Over Voltage Protection IC

1 FEATURES

- **Fully Integrated Protection Function**
  - **-Programmable OCP**
  - **-Input OVP**
  - **-Battery OVP**
- **Withstand High Input Voltage Up to 40V**
- **Over Voltage Turn Off Time Less Than 1µs**
- **High Accuracy Protection Thresholds**
- **Over Temperature Protection**
- **High Immunity of False Triggering Under Transients**
- **Warning Indication Output**
- **Enable Input**
- **RoHS Compliant and Halogen Free**
- **Lead-Free Packages: DFN2X2-8**

2 APPLICATIONS

- **Cellular Phones**
- **Digital Cameras**
- **PDAs and Smart Phones**
- **Portable Instruments**

3 DESCRIPTIONS

The RS2601 is an integrated circuit optimized to protect low voltage system from abnormal high input voltage (up to 40V). The IC monitors the input voltage, battery voltage and the charging current to make sure all three parameters are operated in normal range. When the input voltage exceeds a certain OVP threshold voltage level, the IC will turn off the power MOSFET within 1µs to remove the power before any damage occurs. The RS2601 also can provide a voltage output without the existence of battery.

The current in the power MOSFET is also limited to prevent charging the battery with an excessive current. The current limit can be programmed by an external resistor between ILIM and GND. The OCP function also has a 4-bit binary counter that accumulates during an OCP event. When the total count reaches consecutive 16 times, the power MOSFET is turned off permanently unless the input power is recycled.

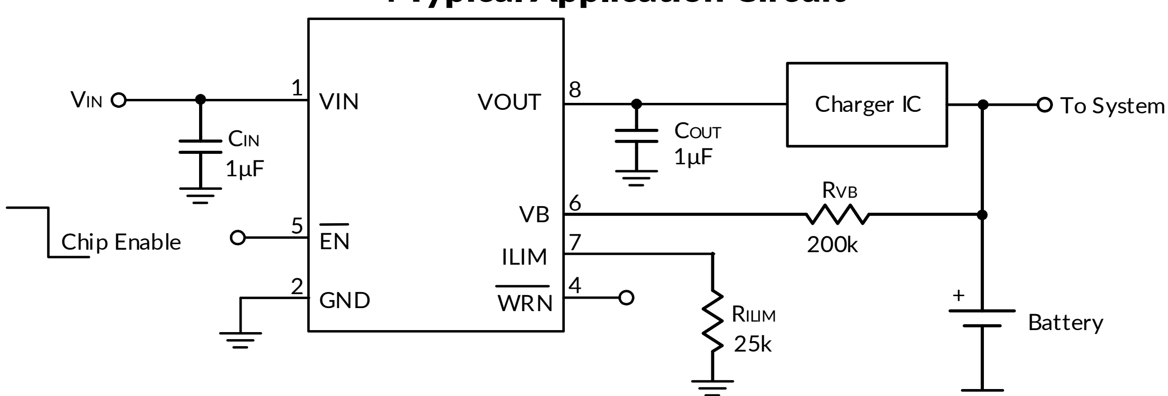
The IC also monitors the battery voltage, Once the battery voltage exceeds 4.35V and last for more then 150µs blinking time, the RS2601 will turn off the MOSFET. The internal logic control will turn off the power MOSFET permanently when the battery over-voltage event occurs for consecutive 16 times.

Device Information (1)

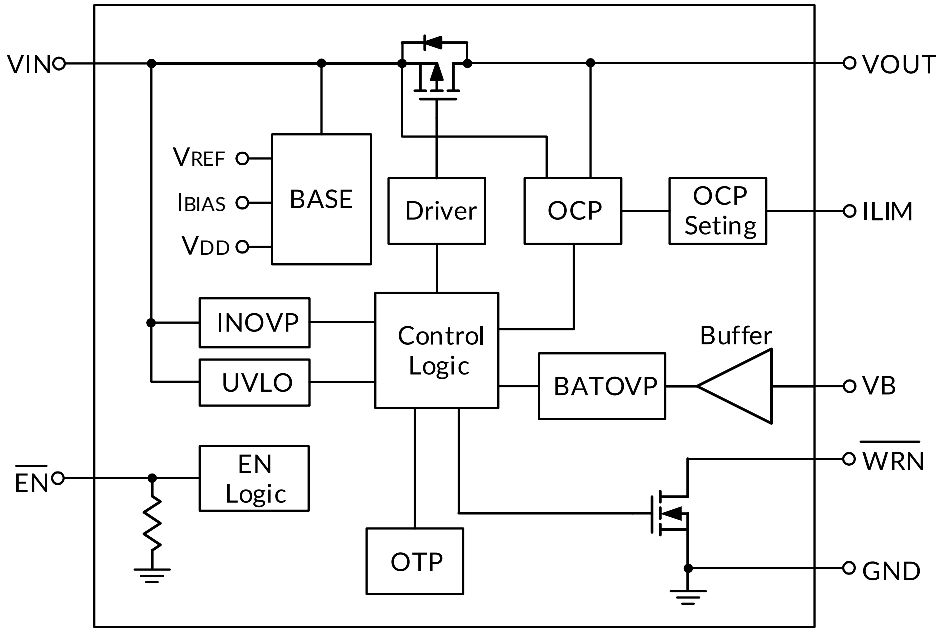
PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS2601	DFN2X2-8	2.00mm×2.00mm

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

4 Typical Application Circuit



5 Functional Block Diagram



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6 Revision History

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

VERSION	Change Date	Change Item
A.0	2023/04/06	Initial version completed
A.0.1	2024/02/23	Modify packaging naming
A.0.2	2024/04/08	1. Add MSL on Page 5@RevA.0.1 2. Update PACKAGE note

7 PACKAGE/ORDERING INFORMATION (1)

PRODUCT	ORDERING NUMBER	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING (2)	MSL (3)	PACKAGE OPTION
RS2601	RS2601YTDE8	-40°C ~ +85°C	DFN2X2-8	2601	MSL3	Tape and Reel, 3000

NOTE:

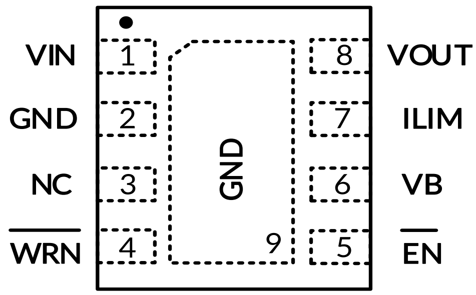
(1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.

