Testing Automotive Fuse Boxes with i1000D SFP In-Circuit Test System

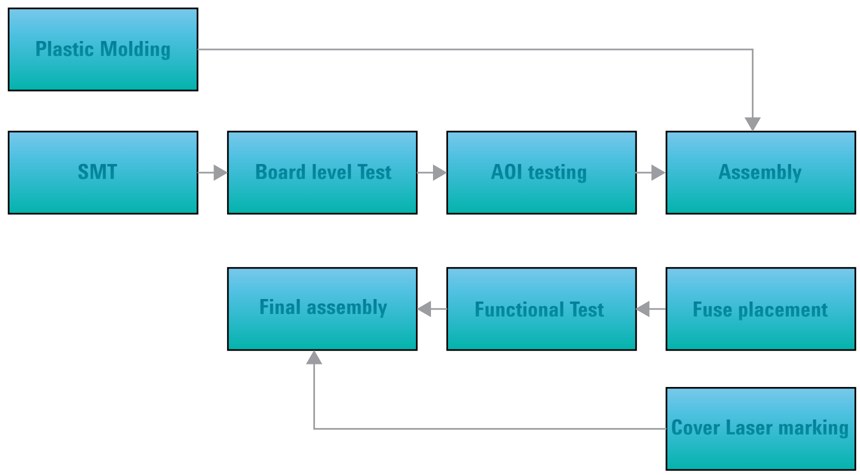
Application Note

The fuse box inside the car is the only part that connects to every electric feature - the lights, the engine, the transmission, and the audio. This fuse box, comprising a board with a bunch of fuse seems to be simple, but it is definitely critical for the smooth running of all the cars on the street. The i1000D small footprint (SFP) inline in-circuit tester is designed to test it with the best fit of features.

Inside this little black box is an array of colorful fuse plugs inserted in terminals mounted on a printed circuit board. Each fuse is color-coded to represent its specifications. A fuse board is not a complicated circuit to comprehend. Basically, it's made up of a bunch of fuse terminals, each soldered and connected on the printed circuit board. There will be some passive components like resistors, capacitors and diodes mounted as well, but nothing complex.

However, it is not as easy as it seems when it comes to testing this board. Being one of the critical components in a vehicle, a simple board like this does warrant some serious test requirement considerations.
Let's begin with a look at a typical manufacturing line setup.

Typical fuse box manufacturing process



The process begins with surface mounting of the components and fuse terminals onto the printed circuit board. The printed circuit board is usually built in a panel of multiple boards to cater for lower manufacturing cost.

The assembled circuit boards then get to their first test station where they are tested at Board level. At this stage, none of the fuse plugs are inserted yet. So the board simply contains only some components and a lot of fuse terminals. Testing at this stage basically ensures that the printed circuit board is in good condition before the rest of the parts are installed.

After passing the Board level test, fuse plugs are then inserted along with the rest of the components and plastic parts. The unit then move onto the Functional test station to undergo a more detailed test for the inserted fuses and parts.

Finally, when the unit passes the Functional Test, it is then boxed up and marked.

Inspection and Test Strategy

Fuse box manufacturing test requirements

- Standard ICT coverage (Open/Shorts, RLC, Diodes, transistors, etc)
- Resistance/Jumper test between fuse terminals on same net
- HIPOT tests on selected fuse terminals
- Automated Inline Panelized testing
- Relay ON/OFF tests
- High Current Relay contact tests
- Shopfloor Data logging
- Test program controls

Inspection and electrical testing are essential to ensure the quality of a product.

Inspection can be manual or automated. Manual inspection by operators is flexible and commonly used. However, its repeatability and efficiency are questionable. Human-based inspection methods are largely limited by the judgment of each operator who inspects the product. Tools and templates are normally provided to help the operator focus on the area of inspection. But fatigue and difference in judgment often overpower the operator, resulting in bad human judgements.

Automated inspection systems on the other hand are more repeatable. These methods rely on one or a few cameras to capture digital images of the inspected area. The images are then digitally analyzed to determine if a fault is detected. However, the variations in colors, shapes or size of the inspected parts or joints create a large grey area margin between Pass and Fail calls. This often results in excessive false calls, which eventually will trigger an operator or technician to check and override the failure if required.

