- Support for multiple protocols independent of MCU
- Hardware integrated for more efficient control and communications

**Challenges:**
- Does not support IRT requirements
- MCU architecture limitations
- Single protocol
- Power not optimized
- High Power requirements
- High NRE
- Interface complexity and performance
- Need for efficient processor architecture
- Limited to MCU configuration
- Power consumption

**Notes:**
- MCU
- MCU + ASIC
- MCU + FPGA
- MCU + ASSP
- System On Chip
How Scalable Is Your System?

- Absorbing the MCU functionality into the FPGA
  - IP model is cost prohibitive – unless very high volume
  - Replacing a low $ MCU to a $$$ FPGA
  - Need for additional external components such as ADCs and memory
  - Do you need this much performance?

- Extending an ASIC-implemented platform to support additional protocols
  - Need to redesign and build multiple boards to support different protocols
  - Different software stacks for each protocol
How Much Space Do You Have?

- **ASICs/ASSPs**
  - Can range up to 20mm x 20mm
  - Limited package options

- **FPGAs**
  - Requires at least 45KLE to fit the protocol
  - FGG 484 is 23 x 23; 1mm pitch
  - Power components needed

- **Key point** – Different device combinations may require a larger PCB space, possibly more than you can afford

<table>
<thead>
<tr>
<th></th>
<th><strong>ASIC</strong></th>
<th><strong>FPGA</strong></th>
<th><strong>MCU</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>BGA 345 1mm pitch</td>
<td>FGG 484 1mm pitch</td>
<td>LQFP 144 0.5 mm pitch</td>
</tr>
<tr>
<td>Size</td>
<td>20mm x 20mm</td>
<td>23mm x 23mm</td>
<td>7mm x 7mm</td>
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</table>

Example of EtherCAT ASICs and FPGA Devices
Power Consumption

- Power consumption is important for fanless, compact systems
  - ASSPs can require up to 300mA
  - Need to consider heat dissipation techniques

- Key point – Consider the power consumption budget as some ASICs and FPGAs can be high

Relative Current Consumption By Device Type

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPGA</td>
<td>High</td>
</tr>
<tr>
<td>ASSP</td>
<td>Medium</td>
</tr>
<tr>
<td>ASIC</td>
<td>Low</td>
</tr>
<tr>
<td>MCU</td>
<td>Very Low</td>
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</table>
## Costs* of Protocol Implementation

<table>
<thead>
<tr>
<th>Resource</th>
<th>Development Time</th>
<th>Protocol IP Core</th>
<th>Switch IP</th>
<th>Software Stack/API</th>
<th>MCU + FPGA + Memory</th>
<th>FPGA Tools</th>
<th>NRE + Per Device</th>
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</thead>
<tbody>
<tr>
<td>MCU</td>
<td>4-6 months</td>
<td>$25K + $5 royalty</td>
<td>$15K</td>
<td>$10K</td>
<td>$5 + $20 + $2/slave</td>
<td>$5,000/one time</td>
<td>$55K + $32/slave</td>
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<tr>
<td>FPGA</td>
<td></td>
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<tr>
<td>Memory</td>
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<tr>
<td>SW Programmers HW Designers FPGA Designers IP Partners</td>
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<tr>
<td>ASIC</td>
<td>2-4 months</td>
<td>Included</td>
<td>included</td>
<td>$10K</td>
<td>$5 + $12 (one protocol)</td>
<td></td>
<td>$10K + $17/slave</td>
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<tr>
<td>MCUs</td>
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<tr>
<td>SW Programmers HW Designers Single-Sourced ASIC Supplier</td>
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<tr>
<td>MCU</td>
<td>2-4 months</td>
<td>Included</td>
<td>included</td>
<td>$10K (NRT protocols)</td>
<td>$5</td>
<td></td>
<td>$10K + $5/slave</td>
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<tr>
<td>PHY</td>
<td></td>
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<tr>
<td>SW Programmers HW Designers Consortia Partner</td>
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</table>

* Estimated costs for comparison only.
Efficient Data Exchange In The MCU Allows For Better System Partitioning

- Parallel bus architecture provides efficient partitioning
- Dedicated DMA for Ethernet channel relieves burden on CPU
- Ethernet controller provides automatic CRC frame check
**Advanced FPU Boosts Performance & Reduces Code Size**

- RX Floating-point Unit (FPU) enables efficient blend of fast execution time and small code size.

