Fujitsu's DFX Application

● Yukio Sekiya ● Hideaki Takahashi

(Manuscript received May 26, 2006)

Improvements in product design are conventionally made after the start of mass-production, followed by reductions in cost and lead-time. However, in light of the shorter product life-cycles and high-mix/low-volume production of recent years, it is increasingly important to carefully optimize productivity from the initial stages of mass-production. It is generally considered that design determines 80% of productivity. To optimize mass-production as early as possible, design and production engineers are asked to make collaborative efforts in productivity improvement from the beginning of development design. Specifically, assembly and test performance must be evaluated, and then the results must be reflected in the design. These activities are collectively called Design For Manufacturing and Test (DFX). Fujitsu has created DFX guidelines for the manufacturing conditions and production know-how in its factories and for building a structure for reviewing productivity at the development stage. This paper outlines DFX and describes some examples of how DFX has improved various products and increased productivity.

1. Introduction

In the development and design of electronic products, it is becoming increasingly important to carefully consider the manufacturing process as well as the performance, cost, and quality. Particularly, activities focusing on assembly and test performance in plants have become essential for faster product marketing and shorter lead-time for development and manufacturing. These activities are collectively called Design For Manufacturing and Test (DFX).

Once mass-production of a product has started, efforts to improve productivity often have to be restricted to prevent them from substantially degrading the basic design specifications. Therefore, the development design stage that focuses on the manufacturing constraints and facility conditions has emerged as a key factor for ensuring superior cost performance and significantly improving the quality (Q), cost (C), and lead-time (D) of a product.

The Fujitsu Group is promoting production innovation across the board, and the Group's production and design engineers have been working together on DFX. This paper gives some examples of DFX in the Fujitsu Group.

2. Overview of DFX

Activities to improve product-related factors at the development design stage are collectively called DFX. DFX broadly consists of Design For Manufacturing (DFM), which focuses on assembly performance; Design For Test (DFT), which focuses on test performance; Design For Environment (DFE), which focuses on the environment; and Design For Service (DFS), which focuses on maintainability.

This paper gives some examples of DFM and DFT that have had a large, beneficial effect on manufacturing.

Although design focusing on assembly performance could be called design for assembly (DFA), this paper uses "DFM" as an extensive interpretation that includes process workability.

3. Examples of DFM

This section describes a guideline for production know-how and some example of how assembly performance has been improved using a 3D simulation tool before the start of mass-production.

3.1 DFM implementation process

In DFM, the production engineers review assembly performance based on the design information at the concept design stage. The results are sent to the design engineers as suggestions for improvements for optimizing assembly from the initial stages of mass-production. Production know-how accumulated through assembly performance review is available to the design engineers in the DFM guideline. The production engineers also check whether the suggestions for improvement are reflected in the product (**Figure 1**).

The DFM to be applied depends on the features of the product. For example, a notebook PC is mass-produced with an emphasis on compact size and low price. When a notebook PC uses surface mount technology (SMT), designers must carefully balance the designs for mounting components on the front and rear surfaces of PCBs and carefully select the sizes and types of screws. To cite another example, a server system has processors and large mechanical components on a large PCB, while a network device has optical fibers and components. For these devices, ease of assembly, inspection, maintenance, and other tasks must be considered.

3.2 Using DFM guideline

Traditionally, design engineers design a PCB using CAD in accordance with the mounting design criteria, which include the spaces used to mount components and the orientations of the electrical components. Then, they use a CAD design rule check (DRC) function to automatically check whether the mounting design criteria have been met. However, because DRC has difficulty in automatically checking certain items concerning the assembly performance for mechanical components and production know-how at the plant, these items are often left unchecked.

