μPD166020T1F

MOS INTEGRATED CIRCUIT

R07DS0441EJ0100
Rev.1.00
Aug 15, 2011

1. Overview

1.1 Description

The μPD166020T1F is a single N-channel high-side switch with charge pump, diagnostic feedback with load current sense and embedded protection functions.

1.2 Features

- Built-in charge pump
- Low on-state resistance
- Short circuit protection
  - Shutdown by over current detection and over load detection
- Over temperature protection
  - Shutdown with auto-restart on cooling
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of abnormal load condition
- Under voltage lock out
- Reverse battery protection by self turn on of N-ch MOSFET
- Small multi-chip package: JEDEC 5-pin TO-252 (MSL: 3, profile acc. J-STD-20C)
- AEC Qualified

Not recommend for new design

1.3 Applications

- Light bulb (to 65 W) switching
- Switching of all types of 14 V DC grounded loads, such as LED, inductor, resistor and capacitor
- Replacement for fuse and relay

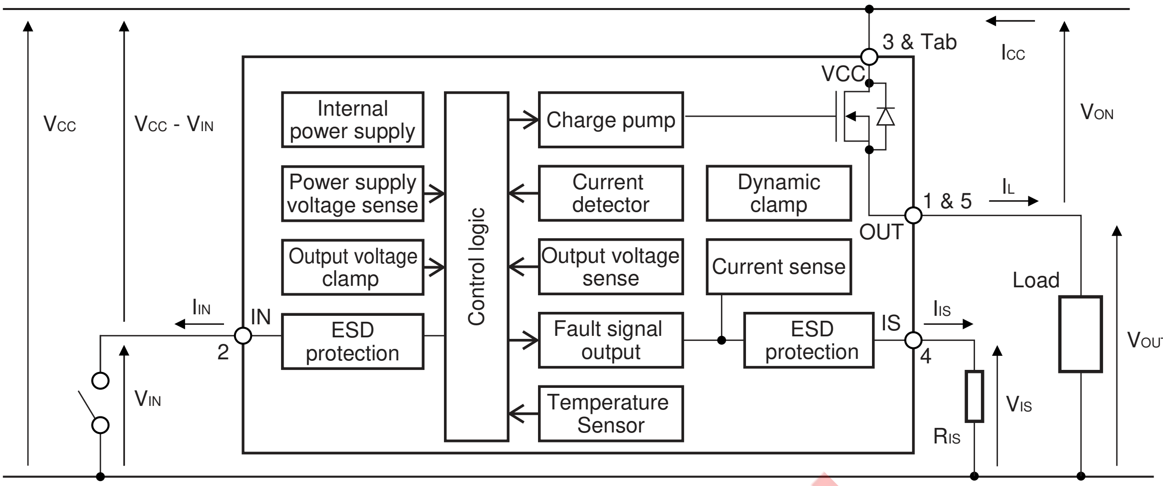
2. Ordering Information

Part No.	Lead plating	Packing	Package
μPD166020T1F-E1-AY *1	Sn	Tape 2500 p/reel	5-pin TO-252 (MP-3ZK)

Note: *1. Pb-free (This product does not contain Pb in the external electrode.)

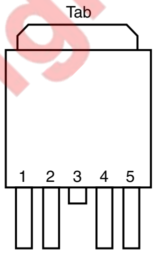
3. Specification

3.1 Block Diagram



3.2 Pin Configuration

Pin No.	Terminal Name
1	OUT
2	IN
3/Tab	VCC
4	IS
5	OUT



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Pin Function

Terminal Name	Pin function	Recommended connections
OUT	Output to load	Pin 1 and Pin 5 must be externally shorted
IN	Activates the output, if it shorted to ground	If reverse battery protection feature is used, refer to **3.6.3 Power Dissipation Under Reverse Battery Condition**.
VCC	Supply Voltage; tab and pin 3 are internally shorted	Connected to battery voltage with small 100 nF capacitor in parallel
IS	Sense output, diagnostic feedback	If current sense and diagnostic feature are not used, connected to GND via resistor

3.3 Absolute Maximum Ratings

T_A = 25°C, unless otherwise specified

Parameter	Symbol	Rating	Unit	Test Conditions	
V_{CC} Voltage	V_{CC1}	28	V		
V_{CC} voltage under Load Dump condition	V_{CC2}	42	V	R_I = 1 Ω, R_L = 1.5 Ω, R_{IS} = 1 kΩ, t_d = 400 ms	
V_{CC} Voltage at reverse battery condition	$-V_{CC}$	–16	V	R_L = 2.2 Ω, 1 min.	
Load Current (Short circuit current)	$I_{L(SC)}$	Self limited	A		
Power dissipation (DC)	P_D	1.2	W	T_A = 85°C, Device on 50 mm x 50 mm x 1.5 mm epoxy PCB FR4 with 6 cm^2 of 70 μm copper area	
Voltage of IN pin	V_{IN}	V_{CC} – 28	V	DC	
		V_{CC} + 14		At reverse battery condition, t < 1 min.	
Voltage of IS pin	V_{IS}	V_{CC} – 28	V	DC	
		V_{CC} + 14		At reverse battery condition, t < 1 min.	
Inductive load switch-off energy dissipation single pulse	E_{AS1}	50	mJ	V_{CC} = 12 V, I_L = 10 A, $T_{ch,start} \leq$ 150°C refer to **3.6.8 Inductive Load Switch Off Energy Dissipation for a Single Pulse**	
Maximum allowable energy dissipation at shutdown operation	E_{AS2}	105	mJ	V_{CC} = 18 V, $T_{ch,star} \leq$ 150°C, L_{supply} = 5 μH, L_{short} = 15 μH refer to **3.6.9 Maximum Allowable Switch off Energy (Single Pulse)**	
Channel Temperature	T_{ch}	–40 to +150	°C		
Dynamic temperature increase while switching	ΔT_{ch}	60	°C		
Storage Temperature	T_{stg}	–55 to +150	°C		
ESD susceptibility	V_{ESD}	2000	V	HBM	AEC-Q100-002 std. R = 1.5 kΩ, C = 100 pF
		400	V	MM	AEC-Q100-003 std. R = 0 Ω, C = 200 pF

Not recommended for new design

3.4 Thermal Characteristics

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions
Thermal characteristics	$R_{th(ch-a)}$		45		°C/W	Device on 50 mm x 50mm x 1.5 mm epoxy PCB FR4 with 6 cm^2 of 70 μm copper area
	$R_{th(ch-c)}$			3.17	°C/W	

3.5 Electrical Characteristics

Operation Function

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

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions
Required current capability of Input switch	I_{IH}		1.0	2.2	mA	T_{ch} = –40 to 150°C
Input current for turn-off	I_{IL}			50	μA	
Standby Current	$I_{CC(off)}$		2.5	5.0	μA	R_L = 2.2 Ω, I_{in} = 0 A, T_{ch} = 25°C
			2.5	15.0	μA	R_L = 2.2 Ω, I_{in} = 0 A, T_{ch} = –40 to 150°C
On State Resistance	R_{on}		8	10	mΩ	I_L = 7.5 A, T_{ch} = 25°C
			14	18		I_L = 7.5 A, T_{ch} = 150°C
Output voltage drop limitation at small load current	$V_{on(NL)}$		30	65	mV	T_{ch} = –40 to 150°C
Turn On Time	t_{on}		120	360	μs	R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to **3.6.6 Measurement Condition**
Turn Off Time	t_{off}		250	500	μs	
Slew rate on [*1]	dv/dton		0.2	0.8	V/μs	25 to 50 % V_{OUT}, R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to **3.6.6 Measurement Condition**
Slew rate off [*1]	–dv/dtoff		0.2	0.6	V/μs	50 to 25 % V_{OUT}, R_L = 2.2 Ω, T_{ch} = –40 to 150°C, refer to **3.6.6 Measurement Condition**

