SK62601 Overvoltage and overcurrent protection IC

Description

The SK62601 provides robust protection for load and source during overvoltage and overcurrent events, especially to protect Li-ion batteries from failures of the charging circuit. The device continuously monitors the input voltage, the input current, and the battery voltage. In the event that an incorrect voltage is applied at input, the output will clamp to 5V to protect the load. If the input voltage exceeds 6.1V, the device disconnects the load to prevent damage to the device and/or load. In the case of an overcurrent condition, it limits the system current at the threshold value, and if the overcurrent persists, switches off the pass FET after blanking time. The input overcurrent threshold is user-programmable. The device also monitors its die temperature and switches off when it exceeds 125°C. When the device is controlled by a processor, the status information about fault conditions can be provided to the host.

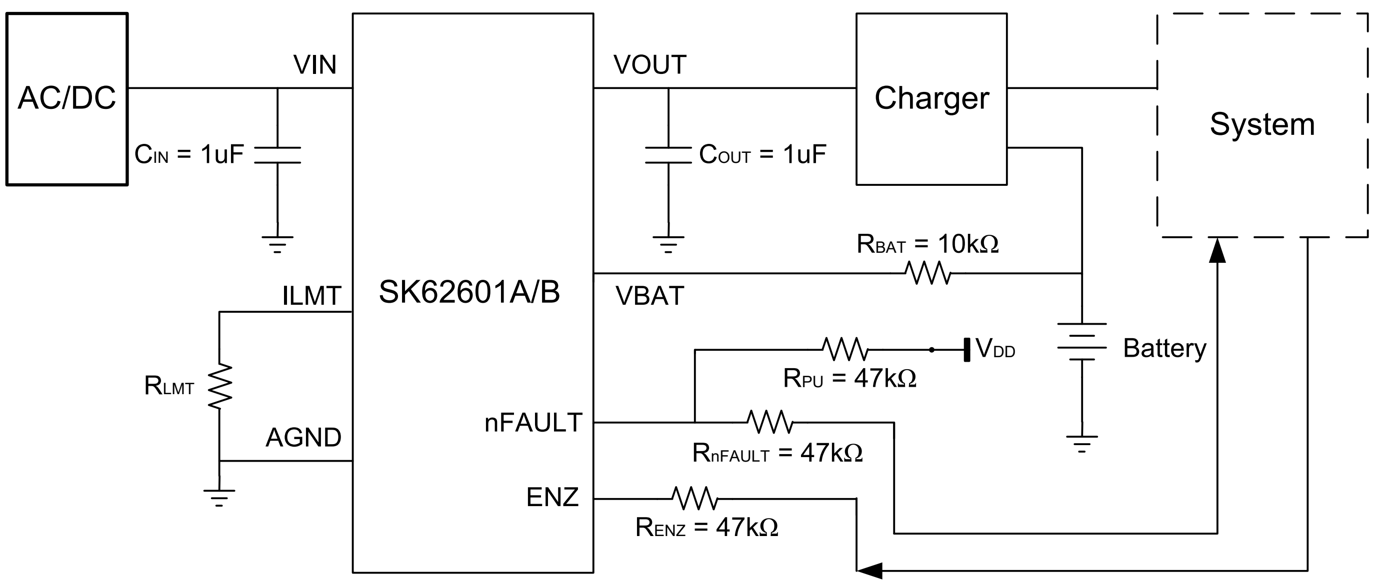
Applications

- E-cigarette
- Mobile Handsets
- Tablets
- Wearable Devices
- Charging Ports

Features

- Input overvoltage with rapid response in 90ns
- TVS integrated for surge protection IEC 61000-4-5: > 300V (Only SK62601A)
- Output voltage clamp
- Input current clamp with user-programmable threshold
- Battery overvoltage protection
- Maximum input voltage
  - a) 7V for SK62601A
  - b) 28V for SK62601B/J
- 2.5A maximum continuous input current
- OTG functionality from VOUT to VIN
- Enable control
- Under voltage lockout
- Output short-circuit protection
- Thermal shutdown
- Fault status indication
- Very low shut-down and stand-by current
- -40°C ~ 125°C operating junction temperature
- RoHS compliant and Lead(Pb)-free DFN2x2-8L package

Typical Application Circuit



Ordering Information

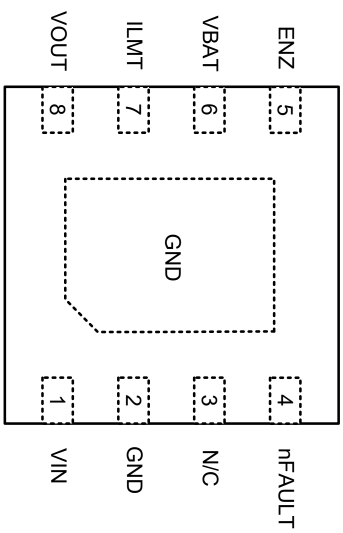
Model	Package Description	Temperature Range	Packaging Option	Marking Information
SK62601A	DFN-2x2-8L	-40°C ~ 125°C	3000/Tape & Reel	2003XXXX
SK62601B	DFN-2x2-8L	-40°C ~ 125°C	3000/Tape & Reel	2003XXXX
SK62601J	DFN-2x2-8L	-40°C ~ 125°C	3000/Tape & Reel	2003XXXX

