

## 50 mΩ, Slew Rate Controlled Load Switch in WCSP

### DESCRIPTION

The SiP32460, SiP32461, and SiP32462 are slew rate controlled integrated high side load switches that operate over the input voltage range from 1.2 V to 5.5 V.

This series of design features slew rate control, reverse blocking when switch is off, output discharge, and control logic pulldown. The devices are logic high enabled.

The SiP32460, 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
- Compatible with 1.2 V to 3.3 V logic
- 7.5 μs turn-on time at 5 V (SiP32462)
- Reverse current blocking when switch is off
- Integrated output discharge switch (SiP32461)
- Integrated pulldown resistor at “EN”
- For enable “low” see SiP32467 and SiP32468
- 4-bump WCSP package
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



**RoHS**  
COMPLIANT  
HALOGEN  
**FREE**  
Available

### APPLICATIONS

- Smart phones
- GPS and portable media players
- Tablet computers
- Medical and healthcare equipment
- Industrial and instrumentation
- Game consoles

### TYPICAL APPLICATION CIRCUIT

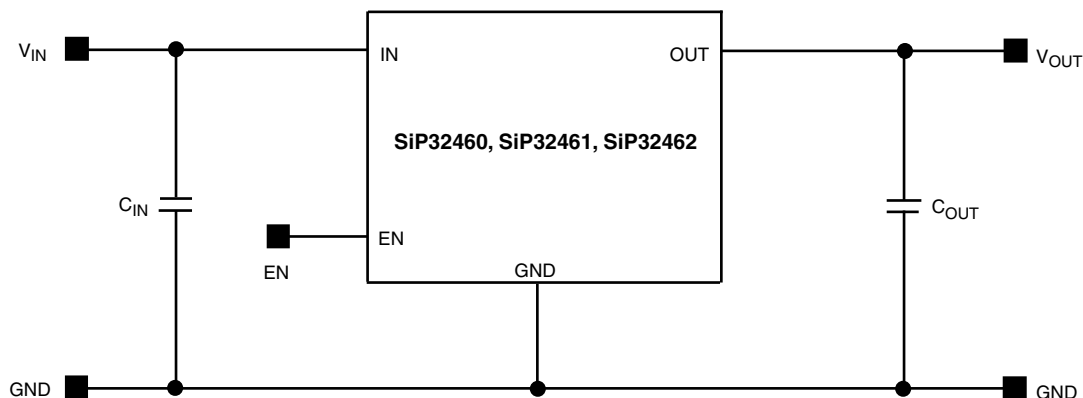


Fig. 1 - Typical Application Circuit

### ORDERING INFORMATION

| PART NUMBER       | PACKAGE                   | $t_{on}$ (μs) | $R_{DISCHARGE}$ | MARK CODE | TEMPERATURE RANGE |
|-------------------|---------------------------|---------------|-----------------|-----------|-------------------|
| SiP32460DB-T2-GE1 | WCSP4 (2x2), 0.4 mm pitch | 300           | No              | AF        | -40 °C to +85 °C  |
| SiP32461DB-T2-GE1 | WCSP4 (2x2), 0.4 mm pitch | 300           | Yes             | AG        | -40 °C to +85 °C  |
| SiP32462DB-T2-GE1 | WCSP4 (2x2), 0.4 mm pitch | 7.5           | No              | AH        | -40 °C to +85 °C  |

**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 $V_{OUT}$          | Pulse at 1 ms reference to GND <sup>a</sup> | -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                |                                             | 205         | °C/W |
| Maximum power dissipation         | $T_A = 25\text{ °C}$                        | 300         | mW   |
| <b>Temperature</b>                |                                             |             |      |
| Operating temperature             |                                             | -40 to +85  | °C   |
| Operating junction temperature    |                                             | 125         |      |
| Storage temperature               |                                             | -65 to +150 |      |

**Note**

a. 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    |
| Output voltage ( $V_{OUT}$ ) | 1.2     | -       | 5.5     |      |

**SPECIFICATIONS**

| PARAMETER                             | SYMBOL        | TEST CONDITIONS<br>UNLESS OTHERWISE SPECIFIED<br>$V_{IN} = 1.2\text{ V to }5.5\text{ V}$ , $T_A = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$<br>(typical values are at $25\text{ }^{\circ}\text{C}$ ) | LIMITS |       |      | UNIT                          |
|---------------------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------|------|-------------------------------|
|                                       |               |                                                                                                                                                                                                                        | MIN.   | TYP.  | MAX. |                               |
| Power Supply                          |               |                                                                                                                                                                                                                        |        |       |      |                               |
| Quiescent current                     | $I_Q$         | $V_{IN} = 3.3\text{ V}$ , $I_{OUT} = 0\text{ mA}$                                                                                                                                                                      | -      | 4.5   | 7    | $\mu\text{A}$                 |
| Shutdown current                      | $I_{SD}$      | 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                         | $R_{DS(on)}$  | $I_{OUT} = 500\text{ mA}$ , $V_{IN} = 1.2\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$                                                                                                                               | -      | 95    | 150  | $\text{m}\Omega$              |
|                                       |               | $I_{OUT} = 500\text{ mA}$ , $V_{IN} = 1.5\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$                                                                                                                               | -      | 80    | 120  |                               |
|                                       |               | $I_{OUT} = 500\text{ mA}$ , $V_{IN} = 1.8\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$                                                                                                                               | -      | 70    | 100  |                               |
|                                       |               | $I_{OUT} = 500\text{ mA}$ , $V_{IN} = 3\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$                                                                                                                                 | -      | 54    | 65   |                               |
|                                       |               | $I_{OUT} = 500\text{ mA}$ , $V_{IN} = 5\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$                                                                                                                                 | -      | 50    | 65   |                               |
| Discharge switch on resistance        | $R_{PD}$      | When $V_{IN} = 3\text{ V}$ at $25\text{ }^{\circ}\text{C}$                                                                                                                                                             | -      | 80    | -    | $\Omega$                      |
|                                       |               | When $V_{IN} = 1.8\text{ V}$ at $25\text{ }^{\circ}\text{C}$                                                                                                                                                           | -      | < 200 | -    |                               |
| EN pin pulldown resistor              | $R_{EN}$      | EN = 1.2 V                                                                                                                                                                                                             | 1      | 2.6   | 5    | $\text{M}\Omega$              |
| On resistance temperature coefficient | $TC_{RDS}$    |                                                                                                                                                                                                                        | -      | 2800  | -    | $\text{ppm}/^{\circ}\text{C}$ |
| On/off Logic                          |               |                                                                                                                                                                                                                        |        |       |      |                               |
| EN input low voltage                  | $V_{IL}$      | $V_{IN} = 1.5\text{ V}$                                                                                                                                                                                                | 0.4    | -     | -    | V                             |
| EN input high voltage                 | $V_{IH}$      | $V_{IN} = 5.5\text{ V}$                                                                                                                                                                                                | -      | -     | 1    |                               |

