DATA SHEET

SKY84632: 3A Slew-Rate Controlled Load Switch with Reverse Blocking

Applications

- Smartphones, tablet PCs, and portable devices

Features

- 1.5 V to 5.5 V input voltage range
- 3 A Maximum continuous current capability
- Typical $R_{DS(ON)}$
  - 38 mΩ at V_{IN} = 5.5 V
  - 40 mΩ at V_{IN} = 4.5 V
  - 76 mΩ at V_{IN} = 1.8 V
  - 97 mΩ at V_{IN} = 1.5 V
- Reverse blocking (RB)
- Input hot plug capability
- Over-temperature protection
- Typical 2.7 ms rise time for slew rate/inrush control
- Low quiescent current (typical 9 μA)
- Less than 1 μA off supply current
- Enable control
  - Logic CMOS IO meets JESD76 standard
  - Active high with internal pull-down resistor
- Ultra small, low-profile WLCSP (6-bump, 0.5 mm pitch, 0.995 x 1.495 mm) package (MSL1, 260 °C per JEDEC-J-STD-020)

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Description

The SKY84632 SmartSwitch is a slew rate controlled P-channel MOSFET power switch designed for high side load switching applications. This switch operates with inputs ranging from 1.5 V to 5.5 V, making it ideal for 1.8 V, 3 V, and 5 V systems. It connects/disconnects up to 3 A continuous loads powered from the DC power rail with stringent off-state current targets and high load capacitances (up to 100 μF) through enable control. The integrated low-impedance PMOSFET switch, together with typical 2.7 ms turn-on slew rate control, prevents large inrush current and excessive voltage drop on power rails.

The SKY84632 has the reverse blocking feature that blocks unexpected reverse current from OUT to IN during the PMOSFET on and off states. The typical 9 μA quiescent current makes it ideal for power saving applications. The exceptional low off-state current drain (maximum 1 μA) facilitates compliance with standby power requirements. The switch enable control is active high with an internal pull-down resistor that eliminates the need for an external pull-down resistor. The SKY84632 also includes over-temperature protection and recovers automatically when the fault is removed.

The SKY84632 is available in a 6-bump, 0.995 x 1.495 mm, Wafer-Level Chip-Scale Package (WLCSP) with 0.5 mm pin pitch, and is rated over the –40 °C to +85 °C temperature range.

A typical application circuit is shown in Figure 1. The pin configuration is shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

Figure 1. SKY84632 Typical Application Circuit

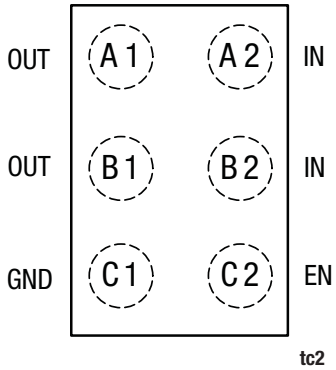


Figure 2. SKY84632 Pinout – 6-Bump WLCSP (Top View)

Table 1. SKY84632 Signal Descriptions

Pin #	Name	Description
A1, B1	OUT	Load switch output. Put at least 0.1 μF output capacitor between OUT and GND.
A2, B2	IN	Supply input. Put at least 1 μF input capacitor between IN and GND.
C1	GND	Ground.
C2	EN	Enable input. Active high with internal pull-down resistor.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY84632 are provided in Table 2. The recommended operating conditions are specified in Table 3, and electrical specifications are provided in Table 4.

Typical performance characteristics of the SKY84632 are illustrated in Figures 5 through 22.

Timing Diagrams

Figure 3 shows the t_R and t_F of V_{OUT}. Figure 4 illustrates the relationship between $t_{D(ON)}$ and $t_{D(OFF)}$.

Table 2. SKY84632 Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Typical	Maximum	Units
IN to GND	V_{IN}	–0.3		+6	V
EN to GND	V_{EN}	–0.3		V_{IN} + 0.3	V
OUT to GND	V_{OUT}	–0.3		V_{IN} + 0.3	V
Maximum continuous DC output current (Note 2)	I_{SW}		3		A
Maximum junction operating temperature	T_J	–40		+150	ºC
Maximum soldering temperature (at leads, 10 sec)	T_{LEAD}		300		ºC
Thermal resistance, junction to ambient (Note 3)	θ_{JA}		136		ºC/W
Maximum power dissipation	P_D		0.9		W

Note 1: Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed may result in permanent damage to the device.

Note 2: Support IN high voltage pulse up to 7 V lasting 8 µs.

Note 3: Mounted on FR4 circuit board.

CAUTION: *Although this device is designed to be as robust as possible, Electrostatic Discharge (ESD) can damage this device. This device must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions should be used at all times.*

Table 3. SKY84632 Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units
Input voltage	V_{IN}	1.5		5.5	V
Enable threshold	V_{ENH}	1.15			V
Disable threshold	V_{ENL}			0.6	V
Continuous switch output current	I_{SW}			3	A
Operating ambient temperature range	T_A	–40		+85	°C

