SmartSwitch™

General Description

The AAT4651 SmartSwitch is a single channel PC card (PCMCIA) power switch. It is used to select between two different voltage inputs, each between 2.7V and 5.5V. An internal switch powers the circuitry from whichever input voltage is higher. The device's output, V_{CC}, is slew rate controlled and current limited, in compliance with PC card specifications. The current limit response time to a short circuit is typically 1µs. The internal P-channel MOSFET switches are configured to break before make; that is, both switches cannot be closed at the same time. Controlled by a 2-bit parallel interface, the three states for V_{CC} are V_{CC5}, V_{CC3}, or ground. When in the ground state, V_{CC} is pulled to ground by an 200Ω resistor. An open drain $\overline{\text{FAULT}}$ output is asserted during over-current conditions. During power-up slewing, $\overline{\text{FAULT}}$ also signals that V_{CC} is out of tolerance. An internal over-temperature sensor forces V_{CC} to a high impedance state when an over-temperature condition exists. Quiescent current is typically a low 15µA, as long as I_{CC} is less than approximately 500mA. Above this load current, the quiescent current increases to 200µA.

The AAT4651 is available in a Pb-free, 8-pin SOP or TSSOP package and is specified over the -40°C to +85°C temperature range.

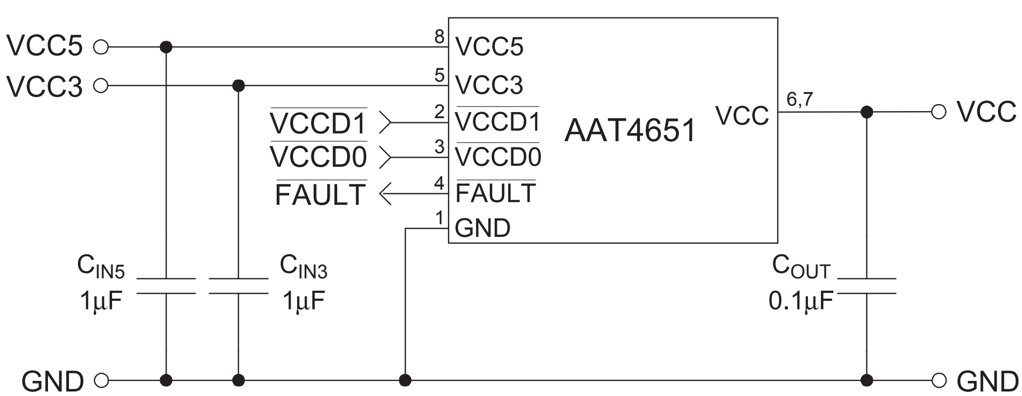
Features

- 2.7V to 5.5V Input Voltage Range
- 80mΩ (5V) Typical $R_{DS(ON)}$
- Low Quiescent Current: 15µA (Typ)
- Reverse-Blocking Switches
- Short-Circuit Protection
- Over-Temperature Protection
- $\overline{\text{FAULT}}$ Flag Output
- Temperature Range: -40°C to +85°C
- 8-Pin SOP or TSSOP Package

Applications

- Notebook Computer
- PDA, Subnotebook
- Power Supply Multiplexer Circuit

Typical Application

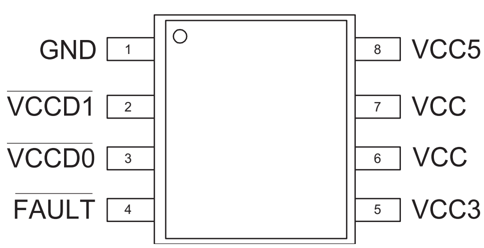


Pin Descriptions

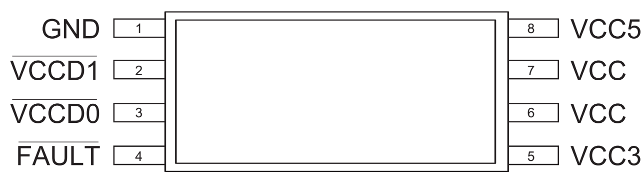
Pin #	Symbol	Function
1	GND	Ground connection.
2	$\overline{\text{VCCD1}}$	Control input (see Control Logic Table below).
3	$\overline{\text{VCCD0}}$	Control input (see Control Logic Table below).
4	$\overline{\text{FAULT}}$	Open drain output; signals over-current condition.
5	VCC3	3V supply.
6, 7	VCC	Output (see Control Logic Table below).
8	VCC5	5V supply.

Pin Configuration

SOP-8
(Top View)



TSSOP-8
(Top View)



Control Logic Table

$\overline{\text{VCCD1}}$	$\overline{\text{VCCD0}}$	Function	Result
0	0	OFF	80Ω V_{CC} to GND
0	1	3.3V	$V_{CC} = V_{CC3}$
1	0	5V	$V_{CC} = V_{CC5}$
1	1	OFF	80Ω V_{CC} to GND

Absolute Maximum Ratings[1]

T_A = 25°C, unless otherwise noted.

