Organising an Electronic Unit for Mass Production

Part II

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Different types of test equipments are required at various stages in an MPU. Let us discuss about them in detail.

Bare-board testers

Bare-board PCBs are those without components. Inspectors at PCB manufacturing units look for shorts and opens with a magnifying glass before they are despatched. Yet some shorts and a few opens may escape their eyes to give problems in the assembly. It is better to detect these before these boards are assembled.

Generally, a self-learn program generator is incorporated in these testers. So the first step is to keep a typical defectless bare board on the fixture and allow the tester to generate its own program. Then, the tester is ready for mass testing.

In-circuit and functional testers

In-circuit testers, in general, receive PCBs on a bed-of-nails fixture. Each component is sequentially connected to the tester which inspects for parametric values, placement etc. This way, one can find out shorts, opens, faulty mounting of components and faulty parts.

Functional testers, usually receive PCBs with edge connectors. They emulate the actual environment of the PCBs under test and verify their dynamic performance.

The lines between the in-circuit and functional methods have been somewhat blurred because in-circuit testing is actually a technique of isolation and functional testing. By isolation we mean that the device under test is removed from the effects of interaction with other components, including feedback and power supply of the PCB. Thus the device now is a passive component on which the tester can conduct its library of tests.

Table I shows the comparison between in-circuit and functional testers.

Some PCBs passing out of in-circuit tester may fail in functional tester. This may be due to the fact that some devices on the PCBs might be of the wrong specification or slow in speed. These factors are sometimes important to get the ultimate desired function.

In an MPU, it is not necessary that we should test PCBs with in-circuit testers first and only then with functional testers. PCBs, after assembly, can be straightaway sent to functional testers. Whatever boards pass out of functional testers can be sent to final assembly and unit test. Boards not passing functional test may be sent to in-circuit tester for detailed fault diagnosis. But this procedure may sometimes

TABLE I
Comparison between In-circuit and Functional Testers

Characteristics	Functional Tester	In-circuit Tester
PCB assembly test	Performance verification	Manufacturing verification
Fault detection	Leads to engineering and manufacturing analysis	Leads to manufacturing analysis only
Fault finding	Done at nodal level	Done at component level
Go/no-go test time	Fast	Slow
Fault diagnosis time	Slow	Fast
Timing sensitivity	Critical	Non-critical

cause costly mistakes because if a few PCBs with some circuit shorts are tested functionally, omitting in-circuit testing, it may lead to total failure of the PCBs. Hence, PCBs after assembly should be inspected for shorts and opens before feeding them into functional testers.

Some manufacturers of automatic test equipments (ATEs) combine both in-circuit testing and functional testing methods and produce a single system which is becoming popular in recent times. In some cases, it is a necessity. For example, a microprocessor can only be tested in-circuit on a functional level.

Let us now see a few types of test systems available.

System 1. A hybrid in-circuit tester 30/330S from Fairchild provides 639 hybrid test points. It performs testing for shorts and opens of analogue components and SSI, MSI and LSI digital components.

An automatic test program generator, an LSI test compiler and a debugger for easy modification of device routines earmarked for special testing requirements are included in the tester. It includes a minicomputer with 256k bytes of main memory, a disc drive, a programmer's keyboard and display, an operator's console with a printer, and a test-fixture receiver.

System 2. A combined in-circuit and functional tester made by Computer Automation can be used to test PCBs containing LSI, VLSI and microprocessors. 32k words memory, floppy disc drive and display unit are included.

A comprehensive software package that includes computer guided fault isolation (GFI), fault detection verification (FDV) and automatic fault isolation (AFI) is also available.

The emulation-simulation option can be used to generate user's own test programs. The analogue option is required to test analogue and hybrid PCBs. High-speed clip option permits faster and more accurate testing of sensitive and high-speed PCBs by minimising cross-talk and loading. Advanced fault resolution (AFR) option isolates and identifies any faulty component by part number and location. Real-time option permits high-speed testing of microprocessor and LSI-based boards.

System 3. Fairchild's in-circuit tester, Model 4400 can take care of 4000 test points. Its high-speed test sequence isolates and identifies shorts and opens in seconds. The tester can learn all typical parametric values easily, though the very first board should be typical and error-free. The tester learns about the PCB itself by 'self-learn program'. There is a pincheck software to verify good contact between fixture pins and PCB nodes. This tester can be used to inspect bare boards also.

