

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_{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
- $\pm 1^{\circ}\text{C}$ (Typical) Accuracy from 25°C to $+70^{\circ}\text{C}$
- 2.8V – 5.5V Operating Range
- TC653 includes Auto Fan Shutdown
- Low Operating Current: 50 μA (Typical)

Applications

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

Related Literature

- Application Note: AN771

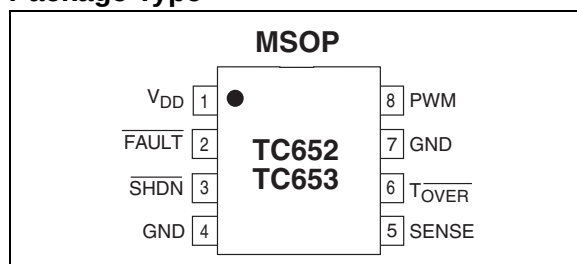
Device Selection Table

Part Number	Package	Temperature Range
TC652XXVUA	8-Pin MSOP	-40°C to $+125^{\circ}\text{C}$
TC653XXVUA	8-Pin MSOP	-40°C to $+125^{\circ}\text{C}$

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



General Description

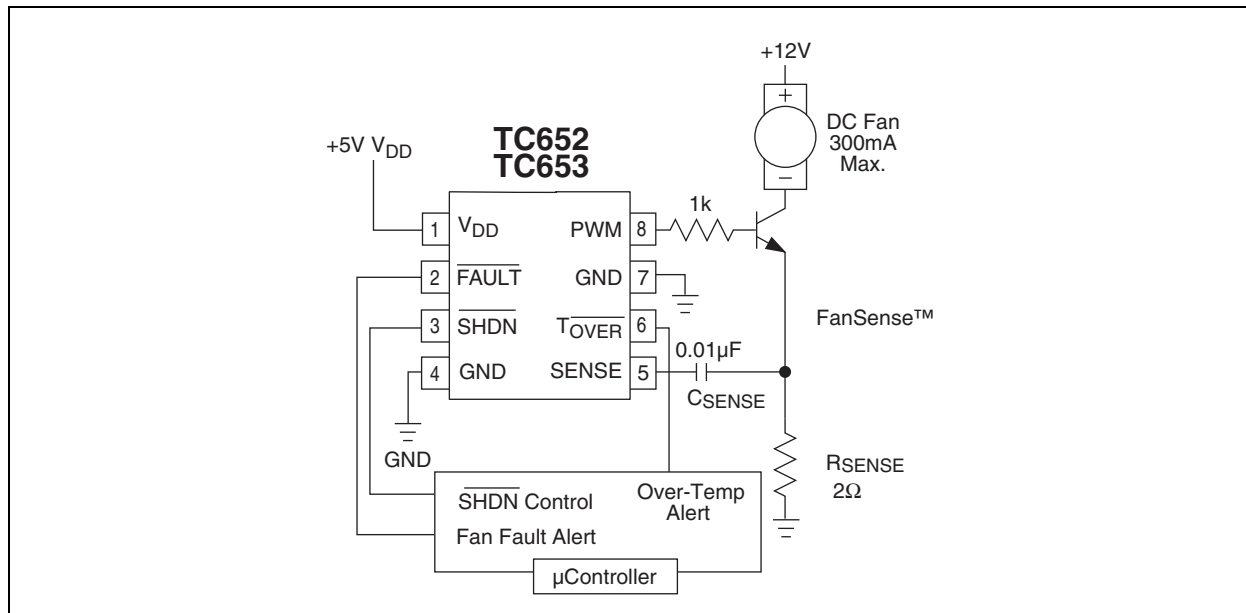
The TC652/TC653 are integrated temperature sensors and brushless DC fan speed controllers with FanSense™ technology. The TC652/TC653 measure their junction temperature and control the speed of the fan based on that temperature, making them especially suited for applications in modern electronic equipment. 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_{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.

