TC652/TC653

Integrated Temperature Sensor & Brushless DC Fan Controller with FanSense™ Detect & Over-Temperature

Features

• Integrated Temperature Sensing and Multi-speed Fan Control
• FanSense™ Fan Fault Detect Circuitry
• Built-in Over-Temperature Alert ($T_{\overline{OVER}}$)
• Temperature Proportional Fan Speed Control for Acoustic Noise Reduction and Longer Fan Life
• Pulse Width Modulation Output Drive for Cost and Power Savings
• Solid-State Temperature Sensing
• ±1°C (Typical) Accuracy from 25°C to +70°C
• 2.8V – 5.5V Operating Range
• TC653 includes Auto Fan Shutdown
• Low Operating Current: 50µA (Typical)

Applications

• Thermal Protection For Personal Computers
• Digital Set-Top Boxes
• Notebook Computers
• Data Communications
• Power Supplies
• Projectors

Related Literature

• Application Note: AN771

Device Selection Table

Part Number	Package	Temperature Range
TC652XXVUA	8-Pin MSOP	-40°C to +125°C
TC653XXVUA	8-Pin MSOP	-40°C to +125°C

X	Temperature
A	25
B	30
C	35
D	40
E	45
F	50
G	55

The "X" denotes a suffix for temperature threshold settings. Contact factory for other temperature ranges.

Package Type

MSOP

TC652
TC653

| Pin	Name		Pin	Name
1	V_{DD}		8	PWM
2	$\overline{FAULT}$		7	GND
3	$\overline{SHDN}$		6	$T_{\overline{OVER}}$
4	GND		5	SENSE
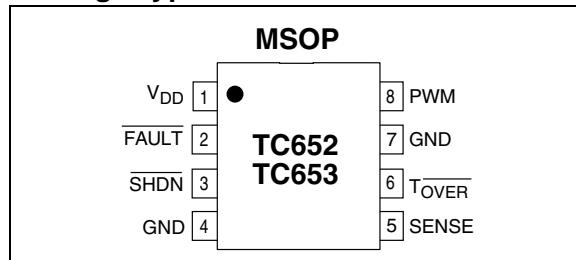
General Description

The TC652/TC653 are integrated temperature sensors and brushless DC fan speed controllers with FanSense™ technology. The TC652/TC653 measure their junction temperature and control the speed of the fan based on that temperature, making them especially suited for applications in modern electronic equipment. The FanSense™ Fan Fault detect circuitry eliminates the need for a more expensive 3-wire fan.

Temperature data is converted from the on-chip thermal sensing element and translated into a fractional fan speed from 40% to 100%. A temperature selection guide in the data sheet is used to choose the low and high temperature limits to control the fan. The TC652/TC653 also include a single trip point over temperature alert ($T_{\overline{OVER}}$) that eliminates the need for additional temperature sensors. In addition, the TC653 includes an auto fan shutdown function for additional power savings.

The TC652/TC653 are easy to use, require no software overhead and are therefore the ideal choice for implementing thermal management in a variety of systems.