Table 4. SKY84632 Electrical Specifications (1 of 2) (Note 1)
(V_{IN} = 1.5 V to 5.5 V, T_A = –40 °C to 85 °C, Typical Values are at V_{IN} = 4.5 V and T_A = 25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Input voltage	V_{IN}		1.5		5.5	V
Off supply current	$I_{Q(OFF)}$	V_{EN} = GND, V_{OUT} = Open			1	µA
Off switch current	I_{SD}	V_{EN} = GND, V_{OUT} = GND, T_A = –40 °C to +85 °C		0.2	4	µA
Quiescent current	I_Q	V_{EN} = High, I_{OUT} = 0 A		9	12	µA
On-resistance	$R_{DS(ON)}$	V_{IN} = 5.5 V, I_{OUT} = 3 A		40		mΩ
		V_{IN} = 5.5 V, I_{OUT} = 2 A		39		
		V_{IN} = 5.5 V, I_{OUT} = 1 A, T_A = 25°C		38	53	
		V_{IN} = 4.5 V, I_{OUT} = 3 A		42		
		V_{IN} = 4.5 V, I_{OUT} = 2 A		41		
		V_{IN} = 4.5 V, I_{OUT} = 1 A, T_A = 25°C		40	54	
		V_{IN} = 3.3 V, I_{OUT} = 500 mA, T_A = 25°C		47		
		V_{IN} = 2.5 V, I_{OUT} = 500 mA, T_A = 25°C		56		
		V_{IN} = 1.8 V, I_{OUT} = 250 mA, T_A = 25°C		76		
		V_{IN} = 1.5 V, I_{OUT} = 250 mA, T_A = 25°C		97	122	
En input logic high voltage	V_{IH}	V_{IN} = 1.5 V to 5.5 V	1.15			V
En input logic low voltage	V_{IL}	V_{IN} = 1.8 V to 5.5 V			0.55	V
		V_{IN} = 1.5 V to 1.8 V			0.5	
En input leakage current	I_{EN}	V_{EN} = V_{IN} or GND			1	µA
Pull-down resistance at EN bump	R_{EN_PD}	V_{EN} = V_{IN} = 1.5 V to 5.5 V, T_A = –40 °C to +85 °C	6	9	12	mΩ
Reverse Blocking (RB)						
RB protection trip point	V_{T_RB}	V_{OUT} – V_{IN}		45		mV
RB protection release trip point	V_{R_RB}	V_{IN} – V_{OUT}		25		mV
RB hysteresis				70		mV
Reverse current at OUT when EN shuts down	I_{SD_OUT}	V_{EN} = 0 V, V_{OUT} = 5.5 V, V_{IN} = GND (Note 2)			2	µA
RB release, device ON	t_{RB_ON}	V_{OUT} – V_{IN} = 100 mV, EN = High		4		µs
RB release, device OFF	t_{RB_OFF}	V_{OUT} – V_{IN} = 100 mV, EN = Low		2.5		µs

Table 4. SKY84632 Electrical Specifications (2 of 2) (Note 1)
(V_{IN} = 1.5 V to 5.5 V, T_A = –40 °C to 85 °C, Typical Values are at V_{IN} = 4.5 V and T_A = 25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Dynamic Characteristics						
Turn-on delay (Note 3)	$t_{D(ON)}$	V_{IN} = 4.5 V, R_L = 5 Ω, C_L = 100 µF, T_A = 25°C		1.7		ms
V_{OUT} rise time (Note 3)	t_R			2.7		
Turn-on time (Note 4)	t_{ON}			4.4		
Turn-on delay (Note 3)	$t_{D(ON)}$	V_{IN} = 4.5 V, R_L = 150 Ω, C_L = 100 µF, T_A = 25°C		1.8		ms
V_{OUT} rise time (Note 3)	t_R			2		
Turn-on time (Note 4)	t_{ON}			3.8		
Turn-off delay (Note 3)	$t_{D(OFF)}$	V_{IN} = 4.5 V, R_L = 150 Ω, C_L = 100 µF, T_A = 25°C		3		ms
V_{OUT} fall time (Note 3)	t_F			35		
Turn-off time (Note 5)	t_{OFF}			38		
Over-Temperature Protection						
Over-temperature shutdown threshold	T_{SD}	Temperature increases		150		°C
Over-temperature shutdown hysteresis	T_{SD_HYS}			20		°C

Note 1: Performance is guaranteed only under the conditions listed in this Table.

Note 2: This parameter's performance is only guaranteed in a completely dark environment. Exposing the WLCSP device to direct sunlight causes the parameter to slightly exceed the maximum value.

Note 3: Turn-on/turn-off delay, and rise/fall times are defined in Figures 3 and 4.

Note 4: $t_{ON} = t_{D(ON)} + t_R$

Note 5: $t_{OFF} = t_{D(OFF)} + t_F$.