TC652/TC653

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 $5.5V$, $\overline{SHDN} = V_{DD}$, $T_A = -40^\circ C$ to $125^\circ C$ 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_{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 Respect to Ground
Temperature Accuracy						
$T_{H ACC}$	High Temperature Accuracy	$T_H - 3$	T_H	$T_H + 3$	$^\circ C$	Note 1
$(T_H - T_L)_{ACC}$	Temp. Range Accuracy	-1.0	—	+1.0	$^\circ C$	$(T_H - T_L) \leq 20^\circ C$
		-2.5	—	+2.5	$^\circ C$	$(T_H - T_L) \geq 20^\circ C$
T_{HYST}	Auto-shutdown Hysteresis	—	$(T_H - T_L)/5$	—	$^\circ C$	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	$I_{SINK} = 2.5mA$
t_{mp}	Missing Pulse Detector Time-out	—	—	$32/f_{OUT}$	Sec	
T_{OVER} Output						
V_{HIGH}	T_{OVER} Output High Voltage	$V_{DD} - 0.5$	—	—	V	$I_{SOURCE} = 1.2mA$
V_{LOW}	T_{OVER} Output Low Voltage	—	—	0.4	V	$I_{SINK} = 2.5mA$
$T_{OVER ACC}$	Absolute Accuracy	—	$T_H + 10$	—	$^\circ C$	At Trip Point
$T_{OVER HYST}$	Trip Point Hysteresis	—	5	—	$^\circ C$	

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 $\overline{FAULT}$ occurs, the device is latched in Shutdown mode with PWM low. Toggling the 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 $\pm 1^\circ\text{C}$. 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 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_{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 FAULT output goes low, and the device is latched in its Shutdown mode. To release the fan from shutdown, toggle the SHDN or V_{DD} pin.

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

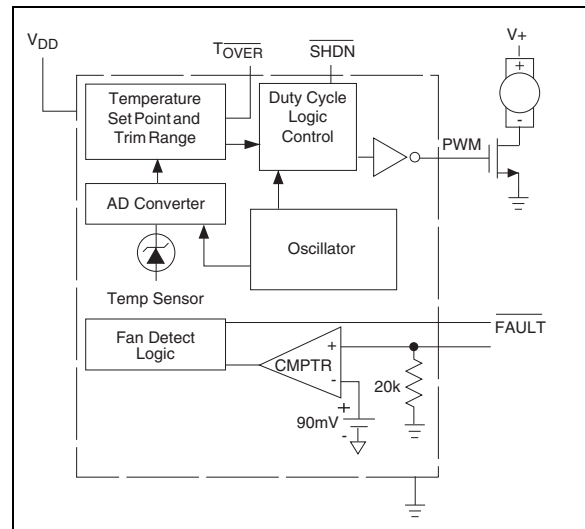
Temperature ($T = T_J$)	PWM Duty Cycle
$T < T_L$	40%
$T_L \leq T < T_1$	50%
$T_1 \leq T < T_2$	60%
$T_2 \leq T < T_3$	70%
$T_3 \leq T < T_4$	80%
$T_4 \leq T < T_H$	90%
$T_H \leq T < T_{OV}$	100%
$T_{OV} \leq T$	100% with Over-Temp Alert ($T_{\text{OVER}} = L$)

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

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

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.

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 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 SHDN or V_{DD} pin, or cycling system power. FAULT remains high during Shutdown mode.

3.5 Over-Temperature Alert (T_{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_{OVER} is asserted. Built-in hysteresis prevents T_{OVER} from "chattering" when 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 T_{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 $\overline{SHDN}$ 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_{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_{OVER} . The TC653 exits Auto-shutdown mode when the temperature rises above the factory set point (T_L).

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.

