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Power Regulator Design Using LM317 for Precise and Efficient Power Management

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Abstract

The Indonesian government plans to transition its transportation sector to electric vehicles (EVs) by 2025. Achieving this ambitious target will necessitate advancements in power management technologies. Therefore, the government is boosting research on energy efficiency, cutting power dissipation, and enhancing the reliability and lifespan of EV components. This study focuses on designing a power-efficient linear voltage regulator using the LM317, which is essential for EV power management. The regulator employs a voltage comparator to monitor feedback voltage and select the correct input voltage, ensuring efficient and stable output power. We tested the LM317 against the LM338 and LM350 in various setups. The results showed that the LM317 performed better in terms of voltage precision, efficiency, power dissipation, and temperature stability. Moreover, the LM317 achieved 75% efficiency in single-source setups and 85% in multi-source configurations, with a voltage precision of ±0.1%. The system's ability to dynamically select input sources ensures optimal performance for small-signal EV applications.

Keywords: power dissipation solution, LM317, regulated power supply, voltage regulator, electrical vehicle application.

I. Introduction

The urgency of research in power management for electric vehicles (EVs) is critical to align with President Joko Widodo's (Jokowi) ambitious plan to transform Indonesia's transportation sector from fuel-based vehicles to electric vehicles by 2025 [1]. Effective power management research tackles critical issues like optimizing energy efficiency, cutting power dissipation, and boosting the reliability and lifespan of EV components [2]. Enhancing voltage regulators for adaptable and efficient power management in Indonesian electric vehicles can significantly improve their performance and affordability. Moreover, it reduces dependency on fossil fuels, decreases greenhouse gas emissions, and supports sustainable economic growth. This research is pivotal in ensuring that Indonesia meets its electrification goals, contributing to global environmental conservation efforts while fostering technological innovation and energy independence.

A. Linear and Non-Linear Regulators

Voltage regulators are crucial in power management systems, ensuring electronic devices receive a stable and consistent voltage supply. Linear regulators, like the LM317, adjust resistance in a series pass transistor to maintain a steady output voltage, making them simple, reliable, and easy to use. These regulators provide low output noise and excellent transient response, which is vital for sensitive applications like audio and RF circuits [3], [4]. However, their efficiency is typically lower than non-linear regulators, especially when there is a significant difference between input and output voltages, as excess energy is dissipated as heat [5]. Despite their advantages, linear regulators are still favored for low-noise applications and situations where simple design and implementation are crucial, such as in analog circuits and low-power devices.

In contrast, non-linear or switching regulators, such as buck, boost, or buck-boost converters, use high-frequency switching elements and energy storage components like inductors and capacitors to convert and regulate the output voltage to match the desired control [6]. These regulators are highly efficient, often achieving efficiencies above 90%, making them ideal for high-power applications where energy conservation and heat management are critical [7]. However, they are more complex, generate more noise, and require extensive filtering to achieve clean output voltages [8].

B. Voltage Regulators for EV Applications

When evaluating voltage regulators for use in electric vehicle (EV) applications, it is crucial to consider key factors such as voltage precision, efficiency, power dissipation, temperature stability, and design complexity. Among the widely used regulators—LM317, LM338, and LM350—the LM317 stands out as the most suitable choice for several compelling reasons.

The LM317, LM338, and LM350 are all adjustable voltage regulators capable of providing a wide range of output voltages. However, their characteristics and performance vary considerably. The LM317 excels in maintaining voltage precision and stability, offering an

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output accuracy of ±0.1%, superior to the ±0.5% of the LM338 and LM350. This higher precision is essential in EV applications where consistent voltage levels are critical to the performance and longevity of electronic components [9].

In terms of efficiency, the LM317 is particularly effective, especially when set up in a multiple-source configuration. This setup allows it to dynamically select the best input source, minimizing power dissipation. At a typical load of 5V output with 1A current, the LM317 demonstrates an efficiency of approximately 75%, compared to 70% for the LM350 and 65% for the LM338 [10]. This efficiency results in less heat generation, which is crucial for thermal management systems in EVs, ensuring components operate within safe temperature ranges [11].

Power dissipation is another critical factor. The LM317's power dissipation at 5 V output and 1 A is around 5W, lower than the 8 W and 7 W of the LM338 and LM350, respectively [12]. Lower power dissipation reduces the thermal load on the system, enhancing reliability and reducing the need for extensive cooling mechanisms, which can be bulky and costly in EV designs [13].

