Battery Protection IC for 1-Cell Pack

Features

- High accuracy voltage detection circuit
  - Over-charge detection: ±15mV
  - Over-discharge detection voltage: ±35mV
  - Discharge over-current detection: ±15%
  - Charge over-current detection: ±15%
  - Load short-circuiting detection voltage: ±25%
- High withstand voltage
  - Absolute maximum ratings: 28V max.
    (COUT, $V_{DD}-V-$)
- Delay times are generated by an internal circuit
- Low current consumption 5.5 (uA) max in a normal mode and 0.1(uA) in a power down mode
- Ultra small package:
  SOT-23-6, DFN-1.5x1.5-6L, SON-1.6x1.6-6L
- Lead-free, Sn 100%, Halogen-free

Description

The NT1715 series are the 1-cell protection IC for lithium-ion/lithium-polymer rechargeable battery pack. The high accuracy voltage, current detector and delay time circuits are built in NT1715 series with state-of-art design and process.

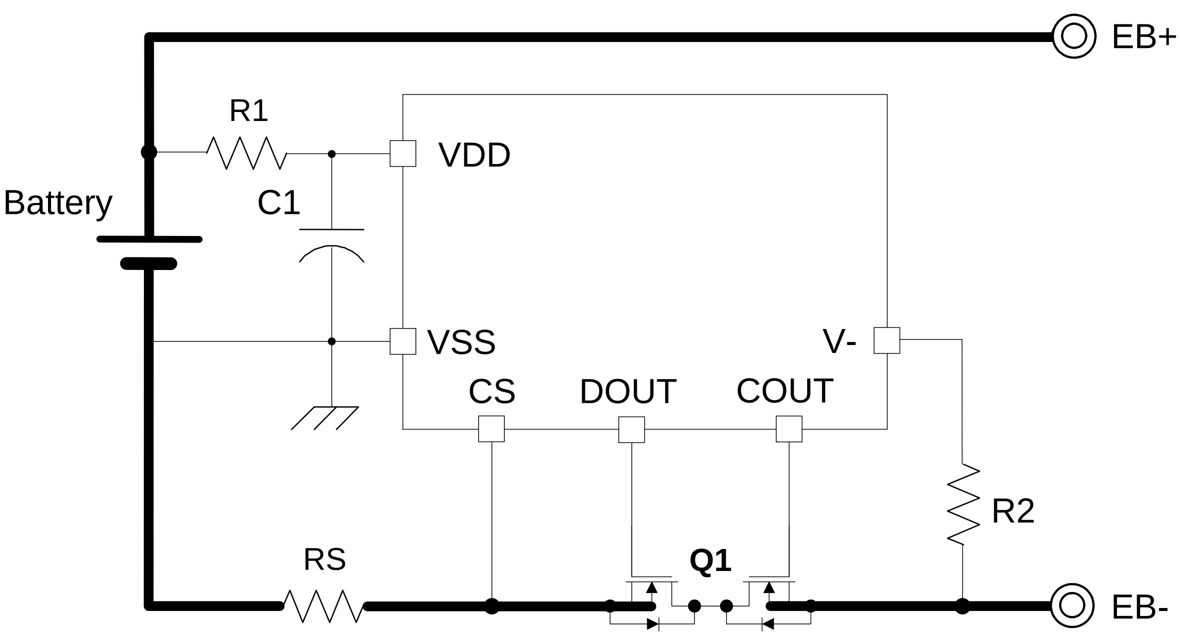
To minimize power consumption, NT1715 series activate power down mode when an over-discharge event is detected (for power-down mode enabled version). Besides, NT1715 series perform protection functions with five external components for miniaturized PCB.

The tiny package is especially suitable for compact portable device, i.e. slim mobile phone, tablet PC battery packs, Digital camera and Bluetooth earphone.

Applications

- Mobile phone battery packs
- Tablet PC battery packs
- Digital camera battery packs

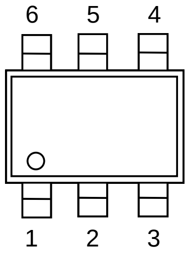
Typical Application Circuit



These devices have limited build-in ESD protection. The leads must be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

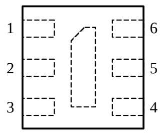
Package and Pin Configurations

SOT-23-6



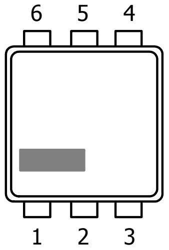
Pin No.	Symbol	Pin description
1	CS	Current sense pin (low-voltage)
2	VDD	Connection for positive power supply input
3	VSS	Connection for negative power supply input
4	DOUT	Connection of discharge control FET gate
5	COUT	Connection of charge control FET gate
6	V-	Voltage detection between V- pin and VSS pin (Power Down and Load Detector pin)

DFN-1.5x1.5-6L



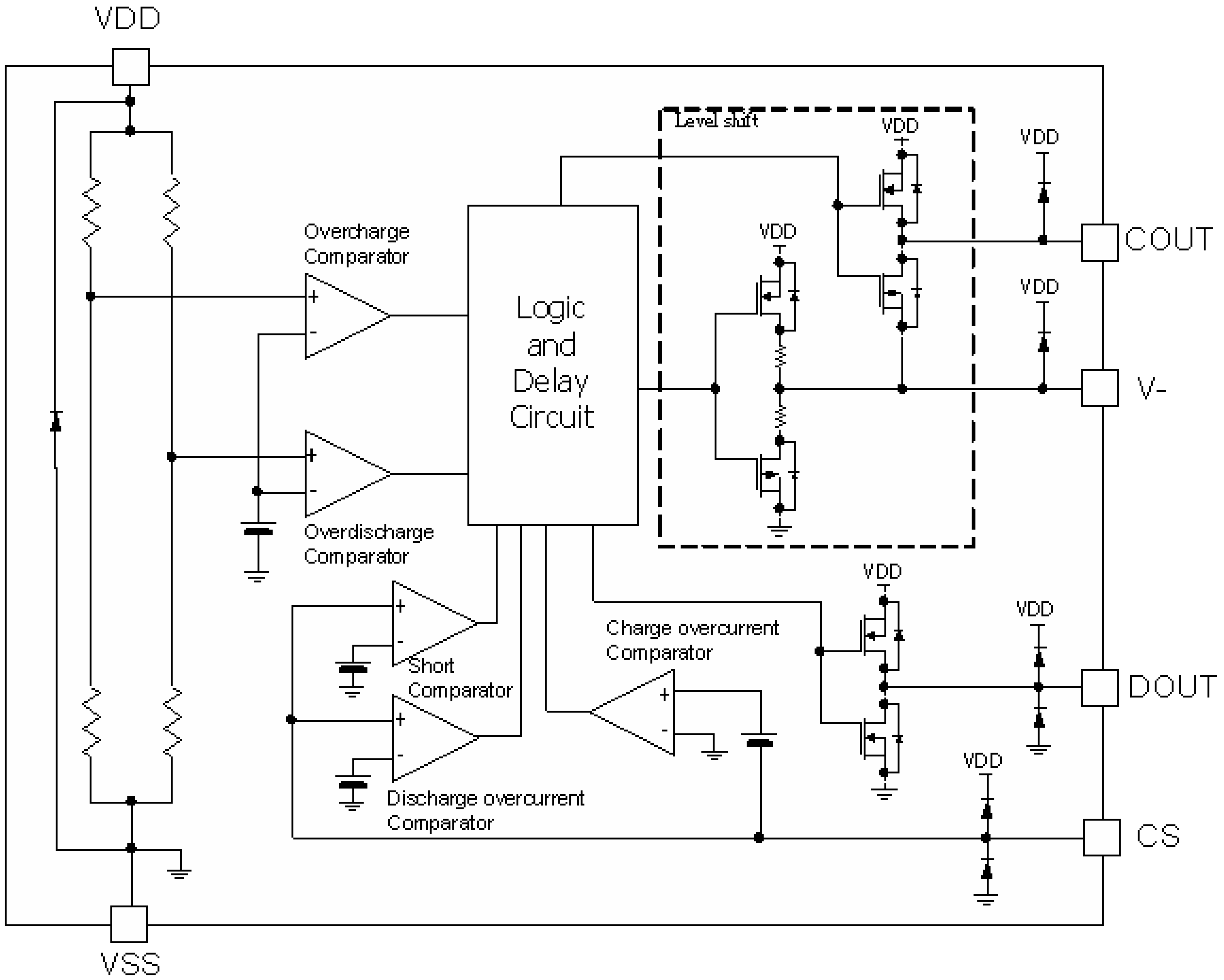
Pin No.	Symbol	Pin description
1	V-	Voltage detection between V- pin and VSS pin (Power Down and Load Detector pin)
2	COUT	Connection of charge control FET gate
3	DOUT	Connection of discharge control FET gate
4	VSS	Connection for negative power supply input
5	VDD	Connection for positive power supply input
6	CS	Current sense pin (low-voltage)

