

Practical electronic maintenance and repair technique to support sustainability development

Trisno Yuwono Putro¹, Dianthika Puteri Andini^{1*}, and Robinsar Parlindungan¹

¹Electronics Engineering, Electrical Engineering Department, Politeknik Negeri Bandung, Indonesia

Abstract. Electronic Maintenance and Repair is fundamentally a combination of theoretical and practical learning to support higher education in the vocational or polytechnic specialization. This material is outlined in a course by conducting experiments with existing problems with objects that are students in practicum classes. In this practice, it is explained about the specifications, damage, ways of measuring and diagnosing damage based on the Project Based Learning (PBL) method. All Standard Operating Procedure (SOP) are explained in Job Safety Analysis (JSA) and Job Safety Operation (JSO) followed by different circuits and work steps for each electronic circuit. In actual fact, after this method is applied, students can determine and make specifications for an electronic equipment/system, understand and also complete calculations about reliability and failure in electronic systems. One more thing is to recognize damage and how to measure electronic components both passive and active. It is also explaining work principles and looking for damage to a simple digital and analog electronic circuit. In the process, this method experiments with various circuits by measuring normal conditions and damage according to the given switch. The entire measurement method is performed through the specified testing point thereby analysis can be implemented based on the comparison of measurement results under normal conditions and damage. Based on the results of data and analysis of student response results aspects of PBL can be applied to tackle and solve the problems diagnosed by damaged conditions of the circuits. It can be used as MR Electronics practicum to gain and collaborate based on theory and data analysis.

1 Introduction

The Electronics Maintenance and Repair (MR) Practicum module has been designed with the aim of providing assistance to students and trainees who are deepening their knowledge of electronic equipment maintenance and repair. This module is designed to provide an in-depth understanding of the basic principles and latest techniques in the maintenance and repair of electronic equipment. The existence of this module is very relevant considering the importance of maintenance and repair of electronic equipment in the context of today's technology and industry. In an era filled with rapid technological advancements, the demand for experts skilled in carrying out maintenance and repair of electronic equipment is

* Corresponding author: dianthika@polban.ac.id

increasing, so this module has a very vital role in meeting these needs. However, students and trainees often face difficulties in understanding the concepts and techniques of maintenance and repair of electronic equipment practically. Therefore, this practicum module has been specifically designed with the aim of providing practical guidance that can be easily understood and followed by students and trainees. In the manufacturing process, it involves collaboration between electronics experts and educators who have deep experience in their fields. The module will also be constantly updated and adapted to the latest technological developments, so that it remains relevant and can be used as a useful practical guide for students and trainees. Some aspects that can be the focus of research in the development of the MR Electronics practicum module include the effectiveness of using the practicum module in improving the practical skills of students or trainees in carrying out maintenance and repair of electronic equipment. Reference sources [1–5] will be used as the main basis in this research methodological approach.

Conducting research on the development of MR Electronics practicum modules holds paramount significance in enhancing the quality of education and addressing the escalating technological challenges and intricate industrial demands. This research is critically urgent due to several compelling some reasons. First, it enhances the inventory of practicum modules available in the MR Electronics laboratory. Next is to enhance educational quality for example this practicum modules play a pivotal role in elevating the quality of education within the electronics domain by offering an interactive and guided learning methodology. This approach aids students and trainees in comprehending and mastering the intricacies of electronic equipment maintenance and repair more efficiently. Developing practical expertise is practicum modules to facilitate the development of practical skills among students and trainees, equipping them with the necessary expertise for effectively handling the challenges present in the professional landscape of electronic equipment maintenance and repair. If the recent discussion is to industry work-ready, this module can be a solution to tackle this problem. by way of illustration to address industry demands. Today's industries necessitate a workforce adept at conducting efficient maintenance and repair of electronic equipment. Through the practicum module, students and trainees will receive comprehensive preparation and training, enabling them to effectively fulfil the industry's demands. Another example is confronting technological advancements related to the continually evolving technological landscape in electronics demands a profound understanding and advanced skills [6–8]. Practicum modules serve as a vital tool in enabling students and trainees to confront these challenges head-on by enhancing their understanding and proficiency. Environment is one of essential thing to mitigate environmental impact. The practicum module equips students and trainees with the knowledge to repair damaged electronic equipment, thus reducing the volume of discarded electronics and subsequently lessening the environmental footprint. This module empowers individuals to contribute significantly to environmental conservation efforts [9,10].

