DATA SHEET

SA57608

One-cell Lithium-ion battery protection with over/undercharge and overcurrent protection

Product data
Supersedes data of 2001 Oct 03

2003 Oct 29

Philips
Semiconductors

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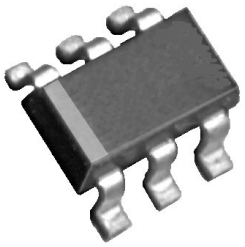
One-cell Lithium-ion battery protection with over/undercharge and overcurrent protection

SA57608

GENERAL DESCRIPTION

The SA57608 is a single-cell Li-ion protection IC, and is an improved version of the NE57600, with different pinout. Its over and under voltage accuracies are trimmed to within ± 25 mV (5%) over the entire battery pack operating temperature range. The SA57608 is available in various over and undervoltage limits.

There is a discharge overcurrent protection circuit which can protect the battery pack against an accidental short-circuit. The overcharge trip point has a time delay which can be programmed externally. It is packaged in a space-saving 6-lead small outline package and requires two external N-channel MOSFETs and a minimum of passive parts.



FEATURES

- Trimmed overvoltage trip point to within ±25 mV
- Programmable overvoltage trip time delay
- Trimmed undervoltage trip point to within ±25 mV
- Very Low undervoltage quiescent sleep current 0.05 mA
- Discharge overcurrent cutoff
- Low operating current (10 μA)
- 6-lead small outline package (SOP004)

APPLICATIONS

- Cellular phones
- Personal digital assistants
- Palmtop computers

SIMPLIFIED SYSTEM DIAGRAM

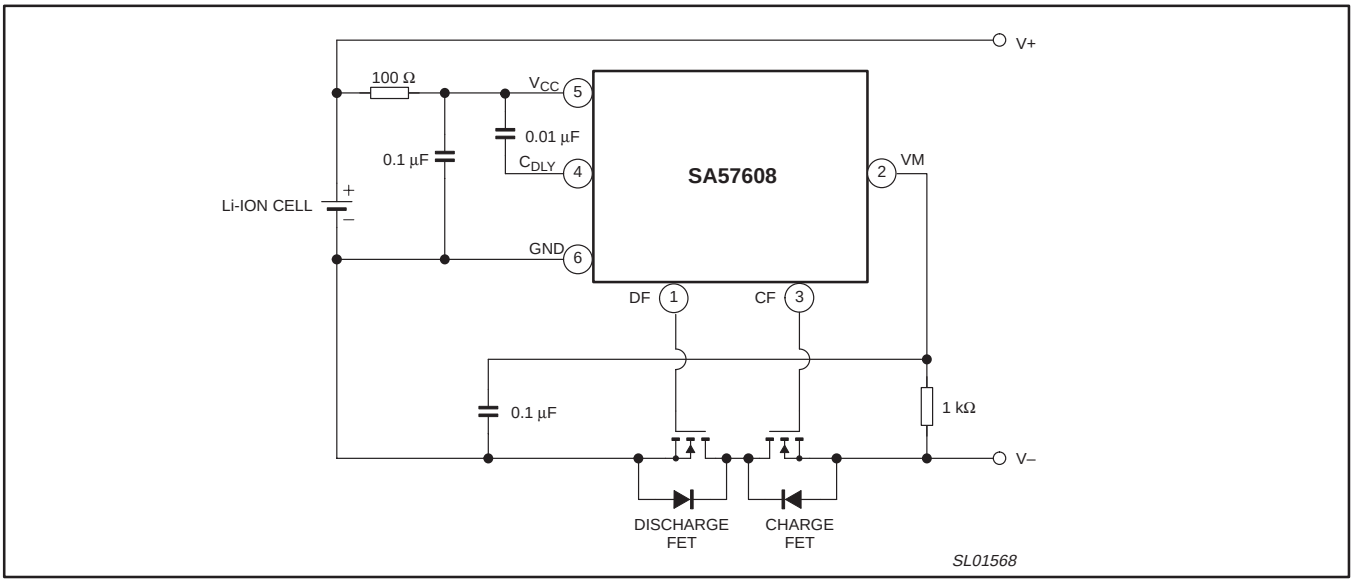


Figure 1. Simplified system diagram.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		TEMPERATURE RANGE
	DESCRIPTION	VERSION	
SA57608**X**D	Plastic small outline package; 6 leads; body width 1.8 mm	SOP004	–20 to +85 °C

NOTE:
The device has six protection parameter options, indicated by the **X** on the order code, and defined in the following table.

