

## Tiny Integrated Temperature Sensor & Brushless DC Fan Controller with Overtemperature Alert

### Features

- Integrated Temperature Sensing and Multi-speed Fan Control
- Built-in Overtemperature Alert ( $T_{\overline{OVER}}$ )
- Temperature-proportional Fan Speed Control for Acoustic Noise Reduction and Longer Fan Life
- Pulse Width Modulation (PWM) Output Drive for Cost and Power Savings
- Solid-state Temperature Sensing
- $\pm 1^{\circ}\text{C}$  (typ.) Accuracy from  $25^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$
- Operating Range: 2.8V – 5.5V
- **TC651** includes Automatic Fan Shutdown
- Low Operating Current: 50  $\mu\text{A}$  (typ.)

### Applications

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

### Related Literature

- Application Note 771 (DS00771)

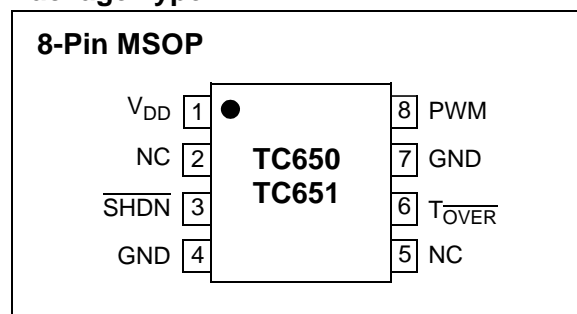
### General Description

The TC650/TC651 are integrated temperature sensors and brushless DC fan speed controllers. The TC650/TC651 measure the 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/TC651 also include a single trip point overtemperature alert ( $T_{\overline{OVER}}$ ) that eliminates the need for additional temperature sensors. In addition, the TC651 features an auto fan shutdown function for additional power savings.

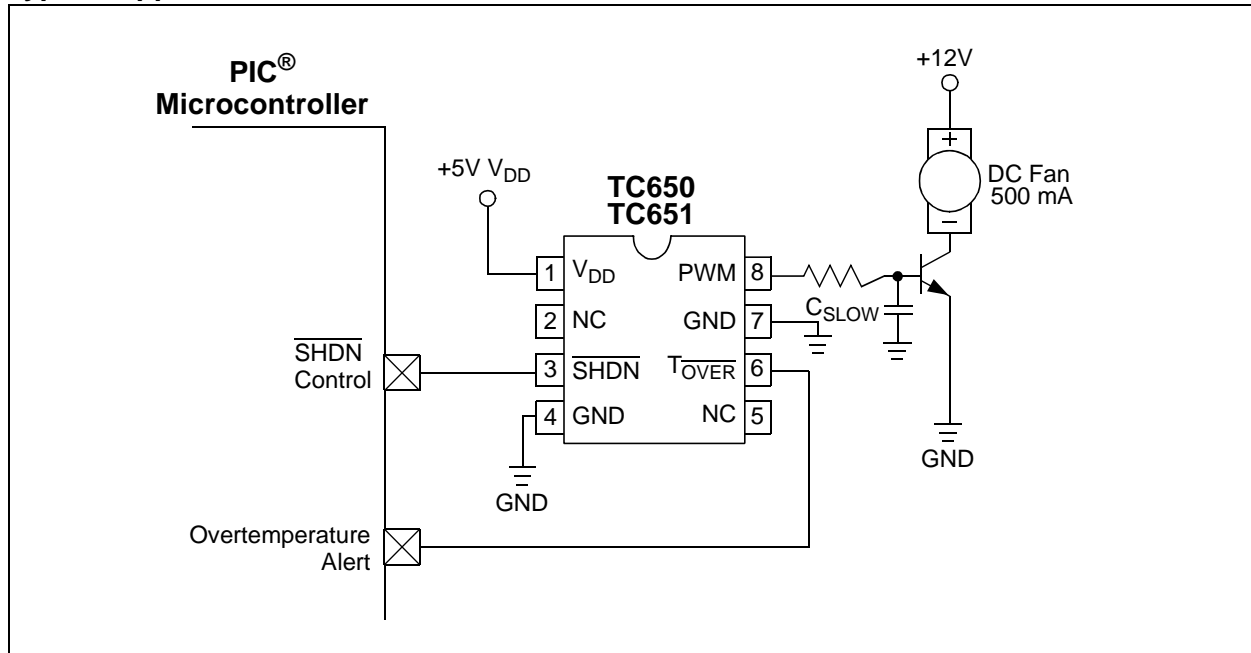
The TC650/TC651 are easy to use, require no software overhead and are, therefore, the ideal choice for implementing thermal management in a variety of systems.