- RX FPU implementation allows direct access to General Registers resulting in even faster execution time – boosting performance by up to 50%.
Efficient Exception Handling Assists Real-Time Applications

- Reduces the amount of wasted bandwidth on time slot networks
- Improves response times of devices with software implementations

Slot Timing Method

Fast interrupts reduce cycle times
Designing For Safety

- Safety requires an independent channel
  - Switching to safety-related commands and messages at the highest priority
  - Extension to protocol definitions
    - PROFIsafe, Safety Over EtherCAT, CIP Sync Safety, etc.

- Designing-in redundancy
  - IEC61508 (Functional Safety) requires a two-chip solution for redundancy

- Need for robust diagnostics and operation
  - CRC checksum
  - Independent watchdog
  - Complex interrupt control
  - Cable diagnosis (PHY layer)
Safety In Hardware Assists In Compliance

(Features in RX63T and RX200)
Understand The Ecosystem & Business Model

- Consortia Compliance
  - Memberships
  - Plugfests

- Local, reliable IE SW partner
  - Business model fit
  - IP quality and compliance

- Design Services partner
  - Experience
  - Transferrable, scalable solution

- Hardware suppliers
  - PLC Master
  - Software application environment (ex. Step 7 or TwinCAT)
  - Device suppliers

- Where do you begin?
  - Hardware and/or software reference
Industrial Networking Design Considerations - Summary

- Multiple hardware choices are available
  - Weigh the features and cost tradeoffs between the various architecture options: MCUs, ASICs, ASSPs, FPGAs or integrated solutions

- What does scalability look like?
  - Adding functionality should not reduce performance nor significantly cost more

- Hardware Specifications
  - Size and Power considerations

- Efficient Partitioning
  - Can the processor handle different I/O and communication requirements?
  - Does the MCU/CPU efficiently handle interrupts, memory accessing, bus communications

- Designing for Safety
  - How will your solution be impacted when implementing safety?

- Business models impact your costs
Considering The PHY Level

EtherPHY Must Fulfill Industrial Networking Requirements

Industrial market needs
- Real time communication
- Faster start up time
- Error free communication
- Fast link down time
- Problem Debug

Requirements for Ethernet PHY’s
- Low latency
- Cable monitor/ BER Counter
- Cable diagnosis
- Stand Alone Initialization
Intelligent Ethernet PHY For Industrial

- Low node latency and low jitter
- Fast link-up time and fast link-down detection
- Multiple cable monitoring and diagnostics features
  - Bit Error Counter due to open cable, single short, etc.
  - TDR (time domain reflectometry) detects location of cable fault
- EMC immunity
  - Tests according to EN61000-4-4
- IEEE1588 PTP support

Single Channel & Dual Channel
Fully compliant with IEEE 802.3 / 802.3u for 100Base-TX, 100Base-FX, 10Base-T
Auto-negotiation and parallel detection
Full and half duplex operation
Single 3.3V power supply
MDI/MDI-X crossover
MII based on 25MHz clock
Renesas TPS-1: Profinet IRT ASIC

**Hardware**
- Single chip solution
  - Integrated CPU
  - Integrated PROFINET IRT Switch
  - Integrated RAM
- BGA housing 15 x 15 mm² with 1 mm pitch
- External serial FLASH required
- Total power consumption: 0.8 W

**Software**
- PROFINET Version 2.3 for RT and IRT
- No license needed

Supported thru Renesas Partner:
Renesas Provides Complete Industrial Ethernet Solutions

Protocols Supported

Application Software

Software API

CPU

Memory

Serial Interface

IO

Custom MAC

Standard MAC

PHY / 1588

PHYs

1 or 2 channel Ethernet PHY
PTP/1588

Software Partners

Microcontrollers
Ideal for IE

ASICs

Protocols Supported

- EtherCAT
- EtherCAT Standardization Group
- EtherCAT
- PTP/1588
- Ethernet
- POWERLINK
- SERCOS Interface
- Modbus-IDA
- PROFINET
- EtherNet/IP

CPU

TCP/IP

OS

Protocol Specific Software Stack

Microcontrollers

- RX

ASICs

- PROFIBUS
- IRT

Software Partners

- XOX
- IXXAT
- Kyocera
- port
- AUTOMATA
How To Get Started...

**Renesas Demonstration Kit (RDK)**

- This board plugs into a PC’s USB port to showcase the features and capabilities of RX600 MCUs
- RX MCU board with J-Link integrated debugger and huge peripheral set including Ethernet, CAN and USB
- Graphic display
- 3-axis accelerometer
- Audio in/out
- Installation CD containing:
  - High-performance Embedded Workshop (HEW)
  - RX Family C/C++ toolchains (Renesas 128KB evaluation version, full GNU version)
  - Quick-start guide, sample projects

**Processor**      **RDK Part Number**
RX62N             YRDKRX62N
RX63N             YRDKRX63N
Renesas – Your IE Solutions Provider

- Comprehensive MCU and peripheral device solutions for your Industrial Ethernet requirements
  - Microcontrollers
  - PHYs
  - ASICs

- Powerful software and tools to help you design robust networking systems

- Strong Industrial Ethernet partner network reduces time to market and risk
  - IE consultants
  - Design service partners
Please Provide Your Feedback...

