

8-Bit Digital-to-Analog Converter with Two-Wire Interface

Features

- 8-bit Digital-to-Analog Converter
- ± 2 LSB INL
- ± 0.8 LSB DNL
- 2.7-5.5V Single Supply Operation
- Simple SMBus/I²C™ Serial Interface
- Low Power: 350 μ A Operation, 0.5 μ A Shutdown
- 8-Pin SOIC and 8-Pin MSOP Packages

Applications

- Programmable Voltage Sources
- Digital Controlled Amplifiers/Attenuators
- Process Monitoring and Control

Device Selection Table

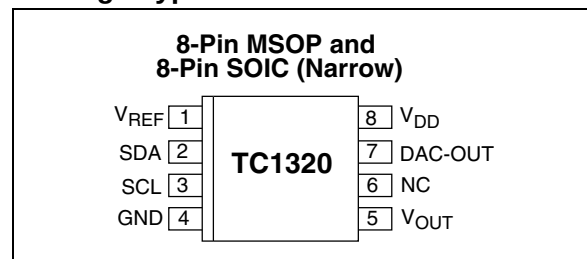
Part Number	Package	Temperature Range
TC1320EOA	8-Pin SOIC (Narrow)	-40°C to +85°C
TC1320EUA	8-Pin MSOP	-40°C to +85°C

General Description

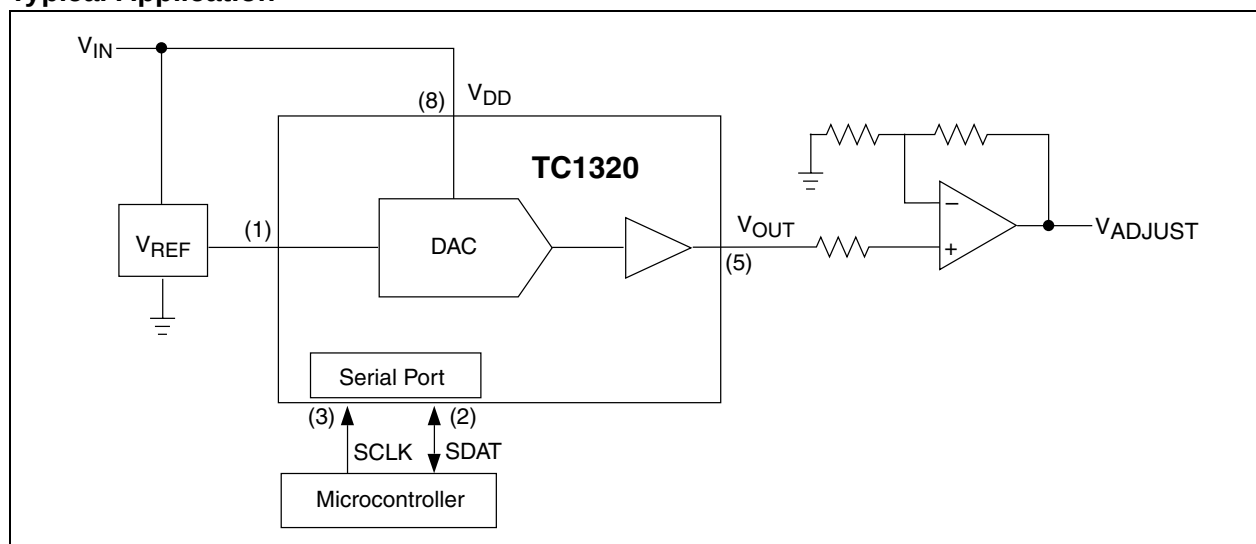
The TC1320 is a serially accessible 8-bit voltage output digital-to-analog converter (DAC). The DAC produces an output voltage that ranges from ground to an externally supplied reference voltage. It operates from a single power supply that can range from 2.7V to 5.5V, making it ideal for a wide range of applications. Built into the part is a Power-on Reset function that ensures that the device starts at a known condition.

Communication with the TC1320 is accomplished via a simple 2-wire SMBus/I²C™ compatible serial port with the TC1320 acting as a slave only device. The host can enable the SHDN bit in the CONFIG register to activate the Low Power Standby mode.

