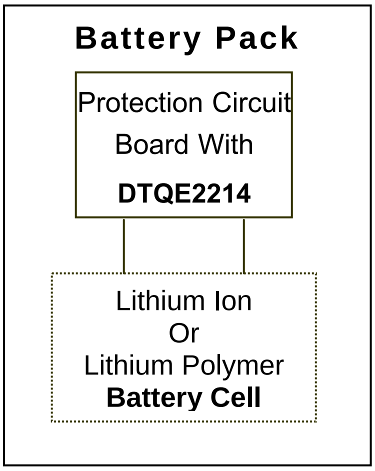
One-Cell Li Battery Protectors

General Description

The DTQE2214-XXXX Series are protectors for lithium-ion and lithium polymer rechargeable battery with high accuracy voltage detection. They can be used for protecting single cell lithium-ion or/and lithium polymer battery packs from overcharge, over-discharge, excess current and short circuit. These ICs have suitable protection delay functions and low power consumption property.

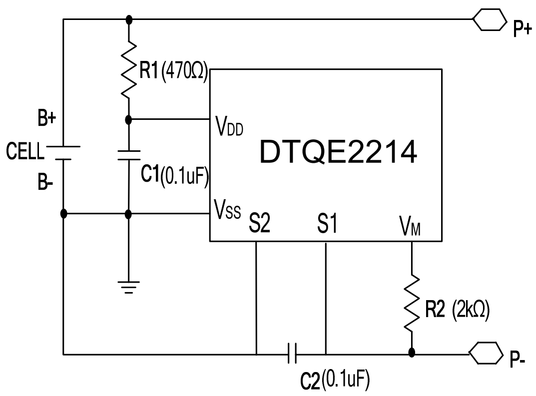
Applications



Features

- **Overcharge Threshold**
  - 4.200~ 4.400V
  - Accuracy ±25mV (25℃)
    ±50mV (-30℃~80℃)
- **Over-discharge Threshold**
  - 2.20V~3.00V
  - Accuracy ±10mV
- **Excess Current Protection Threshold**
  - 0.05V~0.150V @ V_{DD} = 3.30V
  - Accuracy ±0.015V
- **Short Circuit Protection Threshold**
  - Typ. 0.80V @ V_{DD} = 3.30V
  - Accuracy ±0.15V
- **Low Supply Current**
  - Typ. 3.1uA @ V_{DD} = 3.9V (Standard working current)
  - Typ. 0.1uA @ V_{DD} = 2.0V (Without auto wake up)
  - Typ. 1.2uA @ V_{DD} = 2.0V (With auto wake up)
- **Small Package**
  - DFNWB2.2*2.9-6L

Typical Application Circuits



Notes

R_1 and C_1 are to stabilize the supply voltage of the DTQE2214 series. $R_1 C_1$ is hence regarded as the time constant for V_{DD} pin. R_1 and R_2 can also be a part of current limit circuit for the DTQE2214 series.

Recommended values of these elements are as follows:

- $R_1 < 1K\Omega$. A larger value of R1 results in higher detection voltage, introducing errors.
- $R_2 < 3K\Omega$. A larger value of R_2 possibly prevents resetting from over-discharge even with a charger.
- $R_1+R_2 > 1K\Omega$. Smaller values may lead to power consumption over the maximum dissipation rating of the DTQE2214 series.

