Achieve High-Performance Application Processing, Multi-Axis Motor Control, and Industrial Ethernet in Industrial Robots with RZ/T2H MPU

Koichiro Sugata, Application Processor Product Marketing Department, Embedded Processing Business Development Division, Embedded Processing Business Unit, Renesas Electronics Corporation

Overview

As the need for automation and labor saving in factories grows, the demand for industrial robots such as vertical articulated robots are also growing. To build such industrial robots, developers need to have real-time performance to control multiple-axis motors, motor control functions for the number of axes, high-performance application processing performance to calculate the trajectory of the robot arm and executing middleware such as ROS, and network communication support for industrial Ethernet to connect the robot to factory network. The conventional industrial robot controllers use FPGAs for motor control, high-performance CPUs for application processing, and ASSPs for industrial Ethernet. Each of these devices requires a power supply, clock, and memory, requiring a large number of components that not only complicated the system circuit/layout design, but also resulted in many necessary design and evaluation of the functions implemented in the FPGA.

This white paper introduces a way to implement motor control for up to 9 axes, high-performance application processing, and multi-protocol industrial Ethernet on a single chip. This single chip reduces the number of parts used in industrial robots and significantly reduce the development man-hours.

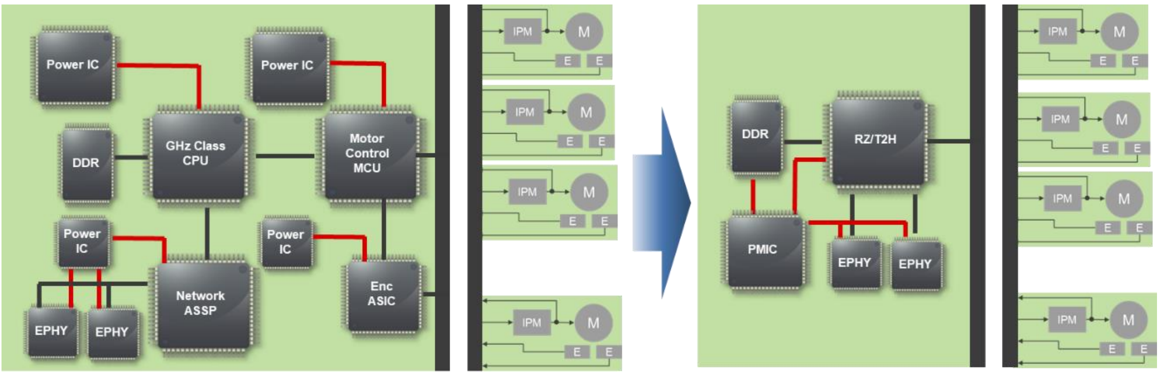

Figure 1: Component Reduction in an Industrial Robot with RZ/T2H MPU

Achieve All Requirements for Multi-Axis Motor Control up to 9 axes on a Single Chip – RZ/T2H has High-Performance CPUs, and All Required Functions

For the control of the servo motors used in industrial robots, it is necessary to execute a current loop process within the specified carrier cycle that acquires the current value flowing through the motor and position information and sets the output of the three-phase PWM timer. Because industrial robots perform this current loop processing for each of the axes they have, they require high-precision real-time performance. Conventional industrial robots achieve the current loop processing for multiple axes using

FPGAs that enable parallel processing or multiple MCUs. In addition, a CPU that is suitable for real-time processing is also required for industrial Ethernet to accurately synchronize between devices.

The RZ/T2H MPU has two real-time Arm® Cortex®-R52 CPUs, with each CPU having a 1GHz operating frequency, and a large capacity tightly coupled memory (576KB), which eliminates the execution time fluctuations that occur when using cache memory, and which enables deterministic high-speed response processing. Furthermore, the trigonometric function unit (TFU) and peripherals used in motor control are located on the low-latency peripheral port bus (LLPP bus) directly connected to the CPU, which enables high-speed access from the CPU and achieves high-speed current loop processing. Using Renesas' sample program, we measured that one CR52 CPU can execute current loop processing for 9 axes in less than 8us, and a carrier frequency of 100kHz (=10us) is achieved with the RZ/T2H. Therefore, developers can perform motor control for 9 axes with one CR52 CPU on the RZ/T2H, while supporting industrial Ethernet with another CR52 CPU.

A multi-axis motor control requires a PWM timer that supports complementary three-phase output, a delta-sigma demodulator for measuring the current flowing through the motor, and an encoder interface for obtaining position information, all of which must be equipped for the required number of axes. In addition, the PWM timer requires synchronized operation between the axes, and the encoder uses different protocols depending on the manufacturer, such as A-format™, EnDat, and BiSS®. In order to achieve the required functions for the number of axes, synchronization between PWM timers and multi-protocol encoders, FPGAs have also been widely used in this application.

The RZ/T2H is equipped with PWM timers, delta-sigma modulators, and encoder interfaces mentioned above, all of which are available for 9 axes. The PWM timers for the 9 axes can operate in synchronization, and the encoder interface also supports multiple protocols. By using the RZ/T2H, which has high real-time performance and a wealth of peripherals for motor control, it is now possible to reduce the number of components and PCB size as well as the development man-hours to implement functions in the FPGA, which was previously needed.

