AUTOMATIC TEST EQUIPMENT

IC1
Patt.
Step

Midata 560 Test :: Pin Data
1 Pin Failed
stopped on STOP inst

72   75

CLK
#f113 6
ABUS

A2
#k81 32
A0
#k101 30
DBUS   C3   55

M1
#k84 27
RD
#f111 21
RESET
#k28 26

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Preface

First, an explanation of terms. Often, writers use terms such as *system under test* (SUT), *board under test* (BUT), *device under test* (DUT) or *unit under test* (UUT) to describe both appliances being tested and measurements taken. This is rather indiscriminate and ambiguous. As it is a specific function of an appliance which is always measured by test equipment – and not the appliance itself (you can find its height, width, depth and so on in the appliance specification!), I refer to the quantity being measured as the **measurand**: a term regularly used in the field of study of electronic instrumentation. I refer to tested systems, printed circuit boards or devices individually.

Electronic test equipment has come a long way since the days of meters and basic oscilloscopes. It used to be that testing of appliances was just a case of measuring a few independent analog measurand parameters such as voltage and current amplitude, frequency and time relationships and so on, at a small number of points. Generally, parameters could be measured one at a time, without problems.

Typical modern appliances, on the other hand, are of a microprocessor-based system nature and demand testing of a large number of digital and analog parameters at a correspondingly large number of points. Additionally, parameters are often so interdependent their values only have significance when monitored in relation with each other. Thus, measurements must be taken simultaneously and in real-time.

Trends in electronic test equipment naturally reflect this change and Figure 1 illustrates the general move from single-time, single-measured test instruments to multi-time, multi-measurand instruments. Simple analog and digital meters represent basic equipment, capable of performing a single measurement at a single time. Oscilloscopes extend measurements by performing them over a period of time. Dual- and four-trace oscilloscopes allow a small number of measurements to be made over this period. Logic analysers take this facility two stages further: first, by

