Development of Rapid Prototype ECU for Power Train Control

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Abstract

In recent years in the automobile industry, there has been demand for shortened development periods and reduced costs, not only for mass-produced electronic control units (ECUs), but also for experimental research ECUs. In order to meet this demand, a multi-purpose, reusable Rapid Prototype ECU is needed.

The Rtype is a Rapid Prototype ECU that Fujitsu Ten planned and developed for the experimental research of power train control. Its design is based on Fujitsu Ten's expertise in both ECU design and the development of the simulator Computer Aided Multi-Analysis System (CRAMAS), and the Rtype achieves extremely high-speed processing and high compatibility with the ECU. The combination of these qualities makes it possible to easily develop an ECU prototype based on a level assumed to exist 5 or 10 years in the future. Fujitsu Ten plans to introduce its Rtype solutions for the innovation of control development processes to automobile manufacturers and suppliers.

1 Background of development

In order to meet emission controls, achieve both fuel economy and high output, and meet other difficult challenges, power train control has become more complex each year. But because of intensifying market competition and economic stagnation, it has become important to shorten development periods and reduce cost, despite the complexity of control. In the early stage of development, it takes considerable time and expense to prepare the experimental research ECU for system development, and therefore drastic improvements in this development stage are especially desired.

The preparation for ECU test manufacture takes considerable time and cost for several reasons, including the fact that the ECU design cannot begin until the newly examined specifications have been determined. Furthermore, even if begun, the design may have to be modified because of specification changes, or other needed corrections may arise. Another problem is that ECU development costs are high for the prototype. A solution is the Rapid Prototype ECU, which is reusable and requires only minimal preparation time. However, the control factor used in the early stage of development consists primarily of newly investigated control algorithms; thus, it is difficult to use a general Rapid Prototype ECU. For these reasons, Fujitsu Ten has been developing an original Rapid Prototype ECU for power train control based on the expertise in both ECU design and in simulator development (hereinafter referred to as the "Rtype").

2 Basic concept

To shorten the development period and reduce development costs, it is desirable to expand the degree of freedom in design and incorporate new development techniques and concepts.

As explained hereinafter, the Rtype has advanced functions and capabilities to accommodate new development techniques and concepts that can greatly change control development.

2.1 Use of intellectual property

Improving the efficiency of development requires the existence of an environment that facilitates the reutilization of technological assets related to design and evaluation. Our company refers to "intellectual property(IP)" as assets that are arranged in a form that enables us to effectively reutilize technological assets and know-how in the various manufacturing stages of development, design, evaluation, and production. In the development stage, past technological assets are accumulated in the intellectual property database as existing intellectual property, while new development items are accumulated as new intellectual property. Combining the accumulated intellectual property makes it possible to proceed with development in an efficient manner. The Rtype is an experimental research ECU that is easily realized by applying these relevant intellectual properties to both the software and the hardware, as the base during the development stage.

As with a conventional experimental research ECU, it is possible to drive a simulator or engine, and developed control algorithms can be evaluated and validated in a short period of time.

2.2 Reuse of system

Changing the combinations of intellectual property that are installed in the Rtype makes it possible to convert the Rtype to an ECU for use in a different project. Thus, compared to the conventional method in which an ECU is newly manufactured for each project, the development period can be shortened and development costs (running costs) can be reduced.

2.3 Adoption of high-performance CPU

A conventional experimental research ECU implements a control microcomputer. Thus hampered by the performance of the microcomputer, the developer often can not program and execute the control algorithm that he/she wished to evaluate. With the Rtype, however, the microcomputer is equipped with the latest chip set and a personal computer CPU having high processing capability. This ensures a processing speed that is several tens of times faster than that of a mass-produced ECU. Combined with the adoption of a flash disk with large-capacity memory, the Rtype eliminates limitations on processing time and program size for executable control algorithms; moreover, the degree of freedom of system development is drastically elevated.

2.4 MATLAB/Simulink operating environment

The program development method using some modeling tools such as MATLAB/Simulink has become popular in order to improve the efficiency of control algorithm development. MATLAB/Simulink is a tool that describes control models via block diagrams. It can also execute simulations and generate program codes from designed control models. Using this tool makes it possible to develop programs with much higher productivity compared with the conventional C language. And because a developed program can immediately be validated through simulation, it becomes easier to develop

theory-based control algorithms. However, with a conventional experimental research ECU, the processing ability of the microcomputer is insufficient; consequently, a control algorithm developed with MATLAB/Simulink could not be executed as is. The Rtype, on the other hand, incorporates the same CPU that is implemented in high-performance personal computers, for the program execution. As described below, the Rtype is also equipped with a function that inputs/outputs program-controlled signals as actual signals. Thus, the Rtype can implement programs that are generated from the block diagrams described on the MATLAB/Simulink, and has the capacity to execute them in real time. Through these features, use of Rtype makes it possible to significantly shorten the time required to develop control algorithms.

