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BDX-613-2424

Plated-Through Hole Testing

By W. B. Abel

Published May 1980

Final Report

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DP00613.

**Kansas City
Division**

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PLATED-THROUGH
HOLE TESTING

By W. B. Abel

Published May 1980

Final Report
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PLATED-THROUGH HOLE TESTING

BDX-613-2424, Final Report, Published May 1980

Prepared by W. B. Abel

An improved microresistance testing method to measure the thickness of copper plating in plated-through holes of double-sided printed wiring boards is presented. A new probe design, combined with a microprocessor controller, makes it possible for a direct reading tester to provide variables data. Tester design and software programs for the system are included. Results of correlation studies, comparing the improved resistance method to cross-sectional measurements are presented. Limitations on the microresistance test method are discussed.

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A prime contractor with the United States
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SUMMARY

This development project was initiated to improve the micro-resistance measurement of plated-through holes in printed circuit boards. The intent of the improved methods is to provide variables data of plating thickness. The improvements include a new probe concept, a positioning fixture, and a microprocessor based controller. A discussion of the history of the microresistance method and past development work is included to point out the deficiencies of available testers.

A new probe design was developed to eliminate effects of annular ring size, positioning, and to automatically measure resistance at four separate locations around the circumference of the hole. A special fixture was developed to hold the new probe system, which makes it possible to align the test hole using a microscope. A complex microprocessor/controller system was developed for use with the new probe system. This system automatically collects four resistance measurements for the test hole while averaging and calculating the thickness of plating in the hole. The calculated thickness is displayed as a direct digital readout.

A comprehensive correlation study was conducted to compare the resistance technique to the conventional cross-section method to determine plating thickness. Within the geometric limits established for the resistance technique, the resistance method will predict the cross-section results within 0.08 mils on the average.

It is recommended that the improved microresistance test method be incorporated into the inspection of double-sided rigid printed circuit boards.

DISCUSSION

SCOPE AND PURPOSE

The microresistance measurement technique for evaluating the quality of plating applied to printed circuit boards has been in use at Bendix and throughout industry for several years. During this time much development effort has been directed toward establishing a relationship between measured resistance and plating thickness in plated-through holes. The complex nature of many different geometric configurations of hole diameter and board thickness has limited the use of this technique. At present, it is used in the inspection department at Bendix as a go-no-go measurement to evaluate printed circuit boards. Although this procedure is useful it does not provide feedback to the processing or Quality Control departments in terms of variables data regarding the plating thickness. In addition, samples of acceptable product are destroyed in metallurgical sectioning to verify adequate plating for holes that are close to the specification limit.

The development described in this report was initiated to improve the microresistance test with a new probe design that permits multiple resistance measurements per hole to establish an average value representing all sides of the hole; an improved fixture for accurately locating the probes in relation to the hole being tested; and incorporation of a microprocessor system to control the measurement and to interpret the resulting resistance value directly in terms of the copper thickness in the hole. The discussion of activity will be divided according to those three subject matters which, although interrelated, are essentially separate development activities. The intent is to document the physical and electrical characteristics of the entire system, and to present data from performance studies conducted to verify the system's capability for use in accepting product.

PRIOR WORK

The resistance test for plated-through holes is based on a low-resistance measuring circuit¹ that was later adapted to evaluate plated-through holes². Figure 1 is a photograph of this original prototype which was evaluated at Bendix in early 1970. It was shown that the resistance measurement is sensitive to the thickness of copper plated in the through holes and that cracks and voids can be detected by higher than expected resistance.

Figure 1. Photograph of Original Plated-Through Hole Tester

This early development prompted two commercial firms to produce testers for use by the printed wiring board manufacturing industry. The first was called simply the microhm tester and Figure 2 shows an early model of this device and a closeup of the probe system. A later model incorporated a digital readout of resistance but was otherwise unchanged. During the past five years three different models of the second commercial tester have become available as shown in Figure 3.

