AAT4625
USB Single-Channel Power Switch

SmartSwitch™

General Description

The AAT4625 SmartSwitch™ is part of AnalogicTech's Application Specific Power MOSFET™ (ASPM™) product family. It is a 1.0A Current Limited P-channel, MOSFET power switch designed for high-side load-switching applications. This switch operates with inputs ranging from 2.7V to 5.5V, making it ideal for both 3V and 5V systems. An integrated current-limiting circuit protects the input supply against large changes in load current which may cause the supply to fall out of regulation. The AAT4625 is also protected from thermal over-load which limits power dissipation and junction temperatures. The current limit threshold is factory programmed at 1.5A, with a maximum of 2.0A. The quiescent supply current is typically a low 16µA. In shutdown mode, the supply current decreases to less than 1µA.

The AAT4625 is available in 8 pin SOP, TSSOP, or MSOP and is specified over a -40 to 85°C temperature range.

The AAT4600 Series is a family of adjustable and fixed SmartSwitch™ products with a range of current handling capabilities. Single versions with adjustable current limit (AAT4601) or fixed current limit (AAT4625) as well as dual versions with fixed current limit (AAT4626) are available.

Features

- Compliant with USB 1.1 and 2.0 specifications
- 2.7V to 5.5V Input voltage range
- 1.0A minimum continuous current
- 2.0A maximum current limit
- 60mΩ typical $R_{DS(ON)}$
- Low quiescent current
  - Typically 16µA
  - 1µA max with Switch off
- Thermal shutdown
- Slew rate limited turn on
- Fault flag with 10ms blanking
- Undervoltage Lockout
- Temp range -40 to 85°C
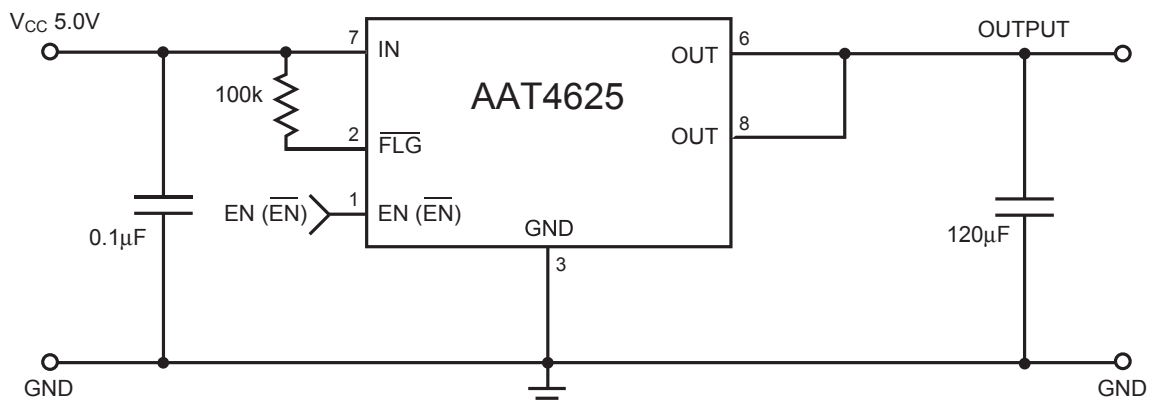- UL Approved—File No. E217765
- 8 pin SOP, TSSOP, or MSOP package

Applications

- USB ports and peripherals
- Notebook computers
- Hot swap supplies
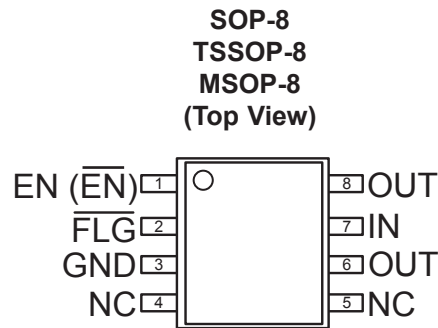- General purpose power switching

UL Recognized Component

Typical Application

Pin Descriptions

Pin #	Symbol	Function
1	EN ($\overline{\text{EN}}$)	Enable Input: Logic-compatible enable input. High input > 2.1V typical. Low input < 1.9V typical. Active high or active low option available; see Ordering Information for details.
2	$\overline{\text{FLG}}$	Fault Flag Output: Active-low, open-drain output. Indicates over current, UVLO and thermal shutdown.
3	GND	Ground connection
4,5	NC	Not internally connected.
6,8	OUT	Switch Output: These pins are the P-channel MOSFET drain connection.
7	IN	Supply Input: This pin is the P-channel MOSFET source connection. Also supplies the IC's internal circuitry.

