μPD166017T1F

INTELLIGENT POWER DEVICE

R07DS0704EJ0100
Rev.1.00
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1. Overview

1.1 Description

μPD166017 is a Single 6 mΩ N-channel high-side driver in space saving TO-252 package. The device has many integrated features to enable the successful design of high side load control circuits.

1.2 Features

- Low on-state resistance: 6 mΩ (MAX. at 25°C)
- Small package: JEDEC 5-pin TO-252
- Built-in charge pump
- 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
- AEC-Q100 Qualified
- RoHS compliant with pure tin plating

1.3 Application

- Incandescent light bulb (55 W to 65 W) switching with PWM control
- Switching of all types of 14 V DC grounded loads, such as LED lighting, resistive heating elements, inductive and capacitive loads.
- Replacement of fuse and relay

2. Ordering Information

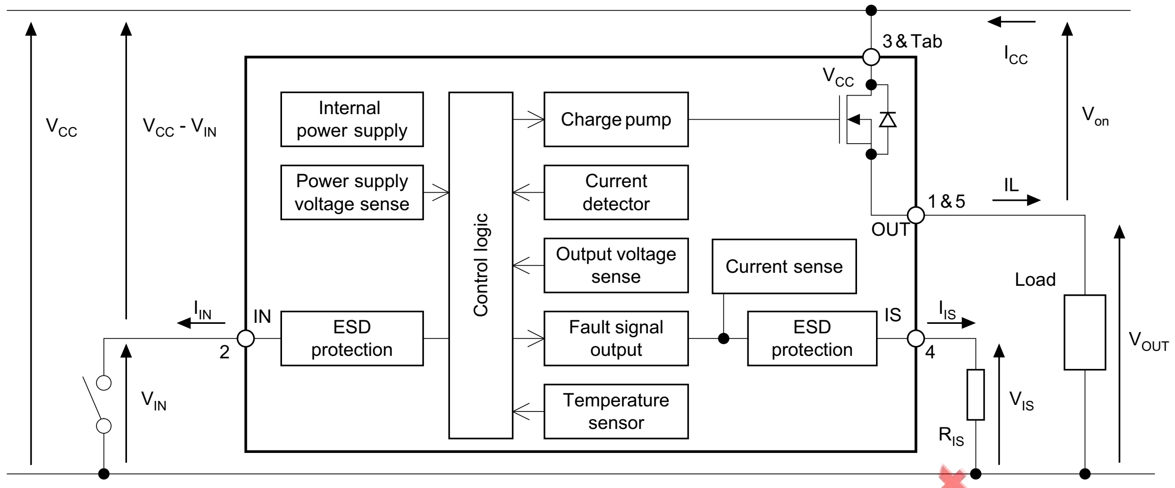
Part No.	Lead Plating	Packing	Package
μPD166017T1F-E1-AY *1	Pure Mate Sn	Tape 2500 p/reel	5-pin TO-252 (MP-3ZK)

Note: *1 Pb-free (This product does not contain Pb in the external electrode.). MSL: 3, profile acc. J-STD-20C

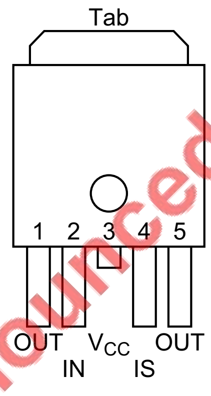
Note: The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.

3. Specification

3.1 Block Diagram



3.2 Pin Arrangement



(Top view)

3.2.1 Pin Function

Pin No.	Pin Name	Pin Function	Recommended Connection
1	OUT	Output to load	Pin 1 and Pin 5 must be externally shorted
2	IN	Activates the output, if it shorted to ground	If reverse battery protection feature is used, refer to "Power Dissipation under Reverse Battery Condition"
3/Tab	V_{CC}	Supply voltage: tab and pin 3 are internally shorted	Connected to battery voltage with small 100 nF capacitor in parallel
4	IS	Sense output, diagnostic feedback	If current sense and diagnostic feature are not used, connected to GND via resistor
5	OUT	Output to load	Pin 1 and Pin 5 must be externally shorted

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 = 1.5 Ω, 1 min.
Load current (short circuit current)	$I_{L(SC)}$	Self limited	A	
Total power dissipation for whole device (DC)	P_D	1.2	W	T_A = 85°C, Device on 50 mm × 50 mm × 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, $T_{ch,start}$ < 150°C
Maximum allowable energy dissipation at shutdown operation	E_{AS2}	105	mJ	V_{CC} = 18 V, $T_{ch,start}$ < 150°C, L_{supply} = 5 μH, L_{short} = 15 μH
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
		200	V	MM: AEC-Q100-003 std. R = 0 Ω, C = 200 pF

Note: All voltages refer to ground pin of the device.

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 × 50 mm × 1.5 mm epoxy PCB FR4 with 6 cm^2 of 70 μm copper area
	$R_{th(ch-c)}$	—	1.7	—	°C/W	

3.5 Electrical Characteristics

3.5.1 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}	—	1.4	3.0	mA	T_{ch} = –40 to 150°C
Input current for turn-off	I_{IL}	—	—	50	μA	
Standby current	$I_{CC(off)}$	—	—	0.5	μA	R_L = 1.0 Ω, I_{in} = 0 A, T_{ch} = 25°C
		—	—	15		R_L = 1.0 Ω, I_{in} = 0 A, T_{ch} = 125°C
		—	—	50		R_L = 1.0 Ω, I_{in} = 0 A, T_{ch} = –40 to 150°C
On state resistance	R_{on}	—	4.7	6.0	mΩ	I_L = 15 A, T_{ch} = 25°C
		—	7.9	10.5		I_L = 15 A, T_{ch} = 150°C
Turn on time	t_{on}	—	170	500	μs	R_L = 1.0 Ω, T_{ch} = –40 to 150°C, refer to "Measurement Condition"
Turn off time	t_{off}	—	220	600	μs	
Slew rate on [*1]	dv/dton	—	0.2	0.6	V/μs	25 to 50% V_{OUT}, R_L = 1.0 Ω, T_{ch} = –40 to 150°C, refer to "Measurement Condition"
Slew rate off [*1]	–dv/dtoff	—	0.2	0.5	V/μs	50 to 25% V_{OUT}, R_L = 1.0 Ω, T_{ch} = –40 to 150°C, refer to "Measurement Condition"

Note: *1 Not tested, specified by design

3.5.2 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 condition *1	$R_{on(rev)}$	—	5.4	7.0	mΩ	T_{ch} = 25°C	V_{CC} = –12 V, I_L = –7.5 A, R_{IS} = 1 kΩ
		—	8.9	12.3		T_{ch} = 150°C	
Short circuit detection current	$I_{L6,3(SC)}$	—	40	130	A	T_{ch} = –40°C	V_{CC} = 6 V, V_{on} = 3 V
		20	35	—		T_{ch} = 25°C	
		10	25	—		T_{ch} = 150°C	
	$I_{L6,6(SC)}$ *1	—	30	100		T_{ch} = –40°C	V_{CC} = 6 V, V_{on} = 6 V
		—	25	—		T_{ch} = 25°C	
		5	20	—		T_{ch} = 150°C	
	$I_{L12,3(SC)}$ *1	—	155	240		T_{ch} = –40°C	V_{CC} = 12 V, V_{on} = 3 V
		76	135	—		T_{ch} = 25°C	
		40	95	—		T_{ch} = 150°C	
	$I_{L12,6(SC)}$ *1	—	130	230		T_{ch} = –40°C	V_{CC} = 12 V, V_{on} = 6 V
		—	110	—		T_{ch} = 25°C	
		30	80	—		T_{ch} = 150°C	
	$I_{L12,12(SC)}$ *1	—	109	180		T_{ch} = –40°C	V_{CC} = 12 V, V_{on} = 12 V
		—	95	—		T_{ch} = 25°C	
		10	76	—		T_{ch} = 150°C	
	$I_{L18,3(SC)}$ *1	—	185	250		T_{ch} = –40°C	V_{CC} = 18 V, V_{on} = 3 V
		—	160	—		T_{ch} = 25°C	
		50	120	—		T_{ch} = 150°C	
	$I_{L18,6(SC)}$ *1	—	153	220		T_{ch} = –40°C	V_{CC} = 18 V, V_{on} = 6 V
		—	133	—		T_{ch} = 25°C	
		50	100	—		T_{ch} = 150°C	
	$I_{L18,12(SC)}$ *1	—	112	170		T_{ch} = –40°C	V_{CC} = 18 V, V_{on} = 12 V
		—	98	—		T_{ch} = 25°C	
		30	73	—		T_{ch} = 150°C	
	$I_{L18,18(SC)}$ *1	—	92	140		T_{ch} = –40°C	V_{CC} = 18 V, V_{on} = 18 V
		—	80	—		T_{ch} = 25°C	
		5	64	—		T_{ch} = 150°C	
Turn-on check delay after input current positive slope	$t_{d(OC)}$	0.9	2.1	3.8	ms	T_{ch} = –40 to 150°C	
Remaining Turn-on check delay after turn-on time	$t_{d(OC)}–t_{on}$	0.65	1.9	—	ms	R_L = 1.0 Ω, T_{ch} = –40 to 150°C	
Over load detection voltage 1	$V_{on(OvL)1}$	0.45	0.65	0.90	V	T_{ch} = –40 to 150°C	
Over load detection voltage 2	$V_{on(OvL)2}$	0.20	0.30	0.50	V	T_{ch} = –40 to 150°C	
Under voltage shutdown	$V_{CIN(Uv)}$	—	—	5.8	V	T_{ch} = –40°C	
		3.6	4.5	5.4		T_{ch} = 25°C	
		3.2	—	—		T_{ch} = 150°C	
Under voltage restart of charge pump	$V_{CIN(CPr)}$	—	—	6.5	V	T_{ch} = –40°C	
		4.1	5.1	6.0		T_{ch} = 25°C	
		3.7	—	—		T_{ch} = 150°C	
Output clamp voltage (inductive load switch off)	$V_{on(CL)}$	37	48	62	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

