SC8802 High Efficiency, Synchronous, Bi-directional Buck-Boost Charger

1 Description

SC8802 is a synchronous 4-switch buck-boost charger controller. It is able to effectively manage charging no matter input/output voltage is higher, lower or equal to battery voltage. When system needs to discharge from battery, SC8802 will deliver desired output from the battery without extra efforts.

SC8802 supports very wide input and output voltage range. It can support applications from 2.7V to 30V input range and 2V to 30V output range. SC8802 hence is suitable for applications of 1 to 6 series battery modules. The driver voltage is set to 10V to fully utilize external MOSFETs for maximum efficiency.

SC8802 supports bi-directional outputs by controlling DIR pin. It supports input current limit, output current limit, dynamic output voltage regulation, internal current limit, output short protection and over temperature protections to ensure safety under different abnormal conditions.

SC8802 adopts 32 pin QFN 4x4 package.

3 Applications

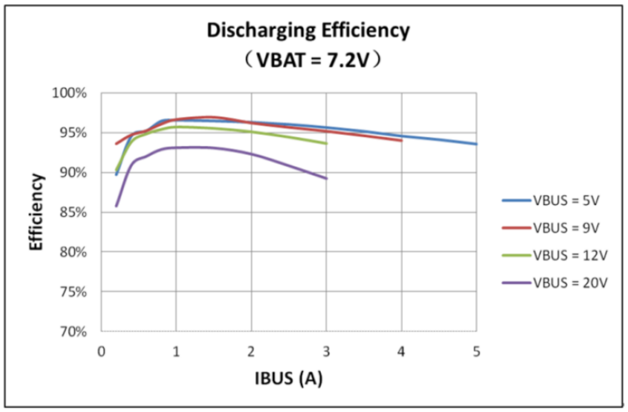
Power Bank
USB HUB
Smart USB Sockets
USB PD
Car Charger
Industrial applications

4 Device Information

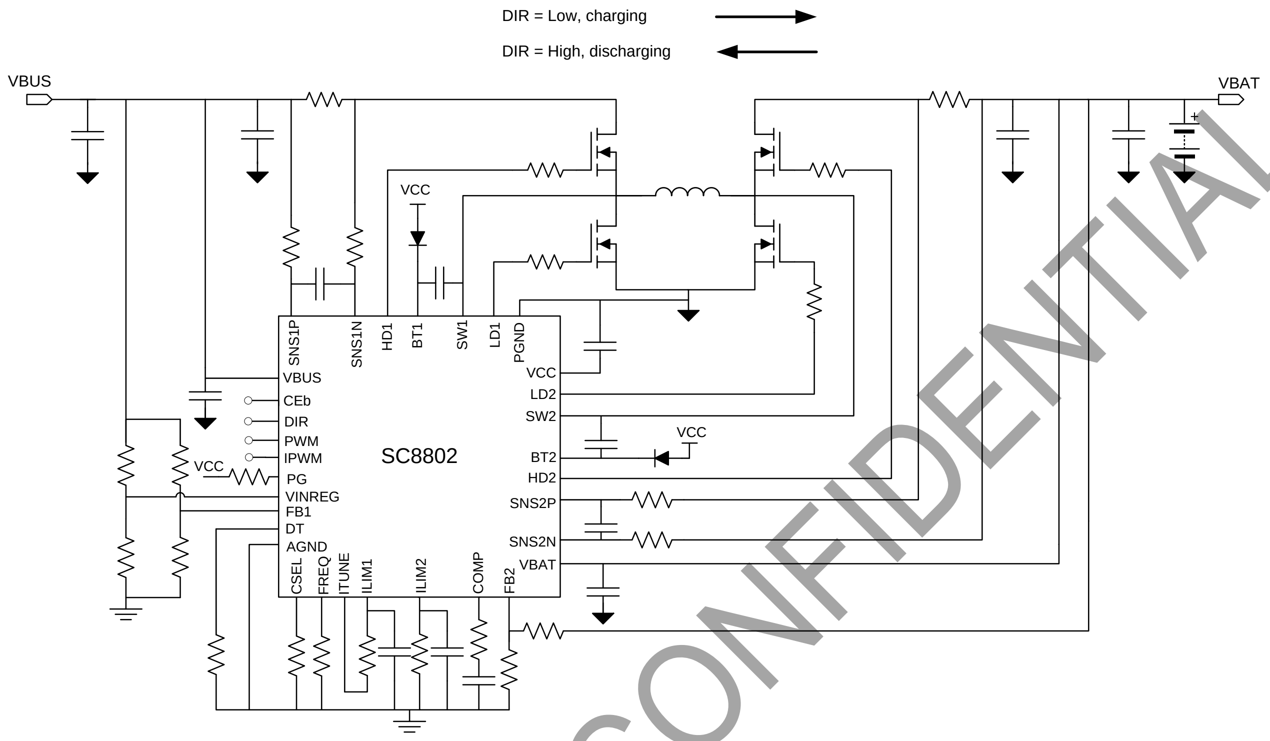
ORDER NUMBER	PACKAGE	BODY SIZE
SC8802QDER	32 pin QFN	4mm x 4mm x 0.75mm

2 Features

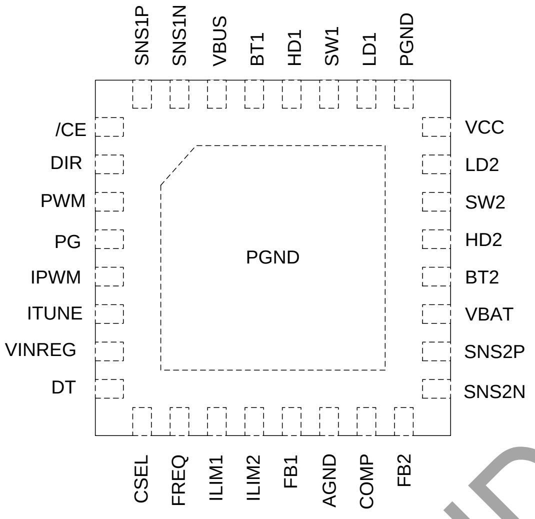
- Buck-Boost battery charging management supports 1 to 6 battery in series, including trickle charging, CC charging, CV charging and charging termination function
- Reverse buck-boost operation output (discharging mode)
- Wide input voltage range: 2.7 V to 30 V
- Wide reverse operation output range : 2V to 30V
- Dynamic adjustable output voltage in discharging mode
- Dynamic adjustable input and output current limit
- High efficient buck-boost operation
- Integrated 10V, 2A gate driver
- Bi-directional output short protection
- Adjustable frequency from 200KHz to 600KHz
- Internal current limit
- Under voltage protection
- QFN-32 package