SON-1.6X1.6-6L



Pin No.	Symbol	Pin description
1	V-	Voltage detection between V- pin and VSS pin (Power Down and Load Detector pin)
2	COUT	Connection of charge control FET gate
3	DOUT	Connection of discharge control FET gate
4	VSS	Connection for negative power supply input
5	VDD	Connection for positive power supply input
6	CS	Current sense pin (low-voltage)

Functional Block Diagram



Ordering Information

NT1715B-XXX XX

- Package Type
  - A6: SOT-23-6
  - BB: DFN-1.5x1.5-6L
  - 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 V_{DET1} (V)	Over-charge Hysteresis Voltage V_{HYS1} (V)	Over-discharge detection voltage V_{DET2} (V)	Over-discharge release voltage V_{REL2} (V)	Discharge over-current detection voltage V_{DET3} (V)	Charge over-current detection V_{DET4} (V)	Load short-circuiting detection voltage V_{SHORT}(V)
NT1715B	NHD	A6/BB/C1	4.425	0.00	2.400	2.400	0.034	-0.022	0.180
NT1715B	QHB	A6/BB/C1	4.475	0.00	2.400	2.400	0.040	-0.025	0.180

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

Table2:

Product Name	Version Code	0V Battery Charge Function	Delay Time (Table 3)
NT1715B	NHD	Unavailable	(1)
NT1715B	QHB	Unavailable	(1)

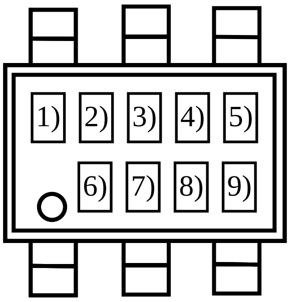
Table3: Delay Time table

Delay time	Over-charge delay time t_{VDET1} (S)	Over-discharge delay time t_{VDET2} (mS)	Discharge over-current delay time t_{VDET3} (mS)	Charge over-current delay time t_{VDET4} (mS)	Load short-circuiting delay time t_{SHORT} (uS)
(1)	1.00 +/- 20%	125 +/- 20%	8.0 +/- 20%	8.0 +/- 20%	250 +40% /- 30%

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

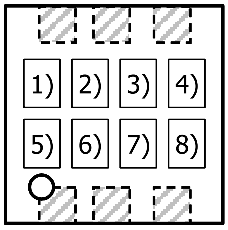
Marking Information

SOT-23-6
Top View



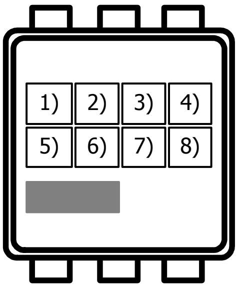
1) to 2): Product code (**BP**)
3) to 5): Version code
6) to 9): Lot number

DFN-1.5x1.5-6L
Top View



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

SON-1.6x1.6-6L
Top view



1) to 2): Product code (**BP**)
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) Version Code	(3)(4) Version Code
		SOT-23-6	DFN-1.5x1.5-6L	SON-1.6x1.6-6L
NT1715B	NHD	NHD	33	33
NT1715B	QHB	QHB	40	40

Absolute Maximum Ratings:

(Ta = 25°C unless otherwise specified)

Symbol	Descriptions		Rating	Unit
V_{DS}	Input voltage between VDD and VSS		V_{SS} - 0.3 to V_{SS}+7.0	V
V_{V-}	V- pin input voltage		V_{DD} – 28 to V_{DD}+0.3	V
V_{CO}	Output Voltage	COUT pin	V_{DD} -28 to V_{DD} + 0.3	V
V_{DO}		DOUT pin	Vss - 0.3 to V_{DD} + 0.3	V
V_{CS}	CS pin input voltage		Vss - 0.3 to V_{DD} + 0.3	V
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:

(Ta = -20~60°C)

Symbol	Item	Conditions	MIN	TYP	MAX	Unit
Current Consumption (power-down function enabled)						
V_{DD}	Operating input voltage	V_{DD} - V_{SS}	1.5		6.0	V
I_{DD}	Supply current	V_{DD}=3.5V, V-=0V		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
V_{0CHA}	0 V battery charge starting charger voltage	0V available	0.5	1.0	1.5	V
V_{0INH}	0V battery charge inhibition battery voltage	0V unavailable	0.5	1.0	1.5	V
Output Resistance						
R_{COH}	COUT pin "H" resistance	V_{DD}=3.5V, V_{CO}=3.0V, V-=0V	1.8	3.6	5.5	KΩ
R_{COL}	COUT pin "L" resistance	V_{DD}=4.5V, V_{CO}=3.0V, V-=0V	0.6	1.3	2.0	KΩ
R_{DOH}	DOUT pin "H" resistance	V_{DD}=3.5V, V_{DO}=3.0V, V-=0V	1.0	2.0	3.0	KΩ
R_{DOL}	DOUT pin "L" resistance	V_{DD}=1.8V, V_{DO}=0.5V, V-=0V	1.0	2.0	3.0	KΩ
R_{DOL}	DOUT pin "L" resistance	V_{DD}=1.8V, V_{DO}=0.5V, V-=0V	1.0	2.0	3.0	KΩ
V- internal Resistance						
R_{VMD}	Internal resistance between V- and V_{DD}	V_{DD}= 1.8V, V-=0V	200	300	400	KΩ
R_{VMS}	Internal resistance between V- and V_{SS}	V_{DD}=3.5V, V-=1V	20	30	40	KΩ

(Ta = 25°C unless otherwise specified)

