Precision Adjustable Current Limited Power Distribution Switches

1 FEATURES

- **Up to 3A Maximum Load Current**
- **Typical 85μA Low Quiescent Current**
- **Typical 0.1μA Shutdown Current**
- **No Reverse Leakage Current When Power Off**
- **Meets USB Current Limiting Requirements**
- **Adjustable Current Limit: 400mA to 3A**
- **Fast Over-Current Response: 2μs**
- **50mΩ High-side MOSFET**
- **Reverse Input-Output Voltage Protection**
- **Under Voltage Lockout**
- **Thermal Shutdown Protection**
- **Operating Range: 2.5V to 5.5V**
- **Built-In Soft-Start Function**
- **Available in the Green DFN3X3-8 Package**
- **UL Certification NO. E545431**
- **CB Certification by IEC 62368-1**

2 APPLICATIONS

- **USB Host and Self-Powered Hubs**
- **USB Bus-Powered Hubs**
- **USB Power Management**
- **General Purpose Power Switch (High Side)**
- **Hot Plug-in Power Supplies**
- **Battery-Charger Circuits**

3 DESCRIPTIONS

The RS2599A is an integrated power switch for self-powered and bus-powered Universal Serial Bus (USB) applications.

The RS2599A is a cost-effective, low voltage, single P-channel MOSFET load switch with 50mΩ $R_{DS(ON)}$, which is free of parasitic body diode to eliminate any reverse current flow across the switch when it is powered off. When the output voltage is higher than input voltage, the power switch is turned off by internal output reverse-voltage protection.

Several Protection features include current limiting and thermal shutdown to prevent catastrophic switch failure caused by increasing power dissipation when continuous heavy loads or short circuit occurs.

FLAG is an open-drain output report over-current or over-temperature event and has typical 13ms deglitch timeout period.

RS2599A is available in the Green DFN3X3-8 package. It is rated over the -40°C to 85°C temperature range.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS2599A	DFN3X3-8	3.00mm×3.00mm

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

4 FUNCTIONAL BLOCK DIAGRAM

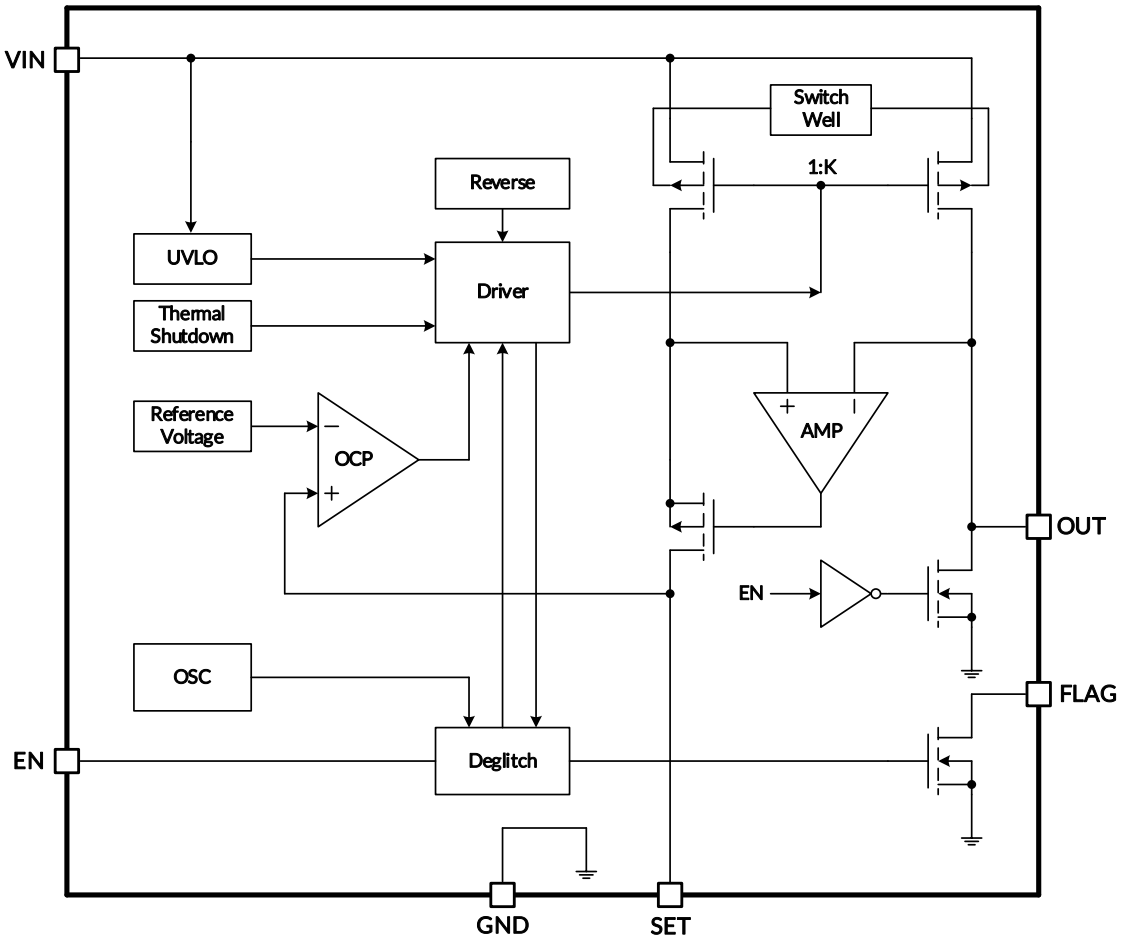


Table of Contents

5 REVISION HISTORY

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

VERSION	Change Date	Change Item
A.1	2024/07/22	Initial version completed
A.2	2025/05/06	Update FEATURES

6 PACKAGE/ORDERING INFORMATION (1)

PRODUCT	ORDERING NUMBER	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING (2)	MSL (3)	PACKAGE OPTION
RS2599A	RS2599AYTDC8	-40°C ~85°C	DFN3X3-8	RS2599A	MSL3	Tape and Reel,5000

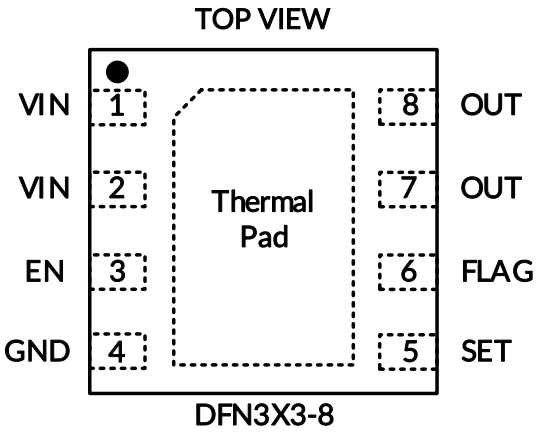
NOTE:

(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.