3 System configuration

The Rtype consists of four types of boards: a motherboard, which effectuates functions equivalent to the role of a microcomputer core; a CORE board, which effectuates functions equivalent to the role of a microcomputer's peripheral I/O; and IF board and function board, which effectuate functions equivalent to the role of ECU hardware.

The motherboard implements a high-speed CPU (Pentium4, operating frequency of 2 GHz) that is used in personal computers, and has a high processing capacity that enables accommodation to the early stage of development.

The CORE board effectuates a microcomputer's peripheral I/O functions through a field-programmable gate array (FPGA), a programmable large-scale integrated circuit. Changing the FPGA program makes it possible to add and correct I/O functions that are needed for controls, and to freely design peripheral I/O functions according to the microcomputer used for the ECU (Figure 1).

The motherboard and CORE board are equipped with an I/O driver that effectuates functions equivalent to the role of a bus connecting the microcomputer core and peripheral I/O unit. They communicate with one another via the PCI bus.

Combining the IF board and function board makes it possible to effectuate functions equivalent to the role of an ECU input/output interface.

3.1 Software configuration

In order to prepare and make actual use of an experimental research ECU in a short time, it is necessary to easily provide the base control software using existing software assets. And if, after the completion of development, the control software developed on the Rtype does not succeed to the product software easily, the expected effect will be reduced by half since it cannot smoothly proceed to the mass production step. For this reason, the portability of the control software is an important consideration, and the development was carried out from such a software configuration standpoint. The configuration of the control software implemented in the Rtype is such that the application part and I/O driver part are separated, but communicate with each other via the standard application programming interface (API). The I/O driver that directly operates the microcomputer depends on the type of microcomputer peripheral I/O. It is necessary to change the I/O driver when the microcomputer changes. The application that communicates with the I/O driver via standard API, however, requires no change and can be stored as a software asset. If, using this configuration, an Rtype I/O driver with standard API is prepared beforehand according to

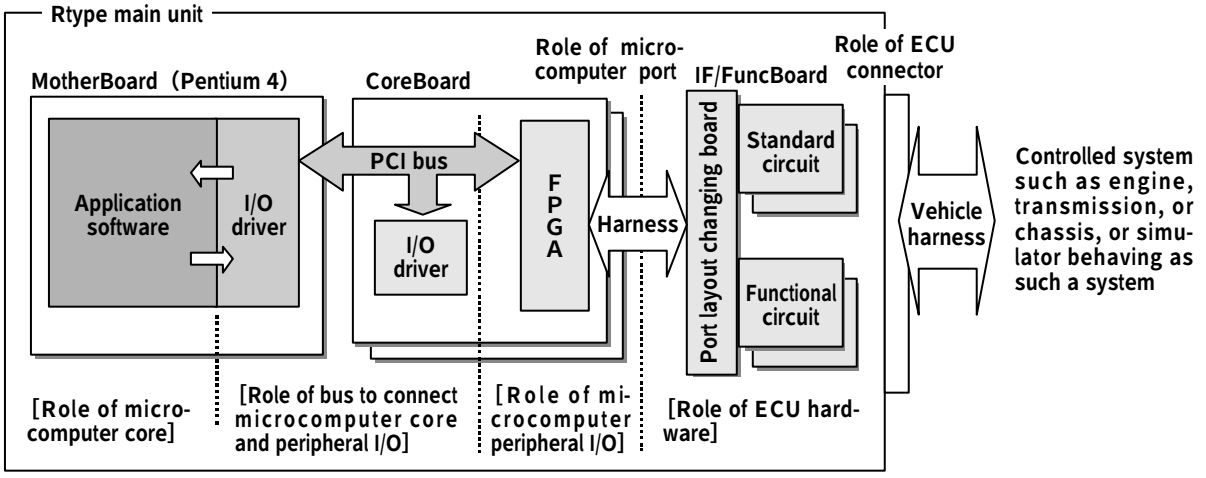

Fig.1 Rtype configuration

the microcomputer's peripheral I/O, there is no need to change the application software. As a result the control software can be coded in a short time period (Figure 2).

