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CREATION OF APPLICATIONS FOR FUNCTIONAL TEST SYSTEM WITH TRACEABILITY FOR CELL PHONE CHARGERS

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ABSTRACT
This project addresses the growing need to ensure the traceability and quality of mobile phone chargers in a globalized market, where transparency in processes is key. The main objective is to perform electrical tests with traceability using QR code scanning and programming through the National Instruments LabWindows/CVI software. The study begins with the contextualization of the problem, highlighting the importance of traceability to ensure the quality and reliability of electronic products, such as cell phone chargers. It was observed the need to implement methods that streamline the testing process, aiming to maximize production efficiency. The materials and methods employed involve the use of LabWindows/CVI software, an ANSI C development environment specific for test and measurement applications. In addition, observations were carried out in the charger testing sector to identify gaps in the process and determine the best strategies to implement traceability. In the proposed process, the first step consists of reading the QR code of the ruler and the chargers, organizing them in numerical sequence for registration in a .txt file. Then, the second step performs data collection, performs the necessary electrical tests, and generates a .csv file for local storage, along with a .xml file for registration in the company's database. The results include a significant improvement in the efficiency of the testing process, the assurance of complete traceability of the loaders and the optimization of the production time of the equipment.

Keywords: Traceability, Software, Process, Functional Testing.

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INTRODUCTION

In the current context of software development, product quality assurance has become a crucial aspect for the success of any technological project. With the increasing adoption of agile methodologies and the demand for continuous delivery, significant challenges emerge that require innovative and efficient solutions. One of the most effective solutions is the implementation of traceability, which links the requirements, architecture, and improvements of the systems in a clear and efficient way. This technique is vital to identify and solve problems quickly and accurately during the development cycle, thus ensuring a continuous and robust improvement in the quality of the systems produced (Barros, 2018).

The transformation brought about by Industry 4.0, driven by technological advances such as the Internet of Things (IoT), artificial intelligence, big data, and automation, is redefining industrial production standards. This revolution not only automates physical processes, but also promotes the complete digitalization of management procedures, which facilitates the creation of smarter and more efficient production environments. In this context, traceability and quality control capacity play crucial roles, ensuring compliance with international standards and monitoring the complete trajectory of products from conception to delivery to the final consumer (Cavalcante, 2019).

Specifically in the cell phone charger manufacturing sector, traceability is even more decisive. Given the high demand for efficient and safe products, each component in the manufacturing process needs to be traceable, allowing not only the identification but also the effective correction of any defects that may compromise the final quality of the product. This challenge is amplified by the variety of charger models and the need to quickly adapt to the technical changes that are required by the dynamic market (Mota et al., 2022).

The proposed project focuses on the development of functional testing applications with advanced traceability capabilities for Salcomp Industrial Eletrônica da Amazônia Ltda., using the LabWindows/CVI software. The implementation of this advanced test system not only facilitates proactive fault detection, but also significantly improves documentation and process management. This optimizes efficiency and quality in the production of mobile phone chargers by introducing modern technologies such as QR codes for fast and efficient traceability, essential to adapt to the rapid cycles of technological innovation and the growing demands of the global market (Kieseberg et al., 2010).

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In addition, the adoption of advanced traceability practices and agile process management methods directly meets the needs of reducing production costs, minimizing material waste, and ensuring the delivery of products that strictly meet quality and safety expectations. Developing a functional test system with traceability for mobile phone chargers not only responds to market demands for quality and efficiency, but also promotes the company's operational sustainability and competitiveness on the global stage. The ability to monitor each component and process in real time provides more efficient resource management, a quick response to quality issues, and greater flexibility to adapt to new regulations and consumer expectations (Pressman, 2014).

The strategic implementation of this traceability system not only improves the company's position in the international market, but also sets a new standard of quality that benefits the entire industry. The project goes beyond mere compliance with established standards, promoting a significant advance in the way quality is ensured and monitored. By adopting this new technology, the company not only ensures an improvement in the quality of its products, but also reinforces its image in the market as a leader in innovation and reliability (Rocha et al., 2018).

In addition, the development of specialized functional testing systems with traceability for mobile phone chargers represents a significant advance in quality assurance for electronic products. These tools allow for more accurate and effective information management, reduce the incidence of errors, and facilitate the early identification of failures. This advanced approach is crucial for consumer satisfaction and the success of companies in the sector in a highly competitive environment dependent on technological innovation (Pedraza et al., 2020).

The relevance of this topic is underlined by the growing need of the software industry to ensure the quality and reliability of products, especially in a scenario marked by agile development and increasing complexity. Efficient traceability, through specialized systems such as the one proposed in this study, is essential to meet market requirements and maintain the competitiveness of companies in the electronic device production sector. This project, therefore, not only responds to the immediate needs of the industry, but also lays a foundation for future innovations that can continue to transform the field of electronic manufacturing.

