Challenges in the Development of Next-generation Motor Control Systems

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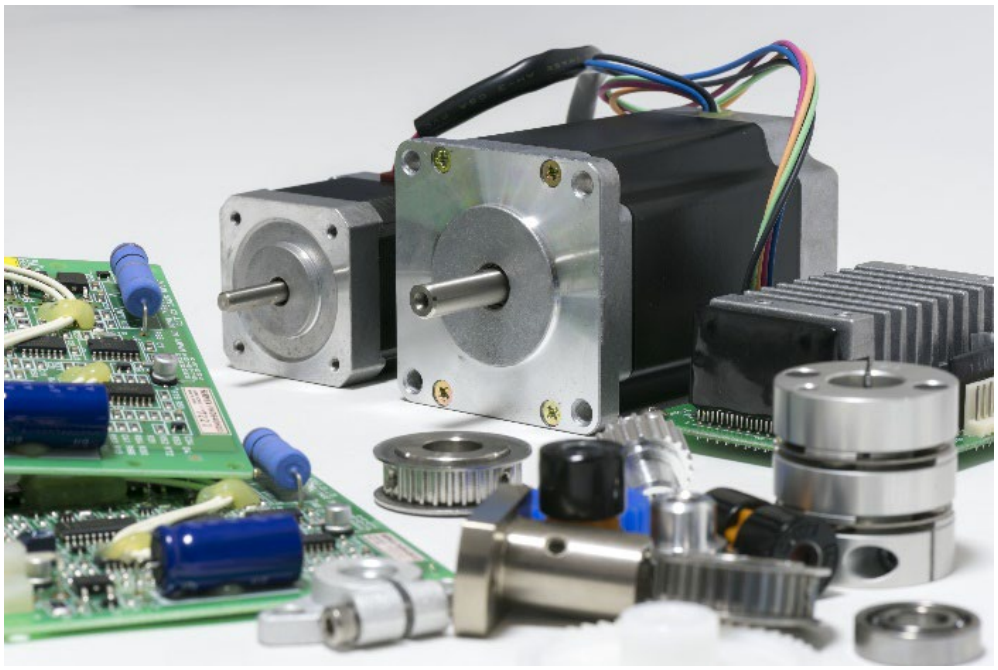


Overview

Many of today's motor control systems are implemented by programming motor control algorithms on the MCU. However, due to the diversification of needs, control algorithms are becoming more and more complicated, and it is required to realize not only motor control but also communication and control of the entire system with one MCU. In this way, developers have to consider the coexistence of complicated real-time processing such as motor control and non-real-time processing such as system control more than ever. In addition, in order to be price competitive in the market, developers are facing major challenges such as early market launch and cost reduction.

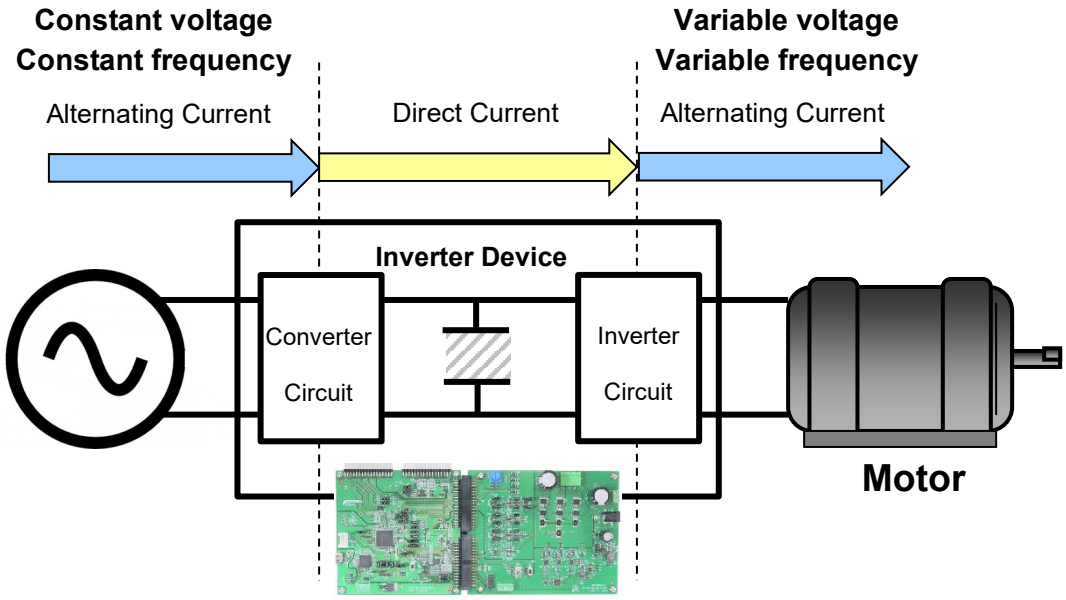
This document describes various solutions based on the RA6T2 MCU to solve these problems.

