

Industrial Networks for Factory Automation

Seamless real-time communication is indispensable to Industry 4.0 and Industrial Internet of Things (IIoT) implementations. Renesas offers a variety of solutions for industrial networks to enable advancement and automation of industrial equipment, with support for protocols such as EtherCAT, EtherNet/IP, and PROFINET.



CONTENT

Industrial Networks for Factory Automation	02
Renesas Industrial Network Solution Contribute to Realize Smart Society	04
RZ/T2M: MPU Enabling High-Speed and Highly Precise Servo Motor Control	06
RZ/T1: Industrial Drives with Multi-Protocol Industrial Ethernet Controllers	07
RZ/N2L: Industrial Ethernet Communication MPU for Adding Network Functionality to Industrial Equipment and Devices	08
RZ/N1: Multi-Protocol Industrial Ethernet Controllers meet Performance	09
R-IN32M3 Module: Industrial Ethernet Embedded Module	10
R-IN32M4-CL3: Industrial Ethernet Controller with CC-Link IE TSN Support	12
R-IN32M3: Industrial Ethernet Controllers	13
EC-1: High Performance EtherCAT® Controller	14
TPS-1: Single Chip for PROFINET RT and IRT	15
RX72M: Flagship Model of RX MCUs with EtherCAT®	16
RX72N, RX66N, RX65N Expands Equipment Control and Networking Portfolio with 32-Bit MCUs	17
ASI4U-V5: Fully Compliant ASi-5 Transceiver ASSP	19
IEC16508 Certified Functional Safety Solutions for Industrial Applications	20
Winning Combinations	22
Tool Kits	24

Absolute Integration

Industrial networks are a big part of achieving communication among devices from sensor to cloud. A common base technology serves to standardise and open the plant floor to the advantages of unbridled connectivity. Sensor data can be analyzed in the cloud to offer innovative services like preventative maintenance.

Distributed Intelligence

Manufacturing is being driven towards an increasing trend of individualised products requiring significant flexibility in the plant. This can only be achieved through distributed intelligence. More and more processing power is needed within individual plant components therefore driving the need for higher performance semiconductor products at all levels of the plant hierarchy.

Vertical Transparency

The cost of deployment and maintenance is related to the visibility of automation equipment in the plant. The ability to adjust parameters and configure individual machines, I/O devices, and processes is becoming a firm requirement. The ability to remotely configure the plant in real time is the ultimate goal of vertical transparency.

Industrial Network Solutions from Renesas






























































Factories and production facilities today are becoming more advanced in order to improve productivity and safety. These advances are based on communication via open industrial networks.

Several technical requirements demanded by equipment used inside factories are ;

1. Support for an open network communication protocol : PROFINET, EtherCAT, and OPC UA
2. High-speed real-time performance to achieve higher productivity from protocols such as EtherCAT, PROFINET IRT, and TSN, as well as low power consumption.
3. Support for functional safety to realize safety operation equipment.

Industrial equipment vendors need to develop equipment that satisfies these requirements, and users will implement and use these equipment. Renesas provides products for industrial networks that make it easy to realize these functions.

Product Lineup

Multi-Protocol								Single Protocol	
Motor Control			PLC, Gateway	Network Controller, Remote I/O				PROFINET	
RZ/T2M <small>NEW</small> Arm®Cortex®-R52 x2 	RZ/T1 Arm®Cortex®-R4 Arm®Cortex®-M3 	RX72M RXv3 Core 	RZ/N1 Arm®Cortex®-A7 x2 Arm®Cortex®-M3 	RZ/N2L <small>NEW</small> Arm®Cortex®-R52 	R-IN32M3-EC Arm®Cortex®-M3 	R-IN32M3-CL Arm®Cortex®-M3 	R-IN32M4-CL3 Arm®Cortex®-M4 	Module R-IN32M3 Module 	TPS-1 PROFINET CPU 
3 port GMAC w/ switch TSN switch EtherCAT slave	2 port w/ switch EtherCAT slave	2 port EtherCAT slave	5 port GMAC w/ switch	3 port GMAC w/ switch TSN switch EtherCAT slave	2 port switch w/ PHY EtherCAT slave	2 port GMAC w/ switch CC-Link IE field	2 port w/ switch gigabit PHY CC-Link IE field and CC-Link IE TSN Class B	R-IN32M3-EC RJ-45x2 SPI for Application CPU	2 port w/ PHY 
									
 	 	 	 	 	 		 	 	
 			 	 			 	 	
 			 	 					
								Fully Compliant ASi-5 	

Renesas Industrial Network Solution Contribute to Realize Smart Society

There are various protocols for industrial network and there are made the best use of various features. However, coexist of various protocols is the challenge for realizing smart society that require interoperability. Renesas has various product/solution and overcomes challenges with customer.

Various products to solve any industrial protocols

Renesas can provide one protocol communication IC and multi protocols communication IC.

One protocol communication IC give benefits as small footprint and low cost for customer.

Multi protocol communication IC give benefits as unique environment for customer.

Usable for any layers/use cases in industrial

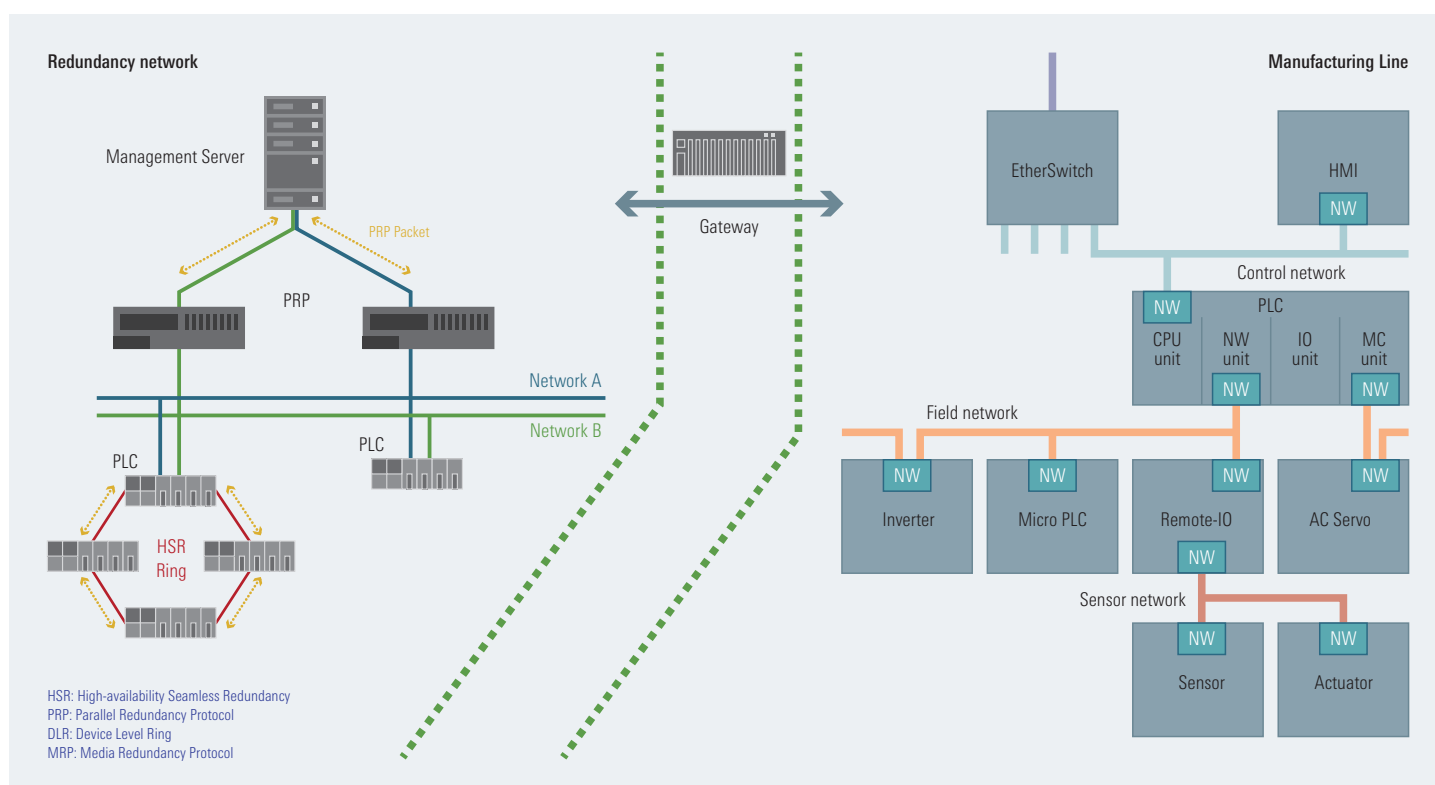
Renesas industrial ethernet IC can realize standard ethernet products by customer.

Further, Renesas industrial ethernet IC supports redundancy network (HSR, PRP, DSR, MRP and so on). Furthermore, Renesas industrial ethernet IC can use expanded communication IC for MCU/MPU. So, Renesas IC can solve/use any layer communication.

Contribute to realize the interoperability for smart society

Some multi protocols communication IC can realize simultaneous operation for two industrial protocols. So, customer can develop the gateway between industrial ethernet protocols.