THEORETICAL FRAMEWORK

This theoretical framework provides a solid foundation for understanding the principles and practices of Agile Software Engineering, Functional Testing and Traceability within the context of Industry 4.0. The interconnections between these areas underpin a methodology that is adaptive, efficient, and quality-driven, ensuring that software development processes not only meet current market needs, but are also resilient and able to evolve with future demands.

AGILE SOFTWARE ENGINEERING

Agile Software Engineering is a methodology that has transformed software development practices by emphasizing flexibility, cross-functional collaboration, and a rapid response to change. Originating from the 2001 Agile Manifesto, this approach was a direct response to the limitations of traditional development methods, considered by many to be too bureaucratic, slow, and inflexible (Pressman, 2014).

Among the most prevalent agile methodologies are Scrum, Kanban, and Extreme Programming (XP), each approaching software development in a way that reinforces adaptability and operational effectiveness. Scrum, for example, structures development in cycles called sprints, Kanban focuses on maximizing workflow efficiency, and XP promotes software development practices with high quality and response to change (Reis, 2005).

These methodologies share common characteristics, such as short and regular development iterations, adaptive planning, and continuous delivery, allowing teams to react flexibly to changing customer requirements. The successful implementation of these agile methodologies requires a significant cultural shift within organizations, fostering a mindset that values transparency, collaboration, and adaptability (Barros, 2018).

FUNCTIONAL TESTING IN SOFTWARE DEVELOPMENT

Functional testing is crucial to ensure that the software works as specified, focusing on verifying the functionalities described in the user requirements. These tests evaluate specific parts of the software to ensure its correct operation and are essential for identifying defects in early stages of the development lifecycle, mitigating future costs associated with fixing flaws (Silva, 2019).

Functional testing is structured around test cases that derive directly from functional requirements, ensuring that all aspects of the software are verified. This includes conducting unit, integration, and system testing, each addressing different components and aspects of the software. The importance of these tests is emphasized by the need for high-quality software deliveries that meet end-user expectations and comply with regulatory standards (Barbosa et al., 2023).

TRACEABILITY IN PRODUCTION SYSTEMS AND SOFTWARE DEVELOPMENT

Traceability is an essential component in quality management, making it easy to track each component of a product throughout its life cycle. In a software context, traceability helps to link requirements, software designs, implementations, and tests, providing a clear view of how each requirement is performed in a final implementation and tested throughout the development process (Eckschmidt et al., 2009).

In the era of Industry 4.0, traceability gains new dimensions due to the integration of technologies such as big data and IoT, which allow the collection and analysis of large volumes of data in real time. These technologies improve the accuracy and effectiveness of traceability processes, allowing companies to respond more quickly to quality issues and adapt processes in the face of real-time feedback (Barros, 2018).

Effectively implementing traceability in development and production processes requires robust data management systems that can capture, store, and analyze detailed information about each stage of development and production. This is crucial to ensure quality and to enable continuous improvement of products and processes (Batista, 2023).

MATERIALS AND METHODS

In this section, the methodology used in the research for the development of functional test system applications with traceability using the LabWindows/CVI software for the company Salcomp Industrial Eletrônica da Amazônia Ltda is described.

MATERIALS USED

Development Software: LabWindows/CVI

- Description: LabWindows/CVI is an integrated development tool that uses the C language for the creation of test and measurement applications.
- Key features:
  - Programming Flexibility: Offers a robust platform that combines the power of C programming with specific functions for test and measurement.

- Graphical User Interface: Allows you to develop custom interfaces that facilitate user interaction and data visualization.
- Hardware Integration: Excellent compatibility with a variety of test and measurement hardware, optimizing data collection and analysis.

Test Instruments

1. General Purpose Interface Bus (GPIB) Control Board
   - Model: National Instruments PCI IEEE 488.
   - Function: Facilitates communication between the computer and test and measurement devices.
   - Key features:
     - Connectivity: Allows connection to up to 14 GPIB devices, making it easy to control multiple instruments simultaneously.
     - Data Transfer Rate: High transfer speed for efficient data acquisition and instrument control.
     - Universal Compatibility: Supports a wide range of instruments from various manufacturers.

2. High-Speed Digital I/O Card
   - Model: PCI 7432 from ADLINK.
   - Function: Offers digital connectivity between the computer system and external devices.
   - Key features:
     - I/O Channels: 32 configurable channels as input or output, providing versatility in controlling and monitoring systems.
     - Applications: Ideal for industrial automation and process control, allowing integration with sensors and actuators.
3. Digital Multimeter
   - Model: Agilent 34401A.
   - Function: Performs precise measurements of various electrical quantities.
   - Key features:
     - Wide Measurement Range: Capable of measuring voltage, current, resistance, frequency, and other quantities with high accuracy.