5 Typical Application Circuit



6 Terminal Configuration and Functions



TERMINAL		I/O	DESCRIPTION
NUMBER	NAME		
1	/CE	I	Chip Logic Enable, /CE=Low, chip enable. Internal pull low
2	DIR	I	DIR sets working directions of the chip. When DIR is logic low, SC8802 is in charging mode, when DIR is logic high, SC8802 enters reverse operation mode.
3	PWM	I	PWM pin accepts PWM waveform from 20K to 100K to adjust the VBUS output voltage in discharging mode. By adjusting duty cycle, output voltage can be adjusted according to needs. When duty=0, output voltage = 1/6 of the preset value by the FB1 resistor divider. When duty = 100%, output voltage = preset value. $VBUS = V_{BUS\_SET} \times (\frac{1}{6} + \frac{5}{6} \times D)$
4	PG	O	Open drain, needs to connect to a pull up resistor. If not used, can be left floating. When DIR = low (charging mode): PG pin outputs high impedance to indicate the End of Charging status. PG pin is pulled to ground internally when SC8802 is in charging status. When DIR = high (discharging mode), PG pin functions as a pure power good indication. It outputs high impedance when VBUS is within 90% to 110% of the output target.
5	IPWM	I	IPWM frequency ranges from 20kHz to 100kHz. User can adjust current limit through the duty cycle of the signal, eg, if ILIMT1 resistor is connected to ITUNE，detailed current limit of VBUS current is set by： $I_{BUS} = I_{LIM1\_SET} \times D$ In the equation above，I_{LIM1_SET} is the current limit value set by the resistor. D is the duty cycle of the IPWM signal.
6	ITUNE	IO	ITUNE selects the current object to be adjusted via IPWM. Eg, If the current limit resistor is connected between ITUNE and ILIM1, the current through VBUS is adjusted by IPWM. If VBAT current needs to be adjusted, connect the current limit resistor between ILIM2 and ITUNE.

7	VINREG	I	Connect a resistor divider to set the minimum VBUS operation voltage to realize the dynamic power management function in charging mode. The IBUS charging current will be reduced automatically to avoid over loading the adapter once the VBUS voltage drops to the set value. Connect to >1.3V voltage to disable VINREG function. VINREG function is only valid in charging mode.
8	DT	I	Dead time program pin. Connect a resistor to ground to program the dead time. Short to ground: 20ns 68 kΩ: 40ns 270 kΩ: 60ns Open: 80ns
9	CSEL	I	A resistor from CSEL pin to ground sets the charging termination voltage in charging mode. Short to ground: to allow adjustable charging termination voltage. Use external resistor divider at FB2 to set the charging termination voltage 68 kΩ: fixed charging termination voltage, 4.2V 270 kΩ: fixed charging termination voltage, 8.4V Open: fixed charging termination voltage, 12.6V
10	FREQ	I	Connect a resistor to set the switching frequency. Short to ground 200kHz 68 kΩ: 400KHz Open: 600KHz
11	ILIM1	I	Connect a resistor to set the current limit value of IBUS current. $I_{BUS\_LIM} = \frac{V_{REF}}{R_{ILIM1}} \times \frac{R_{SS1}}{R_{SNS1}}$ V_{REF} is the internal reference voltage 1.21V; R_{LIM1} is the resistor from ILIMT1 to ground or to ITUNE; R_{SNS1} is the current sense resistor. Recommended 5mΩ-20mΩ， typical 10mΩ; R_{SS1} are the resistors connected to SNS1P， SNS1N. The two resistors must be equal and the recommended value is 1kΩ. A 10nF capacitor from ILIM1 to ground is needed to bypass noise. If current limiting function is not needed, please short ILIM1 to ground.
12	ILIM2	I	Connect a resistor to set the current limit value of IBAT current. $I_{BAT\_LIM} = \frac{V_{REF}}{R_{ILIM2}} \times \frac{R_{SS2}}{R_{SNS2}}$ V_{REF} is the internal reference voltage 1.21V； R_{LIM2} is the resistor from ILIM2 to ground or to ITUNE； R_{SNS2} is current sensing resistor. Recommended 5mΩ-20mΩ， typical 10mΩ； R_{SS2} are the resistors connected to SNS2P， SNS2N. The two resistors must be equal and the recommended value is 1kΩ. A 10nF capacitor to ground is needed to bypass noise. ILIM2 can’t be short to ground.

13	FBI	I	Feedback node of VBUS pin voltage. It is only valid when DIR = High. When DIR = High, the controller works in reverse conduction mode, and the FBI voltage is regulated at a reference voltage. $VBUS = V_{REF} \times \left(1 + \frac{R_{UP}}{R_{DOWN}}\right)$ V_{REF} equals to 1.21V. R_{UP} and R_{DOWN} are the value of voltage divider.
14	AGND	IO	Analog Ground
15	COMP	O	Compensation for the control loop. Connect external RC network to AGND
16	FB2	I	Feedback node of VBAT voltage. It is only valid when DIR = low. When DIR = Low, and CSEL pin is short to ground, the FB2 voltage is regulated at a reference voltage. $VBAT = V_{REF} \times \left(1 + \frac{R_{UP}}{R_{DOWN}}\right)$ V_{REF} equals to 1.22V. R_{UP} and R_{DOWN} are the value of voltage divider. If fixed termination voltage is set by CSEL pin, leave FB2 pin floating..
17	SNS2N	I	Negative input of current sense amplifier. Connect an external current sense resistor between SNS2P and SNS2N.
18	SNS2P	I	Positive input of current sense amplifier. Connect an external current sense resistor between SNS2P and SNS2N.
19	VBAT	I	Output node of the converter when DIR = Low, and input node of the converter when DIR = High. Connect to battery cells.
20	BT2	I	Connect a capacitor between BT2 pin and SW2 pin to bootstrap a voltage to provide the bias voltage for high side MOSFET gate driver 2.
21	HD2	O	High side MOSFET gate driver 2 output.
22	SW2	I	Switching Node 2.
23	LD2	O	Low side MOSFET gate driver 2 output.
24	VCC	O	Output of internal regulator to provide max. 10V voltage for the bias voltage of internal gate drivers. Connect a 1 µF ceramic capacitor from VCC to PGND pin.
25	PGND	I	Power Ground.
26	LD1	O	Low side MOSFET gate driver 1 output.
27	SW1	I	Switching Node 1.
28	HD1	O	High side MOSFET gate driver 1 output.
29	BT1	I	Connect a capacitor between BT1 pin and SW1 pin to bootstrap a voltage to provide the bias voltage for high side MOSFET gate driver 1.
30	VBUS	I	Input node of the converter when DIR = Low, and output node of the converter when DIR = High. Connect to adapter input port or USB port.
31	SNS1N	I	Negative input of current sense amplifier. Connect an external current sense resistor between SNS1P and SNS1N.
32	SNS1P	I	Positive input of current sense amplifier. Connect an external current sense resistor between

			SNS1P and SNS1N.
	Thermal Pad	-	For thermal dissipation. Connect to AGND and PGND.

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Voltage range at terminals(2)	VBUS, VBAT, SNS1P, SNS1N, SNS2P, SNS2N, /CE	-0.3	42	V
	VBUS to SNS1P, SNS1N	-0.3	11	V
	VBAT to SNS2P, SNS2N	-0.3	11	V
	SNS1P to SNS1N	-10	10	V
	SNS2P to SNS2N	-10	10	V
	SW1, SW2	-1	42	V
	VCC, PG, DIR, PWM, VINREG, IPWM	-0.3	20	V
	FREQ, ITUNE, ILIM1, ILIM2, COMP, CSEL, DT, FB1, FB2	-0.3	5.5	V
	LD1, LD2	-0.3	12	V
	BT1, HD1 to SW1	-0.3	12	V
	BT2, HD2 to SW2	-0.3	12	V
	BT1 to HD1	-0.3	12	V
	BT2 to HD2	-0.3	12	V
	BT1, BT2	-0.3	50	V
T_J	Operating junction temperature range	-40	150	°C
T_{stg}	Storage temperature range	-65	150	°C

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal.

