AN10910

Protecting charger interfaces and typical battery charging topologies with external bypass transistors

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Document information

Info	Content
Keywords	BISS, MOSFET-Schottky, low VCEsat, battery charger, Li-Ion battery (Li-polymer battery), overvoltage protection, reverse polarity protection, ESD protection
Abstract	This application note illustrates how to protect a mobile device charger port against overvoltage and reverse polarity and gives an overview of typical battery charging topologies and how to use Nexperia protection devices, bipolar and MOS transistors.

Revision history

Rev	Date	Description
2	20110623	• Table "Document information" updated • Section 7 "Appendix" updated
1	20100428	Initial version

1. Introduction

This application note describes a complete solution for battery charging in mobile devices. This includes how to charge a Li-Ion battery with typical battery charger topologies, particularly with external bypass transistors and ways to effectively protect against overvoltage and overcurrent from the charger connector.

2. Battery charging via USB interface

2.1 Chinese battery charging standard (YDT1591-2006)

This standard describes an AC-to-DC power adapter with a standard USB type A output connector, allowing different vendors to share common AC-to-DC adapters or allow the handset to be charged via a standard PC USB port.

This will enable customers to carry only one cable to charge their handsets when USB ports are available.

The idea behind this is to reduce the overall volume of AC-to-DC adapters, reduce the Bill Of Material (BOM) cost and improve the “think green” factor.

The electrical specifications of the common AC-to-DC adapters are:

- 5 V output voltage (5% tolerance)
- 300 mA to 1800 mA charging current (PC USB port can offer 500 mA/900 mA)
- included overvoltage protection for voltages higher than 6 V

The battery charger circuit is located in the handset. To make sure that the handset can draw more than 500 mA (five unit loads) from the power adapter, the D+ and D– lines must be shorted inside the adapter.

2.1.1 PC USB port

The power distribution of USB devices is divided into different classes. With this separation the classes can be simplified into different unit loads. A unit load is defined to be 100 mA in USB 2.0 and 150 mA into USB 3.0. After configuration the maximum number of loads is five or six (500 mA or 900 mA) in USB 2.0 and USB 3.0 respectively. For configuration, communication with a PC must often be established to ensure so-called high-power, bus-powered function. A USB 3.0 port may support the USB charging specifications (D+/D– shorted).

Note that the USB 2.0 power distribution requirements are mandatory when a USB 3.0 device is operating in USB 2.0 modes (high-speed, full-speed or low-speed).

2.2 Micro-USB connector in smart phone

Beginning in 2010, with a deadline of 2012, all data transfer capable mobile handsets must use a micro-USB connector as the battery charging interface.

This agreement was signed by ten supplier of mobile handsets and network service providers in June 2009. In February 2009 seventeen partners published a memorandum on a volunteer basis.

The idea behind is similar to the chinese battery charging standard, where any device can be charged by a common AC-to-DC adapter or a PC USB port.

Today's mobile handset volume is between 350 million to 400 million units, with a renew rate of approximately 180 million mobile handsets per year. 25% of today's total volume are capable of data communication or can be connected to a PC. In addition the energy efficiency of the AC-to-DC adapter will be improved. All these changes will reduce up to 51.000 tonnes of excess AC-to-DC adapters.

2.3 V_{BUS} electrical characteristics

Table 1. DC electrical characteristics

Symbol	Parameter	Min	Max	Unit
Supply voltage				
Downstream connector				
V_{BUS}	bus supply voltage	4.45	5.25	V
Upstream connector				
V_{BUS}	bus supply voltage	4.0	-	V
Supply current				
I_{CCPRT}	high-power hub port (out) supply current	500/900	-	mA
I_{CCUPT}	low-power hub port (out) supply current	100/150	-	mA
I_{CCHPF}	high-power function (in) supply current	-	500/900	mA
I_{CCLPF}	low-power function (in) supply current	-	100/150	mA
I_{CCINIT}	unconfigured function/hub (in) supply current	-	100/150	mA
I_{CCSH}	suspended high-power device supply current	-	2.5	mA

2.4 General USB requirements

Depending on the communication speed of the USB interface, different prerequisites apply for protection devices that are placed at this interface. Table 2 lists limits for capacitive load on the differential data lines of the USB port.