### Package Type



# TC650/TC651

## Typical Application Circuit



## 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)
Operating Temperature Range .....	–40°C to +125°C
Storage Temperature .....	–65°C to +150°C

† **Notice:** 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.

### DC CHARACTERISTICS

Electrical Specifications: Unless otherwise specified, $V_{DD} = 2.8V$ to $5.5V$ , $\overline{SHDN} = V_{DD}$ , $T_A = -40^\circ C$ to $+125^\circ C$ .						
Parameters	Sym	Min	Typ	Max	Units	Conditions
Supply Voltage	$V_{DD}$	2.8	—	5.5	V	
Supply Current	$I_{DD}$	—	50	90	$\mu A$	PWM, $T_{OVER}$ are open
<b>SHDN Input</b>						
$\overline{SHDN}$ Input High Threshold	$V_{IH}$	65	—	—	% $V_{DD}$	
$\overline{SHDN}$ Input Low Threshold	$V_{IL}$	—	—	15	% $V_{DD}$	
<b>PWM Output</b>						
PWM Output Low Voltage	$V_{OL}$	—	—	0.3	V	$I_{SINK} = 1\text{ mA}$
PWM Output High Voltage	$V_{OH}$	$V_{DD} - 0.5$	—	—	V	$I_{SOURCE} = 5\text{ mA}$
PWM Rise Time	$t_R$	—	10	—	$\mu s$	$I_{OH} = 5\text{ mA}$ , 1 nF from PWM to GND
PWM Fall Time	$t_F$	—	10	—	$\mu s$	$I_{OL} = 1\text{ mA}$ , 1 nF from PWM to GND
PWM Frequency	$f_{OUT}$	10	15	—	Hz	
Start-up Time	$t_{STARTUP}$	—	$32/f_{OUT}$	—	sec	$V_{DD}$ Rises from GND or $\overline{SHDN}$ Released
<b>Temperature Accuracy</b>						
High Temperature Accuracy	$T_{H\text{ ACC}}$	$T_H - 3$	$T_H$	$T_H + 3$	$^\circ C$	<b>Note 1</b>
Temperature Range Accuracy	$(T_H - T_L)_{ACC}$	–1.0	—	+1.0	$^\circ C$	$(T_H - T_L) \leq 20^\circ C$
		–2.5	—	+2.5	$^\circ C$	$(T_H - T_L) \geq 20^\circ C$
Auto-shutdown Hysteresis	$T_{HYST}$	—	$(T_H - T_L)/5$	—	$^\circ C$	<b>TC651 Only</b>
<b><math>T_{OVER}</math> Output</b>						
$T_{OVER}$ Output High Voltage	$V_{HIGH}$	$V_{DD} - 0.5$	—	—	V	$I_{SOURCE} = 1.2\text{ mA}$
$T_{OVER}$ Output Low Voltage	$V_{LOW}$	—	—	0.4	V	$I_{SINK} = 2.5\text{ mA}$
Absolute Accuracy	$T_{OVER\text{ ACC}}$	—	$T_H + 10$	—	$^\circ C$	At Trip Point
Trip Point Hysteresis	$T_{OVER\text{ HYST}}$	—	5	—	$^\circ C$	

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

# TC650/TC651

## TEMPERATURE CHARACTERISTICS

**Electrical Specifications:** Unless otherwise noted,  $V_{DD} = 2.8V$  to  $5.5V$ ,  $\overline{SHDN} = V_{DD}$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Specified Temperature Range	$T_A$	-40	—	+125	$^{\circ}C$	
Maximum Junction Temperature	$T_J$	—	—	+150	$^{\circ}C$	
Storage Temperature Range	$T_A$	-65	—	+150	$^{\circ}C$	
<b>Package Thermal Resistances</b>						
Thermal Resistance, 8L-MSOP	$\theta_{JA}$	—	206.3	—	$^{\circ}C/W$	