Pin Assignments

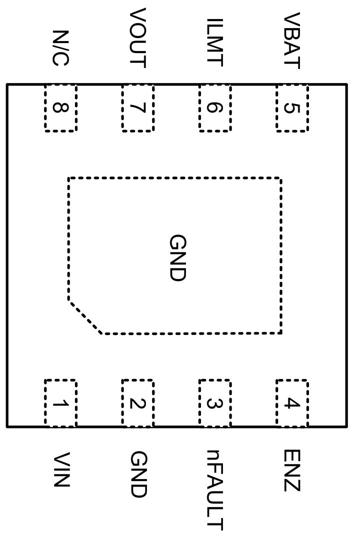
A/B	J	Name	I/O (1)	Description
1	1	VIN	P	Input power, connect to external DC supply. Connect minimum 1μF ceramic capacitor to ground.
2	2	AGND	G	Ground.
3	8	N/C	N/A	No connection.
4	3	nFAULT	DO	Open-drain output device status. nFAULT = Low indicates that the pass FET has been turned off due to input overvoltage, input overcurrent, battery overvoltage, or thermal shutdown.
5	4	ENZ	DI	Chip enable input. Active low. When ENZ = High, the pass FET is off. Internally pulled down.
6	5	VBAT	AI	Battery voltage sense input. Connect to pack positive terminal through a resistor.
7	6	ILMT	AI	Input overcurrent threshold programming. Connect a resistor to ground to set the overcurrent threshold.
8	7	VOUT	P	Output terminal to the charging system. Connect minimum 1μF ceramic capacitor to ground.
9	9	Exposed Pad	P	The exposed thermal pad is internally connected to the AGND pin. The thermal pad must be connected to the same potential as the AGND pin on the PCB. Do not use the thermal pad as the primary ground input for the device.

(1) DI - Digital Input, DI - Digital Input, AI - Analog Input, AO - Analog Output, P - Power, G - Ground

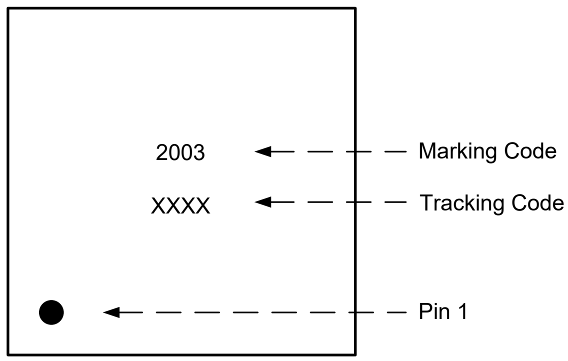
Pin Configuration and Top Mark



Top View of A/B

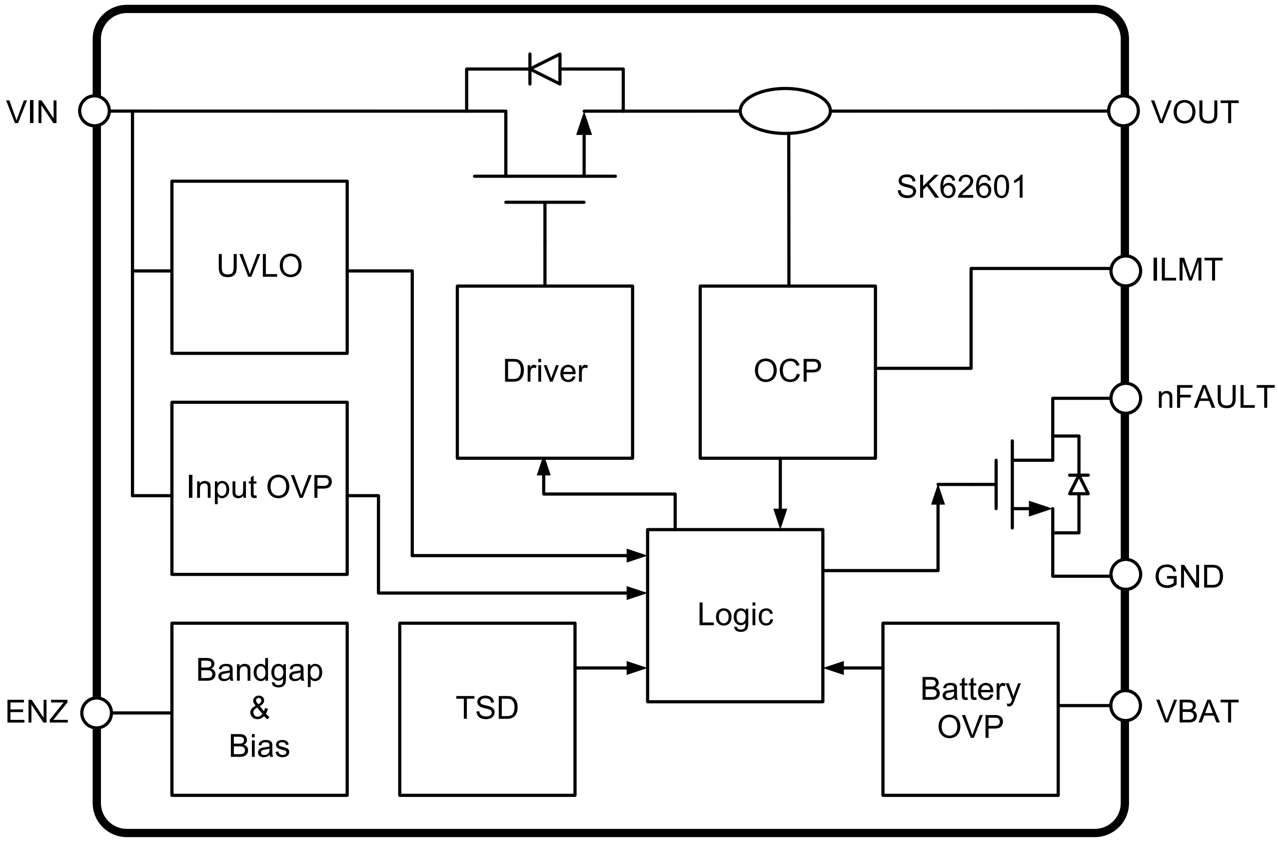


Top View of J



Top Mark of A/B/J

Operational Diagram



Absolute Maximum Ratings [2] (T_A = 25°C unless otherwise specified)

Parameter	Symbol	Min	Max	Unit
Input DC voltage (SK62601A)	V_{IN}	-0.3	7	V
Input DC voltage (SK62601B)		-0.3	28	V
Output voltage	V_{OUT}	-0.3	7	V
ENZ, ILMT, VBAT, nFAULT voltage	V_{LV}	-0.3	6	V
Ambient temperature	T_A	-40	85	°C
Continuous output current	I_{OUT}	Thermally	Limited	A
Junction temperature	T_J	-40	150	°C
Storage temperature	T_{STG}	-55	150	°C
Soldering temperature（At leads，10 seconds)	T_{LEAD}		260	°C

(2) Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.