Industrial Network



Recommended Devices for Industrial Networks

For Master

Fieldbus		RZ/T2M	RZ/T1	RZ/N2L	RZ/N1D	RZ/N1S	RZ/N1L	RX72M	ASI4U-V5
Industrial Ethernet	OPC UA	—	—	—	✓	—	—	—	—
	PROFINET	—	—	—	✓	—	—	—	—
	EtherCAT	✓*	✓	✓*	✓	—	—	—	—
	EtherNet/IP	—	—	—	✓	—	—	—	—
	POWERLINK	—	—	—	—	—	—	—	—
	ModbusTCP	—	—	—	✓	—	—	✓	—
	SercosIII	—	—	—	—	—	—	—	—
	CC-Link IE TSN	—	—	—	—	—	—	—	—
CC-Link IE Field	—	—	—	—	—	—	—	—	
Fieldbus	IO-Link	—	—	—	✓*	✓*	—	—	—
	PROFIBUS	—	—	—	—	—	—	✓	—
	CANopen	—	—	—	✓	—	—	✓	—
	DeviceNet	—	—	—	—	—	—	—	—
	Modbus RTU/ASCII	—	—	—	✓	—	—	✓	—
	CC-Link	—	—	—	—	—	—	—	—
	ASI-5	—	—	—	—	—	—	—	✓

For Slave

Fieldbus		RZ/T2M	RZ/T1	RZ/N2L	RZ/N1D	RZ/N1S	RZ/N1L	R-IN32(CL3)	R-IN32(CL)	R-IN32(EC)	EC-1	TPS-1	ASI4U-V5	RL78	RX72M	RX23E-A	
Industrial Ethernet	OPC UA	✓*	✓	✓*	✓	✓	✓	✓*	✓	✓	—	—	—	—	✓	—	
	PROFINET	✓* RT/IRT	✓ RT	✓* RT/IRT	✓ RT	✓ RT	✓ RT	✓ RT	✓ RT	✓ RT	✓ RT	—	✓ RT/IRT	—	—	✓ RT	—
	EtherCAT	✓	✓	✓	✓	✓	✓	—	—	✓	✓	—	—	—	—	✓	—
	EtherNet/IP	✓	✓	✓	✓	✓	✓	✓	✓	✓	—	—	—	—	—	✓	—
	POWERLINK	✓*	—	✓*	✓	✓	✓	—	—	—	—	—	—	—	—	—	—
	ModbusTCP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	—	—	—	—	✓	—
	SercosIII	—	—	—	✓	✓	✓	—	—	—	—	—	—	—	—	—	—
	CC-Link IE TSN A: ClassA B: ClassB	✓* A	✓* A	✓* A	✓* A	✓* A	✓* A	✓ A, B	✓ A	✓ A	✓ A	—	—	—	—	✓ A	—
CC-Link IE F: Field FB: Field Basic	✓* FB	✓* FB	✓* FB	✓* FB	✓* FB	✓* FB	✓ F	✓* FB	✓ F	✓* FB	—	—	—	—	✓* FB	—	
Fieldbus	IO-Link	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	
	PROFIBUS	✓*	✓*	✓*	—	—	—	—	—	—	—	—	—	—	—	✓	—
	CANopen	✓*	✓*	✓*	—	—	—	—	—	—	—	—	—	—	—	✓	—
	DeviceNet	✓*	✓*	✓*	—	—	—	—	—	✓	—	—	—	—	—	✓	—
	Modbus RTU/ASCII	✓*	✓	✓*	✓	✓	✓	✓	✓	✓	—	—	—	—	✓	✓	—
	CC-Link	—	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—
	ASI-5	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—

* Under consideration. Contact a sales person for details.

RZ/T2M: MPU Enabling High-Speed and Highly Precise Servo Motor Control

Target Applications

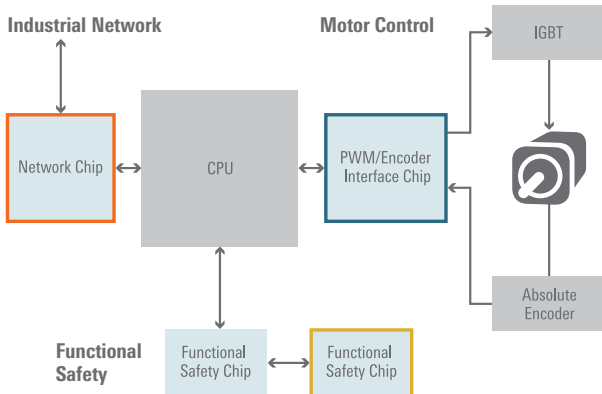
The RZ/T2M combines fast and highly precise real-time motor control capabilities, together with the latest Industrial Ethernet system architecture on a single chip, while supporting functional safety operation.



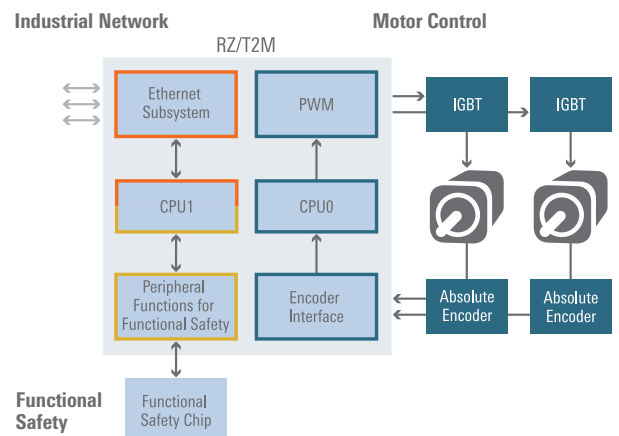
Key Features

- Perform high-speed and high-precision real time control by Cortex®-R52 CPU (Max 800MHz), implement large Tightly Coupled Memory (TCM:576KB) and Low Latency Peripheral Port (LLPP) bus.
- Integrates an Ethernet switch compatible with the TSN standard and supports major Industrial Ethernet protocols such as PROFINET IRT.
- Support functional safety processing with one of the dual CPU and dedicated peripheral functions used together with Functional Safety Software.
- On-chip peripheral functions (PWM, delta-sigma interface, encoder interface, etc.) support up to two-axis motor control.

Conventional System



System Using RZ/T2M



Block Diagram

Arm® Cortex®-R52 800 / 400 / 200MHz		Arm® Cortex®-R52 800 / 400 / 200MHz	
FPU	MPU	Debug	
I Cache 16KB w/ECC	D Cache 16KB w/ECC	GIC	
ATCM 512KB w/ECC			
BTCM 64KB w/ECC			
For motor control w/ safety		For network w/ safety	
CAN-FD (2ch)	SPI (4ch)	EtherCAT Slave Controller	Ether MAC w/ switch + IEEE1588
SCI (6ch) w/FIFO	ΔΣ I/F (6ch)	MTU3 (16bit x 8ch + 32bit x 1ch)	GPT (32bit x 18ch)
I2C (2ch)	xSPI (2ch)	CMT (16b x 6ch)	CMTW (32bit x 2ch)
DMA (16ch x 2unit)	Shared RAM 2MB	WDT (14b x 2ch)	
12bit A/D (8ch+16ch)	External BUS I/F	CRC	DOC
Trigonometric	Encoder-I/F	USB HS Func/Host	Security

Solution Kit

Renesas Starter Kit+ for RZ/T2M includes an on-board emulator, so you can start evaluation by simply connecting the bundled cable to your PC. An encoder library and a variety of sample programs for industrial network communication protocols are available on the Renesas website.

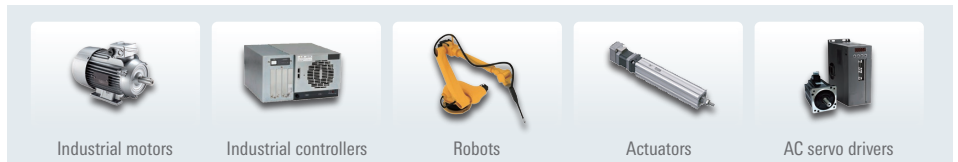


Renesas Starter Kit+ for RZ/T2M
(Product No.: RTK9RZT2MOS00000BE)

RZ/T1: Industrial Drives with Multi-Protocol Industrial Ethernet Controllers

Target Applications

RZ/T1 was specifically developed for Industrial Motors and AC Servos where time is critical, deterministic applications requires minimal latency and jitter, high speed operation providing excellent performance, and improved functionality for industrial equipment. Some RZ/T1 products also incorporate the Renesas R-IN engine which allows for industrial ethernet communication.



Key Features

The RZ/T1 complements Renesas' industrial smart factory solution portfolio.

- **High Performance and Real-Time Capability**

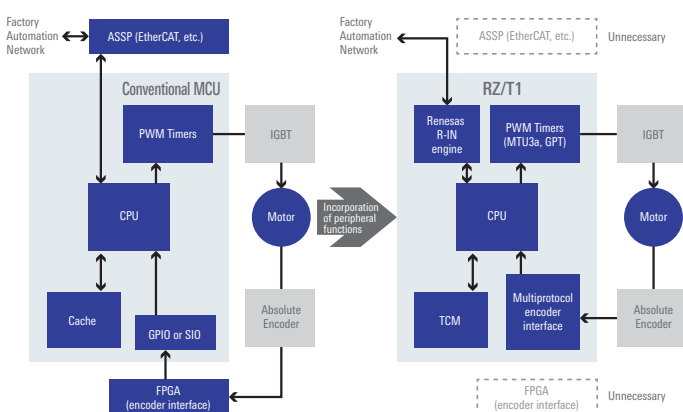
The RZ/T1 Group has the Arm® Cortex®-R4 Processor with FPU core, which was designed for real-time processing, and is capable of high-speed operation at up to 600 MHz. Furthermore, tightly-coupled memory capable of definitive real-time response processing allows high-speed access from the CPU without passing through the cache memory.

- **Industrial Ethernet Network**

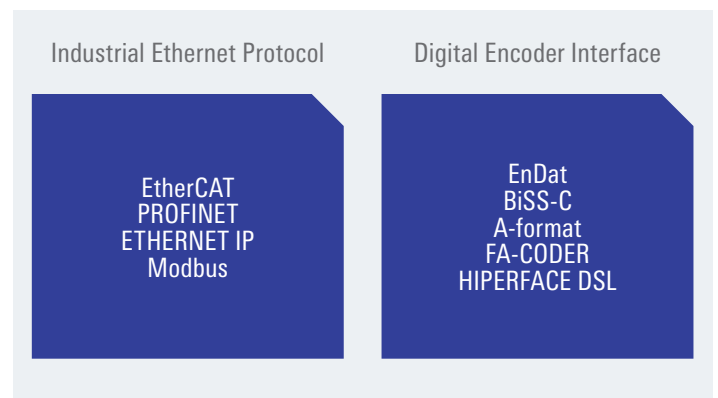
RZ/T1 devices that are equipped with a built-in Renesas R-IN engine, which includes accelerator for industrial Ethernet communications, can perform industrial Ethernet processing without loss of real-time performance by Hardware RTOS (HW-RTOS).

