

Protection IC for 1-Cell Battery Pack

Features

- High Detection Accuracy
 - Over-charge Detection: $\pm 15\text{mV}$
 - Over-discharge Detection: $\pm 35\text{mV}$
 - Discharge Over-current Detection: $\pm 10\text{mV}/\pm 15\text{mV}$
 - Charge Over-current Detection: $\pm 20\text{mV}$
- High Withstand Voltage
 - Absolute maximum ratings: 28V (V- pin and CO pin)
- Ultra Small Package
 - SOT-23-5
 - SOT-23-6
 - DFN-1.6X1.6-6L
 - SON-1.6X1.6-6L

Application

- Mobile phone battery packs
- Digital camera battery packs
- Bluetooth earphone Li-ion battery module

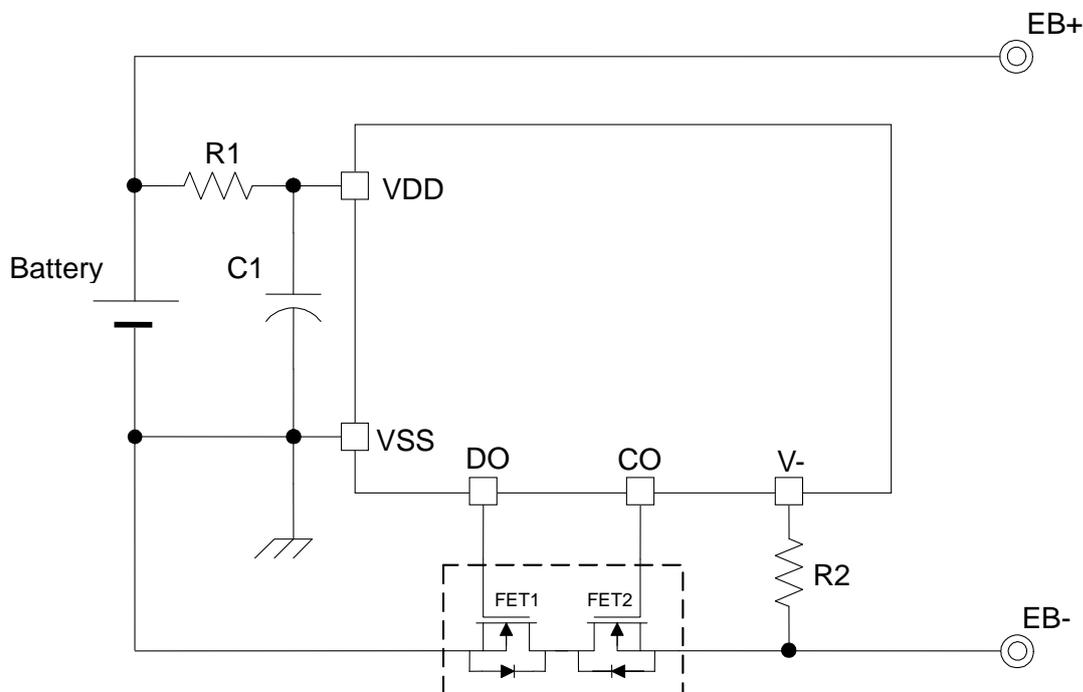
Description

The NT1713 series are the 1-cell protection IC for lithium-ion/lithium-polymer rechargeable battery pack. The high accuracy voltage detector and delay time circuits are built in NT1713 series with state-of-art design and process.

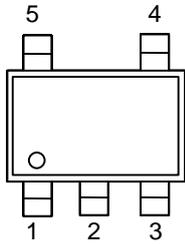
To minimize power consumption, NT1713 series activates power down mode when an over-discharge event is detected (for power-down mode enabled version). Besides, NT1713 series performs protection functions with four external components for miniaturized PCB.

The tiny package is especially suitable for compact portable device, i.e. slim mobile phone and Bluetooth earphone.

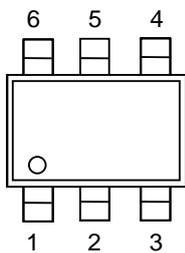
Typical Application Circuit



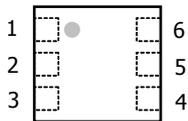
Package and Pin Description

SOT-23-5


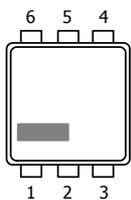
Pin No.	Symbol	Pin description
1	V-	Voltage detection between V- pin and Vss pin (Over-current / charger detection pin)
2	V _{DD}	Connection for positive power supply input
3	V _{SS}	Connection for negative power supply input
4	DO	Connection of discharge control FET gate
5	CO	Connection of charge control FET gate

SOT-23-6


Pin No.	Symbol	Pin description
1	DO	Connection of discharge control FET gate
2	V-	Voltage detection between V- pin and VSS pin (Over-current / charger detection pin)
3	CO	Connection of charge control FET gate
4	NC	No connection
5	V _{DD}	Connection for positive power supply input
6	V _{SS}	Connection for negative power supply input

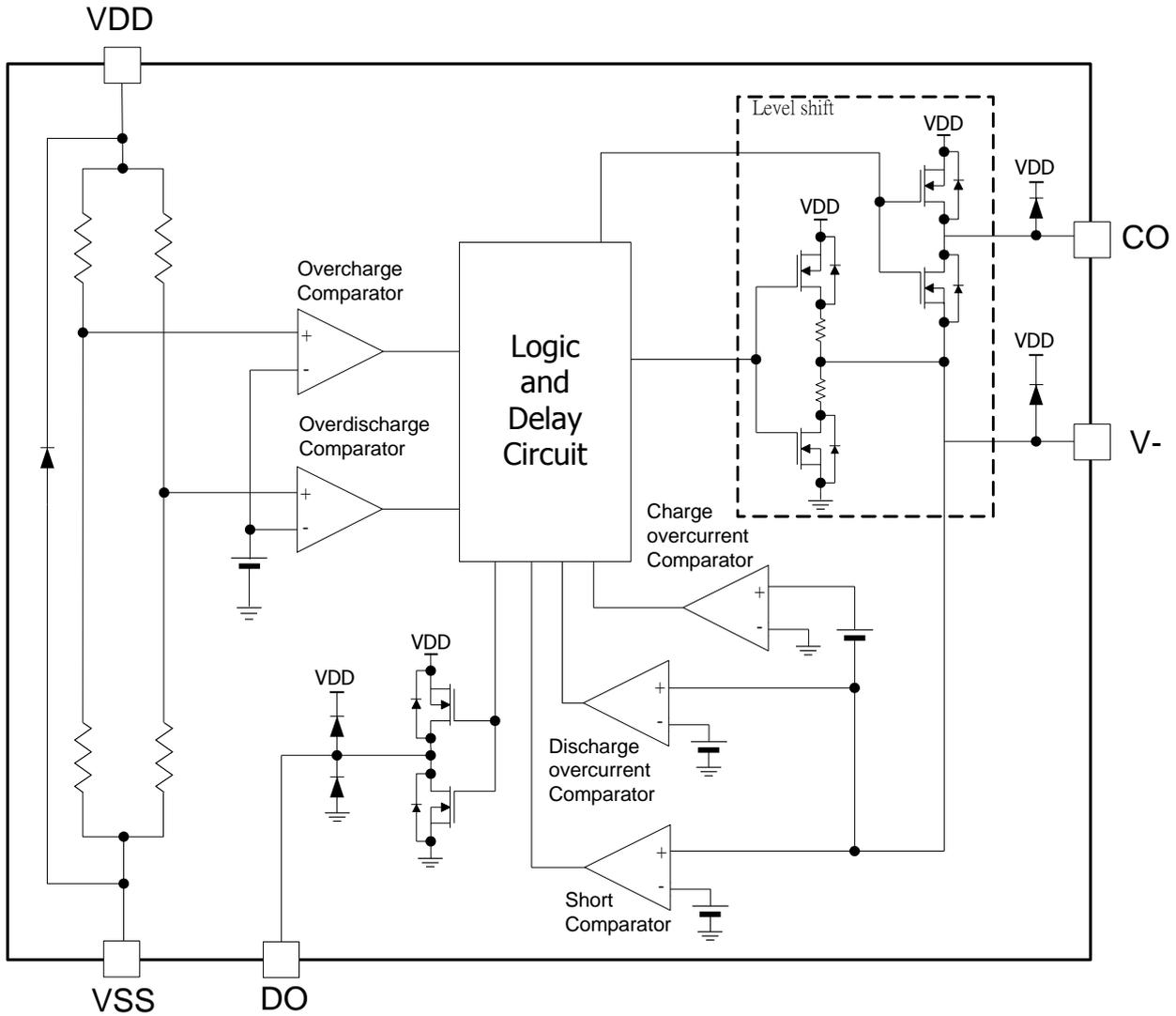
DFN-1.6X1.6-6L


Pin No.	Symbol	Pin description
1	NC	No connection
2	CO	Connection of charge control FET gate
3	DO	Connection of discharge control FET gate
4	V _{SS}	Connection for negative power supply input
5	V _{DD}	Connection for positive power supply input
6	V-	Voltage detection between V- pin and VSS pin (Over-current / charger detection pin)

