DATA SHEET

NE57607

Two-cell Lithium-ion battery protection with overcurrent, over- and under-voltage protection

Product data

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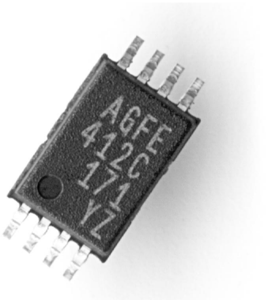
Philips
Semiconductors

GENERAL DESCRIPTION

The NE57607 is a family of 2-cell Li-ion protection ICs. Its over- and under-voltage accuracy is trimmed to within ±25 mV (5%) and is available to match the requirements of all lithium-ion cells manufactured in the market today.

The NE57607 comes in the small VSOP-8A package.



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 sleep quiescent current 0.05 mA
- Discharge overcurrent cutoff
- Low operating current (10 mA)
- Very small package VSOP-8A

APPLICATIONS

- Cellular phones
- Palmtop computers

SIMPLIFIED DEVICE DIAGRAM

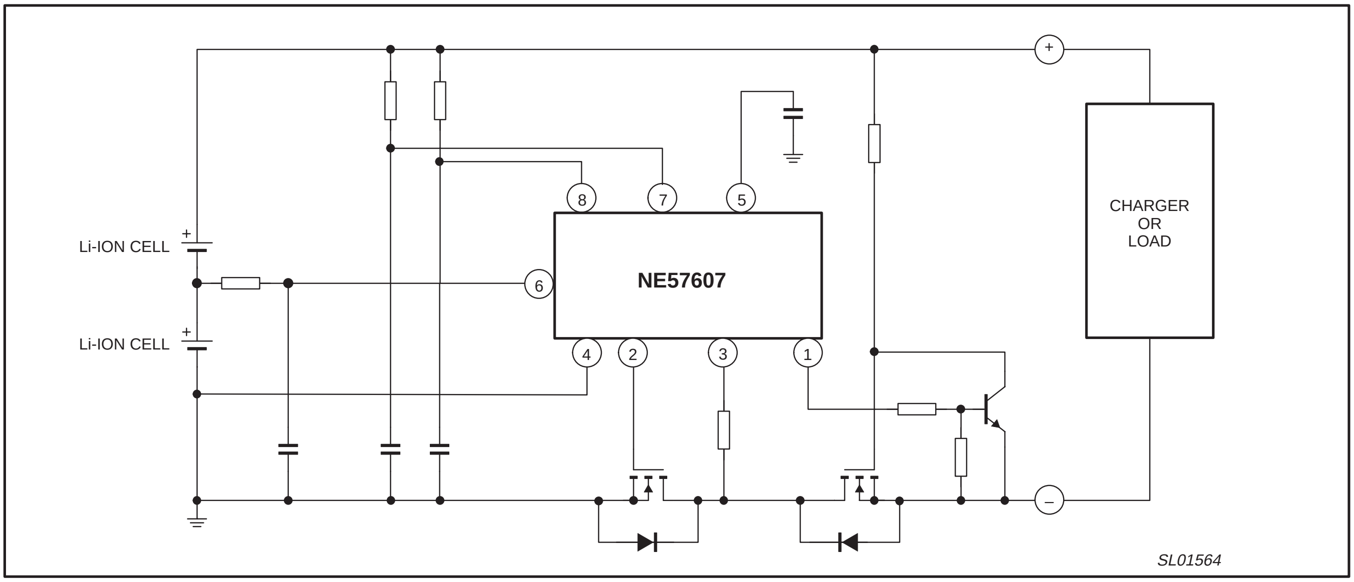


Figure 1. Simplified device diagram.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	**DESCRIPTION**	**TEMPERATURE RANGE**
NE57607**X**DH	VSOP-8A	8-pin surface mount small outline package	–20 to +70 °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 IN THE NE57600 FAMILY

