

Automating fault insertion tests to improve automotive software quality

Transfer case control mechanism (TCCM) testing of engine control units (ECUs), especially safety related models, is as much about software testing as it is about hardware—this is due to the increased intelligence required within ECUs to control braking, prevent rollovers and to ensure that power is applied to the correct wheels in a compromised driving mode. Automotive manufacturers such as Magna Powertrain, Delphi and Continental share the same concerns for testing the safe operation of their products. Here, **Steven Edwards, Switching Product Manager at modular signal switching & simulation experts, Pickering Interfaces** explains how cost-effective, modular PXI products can be combined to create flexible test systems that automate the otherwise lengthy process of inserting faults into a system, thereby helping improve the quality of this critical automotive software.

A transfer case is a mechanical/electronic device that monitors wheel slippage and ensures that power is applied to wheels that are not slipping. As part of the design process, manufacturers run a series of tests to ensure that the software that controls their transfer cases reacts to system failures, such as open, shorted and cross/inline resistance connections, in a predictable and safe manner. Manufacturers sometimes develop test fixtures that allow them to manually inject faults. While this is effective, it is also time-consuming. Manual fixtures also require more frequent maintenance, and this manual insertion is prone to operator error, which can compromise test results.

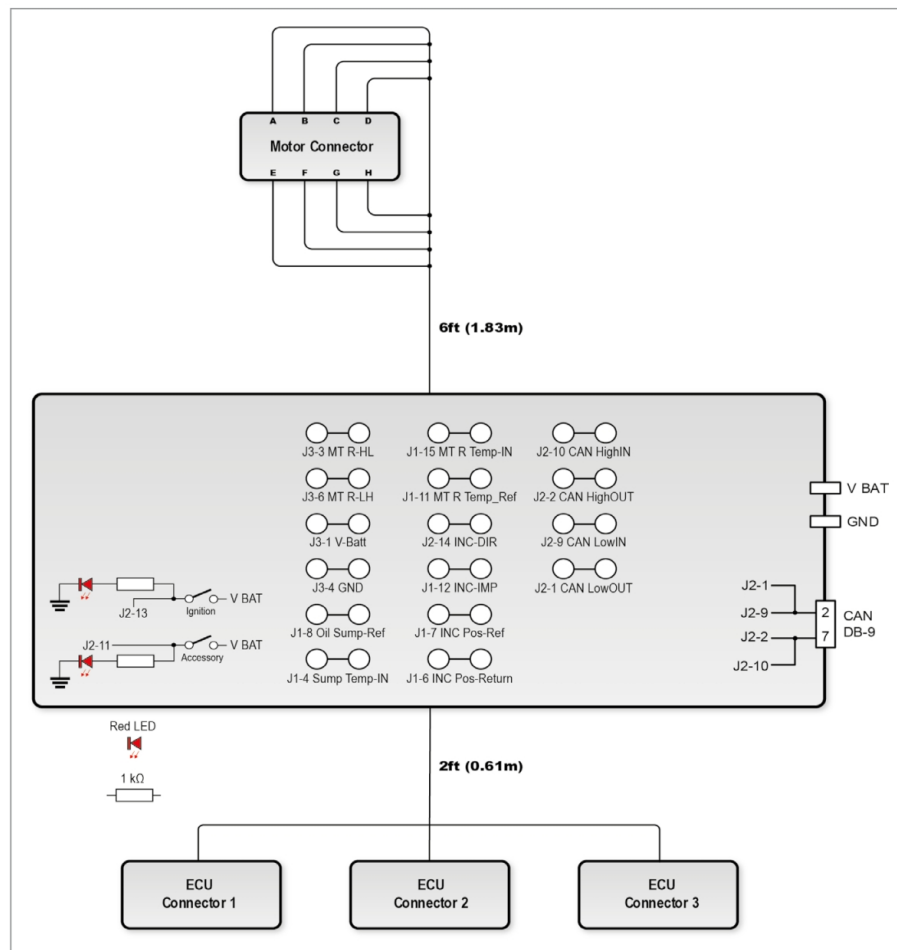


Figure 1. Generic breakout box design used for bench testing

Cost-effective, modular PXI products can be combined to create flexible test systems that automate the otherwise lengthy process of inserting faults into a system, thereby helping improve the quality of critical automotive software.

Pickering's Fault Insertion Unit (FIU) switching solutions for hardware-in-the-loop (HIL) simulation applications and Programmable Resistors can be used to introduce electrical faults into a system, typically duplicating conditions that can occur because of corrosion, short/open circuits and other electrical failures, caused by age, damage or even faulty installation. By automating the fault injection process, users can run more test cases in a shorter period of time, testing is more repeatable and problems can be fixed earlier in the development cycle.

