

# DATA SHEET

## **NE57600**

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

Product data

2001 Oct 03

File under Integrated Circuits, Standard Analog

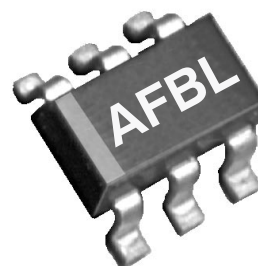
# One-cell Lithium-ion battery protection with over/undercharge and overcurrent protection

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## GENERAL DESCRIPTION

The NE57600 series is a family of small, high-precision lithium-ion battery protection devices that provide protection against the damaging effects of overcharging, overdischarging, short circuit, and excessive current consumption such as happens if the consumer uses the battery for an apparatus it was not meant to power. The NE57600 is a single-cell Li-ion protection IC.

The NE57600 over and under voltage accuracy is trimmed to within  $\pm 25$  mV (5%) and is available to match the requirements of all lithium-ion cells manufactured in the market today.



## FEATURES

- Trimmed overvoltage trip point to within  $\pm 25$  mV
- Programmable overvoltage trip time delay
- Trimmed undervoltage trip point to within  $\pm 25$  mV
- Very Low undervoltage sleep quiescent current 0.05 mA
- Discharge overcurrent cutoff
- Low operating current (10  $\mu$ A)
- Very small SOT-26A package

## APPLICATIONS

- Protecting one-cell Li-ion battery packs for mobile phones or palmtop devices

## SIMPLIFIED SYSTEM DIAGRAM

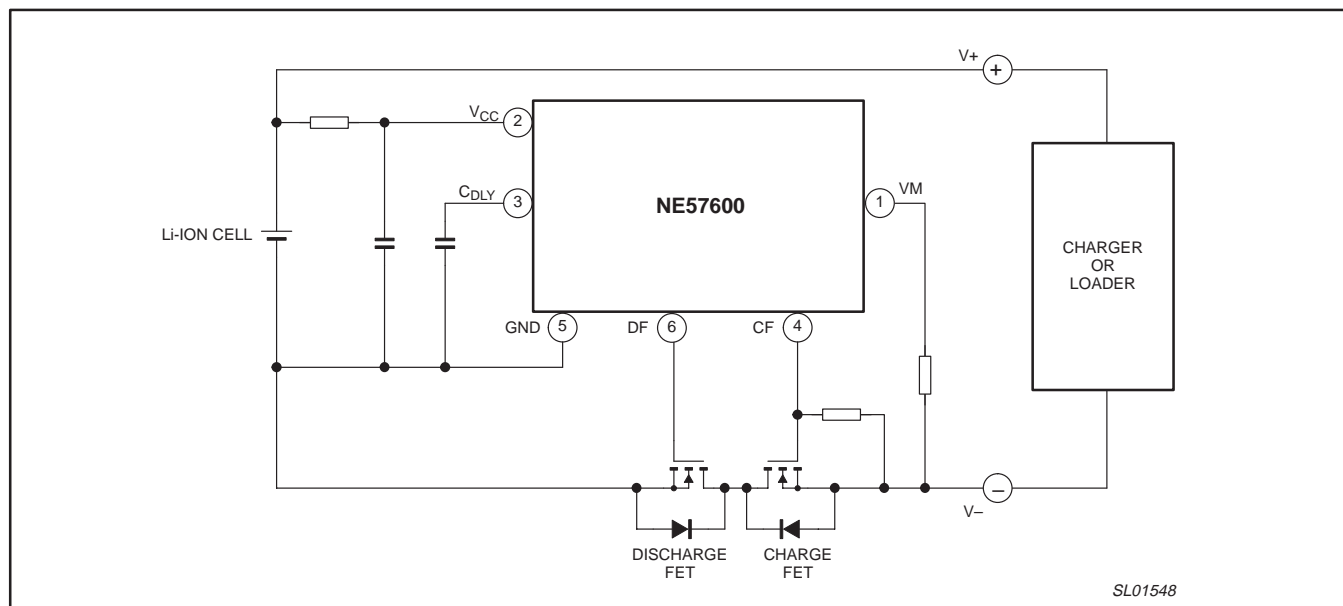


Figure 1. Simplified system diagram.

