Load Switch IC

40 V Breakdown Voltage Variable Overcurrent Detection 1ch Load Switch for Automotive

BV1HACA5EFJ-C

General Description

BV1HACA5EFJ-C is a single Nch MOSFET high side load switch applicable to 8.0 V to 28.0 V input. It has a built-in overcurrent protection, Thermal shutdown protection, soft-start function and low power output OFF function. It is equipped with error flag notification pin to indicate thermal shutdown and overcurrent. Single chip power supply management is possible.

Features

- AEC-Q100 Qualified (Note 1)
- Functional Safety Supportive Automotive Products
- Dual TSD(Note 2)
- Low On-Resistance Single Nch MOSFET Switch
- Variable Output Soft-Start Time
- Overcurrent Protection Function (Latch-Off)
- Thermal Shutdown Protection Function (TSD)
- Low Voltage Output OFF Function (UVLO)
- Error Flag Notification Pin

(Note 1) Grade 1
(Note 2) This IC has thermal shutdown function (Junction temperature detect) and ΔTj Protection function (Power-MOS steep temperature rising detect).

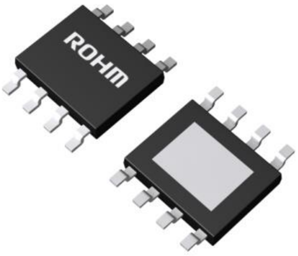
Applications

- Resistance Load, Inductance Load and Capacitance Load for Automotive Application

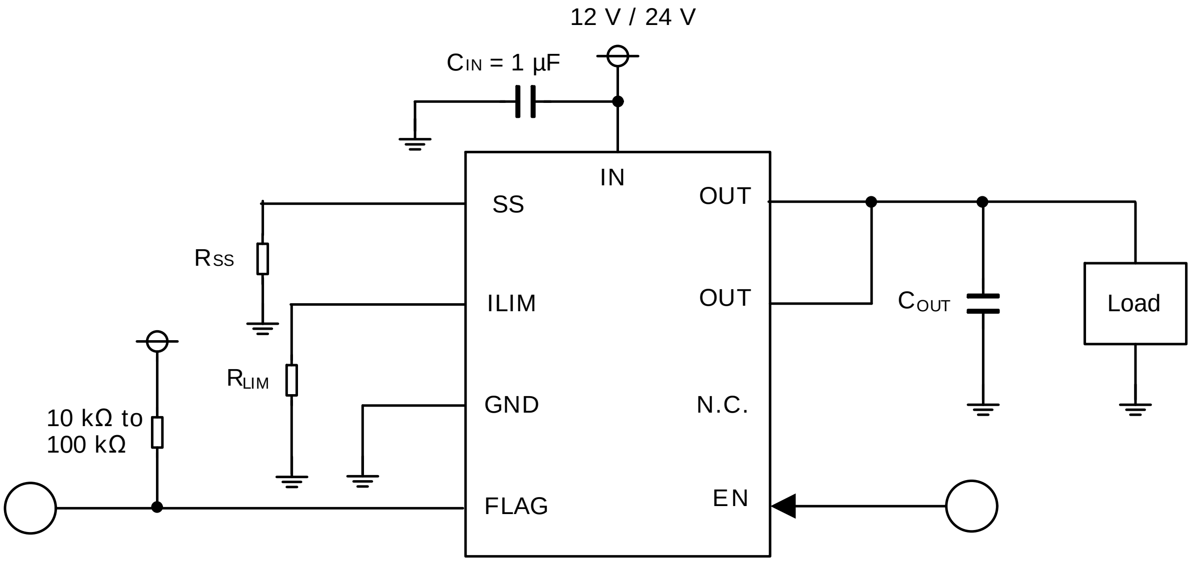
Key Specifications

Input Voltage Range:	8.0 V to 28.0 V
Output ON Resistance:	150 mΩ (Typ)
Variable Overcurrent Detection:	0.75 A to 2.1 A (Typ)
Standby Current:	0.5 µA (Max)
Junction Temperature Range (Tj):	-40 °C to +150 °C

Package	**W (Typ) x D (Typ) x H (Max)**
HTSOP-J8	4.9 mm x 6.0 mm x 1.0 mm



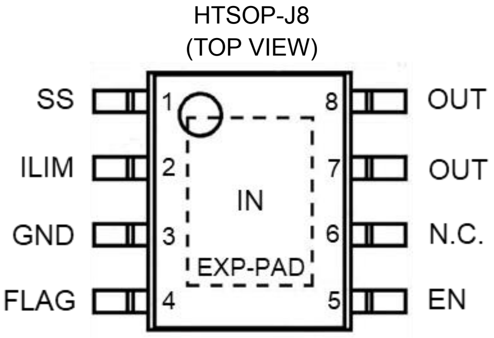
Typical Application Circuit



○Product structure : Silicon integrated circuit ○This product has no designed protection against radioactive rays.

Table of Contents

Pin Configuration

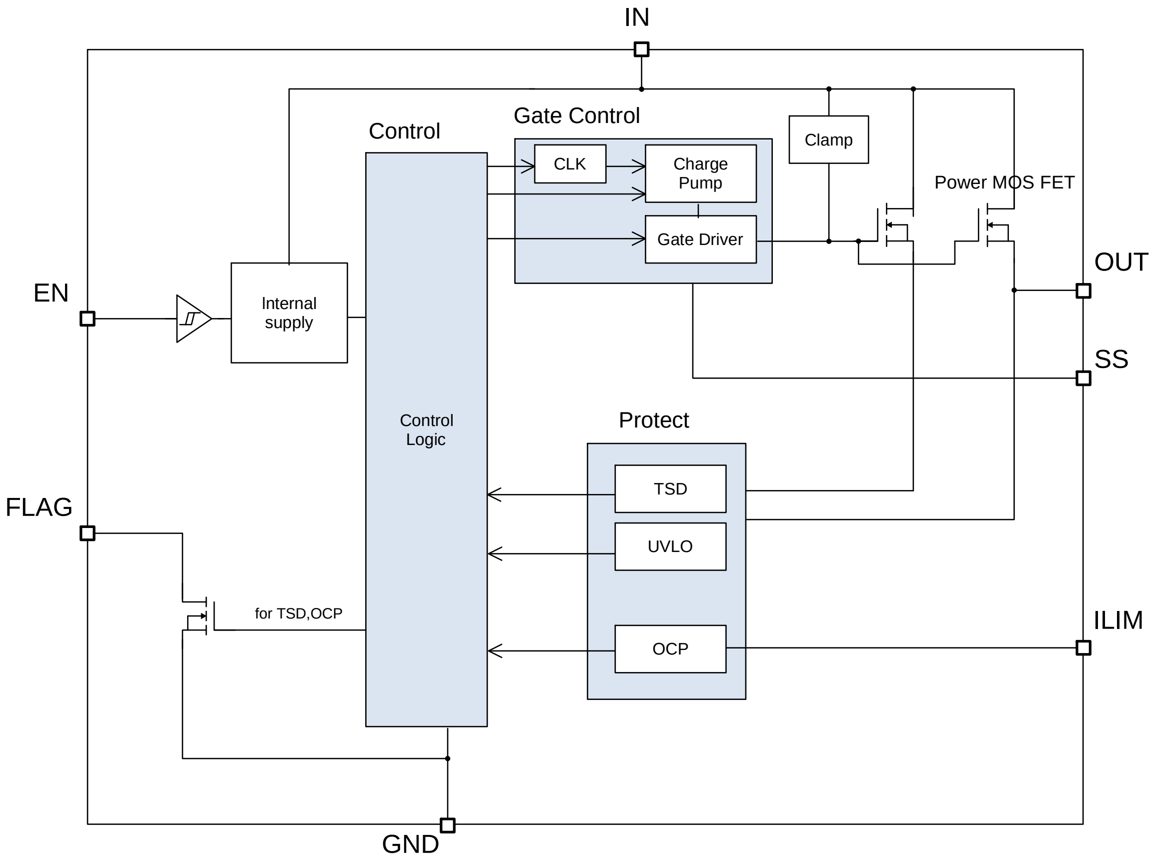


Pin Description

Pin No.	Pin Name	Function
1	SS	Variable soft-start time setting pin
2	ILIM	Variable overcurrent detection setting pin
3	GND	Ground pin
4	FLAG	Error flag output pin (Active low when TSD and OCD is detected.)
5	EN	Enable pin (Pull-down resistor is connected internally.) Active High to turn on the switch
6	N.C.	Not connected pin*(Note 1)*
7,8	OUT	Switch output pin
EXP-PAD	IN	Power input pin, switch input pin

(Note 1) GND short connection is recommended for the N.C. pin. It can also be open since the N.C. pin is not connected inside the IC.

Block Diagram



Definition

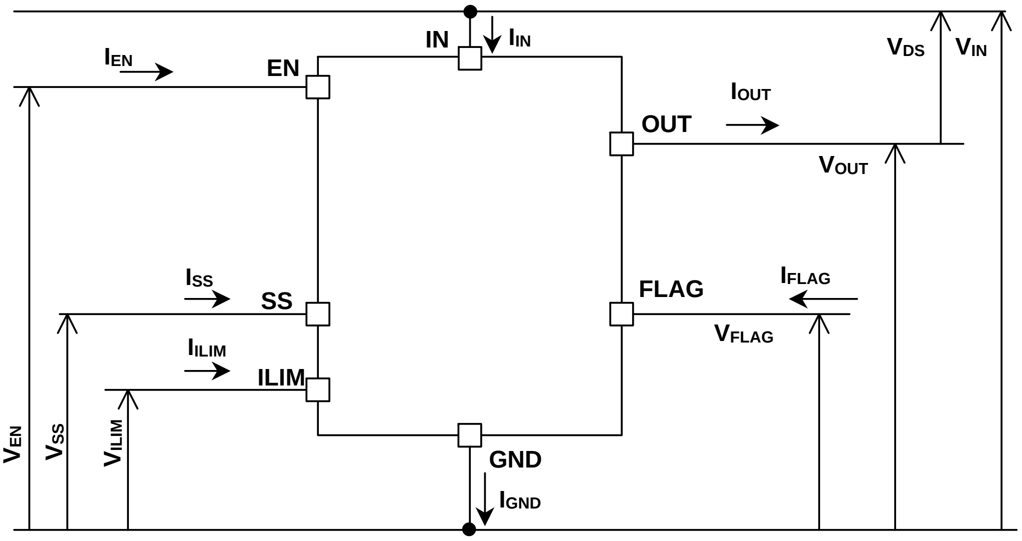


Figure 1. Voltage and Current Definition

Absolute Maximum Ratings

Item	Symbol	Rating	unit
Power Supply Output Voltage	V_{DS}	-0.3 to Internal limit(Note 1)	V
Power Supply Voltage (IN)	V_{IN}	-0.3 to +40	V
Storage Temperature Range	Tstg	-55 to +150	°C
Maximum Junction Temperature	Tjmax	150	°C
EN Input Voltage	V_{EN}	-0.3 to +7.0	V
FLAG Output Voltage	V_{FLAG}	-0.3 to +7.0	V
Output Current	I_{OUT}	Internal limit(Note 2)	A
FLAG Output Current	I_{FLAG}	10	mA
Active Clamp Capability (single pulse) $Tj_{(START)}$ = 25 °C, $I_{OUT(START)}$ = 1 A(Note 3)	$E_{AS(25\ °C)}$	62.1	mJ
Active Clamp Capability (single pulse) $Tj_{(START)}$ = 150 °C, $I_{OUT(START)}$ = 1 A(Note 3)	$E_{AS(150\ °C)}$	19	mJ
Supply Voltage for Short Circuit Protection(Note 4)	V_{INLIM}	24	V

(Note 1) Internal limit according to output clamp voltage
(Note 2) Internal limit according to fixed overcurrent limit
(Note 3) Not 100 % tested.
(Note 4) Maximum power supply voltage that can detect short circuit protection.

Caution 1: *Exposure to the absolute maximum ratings may cause permanent damage to the IC, may affect the device reliability and lifetime. Therefore, operation at or above the absolute maximum ratings is not recommended. The above-described values represent stress ratings and functional operation is not implied. In addition, no destructive conditions such as short or open can be assumed.*

Caution 2: *If the IC is used in a manner that exceeds the maximum junction temperature the original characteristics of the IC will be degraded. If the junction temperature exceeds the maximum specified temperature, increase the board size, increase the area of copper foil for heat dissipation, or use a heat sink. Consider reducing the thermal resistance so that the maximum junction temperature is not exceeded.*

Caution 3: *When an inductive load is turned off, the V_{OUT} voltage drops below ground level. An integrated active-clamp (overvoltage) protection limits the maximum V_{DS} across the power transistor and the inductive energy is dissipated internally. The energy can be calculated using the following simplified equation:*

$$E_L = V_{DSCLP} \times \left[\frac{V_{IN} - V_{DSCLP}}{R_L} \times ln\left(1 - \frac{R_L \times I_{OUT(START)}}{V_{IN} - V_{DSCLP}}\right) + I_{OUT(START)}\right] \times \frac{L}{R_L}$$

Where:
L is the inductance value of the inductive load.
R_L is the resistance value of the load.
V_{IN} is the supply voltage.
V_{DSCLP} is the clamping voltage.
$I_{OUT(START)}$ is the current flowing through the inductive load at the instance the inductive load is turned off.

In simplified form, if R_L is neglected.

$$E_L = \frac{1}{2} \times L \times I_{OUT(START)}{}^2 \times (1 - \frac{V_{IN}}{V_{IN} - V_{DSCLP}})$$

Caution 4: *The maximum E_L energy the device can dissipate for a given $I_{OUT(START)}$ is limited by the maximum thermal transient the power transistor can handle, hence the maximum inductance L must be selected with respect to the maximum given $I_{OUT(START)}$.*

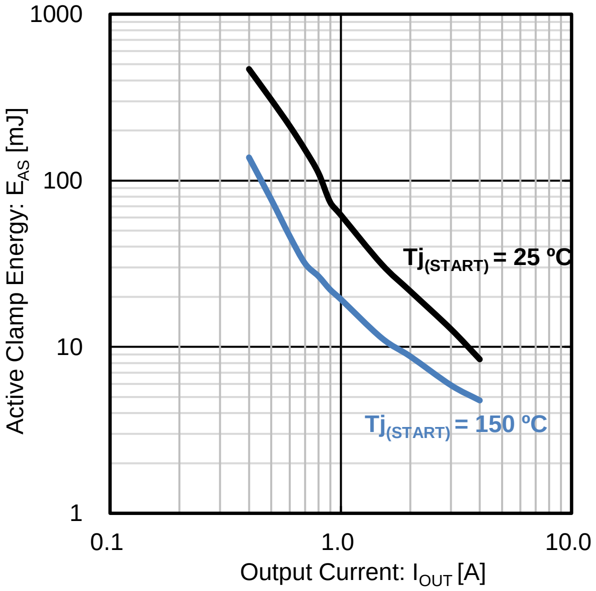


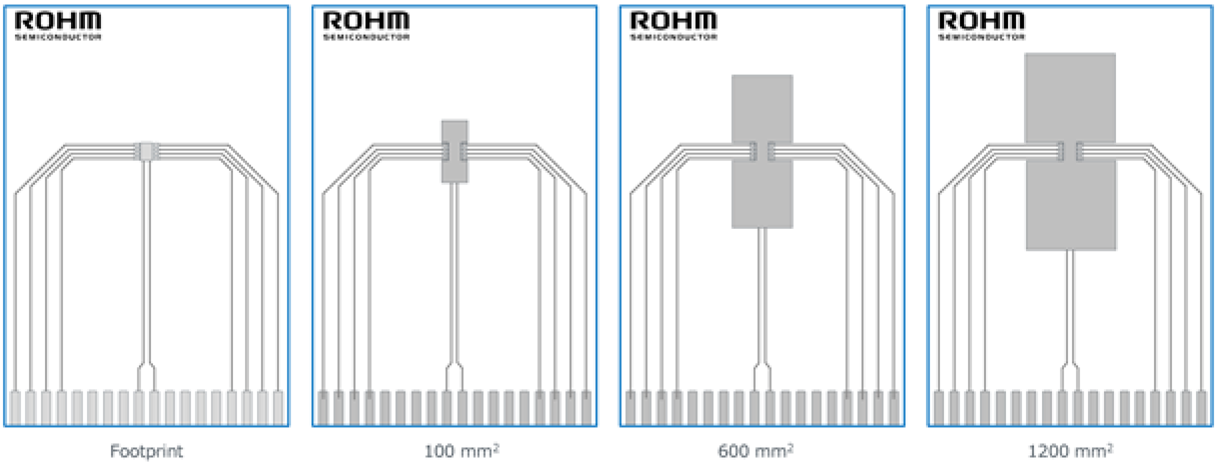
Figure 2. Active Clamp Energy vs Output Current

Thermal Resistance*(Note 1)*

Parameter	Symbol	Typ	Unit	Condition
HTSOP-J8				
Between Junction and Surroundings Temperature Thermal Resistance	θ_{JA}	129.8	°C/W	1s *(Note 2)*
		40.2	°C/W	2s *(Note 3)*
		27.1	°C/W	2s2p *(Note 4)*
Thermal characterization parameter between junction and top center of the outside surface of the component package	Ψ_{JT}	13.6	°C/W	1s *(Note 2)*
		3.4	°C/W	2s *(Note 3)*
		3.0	°C/W	2s2p *(Note 4)*

(Note 1) The thermal impedance is based on JESD51-2A (Still-Air) standard. It is used in the chip of BV1HACA5EFJ-C.
(Note 2) JESD51-3 standard FR4 114.3 mm x 76.2 mm x 1.57 mm 1-layer (1s)
(Top copper foil: ROHM recommended Footprint + wiring to measure, 2 oz. copper.)
(Note 3) JESD51-5 standard FR4 114.3 mm x 76.2 mm x 1.60 mm 2-layers (2s)
(Top copper foil: ROHM recommended Footprint + wiring to measure / Copper foil area on the reverse side of PCB: 74.2 mm x 74.2 mm, copper (top & reverse side) 2 oz.)
(Note 4) JESD51-5/- 7 standard FR4 114.3 mm x 76.2 mm x 1.60 mm 4-layers (2s2p)
(Top copper foil: ROHM recommended Footprint + wiring to measure / 2 inner layers and copper foil area on the reverse side of PCB: 74.2 mm x 74.2 mm, copper (top & reverse side/inner layers) 2 oz./1 oz.)

