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MEASUREMENT DEVICE FOR TESTING PRINTED CIRCUIT BOARD ASSEMBLIES COMING OFF THE PRODUCTION LINE

MERILNA NAPRAVA ZA PREIZKUŠANJE TISKANIH VEZIJ IZ PROIZVODNJE

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Abstract

The paper presents an efficient way to evaluate and determine the quality of an assembled printed circuit board coming off the production line. A printed circuit board assembly consists of electronic devices soldered to the printed circuit board, which provides the electrical connections. After assembling the printed circuit board, a function test needs to be performed to guarantee the quality of the product. Usually, the assembly lines are equipped with cameras that detect inaccuracies such as missing components. This level of quality assurance is sometimes not enough, and we need to add another degree of precaution. In addition to camera inspections, electronic measurements must be conducted. The process needs to be automated to provide repeatability and speed. The paper evaluates such a device and presents its advantages, disadvantages, and complexity. The device includes an electrical part that performs the measurements, a mechanical part that consists of a housing and a mounting nest, and a program that supervises the process.

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Povzetek

Raziskovalno delo predstavi efektiven način ocenjevanja in določanja kakovosti tiskanih vezij iz proizvodnih linij. Sestavljeno tiskano vezje zagotavlja električno povezavo prispojenim elektronskim komponentam. Po sestavi tiskanega vezja je potrebno izvesti funkcionalen preizkus, ki zagotavlja kakovost izdelka. Proizvodnje linije so ponavadi opremljene z inšpekcijskimi kamerami, ki odkrivajo nepravilnosti, kot so manjkajoče komponente. Vendar takšen način zagotavljanja kakovosti v nekaterih primerih ni zadosten, zato je potrebna dodatna raven nadzora. Poleg inšpekcij s kamerami je potrebno izvesti tudi električne meritve. Proces teh meritev mora biti avtomatiziran za zagotovljanje njegove ponovljivosti in hitrejše izvedbe. Raziskovalno delo ovrednoti pomen takšne naprave, predstavi njene prednosti in slabosti ter kompleksnost. Naprava obsega elektronski del, ki izvaja meritve, mehanski del, ki obsega ohišje in vpenjalno mesto, ter program, ki nadzira proces.

1 INTRODUCTION

Printed circuit boards (PCBs) have been a part of our lives for decades, facilitating everyday life as well as bringing more comfort. From an engineering point of view, PCBs make the construction and design of electronic projects easier, as they represent simple electronic connections *[1]*. Electric components are mounted on the PCB with through-hole technology (THT) or surface-mount devices (SMD), put together on advanced assembly lines that solder the desired component to the PCB through automation *[2]*. The assembly line consists of a loader that places the empty PCBs on the line, followed by the glue dispenser, which distributes the solder paste on the surface. The component placement machines place the electrical components on the PCB where the solder pads are located, and the last step consists of the reflow oven, where the components are soldered by hot air. The system is completed with the unloading of the assembled, cooled and camera-inspected PCBs *[3]*.

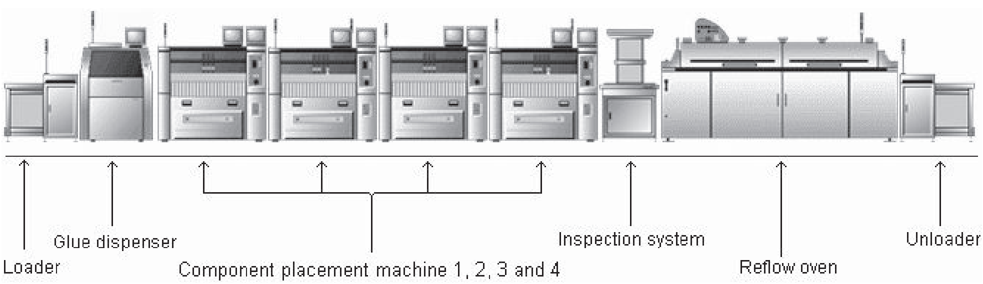

Figure 1: *Assembly line for PCBs [3]*

After assembly, the printed circuit board assembly (PCBA) could still have some errors, like damaged components or poor connections. Those inaccuracies could be detected with an intelligent measuring system *[4]*. That kind of device requires a procedure that can evaluate faults that occur while being assembled. So-called intelligent measuring systems come in the form of testing devices (TDs) that automate the measurement process. They need to measure all the required electrical components and quantities given by the developer of the tested circuit board. The TD needs to be designed with great care because it needs to be reliable and have a quick response time in order to minimise the cost of production. Such a device is extensive because it consists of a mechanical, an electrical, and a programming part of engineering. The electrical part must ensure that all the measurements can be acquired and that any additional damage is prevented in case of PCBA failure. The mechanical part must have a solid housing that provides all connection ports. Add-ons must include a mechanism that ensures an electrical connection with the measured PCBA. The programming part executes the automation of measurements with pre-written protocols.