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## ORDERING INFORMATION

TYPE NUMBER	PACKAGE		TEMPERATURE RANGE
	NAME	DESCRIPTION	
NE57600XD	SOT-26A	small outline plastic surface mount, 6-pin	-20 to +70 °C

### NOTE:

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

## TYPICAL PROTECTION PARAMETERS IN THE NE57600 FAMILY

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)
NE57600Y	4.200	200	2.3	3.00	200
NE57600D	4.200	200	2.3	3.90	200
NE57600E	4.250	200	2.3	3.00	200
NE57600F	4.250	150	2.4	3.00	150
NE57600C	4.280	200	2.3	2.90	120
NE57600G	4.295	150	2.4	3.00	150
NE57600W	4.300	150	2.4	3.00	150
NE57600H	4.325	200	2.5	3.00	200
NE57600J	4.325	200	2.5	3.00	200
NE57600B	4.350	200	2.4	3.00	200

## 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
NE57600YD	A F A x
NE57600BD	A F B x
NE57600CD	A F C x
NE57600DD	A F D x
NE57600ED	A F E x
NE57600FD	A F F x
NE57600GD	A F G x
NE57600HD	A F H x
NE57600WD	A F J x
NE57600JD	A F K x

## PIN CONFIGURATION

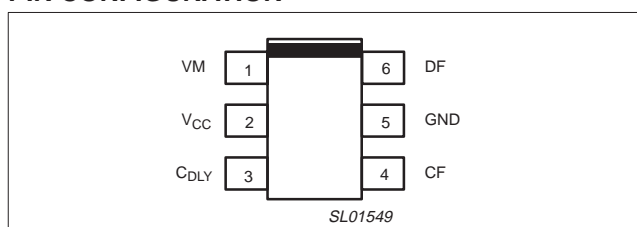


Figure 2. Pin configuration.

## PIN DESCRIPTION

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

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## MAXIMUM RATINGS

SYMBOL	PARAMETER	MIN.	MAX.	UNIT
$V_{IN}$	Input voltage	-0.3	+18	V
$V_{CF(max)}$	CF pin voltage	-	$V_{CC} - 28$	V
$V_{VM(max)}$	VM pin voltage	-	$V_{CC} - 28$	V
$T_{amb}$	Operating ambient temperature range	-20	+70	°C
$T_{stg}$	Storage temperature	-40	+125	°C
$P_D$	Power dissipation	-	200	mW