- PCB Layout 1 Layer (1s)



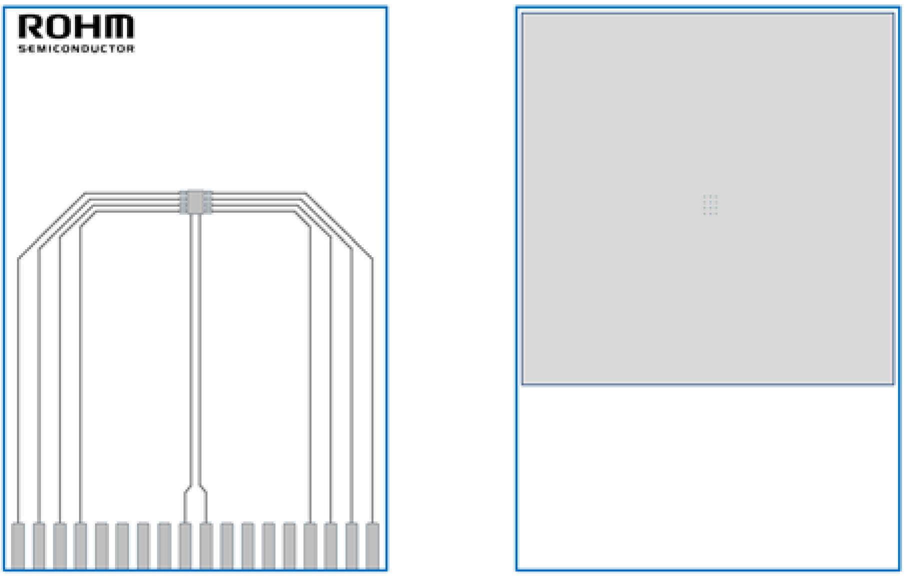
Footprint 100 mm² 600 mm² 1200 mm²

Figure 3. PCB Layout 1 Layer (1s)

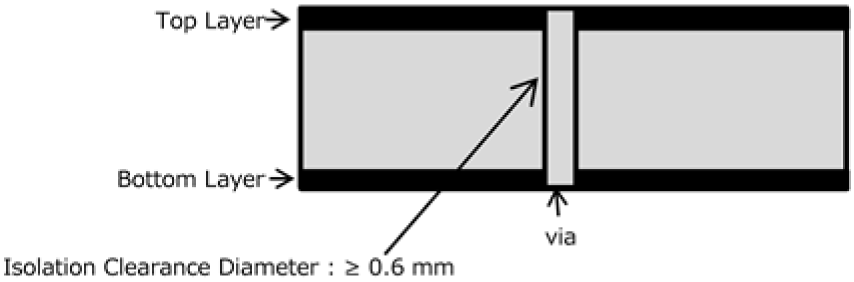
Dimension	Value
Board Finish Thickness	1.57 mm ± 10 %
Board Dimension	76.2 mm x 114.3 mm
Board Material	FR4
Copper Thickness (Top/Bottom Layers)	0.070 mm (Cu : 2 oz)
Copper Foil Area Dimension	Footprint / 100 mm^2 / 600 mm^2 / 1200 mm^2

Thermal Resistance – continued

- PCB Layout 2 Layers (2s)



Top Layer Bottom Layer



Cross Section

Figure 4. PCB Layout 2 Layers (2s)

Dimension	Value
Board Finish Thickness	1.60 mm ± 10 %
Board Dimension	76.2 mm x 114.3 mm
Board Material	FR4
Copper Thickness (Top/Bottom Layers)	0.070 mm (Cu +Plating)
Thermal Vias Separation / Diameter	1.2 mm / 0.3 mm

Thermal Resistance – continued

- PCB Layout 4 Layers (2s2p)

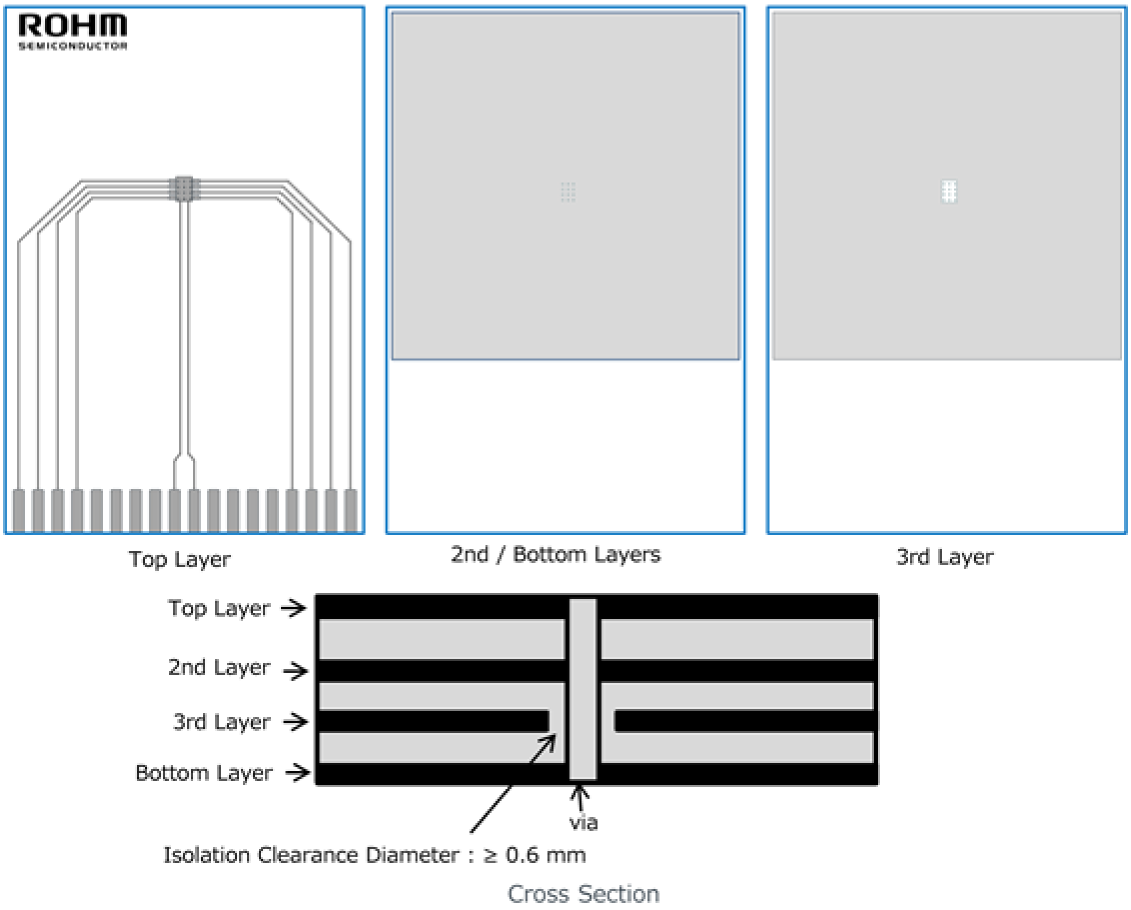


Figure 5. PCB Layout 4 Layers (2s2p)

Dimension	Value
Board Finish Thickness	1.60 mm ± 10 %
Board Dimension	76.2 mm x 114.3 mm
Board Material	FR4
Copper Thickness (Top/Bottom Layers)	0.070 mm (Cu +Plating)
Copper Thickness (Inner Layers)	0.035 mm
Thermal Vias Separation / Diameter	1.2 mm / 0.3 mm

Thermal Resistance – continued

- Transient Thermal Resistance (Single Pulse)

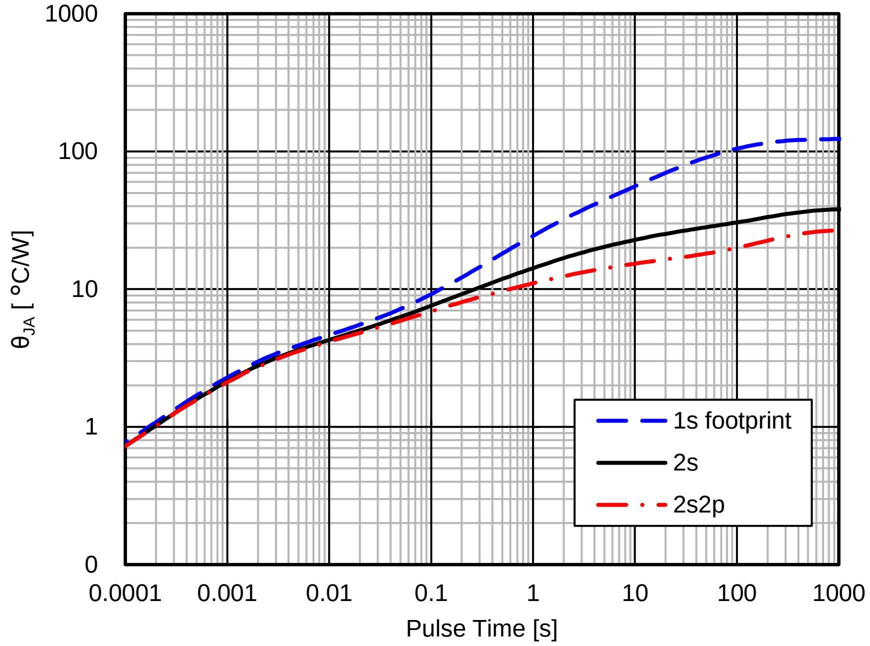


Figure 6. θ_{JA} vs Pulse Time

- Thermal Resistance (θ_{JA} vs Copper foil area - 1s)

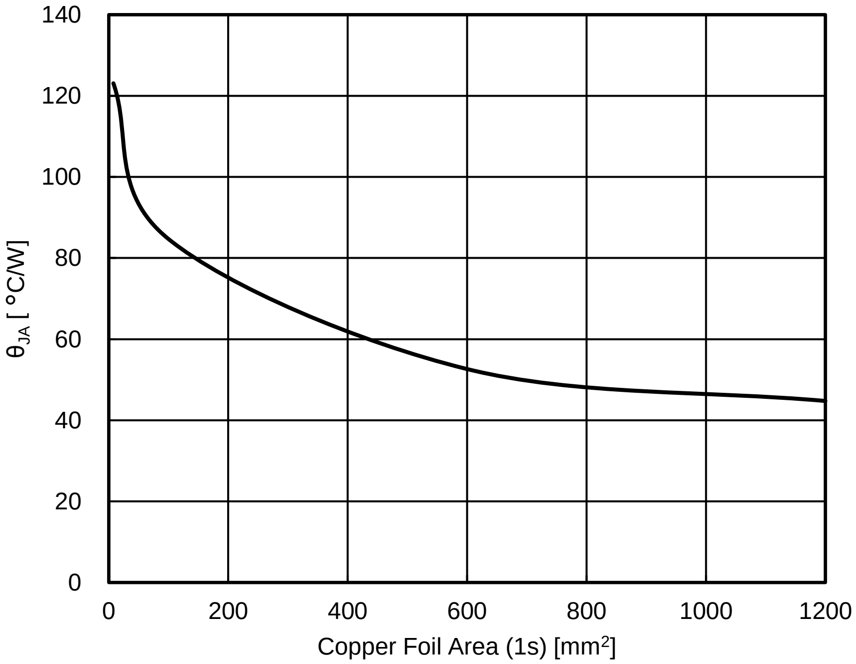


Figure 7. θ_{JA} vs Copper Foil Area (1s)

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Power Supply*(Note 1)*	V_{IN}	8.0	-	28.0	V
Operating Junction Temperature	Tj	-40	-	+150	°C

(Note 1) Do not exceed the maximum junction temperature.

Electrical Characteristics (Unless otherwise specified V_{IN} = 8.0 V to 28.0 V, Tj = -40 °C to +150 °C, R_{LIM} = 100 kΩ)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
[Power Supply]						
Standby Current	I_{STB}	-	-	0.5	µA	V_{IN} = 24 V, V_{EN} = 0 V, Tj = 25 °C
		-	-	20	µA	V_{IN} = 24 V, V_{EN} = 0 V, Tj = 150 °C
Operating Current	I_{CC}	-	2.00	4.50	mA	V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C
UVLO Detection Voltage	V_{UVLO}	-	-	6.0	V	
UVLO Hysteresis Voltage	V_{UVHYS}	0.45	0.90	1.40	V	
[Input (V_{EN})]						
EN High Voltage	V_{ENH}	2.1	-	-	V	
EN Low Voltage	V_{ENL}	-	-	0.9	V	
EN Hysteresis Voltage	V_{ENHYS}	0.10	0.45	0.80	V	
EN High Input Current	I_{ENH}	-	50	100	µA	V_{EN} = 5 V
EN Low Input Current	I_{ENL}	-1	-	+1	µA	V_{EN} = 0 V
[Power MOS Output]						
Output ON Resistance	R_{ON}	-	150	200	mΩ	V_{EN} = 5 V, Tj = 25 °C
		-	-	330	mΩ	V_{EN} = 5 V, Tj = 150 °C
Output Leakage Current	I_{LSW}	-	-	0.5	µA	V_{EN} = 0 V, V_{OUT} = 0 V, Tj = 25 °C
		-	-	10	µA	V_{EN} = 0 V, V_{OUT} = 0 V, Tj = 150 °C
Output ON Slew Rate	SR_{ON}	0.45	0.75	1.05	V/ms	V_{IN} = 24 V, Tj = 25 °C R_{SS} = 100 kΩ, R_L = 100 Ω, V_{OUT}:20 %→80 %
Output OFF Slew Rate	SR_{OFF}	-	0.18	0.60	V/µs	V_{IN} = 24 V, Tj = 25 °C R_{SS} = 100 kΩ, R_L = 100 Ω, V_{OUT}:80 %→20 %
Output ON Delay Time	t_{ON}	18	30	42	ms	V_{IN} = 24 V, Tj = 25 °C R_{SS} = 100 kΩ, R_L = 100 Ω, V_{EN}:50 %→V_{OUT}:80 %
Output OFF Delay Time	t_{OFF}	-	180	450	µs	V_{IN} = 24 V, Tj = 25 °C R_{SS} = 100 kΩ, R_L = 100 Ω, V_{EN}:50 %→V_{OUT}:20 %
Output Clamp Voltage	V_{DSCLP}	45	50	55	V	V_{EN} = 0 V, I_{OUT} = 10 mA
[FLAG]						
FLAG Low Output Voltage	V_{FLAG}	-	-	0.5	V	I_{FLAG} = 1 mA
FLAG Pin Leakage Current	I_{LFLAG}	-	-	1	µA	V_{FLAG} = 5 V
FLAG Output Delay Time	t_{BLANK}	15	30	45	ms	The time from overcurrent detection to V_{FLAG} = Low.
[Diagnostic Functions]						
Thermal Shutdown Detection*(Note 1)*	T_{TSD}	150	175	200	°C	
Thermal Shutdown Hysteresis*(Note 1)*	T_{TSDHYS}	-	15	-	°C	
ΔTj Protection*(Note 1)*	T_{DTJ}	-	105	-	°C	
ΔTj Protection Hysteresis*(Note 1)*	T_{DTJHYS}	-	30	-	°C	
Fixed Overcurrent Limit	I_{OCD1}	5.7	8.5	11.3	A	Tj = 25 °C
Variable Overcurrent Detection	I_{OCD2}	0.74	1.14	1.54	A	R_{LIM} = 100 kΩ, Tj = 25 °C

(Note 1) Not 100 % tested.

