

NEW METHODOLOGIES FOR OBD VALIDATION

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ABSTRACT

Validation of OBD calibration in Electronic Control Units (ECU) is an essential part of the vehicle development process. When faults occur, these must be correctly detected. But false detections must also be avoided to prevent expensive warranty costs. The validation must be done in the vehicle because of the complex functionalities of individual systems and the interactions between each system in the vehicle environment. But in vehicle ECU testing offers many challenges. The testing is done manually and often requires complicated steps or difficult physical activities. In addition measure files need to be manually analyzed to determine the test results, and the results need to be manually documented. The outcome of this is the testing is time consuming, and the same tests must be repeated up to seven to eight times in the vehicle development cycle.

To make the testing more reliable, reduce the test time required and automate the results documentation, automation of the OBD validation is required. An automation solution was evaluated at Tata Motors using INCA-FLOW to control an ES4440 Fault Insertion Unit (FIU), connected to INCA with the ODX diagnostic add-on. In order for the FIU to insert the faults, a break out box to the ECU connectors was required. With this set up the INCA-FLOW script can automatically set an error in the system, check if the expected OBD fault code is present and document the results.

In the paper we describe in detail how the guided calibration solution was used to automate the OBD testing. It details how the INCA-FLOW script can introduce the faults, and check whether the correct DTCs were logged for each failure mode. The results of this evaluation are detailed below, including the reduction in test time compared to the manual method used earlier, reduction in testing errors, and the benefits of automatic data analysis and documentation.

INTRODUCTION

OBD certification is an essential requirement in order to sell automotive vehicles. In modern ECU controllers up to 40% of the ECU software is OBD related. The OBD functionality itself checks aspects of the vehicle operation for the following attributes

- Legislative conformance for emissions related systems
- Checking safety related systems to prevent malfunctions
- Serviceability, to help diagnose problems and determine root causes

There are two important aspects for OBD calibration and validation. First when a problem is present, the fault must be detected. Failure to correctly detect errors can cause serious problems with the emissions certifying authorities. The second aspect is only genuine failures should be detected, so there should be no misdetections. If there are false detections of problems, this can become expensive for the OEM in warranty payments.

Validation of the OBD calibration is best done in vehicle, because this offers the best representation of the complex interactions of the individual systems [1]. In-vehicle testing provides many challenges. Some of the tests are physically difficult to do, because of the location of the components that need to be tested. So disconnecting a sensor may be difficult if the sensor is not easily accessible. In addition the manual aspect of the testing is also difficult, because repeated steps need to be accurately carried out, and the results manually documented. Often these tests need to be carried out a number of times during the vehicle development cycle. So, sometimes only a subset of the tests are conducted in the later stages of the vehicle development cycle to reduce the testing time. This can potentially lead to quality issues because failures could be missed leading to expensive warranty costs or product recalls.

There was a desire at Tata Motors to reduce the amount of testing time required without sacrificing the test quality or test coverage. Very important was the need for automatic report generation to document the test results. For this reason Tata Motors have been working closely with ETAS to develop new OBD automation test methods. This paper describes the test set up, how the test automation was run, and the results of the evaluation.

CURRENT MANUAL TEST PROCEDURE

Currently the testing is done manually. The procedure is shown in Figure 1.

