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Transistor Base (B) Terminal Circuit as a Switch for LED Lighting: Performance Testing

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Abstract

Background: The rapid development of technology presents challenges in electronics education, particularly related to students' ability to observe, identify, and test electronic components such as transistors through practical experiments.
Objective: This study aims to systematically observe and measure transistor characteristics by identifying codes on the transistor body, determining voltage parameters, and analyzing LED load behavior when a transistor operates as a switch.
Methods: The research employed an experimental approach using direct electrical measurements. A BC547 transistor was tested by applying incremental voltage inputs at the base terminal ranging from 2 Vpp to 4 Vpp (2, 2.5, 3, 3.5, and 4 Vpp). Measurements were conducted using a multimeter, power supply, and supporting circuit components under open-switch and closed-switch configurations.
Results: In the closed-switch configuration, a voltage of 2 Vpp produced 0 A current with the LED off, while 2.5 Vpp resulted in 0 A current with dim illumination. Voltage inputs between 3–4 Vpp generated currents ranging from 0.02–0.12 A, causing the LED to illuminate brightly. In the open-switch configuration, all voltage levels resulted in 0 A current and the LED remained off, confirming switching behavior.
Conclusion: The findings confirm that the BC547 transistor base terminal effectively functions as an electronic switch and amplifier. This study contributes to basic electronics learning by providing a clear, measurement-based experimental procedure and supports practical understanding for students and technicians in transistor identification and application.

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INTRODUCTION

The advancement of electronics technology has fundamentally transformed engineering education, particularly in understanding semiconductor devices and their practical applications (Chen et al., 2018; Danković et al., 2022). Transistors, as three-terminal semiconductor devices with N-P-N or P-N-P layer configurations, serve as fundamental building blocks in modern electronic circuits, functioning both as amplifiers and switches (Moudgil & Leong, 2023; Rai et al., 2024; Weimer et al., 2024). In the operating range, the collector current (IC) is a function of the base current (IB), where a change in the base current produces an amplified change in the collector current for a given emitter-collector voltage (VCE), typically with current gain ratios ranging from 15 to 100 (Setekera, 2016).

The effective understanding of transistor characteristics and testing methodologies has become increasingly critical in electronics education, particularly for students who must develop hands-on competencies in component identification, measurement procedures, and circuit analysis (Rahman & Johari, 2022; Tokatlidis et al., 2024). Transistors are equipment that has 3 layers of N-P-N or P-N-P (Maftunzada, 2024). In the operating range, the collector current IC is a function of the base current IB (Chen et al., 2018). A change in the base current IB gives an amplified change in the collector current for a given V CE emitter-collector voltage (Siu, 2022). The comparison of these two currents is on the order of 15 to 100. The symbols on the transistor circuit can be seen in Figure 1 and Figure 2.