Note: [*]1. Not tested, specified by design

Not recommended for new design

Protection Function

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

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions	
On-state resistance at reverse battery conditon *1	$R_{on(rev)}$		9.5	13	mΩ	T_{ch} = 25°C	V_{CC} = –12 V, I_L = –7.5 A, R_{IS} = 1 kΩ
			16	22	mΩ	T_{ch} = 150°C	
Short circuit detection current	$I_{L6,3(SC)}$ *1		50	120	A	T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 6 V, V_{on} = 3 V
			50			T_{ch} = 25°C	
		20	45			T_{ch} = 150°C	
	$I_{L6,6(SC)}$ *1		35	110		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 6 V, V_{on} = 6 V
			35			T_{ch} = 25°C	
		10	35			T_{ch} = 150°C	
	$I_{L12,3(SC)}$		110	180		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 12 V, V_{on} = 3 V
		76	105			T_{ch} = 25°C	
		50	95			T_{ch} = 150°C	
	$I_{L12,6(SC)}$ *1		90	160		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 12 V, V_{on} = 6 V
			85			T_{ch} = 25°C	
		40	80			T_{ch} = 150°C	
	$I_{L12,12(SC)}$ *1		55	120		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 12 V, V_{on} = 12 V
			50			T_{ch} = 25°C	
		10	45			T_{ch} = 150°C	
	$I_{L18,3(SC)}$ *1		130	200		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 18 V, V_{on} = 3 V
			125			T_{ch} = 25°C	
		60	110			T_{ch} = 150°C	
	$I_{L18,6(SC)}$ *1		110	170		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 18 V, V_{on} = 6 V
			110			T_{ch} = 25°C	
		50	110			T_{ch} = 150°C	
	$I_{L18,12(SC)}$ *1		75	120		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 18 V, V_{on} = 12 V
			70			T_{ch} = 25°C	
		30	65			T_{ch} = 150°C	
	$I_{L18,18(SC)}$ *1		50	90		T_{ch} = –40°C	$V_{CC} - V_{IN}$ = 18 V, V_{on} = 18 V
			50			T_{ch} = 25°C	
		5	45			T_{ch} = 150°C	
Turn-on check delay after input current positive slope *1	$t_{d(OC)}$	0.9	2.1	3.8	ms	T_{ch} = -40 to 150°C	
Remaining Turn-on check delay after turn-on time *1	$t_{d(OC)}-t_{on}$	0.65	1.6		ms	R_L = 2.2 Ω, T_{ch} = –40 to 150°C	
Over load detection voltage	$V_{on(OvL)}$	0.65	1	1.45	V	T_{ch} = –40 to 150°C	
Under voltage shutdown	$V_{CIN(Uv)}$			5.5	V	T_{ch} = –40°C	
		3.2	4.0	5.35	V	T_{ch} = 25°C	
		2.7			V	T_{ch} = 150°C	
Under voltage restart of charge pump	$V_{CIN(CPr)}$			6.3	V	T_{ch} = –40°C	
		3.6	4.5	6.2	V	T_{ch} = 25°C	
		3.2			V	T_{ch} = 150°C	
Output clamp voltage (inductive load switch off)	$V_{on(CL)}$	30	34	40	V	I_L = 40 mA, T_{ch} = –40 to 150°C	
Thermal shutdown temperature *1	T_{th}	150	175		°C		
Thermal hysteresis *1	ΔT_{th}		10		°C		

Note: *1. Not tested, specified by design

Not recommend for new design

Diagnosis Function

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

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions	
Current sense ratio	K_{ILIS}					$K_{ILIS} = I_L/I_{IS}$, $I_{IS} < I_{IS,lim}$	
		8300	9200	11000		T_{ch} = –40°C	I_L = 30A
		8300	9200	10600		T_{ch} = 25°C	
		8400	9300	10200		T_{ch} = 150°C	
		7500	9200	11400		T_{ch} = –40°C	I_L = 7.5 A
		8000	9300	10800		T_{ch} = 25°C	
		8300	9300	10400		T_{ch} = 150°C	
		7100	10200	13400		T_{ch} = –40°C	I_L = 2.5 A
		7700	10000	12500		T_{ch} = 25°C	
		8000	9800	12000		T_{ch} = 150°C	
		5000	12000	21000		T_{ch} = –40°C	I_L = 0.5 A
		5500	11500	17000		T_{ch} = 25°C	
		6000	11500	16000		T_{ch} = 150°C	
Sense current offset current	$I_{IS,offset}$		0.1	1	μA	V_{IN} = 0 V, I_L = 0 A	
Sense current under fault condition	$I_{IS,fault}$	3.5	6.0	12.0	mA	Under fault conditions 8 V < $V_{CC} – V_{IS}$ < 12 V, T_{ch} = –40 to 150°C	
Sense current saturation current	$I_{IS,lim}$	3.5	7.0	12.0	mA	$V_{IS} < V_{OUT}$ – 6 V , T_{ch} = –40 to 150°C	
Fault Sense Signal delay after short circuit detection *1	$t_{sdelay(fault)}$		2	6	μs	T_{ch} = –40 to 150°C	
Sense current leakage current	$I_{IS(LL)}$		0.1	0.5	μA	I_{IN} = 0 A	
Current sense settling time to I_{IS}(static) after input current positive slope *1	$t_{son(IS)}$			700	μs	T_{ch} = –40 to 150°C, I_{IN} = 0 A ⎍ I_{IH}, R_L = 2.2 Ω	
Current sense settling time during on condition *1	$T_{sic(IS)}$		50	100	μs	T_{ch} = –40 to 150°C, I_L = 10A ⎍ 20 A	

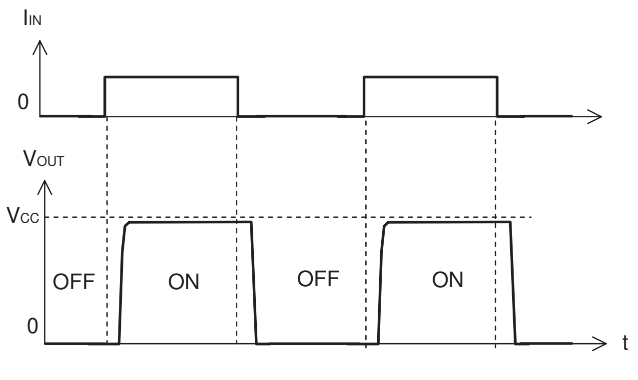
Note: *1. Not tested, specified by design

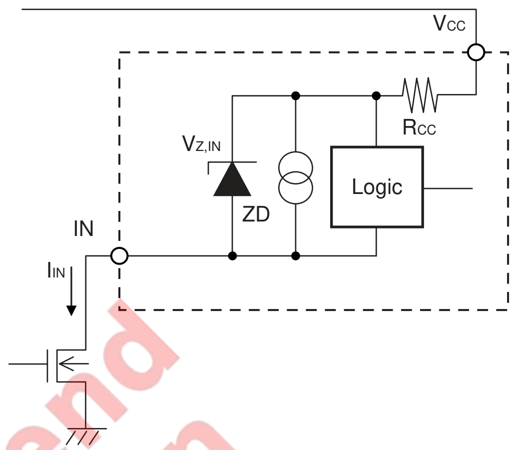
Not recommend for new design

3.6 Feature Description

3.6.1 Driving Circuit

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.





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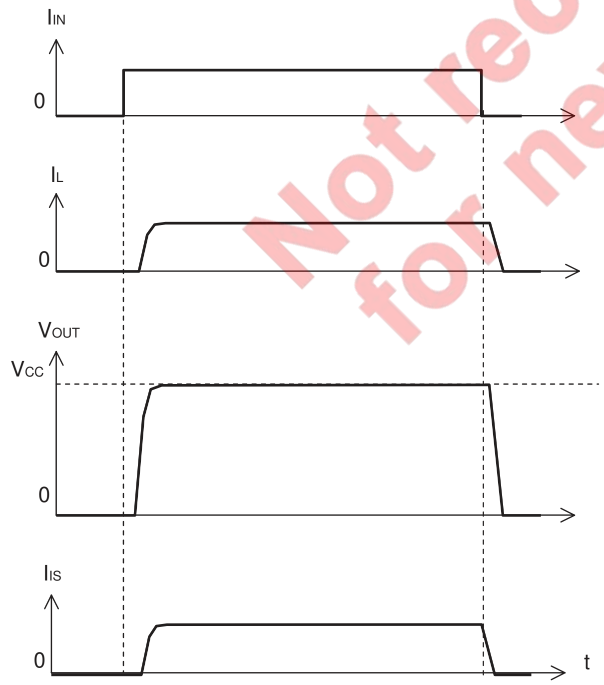
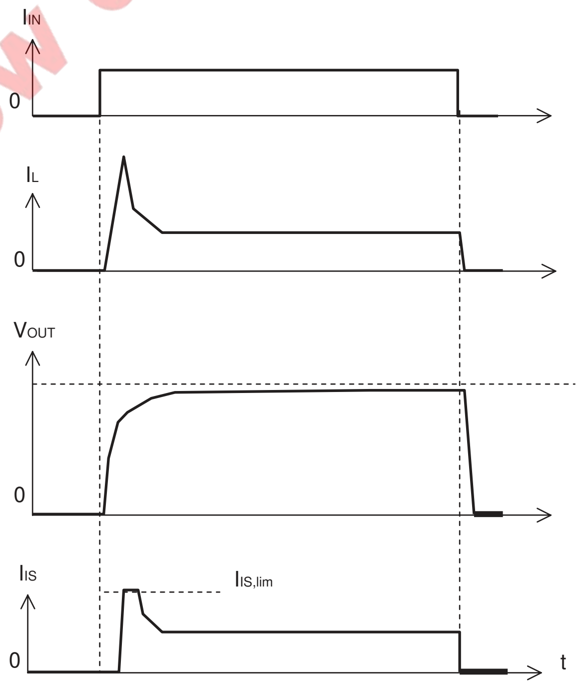
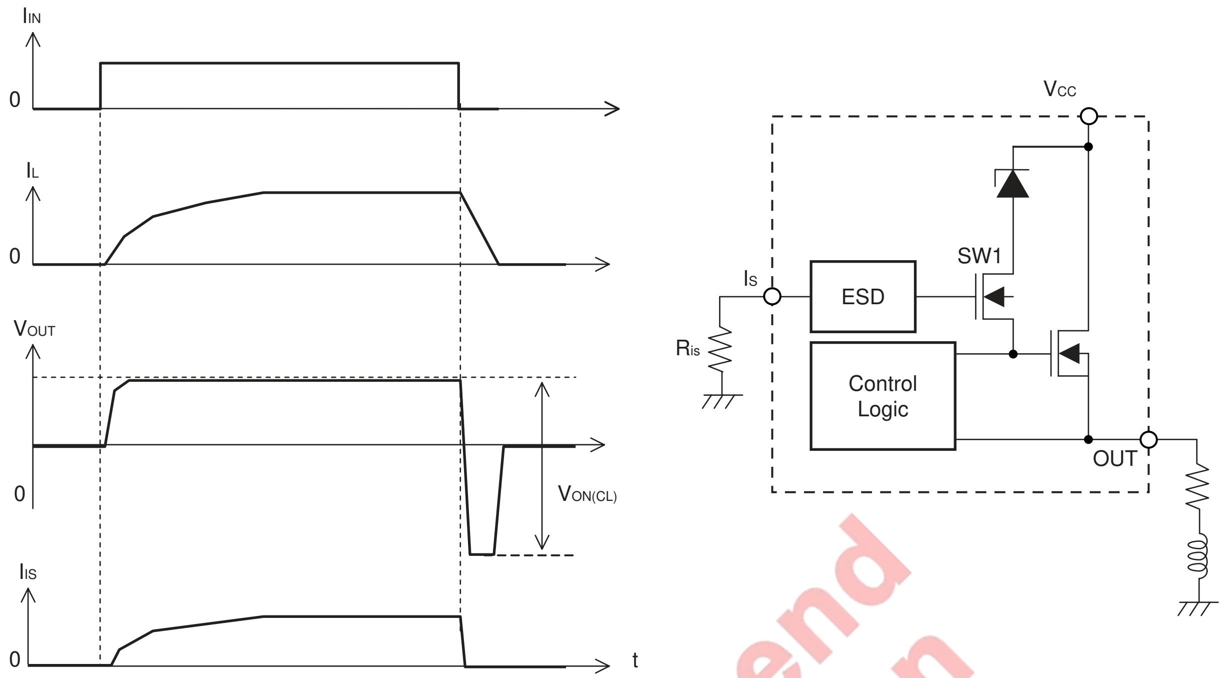
Switching a resistive load

