

Accelerate IO-Link Device Development with a Modular, Production-Ready Platform

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Abstract

Developing a compliant IO-Link sensor or actuator can require significant hardware, software, and validation effort. This white paper introduces the Renesas modular IO-Link device platform, which combines the RH4Z2502 single-channel transceiver, an RA2 microcontroller, and a ready-to-use IO-Link device stack library. It explains how developers can begin with a preconfigured demonstrator, then move efficiently to a customized, production-ready design with lower integration effort, reduced licensing costs, and greater flexibility.

Challenges in IO-Link Device Development

[IO-Link](#) is established as a key technology for enabling smarter, more connected industrial automation systems by providing a standardized, vendor-independent communication interface between sensors, actuators, and control systems (Figure 1). IO-Link simplifies integration into higher-level fieldbus networks while enabling advanced diagnostics, parameterization, and access to valuable device data. These benefits have made IO-Link an attractive solution for end users seeking greater interoperability, reduced system complexity, and enhanced visibility into machine and process performance.

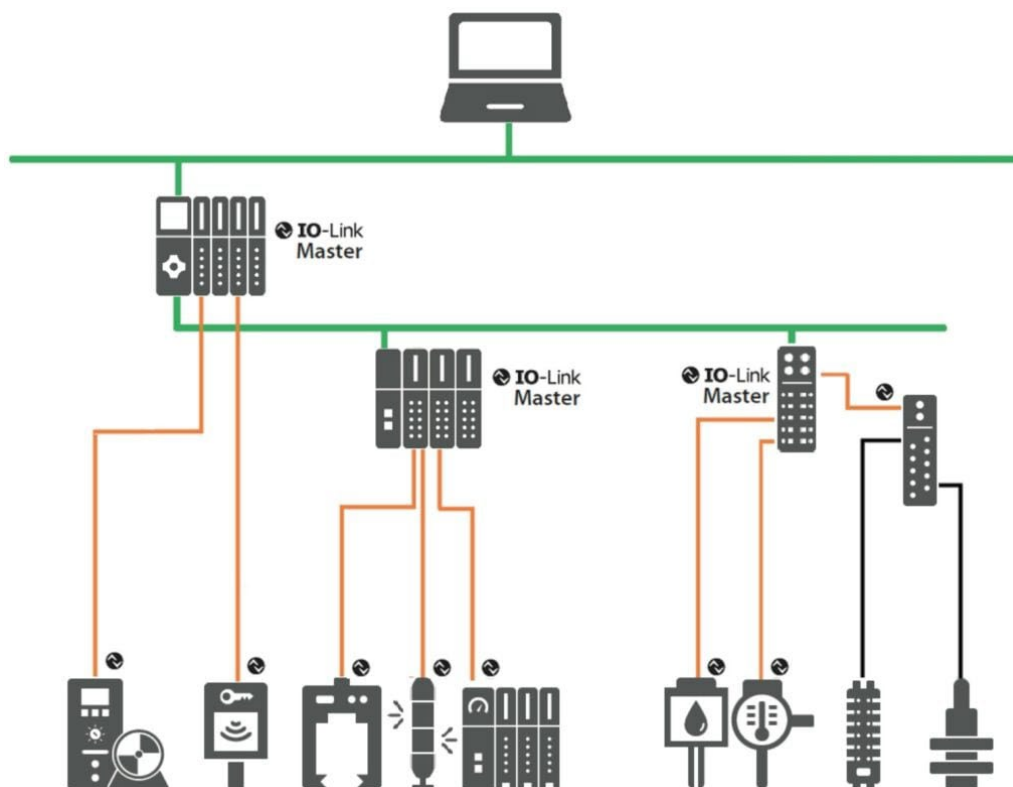


Figure 1. Industrial Network Based on IO-Link - Source: PI North America

The strong market adoption reflects these advantages: Driven by trends such as digitalized manufacturing, predictive maintenance, and Industry 4.0, the global IO-Link market continues to grow rapidly, creating significant opportunities for sensor and actuator manufacturers (Figure 2). To remain competitive, vendors are increasingly launching new IO-Link-enabled products or upgrading existing devices to support the standard.

