

## Slew Rate Controlled Load Switch

### General Description

The AAT4282B SmartSwitch™ is a member of Skyworks' Application Specific Power MOSFET™ (ASPM™) product family. The AAT4282B is a dual P-channel MOSFET power switch designed for high-side load-switching applications. Each MOSFET has a typical  $R_{DS(ON)}$  of 67m $\Omega$ , allowing increased load switch current handling capacity with a low forward voltage drop. The AAT4282B offers a shutdown load discharge circuit to rapidly turn off a load circuit when the switch is disabled. A slew-rate selector pin can switch between fast and slow slew rate.

The AAT4282B load switch operates from 1.5V up to 6.5V, making it ideal for both 3V and 5V systems. Input logic levels are TTL and 2.5V to 5V CMOS compatible. The quiescent supply current is a very low, less than 1 $\mu$ A.

The AAT4282B is available in a Pb-free, low profile 2.0 × 2.0mm TDFN22-8 package and is specified over the -40°C to 85°C temperature range.

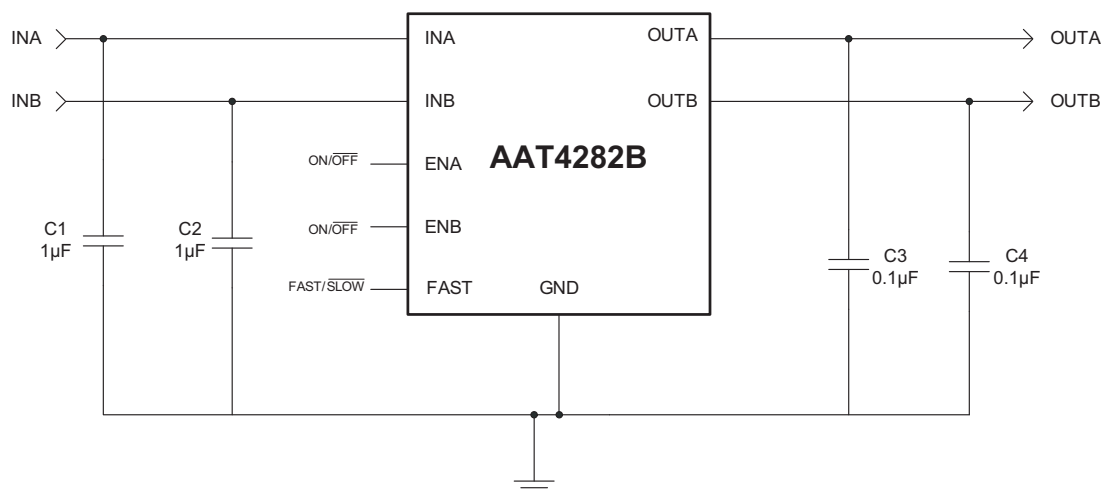
### Features

- $V_{IN}$  Range: 1.5V to 6.5V
- Low  $R_{DS(ON)}$ 
  - 67m $\Omega$  Typical @ 5V
  - 125m $\Omega$  Typical @ 1.8V
- Slew Rate Turn-On Time
  - 750 $\mu$ s - Slow (FAST = Low)
  - 65 $\mu$ s - Fast (FAST = High)
- Fast Shutdown Load Discharge Option
- Low Quiescent Current
  - 40nA Typical
- TTL/CMOS Input Logic Level
- Temperature Range -40°C to 85°C
- TDFN22-8 Package

### Applications

- Cellular Telephones
- Digital Still Cameras
- Hotswap Supplies
- Notebook Computers
- PDA Phones
- PDAs
- PMPs
- Smartphones

### Typical Application



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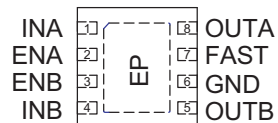
## Slew Rate Controlled Load Switch

### Pin Descriptions

| Pin # | Symbol | Function                                                                                                                                                  |
|-------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | INA    | This is the pin to the P-channel MOSFET source for Switch A. Bypass to ground through a 1 $\mu$ F capacitor. INA is independent of INB                    |
| 2     | ENA    | Active-High Enable Input A. A logic low turns the switch off and the device consumes less than 1 $\mu$ A of current. Logic high resumes normal operation. |
| 3     | ENB    | Active-High Enable Input B. A logic low turns the switch off and the device consumes less than 1 $\mu$ A of current. Logic high resumes normal operation. |
| 4     | INB    | This is the pin to the P-channel MOSFET source for Switch B. Bypass to ground through a 1 $\mu$ F capacitor. INB is independent of INA.                   |
| 5     | OUTB   | This is the pin to the P-channel MOSFET drain connection. Bypass to ground through a 0.1 $\mu$ F capacitor.                                               |
| 6     | GND    | Ground connection                                                                                                                                         |
| 7     | FAST   | Active-high input Switches between FAST (Logic H) and SLOW (Logic L) Slew rate                                                                            |
| 8     | OUTA   | This is the pin to the P-channel MOSFET drain connection. Bypass to ground through a 0.1 $\mu$ F capacitor.                                               |
| EP    | -      | Exposed Paddle. May be connected to ground. A large copper pad under the package is helpful for thermal dissipation.                                      |

