automated measurement systems

Complete testing of integrated circuits may require fifty or more measurements under varied stimulus and load situations. When thousands of devices must be tested, problems become formidable and it is obvious that sophisticated, automatic measurement systems are required. Where fewer measurements on a lesser number of devices are to be made, simpler systems can perform the same tests—and at economical per unit cost rates.
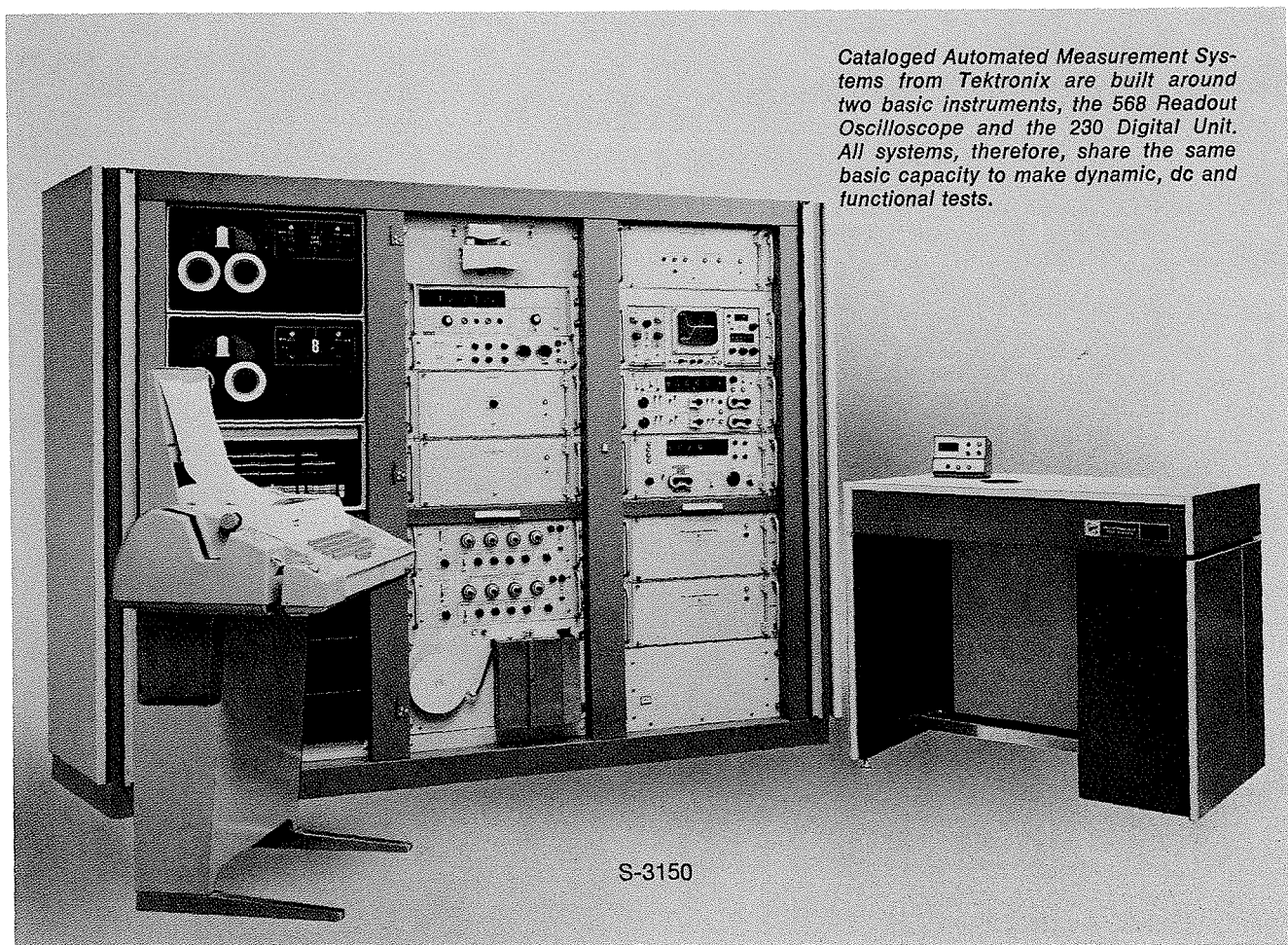

Cataloged Automated Measurement Systems from Tektronix are built around two basic instruments, the 568 Readout Oscilloscope and the 230 Digital Unit. All systems, therefore, share the same basic capacity to make dynamic, dc and functional tests.

S-3150

Automatic Measurement Systems by Tektronix, Inc., simple or sophisticated, are all able to make the same measurements. Measurement repeatability between sophisticated and simple systems makes it possible to correlate results between systems. Now the development lab and manufacturing plant of the integrated circuit producer and the integrated circuit user can make the same tests, using the same basic measurement package and their results will correlate.

Tektronix manufactures a number of automatic measurement systems used in integrated circuit, semiconductor, and board testing. These systems all are built around the same basic measurement package. Differences are in fixturing, stimulus, handling and programming. Sys-

S-3110
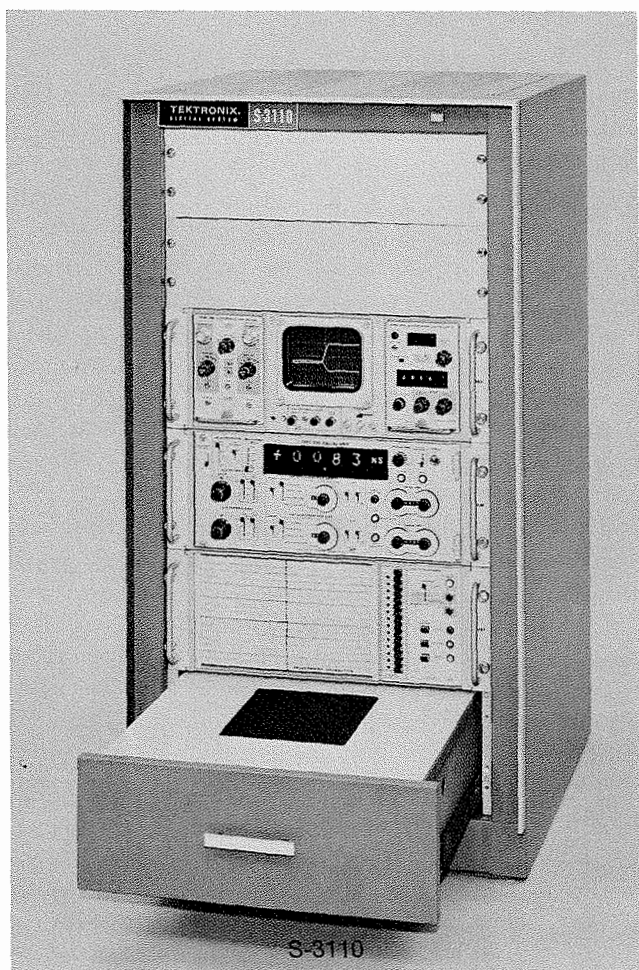
tems by Tektronix, Inc. are built using standard catalog products, supplemented with products from other manufacturers. Since both systems and their components are catalog products, many options and choices are open to the user.

Choice One—Purchase a fully operational system with catalog specified performance. Catalog systems are assembled, tested, and, in the case of the more complex packages, installed by digital systems specialists. Training for systems support personnel is available at no extra cost.

Choice Two—The Tektronix Automated Systems group can add custom measurement capacity to standard catalog systems. A significant number of delivered systems have been tailored to individual customer needs by modification or the addition of products of other manufacturers. Custom systems can include dvm's, power supplies, stimulus sources, fixturing, handlers, etc.

Choice Three—Systems components can be assembled by the customer. It is occasionally an advantage for a customer to use his in-house system assembly capacity. Tektronix catalog products, used in systems, are readily combined using standard accessories and hardware. It may well be that some Tektronix systems instruments are already in use in-house. Integration of these instruments in customer-assembled systems is very practical. Customers can also expand their existing Tektronix systems by adding cataloged items. A 241 Programmer, for example, is an excellent addition to a bench set up that includes a 568 Readout Scope and 230 Digital Unit.

BASIC MEASUREMENT PACKAGE

The basic measurement package in a Tektronix system consists of a 568 Readout Oscilloscope and plug-ins plus a 230 Digital Unit. The prime function of the 230 is conversion of sampled analog data to digital form. An understanding of the 230 Digital Unit and sampling is the key to understanding how Tektronix systems make measurements.