| SPECIFICATIONS                                                                        |               |                                                                                                                                                                                                                          |        |      |      |               |
|---------------------------------------------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|------|---------------|
| PARAMETER                                                                             | SYMBOL        | TEST CONDITIONS<br>UNLESS OTHERWISE SPECIFIED<br>$V_{IN} = 1.2\text{ V to } 5.5\text{ V}$ , $T_A = -40\text{ }^{\circ}\text{C to } +85\text{ }^{\circ}\text{C}$<br>(typical values are at $25\text{ }^{\circ}\text{C}$ ) | LIMITS |      |      | UNIT          |
|                                                                                       |               |                                                                                                                                                                                                                          | MIN.   | TYP. | MAX. |               |
| Switching Speed                                                                       |               |                                                                                                                                                                                                                          |        |      |      |               |
| Switch turn-on delay time (SiP32461)                                                  | $t_{on\_DLY}$ | $R_{LOAD} = 500\text{ }\Omega$ , $C_L = 0.1\text{ }\mu\text{F}$ , $V_{IN} = 5\text{ V}$                                                                                                                                  | -      | 130  | -    | $\mu\text{s}$ |
| Switch turn-on rise time (SiP32461)                                                   | $t_r$         | $R_{LOAD} = 500\text{ }\Omega$ , $C_L = 0.1\text{ }\mu\text{F}$ , $V_{IN} = 5\text{ V}$                                                                                                                                  | -      | 170  | -    |               |
| Switch turn-on time (including turn-on delay and rise time (SiP32462, fast switching) | $t_{on}$      | $R_{LOAD} = 500\text{ }\Omega$ , $C_L = 0.1\text{ }\mu\text{F}$ , $V_{IN} = 5\text{ V}$                                                                                                                                  | -      | 7.5  | 20   |               |
| Switch turn-off delay time                                                            | $t_{off}$     | $R_{LOAD} = 500\text{ }\Omega$ , $C_L = 0.1\text{ }\mu\text{F}$ , (50 % $V_{IN}$ to 90 % $V_{OUT}$ )                                                                                                                     | -      | 2    | -    |               |

## PIN CONFIGURATION

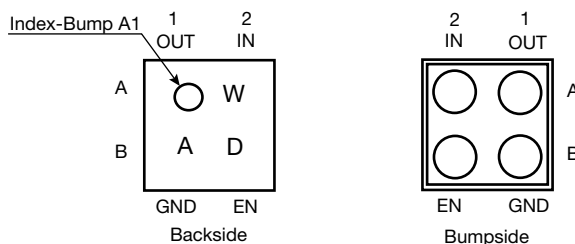
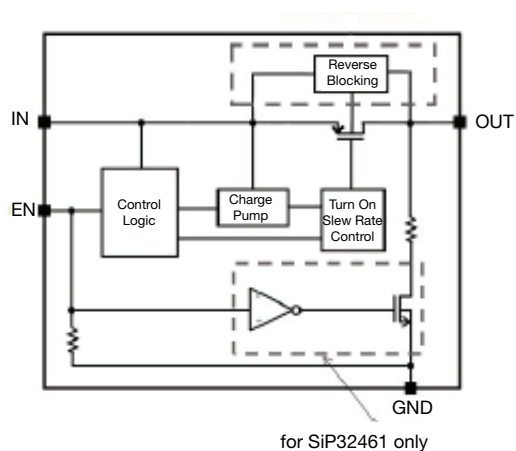


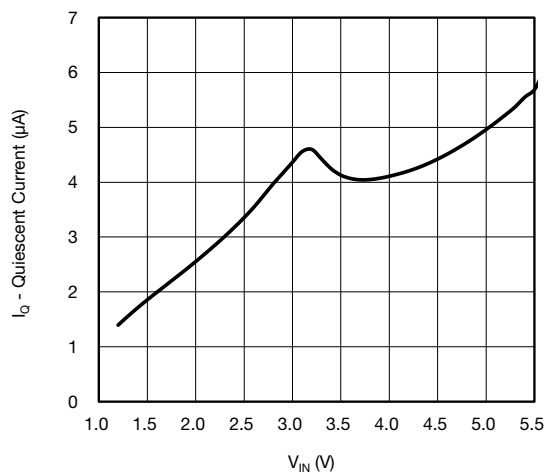
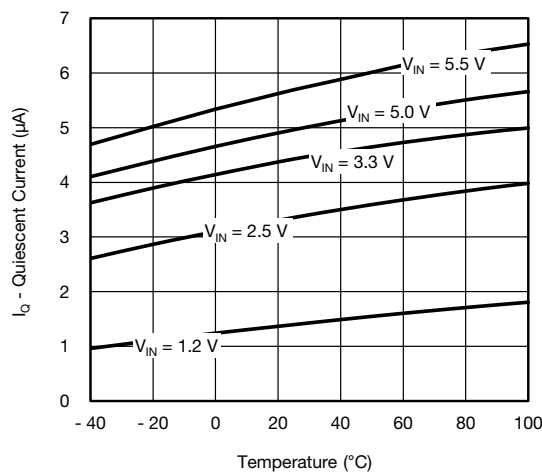
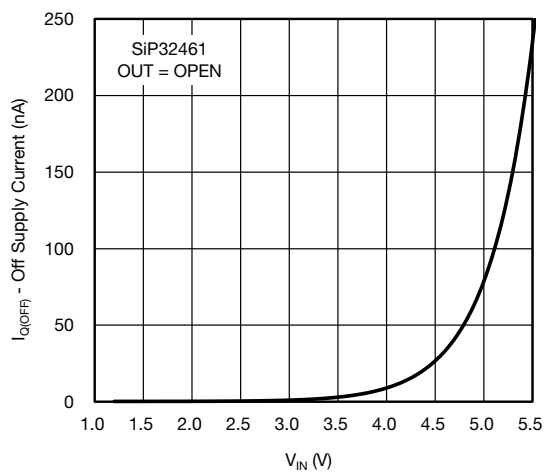
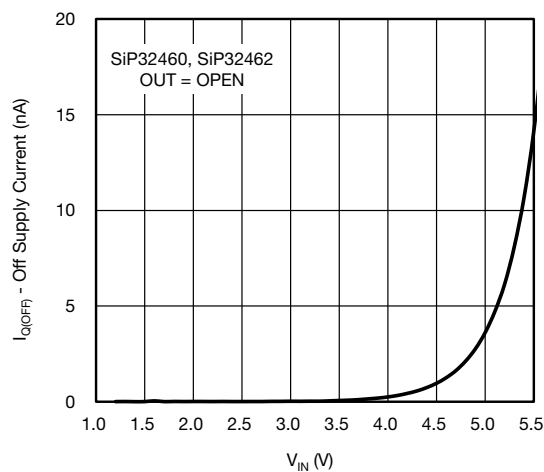
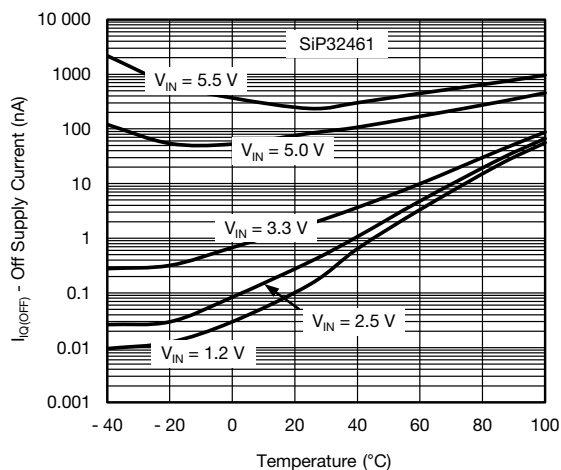
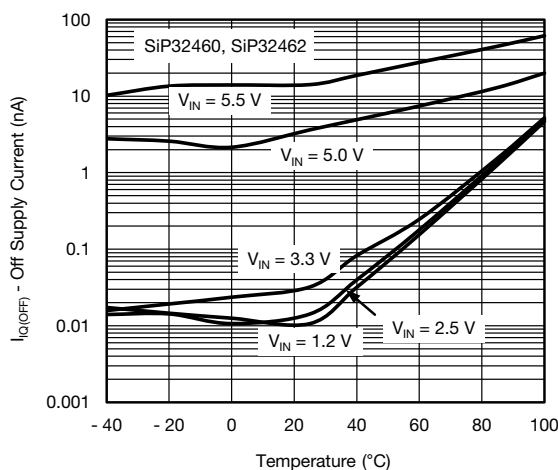
**Fig. 2 - WSCP 2 x 2 Package**