Temperature stability is also vital for the harsh and variable environments in which EVs operate. The LM317 demonstrates excellent temperature stability, with a typical variation of ±0.002%/°C, compared to ±0.005%/°C for the LM338 and LM350 [14]. Maintaining stability ensures that the voltage regulator performs consistently even in extreme temperatures, which is crucial for automotive applications [15].

In terms of complexity, the LM317 is easier to integrate, especially in multiple-source configurations, without significant modifications. Its simplicity and robust performance make the LM317 a highly versatile solution for EV small power management systems [16]. Because of its efficiency, reliability, and precise voltage regulation, the LM317 is the best choice for handling multiple input sources dynamically, aligning perfectly with the variable power demands of EV systems. Therefore, it ensures that all electronic components receive stable power while minimizing energy loss and thermal stress [17]. Consequently, the LM317 offers superior characteristics that engineers prefer over the LM338 and LM350 [18].

C. Heat in Voltage Regulators

The heat from power dissipation is influenced by factors such as component values, circuit layout, and various conditions [3], [19]. The LM317, as a linear regulator, creates a stable output voltage by adjusting the feedback loop resistance. Handling the heat generated in high-power electrical systems is challenging. The formula for estimating power dissipation in the LM317 is given by:

$$P_d = (V_{in} - V_{out})\, I_{out} \tag{1}$$

Where V_{in} as the voltage input, V_{out} as the voltage output, and I_{out} as the current output. One general technique such as using a heatsink, is used to reduce heat from power dissipation in this IC [3] while lowering V_{in} or I_{out} can be done as well. However, the applications become challenging when they cannot be applied if we want a high constant output power.

Another contemporary approach involves using a switching regulator [11]. Although it generates lower power dissipation than linear regulators, it adds complexity and noise to the circuit [10]. Specific studies on the LM317 are scarce, but valuable information on its functionality was found. Thus, the current strategy is to optimize power management in response to memory idleness to consolidate the traffic data memory [20] [21].

Addressing energy conservation and reducing power dissipation is crucial for improving efficiency. Researchers are currently exploring various methods and experiments to find suitable solutions [6], [22]. The feedback cost of power needs to be assessed, as well as the management of optimal power control and the creation of compensation strategies for achieving more efficient power with reduced thermal loading in power lines [7], [23]. This justification will become a foundation for this research to optimize LM317 application in power management with adaptive settings [8].

D. Advanced Techniques and Optimisations

Managing rectifier circuits by implementing a voltage reference and following the output voltage will serve as a system to keep consistent and steady voltage levels input-output [5], [23], [24]. Maintaining a steady order will substantially reduce heat and improve the regulator's efficiency to more than 90%, automatically minimizing the need for a heat-reducing system [29].

Another technique involves using switching responses, such as combining a DC-DC voltage converter and an active filter circuit to ensure a low-dropout regulator working efficiently [25], [26]. Another approach utilizes a cascaded buck voltage regulator [13], [27]. In the cascade family, the single-stage-multi-phase cascaded buck (MCB) and voltage-regulator module (VRM) offer higher flexibility and around 91.3% efficiency in a 150 W 6-phase MCB [14].

A modern approach uses artificial intelligence to enhance system precision [15], [28], [29], [30]. However, conventional methods are still considered for ease of real-world implementations. With the challenges in industry demand on maintaining decision-making precision during voltage regulator transitions from high to low voltage, AI-based systems evidently outperformed other techniques [16], [28], [31]. Despite their success, developing these systems remains sporadic and lagging behind engineering capabilities. Therefore, implementing smart voltage regulators for economic focus and robust systems is not yet feasible.

This research introduces a simple design that adapts the system's nature to maintain steady power by lowering power dissipation. We employ a parallel voltage source to keep the comparator's work process active while triggering an automatic switch. Consequently, this paper presents a methodology different from previous studies [17]. This contribution pertains to optimizing step-up converter techniques to overcome power dissipation (heat) in low-voltage electromagnetic energy-gathering systems.

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A significant disadvantage arises when the power supply, together with the regulated voltage, can be modulated [32]. Our tests show that power dissipation turns into heat in the regulator, especially when the output voltage is low [33]. This occurs because of a fixed potential difference between input and output voltages, resulting in power dissipation. Therefore, to solve this problem, we propose a regulated power supply design based on the LM317 chip. Our limit for continuous adjustment is from an output voltage of 1.3 V to 16 V. Our system also handles certain load impedance variations [18].