Typical Application Diagram
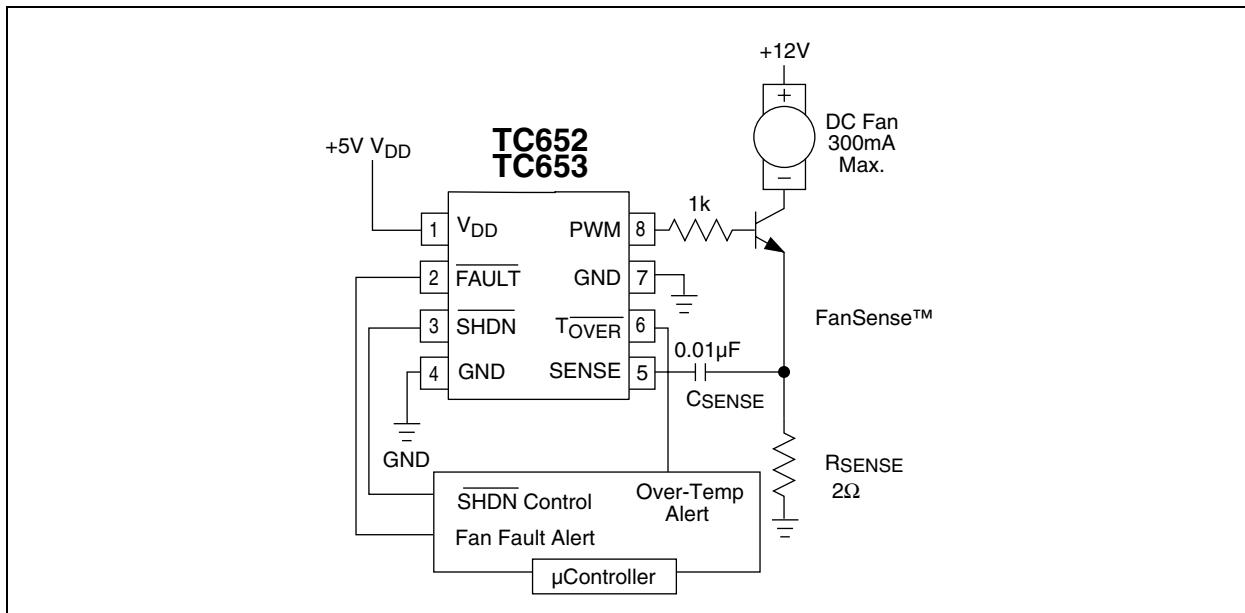
1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Input Voltage (V_{DD} to GND) .... +6V

Output Voltage (OUT to GND) 6V

Voltage On Any Pin .... (GND − 0.3V) to (V_{DD} + 0.3V)

Package Thermal Resistance (θ_{JA}) .... 250°C/W

Operating Temperature Range .... -40°C to +125°C

Storage Temperature .... -65°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.

TC652/TC653 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V_{DD} = 2.8V to 5.5V, $\overline{SHDN}$ = V_{DD}, T_A = -40°C to 125°C unless otherwise specified.

Symbol	Parameter	Min	Typ.	Max	Units	Test Conditions
V_{DD}	Supply Voltage	2.8	—	5.5	V	
I_{DD}	Supply Current	—	50	90	µA	PWM, $\overline{FAULT}$, $T_{\overline{OVER}}$ are open
$\overline{SHDN}$ Input						
V_{IH}	$\overline{SHDN}$ Input High Threshold	65	—	—	%V_{DD}	
V_{IL}	$\overline{SHDN}$ Input Low Threshold	—	—	15	%V_{DD}	
PWM Output						
V_{OL}	PWM Output Low Voltage	—	—	0.3	V	I_{SINK} = 1mA
V_{OH}	PWM Output High Voltage	V_{DD} − 0.5	—	—	V	I_{SOURCE} = 5mA
t_R	PWM Rise Time	—	10	—	µsec	I_{OH} = 5mA, 1nF from PWM to GND
t_F	PWM Fall Time	—	10	—	µsec	I_{OL} = 1mA, 1nF from PWM to GND
f_{OUT}	PWM Frequency	10	15	—	Hz	
$t_{STARTUP}$	Start-up Time	—	$32/f_{OUT}$	—	sec	V_{DD} Rises from GND, or $\overline{SHDN}$ Released
$V_{TH (SENSE)}$	Sense Input	—	70	—	mV	Sense Input Threshold Voltage with Repect to Ground
Temperature Accuracy						
$T_{H\ ACC}$	High Temperature Accuracy	T_H - 3	T_H	T_H + 3	°C	**Note 1**
$(T_H {}_-T_L)_{ACC}$	Temp. Range Accuracy	-1.0	—	+1.0	°C	$(T_H − T_L) \leq 20°C$
		-2.5	—	+2.5	°C	$(T_H − T_L) \geq 20°C$
T_{HYST}	Auto-shutdown Hysteresis	—	$(T_H − T_L)/5$	—	°C	TC653 Only
$\overline{FAULT}$ Output						
V_{HIGH}	$\overline{FAULT}$ Output High Voltage	V_{DD} − 0.5	—	—	V	I_{SOURCE} = 1.2mA
V_{LOW}	$\overline{FAULT}$ Output Low Voltage	—	—	0.4	V	I_{SINK} = 2.5mA
tmp	Missing Pulse Detector Time-out	—	—	$32/f_{OUT}$	Sec	
$T_{\overline{OVER}}$ Output						
V_{HIGH}	$T_{\overline{OVER}}$ Output High Voltage	V_{DD} − 0.5	—	—	V	I_{SOURCE} = 1.2mA
V_{LOW}	$T_{\overline{OVER}}$ Output Low Voltage	—	—	0.4	V	I_{SINK} = 2.5mA
$T_{\overline{OVER}\ ACC}$	Absolute Accuracy	—	T_H + 10	—	°C	At Trip Point
$T_{\overline{OVER}\ HYST}$	Trip Point Hysteresis	—	5	—	°C	

