SC77220BQ Dual Channel 20-mΩ Smart High Side Driver with Advanced Protections and Diagnostics

1 Descriptions

The SC77220BQ is a fully-protected dual channel smart high side driver qualified in automotive grade. Full diagnostics and high accuracy current sense enable intelligent control of the load even in harsh conditions. It integrates two 20mΩ MOSFETs in a compact package size with advanced protections of overload protection, dynamic thermal swing shutdown, absolute thermal shutdown. It features auto-restart mode in fault events. A multiplexed pin delivers proportional current sense, or fault indications in both active mode and standby mode.

2 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified with the Following Results:
  - Device Temperature Grade 1: -40°C to 125°C Ambient Operating Temperature Range
  - Device HBM ESD Classification Level H3A
  - Device CDM ESD Classification Level C4B
- Dual Channel 20mΩ Smart High-Side Driver with Full Diagnostics:
  - 14-pins, Auto-restart Mode, Channel Fault Diagnosis, Proportional Load Current Sense Output.
- Operating Junction Temperature: -40 to 150°C
- Wide Operating Voltage from 4 to 28V with Load Dump Withstand Voltage up to 40V.
- Ultra Low Standby Current < 500 nA
- Input Control, 3.3 V and 5 V Logic Compatible
- Multiplexed Analog Signals Sensing Output, Including
  - Proportional Load Current of Each Channel
  - Power Supply Voltage
  - Chip Junction Temperature
- High Accuracy Current Sense:
  - ±10% @ 5A
  - ±10% @ 3A
  - ±12% @ 0.1A
  - ±20% @ 0.05A
  - ±65% @ 0.01A
- Electrical Transient Disturbance Immunity Certification of ISO7637-2 and ISO16750-2
- Advanced Protections:
  - Short to GND and Overload Protection by Internal Overcurrent Shutdown
  - Dynamic Thermal Swing Shutdown and Absolute Thermal Shutdown with Auto-restart Mode
  - Inductive Load Negative Voltage Clamp with Optimized Slew Rate
  - Loss of GND and Loss of Battery Protection
  - Under Voltage Lockout (UVLO) Protection
- Diagnostics:
  - Overload and Short to Ground Detection in Active Mode
  - Open Load and Short to Battery Detection in Standby Mode

3 Applications

- High Side Power Driver for Sub-module
- Power Switch for Automotive Lamp
- High Side Relays and Solenoids
- General Resistive, Inductive and Capacitive Loads

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4 Device Information

ORDER NUMBER	DESCRIPTION	PACKAGE	BODY SIZE
SC77220BQSHER	○ Auto-restart Mode ○ Channel Fault Diagnosis Output ○ Proportional Load Current Sense Output	eSSOP-14	5.2 mm x 3.9 mm x 1.4mm

5 Revision History

Note: Page numbers for previous revisions may differ from page numbers in the current version.

Revision	Date	Page(s) Changed	Changes Description
1.0	2024.10.12	New	Initial release.
1.0.1	2024.12.03	4	ESD-HBM Info updated.
1.0.2	2025.07.28	6	Update electrical parameter.
1.0.3	2026.06.12	All Pages	Update the parameters names, function description in the datasheet.

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6 Typical Application Circuit

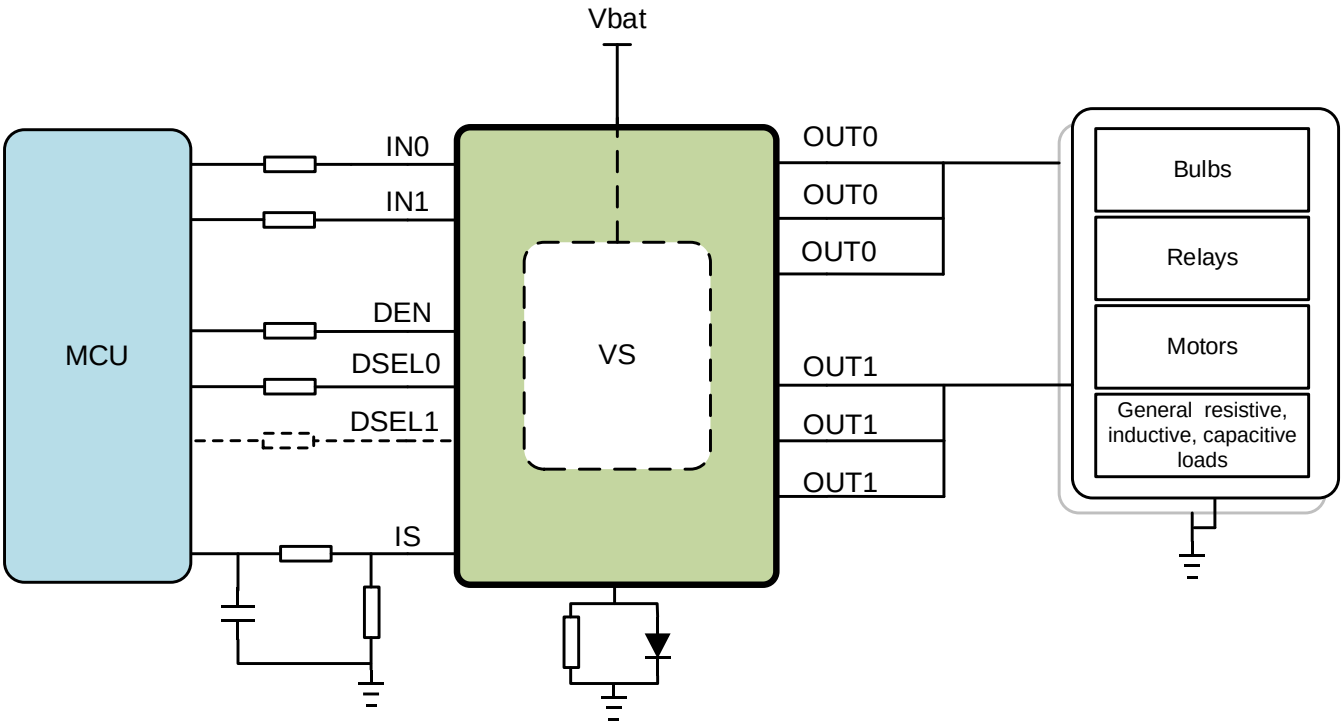

Figure 6-1. Typical Application Circuit

7 Terminal Configuration and Functions

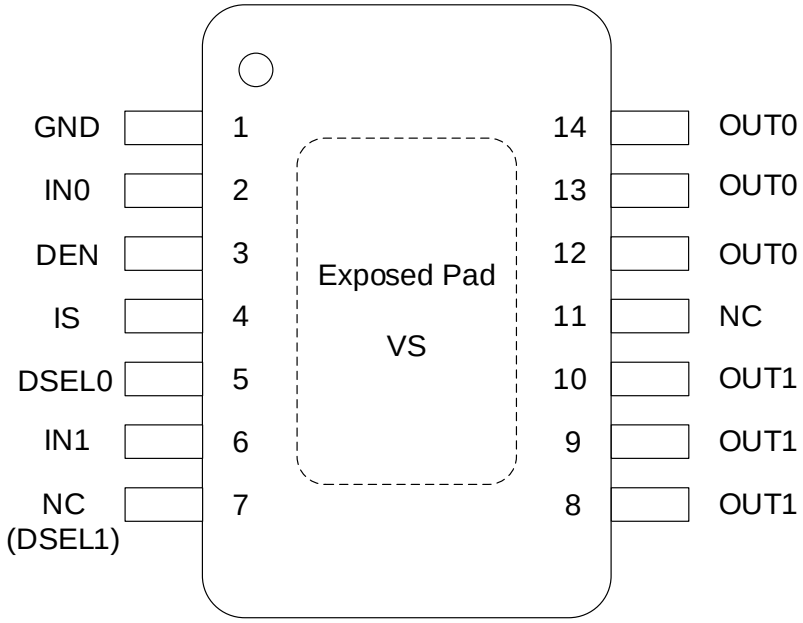

Figure 7-1. Configuration Diagram (Top View)

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Table 7-1. Suggested Connections for Unused and Not Connected Pins

TERMINAL		I/O	DESCRIPTION
NUMBER	NAME		
1	GND	-	Ground connection.
2	IN0	I	Input pin of Channel0. Active high to turn on Channel0. If not used: connect to GND pin or to module ground with resistor R_{IN} = 4.7 kΩ.
3	DEN	I	Diagnosis enable pin. Active high. If not used: connect to GND pin or to module ground with resistor R_{DEN} = 4.7 kΩ.
4	IS	O	Multiplexed sense output. It delivers proportional current sense signals. Besides, fault indications are reported in Active Mode and Standby Mode. If not used: left open.
5	DSEL0	I	Diagnosis selection pin. Active high to select Channel1 to perform diagnosis, low to select Channel 0. If not used: connect with a 10kΩ resistor either to GND pin or to module ground.
6	IN1	I	Input pin of Channel1. Active high to turn on Channel1. If not used: connect to GND pin or to module ground with resistor R_{IN} = 4.7 kΩ.
7	NC (DSEL1)	-(I)	Not connected. (DSEL bit 1 for diagnosis multiplexer selection of T_J and V_S Sense.)
8	OUT1	O	Output of Channel 1.
9	OUT1	O	Output of Channel 1.
10	OUT1	O	Output of Channel 1.
11	NC	-	Not connected.
12	OUT0	O	Output of Channel 0.
13	OUT0	O	Output of Channel 0.
14	OUT0	O	Output of Channel 0.
Exposed Pad	VS	I	Power supply connection.

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8 Specifications

8.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) (1)

PARAMETER	DEFINITION	MIN	MAX	UNIT
Voltage range at Terminals(2)	Supply Voltage (3)	-0.3	40	V
	Reverse Polarity Voltage with External Blocking Diode (4)	-18		V
	Supply Voltage for Short Circuit Protection		18	V
	Voltage on INx, DEN, and DSEL Pins	-0.3	7	V
	Voltage on IS Pin	-2.7	7	V
Current range at Terminals (2)	DC Current on OUTx Pins	-3.5	Internally limited	A
	Current on GND Pin	-50 -250(5)	20	mA
	Current on INx, DEN, and DSEL Pins	-30	2	mA
	Current on IS Pin	-2	30	mA
$f_{IN,MAX}$	PWM Frequency on INx Pins		2	kHz
E_{AS}	Inductive Load Switch-off Energy Dissipation, Single Pulse(6)		23	mJ
T_A	Operating Ambient Temperature Range	-40	125	°C
T_J	Operating Junction Temperature Range	-40	150	°C
T_{STG}	Storage Temperature Range	-65	150	°C

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal.

