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Design and Construction of an Alternative Laptop Power Supply System

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The growing use of tablets, palmtops, and laptops and erratic power supply have necessitated the design of an alternative laptop power source. Occasionally, in-build battery of laptops weakens with time. Moreover, battery can be destroyed for being discharged below its manufacturer's specified discharge voltage limit, when left for few hours. In this regard a boost converter that enables powering a laptop from a DC source has been designed, constructed and tested. The circuit and simulation were prepared with Proteus Intelligent Schematic Input System (ISIS). For the safety of the storage battery circuit and the laptop, a deep discharge and reverse voltage protection was also incorporated in the design. LED indicators show wrong connection, low battery and ON charging state. The circuit was tested with different laptops and inkjet printers and was found be working satisfactorily.

Keywords: Converter, polarity, Potential difference, Discharge

1. Introduction

Computer has a very important impact in our life because it helps in doing nearly all of our work in daily life and giving us knowledge about the world, we live in. With the decrease in size, laptop has become very easy to carry about. Laptops are powered by an internal storage battery which can be weak with time or damage due to deep discharge. A boost converter is being designed to enable a laptop to function properly in the absent of power from the mains or gasoline generator. The converter is being powered by storage battery like that of a motorcycle, car, or directly from solar panel(s). It can operate on low input potential difference (PD) of 5 - 12 volts and stepped up to 18 - 30 volts. The circuit therefore provides the power requirements for laptop operation and charging at the same time. However, the storage battery in use needs to be protected from being deeply discharge. This can be overcome by an additional circuit in the design that monitors the voltage drop of storage battery and cut off the supply when its PD drops to 10 volts. At this stage the storage battery has to be recharge before use, therefore safe battery from being damage.

The common methods of reverse-voltage protection employ diodes to prevent damage to a circuit. In one approach, a series diode allows current to flow only if the correct polarity is applied. A bridge rectifier can be used at the input so that the circuit always receive the correct polarity. The drawback of these approaches is that they waste power in the voltage drop across the diodes [2].

2. Theory

2.1 Boost Converters

The circuit that models the basic operation of the boost converter is shown in Figure 1. The ideal boost converter uses the same components as the buck converter with different placement. The input voltage in series with the inductor acts as a current source. The energy stored in the inductor builds up when the switch is closed. When the switch is opened, current continues to flow through the inductor to the load. Since the source and the discharging inductor are both providing energy with the switch open, the effect is to boost the voltage across the load. The load consists of a resistor in parallel with a filter capacitor. The capacitor voltage is larger than the input voltage. The capacitor is large to keep a constant output voltage and acts to reduce the ripple in the output voltage [6].

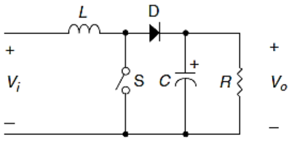

Figure 1. Basic boost converters [6].

In [7], it was reported that the actual building process does not involve complex machining or electronics. The external design is intuitive and easy to understand while the internal circuitry is easy to assemble given a circuit diagram shown in Figure 2. The circuit diagram is a very simple one, with all parts except the step-up chip.

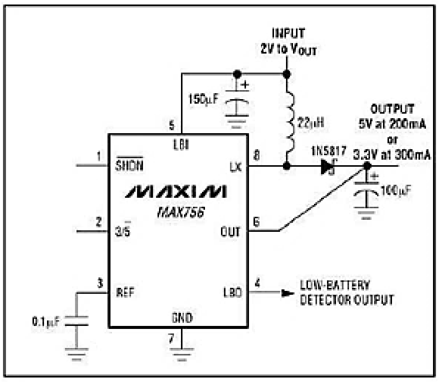

Figure 2. Circuit diagram using the setup chip [7].

2.2 Protection Devices (Reverse-Polarity-Protection)

[4] explained that most of electronic equipment designed to be operated from a battery is fitted with an internal diode in series with one battery lead, to protect the equipment from damage if the connections to the battery are accidentally reversed. But this type of reverse polarity is generally not fitted to DC-AC inverters, because of the heavy current drain involved.