7 PIN CONFIGURATIONS



PIN DESCRIPTION

PIN	NAME	DESCRIPTION
DFN3X3-8		
1	VIN	Power Supply Input. The P-Channel Source of Switch, Which also supplies IC's internal circuitry. Connect to Positive Supply.
2		
3	EN	Enable Input. Logic Level Enable Input, Active high available.
4	GND	Ground.
5	SET	Current limit set pin. Connect a resistor between this pin and ground to program the desired current limit set point.
6	FLAG	Fault Flag. Active low, open-drain output. Indicates over-current or thermal shutdown conditions. Over-current condition must last longer than td in order to assert FLAG
7	OUT	Switch Output. The P-Channel Drain of Switch, Which Typically Connects to Load.
8		
/	Thermal Pad	Thermal pad (exposed center pad) to alleviate thermal stress. Tie to GND.

8 SPECIFICATIONS

8.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V_{IN}	Supply voltage range		-0.3	6.0	V
V_{OUT}	Output voltage range		-0.3	6.0	V
V_{EN}	EN Input Voltage		-0.3	6.0	V
V_{FLAG}	FLAG Output Voltage		-0.3	6.0	V
V_{SET}	SET Output Voltage		-0.3	6.0	V
θ_{JA}	Package thermal impedance (2)	DFN3X3-8		45	°C/W
T_J	Junction temperature (3)		-40	150	°C
T_{stg}	Storage temperature		-65	150	°C
T_L	Lead Temperature (Soldering,10secs)			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) The package thermal impedance is calculated in accordance with JESD-51.

(3) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{\theta JA}$, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$. All numbers apply for packages soldered directly onto a PCB.

8.2 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), JEDEC EIA/ JESD22 - A114	±2000	V
	Charged-device model (CDM), ANSI/ESDA/JEDEC JS-002-2018	±1000	

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.

8.3 Recommended Operating Rating

		MIN	MAX	UNIT
V_{IN}	Supply voltage range	2.5	5.5	V
V_{OUT}	Output voltage range	0	5.5	V
V_{EN}	EN Input Voltage	0	5.5	V
V_{FLAG}	FLAG Output Voltage	0	5.5	V
V_{SET}	SET Output Voltage	0	5.5	V
T_A	Operating Temperature	-40	85	°C

8.4 ELECTRICAL CHARACTERISTICS

(V_{IN}=5.0V, V_{EN}=5.0V, C_{IN}=10μF, T_A = 25°C, unless otherwise noted.) (1)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN(2)	TYP(3)	MAX(2)	UNIT
POWER SUPPLY AND CURRENTS						
Power Input Voltage Range	V_{IN}		2.5		5.5	V
Under-Voltage Lockout Threshold	V_{UVLO}	V_{IN} Rising		1.9	2.4	V
Under-Voltage Lockout Threshold Hysteresis	V_{UVLO_HY}	V_{IN} Falling		0.1		V
Power Supply Current	I_Q	Switch on, V_{OUT}=Open		85	140	μA
Shutdown Supply Current	I_{SD}	Switch off, V_{OUT}=Open		0.1	1	μA
Reverse Leakage Current of V_{IN}	$I_{LKG(VIN)}$	Switch off, V_{IN}=GND, V_{OUT}=0 to 5.5V		0.1	1	μA
POWER SWITCH						
High-side MOSFET On Resistance	$R_{DS(ON)}$	I_{OUT}=500mA		50	60	mΩ
CURRENT LIMIT AND SHOR-CIRCUIT CURRENT						
Current Limit Threshold	I_{LIMIT}	C_L=1μF, R_{SET}=7.5kΩ	1.86	2	2.14	A
Short-Circuit Current Threshold	I_{SHORT}	C_L=1μF, R_{SET}=7.5kΩ		1.5		A
Response Time to Short Circuit (4)	t_{SCR}	C_{IN}=470μF to 1000μF		2		μs
OUTPUT DISCHARGE						
Discharge Resistor	R_{DIS}	Switch off		300	350	Ω
ENABLE AND FLAG						
Enable Input Threshold	V_{IH}	V_{IN}=2.5V to 5.5V	1.6			V
	V_{IL}	V_{IN}=2.5V to 5.5V			0.4	V
EN Pin Pull-Down Resistance	R_{EN}	V_{EN}= 2.5V to 5.5V	400	500	600	kΩ
FLAG Output Low Voltage	V_{FLAG_L}	I_{SINK}=2mA			200	mV
FLAG Output Leakage Current	I_{FLAG_L}	FLAG is HIGH, V_{FLAG}=5.0V		0.1	1	μA
Over-Current FLAG Response Delay Time	t_D	C_L=1μF, V_{OUT}=0 until FLAG is low		13		ms
SWITCHING CHARACTERISTICS						
Output Turn-On Delay Time	t_{ON}	R_L=5Ω, C_L=1μF		2		ms
Output Turn-Off Delay Time	t_{OFF}	R_L=5Ω, C_L=1μF		12		μs
THERMAL SHUTDOWN						
Thermal Shutdown Temperature (4)	T_{SD}	T_J Increasing		150		°C
Thermal Shutdown Hysteresis (4)	T_{SD_HY}			20		°C

NOTE:

(1) Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.

