TC670

Tiny Predictive Fan Failure Detector

Features

- Fan Wear-out Detection for 2-Wire Linear Controlled Fans
- Replacement System for 3-Wire Fans
- Fan Alert Signal when Fan Speed is below Programmed Threshold
- CLEAR Capability for Eliminating False Alarm
- Low Operating Current, 90µA (typ.)
- V_{DD} Range 3.0V to 5.5V
- Available in a 6-Pin SOT-23 Package

Applications

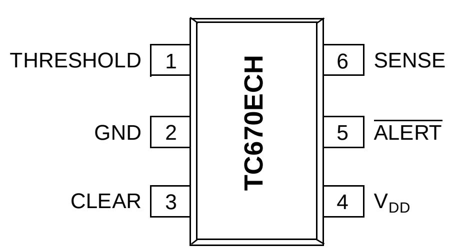
- Protection for Linear Controlled Fans
- Power Supplies
- Industrial Equipment
- PCs and Notebooks
- Data Storage
- Data Communications Equipment
- Instrumentation

Device Selection Table

Part Number	Package	Temp. Range
TC670ECH	6-Pin SOT-23	-40°C to +85°C

Package Type

SOT-23A-6



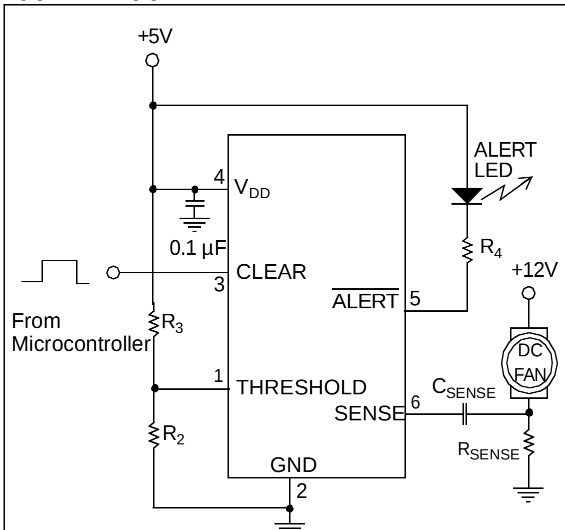
General Description

The TC670 is an integrated fan speed sensor that predicts and/or detects fan failure, preventing thermal damage to systems with cooling fans. When the fan speed falls below a user specified level, the TC670 asserts an $\overline{\text{ALERT}}$ signal. With this design, a critical minimum fan speed is determined by the user. The fan alert level is then set with a resistor divider on the THRESHOLD pin (Pin 1) of the TC670. When the minimum fan speed is reached, the $\overline{\text{ALERT}}$ pin (Pin 5) changes from a digital HIGH to LOW. This failure detection works with all linear controlled 2-wire fans. The TC670 eliminates the need for 3-wire fan solutions.

A CLEAR option can be used to reset the $\overline{\text{ALERT}}$ signal, allowing the flexibility of connecting the $\overline{\text{ALERT}}$ output of the TC670 with other Alert/FAULT interrupts in the system. This feature can be implemented so that false Fan Fault conditions do not initiate system shutdown.

The TC670 is specified to operate over the full industrial temperature range of -40°C to +85°C. The TC670 is offered in a SOT23-6 pin package and consumes 90µA (typ) during operation. The space saving package and low power consumption make this device an ideal choice for systems requiring fan speed monitoring.

Typical Application Circuit



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

V_{DD} 6.0V
All inputs and outputs w.r.t. ..... (GND – 0.3V) to (V_{DD} + 0.3V)
Difference Input voltage .... IV_{DD} - GND
Output Short Circuit Current .... continuous
Current at Input Pin .... +/-2 mA
Current at Output Pin .... +/-25 mA
Junction Temperature, T_J .... 150°C
ESD protection on all pins .... ≥ 4 kV
Operating Temperature Range .... -40°C to +85°C
Storage Temperature Range .... -55°C to +150°C

Stresses above 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 above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

TC670 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Unless otherwise specified, all limits are specified at +25°C, V_{DD} = 3.0V to 5.5V, CLEAR = Low. **Boldface** type specifications apply for temperature range of -40°C to +85°C

