

Studies on portable power banks for recharging electronic gadgets

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Abstract - Rechargeable power banks are increasing significantly for extending the operating duration of portable electronic gadgets and mobile phones which are part of modern life. The in-built battery in the mobile phone can provide power for few hours and then dries out with time. Therefore, the external charger is required to extend the operation of electronic devices e.g. mobile phones. This paper presents the study of the importance of critical components of power bank to understand the insight of it. The performance of the power banks for charging characteristic of the mobile phones at lab scale are discussed.

Key Words: Smart phone, Power bank, Lithium-ion battery, Protection circuit, USB, Step-down and Step-up.

1. INTRODUCTION

The communication system plays a vital role in the present modern society. The size of the electronic devices has shrink from macro to micro and then transforming to nanometer scale with advancement of semiconductor technology [1]. For example, the current mobile phones are designed compactly and operates with touch screen based technology. The unique features of these mobile phones are: data storage, music with audio and video, navigation system, conference calls, e-commerce, e-learning, etc., which requires large capacity battery system [2, 3].

The in-built lithium-ion battery is designed for compatibility and has limited energy storage to operate smart phones. Thus, these batteries are providing energy for hours and maximum a day subjected to usage pattern of the mobile phone. It means that the inbuilt battery is drained out and then need to plug-in for charging the battery. The charging can be done either through plug-in or by external portable energy sources such as power banks [4].

2. POWER BANK

These rechargeable power banks are simple, portable and are extensively used for charging all most all portable electronic gadgets. The mobile phones require high powered

batteries for enhancing the operating duration [2]. Therefore, the power banks with enhanced capacities ranges from 2000 mAh to 20000 mAh or beyond are in a great demand for charging mobile phones. Some of the portable electronic gadgets charged by the power bank are shown in Figure 1.



Fig. 1. Power bank and its applications

The power bank consists of three components such as lithium-ion battery, hardware protection circuit, 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.

The health of the power bank is estimated by the LED profiles for better operation of the device. The block diagram of the power bank is shown in Fig. 2.

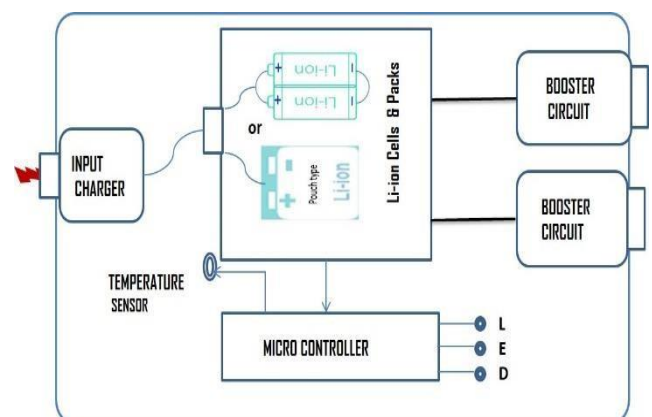


Fig. 2 Block diagram of power bank device

The high energy and compatible Li-ion battery integrated with the power bank apart from the protective circuit are discussed in section 2.1.

2.1 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 are varied with chemistry to chemistry [5].

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) [6]. The design of the lithium-ion battery are of four types and these are (i) button (iii) cylindrical (iii) prismatic (iv) pouch. The button type are 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 are in medium and large sizes. Medium size are mostly used in mobile phones and the larger range are used in electric powertrains etc. The design of the pouch type is the most flexible, light in weight and compatible with electronic circuits and are used in large capacity power bank in view of its flexible geometry and light in weight [5, 6].

2.2.2 Electrical (Protective) Circuit

A set of lithium-ion cells are used in the moderate power bank and these cells are configured by connecting in parallel for higher rating. The battery pack is integrated with electric circuit to improve the safety of the power bank. The electrical protective circuit is to protect the device by controlling the operating voltages, currents and also temperature of the battery [7].

The protective circuit consists of microcontroller, buck/boost converters and USB connectors. The microcontroller is programmed to control the voltage, current and temperature of the battery. The power bank is charged by plug-in and state of charging (SoC) levels are indicated through the light emitting diode (LED) and converters are also used in the power bank such as: (i) buck

By understanding the design and operating mechanism, we have made an attempt to demonstrate the battery and protective circuit to know the insight of the power banks.

and (ii) boost converters. The power bank is charged either by wall charger or laptop and the output voltage is 5V. The buck converter is used to step down the voltage from 5V to 4.2V to charge the Li-ion battery in the power bank. The boost converter is to convert battery output voltage 4.2V to 5V in order to charge the load [8].

The step-down and step-up mechanism through micro USB and USB is represented in Fig.3.