Sampling was developed to display fast information on response limited devices such as the cathode ray tube. It was found that the conversion of fast, repetitive information by sampling not only provided the technique for analog display, but formed a basis for further conversion to digital form. Digitizing of the analog display formed by the sampling process takes place in the 230 Digital Unit.

Fundamental to the 230 digitizing process is the use of a precise number of samples per CRT horizontal division. The horizontal axis of the sampling scope is scaled in equivalent time per division; therefore, each sample represents an equivalent time period. A group of equivalent time periods form an *equivalent time clock*. For
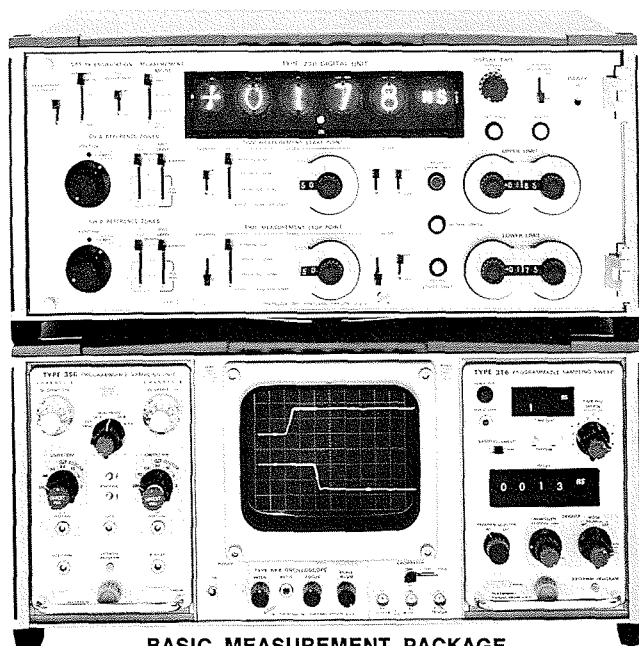
BASIC MEASUREMENT PACKAGE

example, if the number of samples per division is 100 and the time per division is 1 nanosecond, each sample represents 10 pico-seconds.

Many system measurements are of time differences between two levels or percentages of amplitudes. It is a relatively simple process for the 230 to store voltages representative of peak amplitudes on a CRT waveform. These memorized voltages are divided and used to set separate start and stop count comparators. When the 230 is programmed for a period measurement, the count starts at 50% amplitude on the plus (or minus) slope and stops at 50% amplitude on the negative (or plus) slope. The count and scaling of the counted samples (equivalent time clock) provides the digitized value of period. Most 230 time measurements are made with this technique of counting samples between two waveform points.

Voltage measurements require a different, but equally straight-forward technique. The waveform peak voltages stored in memory are used to start and stop a count of an internally generated, 10 MHz clock. The technique used compares a ramp against the memory levels, the resulting count is scaled and presented in alphanumerics.

Time and amplitude data in digital form is also used by the 230 to make decisions as to whether a test result is above, below, or within limits. The readout and limits data is also available for driving external devices such as printers and handlers. The 230's ability to make test result decisions enables less skilled individuals to complete complex tests without using analytical skills. With the 230 Digital Unit and the 568 Readout Oscilloscope, only one more unit is needed to form a basic automatic system. That unit is the 241 Programmer.

FACTORS IN PROGRAMMING A SYSTEM

Any front panel controlled function in a system by Tektronix, Inc. can be duplicated by a program control unit. This generalization applies with very few exceptions. In addition, some system functions are only available through program control units. The degree of programmability and components of the program control group varies with the measurement rate and the number of devices to be tested by the system.

Automatic measurement systems are most used where the same measurements must be made repeatedly. This is particularly true when a large volume of units must be tested. Time required for manual operations are usually more significant than measurement rate in influencing the number of devices that may be tested per hour. The factors influencing time per measurement on a manually controlled instrument system might be arbitrarily listed in descending order of importance when just one measurement on one device must be made:

1. Getting the test system together.
2. Coupling power and stimuli to test system components.
3. Setting up the test conditions.
4. Adjusting instrument controls.
5. Interpreting indicated values.

When more tests on more units are to be made, it is the steps that are repeated often that are candidates for automation.

It is always step 5, interpreting indicated values, that is tackled first in automating measurements. This is so because it is the readout and interpretation process that is repeated in every measurement, while the other time consuming steps are often set up once for a sequence of measurements on the same device. With a simple system, consisting of a 568 Scope and a 230 Digital Unit, we must change the digital unit's instructions to make each of a sequence of tests. It is probable that scope sensitivity and equivalent time controls are only occasionally touched during the same test sequence. Test conditions, stimulus and loads, may seldom be altered. Cabling and test circuitry are often fixed, especially in simple systems. It is the functions of those controls that are most often used that are first put under program control. As more measurements on a greater number of units are required, manual operations are less and less tolerable. In a system like S3150, for example, the insertion of devices and selection or initiation of program are the only conspicuous manual operations.

With one exception, Tektronix systems instruments use parallel, negative logic. A simple ground closure or an applied voltage between 0 and +2 volts represents a logical one. Logical zero is formed by an open circuit

START | STOP
CH B [A] | CH B [A]
HOR mm | HOR mm
% | %
mm | mm
BELOW | BELOW
[ABOVE] | [ABOVE]
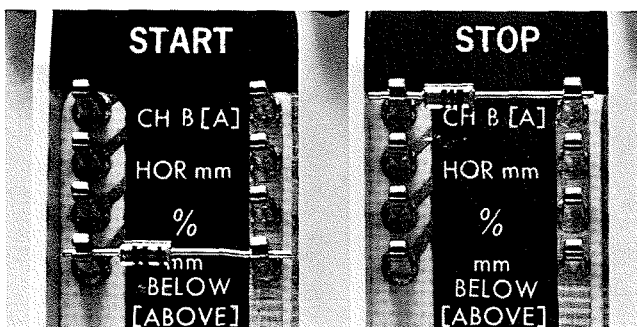
Programming with the 241 is simply a matter of inserting diodes.

or an applied voltage between +6 and +12 volts. A saturated transistor or a closed relay can readily form a logical one. A non-conducting transistor or open relay can form a logical zero.

A common diode to ground can also form a logical one instruction and the absence of a diode forms logical zero. The 241 Programmer works with 15 program circuit cards using diodes and controls the 568/230 basic measurement package in a simple system. In addition, the 241 can program a limited number of functions in the stimulus and/or fixturing areas, including sampling head multiplexers.

Programming the 241 is a simple process. First, set up the system front panel controls for a measurement, then insert diodes on the program card as needed to duplicate that control set up. A test with the card installed in the 241 will quickly prove if the program is correct or if it needs debugging. Any person familiar with the basic instruments can program without special instruction.

When more devices are to be tested, or more than 15 measurements per device are required, a larger number of test programs will be needed. The 240 Program Control Unit with a disc memory, holding up to 1600 measurements, fills the expanded need.

The 240 Program Control Unit converts serial by bit or serial by character program instructions to the parallel form used by systems components. The 240 is used with the 250 Auxiliary Program Unit to control stimulus sources, fixturing, and other systems components in larger systems. A measurement rate of 100 per second is feasible in a system using a 240. The actual measurement rate is dependent on many factors, and sometimes, in actual practice, it is less than 100 per second.

HOW MANY MEASUREMENTS PER SECOND

One factor controlling measurement rate, in dynamic measurement systems using sampling oscilloscopes, is the repetition rate of the stimulus, but stimulus rate limitations usually are not the most limiting factors. Load switching and settling time are more significant. When two or three of the basic tests are to be made, the number of units completely tested per hour is a better indication of system speed than a fast measurement rate emphasized over all the other time consuming operations in device testing.

