

Low Quiescent Current Power Distribution Switch

1 FEATURES

- **70mΩ/54mΩ(TYP) High-side P-Channel MOSFET**
- **Low Quiescent Current**
- **Input Voltage from 2.5V to 5.5V**
- **Four Current Limit Levels 1.1A, 2.1A, 2.6A, 3.0A**
- **Maximum Shutdown Current $\leq 1\mu\text{A}$**
- **Soft-Start Function**
- **Under-Voltage Lockout Protection for VIN**
- **No Reversed Leakage Current**
- **Thermal Shutdown Protection**
- **Operation temperature from -40°C to 85°C**
- **Lead-Free Packages: SOT23-5**

2 APPLICATIONS

- **Smart Phone & LCD TV**
- **Set-Top Boxes**
- **VOIP**
- **USB Bus/Self Powered Hubs/Peripherals**
- **Portable Consumer or Medical Products**

3 DESCRIPTIONS

The RS2588 is an integrated 70mΩ/54mΩ (TYP,70mΩ for RS2588A/B/C, 54mΩ for RS2588D) power switch for self-powered and bus-powered universal series bus (USB) applications.

The RS2588 is internally current limited and has thermal shutdown function to protect device and load from over-current damage. Thermal shutdown shuts off the output MOSFET and asserts the flag pin output if the die temperature exceeds 150°C until the die temperature drops to 130°C.

The soft-start circuit can minimize inrush current in applications where highly capacitive loads are employed.

The flag pin asserts low when during over-current and thermal conditions after a 13ms blanking time to prevent false reporting.

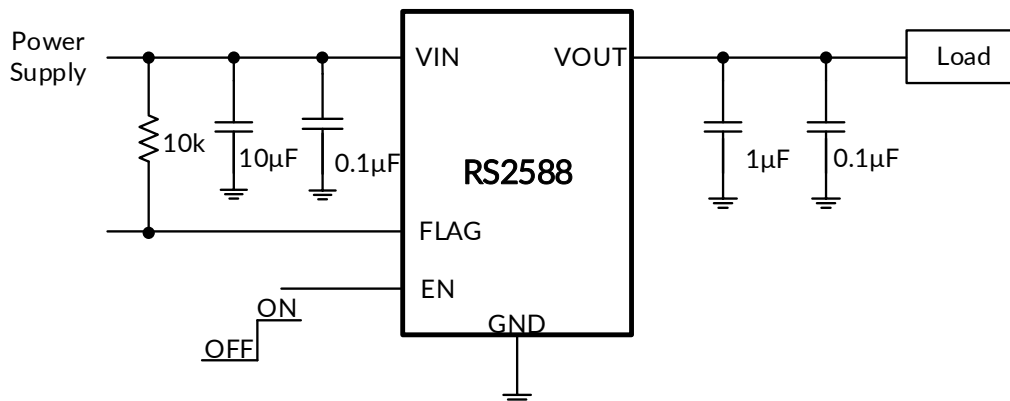
The RS2588 is available in SOT23-5 package. It is rated over the -40°C to 85°C temperature range.

Device Information ⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS2588	SOT23-5	2.92mm×1.60mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 TYPICAL APPLICATION



