1. General Description

The HK01 IC is best created for single-cell lithium-ion/lithium polymer rechargeable battery protection and it also comprises high-accuracy voltage detectors and delay circuits.

This IC is suitable for protecting single-cell rechargeable lithium-ion/lithium polymer battery packs against the problems of overcharge, overdischarge and overcurrent.

2. Features

The features that HK01 comprised is as follows:

(1) High-accuracy voltage detection circuit

- Overcharge detection voltage 4.300V Accuracy: ±50mV
- Overcharge release voltage 4.100V Accuracy: ±50mV
- Overdischarge detection voltage 2.40V Accuracy: ±100mV
- Overdischarge release voltage 3.00V Accuracy: ±100mV
- Discharge overcurrent detection voltage 150mV Accuracy: ±30mV
- Short-circuiting detection voltage 0.85V(fixed) Accuracy: ±300mV

(2)Delay times are generated by an internal circuit (external capacitors are unnecessary).

- Overcharge delay time 100ms typ.
- Overdischarge delay time 50ms typ.
- Discharge overcurrent delay time 10ms typ.

(3) Low current consumption

- Operation mode 3.0μA typ., 6.0μA max. (VDD=3.9V)
- Ultra low power-down current 0.1μA max. (VDD=2.0V)

(4) High-withstanding-voltage device is used for charger connection pins

(CS pin and OC pin : Absolute maximum rating = 20 V)

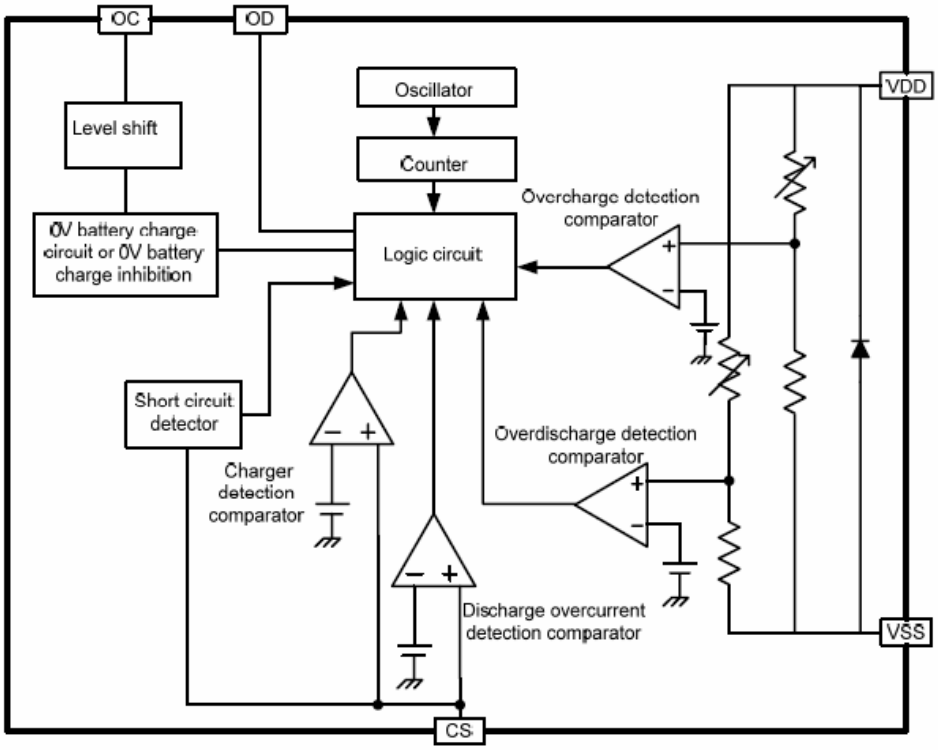
(5) Wide operating temperature range −40°C to +85 °C

(6) Small package SOT-23-6

3. Applications

- 1-cell lithium-ion rechargeable battery packs
- 1-cell lithium polymer rechargeable battery packs

