Tiny Integrated Temperature Sensor and Brushless DC Fan Controller with Over Temperature Alert

FEATURES

- **Digital Temperature Sensing and Multi-Speed Fan Control**
- **Built in Over Temperature Alert ($\overline{\text{Tover}}$)**
- **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**
- **2.8 - 5.5V Operating Range**
- **TC651 includes Auto Fan Shutdown**
- **Low Operating Power: 50µA (Typ)**

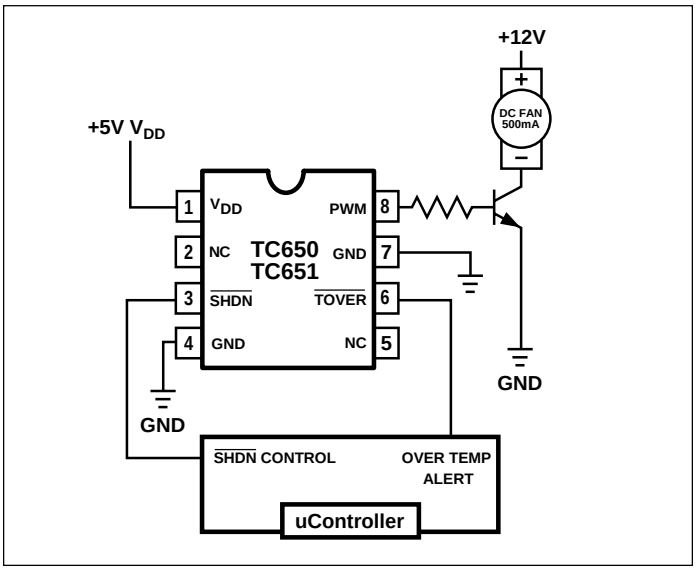
APPLICATIONS

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

RELATED LITERATURE

- **Application Note: 58**
- **Article: "An Integrated Fan Speed Control Solution Can Lower System Costs, Reduce Acoustic Noise and Power Consumption and Enhance System Reliability"**

TYPICAL APPLICATION



GENERAL DESCRIPTION

The TC650/651 are integrated temperature sensors and brushless DC fan speed controllers. The TC650/651 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.

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 TC650/651 also include a single trip point over temperature alert ($\overline{\text{Tover}}$) that eliminates the need for additional temperature sensors. In addition, the TC651 features an auto fan shutdown function for additional power savings.

The TC650/651 are easy to use, and require no software overhead, and are therefore the ideal choice for implementing thermal management in a variety of systems.

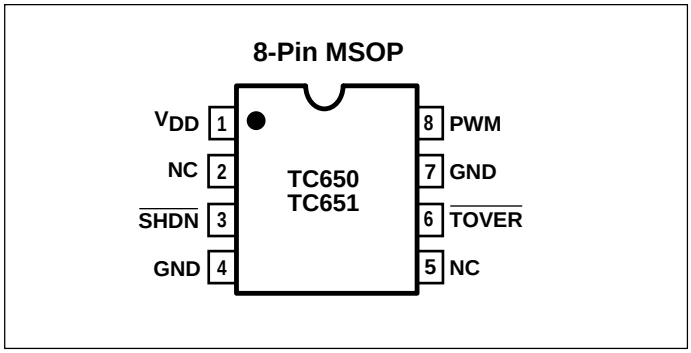
ORDERING INFORMATION

Part Number	Package	Operating Temp. Range
TC650XXVUA	8-Pin MSOP	– 40˚C to +125˚C
TC651XXVUA	8-Pin MSOP	– 40˚C to +125˚C

X (See Page 5)	Temperature
A	25
B	30
C	35
D	40
E	45
F	50
G	55

Notes: 1. The "X" denotes a suffix for temperature threshold settings.
2. Contact factory for other temperature ranges.

PIN CONFIGURATIONS



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 (unbiased) ..... –65°C to +150°C
Lead Temperature
(Soldering, 10sec duration) ..... +300°C

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation section of this specification is not implied. Exposure to absolute maximum ratings conditions for extended periods of time may affect reliability.