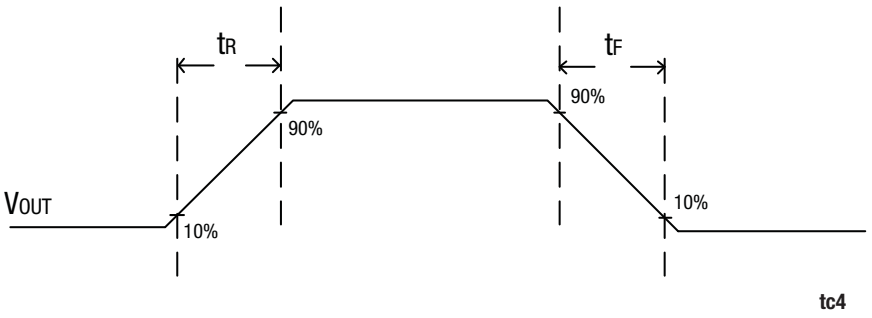


Figure 3. Timing Diagram of t_R/t_F

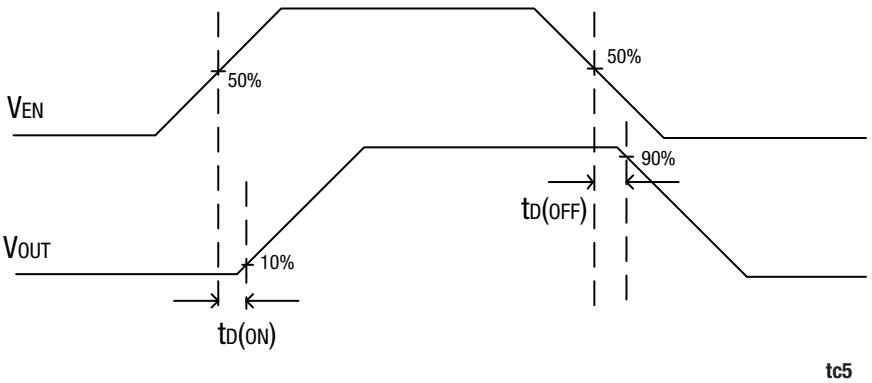


Figure 4. Timing Diagram of $t_{D(ON)}$/$t_{D(OFF)}$

Typical Performance Characteristics

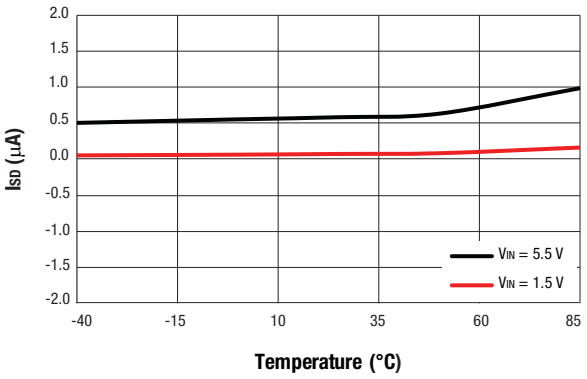


Figure 5. Shutdown Current vs Temperature

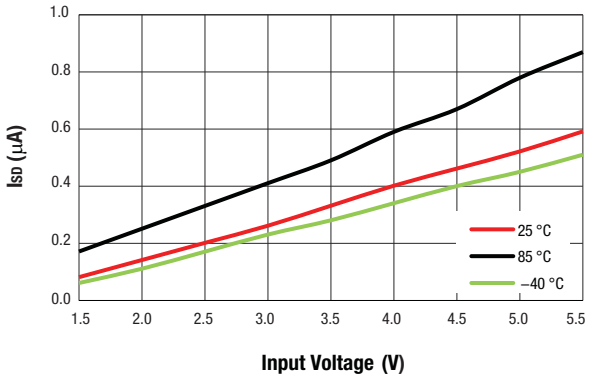


Figure 6. Shutdown Current vs Input Voltage

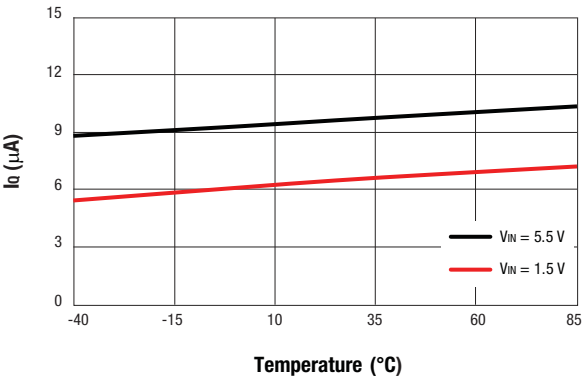


Figure 7. Quiescent Current vs Temperature

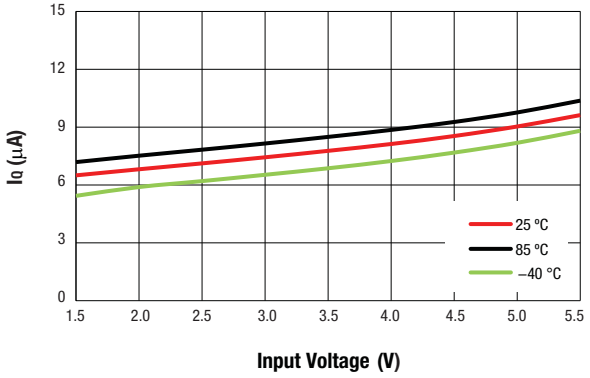


Figure 8. Quiescent Current vs Input Voltage

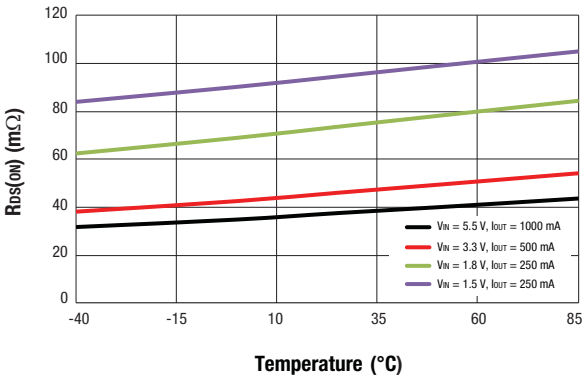


Figure 9. RDS(ON) vs Temperature

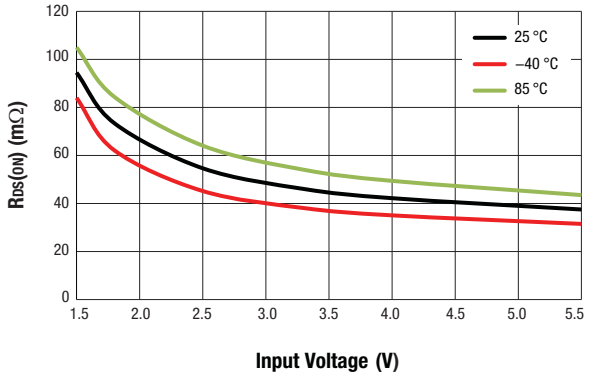


Figure 10. RDS(ON) vs Input Voltage

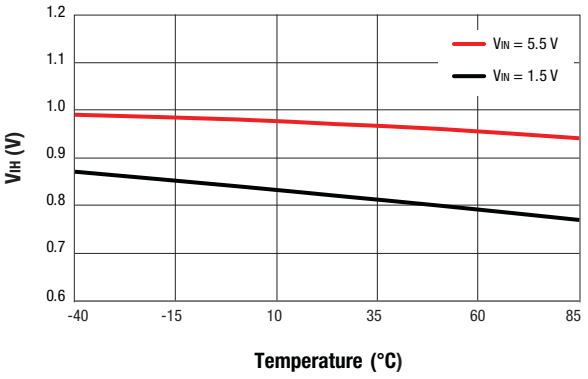