Typical Performance Curves

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

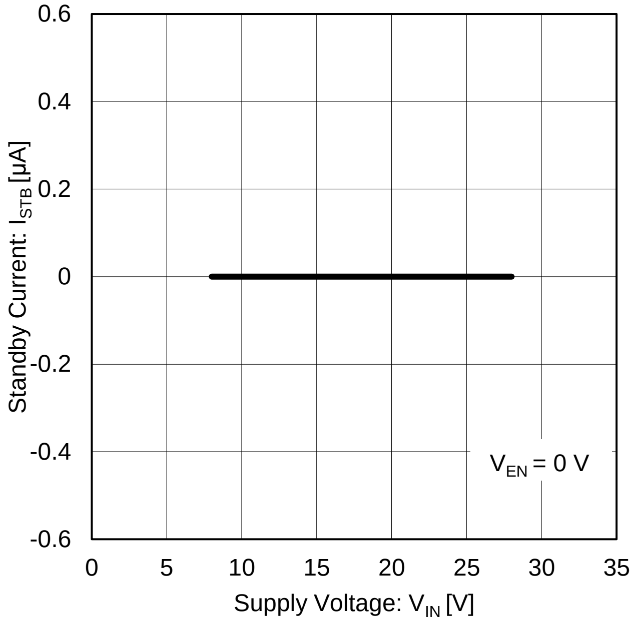


Figure 8. Standby Current vs Supply Voltage

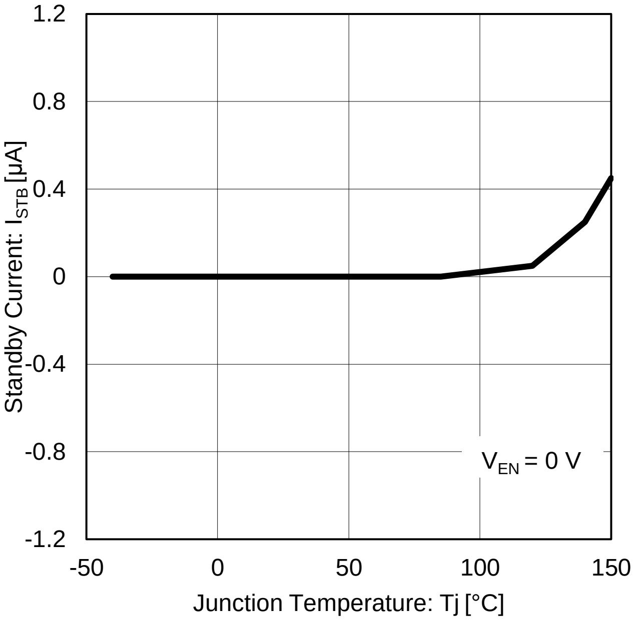


Figure 9. Standby Current vs Junction Temperature

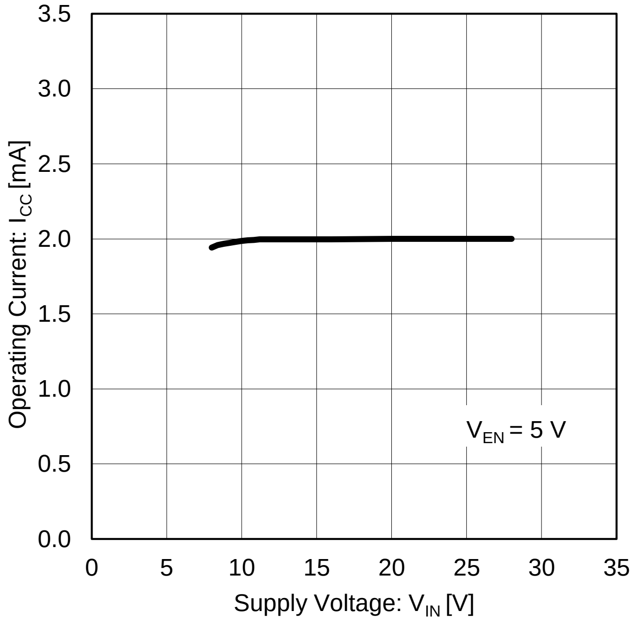


Figure 10. Operating Current vs Supply Voltage

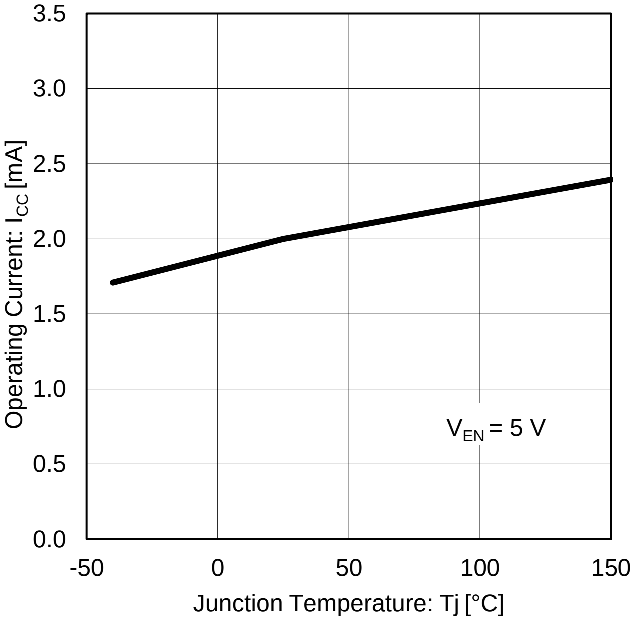


Figure 11. Operating Current vs Junction Temperature

Typical Performance Curves – continued

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

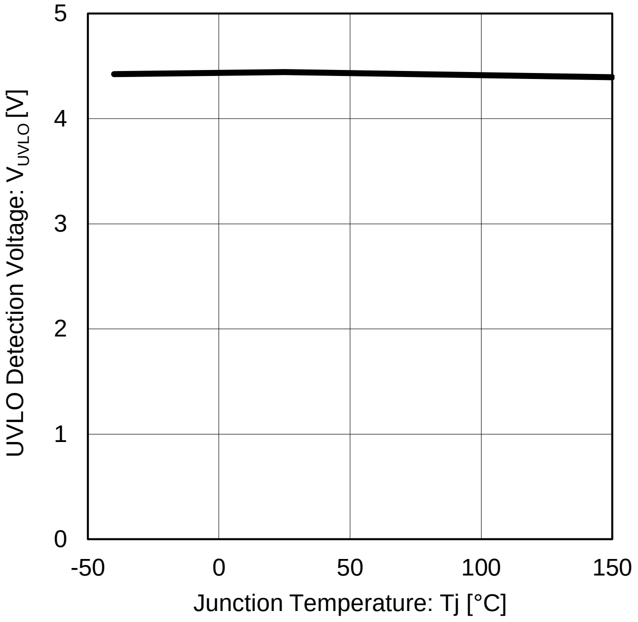


Figure 12. UVLO Detection Voltage vs Junction Temperature

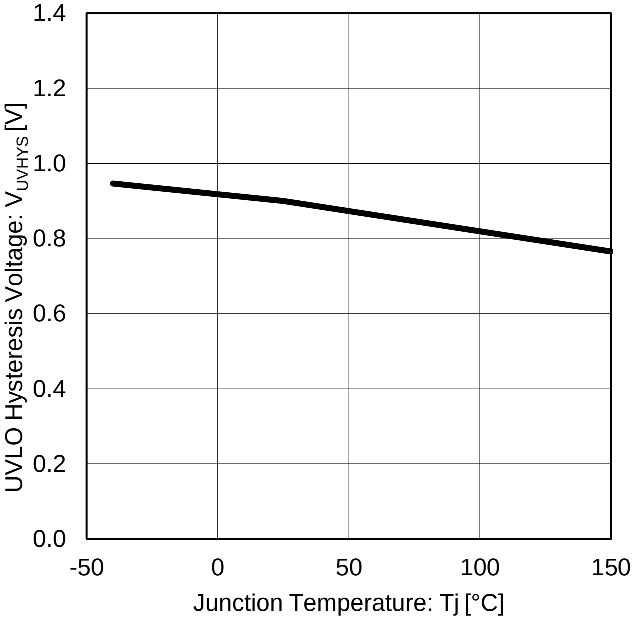


Figure 13. UVLO Hysteresis Voltage vs Junction Temperature

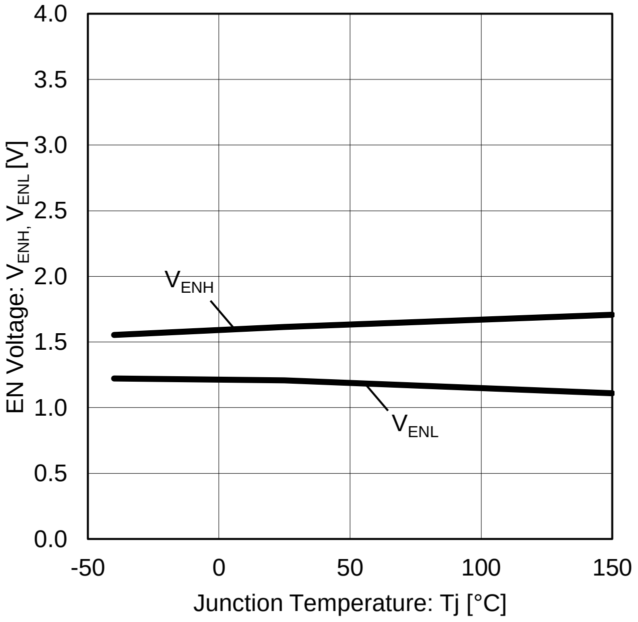


Figure 14. EN Voltage vs Junction Temperature

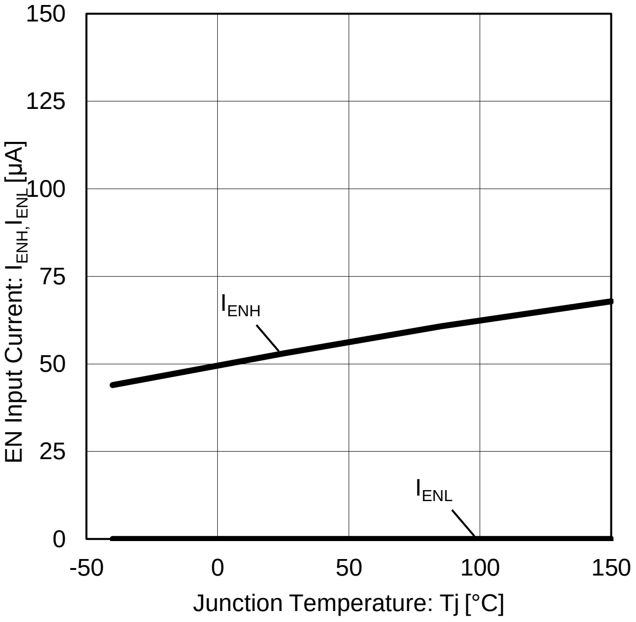


Figure 15. EN Input Current vs Junction Temperature

Typical Performance Curves – continued

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

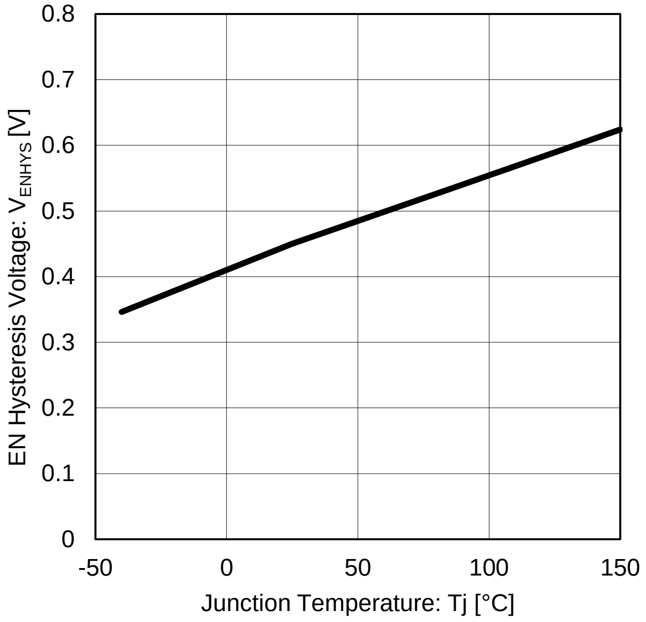


Figure 16. EN Hysteresis Voltage vs Junction Temperature

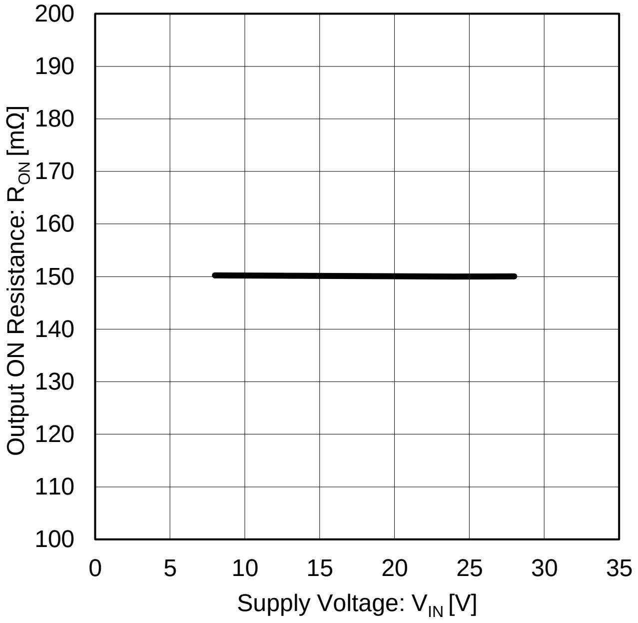


Figure 17. Output ON Resistance vs Supply Voltage

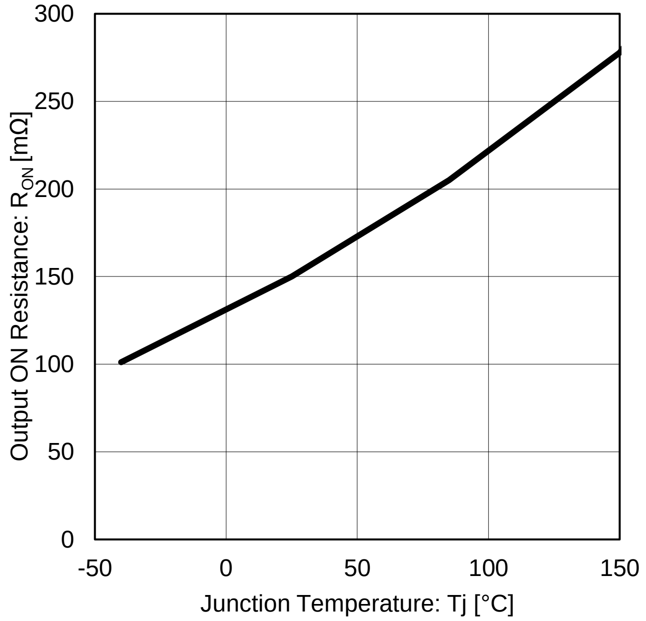


Figure 18. Output ON Resistance vs Junction Temperature

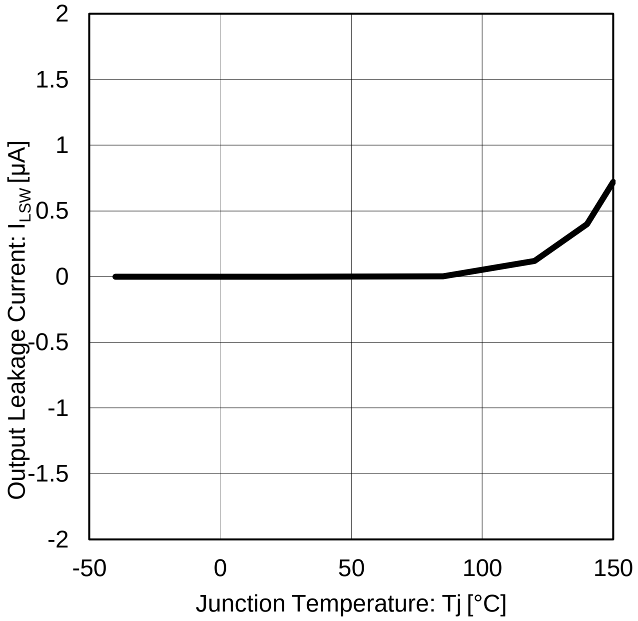


Figure 19. Output Leakage Current vs Junction Temperature

Typical Performance Curves – continued

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

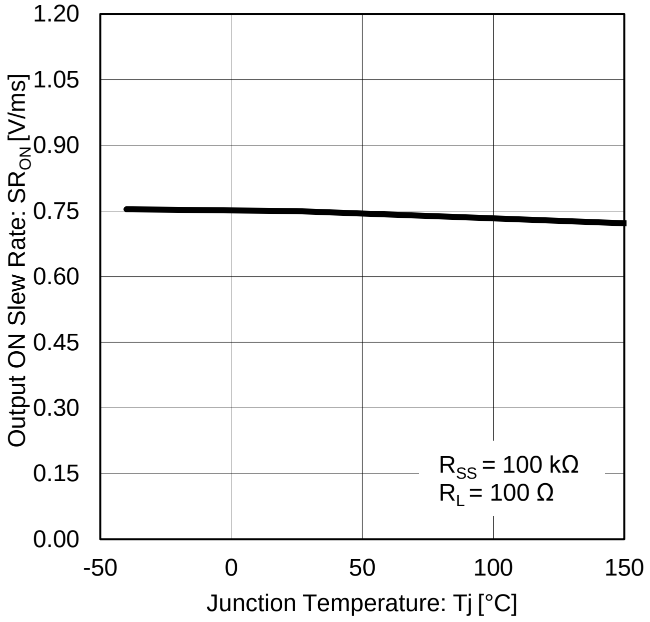


Figure 20. Output ON Slew Rate vs Junction Temperature

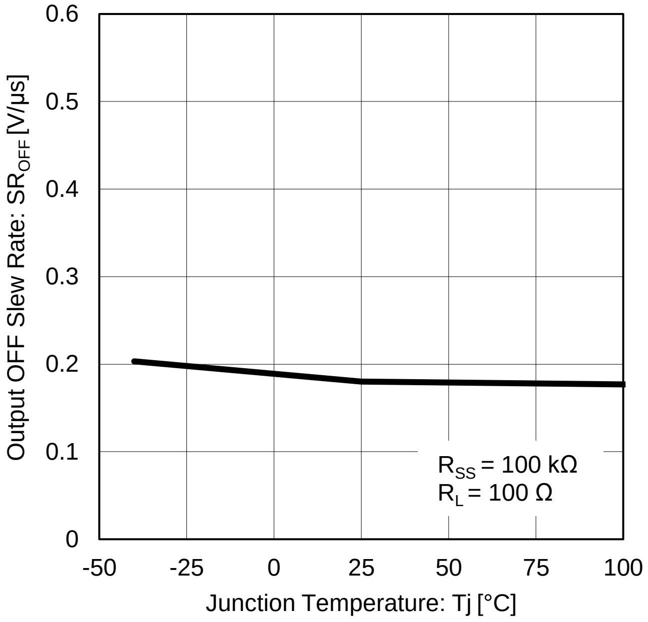


Figure 21. Output OFF Slew Rate vs Junction Temperature

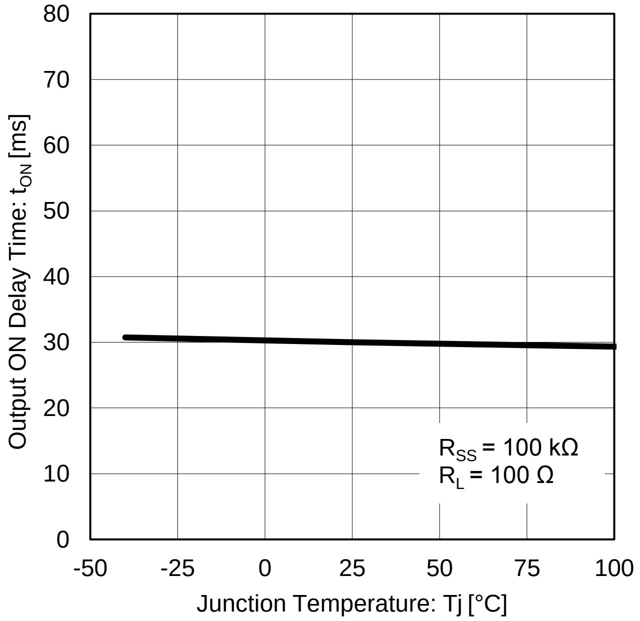


Figure 22. Output ON Delay Time vs Junction Temperature

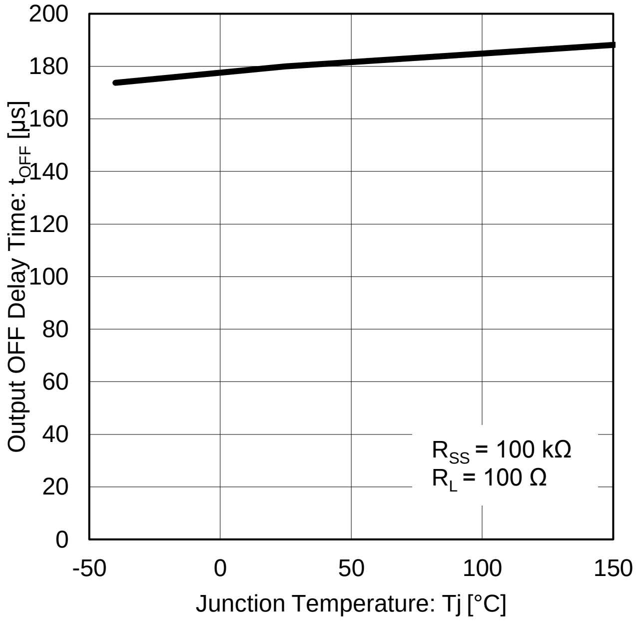


Figure 23. Output OFF Delay Time vs Junction Temperature

Typical Performance Curves – continued

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

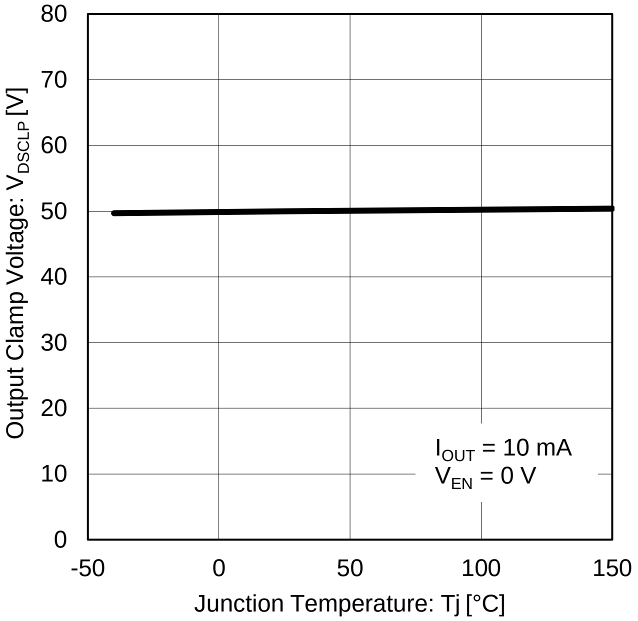


Figure 24. Output Clamp Voltage vs Junction Temperature

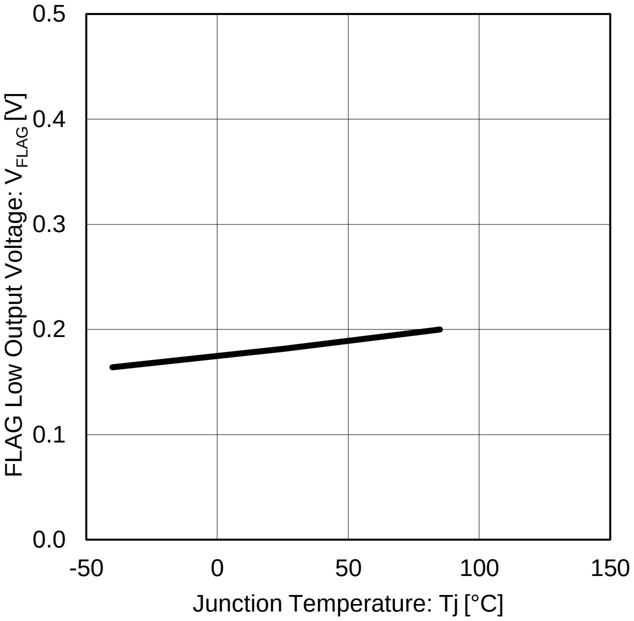


Figure 25. FLAG Low Output Voltage vs Junction Temperature

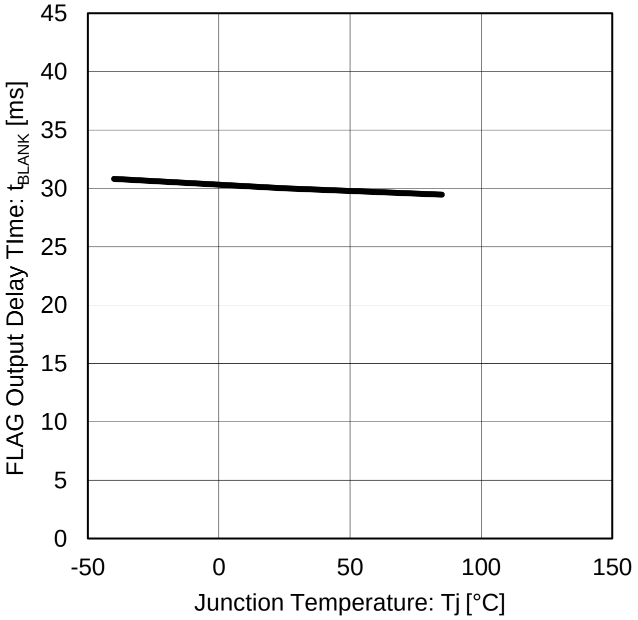


Figure 26. FLAG Output Delay Time vs Junction Temperature

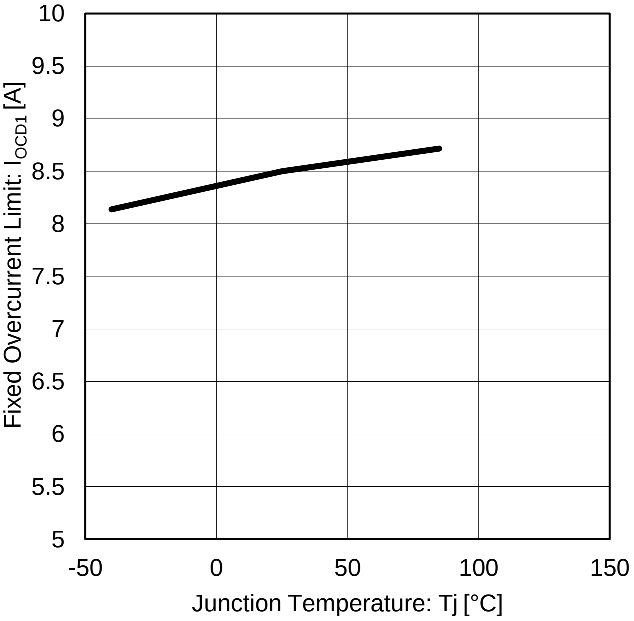


Figure 27. Fixed Overcurrent Limit vs Junction Temperature

Typical Performance Curves – continued

(Unless otherwise specified V_{IN} = 24 V, V_{EN} = 5 V, Tj = 25 °C)

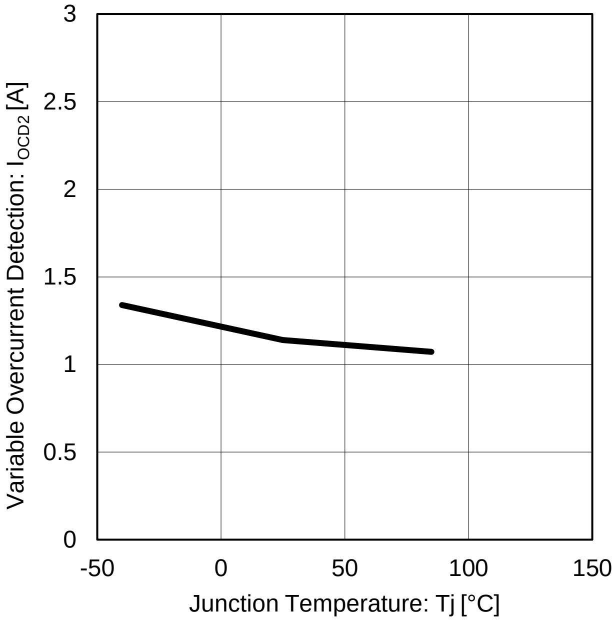