Single measurand,
permanently
available

Time

Analog
digital
meters

Single repetitive
measurand, single
period of time

Time

Oscilloscope

Two repetitive
measurands, slightly
different periods
of time

Dual trace
oscilloscope
with trace
delay

Non-repetitive
measurands

Digital
storage
oscilloscope

Multi-measurands,
non-repetitive,
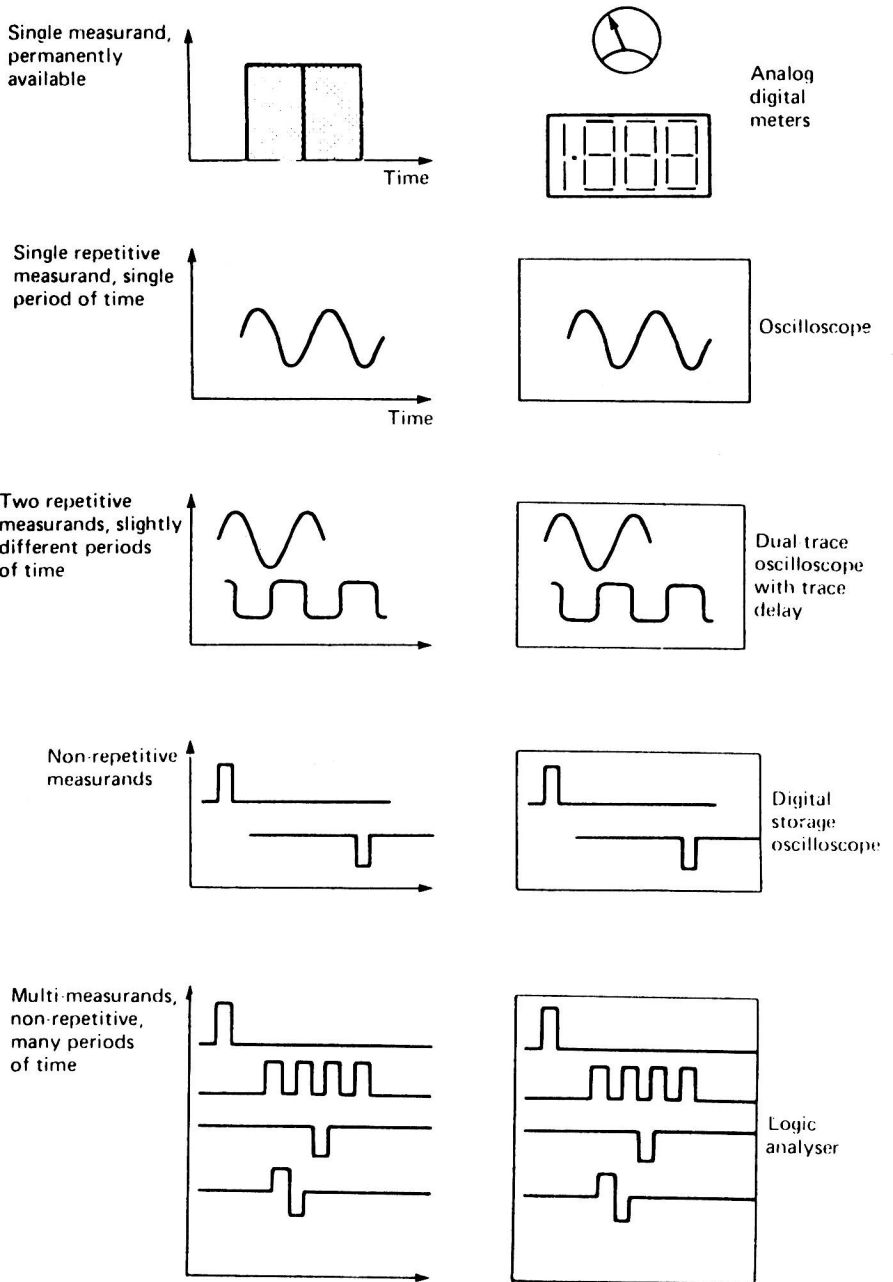many periods
of time

Logic
analyser

Figure 1   *Trends in modern electronic test equipment correspond to a
general move from single-time, single-measured instruments to multi-
time, multi-measured instruments*

allowing a large number of measurements to be made over the period; and second, with recent developments in logic analysis, by allowing a large number of measurements to be made over a number of time periods.

In all these instances, however, a user effectively controls test equipment functions. Consequently, limits suggested here are not, in fact, test equipment limitations but human limitations. It simply becomes increasingly difficult to correlate all the information regarding the many measurements modern test equipment is capable of taking and, in many instances, is even impossible. Where test functions still remain humanly possible test procedures often take so long as to be uneconomic.

Which brings us to automatic test equipment (ATE); capable of doing all the measurements and tests we require, then presenting test results in a requested format – quickly and economically.

My main purpose in writing this book is to demystify automatic test equipment. Existing literature on automatic test equipment is not often written in a clear manner. There are reasons for this – the people who write about automatic test equipment must be the people who understand the topic; and these are usually engineers who look at automatic test equipment from inside-out. However, engineers are not renowned for high qualities of authorship. Other main sources of literature are worldwide standards. These, though, do not *explain* automatic test equipment; instead they merely formalize its component parts. From any existing literature therefore it is impossible to ask the question, *'What is automatic test equipment?'* and find a satisfactory answer. Automatic test equipment is a mystery simply because of this.

Tackling the situation from outside-in, on the other hand, as a writer (with engineering qualifications) trained as a technical author and journalist, I hope I have been able to explain concepts and standards in a much clearer way, passing on my understanding of the topic more successfully. This I hope I have been able to do without shirking technical considerations.

This book is for anyone who has an interest in automatic test equipment. Anyone in the industry who needs to know what types of equipment are available; what each type is capable of doing, what tests are performed, what computer buses are used, what the buses are capable of, and so on will find answers here. Managers, engineers, technicians, scientists, students, teachers, graduates, those in purchasing positions will benefit. It is a general-purpose book, which explains concepts: but is a reference book too, which defines specifications.