There are many ways to speed the measurement rate in a system based on a sampling oscilloscope. High speed programs are used to reduce dot density (number of samples), the number of memory charging sweeps, and to end time bases just after a measurement. These techniques speed up the measurement rate by factors more than 10. Handling of devices and fixture reconfiguration usually slows measurement rate below that of the sampling rate. In a system performing all three basic tests, a measurement rate of 50 plus tests per second and a unit test rate of more than 250 per hour is common. Automatic handlers can increase the unit per hour rate (throughput) to 1000.
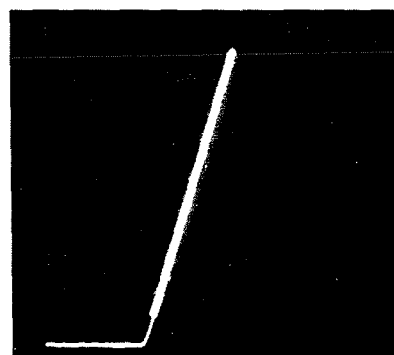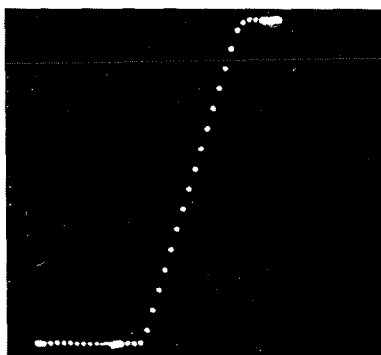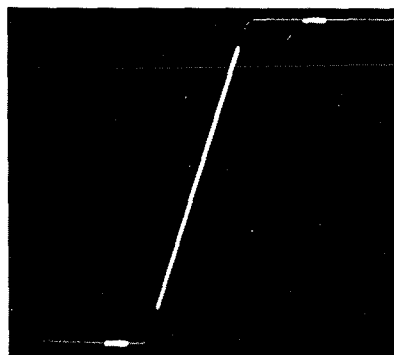
Left — In the absence of high speed program instructions, two sweeps of 1000 samples each are needed per measurement. Center — A single measurement sweep ending after 0% and 100% memories (intensified) are charged requires only 92 samples. Sampling density is reduced except in memory zones. The memory charge sweep is made just once for a number of measurements. Right — A measure sweep ends just after the measurement zone (intensified) requiring only 300 samples. Total time required for this high speed, risetime measurement is approximately 4 milliseconds.
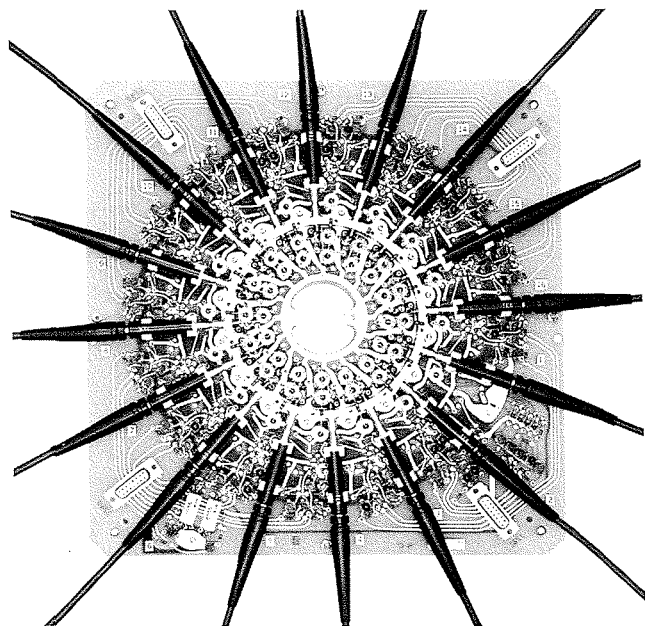
THE S-3150 SYSTEM TEST STATION

The effort required to test one integrated circuit by any of the three methods is not difficult or particularly costly. Problems multiply, however, when great numbers of IC's and tests per IC are added.

There are a wide variety of integrated circuit types available and fifty or more tests must often be made on each device. When the units to be tested reach quantities of hundreds and thousands, connections to the test socket must be automatically reconfigured for many of the tests. This reconfiguration is often by cross bar matrixing in a DC tester, but where device switching speeds are faster than 50 nanoseconds, the cross bar matrix cannot be used because of its excessive capacitance. High speed function and dynamic testing requires a more acceptable switching element.
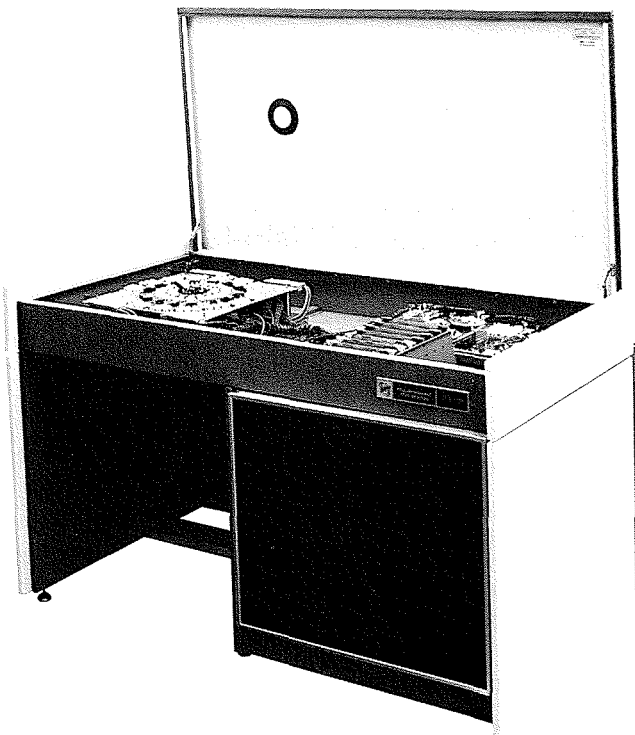
The reed relay proves to be the best switching element. Its low off-capacitance and low on-resistance make the reed relay acceptable in 50 ohm as well as in much higher impedance systems. Operating speeds in milliseconds are practical and life times in millions of operating cycles are to be expected.

The reed has exceptional performance in the nanosecond region. Advantages in capacitance, conductance, isolation and break-down voltages qualify it for the nanosecond environment of S3150 System. It also provides a complete dc matrix for dc and function testing.

A full scale testing system must have facilities for switching load networks. Testing many different integrated circuits requires different load networks and, during a


The Test Station—Here both 10 nanoamp dc as well as 1 nanosecond dynamic measurements are made with only 5 milliseconds required to change test conditions between the two measurements.

One Probe Per IC Pin—The Probe Board of the S-3150 Automated Measurement System is the heart of the IC Test Station. Each pin of the DUT has program controlled individual power and pulse sources with a variety of loads.

sequence of tests, loads must be reassigned to different device pins. In addition, the same pin of a device may be loaded with one network during a turn on propagation delay test and another load for turn off delay. In a TTL device, it may be necessary to switch two or three loads to any pin. In the S3150, each pin has its own set of load networks. Loads are duplicated for each pin to save space and cost while shunt capacitance is minimized.

With three loads available to each of 16 pins, a total of 48 loads are included in an S3150's Test Station. The loads used are usually resistive. Values from 100 to 4000 ohms are used in many cases with 10 to 200 pf shunt capacitances to simulate fan-out loads. Loads and driving sources consisting of semiconductor and integrated circuits are often supplied in addition to passive loads. Naturally, the complexity and lead length of such a system are potentially sources of aberrations. The use of individual loads for each device pin, each with its own reed relay, insures against unacceptable responses.

The S3150's Test Station has the unique feature of a separate sampling probe, dc sub-system, three switchable loads, three switchable power sources, and a pulse source for each IC pin. Very flexible reconfiguration for all testing is achieved in a system that can measure both 10 nanoamps dc current and 1 nanosecond risetime.

