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APPLICATIONS OF AUTOMATIC MEASUREMENT SYSTEMS

Testing thick-film hybrid circuits

A Solution to a Measurement Problem for: THE MAGNAVOX COMPANY
Ft. Wayne, Indiana

Testing thick-film hybrid circuits

The full measure of meaning to "state-of-the-art techniques" applies very well to the thick-film hybrid circuit facility at the Magnavox Company in Ft. Wayne, Indiana. Fully functional since mid-1968, the facility employs modern, automated equipment in manufacturing, complemented by a computer-controlled automatic test system for thoroughly testing the circuits.

Magnavox produces thick-film circuits in many different configurations. They are used extensively in military communications equipment and new Magnavox products to reduce size and weight and to increase reliability. These hybrid circuits combine the versatility of discrete component conventional assemblies with the small size and high reliability of integrated circuits. They are constructed of discrete components which are soldered to screen-printed resistor and conductor patterns. The finished circuit is electronically equivalent to a conventional circuit and is particularly suited to analog and high-speed digital applications. Moreover, the low cost per circuit makes it economically practical to replace an entire failed circuit chip in operational equipment.

CONFIGURING THE TEST SYSTEM

Traditionally, Magnavox has devoted a good deal of time and effort to checking and testing its components and equipment. The results of these efforts have earned Magnavox a well-deserved reputation for producing highly reliable products. When the decision was made to design and construct the thick-film manufacturing facility, it was also determined that a final assembly circuit test system should be an integral part of the new facility. *Furthermore, past experience at another Magnavox installation clearly proved that only an automatic test system would be capable of handling the diverse testing requirements of thick-film circuits.* The need for testing was an established fact – it had to be done to show positive proof of performance. The next step then, was to answer the question: what type of equipment would best suit the testing needs?

For its initial requirements, Magnavox needed the control and data analysis capability of a computerized automatic test system that would provide: (1) a broad range of stimuli including voltages, rf signals, and audio signals (2) measurement of dc, ac, and rf voltages, frequency, and resistance, (3) computer-controlled switching of all low-frequency stimuli and measurements, and (4) punched tape and hard-copy record of measurement results, as required. Besides the instrumentation requirements, Magnavox also wanted a test program language that would enable the system to be placed in operation as quickly as possible and, at the same time, be easily learned by engineers and test technicians. Also, since this was just the beginning of a new project, it was considered very important that the system selected be capable of expansion to handle future needs.

Magnavox selected a Hewlett-Packard automatic test system to perform its thick-film circuit testing. The present system configuration, Figure 1, clearly shows that the stimuli measurement, and switching needs are adequately provided. *The initial installation proved to be so successful that it was expanded by adding the disc memory, pulse stimuli, and waveform analysis capability.*

The three subsystems are programmed through the controller. The HP 2402A Integrating Digital Voltmeter is the basic measurement instrument of the system. It accepts analog data, as switched through the crossbar scanner, and converts it to digital form compatible with the computer input. The computer is an HP 2116A with 16K 16-bit words of memory. One of the two teleprinters is located at the test stations where it is used for editing purposes plus hard-copy printout of end-of-lot information. The printout indicates the quantity of units tested, how many passed or failed, and the reasons for failure. The heavy-duty teleprinter, located in the control room, is primarily used for retrieval of detailed lot-by-lot data, circuit-by-circuit measurements, and other information of interest to design engineers. *The automatic test system, then, simultaneously performs two types of testing: (1) go/no-go production testing and (2) testing to obtain 3-sigma points, trends, etc. for pure engineering design purposes.* New programs are input to the system through the high-speed punched tape input. The high-speed tape punch is used to obtain a permanent copy of test results that can be printed out on an off-line teleprinter or used as input for further computer analysis. The disc memory provides storage for test system programs, temporary storage of data, and program swapping. Programs stored on disc are swapped into computer core memory for execution and then returned to disc.

Present configuration of the system allows operation of as many as six test stations. However, through efficient use of instrumentation and very effective computer programming, all thick-film production testing needs are currently being handled by the three test stations shown in Figure 2. At the far left is the functional abrader station (with vacuum hose attached). From left, the cabinets house the abrader computer interface and test instrumentation. The next two cabinets house the special circuits test station and its computer interface, plus some test instruments. At the far right is the automatic handler station and its computer interface equipment. All are electrically identical such that any test can be performed at any station. Each station, however, has its own special capabilities.