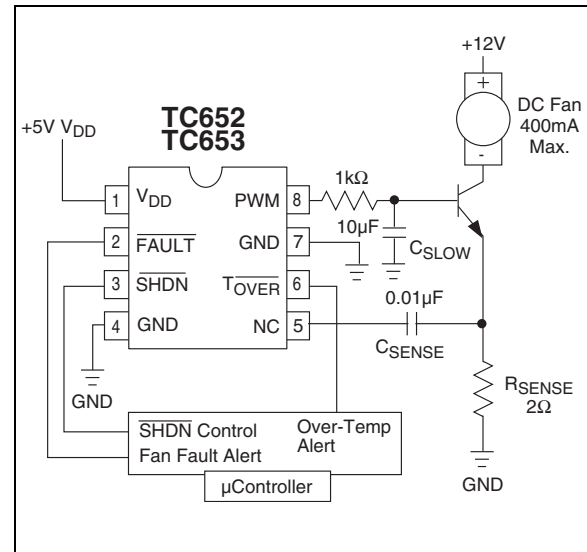
4.0 TYPICAL APPLICATIONS

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.

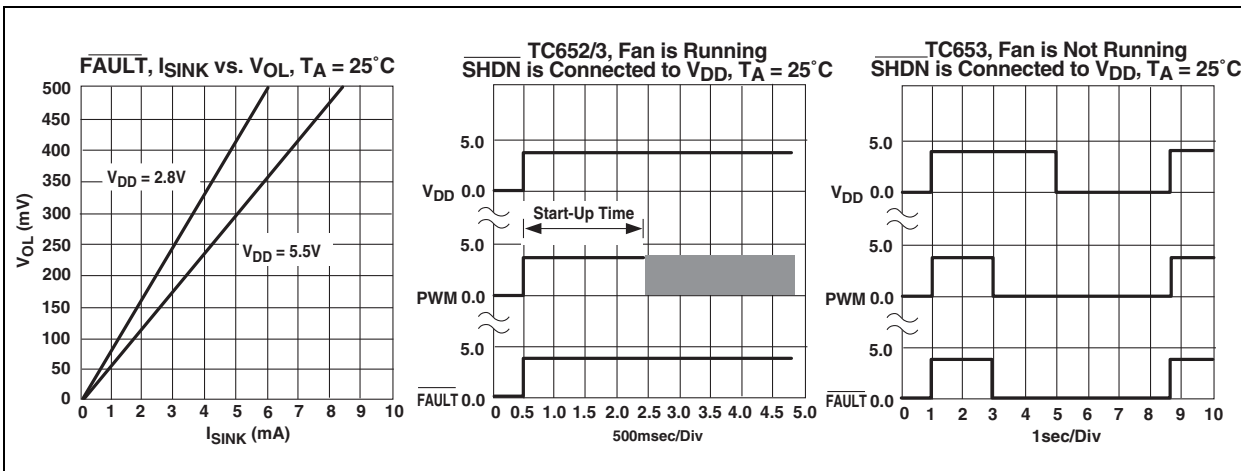
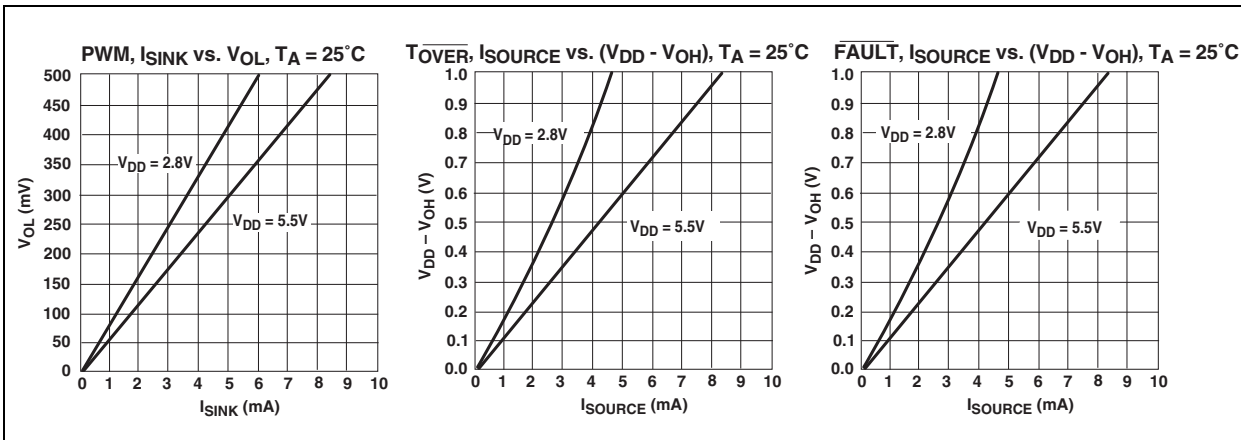
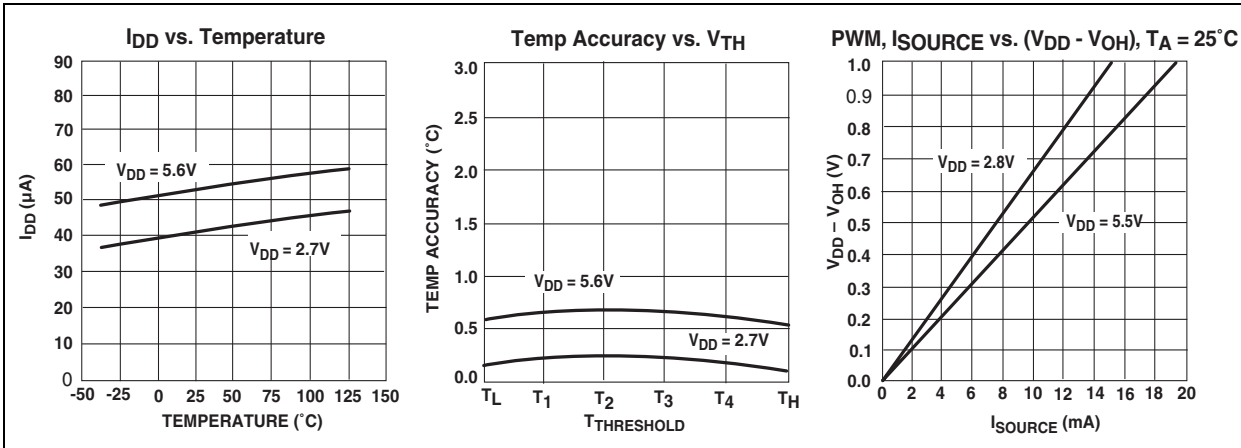
FIGURE 4-1: REDUCING SWITCHING NOISE