I have attempted to organize the book in a reasonably logical manner. My intention in this respect is to allow readers of whatever technical ability and specific knowledge to be able to use it. Chapters describe in successively greater details aspects covered, more generally, in earlier chapters. Consequently, it's a good idea to read from the beginning through to the

end. However, that's not to say specific details cannot be accessed immediately, by turning straight to whichever chapter is required. Further, a glossary of important terms and considerations of automatic test equipment systems is included. This is, of necessity, a fairly involved glossary. After all, automatic test equipment is quite involved, itself. Names and addresses of important organizations in automatic test equipment are included, as is a list of books, articles and papers for suggested further reading.

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Contents

1 What is automatic test equipment?

Automatic test equipment comes in many forms. Indeed, it is difficult to define *precisely* what the term automatic test equipment means. Lowest common denominator suggests automatic test equipment to be any item of test equipment controlled by a computer. Yet this, in itself, is not totally complete because some items of test equipment have an internal computer (in microprocessor form) to monitor and control certain functions automatically, making the equipment easier to use.

Thus, an instrument such as a spectrum analyser could feature automatic control of functions such as frequency scan, centre frequency and resolution bandwidth: it is an example of an **automatic test instrument**. It is not necessarily, however, what we class as automatic test equipment.

Most modern automatic test instruments are **programmable**; they feature an interface allowing their internal microprocessor (and hence their measurement functions) to be controlled by another computer or microprocessor. Usually most, if not all, measurement facilities of an automatic test instrument may be set by a computer via this interface, and measurements taken are similarly relayed back to the computer for correlation and display. When a computer is used to control one or more programmable automatic test instruments the resultant system is what we know as **automatic test equipment** (ATE). This difference is important: automatic test instruments are devices capable of performing and displaying measurements autonomously or in a system; automatic test equipment is a complete measurement system, consisting of one or more automatic test instruments and a computer controller.

Automatic test equipment requires computer control to ensure correct operation, record measurements, correlate vast amounts of measurement data, and present data in a form understandable by human users. In effect, users no longer *directly* control automatic test equipment (although users must still program the computer which *does* control it) and most, if not all, functions are automatic.

Measurements are not limited by users: any number of measurements can be performed in any number of time periods. For example, the user of an analog voltmeter has great difficulty in taking and recording even one measurement a second. Programmed automatic test equipment may take, record and display as many as, say, one thousand measurements in the same time. Alternatively, automatic test equipment may take and record one measurement every second for the next thousand days – non-stop and accurately (without food, drink or sleep!).

Types of automatic test equipment

There is a large number of types of automatic test equipment. These types are defined, basically, by the way they set about testing products. Is power applied to the product? Are external inputs applied, as if the product were in its real-life application? Can individual components within the product be tested, in isolation from all other components? It doesn't take many questions like these to show there are almost as many pure types of automatic test equipment systems as there are manufacturers of automatic test equipment systems. After all, each manufacturer likes to include at least a few features which define its automatic test equipment system as being different, better, cheaper, than the rest.

Fortunately, this large number of types can be generalized into only a handful of categories. These are described in Chapter 2.

Fixtures

Any automatic test equipment system must be connected to the product it is to test. How this connection comes about is usually a matter of electromechanical interfacing; via connectors, probes and so on. Those parts of an automatic test equipment system used to interface to products are given the name fixtures and some basic types exist. These basic fixture types, and some possible future types, are discussed in Chapter 3.

Test strategies

Obviously, the earlier definition of automatic test equipment: a programmable, computer-controlled system, is a basic one. It leads you to reason that such a system is all-encompassing and may, simply by changing the program, be used to perform any measurement task. This is not, of course, the case; you would not use top-of-the-range automatic test equipment costing, perhaps, £1 million to measure resistance of a resistor. That is the test equipment equivalent of using a sledgehammer to crack a nut.