TYPICAL PROTECTION PARAMETERS

Part Number	Overcharge detection voltage (V)	Overcharge detection hysteresis voltage (mV)	Over-discharge detection voltage (V)	Overcurrent detection voltage (mV)
SA57608Y	4.350 ±0.050	180	2.30 ±0.070	150 ±30
SA57608B	4.280 ±0.025	180	2.30 ±0.058	75 ±30
SA57608C	4.295 ±0.025	150	2.30 ±0.058	200 ±30
SA57608D	4.350 ±0.050	180	2.30 ±0.070	200 ±30
SA57608E	4.275 ±0.025	200	2.30 ±0.058	100 ±30
SA57608G	4.280 ±0.025	200	2.30 ±0.058	100 ±30

Part number marking

Each device is marked with a four letter code. The first three letters designate the product. The fourth letter, represented by ‘x’, is a date tracking code.

Part number	Marking
SA57608YD	A G X x
SA57608BD	A G Y x
SA57608CD	A G Z x
SA57608DD	A H A x
SA57608ED	A H B x
SA57608GD	A H D x

PIN CONFIGURATION

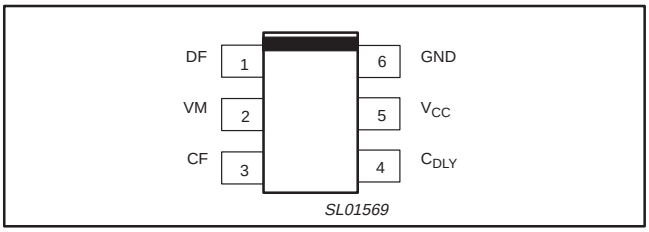


Figure 2. Pin configuration.

PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	DF	Discharge detection pin. This drives the gate of the discharge N-ch FET.
2	VM	Monitor pin. Detects overcurrent and the presence of a charger.
3	CF	Charge FET pin. This drives the gate of the charge control N-ch FET.
4	C_{DLY}	Charge Time Delay pin. The capacitor connected to this pin sets the delay.
5	V_{CC}	Positive supply voltage input pin. Connect to positive terminal of the cell.
6	GND	Ground pin. Connect to negative terminal of the cell.

MAXIMUM RATINGS

SYMBOL	PARAMETER	MIN.	MAX.	UNIT
V_{IN}	Input voltage	–0.3	+12	V
$V_{CF(max)}$	CF pin voltage	V_{CC} – 28	V_{CC} + 0.3	V
$V_{VM(max)}$	VM pin voltage	V_{CC} – 28	V_{CC} + 0.3	V
T_{opr}	Operating ambient temperature range	–40	+85	°C
T_{stg}	Storage temperature	–40	+125	°C
P_D	Power dissipation	–	150	mW

