4A Triple-Cell Lithium Battery Charging Management Integrated Circuit

Description

The SL3763 is a PWM buck-mode three-cell lithium battery charging management integrated circuit, which independently manages the charging of three-cell lithium batteries. It has the advantages of small packaging, few peripheral components, and simple use. The SL3763 features trickle, constant current, and constant voltage charging modes, making it very suitable for lithium battery charging management. In the constant voltage charging mode, the SL3763 modulates the battery voltage to 12.6V, which can also be adjusted upwards through an external resistor; in the constant current charging mode, the charging current is set through an external resistor.

For deeply discharged lithium batteries, when the battery voltage is lower than 66.5% (typical value) of the constant voltage charging voltage, the SL3763 trickle charges the battery at 17.5% of the set constant current charging current.

During the constant voltage charging phase, the charging current gradually decreases, and the charging ends when the charging current drops to 16% of the constant current charging current. In the end of charging state, if the battery voltage drops to 95.5% of the constant voltage charging voltage, a new charging cycle is automatically started. When the input power is cut off or the input voltage is lower than the battery voltage, the SL3763 automatically enters sleep mode.Other features include input under-voltage lockout, over-voltage protection at the battery terminal, and charging status indication, etc. The SL3763 is packaged in a 10-pin SSOP package.

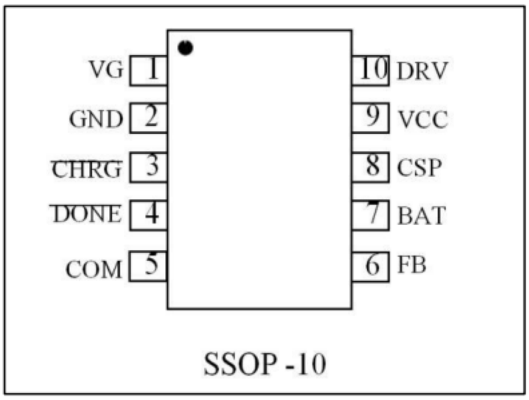
Applications

- Handheld devices
- Spare battery applications
- Portable industrial and medical instruments
- Power tools
- Standalone battery charge

