To our customers,

Old Company Name in Catalogs and Other Documents

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April 1st, 2010
Renesas Electronics Corporation

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RENESAS

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DATA SHEET

RENESAS

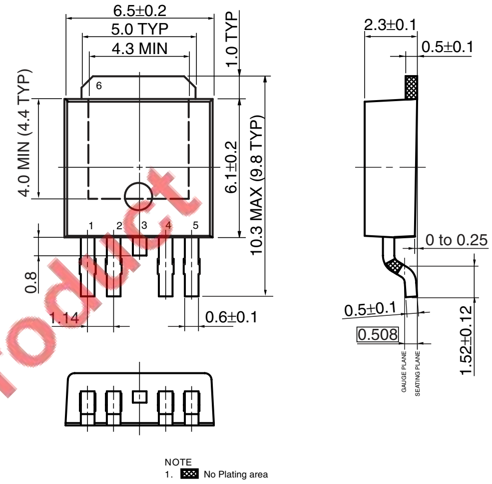
MOS INTEGRATED CIRCUIT
μPD166009

SINGLE N-CHANNEL HIGH SIDE INTELLIGENT POWER DEVICE

GENERAL DESCRIPTION

The μPD166009 device is an N-channel high-side switch with charge pump, current controlled input, diagnostic feedback with load current sense and embedded protection functions.

PACKAGE DRAWING (unit: mm)



FEATURES

- Built-in charge pump
- Low on-state resistance
- Short-circuit protection
  - Shutdown by short-circuit detection
- Over-temperature protection
  - Shutdown with auto-restart on cooling
- Small multi-chip package: JEDEC 5-pin TO-252 (MSL: 3, profile acc. J-STD-20C)
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of thermal shutdown and/or short circuit shutdown
- AEC Qualified

ORDERING INFORMATION

Part Number	Lead plating	Packing	Package
μPD166009T1F-E1-AY Note	Sn	Tape 2500 p/reel	5-pin TO-252 (MP-3ZK)

Note Pb-free (This product does not contain Pb in the external electrode.)

QUALITY GRADE

Part Number	Quality Grade
μPD166009T1F-E1-AY	Special

Please refer to "Quality Grades on NEC Semiconductor Devices" (Document No. C11531E) published by NEC Corporation to know the specification of quality grade on the devices and its recommended applications.

APPLICATION

- Light bulb (to 55 W) switching
- Switching of all types of 14 V DC grounded loads, such as inductor, resistor and capacitor
- Replacement for fuse and relay

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The mark <R> shows major revised points.
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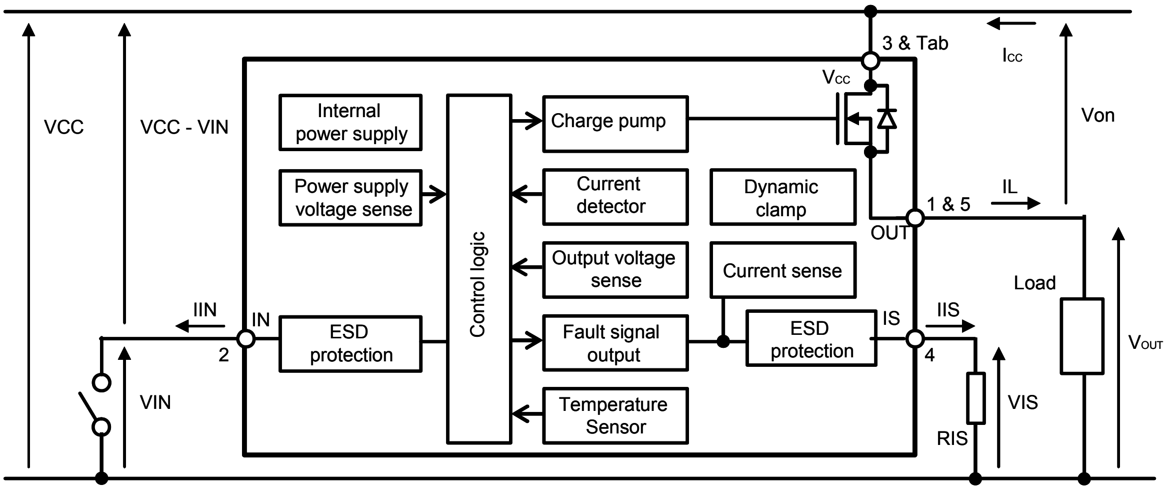
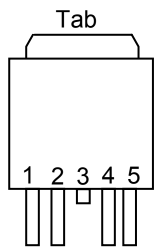
BLOCK DIAGRAM



PIN CONFIGURATION

Pin No.	Terminal Name	Function
1	OUT	Output to load: pin 1 and 5 must be externally shorted.
2	IN	Input; activates the power switch, if shorted to ground.
3&Tab	V_{CC}	Supply Voltage: tab and pin 3 are internally shorted.
4	I_S	Sense Output: diagnostic feedback Note
5	OUT	Output to load: pin 1 and 5 must be externally shorted.



Note If current sense and diagnostic features are not used, IS terminal has to be connected to GND via resistor.

ABSOLUTE MAXIMUM RATING (Ta = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions		Rating	Unit
V_{CC} voltage	V_{CC1}			28	V
V_{CC} voltage (Load Dump)	V_{CC2}	R_I = 1 Ω, R_L = 1.5 Ω, t_d = 400 ms, R_{IS} = 1 kΩ, IN = low or high		40	V
V_{CC} voltage (Reverse polarity)	$-V_{CC}$	R_L = 2.2 Ω, 1 minute		–16	V
Load current	I_L	DC, T_C = 25°C		30	A
Load current (short circuit current)	$I_{L(SC)}$			Self Limited	A
Power dissipation	P_D	T_C = 25°C		59	W
Inductive load switch-off energy dissipation single pulse	E_{AS1}	I_L = 10 A, V_{CC} = 12 V, Tch,start ≤ 150°C, refer to page 16		50	mJ
Maximum allowable energy under over load condition (Single pulse)	E_{AS2}	V_{CC} = 18 V, Tch,start ≤ 150°C, R_{supply} = 10 mΩ, R_{short} = 50 mΩ, L_{supply} = 5 μH, L_{short} = 15 μH, refer to page 16		105	mJ
Channel temperature	T_{ch}			–40 to +150	°C
Storage temperature	T_{stg}			–55 to +150	°C
Electric discharge capability	V_{ESD}	HBM	AEC-Q100-002 std. R = 1.5 kΩ, C = 100pF	2000	V
		MM	AEC-Q100-003 std. R = 0 Ω, C = 200pF	400	V
Voltage of IN pin	V_{IN}	DC		V_{CC}–28 V	V
		Reverse polarity condition, 1 minute		V_{CC}+14 V	V
Voltage of IS pin	V_{IS}	DC		V_{CC}–28 V	V
		Reverse polarity condition, 1 minute		V_{CC}+14 V	V

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Power supply voltage	V_{CC}	T_{ch} = –40 to 150°C	8	–	18	V

Cautions 1. It is assumed that V_{IN} = 0 V when the device is activated.

2. Device operating range is limited by energy dissipation capability of the driver. User must carefully consider worst case load and current conditions in combination of operating voltage.

THERMAL CHARACTERISTICS

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Thermal resistance	$R_{th(ch-a)}$	Device on 50 mm x 50 mm x 1.5 mmt epoxy PCB FR-4 with 6 cm^2 of 70 μm copper area	–	45	55	°C/W
	$R_{th(ch-c)}$		–	–	3.17	°C/W

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, T_{ch} = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Unit
Required current capability of Input switch	I_{IH}	T_{ch} = –40 to 150°C		–	1.0	2.2	mA
Input current for turn-off	I_{IL}			–	–	50	μA
Standby current	$I_{CC(off)}$	I_{IN} = 0 A	T_{ch} = 25°C	–	2.5	5.0	μA
			T_{ch} = –40 to 150°C	–	2.5	15.0	μA
On state resistance	R_{on}	I_L = 7.5 A	T_{ch} = 25°C	–	8	10	mΩ
			T_{ch} = 150°C	–	14	18	
Turn on Time	t_{on}	R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to page 15		–	200	500	μs
Turn off Time	t_{off}			–	250	600	μs
Slew rate on	dV/dton	25 to 50% V_{OUT}, R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to page 15		–	0.2	0.6	V/μs
Slew rate off	-dV/dtoff	50 to 25% V_{OUT}, R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to page 15		–	0.2	0.5	V/μs

