Arduino Based PWM Output Voltage Control of Boost Converter for Fan Load

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***Abstract*:** Power system design has become more exigent and composite than ever before as demand for high-performance and cost-efficient system continues to increase. This has lead to the use of DC-DC converters with higher efficiency and power economy with utmost features. DC-DC converters are traditionally one of the most vibrant segments on the whole power electronics market. Many of the design, topology and architecture novelty take place in these products, and system-level demands can often be tackled at this level. In this paper a DC-DC converter is modelled and simulated using Arduino with two push buttons to endow with gating pulses to control the semiconductor devices. For the boost converter topology, Arduino is used as an efficient negative feedback controller. A closed loop model is developed and output voltage is controlled by varying the duty ratios and waveforms are monitored. The system also could be further used to drive different loads and thus proves to be an integral part of all the conversion system.

***Keywords* :** *Pulse Width Modulation, Boost Converter, Arduino.*

I. INTRODUCTION

In the portable electronics industry evolution, dissimilar requirements progress such as enlarged battery lifetime, small and cheap systems, brighter, full-color displays and a demand for increased talk-time in cellular phones. An ever increasing demand from power systems has placed power consumption at finest level. To keep up with these demands engineers has worked towards developing proficient conversion techniques and also has effect in the subsequent formal expansion of an interdisciplinary field of power electronics [1]. However it comes as no disclosure that this new field has offered to face up the exclusive combination of three major disciplines of electrical engineering: electronics, power and control. These multi-discipline technologies have caught up control theory, filter synthesis, signal processing, thermal control, and magnetic components design.

The conventional flyback DC-DC converter is with a Resistor-Capacitor-Diode (RCD) snubber and Inductor Capacitor Diode (LCD) snubber. The leakage inductance energy is engrossed by the snubber capacitor and dissipated in snubber resistor. The leakage inductance energy is engrossed by the snubber capacitor and the energy stored is reassigned to an auxiliary inductor. This energy is then restored in an input source since there are 3 conduction paths. In the proposed converter the leakage inductance energy is directly stored in an input source and a DC-bus capacitor [2] and this energy is reprocessed by a dual-flyback DC-DC module.

A DC-DC converter is an electronic circuit that converts a source of direct current from one voltage level to another called as Chopper. DC-DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries and regulate the output voltage. Some exemptions include high-efficiency LED power sources, which are a sort of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the input voltage [3]-[5]. DC-DC converters are the power supply that output a fixed voltage proficiently, converting the input voltage. DC/DC converters can be divided into two extensive categories as non-isolated dc/dc converters and isolated DC/DC converters [6].

Modern electronic devices necessitate competent, high eminence, light weight power supplies. Linear power regulators operation depends on current or voltage division and the main area of application is at low power levels. In high power levels switching regulators are used where switch operates in on and off states. Latest power electronic switches can operate at high frequencies [7]. Therefore, quicker dynamic response to quick changes in the load current is possible with high operating frequencies. These high frequency electronic power processors are used in DC-DC power conversion.

Some applications have additional technical restrictions especially the power supplies used in battery powered electronics like laptop computers or mobile phones, have a requisite of maintaining high efficiency over a wide range of loads. In desktop computers and servers, the microprocessor supplies must embrace the capabilities of digitally programmed output voltage. The output must depend on the load as well the dynamic response must be quicker even for large load transients [8]. Voltage regulator modules have multi phase architectures consisting of several buck or similar converter modules which set off in parallel to share the load current in order to get better dynamic response.

This paper is sort out as follows: In the initial part, boost converter is evaluated. In the subsequent section, realization of Arduino and interfacing with Arduino are discussed. Subsequently the hardware description are projected. Lastly, discussions on waveform are presented.

II. BOOST CONVERTER

The competition is to make things portable and flexible so that the usage will be more with less effort [9]-[12]. As stated for electrical components power consumption is the major factor. For the finest usage of electronic components, dc to dc converter plays a major role. The DC-DC converter can be used for many electronic components and it is widely used in telephone components and many other electronic devices. The principle of converter is to convert the voltage from one value to the other and to carry out regulation for the electronic circuit.