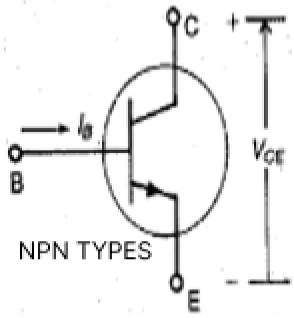


Figure 1. (a) NPN type transistor
source: processed data

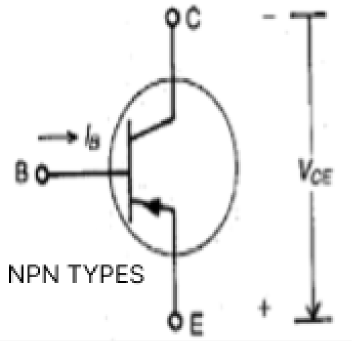


Figure 2. (b). PNP type transistor
source: processed data

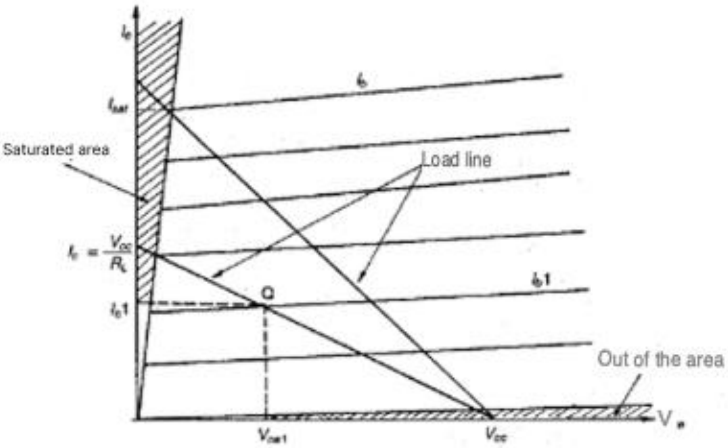


Figure 3. Transistor Characteristics
source: processed data

One way to provide the working voltage of the transistor can be done as in Figure 1. If used for the NPN type, it can be read as Negative, Positive, Negative. The voltage source that Vcc passes through is called the collector base voltage, the collector is positive (Jafari & Habibi, 2020). In figure 2, the type of PNP transistor can be read Positive, Negative, Positive (Hu et al., 2022). The voltage source through which Vce passes called the Emitter collector voltage is Negative (Ali et al., 2016). Figure 3 is the characteristic of a transistor, where in the Figure 3 there is an area that is shaded. In the shaded area, it shows that the transistor is working and the area that is not shaded suggests that the transistor is not working.

Previous research has extensively documented various aspects of transistor testing and characterization in educational contexts (Wen et al., 2011). Ali et al. (2016) established foundational frameworks for understanding transistor biasing configurations and switching applications, demonstrating how transistors operate in saturation and cut-off regions when functioning as switches. Studies by Wang et al. (2025) provided comprehensive analysis of transistor characteristics, emphasizing the importance of load line analysis and Q-point determination in practical circuit design. Recent research Elgenedy et al. (2019) by digital approaches to transistor testing using automated measurement systems, highlighting the significance of systematic observation methods in component characterization.

Furthermore, Sahoo, (2024) documented the dual functionality of transistors as both amplifiers and switches, providing theoretical foundations for understanding voltage-current relationships in transistor circuits. Chen et al. (2023) investigated innovative teaching methodologies for electronics education, emphasizing experiential learning through direct measurement and observation. However, existing literature predominantly focuses on theoretical derivations and complex mathematical formulations, with limited emphasis on practical, measurement-based learning approaches accessible to students at various skill levels (Wang et al., 2025).

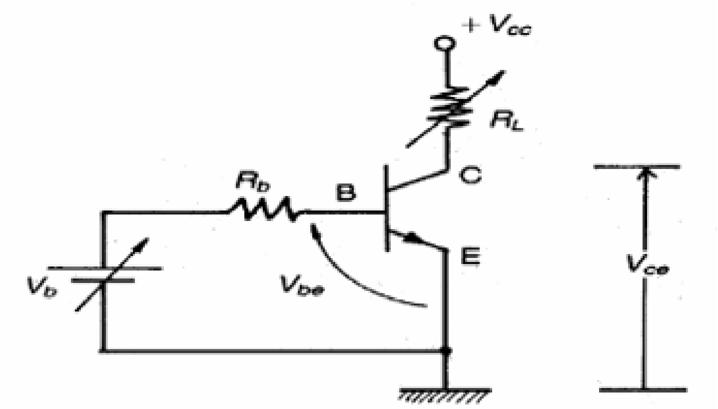


Figure 4. Transistor Network
source: processed data

The Ib current (e.g. Ib1) given by setting Vb will provide a working point to the transistor. At that time the transistor will produce a collector current (Ic) of Ic and a voltage of Vce of Vce1. The Q point (transistor working point) can be obtained from the following equation: Load line equation = Y = Vce = Vcc – Ic x RL So for Ic = 0, then Vce = Vcc and for Vce = 0, then Ic = Vcc/RL is obtained. If the prices for Ic and Ice have been obtained, then by using the characteristics of the transistor in question, the transistor working point or Q point will be obtained (Baliga, 2015). As for the work of the transistor that functions as a switching, it is always in the saturated (saturation) and cut off region (the part shaded in Figure 3 (Tigelaar, 2020). Transistors can work on their saturated regions and cut-off regions (Agarwal, 2019), by regulating the voltage Vb and circuits on its base (Rb resistance) and also its load resistance (RL). To get an on-off that alternates with a certain period, it can be done by giving a voltage Vb in the form of a pulse, as in Figure 5.