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_{DET2}-0.035	V_{DET2}	V_{DET2}+0.035	V
		$V_{DET2} \neq V_{REL2}$	V_{REL2}-0.040	V_{REL2}	V_{REL2}+0.040	V
V_{DET3}	Discharge over-current detection voltage	V_{DD}=3.5V	V_{DET3} x 0.85	V_{DET3}	V_{DET3} x 1.15	V
V_{DET4}	Charge over-current detection	V_{DD}=3.5V	V_{DET4} x 0.85	V_{DET4}	V_{DET4} x 1.15	V
V_{SHORT}	Load short-circuiting detection voltage	V_{DD}=3.5V	V_{SHORT} x 0.75	V_{SHORT}	V_{SHORT} x 1.25	V
Detection Delay Time (1)						
t_{VDET1} *1	Output delay time of over-charge	VDD=3.6V → 4.6V	0.80	1.00	1.20	s
t_{VDET1_REL}	Output release delay time of over-charge	VDD=4.6V → 3.6V V-=0.3V	12.8	16.0	19.2	ms
t_{VDET2} *1	Output delay time of over-discharge	VDD=3.6V → 2.2V	100	125	150	ms
t_{VDET2_REL}	Output release delay time of over-discharge	VDD=2.2V → 3.6V; V-=CS=0V	1.28	1.60	1.92	ms
t_{VDET3}	Output delay time of discharge over- current	VDD=3.5V; V-=0V; CS=0V → 0.10V;	6.4	8.0	9.6	ms
t_{VDET3_REL}	Output release delay time of discharge over-current	VDD=3.5V; CS= 0.10V → 0V; V-= 0V → 0.5V → 0V	1.28	1.60	1.92	ms
t_{VDET4}	Output delay time of charge over-current	VDD=3.5V; V-=0V; CS=0V → -0.1V	6.4	8.0	9.6	ms
t_{VDET4_REL}	Output release delay time of charge over-current	VDD=3.5V; CS=-0.1V → 0V; V-= 0V → 0.5V	1.28	1.60	1.92	ms
t_{SHORT}	Output delay time of Load short-circuiting detection	VDD=3.5V; V-=0V; CS=0V → 1.0V	175	250	350	us

(Ta = -20~60°C) *2

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}-0.025	V_{HYS1}	V_{HYS1}+0.025	V
V_{DET2}	Over-discharge detection voltage	--	V_{DET2}-0.040	V_{DET2}	V_{DET2}+0.040	V
V_{REL2}	Over-discharge release voltage	$V_{DET2} = V_{REL2}$	V_{REL2}-0.040	V_{REL2}	V_{REL2}+0.040	V
		$V_{DET2} \neq V_{REL2}$	V_{REL2}-0.050	V_{REL2}	V_{REL2}+0.050	V
V_{DET3}	Discharge over-current detection voltage	V_{DD}=3.5V	V_{DET3} x 0.83	V_{DET3}	V_{DET3} x 1.17	V
V_{DET4}	Charge over-current detection	V_{DD}=3.5V	V_{DET4} x 0.83	V_{DET4}	V_{DET4} x 1.17	V
V_{SHORT}	Load short-circuiting detection voltage	V_{DD}=3.5V	V_{SHORT} x 0.70	V_{SHORT}	V_{SHORT} x 1.30	V
Detection Delay Time (1)						
t_{VDET1} *1	Output delay time of over-charge	VDD=3.6V → 4.6V	0.65	1.00	1.35	s
t_{VDET1_REL}	Output release delay time of over-charge	VDD=4.6V → 3.6V V-=0.3V	10.4	16.0	21.6	ms
t_{VDET2} *1	Output delay time of over-discharge	VDD=3.6V → 2.2V	81.25	125.00	168.75	ms
t_{VDET2_REL}	Output release delay time of over-discharge	VDD=2.2V → 3.6V; V-=CS=0V	1.04	1.60	2.48	ms
t_{VDET3}	Output delay time of discharge over-current	VDD=3.5V; V-=0V; CS=0V → 0.10V;	5.2	8.0	10.8	ms
t_{VDET3_REL}	Output release delay time of discharge over-current	VDD=3.5V; CS= 0.10V → 0V; V-= 0V → 0.5V → 0V	1.04	1.60	2.48	ms
t_{VDET4}	Output delay time of charge over-current	VDD=3.5V; V-=0V; CS=0V → -0.1V	5.2	8.0	10.8	ms
t_{VDET4_REL}	Output release delay time of charge over-current	VDD=3.5V; CS=-0.1V → 0V; V-= 0V → 0.5V	1.04	1.60	2.48	Ms
t_{SHORT}	Output delay time of Load short-circuiting detection	VDD=3.5V; V-=0V; CS=0V → 1.0V	160	250	490	Us

**1: Test mode is provided on the CS pin by VDD to reduce over-charge and over-discharge delay time.*
**2: 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 release detection functions** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Increase V1 voltage (from 3.5V) gradually. The V1 voltage is the Over-charge detection voltage (V_{DET1}) when COUT pin goes low (from high).
  3) Decrease V1 gradually from higher than Over-charge detection voltage (V_{DET1}) threshold, and then set V3 voltage is higher than 0.25V, till COUT pin goes high (from low), the voltage drop is the over-charge hysteresis voltage (V_{HYS1}).
  4) Continue decreasing V1. The V1 voltage is the over-discharge detection voltage (V_{DET2}) when DOUT pin goes low (from high). Then increase V1 gradually. The V1 voltage is the over-discharge release detection voltage (V_{REL2}), when DOUT 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=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Increase V2 (from 0V) gradually. The V2 voltage is the discharge over-current detection voltage (V_{DET3}) when DOUT pin goes low (from high).

- **Charge over-current detection voltage** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Decrease V2 gradually. The V2 voltage is the charge over-current detection voltage (V_{DET4}) when COUT pin goes low (from high).

- **Load short-circuiting detection voltage** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Increase V2 immediately (within 10uS) till DOUT 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=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Increase V1 from V_{DET1}-0.2V to V_{DET1}+0.2V immediately (within 10us) and V3 = 0.25V. The Over-charge detection delay time (t_{VDET1}) is the period from the time V1 gets to V_{DET1}+0.2V till COUT pin goes to low (from high).
  3) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  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 DOUT pin goes to low (from high).

- **Discharge over-current delay time** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Increase V2 from 0V to 0.10V immediately (within 10us). The discharge over-current detection delay time (t_{VDET3}) is the period from the time V2 gets to 0.10V till DOUT pin goes to low (from high).
  3) Decrease V2 from 0.10V to 0V and then set V3=0.5V. The discharge over-current release delay time (t_{VDET3_REL}) is the period from the time V3 gets to 0V from 0.5V till DOUT pin goes to high (from low).

- **Charge over-current delay time** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode.
  2) Decrease V2 from 0V to -0.1V immediately (within 10us). The charge over-current detection delay time (t_{VDET4}) is the period from the time V2 gets to -0.1V till COUT pin gets to low from high.
  3) Increase V2 from -0.1V to 0V immediately. The charge over-current release delay time (t_{VDET4_REL}) is the period from the time V3 gets to 0.5V from 0V till COUT pin goes to high (from low).

- **Load short-circuiting delay time** (test circuit 1)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enter operating mode.
  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 0.5V till DOUT pin goes to low (from high).
  3) Decrease V2 from 1.0V to 0V and then set V3=0.5V. The Load short-circuiting release delay time (t_{SHORT_REL}) is the period from the time V3 gets to 0V from 0.5V till DOUT pin goes to high (from low).