2 Literature review

In a broader context, these research endeavours demonstrate that the development of electronic maintenance and repair practicum modules significantly enhances students' proficiency and knowledge in the realm of electronic maintenance and repair. Numerous prior studies have been undertaken in the creation of MR Electronics practicum modules, encompassing a range of areas, the current state of research on MR Electronics practicum modules indicates the following trends. Incorporation of Inquiry-Based Learning Methods is Inquiry-based learning fosters for active student engagement, encouraging them to autonomously seek and gather information. Multiple basic electronics studies manifest that

integrating inquiry learning methods into the MR Electronics practicum module substantially enhances the comprehension and skills of students and trainees [11–15].

The creation of the MR Electronics practicum module, employing the problem-based learning (PBL) approach, represents a pedagogical methodology centered on addressing authentic challenges. Numerous research studies substantiate that the implementation of MR Electronics practicum modules grounded in problem-based learning significantly enhances the problem-solving capabilities of students and trainees concerning issues related to electronic equipment maintenance and repair [16–20]. The circuits employed for fault tracing and analysis are constructed based on symptoms and measurement points outlined in commonly used every single day electronic circuits, incorporating information about components and measurement techniques. These symptoms of damage enable real-time measurement analysis, concentrating on resolving specific issues within a given series.

2.1 Modul 1. Regulated power supply

A regulated power supply denotes an essential electronic circuit designed to generate a consistent, precise, and stable voltage or electric current. These supplies find diverse applications in electronic systems, ranging from charging batteries to driving motors and rectifying distorted electrical signals. Typically, a regulated power supply comprises fundamental components, including transformers, rectifier diodes, filter capacitors, voltage regulators, and protective elements. The transformer functions to adjust the AC voltage from the power source, either stepping it up or down according to requirements. Rectifier diodes are employed to convert AC current into DC current, aligning the peak value with the input AC voltage. Subsequently, filter capacitors are utilized to refine the distorted DC waves, ensuring a smoother and more unwavering DC voltage output [21–23].

The voltage regulator within a regulated power supply plays a crucial role in maintaining a constant output voltage, even when faced with fluctuations in input voltage or varying loads. Various types of circuits, including linear and switching regulators, can be employed to create voltage regulators. Furthermore, regulated power supplies incorporate protective elements designed to safeguard the circuit against damage caused by overcurrent or overvoltage resulting from component failure. Moreover, diverse regulated power supply concepts employ distinct topologies such as single-phase or three-phase regulated power supplies, buck or boost regulated power supplies, and flyback or forward regulated power supplies, among others. The selection of an appropriate regulated power supply topology is paramount, as it significantly influences the efficiency and performance of the overall electronic system, a critical consideration in optimizing the functionality of electronic devices [24,25].

Virtually all electronic devices necessitate a direct current (DC) power source for operation. While batteries are occasional sources, power is predominantly derived from units that convert standard single-phase alternating current (AC) power supplies (typically 240 Vac at 50 Hz) into diverse DC voltage levels. The pivotal function of these power supplies is to furnish the required DC voltage and current, ensuring a minimal ripple effect (electric hum) and maintaining robust stability and regulation. Essentially, they must deliver a consistent DC output voltage, irrespective of fluctuations in input voltage and load current.