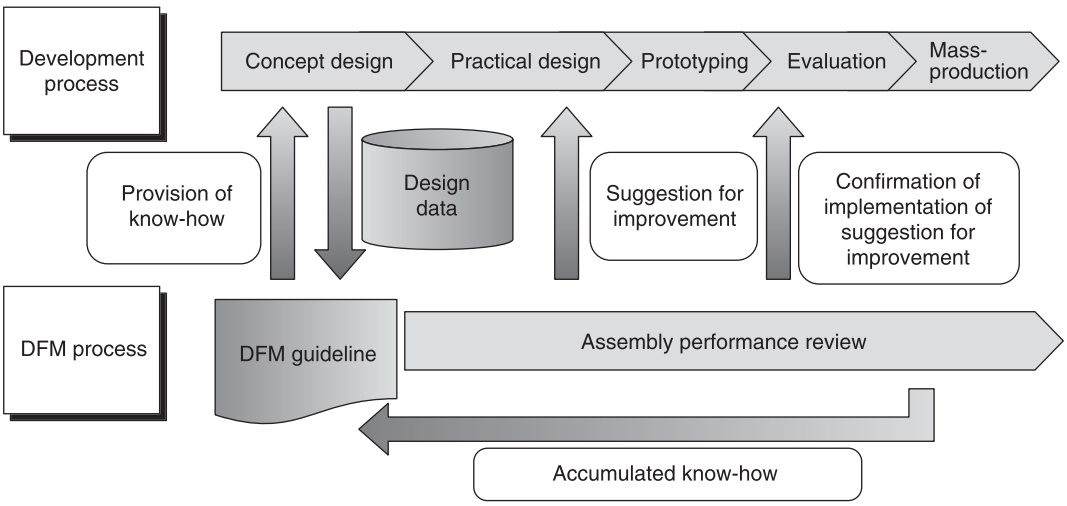


Figure 1
DFM process.

The DFM guideline helps design engineers make suggestions about these items to the upstream processes. It also quantitatively defines the effects of adopting suggestions, which enhances their utility. **Figure 2** shows an example of a DFM guideline. Along with this guideline, a checklist is used to verify whether the items defined in the guideline are reflected in the design at the assembly performance review. The checklist enables an objective evaluation and also ensures that every item is checked.

3.3 Examples of assembly performance review

To avoid production design changes after the start of mass-production and achieve early stabilization of mass-production, it is important to use the preproduction design data at the concept design stage to review the assembly performance. Fujitsu reviews its in-house assembly performance using a 3D simulation tool called Virtual Product Simulator (VPS).[1] VPS combines PCB CAD data at the concept design stage with 3D data for mechanical components such as cabinets and converts it into VPS data. Then, the VPS productivity evaluation function is used to simulate assembly of the product on the VPS so the assembly performance can be evaluated in a virtual environment without the need for prototyping. The main evaluation items are as follows:

1) Assembly performance evaluation
2) Assembly procedure examination
3) Static and dynamic interference check
4) Examination of jigs
5) Process setting

Figure 3 shows an example of assembly performance review using VPS.

The design and production engineers collaboratively review the assembly performance and associate the design data at the concept design stage with the production know-how in the plants. This requires that the engineers of both divisions work in close coordination. The effects of each evaluation item are quantitatively calculated and fed back to the design engineers as suggestions for improvement. The design engineers check the effects and reflect any applicable suggestions in the design before the start of mass-production. Also, production know-how accumulated through repeated DFM steps is added to the DFM guideline to facilitate horizontal development of other models.

The following paragraphs describe some examples of applying DFM to server systems and network devices and describe how DFM can

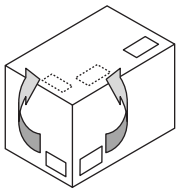
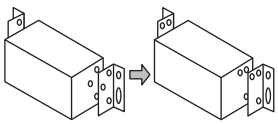
Classification	Contents	Effects
Workability	Attachment direction must be identical for all labels. 	· Product inversion = 2 seconds/inversion · Attachment section wipe = 3 seconds/location
Quality	Part to be attached on either side of product must be symmetrical or have unmistakable assembly orientation. 	· Fail-safe · Prevention of rework

Figure 2
Example of DFM guideline.

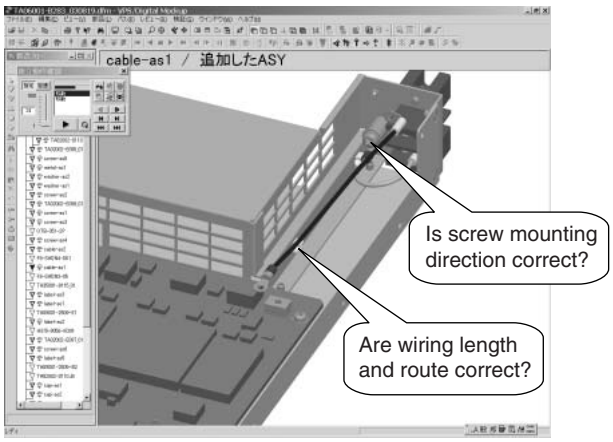


Figure 3
Assembly performance review using VPS.

reduce the number of processes, streamline manufacturing, and bring other advantages.