5 FUNCTIONAL BLOCK DIAGRAM

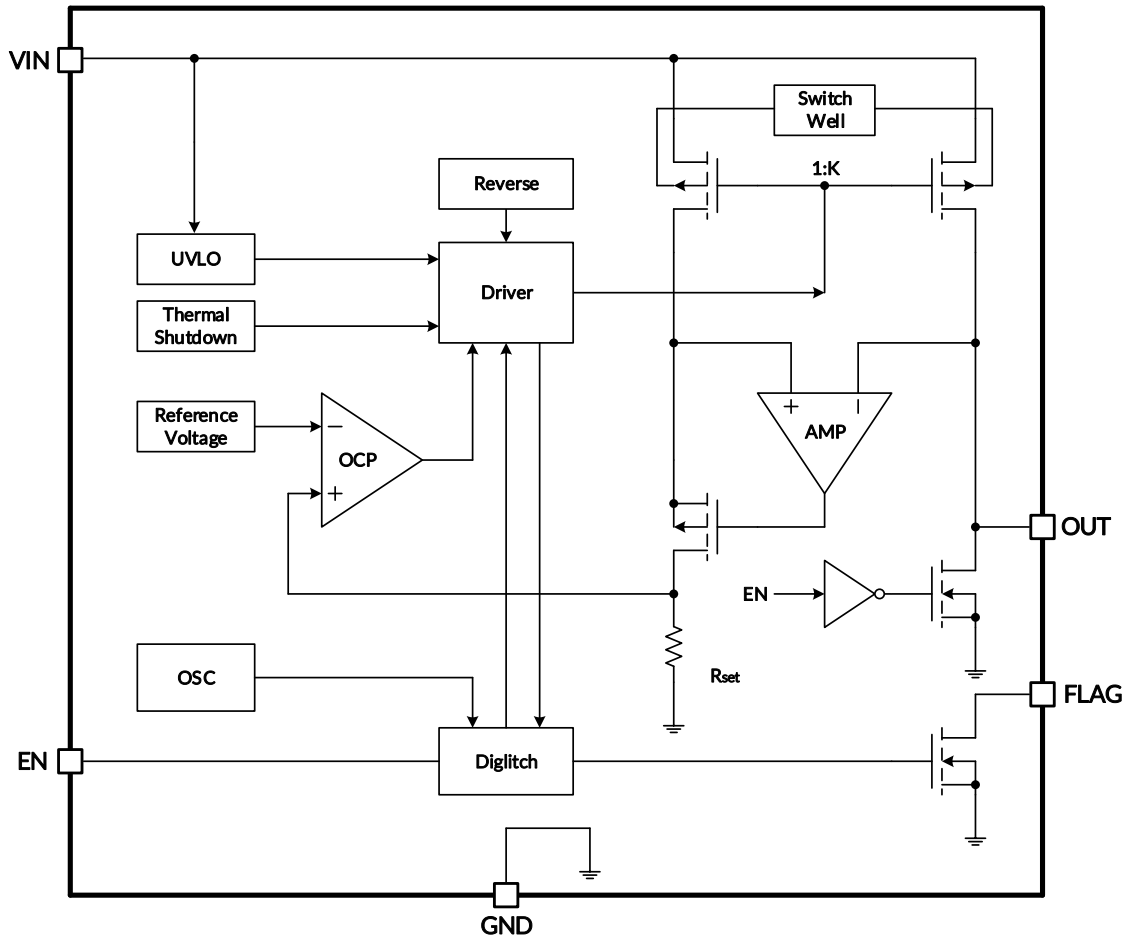


Table of Contents

1 FEATURES	1
2 APPLICATIONS	1
3 DESCRIPTIONS	1
4 TYPICAL APPLICATION	1
5 FUNCTIONAL BLOCK DIAGRAM	2
6 REVISION HISTORY	4
7 PACKAGE/ORDERING INFORMATION ⁽¹⁾	5
8 PIN CONFIGURATIONS	6
9 SPECIFICATIONS	7
9.1 Absolute Maximum Ratings	7
9.2 ESD Ratings	7
9.3 Recommended Operating Conditions	7
9.4 Electrical Characteristics	8
9.5 Typical Performance Characteristics	9
10 PARAMETER MEASUREMENT INFORMATION	14
11 FUNCTIONAL DESCRIPTION	15
11.1 Input and output	15
11.2 Thermal Shutdown	15
11.3 Soft-Start	15
11.4 Current limiting and Short protection	15
11.5 Reverse-voltage protection	15
11.6 FLAG output	15
11.7 Power dissipation	15
12 APPLICATION INFORMATION	16
12.1 Supply filter capacitor	16
12.2 Output filter capacitor	16
12.3 PCB layout guide	16
13 PACKAGE OUTLINE DIMENSIONS	17
14 TAPE AND REEL INFORMATION	18

6 REVISION HISTORY

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

VERSION	Change Date	Change Item
A.0	2021/12/20	Initial version completed
A.1	2022/06/22	Official version completed
A.2	2024/04/07	1. Add MSL on Page 5@RevA.1 2. Update PACKAGE note
A.3	2024/07/04	Add RS2588D

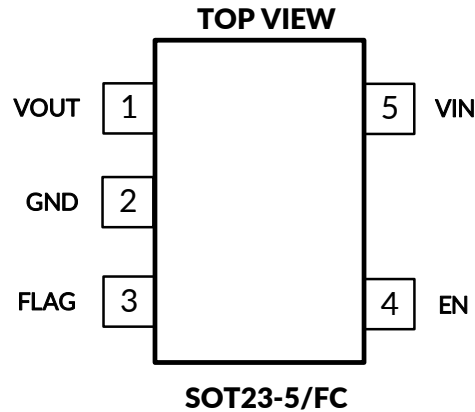
7 PACKAGE/ORDERING INFORMATION ⁽¹⁾

PRODUCT	ORDERING NUMBER	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING ⁽²⁾	MSL ⁽³⁾	PACKAGE OPTION
RS2588	RS2588AYF5	-40°C ~85°C	SOT23-5	2588A	MSL3	Tape and Reel, 3000
	RS2588BYF5	-40°C ~85°C	SOT23-5	2588B	MSL3	Tape and Reel, 3000
	RS2588CYF5	-40°C ~85°C	SOT23-5	2588C	MSL3	Tape and Reel, 3000
	RS2588DYF5	-40°C ~85°C	SOT23-5(FC)	2588D	MSL3	Tape and Reel, 3000

NOTE:

- (1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.
- (2) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.
- (3) RUNIC classify the MSL level with using the common preconditioning setting in our assembly factory conforming to the JEDEC industrial standard J-STD-20F, Please align with RUNIC if your end application is quite critical to the preconditioning setting or if you have special requirement.

8 PIN CONFIGURATIONS



Pin Description

NAME	PIN	DESCRIPTION
VOUT	1	Switch Output. The P-Channel Drain of Switch, Which Typically Connects to Load.
GND	2	Ground
FLAG	3	Flag pin. Active low, open-drain output. Indicates over-current or thermal shutdown conditions. Over-current condition must last longer than t_D in order to assert Flag.
EN	4	Enable Input. Logic Level Enable Input, Active high available.
VIN	5	Power Supply Input. The P-Channel Source of Switch, which also supplies IC's internal circuitry. Connect to Positive Supply.

9 SPECIFICATIONS

9.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) ⁽¹⁾⁽²⁾

Characteristics		Symbol	MIN	MAX	UNIT
Supply Input Voltage		V _{IN}	-0.3	6.0	V
Output Voltage		V _{OUT}	-0.3	6.0	V
EN Input Voltage		V _{EN}	-0.3	6.0	V
FLAG Output Voltage		V _{FLAG}	-0.3	6.0	V
Package thermal impedance ⁽³⁾	SOT23-5	θ _{JA}		230	°C/W
	SOT23-5(FC)			200	
Operating Junction Temperature		T _J	-40	+150	°C
Storage Temperature ⁽⁴⁾		T _{stg}	-65	150	°C
Lead Temperature (Soldering, 10secs)		T _L		260	°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 voltages are with respect to the GND pin.
- (3) The package thermal impedance is calculated in accordance with JESD-51.
- (4) The maximum power dissipation is a function of T_{J(MAX)}, R_{θJA}, and T_A. The maximum allowable power dissipation at any ambient temperature is P_D = (T_{J(MAX)} - T_A) / R_{θJA}. All numbers apply for packages soldered directly onto a PCB.

9.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

		VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human-Body Model (HBM)	±3000
		Charge Device Model (CDM)	±1500



ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

9.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

Characteristics	Symbol	MIN	MAX	UNIT
Input Voltage	V _{IN}	2.5	5.5	V
EN Voltage range	V _{EN}	0	5.5	V
All other pins		0	5.5	V
Operating Temperature Range	T _A	-40	+85	°C
Operating Junction Temperature Range	T _J	-40	+125	°C