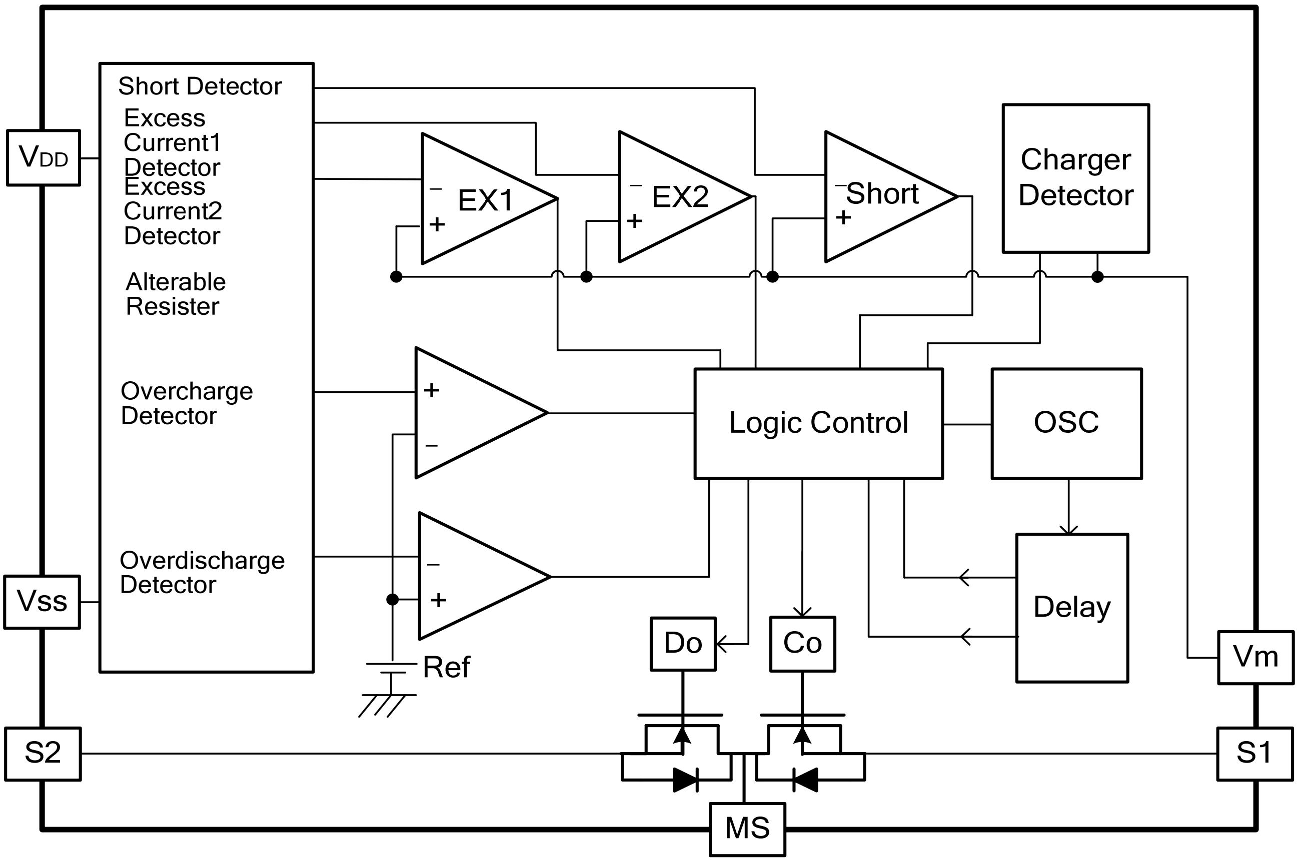
Table 1. The detail of delay time combination (@ 25℃)

Delay time combination	Output Delay Of Overcharge Tvdet1	Abnormal Charge Delay Time Tab	Output Delay Of Over-discharge Tvdet2	Output Delay Of Excess Current 1 Tvdet3
(1)	30~90ms Typ:66ms	5~15ms Typ:10ms	36~108ms Typ:75ms	5~15ms Typ:7.8ms

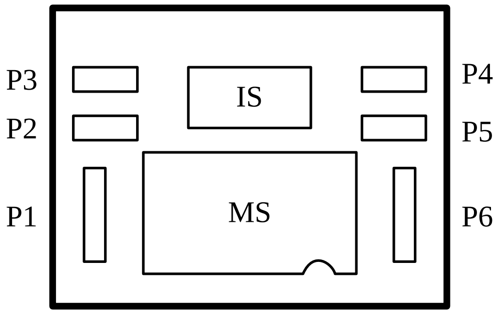
Table 2. The detail of delay time combination (@ -30℃~80℃)

Delay time combination	Output Delay Of Overcharge Tvdet1	Abnormal Charge Delay Time Tab	Output Delay Of Over-discharge Tvdet2	Output Delay Of Excess Current 1 Tvdet3
(1)'	25~100ms Typ:66ms	3~18ms Typ:10ms	30~120ms Typ:75ms	3~18ms Typ:7.8ms

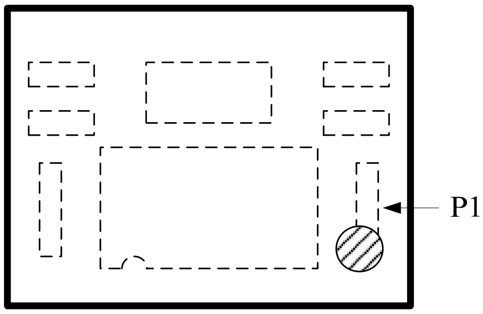
Block Diagram



Pin Description



Bottom View



Top View

Pin	Symbol	Description
P1	S2	The source terminal of MOSFET switch for Over-discharge control
P2	VSS	Ground
P3	VDD	Power supply
P4	NC	No Connection
P5	VM	Connected to charger's negative pin
P6	S1	The source terminal of MOSFET switch for Overcharge control
P7	IS	The substrate of IC, IS should be floating
P8	MS	The common drain terminal of MOS, MS should be floating

Function Description

Normal Condition:

V_{DD} is between the Over-discharge Detection Threshold (Vdet2) and Overcharge Detection Threshold (Vdet1) and the V_M pad voltage is between Charger Detection Voltage (Vcha) and the Excess Current 1 Threshold Voltage (Vdet3), therefore the MOS-FET of charge and discharge are all on. Charging and discharging can be carried out freely.

