Renesas Solution for Broad Encoder Interface Support in Industrial Automation Applications

***Jeffrey Shoemaker**, Principal FAE, REA/GMSU/SINS/SINF, Renesas Electronics Corporation*

Abstract

According to a report by Grand View Research, the U.S. Industrial Automation & Control market is projected to grow at a robust annual rate of 10.3% from 2023 to 2030.This rapid expansion is driving increased demands on AC servo drives, particularly in their ability to support a diverse range of motors and feedback devices. With the variety of encoder types and protocols in use, AC servo drive manufacturers are increasingly required to accommodate both existing and emerging standards. Renesas RZ/T MPU's address this challenge by supporting the most common encoder types and offering customizable encoder interfaces when used with an FPGA.

Types of Encoders

An encoder is device that translates mechanical motion or position into electrical signals for the express purpose of providing positioning information as feedback to a motion control system or a PLC. As shown in Figure 1 below, an encoder can be used with the motor for commutation, and a separate encoder can be used for position feedback on the load side of the overall system.

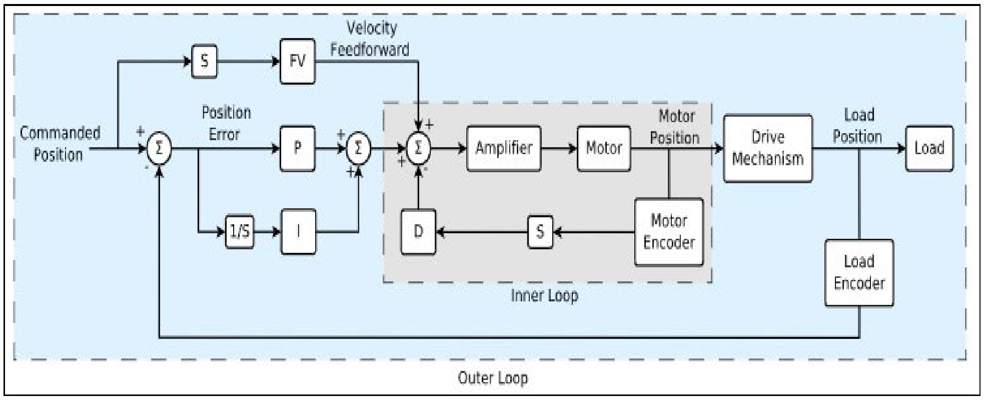


Figure 1: *Dual loop feedback servo system*
(Source: [Galil White Paper])

At a top level, encoders can be broken down into rotary encoders and linear encoders. Rotary encoders can be used to provide angular position and velocity, while linear encoders provide positional information traversing along a linear axis. Rotary and linear encoders can be further sub-divided into absolute and incremental encoder categories. Absolute encoders base its measurement relative to an absolute zero position reference point. Incremental encoders, on the other hand, provide a measurement that is untethered to an absolute position on the device. The user determines the zero-position reference point, and the incremental encoder provides a measurement relative to that reference point. Encoders can also be categorized by the technology that is used. Figure 2 below illustrates logical groupings of the various encoder types by sensing technique, measurement type and by technology.