Finding faults

As part of the TCCM, a transfer case ECU connects to sensors and actuators in the transfer case, as well as interfaces with the vehicle's Controller Area Network (CAN). When a driver shifts into gear, the transfer case ECU receives the command and then determines if it can perform this shift or not. After it has successfully performed a shift, the transfer case ECU reports this to the network. In operation, many different faults can occur. For example, consider an eight-conductor cable that connects actuators and sensors in the transfer case to the control module. These connections can fail open or short to adjacent conductors; in addition, high-resistance connections and high-resistance shorts can develop as automobiles age, and these can cause a transfer case to fail in the field. Therefore, manufacturers simulate these faults in their lab.

HIL testing has become a very popular way to test the ECU. A HIL simulator can provide all of the inputs and outputs of a vehicle without actually building prototype vehicles. They can even test a transfer case ECU without actually having the mechanics of a transfer case. In this mode, the HIL test system simulates the transfer case, in addition to the rest of the vehicle.

To test the transfer case ECU software, designers have developed a number of different operating scenarios. These include vehicle start-up, shutdown and driving scenarios designed to put a transfer case control module through its paces. A typical test fixture, called a breakout box, used to manually insert faults, is shown in Figure 1. While this method is an effective way to get started, it was clear to one



Figure 2. PXI 30A Fault Insertion Switch Module



Figure 3. PXI Programmable Resistor Module

of Pickering's customers that there was much room for improvement.

For this particular customer, using the breakout box, it took up to eight minutes to run a single test case. Since the customer runs thousands of test cases, it was evident that a way to reduce the test time was imperative. Another disadvantage of manually inserting faults in this way is that the customer

could only insert shorts and opens. For thorough testing, resistive faults needed to be inserted too. Finally, breakout boxes are hard-wired, and therefore not very flexible. To test different transfer case ECUs, or different product configurations, a new breakout box is required which is costly and time-consuming.

Automating fault insertion

Clearly, manufacturers have been thinking about how to automate fault insertion. After evaluating switching systems from several vendors, this customer purchased a 19-slot PXI chassis, populated with several PXI bus modules (model 40-191 30A Fault Insertion Switch Module shown in Figure 2) from Pickering, to simulate shorts and opens. This module is capable of carrying 40A on single channel, or 30A on all channels at the same time. It is designed to insert three different fault conditions between the test fixture and the equipment-under-test, including open circuits, short circuits between UUT connections and short circuits to external signals. Solid state relays on each channel enable the test system to set signals to the UUT to open-circuit. Fault-insertion buses allow any channel to be shorted to any other channel and also enable any channel to be connected to an external signal such as Power, Ignition or Ground to simulate fault conditions.

Pickering's Programmable Resistor Modules (model 40-295, shown in Figure 3) are used to simulate high-resistance faults. This module provides up to 18 fully isolated variable resistors at 8-bit resolution or ten fully isolated variable resistors at 16-bit resolution. The resistance of each of the channels can be set between 0 and 16 MΩ.

Figure 4 shows how the switching system connects the HIL simulator, the transfer case ECU being tested and the transfer case, if required.

HIL testing has become a very popular way to test ECUs: an HIL simulator can provide all of the inputs & outputs of a vehicle without having to actually build prototype vehicles.

