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Study of Efficient HVDC Boost Converters: Design Challenges and Solutions

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Abstract

The boost converter is a fundamental circuit topology in power electronics, widely used for voltage step-up applications. This article explores the design principles, operational characteristics, and performance analysis of boost converters. It delves into key components such as the power switch, inductor, capacitor, and control circuitry, elucidating their roles in achieving efficient voltage conversion. The use of a high voltage direct current (HVDC) boost converter for bug zapper purposes is suggested in this research. The purpose of the HVDC boost converter is to effectively increase a low-voltage DC input to a high-voltage output that may be used with insect zappers. The suggested HVDC boost converter's design considerations, operating theories, and performance analysis are covered in this study. The use of HVDC boost converters in insect zapper devices is both feasible and effective, as demonstrated by experimental data, providing a potential approach for pest control in a variety of environments.

Keywords: HVDC boost converter, switched mode power supply, IC MC34063, zapper, Geiger counter

INTRODUCTION

Equipment of high voltage direct current (HVDC) are required for devices like sensors, Nixie tubes, Geiger counters, and insect zappers. There are several different HVDC power supply designs available on the market, such as boost converters, flyback conversion devices, and voltage doublers or quadruplers. Several of these exhibit low current output capabilities. However, by employing precise calculations using fundamental boost conversion principles, it is possible to achieve HVDC supplies capable of delivering clean and substantial current. Manufacturers' application notes provide many helpful formulas designed for their components, derived from these fundamental principles.

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Here, we introduce a boost converter design utilizing an MC34063 DC-DC converter. A HVDC boost converter is an electronic circuit used in power systems to increase the voltage of DC electricity [1].

Power semiconductors like MOSFETs (metal-oxide-semiconductor field-effect transistors) and IGBTs (insulated gate bipolar transistors) are commonly used in HVDC boost converters, along with safeguards and management circuits. Its main function is to step up the input voltage to a higher level for efficient long-distance power transmission, reducing losses, and improving grid stability [2].

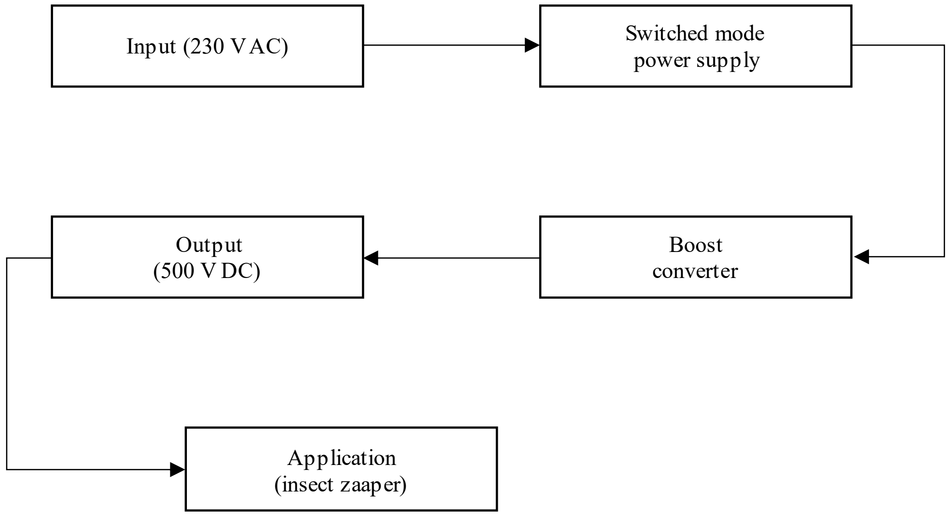

Figure 1. Block diagram of proposed project.

The suggested project's schematic representation is displayed in Figure 1. The schematic diagram's components are all explained.