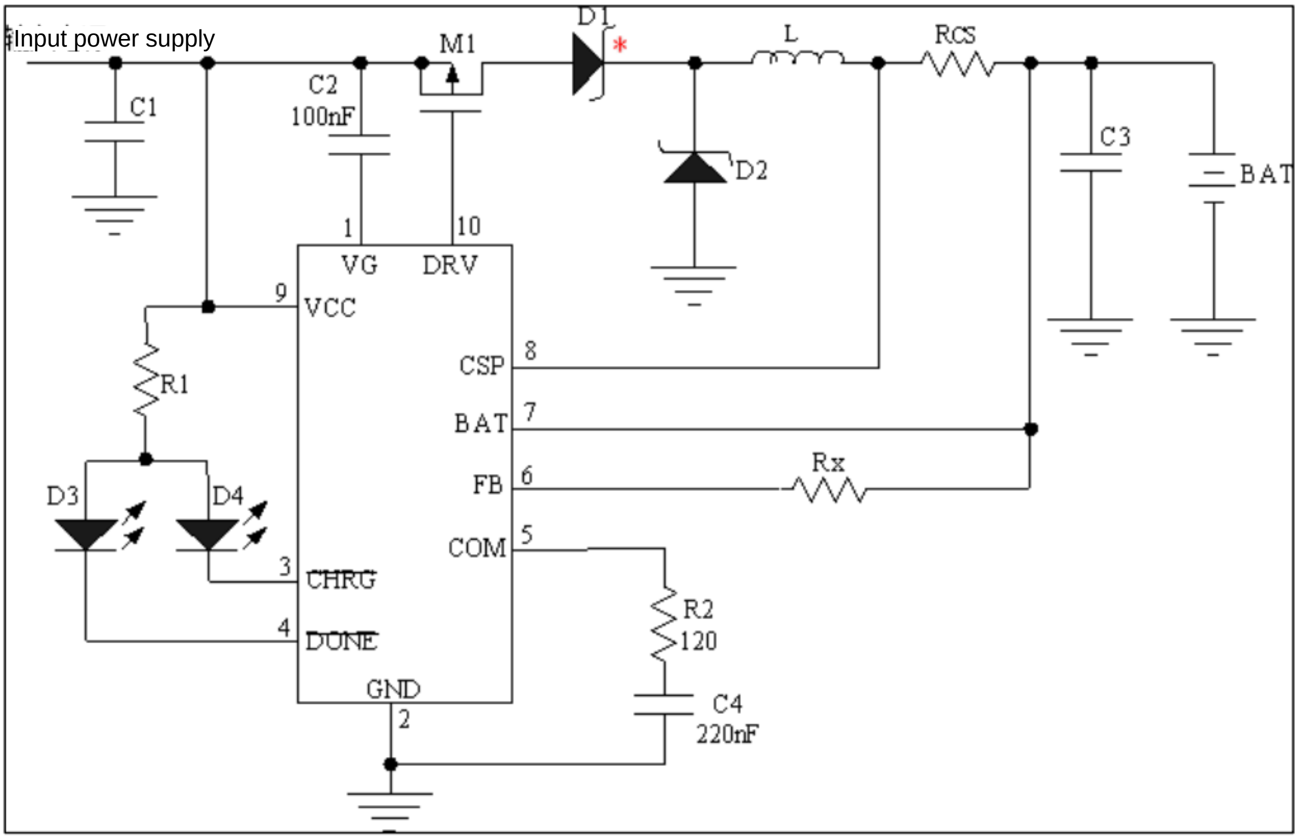
Features

- Wide input voltage range: 6.6V to 30V
- Complete charging management for three-series lithium batteries
- Charging current up to 4A
- PWM switching frequency: 300KHz
- Constant voltage charging voltage adjustable upwards with a resistor
- Constant voltage charging voltage accuracy: ±1%
- Constant current charging current set by an external resistor
- Trickle charging for deeply discharged batteries
- Automatic recharging function
- Indication of charging status and end of charge status
- Soft start function
- Overvoltage protection at the battery end
- Operating ambient temperature: -40°C to +85°C
- Adopts 10-pin SSOP package
- Lead-free product, complies with RoHS, halogen-free

Pin Configuration



Typical Application Circuit



Diode D1 may not be required. For detailed information, please refer to page 9, "Diode D1 Selection" and the section on "Implementing input power reverse polarity protection and preventing battery current backflow using a P-channel field-effect transistor."

Pin function

Pin Number	Pin Name	Pin description
1	VG	The internal voltage regulator outputs.
2	GND	Ground
3	$\overline{CHRG}$	Battery Charging Indicator Terminal.
4	$\overline{DONE}$	Charge end indication terminal.
5	COM	Compensate the input end of the circuit. Connect a 120Ω resistor and a 220nF capacitor in series between this pin and ground
6	FB	The battery voltage detection input pin.
7	BAT	Battery Segment
8	CSP	Charging current detection positive input terminal
9	VCC	Power Supply Terminal
10	DRV	gate drive terminal。

Limit parameters

Voltage from VCC，VG，DRV，CHRG，DONE to GND ....－0.3V to 33V
Voltage from VG pin toVCC pin .... －8V to VCC＋0.3V
Voltage from CSP，BAT，FB to GND .... －0.3V to 25V
Voltage from COM to GND .... －0.3V to 6.5V
Storage temperature………………………………………...…………－65℃to 150℃
Operating ambient temperature………………………………………………－40℃to 85℃
Soldering temperature (10 seconds)...260℃

Exceeding the extreme parameters listed above may cause permanent damage to the device. The limits provided are only the extreme ranges, and operating under these extreme conditions will not guarantee the technical specifications of the device, and long-term operation under these conditions will also affect the reliability of the device.

Electrical characteristics

(V_{cc}=15V, T_A=-40℃to85℃ unless otherwise specified)

Parameter	Symbol	Test conditions	Min	Type	Max	Unit
positive input supply voltage	V_{CC}		6.6		30	V
Low voltage latch threshold	U_{VLO}		4	5.2	6.5	V
chip operating current	I_{VCC}	$V_{BAT} > V_{REG}$	0.7	1.0	1.3	mA
constant voltage charging voltage	V_{REG}	Constant voltage charging，FB Connect to BAT	12.474	12.6	12.726	V
current detection	V_{CS}	$V_{BAT} > V_{PRE}$，$V_{CSP} - V_{BAT}$	110	120	130	mV
		$V_{BAT} < V_{PRE}$，$V_{CSP} - V_{BAT}$	10	21	36	
Current flowing into the BAT pin	I_{BAT1}	End-of-charge mode，V_{BAT}=12.3V		10	16	mA
	I_{BAT2}	Sleep mode，V_{BAT}=11.1V		15		
trickle charging threshold	V_{PRE}	BAT pin voltage rises	64	66.5	69	%V_{REG}
trickle charging threshold hysteresis	H_{PRE}	BATPin voltage drops		2.5		%V_{REG}
Charging termination threshold	I_{term}	The charging current drops		16		%I_{CC}
Recharge threshold	V_{RE}	BAT Pin voltage drops		95.5		%V_{REG}
overvoltage threshold	Vov	BAT pin voltage rises	1.04	1.07	1.1	V_{REG}
overvoltage release threshold	Vclr	BAT Pin voltage drops	1.0	1.02	1.04	
CHRG pin						
CHRG pin Pull-down current	I_{CHRG}	V_{CHRG}=1V，State of charge	7	12	18	mA
CHRG pin Leakage current	I_{LK1}	V_{CHRG}=30V，End-of-charge status		1		mA
DONE pin						
$\overline{DONE}$ pin Pull-down current	I_{DONE}	V_{DONE}=1V，End-of-charge status	7	12	18	mA
$\overline{DONE}$ pin Leakage current	I_{LK2}	V_{DONE}=30V，State of charge		1		mA
oscillator						
rate	f_{osc}		240	300	360	kHZ
Maximum duty cycle	D_{max}			94		%
Sleep mode						
Sleep mode threshold (Measure V_{CC}-V_{BAT})	V_{SLP}	V_{CC} falling / V_{BAT}=12V	0.0	0.05	0.1	V
Sleep mode release threshold(measure $V_{CC} - V_{BAT}$)	V_{SLPR}	V_{CC} rising, / V_{BAT}=12V	0.2	0.32	0.46	V
DRV pin						
V_{DRV} High level ($V_{CC} - V_{DRV}$)	V_H	I_{DRV}=−10mA		60		mV
V_{DRV} Low level ($V_{CC} - V_{DRV}$)	V_L	I_{DRV}=0mA		6.3		V
Rise rime	tr	Cload=2nF, 10% to 90%	30	40	65	ns
Drop time	tf	Cload=2nF, 90% to 10%	30	40	65	ns