3.5.3 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}					$K_{ILIS} = I_L/I_{IS}$, $I_{IS} < I_{IS,lim}$	
		15600	19000	22500		T_{ch} = –40°C	I_L = 20 A
		16100	19100	22300		T_{ch} = 25°C	
		16500	19200	22000		T_{ch} = 150°C	
		14200	18800	24100		T_{ch} = –40°C	I_L = 10 A
		15100	18800	22900		T_{ch} = 25°C	
		16300	19000	22500		T_{ch} = 150°C	
		10100	19000	34400		T_{ch} = –40°C	I_L = 4.0 A
		12200	19000	28200		T_{ch} = 25°C	
		14400	19000	23500		T_{ch} = 150°C	
Sense current offset current	$I_{IS,offset}$	—	—	60	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	$I_{IS,lim}$	2.5	5.0	8.4	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	$I_{IS(LL)}$	—	—	0.5	μA	I_{IN} = 0 A, T_{ch} = –40 to 150°C	
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, R_L = 1.0 Ω, I_{IS} = 85% K_{ILIS}	
Current sense settling time during on condition *1	$T_{sic(IS)}$	—	50	100	μs	T_{ch} = –40 to 150°C, I_L = 10 A ⎍ 20 A	

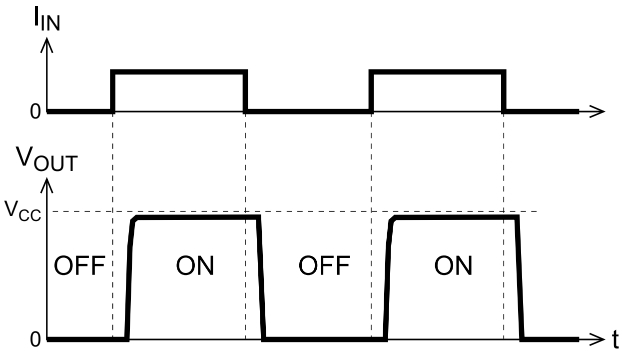
Note: *1 Not tested, specified by design

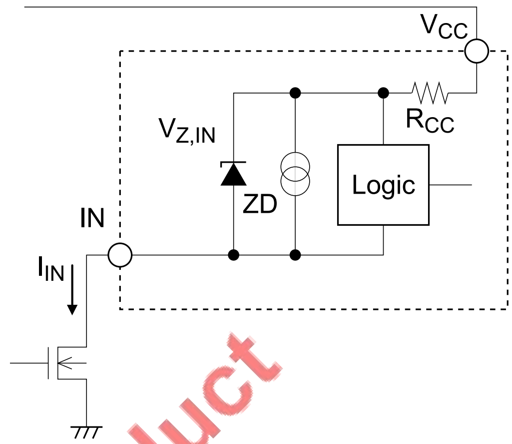
3.6 Function Description

3.6.1 Driving Circuit

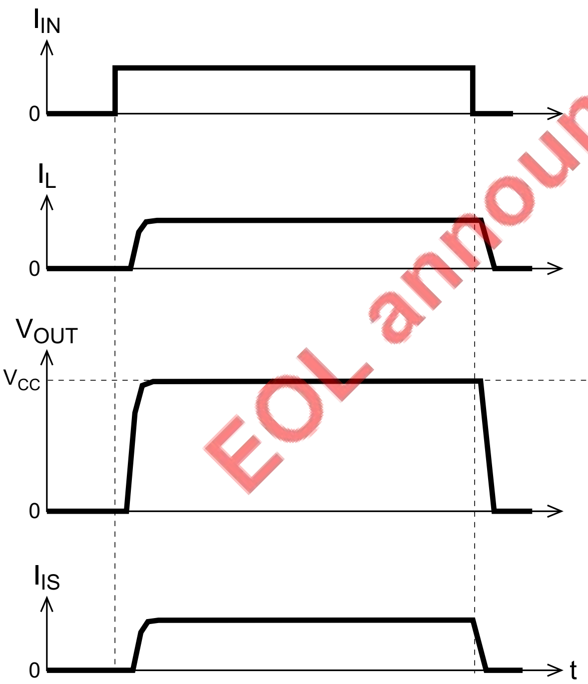
The driver output turns on, when the input pin is connected to ground through a low impedance path allowing a current of I_{IH}. The driver output turns off, when the input current gets below I_{IL}. For Input pin control circuit design when active reverse battery connection is needed, refer to paragraph 3.6.3.

R_{CC} is 100 Ω TYP. ESD protection diode: 46 V TYP.

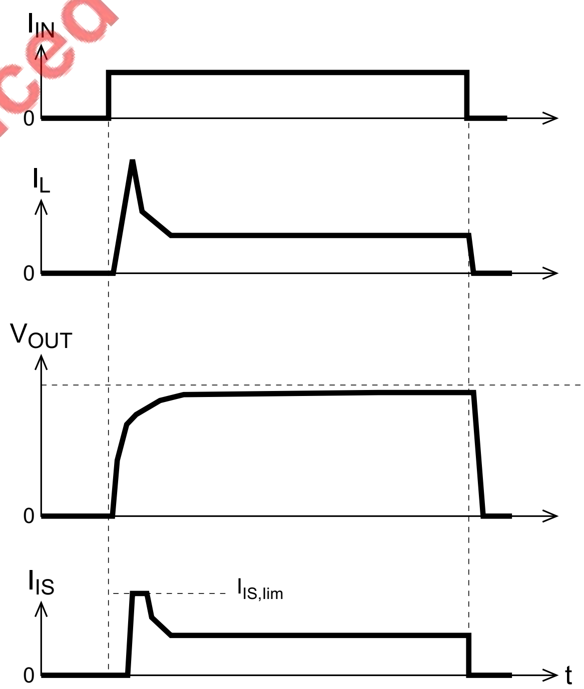




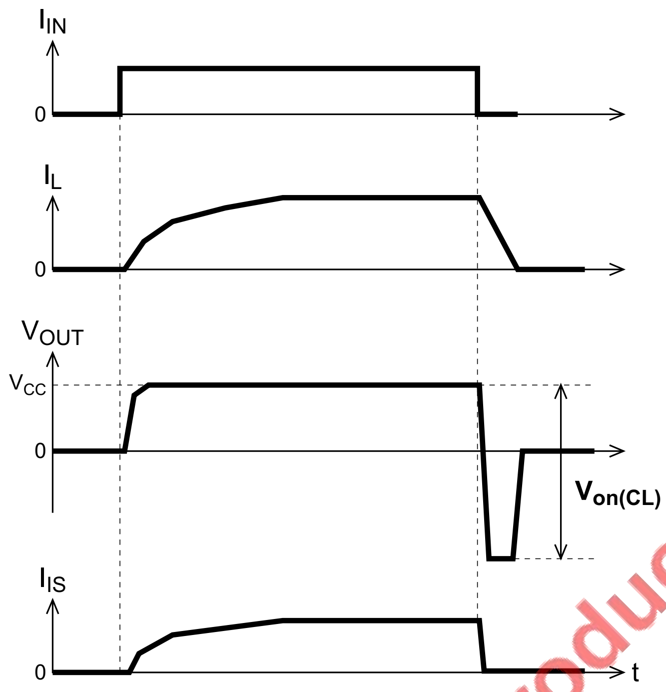
Switching a resistive load



Switching lamps



Switching an inductive load



Avalanche behavior at inductive load switch off

When an inductive load is switched off, the power MOS portion goes into avalanche behavior. Maximum allowable energy in avalanche behavior is specified in "Absolute Maximum Ratings" as E_{AS1}.