Figure 4 shows an example of reducing the number of processes. The product in this example contains multiple PCBs. In the plan provided at the concept design stage, the PCBs were to be assembled from vertical and horizontal directions [Figure 4 (a)]. At this stage, assembly performance review was implemented and it was suggested that assembly be done in a single direction [Figure 4 (b)]. This suggestion was then reflected in the design. A virtual review using VPS before prototyping facilitated communication between the design and production engineers, resulting in a reduction of assembly processes from nine to seven.

Figure 5 shows an example of streamlining manufacturing. In the plan provided at the concept design stage, cabinet components were to be secured to the PCBs separately from different directions using screws [Figure 5 (a)]. To fasten some of these screws, the product would need to be turned upside down. An assembly performance review was implemented, and it was suggested that the cabinet components be jointly secured to a PCB at a single location from above [Figure 5 (b)]. The design engineers determined this would not cause a problem with design comprehensiveness, so the suggestion was reflected in the design. As a result, the screw-fastening person-hours in the assembly process were reduced by 10% compared to the plan at the concept design stage.

4. Examples of DFT application

DFT is a well-known design technique that focuses on test facilities containing an in-circuit tester and a boundary scan tester.[2] This section describes examples of network device tests that have been reformed at the development design stage in terms of sharing and platforming instead of being improved by improving the test facilities.

4.1 DFT implementation process

Figure 6 shows the DFT implementation process. To promote sharing and platforming of the tests intended to improve the Q, C, and D of a product, DFT has been established in synchronization with the development process. In DFT, the design engineers communicate with the test engineers familiar with the production technology in order to improve the product design with a focus on the mass-production tests. They also promote designs for the evaluation and mass-production tests. During the development process, the design and test engineers use the DFT guideline, which can always be referenced to obtain information about the DFT implementation items.

4.2 Integration of the test processes

Mass-production tests of network devices containing multiple PCBs commonly consist of two stages: a PCB unit test and a device test in which functions and features are tested. However, the two-stage system overlaps some test items and

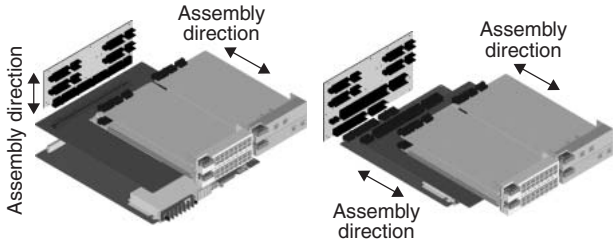


Figure 4
Example of reducing assembly processes.

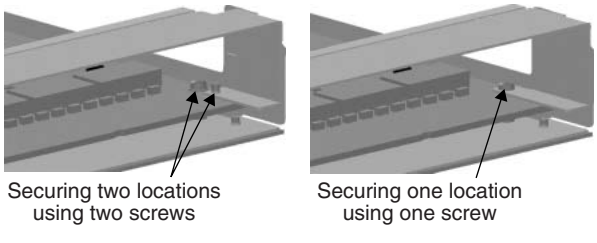


Figure 5
Example of improving assembly after DFM application.

