4A multi-cell battery charging management integrated circuit

Solar power maximum power point tracking feature

Description

SL3795 is a PWM buck mode multi-cell battery charging management integrated circuit that can be powered by a solar panel. It independently manages the charging of multiple batteries, with the advantages of a small package size, few peripheral components, and easy to use.

SL3795 features trickle, constant current, and constant voltage charging modes, making it very suitable for charging management of lithium batteries, lithium iron phosphate batteries, and lithium titanate batteries. In the constant voltage charging mode, SL3795 modulates the battery voltage to the voltage set by an external feedback resistor; in the constant current charging mode, the charging current is set by an external resistor. When powered by a solar panel, the internal circuit can automatically track the maximum power point of the solar panel, allowing users to make the most of the solar panel's output power without considering the worst case, making it very suitable for applications powered by solar panels.

For deeply discharged lithium batteries, when the battery voltage drops below 66.5% of the constant voltage charging voltage (typical value), SL3795 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 charging end state, if the charging current rises again to more than 58.8% of the constant current charging current, a new charging cycle automatically starts. When the input power is cut off or the input voltage is lower than the battery voltage, SL3795 automatically enters sleep mode.

Other functions include input under-voltage lockout, over-voltage protection at the battery end, and charging status indication.

SL3795 is available in a 10-pin SSOP package.

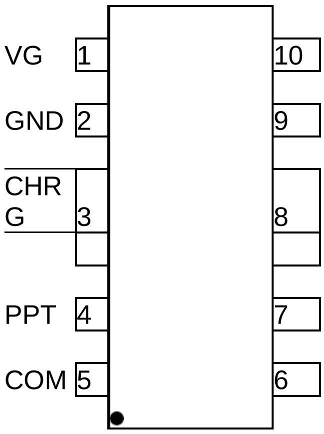
Feature

- Maximum Power Point Tracking (MPPT) for solar panels
- Complete charging management for single or multiple lithium batteries, lithium iron phosphate batteries, or lithium titanate batteries
- Wide input voltage range: 6.6V to 30V
- Can be used as a constant voltage source when no battery is connected
- Charging current up to 4A
- PWM switching frequency: 310KHz
- Constant voltage charging voltage set by external resistor
- Constant current charging current set by external resistor
- Trickle charging for deeply discharged batteries
- Automatic recharging function
- Charging status indication
- Soft start function
- Overvoltage protection at the battery terminal
- Operating temperature range: -40°C to +85°C
- Adopts 10-pin SSOP packaging
- Lead-free product, complies with RoHS, and is halogen-free