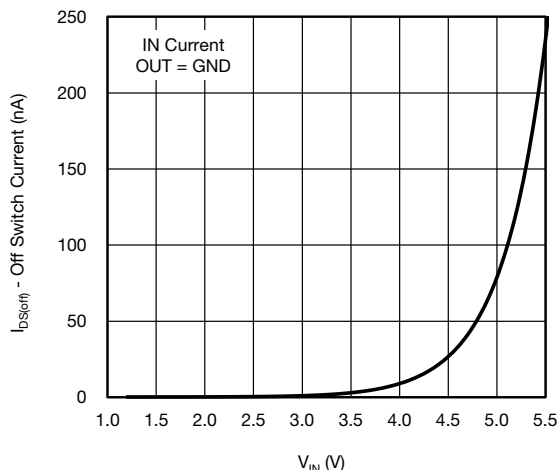
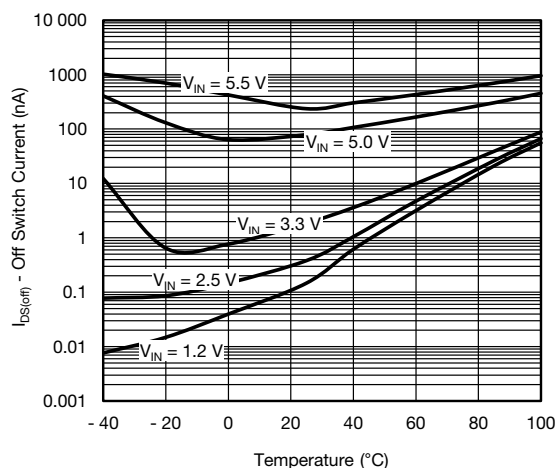
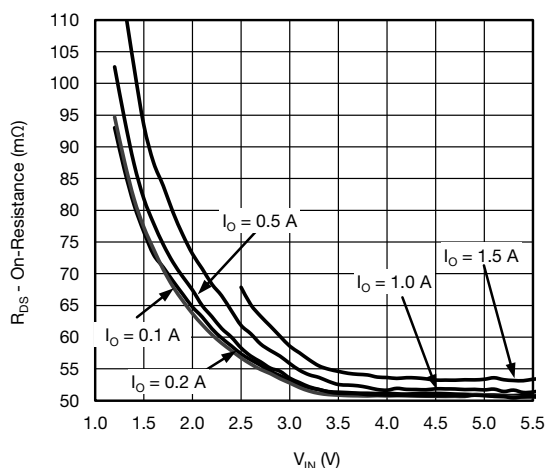
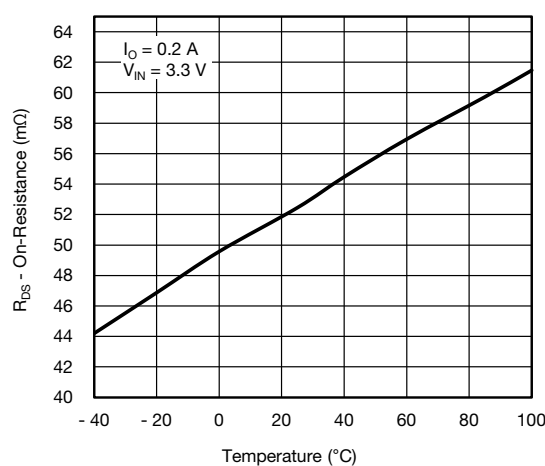
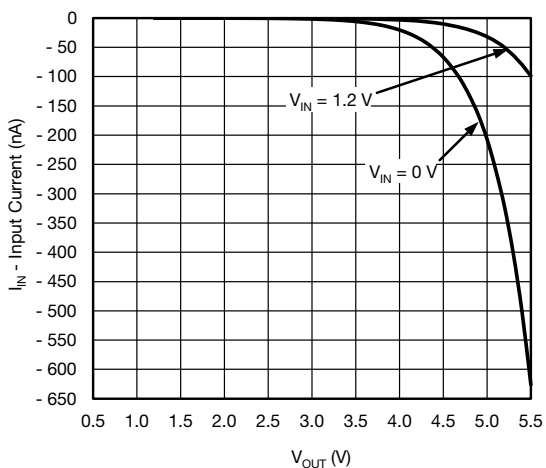
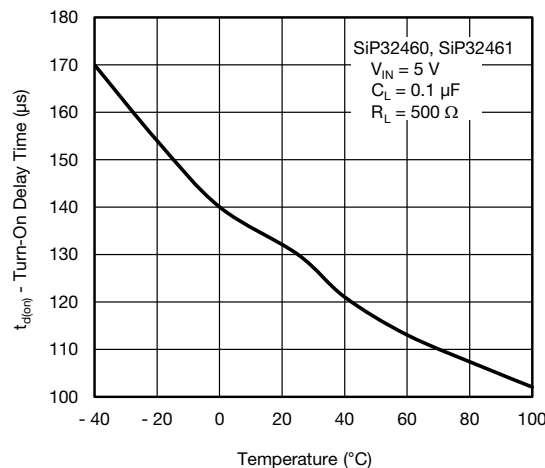
| DEVICE MARKING |                |                                    |
|----------------|----------------|------------------------------------|
| Row 1          | <b>Dot + W</b> | : dot is A1 locator plus week code |
| Row 2          | <b>AB</b>      | : mark code for part number        |
| SiP32460 = AF  |                |                                    |
| SiP32461 = AG  |                |                                    |
| SiP32462 = AH  |                |                                    |

| 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 pulldown resistor is integrated |

| TRUTH TABLE |        |
|-------------|--------|
| EN          | SWITCH |
| 1           | On     |
| 0           | Off    |