PROTECTION FUNCTIONS (V_{CC} = 12 V, T_{ch} = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Unit
On-state resistance at reverse battery condition ^{Note}	$R_{on(rev)}$	V_{CC} = –12 V, I_L = –7.5 A, R_{IS} = 1 kΩ, R_{IN} < 150 Ω					
			T_{ch} = 25°C	–	9.5	13	mΩ
			T_{ch} = 150°C	–	16	22	mΩ
Short circuit detection current	$I_{L6,\,3(SC)}$ ^{Note}	V_{CC} – V_{IN} = 6 V, V_{on} = 3 V	T_{ch} = –40°C	–	50	120	A
			T_{ch} = 25°C	–	50	–	
			T_{ch} = 150°C	20	45	–	
	$I_{L6,\,6(SC)}$ ^{Note}	V_{CC} – V_{IN} = 6 V, V_{on} = 6 V	T_{ch} = –40°C	–	35	110	
			T_{ch} = 25°C	–	35	–	
			T_{ch} = 150°C	10	35	–	
	$I_{L12,\,3(SC)}$	V_{CC} – V_{IN} = 12 V, V_{on} = 3 V	T_{ch} = –40°C	–	110	180	
			T_{ch} = 25°C	76	105	–	
			T_{ch} = 150°C	50	95	–	
	$I_{L12,\,6(SC)}$ ^{Note}	V_{CC} – V_{IN} = 12 V, V_{on} = 6 V	T_{ch} = –40°C	–	90	160	
			T_{ch} = 25°C	–	85	–	
			T_{ch} = 150°C	40	80	–	
	$I_{L12,\,12(SC)}$ ^{Note}	V_{CC} – V_{IN} = 12 V, V_{on} = 12 V	T_{ch} = –40°C	–	55	120	
			T_{ch} = 25°C	–	50	–	
			T_{ch} = 150°C	10	45	–	
	$I_{L18,\,3(SC)}$ ^{Note}	V_{CC} – V_{IN} = 18 V, V_{on} = 3 V	T_{ch} = –40°C	–	130	200	
			T_{ch} = 25°C	–	125	–	
			T_{ch} = 150°C	60	110	–	
	$I_{L18,\,6(SC)}$ ^{Note}	V_{CC} – V_{IN} = 18 V, V_{on} = 6 V	T_{ch} = –40°C	–	110	170	
			T_{ch} = 25°C	–	110	–	
			T_{ch} = 150°C	50	100	–	
	$I_{L18,\,12(SC)}$ ^{Note}	V_{CC} – V_{IN} = 18 V, V_{on} = 12 V	T_{ch} = –40°C	–	75	120	
			T_{ch} = 25°C	–	70	–	
			T_{ch} = 150°C	30	65	–	
	$I_{L18,\,18(SC)}$ ^{Note}	V_{CC} – V_{IN} = 18 V, V_{on} = 18 V	T_{ch} = –40°C	–	50	90	
			T_{ch} = 25°C	–	50	–	
			T_{ch} = 150°C	5	45	–	
Output clamp voltage (inductive load switch off)	$V_{on(CL)}$	I_L = 40 mA, T_{ch} = –40 to 150°C		30	34	40	V
Over load detection voltage	$V_{ON(OvL)}$	T_{ch} = –40 to 150°C		0.65	1	1.45	V
Turn-on check delay after input current positive slope ^{Note}	$t_{d(OC)}$	T_{ch} = –40 to 150°C		0.9	2.1	3.8	ms
Under voltage shutdown	$V_{CIN(Uv)}$	T_{ch} = –40°C		–	–	5.8	V
		T_{ch} = 25°C		3.6	4.5	5.4	V
		T_{ch} = 150°C		3.2	–	–	V
Under voltage restart of charge pump	$V_{CIN(CPr)}$	T_{ch} = –40°C		–	–	6.5	V
		T_{ch} = 25°C		4.1	5.1	6.0	V
		T_{ch} = 150°C		3.7	–	–	V
Thermal shutdown temperature	T_{th}			150	175	–	°C
Thermal hysteresis	ΔT_{th}			–	10	–	°C

Note Not subject to production test, specified by design.

DIAGNOSTIC CHARACTERISTICS (V_{CC} = 12 V, T_{ch} = 25°C, unless otherwise specified)

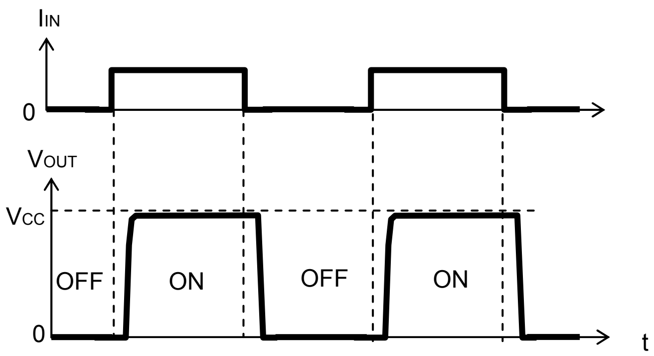
Parameter	Symbol	Test Conditions		Min.	Typ.	Max.	Unit
Current sense ratio	K_{ILIS}	$K_{ILIS} = I_L/I_{IS}$ $V_{IS} < V_{OUT} - 6$ V, $I_{IS} < I_{IS,lim}$					
		I_L = 30 A	T_{ch} = –40°C	8300	9350	10800	
			T_{ch} = 25°C	8300	9400	10600	
			T_{ch} = 150°C	8300	9450	10000	
		I_L = 7.5 A	T_{ch} = –40°C	7500	9400	11400	
			T_{ch} = 25°C	8000	9500	10800	
			T_{ch} = 150°C	8200	9550	10200	
		I_L = 2.5 A	T_{ch} = –40°C	6100	9600	14200	
			T_{ch} = 25°C	6500	9600	12800	
			T_{ch} = 150°C	7600	9600	11500	
Sense current offset current	$I_{IS,offset}$	V_{IN} = 0 V, I_L = 0 A		0	–	60	μA
Sense current under fault condition	$I_{IS,fault}$	Under fault conditions 8 V < $V_{CC} - V_{IS}$ < 12 V, T_{ch} = –40 to 150°C		3.5	6.0	12.0	mA
Sense current saturation current	$I_{IS,lim}$	$V_{is} < V_{out} - 6$ V, T_{ch} = –40 to 150°C		3.5	7.0	12.0	mA
Fault sense signal delay after short circuit detection Note	$t_{sdelay(fault)}$	T_{ch} = –40 to 150°C		–	2	6	μs
Sense current leakage current	$I_{IS(LL)}$	I_{IN} = 0 A		–	0.1	0.5	μA
Current sense settling time after input current positive slope Note	$t_{son(IS)}$	T_{ch} = –40 to 150°C, I_L = 0 A ⎍ 20 A		–	250	1000	μs
Current sense settling time during on condition Note	$T_{sic(IS)}$	T_{ch} = –40 to 150°C, I_L = 10 A ⎍ 20 A		–	50	100	μs

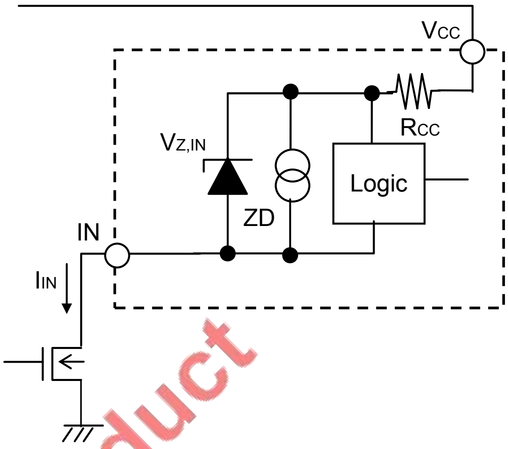
Note Not subject to production test, specified by design.

FEATURES DESCLIPTION

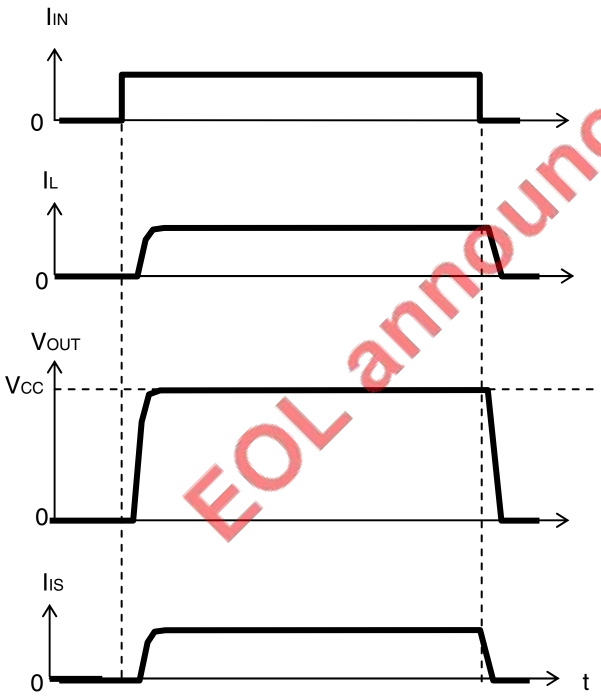
Driver Circuit (On-Off Control)

The high-side output is turned on, if the input pin is shorted to ground. The input current is below I_{IH}. The high-side output is turned off, if the input pin is open or the input current is below I_{IL}. R_{CC} is 100 Ω typ. ESD protection diode: 46 V typ.