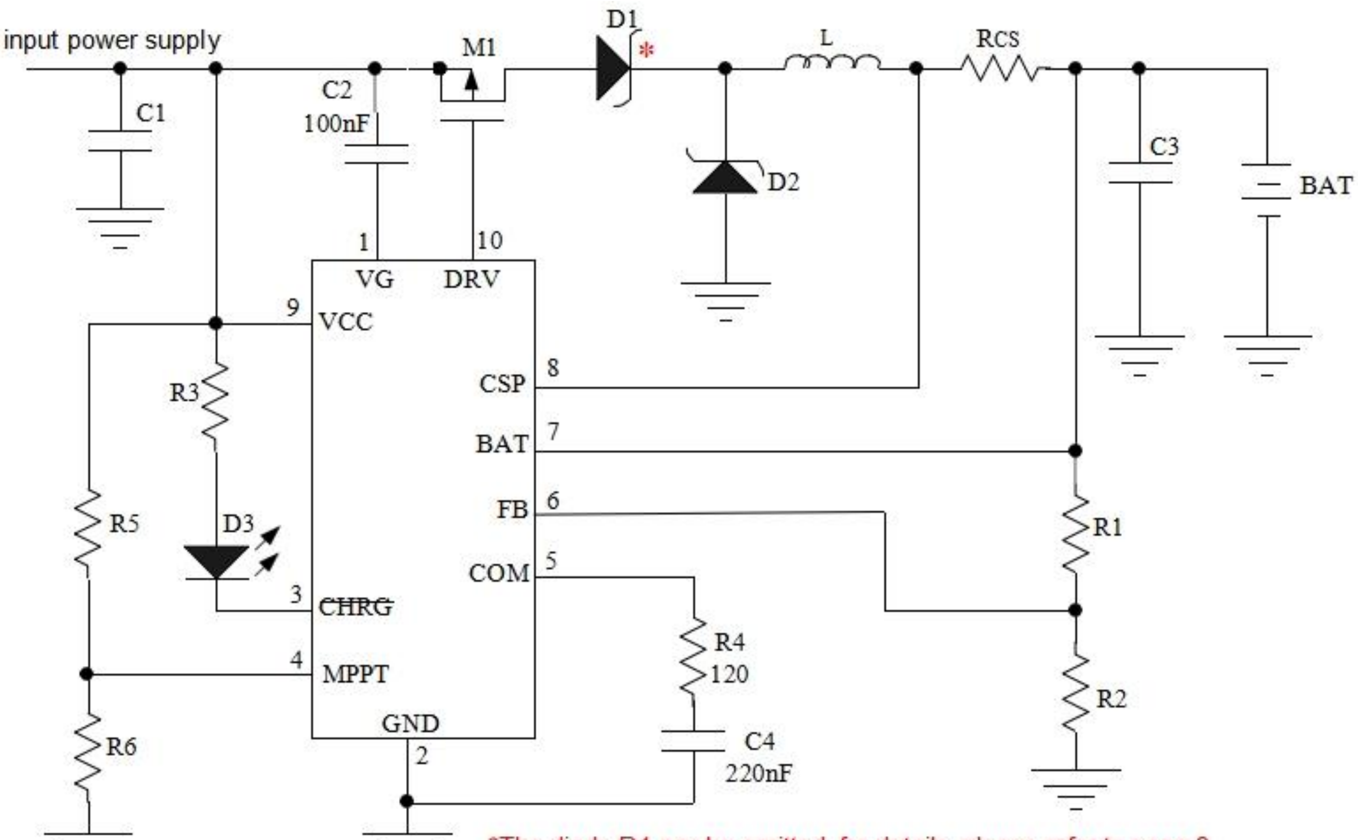
Application

- Handheld Devices
- Emergency Lights
- Spare Battery Applications
- Portable Industrial and Medical Instruments
- Power Tools
- Charging for Lithium Batteries, Lithium Iron
- Phosphate Batteries, and Lithium Titanate Batteries

Pin Configuration



Typical Application



*The diode D1 can be omitted, for details, please refer to page 9 "The Selection of Diodes"Sleep Mode Battery Current section"

Ordering Information

Type	Package	Operating ambient temperature
SL3795	Plates, 3000 pieces per plate	－40℃to ＋85℃

Pin Function

Pin Number	Pin Name	Pin Description
1	VG	The internal voltage regulator outputs.
2	GND	Ground
3	$\overline{\text{CHRG}}$	Battery Charging Indicator Terminal.
4	MPPT	Solar panel maximum power point tracking 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 $\overline{\text{CHRG}}$，DONE to GND .... －0.3V to 33V
Voltage from VG pin, DRV pin to VCC pin...................................... －8V to VCC＋0.3V
Voltage from CSP，BAT，FB to GND .... －0.3V to 27V
Voltage from MPPT, COM, FB 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℃ to 85℃ unless otherwise specified)

Parameter	Symbol	Test conditions	Min	Typ	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	1.193	1.205	1.22	V
FB pin bias current	I_{FB}	VFB=1.2V		60	300	nA
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}＝7.4V		10	15	µA
	I_{BAT2}	Sleep mode，V_{BAT}＝7.4V		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		58.8		%V_{REG}
overvoltage threshold	V_{ov}	BAT pin voltage rises	1.04	1.07	1.1	V_{REG}
overvoltage release threshold	V_{clr}	BAT Pin voltage drops	1.0	1.02	1.04	
$\overline{CHRG}$ pin						
$\overline{CHRG}$ pin Pull-down current	I_{CHRG}	V_{CHRG}＝1V，State of charge	7	12	18	mA
$\overline{CHRG}$ pin Leakage current	I_{LK1}	V_{CHRG}＝30V，End-of-charge status		1		µA
$\overline{MPPT}$ pin						
$\overline{MPPT}$ pin Pull-down current	I_{DONE}	V_{DONE}＝1V，End-of-charge status	7	12	18	mA
$\overline{MPPT}$ pin Leakage current	I_{LK2}	V_{DONE}＝30V，State of charge		1		mA
oscillator						
rate	f_{osc}		260	310	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}＝8V	0.0	0.05	0.1	V
Sleep mode release threshold(measure V_{CC}－V_{BAT})	V_{SLPR}	V_{CC} rising, V_{BAT}＝8V	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 SL3795 is a PWM buck-type multi-cell battery charging management integrated circuit that can be powered by a solar panel. It is suitable for charging management of single or multi-cell lithium batteries, lithium iron phosphate batteries, or lithium titanate batteries. The SL3795 features 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. The constant voltage charging voltage is set by the feedback resistor connected to the FB pin.

