Design and Development of Microcontroller Based Adjustable Power Supply with Embedded Safety Controls

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***Abstract*—The project focused on developing A Microcontroller Based Adjustable Power Supply used for High Energy Material Ignition with in-built Safety Features, a device designed to provide variable current as required, incorporating multiple safety features and capable of checking load continuity. The initial phase involved simulating the partial circuit using Proteus Software, LTSpice, and MPLab X IDE, ensuring accurate modelling and performance verification. Electrical components with safe current and voltage ratings were integrated to enhance safety and efficiency. The circuit was designed and built from scratch, employing advanced components and the latest technology to improve overall functionality. This comprehensive approach resulted in a more reliable, efficient, and safer power supply unit, demonstrating significant improvements over previous iterations. Key challenges included selecting appropriate components to meet the stringent safety and performance criteria and ensuring compatibility with existing technologies.Testing was conducted to validate the circuit design, including component-wise tests and continuity checks to ensure robustness under various operating conditions. Implementing advanced safety features such as automatic shut-off mechanisms and real-time monitoring systems mitigated potential risks. Additionally, the use of modern simulation tools enabled the optimization of circuit performance, reducing the likelihood of failures. The successful completion of this project highlights the importance of integrating simulation, appropriate components, and rigorous testing in developing a desired system. Overall, the enhanced power supply unit is expected to have significant applications in various industrial and technical fields, offering improved control and safety features.**

KEYWORDS: Microcontroller, Current, Voltage, Continuity, Load, Proteus, LTspice, MPLab X IDE, Power Supply, High Energy, Safety Features

I. Introduction

In many industries, especially where high-energy materials are used, a reliable and safe power supply is very important. Traditional power supply systems often cannot provide the safety needed for such critical tasks. When instruments need to be started electrically, the power supply must work properly and safely at every step.

This project focuses on developing a **Microcontroller Based Adjustable Power Supply** that is both adjustable and secure. The system can provide variable current, which makes it useful in situations like controlled ignition.

To make the system safe, it includes features like automatic relay control, a countdown before activation, and checks to ensure the load is connected properly. A microcontroller controls the whole system, so all steps happen at the right time and only under safe conditions.

By using modern circuit design and safety features, this power supply is a better choice for industries where electrical safety and controlled power output are important.

II. Methodology

In this section, we will detail the methodology adopted for the development of the power supply unit used for firing.

The methodology encompasses the design process, simu- lation using Proteus software, component selection, and the construc- tion and assembly phases.

A. Design Process

The design process began with outlining the overall ar- chitecture of the Power Supply Unit, focusing on achieving precise control of variable currents while ensuring safety and functionality. The initial schematic was drafted, emphasizing the integration of various components to achieve the desired operational features. Proteus software was utilized to simulate the entire circuit design. This simulation phase was critical in verifying the accuracy and reliability of the design before proceeding to physical construction. Proteus allowed for detailed modelling of the circuit behaviour, enabling the identification and rectification of potential issues early in the design process. Firstly, we identified that we require 5V and 12V DC which will be used to give power supply to different components. So, in order to achieve it our idea was to use a step-down transformer which will lower down the input AC voltage. After using different turn ratio in the transformer, our goal was to achieve upto 30V stepped down voltage. Secondly, our concern was to generate a current of 2A to 60A. There were different methods from which we can have that much amount. Either we have used some Power booster circuit or a Capacitor Bank or by Voltage Amplification. The most efficient and reliable one was Booster circuit. So, Booster circuit needed to be designed which will amplify our AC voltage which was around 325V up to 480V DC. Thirdly, after achieving such high voltage, some control mechanism should be there which will control all the compo- nents and function as and when desired. A microcontroller was the best option which was satisfying our requirements, which will control the components simultaneously. Also, safety has to be at our top priority and for that we use relay, which can be operated easily with the use of microcontroller. Lastly, there should be a circuit that checks the continuity of the Load. Its main objective is to check if there has not been any breakage in the circuit by any chance. If yes, then it should inform the operator as soon as possible. After conceptualization of the solution to the requirement, it was the most crucial role to select components that would work with such high voltage and current ratings. In the next section, we will discuss the components used in the circuit. These components have been tested well in the Proteus and LTspice software.