System 4. A functional tester for performance verification tests boards for component to component interaction and isolates dynamic failures. Its automatic live data compression option can handle LSIs and VLSIs at full speed. Flo-tracer option isolates faults to the component level at high speed.

When selecting in-circuit and functional testers in addition to the specific needs of a particular unit, the following points should also be considered:

1. Today's PCBs are larger and denser. For achieving greater productivity, the testing speed should be more.
2. 'Self-learn program' facility is a necessity. Program generation speed should be more.
3. Technical knowledge required with the operator should be of low level.
4. The testing system should not demand that analogue and digital circuits should be on separate boards. It is a fact that modern packaging advantages do not allow this separation.
5. Production yield and test yield should be studied.
6 Will the system test complete spectrum the testing personnel normally come across? A satisfactory answer to this question is a must.
7. Expandability and adaptability are yet other points deserving study.

Signature analyser

Signature analysis technique was evolved to help component level troubleshooting. A signature analyser detects and displays the unique digital signatures associated with the data at the nodes in a PCB under test. By comparing these actual signatures to correct ones, a troubleshooter can quickly backtrace to a faulty node.

Whenever a designer makes a relatively complex digital equipment, it is his or her responsibility to add signature analysis capability into the equipment. Then a signature analyser in the production line can troubleshoot PCBs quickly and make mass production of complex digital equipments possible.

Signature analysis capability facilitates customer support since one will be able to provide a quicker field service. Signature analysis stimulus can be given to a product in two ways. It is either by adding some test features to the product itself in the design stage or by providing an external stimulus. By the first method, the designer includes guided-probe capability.

Signature analysers can be of manual or automatic type.

In the manual type, signature tables and procedures for backtracing faults are given in the handbook. The manual unit displays the signatures only. It will not prompt the technician while backtracing faults.

An automatic signature analysis system (SAS) made by Hewlett Packard, HP55005A, consists of a programmable signature multimeter, a desktop computer and the software to knit the two together. The production engineer has to establish an electronic database for the MPU product into the SAS.

It contains a listing of ICs and pin number for the entire product, along with a network listing of the intercorrections among those pins and all their associated signatures. To establish the database, the production engineer selects the learn mode from the main menu of the troubleshooting program and through it enters the stimulus description, instrument setup, collect, verification, and verify-and-revise modes. In the stimulus description mode, the user simply enters a two line prompt to tell the technician which stimulus routine to use.

In the instrument setup mode, the basic troubleshooting system configuration is described by selecting from a menu. From the choices available, the engineer selects the polarities of the start, stop and clock signals as well as the appropriate threshold voltage levels for the data-high, data-low, clock, start, stop and qualifier signals.