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

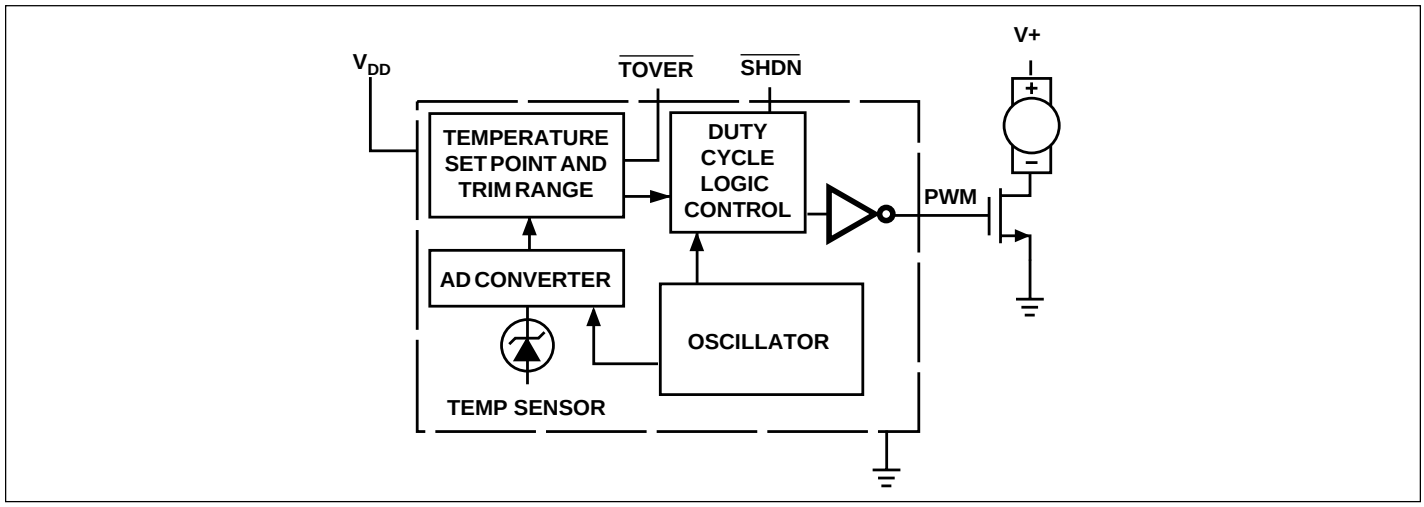
Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
V_{DD}	Supply Voltage		2.8	—	5.5	V
I_{DD}	Supply Current	PWM $\overline{Tover}$ are open	—	50	90	µA
$\overline{SHDN}$ Input						
V_{IH}	$\overline{SHDN}$ Input High Threshold		65	—	—	%V_{DD}
V_{IL}	$\overline{SHDN}$ Input Low Threshold		—	—	15	%V_{DD}
PWM Output						
V_{OL}	PWM Output Low Voltage	I_{SINK} = 1mA	—	—	0.3	V
V_{OH}	PWM Output High Voltage	I_{SOURCE} = 5mA	V_{DD} – 0.5	—	—	V
t_R	PWM Rise Time	I_{OH} = 5mA, 1nF from PWM to GND	—	10	—	µsec
t_F	PWM Fall Time	I_{OL} = 1mA, 1nF from PWM to GND	—	10	—	µsec
f_{OUT}	PWM Frequency		10	15	—	Hz
$t_{STARTUP}$	Startup Time	V_{DD} Rises from GND, or $\overline{SHDN}$ Released	—	32/f_{OUT}	—	sec
Temperature Accuracy						
$T_{H\ ACC}$	High Temp Accuracy	Note 1	T_H – 3	T_H	T_H + 3	°C
$(T_H–T_{L)ACC}$	Temp Range Accuracy	(T_H – T_L) ≤ 20°C	–1.0	—	+1.0	°C
		(T_H – T_L) > 20°C	–2.5	—	+2.5	
T_{HYST}	Auto Shutdown Hysteresis	TC651 Only	—	(T_H – T_L)/5	—	°C
$\overline{Tover}$ Output						
V_{HIGH}	$\overline{Tover}$ Output High Voltage	I_{SOURCE} = 1.2mA	V_{DD} – 0.5	—	—	V
V_{LOW}	$\overline{Tover}$ Output Low Voltage	I_{SINK} = 2.5mA	—	—	0.4	V
$\overline{Tover}_{ACC}$	Absolute Accuracy	At Trip Point	—	T_H + 10	—	°C
$\overline{Tover}_{HYST}$	Trip Point Hysteresis		—	5	—	°C