Figure 28. Variable Overcurrent Detection vs Junction Temperature

Measurement Setup

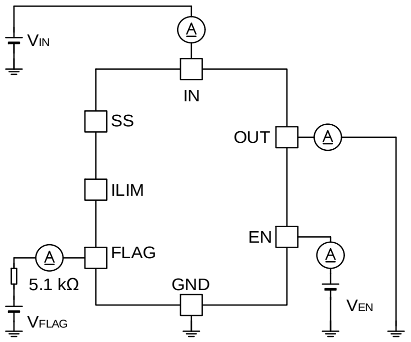


Figure 29. Standby Current
EN Low Input Current
Output Leakage Current
FLAG Pin Leakage Current

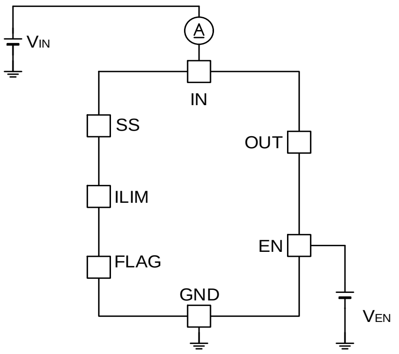


Figure 30. Operating Current

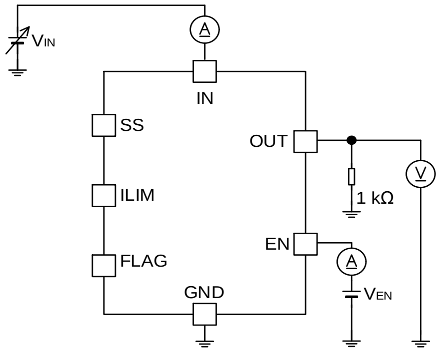


Figure 31. UVLO Detection Voltage
UVLO Hysteresis Voltage
EN High Voltage
EN Low Voltage
EN Hysteresis Voltage
EN High Input Current
EN Low Input Current
Thermal Shutdown Detection
Thermal Shutdown Hysteresis

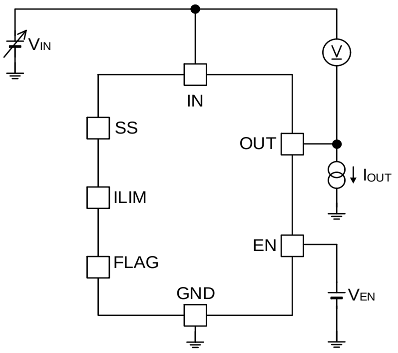


Figure 32. Output ON Resistance
Output Clamp Voltage

Measurement Setup – continued

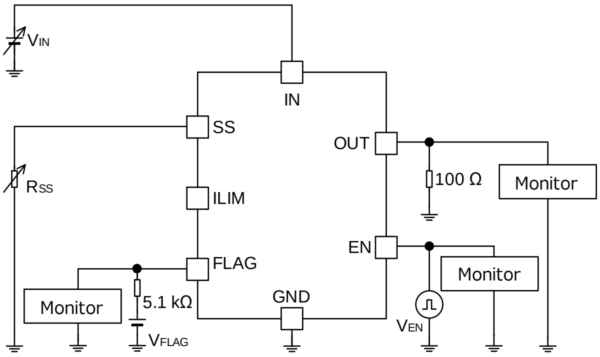


Figure 33. Output ON Slew Rate
Output OFF Slew Rate
Output ON Delay Time
Output OFF Delay Time
FLAG Output Delay Time

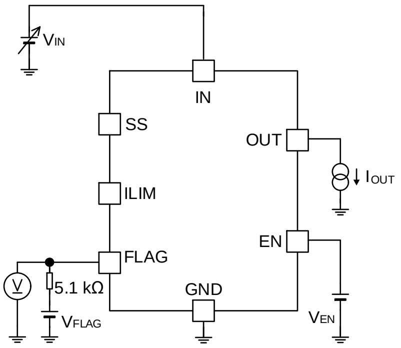


Figure 34. FLAG Low Output Voltage

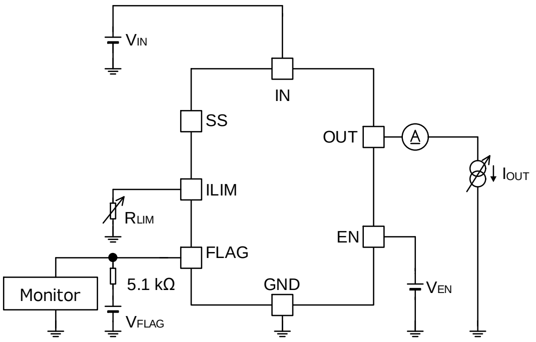


Figure 35. Fixed Overcurrent Limit
Variable Overcurrent Detection

Timing Chart

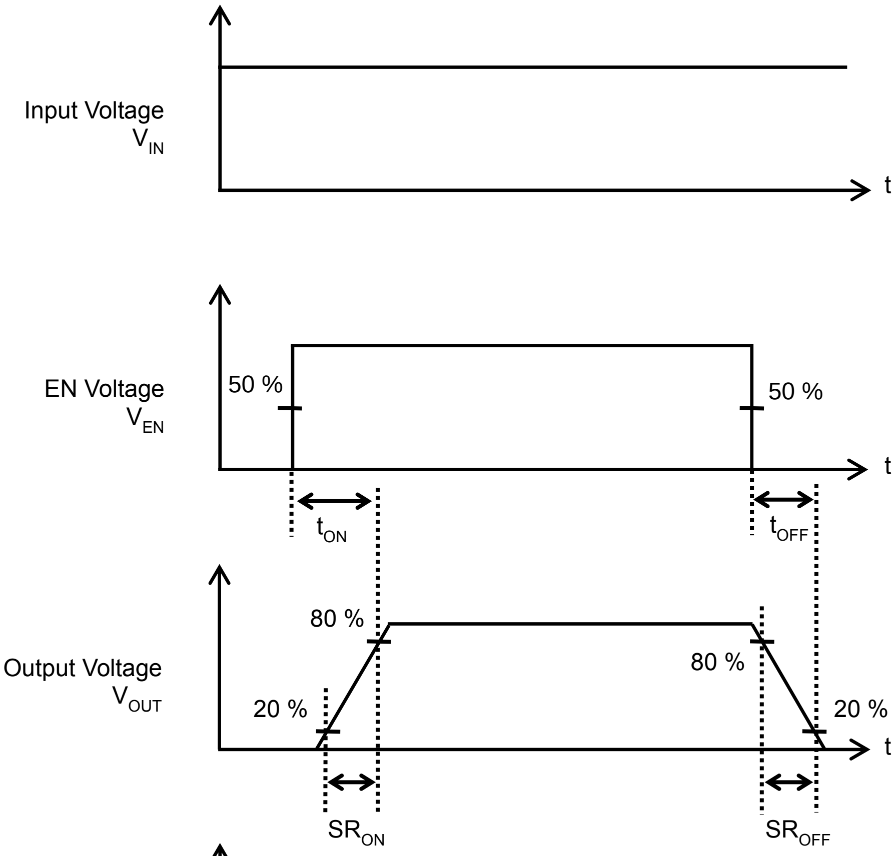


Figure 36. Output ON / OFF Timing Chart

Function Description

1. Truth Table

Table 1. Protection Detection and Error FLAG Output

Control Logic EN	Input Voltage V_{IN}	Junction Temperature Tj	Output Current I_{OUT}	Output State OUT	Error Flag Output V_{FLAG}	Mode
H	$V_{IN} > V_{UVLO}$	$Tj < T_{TSD}$	$I_{OUT} < I_{OCD2}$	ON	H	Normal
			$I_{OUT} > I_{OCD2}$	ON	H	Overcurrent Detection
			$I_{OUT} > I_{OCD2}$ t_{BLANK} after	Latch-Off	L	Latch-Off *(Note 1)*
			$I_{OUT} > I_{OCD1}$	Output Limited	H	Overcurrent Limitation
		$Tj > T_{TSD}$	-	OFF	L	TSD protection
		ΔTj *(Note 2)* $> T_{DTJ}$	-	OFF	L	ΔTj protection
	$V_{IN} < V_{UVLO}$	-	-	OFF	H	Stand-by
L	-	-	-	OFF	H	Stand-by

(Note 1) When thermal shutdown protection is triggered while overcurrent protection is active, output is Latch-Off even if $t < t_{BLANK}$. The condition of Latch-Off release is switching of EN voltage (V_{EN}) or IN voltage (V_{IN}).

(Note 2) The temperature difference of Power MOS FET and control in the IC.

Function Description – continued

2. Overcurrent Protection

This IC has two overcurrent detection functions: Fixed Overcurrent Limit (I_{OCD1}) to protect the IC and Variable Overcurrent Detection (I_{OCD2}) to protect the load. Variable Overcurrent Detection (I_{OCD2}) is set by an external resistor R_{LIM} at the ILIM pin.

2.1 Latch-Off due to Fixed Overcurrent Limit (I_{OCD1})

Figure 37 and Figure 38 show the timing chart of the Latch-Off function when Fixed Overcurrent Limit (I_{OCD1}) is detected.

