Implementation of Quadratic Gain Bidirectional Dc-Dc Converter to Enhance EV Battery Systems with Super-Capacitor Assistance

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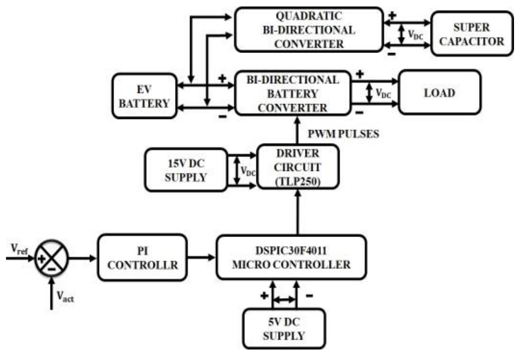
***Abstract* - With advancements in battery technology, EVs offer an environmentally friendly alternative to traditional internal combustion engine vehicles. This project focuses on the design and implementation of a bidirectional power converter system for Electric Vehicle (EV) applications, integrating both a battery and a supercapacitor as energy storage devices. The bidirectional converter facilitates power flow in two directions: from the EV battery to the load and vice versa, allowing for efficient energy transfer and management. The proposed system comprises two main components: an EV battery and a supercapacitor, both connected to a bidirectional power converter. The EV battery serves as the primary energy source for the system, providing high-energy density storage for prolonged operation of the EV. The supercapacitor acts as a complementary energy storage device, offering high-power density storage for rapid energy transfer and regenerative braking applications. The bidirectional converter enables power flow between the EV battery, supercapacitor, and load in both directions. The proposed system utilizes a quadratic bidirectional converter topology, which offers improved efficiency, reduced switching losses, and enhanced control capabilities compared to traditional converter topologies. Through prototype development, and experimental validation, this project seeks to demonstrate the feasibility and effectiveness of the proposed bidirectional power converter system for EV applications.**

INTRODUCTION

Supercapacitor assisted battery system is used in this system. As more than one energy storage systems are connected in parallel the entire system is unaffected by any fault occurring on individual system i.e. the system will work without any interruptions. The Paris Agreement Declaration on Electro-Mobility and Climate Change and Call to Action, which took place on the 12th of December 2015 and went into effect on the 4th of November 2016, called for the deployment of 100 million electric vehicles around the globe by the year 2030. Bidirectional DC-DC converters are employed when the DC bus voltage regulation has to be achieved along with the power flow capability in both the direction. One such example is the power generation by wind or solar power systems, where there is a large fluctuation in the generated power because of the large variation and uncertainty of the energy supply to the conversion unit (wind turbines & PV panels) by the primary source. These sources supplement the main system at the time of energy deficit to provide the power at regulated level and gets recharged through main system at the time of surplus power generation or at their lower threshold level of discharge. Therefore, a bidirectional DC-DC converter is needed to be able to allow power flow in both the directions at the regulated level.

BATTERY SUPERCAPACITOR SYSTEM:

BLOCK DIAGRAM

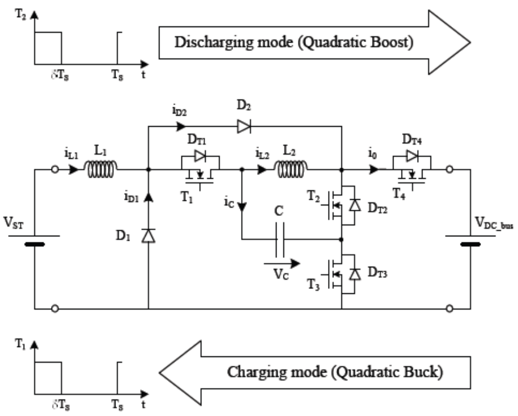


In this proposed system implementation of quadratic gain bidirectional DC-DC converter to enhance electric vehicle battery systems with super-capacitor assistance is proposed. The proposed system focuses on designing and implementing a bidirectional power converter system tailored for Electric Vehicle (EV) applications. It seamlessly integrates a battery and a supercapacitor as energy storage units, enabling smooth power flow in both directions between the EV battery, supercapacitor, and load.

QUADRATIC GAIN BIDIRECTIONAL CONVERTER:

The quadratic gain bidirectional converter has two inductors, two diodes, four switches and a capacitor. The below figure shows the circuit diagram of quadratic gain converter. The input to the converter is supplied by a supercapacitor. The output of the converter is given to a DC link at the input side of the system. Converter has two modes of operation-Buck and Boost modes. In each mode only one switch is responsible for the power flow so control complexity of the circuit is less. This converter is characterized by high gain in both step up and stepdown modes. The converter is assumed to be operating in steady state continuous conduction mode. The capacitor value is taken large enough so that voltage across it is taken constant along one switching cycle.

