Solutions for Industrial IoT

PC LEE
RENESAS ELECTRONICS TAIWAN
Agenda

- The Next Industrial Revolution
- Components of the Industrial IoT Network
- New business models and opportunities
- Summary
Industrial IoT Is Changing The Typical Definition

Mobile Device Are The Center of IoT

Vertically Oriented Machine 2 Machine

Process & Cyber Physical Systems Are The Center

Secure, Global, Real-time Access to Data and Analytics
Industrial IoT: Next Industrial Revolution

1st Industrial Revolution
- Powered loom ca. 1845
- Machines with mechanical gears, powered by water and steam
- 1800s

2nd Industrial Revolution
- Ford Model-T ca. 1927
- Assembly line for mass production, common parts, process efficiency
- 1900s

3rd Industrial Revolution
- Invention of the semiconductor, programmable systems
- Electronic and IT systems to automate production; IE
- Honeywell controls ca. 1970
- First patent of field electric transistor (ca. 1925)
- 2000s

4th Industrial Revolution
- Internet and networking integration
- Trending
Imagining The Industrial IoT – Airlines

- Dispatching service persons before arrival
- Analyzing real-time performance data
- Bringing in the right service part

10% Of Flight Delays from unscheduled maintenance issues

$8B In Additional Costs
Imagining The Industrial IoT – Factory

**Sensor-Enabled Automation**
Sensors throughout factory assets and operators to prevent unplanned downtime and boost productivity

**Virtual Manufacturing**
Using digital and collaborative tools to model plants, operations, product development

**Real-time Analytics**
Data driven analytics to optimize throughput and reduce waste

**Cyber Physical Systems**
Agile production cells and operations between human and robot-supported work for efficiency and customization

**IIoT Economic Impact To Manufacturing Estimated at $1.2 Trillion**

Sources: IIIC, Accenture, GE
IIoT Is Mobilizing The Industry

Machinery Manufacturers Need IIoT

Traditional

Future

Product Transaction Model

Customer Relationship Model

“Gartner estimates IoT suppliers will generate incremental product and service revenue exceeding $300B by 2020”

Lesson: Find Strategic Partners!
Industrial OEMs Creating New Revenue Streams

- Site dashboard
- Customizable metrics
- Track performance
- Sustainability tools
Challenges Related to Widespread Adoption

No definitive technology and approach
- Industry 4.0 vs. IIoT vs. M2M
- Consortia race

Interoperability & Standards
- Data structures that are proprietary
- Industrial Ethernet is very fragmented

Business justification
- Cost of retrofitting into existing infrastructure
- Management of large-scale collection and correlation of data
- Perceived and real security risk

Expertise gaps
- Lack of expertise focused on the ‘digital workplace’
- Differing fields and domain expertise – IT vs. OT gap

Source: Industrial Internet Consortia
Main Components of Industrial IoT Solutions

Seamless Operation of People, Assets, & Process
- Technology-enhanced with sensors, feedback mechanisms
- Autonomous to the point of ‘self-aware’
- Configurable, customizable

Connected
- Real time, non-real time domains
- Wired and Cloud components

Safe & Secure
- Inherent safety
- User authenticated, context aware security

Intelligent Analytics
- Descriptive, Predictive and Prescriptive Analytics
- Conditioned at each plant level

Managed Data
- Reusable, scalable data models
- “Intelligent Information” when and where people are
Industrial IoT Operations at Each Level

Enterprise Level

Control Level

Field Level

IIoT Opportunities Start At The Edge
Volkswagen German Plant Accident: Robot Grabs, Crushes Man To Death
Safety Is Priority #1

Productivity and Safety go hand-in-hand

- OSHA estimates lost productivity of $60B/year

Costs of non-compliance

- Violations/fines, higher insurance premiums, workers compensation, litigation, etc.

- Machinery Directive (IEC 61508) requirement in EU

Market differentiator

- Safety certified products and systems give ‘quality’ confidence

**Challenge: Cost Burden and Lack of Expertise**
Certified Safety Solution Reduces Time And Risks

Developed according to IEC61508:2010
  ▪ Targeting SIL2 and SIL3 applications

Multiple platform solution
  ▪ RX631/RX63N and RX111

Comprehensive Solution
  ▪ Self-Test Diagnostic Software
  ▪ Comprehensive Safety Manual including Test Plan & Analysis, FIT data, etc.
  ▪ Developed with FS certified IAR Systems Embedded Workbench for RX (EWRXFS)
  ▪ Scalable to other RX platforms

Cuts Safety Certification Process by 6 Months!!
Comprehensive Fault Coverage Validation