Symbol	Description	Value	Units
V_{CC3}, V_{CC5}	IN to GND	-0.3 to 6	V
V_{CC}	OUT to GND	-0.3 to 6	V
I_{MAX}	Maximum Continuous Switch Current	Current Limited	A
T_J	Operating Junction Temperature Range	-40 to 150	°C
V_{ESD}	ESD Rating[2] — HBM	4000	V

Thermal Characteristics[3]

Symbol	Description		Value	Units
Θ_{JA}	Thermal Resistance	SOP-8	120	°C/W
		TSSOP-8	150	
P_D	Power Dissipation	SOP-8	1.0	W
		TSSOP-8	833	mW

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. Only one Absolute Maximum Rating should be applied at any one time.
2. Human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.
3. Mounted on an FR4 board.

Electrical Characteristics

V_{CC5} = 5.0V, V_{CC3} = 3.3V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C; **bold** values designate full temperature range.

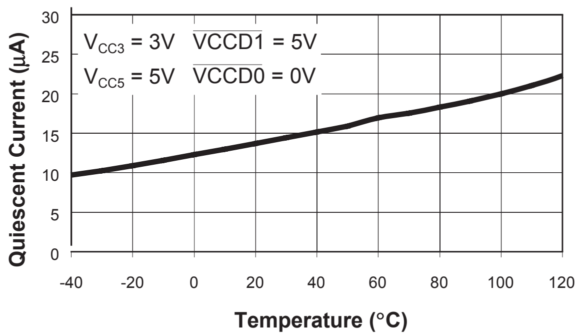
Symbol	Description	Conditions	Min	Typ	Max	Units
V_{CC} Output						
Iccsc	Short-Circuit Current Limit	V_{CC} = V_{CCIN} -0.5V, On Mode V_{CC3} or V_{CC5} Selected, T_A = 25°C	1.0		2.5	A
$R_{DS(ON)}$	On Resistance	V_{CC} = 3.0V, T_A = 25°C		85	110	mΩ
		V_{CC} = 5.0V, T_A = 25°C		80	100	
R_{CLAMP}	Clamp Resistance	V_{CC} = Clamped to GND, I_{CCOUT} = 10mA Sinking		80	200	Ω
Tcrds	Switch Resistance Temperature Coefficient			2800		ppm/°C
V_{CC} Switching Time (Refer to Figure 1)						
t1	Output Turn-On Delay Time	V_{CC} = 0V to 10% of 3.3V, R_{OUT} = 10Ω		500	**2000**	µs
t2	Output Turn-On Delay Time	V_{CC} = 0V to 10% of 5.0V, R_{OUT} = 10Ω		500	**1500**	
t3	Output Rise Time	V_{CC} = 10% to 90% of 3.3V, R_{LOAD} = 10Ω	**300**	1000	**3000**	
t4	Output Rise Time	V_{CC} = 10% to 90% of 5.0V, R_{LOAD} = 10Ω	**300**	1000	**3000**	
t5	Output Turn-Off Delay Time	V_{CC} = 3.3V to 90% of 3.3V, R_{LOAD} = 10Ω			**400**	
t6	Output Turn-Off Delay Time	V_{CC} = 5.0V to 90% of 5.0V, R_{LOAD} = 10Ω			**400**	
t7	Output Fall Time to Off State	V_{CC} = 90% to 10% of 3.3V, R_{LOAD} = 10Ω			**200**	
t8	Output Fall Time to Off State	V_{CC} = 90% to 10% of 5.0V, R_{LOAD} = 10Ω			**200**	
Power Supply						
V_{CC3}	V_{CC3} Operation Voltage		2.7		5.5	V
V_{CC5}	V_{CC5} Operation Voltage		2.7		5.5	V
I_{CC3}	V_{CC3} Supply Current	V_{CC} = 5V or Off, V_{CC3} < V_{CC5}, I_{CC} Out = 0			**1**	µA
		V_{CC} = 3.3V, V_{CC3} < V_{CC5}, I_{CC} Out = 0		5	**20**	
I_{CC5}	V_{CC5} Supply Current	V_{CC} = Off, V_{CC5} > V_{CC3}, I_{CC} Out = 0			**1**	µA
		V_{CC} = 3.3V, V_{CC5} > V_{CC3}, I_{CC} Out = 0		10	**40**	
		V_{CC} = 5V, V_{CC5} > V_{CC3}, I_{CC} Out = 0		15	**40**	
Parallel Interface						
$\overline{VCCD}$ LOW	$\overline{VCCD}$ Input Low Voltage	V_{CC3} or V_{CC5} = 3.0V to 5.5V[1]			**0.8**	V
$\overline{VCCD}$ HI	$\overline{VCCD}$ Input High Voltage	V_{CC3} or V_{CC5} = 2.7V to 3.6V	**2.0**			V
		V_{CC3} or V_{CC5} = 4.5V to 5.5V	**2.4**			
$I_{SINK\ \overline{VCCD}}$	$\overline{VCCD}$ Input leakage	V_{CTL} = 5.5V		0.01	**1**	µA
$V_{\overline{FAULT}LOW}$	$\overline{FAULT}$ Logic Output Low Voltage	I_{SINK} = 1mA			**0.4**	V
$I_{SINK\overline{FAULT}}$	$\overline{FAULT}$ Logic Output High Leakage Current	V_{FAULT} = 5.5V		0.05	**1**	µA
Other						
OTMP	Over-Temperature Shutdown			125		°C

