As the performance of the automobile increasingly evolves, the number of electronic control units (ECUs) and the scale of on-board software continue to grow. Recently, there has been a rapid move to decrease the number of ECUs and integrate multiple ECU functions into one, complicating the matter. In addition, as specifications change more frequently due to the more complex nature of ECUs and the rewriting of programs via communications becomes inevitable, the number of software releases has increased, limiting the development period. Under these circumstances, regression testing has become essential as a means to check for deterioration in the quality of the ECU with each release. As the ECU testing time increases, efficient testing has become an urgent matter in the development department. DENSO CORPORATION is working to automate ECU testing and reduce the testing time by implementing the “CANoe test feature”, a tool for on-board network and ECU development, testing and simulation, and “Test Automation Editor (TAE)”, a test case creation tool. This article looks at the implementation process and results of the project.
Increased testing time

DENSO is a leading Japanese automotive parts supplier that provides automotive technology, systems and products to major automotive manufacturers around the world as well as developing businesses in Japan and overseas in various technical fields, including automobiles, ITS and industrial machinery. DENSO’s Information & Communications Technology Eng. Div.4, which has worked on the implementing project of CANoe Test Feature and Test Automation Editor, has been focused on the development of software for body-related products, such as ECUs for the body, air conditioning and clearance sonar.

In recent years, efforts are being made to integrate ECUs so as to create lighter and more compact on-board ECUs at lower development costs, and as the number of built-in microcontrollers increases, the ECU itself is serving multiple functions. Adding new features to an ECU requires regression testing for those changes. Regression testing is used to check whether changes to an ECU affect its quality, and it is performed even if a single change is made to an internal parameter. The greater the level of integration of an ECU becomes, the number of additional changes increases as does the testing time. Kiichiro Hanzawa, Manager of DENSO’s Information & Communications Technology Eng. Div.4, discusses this trend.

"As less expensive microcontrollers have been introduced in recent years in order to brave the fierce cost competition, it has become common to lower costs by simply changing the microcontroller without changing the shape of the existing ECU and reduce costs by integrating multiple ECUs into one. As regression testing has become essential for ensuring that quality is not affected at each release when a microcontroller is changed or ECUs are integrated, the testing time will continue to increase in the future."

Manual testing has reached its limit

Until now, DENSO used CANoe to perform ECU and entire network simulations in ECU testing, but creating test cases, the testing itself and the determination of the test result had been done manually without using CANoe’s test feature. However, inputting of external stimuli to the ECU on the CANoe panel and monitoring of the responses or the viewing of CAN logs require a huge amount of effort and time. In addition, the conventional manual approach of performing regression testing for each release and testing events that are difficult to reproduce put an extraordinary load on operations. As the integration of ECUs progresses, the burden on testing is only expected to increase.

Hanzawa continues, "Testing takes up 30 to 40 percent of the total work hours of a design engineer, and it is a grueling phase for the engineer. When delivery periods overlap, engineers must push through it and finish the testing. Also, in the case of events that are difficult to reproduce, they had to repeatedly perform tests all night long while changing conditions. However, if testing is not performed enough, problems can occur in the market, so testing has to be done. Moreover, the regression testing performed for each release requires two to three hours manually per model and per destination, and because in most cases nothing ever crops up, maintaining motivation is very difficult."

In addition, because the skill level of the engineer varies even for the same test item, differences may occur in the judgment and response, therefore creating variations in the test level. Consequently, it is difficult to determine whether the testing details are truly valid. With the addition of multiple functions to the ECU and advanced control content, the number of test items and their combinations are now on a grand scale, and it is expected to become even more difficult to satisfy the requested test level while performing all of these tests manually in the future.

"From the perspective of the manager, there is some uncertainty as to whether the testing is really complete. There is no definition of or standards for the testing approach, so there might be inconsistencies in the tests depending on the person," said Hanzawa.

