# 50 mΩ, Slew Rate Controlled Load Switch in WCSP

## DESCRIPTION

The SiP32461 and SiP32462 are slew rate controlled integrated high side load switches that operate in the input voltage range from 1.2 V to 5.5 V.

This series of design feature slew rate control, reverse blocking, output discharge, and control logic pull down. The devices are logic high enabled.

The SIP32461 and SiP32462 are available in compact wafer level WCSP package, WCSP4 0.76 mm x 0.76 mm with 0.4 mm pitch.

## FEATURES

- Low input voltage, 1.2 V to 5.5 V
- Low $R_{on}$, 54 mΩ/typ. at 3 V
- Slew rate control
- Low logic control
- 7.5 µs turn-on time at 5 V (SiP32462)
- Reverse current blocking when disabled
- Integrated output discharge switch (SiP32461)
- Integrated pull down resistor at “EN”
- 4-bump WCSP package
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

Pb-free
RoHS COMPLIANT
HALOGEN FREE Available

## APPLICATIONS

- Smart phones
- GPS and portable media players
- Tablet computer
- Medical and healthcare equipment
- Industrial and instrument
- Game console

## DEVICE OPTIONS

| PART NUMBER | $R_{ON}$ (mΩ) | $t_{on}$ (µs) | $t_{d(off)}$ | REVERSE BLOCKING | $R_{DISCHARGE}$ | $EN_{LOGIC}$ | EN/PULL DOWN RESISTOR (Ω) |
|---|---|---|---|---|---|---|---|
| SiP32461DB-T2-GE1 | 54 | 120 | 2 | Y | Y | High enable | 2 M |
| SiP32462DB-T2-GE1 | 54 | 7.5 | 2 | Y | N | High enable | 2 M |

## TYPICAL APPLICATION CIRCUIT

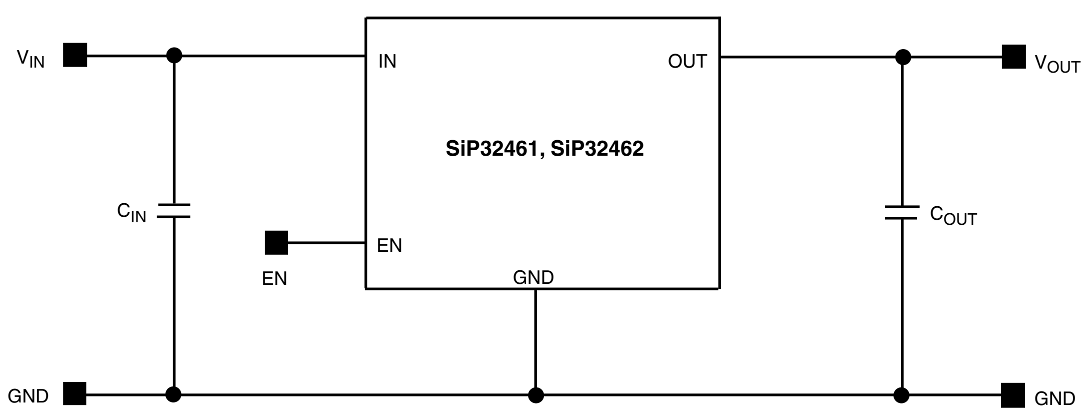



Fig. 1 - Typical Application Circuit

| ABSOLUTE MAXIMUM RATINGS | | | |
|---|---|---|---|
| **PARAMETER** | **CONDITIONS** | **LIMIT** | **UNIT** |
| Supply Input Voltage $V_{IN}$ | Reference to GND | - 0.3 to 6.5 | V |
| Output Voltage $V_{OUT}$ | Reference to GND | - 0.3 to 6.5 | |
| Output Voltage OUT | Pulse at 1 ms reference to GND (1) | - 1.6 | |
| Enable Input Voltage EN | Reference to GND | - 0.3 to 6.5 | |
| Maximum Continuous Switch Current | | 1.2 | A |
| Maximum Pulse Switch Current | Pulse at 1 ms, 10 % duty cycle | 2 | |
| ESD Rating (HBM) | | 4000 | V |
| Thermal Resistance | | 280 | °C/W |
| **TEMPERATURE** | | | |
| Operating Temperature | | - 40 to 85 | °C |
| Operating Junction Temperature | | 125 | |
| Storage Temperature | | - 65 to 150 | |