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.

Not recommend for new design

3.6.2 Short Circuit Protection

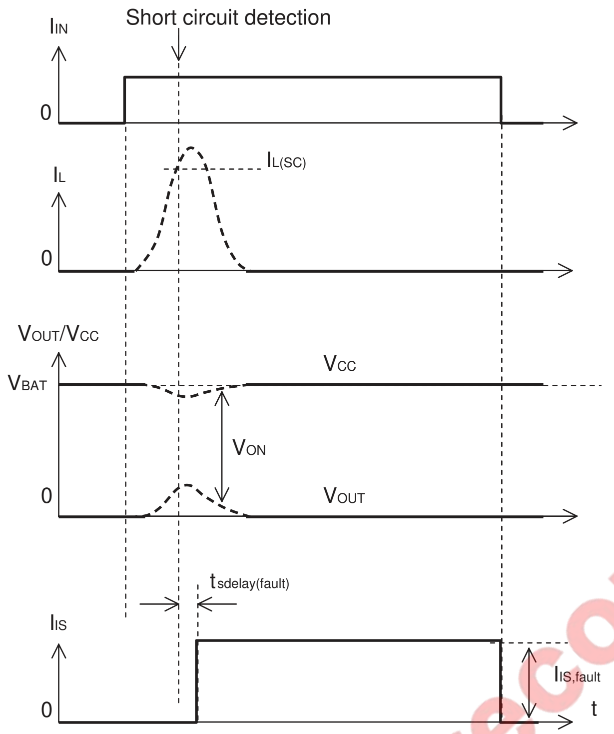
Case 1: I_{IN} pin is shorted to ground in an overload condition, which includes a short circuit condition.

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.

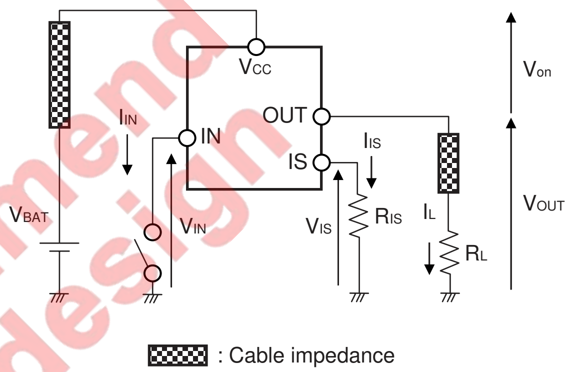
(a) $I_L > I_{L(SC)}$

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

Case 1-(a) $I_L > I_{L(SC)}$



(Evaluation circuit)



- - - - - - Depending on the external impedance

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

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

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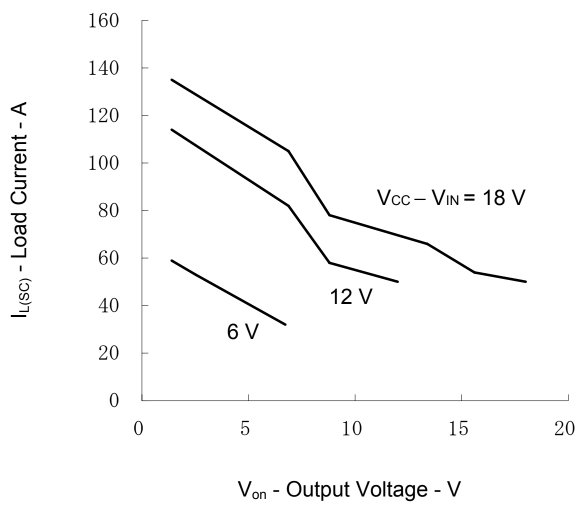
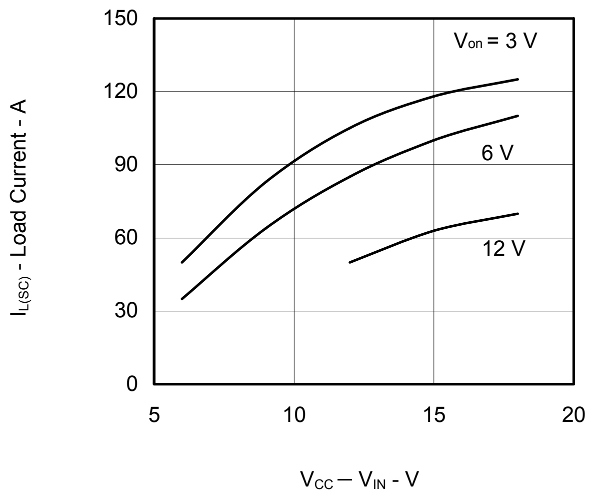
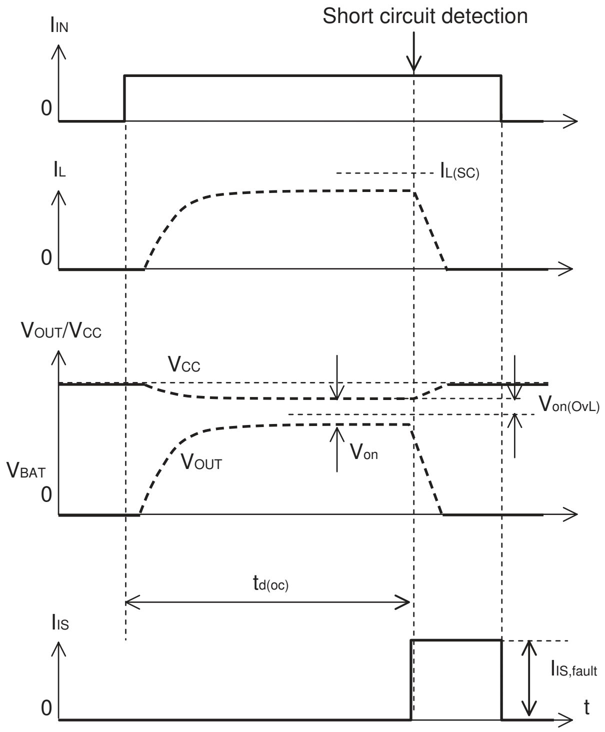
Typical Short circuit detection current characteristics

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.