The principle of all measurements is based on the fundamental laws of electrical engineering, such as Kirchoff's Current Law, which states that for any junction in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node. It is often used with Ohm's Law to perform nodal analysis, which states that current through a conductor between two points is directly proportional to the voltage across the two points. Kirchoff's Voltage Law declares that the directed sum of potential differences or voltages around any closed loop is zero *[5]*. The voltage measurement in this project was performed using an analog-to-digital converter (ADC) with 12-bit resolution *[6]*. The results are represented as measurement errors describing the deviation of measured values to the actual values. As the name suggests, the random error is random and cannot be eliminated in practice. The system error can and must be eliminated from the measurement *[7]*.

2 MATERIALS AND METHODOLOGY

2.1 Protocol of measurements

The TD must satisfy all requirements that the developer of the circuit determines. In our case, two circuits need to be inspected, one with eleven and one with six requirements. The first PCBA has five different voltages applied with linear voltage regulators on the tested board. It has a microprocessor with wireless technology (Wi-fi) and Bluetooth that require evaluation. A long-range (LoRa) module is integrated into the PCBA and needs to be tested. Significant communication and control lines also need to be checked, such as a Universal Asynchronous Receiver-Transmitter (UART), Inter-Integrated Circuit (i2c) protocols, and the operation of the MOSFET transistor. The second PCBA consists of two different voltages that need to be measured, as well as the functionality of the microprocessor and LoRa module. In addition, a 24-bit ADC mounted on the PCBA needs to be examined. On both PCBAs, a program for further use needs to be uploaded.

