International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 13 (2018) pp. 11091-11095


# Analog Signatures to Diagnose Faults in Printed Circuit Boards

**Diego Augusto Cabrera Meza, Robinson Jiménez Moreno**

*Faculty of Engineering, Nueva Granada Military University, Bogotá, Colombia.*

**Abstract**

To use the technique of analysis of analog signatures in the diagnosis of faults in electronic cards, it is necessary to have a tool that allows to characterize the electronic components. The signatures are figures that must be analyzed visually and must be compared between those generated by a card in good condition with those generated on the card under test. This paper presents the design of a low cost and reliable tool to be used by technicians repairing electronic systems through the analysis of signatures, showing an application case in which the functionality of the designed card is evidenced.

**Keywords:** PCB, Printed Circuit Board, Fault Detector, Analog components, V-I Signatures, Lissajous curves, device under test DUT, RMS.

## INTRODUCTION

The electronic devices susceptible to repair have printed circuit boards (PCB) [1], and are in devices such as: consumer electronics (appliances, telephony, computers), appliances with industrial electronics, vehicle electronics and in other sectors. These devices have: voltage sources, signal processing boards, control boards and specialized cards for each sector.

The detection and location of faults in electronic cards is a complex and difficult work, for which there are different methods for its diagnosis [2]. One of them is the technique of analysis of analog signatures or analysis technique V-I [3], where the voltage and current signals that circulate through the devices are analyzed, being an important task of said diagnosis the difference between normal operation and a defective condition [4]. The detection of faults in cards, circuits and electronic components depends on the observation made to the responses to stimuli as does the method of analysis of analog signatures [5] and others that use the inspection of the components using tools such as multimeters to measure the value of resistance, voltages and currents, as well as the use of the oscilloscope to measure the signals in the time domain and verify the response of the circuits to signals that are applied to it. For example, inspecting the noise generated by an amplifier and its frequency [6] is not achieved with a multimeter, so the appropriate tool is necessary for effective diagnosis, i.e. if it is wanted to measure the temperature, the appropriate tool is a thermometer, if the need is to generate analogue signatures, the tool is a V-I TRACER like those manufactured by several companies and are available in the market [7][8]. These tools use the Lissajous figures [9][12] to help in the diagnosis of faults, such as in high voltage transformers [10], this technique is also used for the testing and validation of electronic circuits [11].

In this article, we propose a simple diagnostic tool to apply the technique of analog signatures, which allows to detect damage in electronic cards. Additionally, the general diagram of the circuit is shown, since the specific one depends on the technology that is wanted to use for its control, depending on whether microcontrollers, FPGAs, or other electronic devices are used. Next, an applied example is given where the proposed V-I Tracer and the analysis of the analog signatures obtained in two cards are used, one in good condition and the other with faults.

## TOOL TO APPLY THE ANALOG SIGNATURES

To use the technique of fault detection, a tool is necessary, in this article it is called V-I TRACER, which generates a sinusoidal signal of 12 Vrms at 60 Hz constant in time and which delivers a controlled current to avoid damaging the devices under test. The value of the voltage and the frequency were defined with different consecutive tests, these values can vary depending on the applications and the cards that are desired to diagnose, i.e. high, medium and low frequencies for devices that respond to these variations. With the frequency and voltage established, the tool was used to diagnose faults in mass consumption devices such as: televisions, amplifiers, sound equipment, mobile phones, devices for reading DVD, devices for reading Blu-ray and cards that are not designed to operate in radio frequency (RF) and high frequency (HF). The block diagram of the proposed circuit is shown in Figure 1.

