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# Design and Simulation of Microcontroller Based Laptop Power Bank

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**Abstract:** Power banks are very important for increasing the operating period of portable electronic gadgets, laptops batteries are capable of providing power for few hours and then dries out with time. Therefore, the external charger is required to extend the operation of the laptop battery operation. This paper presents the design and simulation of a microcontroller based laptop power bank. The design involves the use of a battery management system to monitor and control the state of charge /discharge of the battery bank and voltage levels. The simulations were performed using PROTEUS and MATLAB software. Different operation scenarios were presented, and it was discovered that the BMS performed optimally. The results obtained indicate an optimal performance of the design.

**Key words:** battery management system, lithium ion batteries and power bank.

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## I. INTRODUCTION

A laptop or a notebook is a portable personal computer with a clean shell form factor, suitable for mobile use. It combines the components and input of a desktop computer including display, speakers, keyboards, and pointing devices (such as a touch pad or a track pad) into a single device.

A laptop can be powered either from a rechargeable battery, or by mains of electricity via an A.C adapter. Most laptop rechargeable batteries do not supply electrical power for more than two hours. However, laptops are versatile tools that the users need all the time to perform certain tasks that span for more than two hours [1]. Hence the need of an additional battery power bank that will extend the laptop usage hour.

In the design of a laptop power bank, Li-ion batteries are used because of their high specific energy, high output power and long cycle life [2]. While, Li-ion batteries have obvious non-linearity, inconsistency and time-varying characteristics, which means there are more differences between batteries in charging capacity, self-discharge rate and the capacity decay rate during cycles. The growing differences can cause large performance degradation of the power bank [3]. Therefore, it is of great significance to implement an effective battery management system (BMS) to ensure safety as well as prolong the service life of batteries.

## II. BATTERY POWER BANK

A power bank is a device used to insert electrical energy to a rechargeable battery, without having to connect the device to an electrical outlet. These rechargeable power banks are simple, portable and are extensively used for charging portable electronic gadgets. When the energy contained in the power bank has been depleted, the power bank must be recharged by connecting it to an electrical outlet [4].

The power bank consists of three major components such as lithium-ion battery, hardware protection circuit (BMS), and outer case. Among all, the battery is the heart of the power bank and hardware protection controls the current, voltage and temperature as well. Lithium-ion rechargeable battery type 18650 functions as energy storage unit that transforms chemical energy stored into electricity [10]. The BMS consist of an array of electronic device functioning to control electrical current flow / voltage levels when charging power from electric outlet to power bank and when charging power from power bank to recharged device and the casing functions as a storage place of power bank devices [5].

Laptops require high powered batteries for enhancing the operating duration [6]. Therefore, the power banks with enhanced capacities ranges from 2000 mAh to 10000 mAh or beyond. The capacity of a cell in watthour can be determined by taking both the voltage and the quantity of electricity into consideration. This theoretical energy value is the maximum value that can be delivered by a specific electrochemical system and it is given as [7].

Watt-hour (Wh) = voltage (V) *ampere-hour (Ah)

## III. LITHIUM ION BATTERY TECHNOLOGY

The lithium-ion battery is an apt technology to incorporate with all most all portable consumer electronic devices including power banks as well. The electrochemical characteristics of the lithium-ion batteries are well established their superiority among commercial batteries in terms of operating potential, cycle life, foot print, weight, etc. However, the performance of the lithium-ion batteries is varied with chemistry to chemistry [4].

The most prominent chemistries of the Li-ion technologies are Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Iron Phosphate (LFP), Lithium nickel manganese cobalt oxide (NMC), Lithium Nickel Cobalt Aluminum oxide (NCA), Lithium Titanium Oxide (LTO) [8]. The designs of the lithium-ion battery are of four types and these are (i) button (ii) cylindrical (iii) prismatic (iv) pouch. The button type is extensively used for portable electronic devices including portable health care tool kits such as thermometers, wrist watches, etc. The cylindrical type of design is the most robust and reliable. The cylindrical 18650 type is economical and are used in laptops, power banks and other emerging applications e.g. electric-mobility as well. The prismatic type has a hard outer casing and is in medium and large sizes. Medium size is mostly used in mobile phones and the larger range is used in electric power trains etc. The design of the pouch type is the most flexible light in weight and compatible with electronic circuits and is used in large capacity power bank in view of its flexible geometry and its light weight [8].