- Diagnostic coverage of CPU validated by fault injection using real hardware netlist of the MCU
- Evaluated the coverage of each injected fault (detected or not detected)
- Over 39 Test Segments and full set of CPU instruction set
- Exhaustive fault injection tests with >190,000 possible faults (ex. RX631/63N)
- Diagnostic Coverage (DC) value reaches >90%
# Microcontroller Element Analysis

## Relevant MCU elements covered

<table>
<thead>
<tr>
<th>MCU Element</th>
<th>Element Description</th>
<th>Element FIT for failure mode 'permanent'</th>
<th>Element FIT for failure mode 'transient'</th>
<th>Diagnostic measure (DH-ID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O</td>
<td>Chip I/O logic</td>
<td>0.425</td>
<td>1.124</td>
<td></td>
</tr>
<tr>
<td>UART</td>
<td>UART communication interface</td>
<td>0.202</td>
<td>1.472</td>
<td></td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>Temperature sensor circuit</td>
<td>0.150</td>
<td>0.624</td>
<td></td>
</tr>
<tr>
<td>MCK_TRU</td>
<td>Frequency measurement circuit, can be used to monitor the main clock, sub-clock, LOCO, PLL, and HOCO for abnormal frequencies, clock output extension circuit of TRU</td>
<td>0.001</td>
<td>0.002</td>
<td>used for diagnosis</td>
</tr>
<tr>
<td>MCK_MTU2</td>
<td>Frequency measurement circuit, can be used to monitor the main clock, sub-clock, LOCO, PLL, and HOCO for abnormal frequencies, clock output extension circuit of MTU2</td>
<td>0.001</td>
<td>0.002</td>
<td>used for diagnosis</td>
</tr>
<tr>
<td>SPI</td>
<td>SPI communication interface</td>
<td>0.040</td>
<td>0.251</td>
<td></td>
</tr>
<tr>
<td>SPIbus</td>
<td>Renesas Inter Equipment Bus</td>
<td>0.053</td>
<td>0.072</td>
<td></td>
</tr>
<tr>
<td>CRC</td>
<td>CRC calculation module</td>
<td>0.003</td>
<td>0.011</td>
<td>used for diagnosis</td>
</tr>
<tr>
<td>RTOS</td>
<td>Real-Time Clock module</td>
<td>0.003</td>
<td>0.008</td>
<td></td>
</tr>
</tbody>
</table>

FIT rates for both permanent & transient failures modes

Safety mechanisms considered for each element
SW Self-Test covers RX600, RX200, and RX100 family groups.
Synergy Provides Internal Safety Functions

Four Microcontroller Series

- S1: Ultra-Low Power, Core Frequency Up to 32 MHz
- S3: High Efficiency, Core Frequency To 100 MHz
- S5: High Integration, Core Frequency To 200 MHz
- S7: High Performance, Core Frequency To 300 MHz

Safety Certification Is Part of Product Plan

Note: Not all features are on all devices
Connectivity That Links Time Domains

- Real-time and non-realtime domains
- Intelligent gateways partition between factory and enterprise
- Secure-cloud based connectivity
- Multiple protocols and standards
Solutions For Industrial IoT Networking

- Multi-protocol support
- Hardware accelerators
  - License free EtherCAT & CCLink IE
- Single/Dual Channel Ethernet
- Ethernet DMAC
- Cut-through, Store & Forward

Diagram:
- Non-Real Time: 10 to 100ms Cycle Time
- Soft Real Time: 1 to 100ms Cycle Time
- Hard Real Time: < 1ms Cycle Time
R-IN32M3-EC Block Diagram

Supports Multiple Protocols

EtherCAT, EtherNet/IP, CANopen, Modbus-IDA, CC-Link IE

128 bits Hardware Function Bus

- Hardware Function Control
- Header Endec
- Buffer RAM with ECC 64KB
- Buffer Allocator
- INT DMA
- MAC DMA

128 bits Communication Bus

- Ether MAC
- AHB2DMA
- RAM
- EtherCAT
- Ether Switch

AHB-Lite Multi Layer Bus Sub-System

- Real-time Port DMAC
- General DMAC 4th
- General Port
- Real-time Port
- CC-Link
- Serial Flash MEMC
- ROM/ SRAM MEMC
- Host CPU Interface
- Inst. RAM with ECC 768KB

Multiplexed Bus (MUX)

AHB Bus

- Timer Array
- UART x2
- IIC x2
- CAN x2
- CSI x2
- WDT
Outline of R-IN32M3 RTOS In Hardware

Traditional SW-RTOS

- Resource management, queuing, task schedules, context switching, etc. all done in software
- Dependent on CPU loading
- Not deterministic for real-time industrial applications