Package Type

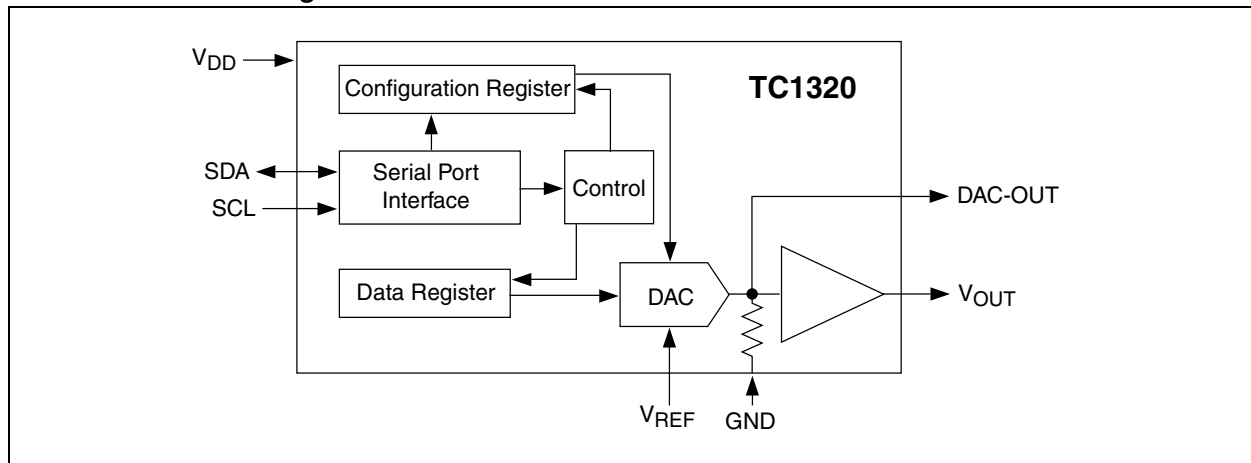


Typical Application



TC1320

Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage (V_{DD}) +6V
 Voltage on any Pin .. (GND – 0.3V) to (V_{DD} + 0.3V)
 Current on any Pin ±50mA
 Package Thermal Resistance (θ_{JA})..... 330°C C/W
 Operating Temperature (T_A)..... See Below
 Storage Temperature (T_{STG}) -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.

TC1320 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: $V_{DD} = 2.7V$ to $5.5V$, $-40^\circ C \leq T_A \leq +85^\circ C$, $V_{REF} = 1.2V$ unless otherwise noted.						
Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
Power Supply						
V_{DD}	Supply Voltage	2.7	350	500	μA	
I_{DD}	Operating Current	—	0.35	0.5	mA	$V_{DD} = 5.5V$, $V_{REF} = 1.2V$ Serial Port Inactive (Note 1)
$I_{DD-STANDBY}$	Standby Supply Current	—	0.1	1	μA	$V_{DD} = 3.3V$ Serial Port Inactive (Note 1)
Static Performance - Analog Section						
	Resolution	—	—	8	Bits	
INL	Integral Non-Linearity at FS, $T_A = +25^\circ C$	—	—	±2	LSB	(Note 2)
FSE	Full Scale Error	—	—	±3	%FS	
DNL	Differential Non-Linearity, $T_A = +25^\circ C$	—	—	±0.8	LSB	All Codes (Note 2)
V_{OS}	Offset Error at V_{OUT}	—	±0.3	±8	mV	(Note 2)
TCV_{OS}	Offset Error Tempco at V_{OUT}	—	10	—	$\mu V/^\circ C$	
PSRR	Power Supply Rejection Ratio	—	80	—	dB	V_{DD} at DC
V_{REF}	Voltage Reference Range	0	—	$V_{DD} - 1.2$	V	
I_{REF}	Reference Input Leakage Current	—	—	±1.0	μA	
V_{SW}	Voltage Swing	0	—	V_{REF}	V	$V_{REF} \leq (V_{DD} - 1.2V)$
R_{OUT}	Output Resistance @ V_{OUT}	—	5	—	Ω	$R_{OUT} (\Omega)$
I_{OUT}	Output Current (Source or Sink)	—	2	—	mA	
I_{SC}	Output Short-Circuit Current $V_{DD} = 5.5V$	—	30 20	50 50	mA mA	Source Sink
Dynamic Performance						
SR	Voltage Output Slew Rate	—	0.8	—	V/ μs	
t_{SETTLE}	Output Voltage Full Scale Settling Time	—	10	—	μsec	
t_{WU}	Wake-up Time	—	20	—	μs	
	Digital Feed Through and Crosstalk	—	5	—	nV-s	SDA = V_{DD} , SCL = 100kHz
Serial Port Interface						
V_{IH}	Logic Input High	2.4	—	V_{DD}	V	
V_{IL}	Logic Input Low	—	—	0.6	—	
V_{OL}	SDA Output Low	—	—	0.4 0.6	V V	$I_{OL} = 3mA$ (Sinking Current) $I_{OL} = 6mA$
C_{IN}	Input Capacitance SDA, SCL	—	5	0.4	pF	
I_{LEAK}	I/O Leakage	—	—	±1.0	μA	