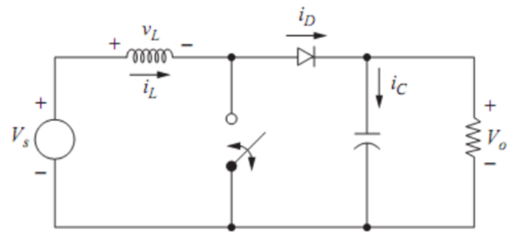

Fig. 1 Boost Converter

The DC-DC boost converter topology is most widely used power management and microprocessor voltage regulator applications. These applications require high frequency and transient response over a wide load current range. They can convert high voltage into low regulated voltage. Boost converter can be used in computers where voltage to be stepped down. Boost converter provides long battery life for mobile phones which spend most of the time in stand-by state.

When the switch is ON the inductor gets charged to its maximum level, because of its flexibility of ON and OFF states it can be switched to OFF state when inductor charges to its maximum capacity. With this feature the usage of heat sinks and cooling agents can be avoided. Because of its advantage we opt for buck converter rather than a linear regulator. Switch mode power supply is generally used to bid the output voltage which is higher than the input voltage to the load from an intermediate DC input voltage bus or a battery source. A simplified boost converter is shown in Fig.1. Buck converter consists of main power switch, a diode, a low pass filter and a load. When the switch is closed current flows through inductor from the voltage source, inductor gets charged to its peak level. When it is in OFF state the inductor acts as additional voltage source to the supply thus boosting its voltage.

The most common form of switch is a manually functioned electromechanical device with one or more sets of electrical contacts, which are connected to external circuits. The mechanism actuating the transition between two states can be either a "toggle" (flip switch for continuous "on" or "off") or "momentary" (push-for "on" or push-for "off") type. An electronic switch is a device that can switch an electrical circuit, interrupting the current or transmitting it from one conductor to another.

The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a transistor used for amplifying or switching electronic signals. Although the MOSFET as shown in Fig 2 is a four-terminal device with source, gate, drain, and body terminals, the body of the MOSFET often is connected to the source terminal, making it a three-terminal device like other field-effect transistors. Because these two terminals are normally linked to each other (short-circuited) internally, only three terminals come out in electrical diagrams.

The MOSFET is by far the most frequent transistor in both digital and analog circuits, though the bipolar junction transistor was at one time much more common. In enhancement mode MOSFET voltage drop across the oxide persuade a conducting channel between the source and drain make contact with the field. The term "enhancement mode" refers to the boost of conductivity with increase in oxide field that put in carriers to the channel referred to as the inversion layer. The channel consists of carriers in a surface impurity layer of opposite type to the substrate, and conductivity is reduced by application of a field that drain carriers from this surface layer.

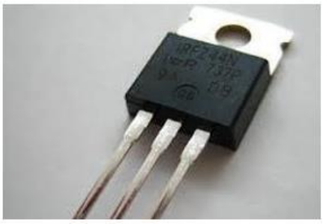

Fig. 2 MOSFET

A capacitor as shown in Fig. 3 is a passive two terminal electrical component used to stock up energy electrostatically in an electric field. The conductors can be thin films of metal, aluminum foil or disks. The 'non conducting' dielectric acts to increase the capacitor's charge capacity. Capacitors are widely used as parts of electrical circuits in frequent common electrical devices. A capacitor does not dissipate energy instead it stores energy in the form of an electrostatic field between its plates.

Capacitor provides the filtering action by providing a path for the harmonic currents away from the load. Output capacitance is required to curtail the voltage overshoot and ripple present at the output of a step-down converter. Large overshoots grounds by insufficient output capacitance and large voltage ripple is caused by insufficient capacitance as well as a high Equivalent Series Resistance (ESR) in the output capacitor. The maximum allowable output-voltage overshoot and ripple are usually précised at the time of design. The ripple content for a step down converter circuit can be deduced by including an output capacitor with ample capacitance and low ESR.