In the other extreme you would not expect a cable harness checker to be able to tell you what is wrong with the mother-board of a malfunctioning nuclear-tipped missile guidance system. Although in the story David won, it would take an even greater fluke to beat Goliath, here.

These two examples serve to illustrate the need for an effective **test strategy**, which carefully plans and defines an organization's requirements for automatic test equipment. A test strategy can not only help an organization to choose the correct type of automatic test equipment for its technical purposes, but also shows the most economically suited solution. This may be a considerable advantage, where equipment can be as cheap as just a few thousands of £s up to a few millions. Test strategies, costs and, indeed, even the reasons for need of automatic test equipment are discussed in Chapter 4.

Test methods and processes

Part of this test strategy an organization must have, is a definition of individual tests which must be performed on products, and a consequent understanding of processes which those tests must follow. Definition of required tests depends almost totally on the products to be tested. Products should be assessed in quality terms: likelihood of failures; where failures are likely to occur; abilities of personnel involved in design to make products easier to test, and so on. Factors such as these have direct relevance to the test processes and, hence, test strategy used. Test methods and processes are discussed in Chapter 5.

Basic methods of creating automatic test equipment

There are three basic methods of creating automatic test equipment. First, a unique system may be designed and made, specifically for the purpose. Figure 1.1 shows an example, capable of taking a number of measurements of voltage and current, while counting events, measuring frequency, distortion and frequency response, and monitoring signals on a data bus. Output from the device to the appliance being measured is a swept sine-wave signal. Control of the various measuring facilities is provided by the microprocessor-controlled heart of the device, which in turn is controlled by programmed instructions from the user. This type of automatic test equipment is, in fact, a computer system complete with the necessary input and output units to allow measurements of the various measurand parameters of the appliance tested. Recording of the values of these measurand parameters and the format of the correlated information again depends on the user's programmed instructions, and is displayed either on a monitor or hard-copied onto paper with a printer.
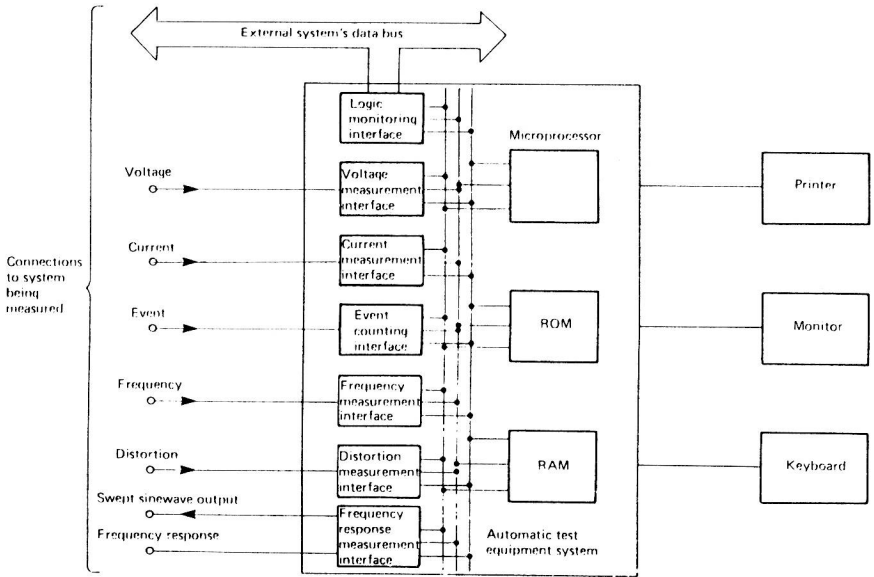
Figure 1.1   *Turnkey automatic test equipment system, in which equipment is a unique device, built for one application*

Such automatic test equipment is known as a **turnkey** system. It is a custom-built *device*, likely to be quite expensive in terms of initial capital outlay, can generally only be used to test one particular appliance and will probably be used to test electronic appliances (such as printed circuit assemblies) manufactured in vast quantities. In such a situation high capital outlay is justified against higher reliability it gives the manufactured appliances.