IO-Link Device Node Count worldwide in million units (MU)

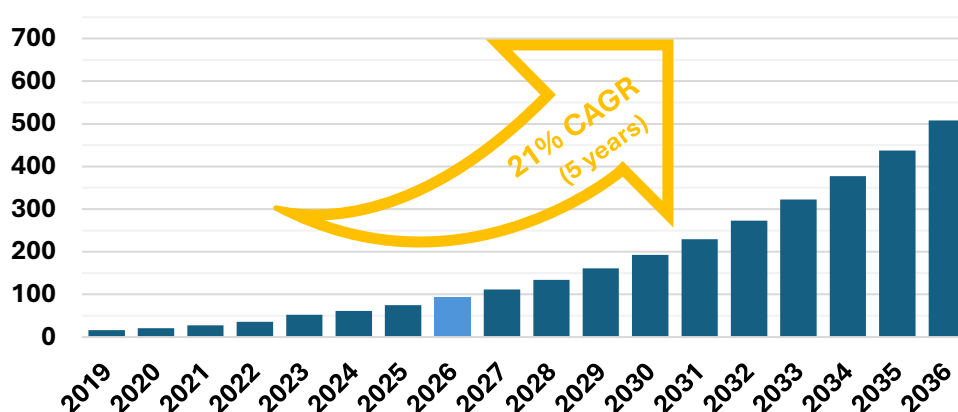


Figure 2. IO-Link Device Node Count Worldwide - Source: PROFIBUS Nutzerorganisation e.V. (PNO) and PI North America

Despite the attractive market potential, developing an IO-Link device remains a complex task. Manufacturers must overcome a range of technical and commercial challenges before they can bring a compliant product to market. This includes selecting and integrating suitable hardware components, such as physical layer transceivers (PHYs) and microcontrollers (MCUs), while ensuring compatibility with the IO-Link device stack. In many cases, stacks must be licensed from third-party providers and adapted or ported to the target hardware platform, adding cost, development effort, and project risk.

In addition, developers face extensive validation, interoperability verification, and conformance testing requirements to ensure compliance with the IO-Link specification. Traditional development approaches often require sourcing technologies from multiple vendors and coordinating hardware, software, and testing activities across different ecosystems. As a result, engineering teams spend considerable time integrating and validating the underlying IO-Link infrastructure instead of focusing on the sensor or actuator functionality that differentiates their products. These challenges can increase development costs, extend time-to-market, and create barriers for companies looking to capitalize on the growing IO-Link opportunity.

Solution Overview: Modular IO-Link Device Platform

Reducing development complexity is critical for manufacturers seeking to capitalize on the growing demand for IO-Link-enabled sensors and actuators. In response, Renesas has created a modular development platform that combines proven hardware and software building blocks into a complete IO-Link device solution (Figure 3).