Pin Configuration

SOP-8
TSSOP-8
MSOP-8
(Top View)

```
EN (EN) ─1        8─ OUT
  FLG ─2          7─ IN
  GND ─3          6─ OUT
   NC ─4          5─ NC
```

Absolute Maximum Ratings (T_A=25°C unless otherwise noted)

Symbol	Description	Value	Units
V_{IN}	IN to GND	-0.3 to 6	V
V_{FLG}	FLG to GND	-0.3 to 6	V
I_{FLG}	FLG Current	50	mA
V_{OUT}	OUT to GND	-0.3 to V_{IN}+0.3	V
I_{OUT}	Output Current (Internally Limited)	2.0	A
V_{EN}	EN to GND	-0.3 to 6	V
T_S	Storage Temperature	150	°C
T_{LEAD}	Maximum Soldering Temperature (at Leads)	300	°C

Note: 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. Only one Absolute Maximum rating should be applied at any one time.

Thermal Information

Symbol	Description	Value	Units
Θ_{JA}	Maximum Thermal Resistance (SOP-8)[1]	120	°C/W
Θ_{JA}	Maximum Thermal Resistance (TSSOP-8)[1]	150	°C/W
Θ_{JA}	Maximum Thermal Resistance (MSOP-8)[1]	150	°C/W
P_D	Maximum Power Dissipation (SOP-8)[1]	1.0	W
P_D	Maximum Power Dissipation (TSSOP-8)[1]	833	mW
P_D	Maximum Power Dissipation (MSOP-8)[1]	833	mW

Note 1: Mounted on an FR4 printed circuit board.

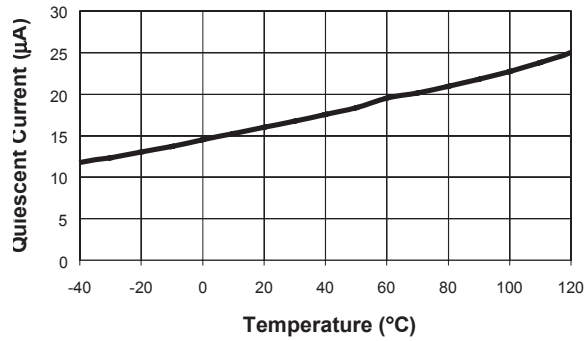## Electrical Characteristics (V_{IN} = 5V, T_A = -40 to 85°C unless otherwise noted. Typical values are at T_A=25°C; **bold** values designate full temperature range)

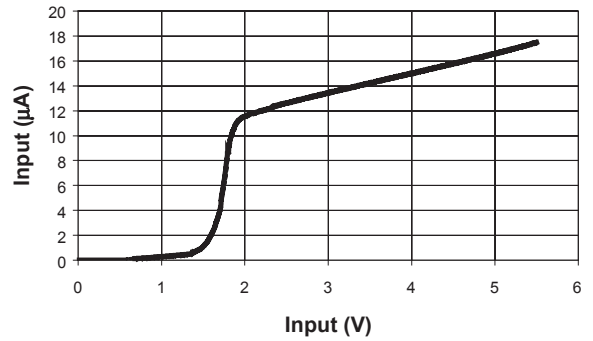| Symbol	Description	Conditions	Min	Typ	Max	Units
V_{IN}	Operation Voltage		2.7		5.5	V
I_Q	Quiescent Current	V_{IN}=5V, EN=active		16	**30**	µA
$I_{Q(OFF)}$	Off Supply Current	V_{IN}=5.5V, EN ($\overline{EN}$)=inactive			**1**	µA
$V_{EN-THRSH}$	Enable Input Threshold	Low-to-high transition			**2.4**	V
		High-to-low transition	**0.8**			V
I_{EN}	Enable Input Current	V_{EN} = 0V to 5.5V		0.01	**1**	µA
C_{EN}	Enable Input Capacitance			1		pF
$R_{ds(ON)}$	On-Resistance	V_{IN} =5V, T_A = 25°C		60	100	mΩ
		V_{IN} =3.0V, T_A = 25°C		70	115	mΩ
T_{ON}	Output Turn-On Delay	V_{IN} =5V, R_L=10Ω		0.25		ms
$T_{ON-RISE}$	Output Turn-On Rise Time	V_{IN} =5V, R_L=10Ω		0.2		ms
T_{OFF}	Output Turn-Off Delay	V_{IN} =5V, R_L=10Ω		5	**20**	µs
$T_{OFF-FALL}$	Output Turn-Off Fall Time	V_{IN} =5V, R_L=10Ω			**20**	µs
$I_{SD(OFF)}$	Output Leakage Current	EN=inactive, V_{IN}=5.5V, V_{OUT}=0V		0.03	**15**	µA
I_{LIMIT}	Current Limit Threshold	ramped load applied to enable output, V_{OUT} < 4.0V	**1.0**	1.5	**2.0**	A
OTMP	Over Temperature Shut Down	T_J increasing		125		°C
		T_J decreasing		115		°C
R_{FLG}	Error Flag Output Resistance	V_{IN} =5V, I_L = 1mA		30		Ω
I_{SINK}	Error Flag Off Current	V_{FLG} = 5.5V		0.05	**1**	µA
V_{UVLO}	Under voltage Lockout	V_{IN} = increasing, 1% hysteresis	**2.0**	2.3	**2.7**	V
T_{BLANK}	FAULT blanking			10		ms