The early models of both testers used a constant AC current and probe systems which essentially were of the same design as the original prototype. Experience proved that these features were undesirable. The alternating current was sensitive to other electrical equipment near the tester, and the probe design was sensitive to the annular ring size of the plated-through hole. Furthermore the probe had to be very carefully positioned across the major diameter of the hole to avoid errors in the resistance measurement. These probe configurations, as well as later cone-shaped probes, required several measurements on each hole to get a representative average measurement.

Figure 2. Photograph of Original Microhm Tester and Probes

Tester calibration was based on the assumption that the resistance of a plated-through hole is equal to the resistance of a copper cylinder having the same dimensions. Empirical studies showed that this relationship does not hold true. A study was conducted to establish calibration curves for printed circuit boards produced by the Bendix plating process. Three different thicknesses of boards were used in the preparation of special test boards having hole diameters ranging from 0.03 to 0.110 inches (0.762 to 2.794 mm). The data from the study established acceptance, verification, and rejection limits. A special operating procedure was written for using the microhm tester as a go-no-go measurement instrument in the inspection department. Destructive testing of plated-through holes was reduced to cases in which the resistance reading fell between the acceptance value (equivalent to 0.0013 inch or 33.02 μm) and the rejection value (equivalent to 0.0008 inch or 20.32 μm). This system has been in use for over three years.

Figure 3. Photographs of Commercial Testers

ACTIVITY

Background of Probe Design

To understand the need for improving the probes a brief discussion of the problems associated with past and present designs is included. The first probe designs (used on the original prototype and the microhm meter) were flat and thus contacted the terminal area around the hole at the highest point on the surface of the pad. This condition caused the resistance measurements to vary for a given hole and made them sensitive to the width and concentricity of the annular ring around the hole. This problem was improved by sloping the probe tips so that they more consistently contacted the edge of the hole. Designs which make only

Figure 3 Continued. Photographs of Commercial Tester

one resistance measurement per hole are sensitive to location of the probe contact relative to the major diameter of the hole and do not detect thickness variations around the hole. The lowest resistance reading is obtained when the current probes are directly across from the voltage measuring probes through the true diameter of the hole. In practice it is very difficult to assure that this condition exists and usually requires making several readings per hole (by repositioning) to obtain the minimum resistance value. Conical probes are less subject to the positioning problem; however, if a sufficient angle is used to assure centering they are limited in the range of holes and laminate thickness that they can measure. It was also found that probes with the major portion of the cone used for current input and small segments (or wedges) for the voltage measurement were subject to variation because of variability of where the current actually originated when applied to the irregular edge of a plated-through hole. Typically several readings had to be taken while rotating the hole relative to the probe to obtain an average repeatable value.

Early experimental probes at Bendix were designed to reduce the effects of these deficiencies. A conical design with an insulated voltage conductor in the center showed promise, however, it had the same limitations as to hole size and laminate thickness as

the commercial probes. A second generation of this concept with a spherical contact face was found extremely sensitive to positioning relative to the hole circumference.

These experimental designs and the continued evaluation of commercial probes led to the concept of an eight point probe (four top and four bottom) which could be electrically switched to provide four measurements around the circumference without relocating relative to the hole. The first design of this type was not satisfactory because excess pressure was required to assure contact of all of the contacts on the irregular surface of the hole edge.

From the evaluation of the experimental probes, guidelines for probe design were established:

- Several (preferably four at 90° increment) measurements should be made on each hole without requiring repositioning and the average resistance value used to determine thickness.
- The contact between the hole and a probe element should be on the inner edge of the hole.
- The angle of element contact to the hole edge should be sufficient to assure contact on the edge but should not limit the board thickness or hole diameter that can be measured.
- The contact pressure should be independently controlled for each element.
- Each element must be electrically isolated from the others.