Note: V_{REG} stands for constant voltage charging voltage; I_{CC} stands for constant current charging current.

Detail:

The SL3763 is a PWM buck-type three-cell lithium battery charging management integrated circuit with trickle, constant current, and constant voltage charging modes. The constant current charging current is set by the current detection resistor RCS between the CSP pin and the BAT pin. In the constant voltage charging mode, the constant voltage charging voltage can be adjusted upwards by the resistor between the BAT pin and the FB pin; when the BAT pin is directly connected to the FB pin, the constant voltage charging voltage is 12.6V with an accuracy of 1%.The SL3763 operates normally when the VCC pin voltage is greater than the low-voltage lock-in threshold and is greater than the battery voltage. If the battery voltage is lower than the trickle charging threshold, the charger automatically enters the trickle charging mode, where the charging current is 17.5% of the set constant current charging current. When the battery voltage is higher than the trickle charging threshold, the charger enters the constant current charging mode, where the charging current is set by the internal 120mV reference voltage and an external resistor RCS, that is, the charging current is 120mV/RCS. As the battery voltage continues to rise and approaches the constant voltage charging voltage, the charger enters the constant voltage charging mode, and the charging current gradually decreases. In the charging state, the internal transistor of the open-drain output pin is turned on, outputting a low level to indicate the charging state. When the charging current decreases to 16% of the constant current charging current, the charging ends, and the DRV pin outputs a high level. The internal transistor of the open-drain output pin is turned off, and the output is in a high impedance state; another open-drain output pin's internal transistor is turned on, outputting a low level to indicate the end of charging state. In the end of charging state, if the input power is disconnected and then reconnected, a new charging cycle will start; if the battery voltage drops to the recharge threshold, a new charging cycle will also start automatically.When the input voltage is lost, the SL3763 automatically enters sleep mode, and the internal circuit is turned off.The SL3763 also has an internal overvoltage comparator. When the voltage at the BAT pin rises due to load changes or sudden battery removal, if the BAT pin voltage rises to 1.07 times the constant voltage charging voltage, the overvoltage comparator acts, turning off the external P-channel MOS field-effect transistor, and the charger temporarily stops until the BAT pin voltage returns to below 1.02 times the constant voltage charging voltage. In some cases, such as when the battery is not connected to the charger, or the battery is suddenly disconnected, the voltage at the BAT pin may reach the overvoltage protection threshold, which is normal.
The charging current and voltage diagram is shown in Figure 2.

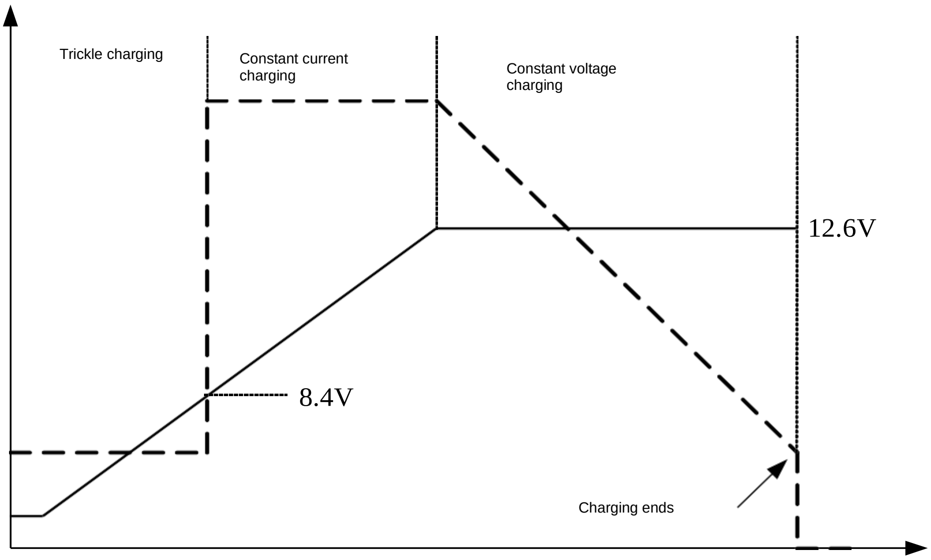


Figure 2 Schematic diagram of the charging process (BAT pins are connected directly to FB pins)

