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.

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

Trademarks
The Microchip name and logo, the Microchip logo, KEELoQ, MPLAB, PIC, PICmicro, PICSTART and PRO MATE are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, microID, MXDEV, MXLAB, PICMASTER, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

dsPIC, dsPICDEM.net, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, PICC, PICDEM, PICDEM.net, rPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

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

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

Printed on recycled paper.
# Table of Contents

## Chapter 1. General Information
- 1.1 Introduction .................................................................................. 1
- 1.2 TC652 Fan Control Demo Board ..................................................... 2
- 1.3 Reference Documents .................................................................... 3

## Chapter 2. Getting Started
- 2.1 TC652 Functional Description ....................................................... 5
- 2.2 Typical Module Configurations ..................................................... 6

## Appendix A. Board Layout
- A.1 Introduction .................................................................................. 9
- A.2 Board Layout and Schematics ...................................................... 9
- A.3 Demo Board Components ............................................................ 10

## Worldwide Sales and Service ............................................................ 12
Chapter 1. General Information

1.1 INTRODUCTION

Thank you for purchasing the TC652 Fan Control Demo Board from Microchip Technology Inc. The Fan Control Demo Board is an evaluation tool that allows the user to quickly prototype fan control circuits based on Microchip’s TC652 or TC653 pulse width modulation (PWM) Fan Control ICs.

A logic level MOSFET drive device allows the Fan Control Demo Board to be used with virtually any brushless DC fan. A red LED status indicator gives a visual indication of a fan fault condition (open stator or blocked rotor). A green LED status indicator gives a visual indication of an over temperature alert (temperature is approximately 10°C higher than the high temperature limit).

The TC652 Fan Control Demo Board has the following features:

1. Complete implementation of TC652 or TC653 fan control circuitry on a 1.0" x 1.2" board.
2. Temperature proportional fan speed control.
3. Over temperature alert.
4. Installs directly into user's end equipment.
5. Speeds up prototyping, system development and system thermal characterization.
1.2 TC652 FAN CONTROL DEMO BOARD

The TC652 Fan Control Board (Figure 1-1) measures only 1.0 inch x 1.2 inch, allowing direct installation to the user’s end equipment for system evaluation. An external 2.8V to 5.5V power supply is required for the operation of the TC652.

The TC652 Demo Board is equipped with the following components:

1. 1 µF, 1206 Chip Capacitor.
2. 1 kΩ, 1206 Chip Resistor (R1).
3. 1 kΩ, 1206 Chip Resistor (R2).
4. 4.5 mA Miniature Red LED.
5. 4.5 mA Miniature Green LED.
6. Logic Level MOSFET (Q1).
7. 4.7Ω Leaded Resistor (RSENSE).
8. 0.01 µF, 1206 Chip Capacitor (CSENSE).
9. TC652AEVUA Fan Control IC.

If any component is damaged or missing, please contact your nearest Microchip sales office listed on the back of this publication.

FIGURE 1-1: The TC652 Fan Control Demo Board
1.3 REFERENCE DOCUMENTS

Other Reference Documents may be obtained by contacting your nearest Microchip sales office (listed on the back of this document) or by downloading via the Microchip website (www.microchip.com).

- Technical Library CD-ROM, (DS00161), or individual data sheet:
  - TC652/TC653 Data Sheet, (DS21450)
- Analog & Interface Families Data Book 2002, (DS00207)
- Suppressing Acoustic Noise in Pulse Width Modulation (PWM) Fan Speed Control Systems Application Note, (AN771)
- Speed Error in Pulse Width Modulation (PWM) Fan Control Systems Application Note, (AN772)
- TC65X Fan Speed Controller Family Sell Sheet, (DS21625)
- TC650DEMO and TC652DEMO, Fan Controller Boards for the TC65X PWM Fan Control ICs Sell Sheet, (DS51254)
Chapter 2. Getting Started

This chapter describes the TC652 Demo Board’s configuration and how it functions. It also provides information on typical fan demo board operating configurations for fan applications.