- **Digital Encoder Interface**

RZ/T1 devices that are equipped with a configurable absolute encoder interface are perfectly suited for precision motion control applications. The range of industry standards supported by configurable encoder interface includes EnDat2.2, BiSS®-C, A-format™, FA-CODER®, and HIPERFACE® DSL.



- The encoder interface is external with conventional FPGA or ASIC approaches but is integrated on-chip with the RZ/T1.
- This one-chip AC servo solution helps reduce the component count and saves space.



Solution Kit

The RZ/T1 solution kit provides full access to the single/dual core drive solution with easy access to multiple industrial Ethernet standards and encoder interface protocols. It is the perfect kit for developers who are new to the RZ/T1.

- Renesas Starter Kit : Perfect starter kit to evaluate RZ/T1 performance.



Renesas Starter Kit

RZ/N2L: Industrial Ethernet Communication MPU for Adding Network Functionality to Industrial Equipment and Devices

Target Applications

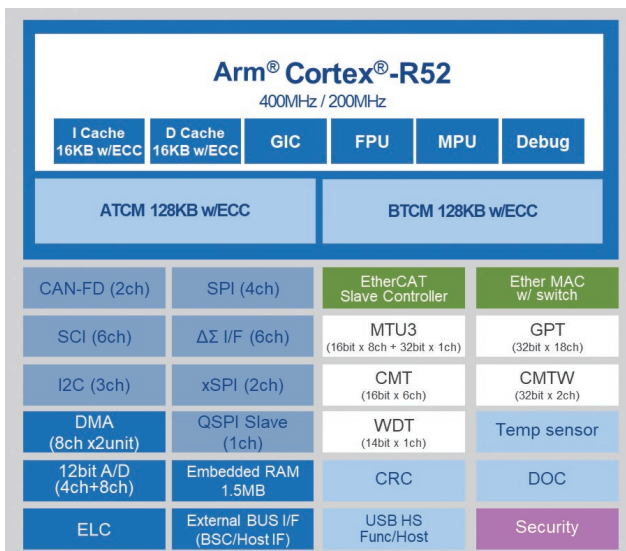
The RZ/N2L is optimized as a dedicated networking companion chip that can easily implement industrial Ethernet communication and TSN in industrial equipment. The RZ/N2L is a single chip solution for both industrial network and application processing.



Key Features

- Arm® Cortex®-R52 operating at a maximum frequency of 400MHz and tightly-coupled memory (256KB).
- 3-port Gigabit Ethernet switch supporting next-generation network standard TSN and EtherCAT® slave controller.
- Host interface allows application CPU to directly connect to RZ/N2L, and access at high speed. Application CPU can directly access to the system RAM of RZ/N2L.
- ELC (Event Link Controller) can be operated without the support of CPU processing.
- Supports functional safety like a safety MCU.

Block Diagram



Solution Kit

Renesas Starter Kit+ for RZ/N2L includes an on-board emulator, so you can start evaluation by simply connecting the bundled cable to your PC. A variety of sample programs for industrial network communication protocols are available on the Renesas website.



Renesas Starter Kit+ for RZ/N2L
(Product No.: RTK9RZN2L0S00000BE)

RZ/N1: Multi-Protocol Industrial Ethernet Controllers meet Performance

Target Applications

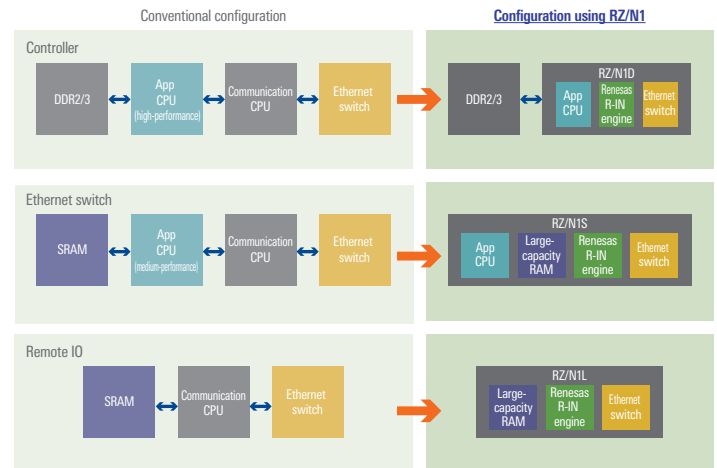
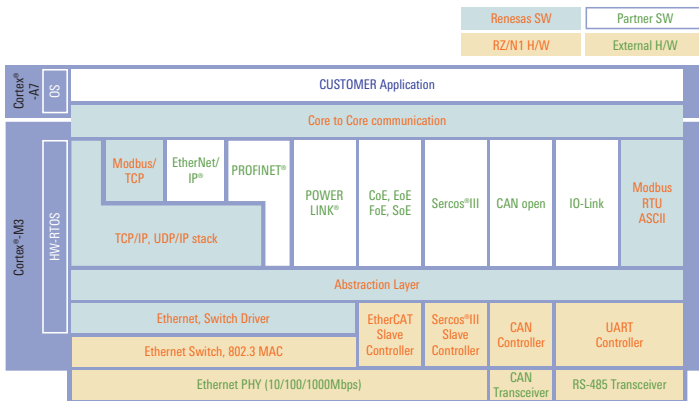
The scalable RZ/N1 family of Arm based communication devices was developed for applications like gateways, PLCs, industrial switches, sensor hubs, and remote I/Os.



Key Features

The products in the RZ/N1 Group provide single-chip solutions that make it possible to realize simultaneously a field network connected to devices requiring real-time control and a highly reliable control network employing a redundant structure. The group lineup comprises three products that can be utilized in a broad array of applications. The RZ/N1D and RZ/N1S are built around the Arm® Cortex®-A7 in dual- and single-core configurations, respectively, while the RZ/N1L consists of the communication block only. Each of these products features the Renesas R-IN engine, an accelerator that supports a wide variety of protocols and delivers fast processing performance. The major functions are as follows:

- Lineup of three CPU types for excellent hardware scalability: Dual-core Cortex®-A7 (500MHz × 2), single-core Cortex®-A7 (500MHz), and Renesas R-IN engine only (125MHz).
- 5-port gigabit Ethernet switch and two independent MAC units support applications such as PLC devices and Ethernet switches. Integration of peripheral components helps reduce BOM cost.



Fast Evaluation and Prototyping

The RZ/N1 Solution Kit is a development package incorporating both hardware and software that implements the main industrial Ethernet protocols such as EtherCAT, EtherNet/IP, and PROFINET. This makes it possible to develop prototypes in less time. By using this kit customers can reduce the time needed to develop a product by up to six months.

In addition to three CPU boards (RZ/N1D, RZ/N1S, and RZ/N1L), expansion boards are available for evaluation of a variety of peripheral functions. Select the evaluation board that best matches your application. This kit is the ideal way to experience the performance and functionality of the RZ/N1.

General Features

- U-boot
- Drivers
- C2C (Core to Core communication), etc.

Operating System

- Linux
- ThreadX

Evaluation version Protocol Stack Master

Software PLC

- PROFINET
- EtherNet/IP
- EtherCAT, etc.

Slave

- PROFINET
- EtherNet/IP DLR
- EtherCAT, etc.

*For full version protocol stack, please contact your nearest stack supplier

Industrial Ethernet Embedded Module

R-IN32M3 Module



The R-IN32M3 is a compact industrial Ethernet embedded module that supports the PROFINET, EtherNet/IP™, and EtherCAT® protocols. By using it in combination with a host MCU to control the user application, it enables users easily to develop supported products without worrying about the details of industrial Ethernet communication. It is also possible to deploy support for Modbus TCP by using the host MCU for control.

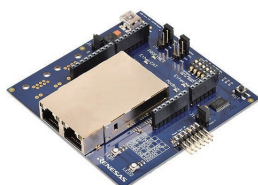
Features

- **An all-in-one solution that shortens time-to-market**
 - This embedded module implements the functionality required by industrial networks.
 - Reduces the burden of software development and component procurement.
- **Multi-protocol**
 - The protocol can be changed without overwriting the firmware.
 - No need to purchase a separate module for each protocol stack.
- **Ample selection of development tools**
 - Sample software is available for Renesas RA, RX, and RL MCUs.
 - Get started with evaluation right away using a simple master tool.
- **Easy-to-implement host interface**
 - SPI connection via pin header connector.
 - No need to mount additional connectors.

Solution Kits

Users can choose between two environments when selecting a solution kit to support development. Sample packages are available for download on the web, so you can get started right away with the development environment that best matches your application.

- **Adapter Board Mounted with R-IN32M3 Module [YCONNECT-IT-I-RJ4501]**
 - Connects to an Arduino™ MCU development board for development work.
 - Ideal for customers who have already decided on the host MCU they plan to use.



YCONNECT-IT-I-RJ4501



- **CPU Card Mounted with R-IN32M3 Module [SEMB1320: Shimafuji Electric Incorporated]**
 - Evaluation board with integrated module and mounted with RX66T host MCU.
 - Ideal for customers just getting started with evaluation of Industrial Ethernet applications.



SEMB1320



Specifications

Product No.	RY9012A0000GZ00 #001 (30 pcs.)/#002 (1 pc.)		
CPU	R-IN32M3-EC		
Protocol			
Size	50×34×12mm		
Power supply voltage	3.3 ± 0.15 VDC		
Power consumption	Typ. 1.3W/max. 2.0W		
Operating temperature range	–40 to 70°C		
Certification/authorization			

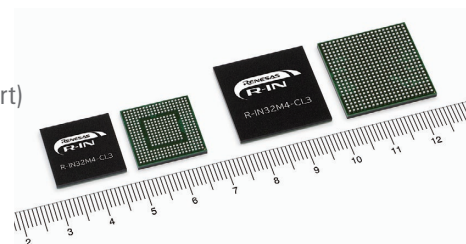
* Each protocol is network certified, but the customer's system still needs to be certified as a finished product.

R-IN32M4-CL3: Industrial Ethernet Controller with CC-Link IE TSN Support

The R-IN32M4-CL3 is a communication SoC with hardware support for CC-Link IE TSN. In addition to Renesas R-IN engine technology it implements a gigabit Ethernet compatible PHY, making it a one-chip solution for the latest in TSN communication.