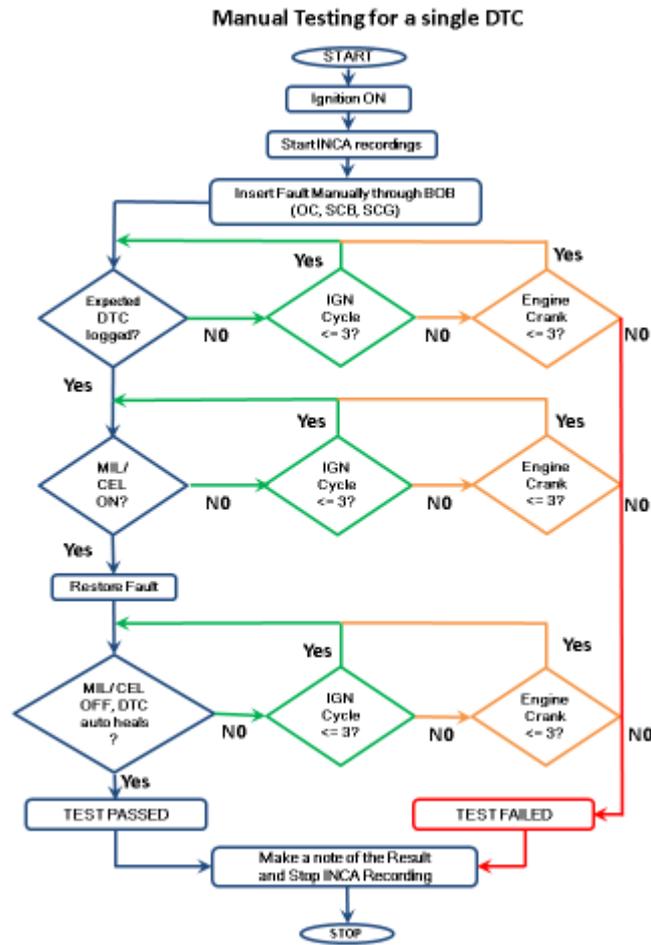


Figure 1 Manual testing flow chart

For each signal, the tester has to start the recording in INCA, go out of the vehicle to the engine compartment, find the relevant pin for the test sensor and set it to either open circuit (OC), short to ground (STG) or short to battery (STB) manually. Then they must go back to the vehicle and manually check that the correct signal was altered, and the fault code was logged. Then the test must be manually documented. The process is very manual intensive and prone to mistakes.

TEST AUTOMATION

The heart of the test automation system was the INCA-FLOW guided calibration system [2]. Typically this communicates with INCA in order to carry out an automated calibration task [3]. For this task, we extended this by using INCA-FLOW to control an ES4440 Fault Insertion Unit [4] provided by ETAS. The connection to INCA was also extended with the ODX Link add on. This allows INCA to connect to the engine ECU using standard OBD on CAN, in the same way an OBD tester communicates with an ECU. With this interface INCA has access to all the standard OBD-II commands. For this evaluation, the important commands are Mode 07 Show Pending DTC, and Mode 04 Clear DTC. The overall system is shown in Figure 2

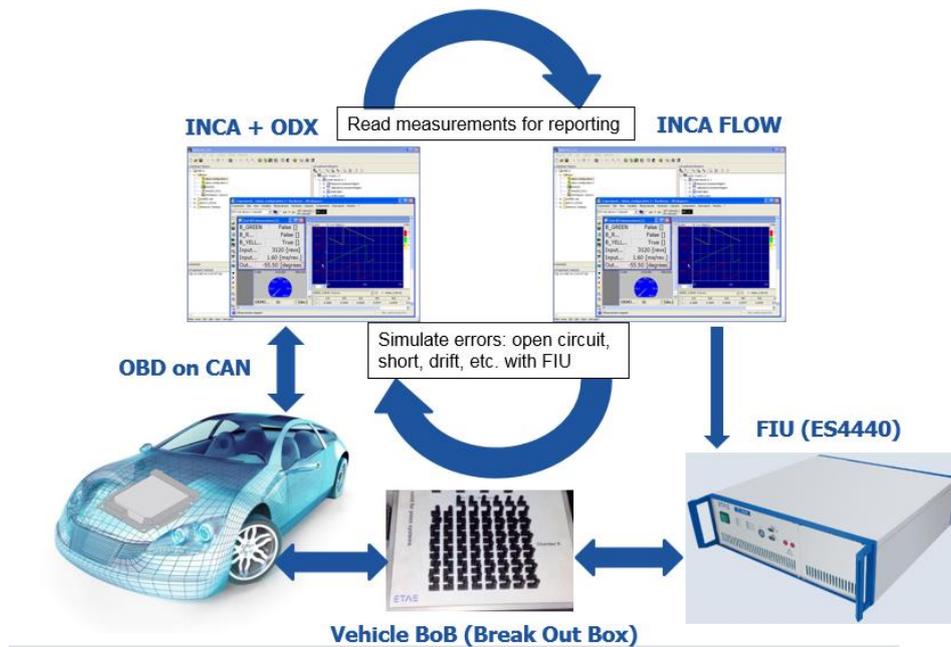
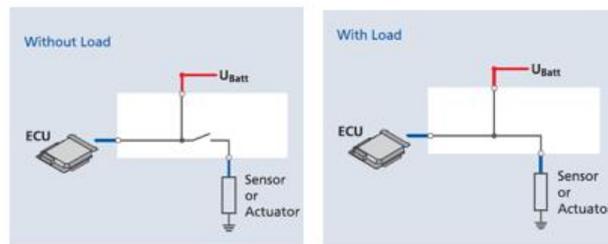