**Note**

(1) Negative current injection up to 300 mA

*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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

| RECOMMENDED OPERATING RANGE | | | | |
|---|---|---|---|---|
| **ELECTRICAL PARAMETER** | **MINIMUM** | **TYPICAL** | **MAXIMUM** | **UNIT** |
| Input Voltage ($V_{IN}$) | 1.2 | - | 5.5 | V |

| SPECIFICATIONS | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **TEST CONDITION UNLESS SPECIFIED** $V_{IN}$ = 1.2 V TO 5.5 V, $T_A$ = - 40 °C to 85 °C (Typical values are at 25 °C) | **LIMITS** | | | **UNIT** |
| | | | **MIN.** | **TYP.** | **MAX.** | |
| **POWER SUPPLY** | | | | | | |
| Quiescent Current | $I_Q$ | $V_{IN}$ = 3.3 V, $V_{OUT}$ = 0 mA | - | 4.5 | 7 | µA |
| Shutdown Current | $I_{SD}$ | $V_{OUT}$ = GND | - | 0.01 | 2 | |
| Off Switch Current | $I_{DS(off)}$ | EN = GND, out = GND | - | 0.01 | 2 | |
| Reverse Blocking Current | $I_{(in)RB}$ | Out = 5 V, IN = 1.2 V, EN = 0 V, (Measured at in pin) | - | 0.01 | 1 | |
| | | Out = 5 V, IN = 0 V, EN = 0 V, (Measured at in pin) | - | 0.01 | 1 | |
| **SWITCH RESISTANCE** | | | | | | |
| On Resistance | $R_{DS(on)}$ | $I_{OUT}$ = 500 mA, $V_{IN}$ = 1.2 V, $T_A$ = 25 °C | - | 95 | 150 | mΩ |
| | | $I_{OUT}$ = 500 mA, $V_{IN}$ = 1.5 V, $T_A$ = 25 °C | - | 80 | 120 | |
| | | $I_{OUT}$ = 500 mA, $V_{IN}$ = 1.8 V, $T_A$ = 25 °C | - | 70 | 100 | |
| | | $I_{OUT}$ = 500 mA, $V_{IN}$ = 3 V, $T_A$ = 25 °C | - | 54 | 65 | |
| | | $I_{OUT}$ = 500 mA, $V_{IN}$ = 5 V, $T_A$ = 25 °C | - | 52 | 65 | |
| Discharge Switch On Resistance | $R_{PD}$ | When $V_{IN}$ = 3 V at 25 °C | - | 80 | - | Ω |
| | | When $V_{IN}$ = 1.8 V at 25 °C | - | < 200 | - | |
| EN Pin Pull Down Resistor | $R_{EN}$ | EN = 1.2 V | 1 | 2.6 | 5 | MΩ |
| On Resistance Temperature Coefficient | $TC_{RDS}$ | | - | 2800 | | ppm/°C |
| **ON/OFF LOGIC** | | | | | | |
| EN Input Low Voltage | $V_{IL}$ | $V_{IN}$ = 1.5 V | 0.4 | - | - | V |
| EN Input High Voltage | $V_{IH}$ | $V_{IN}$ = 5.5 V | - | - | 1 | |

## SPECIFICATIONS

| PARAMETER | SYMBOL | TEST CONDITION UNLESS SPECIFIED $V_{IN}$ = 1.2 V TO 5.5 V, $T_A$ = - 40 °C to 85 °C (Typical values are at 25 °C) | LIMITS MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| **SWITCHING SPEED** | | | | | | |
| Switch Turn-ON Delay time (SiP32461) | $t_{on\_DLY}$ | $R_{LOAD}$ = 10 Ω , $C_L$ = 0.1 µF<br>$V_{IN}$ = 3 V | - | 30 | - | µs |
| Switch Turn-ON Rise Time (SiP32461) | $t_r$ | $R_{LOAD}$ = 10 Ω , $C_L$ = 0.1 µF<br>$V_{IN}$ = 3 V | - | 90 | - | |
| Switch Turn-ON Time (including Turn-ON Delay and Rise Time (SiP32462, fast switching) | $t_{on}$ | $R_{LOAD}$ = 500 Ω , $C_L$ = 0.1 µF<br>$V_{IN}$ = 5 V | - | 7.5 | 20 | |
| Switch Turn-OFF Delay time | $t_{off}$ | $R_{LOAD}$ = 500 Ω, $C_L$ = 0.1 µF,<br>(50 % $V_{IN}$ to 90 % $V_{OUT}$) | - | 2 | - | |

## PIN CONFIGURATION

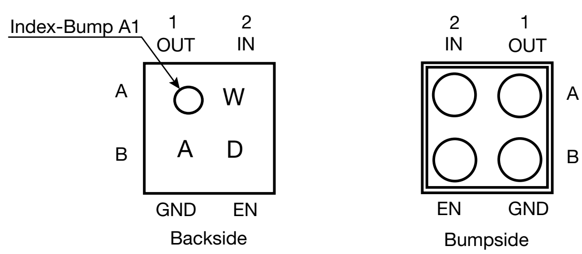



**Fig. 1 - WCSP 2 x 2 Package**

## PIN DESCRIPTION (WSCP PACKAGE)

| PIN# | NAME | FUNCTION |
|---|---|---|
| A1 | OUT | Switch output |
| A2 | IN | Switch input |
| B1 | GND | Ground connection |
| B2 | EN | Switch on/off control. A pull down resistor is integrated |