Table 2. USB differential data line requirements

Interface speed	maximum bit rate	min	max	unit
Low speed	1.5 MB/s	200[1]	450[1]	pF
Full speed	10 MB/s	-	150[2]	pF
High speed	480 MB/s	-	3[3]	pF
Super speed	5 GB/s	-	0.5[3]	pF

[1] Total capacitance of cable and device on D+ or D− lines

[2] Total capacitance of a downstream facing port including cable connector and transceiver.

[3] Approximate value. Not specified by the USB standard.

3. Charger interface and USB protection

Whether a mobile device is charged via the USB port or via a discrete charger connector incorrect polarity or a too high voltage applied to this input poses a threat to the charger circuit and the Power Management Unit (PMU) of the mobile device. In addition to the danger of accidentally applying the wrong charging voltages, the USB/charger port can be subject to ElectroStatic Discharge (ESD) strikes.

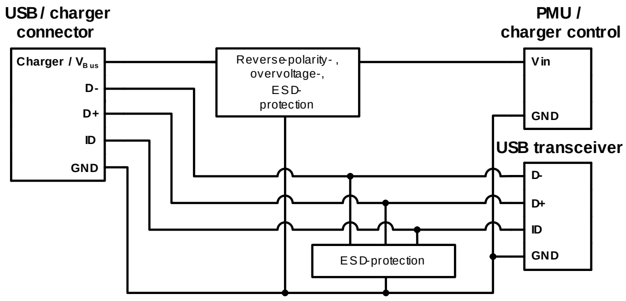


Fig 1. Charger interface and USB protection block diagram

As shown in Figure 1 a complete protection solution for the USB and charger port consists of two blocks. The first block protects the USB V_{BUS} or charger interface against reverse polarity and overvoltage. The second block protects the USB data lines and the downstream components against damage from ESD. The subsequent sections illustrate the protection concepts of these blocks in more detail.

3.1 Reverse polarity protection

In case the charger voltage is accidentally supplied in reverse polarity a PMU and any other downstream circuit needs to be properly protected in order to survive with no damage. A simple and yet effective concept providing this functionality is depicted in Figure 2.

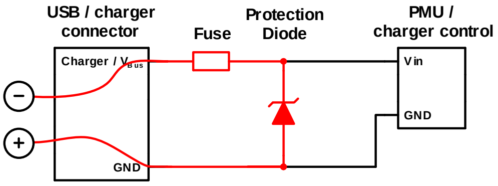


Fig 2. Reverse polarity protection operation

The positive voltage supplied to the GND input of the charger can pass through the forward biased protection diode and the protective fuse, back to the charger negative pole. In this concept the protection diode needs to be able to conduct high currents only until the fuse clears. Fast reacting fuses can clear in 100 ms. Section 3.4 describes protection diodes that are able to conduct up to 5 A for the necessary period of time.

The transient negative voltage that can be observed behind a diode used as reverse polarity protection can be approximated below.

$$V_{diode} = (I \cdot R_{on}) + V_f \qquad (1)$$

For a diode with R_{on} = 0,268 Ω and V_f = 0.85 V that is operating forward biased in linear region at room temperature, the resulting voltage for a current of I = 5 A is V_{diode} = 1.65 V.

3.2 Overvoltage protection

Given the multitude of accessories that are available to replace originally supplied chargers, the threat of a voltage being accidentally applied that is too high is omnipresent. A simple solution means to limit the overvoltage is by adding a Zener diode with a breakdown voltage above the required working voltage.

Figure 3 shows the operation principle of an overvoltage protection based on a Zener diode. A high voltage applied to the charger / V_{BUS} terminal sets the diode into breakdown mode once the diode breakdown voltage is reached. Subsequently the voltage at the PMU / charger input is limited to the breakdown voltage of the diode.

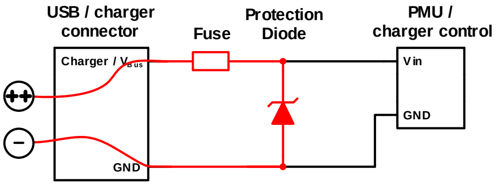


Fig 3. Overvoltage protection operation

If not already present for reverse polarity protection (see Section 3.1), a fuse or Positive Temperature Coefficient (PTC) element should be placed in the supply path. This limits the current if, for example, defective charger supplying the primary voltage is connected and the continuous current that passes via the Zener diode exceeds the limit imposed by the maximum power dissipation.

3.3 USB data ESD protection

While for low speed and full speed USB the constraints for applying additional ESD protection on the differential data lines are relaxed, a high-speed USB port specifies additional capacitance to a much lower value.

