Programming In-System versus Offline

The decision rests on the line beat rate versus ICT test cycle time.

MODERN ELECTRONICS – CELLPHONES, TV set-top boxes, laptops – contain at least one programmable device on board that usually contains boot-up or self-test firmware to enable these products to perform their functions properly. In general, there are two methods by which these devices are programmed: offline or in-system.

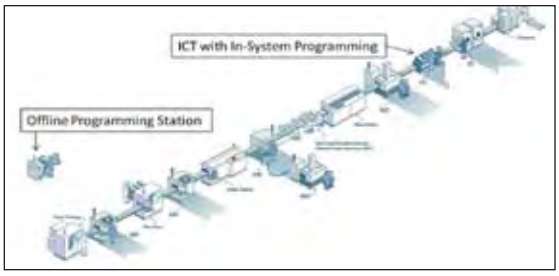
How does one decide on offline programming or ISP? One key consideration is the cost of each method. Let us look at pros and cons of these two methods that contribute to the overall costing.

First, let's define each of these methods:

- Offline programming. Device programming carried out independently of the actual production line before device is attached to the printed circuit board.
- ISP. Device programming carried out in the actual production line; device is installed on the assembly before programming is performed.

The sole benefit of programming offline versus in-system is that it takes out that time from the overall ICT test cycle time equation. If the SMT line beat rate is much faster than the overall ICT test cycle time, the ICT station will be a bottleneck for the production line. Removing the programming portion from the ICT stage will improve the overall efficiency of the production line. The programming time depends on many factors, like the size of the data to be programmed, programmer clock speed, number of devices to be programmed, whether the program is implemented directly onto the device or via an upstream boundary scan JTAG port to program device, etc.

On the other side of the coin, offline programming does have some big challenges. The first is inventory control. There will be multiple firmware versions across the customers' range of products, and there will be even cases of multiple firmware versions for a single product with different functions turned on for different market needs. Having offline programming for all these devices will require a good inventory control process. Imagine loading the wrong preprogrammed devices onto boards: the effort and cost of replacement would be tremendous.



The second challenge with offline programming is the inability to reprogram the device post-soldering. Often, firmware versions are frequently changed, especially during NPI. New firmware may be released during the production build, and the inability to reprogram the device online means one has to replace the device manually. Or, if boards have been returned from repair, functional test or outside the factory, there usually are slight changes to the firmware, and the boards must be reprogrammed in the ICT. This reinforces that the ability to program in the ICT station is critical in a production environment.

An offline programming station requires additional resources: operators, real estate, and of course the programming station itself. On the other hand, implementing ISP may require additional hardware or software on top of the existing ICT, not to mention development of the ISP solution.

Simultaneous Programming

Performing programming on two similar boards simultaneously achieves two boards within one test cycle time. It can also mean programming two or more devices within the same board simultaneously, circuit topology permitting. How fast can ISP be? Consider real-time data I collected from two recent ISP projects. In both cases, the ICT was an Agilent Medalist i3070 Series 5 with plug-in cards.

Project #1:

Product: Smart meter
Fixture: One-up (single board)
Programming three different devices on board: M24512 (EEPROM), M25P10 (SPI flash), STM32F101 (MCU)

OPERATION (M24512 – EEPROM) DATA SIZE = 512 KB	TEST TIME (SEC.)
Programming	4.05
Verify	3.05
Run all script	7.75

OPERATION (M25P10 – SPI FLASH) DATA SIZE = 1 MB	TEST TIME (SEC.)
Erase	1.20
Blank Check	0.65
Program	1.15
Verify	0.40
Run all script	4.15

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EPIC's DfM/DfT system prioritizes recommendations to make it easier for customers to understand how critical each recommended design change is to overall product quality. Documentation control is centralized to make sure production only has access to the most current revision of work instructions. Design travelers accompany each work order to ensure that during shift changes or personnel changes there is a clear trail on what is being processed. Smaller batch sizes also contribute to minimizing this waste.