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- Communication Interface: Equipped with GPIB, RS-232, and USB for easy integration with other systems and test automation.

4. AC Source
   - Model: 6811A AC Power Source.
   - Function: Provides controlled AC power for testing and simulations.
   - Key features:
     - Voltage and Current Control: Precise voltage and current adjustments to simulate different electrical conditions.
     - Safety Protections: Includes overload and over-temperature protections for safe use in rigorous testing.

METHODOLOGY

In this project, an applied research approach was adopted, focused on the development and testing of power supply systems for electronic devices, a critical area within the operations of Salcomp Industrial Eletrônica da Amazônia Ltda. The objective was to address specific challenges and create innovative technological solutions through intensive research and development (R&D) activities.

The methodology employed was based on the integration and effective use of specialized materials and software to perform accurate functional tests and ensure complete traceability of the devices. LabWindows/CVI was used, a flexible development tool that allows detailed interactions with a variety of test instruments, such as the GPIB Interface Control Board and the Agilent 34401A Digital Multimeter. These tests are designed to validate the functionality of electronic devices under varying conditions by monitoring their responses to different stimuli and measurements.

The scope of this research included professionals directly involved in the functional testing processes, such as engineers, technicians and developers, selected based on their experience and familiarity with the LabWindows/CVI software. To ensure ethical and regulatory compliance, all participants provided informed consent.

The development process followed a clear methodological sequence, starting with a detailed requirements gathering through meetings and document analysis. After defining a robust, modular and scalable architecture, the system was implemented, following good programming practices and performing a series of tests, including unit, integration and system tests. These steps ensured that all developed solutions were rigorously tested and validated prior to deployment and training of end users.

This integrated and systematic methodology allows not only to effectively test and validate the products, but also ensures that all aspects of the device are meticulously evaluated and that the test results are traceable, supporting the high quality and safety standards required by the industry and the market.

- Test System Planning

DEFINITION OF REQUIREMENTS

Description: The process began with brainstorming sessions and meetings with Salcomp's technical team to capture and document the requirements of the functional testing system. This included identifying the specific needs of electronic devices that require testing, as well as end-user expectations.

Objectives: To establish a clear understanding of the required functionalities, the expected performance of the system and the acceptance criteria for traceability tests.

- Development and Implementation

Hardware and Software Selection

Software: LabWindows/CVI's choice based on its compatibility with a variety of measurement and test hardware, as well as its flexibility for custom programming.

Hardware: Identification and selection of the most suitable test instruments, including the GPIB Interface Control Board and the Agilent 34401A Digital Multimeter, which are essential for accurate data collection and analysis.

Development of Functional Testing Applications

Test Procedures: Development of customized test routines using LabWindows/CVI, allowing automatic test execution, data collection and report generation.

System Integration: Configuration and integration of the various hardware components with the software to ensure smooth and efficient test operations.

Integration of QR Code Readers and Tracking Devices

Implementation: Installation of QR Code readers and tracking devices to facilitate the identification and traceability of the devices under test, ensuring data integrity and compliance with traceability standards.

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- System Validation and Testing

Functionality Testing

Execution: Conducting a series of functionality tests to validate the performance of the test system in simulating and measuring the operations of the devices under test.

Evaluation: Analysis of the data collected to verify the accuracy and reliability of the functional test system developed.

Traceability Verification

Verification Process: Use of the QR Code readers and built-in tracking devices to test the effectiveness of the traceability system in recording and maintaining accurate data about the tested devices.

- Documentation and Training

System Documentation

Detailing: Creation of complete documentation that describes the operation, configuration and maintenance of the test system, essential for future references and audits.

Availability: Ensure that documentation is accessible to all technicians and engineers involved, promoting a uniform understanding of the system.

Team Training

Training Program: Development and implementation of a training program for end users, focusing on the proper use, maintenance and troubleshooting of the test system.

Feedback and Continuous Improvement: Collecting feedback from users for continuous system improvements and refinement of training processes.

RESULTS AND DISCUSSION

- Requirements Gathering

Before starting development, a detailed collection of requirements was carried out through meetings with all stakeholders. During these meetings, functional and non-functional requirements were identified and documented, including details on performance, security, and usability. Specific traceability requirements were also considered to ensure the ability to trace each functionality of the system back to its corresponding requirements, as demonstrated in Figure 1.