ESD & Latch-up

Parameter	Symbol	Min	Max	Unit
Human Body Model	V_{HBM}	-4	4	kV
Charged Device Model	V_{CDM}	-1	1	kV
Latch-up	$I_{Latch-up}$	-200	200	mA

Thermal Information [3]

Parameter	Symbol	Value	Unit
Thermal resistance from junction to ambient（In free air)	$R_{\Theta JA}$	150	° C/W

(3) Thermal resistance from junction to ambient is highly dependent on PCB layout.

Recommended Operating Conditions

Parameter	Symbol	Min	Max	Unit
Input DC voltage	V_{IN}	0	7	V
Output voltage	V_{OUT}	0	7	V
ENZ, ILMT, VBAT, nFAULT voltage	V_{LV}	0	5	V
Current limit resistor	R_{LMT}	40		kΩ
Fault resistor	R_{FLT}	10		kΩ
Junction temperature	T_J	-40	125	°C

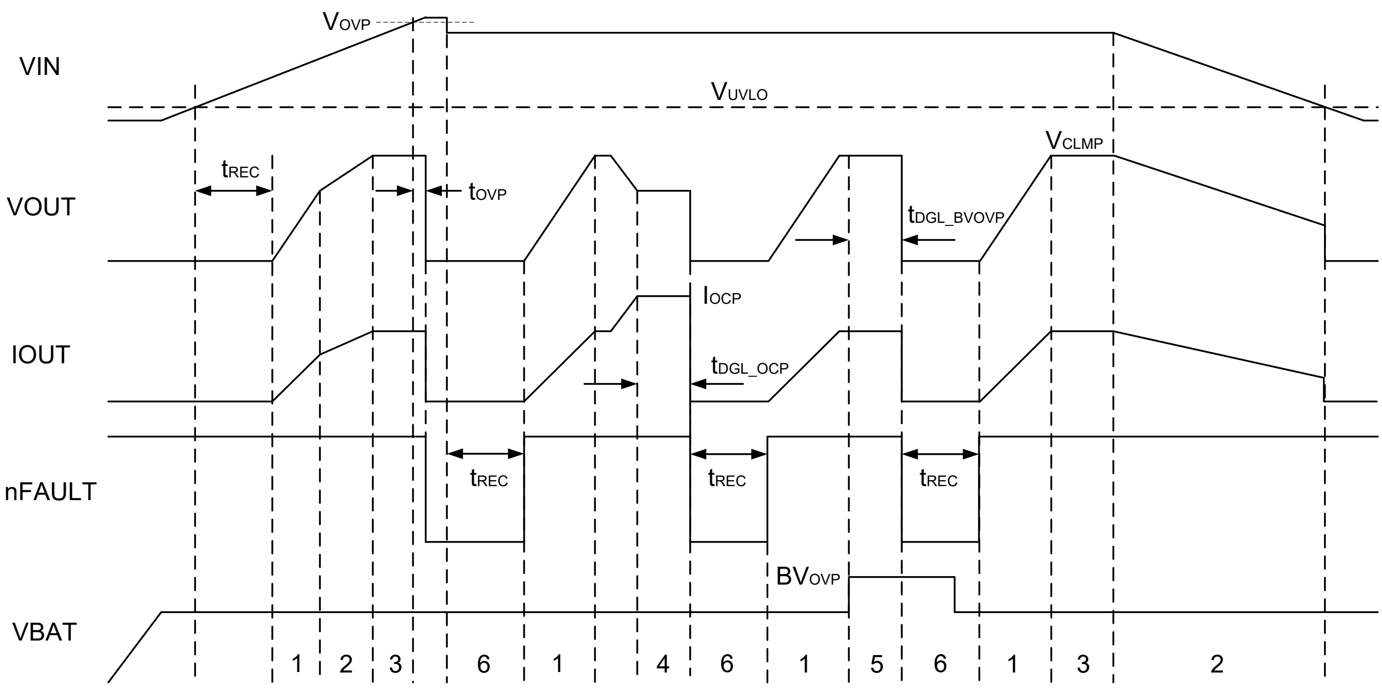
Electrical Characteristics (V_{IN} = 5V, V_{ENZ} = 0V, T_A = 25°C unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Input						
V_{UVLO}	Input voltage UVLO on rising		2.4	2.7	2.9	V
V_{UVLO_HYS}	Input voltage UVLO hysteresis			0.2		V
I_{MAX}	MAX continuous output current				2.5	A
I_{OFF}	Shutdown current	$V_{ENZ} = V_{IN}$		3	5	uA
I_{ON}	Quiescent current	V_{ENZ} = 0V, I_{OUT} = 0A		120	145	uA
Input Overvoltage Protection (OVP)						
V_{CLMP}	Output clamp voltage	5.2V < V_{IN} < V_{OVP}	5	5.2		V
V_{OVP}	Input overvoltage protection thresh-old		5.9	6.1	6.3	V
V_{OVP_HYS}	Hysteresis of V_{OVP}			0.1		V
t_{OVP}	OVP propagation delay			45		nS
t_{REC}	Recovery delay from UVLO, OVP, BOVP, ILMT, TSD			20		mS

Electrical Characteristics (Continued)