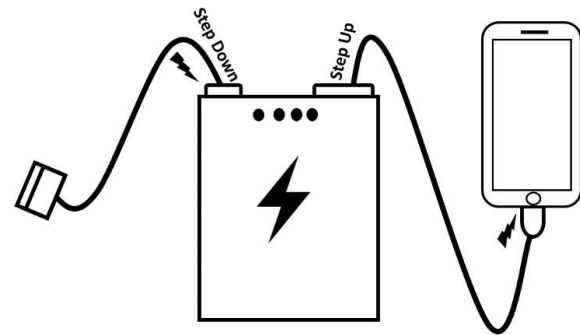


Fig.3 Step-down and Step-up mechanism

The power bank input and output are designed to compatible with universal series bus (USB) and this protects the system from any electrical surges while plug-in. The USB connectors are user friendly to connect with any portable electronic devices such as smart phones, cameras, tabs, etc. [9]. The block diagram of the operation of the power bank with major and minor components are shown in the Fig. 4.

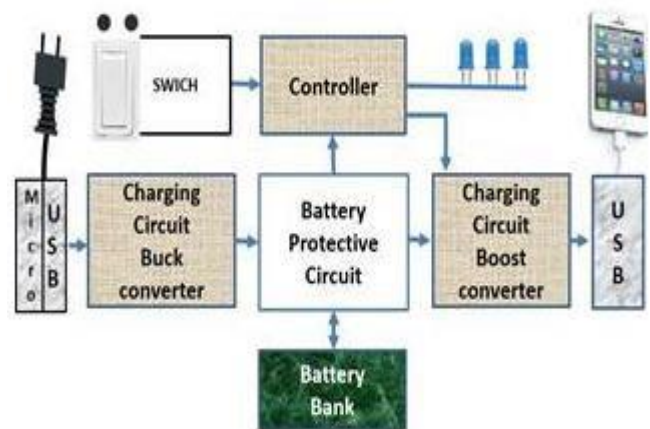


Fig. 4. The function of major and minor electrical components in the power bank

Also the duration that takes for charging the power bank and the practical energy available in the power bank for charging mobile phones of different manufacturers are presented and discussed.

3. EXPERIMENTAL

3.1 Lithium-ion battery

The performance of lithium-ion cells depends upon on the design, chemistry and control system as well. In addition to that charging protocol is important for enhancing the life [10]. The electrical tests on commercial Lithium ion pouch cell with rated capacity of 4500mAh were carried out in the constant current and constant voltage (CC-CV) mode at 0.2C rate in the potential range of 2.5V to 4.1V. The discharge capacity of the cell was evaluated at different cycles at ambient temperature. The typical discharge profile of the lithium-ion cell for limited cycles is presented in Fig.5.

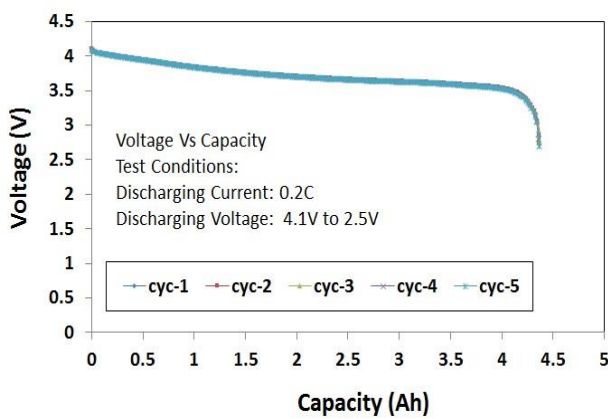


Fig. 5 Discharge profile of the Lithium ion cell.

From the Fig. 5, it is observed that the capacities of Li-ion cell at different cycles are found to be similar at the first cycle and the fifth cycle. It shows that the electrode and electrolytes are stable and expected to improve the life of the battery.

3.2 Energy Density of Power Bank

The amount of energy charge in a battery is the capacity and is expressed in ampere-hour (Ah). The power is the electrical energy of the battery and it is the product of the capacity and nominal voltage and is expressed in watt-hour.

The performance of the power bank could be considered either by energy or power respectively for understanding the efficiency of ampere-hour and watt capacity of 5000Ah. The deliverable capacity of the power bank is reasonably to charge the mobile phone with battery rating of 1500 mAh by two times which means that the operation of the mobile phone duration could be expected to enhance by two times approximately.

hour. Consider the configuration of the power bank with the capacity of 5000mAh and nominal voltage of 3.7V. The energy density of the power bank is 18.5Wh which was obtained by considering the product of capacity and voltage. However, the practical energy density delivered by the power bank is lower than the theoretical due to voltage step-up and step- down conversion.

The power bank nominal voltage 3.7V is to be stepped up to 5V in order to charge the load (e.g. mobile phone). The power bank voltage should be step down from 5V to 3.7V to charge the lithium-ion battery incorporated in the power bank device.