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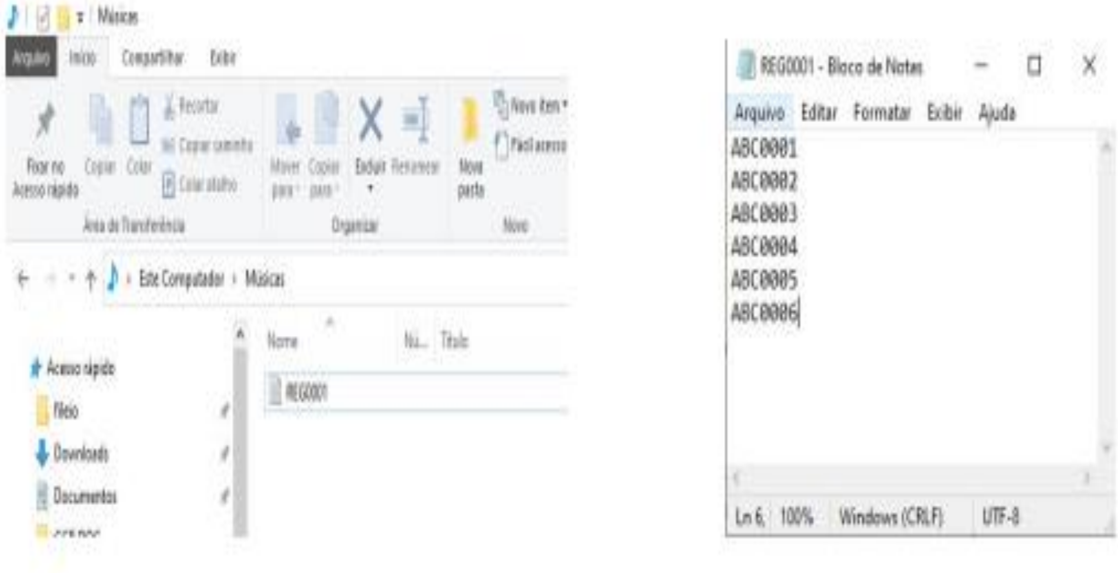
Figure 1: Database Organization



Source: Prepared by the authors

- Design and Architecture

The Design and Architecture phase focused on developing a software architecture that was robust, scalable, and modular. The selection of suitable technologies was based on criteria such as performance and ease of maintenance. The decision for each technology and each aspect of the design has been documented and is represented in Figure 2.

Figure 2: Test Table (.txt)

```
modelo                            ,min    ,max    ,gra    ,seq    ,step   ,start  ,nome
1       ,AC_POWER[90              ,1      ,1      ,OP     ,1
2       ,FREQ[47                  ,1      ,1      ,OP     ,2
3       ,LOAD_CC[1.67             ,1      ,1      ,OP     ,3
4       ,DELAY[4.8                ,1      ,1      ,OP     ,4
6       ,STATIC_VOLTAGE_TEST_1    ,8.9    ,9.45   ,VOLT   ,5      ,       ,       ,TENSAO(9V) 90V 47HZ 1.67A
12      ,OCP_TEST_1               ,1.67   ,2.17   ,ARMS   ,6      ,0.05   ,1.80   ,OCP(9V) 90V 47HZ
4       ,DELAY[1.0                ,1      ,1      ,OP     ,7
6       ,STATIC_VOLTAGE_TEST_2    ,8.9    ,9.45   ,VOLT   ,8      ,       ,       ,TENSAO(9V) 90V 47HZ 0A
5       ,LOAD_CV[7.5              ,1      ,1      ,OP     ,9
4       ,DELAY[0.5                ,1      ,1      ,OP     ,10
10      ,STATIC_CURRENT_TEST_1    ,1.7    ,2.0    ,ARMS   ,11     ,       ,       ,CORRENTE(9V) 90V 47HZ 7.5V
1       ,AC_POWER[264             ,1      ,1      ,OP     ,12
2       ,FREQ[63                  ,1      ,1      ,OP     ,13
5       ,LOAD_CV[7.5              ,1      ,1      ,OP     ,14
4       ,DELAY[0.5                ,1      ,1      ,OP     ,15
10      ,STATIC_CURRENT_TEST_2    ,1.73   ,1.95   ,ARMS   ,16     ,       ,       ,CORRENTE(9V) 264V 63HZ 7.5V
11      ,IO_OUTPUT_CARD[08        ,1      ,1      ,OP     ,17
4       ,DELAY[1.8                ,1      ,1      ,OP     ,18
1       ,AC_POWER[264             ,1      ,1      ,OP     ,19
2       ,FREQ[63                  ,1      ,1      ,OP     ,20
3       ,LOAD_CC[0                ,1      ,1      ,OP     ,21
4       ,DELAY[0.1                ,1      ,1      ,OP     ,22
6       ,STATIC_VOLTAGE_TEST_3    ,4.95   ,5.25   ,VOLT   ,23     ,       ,       ,TENSAO(5V) 264V 63HZ 0A
3       ,LOAD_CC[2.0              ,1      ,1      ,OP     ,24
4       ,DELAY[0.1                ,1      ,1      ,OP     ,25
6       ,STATIC_VOLTAGE_TEST_4    ,4.95   ,5.25   ,VOLT   ,26     ,       ,       ,TENSAO(5V) 264V 63HZ 2A
5       ,LOAD_CV[3.7              ,1      ,1      ,OP     ,27
4       ,DELAY[0.5                ,1      ,1      ,OP     ,28
10      ,STATIC_CURRENT_TEST_3    ,2.03   ,2.4    ,ARMS   ,29     ,       ,       ,CORRENTE(5V) 264V 63HZ 3.7V
12      ,OCP_TEST_2               ,2.00   ,2.50   ,ARMS   ,30     ,0.05   ,2.20   ,OCP(5V) 264V 63HZ
FIM
```