## 2.0 TYPICAL PERFORMANCE CURVES

**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.

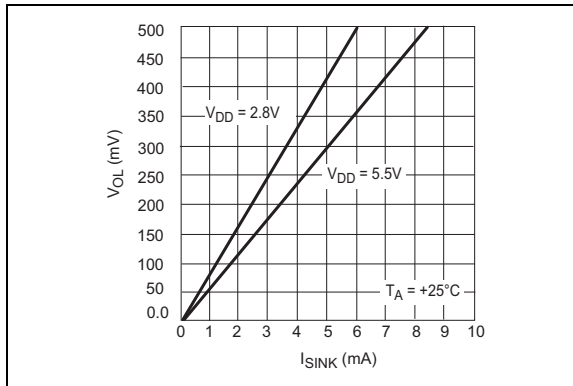
**Note:** Unless otherwise indicated,  $V_{DD} = 2.8V$  to  $5.5V$ ,  $\overline{SHDN} = V_{DD}$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .



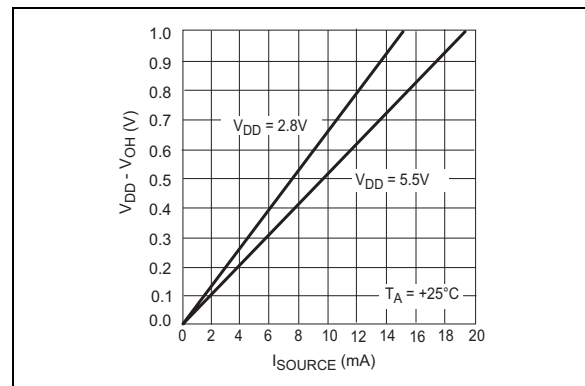
**FIGURE 2-1:**  $I_{DD}$  vs. Temperature.



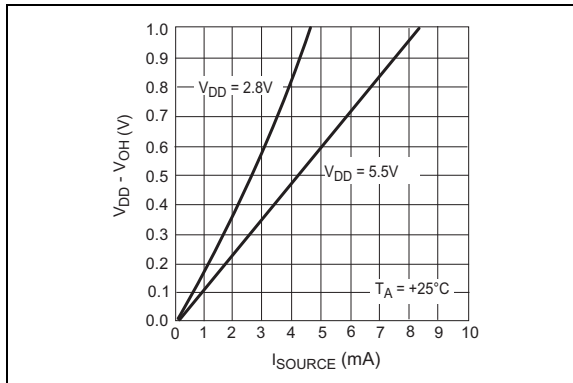
**FIGURE 2-4:** Temperature Accuracy vs.  $V_{TH}$ .



**FIGURE 2-2:** PWM,  $I_{SINK}$  vs.  $V_{OL}$ .



**FIGURE 2-5:** PWM,  $I_{SOURCE}$  vs.  $(V_{DD} - V_{OH})$ .



**FIGURE 2-3:**  $T_{OVER}$ ,  $I_{SOURCE}$  vs.  $(V_{DD} - V_{OH})$ .

# TC650/TC651

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## 3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

**TABLE 3-1: PIN FUNCTION TABLE**

Pin No.	Symbol	Description
1	$V_{DD}$	Power Supply Input
2	NC	No Internal Connect
3	$\overline{\text{SHDN}}$	Fan Shutdown, Active-low Input 1 = Fan in normal operation 0 = Fan in shutdown
4	GND	Ground
5	NC	No Connect
6	$T_{\text{OVER}}$	Overtemperature Alert, Active-low Output 1 = Overtemperature condition does not exist 0 = The device is in the overtemperature condition. The fan is driven at 100%. Potential exists for system over-heating
7	GND	Ground
8	PWM	PWM Fan Drive Output

### 3.1 Power Supply Input

May be independent of fan power supply.

### 3.2 Fan Shutdown, Active-low Input

During Shutdown mode, the chip still monitors temperature.  $T_{\text{OVER}}$  is low if temperature rises above factory set point.

### 3.3 Ground

Ground return for all TC650/TC651 functions.

### 3.4 Overtemperature Alert

Active-low output.

### 3.5 PWM Fan Drive Output

Pulse width modulated rail-to-rail logic output. Nominal frequency is 15 Hz.