## DEVICE MARKING

| | | |
|---|---|---|
| Row 1 | **Dot + W** | : Dot is A1 locator plus week coc |
| Row 2 | **AB** | : Mark code for part number |

SiP32461 = AG

SiP32462 = AH

## TRUTH TABLE

| EN | SWITCH |
|---|---|
| 1 | ON |
| 0 | OFF |

**BLOCK DIAGRAM**

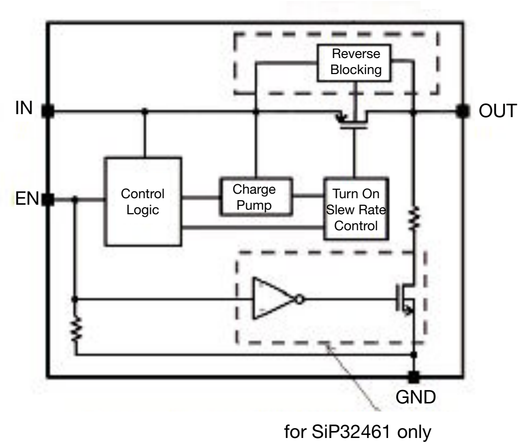



Fig. 2 - Functional Block Diagram

**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)

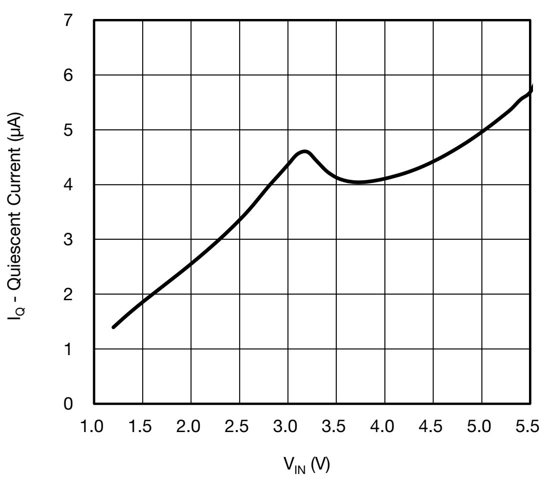



Fig. 3 - Quiescent Current vs. Input Voltage

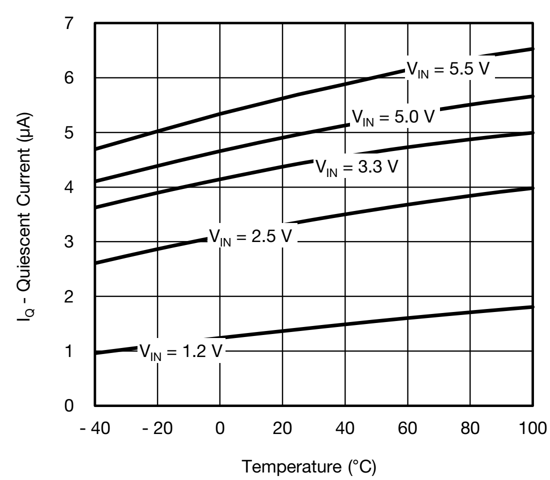



Fig. 5 - Quiescent Current vs. Temperature

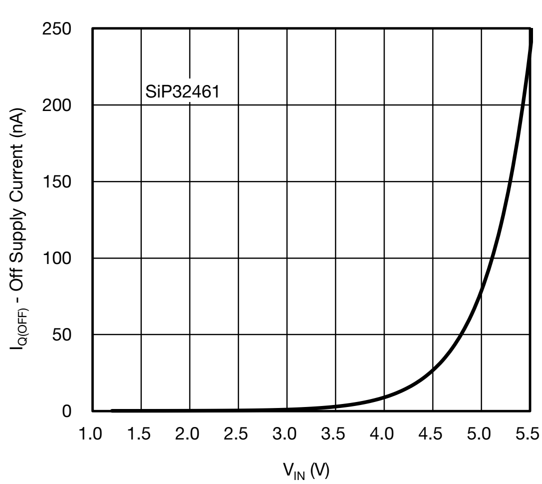



Fig. 4 - Off Supply Current vs. Input Voltage

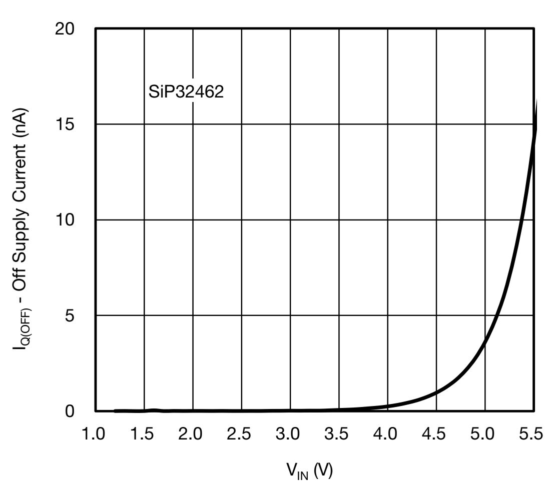



Fig. 6 - Off Supply Current vs. Input Voltage

**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)

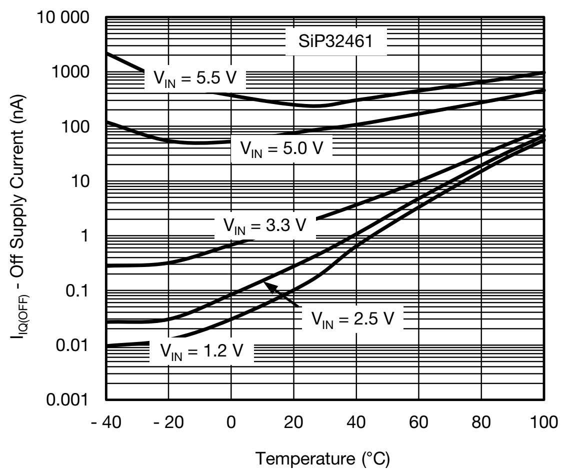