Motor Control

Motor control is a technology that has existed for a long time with a history of about 200 years. There are various types of motors depending on the application and they have developed as an important technology that supports human life. Especially for motors that are highly versatile and easy to maintain, it is common to program the MCU to adjust the rotation speed and torque because the control is complicated.

What is an Inverter?

An inverter basically refers to a device / circuit that converts direct current to alternating current. In the home appliances and industrial fields, it is generally used for the purpose of changing the alternating current to any frequency or voltage. This has the advantage of higher power utilization efficiency than driving with a commercial power supply that has a constant frequency because it can operate at a wide range of rotation speeds.

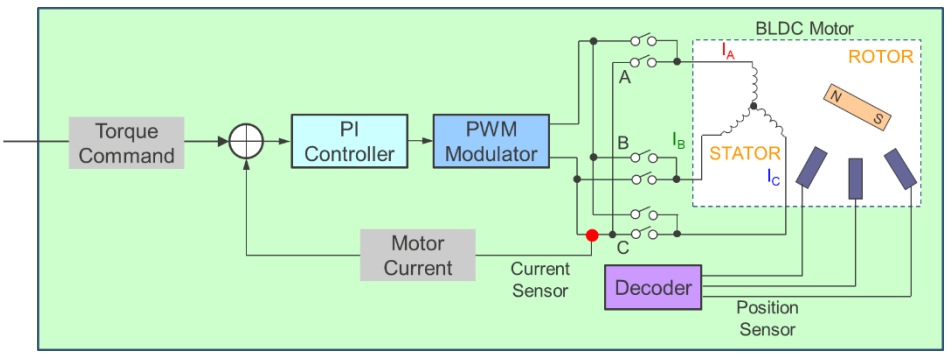


Inverter Circuit

Inverter circuits create the AC voltage by repeating the ON / OFF of the transistor with the DC power supply at a specific cycle. This ON / OFF is utilized in the built-in timer output of the MCU. This is called PWM (Pulse Width Modulation). The operation, quietness, and power efficiency of the motor are determined by how high-speed and highly accurate this PWM is generated and ON / OFF switching is realized.

How speed control works

The figure below shows the signal flow when the MCU controls the motor rotation speed using the above-mentioned inverter device. It contains a software block and peripheral circuits for the MCU that control the BLDC motor.



Schematic diagram of motor speed control by built-in MCU

The MCU converts the speed / torque command into parameters, determines the PWM duty ratio in the PI control unit and outputs the pulse. Although it depends on the control algorithm, the speed and rotor position information are communicated to the MCU using the motor current, shunt current, Hall element, encoder, etc., and loop operation is performed. This operation is repeated to detect and correct the difference in the actual motor operation with respect to the command value. In a motor control system, it is necessary to complete these series of processes within the control cycle. Therefore, motor control is called a real-time application. In addition, by shortening this control cycle, fine control of the motor becomes possible and high response and high efficiency motor applications are realized.

Challenges in the Development of Next-generation Motor Control Systems

Now, let's take a look at the technical challenges faced by developers as they work on the next generation of motor control equipment. Broadly speaking, the key points are to respond to the performance required in the first place to realize an advanced control system, as well as building a development environment for its timely market launch.