3.3.1 Rail-to-rail concept for low capacitance ESD protection

A common architecture utilized to build low capacitance ESD protection devices is the so-called ‘rail-to-rail’ diode concept, which shunts ESD transients from Input/Output (I/O) lines into the ground or power supply “rails.”

While some implementations comprise simply of the rail-to-rail diodes themselves, the typical Nexperia solution also contains an additional Zener diode in parallel to the rail-to-rail diode string. This minimizes the clamping voltages by routing all ESD current (positive and negative strikes) back to ground and also to eliminate external components.

The principle of operation of the rail-to-rail concept is illustrated in Figure 4

a. Discharge path of negative ESD pulse

b. Discharge path of positive ESD pulse

Fig 4. Rail-to-rail ESD protection concept

With the rail-to-rail concept, a negative ESD strike on the I/O pin will cause one rail-to-rail diode (the lower diode at the flash sign in Figure 4, left side) to become forward biased, thereby transferring the ESD strike through the lower diode to ground.

A positive discharge strike will cause the other rail-to-rail diode (the upper diode at the flash sign in Figure 4, right side) to become forward biased transferring the discharge to the cathode of the Zener diode that will clamp voltages exceeding its breakdown voltage by the ESD strike to ground.

3.3.2 USB data line ESD protection with rail-to-rail devices

A common technique to provide such a low capacitive ESD protection, for example with a line capacitance below 1.5 pF, is the rail-to-rail ESD protection architecture. Figure 5 shows how a four-channel rail-to-rail ESD protection device can be used to protect all the lines of a USB On-The-Go (OTG) port.

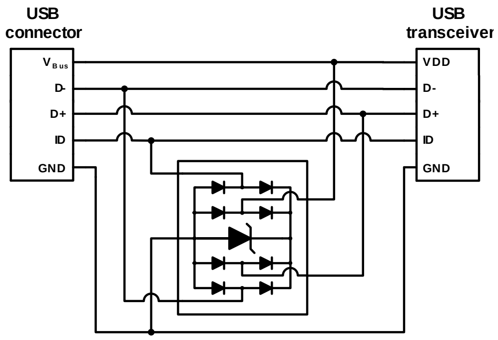
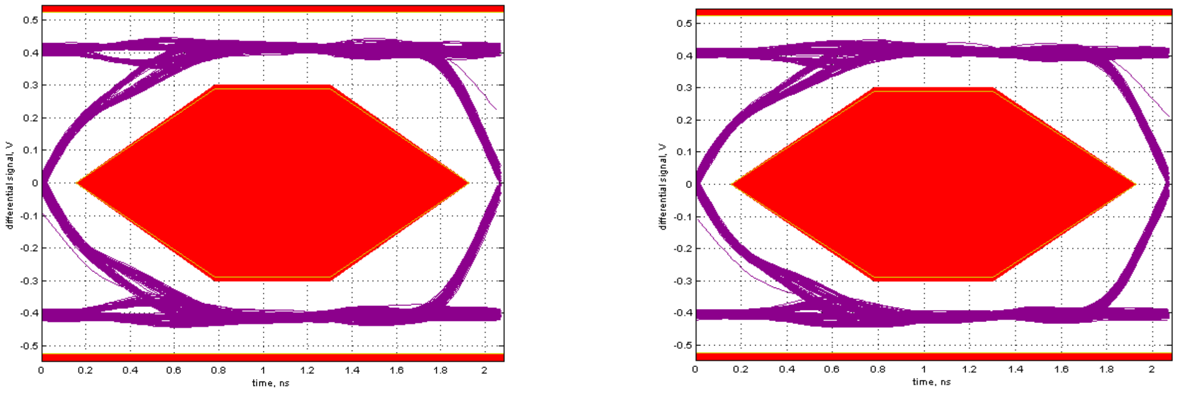


Fig 5. Four-channel rail-to-rail ESD protection

The influence of a low capacitance rail-to-rail protection device on the data transmission can be very small. Figure 6 shows the eye diagram of a high-speed USB transmission captured on the D+/D– lines with and without 1 pF rail-to-rail ESD protection applied. Comparing the two measurements illustrates that the influence of this kind of low capacitance ESD protection is negligible.



f = 480 MHz, V= 400 mV

a. Without ESD protection

(1) f = 480 MHz, V= 400 mV

b. With 1 pF rail-to-rail ESD protection

Fig 6. High-speed USB eye diagrams

3.4 Protection devices

Nexperia offers a wide range of protection devices in order to protect against ESD, overvoltage and reverse polarity at a charger interface. These products can be used to realize simple but effective protection concepts as described in the previous section. Table 5 in Section 7 lists a number of products that meet the special requirements of this application.

