Application Report

SLVA770–April 2016

Port Detection for Power Banks

Yingyang Ou

Asia Power Design Service

ABSTRACT

A power bank is designed for *Portal Devices* (PD). Power banks have different ports for input and output. This paper collects several methods for detecting the attachment and detachment of the input and output ports. Input detection always employs voltage comparators to monitor the input voltage. For output detection, there are three valid options: (1) button control, (2) polling control, and (3) automatic toggling control. Three methods have their own advantages and disadvantages. Button control is simple and power saving. Polling control and automatic toggling control are convenient. Every method, with detailed examples are explained in this paper.

Contents

1 Introduction 1
2 Power Bank Structure 2
3 Input Detection 2
4 Output Detection 3
4.1 Button Control 3
4.2 Polling Control 4
4.3 Automatic Toggling Control 4
5 Summary 6
6 References 6

List of Figures

1 Typical Power Bank Structure 2
2 Input Detection of the bq25895 2
3 On/Off Button Circuit 3
4 Ground Return Path of a Power Bank 4
5 Automatic Toggling Control Circuit 5

1 Introduction

A power bank is essentially a portable charger making Smartphones on-the-go easier and more convenient to use. This technology is a must-have for traveling salespeople, students, and virtually anyone that must ensure they never run out of battery throughout a busy day. These mobile power banks charge phones or other devices as many as three times with one full charge.

2 Power Bank Structure

Though there are a variety of products on the market, a power bank always contains at least two types of ports, as shown in Figure 1:

- **Input port:** The power bank can be charged by plugging the USB cable to the input port while another end of the USB cable can be connected to a USB source such as an electrical adapter, a powered-computer's USB port, or even another power bank that is able to provide the energy to the power bank. The built-in battery is charged through the input port via a built-in charger.
- **Output port:** By plugging the USB Type-A plug of a standard USB cable into the power bank output port, the built-in battery can discharge the stored energy to any devices with a USB port.

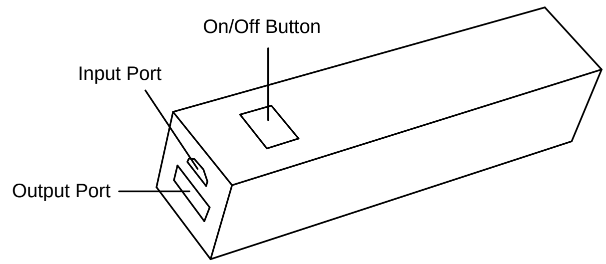

Figure 1. Typical Power Bank Structure

To extend battery life and minimize power when a power bank is powered off during system idle, shipping, or storage, the power bank can turn off the discharge path of the battery so that the output voltage is zero to minimize the battery leakage current. Once the power bank is signaled to be charged or discharged, it wakes up the system from idle mode and re-enables the discharge path; several methods are implemented to detect the input and output attachment events.

3 Input Detection

A simple way to detect the input attachment is to monitor the input voltage with some voltage comparators. Most current products employ this method. Usually, these voltage comparators are built-in. Figure 2 gives an example of the bq25895. There are 3 voltage comparators monitoring the input voltage. When an input source is plugged in, those input comparators check if the VBUS voltage is in a valid range so that a signal can be generated for notifying the control units. After the control unit receives this signal, they continue to work per the input status.

Similarly, if the input source is removed from the input port, the VBUS voltage decreases from the normal level to 0. This triggers one or more input voltage comparators to reverse the signal before and then the control units know the input detachment.