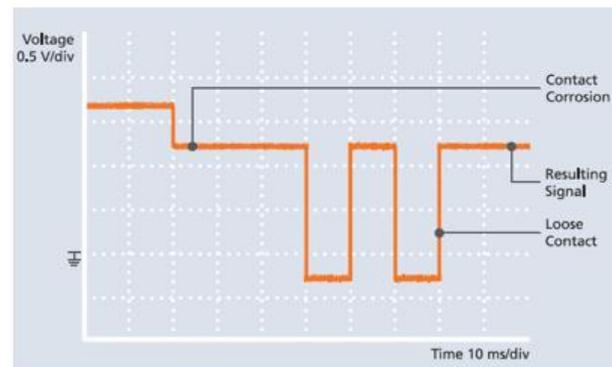
Figure 2 Overall test automation system

ES4440 FAULT INSERTION UNIT

The ES4440 Fault Insertion Unit simulates faults for automotive ECU testing in real-time environments. The module can be used stand-alone or in combination with automation systems. In order to use it for automotive testing, it is connected to the individual pins of the ECU via a break out box (BoB). It is then possible to insert faults on to individual pins, or combination of pins. The faults that can be inserted include short to ground, short to battery, leakage current, effects of corrosion and loose contacts, shown in Figure 3



Short circuits to the supply voltage with open or closed signal line.



Simulation of contact corrosion superimposed on a loose connection.



Figure 3 Typical faults generated by the ES4440

The device can be controlled remotely either by using a CAN or COM API interface, in order to set the fault for each pin. This allows the device to be controlled by automation software, in our case INCA-FLOW using a CAN interface like an ETAS ES581 or an ES592.

INCA FLOW AUTOMATION SCRIPT

INCA FLOW is a scripting tool that controls the INCA MCD software. It is used to automate calibration and measure processes by using a graphical flow chart method. This makes the tool very intuitive to use, and means it is ideally suited for calibrators to create automation scripts because they do not have to learn a programming language. To enable INCA-FLOW to control the ES4440 FIU hardware, the option CAN toolbox was installed. INCA-FLOW is able to send messages on a CAN bus that is connected to the ES4440 device, which controls the device operation.

To use the CAN Toolbox in INCA-FLOW, a CAN device is configured in INCA-FLOW and a dbc file containing signal names within messages with specially chosen CAN IDs is assigned. These CAN IDs are the IDs used by the ES4440 recognized as the control signals. So by sending CAN messages with these IDs, INCA-FLOW is able to control the ES4440. In INCA-FLOW as soon as these CAN signals are parameterized using the SET VALUE block, that value is sent on the CAN bus. The script then sends the correct CAN message for each test. Figure 4 shows the code in order to test Short to Battery for the throttle sensor and then CAN message 0x12 00 FF FF is finally sent to activate the Error Relay. The fault is actually inserted on the ECU pin at this instant in time.