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

PIN DESCRIPTION

Pin No. 8-Pin MSOP	Symbol	Description
1	V_{DD}	Power Supply Input. May be independent of fan power supply.
2	NC	No Connect.
3	$\overline{SHDN}$	Fan Shutdown, Active-Low Input. During shut down mode the chip still monitors temperature and Tover is low if temperature rises above factory setpoint.
4	GND	Ground. Ground return for all TC650/651 functions.
5	NC	No Connect.
6	$\overline{Tover}$	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.

BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

The TC650/651 acquire, and convert, their junction temperature (Tj) information from an on-chip solid state sensor with a typical accuracy of ±1°C (typical) . 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 1). The TC650/651 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 controling the speed of the fan, the TC650/651 include an on-chip over-temperature alarm (Tover) 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.

Table 1: Temperature Range Definition for TC650 (Minimum-Speed Mode)

Temperature (T=Tj)	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 ($\overline{Tover}$ = L)

Table 2: Temperature Range Definition for TC651 (Auto-Shutdown Mode)

Temperature (T=Tj)	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 ($\overline{Tover}$ = 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.

DETAILED DESCRIPTION

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. Various examples of driver circuits will be shown below. 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 timebase for the Start-up Timer (see paragraphs below). The PWM duty cycle has a range of 40% to 100% for the TC650 and 50% to 100% for the TC651.

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.

Over-Temperature Alert (Tover)

This pin goes low when the T_H set point is exceeded by 10°C. 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 Tover is asserted. Built-in hysteresis prevents $\overline{Tover}$ 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 $\overline{Tover}$ output low until measured temperature is 5°C above the trip point setting.

Shutdown ($\overline{SHDN}$)

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

Auto-Shutdown Mode

The TC651 features auto shutdown: when 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 equipment that need to conserve as much battery power as possible and thus run a fan when it is only absolutely needed. The TC651 will continue to be active so as to monitor temperature for Tover. The TC651 exits Auto-Shutdown mode when the temperature rises above the factory set point (T_1).

Temperature Selection Guide (Minimum Fan Speed/Full Speed)

The five temperature regions defined by the six thresholds are defined in the TC650/651 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.

Range	T_L	T_H	Part #
10°C	**25**	**35**	AC
	30	40	BD
	35	45	CE
15°C	25	40	AD
	30	**45**	BE
	35	50	CF
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 TC650AEVUA.

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 TC651BEVUA.

APPLICATIONS INFORMATION

Reducing Switching Noise

For fans consuming more than 300mA, a slowdown capacitor (C_{SLOW}) is recommended for reducing switching PWM induced noise (see Figure 1). The value of this capacitor should be 4.7µF to 47µF, depending on the fan current consumption. Please see Application Note 38 for more information.