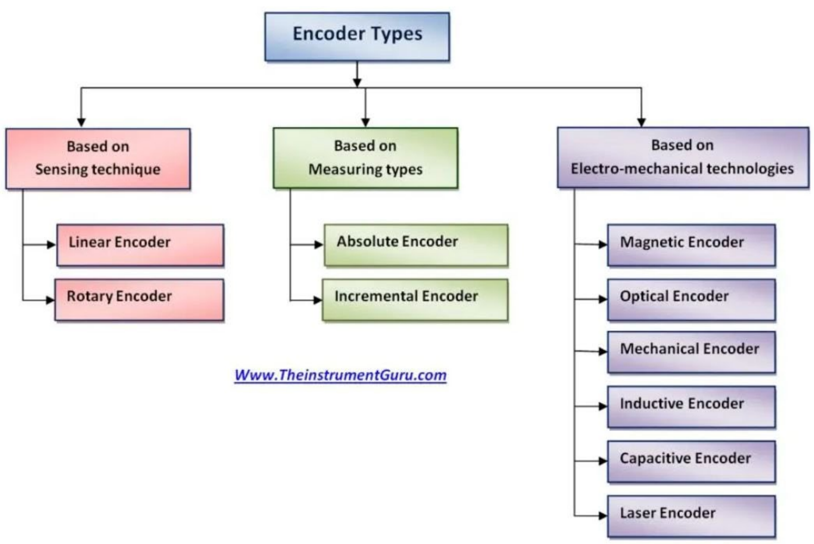


Figure 2: *Encoder types grouped by sensing technique, measuring type and technology*
(Source: [The Instrument Guru])

A detailed description of the encoder technologies outlined in the diagram is outside of the scope of this paper, as there are a variety of references that are available. It is worth noting that Renesas offers a selection of inductive position sensors for applications that require absolute, rotary position information and are lower cost than absolute encoder or resolver alternatives.

Encoder Interfaces and Connectivity

The most common ways to connect an encoder to a motion control system is parallel, serial, FieldBus or EtherNet. See Figure 3 below.

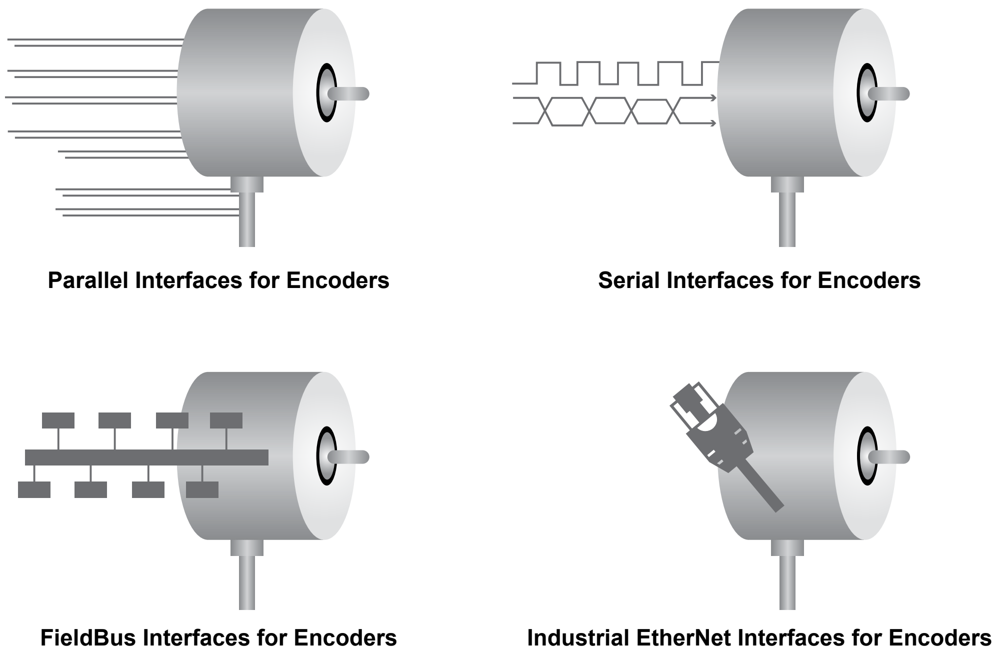


Figure 3: *Encoder connection interfaces*

In the case of a parallel connection, these are intended for very high-speed applications, where data bits are transferred across the interface simultaneously to facilitate minimal latency. The downsides include an increase in wires, which adds complexity and cost, as well as a decrease in reliability due to the introduction of additional potential failure points.

Serial interfaces can be realized as single twisted pair set of wires to implement fast encoder interface where all data bits are sent in series. Serial encoder interfaces realize a variety of different communication protocols that will be explained in the next section. Encoders with a serial interface work well for point-to-point communication, but they are not well suited for coordinated multi-axis systems where several encoders are used simultaneously.