Key points to a solution

To solve the issue of conventional ECU testing, DENSO decided to try to make testing more efficient through automation. Vector proposed a test solution that enables automation while making use of existing assets. By adding automating testing features based on existing tools, the labor spent on implementation can be minimized. DENSO worked to improve the efficiency of creating test cases by expanding on its existing CANoe software and implementing and automating a test feature and also implementing Test Automation Editor (TAE). "The good part was that we could make effective use of existing tools. The team members and myself were used to CANoe, and we regularly use CAPL(*), so by studying the software, we were able to use it, and it became intuitive," said Hanzawa.

* CAPL (Communication Access Programming Language): A programming language similar to C used to construct simulations and test models in CANoe.

The key points for promoting the implementation are easily accessible due to the efforts of DENSO. These points are as follows:

1) Member selection: Improve the skill level of the entire team

Instead of having a lead, each member of the team was assigned between normal operations and worked on the implementation of the test features and TAE, and one person merged the work at the end. The advantages of this method is to reduce the workload on the individual, maintain motivation for the implementation by working as a team without a lead, and be able to continue work even if someone is absent.

Hanzawa explains, "My policy has been to function with all members instead of creating a lead. This is to enable operations..."
even if one person is missing, in the same way as having everyone regularly use CAPL as required knowledge. We have five team members, with some young engineers who have worked about two years in the company, so although not everyone has a wealth of experience, they made voluntary efforts as to the project such as allocating work by themselves."

2) Implementation timing: Consider the project as a prior investment

Choose the appropriate timing for implementing a new system within the daily development operations. DENSO used the time from when one large project ends to the time when the next project begins to implement new systems. By investing in the future when the workload of team members was not so high, the company was able to construct systems so as to reduce the burden at busy times. Even if a long period cannot be set aside for implementation, a system can be implemented by using the short time that is available. "We were fortunate to make use of that timing after finishing a large project," said Hanzawa.

3) Selecting test targets: Set small goals for maintaining motivation

In this project, the implementation target was narrowed down to a small-scale ECU (sonar sensor ECU for LIN). By starting with a small ECU instead of a large ECU as the target, the achievability of each target is increased. As members achieve small targets and build up success, job motivation is maintained. The method of gradually widening the targets from small-scale to a larger-scale is a very effective approach.

Hanzawa explains, "Managers expect a large effect and are apt to start with an ambitious scale. However, when priority is given to obtain a large profit with a small investment, a divergence from the job occurs. It is important to start with a small-scale approach without demanding perfection instead of starting with an unmanageable large-scale operation."

4) Using Vector support

Before starting the actual implementation work, team members received training on Vector’s CANoe test feature during a break in operations. Training was performed in three stages, with members learning the operation method while creating a test model and putting it into practice. Vector also provided TAE on an evaluation basis in advance and allowed member to test drive the software on site.

Reducing average regression testing time from 2 hours to 5 minutes

The CANoe test feature enables the automation of message sending, visual acceptance testing and creation of results reports, which had to be done manually and were factors for the increase in testing time. In addition, TAE has a CANoe test XML editor that
enables easy creation of test sequences and has an intuitive GUI with drag-and-drop operations for convenient creation of new test definitions and expansion of existing test definitions.

With the introduction of DENSO’s CANoe test feature and TAE, regression testing that used to take two to three hours to perform, was shortened to about five minutes. The time spent on regression testing used to create a large burden on operations, but the current automation has significantly reduced the workload. As the number of regression tests increases in the future, the shortened time and the resulting effects will be realized more. While there is some preparation time required to create test sequences in TAE, by reaping the benefit of a shortened time from two hours to five minutes per delivery, the hourly cost for preparation is sure to pay off.

Hanzawa explains, “The reduction in regression testing time from two hours to five minutes has created a significant impact, and the benefits have been greatly felt by everyone on the job, including myself. Although it doesn’t seem as though preparation takes time, operations speed up as you get used to it, and once you realize the merits of automation, the motivation for test preparation increases.”