## ELECTRICAL CHARACTERISTICS

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

SYMBOL	PARAMETER	CONDITIONS	Min.	Typ.	Max.	UNIT
$I_{CC1}$	Current consumption 1	$V_{CC} = 3.6\text{ V}$ : Set between CF-GND: 910 k $\Omega$ connected		10.0	14.0	$\mu\text{A}$
$I_{CC2}$	Current consumption 2	$V_{CC} = 3.6\text{ V}$ : IC only between CF-GND: 910 k $\Omega$ connected		6.0	10.0	$\mu\text{A}$
$I_{CC3}$	Current consumption 3	$V_{CC} = 3.6\text{ V}$ : Discharge FET OFF between CF-GND: 910 k $\Omega$ not connected		TBD	TBD	$\mu\text{A}$
$I_{CC4}$	Current consumption 4	$V_{CC} = 1.9\text{ V}$ : Discharge FET OFF between CF-GND: 910 k $\Omega$ not connected		0.05	0.3	$\mu\text{A}$
$I_{CC5}$	Current consumption 5	$V_{CC} = 4.5\text{ V}$ : Set between CF-BG: 910 k $\Omega$ connected		35	60	$\mu\text{A}$
$V_{OV(th)}$	Over-charge voltage	$T_{amb} = 0\text{ °C} \sim 50\text{ °C}$ $V_{CC}$ : L $\rightarrow$ H	4.325	4.350	4.375	V
$V_{OV(hyst)}$	Over-charge hysteresis	$V_{CC}$ : H $\rightarrow$ L	100	200	300	mV
$V_{UV(th)}$	Over-discharge voltage	$V_{CC}$ : H $\rightarrow$ L	2.30	2.40	2.50	V
$V_{UV(rel)}$	Release over-discharge mode		2.88	3.00	3.12	V
$V_{OC(th)}$	Over-current detect level	$V_{VM}$ : L $\rightarrow$ H	174	200	226	mV
$V_{OC(rel)}$	Release over-current level	$V_{VM}$ : H $\rightarrow$ L		130		mV
	Condition of release over-current mode	Load condition		50		M $\Omega$
$V_{SC}$	Short detect level			1.3		V
$t_{DLY(OD)}$	Over-discharge dead time		7.0	10.0	15.0	ms
$t_{OC(DT)}$	Over-current dead time	$V_{VM}$ : 0 V $\rightarrow$ 0.5 V	7.0	10.0	15.0	ms
$t_{DLY(SC)}$	Short detect delay time	$V_{VM}$ : 0 V $\rightarrow$ 2 V		0.02	0.20	ms
$t_{OLY(OV)}$	Over-charge dead time	$C_{TD} = 0.01\text{ }\mu\text{F}$	50	100	150	ms
$V_{GDH}$	DF pin LOW level	$V_{CC} = 3.6\text{ V}$	$V_{CC}-0.3$	$V_{CC}-0.1$	$V_{CC}$	V
$I_{DFH1}$	DF pin source current 1	$V_{DF} = V_{CC} - 1.0\text{ V}$		-100	-30	$\mu\text{A}$
$I_{DFH2}$	DF pin source current 2	$V_{DF} = V_{CC} - 0.3\text{ V}$		-0.40	-0.07	$\mu\text{A}$
$I_{DFL1}$	DF pin sink current 1	$V_{VM} > 1.0\text{ V}$ ; $V_{DF} = 1.0\text{ V}$	50	300		$\mu\text{A}$
$I_{DFL2}$	DF pin sink current 2	$V_{VM} > 1.0\text{ V}$ ; $V_{DF} = 0.3\text{ V}$	30	100		$\mu\text{A}$
$I_{CF1}$	CF pin source current 1	$V_{CF} = V_{CC} - 1.0\text{ V}$		-20	-10	$\mu\text{A}$
$I_{CF2}$	CF pin source current 2	$V_{CF} = V_{CC} - 0.3\text{ V}$		-15	-5	$\mu\text{A}$
$V_{ST}$	Start trigger voltage	$V_{VM}$ : 0 V $\rightarrow$ -0.5 V	-0.2	-0.1	0	V
$V_{PRO}$	Over-voltage charger protection	$V_{CC} = 3.6\text{ V}$ , between GND-VM voltage	-1.5	-2.5	-3.0	V
$V_{OV}$	OV charge minimum voltage	$V_{CC} = 0\text{ V}$ ; Charger voltage		2.0	3.0	V

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

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## TYPICAL PERFORMANCE CURVES

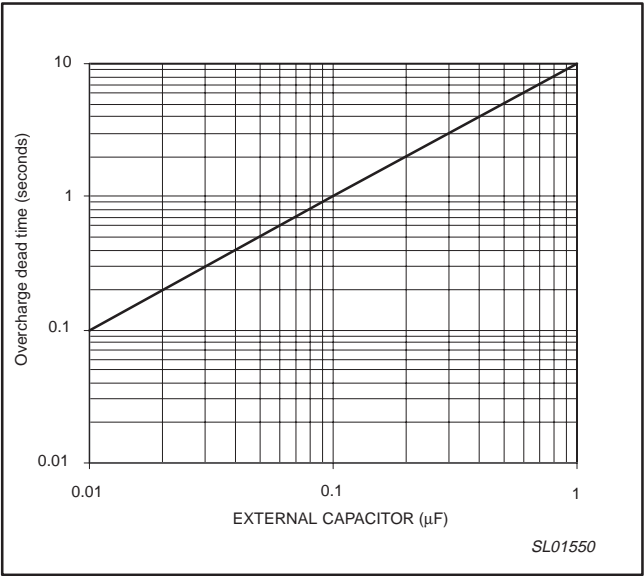


Figure 3. Over-voltage time delay versus external capacitor.

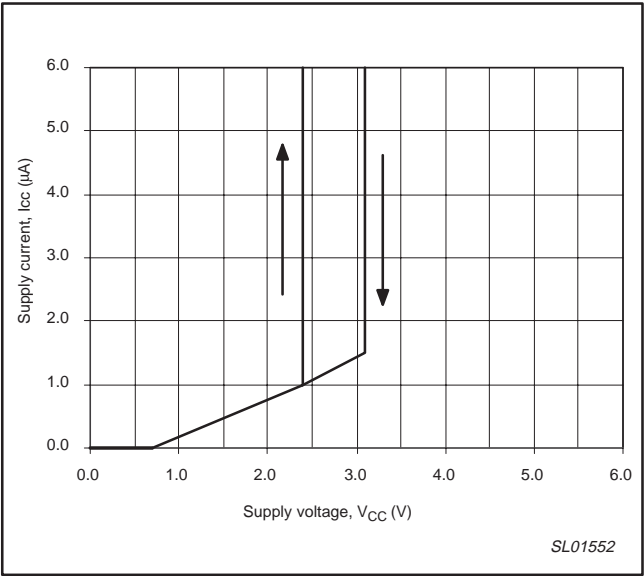


Figure 5. Supply current versus supply voltage.