SON-1.6X1.6-6L


Pin No.	Symbol	Pin description
1	NC	No connection
2	CO	Connection of charge control FET gate
3	DO	Connection of discharge control FET gate
4	V _{SS}	Connection for negative power supply input
5	V _{DD}	Connection for positive power supply input
6	V-	Voltage detection between V- pin and VSS pin (Over-current / charger detection pin)

Block Diagram



Ordering Information

NT1713A -XXX XX

Package Type

A5: SOT-23-5

A6: SOT-23-6

B4: DFN-1.6x1.6-6L

C1: SON-1.6x1.6-6L

Version code

Product version code:

Table1: Detection threshold level table

Product Name	Version Code	Package Type	Over-charge Detection Voltage	Over-charge Hysteresis Voltage	Over-discharge detection voltage	Over-discharge release voltage	Discharge over-current detection voltage	Charge over-current detection voltage	Load short-circuiting detection voltage	0V Battery Charge Function	Delay Time
			V_{DET1} (V)	V_{HYS1} (V)	V_{DET2} (V)	V_{REL2} (V)	V_{DET3} (V)	V_{DET4} (V)	V_{SHORT} (V)	Table 2	
NT1713A	HFA	A6/B4/C1	4.280	0.00	2.3	2.3	0.10	-0.1	0.5	Un-available	(1)
NT1713A	HFB	A6/B4/C1	4.280	0.00	2.3	2.3	0.13	-0.1	0.5	Un-available	(1)
NT1713A	HQA	A5/A6/C1	4.280	0.15	2.8	3.1	0.15	-0.1	0.5	Un-available	(2)
NT1713A	HQB	A5/A6/C1	4.280	0.15	2.8	3.1	0.10	-0.1	0.5	Un-available	(2)
NT1713A	HQC	A6/B4/C1	4.280	0.00	2.8	3.1	0.15	-0.1	0.5	Un-available	(1)
NT1713A	KKA	A5/A6/C1	4.325	0.20	2.5	2.9	0.15	-0.1	0.5	Un-available	(2)
NT1713A	NHA	A5/A6/C1	4.425	0.20	2.4	2.4	0.10	-0.1	0.5	Un-available	(1)
NT1713A	NHB	A5/A6/B4/C1	4.425	0.20	2.4	2.4	0.15	-0.1	0.5	Un-available	(1)
NT1713A	NHC	A5/A6/B4/C1	4.425	0.20	2.4	2.4	0.20	-0.1	0.5	Un-available	(1)
NT1713A	NQA	C1	4.425	0.20	2.8	3.0	0.038	-0.05	0.3	Available	(1)

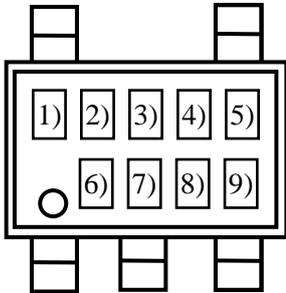
Table2: Delay Time table

Delay time	Over-charge delay time	Over-discharge delay time	Discharge over-current delay time	Charge over-current delay time	Load short-circuiting delay time
	t_{VDET1} (S)	t_{VDET2} (mS)	t_{VDET3} (mS)	t_{VDET4} (mS)	t_{SHORT} (uS)
(1)	1.0 +/- 20%	125 +/- 20%	8.0 +/- 20%	8.0 +/- 20%	400 +/- 20%
(2)	1.2 +/- 20%	150 +/- 20%	9.0 +/- 20%	9.0 +/- 20%	300 +/- 20%

Remark Please contact our sales office for the products with detection voltage value other than those specified above.

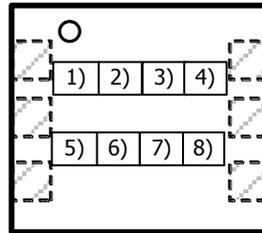
Marking Information

SOT-23-5
Top view



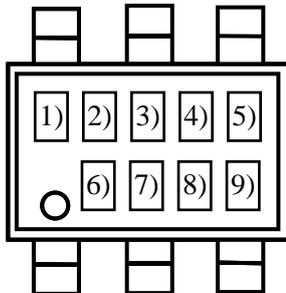
1) to 2) : Product code (**BN**)
 3) to 5) : Version code
 6) to 9) : Lot number

DFN-1.6x1.6-6L
Top view



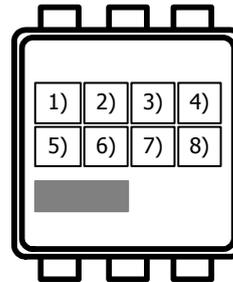
1) to 2) : Product code (**BN**)
 3) to 4) : Version code
 5) to 8) : Lot number

SOT-23-6
Top view



1) to 2) : Product code (**BN**)
 3) to 5) : Version code
 6) to 9) : Lot number

SON-1.6x1.6-6L
Top view



1) to 2) : Product code (**BN**)
 3) to 4) : Version code
 5) to 8) : Lot number

Product name vs. Version code

Product Name	Version Code	Version Code			
		(3)(4)(5) Version Code	(3)(4)(5) Version Code	(3)(4) Version Code	(3)(4) Version Code
		SOT-23-5	SOT-23-6	DFN-1.6X1.6-6L	SON-1.6X1.6-6L
NT1713A	HFA	-	HFA	10	10
NT1713A	HFB	-	HFB	11	11
NT1713A	HQA	HQA	HQA	-	13
NT1713A	HQB	HQB	HQB	-	14
NT1713A	HQC	-	HQC	12	12
NT1713A	KKA	KKA	KKA	-	18
NT1713A	NHA	NHA	NHA	-	15
NT1713A	NHB	NHB	NHB	16	16
NT1713A	NHC	NHC	NHC	17	17
NT1713A	NQA	-	-	-	19

Absolute Maximum Ratings

Symbol	Descriptions	Rating	Units
V _{DD}	Supply Voltage	-0.3 to 7	V
V ₋	V- pin	V _{DD} - 28 to V _{DD} + 0.3	V
V _{CO}	Output Voltage	CO pin	V _{DD} - 28 to V _{DD} + 0.3
V _{DO}		DO pin	V _{SS} - 0.3 to V _{DD} + 0.3
T _{OPT}	Operating Temperature Range	-40 to +85	°C
T _{STG}	Storage Temperature Range	-55 to +125	°C

Applying any over "Absolute Maximum Ratings" practice can permanently damage the device. These data are indicated the absolute maximum values only but not implied any operating performance.

Electrical Characteristics (For Li-ion)

(Ta = 25°C)

Symbol	Item	Conditions	MIN	TYP	MAX	Unit
Detection Voltage						
V _{DET1}	Over-charge detection voltage	--	V _{DET1} -0.015	V _{DET1}	V _{DET1} +0.015	V
V _{HYS1}	Over-charge hysteresis voltage	--	V _{HYS1} -0.020	V _{HYS1}	V _{HYS1} +0.020	V
V _{DET2}	Over-discharge detection voltage	--	V _{DET2} -0.035	V _{DET2}	V _{DET2} +0.035	V
V _{REL2}	Over-discharge release voltage	V _{DET2} ≠ V _{REL2}	V _{REL2} -0.050	V _{REL2}	V _{REL2} +0.050	V
		V _{DET2} = V _{REL2}	V _{REL2} -0.035	V _{REL2}	V _{REL2} +0.035	V
V _{DET3}	Discharge over-current detection voltage	V _{DD} =3.5V V _{DET3} (typ) ≤ 0.150V	V _{DET3} -0.010	V _{DET3}	V _{DET3} +0.010	V
		V _{DD} =3.5V V _{DET3} (typ) > 0.150V	V _{DET3} -0.015	V _{DET3}	V _{DET3} +0.015	V
V _{DET4}	Charge over-current detection	V _{DD} =3.5V	V _{DET4} -0.020	V _{DET4}	V _{DET4} +0.020	V
V _{SHORT}	Load short-circuiting detection voltage	V _{DD} =3.5V V _{SHORT} (typ)=0.50V	V _{SHORT} -0.10	V _{SHORT}	V _{SHORT} +0.10	V
		V _{DD} =3.5V V _{SHORT} (typ)=0.30V	V _{SHORT} -0.05	V _{SHORT}	V _{SHORT} +0.05	V

(Continued)