Application

Low-voltage latching **(UVLO):**

The low-voltage latch circuit inside the chip monitors the input voltage. When the input voltage is below 6.5V (the maximum value), the internal circuit is turned off, and the SL3763 is prohibited from operating.Trickling charge occurs during the charging state. If the battery voltage is below 66.5% (typical value) of the constant voltage charging voltage, the charger enters the trickle charge mode, at which time the charging current is 17.5% of the constant current charging current.Setting of the constant current charging current
The constant current charging current is determined by the following formula:

$$I_{CH} = \frac{120mV}{R_{CS}}$$

In which ICH is the constant current charging current, and RCS is the current detection resistor connected between the CSP pin and the BAT pin. Adjusting the constant voltage charging voltage can offset the voltage drop caused by the battery internal resistance and wiring resistance, making the battery charge more full, as shown in Figure 3.

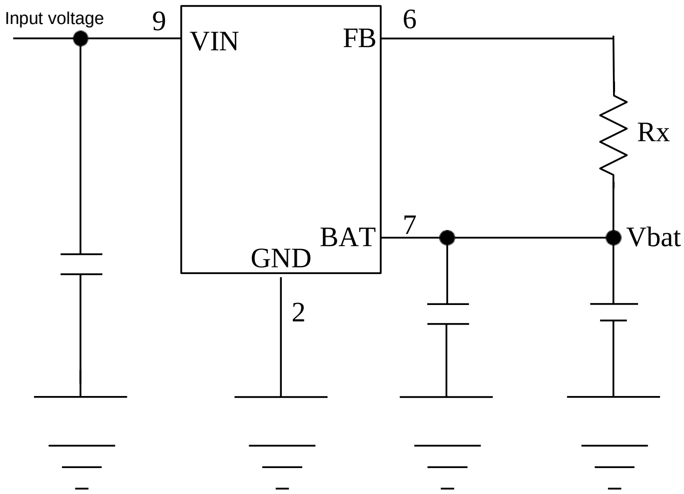


Figure 3 Adjusting the Constant Voltage Charging Voltage

If the connection method in Figure 3 is adopted, then the typical value of the constant voltage charging voltage V_{REG} is: **V_{REG} ＝ 12.6＋8.996×10-6×Rx**

Among them, the unit of VREG is volts. The unit of Rx is ohms. When adjusting the constant voltage charging voltage with the external resistor Rx, due to the differences in internal and external resistance characteristics of the chip and the process deviations during the production of the chip, it may lead to a decrease in the accuracy of the constant voltage charging voltage and an increase in the temperature coefficient. The larger the resistor Rx, the more obvious its impact. Charging ends In the constant voltage charging mode, the charging current gradually decreases. When the charging current drops to 16% of the constant current charging current, the charging process ends, the external P-type field effect transistor is turned off, and the charging current becomes zero. Automatic recharging After the charging ends, if the input power source and the battery are still connected to the charger, due to the battery's self-discharge or the load, the battery voltage gradually decreases. When the battery voltage drops to 95.5% of the constant voltage charging voltage, the SL3763 automatically enters the charging state and starts a new charging cycle, which can ensure that the battery's fullness is maintained at more than 80%Status indication.

The SL3763 has two open-drain status indication outputs: $\overline{DONE}$pin and $\overline{CHRG}$pin. In the charging state, the$\overline{CHRG}$ pin is pulled low by an internal transistor, and in other states, the $\overline{DONE}$pin is in a high-impedance state. In the end-of-charge state, the pin is pulled low by an internal transistor, and in other states, the $\overline{DONE}$ pin is in a high-impedance state.

When the battery is not connected to the charger, the SL3763 will charge the output capacitor to the constant-voltage charging voltage or slightly higher and enter the end-of-charge state. Due to the discharge effect of the working current on the output capacitor at the BAT pin, the voltage at the BAT pin will gradually decrease to the recharge threshold, and the SL3763 will enter the charging state again, forming a saw tooth waveform at the BAT pin, while $\overline{CHRG}$outputting a pulse signal to indicate that no battery is installed.

When the status indication function is not used, connect the unused status indication output to the ground.