T_{amb} = 0 °C to 50 °C

Part Number	Overcharge detection voltage (V)	Overcharge detection hysteresis voltage (mV)	Over-discharge detection voltage (V)	Over-discharge resumption voltage (V)	Overcurrent detection voltage (mV)
NE57607Y	4.350	220 ± 50	2.3 ± 0.1	3.5 ± 0.2	150 ± 15
NE57607C	4.295	TBD	2.3 ± 0.1	3.5 ± 0.2	150 ± 15
NE57607E	4.250	300 ± 50	2.3 ± 0.1	3.5 ± 0.2	150 ± 15
NE57607G	4.300	220 ± 50	2.0 ± 0.1	3.1 ± 0.2	140 ± 15
NE57607H	4.225	TBD	2.3 ± 0.1	3.5 ± 0.2	150 ± 15
NE57607K	4.350	220 ± 50	2.3 ± 0.1	3.5 ± 0.2	100 ± 15

Part number marking

Each device is marked with a four letter code. The first three letters in the top line of markings designate the product. The fourth letter, represented by “x”, is a date code. The remaining markings are manufacturing codes.

Part Number	Marking
NE57607YDH	AGDx
NE57607CDH	AGFx
NE57607EDH	AGHx
NE57607GDH	AGKx
NE57607HDH	AGLx
NE57607KDH	AGNx

PIN CONFIGURATION

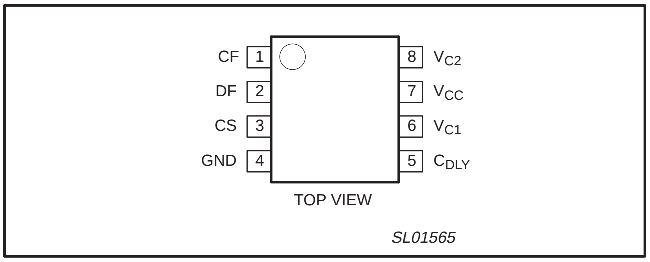


Figure 2. Pin configuration.

PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	CF	Charge FET drive pin, must have common emitter NPN to drive FET gate. Overcharge detection output pin PNP open collector output
2	DF	Discharge control FET (N-ch) control output pin.
3	CS	Overcurrent detection input pin. Monitors discharge current equivalently by the voltage drop between discharge FET source and drain. Stops discharge when voltage between CS pin and GND pin goes above overcurrent detection threshold value, and holds until load is released.
4	GND	Ground pin, or lower cell (C1) negative pin.
5	C_{DLY}	Overcharge detection dead time setting pin. Dead time can be set by adding a capacitor between TD and GND pins.
6	V_{C1}	Voltage input for positive terminal of bottom cell (C10). Connection pin for lower cell (C1) positive electrode side and upper cell (C2) negative electrode side.
7	V_{CC}	Power supply input pin.
8	V_{C2}	Voltage input for top terminal of upper cell (C2).

MAXIMUM RATINGS

SYMBOL	PARAMETER	Min.	Max.	UNIT
$V_{IN(max)}$	Input voltage	–0.3	+18	V
$V_{CF(max)}$	Maximum CF pin voltage	–	V_{IN}–0.6	V
$V_{CS(max)}$	Maximum CS pin voltage	–	V_{IN}–0.6	V
T_{opr}	Operating ambient temperature range	–20	+70	°C
T_{stg}	Storage temperature	–40	+125	°C
P_D	Power dissipation	–	300	mW

ELECTRICAL CHARACTERISTICS

T_{amb} = 25 °C; V_{CEL} = V4–V3 = V3–V2 = V2–V1 = V1–GND; V_{CC} = 4V_{CEL}, except where noted otherwise.