a. *Input 230-V AC:* 230-V AC supply is a common voltage standard used in many countries for household and industrial electrical systems. It is typically used for powering appliances, lighting, and other electrical devices. Alternating current, or AC, refers to the fact that the current regularly changes direction [3].
b. *DC to DC converter:* A DC-to-DC converter is an electrical circuit or apparatus that changes the voltage level, current, or both of a DC voltage source, such as 12 V to 500 V. Here is some basic information about DC-to-DC converters. DC-to-DC converters typically operate by controlling energy transfer from the input to the output using switching elements such as transistors or diodes. By altering the switching signal's duty cycle, they control the output voltage.
c. *IC MC34063:* The IC MC34063 is a versatile DC-DC buck/boost/inverting switching regulator integrated circuit (IC) manufactured by various semiconductor companies. The IC MC34063 is most commonly used in electronic circuits to Step up, step down, or invert voltages. A broad spectrum of input voltages can be converted into a reliable output voltage by the IC MC34063 [4].
d. *Input voltage range:* Generally, the input voltage of the IC MC34063 typically falls within the range of 3 V to 40 V, rendering it applicable to a multitude of scenarios requiring voltage conversion.
e. *Output current:* The IC MC34063's output current capability depends on its configuration and external components, handling currents of up to several hundred milliamperes as shown in Figure 2.

The MC34063 IC is a monolithic control circuit engineered to fulfill essential functions necessary for DC-to-DC converters. These electronic components include a driver, a high-current feedback switch, a regulated duty cycle oscillator with an active current limit mechanism, a comparator, and an internally temperature-compensated standard. IC MC34063 is shown in Figure 3. Specifically engineered for step-down, step-up, and voltage-inverting applications, the MC34063 aims to minimize reliance on external components [5]. Internal diagram of MC34063 is shown in Figure 4.

WORKING

We provide 230 V AC power supply to switch mode power supply (SMPS), which converts the 230 V AC to 12 V DC. 12-V DC supplies power to the circuit input. The internal voltage regulator generates a stable output of 1.25 V for the internal comparator. Consequently, the external voltage divider, consisting of R1 and R2, needs to be configured to produce precisely 1.25 V when the desired output

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voltage is achieved. For instance, to obtain an output voltage of approximately 500 V, the resistor values for the voltage divider must be set to R2 = 2.4 Mohm and R_1 = 6 kohm, respectively [6].

According to the block diagram, the SR latch is activated and deactivated by the comparator output. The oscillator consists of current source and sink components and is powered by the timing capacitor at pin 3. The external timing capacitor is charged and discharged by these components between upper and lower predefined thresholds. The charge and discharge currents are typically 35 mA and 200 mA, respectively, yielding a ratio of roughly 6:1. As a result, the ramp-up phase lasts six times as long as the ramp-down phase. The upper threshold is equivalent to the internal reference voltage of 1.25 V, while the lower threshold is approximately 0.75 V [7].

The oscillator runs continuously, its frequency determined by the timing capacitor's value. It also monitors the voltage that exists across a small-value, higher-wattage detecting resistor attached to pin 7 in order to identify peak current. In this circuit, R6, a 1.5 ohm, 2 W resistor, serves as the sensing resistor. Applications for the MC34063 include buck, boost, and inverter setups. Its maximum collector-emitter saturation voltage at 1.5 A (peak) is 1.3 V, while the peak current of the output switch also reaches 1.5 A. If higher peak output current is required, an external transistor can be utilized. The internal transistors are driven by the oscillating pulses, which enable boost/buck conversion or higher-rated external power transistor driving for improved power output. To balance the charge in both output capacitors, a wire in the main circuit links the junction of resistors R1 and R2 to capacitors C1 and C2 [8].

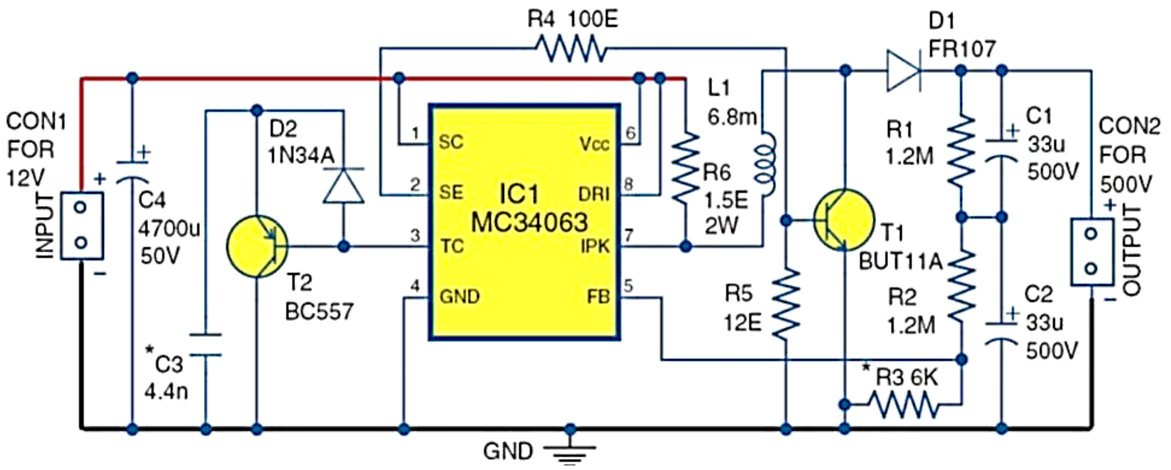

Figure 2. Circuit diagram of boost converter.