Despite extensive theoretical documentation, there remains a significant gap in research providing systematic, step-by-step experimental procedures for transistor characterization specifically designed for educational environments. Current literature lacks comprehensive studies that integrate component identification, voltage parameter determination, and LED load condition analysis in a unified experimental framework suitable for hands-on learning. Additionally, limited research addresses the practical challenges students face when transitioning from theoretical knowledge to actual measurement and testing of transistor components in laboratory settings. The absence of accessible, measurement-focused methodologies that bridge theoretical understanding with practical application represents a critical gap in electronics education research.

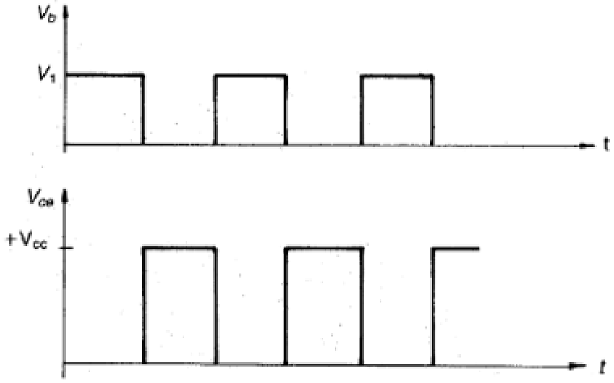


Figure 5. Pulse Trigger and Output Voltage Vce
source: processed data

Figure 5 is the form of the display on a Triger pulse generated by the Output Voltage Vce. If Vb = 0, then the transistor is off (cut off), if Vb = V1 can regulate Rb and R1 so that it produces Ib current and causes the transistor to be saturated. In the state of the emitter collector voltage (Vce) of 0 then the voltage Vsat = 0.2 volts. This is the form of output Vce that occurs under the condition Vb = 0, the price Ic = 0, based on the loop equation: it can be written Vcc + IcR1 + Vce = 0, resulting in Vce = +Vcc Under the condition Vb = V1, the price of Vce = 0 and Iv = I saturation To get a fairly large Ic current, (I saturation) in this switching circuit, in general RL can be designed in such a way that RL has a small resistance. To find out whether the transistor components can work or not, there needs to be a test through a series of transistors that function as a switch can be seen in Figure 6.

This research contributes novel insights by developing a systematic experimental methodology that combines transistor component identification, direct voltage-current measurements, and LED load analysis in a unified framework specifically designed for educational applications (Jayakumar & Balakrishnan, 2025). Unlike previous studies that emphasize theoretical derivations, this research prioritizes hands-on measurement procedures using readily available equipment (multimeter, power supply, BC 547 transistor). The novelty lies in the structured approach to testing transistor base terminals functioning as switches across incremental voltage inputs (2-4 Vpp), systematically documenting LED illumination conditions corresponding to current flow measurements (Muccini & Toffanin, 2016). This practical-oriented methodology provides students and technicians with a replicable experimental procedure that enhances understanding of transistor behavior in real circuit applications, filling the identified gap between theoretical knowledge and practical competency (Fatokun, 2018).

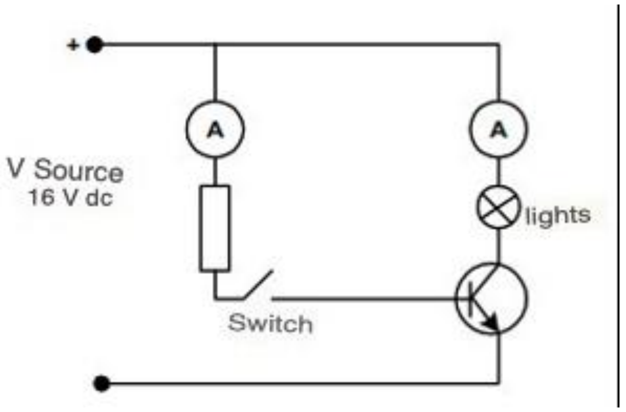


Figure 6. Trasistor Series as Switch
source: processed data

Figure 6 is a transistor circuit that functions as a switch with a voltage input source from a DC source. This transistor circuit can be used as the basis for the test circuit. In the circuit, there are several basic components in the transistor measurement process in the form of: 16 V AC power supply 1 unit, Terminal board 1 pc, Ampermeter 1 pc, Multimeter 1 pc, BC 547 Transistor 1 pc, 200 W 2A Resistor 1 piece and Connecting cable to taste.