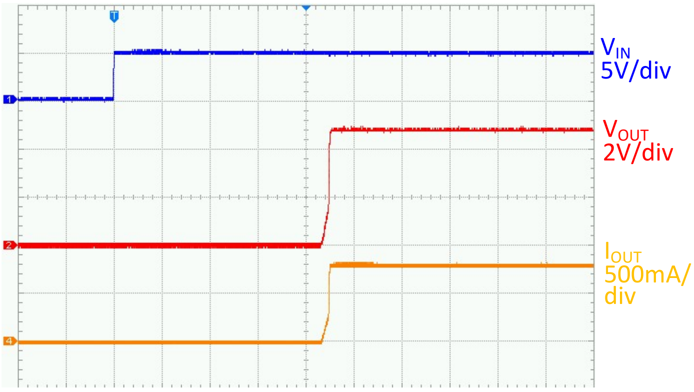
Symbol	Parameter	Conditions	Min	Typ	Max	Units
Battery Overvoltage Protection (BOVP)						
BV_{OVP}	Battery overvoltage protection threshold	$4.5V < V_{IN} < V_{OVP}$	4.25	4.35	4.45	V
V_{BVOVP_HYS}	Hysteresis on BV_{OVP}	$4.5V < V_{IN} < V_{OVP}$		260		mV
I_{VBAT}	Input bias current on VBAT pin				10	nA
t_{DGL_BVOVP}	Deglitch time on BV_{OVP}			340		uS
Current Limit Protection (ILMT)						
K	$I_{OCP} = K / R_{LMT}$			103		A·kΩ
t_{DGL_OCP}	Deglitch time on I_{OCP}			360		uS
Thermal Protection (TSD)						
T_{TSD}	Thermal shutdown temperature			125		°C
T_{TSD_HYS}	Thermal shutdown hysteresis			15		°C
MOSFET						
R_{ON}	ON resistance		52	60	78	mΩ
V_{BR}	Breakdown voltage	$V_{ENZ} = V_{IN}$ for SK62601A	7			V
		$V_{ENZ} = V_{IN}$ for SK62601B/J	28			V
Logic Input (ENZ)						
V_{IH}	ENZ high input voltage		1.2			V
V_{IL}	ENZ low input voltage				0.4	V
I_{IH}	ENZ internal pull-down current			5		uA
Logic Output (nFAULT)						
V_{OL}	nFAULT pull-down voltage	$I_{nFAULT} = 1mA$		150		mV
I_{HI_Z}	Leakage current, nFAULT HI-Z	$V_{nFAULT} = 5V$			1	uA

Timing Diagram



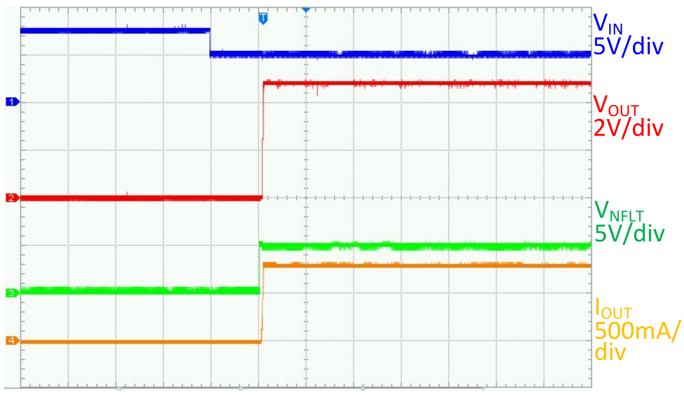
1. Normal start-up
2. V_{UVLO} < VIN < V_{CLMP}, VOUT tracks VIN
3. Input overvoltage
4. Input current limit
5. Battery overvoltage
6. Stand-by

Typical Performance Characteristics (V_{IN} = 5V, C_{IN} = 2.2μF, C_{OUT} = 2.2μF, R_{ILMT} = 40.2kΩ, R_{BAT} = 10kΩ, T_A = 25°C, unless otherwise specified)



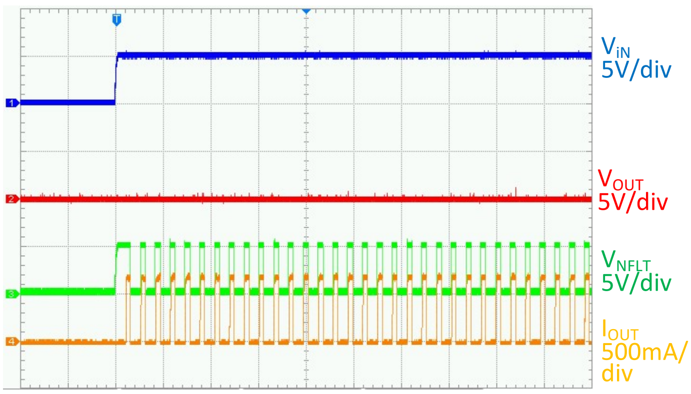
5 ms/div

Normal Power-On (RL=6Ω)



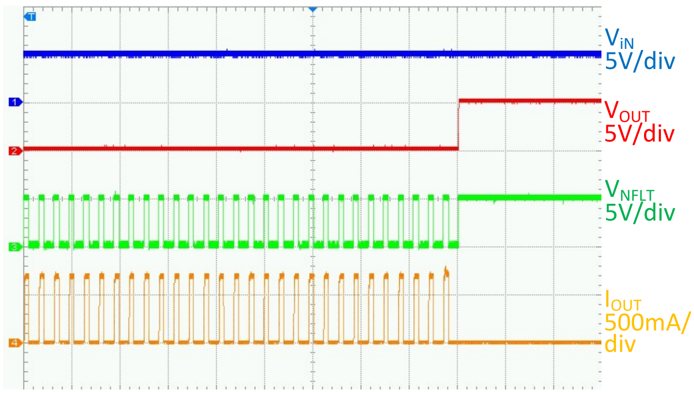
20 ms/div

Recovery from OVP(RL=6Ω)