7.2 Thermal Information

THERMAL RESISTANCE(1)		QFN-32 (4mm x 4mm)	UNIT
Θ_{JA}	Junction to ambient thermal resistance	35	°C/W
Θ_{JC}	Junction to case resistance	7	°C/W

(1) Measured on JESD51-7, 4-layer PCB.

7.3 Handling Ratings

PARAMETER	DEFINITION	MIN	MAX	UNIT
ESD(1)	Human body model (HBM) ESD stress voltage(2)	-2	2	kV
	Charged device model (CDM) ESD stress voltage(3)	-750	750	V

(1) Electrostatic discharge (ESD) to measure device sensitivity and immunity to damage caused by assembly line electrostatic discharges into the device.

(2) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(3) Level listed above is the passing level per EIA-JEDEC JESD22-C101. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.4 Recommended Operating Conditions

		MIN	TYP	MAX	UNIT
V_{BUS}	VBUS voltage range	2.7		36	V
V_{BAT}	VBAT voltage range	2		30	V
C_{BUS}	VBUS Capacitance	30			µF
C_{BAT}	VBAT capacitance	30			µF
L	Inductance	2.2		10	µH
$R_{SNS1/2}$	Current Sensing Resistor	5		20	mΩ
f_{SW}	Operating frequency range	200		600	kHz
f_{PWM}, f_{IPWM}	PWM signal frequency range	20		100	kHz
D_{PWM},D_{IPWM}	PWM signal duty cycle range	0		100	%
T_J	Operating junction temperature	-40		125	°C

7.5 Electrical Characteristics

T_J= 25°C and V_{BUS} = 12V, V_{BAT} = 5V, R_{SS1} = R_{SS2} = 1kΩ unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE (VBUS, VBAT)						
V_{BUS}	Operating voltage	DIR = Low, as input voltage	2.7		36	V
		DIR = High, as output voltage	2		36	V
V_{BAT}	Operating voltage	DIR = Low, as output voltage	1.5		30	V
		DIR = High, as input voltage	2.7		30	V
V_{UVLO_VBUS}	VBUS under-voltage lockout threshold	DIR = Low, rising edge		2.6	2.7	V
		DIR = Low, hysteresis		160		mV
V_{UVLO_VBAT}	VBAT under-voltage lockout threshold	DIR = High, rising edge		2.6	2.7	V
		DIR = High, hysteresis		160		mV
I_Q	Standby current into VBUS or VBAT pin (whichever is higher)	/CE = low, controller non-switching		0.7	2	mA
I_{Q_VBAT}	Standby current into VBAT pin under EOC status	/CE = low, VBUS removed			15	µA
I_{SD}	Shutdown current into VBUS or VBAT pin (which is higher)	/CE = high		6	10	µA
	Shutdown current into VBUS or VBAT pin (which is lower)	/CE = high			2	µA
VCC AND DIRVER						
V_{CC}	VCC clamp voltage		9.4	10	10.6	V
I_{VCC_LIM}	VCC current limit	V_{CC} = 2V ~10V	50	75	100	mA
R_{HVx_pu}	High side driver pull up resistor			1.5		Ω
R_{HVx_pd}	High side driver pull down resistor			1		Ω
R_{LVx_pu}	Low side driver pull up resistor			1.5		Ω
R_{LVx_pd}	Low side driver pull down resistor			1		Ω
ERROR AMPLIFIER						
V_{FB2_REF}	FB2 reference voltage		1.214	1.22	1.226	V
V_{INREG_REF}	VINREG reference voltage		1.196	1.226	1.244	V
V_{ILIMx_REF}	ILIMx reference voltage		1.196	1.212	1.228	V
V_{FB1_REF}	FB1 reference voltage		1.196	1.212	1.228	V
Gm_{EA}	Error amplifier gm			0.16		mS
R_{OUT}	Error amplifier output resistance (1)			20		MΩ
$I_{BIAS(FBx)}$	FBx pin input bias current	FBx in regulation			100	nA
OUTPUT TARGET AND THRESHOLD						
V_{BAT_TRGT}	Battery termination target	R_{CSEL} = 68 kΩ (±10%)	4.158	4.2	4.242	V
		R_{CSEL} = 270 kΩ (±10%)	8.316	8.4	8.484	V
		R_{CSEL} = open	12.474	12.6	12.726	V
V_{BAT_TERM}	Termination threshold over V_{BAT_TRGT}	DIR = Low, rising edge	96.5%	98%	99.5%	
V_{BAT_RECH}	Recharge threshold over V_{BAT_TRGT}	DIR = Low, falling edge		95.8%		
V_{TRK_CH}	Trickle charge threshold over V_{BAT_TRGT}	DIR = Low, rising edge	64%	70%	76%	
		DIR = Low, hysteresis		5%		

I_{BAT_TRK}	Battery trickle charge current, over ILIM2 set current	DIR = Low		10%		
I_{BAT_TERM}	Battery current termination threshold, over ILIM2 set current	DIR = Low, falling edge		4%		
V_{OVP}	OVP threshold, over VBUS target	DIR = high	105%	110%	115%	
CURRENT LIMIT						
I_{LIMx}	ILIM1 current limit accuracy DIR = low	I_{BUS_LIM} R_{SNS1} ≥ 30 mV	-10%		10%	
	ILIM2 current limit accuracy DIR = low	I_{BAT_LIM} R_{SNS2} ≥ 30 mV	-5%		5%	
	ILIM1 current limit accuracy DIR = high	I_{BUS_LIM} R_{SNS1} ≥ 30 mV	-5%		5%	
	ILIM2 current limit accuracy DIR = high	I_{BAT_LIM} R_{SNS2} ≥ 30 mV	-10%		10%	
SWITCHING FREQUENCY						
f_{SW}	Switching frequency	R_{FREQ} = 0Ω	180	210	240	kHz
		R_{FREQ} = 68kΩ (±10%)	360	410	460	kHz
		R_{FREQ} = 270kΩ (±10%)	540	600	660	kHz
INDICATION						
$t_{PG\_deglitch}$	PG signal deglitch time	f_{sw} = 200kHz	27	38.5	50	ms
I_{SINK_PG}	PG sink current	V_{PG} = 0.4 V	3.6	4.1	4.6	mA
V_{BUS_PG}	VBUS power good threshold	DIR = High, high limit falling edge (PG from low to high)		110%		
		DIR = High, high limit hysteresis (PG from high to low)		5%		
		DIR = High, low limit rising edge (PG from low to high)		90%		
		DIR = High, low limit hysteresis (PG from high to low)		5%		
LOGIC CONTROL						
R_{PD}	/CE, DIR pin internal pull down resistor			1		MΩ
	PWM pin internal pull down resistor			0.5		MΩ
	IPWM pin internal pull down resistor			1		MΩ
V_{IL}	/CE, DIR, PWM, IPWM input low voltage				0.4	V
V_{IH}	/CE, DIR PWM, IPWM input high voltage		1.2			V
Soft Start						
t_{SS}	Internal soft-start time	From /CE low to 90% VBUS		8	15	ms
THERMAL SHUTDOWN						
T_{SD}	Thermal shutdown temperature (1)			165		°C
	Thermal shutdown hysteresis (1)			15		°C

(1) Guarantee by design

8 Detailed Description

The SC8802 is 1- to 6-cell bi-directional synchronous buck-boost battery charge controller with supporting a wide input/output voltage range. The charging and discharging mode is selected by DIR pin.

