Implementing a Buck Converter to enhance power management in RC cars.

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***Abstract*— This project aims to create a low-cost remote-controlled toy or robot utilizing a Bluetooth-controlled motor car. The battery-powered model car can be remotely controlled through a mobile app connected via Bluetooth. The system involves the use of ICs, a motor fixed to a chassis, and a receiver module in the car to transmit and receive control signals through radio frequency. Two switches on the remote control enable the power of each motor in the car. The primary objective is to design a cost-effective solution for a remote-controlled vehicle, efficient power management, and overall performance improvement. The assembly process includes placing motors, circuits, and wheels on the chassis. As part of the project, we may explore the possibility of downgrading the voltage by incorporating a buck converter. The expected outcome is a functional and affordable remote-controlled toy or robot capable of precise motor control through the Bluetooth connection.**

***Index Terms*— Buck converter, Power management, RC cars, Remote control, Arduino, Converter**

I. Introduction

A Buck Converter is a kind of voltage converter that reduces a greater input voltage to a lower output voltage. It works with direct current to direct current voltage conversions. It is an effective voltage regulator, or switched-mode power supply (SMPS), that modifies the length of time the input voltage is supplied to the load. An input source, such as a battery or power supply, provides a greater voltage to the Buck Converter. Buck converters are chopper circuits that conduct step-down conversion of the applied DC input signal. In the case of buck converters, the fixed DC input signal is transformed into a lower-valued DC signal at the output. This signifies that it is intended to generate a DC signal with a smaller magnitude than the applied input as its output. The buck converter effectively steps down an input voltage to a lower, controlled output voltage using the fundamental principles of pulse-width modulation (PWM). It consists of a switching device, often a transistor, that cycles on and off. An inductor stores energy

from the input source when the transistor is turned on. Following that, during the off state, this stored energy is delivered to the load via a diode. The inductor and capacitor components work together to smooth out the output voltage, and a control circuit adjusts the switching frequency to maintain the appropriate output level. The buck converter achieves accurate voltage regulation by varying the duty cycle of the switching element, making it an important component in DC-DC power conversion applications such as voltage regulation in electronic devices and power supplies.

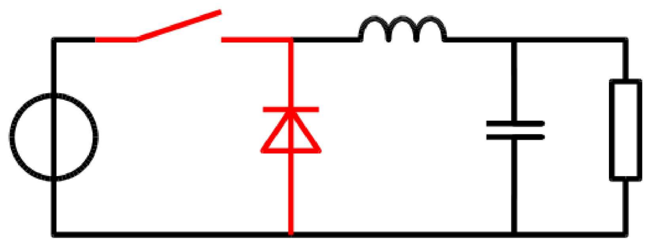

Fig 01: Buck Converter

In their study titled "Electric Vehicle Battery Life Extension Using Ultracapacitors and an FPGA Controlled Interleaved Buck-Boost Converter", Jose M. Blanes et al. [1] Designed an FPGA-controlled interleaved bidirectional buck-boost converter working in a discontinuous conduction mode that increased the consumption of electrical vehicles due to converter losses. In the study "Implementing Sliding Mode Control for Buck Converter", M. Ahmed et al. [2] presented an analysis and experimental study of buck converters and modeled a control circuit. Another study titled "Design and Implementation of Fully Integrated Digitally Controlled Current-Mode Buck Converter" conducted by Man Pun Chan and Philip K. T. Mok [3] illustrated samples and quantized both the output voltage and inductor current of the buck converter for control purposes. "A Low-Power Mixed-Signal Current-Mode DC-DC Converter Using a One-Bit ΔΣ DAC", Olivier Trescases et al. [4] aim to demonstrate a peak-current-mode digital controller for a 500 mA low-power buck converter used in battery-powered devices.