Overcharge Condition:

When V_{DD} increases and passes Vdet1 during charging under the normal condition, the changing control FET turns off after Overcharge Detection Delay Time (Tvdet1)..

If, within Tvdet1, V_{DD} becomes lower than Vdet1 and stays for duration shorter than Overcharge Reset Delay Time (Treset) before rising up over Vdet1 again, this type of instantaneous falling of V_{DD} is ignored. Otherwise, if the time V_{DD} stays lower than Vdet1 is longer than Treset, the timing related to Tvdet1 shall be reset.

Abnormal Charge Current Condition:

If the V_M pin voltage falls below the Charger Detection Voltage (Vcha) during charging under normal condition and it continues for the Abnormal Charge Current Delay Time (Tab) or longer, the charging control FET turns off and charging stops. This action is called the abnormal charge current detection.

Abnormal charge current detection works when the discharging control FET is on and the V_M pin voltage falls below the Charger Detection Voltage (Vcha). To an over-discharged battery, only when charging makes the battery voltage higher than the Over-discharge Detection Threshold (VDT), the Abnormal Charge Current Detection can act. Abnormal charge current state is released, once the voltage difference between VM pin and VSS pin becomes less than the Abnormal Charge Current Detection Threshold Voltage (VAB) value.

Overcharge Protection Release Condition:

The charging state can be reset and changing control FET will turn on when V_{DD} becomes lower than the Overcharge Release Voltage (Vrel1) and stays longer than Overcharge Release Delay Time (Tvrel1).

When a load is connected to V_{DD} after a charger is disconnected from the battery pack, while the V_{DD} level is lower than Vdet1, the changing control FET turns on.

Over-discharge Condition:

While discharging, after V_{DD} lowers below Over-discharge Detection Threshold (Vdet2), the discharging control FET turns off after Over-discharge Detection Delay Time (Tvdet2), discharging is stopped.

Over-discharge Protection Release Condition:

When IC is in over-discharge condition, if a charger is connected to the battery pack, and the battery supply voltage becomes higher than Vdet2, the discharging control FET turns on, allowing discharging action.

The discharging state also can be reset and the discharging control FET turns on when V_{DD} becomes higher than the Over-discharge Release Voltage (Vrel2), and stays longer than Release Delay Time (Tvrel1).

When a charger is connected from the battery pack, while the V_{DD} level is lower than Vdet2, the battery pack makes charger current allowable through the external diode.

Charger Detect Condition:

When a battery in the over-discharge condition is connected to a charger and provided that the V_M pin voltage is lower than the Charger Detection Voltage (Vcha), IC releases the over-discharge condition and turns on the discharging control FET as the battery voltage becomes higher than the Over-discharge Detection Voltage (Vdet2) since the charger detection function works. This action is called charger detection.

When a battery in the over-discharge condition is connected to a charger and provided that the V_M pin voltage is between the Charger Detection Voltage (Vcha) and Excess Current 1 Threshold Voltage (Vdet3), IC releases the over-discharge condition when the battery voltage reaches the Over-discharge Release Voltage (Vrel2) or higher.

Excess Current 1 Protection:

During discharging, the current varies with load, and V_M increases with the rise of the discharging current. Once V_M rises up to the Excess Current 1 Threshold Voltage (Vdet3) or higher and stays longer than the Excess Current 1 Delay Time (Tvdet3), IC will turn off the discharging control FET. After that excess current state is removed, i.e. V_M<Vdet3, and the circuit recovers to normal condition.

Excess Current 2 Protection:

During discharging, the current varies with load, and V_M increases with the rise of the discharging current. Once V_M rises up to Excess Current 2 Threshold Voltage (Vdet4) or higher, and stays longer than Excess Current 2 Delay Time (Tvdet4), IC will turn off the discharging control FET. After that excess current state is removed, i.e. V_M<Vdet3, and the circuit recovers to normal condition.

Short Circuit Protection:

This function has the same principle as the excess current protection. But, the delay time Tshort is far shorter than Tvdet3 and Tvdet4, and the threshold Vshort is far higher than Vdet3 and Vdet4. When the circuit is shorted, V_M increases rapidly. Once V_M≥Vshort, IC will turn off the discharging control FET. After the short circuit state is removed, i.e. V_M<Vdet3, the circuit recovers to the normal condition. The short circuit peak current is related to Vshort and the ON resistance of the two FETs in series.