Note 1: SDA and SCL must be connected to V_{DD} or GND.

Note 2: Measured at $V_{OUT} \geq 50mV$ referred to GND to avoid output buffer clipping.

TC1320

TC1320 ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: $V_{DD} = 2.7V$ to $5.5V$, $-40^{\circ}C \leq T_A \leq +85^{\circ}C$, $V_{REF} = 1.2V$ unless otherwise noted.						
Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
Serial Port AC Timing						
f_{SMB}	SMBus Clock Frequency	10	—	100	kHz	
t_{IDLE}	Bus Free Time Prior to New Transition	4.7	—	—	μsec	
$t_{H(START)}$	START Condition Hold Time	4.0	—	—	μsec	
$t_{SU(START)}$	START Condition Setup Time	4.7	—	—	μsec	90% SCL to 10% SDA (for Repeated START Condition)
$t_{SU(STOP)}$	STOP Condition Setup Time	4.0	—	—	μsec	
t_{H-DATA}	Data In Hold Time	100	—	—	nsec	
$t_{SU-DATA}$	Data In Setup Time	100	—	—	nsec	
t_{LOW}	Low Clock Period	4.7	—	—	μsec	10% to 10%
t_{HIGH}	High Clock Period	4	—	—	μsec	90% to 90%
t_F	SMBus Fall Time	—	—	300	nsec	90% to 10%
t_R	SMBus Rise Time	—	—	1000	nsec	10% to 90%
t_{POR}	Power-on Reset Delay	—	500	—	μsec	$V_{DD} \geq V_{POR}$ (Rising Edge)

- Note** 1: SDA and SCL must be connected to V_{DD} or GND.
 2: Measured at $V_{OUT} \geq 50mV$ referred to GND to avoid output buffer clipping.

2.0 PIN DESCRIPTIONS

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

TABLE 2-1: PIN FUNCTION TABLE

Pin Number	Symbol	Type	Description
1	V_{REF}	Input	Input. Voltage Reference Input can range from 0V to 1.2V below V_{DD} .
2	SDA	Bi-Directional	Bi-directional. Serial data is transferred on the SMBus in both directions using this pin.
3	SCL	Input	Input. SMBus serial clock. Clocks data into and out of the TC1320.
4	GND	Power	Ground.
5	V_{OUT}	Output	Output. Buffered DAC output voltage. This voltage is a function of the reference voltage and the contents of the DATA register.
6	NC	None	No connection.
7	DAC-OUT	Output	Output. Unbuffered DAC output voltage. This voltage is a function of the reference voltage and the contents of the DATA register. This output is unbuffered and care must be taken that the pin is connected only to a high-impedance node.
8	V_{DD}	Power	Positive power supply input. See electrical specifications.

3.0 DETAILED DESCRIPTION

The TC1320 is a monolithic 8-bit digital-to-analog converter, that is designed to operate from a single supply that can range from 2.7V to 5.5V. The DAC consists of a data register (DATA), a configuration register (CONF), and a current output amplifier. The TC1320 uses an external reference, which also determines the maximum output voltage.

The TC1320 uses a current steering DAC, based on an array of matched current sources. This current, along a precision resistor, converts the contents of the Data Register and V_{REF} into an output voltage, V_{OUT} given by:

$$V_{OUT} = V_{REF} (DATA/256)$$

3.1 Reference Input

The reference pin, V_{REF} , is a buffered high-impedance input and because of this, the load regulation of the reference source needs only to be able to tolerate leakage levels of current (less than $1\mu A$). V_{REF} accepts a voltage range from 0 to ($V_{DD} - 1.2V$). Input capacitance is typically 10pF.

