

μPD166013T1J

INTELLIGENT POWER DEVICE

 R07DS0852EJ0100
 Rev.1.00
 Aug 20, 2012

1. Overview

1.1 Description

Dual 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
- Loss of ground protection
- Under voltage lock out
- Active clamp operation at inductive load switch off
- AEC Qualified
- RoHS compliant with pure tin plating

1.3 Application

- Light bulb (~27 W) switching
- Switching of all types of 14 V DC grounded loads, such as LED, inductor, resistor and capacitor

2. Ordering Information

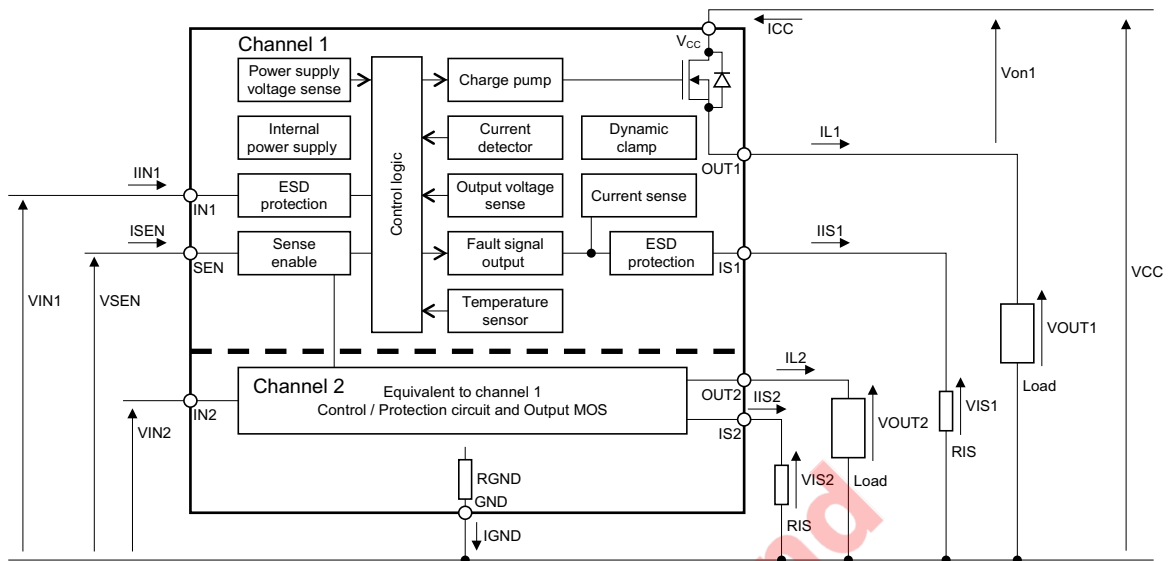
Part No.	Lead Plating	Packing	Package
μPD166013T1J-E1-AY *1	Pure Mate Sn	Tape 1500 p/reel	12-pin Power HSSOP (PRSP0013FA-A)

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

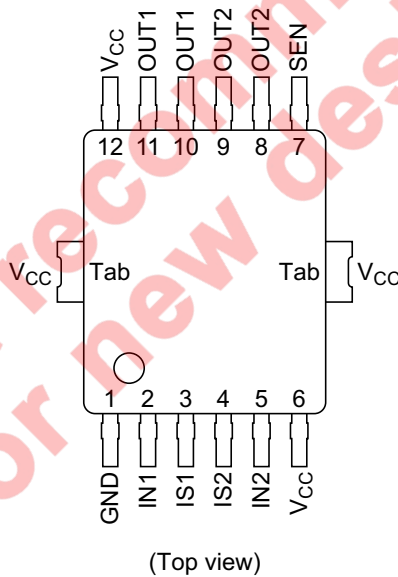
Note: The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.

3. Specification

3.1 Block Diagram



3.2 Pin Arrangement



3.2.1 Pin Function

Pin Name	Pin Function	Recommended Connection
GND	Ground connection	Connected to GND
INn	Input signal for channel n (n = 1 to 2)	Connected to MCU port through 2 k-10 k serial resistor
ISn	Current sense and Diagnosis output signal channel n (n = 1 to 2)	Connected to GND through a 2 k-5 k resistor
SEN	Sense enable input	Connected to MCU port through 2 k-10 k serial resistor
OUTn	Protected high-side power output channel n (n = 1 to 2)	Connected to load with small 50-100 nF capacitor in parallel
V _{CC}	Positive power supply for logic supply as well as output power supply	Connected to battery voltage with small 100 nF capacitor in parallel

3.3 Absolute Maximum Ratings

($T_A = 25^\circ\text{C}$, unless otherwise specified)

Parameter	Symbol	Rating	Unit	Test Conditions	
V_{CC} voltage	V_{CC1}	28	V		
V_{CC} voltage at reverse battery condition	V_{CC2}	-16	V	At nominal load current.	
V_{CC} voltage for full short circuit protection	V_{CC3}	28	V		
V_{CC} voltage under load dump condition	V_{CC4}	40	V	$R_I = 1 \Omega$, $R_L = 6.8 \Omega$, $R_{IS} = 2 \text{ k}\Omega$, $t_d = 400 \text{ ms}$	
Load current	I_L	Self limited	A		
Total power dissipation for whole device (DC)	P_D	2.0	W	$T_A = 85^\circ\text{C}$, Device on $50 \text{ mm} \times 50 \text{ mm} \times 1.5 \text{ mm}$ epoxy PCB FR4 with 6 cm^2 of $70 \mu\text{m}$ copper area	
Voltage at IN pin	V_{IN}	-0.5 to 10	V	$V_{CC} = 9 \text{ V to } 16 \text{ V}$	
		V_{CC2} to 0		$R_{IN} = 2 \text{ k}\Omega$, At reverse battery condition, $t < 2 \text{ min.}$	
Voltage at SEN pin	V_{SEN}	-0.5 to 10	V	$V_{CC} = 9 \text{ V to } 16 \text{ V}$	
		V_{CC2} to 0		$R_{SEN} = 2 \text{ k}\Omega$, At reverse battery condition, $t < 2 \text{ min.}$	
Voltage at IS pin	V_{IS}	-0.5 to $V_{CC} + 0.5$	V	$V_{CC} = 9 \text{ V to } 16 \text{ V}$	
		V_{CC2} to 0		$R_{IS} = 2 \text{ k}\Omega$, At reverse battery condition, $t < 2 \text{ min.}$	
Inductive load switch-off energy dissipation single pulse	E_{AS}	17	mJ	$V_{CC} = 13.5 \text{ V}$, $I_L = 2.0 \text{ A}$, $T_{ch,start} < 150^\circ\text{C}$	
Maximum allowable energy under short circuit condition	$E_{AS(SC)}$	40	mJ	$V_{CC} = 18 \text{ V}$, $T_{ch,start} < 150^\circ\text{C}$, $R_{supply} = 10 \text{ m}\Omega$, $R_{short} = 50 \text{ m}\Omega$ $L_{supply} = 5 \mu\text{H}$, $L_{short} = 15 \mu\text{H}$	
Channel temperature	T_{ch}	-40 to +150	$^\circ\text{C}$		
Dynamic temperature increase while switching	ΔT_{ch}	60	$^\circ\text{C}$		
Storage temperature	T_{stg}	-55 to +150	$^\circ\text{C}$		
ESD susceptibility	V_{ESD}	2000	V	HBM	AEC-Q100-002 std. $R = 1.5 \text{ k}\Omega$, $C = 100 \text{ pF}$
		200	V	MM	AEC-Q100-003 std. $R = 0 \Omega$, $C = 200 \text{ pF}$

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

3.4 Thermal Characteristics

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions	
Thermal characteristics	$R_{th(ch-a)}$	—	30	—	$^\circ\text{C/W}$	All channel	Device on $50 \text{ mm} \times 50 \text{ mm} \times 1.5 \text{ mm}$ epoxy PCB FR4 with 6 cm^2 of $70 \mu\text{m}$ copper area
	$R_{th(ch-c)}$	—	2.4	—	$^\circ\text{C/W}$	All channel	

3.5 Electrical Characteristics

3.5.1 Operation Function

($T_{ch} = -40$ to 150°C , $V_{CC} = 9$ to 16 V, unless otherwise specified)

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions
Operating voltage	V_{CC}	5.5	—	28	V	$V_{IN} = 4.5$ V, $V_{on} < 0.5$ V, $R_L = 12$ Ω
Operating current per channel	I_{GND}	—	2.5	5.5	mA	one channel
		—	5.0	10		all channel
Standby current	$I_{CC(off)}$	—	0.1	1.0	μA	$T_{ch} = 25^{\circ}\text{C}$
		—	—	8.0		$T_{ch} = 125^{\circ}\text{C}$
		—	—	24		$T_{ch} = -40$ to 150°C
On state resistance per channel	R_{on}	—	45	60	mΩ	$I_L = 2.5$ A, $T_{ch} = 25^{\circ}\text{C}$
		—	90	115		$I_L = 2.5$ A, $T_{ch} = 150^{\circ}\text{C}$
Output voltage drop limitation at small load current	$V_{on(NL)}$	—	50	—	mV	$I_L < 0.5$ A
Output clamp	$V_{on(CL)}$	20	24	28	V	$V_{CC} = 13.5$ V, $I_L = 40$ mA
Output leakage current per channel	$I_{L(OFF)}$	—	—	5	μA	$V_{IN} = 0$ V
Input resistance *1	R_{IN}	—	100	—	Ω	
Low level input voltage	V_{IL}	-0.3	—	1.0	V	
High level input voltage	V_{IH}	3.0	—	10	V	
Low level input current	I_{IL}	2	—	30	μA	$V_{IN} = 0.4$ V
High level input current	I_{IH}	5	—	75	μA	$V_{IN} = 5$ V
Sense enable input resistance *1	R_{SEN}	—	100	—	Ω	
Sense enable low level input voltage	V_{SENL}	-0.3	—	1.0	V	
Sense enable high level input voltage	V_{SENH}	3.0	—	10	V	
Sense enable low level input current	I_{SENL}	2	—	30	μA	$V_{SEN} = 0.4$ V
Sense enable high level input current	I_{SENH}	5	—	75	μA	$V_{SEN} = 5$ V
Turn on delay time to 10% V_{CC}	$t_{d(on)}$	—	20	100	μs	$V_{CC} = 13.5$ V, $R_L = 6.8$ Ω
Turn off delay time to 90% V_{CC}	$t_{d(off)}$	—	130	350	μs	
Turn on time to 90% V_{CC}	t_{on}	—	50	150	μs	
Turn off time to 10% V_{CC}	t_{off}	—	130	400	μs	
Slew rate 30% to 70% V_{CC}	$dv/dton$	0.2	0.9	1.4	V/μs	
Slew rate 70% to 30% V_{CC}	$-dv/dtoff$	0.15	0.75	1.7	V/μs	
Energy at turn on	E_{on}	—	0.12	—	mJ	
Energy at turn off	E_{off}	—	0.12	—	mJ	

Note: *1 Not tested, specified by design

3.5.2 Protection Function

(T_{ch} = -40 to 150°C, V_{CC} = 9 to 16 V, unless otherwise specified)

Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions	
Short circuit detection current	I _{L5.5(SC)}	—	—	27.5	A	T _{ch} = -40°C	V _{CC} = 5.5 V, V _{on} = 5 V
		6	15	—		T _{ch} = 25°C	
		5	13	—		T _{ch} = 105°C	
		4	12	—		T _{ch} = 150°C	
	I _{L13.5(SC)}	—	—	55		T _{ch} = -40°C	V _{CC} = 13.5 V, V _{on} = 5 V
		21.25	38	—		T _{ch} = 25°C	
		16.5	32	—		T _{ch} = 105°C	
		14.75	28	—		T _{ch} = 150°C	
	I _{L16,5(SC)}	—	—	60		T _{ch} = -40°C	V _{CC} = 16 V, V _{on} = 5 V
		27.5	43	—		T _{ch} = 25°C	
		21.25	35	—		T _{ch} = 105°C	
		19	30	—		T _{ch} = 150°C	
Driving capability	Dr(capac)	400	—	—	mΩ	T _{ch} = 25°C, V _{CC} = 16 V	
		520	—	—		T _{ch} = 105°C, V _{CC} = 16 V	
		580	—	—		T _{ch} = 150°C, V _{CC} = 16 V	
Over load detection voltage 1	V _{on(OvL)1}	4.0	5.2	6.4	V		
Over load detection voltage 2	V _{on(OvL)2}	0.45	1	1.6	V		
Turn-on check delay after input signal positive slope	t _{d(OC)}	400	—	—	μs		
Thermal shutdown temperature	T _{th}	150	175	—	°C		
Thermal hysteresis	ΔT _{th}	—	10	—	°C		
Output voltage drop per channel in case of reverse battery condition	V _{ds(rev)}	—	0.8	0.85	V	T _{ch} = 25°C	I _L = -2.0 A, V _{CC} = -13.5 V
		—	0.61	0.66		T _{ch} = 150°C	
Reverse current through GND pin *1	-I _{GND}	—	90	—	mA	V _{CC} = -13.5 V	
Integrated resistor in GND line *1	R _{GND}	—	140	—	Ω		
Output current while GND disconnected *1	I _{L(GND)}	—	—	1	mA	I _{IN} = 0 A, I _{SEN} = 0 A, I _{GND} = 0 A, I _{IS} = 0 A	

Note: *1 Not tested, specified by design

3.5.3 Diagnosis Function

($T_{ch} = -40$ to 150°C , $V_{CC} = 9$ to 16 V, $V_{SEN} = 5$ V, unless otherwise specified)

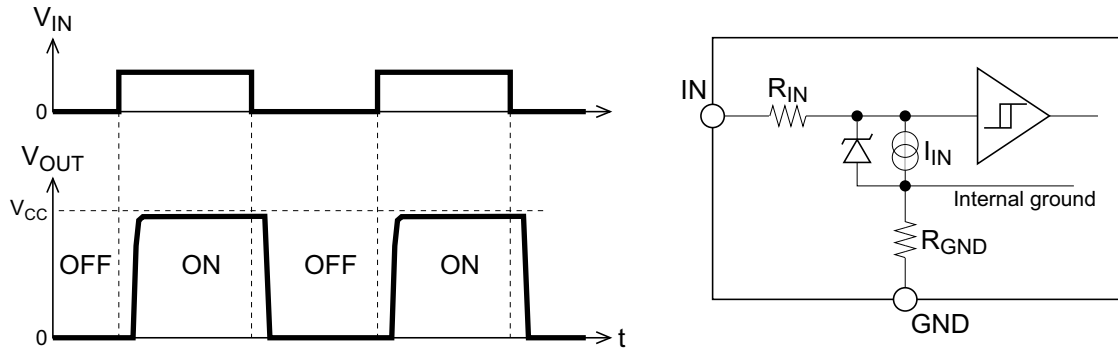
Parameter	Symbol	MIN.	TYP.	MAX.	Unit	Test Conditions		
Open load detection threshold at off-state	$V_{OUT(OL)}$	2.0	3.2	4.4	V	$V_{IN} = 0$ V		
Sense signal in case of fault condition	$V_{IS,fault}$	5.0	6.2	8.0	V	$V_{IN} = 0$ V, $I_{IS} = 2.5$ mA		
Sense signal current limitation	$I_{IS,lim}$	4	—	—	mA	$V_{IN} = 0$ V		
Sense signal invalid after negative input slope	$t_{d(fault)}$	—	—	1.2	ms	$V_{IN} = 5$ V to 0 V, $V_{OUT} = V_{CC}$		
Fault signal settling time	$t_{s(fault)}$	—	—	200	μs	$V_{IN} = 0$ V, $R_{IS} = 2$ kΩ, $V_{OUT} = 0$ to $>V_{OUT(OL)}$		
Current sense ratio	$K_{I,IS}$	2250	2525	2800		$T_{ch} = -40^{\circ}\text{C}$	$I_L = 4.0$ A	$V_{IN} = 5$ V
		2350	2535	2720		$T_{ch} = 25^{\circ}\text{C}$		
		2350	2500	2650		$T_{ch} = 150^{\circ}\text{C}$		
		2160	2580	3000		$T_{ch} = -40^{\circ}\text{C}$	$I_L = 2.2$ A	
		2230	2550	2870		$T_{ch} = 25^{\circ}\text{C}$		
		2250	2500	2750		$T_{ch} = 150^{\circ}\text{C}$		
		1950	2675	3400		$T_{ch} = -40^{\circ}\text{C}$	$I_L = 1.3$ A	
		2150	2600	3050		$T_{ch} = 25^{\circ}\text{C}$		
		2070	2510	2950		$T_{ch} = 150^{\circ}\text{C}$		
		2000	4600	7200		$T_{ch} = -40^{\circ}\text{C}$	$I_L = 40$ mA	
		2500	4700	6900		$T_{ch} = 25^{\circ}\text{C}$		
		1950	4825	7700		$T_{ch} = 150^{\circ}\text{C}$		
		Current sense voltage limitation	$V_{IS(lim)}$	5.0		6.2	8.0	V
Current sense leakage/offset current	$I_{IS(LH)}$	—	—	3	μA	$V_{IN} = 5$ V, $I_L = 0$ A		
Current sense leakage, while diagnostic disable	$I_{IS(dis)}$	—	—	5	μA	$V_{SEN} = 0$ V, $I_L = 3.5$ A		
Current sense settling time to IIS static $\pm 10\%$ after positive input slope ^{*1}	$t_{sIS(ON)}$	—	—	300	μs	$V_{IN} = 0$ to 5 V, $R_L = 6.8$ Ω, $R_{IS} = 5$ kΩ		
Current sense settling time to IIS static $\pm 10\%$ after change of load current ^{*1}	$t_{sIS(LC)}$	—	—	50	μs	$V_{IN} = 5$ V, $R_{IS} = 5$ kΩ, $I_L = 2$ A to 3.5 A		
Sense signal settling time	$t_{sIS(SEN)}$	—	—	10	μs	$V_{SEN} = 0$ V to 5 V, $V_{IN} = 0$ V, $R_{IS} = 5$ kΩ, $V_{OUT} > V_{OUT(OL)}$		
Sense signal deactivation time ^{*1}	$t_{dIS(SEN)}$	—	—	10	μs	$V_{SEN} = 5$ V to 0 V, $V_{IN} = 0$ V, $R_{IS} = 5$ kΩ, $V_{OUT} > V_{OUT(OL)}$		

Note: ^{*1} Not tested, specified by design

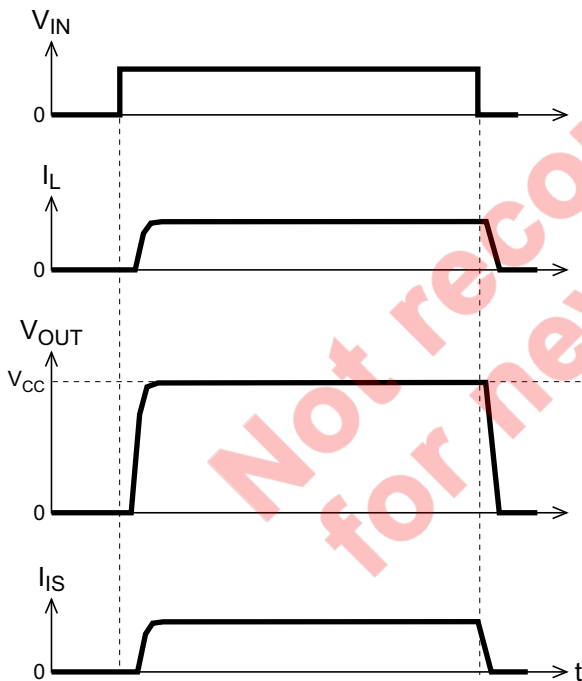
3.6 Function Description

3.6.1 Driving Circuit

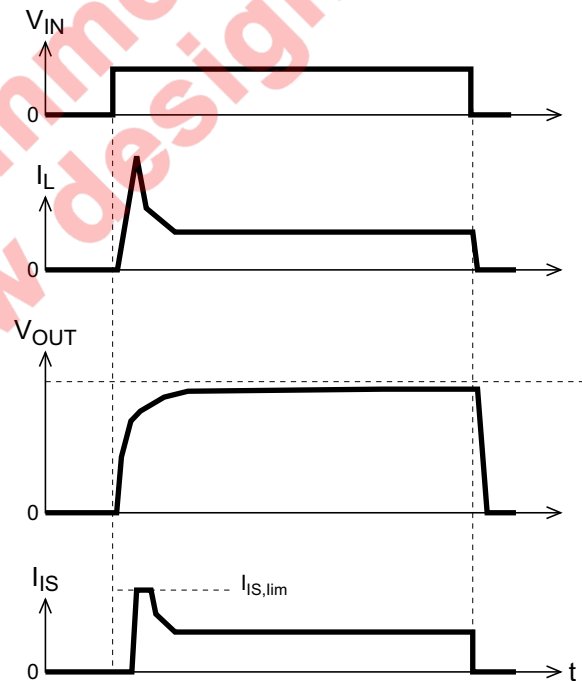
The high-side output is turned on, if the input pin is over V_{IH} . The high-side output is turned off, if the input pin is open or the input pin is below V_{IL} . Threshold is designed between V_{IH} min and V_{IL} max with hysteresis. IN pin is pulled down with constant current source.



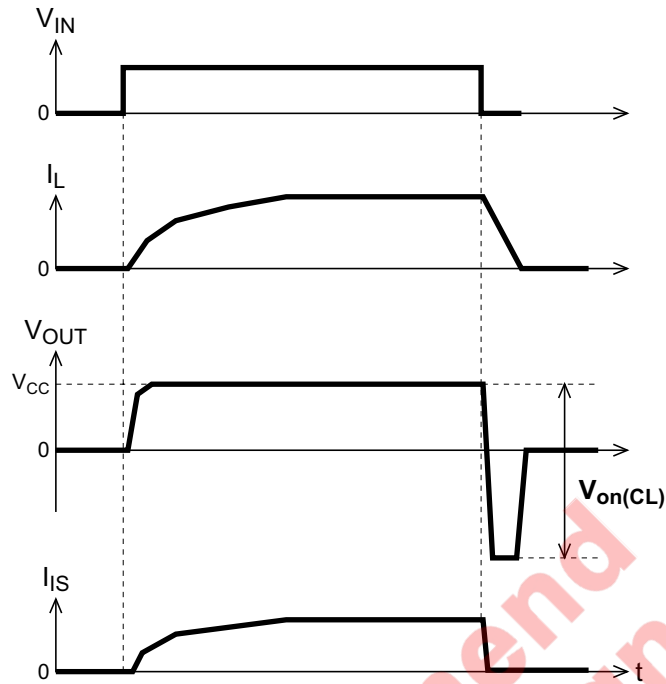
Switching a resistive load



Switching lamps



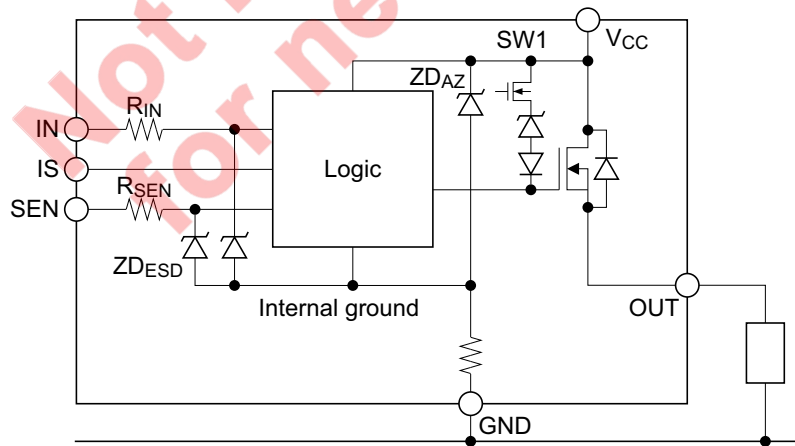
Switching an inductive load



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. 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.