0V battery charge function

This function is used to recharge the connected battery whose voltage is 0V due to the self-discharge. When the 0 V battery charge starting charger voltage (V0cha) or higher is applied between P+ and P− pins (in the Typical Application Circuits of Page1) by connecting a charger, the charging control FET gate is fixed to V_{DD} pin voltage. When the voltage between the gate and source of the charging control FET becomes equal to or higher than the turn-on voltage by the charger voltage, the charging control FET turns on to start charging. At this time, the discharging control FET is off and the charging current flows through the internal parasitic diode in the discharging control FET. When the battery voltage becomes equal to or higher than the Over-discharge Detection Threshold (Vdet2), the IC enters the normal condition.

Electrical Characteristics [1*] (25℃)

(T_{OPT}=25℃ unless otherwise specified)

Symbol	Item	Conditions	Min.	TYP.	Max.	Unit
DETECTION VOLTAGE AND DELAY TIME						
Vdet1[2*]	Overcharge Threshold 4.200~4.400V, Step 5mV	25℃	Vdet1 – 0.025	Vdet1	Vdet1 + 0.025	V
Vrel1[3*]	Release Voltage For Overcharge Detection Vhc[4*] =0.1V~0.3V		VDET1 –1.3Vhc	VDET1–Vhc	VDET1 –0.7Vhc	V
Vdet2[2*]	Over-discharge Threshold 2.2~2.4V	Detect falling edge of supply voltage	Vdet2 – 0.075	Vdet2	Vdet2 + 0.075	V
Vrel2[3*]	Release Voltage For Over-discharge Detection Vhd[4*] =0.1V~0.3V		VDET2+0.7Vhd	VDET2+Vhd	VDET2+1.3Vhd	V
Vdet3[2*]	Excess Current 1 Threshold	V_{DD} = 3.30V	Vdet3-0.015	Vdet3	Vdet3+0.015	V
Vdet4	Excess Current 2 Threshold	V_{DD} = 3.30V	0.35	0.40	0.45	V
Vshort	Short Protection Voltage	V_{DD} = 3.30V	0.65	0.80	0.95	V
Vcha	Charger Detection		Vcha-0.03	Vcha	Vcha+0.03	V
V0cha	0V Battery Charge Starting Charger Voltage	Applied for 0V battery charge function	1.2			V
Tvrel1	Overcharge ReleaseDelay Time	V_{DD} = 4.4V→4.0V	8	25	40	ms
Treset	Overcharge Reset Delay Time	V_{DD} = 4.4V→4.0V→4.4V	5	23	38	ms
Tvrel2	Over-discharge Release Delay Time	V_{DD} = 2.0V→3.0V, V_M = 0V	1.1	2.2	3.3	ms
Tvdet4	Output Delay Of Excess Current 2	V_{DD} = 3.30V	0.6	1.1	1.6	ms
Tshort	Output Delay Of Short Protection	V_{DD} = 3.30V	70	140	210	us
OUTPUT VOLTAGE AND V_M INTERNAL RESISTANCE						
R_{VMD}	Resistance between V_M and V_{DD}	V_{DD}=2.0V, V_M =0V	100	300	900	kΩ
R_{VMS}	Resistance between V_M and V_{SS}	V_{DD}=3.3V, V_M =1V	60	130	300	kΩ
OPERRATION VOLTAGE AND CURRENT CONSUMPTION						
V_{DD}	Operating Input Voltage	V_{DD}-Vss	1.6	V_{DD}	8.0	V
V_M	Operating Input Voltage	V_{DD}-V_M	1.5	--	28	V
I_{DD}	Supply Current	V_{DD} = 3.9V, V_M = 0V		3.1	5.5	uA
$I_{STANDBY}$	Standby Current (for products without Auto wake up)	V_{DD} = 2.0V, V_M = 0V→2.0V		0.1	0.7	uA
$I_{STANDBY}$	Standby Current(for products with Auto wake up)	V_{DD} = 2.0V, V_M = 0V→2.0V		1.2	4.5	uA

1* The Electrical parameters for this temperature range is guaranteed by design, not tested in production.

2* See “Selection Guide” section.

3* VDET1 and VDET2 are the Overcharge and Over-discharge threshold voltage of actual testing.

4* Vhc and Vhd are the Overcharge and Over-discharge hysteresis voltage.