## 4.0 DETAILED DESCRIPTION

The TC650/TC651 acquire and convert their junction temperature ( $T_J$ ) information from an on-chip, solid-state sensor with a typical accuracy of  $\pm 1^\circ\text{C}$ . 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 4-1). The TC650/TC651 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 300 mA. 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 TC650/TC651 include an on-chip overtemperature alarm ( $\overline{T_{\text{OVER}}}$ ) that gives a low signal when the temperature of the chip exceeds  $T_H$  by  $10^\circ\text{C}$  (typical). This feature eliminates the need for a separate temperature sensor for overtemperature monitoring. Figure 4-1 shows the block diagram of the device.



**FIGURE 4-1:** Functional Block Diagram.

### 4.1 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 15 Hz. The PWM is also the time base for the Start-up Timer (see **Section 4.2 “Start-Up Timer”**). The PWM duty cycle has a range of 40% to 100% for the TC650 and 50% to 100% for the TC651.

### 4.2 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.

### 4.3 Overtemperature Alert ( $\overline{T_{\text{OVER}}}$ )

This pin goes low when the  $T_H$  set point is exceeded by  $10^\circ\text{C}$  (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 air-flow obstruction). This output may be treated as a “System Overheat” warning and be used to either trigger system shutdown or bring other fans in the system to full speed. The fan will continue to run at full speed while  $\overline{T_{\text{OVER}}}$  is asserted. Built-in hysteresis prevents  $\overline{T_{\text{OVER}}}$  from “chattering” when the measured temperature is at or near the  $T_H + 10^\circ\text{C}$  trip point. As temperature falls through the  $T_H + 10^\circ\text{C}$  trip point, hysteresis maintains the  $\overline{T_{\text{OVER}}}$  output low until the measured temperature is  $5^\circ\text{C}$  above the trip point setting.

### 4.4 Shutdown ( $\overline{\text{SHDN}}$ )

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

### 4.5 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 in order to monitor temperature for  $\overline{T_{\text{OVER}}}$ . The TC651 exits Auto-shutdown mode when the temperature rises above the factory set point ( $T_1$ ).

# TC650/TC651

## 4.6 Temperature Selection Guide (Minimum Fan Speed/Full Speed)

There are two temperature thresholds that determine the characteristics of the device. The minimum fan speed temperature ( $T_L$ ) and the full fan speed temperature ( $T_H$ ). Depending on the TC65X device selected, when the temperature is below the  $T_L$  trip point, the PWM output will perform a different operation. For the TC650, the PWM will be driven at the minimum PWM frequency, while the TC651 will shut down the PWM ( $PWM = L$ ).

$T_L$  and  $T_H$  can be selected in 5°C increments.  $T_L$  can range from 25°C to 35°C.  $T_H$  can range from 35°C to 55°C and must be 10°C (or more) than the specified  $T_L$ .

The five temperature regions defined by the six thresholds are defined in the TC650/TC651 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 4-1 shows these 5 regions and what the corresponding PWM duty cycle is.

**TABLE 4-1: TEMPERATURE RANGE DEFINITION**

Temperature ( $T = T_J$ ) (Note 1)	PWM Duty Cycle	
	TC650 (Minimum Speed mode)	TC651 (Auto-shutdown mode)
$T < T_L$	40%	Off
$T_L \leq T < T_1$	50%	50%
$T_1 \leq T < T_2$	60%	60%
$T_2 \leq T < T_3$	70%	70%
$T_3 \leq T < T_4$	80%	80%
$T_4 \leq T < T_H$	90%	90%
$T_H \leq T < T_{OV}$	100%	100%
$T_{OV} \leq T$	100% with Overtemperature Alert ( $T_{OVER} = L$ )	

**Note 1:** The temperature regions defined by the six temperature thresholds are pre-defined in the TC650/TC651 by means of factory trimming. Once a  $T_L$  and  $T_H$  are programmed, the  $T_1 - T_4$  thresholds are automatically equally spaced between  $T_L$  and  $T_H$ .

Table 4-2 shows the device codes that specify the  $T_H$  and  $T_L$  temperature thresholds. The following examples are given to assist in understanding the device-ordering nomenclature.