Typical Characteristics

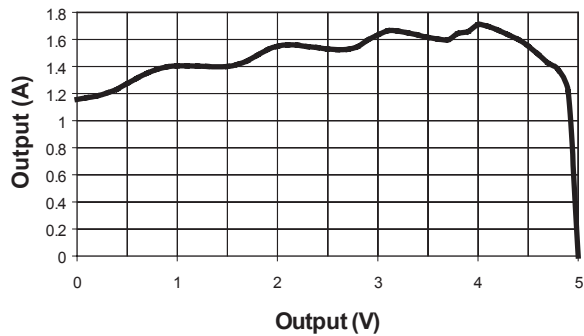(Unless otherwise noted, V_{IN} = 5V, T_A = 25°C)
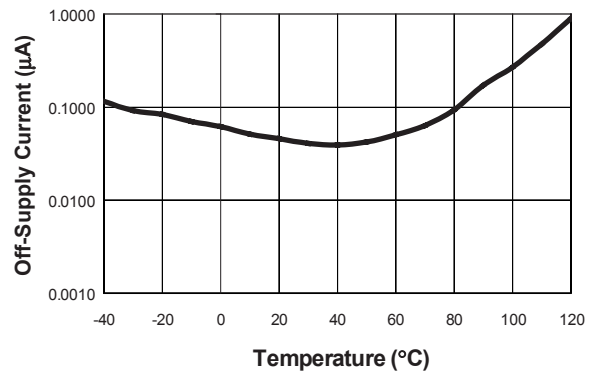
Quiescent Current vs. Temperature
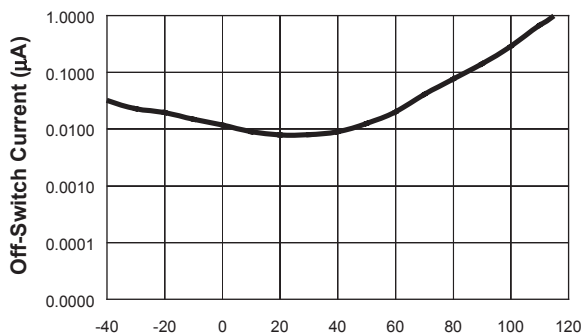

Quiescent Current
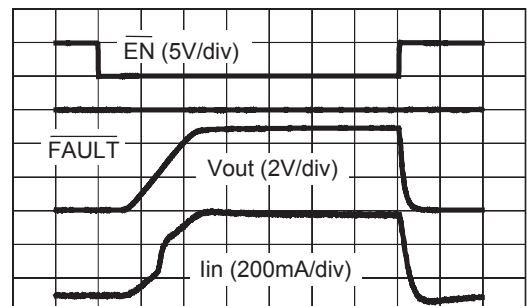

Current Limit

Off-Supply Current vs. Temperature
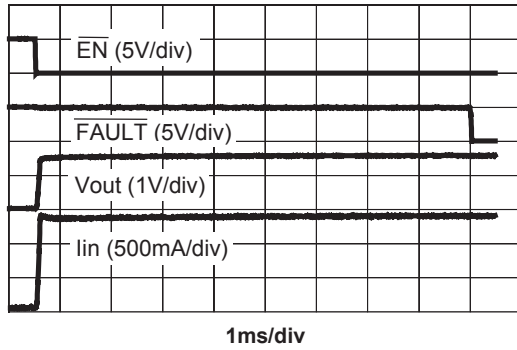

Off-Switch Current vs. Temperature

Turn-ON/OFF Response with 10 Ohm 1µF load

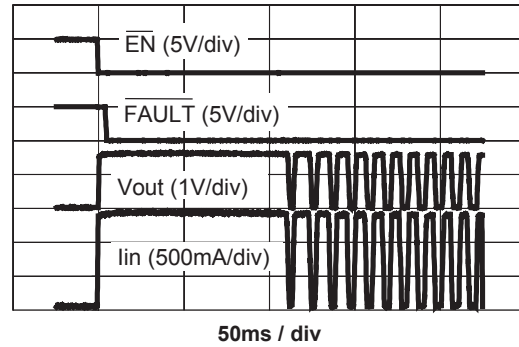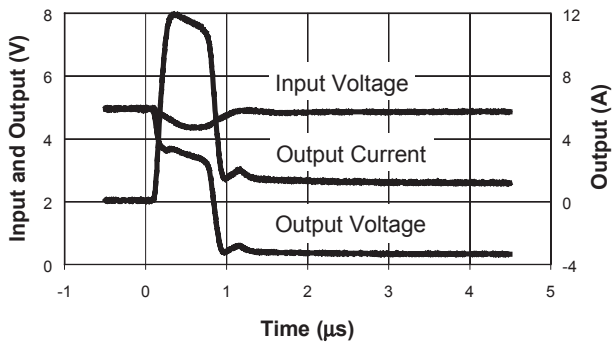(Unless otherwise noted, V_{IN} = 5V, T_A = 25°C)