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

(3) 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.

(4) Guaranteed by design and characterization, not a FT item.

8.5 PARAMETER MEASUREMENT INFORMATION

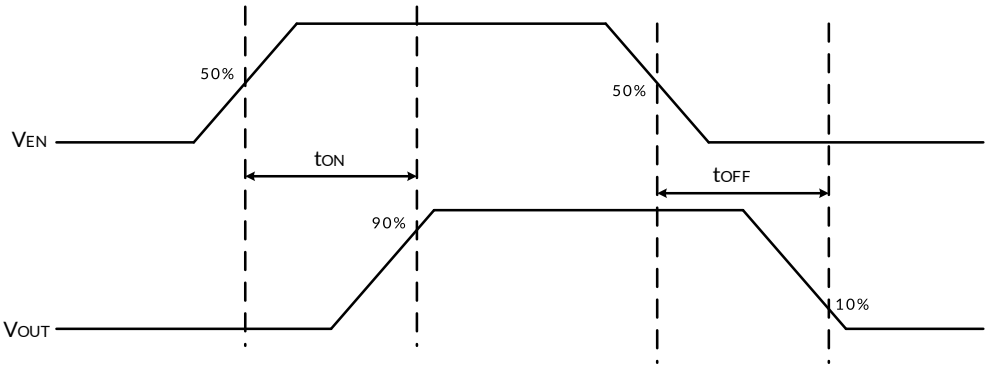


Figure 1. Switch Turn-On and Turn-Off Delay Time

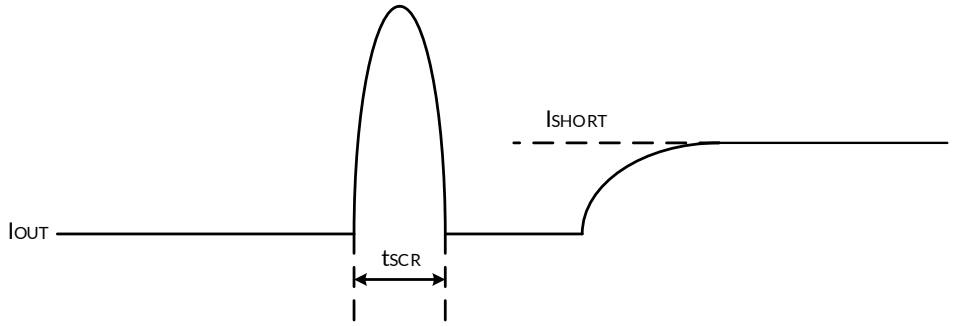


Figure 2. Short-Circuit Response Time

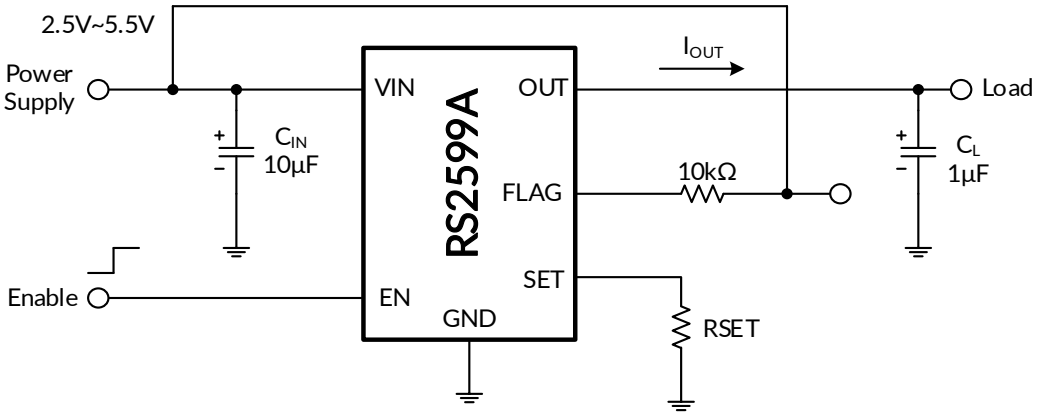


Figure 3. Typical Application Circuit

8.6 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.