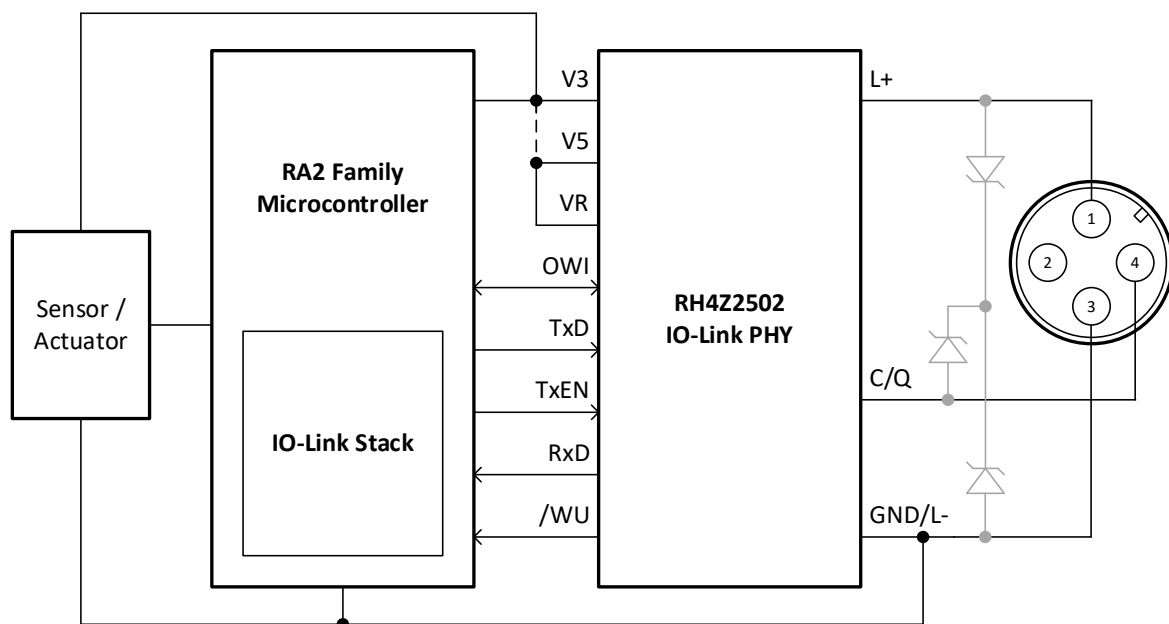


Figure 3. Modular IO-Link Device Solution Architecture

The platform combines [the RH4Z2502 single-channel IO-Link transceiver](#) and the [RA2 Family of Arm® Cortex®-M microcontrollers](#), complemented by a fully customizable IO-Link device stack library delivered as a ready-to-use Visual Studio Code project. The stack is developed by [TEConcept GmbH](#), optimized for the microcontroller family to deliver high efficiency.

Key benefits include:

- Proven IO-Link hardware combination for reduced integration risk
- Simplified hardware selection process with scalable MCU options across the RA family
- Elimination of separate stack licensing costs
- Full IO-Link stack flexibility for covering all application use cases
- Reduced engineering effort for integration, validation, and maintenance
- Faster development cycles and accelerated time-to-market

RH4Z2502 Single-Channel IO-Link Transceiver

As the enabler for an IO-Link solution, the RH4Z2502 embeds a stack license in a proven single-channel physical-layer transceiver architecture. Configurable driver performance, integrated voltage regulators as well as protection and diagnostic features place it as a cornerstone for both sensor and actuator applications.



Key features:

- Embedded IO-Link stack license
- Voltage supply range from 9 V to 36 V
- Integrated surge and reverse polarity protection and over-voltage robustness
- Configurable driver output current (50 mA DC to 400 mA DC) and driver slew rate
- Integrated wake-up detection
- On-chip diagnostics for overtemperature, supply voltage and broken chip detector
- Ambient temperature range -40°C to 125°C

RA2 ARM Cortex-M Microcontroller Series

Within the Renesas modular platform solution, the RA2 microcontroller provides the application processing and control layer. It runs the IO-Link device stack, exchanges process and diagnostic data with the RH4Z2502 physical-layer transceiver and executes the sensor- or actuator-specific functions. The RA2 platform allows to select the right fit variant according to the required processing performance, memory, package size, analog capability, and control peripherals (Table 1).



Key features:

- Arm Cortex-M23 core at up to 64 MHz
- 16- to 100-pin package options
- Up to 512 KB code flash and 48 KB SRAM
- 1.6 V to 5.5 V operating-voltage range
- 12-, 16-, and 24-bit ADC options plus DACs, op-amps, and comparators
- PWM timers, synchronized ADC sampling, and operation up to 125°C on selected variants

