A Survey of Contact Testing Techniques for the Diagnosis of Printed Circuit Boards

Salim A. Jayousi, M. Saufee Muhammad

Abstract—This paper studies the testing methods of printed circuit boards using direct contact techniques. Due to the complexity and the shrinking of electronic circuits, a parallel development in testing methods is highly recommended. The paper analyses two major categories of direct contact testing methods which is analog signature analysis testing and in-circuit testing. The compatibility of those testing methods with the recent circuits also checked in this paper.

Index Terms— Printed circuit board testing, analog signature analysis, in-circuit testing, defective chips, circuit manufacturing quality.

1 Introduction

During handling or even manufacturing printed circuit boards and integrated circuits, defects may develop [1]. Those defects such as open circuits or short circuits may appear in or between circuit pathways and electronic components. Effective testing system is necessary for maintenance purposes and also for manufacturing quality insurance. The rapid development of electronic module assembly manufacturing requires a parallel development in test procedures [2-5].

Printed circuit boards (PCBs) testing is becoming more expensive and difficult due to the complexity of PCBs design. The common methods for diagnosing PCBs still suffering from many difficulties; it needs long time, a lot of manual work, direct contact with PCB, and it is so expensive [6].

Testing has to be good (by having high defect coverage), cheap and fast. The IC defect level in 1970 was 1000 defective chips per million (DPM) delivered, but nowadays it bellows 10 DPM. Experts still pushing this number to reach 0 DPM level [7].

Previously, the unique method to inspect printed circuit boards was manual testing method; it involves using visual inspection, multimeters, oscilloscopes and other testing equipments. This method is almost inapplicable for the recent printed circuit boards since the huge mounted number of components installed on PCBs. Moreover, using integrated circuits (ICs) limits the ability of manual testing and makes it so difficult. Manual testing takes long time to be performed. The efficiency of such diagnose method depends on the repairer knowledge and experience [8]. In manual testing, always the repairer needs to choose the suitable testing equipment according to the device to be tested [9].

- *Salim A. Jayousi is currently pursuing Ph.D degree program in computer engineering program, Universiti Malaysia Sarawak , Malaysia, PH-0128573502. E-mail: sjayousi@qou.edu.*
- *M. Saufee Muhammad is an Associate Professor in electronic engineering department, Universiti Malaysia Sarawak , Malaysia, msaufee@feng.unimas.my.*

Direct contact testing based on attaching the tester terminals or clips to the device under test DUT pins. It relies on a nails with a sharp edges for more accurate connection. Commonly, an electrical signal is introduced via the attaching clips to the DUT, and the corresponding signal is also received by the clips or nails. The attaching clips can be moved manually or by automatic apparatus.

2 Analog Signature Analysis

One alternative method of PCB direct contact testing is Analog Signature Analysis (ASA); it is a "power off" troubleshooting technique that applies a sine wave (AC) stimulus to a component on PCB creating a voltage vs. current waveform, and this waveform is shown through a signature display [10-12].

ASA can be performed by holding one of the tester probes to the component pin and the other one to ground or Vcc on the circuit board. Then, a preselected input signal will be applied through the probes to component under test. A special display plots V vs. I curve, this curve is called the signature. After that, the system compares this signature with a signature of known good component, and any considerable difference between the two signatures means that this component is defected [13].

Fig.1 shows a typical ASA instrument while testing a component such as resistor. The red probe connected to channel A and the black probe connected to the common.

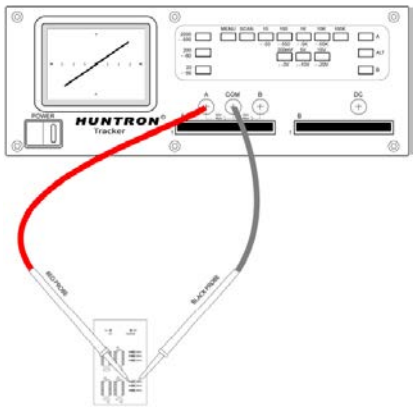

Fig.1: Typical ASA Testing Instrument

The display plots the voltage across the component on the horizontal axis, and the current on the vertical axis. Each type of components has its own signature. Fig.2 shows the signatures for the basic four components: resistor, capacitor, inductor and semiconductor while responding to the sign wave test signal.