Symbol	Parameters	Min	Typ	Max	Unit	Conditions
Power Supply:						
V_{DD}	Supply Voltage	3.0	—	5.5	V	
I_{DD}	Supply Current	—	90	150	µA	
CLEAR Input:						
V_{IH}	CLEAR Logic Input High Level	**0.8V**$_{DD}$	—	—	V	
V_{IL}	CLEAR Logic Input Low Level	—	—	**0.2V**$_{DD}$	V	
SENSE Input:						
$V_{TH(SENSE)}$	SENSE Input Level Threshold Voltage	—	124	—	mV	
R_{SENSE}	SENSE Input Resistance	—	50	—	kΩ	
THRESHOLD Input:						
	THRESHOLD Input Voltage Minimum	—	0.0	—	V	
	THRESHOLD Input Voltage Maximum	—	2.4	—	V	
	THRESHOLD Input Resistance	—	100	—	MΩ	
$\overline{\text{ALERT}}_{ACC}$	Programmed Fan Speed Alert Accuracy [(1)]	-10	—	+10	%	V_{DD} = 3.0V
$\overline{\text{ALERT}}$ Output:						
V_{LOW}	$\overline{\text{ALERT}}$ Output Low Voltage	—	—	0.3	V	I_{SINK} = 2.5 mA
t_{DELAY}	$\overline{\text{ALERT}}$ Output Delay Time	—	176	—	ms	

Note 1: The TC670 will operate properly over the entire power supply range of 3.0V to 5.5V. As V_{DD} varies from 3.0V, accuracy will degrade based on the percentage of V_{DD} as shown in Section 3.0.

TEMPERATURE SPECIFICATIONS

Electrical Characteristics: Unless otherwise specified, all limits are specified for -40°C to +85°C and V_{DD} = 3.0V to 5.5V

Symbol	Parameters	Min	Typ	Max	Unit	Conditions
Temperature Ranges:						
T_A	Specified Temperature Range	-40	—	+85	°C	
T_A	Operating Temperature Range	-40	—	+85	°C	
Thermal Package Resistances:						
θJA	Thermal Resistance, 6L-SOT-23	—	230	—	°C/W	

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

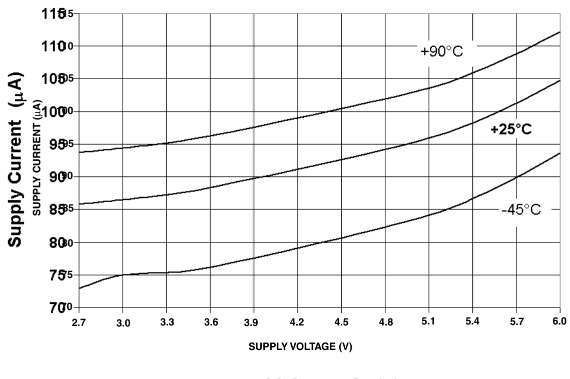
TABLE 2-1: PIN FUNCTION TABLE

Pin No. (6-Pin SOT-23)	Symbol	Description
1	THRESHOLD	Analog Input used to set Fan $\overline{\text{ALERT}}$ Threshold Voltage. Input range = 0.0V to 2.4V.
2	GND	Ground Terminal.
3	CLEAR	Digital Input. Active High. The $\overline{\text{ALERT}}$ Output is cleared when a high level signal is applied to this input.
4	V_{DD}	Power Supply Input, 3.0V to 5.5V.
5	$\overline{\text{ALERT}}$	Digital (Open Drain) Output, active low. This pin goes low to indicate an alert condition when the fan speed at the SENSE pin reaches the alert threshold applied on the THRESHOLD pin.
6	SENSE	Analog Input. Current spikes are detected at this pin as the fan excitation signal transitions from high to low and low to high.