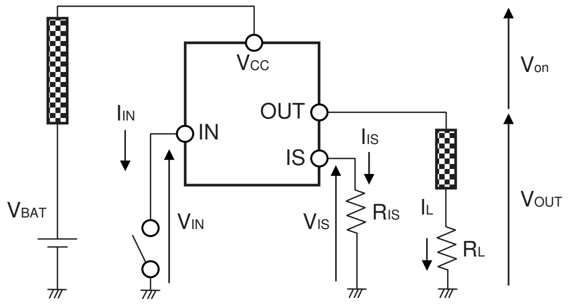


Case 1-(b) $V_{on} > V_{on(OvL)}$ after $t_{d(OC)}$



Depending on the external impedance

(Evaluation circuit)



: Cable impedance

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

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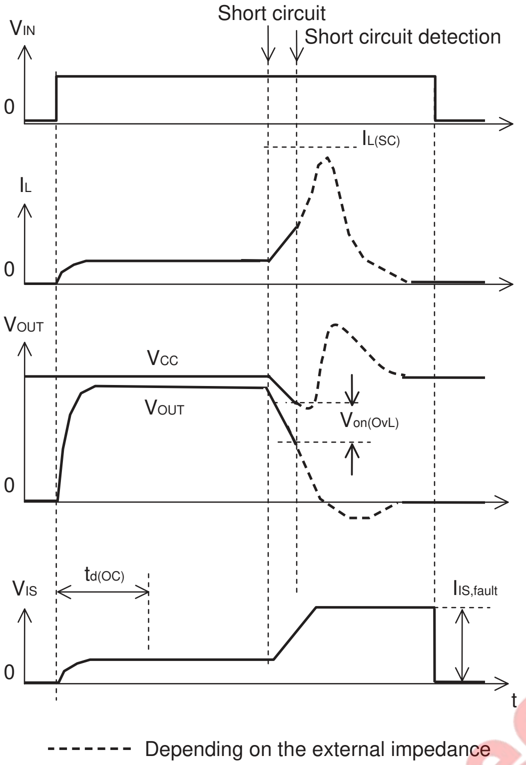
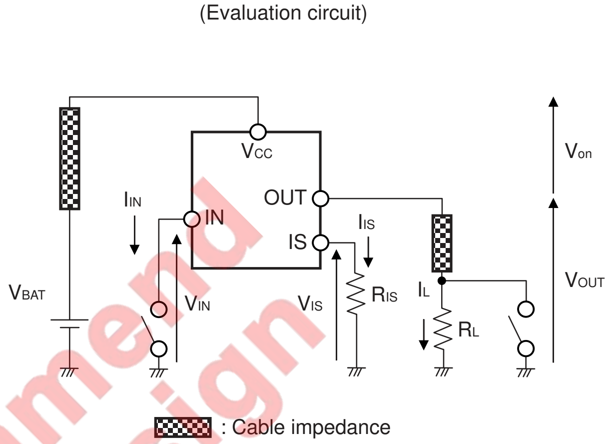
Case 2:Short circuit during on-condition

The device shuts down automatically when following conditions (a) is detected. The sense current is fixed at $I_{IS,fault}$. Shutdown is latched until the next reset via input. In the case of $V_{on(NL)}$ works such open load condition at on-state, $t_{d(OC)}$ is expired.

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

Case 2-(a) $V_{on} > V_{on(OvL)}$ after $t_{d(OC)}$





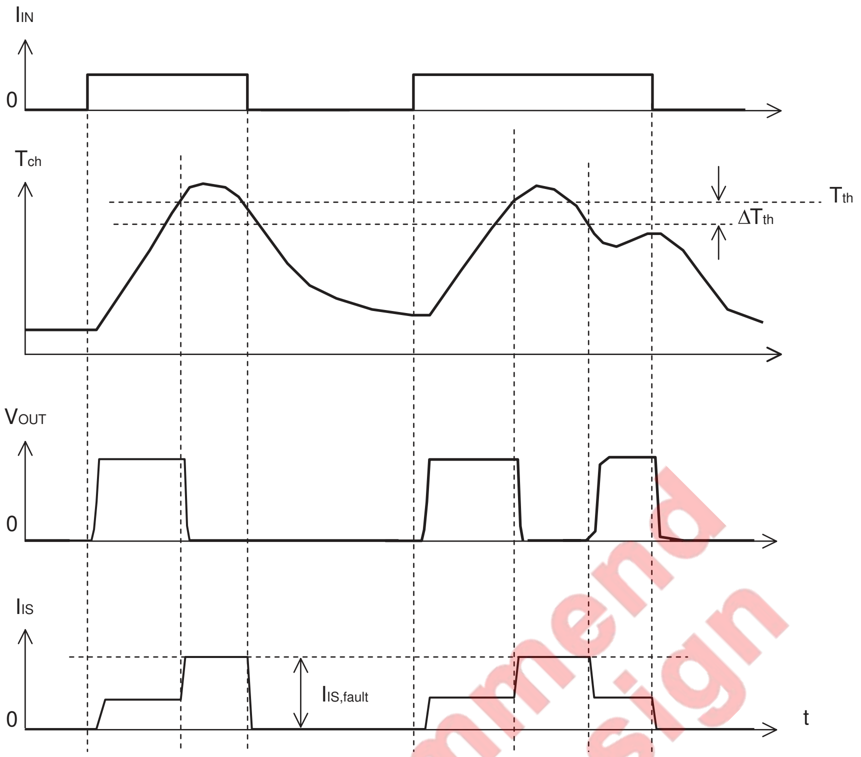
$t_{d(oc)}$:Turn-on check delay after input current positive slope

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

Not recommend for new design

Over-temperature protection

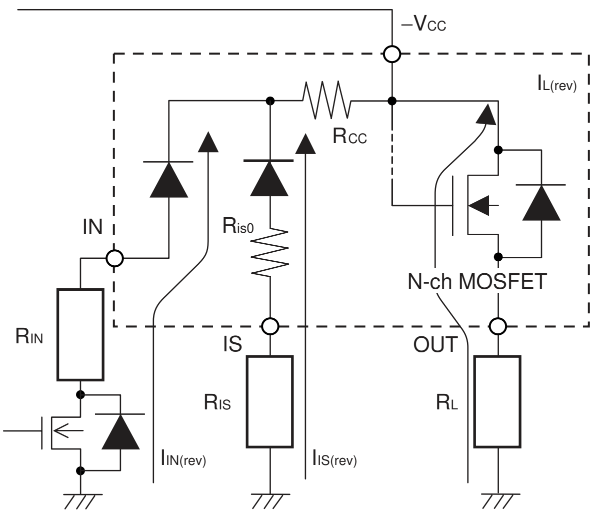
The output is switched off if over-temperature is detected. The device switches on again after it cools down.



Not recommend for new design

3.6.3 Power Dissipation under Reverse Battery Condition

In case of reverse battery condition, internal N-ch MOSFET is turned on to reduce the power dissipation by body diode. Additional power is dissipated by the internal resister. Following is the formula for estimation of total power dissipation Pd(rev) in reverse battery condition.



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

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

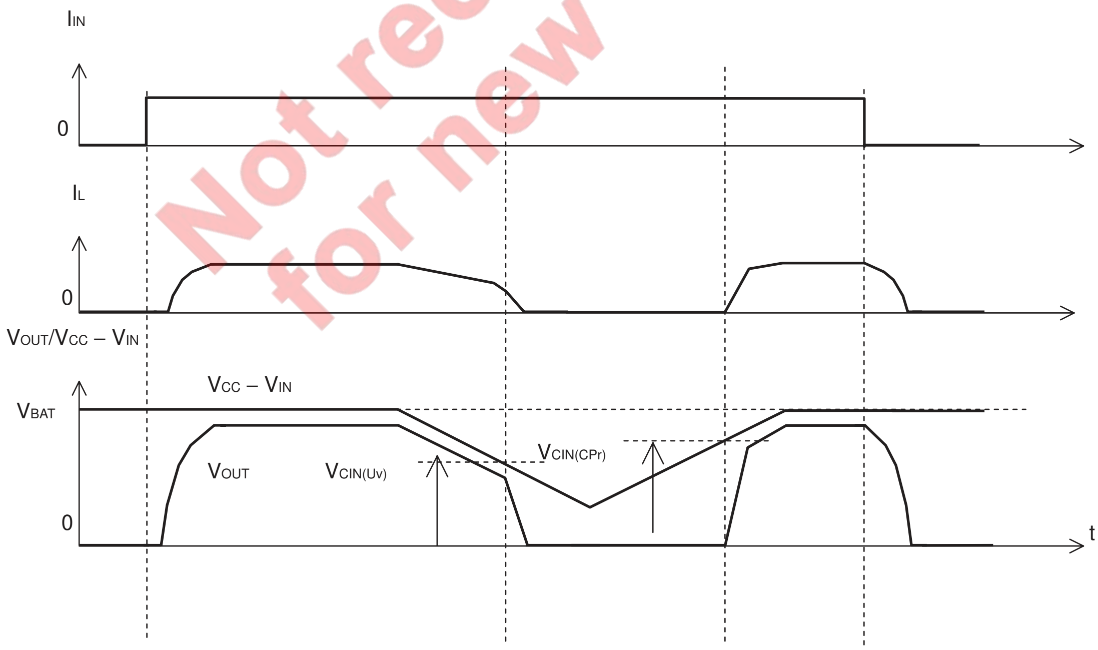
$$I_{is(rev)} = (V_{CC} - V_f)/(R_{CC} + R_{is0} + R_{IS})$$

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

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

3.6.4 Device Behavior at Low Voltage Condition

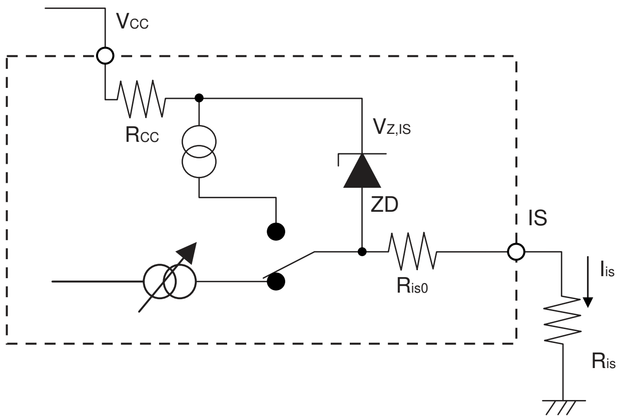
If the supply voltage ($V_{CC} - V_{IN}$) goes down under $V_{CIN(Uv)}$, the device shuts down the output. If supply voltage ($V_{CC} - V_{IN}$) increase over $V_{CIN(CPr)}$, the device turns on the output automatically. The device keeps off state if supply voltage ($V_{CC} - V_{IN}$) does not increase over $V_{CIN(CPr)}$ after under voltage shutdown. It is assumed that V_{IN} = 0 V when I_{IN} is activated.