Automating testing with the CANoe test feature is as simple as selecting the target test items and clicking the start button. During testing, the pass-fail results are shown in real-time, giving the engineer a quick understanding of the testing status.

“Conventional manual and visual operations have been automated, and the test performance and results are automatically displayed on the screen, making it easy to see whether the test has passed or failed. The engineers enjoy watching it,” explains Hanzawa.

Instead of fully automating test processes, DENSO adopted "semi-automation". While the pass-fail test results are displayed automatically when performing an automated test with the CANoe test feature, some items are left for manual determination by the engineer. For example, the "sound" test item for the sonar sensor ECU is difficult to automate and can be performed faster by human response testing, so an engineer checks this, completes the evaluation sheet and coordinates the data with the automated result.
The CANoe test feature can be used in this way to flexibly respond to items that are better determined manually. "The big advantage of the test feature and TAE is the ability to perform ‘semi-automation’, which flexibly combines automation with manual operation without imposing complete automation. There is no benefit to that in tests that require more hours than design, so automated and manual operations are separated to serve the needs of the job," explains Hanzawa.

**Future Outlook**

Based on the use of the CANoe test feature and TAE, DENSO will further expand its test target products in future. Now, work has started on incorporating the CANoe test feature from the design phase into new products. Furthermore, DENSO is planning to use TAE as the standard tool in future, but in the meantime, they use it flexibly depending on the test cases. "We’d like to continue to use and expand on the application of these functions and have other teams also learn the CANoe test feature," explains Hanzawa.

To improve the ECU testing technology and accuracy from the view of hardware and software, Vector provides solutions linking the CANoe test feature and the VT System. VT System is the exclusive hardware for use with CANoe. It integrates all circuit elements required for connecting the I/O channels into a single module, therefore enabling a significantly streamlined test bench setup. The implementation of this tool will also be effective in improving the ECU test configuration.

Hanzawa explains, "We haven’t looked at it too closely, but the I/O cab(*) is believed to have limitations, so we are considering automation that includes the VT System."

* I/O cab is an input/output interface cable provided by Vector.

**Conclusion**

By automating ECU testing, DENSO has reduced the testing time drastically. Also, the variation in the test level depending on the engineer has been improved upon by automating testing and the determination of the test results.

The practical know-how for deriving these results can be greatly seen in this implementation project. The approach of starting with something small and achievable, such as by targeting a small sonar sensor ECU and expanding from a small-scale to a large-scale implementation and by selecting a flexible "semi-automated" test solution that incorporates manual operations instead of being fully automated, has produced considerable results. In addition, the key elements to success are that the manager clearly indicates the implementation plan and expected results to the team members in advance, ensure that everyone has a clear goal, and guide them to the end without eroding motivation.

This set of implementation processes shows suppliers that are looking for efficient ECU testing the way to achieve it together with development operations by making use of limited time and personnel resources.

**Reviewing the Project**

Kiichiro Hanzawa
Manager, Information & Communications Technology Eng. Div.4
DENSO CORPORATION

"Overall, we are very satisfied with the implementation project. The team members worked hard, and we were able to finish the project without interruption. The goals were easy for anyone to understand, so they were easy to achieve on the job. Our future operations depend on how much time we can spare for test preparations and how well I can communicate to the team members the importance of that preparation. As a manager, I try to keep good balance between automated tasks and manual tasks and not to rely too much on automated tools because test sequences may not always be perfect and replacing everything with automation may lead to oversights somewhere. Also, in terms of nurturing our engineers, it is best to have both automated and manual test experiences."

Kiyotsugu Tanno
Team Leader, Networks & Distributed Systems (PND)
Vector Japan Co., Ltd.

"I am very happy that we were able to help reduce DENSO’s ECU testing time and improve operations by implementing the CANoe test feature and TAE. The implementation process of this project was informative and we learned a lot from it. We will continue to work to provide products and services that meet greater customer needs in the future."

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