In-circuit tests (ICT) are Electrical tests which are by far the most accurate and efficient methods to detect a fault functionally. It is automated, quick and precise. Unlike inspection, electrical test does not have a grey area margin between Pass and Fail. The joints of each component can be measured and tested precisely within a set of pre-defined tolerances. This makes the test process fast, reliable and repeatable.

Components on a fuse board are to be tested for manufacturing defects like open/shorts circuits, defective/wrong components, wrong placements and bad connectivity. These are all part of the standard test capabilities which an ICT system can offer.

To meet the high production output targets, automated inline ICT systems are normally used and boards are usually manufactured in a panelized form which also means that the ICT system that is used needs to be able to handle the board in panel automatically as well.

However, ICT test coverage is not all. The product needs to be further tested to ensure its functionality in the high current and high voltage environment. High Potential tests (HIPOT) are required to be perform on selected points on the board to ensure minimum current leakage at high voltage. High Current Relays are not just being tested for ON and OFF conditions, but also tested for its current carrying capability. These are non-standard ICT test capabilities and user often builds a separate test station to perform these tests.

Understanding the Test Challenges – Board Level

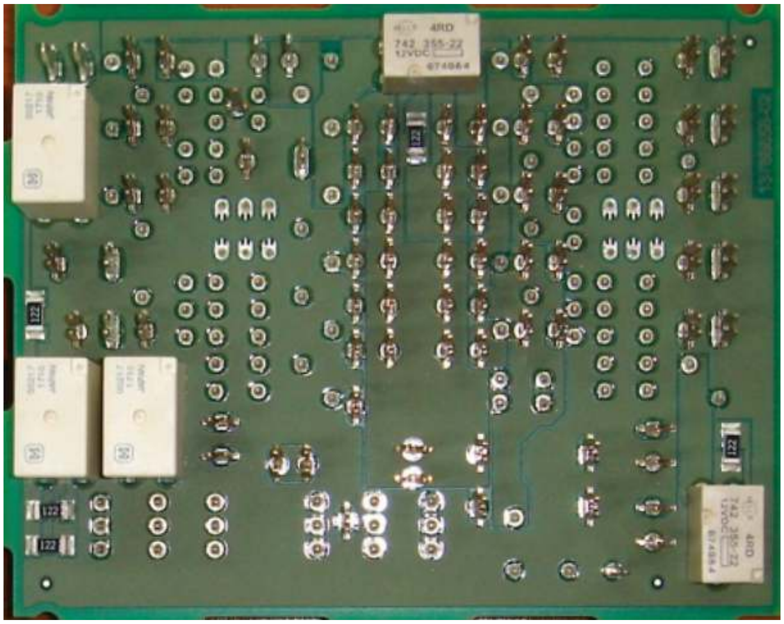
Typically, the user will want defects to be detected as early as possible along the manufacturing line because it is easier and cheaper to rectify as compared to when the product is completely assembled. Therefore, depending on the assembly stage of the product, different test stations are inserted into the production line to achieve the required test coverage.

In the example given in this document, electrical tests had been split into two stations. The first station is positioned at the end of the Surface Mount assembly process but before the insertion of the fuse plugs and relays. The printed circuit board, which is inserted with the fuse terminals and other components, passes through the Wave soldering process. At this stage, the product is ready for its first test to ensure that the components and terminals are loaded correctly and also, there are no defects resulting from the soldering process. This is the Board level test stage.

Testing the product at this stage requires the testing station to be capable of handling the product in a panelized form. In most cases, an automated inline test system will be used in order to cater for high production output and repeatability. Other than the normal test strategies that detect soldering defects and wrong/defective components, the test strategy at this stage also includes some unconventional ICT test methods.