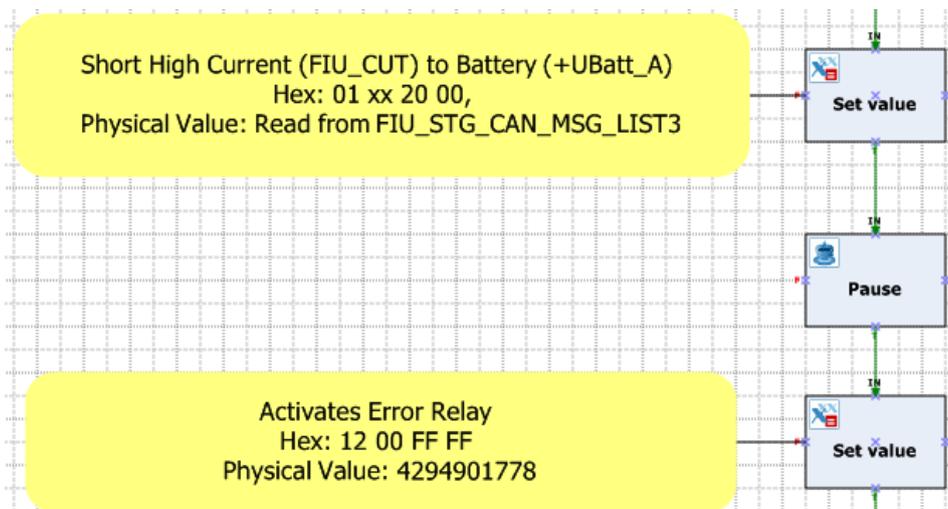


Figure 4 Setting the CAN signals for the Short to battery test in INCA_FLOW

After setting the fault in the ES4440, the next step is to read the DTC code to check if the expected code is set. This is done using a toolbox in INCA-FLOW called ODX query HEX Service. This command allows the INCA-FLOW to send a hex command over the ODX link in INCA, and to read the response. In order to read DTCs, the OBDOnCAN command Mode 07 show pending DTC is sent, see Figure 5

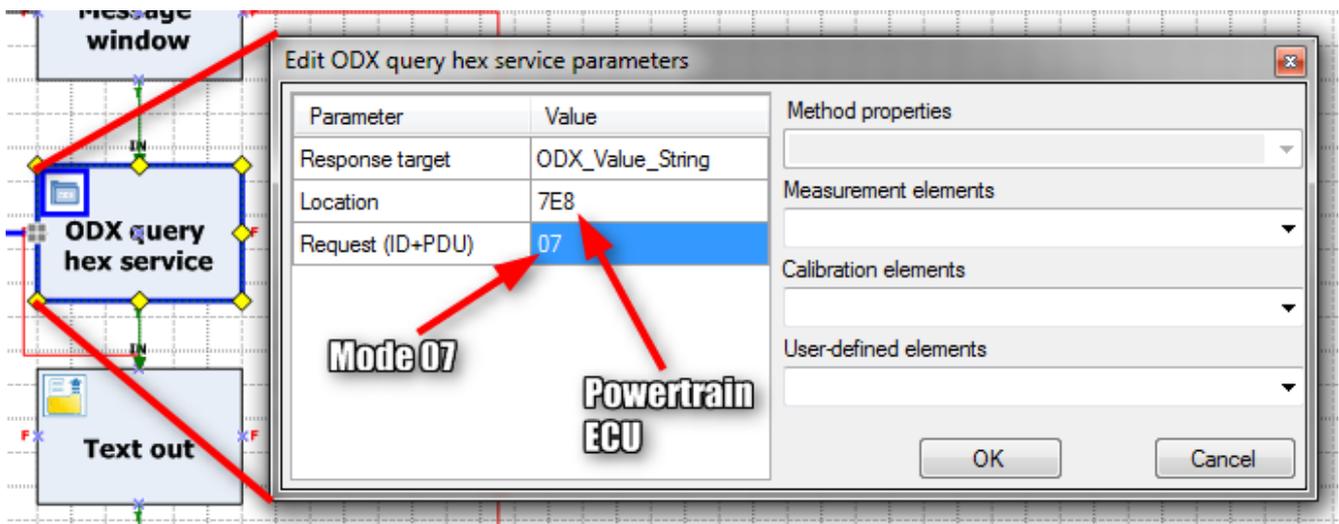


Figure 5 Sending Show pending DTC command in INCA FLOW

Once the DTC is read, this needs to be compared with the expected result and the result with a PASS or FAIL needs to be documented. The INCA-FLOW script is shown in Figure 6.