Note 1: Transition from 90% to 100% Duty Cycle.

TC652/TC653

2.0   PIN DESCRIPTIONS

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

TABLE 2-1:   PIN FUNCTION TABLE

Pin No. (8-Pin MSOP)	Symbol	Description
1	V_{DD}	Power Supply Input. May be independent of fan power supply.
2	$\overline{FAULT}$	Fan Fault Alert, Active-Low Output. FAULT goes low to indicate a fan FAULT condition. When FAULT occurs, the device is latched in Shutdown mode with PWM low. Toggling the $\overline{SHDN}$ pin or cycling the V_{DD} will release the part and fan from shutdown. FAULT will unconditionally remain high during shutdown.
3	$\overline{SHDN}$	Fan Shutdown, Active-Low Input. During Shutdown mode the chip still monitors temperature and $T_{\overline{OVER}}$ is low if temperature rises above factory set point.
4	GND	Ground return for all TC652/TC653 functions.
5	SENSE	Detect Fan Pulses Input. Pulses are detected at this pin as fan rotation chops the current through the sense resistor, R_{SENSE}. The absence of pulses indicates a Fan Fault.
6	$T_{\overline{OVER}}$	Over-Temperature Alert, Active-Low Output.
7	GND	Ground.
8	PWM	PWM Fan Drive Output. Pulse width modulated rail-to-rail logic output. Nominal Frequency is 15Hz.

3.0 DETAILED DESCRIPTION

The TC652/TC653 acquire and convert their junction temperature (T_J) information from an on-chip solid state sensor with a typical accuracy of ±1°C. The temperature data is digitally stored in an internal register. The register is compared with pre-defined threshold values. The six threshold values are equally distributed over a pre-defined range of temperatures (See Table 3-1 and Table 3-2). The TC652/TC653 control the speed of a DC brushless fan using a fractional speed control scheme. The output stage requires only a 2N2222-type small-signal BJT for fans up to 300mA. For larger current fans (up to 1 Amp) a logic-level N-channel MOSFET may be used. In addition to controlling the speed of the fan, the TC652/TC653 include an on-chip over-temperature alarm ($T_{\overline{OVER}}$) that gives a low-true signal when the temperature of the chip exceeds T_H by 10°C. This feature eliminates the need for a separate temperature sensor for over-temperature monitoring.

In normal fan operation, a pulse-train is present at SENSE, Pin 5. A Missing Pulse Detector monitors this pin during fan operation (FanSense™ technology). A stalled, open, or unconnected fan causes the TC652/TC653 to trigger its Start-up Timer once. If the FAULT persists, the $\overline{FAULT}$ output goes low, and the device is latched in its Shutdown mode. To release the fan from shutdown, toggle the $\overline{SHDN}$ or V_{DD} pin.