### Pin Configuration

#### TDFN22-8 (Top View)



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### Absolute Maximum Ratings<sup>1</sup>

| Symbol         | Description                                      | Value                  | Units |
|----------------|--------------------------------------------------|------------------------|-------|
| $V_{IN}$       | IN to GND                                        | -0.3 to 6.5            | V     |
| $V_{EN, FAST}$ | EN, FAST to GND                                  | -0.3 to 6.5            |       |
| $V_{OUT}$      | OUT to GND                                       | -0.3 to $V_{IN} + 0.3$ |       |
| $I_{MAX}$      | Maximum Continuous Switch Current                | 3                      | A     |
| $I_{DM}$       | Maximum Pulsed Current (Duty Cycle $\leq 10\%$ ) | 5.5                    |       |
| $T_J$          | Junction Temperature Range                       | -40 to 150             | °C    |
| $T_{LEAD}$     | Maximum Soldering Temperature (at leads)         | 300                    |       |
| $V_{ESD}$      | ESD Rating <sup>2</sup> – HBM                    | 4                      | kV    |

### Thermal Characteristics<sup>3</sup>

| Symbol        | Description                            | Value | Units |
|---------------|----------------------------------------|-------|-------|
| $\theta_{JA}$ | Thermal Resistance                     | 74    | °C/W  |
| $P_D$         | Maximum Power Dissipation <sup>4</sup> | 1.35  | W     |

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied.
2. Human body model is a 100pF capacitor discharged through a 1.5k $\Omega$  resistor into each pin.
3. Mounted on a AAT4282B demo board in still 25°C air.
4. Refer to the section of "Thermal Considerations and High Output Current Applications" for the details.

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## Slew Rate Controlled Load Switch

### Electrical Characteristics<sup>1</sup>

$V_{IN} = 5V$ ,  $T_A = -40$  to  $85^\circ C$  unless otherwise noted. Typical values are at  $T_A = 25^\circ C$ .

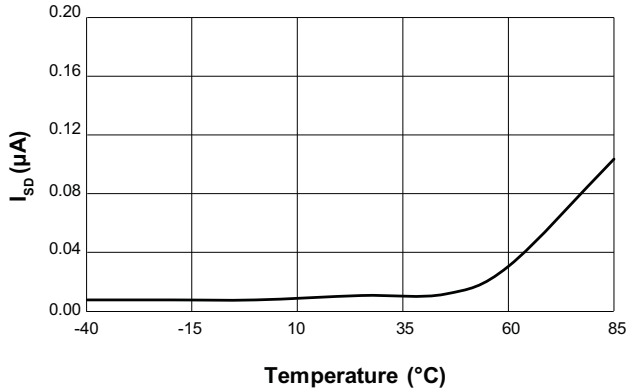
| Symbol        | Description                            | Conditions                                                               | Min | Typ  | Max  | Units           |
|---------------|----------------------------------------|--------------------------------------------------------------------------|-----|------|------|-----------------|
| $V_{IN}$      | Operation Voltage                      |                                                                          | 1.5 |      | 6.5  | V               |
| $I_Q$         | Quiescent Current                      | ON/OFF = ACTIVE, FAST = $V_{IN}$ , $I_{OUT} = 0$                         |     |      | 1.0  | $\mu A$         |
| $I_{Q(OFF)}$  | Off Supply Current                     | ON/OFF = INACTIVE, OUT = OPEN                                            |     |      | 1.0  |                 |
| $I_{SD(OFF)}$ | Off Switch Current                     | ON/OFF = GND, $V_{OUT} = 0$                                              |     |      | 1.0  |                 |
| $R_{DS(ON)}$  | On-Resistance A or B                   | $V_{IN} = 6.5V$ , $I_{LOAD} = 300mA$                                     |     | 63   |      | $m\Omega$       |
|               |                                        | $V_{IN} = 5.0V$ , $I_{LOAD} = 300mA$                                     |     | 67   | 130  |                 |
|               |                                        | $V_{IN} = 4.2V$ , $I_{LOAD} = 300mA$                                     |     | 71   | 140  |                 |
|               |                                        | $V_{IN} = 3.0V$ , $I_{LOAD} = 300mA$                                     |     | 82   | 160  |                 |
|               |                                        | $V_{IN} = 1.8V$ , $I_{LOAD} = 300mA$                                     |     | 125  | 230  |                 |
| $TCR_{RDS}$   | On Resistance Temperature Coefficient  |                                                                          |     | 2800 |      | ppm/ $^\circ C$ |
| $V_{IL}$      | ON/OFF Input Logic Low Voltage         | $V_{IN} = 1.5V$                                                          |     |      | 0.4  | V               |
| $V_{IH}$      | ON/OFF Input Logic High Voltage        | $V_{IN} = 5V$                                                            | 1.4 |      |      |                 |
| $I_{SINK}$    | ON/OFF Input Leakage                   | $V_{ON/OFF} = 5.5V$                                                      |     |      | 1.0  | $\mu A$         |
| $t_{D(ON)}$   | Output Turn-On Delay Time              | $V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$ , $T_A = 25^\circ C$               |     | 13   | 40   | $\mu s$         |
| $t_{ON}$      | Turn-On Rise Time                      | $V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$ , FAST = $5V$ , $T_A = 25^\circ C$ |     | 65   | 150  |                 |
| $t_{ON}$      | Turn-On Rise Time                      | $V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$ , FAST = $0V$ , $T_A = 25^\circ C$ |     | 750  | 1500 |                 |
| $t_{D(OFF)}$  | Output Turn-OFF Delay Time             | $V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$ , $T_A = 25^\circ C$               |     | 1    | 10   |                 |
| $R_{PD}$      | Output Pull-Down Resistance During OFF | ON/OFF = Inactive, $T_A = 25^\circ C$                                    |     | 150  | 250  | $\Omega$        |

1. The AAT4282B is guaranteed to meet performance specifications over the  $-40^\circ C$  to  $+85^\circ C$  operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

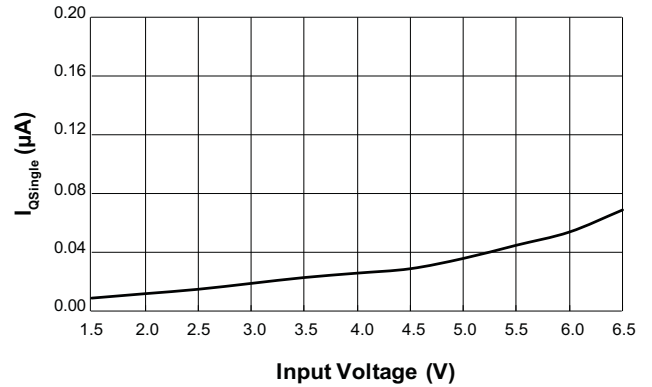
### Typical Characteristics

Unless otherwise noted,  $V_{IN} = 5V$ ,  $T_A = 25^\circ C$ .