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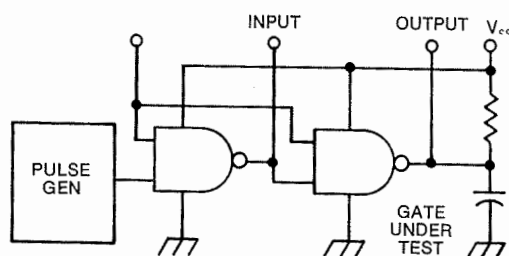# COMPLETELY TESTING THE QUADRUPLE 2-INPUT POSITIVE NAND GATE
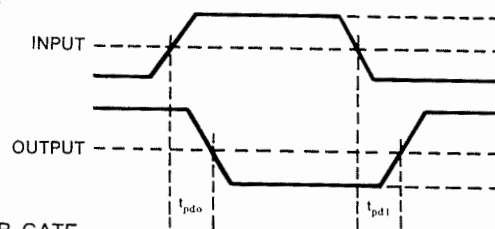## 60 TESTS IN LESS THAN 1 SECOND
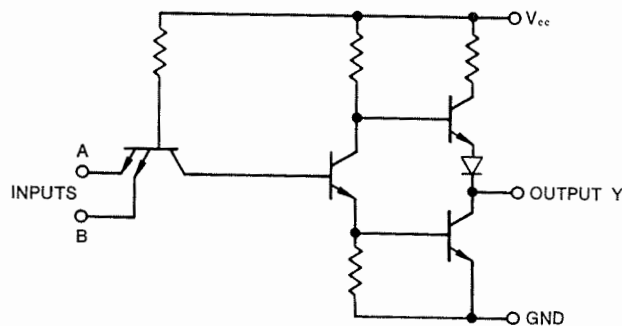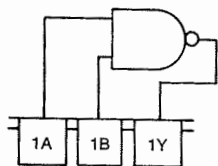
INDIVIDUAL GATE CIRCUIT
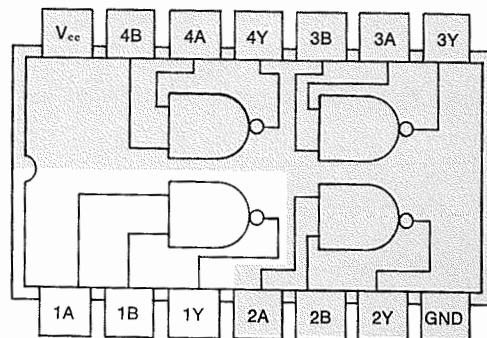
4 GATES ON 1 IC

DYNAMIC

INPUT

OUTPUT

2 PROPAGATION
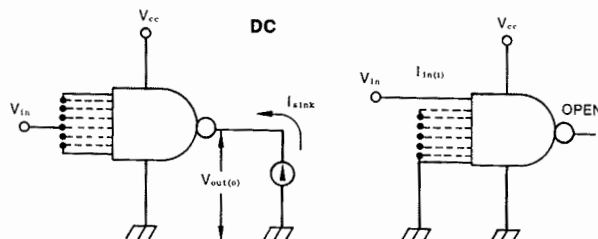DELAY TESTS PER GATE
ASSURE PROPER ARRIVAL TIME OF LOGIC BITS

t_{pdo} t_{pd1}

FUNCTIONAL

POSITIVE
LOGIC
$Y = \overline{AB}$

1	2	Y
H	L	H
L	H	H
H	H	L
L	L	H

4 TESTS PER GATE VERIFY PROPER LOGIC
FUNCTION

DC

9 DC TESTS PER GATE INCLUDE INPUT AND OUTPUT CURRENTS
AND VOLTAGES UNDER 6 CONFIGURATIONS PER GATE

INTEGRATED CIRCUIT TESTING

There is no consensus on how an integrated circuit should be tested. The decision on how to test must be resolved by each user, considering the expected performance of the device he is manufacturing or buying, and the cost of testing or not testing. There are three tests commonly made today: dc tests, functional tests, and dynamic tests. Each type of test has merits and each test has proponents favoring it to the point of excluding the other tests as "not needed".

DC Testing applies steady state voltages and currents as stimuli to the integrated circuit. After a brief settling interval, measurements are made of the response to the dc stimuli. Both input and output parameters are measured while the device is loaded with standard test loads. DC testing, during the manufacturing process, often requires a high degree of measurement accuracy. DC testing by the user, performing acceptance tests on purchased integrated circuits, can be of 1% to 3% accuracy.

Digital integrated circuits are often tested for conformity to their truth table. This is **Functional Testing**. Thorough exercising of a device's logic functions is of value, but often is not sufficient. Functional testing will not reveal excessive leakage

conditions or high saturation voltages. The loading effects of the integrated circuit on other devices are not detected by this test. Symptoms of potential early failure can also be missed completely in the process of function testing only.

Dynamic Testing is testing in the time domain. Another term used for this process is switching time testing. Risetimes, falltimes, and propagation delays of a device are measured in a system based on a digital readout oscilloscope. Dynamic testing was said to be more costly than just dc or functional testing, but dynamic testing combined with dc and functional testing in a single system is economical. It is especially economical when related to the repair and troubleshooting costs that are incurred when defective integrated circuits are not caught before installation in a final product.

Full characterization of packaged, integrated circuits require all three basic tests. Integrated circuit performance is specified in values that can only be measured by a complete system. Specifications are formed from the results of all tests. Users of integrated circuits, therefore, require elements of all tests to assure themselves that the purchased items will perform according to expectations.

SOME EXPERIENCES IN IC TESTING

By Oris Nussbaum
Manager, Integrated Circuits Manufacturing Test
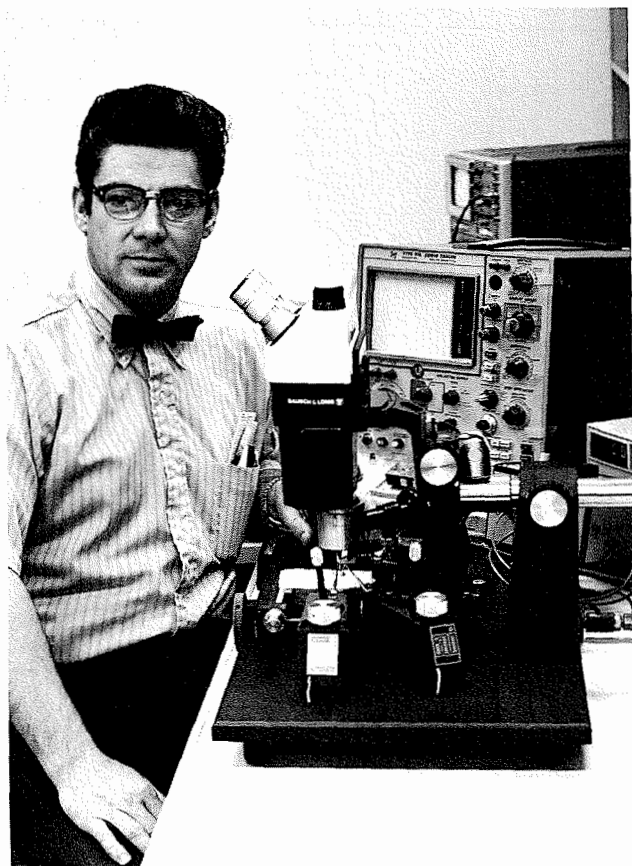
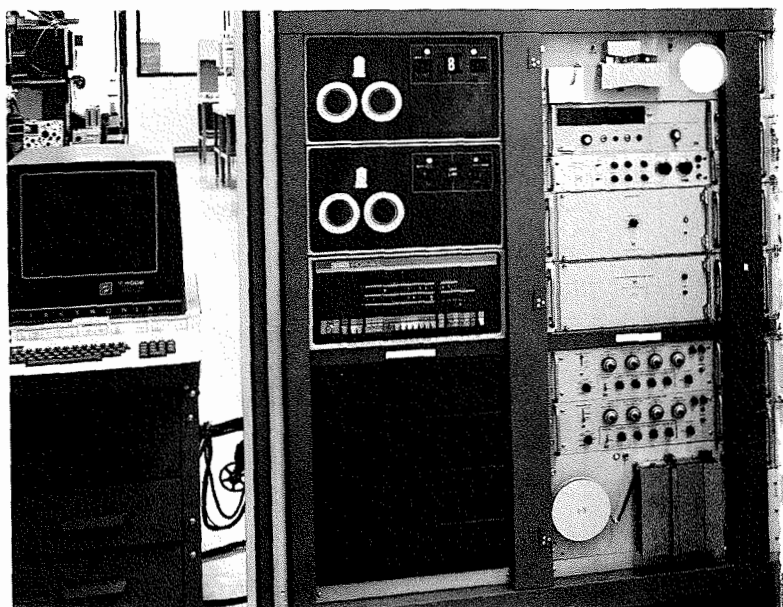We are using integrated circuits in volume and the volume is increasing significantly. All our new instruments are heavily populated with both commercially available and Tektronix developed and manufactured integrated circuits. This commitment in integrated circuits has made it necessary for us to develop testing routines suitable for both integrated circuit manufacturing routines and acceptance inspection of purchased devices.