Circuits received at the functional abrader are considered to be completely operational except that the resistors have not yet been adjusted to their final values. Each circuit is first given a preliminary test to determine general overall operation. If it passes, the resistance material on the substrate is abraded (with sand) to its final value. Under computer control, the abrader nozzle is routed around the components to the exact location where a resistor should be, abrades that area to form a specific resistance value, and then moves to another position to continue the abrading process. After abrading, the entire circuit is tested again. Thus, in addition to the normal circuit testing at this station, *the abrader performs a process control function as well.* The special circuits tester is designed specifically for testing circuits not readily tested on the automatic handler, such as those involving high frequencies. An operator is usually needed at this station, since these circuits often must be inserted individually into special handlers, or test jigs. The automatic handler station accepts up to 80 circuits on its test table at one time for testing. Under computer control, each circuit is tested as the handler moves from circuit to circuit in a sequential manner.

PROGRAMMED FOR FLEXIBILITY

While the testing requirements for its thick-film circuits are complex, Magnavox has found that actually operating its automatic test system has proved to be quite easy – to a large extent due to the use of BASIC language programming. BASIC has very well satisfied the original system requirement to use an easily-learned programming language. Moreover, in-house experience has shown that the time from initial installation to a fully-working system was relatively short in comparison with systems using other languages. *The benefits realized were two-fold: a greatly reduced initial investment in software, plus the fact that fully-tested circuits were made available to end users at a much earlier date.*

The automatic test system was supplied complete with BASIC-callable drivers for all system instruments. *Thus, Magnavox had only to write individual test programs before placing the system in operation.*

The flexibility of the hardware/software combination has given Magnavox a wide latitude in selecting the techniques best suited to handle its testing needs. A good indication of the amount of work being done by the system can be noted from the fact that hundreds of programs have been written and stored on disc memory, ready to be called into core only when needed for execution. *Thus, the operator looks upon each test station as though it were the only station in the system, and selects any of the test programs desired.*

GENERAL SYSTEM CONCEPT

The thick-film test facility performs its multi-testing functions by sharing the automatic test system's instruments between the test stations; this is done under program (software) control.

A master program, designated program No. 1, links the test stations to all of the programs in the system. When no tests are in progress, this program waits in core looking for a test station to ask for service. If no service is requested, it jumps to the next station. If service is requested, the program asks whether the station wants a printout of the end-of-lot-information (measurement results from a group of similar circuits previously tested at that stand) or whether the station wants to begin testing. If test service is requested, the program directs the switching subsystem to transfer the test equipment to that station, and then jumps to the specific test program requested.

Any of the hundreds of programs available can be requested at any test station. All tests at the requesting station are then run through to completion and, immediately thereafter, program control is transferred to the next station requesting service. Thus, the loops are closed at both the station (with links to and from test programs) and the system (with links between station programs).

RUNNING THE TESTS

Thick-film circuits are received at the test stations before they are encapsulated. All circuits are tested before encapsulation because, in some instances, it is possible to repair a faulty circuit and return it to good stock. After encapsulation, internal repairs cannot be made. All circuits that passed the original tests are encapsulated and tested again. This provides a check against possible failures due to the encapsulation process and, at the same time, offers greater assurance that the circuits will perform according to specifications.

A closeup view of the automatic handler station is shown in Figure 3. The circuits are placed in the test jig and clamped onto the positioning table pin side up. A "performance board" (in vertical position above the circuits under test) routes the various stimuli inputs and measurement outputs between the circuits under test and the computer through the connectors shown attached to the board. Performance boards are available in a variety of configurations, each corresponding to a particular type of thick-film circuit. The proper board is mounted on the handler to match the circuit under test.

Figure 2. Thick-film circuits multi-testing facility is controlled by computer system behind window. Test stations, from left, are: functional abrader, special circuits, and automatic handler.