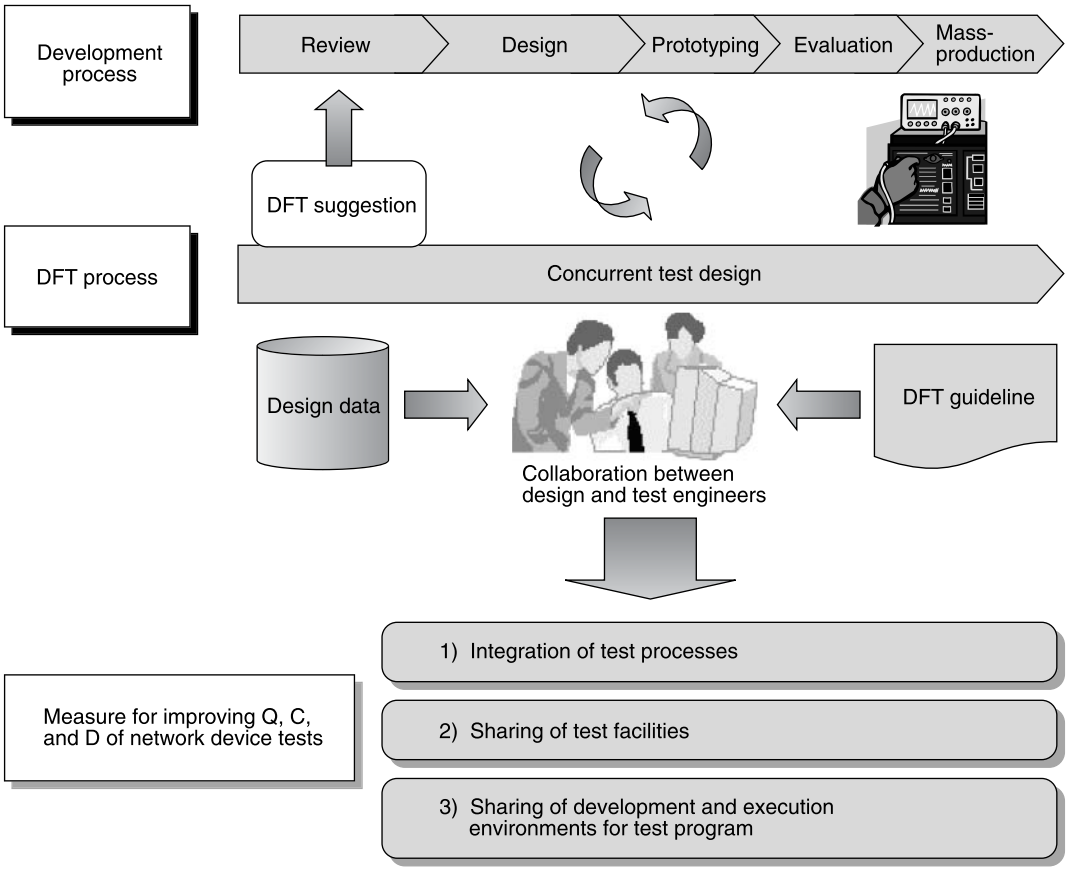


Figure 6
DFT process.

facilities and causes a long lead-time. Therefore, Fujitsu developed a new test system in which functions and features were fully tested in a single stage. The new system had to meet two conditions: 1) it must at least perform the same tests as the existing system and 2) it must essentially perform an operation test (device test) at the device operation level. The new system is called the one-stage test.

Some items could only be tested on the PCB unit. To test them on the test device, a suggestion was made and implemented as a DFT activity. The activity incorporated several functions for improving the test performance in the product's hardware and software (**Figure 7**). Specifically, the following four functions were added to the product:

1) An internal interface access control function implemented in the test control software
2) A test pattern and alarm generation function in final frame processing of a pair of PCB units
3) A test pattern check function in final frame processing of a pair of PCB units
4) A product loopback function in a switch (SW) unit

DFT implementation reduced the test time by 40% and the lead-time by 50% and retained all of the tests of the existing test system.

4.3 Sharing of test facilities

After assuring the test quality, to reduce the cost of the test facilities and the test time, it is essential to enhance the cooperation between the design engineers and the test engineers familiar with the production technology. The following

