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A DC-DC Converter with a Single Switch Design for Battery-Powered Electrical Vehicles

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Abstract: We recommend a new single-switch transformer with a lower-lift DC-DC converter for vehicles that use energy components. The designed topology enhances the converter's voltage addition while decreasing the voltage load on the force switch using an integrated LC2D yield and an exchanged capacitor multiplier. In addition, the suggested converter can accommodate the energy component's large voltage fluctuations because of its broad voltage gain range. As the acid dissolves, the sulfuric acid molecules disintegrate into free-moving sulphate ions and positive hydrogen ions (2H+). Consider a situation where two electrodes are linked to a DC source and submerged in a solution. The hydrogen ions would then be brought to the electrodes, which would be positively charged and connected to the supply's negative terminal. The SO ions, which are negatively charged, made their way to the electrodes that were linked to the positive end of the power main's supply (i.e., anode). Sulfuric and hydrogen acids are produced when hydrogen ions remove one electron from the cathode and sulphate ions remove two negative ions from the anodes in a reaction with water. Lead peroxide is formed when oxygen, generated from the preceding equation, combines with lead oxide (PbO2.) Consequently, although the lead anode is transformed into lead peroxide a chocolate-coloured substance the lead cathode stays lead. The proposed converter's operational requirements and consistent state evaluations are presented. Because the suggested converter's semiconductor components are only subjected to a voltage stress of around 50% of the output voltage, a power switch with a lower rated voltage can be used.

Keywords: Electromagnetic Interference, Three-level boost (TLB), energy component, CO2 emissions, Energy Model and State of Charge

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Introduction

Many people are interested in electrifying transportation because sustainable energy systems are becoming more affordable. There is a worldwide effort to reduce carbon dioxide emissions, and we rely too much on fossil fuels. Within the clean energy vehicle market, fuel cell electric vehicles (EVs) hold significant sway [8]. A clean energy source, fuel cells produce no pollutants, are very efficient, and have a high output current density. However, the fuel cell isn't suitable for feeding the electric vehicle's inverter directly due to its soft output characteristics, where the voltage declines significantly with increasing output current [9-12].

Traditional boost converters theoretically provide an unlimited voltage gain at the unity duty cycle. Still, in practice, the voltage gain degrades at very high duty cycles because of parasitic elements in the active components and comparable series resistances in the passive components [13-17]. At very high duty cycle values, the efficiency of the traditional boost converter reduces significantly, and the voltage stress on the semiconductor devices is substantial (equivalent to the output voltage). There are a lot of publications on various high-step-up-gain DC-DC converter topologies; in general, they can be grouped into two types: those with magnetic coupling and those without. Various step-up DC-DC converters that use magnetic coupling components, such as coupled inductors, high-frequency transformers, or even both, are showcased.

These converters extend the voltage gain and reduce the voltage stress on semiconductor devices by modulating the magnetic coupling component's turn ratio [18-24].

The magnetic coupling component's leakage inductance is the main problem with this converter; its energy can cause EMI, high voltage spikes across the transistors, and a decrease in the DC-DC converter's overall efficiency [25-31]. On the other hand, DC-DC converter topologies that exclude magnetic coupling components are highly sought after due to their reduced cost, more straightforward circuit construction, increased power density, and reduced overall complexity. Due to its low voltage stress on its semiconductor devices, the three-level boost (TLB) converter underwent extensive analysis (equal to half the output voltage) [32-39]. The converter's broad voltage gain range works well with the fuel cell's gentle output properties [40]. Due to its many desirable characteristics, the suggested converter is a top pick for electric vehicle inverters that incorporate fuel cells into their DC links. The virtues of the 800 V powertrain architecture in simplifying the wiring between the various powertrain components led to its adoption in this work.