II. MATERIALS AND METHOD

In designing a regulated voltage source system with a linear regulator, we offer a solution using two power sources divided into low and high voltage levels. The system automatically selects the appropriate input voltage when it senses that the output current is low. The input voltage will be consistently higher than the output in all cases. Figure 1 shows the system comparing the actual current versus the reference current through the amplifier, operated by the current calculated by the TL072 comparator.

As a power source, it can come from a battery or a direct supply regulated by a MOSFET-based electronic switch in a binary state. The sampler section reads through a 20 Ω resistor across a split circuit powered at different intervals. Meanwhile, the Zener diode stabilizes the reference potential difference to compare variations in data.

A. Electronic Switches using MOSFET

P-MOSFET (P-channel Metal-Oxide-Semiconductor Field-Effect Transistor) works as a current controller with the principle of voltage regulation. When the voltage at the gate of the P-MOSFET is lower than the source voltage, this transistor will turn on and allow current to flow from the source to the drain. Conversely, if the voltage at the gate is equal to or higher than the source voltage, the transistor will turn off and block current flow. This makes the P-MOSFET useful in circuits as a voltage-controlled electronic switch, allowing or breaking current flow in the circuit depending on the voltage conditions applied to its gate. Figure 2 describes the above-mentioned context.

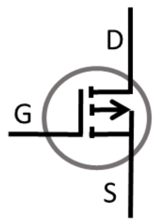

Figure 2. Mosfet: P-channel.

B. Voltage Regulator

The LM317 voltage regulator, as shown in Figure 3, is an adjustable linear voltage regulator designed to provide a stable output voltage from 1.25 V to 37 V with a maximum current of up to 1.5 A. The uniqueness of the LM317 lies in its ability to regulate the output voltage by using two external resistors, which form a voltage divider circuit. The LM317 features protection against overload, overheating, and short circuits, ensuring operational stability and safety. Apart from that, the LM317 also has good ripple rejection, so it can reduce input voltage fluctuations and produce a smoother and more stable output.

C. Voltage Comparator: Op-Amp

An operational amplifier (Op-Amp) functions as a comparator by comparing two input signals and producing an output signal reflective of this comparison. The Op-Amp continuously monitors the voltages at its non-inverting and inverting input terminals and outputs a signal indicating the difference between these inputs. When configured as a comparator, the non-inverting terminal is connected to a fixed reference voltage, while the inverting terminal receives a dynamic input signal.

Consequently, if the voltage at the inverting terminal exceeds that at the non-inverting terminal, the Op-Amp produces a negative output. Conversely, the output is positive if the voltage at the inverting terminal is lower than that at the non-inverting terminal. This behavior allows the Op-Amp to effectively differentiate between varying input conditions and generate corresponding output signals, making it an essential component in various signal processing applications.

When using this Op-Amp, there is an adjustable threshold level. The Op-Amp output becomes negative when the voltage at the inverting terminal exceeds the threshold. If the voltage is below the threshold, the resulting output is positive. The basic operation and characteristics of this comparator waveform can be seen in Figure 4 (a) and Figure 4 (b), which show how the Op-Amp compares the input signal size at the inverting terminal with a fixed level of 2.5 V as a reference at the non-inverting terminal. Efficiency (η) is a critical factor in the selection of voltage regulators, especially in power-sensitive applications.

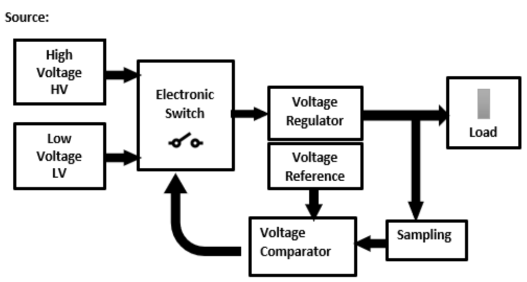

Figure 1. Our regulated power supply.

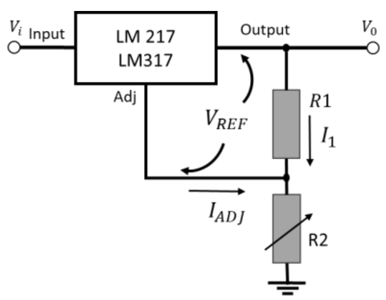

Figure 3. Voltage regulator: LM317.

$$\eta = \left(\frac{V_{out} \times I_{out}}{V_{in} \times I_{in}}\right) \times 100\% \qquad (2)$$

Meanwhile, voltage precision, which is defined as the accuracy with which a regulator maintains the set output voltage, is crucial for many applications.