9.4 Electrical Characteristics

(At $V_{IN}=5V$, $T_A = 25^{\circ}C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN ⁽¹⁾	TYP ⁽²⁾	MAX ⁽¹⁾	UNITS
Input Voltage	V_{IN}		2.5		5.5	V
Quiescent Supply Current	I_Q	Switch on, $V_{OUT} = \text{open}$	10	30	50	μA
Shutdown Supply Current	I_{SD}	Switch off, $V_{OUT} = \text{open}$		0.1	1.0	μA
Reverse Leakage Current of V_{IN}	$I_{LKG(VIN)}$	Switch off, $V_{IN}=\text{GND}$, $V_{OUT}=0$ to 5.5V		0.1	1.0	μA
Enable Input Threshold	V_{IL}	$V_{IN} = 2.5V$ to 5.5V			0.4	V
	V_{IH}	$V_{IN} = 2.5V$ to 5.5V	1.6			V
EN Input Current	I_{EN}	$V_{EN} = 0V$ to 5.5V		10	15	μA
EN Pin Pull-Down Resistance	R_{PULL_DOWN}	$V_{EN} = 2.5V$ to 5.5V	450	520	600	k Ω
Switch Resistance	$R_{DS(ON)}$	RS2588A/B/C, $I_{OUT} = 500mA$		70	80	m Ω
		RS2588D, $I_{OUT} = 500mA$		54	65	m Ω
Output Turn-On Delay Time	t_{ON}	$R_L = 10\Omega$, $C_L = 1\mu F$, Figure 4,5		2		ms
Output Turn-Off Delay Time	t_{OFF}	$R_L = 10\Omega$, $C_L = 1\mu F$, Figure 6,7		20		μs
Current Limit Threshold	I_{LIMIT}	RS2588A, Ramped load	0.99	1.1	1.21	A
		RS2588B, Ramped load	1.89	2.1	2.31	A
		RS2588C, Ramped load	2.34	2.6	2.86	A
		RS2588D, Ramped load	2.7	3.0	3.3	A
Under-Voltage Lockout Threshold	V_{UVLO}	V_{IN} rising		1.9	2.3	V
Under-Voltage Lockout Threshold Hysteresis	V_{UVLO_HY}			0.15		V
Over-Current FLAG Response Delay Time	t_D	Apply $V_{OUT} = 0$ until FLAG is low		13		ms
Leakage Current of FLAG	$I_{LKG(FLAG)}$	FLAG is HIGH		0.1	1.0	μA
Flag Output Low Voltage	V_{FLAG-L}	$C_{IN}=10\mu F$, $I_{SINK} = 2mA$			0.4	V
V_{OUT} Shutdown Discharge Resistance	R_{DIS}	Switch off	250	300	350	Ω
Thermal Shutdown Temperature	T_{SD}	T_J Increasing		150		$^{\circ}C$
Thermal Shutdown Hysteresis	T_{SD_HY}			30		$^{\circ}C$

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

9.5 Typical Performance Characteristics

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_{IN} = 5V$, $T_A = 25^{\circ}C$, unless otherwise noted.