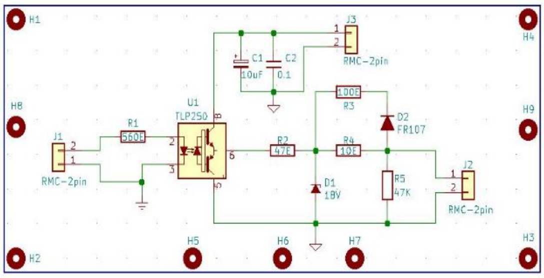
CIRCUIT DIAGRAM:



DRIVER CIRCUIT TLP250:

Optical isolation is the primary advantage of using this driver when compared to other drivers. It is an 8-pin IC with input current threshold at 7-10mA and an ideal voltage input of 5V. Input supply is rectified by a full wave rectifier cascaded to each input. There are a total of 6 drivers in the circuit, 4 primary drivers and 2 backup drivers to provide firing pulses in the intermediate delay interstices. A capacitor of rating 470uF is attached to each driver so as to prevent damage to the drivers. A power inverter, or inverter, is an electronic device or circuitry that changes Direct Current (DC) to Alternating Current (AC).

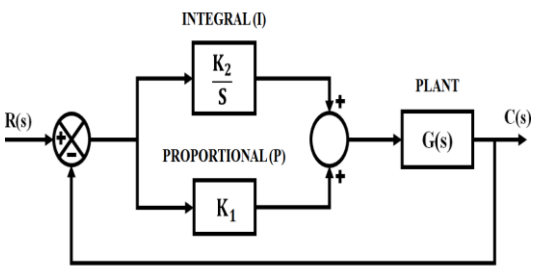
TLP250 CONNECTION DIAGRAM:



PI CONTROLLER:

The PI controller (proportional integral controller) is a feedback controller. It drives the plant which is to be controlled with a weighted sum of error and the integral of that value. PI-Controllers have been applied to control almost any process in current use, from aerospace to motion control, from slow to fast systems. Alongside this success, however the problem of tuning PI-controllers has remained an active research area. Furthermore, with changes in system dynamics and variations in operating points PI- Controllers should be returned on a regular basis. This has triggered extensive research on the possibilities and potential of the so-called adaptive PI controllers. Loosely defined, adaptive PI-controllers avoid time-consuming manual tuning by providing optimal PI-controller settings automatically as the system dynamics or operating points change.

BASIC BLOCK OF PI CONTROLLER:



DSPIC30F4011 CONTROLLER:

The dsPIC30F devices contain extensive Digital Signal Processor (DSP) functionality within a high-performance, 16-bit architecture. When multiplexing occurs, the peripheral module's functional requirements may force an override of the data direction of the port pin. The core has a 24-bit instruction word. The Program Counter (PC) is 23 bits wide with the Least Significant bit (LSB) always clear, and the Most Significant bit (MSB) is ignored during normal program execution, except for certain specialized instructions. Thus, the PC can address up to 4M instruction words of user program space. An instruction prefetch mechanism is used to help maintain throughput. Program loop constructs, free from loop count management overhead, are supported using the DO and REPEAT instructions, both of which are interruptible at any point.

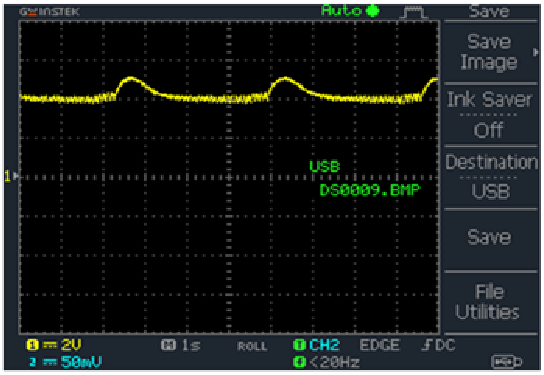
HARDWARE RESULTS

HARDWARE VIEW:

The hardware implementation of this project involves the use of a DSPIC30F4011 microcontroller to control the bidirectional power converter system. The microcontroller serves as the brain of the system, orchestrating the flow of power between the EV battery, supercapacitor, and load. Through its programmable features, the DSPIC30F4011 enables precise control of the converter topology, ensuring efficient energy transfer and management. The bidirectional power converter, integrated with the EV battery and supercapacitor, forms the heart of the system. This converter facilitates power exchange in both directions, allowing for seamless energy flow between the energy storage devices and the load. Its quadratic gain topology enhances efficiency, minimizes switching losses, and provides advanced control capabilities, making it ideal for EV applications. Overall, the hardware setup comprises the DSPIC30F4011 microcontroller, the bidirectional power converter, the EV battery, the supercapacitor, and the load. Together, these components create a robust and efficient power management system for electric vehicles, paving the way for sustainable and high-performance electric mobility solutions.

