Plug
& Play Various ECUs tested by automated sequences

Delphi Diesel Systems has successfully developed automated integration and feature tests for various ECUs for diesel engine management systems. The challenge was to adapt the test system to other ECU versions as smoothly as possible. A wide range of dSPACE software and hardware offered the seamless tool environment for this task.

The Challenge

The growing complexity of embedded controllers for automotive applications has dramatically increased the need for HIL (hardware-in-the-loop) bench testing and validation. ECU (electronic control unit) software releases, in fact, have to meet an ever-increasing number of tough customer requirements. For this reason, Delphi Diesel Systems (DDS), supported by dSPACE Ltd., has been working on developing a series of HIL-based automated tests to be utilized with different ECUs for diesel engine management systems.

HIL-Based Automated Tests

Nowadays, manual ECU testing is a viable alternative only for a very limited set of validation tasks. This explains why every tool vendor has been working hard to provide customers with real-time platforms capable of supporting the development and execution of automated tests.
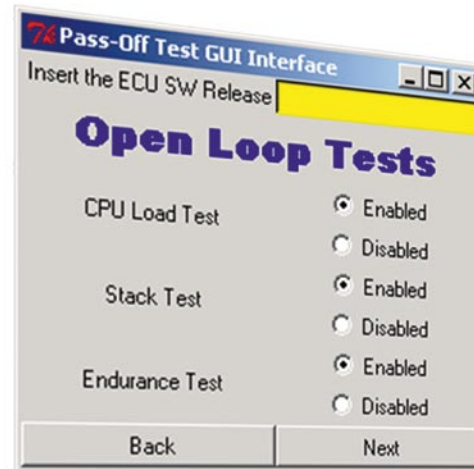

Figure 1: GUI created with the use of the Python module Tkinter. These graphical interfaces can be used to configure AutomationDesk projects.

ects in place that incorporate ControlDesk macros, third-party Python modules, such as Pylab and Matplotlib, and Tkinter-based GUIs. An example graphical interface is shown in figure 1. In addition to this, DDS has developed its own Python library to enhance standardization, code components reuse and version control in the development process of new automated sequences.

- AutomationDesk includes a COM interface that allows the user to invoke dSPACE ControlDesk (test and experiment software) MATLAB® and, above all, CalDesk, dSPACE's measurement and calibration software. No additional code is needed, as these tools can be called by means of standard AutomationDesk library blocks. The possibility of interacting with the dSPACE cali-

bration environment CalDesk (in particular, via CCP on CAN) proved extremely effective, simply because the ECU software can be monitored or re-calibrated while the sequence is running, with no other tool necessary.

As a result, all the HIL-based automated tests developed by DDS have been implemented using the components shown in figure 2.

Hardware Set-Up

To maximize the return on investment, DDS chose a simulator based on dSPACE double mid-size configuration (figure 3). Being an off-the-shelf product, this platform allowed the company to reduce initial costs without any significant performance limitation.

Thanks to the open architecture of the double mid-size system, which incorporates a DS1005 processor board and a DS2211/DS2202 pair of HIL boards, DDS achieved the following results:

- Easy management and support of different ECU configurations. A simulator is connected with the

> ## "The interaction of the dSPACE tools was very efficient and saved us a lot of time."
>
> *Giuseppe Raffa, Delphi Diesel Systems*

dSPACE has succeeded in tackling this problem thanks to AutomationDesk, which has been playing a crucial role for many DDS development activities since early 2008. Apart from the flowchart-like approach, which noticeably simplifies both test design and sequence debugging, this tool basically has two main advantages:

- AutomationDesk is Python-based. Consequently, any custom script or library developed in standard Python can easily be integrated into automated tasks. DDS has already put AutomationDesk proj-

embedded controller via an ECU-specific test harness that features a standardized structure. Consequently, when the HIL simulator has to be used for a different project, a suitable interface loom is needed. However, since this installation takes minutes, the chosen platform significantly increases the bench uptime.

■ The majority of the ECU pins are always assigned to DS2211 channels. In fact, in comparison to the DS2202, this HIL I/O board is equipped with an angular processing unit (APU). This design solution automatically frees up many channels on the DS2202 that are currently exploited to drive additional boards and controllers which need to be interfaced with the main ECU.