B. System Requirements

Software Requirements (Platform Choice)
Operating system: Windows 7 or more.
Coding Language: C Language
IDE: MPLAB X IDE
Circuit simulation: Proteus 8 and LTspice

III. Block Diagram

Explanation: The block diagram in Figure 1.1 depicts the structure of the power supply system, starting with the AC Input, which provides the initial alternating current. This AC voltage is then converted into direct current (DC) using a Bridge Rectifier. The rectified DC voltage is fed into a Boost Converter to increase its level as required. A Switching Circuit controls the power delivery to the Load, ensuring efficient operation. The system is regulated by a Microcontroller, which generates a PWM Signal to manage the switching operations. A Voltage Regulator ensures a stable 5V DC output, while a Continuity Check circuit verifies proper load connectivity be- fore enabling power flow. This design highlights a streamlined approach to power conversion, regulation, and control, making it suitable for various low-voltage applications.

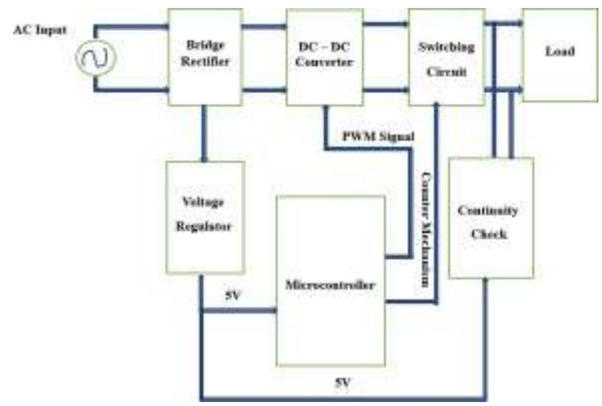

Fig. 1. Block diagram of the proposed system.

IV. Design and simulation results

A. Rectification

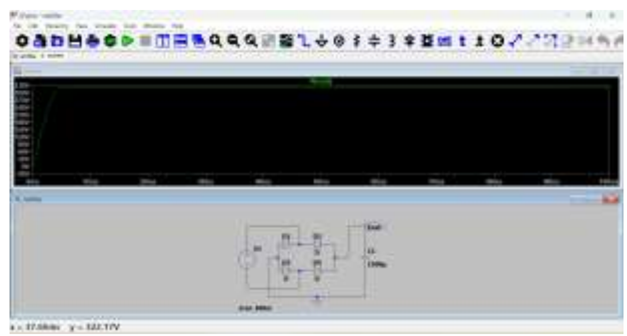

Fig. 2. RECTIFICATION

The circuit described is a full-wave bridge rectifier, which uses four diodes (D1, D2, D3, and D4) arranged in a bridge configuration to convert an alternating current (AC) input into a pulsating direct current (DC) output. An AC voltage source, represented by a circle with a sine wave symbol and labeled V1, provides the input to the rectifier. At the output of the bridge, a capacitor (C1) with a capacitance of 1000µF is connected to act as a filter, helping to smooth the rectified voltage and reduce the ripple, thereby producing a more stable DC output. The output voltage is measured at the point labeled ”Vout”.

B. Voltager Regulator

voltage regulator circuit begins with a transformer labeled ”TRAN-2P2S,” which features two primary and two secondary windings, typically used to step down the AC mains voltage to a lower AC voltage suitable for further processing. This stepped-down AC voltage is then fed into a full-wave bridge rectifier composed of four 1N4007 diodes (D1 to D4), which converts the AC into pulsating DC. Immediately after the rectifier, a 1000µF capacitor (C1) is placed to filter and smooth the DC voltage, reducing ripples and providing a more stable

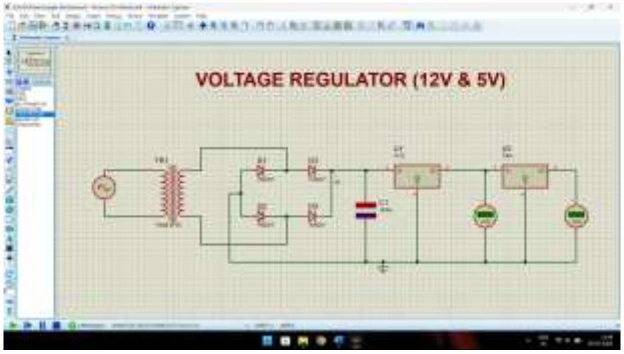

Fig. 3. Voltage Regulation

output. The smoothed DC voltage is then regulated by two voltage regulators: U1 (7812) outputs a fixed 12V, and U2 (7805) provides a fixed 5V. To monitor the outputs of these regulators, two DC voltmeters are connected—one showing 12.0V from the 7812 regulator and the other displaying 5.0V from the 7805 regulator—ensuring both regulated outputs are functioning correctly and delivering the expected voltages.