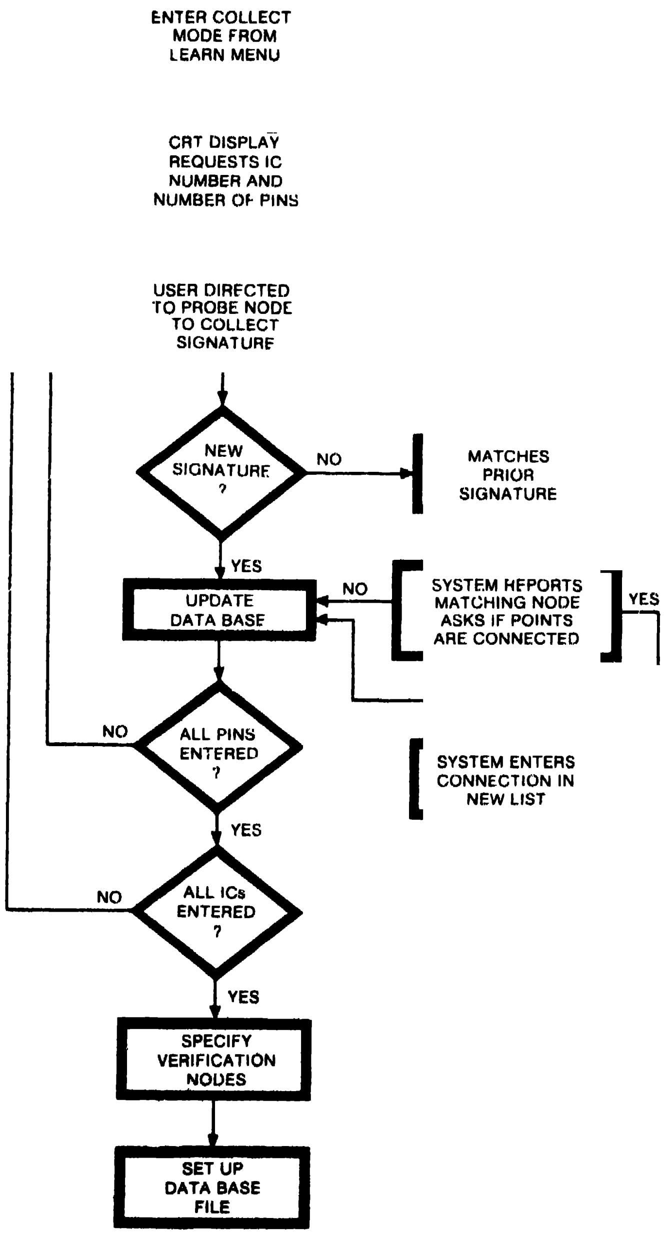

Fig. 10: Preparing database for SAS collection mode.

In the collect mode shown in Fig. 10, the number of pins on that device are specified. As each pin is entered, it is designated as an input, output, power supply, or ground pin. At that point, the actual measurement of signatures on the product begins.

A signature is taken for the pin and automatically entered into the database. If that signature matches one already stored in the database, the software asks if that pin is connected to the pin with the matching signature. If the answer is yes, then the connection is automatically entered into the circuit topology description. The repetition of this process builds up an entire description of the circuit topology as well as the measurement of a signature for each mode in the product.

When the collection process is complete, the engineer enters the set of critical verification nodes which often indicate the status of an entire section of circuitry, such as input/output pins, data or address buses. Once the circuit database exists, reprobing the product is done in the verify mode to ensure that the signatures at the circuit nodes correspond to those in the database.

Whenever the product under test is changed, the corresponding database may be edited in the revise mode, which lets a part of the database to be revised without having to recreate the entire base. Full editing capabilities are also available during the initial establishment of the database in the other modes.

Database can be created for a number of PCBs or products by storing the nodal maps on a diskette or tape car-

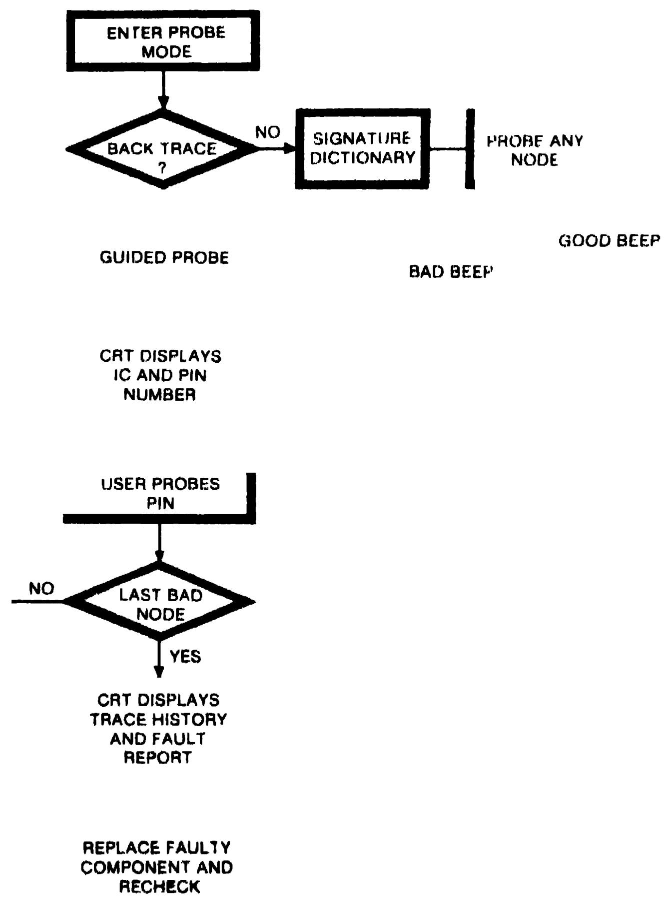

Fig. 11: SAS probing faults.

tridge. This way, there is no need for maintaining separate device libraries in SAS; the SAS creates its own signature dictionary once a nodal map is entered.