**Example 1:** 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.

**Example 2:** 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.

**TABLE 4-2: DEVICE CODES FOR TEMPERATURE THRESHOLDS**

Temp. Threshold Difference	$T_L$	$T_H$	Threshold Limits Code
10°C	25	35	AC <sup>(1)</sup>
	30	40	BD <sup>(2)</sup>
	35	45	CE <sup>(2)</sup>
15°C	25	40	AD <sup>(2)</sup>
	30	45	BE <sup>(1)</sup>
	35	50	CF <sup>(2)</sup>
20°C	25	45	AE <sup>(1)</sup>
	30	50	BF <sup>(2)</sup>
	35	55	CG <sup>(1)</sup>
30°C	25	55	AG <sup>(1)</sup>

- Note 1:** This temperature threshold option is available for ordering.
- 2:** This is a custom temperature threshold option. Please contact the factory for more information.



## 5.0 TYPICAL APPLICATIONS

### 5.1 Reducing Switching Noise

For fans consuming more than 300 mA, a slowdown capacitor ( $C_{SLOW}$ ) is recommended for reducing switching PWM induced noise (see Figure 5-1). The value of this capacitor should be 4.7  $\mu$ F to 47  $\mu$ F, depending on the fan current consumption.

See Application Note 771, "Suppressing Acoustic Noise in PWM Fan Speed Control Systems" (DS00771), for more information.



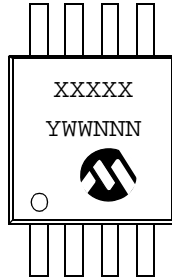
**FIGURE 5-1:** Reducing Switching Noise.

# TC650/TC651

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

8-Lead MSOP



Example:



<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

## 8-Lead Plastic Micro Small Outline Package (MS) (MSOP)

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Dimension Limits	Units	INCHES			MILLIMETERS*		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p	.026 BSC			0.65 BSC		
Overall Height	A	-	-	.043	-	-	1.10
Molded Package Thickness	A2	.030	.033	.037	0.75	0.85	0.95
Standoff	A1	.000	-	.006	0.00	-	0.15
Overall Width	E	.193 TYP.			4.90 BSC		
Molded Package Width	E1	.118 BSC			3.00 BSC		
Overall Length	D	.118 BSC			3.00 BSC		
Foot Length	L	.016	.024	.031	0.40	0.60	0.80
Footprint (Reference)	F	.037 REF			0.95 REF		
Foot Angle	φ	0°	-	8°	0°	-	8°
Lead Thickness	c	.003	.006	.009	0.08	-	0.23
Lead Width	B	.009	.012	.016	0.22	-	0.40
Mold Draft Angle Top	α	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°	5°	-	15°