Key Features

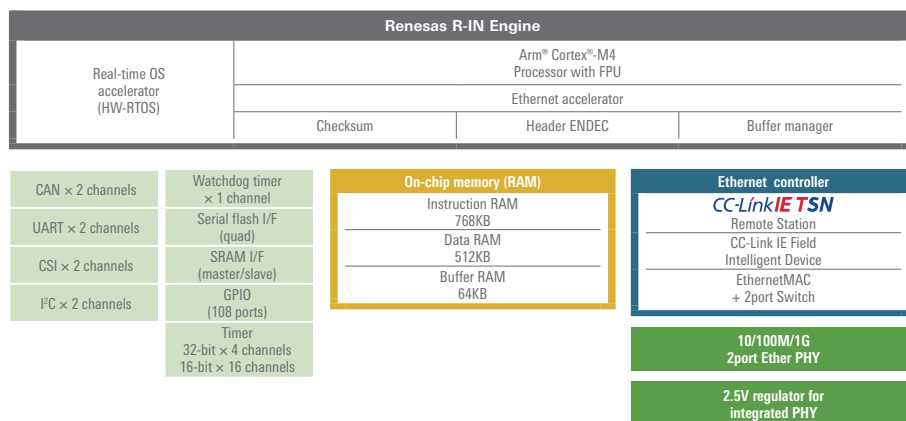
- Time synchronization accuracy between devices of $\pm 1 \mu\text{s}$ or less (CC-Link IE TSN Class B support)
- 2-port gigabit Ethernet compatible PHY, CPU, and RAM (1.3MB) on an one-chip
- Renesas R-IN engine for same multi-protocol support as preceding product
- Compact package and on-chip PHY regulator for reduced mounting area
- Low power consumption (35% less than R-IN32M3-CL2)



Product Specifications

- CPU Cortex-M4 (100MHz)
- RAM 1.3MB ECC support
- Power supply voltage $3.3\text{V} \pm 5\%$, $1.15\text{V} \pm 5\%$
- I/O 106 channels (max.)
- 2 Ethernet ports (integrated 10/100/1000 PHY)
- Numerous peripheral functions
 - 32-bit external MCU interface
 - UART – I²C
 - CSI – Timer
- Operating temperature range
 - T_j = -40 to +125°C
 - T_a = -40 to +85°C

R-IN32M4-CL3 Block Diagram

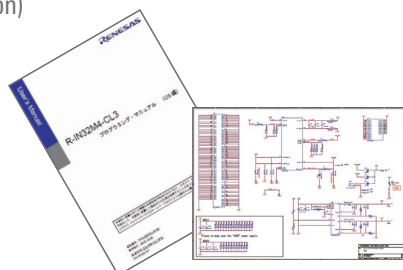


Development Environment

Verify your CC-Link IE TSN communication application within an hour of launching the development environment!

Solution set

- Startup manual
- Evaluation board mounted with R-IN32M4-CL3 (SBEV-RIN32M4CL3, manufactured by Shimafuji Electric Incorporated)
- IAR Embedded Workbench integrated development environment (evaluation version)
- I-jet Lite (JTAG-ICE)
- Sample software*
 - CC-Link IE TSN
 - CC-Link IE Field
 - Peripheral drivers
- Settings file for master station
- User's manuals



Solutions for Renesas R-IN32M4 | IAR Systems

Note: Supplied as IAR Embedded Workbench® for ARM projects.

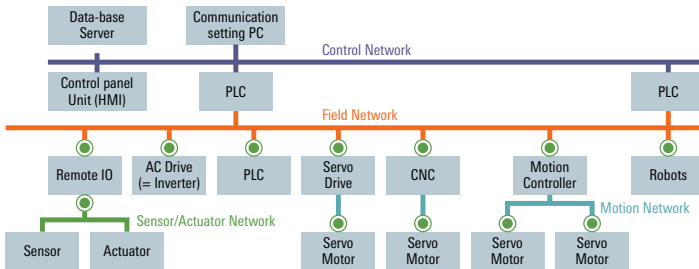
Advantages of CC-link IE TSN

Time synchronization and time sharing among devices makes possible ultrahigh-speed, highly accurate motor control. It is also possible to seamlessly connect information technology (IT) networks and operational technology (OT) networks so they can interoperate with each other, enabling flexible support for multiproduct variable-quantity production in which models and manufacturing volumes can be changed in real time for higher plant productivity overall.

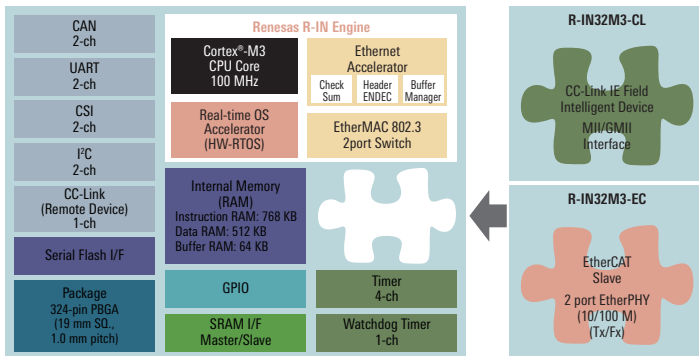
R-IN32M3: Industrial Ethernet Controllers

Target Applications

The R-IN32M3 Series is suitable for use in the communication unit of slave devices in field networks and motion networks indicated by .



Target products: PLC, remote IO, CNC, AC drive (inverter), robot, servo drive, servo motor



Characterized by Innovation

R-IN32M3 is an Industrial Network Controller with multiprotocol support for industrial applications like Remote IOs, Sensors, Actuators, PLCs, Drives, Motion Controllers or robots. The design philosophy is characterized by three design rules:

- Low power dissipation despite the highest level of integration
- Perform time sensitive and process intensive tasks in hardware
- Support all major industrial Ethernet standards

The Renesas R-IN engine also features a Hardware Accelerator for both the real-time operating system and higher layer network frame processing.

Arm® Cortex®-M3
+ SW-RTOS

15.16

Arm® Cortex®-M3
+ HW-RTOS

1.84

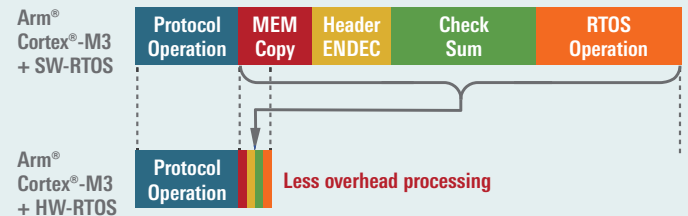
8 times faster

Interrupt response time (µs) @ 100 MHz

The new Dimension of Real-Time

The Renesas R-IN engine is an integrated processor subsystem that includes hardware Ethernet and RTOS accelerators, developed for high speed and real-time communication under very low power consumption. These mechanisms do not just reduce the number of cycles needed to process one Ethernet frame drastically, but they also provide an unmatched determinism with response times beyond the capabilities of pure CPU based systems. The device supports industrial Ethernet protocols like EtherCAT, PROFINET, EtherNet/IP and CC-Link IE. Some variants also include an integrated Ethernet PHY.

TC/IP Communication



Effects on Ethernet Frame Processing: Drastic Reduction of Overhead Processing

R-IN Solution Kits

The R-IN solution kit is an all-in-the-box package for fast evaluation and rapid prototyping of multiple industrial Ethernet protocols. It features a small R-IN32M3-EC board for evaluation of the industrial Ethernet interfaces, an evaluation version of IARs embedded workbench for Arm®, an I-jet Lite Arm® Cortex®-M3 JTAG debugger, as well as sample software including evaluation versions of several industrial Ethernet protocols like EtherCAT, PROFINET, EtherNet/IP and Modbus TCP.

EC-1: High Performance EtherCAT® Controller

Target Applications

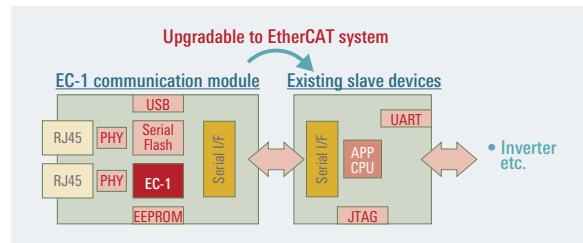
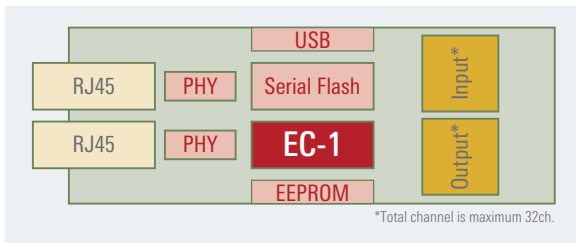
EC-1 is a dedicated device with a built-in EtherCAT slave controller. This is an optimal solution to design high performance EtherCAT protocol in Industrial automation and manufacturing.

1. Remote IO

EC-1 handle both EtherCAT communication and I/O control at the same time thus, eliminating the need for additional external CPU for I/O control. Get started quickly using provided application software for EtherCAT and I/O Control.

2. Communication Module

Can easily upgrade to EtherCAT communication from existing serial interfaces.



Key Features

Solution certified by EtherCAT Test Center (ETC) conformance testing

- Software environment and evaluation board are certified by official conformance test based on BECKHOFF's EtherCAT slave stack code.

Easy transition from low-speed serial communication to EtherCAT

- Customer can easily change communication protocol to legacy serial interfaces, allowing user to focus on their end application.
- Sample software is provided that targets various devices with different profiles :
 - √ CiA402 drive profile for motor driving devices.
 - √ ETG.5003 profile for semiconductor manufacturing equipment.

Optimized for EtherCAT applications. Best suited for designing slave devices with High-Speed connectivity.