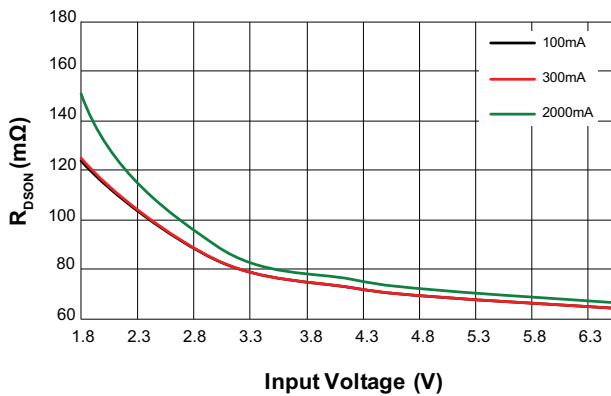
**Off Supply Current vs. Temperature**  
( $V_{IN} = 5.0V$ ,  $EN = 0V$ ; No Load)



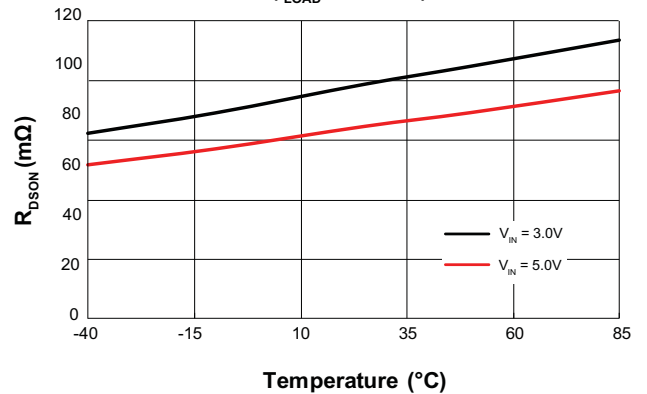
**Quiescent Current vs. Input Voltage**  
(No Load; Single Switch)



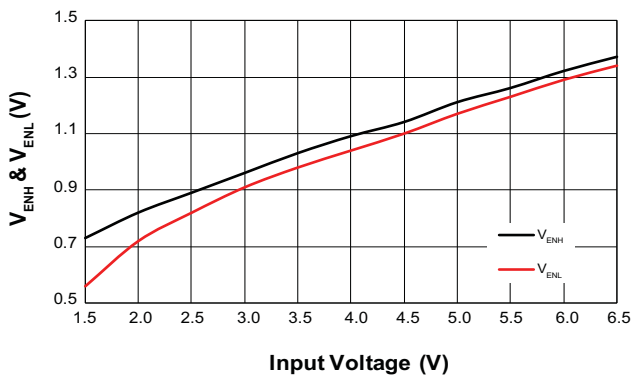
**On-Resistance vs. Input Voltage**



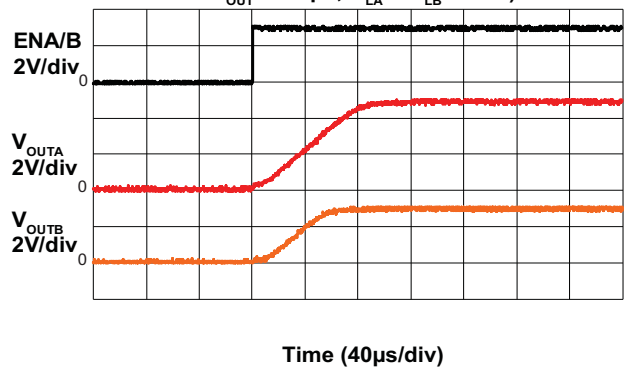
**On-Resistance vs. Temperature**  
( $I_{LOAD} = 300mA$ )