Start Into 1 Ohm load

EN (5V/div)

FAULT (5V/div)

Vout (1V/div)

Iin (500mA/div)

1ms/div

Thermal Shutdown Response

EN (5V/div)

FAULT (5V/div)

Vout (1V/div)

Iin (500mA/div)

50ms / div

Short Circuit Through 0.3 Ohm

Input Voltage

Output Current

Output Voltage

Short Circuit Through 0.6 Ohm

Input Voltage

Output Current

Output Voltage

$R_{ds(ON)}$ vs. Temperature

V_{CC}=3V

V_{CC}=5V

Functional Block Diagram

Functional Description

The AAT4625 is an integrated MOSFET load switch with a fixed current limit, over temperature protection, level shifted input and a fault flag. The current limit control is combined with an over temperature thermal limit circuit to provide a comprehensive system to protect the load switch under short circuit or other adverse operating conditions. The AAT4625 is ideally suited for control and protection of peripheral ports such as USB, RS232 and parallel ports.

The current limit and over temperature circuits will act independently. The device current limit is activated when the output load current exceeds a preset internal threshold level. The minimum current limit threshold characteristic is specified by $I_{LIM(MIN)}$. If the load switch ambient temperature becomes excessive or if a short circuit condition persists, the die temperature will rise causing the over temperature protection circuit to activate.

If the current limit or over temperature protection circuits are active for more then two milliseconds, the system will be informed via the FAULT Flag. A ten millisecond fault blanking delay allows the AAT4625 to be turned on into large capacitive loads without activating the FAULT Flag. The open drain FAULT output can be connected directly to system controllers driven by voltage levels less than the IN pin voltage without additional level shifting circuitry.

The load switch is turned on and off by applying a logic level signal to the EN pin. The AAT4625 enable function is available in both active high and active low logic level versions. The AAT4625 typically consumes 16µA when operating, when off, the device draws less then 1µA. In the off state, current is prevented from flowing between the input and output. The EN function has logic level thresholds that allow the AAT4625 to be TTL compatible and may also be controlled by 2.5V to 5.0V CMOS circuits. The voltage level on either EN or FAULT should not exceed the input supply level present on the IN pin.

Applications Information

Operation in Current Limit

If an excessive load is applied to the output of an AAT4625, the load current will be limited by the AAT4625's current limit circuitry. Refer to the "Current Limit" figure in the typical characteristics section of this data sheet. If a short circuit were to occur on the load, there would be a demand for more current than what is allowed by the internal current limiting circuit and the voltage at the device output will drop. This causes the AAT4625 to dissipate more power than in normal operation, causing the die temperature to increase. When die temperature exceeds the internal over temperature threshold, the AAT4625 will shut down. After shutting down, the AAT4625 cools to a level below the over temperature threshold, at which point it will start up again. The AAT4625 will continue to cycle off and on until one of the following events occurs; the load current is reduced to a level below the AAT4625's current limit setting, the input power is removed, or until the output is turned off by a logic high level applied to the EN pin.

Thermal Considerations

Since the AAT4625 has internal current limit and over temperature protection, junction temperature is rarely a concern. If an application requires a large load current in a high temperature operating environment, there is the possibility that the over temperature protection circuit rather than the current limit circuit will regulate the current available to the load. In these applications, the maximum current available without risk of activation of the over temperature circuit can be calculated. The maximum internal temperature while current limit is not active can be calculated using Equation 1.

$$T_{J(MAX)} = I_{MAX}^2 \times R_{DS(ON)}(MAX) \times R_{\theta JA} + T_A(MAX)$$

In Equation 1, I_{MAX} is the maximum current required by the load. $R_{DS(ON)}(MAX)$ is the maximum rated $R_{DS(ON)}$ of the AAT4625 at high temperature. $R_{\theta JA}$ is the thermal resistance between the device die and the board onto which it is mounted. $T_A(MAX)$ is the maximum ambient temperature for the printed circuit board assembly under the AAT4625 when the load switch is not dissipating power. Equation 1 can be transformed to provide I_{MAX}; Refer to Equation 2.

$$I_{MAX} = \sqrt{\frac{T_{SD}(MIN) - T_A(MAX)}{R_{DS(ON)}(MAX) \times R_{\theta JA}}}$$

$T_{SD}(MIN)$ is the minimum temperature required to activate the device over temperature protection. The typical thermal limit temperature specification is 125°C for the AAT4625, for calculations, 115°C is a safe minimum value to use.