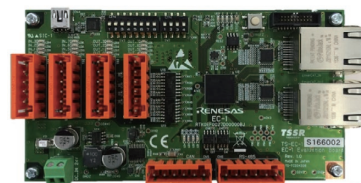
- Integrated Arm® Cortex®-R4F Core @ 150MHz with double and single precision floating point unit. The Tightly Coupled Memory (TCM), EtherCAT slave controller is ideal for deterministic high-speed connectivity.
- Compatibility has been verified with master devices from more than ten manufacturers. This is a proven solution and significantly reduces the development time for EtherCAT slave applications.

Fast Evaluation

Remote I/O Solution for EC-1 (Tessera Products: TS-EC-1)

Solution kits packaging the hardware, software and integrated development environment necessary for enabling many users to start evaluation and development safely, quickly and easily.

EtherCAT®
Conformance tested



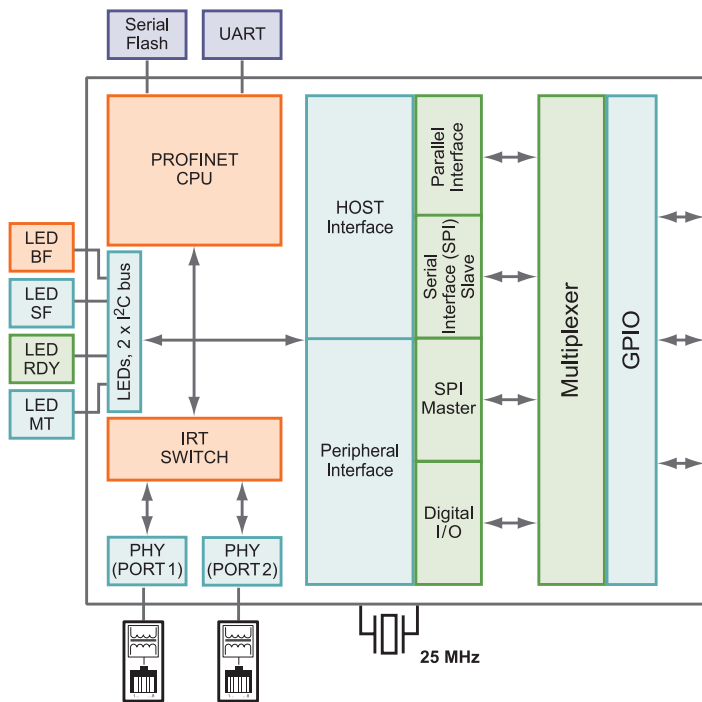
TPS-1: Single Chip for PROFINET RT and IRT

Certified RT/IRT Functionality for PROFINET V2.3

The PROFINET Device Chip TPS-1 is designed for easy and cost-efficient implementation of PROFINET interfaces for automation devices. It is a highly integrated single chip solution that complies with the PROFINET Conformance Class C.

The internal structure is designed to fulfill the requirements of the IRT protocol and the time-critical PROFINET protocols are supported by hardware.

The configurable interfaces facilitate the flexible realization of different use cases like direct connection of an external host CPU or digital I/Os without additional circuitry. Special synchronization signals allow to lock the host application program to the PROFINET I/O cycle. To support line topologies in PROFINET networks, the TPS-1 is equipped with two integrated PHYs and an integrated IRT switch.



TPS-1 Block Diagram

Efficiency - Sustainable Low Cost

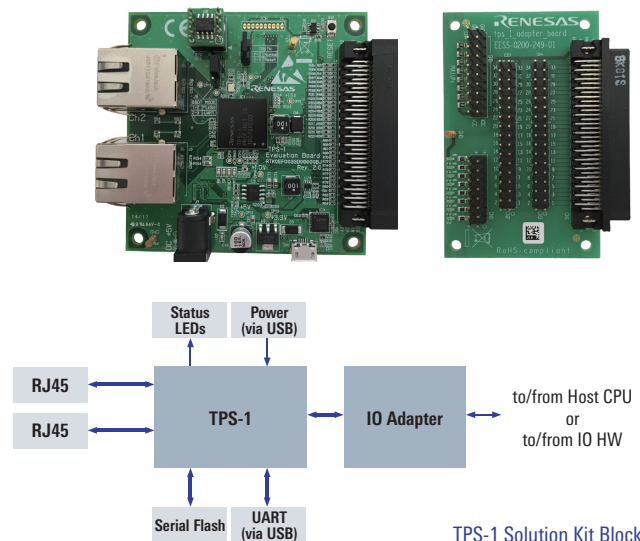
For the complete implementation of a PROFINET device interface, only the TPS-1, a serial Flash device, an oscillator, and the physical adaptations for the Ethernet interface (transformers and connectors) are needed. The serial flash component contains the individual chip configuration and the PROFINET stack firmware.

Due to the low space requirement (just 260 mm²) and low power dissipation (0.8 W) of the TPS-1, a PROFINET interface can also be integrated into automation devices with special requirements regarding housing size and protection classes. Conductor routing between the balls is still possible in order to keep down PCB cost.

Low-cost Solution Kit for TPS-1 "Y-CONNECT-IT-TPS-1L"

The new TPS-1 low-cost Solution Kit allows a simple and efficient PROFINET IRT design with the TPS-1 PROFINET IRT device chip. Beside the TPS-1 board, the kit features a passive adapter board that allows a simple connectivity to almost any MCU, a DVD with software and several cables.

The TPS-1 board runs the latest PROFINET IRT software and features only the basic circuitry needed for a PROFINET IRT network. Due to the optimized hardware there is a significantly lower entry cost to the PROFINET world and not at the expense of the usability. All the GPIOs and additional control signals are available on the connector and can be easily accessed.



TPS-1 Solution Kit Block Diagram

RX72M: Flagship Model of RX MCUs with EtherCAT®



Overview

RX72M is high performance products with RX's 3rd generation CPU core "RXv3 core".

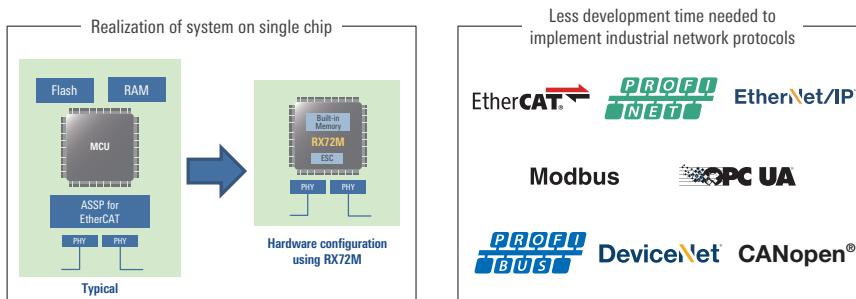
It supports the major industrial network protocols such as EtherCAT® and realizes operating main industrial applications including motor control on a single chip.

Key Features

1. Built-in EtherCAT® slave controller contributes BOM reduction and space saving.
2. Operates at 240MHz (CoreMark score: 1441) and integrates a double-precision floating point unit (FPU) that considerably accelerates processing performance.
3. 4MB flash memory (120MHz read access, Dual bank function), 1MB SRAM
4. Arithmetic unit for trigonometric functions and Register bank save functions support processing of diverse high-precision operations used for motor control.
5. The Trusted Secure IP enables secure management of hardware and memory using encryption keys, protecting application systems from viral infections and eavesdropping.

RX72M Network Solution

Application notes and sample program packages for the RX72M Group communication board are available on Renesas website, and sample code for the major industrial network protocols is also available for download.

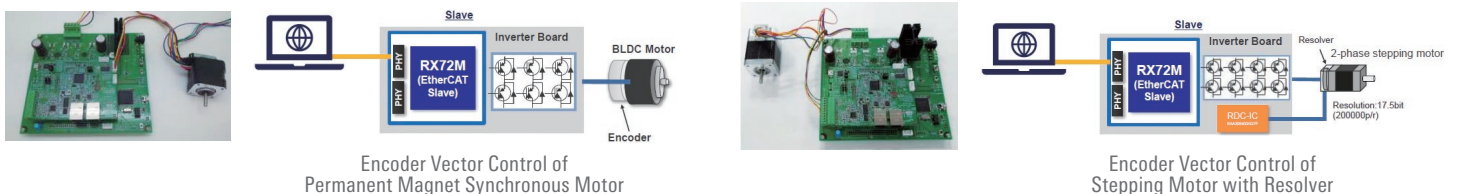


RX72M CPU Card Motor Solution

- RX72M CPU Card with RDC-IC is mounted with a resolver-to-digital converter (RDC) IC and can evaluate two types of motors via EtherCAT communication.
 - Vector Control for Permanent Magnet Synchronous Motor
 - Vector Control of Stepping Motor with Resolver
- Application notes, sample code, and evaluation stacks contribute to shorter development time.
- EtherCAT® complies with CiA402 drive profile.

Note: Combination of CPU card and inverter board realize evaluation for motor applications.

System Block Diagram



RX72N, RX66N, RX65N

Expands Equipment Control and Networking Portfolio with 32-Bit MCUs

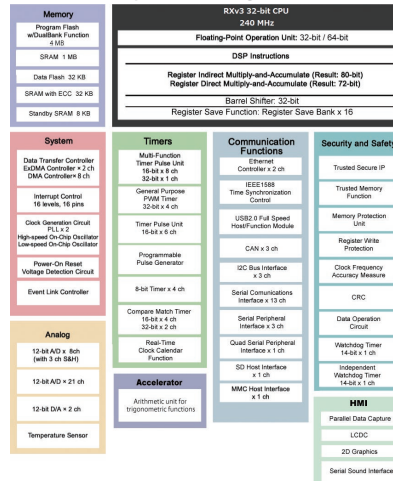
Outstanding real-time performance and one-chip solutions



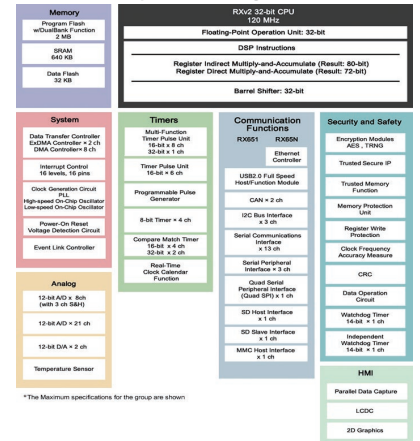
Overview

Delivered more than one billion microcontrollers from the RX Family of 32-bit MCUs, and enable to pick up the Ethernet supported MCU that best suits the application from a large selection of line-up. In addition to CPU performance from 120MHz to 240MHz, a wide range of memory options is available such as on-chip flash memory is from 512KB to 4MB and on-chip SRAM is from 256KB to 1MB. Other features include multiple communication interfaces, cloud connections, security, and HMI functions.

