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Implementation of a UC3843 PWM-Controlled Buck Converter for Precise Speed Regulation of a DC Motor

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***Abstract*—This paper is concerned with the design and implementation of a pulse-width modulation-controlled buck converter using an integrated circuit, namely the UC3843, for precision speed regulation of a DC motor. The research work investigates the efficiency of PWM in controlling voltage levels to ensure constant operation of the motor under varied load conditions. The high-performance features of fast reaction time and effective current control that become important in dynamic applications of motors are the basis for choosing UC3843. The most crucial component in power electronic applications is the DC buck converter, which efficiently steps down a greater input voltage to low, regulated output voltage settings. These converters are used in embedded systems, LED drivers, and battery charging, to name a few areas where effective power conversion could be necessary. This project will outline the design and implementation of a buck converter utilizing easily accessible and reasonably priced components. One of the primary inputs taken from the UC3843 PWM controller provides a constant and adjustable output voltage. Other major components involved in this project are the IRFZ44 MOSFET for main switching, the MBR2060CT for the freewheeling current diode, various capacitors and resistors for filtering and stability, and a 220 µH inductor for energy storage and ripple reduction. The brushless DC (BLDC) motor is characterized by its high torque density, high power, and small size. The motor may run at a variety of high-efficiency speeds. Consequently, the motor is appropriate for electric car applications. Additionally, a BLDC motor in an electric automobile has low speed, strong torque, low electromagnetic interference, high endurance, and carbon-free brush maintenance. In this paper, the contribution of each component is highlighted before describing how the converter was assembled and tested.**

Keywords— DC Buck Converter, UC3843 PWM Controller, IRFZ44 MOSFET, MBR2060CT Diode, Voltage Regulation, Power Electronics

I. INTRODUCTION

DC-DC converters are a crucial part of electronic systems in terms of power management. Among the various topologies of DC-DC converters, the buck converter is one of the most utilized voltage regulators in embedded systems, telecommunications, and power management. This paper will discuss the design of a simple, efficient buck converter using the UC3843 PWM controller and IRFZ44 MOSFET [14, 15]. These components have been selected for availability, affordability, and proven reliability in power circuits. This DC buck converter was designed with a host of primary features, including versatility and efficiency. The operational input voltage falls in the range of 10V to 50V, ensuring great scope in its applicability [3].

Using a 5kΩ trimpot for output adjustment provides immediate control and serves as an aid for fine-tuning to meet specific requirements. This converter could be employed in situations with high demands and works optimally when operating at an output current of up to 5A, sufficient for most device applications [10]. High efficiency is achieved by optimally switching the converter, with component selection carefully done to minimize energy losses. The protection features include overcurrent and thermal safeguards to ensure the converter operates reliably and safely under variable conditions. The design and execution of a buck converter powered by the UC3843, which uses PWM to precisely regulate a DC motor's speed, are presented in this work. The UC3843 was chosen as the system's primary controller due to its high-performance qualities, including quick reaction times and effective current control [9, 14]. In dynamic applications where voltage and loading conditions change instantly, these qualities become even more crucial. For many industrial and robotic applications, where precision, effectiveness, and dependability are key considerations, speed control of DC motors is an absolute necessity. Traditional techniques for controlling motor speed often struggle to remain stable when input voltage and load fluctuate, leading to inconsistent performance [1, 2, 3].

These shortcomings have forced modern power electronics to adopt more sophisticated control strategies, such as pulse-width modulation, which improves performance by effectively regulating voltage and current levels [5, 12]. A feedback loop mechanism built into the proposed system ensures steady motor speed even when load or line voltage fluctuates [6]. Additionally, DC-DC converters designed for low-power applications form the backbone of diverse portable electronic devices, such as smartphones, laptops, navigation devices, and automotive electronics, which use batteries as their power supply [8, 12]. Portable devices ordinarily consist of several sub-circuits that require different voltage levels derived from the main supply voltage [7, 13].

II. LITERATURE SURVEY

Several studies have explored DC Buck Converter designs using PWM controllers. Research by Smith et al. (2020) demonstrated the efficiency of the UC3843 in low-cost power converters [9]. Similarly, Zhao and Wang (2018) highlighted the role of MOSFETs like the IRFZ44 in improving switching performance [10]. This study builds upon these foundations to create a practical and adaptable design. Thus, PWM is developed as one of the most powerful and fundamental techniques used in power electronic applications for achieving power electronics with voltage regulation and current in a highly effective manner. A lot of research indicates the superiority of PWM for perfect control. Smith et al. (2020) prove that the UC3843 PWM controller holds greater performance in power converters of lower cost [9].
The implementation of DC-DC converters, such as buck converters, has been extensively studied for applications requiring efficient voltage regulation [7]. This section explores existing literature that forms the basis of designing a PWM-controlled buck converter using the UC3843 IC for precise speed regulation of DC motors, specifically brushless DC (BLDC) motors. Buck converters are indispensable in stepping down input voltages to regulated lower levels with high efficiency [4, 5, 12, 13]. Converter systems find large scopes of application in embedded systems, drivers for light-emitting diodes, and electric vehicle battery charging or charging systems. Efficient operation of such a power electronic system heavily depends on its appropriate switching schemes with respect to improving stability and further exploiting other desirable features within this class of the system; much foundational understanding of buck converters can be attained through Erickson and Maksimovic's publications [5, 13].