## IV. BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack) by protecting the battery from operating outside its safe operating area[9]. A BMS can be composed of many functional blocks including cut-off a switching transistor(s), cell voltage monitor, cell voltage balance, real-time clock (RTC), temperature monitors, and state machine.

There are many types of battery management ICs available. The grouping of the functional blocks varies widely from a simple analog front end that offers balancing and monitoring and requires a microcontroller (MCU), to a stand-alone, highly integrated solution that runs autonomously[9] .

Battery management system (BMS) is a sophisticated hardware and software system which is generally a required part of any high voltage battery pack. The common functions of the BMs include:

- cell voltage measurement and control
- contactor control
- Isolation monitoring
- Temperature measurement and control
- State of charge/health calculation and
- Communications.

These functions are necessary to ensure the safety and performance of a battery power bank with extended battery life.

## V. DESIGN OF LAPTOP POWER BANK

The laptop power bank supplies a regulated 25DC volt for charging of the battery bank from an AC supply. During power failure, it is used as a backup power source that supplies a regulated 19.5DCvolt to 22.5DCvolt to charge the laptop battery and extend the duration of operation of the laptop. Figure 1.0 shows a block description of the power bank circuit. The circuit consists of the following main sections: power supply,boost converter section, battery management section (BMS), battery bank section and output section.

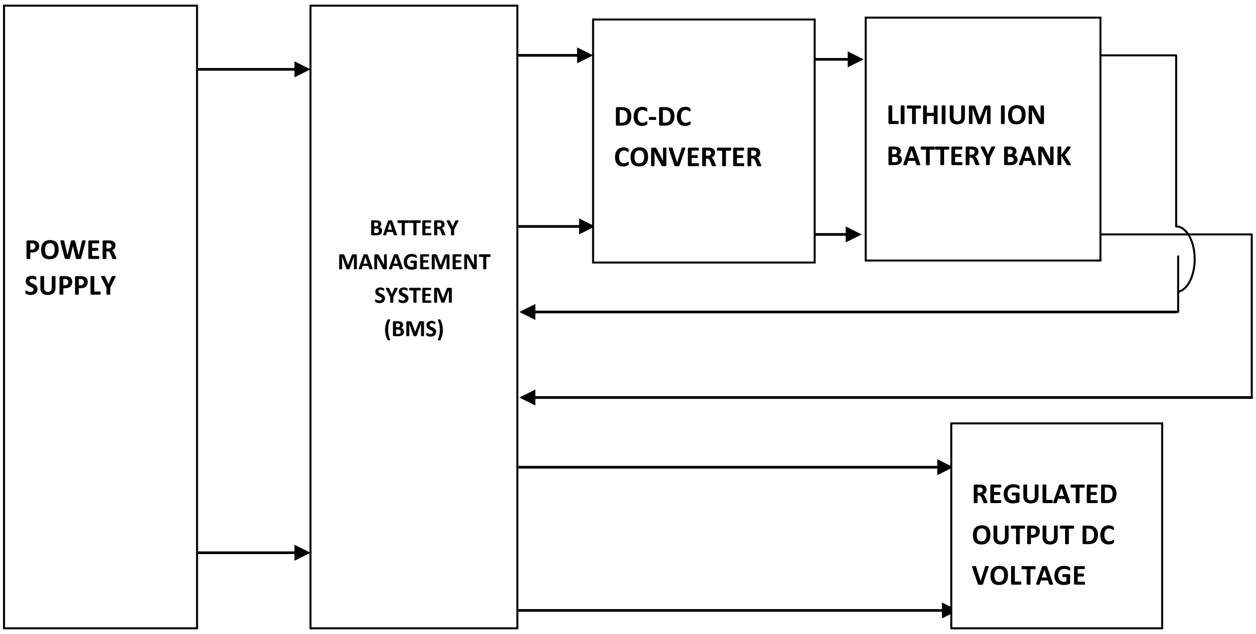


**Figure 1.0:** Block diagram of a laptop power bank

**Power supply**

The power supply section is used to provide a constant DC voltage supply to the circuit. The AC supply voltage is step down using a transformer and bridge diode to provide an unregulated DC voltage. The DC voltage passed through a filter capacitor to provide noise filtering as well as suppressing interference and provides a regulated DC voltage to the boost converter.

**Boost Converter**

A DC-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another [11]. If the voltage magnitude level at the output is greater than the input, then the converter is called a boost converter, while if the voltage magnitude level at the output is less than the input, then the converter is called a buck converter. In this design a boost converter was used.