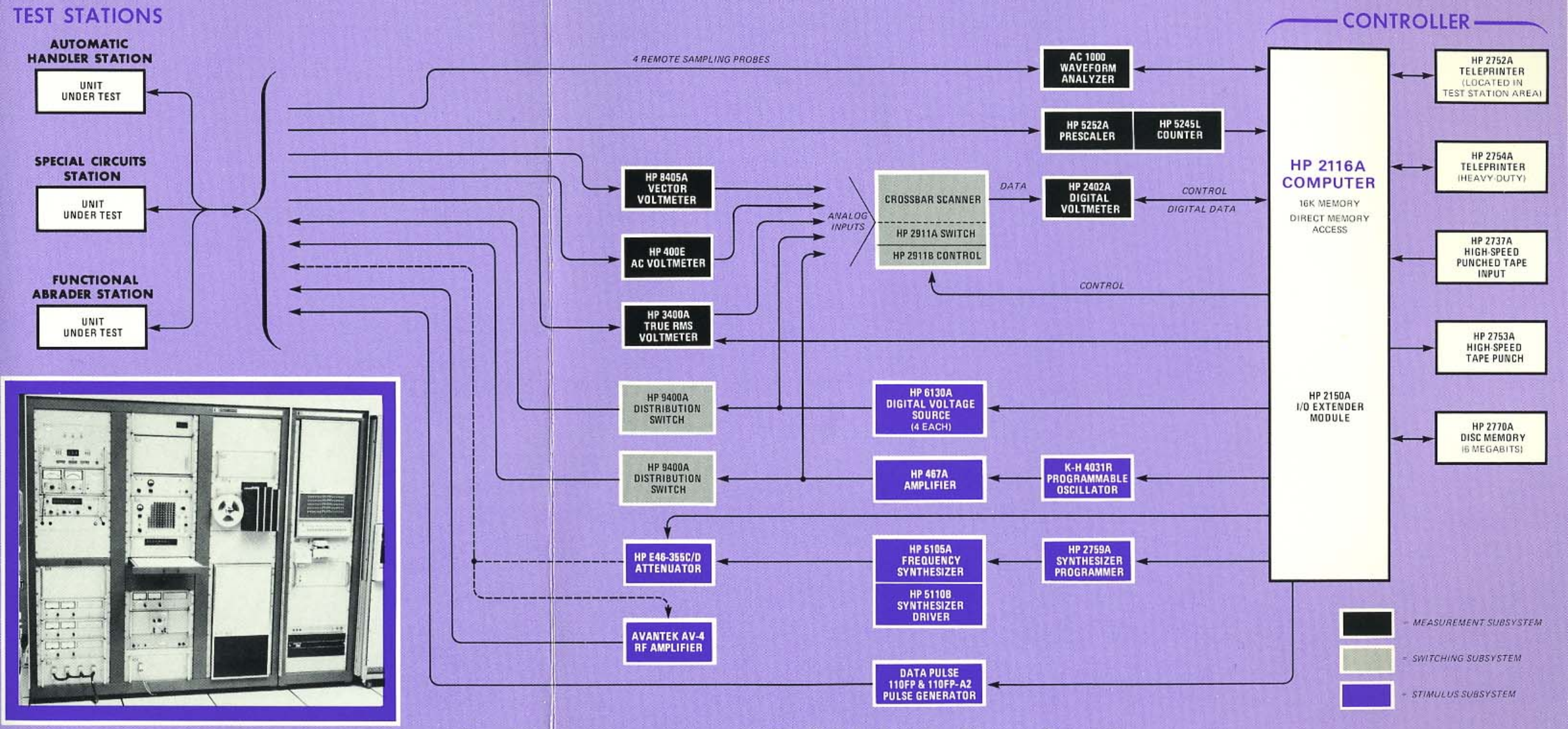

Figure 1. Automatic test system for testing thick-film hybrid circuits at Magnavox. Photo inside the control room shows the computer (top, right) with associated instruments and peripherals.

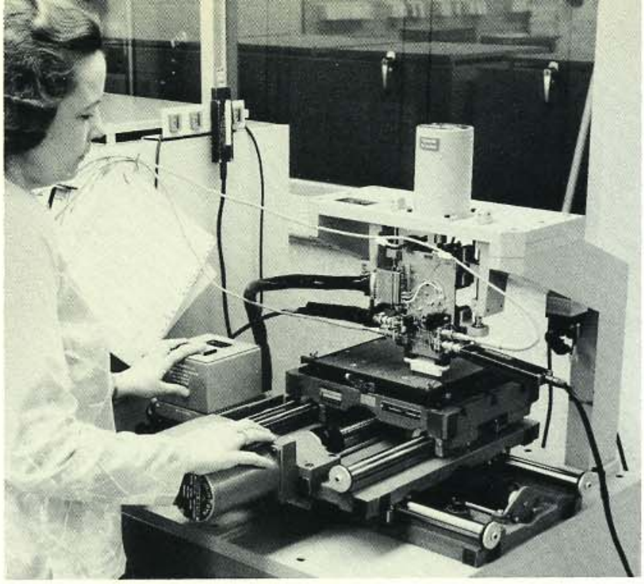

Figure 3. Closeup view of automatic handler test station. Test programs, corresponding to circuits under test, are selected by thumbwheel switches on the test control sequencer (left). Tests proceed without further operator intervention.