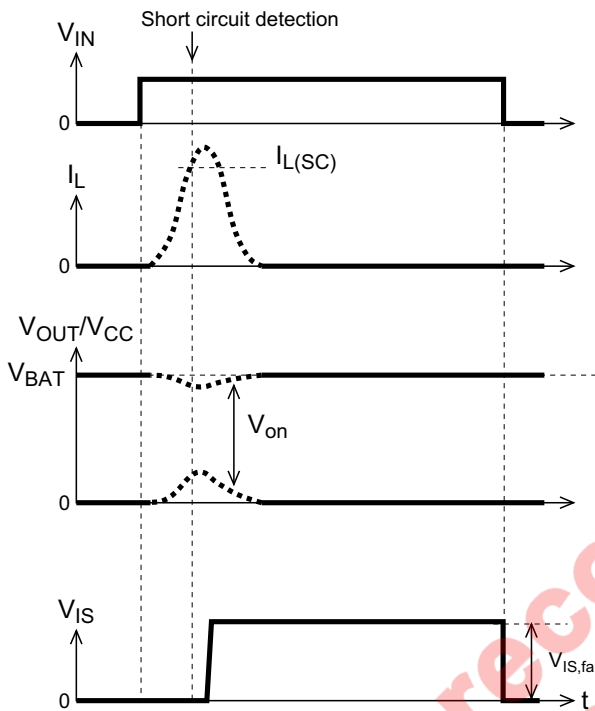
3.6.2 Short Circuit Protection

Case 1: IN pin is high 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 signal is fixed at $V_{IS, fault}$. Shutdown is latched until the next reset via input. The device shuts down automatically when condition (c) is detected with auto restart by cooling down.

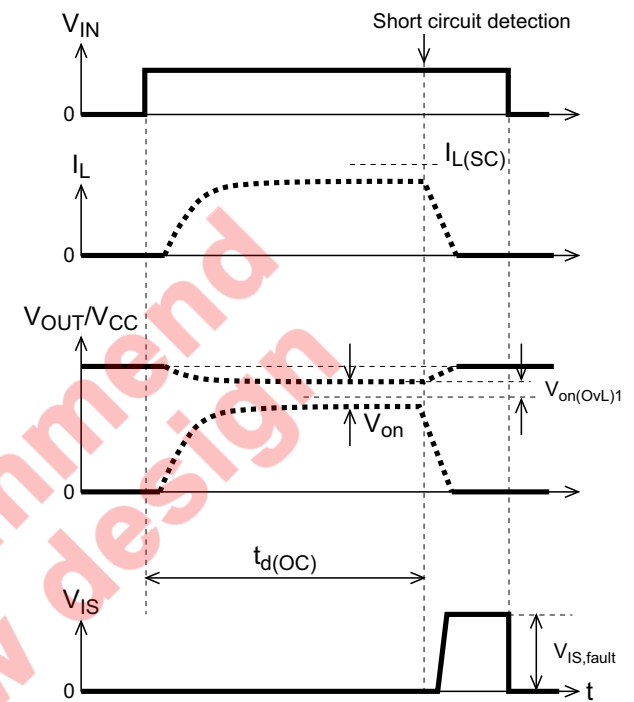
- (a) $I_L > I_{L(SC)}$
- (b) $V_{on} > V_{on(OvL)1}$ after $t_{d(OC)}$
- (c) $T_{ch} > T_{th}$

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



..... Depending on the external impedance

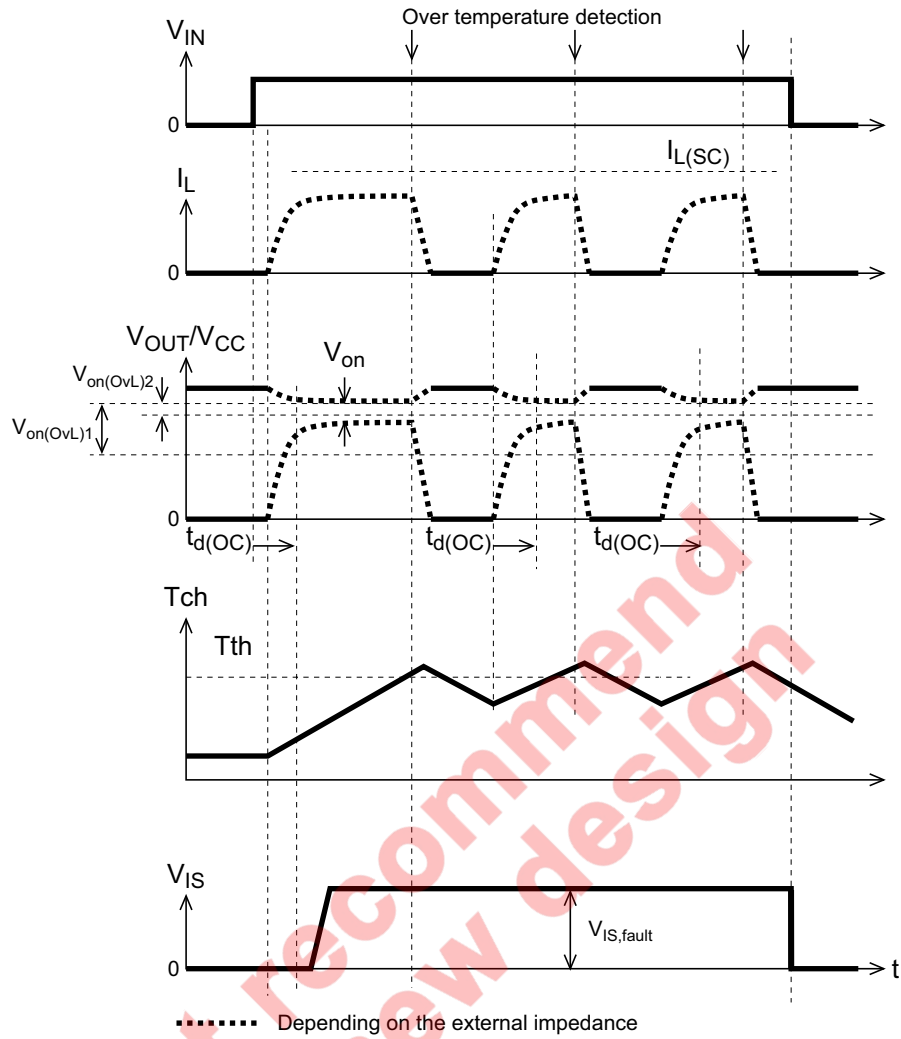
Case 1-(b) $V_{on} > V_{on(OvL)1}$ after $t_{d(OC)}$



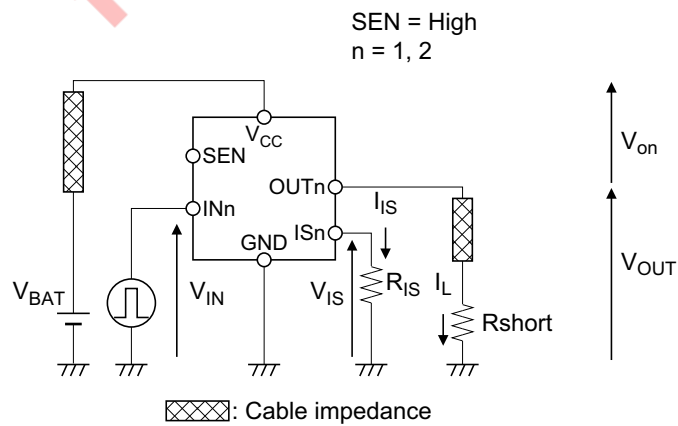
..... Depending on the external impedance

Not recommended for new designs

Case1-(c) $T_{ch} > T_{th}$



(Evaluation circuit)