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

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

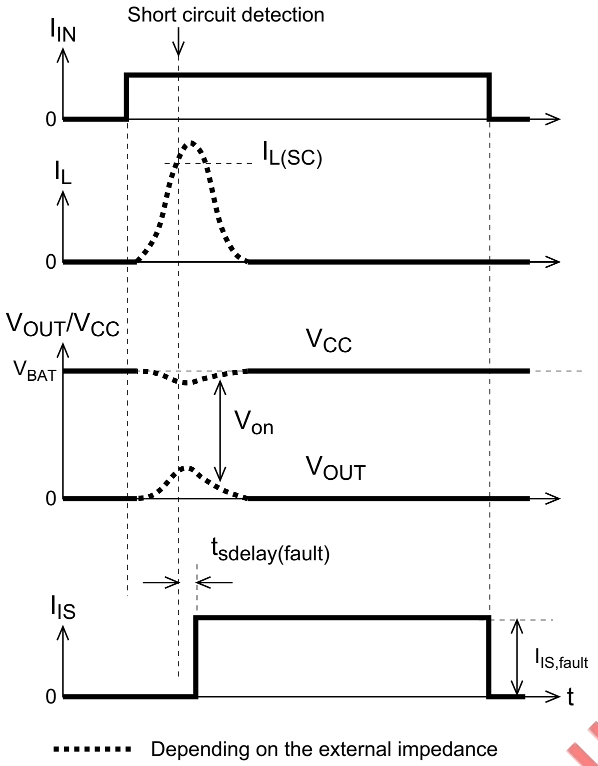
3.6.2 Short Circuit Protection

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

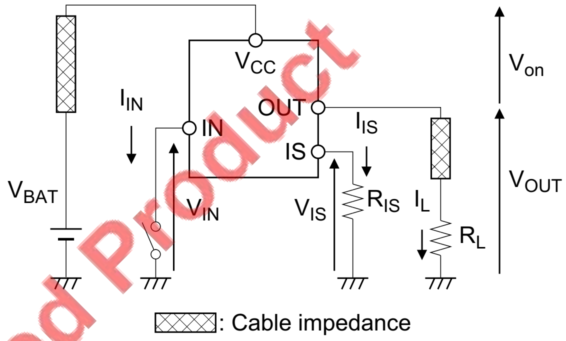
(a) $I_L > I_{L(SC)}$

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

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



(Evaluation circuit)

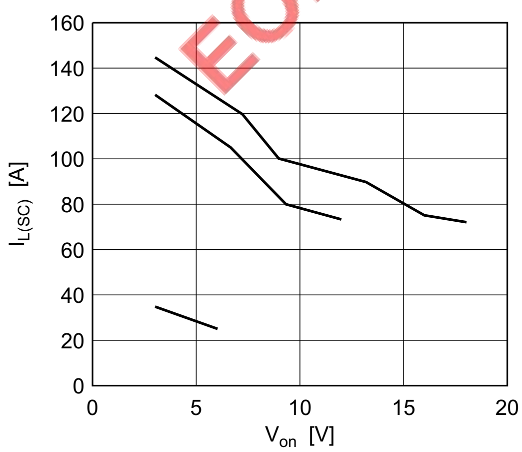


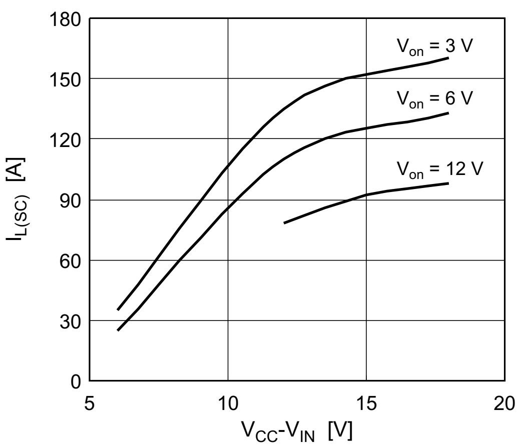
$t_{sdelay(fault)}$: Fault sense signal delay after short circuit detection

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

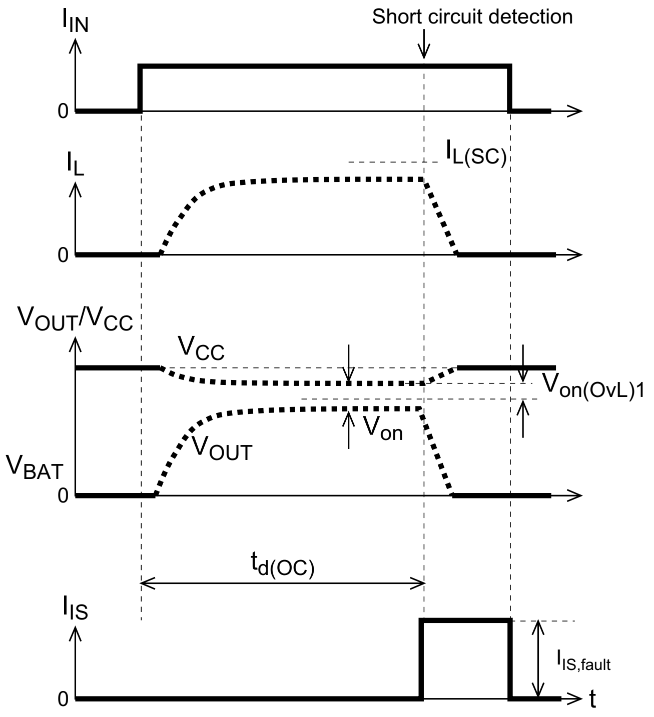
Typical short circuit detection current characteristics

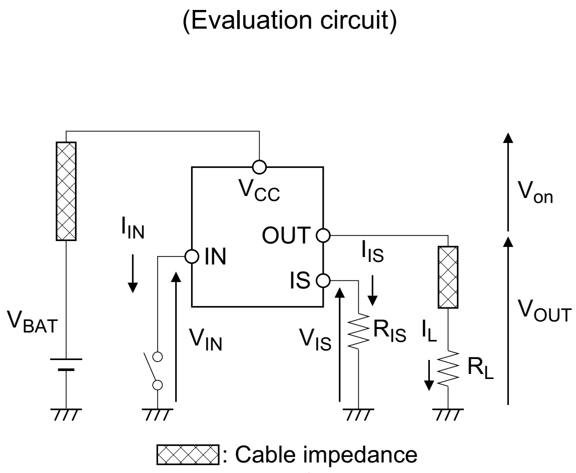
The short circuit detection current $I_{L(SC)}$ changes according to V_{CC} voltage and V_{on} voltage for the purpose of strengthening the robustness under short circuit conditions.