(2) There may be additional marking, which relates to the lot trace code information (include data code and vendor code), the logo or the environmental category on the device.

(3) MSL, The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications.

8 PIN CONFIGURATIONS

TOP VIEW



DFN2X2-8

PIN DESCRIPTION

PIN DFN2X2-8	NAME	TYPE (1)	DESCRIPTION
1	VIN	P	The input power source. The VIN can withstand up to 40V input.
2	GND	--	Analog Ground.
3	NC	--	No Internal Connection.
4	$\overline{WRN}$	O	This is an open-drain logic output that turns LOW when any protection event occurs.
5	$\overline{EN}$	I	Chip Enable (Active Low). Pull this pin to low or leave it floating to enable the IC and force it to high to disable the IC.
6	VB	I	Battery voltage monitoring input. This pin is connected to the battery pack positive terminal via an isolation resistor.
7	ILIM	O	Over current protection threshold setting pin. Connect a resistor between this pin and GND to set the OCP threshold.
8	VOUT	P	Output through the power MOSFET.
9 (Thermal Pad)	GND	--	The exposed pad must be soldered to a large PCB and connected to GND for maximum thermal dissipation.

(1) I = Input, O = Output, P=Power.

9 SPECIFICATIONS

9.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V_{IN}	Supply Input Voltage		-0.3	40	V
V_{WRN}	WRN Output Voltage		-0.3	6	V
V_{EN}	EN Input Voltage		-0.3	6	V
V_{VB}	VB Input Voltage		-0.3	6	V
V_{ILIM}	ILIM Output Voltage		-0.3	6	V
V_{OUT}	Output voltage range		-0.3	6	V
θ_{JA}	Package thermal impedance (3)	DFN2X2-8		165	°C/W
Temperature	Lead Temperature (Soldering,10secs)			260	°C
	Junction, T_J (4)		-40	125	°C
	Storage, T_{stg}		-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 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 $T_{J(MAX)}$, $R_{\theta JA}$, 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.

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), per ANSI/ESDA/JEDEC JS-001 (1)	±2500	V
		Charged-Device Model (CDM), per ANSI/ESDA/JEDEC JS-002 (2)	±1500	V
		Machine Model (MM)	±100	V

(1) JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250 V CDM allows safe manufacturing with a standard ESD control process.

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	NOM	MAX	UNIT
Input Voltage	V_{IN}	3		5.5	V
EN Input Voltage	V_{EN}	0		5.5	V
WRN Output Voltage	V_{WRN}	0		5.5	V
VB Input Voltage	V_{VB}	0		5.5	V
Operating Temperature	T_A	-40		85	°C

9.4 Electrical Characteristics

(Full = -40°C to +85°C, and V_{IN}=3V~5.5V, typical values are at V_{IN}=5V, T_A = +25°C, unless otherwise noted.) (1)

PARAMETER		SYMBOL	Test Conditions	MIN(2)	TYP(3)	MAX(2)	UNIT
VIN Supply Voltage		V_{IN}		3		5.5	V
VIN Input Under Voltage Lockout		V_{UVLO_H}	V_{IN} Rising	2.5	2.7	2.9	V
		V_{UVLO_L}	V_{IN} Falling	2.4	2.6	2.8	V
UVLO Deglitch Time		T_{UVLO}			10		ms
VIN Input Quiescent Current		I_Q	V_{EN}=0V		400	500	µA
VIN Input Shutdown Current		I_{SHDN}	V_{EN}=5V		85	95	µA
VIN OVP Threshold Voltage		V_{IN_OVP}			5.85		V
VIN OVP Hysteresis		$V_{IN\_OVP\_HY}$			60	100	mV
VIN OVP Propagation Delay		T_{VIN_OVP}	V_{OUT}=V_{IN} x 80%		0.3	1	µs
VIN OVP Recovery Delay		$T_{VIN\_OVP\_R}$			10		ms
Over Current Protection Threshold		I_{OCP}	R_{ILIM}=25kΩ		1		A
Over Current Protection Blanking Time		T_{OCP}			150		µs
Over Current Protection Recovery Delay		T_{OCP_R}			64		ms
Battery OVP Threshold Voltage		VB_{OVP_H}	VBAT Rising		4.35		V
		VB_{OVP_L}	VBAT Falling		4.34		V
Battery OVP Blanking Time		T_{VB_OVP}			150		µs
Battery OVP Recovery Delay		$T_{VB\_OVP\_R}$			10		ms
VB Pin Leakage Current		I_{VB_LKG}				20	nA
OTP Threshold		T_{OTP_H}	Temperature Rising		140		°C
		T_{OTP_L}	Temperature Falling		105		°C
OTP Recovery Delay		T_{OTP_R}			8		ms
Soft-Start Time		T_{SS}			10		ms
EN Threshold Voltage	High	V_{IH}		1.5			V
	Low	V_{IL}				0.4	V
EN Pull Down Resistor		R_{EN}		100	225	400	kΩ
WRN Output Logic Low		V_{WRN_L}	Sink=5mA		0.35		V
WRN Output Logic High Leakage Current		I_{WRN_LKG}				1	µA
Power-MOSFET ON Resistance		R_{ON}	I_{OUT}=0.5A		230		mΩ

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.