**EN Input ON/OFF Threshold vs. Input Voltage**



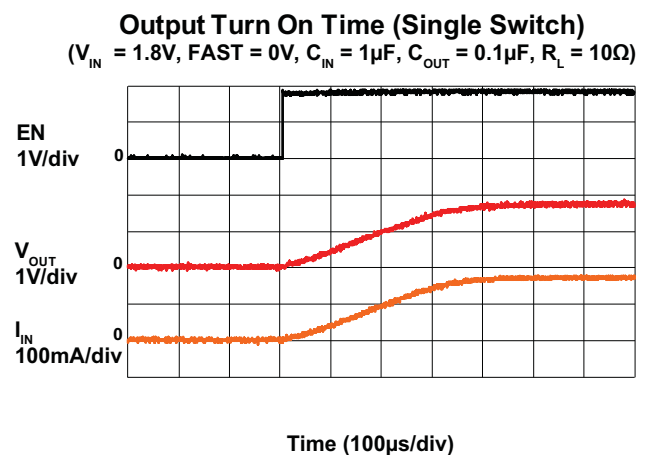
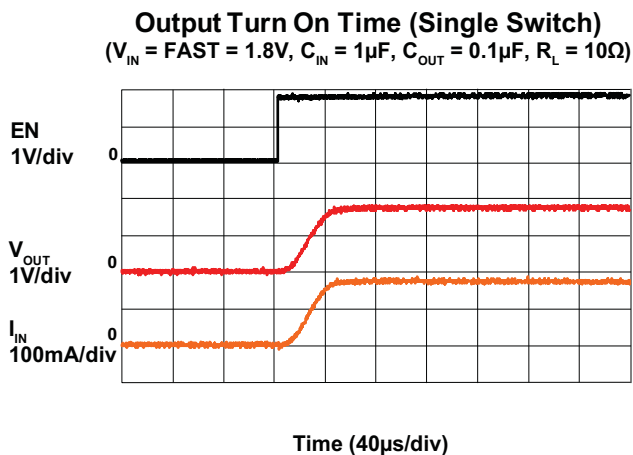
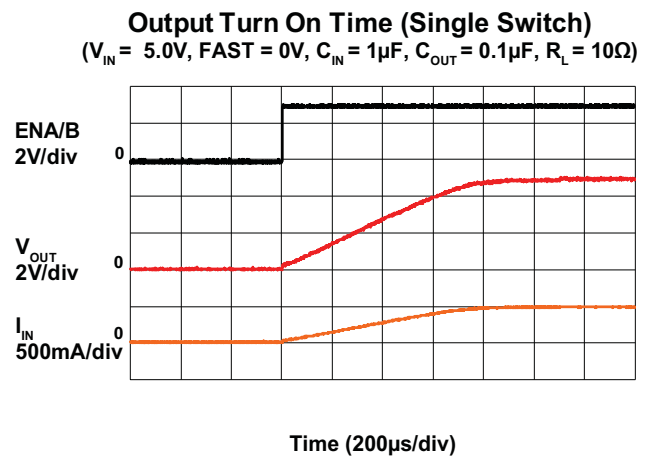
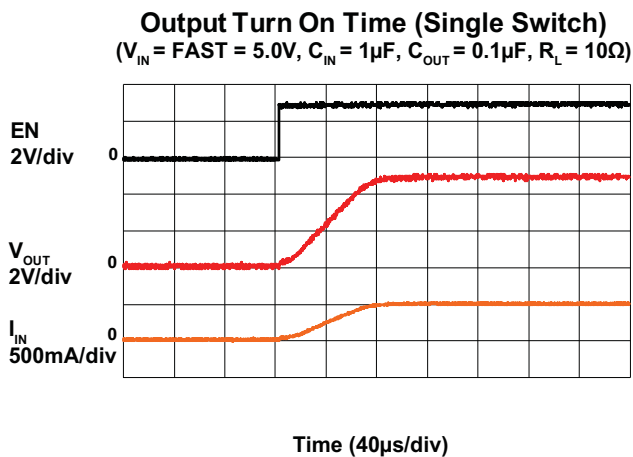
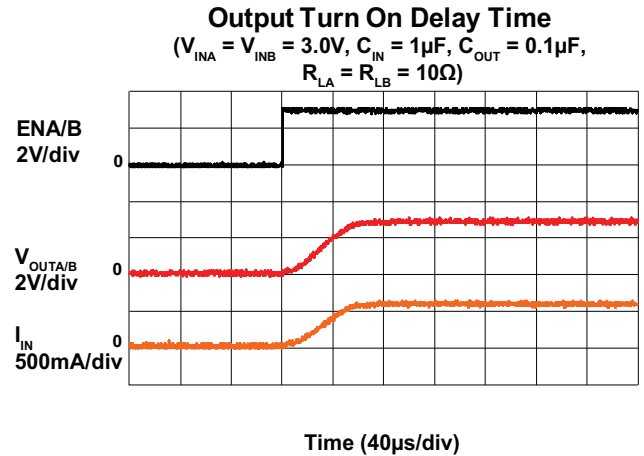
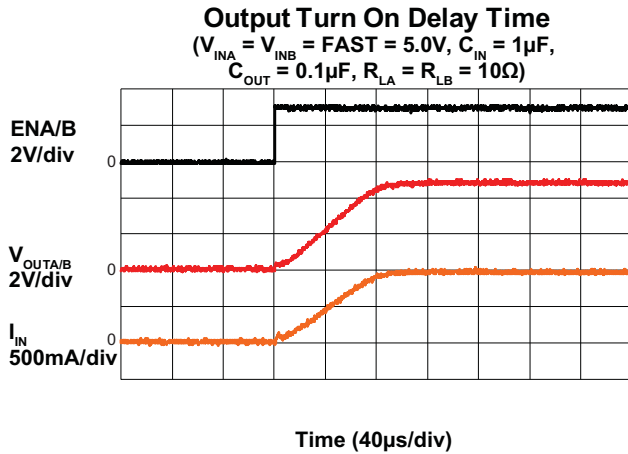
**Output Turn On Delay Time**  
( $V_{INA} = 5.0V$ ,  $V_{INB} = 3.0V$ ,  $FAST = 3.0V$ ,  $C_{IN} = 1\mu F$ ,  
 $C_{OUT} = 0.1\mu F$ ,  $R_{LA} = R_{LB} = 10\Omega$ )



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### Typical Characteristics

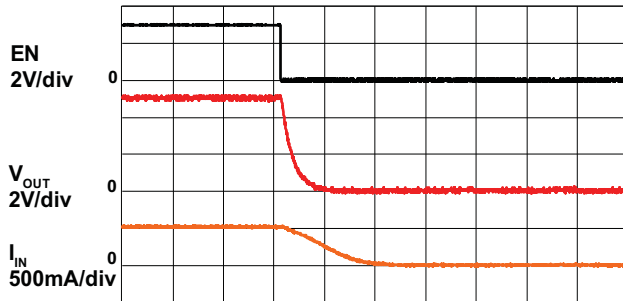
Unless otherwise noted,  $V_{IN} = 5V$ ,  $T_A = 25^\circ C$ .