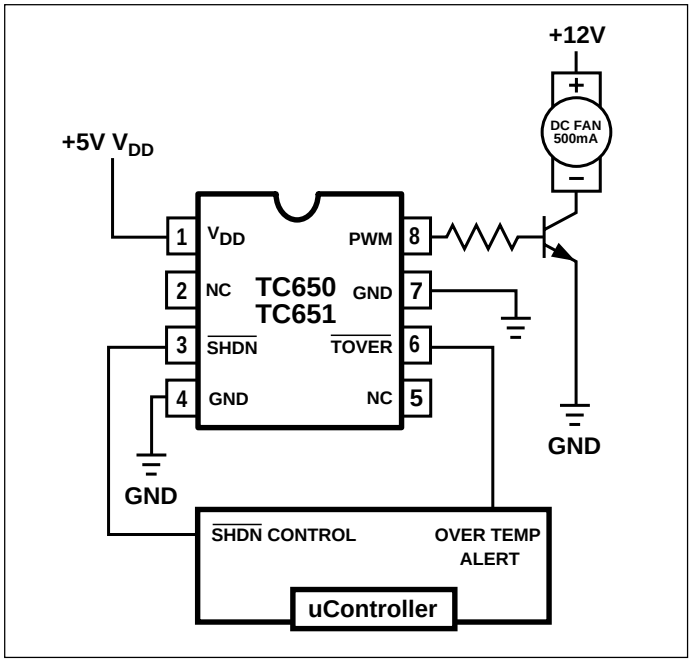
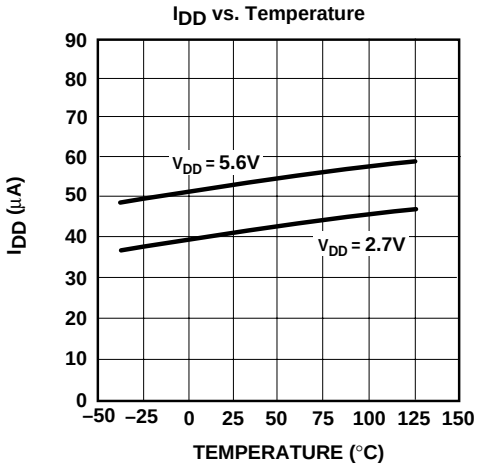
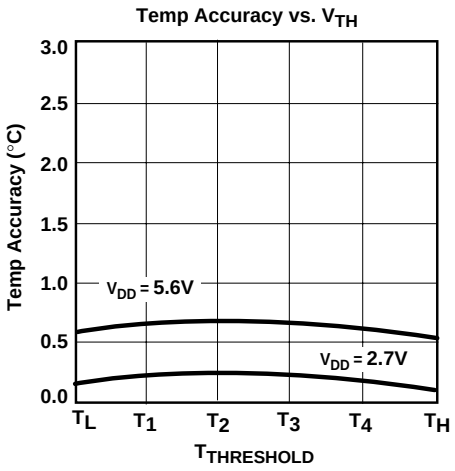
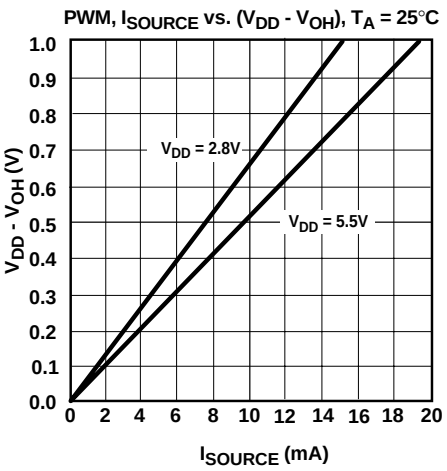