**TABLE 3-1: TEMPERATURE RANGE DEFINITION FOR TC652 (MINIMUM-SPEED MODE)**

Temperature ($T = T_J$)	PWM Duty Cycle
$T < T_L$	40%
$T_L <= T < T_1$	50%
$T_1 <= T < T_2$	60%
$T_2 <= T < T_3$	70%
$T_3 <= T < T_4$	80%
$T_4 <= T < T_H$	90%
$T_H <= T < T_{OV}$	100%
$T_{OV} <= T$	100% with Over-Temp Alert ($T_{\overline{OVER}} = L$)

TABLE 3-2: TEMPERATURE RANGE DEFINITION FOR TC653 (AUTO-SHUTDOWN MODE)

Temperature ($T = T_J$)	PWM Duty Cycle
$T < T_L$	"OFF"
$T_L <= T < T_1$	50%
$T_1 <= T < T_2$	60%
$T_2 <= T < T_3$	70%
$T_3 <= T < T_4$	80%
$T_4 <= T < T_H$	90%
$T_H <= T < T_{OV}$	100%
$T_{OV} <= T$	100% with Over-Temp Alert ($T_{\overline{OVER}} = L$)

Note: The temperature regions defined by the six temperature thresholds are pre-defined in the TC650/651 by means of trimming. Once a T_L and T_H are programmed, the T_1 - T_4 thresholds are automatically equally spaced between T_L and T_H.

FIGURE 3-1: FUNCTIONAL BLOCK DIAGRAM
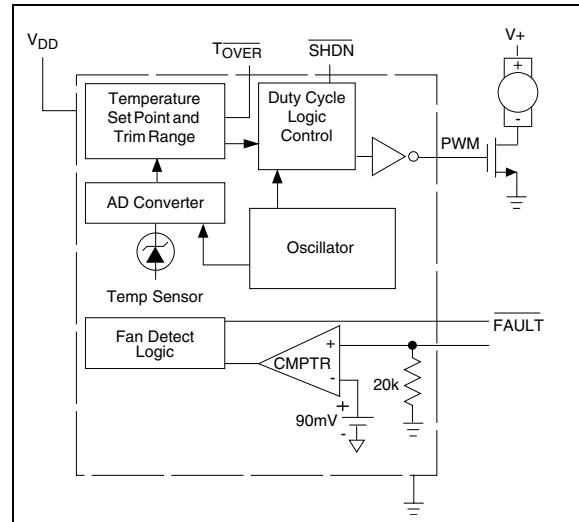
3.1 PWM Output

The PWM pin is designed to drive a low cost transistor or MOSFET as the low side power switching element in the system. This output has an asymmetric complementary drive and is optimized for driving NPN transistors or N-channel MOSFETs. Since the system relies on PWM rather than linear power control, the dissipation in the power switch is kept to a minimum. Generally, very small devices (TO-92 or SOT packages) will suffice. The frequency of the PWM is about 15Hz. The PWM is also the time base for the Start-up Timer (see paragraphs below). The PWM duty cycle has a range of 40% to 100% for the TC652 and 50% to 100% for the TC653.

TC652/TC653

3.2 Start-Up Timer

To ensure reliable fan start-up, the Start-up Timer turns PWM high for about 2 seconds whenever the fan is started from the off state. This occurs at power-up and when coming out of Shutdown mode.

3.3 SENSE Input (FanSense™ Technology)

The SENSE input, Pin 5, is connected to a low value current sensing resistor in the ground return leg of the fan circuit through the capacitor. 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. If the device is not in Shutdown mode, and pulses are not appearing at the SENSE input, a FAULT exists. The short, rapid change in fan current (high di/dt) causes a corresponding dv/dt across the sense resistor, R_{SENSE}. The waveform on R_{SENSE} is differentiated and converted to a logic-level pulse-train by C_{SENSE} and the internal signal processing circuitry. The presence and frequency of this pulse-train is a direct indication of fan operation.