Figure 3. IC MC34063.

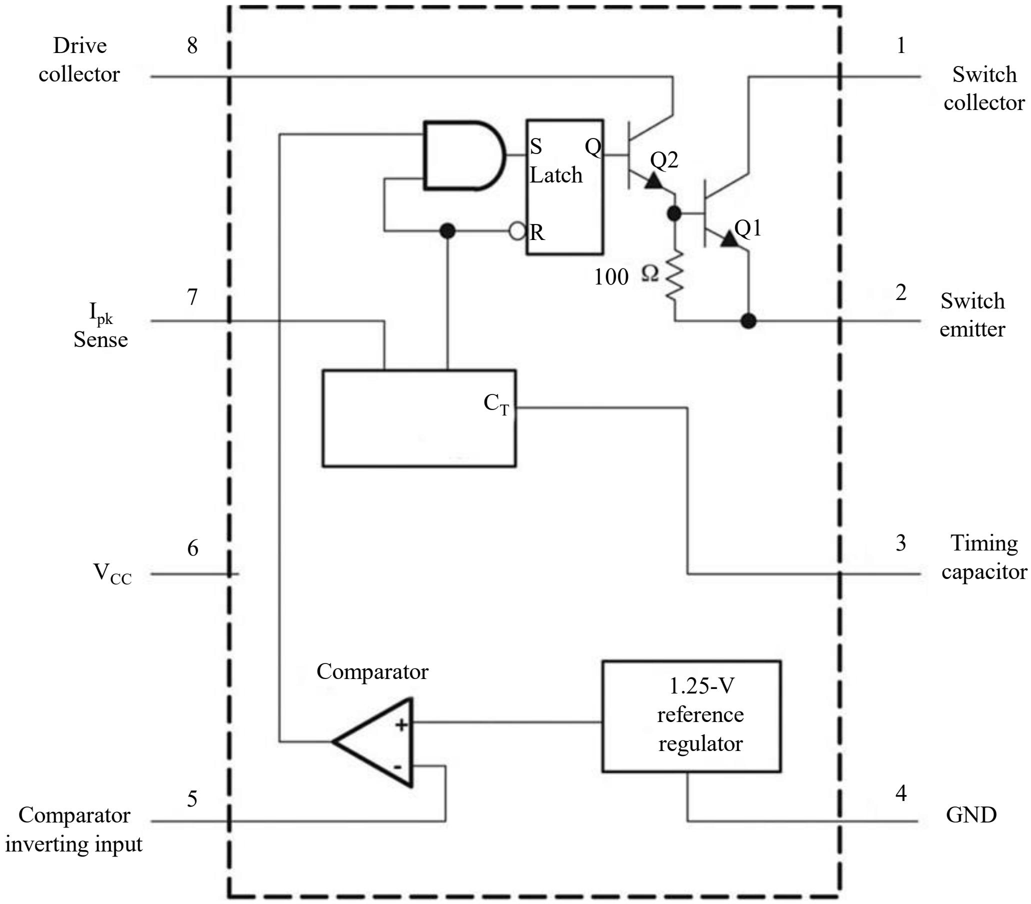

Figure 4. Internal diagram of MC34063.

The only resistor forming the voltage divider, connected to pin 5 of the MC34063, is R3. Some circuit designs demand a $t_{on}/(t_{on} + t_{off})$ ratio larger than 0.857, primarily step-up and voltage-inverting circuits. This can be achieved by including a temperature-sensitive ratio extender circuit that makes use of germanium diodes. This sensitivity can be lessened by using a timing capacitor with a negative temperature coefficient. Timing capacitor C3, germanium diode D2 (1N34A), and transistor T2 (BC557) make up the extender circuit as shown in Figure 2. Here, T2 is only powering a switch that charges and discharges capacitor C3, which is powered by pin 3 of the integrated circuit. All step-up and voltage-inverting designs that use the ratio extender circuit must incorporate current limiting. This gives the inductor time to reset in between over-current cycles when the switcher is first powered on. The voltage feedback loop regulates when the nominal voltage of the output filter capacitor is reached [9].