ELECTRICAL CHARACTERISTICS

Characteristics measured with T_{amb} = 25 °C, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN.	TYP.	MAX.	UNIT
V_{DD1}	Operating input voltage	V_{CC} – GND; Voltage defined as V_{DD} to VM		1.5	–	10	V
I_{DD}	Supply current	V_{CC} = 3.9 V; VM = 0 V		–	3.0	8.0	mA
I_{SLP}	Sleep current	V_{CC} = 2.0 V		–	0.3	0.6	mA
$V_{DD(min)}$	Minimum operating voltage for 0 V charging	V_{CC} – GND		–	–	1.2	V
$V_{OV1(th)}$	Over-charge voltage threshold	T_{amb} = 0 °C ~ 50 °C; V_{BATT} : L → H	SA57608Y	4.30	4.35	4.40	V
			SA57608B	4.255	4.280	4.305	V
			SA57608C	4.27	4.295	4.32	V
			SA57608D	4.30	4.350	4.40	V
			SA57608E	4.25	4.275	4.3	V
			SA57608G	4.255	4.280	4.305	V
$V_{OV1(hyst)}$	Over-charge hysteresis	V_{CC} : H → L	SA57608Y	–	180	–	mV
			SA57608B	–	180	–	mV
			SA57608C	–	150	–	mV
			SA57608D	–	180	–	mV
			SA57608E	–	200	–	mV
			SA57608G	–	200	–	mV
$V_{UV(th)}$	Over-discharge threshold voltage	V_{CC} : H → L	SA57608Y	2.23	2.30	2.37	V
			SA57608B	2.242	2.30	2.358	V
			SA57608C	2.242	2.30	2.358	V
			SA57608D	2.23	2.30	2.37	V
			SA57608E	2.242	2.30	2.358	V
			SA57608G	2.242	2.30	2.358	V
$V_{OC1(th)}$	Overcurrent threshold	V_{VM} : L → H	SA57608Y	120	150	180	mV
			SA57608B	45	75	105	mV
			SA57608C	170	200	230	mV
			SA57608D	170	200	230	mV
			SA57608E	70	100	130	mV
			SA57608G	70	100	130	mV
$V_{OV(rel)}$	Release voltage for over-discharge			4.12	4.17	4.22	V
$t_{OV(DLY)}$	Over-charge delay time	C_{TD} = 0.01 µF; V_{CC} = 4.0 V to 4.4 V		61	77	93	ms
t_{OV}	Over-discharge delay time	V_{CC} = 3.6 V to 2.2 V		5	8	11	ms
$t_{OC(DLY)}$	Over-current delay time	VM : 0 V → 0.5 V		9	13	17	ms
V_{OC2}	Short protection voltage	V_{CC} = 3.0 V		V_{CC}–1.2	V_{CC}–0.9	V_{CC}–0.6	V
$t_{DLY(SC)}$	Short detect delay time	V_{CC} = 3.0 V		–	5	50	ms
R_{SC}	Reset resistance for excess current protection	V_{CC} = 3.6 V; VM = 1.0 V		50	100	150	kW
$V_{CFET(off)}$	Nch ON voltage of CFET	I_{OL} = 50 mA; V_{CC} = 4.4 V		–	0.35	0.5	V
$V_{CFET(on)}$	Pch ON voltage of CFET	I_{OH} = 50 mA; V_{CC} = 3.9 V		3.4	3.7	–	V
$V_{DFET(off)}$	Nch ON voltage of DFET	I_{OL} = 50 mA; V_{CC} = 2.2 V		–	0.2	0.5	V
$V_{DFET(on)}$	Pch ON voltage of DFET	I_{OH} = 50 mA; V_{CC} = 3.9 V		3.4	3.7	–	V

TECHNICAL DISCUSSION

Lithium cell safety

Lithium-ion and lithium-polymer cells have a higher energy density than that of nickel-cadmium or nickel metal hydride cells and have a much lighter weight. This makes the lithium cells attractive for use in portable products. However, lithium cells require a protection circuit within the battery pack because certain operating conditions can be hazardous to the battery or the operator, if allowed to continue.

Lithium cells have a porous carbon or graphite anode where lithium ions can lodge themselves in the pores. The lithium ions are separated, which avoids the hazards of metallic lithium.

If the lithium cell is allowed to become overcharged, metallic lithium plates out onto the surface of the anode and volatile gas is generated within the cell. This creates a **rapid-disassembly hazard** (the battery ruptures). If the cell is allowed to over-discharge (V_{cell} less than approximately 2.3 V), then the copper metal from the cathode goes into the electrolyte solution. This shortens the cycle life of the cell, but presents no safety hazard. If the cell experiences excessive charge or discharge currents, as happens if the wrong charger is used, or if the terminals short circuit, the internal series resistance of the cell creates heating and generates the volatile gas which could rupture the battery.

The protection circuit continuously monitors the cell voltage for an **overcharged condition** or an **overdischarged condition**. It also continuously monitors the output for an **overcurrent condition**. If any of these conditions are encountered, the protection circuit opens a series MOSFET switch to terminate the abnormal condition. The lithium cell protection circuit is placed within the battery pack very close to the cell.

Charging control versus battery protection

The battery pack industry does not recommend using the pack's internal protection circuit to end the charging process. The external battery charger should have a charge termination circuit in it, such as that provided by the SA57611. This provides two levels of overcharge protection, with the primary protection of the external charge control circuit and the backup protection from the battery pack's protection circuit. The charge termination circuit will be set to stop charging at a level around 50 mV less than the overvoltage threshold voltage of the battery pack's own protection circuit.