Second, microprocessor-based computers may be used to control general-purpose automatic test instruments such as meters, universal counter timers, logic analysers and signal generators, treating them as peripheral devices, as illustrated in Figure 1.2. In this method each peripheral test instrument performs measurements on the system being tested under central computer control, relaying readings to the computer which records and displays the correlated data onto a monitor or onto paper. As in the first method, the user controls overall system operation with programmed instructions.

This method gives a custom-built automatic test equipment *system*, still quite expensive but which can be adapted to allow its use in other test applications. Thus more than one particular appliance can be tested, so the system will most probably be used to test electronic appliances, say, manufactured in quite small quantities (with the knowledge that the system
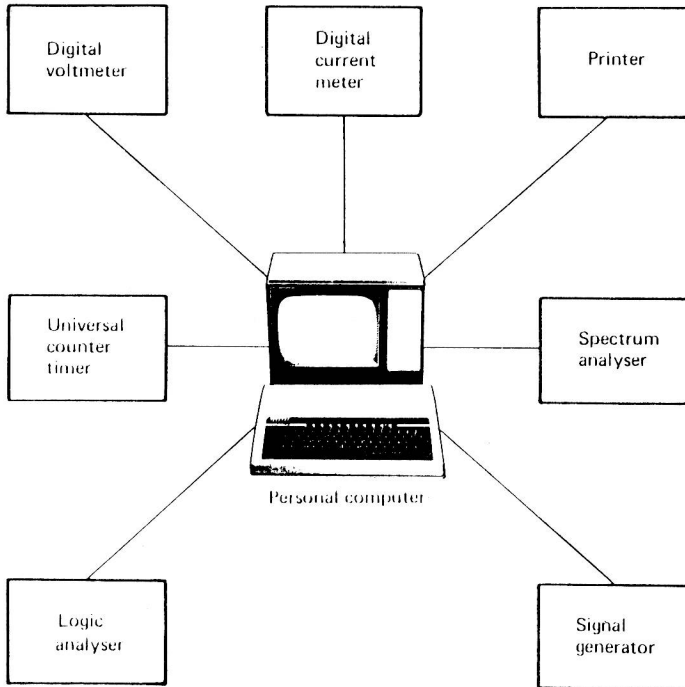
Figure 1.2 *Rack and stack automatic test equipment system, in which a personal computer or any other microprocessor-based computer is used to control programmable readily-available test instruments*

can be easily adapted to suit other applications as and when necessary). Often an automatic test equipment system along these lines is called a **rack and stack** system.

In practice even the first method can usually be adapted to test more than one appliance, as a modular design approach is often used which allows the user (or at least the automatic test equipment supplier) to change measurement modules and software to suit other applications. These two methods are merely simplified representations of extremes of automatic test equipment design philosophy. In the first method, the range of test instruments is built into a complete computer-controlled device; in the second method the range is simply a collection of individual but interconnected instruments, controlled by a central computer.

If a number of instruments are to be controlled by a single, central computer it makes sense if each instrument's two-way interface to and from the computer links to common data and control buses. Connections between individual instruments and computer are simplified enormously – often wiring is simply a matter of linking instruments with ribbon cable, as
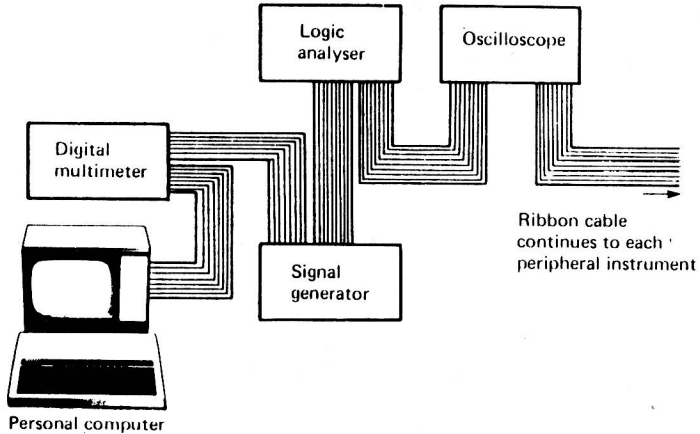
Figure 1.3   *Another method of creating a rack and stack automatic test equipment system, in which instruments and controller are connected with common data and control buses*