## Typical Characteristics

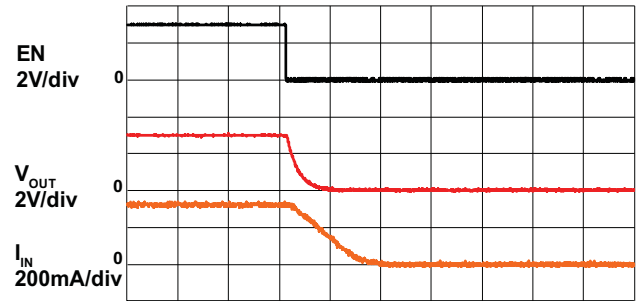
Unless otherwise noted,  $V_{IN} = 5V$ ,  $T_A = 25^\circ C$ .

**Output Turn Off Delay Time (Single Switch)**  
 $(V_{IN} = 5.0V, C_{IN} = 1\mu F, C_{OUT} = 0.1\mu F, R_L = 10\Omega)$



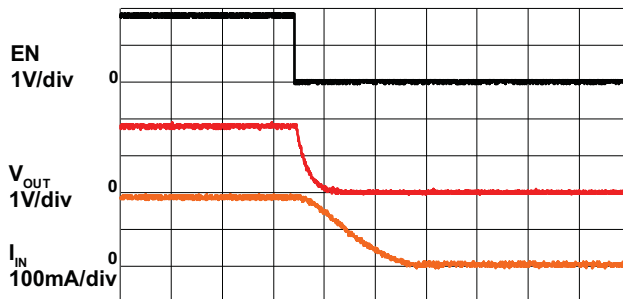
Time (4μs/div)

**Output Turn Off Delay Time (Single Switch)**  
 $(V_{IN} = 3.0V, C_{IN} = 1\mu F, C_{OUT} = 0.1\mu F, R_L = 10\Omega)$



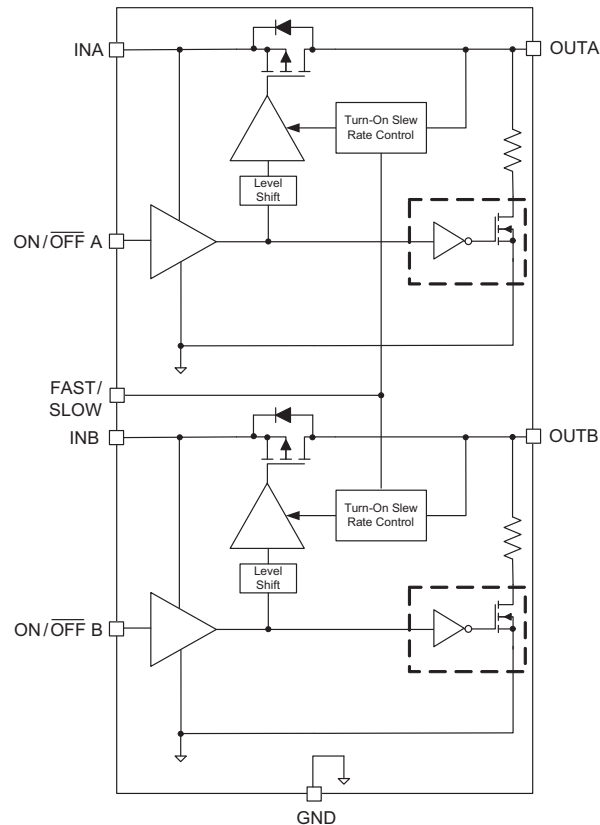
Time (4μs/div)

**Output Turn Off Delay Time (Single Switch)**  
 $(V_{IN} = 1.8V, C_{IN} = 1\mu F, C_{OUT} = 0.1\mu F, R_L = 10\Omega)$



Time (4μs/div)

## Functional Block Diagram



## Functional Description

The AAT4282B is a flexible dual P-channel MOSFET power switch designed for high-side load switching applications. During turn-on slewing, the current ramps linearly until it reaches the level required for the output load condition. The proprietary turn-on current control method works by careful control and monitoring of the MOSFET gate voltage. When the device is switched ON, the gate voltage is quickly increased to the threshold level of the MOSFET. Once at this level, the current begins to slew as the gate voltage is slowly increased until the MOSFET becomes fully enhanced. Once it has reached this point, the gate is quickly increased to the full input voltage and the  $R_{DS(ON)}$  is minimized.

The AAT4282B has a minimized slew rate limited turn-on function and a shutdown output discharge circuit to rapidly turn off a load when the load switch is disabled through the ON/OFF pin. Using the FAST input pin on the AAT4282B, the device can be manually switched to a slower slew rate.

The AAT4282B operates with input voltages ranging from 1.5V to 6.5V. This device has an extremely low operating current, making it ideal for battery-powered applications.

The ON/OFF control pin is TTL compatible and will also function with 2.5V to 5V logic systems, making the AAT4282B an ideal level-shifting load switch.



## *Slew Rate Controlled Load Switch*

### Applications Information

#### Input Capacitor

A 1 $\mu$ F or larger capacitor is typically recommended for C<sub>IN</sub> in most applications. A C<sub>IN</sub> capacitor is not required for basic operation; however, it is useful in preventing load transients from affecting upstream circuits. C<sub>IN</sub> should be located as close to the device VIN pin as practically possible. Ceramic, tantalum, or aluminum electrolytic capacitors may be selected for C<sub>IN</sub>. There is no specific capacitor equivalent series resistance (ESR) requirement for C<sub>IN</sub>. However, for higher current operation, ceramic capacitors are recommended for C<sub>IN</sub> due to their inherent capability over tantalum capacitors to withstand input current surges from low-impedance sources, such as batteries in portable devices.