Table 1 lists the charger states corresponding to the two status indication ports. It is assumed that the red LED is connected to the pin, and the green LED is connected to the $\overline{CHRG}$pin, as shown in Figure 1.

$\overline{CHRG}$ pin	$\overline{DONE}$pin	Status reason
Low level (red LED on)	High impedance state (green LED off)	charging
High impedance state (red LED off)	Low level (green LED on)	Charging ends
Pulse signal (red LED flashing)	Pulse signal (green LED on or flashing)	There is no battery attached
High impedance state (red LED off)	High impedance state (green LED off)	1.Two possible scenarios. 2.The VCC pin voltage is lower than the low voltage latching voltage. 3.The voltage of the VCC pin is lower than that of the BAT tube Foot voltage.

Table 1 Status indication description

Off-chip power drive

The DRV pin of the SL3763 is used to drive the gate of external MOSFETs, which can provide a large transient current to quickly turn on and off the external MOSFETs. Under the condition of driving a 2nF load, the typical rise time and fall time are 30ns. Generally speaking, a MOSFET with a conduction resistance of 35 milliohms and a 30V rating has an equivalent capacitance of about 2nF.

The SL3763 has an internal clamping circuit to ensure that the low level of the DRV pin is 8V (maximum) lower than the voltage of the VCC pin. For example, if the voltage of VCC is 20V, then the low level of the DRV pin is at least 12V. This allows some low-voltage P-channel MOSFETs with very low on-resistance to be used in conjunction with the SL3763, thereby improving the efficiency of the charger and providing customers with more options.

Loop Compensation

To ensure the stability of the current modulation loop and the voltage modulation loop, a 120Ω resistor and a 220nF ceramic capacitor need to be connected in series between COM and ground.

Battery Connection Check

The SL3763 does not have a battery connection check function. When the battery is not connected to the charger, the SL3763 will charge the output capacitor as a battery to the constant voltage charging voltage or slightly higher, and then enter the charging end state. Due to the discharge effect of the working current of the BAT pin on the output capacitor, the voltage of the BAT pin will slowly drop to the recharging threshold, and the SL3763 will enter the charging state again. The charger will cycle between the charging state and the charging end state, forming a sawtooth waveform on the BAT pin, and at the same time, outputting pulse signals to indicate that no battery is installed.It is best not to connect the battery to the charger while the charger is running, otherwise, the charger may be in an uncertain state, and it may also pour a large current into the battery in a short time.

Input Capacitor

The input capacitor (C1 in Figure 1) serves as a filter for the input power supply and needs to absorb the ripple current generated on the input power supply. Therefore, the input capacitor must have a sufficient rated ripple current. In the worst case, the rated RMS ripple current of the input capacitor needs to reach half of the charging current. At the same time, in order to suppress high-frequency oscillations caused by parasitic inductance and others at the switching moment, the input capacitor is best composed of the following three capacitors in parallel:

- Electrolytic capacitor: The capacitance value is determined by factors such as the characteristics of the input power supply and the charging current.
- Ceramic capacitor: The capacitance value is between 1uF and 10uF.
- High-frequency ceramic capacitor: The capacitance value is between 47nF and 1uF.

Output Capacitor

To reduce the ripple voltage at the output end and improve transient characteristics, the output capacitor (C3 in Figure 1) should be chosen with a smaller equivalent series resistance (ESR). The output capacitor is best composed of the following two capacitors in parallel:
Electrolytic capacitor: Capacitance value of 10uF
Ceramic capacitor: Capacitance value between 1uF and 10uF If the output capacitor can only use ceramic capacitors, it should be noted that some ceramic capacitors have a larger voltage coefficient, which reduces the effective capacitance value. When the battery is not connected, the voltage at the BAT pin may be too high. In this case, the output capacitance value should be appropriately increased, or several small capacitance ceramic capacitors should be connected in parallel to ensure that the voltage at the BAT pin is within a safe range when the battery is not connected.

Selection of Inductor

During normal operation, the inductor's transient current varies periodically. When the P-channel MOSFET is on, the input voltage charges the inductor, and the inductor current increases; when the P-channel MOSFET is off, the inductor discharges to the battery, and the inductor current decreases. The ripple current of the inductor increases as the inductance value decreases and increases with the increase of input voltage. A larger inductor ripple current can lead to a larger ripple charging current and magnetic loss. Therefore, the ripple current of the inductor should be limited within a reasonable range.

The ripple current of the inductor can be estimated by the following formula:

$$\triangle I_L = \frac{1}{(f)(L)} V_{BAT} \left(1 - \frac{V_{BAT}}{VCC}\right)$$

Among them: f is the switching frequency, 300KHz; L is the inductance value. V_{BAT} is the battery voltage, and VCC is the input voltage. When selecting the inductance value, the inductor ripple current can be limited to $\triangle IL \leqslant 0.3 \times I_{CH}$, where I_{CH} is the charging current. Please note that the maximum inductor ripple current △IL occurs at the maximum input voltage and the minimum inductance value. In addition to the aforementioned formula, the inductance value should also meet the requirements of the following formula:

$$L > 5 X (VCC - V_{BAT}) \quad (uH)$$

To ensure low electromagnetic radiation, the inductor should preferably be a surface-mount shielded inductor.