This report illustrates the implementation of a buck converter to enhance the power management system of an RC car equipped with a 4-wheel chassis. The RC car is powered by four separate lithium-ion batteries, each with a 3.7-volt nominal voltage. As these batteries deplete while in use, the overall voltage provided to the system decreases, resulting in a visible loss in performance. To address this issue, we use a buck converter to control and optimize the voltage given to the car's motors. An Arduino microcontroller for precise control, a PWM motor for effective speed regulation, a Bluetooth module for distant communication, and a buck converter to alter the input voltage are the system's key components. The four independent batteries, which give a total of 15.8 volts, are regulated to produce a consistent output voltage ranging from 14.9 to 15 volts. This project not only guarantees that the motors receive steady power, but it also allows users to remotely operate the RC vehicle using the inbuilt Bluetooth module. The buck converter is an important component in attaining improved power management, which maximizes the performance and lifespan of the RC car over time.

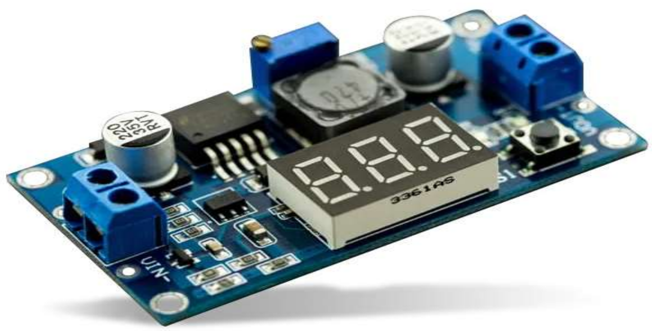

Fig 02: LM2596 DC-DC step down Buck Converter with digital tube display

To maintain a steady output voltage, the control circuitry, which is frequently built using a feedback loop, monitors the output voltage and modifies the duty cycle of the switching element. The ratio of the switching elements on time to the entire switching period is known as the duty cycle. The Buck Converter controls the output voltage by varying the duty cycle. Over the load, the controlled output voltage is achieved. The input voltage can be stepped down by the Buck Converter to a level appropriate for the components or devices that are attached. Buck converters are renowned for their excellent power conversion efficiency. Low power loss and energy dissipation are made possible by the switching operation. Where effective voltage regulation and power management are crucial, Buck Converters are frequently employed in electronic devices, power supply, and battery-powered systems. The purpose of the Buck Converter in our RC vehicle project is to guarantee that the motor supplies the batteries with a steady and suitable conclusion. A Buck Converter plays a crucial role in power electronics by offering effective control and regulation of voltage levels in a range of electronic systems and applications.

II. BLOCK DIAGRAM

The following diagram is a buck converter-

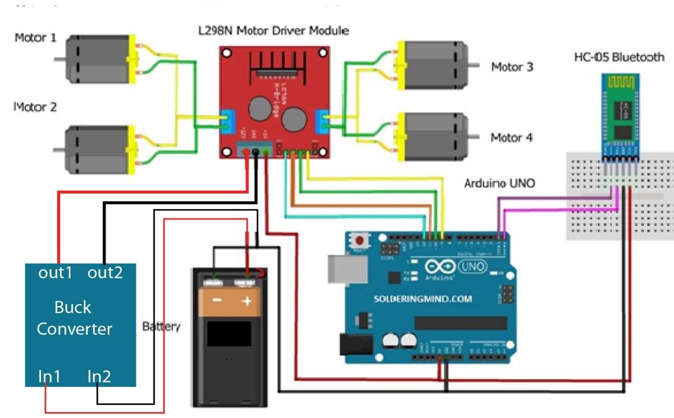

Fig 03: Block Diagram of buck converter

This block diagram shows that the system's core is an Arduino microcontroller, which manages the full functionality. An L298N motor driver module is connected to the Arduino and controls four motors with accuracy in speed and direction. A buck converter adjusts the voltage drawn from a battery system, ensuring a consistent and appropriate supply for the entire system. The battery system, which provides the required power, may be made up of separate batteries connected in series or parallel. A Bluetooth module also provides wireless connectivity, allowing external devices to communicate with the Arduino remotely. The linked components are smoothly assembled on a breadboard, providing a flexible and readily adaptable platform for applications like robotics or remote-controlled devices. This complete setup is an integrated system in which the Arduino serves as the central hub, providing coordination between motor drivers, power control, battery supply, and wireless communication.

III. SIMULATION MODEL AND RESULTS

The simulation of the buck converter is given below.