Lithium cell operating characteristics

The internal resistance of lithium cells is in the 100 mΩ range, compared to the 5–20 mΩ of the nickel-based batteries. This makes the Lithium-ion and polymer cells better for lower battery current applications (less than 1 ampere) as found in cellular and wireless telephones, palmtop and laptop computers, etc.

The average operating voltage of a lithium-ion or polymer cell is 3.6 V as compared to the 1.2 V of NiCd and NiMH cells. The typical discharge curve for Lithium cell is shown in Figure 3.

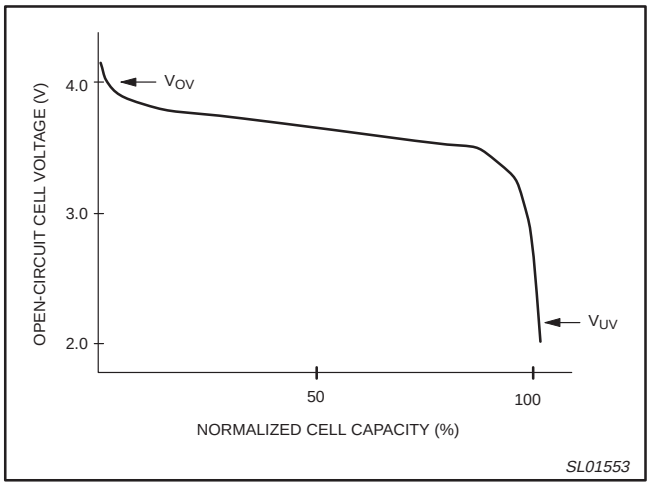


Figure 3. Lithium discharge curve.

Charging Lithium cells

The lithium cells must be charged with a dedicated charging IC such as the NE57600. These dedicated charging ICs perform a current-limited, constant-voltage charge, as shown in Figure 4.

The charger IC begins charging with a current that is typically the rating of the cell (1C) or the milliampere rating of the cell. As the cell approaches its full-charge voltage rating (V_{OV}), the current entering the cell decreases, and the charger IC provides a constant voltage. When the charge current falls below a preset amount, 50 mA for example, the charge is discontinued.

If charging is begun below the overdischarged voltage rating of the cell, it is important to slowly raise the cell voltage up to this overdischarged voltage level. This is done by a **reconditioning charge**. A small amount of current is provided to the cell (50 mA for example), and the cell voltage is allowed a period of time to rise to the overdischarged voltage. If the cell voltage recovers, then a normal charging sequence can begin. If the cell does not reach the overdischarged voltage level, then the cell is too damaged to charge and the charge is discontinued.

To take advantage of the larger energy density of lithium cells it is important to allow enough time to completely charge the cell . When the charger switches from constant current to constant voltage charge (Point B, Figure 4) the cell only contains about 80 percent of its full capacity. When the cell is 100 mV less than its full rated charge voltage the capacity contained within the cell is 95 percent. Hence, allowing the cell to slowly complete its charge takes advantage of the larger capacity of the lithium cells.