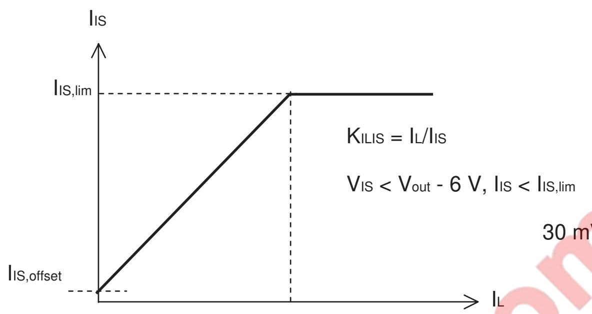
Remark It is assumed that V_{IN} = 0 V when I_{IN} is activated.

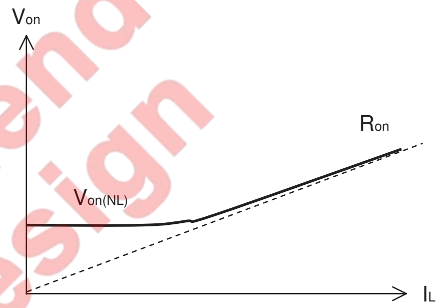
Not recommend for new design

3.6.5 Current Sense Output

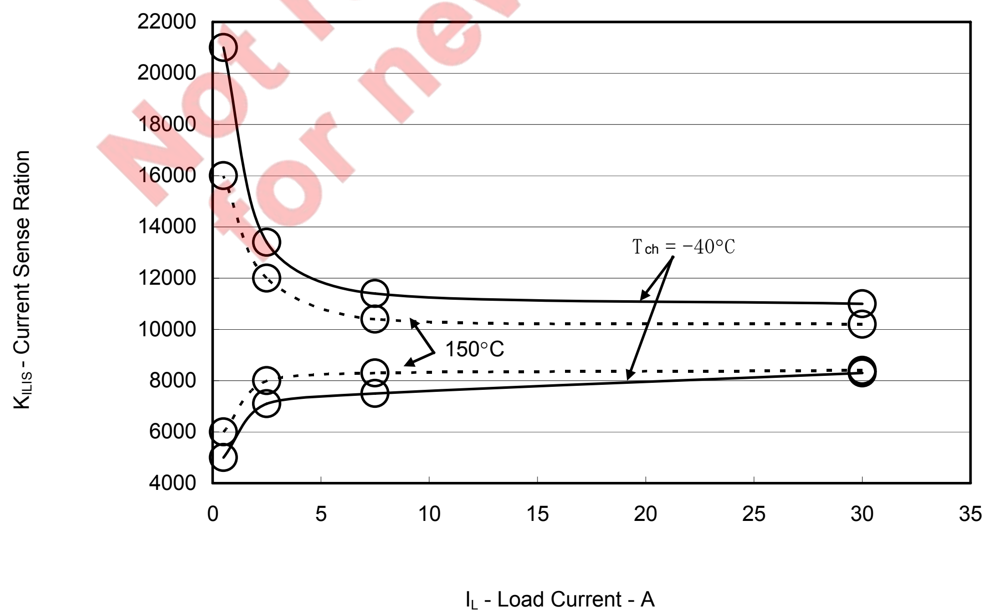


R_{CC} and R_{is0} are 100 Ω (TYP.). $V_{z,IS}$ = 46 V (TYP.), R_{IS} = 1 kΩ nominal.