When the voltage at the VCC pin is greater than the low-voltage lockout threshold and also greater than the battery voltage, the SL3795 operates normally. 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 an internal 120mV reference voltage and an external resistor RCS, i.e., 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 status. 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 to indicate the end of charging.In the end-of-charging state, if the input power is disconnected and then reconnected, a new charging cycle will start; if the charging current rises above the recharge threshold again, a new charging cycle will also be automatically initiated.The SL3795 can be powered by a solar panel and has a maximum power point tracking (MPPT) function for solar panels. The maximum power point voltage of the solar panel is fed back to the MPPT pin after being divided by two resistors.

In the MPPT state, the voltage at the MPPT pin is modulated to 1.205V (typical value).When the input voltage is lost, the SL3795 automatically enters sleep mode, and the internal circuit is turned off.There is also an overvoltage comparator inside the SL3795.

When the voltage at the BAT pin rises due to load changes or sudden removal of the battery, 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 MOSFET, 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.

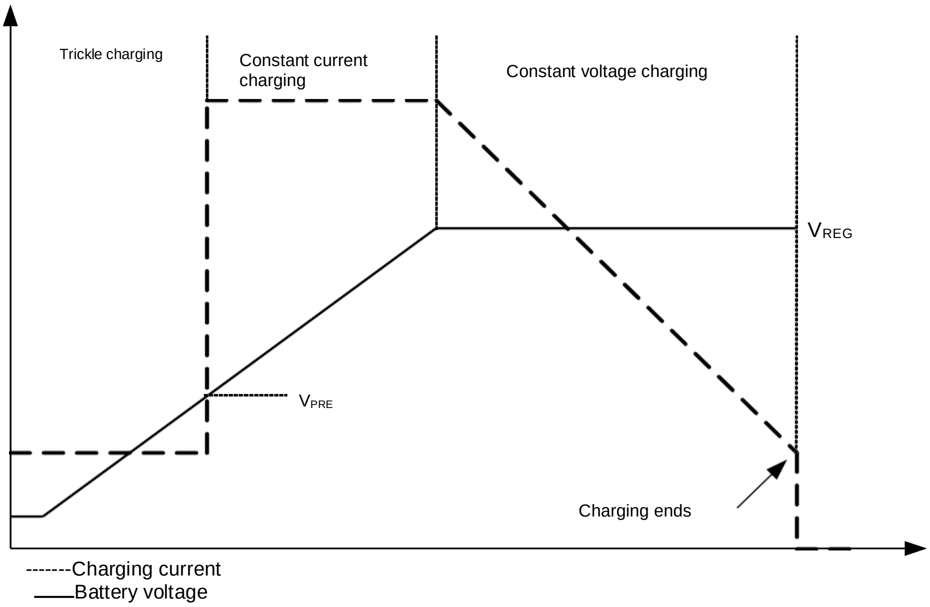


Figure 2 Schematic diagram of the charging process

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 SL3765 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 :

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

Among them:

ICH is the constant current charging current.

RCS is the current detection resistor connected between the CSP pin and the BAT pin.