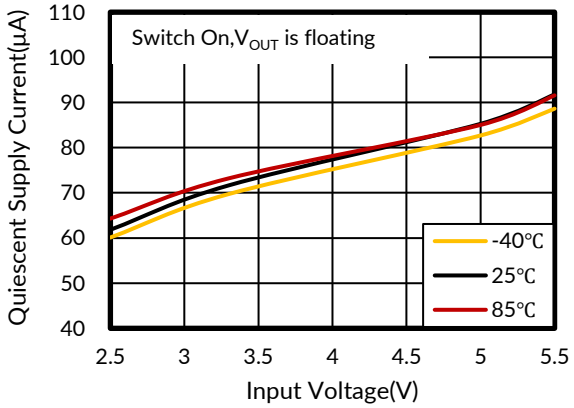


Figure 4. Quiescent Supply Current vs Input Voltage

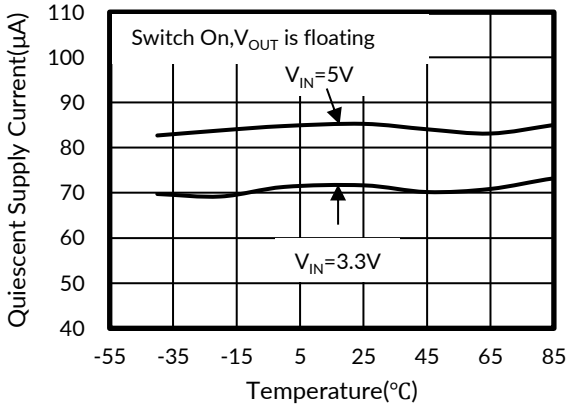


Figure 5. Quiescent Supply Current vs Temperature

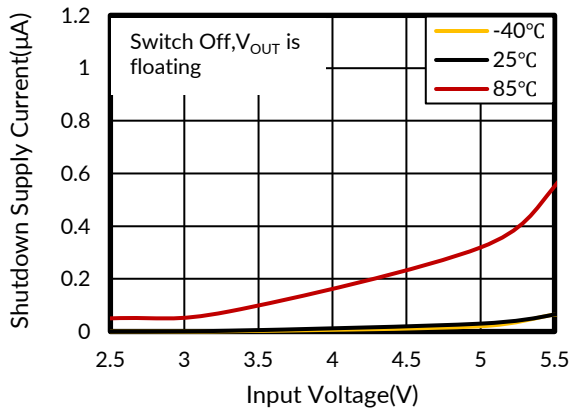


Figure 6. Shutdown Supply Current vs Input Voltage

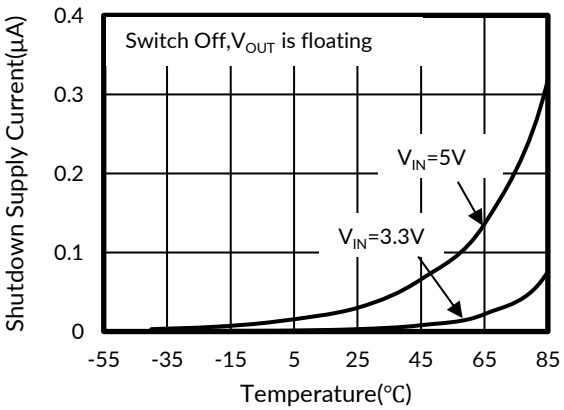


Figure 7. Shutdown Supply Current vs Temperature

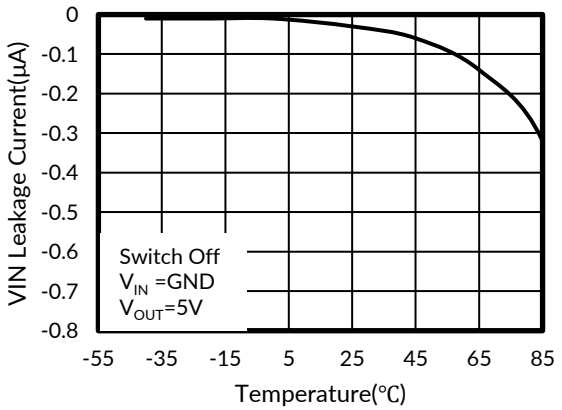


Figure 8. VIN Leakage Current vs Temperature

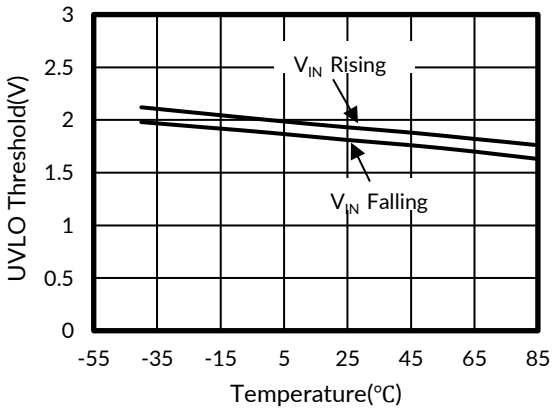


Figure 9. UVLO Threshold vs Temperature

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.