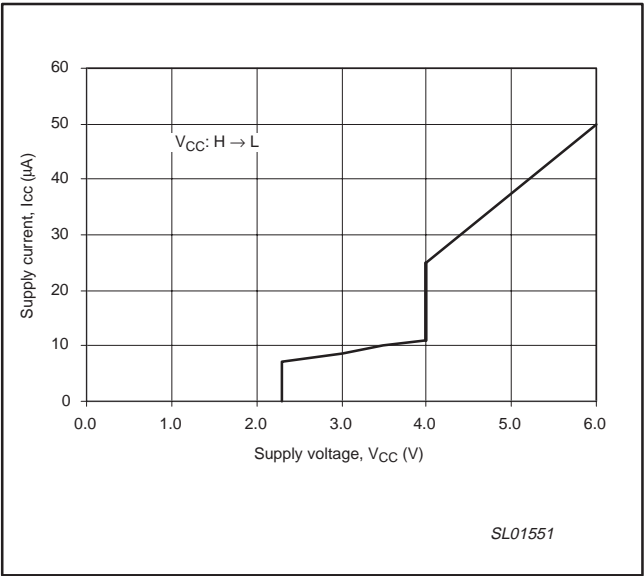


Figure 4. Supply current versus supply voltage.

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## 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 ( $V_{\text{cell}}$  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 6.

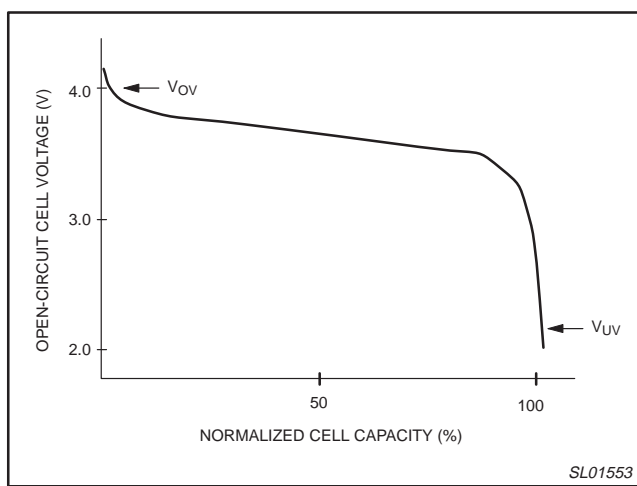


Figure 6. Lithium discharge curve.

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## 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 7.

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 7) 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.