The SC8802 operates as charger when it is in charging mode. No matter the input voltage is higher or lower compared to battery voltage, the SC8802 charges the battery by changing the mode to buck or boost automatically.

The SC8802 features trickle charging, CC charging, CV charging and charging termination functions. Charging current is monitored by the voltage across the sense resistor and controlled dynamically. The SC8802 supports self-adaptive feature for different adaptors and can limit the charging current automatically to avoid overloading adaptors.

In discharging mode, because of a synchronous 4-switch buck-boost structure, SC8802 regulates the output voltage at, above, or below, the input voltage. The SC8802 also features automatic buck, boost mode change, smooth transition and maximum input and output current limit capability using additional resistors. Accompany with USB PD IC, the SC8802 can achieve quick charge and PD feature easily.

8.1 Charging Mode

Charging mode and Discharging mode is selected by DIR pin.

When DIR pin is below the threshold (0.4V typical), SC8802 works as charging mode and current flows from adaptor connector (VBUS) to battery (VBAT) to charge

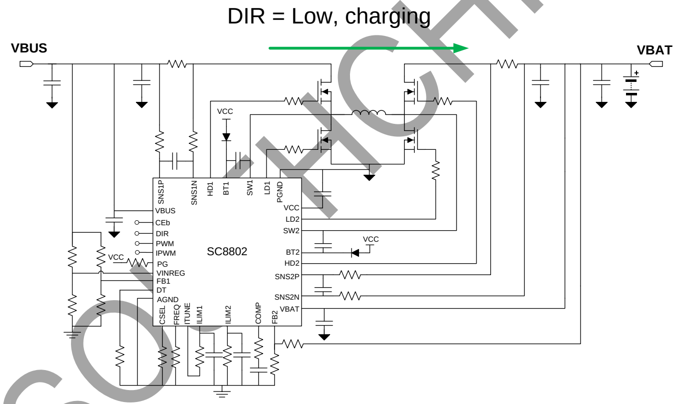


Figure 1. SC8802 Charging mode

8.1.1 Charge termiantion voltage setting (CSEL and FB1)

In Charging mode, termination voltage is set by one of two cases.

Case 1: Set the termination voltage using CSEL pin. When the SC8802 is enabled, the IC checks the resistor value at CSEL pin and set the charge termination voltage internally.

Table 1 shows the resistor value for different charge termination voltage.

Table 1. CSEL resistor value vs Charge termination voltage

CSEL resistor value	Charge termination voltage
68kΩ	4.2V (1S battery)
270kΩ	8.4V (2S battery)
Open	12.6V (3S battery)
0Ω	Set by FB2 pin resistors

When setting the charge termination voltage by CSEL pin, the battery voltage is monitored by VBAT pin voltage directly. In this case, FB2 pin should be open or connected to GND.

The SC8802 checks the resistor value at CSEL pin only during the startup process. After SC8802 is enabled, termination voltage change by changing resistor value at CSEL pin will not be valid until system restarts (Off and on the VBUS voltage or cycling the /CE voltage)

Case 2: Set the termination voltage using resistor divider at FB2 pin. When CSEL pin is connected to GND, termination voltage is adjusted by external resistor divider at FB2 pin and is calculated as:

$$VBAT = V_{FB2\_REF} \times \left(1 + \frac{R_{UP}}{R_{DOWN}}\right)$$

With V_{FB2_REF} voltage is 1.22V and R_{UP} and R_{DOWN} resistors are the resistor divider between VBAT to FB2 pins.

8.1.2 CC Charge current setting (ILIMx)

The SC8802 can adjust the current limit of both adaptor side (VBUS) and battery side (VBAT) by resistors at ILIM1 and ILIM2 pins.

Table 2 Charge current limit setting

Control Pins	Description
ILM1	Monitor R_{SNS1} to set the adaptor side (VBUS) charge current (IBUS_LIM)
ILM2	Monitor R_{SNS2} to set the battery side (VBAT) charge current (IBAT_LIM)

The SC8802 senses the VBUS and VBAT current by monitoring R_{SNS1} and R_{SNS2} respectively as below figure shows.

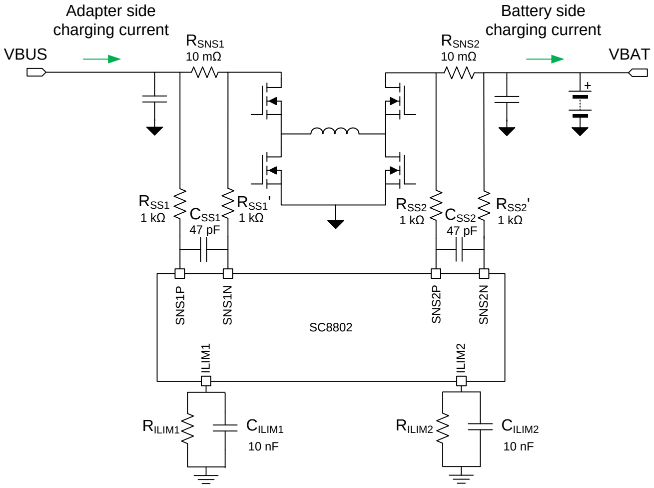


Figure 2 Charge current monitoring circuit

R_{SNSX} is the current sense resistor (x means 1 or 2) connected in series with the input supply or output of the charger. The SC8802 monitors the voltage across the sense resistors R_{SNSx} through R_{SSX} and $R_{SSX'}$ and calculate the input and output current. C_{SSX} is the filter capacitor and typically 47pF is sufficient.

The ILIMx pin is used to set the charge current limit. Connect the R_{ILIMX} resistor between $ILIM_X$ pin and GND with 10nF capacitor in parallel.

The current limit is calculated as:

$$I_{BUS\_LIM} = \frac{V_{LIM\_REF}}{R_{ILIM1}} \times \frac{R_{SS1}}{R_{SNS1}}$$

$$I_{BAT\_LIM} = \frac{V_{LIM\_REF}}{R_{ILIM2}} \times \frac{R_{SS2}}{R_{SNS2}}$$

Where:

V_{LIM_REF} = Internal reference voltage 1.21V;

R_{ILIMx} = Resistors at ILIMx pin;

R_{SNSx} = Current sense resistors;

R_{SSx} = Resistors between current sense resistor and the SC8802 pins (SNSxP, SNSxN).