Source: Prepared by the authors

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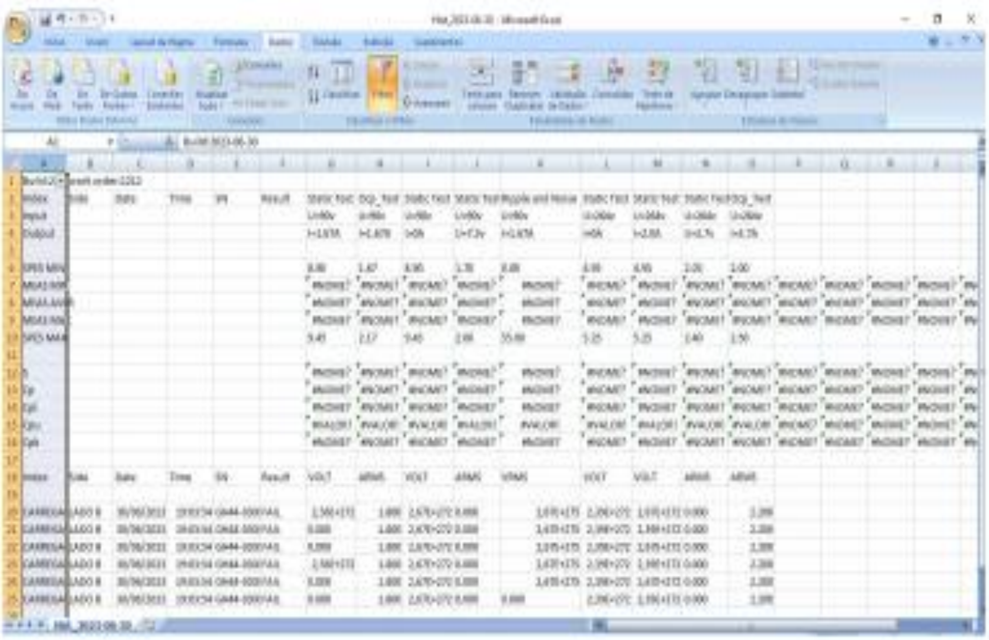
- Implementation

During implementation, the system components were coded as specified in the previous phases. This process was meticulously documented and traceability mechanisms were integrated to capture detailed information during testing, as illustrated in Figures 3 and 4.

- Tests

The tests covered several phases, including unit, integration and system testing. The planning and results of these tests are detailed in Figures 5 and 6 (included later), where voltage and Over Current Protection (OCP) test graphs are shown, demonstrating how the chargers respond under specific test conditions.

Figure 3: File (.csv)