Figure 11. EN Input Logic High Voltage vs Temperature

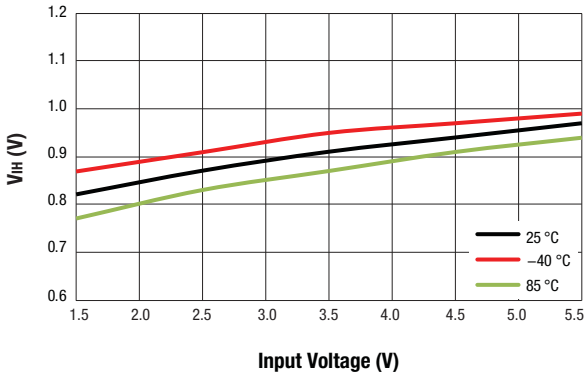


Figure 12. EN Input Logic High Voltage vs Input Voltage

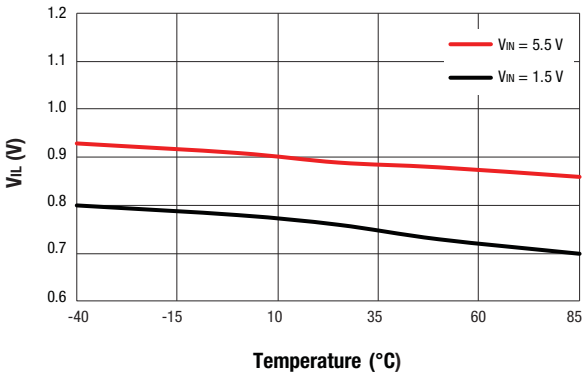


Figure 13. EN Input Logic Low Voltage vs Temperature

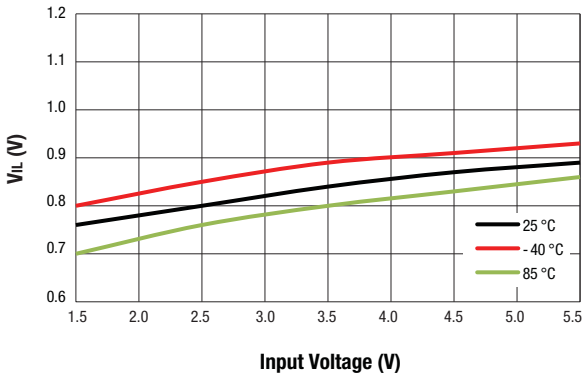


Figure 14. EN Input Logic Low Voltage vs Input Voltage

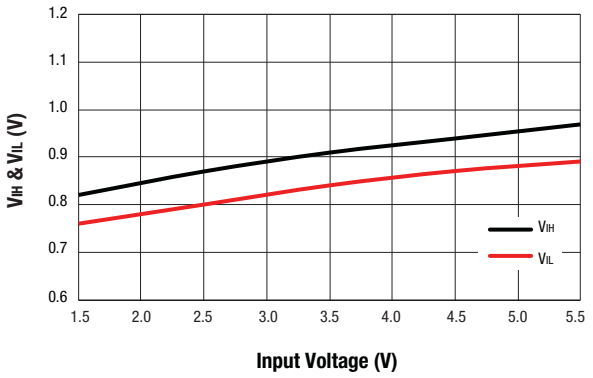


Figure 15. EN Input Logic High/Low Voltage vs Input Voltage

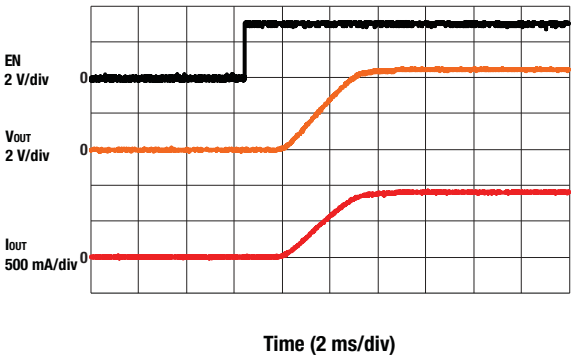
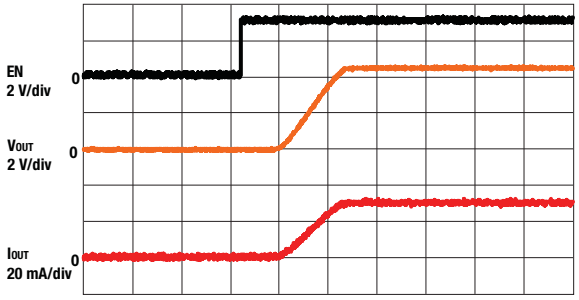
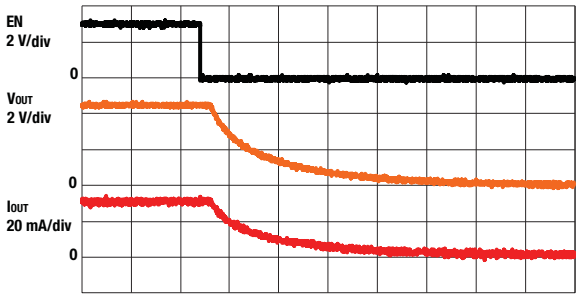


Figure 16. Output Turn-On Time
(V_{IN} = 4.5 V, C_{IN} = 10 µF, C_{OUT} = 100 µF, R_L = 5 Ω)



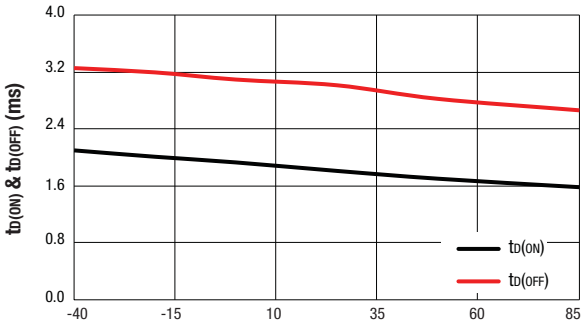
Time (2 ms/div)