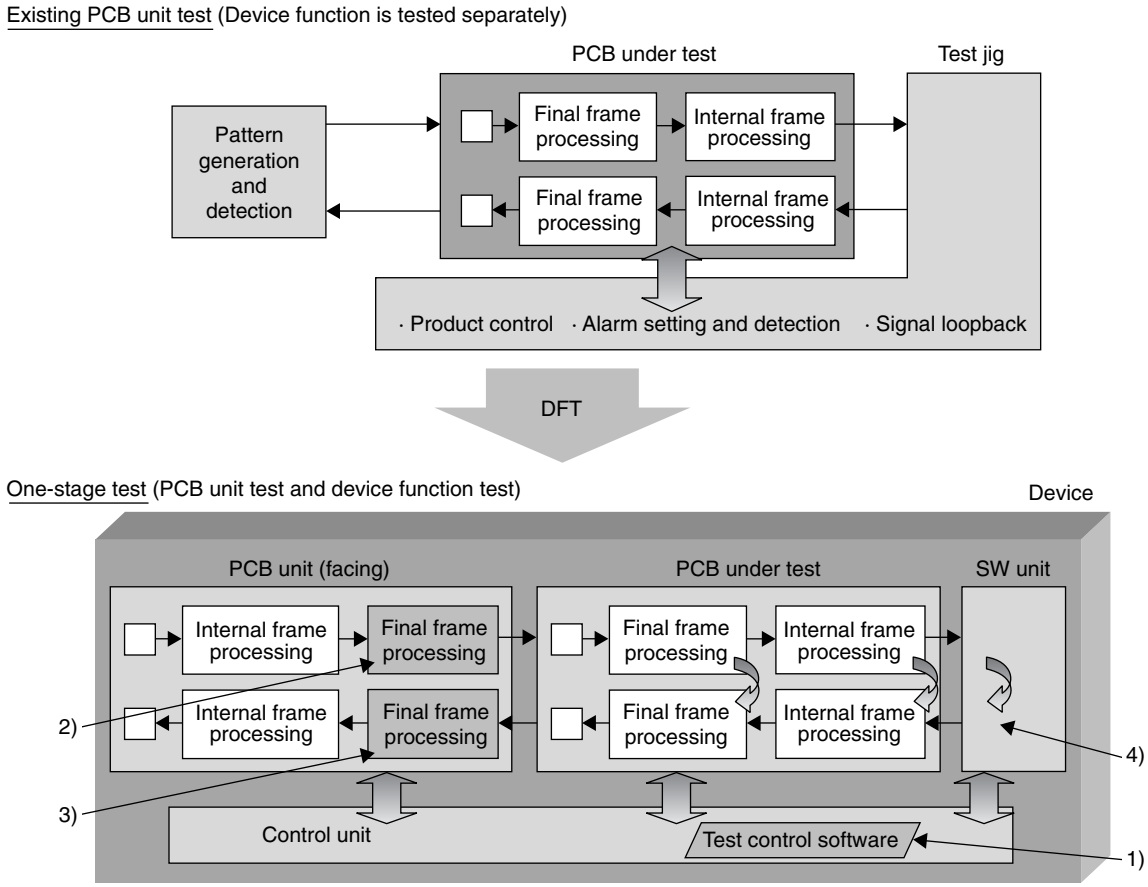


Figure 7
Integration of test functions into product.

paragraphs describe examples of reductions in the cost of test facilities that were accomplished through cooperation between design and test engineers.

Figure 8 shows a test system for IP products that was developed using DFT. On two IP devices, 22 ports for Fast Ethernet (FE) were connected in pairs and an analyzer was connected to four Gigabit Ethernet (GbE) ports and four FE ports. DFT multiplexed and isolated GbE for 10 ports for FE so that all ports could transfer signals at full load. As a result, the utilization rate of the analyzer ports was reduced to 25%.

The new test technique reduced the port utilization rate, but there was no decrease in the cost of test facilities in the case of the traditional test system because each automatic test device has its own analyzer (**Figure 9**).

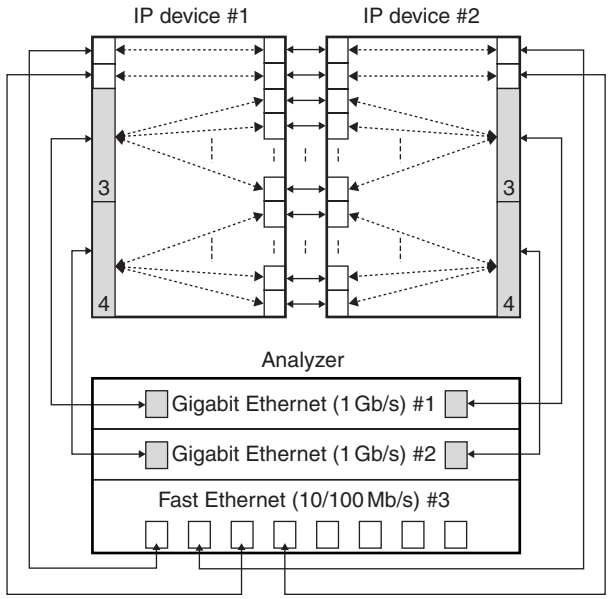


Figure 8
Test system of IP devices.