To get accurate values, keep below two conditions;

1) R_{SNSx} should be placed between MOSFET and input/ output capacitor.

2) R_{SS1} and $R_{SS1'}$ should be same value; R_{SS2} and $R_{SS2'}$ should be also same value. Typically 1kΩ resistor is used.

RSNS1 and RSNS2 current sense resistors must be used for normal operation. SNS1P pin must connect to VBUS so the SNS1P and VBUS pins have the same voltage; SNS2N pin must connect to VBAT so the SNS2N and VBAT pins have the same voltage.

If R_{SNSx} is changed, $R_{SSX}/R_{SSX'}$ values need to be adjusted accordingly with below calculation:

$$\frac{R_{SNSx}}{R_{SSx}} = \frac{10\ m\Omega}{1\ k\Omega}$$

For example, If R_{SNSX} is 20mΩ, then $R_{SSX}/R_{SSX'}$ should be 2kΩ; if R_{SNSX} is 5mΩ, then $R_{SSX}/R_{SSX'}$ should be 500Ω.

In charging mode, if both VBUS and VBAT current limits are programmed, the SC8802 controls the charge current as soon as one of VBUS and VBAT current reaches its current limit.

For example, if the adaptor side (VBUS) current reaches its current limit set value (ex. 3A) first, then adaptor side current is regulated to 3A; whereas if battery side (VBAT) current limit reaches its current limit set value (ex. 6A) first, then battery side current is regulated to 6A, and at this case, adaptor side current could be lower than VBUS current limit set value.

If VBUS current limit is not required, connect ILIM1 pin to GND. Then VBUS current is not regulated and the SC8802 regulates VBAT current limit for constant current charge.

In charging mode, VBAT current limit is necessary, otherwise, the SC8802 will misjudge the end of charge condition.

8.1.3 Real-Time Charge current control (IPWM)

The SC8802 is able to control charge current by PWM signal to IPWM pin.

The PWM signal should be in the range of 20kHz ~ 100kHz to IPWM pin input, and charge current is decided in between 0% ~ 100% by PWM duty cycle and is calculated as:

$$I_{LIMx}=I_{LIMx\_SET}\times D$$

Where:

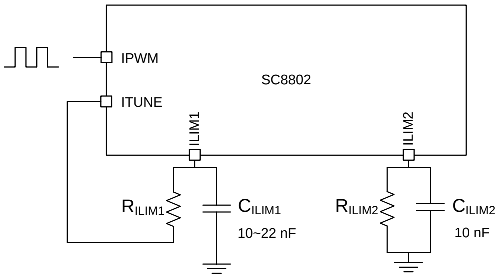
I_{LIMX_SET} = I_{LIMX} Charge current limit value;

D = IPWM duty cycle;

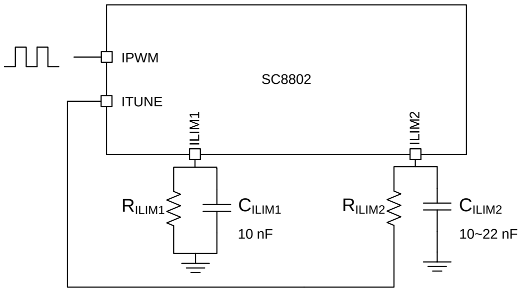
I_{LIMx} = Target current limit of charge current.

ITUNE pin selects the target which current is controlled by IPWM. If VBUS charge current should be controlled, the resistor at ILIM1 should be connected to ITUNE; If VBAT charge current should be controlled, the resistor at ILIM2 should be connected to ITUNE.

Refer to Figure 3. IPWM real-time charge current control.



a. IPWM controls VBUS charging current, ILIM1 = ILIM1_set x D，as above



b. IPWM controls VBAT charging current，ILIM2 = ILIM2_set x D，as above

Figure 3. IPWM real-time charge current control.

Keep below 4 conditions for IPWM real-time charge current control:

1) When the IPWM pin signal is "H", means the duty cycle is 100%, charge current become the ILIMx programmed value.

2) ILIMx pin, which is controlled by IPWM signal, needs bypass capacitor in the range of 10nF ~ 22nF. If IPWM pin PWM frequency is low, higher capacitance bypass capacitor is required. For example, 22nF capacitor is required at 20kH PWM frequency.

3) If real-time charge current control is not required, connect ILIMx resistor to GND and float IPWM and ITUNE pins.

4) If ITUNE pin is connected to the resistor at ILIMx pin, do not connect IPWM pin to GND or remain open, otherwise, the SC8802 cannot operate normally.

It is not allowed to set any of the current limits to 0A. Keep the minimum current limit above 0.3A.

8.1.4 Dynamic Power management (VINREG)

The SC8802 features dynamic power management. The valid minimum VBUS threshold is programmed by VINREG pin. When VBUS reaches minimum VBUS threshold, the charge current is reduced automatically. With this feature, even in case the adaptor output current capability is lower than the SC8802 charge current set value, the SC8802 can automatically reduce the charge current to adaptor output current to avoid the adaptor overload and abnormal charging, and keep VBUS voltage to minimum operating voltage.

The minimum operating VBUS voltage is calculated as:

$$V_{BUS\_min} = V_{INREG\_REF} \times \left(1+\frac{R_{UP}}{R_{DOWN}}\right)$$

Where;

V_{INREG_REF} = 1.226V;

R_{UP} and R_{DOWN} = The divider resistor connected to VINREG pin.

The SC8802 operates normally when VBUS voltage is higher than programmed threshold voltage (V_{BUS_min}). This function is valid only in charge mode. If this function is not required, connect VINREG pin to VCC.

8.2 Charging curve

When DIR pin is "L", the SC8802 enters into charge mode with charge management such as trickle charging, CC charging, CV charging and charging termination (end of charging).

Typical charge curve is shown in Figure 4.

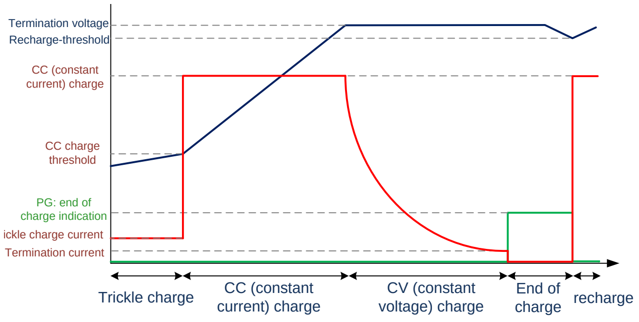


Figure 4. SC8802 Charge curve

8.2.1 Trickle Charging

The SC8802 operates in trickle charging mode if the VBAT voltage is lower than CC (constant current) charge threshold voltage. The CC charge threshold voltage is typically 70% of charge termination voltage.

In trickle charge mode, the SC8802 reduces the VBAT charge current to 10% of programmed current limit (IBAT_LIM). For example, if VBAT current limit (IBAT_LIM) is programmed to 6A, in trickle charge mode, charge current is reduced to 0.6A automatically. When VBAT voltage exceeds CC charge threshold voltage, the SC8802 recovers the charge current to VBAT current limit value and operates as CC charge mode.