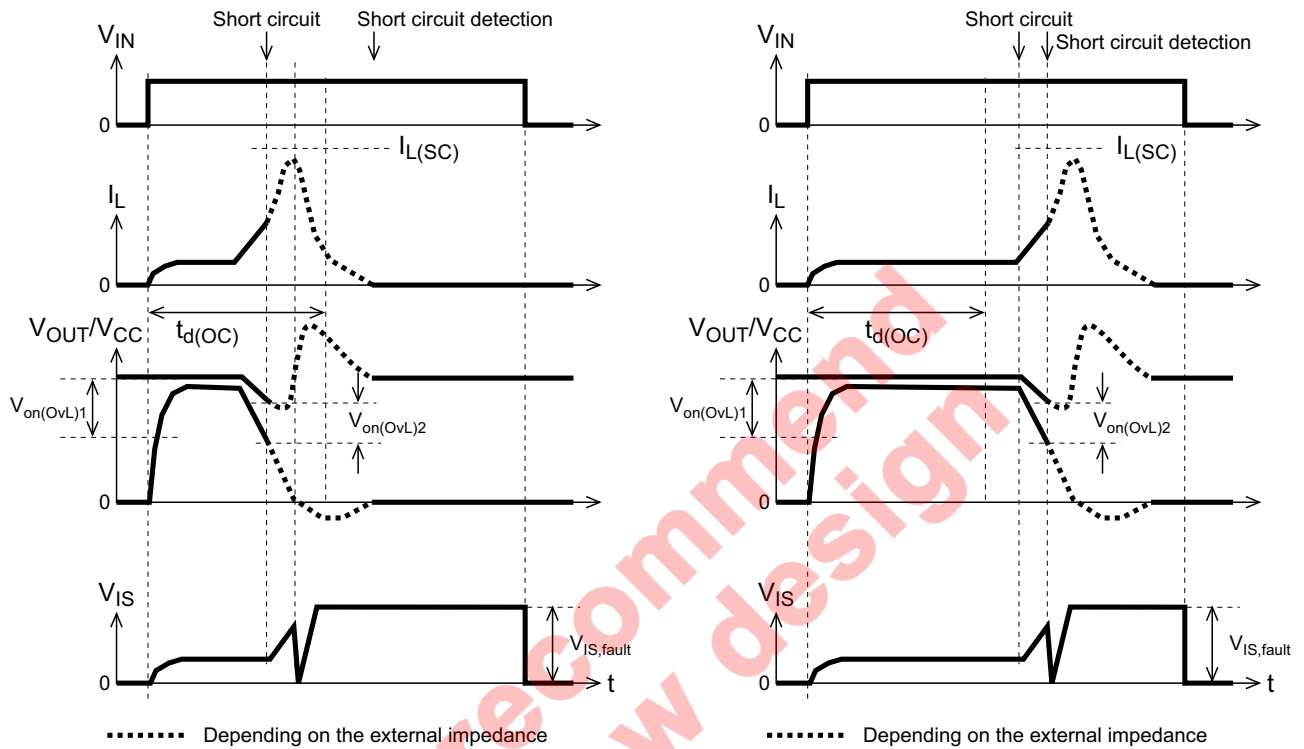


Case 2: Short circuit during on-condition

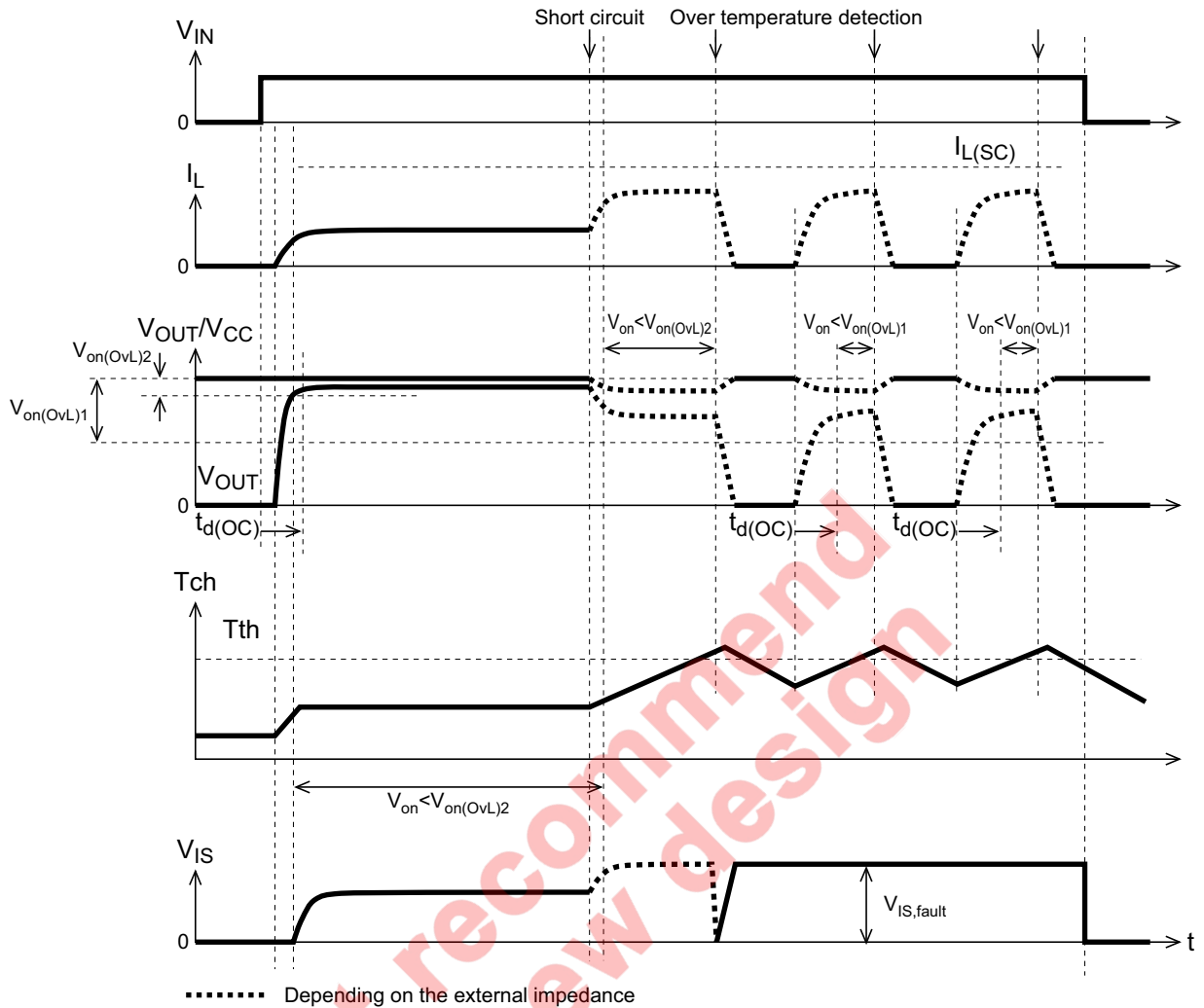
The device shuts down automatically when either or both of following conditions (a) is detected. Detection (a) value is activate after $V_{on(OvL)2}$. There is hysteresis between detection (a) value and activate (a) value. The sense signal is fixed at $V_{IS, fault}$. Shutdown is latched until the next reset via input. The device shuts down automatically when condition (b) is detected with auto restart by cooling down.

- (a) $V_{on} > V_{on(OvL)2}$ after $V_{on} < V_{on(OvL)2}$
- (b) $T_{ch} > T_{th}$

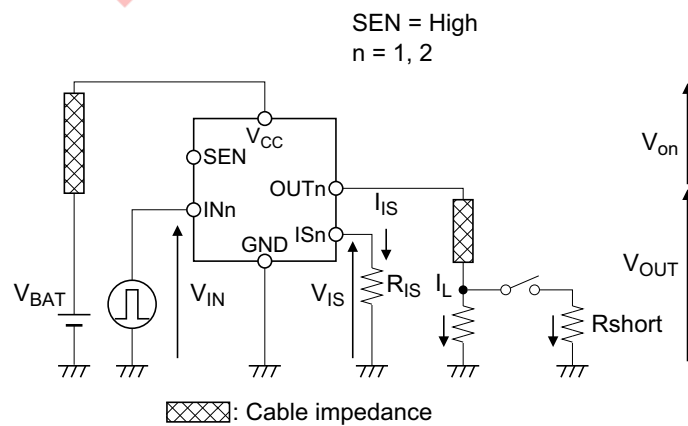
Case 2-(a) $V_{on} > V_{on(OvL)2}$ after $V_{on} < V_{on(OvL)2}$



Case2-(b) Tch > Tth

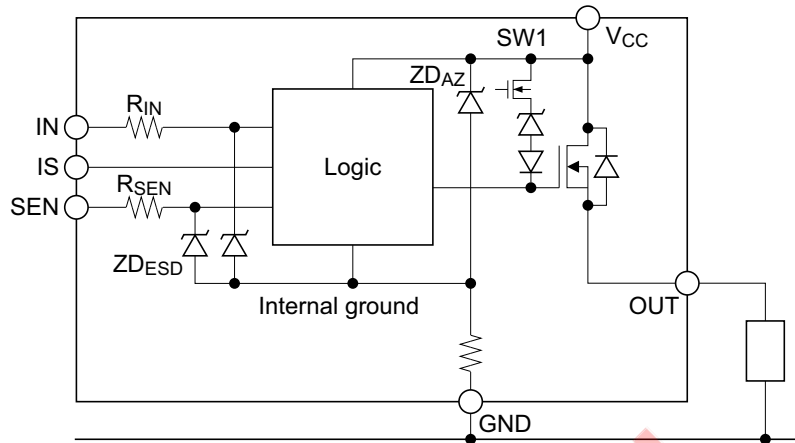


(Evaluation circuit)



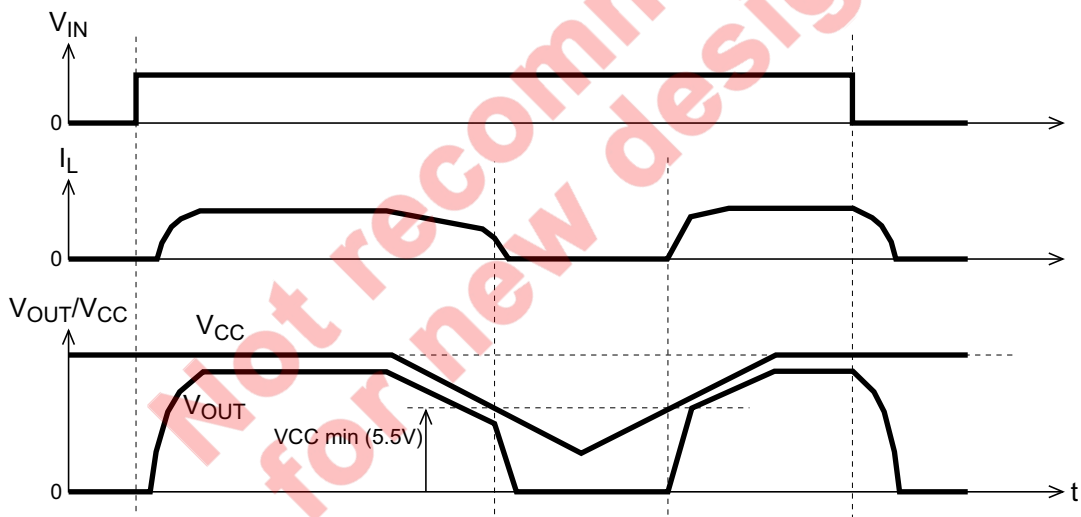
3.6.3 Device Behavior at Over Voltage Condition

In case of supply voltage greater than V_{CC4} , logic part is clamped by ZD_{AZ} . And current through of logic part is limited by internal ground resistor. In addition, the power transistor switches off in order to protect the load from over voltage. Supply voltage at V_{CC} pin must not apply over V_{CC4} .



3.6.4 Device Behavior at Low Voltage Condition

If the voltage supply (V_{CC}) goes down under V_{CC} min (5.5 V), the device shuts down the output. If voltage supply (V_{CC}) increase over V_{CC} min (5.5 V), the device turns on the output automatically. The device keeps off state after under voltage shutdown.



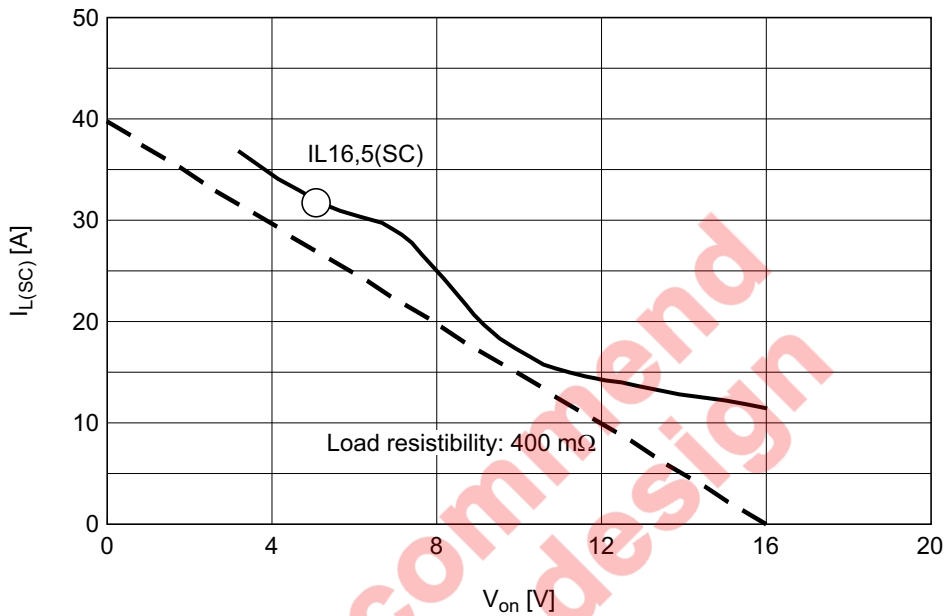
3.6.5 Loss of Ground Protection

In case of complete loss of the device ground connections, but connected load ground, the device keeps in on state or securely changes to or keeps in off state depend on V_{IN} condition.

3.6.6 Driving Capability

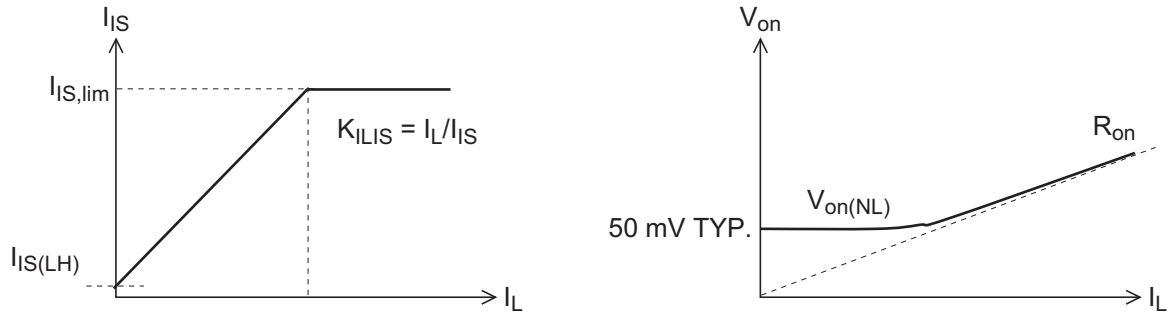
μPD166013 can drive above 400 mΩ as load resistibility include load itself, wire harness, contact resistance of connector, wiring resistibility of PCB at $V_{CC} = 9$ to 16 V, $T_{ch} = 25^{\circ}\text{C}$ condition.

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.