Moreover, contemporary power supply units must fulfil additional vital criteria. They must have the capacity to curtail the output current in case of overload (current limiting) and restrict the maximum output voltage. This is imperative to prevent potential damage to delicate components like Integrated Circuits (ICs) in electronic instruments, which is likely to occur if an excessive voltage surge appears in the power supply line. These stringent requirements underscore the critical role played by power supplies in ensuring the integrity and longevity of electronic instruments. Several techniques exist to obtain a stable direct

current (DC) voltage from alternating current (AC) electricity, yet only two methods are prevalent: (i) employing linear stabilizers and (ii) utilizing switching mode stabilizers. Each method possesses distinct merits and demerits, which will be examined in the following discussion. Switching mode power supply units (SMPUs) represent a relatively recent innovation and are predominantly employed in high-power applications, typically exceeding 100 W [26,27].

2.2 Modul 2. Ramp generator

A ramp generator is a fundamental electronic circuit capable of generating an output signal in the form of a triangular wave or ramp, featuring adjustable amplitude and frequency. These circuits have versatile applications in the realm of electronics, including their utilization in signal generators, frequency meters, and signal processing equipment [28]. Digital circuits offer a distinctive advantage in their ability to generate specialized waveforms, especially catering to very low-frequency signals. Among these waveforms, the ramp waveform finds extensive application in various equipment and measurements, demanding precise linearity and swift flyback capabilities. Digital techniques are frequently employed to compute pulses from an unstable oscillator, utilizing components such as an 8-bit counter. These pulses are then converted into ramps through a digital-to-analog converter (DAC) conversion circuit. Through this conversion mechanism, the erratic pulses are meticulously shaped into smooth and linear triangular waveforms. This methodical transformation ensures that even signals originating from unstable sources can be transformed into reliable and predictable ramps, making the ramp generator an invaluable asset in scenarios where stable waveforms are essential [28–30].

A ramp generator is a pivotal electronic circuit employed extensively in the field of electronics. Its primary function is to generate an output signal characterized by a triangular waveform or ramp, with the flexibility of adjusting both amplitude and frequency. This fundamental circuit plays a crucial role in a myriad of electronic applications, demonstrating remarkable versatility and precision. Its ability to produce linear waveforms makes it indispensable in various contexts, including signal generators, frequency meters, and signal processing equipment. Engineers and researchers rely on ramp generators for their capability to deliver consistent and controlled waveforms, making them essential tools in the realm of electronic design and experimentation [31–34].

The significance of ramp generators becomes evident when considering their wide-ranging applications. In signal generators, they are pivotal for producing various waveforms essential for testing and calibrating electronic devices. Frequency meters leverage ramp generators to measure frequencies accurately. In signal processing, particularly in modulation and demodulation processes, ramp generators are instrumental. Their precise linear output is crucial in applications where the linearity of the waveform directly impacts the performance of the entire system. As technology advances, the ramp generator continues to evolve, adapting to the demands of modern electronic systems, reaffirming its status as a fundamental and indispensable component in the toolkit of electronics engineers and researchers worldwide. In summary, the ramp generator is a versatile electronic circuit capable of producing adjustable triangular waveforms. Its applications span from signal generation and frequency measurement to signal processing, highlighting its importance in various aspects of electronics and telecommunications.

3 Research methodology

The tested circuit involves several basic and intermediate circuits in the context of understanding and their level of difficulty in the field of electronics. Within the scope of this

study, two different types of modules will be analysed, namely the Regulated Power Supply Specification module and the Generator Ramp. The evaluation process begins with measurements of the specifications of the two modules, which are then compared with manual data that includes data sheets from the power supply. Furthermore, the damage module involves intentionally damaged components to identify the type of damage based on the basic theory and measurement results obtained in Figure 1. Within a practical module, a circuit is presented featuring an input sourced from either a power supply or a signal generated by a function generator. This input subsequently interfaces with the main circuit, comprising several functional block diagrams, each delineated by specific measurement points. Ultimately, an output is produced, observable through the use of appropriate measuring instruments. Various parameters are manipulated, including a potentiometer employed to adjust the minimum and maximum limits. Concurrently, switches numbered 1 through 7 serve the purpose of diagnosing faults within the circuit. In this context, Problem-Based Learning (PBL) is implemented to enhance problem-solving skills and foster critical thinking among students. They are required to address the problem by conducting a detailed analysis, comparing theoretical knowledge with practical results to substantiate their conclusions.