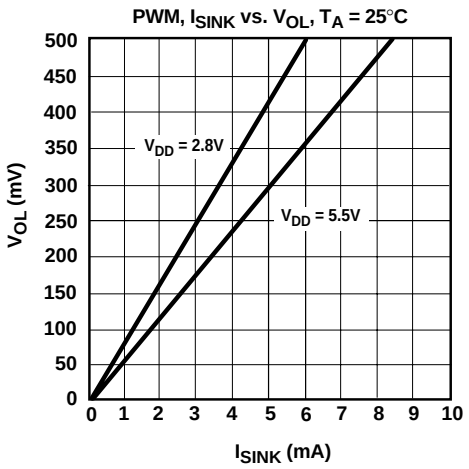
Figure 1. Reducing Switching Noise

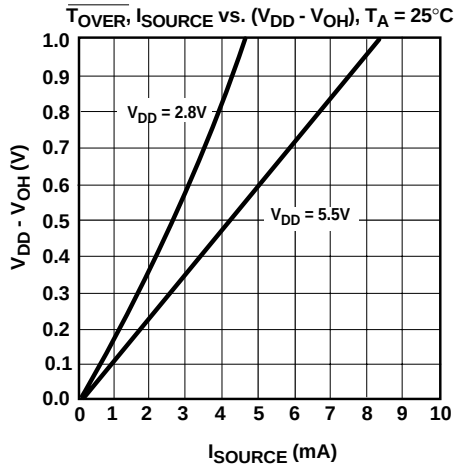
TYPICAL CHARACTERISTIC CURVES





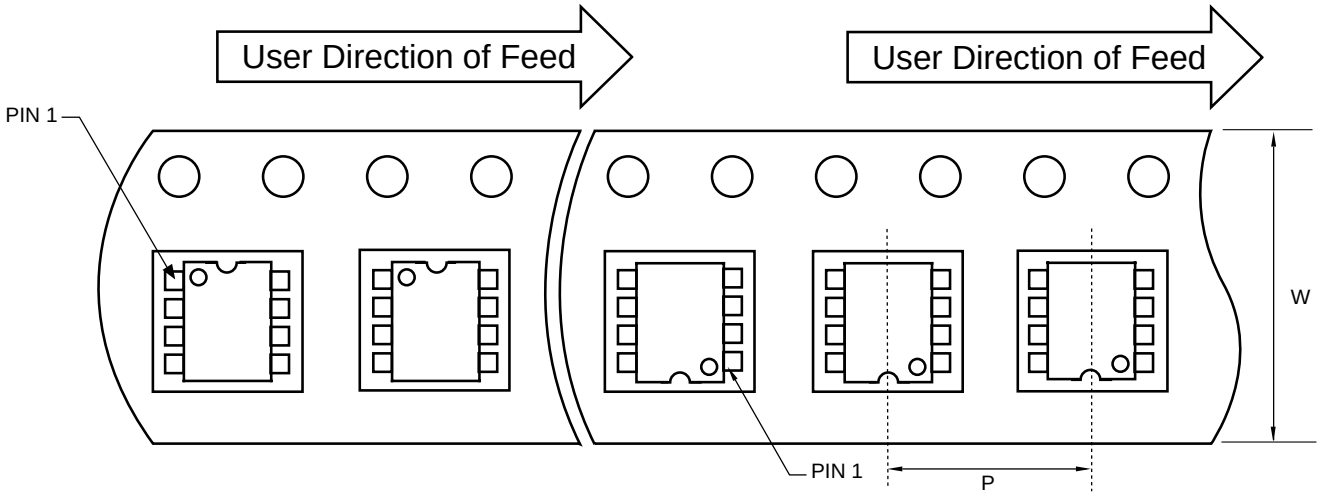






TAPE AND REEL DIAGRAM

Component Taping Orientation for 8-Pin MSOP Devices



Standard Reel Component Orientation
for TR Suffix Device

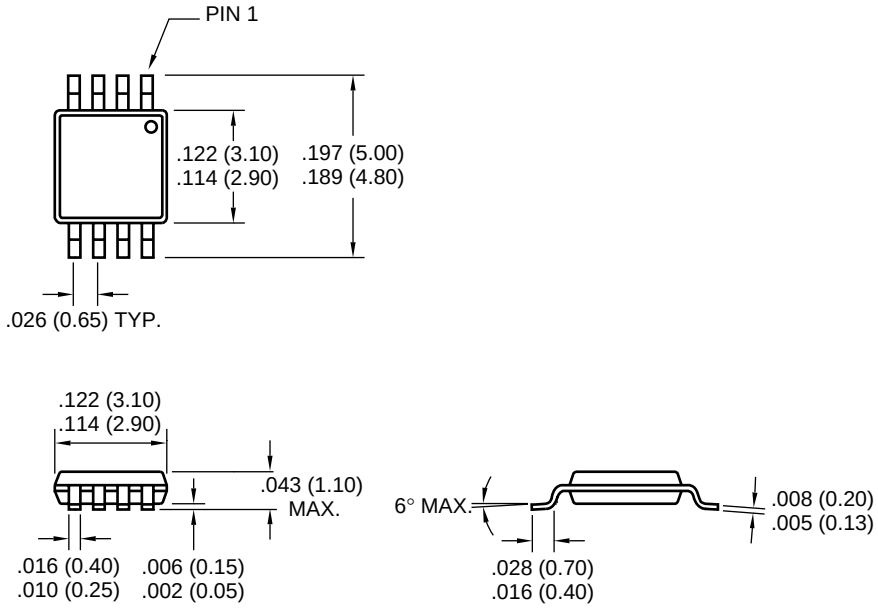
Reverse Reel Component Orientation
for RT Suffix Device

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

PACKAGE DIMENSIONS

8-Pin MSOP



Dimensions: inches (mm)

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