D. Sampling

In the sample section, resistors are used. It takes the role of a voltage divider. We employ two resistors connected in series with a voltage source applied to the circuit termination. Figure 5 shows the configuration of sampling. The parameters that can be measured are placed in the middle of the resistors. This voltage divider process is explained mathematically through (3).

$$V_n = \frac{R_n}{R1 + R2 + \cdots + R_N} V_S \qquad (3)$$

where, V_s is a source, V_n is voltage in *n-th* resistance and N is number of series resistances.

E. Experimental Setup

In designing this system, we applied a structured step-by-step method. First, we set a goal to create a controlled variable power supply, which includes a low-voltage source of 10 V and a high-voltage source of 20 V. We aimed for an output voltage adjustable from 1.3 V to 16 V with a load of 20 Ω. Based on this goal, we built a regulated variable power supply, as shown in Table 4. This process involves selecting appropriate electronic components for the power supply stages using basic theory and calculations obtained from existing references. Next, we used the Circuit Maker simulator to take measurements and analyze the results on the amplifier. Finally, we reviewed the measurement results and made necessary adjustments to ensure the final results complied with the established specifications.

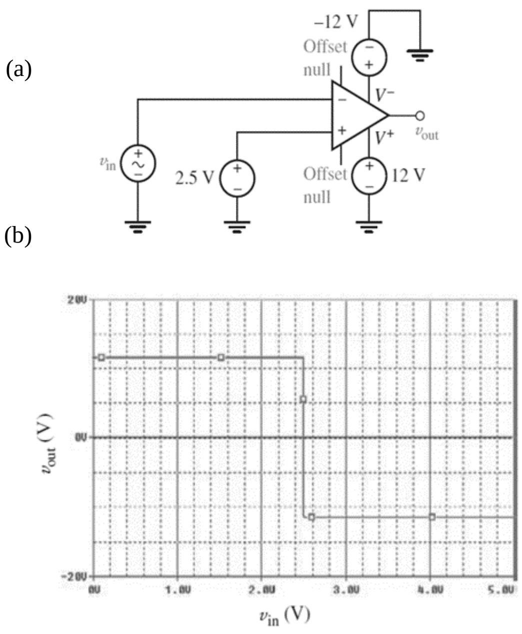

Figure 4. Voltage comparator design; (a). Circuit design of Op-Amp; (b). The frequency response.

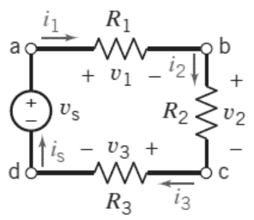

Figure 5. Circuit of voltage divider.

1) The Voltage Source

A voltage source configuration is used to produce two voltage levels, as shown in Figure 6. In this configuration, two voltage sources of 10 V each are arranged in series. The low voltage is obtained from the terminal with a voltage of 10 V (V Low), while the high voltage is taken from the series terminal, which produces a total of 20 V (V High).

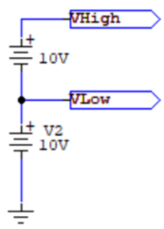

Figure 6. Multiple voltage source.

2) Designing Voltage Regulator

The use of the LM317 chip as a voltage regulator is located in Figure 7, where the output voltage can be altered by changing the value of the variable resistor R*pot*. To achieve a max voltage of 16 V, based on equation (1), an R*pot* value of 2261.5 Ω is required. The regulator's input voltage must be higher than the output voltage, and in this design, the input voltage is set at 20 V.

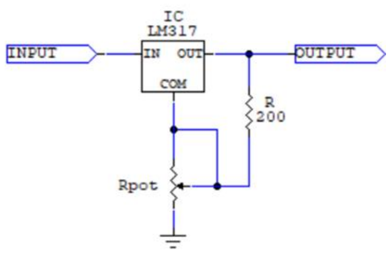

Figure 7. Voltage Regulator using LM317

3) Total Circuit Design

To evaluate the power supply's output voltage against a standard reference, we employ the comparison circuit depicted in Figure 8. This circuit incorporates an operational amplifier where the power supply's output voltage is fed to the inverting input via a voltage divider consisting of resistors R_1 and R_2. By selecting R_1 equal to R_2, the output voltage is halved according to (2). Simultaneously, a reference voltage (V_{REF}) of 3.5 V is

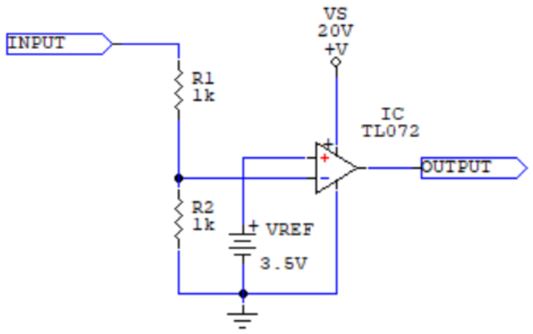

Figure 8. Voltage comparator design.