MOSFET Selection

For the SL37 63 application circuit, a P-channel MOSFET is required. When selecting this MOSFET, it is important to consider factors such as conversion efficiency, power consumption of the MOSFET, and the highest operating temperature.Internally within the chip, the gate drive voltage is clamped at 6.3V (typical value), which allows for the use of a P-channel MOSFET with a low threshold voltage. Therefore, it is necessary to pay attention to the breakdown voltage BVDSS of the MOSFET, ensuring it is greater than the maximum input voltage.Factors to consider when selecting a P-channel MOSFET include the on-resistance Rds(on), gate charge Qg, reverse transfer capacitance CRSS, input voltage, and maximum charging current.

The maximum power dissipation of the MOSFET can be approximated by the following formula:

$$Pd = \frac{VBAT}{VCC} \times Rds(on) \times ICH^2 \times (1+0.005dT)$$

Among them: Pd is the power consumption of the MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) VBAT is the maximum voltage of the battery VCC is the minimum input voltage Rds(on) is the on-state resistance of the P-channel MOSFET at room temperature (25° C) ICH is the charging current dT is the temperature difference between the actual temperature of the P-channel MOSFET and the room temperature (25° C) .

In addition to the on-state loss I2Rds(on) described by the previous formula, the MOSFET also has switching loss, which increases with the increase of the input voltage. Generally speaking, when the input voltage is less than 20V, the on-state loss is greater than the switching loss, and MOSFETs with smaller on-state resistance should be given priority; when the input voltage is greater than 20V, the switching loss is greater than the on-state loss, and MOSFETs with a smaller reverse conduction capacitance CRSS should be given priority. The value of CRSS is generally listed in the technical specifications of the MOSFET, if the capacitance value is not clearly stated, it can be estimated by the formula CRSS = $Q_{GD}/\Delta V_{DS}$.

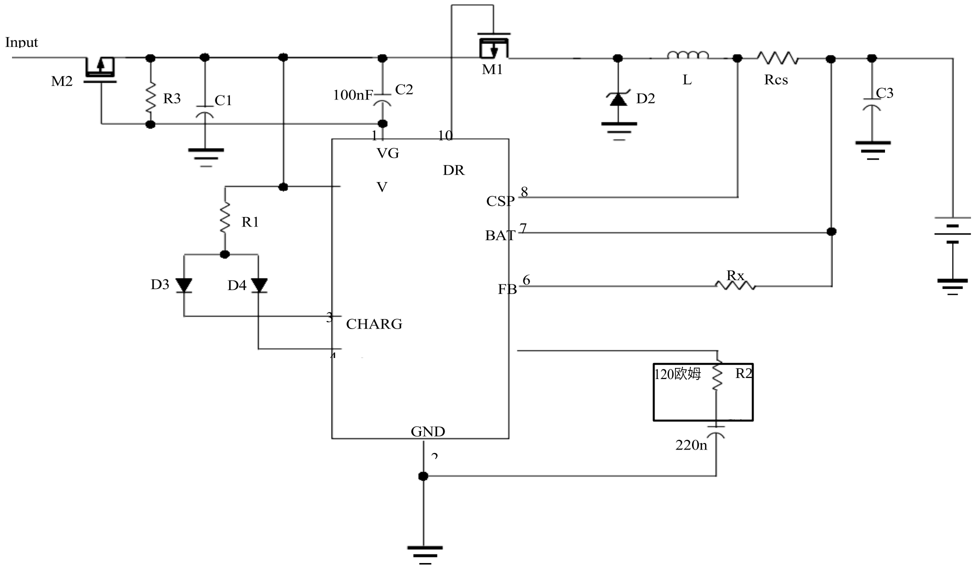
Diodes Selection In the typical application circuit diagram 1, diodes D1 and D2 are both Schottky diodes. The current passing capability of these two diodes must be at least greater than the charging current; the voltage resistance of the diodes must be greater than the requirement of the maximum input voltage. The selection principle for diodes D1 and D2 is to be sufficient, if the current passing capability or voltage resistance of the selected diode far exceeds the required value, due to the higher junction capacitance of such diodes, it will increase the switching loss of the charger and reduce efficiency. Diode D1 is used as a blocking diode to prevent the consumption of battery energy when the input power is cut off. In sleep mode, if diode D1 is not used, the battery current consumed by SL3763 is about 51 microamperes, so the use of diode D1 can be considered based on factors such as battery capacity. Sleep Mode Battery Current In the typical application circuit shown in Figure 1, when the input voltage is cut off or the input voltage is lower than the battery voltage, SL3763 enters sleep mode. The current consumed by the battery in sleep mode includes:

The current flowing into the BAT pin and CSP pin, which is about 9 microamperes (V_{BAT} = 12V).