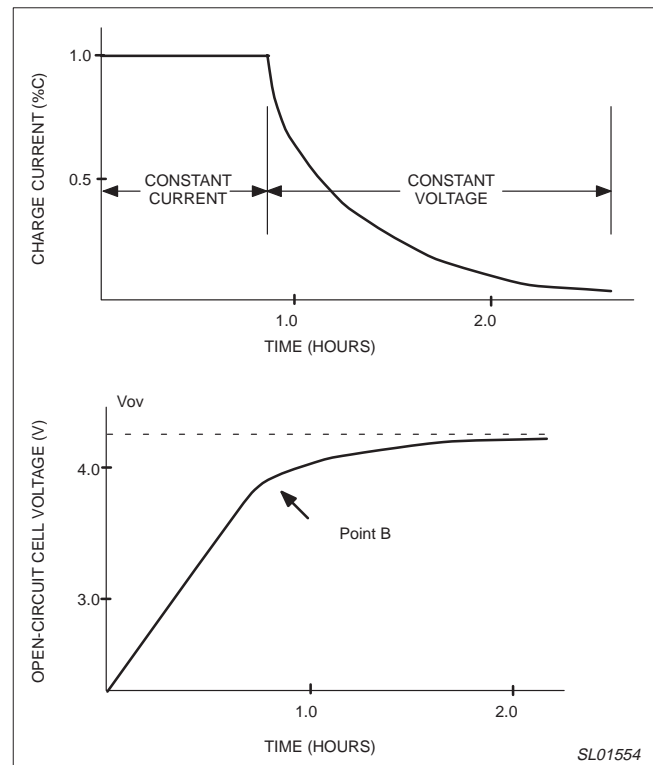
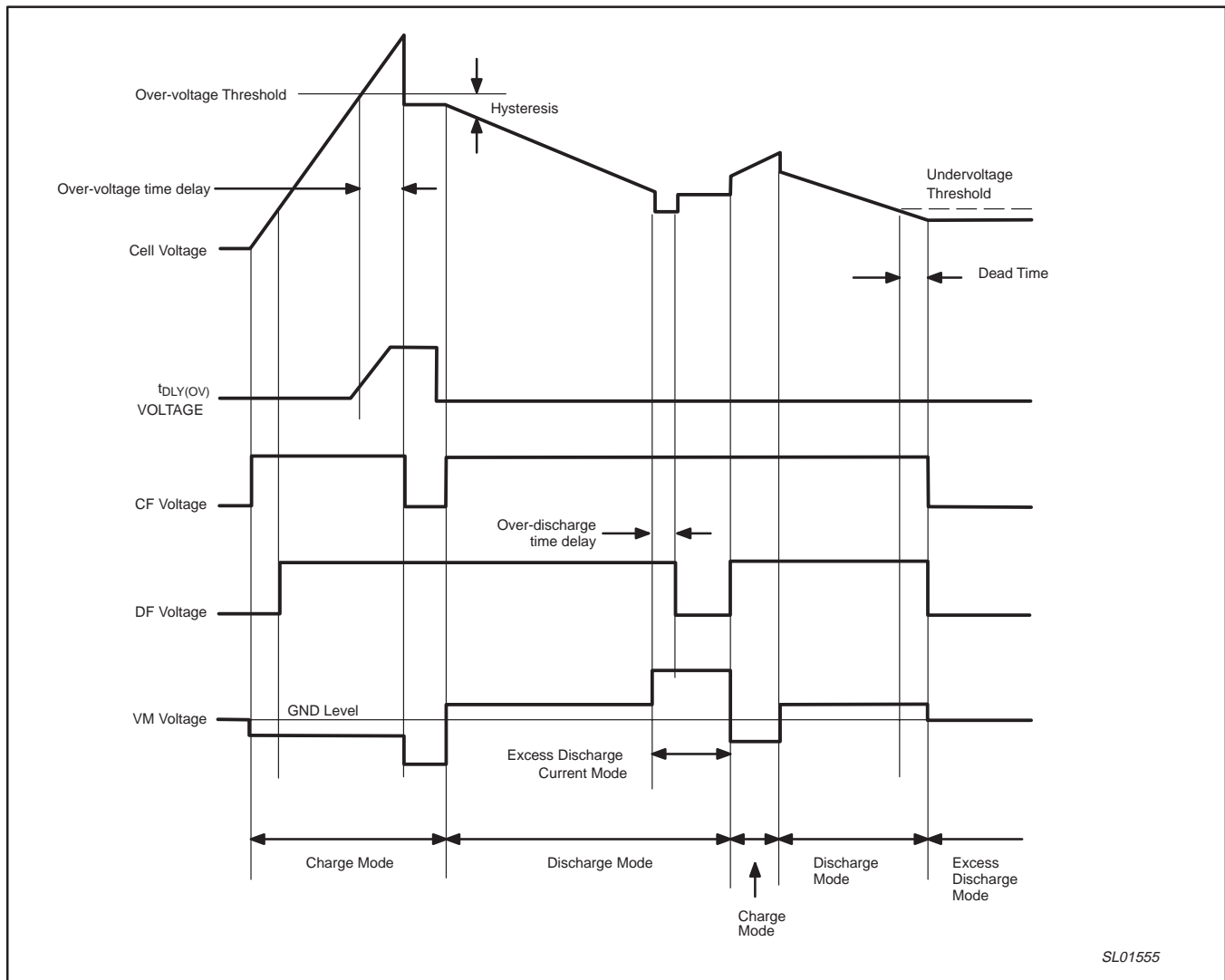


Figure 7. Lithium cell charging curves.

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**Figure 8. Timing diagram.**



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

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## APPLICATION INFORMATION

The NE57600 drives the series N-Channel MOSFETs to states determined by the cell's voltage and the battery pack load current. During normal operation, both the discharge and charge MOSFETs are ON, 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. The cell's voltage must fall lower than the overvoltage hysteresis voltage ( $V_{OV(Hyst)}$ ) before the charge MOSFET is again turned ON.