Adapting the HIL simulator for future projects will require relatively little effort. A new harness will have to be designed, but this can be done in such a way that a certain ECU func-
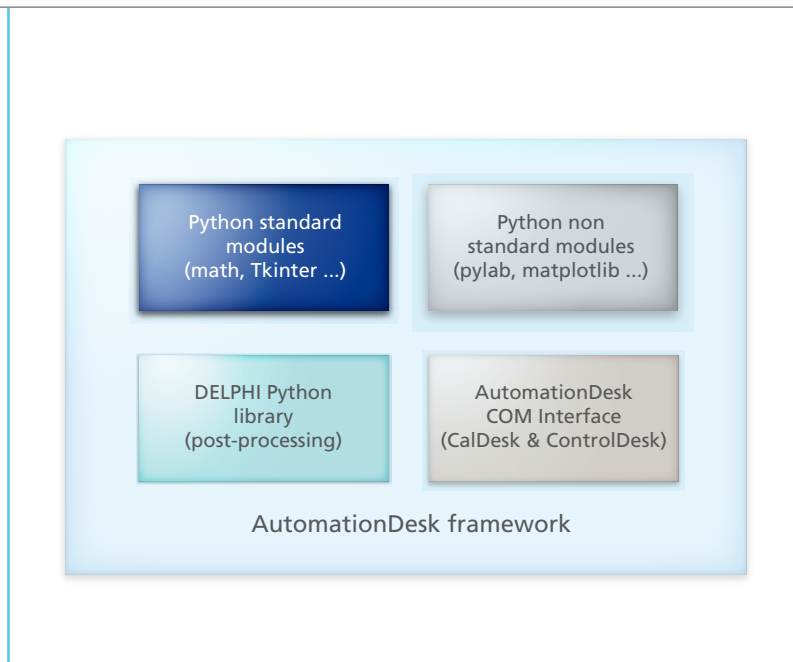

Figure 2: Components used by DDS to implement HIL-based tests. They can be integrated into AutomationDesk sequences.

tionality will always be mapped to the same simulator channel. With this in mind, the platform configuration can undoubtedly be simplified.

CPU Load Evaluation
Thanks to the architecture described above, DDS has developed automated test sequences for both integration and feature tests. Among

them, the CPU load test is one of the most interesting. Quantifying the CPU usage when the controller receives a variety of stimuli is the key to assessing whether a given hardware-software integration actually meets the initial requirements and what margins may be available to further developments.

As shown in figure 4, AutomationDesk

Figure 3: Double dSPACE Simulator Mid-Size.

Glossary

Tkinter – Standard module used to create object-oriented GUIs in Python: For more information see M. Lutz, "Programming Python", 3rd edition published by O'Reilly.

Matplotlib – Python plotting library for creating 2D figures. For more information see www.matplotlib.sourceforge.net
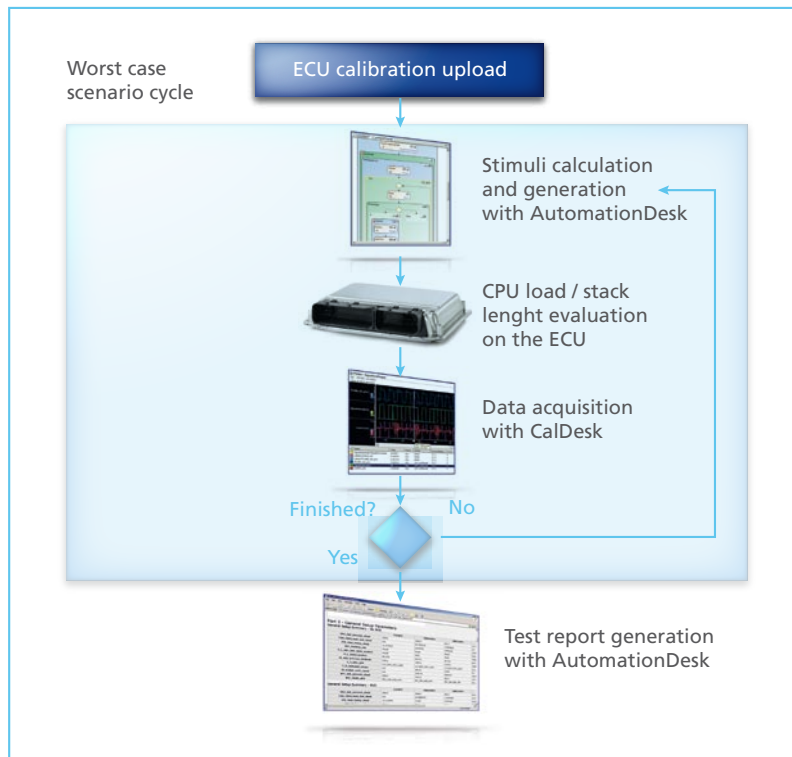
| Worst case scenario cycle |
| ECU calibration upload |
| Stimuli calculation and generation with AutomationDesk |
| CPU load / stack lenght evaluation on the ECU |
| Data acquisition with CalDesk |
| Finished? No Yes |
| Test report generation with AutomationDesk |

Figure 4: CPU load test developed by DDS.

by driving the power supplies included in the simulator according to predefined cycles.