8.2.2 Constant Current Charge mode

The SC8802 operates in CC quick charge mode if the VBAT voltage is higher than quick charge threshold voltage. During CC quick charge mode, the output current is controlled by ILIMx pin. For the detail information, please refer to 8.1.2 CC charge current setting (ILIMx)

8.2.3 Constant Voltage Charging

The SC8802 operates in CV charging mode if VBAT voltage reaches to 98% of VBAT termination voltage. In CV charging mode, the SC8802 maintains battery voltage and reduce the charge current automatically until the battery is charged fully.

8.2.4 Charge termination / End of charge indication (PG)

In charging mode, once below two conditions are all valid, the SC8802 recognizes as the battery is fully charged and it will terminate charging automatically:

1) The battery voltage is higher than 98% of battery termination threshold.

2) With monitoring the R_{SNS2}, VBAT current becomes lower than 1/25 of ILIM2 programmed current.

After stopping charging, the SC8802 turns off VCC voltage and operates in a low power standby mode and reduces the current consumption from battery side.

The SC8802 indicates the end of charge status with PG pin. PG is open drain output and it requires an external pullup resistor.

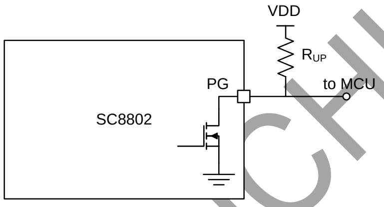


Figure 5 PG pin structure

In charging mode, PG output is pulled LOW but after end of charge, PG output is pulled HIGH by external pullup resistor and indicates that the battery is fully charged.

If MCU does not need to check PG, remain PG pin open.

8.2.5 Recharging

After charging termination due to battery is fully charged status, the SC8802 automatically restarts charging in CC quick charging mode once it detects the battery voltage falls below 95% of programmed termination voltage. In this period, VCC voltage is turned on, PG voltage is pulled "L" to indicate that the SC8802 is in charging mode.

8.3 Reverse Direction Discharge mode

When DIR pin is "H", the SC8802 enters into reverse direction discharging mode.

In discharging mode, the battery (VBAT) is discharged to adaptor/USB (VBUS), which becomes output. Figure 6 shows the power path at discharging mode.

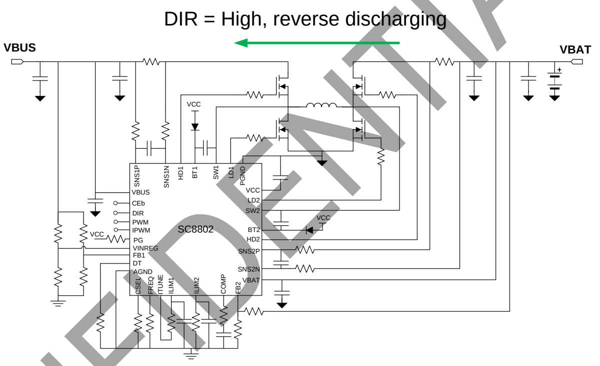


Figure 6 SC8802 Reverse direction discharge mode.

8.3.1 VBUS discharge voltage setting (FB1)

In discharging mode, VBUS discharge voltage is set by external resistor divider as FB1 pin and is calculated as:

$$VBUS = V_{FB1\_REF} \times \left(1 + \frac{R_{UP}}{R_{DOWN}}\right)$$

Where:

V_{FB1_REF} = Internal reference voltage 1.21V

R_{UP} and R_{DWON} = Resistor divider at FB1 connected to VBUS.

The SC8802 can operate with quick charge or PD controller ICs and these ICs can change the FB1 pin voltage for real-time discharge output voltage control.

8.3.2 VBUS Discharge voltage real-time control (PWM)

In discharging mode, the SC8802 supports VBUS output voltage change in two ways: one is to change FB1 pin divider ratio, the other is to control VBUS voltage by PWM signal input.

For the 2^{nd} way, the FB1 resistor divider value is fixed, VBUS output voltage is controlled by duty cycle (D) of PWM signal, which is supplied to PWM pin and in the range of 10kHz to 100kHz. VBUS output voltage is calculated as:

$$VBUS = V_{BUS\_SET} \times \left(\frac{1}{6} + \frac{5}{6} \times D\right)$$

Where;

V_{BUS_SET} = VBUS output voltage which is set by FB1 resistor divider;

D = Duty cycle of PWM signal.

The relationship between VBUS output voltage and D is showed in Figure 7.

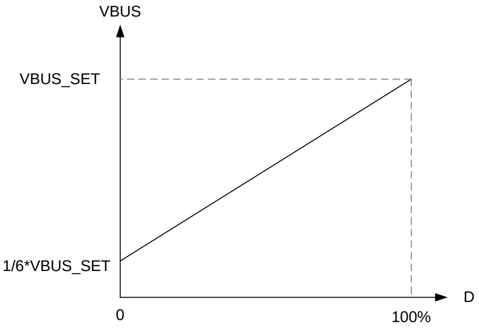


Figure 7 VBUS output voltage vs PWM duty cycle.

If PWM input signal keeps “H”, means 100% of duty cycle, then the output voltage become the programmed voltage by FB1 resistor divider.

If PWM input signal keeps “L”, means 0% of duty cycle, then the output voltage become the 1/6 of programmed voltage by FB1 resistor divider.

If PWM pin remains open, due to the IC internal pull down circuit, VBUS output voltage becomes the 1/6 of programmed voltage.

Real-time PWM output control is valid only in discharging mode.

8.3.3 Discharge current setting (ILIMx)

In discharging mode, the VBUS and VBAT current is sensed by R_{SNS1} and R_{SNS2} current sense resistors.

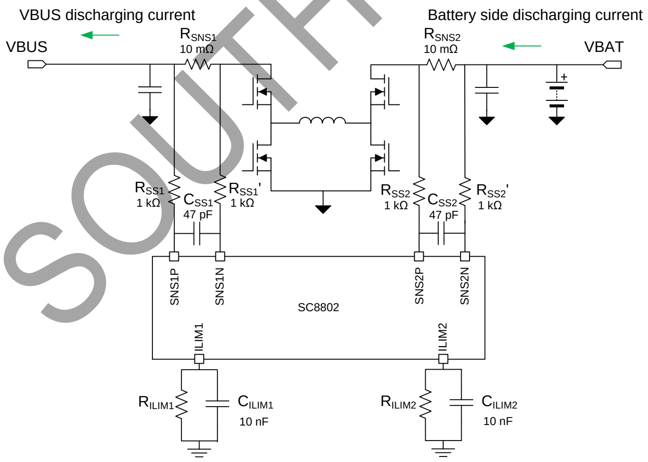


Figure 8 Discharge current monitoring circuit.

The SC8802 features current limit function. VBUS and battery side current limits are set by ILIM1 and ILIM2 pins and current limits are calculated as:

$$I_{BUS\_LIM} = \frac{V_{LIM\_REF}}{R_{ILIM1}} \times \frac{R_{SS1}}{R_{SNS1}}$$

$$I_{BAT\_LIM} = \frac{V_{LIM\_REF}}{R_{ILIM2}} \times \frac{R_{SS2}}{R_{SNS2}}$$

Please refer to 8.1.2 CC Charge current setting (ILIMx) for proper R_{SNSx} and R_{SSx} values.