One product in the comparison table that deserves special attention is IP4389CX4 as it offers a complete reverse polarity and overvoltage protection solution by integrating a fast reacting fuse.

Products that are ideally suited to protecting USB data lines are listed in Table 4 of Section 7. Further information on USB data line protection can be found in AN10753.

4. Li-Ion batteries

Li-Ion batteries have some advantages compared to Ni-based batteries, like NiCd or NiMH batteries.

- High average operating cell voltage of 3.6 V, instead of 1.2 V (Ni-based batteries)
- High energy density - smaller and lighter batteries
- Lower self-discharge rates
- Little or no memory effect

For these reasons Li-Ion batteries are widely used in mobile applications. On the other hand Li-Ion batteries must be protected against undervoltage, overvoltage, over current and over temperature. Therefore battery management and system monitoring are built into battery packs and most PMU also measure the battery temperature.

Li-Ion batteries need a different charging algorithm compared to Ni-based batteries. This algorithm is called CC/CV (constant current/constant voltage)-algorithm.

The CC/CV charging algorithm is shown in Figure 7.

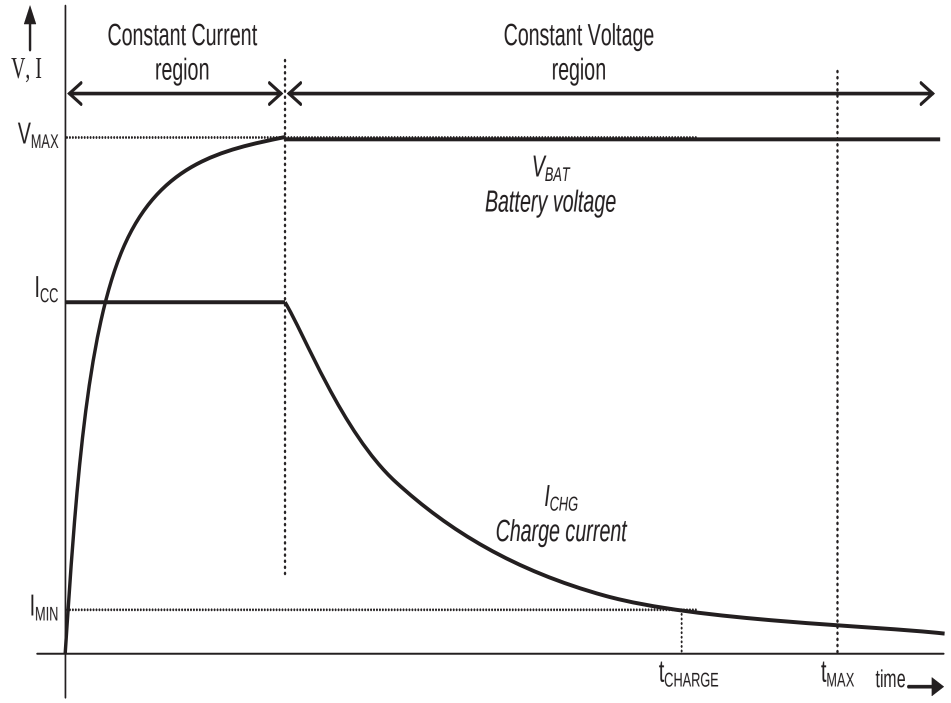


Fig 7. Charging algorithm Li-Ion battery

The value of V_{MAX} and I_{CC} depends on the type of battery that is used. The maximum charge rate in CC mode is 1C, where 1C indicates the capacity of the battery e.g. 1000 mAh. The value of V_{MAX} is typically in the range of 4.1 to 4.2 volts.

During the CV mode the voltage is constant and the charge current decreases as the battery is charged. There are two possibilities to terminate the charging process. First when the charge current drops below the I_{MIN}. Alternatively, a fixed total charging time (t_{MAX}) could be used to stop the charging process.