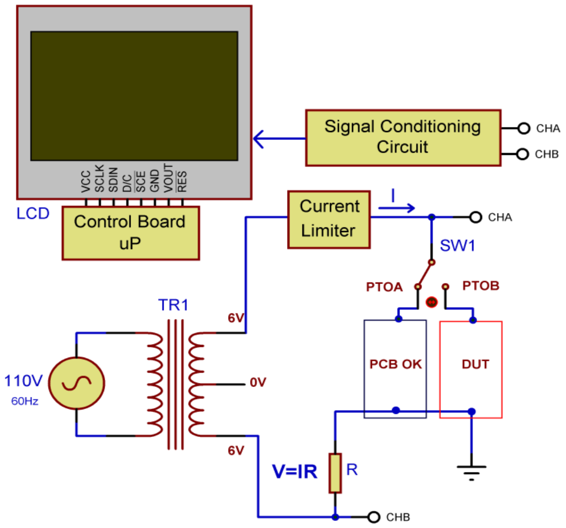


**Figure 1.** V-I TRACER diagram

The signal generator is built with a transformer of 110Vrms in the primary and 12Vrms (6V-0-6V) in the secondary one. The current limiter is a regulating circuit that allows to keep the current stable to avoid damages in the devices that are going to be tested. SW1 is a switch that is controlled by the controller card and allows the signal to be switched between the good card and the device under test (DUT), in such a way that the operator of the tool has enough time to compare the figures. Other functions can be included, such as delay times, numerical calculation to generate percentages of difference between the signatures of the cards, this allows the operator to make better decisions and not be subject to the visual analysis. The resistance R can be adapted to different values in order to allow more or less passage of current through the cards, this gets to excite the components that need currents of the order of tens of milli Amperes (mA). The value of these resistances can be 100Ω, 1KΩ, 10KΩ and 100KΩ, multiples of 10 for ease of calculations, by supplying different currents, more detailed and easily comparable analog signatures are generated. The signal conditioning circuit is used to deliver the voltage and current signals indirectly measured in the resistance R to the microprocessor that processed them to be displayed on the LCD graphically for analysis by the repairman. The microcontroller will be responsible for managing the switch SW1, the LCD to the R resistors and the calculation processes that are wanted to add.

The programming algorithms of the microcontroller will vary depending on the needs of the operators and manufacturers of the tool. The base flow diagram that can be implemented in any programming language is presented in Figure 2.

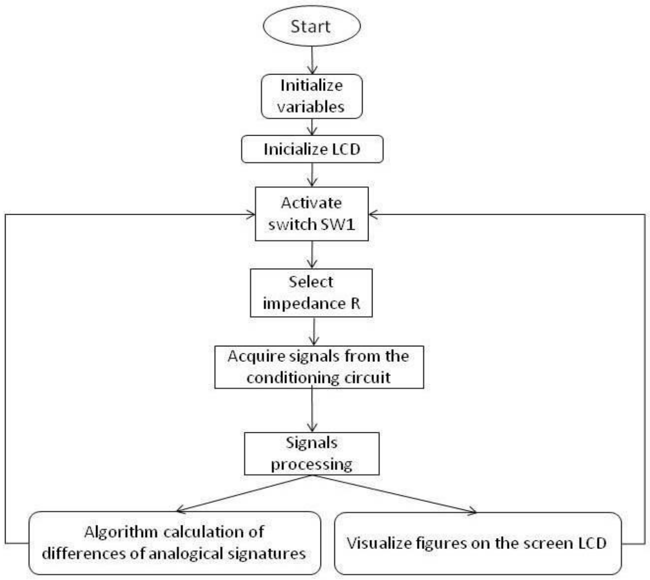


**Figure 2.** Microcontroller algorithm used in the tool

The programming is focused on: Control of switches SW1 and those that activate the selected impedance R. Afterwards, the samples that enter the microcontroller are processed by means of the signal conditioning circuit to generate two responses: the first, to calculate the difference between the figures and the second, to present the analog signatures on the LCD to be observed by the operator. In this article, the results of applying these circuits in two cards and the analog signatures that characterize them graphically are presented, after processing the signals in MATLAB. The following algorithm that performs the processing of signals acquired by means of the conditioning module to the microcontroller is cited as an example. In this work, Arduino Nano is used [14].

***Algorithm***

Step 1: Configure device to capture analog signals.

Step 2: Define the scales to present the analog signatures graphically in the visualization devices such as: LCD, oscilloscopes and computer.

Step 3: Switch SW1 between the cards.

Step 4: Select R.