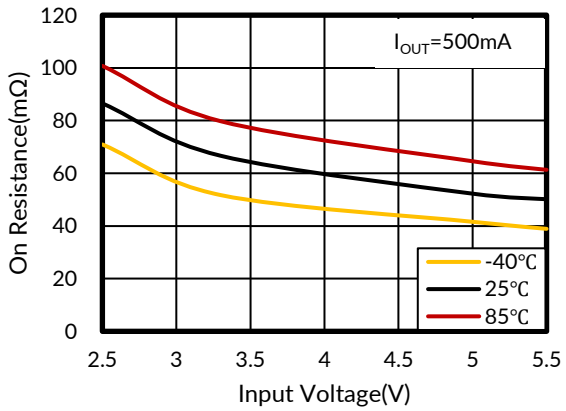


Figure 10. On Resistance vs Input Voltage

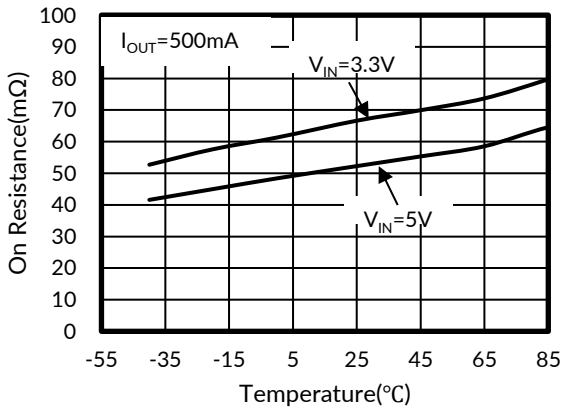


Figure 11. On Resistance vs Temperature

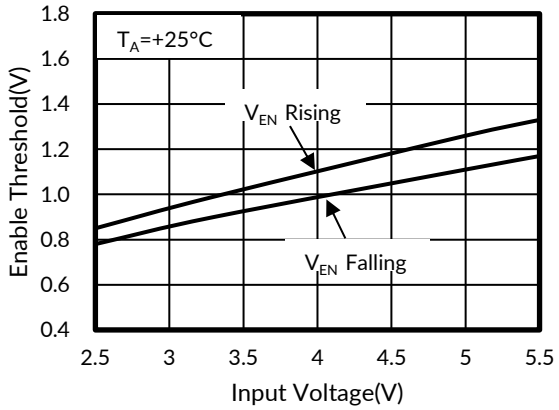


Figure 12. Enable Threshold vs Input Voltage

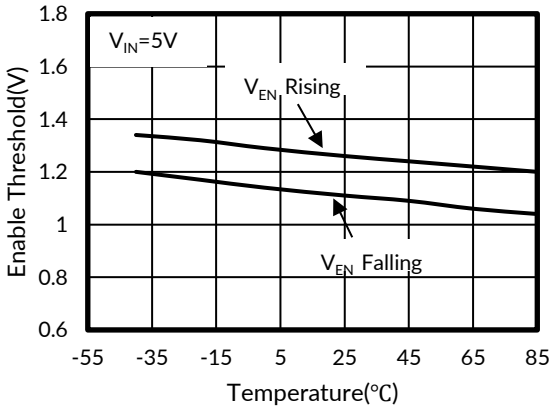


Figure 13. Enable Threshold vs Temperature

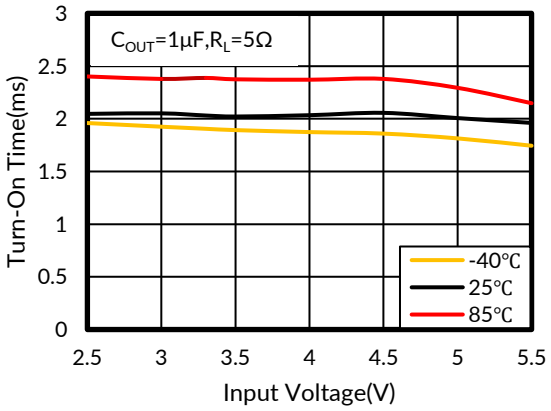


Figure 14. Turn-On Time vs Input Voltage

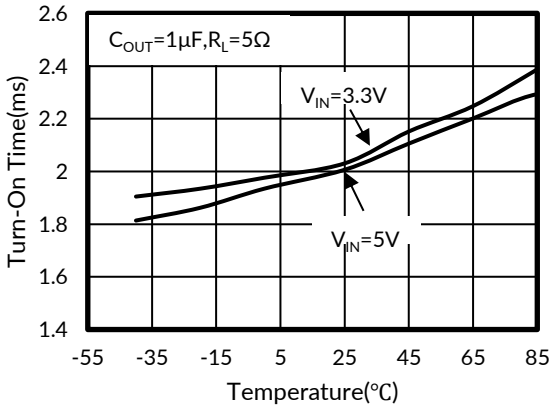


Figure 15. Turn-On Time vs Temperature

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.