SYMBOL	PARAMETER	CONDITIONS	Min.	Typ.	Max.	UNIT
V_{OC}	Overcharge detection voltage	T_{amb} = 0 °C ~ 50 °C	4.325	4.350	4.375	V
V_{OC}	Overcharge detection hysteresis voltage		170	220	270	mV
V_{OD}	Overdischarge detection voltage		2.20	2.30	2.40	V
$I_{VC2(1)}$	Consumption current 1	$V_{C2} = V_{C1}$ = 1.0 V; V_{CS} = 1.4 V	–	–	0.1	µA
$I_{VC2(2)}$	Consumption current 2	$V_{C2} = V_{C1}$ = 1.9 V; V_{CS} = 3.2 V	–	0.5	0.8	µA
I_{VC23}	Consumption current 3	$V_{C2} = V_{C1}$ = 3.5 V	–	15.0	20.0	µA
I_{VC24}	Consumption current 4	$V_{C2} = V_{C1}$ = 4.5 V; R_{OC} = 270 kΩ	–	–	150	µA
I_{VC1}	V_{C1} pin input current	$V_{C2} = V_{C1}$ = 3.5 V	–0.3	0	0.3	µA
V_{DF}	Overdischarge release voltage	Discharge resume by voltage rise	3.30	3.50	3.70	V
V_{GDH}	GD pin HIGH output voltage	$V_{C2} = V_{C1}$ = 3.5 V; I_L = –10 µA	V_{C2}–0.3	V_{C2}–0.2	–	V
V_{GDL}	GD pin LOW output voltage	$V_{C2} = V_{C1}$ = 3.5 V; I_L = 10 µA	–	0.2	0.3	V
I_{CFH}	CF pin output current	$V_{C2} = V_{C1}$ = 4.5 V	–	30	150	µA
V_{CS1}	Overcurrent detection threshold value		135	150	165	mV
V_{CS2}	Short circuit threshold value	When both battery pack pins are shorted	0.35	0.45	0.55	V
	Overcurrent release	Load release: Load of 5MEG& or more between both battery pack pins				
t_{OC1}	Overcurrent detection delay time 1		7	12	18	ms
t_{OC2}	Overcurrent detection delay time 2	Note 1	–	30	100	µs
t_{OD}	Overdischarge detection delay time		8	13	20	ms
t_{OCH}	Overcharge detection dead time	C_{DLY} = 0.18 µF; Note 2	0.5	1.0	1.5	s
V_{ST}	Start-up voltage	$V_{C2} = V_{C1}$ = 2.5 V	–0.24	–0.12	–0.04	V

NOTES:

1. The short-circuit delay time is for the IC only. This time will increase with the discharge FET gate capacitance. The short-circuit condition may cause the cell voltage to collapse and lengthen the delay.
2. Calculate overcharge dead time according to the following formula: $T_{alm} – 5.55 \times C_{TD}$ (time expressed in seconds, capacitance in µF)

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.

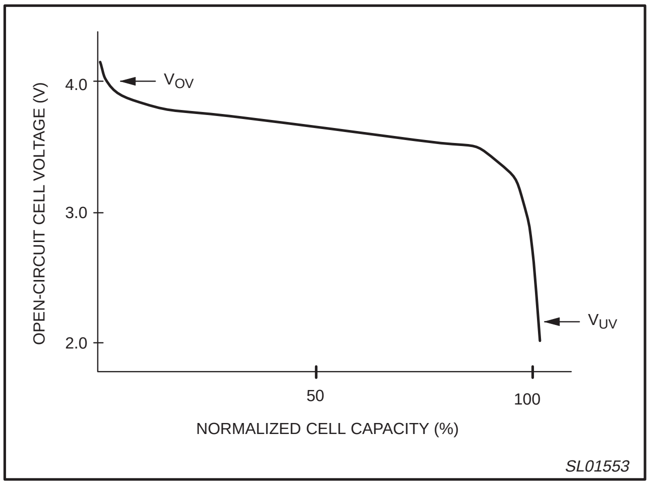


Figure 3. Lithium discharge curve.

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.