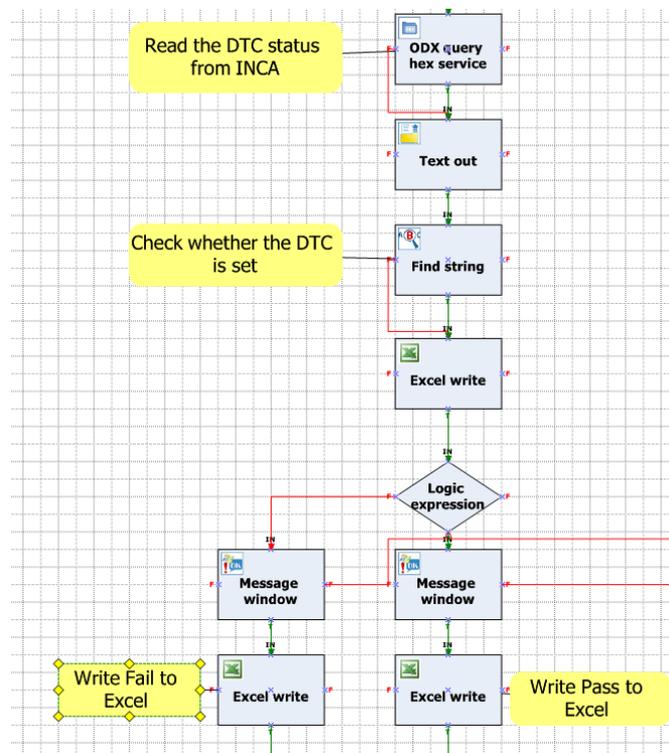


Figure 6 Determining and documenting the test result

AUTOMATION OF ECU IGNITION CYCLE AND ENGINE START

After detecting a fault, the ECU will monitor the fault for up to 3 Drive Cycles before logging the DTC. Similarly, for automatic healing of the logged DTCs, the ECU will monitor the status of the fault for up to 3 Drive Cycles before it is healed. This means for automating Diagnostics validation, the automation must also control the ignition ON/OFF cycle. So, if the fault is not present first time, the ignition can be cycled up to 3 times and the fault checked again. For some faults, it is necessary that the engine is running before the fault can be read. In this case the Automation solution would need to automate the engine start by automating the cranking procedure.

Both the above requirements were easy to implement with INCA-FLOW and CAN Control of ES4440. Ignition could be switched ON and OFF by providing the required signals to the KL15 pin of the ECU through the BoB. Similarly, INCA FLOW was also able to automatically start the engine by providing the required signals to the KL50 terminal of the ECU. In order to automate the cranking, it was required to simulate the pressing of Clutch to disable the cranking inhibit. This was achieved by providing the required signals to the clutch input pins on the ECU. The in-built STARTER CONTROL feature in the ECU facilitated the easy integration of this requirement into the solution, because his feature dis-engages the Starter Motor immediately once the ECU has detected that the Engine has started. For ECUs lacking this feature, the INCA FLOW script will have to monitor the Engine Running status and ensure to dis-engage the Starter Motor by immediately providing appropriate signal to the KL50 pin of ECU.

DOCUMENTING THE RESULTS

The Excel write command writes the result to a template excel file. A template is used to ensure that the correct layout is written. Then the fault code string is compared with the expected code string using Find String, using the Logic expression toolbox, and a PASS or FAIL is written to the excel file. If the test is PASSED, the next test is activated. Once all the testing is complete, a final report document in .pdf format is produced, shown in Figure 7.

Sr. No.	DTC Description for SHORT TO GROUND TESTS	ECU Pin Numbers	DTC Expected	No. of Cycles to LOG DTC		No. of Cycles to Heal DTC		RESULT
				IGN	Crank	IGN	Crank	
2	Throttle Position Sensor "A" Circuit Low - circuit short to ground or open	B03	01 22	1		3		PASS
11	Injector 2, Short to Ground	B43	02 64	1		3		PASS
4	Manifold Absolute Pressure Circuit Low,ie., Signal pin short circuit to ground	A12	01 07	3		3		PASS
10	Injector 1, Short to Ground	B44	02 61	1		3		PASS
3	Throttle Position Sensor "B" Circuit Low - circuit short to ground or open	B20	02 22	1		3		PASS
12	Injector 3, Short to Ground	B45	02 67	1		3		PASS
26	Intake Air Temperature Sensor Circuit Low - Short to ground	B27	01 12	1		3		PASS
28	Engine Coolant Temperature Sensor Circuit Low - short to ground	B15	01 17		3		3	FAIL
9	Camshaft Position Actuator Circuit - Short to ground	B31	03 40	1		3		PASS
16	Ignition Coil A Primary/Secondary Circuit - short to ground	B56	03 51	1		3		PASS
17	Ignition Coil B Primary/Secondary Circuit - short to ground	B54	03 52	1		3		PASS
18	Ignition Coil C Primary/Secondary Circuit - short to ground	B55	03 53	1		3		PASS

Figure 7 Final Test Report

EVALUATION TESTS

ON VEHICLE TESTS

The total number of tests that need to be done on the vehicle is about 170. For the evaluation, 38 tests were automated.