#### Output Capacitor

For proper slew operation, a 0.1 $\mu$ F capacitor or greater is required between VOUT and GND. Likewise, with the output capacitor, there is no specific capacitor ESR requirement. If desired, C<sub>OUT</sub> may be increased without limit to accommodate any load transient condition without adversely affecting the slew rate.

#### Enable Function

The AAT4282B features an enable / disable function. This pin (ENx) is active high and is compatible with TTL or CMOS logic. To assure the load switch will turn on, the signal level must be greater than 1.4V. The load switch will go into shutdown mode when the voltage on the ENx pin falls below 0.4V. When the load switch is in shutdown mode, the OUT pin is tri-stated, and the quiescent current drops to leakage levels below 1 $\mu$ A.

#### Reverse Output-to-Input Voltage Conditions and Protection

Under normal operating conditions, a parasitic diode exists between the output and input of the load switch. The input voltage should always remain greater than the output load voltage, maintaining a reverse bias on the internal parasitic diode. Conditions where V<sub>OUT</sub> might exceed V<sub>IN</sub> should be avoided since this would forward

bias the internal parasitic diode and allow excessive current flow into the VOUT pin, possibly damaging the load switch. In applications where there is a possibility of V<sub>OUT</sub> exceeding V<sub>IN</sub> for brief periods of time during normal operation, the use of a larger value C<sub>IN</sub> capacitor is highly recommended. A larger value of C<sub>IN</sub> with respect to C<sub>OUT</sub> will effect a slower C<sub>IN</sub> decay rate during shutdown, thus preventing V<sub>OUT</sub> from exceeding V<sub>IN</sub>. In applications where there is a greater danger of V<sub>OUT</sub> exceeding V<sub>IN</sub> for extended periods of time, it is recommended to place a Schottky diode from V<sub>IN</sub> to V<sub>OUT</sub> (connecting the cathode to V<sub>IN</sub> and anode to V<sub>OUT</sub>). The Schottky diode forward voltage should be less than 0.45V.

#### Thermal Considerations and High Output Current Applications

The AAT4282B is designed to deliver a continuous output load current. The limiting characteristic for maximum safe operating output load current is package power dissipation. In order to obtain high operating currents, careful device layout and circuit operating conditions must be taken into account.

The following discussions will assume the load switch is mounted on a printed circuit board utilizing the minimum recommended footprint as stated in the Printed Circuit Board Layout Recommendations section of this data-sheet.

At any given ambient temperature (T<sub>A</sub>), the maximum package power dissipation can be determined by the following equation:

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

Constants for the AAT4282B are maximum junction temperature (T<sub>J(MAX)</sub> = 125°C)<sup>1</sup> and package thermal resistance ( $\theta_{JA}$  = 74°C/W). Worst case conditions are calculated at the maximum operating temperature, T<sub>A</sub> = 85°C. Typical conditions are calculated under normal ambient conditions where T<sub>A</sub> = 25°C. At T<sub>A</sub> = 85°C, P<sub>D(MAX)</sub> = 541mW. At T<sub>A</sub> = 25°C, P<sub>D(MAX)</sub> = 1351mW.

The maximum continuous output current for the AAT4282B is a function of the package power dissipation and the R<sub>DS</sub> of the MOSFET at T<sub>J(MAX)</sub>. The maximum R<sub>DS</sub> of the MOSFET at T<sub>J(MAX)</sub> is calculated by increasing the

1. The actual maximum junction temperature of AAT4282B is 150°C. However, good design practice is to derate the maximum die temperature to 125°C to prevent the possibility of over-temperature damage.

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maximum room temperature  $R_{DS}$  by the  $R_{DS}$  temperature coefficient. The temperature coefficient (TC) is 2800ppm/°C. Therefore, at 125°C:

$$R_{DS(MAX)} = R_{DS(25^{\circ}C)} \cdot (1 + TC \cdot \Delta T)$$

$$R_{DS(MAX)} = 130m\Omega \cdot (1 + 0.002800 \cdot (125^{\circ}C - 25^{\circ}C))$$

$$R_{DS(MAX)} = 166.4m\Omega$$

For maximum current, refer to the following equation:

$$I_{OUT(MAX)} < \sqrt{\frac{P_{D(MAX)}}{R_{DS}}}$$

For example, if  $V_{IN} = 5V$ ,  $R_{DS(MAX)} = 166.4m\Omega$ , and  $T_A = 25^{\circ}C$ ,  $I_{OUT(MAX)} = 2.93A$ . If the output load current were to exceed 2.93A or if the ambient temperature were to increase, the internal die temperature would increase and the device would be damaged. Higher peak currents can be obtained with the AAT4282B. To accomplish this, the device thermal resistance must be reduced by increasing the heat sink area or by operating the load switch in a duty cycle manner. Duty cycles with peaks less than 2ms in duration can be considered using the method described in the High Peak Current Applications section of this datasheet.