Literature Review

In his article presentation, Lequesne [1] focuses on the non-hybrid and non-fully electric propulsion technologies that make up transportation electrification. With an emphasis on electro-mechanical systems, this analysis will cover the most recent developments (the past 10–20 years) and ongoing efforts to electrify road transport, including everything from chassis to powertrains. Along the journey, we'll examine the various obstacles engineers have conquered or are still working to overcome. This will show how electrical engineering is making a difference by creating better, safer, more efficient, and more enjoyable methods to get around.

The electrification of automobiles during the last decade has been accompanied by improvements to the electric power industry's infrastructure, according to Raghavan and Khaligh [2]. The plug-in hybrid electric vehicle (PHEV) appeals to the electric power and automotive sectors due to its multiple operation modes, which allow it to run on gasoline and electricity, as well as from the grid to the car. Fuel efficiency, pollutants, battery lifetime, and added premium above a hybrid electric or conventional car are critical factors determining the customer and automotive value proposition of PHEVs.

In this study, Zhang et al. [3] propose a single-switch Boost DC-DC converter with diode-capacitor modules to harmonise the voltages of fuel cell stacks and fuel cell cars' DC link buses. A series discharge occurs after the capacitors have been charged in parallel. A basic construction can achieve a sizeable voltage-gain range. Also covered are the converter's steady-state properties, fault tolerance, extended stages, and fundamental operating principles.

Emadi and Williamson [4] suggested a standard means of transportation for reducing carbon emissions: the hybrid electrical vehicle (HEV). The best option for these uses would be switched reluctance motors or SRMs. Three energy components—a photovoltaic module, a battery bank, and an SRM—comprise an SRM-based series-type HEV. A tri-port converter is required to integrate all three energy sources into a single power converter. A compact and modular design characterises the tri-port converter, making it ideal for use in HEVs. While driving, the suggested tri-port converter can switch between five different modes of operation: PV module to SRM, battery bank to SRM, PV module and battery bank to SRM, PV module to SRM and battery bank, and battery bank to SRM and PV module. When at a standstill, it can switch between a PV module to a battery bank and a battery bank to a PV module without additional converters. To work in tandem with various modes of operation, matching control strategies are also created. Additionally, to increase its viability under severe HEV application conditions, the fault tolerance properties of the tri-port converter are explored. To assess how well the suggested tri-port converter works for HEV uses, simulations and experiments are carried out using a 750W prototype.

One potential new mode of transportation that could help reduce carbon emissions is plug-in hybrid electrical trucks, or PHETS, proposed by Wu and Gao [5]. The many advantages of switched reluctance motors (SRMs) for PHET applications include good fault tolerance, an extensive speed range, a high starting torque, and the fact that they do not require a back earth. A modular tri-port high-power converter for SRM-based PHETs is suggested in this research as a means to integrate several electrical energy components into a single converter. Depending on the situation, the tri-port high-power converter's modular design allows for a parallel or series winding connection and supports variable energy flow. The suggested converter can also function as a charger that connects to the grid without additional infrastructure because AC grid-connecting nodes are also implemented in the drive. The proposed converter and associated control procedures are tested and proven to be feasible through the use of simulation and tests.

Both plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) applications can benefit from the model-based methodologies used in the approach proposed by Zhang et al. [6] to correctly anticipate the EV range. The method utilises a physical model, an energy model, and a State of Charge (SoC) model. Once the ignition is turned on, methods give the driver an accurate startup range. This uses information about prior drives to get a result based on the most recent driving cycle. This paper details the EV range function's flow sequence. Analyses of results from multiple drive cycles demonstrate that the system successfully predicts EV range.

Prasanna et al. successfully developed and commercialised hybrid electric vehicles (HEVs), which depend heavily on energy storage devices [7]. There may be energy, power, and money savings when using lithium-ion batteries. Thermal management is one of the difficulties brought about by lithium-ion batteries. Temperatures between -10°C and 50°C are optimal for operating lithium-ion batteries. An efficient temperature management system is essential to keep the battery healthy and extend its life. Predicting the battery's temperature accurately is the first step in developing an effective thermal management system. Using electric characteristics and experiments to estimate the thermal loss, predicting the temperature rise from test results of a single cell, and modelling the temperature gradients of the battery pack under different operating conditions, this paper aims to evaluate the thermal management system of a lithium-ion battery pack designed for HEV applications.