Fig. 7 - Off Supply Current vs. Temperature

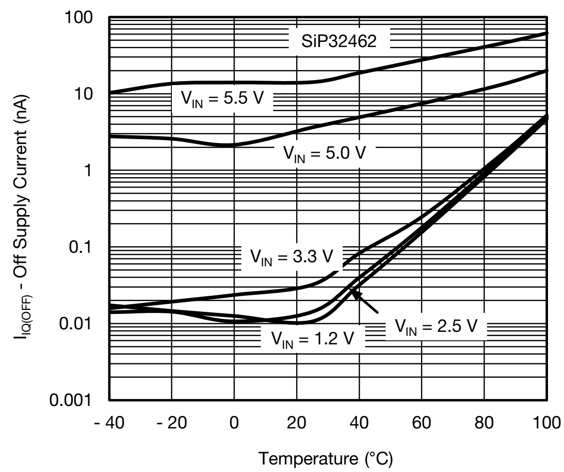



Fig. 10 - Off Supply Current vs. Temperature

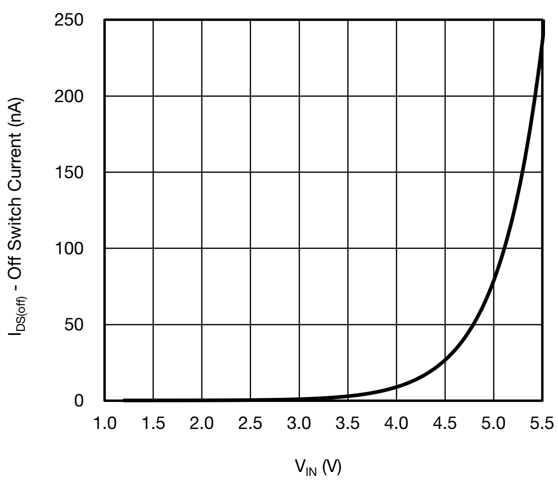



Fig. 8 - Off Switch Current vs. Input Voltage

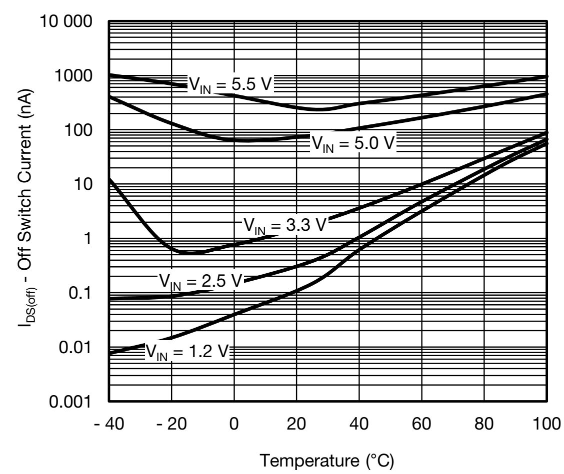



Fig. 11 - Off Switch Current vs. Temperature

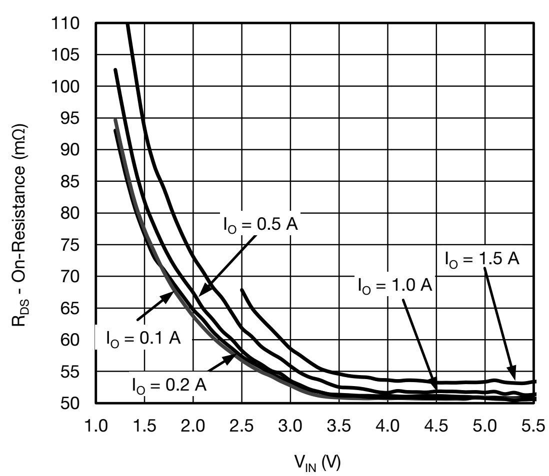



Fig. 9 - $R_{DS(on)}$ vs. Input Voltage

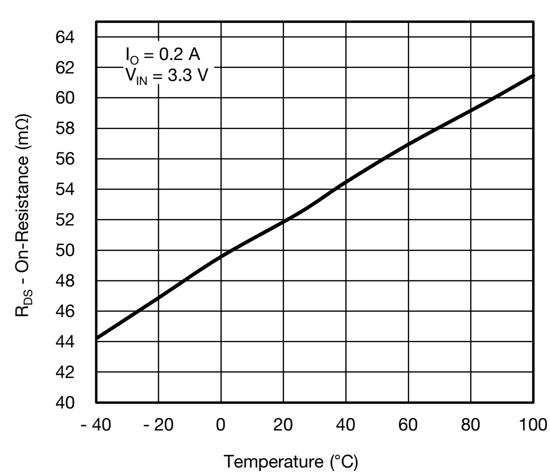



Fig. 12 - $R_{DS(on)}$ vs. Temperature

**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)

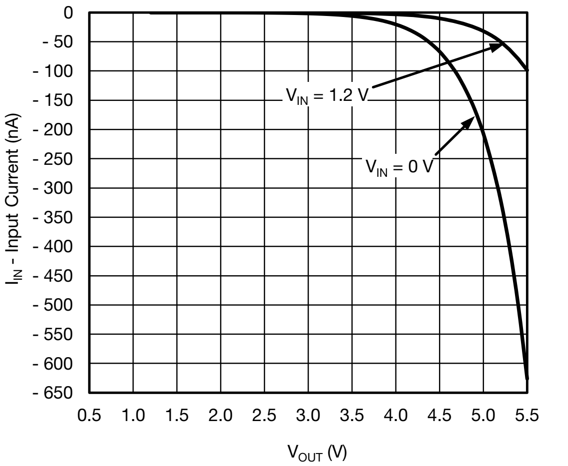



Fig. 13 - Reverse Blocking Current vs. Output Voltage

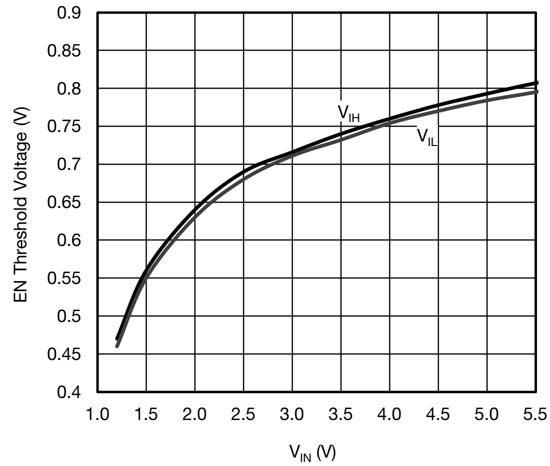



Fig. 16 - EN Threshold Voltage vs. Input Voltage

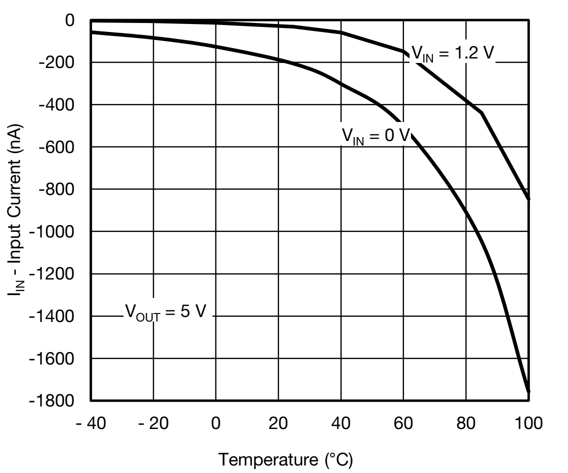