3.4 $\overline{FAULT}$

This pin goes low to indicate a fan FAULT condition. Pulses appearing at SENSE pin due to the PWM turning on are blanked and the remaining pulses are filtered by a Missing Pulse Detector. If consecutive pulses are not detected for 32 PWM cycles (about 2 sec), the PWM is Low and $\overline{FAULT}$ goes low. $\overline{FAULT}$ can be disabled by momentarily toggling $\overline{SHDN}$ or V_{DD} pin, or cycling system power. $\overline{FAULT}$ remains high during Shutdown mode.

3.5 Over-Temperature Alert ($T_{\overline{OVER}}$)

This pin goes low when the T_H set point is exceeded by 10°C (typical). This indicates that the fan is at maximum drive, and the potential exists for system overheating: either heat dissipation in the system has gone beyond the cooling system's design limits, or some FAULT exists such as fan bearing failure or an airflow obstruction. This output may be treated as a "System Overheat" warning and used to trigger system shutdown, or bring other fans to full speed in the system. The fan will continue to run at 100% speed while $T_{\overline{OVER}}$ is asserted. Built-in hysteresis prevents $T_{\overline{OVER}}$ from "chattering" when measured temperature is at or near the T_H + 10°C trip point. As temperature falls through the T_H + 10°C trip point, hysteresis maintains the $T_{\overline{OVER}}$ output low until measured temperature is 5°C above the trip point setting.

3.6 Shutdown ($\overline{SHDN}$)

The fan can be unconditionally shutdown by pulling low the SHDN pin. During shutdown, $\overline{FAULT}$ output is high and PWM output is low. This is ideal for notebook computers and other portable applications when you need to change batteries and must not have the fan running at that time. Thermal monitoring and $T_{\overline{OVER}}$ are still in operation during shutdown. I_{DD} shutdown current is around 50μA.

3.7 Auto-Shutdown Mode

The TC653 has auto-shutdown. If the temperature is below the factory set point at minimum speed (T_L), PWM is low and the fan is automatically shut off (Auto-shutdown mode). This feature is ideal for notebook computers and other portable applications that need to conserve as much battery power as possible and thus run a fan when it is only absolutely needed. The TC653 will continue to be active so as to monitor temperature for $T_{\overline{OVER}}$. The TC653 exits Auto-shutdown mode when the temperature rises above the factory set point (T_1).

3.8 Temperature Selection Guide (Minimum Fan Speed/Full Speed)

The five temperature regions defined by the six thresholds are defined in the TC652/TC653 by means of factory trimming. Once a T_L and T_H are set, the $T_1 – T_4$ thresholds are automatically equally spaced between T_L and T_H.

TABLE 3-3: TEMPERATURE SELECTION GUIDE

Temp. Range °C	T_L	T_H	Part #
10°C	25	35	AC
	30	40	BD
	35	45	CE
15°C	25	40	AD
	30	45	BE
20°C	**25**	**45**	AE
	30	50	BF
	35	55	CG
30°C	25	55	AG

Note: The **Bold Type** temperature settings are available for ordering. Contact factory for other temperature selections.

T_L and T_H can be selected in 5°C increments. T_H must be chosen at least 10°C higher than T_L. T_L can range anywhere from 25°C to 35°C.

As an example, suppose you wanted the fan to **run at 40% speed at 25°C** or less and go to **full speed at 45°C.** You would order the part number TC652AEVUA.

As another example, suppose you wanted the fan to **turn on at 30°C** and go to **full speed at 45°C.** You would order the part number TC653BEVUA.

4.0 TYPICAL APPLICATIONS

4.1 Reducing Switching Noise

For fans consuming more than 300mA, a slowdown capacitor (C_{SLOW}) is recommended for reducing switching PWM induced noise (see Figure 4-1). The value of this capacitor should be 4.7µF to 47µF, depending on the fan current consumption.

See Application Note AN771 "Suppressing Acoustic Noise in PWM Fan Speed Control Systems" for more information.