Symbol	Item	Conditions	MIN	TYP	MAX	Unit
Detection Delay Time 【Table 2 Delay time (1)】						
t_{VDET1}	Output delay time of over-charge	-	0.8	1.0	1.2	s
t_{VDET2}	Output delay time of over-discharge	-	100	125	150	ms
t_{VDET3}	Output delay time of discharge over current	$V_{DD}=3.5V$	6.4	8.0	9.6	ms
t_{VDET4}	Output delay time of charge over current	$V_{DD}=3.5V$	6.4	8.0	9.6	ms
t_{SHORT}	Output delay time of Load short-circuiting detection	$V_{DD}=3.5V$	320	400	480	us
Detection Delay Time 【Table 2 Delay time (2)】						
t_{VDET1}	Output delay time of over-charge	-	0.96	1.2	1.44	s
t_{VDET2}	Output delay time of over-discharge	-	120	150	180	ms
t_{VDET3}	Output delay time of discharge over current	$V_{DD}=3.5V$	7.2	9.0	10.8	ms
t_{VDET4}	Output delay time of charge over current	$V_{DD}=3.5V$	7.2	9.0	10.8	ms
t_{SHORT}	Output delay time of Load short-circuiting detection	$V_{DD}=3.5V$	240	300	360	us
Current Consumption (power-down function enabled)						
V_{DD}	Operating input voltage	$V_{DD} - V_{SS}$	2.0		6.0	V
I_{DD}	Supply current	$V_{DD}=3.5V, V-=0V$	1.0	3.0	5.5	uA
$I_{STANDBY}$	Power-down current (power-down function enabled IC only)	$V_{DD}=1.8V, V-$ floating			0.1	uA
0V battery Charging Function						
V_{OCHA}	0 V battery charge starting charger voltage	0 V battery charging function "available"	0.5	1.0	1.5	V
V_{OINH}	0V battery charge inhibition battery voltage	0 V battery charging function "unavailable" (Vcharger=4V~14V)	0.5	1.0	1.5	V
Output Resistance						
R_{COH}	CO pin H resistance	$V_{CO}=3.0V, V_{DD}=3.5V, V-=0V$	1.25	2.50	5.00	K Ω
R_{COL}	CO pin L resistance	$V_{CO}=0.5V, V_{DD}=4.5V, V-=0V$	0.75	1.50	3.00	K Ω
R_{DOH}	DO pin H resistance	$V_{DO}=3.0V, V_{DD}=3.5V, V-=0V$	1.25	2.50	5.00	K Ω
R_{DOL}	DO pin L resistance	$V_{DO}=0.5V, V_{DD}=1.8V, V-=0V$	1.75	3.50	7.00	K Ω
V- internal Resistance						
R_{VMD}	Internal resistance between V- and V_{DD}	$V_{DD}=1.8V, V-=0V$	100	300	900	K Ω
R_{VMS}	Internal resistance between V- and V_{SS}	$V_{DD}=3.5V, V-=1.0V$	50	100	300	K Ω

Electrical Characteristics (For Li-ion)

(Ta = -10 ~ 60°C)*

Symbol	Item	Conditions	MIN	TYP	MAX	Unit
Detection Voltage						
V _{DET1}	Over-charge detection voltage	--	V _{DET1} -0.025	V _{DET1}	V _{DET1} +0.025	V
V _{HYS1}	Over-charge hysteresis voltage	--	V _{HYS1} -0.030	V _{HYS1}	V _{HYS1} +0.030	V
V _{DET2}	Over-discharge detection voltage	--	V _{DET2} -0.050	V _{DET2}	V _{DET2} +0.050	V
V _{REL2}	Over-discharge release voltage	V _{DET2} ≠ V _{REL2}	V _{REL2} -0.080	V _{REL2}	V _{REL2} +0.080	V
		V _{DET2} = V _{REL2}	V _{REL2} -0.050	V _{REL2}	V _{REL2} +0.050	V
V _{DET3}	Discharge over-current detection voltage	V _{DD} =3.5V V _{DET3} (typ) ≤ 0.150V	V _{DET3} -0.015	V _{DET3}	V _{DET3} +0.015	V
		V _{DD} =3.5V V _{DET3} (typ) > 0.150V	V _{DET3} -0.020	V _{DET3}	V _{DET3} +0.020	V
V _{DET4}	Charge over-current detection	V _{DD} =3.5V	V _{DET4} -0.030	V _{DET4}	V _{DET4} +0.030	V
V _{SHORT}	Load short-circuiting detection voltage	V _{DD} =3.5V V _{SHORT} (typ)=0.50V	V _{SHORT} -0.15	V _{SHORT}	V _{SHORT} +0.15	V
		V _{DD} =3.5V V _{SHORT} (typ)=0.30V	V _{SHORT} -0.09	V _{SHORT}	V _{SHORT} +0.09	V
Detection Delay Time 【Table 2 Delay time (1)】						
t _{VDET1}	Output delay time of over-charge	-	0.7	1.0	1.3	s
t _{VDET2}	Output delay time of over-discharge	-	88	125	163	ms
t _{VDET3}	Output delay time of discharge over current	V _{DD} =3.5V	5.0	8.0	11.0	ms
t _{VDET4}	Output delay time of charge over current	V _{DD} =3.5V	5.0	8.0	11.0	ms
t _{SHORT}	Output delay time of Load short-circuiting detection	V _{DD} =3.5V	280	400	520	us
Detection Delay Time 【Table 2 Delay time (2)】						
t _{VDET1}	Output delay time of over-charge	-	0.84	1.2	1.56	s
t _{VDET2}	Output delay time of over-discharge	-	105	150	195	ms
t _{VDET3}	Output delay time of discharge over current	V _{DD} =3.5V	6.0	9.0	12.0	ms
t _{VDET4}	Output delay time of charge over current	V _{DD} =3.5V	6.0	9.0	12.0	ms
t _{SHORT}	Output delay time of Load short-circuiting detection	V _{DD} =3.5V	210	300	390	us

(Continued)

Current Consumption (power-down function enabled)						
V_{DD}	Operating input voltage	$V_{DD} - V_{SS}$	2.0		6.0	V
I_{DD}	Supply current	$V_{DD}=3.5V, V-=0V$	1.0	3.0	6.0	μA
$I_{STANDBY}$	Power-down current (power-down function enabled IC only)	$V_{DD}=1.8V, V-$ floating			0.1	μA
0V battery Charging Function						
V_{OCHA}	0 V battery charge starting charger voltage	0 V battery charging function "available"	0.3	1.0	1.7	V
V_{OINH}	0V battery charge inhibition battery voltage	0 V battery charging function "unavailable" (Vcharger=4V~14V)	0.3	1.0	1.7	V
Output Resistance						
R_{COH}	CO pin H resistance	$V_{CO}=3.0V, V_{DD}=3.5V, V-=0V$	1.00	2.50	5.00	$K\Omega$
R_{COL}	CO pin L resistance	$V_{CO}=0.5V, V_{DD}=4.5V, V-=0V$	0.60	1.50	3.00	$K\Omega$
R_{DOH}	DO pin H resistance	$V_{DO}=3.0V, V_{DD}=3.5V, V-=0V$	1.00	2.50	5.00	$K\Omega$
R_{DOL}	DO pin L resistance	$V_{DO}=0.5V, V_{DD}=1.8V, V-=0V$	1.40	3.50	7.00	$K\Omega$
V- internal Resistance						
R_{VMD}	Internal resistance between V- and V_{DD}	$V_{DD}=1.8V, V-=0V$	78	300	900	$K\Omega$
R_{VMS}	Internal resistance between V- and V_{SS}	$V_{DD}=3.5V, V-=1.0V$	26	100	300	$K\Omega$

*: The specification for this temperature range is guaranteed by design because products are not screened at high to low temperature.

Test Circuits

- **Over-charge, over-discharge and the release detection voltages** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$, then NT1713 series enters operating mode.
 - 2) Increase $V1$ voltage (from 3.5V) gradually. The $V1$ voltage is the over-charge detection voltage (V_{DET1}) when CO pin goes to low (from high).
 - 3) Decrease $V1$ gradually. The voltage gap is the over-charge hysteresis detection voltage (V_{HYS1}) when CO pin goes to high (from low) again.
 - 4) Continue decreasing $V1$. The $V1$ voltage is the over-discharge detection voltage (V_{DET2}) when DO pin goes to low (from high). Then increase $V1$ gradually. The $V1$ voltage is the over-discharge release detection voltage (V_{REL2}), when DO pin goes to high (from low).Note: The over-charge and over-discharge release voltages are defined in versions.

- **Discharge over-current detection voltage** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ and NT1713 series enters operating condition.
 - 2) Increase $V2$ (from 0V) gradually. The $V2$ voltage is the discharge over-current detection voltage (V_{DET3}) when DO pin goes to low (from high).

- **Charge over-current detection voltage** (test circuit 1)
 - 1) Set $V1=3.5V$, $V3=0V$, $S1=OFF$ and $S2=ON$ and NT1713 series enters operating condition.
 - 2) Increase $V3$ gradually. The $V3$ voltage is the charge over-current detection voltage (V_{DET4}) when CO pin goes to low (from high).