Source: Prepared by the authors

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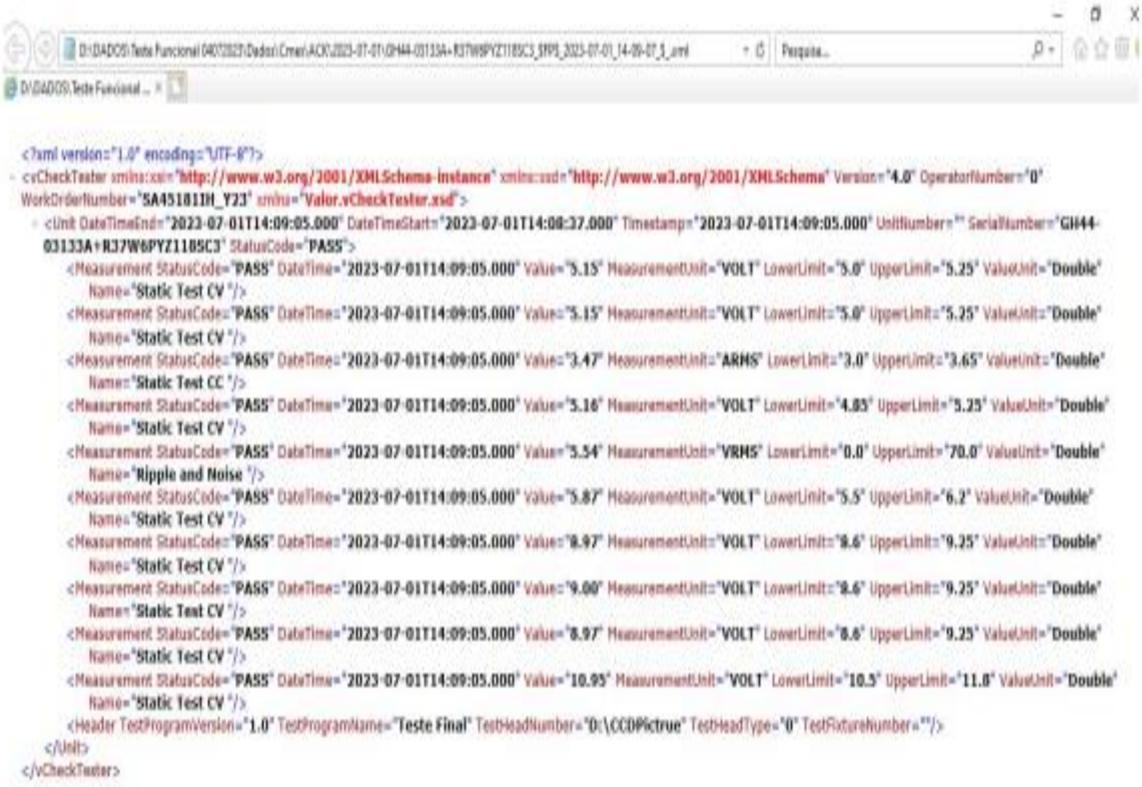
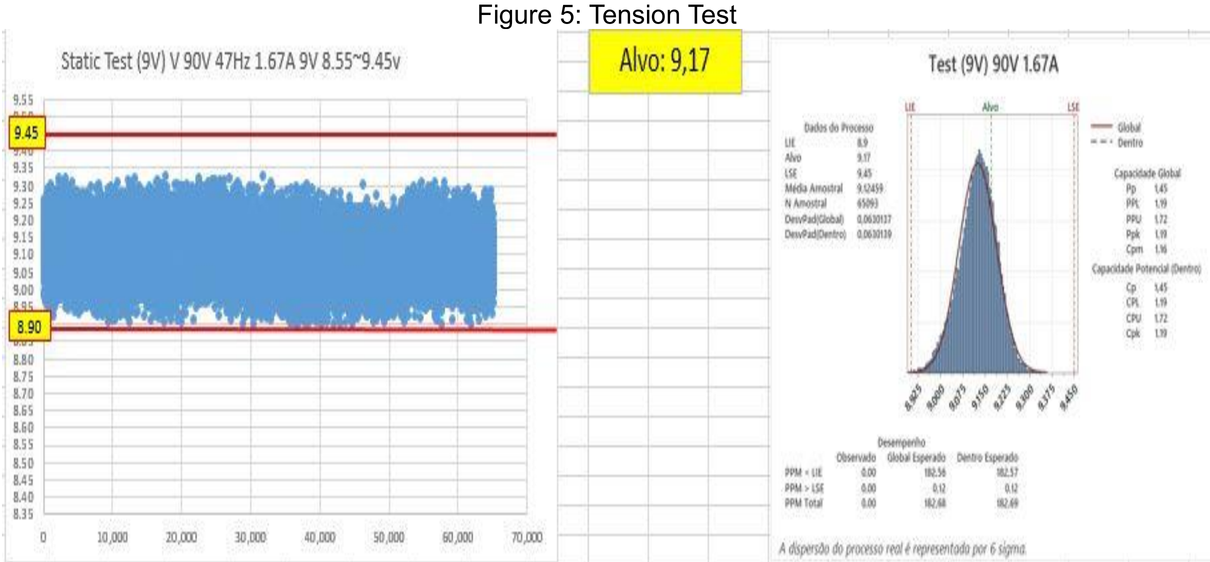
Figure 4: File (.xml)



```
&lt;?xml version="1.0" encoding="UTF-8"?&gt;
<vCheckTester xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xsd="http://www.w3.org/2001/XMLSchema" Version="4.0" OperatorNumber="0"
WorkOrderNumber="SA451811H_Y23" xmlns="Valor.vCheckTester.xsd">
  &lt;Unit DateTimeEnd="2023-07-01T14:09:05.000" DateTimeStart="2023-07-01T14:08:37.000" Timestamp="2023-07-01T14:09:05.000" UnitNumber="" SerialNumber="GH44-03133A+R37W6PYZ1185C3" StatusCode="PASS"&gt;
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="5.15" MeasurementUnit="VOLT" LowerLimit="5.0" UpperLimit="5.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="5.15" MeasurementUnit="VOLT" LowerLimit="5.0" UpperLimit="5.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="3.47" MeasurementUnit="ARMS" LowerLimit="3.0" UpperLimit="3.65" ValueUnit="Double"
      Name="Static Test CC "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="5.16" MeasurementUnit="VOLT" LowerLimit="4.85" UpperLimit="5.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="5.54" MeasurementUnit="VRMS" LowerLimit="0.0" UpperLimit="70.0" ValueUnit="Double"
      Name="Ripple and Noise "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="5.87" MeasurementUnit="VOLT" LowerLimit="5.5" UpperLimit="6.2" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="8.97" MeasurementUnit="VOLT" LowerLimit="8.6" UpperLimit="9.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="9.00" MeasurementUnit="VOLT" LowerLimit="8.6" UpperLimit="9.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="8.97" MeasurementUnit="VOLT" LowerLimit="8.6" UpperLimit="9.25" ValueUnit="Double"
      Name="Static Test CV "/>
    <Measurement StatusCode="PASS" DateTime="2023-07-01T14:09:05.000" Value="10.95" MeasurementUnit="VOLT" LowerLimit="10.5" UpperLimit="11.0" ValueUnit="Double"
      Name="Static Test CV "/>
    &lt;Header TestProgramVersion="1.0" TestProgramName="Teste Final" TestHeadNumber="D:\CCDPictrue" TestHeadType="0" TestFixtureNumber=""/&gt;
  &lt;/Unit&gt;
&lt;/vCheckTester&gt;
```