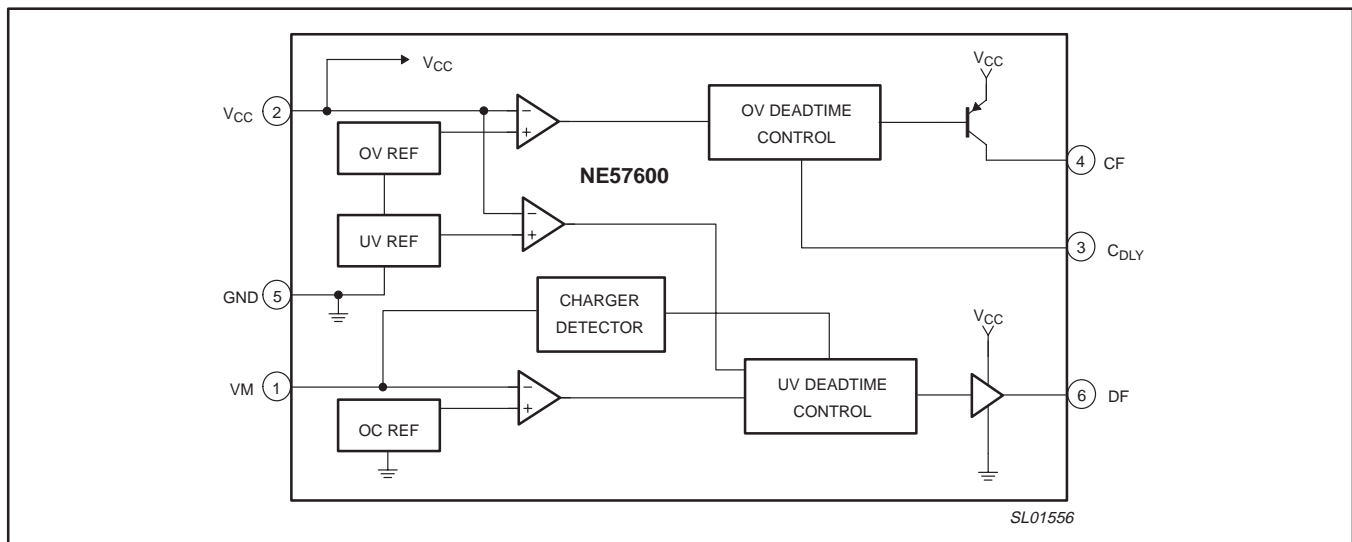
If the battery pack is being discharged and the undervoltage threshold ( $V_{UV(Th)}$ ) is exceeded, then the discharge MOSFET is turned OFF. It will not turn back ON until a charger is applied to the pack's external terminals AND the cell's voltage rises above the undervoltage hysteresis voltage ( $V_{UV(Hyst)}$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

When the battery pack is being discharged, if the load current causes the voltage across the discharge MOSFET to exceed the

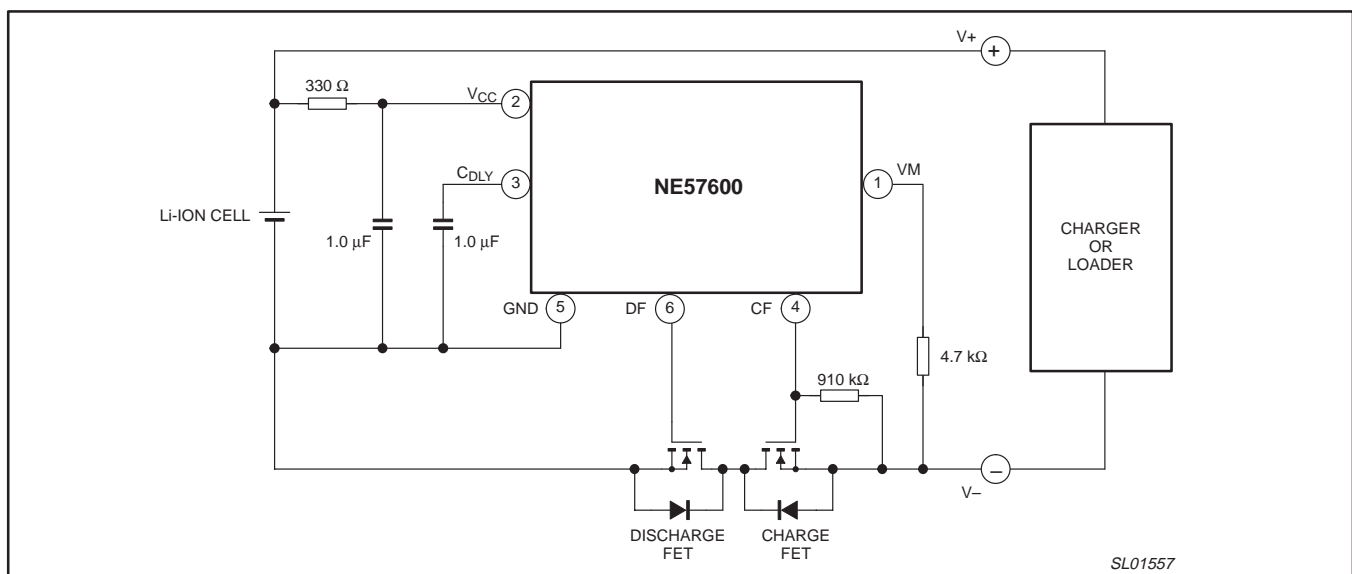
overcurrent threshold voltage ( $V_{OC(TH)}$ ), then the discharge MOSFET is turned OFF after a fixed 7–18 ms delay. If short-circuit is placed across the pack's terminals, then the discharge MOSFET is turned OFF after a 100–300 ms delay to avoid damaging the MOSFETs.