3.2 Hardware configuration

The part that corresponds to the input/output interface of the ECU consists of two types of boards: the IF board and function board. The former consists of input processing circuits that are implemented in the ECU to receive standard switch signals and sensor signals, and output circuits to drive solenoids and lamps. In contrast, the latter removes sensor signal processing circuits and actuator drive circuits, and consists of other functions that do not require new validation, making it possible to configure the Rtype in a short time period.

The vehicle or engine bench is connected to the Rtype by a wire-harness, while the IF board and the function board are connected to the CORE board, which corresponds to the microcomputer peripheral I/O, via a layout changing board. Combining these boards makes it possible for the Rtype to have functions that are equivalent to the role of a mass-produced ECU.

4 Example of engine control ECU application

To validate the feasibility of the Rtype system, a mass-produced ECU and the developed Rtype were compared and evaluated.

First, the ECU to be evaluated was determined and the ECU's application software was transferred to the Rtype; then the Rtype and ECU implementing the same application software were prepared. Next, measurement conditions for the primary functions of engine control ECU were selected; then the ECU and Rtype were evaluated and compared under these conditions. The results confirmed that the ECU and Rtype had nearly the same performance and that the developed Rtype could be given practical effect (Figure 3).

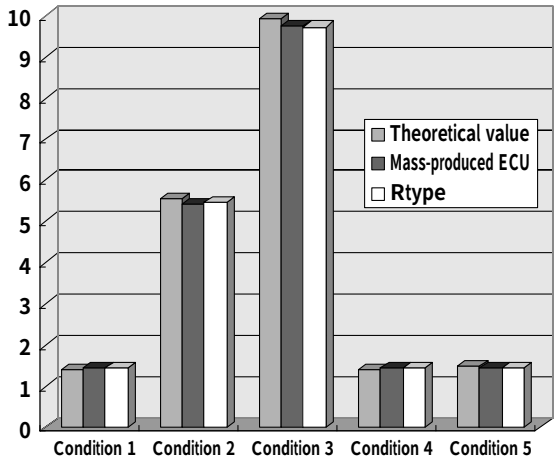

Fig.3 Comparison of fuel injection characteristics

Through the work of transferring the mass-produced ECU's control software to the Rtype during this evaluation process, it was confirmed that the application software can be transferred without change through means other than an I/O driver that uses microcomputer-dependent instructions.

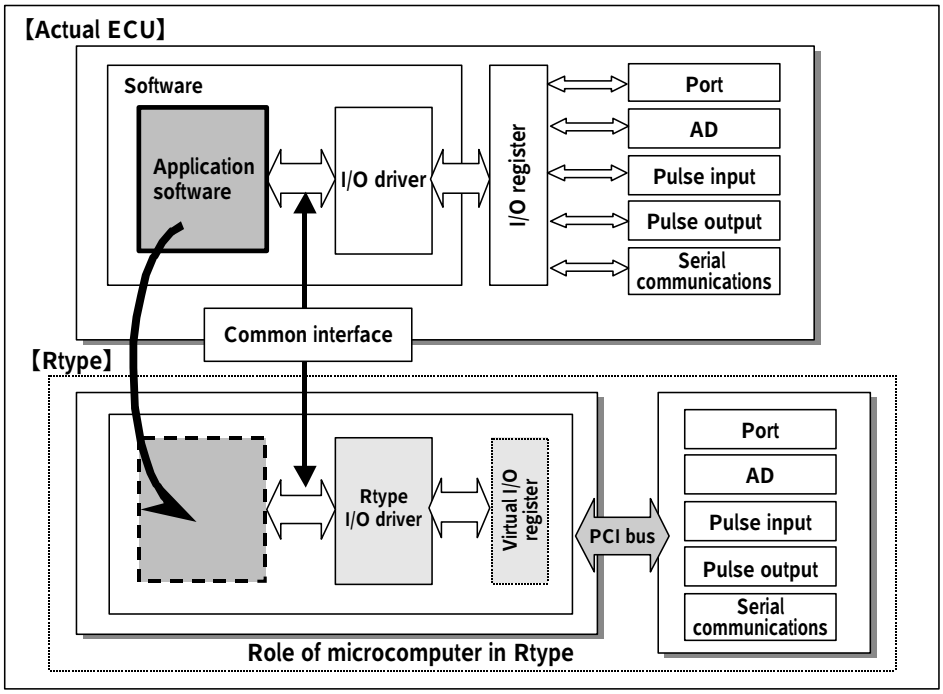

Fig.2 Rtype software configuration

Furthermore, in a trial driving test using an actual vehicle with Rtype, driving performance was confirmed to be equivalent to that obtained with a mass-produced ECU.