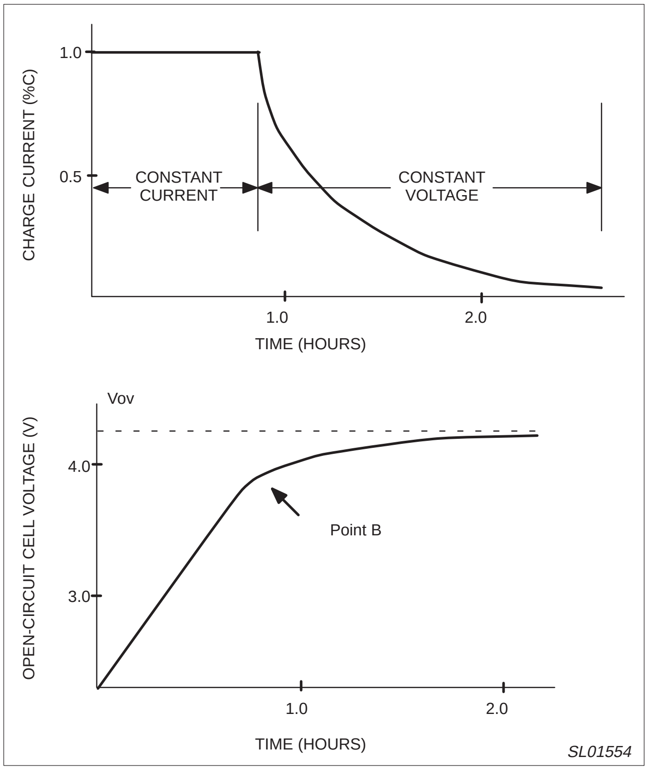


Figure 4. Lithium cell charging curves.