Unnecessary inventory is also a challenging waste to minimize in the EMS environment. Unnecessary inventory comprises raw material, work-in-process and finished goods inventory. While smaller lot sizes can minimize WIP, the relationships with customers found in EMS means forecasting and supply base choices are often a compromise between customer preferences and Lean best practices. Economy-driven variable demand further tests the system.

In the EPIC model, the program manager starts by developing the customer order replenishment methodology. The tool for determining visibility into the customer's demand is defined (i.e., ERP, EDI, etc.), and replenishment "pull" signals are defined.

Once these issues are addressed, initial finished goods kanban bin sizes are established. Trends are analyzed and bins resized as appropriate with customer approval. Strategic suppliers produce to the MRP forecast and ship to EDI release signals. Consignment, in-house stores and vendor managed inventory programs are used with strategic suppliers to maintain buffers closest to the point of use.

Pipeline status or "bond" reports are regularly reviewed with supplier teams to ensure buffers and replenishment streams are able to support planned production within a range of variation based on past historical demand, current forecasts, customer service lead-time guarantees to their end-market, manufacturing lead-times and transit lead-times.

Like the wastes of transport and inappropriate processing, unnecessary or excessive motion costs money and slows throughput. And, as with the waste of inappropriate processing, customer reluctance to implement DfM/DfT recommendations can be a constraint in improving efficiency.

EPIC's automation strategies, DfM/DfT process and focus on designing factories with sequential processes all help improve efficiency, but ultimately, the most success in reducing this waste comes when customers are willing to adopt DfM/DfT recommendations. Engaging the EMS provider during the design stage ensures optimal process efficiencies, translating to a successful and cost-effective product launch.

Excessive defects represent both the seventh waste and a byproduct of most of the other wastes. They drive unnecessary inventory and overproduction. However, completely eliminating defect opportunities carries a high cost, and most EMS providers make tradeoffs to minimize defects while aligning with customer cost goals. Other defect minimization practices include:

- Eliminating non-value-added activities.
- Minimizing touch labor.
- Maintaining a well-trained workforce.
- Using Six Sigma tools to analyze root cause of defects.

There is no one right formula for eliminating any of these wastes. The best course is developing a strong production framework with processes that accommodate the bulk of customer requirements, and fine-tuning as required. CA

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OPERATION (STM32F101 – MCU) DATA SIZE = 256 KB	TEST TIME (SEC.)
Erase	0.10
Blank Check	1.25
Program	14.55
Verify	10.50
Run all script	27.10

Project #2:

Product: TV setup box
Fixture: Two-up with throughput mode
Programming AT26DF081A (flash) on board.

Note that for this project, programming was performed on two boards simultaneously. The test time shown below is actually for two boards. The programming time for one flash device by the EMS company's offline programming station took 35 sec., which was significantly slower than the ISP programming time in the table below.

OPERATION (AT26DF081A – FLASH) DATA SIZE = 1 MB	TEST TIME (SEC.)
Erase	5.359
Blank Check	4.375
Program	6.297
Verify	6.484
Run all script	23.515

Design for programmability. When adapting ISP, other than the program time incurred in the total test cycle time, one should consider design for programmability. Simply put, there must be test access to the data, clock and control signal lines of the programmable device. In most cases, there usually is a processor or controller that accesses the firmware from these downstream programmable devices. One must also consider the means for disabling these upstream devices to the programmable devices. There must be ways to disable the upstream devices properly in order for the programming to perform successfully. If upstream devices are not properly disabled, there will be interference, and programming success will be intermittent, if at all.

In conclusion, there is no absolute answer to whether to adopt offline programming or ISP. One has to decide, based on the factors above, the method that best suits the products and the production environment. Both methods complement each other.

My opinion is that ISP capability has to be implemented for every product with devices that require programming. Whether an offline programming station should be added depends on the SMT line beat rate versus the ICT test cycle time. ISP is an available and viable option to address the gaps in offline programming. It can double up as a check point to verify the data content pre-programmed by the offline programming station. Where necessary, more ICT machines with ISP can be added to match the SMT line beat rate. CA

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