Electrical Characteristics [1*] (-30℃~80℃)

(T_{OPT}=-30℃～80℃ unless otherwise specified)

Symbol	Item	Conditions	Min.	TYP.	Max.	Unit
DETECTION VOLTAGE AND DELAY TIME						
Vdet1[2*]	Overcharge Threshold 4.200~4.400V, Step 5mV	-30～80℃	Vdet1 – 0.050	Vdet1	Vdet1 + 0.050	V
Vrel1[3*]	Release Voltage For Overcharge Detection Vhc[4*] =0.1V~0.3V		VDET1 –1.4Vhc	VDET1–Vhc	VDET1 – 0.6Vhc	V
Vdet2[2*]	Over-discharge Threshold 2.2~2.4V	Detect falling edge of supply voltage	Vdet2 – 0.1	Vdet2	Vdet2 + 0.1	V
Vrel2[3*]	Release VoltageForOver-discharge Detection Vhd[4*] =0.1V~0.3V		VDET2 +0.6Vhd	VDET2+Vhd	VDET2 + 1.4Vhd	V
Vdet3	Excess Current 1 Threshold	V_{DD} = 3.30V	Vdet3-0.020	Vdet3	Vdet3+0.020	V
Vdet4	Excess Current 2 Threshold	V_{DD} = 3.30V	0.27	0.40	0.53	V
Vshort	Short Protection Voltage	V_{DD} = 3.30V	0.50	0.80	1.30	V
Vcha	Charger Detection		Vcha-0.04	Vcha	Vcha+0.04	V
V0cha	0V battery Charge Starting Charger Voltage	Applied for 0V battery charge function	1.2			V
Tvrel1	Overcharge ReleaseDelay Time	V_{DD} = 4.4V→4.0V	5	25	42	ms
Treset	Overcharge Reset Delay Time	V_{DD} = 4.4V→4.0V→4.4V	3	23	40	ms
Tvrel2	Over-discharge Release Delay Time	V_{DD} = 2.0V→3.0V, V_M = 0V	0.9	2.2	3.6	ms
Tvdet4	Output Delay Of Excess Current 2	V_{DD} = 3.30V	0.45	1.1	1.8	ms
Tshort	Output Delay Of Short Protection	V_{DD} = 3.30V	55	140	230	us
OUTPUT VOLTAGE AND V_M INTERNAL RESISTANCE						
R_{VMD}	Resistance Between V_M And V_{DD}	V_{DD}=2.0V, V_M = 0V	78	300	1310	kΩ
R_{VMS}	Resistance Between V_M And V_{SS}	V_{DD}=3.3V, V_M =1V	40	130	400	kΩ
OPERRATION VOLTAGE AND CURRENT CONSUMPTION						
V_{DD}	Operating Input Voltage	V_{DD}-Vss	1.6	V_{DD}	8.0	V
V_M	Operating Input Voltage	V_{DD}-V_M	1.5	--	28	V
I_{DD}	Supply Current	V_{DD} = 3.9V, V_M = 0V		3.1	6.0	uA
$I_{STANDBY}$	Standby Current (for products with power-down function)	V_{DD} = 2.0V, V_M = 0V→2.0V		0.1	1.0	uA
$I_{STANDBY}$	Standby Current (for products without power-down function)	V_{DD} = 2.0V		1.2	5.0	uA

1* The Electrical parameters for this temperature range is guaranteed by design, not tested in production.
2* See "Selection Guide" section.
3* VDET1 and VDET2 are the overcharge and over-discharge threshold voltage of actual testing.
4* Vhc and Vhd are the Overcharge and Over-discharge hysteresis voltage.

Absolute Maximum Ratings(Ta= 25 ºC ， V_{SS}=0 V)

Symbol	Item	Ratings	Unit
V_{DD}	Supply Voltage	-0.3 to 8	V
V_M	V_M Pin Input Voltage	V_{DD} -28 to V_{DD}+0.3	V
Pd	Power Dissipation	150	mW
Topt	Operating Temperature Range	-30 to 80	℃
Tstg	Storage Temperature Range	-55 to 125	℃

Caution: These values must not be exceeded under any conditions!

Electrical Characteristics [1*] (25℃，GND=0V unless otherwise specified)

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Drain current at cut off of MOS-FET	I_{DSS}	-	-	1.0	uA	Vds=20V
Source -source on state resistance 1	$R_{DS(on)}1$	-	22	25	mΩ	Vdd=3.8V I_D=1.0A
Body Diode-Forward Voltage	V_{SD}	0.6	0.73	1.2	V	Is=6.0A, V_{GS}=0V

Test Circuits

(1) Overcharge detection voltage and overcharge release voltage

Test circuit 1

The Overcharge Detection Voltage (Vdet1) is the voltage between V_{DD} and V_{SS} to which when V1 increases and keeps the condition for overcharge delay time, The charging control FET turns off, Vs_1 is the threshold of a diode, The Overcharge Release Voltage (Vrel1) is the voltage between V_{DD} and V_{SS} to which when V1 decreases, The charging control FET turns on, Vs_1=0V.