The current flowing from the battery end through the blocking diode D1 to the input voltage end, which is determined by the leakage current of diode D1; If diode D1 is not used, the battery voltage is applied to the V_{CC} pin of SL3763 through the inductor, the body diode of the MOSFET, and the current flowing into the V_{CC} pin is about 44 microamperes (V_{BAT} = 12V).

The current flowing from the battery end through diode D2 to the ground (GND), which is determined by the leakage current of diode D2. Implementing input power reverse protection and preventing battery current backflow using P-channel MOSFET In the typical application circuit diagram 1, diode D1 is used to prevent battery current backflow. However, due to the forward voltage drop of the diode, when the current passing through is relatively large, the power consumption of the diode is relatively large. To solve this problem, in the circuit of Figure 4, the P-channel MOSFET M2 is used instead of diode D1, which can prevent battery current backflow and also achieve the function of input power reverse protection. Under normal circumstances, the technical requirements for the P-channel MOSFET M2 are: the voltage resistance between the drain and source must be greater than the maximum input power voltage, the voltage resistance between the source and gate must be greater than the battery voltage, the on-state resistance and the maximum drain current Id meet the requirements of the charging current. The resistor R3 is generally chosen to be 22 kilohms.

Figure 4: Implementing reverse polarity protection and preventing battery current backflow using a PMOS transistor.



About the suppression of high-frequency oscillations

In situations of high input voltage or large charging current, if the PCB layout and wiring are not reasonable, or if the parasitic inductance of the diodes and P-channel MOSFETs is relatively large, high-frequency oscillations above several hundred megahertz can be generated at the moment of the P-channel MOSFET's conduction or cutoff. Oscilloscopes can observe high-frequency oscillation waveforms at the positive pole of the input power supply and the negative pole of diode D2.

To suppress high-frequency radiation, in addition to improving the PCB layout and wiring, high-frequency suppression circuits can also be added, such as R5 and C5 shown in Figure 5.

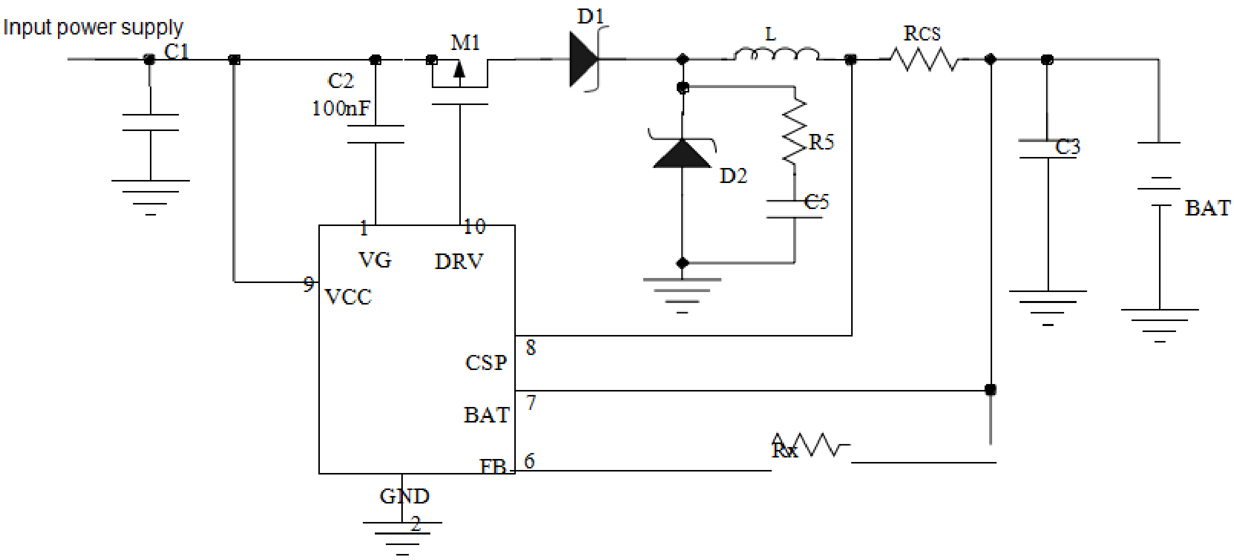


Fig.5. High-frequency oscillation suppression

Design Considerations for PCB

A well-designed PCB is crucial for ensuring the normal operation of SL3763, reducing electromagnetic radiation, and improving conversion efficiency. For the circuit shown in Figure 1, the following considerations should be made when designing the PCB:

(1) The positive terminal of the input filter capacitor should be close to the source of the P-channel MOSFET;

(2) Diodes D1 and D2 must be placed near the inductor, and the current sense resistor should be near the inductor;

(3) The output capacitor should be close to the current sense resistor;

(4) The leads of the input filter capacitor, P-channel MOSFET, diodes D1 and D2, inductor, current sense resistor, and output filter capacitor should be as short as possible;

(5) The ground end of the loop compensation components at the GND pin and COM pin of the SL3763 should be connected to the system ground separately to avoid switch noise affecting the stability of the loop. The ground end of the input capacitor, the positive terminal of diode D2, and the ground end of the output capacitor should be connected to the same copper plane before returning to the system ground. This point is very important to ensure the normal operation of SL3763.