3.2 Output Amplifier

The TC1320 DAC output is buffered with an internal unity gain rail-to-rail input/output amplifier, with a typical slew rate of $0.8V/\mu sec$. Maximum full scale transition settling time is $10\mu sec$ to within $\pm 1/2LSB$ when loaded with $1k\Omega$ in parallel with $100pF$.

3.3 Standby Mode

The TC1320 allows the host to put it into a Low Power ($I_{DD} = 0.5\mu A$, typical) Standby mode. In this mode, the D/A conversion is halted. The SMBus port operates normally. Standby mode is enabled by setting the SHDN bit in the CONFIG register. The table below summarizes this operation.

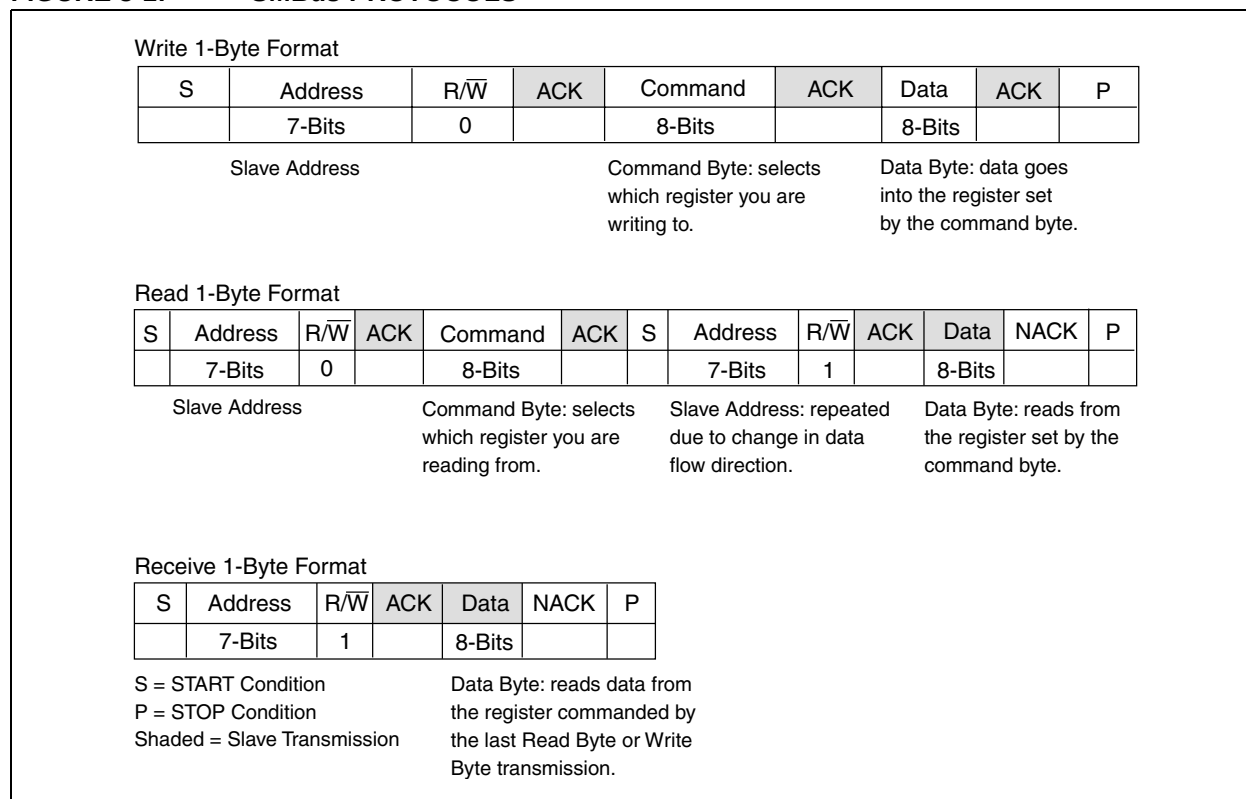
TABLE 3-1: STANDBY MODE OPERATION

SHDN Bit	Operating Mode
0	Normal
1	Standby

3.4 SMBus Slave Address

The TC1320 is internally programmed to have a default SMBus address value of $1001\ 000b$. Seven other addresses are available by custom order (contact factory). See Figure 3-1 for locating address bits in SMBus protocol.