The current limit, set by ILIMx, in discharging mode is equally applied to charging mode: in charging mode, the current limit is charging current and in discharging mode, the current limit is maximum discharging current.

If the current limits required by charging mode and discharging mode are different, please refer to the circuit in Figure 9 to change the limits accordingly.

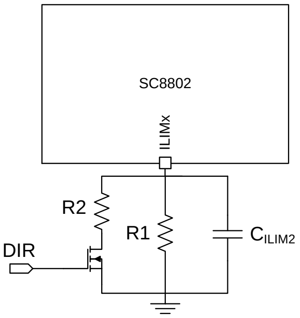


Figure 9 Current limit control using DIR signal

8.3.4 Real-time discharge current limit control (IPWM)

Similar to charging mode real-time current limit control using IPWM pin, in discharging mode, IPWM pin is also used for real-time discharge current limit control. The discharge current limit is controlled by duty cycle of PWM signal, which frequency is in the range of 20kHz ~100kHz and is supplied to IPWM pin. The current range is in between 0% to 100% of charge current limit value and it is decided by duty cycle as:

$$I_{LIMx}=I_{LIMx\_SET}\times D$$

Where;

I_{LIMx_SET} = Programmed charge current limit by ILIMx pin;

D = Duty cycle of PWM signal at IPWM pin;

I_{LIMx} = Target current limit.

It is not allowed to set any of the current limits to 0A. Keep the minimum current limit above 0.3A.

8.3.5 Discharge voltage POWER GOOD indicator (PG)

In discharging mode, PG signal indicates discharge voltage status.

If VBUS output voltage remains in between 90% ~ 110% of programmed voltage, PG pin become high impedance and due to the output pullup resistor, PG out becomes “H” to indicate the output voltage is normal.

If VBUS voltage is out of normal voltage range, PG out becomes “L”.

If this indication is not required, remain PG pin open.

8.3.6 Over voltage protection

The SC8802 provides an OVP protection function that turns off the IC automatically when the FB1 voltage is over 110% of VFB1_REF. The SC8802 returns to normal operation when FB1 falls below 110%.

8.4 Other signals

8.4.1 Chip Enable (/CE)

The SC8802 turns on/off by /CE signal. When /CE input is “L”, the SC8802 turns on; when /CE input is “H”, the SC8802 turns off.

8.4.2 Charging/Discharging mode control (DIR)

The charging mode and discharging mode is decided by DIR signal. When DIR input is “L”, the SC8802 operates in charging mode; when DIR input is “H”, the SC8802 operates in discharging mode.

8.4.3 Switching frequency setting (FREQ)

The one of three switching frequency is selectable by resistor value at FREQ pin:

FREQ resistor	Switching frequency f_{sw}
0Ω	200kHz
68kΩ（±10%）	400kHz
Open	600kHz

The accuracy of the resistor at FREQ is allowed ±10%. The real-time switching frequency change is not valid and new resistor value change will be applied in next turn on.

8.4.4 Dead time setting (DT)

The one of four dead time is selectable by resistor value at DT pin:

DT resistor	Dead time
0Ω	20ns
68kΩ（±10%）	40ns
270kΩ（±10%）	60ns
Open	80ns

The accuracy of the resistor at DT is allowed ±10%. DT does not support the real-time change and new resistor value change will be applied in next turn on.

When driving large power MOSFET with high C_{ISS} value, or adding driver resistors at LDx or HDx to adjust the MOSFET turning on/off time, it is suggested to check and change the dead time to prevent MOSFET shoot-through.

8.4.5 VCC driver voltage

The SC8802 generates driver voltage VCC internally. The VCC is selected higher voltage between VBUS and VBAT, and clamped to 10V if it is higher than 10V.

The driving signal LDx to drive low side MOSFET (Q2 and Q3) is directly supplied from VCC; the driving signal HDx to drive high side MOSFET (Q1 and Q4) is supplied from the diode in between VCC to BTx pin, which is generated by bootstrap circuit with bootstrap capacitor between BTx and SWx.

8.4.6 Feedback compensation (COMP)

The feedback loop can be compensated by adjusting the external components to the COMP pin. Typically, the values in Figure 10 are sufficient in most of applications, and don’t need to be changed.

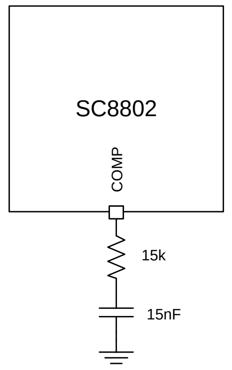


Figure 10 Feedback loop compensation setting

9 Application Information

9.1 Input and output capacitor selection

The switching frequency of the SC8802 is in the range of 200kHz ~ 600kHz. Since MLCC ceramic capacitor has good high frequency filtering with low ESR, above 60μF X5R or X7R capacitors with higher voltage rating then operating voltage with margin is recommended. For example, if the highest operating Vin/Vout voltage is 12V, select at least 16V capacitor and to secure enough margin, 25V voltage rating capacitor is recommended.

The high capacitance electrolytic capacitor and tantalum capacitor can be used for stable input and output but capacitor voltage rating should be higher than the highest operating voltage. When the tantalum capacitor is used, at least 1μF ceramic capacitor is placed in parallel. If the electrolytic capacitor is used, much more ceramic capacitors are required. For example, if a 47μF electrolytic capacitor is used, the ceramic capacitors' capacitance is allowed to reduce to 30μF ~ 40μF. Even higher capacitance electrolytic capacitor is used, at least 20μF ceramic capacitor is required.

9.2 Inductor selection

For the SC8802 system stability, the inductance of 2.2μH ~ 10μH inductor is required. High inductance (4.7μH ~ 10μH) is used in the system where the input voltage and output voltage difference is big, such as 5V Vin and 20V Vout; Low inductance (2.2μH) is used in the system which the input voltage and output voltage difference is small but high current is required. Typically, 3.3μH inductor is recommended. The inductance can be adjusted for high efficiency and optimization in application.

The inductor DC resistance value (DCR) affects the conduction loss of switching regulator, so around 10mΩ DCR is recommended for the first selection. If the power is relatively small, high DCR inductor can be selected. But if switch on current is high, just like around 10A, then select the lowest DCR inductor as much as possible because 10mΩ DCR also causes 1W power loss.

The inductor saturation current I_{SAT} should be higher than input output current with sufficient margin.

9.3 Current sense resistor

The RSNS1 and RSNS2 are current sense resistors and 5mΩ ~ 20mΩ resistor value is recommended.

Using higher resistor value in high current application causes higher conduction loss. Typically, 10mΩ is recommended. Resistor value can be adjusted depending on current limit and target power efficiency. If R_{SNSx} valued is adjusted, related R_{SSx} value should be adjusted simultaneously.

Please refer to 8.1.2 CC Charge current setting (ILIMx) for proper R_{SNSx} and R_{SSx} values.

The resistor power rating and temperature coefficient should also be considered.