The board is equipped with a TC652AEVUA device, which features a minimum temperature limit (T_L) of 25°C (40% duty cycle) and a maximum temperature limit (T_H) of 45°C (100% duty cycle).

2.1 TC652 FUNCTIONAL DESCRIPTION

2.1.1 PWM Output

The pulse width modulation (PWM) pin is designed to drive a low cost transistor or MOSFET as the low side power switching element in the system. A 2N2222 type, small signal (BJT) can be used for fans up to 300 mA. For larger current fans (up to 1 amp), a logic-level N-channel MOSFET must be used. Since the system relies on pulse width modulation, rather than linear power control, the dissipation in the power switch is kept to a minimum. Generally, very small devices, such as the TO-92 or SOT, will suffice. Test Point TP1 can be connected to an oscilloscope for observing PWM output characteristics.

2.1.2 SHDN

The fan can be unconditionally shut down by pulling the SHDN pin low. This function can be implemented by removing jumper JP1, and then grounding pin 3. For details see Figure A-2, in the Appendix A section.

2.1.3 FAULT

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 R3. If the device is not in shutdown or auto-shutdown (TC653), and pulses are not appearing at the SENSE input, a fault exists. In this case, the LED1 light turns on to indicate the fan failure.

2.1.4 SENSE Input

The sense network, comprised by R_SENSE and C_SENSE, allows the TC652/TC653 to detect and monitor commutation of the fan motor (and therefore fan operation). A 0.01 µF capacitor is recommended for C_SENSE (C2). The TC652 Demo Board is populated with a 4.7Ω current sense resistor (R_SENSE). This resistor value should be scaled based on the current rating of the fan. This resistor is socketed on the demo board to allow for easy value changes (see Table 2-1 for resistor value selections).
Table 2-1 lists various resistor value selections for \( R_{SENSE} \) vs. Fan Current.

<table>
<thead>
<tr>
<th>Nominal Fan Current (mA)</th>
<th>( R_{SENSE} ) (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 mA</td>
<td>9.1</td>
</tr>
<tr>
<td>100 mA</td>
<td>4.7</td>
</tr>
<tr>
<td>150 mA</td>
<td>3.0</td>
</tr>
<tr>
<td>200 mA</td>
<td>2.4</td>
</tr>
<tr>
<td>250 mA</td>
<td>2.0</td>
</tr>
<tr>
<td>300 mA</td>
<td>1.8</td>
</tr>
<tr>
<td>350 mA</td>
<td>1.5</td>
</tr>
<tr>
<td>400 mA</td>
<td>1.3</td>
</tr>
<tr>
<td>450 mA</td>
<td>1.2</td>
</tr>
<tr>
<td>500 mA</td>
<td>1.0</td>
</tr>
</tbody>
</table>

2.1.5 Over-Temperature Alert

The TC652/TC653 devices include an on-chip, over temperature alarm signal (\( T_{OVER} \)) that goes low when the temperature of the chip exceeds \( T_H \) by 10°C (typical). When the junction temperature rises to approximately 55°C (\( = T_H +10^\circ C = 45^\circ C + 10^\circ C \)), the \( T_{OVER} \) signal is asserted and the green LED light turns on.

2.2 TYPICAL MODULE CONFIGURATIONS

The TC652/TC653 are designed to drive an external transistor or MOSFET for modulating power to the fan. The pulse width modulation (PWM) pin has a minimum source current of 5 mA and a minimum sink current of 1 mA. Bipolar transistors or MOSFETs may be used as the power switching element. Table 2-2 lists the suggested output drive device vs. fan motor currents. See Figure 2-1 for output driver configuration options.

<table>
<thead>
<tr>
<th>Full Speed Fan Motor Current</th>
<th>Logic MOSFET (Q1 Standard)</th>
<th>Bipolar Transistor (Optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mA</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>200 mA</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>300 mA</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>400 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>500 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>600 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>700 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>800 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>900 mA</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>1A</td>
<td>X</td>
<td>—</td>
</tr>
</tbody>
</table>
2.2.1 Using Logic Level MOSFETs

The TC652 Board is equipped with a logic level MOSFET (Si2302). Using this type of drive device results in low system voltage losses and reduced output loading on the TC652/TC653. The low $R_{DS(ON)}$ of this MOSFET (0.085 $\Omega$) enables it to be used in high current fan applications (>200 mA). Table 2-3 lists examples of MOSFETs that can be utilized for Q1.