(3) Supply voltage to withstand 40V load dump test for 400ms, according to ISO 16750-2:2010 Test B

(4) Reverse polarity condition: t < 60 s, reverse current < $I_{L,REV1}$, GND pin 4.7kΩ resistor in parallel with diode.

(5) For limited time range: t < 120s

(6) Test condition: VS = 28 V, $I_L = 2*I_{L,NOM}$, T_J = 150°C. FR4 2s2p board, 2 × 70 µm Cu, 2 × 35 µm Cu. 600 mm^2 thermal pad copper area.

8.2 Handling Ratings

PARAMETER	DEFINITION		MIN	MAX	UNIT
ESD(1)	Human Body Model (HBM) ESD Stress Voltage (2)	All Pins	-4	4	kV
	Charged Device Model (CDM) ESD Stress Voltage (3)	All Pins	-750	750	V

(1) Electrostatic discharge (ESD) to measure device sensitivity and immunity to damage caused by assembly line electrostatic discharges into the device.

(2) Level listed above is the passing level per AEC-Q100-002. The human-body model is a 100-pF capacitor discharged through a 1.5 kΩ resistor into each terminal.

(3) Level listed above is the passing level per AEC-Q100-011.

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8.3 Recommended Operating Conditions

PARAMETER	DEFINITION	MIN	TYP	MAX	UNIT
V_S	Voltage on VS pin	5		28	V
V_{IH}	Input Logic High on INx, DEN, and DSELx Pins	2.1		5.5	V
V_{IL}	Input Logic Low on INx, DEN, and DSELx Pins	0		0.9	V
$I_{L,NOM}$	Nominal DC load current		5		A
T_A	Operating ambient temperature	-40		125	°C
T_J	Operating junction temperature	-40		150	°C

8.4 Thermal Information

THERMAL RESISTANCE(1)		eSSOP-14	UNIT
$R_{\Theta JA}$	Junction to ambient thermal resistance(2)	33.3	°C/W
$R_{\Theta JC(top)}$	Junction to case(top) thermal resistance	24.3	°C/W
$R_{\Theta JC(bottom)}$	Junction to case(bottom) thermal resistance	1.5	°C/W
$R_{\Theta JB}$	Junction-to-board thermal resistance	9.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	3.2	°C/W
ψ_{JB}	Junction-to-board characterization parameter	9.3	°C/W

(1) Measured on JESD51-7, 4-layer PCB.

(2) The thermal data is based on JEDEC standard high-K profile – JESD 51-7. The copper pad is soldered to the thermal land pattern. Also, correct attachment procedure must be incorporated.

8.5 Electrical Characteristics

-40°C < T_J <150°C and 5V < V_S < 28V unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY VOLTAGE						
$V_{S,NOM}$	Normal Operating Voltage		5	13.5	28	V
$V_{S,EXT}$	Extended Operating Voltage	R_{ON} and switching characteristics may vary compared to those in $V_{S,NOM}$, but protection functions are still operative.	4		5	V
$V_{S,UVR}$	Undervoltage Restart	V_S Rising threshold to exit undervoltage, V_{IN} = 5 V	3.5	3.7	4	V
$V_{S,UVF}$	Undervoltage Shutdown	V_S Falling threshold to enter undervoltage, V_{IN} = 5 V	3	3.2	3.5	V
$V_{S,UVhys}$	Undervoltage Shutdown Hysteresis	$V_{S,UVR}$ - $V_{S,UVF}$		0.5		V

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t_{D_SLEEP}	Blanking Time into Sleep Mode	V_S =13.5 V, V_{DEN} = 5 V to 0 V, $V_{IN0,1}$ = $V_{OUT0,1}$ = $V_{DSEL0,1}$ = 0 V		12.5		ms
OPERATING CURRENT						
$I_{S,SLEEP}$	Supply Current in Sleep Mode	V_S = 13.5 V, $V_{IN0,1}$ = V_{DEN} = $V_{DSEL0,1}$= $V_{OUT0,1}$ = 0 V, T_J = 25°C			0.5	µA
		V_S = 13.5 V, $V_{IN0,1}$ = V_{DEN} = $V_{DSEL0,1}$= $V_{OUT0,1}$ = 0 V, T_J = 125°C			3	µA
$I_{GND,STBY}$	Supply Current in Standby Mode	V_S = 13.5 V, V_{OUT} = 0 V, $V_{IN0,1}$ = 0 V, V_{DEN} = 5 V, $V_{DSEL0,1}$ = 0 V		2	3	mA
$I_{S,ON}$	Supply Current for No Load, No Diagnosis	V_S = 13.5 V, I_L = 0 A, $V_{IN0,1}$ = 5 V, V_{DEN} = 0 V		2	3	mA
$I_{GND,ON}$	Operating Current in Active Mode	V_S = 13.5 V, I_L = 2 A, $V_{IN0,1}$ = 5 V, V_{DEN} = 5 V			3	mA
$I_{L,OFF}$	Output Leakage Current in Sleep Mode	V_s =13.5 V, $V_{IN0,1}$ = V_{DEN} = $V_{DSEL0,1}$= $V_{OUT0,1}$ = 0 V, T_J = 25°C		0.01	0.5	µA
		V_s =13.5 V, $V_{IN0,1}$ = V_{DEN} = $V_{DSEL0,1}$= $V_{OUT0,1}$ = 0 V, T_J = 125°C			3	µA
POWER STAGE						
R_{ON}	ON-state Resistance	V_S=13.5 V, I_L = 2 A, T_J= 25°C		21.5	26	mΩ
		V_S =13.5 V, I_L = 2 A, T_J= 150°C			45	mΩ
I_{LOVL}	Overload Detection Current	V_S = 13.5 V	30	40	55	A
$I_{LOVL,TC}$ (1)	Current Limit during Thermal Cycling	V_s = 13 V, T_R < T_J < T_{SD}		20		A
$V_{DS,CLP}$	Drain to Source Clamp Voltage	I_L = 2 A, T_J = -40°C	38			V
		I_L = 2 A, T_J = 25°C ~150°C	42	48	52	V
OUTPUT DIODE CHARACTERISTICS						
$V_{OUT,F}$	Drain Source Diode Voltage	$V_{IN0,1}$ = 0, I_L = -2 A		0.7		V
$I_{L,REV}$ (1)	Continuous Reverse Current when Reverse Polarity	t < 60 s, V_S = 13.5 V, GND pin 4.7 kΩ resistor in parallel with diode. T_J = 25°C		2		A
$I_{L,INV}$ (1)	Continuous Inverse Current When V_{OUT} > V_S + $V_{OUT,F}$	t < 120 s, V_S = 13.5 V, T_J = 25°C		2		A
LOGIC INPUT (IN, DEN)						
V_{IH}	Input Logic High		2.1			V
V_{IL}	Input Logic Low				0.9	V
$V_{I,HYS}$	Input Logic Hysteresis			170		mV
I_{IH}	High Level Pull-down Current	V_{IH} = 2.1 V			10	µA
I_{IL}	Low Level Pull-down Current	V_{IL} =0.9 V	1		10	µA
DIAGNOSTICS AND PROTECTION						

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$I_{loss,GND}$	Output Leakage Current when Loss of Ground	V_S = 13.5 V, $V_{IN0,1}$ = V_{DEN} = 3.3 V			100	μA
$V_{OL,OFF}$	Open Load Detection Threshold in Standby Mode (V_{OUT}-GND)	$V_{IN0,1}$ = 0 V, V_{DEN} = 5 V, V_{DSEL1} = 0V	2	3	4	V
$I_{OL,OFF}$	Standby Mode Output Sink Current with Open Load	V_S = 13.5 V, V_{OUT} = 4V, $V_{IN0,1}$ = 0 V, V_{DEN} = 5 V	-100			μA
$t_{D,OL,IN}$	Standby Mode Diagnostic Delay Time from Falling Edge of Input	V_S = 13.5 V, V_{OUT} = 13.5 V, $V_{IN0,1}$ = 5 V to 0 V, V_{DEN} = 5 V	350	500	700	μs
$t_{D,OL,VO}$	Standby Mode Diagnostic Delay Time from Rising Edge of V_{OUT}	V_S = 13.5 V, V_{OUT} =0 to 4 V, $V_{IN0,1}$ = 0 V, V_{DEN} = 5 V		150	250	μs
$t_{D,OL,DEN}$	Standby Mode Diagnostic Delay Time from Rising Edge of DEN	V_S = 13.5 V, V_{OUT} = V_S, $V_{IN0,1}$ = 0 V, V_{DEN} = 0 to 5 V		150	250	μs
T_{SD} (1)	Thermal Shutdown Temperature			170		°C
T_R (1)	Thermal Shutdown Reset Temperature			145		°C
T_{SW} (1)	Thermal Swing Shutdown Threshold			60		°C
T_{HYS} (1)	Hysteresis for Resetting the Thermal Shutdown and Swing			20		°C
Multiple SENSE Functions						
K_{IS}	Ratio of Current Sense			1800		
dk_{IS}/K_{IS}	Accuracy of Current Sense ($I_{IS} \times K_{IS} - I_L$) / $I_L \times 100$	I_L = 0.01 A	-65		65	%
		I_L = 0.05 A	-20		20	
		I_L = 0.1 A	-12		12	
		I_L = 3 A	-10		10	
		I_L = 5 A	-10		10	
$V_{IS,SAT}$	IS Saturation Voltage	V_S = 7V to 18 V, R_{IS} = 2.5 kΩ, V_{IN0} = 5 V, V_{DEN}= 5 V, $V_{DSEL0,1}$ = 0 V	4.8			V
$V_{IS,H}$	Fault High Voltage of IS	$V_S \geq 7$ V	5	5.5	6	V
		5 V ≤ V_S < 7 V	4.3		6	V
$I_{IS,SAT}$	IS Saturation Current	V_s= 7 V to 18 V, R_{IS} = 1.2 kΩ, V_{IN0} = 5 V, V_{DEN}= 5 V, $V_{DSEL0,1}$ = 0 V	4			mA
$I_{IS,FAULT}$	Fault Current of IS	V_S = 7 V to 18 V, R_{IS} = 1.2 kΩ, V_{IN0} = 5 V, V_{DEN}= 5 V	10			mA
V_{sense_TC}	Cureent Sense Output Voltage Proportional to T_J	V_{IS_TC} (T) = V_{IS_TC} (T0) + dV_{IS_TC} / dT * (T - T0)				
		V_{DEN} = 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5 V, $V_{IN0,1}$ = 0 V, R_{IS} = 1 kΩ, T_J = -40°C	2.2	2.3	2.4	V