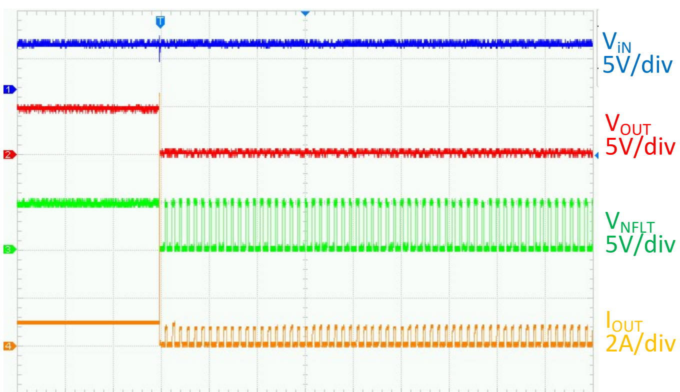
100 ms/div

power up with output short circuit



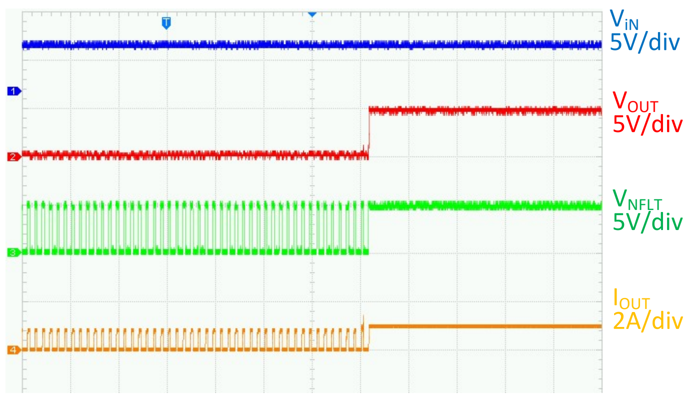
100 ms/div

remove output short circuit



200ms/div

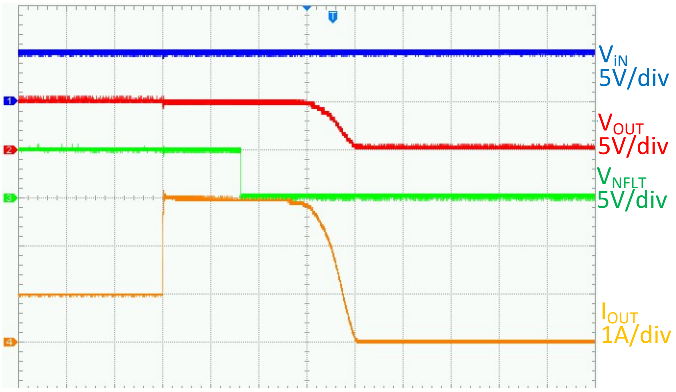
output short circuit under loading



200ms/div

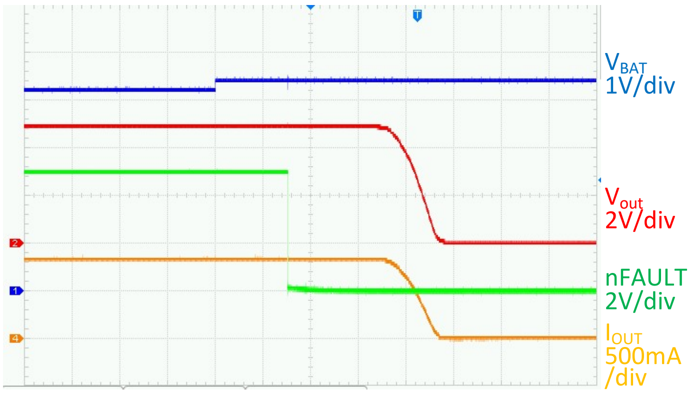
output short circuit recovery

Typical Performance Characteristics (Continued)