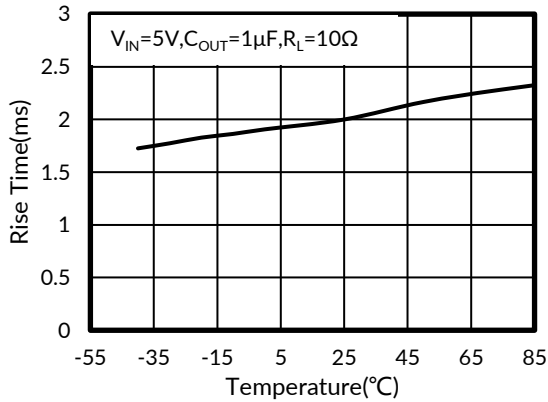


Figure 1. Turn-On Rise Time vs Temperature

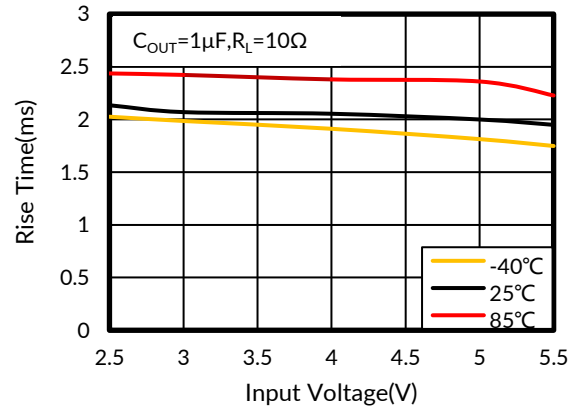


Figure 2. Turn-On Rise Time vs Input Voltage

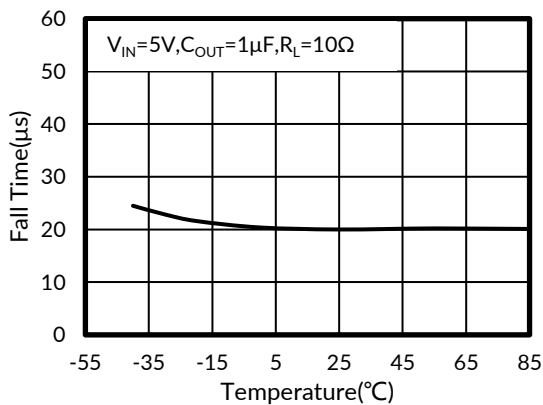


Figure 3. Turn-Off Fall Time vs Temperature

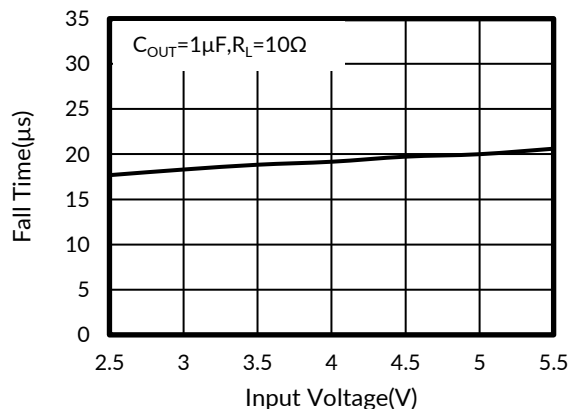


Figure 4. Turn-Off Fall Time vs Input Voltage

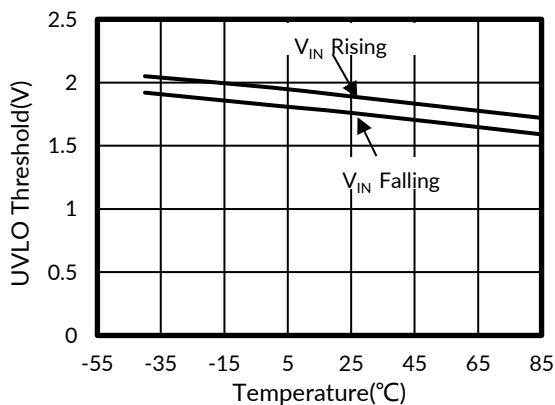


Figure 5. UVLO Threshold vs Temperature

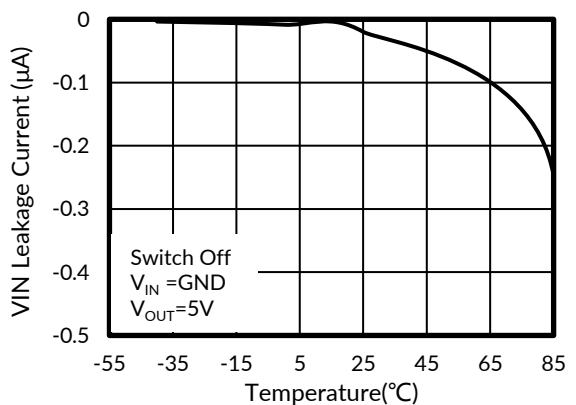


Figure 6. VIN Leakage Current vs Temperature

Typical Performance Characteristics (Continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_{IN} = 5V$, $T_A = 25^\circ C$, unless otherwise noted.

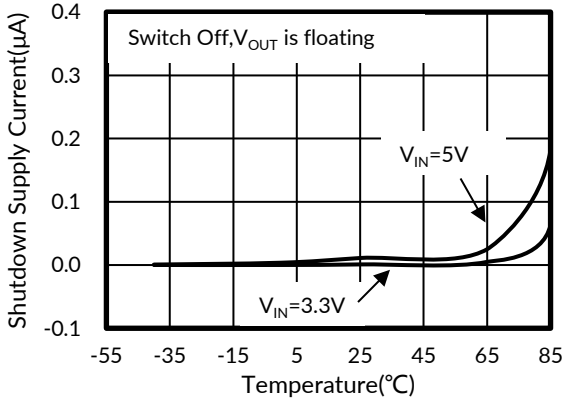


Figure 7. Shutdown Supply Current vs Temperature

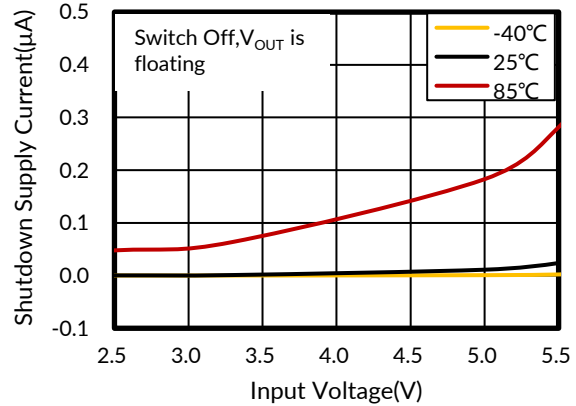


Figure 8. Shutdown Supply Current vs Input Voltage

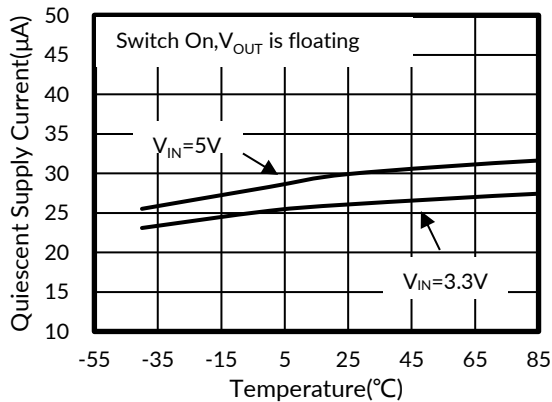


Figure 9. Quiescent Supply Current vs Temperature

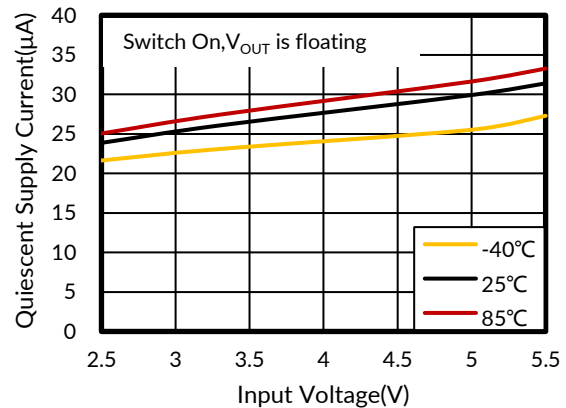


Figure 10. Quiescent Supply Current vs Input Voltage

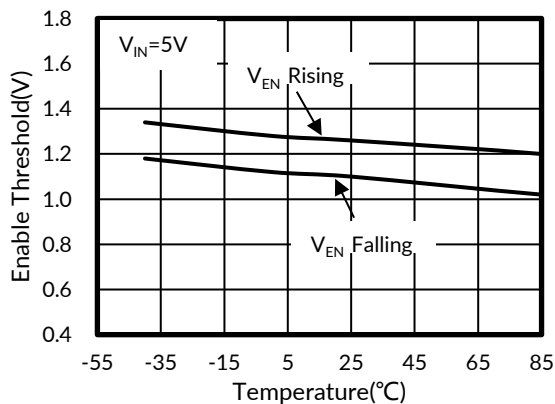


Figure 11. Enable Threshold vs Temperature

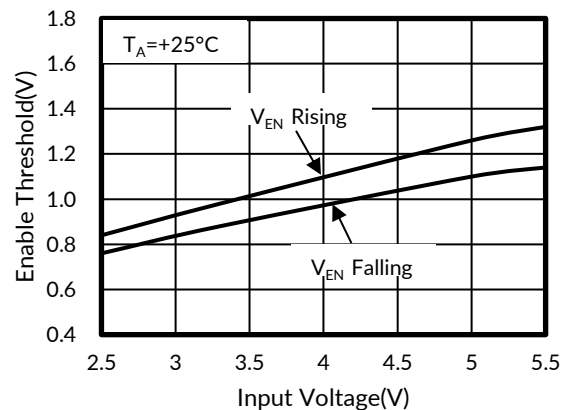


Figure 12. Enable Threshold vs Input Voltage

Typical Performance Characteristics (Continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_{IN} = 5V$, $T_A = 25^\circ C$, unless otherwise noted.