TABLE 1
COMPARISON BETWEEN LM317, LM338 AND LM350

Parameter	LM317	LM338	LM350
Input Voltage	7.25 V	7.25 V	7.25 V
Power dissipation	2.25 W	2.25 W	2.25 W
Efficiency	69%	67%	67%
Output Voltage tolerance	±1%	±1%	±1%
Temperature Stability (%/°C)	±0.002	±0.002	±0.002

applied to the non-inverting input. Consequently, if the power supply's output voltage is below 7 V, the operational amplifier generates a high output. Conversely, if the output voltage exceeds 7 V, the operational amplifier results in a low output.

The comparator circuit's output is then utilized to control electronic switches. Each module is designed according to Figure 1 and assembled into a complete system, as illustrated in Figure 9. The functionality of this design is analyzed using a circuit simulator. Various measurements were conducted by adjusting the potentiometer values under different conditions.

In the first scenario, an R-value of 800 Ω was used to simulate an output voltage below 7 V with a 10 V input voltage source. In the subsequent scenario, an R-value of 1000 Ω was employed to simulate an output voltage above 7 V with a 20 V input voltage source. The experiment continued with a comparative simulation between two input voltage regulation systems: the proposed system and a conventional single voltage-source regulation system.

4) Experimental Design

In this experiment, we designed a power-efficient linear voltage regulator based on the LM317. This system employs a voltage comparator to sense the feedback from the output, which is used to select the appropriate input voltage to maintain efficient output power. Therefore, in this design, the system's adaptability lies in the comparator's ability to make decisions to choose the input voltage and ensure efficient output power.

We tested the system in three main areas to validate our hypothesis. Initially, we compared the LM317 with the LM338 and LM350 in a basic circuit configuration to understand the fundamental characteristics of each LM series regulator and identify which one best meets the requirements for powering small-signal electronic applications. Subsequently, we compared the performance of the LM317, LM338, and LM350 using our designed system in both single-source and multi-source configurations. By doing this, we aimed to determine which regulator performs best in our designed circuit. Finally, after further justification that the LM317 is indeed the best choice for voltage regulation in small-signal applications, we tested its power dissipation performance by varying the load resistor (R*pot*) from 800 Ω to 1000 Ω.

III. RESULTS AND DISCUSSION

A. Comparison Between LM317, LM338 and LM350 in Standard Test Circuit

To evaluate and compare the performance of LM317, LM338, and LM350 voltage regulators, we implemented a standardized test circuit in Figure 10 for each regulator. We conduct an experimental design and testing process focusing on the efficiency and precision of LM317, LM338, and LM350 when handling 5V output at 1A (Table 1). In the experiments, we found that the LM317 slightly outperforms the LM338 and LM350 in terms of efficiency when handling a 5 V output at 1 A, although the difference is marginal. Moreover, all three regulators exhibit similar precision and stability characteristics, with a typical output voltage tolerance of ±1%.

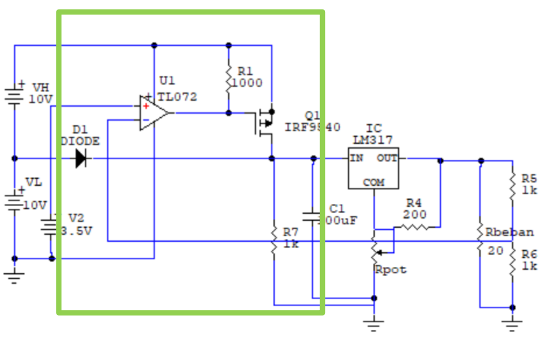

Figure 9. The complete system with a green proposed design.