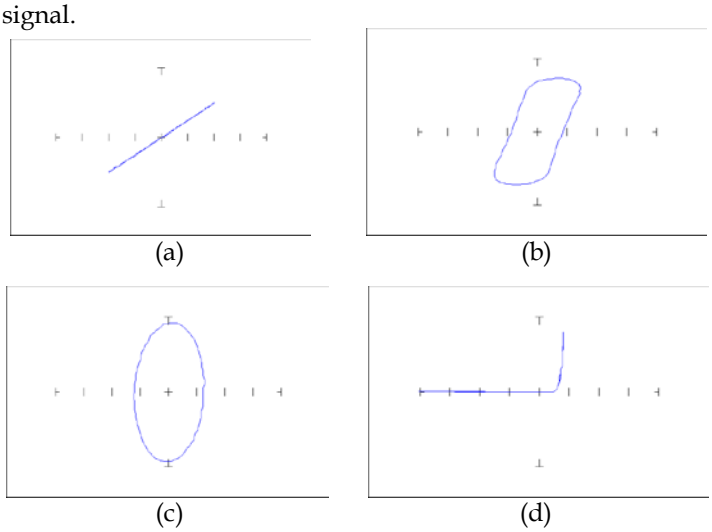

Fig.2 Analog Signatures of the Four Basic Components

As seen obviously from **Fig.2**.a, the resistor signature is a straight line with slope between 0^o - 90^o. When the signature line is exactly 0^o (horizontal) it indicates that the resistor is defected and it is short circuit, whereas the vertical line indicates open circuit resistor [14]. See **Fig. 3**.

.

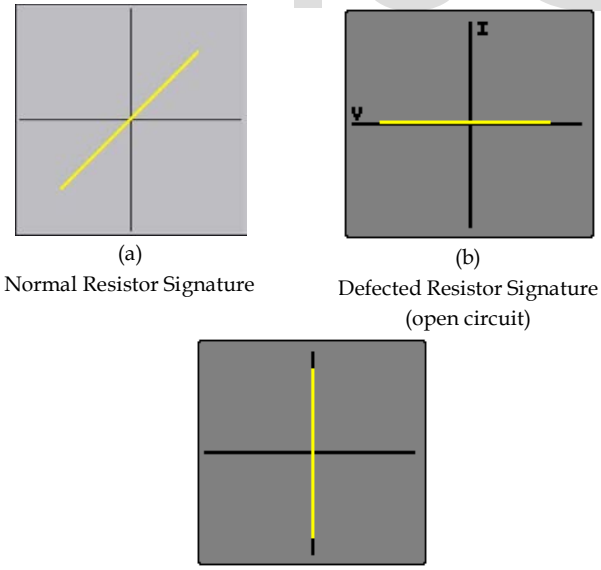

Fig. 3: Signatures for Normal and Defected Resistors

A major advantage of ASA method is that it doesn't require to power on the device under test. Also, ASA can be used even if there are no documentations or circuit diagrams for the suspect PCB. Other advantages are: it gives the feedback immediately for each component, it is easy to be applied and no need for detailed analysis.

ASA method has many deficiencies. First, performing ASA for all the PCB needs long time to be completed since it is being done manually. Second, low accurate because ASA needs direct contact between the tester probe and component leads. Third, it only tests the components and doesn't test any traces between components along the PCB.

3 In circuit testing (ict)

Another Conventional and popular direct contact technique for PCB testing is In Circuit Testing (ICT) which is also called "Bed of Nails" testing. Most of manufacturers prefer ICT because it is simple, fast and accurate. ICT comprises too many pins to perform test, and that is the reason it's called "bed of nails" system. It can be used to check shorts, opens, resistance, capacitance and also to perform other basic measurements [15].

ICT technique relies on a part of pins that contacts copper traces on PCB under test so that applying a predefined set of input signals at various nodes, corresponding output signals will be measured at other nodes of the PCB by another part of the pins. The bed of nails (pins) is controlled by Automatic Test Generation (ATG) software that is used to describe how to isolate and test component on DUT [16], hence each pin is controlled automatically to move up and down [17]. **Fig. 4** shows ICT system located down of board under test. It's clear from the figure that pins (nails) contacting certain nodes on PCB.

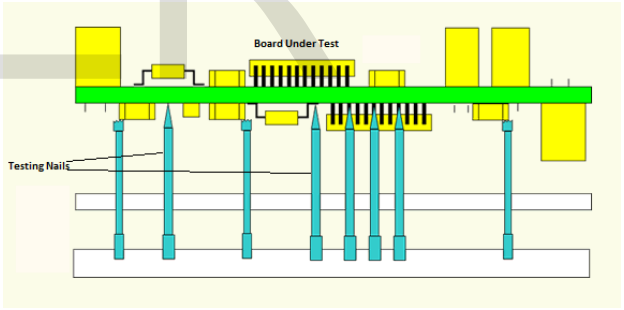

Fig. 4: ICT System with a Pins Contacting PCB Under Test

One alternative ICT method is disclosed in U.S. Pat. No. 5,436,567. That patent disclosed a double-sided "Bed of Nails" probe fixtures to test the top and bottom side of the PCB under test. The bottom "Bed of Nails" is vacuum-actuated, while the top side is pushrod-actuated, therefore the both sides of PCB under test are engaged perpendicularly by this system [18].