4. Block Diagram



5. Pin Configuration and Package Marking Information

Pin No.	Symbol	Descriptio
1	OD	MOSFET gate connection pin for discharge control
2	CS	Input pin for current sense, charger detect pin
3	OC	MOSFET gate connection pin for charge control
4	DS	Test pin for reduce delay time
5	VDD	Power supply pin
6	VSS	Ground pin

6. Absolute Maximum Ratings

(VSS=0V, Ta=25°C unless otherwise specified)

Item	Symbol	Rating	Unit
Input voltage between VDD and VSS pin	V_{DD}	VSS-0.3 to VSS+10	V
OC output pin voltage	V_{OC}	VDD -20 to VDD +0.3	V
OD output pin voltage	V_{OD}	VSS-0.3 to VDD +0.3	V
CS input pin voltage	V_{CS}	VDD -20 to VDD +0.3	V
Operating Temperature Range	T_{OP}	-40 to +85	°C
Storage Temperature Range	T_{ST}	-40 to +125	°C
Power dissipation	P_D	250	mW

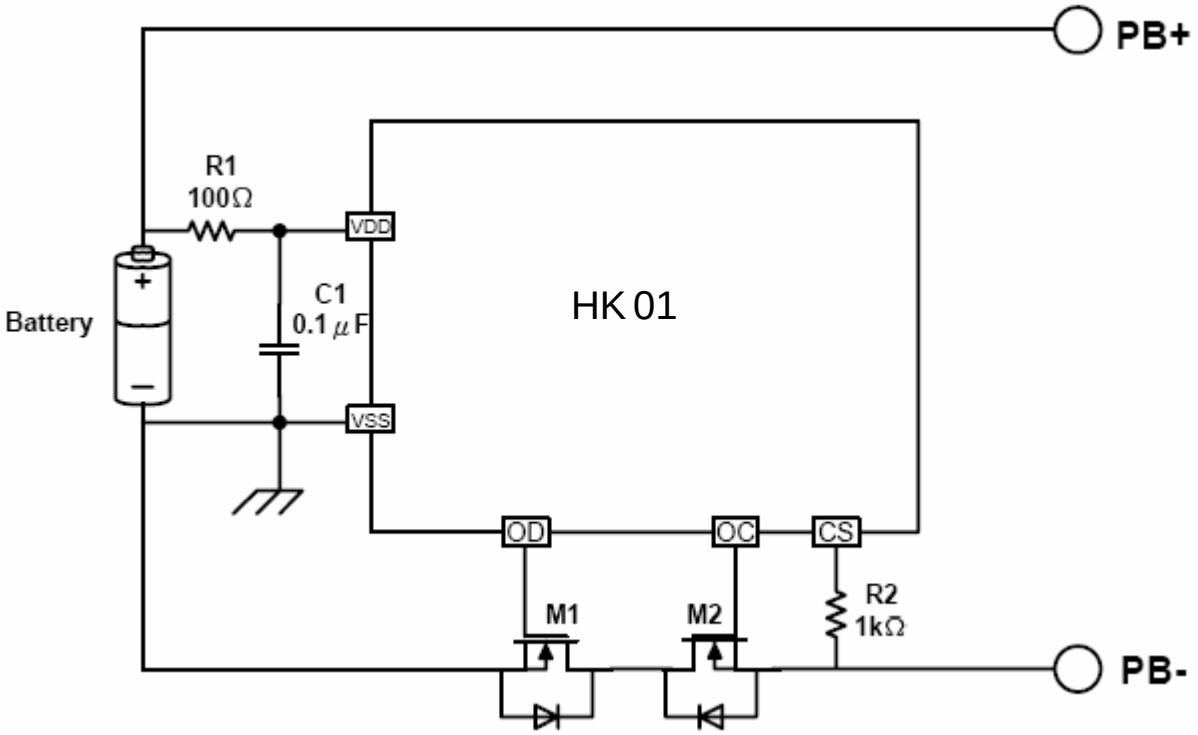
7. Electrical Characteristics

(VSS=0V, Ta=25°C unless otherwise specified)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
SUPPLY POWER RANGE						
Operating voltage between VDD pin and VSS pin	V_{DSOP1}	-	1.5	-	8	V
Operating voltage between VDD pin and CS pin	V_{DSOP2}	-	1.5	-	20	V
INPUT CURRENT						
Supply Current	I_{DD}	VDD=3.9V		3.0	6.0	μA
Power-Down Current	I_{PD}	VDD=2.0V			0.1	μA
DETECTION VOLTAGE						
Overcharge Detection Voltage	V_{CU}	4.30V	V_{CU} -0.05	V_{CU}	V_{CU} +0.05	V
Overcharge Release Voltage	V_{CR}	4.10V	V_{CR} -0.05	V_{CR}	V_{CR} +0.05	V
Overdischarge Detection Voltage	V_{DL}	2.4V	V_{DL} -0.1	V_{DL}	V_{DL} +0.1	V
Overdischarge Release Voltage	V_{DR}	3.0V	V_{DR} -0.1	V_{DR}	V_{DR} +0.1	V
Discharge Overcurrent Detection Voltage	V_{DIP}	VDD=3.6V	V_{DIP} -30	V_{DIP}	V_{DIP} +30	mV
Short Circuit Detection Voltage	V_{SIP}	VDD=3.0V	0.55	0.85	1.15	V
Charger Detection Voltage	V_{CHA}			-0.3		V
DELAY TIME						
Overcharge Delay Time	T_{OC}	VDD=3.9V to 4.5V	50	100	150	ms
Overdischarge Delay Time	T_{OD}	VDD=3.6V to 2.0V	25	50	80	ms
Discharge Overcurrent Delay Time	T_{DIP}	VDD=3.6V	5	10	15	ms
Short Circuit Delay Time	T_{SIP}	VDD=3.0V		500	700	μs