RX72N Group Block Diagram



RX65N Group Block Diagram



Key Features

RX72N, RX66N

- Outstanding Real-Time performance: With the fastest flash memory operation in the industry, even if the cache miss occurred, program instructions execute promptly no wait cycles for the RX66N and with only one wait cycle for the RX72N.
- Multiple Functions and Small Footprint: The largest memory of industry's and general-purpose I/O interface enable to implement many functions, it contributes space saving and shorter development time.
- Robust Security: Perfect application from various threats by Trusted Secure IP (TSIP), as TSIP outputs key generation related unique ID, this avoids to use in other devices, even if the key generation is eavesdropped.
- Advanced HMI function: LCD controller, 2D drawing engine, serial sound I/F, and 1MB SRAM realize HMI functions without external RAM.

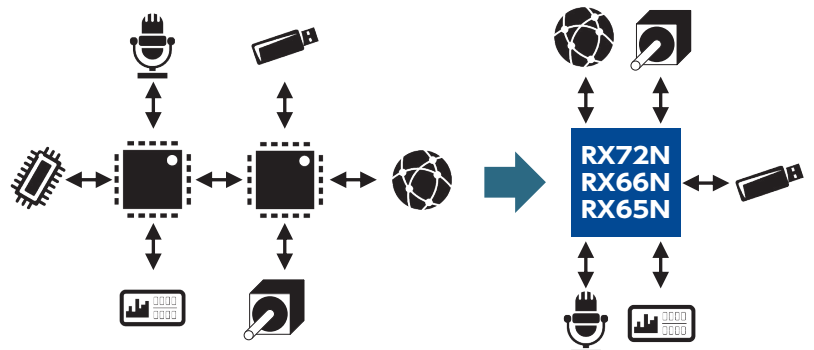
RX65N

- A variety of communication interfaces are implemented on-chip, including Ethernet (1 channel), USB, CAN, SD host/slave, and quad SPI.
- 2MB flash memory and 640KB SRAM relate to downsizing and large-capacity memory, suitable for a variety of applications.

New RX Portfolio

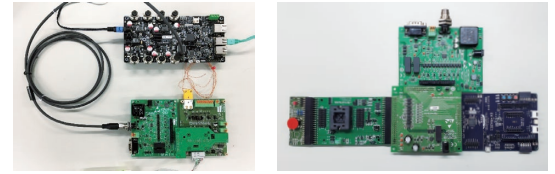
	Industrial network protocol support	Flagship product offering highest performance	No-wait state real-time performance	Mainstream Device with Excellent Power Efficiency
Group	RX72M	RX72N	RX66N	RX65N
CPU	240MHz Rxv3 core Double-precision FPU Register bank save function	240MHz Rxv3 core Double-precision FPU Register bank save function	120MHz Rxv3 core Double-precision FPU Register bank save function	120MHz Rxv2 core Single-precision FPU
Memory	4MB flash memory (120MHz read access) 1 MB SRAM	4MB flash memory (120MHz read access) 1 MB SRAM	4MB flash memory (120MHz read access) 1 MB SRAM	2MB flash memory (50MHz read access) Max. 640KB of SRAM
Network	Ethernet: 2 channels EtherCAT: 2 channels + support for major protocols	Ethernet max. 2 channels	Ethernet: 1 channel	Ethernet: 1 channel

System Configuration



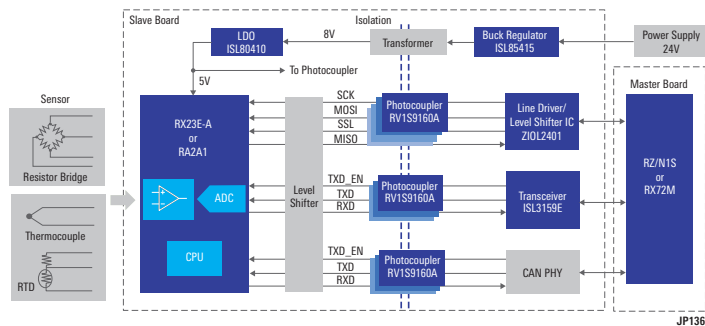
IO-Link

Toward realization the the smart factory that is at the core of Industry 4.0., the market trend shifted from general Ether to Industrial Ether. The challenge is to “Connect” all product devices from upper layers such as PLCs to lower layers such as sensors and actuators and common network communication is required in the market. IO-Link supports bidirectional communication and gather attention as a key technology to realize the goal of bringing IoT to the factory.



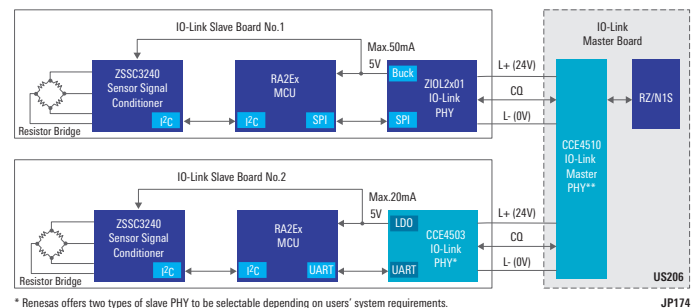
RX23E-A Temperature Sensor Solution

- This solution uses 32-bit MCU RX23E-A built-in a high-precision analog front-end (AFE) to measure temperature, process sensing and signals, and realizes IO-Link communications via ZIOL2401 IO-Link PHY chip.
- IO-Link tool on user’s PC enables to provide data check, monitor the value of temperature measurement, and set parameter. With IO-Link Teach In, enables to control LED on/off based on the temperature measurement.



RA2E1 Pressure Sensor Solution

- The combination of RA2E1 ultra-compact (CSP package) with low-power and ZSSC3240 kit (sensor + sensor signal conditioner) realize pressure measurement, signal processing, and IO-Link communication, suitable for space-constrained applications.
- IO-Link tool on user’s PC enables to provide data check, monitor the value of pressure measurement, and set parameter. With IO-Link Teach In, enables to control LED on/off based on the pressure measurement.



* Renesas offers two types of slave PHY to be selectable depending on users' system requirements.

RA2E1 Pressure Sensor Solution

Block	Recommended Product	Operating Frequency (MHz)	Operating Voltage (V)	Memory (Max.)	Features, Etc.
MCUs for sensors	RX23E-A	32MHz	1.8V to 5.5V	256KB flash, 32KB RAM, 8KB data flash	The product integrates a low-noise, low-drift analog front-end, making it ideal for applications such as sensing, control, and testing/measuring that utilizes very small analog signals from temperature, pressure, flow, weight, or distortion sensors. Built around the RXv2 CPU core, this MCU integrates high-precision measurement, control, and communication capabilities on a single chip.
	RA2E1	48MHz	1.6V to 5.5V	128KB flash, 16KB RAM, 4KB data flash	This high-performance, power-efficient, and low-cost MCU provides high-speed and high-precision analog, timer, safety, security, and communication functionality. Support for a variety of operating voltage ranges and package sizes; and suitability for applications in the industrial equipment field requiring compact size.
	RA2E2	48MHz	1.6V to 5.5V	64KB flash, 8KB RAM, 2KB data flash	Suitable for a wide range of applications requiring compact size, combines ultra low-power operation and high-speed serial communication, and available in compact 20-pin and 24-pin as CSP packages. Ideal for IoT sensor node applications requiring cost competitiveness, compact size, and low power consumption.
	RL78/G14	32MHz	1.8V to 5.5V	512KB flash, 48KB RAM, 8KB data flash	Current consumption among the lowest in the industry alongside high operation performance (best in the RL78 Family). With package pin counts from 20 to 100 pins, and flash memory capacity of up to 512KB, this MCU is suitable for a wide range of applications such as motor control and industrial equipment.

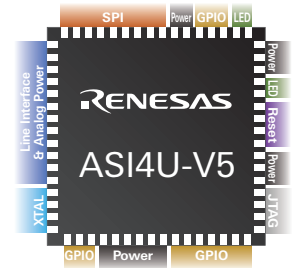
Block	Recommended Product	Type	Channels	Features, Etc.
IO-Link PHY	ZIOL2401	IO-Link master/slave	Dual/single	Physical layer driver and level shifter for sensor and actuator applications used in the factory automation and process automation fields. SPI and I ² C interfaces.
	CCE4510	IO-Link master	Dual	Include peak drive current of 1A and supports two channels. It has an integrated frame handler and can automate most lower-layer communication tasks. SPI and UART (× 2) interfaces.
	CCE4502	IO-Link slave	Dual	Integrated frame handler and can flawlessly handle protocol processing, making it simple to connect to a host microcontroller via a UART interface. LDO (× 2), UART, and SPI interfaces.
	CCE4303	IO-Link slave	Single	With support for temperatures up to 125°C and three LDO options, this cost-optimized device is suitable for compact and simple applications while supporting protection circuits and additional functions. UART interface.

ASI4U-V5: Fully Compliant ASi-5 Transceiver ASSP

The ASI4U-V5 is the industry's first silicon solution to fulfill the ASi-5 (Actuator-Sensor-Interface version 5) standard for industrial network equipment that enables comprehensive Industry 4.0 applications. The ASI4U-V5 ASSP comes with a completely verified and field-proven firmware that fully implements ASi-5. Hence, integration of ASi-5 into any application is very easy, as the complexity of the fieldbus is hidden by the chip and the firmware.