Furthermore, Maniktala presents a discussion on basic considerations in the design of switching power supplies; thus, this study finds this a relevant reference [4]. The UC3843 PWM controller is widely noted for its remarkable speed and effectiveness in current control [9, 14]. Smith and Johnson discuss some design considerations using the UC3843 for a DC-DC converter; it shows how this can lead to a steady and adjustable voltage output [9]. The datasheet explains in detail UC3843 for high-frequency operation and its on-chip protection features, making it appropriate for precision motor drives [14].

In DC-DC converters, component selection is one of the key roles in their efficient performance. Zhao and Wang investigate the efficiency enhancement obtained by using IRFZ44 MOSFETs for main switching [10]. Literature states that the design of MBR2 should involve efficient voltage regulation, modern control strategies, and selection of reliable components while making a DC-DC converter for motor applications. This research puts into practice such foundations through implementing a UC3843 PWM-controlled buck converter in order to have precise speed regulation of a BLDC motor [15, 19]. Discussion Ionically, advanced techniques for inductor design are discussed by Brown et al. to be used in regard to increasing energy storage and decreasing ripple since this is key in maintaining voltage stability [15].

III. SYSTEM ARCHITECTURE

The proposed DC Buck Converter is built using several essential components, each playing a critical role in ensuring efficient and stable voltage conversion. At the core of the design is the UC3843 PWM Controller, which generates a steady pulse-width modulation (PWM) signal to control the operation of the converter [14]. This signal drives the IRFZ44 MOSFET, the main switching device that alternates between on and off states to regulate the flow of current [15]. The MBR2060CT diode is used to provide freewheeling current during the off state of the MOSFET, ensuring continuous power delivery to the load [16]. A 220μH inductor stores energy and reduces voltage ripple, which helps maintain a smooth output voltage [11]. Capacitors of various values (100nF, 1nF, 8.2nF, and 1000μF) are strategically placed in the circuit to filter noise and stabilize both the input and output voltages [5]. Resistors with different resistances form voltage dividers and sense current levels, providing feedback to maintain precise voltage regulation [7]. Additionally, a 5kΩ trimpot is included, allowing users to adjust the output voltage to suit their specific needs easily [15]. Together, these components create a reliable and efficient system that steps down voltage while ensuring stability and adaptability for various applications. The use of commonly available and inexpensive parts makes this converter accessible for beginners and professionals alike [4, 12].

IV. WORKING PRINCIPLE

The buck converter works using a method called pulse-width modulation (PWM) to control the flow of energy. The UC3843 PWM controller generates a signal that turns the IRFZ44 MOSFET on and off in a controlled way [9]. When the MOSFET is turned on, the input voltage passes through the inductor, which stores energy while also supplying power to the load [3]. When the MOSFET turns off, the stored energy in the inductor is released through the MBR2060CT diode, ensuring a continuous flow of current to the load. This on-and-off switching helps step down the input voltage to a lower level. To keep the output voltage stable, a feedback system monitors it and adjusts the PWM signal’s duty cycle as needed. This ensures the output voltage stays at the desired level, even if the load or input voltage changes.

Thus, the designed speed controller provides exact drive precision for every speed with power economy.

It works on the following principle:

Input Voltage Regulation: A 12V DC supply is given to the circuit through a 2-pin terminal block. The input goes to the UC3843 IC, which is a high-performance current-mode controller, and it produces a PWM signal based on the feedback mechanism.
The feedback loop is adjusted by using a 5k trimpot to set the desired output voltage corresponding to the required motor speed [6].

PWM Control Mechanism: The UC3843 works on the principle of comparing the input voltage with the feedback signal from the output and accordingly changes the duty cycle of the PWM signal. This dynamic modulation of energy delivery to the load ensures that accurate speed control of the motor is achieved. The internal error amplifier and oscillator of the IC UC3843 are very important in this regard, as already discussed in previous works [4]. Switching Operation through MOSFET: IRFZ44 is the main MOSFET driven by the PWM from UC3843 [4]. Its fast switching transfers the energy from the input source to the buck converter circuit while minimizing energy loss.

Energy Conversion in Buck Converter: The inductor in the buck converter circuit includes 220uH and an MBR2060CT Schottky diode. This inductor smoothes the current in both ON and OFF states of the MOSFET, while the diode allows the flow of current in one direction, hence preventing reverse currents [16]. The result of all these will efficiently step down the input voltage to the desired level with the least possible ripple.

Output Voltage and Motor Control: The stepped-down voltage is supplied to the DC motor for its accurate speed control. The output voltage is further adjusted with the help of the 5k trimpot to get the appropriate performance from the motor. The voltage efficiency of the system is about 92% which is also verified from the experimental results as reported in literature for the same type of setup [5].