Operation Mode

There are three distinct operational states shown in Table 1 for the proposed converter, depending on the switch's conduction state and the four diodes. This mode is characterised by the switch being off, forward bias in D1 → D3, and reverse bias in D4. In both CCM and DCM modes of operation, the converter enters this state, which lasts for either deT (in DCM) or (1-d)T (in CCM) (in DCM). In operational state II, the converter is active when t1 < t < t2. Capacitors (C1, C2, and C4) charge, inductors (C3 and C5) discharge, and the state is transitioning between the two. The Pulse Generator block periodically produces pulses with a square waveform. The block's Amplitude, Pulse Width, Period, and Phase Delay waveform characteristics dictate the output waveform's form. The impact of each parameter on the waveform is illustrated in the following diagram. See Figure 1.

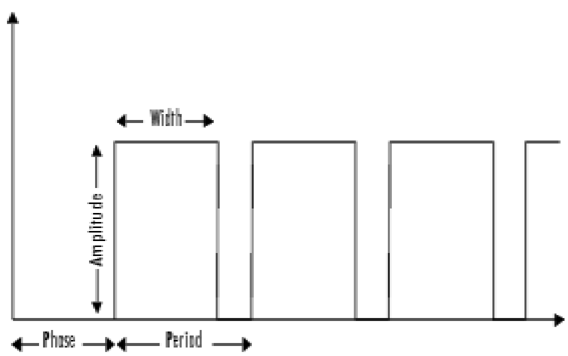

Figure 1: PWM modulation

The properties of the pulse's waveform determine the intervals between changes in the block's output. This means a time-based pulse generator's output cannot be calculated using a fixed solver in Simulink. Models with time-based pulse generators can have a fixed-step solver specified in Simulink. In this instance, Simulink determines a constant sample duration for the time-based pulse generators. It then acts as a sample-based simulator for the time-based pulse generators [41-47]. If you want your block's pulses to be time-based, you'll need to give it a period and phase delay in seconds. If you want your block to be sample-based, you'll need to use the Sample Time option to set the sample time in seconds. For the sake of argument, imagine giving a sample duration of half a second. Take the example of a two-second pulse repeat [48-55]. Therefore, the block's Period parameter would be set to four in this example. The number of seconds is the sample duration for this block. If the pulse type of the block is sample-based, then this parameter will be visible. For further details, go to Customising the Sample Duration. Visualise vector parameters as one-dimensional. After scalar expansion, the block produces a 1-D signal (vector) if this option is chosen and the remaining parameters are one-row or one-column matrices. The dimensionality of the output remains unchanged regardless of the other parameters in this case [56-61].

The suggested circuit uses pulse width modulation (PWM) to create the pulses the switches need. You can use the simulation's start and stop times with the sample-based PWM generator. Low gain ratio and strong output voltage ripples cause stress on the switches in the traditional circuit, another problem of the typical interleaved boost converter. The three-terminal insulated-gate bipolar transistor (IGBT) was designed to combine high efficiency with quick switching and is mainly used as an electronic switch [62-69]. It controls the flow of electricity in several devices, including electric vehicles, trains, refrigerators with variable speeds, ballasts for light bulbs, air conditioners, and even stereo systems that use switching amplifiers. An IGBT is a non-regenerative semiconductor device with four alternating layers (P-N-P-N) controlled by a metal oxide and semiconductor (MOS) gate structure. Its fast on/off timing makes it ideal for amplifiers that employ pulse-width modulation and low-pass filters to create complicated waveforms [70-75]. When used as an analogue audio amplifier, current devices have pulse repetition rates that reach into the ultrasonic range, at least ten times higher than the highest audio frequency the device can handle. This is for switching purposes [80].