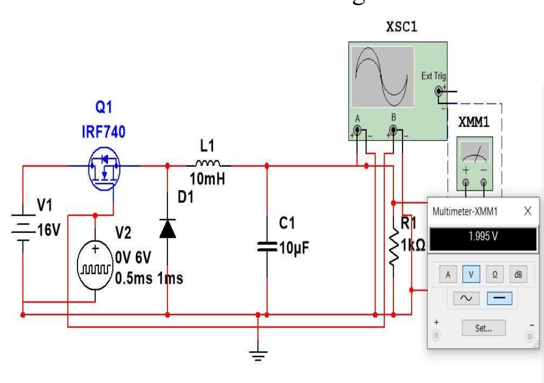

Fig 04: Buck Converter circuit diagram

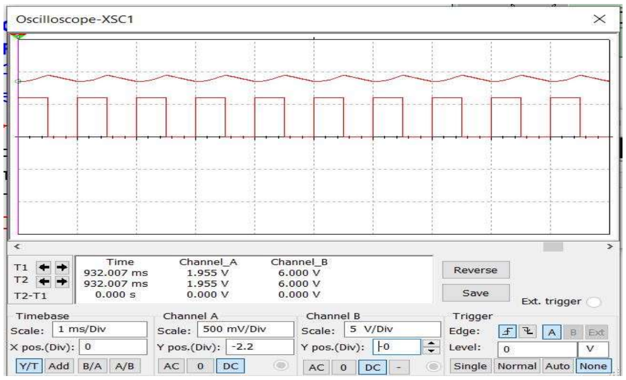

Fig 05: Oscilloscope Measurement

The power management system features a buck converter circuit using an IRF740 transistor for switching, driven by a 16V supply and controlled by a 6V pulse with a 0.5 ms delay. Components include a 10mH inductor, a diode, a 10µF capacitor, and a 1kΩ resistor. Voltage waveforms are monitored using an oscilloscope with external triggering, while a multimeter measures voltage across the resistor R1.

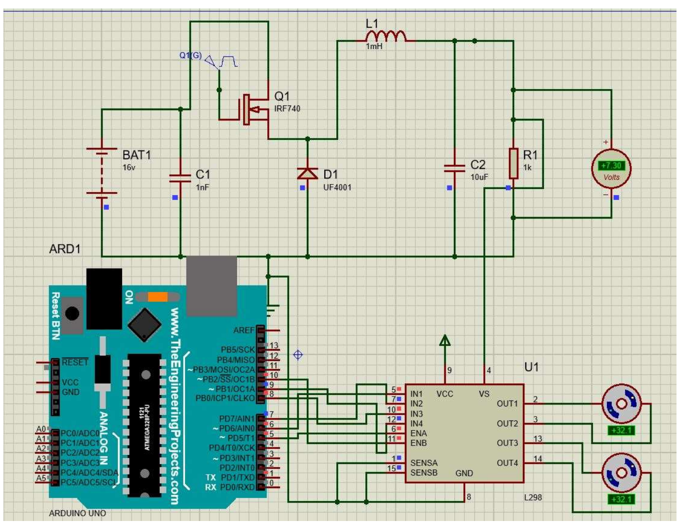

Fig 06: Circuit diagram of the project

In the simulation conducted in Proteus software for the implementation of a Buck Converter in enhancing power management for RC cars, key components include the Buck Converter circuit, an L298N motor driver, and an Arduino microcontroller. The Buck Converter regulates voltage efficiently, contributing to optimal power utilization in RC car systems. The L298N motor driver facilitates precise control over motor functions, ensuring effective power delivery to the motors. The Arduino microcontroller serves as the central control unit, orchestrating the entire system and enabling programmable features for enhanced functionality. This simulation provides valuable insights into the performance and integration of these components, demonstrating their collaborative role in achieving efficient power management for RC cars.

IV. USED/REQUIRED COMPONENTS

In our project, the following key components were employed:

1. **Arduino Uno:** Utilized as the central microcontroller to control and coordinate various functions within the system. Arduino UNO is a microcontroller board based on ATmega328P. It has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino UNO is a flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, and raspberry pi boards and can control relays, LEDs, servos, and motors as outputs. This electronic platform includes interconnects, LEDs, and more. There are different types of Arduino boards in the market including Arduino UNO. Five key advantages of the Arduino programming language are that it is easy to learn and use. Arduino programming language is based on C++, with a simple syntax that is easy to pick up even for beginners.