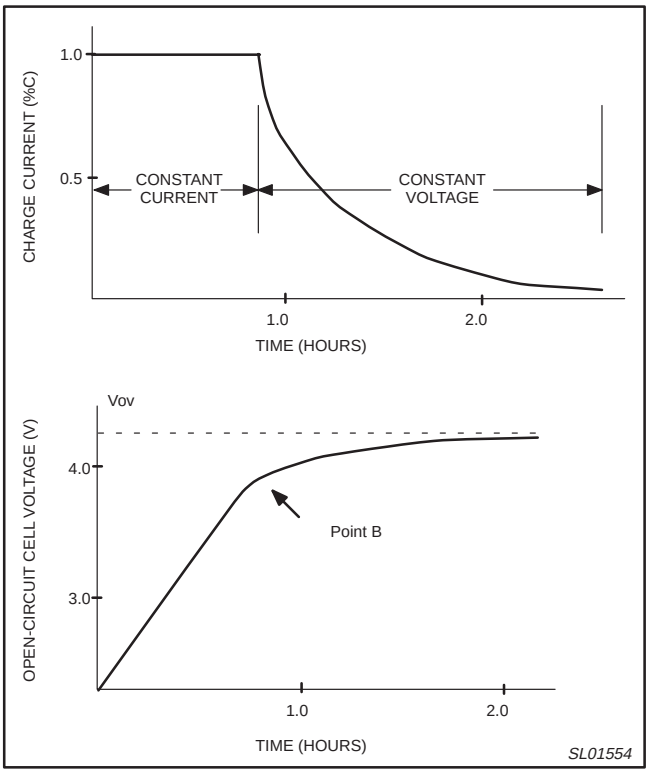


Figure 4. Lithium Cell charging Curves

SA57608 OPERATION

The SA57608 continuously monitors the terminal voltage and battery pack current of a single Li-ion battery pack. Li-ion cells must be maintained within a set of a very defined operating conditions to operate safely and with with a long life. If the cell voltage exceeds the cell's full-charge voltage, the charge current is interrupted. If the cell voltage falls below the overdischarge rating of the cell, the discharge current is interrupted. Also, whenever the discharge current exceeds the threshold voltage across the $R_{DS(on)}$ of the two MOSFETs, the short-circuit current is interrupted.

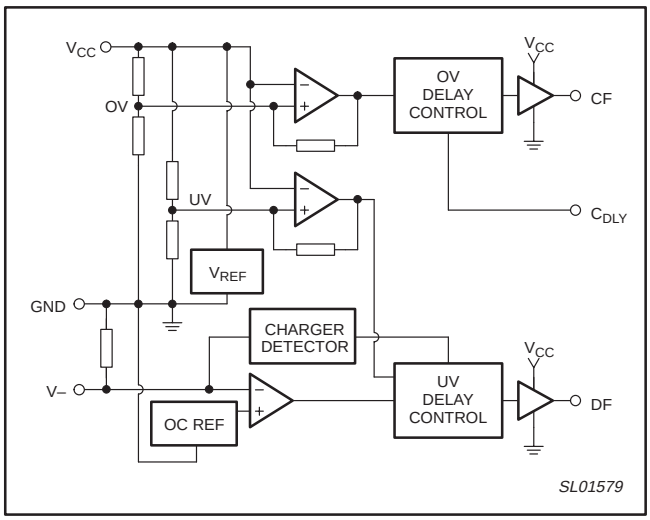


Figure 5. SA57608 block diagram.

Overvoltage condition

When the cell's terminal voltage exceeds the value of V_{OV1}, measured from V_{CC} (pin 5) to GND (pin 6), the overvoltage time delay is initiated. After this time has elapsed, the gate of the charge MOSFET (CF, pin 3) is driven LOW and the charge current is interrupted. The terminal voltage of the cell may immediately fall due to the amount of the charge current times the series resistance of the Li-ion cell ($I_{chg} \times R_{ESR}$). The charge MOSFET will not turn on again until the cell voltage has fallen below $V_{OV(rel)}$, or when a load is detected across the battery pack terminals. A load is detected when the VM pin (pin 2) is drawn **0.7 V** above the cell's negative terminal (GND, pin 6).

The timing capacitor C_{DLY} (pin 4) provides a time period between the overvoltage threshold (V_{OV1}) being exceeded and when the charge MOSFET is turned off. Its timing period is approximately:

$$t_{DLY} = C_{DLY} (V_{CC} - 0.7\ V) / 0.43\ \mu A \qquad \text{(Equation 1)}$$

The variation in timing is approximately ±16 percent.

Undervoltage condition

When the cell voltage falls below the overdischarge threshold, (V_{UV1}), as measured between V_{CC} (pin 5) and GND (pin 6), the gate of the discharge MOSFET (DF, pin 1) is brought LOW (OFF) after an internal time delay. The SA57608 then assumes a sleep condition where its I_{CC} assumes a very low state ($I_{CC(SLP)}$) The gate is then brought HIGH (ON) when a charge current is detected, or when the VM pin (pin 2) is brought to 0.7 V higher than the negative terminal of the cell (GND, pin 6) or when the cell voltage is higher than the hysteresis voltage (V_{UV2}).

Discharge overcurrent condition

If a discharge overcurrent condition is experienced as seen when a short-circuit is experienced across the battery terminals, the SA57608 views a high voltage across the MOSFET's $R_{DS(on)}$. If this voltage exceeds the threshold voltage (V_{SC}), the discharge gate is brought to a LOW condition (OFF) after an internally set of time delays are exceeded. If the overcurrent is LOW, then the t_{SC1} is enacted. If the the overcurrent is higher, as experienced in a hard short-circuit, the time delay is less than 400 ns. This prevents the MOSFETs from failing from an FBSOA failure.