\*Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

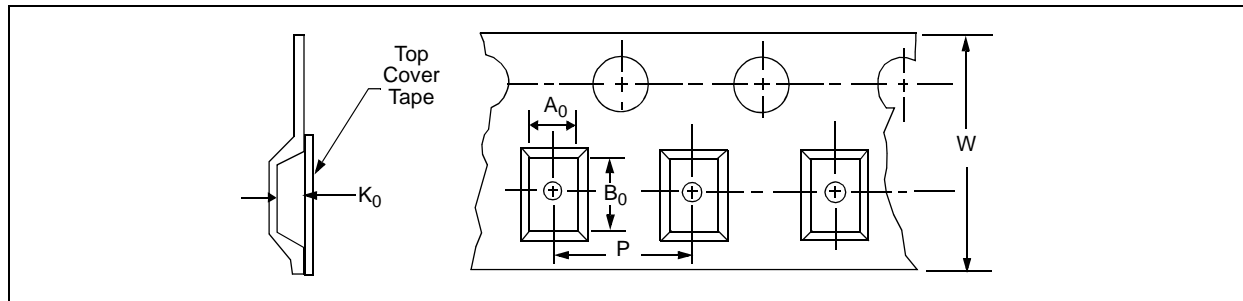
JEDEC Equivalent: MO-187

Drawing No. C04-111

# TC650/TC651

## 6.2 Product Tape and Reel Specifications

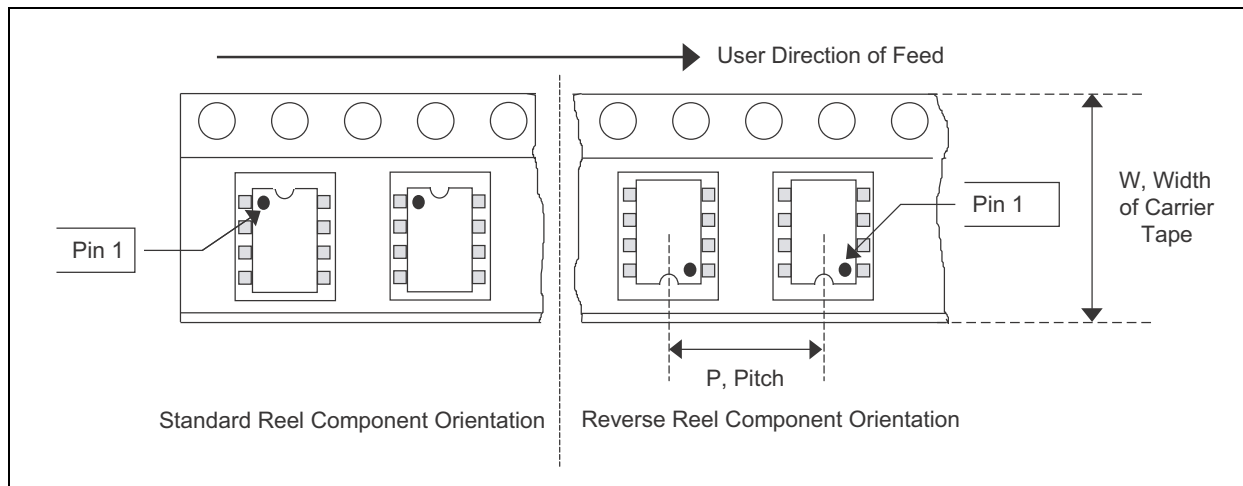
**FIGURE 6-1: EMBOSSED CARRIER DIMENSIONS**



**TABLE 1: CARRIER TAPE/CAVITY DIMENSIONS**

Case Outline	Package Type		Carrier Dimensions		Cavity Dimensions			Output Quantity Units	Reel Diameter in mm
			W mm	P mm	A0 mm	B0 mm	K0 mm		
MS	MSOP	8L	12	8	5.3	3.6	1.4	2500	330

**FIGURE 1: MSOP DEVICES**



## 7.0 REVISION HISTORY

### Revision D (December 2012)

Added a note to the package outline drawing.

# TC650/TC651

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NOTES:

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	XX	X	XX	
Device	Temperature Threshold Limit	Temperature Range	Package	
Device:	TC650: Temp Sensor & Brushless DC Fan Controller / Overtemperature Alert (minimum speed)			
	TC651: Temp Sensor & Brushless DC Fan Controller / Overtemperature Alert (auto shutdown)			
Temperature Threshold Limit:	Temperature Difference	$T_L$ (1,2)	$T_H$ (1,3)	Threshold Limit Code
	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
1. $T_L$ and $T_H$ can be selected in 5°C increments.				
2. $T_L$ can range from 25°C to 35°C.				
3. $T_H$ can range from 35°C to 55°C and must be at least 10°C higher than $T_L$ .				
Temperature Range: V = -40°C to +125°C (Extended)				
Package:	UA = Plastic Micro Small Outline (MSOP), 8-lead			
	UATR = Plastic Micro Small Outline (MSOP), 8-lead (Tape and Reel)			

**Examples:**

a) TC650ACVUA: Temp Sensor  
 $T_L = 25, T_H = 35$

b) TC651ACVUATR: Temp Sensor  
 $T_L = 25, T_H = 35$   
Tape and Reel

c) TC650AEVUA: Temp Sensor  
 $T_L = 25, T_H = 45$

d) TC651AGVUA: Temp Sensor  
 $T_L = 25, T_H = 55$

e) TC650BEVUA: Temp Sensor  
 $T_L = 30, T_H = 45$

f) TC651CGVUA: Temp Sensor  
 $T_L = 35, T_H = 55$

g) TC650CGVUATR: Temp Sensor  
 $T_L = 35, T_H = 55$   
Tape and Reel

## Sales and Support

### 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:

1. Your local Microchip sales office
2. The Microchip Worldwide Site ([www.microchip.com](http://www.microchip.com))

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

### Customer Notification System

Register on our web site ([www.microchip.com/cn](http://www.microchip.com/cn)) to receive the most current information on our products.

# TC650/TC651

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NOTES:



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**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
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*Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC<sup>®</sup> MCUs and dsPIC<sup>®</sup> DSCs, KEELOQ<sup>®</sup> code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*



# MICROCHIP

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11/29/12

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