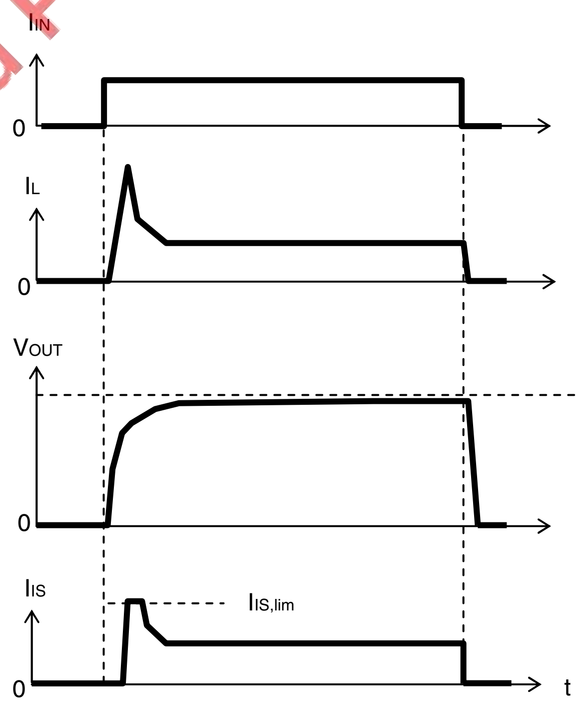




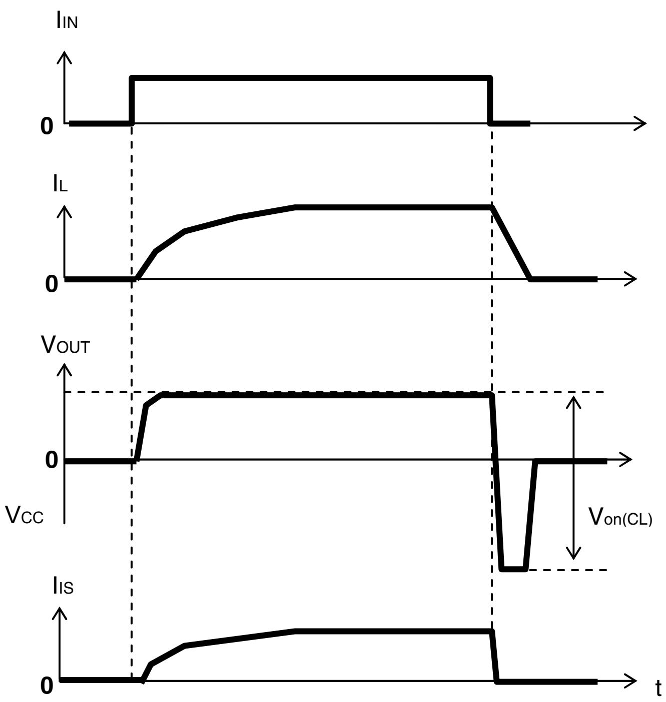
Switching a resistive load

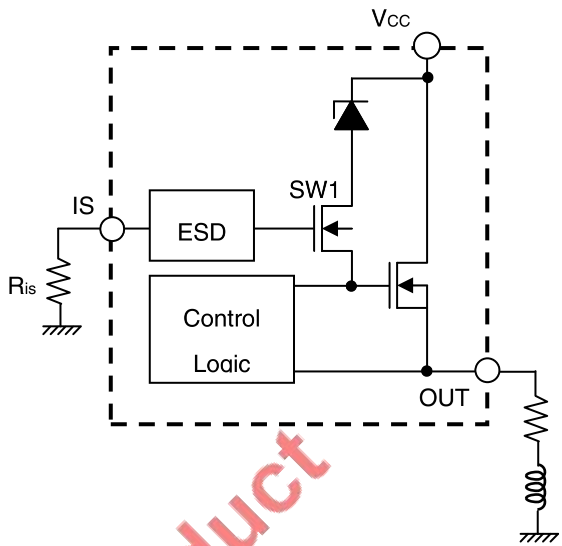


Switching lamps



Switching an inductive load





Dynamic clamp operation at inductive load switch off

The dynamic clamp circuit works only when the inductive load is switched off. When the inductive load is switched off, the voltage of OUT falls below 0 V. The gate voltage of SW1 is then nearly equal to GND because the IS terminal is connected to GND via an external resister. Next, the voltage at the source of SW1 (= gate of output MOS) falls below the GND voltage. SW1 is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

When the over-voltage is applied to V_{CC}, the gate voltage and source voltage of SW1 are both nearly equal to GND. SW1 is not turned on, the clamp diode is not connected to the gate of the output MOS, and the dynamic clamp circuit is not activated.

Short circuit protection

Case 1: IN pin is shorted to ground in an overload condition, which includes a short circuit condition.

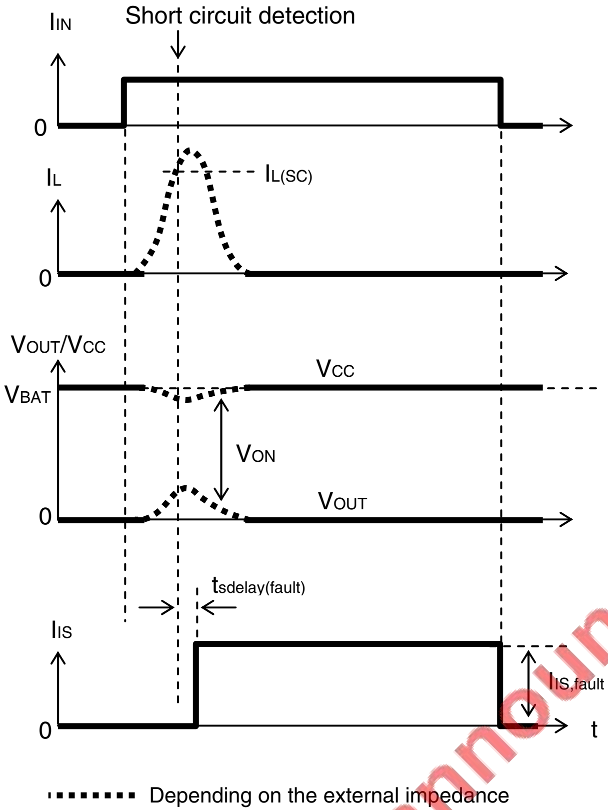
The device shuts down automatically when either or both of following conditions (a, b) is detected.

The sense current is fixed at $I_{IS,fault}$. Shutdown is latched until the next reset via input.

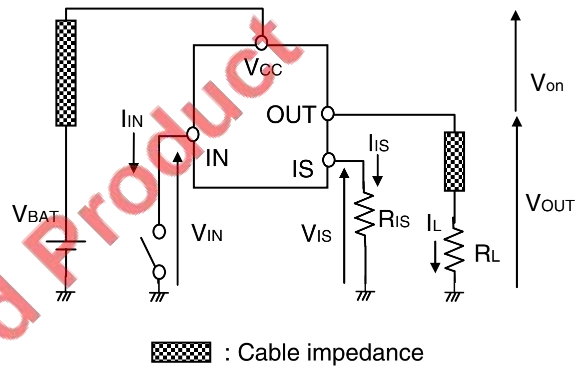
(a) $I_L > I_{L(sc)}$

(b) $V_{on} > V_{on(OvL)}$ after $t_{d(OC)}$

Case1-(a) $I_L > I_{L(sc)}$



(Evaluation circuit)

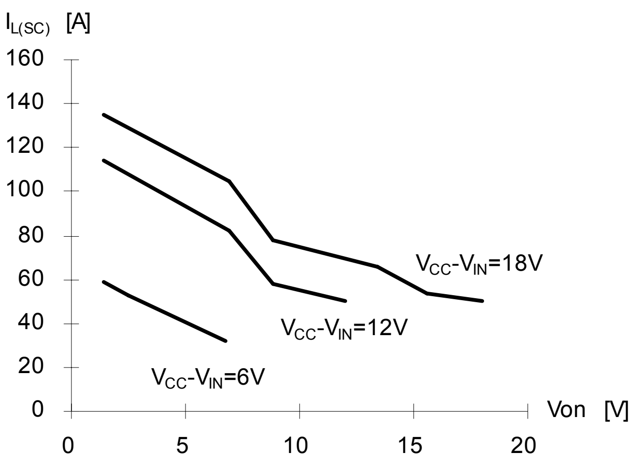


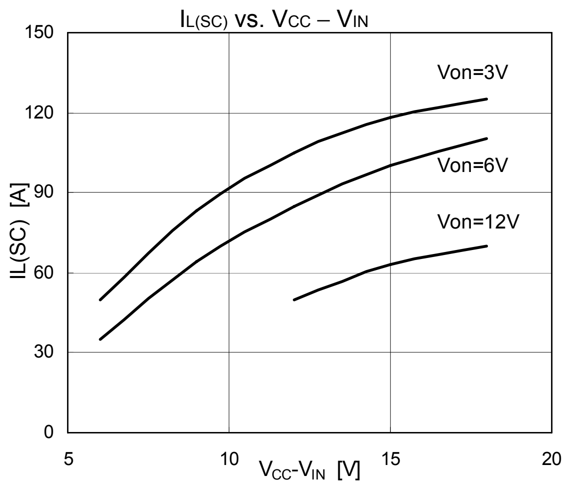
$t_{sdelay(fault)}$: Fault sense signal delay after short circuit detection

$I_{L(SC)}$: Short circuit detection current

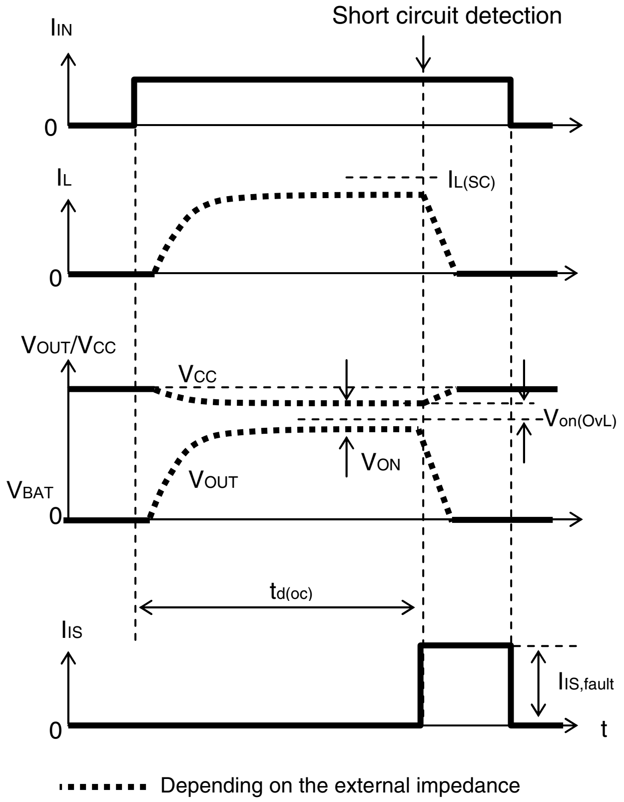
Typical Short circuit detection current characteristics

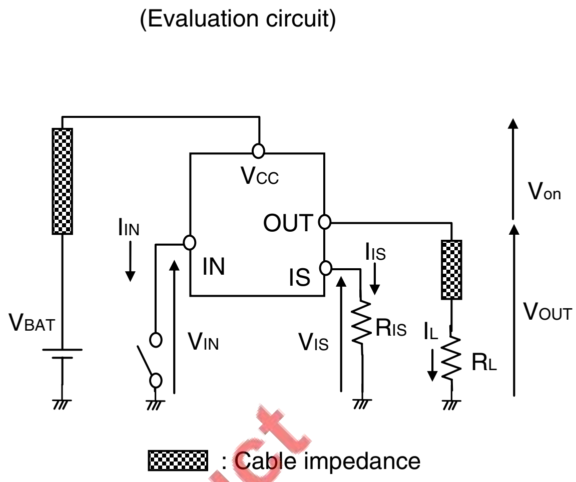
The short circuit detection current changes according V_{CC} voltage and V_{on} voltage for the purpose of to be strength of the robustness under short circuit condition.