Fig. 14 - Reverse Blocking Current vs. Temperature

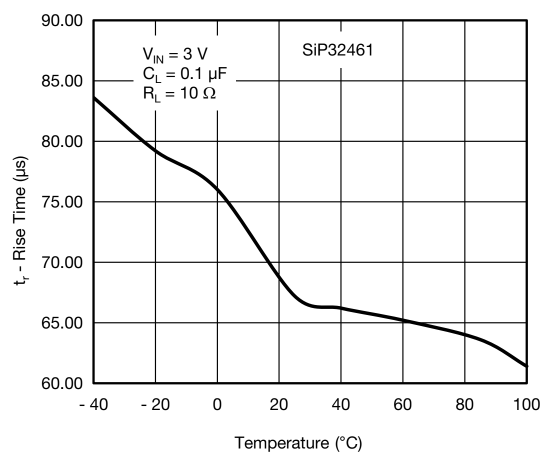



Fig. 17 - Rise Time vs. Temperature

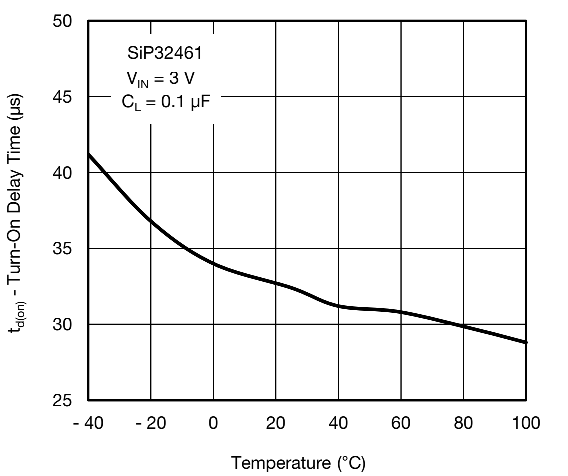



Fig. 15 - Turn-On Delay Time vs. Temperature

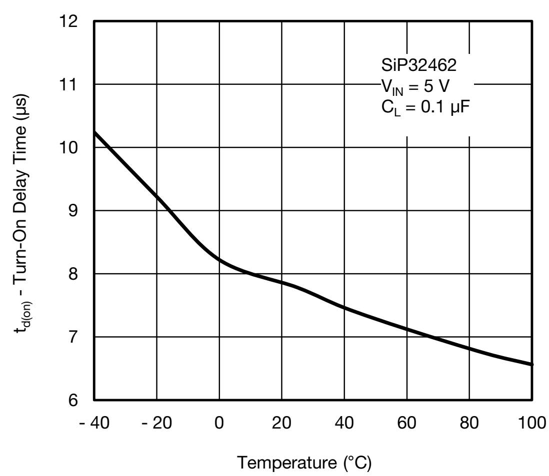



Fig. 18 - Turn-On Delay Time vs. Temperature

**TYPICAL CHARACTERISTICS** (internally regulated, 25 °C, unless otherwise noted)

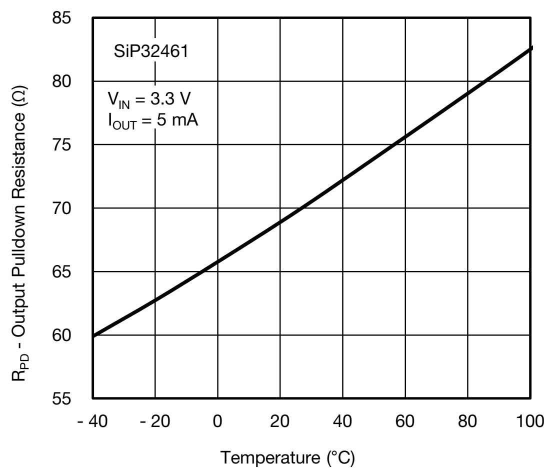



Fig. 19 - Output Pulldown Resistance vs. Temperature

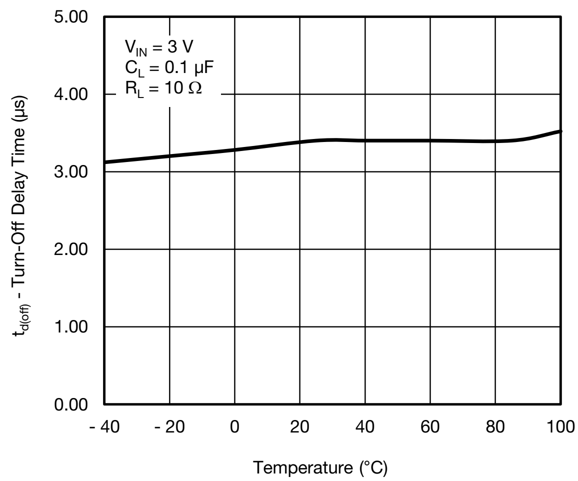



Fig. 20 - Turn-Off Delay Time vs. Temperature

**TYPICAL WAVEFORMS**

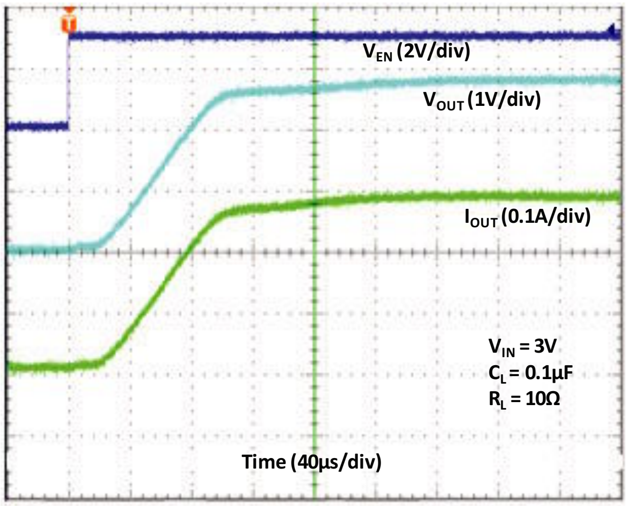



Fig. 21 - Turn-On Time, SiP32461
($V_{IN}$ = 3 V, $R_L$= 10 Ω, $C_L$ = 0.10 µF)

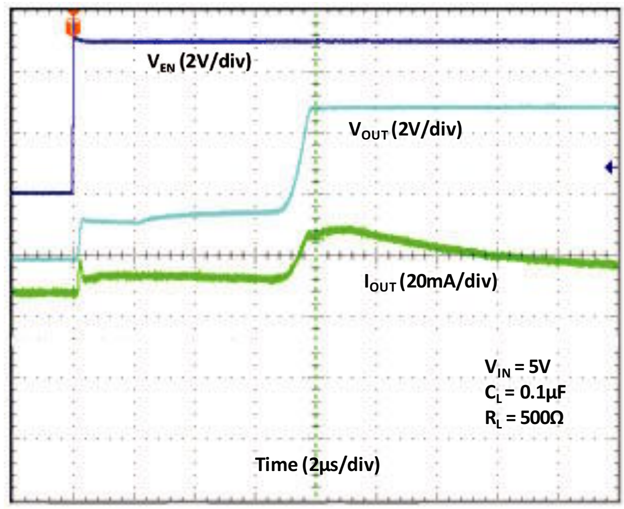



Fig. 23 - Turn-On Time, SiP32462