**BLOCK DIAGRAM**

**Fig. 3 - Functional Block Diagram**

**TYPICAL CHARACTERISTICS** ( $T_J = 25^\circ\text{C}$ , unless otherwise noted)

**Fig. 4 - Quiescent Current vs. Input Voltage**

**Fig. 7 - Quiescent Current vs. Temperature**

**Fig. 5 - Off Supply Current vs. Input Voltage**

**Fig. 8 - Off Supply Current vs. Input Voltage**

**Fig. 6 - Off Supply Current vs. Temperature**

**Fig. 9 - Off Supply Current vs. Temperature**

**TYPICAL CHARACTERISTICS** ( $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted)

**Fig. 10 - Off Switch Current vs. Input Voltage**

**Fig. 13 - Off Switch Current vs. Temperature**

**Fig. 11 -  $R_{DS(on)}$  vs. Input Voltage**

**Fig. 14 -  $R_{DS(on)}$  vs. Temperature**

**Fig. 12 - Reverse Blocking Current vs. Output Voltage**

**Fig. 15 - Turn-on Delay Time vs. Temperature**



**TYPICAL CHARACTERISTICS** ( $T_J = 25^\circ\text{C}$ , unless otherwise noted)

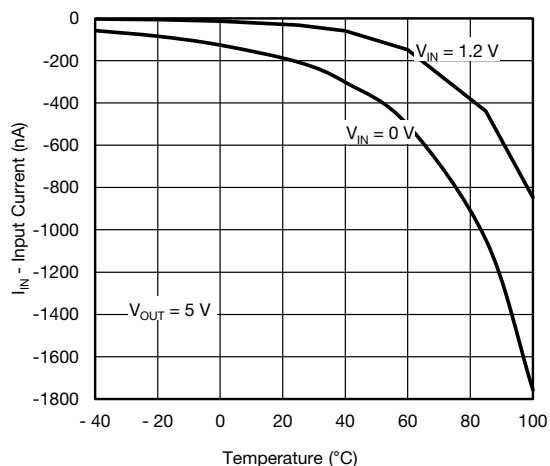


**Fig. 16 - Reverse Blocking Current vs. Temperature**

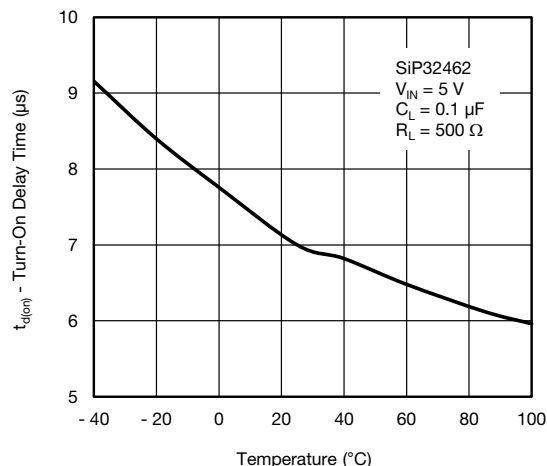


**Fig. 19 - Turn-on Delay Time vs. Temperature**

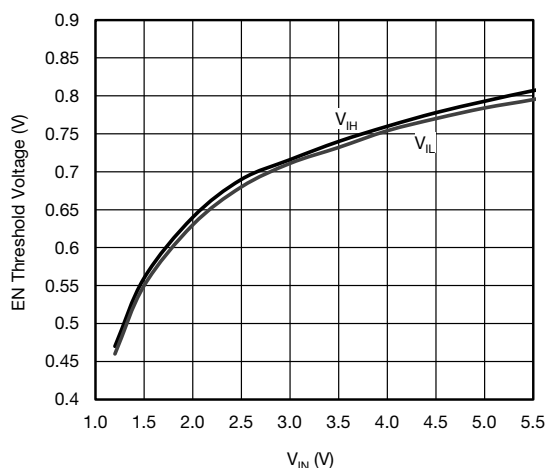