FieldBus interfaces are designed as a master-slave architecture, unlike point-to-point implementations. This allows a single master device to communicate with multiple slave devices simultaneously within the same network. The key advantages of FieldBus include increased speed, reliability, standardization, and flexibility. However, the system's complexity and cost are significant drawbacks. Additionally, a bus fault can cause part of the control system to go offline, potentially leading to hazardous situations. To mitigate this risk, redundant bus systems must be implemented further increasing both cost and complexity.

As is the case with FieldBus interfaces, an EtherNet interface allows for multiple devices to be connected to a network that could have a variable topology. The biggest advantages that EtherNet offers over FieldBus is that it is faster, has more bandwidth and is easily scalable. The one notable disadvantage of EtherNet for encoder usage is that it is not as deterministic as FieldBus. FieldBus guarantees a response, while EtherNet can't. However, modern day industrial EtherNet networks are getting faster, time invariant, and the specific implementation and the type of encoder protocol can ensure a high level of determinism and fault tolerance.

Encoder Protocols

With each encoder type of interface, it will support one or more encoder protocols.

Parallel Encoder Interface

Parallel encoder output is typically Gray code. Gray code increments position information one data bit at a time to facilitate precise and consistent measurements. See Table 1 below.

Decimal	Gray Code	Binary
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111
8	1100	1000
9	1101	1001
10	1111	1010
11	1110	1011
12	1010	1100
13	1011	1101
14	1001	1110
15	1000	1111

Table 1: *Gray code decoder ring*

Serial Encoder Protocols

As mentioned previously, a serial encoder interface is point-to-point. As such it is one master that connects to a single slave device. The most used serial protocols are shown in Table 2 below:

1.) SSI Encoder Protocol. See the link here for more information.

2.) BISS Encoder Protocol. See the link here for more information.

The two protocols mentioned above are open source. When used with a sin/cos encoder, these serial protocols can provide very high-speed, real-time control feedback. There are a number of proprietary serial encoder protocols that exist, but these will not be covered in this paper.

Dedicated Serial Interfaces				
	HIPERFACE®	**SSI + Sine/Cos**	**EnDat®**	**BiSS**
Open Protocol	No	No (License available)	No	Yes
Connection	RS-485: Bus or Point-to-Point Analog: Point-to-Point	Point-to-Point	Point-to-Point	Bus or Point-to-Point
Analog Signals Required	Yes	Yes	No	No
Transmission Mode (Digital)	Bidirectional, asynchronous	Unidirectional, synchronous	Bidirectional, synchronous	Bidirectional, synchronous
Digital Data Transmission Rate	38.4 kBaud	1.5 MHz	4 MHz	10 MHz
Cable Length Compensation	No	No	Yes	Yes
Protocol Length Adjustable	No	No	Yes	Yes
No. of Wires	8	6-8	6 to 12	6
Hardware Compatible				
Alarm/Warming Bit	No	Definable	Yes	Definable

Table 2: *Commonly used serial encoder protocols*

Field Bus Encoder Protocols

Field bus encoder protocols are not limited to point-to-point and can support a single master interfacing to several slave devices. These protocols can report both absolute and incremental encoder information. The most used field bus protocols are:

1.) InterBus Encoder Protocol

2.) CANOPEN Encoder Protocol

3.) ProfiBus Encoder Protocol

4.) DeviceNet Encoder Protocol

EtherNet Encoder Protocols

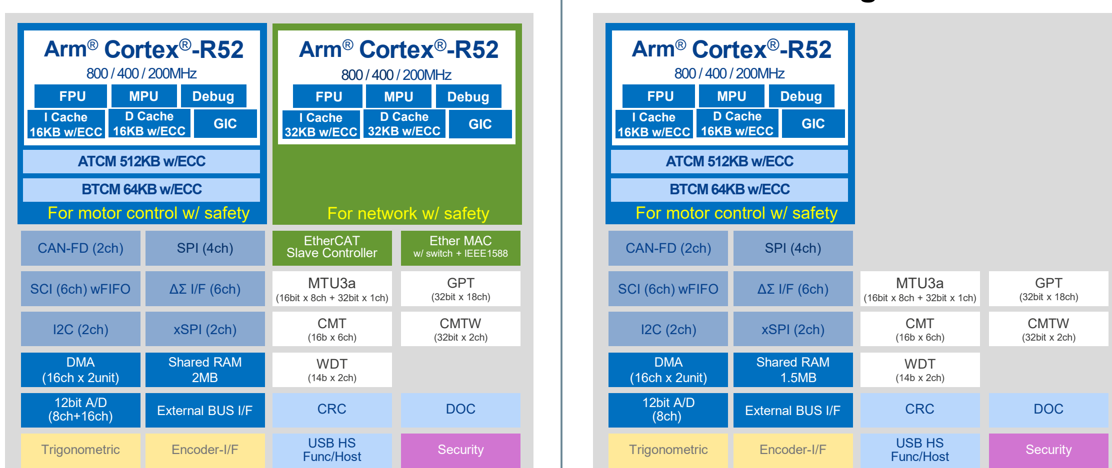
EtherNet encoder protocols allow for maximum flexibility and scalability when adding devices to the network that could have different topologies. Modern day EtherNet encoder protocols involve specialized hardware that works with the EtherNet peripheral in an MCU, FPGA or ASIC to implement hard-real time and deterministic position feedback. The most used field bus protocols are:

1.) Profinet Encoder Protocol

2.) EtherCat Encoder Protocol

Renesas RZ/T2M Encoder Interfaces

The RZ/T2M lineup of Renesas MPU's supports a wide range of encoder interfaces and protocols. The RZ/T2M is an industry-leading high-performance multi-function MPU that realizes high-speed processing, high precision control, and functional safety required for industrial equipment such as AC servos and industrial motors. Powered by dual Arm® Cortex®-R52 cores with a maximum frequency of 800MHz for real-time control and embedded with a large tightly coupled memory (576KB) directly connected to the CPU to realize high-performance real-time processing, RZ/T2M enables low latency access by arranging the peripherals for motor control to the LLPP (Low Latency Peripheral Port) that is directly connected to the CPU. RZ/T2M has a multi-protocol encoder interface that supports various absolute encoder protocols such as A-format™, EnDat, and BiSS® (see Table 3). Additionally, RZ/T2M has a 3-port Gigabit EtherNet switch supporting the TSN standard and EtherCAT slave controller. RZ/T2M realizes high speed and highly precise motor control and industrial EtherNet communication such as EtherCAT, PROFINET RT/IRT and EtherNet/IP on a single chip. As shown in Figure 4 below, there are single- and dual core Arm R52 options. These options will enable encoder support depending on the specific application.



	RZ/T2M Dual Core R52	RZ/T2M Single Core R52
Motor Control Peripherals	• Timers/GPIO/Communication/ ADC/ΔΣ • Flexible Encoder Interface	• Timers/GPIO/Communication/ ADC/ΔΣ • Flexible Encoder Interface
Industrial EtherNet Protocol	Ind. Eth. Switch inc. TSN	-
System RAM	2MB Shared RAM	1.5MB Shared RAM