Source: Prepared by the authors

Figure 5: Tension Test



Source: Prepared by the authors

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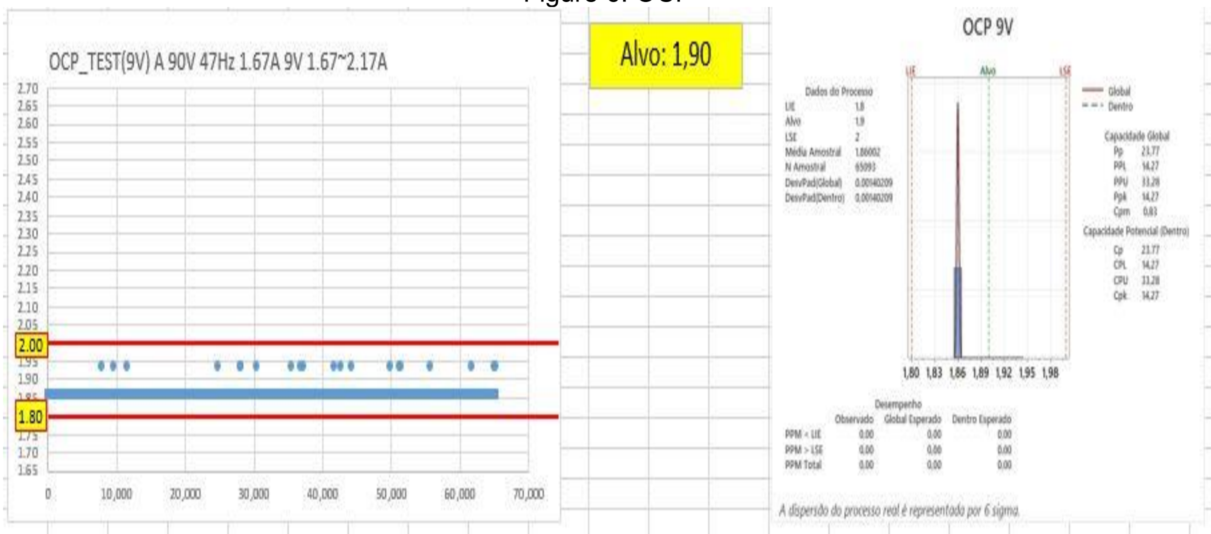
Figure 6: OCP



Source: Prepared by the authors

- Implantation

Integration and testing in the production environment was carefully planned and executed. The Test Rack and its components are detailed in Figure 7, and the system configuration and connection procedures are illustrated in Figure 8.

Figure 7: Test rack and its components

Source: Salcomp Company – 2024.

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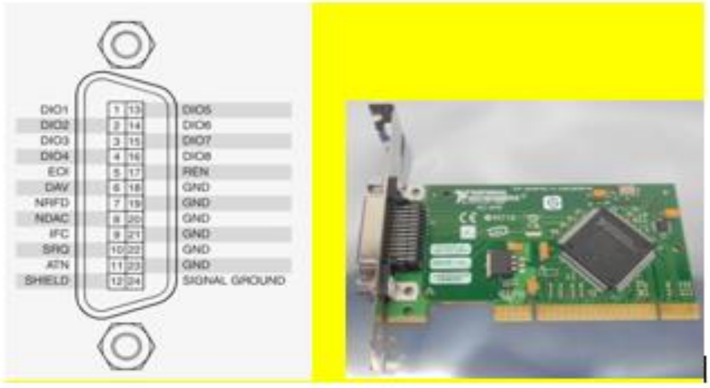
Figure 8: PCI GPIB

