

+1.8 Low Power, Quad Input, 16-Bit Sigma-Delta A/D Converter

Features

- 16-bit Resolution at Eight Conversions Per Second, Adjustable Down to 10-bit Resolution at 512 Conversions Per Second
- 1.8V – 5.5V Operation, Low Power Operating 250 μ A; Sleep: 0.75 μ A
- Four True Differential Inputs with Built-in Multiplexer
- microPort™ Serial Bus Requires only two Interface Lines
- Uses Internal or External Reference
- Automatically Enters Sleep Mode when not in use

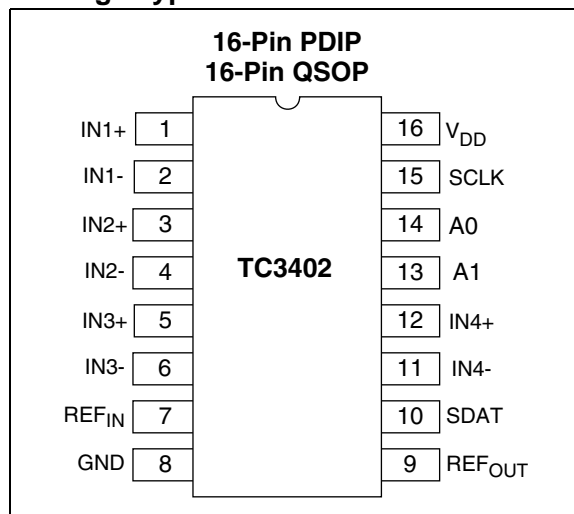
Applications

- Consumer Electronics, Thermostats, CO Monitors, Humidity Meters, Security Sensors
- Embedded Systems, Data Loggers, Portable Equipment
- Medical Instruments

Device Selection Table

Part Number	Package	Temperature Range
TC3402VPE	16-Pin PDIP (Narrow)	0°C to +85°C
TC3402VQR	16-Pin QSOP Narrow)	0°C to +85°C

Package Type



General Description

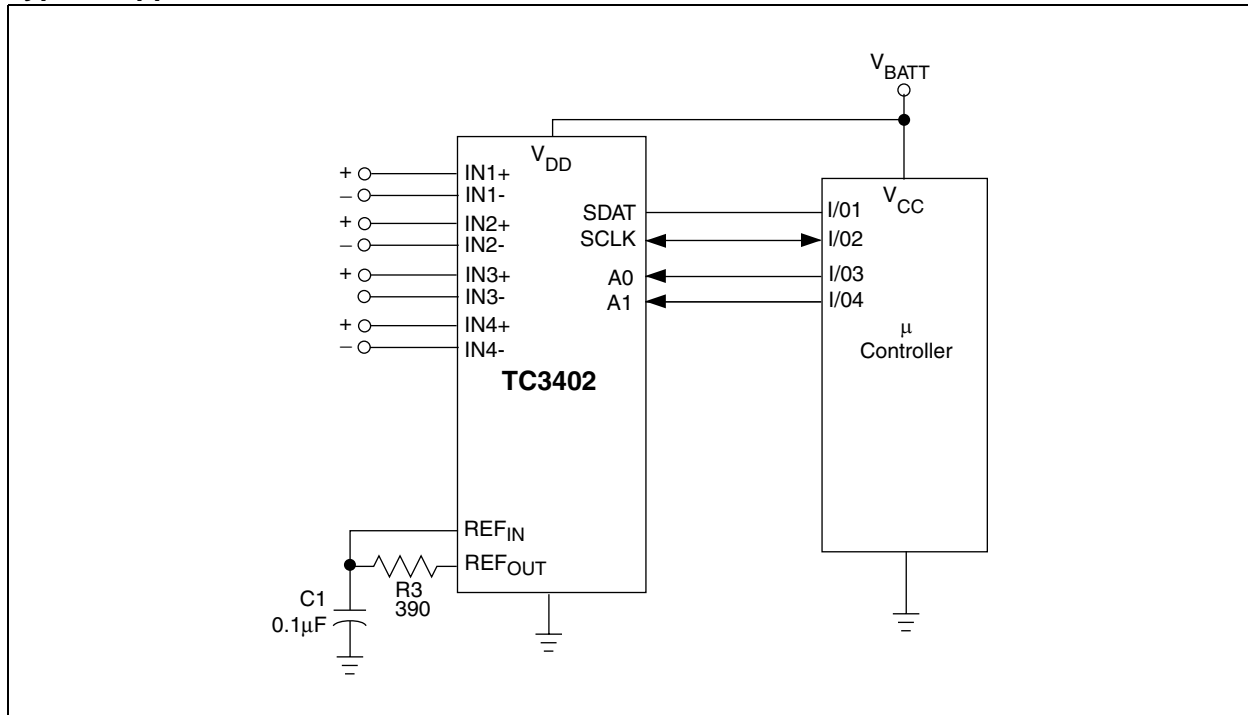
The TC3402 is a low cost, low power analog-to-digital converter based on Microchip's Sigma-Delta technology. It will perform 16-bit conversions (15-bit plus sign) at up to eight per second. The TC3402 is optimized for use as a microcontroller peripheral in low cost, battery operated systems. A voltage reference is included, or an external reference can be used.