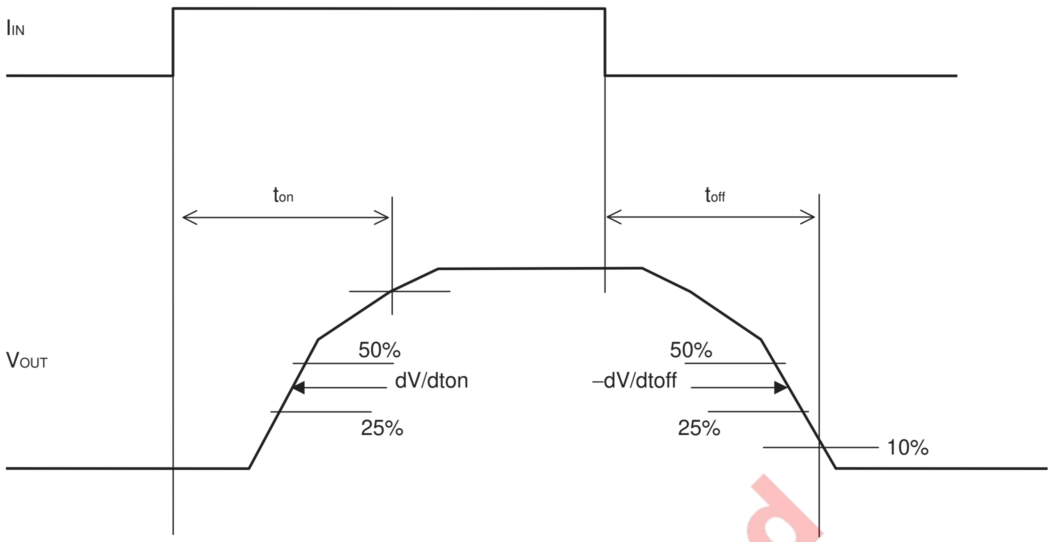
Current sense ratio



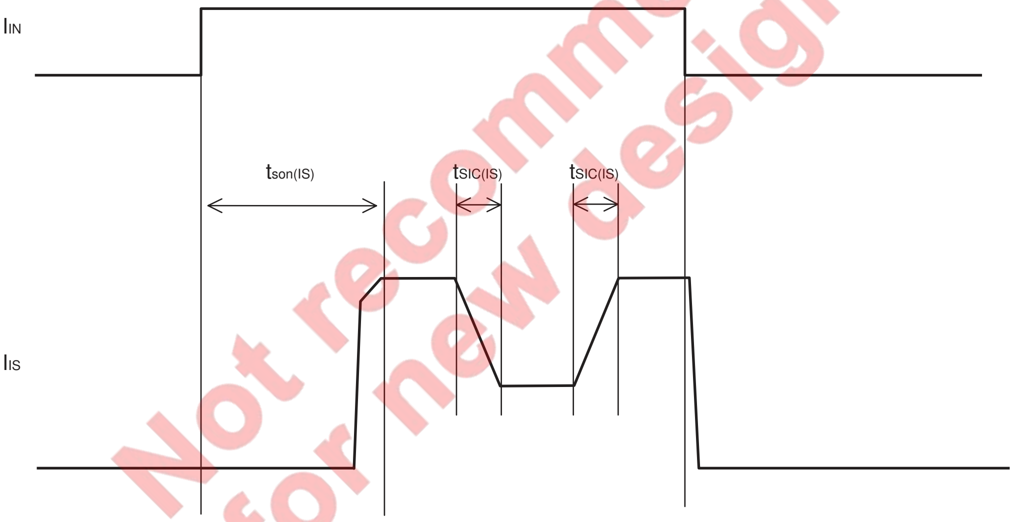
Not recommend for new design

3.6.6 Measurement Condition

Switching waveform of OUT Terminal



Switching waveform of IS terminal



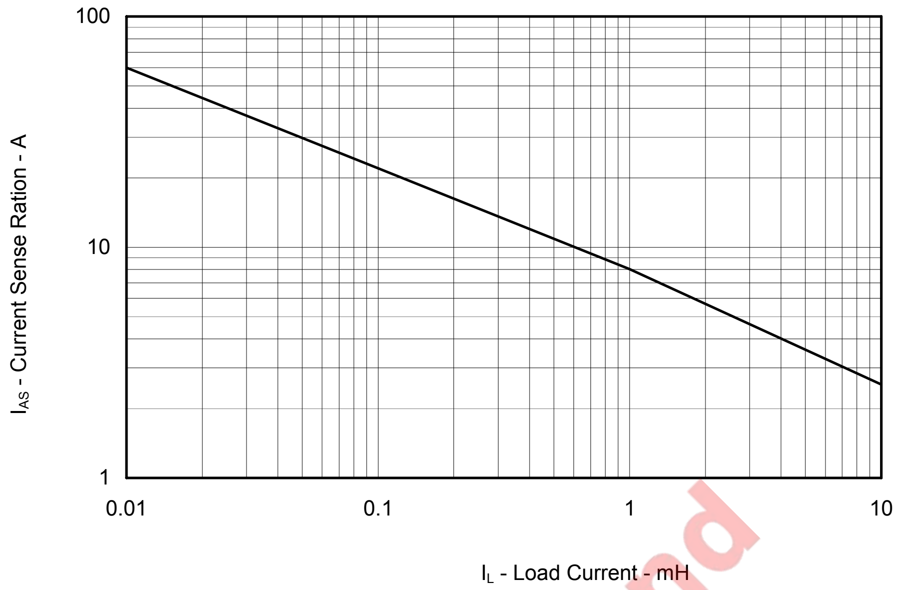
Not recommend for new design

3.6.7 Truth Table

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

3.6.8 Inductive Load Switch Off Energy Dissipation for a Single Pulse

MAXIMUM ALLOWABLE LOAD INDUCTANCE for a SINGLE SWITCH OFF

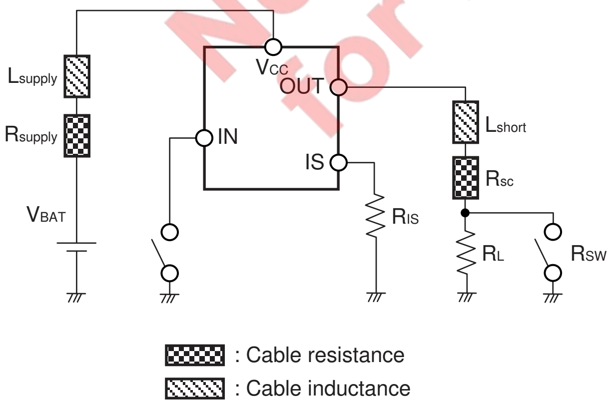


The energy dissipation for an inductive load switch-off single pulse in device (E_{AS1}) is estimated by the following formula as $R_L = 0$ Ω.

$$E_{AS1} = \frac{1}{2} I^2 L \left(\frac{V_{on(CL)}}{V_{on(CL)} - V_{CC}} \right)$$

3.6.9 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 E_{AS2}, the maximum switch-off energy (single pulse) for abnormally high current.

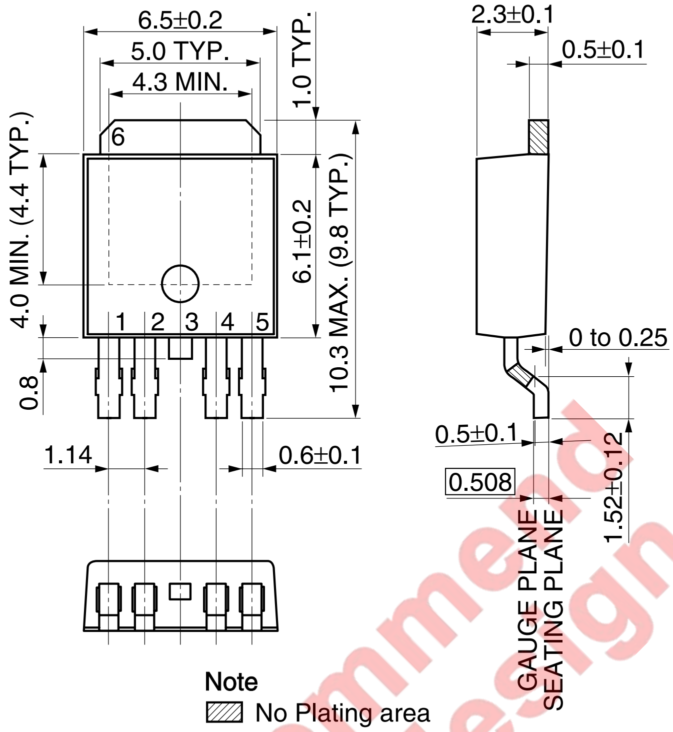


V_{BAT} = 18 V,
R_{supply} = 10 mΩ, R_{short} = R_{sc} + $R_{SW(on)}$ = 50 mΩ,
L_{supply} = 5 μH, L_{short} = 15 μH,
$T_{ch,start} \leq$ 150°C

Not recommend for new design

3.7 Package Drawing (unit: mm)

5-pin TO-252 (MP-3ZK)



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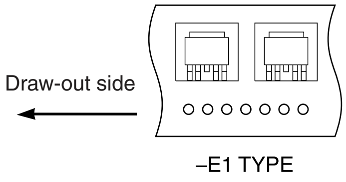
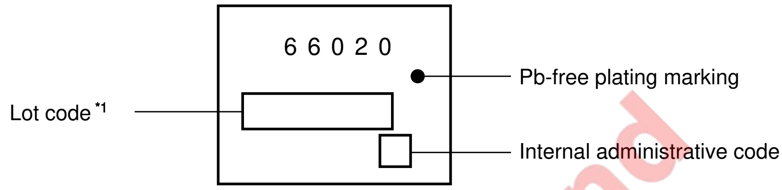
3.8 Taping Information

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

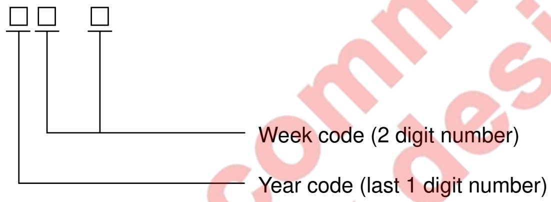


3.9 Marking Information

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



Note: *1. Composition of the lot code



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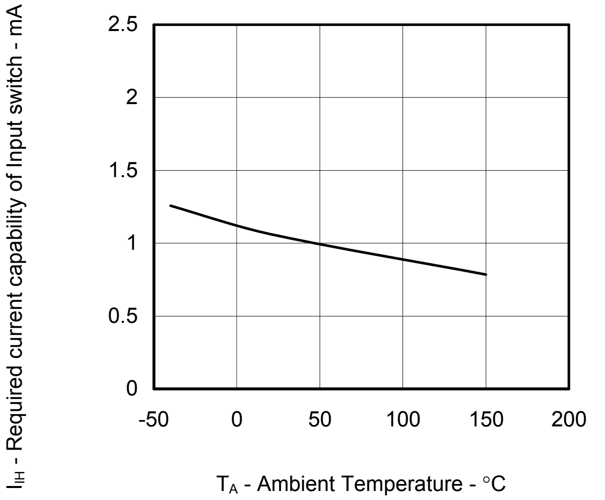
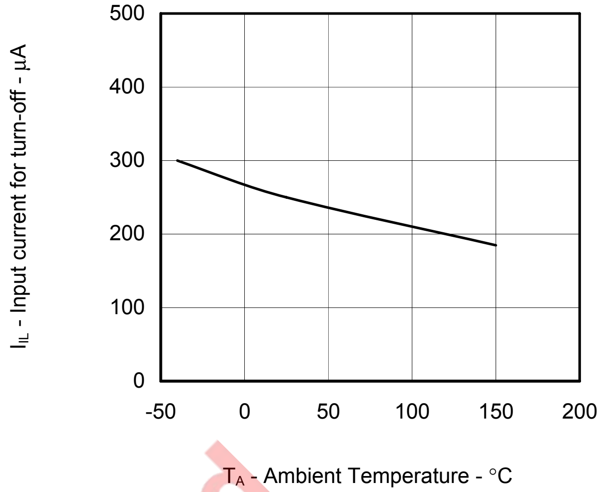
4. Typical Characteristics