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.

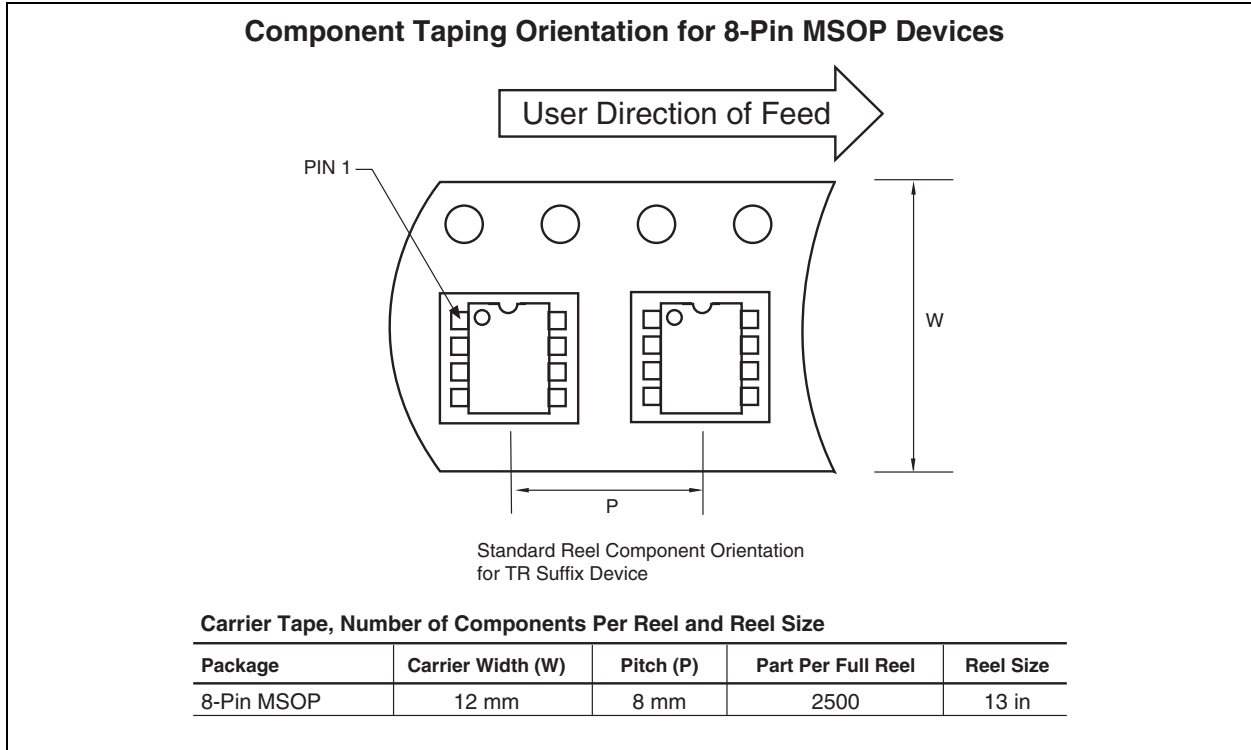


6.0 PACKAGING INFORMATION

6.1 Package Marking Information

Package marking data not available at this time.

6.2 Taping Form

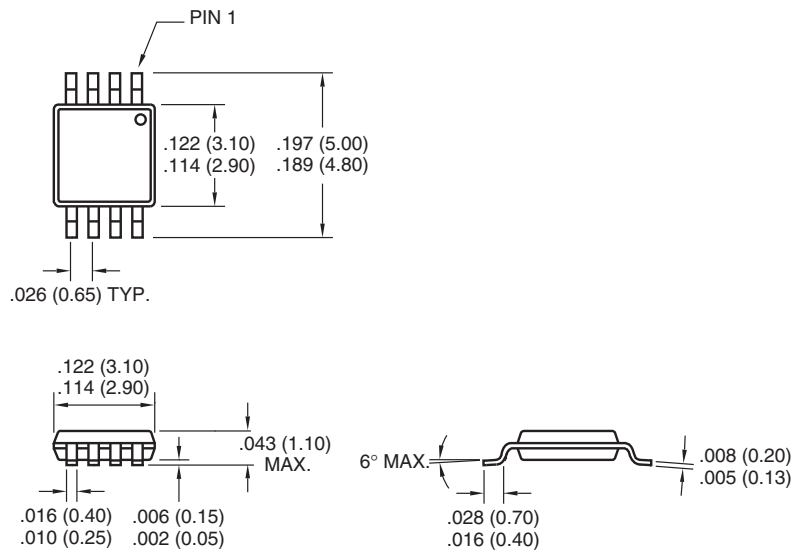


TC652/TC653

6.3 Package Dimensions

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

8-Pin MSOP



Dimensions: inches (mm)

7.0 REVISION HISTORY

Revision C (December 2012)

Added a note to each package outline drawing.

TC652/TC653

NOTES:

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)

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

New Customer Notification System

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

TC652/TC653

NOTES:

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.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELoQ, KEELoQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniclient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. & KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2002-2012, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.



Printed on recycled paper.

ISBN: 9781620768334

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =

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® MCUs and dsPIC® DSCs, KEELoQ® 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.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://www.microchip.com/support>
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

Santa Clara
Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto
Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Hangzhou
Tel: 86-571-2819-3187
Fax: 86-571-2819-3189

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828
Fax: 886-7-330-9305

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham
Tel: 44-118-921-5869
Fax: 44-118-921-5820