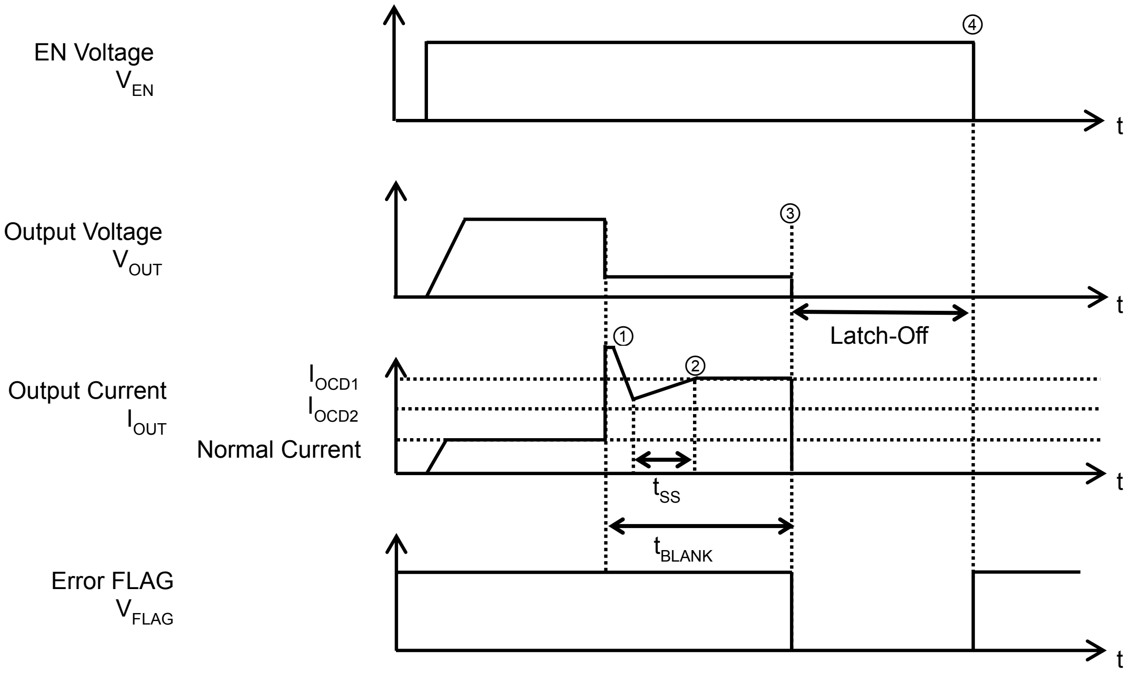


Figure 37. The timing chart with Latch-Off when I_{OUT} after Fixed Overcurrent Limit (I_{OCD1}) detection is equal to I_{OCD2} or higher

① When I_{OUT} exceeds the Fixed Overcurrent Limit (I_{OCD1}), I_{OUT} decreases momentarily then becomes $I_{OUT} \geq I_{OCD2}$.

② I_{OUT} increases until it reaches I_{OCD1}.
The time it takes for $I_{OUT} = I_{OCD1}$ (t_{SS}) depends on the setting of Soft Start Function by external resistor R_{SS} (Table 3, 4). When $I_{OUT} = I_{OCD1}$, Output voltage (V_{OUT}) = Load resistance (R_L) × Fixed Overcurrent Limit (I_{OCD1})

③ When I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) and the duration exceeds t_{BLANK}, output is latched off and Error FLAG V_{FLAG} is set to Low.

④ When EN is turned OFF, Latch-Off function is released and Error FLAG V_{FLAG} is set to High.

2.1 Latch-Off due to Fixed Overcurrent Limit (I_{OCD1}) – continued

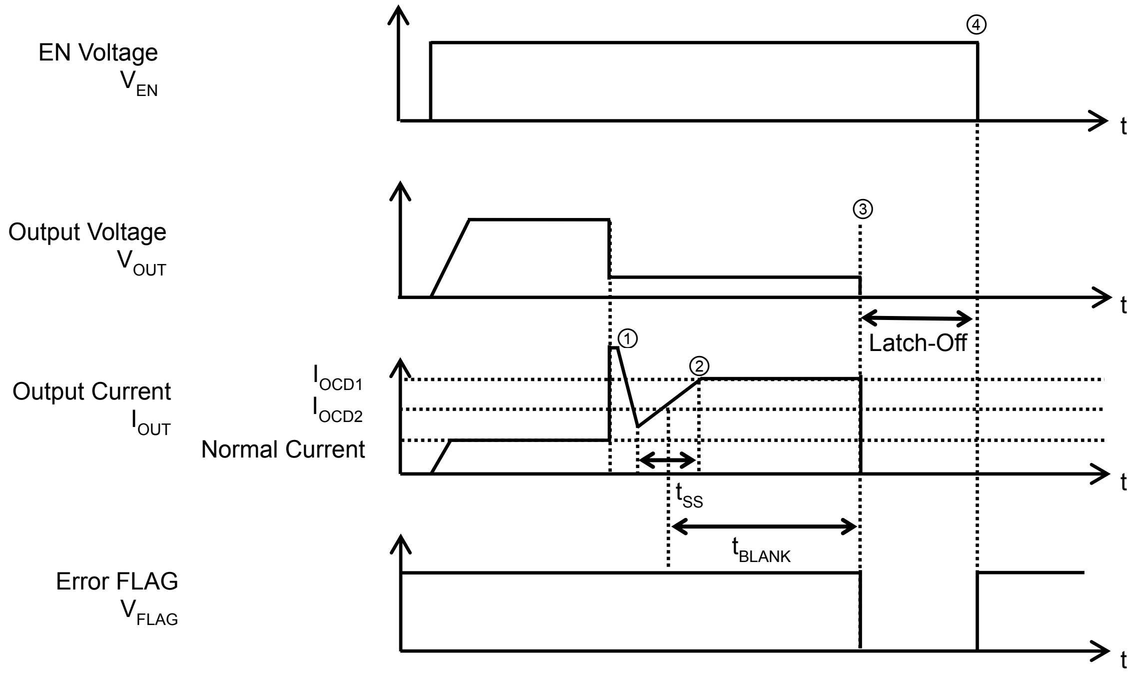


Figure 38. The timing chart with Latch-Off when I_{OUT} after Fixed Overcurrent Limit (I_{OCD1}) detection is less than I_{OCD2}

① When I_{OUT} exceeds the Fixed Overcurrent Limit (I_{OCD1}), I_{OUT} decreases momentarily then becomes $I_{OUT} < I_{OCD2}$.

② I_{OUT} increases until it reaches I_{OCD1}.
The time it takes for $I_{OUT} = I_{OCD1}$ (t_{SS}) depends on the setting of Soft Start Function by external resistor R_{SS} (Table 3, 4). When $I_{OUT} = I_{OCD1}$, Output voltage (V_{OUT}) = Load resistance (R_L) × Fixed Overcurrent Limit (I_{OCD1})

③ When I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) and the duration exceeds t_{BLANK}, output is latched off and Error FLAG V_{FLAG} is set to Low.

④ When EN is turned OFF, Latch-Off function is released and Error FLAG V_{FLAG} is set to High.

2. Overcurrent Protection – continued

2.2 Duration of Fixed Overcurrent Limit (I_{OCD1}) is less than t_{BLANK}

Figure 39 and Figure 40 show the timing chart without the Latch-Off function when Fixed Overcurrent Limit (I_{OCD1}) is detected.

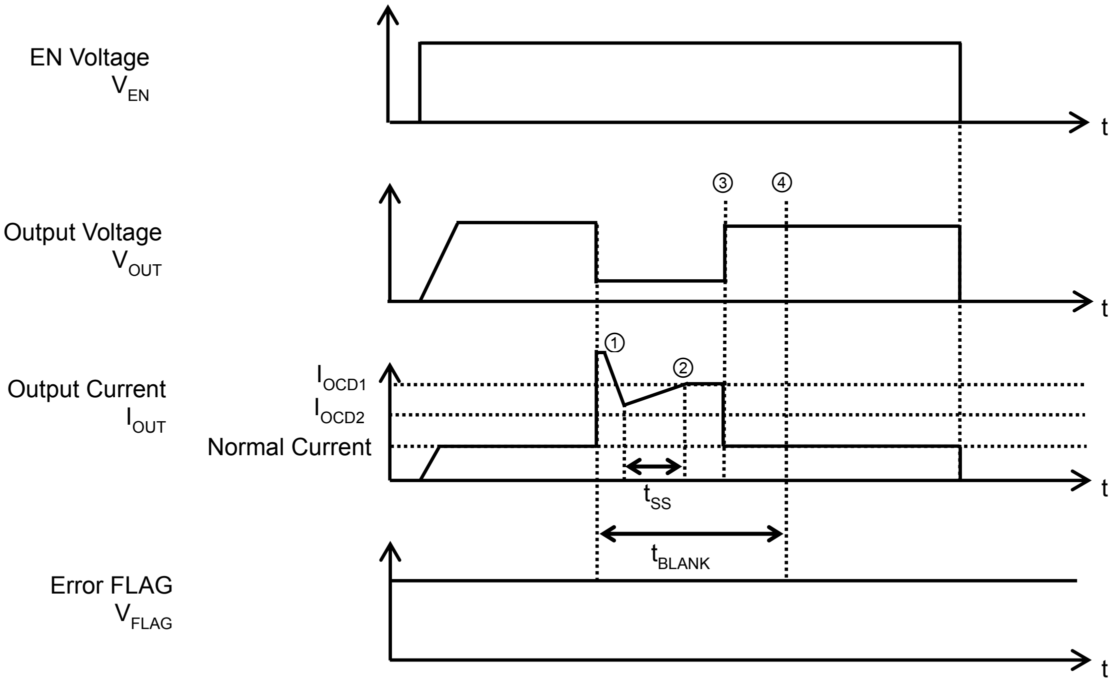


Figure 39. The timing chart without Latch-Off when I_{OUT} after Fixed Overcurrent Limit (I_{OCD1}) detection is equal to I_{OCD2} or higher

① When I_{OUT} exceeds the Fixed Overcurrent Limit (I_{OCD1}), I_{OUT} decreases momentarily then becomes $I_{OUT} \geq I_{OCD2}$.

② I_{OUT} increases until it reaches I_{OCD1}.
The time it takes for $I_{OUT} = I_{OCD1}$ (t_{SS}) depends on the setting of Soft Start Function by external resistor R_{SS} (Table 3, 4). When $I_{OUT} = I_{OCD1}$, Output voltage (V_{OUT}) = Load resistance (R_L) × Fixed Overcurrent Limit (I_{OCD1})

③ When the duration where I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) is less than t_{BLANK}, the output does not Latch-Off.

④ Indicates t_{BLANK}.

2.2 Duration of Fixed Overcurrent Limit (I_{OCD1}) is less than t_{BLANK} – continued

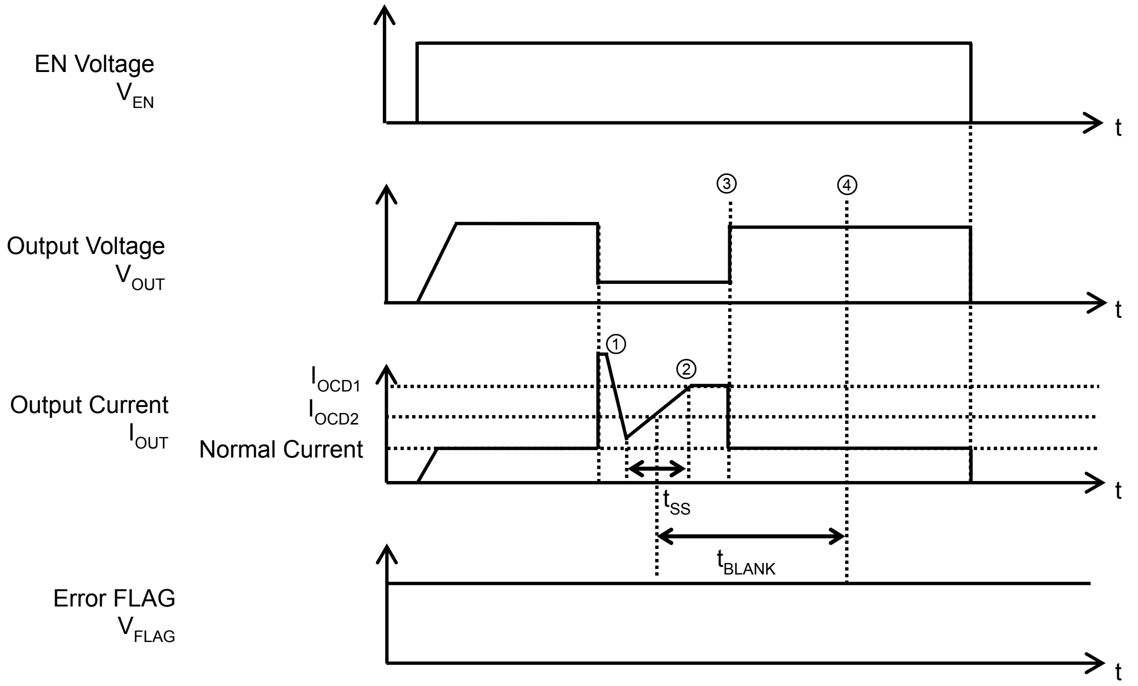


Figure 40. The timing chart without Latch-Off when I_{OUT} after Fixed Overcurrent Limit (I_{OCD1}) detection is less than I_{OCD2}

① When I_{OUT} exceeds the Fixed Overcurrent Limit (I_{OCD1}), I_{OUT} decreases momentarily then becomes $I_{OUT} < I_{OCD2}$.

② I_{OUT} increases until it reaches I_{OCD1}.
The time it takes for $I_{OUT} = I_{OCD1}$ (t_{SS}) depends on the setting of Soft Start Function by external resistor R_{SS} (Table 3, 4). When $I_{OUT} = I_{OCD1}$, Output voltage (V_{OUT}) = Load resistance (R_L) × Fixed Overcurrent Limit (I_{OCD1})

③ When the duration where I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) is less than t_{BLANK}, the output does not Latch-Off.

④ Indicates t_{BLANK}.

2. Overcurrent Protection – continued

2.3 Latch-Off due to Variable Overcurrent Detection (I_{OCD2})

Figure 41 shows the timing chart of the Latch-Off function when Variable Overcurrent Detection (I_{OCD2}) is detected.

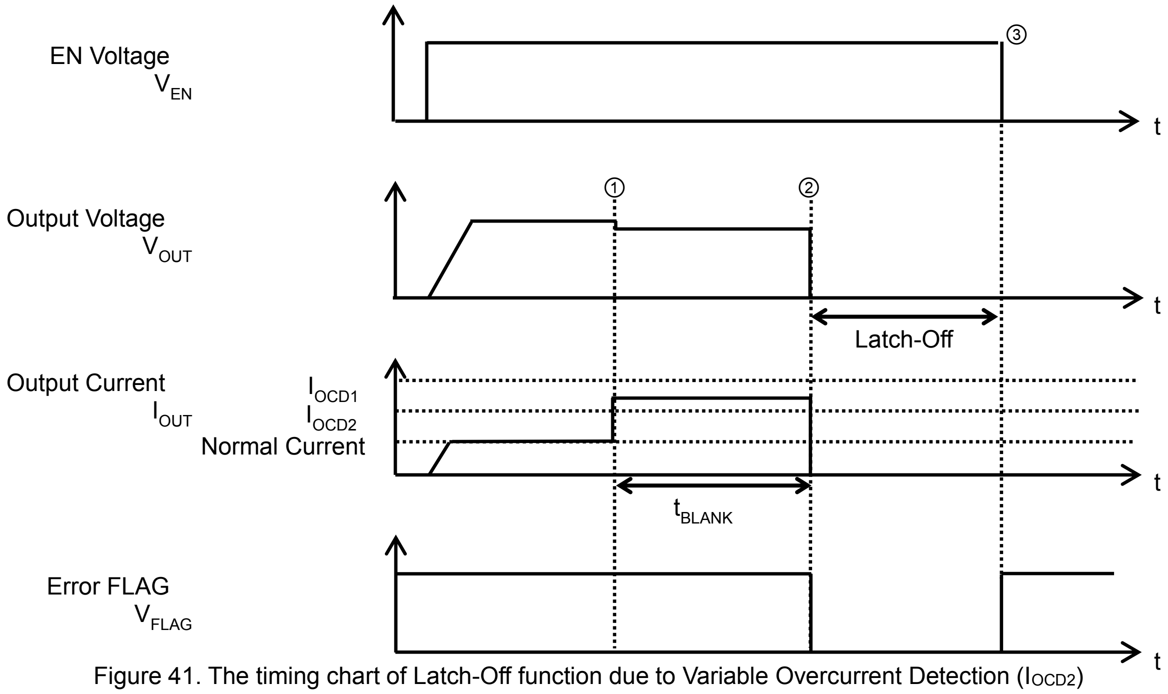


Figure 41. The timing chart of Latch-Off function due to Variable Overcurrent Detection (I_{OCD2})

① When I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) but is the Fixed Overcurrent Limit (I_{OCD1}) or less, I_{OUT} is not limited.

② When I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) and the duration exceeds t_{BLANK}, output is latched off and Error FLAG is set to Low.

③ When EN is turned OFF, Latch-Off function is released and Error FLAG is set to High.

2.4 Duration of Variable Overcurrent Detection (I_{OCD2}) is less than t_{BLANK}

Figure 42 shows the timing chart without the Latch-Off function when Variable Overcurrent Detection (I_{OCD2}) is detected.