(2) Over-discharge detection voltage and over-discharge release voltage

Test circuit 1

The Over-discharge Detection Voltage (Vdet2) is the voltage between V_{DD} and V_{SS} to which when V1 decreases and keep the condition for over-discharge delay time, The discharging control FET turns off, Vs_1=V1. The over-discharge Release Voltage (Vrel2) is the voltage between V_{DD} and VSS to which when V1 increases, The discharging control FET turns on, Vs_1=0V.

(3) Over current detection voltage and short circuit detection voltage

Test circuit 2

The Excess Current 1 Detection Voltage (Vdet3) is the voltage between V_M and V_{SS} to which when V_M increases within 10 us and keep the condition for Excess Current 1 Delay Time (Tvdet3), The discharging control FET turns off, Vs_1=V1.

The Excess Current 2 Detection Voltage (Vdet4) is the voltage between V_M and V_{SS} to which when V_M increases within 10 us and keep the condition for Excess Current 2 Delay Time (Tvdet4), The discharging control FET turns off, Vs_1=V1.

The Short Circuit Detection Voltage (Vshort) is the voltage between V_M and V_{SS} to which when V_M increases within 10us and keep the condition for Short Circuit Delay Time (Tshort), The discharging control FET turns off, Vs_1=V1.

(4) Charger detection voltage and abnormal charge current detection voltage

Test circuit 2

In the over-discharge condition, increase V1 gradually until it is between Vdet2 and Vrel2. The voltage between V_M and V_{SS} to which when V2 decreases, The discharging control FET turns on, Vs_1=0V, is the Charger Detection Voltage (Vcha).

In the normal charging condition, the voltage between V_M and V_{SS} to which when V2 decreases, The charging control FET turns off, Vs_1 is the threshold of a diode, is the abnormal charge current detection voltage. It has the same value as the Charger Detection Voltage (Vcha).

(5) 0V battery charge starting charger voltage

Test circuit 2

Set V1=V2=0V and decrease V2 gradually. The voltage between V_{DD} and V_M when the charging control FET turns on, Vs_1 is the threshold of a diode, is the 0V battery charge starting charger voltage.

(6) Normal operation current consumption and power down current consumption

Test circuit 2

Set V1=3.5V and V2=0V under normal condition, the current I_{DD} flowing through V_{DD} pin is the normal operation consumption current (I_{DD}).

Set V1=3.5V and V2=0V，let IC work in normal condition, set V1 from 3.5V to 2.0V, then set V2=2.0V under over-discharge condition, the current I_{DD} flowing through V_{DD} pin is the power down current consumption ($I_{STANDBY}$).

(7) Overcharge detection (release) delay time and over-discharge detection (release) delay time

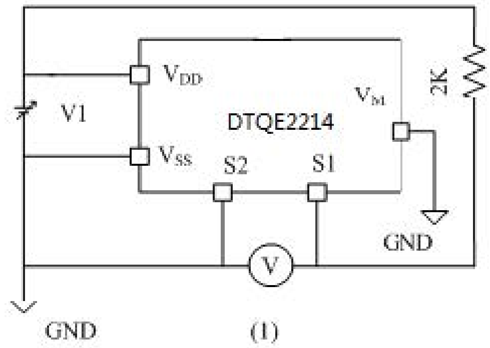
Test circuit 3

If V1 increases to be Vdet1 or over Vdet1 and keeps the condition for some time, the charging control FET will turn off, Vs_1 is the threshold of a diode, The time is called overcharge detection delay time. It is used to judge whether overcharge happens indeed.

If V1 decreases from Vdet1 or over Vdet1 to below Vrel1, the charging control FET will turn on, Vs_1=0V. The difference between this time and Treset is called overcharge release delay time.

If V1 decreases to be Vdet2 or below Vdet2 and keeps the condition for some time, the discharging control FET will turn off, Vs_1=V1. The time is called over-discharge detection delay time. It is used to judge whether over-discharge happens indeed.

If V1 increases from Vdet2 or below Vdet2 to over Vrel2 and keeps the condition for some time, the discharging control FET will turn on, Vs_1=0V. The time is called over-discharge release delay time.



(1)

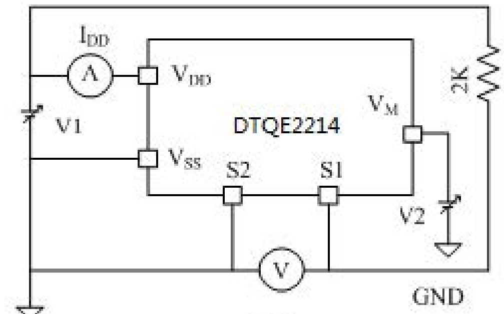
(8) Over current detection delay time and short circuit detection delay time

Test circuit 4

If V2 increases to be Vdet3 or over Vdet3 and keeps the condition for some time, the discharging control FET will turn off, Vs_1=V1. The time is called over current 1 delay time. It is used to judge whether over current 1 happens indeed.