1. **Response to higher performance and complexity of processing:** As mentioned above, the motor control itself detects the difference between the command value and the actual motor operation and repeats the control. In order to achieve high response and high efficiency, the control cycle must be further shortened and the motor control calculation must be completed within that control cycle. However, in order to succeed in the motor market, the MCU needs to have higher processing power because of the coexistence of additional processing to realize additional functions and non-real-time processing such as communication and control of the entire system.
2. **Construction of evaluation environment for motor control:** In order to control various motors, it is necessary to understand the characteristics of each motor and develop hardware to evaluate them. This requires a lot of engineering hours. Also, with a new MCU, it takes an enormous development period to port or create software for peripheral functions such as control algorithms and PWM timers built into the MCU.

These common motor control issues can be solved with the RA6T2, an RA family ASSP product for motor control and motor development solutions such as its development kits, application notes, and development tools. First, let’s look at an approach to the first challenge.

RA6T2 – Designed for Motor Control

The RA6T2 is an MCU that realizes the real-time control performance required by next generation motor applications. Renesas has developed a large number of MCUs for motor control in the past, and PWM timers and analog functions have evolved to realize more advanced control. The RA family, which uses the Arm Cortex-M core, inherits this excellent DNA and is developing ASSP products for motor control. The first released was RA6T1 equipped with Arm Cortex-M4. RA6T2 was recently introduced and is the second product equipped with Cortex-M33 core and operating at 240 MHz. These MCUs are real-time engine that combines a 32-bit motor timer and enhanced analog functions with Renesas' original flash memory.

The RA6T2 has two major hardware improvements to achieve high real-time performance for next-generation motor control – built-in high-speed flash memory and hardware accelerators.

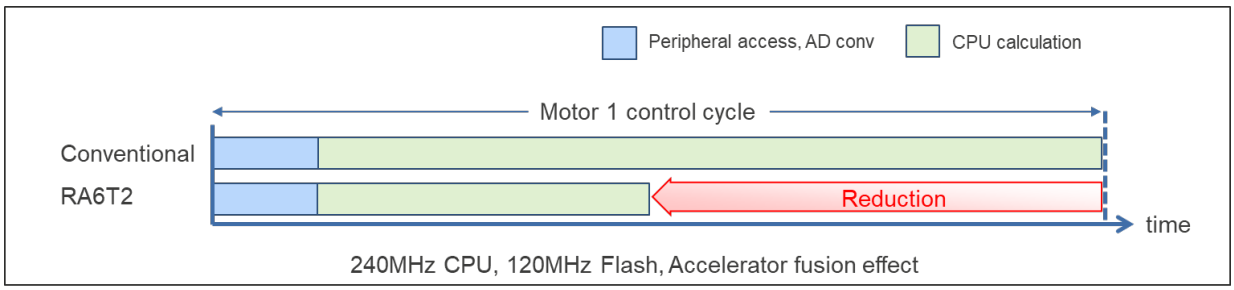
High-speed flash memory

Generally, when the CPU accesses slow memory, cache memory is used to reduce this overhead because it waits for the access to complete. However, in the motor control program, cache misses occur and performance deteriorates due to frequent branch processing and interrupts. Therefore, the RA6T2 has a built-in high-speed flash memory that operates at 120MHz with no wait state, which is unique to Renesas, helping to reduce the penalty even in the case of a cache miss and realizes real-time performance with less fluctuation.