- **Load short-circuiting detection voltage** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ and NT1713 series enters operating condition.
 - 2) Increase $V2$ immediately (within 10uS) till DO pin goes to low (from high) with a delay time which is between the minimum and the maximum of Load short-circuiting delay time.

- **Over-charge, over-discharge delay time** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ to enter operating condition.
 - 2) Increase $V1$ from $V_{DET1}-0.2V$ to $V_{DET1}+0.2V$ immediately (within 10us). The over-charge detection delay time (t_{VDET1}) is the period from the time $V1$ gets to $V_{DET1}+0.2V$ till CO pin goes to low (from high).
 - 3) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ to enter operating condition.
 - 4) Decrease $V1$ from $V_{DET2}+0.2V$ to $V_{DET2}-0.2V$ immediately (within 10us). The over-discharge detection delay time (t_{VDET2}) is the period from the time $V1$ gets to $V_{DET2}-0.2V$ till DO pin goes to low (from high).

- **Discharge over-current delay time** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ to enter operating condition.
 - 2) Increase $V2$ from 0V to 0.25V immediately (within 10us). The discharge over-current detection delay time (t_{VDET3}) is the period from the time $V2$ gets to 0.25V till DO pin goes to low (from high).

- **Charge over-current delay time** (test circuit 1)
 - 1) Set $V1=3.5V$, $V3=0V$, $S1=OFF$ and $S2=ON$ to enter operating condition.
 - 2) Increase $V3$ from 0V to 0.3V immediately (within 10us). The charge over-current detection delay time (t_{VDET4}) is the period from the time $V3$ gets to 0.3V till CO pin goes to low (from high).

- **Load short-circuiting delay time** (test circuit 1)
 - 1) Set $V1=3.5V$, $V2=0V$, $S1=ON$ and $S2=OFF$ to enter operating condition.
 - 2) Increase $V2$ from 0V to 1.0V immediately (within 10us). The Load short-circuiting detection voltage delay time (t_{SHORT}) is the period from the time $V2$ gets to 1.0V till DO pin goes to low (from high).

- **Operating & power down current consumption** (test circuit 2)
 - 1) Set $V1=3.5V$, $V2=0V$ and $S1=ON$ to enter operating condition and measure the current $I1$. $I1$ is the operating condition current consumption (I_{DD}).
 - 2) Set $V1=V2=1.8V$ and $S1=ON$ enter over-discharge condition and measure current $I1$. $I1$ is the power down current consumption ($I_{STANDBY}$). (for power-down mode enabled version)

- **Resistance between V- and VDD, V- and VSS** (test circuit 2)
 - 1) Set $V_1=1.8V$, $V_2=0V$ and $S_1=ON$ and NT1713 series enters over-discharge condition. V_1/I_2 is the internal resistance between V- and VDD pin (R_{VMD}).
 - 2) Set $V_1=3.5V$, $V_2=1.0V$ and $S_1=ON$ and NT1713 series enters discharge over-current condition. V_2/I_2 is the internal resistance between V- and VSS pin (R_{VMS}).

- **Output resistance** (test circuit 3)
 - 1) Set $V_1=3.5V$, $V_2=0V$, $V_3=3.0V$, $S_1=OFF$ and $S_2=ON$ to enter operating condition. $(V_3-V_1)/I_2$ is the internal resistance (R_{COH}).
 - 2) Set $V_1=4.5V$, $V_2=0V$, $V_3=0.5V$, $S_1=OFF$ and $S_2=ON$ to enter over-charge condition. V_3/I_2 is the internal resistance (R_{COL}).
 - 3) Set $V_1=3.5V$, $V_2=0V$, $V_3=3.0V$, $S_1=ON$ and $S_2=OFF$ to enter operating condition. $(V_3-V_1)/I_2$ is the internal resistance (R_{DOH}).
 - 4) Set $V_1=1.8V$, $V_2=0V$, $V_3=0.5V$, $S_1=ON$ and $S_2=OFF$ to enter over-discharge condition. V_3/I_2 is the internal resistance (R_{DOL}).

- **0V battery charge starting charger voltage (products with 0V battery charging function is "Available")** (test circuit 4)
 - 1) Set $V_1=V_2=0V$, decrease V_2 gradually.
 - 2) The V_2 voltage is the 0V charge starting voltage (V_{0CHA}) when CO pin voltage goes to $(V_2+0.1)$ from V_2 .

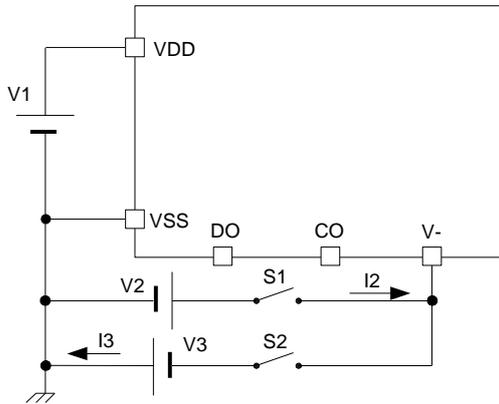
- **0V battery charge inhibition battery voltage (products with 0V battery charging function is "Unavailable")** (test circuit 4)
 - 1) Set $V_1=1.6V$, $V_2=-4V$ then decrease V_1 gradually.
 - 2) The V_1 voltage is the 0V charge inhibition voltage (V_{0INH}) when CO pin voltage goes to V_2 from V_1

Note: The charger voltage should not be higher than 14V.

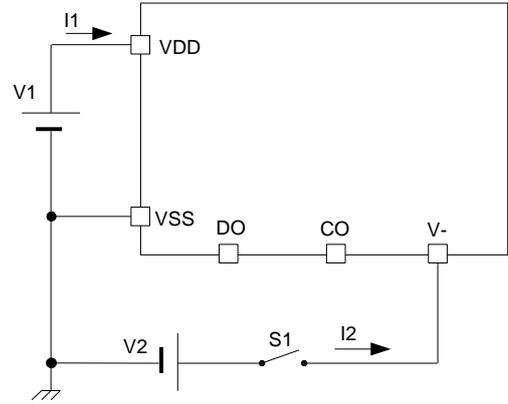
- **Shorten mode for overcharge and over-discharge functions by force voltage to DO pin** (test circuit 5)
 - 1) Set $V_1=3.5V$ then NT1713 series enters operating mode.
 - 2) Set $V_2=0.5V$, increase V_1 voltage (from 3.5V) gradually. The V_1 voltage is the over-charge detection voltage (V_{DET1}) when CO pin goes to low (from high).
 - 3) Decrease V_1 gradually. The voltage gap is the over-charge hysteresis detection voltage (V_{HYS1}) when CO pin goes to high (from low).
 - 4) Continue decreasing V_1 . The V_1 voltage is the over-discharge detection voltage (V_{DET2}) when the voltage drop ($V_{R1K} \cdot I_1$) on DO pin by shorten mode circuit. Then increase V_1 gradually. The V_1 voltage is the over-discharge release detection voltage (V_{REL2}), when DO pin goes to high (from low).

Recommended:

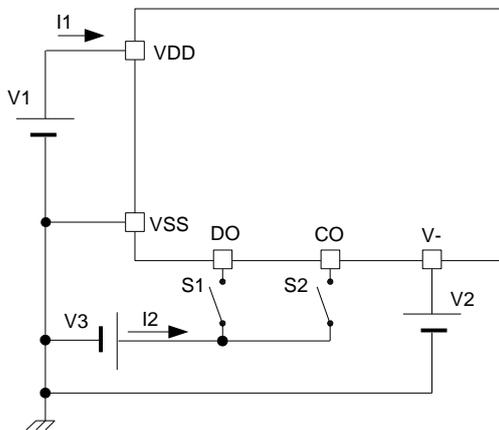
- 1) "0 V charge available" doesn't mean NT1713 series can recover the zero-V cell to be full charged if this cell has been already damaged due to too low voltage.
- 2) For safety consideration, we strongly recommended to select "0 V charge inhibition" version to prevent from charging a damaged cell.