**Fig. 17 - EN Threshold Voltage vs. Input Voltage**

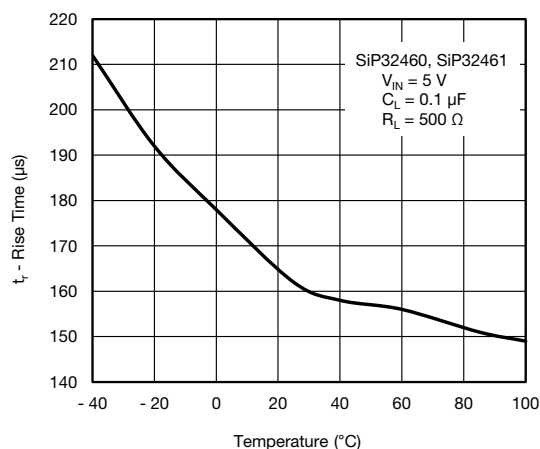


**Fig. 20 - Rise Time vs. Temperature**

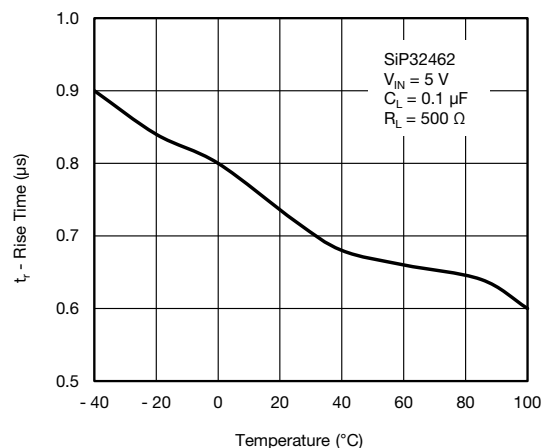


**Fig. 18 - Rise Time vs. Temperature**

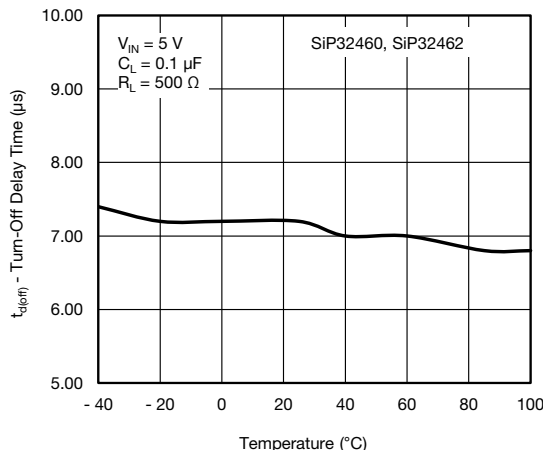


**Fig. 21 - Turn-off Delay Time vs. Temperature**



**TYPICAL CHARACTERISTICS** ( $T_J = 25^\circ\text{C}$ , unless otherwise noted)

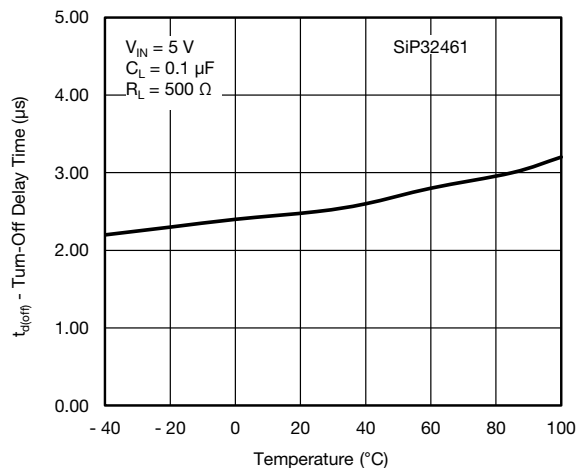


Fig. 22 - Turn-off Delay Time vs. Temperature

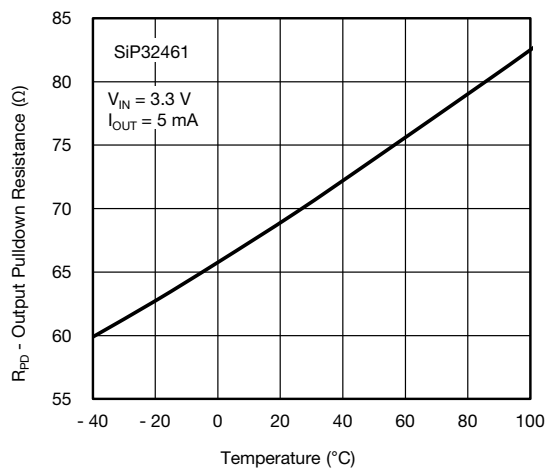


Fig. 23 - Output Pulldown Resistance vs. Temperature

**TYPICAL WAVEFORMS**

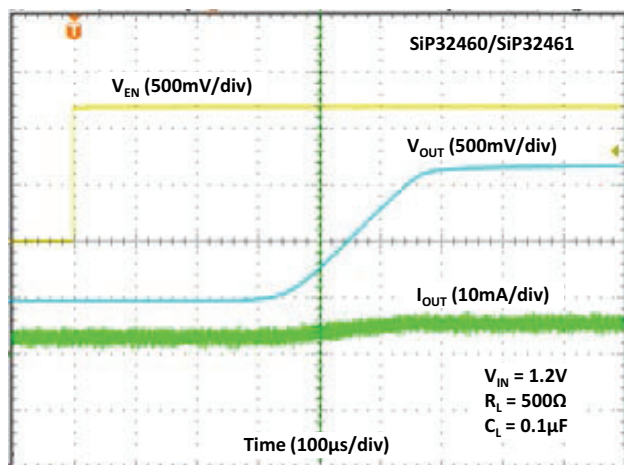


Fig. 24 - Turn-on Time

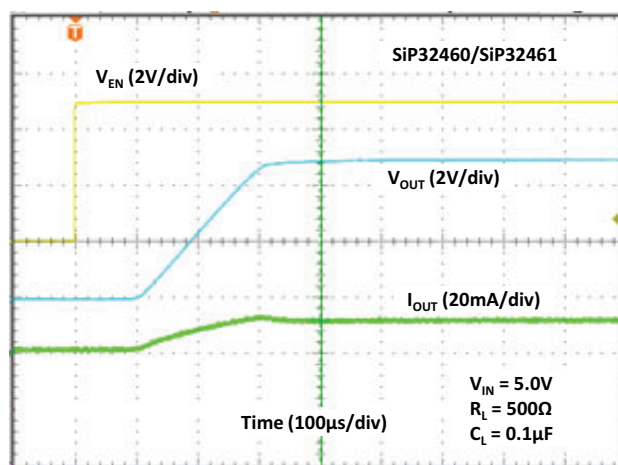


Fig. 25 - Turn-on Time



## TYPICAL WAVEFORMS

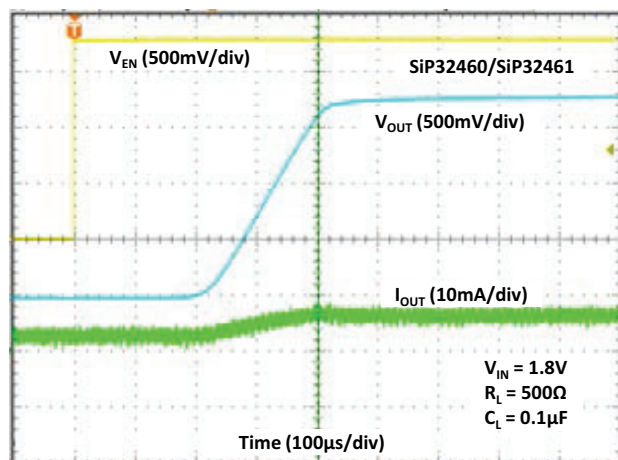


Fig. 26 - Turn-on Time

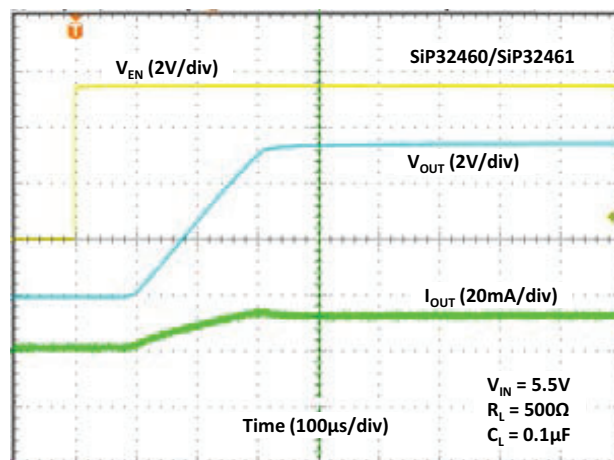


Fig. 29 - Turn-on Time

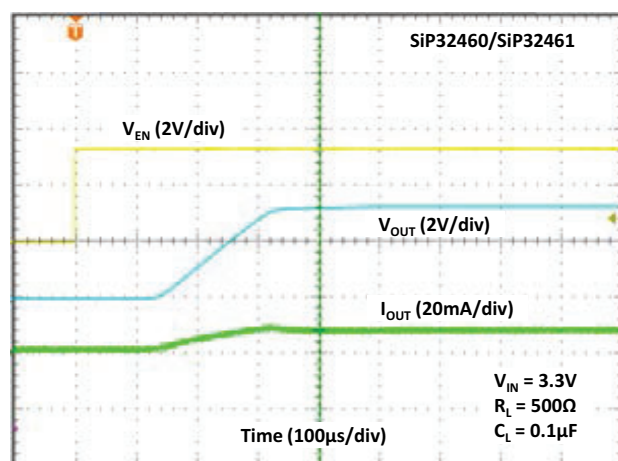


Fig. 27 - Turn-on Time

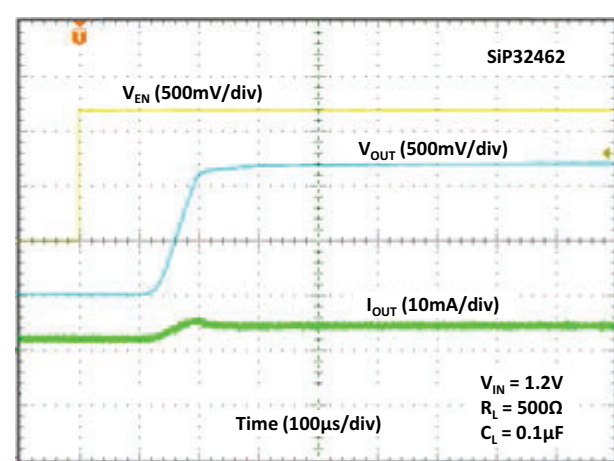


Fig. 30 - Turn-on Time

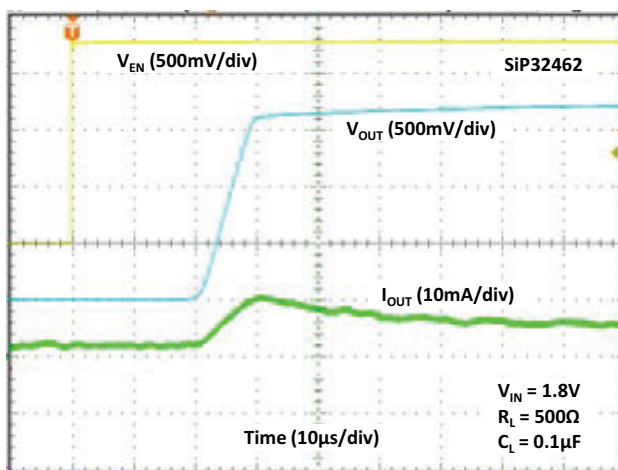


Fig. 28 - Turn-on Time

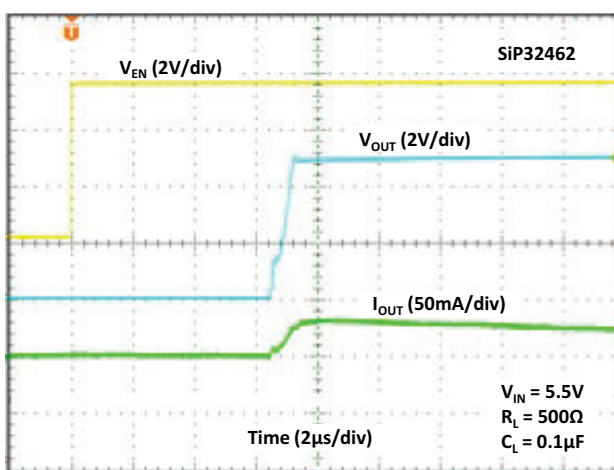


Fig. 31 - Turn-on Time