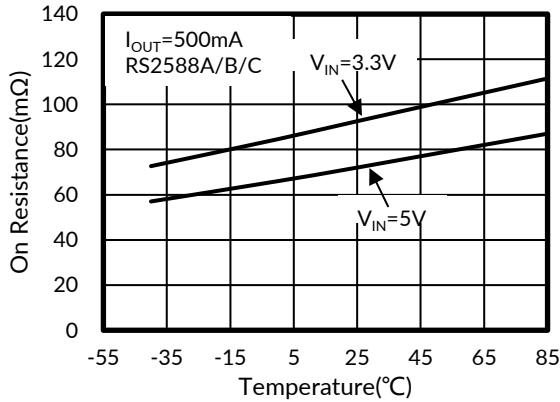


Figure 13. On Resistance vs Temperature

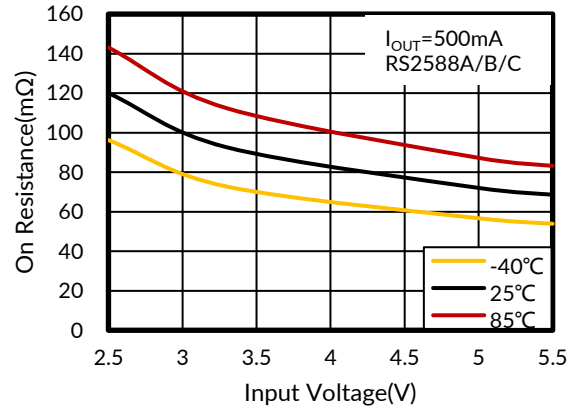


Figure 14. On Resistance vs Input Voltage

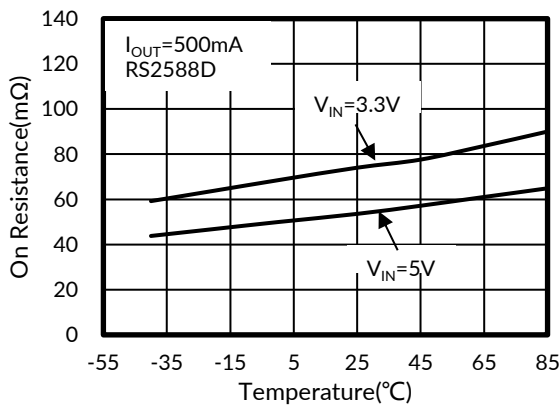


Figure 15. On Resistance vs Temperature

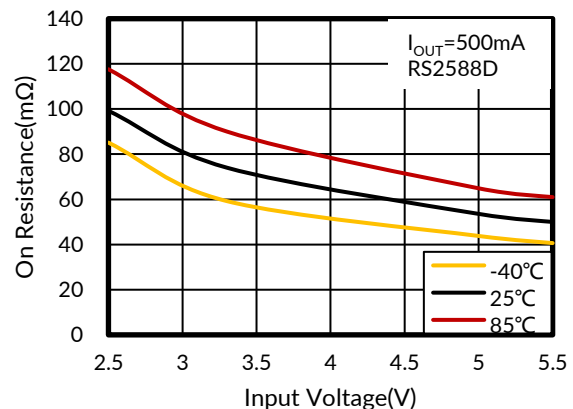


Figure 16. On Resistance vs Input Voltage

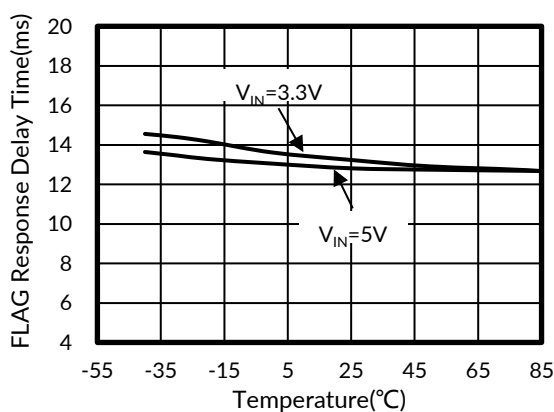


Figure 17. FLAG Response Delay Time vs Temperature

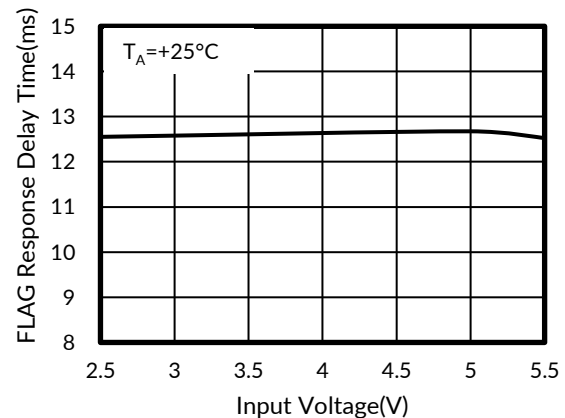


Figure 18. FLAG Response Delay Time vs Input Voltage

Typical Performance Characteristics (Continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_{IN} = 5V$, $T_A = 25^\circ C$, unless otherwise noted.