Future Development
Several AutomationDesk-related development activities are going on at DDS. The currently available HIL-based sequences need to be improved to incorporate a wider range of configuration parameters and facilitate their execution. Furthermore, more comprehensive integration tests will certainly be created to deal with potential problems arising from new ECU functions and automatically generated code.
More precisely:

- Other software performance metrics will have to be taken into account as well. For instance, a variant of the CPU load test sequence implementing a stack size measurement is now available.

enabled DDS to implement an automated sequence that stimulates the embedded controller according to selected worst-case scenarios. The ECU software includes a function measuring the CPU load in terms of percentage of main cycle time spent on required tasks; the results are made available to calibration tools through a series of measurement parameters that can be used to evaluate the average CPU load in each test condition. To generate a testing report, these parameters are finally post-processed in such a way that they are displayed as a function of the received stimuli.

Endurance Test Implementation
DDS has always been focused on safety and reliability. Consequently, a set of automated sequences that aim at coping with possible endurance-related problems have been

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Riccardo Carrozzo, Delphi Diesel Systems

designed. The principle underlying this group of tests consists of creating faulty conditions on the ECU physical interface to evaluate the robustness of the controller both from the hardware and the software point of view.
An example of these tests is summarized in figure 5. Cutting off the battery voltage repeatedly while the controller is operating is an effective way of testing how the ECU non-volatile memory responds. A sequence of this kind, which can be executed hundreds of times overnight, can quickly be implemented

- Integrating GUIs into Automation-Desk projects is a key priority, in order to build a user-friendly test-process management environment. This can be used effectively to configure and launch the desired set of test sequences, without requiring a developer-level knowledge of AutomationDesk.
- A combined sequence to evaluate injection management and rail pressure control performances is currently under study. The final target consists of creating a complete set of automated test sequences that will be executed

Riccardo Carrozzo (left) –
HIL Team Manager. He coordinates activities focused on modelling and HIL validation.

Giuseppe Raffa (center) –
Principal System Engineer. He designs HIL / ECU interface harnesses and develops auto-mated tests for embedded controllers.

Darren Walker (right) –
Core Software Manager. He is responsible for core software engineering, encompassing ECU platform software, and associated tools and processes.

as a standard HIL bench validation before starting any in-vehicle vali-dation activity.

Conclusion

AutomationDesk has enabled DDS to develop a variety of automated tests, which have been shared across different ECU projects. In fact, this dSPACE tool, with its wide set of built-in block libraries, has allowed developers to interface seamlessly with calibration tools, such as CalDesk, and with the real-time HIL simulator. Moreover, integrating customized, standard and third-party Python modules has significantly facilitated the final data post-pro-cessing, thus guaranteeing high-quality test reports.

The reusability of these automated sequences has been improved even further thanks to the openness of the selected hardware platform, namely the dSPACE mid-size HIL simulator. In fact, every time the bench has to be switched to a different controller, only a suitable interface harness has to be installed. Two real examples of HIL-based automated sequences are finally presented. They illustrate not only the effectiveness of integrating AutomationDesk and CalDesk, but also how DDS intends to improve the quality and reliability of its embedded controllers. ∎

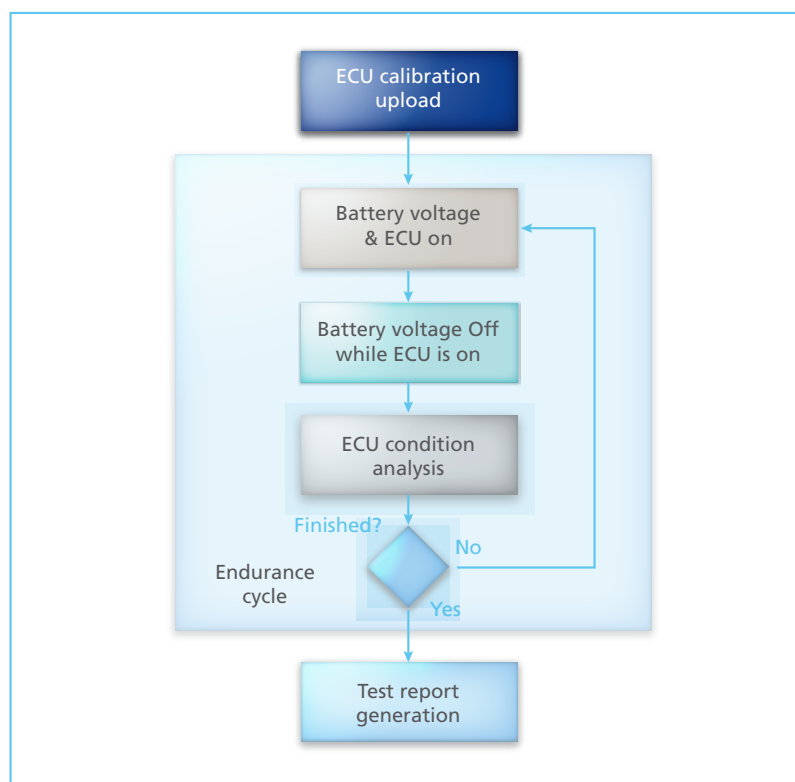*Riccardo Carrozzo, Giuseppe Raffa, Darren Walker*
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Figure 5: Endurance test developed by DDS.