In taking measurements on transistor components, there are several processes that are as follows:

1. Assemble the transistor circuit as a switch as shown in the diagram below
2. After the circuit is carefully inspected and there is no fault on the circuit, Connect the switch and power supply
3. Set the voltage of the function generator until the output voltage is 2 Vpp and frequency = 5 KHz
4. Measure the amount of collector current and base current, record the measurement results in the Table Under!
5. Do the experimental steps by increasing the voltage output generator function up to 4 Vpp

This study aims to systematically observe and measure transistor characteristics through three specific objectives: (1) to identify codes and numbers on transistor body components for proper component selection and verification, (2) to determine voltage parameters and current measurements when transistor base terminals function as switches under varying input conditions, and (3) to analyze LED lamp load conditions corresponding to different voltage inputs (2, 2.5, 3, 3.5, and 4 Vpp) in both closed and open switch configurations. The research employs BC 547 transistor components with direct measurement techniques to establish correlations between voltage inputs, current flow, and LED illumination states, providing practical insights for electronics education and technician training.

METHOD

This research is an instrument research that aims to analyze the measurement results on the basic components of electronics, especially the transistor components that function as switches. This research was carried out with real measurements to find out whether the LED lights were installed on and not. large voltage values and conditions on the lamp. This research was conducted at the Electronics Laboratory of the Kupang State Polytechnic. This research uses a quantitative approach with the Instrument method. The transistor components tested use an LED load by setting the voltage from 2vpp - 4 vpp to obtain the maximum current value contained in a transistor. each resistor. The measurement results were discussed to obtain the amount of resistance value and analyzed. Systematically to obtain the large Voltage and Current contained in each resistor color bracelet. the rare steps taken at the time of testing:

Equipment and materials

1. 16 VAC power supply
2. Terminal board
3. Multimeter
4. Transistor BC 547

5. 200 W 2A Resistor
6. Connecting cable to taste.
7. Auxiliary equipment
8. Computer/Labtop equipment
9. LED Lights

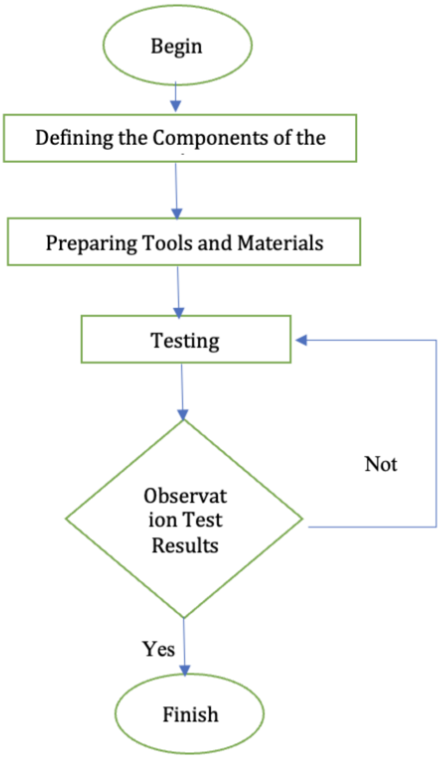


Figure 7. Research flow diagram

Data collection in this study was carried out through the following methods

1. Direct observation of the testing process of transistor components
2. Technical measurement using measuring instruments such as Avometer, Satupower voltage and record the size of the voltage value.
3. Documents in the form of photos at the time of testing and recording the results of the voltage test on transistor circuit and observe the load of the LED lamp. The test results obtained can be made