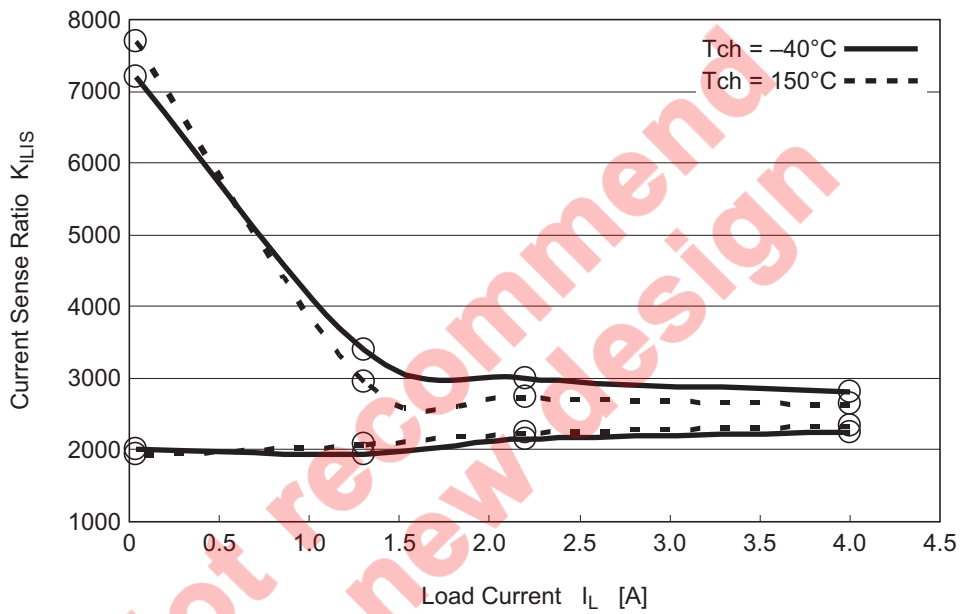


Not recommended for new design

3.6.7 Current Sense Output

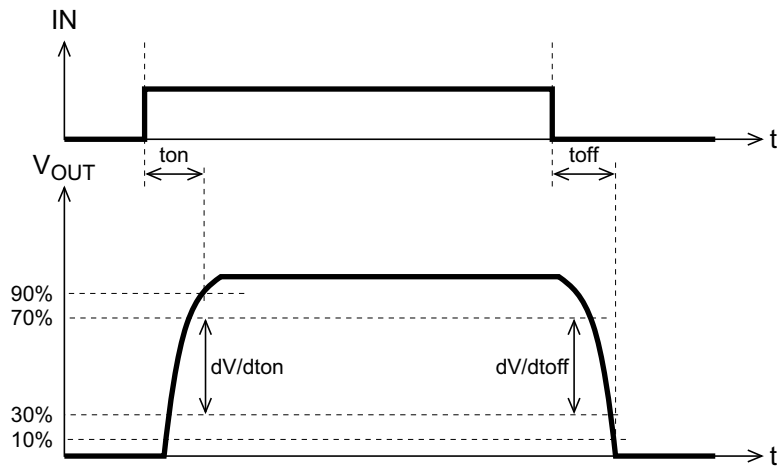


Current Sense Ratio



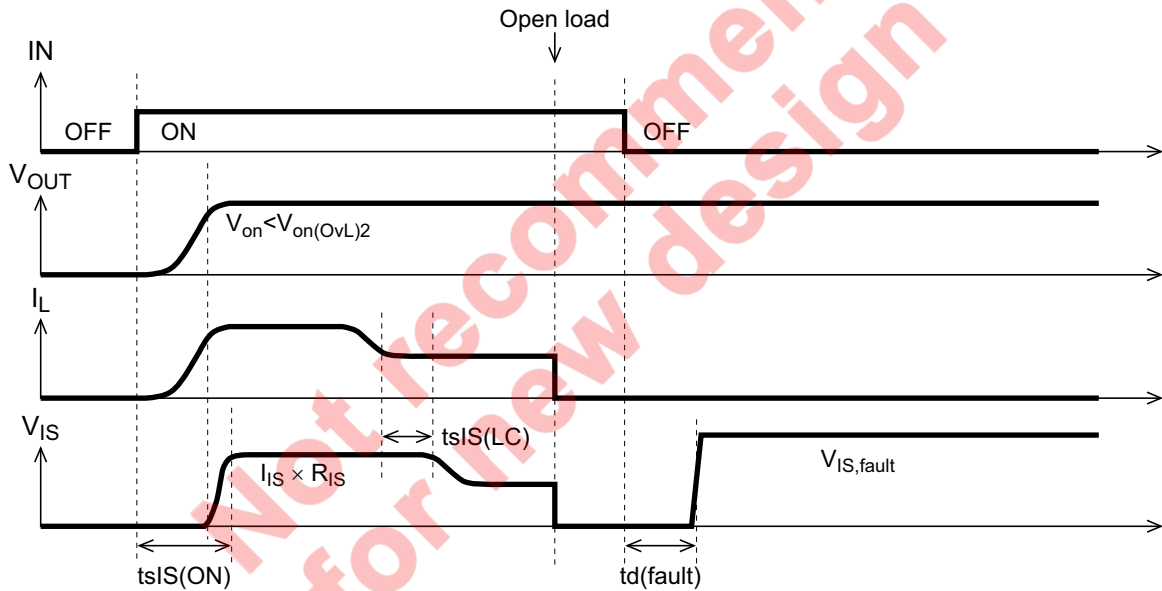
3.6.8 Measurement Condition

Switching waveform of OUT pin

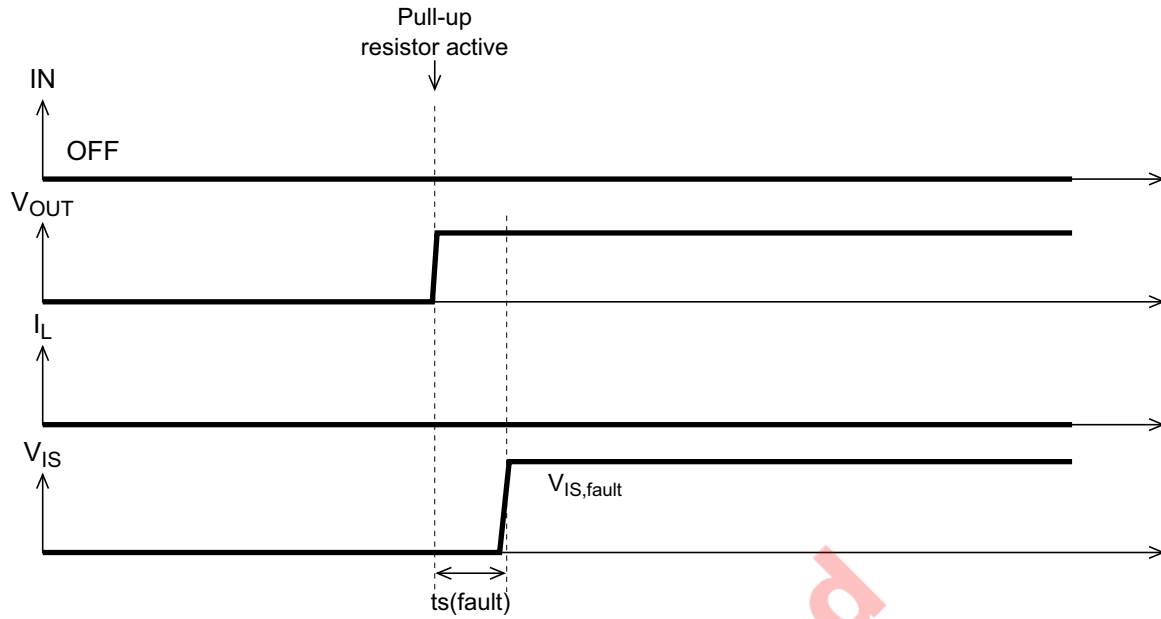


3.6.9 Diagnostics

- Normal operation to open load condition, pull-up resistor active condition



- Pull-up resistor inactive to active during open load condition



3.6.10 Truth Table

	SEN	INPUT	OUTPUT	Diagnostic Output
Normal operation	H	H	V _{CC}	$I_{IS} = I_L/K_{ILIS}$
	H	L	L ^{*1}	L ^{*2}
Short circuit to GND	H	H	L ^{*1}	V _{IS,fault}
	H	L	L ^{*1}	L ^{*2}
Short circuit to V _{CC}	H	H	V _{CC}	$<I_{IS} = I_L/K_{ILIS}$
	H	L	V _{CC}	V _{IS,fault}
Over temperature	H	H	L ^{*1}	V _{IS,fault} ^{*3}
	H	L	L ^{*1}	L ^{*2}
Open load	H	H	V _{CC}	L ^{*2}
	H	L	Hi-Z	V _{IS,fault} in case of OUT>V _{OUT(OL)}

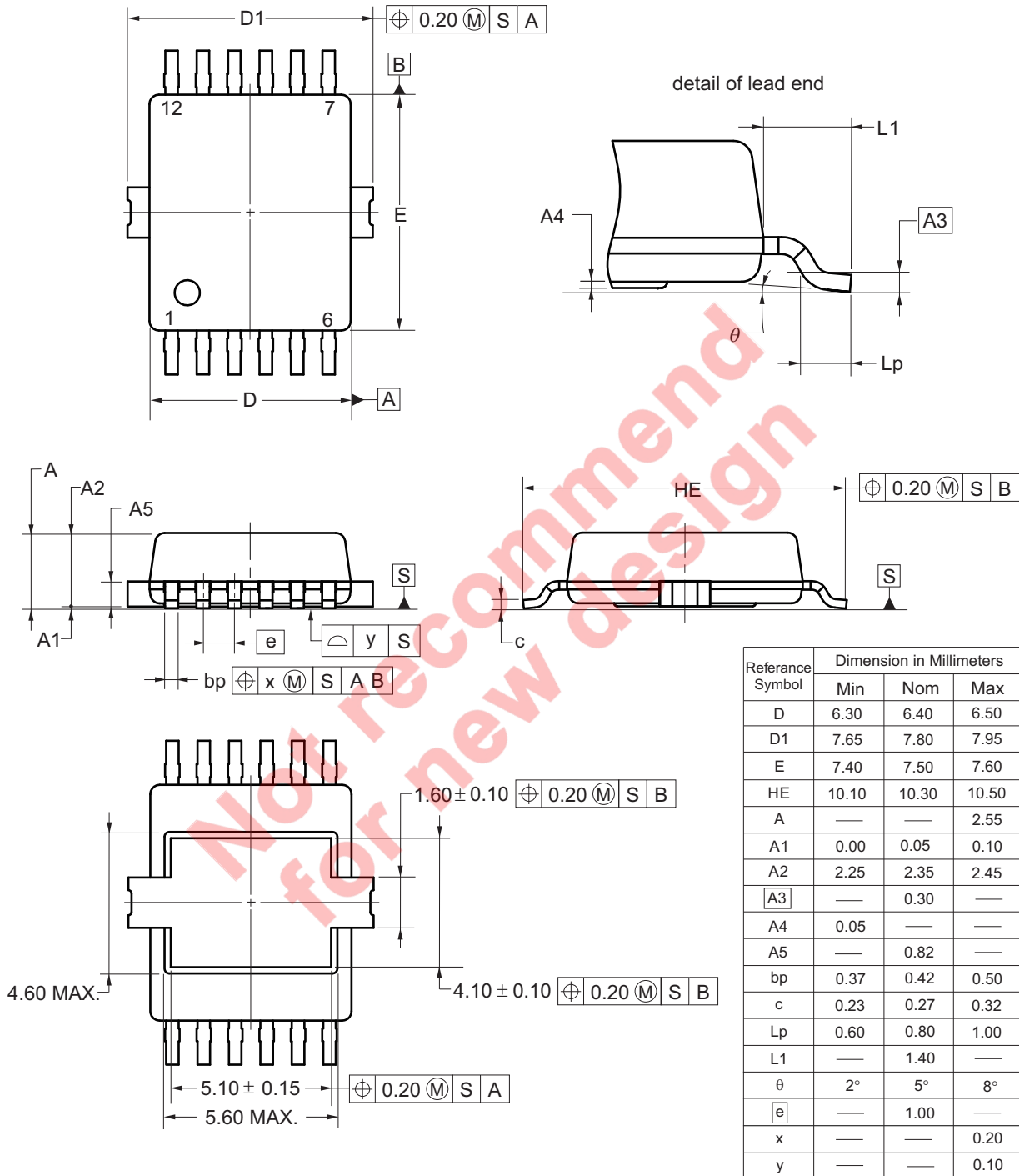
Notes: *1 In case of OUT pin is connected to GND via load.

*2 In case of IS pin is connected to GND via resistor.

*3 IS pin keeps V_{IS,fault} as long as input signal activate after the first thermal shutdown.