For example, a portable device is specified to operate in a 50°C environment. The printed circuit board assembly will operate at temperatures as high as 85°C. This portable device has a sealed case and the area of the printed board assembly is relatively small causing $R_{\theta JA}$ to be approximately 120°C/W. Using Equation 2,

$$I_{MAX} = \sqrt{\frac{115 - 85}{130 \times 120}} = 1.4 \text{ A}$$

If this system requires less than 1.4 A, the thermal limit will not activate during normal operation.

Input Capacitor

The input capacitor serves two purposes. First, it protects the source power supply from transient current effects generated by the application load circuit. If a short circuit is suddenly applied to the output of an AAT4625, there is a microsecond long period during which a large current can flow before the current limit circuit becomes active. Refer to the characteristic curve named "Short Circuit Through 0.3Ω." A properly sized input capacitor can dramatically reduce the load switch input transient response effects seen by the power supply and other circuitry upstream from the AAT4625.

The second purpose of the input capacitor is to prevent transient events generated by the load circuit from effecting the operation of the AAT4625. For example, if an AAT4625 is used in a circuit that operates from a 5 volt power supply with poor step load response, it is possible that turning on the load switch could cause the input power supply to droop below the AAT4625's under voltage lockout threshold. This drop in voltage would cause the AAT4625 to turn off until the input power supply voltage levels recovers. Since this cycle would be self-perpetuating, the entire circuit could be seen to be unstable. In the very rare case where capacitor cost is prohibitive and the input capacitor is omitted, the output load circuit should be slew rate limited when turned on.

Output Capacitor

In order to insure stability while the device current limit is active, a small capacitance of approximately 1µF should be used. When the AAT4625 is activated using the ON function, there are no momentary current transients as in the case of when a short circuit suddenly applied to a device that is already on. Refer to the characteristic curve named "Turn-On/OFF Response". Regardless of output capacitor size, output current is limited to the value allowed by the threshold determined by the internal current limiting circuitry. Refer to the internal current limit threshold specifications stated in the electrical characteristics section of this datasheet. This permits very large output capacitors to be used.

For example, USB ports are specified to have at least 120µF of down stream capacitance from their controlling power switch. An output capacitance as large as 1000µF would not disturb the input power supply to an AAT4625 used to control a USB port.

EN Input

The AAT4625 is available in both active high EN enable and active low (EN) enable versions. For specific part numbers, refer to the ordering information section. When the AAT4625 is in the off state, the output is an open circuit and the device quiescent current consumption is reduced to less than 1µA. The EN threshold voltage is set to allow the AAT4625 to be controlled by 5 volt TTL levels as well as CMOS compatible levels ranging from

2.5 volts to 5 volts. The EN function control voltage level should not exceed the input supply level applied to the IN pin.

Fault Flag Output

The AAT4625 features an active low fault flag output. The fault flag is provided to alert the system if the over current or over temperature circuits become active or if the load switch is not receiving a sufficient voltage level to operate properly. If either the current limit or over temperature circuits in any combination are constantly active for more than approximately ten milliseconds, the FAULT pin is pulled to ground internally through an open drain device. The 10 millisecond delay on the FAULT function is intended to prevent capacitive loads connected to the load switch output from activating FAULT flag when the device is turned on. The placement of a pull up resistor between the FAULT pin and the IN pin is recommended. Reasonable values for the pull up resistor should range from 10kΩ to 100kΩ. Since FAULT flag is an open drain terminal, it may be pulled up to any voltage that is not greater than the level present on the IN pin. This is done to allow the AAT4625 to signal ancillary circuitry that is powered by voltage levels less than the level on the IN pin.

If a fault flag delay greater then 10ms is required, addition delay may be added by use of an RC filter. Referencing to Figure 1, an RC filter can be added to the fault flag output.
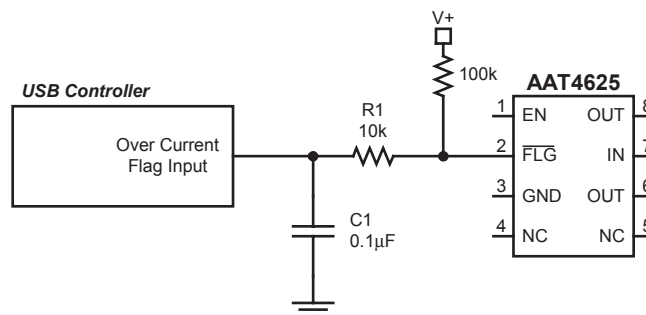

Figure 1: Fault Flag delay RC filter

Reverse Voltage

The AAT4625 is designed to control current flowing from IN to OUT. If a voltage is applied to OUT which is greater than that on IN, a large resulting reverse current may flow, potentially damaging the AAT4625.