Step 5: Acquisition of data from channel A (CHA) and channel B (CHB).

Step 6: Process analogous data in digital format.

Step 7: Calculate difference between CHA and CHB signals (optional).

Step 8: Present the analog signatures and data on the display devices. GOTO Step 3.

## APPLICATION IN FAULT DETECTION

To validate the exposed design, the following example illustrates how to use the technique of analog signatures, where it is wanted to detect the faults of a simple monophonic amplifier that uses three transistors to amplify the audio of 2W of power [13]. For this purpose two cards are needed: one card in good condition (Figure 3a) and another card that is defective (Figure 3b), the cards must be physically and electronically the same. Figure 4 shows the diagram of the Amplifier to be diagnosed and the nodes are indicated where the voltage signal and the reference point will be applied, which must be the same in both the good and the defective cards.

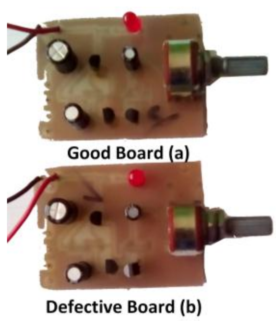


**Figure 3.** Board to diagnose: (a) Good Board, (b) Defective Board

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 13 (2018) pp. 11091-11095


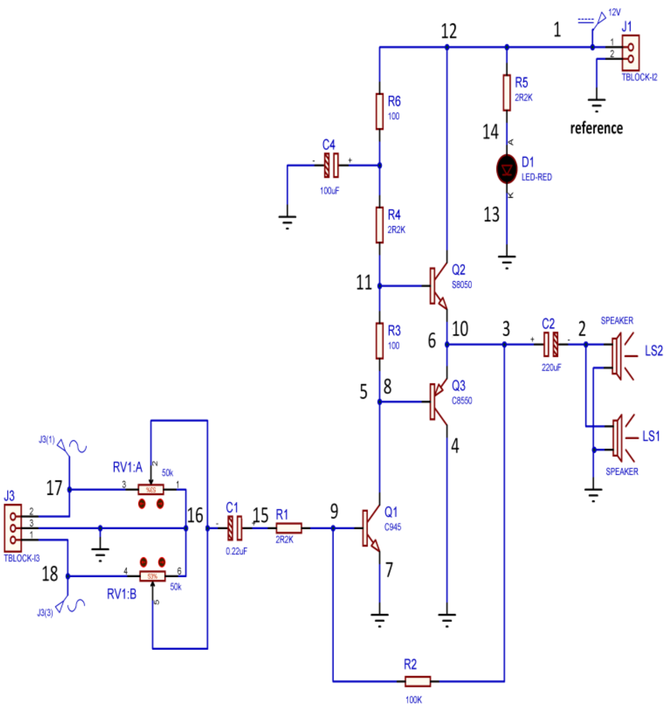


**Figure 4.** 2W Amplifier Schematic

The wave applied to the V-I Tracer is the one indicated in Figure 5 and its equation is:

$y(t) = A \sin(2\pi f t)$ (1)

Where:

A = Peak voltage =18 V

$\omega = 2\pi f t$

f = 60 Hz

t = Time

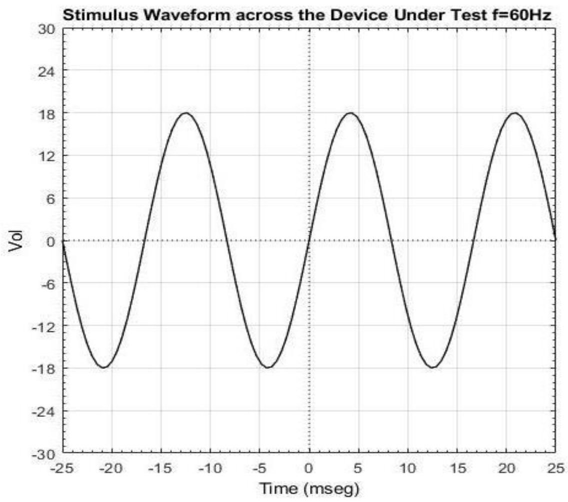


**Figure 5.** Signal applied to V-I TRACER

Figures 6 and 7 show the analog signatures of nodes 1 and 8, the signature on the left is of the card in good condition, the one on the right is the signature of the card under test. The graphs are obtained using the V-I TRACER explained in the previous section and the MATLAB software that allows the acquisition of data to graph them and analyze them. Graphs are observed in the voltage domain, in the Y axis is the A channel and in the X axis the B channel, they are graphed in such a way that generate the Lissajous figures [12] of all the elements that are connected in each of the nodes.