FIGURE 4-1: REDUCING SWITCHING NOISE
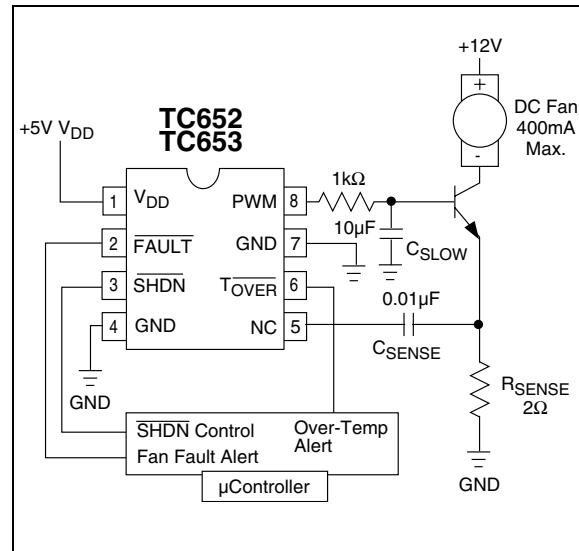
TC652/TC653

5.0 TYPICAL CHARACTERISTICS

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.

I_{DD} vs. Temperature

Temp Accuracy vs. V_{TH}

PWM, I_{SOURCE} vs. $(V_{DD} - V_{OH})$, $T_A = 25°C$

PWM, I_{SINK} vs. V_{OL}, $T_A = 25°C$

$T_{\overline{OVER}}$, I_{SOURCE} vs. $(V_{DD} - V_{OH})$, $T_A = 25°C$

$\overline{FAULT}$, I_{SOURCE} vs. $(V_{DD} - V_{OH})$, $T_A = 25°C$