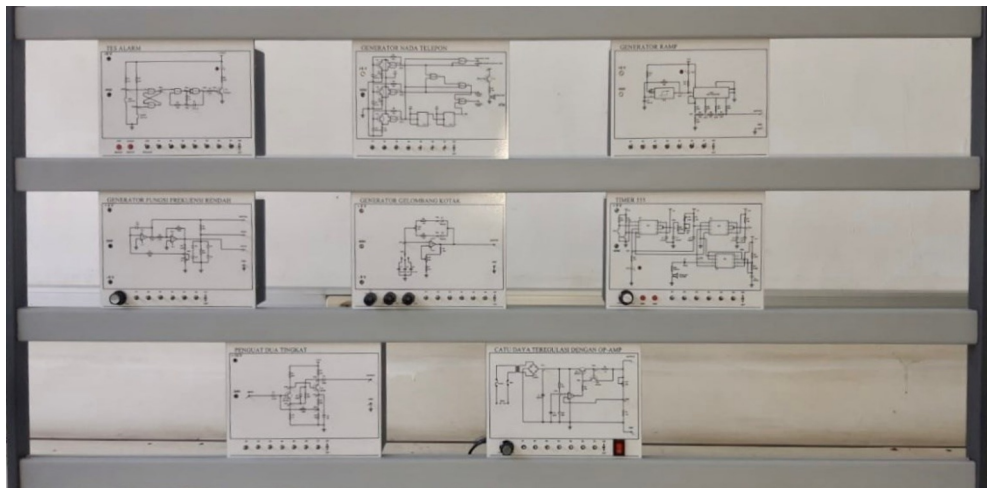


Fig. 1. Maintenance and repair practice modul.

The stable operation of electronic devices hinges on a consistent power supply, a requirement met through the utilization of regulated power supplies. While numerous regulated power supply circuits are accessible in the market, they share a fundamental underlying design. In this practical session, the focus will be on employing a regulated power supply module utilizing operational amplifiers (Op-amps). This module not only demonstrates the foundational principles of regulated power supplies but also showcases the universal aspects of their circuitry, underscoring their significance in the broader context of electronics engineering. The specification of Figure 2 is output voltage, no load current, load regulation, voltage regulation, ripple, maximum current. Some of electronics measurement parameter are description of module, electrical, environmental, and mechanical data.

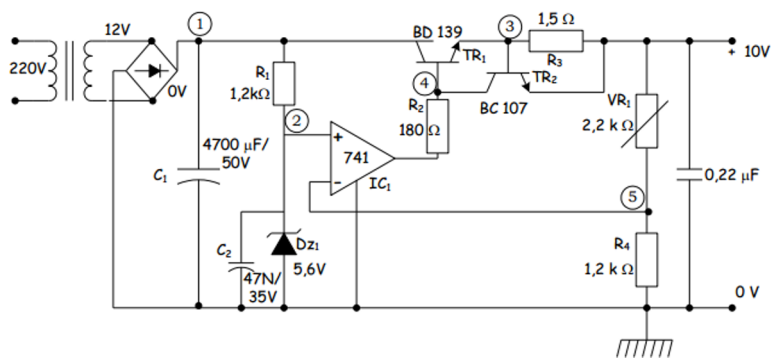


Fig. 2. Circuit of regulated power supply.

Figure 3 depicts a straightforward digital ramp generator circuit constructed using the IC 7493. The counter's output is directly connected to an R-2R ladder network, a widely utilized component in digital-to-analog converter (DAC) circuits. This configuration operates on transistor-transistor logic (TTL) principles and generates a ramp output comprising 16 distinct levels. In this circuit, pulse-generating oscillators, employing Schmitt triggers, are employed to increment a 4-bit binary counter (7493). This counter divides the input frequency by 2, 4, 8, and 16, ensuring that the output of the R-2R ladder network manifests as a 16-step waveform. The oscillator produces pulses at a frequency of approximately 2Hz, facilitating clear observation of the ladder waveform. This circuit not only exemplifies the utilization of fundamental IC components but also demonstrates the meticulous engineering required to generate precise and structured waveforms in electronic applications.