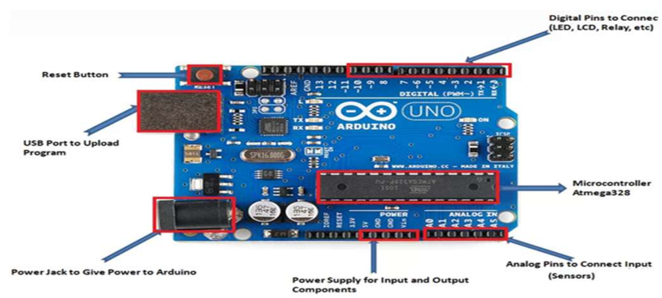

Fig 07: Arduino Uno

2. **Motor Driver L298n:** Responsible for driving and controlling the motors in the RC car. The L298N motor driver is an integrated circuit that allows for the control of two DC motors simultaneously. It is widely used in robotics and other applications where motor control is required. Here's a brief overview of its features and how it is typically used:

Dual H-Bridge: The L298N contains two H-Bridge circuits which can independently control two DC motors, or they can be combined to control a single bipolar stepper motor.

Voltage Range: It typically operates at a supply voltage of up to 46V, which makes it suitable for a wide range of motors.
Current Capacity: The L298N can handle peak currents of up to.

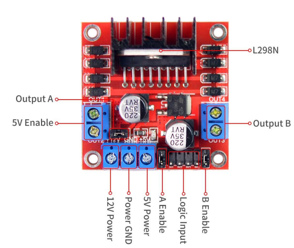

Fig 08: Motor Driver L298n

3. **Battery:** Serves as the primary power source for the entire system.
4. **Motor Car Chassis Kit:** Comprising essential mechanical components for the RC car's structure and movement.
5. **Buck Converter With Display:** Incorporated for efficient voltage regulation and real-time monitoring of pow parameters.
6. **Battery Holder Li-ion (4 cells):** Used to organize and supply power from Li-ion cells.
7. **Bluetooth Module HC 05:** Integrated for wireless communication, enabling remote control and data exchange.
8. **Connecting Wire All Set:** Employed to establish connections between various components, ensuring wireless communication and power distribution.

V. DESCRIPTION OF HARDWARE STRUCTURE

In our project, the Arduino Uno serves as the project's brain, orchestrating the functions of various components. It provides a centralized control hub, enabling the seamless coordination of operations. Two Motor Driver L298n modules facilitate precise control over the RC car's motors, enhancing its maneuverability. Additionally, the four batteries act as the primary power source, delivering the necessary electrical energy for the entire system. The Motor Car Chassis Kit forms the structural foundation, providing stability for the integration of electronic components. The Buck Converter with Display is a pivotal component, ensuring efficient voltage regulation and real-time monitoring. This feature enhances power management, optimizing the performance of the RC car. The Bluetooth Module HC 05 introduces wireless communication capabilities, enabling remote control and data exchange, thereby enhancing user interaction. The Li-ion Charger ensures the timely recharge of the Li-ion battery cells, promoting longevity and sustained performance. Lastly, the Connecting Wire All Set establishes seamless connections, facilitating communication and power distribution between components, and creating a cohesive and well-integrated RC car system.

VI. HARDWARE RESULTS

Here is the hardware structure of our project-

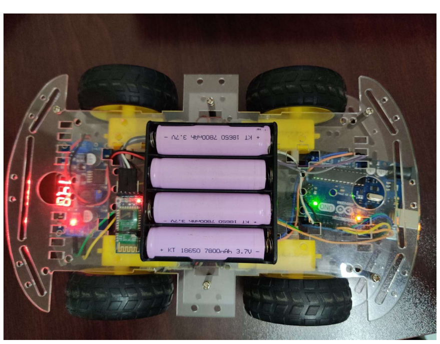

Fig 09: Hardware structure of our project (1)