Key Features

- Fully compliant to the AS-i version 5 standard
- Fully compatible to the AS-i version 3 standard
- The solution consists of the ASSP and a self contained ASi-5 firmware
- 64-pin QFN package
- Support for simple slave applications (digital-IO connection)
- Support for complex slave applications (SPI/IF to the application)
- Operating temperature -40°C to +85°C
- Supply voltages: 5V and 3.3V
- Package dimensions: 9 × 9 mm, 0.5 mm pitch
- Part Number: R9J06G039UGNP



ASi-5 Key Technology Advantages

Faster and more efficient for Industry 4.0 applications

- ASi-5 supports 1.2ms cycle time with a jitter of less than 10ns vs 5ms of ASi-3
- ASi-5 allows for 96 devices being attached to the same cable vs 62 in ASi-3
- ASi-5 can run up to 200m cable vs 100m in ASi-3
- ASi-5 supports diagnostics and event handling needed for industry 4.0 applications

Robustness

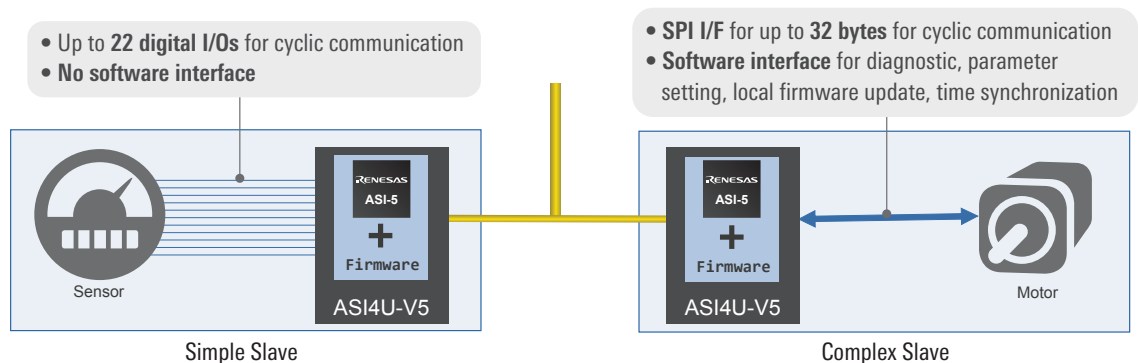
- ASi-5 is the most robust field bus due to its 3D redundancy concept, which ensures that all data reaches the destination in time without any errors. Robustness is a key asset in industrial communication.

Ease of integration

- ASI4U-V5 is an ASi-5 silicon solution, which consists of the ASi-5 ASSP and a fully self-contained firmware image that handles all ASi-5 specific items. Hence, it is the easiest fieldbus integration option.
- ASI4U-V5 is fully backwards compatible to ASi-3
- ASI4U-V5 supports all bus topologies (line, star, tree)
- ASI4U-V5 supports and easy integration with IO-Link

Application Examples

Supports simple slave and complex slave applications



IEC16508 Certified Functional Safety Solutions for Industrial Applications

Renesas' functional safety solutions provide the core technologies needed to obtain IEC 61508 SIL* certification. Certified software, kits, and reference boards, backed by reference documentation, ensure that the process of building a functional safety system is a smooth one. These solutions can dramatically shorten the time required for development and help you realize functional safety systems that perform appropriate processing when malfunctions occur.

* SIL: Safety Integrity Level. Designates the safety level under functional safety standards.



TÜV Certified Solution

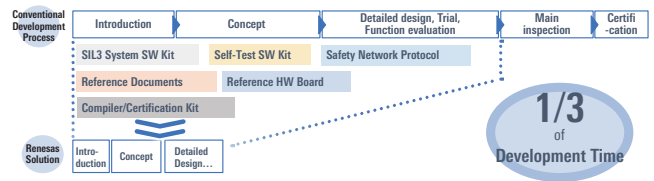
Safety system development is a very complex process. Therefore it is very important to build up an application piece by piece considering functional safety standards in both hardware and software modules. Ideally the parts should come with certification. While every application is different per usage for safety components, hardware as well as software, Renesas provides less extensive workload for safety system developers.



Renesas Solutions vs Certification Process

Renesas solutions cover the certification process and will shorten customer's actual development TAT.

Renesas' certified SW will complete the functional safety diagnosis on MCU so customer will be able to focus more on their own application development.



Target Application

- AC servos/drives
- Remote I/O
- Programmable logic controllers
- Sensors/actuators



Usage Example : Safe Motor Control

Application and Safety Functionality separated

Two channel concept (1oo2 architecture)

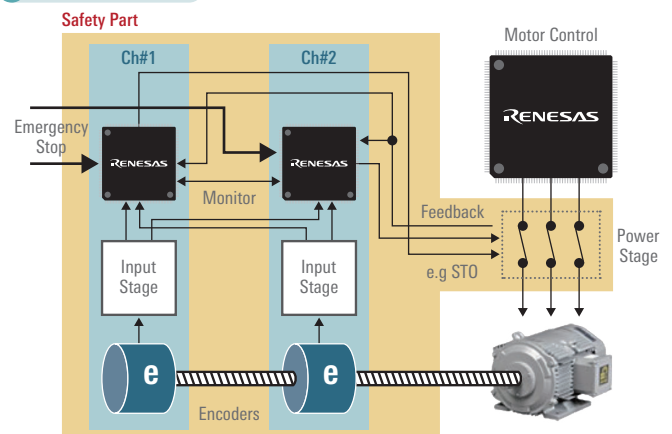
Cross Monitoring

Standard Compliant

- IEC 61508 SIL3
- ISO 13849 Ple Cat4
- IEC 62061 SILCL3

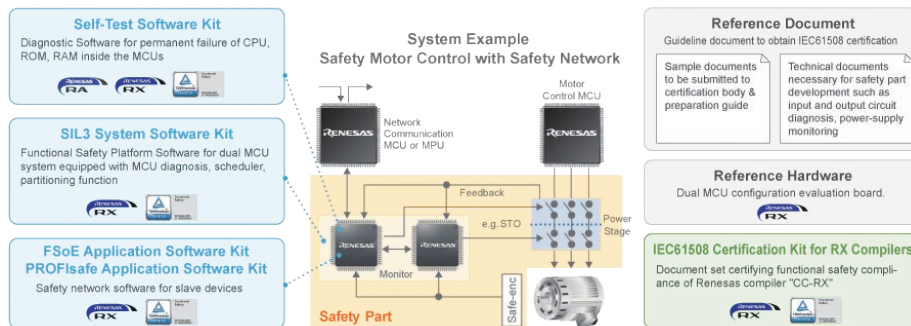
Safety functions according to IEC61800-5-2 (e.g. STO, SLS, etc.)

Ex. Safety motor control unit



Renesas Functional Safety Solution List

1. Self-test SW Kit*;
Free package of MCU Self-diagnostics SW for diagnosing CPU, ROM, and RAM in MCU.
2. SIL3 System SW Kit*;
Package of Functional Safety Platform SW for cross-monitoring dual MCU and controlling user's application behavior. Evaluation version available.
3. Safety Network Protocol*;
SIL3 certified: FSoE and PROFIsafe.
4. Reference Document*;
Guidebook for safety system design following IEC61508 standard. Safety-related documents covering diagnostic, control methods, required CPU performance, system architecture reference, etc.
This document is apart from MCU.
5. Reference Hardware Board;
Evaluation board verified by certification body. Packed with functional safety know-how e.g. designed incl diagnosis and monitoring circuit required by functional safety standard. Can immediately start prototype and SW development. Renesas Safety SWs can also be evaluated.
6. Safety certified compilers*;
Renesas original certified compiler and certification kit. Certified IAR compiler also available from IAR.



* Commercial version requires a license agreement.

Renesas Functional Safety Overview & Supporting Family

Based upon market requirement, Renesas have completed the supporting menu on RX Family from RXv1 core family also up to RXv3 core family today.

This year Renesas have extended the supporting cores to RXv3 and released safety network protocol : FSoE (Functional Safety over EtherCAT). Also our first generation of RA Family started its solution support, and to be extended.

#	Product	Family	RX			RA		
		Core	RXv1	RXv2	RXv3	CM4	CM23	CM33
		Group	RX111, RX113, RX130	RX71M, RX651/N, RX64M, RX24U, RX24T, RX230/1, RX23T, RX23W, RX23E-A	RX72M, RX72N, RX72T, RX66N, RX66T	RAGM1, RAGM2, RAGM3, RAGT1, RA4M1	RA2A1, RA2L1, RA2E1	RAGM4, RAGM5, RA4M2, RA4M3
1	Self-Test Software Kit		✓	✓	✓	✓	✓	✓
2	SIL3 System Software Kit			✓	✓			
3	FSoE Application Software Kit			✓	✓			
4	PROFIsafe Application Software Kit			✓	✓			
5	Reference Document		✓	✓	✓	✓ *1	✓ *1	✓ *1
6	Reference Hardware		✓	✓	✓			
7	IEC61508 Certification Kit for RX Compilers		✓	✓	✓	*2	*2	*2

*1: Although the description in the document use RX MCU, it can be used to other MCUs since this is a technical document of functional safety standard which is not dedicated specific MCU Family.

*2: IAR Systems support certified compiler for RA Family. Please contact IAR for detail.

Web site: IEC61508 Functional Safety Solution



Flyer: Functional Safety Solution for Industrial Automation



What are Winning Combinations?

Winning combinations are comprehensive solutions that combine complementary Renesas products from our portfolio, such as analog + power + embedded processing devices. These winning combinations bring together products that work together optimally, enabling customers to speed up the design process and bring their finished products to market more quickly. With the focus on the industrial, infrastructure, and automotive fields, Renesas is working to provide an optimal portfolio of products to customers and partners worldwide.