Figure 4: *RZ/T2M single and dual core options*

	EnDat 2.2	BiSS-C	NIKON A-format	FA-CODER	HIPERFACE DSL
Related specification	Heidenhein Corp	iC-Haus GmbH	NIKON Corporation	TAMAGAWA SEIKI CO.,LTD.	SICK STEGMANN GmbH
	http://www.heidenhain.de	http://www.biss-interface.com	http://www.nikon.co.jp	http://www.tamagawa-seiki.co.jp	http://www.sick.com
Comm. method	Synchronous	Synchronous	Asynchronous	Asynchronous	Asynchronous
Transceiver	RS-485	RS-422	RS-485	RS-485	RS-485
Supported data rate/ frequency	100kHz to 16.7MHz	80.12KHz to10MHz	2.5Mbps/4Mbps/ 6.67Mbps/8Mbps	2.5Mbps/5Mbps	9.375MBaud
# of I/F pins / Signal level	4 / 3.3V TTL level	2 / 3.3V TTL level	3 / 3.3V TTL level	3 / 3.3V TTL level	3 / 3.3V TTL level
Other feature	• Support transmission delay • Incremental signals are not supported.	• Support delay compensation • Support C mode (B mode is not supported) • Incremental signals are not supported • 1 to 1 connection is supported (Bus connection is not supported)	• 1 to 1 connection and bus connection are supported • A-Safety is not supported.	• Support baseband NRZ data code • Incremental signals and synchronized Manchester code are not supported.	• External Synchronous Communications (SYNC mode) • Asynchronous communications (Free running mode) • Estimator (Position estimation when an error occurs) • RSSI, Quality monitoring

Table 3: *RZ/T2M single and dual core options*

In a conventional motion control system, in order to support a variety of encoder interfaces, and ASIC or FPGA is required as an intermediary between the encoder and the MCU/MPU. Since the encoder interface on the RZ/T2M supports multiple encoder protocols, this facilitates a higher level of integration and alleviates the need for an external ASIC or FPGA in most cases. See Figure 5 below.

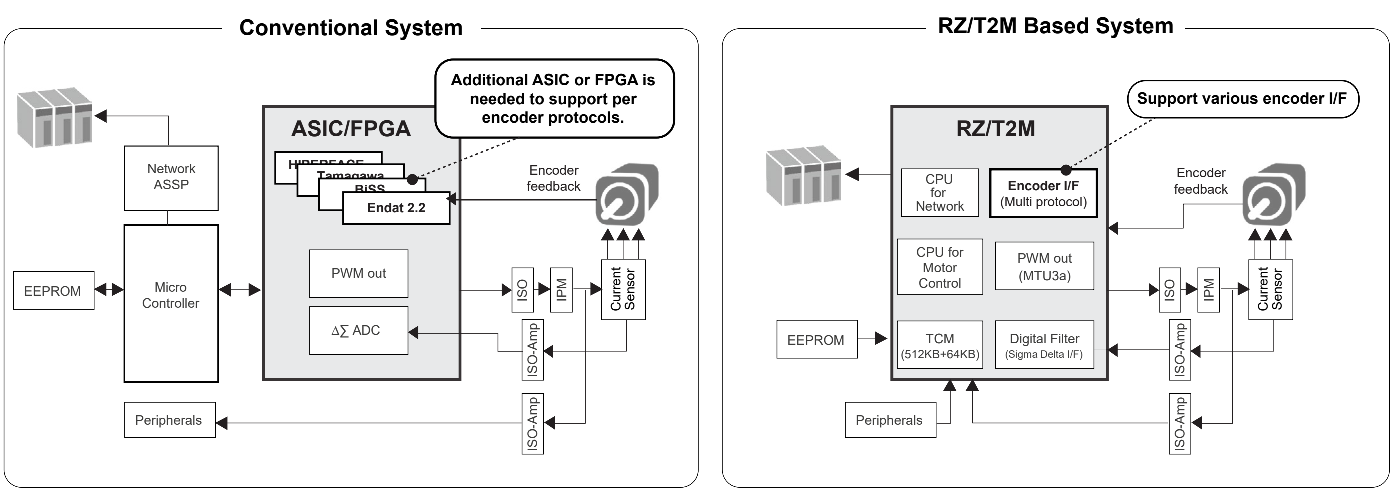


Figure 5: *Encoder interfacing in a conventional MCU/MPU setup versus a streamlined RZ/T2M connection*

If the application requires a protocol that is not supported in the RZ/T2M encoder interface, such as a custom encoder protocol, a small, low-cost FPGA can be used that easily interfaces to the RZ/T2M. A small, low-cost serial flash can be used to store multiple encoder protocols that can be loaded into the FPGA by the RZ/T2M. Renesas also offers the ForgeFPGA™ family that fulfills the design need for relatively small amounts of programmable logic that can be quickly and efficiently designed into cost-sensitive applications. ForgeFPGA devices provide dramatic cost savings versus other alternatives, including non-FPGA designs. See Figure 6 below.