Improved Probe Design

To meet these requirements, the new probe design was developed as shown in the exploded view in Figure 4. Four contactors are arranged so that they contact the hole at 90° apart. Four pieces of square brass tubing are cemented together, to form guides, using an epoxy sheet adhesive which also provides electrical isolation between the four pieces of tubing. Square tubing is used to prevent rotation of the contactor bars. The bars are machined to a sliding fit inside the square brass tubing segments and are designed so that they are free to slide up and down. One end butts against a silicone rubber pad applying a uniform pressure to each contactor even though the hole being contacted may have an irregular or uneven surface. The other end of the sliding bar has a ten-mil-wide slot milled diagonally across the end. A

Figure 4. Exploded View of New Probe Design

contactor blade is soldered into the slot. These small blades are oriented toward the center of the probe assembly and sloped at 10° from the center out. The 10° angle assures contact on the edge of the hole but also makes it possible to measure holes up to 90 mils in diameter in thin boards. The contactor blades are designed to extend in toward the center within five mils of each other to make it possible to measure holes as small as 20 mils in diameter. Electrical leads to each contactor are soldered into the bar just below where it butts against the silicone rubber pad. These leads are connected by a cable to the microprocessor controller. The entire assembly is held together in a nylon sleeve which is inserted into the probe body.

Two of these assemblies are used, one on the top and one on the bottom, Figure 5 providing eight individual contacts with the hole. Each contact can be made either a current injection point, or a voltage measuring point through a series of relays that are in the microprocessor controller. The measurement of resistance around the hole at 90° increments can be accomplished without physically moving the probe system relative to the hole. The microprocessor/controller automatically shifts the current and voltage connections to the ESI meter by opening and closing relays. This shifting provides four individual resistance readings around the hole. Small displacements from the center of the hole are averaged out, and the variations in plating thickness that may

Figure 5. Photograph and Illustration of New Probe

exist in the hole itself are detected. The average value obtained is a representative resistance value for the specific hole being tested. Figure 6 shows how this rotation of resistance around the hole can be used.

It should be noted that this probe design is an experimental device to test the concept of an eight-point probe. Improvements in the physical design and characteristics of the materials used could reduce the size of the probe and improve its consistent function; however, the prototype design is adequate for use on product.

Fixture for Probe Location

To apply the probes to a plated-through hole it is necessary that they be held in a fixture that can move both the upper probe and the lower probe in contact with the hole while maintaining a constant relationship between the two probe assemblies. Furthermore, the probes must be aligned with the hole being tested.

Figure 7 shows a fixture designed for this purpose. By pulling down on the actuator handle, the bottom probe and the top probe simultaneously come together on the hole. The PC board being tested is held on the fixture table and the hole to be measured is positioned by aligning it with concentric circles on the reticle of the microscope. The table swivels so that the board can be moved from the position under the microscope to a corresponding fixed position under the probes. This movement is demonstrated in Figure 8.

The table is controlled by stops located under the bottom side, which contact permanent magnets. They hold the table in position while the hole is being lined up under the microscope in one direction, and while the probes are in contact with the hole in the opposite position. These magnets provide a stable reproducible positioning without latching or pinning the table, thus simplifying the procedure. The actuator handle and the probe assemblies are spring loaded so that they return to their open position when the actuator handle is released.

Microprocessor/Controller System

The controller system performs three major functions in establishing the copper plating thickness in a plated-through hole.

MEASUREMENT NUMBER	CURRENT INPUT	VOLTAGE
1	1-5	3-7
2	2-6	4-8
3	3-7	1-5
4	4-8	2-6

Figure 6. Illustration of Probe Switching Sequence

- It controls the resistance measurement by making four separate measurements around the hole circumference.
- The four resistance values are stored and later used to calculate the average resistance of the hole being tested.
- The plating thickness is calculated using the average resistance; the hole diameter and board thickness, which are input through thumbwheel switches on the front panel of the tester; and the appropriate constants that are stored in the microprocessor memory.