Under Voltage Lockout

The AAT4625 has been designed with an under voltage lockout (UVLO) control circuit. The under voltage lockout prevents the output MOSFET device from turning on until the VIN exceeds the typical UVLO threshold of 2.3 volts. During operation, the device will automatically shutdown if VIN falls below the UVLO threshold and the fault flag will be toggled.

Hot-Plug Applications

Application circuit cards with a high in-rush current potential can be limited by use of the AAT4625. The AAT4625 has both slew rate limited turn on characteristics and a current limit controlled output which make it ideally suited for power port hot-plug applications. A host power back plane or hot plug receptacle may be sensitive to short duration high power surges. The AAT4625 will turn on in a linear ramping fashion and regulate the inrush current with in the specified current limit for the device. The error flag usually will not be effected during application turn on since the 10ms Flag blanking time is intended for these types of events. If an application turn on current surge exceeds 10ms, an RC delay filter may be added to the Flag output to prevent the system from receiving an error during the start up sequence.
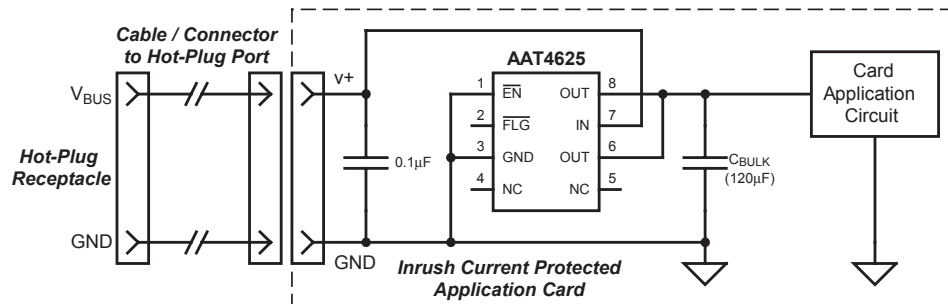
Figure 2: AAT4625 Inrush Current Protected Application

PCB Layout Information

In order to obtain the maximum performance from the AAT4625, very careful attention must be considered in regard to the printed circuit board layout. In most port power switch and port protection appli-

cations, high voltage and current transient events will occur. Proper PCB layout can help reduce the effects of transient events. PCB trace resistance will effect over all circuit transient response, in addition small voltage drops will be incurred.

Refer to the following guide lines for power port PCB layout:

1. PCB traces should be kept as short and direct as possible to minimize the effects of the PCB on circuit performance.
2. Make component solder pads large to minimize contact resistance
3. The AAT4625 output bulk capacitor and ferrite beads should be placed as close to the device as possible. PCB traces to the output

connector should be kept as short as possible to minimized trace resistance and the associated voltage drop (I2R loss).

4. If ferrite beads are used in the circuit, select ferrite beads with a minimum series resistance.
5. The use of PCB trace vias should be avoided on all traces that conduct high currents. If vias are necessary, make the vias as large as possible and use multiple vias connected in parallel to minimize their effect.
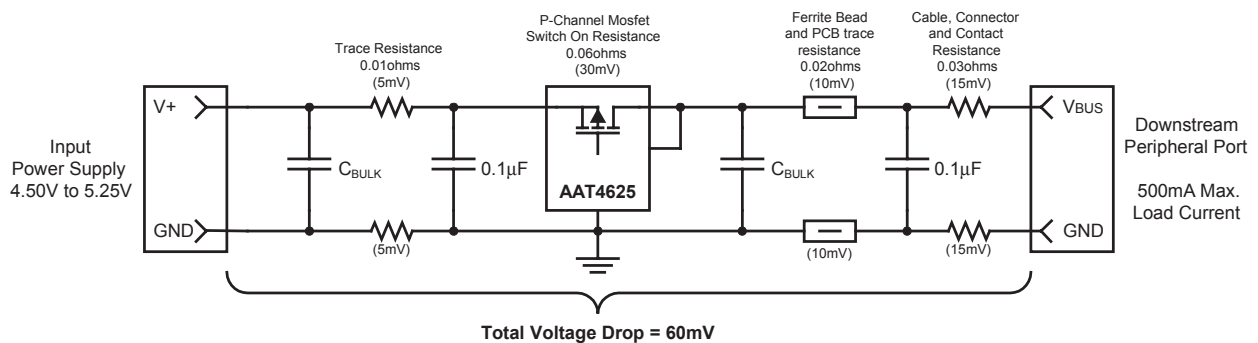
Figure 3: Summary of typical circuit voltage drops caused by AAT4625 circuit components and PCB trace resistance.