Board Level Test Challenges

Poor Contact	Non-soldered surface of terminals offers very bad probe contact quality
Test Generation	Tests needs to be created for each terminals on the same net.
HIPOT Capability	Terminals need to be HIPOT tested which regular ICT system does not support
Automated Test System	Automated board handling and testing for high throughput
Panel Test Capability	Panelized board testing is required to meet high throughput



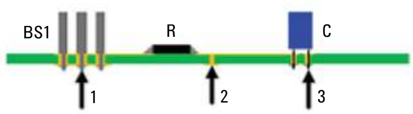
Test Generation

Conventional in-circuit test system software generates tests automatically using information provided, like Bill-of-Materials, Net list, etc. in the test generation process. The software looks at each component in the BOM and expects it to connect between two or more nets in the circuit. It then generates a test in between the nets in order to test that component. For example, a Resistor will have two pins, each connected to a different net in the circuit. The software will generate a resistance test between the two nets which the resistor is connected to. However, this does not work with fuse terminals. One fuse terminal contains multiple pins, but all of the pins are connected to the same net in the circuit. From the ICT software point of view, these pins are considered as one single pin. Therefore, the software cannot find the corresponding net to create a test for it. In the example on the right, BS1 is left untested because it does not connect to anywhere on the circuit.

Therefore in order to have complete coverage on each of the contact pins of a fuse terminal, user have to manually create the test for each pin .This is extremely tedious and time consuming, not to mention the potential number of mistakes that can happen.

The user will first need to ensure that additional test probes are added for each of the contact pins. In this example above, probe 1 is moved from the bottom to the top of one of the contact pins of BS1. Probe 4 and 5 are added for the rest of the two contact pins. The user will then manually create the test required for BS1.

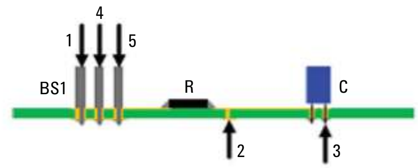
Standard ICT tests generation are based on NETs. Tests are automatically generated between NETs, but not between pins in the same NET.



Test generated only for R and C. No test is generated for BS1(Terminals) because all its pins are on the same NET

Test Generated:

Test R using Nail 1 and 2
Test C using Nail 2 and 3
BS1 not tested



To test the Terminals, additional nails 4 and 5 are added.

Test Generated:

Test R using Nail 1 and 2
Test C using Nail 2 and 3

Test manually created:

Test BS1 using nail 1 and 4
Test BS1 using nail 1 and 5
Test BS1 using nail 4 and 5

Poor Contact

However, the surfaces of the contact pins are not coated with solder. This creates another problem for testing. Without the soft solder layer, the test probes cannot penetrate the surface of the contact pin, thus resulting in very poor contact quality and higher contact resistance.

HIPOT Capability

These are the requirements to test every terminal pin within a same net on the circuit and also to perform a High Potential Test of selected terminal pins against other pins to make sure the isolation between the nets are good. However, with the high potential source applied to the board, components can be damaged by the source if it is not handled carefully. And switching the source between the tests can be a challenging task, too.

Automated Test System

The terminals need to be strong enough in terms of connection to ensure your car won't stop smack in the middle of the road because of a bad connection. Those terminals are longer than regular applications and automated systems needs to be redesigned to fit those terminals from both the top side and bottom side of the board. Due to differences in the height of terminals, the alignment of the board on the test fixture when getting automated is another challenge. Bent terminals are considered failed if the automated test system presses on the misaligned boards.

Panel Test Capability

All fuse boxes boards come in panelized form. Simpler boards come in more boards per panel while complicated boards come in two or three boards in a panel. Test program generation including regular ICT test and HiPot tests are important, especially since high potential voltage are running between the boards.

Understanding the Test Challenges – Functional Level

The second test station is positioned at the end of the fuse placement process where all the different fuse plugs and high current relays are already inserted. Plastic covers are also partially assembled at this stage.

Functional Level Test Challenges

Relay Functional Test	Relays on board required functionality tests for ON/OFF
Relay Specification Test	Relays on board required current specification tests
Shopfloor Data Control	Production Data logging and tracking for each unit under test
Test Program Control	User access control is required to ensure the correct test program is used.

Poor Contact

With the fuses now installed, the circuit now becomes complete with terminals connecting to other terminals through the fuse between them. Test accesses are now changed from contacting directly at the terminal contact pins to the bottom of the PCB where the terminal pins are soldered. Probing at the soldered joints now gets trickier because the probes need to be inserted into the terminals inside the black box.

Relay Functional and Specification Test

High current relays are also inserted into the circuit at this stage and will need to be tested for their functionality. Therefore, other than the usual ON/OFF testing of the relays, there is a need to test these high current relays with a much higher current source in order to check on its current carrying capability.