R-IN32M3 RTOS operation in Hardware

- Familiar SW RTOS environment (Micrium’s uC/OS-III HW-RTOS)
- OS library for system call commands and dispatch only
- Task scheduling and queuing function in hardware
- Up to 30 System Calls: Events, Semaphores, Mailbox operation, etc.
Synergy S7 Dual Ethernet Controller

- Two integrated Ethernet MACs, 10/100 Mbps
- IEEE 802.3x-compliant flow control (MII/RMII)
- Supports IEEE 1588v2 PTP
- Dedicated Ethernet DMA controller for data transfer without CPU intervention
- Supports full-duplex and half-duplex transfer modes
- Supports Magic Packet™ detection and Wake-on-LAN (WOL) functionality
Real Time Motor Control
RZ/T – New Motion Control Solution Family

- ARM based solution
- Multi-protocol Industrial Ethernet
- High performance
- Real-time OS
- Large embedded RAM
- Ethernet Accelerator
- Encoder protocols
- Starter Kit
- Compatible upgrade path
- Extensive tool chain
Standard Drive System – 3 Device Solution

Communication device
- to support Ethernet TCP/IP or dedicated industrial Ethernet Protocols, like DeviceNet, EtherNet/IP, PROFIBUS, PROFINET RT/IRT and EtherCAT

Application device
- to handle and control the complex algorithms of the motor

Encoder device
- To provide the position feedback of the motor
RZ/T – 1 Device Solution

- RZ/T allows to migrate all function into one single device.
- Reduces the Total Cost of Ownership (TOC) for overall drive system.
What Makes RZ/T Unique?

600MHz Real-time CPU + SH/RX Compatibility

Real-time performance, R-IN and Multi-protocol encoder I/F
RZ/T1 provides values no other competitor has.
- High Performance CPU (ARM Cortex-R4F)
  - Max. operating freq.: 450MHz / 600MHz
  - High-speed real-time response
  - Single/Double precision FPU

- On-chip memory:
  - Tightly Coupled RAM 512KB + 32KB w/ECC
  - Instruction RAM 512KB + Data RAM 512KB w/ECC for R-IN engine

- Features
  - Multi protocol Industry Network Accelerator (R-IN Engine)
  - EtherCAT slave controller
  - Ethernet Accelerator
  - 100Mbps EtherMAC w/ switch
  - PWM timer: MTU3a, GPT
  - Encoder I/F (Endat2.2, BiSS-C, A-Format, Tamagawa Seiki) (option)
  - High-speed USB
  - Secure boot (option)
  - Safety Feature
    - ECC RAM supported
    - CRC(32bit)
    - Independent WDT with dedicated on-chip oscillator
  - Σ I/F

- Power supply voltage: 1.2V, 3.3V

- Package
  - FBGA 320pin (17mm², 0.8mm pitch)
## RZ/T1 Product Lineup

<table>
<thead>
<tr>
<th>CPU</th>
<th>TCM</th>
<th>exRAM</th>
<th>Package</th>
<th>Encoder Interface</th>
<th>Industrial Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td>600MHz</td>
<td>512KB + 32KB</td>
<td>- (1MB for R-IN)</td>
<td>176QFP</td>
<td>Yes</td>
<td>EtherCAT</td>
</tr>
<tr>
<td>+ R-IN engine (150MHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multiprotocol support</td>
</tr>
<tr>
<td>450MHz</td>
<td>512KB + 32KB</td>
<td>- (1MB for R-IN)</td>
<td>1MB</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>+ R-IN engine (150MHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **R7S910001**
- **R7S910002**
- **R7S910003**
- **R7S910004**
- **R7S910005**
- **R7S910006**
- **R7S910007**
- **R7S910008**
- **R7S910009**
- **R7S910010**
- **R7S910011**
- **R7S910012**
- **R7S910013**
- **R7S910014**
- **R7S910015**
- **R7S910016**
- **R7S910017**
- **R7S910018**

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Renesas RZ/T1-R Starter Kit (RSK)

- The RZ/T1 Starter Kit provides full access to the single/dual core drive solution with easy access to multiple Industrial Ethernet standards and encoder interface protocols.