Our objectives in testing our own manufactured IC's are: 1. Assurance of conformity to design parameters. 2. Reduction or elimination of troubleshooting and repair during product manufacture. 3. Elimination of those devices most likely to fail in service. 4. Reduction of integrated circuit testing costs in manufacturing to less than 10% of the IC production expense.

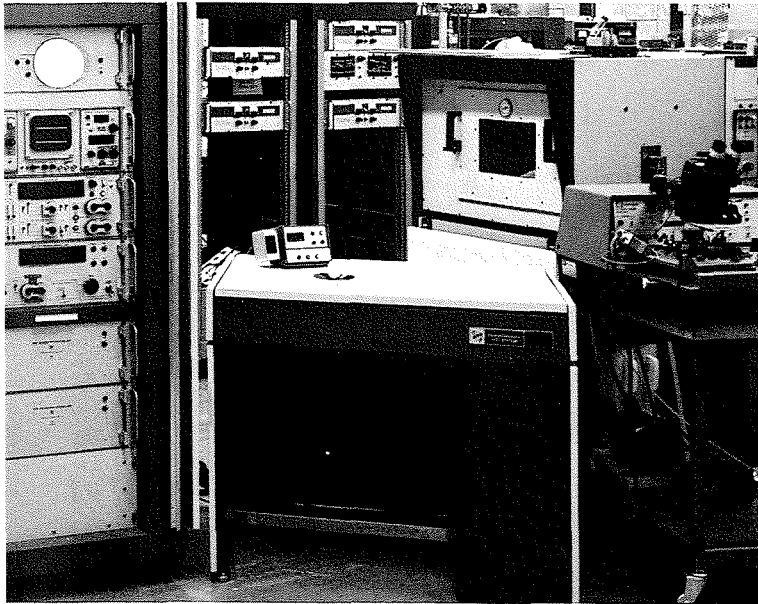Our objectives in testing integrated circuits from outside sources are essentially the same as for internally produced units, except that testing costs are related to purchase price rather than production costs. It has been our experience that extensive testing of purchased integrated circuits is a worthwhile investment in total product quality. We have been performing dc, dynamic and functional tests for more than two years with a Tektronix S3130 Automatic Measurement System. Recently we have added the new S3150 to our facility and both systems are used heavily. At this time the S3130 has accumulated 17,000+ hours of ON time. Although we have the unique advantage of "living" with the source of our systems, maintenance of these systems is the responsibility of technicians from our service group. The reliability of both systems has been excellent.

Presently we are testing 200 to 250 integrated circuits per hour, per system. A typical test sequence consists of more measurements than 50 per device, averaging less than one second from test number one until completion. We find the slowest part of the process is hand insertion of devices in test sockets. To minimize this step, we are adding automatic handlers and expect to reach a throughput rate of 1000 tested units per hour, per system.

The flexibility of the S3150 allows us to use it in wafer probing. At the present time, we are dc testing in the wafer stage. We also make automatic measurements with DUT's in environmental chambers. The S3150's capacity for reprogramming, while regular tests are being simultaneously run, increases the number of units that can be completely tested per day. The S3150 also allows us to data log, analyze data, as well as write programs without disrupting regular testing runs.

In conclusion, it is my opinion that our function of supplying high quality integrated circuits for use in Tektronix, Inc. products would be very difficult without our two automatic measurement systems.

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The Automated Systems department is a part of Tektronix Marketing to keep in close contact with customers needs for special requirements. This is unique in that we function within the company as a purchaser of Tektronix products, a purchaser of other peoples' products and as a system engineering and assembly activity. We provide support for Tektronix Field Engineers and Representatives in their contacts with customers. We can supply a variety of systems composed of catalog products and supported by all our field people. This makes our position a good one.

I would suggest that individuals and organizations needing systems' information talk to their local Tektronix Field Engineer or Representative. He is equipped to answer your questions, provide systems proposals, and help you support any Tektronix System. The support services are of the same high quality of that support available on all Tektronix products. The services are tailored to meet the demand of customers production effort.

We will be at WESCON and other trade shows. If you are unable to attend a system demonstration, contact your Field Engineer or Representative. He can suggest other ways of getting the facts on systems. There is, for example, a 17 minute demonstration film available.

SOME THOUGHTS FROM A SYSTEM BUILDER

By Morgan Howells
Manager Tektronix Automated Systems

New activities are exciting and the activities related to automatic testing of integrated circuits are new. The competition in all aspects of automatic measurement keeps things lively. We have received no easy orders in the automatic measurement field. The customer contemplating an automated system presses hard for factual information on: What can we measure? How many units per hour will our systems process? How much will it cost? How does he keep the thing going? The customer knows the strong points offered by competitive systems and he asks excellent questions. I think I can give some pretty good answers, but more important, I believe I can raise a few questions in return.
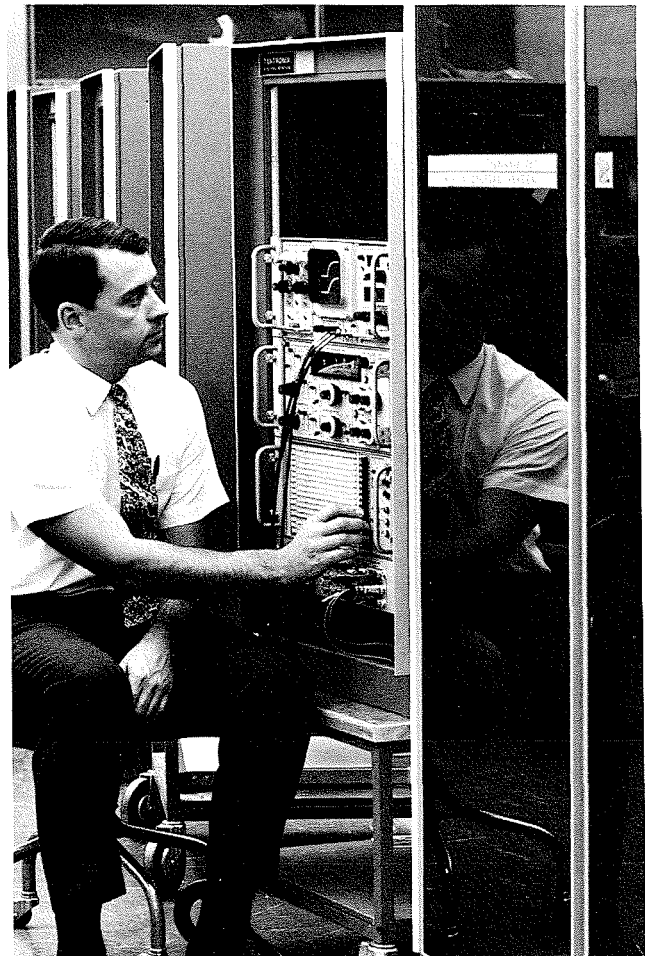
The rough and tumble is all to the good of the industry. The better approaches will survive. Some better approaches are already Tektronix catalog products, fully spec'd and supported. These systems, the S3110, S3111, S3120, S3130, and S3150, meet recognized, consistent requirements by customers. Options to these systems adapt performance to the individual need.

Even with a group of catalog systems, we get requests for special systems—systems that don't exist complete in our catalog. We eagerly respond to these requests. Our automated system department has the capacity to design and build systems to meet many needs in many areas of automatic measurement. Multi-pin IC's, a variety of semiconductors, logic boards, we take a crack at them all.