For the CC/CV charging, there are different modes available, depending on the PMU:

- **Idle mode:** No valid charger adapter is connected. Once a charger adapter is detected most PMUs will enter the qualification mode. The PMU will return to Idle mode when the end-of-charge condition is reached.
- **Qualification mode:** This mode is used for qualifying a discharged battery. Most PMUs remain in qualification mode as long as the battery voltage is below the $V_{VERYLOWBAT}$-level, typically 2.7 V.
- **Pre charge mode:** After qualification mode the PMU will enter the pre charge mode. A low charge current is used. Normally the battery is charged until the battery level is higher than V_{LOWBAT} and the fast charge mode will be activated.
- **Fast charge mode (CC/CV):** The battery will be charged with I_{CC} charging rate until the CV condition, $V_{BAT} > V_{MAX}$, is reached. CV mode will stop after the end-of-charge condition is reached (I_{MIN} or t_{MAX}).

5. Li-Ion battery charging topologies

There are several different battery technologies available in the market. This application note highlights the battery chargers, that are using external pass elements. You can differ between two main paths:

- Bipolar Junction Transistor (BJT) as pass element
  - BJT as current regulator
  - BJT as current regulator + MOSFET as control switch (load switch)
- MOSFET as pass element
  - Single MOSFET-Schottky diode module
  - Double MOSFET in back-to-back configuration

Often PMU with external bypass transistor are capable of driving a MOSFET. As an alternative a lower cost bipolar transistor can be used. Nexperia low V_{CEsat} Breakthrough In Small Signal (BISS) transistor perform the same function as a MOSFET at a lower cost, as an advantage there is no need for a blocking diode.

So a MOSFET-Schottky diode module or a double MOSFET can be replaced by a low V_{CEsat} BISS transistor and a resistor, if the PMU is capable of direct biasing the low V_{CEsat} BISS transistor.

5.1 Low V_{CEsat} BISS transistors as pass element

The Bipolar Junction Transistor (BJT) is a current-driven device, compared to the MOSFET which is a voltage-driven device. When designers want to use a BJT, as replacement of the MOSFET, they have to understand the current limitations of the PMU.

To ensure the low V_{CEsat} BISS transistor goes into saturation, the control pin of the PMU must be able to supply the base current (I_B), otherwise an additional control transistor would be required.

For example:

- Charging current 1000 mA
- Worst case current gain (h_{FE}) of 100

The control pin must be able to provide 10 mA for the low V_{CEsat} BISS transistor.

Low V_{CEsat} BISS transistors can be used in saturation mode and in linear mode. Both modes will be shown in the next two chapters.

5.1.1 BJT as current regulator

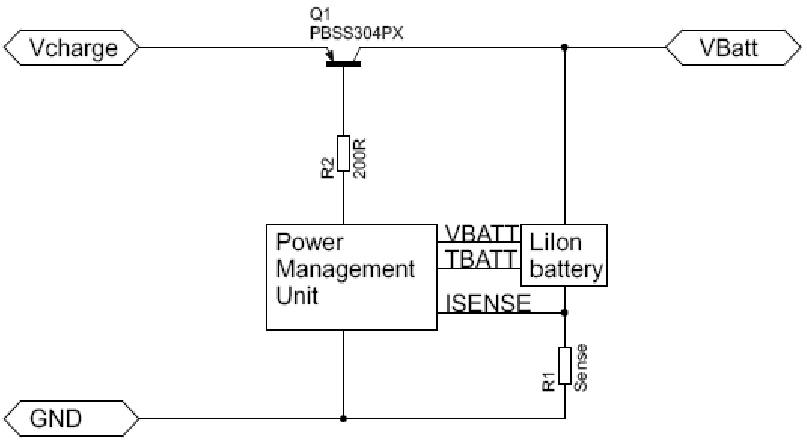


Fig 8. PMU with external low V_{CEsat} (BISS) pass transistor

In switched current sources the low V_{CEsat} transistor is used in saturation mode, the minimum gain should be taken into account, at 1 A the gain of the PBSS304PX is 200. Therefore a minimum base current of 5 mA is needed, to ensure we will set the base current to 10 mA. The additional resistor R2 should limit the maximum current of the drive stage.

$$P_{tot} = P_T + P_R \tag{2}$$

$$P_{tot} = (I_C \times V_{CEsat}) + (I_B^{\ 2} \times R) \tag{3}$$

$$P_{tot} = (1A \times 80mV) + (10mA^2 \times 200\Omega) = 100mW \tag{4}$$

In linear mode the power dissipation of the low V_{CEsat} BISS transistor increases due to higher voltage drops across the collector-emitter junction. In this case the PMU has to provide lower base currents compared to the switched mode. If the battery has to be charged via the USB interface the maximum supply voltage is 5.25 V. In worst case the minimum allowed battery voltage is 3.6 V, depends on the battery supplier specifications, for fast charge-mode.

$$P_{tot} = (1A \times \dot{1}, 65V) = (1, 65W) \tag{5}$$

Therefore a package must be chosen that fits mechanically in the application and the charging current must be adopted to the thermal capability of the transistor package.