The gate of the discharge MOSFET is turned on again only when the voltage of the VM pin is allowed to fall within the 0.7 volts of the negative terminal of the cell (GND, Pin 6). If the short-circuit persists, the gate of the discharge MOSFET is immediately brought LOW (OFF) again until the short-circuit condition is again removed.

APPLICATION INFORMATION

The typical single-cell lithium-ion or polymer protection circuit based upon the SA57608 is seen in Figure 6.

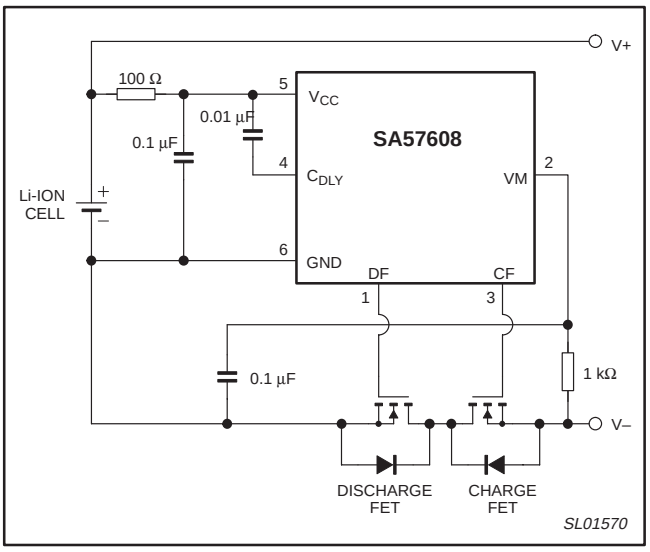


Figure 6. Typical protection circuit

The SA57608 drives the series N-Channel MOSFETs to states determined by the cell's voltage and the battery pack load current. During normal periods of operation, both the discharge and charge MOSFETs are in the ON state, thus allowing bidirectional current flow.

If the battery pack is being charged, and the cell's voltage exceeds the overvoltage threshold, then the charge MOSFET is turned OFF (FET towards the pack's external terminal). The cell's voltage must fall lower than the overvoltage hysteresis voltage ($V_{OV(Hyst)}$) before the charge MOSFET is again turned ON.

If the battery pack is being discharged and the undervoltage threshold ($V_{UV(Th)}$) is exceeded, then the discharge MOSFET is turned OFF. It will not run back ON until a charger is applied to the pack's external terminals **and** the cell's voltage rises above the undervoltage hysteresis voltage ($V_{UV(Hyst)}$).

When the battery pack is being discharged, the load current causes the voltage across the discharge MOSFET to increase past the overcurrent threshold voltage ($V_{OC(TH)}$), then the discharge MOSFET is turned OFF after a fixed 7–18 ms delay. If short-circuit is placed across the pack's terminals, then the discharge MOSFET is turned OFF after a 100–300 µs time delay to avoid damaging the MOSFETs.

The R-C filter on the V_{CC} pin

One needs to place an R-C filters on the V_{CC} pin. It is to primarily shield the IC from electrostatic occurrences and spikes on the terminals of the battery pack. A secondary need is during the occurrence of a short-circuit across the battery pack terminals. Here, the Li-ion cell voltage could collapse and cause the IC to enter an unpowered state. The R-Cs then provide power during the first instant of the short circuit and allow the IC to turn OFF the discharge MOSFET. The IC can then enter an unpowered state. Lastly, the R-C filter filters any noise voltage caused by noisy load current.

The values shown in Figure 6 are good for these purposes.

Selecting the Optimum MOSFETs:

For a single-cell battery pack, a logic-level MOSFET should be used. These MOSFETs have turn-on thresholds of 0.9 V and are considered full-ON at 4.5 V VGS. Some problem may be encountered in not having enough gate voltage to fully turn-ON the series MOSFETs over the battery pack's entire operating voltage. If one deliberately selects an N-Channel MOSFET with a much greater current rating, a lower $R_{DS(on)}$ over the entire range can be attained.