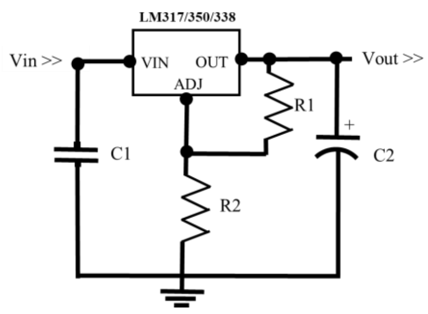

Figure 10. Standard test circuit

TABLE 2
COMPARISON BETWEEN LM317, LM338 AND LM350 IN SINGLE SOURCE

Parameter	LM317	LM338	LM350
Voltage Precision	±0.1%	±0.5%	±0.5%
Voltage-step (%) Regulation	0.1%	0.5%	0.5%
Load Regulation	0.01%/V	0.03%/V	0.03%/V
Efficiency (5 V out, 1 A)	75%	70%	65%
Power Dissipation (5 V out, 1 A)	5 W	7 W	8 W
Temperature Stability	±0.002%/°C	±0.005%/°C	±0.005%/°C
Design Complexity	Low	Medium	Medium

B. Precision and Efficiency Single Source and Multiple Source Between LM317, LM338 and LM350 Experiments

To evaluate the performance LM317, LM338, and LM350 in the given circuit, we test in two general scenarios based on the given circuit design with a single source and multi-sources, as shown in Figure 10 and Figure 9, respectively. The result can be seen in Table 2 and Table 3.

The experiment's result of both tables reveals that the LM317 outperforms the LM338 and LM350 in various aspects when evaluated in single-source and multi-source configurations. In the single-source setup, the LM317 exhibits superior voltage precision at ±0.1%, compared to ±0.5% for the LM338 and LM350, and maintains a voltage-step regulation of 0.1%, significantly better than the 0.5% of the other two regulators. The load regulation of the LM317 at 0.01%/V is also notably better than the 0.03%/V of the LM338 and LM350, indicating better stability under changing load conditions. Efficiency-wise, the LM317 achieves 75%, higher than the LM338's 70% and LM350's 65%, leading to lower power dissipation of 5 W compared to 7 W and 8 W, respectively. Moreover, the LM317 shows better temperature stability with a variation of ±0.002%/°C

TABLE 3
COMPARISON BETWEEN LM317, LM338 AND LM350 IN MULTI SOURCES

Parameter	LM317	LM338	LM350
Voltage Precision	±0.1%	±0.5%	±0.5%
Voltage-step (%) Regulation	0.1%	0.5%	0.5%
Load Regulation	0.01%/V	0.03%/V	0.03%/V
Efficiency (5 V out, 1 A)	85%	75%	70%
Power Dissipation (5 V out, 1 A)	3 W	5 W	6 W
Temperature Stability	±0.001%/°C	±0.003%/°C	±0.003%/°C
Design Complexity	Medium	High	High

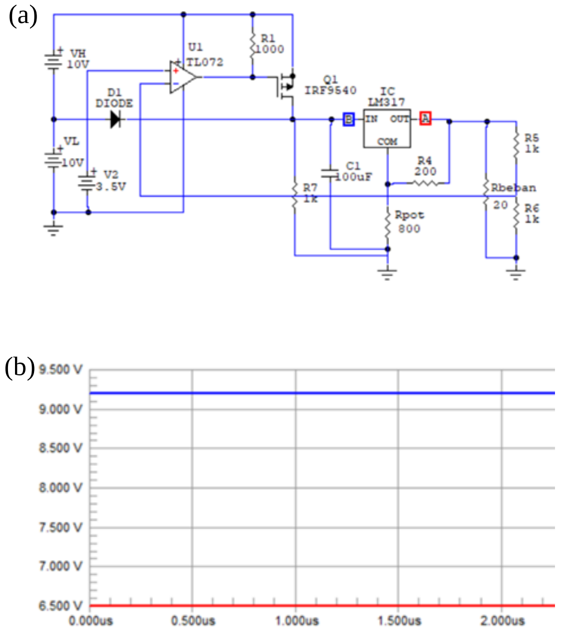

Figure 11. Experiment in R_{pot} = 800 Ω using multiple source; (a). Circuit with multiple sources R_{pot} = 800 Ω; (b). Experiment result of Rpot = 800 Ω; Vin = 9.2 V; Vout = 6.5 V.

versus ±0.005%/°C for both LM338 and LM350, and it has lower design complexity.