9.5 Typical 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.

At T_A = +25°C, V_{IN} = 5V, R_L = NC, V_{BAT} = 4V, V_{EN} = 0V, R_{ILIM} = 25KΩ, C_{IN} = C_{OUT} = 1μF, unless otherwise noted.

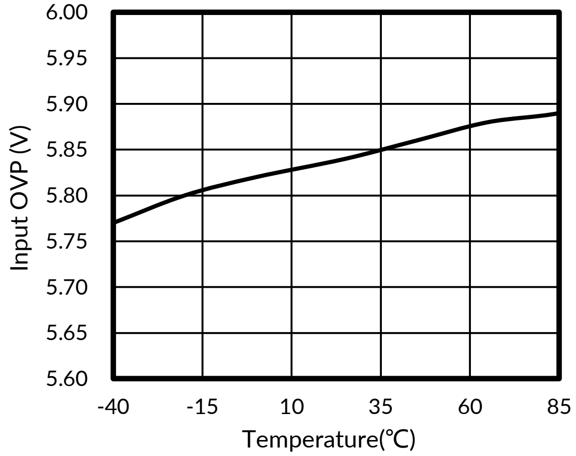


Figure 1. Input OVP vs Temperature

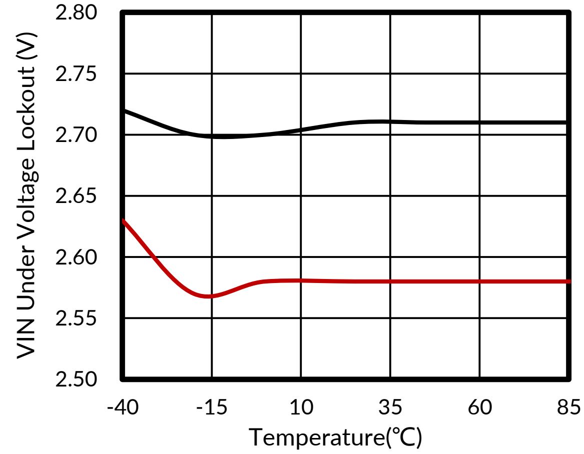


Figure 2. VIN Under Voltage Lockout vs Temperature

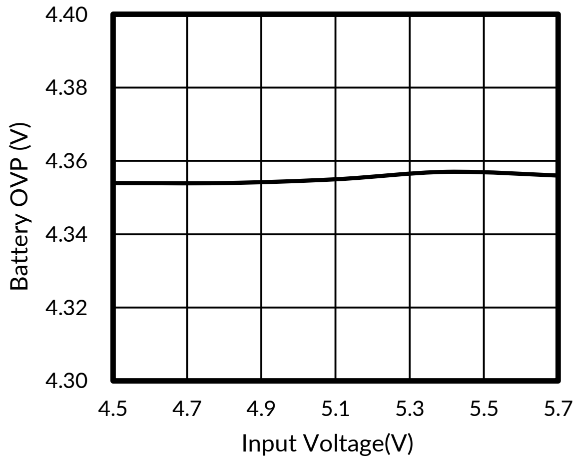


Figure 3. Battery OVP vs Input Voltage

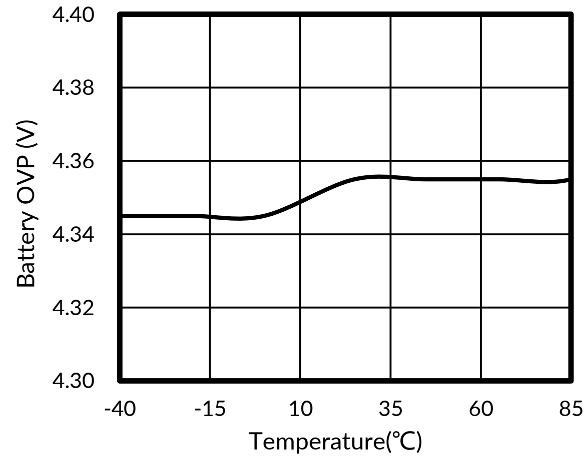


Figure 4. Battery OVP vs Temperature

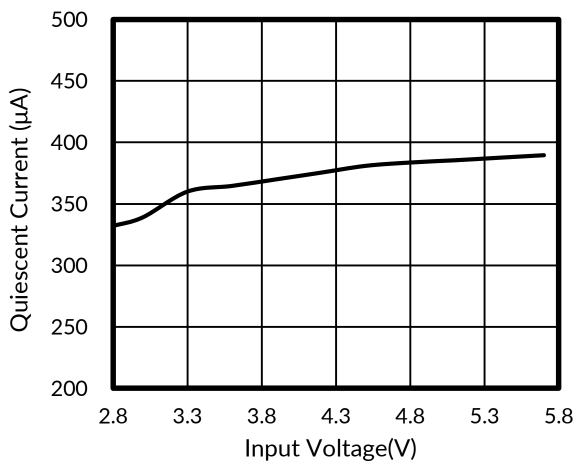


Figure 5. Quiescent Current vs Input Voltage

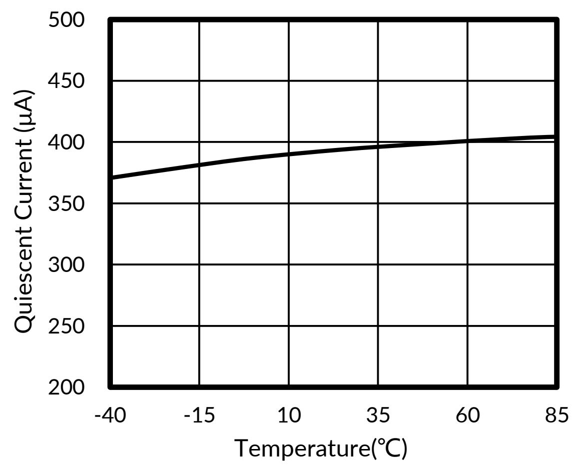


Figure 6. Quiescent Current vs Temperature

Typical 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.