By swapping out the n+ drain for a p+ collector layer, an IGBT cell becomes a vertical PNP bipolar junction transistor structurally identical to an n-channel vertical construction power MOSFET. A PNP bipolar junction transistor and the surface n-channel MOSFET are connected in a cascade manner employing this extra p+ area [81-86]. The IGBT is a hybrid device that combines the gate-drive simplicity of MOSFETs with the bipolar transistors' high current and low saturation voltage capabilities. Integrating a bipolar power transistor (BPT) with an isolated-gate field-effect transistor (FET) creates a single device that is both a switch and a control input. It is common for large IGBT modules to have numerous devices connected in parallel. With a blocking voltage of 6500 V, they can handle currents in the hundreds of amperes range. With these IGBTs, loads of hundreds of kilowatts are within control [87-93].

A passive electrical component inductor stores energy as a magnetic field. An inductor is just a coil or loop of wires at its most basic. The inductance grows in a straight line with the coil's winding diameter. The material used to wind the coil and its radius affect its inductance. No matter the coil's radius or number of turns, the inductance will be lowest with an air core [94-99]. Dielectric materials such as wood, glass, and plastic are functionally equivalent to air for winding inductors. For a given number of turns in a coil, the inductance can be increased by adding ferromagnetic substances like iron, laminated iron, or powdered iron. The magnitude of this rise can reach hundreds in certain instances. It is also essential to consider the core's form [100].

Compared to solenoid cores, shaped like rods, toroidal cores, which resemble doughnuts, offer greater inductance for the same core material and number of turns. Henry, abbreviated as "H," is the conventional unit of inductance. This unit is quite massive. Units such as the microhenry, abbreviated as μH (1 μH = 10-6H), and the millihenry, abbreviated as mH (1 mH = 10-3 H), are more frequently used. With one nH= 10-9 H, the nanohenry (nH) is sometimes employed. Putting inductors onto IC chips is a challenging process. Sometimes, basic electronic circuits built into integrated circuit chips with transistors, resistors, and capacitors can mimic inductance. Several wireless communications applications make use of inductors in conjunction with capacitors [101-104]. Discrimination against undesired signals can be achieved by connecting an inductor in series or parallel with a capacitor. The power sources of various electronic devices, including computers and their peripherals, use large inductors. The inductors in these setups smooth out the rectified utility AC and provide DC, similar to what you would get from a battery.

One electrical component that can store electric charge is the capacitor. A capacitor is made of a dielectric material that separates two nearby conductors, often plates. When the plates are linked to a power source, they gather electric charge [105-111]. As time passes, one plate gains a positive charge, and the other loses it. At a voltage of 1 volt, the capacitance measures the quantity of electric charge stored in the capacitor. Farads are the units of measurement for capacitance (F). In DC circuits, the capacitor cuts off current, while in AC circuits, it prevents short circuits. A diode is an electrical component with two terminals allowing current to flow in just one direction (as long as it is operated within a specified voltage level) [112-117].

In an electrical circuit, a diode functions similarly to a valve. The forward (or "low resistance") direction must have a specific threshold voltage for these diodes to start conducting current. This direction of current flow is called the "forward bias" of the diode. A voltage is referred to as the "reverse breakdown voltage" when this breakdown takes place [118-123]. The diode can conduct electricity in the "high resistance" direction when the circuit voltage exceeds the reverse breakdown voltage. So, in reality, we say that diodes have a significant resistance in the other way rather than an infinite resistance. A semiconductor diode in its most basic form is a PN junction. Under perfect circumstances, this PN junction is a short circuit when biassed forward and an open circuit when biassed backwards. A "diode" is a device that uses two electrodes; the word "diode" comes from that [124-129].