The copper thickness is related to the measured resistance by the following expression:

$$t = aD^b [R]^{mD+C}$$

where:

Figure 7. Photograph of Probe Holding Fixture

t = copper plating thickness in the hole (mils)

D = hole diameter (inches)

R = measured resistance (microhms)

a , b , m and c = constants dependent on the laminate thickness (Table 1).

The physical and electrical design of the complete controller system have been published in an interim report to this project entitled "Electrical Compensation System for Plated-Through Hole Tester" (BDX-613-1943, Available From NTIS). Several changes were incorporated after publication of that report. The appendix of this report contains the revisions to the text of the original report. A revised software program has not yet been completed.

Repeatability

During the prove-in study of the system in inspection, three holes were selected to use as reference units to assure that the probe system and controller were functioning consistently from

Figure 8. Photographs Showing Moving Table for Microscopic Positioning

day to day. These holes were tested prior to using the tester each time it was used over a period of three months. Data from these tests are summarized in Table 2. The standard deviation is less than 0.02 mils for the three holes studied.

Correlation Study

A comprehensive study was designed to evaluate the microresistance system relative to the destructive method of cross-sectioning to measure the copper thickness in the holes. Special panels were prepared from the following laminate thicknesses: (0.015, 0.031, 0.047, 0.062, and 0.125 inches). Hole diameters, ranging from 0.023 to 0.094 inches were selected on each panel for comparison. Four panels were plated for each board thickness to cover a range of plating thickness from 0.5 to 2.5 mils. The panels were plated using the Bendix standard process for double-sided boards. All panels were etched, solder dipped, and leveled in the standard process.

Table 1. Table of Constants

Values of a, b, m, and c (for different board thickness) where:

$$t = aD^b [R]^{mD+C}$$

t = Copper thickness in the hole (mils)

D = Hole diameter before plating (inches)

R = Measure resistance (microhms)

Board Thickness (inches)	a	b	m	c
0.015	0.0000069	-4.5087	19.536	-1.5074
0.031	0.00047	-3.7248	10.897	-1.3743
0.047	0.01891	-2.9810	6.1371	-1.3300
0.062	0.20841	-2.3907	3.3572	-1.2608
0.125	0.00655	-4.0504	5.9595	-1.4175

The resultant resistance values, thickness measurements (both by microresistance method and cross-section method) and the differences for each hole are shown in Table 3.

Larger diameter holes in the thin boards had resistance values too small for meaningful thickness measurements. Also, small diameter holes in thick boards resulted in resistance values too high for adequate correlation. The following is suggested as the overall guide for using the microresistance tester.

<u>Board Thickness</u>	<u>Hole Diameter Limit</u>
0.015	0.020 to 0.060
0.031	0.020 to 0.080
0.047	0.020 to 0.080
0.062	0.020 to 0.080
0.125	0.050 to 0.100

Within the above limits and for plating thicknesses less than 2.5 mils, the average difference between the two methods is 0.08 mils with a standard deviation of 0.07 mils.

Table 2. Reference - Units Repeatability

Test Hole Number	Diameter (inches)	Board Thickness (inches)	Number of Tests	Mean Thickness Reading (mils)	3-Sigma Variation (mils)
1	0.055	0.062	79	1.31	0.058
2	0.035	0.047	42	1.42	0.042
3	0.074	0.062	42	1.68	0.049

ACCOMPLISHMENTS

- The improved microresistance test method is satisfactory for providing variable data of copper plating thickness in plated-through holes of double-sided printed wiring boards.
- The improved test method can be used as a replacement for cross-sectioning in testing product. (Within the limitations stated above.)
- The eight contactor probe design improves the repeatability and reliability of the resistance measurement.
- The relationship of resistance to plating thickness in the hole, relative to the hole diameter, has been established. Separate constants are required for different board thicknesses and these constants have been established for board thicknesses of normal use.
- Large diameter holes in thin boards and small diameter holes in thick boards cannot be measured with the microresistance method using the same theoretical relationship of resistance to thickness. Hole geometry limits for the resistance method have been established.