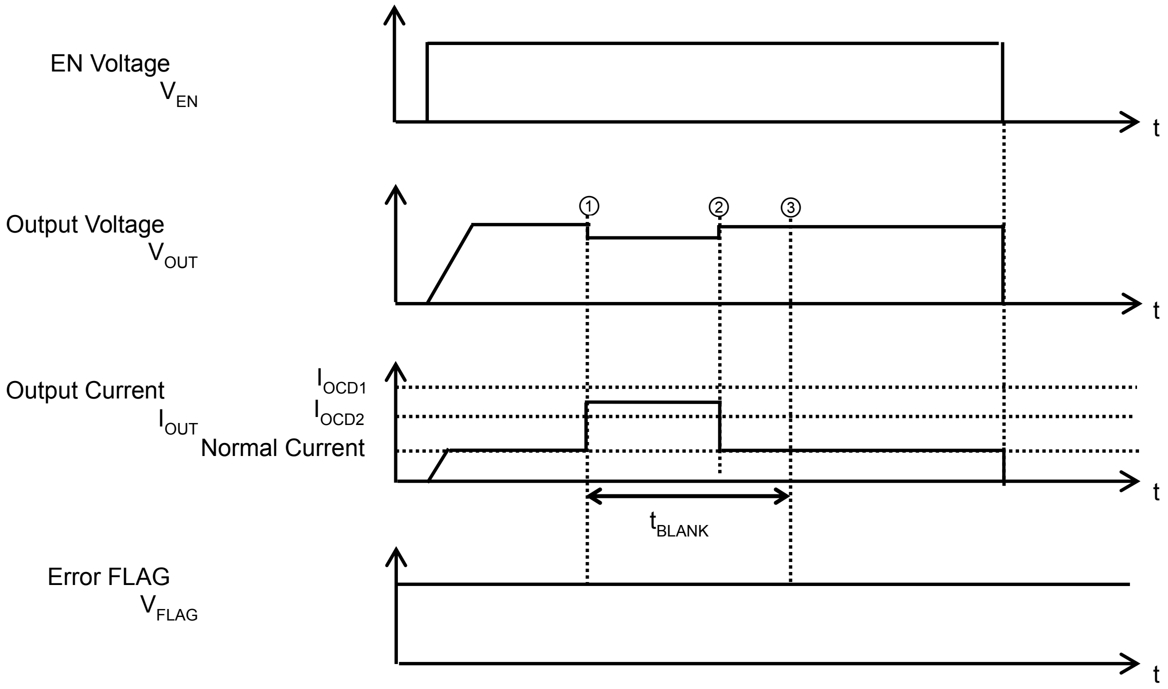


Figure 42. The timing chart of Variable Overcurrent Detection (I_{OCD2}) without Latch-Off function

① When I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) but is the Fixed Overcurrent Limit (I_{OCD1}) or less, I_{OUT} is not limited.

② When the duration where I_{OUT} exceeds the Variable Overcurrent Detection (I_{OCD2}) is less than t_{BLANK}, the output does not Latch-Off.

③ Indicates t_{BLANK}.

2. Overcurrent Protection – continued

2.5 Setting Variable Overcurrent Detection

This IC has a Variable Overcurrent Detection (I_{OCD2}) that can be set by an external resistor R_{LIM}. The Variable Overcurrent Detection (I_{OCD2}) value is set by R_{LIM} value as shown below. R_{LIM} should be set from 50 kΩ to 200 kΩ.

Table 2. Variable Overcurrent Detection against R_{LIM} Value

R_{LIM} [kΩ]	Variable Overcurrent Detection (I_{OCD2}) [A]		
	Min	Typ	Max
50	1.35	2.07	2.80
70	0.91	1.40	1.89
100	0.74	1.14	1.54
120	0.64	0.99	1.33
130	0.59	0.91	1.23
170	0.53	0.82	1.10
200	0.48	0.75	1.02

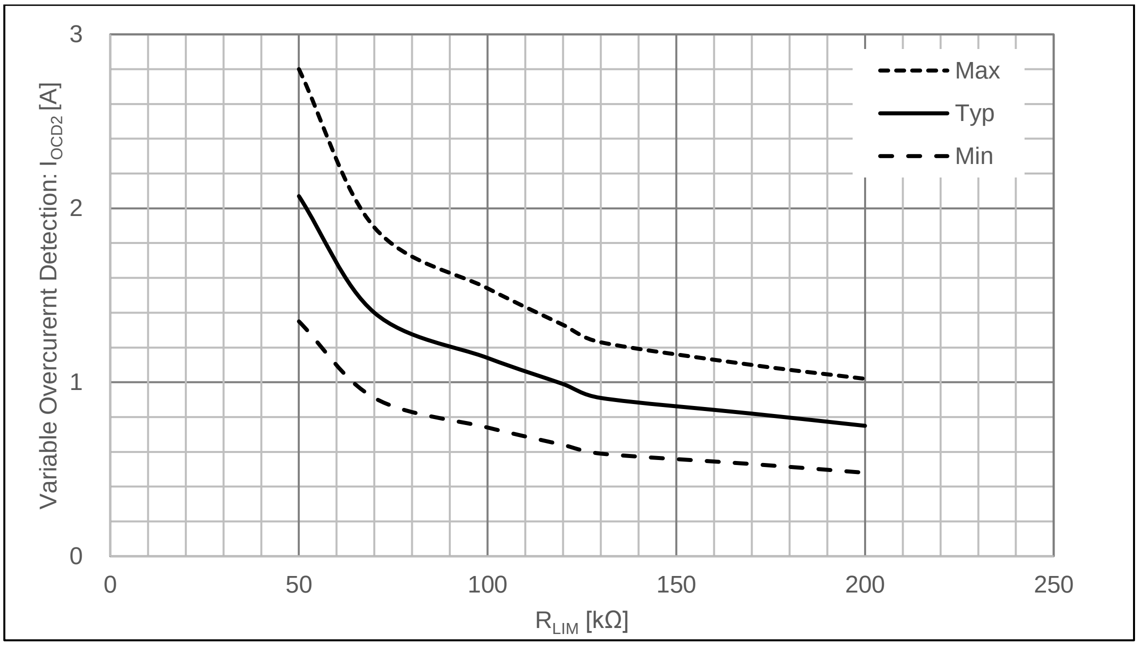


Figure 43. Variable Overcurrent Detection vs R_{LIM}

Function Description – continued

3. Setting Soft Start Function

This IC has a soft start function that can be set by an external resistor R_{SS}.

The output on delay time (t_{ON}) and output on slew rate (SR_{ON}) set against R_{SS} value at V_{IN} = 12 V and V_{IN} = 24 V is shown below. Set R_{SS} within 15 kΩ to 120 kΩ range. *(Note 1) (Note 2)*

Table 3. Output On Delay Time against R_{SS} Value (Tj = 25 °C)

R_{SS} [kΩ]	Output ON Delay Time (t_{ON}) [ms]					
	V_{IN} = 12 V			V_{IN} = 24 V		
	Min	Typ	Max	Min	Typ	Max
15	3.27	5.45	7.64	4.13	6.89	9.64
20	3.95	6.58	9.21	4.99	8.32	11.65
30	5.21	8.68	12.15	6.60	11.00	15.40
40	6.63	11.05	15.46	7.92	13.20	18.48
50	8.43	14.06	19.68	9.94	16.56	23.19
60	9.42	15.70	21.97	11.51	19.18	26.85
100	14.70	24.50	34.30	18.00	30.00	42.00
120	17.76	29.60	41.44	21.42	35.69	49.97

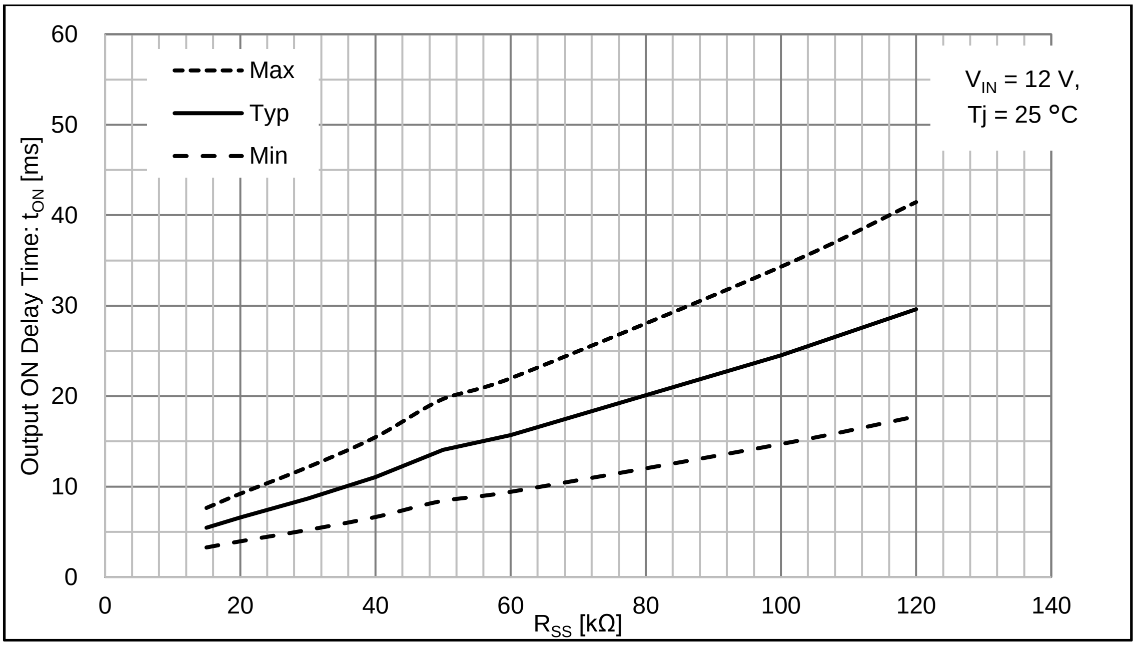


Figure 44. Output ON Delay Time vs R_{SS} (V_{IN} = 12 V, Tj = 25 °C)

(Note 1) In the case that V_{IN} is 12 V, the Approximate expression for the output rising edge delay time (t_{ON}) set against R_{SS} value is expressed in the equation below.

$$t_{ON}\ (Typ) = 0.23 \times R_{SS} + 1.5$$

3. Setting Soft Start Function – continued

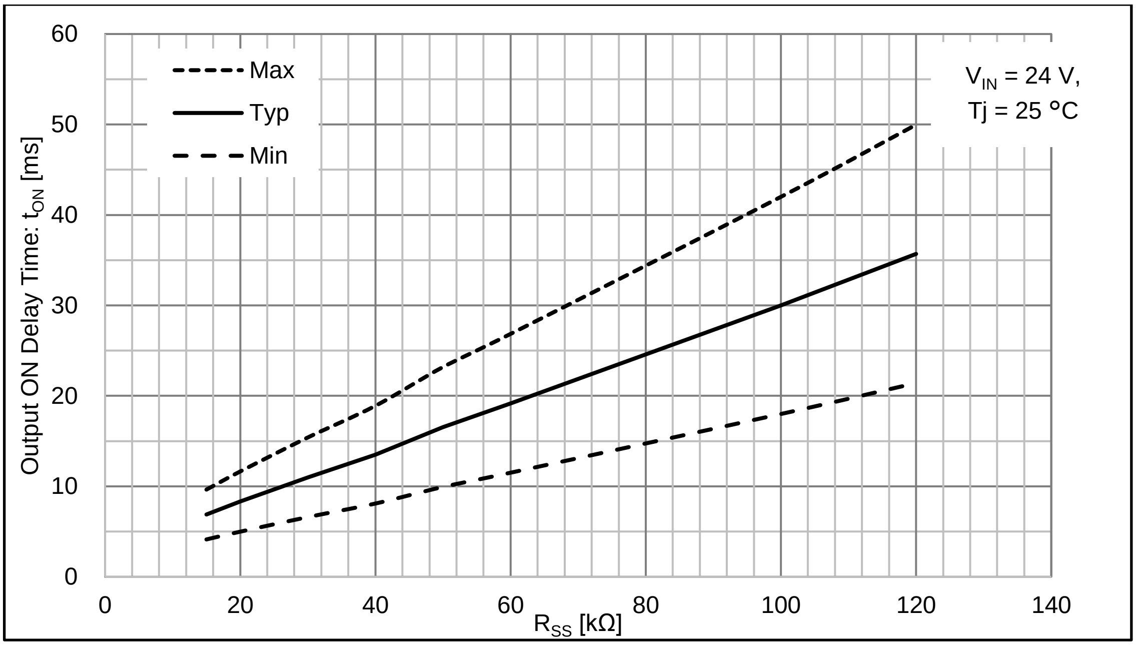


Figure 45. Output ON Delay Time vs R_{SS} (V_{IN} = 24 V, Tj = 25 °C)

(Note 2) In the case that V_{IN} is 24 V, the Approximate expression for the output rising edge delay time (t_{ON}) set against R_{SS} value is expressed in the equation below.

$$t_{ON}\ (Typ) = 0.27 \times R_{SS} + 2.56$$

3. Setting Soft Start Function – continued

Table 4. Output ON Slew Rate against R_{SS} Value (Tj = 25 °C)

R_{SS} [kΩ]	Output ON Slew Rate (SR_{ON}) [V/ms]					
	V_{IN} = 12 V			V_{IN} = 24 V		
	Min	Typ	Max	Min	Typ	Max
15	1.46	2.44	3.42	1.89	3.15	4.42
20	1.30	2.17	3.03	1.71	2.84	3.98
30	1.00	1.66	2.32	1.27	2.12	2.97
40	0.74	1.24	1.73	0.93	1.55	2.17
50	0.56	0.93	1.30	0.80	1.34	1.88
60	0.49	0.81	1.13	0.65	1.09	1.52
100	0.32	0.54	0.75	0.45	0.75	1.05
120	0.29	0.49	0.69	0.37	0.61	0.86

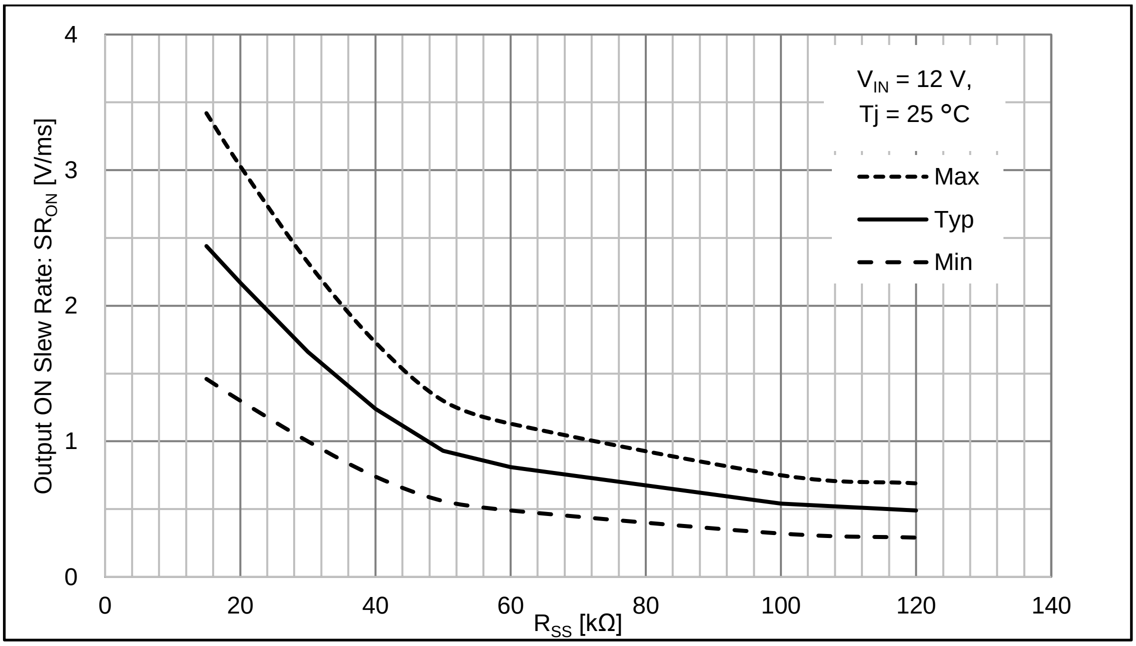


Figure 46. Output ON Slew Rate vs R_{SS} (V_{IN} = 12 V, Tj = 25 °C)

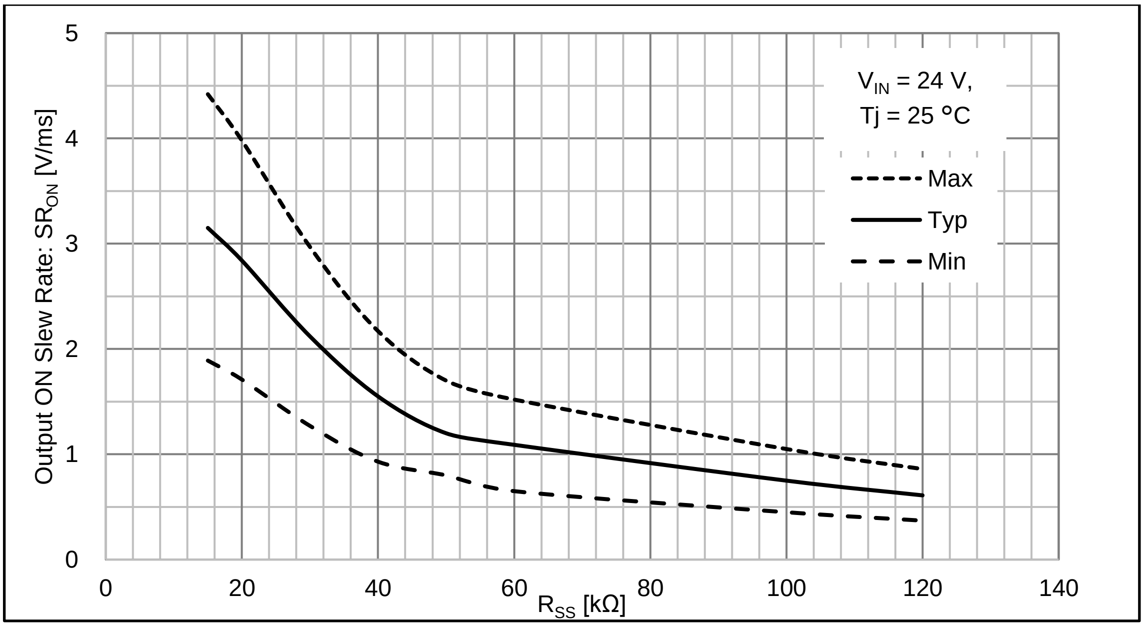


Figure 47. Output ON Slew Rate vs R_{SS} (V_{IN} = 24 V, Tj = 25 °C)

Function Description – continued

4. Thermal Shutdown Function, ΔTj Protection Function

4.1 Thermal Shutdown Function (Thermal Shutdown Detection T_{TSD}, Thermal Shutdown Hysteresis T_{TSDHYS})

This IC has a built-in TSD function. When the temperature of the IC reaches Thermal Shutdown Detection (T_{TSD}) = 175 °C (Typ) or more, the output is turned off, and the FLAG outputs Low. Hysteresis (T_{TSDHYS}) is installed for thermal shutdown function, and output automatically returns to normal when chip temperature become 160 °C (Typ) or less. The condition for Latch-Off is when Variable Overcurrent Detection (I_{OCD2}) is reached and the temperature of IC reaches Thermal Shutdown Detection (T_{TSD}) = 175 °C (Typ) or more. The condition for Latch-Off Release is the switching of EN voltage (V_{EN}) or IN voltage (V_{IN}).