HVDC BOOST CALCULATOR BY USING WAMP SERVER

Systems that use HVDC have grown to be essential for long-distance electrical energy transmission. HVDC boost calculator output is shown in Figure 5. HVDC systems are a great option for contemporary power grids because of their efficiency, dependability, and decreased power losses. The HVDC boost converter, which raises the DC voltage to higher levels for effective gearbox, is a vital part of these systems. This article explores an HVDC boost converter's construction, parts, and functionality [10]. HVDC boost converter simulation diagram is shown in Figure 6.

Difficulties in the Design of HVDC Boost Converters

The challenges of designing an HVDC boost converter are numerous.

- *High voltage stress:* It is necessary for the parts to be able to sustain high voltage levels without failing.

- Optimizing efficiency is essential, particularly for systems where power losses might result in substantial energy waste.
- Electromagnetic interference (EMI) and noise can be introduced by high switching frequencies. Appropriate design and filtering techniques are necessary to limit these effects.
- *Reliability:* High reliability is required for HVDC systems, which calls for strong designs that can endure long periods of operation in challenging environments.

ADVANTAGES OF BOOST CONVERTER

Voltage Step-up

Boost converters excel at increasing input voltage levels to meet the requirements of electronic devices such as the insect zapper, which may operate at higher voltage levels than the available power source.

Compactness

Boost converters can be designed to be compact and lightweight, making them suitable for portable or handheld devices like the insect zapper, where space and weight constraints are important considerations.

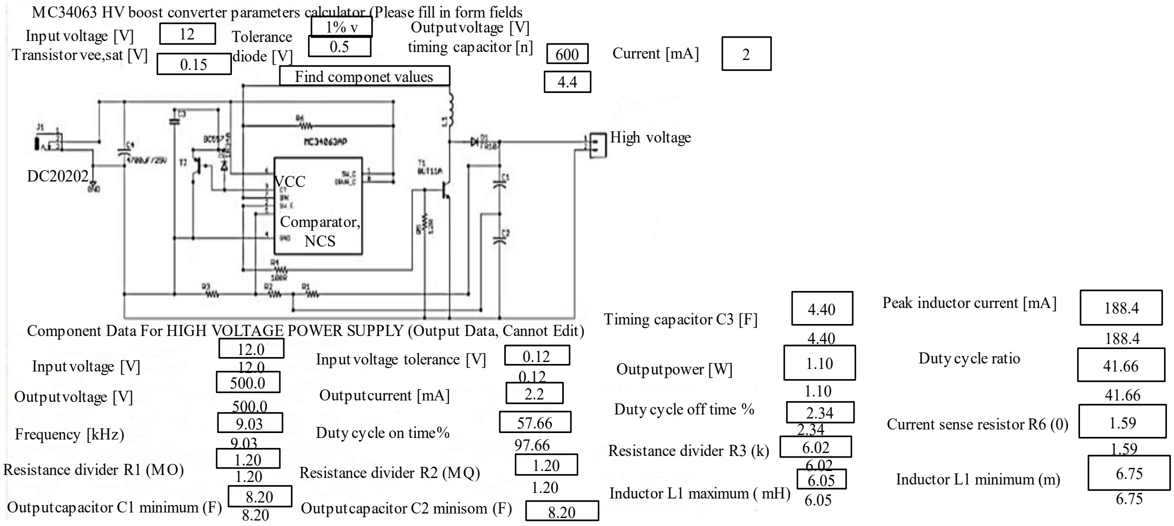

Figure 5. High voltage direct current (HVDC) boost calculator output.