C. Pwm Signal Generation using Microcontroller

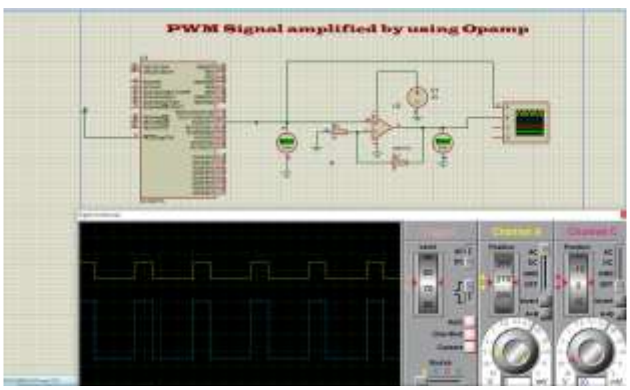

Fig. 4. **Pwm Signal Generation using Microcontroller**

The circuit features a PIC16F877A microcontroller (U1) as its central control component, most likely responsible for generating a Pulse Width Modulation (PWM) signal. This PWM signal is then sent to the next stage of the circuit, which includes an LM741A operational amplifier (U2). The LM741A is a general-purpose op-amp used here to amplify the signal from the microcontroller. Two resistors, R1 and R2, are connected to the op-amp, serving to set the gain and define the amplification level of the output signal. Additionally, a 35V DC voltage source (V1) is connected to the op-amp, supplying the necessary power for the amplification process. This configuration allows the weak PWM signal from the microcontroller to be effectively boosted for further use or control applications.

D. Boost Converter

The Booster circuit is designed as a boost converter, a type of DC-DC converter that increases the input voltage to a

Fig. 5. **Boost Converter**

higher output voltage. The input is provided by a DC voltage source (V1) rated at 325V. An inductor (L2) with a value of 20µH is used to store energy during the switching process. A MOSFET switch (M1), labeled ”SPA11N60C3,” acts as the main switching element, turning on and off rapidly to control the energy transfer. A diode (D2), labeled ”RFL60TZ6S,” allows current to flow to the output while preventing reverse flow, effectively rectifying the voltage. The output capacitor (C1), with a large capacitance of 50mF (50,000µF), smooths the output voltage by reducing ripples. A load resistor (R1) with a value of 8 ohms is connected across the output to simulate a load. The gate of the MOSFET is controlled by a pulse voltage source (V2), which delivers a PULSE signal defined as PULSE(0 18.5 0 0 6.6u 20u). This means the gate signal starts at 0V, pulses up to 18.5V with no delay or rise time, stays high for 6.6 microseconds, and repeats every 20 microseconds. This pulsing action is what enables the boost converter to efficiently step up the input voltage to the desired higher level.

E. Buck Converter

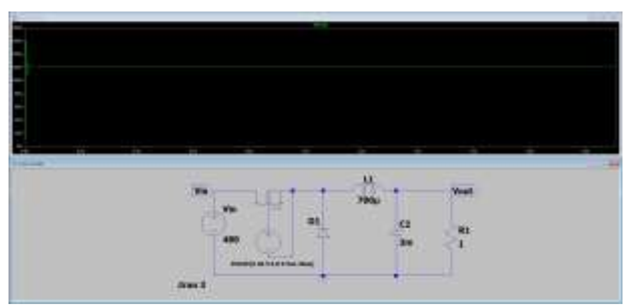

Fig. 6. **Buck Converter**

The circuit described is a buck converter, a type of DC-DC converter designed to step down a higher input voltage to a lower output voltage. It begins with a DC voltage source (Vin) supplying 480V as input. A MOSFET is used as the switching element, rapidly turning on and off to control energy flow. A diode (D1) acts as a freewheeling diode, allowing current to continue flowing through the inductor when the MOSFET is off. The inductor (L1), valued at 700µH, stores energy and helps smooth the current. An output capacitor (C2) rated at

3mF (3000µF) further smooths the voltage to provide a steady DC output. A load resistor (R1) of 1 ohm is connected across the output to represent the load. The gate of the MOSFET is driven by a pulse voltage source with parameters PULSE(0 18.5 0 0 5us 20us), meaning it switches between 0V and 18.5V with a pulse width of 5 microseconds and a period of 20 microseconds, effectively controlling the MOSFET's operation to regulate the output