At T_A = +25°C, V_{IN} = 5V, R_L = NC, V_{BAT} = 4V, V_{EN} = 0V, R_{ILIM} = 25KΩ, C_{IN} = C_{OUT} = 1μF, unless otherwise noted.

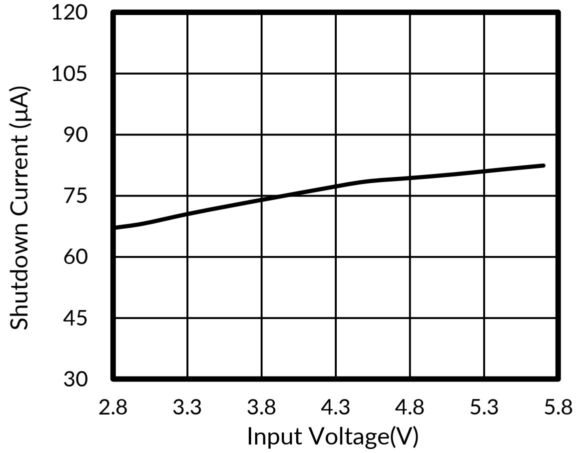


Figure 7. Shutdown Current vs Input Voltage

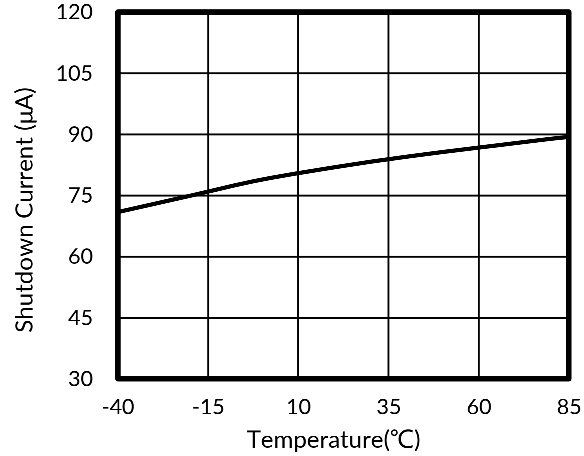


Figure 8. Shutdown Current vs Temperature

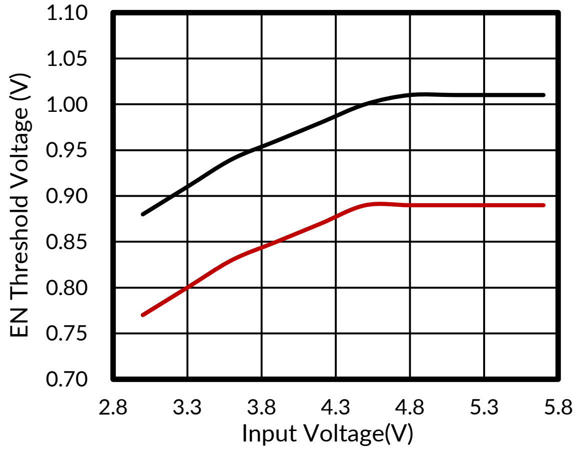


Figure 9. EN Threshold Voltage vs Input Voltage

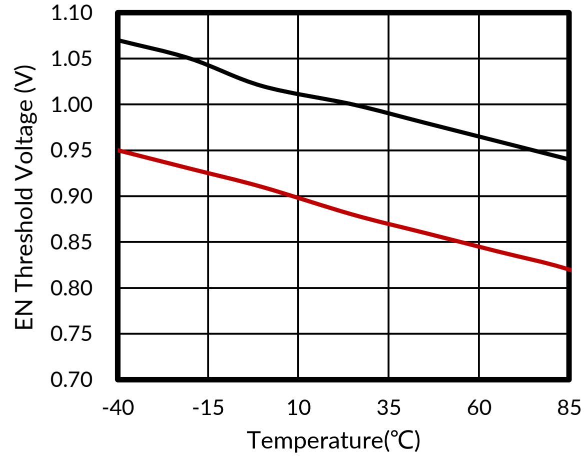


Figure 10. EN Threshold Voltage vs Temperature

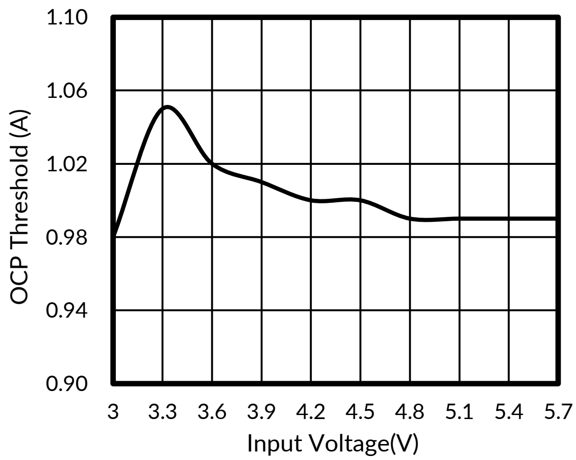


Figure 11. OCP Threshold vs Input Voltage

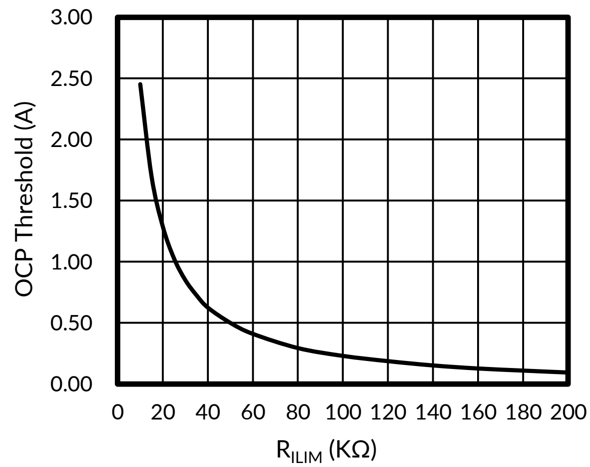


Figure 12. OCP vs R_{ILIM}