A boost converter is designed by using the following components; an inductor, capacitor, diode, a field effect transistor (FET) and a pulse width modulation (PWM) signal that controls the rate of switching of the FET as shown in figure 2.0.

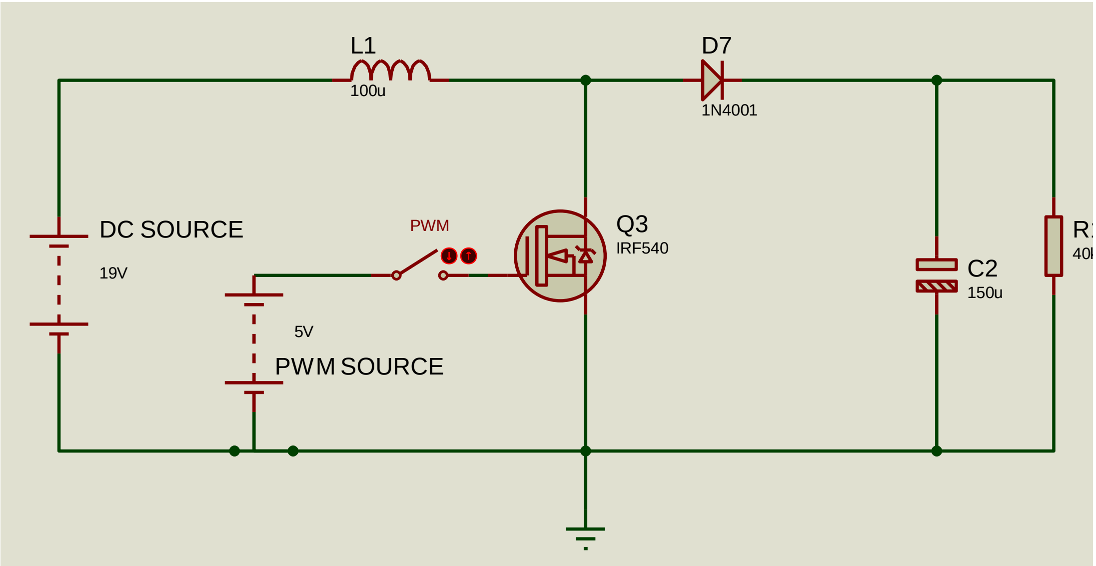


**Figure 2.0:** DC boost converter Circuit.

The inductor (L1) in figure 2.0, stores energy in its magnetic field when the switch is closed and then when it collapses (switch opens), it will resist the current change and reverse its magnetic field polarity so as to keep current moving. The voltage at the switch node can then be summed from the input to output to create a higher voltage at the output. As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode (D7).

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor (C2) in parallel with the load (R18) is charged to this combined voltage. When the switch is closed, the right hand side is shorted out from the left hand side; the capacitor is therefore able to provide the voltage and energy to the load.

**Battery Bank Section**

The battery bank consists of rechargeable lithium ion batteries (18650)($LiCoO_2$) of 3.7Volts and 2000mAh from data sheet [7]. A total of twelve (12) batteries will be used for the design. Two sets of Six (6) batteries connected in series to increase the total voltage of the battery bank to 22.2 Volt (3.7 *6) and also connected in parallel to increase the current capacity of the battery bank. The total power capacity to in watt hour is 44400mWh (22.2*2000) or 44.4Wh.

**Controller Section (BMS)**

The battery management unit comprises of arduino Uno microcontrollerboard that carries out the control and monitoring of the battery bank. The arduino microcontroller via its output and inputs pins monitors the voltage level for boost converter control, over charging, low voltage and normal operations. When the battery bank voltage goes above 22.5DCV the arduino PWM pin reduces the PWM rate so as to maintain a trickle charging voltage thereby maintaining the appropriate voltage level. If the battery bank voltage goes below 18V the controller increases the PWM of the boost converter when the power supply is available.

During no power supply the controller shuts down the system to prevent over draining the battery and hence battery failure. Other functions carried out by the BMS include; Monitoring and control of the charging rate of the power bank and increases the voltage of the boost converter. Figure 3.0 represents the complete circuit design of a laptop power bank circuit.