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





Depending on the external impedance

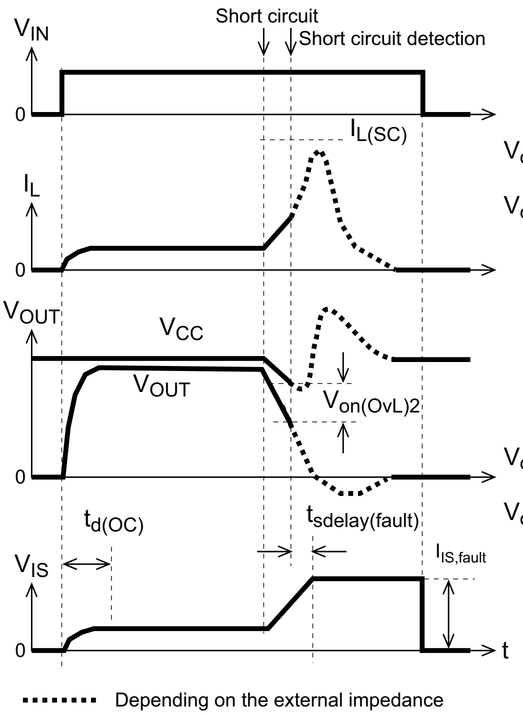
$t_{d(oc)}$: Turn-on check delay after input current positive slope

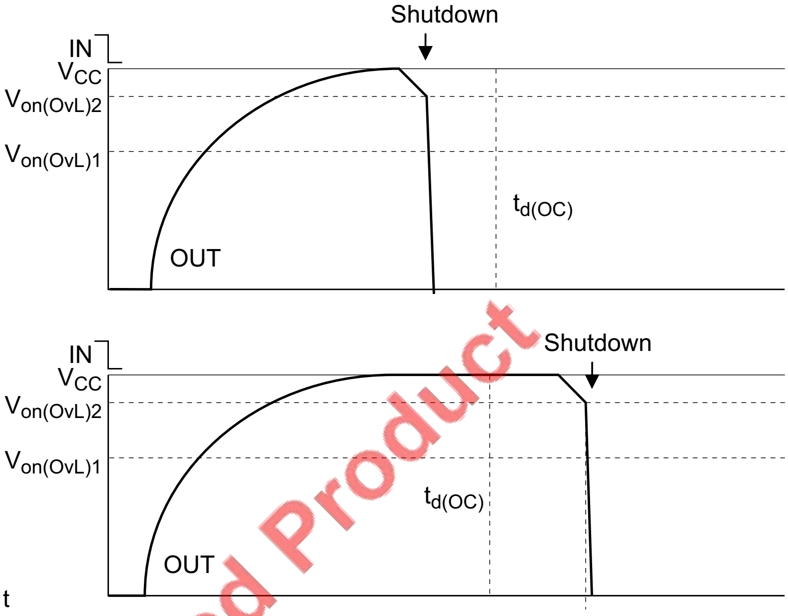
Case 2: Short circuit during on-condition

The device shuts down automatically when the following condition (a) is detected. Detection of value (a) is activated after $V_{on} < V_{on(OvL)2}$ with hysteresis between detection (a) value and activation of (a) value. The sense current is fixed at $I_{IS,fault}$. Shutdown is latched until the next reset via input.

(a) $V_{on} > V_{on(OvL)2}$ after $V_{on} < V_{on(OvL)2}$

Case 2-(a) $V_{on} > V_{on(OvL)2}$ after $V_{on} < V_{on(OvL)2}$



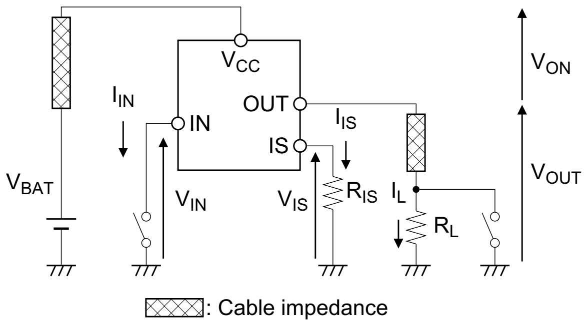


(Evaluation circuit)

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

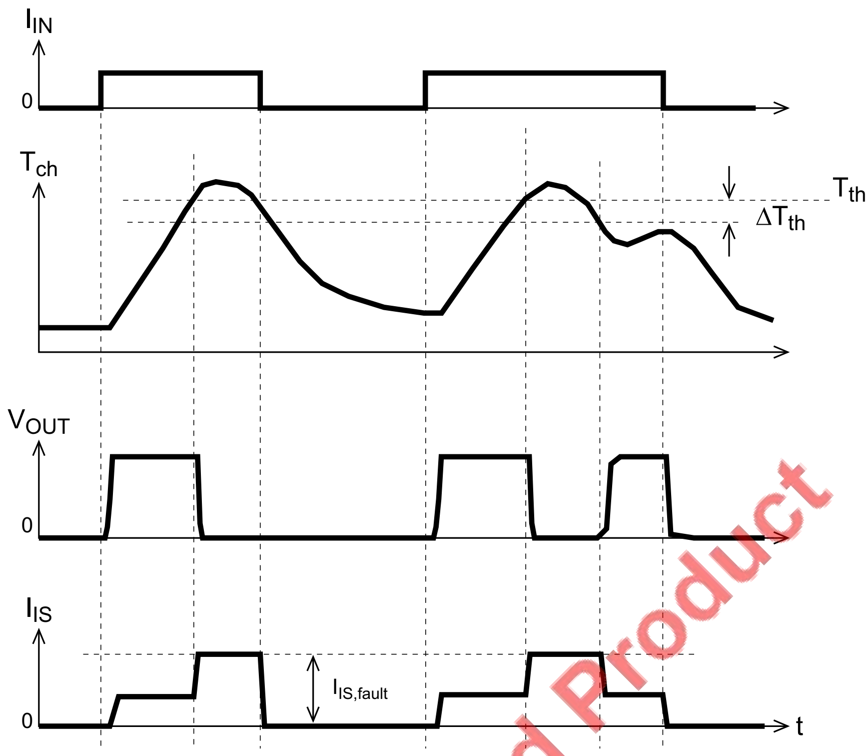
$t_{sdelay(fault)}$: Fault sense signal delay after short circuit detection

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



Over-temperature protection

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

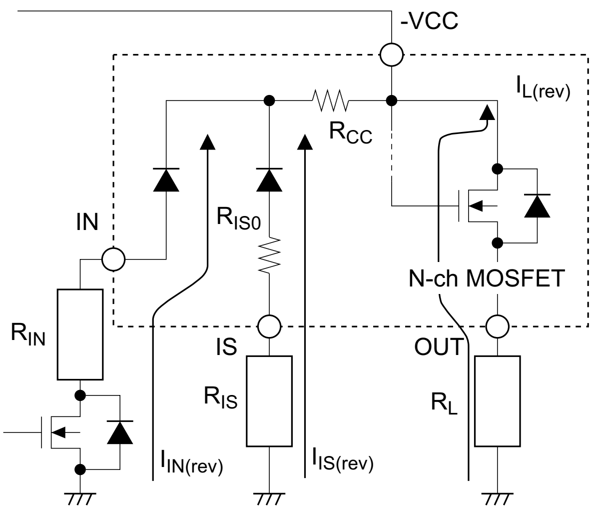


3.6.3 Power Dissipation under Reverse Battery Condition

In case of a reverse voltage is applied to the device, the N-Ch MOSFET will turn on only if a reverse current can flow from IN pin through R_{CC} and if $|V_{CC} – V_{IN}|$ voltage is in range of 8 V (TYP).

In above conditions, power dissipation in the driver is generated by N-Ch Mosfet as well as R_{CC} and R_{IS0}. The power dissipation in the N-Ch MOSFET depends on the load condition.

Overall power dissipation $P_{d(rev)}$ can be calculated as follow.



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

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

$$I_{IS(rev)} = (V_{CC} - V_f) / (R_{CC} + R_{IS0} + R_{IS})$$

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

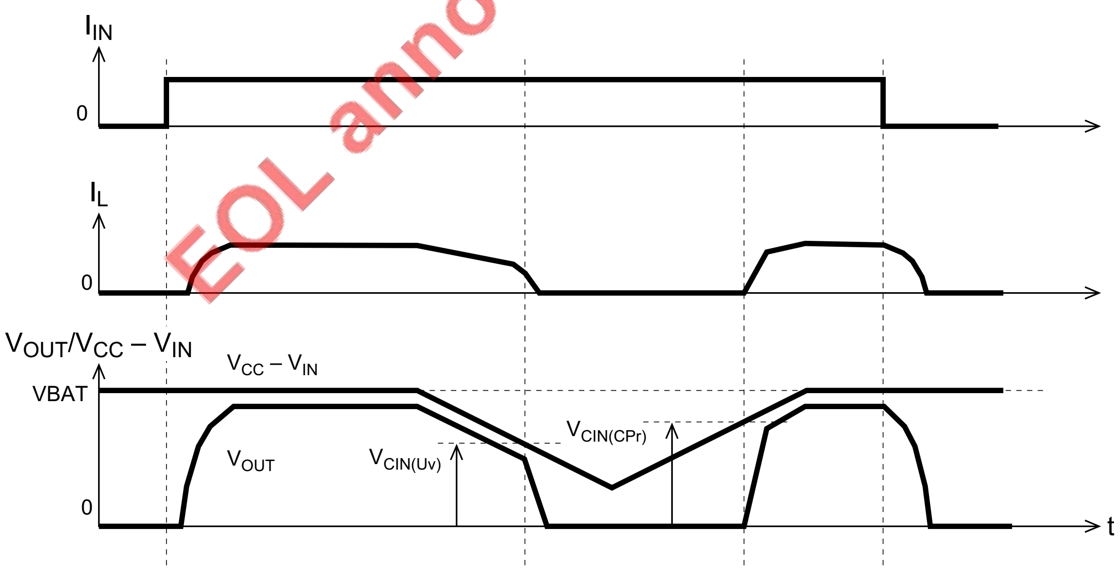
In order to turn on the N-ch MOSFET at reverse polarity condition, the voltage at IN should be around 8V by using a MOSFET or small diode in parallel to the input switch. R_{IN} should be estimated using the following formula.