5 Expected effects

Introduction of the Rtype is expected to promote the development and accumulation of intellectual property in each step of development, including hardware, software, and evaluation. As a result, effects such as shortened development periods and reduced development costs can be expected. This chapter will describe the effects of introducing the Rtype in power train control development.

5.1 Early offering of experimental research ECU

Our company has been building intellectual property database that can be used in the software, hardware, and evaluation fields, as well as all fields related to ECU design. In the field of software, the standardization of program modules is advancing. This information is controlled in intellectual property database and is utilized by the software mass-production design division. In order to effectively utilize such assets for the Rtype as well, I/O driver parts are being transferred from intellectual property for mass-production design software to Rtype use and have started being registered as intellectual property database items. Also, application parts can be used without change with the Rtype. In the hardware field also, the development of intellectual property database for circuit functional blocks, including specifications, circuit information, and input/output characteristics, is proceeding and is beginning to be used for ECU circuit design.

With the Rtype, the ECU interface circuits are converted to intellectual property in functional units, and steps are taken to build them into the IF board. With the Rtype, such software and hardware intellectual property is used to quickly configure an experimental research ECU, which is required for system development. The aim is to create an ECU within two weeks after the specifications have been confirmed.

5.2 Model Based Development (MBD)

Today's mainstream in the automobile control field still depends on PID control that is based on experiment data, and an extremely large number of man-hours is being spent on calibration work (adjustment of control dynamics). When the Rtype is used, it becomes easy to validate theory-based control algorithms that are developed on MATLAB/Simulink, and a development environment can be constructed in which so-called Model Based Development(MBD) is carried out. Combining the Rtype with the CRAMAS, Hardware In the Loop(HIL) Simulator manufactured by Fujitsu Ten, makes it possible to perform the development of control algorithms, the execution of simulations, and verification of operations as deskwork. After rough calibration is confirmed, the Rtype can also be installed in an actual vehicle and a driving test can be carried out. In the evaluation field also, evaluation items including test conditions, data to be measured, and criteria for validation are being changed to automatic evaluation tests, and a mechanism is now being built in order to register them as intellectual property. Utilizing this intellectual property will make it possible to quickly, repeatedly, and efficiently execute these tests ranging from development to operation validation. As a result it will be possible to create high-quality control algorithms from the initial stage of development, and to significantly shorten the development period (Figure 4).

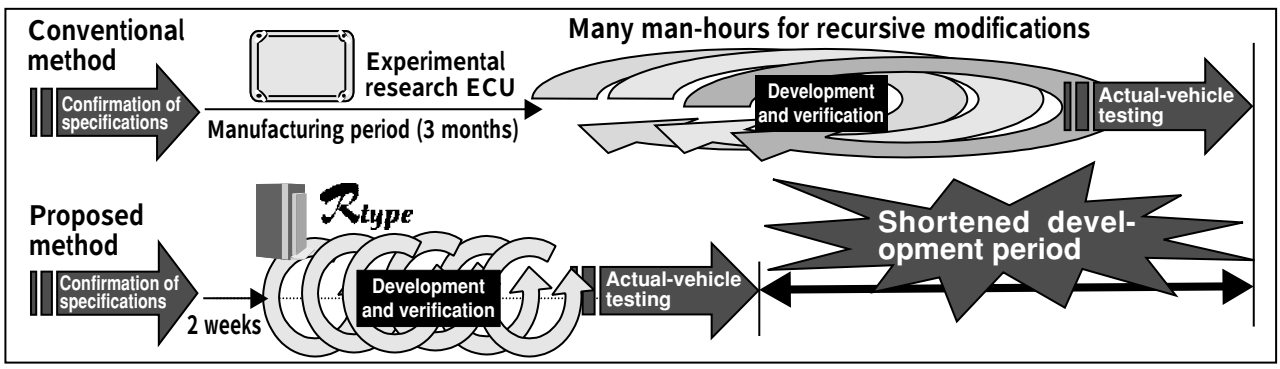

Fig.4 Shortening of development period

6 Future Plans

The Rtype is currently in the trial stage. User-friendly improvements in the development environment are being made, and system verification methods are being established. Various preparations are now being made so that full-fledged use can begin in a broad range of fields beginning in FY 2003.

Challenges that remain for FY 2002 (as of October 2002) include improving in-car durability, developing new control techniques, and developing option boards that correspond to sensors and actuators.

There will be many opportunities for the Rtype to be used in the early stage of development. Thus, development of the Rtype will proceed in order to create an evaluation environment that can be used in the development of commercialized technology five or ten years from now.

In conclusion the authors wish to express our sincere gratitude to those persons, whether affiliated or not affiliated with Fujitsu Ten, who cooperated in the development of Rtype.

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