$\overline{FAULT}$, I_{SINK} vs. V_{OL}, $T_A = 25°C$

TC652/3, Fan is Running $\overline{SHDN}$ is Connected to V_{DD}, $T_A = 25°C$

TC653, Fan is Not Running $\overline{SHDN}$ is Connected to V_{DD}, $T_A = 25°C$
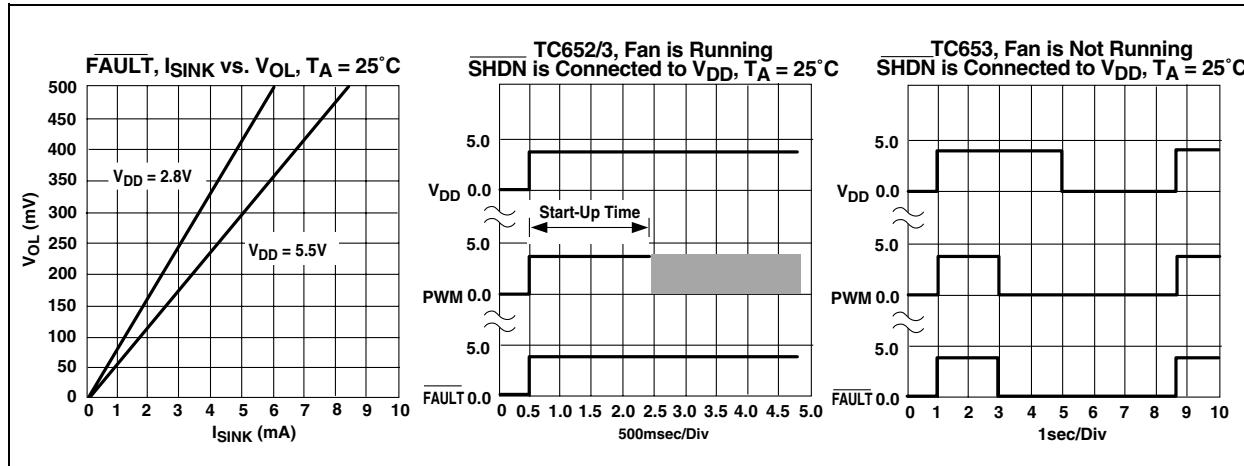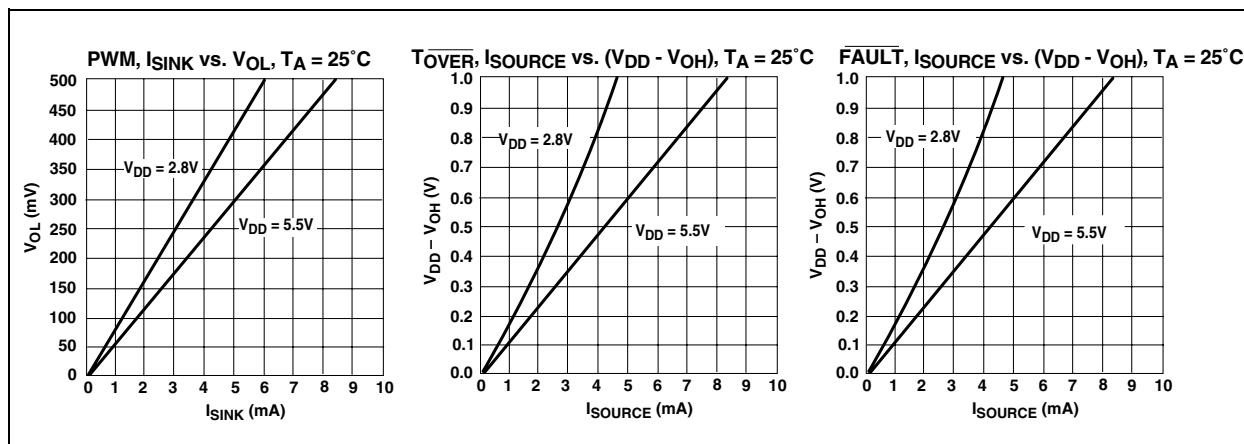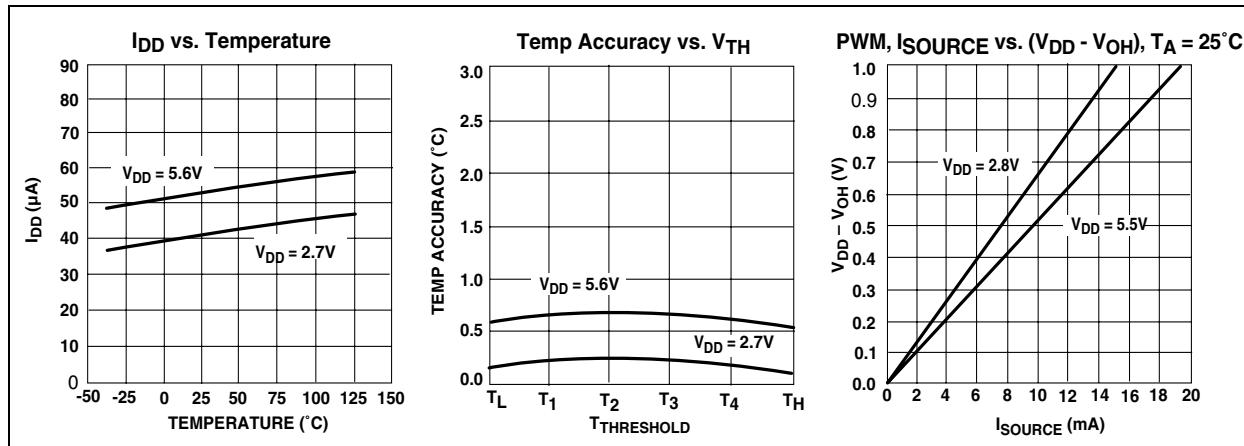
6.0   PACKAGING INFORMATION

6.1   Package Marking Information

Package marking data not available at this time.