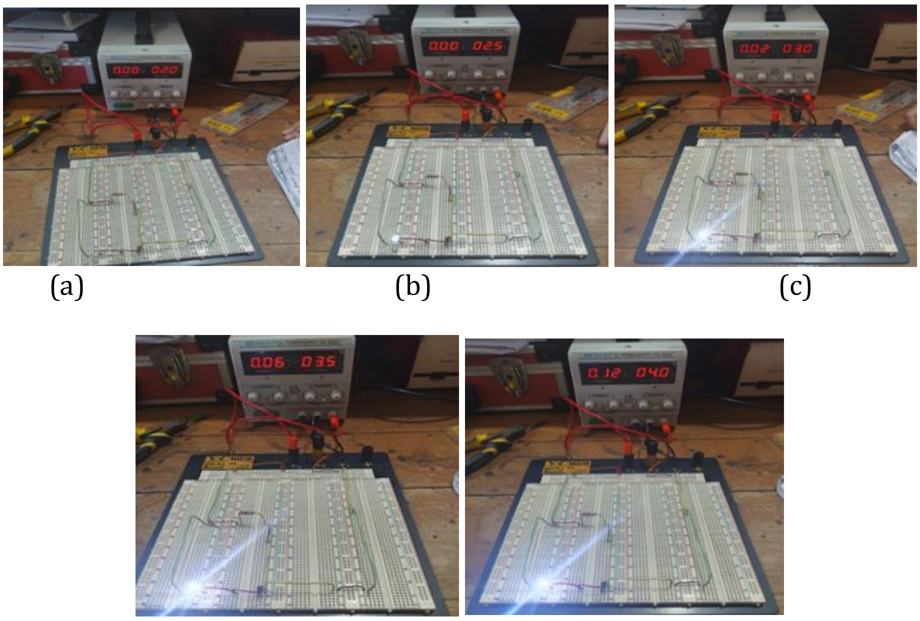
In the form of a table and analyzed using a quantitative method with the following as follows:

1. Large observation of voltage to load LED Lamp
2. The test was carried out in two stages: closed switch position and open switch position.
3. Evaluation on all components of the transistor circuit is tested based on the magnitude of the voltage measured.

RESULTS AND DISCUSSION

Testing

Testing on transistors that have been designed in the form of a circuit, where the transistor functions as a switch that is loaded by a lamp, the test process is carried out by adjusting the voltage set from 2Vpp to 4Vpp, then retested the position of the open switch from the process to the voltage position of 2Vpp to 4Vpp. This result can confirm that the voltage position of how many led lights turn off and the voltage position of how bright the led lights are, the test was carried out at the Kupang State Polytechnic electronics workshop.