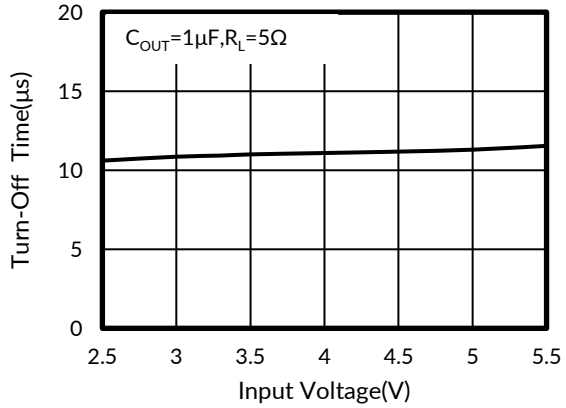


Figure 16. Turn-Off Time vs Input Voltage

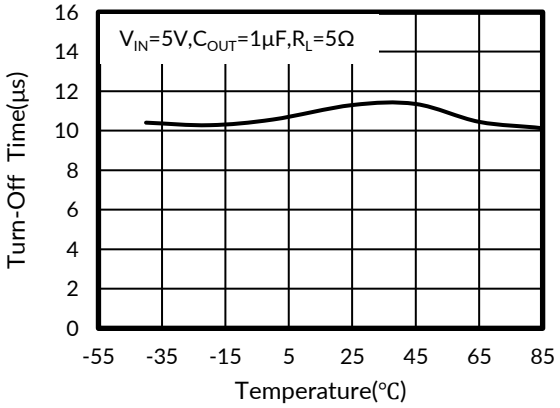


Figure 17. Turn-Off Time vs Temperature

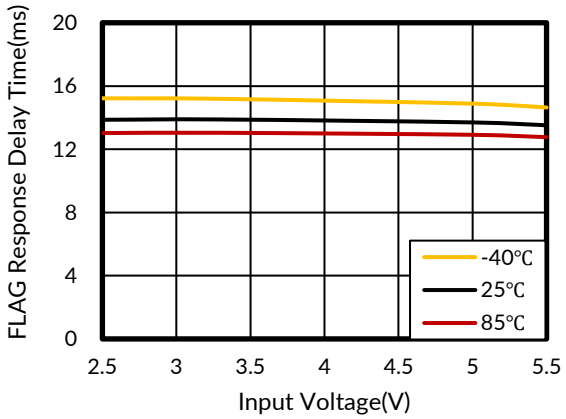


Figure 18. FLAG Response Delay Time vs Input Voltage

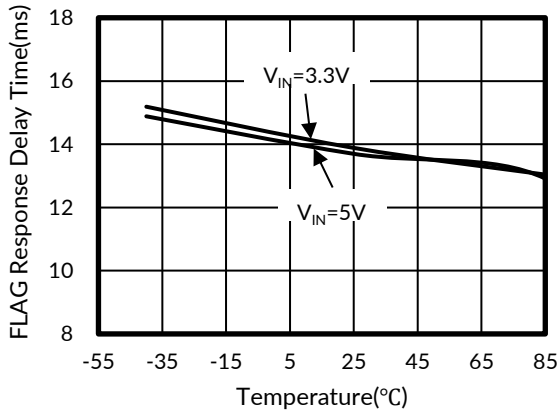


Figure 19. FLAG Response Delay Time vs Temperature

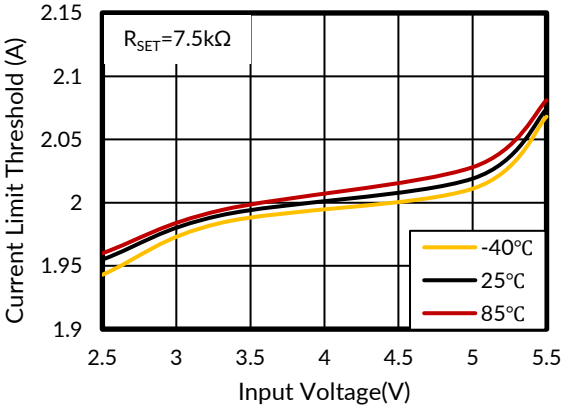


Figure 20. Current Limit Threshold vs Input Voltage

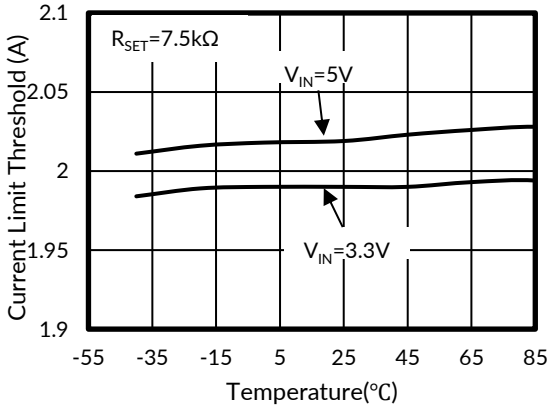


Figure 21. Current Limit Threshold vs Temperature

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.

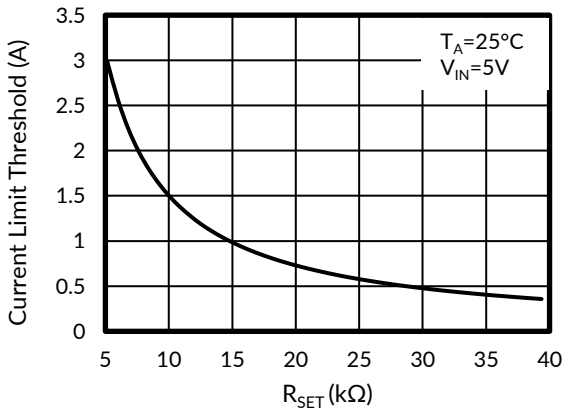


Figure 22. Current Limit Threshold vs R_{SET}

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.

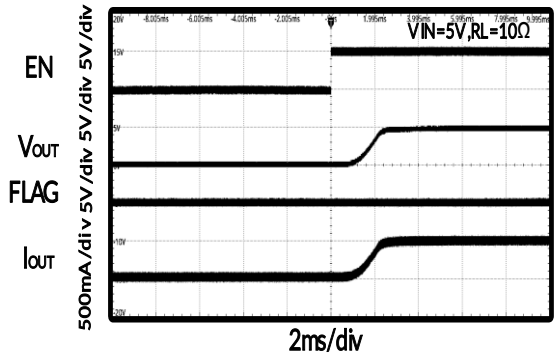


Figure 23. Turn-On Delay Time

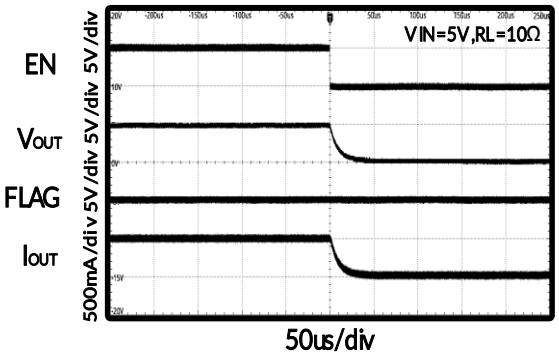


Figure 24. Turn-Off Delay Time

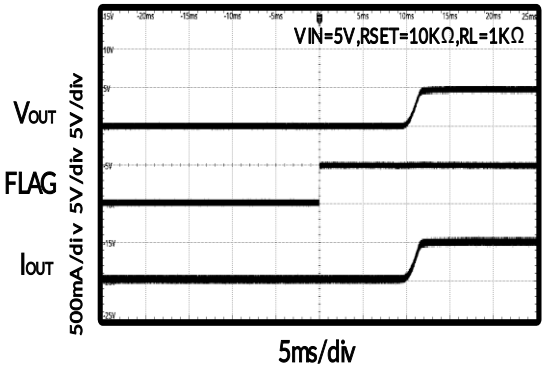


Figure 25. Exit Over Temperature Protection

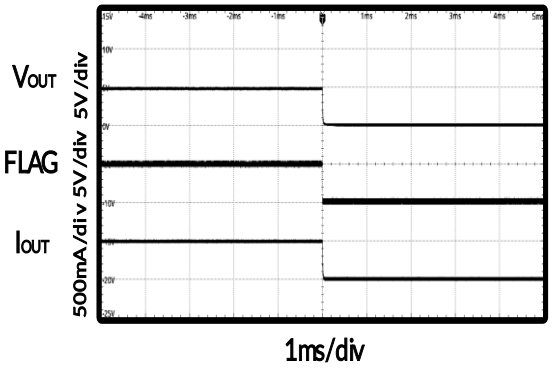


Figure 26. Enter Over Temperature Protection

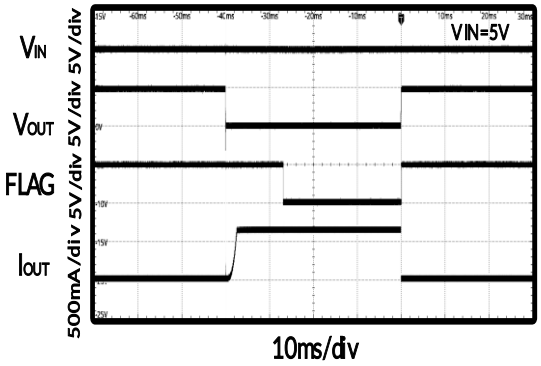


Figure 27. No Load into Short-Circuit

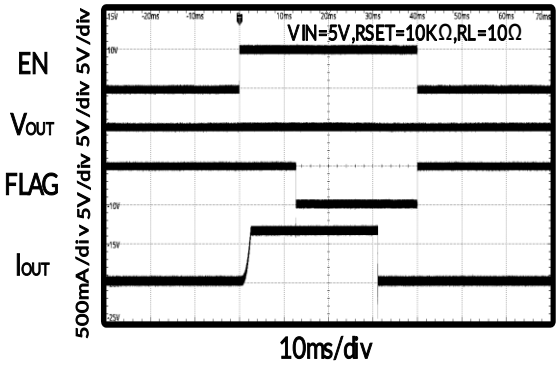


Figure 28. Device Enabled into Short-Circuit

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.