($V_{IN}$ = 5 V, $R_L$= 500 Ω, $C_L$ = 0.10 µF)

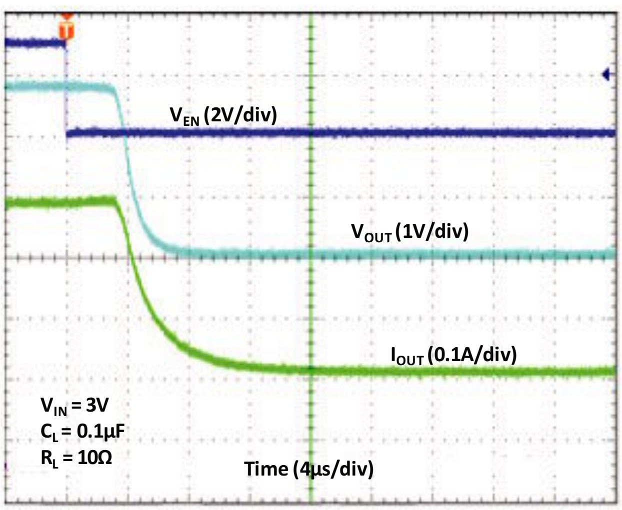



Fig. 22 - Turn-Off Time
($V_{IN}$ = 3 V, $R_L$= 10 Ω, $C_L$ = 0.10 µF)

## DETAILED DESCRIPTION

SiP32461 and SiP32462 are P-channel power MOSFET designed as high side load switches. They incorporate a negative charge pump at the gate to keep the gate to source voltage high when turned on therefore keep the on resistance low at lower input voltage range. SiP32461 are designed with slow slew rate to minimize the inrush current during turn on. This device has a reverse blocking circuit to prevent the current from going back to the input in case the output voltage is higher than the input voltage. The SiP32461 has an output pulldown resistor to discharge the output capacitance when the device is off.

## APPLICATION INFORMATION

### Input Capacitor

While a bypass capacitor on the input is not required, a 4.7 µF or larger capacitor for $C_{IN}$ is recommended in almost all applications. The bypass capacitor should be placed as physically close as possible to the input pin to be effective in minimizing transients on the input. Ceramic capacitors are recommended over tantalum because of their ability to withstand input current surges from low impedance sources such as batteries in portable devices.

### Output Capacitor

A 0.1 µF capacitor across $V_{OUT}$ and GND is recommended to insure proper slew operation. There is inrush current through the output MOSFET and the magnitude of the inrush current depends on the output capacitor, the bigger the $C_{OUT}$ the higher the inrush current. There are no ESR or capacitor type requirement.