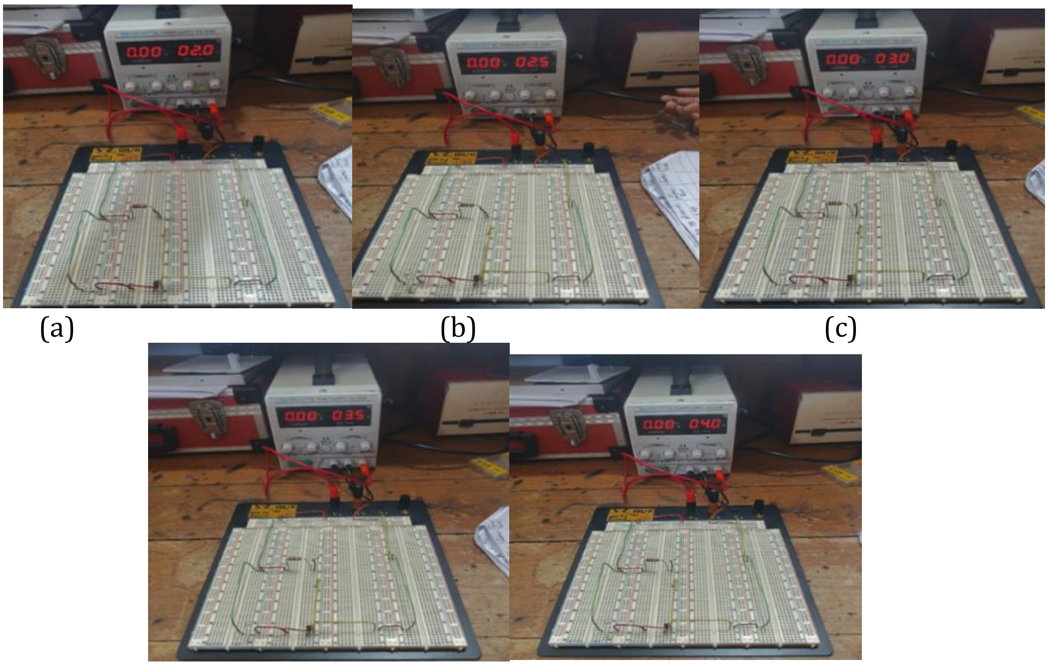


(a) (b) (c)

(d) (e)

Figure 8. Closed-position transistor testing (a,b,c,d,e)
source: processed data

Figure 8 shows the transistor measurement process carried out, where the transistor functions as a switch with a load installed by an LED lamp. The measurement process is carried out 5 times as shown in figure 8 (a) the voltage position is set to 2 Vpp the lamp does not turn on, the voltage is increased to 2.5 Vpp The lamp is still dim, the voltage is raised to the position of 3 Vpp the lamp is on and bright, the voltage is raised to the position of 3.5 Vpp the led lamp is bright and the voltage is raised to the position of 4 Vpp the led lamp is bright very bright. The amount of current produced where the Voltage of 2 Vpp produces a current of 0 A, the voltage of 2.5 Vpp the amount of current has not changed at 0 A, then the voltage is increased by 3 Vpp the amount of current produced is 0.2 A, the voltage is increased by 3.5 Vpp the amount of current is 0.6 A, the voltage is 4 Vpp the amount of current reaches 0.12 A.



(a) (b) (c)

(d) (f)

Figure 9. (a,b,c,d,e) Open-position Transistor Testing
source: processed data

Figure 9 shows the transistor measurement process, where the transistor functions as a switch with the load installed by the LED light. The measurement process is carried out 5 times as shown in figure 9 (a) the voltage position is set to 2 Vpp the lamp does not turn on, the voltage is increased to 2.5 Vpp the lamp does not blame, the voltage is increased to the position of 3 Vpp the lamp does not turn on, the voltage is increased to the position 3.5 Vpp the led lamp does not turn on and the voltage is increased to the position of 4 Vpp the led lamp does not turn on. The amount of current produced where the voltage is 2 Vpp - 4 Vpp the amount of current reaches 0 A. The results of the trasistor measurement can be contained in the table 1, where the position table of the transistor is closed and the position table of the transistor is open.

Table 1. Closed Transistor Position

Switch position	Voltage DC(Volt)	Current DC(Ampere)	Lamp condition
Closed transistor	2 Vpp	0 A	Not Lighting Up
	2.5 Vpp	0 A	Dim Lit
	3 Vpp	0.2 A	Turn on
	3.5 Vpp	0.6 A	Bright lighting
	4 Vpp	0.12 A	Lights up very brightly

source: processed data

Table 1 shows density of the transistor switch is closed and then by adjusting the voltage from the lowest to the highest to find out the amount of current produced and the load on the led light to light or not on. It can be known that the lowest voltage position is 2 Volts with the amount of current produced 0 A, then the condition of the lamp does not turn on. Then the voltage position is 4 Volts with the amount of current produced by 0.12 A, the led light turns on and is very bright.

Table 2. Open Transistor Positions

Transistor Position	Voltage DC (Volt)	Current DC(Ampere)	Lamp condition
Open transistors	2 Vpp	0 A	Extinguished
	2.5 Vpp	0 A	Extinguished
	3 Vpp	0 A	Extinguished
	3.5 Vpp	0 A	Extinguished
	4 Vpp	0 A	Extinguished

source: processed data

Table 2 shows when the transistor is open, then by adjusting the voltage from the lowest to the highest to find out the amount of current produced and the load on the led light on or not on. It can be known that the lowest voltage position is 2 Volts with the amount of current produced 0.0A, then the condition of the lamp does not turn on. Then the highest voltage position of 4 Volts with the amount of current generated 0.0A led light remains unlit.