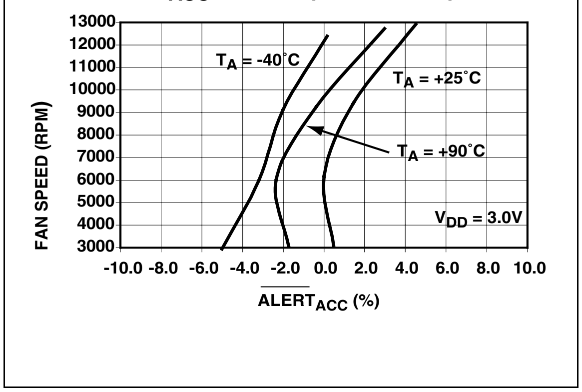
3.0 TYPICAL PERFORMANCE CHARACTERISTICS

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

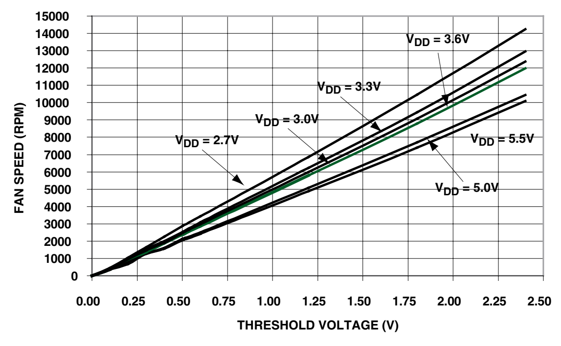
Supply Current I_{DD} vs. Supply Voltage (V_{DD}) vs. Temperature (T_A)



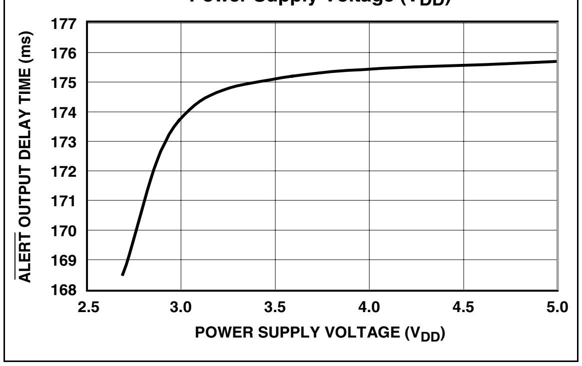
$\overline{ALERT}_{ACC}$ vs. Fan Speed vs. Temperature



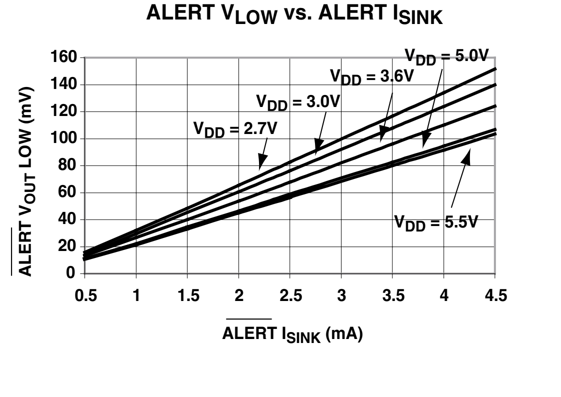
THRESHOLD Voltage vs. Fan Speed vs. Supply Voltage (V_{DD})



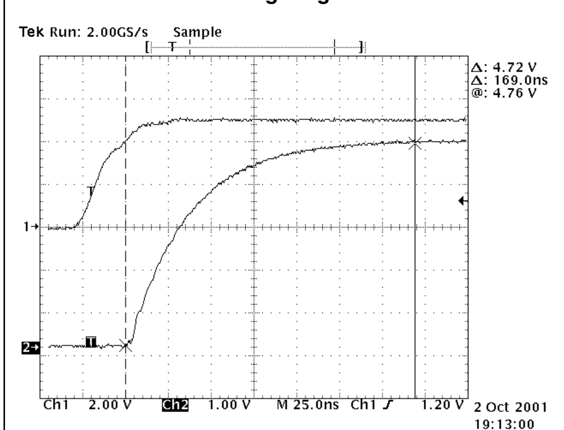
Alert Output Delay (T_{DELAY}) vs. Power Supply Voltage (V_{DD})