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		V_{DEN} = 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5 V, $V_{IN0,1}$ = 0 V, R_{IS} = 1 kΩ, T_J = 25°C	1.8	1.9	2	V
		V_{DEN} = 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5 V, $V_{IN0,1}$ = 0 V, R_{IS} = 1 kΩ, T_J = 125°C	1.2	1.3	1.5	V
dV_{SENSE_TC}/dT	Temperature Coefficient	T_J = -40°C to 150°C		-6.0		mV/°C
V_{sense_Vs}	Current Sense Output Voltage Proportional to Vs	V_{IS_Vs} = Vs / 4				
		V_s = 13 V, V_{DEN} = 5 V, V_{DSEL0} = 5 V, V_{DSEL1} = 5 V, $V_{IN0,1}$ = 0 V, R_{IS} = 1 kΩ	3.17	3.23	3.32	V
$I_{IS,LEAK1}$	Leakage Current of IS in Diagnostic Disable State	V_{IN0} = 5 V, V_{DEN} = 0 V, V_{IS} = 0 V, I_L = 3 A			0.5	μA
$I_{IS,LEAK2}$	Leakage Current of IS in Diagnostic Enable State	V_{IN0} = 5 V, V_{DEN} = 5 V, V_{IS} = 0 V, I_L = 0 A, T_J = 125°C			6	μA
$t_{IS,ON1}$	Current Sense Settling Time from DEN Rising Edge	I_L ≥ 1 A, R_{IS} = 1.2 kΩ, V_{IN0} = 5 V, V_{DEN} = 0 to 5 V, V_{IS} to 90% of sense value			20	μs
$t_{IS,OFF1}$	Current Sense Settling Time from DEN Falling Edge	I_L ≥ 1 A, R_{IS} = 1.2 kΩ, V_{IN0} = 5 V, V_{DEN} = 5 to 0 V, V_{IS} to 10% of sense value			20	μs
$t_{IS,ON2}$	Current Sense Settling Time from IN Rising Edge	I_L ≥ 1 A, R_{IS} = 1.2 kΩ, V_{IN0} = 0 to 5 V, V_{DEN} = 5 V, V_{IS} to 90% of sense value			150	μs
$t_{IS,OFF2}$	Current Sense Settling Time from IN Falling Edge	I_L ≥ 1 A, R_{IS} = 1.2 kΩ, V_{IN0} = 5 to 0 V, V_{DEN} = 5 V, V_{IS} to 10% of sense value			20	μs
$t_{IS,ON3}$	V_{SENSE_TC} Settling Time from Rising Edge of DEN	V_{DEN} = 0 V to 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5 V, R_{IS} = 1 kΩ			20	μs
$t_{IS,OFF3}$	V_{SENSE_TC} Disable Delay Time from Falling Edge of DEN	V_{DEN} = 5 V to 0 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5 V, R_{IS} = 1 kΩ			20	μs
$t_{IS,ON4}$	V_{SENSE_VS} Settling Time from Rising Edge of DEN	V_{DEN} = 0 V to 5 V, V_{DSEL0} = 5 V, V_{DSEL1} = 5 V, R_{IS} = 1 kΩ			60	μs
$t_{IS,OFF4}$	V_{SENSE_VS} Disable Delay Time from Falling Edge of DEN	V_{DEN}= 5 V to 0 V, V_{DSEL0} = 5 V, V_{DSEL1} = 5 V, R_{IS} = 1 kΩ			20	μs
t_{D_XtoY}	Current Sense Transition Delay from CHx to CHy	V_S=13.5V, V_{IN0} = 5 V, V_{IN1} = 5 V, V_{DEN}= 5 V, V_{DSEL1} = 0 V, V_{DSEL0} = 0 V to 5 V, I_{OUT0} = 0 A, I_{OUT1} = 3 A, R_{IS} = 1 kΩ			20	us
$t_{D_CS,H}$	SNS Transition Delay from Stable Current Sense on CHx to Vcs,h on CHy	V_S=13.5V, V_{IN0} = 5 V, V_{IN1} = 0 V, V_{DEN} = 5 V, V_{DSEL1} = 0 V, V_{DSEL0} = 0 V to 5 V, I_{OUT0} = 3 A, V_{OUT1} = 13.5 V, R_{IS} = 1 kΩ			20	us
t_{D_CSoTC}	SENSE Transition Delay from Stable Current Sense to TC sense	V_S=13.5V, V_{IN0} = 5 V, V_{DEN} = 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 0 V to 5 V, I_{OUT0} = 1.5 A, R_{IS} = 1 kΩ			60	μs
t_{D_TCtoCS}	SENSE Transition Delay from TC sense to Stable Current Sense	V_S=13.5V, V_{IN0} = 5 V, V_{DEN} = 5 V, V_{DSEL0} = 0 V, V_{DSEL1} = 5V to 0V, I_{OUT0} = 1.5 A, R_{IS} = 1 kΩ			20	μs

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t_{D_CStoVS}	SENSE Transition Delay from Stable Current Sense to Vs sense	V_S=13.5V, V_{IN1} = 5 V, V_{DEN} = 5 V, V_{DSEL0} = 5 V, V_{DSEL1} = 0 V to 5 V, I_{OUT1} = 1.5 A, R_{IS} = 1 kΩ			60	µs
t_{D_VStoCS}	SENSE Transition Delay from Vs sense to Stable Current Sense	V_S=13.5V, V_{IN1} = 5 V, V_{DEN} = 5 V, V_{DSEL0} = 5 V, V_{DSEL1} = 5 V to 0 V, I_{OUT1} = 1.5 A, R_{IS} = 1 kΩ			20	µs
t_{D_TCtoVS}	SENSE Transition Delay from TC sense to Vs sense	V_S=13.5V, T_J = 125°C, V_{DEN} = 5 V, V_{DSEL1} = 5V, V_{DSEL0} = 0 V to 5 V, R_{IS} = 1 kΩ			20	µs
t_{D_VStoTC}	SENSE Transition Delay from Vs sense to TC sense	V_S=13.5V, T_J = 125°C, V_{DEN} = 5 V, V_{DSEL1} = 5V, V_{DSEL0} = 5 V to 0 V, R_{IS} = 1 kΩ			20	µs
Switching Characteristics						
$t_{D,ON}$	Turn-on Delay Time	V_{IN0} rising edge to V_{OUT} = 20% * V_S, V_S =13.5 V, R_L= 4.3 Ω, T_J = 25°C	30	70	100	µs
$t_{D,OFF}$	Turn-off Delay Time	V_{IN0} falling edge to V_{OUT} = 80% * V_S, V_S =13.5 V, R_L= 4.3 Ω, T_J = 25°C	40	100	160	µs
dV/dt_{ON}	Turn-on Slew Rate	V_{OUT}= 20% to 80%, V_S= 13.5 V, R_L= 4.3 Ω, T_J = 25 °C	0.3	0.45	0.6	V/µs
dV/dt_{OFF}	Turn-off Slew Rate	V_{OUT}= 80% to 20%, V_S= 13.5 V, R_L= 4.3 Ω, T_J = 25°C	0.3	0.45	0.6	V/µs
t_{skew}	Pulse Skew $t_{D,ON}$ - $t_{D,OFF}$	V_S=13.5V, R_L=4.3 Ω, T_J= 25°C	-150		50	µs

(1) Parameter guaranteed by design and characterization; not subject to production test.

8.6 Typical Characteristics

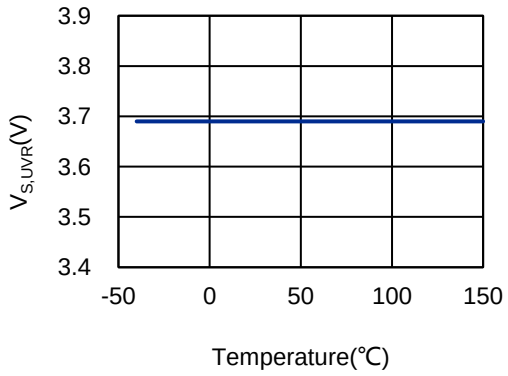

Figure 8-1. $V_{S,UVR}$ vs T_A

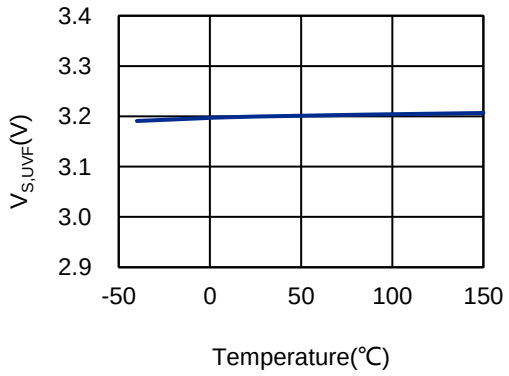

Figure 8-2. $V_{S,UVF}$ vs T_A

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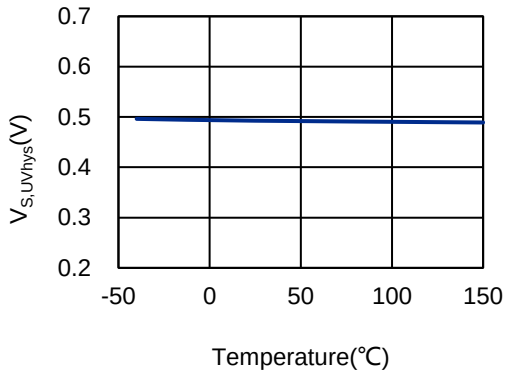