Accelerators for motor control

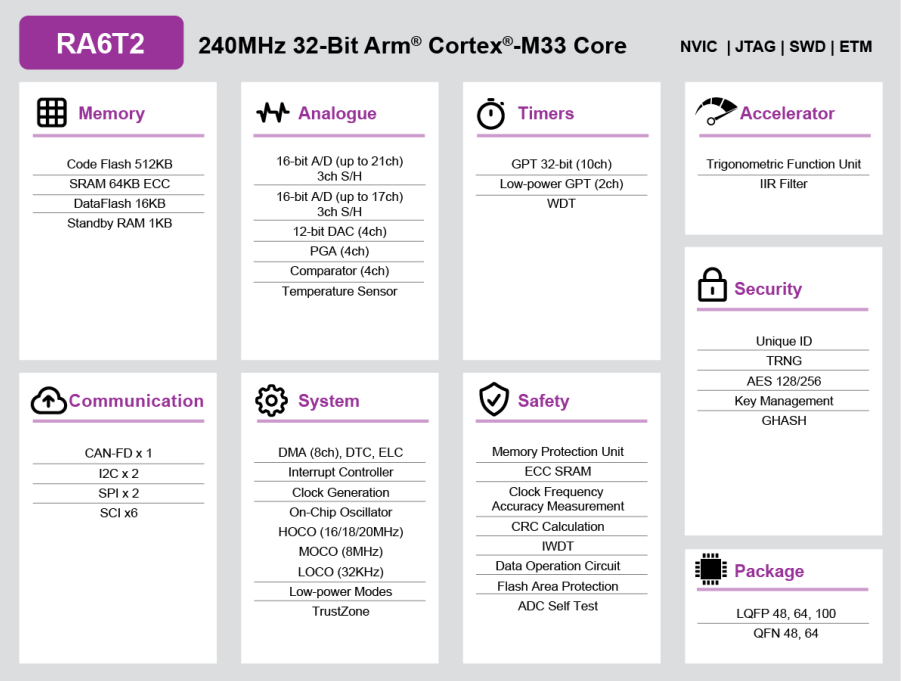
The RA6T2 is equipped with two hardware accelerators, TFU (Trigonometric Function Unit) and IIRFA (IIR Filter Accelerator), for high-speed motor control operations. TFU handles fast computations of sinf, cosf, atan2f, and hypotf functions, and is very useful in vector-controlled dq conversion. Similarly, IIRFA can be applied to notch filters for suppressing mechanical resonance. Since the coefficient and delay data can be saved in the local memory, the calculation result can be obtained simply by setting the input value. These accelerators support only the basic elements of motor control which makes them easy to apply to a variety of existing algorithms.

Due to these two features specialized in real-time performance, it is possible to reduce performance variation and significantly reduce the CPU load. As a result, it is possible to add high-response and high-efficiency control and non-real-time processing by shortening the control cycle.



In addition to improving real-time performance, RA6T2 has a lineup of 48-pin, 64-pin, and 100-pin LQFP packages. Functionality is compatible between these packages and the pinouts are scalable, making it easy to share development assets with each other, even in different packages. It will be possible to develop a platform to realize multi-model development of white goods and industrial equipment and get to market faster. In addition, 48- and 64-pin QFN packages meet small size requirements such as power tools, robotics, and drones.

Pin Count	48pin		64pin		100pin
Package type	QFN	LQFP	QFN	LQFP	LQFP
Package view	7 mm × 7 mm QFN 48 0.5 mm pitch	7 mm × 7 mm QFP 48 0.5 mm pitch	8 mm × 8 mm QFN 64 0.4 mm pitch	10 mm × 10 mm LQFP 64 0.5 mm pitch	14 mm × 14 mm QFP 100 0.5 mm pitch



RA6T2 Motor Development Solution

The next major issue is the construction of an evaluation environment for motor control. RA6T2 has various solutions to solve the needs of developers.

Motor Control Kit MCK-RA6T2

Hardware reference kit for evaluation of and development with RA6T2

- **One package with all components for turning the motor**

  The inverter board is directly connected to the CPU board equipped with RA6T2 via a connector. A BLDC motor is also included, so you can start turning the motor as soon as you open the box.

- **A wide choice of sample code and development tools are available**

  Not only is the motor control program pre-programmed to the MCU to allow you a good experience, but various application notes are available online, as well. All sample programs provided were developed specifically to run on this kit.

Name	MCK-RA6T2 (Renesas Flexible Motor Control Kit for RA6T2 MCU Group)
Product model name	RTK0EMA270S00020BJ
On-board CPU	RA6T2 (R7FA6T2BD3CFP)
Included items	・Motor control CPU board ・48V / 10A inverter board ・COM board for Renesas MCU ・BLDC motor ・Accessories (USB cable, COM cable, standoffs, screws)
I/F	・Hall, Encoder, Inductive sensor ・CAN, SPI ・User I/Fs (SWs, LEDs and variable resistors)

Overview of MCK-RA6T2

Application notes and sample code for motor control

RA6T2 is supported by application notes and sample code for controlling various motors. All can be downloaded from the website according to the motor type and control algorithm used.