Table 1. RA2 Variant Selection for IO-Link Devices

RA2 variant	Key differentiation	Typical IO-Link design fit	Product application examples
RA2E2	• 48 MHz Cortex-M23 • Up to 64 KB flash and 8 KB SRAM • 16- to 24-pin packages • 12-bit ADC • Operation up to 125°C	Smallest, cost-sensitive devices with limited I/O and compact firmware	Inductive proximity sensor, photoelectric switch, compact digital pressure switch
RA2E3	• 48 MHz Cortex-M23 • Up to 64 KB flash and 16 KB SRAM • 32- and 48-pin packages • 12-bit ADC • Pin and peripheral compatibility with RA2E1	Cost-sensitive, energy-efficient sensor or simple actuator designs that need more SRAM and I/O than RA2E2	Compact pressure or temperature sensor, optical sensor, smart switch, simple pneumatic valve interface
RA2E1	• 48 MHz Cortex-M23 • Up to 128 KB flash and 16 KB SRAM • 25- to 64-pin packages • 12-bit ADC • Capacitive touch	General-purpose sensor or simple actuator platform balancing cost, memory, and I/O	Temperature or humidity sensor, capacitive level switch, valve terminal interface, simple solenoid actuator
RA2L1	• 48 MHz Cortex-M23 • Up to 256 KB flash and 32 KB SRAM • 48- to 100-pin packages • 12-bit ADC and DAC • Capacitive touch and CAN • Extensive timers	Feature-rich low-power devices requiring additional I/O, timers, local user interface, or control functions	Multi-channel condition-monitoring sensor, smart valve positioner, motorized actuator, sensor with touch keys or local display
RA2L2	• 48 MHz Cortex-M23 • Up to 128 KB flash and 16 KB SRAM • 32- to 64-pin packages • 12-bit ADC, CAN, and I3C • Crystal-less USB FS and USB Type-C • Operation up to 125°C	Connected service or configuration devices that combine IO-Link with a local USB maintenance interface	IO-Link data logger, configurable barcode or RFID reader, smart actuator with USB service port
RA2T1	• 64 MHz Cortex-M23 • 64 KB flash and 8 KB SRAM • 24- to 48-pin packages • Motor-control PWM timers • 12-bit ADC with three sample-and-hold circuits • High-speed comparators • Operation up to 125°C	Compact IO-Link actuators requiring integrated single-motor control, synchronized current sensing, and fast protection	BLDC fan or pump actuator, motorized valve, conveyor drive, automated blind or damper actuator
RA2A1	• 48 MHz Cortex-M23 • 256 KB flash and 32 KB SRAM • 16-bit SAR ADC • 24-bit sigma-delta ADC • DACs, op-amps, and comparators	Precision analog sensing and closed-loop measurement with reduced external signal-conditioning circuitry	Pressure transmitter, load-cell or strain-gauge sensor, RTD or thermocouple transmitter, precision flow sensor
RA2A2	• 48 MHz Cortex-M23 • 512 KB dual-bank flash and 48 KB SRAM • 24-bit sigma-delta ADC • 12-bit ADC • Segment-LCD controller • 64- to 100-pin packages	Complex precision devices requiring larger firmware, secure field updates, many I/Os, or a local segment display	Multi-channel process transmitter, weighing or dosing controller, intelligent valve positioner with display, compact analytical sensor

IO-Link Device Stack Library

The software library is delivered as a C-based project for the [Visual Studio Code](#) development environment. Developers only need to add application-specific code, map process data through the API, and configure the stack.

The project includes a README.md file for easy setup. For a quick start to IO-Link device development, the delivered project implements a preconfigured IO-Link actuator demonstrator, using the RA2E1 as a platform. Without project modification, the demonstrator builds immediately.

Starting Evaluation

The software library project implements a simple signal light IO-Link actuator as a demonstrator. It runs on the EK-RA2E1 evaluation board combined with the RH4Z2502-PMOD (Figure 4). If the software library project is built without changes, the resulting firmware implements a three-segment tower light using the three on-board LEDs of the EK-RA2E1, supporting:

- Independent activation of LED1, LED2, and LED3.
- Four output modes: permanently on, slow blinking, fast blinking, and flashing.
- A device input named SW1, driven by the EK-RA2E1 S1 user button.