- Please utilize the ‘Guidebook’ application to leave feedback

or

- Ask me for the paper feedback form for you to use...
Questions?
RX Microcontroller Family

**Real-time Performance**
- Zero-wait Flash @ 100MHz
- Ultra-fast 5-cycle interrupt response
- Digital Signal Processing
- Floating Point Unit

**Extensive Software, Tools, & Support**
- Industry-standard tools
- Third-party support
- Online resources
- Solution Kits (DD-LCDs, WiFi, Audio, Cloud Connectivity, Motor Control... and more)

**Top Quality and Safety**
- Best-in-class ESD
- IEC607030 safety functions
- Electromagnetic susceptibility up to 500V immunity

**Broad Scalability**
- 48 to 177 pins
- 32KB to 2MB Flash
- Core and peripheral compatibility

**Holistic Peripheral Sets**
- Enhanced system functionality
- Connectivity (Ethernet, Dual-USB, 3xCAN... and more)
- Advanced timers and analog

**High Efficiency**
- Up to 1.65 DMIPS per MHz
- 28% less code size
- As low as 130μA per DMIPS

**Perfect Balance of Performance, Efficiency & Scalability**
The Revolutionary New RX CPU Core

Drawing on the best of the best

**RISC**
- Multiple register sets
- Single clock instructions
- Highly pipelined
- Fast interrupts
- Load/stores needed
- Few instructions
- Few addressing modes
- Fixed length instructions

**CISC**
- Avoid load/stores
- Many instructions
- Many addressing modes
- Variable length instructions
- Single register set
- Multi-clock instructions
- Little pipelining
- Slow interrupts

**MCU**
- Efficient general instructions
- Easily programmed in C
- Fine power management
- Wide connectivity options
- Rich supervisory functions
- Simple low-cost tools
- Broad third-party support
- Simple integer math

**DSP**
- Hardware MAC
- Barrel shifters
- Harvard architecture
- Floating point unit
- Single task oriented
- Complex software
- High power
- Limited connectivity

Traditional Architectures
RX600 Series – Performance & Connectivity

**Superior Performance**
- RX 32-bit CPU Core with FPU and DSP
- 165 DMIPS @ 100MHz; 2.77 CoreMark™/MHz
- 100MHz Flash with zero-wait states; up to 2MB
- Parallel busses for simultaneous data transfers optimize throughput
- Multiple Direct Memory Access control
- Flexible interrupt handling

**Code Efficiency**
- Up to 28% code size savings compared to popular 32-bit RISC MCUs
- Variable-length CISC instructions
- FPU, DSP and bit manipulation instructions

**Comprehensive Peripherals**
- 12-bit A/D (1µs), 3 independent S/H, PGAs
- 10/100 MAC with DMA (supports MII, RMII)
- USB (Host/Device/OTG); CAN 2.0B; LIN
- Advanced Motor Control; multiple timers; flexible PWM
- 10-bit DAC; temperature sensor; RTC
- SPI, UART (synch/asynch), I2C, Ext Bus (24-bit addr)

**Hardware Safeguards**
- Built-in Power-on Reset generation
- Precision Low-voltage Detect warning
- Flash with ECC
- Options for Built-in pull-up and 5V tolerance
- Independent WDT; CRC checker

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2 Source: www.coremark.org as of June 2012
3 Source: Renesas internal testing
## Renesas MCU Device Roadmap - Ethernet

<table>
<thead>
<tr>
<th>Legacy</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013 &amp; Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>V850/Mx4</td>
<td>Ethernet, FPU</td>
<td>RX62N</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>RX xxx</td>
</tr>
<tr>
<td>SH7216</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>SH7670</td>
<td>Ethernet, USB, FPU, Audio</td>
<td>100 MHz + FPU</td>
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<tr>
<td>SH7670</td>
<td>Ethernet, USB, FPU, Audio</td>
<td>RX63N</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>Up to 4MB Flash</td>
</tr>
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<td>RX62N</td>
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<td>RX xxx</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>Dual Ethernet</td>
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<td>RX63N</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>RX xxx</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>Safety Features</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RX xxx</td>
<td>Ethernet, USB, CAN, FPU</td>
<td>16-bit ADC</td>
</tr>
</tbody>
</table>

- **Safety Features**: 16-bit ADC