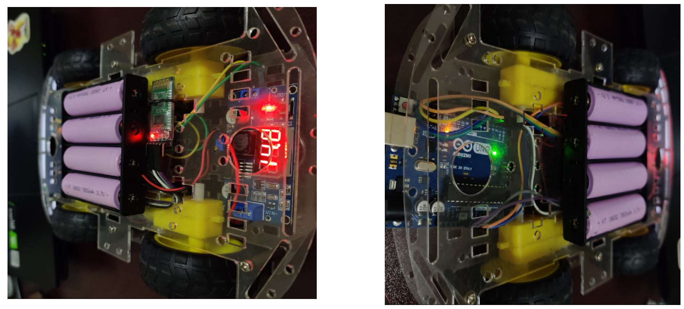

Fig 10: Hardware structure of our project (2)

In our project aimed at enhancing power management in RC cars, we have employed a Buck Converter to optimize voltage supply. We utilize four 3.7-volt batteries, resulting in a combined voltage of 14.8 volts. However, the PWM motor in our RC car operates efficiently at 12 volts. To bridge this voltage gap, we strategically integrated a Buck Converter. The primary function of the Buck Converter is to step down the input voltage from 14.8 volts to the required 12 volts. This conversion is pivotal for ensuring that our RC car's PWM motor can operate within its specified voltage range.

The control mechanism for the Buck Converter is facilitated by an Arduino microcontroller. The Arduino communicates with the RC car's motor through PWM (Pulse Width Modulation). By modulating the width of the electrical pulses it sends, the Arduino effectively regulates the voltage output from the Buck Converter to the motor, allowing us to precisely control the speed and direction of the RC car.

This integrated system not only optimizes power management but also grants us fine-grained control over the RC car's motor, enhancing its overall performance and responsiveness to our commands.

VII. ANALYSIS ON ENGINERRING MANAGEMENT OF THE PROJECT

To maximize power efficiency, this project incorporates a number of different components. Advanced power management and wireless control are among the strengths; complexity and power consumption might be disadvantages. There are opportunities for customization and instructional usage, but there are risks due to technological issues and financial limitations. Personal responsibility guarantees a well-organized endeavor. Together, the experts in power management, chassis, Arduino, L298n, and Buck Converters reduce possible problems and maximize performance. The effectiveness of each position in handling the project's possibilities, threats, weaknesses, and strengths will determine how well it turns out. Consistent feedback and communication foster ongoing development, enabling the team to overcome obstacles and improve the project's overall engineering management for the remote-controlled automobile.

VIII. ANALYSIS OF THE ECONOMIC ASPECTS OF THE PROJECT

Pest Analysis: Many outside elements that are listed in a PEST study are relevant to the project. From an economic perspective, financial planning is greatly impacted by budgetary restrictions and variations in the price of electrical components. Social interest in technology and education, as well as consumer preferences for features in remote-controlled cars, might have an impact on how well the idea is received. Regarding technology, design decisions and overall project feasibility can be influenced by innovation potential and reliance on developing technologies. To manage projects effectively, one must have a thorough awareness of these economic, social, and technological aspects.

Cost Analysis: Table 01- Costing

Name of product	Quantity	Price
Arduino Uno	1	950 tk
Motor Driver L298n	1	160 tk
Battery	4	80*4= 320 tk
Motor Car Chassis Kit	1	900 tk
Buck converter with display	1	230 tk
Battery Holder Li-io (4 cells)	1	230 tk
Bluetooth Module HC 05	1	250 tk
Connecting wire all set	1	210 tk
		Total = 3070 tk

Standard Deviation Calculation and Comment: One useful statistic to evaluate the project's financial variability is the standard deviation. We may determine the level of financial uncertainty by calculating the standard deviation of costs related to labor, components, tools, and possibly hidden charges. Greater unpredictability is implied by a higher standard deviation, which might provide difficulties in cost prediction and management due to unforeseen expenses or changes in the market. On the other hand, a smaller standard deviation denotes more constant and steady expenses, offering financial certainty throughout the project's implementation. This knowledge of standard deviation facilitates risk assessment, enabling careful budget planning and flexibility in the face of unanticipated events throughout the RC vehicle project.

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