- **Application note**

  There are several different application notes published. Some detail the control software of 120-degree energization method that operates various motors based on sensor-less vector control. Others explain how to use the Renesas Motor Workbench motor control development support tool with detailed descriptions of functions and control flows, which are very useful for development and evaluation.

- **Sample code**

  Each application note comes with sample code that can be downloaded to the MCU. Various software and drivers are used with MCK-RA6T2, the Motor Control evaluation kit for RA6T2, including control algorithms, system control, PWM control and AD converters.

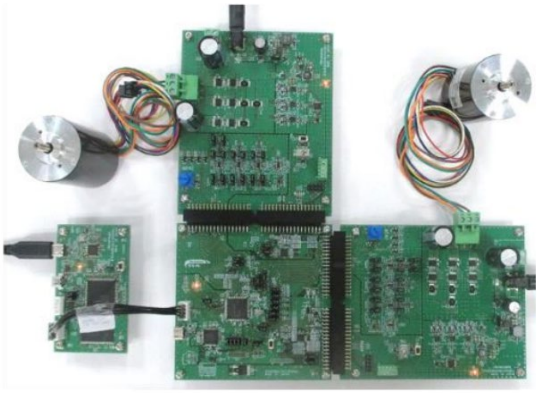
Currently, we have released 10 application notes for motor control, and we will continue to release more that contribute to user development.

Title	Release date
RA6T2 120-degree conducting control of permanent magnetic synchronous motor using hall sensors	Dec 9, 2021
RA6T2 Sensorless 120-degree conducting control of permanent magnetic synchronous motor	Dec 9, 2021
RA6T2 Sensorless vector control for permanent magnet synchronous motor	Dec 9, 2021
RA6T2 Sensorless vector control with one shunt for permanent magnet synchronous motor	Dec 9, 2021
RA6T2 Vector control for permanent magnet synchronous motor with encoder	Dec 9, 2021
RA6T2 Sensorless vector control for dual permanent magnetic synchronous motor	May 16, 2022
Digital Filtering using the IIR Filter Accelerator - Application Project	Jun 7, 2022
RA6T2 Accelerators (IIRFA/TFU) performance in motor application	Jun 17, 2022
RA6T2 Vector control for permanent magnetic synchronous motor with hall sensors	Jun 29, 2022
RA6T2 Vector control for permanent magnetic synchronous motor with inductive sensor	Jun 29, 2022

Initial application notes combine basic motor types and control methods, later releases are more specific to actual applications.

Dual Motor Control Solution

Explains how to implement sensor-less vector control software that drives dual permanent magnet synchronous motors (PMSMs) using RA6T2. Since the MCK-RA6T2 CPU board has two connector I/Fs to add inverter boards, users can start evaluation immediately by preparing an additional inverter board.