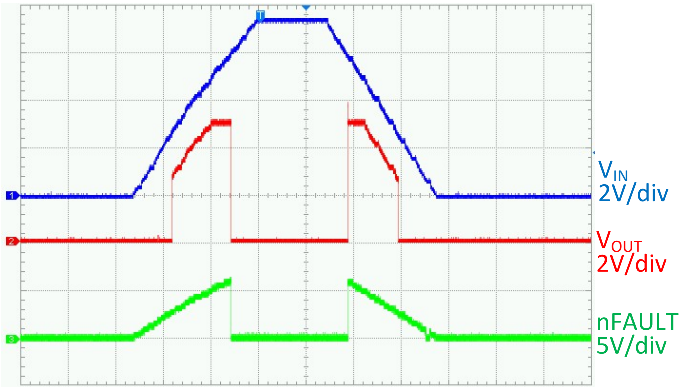
200 us/div

Output over current protection from 1A load



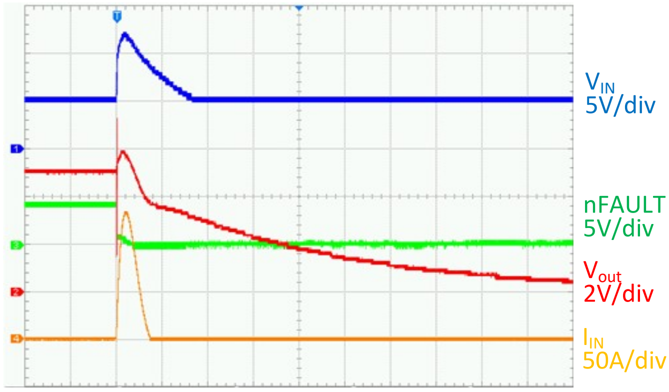
200 us/div

Response for VBAT OVP



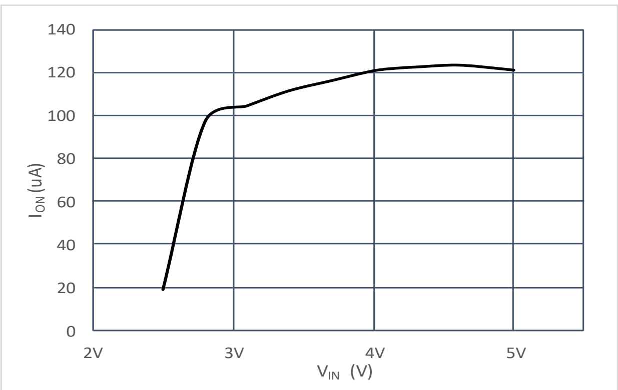
2s/div

Output Clamp as Input Ramps up

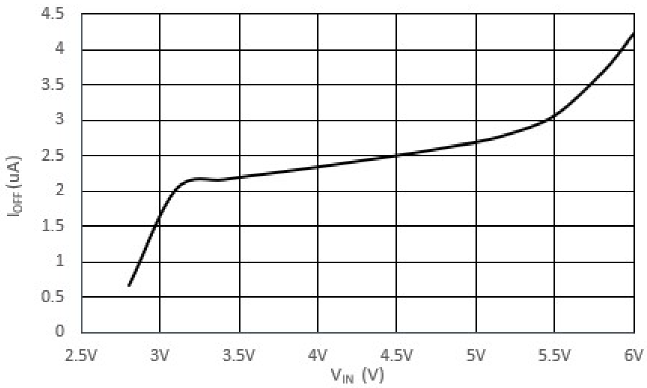


50us/div

OVP Response for Input 300V Surge

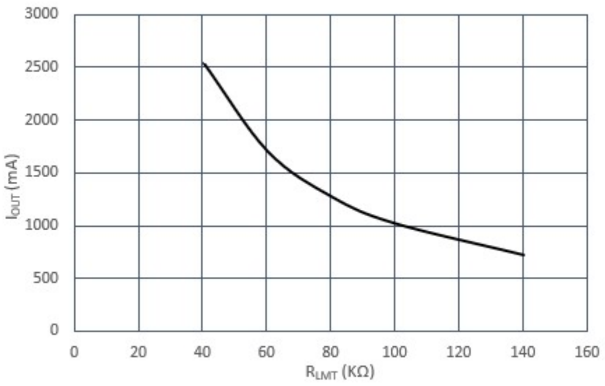


I_{ON} vs. Input Voltage

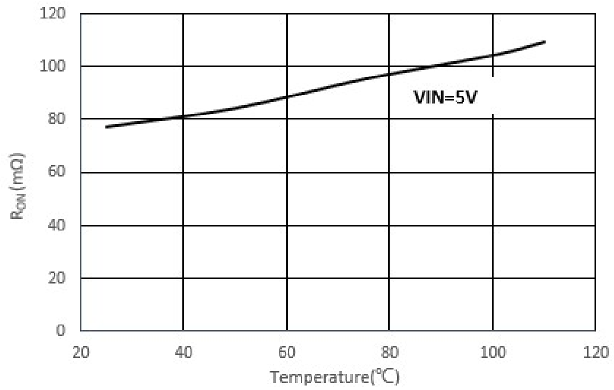


I_{OFF} vs. Input Voltage

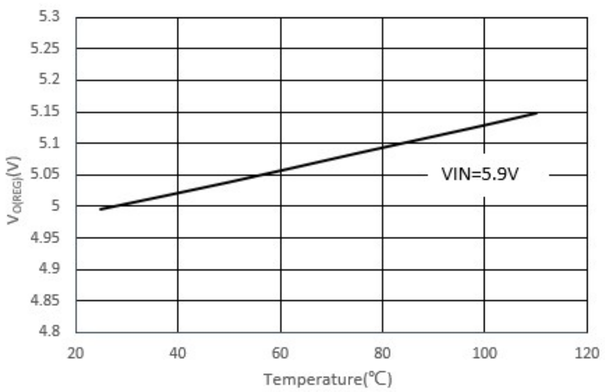
Typical Performance Characteristics (Continued)