RECOMMENDATIONS

- A microresistance tester of the improved design should be incorporated into inspection departments and used to replace the cross-section method.

Table 3. Data Summary of Resistance, Cross-Section Thickness, and Microresistance Thickness

Hole Diameter (inches)	Average Resistance ($\mu\Omega$)	Cross-Section Thickness (mils)	Resistance Tester Thickness (mils)	Difference (mils)
------------------------	------------------------------------	--------------------------------	------------------------------------	-------------------

Laminate Thickness - 0.015 inches

a = 0.0000069: b = 4.50873: m = 19.536: c = 1.50741

0.023	128	0.81	0.99	+.18
0.023	81	1.54	1.60	+.08
0.023	50	2.55	2.67	+.12
0.023	35	3.85	3.90	+.05
0.033	72	0.75	0.82	+.07
0.033	36	1.49	1.50	+.01
0.033	20	2.43	2.49	0.06
0.033	10	4.65	4.52	-.13
0.042	40	0.75	0.88	+.13
0.042	18	1.45	1.52	+.07
0.042	9	2.45	2.46	+.01
0.042	5	3.20	3.68	+.48
0.052	35	0.80	0.74	-.06
0.052	11	1.40	1.31	-.09
0.052	4	2.08	2.15	+.07
0.052	2	3.00	3.02	+.02
0.073				
0.073				
0.073				
0.073				
0.094				
0.094				
0.094				
0.094				

Laminate Thickness - 0.031 inches

a = 0.00047: b = -3.7248: m = 10.8966: c = 6.3743

0.023	581	0.46	0.47	+.01
0.023	237	1.30	1.28	-.02
0.023	136	2.35	2.38	+.03
0.023	101	3.25	3.33	+.08
0.033	295	0.45	0.48	+.03

Table 3 Continued. Data Summary of Resistance, Cross-Section Thickness, and Microresistance Thickness

Hole Diameter (inches)	Average Resistance ($\mu\Omega$)	Cross-Section Thickness (mils)	Resistance Tester Thickness (mils)	Difference (mils)
0.033	119	1.31	1.21	-.10
0.033	66	2.30	2.21	-.09
0.033	40	3.50	3.67	+.17
0.042	203	0.40	0.48	+.08
0.042	78	1.18	1.16	-.02
0.042	40	2.30	2.15	-.15
0.042	26	3.60	3.19	-.41
0.052	179	0.45	0.43	-.02
0.052	69	1.10	0.93	-.17
0.052	26	2.35	2.05	-.30
0.052	21	2.85	2.43	-.42
0.073	125	0.40	0.49	+.09
0.073	28	1.16	1.17	+.01
0.073	10	1.85	2.12	+.27
0.073	3	3.20	4.20	+1.00
0.094				
0.094				
0.094				
0.094				

Laminate Thickness - 0.047 inches

a = 0.01891: b = 2.98104: m = 6.13709: c = 1.33004

0.023	940	--	0.42	--
0.023	599	0.74	0.72	-.02
0.023	280	1.70	1.78	+.08
0.023	175	3.09	3.12	+.03
0.033	453	0.50	0.50	--
0.033	271	0.80	0.89	+.09
0.033	151	1.83	1.72	-.11
0.033	98	2.78	2.80	+.02
0.042	364	0.49	0.43	-.06
0.042	232	0.70	0.70	0
0.042	106	1.83	1.62	-.21
0.042	64	2.80	2.78	-.02
0.052	283	0.55	0.42	-.13
0.052	141	0.80	0.63	-.17
0.052	79	1.80	1.54	-.26

Table 3 Continued. Data Summary of Resistance, Cross-Section Thickness, and Microresistance Thickness

Hole Diameter (inches)	Average Resistance ($\mu\Omega$)	Cross-Section Thickness (mils)	Resistance Tester Thickness (mils)	Difference (mils)
0.052	49	2.60	2.49	-.11
0.073	249	0.30	0.36	+.06
0.073	113	0.70	0.71	+.01
0.073	43	1.78	1.68	-.10
0.073	18	2.90	3.61	+-
0.094	124	0.49	0.57	+.08
0.094	45	0.70	1.23	+.53
0.093	13	2.11	3.15	+1.04
0.094	3	2.90	--	--