Shop-Floor Data Control

Most, if not all manufactures of automotive parts will require some sort of production tracking system to be in place so that each product that they ship can be tracked. This is referred to as Shopfloor Data Control.

Shopfloor data control systems are usually developed by the manufactures and they collect production data from different stations along the production line. With the serial number of each product recorded, the Shopfloor system can show when the product is built, where is it tested, what passes and what failures were encountered. This offers valuable information if the product fails in the future. To collect this information, each station in the production line is linked to the production server where the Shopfloor software normally resides. Some user simply upload the results of each station to the server, but some will even valid the product serial number with the server before allowing it to be processed at that station. To track a product along the production line, the product must bear Identification. The simplest method is to label each unit with a barcoded serial number. All information is then transmitted to the Shopfloor server using the serial number as a unique identitifier.

Because Shopfloor software is fully customized, it is not possible for the ICT system to offer a standard data log output format that will fit all users. Therefore, it is commonly seen that user needs to develop some special scripts to process the data log files that are exported by each of their systems on the production line. This requires some level of software programming capability and can be difficult to handle if the output data log file format is too complex.

Test Program Control

And lastly, Test Program control. It is essential that the correct test program is used for production testing. Operators are normally not allowed to modify any parameter in the test program except to be able to load them into the test system. Test programs are normally validated by the engineers and then released for production use. The operators will then only be allowed to load the test programs which are released. This will ensure that only the validated programs are used.

Selecting the right Test Solution

Given the challenges discussed earlier, selecting the right test solution can mean a huge difference in achieving a highly efficient and stable manufacturing operation. This is especially so in a high volume manufacturing environment where automation is employed – every single piece of equipment on the line needs to perform at its best. Any drop in operation efficiency on any equipment will bring the entire production line down easily.

The Agilent i1000 Small Foot Print ICT system's versatile design provides a good fit for this challenging environment. With a system foot print of 850 mm x 900 mm, and operating at 200~240 V single phase AC, this lightweight ICT system can be easily deployed to different production line setup environments. Its unique design offers both an Automated Inline model and Offline Model using the exact same chassis and even the same test fixture. This provides an upgrade path and thus delivers excellent investment protection.

Same Fixture!

Same Software!

Same Architecture!

Maximum Investment Protection

i1000D SFP Inline

i1000D SFP Offline

Apart from the compatibility between the two models, optional hardware can be included to expand the test capability from standard ICT to high power capabilities like HIPOT and High Current Relay testing. And with the release of software version v2.5.0p, additional features have also been added to support the unique test development needs for the terminals and other test methods.

Board Level Test Challenges	Agilent i1000 SFP Systems
Poor Probe Contact	Option to enable higher test stimulus with Safe Mode[1] selection
Test Generation for terminals	Specific test generation option for terminal pins in BOMtoATD[1]
HIPOT Capability	Option to include 150 V or 350 V HIPOT test cards. 100% software supported.[2]
Automated Test system	High top and bottom clearance. Small system foot print. Versatile.
Panel test Capability	Panel test supported with Group linking feature for easier debugging. Automatic disabling of crossed out boards in panel during testing.

Functional Level Test Challenges	Agilent i1000 SFP Systems
Relay Functional Test	Unpowered test option NCV mode tests for Relay ON/OFF using built in DC sources.
Relay Specification Tests	Option to include 1 Amp High Current card[2] to test Relay to their specifications. 100% software supported.
ShopFloor Data control	User customizable log output. Easy to read and extract. External script mode allows easy processing of log files.
Test Program Control	Software restricts the selection of test program in operator mode. Barcode verification prevents wrong programs used.

Conclusion

While a fuse box contains simple circuitry, it is not a straight forward test when considering all the aspects, including automation, high voltage potential tests, contact issues, relays tests and Shopfloor control, etc.
The Agilent i1000D SFP automation systems offers the right mix of technologies to overcome the challenges systematically and provides stable and robust test while keeping a simple test philosophy – we are testing a bunch of fuses. The automation portion is also simple for technicians and engineers to maintain the system with a high system uptime.

1. Available with software release v2.5.0p
2. Customized hardware integration

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