1. For $\overline{VCCD}$ outside this range, consult Typical $\overline{VCCD}$ Threshold curve.

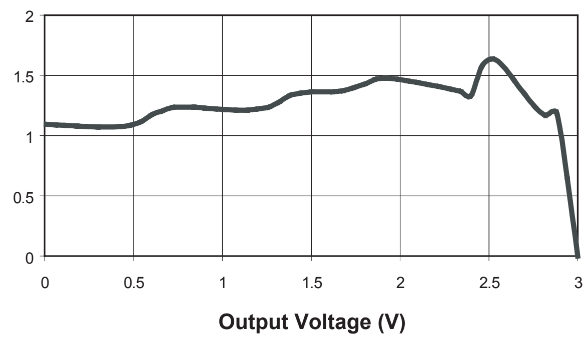
Typical Characteristics

Unless otherwise noted, T_A = 25°C.

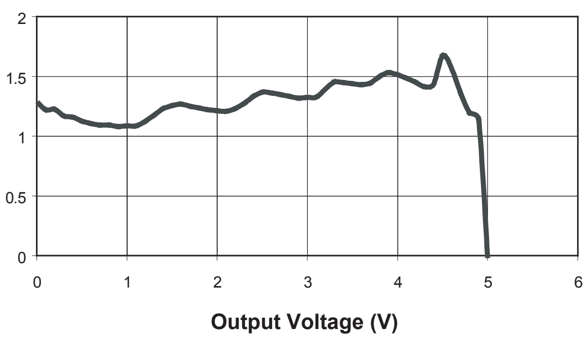
Quiescent Current vs. Temperature
(I_{CC5})



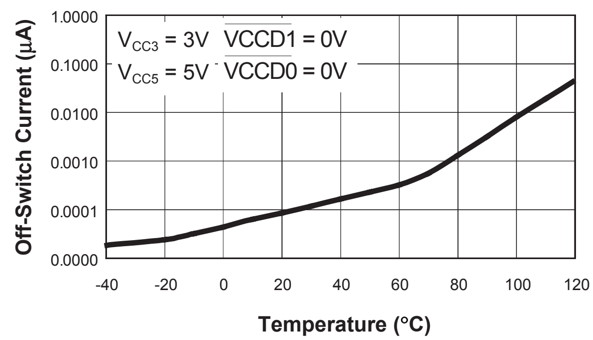
Current Limit
(V_{CC} = V_{CC3})



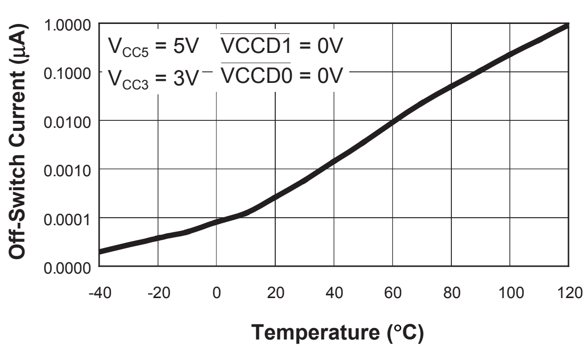
Current Limit
(V_{CC} = V_{CC5})



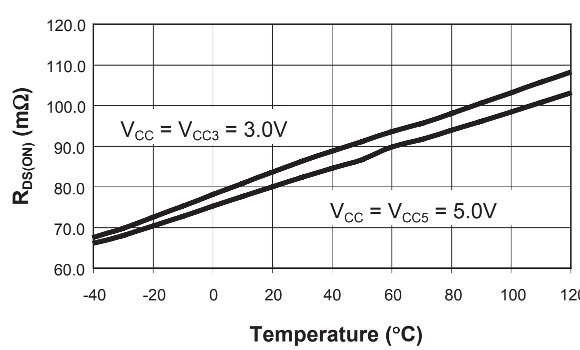
Off-Switch Current vs. Temperature
(I_{CC3})