3. Materials and Method

3.1 Circuit Design

The design has various functional circuits assembled as a device. Each functional circuit is designed as a separate entity. The construction intended to be stand-alone system with the various functional circuits assembled. The general block diagram of the system is as shown in Figure 3. The stages include storage battery, reverse voltage/deep discharge boost converter and voltage control.

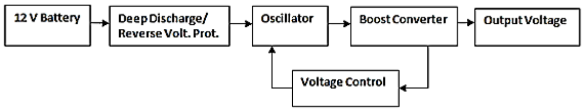

Figure 3. Block diagram of the setup

3.2 Choice of the Oscillator

Integrated circuit (IC) used in the pulse generator (oscillator) circuit is the 555 precision timer, It is chosen due to its simplicity and availability. In an astable mode of operation, the frequency and duty cycle may be independently controlled with two external resistors and a single external capacitor.

The threshold and trigger levels are normally two-thirds and one-third, respectively, of VCC. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. RESET can override all other inputs and can be used to initiate a new timing cycle. When RESET goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between discharge and ground [10].

The circuit was connected to trigger itself and free run as a multivibrator. The output swings needed from rail to rail is around 50% duty cycle square wave while the frequency of oscillations is 30 kHz. The circuit, charge and discharge times are independent of the supply voltage.

The circuit frequency is:

$$f = \frac{1.4}{(R_A+2R_B)C} \qquad (1)$$

Where c is the discharge capacitor, R_A and R_B are the upper and lower level of the discharge resistors

[3] Shows the duty cycle is controlled by the same values of R_A and R_B, by the equation

$$D = \frac{(R_A+R_B)}{(R_A+2R_B)} \qquad (2)$$

From equations 1 and 2 R_A and R_B were chosen to be 1 KΩ and 22 KΩ respectively and C to be 1 nF.

3.3 Deep Discharge/Reverse Voltage Protection Circuit Design

This circuit is designed to protect the battery from deep discharge and protect the circuit from damage due to reverse polarity by having the relay switch OFF when the applied voltage drops to a cut OFF voltage (10 V). Relay switch ON when the applied voltage is greater than the cut off voltage and hence keep the boost converter ON. Prevent the current flow when connected in reverse direction. Green LED glows when the potential difference (PD) is greater than the cut OFF voltage while Red LED glows when the voltage drops to 10 V.

The switching method employed two NPN transistors Q_1 and Q_2. For Q_2 to derive a coil relay, it was ensured that the maximum collector current (I_c) is greater than the load current. The transistor is biased so that the maximum amount of base current is applied, resulting in maximum collector current. This causes the minimum collector emitter voltage to drop as a result in the depletion layer being as small as possible and maximum current flow through the transistor. Therefore, the transistor is switched “Fully-ON” when using the transistor as a switch, a small base current controls a much larger collector load current [9].

That is;

$$I_c(\max) > \frac{\text{supply voltage(Vc)}}{\text{load resistance(RL)}} \quad (3)$$

In actual practice, it is better to calculate about 30% more current than needed to guarantee our transistor switch is always saturated [5]

In this case, it was assumed that 180 mA is needed to drive the load (relay) and the applied PD is 12 V. 2N2222 general-purpose transistor is also chosen. 1 mA was assumed to saturate Q_2 and Q_1 is to be operating at quiescent point, V_C is $V_{CC}/2$. From Kirchhoff’s law,

$$I_C = \frac{V_{cc} - V_{BE}}{R_c} \quad (4)$$

The 5.0 kΩ potentiometer enabling cut off voltage to be setup while the diode (1N4001) is to prevent current passing into the circuit if the input terminals were mistakenly interchanged. When using a transistor to turn on a relay coil, it is very important to use a 1N4001 diode reversed biased in parallel with the relay coil. This is to prevent the kickback voltage in the reverse polarity from destroying the transistor [5]. The materials used in system construction are listed in table 1.0. The circuit diagram prepared with “Proteus Intelligent Schematic Input System (ISIS)”, is presented in Figure 4.