Figure 8-3. $V_{S,UVhys}$ vs T_A

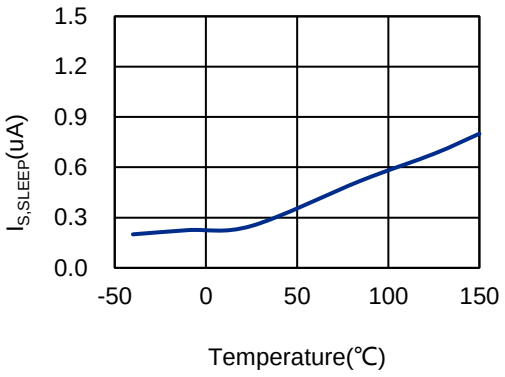

Figure 8-4. $I_{S,SLEEP}$ vs T_A

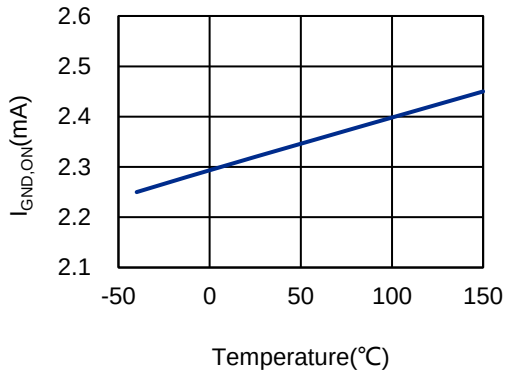

Figure 8-5. $I_{GND,ON}$ vs T_A

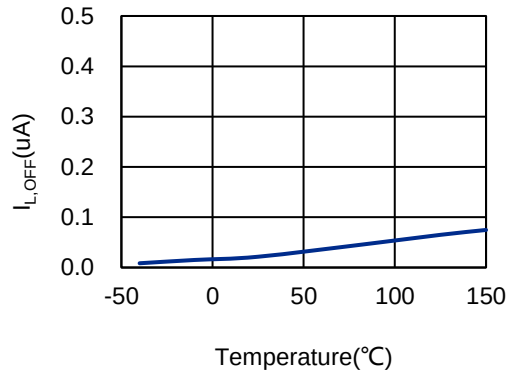

Figure 8-6. $I_{L,OFF}$ vs T_A

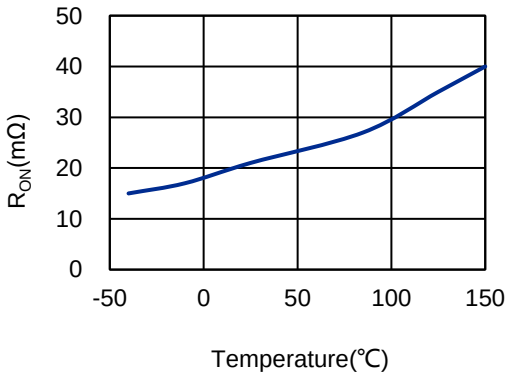

Figure 8-7. R_{ON} vs T_A

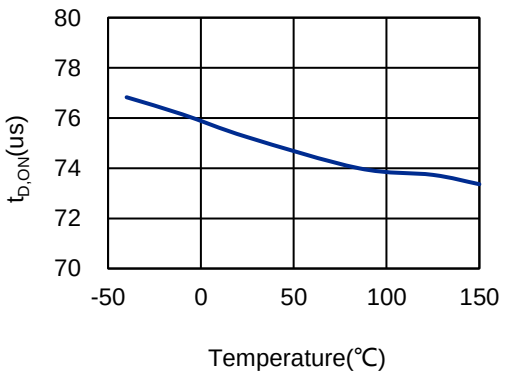

Figure 8-8. $t_{D,ON}$ vs T_A

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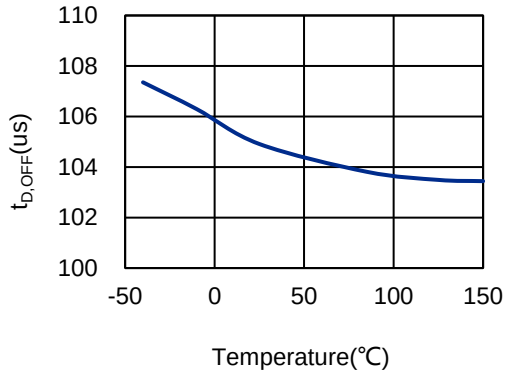

Figure 8-9. $t_{D,OFF}$ vs T_A

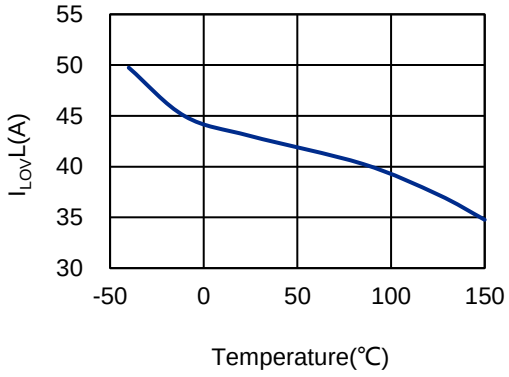

Figure 8-10. I_{LOVL} vs T_A

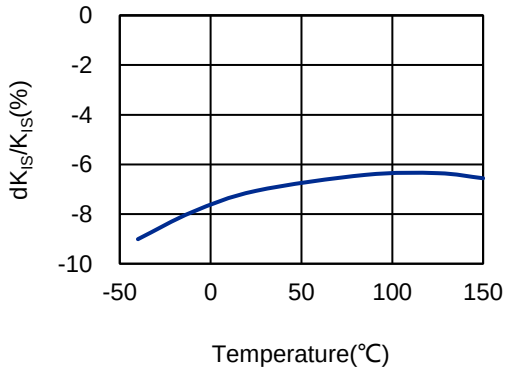

Figure 8-11. dK_{IS} / K_{IS} vs T_A (I_L = 0.01A)

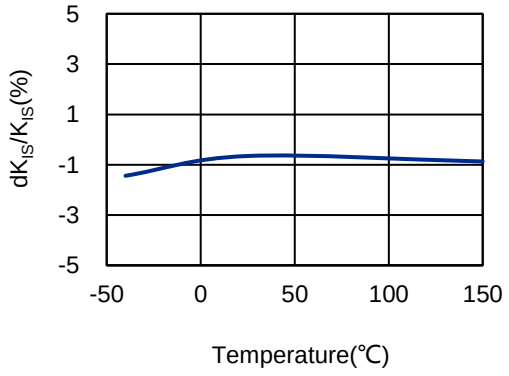

Figure 8-12. dK_{IS} / K_{IS} vs T_A (I_L = 5A)