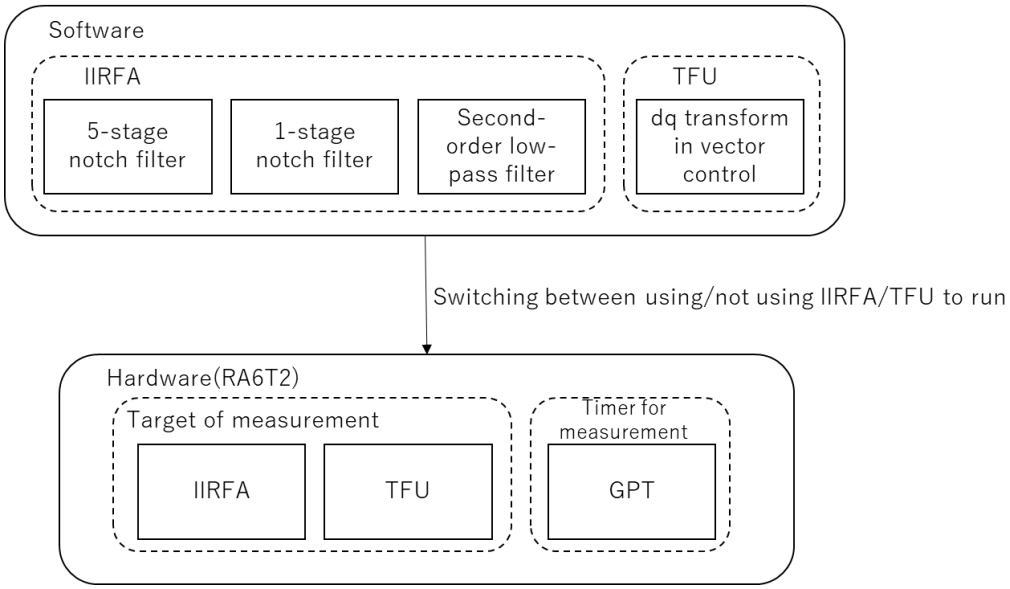


In the field of home appliances, there is a need for multiple motors for washing machine main motors, fans, blower control, and industrial motors, and the ability for users to evaluate dual motors without having to prepare an evaluation board by themselves contributes to shortening the development period.

In addition, RA6T2 is equipped with peripheral functions specialized for dual motor control, and also realizes dual motor control with low system load using the high 240 MHz CPU performance. Get this kit and application notes to experience the high performance of the RA6T2 for yourself.

Accelerators (IIRFA / TFU) performance in motor application

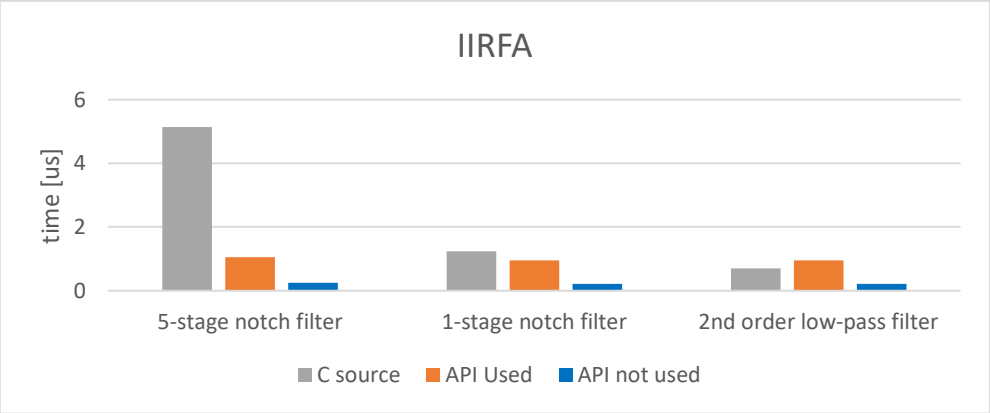
This is an application note for evaluating the processing time reduction effect of IIRFA and TFU installed in RA6T2. It is possible to measure and compare the processing time in the sample code using IIRFA and TFU and the sample code written in C source without using them. The structure of the program is as follows:



It is very difficult to estimate the performance of the hardware accelerator installed in the MCU even by referring to the user manual. However, this application note includes guidance and sample projects that take advantage of accelerators, allowing you to measure performance by actual measurement. Since IIRFA and TFU have different processing blocks that they are good at, I will explain the target processing.

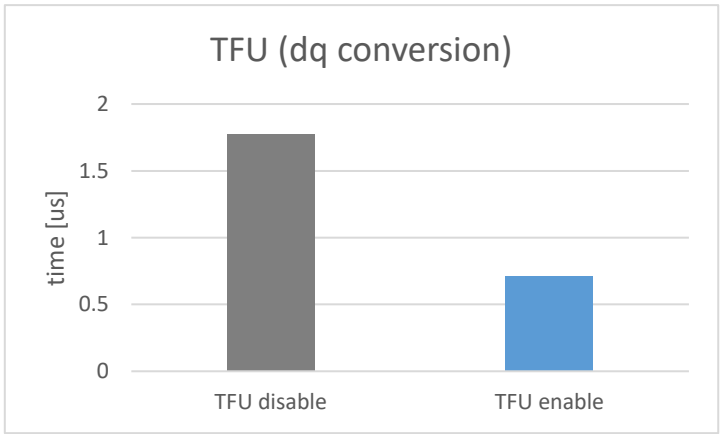
Filter processing for IIRFA measurement (notch filter, low-pass filter)