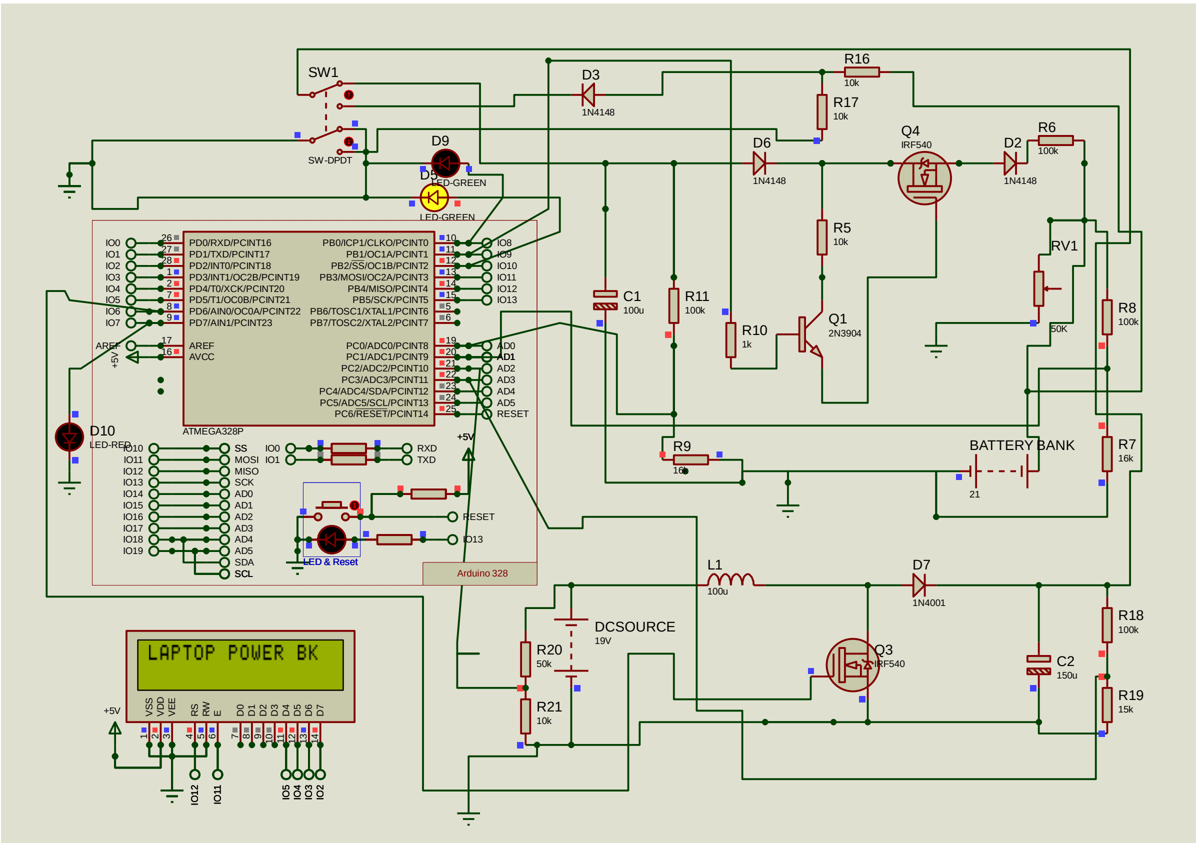


**Figure 3.0:** Circuit design of a laptop power bank

## VI. RESULTS AND DISCUSSION

Figure 4.0, represents the simulation result of a BMS controlled DC-boost converter. The results show an increase in input DC-voltage from 19.5volts to 25volts.