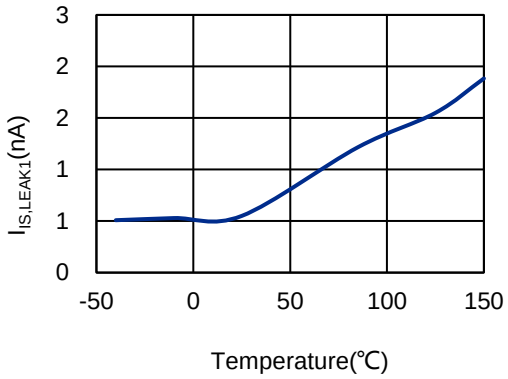

Figure 8-13. $I_{IS,LEAK1}$ vs T_A

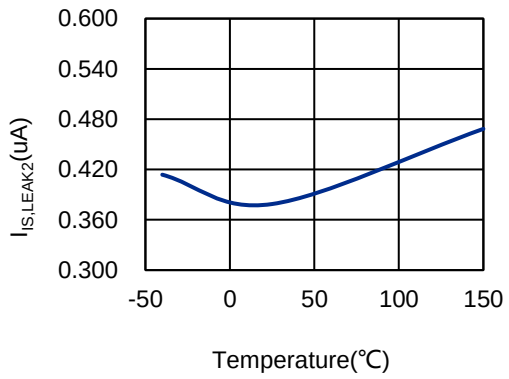

Figure 8-14. $I_{IS,LEAK2}$ vs T_A

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9 Functional Block Diagram

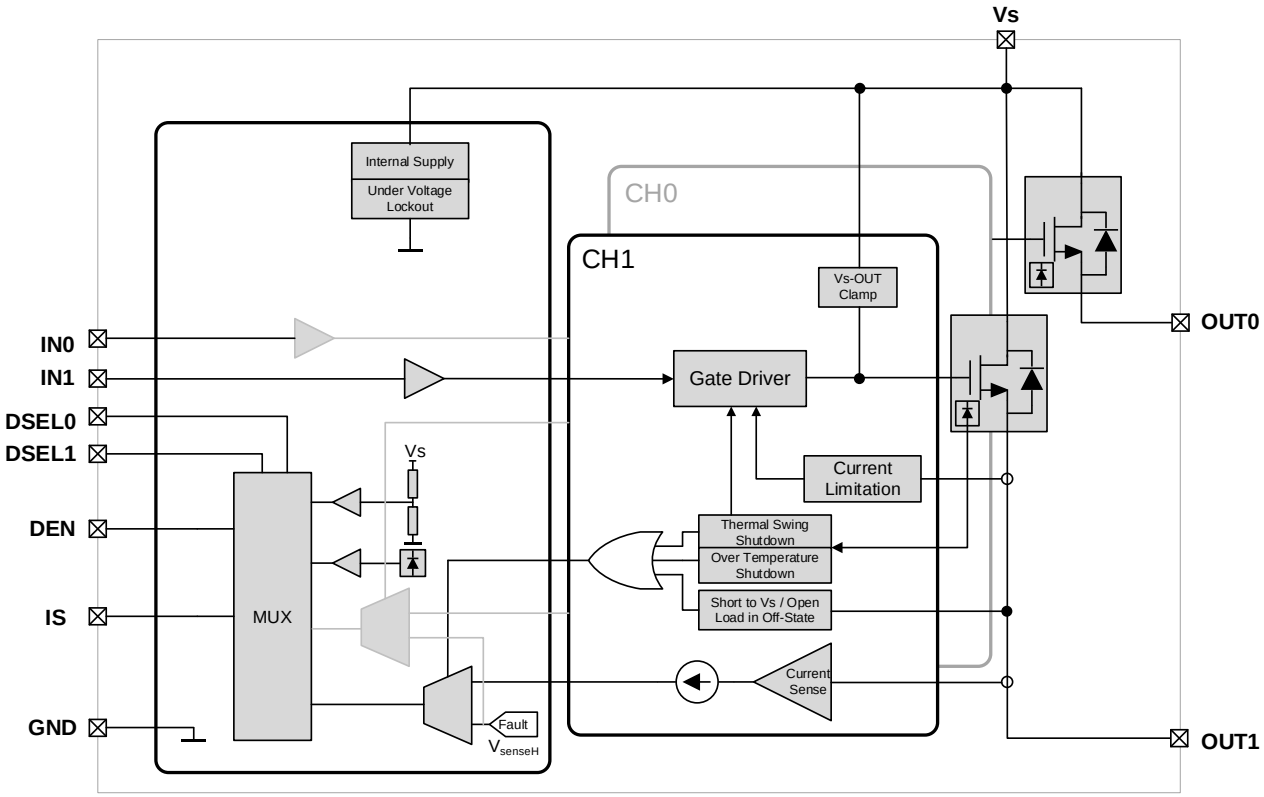

Figure 9-1. Functional Block Diagram

10 Feature Description

10.1 Operating States Diagram

The device has three operating states called ‘Sleep Mode’, ‘Standby Mode’ and ‘Active Mode’, which are decided by the logic level of INx pin and DEN pin, the operating mode diagram is shown as below.

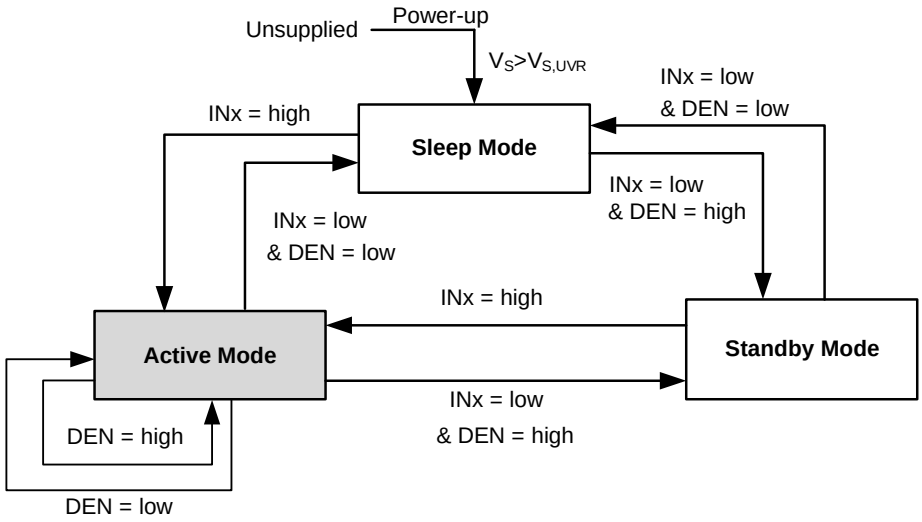

Figure 10-1. Operating Mode Diagram

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10.1.1 Sleep Mode

During Sleep Mode, the output channel of the device is turned OFF. Current consumption is minimum (see parameter $I_{S,SLEEP}$). No overtemperature protection, overload protection or diagnostic functions are active in this mode.

10.1.2 Standby Mode

The device operates in Standby Mode when DEN = high and INx = low. The output channel is OFF. Current consumption is specified as $I_{GND,STBY}$.

10.1.3 Active Mode

When the device is in Active Mode, the output channel is ON if no fault event occurs. Current consumption is specified as $I_{GND,ON}$ (measured at the GND pin). Overload and overtemperature protections are active. The diagnostic function is active when DEN = high.

10.2 Power Stages

10.2.1 Switching Resistive Loads

When switching resistive loads, the switching time and slew rates are shown in Figure 10-2.

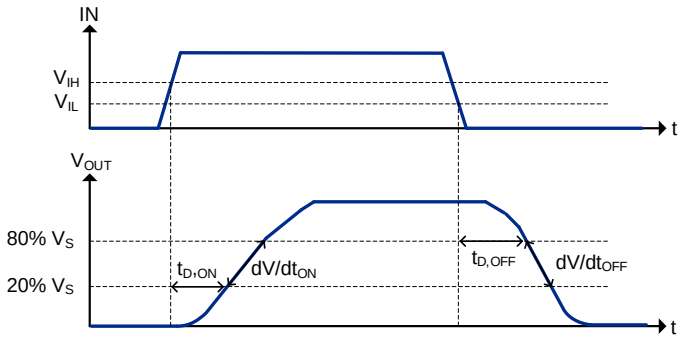

Figure 10-2. Switching a Resistive Load

10.2.2 Switching Inductive Loads

When turning OFF inductive loads with high-side switches, the output voltage V_{OUT} drops to a negative potential, because the inductance tends to maintain the current flow. To prevent the device from damage due to overvoltage, a voltage clamp mechanism is implemented. The clamping mechanism limits the negative output voltage to a safe value. Figure 10-3 shows a concept drawing of implementation.

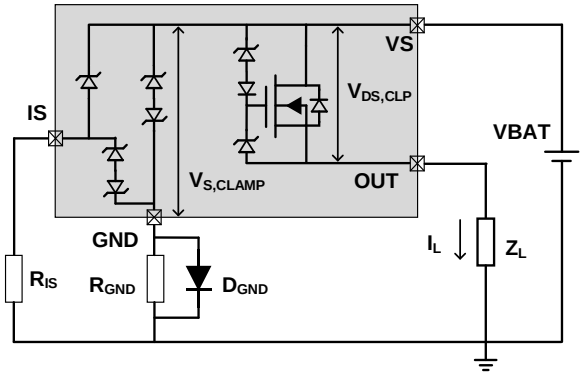

Figure 10-3. Output Clamp Diagram

During switching OFF of inductive loads, all energy stored in the inductive loads must be dissipated in the device. The maximum allowable energy is limited by the component's thermal design. Refer to Chapter 8.1 for the maximum allowable values of E_{AS} (single pulse energy).

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10.3 Protections

10.3.1 Overtemperature Protection

To prevent the junction temperature from exceeding the threshold, the device features both absolute thermal shutdown (T_{SD}) and dynamic thermal swing shutdown (T_{SW}) protection mechanisms. Once the temperature exceeds the threshold T_{SD}, or the temperature swing exceeds the threshold T_{SW}, the overheated channel is turned OFF and remains OFF until T_J has reached the "Auto-restart" condition described in Chapter 10.3.5. Figures 10-4 and 10-5 respectively demonstrate these two over-temperature protection mechanisms. $T_{J,REF}$ is the reference temperature used for dynamic temperature protection.

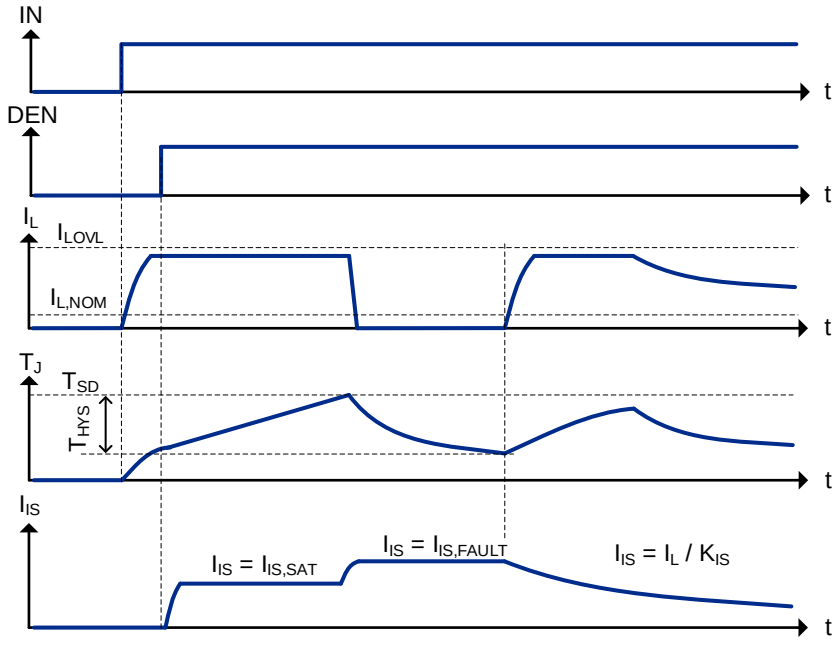

Figure 10-4. Overtemperature Protection (Thermal Shutdown)

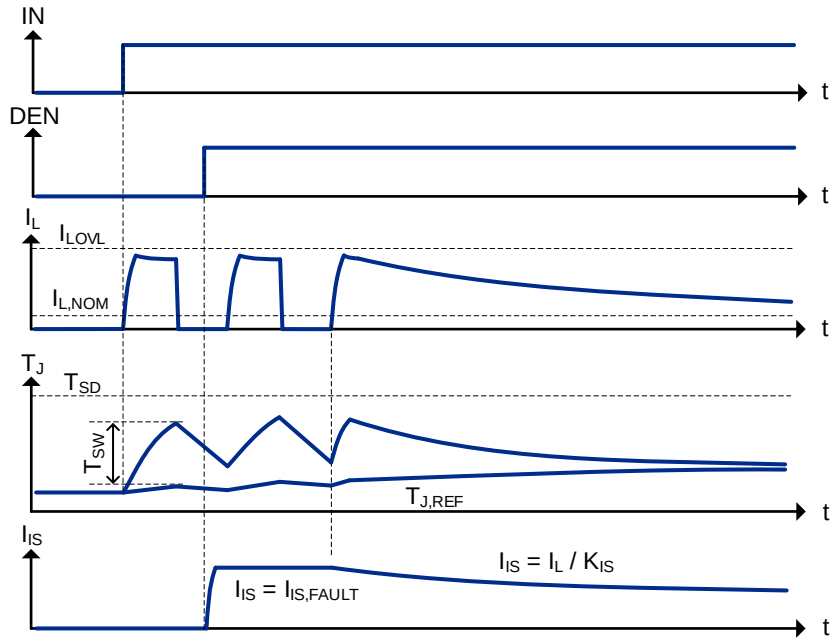

Figure 10-5. Overtemperature Protection (Thermal Swing Shutdown)

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10.3.2 Overload Protection

The device features protection against overload and short circuit to ground. Its overload threshold decreases as junction temperature rises: at high temperatures, the overload threshold is reduced to prevent device damage. When the supply voltage V_S exceeds 20V-24V, the overload detection current decreases to I_{LIML} as shown in Figure 10-6.