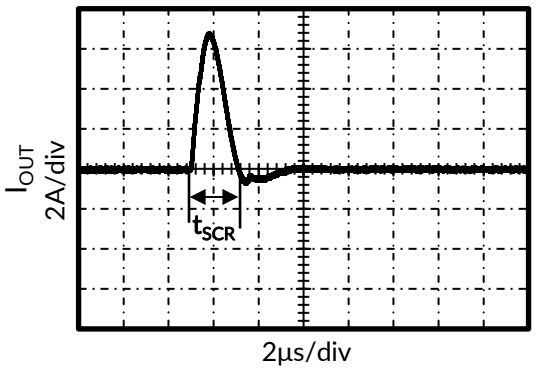


Figure 29. Short-Circuit Response Time

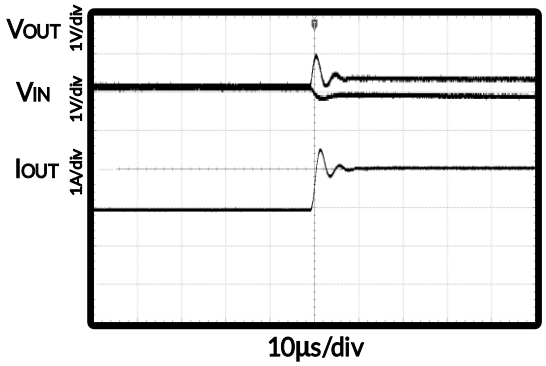


Figure 30. Reverse Input-Output Voltage Protection

9 DETAILED DESCRIPTION

9.1 Overview

The RS2599A is an integrated power switch for self-powered and bus-powered Universal Serial Bus (USB) applications.

The RS2599A is a cost-effective, low voltage, single P-channel MOSFET load switch with 50mΩ $R_{DS(ON)}$, which is free of parasitic body diode to eliminate any reverse current flow across the switch when it is powered off. When the output voltage is higher than input voltage, the power switch is turned off by internal output reverse-voltage protector.

Several Protection features include current limiting and thermal shutdown to prevent catastrophic switch failure caused by increasing power dissipation when continuous heavy loads or short circuit occurs.

FLAG is an open-drain output report over-current or over-temperature event and has typical 13ms deglitch timeout period.

9.2 Input and Output

VIN is the power supply connection to the logic circuitry and the source of the P-channel MOSFET. OUT is the drain of the P-channel MOSFET. In a typical circuit, current flows from VIN to 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.

9.3 Thermal Shutdown

Thermal shutdown is employed to protect device and load from damage because of excessive power dissipation. 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.

9.4 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.

9.5 Under-Voltage Lockout (UVLO)

UVLO prevents the MOSFET switch from turning on until input voltage exceeds 1.9 (Typical). If input voltage drops below 1.8V (Typical), UVLO shuts off the MOSFET switch. Under-voltage detection functions only when the switch is enabled.

9.6 Current Limiting and Short-Circuit Protection

The current limit circuit is designed to limit the output current to protect the upstream power supply. Current limit threshold is programmed with a resistor from SET to ground marked as R_{SET}. It can be estimated by the following equation:

$$I_{LIMIT}(mA) = \frac{14728}{R_{SET}}(k\Omega) + 44.97, I_{SHORT}(mA) = 0.75 * (\frac{14728}{R_{SET}}(k\Omega) + 44.97), R_{SET} \leq 43k\Omega$$

Under output short-circuit condition; the typical current limit folded back 75%. If the RS2599A 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 130°C or limit (short-circuit) condition is removed.

9.7 Reverse-Voltage Protection

The reverse-voltage protection feature turns off the MOSFET switch whenever the output voltage exceeds the input voltage by 50mV (Typical). Its hysteresis voltage is 20mV (Typical).

9.8 Fault Flag (FLAG)

The signal is an open-drain N-MOSFET output. FLAG is asserted (active low) when an over-current, short-circuit or thermal shutdown condition occurs.

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 condition and that erroneous error reporting is eliminated.
False over-current condition 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 13ms (Typical).

9.9 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

9.10 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 6.0V which is the absolute maximum supply voltage even for a short duration.
If the upstream supply cable is long or the VIN transient exceeds 6.0V during the V_{OUT} short, recommend adding a second filter capacitor at the upstream supply output terminal.