5.1.2 BJT - MOSFET as load switch

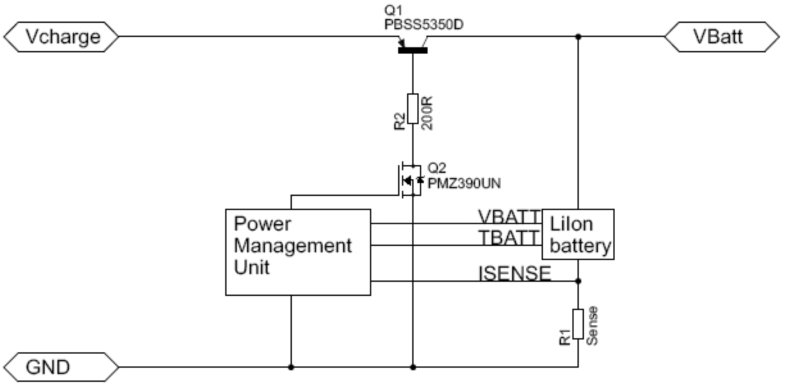


Fig 9. PMU with external low V_{CEsat} BISS pass transistor with additional small-signal MOS control transistor

$$P_{tot} = P_T + P_R + P_M \tag{6}$$

$$P_{tot} = (I_C \times V_{CEsat}) + (I_B{}^2 \times R) + \langle I_B^2 \times R_{DSon} \rangle \tag{7}$$

$$P_{tot} = (1A \times 80mV) + (10mA^2 \times 200\Omega) + (10mA^2 \times 390m\Omega) = (100, 04mW) \tag{8}$$

5.2 MOSFETs as pass elements

Due to the fact that MOSFETs are voltage-driven, most PMUs will drive the MOSFET in a switched-mode. In addition to a MOSFET there is a need for a blocking diode in series connection to the MOSFET, because the body diode of each MOSFET conducts in reverse mode to prevent any reverse current from the battery.

5.2.1 MOSFET-Schottky diode module solution

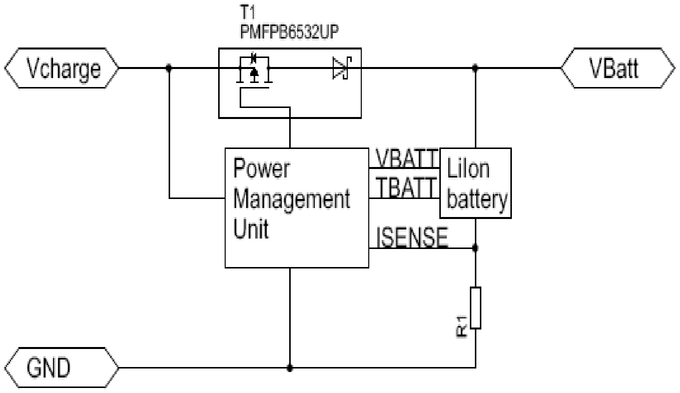


Fig 10. PMU with external pass MOSFET-Schottky diode module

The typical power dissipation through the MOSFET-Schottky diode module can be calculated as follows:

$$P_{tot} = P_T + P_D \tag{9}$$

$$P_{tot} = (I_D^2 \times R_{DSon}) + (I_D \times V_F) \tag{10}$$

$$P_{tot} = (1A^2 \times 65m\Omega) + (1A \times 325mV) = 390mW \tag{11}$$

5.2.2 Double FET solution

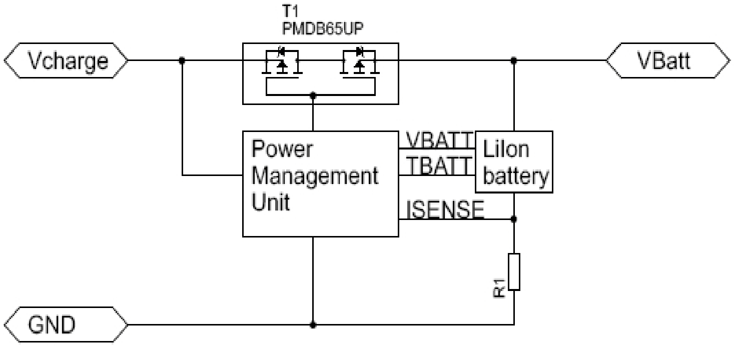


Fig 11. PMU with external double MOSFET as pass element

By connecting the MOSFET in this configuration, the Schottky diode has been eliminated. If both gates can be controlled independently, the PMU can control the charging current and also the discharging current if the USB port has to supply power. It is a superior solution compared to using a MOSFET-Schottky diode module, but it does cost more.