Once the load current meets or exceeds the applicable overload threshold, the output channel is switched off. The channel is allowed to restart according to the auto-restart strategy described in Chapter 10.3.5.

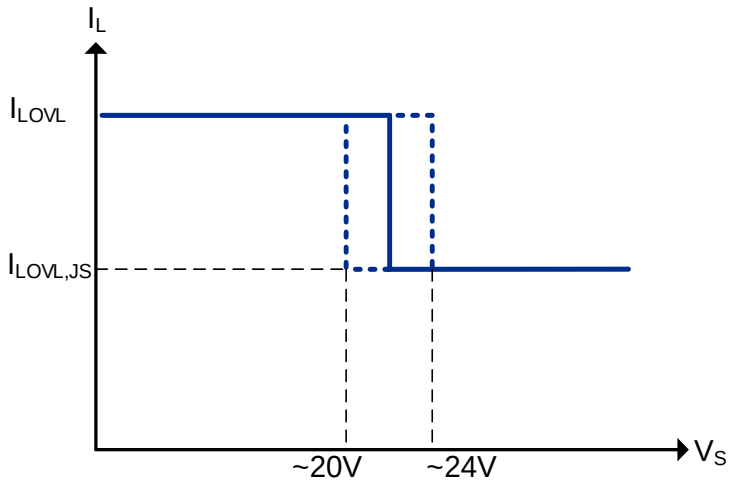

Figure 10-6. Overload Detection Current Variation with VS Voltage

10.3.3 Undervoltage Protection

Undervoltage protection monitors the supply voltage (V_S). If V_S drops below the minimum undervoltage threshold ($V_{S,UVF}$), the output is turned off regardless of the input status. As soon as V_S is above the operative threshold ($V_{S,UVR}$), the channel is switched ON again as shown in Figure 10-7.

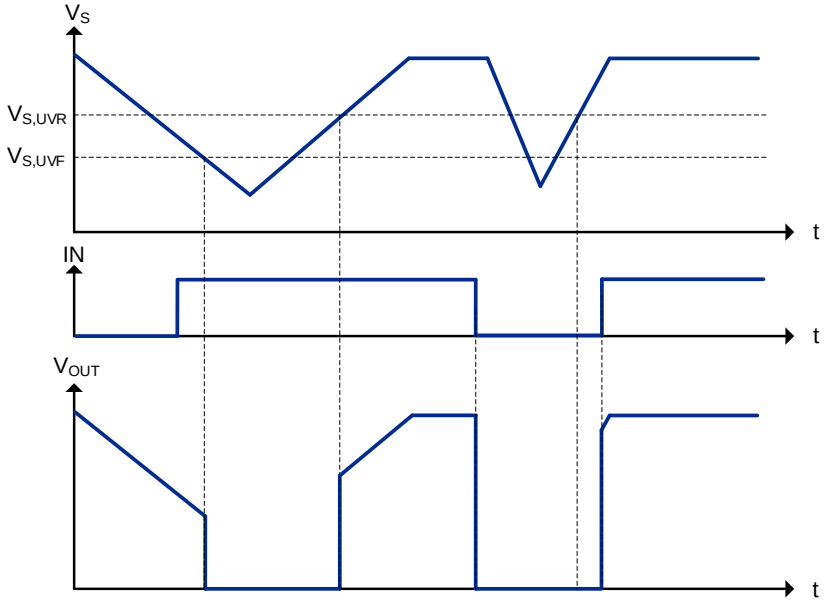

Figure 10-7. Vs Undervoltage Protection

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10.3.4 Loss of Ground Protection

In the event of Loss of Ground, the device automatically switches off the power MOSFET, ensuring no current flows into the load. It is recommended to connect a resistor between any logic pins and the microcontroller to ensure the channel switch OFF.

Note: In case any logic pin is pulled to ground (either by a resistor or active) a parasitic ground path is available, which could keep the device operational during loss of device ground.

10.3.5 Auto-restart Strategy

The auto-restart strategy is a protection mechanism designed to ensure device safety and reliability. When a protection event occurs during INx = high, the channel is switched off and the IS pin outputs a fault current $I_{IS,FAULT}$ in case of DEN = high.

The channel can be allowed to restart automatically if the “restart” conditions for the protection mechanisms are fulfilled:

- For overtemperature: $T_J < T_R$ and $T_J – T_{J,REF} < T_{SW}$-T_{HYS} (including hysteresis).
- For overload: I_L < 50mA and T_J within T_{SD} and T_{SW} ranges (including hysteresis).

The auto-restart strategy timing diagram as shown in Figure 10-8.

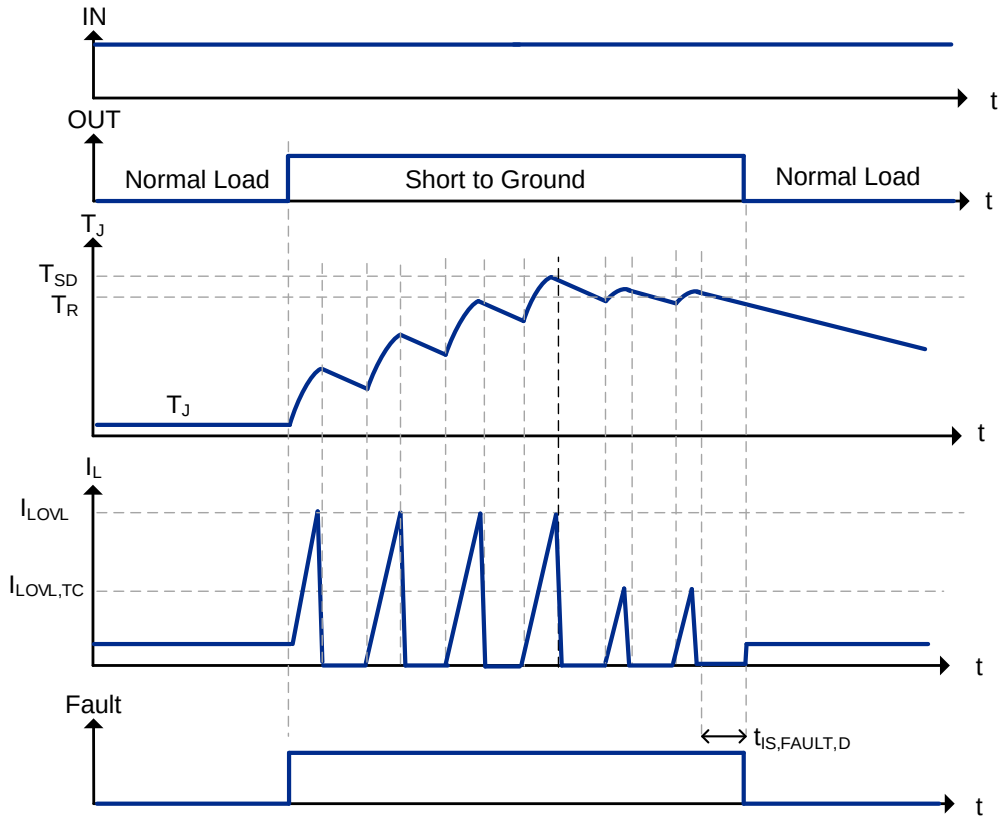

Figure 10-8. Auto-restart strategy

10.4 Diagnosis

The device integrates comprehensive diagnostic capabilities via IS pin, which delivers proportional current sense signals or fault indications when DEN = high and a channel is selected using DSEL0 pin. When DEN = low, the IS pin enters a high-impedance state. A sense resistor (R_{IS}, typically 1.2kΩ) must be connected between the IS pin and module ground to limit power dissipation. Table 10-1 gives a quick reference to the multiplexed output state of the IS pin during the device operation.

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Table 10-1. Sense Signal, Function of Application Condition

Conditions	INx	DEN	OUT	IS
Normal Operation	Low	High	~GND	Z
Short Circuit to GND			~GND	Z
Overtemperature			Z	$I_{IS,FAULT}$
Short Circuit to V_S			V_S	$I_{IS,OLOFF}$
Open Load			> $V_{OL,OFF}$	$I_{IS,OLOFF}$
Inverse Current			$V_{OUT} > V_S$	$I_{IS,OLOFF}$
Normal Operation	High		~V_S	$I_{IS} = I_L / K_{IS}$
Short Circuit to GND			~GND	$I_{IS,FAULT}$
Overload			< V_S	$I_{IS,FAULT}$
Overtemperature			Z	$I_{IS,FAULT}$
Short Circuit to V_S			V_S	$I_{IS} < I_L / K_{IS}$
Open Load			~V_S	$I_{IS} = I_{IS,LEAK2}$
Inverse Current			$V_{OUT} > V_S$	$I_{IS} = I_{IS,LEAK2}$
All Conditions	n.a.	Low	n.a.	Z

In case DEN is set to “high”, the Sense for the selected channel is enabled or disabled using DSEL0 pin. Table 10-2 gives the truth table.

Table 10-2. Diagnostic Truth Table

DEN	DSEL0	IS
“Low”	Not Relevant	Z
“High”	“Low”	Sense Output 0
“High”	“High”	Sense Output 1

10.4.1 Diagnosis in Active Mode

Diagnosis in Active Mode is enabled when DEN = high. The channel is selected using DESL0 pin, and diagnostic signals are delivered via the IS pin. It includes two functions: proportional current sense and fault indications.