Winning Combinations

Analog + Power + Embedded Processing + Connectivity



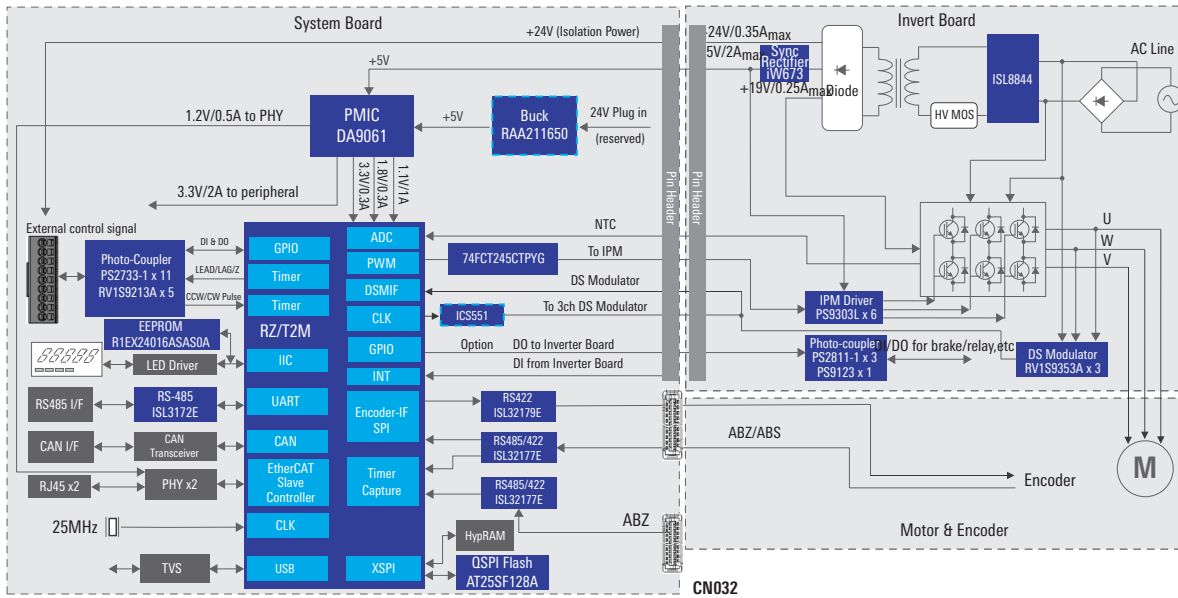
Application	Title	ID
Network	Gigabit Industrial Ethernet System-on-Module (SoM) Solution	EU140
	Multi-Protocol Industrial Ethernet Switch	EU012
	CC-Link IE TSN Solution	JP135
	Real-Time Industrial Ethernet Switch (Low Cost) with RZ/N1S	EU013
	Industrial Automation Solution with Industrial Ethernet Module	JP205
Motor	Motor Control System with Industrial Network and Functional Safety	JP191
	AC Servo Solution	CN032
	Functional Safety Network with Safety Drive System	JP148
Sensor	Industrial Ether Connectable IoT Sensor Hub	JP129
	Time of Flight (ToF) Sensor Module	JP084
	Industrial Sensor Network Solution	JP136
	IO-Link Master Solution	US206
	IO-Link Slave Sensor Solution	JP174
	IO-Link Enabled Sensor System	US020
	Multi-Sensor Module for Industrial Ethernet	EU025
	Industrial Ethernet Connected Sensor	EU113

Visit the website below to see examples of a variety of solutions for industrial equipment.

<https://www.renesas.com/winning-combinations>

Notable Winning Combinations

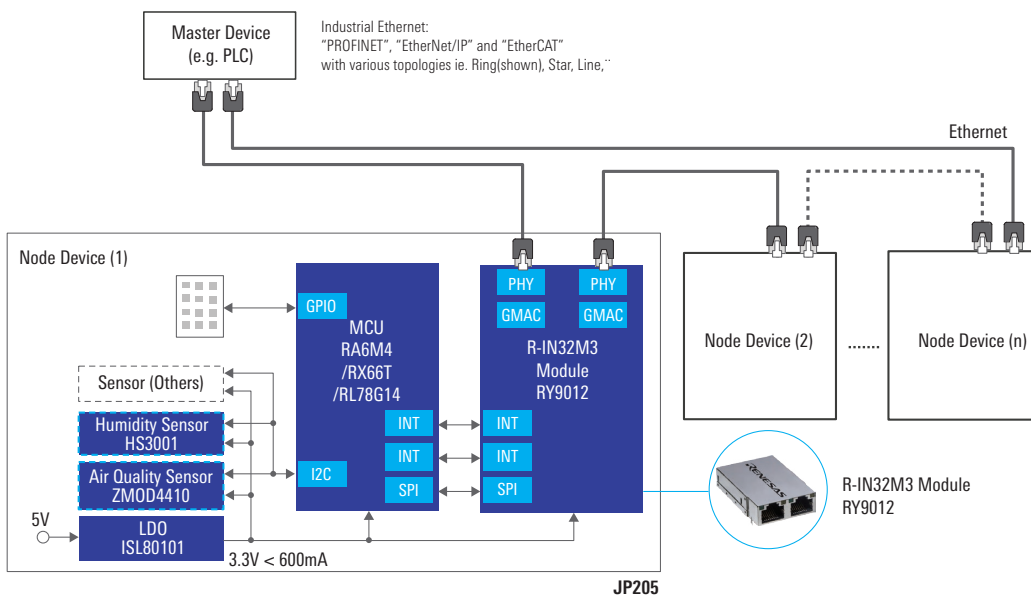
• AC Servo Solution (CN032)



<Overview>

This Renesas AC servo solution integrates motor control and EtherCAT design to support high-speed and high-precision motor control through synchronizing time-sensitive industrial Ethernet communications. This solution is composed of three blocks: system control, power drive and motor encoder, which are physically isolated while maintaining a high degree of interconnect. By utilizing the high-performance RZ/T2M or RZ/N2L microprocessor, this monolithic solution design outperforms traditional two-chip platforms on performance and cost.

• Industrial Automation Solution with Industrial Ethernet Module (JP205)



<Overview>

Previous industrial automation solutions used conventional bus connections such as RS-485 between master and node devices. This solution using the Renesas R-IN32M3 module allows ease of migration from an industrial field bus system to an industrial Ethernet system. It supports three major industry standard protocol stacks: PROFINET, EtherNet/IP and EtherCAT. This enables customers to develop industrial Ethernet systems easily.

Tool Kits

TABLE OF AVAILABLE TOOL KITS

	Related Product	Available Kit	Order Number
	R-IN32M3-EC	Solution Kit	YCONNECT-IT-RIN
	R-IN32M3-EC	Evaluation Kit	Y-SK-RIN32M3-EC (EtherCAT)
	R-IN32M3-CL	Evaluation Kit	Y-SK-RIN32M3-CL (CC-Link IE)
	R-IN32M3 Module	Evaluation Kit	YCONNECT-IT-I-RJ4501
	EtherCAT EC-1	Solution Kit	YCONNECT-IT-EC1
	RX72M	CPU card with RDC/IC	RTK0EMXDE0C00000BJ
	TPS-1	Low Cost Solution Kit	YCONNECT-IT-TPS-1L
	ZIOL2401	Evaluation Board	IOLINKLABKITV2P0
	RX23E-A	Solution Kit	RTK0ESXB10C00001BJ
	RX65N	Renesas Starter Kit	RTK50565N2S80000BE
	RX65N	Cloud Kit	RTK5CK65N0S04000BE
	RX66N	Target Board	RTK5RX66N0C00000BJ
	RX72N	Envision Kit	RTK5RX72N0C00000BJ
	RX72M	Renesas Starter Kit	RTK5572MNDS10000BE
	RX72M	RX72M CPU Card with RDC-IC	RTK0EMXDE0C00000BJ
	RX71M, RX651	Functional Safety, Reference Board for RX71M-RX651	RTK0EF0058D01001BJ
	RX72N	Functional Safety, Reference Board for RX72N-RX72N	RTK0EF0058D02001BJ
	RZ/T2M	Renesas Starter Kit	RTK9RZT2M0S00000BE
	RZ/N2L	Renesas Starter Kit	RTK9RZN2L0S00000BE
	RZ/T1	Renesas Starter Kit	RTK7910018S00000BE
	RZ/T1	Renesas Starter Kit (without debugger)	RTK7910018S90000BE
	RZ/T1	Solution Kit	YDRIVE-IT-RZT1
	RZ/N1D	Solution Kit	YCONNECT-IT-RZN1D
	RZ/N1D or RZ/N1S	Expansion Board	YCONNECT-IT-RZN1-EB
	RZ/N1S	Solution Kit	YCONNECT-IT-RZN1S
	RZ/N1L	Solution Kit	YCONNECT-IT-RZN1L
	RA2E1	Evaluation Board	RTK7EKA2A1S00001BU

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
 3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
 5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
 6. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
 - "Standard": Computers, office equipment, communications equipment, test and measurement equipment, audio and visual equipment, home electronic appliances, machine tools, personal electronic equipment, industrial robots, etc.
 - "High Quality": Transportation equipment (automobiles, trains, ships, etc.), traffic control (traffic lights), large-scale communication equipment, key financial terminal systems, safety control equipment, etc.
 Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system, undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
 7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION ("Vulnerability Issues"). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
 8. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
 9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
 10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
 12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
 13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
- (Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

SALES OFFICES

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics Corporation

TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan

Renesas Electronics America Inc. Milpitas Campus

1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics America Inc. San Jose Campus

6024 Silver Creek Valley Road, San Jose, CA 95138, USA
Tel: +1-408-284-8200, Fax: +1-408-284-2775

Renesas Electronics Canada Limited

603 March Road, Ottawa, ON K2K 2M5, Canada
Tel: +1-613-595-6300, Fax: +1-613-595-6329

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

Room 101-T01, Floor 1, Building 7, Yard No. 7, 8th Street, Shangdi, Haidian District, Beijing 100085, China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai 200333, China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited

Unit 3501-03, 35/F, One Kowloon, 1 Wang Yuen Street, Kowloon Bay, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

80 Bendemeer Road, #06-02 Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.

Unit No 3A-1 Level 3A Tower 8 UOA Business Park, No 1 Jalan Pengaturcara U1/51A, Seksyen U1, 40150 Shah Alam, Selangor, Malaysia
Tel: +60-3-5022-1288, Fax: +60-3-5022-1290

Renesas Electronics India Pvt. Ltd.

Bagmane Tech Park, Municipal No. 66/1-4, Lakeview Block, Block B, Ground Floor, Krishnappa Garden, CV Raman Nagar, Bengaluru, Karnataka 560 093, India
Tel: +91-80-67208700

Renesas Electronics Korea Co., Ltd.

7F, Hae-seong 2nd building, 508, Teheran-ro, Gangnam-gu, Seoul, Korea 06178
Tel: +82-2-558-3737, Fax: +82-2-558-5338