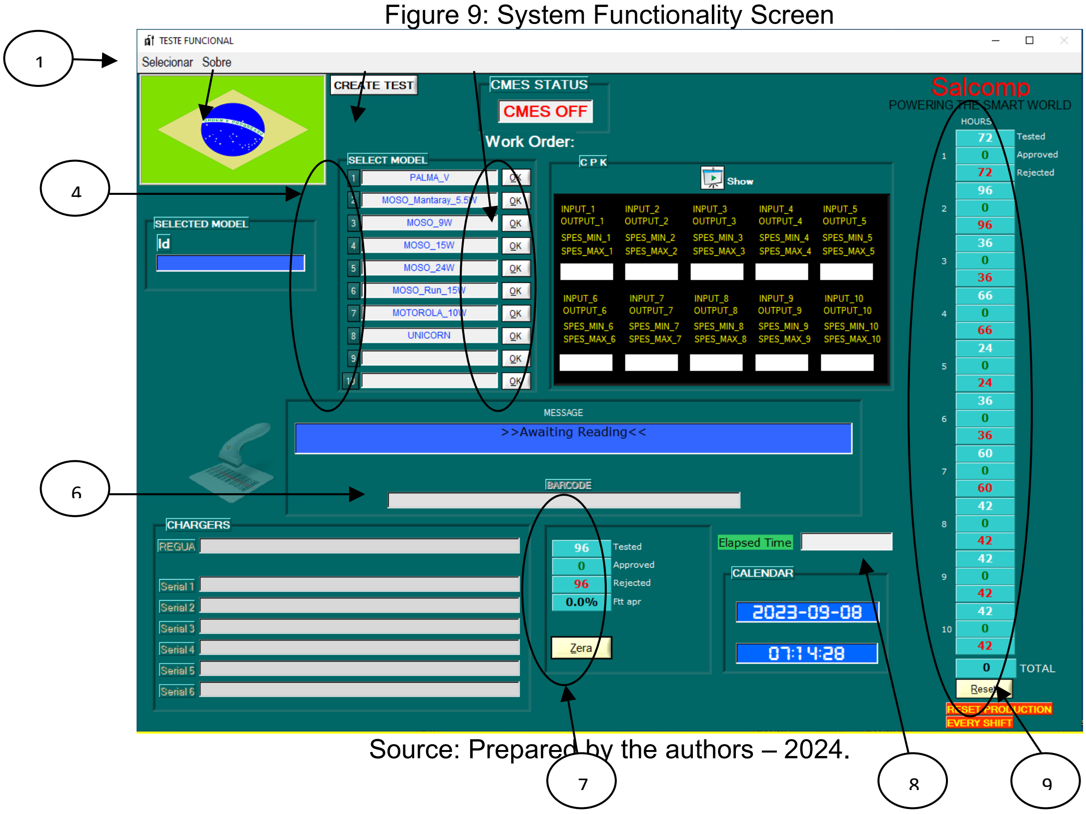


Source: Prepared by the authors - 2024

- Training

Comprehensive training materials were developed and implemented, the practical sessions of which are depicted in Figure 9. This material helped ensure that all users fully understood the operation and maintenance of the new system.

Figure 9: System Functionality Screen



Source: Prepared by the authors – 2024.

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FINAL CONSIDERATIONS

The development of this research project for the functional testing with traceability of mobile phone chargers at Salcomp addressed significant challenges related to the development and testing of power supply systems for electronic devices. Through a methodology that integrated research and development (R&D), we sought to create innovative technological solutions that would meet the specific needs of the company.

During the execution of the project, several learnings and conclusions were evidenced. Selecting a sample consisting of experienced functional testing professionals familiar with LabWindows/CVI software proved to be crucial. This focus allowed for a deep and accurate understanding of the system requirements, which is essential for successful development.

The software architecture adopted stood out for its scalability and modularity, facilitating the development of robust and effective solutions. The tests carried out, which included unitary, integration and systemic evaluations, were vital to validate the functionality and compliance of the system with the defined standards and expectations.

The results demonstrated significant advantages of the applied methodology, such as the comprehensiveness and depth in the treatment of the development phases, culminating in the delivery of a reliable and effective functional test system. However, challenges were faced, especially in integration and implementation in an industrial environment. These challenges highlighted the need for continuous monitoring strategies and robust post-deployment support, which are key to ensuring the system's operability and long-term sustainability.

In conclusion, the project achieved its goal of developing functional test applications with traceability for mobile phone chargers, effectively using the LabWindows/CVI software. The results not only satisfied the customer's requirements, but also reinforced the importance of applied research in advancing the electronic device development industry. This success underlines the relevance of continuing to invest in technologies and methodologies that drive innovation and efficiency in industrial production.

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