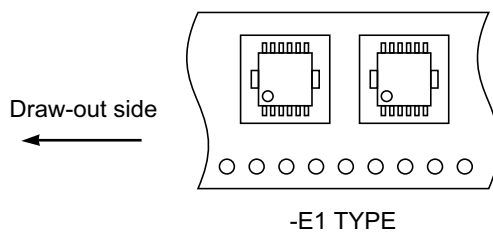
3.7 Package Drawings (Unit: mm)

JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
-	PRSP0013FA-A	P12S1-100-111	0.4



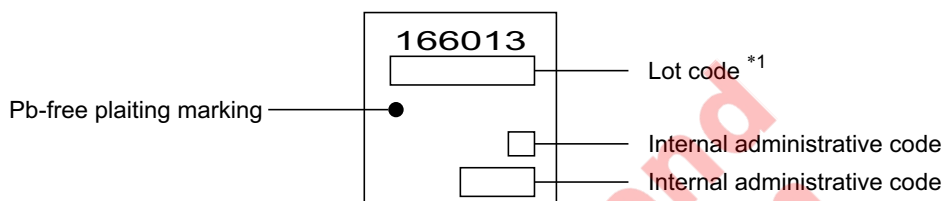
3.8 Taping Information

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

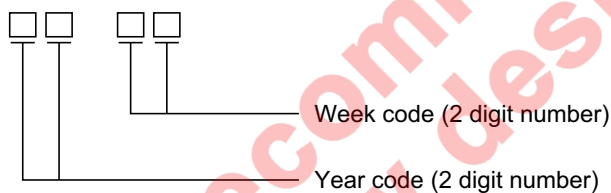


3.9 Marking Information

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



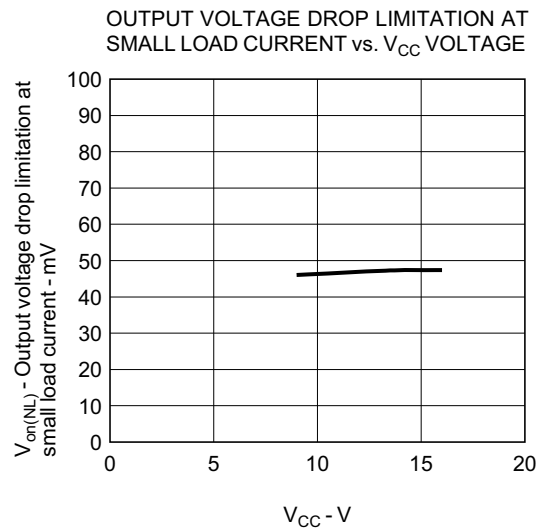
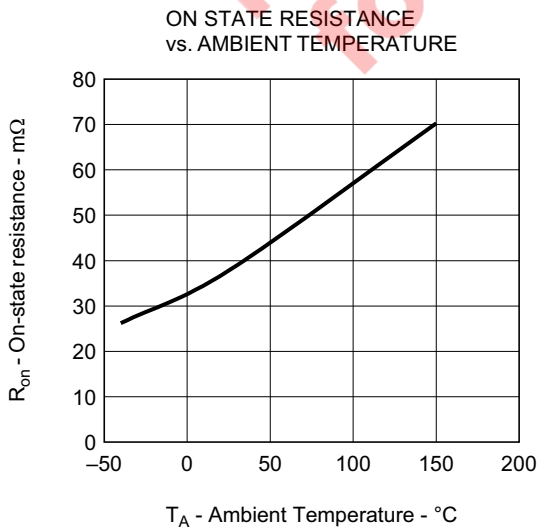
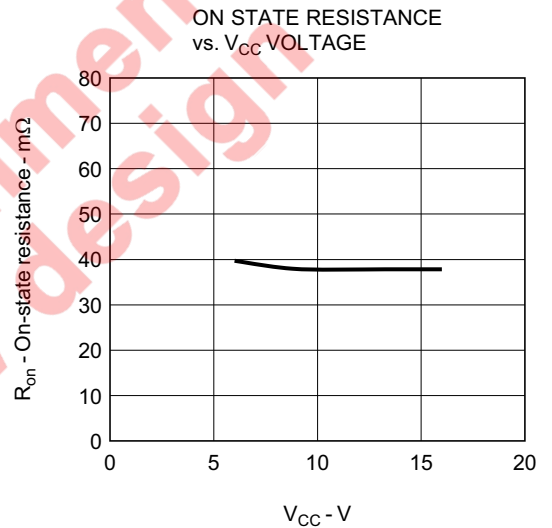
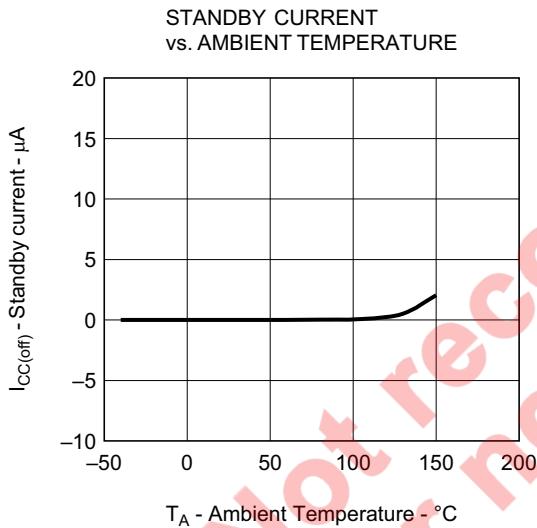
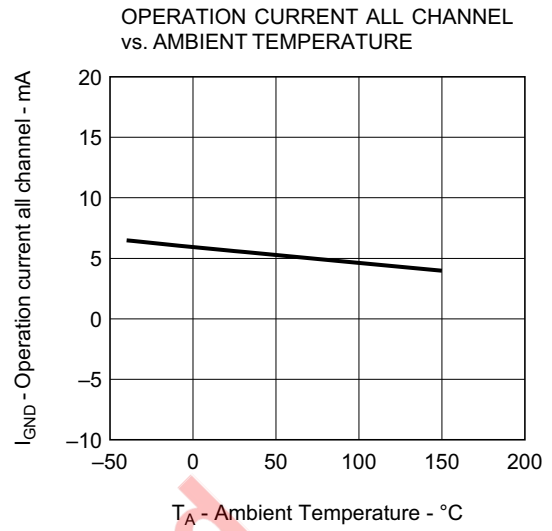
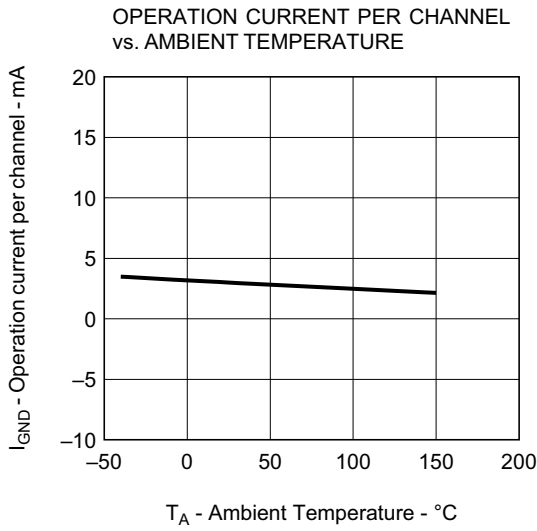
Note: *1. Composition of the lot code

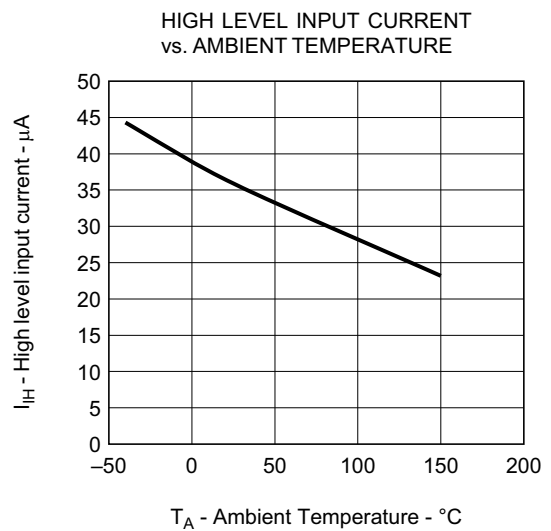
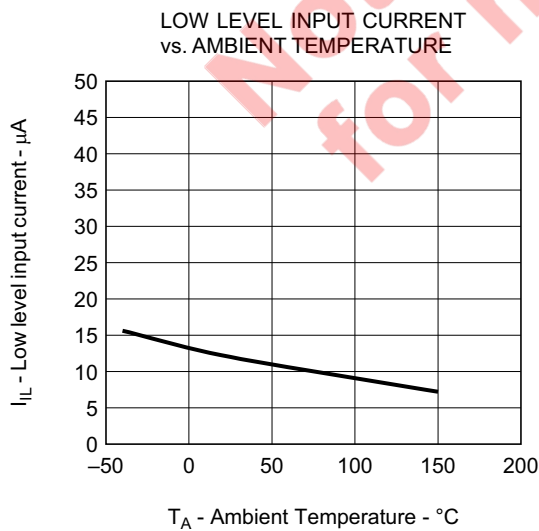
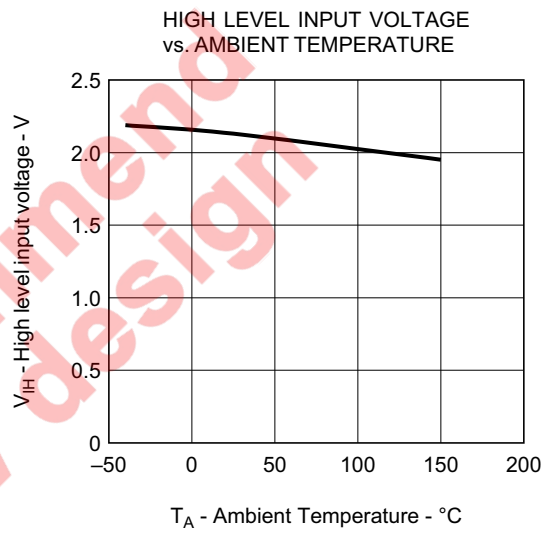
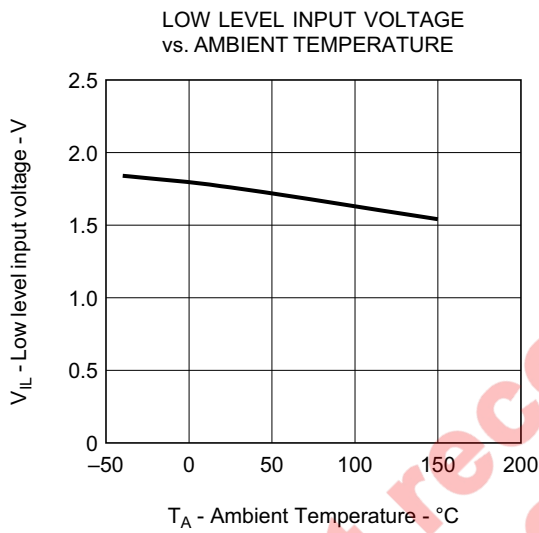
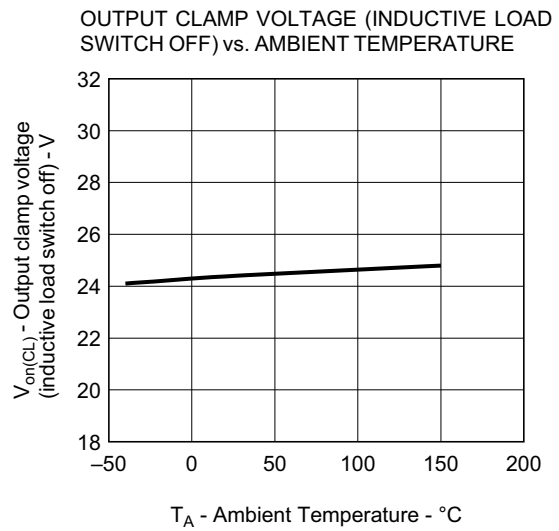
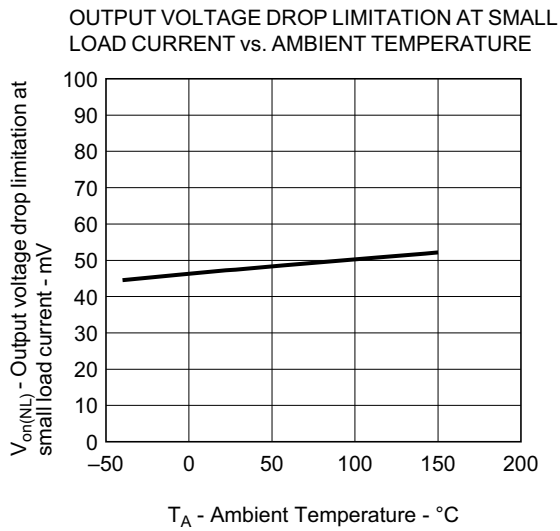