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_{DS}$ (V)</th>
<th>$V_{GS(TH)}$ (V)</th>
<th>$I_D$ (A)</th>
<th>$R_{DS(ON)}$ ($\Omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si2302</td>
<td>20</td>
<td>1.5</td>
<td>2.8</td>
<td>0.085</td>
</tr>
<tr>
<td>Si4410</td>
<td>30</td>
<td>3.0</td>
<td>8</td>
<td>0.02</td>
</tr>
<tr>
<td>MG5F1N02E</td>
<td>20</td>
<td>1.5</td>
<td>0.75</td>
<td>0.10</td>
</tr>
</tbody>
</table>

2.2.2 Using Bipolar Driver Transistors

Fan motors of 50 mA to 300 mA can be driven using a single bipolar transistor. The main requirement for this transistor is that it have a minimum $h_{FE}$ of 50. This will ensure that the minimum PWM output current of the TC652/TC653 device is enough to saturate the transistor for the given fan current range. A 2N2222A is a good choice. A base current limiting resistor is required with bipolar transistors.

The correct value for this resistor can be determined as follows:

**EQUATION:**

$$R_{BASE} = \frac{V_{OH} - V_{BE(SAT)}}{I_{R(BASE)}}$$
Table 2-4 lists suggested Bipolar transistors for Q1.

### TABLE 2-4: BIPOLAR TRANSISTORS FOR Q1 (VDD = 5.0V, I_BASE = 5 mA)

<table>
<thead>
<tr>
<th>Device</th>
<th>V_CESAT (mV)</th>
<th>h_FE</th>
<th>V_BRCEO (V)</th>
<th>I_C (mA)</th>
<th>R_BASE (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPS2222</td>
<td>100</td>
<td>30</td>
<td>30</td>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>MPS2222A</td>
<td>100</td>
<td>30</td>
<td>40</td>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>2N4400</td>
<td>150</td>
<td>20</td>
<td>40</td>
<td>100</td>
<td>820</td>
</tr>
<tr>
<td>2N4401</td>
<td>150</td>
<td>20</td>
<td>40</td>
<td>100</td>
<td>820</td>
</tr>
<tr>
<td>MPS6601</td>
<td>180</td>
<td>50</td>
<td>25</td>
<td>250</td>
<td>780</td>
</tr>
<tr>
<td>MPS6602</td>
<td>180</td>
<td>50</td>
<td>40</td>
<td>250</td>
<td>780</td>
</tr>
</tbody>
</table>

**Note:** The values that are listed in the table represent typical values for T_A = 25°C.

### 2.2.3 System Connection for +5V Operation

Figure 2-2 shows typical wiring connections to the Fan Control Demo Board. The fan operating voltage is +12V, while the Fan Control Board operates from a supply voltage of +5V.

![Typical Wiring Connections to Fan Module for 12V Fan and 5V Demo Board Supply](image)

**Note:** The grounds for the 12V fan supply and the 5V V_DD supply should be tied together at the power supply.
Appendix A. Board Layout

A.1 INTRODUCTION

This appendix contains general information concerning the layout, schematics and components for the TC652 Demo Board.

A.2 BOARD LAYOUT AND SCHEMATICS

Figure A-1 depicts the top and bottom layers of the TC652 board. Figure A-2 shows a functional block diagram for the TC652 Demo Board.

**FIGURE A-1:** TC652 Demo Board, Top and Bottom Layer
A.3 DEMO BOARD COMPONENTS

Table A-1 lists the various components and values associated with the TC652 demonstration board.