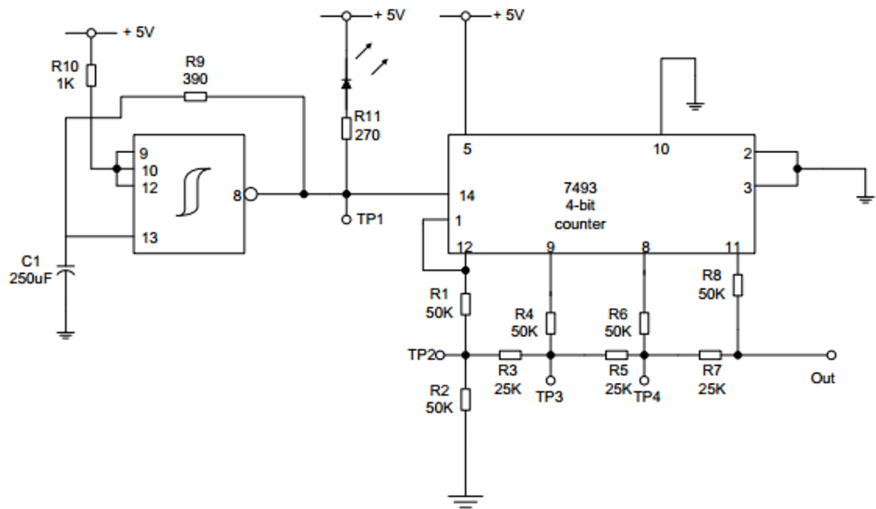


Fig. 3. Circuit of generator ramp.

4 Results and discussion

In this study, several tools and materials have been used to measure the specifications of the two-level power supply module using experimental methods. The following is an explanation

of the function of each tool and material in measuring the specifications of the regulated power supply using Op-Amp

4.1 Regulated power supply module with Op-Amp

As the main object in the experiment, this power supply module is the one to be tested and measured specifications. Measurements are made to assess the output stability, efficiency, and other characteristics of this module.

4.2 Variac with output voltage 0 Vrms to 240 Vrms

Variac is used to regulate the input voltage to be applied to the power supply module. With the ability to produce various AC voltage levels, Variac allows measurement of power supply module specifications under various input conditions.

4.3 Analog and digital multimeters

Multimeter is used to measure voltage, current, and resistance in the power supply module. Analog and digital multimeters each have specific uses; Analog provides continuous readings, while digital provides more precise readings in the form of numbers.

4.4 Oscilloscope

Oscilloscope is used to observe the output waveform of the power supply module. This allows a clear visualization of how the output signal responds to changes in input or load.

4.5 Variable load resistance (110 ohms, $\pm 10\%$, 0.5 A)

Load resistance is used to simulate diverse loads on the power supply module. By using different resistances, research can measure the response of modules to load variations, allowing a comprehensive assessment of the performance of those power supply modules.

4.6 Connecting cable

The connecting cable is used to connect various components in the circuit, ensuring stable and accurate signal transmission during measurement. Quality connecting cables are essential to avoid interference and ensure the data obtained is accurate and reliable. Using such tools and materials, research can analyse in detail the specifications of two-level power supply modules, understand their performance in various input and load situations, and gain deep insights into the reliability and stability of such modules.