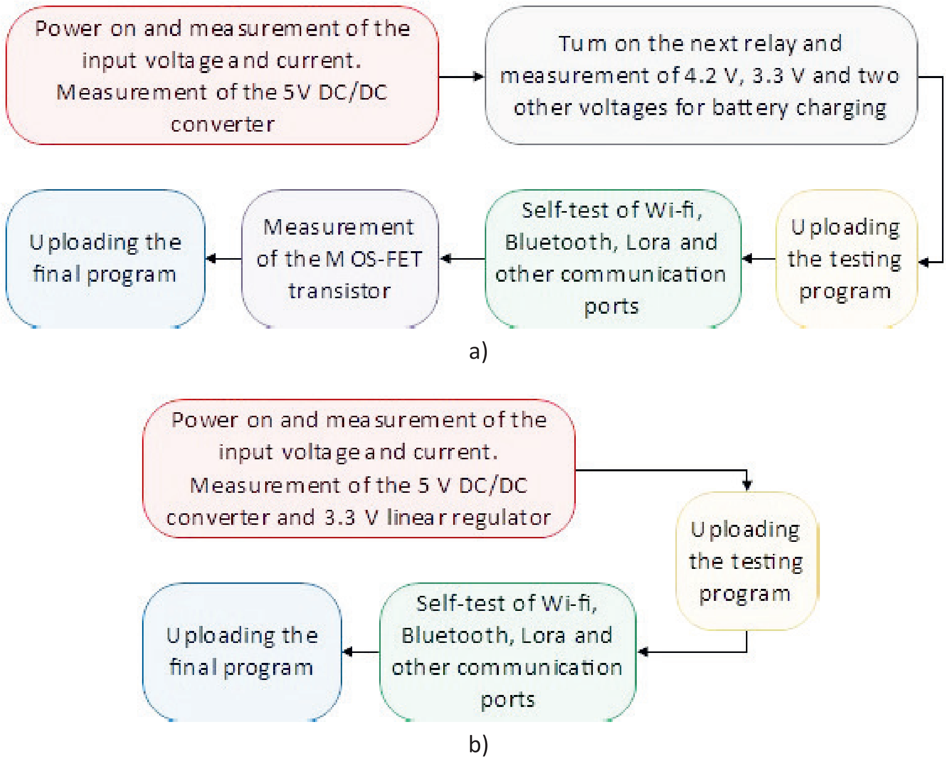

Figure 2: *Protocol of measurements for the first (a) and second (b) PCBA*

2.2 The electrical part of the testing device

The fundamental parts of the TD are the power supplies. The device is powered by 230 V AC and consists of an alternating to direct current (AC/DC) power supply that powers the testing device, and separate AC/DC power supplies for the tested devices. Separate power supplies are mandatory because the testing device needs to stay in operation in case of a short circuit on the tested board. The heart of the testing device is an LX6 microprocessor (240 MHz) powered by 3.3 V and consists of a 12-bit ADC and 17 general-purpose input/output pins *[8]*. The processor can be programmed with C or C++ via Universal Serial Bus (USB) to Time To Live (TTL). The processor executes the measurements, evaluates them, and sends the results to a server. To complete the measurements, we need to provide an electrical connection from the testing device to the tested PCBA. Various contact probes are used to provide the connection, as shown in Figure 3. The model of the probe is selected based on the PCBA surface connection port. Usually, the developer of the tested board has already determined special pins that are only for testing purposes.

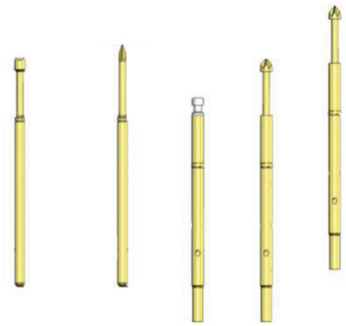

Figure 3: *Contact probes [9]*

2.3 The mechanical part of the testing device

The mechanical part consists of a housing and the mechanical clamping of the testing PCBA to the TD. The housing must be compact and provide the necessary connection ports and component mountings. Part of the top housing comprises the mechanical clamping, also known as the nest, consisting of AL4040 profiles where AMF clamps are mounted. The clamp pushes the tested PCBA into the nest, where the contact probes are located (Figure 4).

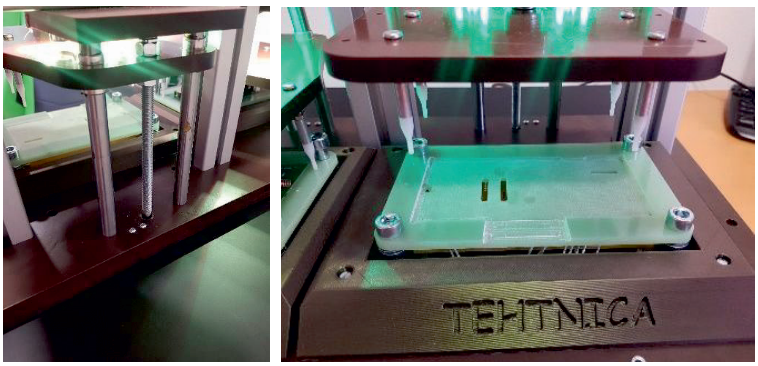

Figure 4: *Clamping mechanism*

The nest is protected by a 3-dimensional printed shield that protects the worker performing the measurements. The measurement starts when the clamp is fully pushed down, triggering a limit switch. The construction is shown in Figure 5.

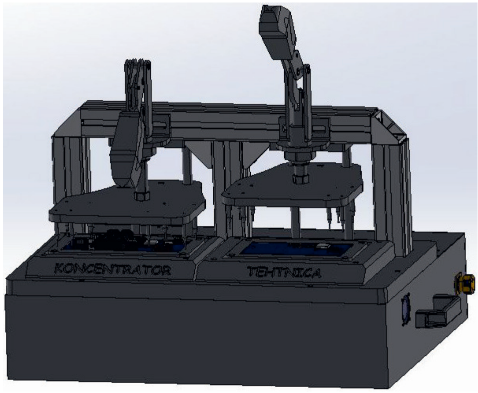

Figure 5: *The testing device*

2.4 Programming of the testing device

Programming of the microprocessor is done with the C++ programming language. The measured data is sent via USB to the server, and the TD functions with two processors, one for each nest and its program. Two additional programs were written and uploaded to the testing PCBAs, which carry out self-testing. The voltage is measured with the ADC with the help of resistor voltage dividers, whose characteristic is non-linear (shown in Figure 6). Therefore, the measurement can be solved using the characteristic transformation given by (1.1).