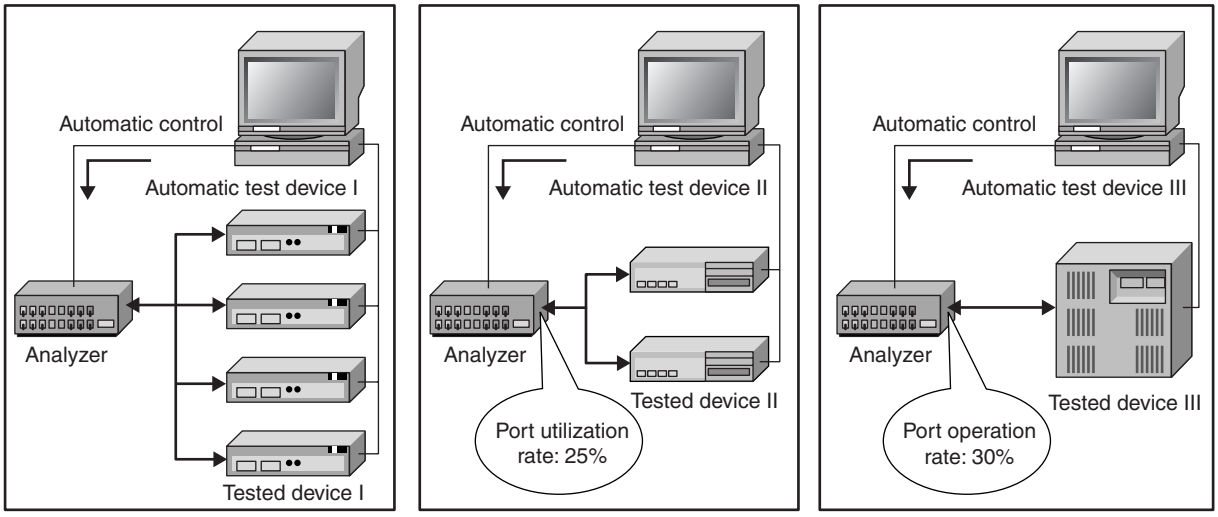


Figure 9
Traditional test system.