Now, let us see how to use the SAS to troubleshoot a board for which a database has been entered earlier (Fig. 11). The user will have two modes to choose from: the signature dictionary and the backtrace modes. In the signature dictionary mode, the SAS generates two types of beeps a good beep for the correct signature and a bad beep for incorrect signature. Hence, the user need not see the CRT display in SAS at all.

If the operator comes across a bad signature, he selects the backtrace mode of the SAS to trace the faulty component. In this mode, the user is prompted with the help of the CRT display to probe a set of points in sequence, tracing a trail of bad signatures back to the bad circuit node.

The user can also choose the backtrace mode directly. The SAS will first direct to probe the critical verification nodes. When a signature is found, the backtrace algorithm searches the database for those points that influence the node containing that signature. It then directs the user to probe those points by displaying the IC and pin numbers of the points to be probed on the computer's CRT. If all the input points affecting an output have good signatures while the output itself has a bad signature, then the user has found the faulty node.

In an MPU, one will not have time to look up signature tables and decide about backtrace steps. Also, human error will creep in if the signature on the display is misread. These two facts associated with manual signal analyser, influence the manufacturing manager to add an automatic signature analyser in the production line. Signature analyser is thus very useful in an MPU producing microprocessor-based equipments.

Data acquisition systems

A modern data acquisition system would make a series of events take place, make measurements that can ensure certain qualities in those events, control certain other events according to the results including alarms, keep a record of happenings, and periodically report to a central database.

A data acquisition system is a computer-based system which can measure outputs of thermocouples, flowmeters, strain gauges and similar transducers. It has digital inputs and outputs. D/A converters are necessarily available. Measurement speed of 4500 channels per second is possible. Measurement and display resolution of 6½ digits is available. The desktop computer attached automates the system, stores data, linearises transducers, and provides computational and analysis facilities. A 20-channel reed relay assembly provides low level guarded switching. High-speed scanning of 4500 channels is achieved with FET assemblies. A non-volatile real time clock is available to time the system. Softwares like operational verification programs, system sub-programming routines and typical application programs are provided.

It is not necessary that a computer should be exclusively connected to a data acquisition system. A computer already in use for operations like inventory control can become the host for a data acquisition system.

A sequential events recorder can be incorporated as a part of data acquisition system. One of the sequential events recorder available today has 128 channels recording the occurrence of digital events like contact openings and closures to within 1 ms. A software option tells the equipment to print a listing of events prior to a program listing trigger event, and then to continue listing backlogged events following the trigger. Another option is to present colour-coded, 64-character single-event descriptions, at 20 events per frame, on a multicolour CRT display.

Sometimes it is necessary to have a dedicated data acquisition system situated very close to the processes to be controlled. This is the case with processes with severe environments where degradation in signal quality can be expected if it is taken to a host computer which is far off.

Nowadays, single board microprocessor-based data acquisition systems are available. For example, a commercially available system with a 8085A microprocessor, 6k bytes of ROM and 1k byte of RAM provides input protection and isolation, cold junction compensation for thermocouples, sensor linearisation and scaling. It checks alarm limits and senses contact closures. A variety of measurements can be made.

Burn-in tester

Nowadays, most of the equipments or PCBs are burnt at an elevated temperature for a number of hours which can vary from simple 1 hour to 96 hours. The equipments or PCBs are kept operating at a temperature which is much more than the normal working one. Due to this, all devices will be required to operate at their extreme specification limits and any failure at this stage would amount to avoiding a potential field failure. In case such a tester is used in MPU, it has to be automated.

A typical tester carries a Z80 microprocessor-based controller. There is a keypad and 24-digit display with which the operators can set various burn-in cycle programs and check the status of the equipment in the burn-in chambers. If the tester is connected to a host computer, burn-in cycles can be set and monitored from a central location. The host is capable of downloading such instructions to the controller memory as the sequence of on-off states for power supplies, temperature settings and the duration of burn-in.