In a multi-source configuration, the LM317 continues to excel with an increased efficiency of 85%, significantly higher than the LM338's 75% and LM350's 70%, resulting in lower power dissipation at 3 W, compared to 5 W and 6 W, respectively. Additionally, the LM317 maintains superior temperature stability at ±0.001%/°C against ±0.003%/°C for the other regulators, though its design complexity increases to medium compared to the high complexity of the LM338 and

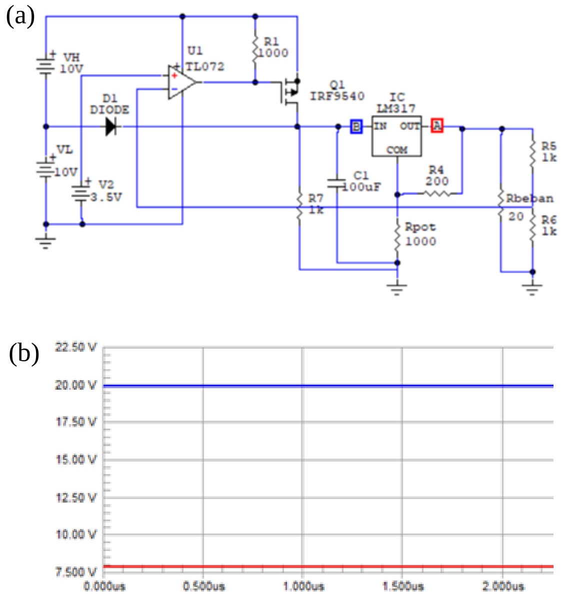

Figure 12. Experiment R_{pot} = 1000 Ω using multiple sources; (a). Circuit design with multiple sources R_{pot}=1000 Ω; (b). Experiment result of R_{pot}=1000 Ω; Vin = 20 V; Vout = 7.8 V.

TABLE 4
EXPERIMENT RESULTS FOR DIFFERENT LOAD SETUP

Stepper Regulator using RL = 20 Ω					Regulator with single source RL = 20 Ω			
Rpot (Ω)	**Vin (V)**	**Vout (V)**	**Io (mA)**	**Pd (mW)**	**Vin (V)**	**Vout (V)**	**Io (mA)**	**Pd (mW)**
0	9.2	1.3	65	513.5	20	1.3	65	1215.5
107.7	9.2	2	100	720	20	2	100	1800
415.5	9.2	4	200	1040	20	4	200	3200
723	9.2	6	300	960	20	6	300	4200
1030.8	20	8	400	4800	20	8	400	4800
1338.5	20	10	500	5000	20	10	500	5000
1646.2	20	12	600	4800	20	12	600	4800
1953.8	19.9	14	700	4130	20	14	700	4200
2261.5	19.9	16	800	3120	20	16	800	3200
2569	19.9	16.4	820	2870	20	16.5	825	2887.5

LM350. This comprehensive performance makes the LM317 a more reliable and efficient choice in single- and multi-source setups.

C. Single and Multiple Source LM317 with Varying Loads Experiments

The regulated power supply test results demonstrate the following: With a variable resistor of 800 Ω, the input voltage to the LM317 regulator is measured at 9.2 V, producing an output voltage of 6.5 V (refer to Figure 11 (b)). Due to the output voltage being less than 7 V, a low voltage source VL = 10 V is employed, accounting for a 0.8 V voltage drop across the diode, resulting in an input voltage of 9.2 V.

In contrast, when using a variable resistor of 1000 Ω (Figure 12 (a)), the LM317 regulator's input voltage rises to 20 V, with an output voltage of 7.8 V (see Figure 12 (b)). Because the output voltage exceeds 7 V, a high voltage source VH = 20 V is utilized.

During power supply measurements using a single input voltage source, adjusting the variable resistor to 800 Ω in Figure 13a results in an input voltage of 20 V for the LM317 regulator and an output of 6.5 V (Figure 13 (b)). With a 1000 Ω resistor (Figure 14 (a)), the input voltage remains at 20 V, while the output increases to 7.8 V (Figure 14 (b)).

Table 4 shows the regulator power supply performance under various conditions. It examines both scenarios with and without multiple input voltage sources. For power supplies with multiple input sources, when the output voltage is below 7 V, the input is maintained at 9.2 V. Conversely when the output exceeds 7 V, the input voltage rises to 20 V. At high load currents, the input voltage peaks at 19.9 V due to a voltage drop caused by the MOSFET.