- The kit includes:
  - CPU board with target microcontroller
  - LCD panel for user/diagnostic interaction
  - e2Studio with KIPT GCC (for Cortex-R4, Cortex-M3) code generator for GCC and IAR compiler
  - Jlink-Lite ICE
  - Tutorial guide
  - Sample application code for GCC generated driver code

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Status</th>
<th>Part Number</th>
<th>Debugger supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renesas Starter Kit+ for RZ/T1 (Kit with Segger J-LINK Lite)</td>
<td>available</td>
<td>RTK7910018S00000BE</td>
<td>Segger J-LINK Lite</td>
</tr>
<tr>
<td>Renesas Starter Kit+ for RZ/T1 (Kit without Debugger)</td>
<td>available</td>
<td>RTK7910018S900000BE</td>
<td>(No Debugger in Kit)</td>
</tr>
</tbody>
</table>
Renesas RZ/T1-R Solution Kit

Shorten Time to Market - Build a Motion Controller from a Single RZ/T1 MPU -

- RZ/T1 motion control solution kit "DRIVE IT!" is the best way for your jumpstart on your evaluation of the RZ/T1 features, performance. The kit includes all of the required equipment including inverter board, motor, firmware, utility tool for windows, documents, to drive a motor and evaluate it's performance easily and quickly.

Solution Kit Content

- RZ/T1 CPU card
- Low-voltage inverter board supporting dual servo motors
- Motion control utility tool (for Windows)
- Quick-start guide and users manuals
- Installation CD including tools, firmware, evaluation software, documentation
- BLDC servo motor with incremental encoder
- Debug prove (IAR i-Jet Lite)
- Cables for connecting the motor

Part number: YDRIVE-IT-RZT1
RZ/T Summary

- High-end motor control solution for the Industry 4.0
- Embedded Encoder interface
- Multi protocol capability (embedded R-IN engine)
- 2-4 times higher performance compared to competition
IIoT Analytics by Functional Domain

Control Domain
- Sensor data Validation
- Real-time Monitor & Diagnosis
- Safety/Security analysis
- Descriptive analytics

Information Domain
- Ingestion & transformation
- Streaming & Batch analytics
- Contextual security
- Predictive analytics

Operations Domain
- Provisioning/Deployment
- Prognostics & Optimization
- Process Monitor & Diagnosis

Business Domain
- Business Analytics
- Decision Support Services
- Decisive Analytics

Reference: IIoT Reference Architecture, IIC

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Edge Analytics Using Industrial Sensor MCUs

- Temperature/Pressure Sensors
- Ultrasonic Sensors
- Proximity Sensors; Inductive, capacitive
- Flow Sensors
- Conductivity sensors

**ADC Resolution (bits)**
- 24-bit ΔΣ ADC
- 16-bit ΔΣ ADC w/ sensor Amp
- 12-bit SAR
- 10-bit SAR

**Sampling rate (samples/sec)**
- 10k
- 100k
- 1M
- 2M

- 24-bit SAR 1.4 MSPS
- 12-bit SAR 2.5 MSPS
- 10-bit SAR 470ksps
- 14-bit SAR
- 24-bit ΔΣ ADC

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Event Link Controller (ELC)

Allows direct interaction between different modules without CPU intervention

Routes source events generated by a peripheral to event inputs on other peripherals

Event signal can activate a peripheral for the desired operation
  - Start/stop/clear timer, up/down counting
  - Start ADC and DAC conversion
  - Start Captouch measurement
  - Start DMA/DTC transfer
  - Issue interrupts to the CPU
  - Change state of GPIOs

Most peripherals generate event signals

Peripheral classification based on event signals

Synergy MCU

Simplified implementation of the ELC
Industrial IoT Is Expanding Value Chain

Expanding Traditional Business

Secure
Managed Data
Intelligent Analytics

Data Analytics
Cloud Security
Analytics Integration
Cloud SaaS

Enterprise Services
Factory SW/Eqpt
System Integrators
Industrial OEM
Embedded HW/SW
Middleware
Silicon

Factory-Enterprise HW
Software analytics
Cloud Connectivity
Ready to use hardware
Safety & security integrated
Revenue Services Resulting From Industrial IoT

Big Data Management
- IT/OT Integration
- Data As An Asset
- Enterprise to Mobile Connectivity

Enhancement Services
- Predictive Maintenance
- Systems Performance
- Closed loop Product Lifecycle Management
- Process Analytics
- Process Visualization
- Provisioning & Key Management
- Process to Cloud Connectivity

Start At The Edge
- Safety certified modules, sensors, controllers
- Industrial network protocols
- Sensor & Actuator analytics
- Secure remote upgrade from trusted sources
- Device to Fog connectivity

Big Data
Summary
Industrial IoT Summary

Industrial IoT will reshape manufacturing of the future

- Collaborative and self-managing real time machines
- Big Data with cloud connectivity
- Context based analytics
- Security and safety at every level

Intelligent sensors and digital devices

IIoT Solutions Start at the *Edge*

- *Accelerate* designs with systems on chip solutions and pre-certified software
- *Innovate* by leveraging a platform that provides edge to cloud connectivity
- *Differentiate* with better security, analytics and new business models