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

An R-C filter is needed on the  $V_{CC}$  pin, primarily to shield the IC from electrostatic energy 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-C filter provides power during the first instant of the short circuit, allowing the IC to turn OFF the discharge MOSFET before the IC loses power. The R-C filter also filters any voltage noise caused by noisy load current. The values shown in Figure 9 are adequate for these purposes.



**Figure 9. Functional diagram.**



**Figure 10. Typical application circuit.**

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## 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)

## 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 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 1.

$$R_{bat(tot)} = R_{DS(on)} + R_{cell} \quad (\text{Equation 1})$$

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.

## PACKING METHOD

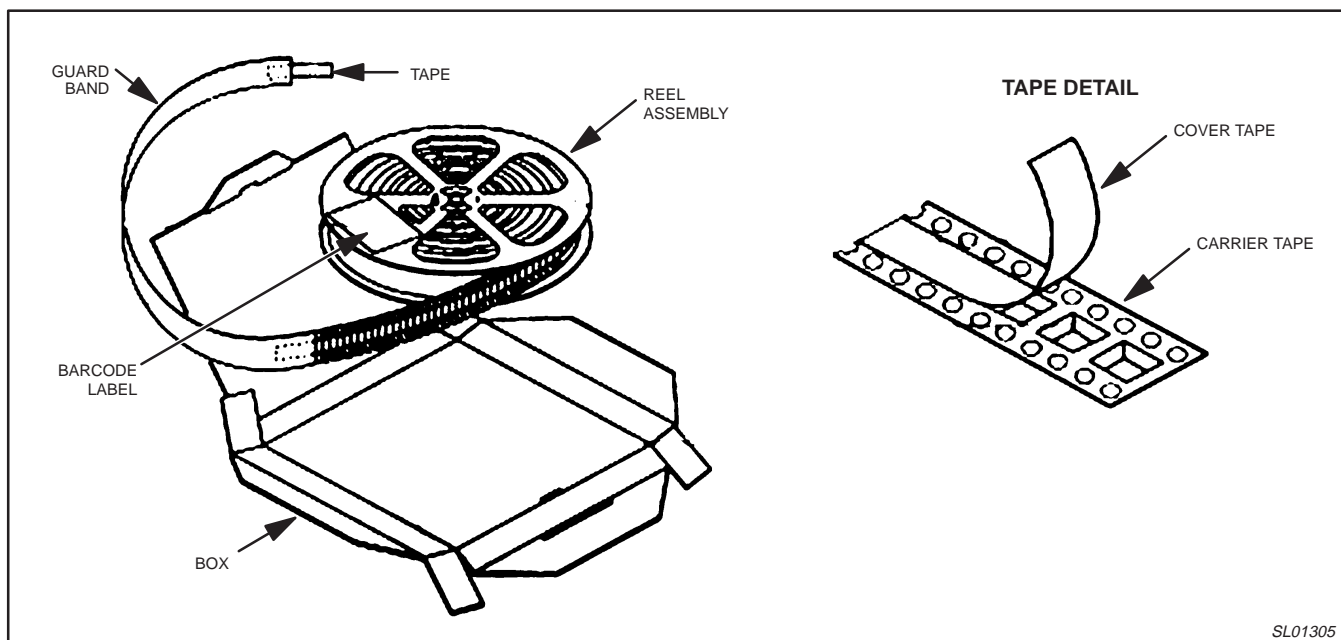
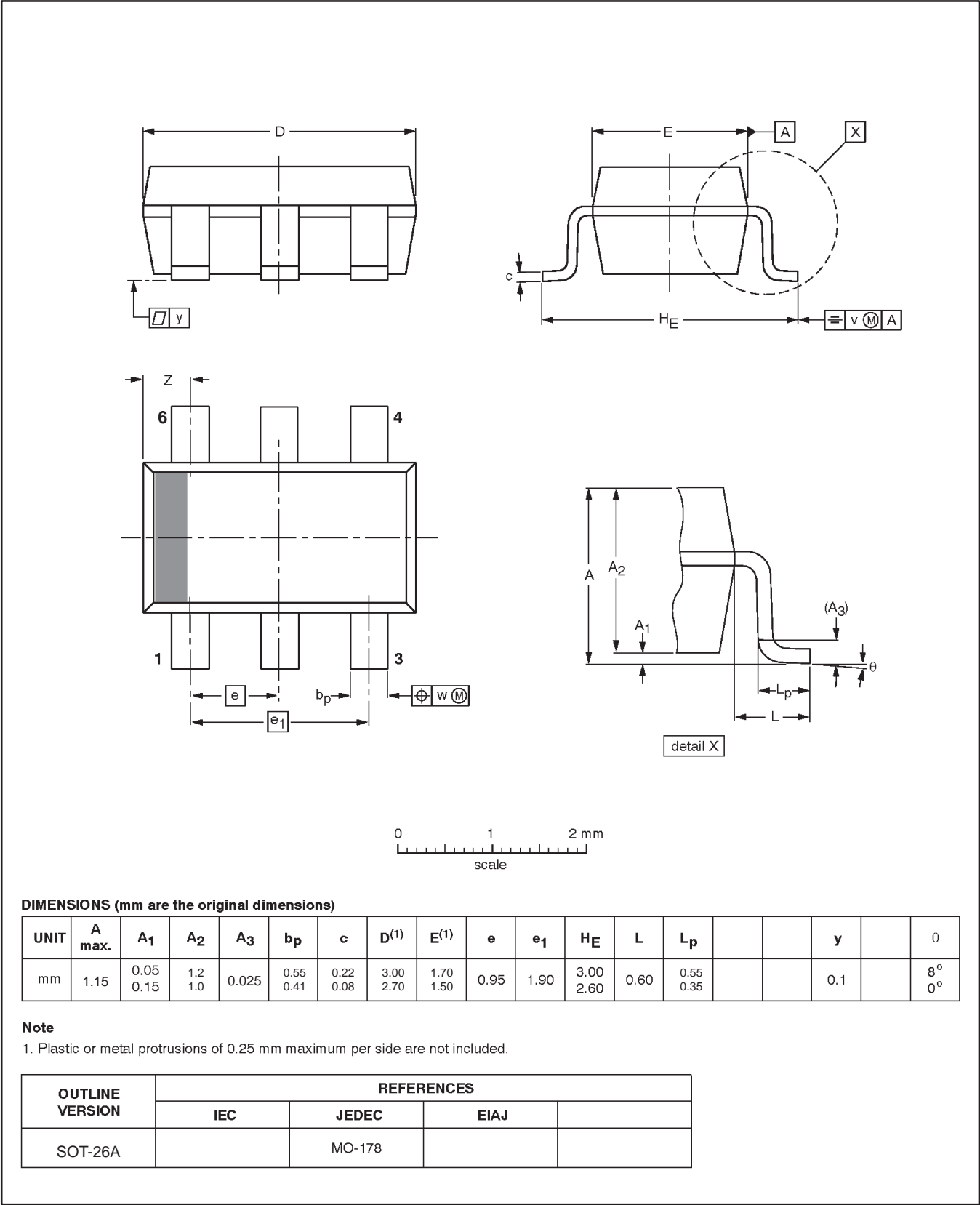


Figure 11. Tape and reel packing method.

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SOT-26A: plastic small outline package; 6 leads; body width 1.8 mm



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## Data sheet status

Data sheet status <sup>[1]</sup>	Product status <sup>[2]</sup>	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.
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