$\overline{ALERT}$ V_{LOW} vs. $\overline{ALERT}$ I_{SINK}



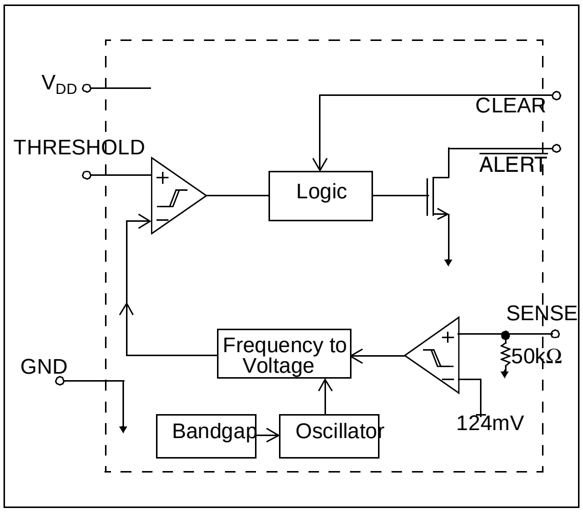
CLEAR Pin HIGH to $\overline{ALERT}$ pin HIGH Timing Diagram



4.0 DETAILED DESCRIPTION

The TC670 is an integrated fan speed sensor that predicts/detects fan failure, consequently preventing thermal damage to systems with cooling fans. When the fan speed falls below a user programmed threshold level, the TC670 asserts an ALERT signal. This threshold is set with an external resistor divider network.

FIGURE 4-1: TC670 BLOCK DIAGRAM

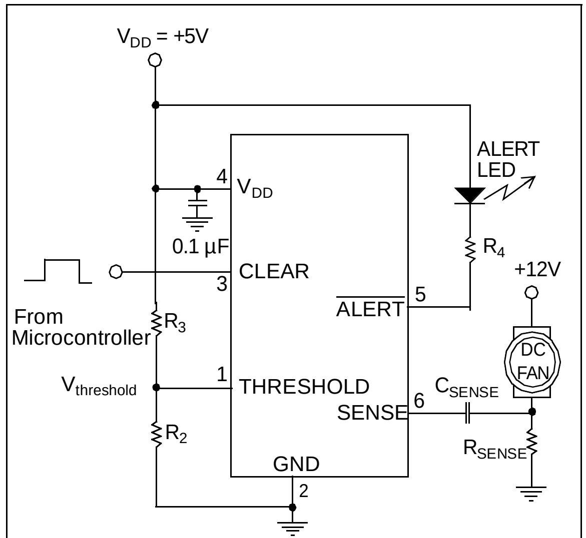


As shown in Figure 4-1, the TC670 senses the fan pulses and internally converts those pulses from a frequency into an analog voltage. This voltage is then compared with a DC voltage present on the THRESHOLD pin. If the converted frequency-to-voltage value from the fan's pulses falls below the THRESHOLD voltage, a FAULT signal is asserted through the ALERT pin (active LOW).

In a 3.0V system, the external fan alert level on the THRESHOLD pin can be designed from 0.0V (stalled fan) and up to 2.4V (for 13,000 RPM) to cover most of the common fan speeds. This failure detection system works with linear controlled 2-wire fans and eliminates the need for 3-wire fans. The TC670 can work with 3-wire fans as well either by using the SENSE circuit or by directly sensing the RPM output from the 3rd wire.

A CLEAR pin is provided to allow the user to reset the ALERT pin status back to a HIGH state. This CLEAR option also allows the flexibility of connecting the ALERT output of the TC670 with other Alert/FAULT interrupts in the system without having a risk of a system shutdown due to false Fan Fault condition.

FIGURE 4-2: TYPICAL APPLICATION CIRCUIT



$$V_{THRESHOLD} = V_{DD}\left(\frac{R_2}{R_2 + R_3}\right)$$

Note: This typical application circuit uses an LED to indicate that a fan failure has occurred.