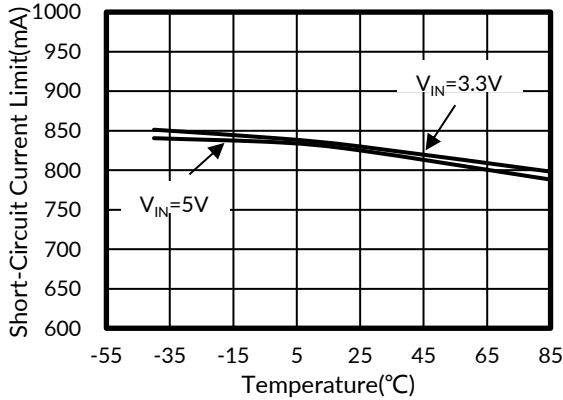


Figure 19. Short-Circuit Current Limit vs Temperature

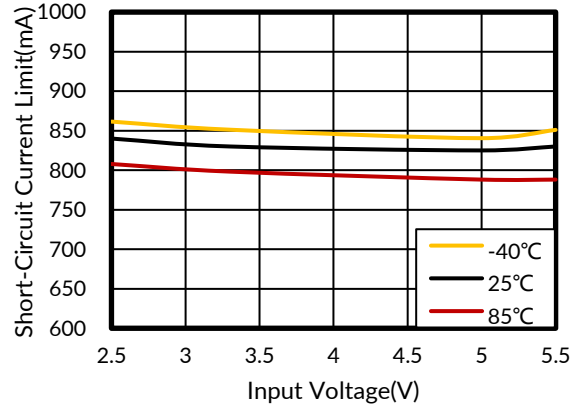


Figure 20. Short-Circuit Current Limit vs Input Voltage

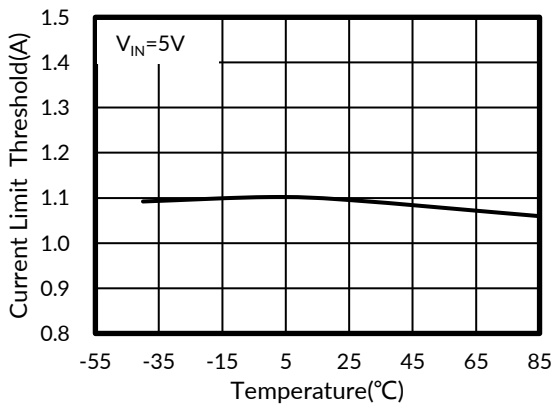


Figure 21. Current Limit Threshold vs Temperature

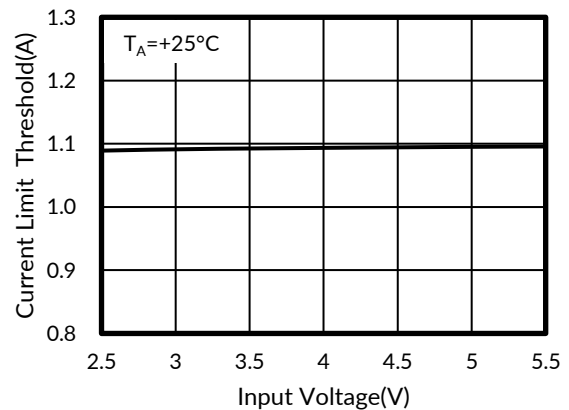


Figure 22. Current Limit Threshold vs Input Voltage

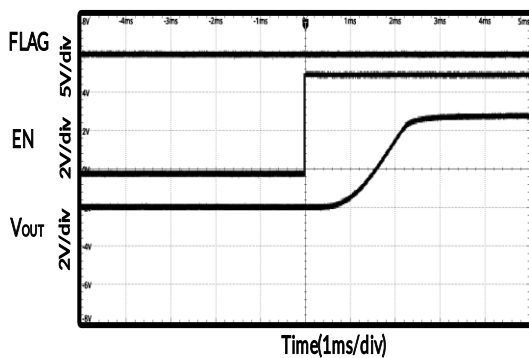


Figure 23. Turn-On Response

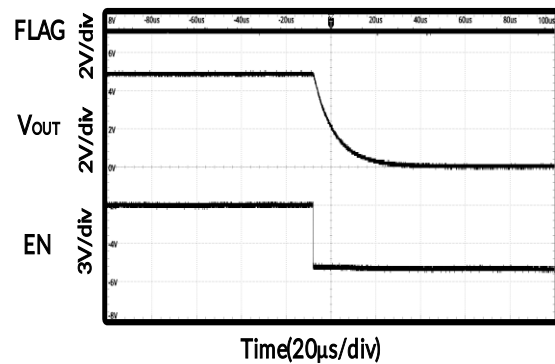


Figure 24. Turn-Off Response

Typical Performance Characteristics (Continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_{IN} = 5V$, $T_A = 25^\circ C$, unless otherwise noted.