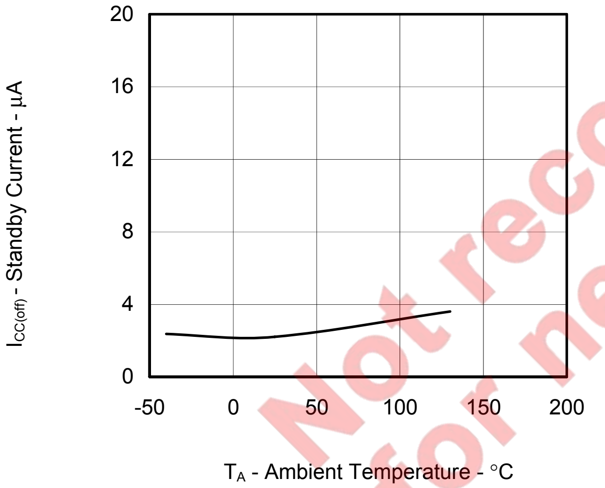
REQUIRED CURRENT CAPABILITY OF INPUT SWITCH vs. AMBIENT TEMPERATURE



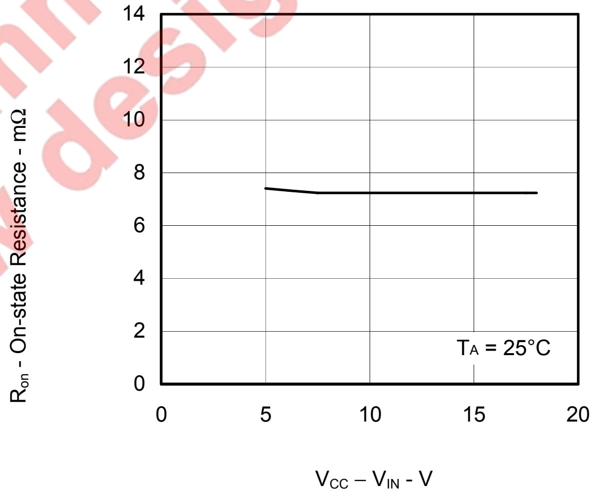
INPUT CURRENT FOR TURN OFF vs. AMBIENT TEMPERATURE



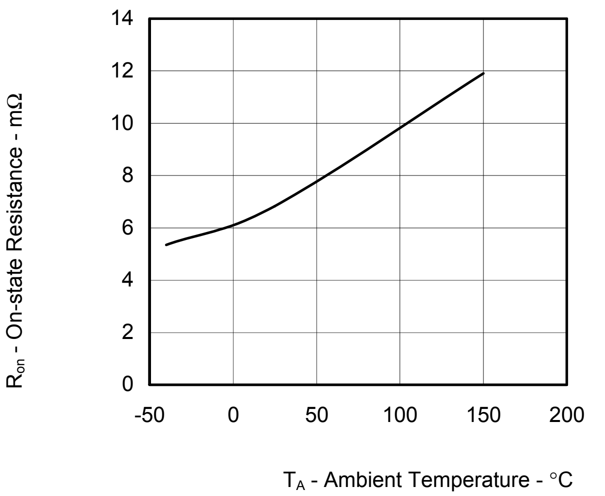
STANDBY CURRENT vs. AMBIENT TEMPERATURE



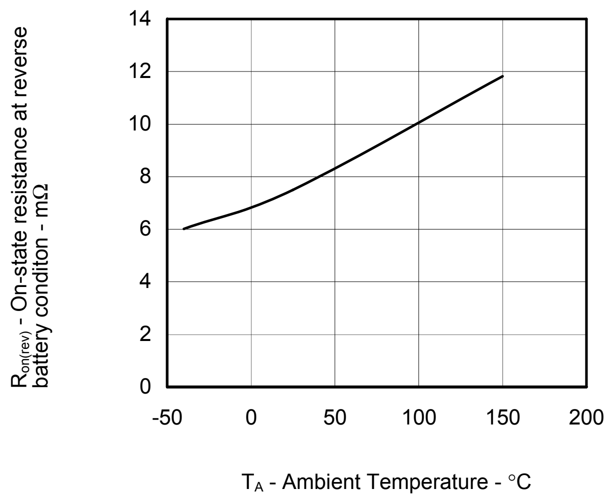
ON STATE RESISTENCE vs. $V_{CC} – V_{IN}$ voltage



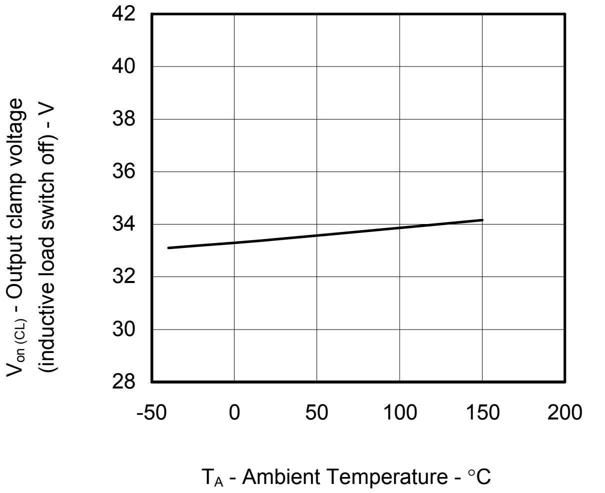
ON STATE RESISTENCE vs. AMBIENT TEMPERATURE



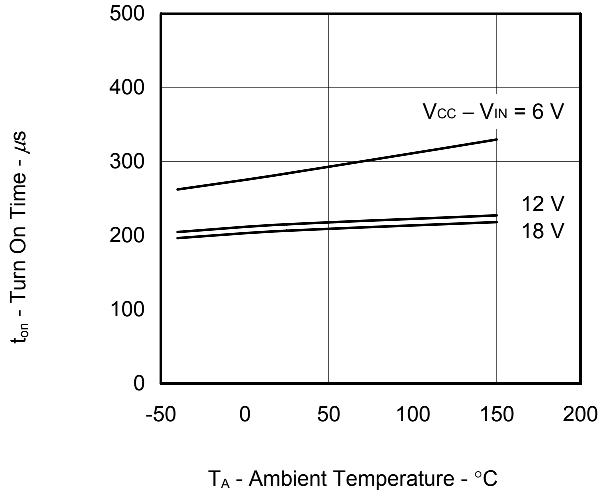
ON STATE RESISTENCE AT REVERSE BATTERY CONDITION vs. AMBIENT TEMPERATURE



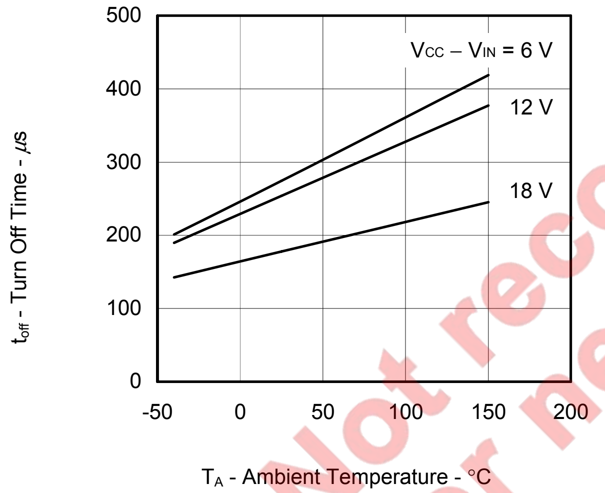
OUTPUT CLAMP VOLTAGE (INDUCTIVE LOAD SWITCH OFF) vs. AMBIENT TEMPERATURE



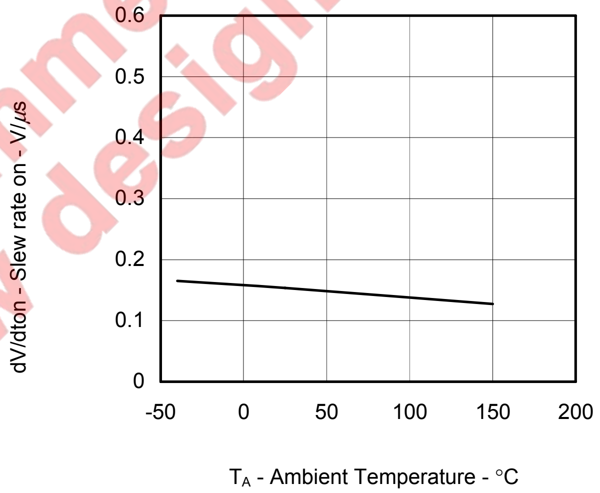
TURN ON TIME vs. AMBIENT TEMPERATURE



TURN OFF TIME vs. AMBIENT TEMPERATURE



SLEW RATE ON vs. AMBIENT TEMPERATURE



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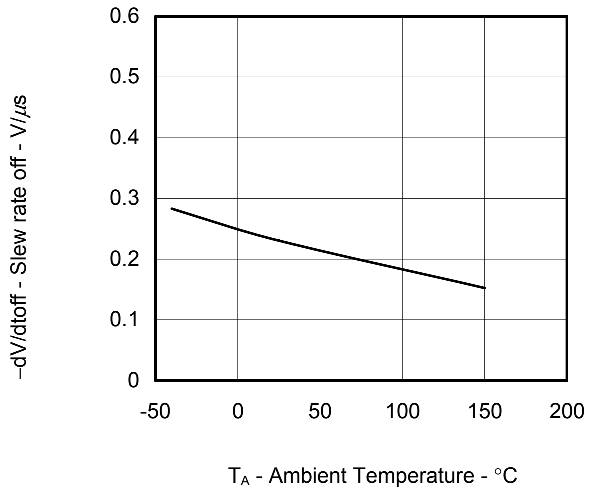
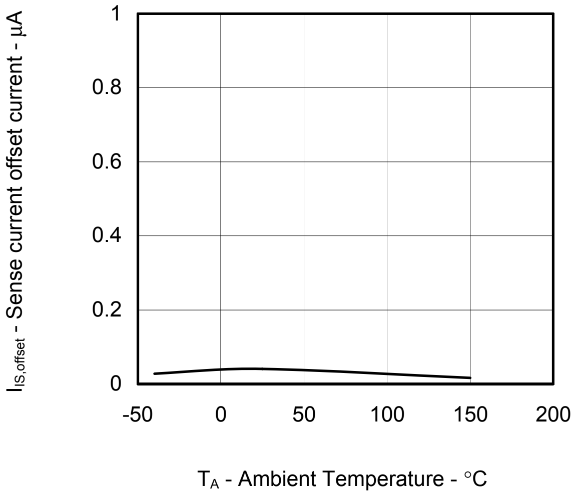
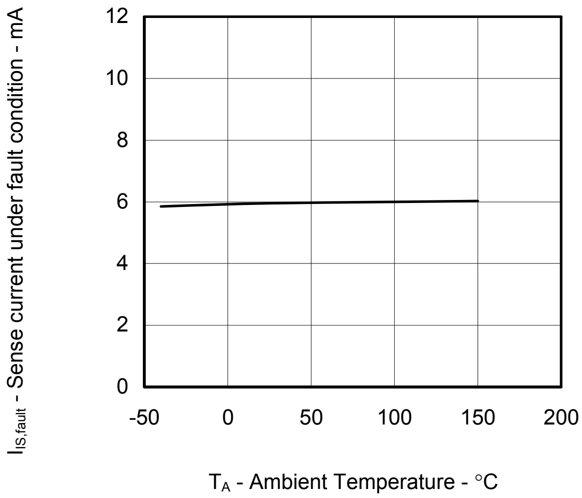
SLEW RATE OFF vs. AMBIENT TEMPERATURE