4.2 ΔTj Protection Function (ΔTj Protection T_{DTJ}, ΔTj Protection Hysteresis T_{DTJHYS})

This IC has a ΔTj protection function. The output is turned off when chip temperature difference (ΔTj) of Power MOS FET ($T_{POWER-MOS}$) and control (T_{AMB}) in the IC rises to 105 °C (Typ) or more. Furthermore, hysteresis (T_{DTJHYS}) is installed for ΔTj protection function, and returns to its normal state when ΔTj becomes 75 °C (Typ) or less.
Figure 48 is shown that the timing chart of thermal shutdown function and ΔTj protection function with Latch-Off function. The condition for Latch-Off is when Thermal Shutdown Detection (T_{TSD}) is operated and Variable Overcurrent Detection (I_{OCD2}) is reached.

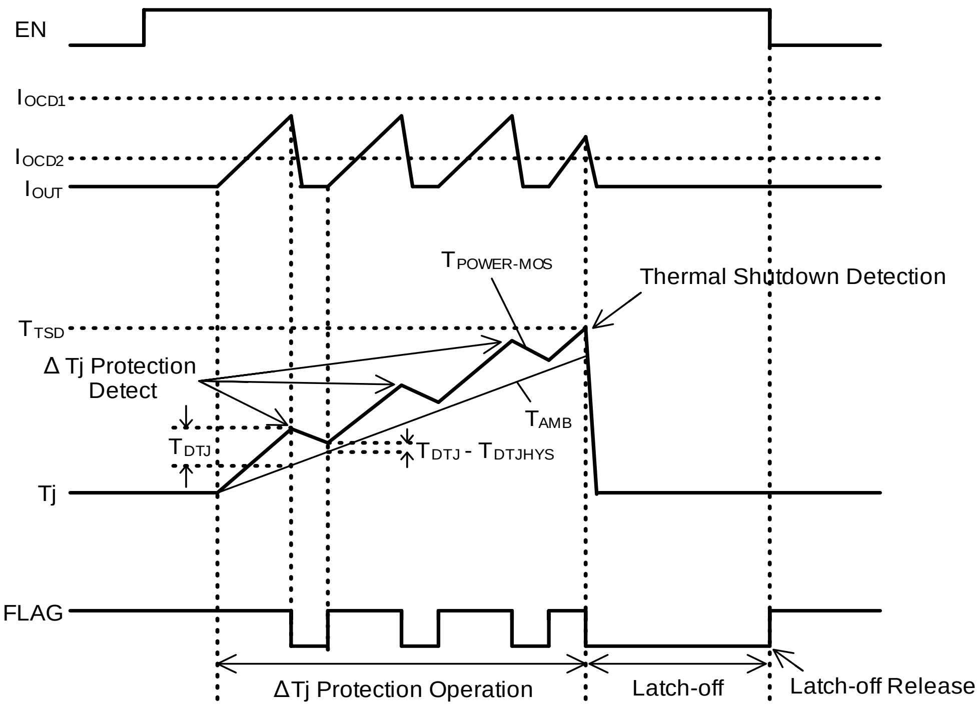


Figure 48. Timing chart of thermal shutdown function and ΔTj protection function with Latch-Off function

4.2 ΔTj Protection Function (ΔTj Protection T_{DTJ}, ΔTj Protection Hysteresis T_{DTJHYS}) – continued

Figure 49 is shown that the timing chart of thermal shutdown function and ΔTj protection function without Latch-Off function.
The condition for without the activation of the Latch-Off is when Thermal Shutdown Detection (T_{TSD}) is operated and Variable Overcurrent Detection (I_{OCD2}) is not reached.

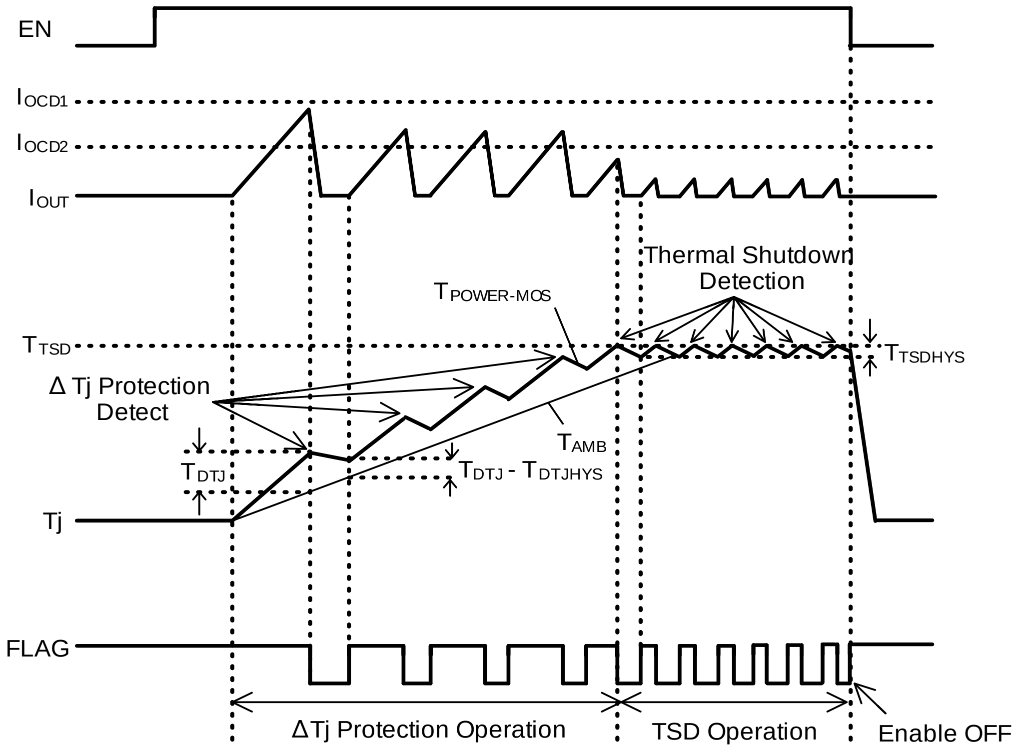


Figure 49. Timing chart of thermal shutdown function and ΔTj protection function without Latch-Off function

4.3 The case of connecting the capacitance load

At startup, the load connected is used to detect ΔTj protection function. The R_{SS} region where ΔTj protection function is detected versus the output current (I_{OUT})*(Note 3)* are shown in Figure 50 to Figure 55 *(Note 4)*. Pay attention to detect ΔTj protection function.

(Note 3) I_{OUT} is not including the capacitance load current at startup.
(Note 4) This results are used evaluation board of ROHM.

4.3 The case of connecting the capacitance load – continued

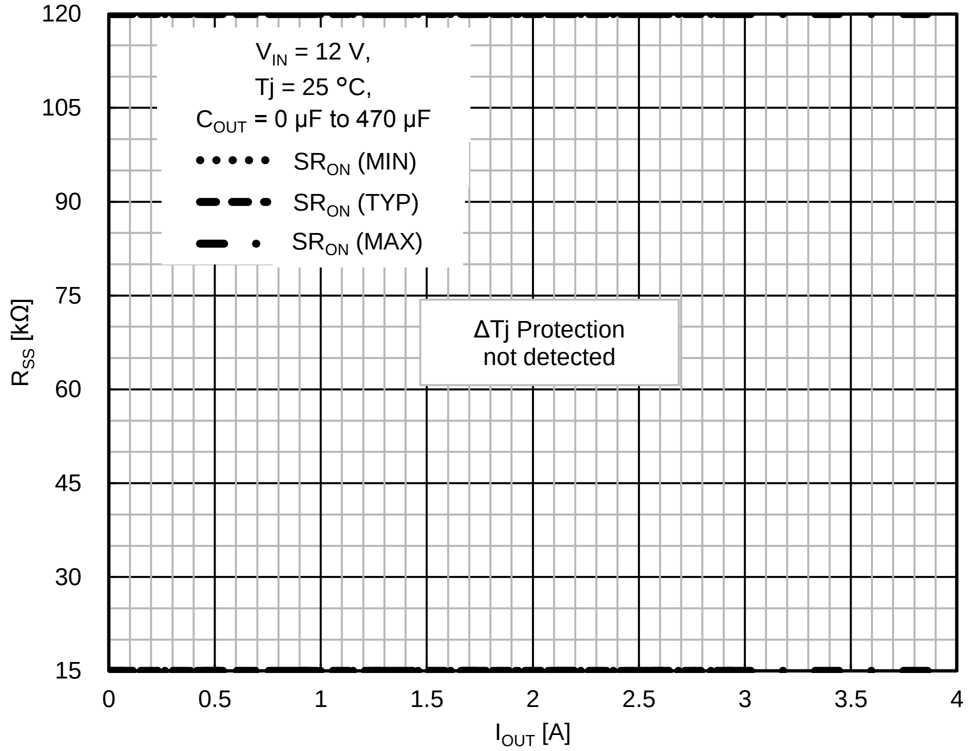


Figure 50. ΔTj protection function detection region at startup (V_{IN} = 12 V, C_{OUT} = 0 µF to 470 µF)

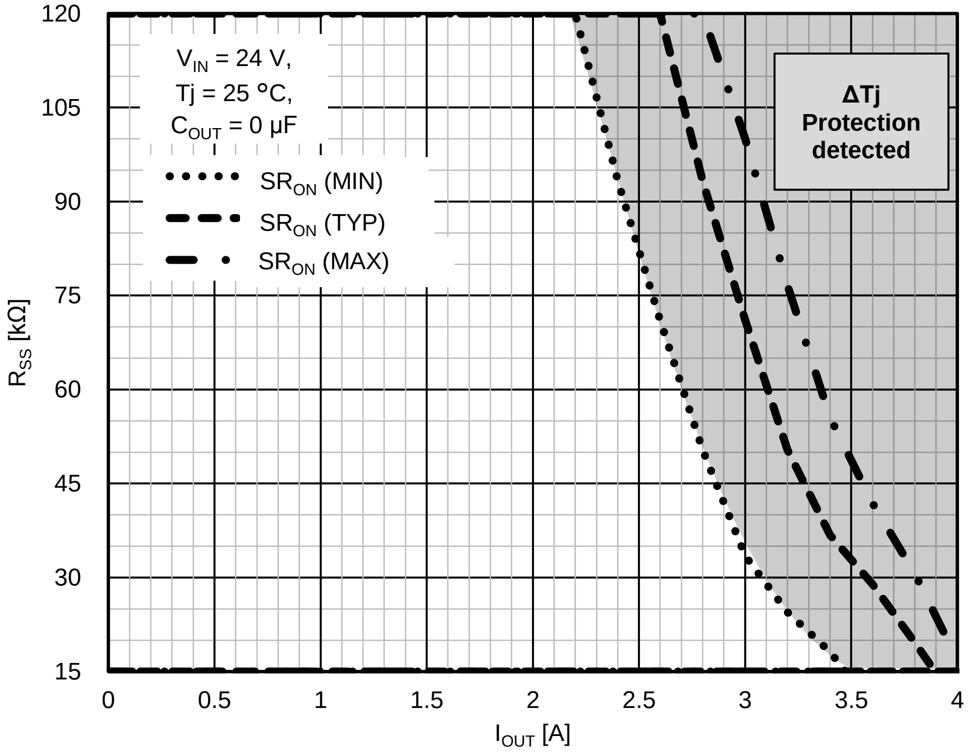


Figure 51. ΔTj protection function detection region at startup (V_{IN} = 24 V, C_{OUT} = 0 µF)

4.3 The case of connecting the capacitance load – continued

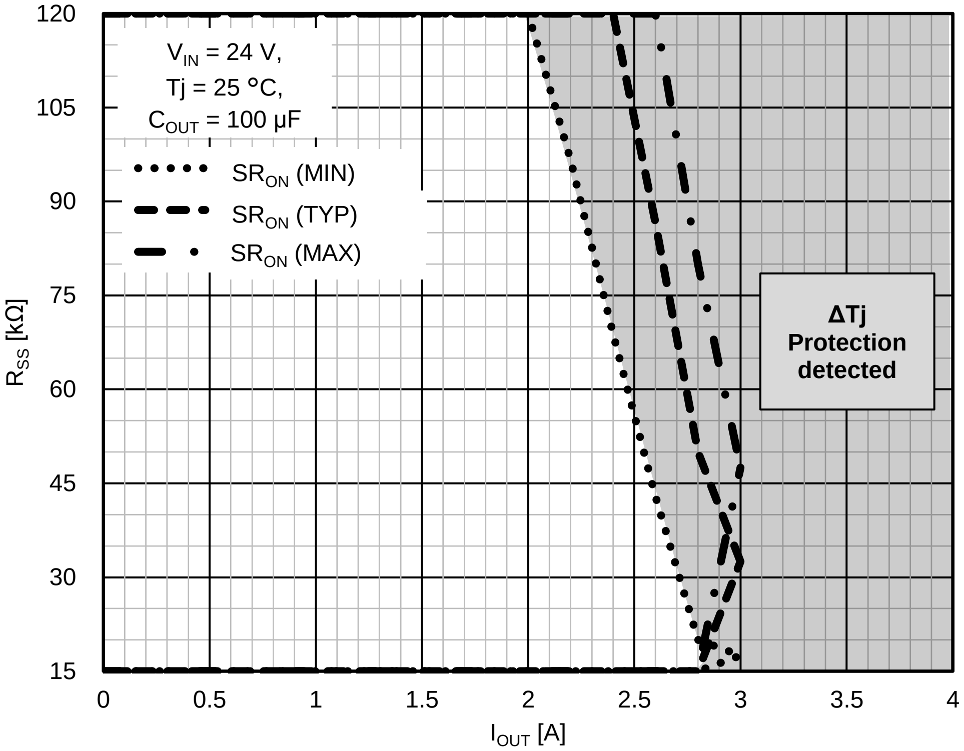


Figure 52. ΔTj protection function detection region at startup (V_{IN} = 24 V, C_{OUT} = 100 µF)

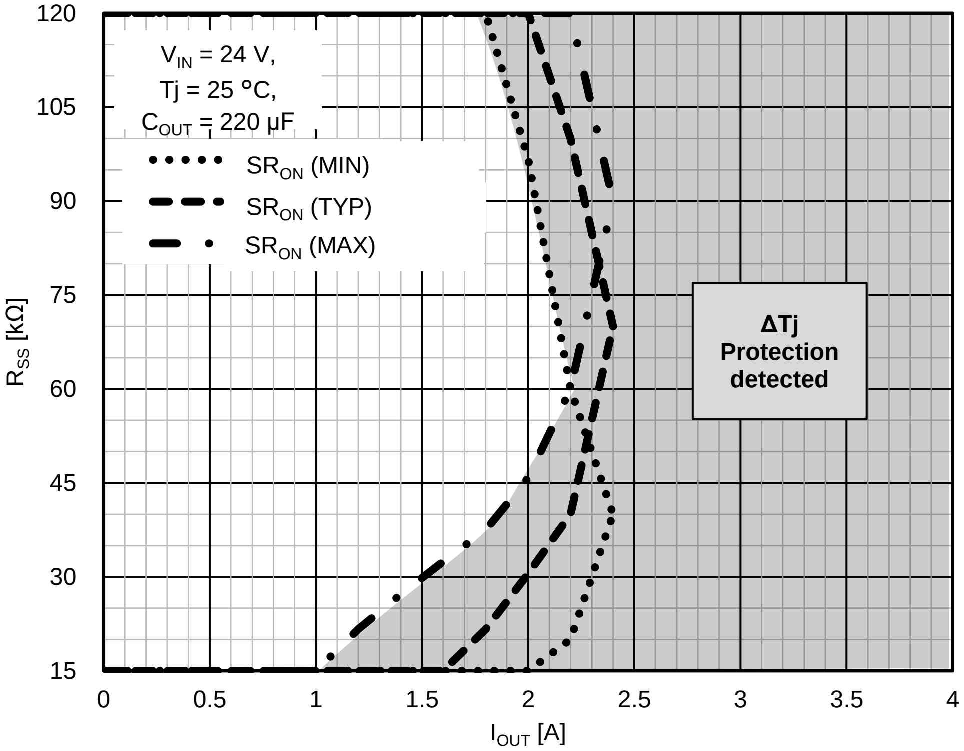


Figure 53. ΔTj protection function detection region at startup (V_{IN} = 24 V, C_{OUT} = 220 µF)