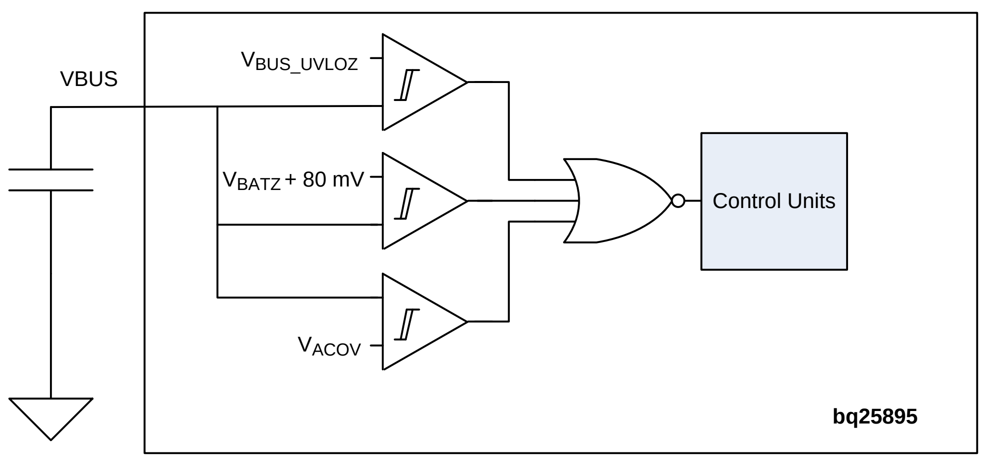

Figure 2. Input Detection of the bq25895

4 Output Detection

There are serval ways to detect the output attach and detach events. Considering the role of a power bank, its main purpose is to supply the power to the devices whenever they are attached.

4.1 Button Control

The On/Off button shown in Figure 1 gives a simplest method to achieve this goal. The output of the power bank is enabled and disabled by pressing that button. The internal button pressing circuit is shown in Figure 3. The signal transmitted to the control units is high when the S1 is not pressed. When S1 is pressed, this signal gets pulled down so that the control units can capture this transition. After that, the control unit starts to detect the input and output port. If a device is detected at the input or output port, the power bank is forced to change its own role according to the input or output detection result. If nothing is attached, the control units enable the output and start the discharging function. On the contrary, if the discharging path is already working when that button is pressed, the control units stop discharging and shutdown the output of the power bank. In this case, the system can shut down most of the control units and the quiescent current is reduced to be very low.