The burn-in cycle can be divided into ten different phases with variables being redefined for each phase. In addition to logging burn-in events, the host computer keeps up with the use of individual burn-in boards by means of serial numbers and protects the user from the use of faulty boards. Also, it has got a 5-hour battery backup to save burn-in programs in RAM chips during power failures.

Tester for backplane wiring, harness assemblies and cables

A typical tester will allow a backplane with about 2000 points to be tested in seconds. Typical speed is 500 test points/sec. The tester is microprocessor-controlled and entries are through a keypad. To start with, a correct backplane, harness assembly or cable is connected. Equipment is switched to self-learn mode. Once the equipment has programmed itself, it is ready for mass testing. Test sequence can be edited. A 14-character display is available. Apart from internal memory, provision for cassette memory is also made. There is a 20-column thermal printer attached to automatically print out errors.

This tester is ideal for an MPU producing equipments with complex wired assemblies.

Discrete component tester

A computer-controlled unit to test all common discrete components bipolars, diodes, switching diodes, rectifiers, darlingtons, FETs, SCRs, triacs, diacs, optocouplers is available. Dual floppy disc storage with optional cassette backup is provided.

Programmable controller

As defined by the National Electrical Manufacturers Association, a programmable controller is a digital electronic apparatus with a programmable memory for storing instructions that implement specific functions such as logic, sequencing, timing, counting, and arithmetic to control machines and processes.

A programmable controller is broken down into five major sections, each of which may reside at different physical locations or together under one housing: the CPU, program memory, I/O modules, power supply and programming device. The CPU scans the I/O modules to determine the status of the switches and values that the modules control as well as the program memory to receive instructions. It then generates appropriate control commands to the output devices on the I/O modules. Process or machine-status information is continuously fed to the CPU via the I/O modules' input sections.

Common programming devices for the programmable controllers include CRT terminals, keyboards, and other manual programmers with keypads, and thumbwheel switches. The switches employ alphanumeric displays that allow the programmer to follow program steps as they are entered into memory.

Available systems can now handle anywhere from 4 to more than 8000 points. Memories can range in size from 250 to over 1000k bytes, and words can be 8, 16, or 24 bits wide.

Clip-on DC milliammeters

One should be able to measure current faster without physically cutting a circuit line and inserting a current meter. For this purpose, clip-on ammeters are available which, with a transducer, convert the magnetic field around a conductor to AC voltage proportional to DC current. They are available with wide range, as much as 1 mA to 10 amp.

Digital displays

Instruments with digital display offer the following advantages compared to their analogue counterparts:

1. Results are read faster.
2. Readings are accurate and less ambiguous.
3. Good resolution is possible.
4. Operator fatigue is virtually avoided to make minimum errors.
5. Readings can be noted from a distance.

In an MPU, usage of digital display equipments will definitely give better results.

Digital multimeter

Usually, all the digital multimeters available have auto-range, auto-zero and auto-polarity capabilities. With auto-range, one can avoid the need to change the range multiplier and auto-zero eliminates the need to zero the multimeter prior to measurement. Without the inconvenience of reversing test leads, the operator can measure both positive and negative voltages, with the auto-polarity circuit included in the multimeter.

Multimeters which can dispiay 3½ digits to 6½ digits are available and can be chosen according to specific requirements.

Some manufacturers make multi-input multimeters which have a thermal printer also. By pushbutton selection, all parameters can be digitally measured, one by one. Printer gives out readings at will. It can automatically scan, measure and print any parameter at preset time intervals.

Digital LCR meter

This is used to measure inductance, capacitance, and resistance parameters of components.

The instruments available today do not require the operator to do any tedious balancing as in older instruments. They offer high accuracy (like 0.2%), both 120Hz and 1kHz measurement frequencies and high measurement speed (as high as 4 per second). Most instruments have autoranging capability.

Digital IC tester

One of the commonly available IC tester has the following facilities:

1. For testing any IC, first the corresponding program card given by the manufacturer should be inserted into the unit.
2. A single unit can test almost all IC families, i.e. ECL, CMOS, TTL, HTL and DTL. All logic gates, arithmetic logic ICs and ROMs can be tested.
3. The tester not only conducts functional tests on the ICs as per their respective truth tables, but also the DC paramet-

ric tests.