F. Countdown Mechanism with switching circuit(Relay)

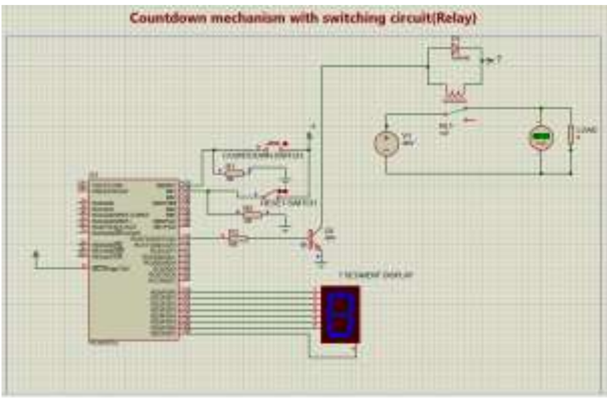

Fig. 7. **Countdown Mechanism with switching circuit(Relay)**

The circuit is centered around a PIC16F877A microcontroller (U1), which is responsible for handling the countdown logic, controlling the 7-segment display and operating the relay. A 7-segment display is connected to the microcontroller and is used to visually represent the countdown value. A relay (RL1) is included to control the switching of a connected load through its normally open (NO) contact, allowing the microcontroller to manage higher power devices. Since the microcontroller cannot directly supply sufficient current to energize the relay, an NPN transistor (Q1) is used as a driver switch. A diode (D1) is connected across the relay coil as a flyback diode to protect the transistor from voltage spikes caused by the coil's inductive kickback when turned off. The circuit also features two push buttons: a countdown switch to initiate the countdown and a reset switch to reset the timer, both interfaced with the microcontroller. Resistors (R1, R2, R3) are used for current limiting and as pull-up or pull-down resistors for stable button operation. A 12V power supply (V1) powers the relay and other components, while a regulated +5V supply is used for the microcontroller and digital circuitry, ensuring proper operation of the entire system

G. Continuity Check Circuit

The "Continuity Check Circuit" is designed to detect whether a complete electrical path exists and indicate the result using visual signals. It operates as part of a larger system, with the input labeled "BOOSTER CIRCUIT OUTPUT" providing 480V,.A relay is used as a switching element on the 12V side and is connected to a load through its normally open (NO) contact, allowing the load to be activated only when

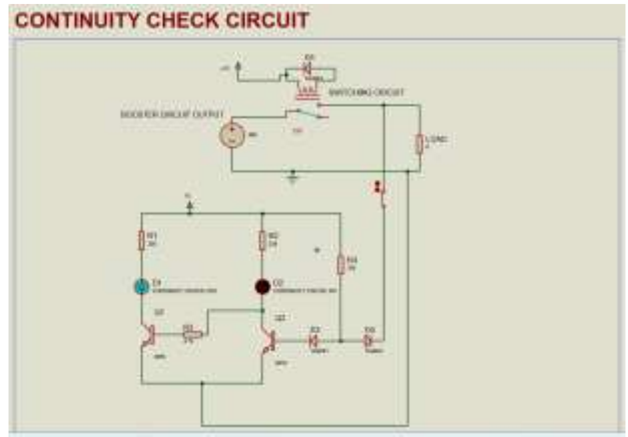

Fig. 8. **Continuity Check Circuit**

continuity is detected. Two NPN transistors (Q1 and Q2) are used to control the relay and two status LEDs: a green LED (D1), labeled "CONTINUITY STATUS: YES," lights up when continuity is present, while a red LED (D2), labeled "CONTINUITY STATUS: NO," lights up in its absence. Additional diodes (D3, D4, and D5) are included to protect the circuit from reverse current and voltage spikes, especially across the relay coil. Resistors (R1 to R4) are used to limit current and properly bias the transistors, ensuring stable operation of the continuity detection and indication system.

V. Conclusion

In conclusion, the development of the Power Supply Unit represents a signifi cant advancement in electronic system design, focusing on precise current control, robust safety features, and reliable operation. Utilizing Proteus software for sim ulation enabled thorough testing and optimization of the circuit design, ensuring its functionality and efficiency before physical implementation. The integration of new components and advanced technologies not only enhanced performance but also improved the safety and usability of the console across various industrial appli cations. Key innovations such as the step-down transformer for voltage regulation, bridge rectifier for AC to DC conversion, and microcontroller-based relay control system demonstrated the project's capability to meet stringent operational require ments while maintaining safety protocols. The inclusion of continuity-checking mechanisms further ensured operational integrity, facilitating quick diagnostics and maintenance. The developed Power Supply Unit stands poised to contribute significantly to industrial processes, offering enhanced control, safety, and reliabil ity in managing variable currents and firing sequences. The successful integration of Proteus simulation ensured that potential issues were identified and resolved early in the development process, mitigating risks and enhancing overall reliabil ity. The design's emphasis on safety demonstrated through features like voltage regulation and continuity checks, underscores its suitability for high-stakes indus trial environments. By incorporating modern components and innovative design approaches, the

Power Supply Unit not only meets current industry standards but also anticipates future technological advancements.

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