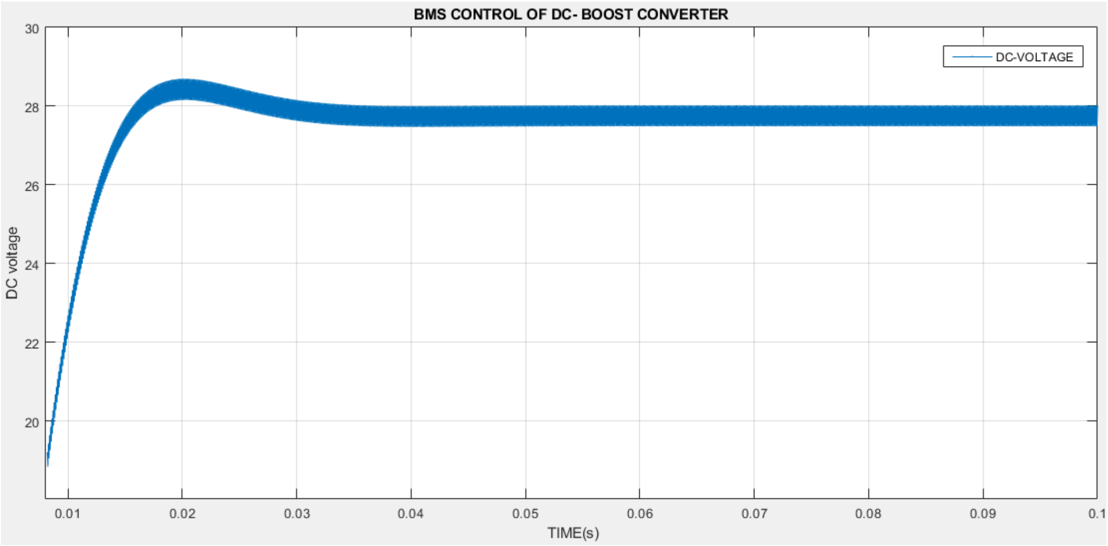


**Figure 4.0:** BMS controlled DC-boost converter

The increase in voltage is as a result of the PWM switching of the MOSFET transistor done by the arduino microcontroller. The graph shows a fast rise in voltage to the set threshold point at 0.02seconds. When the voltage is at its threshold of 25volt; the controller output controlled PWM to maintain a constant voltage for charging of the power bank. Without the BMS control system, the voltage from the boost converter will increase to a value that is very high for charging of the batteries and hence leads to battery malfunctioning and explosion.

In figure 5.0, the normal charging operation of the battery bank and the BMS control is shown.The graph indicates the charging voltage, the battery voltage and the PWM switching frequency. The charging of a low power bank battery voltage of 18V is shown in the graph; when the controller detects a low battery voltage, it increases the PWM connected to the switching transistor for fast charging, resulting to an increase in voltage from 0s to 4s.At 4s to 10s, the BMS controller outputs a trickle charging voltage when it detects that the battery voltage is fully charged in other to maintain normal operation of the battery bank an improve battery performance.

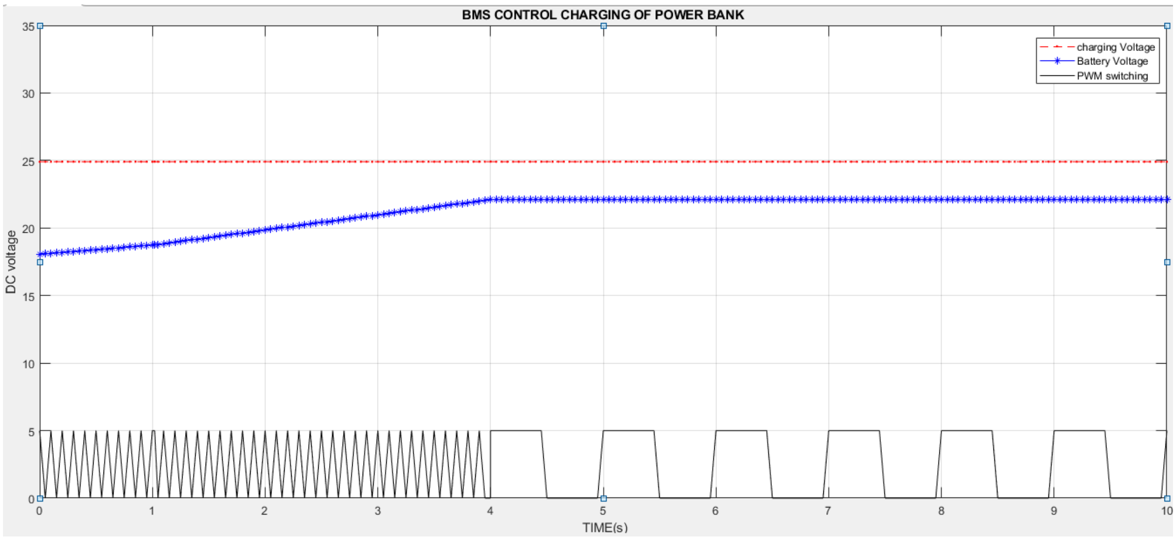


**Figure 5.0:** BMS control charging of power bank.

## VII. CONCLUSION

In this study, the design of a power bank for charging of laptop batteries was presented. The design involves the programming of an arduino Uno microcontroller as a battery management system for the control, monitoring and operation of a power bank with the aid of a C-language programming code. The simulations were performed using proteus and Matlab software. Different operation scenarios were presented, and it was discovered that the BMS performed optimally. This research work is ongoing and involves the development and implementation of the hardware design in future.

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