Typical 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.

At T_A = +25°C, V_{IN} = 5V, R_L = NC, V_{BAT} = 4V, V_{EN} = 0V, R_{ILIM} = 25KΩ, C_{IN} = C_{OUT} = 1μF, unless otherwise noted.

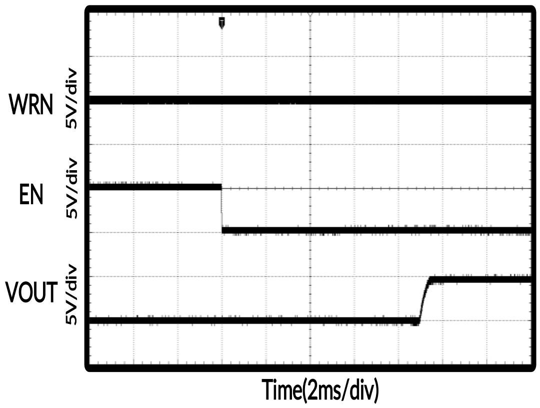


Figure 13. EN Turn-On

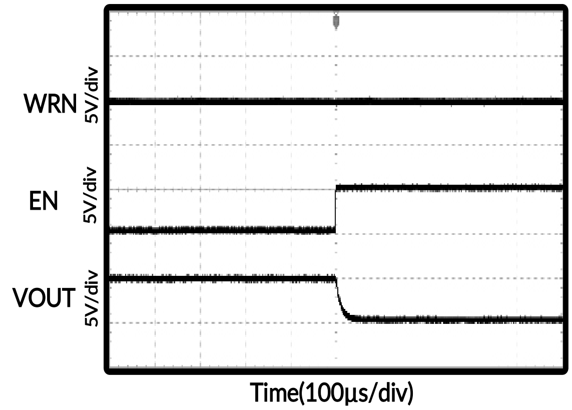


Figure 14. EN Turn-Off

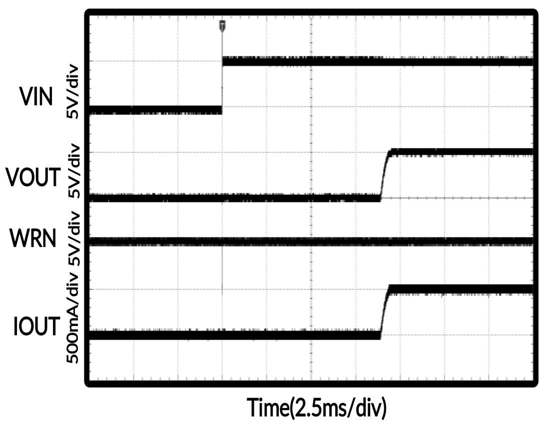


Figure 15. POWERON-10Ω

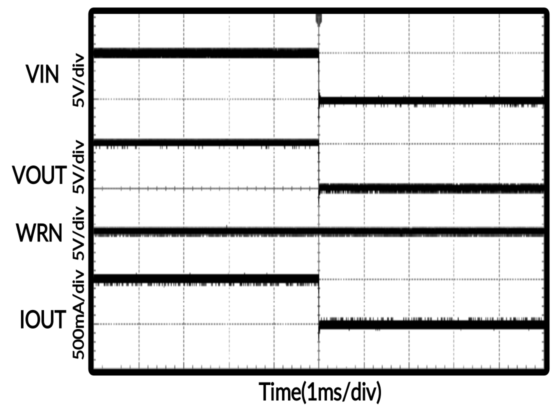


Figure 16. POWEROFF-10Ω

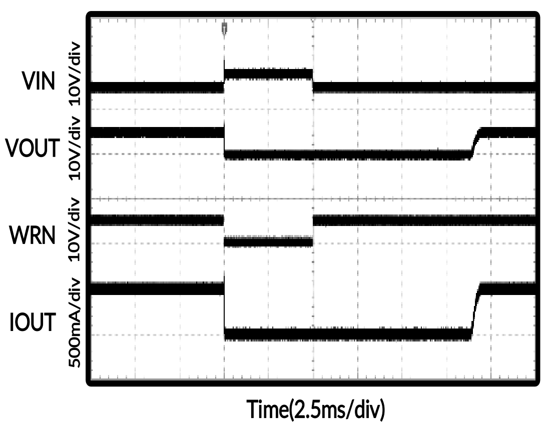


Figure 17. INPUT OVP

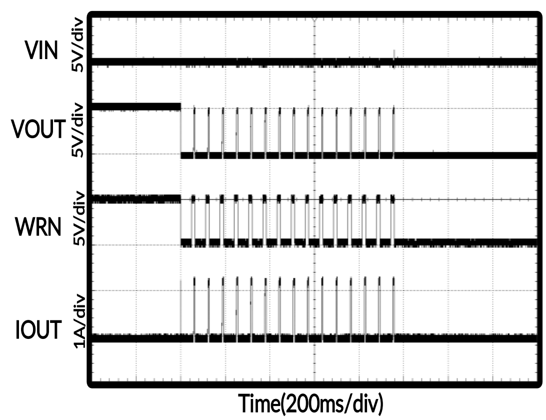


Figure 18. OCP-16

Typical 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.