Test Circuit


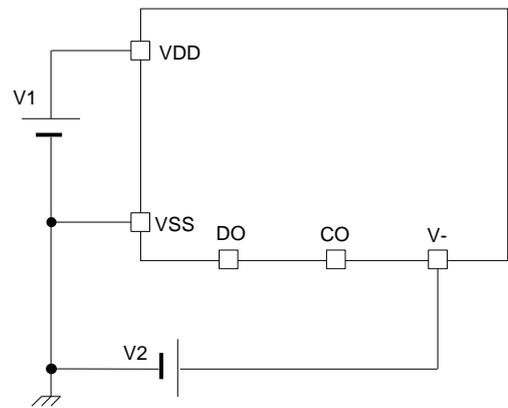
Test circuit 1



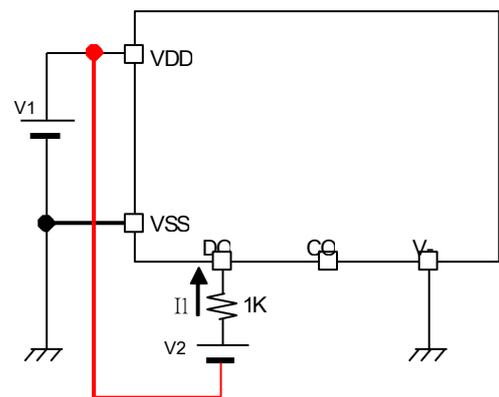
Test circuit 2



Test circuit 3



Test circuit 4



Test circuit 5

Operation

The NT1713 series provides over-charge, over-discharge, discharge over-current, charge over-current and load short-circuiting protections for the 1-cell battery pack. NT1713 series continuously monitors the voltage of battery between VDD pin and VSS pin to control over-charge and over-discharge protections. When the battery pack is in charging stage, the current flows from the charger to the battery through EB+ and EB-; the voltage between V- pin and VSS pin is negative. On the other hand, when the battery pack is in discharging stage, the current flows from battery to the load through EB+ and EB-; the voltage between V- pin and VSS pin is positive. The NT1713 series also monitors the voltage which is determined by the current of charge and discharge and the series Rds(on) of MOSFETs between V- pin and Vss pin to detect charge over-current and discharge over-current current conditions.

(1) Normal Condition (Operation mode)

The NT1713 series turns both the charging and discharging control MOSFETs on when the voltage of battery is in the range from over-charge detection voltage (V_{DET1}) to over-discharge detection voltage (V_{DET2}), and the V- pin voltage is in the range from over-current detection voltage (V_{DET4}) to discharge over-current detection voltage (V_{DET3}). This is called the normal condition that charging and discharging can be carried out freely.

Caution: The NT1713 series may be needed connecting a charger to return to normal condition, when the battery is connected for the first time.

(2) Over-charge Condition

1) Over-charge Protection:

When the VDD voltage is higher than the over-charge detection voltage (V_{DET1}) and lasts for longer than the over-charge detection delay time (t_{VDET1}), NT1713 series turns off the external charging MOSFET to protect the pack from being over-charged, which CO pin goes to "L" from "H" level.

2) Over-charge Protection Release:

When the battery voltage is lower than $V_{DET1} - V_{HYS1}$ and the V- pin voltage is between charge over-current detection voltage (V_{DET4}) and discharge over-current detection voltage (V_{DET3}), the NT1713 series would be automatically released from this condition.

When the battery voltage is lower than V_{DET1} and charger is removed, the NT1713 series can be automatically released from this condition.

(3) Over-discharge Condition

1) Over-discharge Protection:

When the VDD voltage is lower than the over-discharge detection voltage (V_{DET2}) and lasts longer than over-discharge detection delay time (t_{VDET2}), NT1713 series turns off the external discharge MOSFET to protect the pack from being over-discharged, which DO pin goes to "L" from "H" level. In over-discharge condition V- pin is pulled-up to VDD by a resistor (RVMD) between the V- pin and VDD pin. After that, when V- pin voltage is higher than $V_{DD}/2(\text{Typ})$, the IC gets to power down mode.

2) Over-discharge Protection Release:

The over-discharge protection is automatically released when

(a) a charger is connected and V- pin voltage is lower than $-0.7V$ (Typ.) and battery voltage is higher than the over-discharge voltage (V_{DET2}), or

(b) a charger is connected, and V- pin voltage is higher than $-0.7V$ (Typ.) and battery voltage is higher than the over-discharge release voltage (V_{REL2}).

(4) Discharge Over-current Condition

1) Discharge Over-current Protection:

- (a) Discharge over-current protection occurs when V- pin voltage is between V_{DET3} and V_{SHORT} and lasts for a certain delay time (t_{VDET3}).
- (b) Load short-circuiting protection occurs when V- pin voltage is higher than V_{SHORT} and lasts for a certain delay time (t_{SHORT}).

When above conditions happen, the DO pin goes to "L" from "H" to turn off the discharging MOSFET.

In discharge over-current and load short-circuiting conditions, V- pin is pulled-down to VSS pin by the internal resistor (RVMS).

2) Discharge Over-current and Load Short-Circuiting Protection Release:

The IC detects the status by monitoring V- pin voltage that is inversely proportional to the impedance (Rload) between two terminals (EB+ and EB-). The Rload increases while the V- pin voltage decreases. When the V- pin voltage equals to V_{SHORT} or lower, discharge over-current status returns to normal mode and the circuit will be automatic recovery.

The relation between V- and Rload is shown as follows:

$$V- = \frac{RVMS}{RVMS + Rload} \times VDD ; \text{ when } V- \leq V_{short}$$

(5) Charge Over-current Condition

1) Charge Over-current Protection:

When the voltage of V- pin is lower than charge over-current detection voltage (V_{DET4}) and lasts for a certain delay time (t_{DET4}) or longer, the CO pin goes to "L" from "H" to turn off the charging MOSFET.

2) Charge Over-current Release:

Charge over-current protection can be automatically released by disconnecting the charger.

(6) Power Down Condition

1) Entering to Power Down Mode:

NT1713 series enters the power down mode when over-discharge protection occurs and V- pin voltage is higher than $VDD/2$ (typical). The V- pin voltage is pulled-up to the VDD through the R_{VMD} resistor. The internal circuits is shut off, therefore, the power-down current ($I_{STANDBY}$) is reduced to be low 0.1uA (Max.).

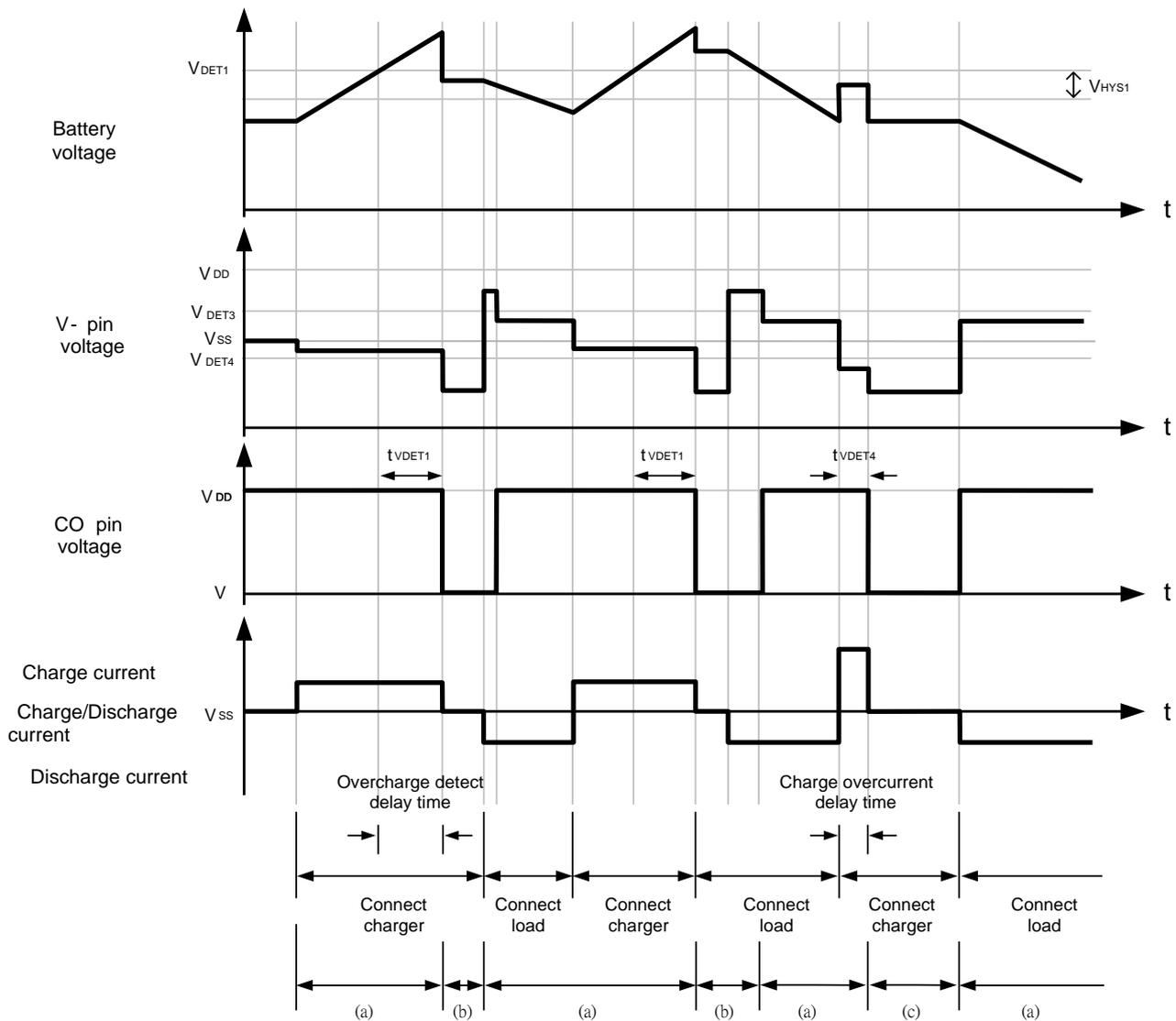
2) Power Down Mode Release:

The power down mode is automatically released when a charger is connected and V- pin voltage is lower than $VDD/2$ (typical).