When no faults are present, the IS pin outputs an analog current I_{IS} proportional to the load current I_L, following the ratio $K_{IS} = I_L/I_{IS}$. An external RC filter is recommended for the IS pin to reduce signal ripple.

If overtemperature, overload, or short circuit to ground occurs, the IS pin outputs a fault current $I_{IS,FAULT}$ as long as diagnosis is enabled.

10.4.2 Diagnosis in Standby Mode

Diagnosis is activated in Standby Mode. The open load detection signal is delivered via the IS pin.

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The device compares the voltage V_{OUT} with the threshold voltage $V_{OL,OFF}$ to detect load conditions. If open load occurs ($V_{OUT} \geq V_{OL,OFF}$), the IS pin outputs an open load fault current ($I_{IS,OLOFF}$). To differentiate open load and short circuit to V_S, an external switch and a pull-up resistor are recommended. It is necessary to wait a time $t_{D,OL,IN}$ between the falling edge of the input pin and the sensing at pin IS for Open Load in Standby Mode to allow the internal comparator to settle (see Figure 10-9).

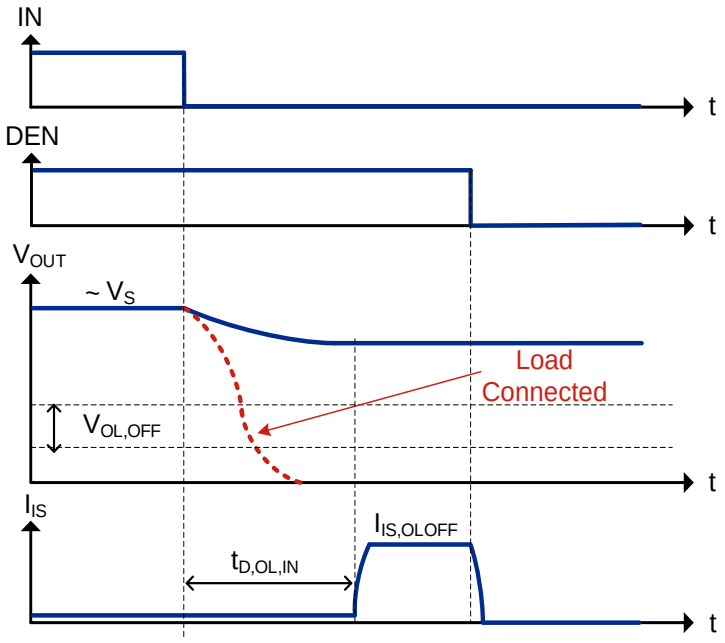

Figure 10-9. Timings for an Open Load Detection

10.4.3 Sense Time

Sense timings of the device define the response characteristics of the IS pin during INx/DEN activation and deactivation, with all parameters are specified under the test conditions given in Section 8.5. Figure 10-10 presents the sense settling and disabling time.

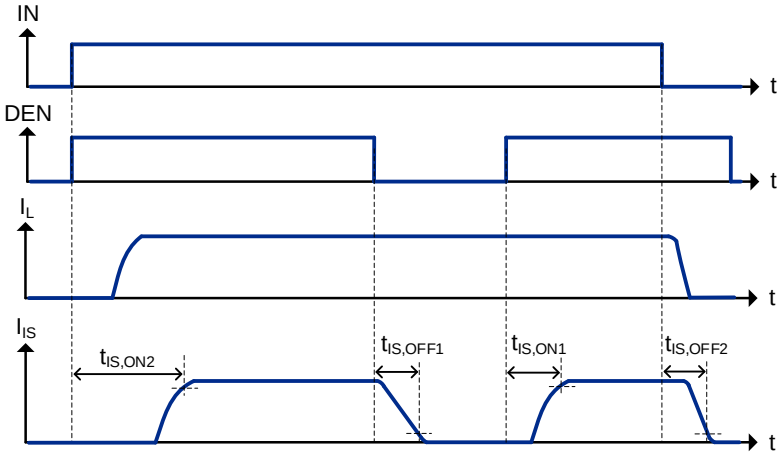

Figure 10-10. Sense Settling and Disabling Time

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11 Application Information

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device. This is a very simplified example of an application circuit. The function must be verified in the real application.

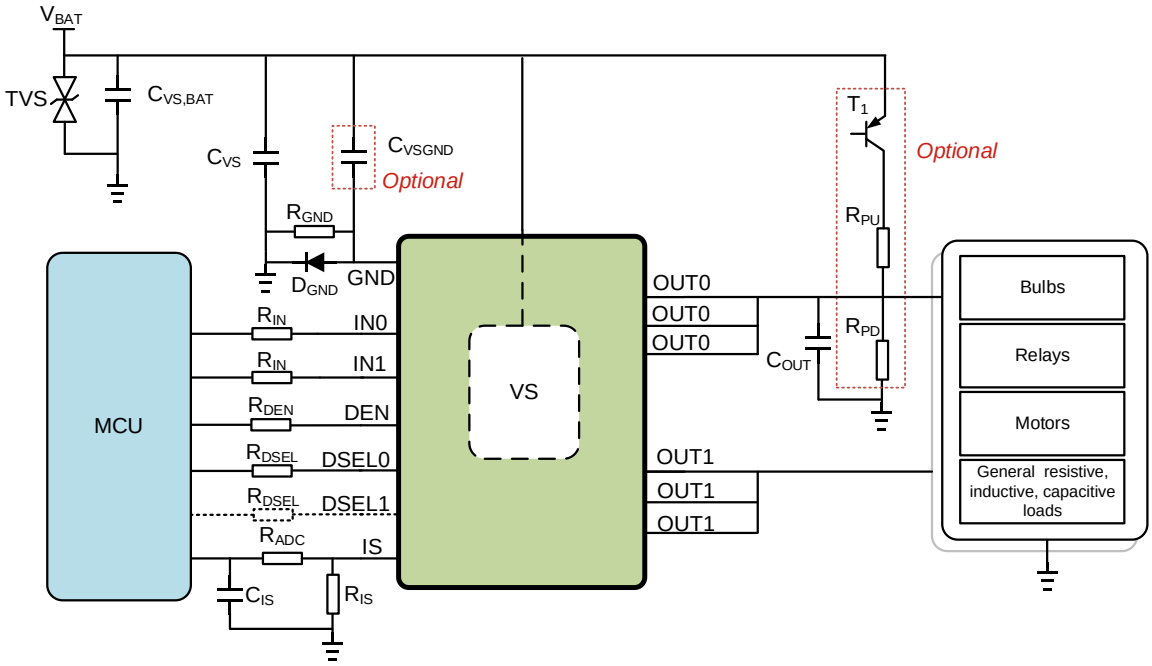

Figure 11-1. Application Diagram

Table 11-1. Suggested Component Values

Reference	Value	Purpose
R_{IN}	4.7kΩ	Protection of the microcontroller during Overvoltage and Reverse Battery
R_{DEN}	4.7kΩ	Protection of the microcontroller during Overvoltage and Reverse Battery
R_{DSEL}	4.7kΩ	Protection of the microcontroller during Overvoltage and Reverse Battery
R_{PD}	47kΩ	Output pull-down Ensure polarization of the device outputs to distinguish between Open Load and Short to VS in Standby Mode
R_{PU}	1.5kΩ	Output pull-up Ensure polarization of the device output during Open Load in Standby Mode
C_{OUT}	10nF	Protection of the device output during ESD events
T_1	-	Switch the battery voltage for Open Load in Standby Mode
C_{VS}	100nF	Filtering of voltage spikes on the battery line
C_{VSGND}	47nF	Buffer capacitor for fast transient
TVS	33V	Diode transient voltage suppressor diode
$C_{VS,BAT}$	-	Filtering / buffer capacitor located at V_{BAT} connector
R_{IS}	1.2kΩ	Sense resistor
R_{ADC}	4.7kΩ	Protection of microcontroller ADC input during Overvoltage, Reverse Battery, Loss of Ground
C_{IS}	220pF	Sense signal filtering
D_{GND}	-	Reverse polarity protection diode.
R_{GND}	4.7kΩ	Protection in case of Loss of Battery while driving inductive loads

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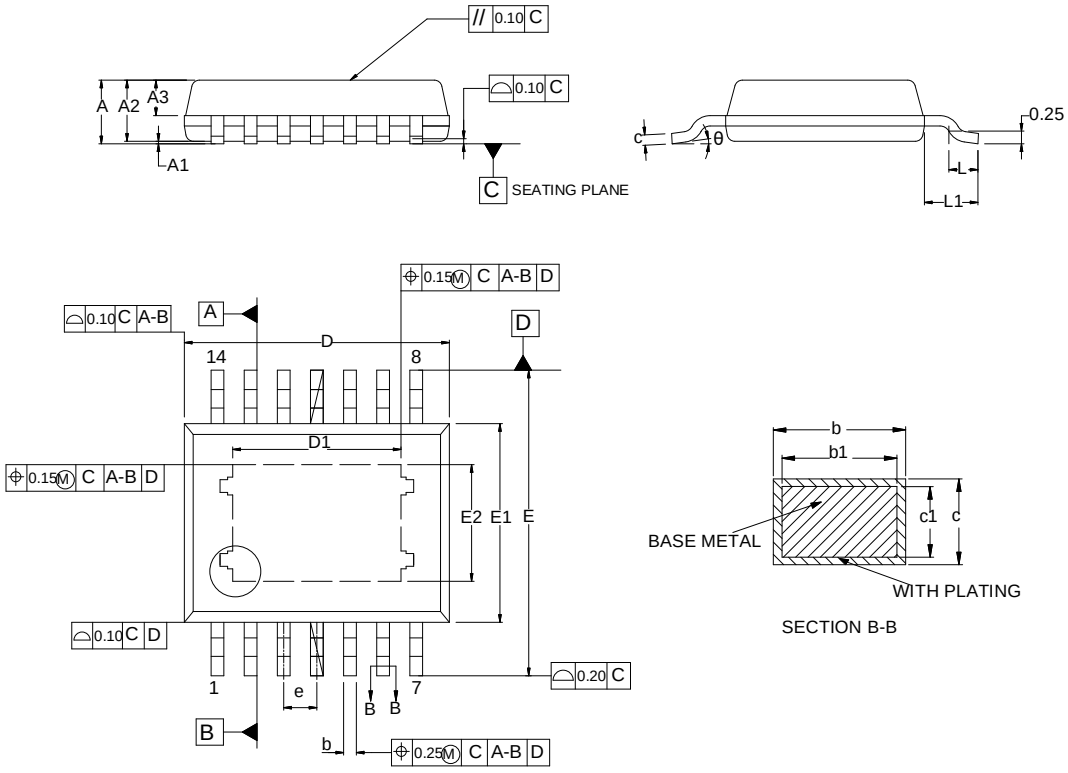
MECHANICAL DATA

eSSOP-14



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	1.10	—	1.35
A1	0.00	—	0.10
A2	1.10	1.15	1.25
A3	0.60	0.70	0.80
b	0.23	—	0.31
b1	0.22	0.25	0.28
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	5.10	5.20	5.30
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	0.65BSC		
L	0.40	0.57	0.80
L1	1.05REF		
θ	0	—	8°