(6) The placement direction of the current sense resistor RCS should ensure that the wiring from the CSP pin and BAT pin of the chip to RCS is relatively short. The wiring from the CSP pin and BAT pin to RCS should be on the same layer and as close as possible. To ensure the accuracy of the charging current detection, the CSP pin and BAT pin should be directly connected to the current sense resistor. As shown in Figure 6.

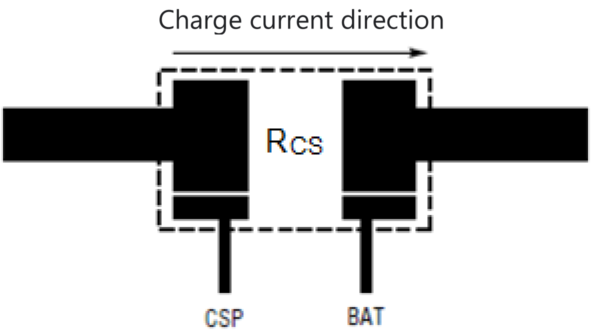
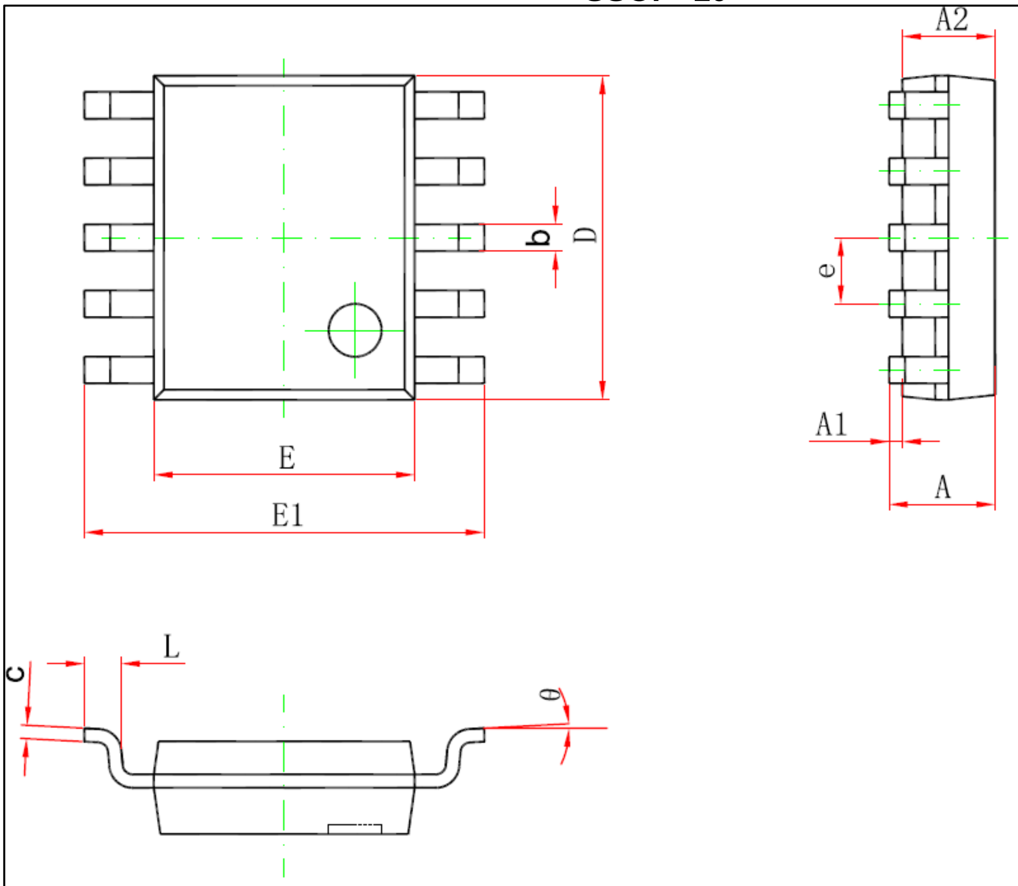


Figure 6 Detection of charging current

Package Dimensions

SSOP -10



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.300	0.450	0.012	0.018
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.000(BSC)		0.039(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	1°	8°