Evaluation Board Layout

The AAT4625 evaluation layout follows the recommend printed circuit board layout procedures and can be used as an example for good application layouts. Note that ferrite beards are not used on this simple device evaluation board. The board layout shown is not to scale.
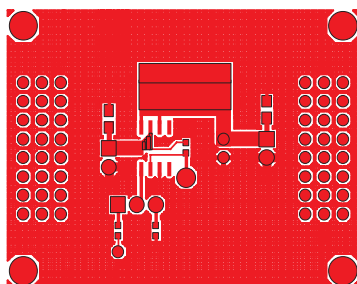
Figure 4: Evaluation board component side layout
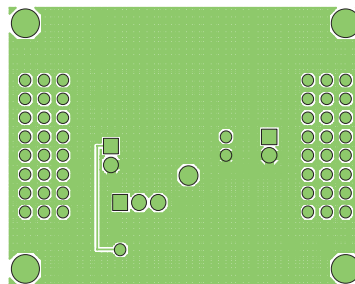
Figure 5: Evaluation board solder side layout
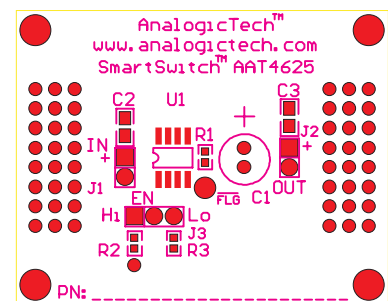
Figure 6: Evaluation board top side silk screen layout / assembly drawing
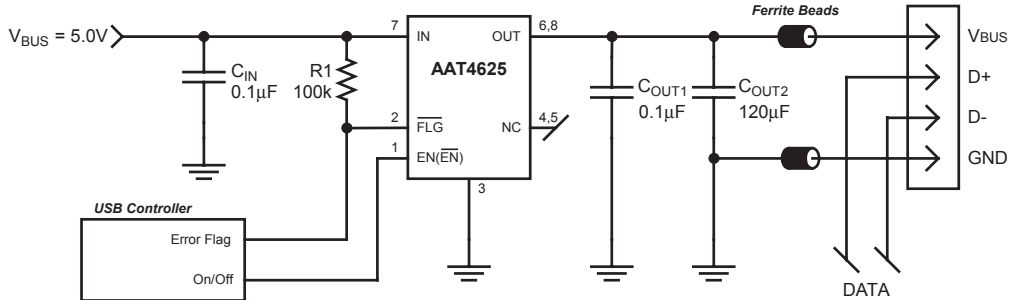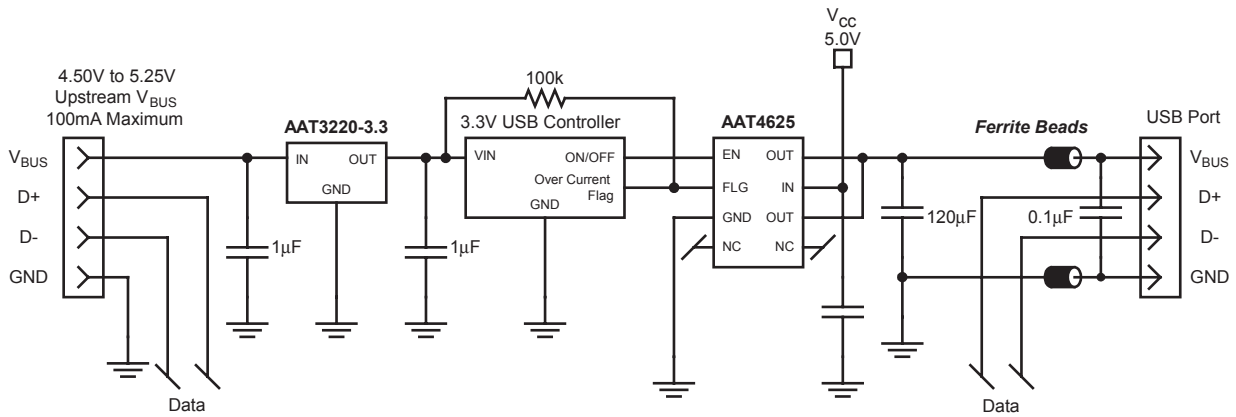
Application Circuits