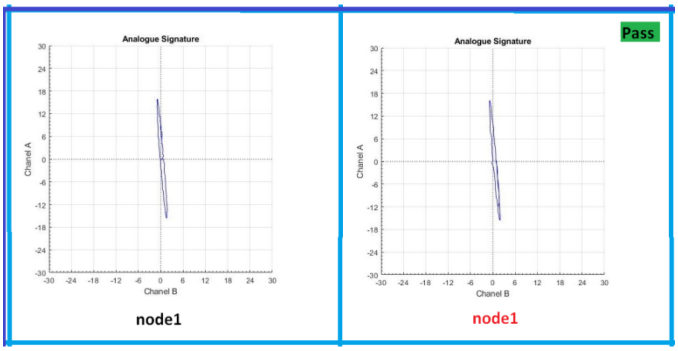


**Figure 6.** Analog signatures on node1 of the cards

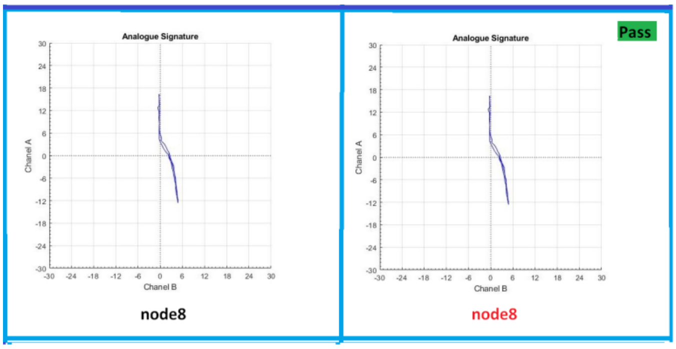


**Figure 7.** Analog signatures on node8 of the cards

## ANALYSIS OF THE ANALOG SIGNATURES

### *A. Equal analog signatures*

With the information obtained, it is possible to analyze the answers and make the appropriate decisions to diagnose the failure of the 2W Amplifier. The difference between the analog signatures of the good card and the one that is failing is evidenced by a visual comparison. For ease of the method, the direct observation of the graphs by the operator of the V-I TRACER is used. The repair technician must have a margin of tolerance that applies to the forms of analog signatures and use their knowledge and experience in repairing PCBs.

For greater clarity and simplicity of the analysis, in this work, the analog signatures obtained in the nodes are represented: node1 (Figure 6) and node8 (Figure 7). It must be taken into account that the analog signature of the good card is labeled as node1 in black color, left box, and the analog signature generated by the card under test is labeled as node1 in red color, right frame in Figure 6.

The analog signatures that are generated in the nodo1 are the same in the two cards therefore there is no failure (*Pass*). The same visual analysis is done in node8, the two analog signatures are equal it is concluded that the devices where the applied current and voltage circulates behave the same and having a card in good condition this defines the behavior of the analog signatures.

### *B. Different analogue signatures*

The damage to the amplifier is that there is no sound. If the signatures of node15 (Figure 8) and node16 (Figure 9) are observed, evident differences are found between the two analog signatures in each node, i.e. analyzing the responses in node15, the analog signature shown in the left box of Figure 8, which corresponds to the good card, is different from the analog signature shown in the right box of Figure 8, corresponding to the card under test, for this reason they are labeled as *Fault*. The same visual analysis is performed on node16.

The components that are related to these nodes are: potentiometer RV1:A, RV1:B and capacitor C1, as can be seen in the schematic of the amplifier in Figure 4. The tool allows detecting where there is difference in the analog signatures and shows them in a visual way.