FIGURE 3-1: SMBus PROTOCOLS



4.0 SERIAL PORT OPERATION

The Serial Clock input (SCL) and bi-directional data port (SDA) form a 2-wire bi-directional serial port for programming and interrogating the TC1320. The following conventions are used in this bus architecture:

TABLE 4-1: TC1320 SERIAL BUS CONVENTIONS

Term	Explanation
Transmitter	The device sending data to the bus.
Receiver	The device receiving data from the bus.
Master	The device which controls the bus: initiating transfers (START), generating the clock, and terminating transfers (STOP).
Slave	The device addressed by the master.
START	A unique condition signaling the beginning of a transfer indicated by SDA falling (High - Low) while SCL is high.
STOP	A unique condition signaling the end of a transfer indicated by SDA rising (Low - High) while SCL is high.
ACK	A Receiver Acknowledges the receipt of each byte with this unique condition. The Receiver drives SDA low during SCL high of the ACK clock pulse. The Master provides the clock pulse for the ACK cycle.
Busy	Communication is not possible because the bus is in use.
Not Busy	When the bus is IDLE, both SDA and SCL will remain high.
Data Valid	The state of SDA must remain stable during the High period of SCL in order for a data bit to be considered valid. SDA only changes state while SCL is low during normal data transfers. (See START and STOP conditions.)

All transfers take place under control of a host, usually a CPU or microcontroller, acting as the Master, which provides the clock signal for all transfers. The TC1320 *always* operates as a Slave. The serial protocol is illustrated in Figure 3-1. All data transfers have two phases; all bytes are transferred MSB first. Accesses are initiated by a START condition (START), followed by a device address byte and one or more data bytes. The device address byte includes a Read/Write selection bit. Each access must be terminated by a STOP Condition (STOP). A convention called *Acknowledge* (ACK) confirms receipt of each byte. Note that SDA can change only during periods when SCL is LOW (SDA changes while SCL is HIGH is reserved for START and STOP Conditions).

4.1 START Condition (START)

The TC1320 continuously monitors the SDA and SCL lines for a START condition (a HIGH to LOW transition of SDA while SCL is HIGH), and will not respond until this condition is met.

4.2 Address Byte

Immediately following the START Condition, the host must transmit the address byte to the TC1320. The 7-bit SMBus address for the TC1320 is 1001000. The 7-bit address transmitted in the serial bit stream must match for the TC1320 to respond with an Acknowledge (indicating the TC1320 is on the bus and ready to accept data). The eighth bit in the Address Byte is a Read/Write bit. This bit is a 1 for a read operation, or 0 for a write operation. During the first phase of any transfer, this bit will be set = 0 to indicate that the command byte is being written.

4.3 Acknowledge (ACK)

Acknowledge (ACK) provides a positive handshake between the host and the TC1320. The host releases SDA after transmitting eight bits, then generates a ninth clock cycle to allow the TC1320 to pull the SDA line LOW to Acknowledge that it successfully received the previous eight bits of data or address.