L/F Size (mil) \ Size(mm)	E2	D1
98*138	2.29±0.10	3.30±0.10

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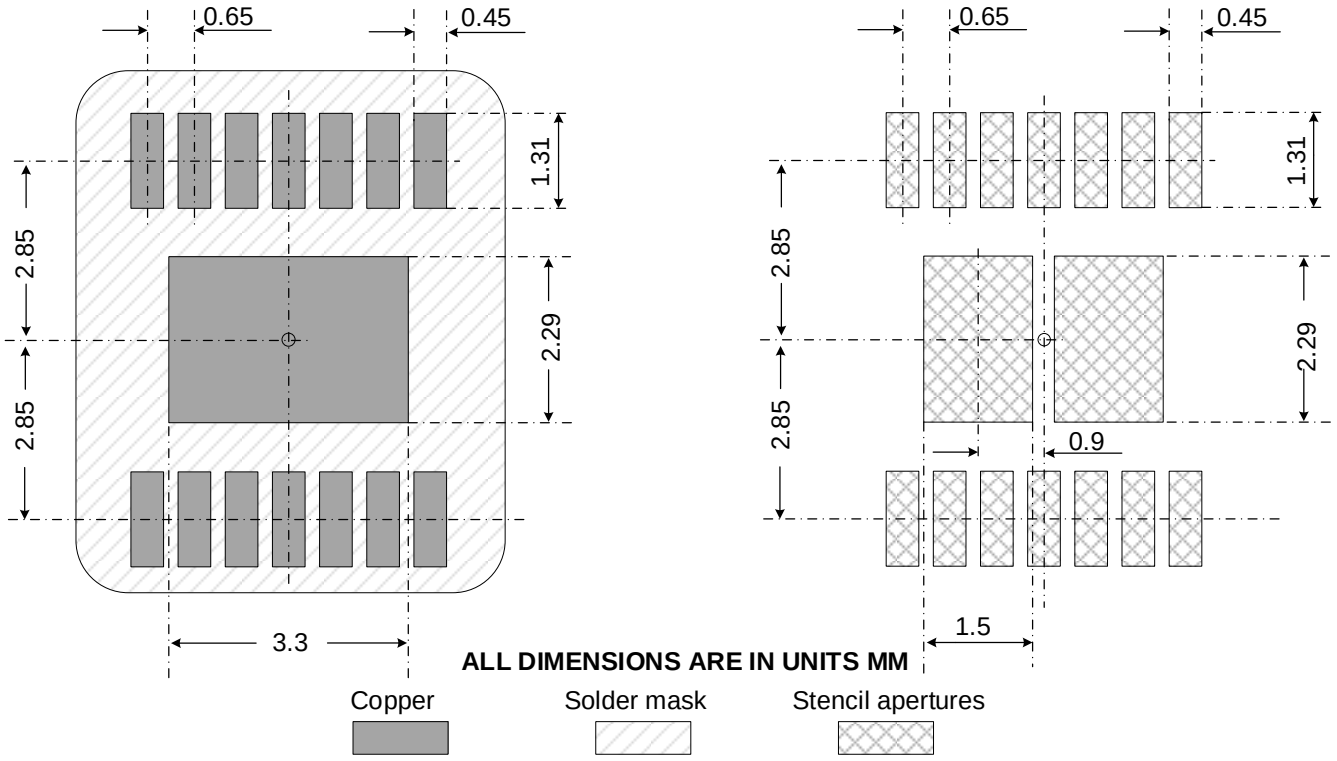
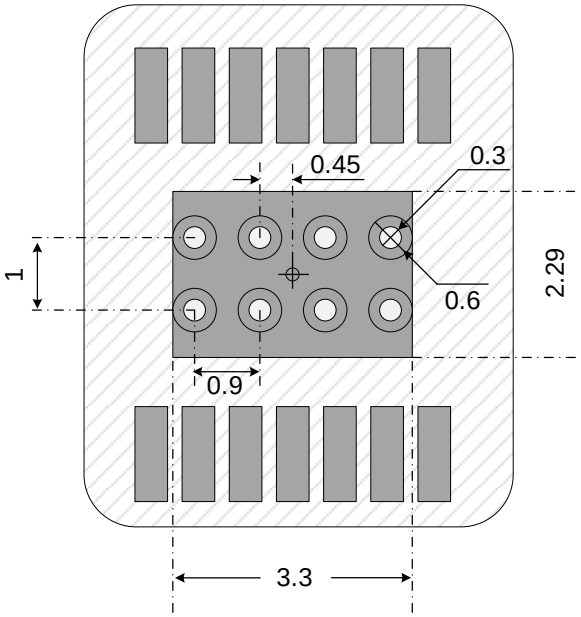
RECOMMENDED FOOTPRINT

eSSOP-14



ALL DIMENSIONS ARE IN UNITS MM

Copper Solder mask Stencil apertures



ALL DIMENSIONS ARE IN UNITS MM

Copper Solder mask

NOTE: Via diameters and positions shall be set according to the actual PCB situation

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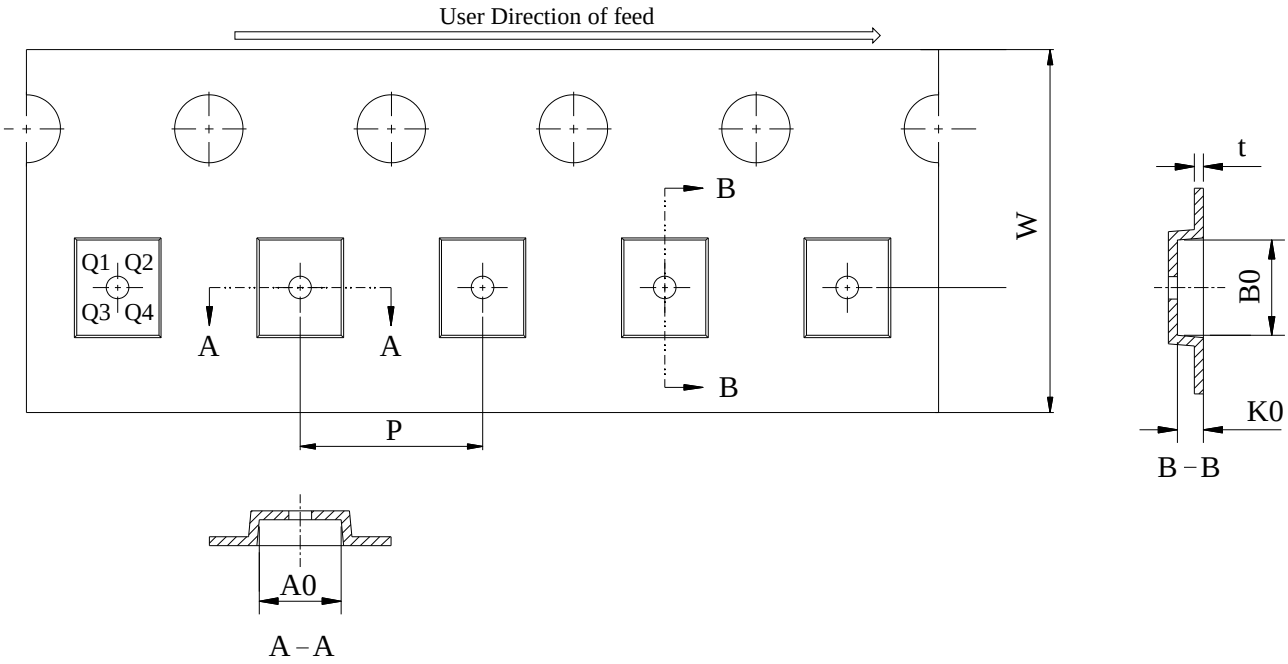
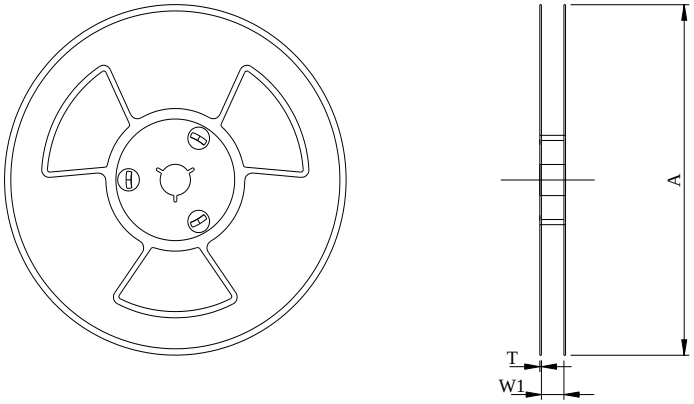
TAPE AND REEL INFORMATION

Carrier Tape



Item	W	P	A0	B0	K0	t	Pin1 Quadrant
Size (mm)	12.00+0.30/-0.1	8.00±0.10	6.50±0.10	5.50±0.10	1.75±0.10	0.30±0.05	Q1

REEL



Item	A	W1	T
Size (mm)	330±1	12.4 +1/-0	2.1±0.3

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