### Enable

The EN pin is compatible with CMOS logic voltage levels. It requires at least 0.4 V or below to fully shut down the device and 1 V or above to fully turn on the device. There is a 2.8 MΩ resistor connected between EN pin and GND pin.

### Protection Against Reverse Voltage Condition

This device contains a reverse blocking circuit to keep the output current from flowing back to the input in case the output voltage is higher than the input voltage.

### Thermal Considerations

This device is designed to maintain a constant output load current. Due to physical limitations of the layout and assembly of the device the maximum switch current is 1.2 A as stated in the Absolute Maximum Ratings table. However, another limiting characteristic for the safe operating load current is the thermal power dissipation of the package. To obtain the highest power dissipation (and a thermal resistance of 280 °C/W) the device should be connected to a heat sink on the printed circuit board.

The maximum power dissipation in any application is dependant on the maximum junction temperature, $T_{J(max.)}$ = 125 °C, the junction-to-ambient thermal resistance, $\theta_{J-A}$ = 280 °C/W, and the ambient temperature, $T_A$, which may be formulaically expressed as:

$$P\,(\text{max.}) = \frac{T_J\,(\text{max.}) - T_A}{\theta_{J-A}} = \frac{125 - T_A}{280}$$

It then follows that, assuming an ambient temperature of 70 °C, the maximum power dissipation will be limited to about 196 mW.

So long as the load current is below the 1.2 A limit, the maximum continuous switch current becomes a function two things: the package power dissipation and the $R_{DS(ON)}$ at the ambient temperature.

As an example let us calculate the worst case maximum load current at $T_A$ = 70 °C. The worst case $R_{DS(ON)}$ at 25 °C is 65 mΩ at $V_{IN}$ = 1.5 V. The $R_{DS(ON)}$ at 70 °C can be extrapolated from this data using the following formula:

$R_{DS(ON)}$ (at 70 °C) = $R_{DS(ON)}$ (at 25 °C) x (1 + $T_C$ x ΔT)

Where $T_C$ is 2820 ppm/°C. Continuing with the calculation we have

$R_{DS(ON)}$ (at 70 °C) = 65 mΩ x (1 + 0.00282 x (70 °C - 25 °C)) = 73.2 mΩ

The maximum current limit is then determined by

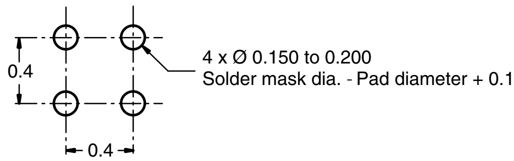
$$I_{LOAD}\,(\text{max.}) < \sqrt{\frac{P\,(\text{max.})}{R_{DS(ON)}}}$$

which in this case is 1.6 A. Under the stated input voltage condition, if the 1.6 A current limit is exceeded the internal die temperature will rise and eventually, possibly damage the device.

To avoid possible permanent damage to the device and keep a reasonable design margin, it is recommended to operate the device maximum up to 1.2 A only as listed in the Absolute Maximum Ratings table.

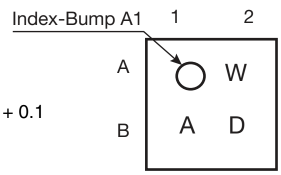
## PACKAGE OUTLINE

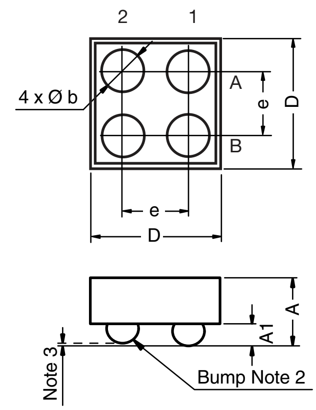
**WCSP: 4 Bumps (2 x 2, 0.4 mm Pitch, 208 µm Bump Height, 0.8 mm x 0.8 mm Die Size)**




Recommended Land Pattern
All dimensions in millimeters

Mark on backside of die




| DIMENSION | MILLIMETERS | | | INCHES | | |
|---|---|---|---|---|---|---|
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | 0.515 | 0.530 | 0.545 | 0.0202 | 0.0208 | 0.0214 |
| A1 | | 0.208 | | | 0.0081 | |
| b | 0.250 | 0.260 | 0.270 | 0.0098 | 0.0102 | 0.0106 |
| e | | 0.400 | | | 0.0157 | |
| D | 0.720 | 0.760 | 0.800 | 0.0283 | 0.0299 | 0.0315 |

**Notes**

(1) Laser mark on the backside surface of die.
(2) Bumps are SAC396.
(3) 0.050 max. coplanarity.

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