If V2 increases to be Vdet4 or over Vdet4 and keeps the condition for some time, the discharging control FET will turn off, Vs_1=V1. The time is called over current 2 delay time. It is used to judge whether over current 2 happens indeed.

If V2 increases to be Vshort or over Vshort and keeps the condition for some time, the discharging control FET will turn off, Vs_1=V1. The time is called short circuit delay time. It is used to judge whether short circuit happens indeed.



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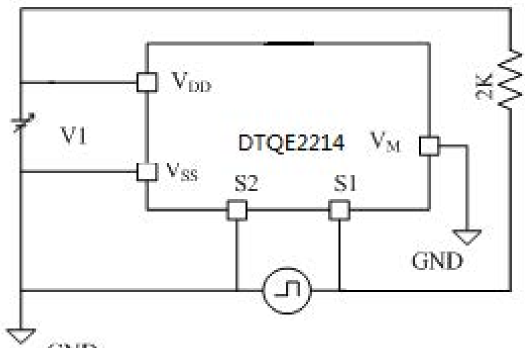


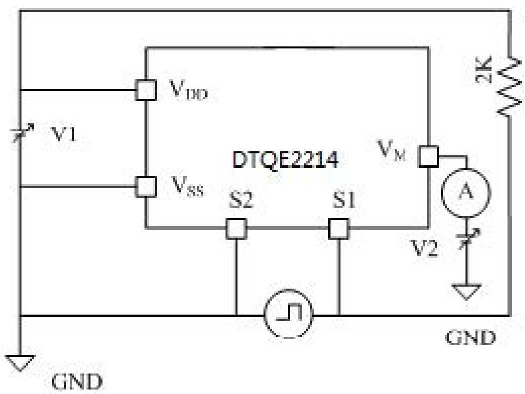
(3)

(9) Internal resistance V_M-V_{DD} and V_M-V_{SS}

Test circuit 4

Set V1=2.0 V, V2=0 V, V1/I_{VM} is the internal resistance R_{VMD}.

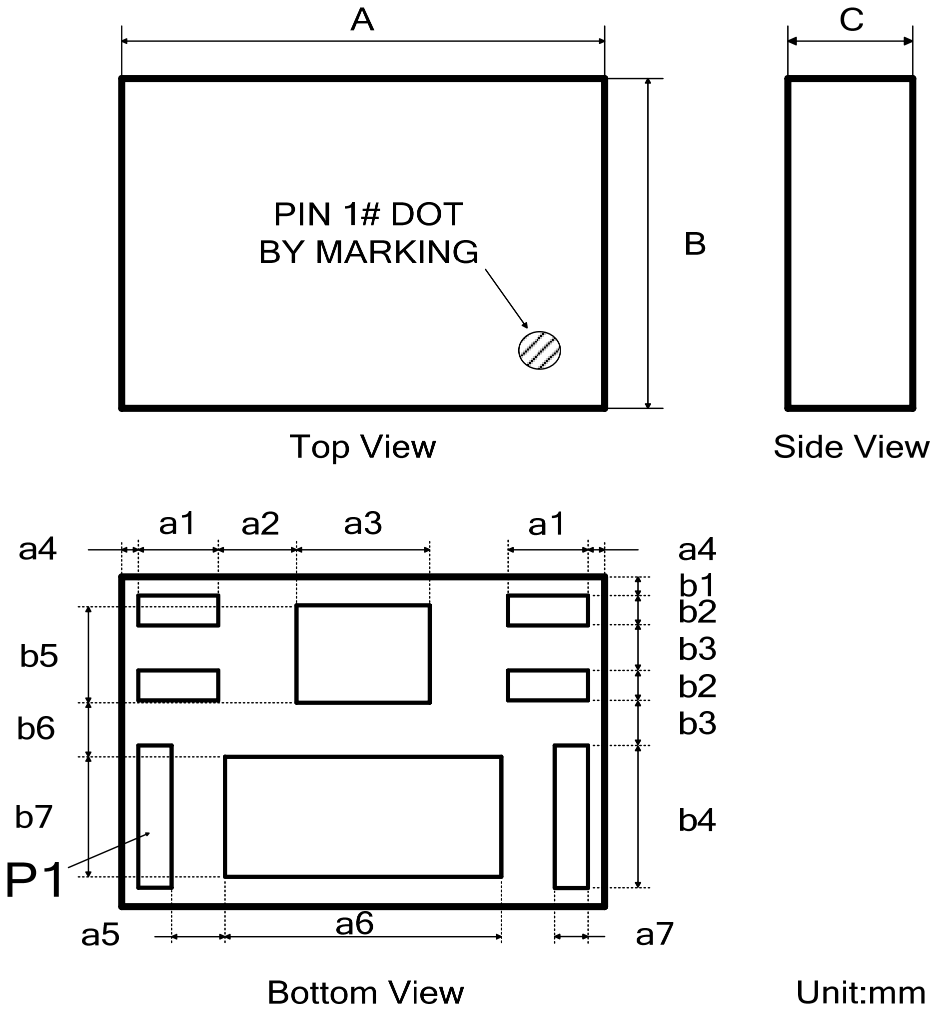
Set V1=3.3 V, V2=1 V, V2/I_{VM} is the internal resistance R_{VMS}.