CONTROL OUTPUT VOLTAGE(OD&OC)						
OD Pin Output “H” Voltage	V_{DH}		VDD -0.1	VDD -0.02		V
OD Pin Output “L” Voltage	V_{DL}			0.1	0.5	V
OC Pin Output “H” Voltage	V_{CH}		VDD -0.1	VDD -0.02		V
OC Pin Output “L” Voltage	V_{CL}			0.1	0.5	V

NOTE: Since products are not screened at high and low temperature, the specification for this temperature range is guaranteed by design, not tested in production.

8. Example of Battery Protection IC Connection



Symbol	Device Name	Purpose	Min.	Typ.	Max.	Remark
R1	Resistor	limit current, stabilize VDD and strengthen ESD protection	100Ω	**100Ω**	470Ω	*1
R2	Resistor	limit current	300Ω	**1kΩ**	2kΩ	*2
C1	Capacitor	stabilize VDD	0.01μF	**0.1μF**	1.0μF	*3
M1	N-MOSFET	Discharge control	-	-	-	*4
M2	N-MOSFET	Charge control	-	-	-	*5

*****1. R1 should be as small as possible to avoid lowering the overcharge detection accuracy due to current consumption. When a charger is connected in reversed, the current flows from the charger to the IC. At this time, if R1 is connected to high resistance, the voltage between VDD pin and VSS pin may exceed the absolute maximum rating.

*2. If R2 has a resistance higher than 2kΩ, the charging current may not be cut when abnormal over-current appeared during charging. Please select as large a resistance as possible to prevent current when a charger is connected in reversed.

*3. C1 will stabilize the supply voltage of VDD，the value of C1 should be equal to or more than 0.01μF.

*4. If a FET with a threshold voltage equal to or higher than the overdischarge detection voltage is applied, discharging may be stopped before overdischarge is detected.

*5. If the withstanding voltage between the gate and source is lower than the charger voltage, the FET may be destroyed.

9. Description of Operation

9.1.Normal Status

This IC monitors the voltage of the battery connected between the VDD pin and VSS pin and the voltage difference between the CS pin and VSS pin to control charging and discharging.