Fig. 3 Capacitor

Resistors may have fixed resistances or variable resistances, such as in thermistor, trimmer, photoresistor, varistor and potentiometer. Practical resistors can be composed by a variety of compounds and films as well as resistance wires made of a high resistivity alloy as nickel-chrome. Resistors are also implemented within integrated circuits, particularly analog devices and can also be incorporated into hybrid and printed circuits

A diode as shown in Fig. 3 is a two-terminal electronic component with asymmetric conductance; it has low resistance to current in one direction, and high ideally infinite resistance in the other. The most common function of a diode is to allow an electric current to pass in one direction while blocking current in the opposite direction. This unidirectional performance is called rectification to convert alternating current to direct current including extraction of modulation from radio signals in radio receivers. Diodes can have more intricated behavior than this simple on–off action due to their nonlinear current voltage characteristics. The voltage drop across a forward biased diode varies only a little with the current, and is a function of temperature; this upshot can be used as a temperature sensor or voltage reference.

Fig. 4 Diode

An inductor, also called a coil or reactor, is a passive two terminal electrical component which resists changes in electric current passing through it as shown in Fig. 5. It consists of a conductor such as a wire, usually wound into a coil. When a current flows through it energy is stored temporarily in a magnetic field in the coil. When the current flowing through an inductor changes, the time-varying magnetic field persuade a voltage in the conductor according to Faraday's law of electromagnetic induction, which opposes the change in current that created it.

Fig. 5 Inductor

When the current through an inductor tends to fall, the inductor tends to sustain the current by acting as a source. This limits the high-peak current that would be restricted by the switch resistance alone. The inductor manages the percent of the ripple and determines the continuous mode of operation. Peak current through the inductor determines the inductor's required saturation current rating which in turn read outs the approximate size of the inductor.

III. ARDUINO

An open-source hardware platform based on an Atmel AVR 8-bit microcontroller developed in Trondheim, Norway in 1996. A computer based on this strategy is a reduced instruction set computer called RISC. An Arduino board has harmonizing components to facilitate programming and incorporation into other circuits as in Fig. 6. Shields communicate with the Arduino board directly over a variety of pins, but many shields are individually addressable via an I²C serial bus, allowing many shields to be stacked and used in parallel. Official Arduino's have used the mega AVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560. A handful of other processors have been used by Arduino compatibles. Most boards include a 5 volt linear regulator and a 16 MHz crystal oscillator although some designs such as the LilyPad run at 8 MHz and dole out with the onboard voltage regulator due to specific form-factor restrictions.

An Arduino's microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer. This makes using an Arduino more straightforward by allowing the use of an ordinary computer as the programmer. Serial Arduino boards contain a level shifter circuit to convert between RS-232-level and TTL-level signals. Current Arduino boards are programmed via USB, implemented using USB-to-serial adapter chips such as the FTDI FT232.

Fig. 6 Arduino Board

The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The Diecimila, Duemilanove, and current Uno provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs. The Arduino Nano, and Arduino-compatible Bare Bones Board and Boarduno boards may provide male header pins on the underside of the board to be plugged into solderless breadboards.

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IV. HARDWARE IMPLIMENTATION

The block diagram for the boost converter with Arduino is shown in Fig. 7. It consists of a dc supply of 9V, inductor , electrolytic capacitor ,n channel MOSFET, a normal p-n junction diode ,a potential or voltage divider circuit and load.

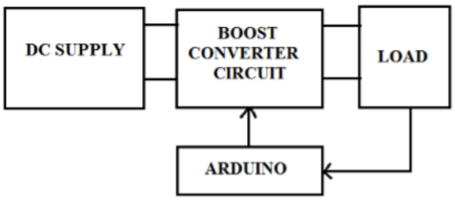

Fig. 7 Block diagram representation

The Arduino reference design can use an Atmega8, 168, or 328 the pin configuration is identical on all three processors. The Arduino Uno can be power-driven via the USB connection or with an external power supply. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Arduino Uno has a number of facilities for communicating with a computer. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer. A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. For SPI communication, use the SPI library.

For the boost converter topology, Arduino is used as an effective negative feedback controller circuit. A dc voltage of 9V from battery or AC-DC rectifier with a regulated device used as an input voltage .In the load side of boost converter a potential divider circuit is implemented to read the voltage on the output side through Arduino using the command “Analogread”. In Arduino, the analog pins numbering from 0 to 5, A0 pin is used to read the voltage across a resistor in potential divider circuit. This load or output voltage will be compared with a reference or desired voltage which has to be obtained from the boost converter circuit.