Figure 17. Output Turn-On Time
(V_{IN} = 4.5 V, C_{IN} = 10 µF, C_{OUT} = 100 µF, R_L = 150Ω)



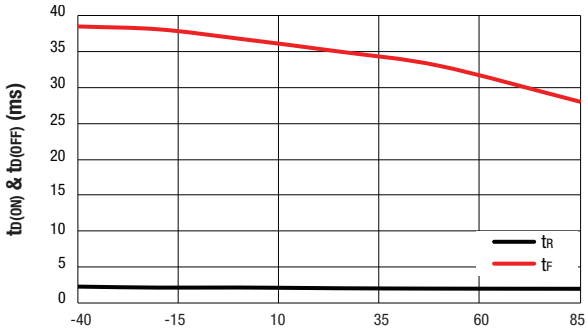
Time (10 ms/div)

Figure 18. Output Turn-Off Time
(V_{IN} = 4.5 V, C_{IN} = 10 µF, C_{OUT} = 100 µF, R_L = 150Ω)



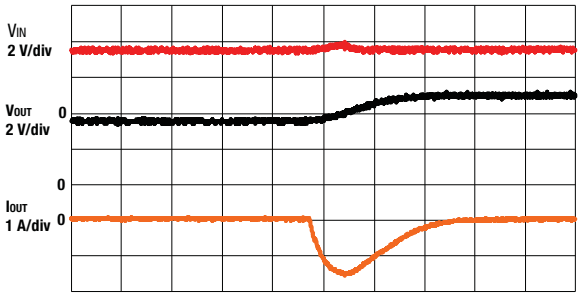
Temperature (°C)

Figure 19. Turn On/Off Delay Time vs Temperature



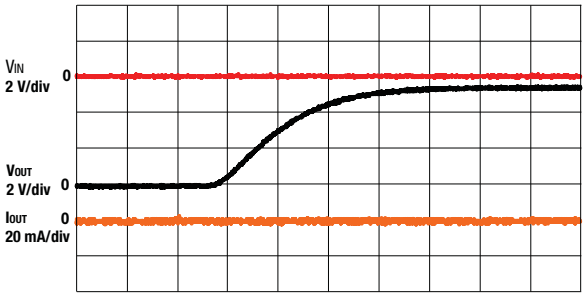
Temperature (°C)

Figure 20. Turn On Rising & Trun-Off Falling Time vs Temperature



Time (20 µs/div)

Figure 21. RB Response Time During On
(V_{IN} = V_{EN} = 3.6 V, V_{OUT} = 5.5 V, C_{IN} = 10 µF, C_{OUT} = 100 µF)



Time (40 µs/div)

Figure 22. RB Response Time During Off
(V_{IN} = V_{EN} = 0 V, V_{OUT} = 5.5 V, C_{IN} = 10 µF, C_{OUT} = 100 µF)