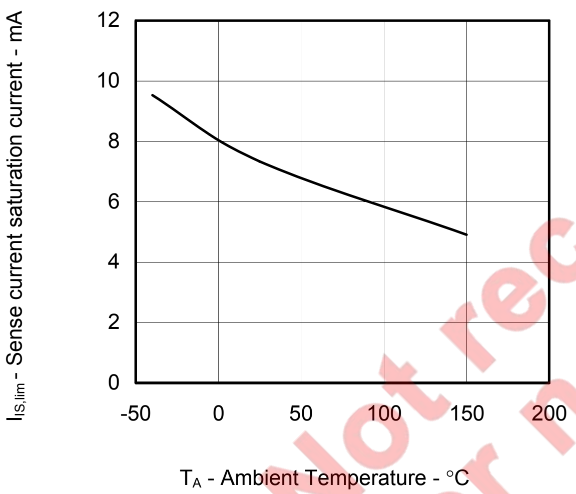
SENSE CURRENT OFFSET CURRENT
vs. AMBIENT TEMPERATURE



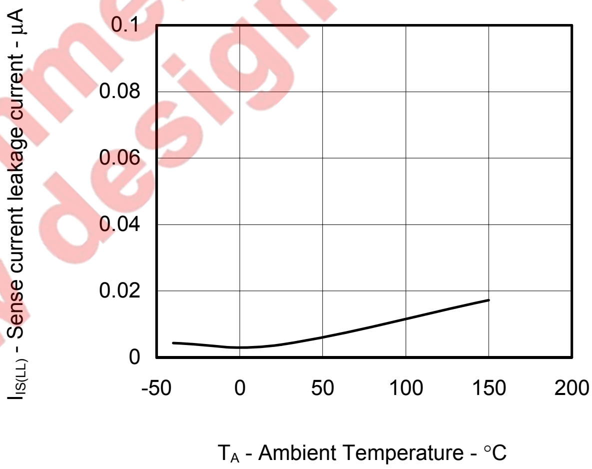
SENSE CURRENT UNDER FAULT CONDITION
vs. AMBIENT TEMPERATURE



SENSE CURRENT SATURATION CURRENT
vs. AMBIENT TEMPERATURE



SENSE CURRENT LEAKAGE CURRENT
vs. AMBIENT TEMPERATURE



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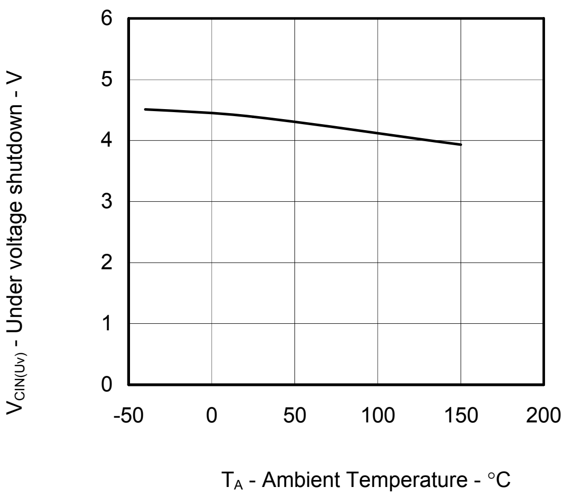
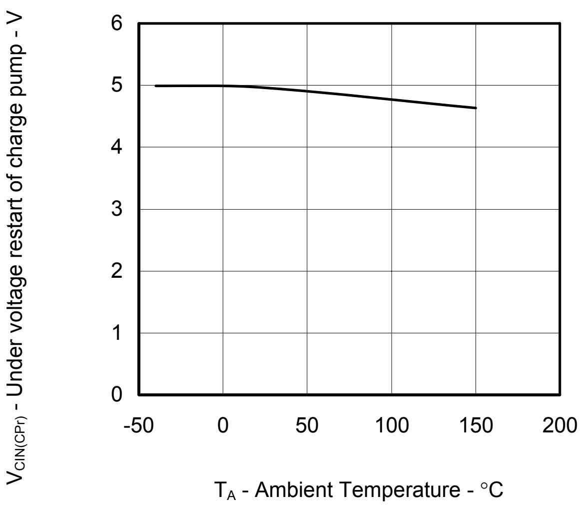
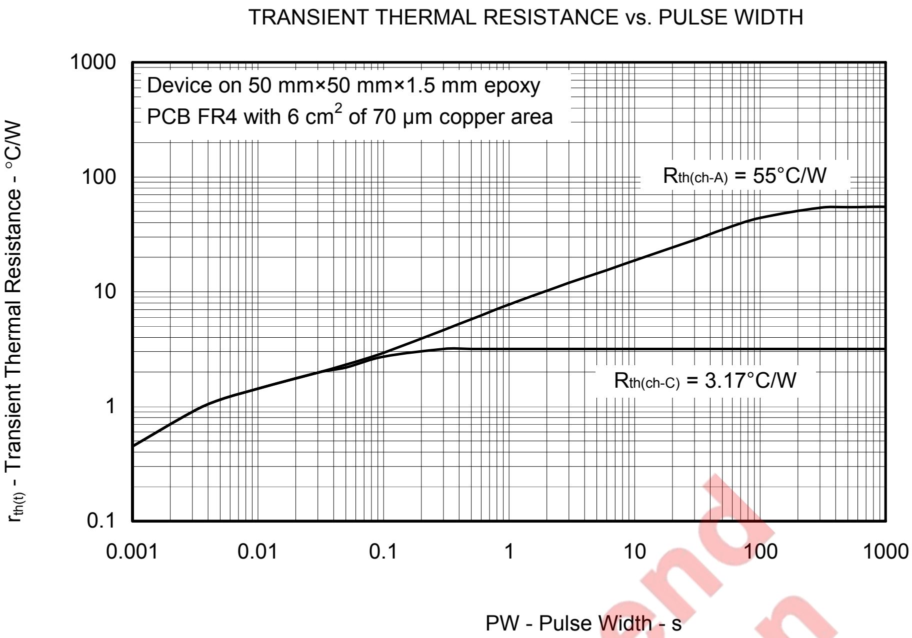
UNDER VOLTAGE SHUTDOWN
vs. AMBIENT TEMPERATURE



UNDER VOLTAGE RESTART OF CHARGE PUMP
vs. AMBIENT TEMPERATUR



5. Thermal Characteristics



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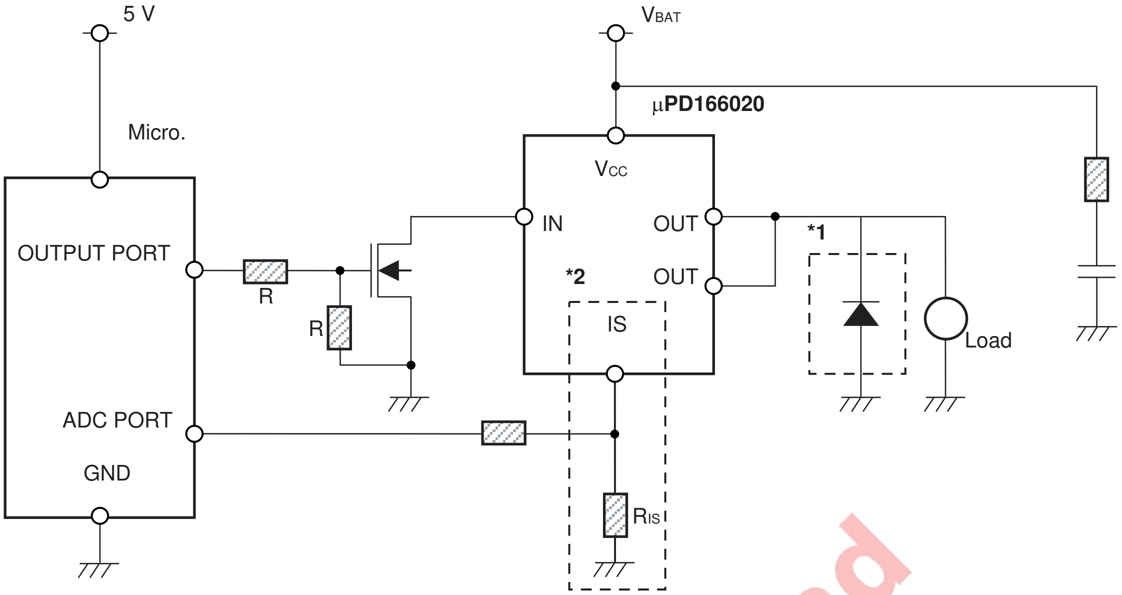
6. Application Example in Principle



Notes: *1. If output current is over the maximum allowable current for inductive load at a single switch off, or if energy at a single switch off is over E_{AS1}/E_{AS2}, then a free wheeling diode must be connected in parallel the load.

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

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Revision History	μPD166020T1F Data Sheet

Rev.	Date	Description	
		Page	Summary
1.00	Aug 15, 2011	–	First Edition Issued

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