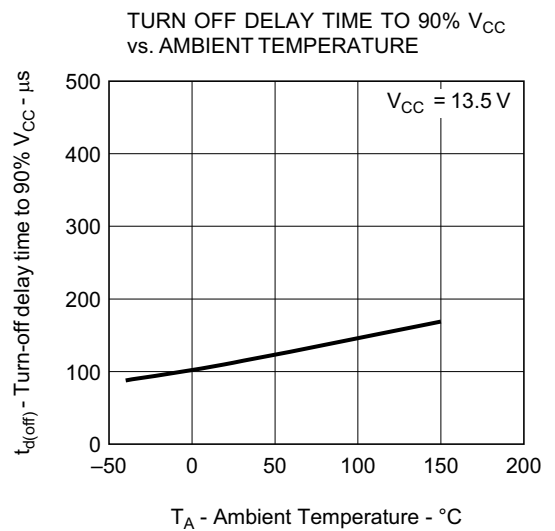
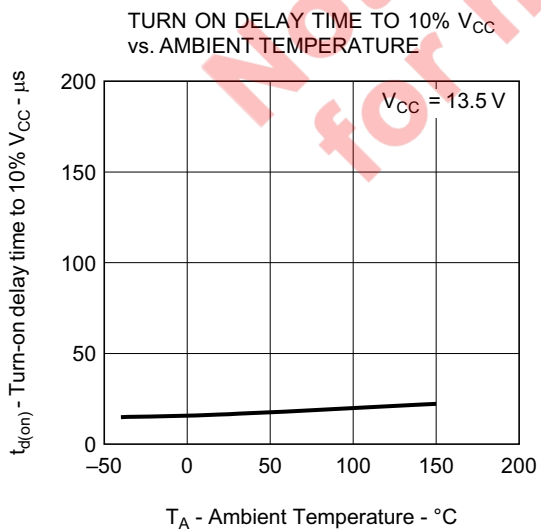
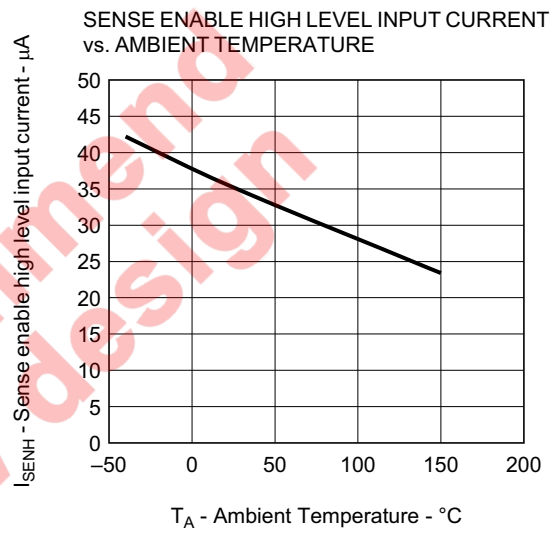
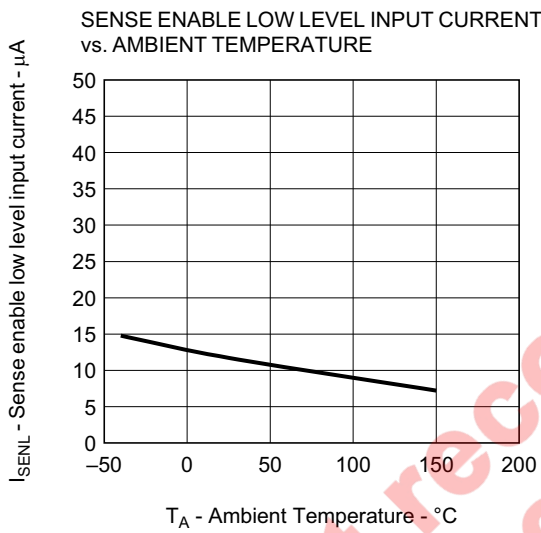
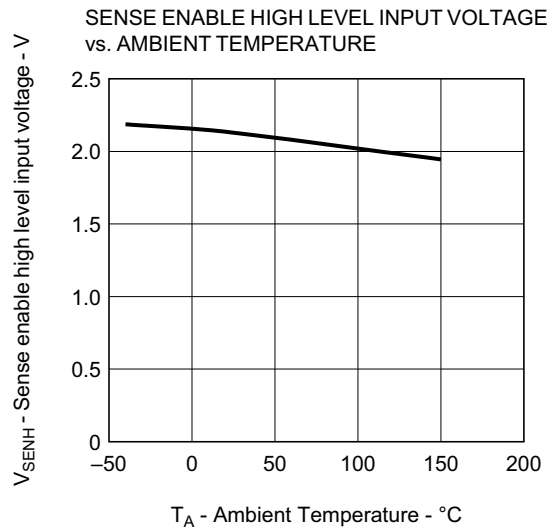
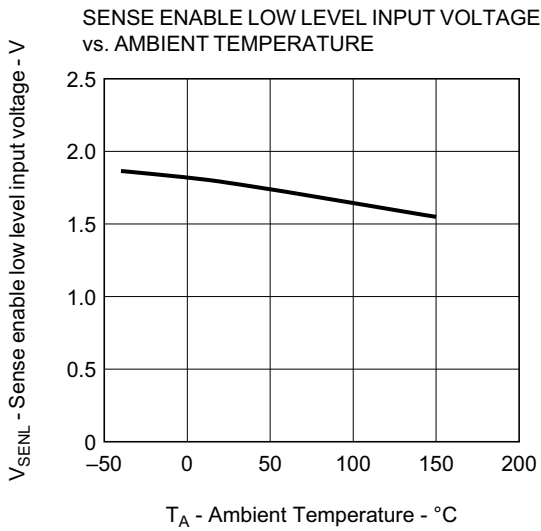
Not recommended for new design

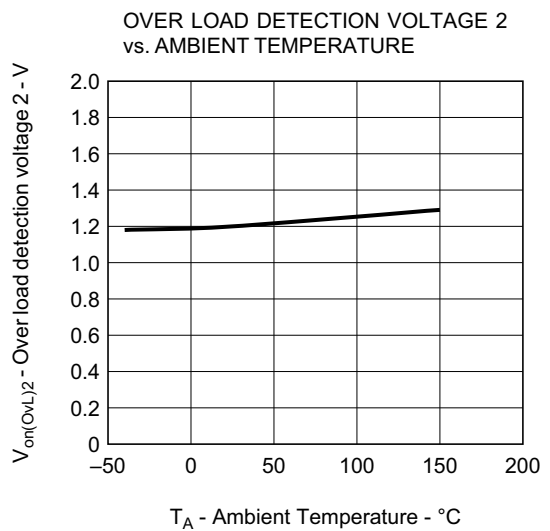
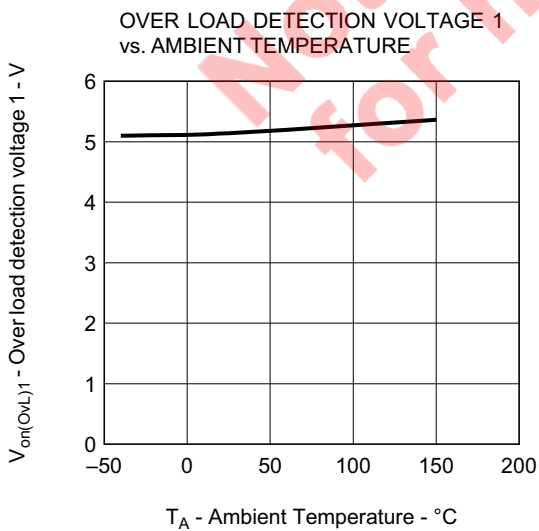
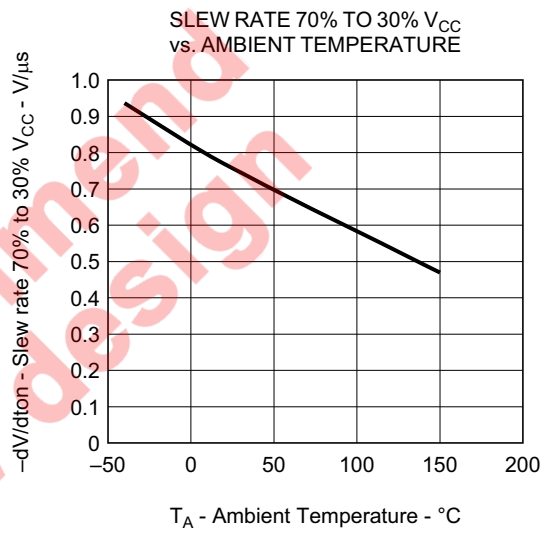
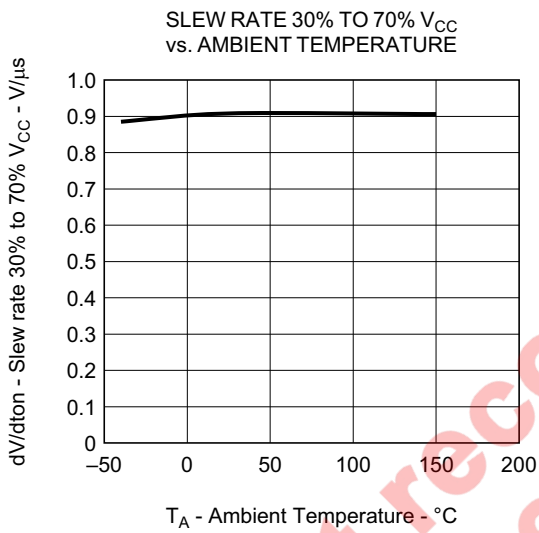
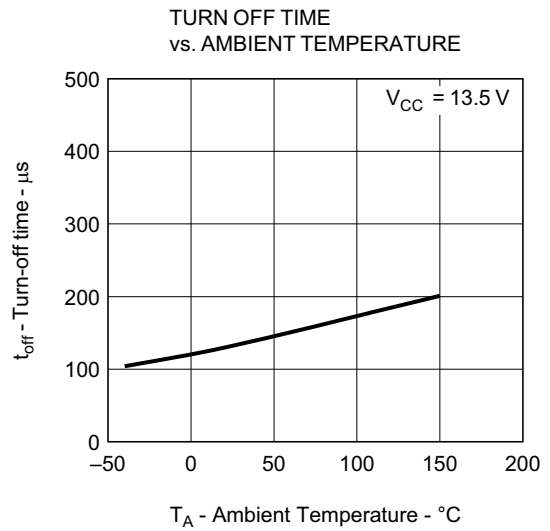
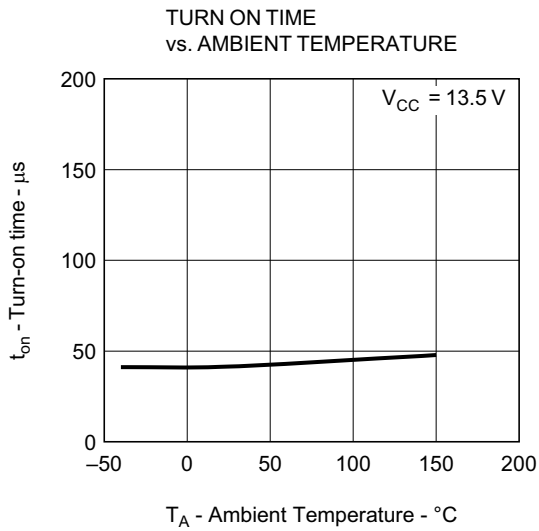
4. Typical Characteristics