When the battery voltage is in the range from overdischarge detection voltage (V_{DL}) to overcharge detection voltage (V_{CU}), and the CS pin voltage is in the range from the charger detection voltage (V_{CHA}) to discharge overcurrent detection voltage (V_{DIP}), the IC turns both the charging and discharging control MOSFET on. This condition is called the normal status. Under this condition, charging and discharging can both be carried out freely.

Caution: Discharging may not be enacted when the battery is first time connected.

To regain normal status, CS and VSS pin must be shorted or the charger must be connected.

9.2.Overcharge Status

Under the normal status, as soon as the battery voltage becomes higher than the overcharge detection voltage (V_{CU}) during charging and the detection continues longer than the overcharge detection delay time (T_{OC}), the HK 01 will turn the charging control MOSFET off (OC pin) to stop charging .This condition is called the overcharge status.

The overcharge status can be released by the following two cases:

(1)The voltage of the battery cell is equal to or lowers than the overcharge release voltage (V_{CR}) due to self-discharge.

(2)When load is connected and the battery voltage falls below the overcharge protection voltage (V_{CU}).

9.3.Overdischarge Status

When the battery voltage falls below than the overdischarge detection voltage (V_{DL}) during discharging in the normal status and the detection continues longer than the overdischarge detection delay time (T_{OD}), the HK 01 will turn the discharging control MOSFET off(OD pin) so as to stop discharging. This condition is called the overdischarge status.

When the MOSFET is off, CS pin voltage is pulled up by the resistor to VDD in the IC, at this time, the power consumption is reduced to the lowest. This condition is called the "SLEEP MODE".

The overdischarge status will be released by two cases:

(1) When CS pin voltage is equal to or lower than the charger detection voltage (V_{CHA}) by charging and the VDD pin voltage is higher than overdischarge detection voltage(V_{DL}).

(2) When CS pin voltage is equal to or higher than the charger detection voltage (V_{CHA}) by charging and the VDD pin voltage is higher than overdischarge release voltage (V_{DR}).

9.4.Charger detection Status

When the charger is connected to the overdischarge battery, if the voltage of CS pin is lower than charger detection voltage(V_{CHA}), based on the charger detection function, as long as the battery voltage

is higher than overdischarge voltage(V_{DL}), the discharge status will be released and discharging control MOSFET (OD pin) will be turned on. This process is called the “charger detection status”.

Conversely, if CS pin’s voltage is not lower than charger detection voltage (V_{CHA}), the battery voltage has to reach the overdischarge release voltage(V_{DR}) to relieve the overdischarge status as usual.

9.5.Discharge Overcurrent Status (Discharge Overcurrent & Short Circuit)

Under normal condition, the HK 01 continuously monitors the discharge current by sensing the voltage of CS pin.

If the voltage of CS pin exceeds the overcurrent detection voltage (V_{DIP}) and the condition lasts beyond the overcurrent delay time (T_{DIP}), discharging will be suspended by turning off the discharge control MOSFET (OD pin). This condition is called the discharge overcurrent status.

If the voltage of CS pin exceeds the short circuit detection voltage (V_{SIP}) and the condition lasts beyond the short circuit delay time (T_{SIP}), discharging will be suspended by turning off the discharge control MOSFET (OD pin). This condition is called the short circuit status.

When the impedance between PB+ and PB-is higher than 1.4MΩ (typ.), the discharge overcurrent condition will be released.

9.6.Abnormal Charge Current detection

Batteries under normal condition during the charging process, if the voltage of CS pin is lower than charger detection voltage (V_{CHA}), and this condition lasts for more than 12ms(typ.), the charging control MOSFET will be switched off (OC pin) to stop charging. This status is called “abnormal charge current detection”.