$$U_{real} = -1.6 \cdot 10^{-12} \cdot U^4 + 118.171 \cdot 10^{-12} \cdot U^3 - 301 \cdot 10^{-9} \cdot U^2 + 1.10902 \cdot 10^{-3} \cdot U + 0.034 \qquad (1.1)$$

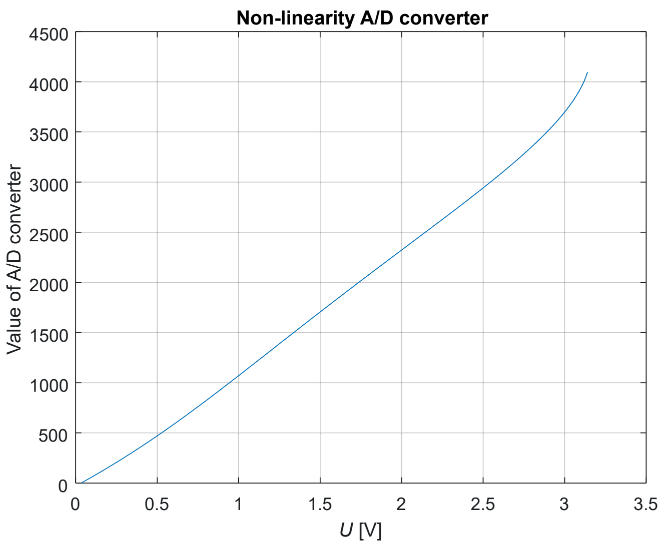

Figure 6: *Non-linearity of the ADC*

3 RESULTS

In the process of designing the testing device, we need to take into consideration the needs of production in the factory. The safety of workers and the provision of quality are the primary concerns. Safety is ensured with features such as 3D printed parts by the nest, low resistance grounding of the metal objects, and an emergency stop button. A functional test must be performed to provide quality measurements before every series. The functionality test is necessary to discover all the failures on the PCBA. Figure 7 presents all the possible failures and PCBAs with errors.