Note: Power down condition is for power down mode enabled version only.

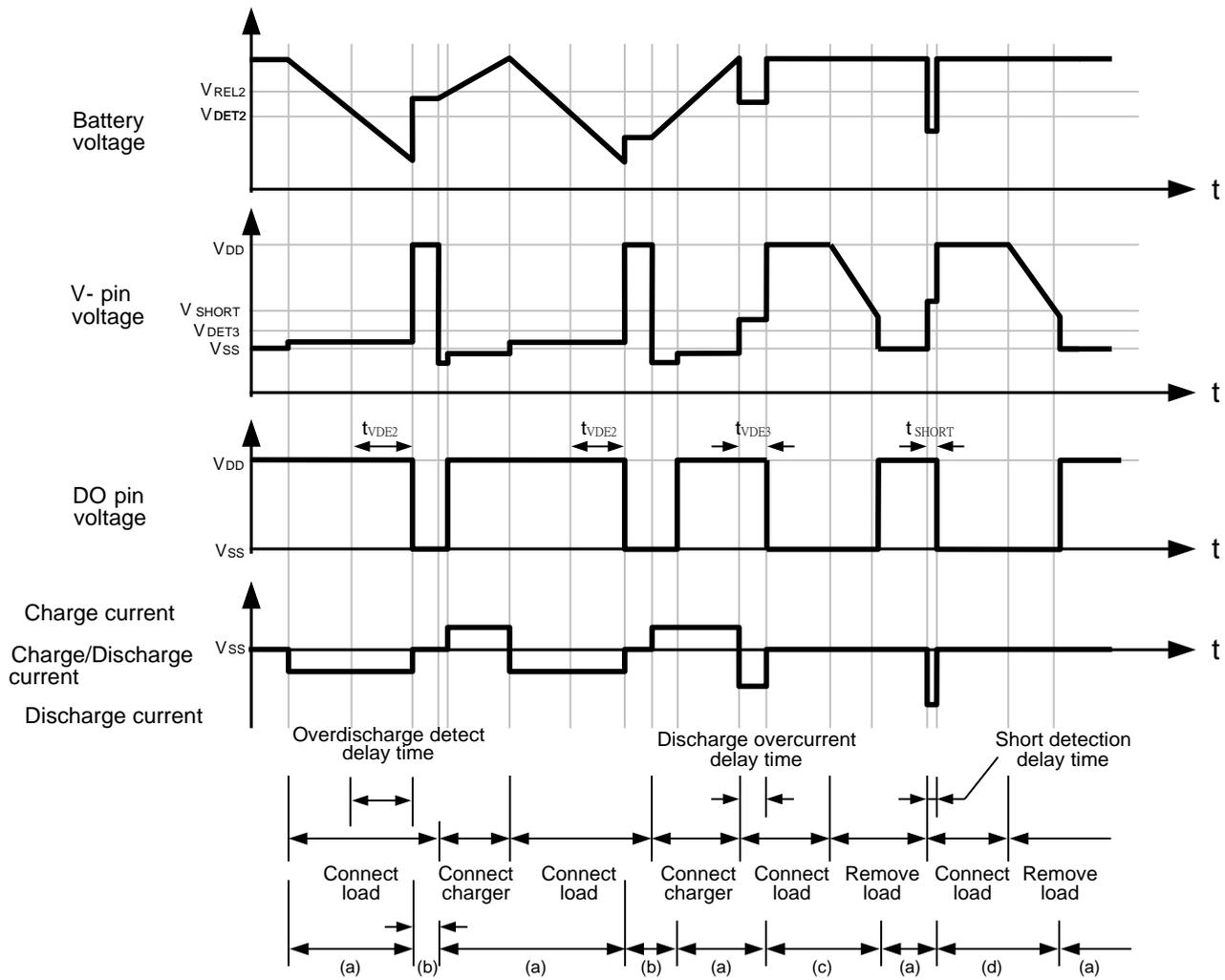
Timing Chart

(1) Over-charge, Charge Over-current Operation



- (d) Normal condition
- (e) Overcharge condition
- (f) Charge over-current condition

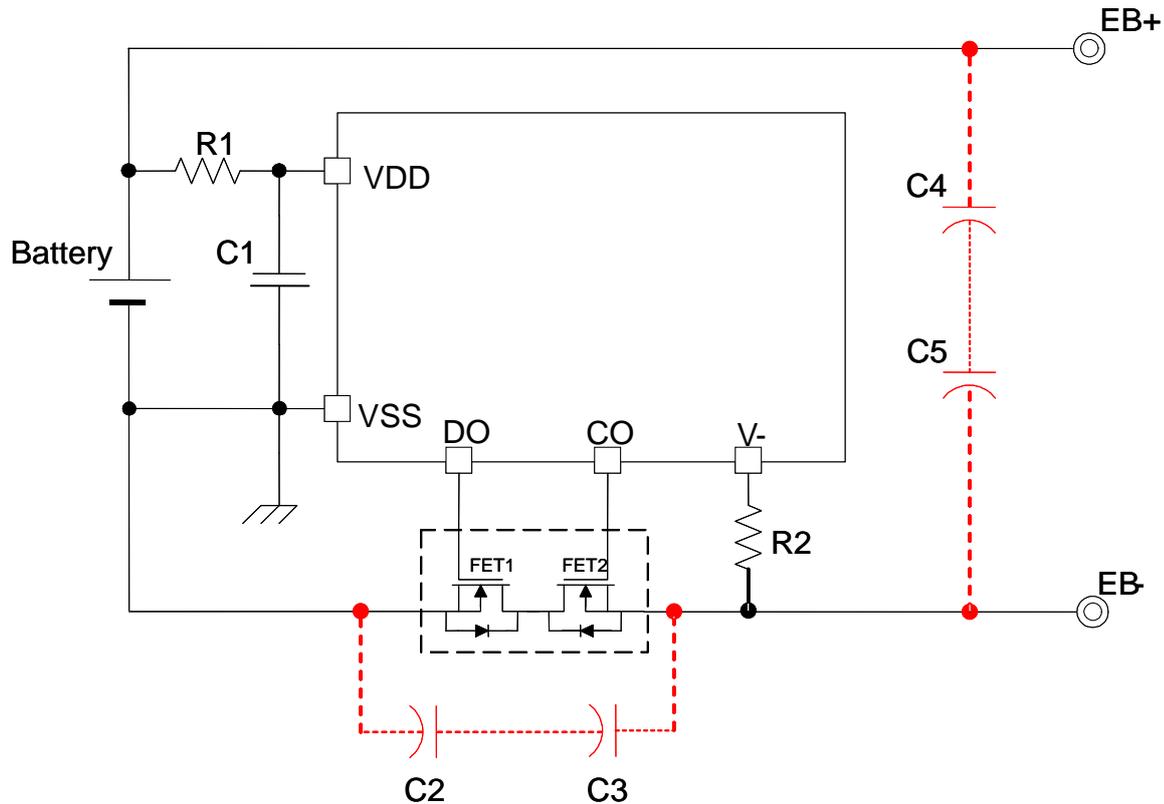
***: The charger is assumed to charge with a constant current.**

(2) Over-discharge, Discharge Over-current, Load Short-Circuiting Operation


- (e) Normal condition
- (f) Over-discharge condition
- (g) Discharge over-current condition
- (h) Load short-circuit condition

***: The charger is assumed to charge with a constant current.**

Recommended Application Circuit



Constant for external components

Symbol	Parts	Purpose	Recommended	Min.	Max.	Remarks
FET1	N channel MOSFET	Discharge control	-	-	-	*1) Gate to source withstand voltage \geq Charger voltage.
FET2	N channel MOSFET	Charge control	-	-	-	
R1	Resistor	ESD protection, for power fluctuation	470 Ω	100 Ω	1K Ω	*2) Set Resistance to the value $2R1 \leq R2$.
C1	Capacitor	For power fluctuation	0.1 μ F	0.022 μ F	1.0 μ F	*3) Install a 0.022 μ F capacitor or higher.
R2	Resistor	Protection for reverse connection of a charger	1K Ω	300 Ω	10K Ω	*4) The resistor is preventing big current when a charger is connected in reverse.
C2	Capacitor	For ESD protection	0.1 μ F	-	-	*5) Protected MOSFET after system ESD
C3	Capacitor	For ESD protection	0.1 μ F	-	-	
C4	Capacitor	For ESD protection	0.1 μ F	-	-	*5) Reduce noise of load and improve system ESD performance.
C5	Capacitor	For ESD protection	0.1 μ F	-	-	