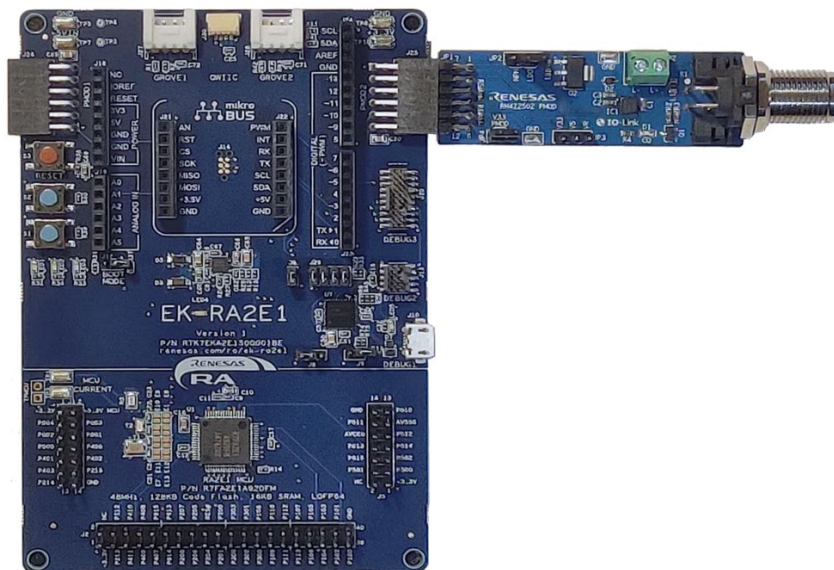


Figure 4. Demonstrator Hardware: EK-RA2E1 with RH4Z2502-PMOD

Use the [IO-Link Device Stack Library Quick Start Guide](#) as starting point for setting up hardware and software for the development environment and guide through the evaluation process.

Once the demonstrator has been set up and programmed, begin the IO-Link evaluation by connecting a master through the RH4Z2502-PMOD. A commercial IO-Link master with a compatible interface tool and an IO-Link cable with M12 connectors are needed. After loading the included IO Device Description (IODD) file to the master interface tool, the LEDs of the EK-RA2E1 board can be controlled via the demonstrator's Process Data Output (PDOOut) byte as described in Table 2.

Table 2. Process Data Out Byte Structure

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Mode		LED3	LED2	LED1
-	-	-	0	0	0: Deactivated	0: Deactivated	0: Deactivated
			Permanently On		1: Activated	1: Activated	1: Activated
			0	1			
			Blinking Slow				
			1	0			
			Blinking Fast				
			1	1			
			Flashing				

Pressing the S1 user button on the EK-RA2E1 board changes the Process Data Input (PDInput) value until the button is released. This simulates sensor or diagnostic data of an IO-Link device.

Moving to Custom Device Development

The demonstrator is a reference for starting custom device development. Additional device solutions are available on [IO-Link Sensors](#). For both sensor and actuator devices, the development of a custom device design should follow these steps:

- 1. RA2 MCU Variant Selection**

Depending on the solution's hardware needs, the project must be adapted to a specific RA2 microcontroller variant. For easy porting within the RA2 series, download and install Renesas [Smart Configurator](#). The tool enables pin configuration and code generation for Renesas MCUs. It is recommended to order the respective evaluation board for the selected MCU for fast prototype setup.

Note: For support of other Renesas microcontroller series, contact Renesas directly.

- 2. Application Code Implementation**

The application-specific sensor or actuator code can be added directly to the Visual Studio Code project to implement the device's functionality such as motor control algorithms or sensor signal conditioning.

- 3. Process Data Definition**

The layout of the Process Data (PDIn, PDOOut) is tightly coupled to the application code and depends on input and output data requirements (type, range) of the solution such as measurement values, threshold switching values, speed or angle setpoints etc.

- 4. IO-Link Device Attributes and Functions**

All other IO-Link device parameters, diagnostics and functions must be adjusted through the mechanisms supported by the library package, including identification parameters and events.

- 5. IODD Generation**

Finally, the associated IODD file must be created, matching all the device's attributes described above. The demonstrator IODD provided in the software package can be used as a reference.

Conclusion

The Renesas IO-Link Device Stack Library solution enables rapid IO-Link device development on the RA2 microcontroller platform. It combines the RH4Z2502 single-channel physical-layer transceiver, an embedded stack license, and an IO-Link stack library package. Flexible hardware and software options enable developers to build fully customized sensors and actuators.

The included demonstrator is a useful validation baseline before integrating the stack into a custom application. Using the Renesas development toolchain, the stack library can be easily ported within the RA2 microcontroller series.

The solution is designed for projects with limited or no prior IO-Link experience, aggressive time-to-market requirements, constrained software resources or budgets, or a need for scalable hardware platforms that simplify IO-Link device development.

Related Documents

- [IO-Link Device Stack Library Quick Start Guide](#)

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