Case1-(b) Von > $V_{on(OvL)}$ after $t_{d(OC)}$





$t_{d(oc)}$: Turn-on check delay after input current positive slope

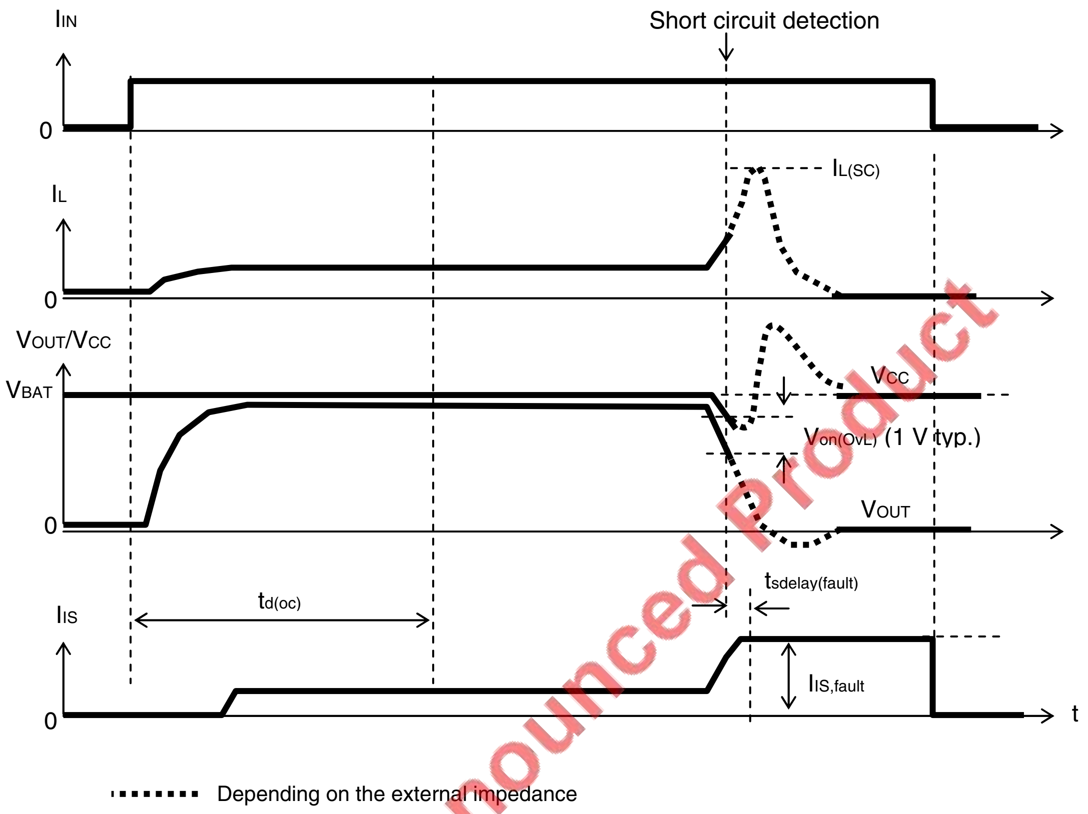
Case 2: Short circuit during on-condition

The device shuts down automatically when either or both of following conditions (a) is detected.

The sense current is fixed at $I_{IS,fault}$. Shutdown is latched until the next reset via input.

(a) Von > $V_{on(OvL)}$ after $t_{d(oc)}$

Case2-(a) Von > $V_{on(OvL)}$ after $t_{d(OC)}$

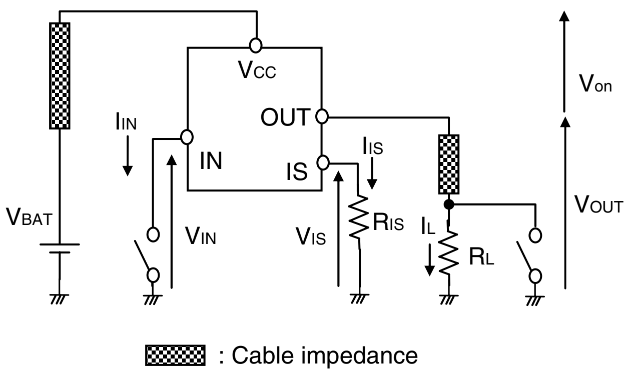


$t_{d(oc)}$: Turn-on check delay after input current positive slope

$t_{sdelay(fault)}$: Fault sense signal delay after short circuit detection

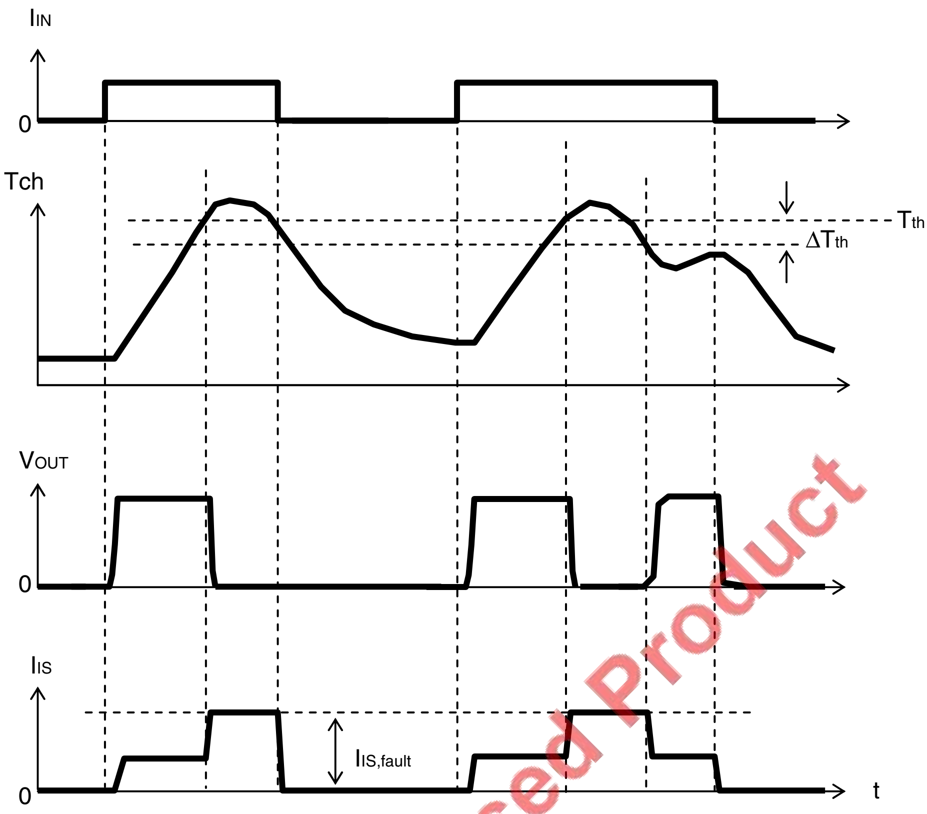
$I_{L(SC)}$: Short circuit detection current

(Evaluation circuit)



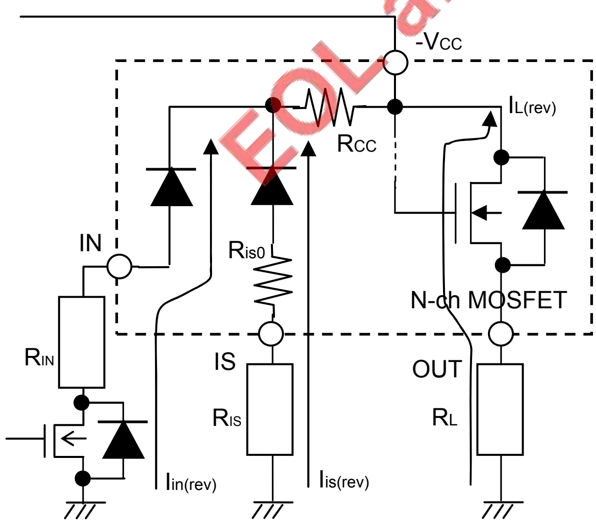
Over-temperature protection

The output is switched off if over-temperature is detected. The device switches on again after it cools down.