FUNCTIONAL DIAGRAM

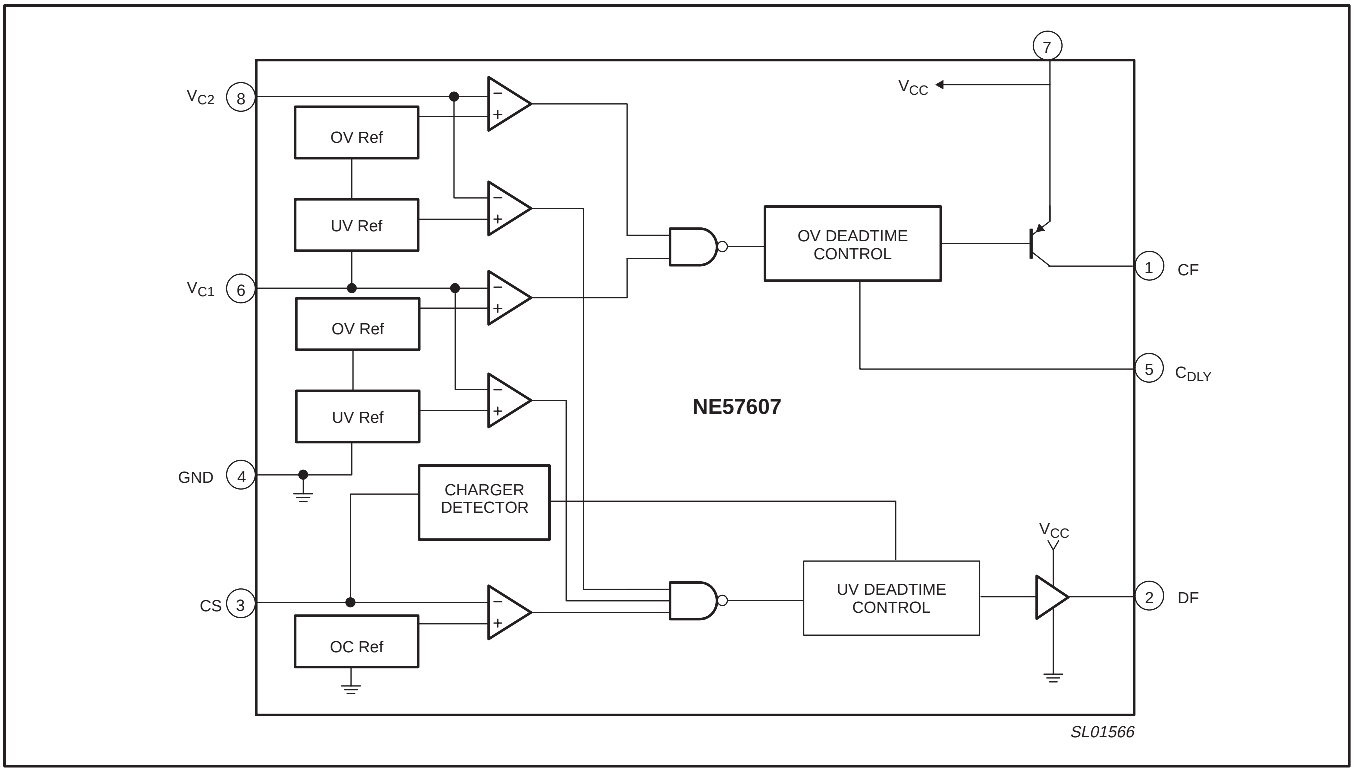


Figure 5. Functional diagram.

APPLICATION INFORMATION

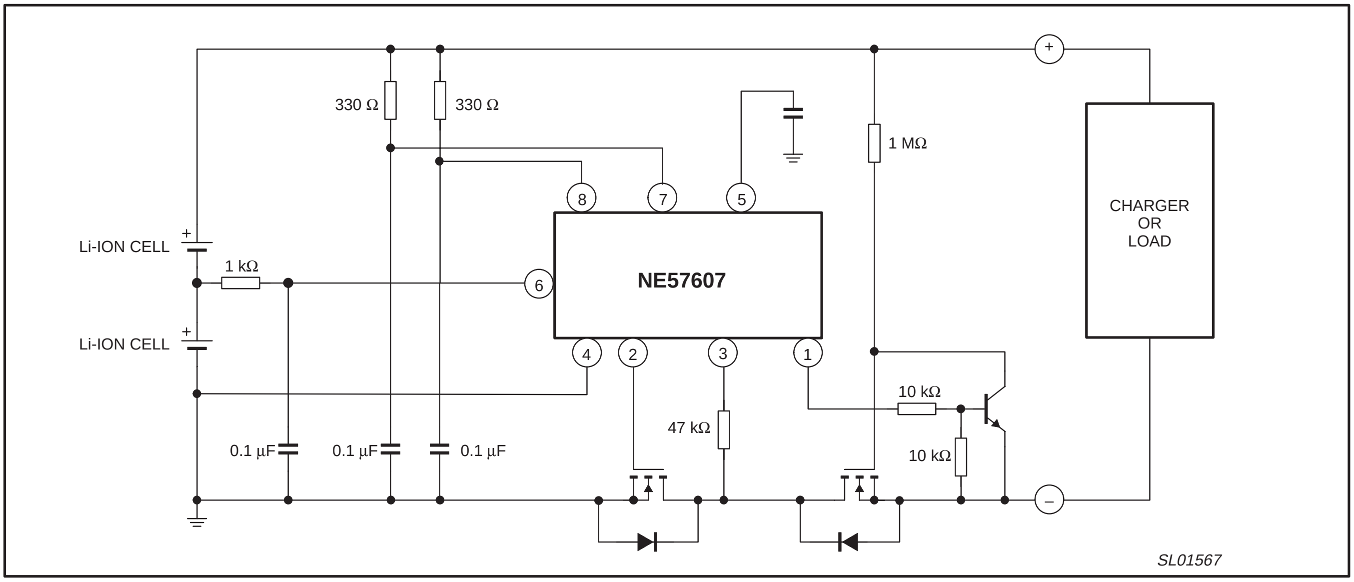


Figure 6. Typical application circuit

The NE57607 drives the series N-Channel MOSFETs to states determined by each of 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 either of 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.