Off-Switch Current vs. Temperature
(I_{CC5})



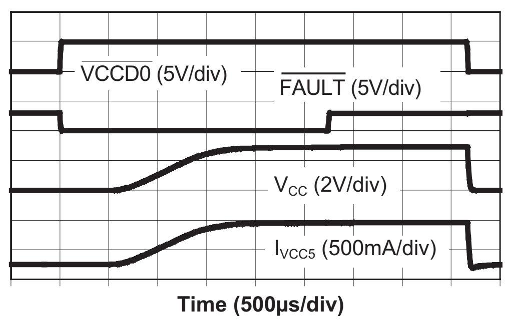
$R_{DS(ON)}$ vs. Temperature



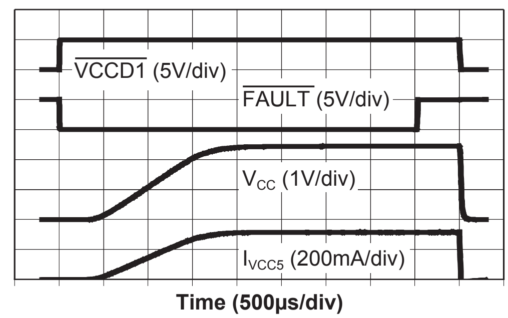
Typical Characteristics

Unless otherwise noted, T_A = 25°C.

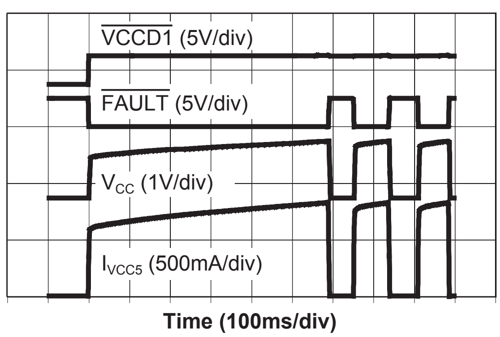
Turn-On/Off Response with 10Ω, 1μF Load
($\overline{VCCD1}$ = 0V)



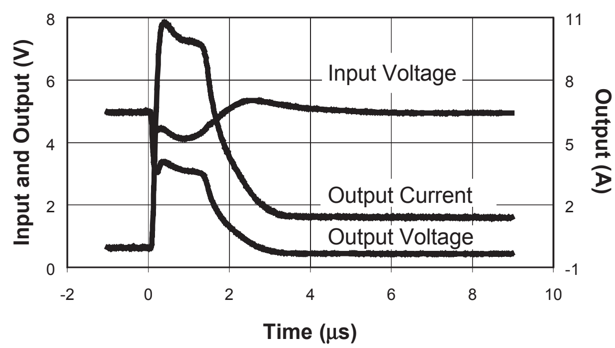
Turn-On/Off Response with 15Ω, 1μF Load
($\overline{VCCD0}$ = 0V)



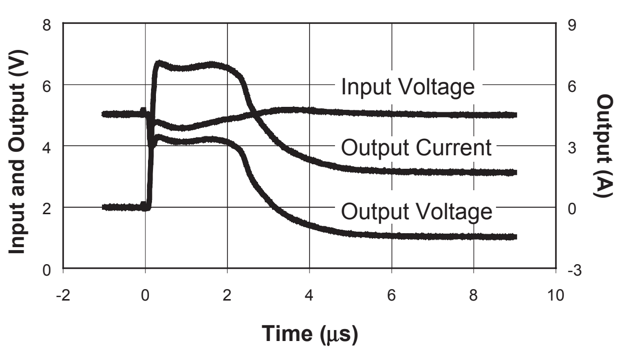
Thermal Shutdown Response
($\overline{VCCD0}$ = 0V)