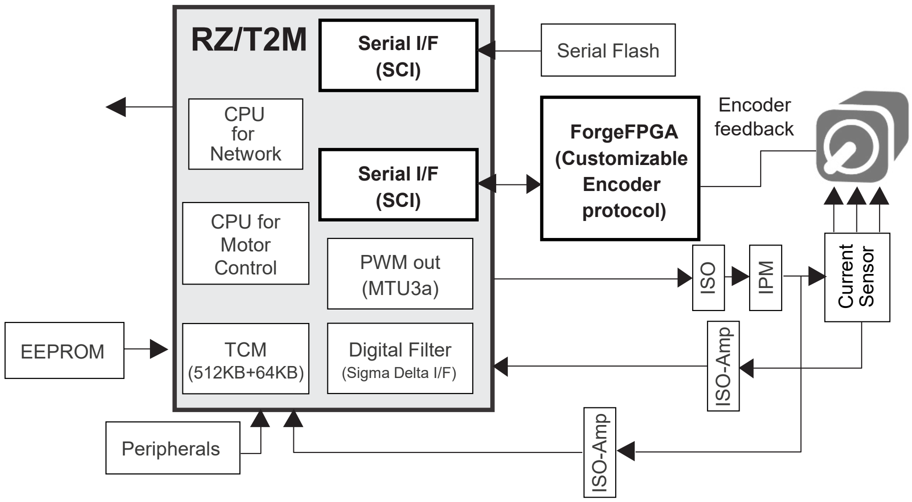


Figure 6: *RZ/T2M based system with FPGA for custom encoder protocols*

Conclusion

As the industrial automation market continues its rapid expansion, the demand for motor drives and controllers capable of supporting a diverse array of encoder interfaces and protocols will also intensify and become increasingly complex. The RZ/T2M is uniquely positioned to meet these evolving needs. As highlighted in Table 4 below, the RZ/T2M offers robust support for parallel, serial, FieldBus and EtherNet encoder interfaces. Its dedicated encoder interface is compatible with the most widely used serial encoder protocols, and with the addition of a small FPGA, it provides the flexibility to accommodate customized encoder protocols, seamlessly integrating with the RZ/T2M.

Encoder Interface/Protocol		RZ/T2M Support?
Parallel (Gray Code)		Yes
Serial		Yes
	EnDat 2.2	Yes
	BiSS-C	Yes
	NIKON A-Format	Yes
	FA-CODER	Yes
	HIPERFACE DSL	Yes
FieldBus		
	InterBus	Yes
	CANOPEN	Yes
	ProfiBus	Yes
	DeviceNet	Yes
Custom Protocol using FPGA		Yes

Table 4: *RZ/T2M supports a wide variety of encoder types and encoder protocols*

References

Industrial Automation And Control Systems Market Report, 2030 (grandviewresearch.com)

Motor Encoders | How it works, Application & Advantages (electricity-magnetism.org)

Different types of encoders and their applications - HEIDENHAIN

Encoder | THE INSTRUMENT GURU

Encoder Interfaces | Encoder Protocols Overview | Dynapar

Advantages and Tradeoffs of Encoder Technologies | DigiKey

Industrial Ethernet vs Fieldbus Network |Library.AutomationDirect

Encoder Interfaces: Find the interface you need! (posital.com)

FAQ: What are the ways to wire an absolute encoder into a motion system? (designworldonline.com)

RZ/T2M: High-Performance Multi-Function MPU for Industrial AC Servos and Controllers

ForgeFPGA Low-density FPGAs

Renesas FPGA Designs

Corporate Headquarters
TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan
https://www.renesas.com

Contact Information
For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
https://www.renesas.com/contact-us

Renesas Electronics Corporation
www.renesas.com

Doc Number: R01WP0024EU0100