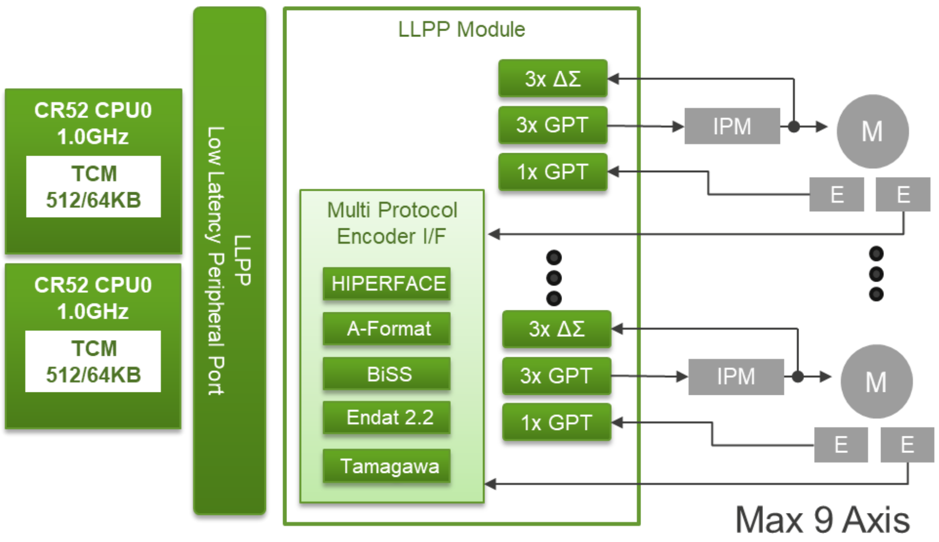

Figure 2: Hardware Configuration that Achieves High-Speed Control of 9-Axis Motors

Achieve High-Speed Processing by High-Performance Application CPU

Controllers for industrial robots need to be able to control multiple axes as well as handle high-speed application processing. In addition to calculating the trajectory planning for the arm to move accurately and smoothly, and calculating the command values for controlling each axis based on the trajectory plan, high-performance CPUs and DDR support are also required in recent years to run open-source software on Linux, such as ROS which provides middleware for robot control, and ORiN enabling connection with devices from other manufacturers and versions.

The RZ/T2H is equipped with a quad-core Cortex-A55 1.2GHz processor for application processing. It has 32 KB/32 K B L1 I/D-cache per core, and 1024 KB L3 cache implemented as a common cache. It is equipped with a DDR IF that supports LPDDR4-3200 32-bit and SD/eMMC for storing large programs and can run Linux applications. In addition, it is possible to use a combination of Linux, RTOS, and bare metal on the four cores and supports cache partitioning, which allocates areas of the L3 common cache to each core.

The following graph shows the results of running UNIXBENCH on Linux using an RZ/T2H and a microprocessor from another company which has four application CPUs. The results showed that the RZ/T2H achieves high scores of 35-75% in each category. It is possible to speed up the update cycle of the command values for each axis motor and to process more complex trajectory planning algorithms by using the RZ/T2H, contributing to the realization of more precise robot motion.