After entering the status of abnormal charge current detection, one way to revert it to normal is to have the CS pin voltage higher than charger detection voltage (V_{CHA}). Abnormal charge current detection voltage(V_{CHA}) for **formularize :**

{I_{CHA}=|V_{CHA}|/R_{ON}}. R_{ON} is turn on resistance of MOSFET

9.7.DS pin

For individual model number, the fourth pin of the IC is NC，no DS pin. For details, please refer to Chapter 7-Pin Configuration and Package Marking Information.

For the ICs equipped with DS pin, in order to shorten testing time for production, the DS pin can decrease IC's overcharge delay time within 10ms by connecting it to VDD pin. The DS pin should be open in the actual application.

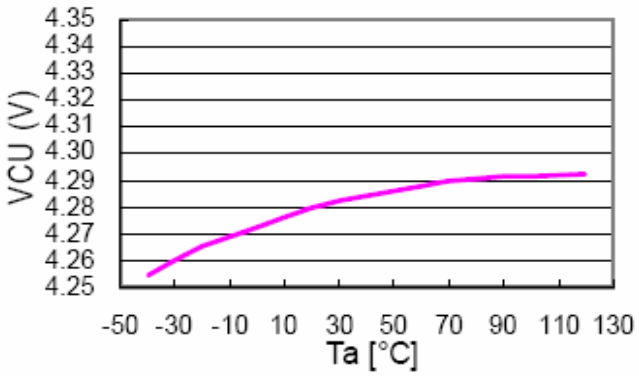
9.8.0V Battery Charging Function “Unavailable”

When a battery which is internally short-circuited (0V battery) is connected, the unavailable 0V charging function will prohibit recharging. When the battery voltage equals to the 0V battery charge inhibition battery voltage (V_{0IN}) or lower, the charging control MOSFET gate is fixed to the PB- pin voltage to prohibit charging. When the battery voltage equals to the 0V battery charge inhibition battery voltage(V_{0IN}) or higher, charging can be implemented.

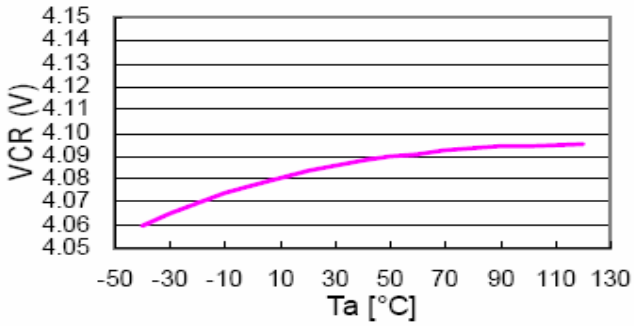
10. Characteristics (Typical Data)

10.1. Overcharge Detection / Release Voltage, Overdischarge Detection / Release Voltage, Overcurrent Detection Voltage, and Delay Time