9.11 Output Filter Capacitor

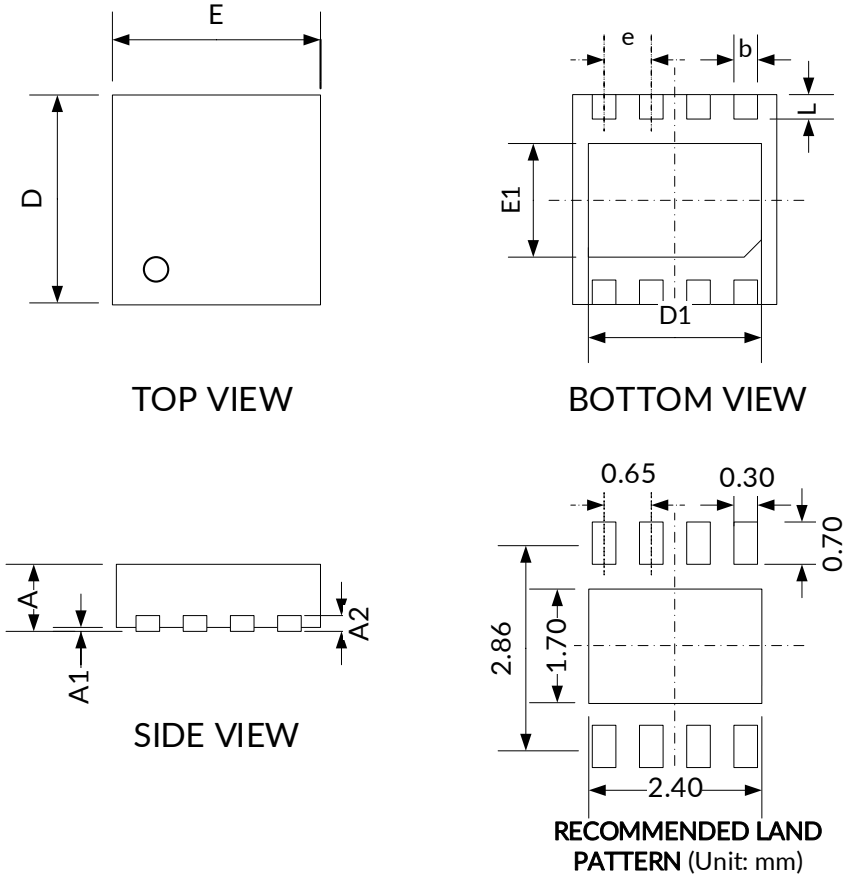
A low-ESR 10uF ceramic capacitor between OUT and GND is strongly recommended to reduce the voltage droop during hot-attachment of downstream peripheral. Higher value output capacitor is better when the output load is heavy. Additionally, bypassing the output with a 0.1uF ceramic capacitor improves the immunity of the device to short-circuit transients.

9.12 PCB Layout Guide

For best performance of the RS2599A, the following guidelines must be strictly followed:
1.Please place the input capacitors near the VIN pin as close as possible.
2.Keep VIN and OUT traces as wide and short as possible.
3.Locate RS2599A and output capacitors near the load to reduce parasitic resistance and inductance for excellent load transient performance.
4.Input and output capacitors should be placed closed to the IC and connected to ground plane to reduce noise coupling. Place a ground plane under all circuitry to lower both resistance and inductance and improve DC and transient performance
5.The traces routing the R_{ILIM} resistor to the RS2599A should be as short as possible to reduce parasitic effects on the current limit accuracy.

10 PACKAGE OUTLINE DIMENSIONS

DFN3X3-8 (2)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203		0.008	
b	0.250	0.350	0.010	0.014
D (1)	2.900	3.100	0.114	0.122
D1	2.350	2.450	0.093	0.096
E (1)	2.900	3.100	0.114	0.122
E1	1.650	1.750	0.065	0.069
e	0.650 TYP		0.026 TYP	
L	0.370	0.470	0.015	0.019

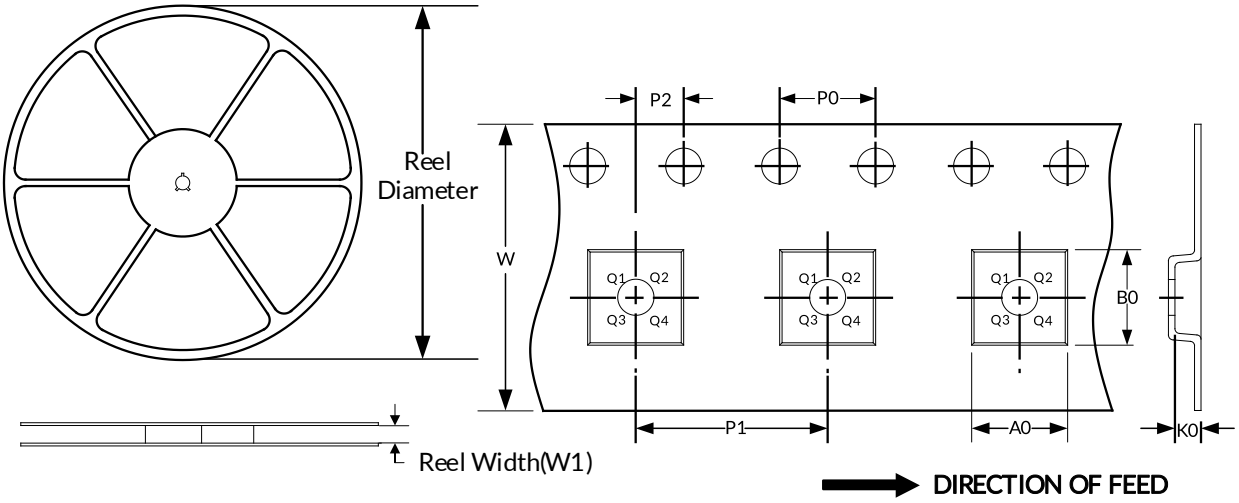
NOTE:

1. Plastic or metal protrusions of 0.075mm maximum per side are not included.
2. This drawing is subject to change without notice.

11 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
DFN3X3-8	13"	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

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

IMPORTANT NOTICE AND DISCLAIMER

Jiangsu RUNIC Technology Co., Ltd. will accurately and reliably provide technical and reliability data (including data sheets), design resources (including reference designs), application or other design advice, WEB tools, safety information and other resources, without warranty of any defect, and will not make any express or implied warranty, including but not limited to the warranty of merchantability Implied warranty that it is suitable for a specific purpose or does not infringe the intellectual property rights of any third party.

These resources are intended for skilled developers designing with RUNIC products You will be solely responsible for: (1) Selecting the appropriate products for your application; (2) Designing, validating and testing your application; (3) Ensuring your application meets applicable standards and any other safety, security or other requirements; (4) RUNIC and the RUNIC logo are registered trademarks of RUNIC INCORPORATED. All trademarks are the property of their respective owners; (5) For change details, review the revision history included in any revised document. The resources are subject to change without notice. Our company will not be liable for the use of this product and the infringement of patents or third-party intellectual property rights due to its use.