To the left of the table is the test control sequencer (built in-house by Magnavox), a digital thumb-wheel device for selecting the test programs desired. When the operator wishes to get the attention of the system, she merely sets the switches to the test number (program code) corresponding to the particular type of circuit. An indicator lamp on the sequencer turns on when that station has control of the system. (Instead of a test sequence, the operator could have set the switches to request a program to print out end-of-lot information only, as mentioned earlier.) The system then responds by transferring both the test program and the 3-sigma lot data, corresponding to the circuit to be tested, from disc memory to core memory. At the automatic handler, testing begins with the circuit in the upper right-hand position and continues sequentially until all circuits are tested. The last circuit tested is followed by three empty test positions. The system recognizes this as an end-of-test signal, and stops the tests at that station.

Utilizing the system's data analysis capability, the test data are extensively reduced and printed out on the test station teleprinter. The operator, then, has an easy-to-read summary showing the quantity of circuits tested, quantity accepted, quantity rejected, and test position number of each circuit rejected along with a reason for failure. Thus, the operator is not burdened with reading a long list of measurement parameters to search for the information needed. On the other hand, if desired, the operator can request a printout of the measurement parameters on those circuits that failed to pass the tests. This flexibility is particularly valuable when performing incoming-testing on vendor-supplied thick-film circuits, as a service for other departments within Magnavox. An example of a summary printout is shown in Figure 4.

CIRCUITS REJECTED; 2-DIGIT CIRCUIT NUMBER FOLLOWED BY A 4-DIGIT FAILURE CODE.

THREE EMPTY POSITIONS; INDICATES END-OF-TEST AND LAST CIRCUIT TESTED WAS IN POSITION 61.

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CHIP TYPE       802
REJECT OR EMPTY POSITIONS
 13.0101        23.0101
 62             63            64
 61 TESTED
 59 ACCEPTED
 2  REJECTED
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Figure 4. Summary printout at test stations enables operator to quickly determine disposition of circuits just tested.

As part of the test program, the computer calculates new 3-sigma points from the circuit-by-circuit and point-by-point measurements just made, and updates the 3-sigma lot data. The updated data is written onto disc, *thus providing an always up-to-date statistical data base for every type of circuit tested.* Magnavox engineers derive very meaningful design information from the trends observed in this manner because *the 3-sigma points often represent data obtained from hundreds of similar circuits.* While the maintenance of a reliable source of 3-sigma statistical data is valuable to Magnavox, it is also of significance to certain military programs which specify that this type of information be furnished as proof of performance. Test results can also be punched out on paper tape whenever a permanent record is desired. This is particularly useful to designers who want to follow trends in new circuits. After completion, the test program jumps back to program No. 1, which transfers control to the next station requesting service.

A CONCERN FOR ACCURACY

Contributing significantly to the successful operation of its automatic test system, is the attention given by Magnavox to overall system accuracy. While all instruments, connectors, cable lengths, etc. are involved, the accuracy of the system is mainly dependent upon the accuracy of its basic measuring instrument, the HP 2402A Integrating Digital Voltmeter. To assure maximum and consistent accuracy of all testing, a DVM calibration check is included in program No. 1. Since this program is always entered after every test (same as saying before every test), the DVM is checked, by means of its internal calibrator, many times during a normal day of testing. In addition, a full internal check of the entire system is run approximately once a month. This test, consisting of a series of tests linked together, can be initiated from any test station. Thus, Magnavox assures its customers, with a high degree of confidence, that all test results represent the true performance to be expected.

BENEFITS OF COMPUTERIZED AUTOMATIC TESTING

Several years of experience has proved to Magnavox that computerized automatic testing provides a significant contribution to the successful operation of its thick-film production facility. Contrasted with the alternative of manual testing, automatic testing is much faster, requires fewer people, fewer instruments, and correspondingly less floor space. Moreover, the automatic system is not subject to human interpretation errors often caused by manually recording instrument readings. The system consistently provides high-quality measurement stimuli to the units under test, giving the kind of repeatability that is virtually impossible to obtain using manual methods. The system's excellent repeatability and accuracy, combined with 100% testing, give Magnavox a high degree of assurance that its thick-film circuits fully comply with customer's specifications. The modular expansion capability and ease of BASIC language programming offer the imagination and ingenuity of the system programmer a wide latitude in determining techniques for possible new applications in the future.

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APPLICATION NOTE 135-19

Printed in U.S.A. 9/72 (06)
5952-1631