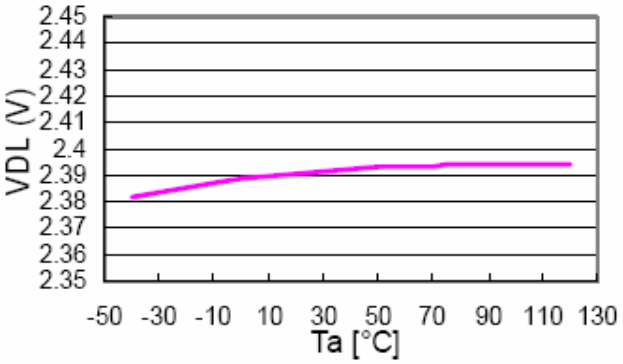
(1)V_{CU} vs. Ta



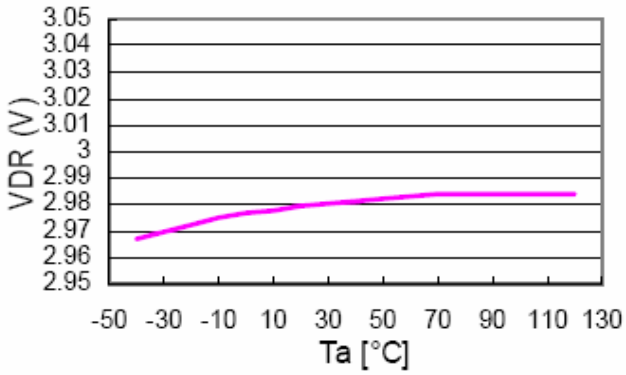
(2)V_{CR} vs. Ta



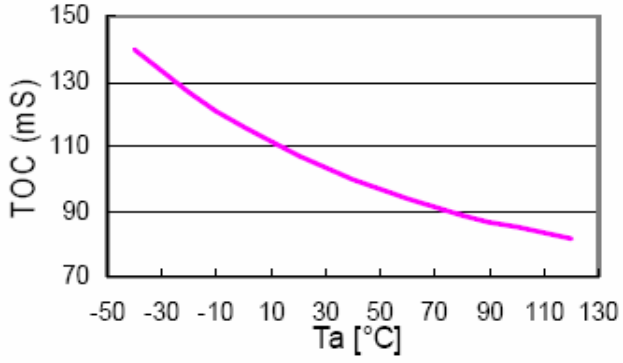
(3)V_{DL} vs. Ta



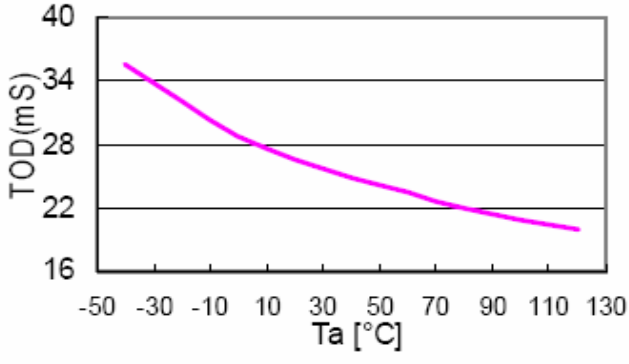
(4)V_{DR} vs. Ta

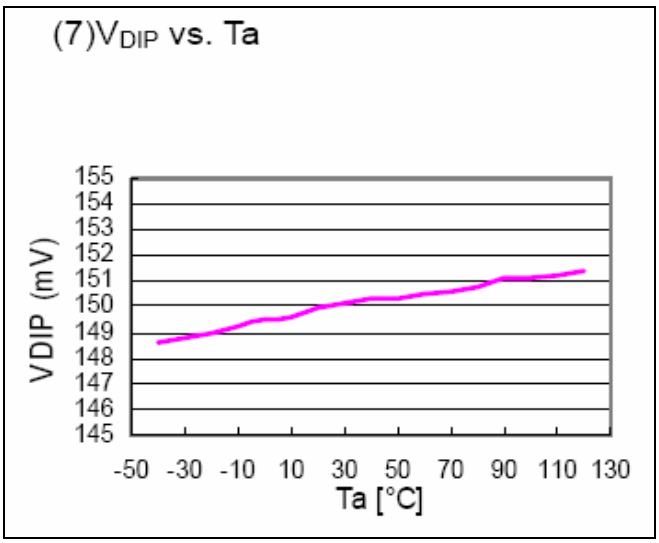


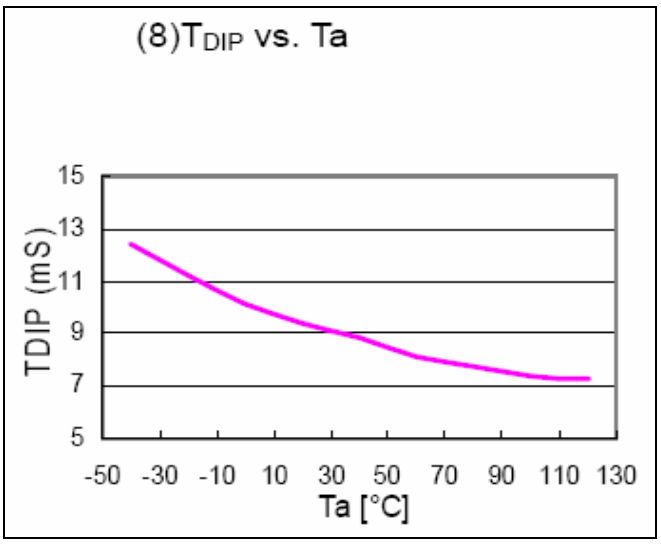
(5)T_{OC} vs. Ta

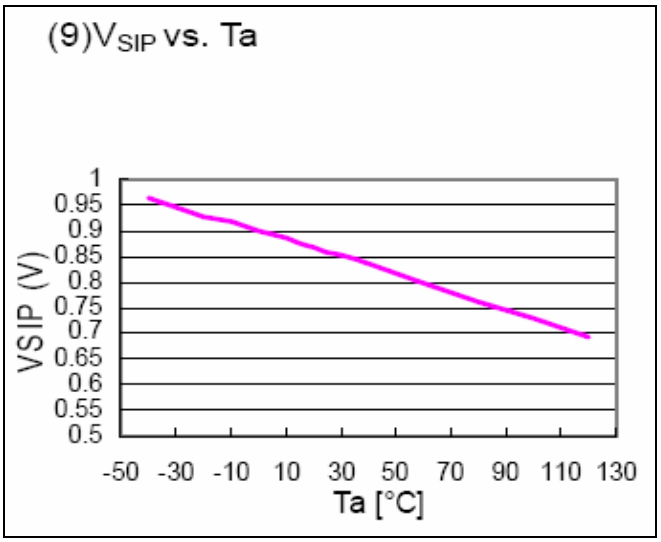