HAZARDOUS MATERIAL IDENTIFICATION

By Chet Schink, PhD
Manager, Electrochemistry Engineering

HAZARDOUS CHEMICAL OR MATERIAL IDENTIFICATION LABEL

BLUE INDICATES **HEALTH**

RED ,, **FIRE**

YELLOW ,, **STABILITY**

THE NUMBERS INDICATE

THE DEGREE OF DANGER

TOXICITY — BLUE	FLAMMABILITY — RED	REACTIVITY — YELLOW
HEALTH	**FIRE**	**STABILITY**
4 HIGHLY TOXIC OR POISON Produces death in laboratory animals in specified length of time.	**EXPLOSIVE** When subjected to flame, spark, or excessive heat.	**4** SHOCK SENSITIVE Capable of detonation or explosive decomposition or reaction in the absence of confinement under normal temperatures and pressures.
3 TOXIC AND/OR CORROSIVE The capacity to produce personal injury through ingestion, inhalation, absorption or destruction of skin or mucous membranes	EXTREMELY FLAMMABLE Flash point at or below 20°F.	**3** Will undergo chemical change due to ordinary or elevated temperatures and pressures, daylight or artificial light, or capable of detonation under confinement.
2 IRRITANT OR STRONG SENSITIZER Prolonged or repeated contact may produce inflammatory or allergic reaction.	FLAMMABLE Flash point from 20°F to and including 80°F.	**2** Will react with water with release of significant quantities of energy and/or may react with organic materials such as sawdust, cloth, paper, etc. to cause fires.
1 TEMPORARY DISCOMFORT May cause discomfort which is relieved on removal from exposure.	COMBUSTIBLE Flash point above 80°F.	**1** One or more constituents of material highly volatile. Composition & properties may change with time & temperature.
0 No unusual hazard.	NON-FLAMMABLE Flash point – none.	**0** Normally stable.

Everyday exposure to material hazards, particularly chemical hazards, are increasingly a part of everyone's job. Many materials in common use offer little danger but still are not to be lightly treated. Several years ago, we at Tektronix set up an in-plant chemical safety program that has as an objective positive identification and labeling of the specific degree and classification of chemical hazard. To this end, hazardous materials are labeled with a four color, diamond shaped tag. This tag includes the chemical or trade name in a white area near the bottom. The other three colors, blue, red, and yellow, each represent a specific area of safety concern. Blue, for example, represents toxicity—a health hazard. Red represents flammability—the potential for fire. Yellow is assigned to reactivity or stability when exposed to common materials such as water or common events such as jarring shocks. In each colored area a number from 0 through 4 has been assigned, proportional to the degree of hazard. 0 represents a relatively harmless classification. Posters explaining the tag are displayed wherever people are likely to be working with chemicals. Today, that means almost everywhere.

In addition to the Hazardous Material Tag, detailed information is made available through a loose leaf, Chemical Safety Book. One edition contains data based on reports from chemical manufacturers, recognized reference texts,

A conspicuous poster gives further information to Tektronix employees about the Hazardous Material Label.

and medical advisors. (When we are uncertain as to the chemical contents of brand name items, we request details from our suppliers or make our own analysis.) This edition is used by those whose work exposes them to potential harm. An augmented edition of the Chemical Safety Book contains medical treatment information beyond first aid. This edition is available only to qualified medical personnel at our facilities.

The hazard label we use is an adaptation of a tagging system originated by the National Fire Protection Association. The label developed by this group is primarily based on hazards of materials in flame or exposed to heat. Our adaptation attempts to indicate hazards under "normal" use conditions.

We are printing this information in TEKSCOPE for its possible value to those implementing safety practices in their organization. The Chemical Safety Book mentioned is *not available* for distribution since it represents some arbitrary classifications of hazard levels based on our judgments.

CHEMICAL SAFETY DATA

Tek Part No. ▓▓▓▓

Uses: Alkaline cleaner

Hazardous Properties:

Fire Hazard: nonflammable.

Health Hazard: Toxic and corrosive. This material is caustic and is very corrosive to the eyes and skin, if not washed off immediately. Dust and mists can cause serious damage to the upper respiratory tract and to the lungs.

Precautions:

Personal Protection: Use with adequate ventilation. Avoid breathing dust or mists. Avoid skin or eye contact. Wear safety glasses and rubber gloves.
CAUTION: Do not add to solutions that are hotter than 60°C (140°F). ▓▓ generates heat when mixed with water.

Spillage:

Shovel up dry material immediately and flush area with water. Dilute acetic acid may be used to neutralize final remaining traces. If liquid is spilled, mop up with mop or rags. Wash mop or rags in water. Wear safety glasses and rubber gloves. No spillage of this material should ever be left unattended. It is very slippery and someone might slip and fall and be severely injured.

Repackaging and Storing:

Repackage and store in tightly covered containers in a dry place.

Technical Data:

Specific gravity (water=1)   1.14
pH   13

Respirator: AO 30   30 W 600A Monomask

VH:is
2/8/67

EMERGENCY PROCEDURES

Fire: Nonflammable

Inhalation: Remove from exposure. If breathing has slowed or stopped give artificial respiration. Call the company nurse.

Skin: WASH IMMEDIATELY with copious amounts of water. Remove contaminated clothing. Call the company nurse.

Eyes: IMMEDIATELY flush with copious amounts of water for 15 minutes. Call the company nurse.

Internal: Do not induce vomiting. Give two glasses of water or, if available, dilute acetic acid (1%), vinegar (1:4) or lemon juice, followed with milk. Call the company nurse immediately.

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14. Manufacturing Chemists' Assn., Inc. **Chemical Safety Data Sheets.**
15. **National Safety Council Data Sheets.**
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17. **Fire Protection Guide on Hazardous Material.** National Fire Protection Association, 2nd Ed.
18. **Chemical Data Sheets.** Manufacturing Chemists Association, Inc.

TECHNIQUE: *Time measurements to better than 1%*

Your Oscilloscope was adjusted to nearly perfect accuracy during its last calibration—but only on one postion on each time base and one range of the delay time multiplier.

Time base accuracy is often specified as 3%, an uncertainty statement that accounts for worst case system differences over all time base ranges. It is unusual in practice to actually find an error as great as 3%. Often overlooked is that other source of measurment uncertainty: Resolution. Some aspects of specified accuracy and resolution limits are illustrated on this page.
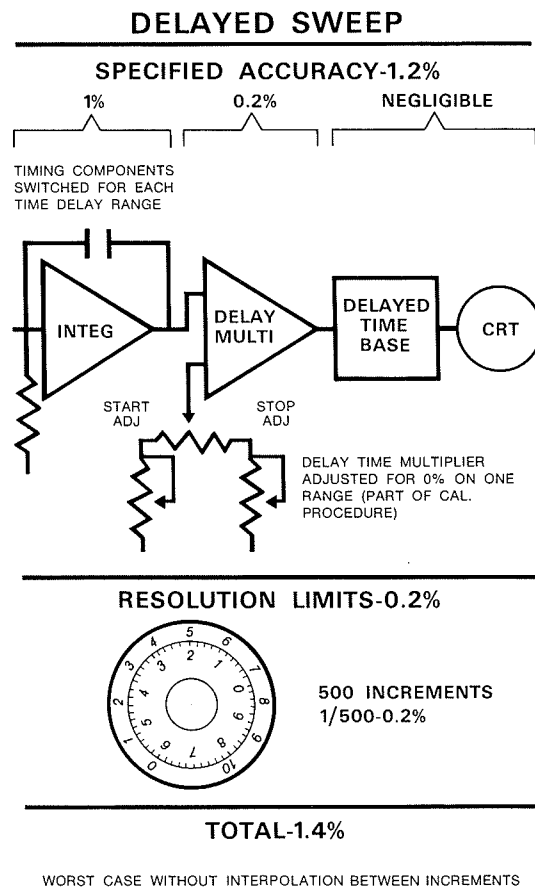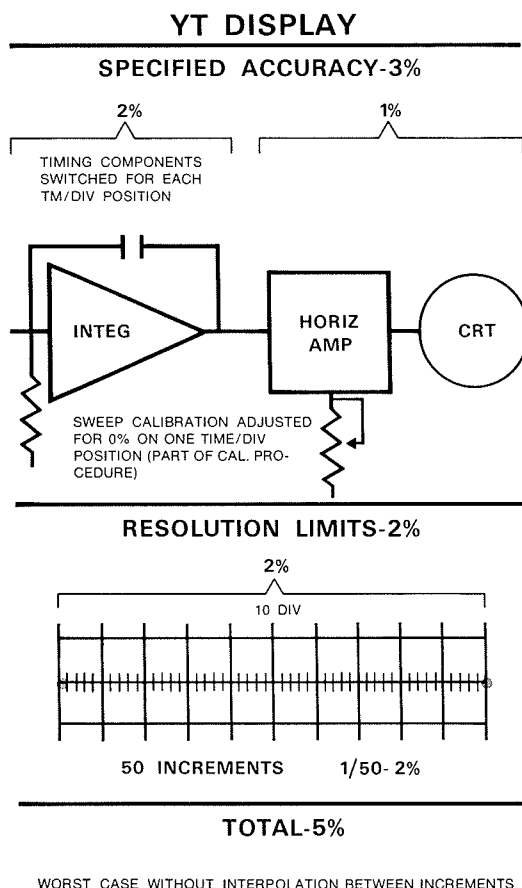
When you must make better than 5% time measurements, resolution uncertainties can be minimized by using proper delaying sweep techniques. To assure better than 1% ac-curacies, on a selected delay time range, a standard period source must be used for verification*. If you find that the specific delay accuracy is not as desired, that range can be adjusted by a knowledgeable calibration technician to be better than 1%.**

Specified accuracies are statements of possible worst case conditions, but in most cases, a well maintained instrument will do much better than specifications indicate.