The typical power dissipation through the double MOSFET can be calculated as follows:

$$P_{tot} = 2 \times P_T \tag{12}$$

$$P_{tot} = 2 \times (I_D^2 \times R_{DSon}) \tag{13}$$

$$P_{tot} = 2 \times (1A^2 \times 65m\Omega) = 130mW \tag{14}$$

6. Conclusion

Nexperia offers a wide variety of low V_{CEsat} BISS transistor, small signal Trench MOSFET and Maximum Efficiency General Application (MEGA) Schottky rectifier for Li-Ion battery charging applications in mobile device, as cellular phones, navigation systems and low power mobile computing.

Every solution has it own advantage and disadvantage, so every proposal is specific to customer's requirements and often other products can fit in a given customer's application. The usage of a low V_{CEsat} BISS transistor or a MOSFET / MOSFET-Schottky diode module depends initially on the technology of the PMU. But with an extra small-signal MOS, to control the base current, any MOSFET / MOSFET-Schottky diode module can be replaced by low V_{CEsat} BISS transistor.

Nexperia low V_{CEsat} BISS is less sensitive to ESD damage compared to the MOSFET without internal ESD protection. It has a lower turn on voltage (typical V_{BE} = 0.7 V) compared to a MOSFET (V_{GS} = 1.8 V to 10 V). These advantages are very attractive for low voltage, battery-driven devices like cell phones. Because of the blocking voltages in both directions, the low V_{CEsat} BISS transistors eliminate the need for a blocking diode which is required when using a MOSFET, included in a MOSFET-Schottky diode module.

The IP428x family is designed for the tough requirements of reverse polarity and over-voltage protection. These products enable a simple and very effective protection concept for mobile device charger inputs. A further simplified solution with even higher integration density can be found in the IP4389CX4 which integrates a fast reacting fuse.

7. Appendix

Table 3. Transistor product portfolio

Name	Description	Dimension [mm]	Package	Release
PBSS304PD	PNP low V_{CEsat}, V_{CEO} = 80 V, I_C = 3 A	2.9 x 1.5 x 1.0	SOT457	Released
PBSS304PX	PNP low V_{CEsat}, V_{CEO} = 60 V, I_C = 4.2 A	4.5 x 2.5 x 1.5	SOT89	Released
PMV65XP	P-ch. MOSFET-Schottky, V_{DS} = 20 V, R_{DSon}= 65 mΩ	2.9 x 1.3 x 1.0	SOT23	Released
PMN50XP	P-ch. MOSFET-Schottky, V_{DS} = 20 V, R_{DSon} = 48 mΩ	2.9 x 1.5 x 1.0	SOT457	Released
PMZ390UN	N-ch. MOSFET, V_{DS} = 30 V, R_{DSon} = 390 mΩ	1.0 x 0.6 x 0.5	SOT883	Released
PMFPB6545UP	P-ch. MOSFET-Schottky, V_{DS} = 20 V, R_{DSon} = 65 mΩ, V_F = 455 mV	2.0 x 2.0 x 0.65	SOT1118	Released
PMFPB6532UP	P-ch. MOSFET-Schottky, V_{DS} = 20 V, R_{DSon} = 65 mΩ, V_F = 325 mV	2.0 x 2.0 x 0.65	SOT1118	Released
PBSS5330X	PNP low V_{CEsat}, V_{CEO} = 30 V, I_C = 3 A	4.5 x 2.5 x 1.5	SOT89	Released
PBSS5330PA	PNP low V_{CEsat}, V_{CEO} = 30 V, I_C = 3 A	2.0 x 2.0 x 0.65	SOT1061	Released
PMR400UN	N-ch. MOSFET, V_{DS} = 30 V, R_{DSon} = 400 mΩ	1.6 x 0.8 x 0.77	SOT416	Released
PMDPB70XP	Double P-ch. MOSFET, V_{DS} = 30 V, R_{DSon} = 70 mΩ	2.0 x 2.0 x 0.65	SOT1118	Dec. 2011
PBSM5240PF	PNP low V_{CEsat}, V_{CEO} = 40 V, I_C = 2 A N-ch. MOSFET, V_{DS} = 30 V, R_{DSon}=400 mΩ	2.0 x 2.0 x 0.65	SOT1118	Released
PMDPB65UP	Double P-ch. MOSFET, V_{DS} = 20 V, R_{DSon} = 65 mΩ	2.0 x 2.0 x 0.65	SOT1118	Released