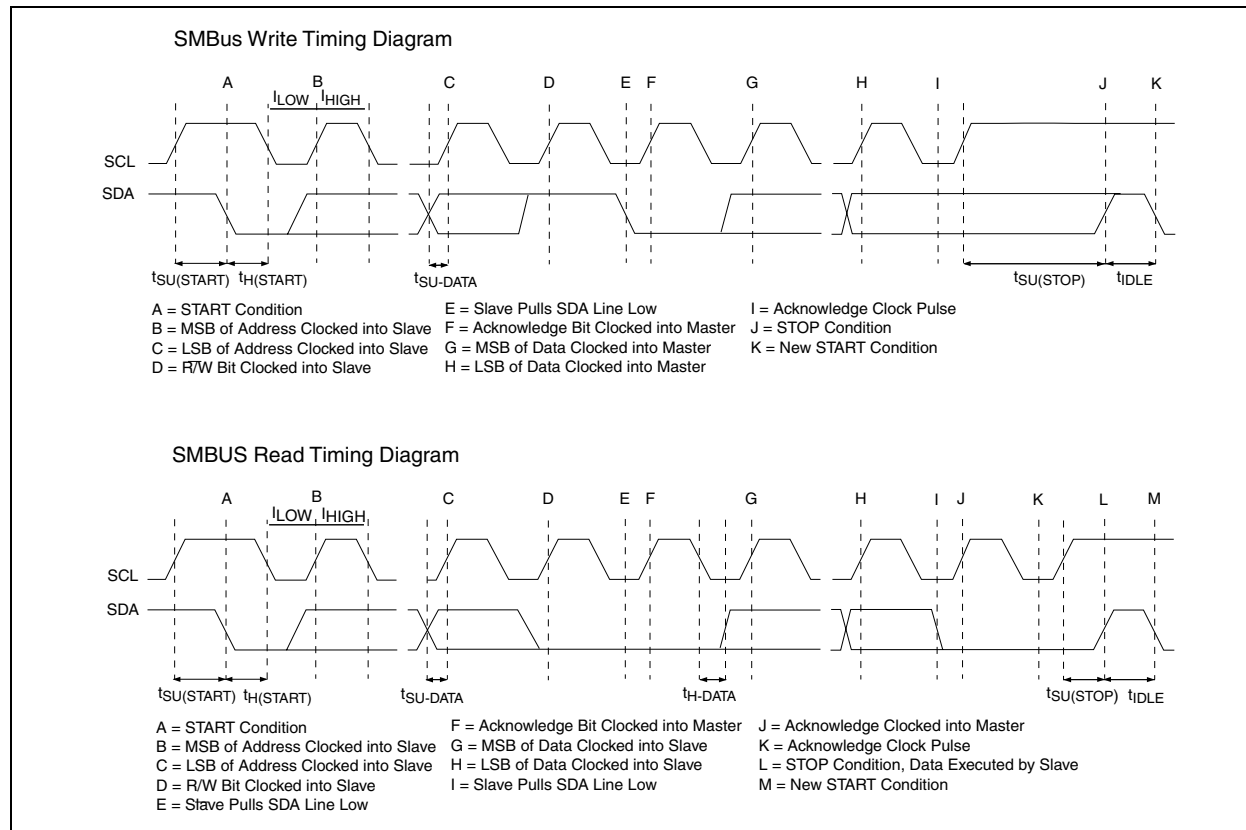
4.4 Data Byte

After a successful ACK of the address byte, the host must transmit the data byte to be written, or clock out the data to be read. (See the appropriate timing diagrams.) ACK will be generated after a successful write of a data byte into the TC1320.

4.5 STOP Condition (STOP)

Communications must be terminated by a STOP condition (a LOW to HIGH transition of SDA while SCL is HIGH). The STOP Condition must be communicated by the transmitter to the TC1320. Refer to Figure 4-1, Timing Diagrams for serial bus timing.

FIGURE 4-1: TIMING DIAGRAMS



4.6 Register Set and Programmer's Model

TABLE 4-2: TC1320 COMMAND SET (SMBus READ_BYTE AND WRITE_BYTE)

Command Byte Description		
Command	Code	Function
RWD	00h	Read/Write Data (DATA)
RWCR	01h	Read/Write Configuration (CONFIG)

TABLE 4-3: CONFIGURATION REGISTER (CONFIG), 8-BIT, READ/WRITE

Configuration Register (CONFIG)							
D[7]	D[6]	D[5]	D[4]	D[3]	D[2]	D[1]	D[0]
Reserved							SHDN
Bit	POR	Function	Type	Operation			
D[0]	0	Standby Switch	Read/Write	1 = Standby 0 = Normal			
D[7]-D[1]	0	Reserved; Always returns Zero when Read	N/A	N/A			

TABLE 4-4: DATA REGISTER (DATA), 8-BIT, READ/WRITE

Data Register (DATA)							
D[7]	D[6]	D[5]	D[4]	D[3]	D[2]	D[1]	D[0]
MSB	X	X	X	X	X	X	LSB

The DAC output voltage is a function of reference voltage and the binary value of the contents of the Data register. The transfer function is given by the expression:

EQUATION 4-1:

$$V_{OUT} = V_{REF} \times \left[\frac{DATA}{256} \right]$$

4.7 Register Set Summary

The TC1320's register set is summarized in Table 4-5 below. All registers are 8-bits wide.