Laminate Thickness - 0.062 inches

a = .20841: b = 2.39071: m = 3.35718: c = 1.26081

0.023	1246	0.38	0.37	-.01
0.023	552	1.00	0.98	-.02
0.023	346	1.68	1.70	+.02
0.023	264	2.25	2.34	+.09
0.033	668	0.40	0.41	+.01
0.033	329	1.02	0.92	-.10
0.033	201	1.70	1.63	-.07
0.033	131	2.64	2.67	+.03
0.043	575	0.40	0.33	-.07
0.042	229	1.01	0.93	-.08
0.042	145	1.75	1.55	-.20
0.042	82	3.21	2.93	-.28
0.052	439	0.33	0.33	+0
0.052	170	1.10	0.93	-.17
0.052	94	1.92	1.76	-.16
0.052	59	3.20	2.92	-.28
0.073	297	0.30	0.34	+.04
0.073	93	1.05	1.09	+.04
0.073	49	1.88	2.09	+.21
0.073	28	2.85	3.68	+.83
0.094	150	0.30	0.52	+.22
0.094	39	1.19	1.86	+.67
0.094	22	1.80	3.19	+1.39
0.094	9	3.10	7.45	--

Table 3 Continued. Data Summary of Resistance, Cross-Section Thickness, and Microresistance Thickness

Hole Diameter (inches)	Average Resistance ($\mu\Omega$)	Cross-Section Thickness (mils)	Resistance Tester Thickness (mils)	Difference (mils)
Laminate Thickness - 0.125 inches				
a = .00655: b = -4.0504: m = 5.9595: c = 1.41745				
0.042	1088	0.53	0.70	+.17
0.042	718	--	1.14	--
0.042	450	1.50	1.97	+.47
0.042	328	2.02	2.86	+.84
0.052	960	0.50	0.52	+.02
0.052	590	0.88	0.89	+.01
0.052	352	1.53	1.57	+.04
0.052	245	2.30	2.35	+.05
0.073	614	0.50	0.48	-.02
0.073	362	0.83	0.81	-.02
0.073	214	1.46	1.35	-.11
0.073	123	2.35	2.33	-.02
0.094	276	0.75	0.76	+.01
0.094	142	1.30	1.35	+.05
0.094	109	1.74	1.69	-.05
0.094	80	2.14	2.21	+.07

- Reference units should be established and monitored by Quality Control Engineering.

APPENDIX

REVISIONS TO TEXT OF INTERIM REPORT

The following pages are revisions of BDX-613-1943 "Electrical Compensation System for Plated-Through Hole Tester;" Milestone Report, November 1978 (Available From NTIS).

Revision of Page 9,
BDX-613-1943

- The plating thickness is determined by using the data input to the system, the resistance value (as previously determined), the hole diameter, and the hole length (board thickness). The latter two parameters are dialed into the system through the use of the thumbwheel switches located on the front panel of the controller (Figure 2). There also are thumbwheel switches which can be used by the operator to identify the part number and the number of the hole being tested.

Three techniques for converting the measured resistance values to plating thickness are now being evaluated: (1) using an equation for a direct calculation of the plating thickness; (2) storing tables of calibration data in the memory of the microprocessor system and having the system search for the thickness value associated with a given resistance value and set of geometry factors; and (3) combining both of the first two methods. Details concerning the equations and the calibration data involved will be published in a later report. The important point is that the specific technique used is dependent only on the software program for the microprocessor system and does not require hardware changes.

Theory of Operation

The microcomputer used in the system contains 4K of random-access memory, and 8K of Rom. Two parallel interfaces are employed: is used to output information to the relays and LED display, and to read the thumbwheel settings; and the second interfaces to the ESI resistance meter, and is read in five BCD digits.