- *1) If the threshold voltage of FET is lower than 0.4V, the FET may failed to stop the charging current.
If the FET has a threshold voltage equal to or higher than the over-discharge detection voltage, discharging may be stopped before over-discharge is detected.
If the charger voltage is higher than the withstanding voltage between the gate and source, the FET may be damaged.
- *2) Employing an over-specification (listed in above table) R1 may result in over-charge detection voltage and release voltage higher than the defined voltage
If R1 has a higher resistance, the IC may be damaged caused by over absolute maximum rating of VDD voltage when a charger is connected reversely.
- *3) Applying a smaller capacitance C1 to system, DO may failed to function when load short-circuiting is detected.
- *4) R1 and R2 resistors are current limit resistance for a charger connected reversibly or a large voltage charger that exceeds the absolute rating for VCC is connected, when we connect reverse charger the current flows from charger to R2, internal ESD diode and R1. This current will increase R1 voltage drop. Which can exceed VCC(max). In this case better to use smaller value for R1 and bigger value for R2. But small value of R1 will reduce R-C filter performance and system ESD reliability. Too big value of R2 can cause over-current automatic release problem.
If R2 resistance is higher than 2k Ω , the charging current may not be cut when a high-voltage charger is connected.
- *5) As followed this recommended table, the system ESD level could be reached at least $\pm 12\text{KV}$. We can improve system ESD by connect C2 ~ C5 capacitor of 0.1 μF . Both C2 and C3 are protected MOSFET from being assaulted by system ESD. C4 and C5 are improved system ESD and reduce imported noise by load.

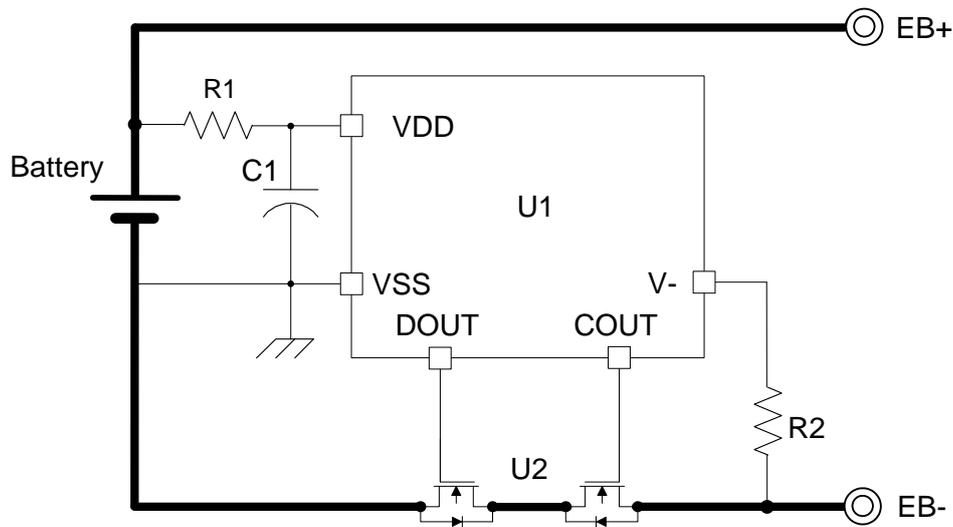
Caution: 1) The above constants may be changed without notice.

2) The application circuit above is for reference only. To determine the correct constants, evaluation of actual application is required.

Precautions: 1) The application condition for the input voltage, output voltage, and load current should not exceed the package power dissipation.

2) Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.

PCB Schematic

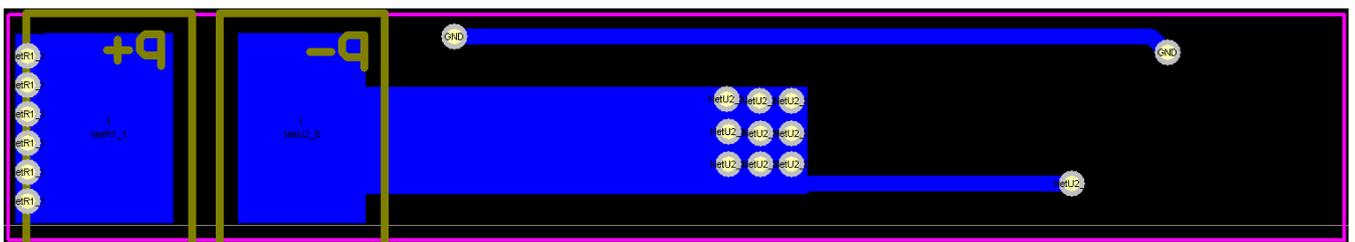


Layout Reference (takes DFN-1.6x1.6-6L for example)

Top layer



Bottom layer



Note: To leave thermal pad floating is suggested (shown above). It can connect to VSS/VDD level as well.

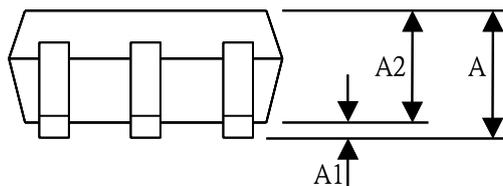
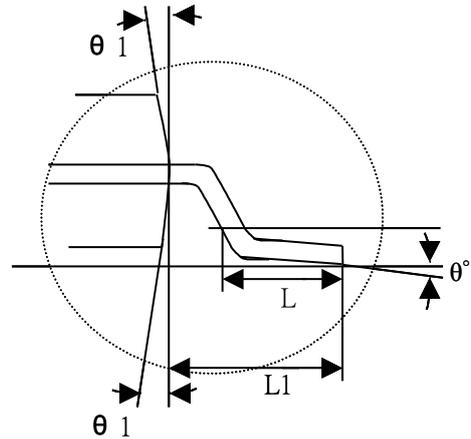
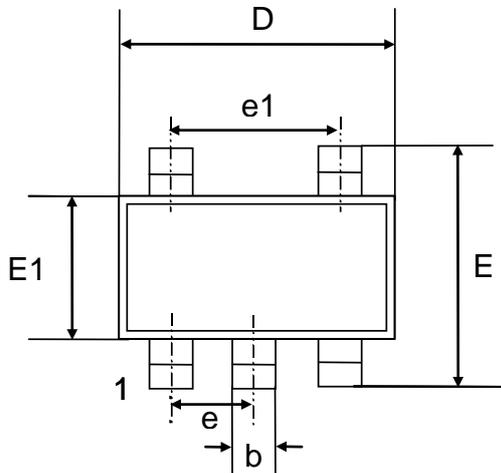
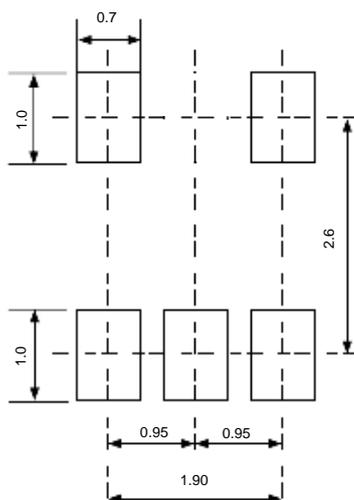
PCB symbol list:

Symbol	Parts	Symbol	Parts
B+	Positive terminal of Battery	P+	Positive terminal of charger or load
B-	negative terminal of Battery	P-	negative terminal of charger or load

BOM list:

Standard application circuit:

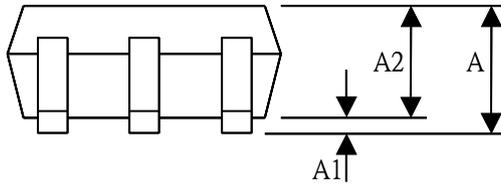
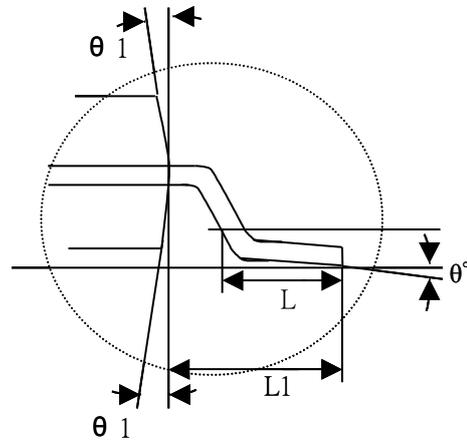
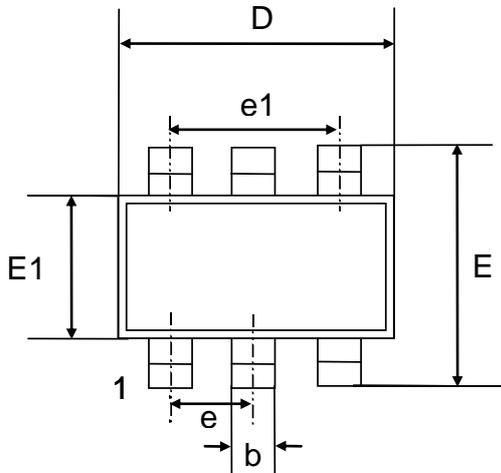
Symbol	Parts	Footprint	Value	Remarks
U1	NT1713 Series	DFN-1.6x1.6-6L	-	-
U2	N-MOSFET	TSSOP8	AO8810	Cut off charge or discharge current
R1	Resistor	0402 @ 1/16W	470Ω	Low pass filter with C1 and ESD protection
R2	Resistor	0402 @ 1/16W	1KΩ	ESD protection
C1	Capacitor	0402 @ 1/16W	0.1uF	Low pass filter with R1 and ESD protection