Throttle Position Sensor "A" Circuit Low - circuit short to ground or open
Throttle Position Sensor "B" Circuit Low - circuit short to ground or open
Manifold Absolute Pressure Circuit High,ie., Signal pin open or short circuit to battery or sensor ground pin open
Manifold Absolute Pressure Circuit Low i.e., signal pin short circuit to ground or sensor supply pin open
Injector 1 Open Circuit
Injector 2 Open Circuit
Injector 3 Open Circuit
Intake Air Temperature Sensor Circuit High - Open/Short to battery
Evaporative Emission System Purge Control Valve Circuit open
Engine Coolant Temperature Sensor Circuit High - circuit short to battery or open
Throttle Actuator Control Motor Circuit - open Circuit
Camshaft Position Actuator Circuit - Open Circuit
Upstream Oxygen Sensor Heater Control Circuit Open
Ignition Coil A Primary/Secondary Circuit - circuit open
Ignition Coil B Primary/Secondary Circuit - circuit open
Ignition Coil C Primary/Secondary Circuit - circuit open

The ES4440 and BoB were fitted to the vehicle, and the INCA-FLOW script run. For each of the signals, the tests set to Open Circuit (OC), Short to Battery (STB) and Short to Ground (STG) were performed. Therefore the evaluation represented 38 tests, just over 22% of the total tests.

Manual testing of the evaluation tests would take about 5 man days in total. Running the automation, including the time to set up the equipment took under 3 hours. The test script itself took about 45 minutes to run. In addition the tests were done without errors, and after the test was completed, a complete test results documentation was immediately available.

BENEFITS:

The first evaluation of the automation showed a number of advantages over the manual testing. These include:

- 1) Time saved – From approx. 5 man days required for Manual Testing to less than three hours for Automated Tests with only one engineer present.
- 2) In the earlier Manual Test Method, a significant amount of time is also spent in preparation of the Test Report. But, with the Automated Test using INCA FLOW, the Test Report generated automatically immediately at the end of the test.
- 3) 100 % Test coverage can be maintained in each development phase
- 4) Some tests like simulating loose connections, sensor drift, contact corrosion and introduction of offsets can be easily performed in addition to basic tests like OC, STB, STC tests.
- 5) Elimination of human errors leads to accurate and highly reliable Test Reports.
- 6) Standardization of Test Procedures and Results Documentation across all teams in the Organization is easily possible.
- 7) High level of dis-comfort due to the monotonous and repetitive nature of the tests sometimes leading to mental fatigue and dis-interest among the validation team is avoided.
- 8) Re-Usability of Test Procedures on new projects with very little or no effort for Test Preparation. Thus, having a positive impact on reduction in development time and improvement in Time to Market for New Products.
- 9) Significant cost savings can be achieved by reduction in the time required on each prototype vehicle.

FUTURE SCOPE

TATA see a big potential in automation of validation functionalities, based on the OBD –I verification evaluation. They are keen to extend the methods to the following areas:

- 1) OBD-II functional diagnostics,
- 2) CAN signal verification with plausible & implausible status,
- 3) ECU functionalities – e.g. Fan control, AC control, gear information and shift indication, Starter Control, etc.

CONCLUSION

A successful evaluation of OBD-I verification automation was built and run. It was the first ever evaluation that combined INCA-FLOW with the ES4440 device. All the objectives of the evaluation were fulfilled with INCA-FLOW, and importantly the scripting had very little complexity. It shows INCA-FLOW is highly suitable for this automation task.

Using the automation script provided very significant reduction in test time, while improving the test quality and test documentation. This should not only result in an improvement in the final vehicle quality, it also represents a cost saving because of the significant reduction in in vehicle test time.

TATA have seen enough benefits in the system not only to continue using INCA-FLOW, but to extend its use to other validation activities.

REFERENCES

1. [D. Madhusudananan, A. S. Bharmal, TACKLING ON-BOARD DIAGNOSTICS IN A STANDARDISED WAY, CMC Congress 2015, Pune.](#)
2. http://www.etas.com/en/products/inca_flow.php?langS=true&
3. H. Padmavar, S. Devanathan,, H.C. Viswanatha, K. Malpure, D. G. Hickman AUTOMATION TECHNIQUE FOR THE VALIDATION AND RE-CALIBRATION OF BASE AIR AND FUEL ON THE VEHICLE, CMC Conference 2016, Pune, India.
4. <http://www.etas.com/en/products/es4440.php>.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

FIU: Fault insertion until

MC Measurement and Calibration

ECU Electronic control unit

OBD On Board Diagnostics

DTC Diagnostic Trouble Code

BoB Break-out Box

CAN Controller Area Network

OC Open Circuit

STB Short to Battery

STG Short to Ground