4.1 SENSE Input

As shown in Figure 4-2, the SENSE input (Pin 6) is connected through a sensing capacitor (C_{SENSE}). A low value current sensing resistor (R_{SENSE}) is also connected to the low side of the fan to the ground return leg of the fan. During normal fan operation, commutation occurs as each pole of the fan is energized. This causes brief interruptions in the fan current, seen as pulses across the sense resistor.

These short rapid changes in fan current cause a corresponding dV/dt voltage across the sense resistor as well as a corresponding dI/dt current across the sense capacitor. The current across C_{SENSE} is terminated with the internal 50kΩ input resistance at the SENSE pin of the TC670. When positive going fan pulses at the SENSE input are greater than 124mV (typ) the TC670 latches in those voltage spikes. This 124mV (typ) SENSE input built-in threshold reduces false triggering errors caused by extraneous noise pulses associated with a running fan. The presence and frequency of these pulses is a direct indication of fan operation and fan speed.

The design of the proper input SENSE circuitry is a matter of scaling R_{SENSE} to provide the necessary amount of gain and proper selection of the sensing capacitor. The following table (Table 4-1) lists some recommended values for R_{SENSE} according to the nominal operating current of the fan. Please note that the current draw specified by the fan manufacturer may not be the fan's nominal operating current, but a worst-case rating. If the fan current falls between two of the values listed, it is recommended that the higher value resistor is used.

TABLE 4-1: RECOMMENDED VALUES FOR R_{SENSE} PER FIGURE 4-2

Nominal Fan Current (mA)	R_{SENSE} (Ω)
100	4.7
200	2.4
300	1.8
400	1.3
500	1.0
600	0.8

A 0.1µF ceramic capacitor is recommended for C_{SENSE}. Smaller capacitor values will require larger sense resistors whereas larger capacitors are more expensive and occupy more board space.

4.2 THRESHOLD Input

The voltage at the THRESHOLD input sets the equivalent minimum allowable fan speed for the application. As shown in Section 3.0 typical performance curves, the relationship between the THRESHOLD voltage and minimum fan speed is also power supply and temperature dependant.

All the values for the THRESHOLD voltage that are shown in these graphs represent typical numbers and might not be optimized for all fans in all applications. To ensure accurate fan speed monitoring of a specific fan in a specific application, the user must perform a one-time correlation check with the prototype.

There are two techniques that can be used to calibrate the system. One approach is to find the fan's full scale capability and mathematically estimate the minimum acceptable speed of the fan. A second technique is to identify the fan's minimum speed and calibrate the THRESHOLD voltage accordingly.

4.2.1 THRESHOLD CALIBRATION USING FAN'S FULL SCALE SPEED

The fan should first be run at full speed. At full speed the THRESHOLD voltage level should be adjusted until the $\overline{\text{ALERT}}$ output is asserted. With this full scale value of the THRESHOLD voltage, the value can be scaled down to the Fan Fault speed as a percentage of the full speed. For example, if the fan full speed THRESHOLD voltage is 1.5V, then the Fan Fault THRESHOLD voltage at 30% of full speed would be 30% x 1.5V = 0.45V.

4.2.2 THRESHOLD CALIBRATION USING FAN'S MINIMUM ALLOWABLE SPEED ESTIMATE

For a more exact Fan Fault trip point, the user can run the fan at its minimum allowed speed. At this speed, the THRESHOLD voltage can be adjusted until the $\overline{\text{ALERT}}$ output is asserted.

4.3 CLEAR Input

The CLEAR input allows the user to reset the $\overline{\text{ALERT}}$ pin to a high status. This is an active HIGH input. Consequently, as long as CLEAR is HIGH, $\overline{\text{ALERT}}$ will always be HIGH as well. To allow $\overline{\text{ALERT}}$ to operate correctly CLEAR must be held LOW. This feature can be implemented so that false Fan Fault conditions do not initiate system shutdown.

4.4 $\overline{\text{ALERT}}$ Output

The $\overline{\text{ALERT}}$ output is an open drain output capable of sinking 2.5mA (typ). The $\overline{\text{ALERT}}$ output is asserted whenever the detected fan speed equals or falls below the equivalent voltage set at the THRESHOLD pin. The $\overline{\text{ALERT}}$ output is only deactivated once the CLEAR pin is brought to a HIGH state. Although the absolute maximum output current of this pin is 25mA, it is recommended that this current sinking into the $\overline{\text{ALERT}}$ Output does not exceed 20mA.