- **Operating & power down current consumption** (test circuit 2)
  1) Set V1=3.5V, V2=V3=0V, S1=ON and S2=ON, then NT1715 series enters operating mode and measure the current I1. I1 is the operating condition current consumption (I_{DD}).
  2) Set V1=V3=1.8V, V2=0V, S1=ON and S2=ON enter over-discharge condition and measure current I1. I1 is the power down current consumption ($I_{STANDBY}$).

- **Resistance between CS and Vss** (test circuit 2)
  1) Set V1=3.5V, V2=0V, S1=0N and S2=ON then NT1715 series enter operating mode.
  2) Increase V2 from 0V to 0.2V. 0.2V/I2 is the internal resistance (R_{CS}).

- **Resistance between V- and VDD, V- and Vss** (test circuit 3)
  1) Set V1=1.8V, V2=V3=0V, V4=0V, S1=OFF, S2=0FF and S3=ON and NT1715 series enters over-discharge condition. V1/I1 is the internal resistance between V- and VDD pin (R_{VMD}).
  2) Set V1=3.5V, V2=V3=0V, V4=1.0V, S1=OFF, S2=0FF and S3=ON and NT1715 series enters operating mode. V4/-I1 is the internal resistance between V- and Vss pin (R_{VMS}).

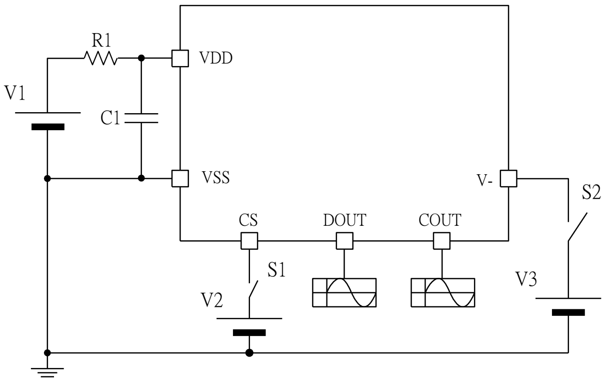
- **Output resistance** (test circuit 3)
  1) Set V1=3.5V, V2=V4=0V, V3=3.0V, S1=OFF, S2=0N and S3=ON to enter operating condition. (V1-V3)/I3 is the internal resistance (R_{COH}).
  2) Set V1=4.4V, V2=V4=0V, V3=0.5V, S1=OFF, S2=0N and S3=ON to enter Over-charge condition. V3/I3 is the internal resistance (R_{COL}).
  3) Set V1=3.5V, V3=V4=0V, V2=3.0V, S1=ON, S2=0FF and S3=ON to enter operating condition. (V1-V2)/I2 is the internal resistance (R_{DOH}).
  4) Set V1=1.8V, V3=V4=0V, V2=0.5V, S1=ON, S2=0FF and S3=ON to enter over-discharge condition. V2/I2 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 V1=V2=0V, and then increase V2 gradually to emulate charger voltage.
  2) The V2 voltage is the 0V charge starting voltage (V_{0CHA}) when COUT pin goes to high (from low) (V_{V-} + 0.1V or higher).

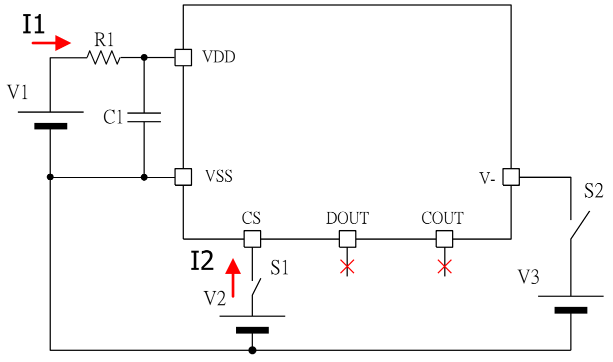
- **0V battery charge inhibition battery voltage (products with 0V battery charging function is "Unavailable")** (test circuit 4)
  1) Set V1=0V, V2=4V and increase V1 gradually to emulate battery cell.
  2) The V1 voltage is the 0V charge inhibition voltage (V_{0INH}) when COUT pin goes to high (from low) (V_{V-} + 0.1V or higher).

  Recommendation:
  1) '0 V charge available' doesn't mean NT1715 series can recover the zero-V cell to be full charged if this cell has been already damaged due to too low voltage.
  2) In NT1715 series, the '0 V charge inhibition' voltage is rather lower (0.5V). That is, NT1715 series allow charging such low voltage cell and recover it.
  3) For safety consideration, we strongly recommend to select '0 V charge inhibition' to prevent from charging a damaged cell.

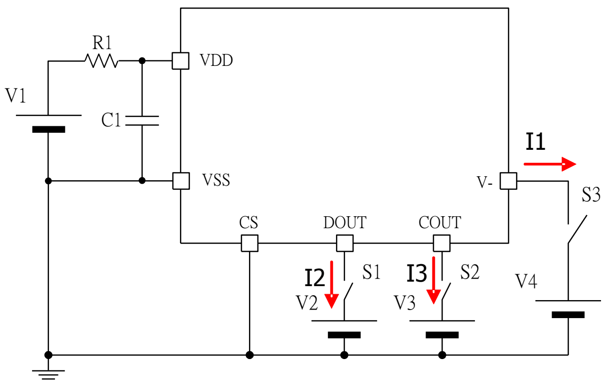
Test Circuit



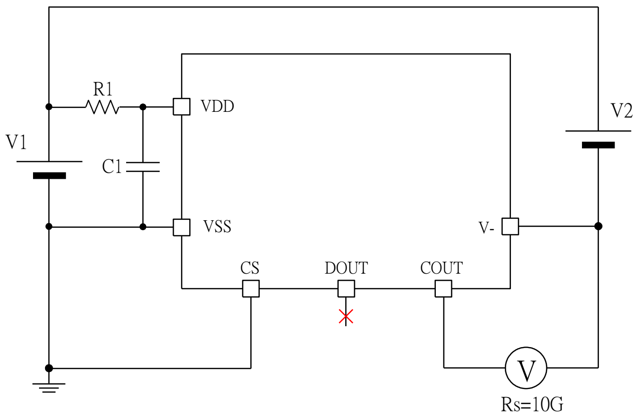
Test circuit 1



Test circuit 2



Test circuit 3



Test circuit 4

Recommendation:

As "Recommended Application Circuit", R1 = 330ohm, C1 = 0.1uF.

Operation

The NT1715 series provides Over-charge, over-discharge, discharge over-current, charge over-current and load short-circuiting protections for the 1-cell battery pack. NT1715 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 Vcs 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 Vcs pin and VSS pin is positive. The NT1715 series also monitors the voltage which is determined by the current of charge and discharge and the series between Vcs pin and VSS pin to detect charge over-current and discharge over-current current conditions.

(1) Normal Condition (Operation mode)

The NT1715 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 Vcs pin voltage is in the range from the charge 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 NT1715 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}), NT1715 series turns off the external charging MOSFET to protect the pack from being over-charged, which COUT pin turns to "L" from "H" level.

2) Over-charge Protection Release:

When the battery voltage is lower than (V_{DET1} - V_{HYS1}) then remove charger and connect load (V- pin voltage is higher than 0.25V (typical)) for longer than overcharge release delay time (t_{VDET1_REL}). The NT1715 series would be automatically released from release over-charge protection (COUT pin turns to "H" from "L" level.)