shown in Figure 1.3. Bus structures for automatic test equipment make corresponding systems very flexible as extra instruments may be added with little fuss, and changing system test requirements is simply a matter of changing instruments and reprogramming computer controllers. There are, needless to say, many bus standards in use, and main types are discussed in Chapter 6.

Rack and stack automatic test equipment systems' use of central computer controllers with peripheral instruments points the way to the third method of making automatic test equipment. Recently a trend has developed, building on the automatic test equipment bus principle, in which the bus is controlled not by a stand-alone computer but by a purpose-built, standard-sized computer controller. Further, peripheral instruments under computer control are also standard-sized and in modular form. A major benefit of this trend is that a single housing may then be used to hold all instrument modules. All functions and features of each peripheral instrument (including power supply) are controlled and adjusted by the computer via the buses.

Obviously system cost can be much lower (estimated at around one-third the price of an equivalent non-modular system) and overall size is considerably reduced (about one-tenth the equivalent non-modular system). A modular system ensures an automatic test equipment system is easily adaptable to future requirements: when a different system is needed, unwanted modules may be taken out of the housing and new modules simply slotted in.

Another important benefit is the extremely high data rates which may be allowed with a purpose-built bus, a factor important where a large automatic test equipment system, with many measurands and programmed steps, is required.

For want of a better generic name, such automatic test equipment systems may be called **modular** instrument bus systems.

On a broad outlook, the method used to make automatic test equipment is irrelevant. Although each has its advantage and disadvantages which guide prospective users to choose one particular method to suit a particular application, in the end each method of construction is there to do but one job – to test manufactured products. The method used to make the automatic test equipment needed to test the products a user manufactures is simply a means to that end.

A comparison of automatic test equipment system types

In reality, of course, all automatic test equipment systems constructed by whatever method are organized around computer-controlled instrument bus systems. Table 1.1 is a comparison of all three methods, giving details about each part of each system type.

Such is the importance of the three methods of making automatic test equipment, however, now and in the foreseeable future, that the last three chapters in this book discuss specific ways these three methods are usually (not always!) organized – detailing important characteristics and attributes. The usual way rack-and-stack automatic test equipment systems are organized is with an interface bus known as the **general-purpose interface bus** (GPIB), which is discussed in Chapter 7. A common interface bus used to organize turnkey automatic test equipment systems is **VMEbus**, discussed in Chapter 8. Modular automatic test equipment systems are most often organized around the **VXIbus** interface bus, discussed in Chapter 9.

Advantages of automatic test equipment systems

In many instances, use of automatic test equipment systems is a foregone conclusion. Where manufactured appliances are complex, human testing ability is stretched beyond its possibilities. Here the advantages of automatic test equipment systems are taken as a matter of course:

- More measurements – all measurements in an automatic test equipment are performed automatically, with a consequent increase of speed, so it is possible to increase the number of measurements made.
- Greater accuracy – many errors may be introduced in manual test equipment systems, often because measurements are taken once, at a

Table 1.1 Comparing automatic test equipment systems of three main types

Automatic test equipment method	Instruments	Bus	Controller	System
Turnkey	Often purpose-built May be modular	Often specific to system May be a standard bus	Specific to system	Custom-built device
Rack and stack	Individual	Standard bus (e.g. GPIB) May be specific	Often a personal computer	Custom-built system, adapted devices
Modular	Modular May be purpose-built	Standard bus (e.g. VXIbus)	Often specific to system May be personal computer	Modular, off-the-shelf, integrated