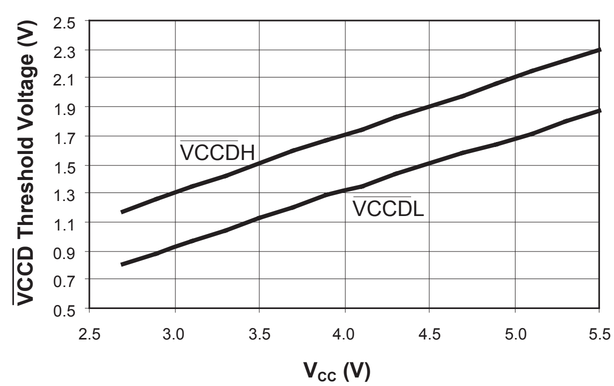
Short Circuit Through 0.3Ω



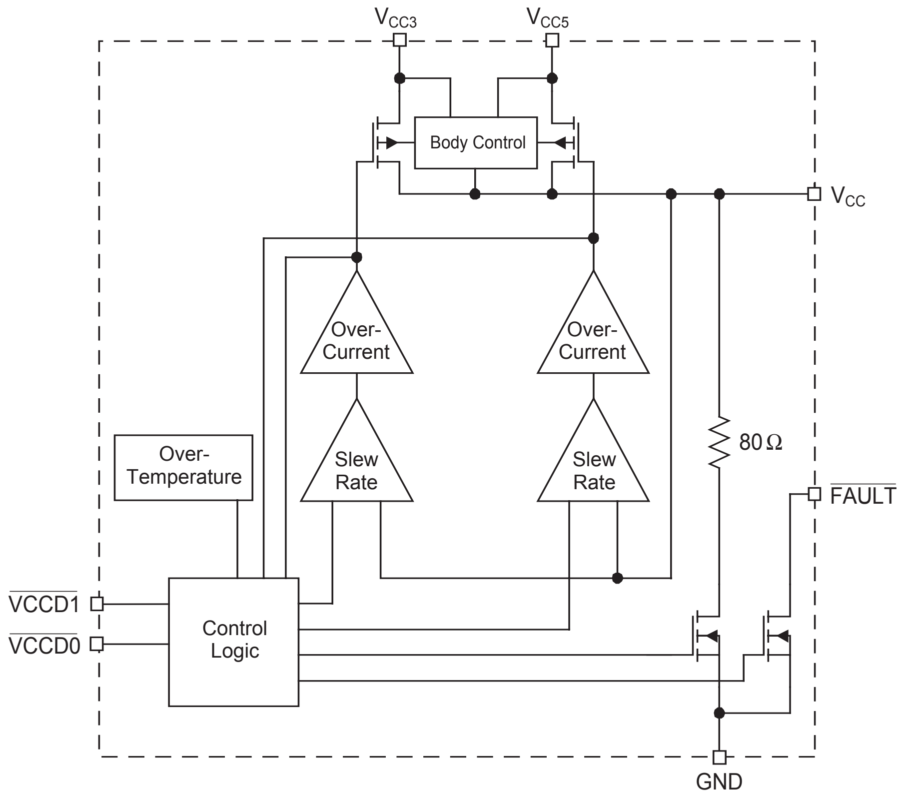
Short Circuit Through 0.6Ω



$\overline{VCCD}$ Threshold vs. V_{CC}



Functional Block Diagram



Functional Description

The AAT4651 is a single channel power switch that can be used in any application where dual power supply multiplexing is required. Typical applications for this include PC card applications not requiring a 12V power supply, or applications where power is switched, for example, between 5V for operation and 3.3V for standby mode. The AAT4651 operates with input voltages ranging from 2.7V to 5.5V in any combination and automatically powers its internal circuitry from whichever input voltage is higher. Two identical low $R_{DS(ON)}$ P-channel MOSFETs serve as the power multiplexing circuit with a common drain as the V_{CC} output and independent sources as the two V_{CC3} and V_{CC5} inputs. A 2-bit parallel interface determines the state of the multiplexer: $V_{CC} = V_{CC3}$, $V_{CC} = V_{CC5}$, or V_{CC} with resistive pull down to ground. When the state is set to either of the two inputs, the multiplexing circuit will slowly slew the V_{CC} output to the new voltage level which protects the upstream power supply from sudden load transients. When the resistive pull down is chosen for V_{CC}, the V_{CC} output is quickly discharged by the resistive pull down. The AAT4651 always serves as an electronic fuse by limiting the load current if it exceeds the current limit threshold. During power-up into a short, the current will gradually increase until the current limit is reached. During a sudden short circuit on the output, the current limit will respond in 1µs to isolate and protect the upstream power supply from the load short circuit. In most applications, because the response time is so fast, a short circuit to V_{CC} will not affect the upstream supply, so system functionality will not be affected. In the case of an over-current condition, an open drain $\overline{\text{FAULT}}$ flag output will signal the event. The $\overline{\text{FAULT}}$ output is also active during output voltage slew, and becomes inactive once the output is within regulation.

Applications Information

Input Capacitor

A 1µF or larger capacitor is typically recommended for C_{IN}. A C_{IN} capacitor is not required for basic operation; however, it is useful in preventing load transients from affecting upstream circuits. C_{IN} should be located as close to the device VIN pin as practically possible. Ceramic, tantalum, or aluminum electrolytic capacitors may be selected for C_{IN}. There is no specific capacitor equivalent series resistance (ESR) requirement for C_{IN}. However, for higher current operation, ceramic capacitors are recommended for C_{IN} 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

A 0.1µF or greater capacitor is generally required between V_{CC} and GND. Likewise, with the output capacitor, there is no specific capacitor ESR requirement. If desired, C_{OUT} may be increased to accommodate any load transient condition.