Table 1. Material and tools use for system construction

S/N	Components	Description	Quantity
1	Capacitor	2200 µF	1
2	Capacitor	1000 µF	1
3	Capacitor	1 nF	1
4	Inductor	100 mH	1
5	Integrated circuit	LM555	1
6	Resistor	33 KΩ	1
7	Resistor	1 kΩ	3
8	Resistor	10 kΩ	2
9	Resistor	22 kΩ	1
10	Resistor	1 kΩ	1
11	Resistor	4.7 kΩ	1
12	Resistor	2.2 kΩ	1
13	Transistor	22N222	3
14	MOSFET	IRFZ44	1
15	Diode	1Z100	1
16	Potentiometer	5 kΩ	2
17	Diode	1N4001	2
18	Zener Diode	4.7 V	1
19	LED	3	3
20	Coil Relay	12 V	1

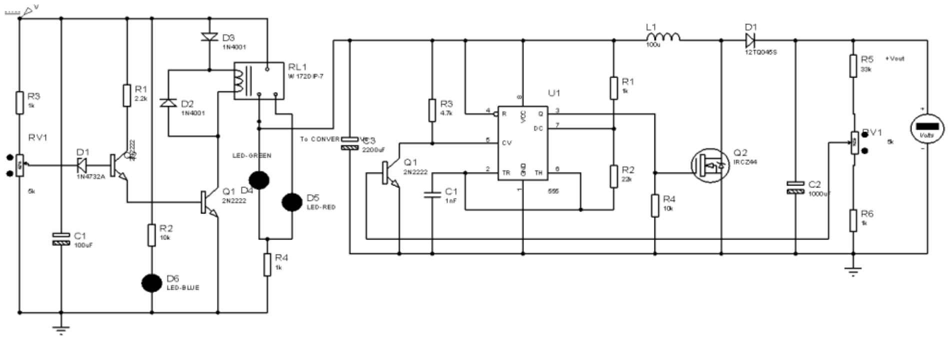

Figure 4. Complete circuit design.

3.4 System Construction

The components: transistors, diodes, capacitors, relay, and resistors were fist tested individually to ascertain their working conditions. A multimeter was used to conduct a continuity test for the diodes and transistors. The values of the resistors were also found to be within their tolerance value. The conducting surfaces were sand papered to ensure cleaned surface and prevent dry joints during soldering. The tips of the components were thinned using lead for easier soldering. One after the other, the components was soldered to their places in the circuit. Continuity test was also conducted using the multimeter to ensure that the joints are properly done. During the soldering the temperature sensitive components such as the diodes and transistor, were held by the pliers to help radiate the heat quickly. To prevent the 555 timer IC from damage due to overheating an IC socket was used. The components were also fixed on the plane Vero board as shown in plate 1.

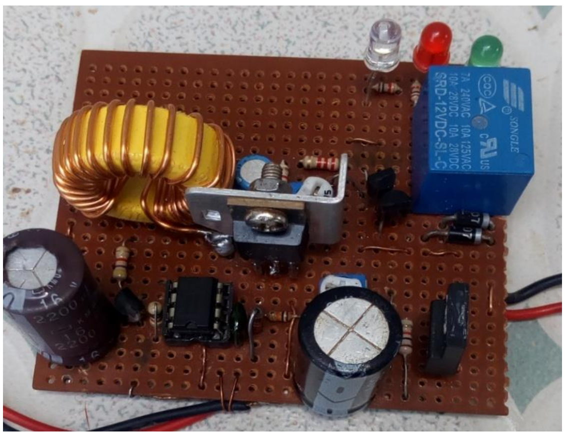

Plate 1. Photograph of the constructed circuit

4. Results and discussion

4.1 Simulations Test Results

Simulations of the circuit were captured as shown in Figures 5, 6 and 7.

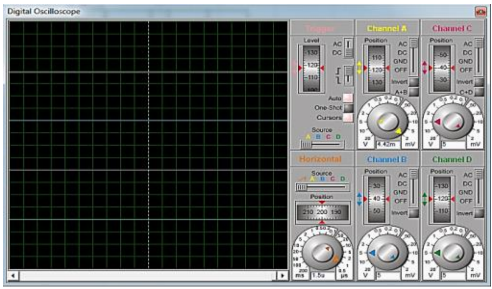

Figure 5. Simulations of deep discharge circuit protection output in Proteus

The output voltage is same with that of the input when connected in forward direction and indicating no voltage drop in the circuit.