FET STATUS FOR NORMAL AND ABNORMAL CONDITIONS

Operating Mode and Charging Condition	Charge FET (CF)	Discharge FET (DF)
Normal (charging or discharging)	ON	ON
Overcharge (charging)	OFF	ON
Overcharge (discharging)	ON	ON
Overdischarge (discharging)	OFF	OFF
Overdischarge (charging)	ON	ON
Overcurrent (charging or discharging)	OFF	OFF

Normal mode:

Overdischarge detection voltage < battery voltage <overcharge detection voltage

Discharge current < overcurrent detection level

Overcharge mode:

Battery voltage > overcharge detection voltage

Overdischarge mode:

Overdischarge detection voltage > battery voltage

Overcurrent mode:

Discharge current > overcurrent detection level

voltage between VM and GND = discharge current × FET ON resistance (discharge or charge FET)

The R-C filters around the NE57607

One needs to place R-C filters on the positive input pins of the NE57607. These are primarily to 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 instance 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 on the node between the two cells 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 2-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. The total pack voltage will be a maximum of 8.6 V which is within safe operating range of the gate voltage which is typically more than two times the full-on voltage.

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 1.

$$R_{bat(tot)} = 2(R_{DS(ON)}) + 2R_{cell} \qquad \text{(Equation 1)}$$

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.

The Charge MOSFET Circuit.

The NE57607 uses an isolated charge MOSFET drive arrangement. This is to help keep ESD charges from entering the IC. The charge MOSFET is normally ON until turned off by the IC. The CF pin uses a current source to drive an external NPN transistor to turn OFF the charge FET. If a charge has poor “compliance” or the no load voltage of the charge can rise significantly above the rating of the battery pack. This condition causes the source of the charge FET to go very negative compared to the cell GND voltage after the charge FET opens. This design allows the charge FET gate drive to “float” down to this very negative voltage without upsetting the operation of the IC.