4.5 Power Supply Input, V_{DD}

To assure proper operation of the TC670 in a noisy environment where the fans are running, the V_{DD} pin (Pin 4) must be decoupled with a 0.1µF capacitor as shown in Figure 4-1. This capacitor should be located as close to the TC670 V_{DD} pin as possible as well being promptly terminated to the ground plane. A Ceramic capacitor is recommended.

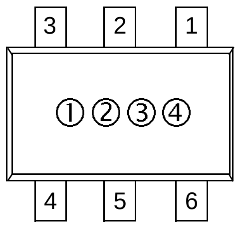
4.6 Ground Terminal, GND

The GND pin (Pin 2) of the TC670 should be connected directly to the analog ground plane of the circuit board. Care should be taken in circuit layout to keep this pin away from switching signals, such as the fan excitation signals in order to avoid false signals on the SENSE pin.

5.0 PACKAGE INFORMATION

5.1 Package Marking Information

6-Pin SOT-23A (EIAJ SC-74) Device



1 & 2 = part number code + temperature range and voltage

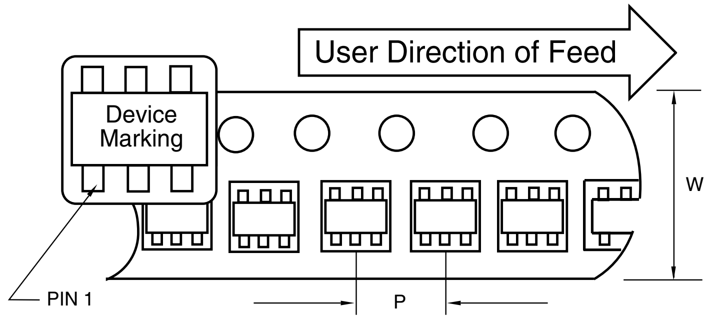
Part Number	Code
TC670ECH	

3 = year and quarter code

4 = lot ID number

5.2 Taping Form

Component Taping Orientation for 6-Pin SOT-23A (EIAJ SC-74) Devices



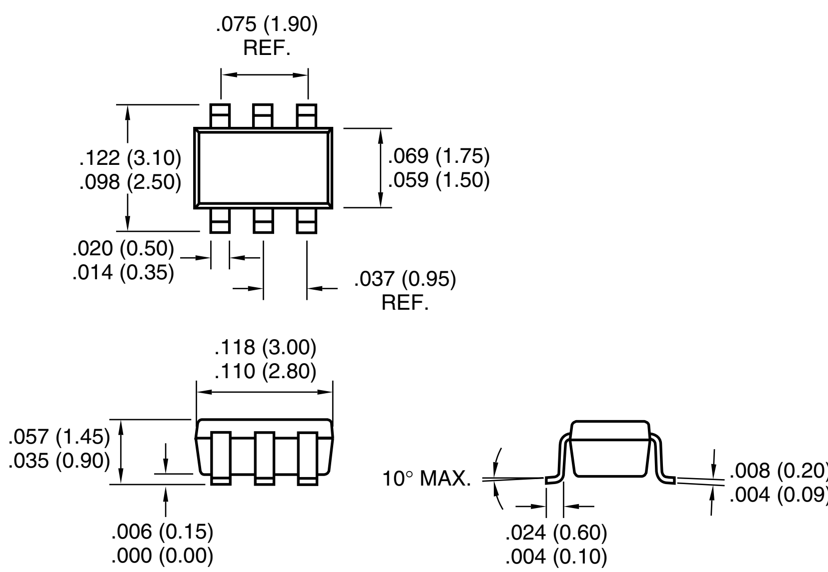
Standard Reel Component Orientation
For TR Suffix Device
(Mark Right Side Up)

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
6-Pin SOT-23A	8 mm	4 mm	3000	7 in

5.3 Package Dimensions

SOT-23A-6



Dimensions: inches (mm)

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Data Sheets
Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

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