ICT has the following disadvantages. First, the positioning accuracy of the test nodes became more difficult as the emplacement density was increasing and the dimensions of components were shrinking. Second, Bed of nails design is very costly and each system is specified to one type of PCB. However, flying-probe ICT system is cheaper but it takes long time to finish testing. Third, ICT can only examine finished product. Fourth, ICT still can't prevent failures; it can only detect failures [8]. Fourth, ICT requires that the functionality of each component on DUT to be known, and also the software libraries for those components to be provided [16]. Another disad-

vantage is that the number of integrated circuits under test may exceed the number of probes for ICT system. Additionally, the circuit under test frequency may exceed the frequency of ICT system [19].

4 Conclusion

Direct contact testing techniques based totally on direct contact between the tester probes and the leads of the component under test. Such techniques suffer from several deficiencies; Most of those test systems are limited to 100 MHz while the new PCBs operate at higher frequencies. Moreover, those methods also inherently limited since its large size. Moreover, it consists of hundreds of tiny needle probes which require simultaneous contact around the chip's periphery. Hence, due to the complexity of integrated circuits and printed circuit boards and the increasing of the surface mount technology, it became necessary to develop new testing techniques to avoid precise and complex fixtures.

REFERENCES

[1] Tseng, T.-L.B., M.C. Jothishankar, and T.T. Wu, Quality control problem in printed circuit board manufacturing—An extended rough set theory approach. Journal of Manufacturing Systems, 2004. 23(1): p. 56-72.

[2] Moganti, M., et al., Automatic PCB Inspection Algorithms: A Survey. Computer Vision and Image Understanding, 1996. 63(2): p. 287-313.

[3] Moganti, M. and F. Ercal, A Subpattern Level Inspection System for Printed Circuit Boards. Computer Vision and Image Understanding, 1998. 70(1): p. 51-62.

[4] Kusiak, A. and C. Kurasek, Data mining of printed-circuit board defects. Robotics and Automation, IEEE Transactions on, 2001. 17(2): p. 191-196.

[5] Tong, J., F. Tsung, and B. Yen, A DMAIC approach to printed circuit board quality improvement. The International Journal of Advanced Manufacturing Technology, 2004. 23(7-8): p. 523-531.

[6] Sheen, T.W., et al., Printed Circuit Board Tester Using Magnetic Induction. Sheen et al., 1997. 5,631,572(227,854): p. 13.

[7] Vermeulen, B., et al. Trends in testing integrated circuits. in Test Conference, 2004. Proceedings. ITC 2004. International. 2004: IEEE.

[8] Janóczki, M., et al., Automatic Optical Inspection of Soldering. Materials Science - Advanced Topics. 2013.

[9] Maxim, Automatic Test Equipment on a Budget, in TUTORIAL. 2001, Maxim Integrated Co.: california. p. 12.

[10] Frye, J.T. (1975) Analog Signature Analysis Using a Curve Tracer. 9.

[11] Lupea, D., U. Pursche, and H.-J. Jentschel. RF-BIST: loopback spectral signature analysis. in Design, Automation and Test in Europe Conference and Exhibition, 2003. 2003: IEEE.

[12] Damarla, T., Implementation of signature analysis for analog and mixed signal circuits. 2002, Google Patents.

[13] Lowne, A. Analog Signature Analysis – Testing Unpowered PCBs., 1-4.

[14] Voorakaranam, R., et al., Signature Testing of Analog and RF Circuits: Algorithms and Methodology. Circuits and Systems I: Regular Papers, IEEE Transactions on, 2007. 54(5): p. 1018-1031.

[15] O'Connell, J., Study and recommendations into using lead free printed circuit board finishes at manufacturing in circuit test stage. Agilent Technologies UK Ltd, Automated Test group, 2004.

[16] Albee, A. (2002) Boundary-Scan and In-Circuit Test Combined: Strategy and Benefits. 1-12.

[17] Collins, R.J., Programmable bed-of-nails test access jigs. 1988, Google Patents.

[18] Wexler, D.J. and J.L. Smith, Double-sided automatic test equipment probe clamshell with vacuum-actuated bottom probe contacts and mechanical-actuated top probe contacts. 1995, Google Patents.

[19] Rohrbaugh, J.G., J.R. Rearick, and S.R. Shepston, Systems and methods for facilitating automated test equipment functionality within integrated circuits. 2003, Google Patents.