At T_A = +25°C, V_{IN} = 5V, R_L = NC, V_{BAT} = 4V, V_{EN} = 0V, R_{ILIM} = 25KΩ, C_{IN} = C_{OUT} = 1μF, unless otherwise noted.

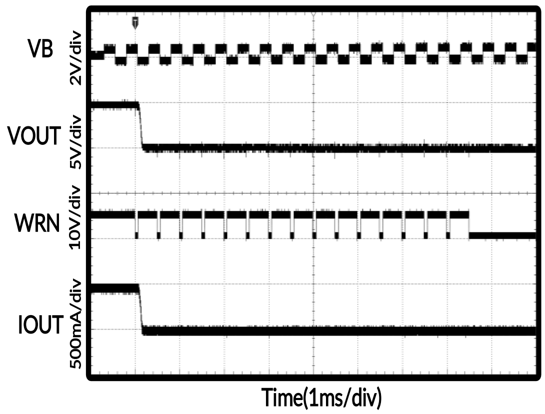


Figure 19. VBOVP-16

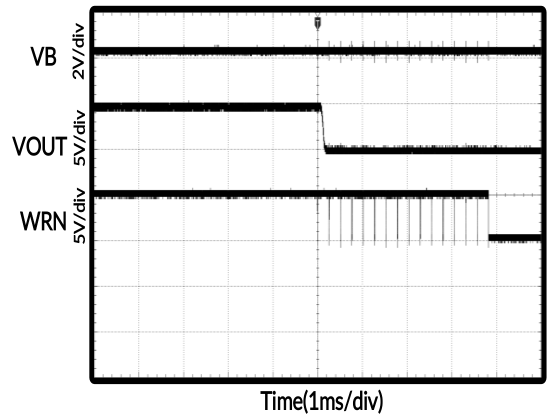


Figure 20. VBOVP Small Signal Trigger

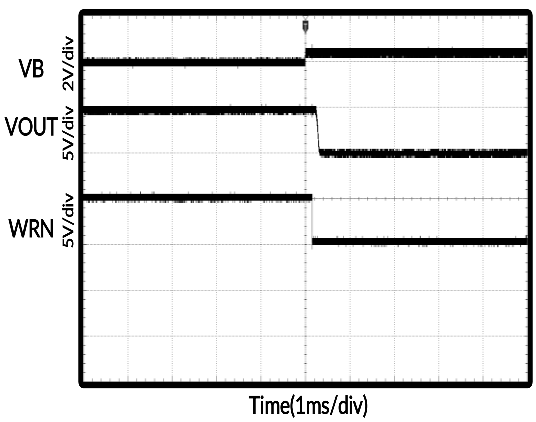


Figure 21. VBOVP Large Signal Trigger

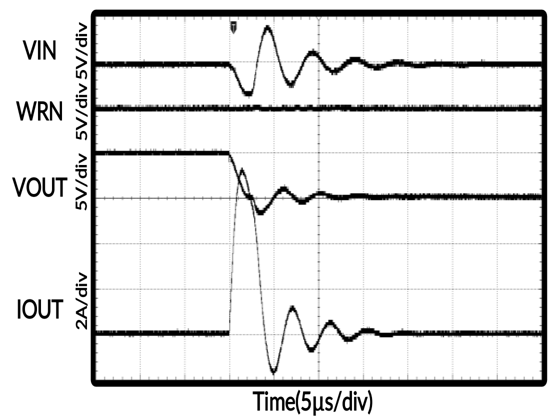


Figure 22. Short-Circuit Response Time

10 Application and Implementation

Information in the following applications sections is not part of the RUNIC component specification, and RUNIC does not warrant its accuracy or completeness. RUNIC's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Power Up

The RS2601 has a threshold of 2.7V power on reset (POR) with a built-in hysteresis of 100mV. Before the input voltage reaches the POR threshold, the RS2601 is off. When the input voltage is over the POR threshold; the RS2601 will delay for 10ms and the soft-start will be activated after the 10ms delay. The 10ms delay allows any transients at the input during a hot insertion of the power supply to settle down before the IC starts to operate. During the soft-start transition, the RS2601 slowly turns on the internal MOSFET to reduce the inrush current.

10.2 Enable Control

The RS2601 offers an enable ($\overline{\mathrm{EN}}$) input. When the $\overline{\mathrm{EN}}$ pin is pulled to logic high (>1.5V), the RS2601 will be shut down. When the $\overline{\mathrm{EN}}$ pin is pulled to logic low (<0.4V), the RS2601 will be powered on. The $\overline{\mathrm{EN}}$ pin has an internal pull-down resistor. Leaving the $\overline{\mathrm{EN}}$ pin floating can enable the IC.

10.3 Warning Indication Output

The $\overline{\mathrm{WRN}}$ pin is an open-drain output that indicates a LOW signal when any protection event occurs (Input OVP, Output OCP and Battery OVP). When the protection events are released and then the $\overline{\mathrm{WRN}}$ pin indicates a HIGH signal.

10.4 Over Temperature Protection (OTP)

The RS2601 monitors its own internal temperature to prevent thermal failures. The chip turns off the MOSFET when the internal temperature reaches 140°C. The IC will resume after the internal temperature is cooled down 35°C.