TABLE 4-5: TC1320 REGISTER SET SUMMARY

Name	Description	POR State	Read	Write
Data	Data Register	0000 0000b	X	X
Config	CONFIG Register	0000 0000b	X	X

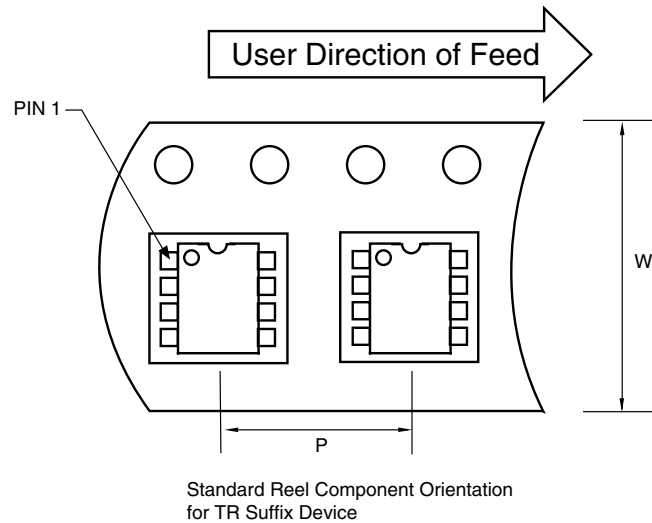
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

Package marking data not available at this time.

5.2 Taping Forms

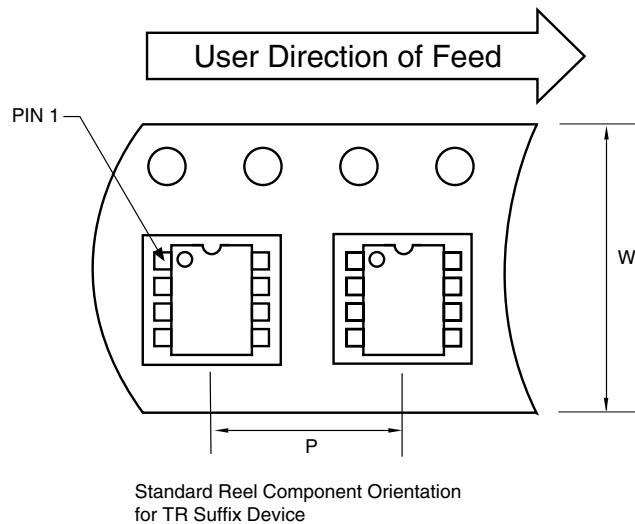
Component Taping Orientation for 8-Pin MSOP Devices