To verify which component is defective the operator will need to remove the component from the card and compare it individually to generate the new signatures as shown in [9], verifying separately the potentiometers that are found to be defective, the capacitor C1 does not present damage. This procedure is done focusing on the components where there are differences with the signatures. To avoid damaging the cards with the rework, it is suggested to desolder one of the pins of the component, change the test reference and generate the analog signatures again, in this way the device that is malfunctioning is isolated.

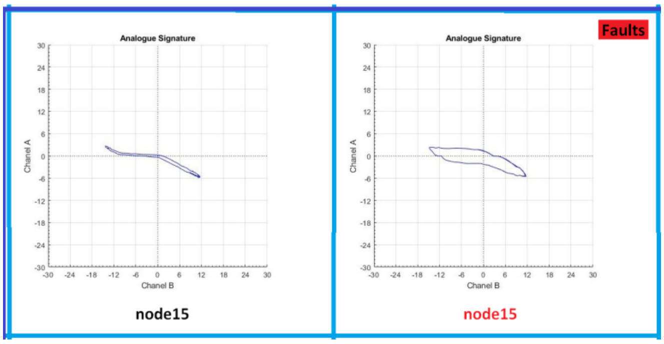


**Figure 8.** Analog signatures on node15 of the cards

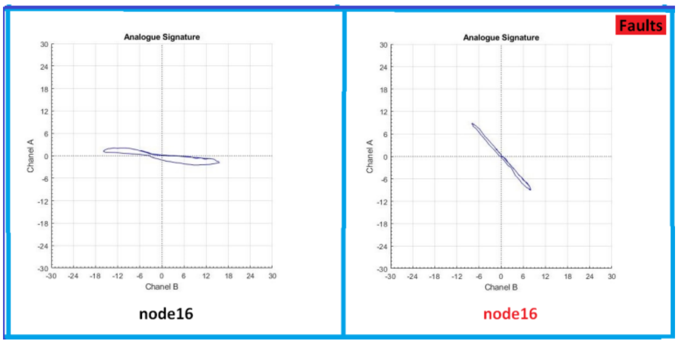


**Figure 9.** Analog signatures on node16 of the cards

The repair consists of replacing the defective potentiometers and performing the analysis again, where it is found that the signatures change and are now the same, consequently the damaged amplifier is repaired, the analog signatures can be observed once the changes of the potentiometers are made in the following Figures 10 and 11. When comparing the analog signatures of nodes16 of both electronic cards, it is observed that they are now equal. The repair technician is in charge of interpreting the signatures and making decisions, the tool is only an instrument that helps detect the failure. If desired, more sophisticated algorithms can be adapted to help the repairman make better decisions.