The charging process is carried out at ambient temperature through USB. During the process, there is a change in the voltages which consume energy. The consumption of energy is obtained and estimated the actual usable capacity of the power bank. The capacity is calculated by considering the rated capacity and nominal potentials of power bank and USB conversion as given below.

$$\text{Capacity} = (\text{Capacity} \times \text{Voltage}) / \text{USB} \quad (1)$$

$$= (5000 \times 3.7) / 5.0 = 3700 \text{ mAh} \quad (1a)$$

The available power bank energy for charging the mobile phone is 3700mAh against to the rated capacity of 5000mAh. In other words, the usable capacity of the power bank is around 74%, and the balance capacity of 26% is compensated for conversion factor for step-up and step-down through USB port. In addition to the USB conversion, there is an energy consumption with the harness of the electrical wiring in power bank device. The variation of the capacities for the rated and practical values also depends on the quality of the components and type of connectors that are used in the device. The energy consumption in the electrical circuit is expected to be 5% to 12% subjected to efficiency of the components in the circuit. Here the average consumption of energy is considered as 10% and the estimated net efficiency of the power bank device is 90%. By considering the compensation of energy through USB and electrical harness in the power bank circuit, the deliverable capacity is around 3300mAh (i.e., 3700 x 90%).

The practical deliverable capacity of the power bank for charging the mobile phone is 3330mAh against the rate

4. RESULTS AND DISCUSSION

Wide range of power banks with different capacities are available in the market. This report presents the performance of different branded power banks, (namely A, B & C) with battery rating of 5000 mAh and charge duration and deliverable capacity of power bank are validated by measuring the charging the power bank and discharging it through mobile phones to understand the practical charge duration and the delivering capacity. Here the charging and

discharging is done through the USB cables provided by the respective manufacturers. The charging characteristics of the power bank are monitored at different cycles at ambient temperature. While charging, the state of charge of the power bank can be estimated with LED indicators which are connected in the hardware circuit. The charging profiles of different power banks are shown in the Fig.6.

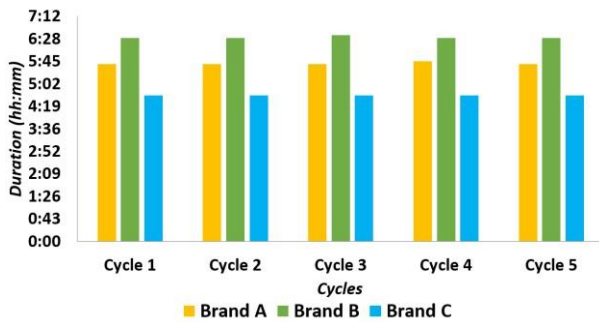


Fig. 6. Charging profile of commercial power banks

From the Fig.6, it is observed that the charging duration is similar at the first cycle and also at 5th cycle which indicate that there is no change in the performance mark within the brands but the charge duration is marginally varied from manufacturer to manufacturer. The variation in the charging time of the particular power bank may be due to the voltage potentials, current restriction in the protection circuit that is incorporated with the battery [10].

The same power banks (A, B & C) are considered for studying the discharge characteristics in order to understand the practical discharge capacity of the power bank.

The typical discharging profile of power banks are shown in the Fig.7

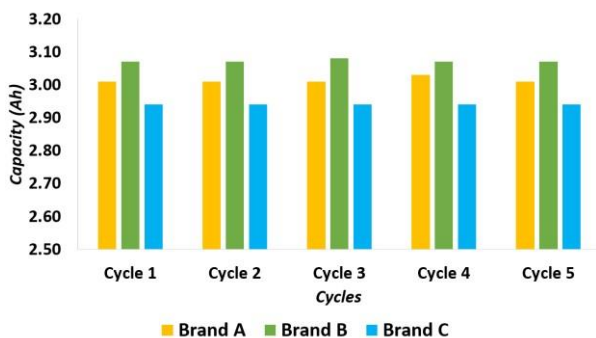


Fig. 7. Discharging profile of commercial power banks

From the Fig. 7, it is observed that the capacity delivered at the first cycle and also at 5th cycles are same within the manufacturers. However, it was noteworthy to mention that the delivered capacity is slightly varied from manufacturer

to manufacturer and this can be attributed to the efficiency of the Li-ion cell and the restriction of the potentials in the protection circuit of the respective manufacturer [10].

5. CONCLUSIONS

The power bank is an essential power source for charging the mobile phones which is part of modern life. The importance of the power bank and uniqueness of the lithium-ion battery technologies are explained for better understanding of the technology. The performance of the lithium ion cell like capacities are found to be same within the studied cycles and the variation in the rated and actual capacities of the power bank are clarified. The lab results shows that the charging duration of the power banks from manufacturer to manufacturer are found to be different may be due to the protective circuit and also the practical deliverable capacity is comparatively lesser than the rated capacity of 5000mAh power bank.

Large capacity power banks with multi features such as torch, dual output ports, solar, wireless charging etc., are available commercially and user has to select the branded products for better life and safety of the device.

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