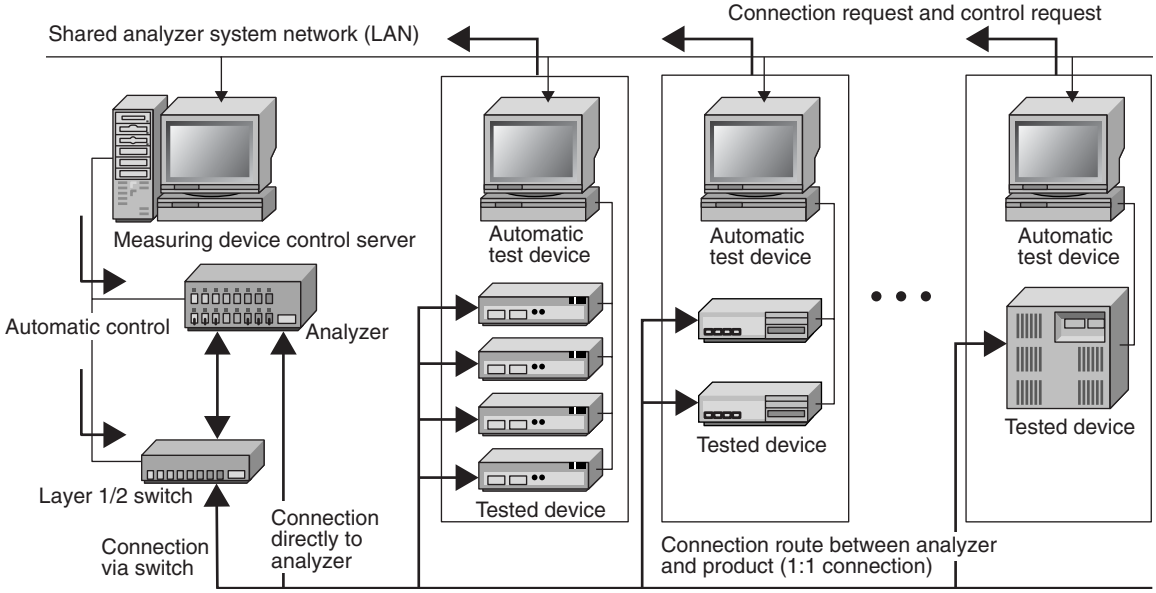


Figure 10
Test system for sharing measuring devices.

Because the design engineers working in the existing process did not understand the mass-production test environment, they could not reduce the cost for the mass-production test facilities.

Figure 10 shows the measuring device sharing system that the test engineers developed. This system enables the shared server to control the analyzer so it can be shared between the automatic test devices. By using this system, the analyzer port utilization rate can be enhanced to 100%. The system also employs a switch between the analyzer and tested device so the tested device can be connected only when the analyzer is used, which improves the port operation rate from 30% to 60%. (If the latency time is ignored, the

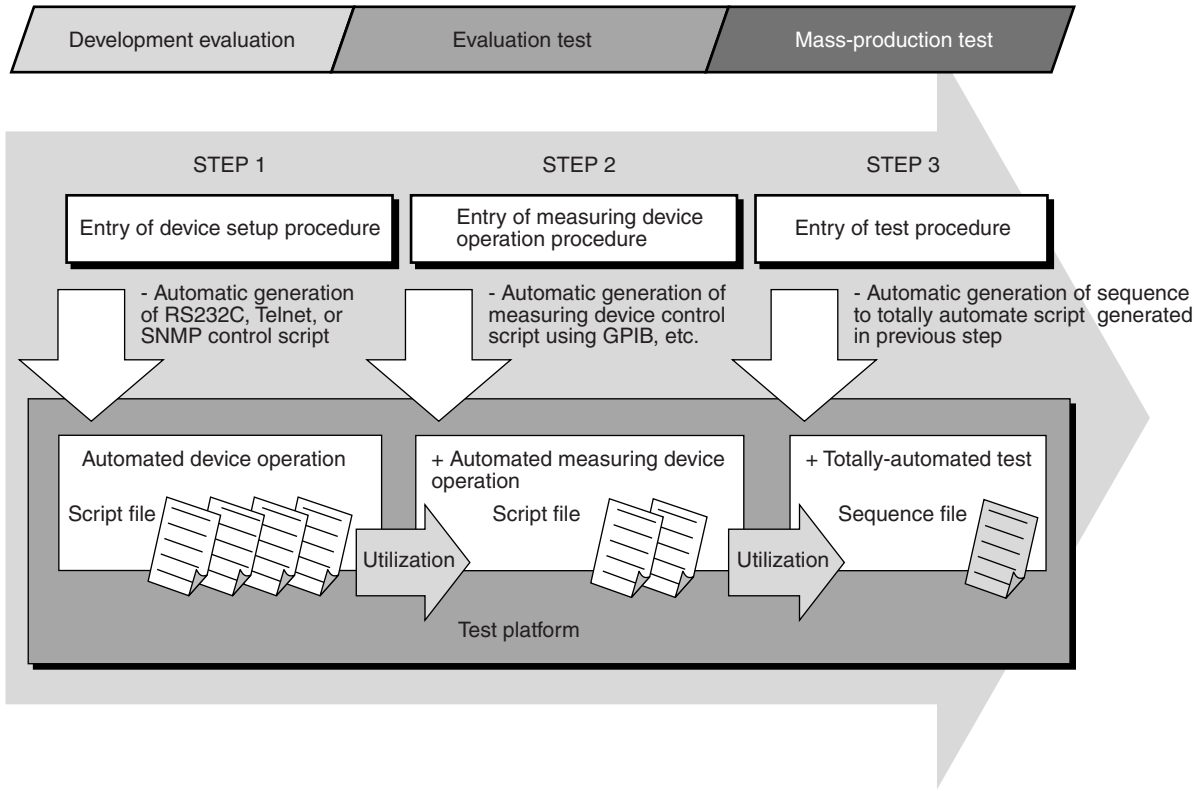


Figure 11
Efficient development of test program.

port operation rate can be enhanced to 100%.)