4.3 The case of connecting the capacitance load – continued

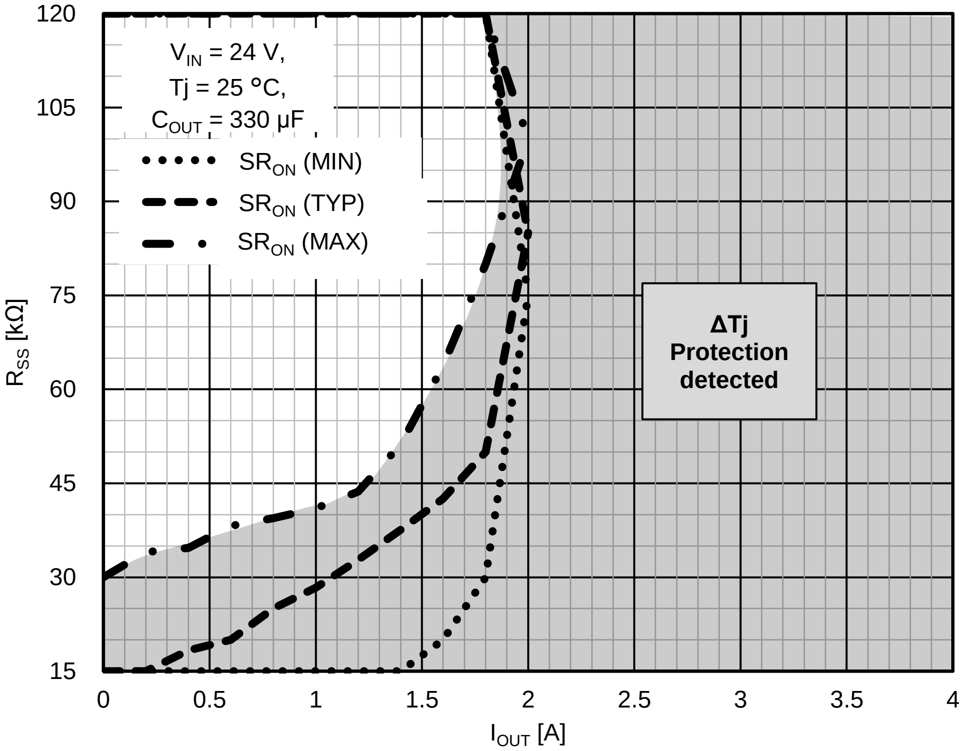


Figure 54. ΔTj protection function detection region at startup (V_{IN} = 24 V, C_{OUT} = 330 µF)

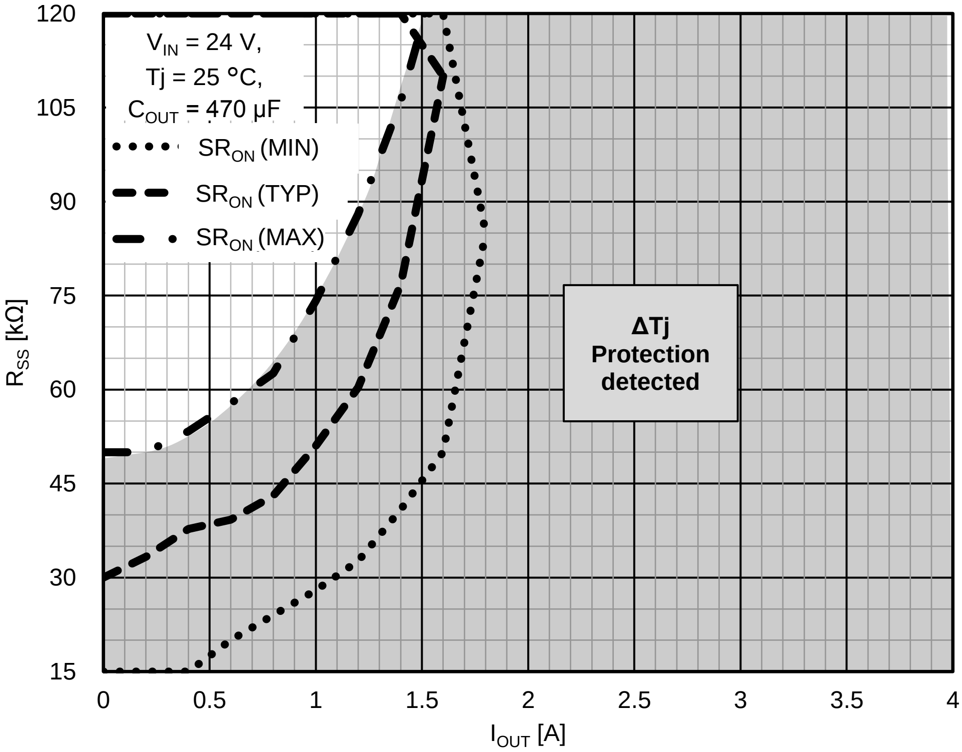


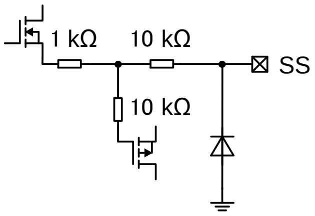
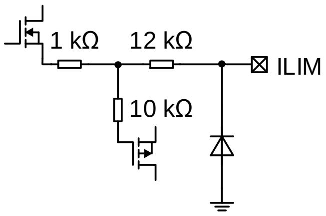
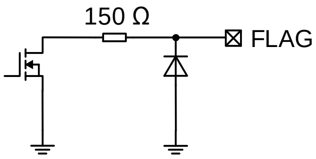
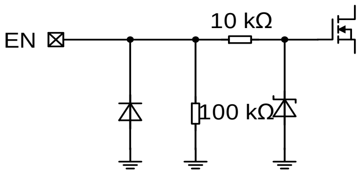
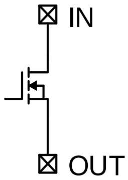
Figure 55. ΔTj protection function detection region at startup (V_{IN} = 24 V, C_{OUT} = 470 µF)

Function Description – continued

5. Output Load is Open

When EN is OFF and no load is connected to OUT, output voltage does not fall to GND potential.

I/O Equivalence Circuit

SS	ILIM
	
FLAG	**EN**
	
OUT	
	

Resistance in the figures are typical values.

Operational Notes

1. **Recommended Operating Conditions**
The IC is designed to operate in 12 V automotive board net applications. The functions and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions specified by the electrical characteristics. The IC can withstand transient voltages beyond the recommended operating conditions; however, parameter deviations are possible when used outside of the supply nominal voltage range. Exposure to the absolute maximum ratings may cause permanent damage to the IC.

2. **Inrush Current**
When a load is being activated by the IC inrush currents may flow. The IC is designed to drive high inrush current loads; however, careful consideration must be completed when pairing the IC with the load. In case special recommendations are not available in the Datasheet the minimum overcurrent protection level of the IC should be higher than the maximum expected inrush current for proper load driving.

3. **Testing on Application Boards**
When testing the IC on an application board, it is recommended to always discharge capacitors completely after each evaluation step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

4. **Inter-pin Short and Mounting Errors**
Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

5. **Ceramic Capacitor**
When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

6. **Thermal Shutdown Function (TSD)**
This IC has a built-in thermal shutdown function that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (Tj) will rise which will activate the TSD function that will turn OFF power output pins. When the Tj falls below the TSD threshold, the circuits are automatically restored to normal operation.
Note that the TSD function operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD function be used in a set design or for any purpose other than protecting the IC from heat damage.

7. **Over Current Protection Function (OCP)**
This IC integrates an overcurrent limitation protection function that is activated when the load is shorted towards ground. This protection function is effective in preventing damage due to sudden and unexpected fault events. However, the IC should not be used in applications characterized by continuous operation of the protection function.

8. **Functional Safety**
"ISO 26262 Process Compliant to Support ASIL-*"
A product that has been developed based on an ISO 26262 design process compliant to the ASIL level described in the datasheet.
"Safety Mechanism is Implemented to Support Functional Safety (ASIL-*)"
A product that has implemented safety mechanism to meet ASIL level requirements described in the datasheet.
"Functional Safety Supportive Automotive Products"
A product that has been developed for automotive use and is capable of supporting safety analysis with regard to the functional safety.
Note: "ASIL-*" is stands for the ratings of "ASIL-A", "-B", "-C" or "-D" specified by each product's datasheet.

9. **Active Clamp Operation**
The IC integrates the active clamp function to internally absorb the reverse energy E_L which is generated when the inductive load is turned off. When the active clamp operates, the thermal shutdown function does not work. Decide a load so that the reverse energy E_L is active clamp energy (Single Pulse) E_{AS} (refer to Figure 2. Active Clamp Energy vs Output Current) or under when inductive load is used.

Operational Notes – continued

10. **Reverse Battery Connection**
Connecting the power supply i.e., the battery with a reversed polarity can damage the IC. Precautions must be taken against reverse polarity when connecting the power supply, such as mounting an external diode between the battery feed and the IC's power supply, blocking all current paths. Alternatively, inserting a blocking diode or resistance in series with the IC's GND pin will prevent or limit the current from flowing into the control circuits of the high side switch respectively. However, current through the body diode of the integrated power FET must be limited by the resistive component of the load. The current through the Digital inputs and SENSE pins must be limited too with protection resistors.

11. **Power Supply and PCB Layout**
Design the PCB layout in order to provide sufficient cooling to the IC. Connect the exposed pad with sufficient thermal vias to power supply copper plane to dissipate as much as possible thermal energy to the environment. Furthermore, connect as close as possible to the IC a capacitor between power supply and ground pins. Minimize the input capacitance of the digital input pins by placing the protection resistors as close as possible to the IC. Place the ground network as close as possible to the IC. Place the sense pin resistance as close as possible to the IC and the R-C filtering network close to the microcontroller. Place the output capacitors as close as possible to the IC. Short all output pins of the respective channel on the PCB to ensure equal current distribution. It is usually recommended to use a PCB with an internal copper layer as a power supply plane and another internal copper layer as a ground plane for thermal and EMC considerations respectively.

12. **Ground Shift and Ground Wiring Pattern**
When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. The IC is robust against small ground shift, however, ensure that the ground traces of external components do not cause big variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance. Big ground shifts could cause additional switching losses and electromagnetic emissions.

13. **Reverse Current**
A capacitive or inductive type of load can cause the output of the IC to rise above the input power supply level. The IC is designed to accept reverse current and normal operation is maintained as long as the reverse current is below the specified levels. Therefore, give special consideration to the maximum amount of reverse current that can flow through the device.

14. **Undervoltage or Loss of Battery**
The IC is designed to automatically switch off in case of loss of battery/power supply or undervoltage events. The IC will restart once the battery exceeds the specified operation threshold. In case the load is inductive a resistor on the ground network is recommended if loss of battery is foreseen at the same time in the application.

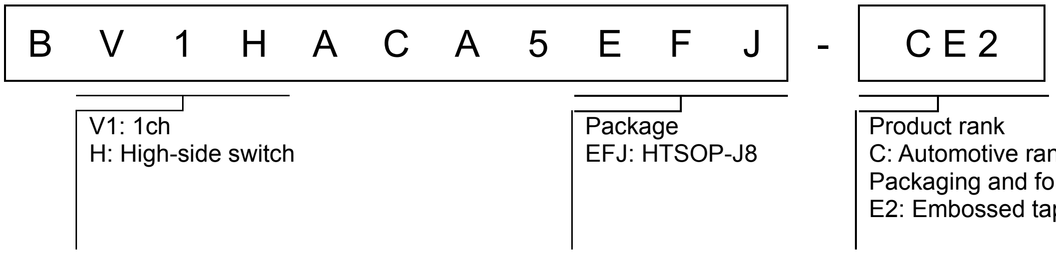
15. **Loss of Ground**
The IC cannot operate without the appropriate ground connection; nonetheless, the IC will automatically switch off in case of loss of ground. However, careful consideration of the external state of the inputs must be considered in order to avoid creating parasitic paths to another ground in the application via the external circuitry.

16. **Load Dump and Overvoltage Protection**
The IC is designed with integrated overvoltage protection to safeguard its internal circuits. For the overvoltage protection to work a ground resistance RGND is necessary. Furthermore, input pins' protection resistors are mandatory. In case of Load dump external TVS protection diodes must be connected to safeguard the system.

17. **Open Load or Short to Battery**
An open load event is not considered dangerous to the IC; moreover, the IC can detect such failure and signal the fault to the microcontroller. In case a short to battery is present the load is turned on independent of the state of the IC. The device can be used to detect such a failure and signal the fault to the microcontroller.

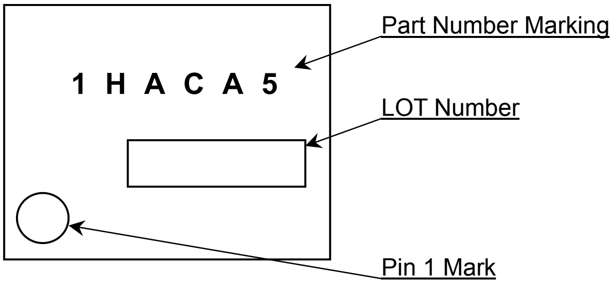
18. **Internally Not Connected (N.C.) Pins**
Pins that are specified as internally not connected have no physical connection to the IC. For mechanical reasons it is recommended to solder them on the PCB. Electrically they can remain not connected in the circuit or may be connected to different signals especially when using high current outputs.

Ordering Information



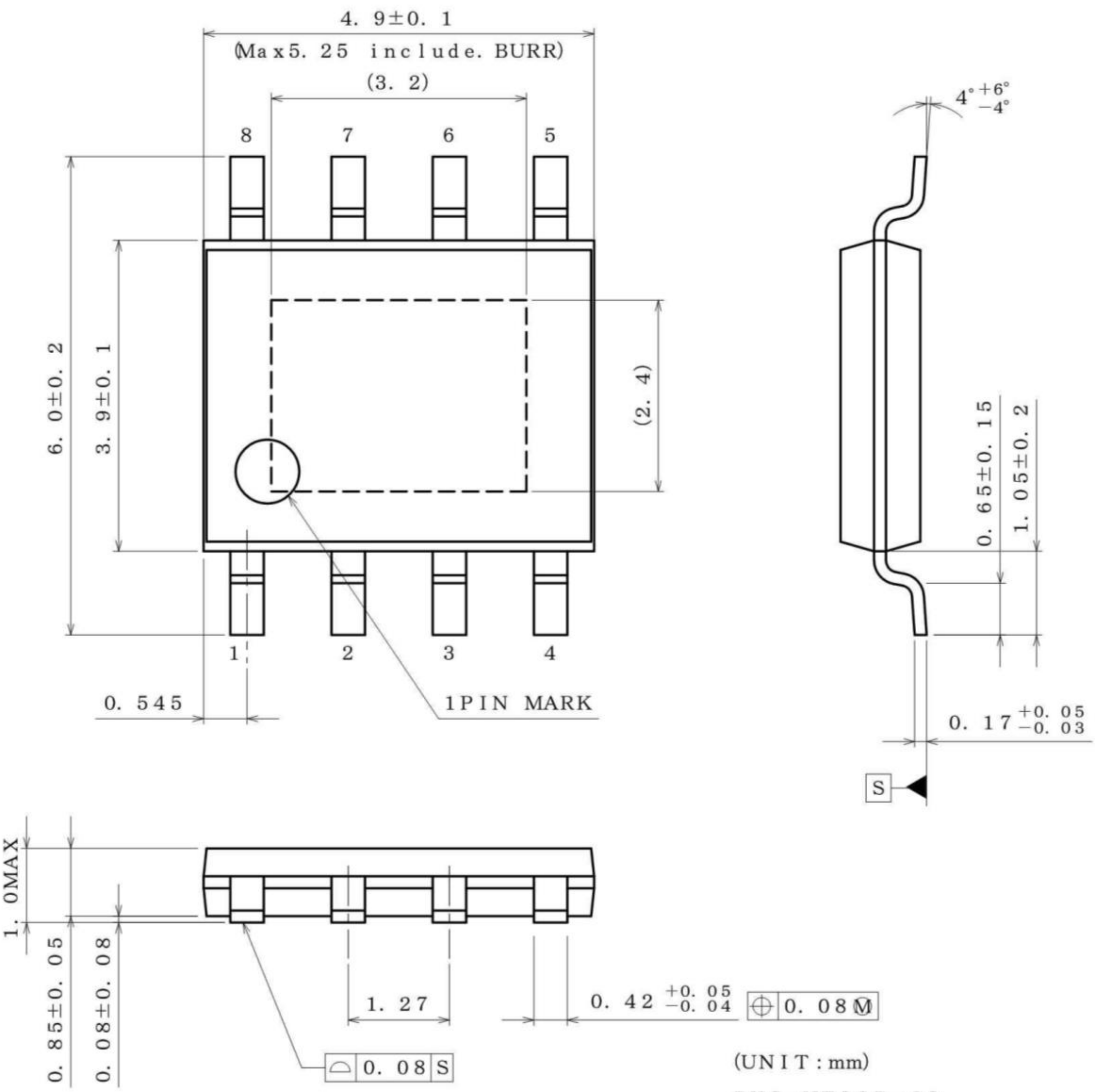
Marking Diagram

HTSOP-J8 (TOP VIEW)



Physical Dimension and Packing Information

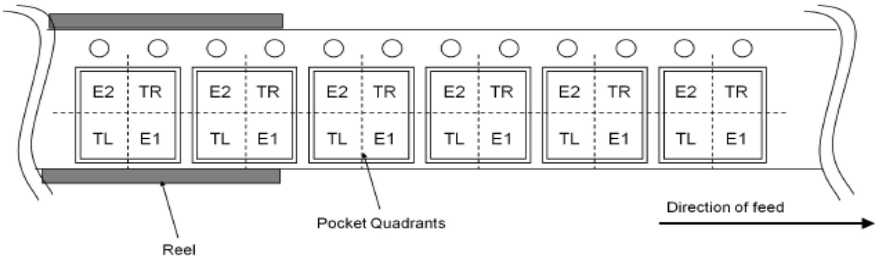
Package Name	HTSOP-J8



(UNIT : mm)
PKG : HTSOP−J8
Drawing No. EX169−5002−2

< Tape and Reel Information >

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 The direction is the pin 1 of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand



Revision History

Date	Revision	Changes
28.Feb.2025	001	New Release

Notice

Precaution on using ROHM Products

1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

   (Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   - [a] Installation of protection circuits or other protective devices to improve system safety
   - [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are not designed under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   - [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   - [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   - [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   - [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   - [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   - [f] Sealing or coating our Products with resin or other coating materials
   - [g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   - [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
    [a] the Products are exposed to sea winds or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
    [b] the temperature or humidity exceeds those recommended by ROHM
    [c] the Products are exposed to direct sunshine or condensation
    [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM’s internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

Precaution for Foreign Exchange and Foreign Trade act

Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

Precaution Regarding Intellectual Property Rights

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