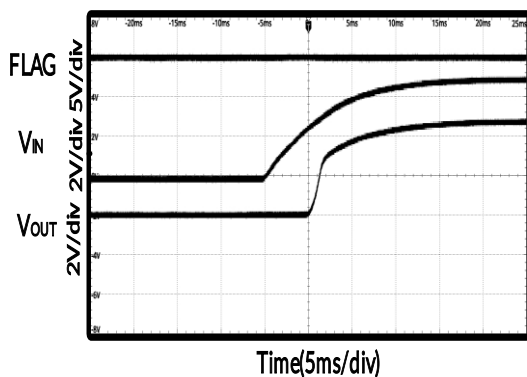


Figure 25. UVLO at V_{IN} Rising

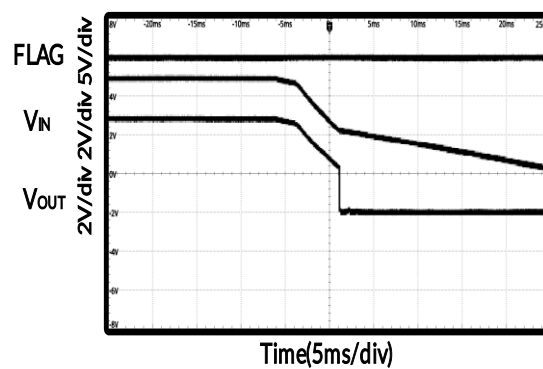


Figure 26. UVLO at V_{IN} Falling

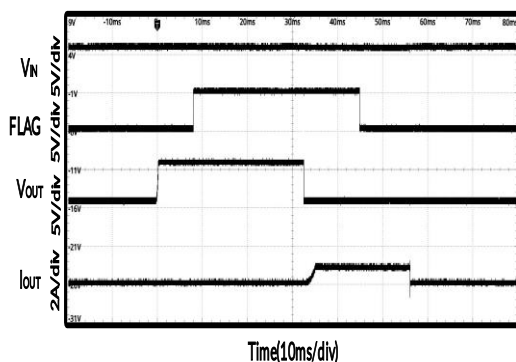


Figure 27. No Load into Short-Circuit

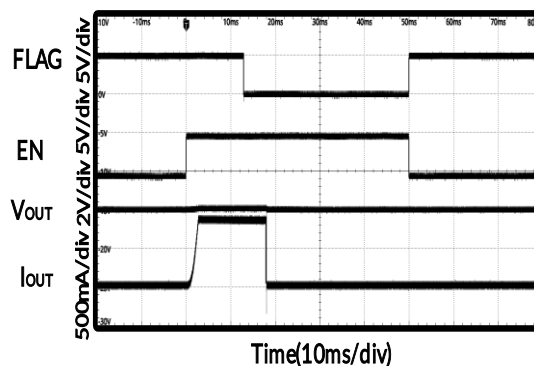


Figure 28. Device Enabled into Short-Circuit

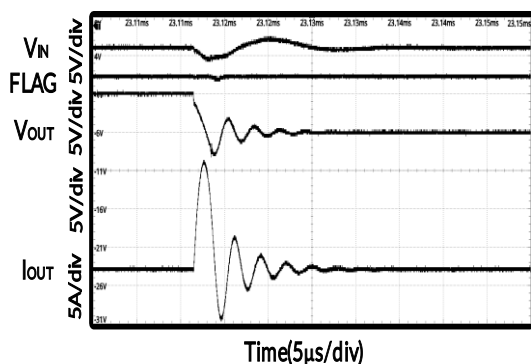


Figure 29. Short-Circuit Response Time

10 PARAMETER MEASUREMENT INFORMATION

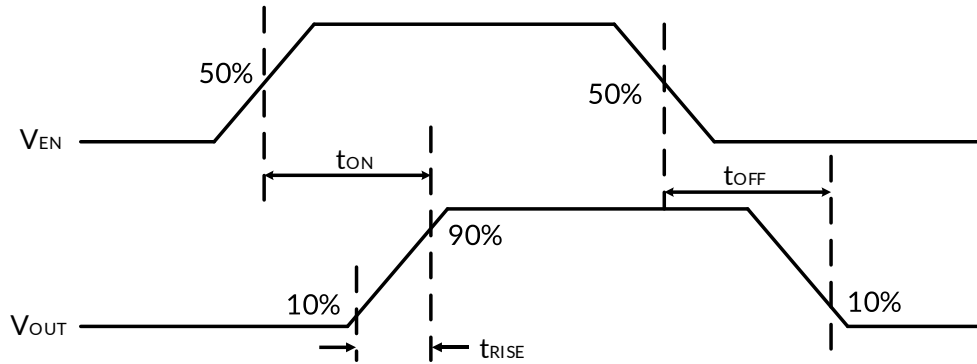


Figure 30. Switch Turn-On and Turn-Off Delay Times

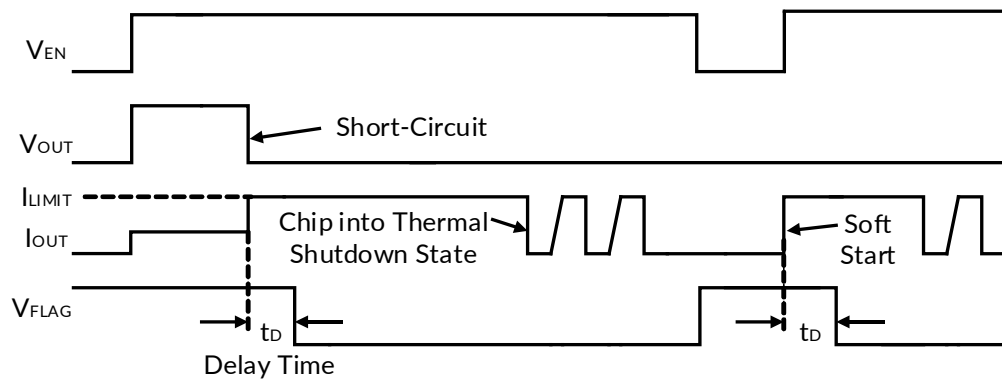


Figure 31. Fault Timing: Output Reset by Toggling EN

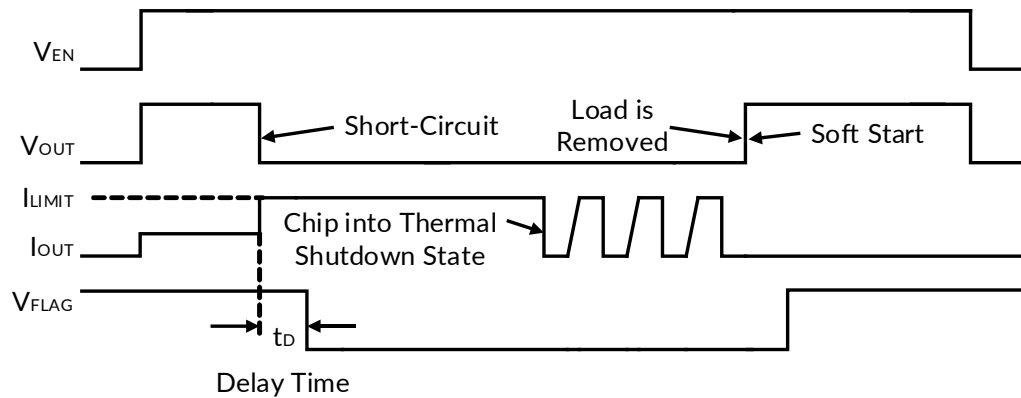


Figure 32. Fault Timing: Output Reset by Removing Load

11 FUNCTIONAL DESCRIPTION

11.1 Input and output

V_{IN} is the power supply connection to the logic circuitry and the source of the P-channel MOSFET. V_{OUT} is the drain of the P-channel MOSFET. In a typical circuit, current flows from V_{IN} to V_{OUT} toward the load. The output P-channel MOSFET and driver circuit are also designed to allow the MOSFET drain to be externally forced to a higher voltage than the source (V_{OUT} > V_{IN}) when the switch is disabled.

11.2 Thermal Shutdown

Thermal shutdown is employed to protect device and load from damage. It shuts off the output MOSFET and asserts the FLAG output, if the die temperature exceeds 150°C until the die temperature drops to 130°C.

11.3 Soft-Start

In order to eliminate the upstream voltage sag caused by the large inrush current during hot-plug events, the soft-start feature effectively isolates power supplies from such highly capacitive loads.

11.4 Current limiting and Short protection

The current limit circuit is designed to limit the output current to protect the upstream power supply. The typical current limit threshold is set by internally to approximately 1.1A, 2.1A, 2.6A and 3.0A. Under output short-circuit condition, the typical current limit folded back 75%. If the chip keeps at over-current condition for a long time, the junction temperature may exceed 150°C, and over-temperature protection will shut down the output until temperature drops below 130°C or limit (short) condition is removed.

11.5 Reverse-voltage protection

The reverse-voltage protection feature turns off the P-MOSFET switch whenever the output voltage exceeds the input voltage by 40mV.