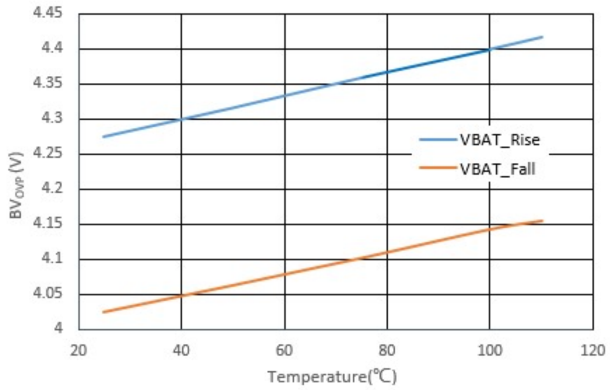
I_{OCP} vs. R_{LMT}



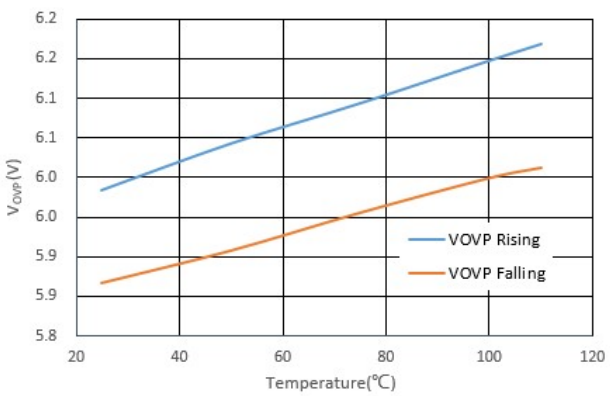
R_{ON} vs. Temperature



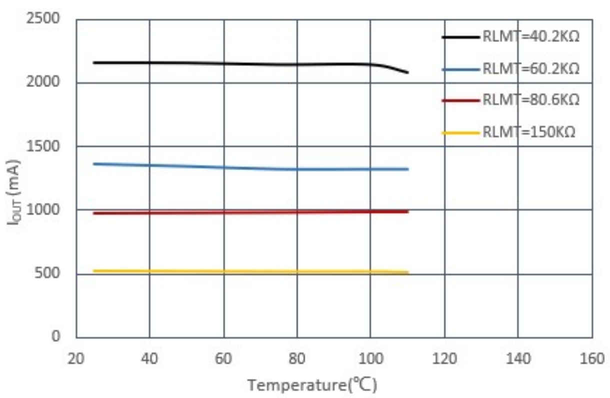
V_{CLMP} vs. Temperature



BV_{OVP} vs. Temperature



V_{OVP} vs. Temperature



I_{OCP} vs. Temperature

Functional Description

Device Operation

The SK62601 is designed to provide protection to Li-ion batteries from failures of the charging circuit. The device continuously monitors the input voltage, the input current and the battery voltage. In case of an input overvoltage condition, the device immediately removes power from the charging circuit by turning off the pass FET. In the case of an overcurrent condition, it limits the system current at the threshold value, and if the overcurrent persists, switches the pass FET off after a blanking period. If the battery voltage rises to an unsafe level, the device disconnects power from the charging circuit until the battery voltage returns within safe range. Also the device monitors its own die temperature and switches off if it becomes too hot. The input overcurrent threshold is user-programmable. The device can be controlled by a processor, and also provides status information about fault conditions to the host.

Power-Down

The device remains in power down mode when the input voltage at the VIN pin is below the under-voltage threshold V_{UVLO}. The pass FET connected between VIN and VOUT pins is off, and the status output, nFAULT, is set to Hi-Z.

Power-On-Reset

The device resets when the input voltage at the VIN pin exceeds the V_{UVLO}. All internal counters and other circuit blocks are reset. The device then waits for duration t_{REC} for the input voltage to stabilize. After t_{REC}, if the input voltage and battery voltage are safe, pass FET is turned on. Because of the deglitch time at power-on, if the input voltage rises rapidly to beyond the OVP threshold, the device will not switch on at all, instead it will go into protection mode and indicate a fault on nFAULT pin. Once the device powers up, it continuously monitors the input voltage, the input current, and the battery voltage.

Input Overvoltage Protection

If the input voltage rises above V_{OVP}, the pass FET is turned off, removing power from the circuit. The response is very fast, with the FET turning off in less than a microsecond. The nFAULT pin is driven low. When the input voltage returns between V_{UVLO} and $V_{OVP} – V_{OVP\_HYST}$, the pass FET is turned on again after a deglitch time of t_{REC} to ensure that the input supply has stabilized.

Input Overcurrent Protection

The overcurrent threshold is programmed by a resistor R_{LMT} connected from the ILMT pin to GND. The relationship between current limit threshold and R_{LMT} can be approximated by the following equation:

$$I_{OCP}\ (A) = 103\ (A\cdot k\Omega) / R_{LMT}\ (k\Omega)$$

When the output is overloaded, the device will try to limit the current to I_{OCP}. If the overload condition is removed before blanking duration of t_{DGL_OCP}, the device continues to operate as normal. If the overcurrent situation persists longer than t_{DGL_OCP}, the pass FET shuts off, and nFAULT pin is driven low. Then the device will wait for a duration of t_{REC} before turning the FET back on to re-try. Once the FET is on, the current monitor is resumed to determine if overcurrent condition still exists. If yes, the FET shuts off again, and remains off for t_{REC} until next try. This hiccup cycle repeats until overload condition is removed or device is disabled.

Battery Overvoltage Protection

The battery overvoltage threshold BV_{OVP} is internally set to 4.35V. If the battery voltage exceeds BV_{OVP} longer than t_{DGL_BVOVP}, the FET is turned off with nFAULT pin driven low. The FET remains off as long as overvoltage condition persists. Once the battery voltage drops below $BV_{OVP} – BV_{OVP\_HYST}$, the FET will be turned back on after t_{REC}. Once VBAT is set to 0V, battery overvoltage function will be disabled.

Functional Description (Continued)

Thermal Protection

The device has an Over-Temperature Protection circuit to protect device against system fault or improper use. When the junction temperature exceeds the threshold, 125°C typically, the device shuts down and stays off until the temperature cools down to a safe region (below falling threshold). Once the falling threshold, the device will automatically resume the normal operation after t_{REC}.

Enable Function

The device can be enabled or disabled through ENZ pin. When the ENZ pin is driven high, the internal FET is turned off. When the ENZ pin is low, the FET is turned on if other conditions are safe. The ENZ pin has an internal pull-down current and can be left floating. Note that the nFAULT pin functionality is also disabled when the ENZ pin is high.

Fault Indication

The nFAULT pin is an active-low open-drain output. It is in a high-impedance state when operating conditions are safe, or when the device is disabled by setting ENZ high. With ENZ low, the nFAULT pin goes low to indicate fault condition whenever any of these events occurs:

- Input overvoltage
- Input overcurrent
- Battery overvoltage
- Over temperature

OTG Function

In some applications, the equipment that SK62601 resides in may be required to provide power to an accessory (e.g. a cellphone may power a headset or an external memory card) through the same connector pins that are used by the adapter for charging. In this situation, the device is required to support current flow from VOUT pin to VIN pin. If the following condition is met,

$$V_{OUT} > V_{UVLO} + 0.7V$$

the pass FET is turned on, and the reverse current flows through the channel of the pass FET. The pass FET will remain on as long as the following condition is met,

$$V_{OVP} + R_{DSON} \times I_{ACCESSORY} > V_{OUT} > V_{UVLO} - V_{UVLO\_HYST} + R_{DSON} \times I_{ACCESSORY}$$

Within this voltage range, the reverse current capability is the same as the forward capability. It should be noted that there is no overcurrent protection in this direction.

Application Information

Selection of R_{BAT}

It is strongly recommended that the battery not be tied directly to the VBAT pin of the device, as under some failure modes of the device, the voltage at the VIN pin may appear on the VBAT pin. This voltage can be as high as 30V, and applying 30V to the battery can be hazardous. Connecting the VBAT pin through R_{BAT} prevents a large current from flowing into the battery in case of a failure of the device. In the interests of safety, R_{BAT} should have a very high value. The problem with a large RBAT is that the voltage drop across this resistor because of the VBAT bias current I_{VBAT} causes an error in the BV_{OVP} threshold. This error is on top of the tolerance of the nominal 4.35V BV_{OVP} threshold.