The power dissipation is roughly calculated as $P=I^2R$, and I is the highest current flowing through the resistor. The resistor power rating should be higher than roughly calculated power dissipation.

The resistor value can be varied if the temperature increased and the variation is decided by temperature coefficient along with temperature change. If high accuracy of current limit is required, select lower temperature coefficient resistor as much as possible.

9.4 MOSFET selection

The SC8802 is a synchronous 4-switch buck-boost charger controller and it requires 4 NMOS for power switching circuit.

The V_{DS} of MOSFET should be higher than the highest operating voltage with enough margin (recommend more than 10V higher). For example, if the highest operating voltage is 20V, at least 30V rated V_{DS} MOSFET should be selected; If the highest operating voltage is 24V, 40V V_{DS} voltage rating should be selected.

In the application, if the input and output voltage are higher than 10V, driver circuit voltage can reach 10V, and V_{GS} voltage rating of MOSFET should be selected higher than ±10V.

Considering PCB parasitic parameters during operation, driver voltage can be higher than VCC due to transient overshoot, and ±20V V_{GS} is recommended to secure sufficient margin.

The MOSFET current I_D should be higher than the highest input and output current with enough margin.

To ensure the sufficient current capability in relatively high temperature circumstance, the current rate at T_A=70˚C or T_C = 100˚C should be considered. In addition, the power dissipation value P_D should also be considered and higher P_D is better in applications. Make sure that MOSFET power consumption must not exceed P_D value.

The MOSFET $R_{DS(ON)}$ and input capacitor C_{ISS} impact power efficiency directly. Typically, lower $R_{DS(ON)}$ MOSFET has higher C_{ISS}. The $R_{DS(ON)}$ is related to conduction loss. Higher R_{DSON} results in higher conduction loss, thus lower efficiency and higher thermal dissipation; the C_{ISS} is related to MOSFET switch on/off time, and longer on/off time results in higher switching loss and lower efficiency. The proper MOSEFT should be selected based on tradeoff between the $R_{DS(ON)}$ and C_{ISS}.

Normally, if the output power is around 20W ~ 30W, the

MOSFET with about 10mΩ of $R_{DS(ON)}$ and lower than 1000pF of C_{ISS} is recommended. If the output power is increased, the MOSFET with lower $R_{DS(ON)}$ and under 2000pF C_{ISS} is recommended. The highest C_{ISS} is suggested not to exceed 3000pF.

If high C_{ISS} MOSFET is selected, the switching on and off time become longer, then the dead time should be adjusted with DT pin to avoid simultaneous turn on for both high side and low side MOSFETs.

9.5 Driver resistor and SWx snubber circuit

For a convenient adjustment of MOSFET switching time and transient overshoot at EMI debugging, recommend to add 0603 series resistor between driver pins (LD1, LD2, HD1, HD2) and MOSFET Gate pins, and add RC snubber (0603) circuit at SW1 and SW2 (refer to Figure 11 Driver resistor and SWx snubber circuit)

The driver resistor should be placed near to MOSFET Gate pin. At first, add 0Ω and adjust the resistor value appropriately within 10Ω. After increasing the driver resistor value, the on time of high side and low side MOSFET should be monitored. If the dead time is insufficient, adjust dead time accordingly.

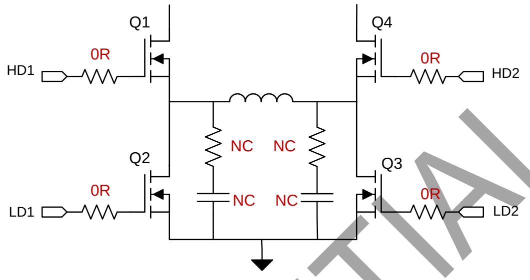
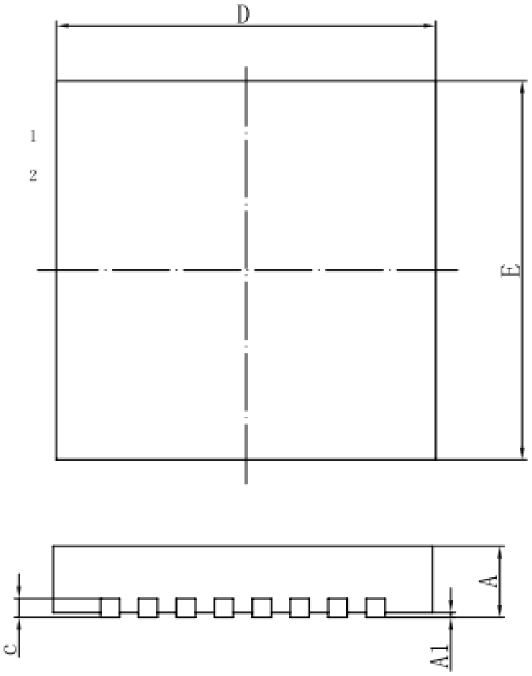


Figure 11 Driver resistor and SWx snubber circuit

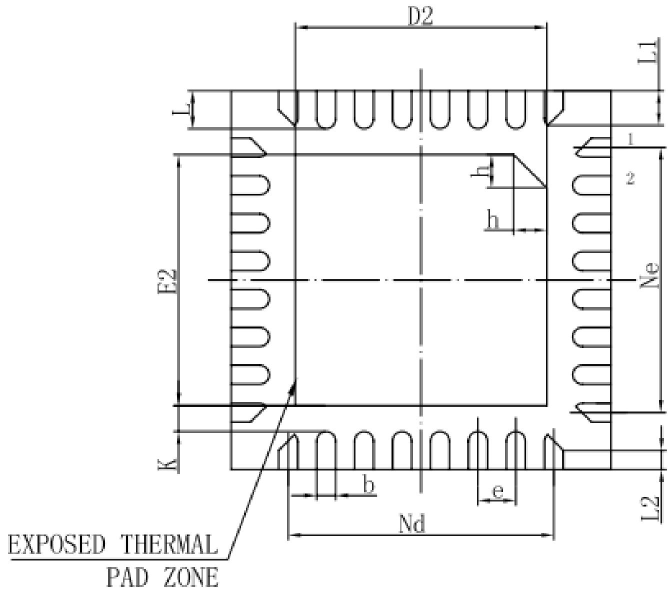
The RC snubber circuit is required when the overshoot at SWx needs to supporessed. Leave RC snubber circuit as NC at the first time.

MECHANICAL DATA

QFN32L(0404x0.75-0.40)



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0. 70	0.75	0. 80
A1	0	0. 02	0. 05
b	0. 15	0.20	0. 25
c	0.18	0.20	0.25
D	3. 90	4. 00	4. 10
D2	2. 60	2. 65	2. 70
e	0. 40BSC		
Nd	2. 80BSC		
E	3. 90	4. 00	4. 10
E2	2. 60	2. 65	2. 70
Ne	2. 80BSC		
K	0. 20	-	-
L	0. 35	0. 40	0. 45
L1	0. 30	0. 35	0. 40
L2	0. 15	0. 20	0. 25
h	0. 30	0. 35	0. 40
L/F载体尺寸 (Mil)	112*112		



BOTTOM VIEW