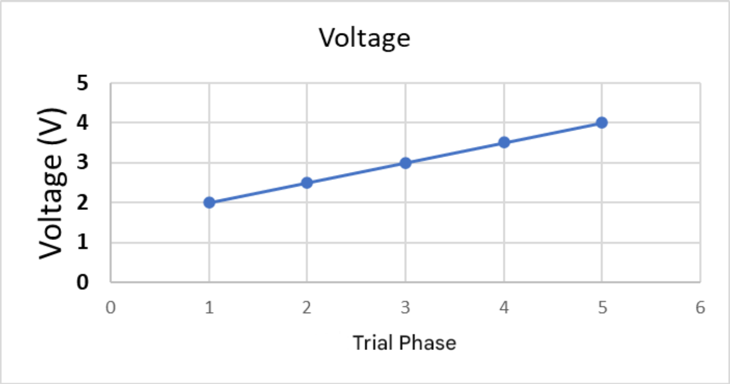


Figure 10. Voltage Curve
source: processed data

Figure 10 shows the amount of voltage set through the regulator. The voltage set starts from 2Volt to the highest of 4 Volts. Measurements are made in two stages: The transistor is closed and the transistor is open with the same voltage set.

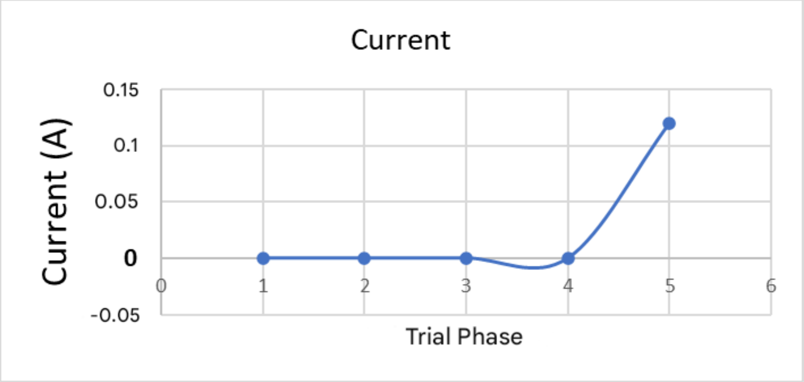


Figure 11. Current Curve
source: processed data

Figure 11 explains the current curve produced when testing the Transistor circuit. In the measurement, in addition to adjusting the voltage, the current generated at each voltage is set. The lowest current reting is at 0.0 A to the highest reting 0.12 A, to determine the movement of the current produced.

CONCLUSION

Based on measurements and observations of transistors connected to LED load, the following conclusions are drawn. The transistor body displays numerical codes (BC 547 type) enabling technicians to identify voltage and current specifications. Testing employed a circuit connecting a 200Ω 2A resistor, transistor, and LED lamp, where the transistor functioned as a switch. The experimental procedure consisted of two stages: closed transistor position with voltage adjustments from 2 Vpp to 4 Vpp, followed by open position testing across the same range. Results recorded in observation tables demonstrate that in closed configuration, 2 Vpp generated 0 A current with lamp off, 2.5 Vpp produced 0 A with dim illumination, while 3-4 Vpp generated 0.02-0.12 A current yielding bright to very bright conditions. In open position with voltage from 2-4 Vpp, current remained 0 A with lamp consistently off. These findings confirm transistor components function correctly as switches, with lamp brightness influenced by voltage settings and current flow. This research serves as practical reference material in electronics education for students, educators, and technicians, contributing to the development of experimental electronics knowledge.

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AUTHOR CONTRIBUTION STATEMENT

FS conceived the research idea, designed the experimental framework, supervised the data collection process, and drafted the initial version of the manuscript. R contributed to the experimental measurements, instrumentation setup, and validation of the electronic circuit testing procedures. OAM was responsible for data analysis, interpretation of experimental results, and visualization of findings. DR contributed to the literature review, methodological refinement, and critical revision of the manuscript to improve its academic quality. All authors reviewed, revised, and approved the final manuscript and agree to be accountable for all aspects of the work.

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