Keysight Technologies
Are you getting everything from In-Circuit Test?
With the demands of new technology and diminishing test access, some naysayers think that in-circuit test (ICT) has reached the end of the road as the board tester of choice. However, innovative ICT users beg to differ and continue to stretch the capabilities of their systems with new applications. This article examines two customer scenarios in the smart energy and automotive sectors where Keysight Technologies, Inc. has implemented solutions that combine the very latest technology with additional functional and programming features. This innovative approach shows that ICT has been able to deliver huge cost savings and ROI to the customer by combining several phases into one stage.

One of the most recurrent questions in the electronic manufacturing arena is if in-circuit test is really needed. In-circuit test (ICT) technology requires real testpoints to be included in the design, and accessed via a ‘bed of nails’ fixture. One well known limitation to the use of ICT in electronic manufacturing is the loss of accessibility to some modern PCBAs, and this is the reason why many experts believed that ICT era was at its end. Despite the challenges to providing test access, ICT systems are still widely used and still represent the workhorse of today’s electronic manufacturers. ICT technology has been able to adapt itself to the changes in the electronic world, addressing new devices, new package styles and also offering new solutions to the limited access issue. No other test technology has been able to provide accurate manufacturing defect detection, at such speed and test to device tolerance level so reliably.

Case studies on how customers are successfully combining additional test features with ICT using Keysight i3070 Series 5 technology.
In this article, we will look at a couple of scenarios where combining ICT with other functions such as on board programming (OBP), the test solution provides much value beyond standard test coverage. In these scenarios, accessibility was not an issue, but due to the complexity of the boards, implementing ICT would had been a costly affair had it not been for the additional features which improved overall test efficiency of the ICT strategy.

We would examine a couple of solutions which opens new possibilities for the use of the ICT system. The boards have mainly analog components and few digital devices. The digital devices are microcontrollers (MCU’s) which have to programmed during production phase.

The idea behind the solutions was very simple, but quite complex to implement: *What if we could execute ICT + OBP and finally + FCT on the same platform?*

This is not a brand new idea, and traditionally, it has its biggest limitation in the time required to perform all these tasks during the ICT stage. Time is money, and this is particularly true in the electronic manufacturing market.

For this reason, Keysight has been focusing on achieving the highest speed tests at ICT, while keeping the highest possible precision. This allows the customer to have the fastest possible ICT test stage so besides being able to keep up with the production flow, they can also have additional time with which to implement additional programming or test phases if needed.

One technology example is the introduction of new hardware, like the new analog stimulus resource unit (ASRU-N) and system card which were introduced on the i3070 Series5 platform in 2010. These new features managed to increase the speed of the standard ICT test phase for many components.
Having a faster ICT is the first step of implementing the solution. The second one is combining a solution which is able to program MCUs on board the ICT system at high speed. The solution adopted by Keysight was to use third party programmers, but embedded in the system. Keysight has introduced the utility card on the i3070 Series 5 system, allowing the installation of external hardware which in this case was programmers from third parties.

One of the biggest problems to address during OBP phase is the integrity of the digital signals. Long wire length used in some test interface styles easily affects the signal quality, so having a short wire fixture is a must in this kind of applications. The “old” technology of short wire fixture introduced by HP/Keysight at the end of 1980s, combined with the utility card, addresses this challenge in a very efficient way.

Because of the high quality signals provided by short wire fixtures, it will always be possible to run any OBP phase on the i3070 equipped with third party programmers at the highest speed possible. This fixture technology provides the highest stability, reliability and repeatability required in the high volume manufacturing arena.

Key points to note so far: The i3070 Series 5 means we have a much faster ICT test, and allows us to combine 3rd party application to achieve the fastest OBP phase.

So it is very likely that at the end of these optimizations, we will have some time to implement functional test (FCT), so why not try it?

In many cases it may be required to use external software to verify the functionality of the device under test (DUT). To increase the flexibility of the i3070 platform, new software has been released that is able to deal with external DLL’s. This opens a complete new world to easily integrate many kinds of software and hardware tools in the i3070, thus making it the most flexible test platform on the market.
Case Study One: Smart meter testing

Smart meter is an emerging market. Every house will very soon have a smart meter for monitoring and even managing the efficient usage of electricity, gas or water. With special regard to the electricity market segment, Keysight has over the past decade developed several solutions for our customers, helping them to produce power meters in an efficient and fast way.

Typical printed circuit board assembly (PCBA) designs adopted in this market segment may have one or two MCUs (8 or 32-bit), one EEPROM, one serial peripheral interface (SPI) flash and require a real time clock (RTC) to be calibrated. In the last 10 years we have seen a migration from 8-bit MCUs to more complex 32-bit MCUs. The meters have to implement more complex functions like cryptography to guarantee the safety of customer information stored and the number of measurements done by the meter has increased to better match what the customer needs. As a result we have seen the size of the memory increasing up to 2 Mbit. Whoever manufactures these kinds of products, has to provide a solution able to program the MCUs, the EEPROM and SPI flash (typically also with variable data like SN, calibration values etc.), to execute a very accurate calibration of the RTC, and execute a low voltage functional test, which includes a communication with the DUT using special serial protocols. At the end of the day we are talking about producing a high precision and complex instrument in high volume. For instance, Italy was one of the first nations to introduce smart meters at the beginning of Y2K, and the number of meters to be produced and installed was in the range of 30 million.