By sending the appropriate code word through the first interface, the decoder Integrated Circuit 1 (IC1) causes the appropriate thumbwheels to be read into the computer through the NAND gates and the interface. The digits are read in groups of three until all of the thumbwheel settings for ID, S/N, hole number, diameter, and board thickness have been read.

When the READ pushbutton PB1 is activated, the computer issues code words through the first interface to set the relays into various configurations to control the location of the voltage and current probes around the hole. The probes are set into four different configurations, and the resistance of the plated-through hole is read from the ESI resistance meter for each configuration.

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Figure 2. Block Diagram of Electrical Compensation System

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An average resistance, $\bar{R}$, is calculated from the four readings. This average resistance value is used with the test-hole geometric parameters for the conversion to the plating thickness of the hole wall. The plating thickness is displayed on the three-digit LED display in thousandths of an inch, and the display data are output from the first interface. The PRINT pushbutton switch is activated when desired to indicate the last hole to be measured.

Detailed electrical schematics and other diagrams which explain the microprocessor system are included in Appendix A. Figures A-1 through A-3 show, in detail, the interface electronics to the thumbwheels, relays, and display. Figure A-4 shows the wiring configuration and pin numbers to switch the arrangement of the probes, while Figure A-5 shows the physical location of the ICs and relays on the printed circuit board. Figure A-6 shows the power supplies that are required together with a schematic of the additional circuitry used to control the microprocessor from the front panel of the tester.

Figure A-7, along with Tables A-1 and A-2, outlines the pin connections from the computer interface cards to the outside circuitry. Table A-3 lists the integrated circuits, thumbwheels, relays, and displays that are required in the construction of the tester.

Table A-4 shows the method used to construct the software code word to store in the memory which causes the probes to switch into the desired arrangement. An example of the code is provided in Table A-5.

Figure 2 is a block diagram which shows the interrelationship of the major components of the system.

Figure 3 is a flow diagram illustrating the interaction of the operator with the tester. The first operational step consists of setting the thumbwheel switches on the front panel to identify the part number of the part to be tested. The specific hole to be tested then is selected, and the hole number, the hole diameter, and the laminate thickness are set by using the appropriate thumbwheel switches. The value used for the hole diameter is the diameter of the drill that has been used, and the laminate thickness is the nominal thickness of the laminate before plating.

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The operator locates the test hole by centering it in relation to the reticle in the microscope portion of the test fixture. The table then is rotated to the left to position the hole in line with the probe system, and the lever is pulled down to bring the probes in contact with the hole. The READ button on the front panel is pushed to initiate the test. This procedure is repeated until all of the holes on the board have been tested. After the last hole has been tested, the operator again pushes the READ button to reset the program for a new board.

The front panel and the back of the microprocessor system are shown in Figures 4 and 5, respectively. The thumbwheel switches, the ESI measuring system, and the thickness readout can be seen in the front view. The back view shows the reed relays, the basic microprocessor, the back of the ESI unit, the power supply, and the connecting electrical circuitry.

Figure B-1 of Appendix B shows the location in the memory where each of the software programs and the data are stored, while Figure B-2 shows the major operations that are performed. Details can be obtained by examining the computer listings that are now being used (Appendices C and D). The Plated-Through Hole Program (Appendix C) was written by Bendix Kansas City personnel to perform the desired operations. The Conversion Routines (Appendix D) were supplied by the vendor to perform standard conversions of data from one mode to another.

ACCOMPLISHMENTS

The development of the electrical compensation system, described in this report, demonstrates the feasibility of using a microprocessor to control the acquisition of resistance data from a multiple-contact probe, and to convert the measured resistance of plated-through holes to plating thickness. The use of this concept makes possible the determination of the average thickness of a connection through a printed circuit board by determining its average resistance without reorienting the test hole.