The actuating or error signal is augmented or incremented proportionately through a multiplier called proportional controller. Pin 9 is used to trigger the MOSFET through this actuating signal as Pulse Width Modulated (PWM) from Arduino through the command “Analogwrite (pin, duty cycle)”.The setup used for the sensing of the load voltage and generating PWM pulses for giving them to gate of MOSFET is termed as Negative feedback circuit. This is how the Arduino is used as feedback controller circuit as shown in Fig. 8.

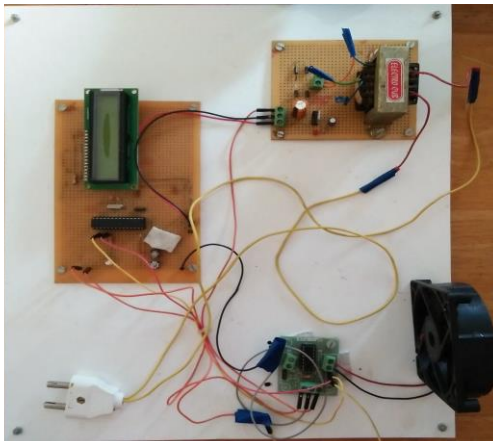

Fig.8 Practical Implementation System

V. SIMULATION

The Simulink/MATLAB model of boost converter is shown in Fig. 9. Figure 10 and 11 shows the input and output voltage waveforms for variations in duty ratios.

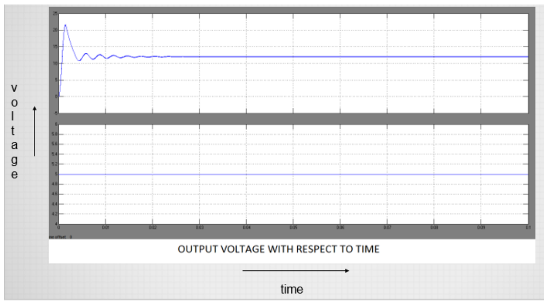

Fig. 9 Output Voltage Waveform of Boost Converter

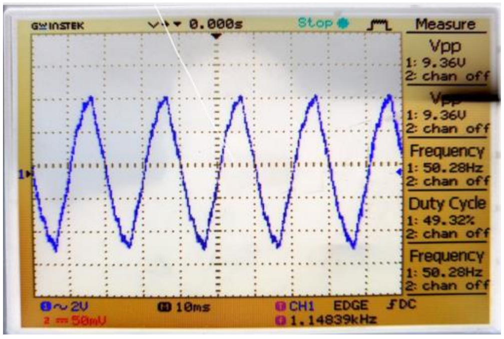

Fig. 10 Input voltage waveform

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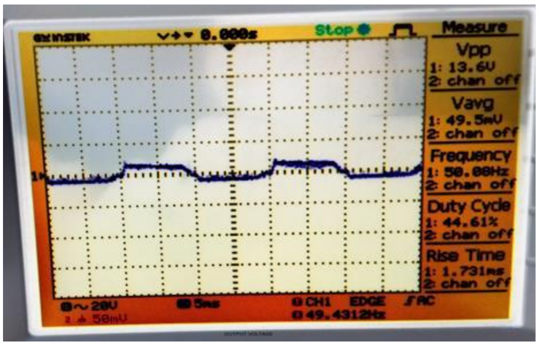

Fig. 11 Output voltage waveform

VI. CONCLUSIONS

Boost Converter is an efficient step-up DC-DC converter used in numerous electronics devices. It is modeled and simulated using Arduino. A closed loop model is developed and used successfully for simulation. This converter has advantages like reduced hardware, high performance, less weight and accuracy. The simulation results are in line with the predictions. The same was implemented as a hardware project and an output voltage of 12V was obtained with an input of 5V DC supply. Also the waveforms across capacitors and various test points were obtained, studied and compared with the theoretical waveforms. The waveforms were found to be in precise proximity of theoretical waveforms.

The minimization in DC-DC converter design for diminishing board sizes and close component density have led to a continuous shrinkage in board space over the past few years. Although it is a smaller market than AC-DC power supplies, pricing has kept revenues high. This model has slowly been changing over the past several years, however, as DC-DC converter module and semiconductor products have moved closer and closer together. The applications driving the DC-DC converter market continue to be computer and communications technologies, such as blade servers and Power-over-Ethernet.

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