Job Safety Analysis (JSA) is a meticulous and methodical approach employed to pinpoint the potential risks and hazards inherent in a particular job or task. This systematic process delves into dissecting each job step, meticulously assessing conceivable hazards at every stage, and devising precise control measures and preventive actions. Through comprehensive analysis and scrutiny, JSA ensures the identification of potential dangers and facilitates the development of strategic protocols, thereby minimizing risks effectively. Job Safety Operation (JSO) encompasses the practical application of safety protocols derived from the thorough analysis provided by Job Safety Analysis (JSA) during the execution of specific tasks or operations. It entails the precise implementation of prescribed procedures grounded in the risk assessments conducted in the JSA. JSO involves the diligent steps taken by

workers or teams to uphold safety standards, which includes the meticulous use of personal protective equipment, strict adherence to safety protocols, and vigilant real-time monitoring of the work environment. This proactive approach ensures immediate identification and timely addressing of potential hazards, fostering a secure and conducive workplace atmosphere. So, JSA is the process of risk analysis and safety plan development, while JSO is the implementation of that plan during task or operation execution. Both approaches are crucial to ensuring that work or operations are performed safely and free from the risk of injury or accidents. Implementation of JSA and Job JSO in Practicum are practice work preparation, measurement, conclusion and journaling, and comprehensive report.

Students identifies practicum tasks to be performed, assess potential hazards associated with each step of the work, and determine the necessary risk control measures. At this stage, preparing all the tools, materials, and instruments are needed for the practicum. Make sure that the tools are in good condition, and that safety instructions are checked before the start of lab work. Practicum is carried out in accordance with safety procedures set out in the JSA. Workers and teachers must ensure that every step is carried out carefully and according to safety standards. Practicum will be undertaken by ensuring that every tool and material is used according to the correct instructions for use. Measurement is executed to ensure that all test points are included by seeing the results. Post-practicum evaluation is conducted to ensure that all safety measures have been followed correctly and no incidents have occurred during practicum. After the practicum is complete, tools and materials are put back to the first place, stored properly, and all instruments are inspected to ensure there is no damage or that could occur next. After the practicum is completed, a comprehensive report is compiled. The report includes details regarding the practicum, potential hazards identified, risk control measures taken, and post-practicum evaluation of the successful implementation of safety measures. The report includes information on the tools and materials used, safety measures implemented during the practicum, and an evaluation of the effectiveness of risk prevention measures taken during the practicum assignment and also analyse all the measurements. All the measurement are measured in the laboratory directly based on its job sheet.

Table 1 provides a comprehensive overview of the specifications resulting from the meticulous measurements carried out on Module 1. These measurements, meticulously executed according to the prescribed procedural steps, encompass a range of critical parameters as outlined in the manual book. Each parameter was subjected to careful scrutiny, and the ensuing measurements were meticulously recorded and analyzed. The purpose of measuring the specifications of an equipment module, as emphasized in the manual book, is multifaceted. Firstly, it serves the fundamental role of discerning the pivotal parameters inherent to the module under study. Understanding these parameters is indispensable in comprehending the module's operational intricacies and its potential applications in real-world scenarios. Moreover, these measurements are conducted with an acute eye for detail to ascertain whether the module aligns with the stipulated standards and specifications. This meticulous comparison of measured values against the standards not only ensures the module's adherence to quality benchmarks but also highlights any discrepancies that might exist. The measurement process, elucidated in Table 1, encompasses a diverse array of components. From scrutinizing the input parameters to evaluating the nuances captured at measurement points 1-5, every facet of Module 1's functionality was thoroughly explored. Additionally, the measurements extended to the module's output, allowing for a comprehensive understanding of its performance characteristics under various conditions. In essence, the data presented in Table 1 encapsulates a rigorous and systematic approach to evaluating Module 1. These measurements not only validate the module's adherence to specifications but also provide valuable insights into its operational behavior. Such detailed analysis and measurement are indispensable for ensuring the module's efficacy, reliability, and applicability in practical contexts.

Table 1. Modul 1 measurement result (Specification).

No	Parameter	
1.	Joint, insulation and resistance tests: a. Terminal +, GND (0) b. GND, Chassis c. Line, Chassis d. Neutral, Chassis	
2.	Voltage testing and measurement: a. DC voltage at C1 b. DC voltage on DZ1 c. DC voltage at R4	
3.	Voltage Output	
4.	Output voltage at: I no_load = 100 mA I no_load = 300 mA Changes in output voltage	
5.	Output voltage at : I no_load = 300 mA , Vrms = 220 V I no_load = 300 mA , Vrms = 198 V I no_load = 300 mA , Vrms =187V Change in output voltage (from 220 to 198)	
6.	a. Ripple voltage at C1 b. Ripple voltage at output	

Fig. 4. Ripple voltage at C1.