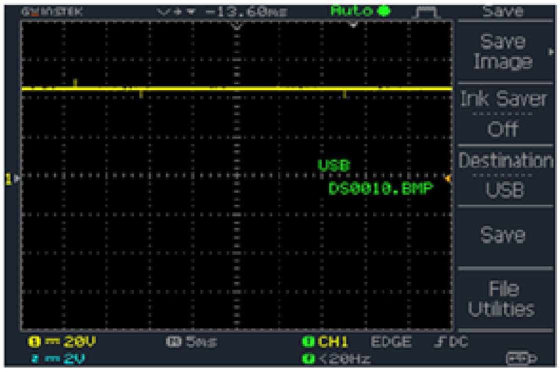
EXPERIMENTAL ANALYSIS:

INPUT DC VOLTAGE SUPPLY WAVEFORM:



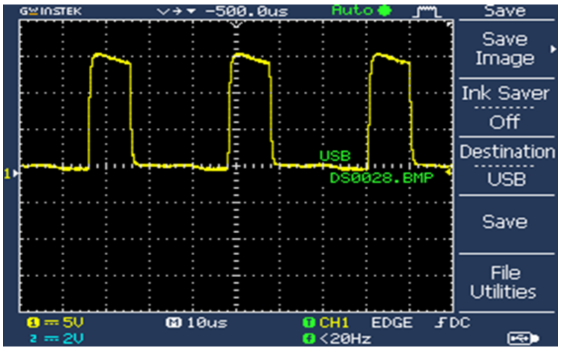
The above figure represents that Input DC Voltage supply waveform. A DC power supply is a type of power supply that gives direct current (DC) voltage to power a device. Because DC power supply is commonly used on an engineer or technician bench for a ton of power tests, they are also often called a bench power supply.

CONVERTER OUTPUT DC VOLTAGE WAVEFORM:



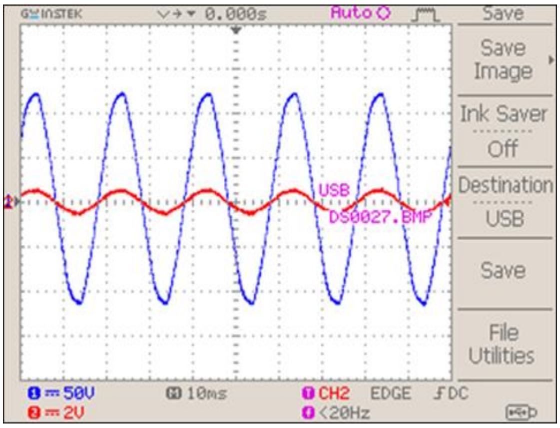
The above figure shows that converter output DC voltage waveform. The converter produces a regulated output voltage V, having a magnitude (and possibly polarity) that differs from Vg.

PULSE WAVEFORM FOR CONVERTER:



The above figure shows that Pulse waveform for converter. Pulse number is defined as the number of pulses in the dc output voltage within one time period of the ac source voltage.

GRID SYNCHRONIZATION OUTPUT:



The above figure represents that grid synchronization output. In an alternating current (AC) electric power system, synchronization is the process of matching the frequency and phase and voltage of a generator or other source to an electrical grid in order to transfer power. This wave form shows that current and voltage are in phase. It maintains unity.

CONCLUSION

This project was developed to design and implement a bidirectional power converter system tailored for electric vehicle (EV) application. By seamlessly integrating both a battery and a supercapacitor as energy storage devices, the system facilitates efficient power flow between the EV battery, supercapacitor, and load in both directions. The utilization of a quadratic bidirectional converter topology offers improved efficiency, reduced switching losses, and enhanced control capabilities compared to conventional converter topologies. This, combined with the integration of advanced converter topologies and the DSPIC30F4011 Microcontroller, aims to enhance the performance, reliability, and efficiency of EV power systems. Through prototype development and experimental validation, this project seeks to demonstrate the feasibility and effectiveness of the proposed bidirectional power converter system for EV applications. The insights gained are expected to inform future advancements in the design, optimization, and integration of energy storage and power management solutions in electric vehicles, ultimately contributing to the development of more sustainable and efficient transportation systems.

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