Parallel Interface / Break Before Make

A 2-bit parallel interface determines the state of the V_{CC} output. The logic levels are compatible with CMOS or TTL logic. A logic low value must be less than 0.8V, and a logic high value must be greater than 2.4V. In cases where the interface pins rapidly change state directly from 3V to 5V (or vice versa), internal break-before-make circuitry prevents any backflow of current from one input power supply to the other. In addition, the body connections of the internal P-channel MOSFET switches are always set to the highest potential of V_{CC3}, V_{CC5}, or V_{CC}, which prevents any body diode conduction, power supply backflow, or possible device damage.

$\overline{\text{FAULT}}$ Output

The $\overline{\text{FAULT}}$ output is pulled to ground by an open drain N-channel MOSFET during an over-current or output slew condition. It should be pulled up to the reference power supply of the controller IC via a nominal 100kΩ resistor.

Voltage Regulation

The PC card specification calls for a regulated 5V supply tolerance of +/-5%. Of this, a typical power supply will drop less than 2%, and the PCB traces will drop another 1%. This leaves 2% for the AAT4651 as the PC card switch. In the PC card application, the maximum allowable current for the AAT4651 is dominated by voltage regulation rather than by thermal considerations, and is set by either the current limit or the maximum $R_{DS(ON)}$ of the P-channel MOSFET. The maximum $R_{DS(ON)}$ at 85°C is calculated by applying the $R_{DS(ON)}$ temperature coefficient to the maximum room temperature $R_{DS(ON)}$:

$$R_{DS(ON)(MAX)} = R_{DS(ON)25} \cdot (1 + [TC \cdot \Delta T])$$

-or-

$$R_{DS(ON)(MAX)} = 100m\Omega \cdot (1 + [0.0028 \cdot 60]) = 116.8m\Omega$$

The maximum current is equal to the 2% tolerance of the 5V supply (100mV) across the AAT4651 divided by $R_{DS(ON)(MAX)}$. Or:

$$I_{MAX5} = \frac{100mV}{116.8m\Omega} = 856.2mA$$

For the 3.3V supply in the PC card application, the conditions are a bit relaxed, with the allowable voltage regulation drop equal to 300mV. With a 2% supply and 1% PCB trace regulation, the PC card switch can have a 200mV drop. So:

$$I_{MAX3} = \frac{200mV}{134m\Omega} = 1.5A$$

Since 1.5A is the nominal current limit value, the AAT4651 will current limit before I_{MAX3} is reached.

Thermal issues are not a problem in the SOP-8 package since Θ_{JA}, the package thermal resistance, is only 120°C/W. At any given ambient temperature

(T_A), 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 AAT4651 are maximum junction temperature, $T_{J(MAX)}$ = 125°C, and package thermal resistance, Θ_{JA} = 120°C/W. Worst case conditions are calculated at the maximum operating temperature where T_A = 85°C. Typical conditions are calculated under normal ambient conditions where T_A = 25°C. At T_A = 85°C, $P_{D(MAX)}$ = 333mW. At T_A = 25°C, $P_{D(MAX)}$ = 833mW.

Maximum current is given by the following equation:

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

For the AAT4651 at 85°C, $I_{OUT(MAX)}$ = 1.65A, a value greater than the internal minimum current limit specification.

Over-Current and Over-Temperature Protection

Because many AAT4651 applications provide power to external devices, it is designed to protect its host device from malfunctions in those peripherals through slew rate control, current limiting, and thermal limiting. The AAT4651 current limit and thermal limit serve as an immediate and reliable electronic fuse without any increase in $R_{DS(ON)}$ for this function. Other solutions, such as a poly fuse, do not protect the host power supply and system from mishandling or short circuiting peripherals; they will only prevent a fire. The AAT4651 high-speed current limit and thermal limit not only prevent fires, they also isolate the power supply and entire system from any activity at the external port and report a mishap by means of a FAULT signal.

Over-current and over-temperature go hand in hand. Once an over-current condition exists, the current supplied to the load by the AAT4651 is limited to the over-current threshold. This results in a voltage drop across the AAT4651 which causes excess power dissipation and a package temperature increase. As the die begins to heat up, the over-temperature circuit is activated. If the temperature reaches the maximum level, the AAT4651 automatically switches off the P-channel MOSFETs. While they are off, the over-temperature circuit remains active. Once the temperature has cooled by approximately 10°C, the P-channel MOSFETs are switched back on. In this manner, the AAT4651 is thermally cycled on and off until the short circuit is removed. Once the short is removed, normal operation automatically resumes.