Power dissipation under reverse battery condition

In case of reverse battery condition, the internal N-ch MOSFET is turned on to reduce the power dissipation caused by the body diode. Additional power is dissipated by the internal resisters. Following is the formula for estimation of total power dissipation $P_{d(rev)}$ in reverse battery condition.



$$P_{d(rev)} = R_{on(rev)} \times I_{L(rev)}^2 + (V_{CC} - V_f - I_{in(rev)} \times R_{IN}) \times I_{in(rev)} + (V_{CC} - I_{is(rev)} \times R_{IS}) \times I_{is(rev)}$$

$$I_{in(rev)} = (V_{CC} - 2 \times V_f) / (R_{CC} + R_{IN})$$

$$I_{is(rev)} = (V_{CC} - V_f) / (R_{CC} + R_{is0} + R_{IS})$$

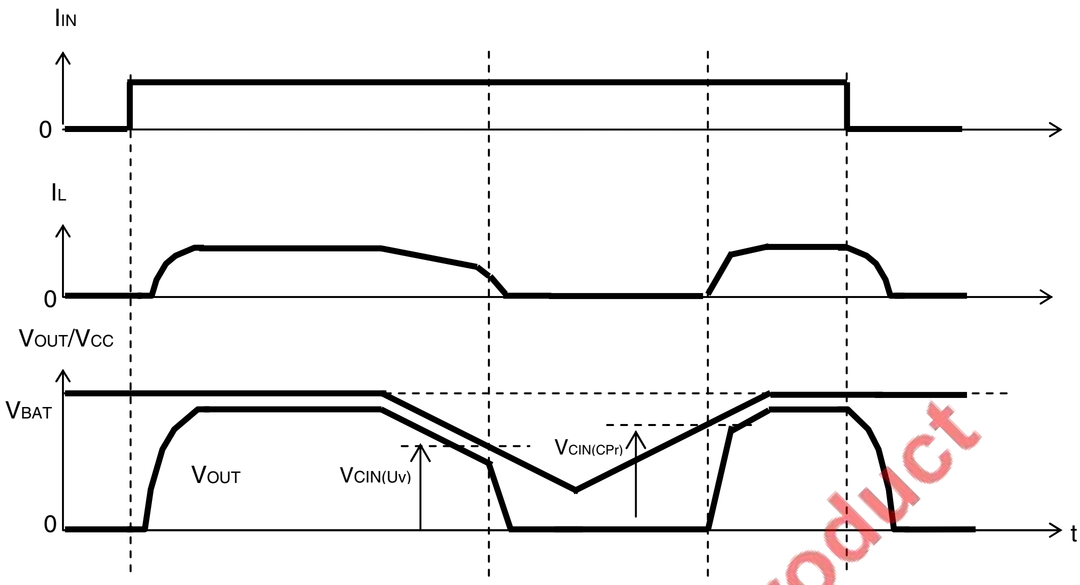
The reverse current through the N-ch MOSFET has to be limited by the connected load.

In order to turn on the N-ch MOSFET at reverse polarity condition, the voltage at IN should be around 8 V by using a MOSFET or small diode in parallel to the input switch. RIN should be estimated following formula.

$$R_{IN} < (|V_{CC}| - 8\ V) / 0.08\ A$$

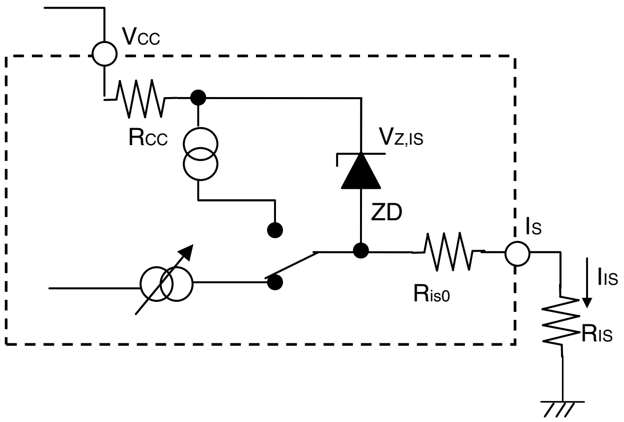
Device behavior at low voltage condition

If the supply voltage (V_{CC} – V_{IN}) goes below $V_{CIN(Uv)}$, the device shuts off the output. If supply voltage (V_{CC} – V_{IN}) increases above $V_{CIN(CPr)}$, the device turns on the output automatically. The device stays off if supply voltage (V_{CC} – V_{IN}) does not increase above $V_{CIN(CPr)}$ after an under voltage shutdown.

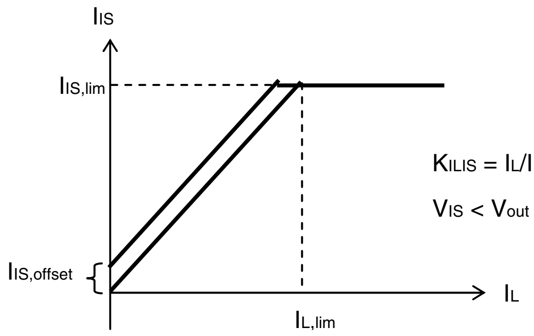


Caution It is assumed that V_{IN} = 0 V when I_{IN} is activated.

Current sense output



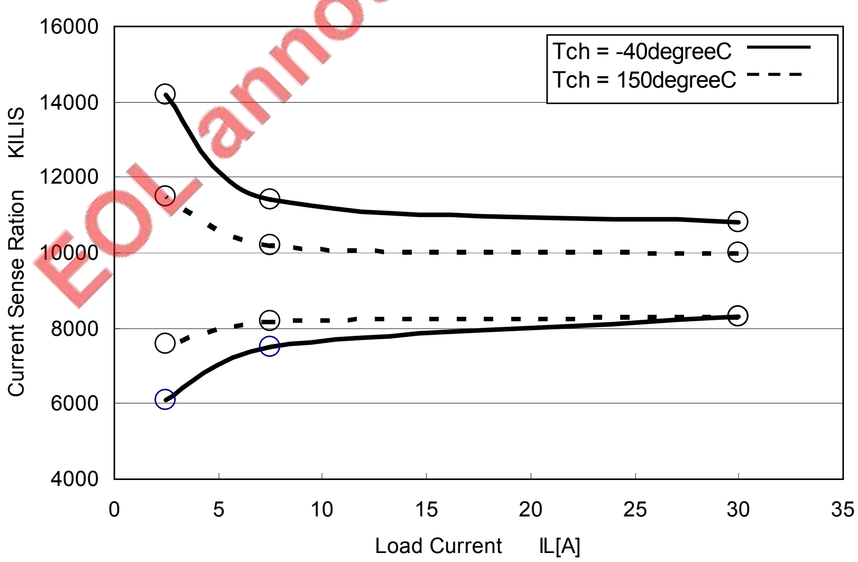
R_{CC} and R_{is0} are 100 Ω typ. $V_{z,IS}$ = 46 V (typ.), R_{IS} = 1 kΩ nominal.



$K_{ILIS} = I_L/I_{IS}$

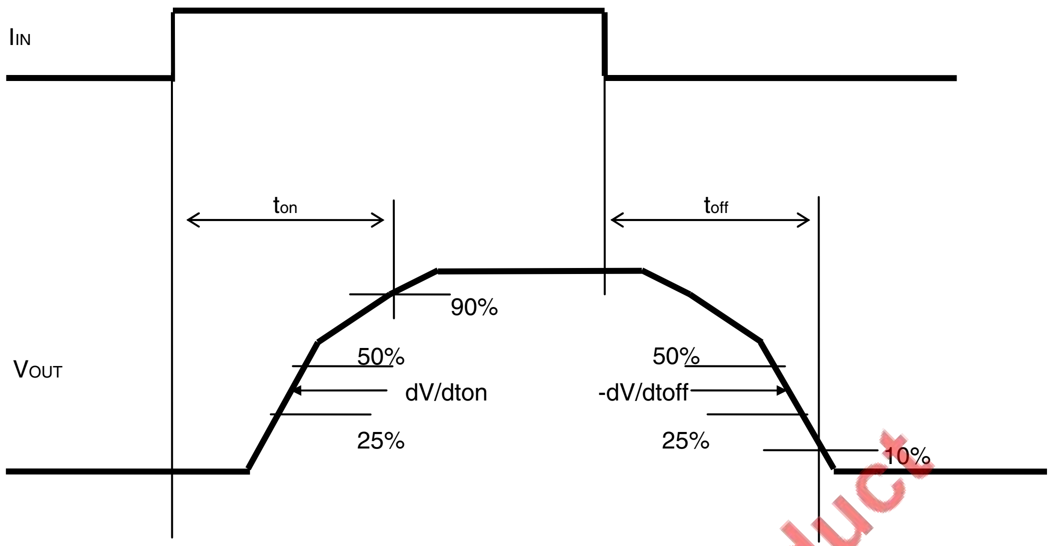
$V_{IS} < V_{out} - 6$ V, $I_{IS} < I_{IS,lim}$