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

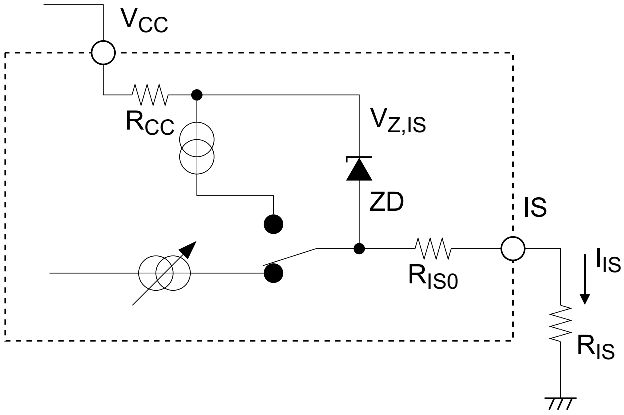
In case no current would flow from IN pin through R_{CC}, the N-Ch MOSFET will not turn-on. Then power dissipation mainly result from the body diode of the N-Ch MOSFET.

3.6.4 Device Behavior at Low Voltage Condition

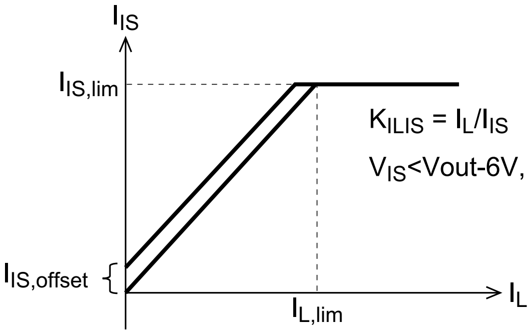
If the supply voltage ($V_{CC} – V_{IN}$) drops below $V_{CIN(Uv)}$, the device will shut off and will remain off until the supply voltage ($V_{CC} – V_{IN}$) recovers above $V_{CIN(CPr)}$.

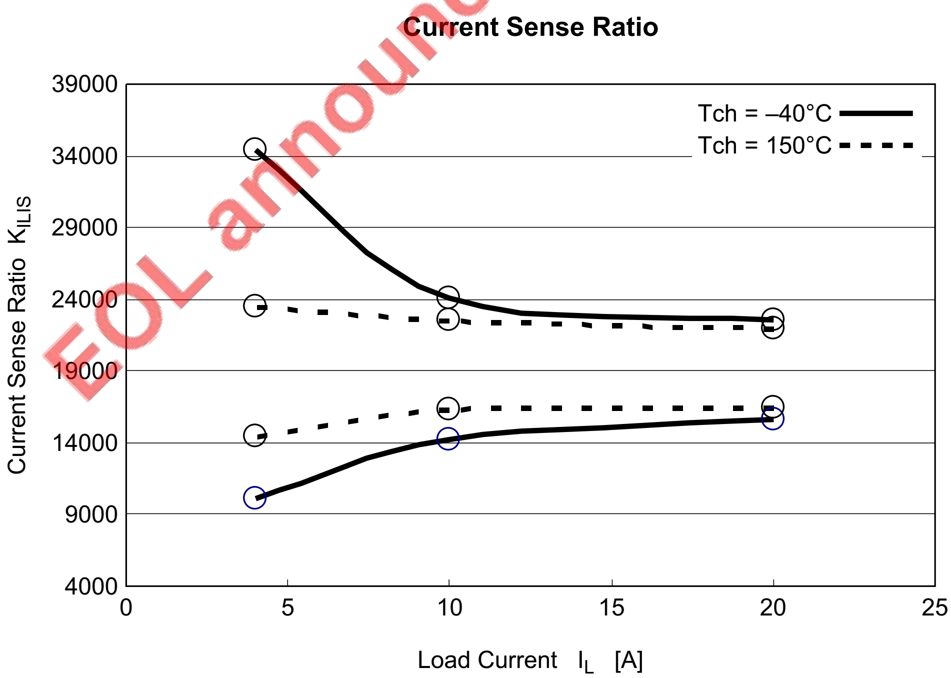


3.6.5 Current Sense Output



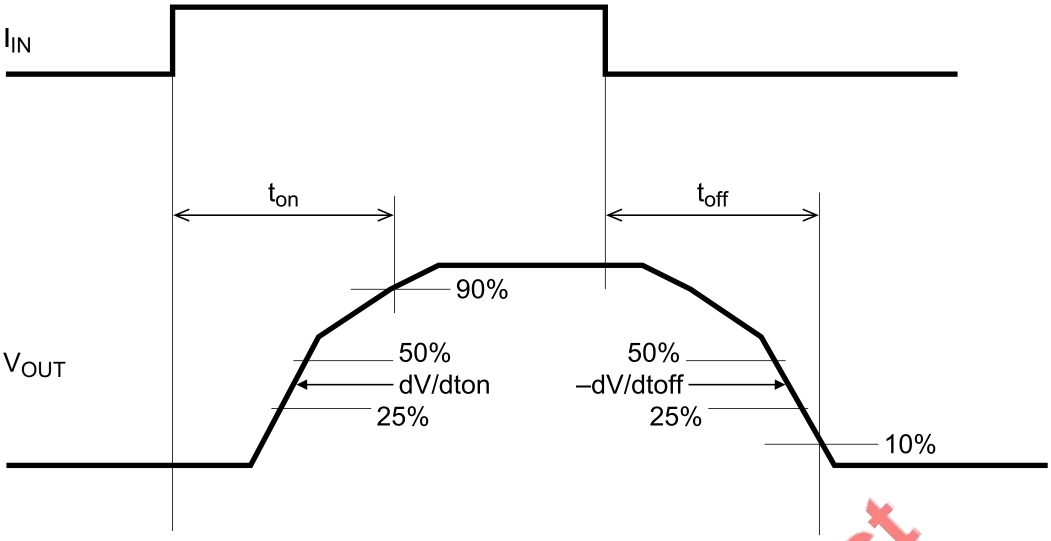
R_{CC} is 100 Ω (typ.), $V_{Z,IS}$ = 46 V (typ.), R_{IS} = 1 kΩ nominal.