Results and Discussion

Simulation is employed in the vast majority of R&D projects (Figure 2). It isn't easy to move forward without simulation. It is worth noting that a hardware proof of concept prototype in the lab and computer simulation work hand in hand with power electronics. However, hardware prototypes are still necessary, and computer simulation is not a replacement for them [130-132]. The purpose of this chapter is to describe the MATLAB tool's ability to simulate an impedance source inverter with R, R-L, and RLE loads. Power electronics, transformers, lines, and machinery are all represented in the libraries' model collections (Table 1).

Table 1: Parameters Table

Parameters	Values
Input Voltage	90V
Rated Power Po	1.3KW
L1	250e-6
L2	250e-6
L3	10Mh
C1	220e-6
C2	220e-6
C3	220e-6
C4	220e-6
C5	220e-6
Output Voltage Vo	800V

The input supply to the power circuit is provided by a step-down transformer, which operates at 230/12 V. A complete bridge rectifier circuit converts the 12V AC input into 12V pulsing DC. A capacitor filter isolates the DC signal from any ripples in the pulsating DC, resulting in pure DC. The 7812 regulator's input pin is linked to the capacitor's positive terminal for voltage regulation. The pulse amplifier receives power from a 12V source acquired from the 7812 output pin. The microcontroller gets its power from a 5V source supplied from the output pin 7805 [133-137]. An LED is linked in series with the resistor and output from the same pin, 7805, to show that power is on. The PIC micro® Range Reference Manual (DS33023) has more information; it can be ordered from a local Microchip sales representative or downloaded from the Microchip website [138-139]. The PIC16F87XA chips all have three memory blocks. This section explains how concurrent access is possible since the program and data memory use distinct buses. Section 3.0, "Data EEPROM and Flash Program Memory," describes the EEPROM data memory block in depth.

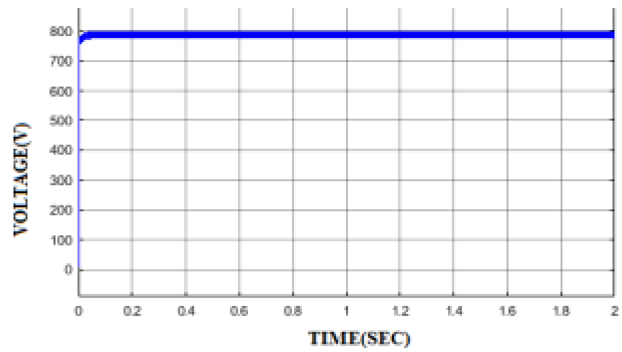

Figure 2: Output Voltage

An electrical circuit type known as transistor-transistor logic (TTL) is constructed using resistors and bipolar junction transistors (BJT). This type of logic is known as transistor-transistor logic since transistors are used for amplification and logic gating functions (like AND) (contrast this with RTL and DTL). Notable among the many uses for TTL integrated circuits (ICs) are computers, industrial controllers, consumer electronics, synthesisers, test equipment and instruments, and a host of others. Despite its lack of association with TTL integrated circuits, the abbreviation TTL can sometimes denote logic levels that are compatible with them; this is seen, for instance, on the inputs and outputs of many electronic devices.

The input transistor's low-resistance emitter(s) is the only point of entry for a TTL circuit. Yet, when the input voltage to the emitter(s) is logic '0' or close to ground, the input transistor will pass a current of approximately 1.6 mA because its base is connected to the Vcc line. It is recommended to connect TTL inputs to Vcc using 1 k ohm pull-up resistors, as leaving them disconnected (or "floating") can cause them to go to logic "1," but also leaves them susceptible to stray signals. A simple one-output transistor-transistor (TTL) circuit consists of a grounded emitter, a pull-up resistor connecting the collector to Vcc, and an output obtained from the collector. On the other hand, a totem pole output circuit is commonly used in TTL circuits; this layout swaps out the pull-up resistor for a transistor with the Vcc side stacked on top of the GND side. Diodes link the collectors of the two transistors, one with a grounded emitter and the other with a collector attached to Vcc. The output is drawn from the transistor's collector on the ground side.