Current sense ratio

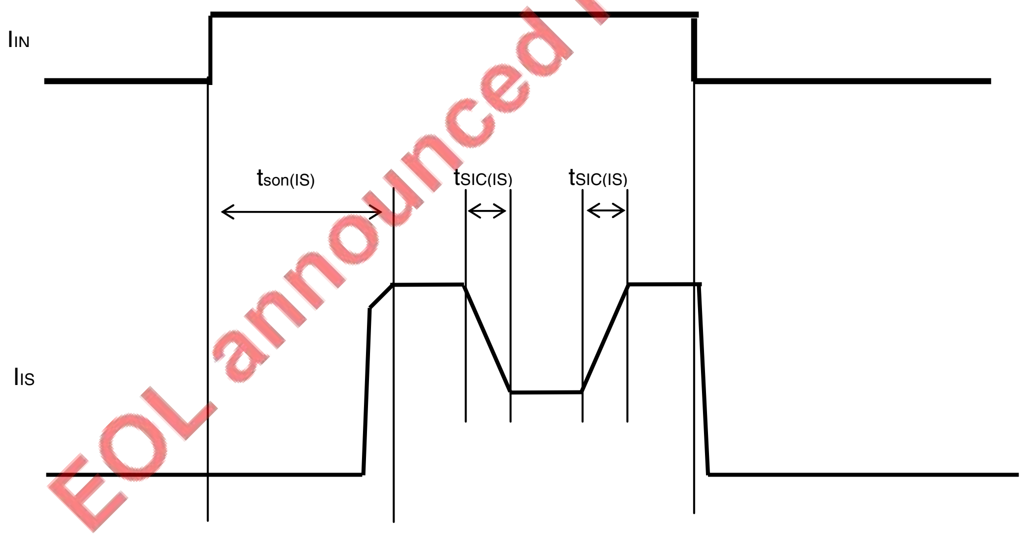


Measurement condition

Switching waveform of OUT Terminal



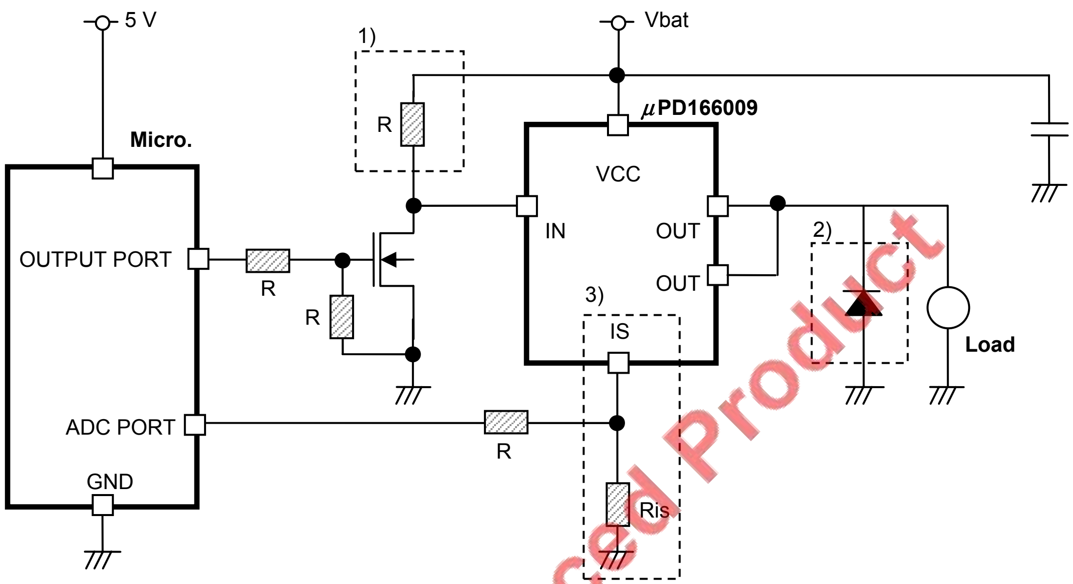
Switching waveform of IS terminal



Truth table

Input Current	State	Output	Sense Current
L	–	OFF	$I_{IS(LL)}$
H	Normal Operation	ON	IL/KILIS
	Over-temperature or Short circuit	OFF	$I_{IS,fault}$
	Open Load	ON	$I_{IS,offset}$

<R> **Application example in principle**



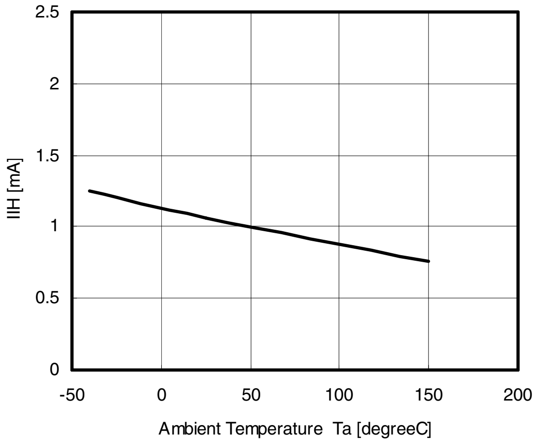
1) In order to prevent leakage current through at IN terminal via PCB,
it is recommended to pull up the IN terminal to VCC using around 1 to10 kΩ (approx.) resistor.

2) If output current is over destruction current characteristics for inductive load at a single off,
it must be connected through an external component for protection purpose.

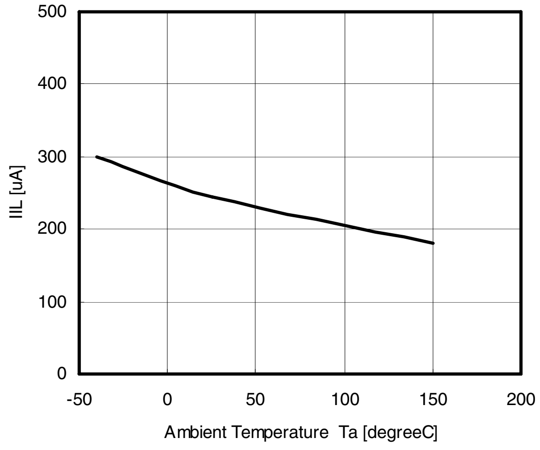
3) If current sense and diagnostic features are not used, IS terminal has to be connected to GND via resistor.

TYPICAL CHARACTERISTICS

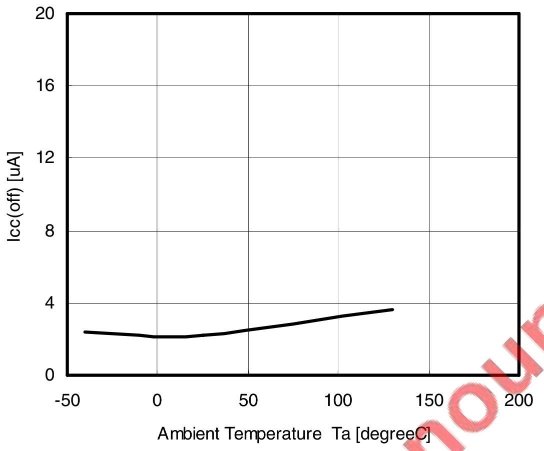
REQUIRED CURRENT CAPABILITY OF INPUT SWITCH
VS. AMBIENT TEMPERATURE



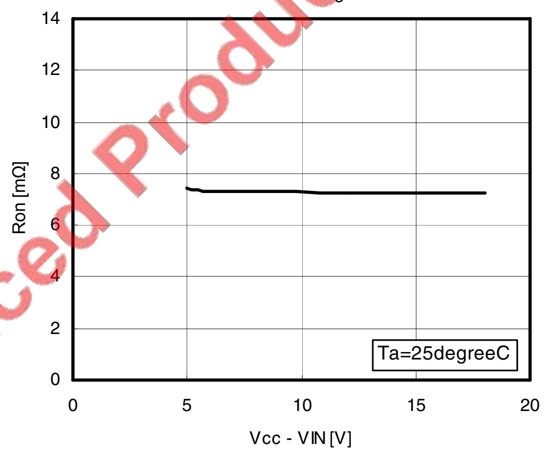
INPUT CURRENT FOR TURN OFF
VS. AMBIENT TEMPERATURE



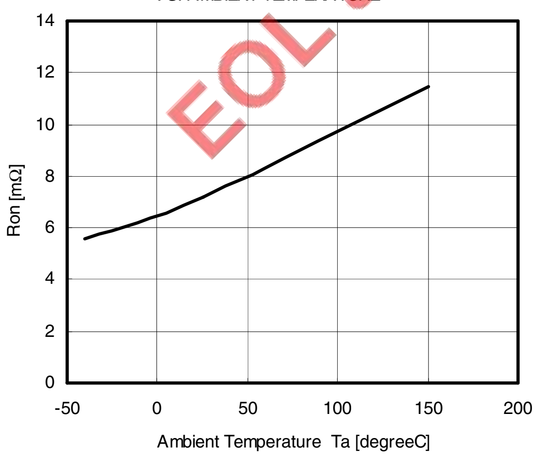
STANDBY CURRENT
VS. AMBIENT TEMPERATURE



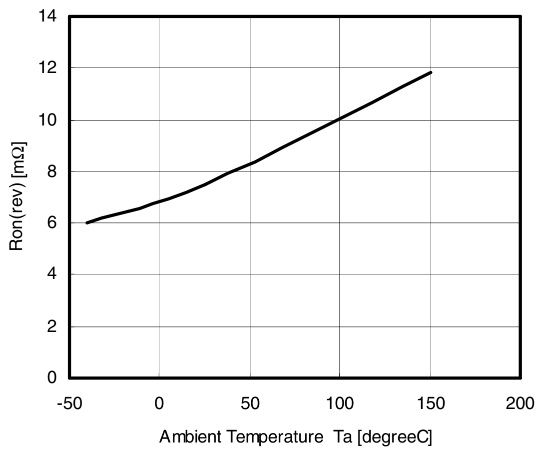
ON STATE RESISTENCE
VS. VCC - VIN voltage