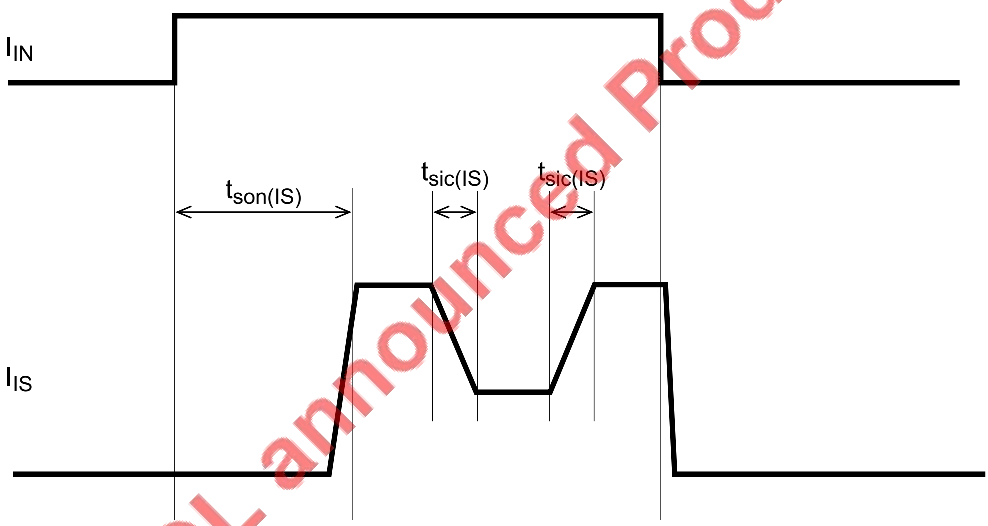


3.6.6 Measurement Condition

Switching waveform of OUT pin



Switching waveform of IS pin

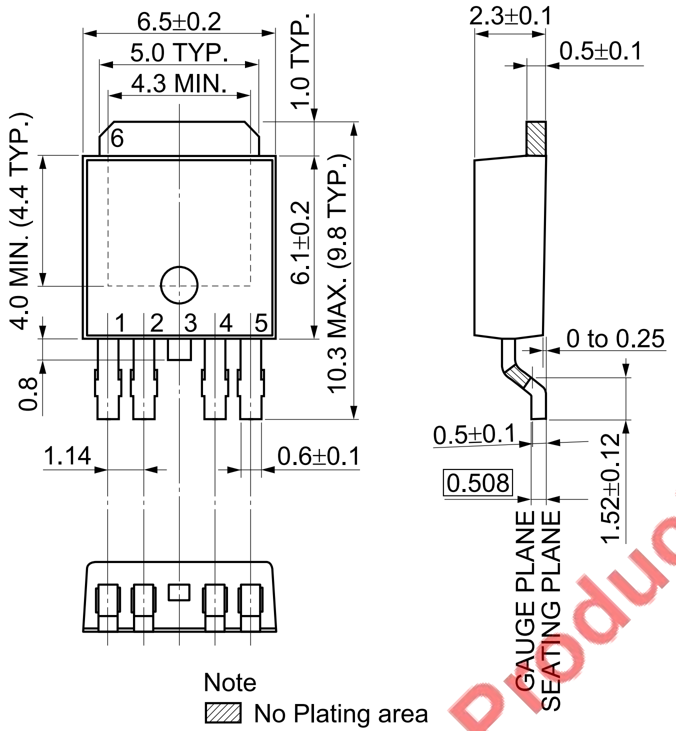


3.6.7 Truth Table

Input Current	State	Output	Sense Current
L	—	OFF	0 mA ($I_{IS(LL)}$)
H	Normal operation	ON	Nominal
	Over-temperature or Short circuit	OFF	$I_{IS,fault}$
	Open load	ON	$I_{IS,offset}$

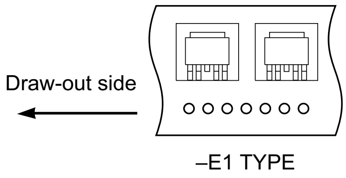
3.7 Package Drawings (Unit: mm)

3.7.1 5-pin TO-252 (MP-3ZK)



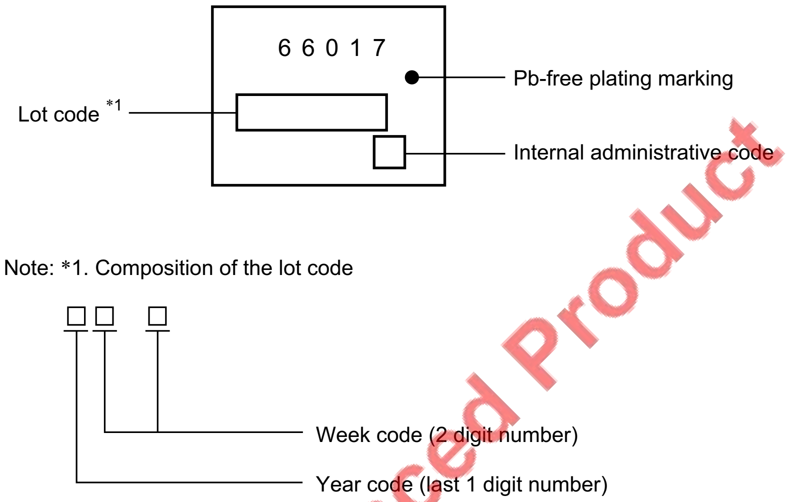
3.8 Taping Information

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



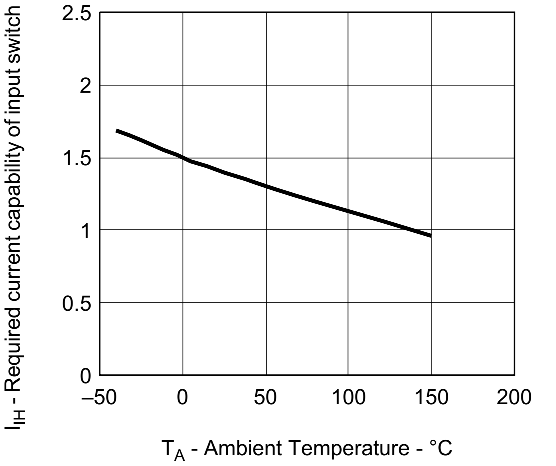
3.9 Marking Information

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

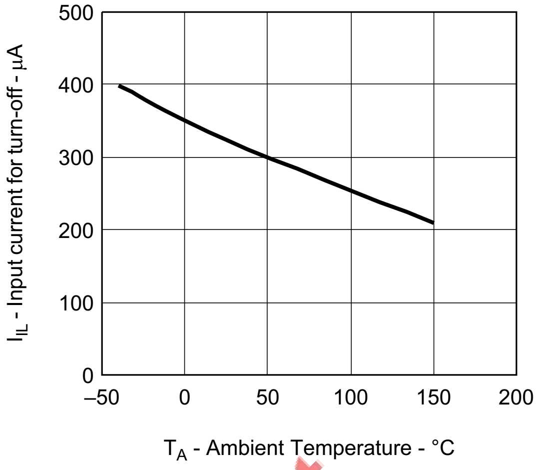


4. Typical Characteristics

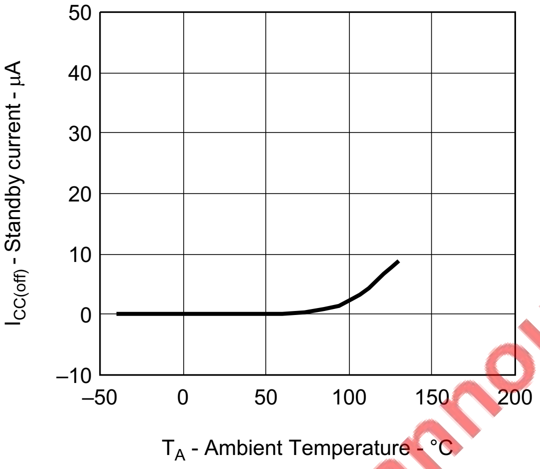
REQUIRED CURRENT CAPABILITY OF INPUT SWITCH
vs. AMBIENT TEMPERATURE



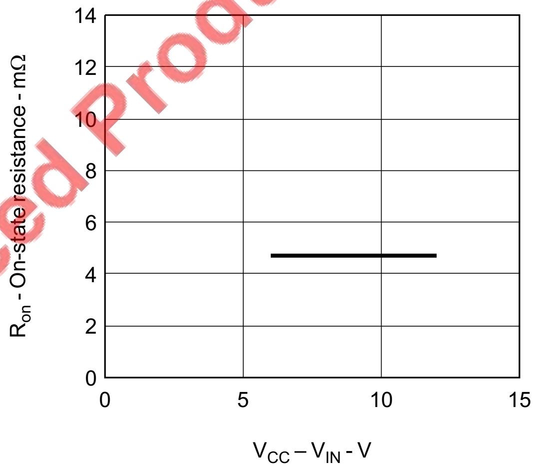
INPUT CURRENT FOR TURN OFF
vs. AMBIENT TEMPERATURE



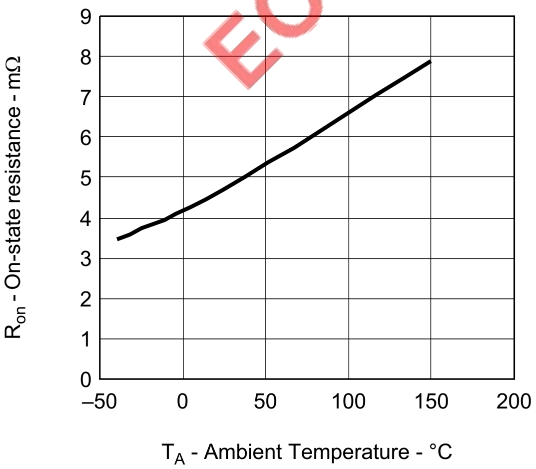
STANDBY CURRENT
vs. AMBIENT TEMPERATURE



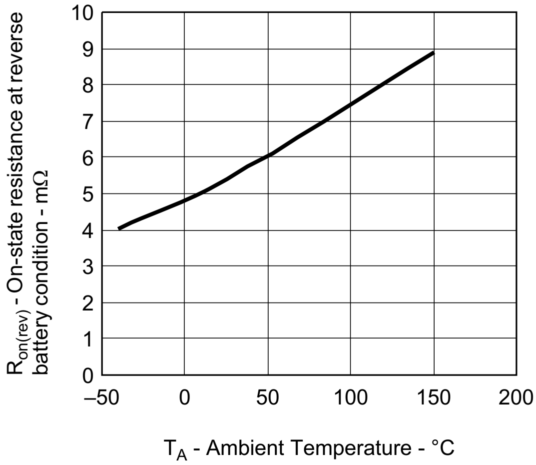
ON STATE RESISTENCE
vs. $V_{CC} - V_{IN}$ VOLTAGE