Table 4. ESD protection product portfolio

Name	Description	Dimension [mm]	Package	Release
IP4221CZ6-S	V_{RWM} = 5.5 V, C_d = 1.0 pF, $V_{ESD(max)}$ = 8 kV, quad	1.45 x 1.0 x 0.5	SOT886	Released
IP4221CZ6-XS	V_{RWM} = 5.5 V, C_d = 1.0 pF, $V_{ESD(max)}$ = 8 kV, quad	1.0 x 1.0 x 0.5	SOT891	Released
IP4282CZ6	V_{RWM} = 5.5 V, C_d = 0.7 pF, $V_{ESD(max)}$ = 8 kV, dual	1.45 x 1.0 x 0.5	SOT886	Released
IP4284CZ10-TB	V_{RWM} = 5.5 V, C_{ch} = 0.5 pF, $V_{ESD(max)}$ = 8 kV, quad	2.5 x 1.0 x 0.5	SOT1059	Released
IP4059CX5	V_{RWM} = 5.5 V, C_d = 3.0 pF, $V_{ESD(max)}$ = 15 kV, triple	0.96 x 1.34 x 0.65	WLCSP5	Released
IP4359CX4/LF	V_{RWM} = 5.5 V, C_d = 1.3 pF, $V_{ESD(max)}$ = 15 kV, dual	0.91 x 0.91 x 0.65	WLCSP4	Released
PESD5V0F1BL	V_{RWM} = 5.5 V, C_d = 0.4 pF, $V_{ESD(max)}$ = 10 kV, single	1.0 x 0.6 x 0.5	SOD882	Released
PESD5V0X1BL	V_{RWM} = 5 V, C_d = 0.9 pF, $V_{ESD(max)}$ = 9 kV, single	1.0 x 0.6 x 0.5	SOD882	Released
PRTR5V0U2F	V_{RWM} = 5 V, C_L = 1.0 pF, $V_{ESD(max)}$ = 8 kV, dual	1.45 x 1.0 x 0.5	SOT886	Released

Table 5. Reverse polarity and overvoltage protection product portfolio

Name	Description	Dimension [mm]	Package	Release
IP4085CX4/LF	V_{RWM} = 14 V, $I_{PP(min)}$ = 60 A, P_{tot} = 1 W, $V_{ESD(max)}$ = 30 kV	0.91 x 0.91 x 0.65	WLCSP4	Released
IP4385CX4	V_{RWM} = 5.5 V, $I_{PP(min)}$ = 33 A, P_{tot} = 0.7 W, $V_{ESD(max)}$ = 30 kV	0.76 x 0.75 x 0.61	WLCSP4	Released
IP4386CX4	V_{RWM} = 14 V, $I_{PP(min)}$ = 28 A, P_{tot} = 0.7 W, $V_{ESD(max)}$ = 30 kV	0.76 x 0.75 x 0.61	WLCSP4	Released
IP4387CX4	V_{RWM} = 8 V, $I_{PP(min)}$ = 33 A, P_{tot} = 0,7 W, $V_{ESD(max)}$ = 30 kV	0.76 x 0.75 x 0.61	WLCSP4	Released
IP4389CX4	V_{RWM} = 8 V, $I_{PP(min)}$ = 24 A, P_{tot} = 0.7 W, $V_{ESD(max)}$ = 30 kV, $I_{fuse(M)}$ = 2 A, $t_{fuse(max)}$ = 100 ms	0.76 x 0.75 x 0.61	WLCSP4	Released

8. References

[1] **“PCF50603 Application Note” —** Charging a Li-Ion battery with PCF50603, Philips Semiconductors BL Power Management

9. Legal information

9.1 Definitions

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For more information, please visit: http://www.nexperia.com
For sales office addresses, please send an email to: salesaddresses@nexperia.com

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