Fig. 5. Ripple voltage at output.

In the course of this practicum, an array of tools and materials are employed to facilitate the successful execution of experiments. Firstly, a ramp generator circuit module plays a pivotal role by generating triangular waveforms or ramps tailored to the specific requirements of the experiment. Additionally, a 5 Volt DC power supply is utilized to deliver stable and controlled power, enabling the operation of various electronic components. To visually monitor the experiment's progress, an oscilloscope becomes indispensable, providing real-time visualization of signal waveforms. Further data collection and analysis are carried out using a multimeter, a versatile device adept at measuring diverse electronic parameters. To establish seamless connections between these components, a selection of sufficiently long and flexible cables is provided, ensuring accurate and stable links among tools and devices throughout the experiment. The meticulous utilization of these tools and materials ensures the practicum proceeds smoothly, generating precise data crucial for in-depth analysis and continued learning.

In general damage diagnosis techniques, the measurement process consists of two key stages. Initially, measurements are conducted under normal operating conditions of the ramp generator circuit. Additionally, there are 7 switches which are giving the number 1 to designed to simulate various damage scenarios. Seven switches are systematically designated as switch 1 through 7. Each switch is assigned this nomenclature because it signifies a distinct component or block within the system that is identified through diagnostic measurements when the respective switch is deactivated. If any of these switches is faulty, it alters the measurement results, indicating distinct damage conditions. By comparing these conditions with the normal state, it becomes possible to pinpoint the specific block within the diagram that has been affected and discern the type of damage incurred by the component. To simulate damage, specific switches are turned off, allowing for a detailed observation of the resulting

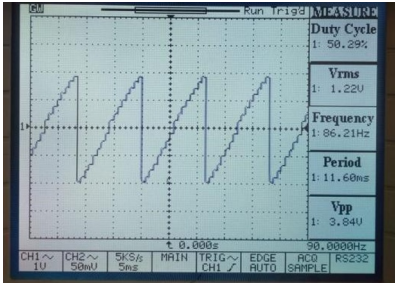
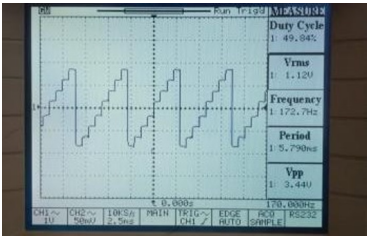
symptoms. Measurements are meticulously taken at all module testing points (TP), encompassing both inputs and outputs, to comprehensively assess the impact of the damage. Illustrating from fundamental theories and circuit block diagrams, in-depth analyses and studies concerning damages are conducted. After identifying potential issues, a comprehensive diagnosis is pursued, drawing from the gathered information. Every supporting factor for the diagnosis is meticulously detailed, fostering the application of problem-solving techniques and critical thinking. This approach not only enhances the quality of student learning but also nurtures a more practical understanding of maintenance and repair science. By employing this practicum method, students establish a robust foundation, enriching their skills and comprehension in the realm of electronic equipment maintenance and repair.