FUTURE WORK

The electrical compensation system will be evaluated in conjunction with the entire plated-through hole testing program to establish its reliability. The evaluation will include a joint study with the Design Laboratory at SLL, and it will be designed and conducted by the Quality Control Engineering group.

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Figure A-2. Schematic of Relay Section of Electrical Compensation System

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Figure A-4. Relay Matrix

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Figure A-5. Location of Integrated Circuits and Relays on Printed Circuit Board

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Figure A-6. Power Supply and Control Circuits for Microprocessor

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Table A-1. First Interface Pin Connections*

Signal	Connector and Pin	Relay Function	Display Function	
OUT00	1 - C	A	LSD	A
OUT01	1 - K	B Group 1	LSD	B
OUT02	1 - NN	C IC20 & 21	LSD	C
OUT03	1 - V		LSD	D
OUT04	1 - L		Center	A
OUT05	1 - N		Center	B
OUT06	1 - R		Center	C
OUT07	1 - T		Center	D
OUT08	1 - W		MSD	A
OUT09	1 - X	A	MSD	B
OUT10	1 - Z	B Group 4	MSD	B
OUT11	1 - AA	C IC22 & 23		
OUT12	1 - BB	A		
OUT13	1 - FF	B		
OUT14	1 - HH	C Decoder		
OUT15	1 - JJ	D 1C1		
CND	1 - UU			
<hr/>				
Thumbwheel Function				
IN00	2 - TT	MSD A		
IN01	2 - LL	MSD B		
IN02	2 - H, E	MSD C		
IN03	2 - BB	MSD D		
IN04	2 - KK	Center A		
IN05	2 - HH	Center A		
IN06	2 - EE	Center C		
IN07	2 - CC	Center D		
IN08	2 - Z	LSD A		
IN09	2 - Y	LSD B		

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Table A-3. Parts List for Integrated Circuits, Relays, Readouts, and Thumbwheel Switches.

Part	Serial Number	Quantity	Manufacturer and/or Description
Integrated Circuit	SN7438N	18	NAND Gates
	SN74154N	1	4-to-16 Decoder
	SN74155N	2	3-to-8 Decoder
	SN7404	5	Inverter
	SN7474	1	Flip-Flop
	2N3906	16	Transistor
Reed Relay	W101MPCX-122	16	
LED Readout	5082-7302	3	
Thumbwheel Switch	29102/B-3	5	
	29102/B-6	1	

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Table A-4. Codes for Probe Configurations*

ESI-Input Connector Pin	Word-Bit Position	Probe and Connector Pin							
		1	2	3	4	5	6	7	8
		A	B	C	D	E	F	H	J
Pin 1 (Current 1)	00	0	1	0	1				
	01	0	0	1	1				
	02	0	0	0	0				
Pin 2 (Voltage 1)	03								
	04								
	05								
Pin 4 (Voltage 2)	06								
	07								
	08								
Pin 5 (Current 2)	09					0	1	0	1
	10					0	0	1	1
	11					1	1	1	1
Output Code	12	0	0	0	0	0	0	0	0
	13	1	1	1	1	1	1	1	1
	14	1	1	1	1	1	1	1	1
	15	0	0	0	0	0	0	0	0

To use the table, add the bit positions to make a 16-bit word.

Example: Refer to Table A-5 for an example to set Current 1 = Probe 2, 3, 4, Voltage 1 = Probe 1, Voltage 2 = Probe 7, Current 2 = Probe 5, 6, and 8.

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Table A-5. Probe-Configuration-Code Example

	Word-Bit Position															
	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
Function					12			V2			V1			I1		
Binary	0	1	1	0	1	1	0	X	X	X	X	X	X	0	0	0
Octal	0		6			6				X			X	0		
X = Doesn't matter, selects unused relay.																

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Figure B-1. Memory-Organization Diagram

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Figure B-2. Software Flow Diagram

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PLATED-THROUGH HOLE TESTING, W. B. Abel, Final,
May 1980

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SPECIAL PROJECTS: Nondestructive Testing

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