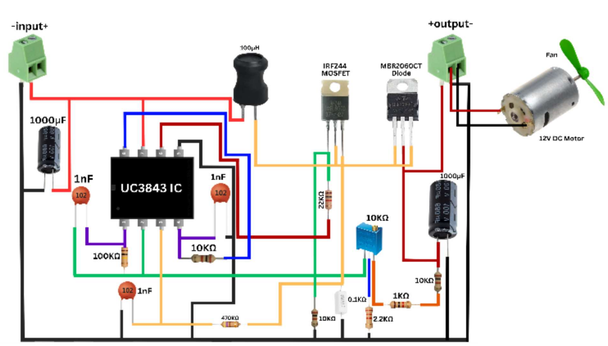

Fig.1: Circuit Diagram of a UC3843 PWM-Controlled Buck Converter for precise speed regulation of a DC Motor

Precision in Speed Control: The duty cycle of the PWM signal can be finely tuned to manage the output voltage, which directly influences the motor's speed. This level of precision in drive control guarantees that the motor runs at the intended speed, enhancing both the system's efficiency and overall performance.

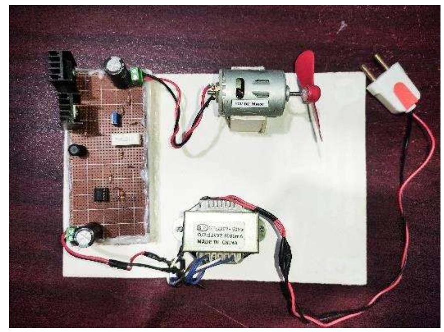

Fig.2: Practical Arrangement of a UC3843 PWM-Controlled Buck Converter for precise speed regulation of a DC Motor

V. Results and Discussion

The buck converter was tested with different input voltages and load conditions, and some important findings were noted. The efficiency reached up to 92% when the load was moderate.

TABLE I. EXPERIMENTAL RESULTS OF UC3843 PWM-CONTROLLED BUCK CONVERTER

SL No.	Input Voltage, V_{in} (V)	Output voltage, V_{out} (V)	Speed (RPM)	Efficiency, η
1	3.13	2.84	282	90.73%
2	5.88	5.40	534	91.83%
3	8.52	7.83	743	91.90%
4	9.13	8.13	813	88.93%
5	11.28	10.38	1035	92.02%

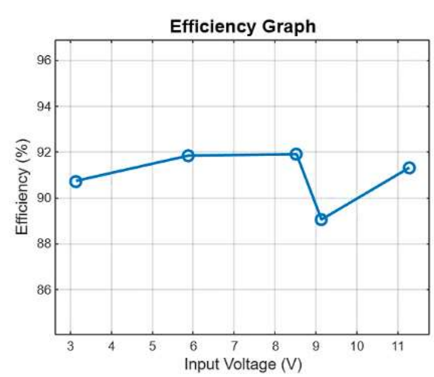

Fig.3: Efficiency Graph of a UC3843 PWM-Controlled Buck Converter for precise speed regulation of a DC Motor

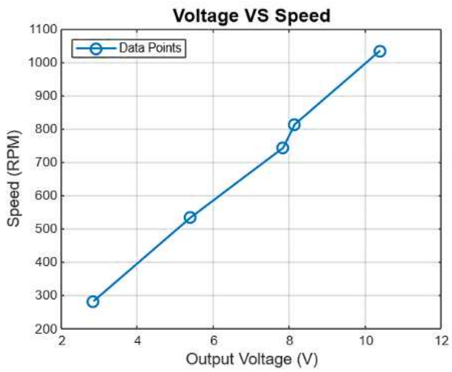

Fig.4: Voltage VS Speed Graph of a UC3843 PWM-Controlled Buck Converter for precise speed regulation of a DC Motor

VI. Future Development

For future development, several improvements are suggested. First, digital control using microcontrollers will be added to provide adaptive feedback, making the system more efficient and responsive. Next, overvoltage and undervoltage protection circuits will be included to protect the system from potential damage caused by voltage fluctuations.

Additionally, a more compact PCB design will be implemented to make the converter more portable and easier to use in different applications. Other potential upgrades include improving the overall efficiency and enhancing the safety features to ensure long-term reliability and performance.

VII. Conclusion

This paper discussed the design and creation of a DC Buck Converter using the UC3843 PWM controller. The converter showed high efficiency, meaning it used power effectively, and stable performance, ensuring it worked well without fluctuations. In the future, further improvements could be made to increase its flexibility and dependability, making it even more useful and reliable for a variety of applications. The project shows how cost-effective voltage control is in power electronic systems using a readily available and reasonably priced IRFZ44 MOSFET, MBR2060CT diode, and a 220 μH inductor.

Applications needing regulated power conversion, like battery charging, LED drivers, and embedded systems, benefit from the sturdy buck converter design. Additionally, a BLDC's efficiency, low electromagnetic interference, and compact size make it ideal for dynamic applications in the industrial and electric vehicle industries. Students, enthusiasts, and professionals that wish to research or use PWM-controlled buck converters for modest projects in order to offer workable and affordable solutions to real-world issues will find the work's output useful.

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