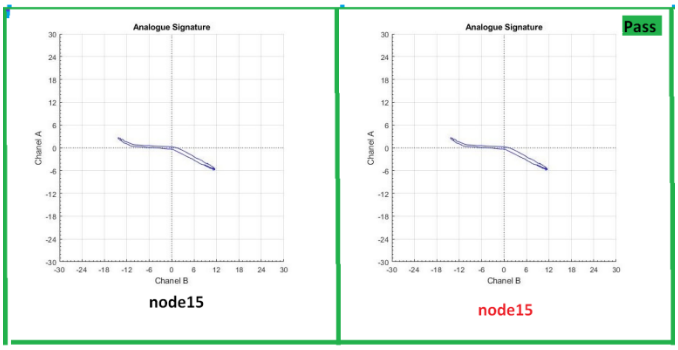


**Figure 10.** Analog signature on node15 of the cards after changing defective components

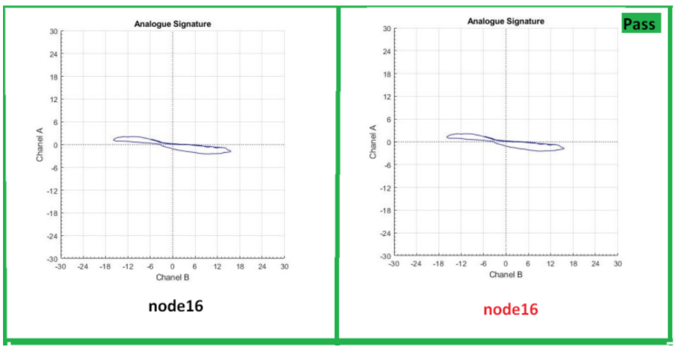


**Figure 11.** Analog signature on node16 of the cards after changing defective components

## CONCLUSIONS

A tool that allows to characterize the cards, and that is easy to acquire by the technical community is the challenge for designers and manufacturers, the costs of conventional tools used as the oscilloscope and the computer make it difficult to acquire and put into practice. For this reason the design of a tool that applies the concepts of the technique, taking advantage of the massification of the microcontrollers and its low costs to build it and make it available to electronic technicians, in this work its effectiveness was proved. The tools that are offered in the market can be acquired, but if their costs are quoted, they are beyond the reach of repair technicians. Using the MATLAB software for data acquisition is not practical because of the speed of response, the cost of the license and the need for a computer to present the graphs on the screen. The circuits that make the tool viable must be designed with low cost and quality electronics that include high-end microcontrollers because of their speed of response and processing capacity.

In this paper, there is an invitation to generate more detailed algorithms so that the tool helps the repairman to make better decisions. These can be: to show the figures on the same screen, both good and defective, to present pass or fail messages, to present percentages of differences of the analog signatures, to design a tool that is easy to acquire and that is portable so that it can be used in the field.

## REFERECES

[1] ROCCHETTI, Laura; AMATO, Alessia; BEOLCHINI, Francesca. Printed circuit board recycling: A patent review. *Journal of Cleaner Production*, 2018.

[2] HONGXIA, Pan; JINYING, Huang; GUANGMIN, Liu. Fault diagnosis of circuit board based on fault tree. In *Control, Automation, Robotics and Vision, 2008. ICARCV 2008. 10th International Conference on*. IEEE, 2008. p. 1666-1671.

[3] INSAF, Ambreen, et al. Techniques to Identify and Test PCB Faults with Proposed Solution. *Journal of Basic & Applied Sciences*, 2014, vol. 10, p. 532.

[4] GERMÁN-SALLÓ, Zoltán; STRNAD, Gabriela. Signal processing methods in fault detection in manufacturing systems. *Procedia Manufacturing*, 2018, vol. 22, p. 613-620.

[5] BINU, D.; KARIYAPPA, B. S. A survey on fault diagnosis of analog circuits: Taxonomy and state of the art. *AEU-International Journal of Electronics and Communications*, 2017, vol. 73, p. 68-83.

[6] R.S. Khandpur, *Troubleshooting Electronic Equipment Includes Repair And Maintenance*, Second Edition. Tata McGraw-Hill Education, 2003

[7] ABI Electronics Ltd, Ian Fletcher, TB007 - Introduction to V-I testing, February 2012.

[8] Fluke, 867B/863, Graphical Multimeter, User Manual, 1997.

[9] Diego A. Cabrera M., Robinson Jiménez M. “Detection Of Electronic Card Failures Using The Analog Signature Analysis Technique” *International Journal of Applied Engineering Research*, Vol. 13, No. 11, 2018, pp. 9320-9327

[10] KARACOR, Deniz, et al. Discrete Lissajous Figures and Applications. *IEEE Transactions on Instrumentation and Measurement*, 2014, vol. 63, no 12, p. 2963-2972.

[11] KIM, Bruce C., et al. *Method and system for testing an electric circuit*. U.S. Patent No 8,742,777, 3 Jun. 2014.

[12] GREENSLADE JR, Thomas B. All about Lissajous figures. *The Physics Teacher*, 1993, vol. 31, no 6, p. 364-370.

[13] SAN MIGUEL, Pablo Alcalde. *Electrónica aplicada*. Editorial Paraninfo, 2010.

[14] CORTÉS, Fernando Reyes; MONJARAZ, Jaime Cid. *Arduino: aplicaciones en robótica, mecatrónica e ingenierías*. Alfaomega, 2015.