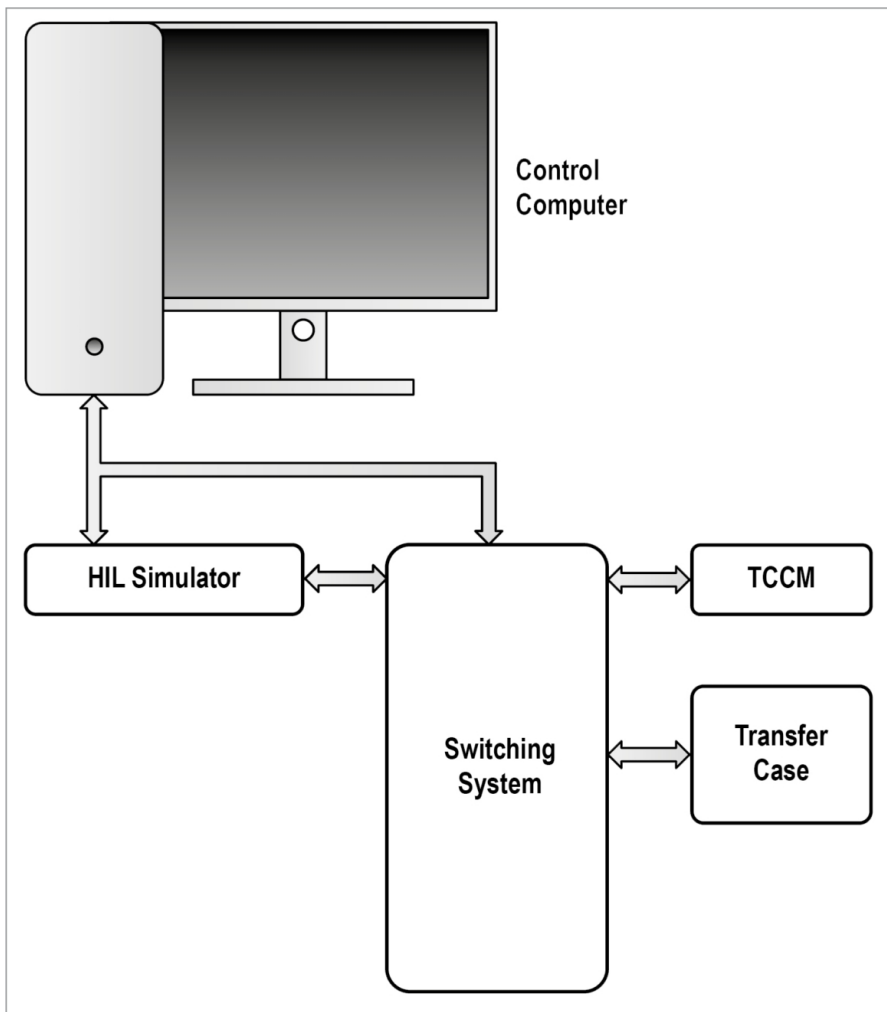


Figure 4. Switching system diagram

The switching system is used to inject all of the potential faults. For example, to inject open faults, they simply have to open the line. To short two lines, they connect each of the two lines to a Fault Insertion module and connect the two signals to one of the module's fault buses. To simulate a short to power or ground, they connect the signal line to one of the fault buses, and then connect that bus to ground or to an external voltage.

To inject a resistance fault into one of the signal lines running between the transfer case and the transfer case ECU, the control computer would command the switching system to switch in one of the variable resistors on the 40-295 Programmable Resistor Module. Next, the resistance is varied in discreet steps: 0Ω, 5Ω, 10Ω, 20Ω, 50Ω, 100Ω, 200Ω, 500Ω, 1,000Ω, and so on until 1 MΩ is reached, or the line reacts as an open circuit.

Once a fault has been inserted, one or more driving scenarios are run and test data is gathered. The current that the system is drawing is significant, as an unusually high current is a sure sign of problems. Other parameters considered include CAN signals, electrical signals generated by the transfer case ECU and overall system behaviour.

By automating the fault insertion, the time taken to run a single test has been halved from eight minutes to around four minutes—this is a huge saving considering that a typical test run might include 20,000 test cases. Also, while with manual insertion, a technician had to be present all the time, now, personnel only need to be present when sensitive tests are being performed, and most tests are run overnight, unsupervised.

By automating fault insertion, the time taken to run a single test has been halved from 8 minutes to around 4 minutes—a huge saving considering that a typical test run might include 20,000 test cases.

Interestingly, the time-savings are not necessarily used to make the test runs shorter, but to run more test cases, such as resistance faults. This is an indication of the emphasis that companies put on software quality and reliability.

Analysing test results

Analysing test data is a big task. The first thing test engineers look for is whether the test has caused any damage to the UUT. No fault should damage the transfer case of the transfer case ECU, so any indication that the unit has been damaged throws up a red flag.

If none of the test cases have caused any damage, analysing the rest of the test data can proceed. Of particular interest at this point are the CAN signals and overall system behaviour. In the case in point, the customer is looking for data that would indicate unintentional motor movement in a transfer case. They might also check to see that the transfer case ECU generated the appropriate diagnostic codes.

The future is automated

While the customer is pleased with the way that the Pickering switching system has allowed them to automate their test, there is more work to do. For example, instead of building separate test fixtures for each transfer case, the customer is working on a universal test system. The customer is also looking to automatically analyse the test data. An effort is also underway to reduce the number of test cases. In our customer's case, their team thinks that they can do this by identifying test cases that are really testing the same thing and eliminating them from the test program.

About the author:



Steven Edwards,
Switching Product
Manager for
Pickering Interfaces
has held a number
of design and
management roles at
Pickering Interfaces

since 2004. He is based at the company's headquarters in the UK and supports the switching requirements of clients globally across many industries. With multiple decades of electronics industry experience, he contributes to the expansion of the Pickering Interfaces product portfolio.