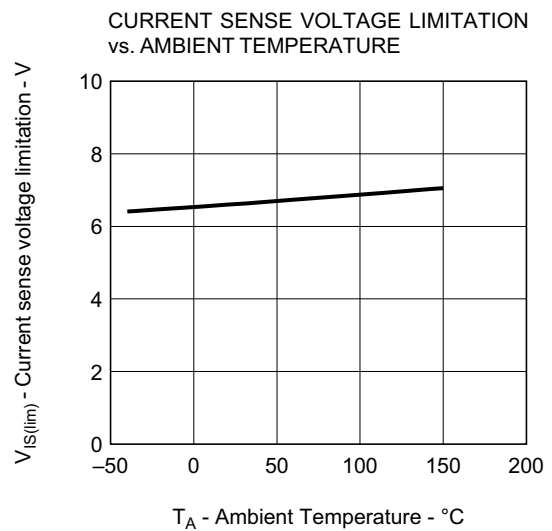
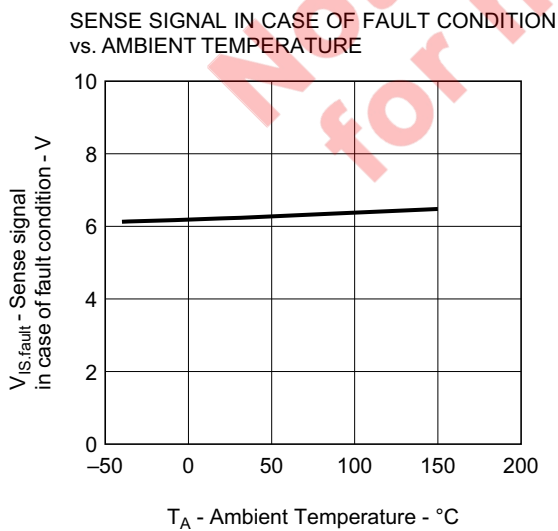
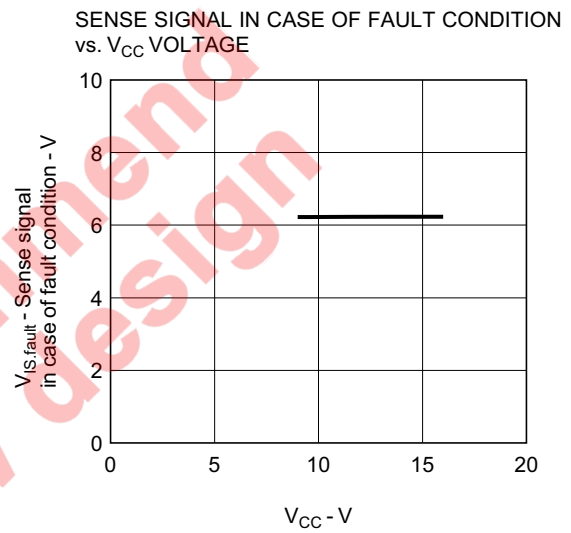
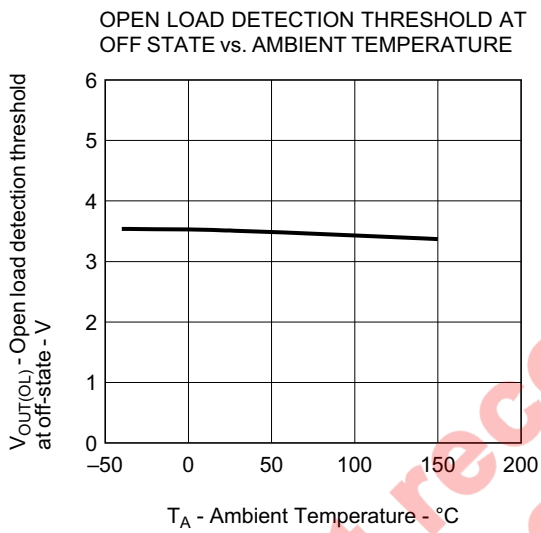
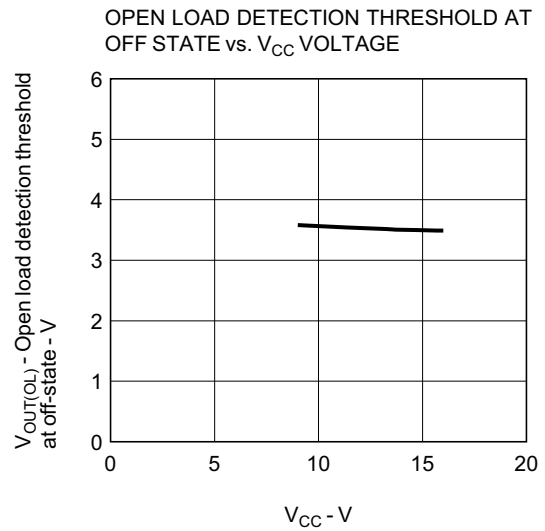
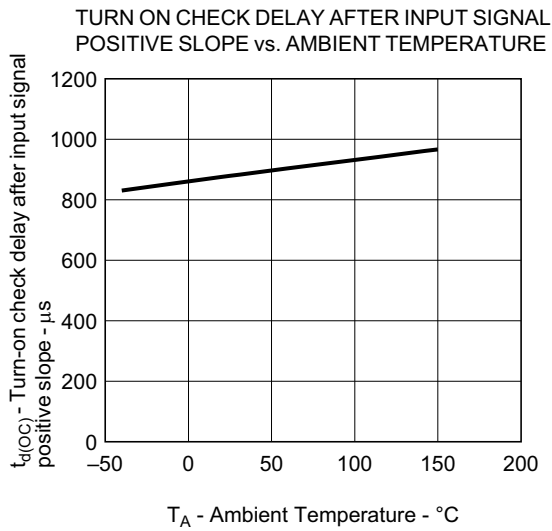
($T_{ch} = 25^{\circ}C$, $V_{CC} = 12V$, unless otherwise specified)

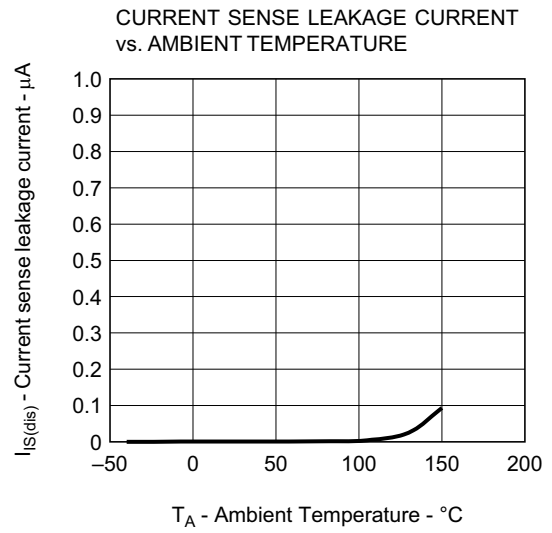
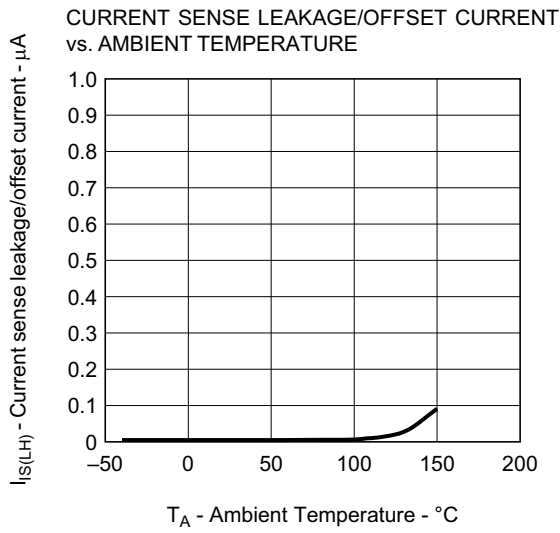






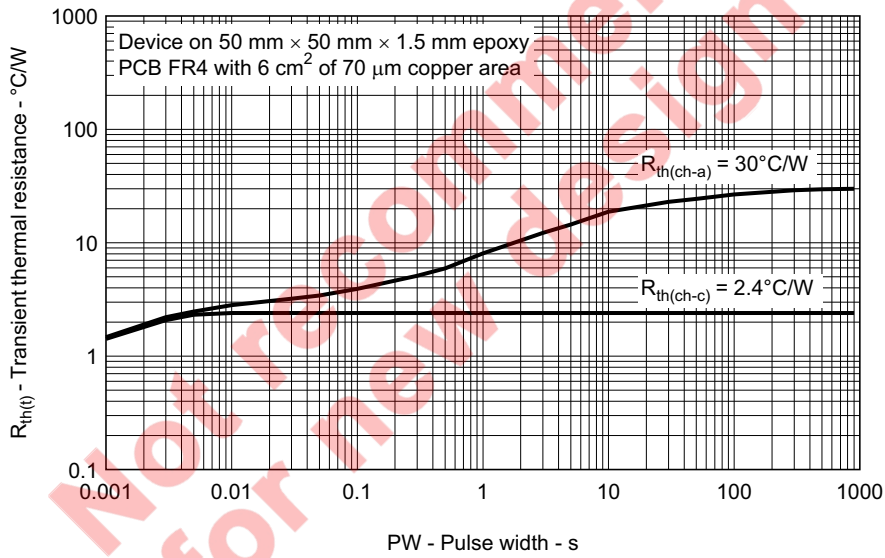




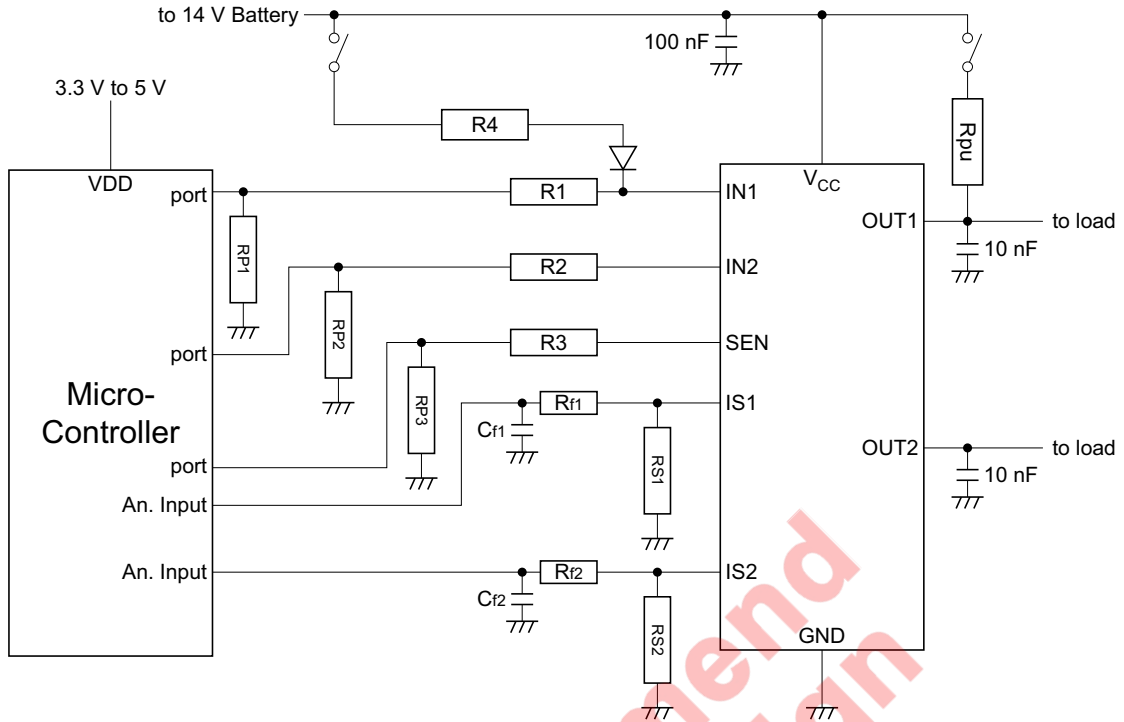


5. Thermal Characteristics

TRANSIENT THERMAL RESISTANCE vs. PULSE WIDTH



6. Application Example in Principle



Note: R4 is for Limp home mode for channel 1. When R4 is used, RP1 are necessary.

Revision History	μPD166013T1J Data Sheet
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Rev.	Date	Description	
		Page	Summary
1.00	Aug 20, 2012	—	First Edition Issued

Not recommend
for new design

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