Choosing R_{BAT} in the range 100kΩ to 470kΩ is a good compromise. In the case of an IC failure, with R_{BAT} equal to 100kΩ, the maximum current flowing into the battery would be (30V – 3V) / 100kΩ = 246μA, which is low enough to be absorbed by the bias currents of the system components. R_{BAT} equal to 100kΩ would result in a worst-case voltage drop of R_{BAT} x I_{VBAT} = 1mV. This is negligible to compared to the internal tolerance of 50mV on BV_{OVP} threshold.

If the VBAT OVP function is not required, the VBAT pin should be connected to GND.

Selection of R_{EN}, R_{FAULT}, and R_{PU}

The ENZ pin can be used to enable and disable the IC. If host control is not required, the CE pin can be tied to GND or left unconnected, permanently enabling the device. In applications where external control is required, the ENZ pin can be controlled by a host processor. The ENZ pin should be connected to the host GPIO pin through a resistor. The limitation on the resistor value is that the minimum V_{OH} of the host GPIO pin less the drop across the resistor should be greater than V_{IH} of the ENZ pin. The drop across the resistor is given by R_{ENZ} x I_{IH}.

The nFAULT pin is an open-drain output that goes low during OVP, OCP, BVOVP, and TSD events. If the application does not require monitoring nFAULT pin, it can be left unconnected. However if required, it should be pulled high externally through R_{PU}, and connected to the host through R_{FAULT}. R_{FAULT} prevents damage to the host controller if the device fails. The resistors should be of high value, in practice values between 22kΩ and 100kΩ should be sufficient.

Selection of Input and Output Bypass Capacitors

The input capacitor C_{IN} is for decoupling and serves an important purpose. Whenever a step change downwards in the system load current occurs, the inductance of the input cable causes the input voltage to spike up. C_{IN} prevents the input voltage from overshooting to dangerous levels. It is recommended that a ceramic capacitor of at least 1μF be used at the input of the device. It must be located in close proximity to the VIN pin.

C_{OUT} is also important. During an over-voltage transient, this capacitance limits the output overshoot until the pass FET is turned off by the over-voltage protection circuitry. C_{OUT} must be a ceramic capacitor of at least 1μF, located close to the VOUT pin. C_{OUT} also serves as the input decoupling capacitor for the charging circuitry downstream.

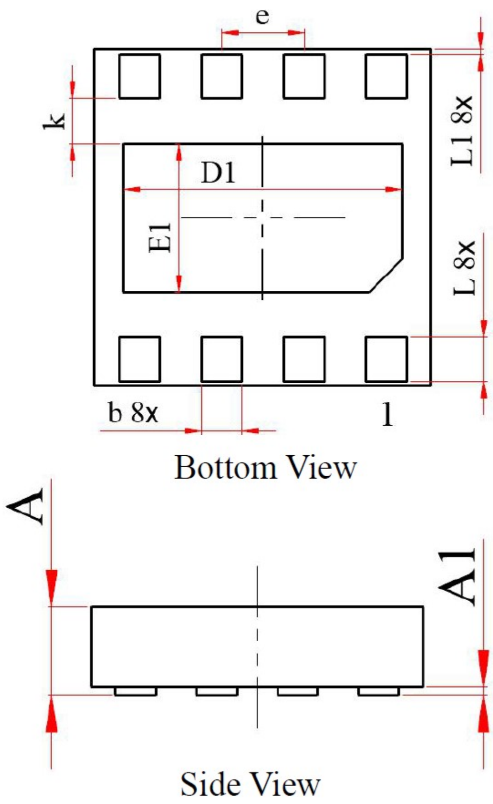
PCB Layout Guideline

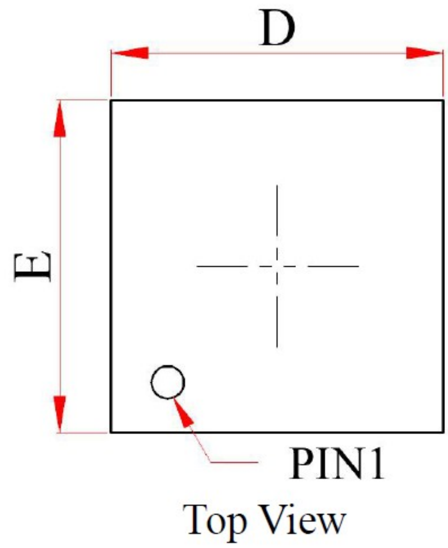
This device is a protection device, and is meant to protect down-stream circuitry from hazardous voltages. Potentially, high voltages may be applied to this device. It has to be ensured that the edge-to-edge clearance of PCB traces satisfy the design rules for high voltages.

For good thermal performance, the exposed pad should be thermally coupled with the PCB ground plane. Usually this will require a copper pad directly underneath. This copper pad should be connected to the ground plane with an array of thermal vias.

C_{IN} and C_{OUT} should be put close to the device. Other components like R_{LMT} and R_{BAT} should sit close-by also.

Package Outline





Symbol	Dimension In Millimeters			Dimension In Inches		
	Normal	Min	Max	Normal	Min	Max
A	--	0.500	0.600	--	0.020	0.024
A1	0.050	0.025	0.075	0.002	0.001	0.003
D	2.050	2.000	2.100	0.081	0.079	0.083
E	2.050	2.000	2.100	0.081	0.079	0.083
D1	1.700	1.600	1.800	0.067	0.063	0.071
E1	0.900	0.800	1.000	0.035	0.031	0.039
b	0.250	0.200	0.300	0.010	0.008	0.012
L	0.270	0.220	0.320	0.011	0.009	0.013
L1	0.030	0.000	0.060	0.001	0.000	0.002
k	0.275 REF			0.011 REF		
e	0.500 BSC			0.020 BSC		