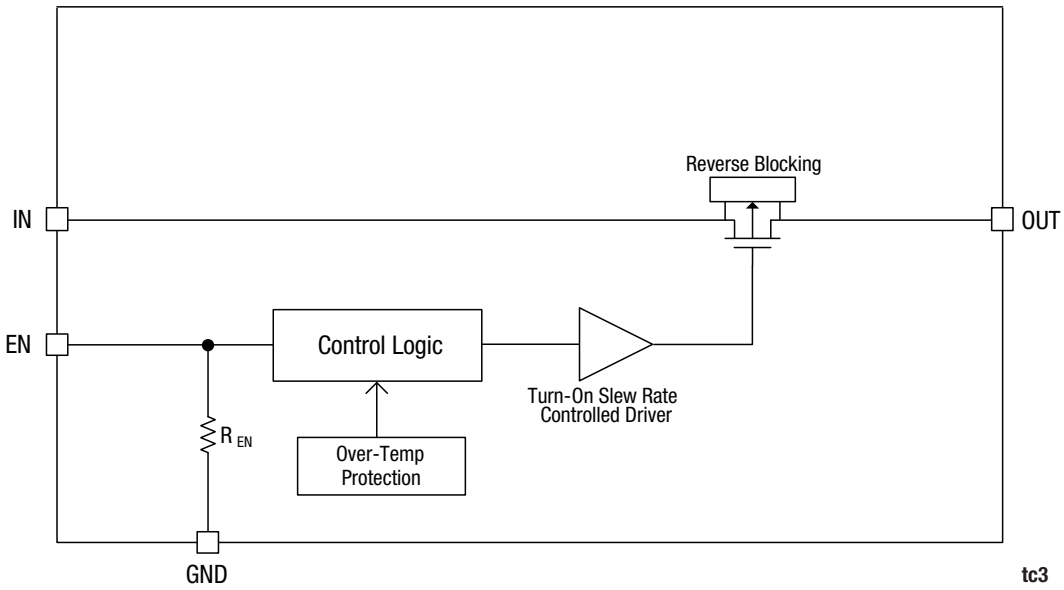


Figure 23. SKY84632 Functional Block Diagram

Functional Description

The SKY84632 is an integrated low-$R_{DS(ON)}$ P-channel load switch with enable activity and reverse blocking. A wide input voltage range from 1.5 V to 5.5 V allows the SKY84632 to be compatible with GPIO/CMOS input. Logic high at the EN bump activates the device. The reverse blocking feature prevents current flow from output to input at the load switch for both on/off states. The SKY84632 typically consumes 9 µA when operating. When switched off, the device draws less than 1 µA.

The SKY84632 also integrates over-temperature protection for high ambient temperature or junction temperature caused by excess current.

A functional block diagram of the SKY84632 is provided in Figure 23.

Application Information

Slew Rate and Inrush Current Control

To avoid large inrush current when the load switch is turned on, the slew rate controller feature allows the output voltage to rise slowly. The inrush current is dependent on slew rate control capability and output capacitance as expressed by:

$$I_{INRUSH} = I_{LOAD} + \frac{C_{OUT} \times (V_{IN} - V_{OUT})}{t_R}$$

Where:

C_{OUT} = Output capacitance in µF

V_{IN} = Input voltage in V

t_R: = Rise time at V_{OUT} in ms

$V_{INITIAL}$ = Initial voltage at C_{OUT} in V

I_{LOAD} = Load current in mA

For example, the SKY84632 has a 2.7 ms of slew rate capability under 4.5 V at 100 µF of C_{OUT} and no load, so inrush current can be minimized under 200 mA as Figure 24 shows.

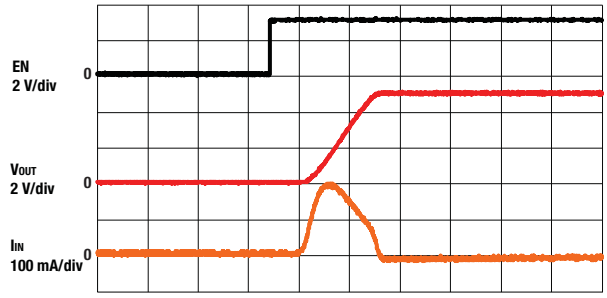


Figure 24: Inrush Current Waveform
(V_{IN} = 5.0 V, C_{IN} = 10 µF, C_{OUT} = 100 µF, No Load)

High inrush current makes the input voltage drop. The voltage drop value depends on the inrush current, power line equivalent parasitic resistance, and input capacitor. A large input voltage drop can cause system application problems.

Reverse Blocking

The reverse blocking feature protects the input source against current flow from output to input regardless of whether the load switch is on or off.

Thermal Protection

The SKY84632 includes thermal protection that disables the load switch when the die temperature reaches 140 °C. It automatically restarts when the temperature drops by 15 °C or more.

When an overload or output short to GND occurs, the power dissipation on device increases rapidly, triggering the thermal protection to prevent damage to the part.

Input Capacitor

Select a low Equivalent Series Resistance (ESR) ceramic capacitor with a value of at least 1 μF as the input capacitor. The input capacitor should be placed as close to the IN and GND bumps as possible to minimize the stray resistance from the device to the input power source.

Output Capacitor

Select a low ESR ceramic capacitor with a value of at least 0.1 μF as the output capacitor. The output capacitor should be placed as close to the OUT and GND bumps as possible to minimize the parasitic board inductance against forcing VOUT below GND when the switch is on.

Layout Guidance

For best performance of the SKY84632, the following guidelines should be followed when designing the PCB layout:

- Make the power trace as short and wide as possible, including the input/output power lines
- Connect the input/output capacitor to GND as close as possible to decrease the effect of parasitic inductance and to get a better noise filtering effect.