11.6 FLAG output

The FLAG signal is an open-drain output pin. FLAG is asserted when an over-current or thermal shutdown condition occurs, and active low output.

In the case of an over-current condition, FLAG will be asserted only after the response delay time (t_D) has elapsed. This ensures that FLAG is asserted only upon valid over-current conditions and that erroneous error reporting is eliminated.

For example, false over-current conditions can occur during hot-plug events when a highly capacitive load is connected and causes a high transient inrush current that exceeds the current limit threshold for up to 1ms, The FLAG response delay time t_D is about 13ms.

11.7 Power dissipation

The device's junction temperature depends on several factors such as the load, PCB layout, ambient temperature, and package type. Equations that can be used to calculate power dissipation and junction temperature are found below:

$$P_D = R_{DS(ON)} \times I_{OUT}^2$$

To relate this to junction temperature, the following equation can be used:

$$T_J = P_D \times \theta_{JA} + T_A$$

Where:

T_J = junction temperature

T_A = ambient temperature

θ_{JA} = the thermal resistance of the package

12 APPLICATION INFORMATION

12.1 Supply filter capacitor

In order to prevent the input voltage drooping during hot-plug events, connect a ceramic capacitor C_{IN} from VIN to GND. The C_{IN} is positioned close to VIN and GND of the device. However, higher capacitor values could reduce the voltage sag on the input further. Furthermore, an output short will cause ringing on the input without the input capacitor. It could destroy the internal circuitry when the input transient exceeds 6V which is the absolute maximum supply voltage even for a short duration.

If the upstream supply cable is long or the VIN transient exceeds 6V during the VOUT short, recommend adding a second filter capacitor (not less than 47 μ F) at the upstream supply output terminal.

12.2 Output filter capacitor

Between VOUT and GND, connect a at least 1 μ F low-ESR ceramic capacitor is recommended. Standard bypass methods should be used to minimize inductance and resistance between the bypass capacitor and the downstream connector. This will reduce EMI and improve the transient performance.

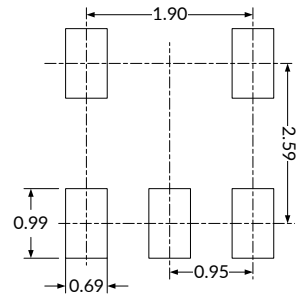
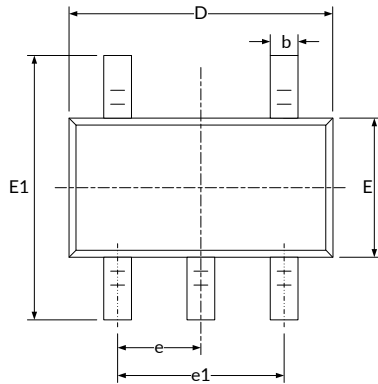
12.3 PCB layout guide

For best performance of the RS2588, the following guidelines must be strictly followed:

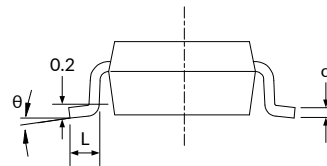
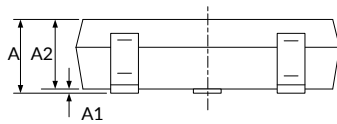
- 1) Keep all power line as short and wide as possible and use at least 1-ounce copper for all power line.
- 2) Dual low-ESR 10 μ F ceramic capacitors between VOUT and GND, VIN and GND.
- 3) Locate the output capacitor as close to the connectors as possible to lower impedance between the port and the capacitor and improve transient performance.
- 4) Input and output capacitors should be placed closed to the chip and connected to ground plane to reduce noise coupling.
- 5) Locate the ceramic bypass capacitors as close as possible to the VIN pin and VOUT pin.

13 PACKAGE OUTLINE DIMENSIONS

SOT23-5⁽³⁾



RECOMMENDED LAND PATTERN (Unit: mm)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A ⁽¹⁾	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D ⁽¹⁾	2.820	3.020	0.111	0.119
E ⁽¹⁾	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 (BSC) ⁽²⁾		0.037 (BSC) ⁽²⁾	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

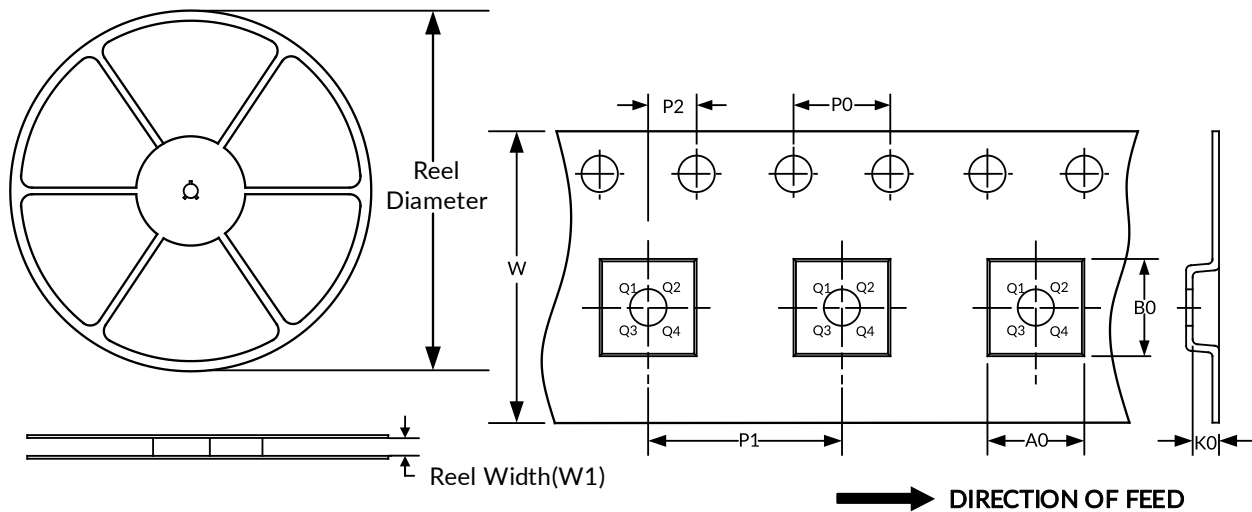
NOTE:

1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. This drawing is subject to change without notice.

14 TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSION



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT23-5	7"	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3

NOTE:

1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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