A notch filter removes a specific resonance frequency component. It is used for damping control of servo motors and robot arms. In addition, when using an operational amplifier, a second-order low-pass filter is often used because it is easy to adjust the cutoff frequency. In this application, these operations were compared when (1) IIRFA was not used, (2) FSP API was used and (3) the input data register was set directly. IIRFA is effective in multi-stage processing and the operation is completed in 1/5 when using the API with a 5-stage notch filter and 1/21 when using the register directly.



TFU measurement processing (dq conversion)

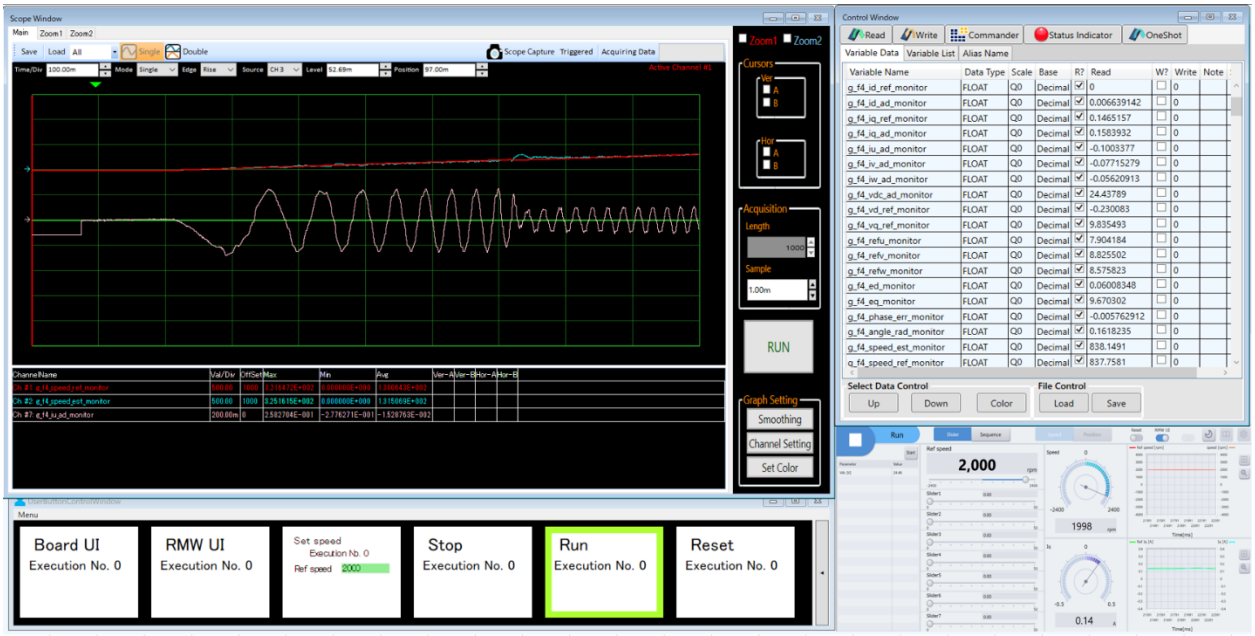
In vector control, the calculation to obtain the active current (q-axis current) and reactive current (d-axis current) from the actual phase current is called dq conversion. The sin and cos operations at the time of this conversion are measured using TFU. The results of measurements and comparisons with and without TFU are also shown below. It can be seen that the Renesas software can be executed in less than half the processing time.



In general, hardware accelerators combine many operation blocks with vendor-specific algorithms, so porting existing software for users is extremely difficult and expected performance may not be achieved. Because RA6T2 targets motor control for both IIRFA and TFU, one of the features is that it can be implemented flexibly because it is hardware acceleration for basic processing that any user can use. Please refer to this Accelerators application note and experience the ease of use and high performance of IIRFA and TFU.