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

Component Taping Orientation for 8-Pin SOIC (Narrow) Devices

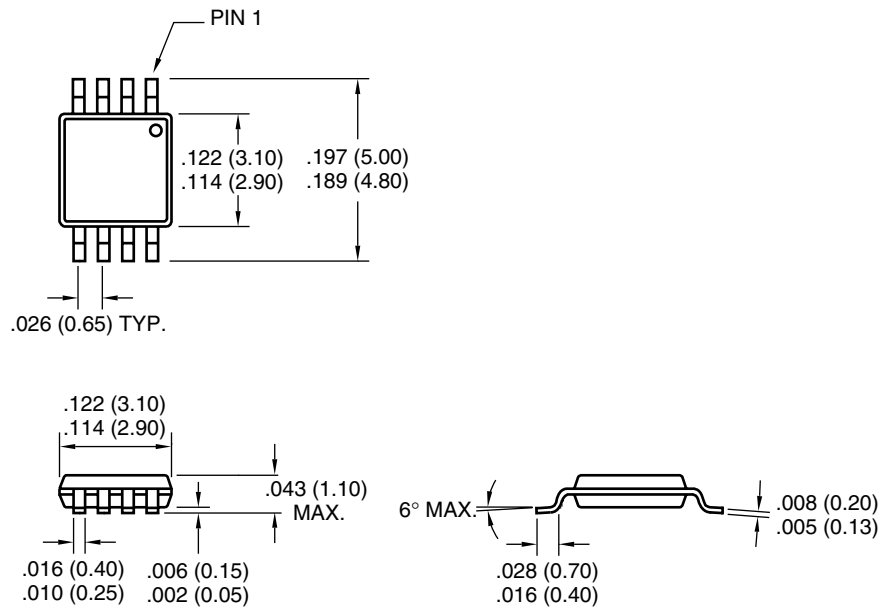


Carrier Tape, Number of Components Per Reel and Reel Size

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

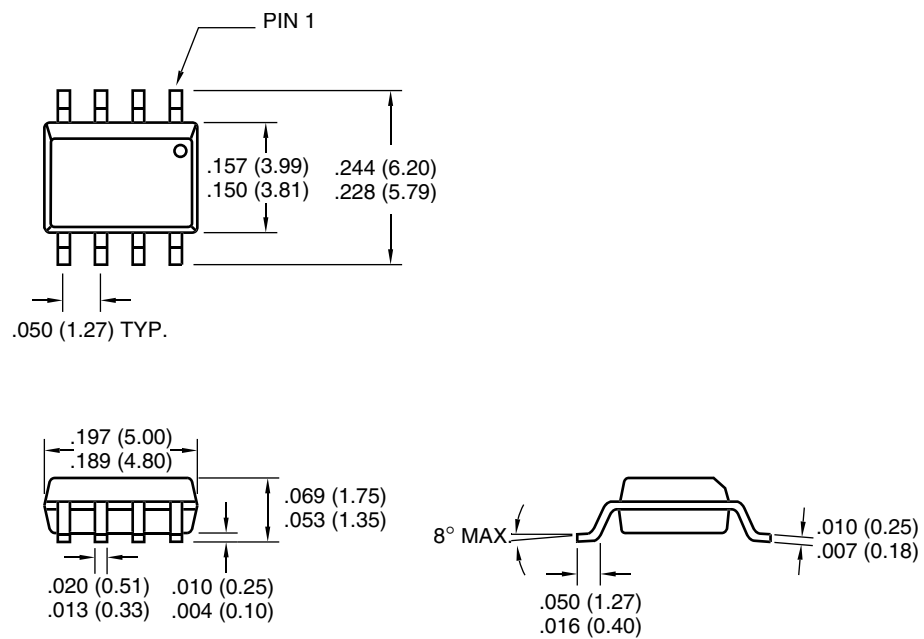
5.3 Package Dimensions

8-Pin MSOP



Dimensions: inches (mm)

8-Pin SOIC



Dimensions: inches (mm)

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 Corporate Literature Center U.S. FAX: (480) 792-7277
3. 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.

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.

Trademarks

The Microchip name and logo, the Microchip logo, FilterLab, KEELOQ, microID, MPLAB, PIC, PICmicro, PICMASTER, PICSTART, PRO MATE, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

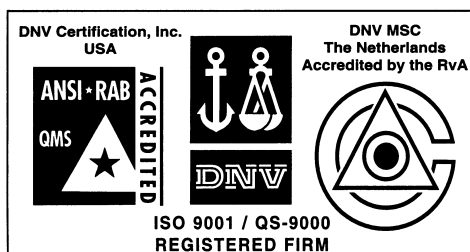
dsPIC, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, MXDEV, PICC, PICDEM, PICDEM.net, rfPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A.

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.



Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 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: 480-792-7627
Web Address: <http://www.microchip.com>

Rocky Mountain

2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-7456

Atlanta

500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
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

New York

150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

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
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu

Microchip Technology Consulting (Shanghai)
Co., Ltd., Chengdu Liaison Office
Rm. 2401, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-6766200 Fax: 86-28-6766599

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 - Shanghai

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

China - Shenzhen

Microchip Technology Consulting (Shanghai)
Co., Ltd., Shenzhen Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-2350361 Fax: 86-755-2366086

Hong Kong

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

India

Microchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan

Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea

Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
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 Taiwan
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Denmark

Microchip Technology Nordic ApS
Regus Business Centre
Lautrup høj 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 - 1er Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany

Microchip Technology GmbH
Gustav-Heinemann Ring 125
D-81739 Munich, 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
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

United Kingdom

Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

03/01/02