### High Peak Output Current Applications

Some applications require the load switch to operate at a continuous nominal current level with short duration, high-current peaks. Refer to the  $I_{DM}$  specification in the Absolute Maximum Ratings table to ensure the AAT4282B's maximum pulsed current rating is not exceeded. The duty cycle for both output current levels must be taken into account. To do so, first calculate the power dissipation at the nominal continuous current level, and then add the additional power dissipation due to the short duration, high-current peak scaled by the duty factor. For example, a 4V system using an AAT4282B which has channel A operates at a continuous 1A load current level, and channel B operates at a continuous 100mA load current level and has short 3A current peaks, as in a GSM application. The current peak occurs for 576μs out of a 4.61ms period. First, the current duty cycle is calculated:

$$\% \text{ Peak Duty Cycle} = \frac{x}{100} = \frac{576\mu s}{4.61ms}$$

$$\% \text{ Peak Duty Cycle} = 12.5\%$$

The load current is 100mA for 87.5% of the 4.61ms period and 3A for 12.5% of the period. Since the Electrical Characteristics do not report  $R_{DS(MAX)}$  for 4V

operation, it must be approximated by consulting the chart of  $R_{DS(ON)}$  vs.  $V_{IN}$ . The  $R_{DS}$  reported for 5V at 100mA and 3A can be scaled by the ratio seen in the chart to derive the  $R_{DS}$  for 4V  $V_{IN}$  at 25°C:  $130m\Omega \cdot 72m\Omega/67m\Omega = 139.7m\Omega$ . De-rated for temperature:  $139.7m\Omega \cdot (1 + 0.002800 \cdot (125^{\circ}C - 25^{\circ}C)) = 178.8m\Omega$ .

For channel A, the power dissipation for a continuous 1A load is calculated as follows:

$$P_{D(CHA)} = I_{OUT}^2 \cdot R_{DS} = (1A)^2 \cdot 178.8m\Omega = 178.8mW$$

For channel B, the power dissipation for 100mA load is calculated as follows:

$$P_{D(MAX)} = I_{OUT}^2 \cdot R_{DS}$$

$$P_{D(100mA)} = (100mA)^2 \cdot 178.8m\Omega$$

$$P_{D(100mA)} = 1.79mW$$

$$P_{D(87.5\%D/C)} = \%DC \cdot P_{D(100mA)}$$

$$P_{D(87.5\%D/C)} = 0.875 \cdot 1.79mW$$

$$P_{D(87.5\%D/C)} = 1.57mW$$

The power dissipation for 100mA load at 87.5% duty cycle is 1.57mW. Now the power dissipation for the remaining 12.5% of the duty cycle at 3A is calculated:

$$P_{D(MAX)} = I_{OUT}^2 \cdot R_{DS}$$

$$P_{D(3A)} = (3A)^2 \cdot 178.8m\Omega$$

$$P_{D(3A)} = 1609mW$$

$$P_{D(12.5\%D/C)} = \%DC \cdot P_{D(3A)}$$

$$P_{D(12.5\%D/C)} = 0.125 \cdot 1609mW$$

$$P_{D(12.5\%D/C)} = 201.1mW$$

Finally, the total power dissipation for channels A and B is determined as follows:

$$P_{D(total)} = P_{D(CHA)} + P_{D(100mA)} + P_{D(3A)}$$

$$P_{D(total)} = 178.8mW + 1.57mW + 201.1mW$$

$$P_{D(total)} = 381mW$$

The maximum power dissipation for the AAT4282B operating at an ambient temperature of 85°C is 381mW. The device in this example will have a total power dissipation of 541mW. This is well within the thermal limits for safe operation of the device; in fact, at 85°C, the AAT4282B will handle a 3A pulse for up to 22 duty cycle. At lower ambient temperatures, the duty cycle can be further increased.

# AAT4282B

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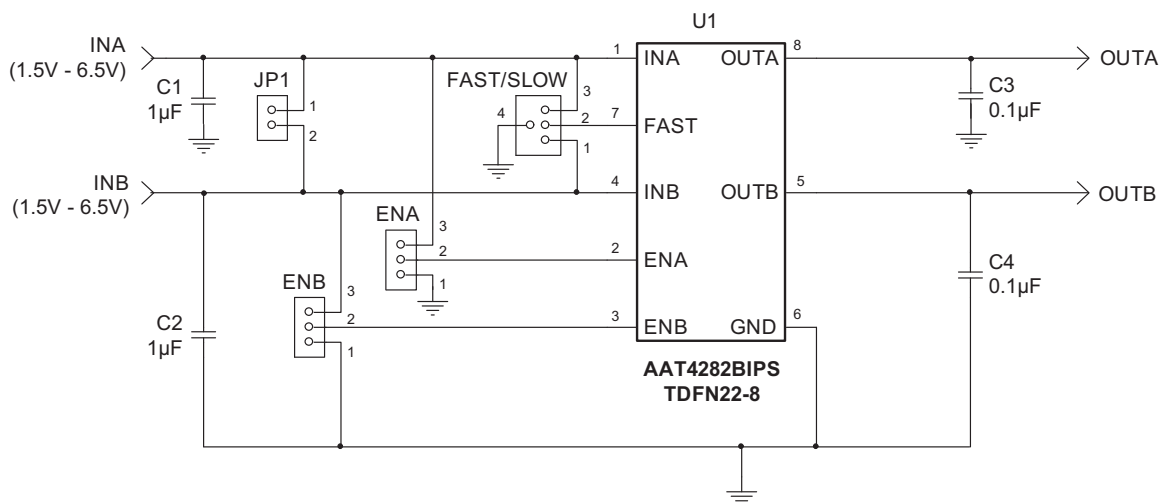
### Printed Circuit Board Layout Recommendations

For proper thermal management, and to take advantage of the low  $R_{DS(ON)}$  of the AAT4282B, a few circuit board layout rules should be followed:  $V_{IN}$  and  $V_{OUT}$  should be routed using wider than normal traces, and GND should be connected to a ground plane. For best performance,  $C_{IN}$  and  $C_{OUT}$  should be placed close to the package pins.