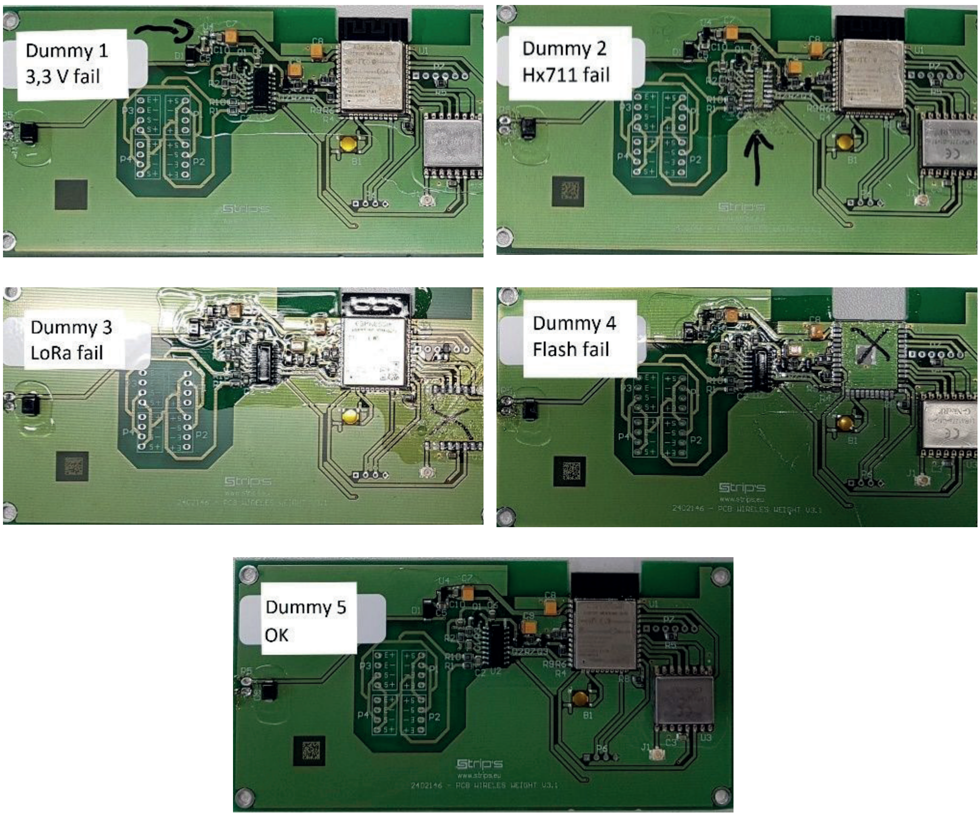

Figure 7: *PCBA functional tests*

The function test must be planned for both nests and cover all possible errors. Maintenance of the testing device is crucial because we need to ensure reliable operation for a long lifespan. The device must be maintained by lubricating the rods and the AMF clamp. The pushrods that push the tested PCBA in the nest need to be checked so they are not loosened, and the contact probes need to be inspected for any damage or dirt so there is no extra electrical resistance.

An analysis of a small series of 120 measurements was made on the second PCBA. The essential evaluation is the time of the measurement and the successful search for errors. In the series of 120 measurements, only three failures were detected, one defect of the 3.3 V linear voltage regulator and two failures on the LoRa module. The success of the measurements is shown in Figure 9.

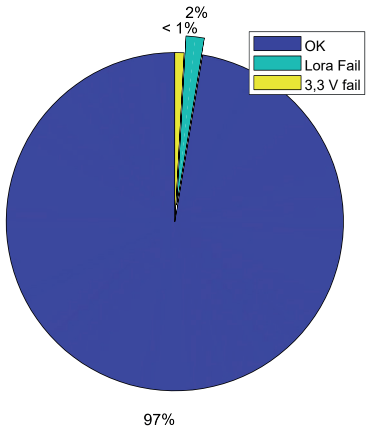

Figure 8: *Success of measurements*

The average time of the measurements without errors is 28.5 seconds. Most of the time is consumed when the testing and final program are uploaded. In case of failure, the time is shorter and depends on the error. The 3.3 V linear regulator measurements were analysed, and their results are presented in Table 1.

Table 1: *Statistical parameters of the 3.3 V linear regulator*

Parameter	Value
Maximal value	3.312205 V
Minimal value	3.278544 V
Average	3.293518 V
Median	3.292965 V
Variance	0.000030588
Standard deviation	0.00555526

The normal distribution of the 3.3 V linear regulator is shown in Figure 9, which displays minimal deviation, indicating positive results and quality of the measurement method with the ADC of the linear regulator.

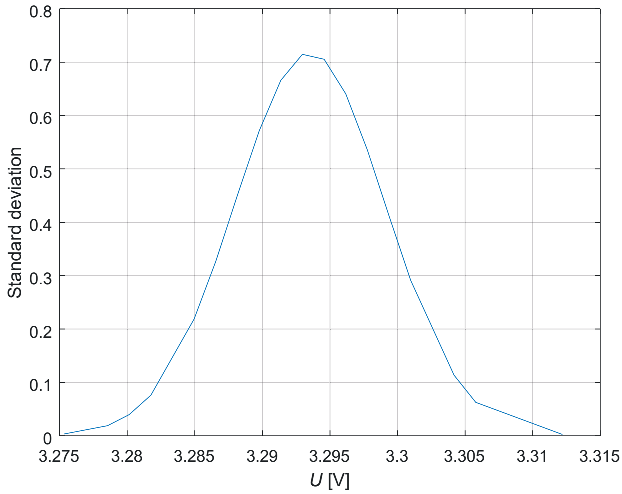

Figure 9: *Normal distribution of the 3.3 V linear regulator*

4 CONCLUSION

The intelligent measuring system, or the so-called testing device, ensures quality from the assembly line. Through the paper, an innovative method of designing a smart measurement system is presented, and therefore an advanced method for quality assurance of the product is realised. Electrical, mechanical and computer engineering knowledge is concentrated in a very complex product like the testing device. The housing protects the measurement equipment, allowing us to provide a safe work environment for workers. A reliable electrical connection with the tested PCBA is provided by the nest, which is one of the most crucial parts of the testing device. The electronics enable an intelligent measuring system that automates the measurements and speeds up the process in combination with programming. Successfully integrated testing devices are raising the quality of the products, lowering the proportion of defective devices being sold, and lowering the number of product returns. Testing devices are crucial in the PCBA industry and can be used for testing different products and materials. Unfortunately, the indestructible method is not always the most convenient technique to determine a product's functionality. However, it is desirable because it does not damage the product while testing its workflow. Intelligent measuring systems are also used in some maintenance programs and by some buyers in-house.

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