PACKING METHOD

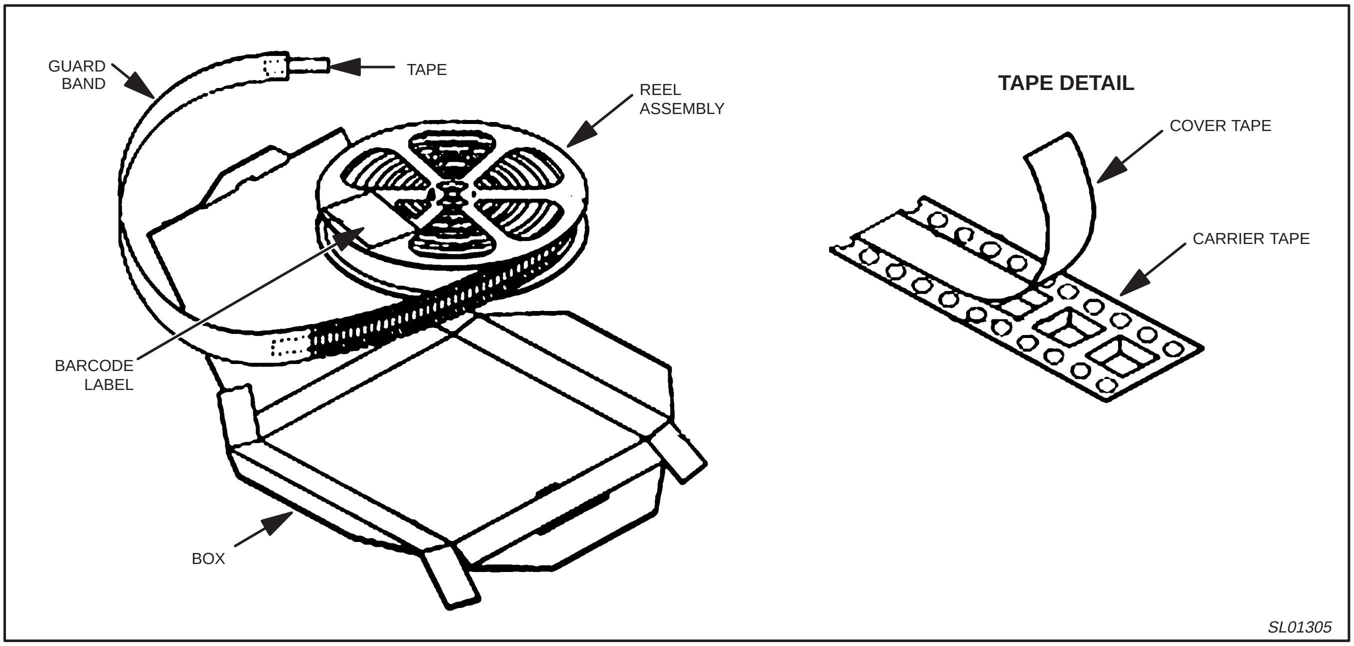
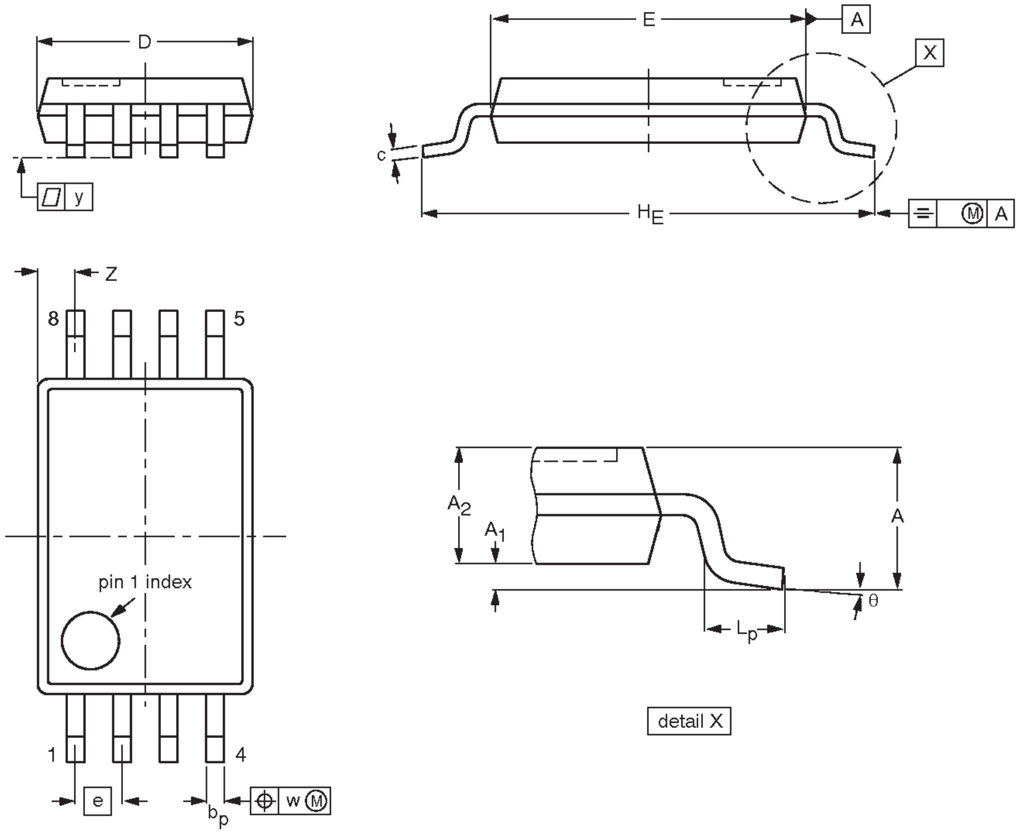


Figure 7. Tape and reel packing method.

VSOP-8A: plastic small outline package; 8 leads; body width 4.4 mm



DIMENSIONS (mm are the original dimensions)

UNIT	A	A_1	A_2		b_p	c	$D^{(1)}$	$E^{(2)}$	e	H_E		L_p		w	y	$Z^{(1)}$	θ
mm	1.35 1.15	0.15 0.05	1.15		0.23 0.21	0.16 0.10	3.4 2.8	4.6 4.2	0.65	6.7 6.1		0.7 0.3		0.12	0.10	0.875 max.	10° 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
	IEC	JEDEC	EIAJ		
VSOP-8A					

Data sheet status

Data sheet status [1]	Product status [2]	Definitions
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.
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.
Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Changes will be communicated according to the Customer Product/Process Change Notification (CPCN) procedure SNW-SQ-650A.

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.

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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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