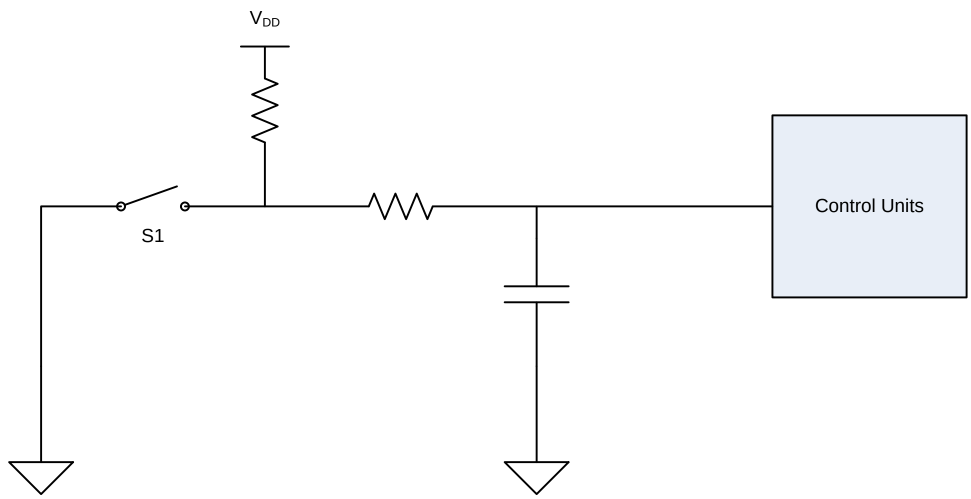

Figure 3. On/Off Button Circuit

4.2 Polling Control

Polling the output current periodically is a convenient method for determining attach and detach events compared with button control. Figure 4 shows a ground return path for output port in power bank employing the polling control. Generally, the output current of a power bank flows from the VBUS of a USB receptacle to a PD through a USB cable and then flows back to GND of the USB receptacle from the PD. In Figure 4, there is a blocking MOSFET Q_{gnd} and a shunt resistor R_{gnd} being inserted between the system ground (PGND) and the ground of the USB receptacle (GND). Once Q_{wk} is turned on, the output current flows through Q_{wk} and R_{gnd}. During the attach check period, the control units are configured to enable Q_{wk} and sample the current flowing from R_{gnd} periodically. A pre-determined low current threshold is employed to compare with the reported output current. If the output current is 0 or close to 0, it can be recognized as an unattached status so that the Q_{wk} can be turned off until the next check period to eliminate the undesirable current at output port. If the output current is higher than that low current threshold, which means the load is sinking the current from the output port and the output discharge continues to be enabled.