10.5 Input Over Voltage Protection

The RS2601 monitors input voltage to prevent the input voltage lead to output system failures. The RS2601 input OVP threshold is set by the internal resistor. When the input voltage exceeds the threshold, the RS2601 outputs a logic signal to turn off the internal MOSFET within 1us to prevent the high input voltage from damaging the electronics in the handheld system. The hysteresis of the input OVP threshold is 100mV. When the input voltage returns to normal operation voltage rage, the RS2601 reenables the MOSFET.

10.6 Battery Over Voltage Protection

The battery OVP threshold voltage is set at 4.35V in typical and the RS2601 has a built-in 150us blanking time to prevent any transient voltage from triggering the battery OVP. If the OVP situation still exists after 150us, the internal MOSFET will be turned off and the $\overline{\mathrm{WRN}}$ pin indicates a LOW signal. The battery OVP threshold has a 10mV built-in hysteresis. The control logic contains a 4-bit binary counter. If the battery over voltage event occurs for consecutive 16 times, the MOSFET will be turned off permanently unless the input power or the enable pin is reset.

10.7 Selecting RVB

The RS2601 monitors the battery voltage by the VB pin. The RS2601 will be turned off when the battery voltage exceeds the 4.35V battery OVP threshold. The VB pin is connected to the battery pack positive terminal via an isolation resistor (RVB) and the resistor is an important component. The RVB determines some parameters such as battery OVP threshold error and VB pin leakage current. Generally, it is necessary to decrease the RVB for reducing the battery OVP threshold error. However, this will increase the VB pin leakage current. So, it is an important issue to get a trade-off between the battery OVP threshold error and the VB pin leakage current. The resistance of 200kΩ to 1MΩ is allowed for RVB.
VB PIN is not used, cannot be left floating, can be ground.

10.8 Over Current Protection (OCP)

The RS2601 monitors the output current to prevent the output short or the charging of the battery with an excessive current. The OCP (Over Current protection) threshold can be set by the ILIM pin. The RS2601 has a built-in 150us delay time to prevent any transient noise from triggering the OCP. If the OCP situation exists for 150us, the internal MOSFET will be turned off and the $\overline{WRN}$ pin indicates a LOW signal. When the OCP happens for consecutive 16 times, the internal MOSFET will be turned off permanently unless the input power is recycled or the enable pin is toggled.
The OCP threshold can be set by the resistor connected between the ILIM pin and GND. Please refer to Figure 12 for the relationship between OCP threshold and R_{ILIM} resistance. R_{ILIM} resistance values between 20K and 30K can be approximately calculated using the following formula:

$$I_{OCP} \approx \frac{25000}{R_{ILIM}}$$

10.9 Selecting Capacitors

To get the better performance of the RS2601, it is very important to select peripherally appropriate capacitors. These capacitors determine some parameters such as input inrush current and input over shoot voltage. Generally, it is necessary to increase the input capacitance C_{IN} for reducing the input over shoot voltage. However, this will increase the inrush current of input. There are two scenarios that can cause the input over shoot voltage. The first one is that when the AC adapter is hot-plugged and the second one is when the RS2601 has a step-down change. The cable between the AC adapter output and the handheld system input has a parasitic inductance causing the input over shoot voltage. Generally, the input over shoot voltage range is 1.5 to 2 times of the input voltage. It is recommended to use 1μF capacitance for C_{IN} and C_{OUT} and the rated voltage should be higher than at 1.5 to 2 times of the operation voltage.

10.10 Thermal Considerations

Thermal protection limits power dissipation in RS2601. When the operation junction temperature exceeds 140°C, the OTP circuit starts the thermal shutdown function and turns the pass element off. The pass elements turn on again after the junction temperature cools by 20°C.
The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula:

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.
For recommended operating conditions specification of RS2601, the maximum operating junction temperature is 125°C. The junction to ambient thermal resistance θ_{JA} for DFN2x2-8 package is 165°C /W on the standard JEDEC 51-3 single-layer thermal test board. The maximum power dissipation at T_A =25°C can be calculated by following formula:

$P_{D(MAX)}$ = (125°C - 25°C) / (165°C /W) = 0.606W for DFN2x2-8 packages

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA}.

11 Layout

11.1 Layout Consideration

For best performance of the RS2601 series, the following guidelines must be strictly followed.

- Input and output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.
- The GND and exposed pad should be connected to a strong ground plane for heat sink.
- Keep the main current traces as possible as short and wide.