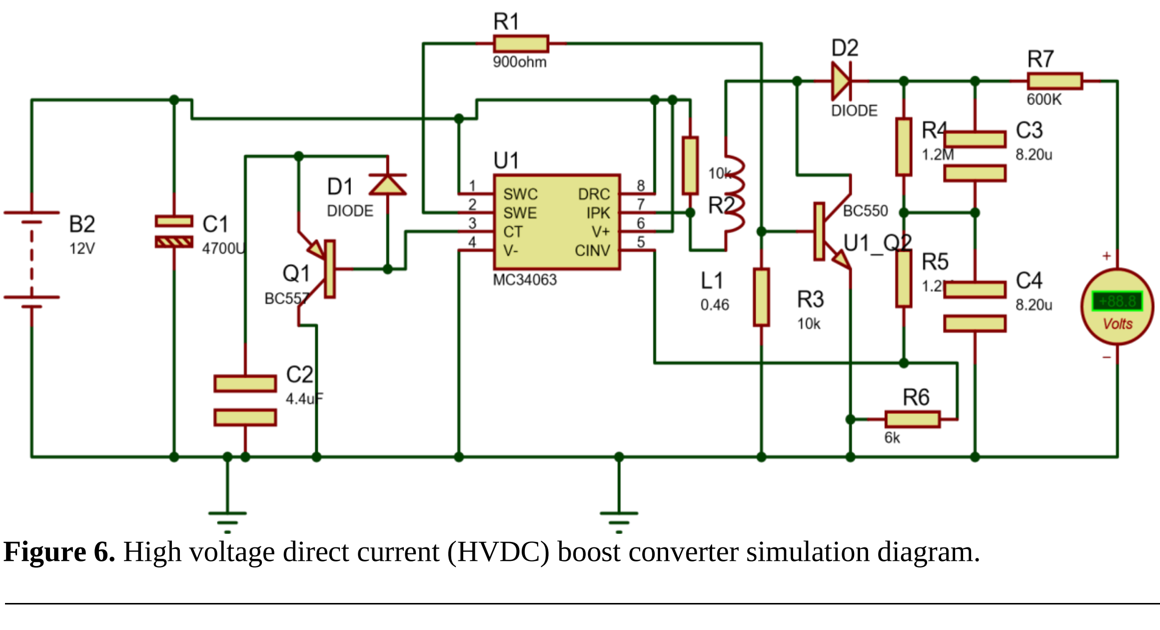

Figure 6. High voltage direct current (HVDC) boost converter simulation diagram.

Efficiency

Modern boost converter designs can achieve high efficiency levels, minimizing energy losses during voltage conversion. For battery-operated devices such as the insect zapper, it is imperative to maximize the battery life.

APPLICATION

Zapper

An insect zapper is a mechanism that captures and eliminates flying insects that are drawn to light. It is also known by other names, such as an electrical discharge insect control mechanism, electric insect killer, or (insect) electrocutor catch.

Geiger Counter

A Geiger counter, also known as a Geiger–Müller counter or G-M counter, is an electronic device used to detect and measure ionizing radiation. It operates by detecting the ionization effect caused by interactions between ionizing radiation such as alpha particles, beta particles, and gamma rays and matter. Typically, it contains a gas-filled tube with a low-pressure inert gas like helium, neon, or argon. Ionizing radiation entering the tube ionizes gas molecules, creating a brief but detectable pulse of current, allowing the device to quantify radiation levels accurately.

A Nixie Tube

A Nixie tube, also referred to as a cold cathode display, serves as an electronic device designed to showcase numerals or various characters by leveraging glow discharge. Widely utilized in mid-20th-century electronic equipment such as digital clocks, frequency counters, and calculators, Nixie tubes have since been overshadowed by more contemporary display technologies like light-emitting diodes (LEDs) and liquid crystal displays (LCDs).

CONCLUSION

DC-DC boost converter used to power applications like an insect zapper yields several significant benefits. The boost converter efficiently steps up the input voltage to levels suitable for operating the zapper, enhancing its performance and functionality. By converting a lower input voltage, such as from batteries or solar panels to the required higher voltage, the boost converter ensures that the zapper operates reliably and effectively.

Furthermore, the compact and lightweight nature of boost converters makes them ideal for portable devices like insect zappers, allowing for convenient usage in various environments. The high efficiency of modern boost converter designs minimizes energy losses during voltage conversion, maximizing the overall energy efficiency of the zapper and potentially extending battery life.

Additionally, the flexibility and control offered by boost converters enable precise regulation of output voltage and current, optimizing the zapper's performance and ensuring consistent operation. Cost-effectiveness and widespread availability of boost converter components further contribute to their suitability for powering and similar consumer electronic devices.

In essence, integrating a DC-DC boost converter into the power supply system enhances its reliability, efficiency, and performance, ultimately providing users with a more effective solution for insect control.

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