To save power, the full high-speed over-current circuit is not activated until a lower threshold of current (approximately 500mA) is exceeded in the power device. When the load current exceeds this crude threshold, the AAT4651 quiescent current increases from 15µA to 200µA. The high-speed over-current circuit works by linearly limiting the current when the current limit is reached. As the voltage begins to drop on V_{CC} due to current limiting, the current limit magnitude varies and generally decreases as the V_{CC} voltage drops to 0V.

Switching V_{CC} Voltage

The AAT4651 meets PC card standards for switching the V_{CC} output by providing a ground path for V_{CC} as well as "off" state. The PC card protocol for determining low voltage operations is to first power the peripheral with 5V and poll for 3.3V operation. When transitioning from 5V to 3.3V, V_{CC} must be discharged to less than 0.8V to provide a hard reset. The resistive ground state ($\overline{VCCD0}$ = VCCD1) will accommodate this. The ground state will also guarantee the V_{CC} voltage to be discharged within the specified 100ms amount of time.

Printed Circuit Board Layout Recommendations

For proper thermal management, to minimize PCB trace resistance, and to take advantage of the low $R_{DS(ON)}$ of the AAT4651, a few circuit board layout rules should be followed: V_{CC3}, V_{CC5}, and V_{CC} should be routed using wider than normal traces; the two V_{CC} pins (Pins 6 and 7) should be connected to the same wide PCB trace; 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.

Timing Diagram

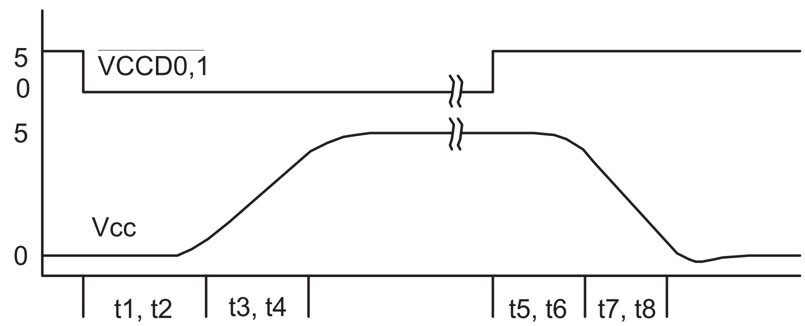
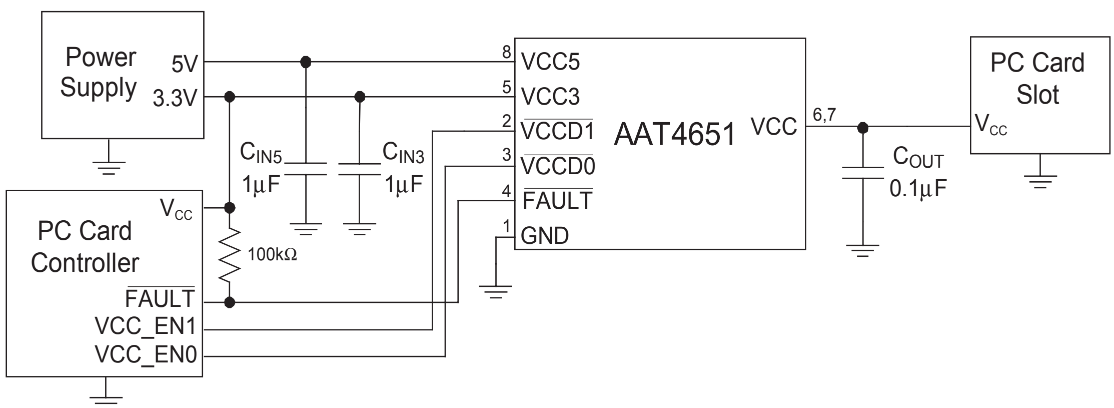


Figure 1: VCC Switching Time Diagram.

Refer to V_{CC} Switching Time specifications in the Electrical Characteristics section of this datasheet for definitions of t1 to t8.

Typical PC Card Application Circuit



Evaluation Board Layout

The AAT4651 evaluation board layout follows the printed circuit board layout recommendations, and can be used for good applications layout.

Note: Board layout shown is not to scale.

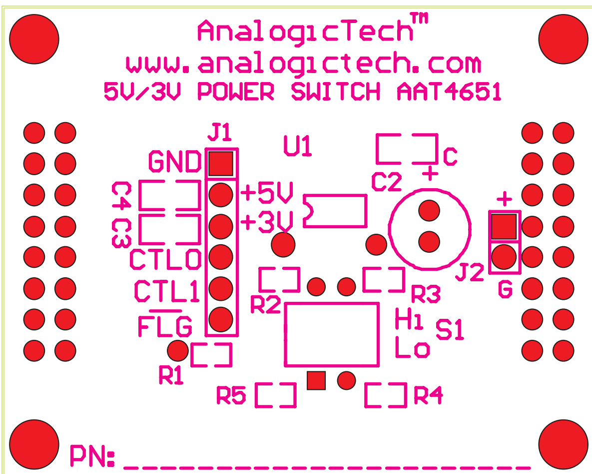


Figure 2: Evaluation Board Top Side Silk Screen Layout / Assembly Drawing.