TYPICAL WAVEFORMS

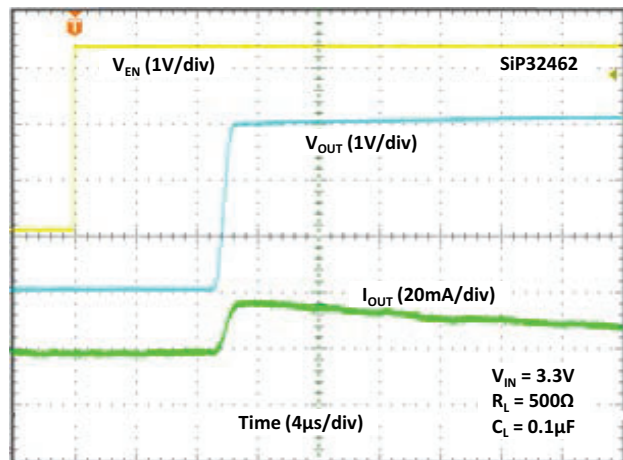


Fig. 32 - Turn-on Time

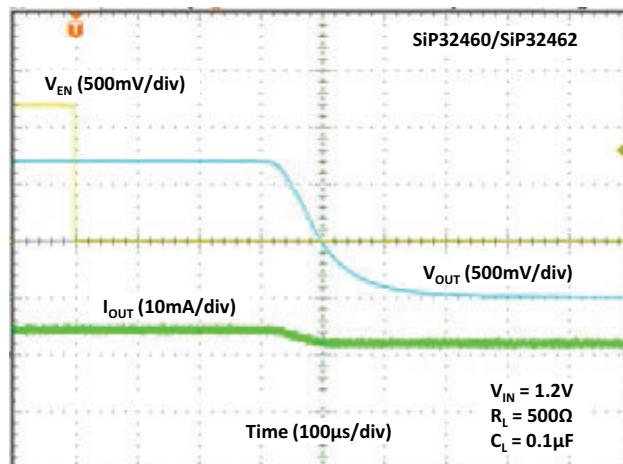


Fig. 35 - Turn-off Time

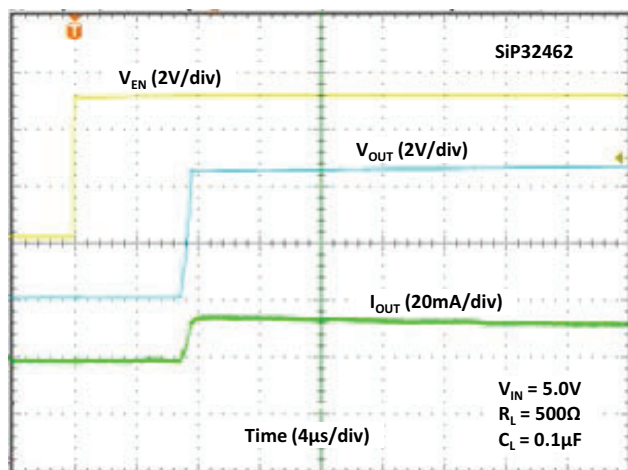


Fig. 33 - Turn-on Time

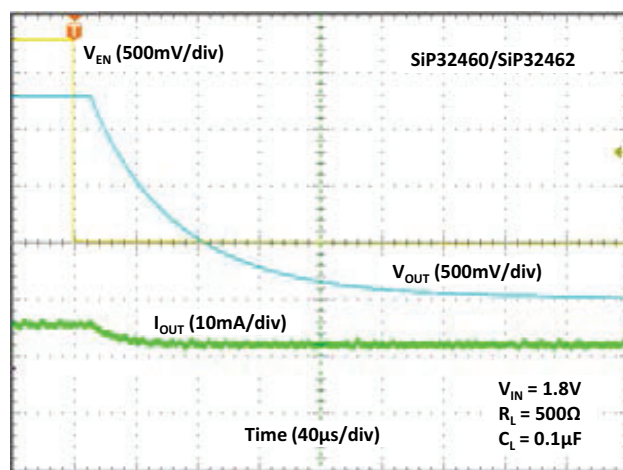


Fig. 36 - Turn-off Time

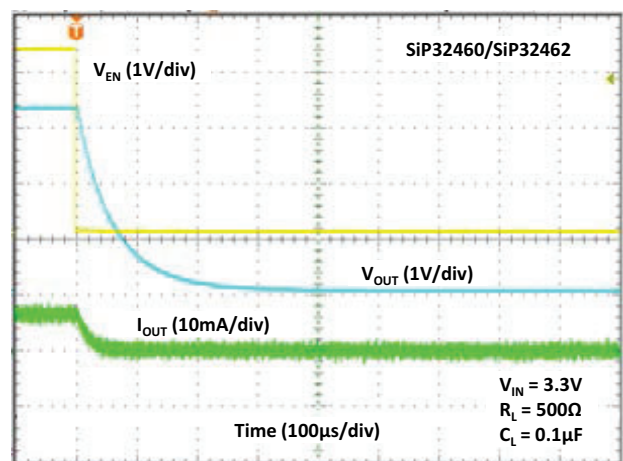


Fig. 34 - Turn-off Time

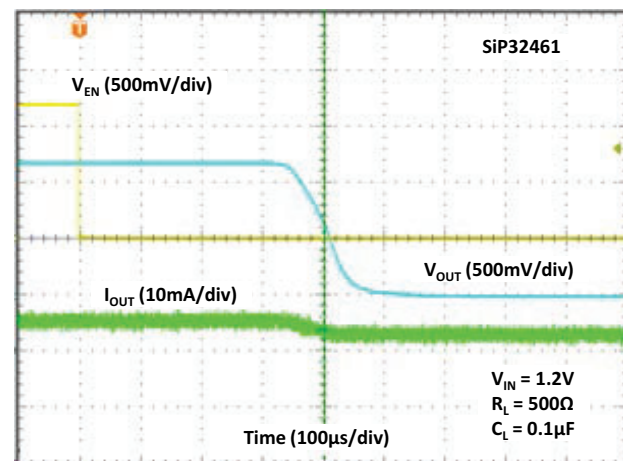


Fig. 37 - Turn-off Time



## TYPICAL WAVEFORMS

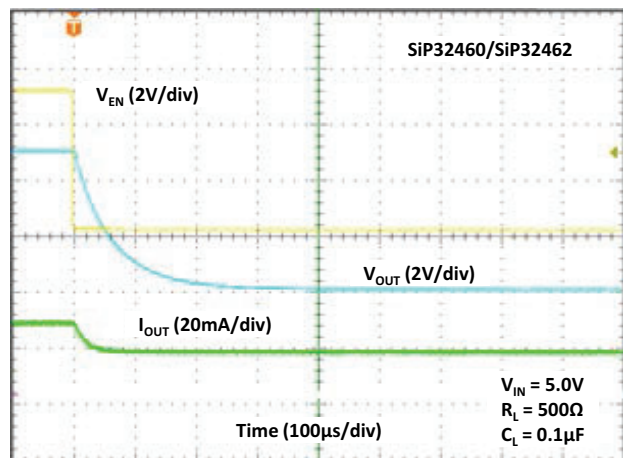


Fig. 38 - Turn-off Time

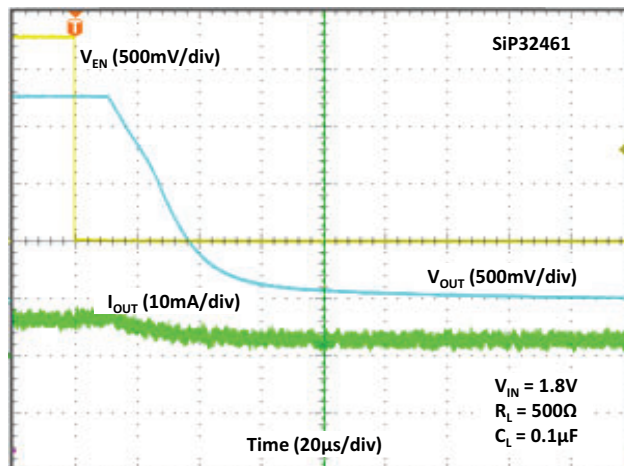


Fig. 41 - Turn-off Time

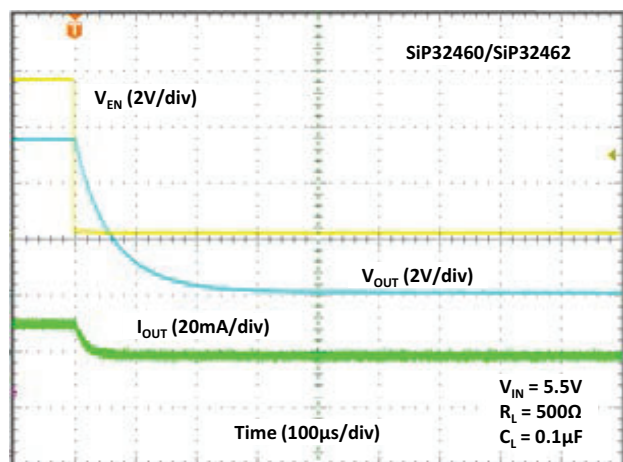


Fig. 39 - Turn-off Time

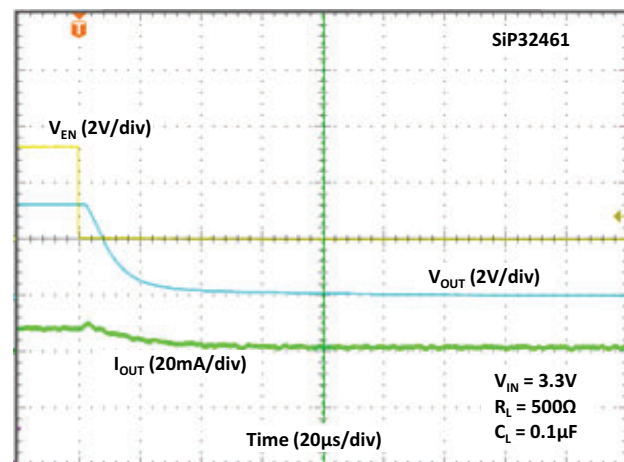


Fig. 42 - Turn-off Time

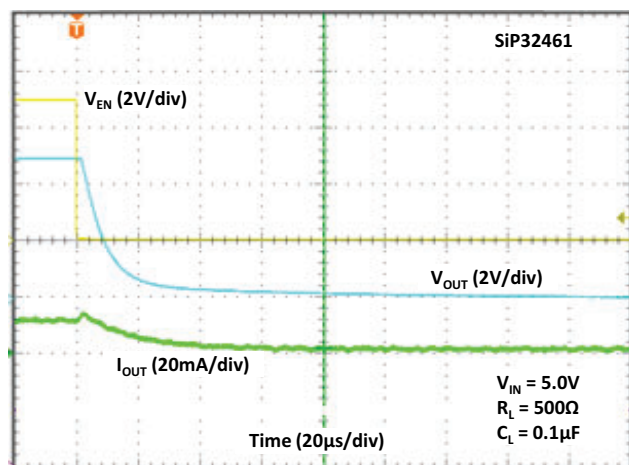


Fig. 40 - Turn-off Time

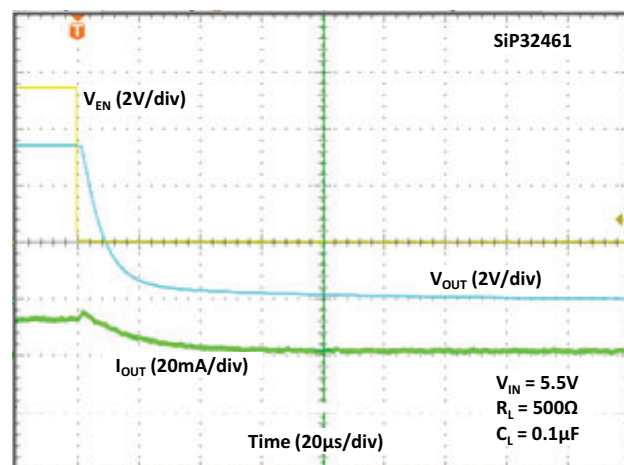


Fig. 43 - Turn-off Time

**DETAILED DESCRIPTION**

SiP32460, SiP32461, and SiP32462 are high side, slew rate controlled, load switches. They incorporate a negative charge pump at the gate to keep the gate to source voltage high when turned on. This keeps the on resistance low at lower input voltages. SiP32460 and SiP32461 are designed with slow slew rate to minimize inrush current during turn on. These devices have a reverse blocking circuit, when disabled, to prevent the current from going back to the input when the output voltage is higher than the input voltage. The SiP32460 and SiP32462 can be used as bidirectional switches and can be turned on and off when power is at either in or out. 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  $\mu\text{F}$  or larger capacitor for  $C_{\text{IN}}$  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  $\mu\text{F}$  capacitor across  $V_{\text{OUT}}$  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  $C_{\text{OUT}}$  the higher the inrush current. There is 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 2.6 M $\Omega$  resistor connected between EN pin and GND pin.

**Protection Against Reverse Voltage Condition**

This device contains a reverse blocking circuit. When disabled ( $V_{\text{EN}}$  less than 0.4 V) this circuit keeps the output current from flowing back to the input when the output voltage is higher than the input voltage.

**Thermal Considerations**

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.