In Table 2, a comparison of the measurement results for Module 2 is presented under normal operating conditions and when a fault is introduced by disabling one of the switches. Module 2 functions as a ramp generator, producing ramp waveforms. Consequently, variations in waveforms can be observed at each Testing Point (TP) when comparing normal and faulty conditions. Initially, students are tasked with a preliminary assignment to comprehend the principles and operations of the module along with its individual components. In the normal operating state, students gain theoretical insights into the expected outcomes at each TP. First, under normal conditions, students compare theoretical expectations with actual measurement results to enhance their understanding of both theoretical concepts and practical applications. Once the normal condition analysis is completed, the focus shifts to observing waveform alterations across all TPs in the presence of the fault. Upon analyzing the obtained data, significant deviations in voltage are evident starting from TP 1 in the faulty condition, followed by waveform distortions observed at TP 2. This empirical evidence enables students to analyze these alterations based on theoretical knowledge and measurements obtained under normal conditions. Through this comparative analysis, students can deduce which functional block is affected and, in specific terms, identify the exact component malfunctioning, thereby representing the switch in the off state. This approach provides a comprehensive learning experience, integrating theoretical understanding with practical diagnostics and analysis. These empirical observations provide a rich dataset for analytical dissection. This comprehensive approach empowers students to engage in a multifaceted analysis grounded in both theoretical knowledge and empirical evidence. By meticulously comparing the theoretical expectations with the real-time measurements obtained under altered conditions, students gain invaluable insights. This analytical endeavor allows for the deduction of specific malfunctioning components, effectively representing the switches in their deactivated states. Consequently, this methodological rigor not only enhances theoretical understanding but also refines the diagnostic acumen of students, nurturing a generation of astute engineers adept in the practical applications of theoretical concepts.

Table 2. Modul 2 measurement result.

Test Point (TP)	Voltage and Signal (Normal Condition)	Voltage and Signal (Switch Off)
1		
2		
3		
4		

Table 2. Cont.

Output		
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5 Conclusion

The research findings on the development of the MR Electronics module highlight its significant contributions. This module not only enhances comprehension of fundamental principles but also imparts advanced techniques for maintaining and repairing electronic equipment. It stands out for its effectiveness in honing the practical skills of students and trainees in the realm of electronic equipment maintenance and repair. The instructional materials within the module are crafted to be accessible and comprehensible, fostering interactive and engaging learning experiences for students. Moreover, the careful incorporation of suitable metrics and transparent standards in assessing learning outcomes ensures a precise evaluation of student progress. These meticulous measurements provide valuable insights into the effectiveness of the module, enhancing the overall educational experience and empowering students with practical expertise in the field of electronics maintenance and repair based on problem solving and critical thinking that suites on practical work as technical. The entirety of the practical steps is executed through the practical application of real-world scenarios within the industrial domain, albeit within the confines of a smaller scope - the laboratory environment. This is achieved through the precise implementation of Job Safety Analysis (JSA) and Job Safety Observation (JSO) protocols during each practical session. The comprehension of MR electronic in the practical context is further reinforced by a strong theoretical underpinning related to the specific module being studied. This is accomplished by deliberately inducing faults in switches, which serve as symbolic representations of functional and component failures.

Continued progress necessitates the creation of modules with an intermediate level of complexity, acknowledging the foundational nature of the current modules. Assessing learning outcomes becomes pivotal, offering invaluable insights to educators. It enables them to gauge the depth of students' abilities following their hands-on experience with the compiled modules. This feedback serves as the cornerstone for ongoing enhancements and refinements in the teaching methodology, ensuring a continuous evolution of the educational process.

Authors' contributions

The contribution of researchers in making MR Electronic modules in laboratory capacity development research is very significant. Through this research, the researchers designed the MR Electronics module which is not only in-depth in content, but also designed with interactive and targeted teaching methods. This module takes knowledge of electronic equipment maintenance and repair to another level, delving into basic principles as well as

techniques as Problem Based Learning to contribute in good quality education enhancement as sustainability development. Researchers also play an important role in identifying laboratory needs in depth. They understand the day-to-day challenges faced by students or trainees in the context of electronic equipment maintenance and repair. With this understanding, the modules created become very relevant to the needs of today's industrial and technological world.

In addition, researchers also contribute important insights in laboratory capacity building. By understanding the abilities and skills required by students or trainees, researchers can provide appropriate direction in strengthening laboratory facilities. This includes the selection of up-to-date equipment, efficient organization of laboratory space, and the development of accurate and standards-based evaluation methods. Through this research, researchers not only create modules with quantity and quality, but also provide a solid foundation to increase laboratory capacity. Thus, the contribution of researchers in this research not only enriches the learning experience of students, but also strengthens the foundation of the laboratory to support better electronic technology education in the future.

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