(4)

Package Outline

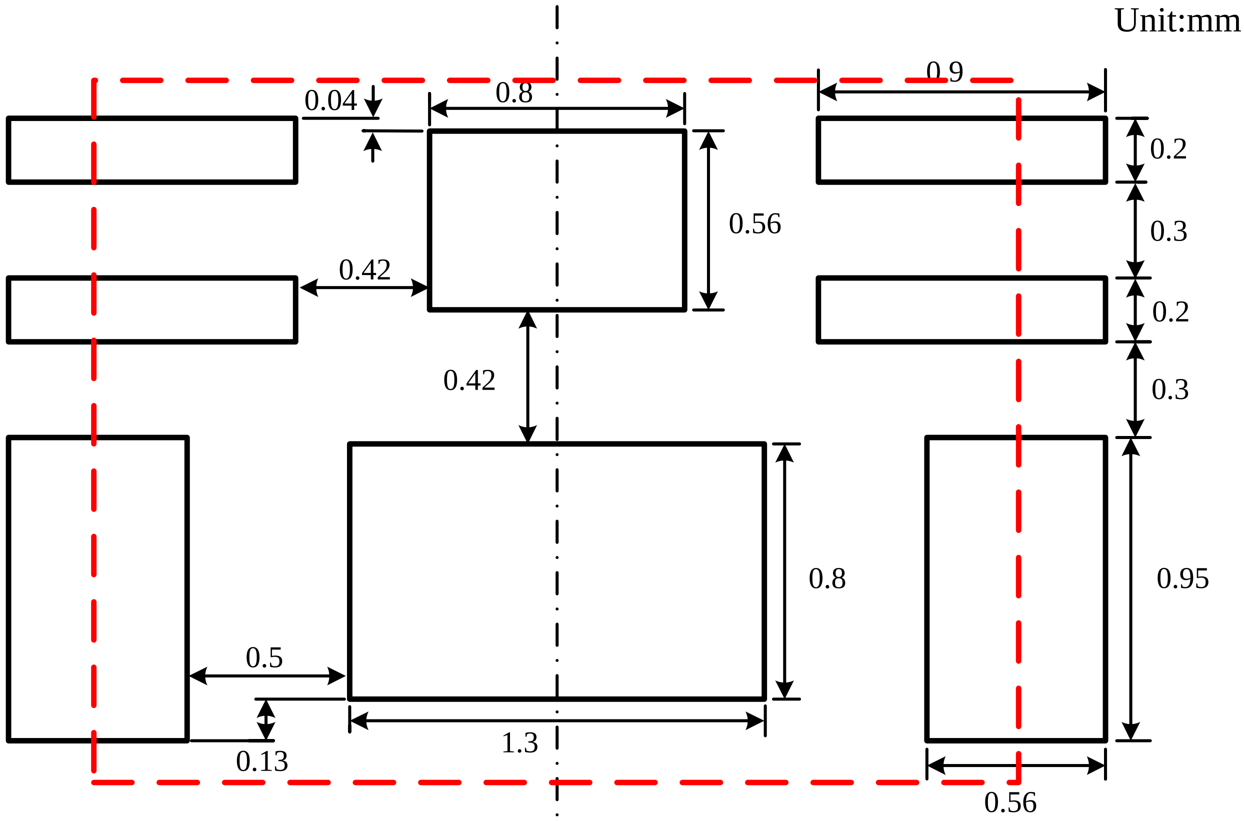
DFNWB 2.2*2.9



Dimensions (mm)

A	a1	a2	a3	a4	a5	a6	a7	B	b1	b2	b3	b4	b5	b6	b7	C
2.95	0.53	0.52	0.85	0.15	0.35	1.75	0.25	2.25	0.18	0.25	0.35	1	0.59	0.53	0.85	0.8
2.85	0.43	0.42	0.75	0.05	0.25	1.65	0.15	2.15	0.08	0.15	0.25	0.9	0.49	0.43	0.75	0.7

PCB Layout



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