Tektronix 2901 Time Mark Generator

**A cautionary note: This technique does not conform to standard calibration procedures and if used, the instrument should be tagged with appropriate information. Conformance with the standard manual procedures will assure that accuracy specifications will be met on all ranges. Deviation may result in out of specification results on some ranges.*

YT DISPLAY

SPECIFIED ACCURACY-3%

2%   1%

TIMING COMPONENTS
SWITCHED FOR EACH
TM/DIV POSITION

INTEG   HORIZ AMP   CRT

SWEEP CALIBRATION ADJUSTED
FOR 0% ON ONE TIME/DIV
POSITION (PART OF CAL. PRO-
CEDURE)

RESOLUTION LIMITS-2%

2%

10 DIV

50 INCREMENTS   1/50- 2%

TOTAL-5%

WORST CASE WITHOUT INTERPOLATION BETWEEN INCREMENTS

DELAYED SWEEP

SPECIFIED ACCURACY-1.2%

1%   0.2%   NEGLIGIBLE

TIMING COMPONENTS
SWITCHED FOR EACH
TIME DELAY RANGE

INTEG   DELAY MULTI   DELAYED TIME BASE   CRT

START ADJ   STOP ADJ

DELAY TIME MULTIPLIER
ADJUSTED FOR 0% ON ONE
RANGE (PART OF CAL.
PROCEDURE)

RESOLUTION LIMITS-0.2%

500 INCREMENTS
1/500-0.2%

TOTAL-1.4%

WORST CASE WITHOUT INTERPOLATION BETWEEN INCREMENTS

SERVICE SCOPE

TROUBLESHOOTING THE 453

By Charles Phillips
Product Service Technician, Factory Service Center

The 453 Oscilloscope has become the most widely used instrument in field servicing. It's also a popular lab item. This popularity makes it likely that you will work on one some day soon. When that day comes and a 453 turns up on your bench needing service, normal scope troubleshooting procedures and the manual are sufficient to locate the source of trouble. All of us develop extra problem solving techniques when we work regularly on a particular series of instruments. We come to recognize and look for troubles we have seen before. I would like to share a few experiences and ideas related to the 453, particularly those with serial numbers above 20,000.

TIME BASE

When time base troubles are suspected, the first thing to do is eliminate possible front panel problems. Remember, all four levers up in the A Sweep control area will produce a time base functioning scope. Then push the TRACE FINDER button to reveal a trace. If no trace appears, we must then positively eliminate the horizontal amplifier as the trouble area. To do this, set the Horizontal Display to EXT. HORIZ. Use the Trace Finder and Horizontal Position controls; you should have a spot that can be moved freely across the CRT.

O.K., we have established the trouble is in Time Base A (A Sweep).

Time base generators consist of a gate generator and an integrating circuit. There are a number of auxiliary circuits tied into the complete time base package. Since everything in this package is dc coupled, chasing voltages around a defective sweep circuit can be confusing. Something more is needed to reveal the component at fault and simplify your task. Here are a few techniques that I have found. They get answers quickly.

When a time base generator malfunctions, almost always we have four conditions. That is, the beam is at the left side of the CRT, on or off; or it is on the right side, on or off. If the beam or spot is hung up at the left side, try grounding Test Point 504 (collector of Q504). This should force the integration circuits into running once. You may find it helpful to use a sweep time slower than 0.1 second per divi-

sion to give you time to see a sweep more readily. If you have problems getting a spot on screen, rotate focus to extreme CW position and use maximum intensity. Defocusing will eliminate any possibility of phosphor burn.

If grounding Test Point 504 starts the time base, the spot will hang up on the right after one sweep until the ground is removed. This is a positive indication that D533, Q533 and Q531 are O.K. If the trace brightened when TP 504 was grounded, Q524 and Q514 are also functioning properly.

The most suspect components are D505, Q585 or Q504. With the sweep forced over to the right, a full rundown condition exists at collector of Q531. The voltage at the collector (Pin AA is a convenient test point) should be about 0. This will be coupled through Q543 and D555 the base of Q575 (use Pin N as a handy test point).

The voltage at the base of Q575 should be about 0, and now you should test or substitute D505, Q585 and Q504. Preferably a curve tracer should be used for tests.

When the spot is hung up at the right side of the screen, the integrator circuit has run down, but has not been reset, Q514, Q543 and Q575 are suspect.

There are occasions when you will find a bright spot at the start of an otherwise normal sweep. There is no unblanking and Q544 should be checked. This is not an obvious effect from the schematic.
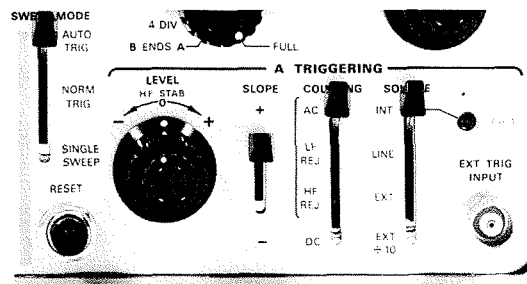
All levers up—A quick way to get a sweep on the 453.

If after the above checks, no active devices are found faulty, I have found that it is usually best to verify the values of precision resistors used in transistor base circuits.

B Time Base (sweep) is very similar to A Time Base. Troubleshooting procedures based on forcing the integrator into action can also be used. Just ground Test Point 704 and proceed as in Sweep A.

POWER SUPPLY

Power supply failures in the 453 can be easy to find. Here are some problems and cures.

Problem: Fuse blowing.

Check: Bridge rectifier diodes with ohmeter. Typically, forward readings will be about 2 kilohms, reverse readings should be high.

Problem: Wrong voltages.

Check: If the bridges are O.K., perhaps an overload condition exists somewhere and the protection amplifiers, built in each supply, are *saving* the supply components from destruction. If the base-emitter voltages on a protection amplifier transistor is high, you have a positive indication that an excess load exists. See the tables for typical voltages and resistance under normal conditions.

Problem: High ripple voltages on regulated supplies.

Check: Bridge output filter capacitor may be open.

Problem: Ripple voltages in excess of specifications, but still relatively low.

Check: Filter capacitor at output of each regulated supply. It may be open.

Problem: Wrong output voltage, (voltage emitter/base of protection amplifier within limits).

Check: Protection amplifier transistor for defect. If supply works properly without this transistor, the transistor is bad, replace it.

Problem: Voltages are regulated but somewhat out of tolerance.

Check: Precision resistance values.

Problem: +12 volt supply output low.

Check: Remove Q970 from CRT high voltage supply. The bridge in the +12 volt supply is the source of unregulated dc for the CRT high voltage supply.

CRT HV SUPPLY

Most scopes use a dc to dc converter to produce CRT voltages. An oscillator is used to convert a low dc level to RF. The RF is stepped up through a transformer, rectified and filtered. A sample of the resulting high dc voltage is fed back to control the oscillator voltage. This feedback is necessary to regulate the whole system.

Problem: No significant voltage at TP —1950 V.

Check: Oscillator may be overloaded, pull lead of Pin L on Z Axis Board. This kills the feedback and the oscillator may work, producing higher than normal CRT voltages.

Problem: Oscillator not working after lead to Pin L is removed.

Check: Remove CRT socket. If oscillator functions, the CRT has a problem.

Problem: Oscillator still does not work with Pin L disconnected.

Check: Lift one end of each high voltage rectifier D952, D940, V952, and V962. This "unloads" the secondary and the oscillator will probably start operating. Test semiconductor high voltage diodes D940, D952, and vacuum tube rectifiers (V952, V962) by replacing one at a time. If this does not work, the H.V. filter capacitors should be checked.