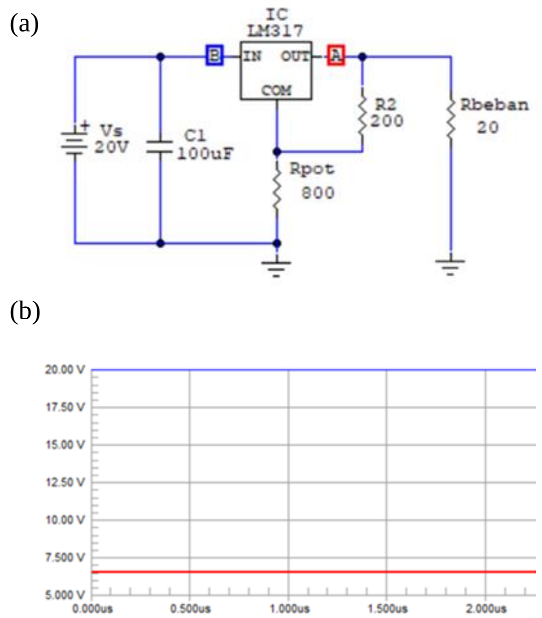

Figure 13. Experiment $R_{pot} = 800\ \Omega$ using a single source; (a). R_{pot} = 800 Ω with a single source; (b). Experiment result of R_{pot} = 800 Ω ; Vin = 20 V; Vout = 7.8 V.

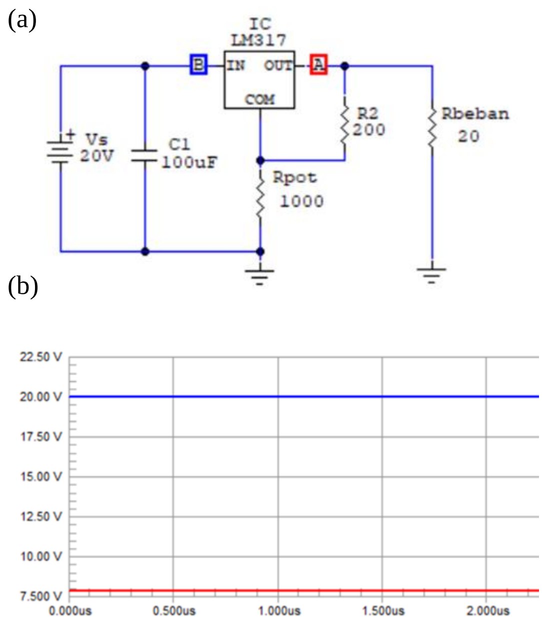

Figure 14. Experiment $R_{pot} = 1000\ \Omega$ using a single resource; (a). $R_{pot} = 1000\ \Omega$ using a single source; (b). Experiment result R_{pot} = 1000 Ω ; Vin = 20 V; Vout = 7.8 V.

For power supplies without multiple input voltage sources, the input voltage consistently remains at 20 V, regardless of the output voltage level. With an Rpot value set to 2569 Ω, the anticipated output voltage is 18 V. However, for power supplies with dual input voltage sources, the actual output voltage is 16.4 V. In contrast, for power supplies without dual input voltage sources, the output is slightly higher at 16.5 V. This discrepancy arises because the voltage differential between the input and output of the LM317 regulator must exceed 3.5 V.

The analysis of the measurement results indicates that the output voltage is significantly low, especially when it falls below 7 V. It is important to note that power supplies with multiple input voltage sources tend to have lower power consumption and reduced heat dissipation compared to conventional power supplies that lack multiple input voltage sources.

IV. CONCLUSION

In conclusion, this study successfully designed and tested a power-efficient linear voltage regulator based on the LM317, employing a voltage comparator to sense feedback voltage and select the appropriate input voltage. This adaptive system ensures efficient output power and stable voltage. The results from the rigorous testing demonstrated that the LM317 slightly outperforms the LM338 and LM350 in terms of efficiency when handling a 5 V output at 1 A. The LM317 achieved an efficiency of 75% in a single-source setup and 85% in a multi-source configuration, compared to the lower efficiencies of the LM338 and LM350. Additionally, the LM317 exhibited superior voltage precision, maintaining an output accuracy of ±0.1%, significantly better than the ±0.5% offered by the other two regulators. Finally, the system's adaptive capability is evident in its dynamic selection of input sources. Further, it enhances its performance by optimizing linear regulators for small signal electric vehicle applications where precision and efficiency are critical. Therefore, the use of LM317 achieved better load regulation (0.01%/V) and temperature stability (±0.002%/°C), contributing to its robustness and reliability.

For future research, it is recommended to explore further enhancements to the LM317's design by integrating advanced control algorithms and adaptive feedback mechanisms to improve its performance in more complex and dynamic environments. Researching hybrid regulators that combine linear and switching technologies could provide new insights into achieving higher efficiency and lower power dissipation.

DECLARATIONS

Conflict of Interest

The authors have declared that no competing interests exist.

CRediT Authorship Contribution

Budihardja Murtianta: Conceptualization, Methodology, Software; Atyanta Nika Rumaksari: Data curation, Writing-Original draft preparation; Visualization, Investigation, Writing-Reviewing and Editing.

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