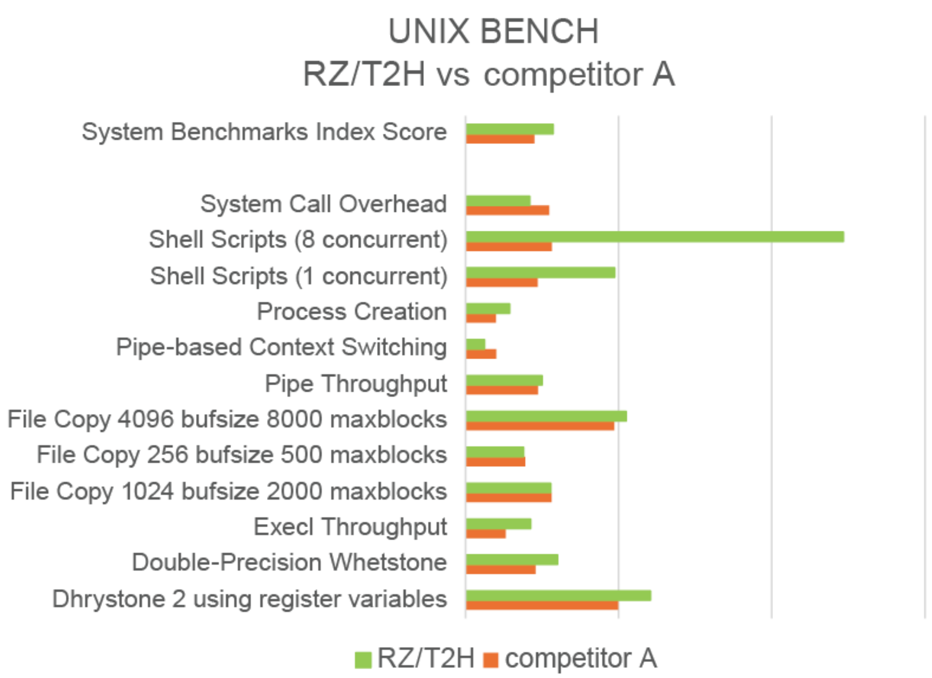

Table 1: UNIXBENCH Results

Support Multiple Ethernet Communications with Multiple Protocols

In factories using industrial robots, devices from various manufacturers will be connected to a network, and industrial Ethernet protocols such as EtherCAT, PROFINET, and EtherNet/IP, which specialize in real-time communication are used to further increase the synchronization accuracy between devices. The synchronization accuracy between devices has a significant impact on production efficiency, as this is used for simultaneous operations by multiple robots as well as to reduce waiting times. In conventional industrial robots, dedicated ASSPs have been used to support these multiple industrial Ethernet protocols. In addition to industrial Ethernet, there is a need to have Ethernet communication that is independent of industrial Ethernet to communicate with PCs and management systems for condition monitoring and software version upgrades, as well as to connect to external HMI devices.

The RZ/T2H is equipped with four external Ethernet ports, three Gigabit Ethernet MACs (GMACs), a Gigabit Ethernet switch (ETHSW), and an EtherCAT® slave controller (ESC); and is compatible with major industrial Ethernet communication protocols such as EtherCAT, PROFINET RT/IRT, EtherNet/IP™, and OPC UA, as well as the next-generation TSN (Time-Sensitive Networking) standard. Multiple Ethernet implementations are possible by assigning GMAC, ETHSW and ESC to the four external Ethernet ports. For example, two ports can be used for industrial Ethernet, and the remaining two ports can be used for general-purpose Ethernet. If industrial Ethernet is not needed, up to three ports can be used for general-purpose Ethernet, allowing users to flexibly implement network functions. In addition, the network synchronization signals for ETHSW, such as TDMA and the DC (Distribute Clock) of ESC, are connected to the Event Link Controller (ELC) in the RZ/T2H, making it possible to operate peripheral functions with low latency, and synchronize operations with different devices connected to the network. This enables high-precision synchronization along with linked operation with devices connected to the network and is expected to improve productivity.

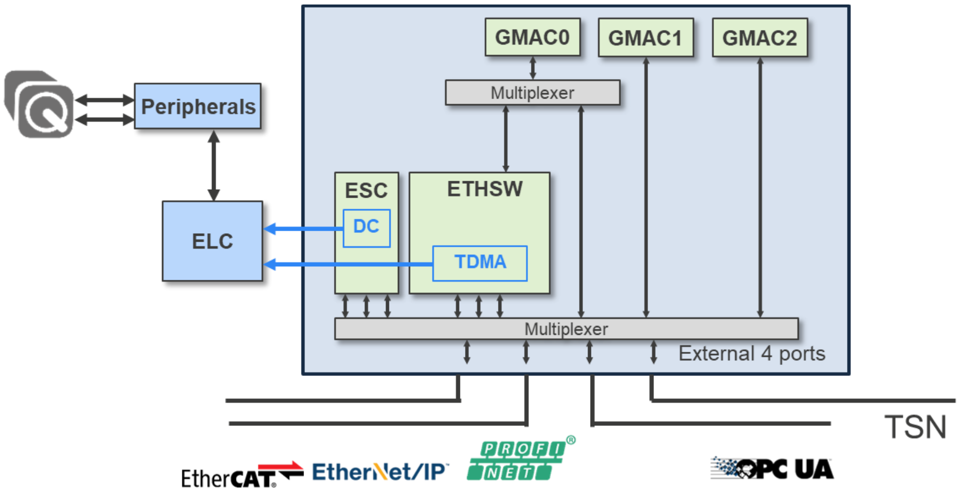

Figure 3: Hardware Configuration to Support Multiple Ethernet Communications with Multiple Protocols

Summary

This white paper introduces methods to improve the performance of industrial robots using RZ/T2H and to significantly reduce the number of components and development man-hours. This enables RZ/T2H users to not only enhance the competitiveness of their industrial robots, but also improve their time to market.

Renesas provides a solution where you can experience 9-axis motor control using the RZ/T2H. The sample programs for 9-axis motor control can be downloaded from the Renesas website. The RZ/T2H evaluation board and inverter board, which can drive 9-axis motors, are available for purchase from the Renesas online store. For more information, please refer to the RZ/T2H product page.

Related Information

RZ/T2H: Advanced High-End MPU with Integrated Powerful Application Processing and High-Precision Real-Time Control for 9-Axis Motor Control

RZ/T2H Evaluation Kit: An evaluation and development kit for RZ/T2H

ROS: Robot Operating System is open-source software used in robot development

ORiN: ORiN Consortium - Middleware that connects equipment and integrates systems, overcoming the barriers of standards

Corporate Headquarters

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

Contact Information

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