One of the solutions provided by Keysight had to perform the following tasks:

1. In-circuit test: 200 nodes, 280 components, 140 resistors, 70 capacitors, 20 diodes, 10 digital devices, VTEP etc...).
2. OBP of one MCU STM32F1XX, one M25P10 and one M24512 with data files of 450 K, and two binary files of 32 K and 64 K.
3. RTC calibration of 32 Khz crystal with a precision better than 5 ppm.
4. FCT test with UART communication at 9600 bps to write SN and other values, send special commands to open and close relays on the board, current measurements, voltages measurements and frequency measurements.
5. Data logging of each test for traceability.
6. The boards were produced in panels of four.

The high volume of smart meters to be produced, necessarily pushes the test technology and other requirements to its limits. The boards are normally produced in panel form (4 seems to be the de-facto standard), so the ICT should perform the test in parallel, and obviously also the OBP should be done in parallel.

The RTC calibration should also be performed in parallel, and possibly also the low voltage FCT tests and communication tests. The FCT test normally requires communicating with the DUT via specific communication protocols like the FLAG protocol, to write or read specific values from the DUT, and to measure voltages, currents and frequencies.
It is clear that only a system which embraces parallel test architecture, can afford to test and program these products in a reasonable time. Throughput multiplier was introduced 20 years ago to the i3070 family and this solution provides exactly the parallel test features needed to address optimization of the standard ICT tests. The utility card, equipped with several programmers, allows the assignment of a programmer to each board on the panel, so also the OBP part can be performed in real parallel.

As a result, the overall “test” time for a panel of four was less than 60 s, which means each board was fully tested, programmed and performed RTC calibration in less than 15 s. In this application, the OBP + RTC calibration on a panel of four was executed in 11 s, which means 1 board every 2.75 s.

The key benefit for the customer was that the in-circuit test stage was keeping the production process under control, while the OBP part was helping the customer to simplify parts management and finally, the low voltage FCT was guarantying that the DUT was really working and ready to pass the high voltage FCT test with the highest yield possible. All these capabilities were able to be combined within one test platform, one operator and one test fixture, which provided huge value during the production test phase.
Another important aspect addressed by Keysight is related to the functional test (FCT) stage of manufacturing. In this case, once the board has been programmed, the FCT may require communicating with the DUT via automotive communication protocols like CAN, VAN, LIN etc. The big challenge is to try to execute these communications in parallel as almost all the automotive boards are produced in panels.

Over the last few years, Keysight has successfully implemented many similar solutions.

As an example, we can refer to the electronic board used in a steering wheel of an economic car. The board is not really complex, but still has a 16-bit automotive microcontroller to be programmed with a 280 KB data file, an EEPROM to be programmed with variable data (containing production data, SN, calibration values etc.).

From an ICT point of view, as previously mentioned, the board is not really complex, having less than 200 components; however, quality is a big driver with many suppliers trying to achieve failure rates lower than 50 ppm. The ICT stage is typically one of the final stages where you can still get access to repair the board before it is placed in its final packaging. Any additional repairs needed at later stages are therefore much more difficult and costly to implement.

The challenge is on the FCT side. Today’s boards have a lot of input features to verify the status of different buttons, with levers available from the steering wheels to control the lights, radio buttons, cruise control, horn etc.

Each input needs to be functionally tested to verify that the right CAN datagram is sent by the MCU. The full test sequence required by this customer had more than 120 individual tests like this.

The first challenge is to simulate the inputs with ICT. This isn’t such a problem as per definition at the ICT stage, since the fixture has a wire to each node (ideal world). The decision to go or not to go for a fully integrated solution at ICT stage is driven only by the overall test time.
The Keysight solution provided was required to perform the following tasks:

1. In-circuit test: Approximately 160 nodes, 200 components, 110 resistors, 83 capacitors, 10 digital devices, VTEP etc...).
2. OBP of one MCU R5F with one Intel HEX files of 280 KB, and one EEPROM with variable data.
3. FCT applying stimulus to the DUT and reading the results over the CAN bus for a total of about 120 tests.
4. Data logging of each test for traceability.
5. The boards were produced in panels of four.

In this application, particular care was taken in order to execute in parallel the most time consuming tests. Particular care was also taken on the CAN side as this test sequence on its own for a single board was in the range of 18 s. In this case, the new open architecture of the i3070 allows us to easily include solutions from third party in order to perform both OBP and CAN tests in parallel.

The overall “test” time achieved was about 36 s for a panel of four, which resulted in a board every 9 s. This allowed the customer to remove one test step from their process, and having a fully working and ready to ship board at the end of ICT stage.
As you can see from both manufacturing scenarios above, there are common factors that prompted the customers to add real value beyond the standard ICT test capabilities and really stretch their ROIC on their test systems:

1. High quality is key - PCBA need to have very low field failure rate and long lifetime.
2. PCBA are manufactured in panels.
3. Each board has microcontrollers that require programming.
4. Each board also has functional tests that can be combined at ICT, thus removing or simplifying the later functional verification stage.
5. Utilizing parallel testing features on ICT platform allows the test engineers to reach the fast cycle times required to be within the beat rate of the production line.
6. Customer implemented/upgraded their ICT platforms to tap into the Keysight i3070 Series 5 technology in order to combine the latest features and high speed testing.

So coming back to the original question, can we consider that ICT is dead?

At Keysight, our manufacturing test specialists believe that ICT is still very much alive and with thanks to the innovations introduced over the last decade, ICT is now delivering something different from the past. ICT can even help in areas where previously, it would never have been considered as a potential solution.
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