The MOSFETs should have a voltage rating greater than 20 V and should have a high avalanche rating to survive any spikes generated across the battery pack terminals.

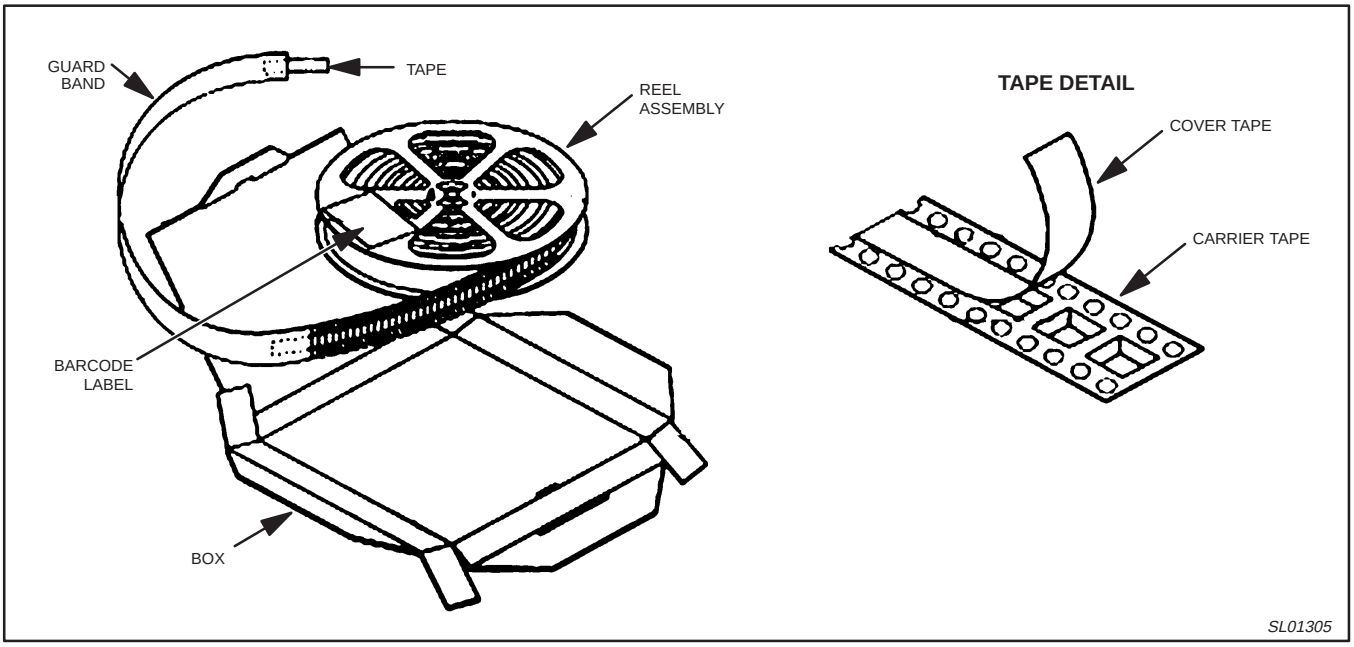
The current rating of the MOSFETs should be greater than four times the maximum "C-rating" of the cells. The current rating, though, is more defined by the total series resistance of the battery pack. The total resistance of the battery pack is given by Equation 2.