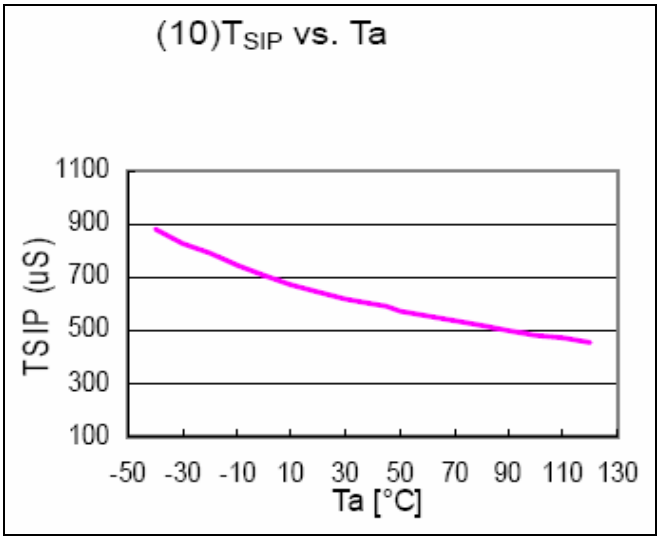
(6)T_{OD} vs. Ta



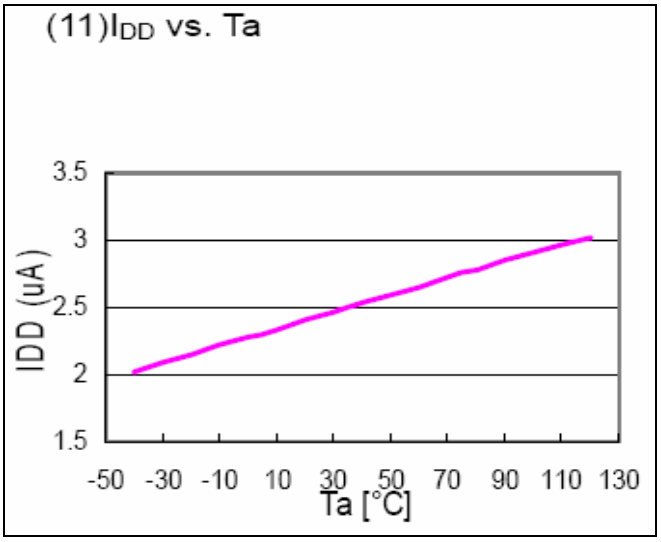


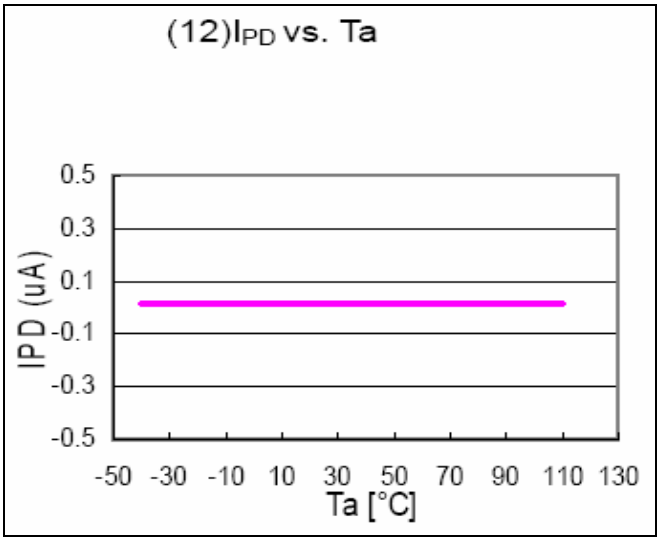






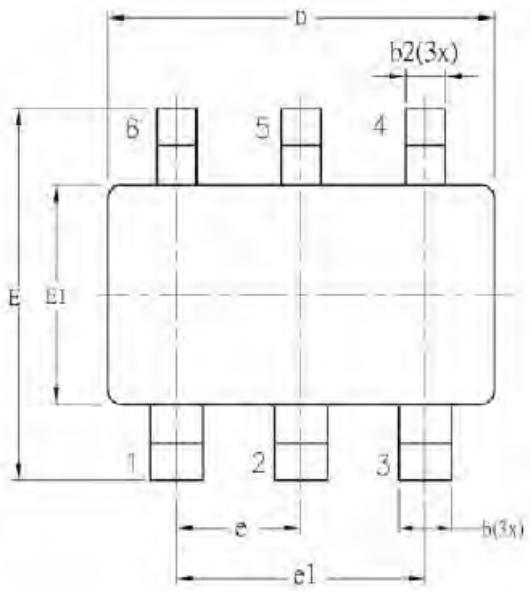
10.2.Current Consumption

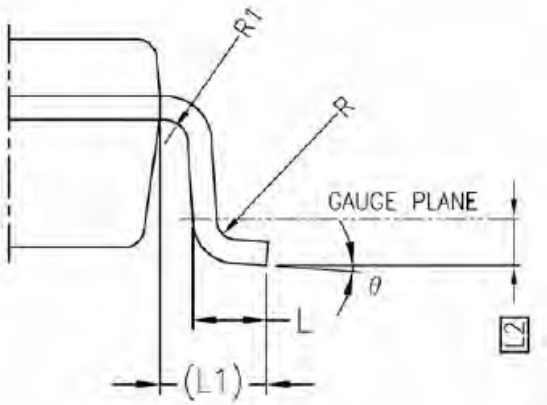




13.Package information

NOTE: All dimensions are in millimeters.





SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	1.05	1.20	1.35
A1	0.05	0.10	0.15
A2	1.00	1.10	1.20
b	0.40	———	0.50
b1	0.40	———	0.45
b2	0.30	———	0.40
c	0.08	———	0.22
c1	0.08	0.13	0.20
D	2.80	2.90	3.00
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
e	0.95 BSC		
e1	1.90 BSC		
L	0.35	0.43	0.60
L1	0.60 REF		
L2	0.25 BSC		
R	0.10	———	———
R1	0.10	———	0.25
θ	0°	4°	8°
θ1	5°	6°	15°
θ2	5°	8°	15°