The TC3402's 2-wire microPort™ digital interface is used for starting conversions and for reading out the data. Driving the SCLK line low starts a conversion. After the conversion starts, each additional falling edge (up to six) detected on SCLK for t_4 seconds reduces the A/D resolution by one bit and cuts conversion time in half. After a conversion is completed, clocking the SCLK line puts the MSB through LSB of the resulting data word onto the SDAT line, much like a shift register. The part automatically sleeps when not performing a data conversion.

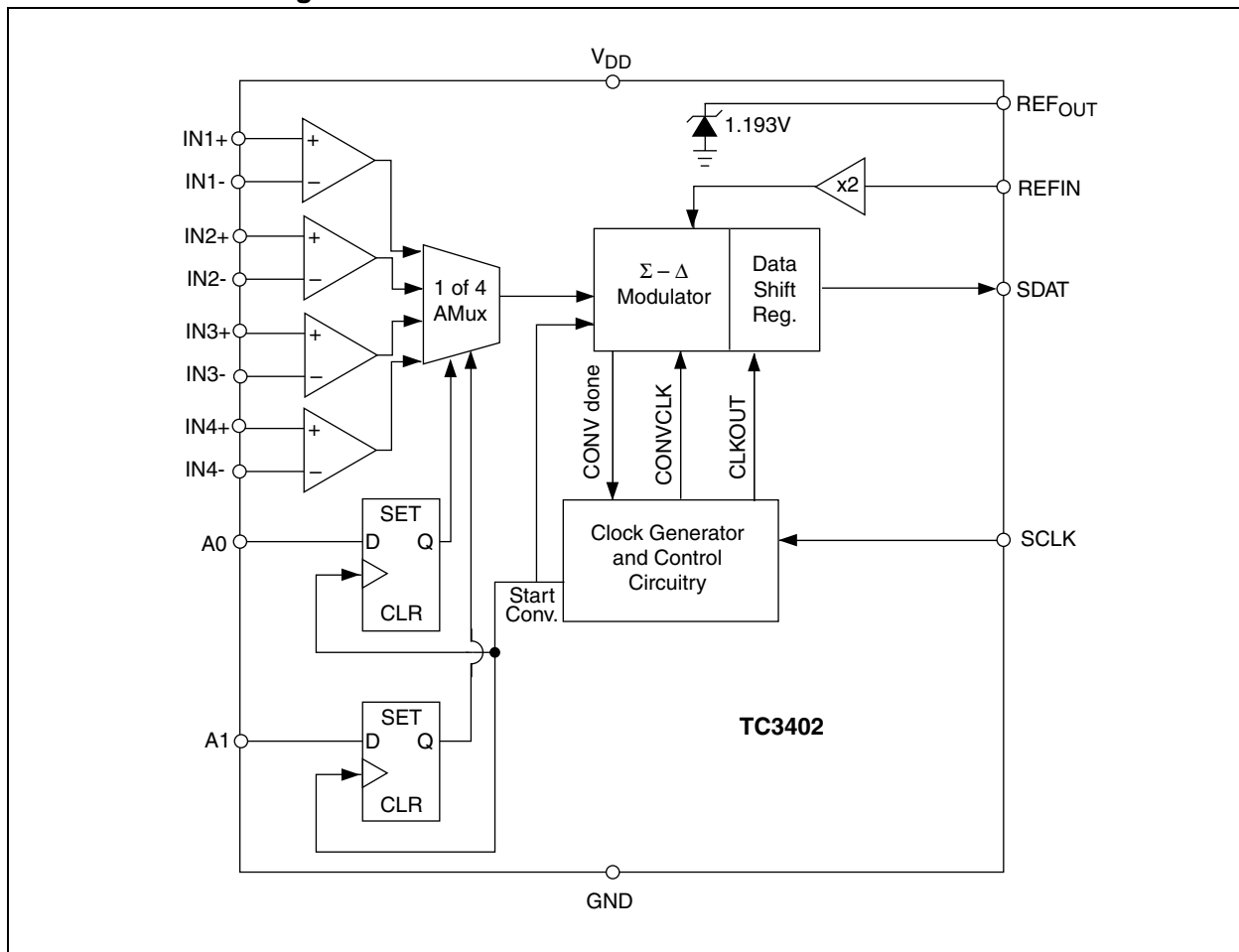
The TC3402 is available in a 16-Pin PDIP and a 16-Pin QSOP package.