$$R_{bat(tot)} = R_{DS(on)} + R_{cell} \qquad \text{(Equation 2)}$$

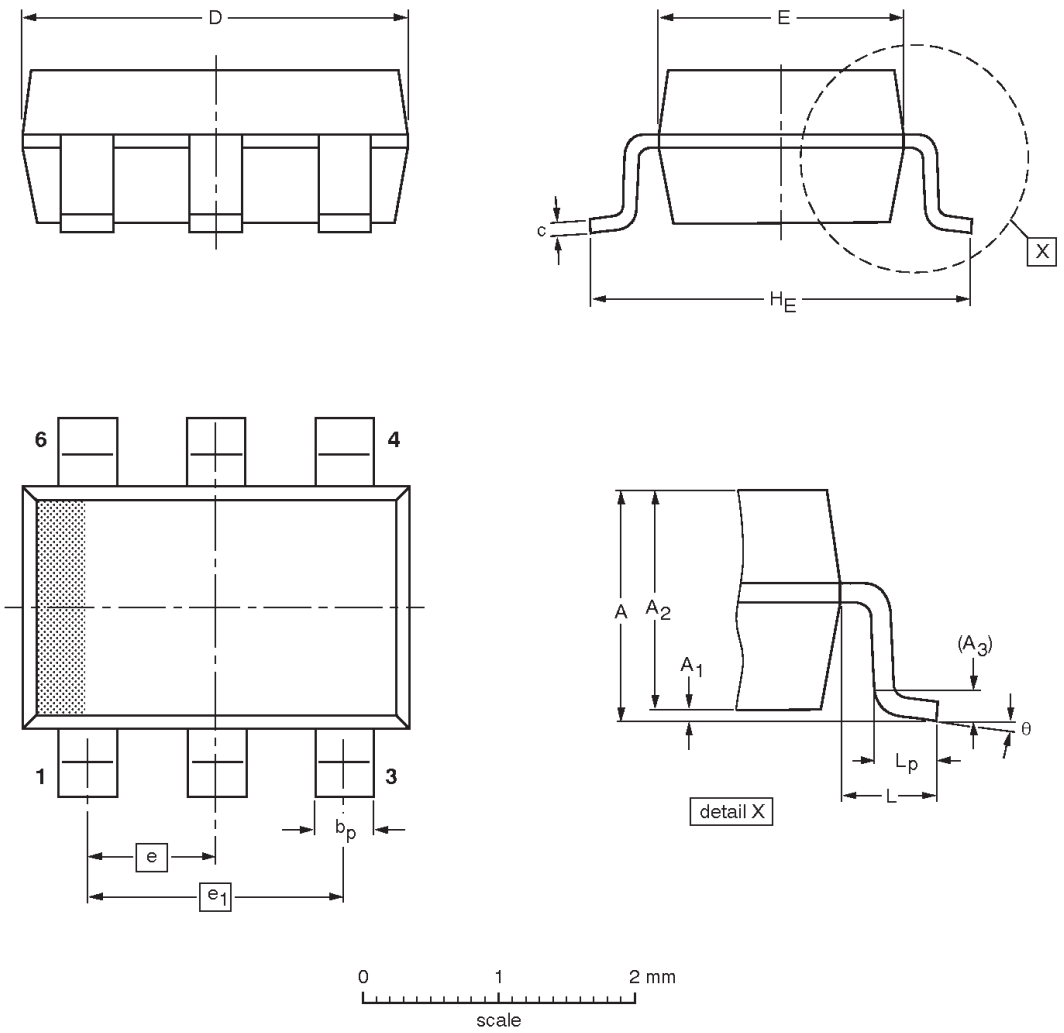
The total pack resistance is typically determined by the system requirements. The total pack resistance directly determines how much voltage droop will occur during pulses in load current.

Another consideration is the forward-biased safe operating area of the MOSFET. During a short-circuit, the discharge current can easily reach 10–15 times the "C-rating" of the cells. The MOSFET must survive this current prior to the discharge MOSFET can be turned OFF. So having an FBSOA envelope that exceeds 20 amperes for 5 ms would be safe.

PACKING METHOD



Plastic small outline package; 6 leads; body width 1.8 mm **SOP004**



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (2)	e	e_1	H_E	L	L_p min.	θ
mm	1.15	0.1 0.0	1.1	0.25	0.50 0.35	0.25 0.10	3.1 2.7	2.0 1.6	0.95	1.9	3.0 2.6	0.6	0.1	8° 0°

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOP004		MO-178				~~03-07-15~~ 03-10-06

One-cell Lithium-ion battery protection with over/undercharge and overcurrent protection

SA57608

REVISION HISTORY

Rev	Date	Description
_1	yyyymmdd	**Product data (9397 750 12192). ECN 853-2298 30337 of 09 September 2003. Supersedes data of 2001 Oct 03 (9397 750 08994).** Modifications: ● Change package outline version to SOP004 in Ordering information table and Package outline sections.
_1	20011003	**Product data (9397 750 08994). ECN 853-2298 27198 of 03 October 2001.**

Data sheet status

Level	Data sheet status [1]	Product status [2] [3]	Definitions
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
II	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
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[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

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Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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Date of release: 10-03

Document order number: 9397 750 12192

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