However, the V- pin voltage is also depending on the characteristics of external components such as MOSFETs after remove charger, release conditions may be touched, because a kind of load is set to release the over-charge. Then, the output level of COUT pin becomes "H" from "L" level, and by turning on the external Nch-MOSFET, the battery charger is ready to work again.

(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}), NT1715 series turns off the external discharge MOSFET to protect the pack from being over-discharged, which DOUT pin turns 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 VDD/2 (typical), the IC gets to power down mode.

2) Over-discharge Protection Release:

When the battery voltage is higher than V_{REL2} and connect a charger, the NT1715 series would be automatically release this condition after the timer is longer than over-discharge release delay time (t_{VDET2_REL}).

(4) Discharge Over-current and Short-circuiting Condition

1) Discharge Over-current Protection:

The NT1715 series provides discharge over-current protection and load short-circuiting protection:

(a) Discharge over-current protection occurs when Vcs pin voltage between V_{DET3} and V_{SHORT} and lasts for a certain delay time (t_{VDET3}) or longer.

(b) Load short-circuiting protection occurs when Vcs pin voltage higher than V_{SHORT} and lasts for a certain delay time (t_{SHORT}) or longer.

When above conditions happen, the DOUT pin goes "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 0.25V 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:

$$V- = \frac{RVMS}{RVMS + Rload} \times VDD \text{ ; where } V- < 0.25V\text{(typical)}$$

(5) Charge Over-current Condition

The NT1715 series provides charge over-current protection to prevent the battery pack from being connected to an unexpected charger.

1) Charge Over-current Protection

When the voltage of Vcs pin is lower than charge over-current detection voltage (V_{DET4}) and lasts for a certain delay time (t_{DET4}) or longer, the COUT pin goes "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 and connecting a load (V- voltage is higher than 0.25V (typical)). Note that for some cases (some specific external MOSFET characteristic) NT1715 series can release OV without external load.

(6) Power Down Condition

1) Entering to Power Down Mode:

NT1715 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.).

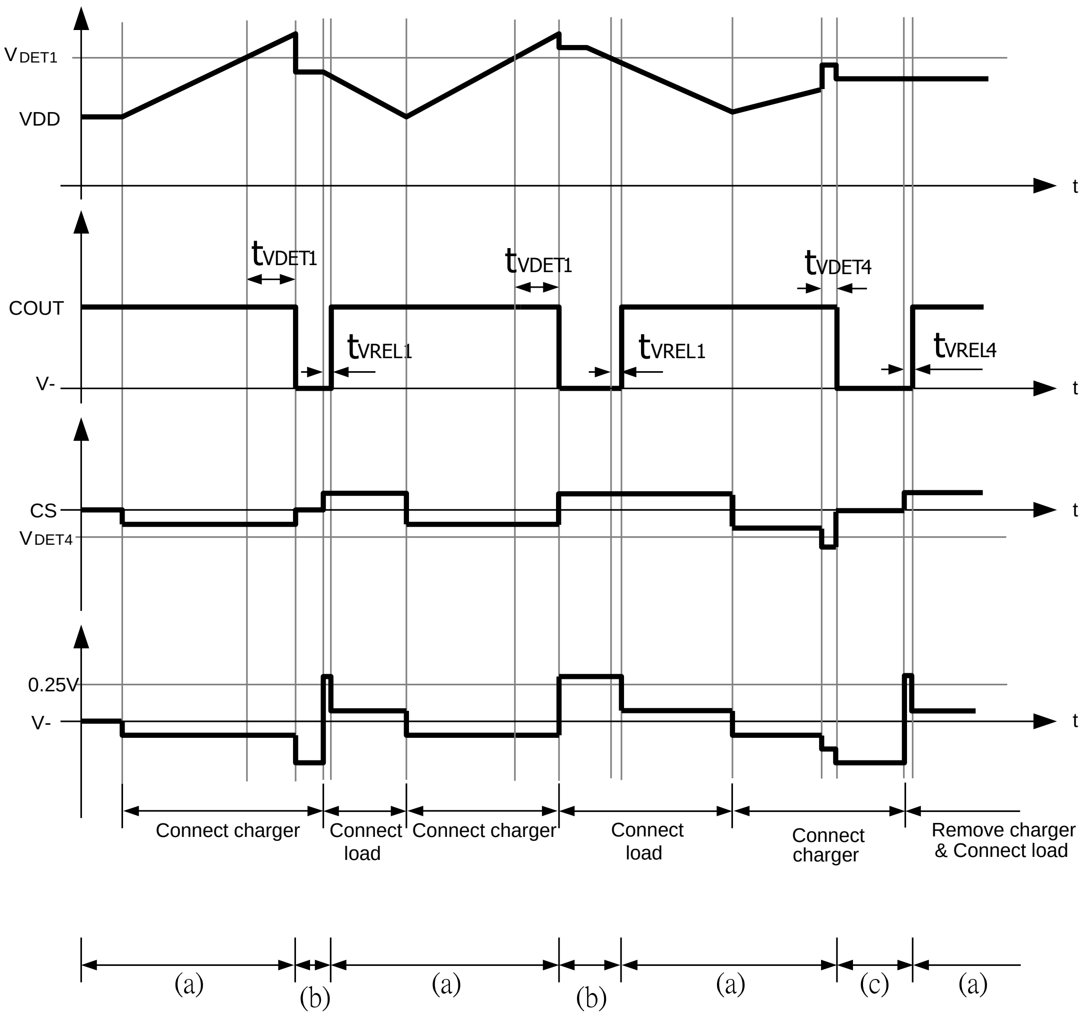
2) Power Down Mode Release:

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

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

Timing Chart

Over-charge, Charge Over-current Operation



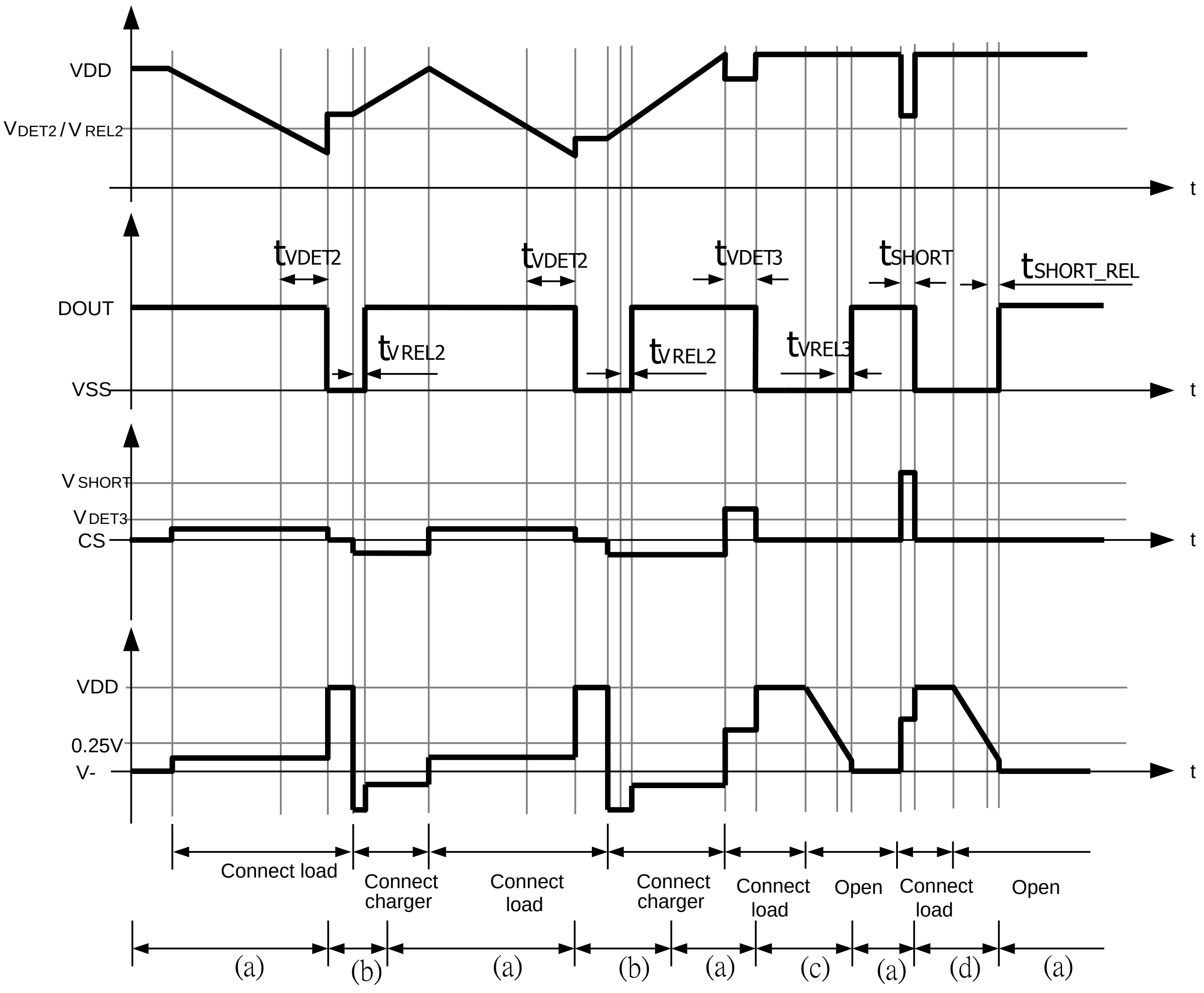
(a) Normal condition

(b) Overcharge condition

(c) Charge overcurrent condition

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

Over-discharge, Discharge Over-current, Load Short-Circuiting Operation



(a) Normal condition

(b) Overdischarge condition

(c) Discharge overcurrent condition

(d) Load short-circuit condition

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

Recommended Application Circuit

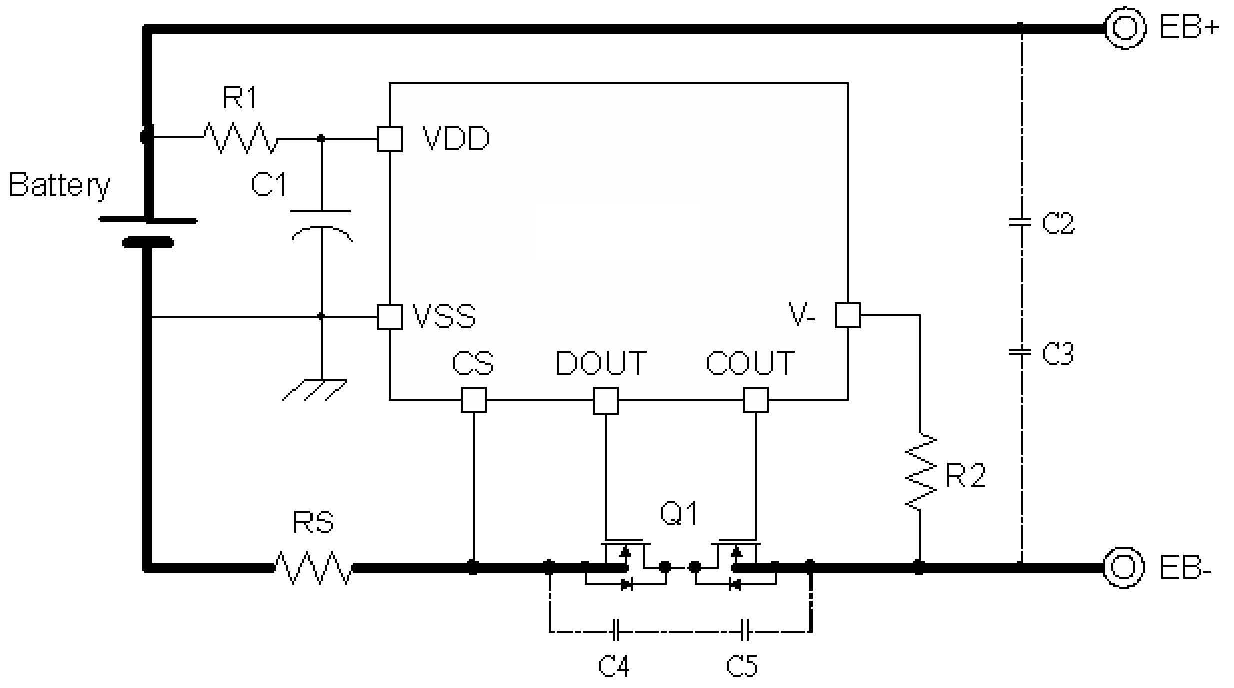


Table Constant for external components

Symbol	Parts	Purpose	Recommended	Min.	Max.	Remarks
Q1	Single N-channel MOSFET RDS (ON)	Charge/Discharge control	15mΩ	-	-	*(1) Gate to source breakdown voltage ≥ Charger voltage.
R1	Resistor	ESD protection for power fluctuation	330Ω	100Ω	1KΩ	*(2) Set Resistance to the value 2R1≤ R2.
R2	Resistor	Protection for reverse connection of a charger	1KΩ	300Ω	2KΩ	*(2) The resistor is preventing big current when a charger is connected in reverse.
RS	Sense resistor	For over-current and discharge over-current	10mΩ	-	-	-
C1	Capacitor	For power fluctuation	0.1uF	0.022uF	1.0uF	*(3) Install a 0.022uF capacitor or higher.
C2	Capacitor	For ESD protection	0.1uF	-	-	*(4) Reduce noise of load and improve system ESD performance.
C3	Capacitor	For ESD protection	0.1uF	-	-	
C4	Capacitor	For ESD protection	0.1uF	-	-	*(4) Protected MOSFET after system ESD.
C5	Capacitor	For ESD protection	0.1uF	-	-	

*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. 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.