4. All tests are automatically done.

5. A printer prints out details regarding whether a program is loaded correctly and what program it is. Also, it records the number of failed and passed ICs and provides failure analysis information for each failed IC.

6. If program cards are not available for some special ICs, their testing can be programmed by the users.

Dedicated instruments

By dedicated instrument we mean an instrument which serves only one purpose continuously. This way, virtually no adjustments and settings are required to be done before the measurement. There is nothing called setting time with this kind of instruments. They contrast with multipurpose instruments. Although multipurpose instruments will in general be cost-effective, dedicated instruments will save a lot of time and labour compared to multipurpose instruments. This point must be considered when one plans to make or buy instruments for an MPU.

Also, all strategic equipments and machines should be made available in number and adequate spares should be stocked. That is to say that one should be able to put back a defective equipment into operation faster so that downtime will rarely become a significant factor.

Software for testers and production aids in MPU

Manufacturers of automatic test equipments and automatic assembly equipments generally supply software with different utility objectives. When buying such equipments two things should be kept in mind:

1. Present software requirement should be fully met by the equipment supplier.

2. Not a day passes without the introduction of at least one new device. The new devices find their way very quickly into new products. The test equipments are required to test these products also. Hence one should see whether software for these products can also be prepared without much difficulty and modification.

Frequent modification of software may end up in software costing more than hardware!

Device engineers are always trying to bring out chips which can do more functions and they accommodate stringent performance needs of equipment designers. The result is the birth of complex devices and for testing these, complex software is required. Since time available for preparing this software is limited, people have started resorting to computer-aided design (CAD) techniques for preparing it.

Most of the automatic test equipments employ a software called automatic test program generator which generates test vectors and supplies fault-detection and isolation data. A typical automatic test program generator is shown in Fig. 12.

The program generator has all major combinational logic devices like NAND, NOR, AND, inverter etc, and sequential logic devices like latches, flip-flops etc. ROM and RAM devices are listed as primitives of the system.

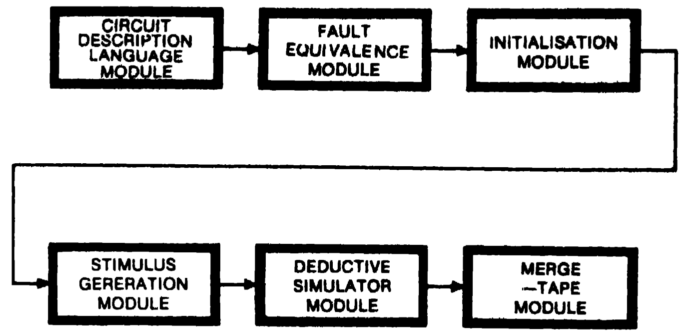

Fig. 12: Automatic test program generator.

The circuit description language module accepts the user's description of a circuit to be tested which is presented in the form of connections between ICs, listed as primitives. This module checks syntax to verify that the user has followed the system's language standards and then creates database topology tables for subsequent processing in the system.

The fault equivalence module identifies failures and organises them into fault equivalence classes. Each class comprises a group of failures whose responses are indistinguishable from one another; that is, their failed response is the same. Processing by equivalence classes rather than by individual failures significantly reduces computer storage requirements and speeds up failure handling. From this module come the digital topology and failure-universe data that are necessary to generate a test program. Successive modules employ that data to perform their functions.

The initialisation module, as the name indicates, generates appropriate input stimuli that place all sequential devices in a known state.

The stimulus generation module includes a path-selection and path-priming algorithm for simplifying subsequent failure propagation to an output pin. A functional set-up algorithm automatically generates tests for counters, shift registers etc. This program is the heart of the automatic test generation process itself, i.e. it contains a backtrace procedure that creates a test for the candidate failure, and a forward-trace process that propagates the failure to a primary output along a previously selected path.

The merge-tape module formats the test and isolation data and writes onto magnetic tape. Now the program generation is complete.

We can see that the software automatic test program generator can also be used for design verification and testability of a circuit prior to manufacturing it. The circuit description language module identifies errors in IC interconnections. The stimulus generator module provides patterns for inputs of devices and prompts an output response for these inputs for the designer to study.

(To be continued)