11.2 Layout Example

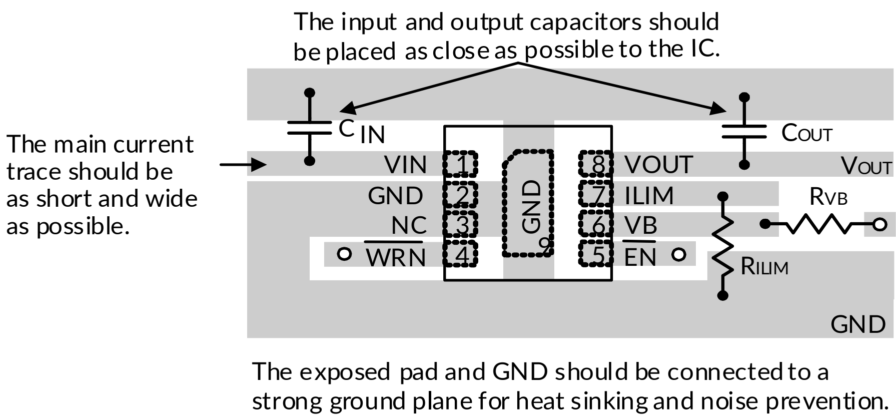
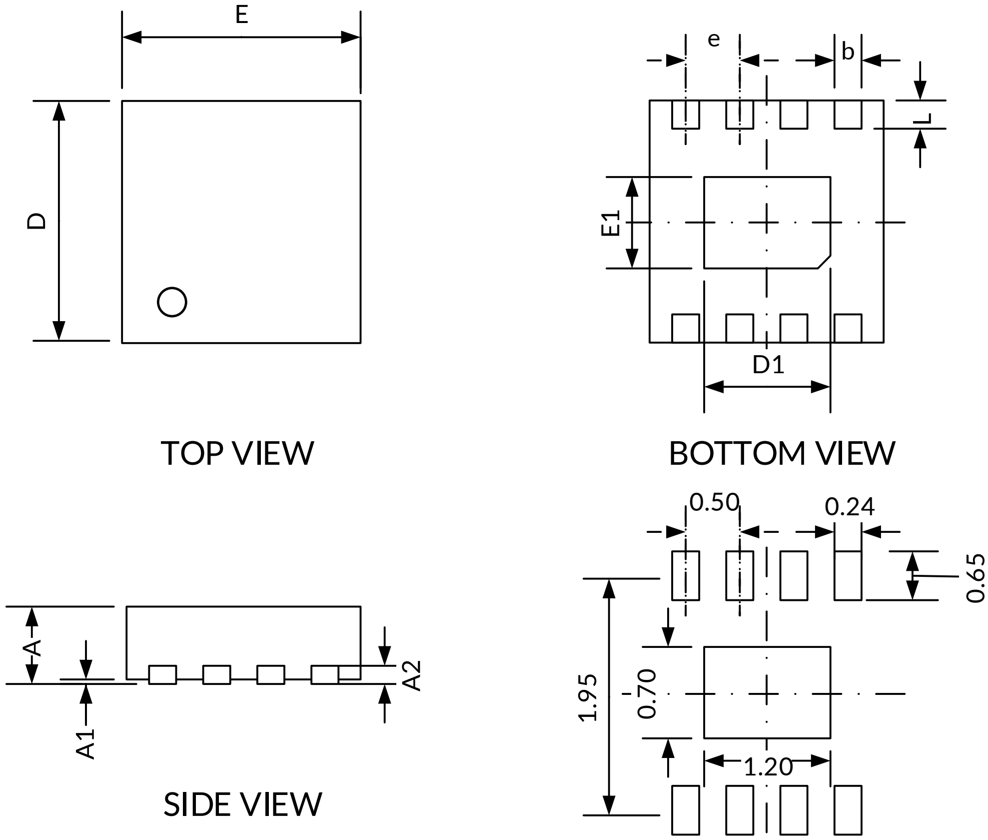


Figure 23. PCB Layout Guide

12 PACKAGE OUTLINE DIMENSIONS

DFN2X2-8 (2)



RECOMMENDED LAND PATTERN (Unit: mm)

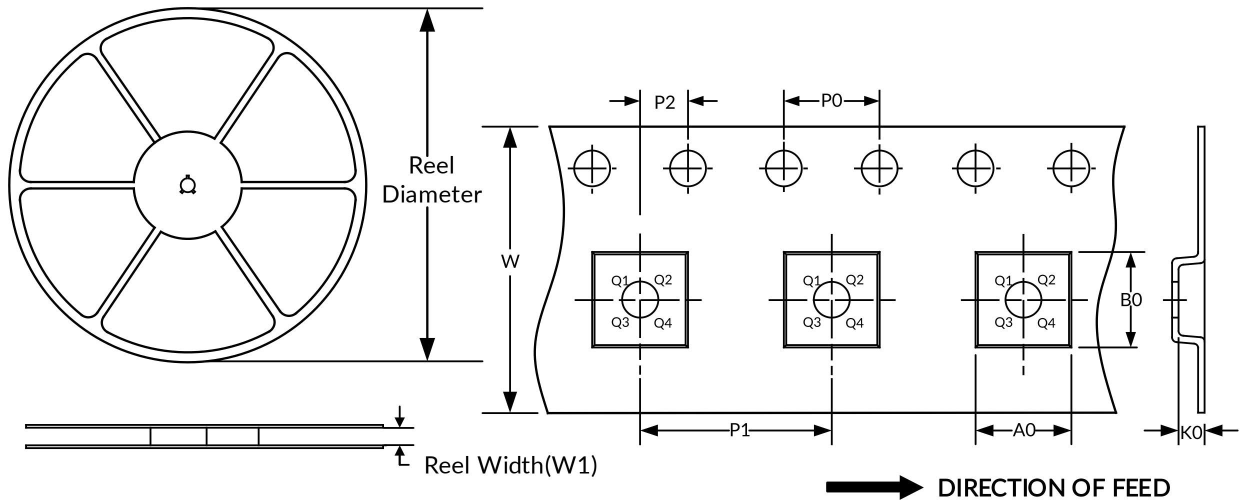
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	**Max**	**Min**	**Max**
A (1)	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203(TYP)		0.008(TYP)	
b	0.180	0.300	0.007	0.012
D (1)	1.900	2.100	0.075	0.083
D1	1.100	1.300	0.043	0.051
E (1)	1.900	2.100	0.075	0.083
E1	0.600	0.800	0.024	0.031
e	0.500(TYP)		0.020(TYP)	
L	0.250	0.450	0.010	0.018

NOTE:

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

13 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
DFN2X2-8	7”	9.5	2.30	2.30	1.10	4.0	4.0	2.0	8.0	Q2

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

IMPORTANT NOTICE AND DISCLAIMER