4.4 Sharing of development and execution environments for test programs

Next, we describe some examples of making test program development environments — from development to mass-production tests — more efficient and reducing the development lead-time.

Similar measurements and tests are performed in the development, evaluation, and mass-production processes. However, if the persons in charge of these processes develop test programs in their own way, only partial optimization is assured because the resulting differences between languages and program structures lowers their versatility and reduces the overall development efficiency.

Consequently, in some cases, when there is an increase in development scale, it might be impossible to provide an optimized mass-production test program at the start of mass-production.

Figure 11 shows how DFT increased development efficiency. New test programs were obtained simply by adding new functions to the test programs of previous steps. In this way a mass-production test program was provided at the start of mass-production.

To implement this plan, the test program had to match the requirements of each step. Moreover, a test platform that operates in the shared development and execution environments was required.

The test platform consists of three layers (**Figure 12**). Each layer can independently execute the program in accordance with the intended use. Furthermore, because the layers can share the test commands and programs, all the programs that were developed between development and mass-production were available,

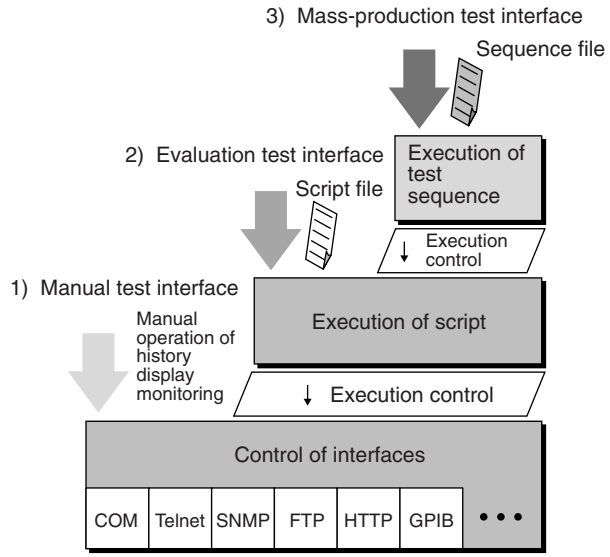


Figure 12
Architecture of test program platform.

which improved development efficiency.

This test platform halved the number of person-hours needed to develop the test program, increased the efficiency of evaluation, and made it possible to provide a mass-production test program at the start of mass-production.

5. Conclusion

Two of the benefits of DFM and DFT activities are design focusing on manufacturing aspects and efficient production without design changes. Particularly, the biggest benefits are achieved through joint efforts by the development and production engineers in operations upstream from the development stage. Development and design focusing on manufacturing facilitates standardization and sharing in production and enables preparation for stable, mass-production at the early stages of development.

In the future, Fujitsu will promote reviews of manufacturing aspects through collaborations with the development and production engineers in upper-stream operations of development. We will also enhance the platform for assembly and test processes and engage in higher DFX activities.

References

1) K. Ujiie and H. Inoue: Development of VPS and Physical Simulation Technologies. (in Japanese), *FUJITSU*, **55**, 3, p.221-226 (2004).
2) A. Verma: Optimizing Test Strategies During PCB Design For Boards With Limited ICT Access. 2002 SEMI/IEEE IEMT, p.364-371.

Yukio Sekiya, *Fujitsu Ltd.*
Mr. Sekiya received the B.S. degree in Electronics Engineering from Shinshu University, Nagano, Japan in 1979. He joined Fujitsu Ltd., Kawasaki, Japan in 1979, where he has been engaged in production engineering for communication systems.

Hideaki Takahashi, *Fujitsu Ltd.*
Mr. Takahashi received the B.S. degree in Mechanical Engineering from Waseda University, Tokyo, Japan in 1990. He joined Fujitsu Ltd., Kawasaki, Japan in 1999, where he has been engaged in production engineering for communication systems.