The innovative technician can often build upon the manual and other routine maintenance information. The only thing required is imagination and experience.

POWER SUPPLY

TYPICAL PROTECTION
AMPLIFIER BASE-EMITTER VOLTAGES

SUPPLY	ACROSS	NORMAL VOLTAGE
—12 V	R1129	0.175 V
+12 V	R1159	0.125 V
+75 V	R1187 & R1188	0.375 V
+150 V	--	--

TYPICAL NORMAL RESISTANCES

| SUPPLY	TEST POINT	RESISTANCE*
—12 V	H	80 Ω
+12 V	D	70 Ω
+75 V	B	1 kΩ
+150 V Unreg.	F1204	2.6 kΩ

*Negative lead of meter to ground

TEST POINTS

Where can you hang that scope probe or touch that meter lead? This question is a regular part of servicing. You will find very useful test points built into many recent Tektronix instruments. There are even more "test points" where you find metal case transistors.

Did you know that most metal case transistors have their case tied to collector? It makes for better thermal characteristics and it also allows secure mounting of the chip inside the can. You can use the case as a test point, you can touch a probe, but you probably won't be able to clip on to most cases. The "test point" is also labeled by Q number, making it easy to locate.

Square pin connectors on our printed circuit boards are clearly identified by letters and numbers. These connectors and attached leads make excellent test points. Individual instrument manuals contain schematics and detailed board photographs. These aid in pinpointing the connector location, electrically and physically.

Resistors and other components are purposely mounted with sufficient lead-to-board clearance to attach most probe tips.

Some caution is advised when clipping on to some of the sub-miniature resistors used today; they can break with rough handling.
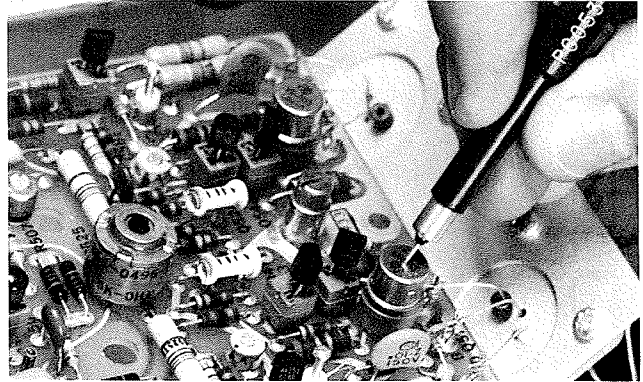
Metal case transistors have easy to reach collector test points—the case itself.

INSTRUMENTS FOR SALE

LC130, 317, 503, 515, 516, several 530/540 Scopes with Plug-ins. Henry Posner, Pacific Combustion Engineering Co., 5272 E. Valley Blvd., Los Angeles, California 90032. (213) 255-6191.

524AD, $450. Larry Lawrence, Lawrence Engineering, Inc., 11965 Beach Blvd., Jacksonville, Florida 32216.

3A72, $200. Mr. Myhre, Mission Engineering, Inc., Hiawatha, Iowa 52233. (319) 393-2253.

565, 3A3, 3C66. Mr. H. Everett, c/o Dr. C. P. Bailey, St. Barnabas Hospital, 183rd Street & 3rd Avenue, Bronx, New York 10457.

127. Pat McCusker, Comsat Labs, P.O. Box 115, Clarksburg, Maryland 20734. (301) 428-4401.

531/53B, 310, 512. Fred Muessigmann, Watson Instruments, Inc., 446 Lancaster Pike, Malvern, Pa. 19335. (215) 647-3777.

547, 1A1. George Schneider, Space Electronics, Inc., 40 Cottontail Lane, Irvington, New York 10533. (914) 519-8681.

535/B, $600. Dr. J. Toole, 27 Sheldon Street, Wilkes Barre, Pennsylvania 18703.

551 with P/S. Plug-ins, D, G, Q. Scope-Mobile® Cart, 500/53A. $1800 or offer. Joe Laub, Unitek Corp., Monrovia, California. (213) 358-0123.

3T77. Les Jacobson, Allen Avionics, 255 E. 2nd Street, Mineola, New York 11501. (516) PI 7-5450.

556, 1A4, 1A5, all $4178. Howard Davis, Silton, 16222 S. Maple Avenue, Gardena, California 90247. (213) 770-0985.

514D. Robert Powers, Stellar Industries, Inc., 10 Graham Rd., W., Ithaca, New York 14850. (607) 273-9333.

181, $100. Dan Wirtz, McGraw-Edison Co., Franksville, Wisconsin. (414) 835-2921.

3—2A63. Make offer. Jack von der Heide, Optron, 50 Fitch Street, New Haven, Conn. (203) 389-5384.

530 Series Scope/1A7A/160 Series/360/1121. Sigmund Hoverson, Physics Department, Texas A & M University, College Station, Texas 77843. (713) 845-5455.

567 Readout Scope, $405/6R1A, $1800/3S1, $900/3T77A, $495/114 Pulse Generators, $288/P6032 Probes, $67.50. John Mattson, Laminar Corp., 222 Plato Blvd., St. Paul, Minnesota 55107. (612) 222-8411.

310A, $600. Mr. Yeomans, Mergenthaler Linotype, 300 Luckie Street, Atlanta, Georgia 30313. (404) 525-7448.

502, $300. John Breickner, Fifth Dimension, Inc., Route 206 Center, Princeton, N.J. (609) 924-5990.

517. Will swap for 15 MHz Scope. Bob Schafer, Midwest Research Institute, 425 Volker Blvd., Kansas City, Mo. 64110. (816) 561-0202, Ext. 374.

63 Plug-in Differential Amplifier, $100. 2B67 Time Base, $200. Roger Kloepfer, (517) 487-6111, Ext. 392.

410 Physiological Monitor. Rudy Kranys, Medrad, Inc., 4084 Mt. Royal Blvd., Allison Park, Pa. 15101. (412) 961-0393.

535A, $700. D Plug-in, $110, A Plug-in, $60. Summers, Simplec Mfg. Company, Inc., 8710 Empress Row, Dallas, Texas 75247. (214) 637-5470.

454, $2500. C-31 w/Pack & Roll Back and 560 Series Adapter, $400. Virgil A. Wiest or Marty Bos, Automix Keyboards, Inc., 13256 Northrup Way, Bellevue, Wash. 98004. (206) 747-6960, Ext. 21.

INSTRUMENTS WANTED

310A, 321A with probes. Mr. C. H. Wexler, Engineering Department, Phoenix Steel Corporation, Claymont, Delaware 19703 (302) 798-1411.

531 with M Plug-in. Stanley Kneppar, Technical Concepts, Inc., 580 Jefferson Rd., Rochester, N.Y. 14623 (716) 271-7953.

3A6. Jack von der Heide, Optron, 50 Fitch Street, New Haven, Conn. (203) 389-5384.

515, 516, or 524. Phil Hester, 546 Evergreen Dr., Corpus Christi, Texas 78412.

3B3 Time Base. Roger Kloepfer, (517) 487-6111, Ext. 392.

7 cm/ns
without prefogging

Photographic writing speed is a figure of merit that describes the ability of a particular camera, film, oscilloscope, and phosphor to record a fast moving trace. This figure expresses the maximum single-event spot velocity which may be recorded on film as a trace discernible to the eye.

The results achieved are a function of the combined system performance of the oscilloscope, camera, film, recording technique, and the ability of the film reader to make a consistent interpretation of the results. Prefogging and postfogging of the recording film improve the apparent photographic writing speed of a particular system but the results are unpredictable and difficult to repeat. Because of this fact, Tektronix specifications are determined without using fogging techniques. Should the user employ fogging, then the writing speed will be increased according to his skill. Writing speed figures 50-100% higher are possible with controlled techniques on *Polaroid Type 107 and Type 410 film.

7 cm/ns is the *minimum* photographic writing speed of the Tektronix 7704 Oscilloscope with P11 phosphor. Writing speed was measured using a new P11 phosphor, a C-51 Camera and Polaroid Type 410 10,000 ASA film. The significance of the fast writing speed specification of the 7704 extends beyond an unparalleled ability to record transient events without fogging techniques—It is now possible to use the readily available, but slower 3,000 ASA film to capture extremely fast transients.

*Registered Trade Mark Polaroid Corporation