Evaluation Board Description

The SKY84632 Evaluation Board is used to test the performance of the SKY84632. An Evaluation Board schematic diagram is provided in Figure 25. The PCB layout is shown in Figures 26 and 27. Component values for the SKY84632 Evaluation Board are listed in Table 5.

Package Information

Typical case markings for the 6-bump WLCSP are shown in Figure 28. Package dimensions are shown in Figure 29, and the tape and reel dimensions are provided in Figure 30.

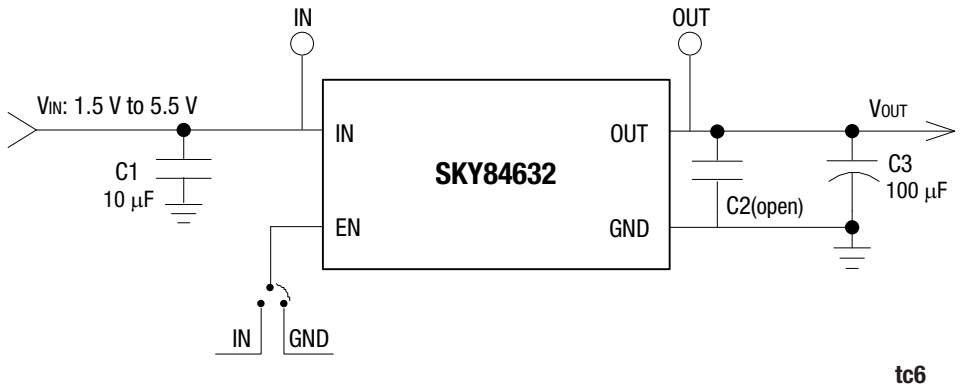


Figure 25. SKY84632 Evaluation Board Schematic

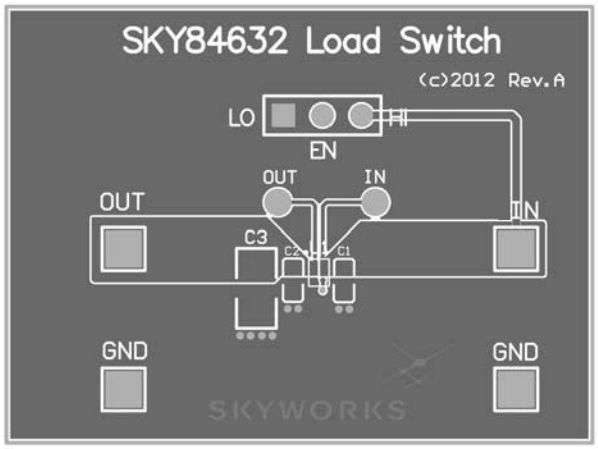


Figure 26. SKY84632 Evaluation Board PCB Top Side

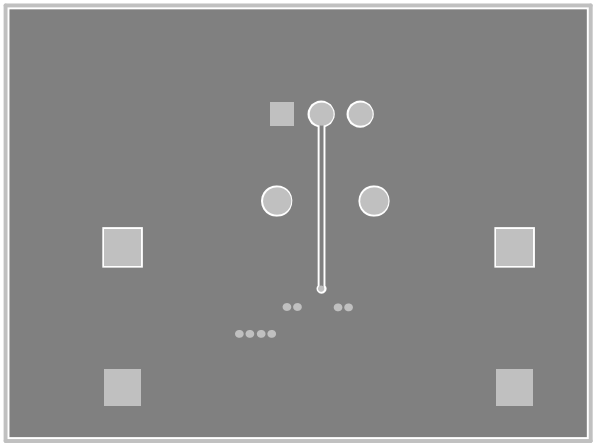


Figure 27. SKY84632 Evaluation Board PCB Bottom Side

Table 5. SKY84632 Evaluation Board Bill of Materials

Component	Part Number	Description	Manufacturer
U1	SKY84632	3A Slew-Rate Controlled Load Switch with Reverse Blocking	Skyworks
C1	GRM188R60J106ME47D	Cap Ceramic, 10 μF, 0603 X5R, 6.3 V, 20%	Murata
C2	GRM188R61E104KA01D	Cap Ceramic, 0.1 μF, 0603 X5R, 25 V, 10%	Murata
C3	GRM31CR60J107ME39L	Cap Ceramic, 100 μF, 1206 X5R, 6.3 V, 20%	Murata