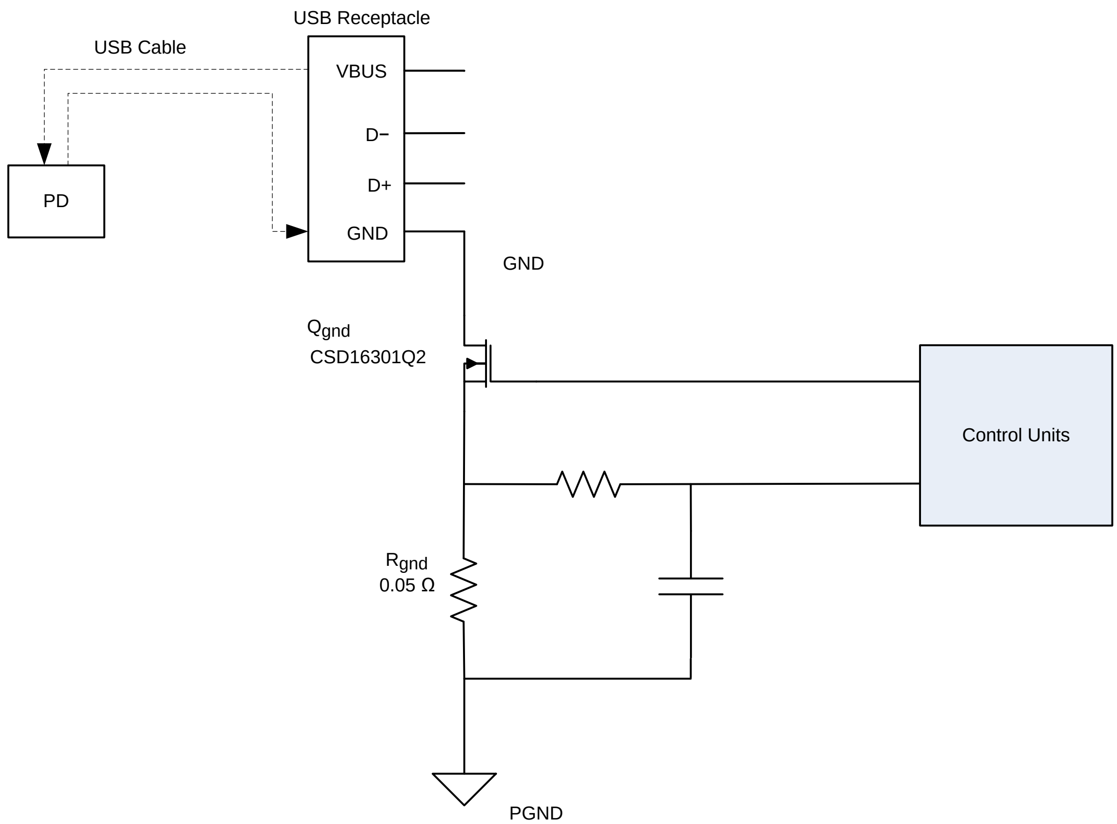

Figure 4. Ground Return Path of a Power Bank

4.3 Automatic Toggling Control

Though the polling control is convenient for the users, it has a drawback that requires the output power path to be enabled periodically when the output port is not attached. That requires an additional quiescent current even when nothing is attached and reduces the storage time of power banks. Automatic toggling control can resolve this problem perfectly. Figure 5 gives an example of this method employed in the *TI Designs* – PMP4451 and PMP11536. As shown in Figure 5, another small signal MOSFET Q_{wk} is added at the USB receptacle ground (GND). Its drain is tied to a DC voltage (V_{DD}) via a pullup resistor (R_{up}) so that the status of the drain of Q_{wk} (named as WAKE_N in Figure 5) is clamped as '1' when Q_{wk} is not turned on. This signal (WAKE_N) is also fed to the general purpose input port of control units. A resistor with large resistance, R_{wk}, in Figure 5 is bridged between the USB receptacle ground (GND) and system ground (PGND). Meanwhile, this resistor is also in parallel with shunt resistor R_{gnd} and blocking MOSFET Q_{wk}.

4.3.1 Output Attach

In unattached mode, control units shut down Q_{wk} and do not sample R_{gnd}. The gate of Q_{wk} is tied to PGND and no voltage is applied at gate and the source of Q_{wk}. Therefore, Q_{wk} stays disabled and the voltage level of the drain of Q_{wk} remains '1', resulting in the control units being in sleep state. There is not any additional quiescent current flowing though the output power path since all of the power MOSFETs are turned off all the time.