6.2   Taping Form

Component Taping Orientation for 8-Pin MSOP Devices

User Direction of Feed

PIN 1

W

P
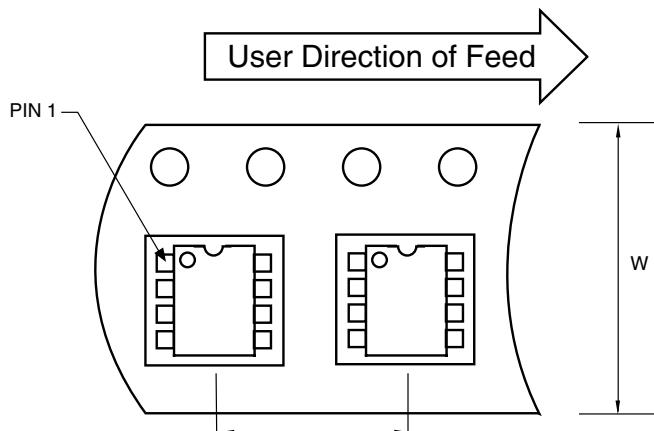
Standard Reel Component Orientation
for TR Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin MSOP	12 mm	8 mm	2500	13 in

6.3   Package Dimensions

8-Pin MSOP

PIN 1

.122 (3.10)
.114 (2.90)

.197 (5.00)
.189 (4.80)

.026 (0.65) TYP.

.122 (3.10)
.114 (2.90)

.043 (1.10)
MAX.

6° MAX.

.008 (0.20)
.005 (0.13)

.016 (0.40)
.010 (0.25)

.006 (0.15)
.002 (0.05)

.028 (0.70)
.016 (0.40)
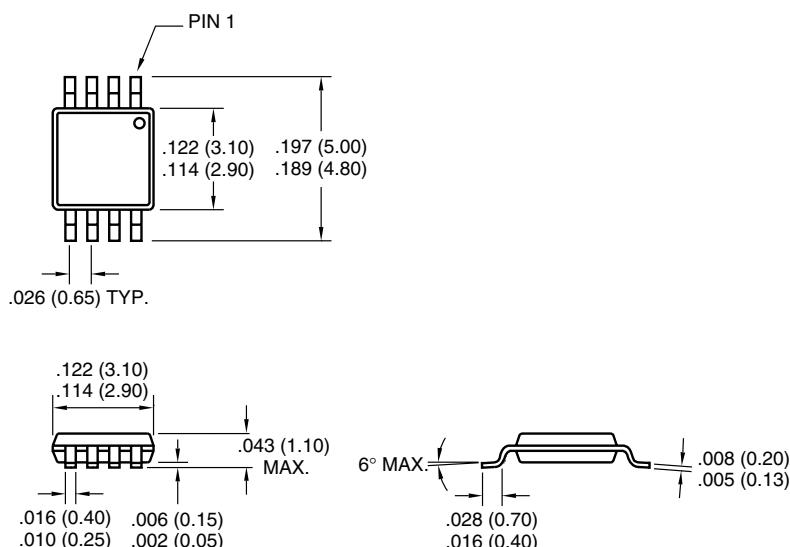
Dimensions: inches (mm)

NOTES:

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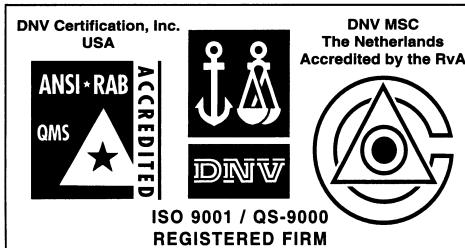
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  TC652BFVUA   TC652AGVUA   TC652BEVUA   TC652CGVUA   TC652AEVUA   TC653BFVUA   TC653CGVUA
TC653BEVUATR   TC653AEVUATR   TC652AEVUATR   TC652BEVUATR   TC653AEVUA   TC653ACVUATR
TC652ACVUATR   TC652ACVUA   TC653BEVUA   TC652BFVUATR   TC653BFVUATR   TC653CGVUATR
TC652AGVUATR   TC653AGVUATR   TC652CGVUATR   TC653ACVUA   TC653AGVUA