Figure 7: Typical USB Host Port Application
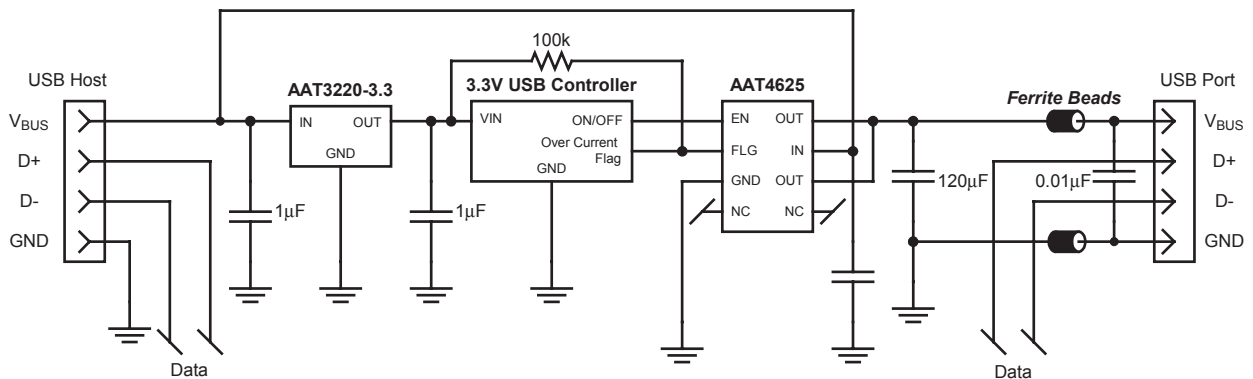

**Figure 8: Self-Powered Single Port USB Hub**


Figure 9: USB Bus Powered Single Port USB Hub
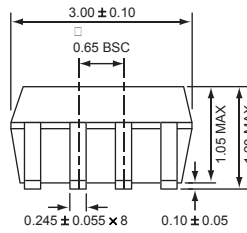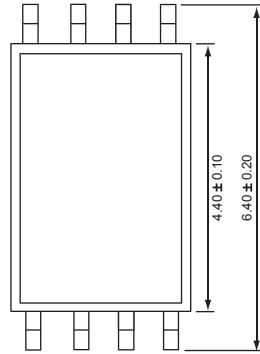
Ordering Information

Package	Enable	Marking	Part Number	
			Bulk	Tape and Reel
SOP8	EN (Active-high)		N/A	AAT4625IAS-1-T1
SOP8	EN (Active-low)		N/A	AAT4625IAS-T1
TSSOP8	EN (Active-high)		N/A	AAT4625IHS-1-T1
TSSOP8	EN (Active-low)		N/A	AAT4625IHS-T1
MSOP8	EN (Active-high)		N/A	AAT4625IKS-1-T1
MSOP8	EN (Active-low)		N/A	AAT4625IKS-T1

Package Information

SOP-8

TSSOP-8

DETAIL A
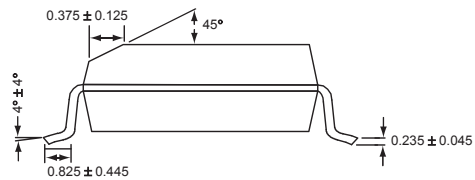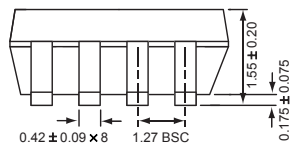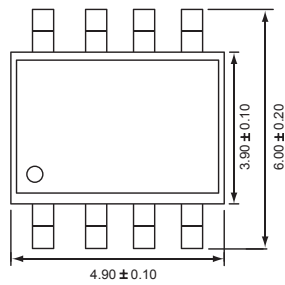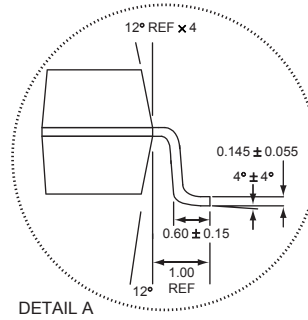
MSOP-8
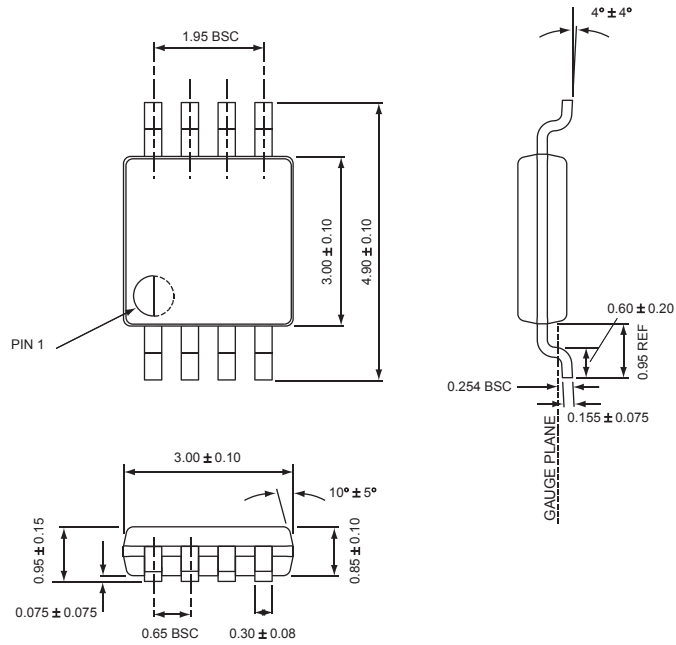
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