Set the constant voltage charging voltage.As shown in Figure 1, the voltage at the battery end is fed back to the FB pin through the voltage divider network composed of resistors R1 and R2. The SL3795 determines the charging state based on the voltage at the FB pin. When the voltage at the FB pin approaches 1.205V, the charger enters the constant voltage charging state. In the constant voltage charging state, the charging current gradually decreases while the battery voltage remains constant.Considering the bias current flowing into the FB pin, the corresponding voltage at the battery end in the constant voltage charging state is:

$$V_{BAT} = 1.205 \times (1 + R_1 / R_2) + I_B \times R_1$$

From the above formula, it can be seen that the bias current of the FB pin causes an error in the voltage division result of the resistor network, and the error value is IB×R1. Assuming R1＝500KΩ, the error value is approximately 30mV. Therefore, when designing the resistor divider network, the above error should be taken into account. The set constant voltage charging voltage should not exceed 25V. Since resistors R1 and R2 will consume a certain current from the battery, when selecting the resistance values of R1 and R2, one should first choose the value of R1＋R2 based on the allowable consumed current, and then calculate the values of R1 and R2 separately according to the above formula.

Solar Cell Maximum Power Point Tracking

The SL3795 uses a constant voltage method to track the maximum power point of the solar panel. In the IV characteristic curve of the solar panel, when the ambient temperature is constant, the output voltage corresponding to the maximum power point is basically the same under different light intensities. That is, as long as the output voltage of the solar panel is kept at a constant voltage, the solar panel can output the maximum power under different light intensities at that temperature.The voltage of the MPPT pin for tracking the maximum power point of the solar panel in the SL3795 is modulated at 1.205V, in conjunction with the external two resistors (R5 and R6 in Figure 1) forming a voltage divider network, which can track the maximum power point of the solar panel.

The maximum power point voltage of the solar panel is determined by the following formula:

$$V_{MPPT} = 1.205 \times (1 + R_5 / R_6)$$

Charging Completion

In the constant voltage charging mode, the charging current gradually decreases. When the charging current decreases to 16% of the constant current charging current, the charging process ends, and the pin outputs a high-impedance state, indicating the end of charging. At this time, the SL3795 continues to charge the battery in a constant voltage manner to ensure the battery is fully charged.When the battery voltage is lower than 95.8% of the constant voltage charging voltage, even if the charging current decreases to 16% of the constant current charging current, the charging process does not end. That is to say, there are two conditions for the end of charging: one is that the battery voltage is greater than 95.8% of the constant voltage charging voltage; the other condition is that the charging current decreases to 16% of the constant current charging current.

Automatic Recharge

After the charging is completed, if the input power supply and the battery are still connected to the charger, due to the battery self-discharge or the load, causing the charging current to rise above 58.8% of the constant current charging current, the SL3795 automatically enters the charging state and starts a new charging cycle.

Status Indication

The SL3795 has an open-drain status indication output pin: $\overline{CHRG}$ Pin .During the charging state, $\overline{CHRG}$ Pin is pulled low by an internal transistor, and in other states, the $\overline{CHRG}$ pin is in a high-impedance state.When the battery is not connected to a charger, the SL3795 can output a constant voltage as a voltage source, with the voltage value set to the constant voltage charging voltage. At this time, the $\overline{CHRG}$ pin is in a high-impedance state.When the status indication function is not used, connect the pin to ground.

Table 1 lists the charger status corresponding to the $\overline{CHRG}$ pin. It is assumed that a red LED is connected to the pin, and the connection method is shown in Figure 1.

$\overline{CHRG}$ **pin**	**Status reason**
Low level (red LED on)	charging
High impedance state (red LED off)	Three possible scenarios ● The VCC pin voltage is lower than the low-voltage latching voltage, ● The voltage of the VCC pin is lower than that of the BAT tube Foot voltage ● Charging ends

Table 1 Status indication description

Off-chip power MOSFET driver

The DRV pin of the SL3795 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 SL3795 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 SL3795, 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

When the battery is not connected to the charger, the SL3795 can be used as a constant voltage source, with its output voltage value set to the constant voltage charging voltage, and the maximum output current set to the constant current charging current.

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,
- VCC is the input voltage.

When selecting the inductance value, the inductor ripple current can be limited to $\triangle IL \leqslant 0.3 \times ICH$, where ICH is the charging current. Please note that the maximum inductor ripple current $\triangle IL$ 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:

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

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

MOSFET Selection

For the SL3795 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)
- V_{BAT} 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 $CR_{SS} = Q_{GD} / \Delta V_{DS}$.