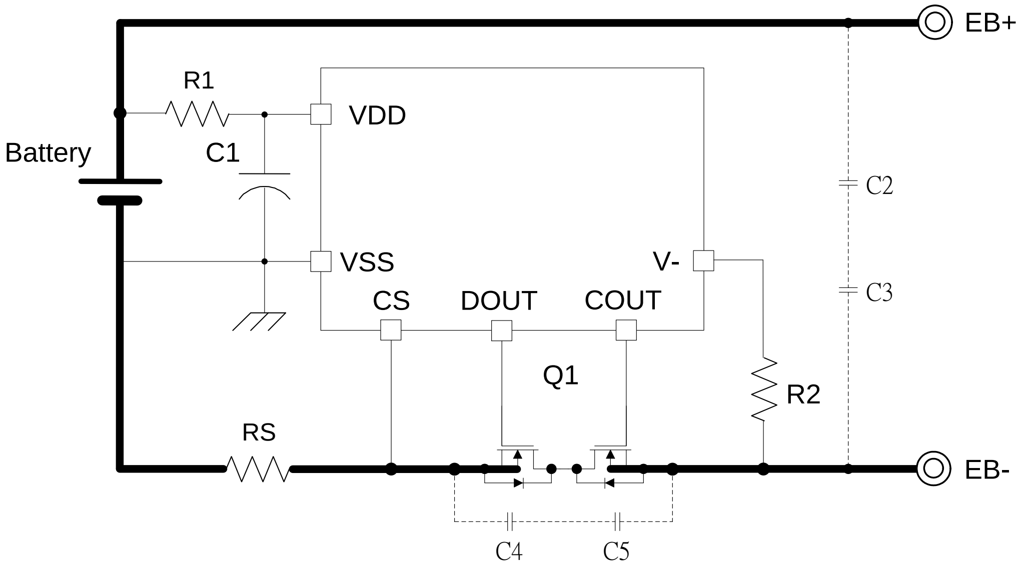
*3) Applying a smaller capacitance C1 to system, DOUT may failed to function when load short-circuiting is detected.
If R2 resistance is higher than 2kΩ, the charging current may not be cut when a high-voltage charger is connected.

*4) Followed this recommended table, the system ESD level can reach at least ±12KV. We can improve system ESD by connect C2 ~ C5 capacitors with 0.1uF value. Both C4 and C5 can protect MOSFET from being assaulted by system ESD. C2 and C3 can improve system ESD immunity 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.

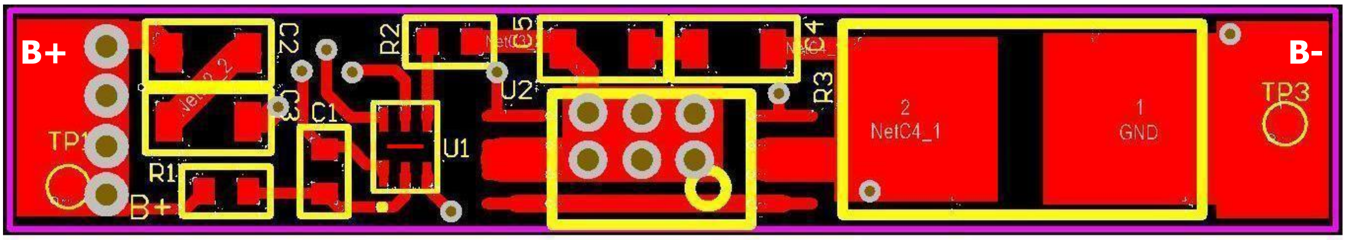
Precautions: 1) The application condition for the input voltage, output voltage, and load current should not exceed the package power dissipation.
2) Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.

PCB Schematic

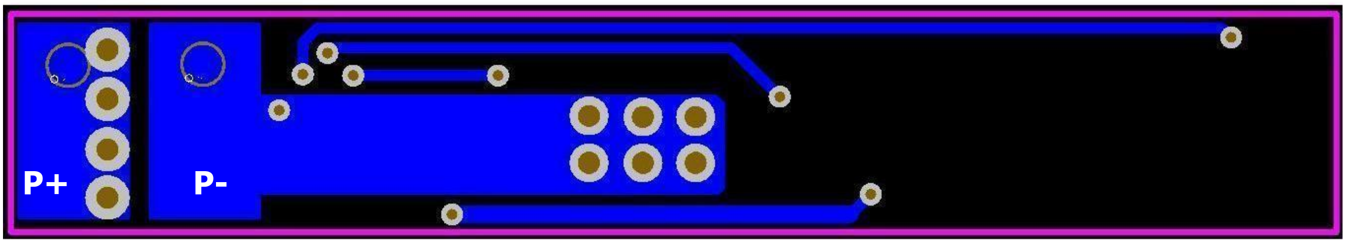


Layout Reference *(takes DFN-1.5x1.5-6L for example)*

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:

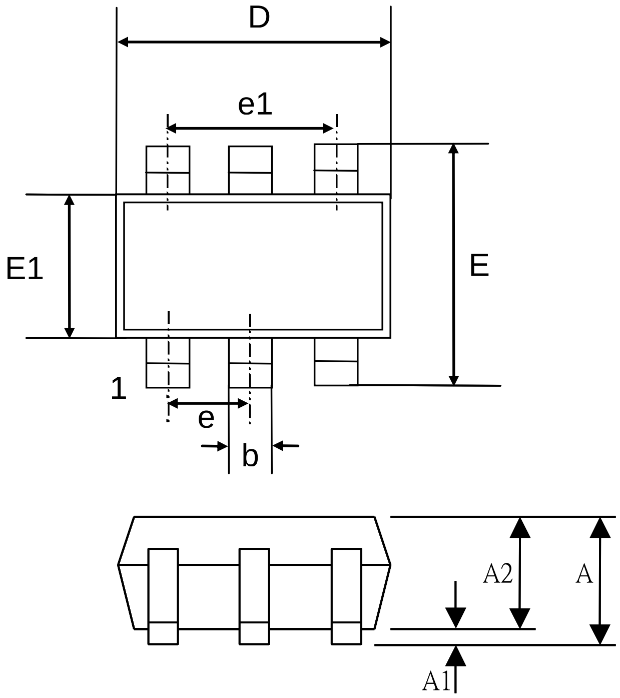
Symbol	Parts	Footprint	Value	Remarks
U1	NT1715 Series	DFN-1.5x1.5-6L	-	-
U2	N-MOSFET	TSSOP8	AO8810	Cut off charge or discharge current
R1	Resistor	0402 @ 1/16W	330Ω	Low pass filter with C1 and ESD protection
R2	Resistor	0402 @ 1/16W	1KΩ	ESD protection
RS	Current sense	2512 @ 1W	10mΩ	Current detection
C1	Capacitor	0402 @ 1/16W	0.1uF	Low pass filter with R1 and ESD protection

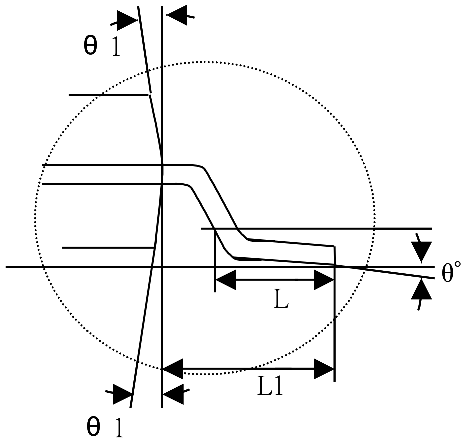
Special application circuit: (Reserve component)

Symbol	Parts	Type	Value	Remarks
C2	Capacitor	0603 Y5V	0.1uF/50V	ESD Protection for connected external load
C3	Capacitor	0603 Y5V	0.1uF/50V	ESD Protection for connected external load
C4	Capacitor	0603 Y5V	0.1uF/50V	ESD Protection for MOSFET
C5	Capacitor	0603 Y5V	0.1uF/50V	ESD Protection for MOSFET