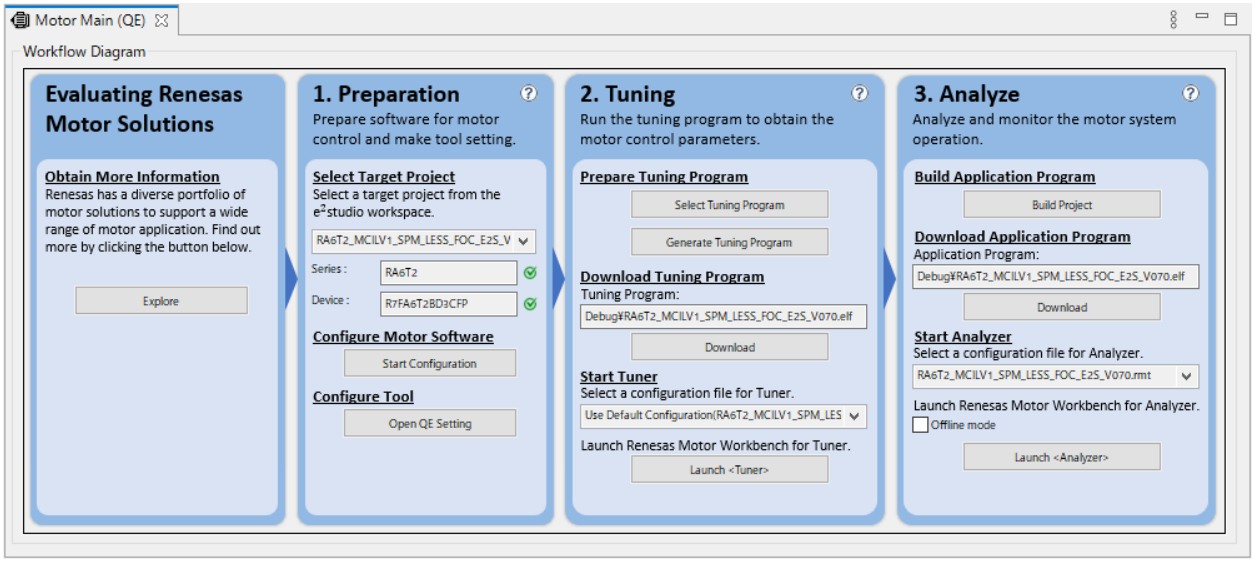
Motor control development support tool 3.0 (Renesas Motor Workbench 3.0)

Renesas Motor Workbench is a debugging tool for motor control. With the Analyzer function, you can read and write variables inside the microcomputer and display the waveform of variables. The Tuner function can identify motor parameters and automatically acquire the control parameters used in vector control. With Renesas Motor Workbench, even beginners can operate a motor using the intuitive GUI.



QE for Motor

QE for Motor is a software development support tool that allows you to develop motor control software simply by operating according to the provided workflow. It can be downloaded free of charge as an extension of the Renesas integrated development environment e² studio. By linking with the Flexible Software Package (FSP), you can efficiently set the middleware and driver for motor control while checking the configuration diagram within a hierarchical structure.



QE for Motor also works with Renesas Motor Workbench, which tunes and analyzes motors. Since the settings required for Renesas Motor Workbench are automated, you can use these functions with a simple push of a button.

Summary

Next-generation motor control systems are becoming more complex and multi-functional, while severe cost reductions are demanded. RA6T2 responds to customer needs by realizing control, multi-tasking processing, and platform development with an eye on the next-generation with excellent performance and various package deployments. In addition, we provide various evaluation and development solutions to provide a shortcut to realize a high-performance motor control equipment system and shorten the development period.

Resources

- RA6T2 product page
- RA6T2 Motor Evaluation and Development Kit MCK-R A6T2 Tool Page
- Motor Control Development Support Tool Renesas Motor Workbench 3.0
- QE for Motor: Development Assistance Tool for Motor Applications

(Rev.1.0 Mar 2020)

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