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 SL3795 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, SL3795 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 10 uA (V_{BAT} = 8 V)
- 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 SL3795 through the inductor, the body diode of the MOSFET, and the current flowing into the V_{CC} pin is about 42uA(V_{BAT}＝8V)
- The current that flows from the battery terminal through diode D2 to ground (GND) is determined by the leakage current of diode D2.

Regarding the Suppression of High-Frequency Oscillation

In the case of high input voltage or large charging current, if the PCB layout and wiring are not reasonable, or if the parasitic inductance of the diode and the P-channel MOSFET is relatively large, high-frequency oscillations above several hundred megahertz can be generated at the moment when the P-channel MOSFET is turned on or off. High-frequency oscillation waveforms can be observed on the positive pole of the input power supply and the negative pole of diode D2 using an oscilloscope. To suppress high-frequency radiation, in addition to improving the PCB layout and wiring, high-frequency suppression circuits can be added, such as R5 and C5 in Figure 3.

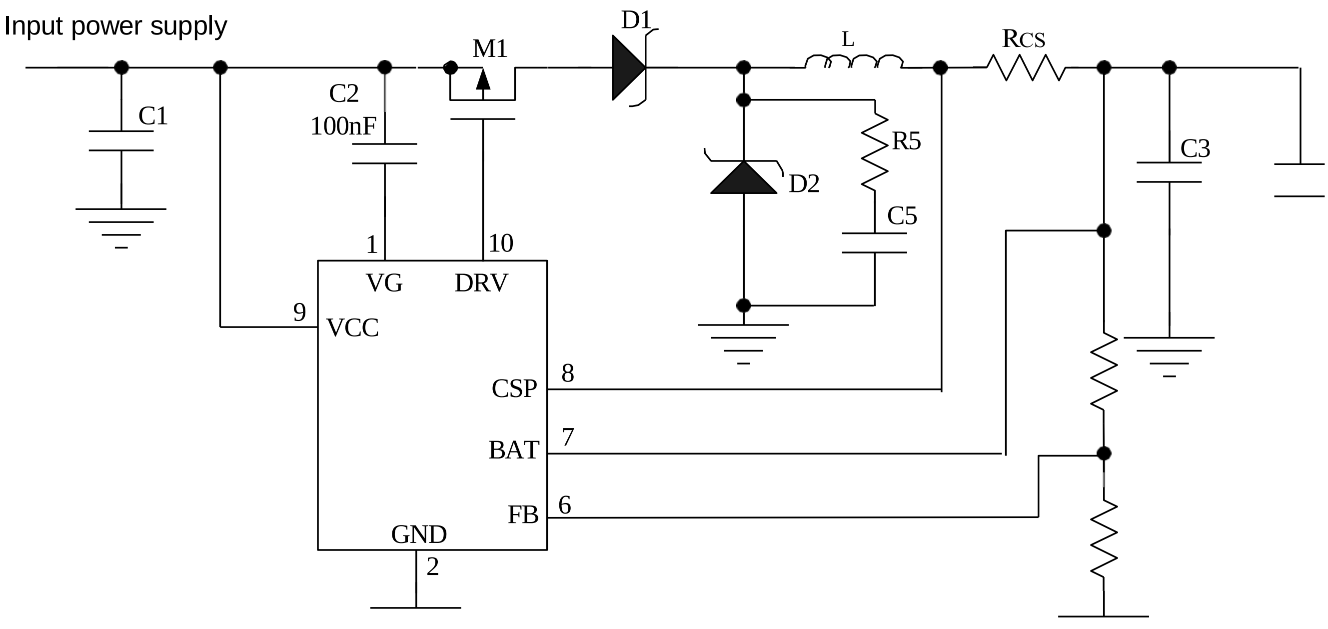


Fig.3. Suppression of high-frequency oscillations

Design Considerations for PCB

A well-designed PCB is crucial for ensuring the normal operation of SL3795, 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) Resistors R1, R2, R4, R5, R6, and capacitor C4 should be placed as close as possible to the SL3795.

(6) The ground terminals of the SL3795's GND pin, resistors R2 and R6, and the ground terminal of the COM pin's loop compensation components should be connected to the system ground separately to avoid switch noise affecting the stability of the loop. The ground terminal of the input capacitor, the anode of diode D2, and the ground terminal of the output capacitor should first be connected to the same copper pad before returning to the system ground. This point is very important to ensure the normal operation of the SL3795.