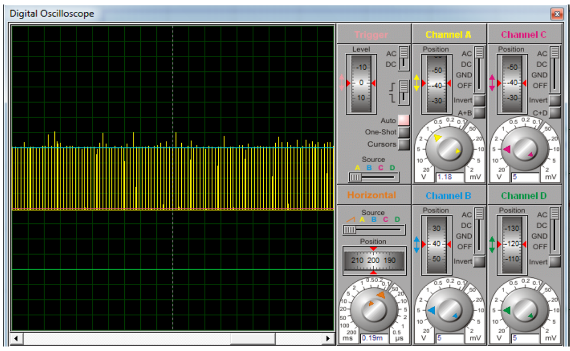

Figure 6. Simulations of the boost oscillator circuit in Proteus

An oscillation frequency of 32 kHz was observed, which is close to the calculated value.

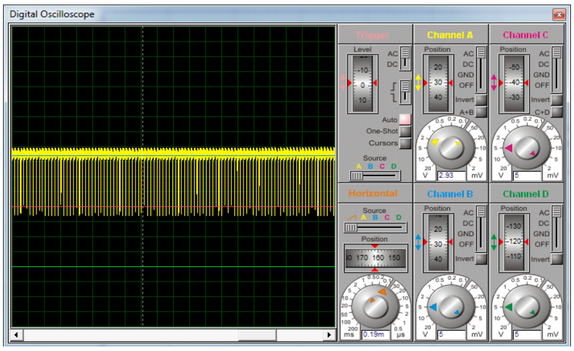

Figure 7. Simulations result of the oscillator at drain pin in Proteus

Drain switching simulation is as shown in Figure 7; frequency of oscillation is still maintained.

If the transistor Q_2 becomes saturated, the coil relay found to be in ON state. But when the potentiometer was adjusted to a particular level, Q_2 becomes unsaturated and the DC output gradually diminishing to zero level, therefore the relay circuit turns OFF. Hence the cut-off reference voltage can be adjusted to a required level needed. For the system to function, cut-off voltage was set at 10 V. That is the boost converter is ON only when the applied PD is greater than 10 V. Green LED indicator stays ON when the voltage across the battery terminals is more than 10 V. Red LED turns ON when the voltage drops to 10 V, which is an indication that charging is required. White LED is ON only when input connection is in the reverse direction. The simulation has yielded useful results when compared with the calculations. Figure 6 shows a high frequency square wave output of around 32 kHz, which is very close to the design procedure. Drain switching is also shown in Figure 7. The boost converter PD output is easily altered by adjusting the potentiometer across the output terminals. The simulation has yielded useful results when compared with the calculations.

4.2 System Tests

After the construction, the circuit was subjected to appropriate tests to ascertain the working condition of the sections of the circuit. A variable voltage supply was connected to the 'circuit protection' terminals and was found to be working as anticipated. Boost circuit was tested with digital multimeter and found the PD being step up. The system is conversely useful in an off grid environments and in absent of power from the mains. It also saves it user from purchasing a gasoline generator or an inverter for the same purpose. It was tested with different laptops by simply adjusting the output PD of the system to tally with that of laptop's or ink jet printer input. Test conducted with Hp, lenovo, Dell and some customized NCC laptops yield satisfactory result. During each test the charging system was kept ON until the laptop is fully charged. It was found working properly with power requirements not more than 65 watts.

5. Conclusion

The converter circuit can step up 12 volts DC input to 35 volts DC. To power a laptop, the potentiometer needs to be adjusted to a steady output voltage (15 - 20 V) depending on the manufacturer's requirement. While for the ink jet the output should be adjusted to 30 volts. The circuit was tested on different laptops and printers and found to be working properly. Deep discharge and reverse voltage protections were also found to be alright. It can therefore power a laptop in the absence of an AC adaptor, battery or both.

Conflict of Interest

The author declares no conflict of interest.

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