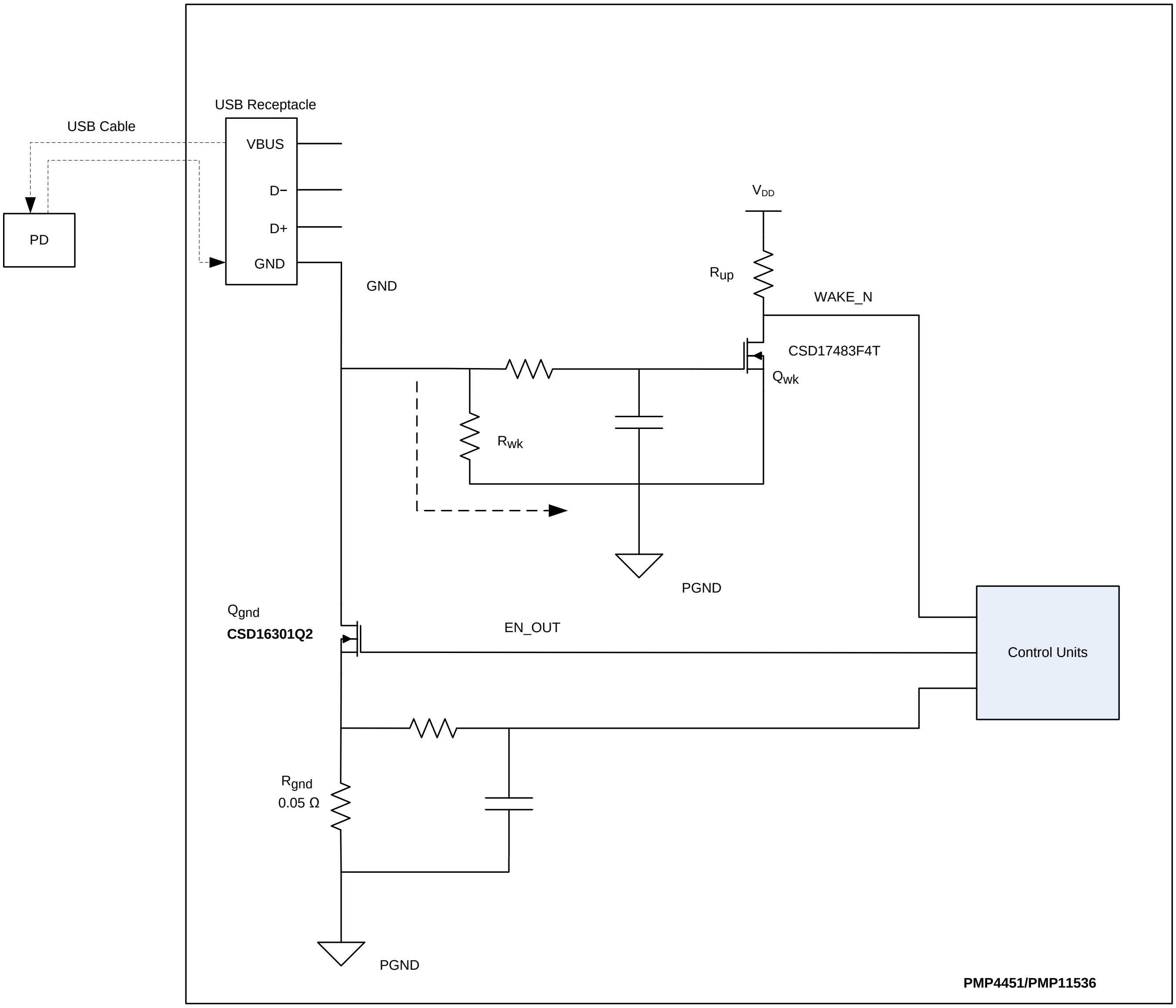

Figure 5. Automatic Toggling Control Circuit

Once a PD is attached, VBUS and GND of the USB receptacle are connected instead of floating. Though the power path is still blocked by Q_{wk}, a leakage current is flowing from VBUS to system ground (PGND), as shown in Figure 5. This leakage current generates a voltage drop V_R_{wk} across R_{wk}. As the large resistance of R_{wk}, V_R_{wk} is easily increased and clamped at VBUS. Therefore, Q_{wk} is turned on when V_R_{wk} exceeds Q_{wk}'s gate threshold voltage. The transition of WAKE_N, as well as the voltage level of Q_{wk}'s drain, triggers an interruption in control units to wake up all of the control circuit. Then the control units are ready for performing the discharging control.

4.3.2 Output Detach

After the system is awaken for discharging, the control units turn on Q_{wk} with EN_OUT and WAKE_N is pulled up again. In this case, WAKE_N is unable to indicate the availability of a PD. In order to detect the output attachment correctly, the output current sample mechanism used in polling control is employed. During discharging mode, control units monitor the output current flowing through R_{gnd}. When the reported output current is 0 or close to 0 for a while, the control units shut down Q_{wk} and check the status of WAKE_N. If the PD is removed, WAKE_N remains ‘1’, otherwise WAKE_N transit from ‘1’ to ‘0’ and then EN_OUT is re-enabled. This polling mechanism can run periodically until the output port is actually detached.

5 Summary

This report collects the methods for detecting the input and output ports of a power bank. A power bank is designed for portal devices. Long-running time of a built-in battery is the critical requirement. The input and output, attach and detach methods previously mentioned provide a way for power banks to reduce the standby power loss in unattached mode while enhancing the convenience of a product. Input detection is easy to implement. For different methods of output detection, button control is simple and power saving. Polling control is convenient but may consume an additional quiescent current and limits the max running time of built-in batteries. Automatic toggling control can resolve the problem of polling control by adding a simple patch making it a better choice for the portable application.

6 References

- *bq25895 I2C Controlled Single Cell 5-A Fast Charger with MaxCharge™ for High Input Voltage and Adjustable Voltage 3.1 A Boost Operation*, data sheet (SLUSC88)
- *PMP4451* USB-C DFP + USB-A Power Bank with Input & Output Fast Charger Reference Design, http://www.ti.com/tool/pmp4451
- *PMP11536* USB-C DFP + 5V2A Power Bank With Input Fast Charger Reference Design, http://www.ti.com/tool/pmp11536

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265