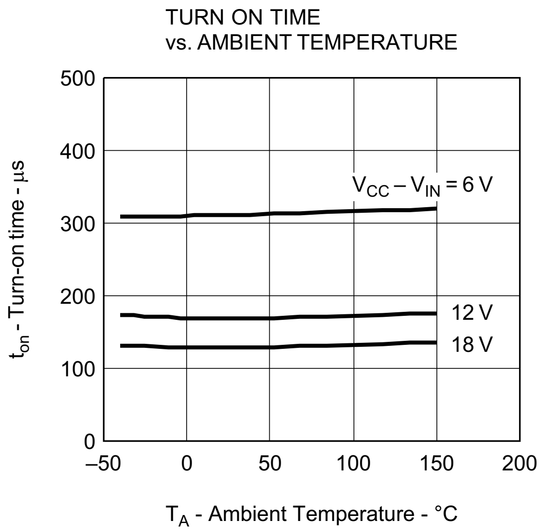


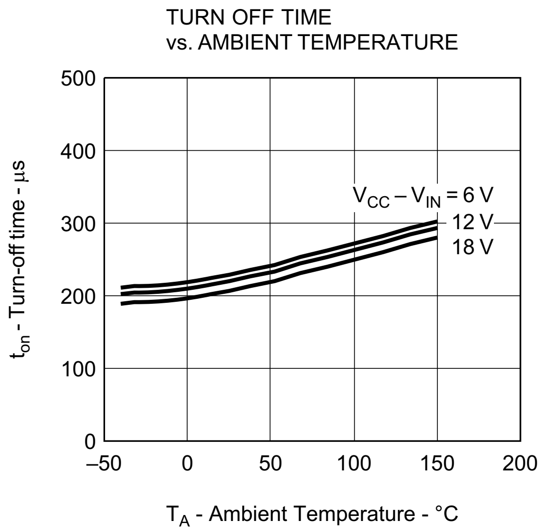
ON STATE RESISTENCE
vs. AMBIENT TEMPERATURE

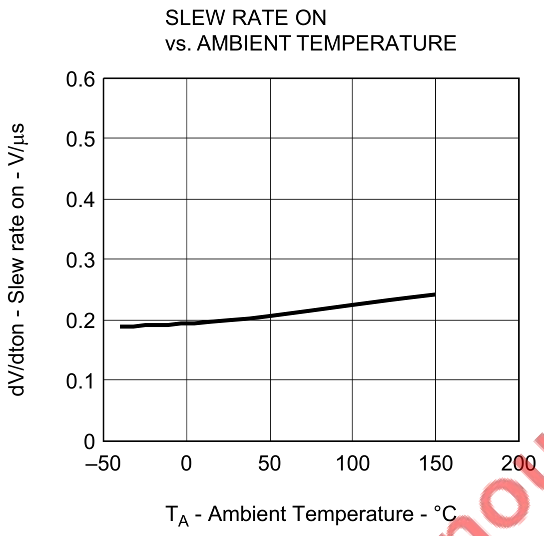


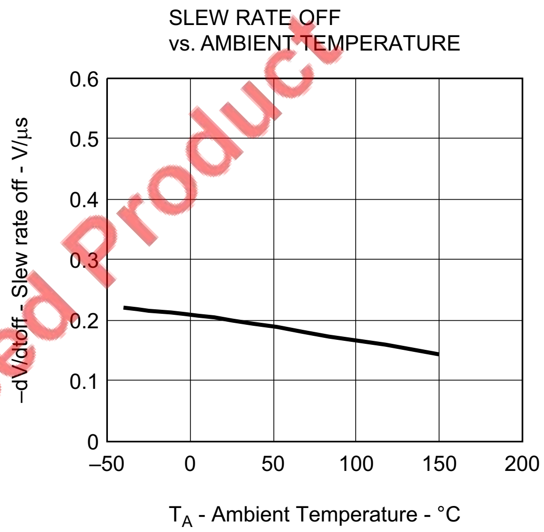
ON STATE RESISTENCE AT REVERSE BATTERY
CONDITION vs. AMBIENT TEMPERATURE

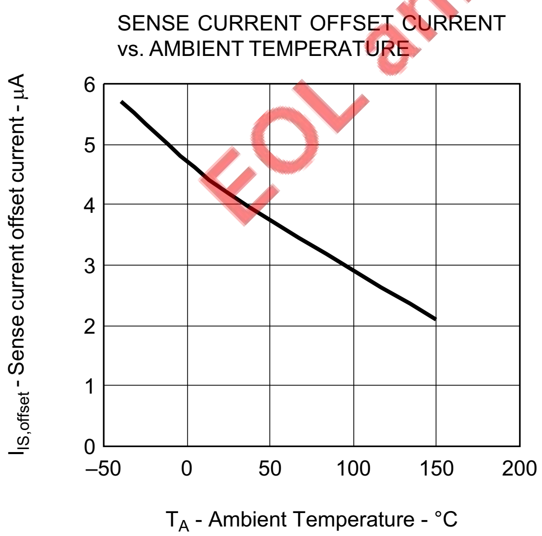


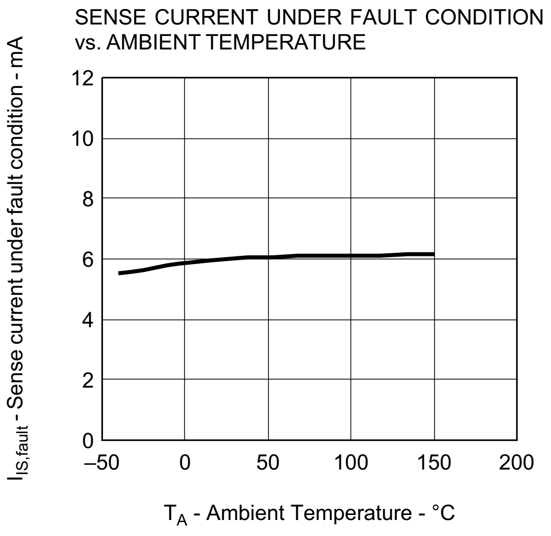

TURN ON TIME
vs. AMBIENT TEMPERATURE
t_on - Turn-on time - μs
VCC – VIN = 6 V
12 V
18 V
0
100
200
300
400
500
–50
0
50
100
150
200
TA - Ambient Temperature - °C

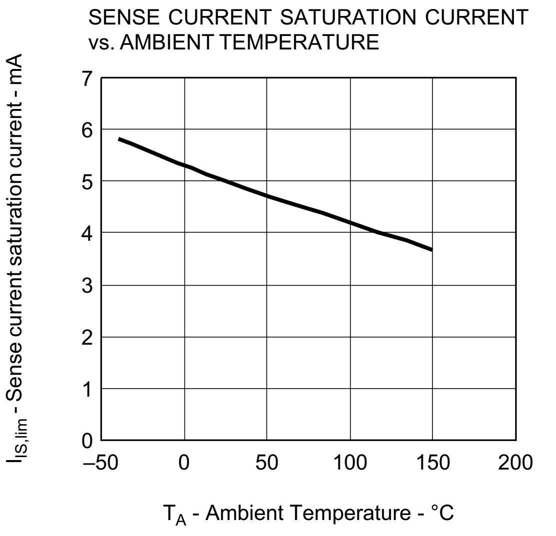

TURN OFF TIME
vs. AMBIENT TEMPERATURE
t_on - Turn-off time - μs
VCC – VIN = 6 V
12 V
18 V
0
100
200
300
400
500
–50
0
50
100
150
200
TA - Ambient Temperature - °C