### Evaluation Board Layout

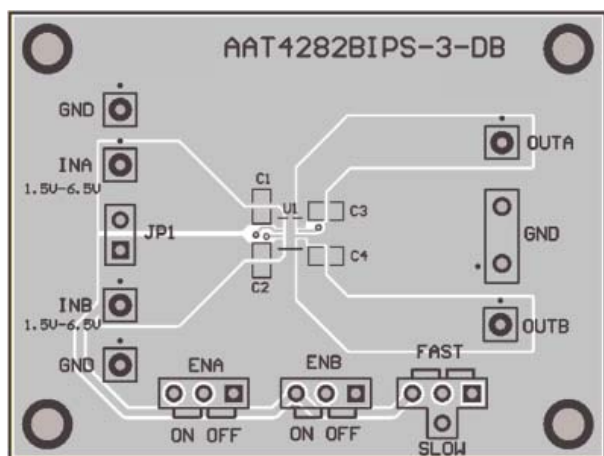
The AAT4282B evaluation layout follows the printed circuit board layout recommendations and can be used for good applications layout. Refer to Figures 1 and Figure 2.

Note: Board layout shown is not to scale.

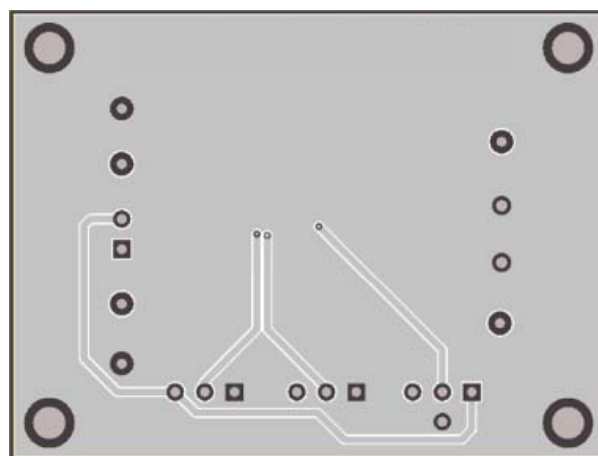


C1, C2 1µF 0603 X5R 10V (P/N: GRM188R61A105KA61D)  
C3, C4 0.1µF 0603 X5R 10V (P/N: GRM188R71C104KA01D)

**Figure 1: AAT4282BIPS Evaluation Board Schematic.**



**(a) Top Side**



**(b) Bottom Side**

**Figure 2: AAT4282BIPS Evaluation Board Layout.**

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## Slew Rate Controlled Load Switch

### Ordering Information

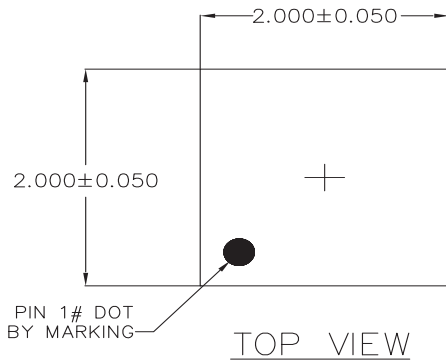
| Package  | Marking <sup>1</sup> | Part Number (Tape and Reel) <sup>2</sup> |
|----------|----------------------|------------------------------------------|
| TDFN22-8 | W9XYY                | AAT4282BIPS-3-T1                         |



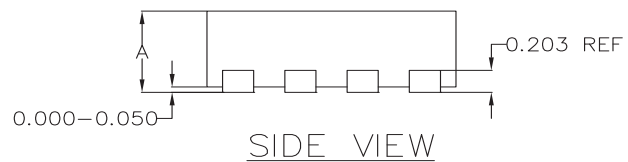
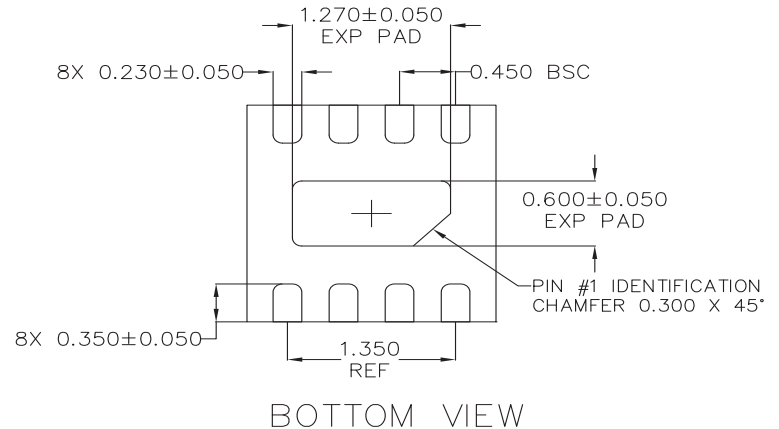
Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

### Package Information<sup>3</sup>

#### TDFN22-8



|   |      |       |
|---|------|-------|
| A | MAX. | 0.800 |
|   | NOM. | 0.750 |
|   | MIN. | 0.700 |



NOTES:  
1. PLATING REQUIREMENT PER SOURCE CONTROL DRAWING (SCD) 2504.

OUTLINE: DFN  
8 LEADS, 2 X 2 X 0.75 MM  
1.27 X 0.6 MM EXPOSED PADDLE  
0.450 MM PITCH

All dimensions in millimeters.

1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.
3. The leadless package family, which includes QFN, TQFN, DFN, FTDFN, TDFN and STDFN, has exposed copper (unplated) at the end of the lead terminals due to the manufacturing process. A solder fillet at the exposed copper edge cannot be guaranteed and is not required to ensure a proper bottom solder connection.

# DATA SHEET

# AAT4282B

## *Slew Rate Controlled Load Switch*

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