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1 µF, 1206 chip capacitor</td>
<td>Power supply filter.</td>
</tr>
<tr>
<td>C2</td>
<td>0.01 µF, 1206 chip capacitor</td>
<td>SENSE input coupling capacitor.</td>
</tr>
<tr>
<td>D1</td>
<td>4.5 mA miniature red LED</td>
<td>D1 lights when FAULT output is LOW (active).</td>
</tr>
<tr>
<td>D2</td>
<td>4.5 mA miniature green LED</td>
<td>D2 lights when T OVER output is LOW (active).</td>
</tr>
<tr>
<td>Q1</td>
<td>Logic Level MOSFET</td>
<td>Transistor output option. A logic level MOSFET (Si2302) is used on the TC652 to accommodate various types of fans. The output drive device can also be an NPN transistor, depending on cost constraints and fan current.</td>
</tr>
<tr>
<td>R1</td>
<td>1 kΩ, 1206 chip resistor</td>
<td>D1 (red LED) current limiting resistor.</td>
</tr>
<tr>
<td>R2</td>
<td>1 kΩ, 1206 chip resistor</td>
<td>D2 (green LED) current limiting resistor.</td>
</tr>
<tr>
<td>R3</td>
<td>4.7Ω leaded resistor</td>
<td>Fan current sensing resistor. Value depends on full speed fan current. Typical values appear in Table 2-1.</td>
</tr>
<tr>
<td>U1</td>
<td>TC652AEVUA; low temperature limit: T L 25°C, high temperature limit: T H 45°C</td>
<td>TC652 or TC653 fan control IC.</td>
</tr>
</tbody>
</table>
**AMERICAS**

**Corporate Office**
2335 West Chandler Blvd.,
Chandler, AZ 85224-6199
Tel: 480-792-7200 Fax: 480-792-7277
Technical Support: 480-792-7627
Web Address: http://www.microchip.com

**Rocky Mountain**
2355 West Chandler Blvd.,
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-4338

**Atlanta**
3780 Mansell Road, Suite 107,
Alpharetta, GA 30022
Tel: 770-640-0034 Fax: 770-640-0307

**Boston**
2 Lan Drive, Suite 120,
Westford, MA 01886
Tel: 978-692-3848 Fax: 978-692-3821

**Chicago**
333 Pierce Road, Suite 180,
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

**Dallas**
4570 Westgrove Drive, Suite 160,
Addison, TX 75001
Tel: 972-818-7423 Fax: 972-818-2924

**Detroit**
Tri-Atria Office Building,
32255 Northwestern Highway, Suite 190,
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

**Kokomo**
2767 S. Albright Road,
Kokomo, Indiana 46902
Tel: 765-864-8360 Fax: 765-864-8387

**Los Angeles**
18201 Von Karman, Suite 1090,
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

**San Jose**
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

**Toronto**
6285 Northam Drive, Suite 108,
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

**ASIA/PACIFIC**

**Australia**
Microchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

**China - Beijing**
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Beijing, 100027, No. China
Tel: 86-10-85828104 Fax: 86-10-85828200

**China - Chengdu**
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
6th Floor, Ridgebrook Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-68766200 Fax: 86-28-68766599

**China - Fuzhou**
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

**China - Hong Kong SAR**
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

**China - Shanghai**
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xai Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

**Japan**
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinykokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471-6168 Fax: 81-45-471-6122

**Korea**
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-892
Tel: 82-2-554-7200 Fax: 82-2-558-5934

**Singapore**
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

**Taiwan**
Microchip Technology (Barbados) Inc.,
Taiwan Branch
Tel: 866-2-2717-7175 Fax: 866-2-2545-0139

**EUROPE**

**Austria**
Microchip Technology Austria GmbH
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399 Fax: 43-7242-2244-393

**Denmark**
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup Hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

**France**
Microchip Technology SARL
Parc d’Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

**Germany**
Microchip Technology GmbH
Steinheilstrasse 10
D-85737 Ismaning, Germany
Tel: 49-89-627-144-0 Fax: 49-89-627-144-44

**Italy**
Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

**United Kingdom**
Microchip Ltd.
505 Esksdale Road
Winsmers Triangle
Wokingham
Berksire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

---

12/05/02