Typically, optocouplers are packaged in tiny ICs with either 6 or 8 pins. The two components that make them work together are a light-emitting diode (LED) made of gallium arsenide and a phototransistor or light-triggered disc, which are optical receivers. A transparent barrier separates them, preventing the flow of electrical current but letting light pass through. The current transfer ratio (CTR) is the most used metric for assessing an Optocoupler's transfer efficiency and the most critical characteristic. This means that the output transistor's current change divided by the input LED's current change is the same as a ratio. The typical CTR value is between 10% and 50% for devices that use an output phototransistor. For devices that use a Darlington transistor pair, the value can reach about 2000%. Remember that CTR typically fluctuates at the absolute present level in most devices.

With a power dissipation level of about 50 watts, the TO-220 package is the clear winner in every commercial and industrial application. Part of the reason for the TO-220's widespread acceptance in the industry is its low package cost and heat resistance. Battery technology involves storing chemical energy in electrochemical cells, which are then used to generate electricity. Ever since Alessandro Volta invented the first battery (or "voltaic pile") in 1800, particularly after the technically superior Daniell cell was introduced in 1836, batteries have grown ubiquitous as a power source for several industrial and domestic uses. A 2005 estimate placed the yearly sales of the global battery sector at US$48 billion, with a growth rate of 6%. A primary battery, often known as a throwaway battery, is one kind of battery; the other is a secondary battery, intended to be used more than once before being discarded (rechargeable batteries).

Once assembled, primary batteries are ready to produce current right away. The point of using disposable batteries is to use them once and then throw them away. These are ideal for use in portable devices that do not draw a lot of electricity, are used occasionally, or are located far from a power supply that is always on, like in communication and alarm circuits. Because the chemical changes are irreversible and the active ingredients may not return to their original forms, it is not possible to successfully recharge disposable primary cells. Recharging primary cells is not something that battery manufacturers encourage doing. Disposable batteries typically come in two types: alkaline and zinc-carbon. Primarily constructed with active components in a depleted state, secondary batteries typically require charging before usage. Reversing the chemical reactions using electric current allows rechargeable batteries or secondary cells to be used repeatedly. Charging devices, often known as rechargers, are used to provide the correct current.

Rechargeable lead-acid batteries have been around for a long time. Because it is an open container containing liquid, this battery must be maintained upright and in a well-ventilated place to prevent the release of hydrogen gas when overcharged. The lead-acid battery's massive electrical energy capacity also makes it hefty. Regardless, it is often used in situations requiring a big capacity (more than 10 Ah) or when weight and handling comfort are not issues because of its low production cost and a strong surge in current levels. Both the hardware and the simulation make use of lead-acid batteries. Additionally, the material should not include contaminants that could harm the electrolyte. The lead-acid cell plate has various designs, but they all have a grid structure with lead and active materials. A grid is needed to conduct the electric current and distribute it evenly over the active material. The active material can become loose and fall if the current isn't evenly distributed.

Conclusion

Lead and antimony alloys make up the grids. The transverse rib, which typically crosses the spots at right angles or diagonals, is commonly used to make these. Although both the positive and negative plates have identical designs, the negative plates' grids are lighter since they aren't crucial for the current's uniform conduction. Both types of battery plates are available. These are the two types of plates: formed plates and pasted plates. Plante's plates are primarily utilised in stationary batteries because of their greater weight and expense than pasted plates. But the plates last longer and don't lose active material as easily when charged and discharged quickly. There is a poor ratio of capacity to weight on the plant plate. Producing negative plates instead of positive ones is more suited to the failure process. The harmful active substance resists damage and changes very little when charged and discharged. During charging or discharging, the substance that takes part in a chemical reaction—the absorption or evolution of electrical energy is called the cell's active material. You can see the potential difference between the electrodes when you connect the voltmeter between them and disconnect the DC power source.

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