The maximum power dissipation in any application is dependent on the maximum junction temperature,  $T_{\text{J(max.)}} = 125\text{ }^{\circ}\text{C}$ , the junction-to-ambient thermal resistance,  $\theta_{\text{J-A}} = 205\text{ }^{\circ}\text{C/W}$ , and the ambient temperature,  $T_{\text{A}}$ , which may be expressed as:

$$P(\text{max.}) = \frac{T_{\text{J(max.)}} - T_{\text{A}}}{\theta_{\text{JA}}} = \frac{125 - T_{\text{A}}}{205}$$

It then follows that, assuming an ambient temperature of 70  $^{\circ}\text{C}$ , the maximum power dissipation will be limited to about 268 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  $R_{\text{DS(on)}}$  at the ambient temperature.

As an example let us calculate the worst case maximum load current at  $T_{\text{A}} = 70\text{ }^{\circ}\text{C}$ . The worst case  $R_{\text{DS(on)}}$  at 25  $^{\circ}\text{C}$  is 120 m $\Omega$  at  $V_{\text{IN}} = 1.5\text{ V}$ . The  $R_{\text{DS(on)}}$  at 70  $^{\circ}\text{C}$  can be extrapolated from this data using the following formula:

$$R_{\text{DS(on)}}(\text{at } 70\text{ }^{\circ}\text{C}) = R_{\text{DS(on)}}(\text{at } 25\text{ }^{\circ}\text{C}) \times (1 + T_{\text{C}} \times \Delta T)$$

Where  $T_{\text{C}}$  is 2800 ppm/ $^{\circ}\text{C}$ . Continuing with the calculation we have

$$R_{\text{DS(on)}}(\text{at } 70\text{ }^{\circ}\text{C}) = 120\text{ m}\Omega \times (1 + 0.0028 \times (70\text{ }^{\circ}\text{C} - 25\text{ }^{\circ}\text{C})) = 135\text{ m}\Omega$$

The maximum current limit is then determined by

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

which in this case is 1.99 A. Under the stated input voltage condition, if the 1.99 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.

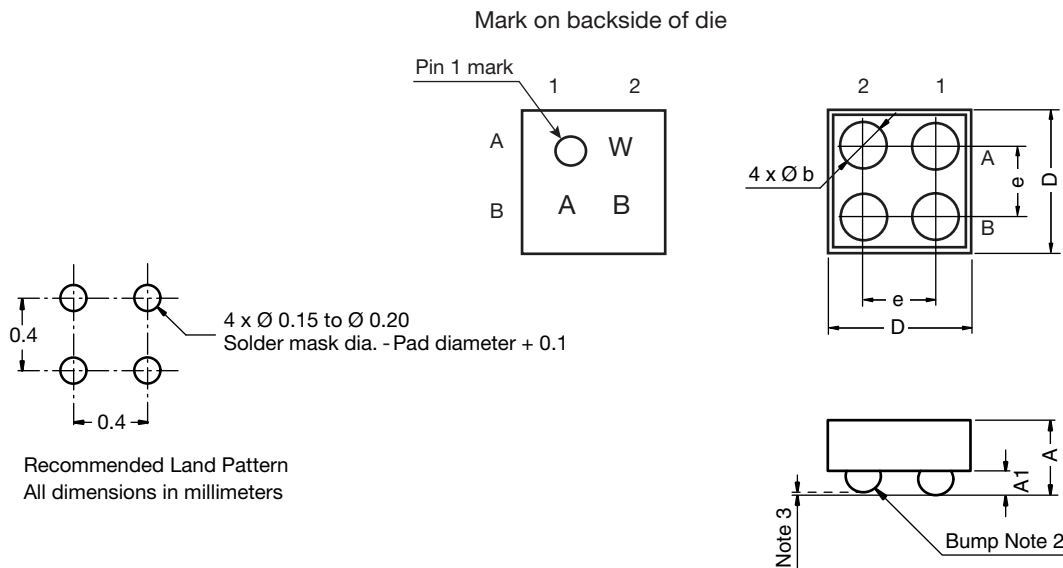
**PRODUCT SUMMARY**

| Part number                                        | SiP32460                                                                                 | SiP32461                                                                                                      | SiP32462                                                                                 |
|----------------------------------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Description                                        | 1.2 V to 5.5 V, 50 m $\Omega$ ,<br>200 $\mu$ s rise time,<br>bidirectional off isolation | 1.2 V to 5.5 V, 50 m $\Omega$ ,<br>200 $\mu$ s rise time,<br>bidirectional off isolation,<br>output discharge | 1.2 V to 5.5 V,<br>50 m $\Omega$ , 7.5 $\mu$ s rise time,<br>bidirectional off isolation |
| Configuration                                      | Single                                                                                   | Single                                                                                                        | Single                                                                                   |
| Slew rate time ( $\mu$ s)                          | 170                                                                                      | 170                                                                                                           | 7.5                                                                                      |
| On delay time ( $\mu$ s)                           | 130                                                                                      | 130                                                                                                           | -                                                                                        |
| Input voltage min. (V)                             | 1.2                                                                                      | 1.2                                                                                                           | 1.2                                                                                      |
| Input voltage max. (V)                             | 5.5                                                                                      | 5.5                                                                                                           | 5.5                                                                                      |
| On-resistance at input voltage min. (m $\Omega$ )  | 95                                                                                       | 95                                                                                                            | 95                                                                                       |
| On-resistance at input voltage max. (m $\Omega$ )  | 50                                                                                       | 50                                                                                                            | 50                                                                                       |
| Quiescent current at input voltage min. ( $\mu$ A) | 1.2                                                                                      | 1.2                                                                                                           | 1.2                                                                                      |
| Quiescent current at input voltage max. ( $\mu$ A) | 5.5                                                                                      | 5.5                                                                                                           | 5.5                                                                                      |
| Output discharge (yes / no)                        | No                                                                                       | Yes                                                                                                           | No                                                                                       |
| Reverse blocking (yes / no)                        | Yes                                                                                      | Yes                                                                                                           | Yes                                                                                      |
| Continuous current (A)                             | 1.2                                                                                      | 1.2                                                                                                           | 1.2                                                                                      |
| Package type                                       | WCSP4                                                                                    | WCSP4                                                                                                         | WCSP4                                                                                    |
| Package size (W, L, H) (mm)                        | 0.8 x 0.8 x 0.5                                                                          | 0.8 x 0.8 x 0.5                                                                                               | 0.8 x 0.8 x 0.5                                                                          |
| Status code                                        | 2                                                                                        | 2                                                                                                             | 2                                                                                        |
| Product type                                       | Slew rate                                                                                | Slew rate                                                                                                     | Slew rate                                                                                |
| Applications                                       | Computers, consumer,<br>industrial, healthcare,<br>networking, portable                  | Computers, consumer,<br>industrial, healthcare,<br>networking, portable                                       | Computers, consumer,<br>industrial, healthcare,<br>networking, portable                  |

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## WCSP4: 4 Bumps

(2 x 2, 0.4 mm pitch, 208 µm bump height, 0.8 mm x 0.8 mm die size)



DWG-No: 6004

### Notes

- (1) Laser mark on the backside surface of die
- (2) Bumps are SAC396
- (3) 0.05 max. coplanarity

| DIM. | MILLIMETERS <sup>a</sup> |       |       | INCHES |        |        |
|------|--------------------------|-------|-------|--------|--------|--------|
|      | MIN.                     | NOM.  | MAX.  | MIN.   | NOM.   | MAX.   |
| A    | 0.515                    | 0.530 | 0.545 | 0.0203 | 0.0209 | 0.0215 |
| A1   | 0.208                    |       |       | 0.0082 |        |        |
| 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 |

### Note

- a. Use millimeters as the primary measurement



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