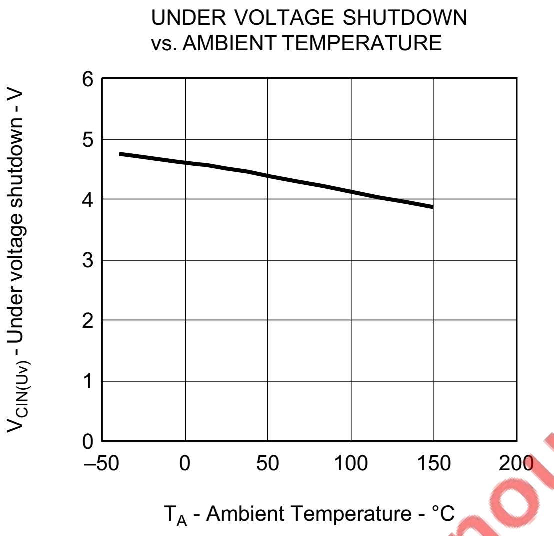

SLEW RATE ON
vs. AMBIENT TEMPERATURE
dV/dton - Slew rate on - V/μs
0
0.1
0.2
0.3
0.4
0.5
0.6
–50
0
50
100
150
200
TA - Ambient Temperature - °C

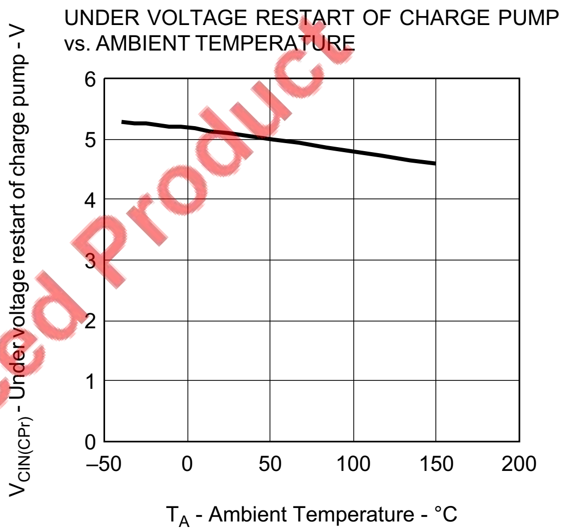

SLEW RATE OFF
vs. AMBIENT TEMPERATURE
–dV/dtoff - Slew rate off - V/μs
0
0.1
0.2
0.3
0.4
0.5
0.6
–50
0
50
100
150
200
TA - Ambient Temperature - °C


SENSE CURRENT OFFSET CURRENT
vs. AMBIENT TEMPERATURE
IIS,offset - Sense current offset current - μA
0
1
2
3
4
5
6
–50
0
50
100
150
200
TA - Ambient Temperature - °C


SENSE CURRENT UNDER FAULT CONDITION
vs. AMBIENT TEMPERATURE
$I_{IS,fault}$ - Sense current under fault condition - mA
12
10
8
6
4
2
0
–50
0
50
100
150
200
T_A - Ambient Temperature - °C

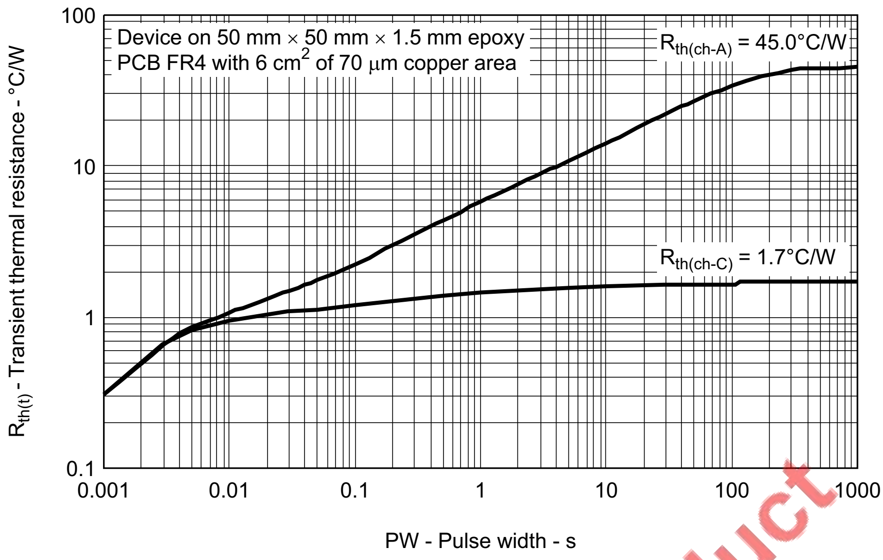

SENSE CURRENT SATURATION CURRENT
vs. AMBIENT TEMPERATURE
$I_{IS,lim}$ - Sense current saturation current - mA
7
6
5
4
3
2
1
0
–50
0
50
100
150
200
T_A - Ambient Temperature - °C


UNDER VOLTAGE SHUTDOWN
vs. AMBIENT TEMPERATURE
$V_{CIN(Uv)}$ - Under voltage shutdown - V
6
5
4
3
2
1
0
–50
0
50
100
150
200
T_A - Ambient Temperature - °C

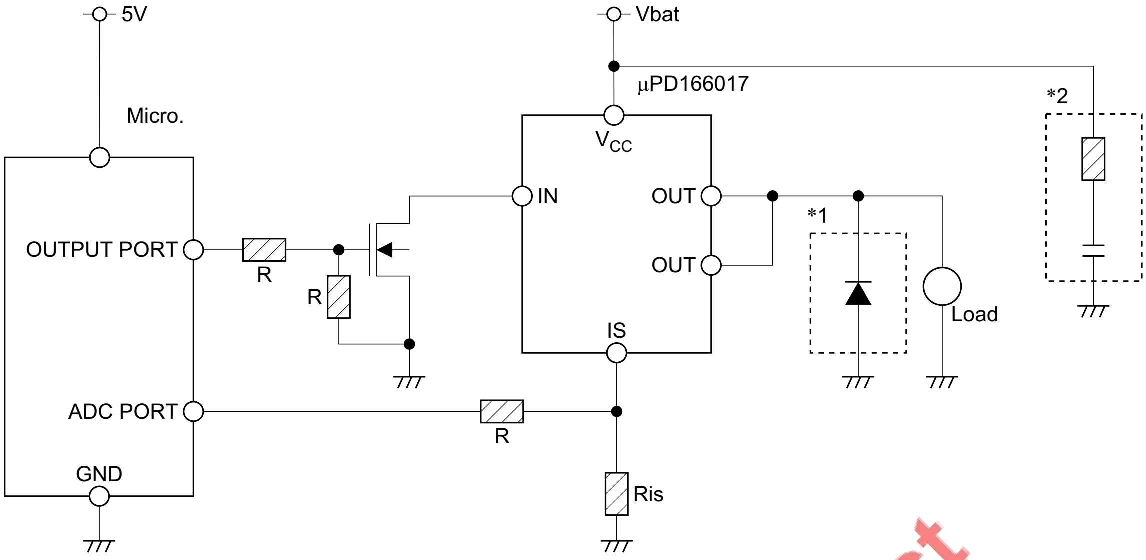

UNDER VOLTAGE RESTART OF CHARGE PUMP
vs. AMBIENT TEMPERATURE
$V_{CIN(CPr)}$ - Under voltage restart of charge pump - V
6
5
4
3
2
1
0
–50
0
50
100
150
200
T_A - Ambient Temperature - °C

5. Thermal Characteristics

TRANSIENT THERMAL RESISTANCE vs. PULSE WIDTH



6. Application Example in Principle



Notes: *1 A free wheel diode is necessary if one of below conditions is fulfilled:

a. μPD166017 is driving an inductive load and the energy dissipated in the driver during avalanche mode may exceed E_{AS1}.

b. The energy that may be dissipated at device turn-off in any type of load condition (i.e: nominal or overload) exceed E_{AS2}. It is recommended that user carefully consider the harness conditions in the target application.

*2 When no freewheel diode is used in parallel to the driver load and to prevent oscillation of the V_{CC} voltage during turn-off at high load current, a snubber [R,C] circuit must be connected between V_{CC} and GND as shown on application schematic.

Recommended value of R: 10 Ω / 5% 0, 125 W

Recommended value of C: 0.25 μF / 50 V Ceramic capacitor

Revision History	μPD166017T1F Data Sheet

Rev.	Date	Description	
		Page	Summary
1.00	Apr 26, 2012	—	First Edition Issued

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