Package Information
SOT-23-5 Dimensions

PCB Land Pattern


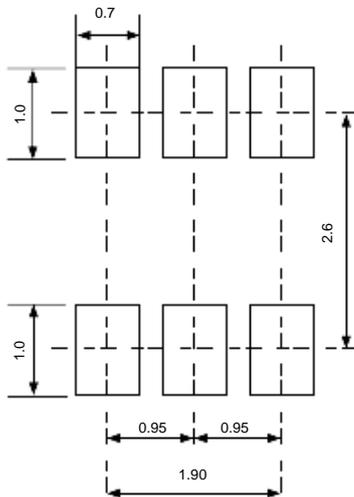
SYMBOL	MIN	NOM	MAX
A	—	—	1.45
A1	0.00	—	0.15
A2	0.90	1.15	1.30
b	0.30	0.4	0.50
c	0.08	—	0.22
D	2.70	2.90	3.10
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	—	0.95 BSC	—
e1	—	1.90 BSC	—
L	0.30	0.45	0.60
L1	—	0.6 REF	—
L2	—	0.25 BSC	—
θ	0°	4°	8°
$\theta 1$	5°	10°	15°

NOTES: 1. All dimensions show in mm
 2. Reference: JEDEC MO-178AA
 3. SOT23-5 / SOT23-6

SOT-23-6 Dimensions



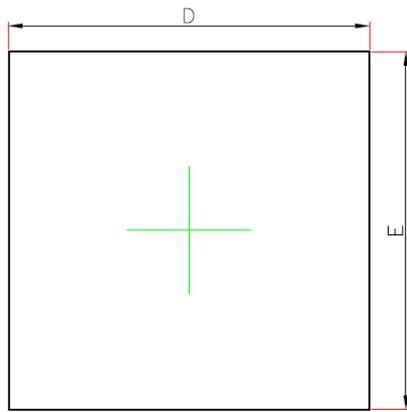
PCB Land Pattern



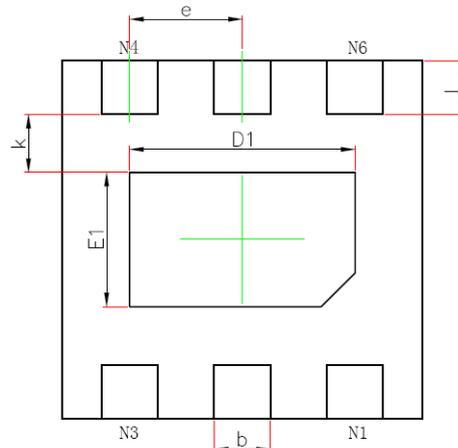
SYMBOL	MIN	NOM	MAX
A	—	—	1.45
A1	0.00	—	0.15
A2	0.90	1.15	1.30
b	0.30	0.4	0.50
c	0.08	—	0.22
D	2.70	2.90	3.10
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	—	0.95 BSC	—
e1	—	1.90 BSC	—
L	0.30	0.45	0.60
L1	—	0.6 REF	—
L2	—	0.25 BSC	—
θ	0°	4°	8°
$\theta 1$	5°	10°	15°

NOTES: 1. All dimensions show in mm
 2. Reference: JEDEC MO-178AA
 3. SOT23-5 / SOT23-6

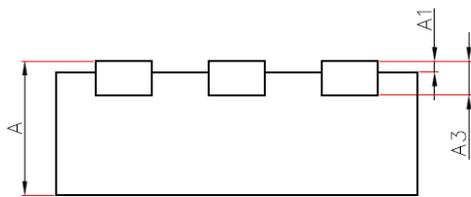
DFN-1.6X1.6-6L Dimension



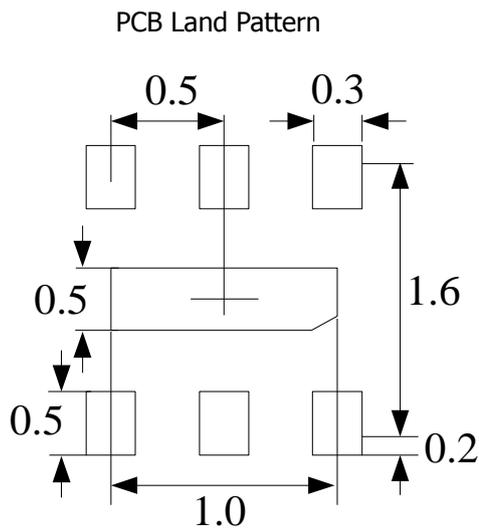
TOP VIEW



BOTTOM VIEW



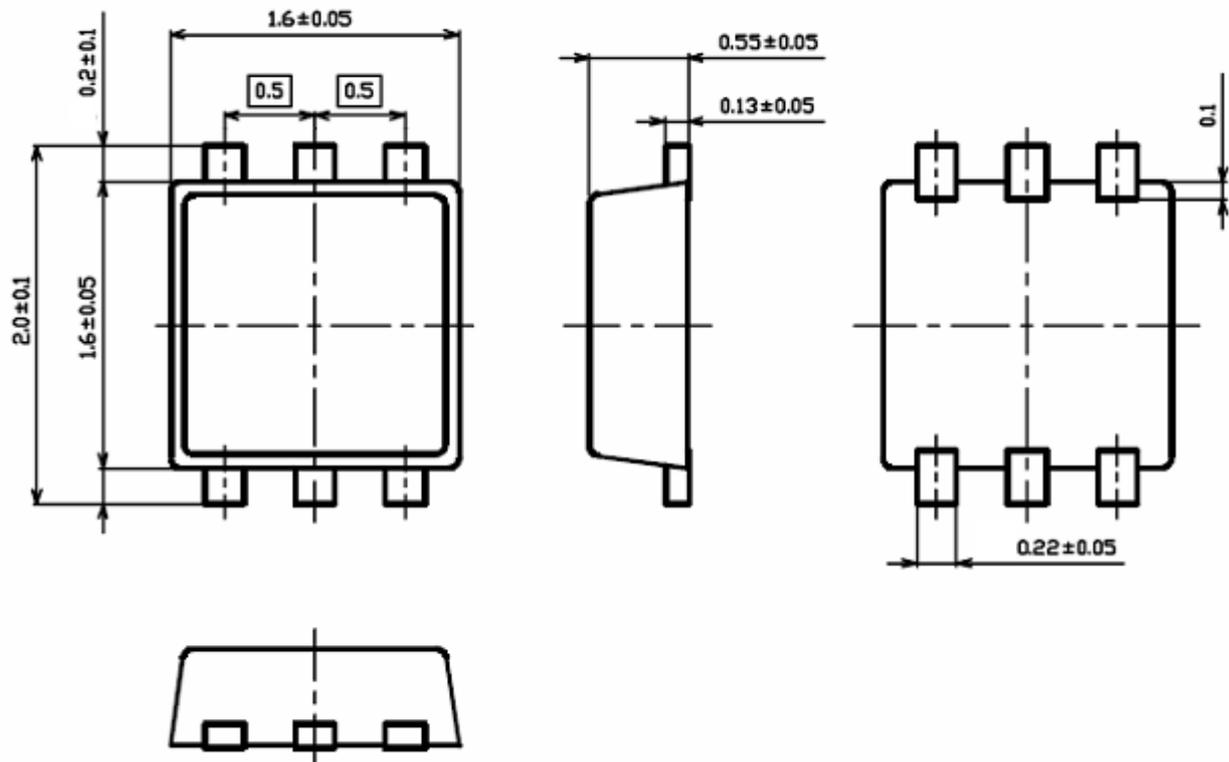
SIDE VIEW



Symbol	Dimensions in Millimeters	
	Min.	Max.
A	0.500	0.800
A1	0.000	0.050
A3	0.152REF.	
D	1.550	1.650
E	1.550	1.650
E1	0.500	0.700
D1	0.900	1.100
k	0.200MIN.	
b	0.180	0.300
e	0.500BSC.	
L	0.164	0.316

SON-1.6x1.6-6L Dimension

Note: All dimensions show in mm



PCB Land Pattern