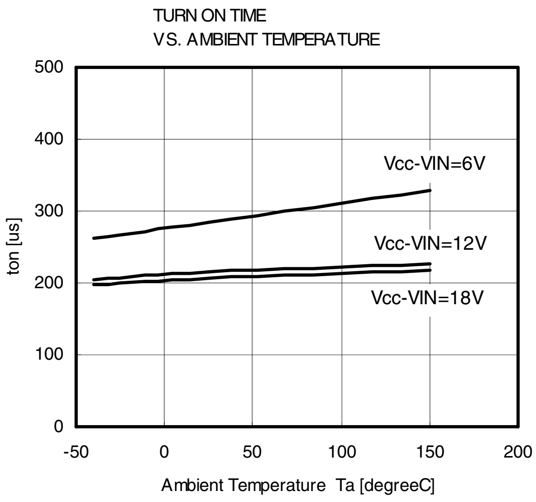


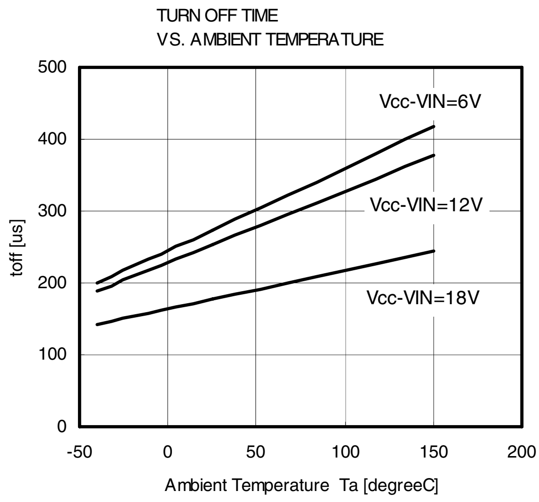
ON STATE RESISTENCE
VS. AMBIENT TEMPERATURE

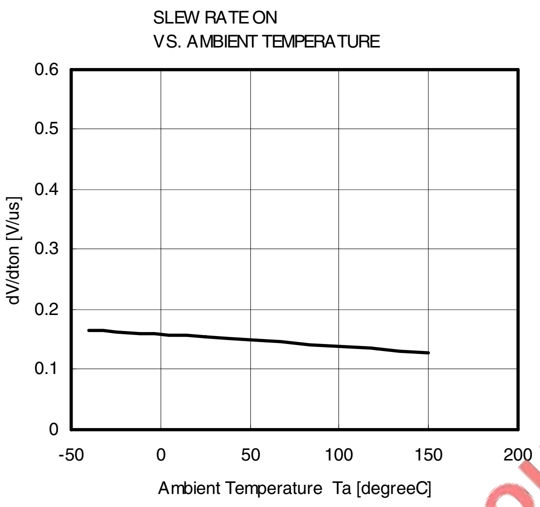


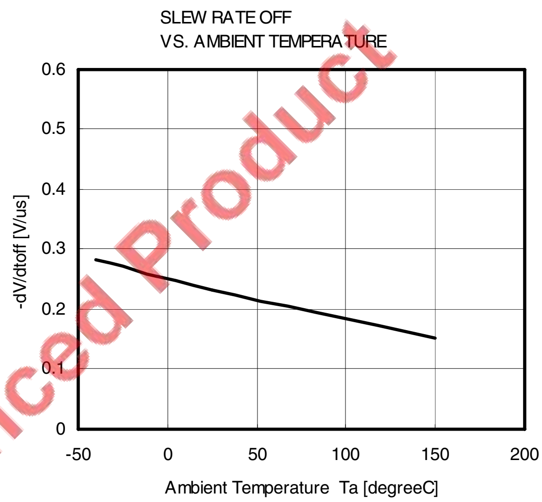
ON STATE RESISTENCE AT REVERSE BATTERY
CONDITION VS. AMBIENT TEMPERATURE

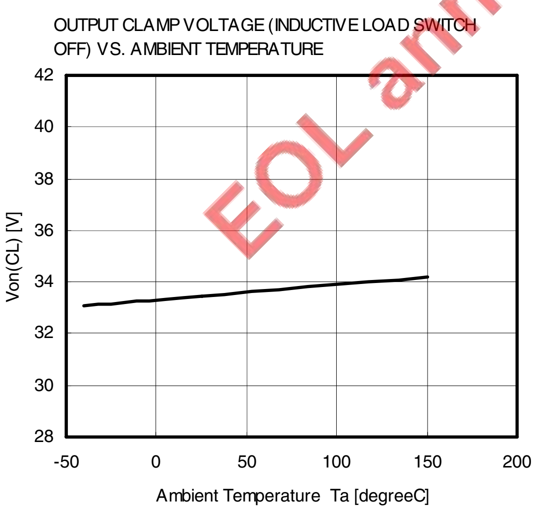



TURN ON TIME
VS. AMBIENT TEMPERATURE
ton [us]
Vcc-VIN=6V
Vcc-VIN=12V
Vcc-VIN=18V
500
400
300
200
100
0
-50
0
50
100
150
200
Ambient Temperature Ta [degreeC]

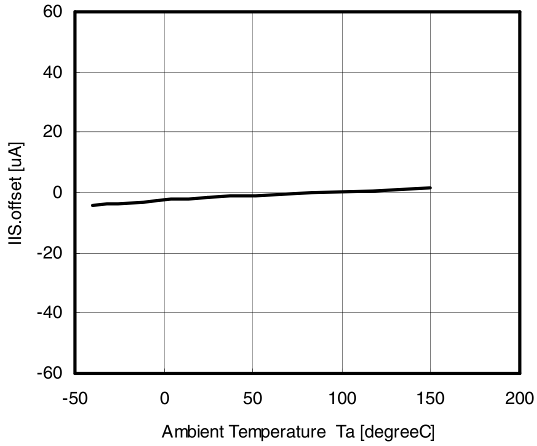

TURN OFF TIME
VS. AMBIENT TEMPERATURE
toff [us]
Vcc-VIN=6V
Vcc-VIN=12V
Vcc-VIN=18V
500
400
300
200
100
0
-50
0
50
100
150
200
Ambient Temperature Ta [degreeC]


SLEW RATE ON
VS. AMBIENT TEMPERATURE
dV/dton [V/us]
0.6
0.5
0.4
0.3
0.2
0.1
0
-50
0
50
100
150
200
Ambient Temperature Ta [degreeC]

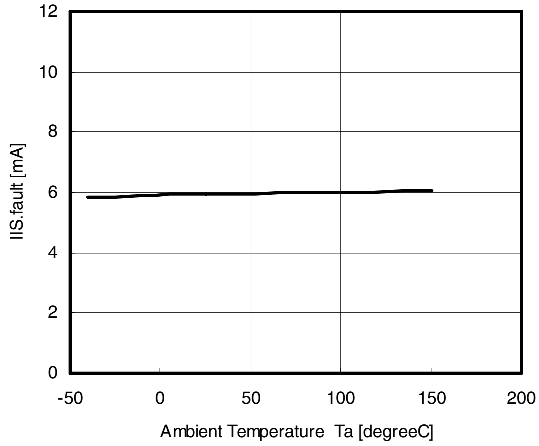

SLEW RATE OFF
VS. AMBIENT TEMPERATURE
-dV/dtoff [V/us]
0.6
0.5
0.4
0.3
0.2
0.1
0
-50
0
50
100
150
200
Ambient Temperature Ta [degreeC]


OUTPUT CLAMP VOLTAGE (INDUCTIVE LOAD SWITCH OFF) VS. AMBIENT TEMPERATURE
Von(CL) [V]
42
40
38
36
34
32
30
28
-50
0
50
100
150
200
Ambient Temperature Ta [degreeC]