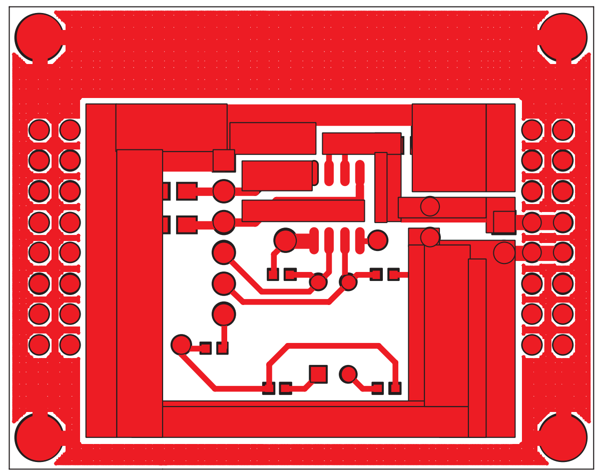


Figure 3: Evaluation Board Component Side Layout.

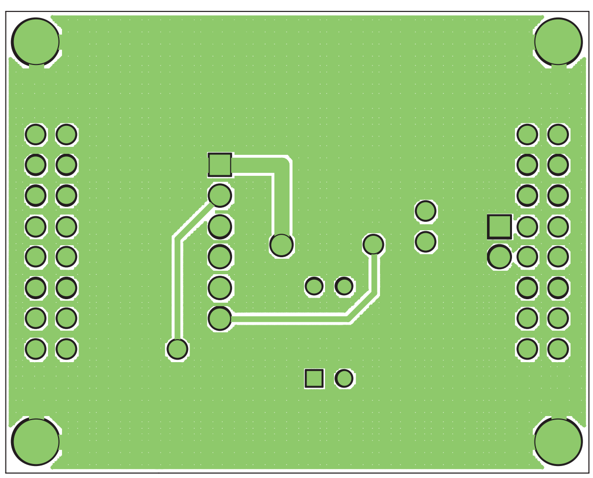


Figure 4: Evaluation Board Solder Side Layout.

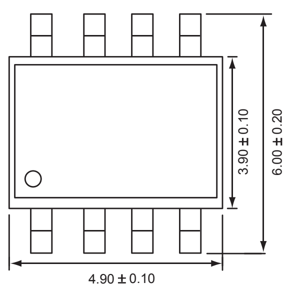
Ordering Information

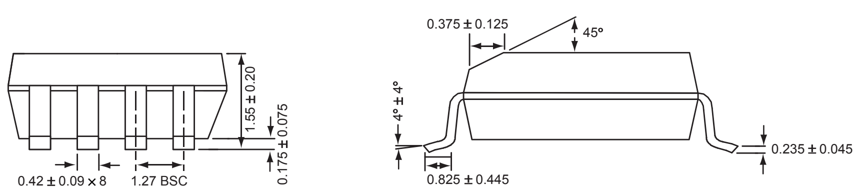
Package	Marking	Part Number (Tape and Reel)[1]
SOP-8	4651	**AAT4651IAS-T1**
TSSOP-8	4651	**AAT4651IHS-T1**

All AnalogicTech products are offered in Pb-free packaging. The term "Pb-free" means semiconductor products that are in compliance with current RoHS standards, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. For more information, please visit our website at http://www.analogictech.com/pbfree.

Package Information

SOP-8

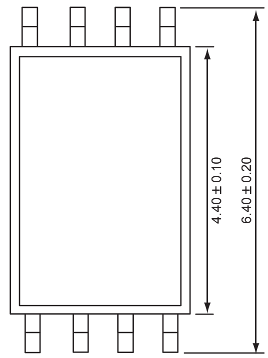


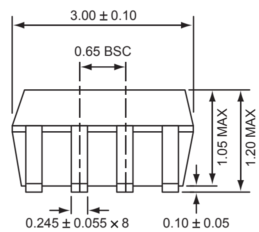


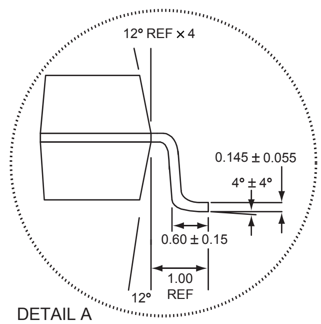
All dimensions in millimeters.

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

TSSOP-8







All dimensions in millimeters.

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