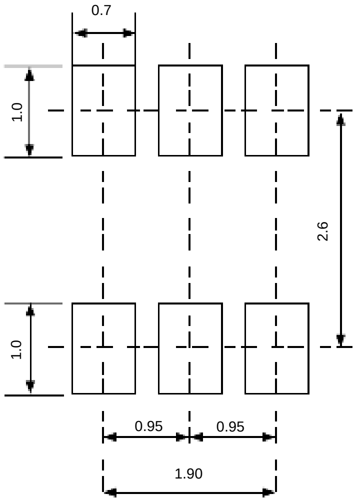
Package Information

SOT-23-6 Dimension





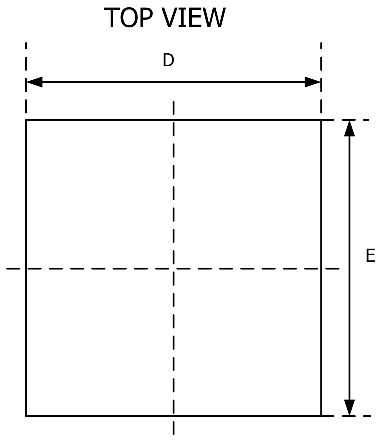
PCB Land Pattern

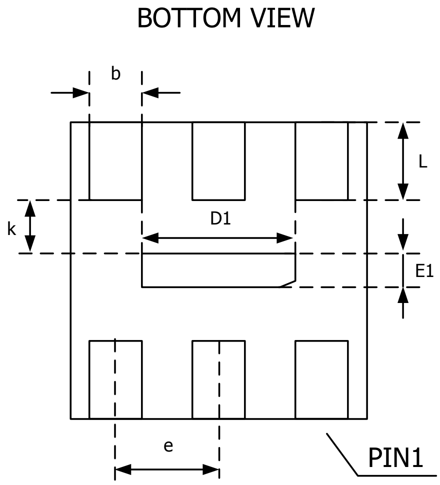


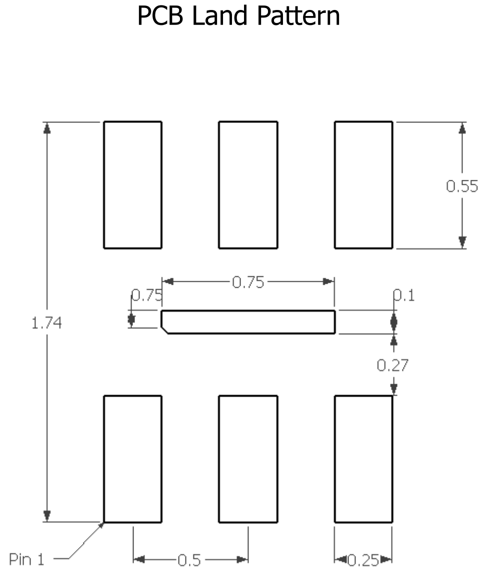
SYMBOL	MIN	NOM	MAX
A	—	—	1.45
A1	0.00	—	0.15
A2	0.90	1.15	1.30
b	0.30	0.4	0.50
c	0.08	—	0.22
D	2.70	2.90	3.10
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	—	0.95 BSC	—
e1	—	1.90 BSC	—
L	0.30	0.45	0.60
L1	—	0.6 REF	—
L2	—	0.25 BSC	—
θ	0°	4°	8°
θ 1	5°	10°	15°

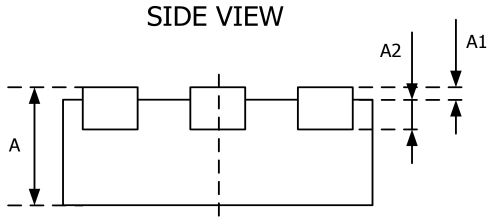
NOTES: 1. All dimensions show in mm
2. Reference: JEDECMO-178AA
3. SOT23-5 / SOT23-6

DFN-1.5x1.5-6L Dimension





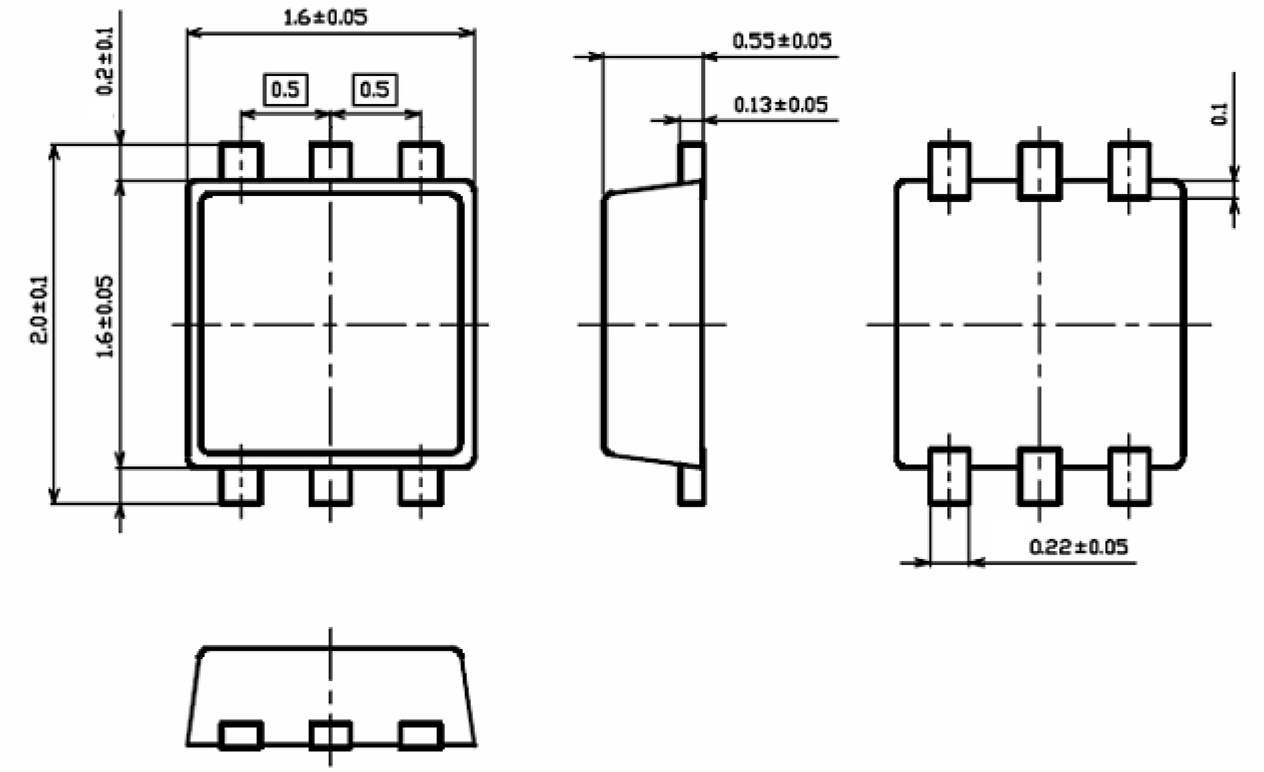




SYMBOL	Dimension In Millimeters	
	Min.	Max.
A	0.500	0.800
A1	0.000	0.050
A2	0.152 REF.	
D	1.424	1.576
E	1.424	1.576
D1	0.700	0.900
E1	0.050	0.250
k	0.200 MIN.	
b	0.150	0.250
e	0.500 TYP.	
L	0.274	0.426

SON-1.6x1.6-6L Dimension

Note: *All dimensions show in mm*



PCB Land Pattern