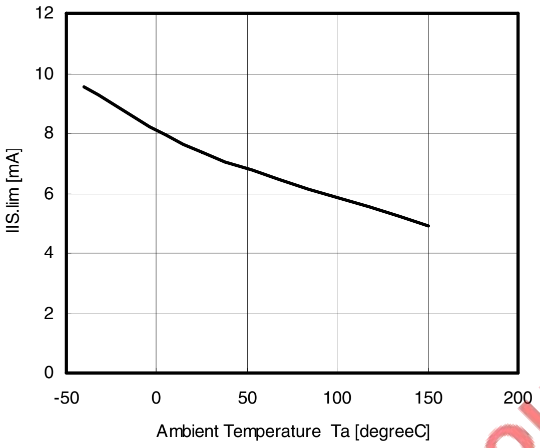
SENSE CURRENT OFFSET CURRENT
V.S. AMBIENT TEMPERATURE



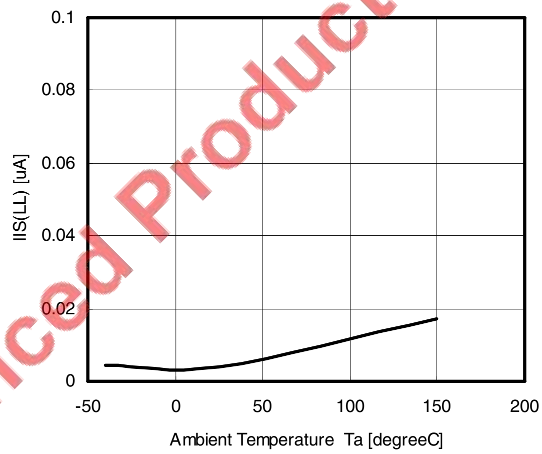
SENSE CURRENT UNDER FAULT CONDITION
V.S. AMBIENT TEMPERATURE



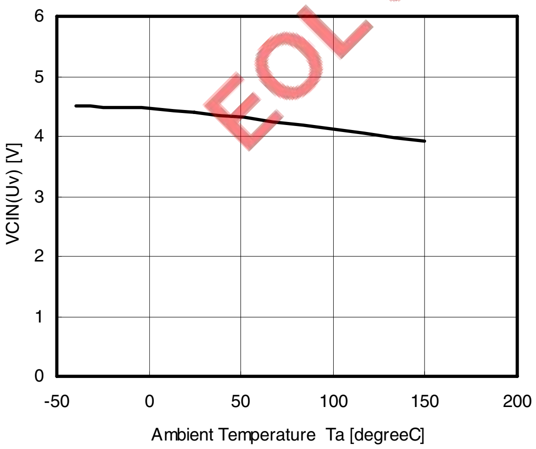
SENSE CURRENT SATURATION CURRENT
V.S. AMBIENT TEMPERATURE



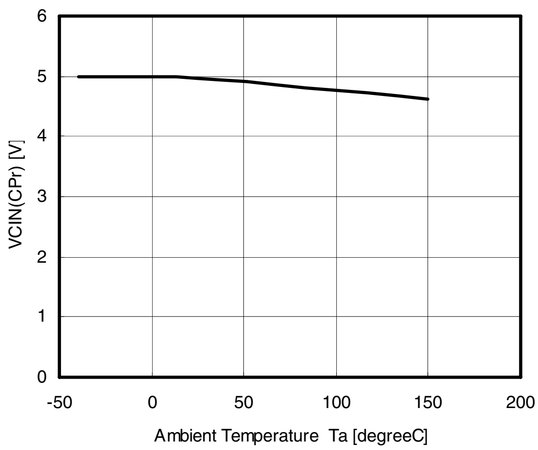
SENSE CURRENT LEAKAGE CURRENT
V.S. AMBIENT TEMPERATURE



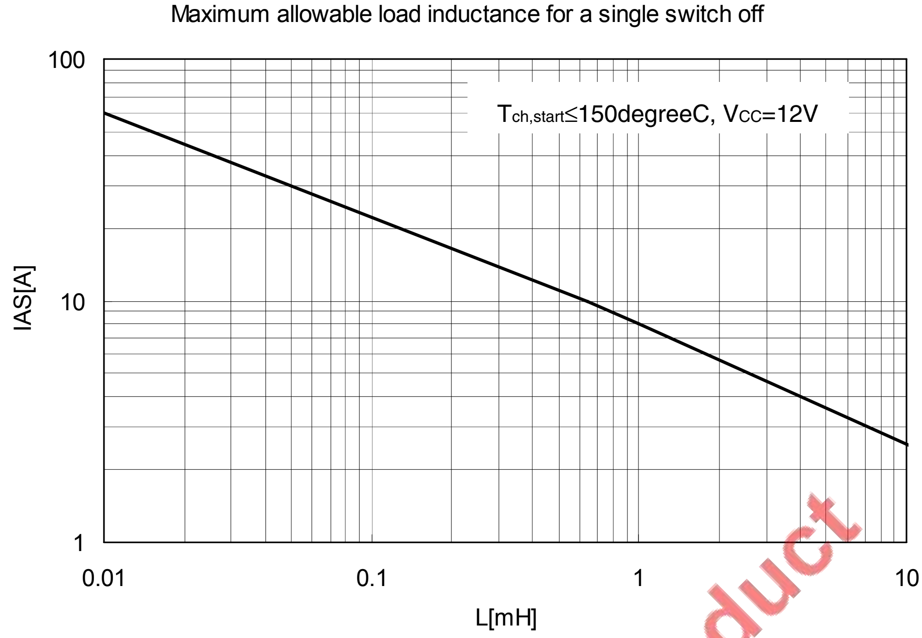
UNDER VOLTAGE SHUTDOWN
V.S. AMBIENT TEMPERATURE



UNDER VOLTAGE RESTART OF CHARGE PUMP
V.S. AMBIENT TEMPERATUR



INDUCTIVE LOAD SWITCH-OFF ENERGY DISSIPATION FOR A SINGLE PULSE

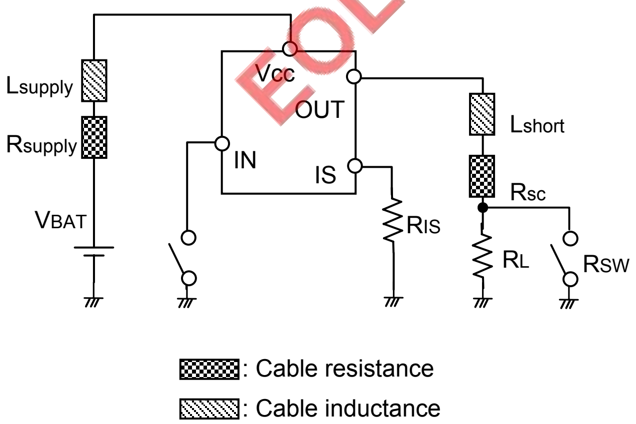


The energy dissipation for an inductive load switch-off single pulse in device (EAS1) is estimated by the following formula as $R_L = 0\Omega$.

$$EAS1 = \frac{1}{2} \cdot I^2 \cdot L \left(\frac{Von(CL)}{Von(CL) - VCC} \right)$$

MAXIMUM ALLOWABLE SWITCH OFF ENERGY (SINGLE PULSE)

The harness connecting the power supply, the load and the device has a small inductance and resistance. When the device turns off, the energy stored in the harness inductance is dissipated by the device, the harness resistance and the internal resistance of power supply. If the current is abnormally high due to a load short, the energy stored in the harness can be large. This energy has to be taken into consideration for the safe operation. The following figure shows the condition for Eas2, the maximum switch-off energy (single pulse) for abnormally high current.



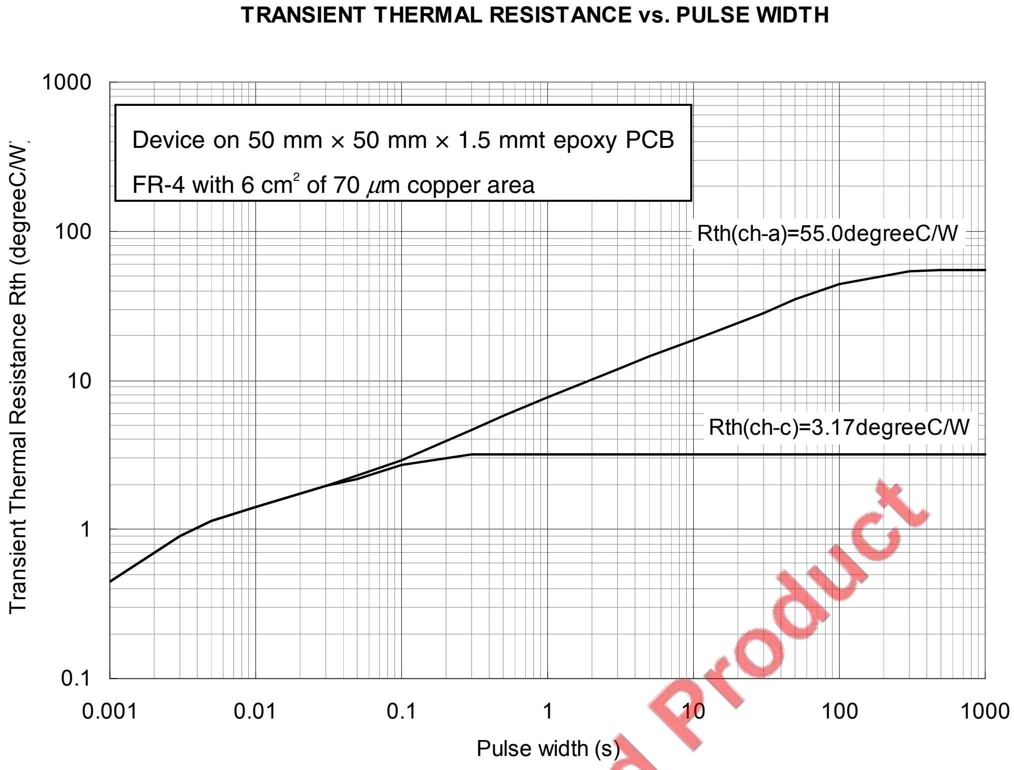
V_{BAT} = 18 V,

R_{supply} = 10 mΩ, R_{short} = R_{sc} + $R_{SW(on)}$ = 50 mΩ,

L_{supply} = 5 μH, L_{short} = 15 μH,

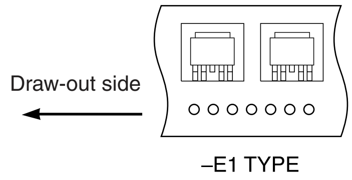
Tch,start ≤ 150°C

THERMAL CHARACTERISTICS



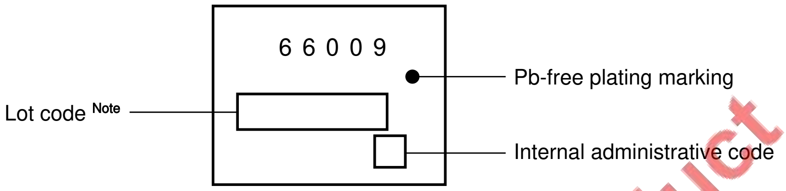
TAPING INFORMATION

This is one type (E1) of direction of the device in the career tape.

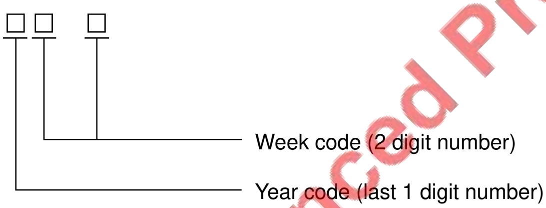


MARKING INFORMATION

This figure indicates the marking items and arrangement. However, details of the letterform, the size and the position aren't indicated.



Note Composition of the lot code



REVISION HISTORY

Revision	Major changes since last version	Page
1st edition	Released 1st edition March 2009	
2nd edition	Released 2nd edition January 2010	
	Revised application example in principle	16

NOTES FOR CMOS DEVICES

(1) VOLTAGE APPLICATION WAVEFORM AT INPUT PIN: Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between VIL (MAX) and VIH (MIN) due to noise, etc., the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between VIL (MAX) and VIH (MIN).

(2) HANDLING OF UNUSED INPUT PINS: Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to VDD or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.

(3) PRECAUTION AGAINST ESD: A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.

(4) STATUS BEFORE INITIALIZATION: Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.

(5) POWER ON/OFF SEQUENCE: In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current. The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.

(6) INPUT OF SIGNAL DURING POWER OFF STATE : Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.