(7) The placement of the current detection resistor RCS should ensure that the connections from the chip's CSP pin and BAT pin to the RCS are relatively short. The connections from the CSP pin and BAT pin to the 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 detection resistor. As shown in Figure 4.

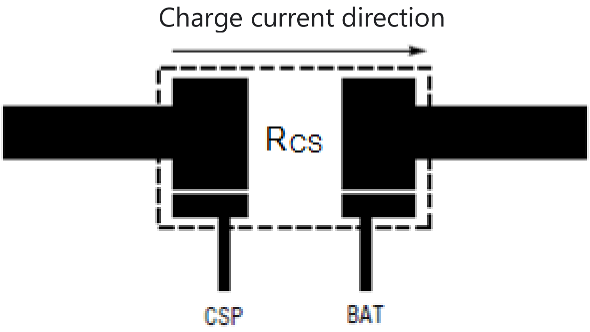
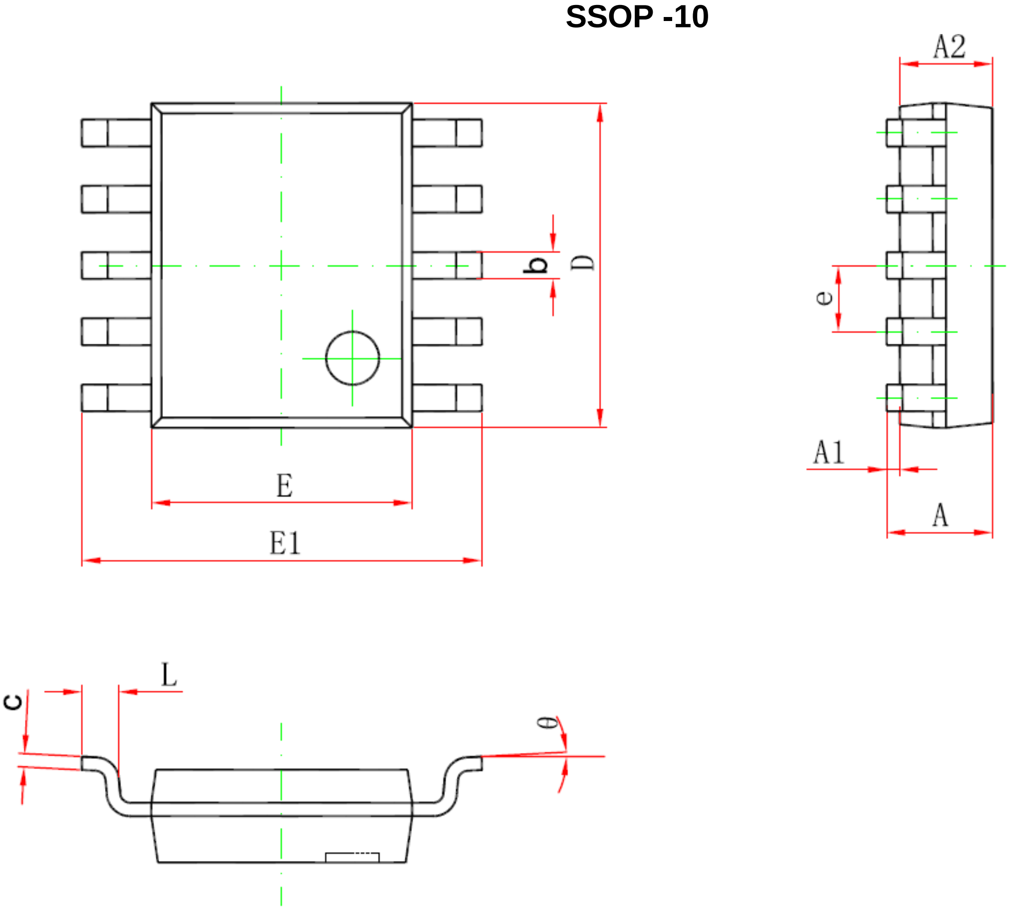


Figure 4 Detection of charging current

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°