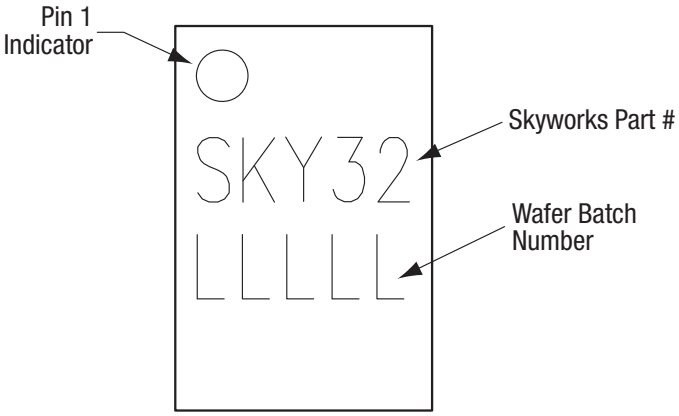
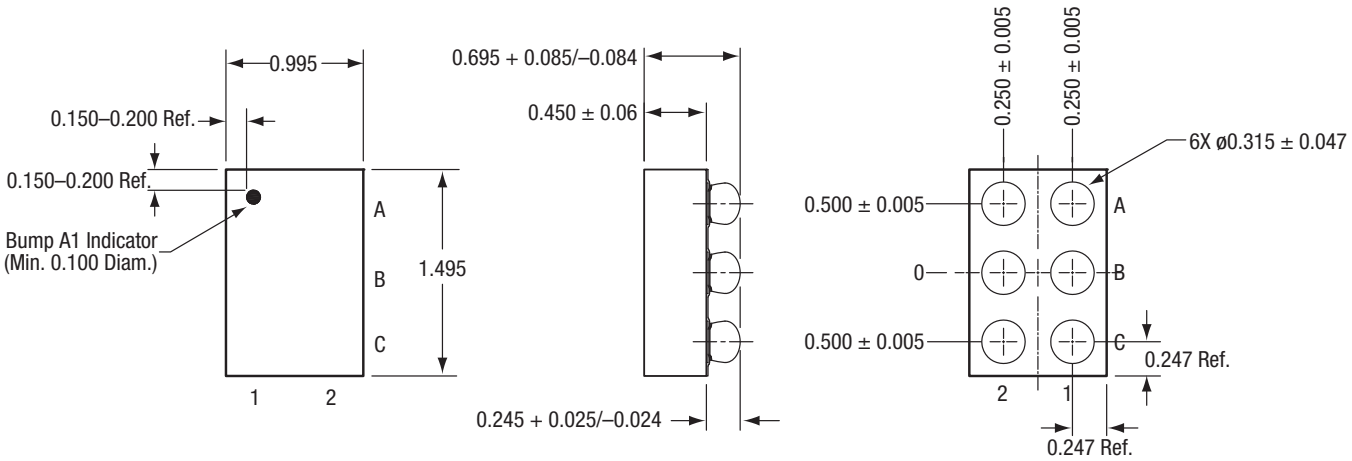
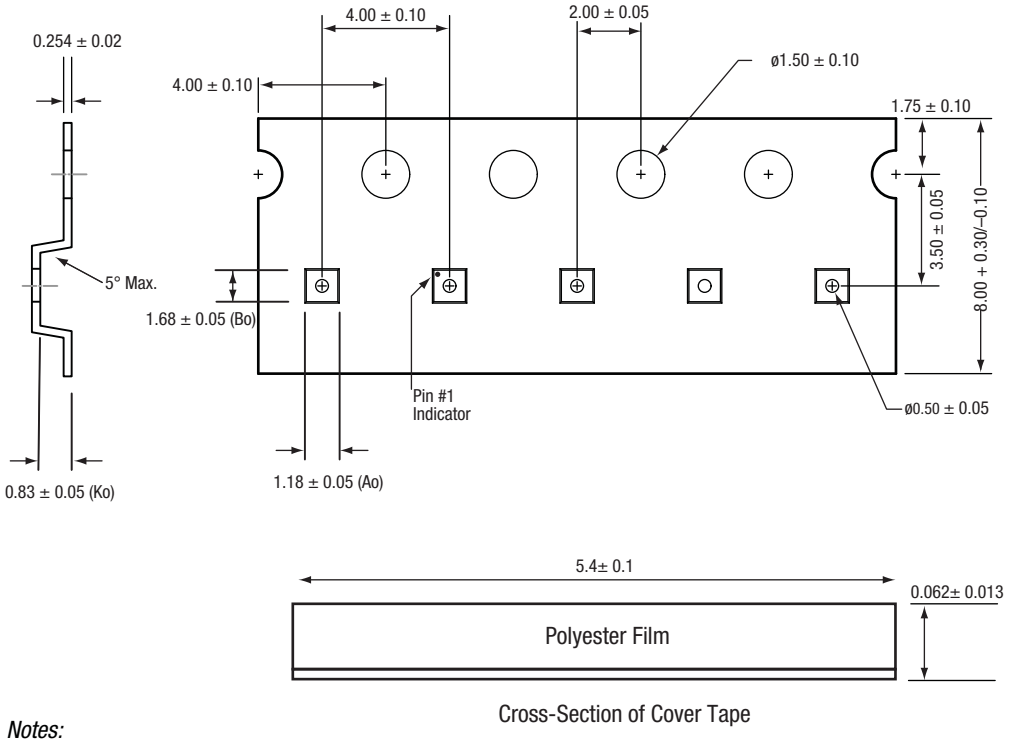


Figure 28. Typical Case Markings (Top View)



All measurements are in millimeters **S3486**

Figure 29. SKY84632 6-Bump WLCSP Package Dimensions



Notes:
1. Carrier tape: Black conductive polycarbonate
2. Cover tape: Transparent conductive material
3. 10 sprocket hole pitch cumulative tolerance: ± 0.20 mm
4. Pocket position relative to sprocket hole measured as true position of pocket
5. All dimensions are in millimeters

Y0019

Figure 30. SKY84632 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number (Note 1)	Evaluation Board Part Number
SKY84632 Load Switch with Reverse Blocking	**SKY84632-11-001**	SKY84632-11-001-EVB

Note 1: Sample stock is generally held on part numbers listed in **BOLD**.