TC3402

Typical Application



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage	6.0V
Input Voltage	(GND – 0.3V) to (V _{DD} + 0.3V)
Operating Temperature Range	0°C to 85°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.

TC3402 DC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: T_A = 25°C and V_{DD} = 2.7V, unless otherwise specified. **Boldface** type specifications apply for temperatures of 0°C to 85°C. V_{REF} = 1.25V, Internal Clock Frequency = 520kHz

Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
Power Supply						
V _{DD}	Supply Voltage	1.8	—	5.5	V	
I _{DD}	Supply Current, During Data Conversion	—	250	—	μA	
I _{DD} SLEEP	Supply Current, Sleep Mode	—	0.75	1.5	μA	T _A = +25°C
		—	1.8	3.0	μA	
Accuracy (Differential Inputs)						
RES	Resolution	—	16	—	Bits	
INL	Integral Non-Linearity	—	.0038	—	%FSR	V _{DD} = 2.7V
V _{OS}	Offset Error	—	—	±0.9	%FSR	IN+, IN- = 0V
V _{NOISE}	Referred to input	—	60	—	μVrms	
CMR	Common Mode Rejection	—	75	—	dB	At DC
FSE	Full Scale Error	—	0.4%	—	%FS	
PSRR	Power Supply Rejection Ratio	—	75	—	dB	V _{DD} = 2.5V to 3.5V
IN+, IN-						
V _{IN±}	Differential Input Voltage	—	—	V _{DD}	V	Note 1
	Absolute Voltage Range on INn+, INn- INn	GND	—	V _{DD}	V	
	Input Bias Current	—	1	100	nA	
C _{IN}	Input Sampling Capacitance	—	2	—	pF	
R _{IN}	Differential Input Resistance	—	2.0	—	MΩ	Note 2
REF_{IN}, REF_{OUT}						
V _{REF}	REF _{IN} Voltage Range	0	—	1.25	V	
I _{REF}	REF _{IN} Input Current	—	1	—	μA	
V _{REFOUT}	REF _{OUT} Voltage	—	1.193	—	V	
REF _{SINK}	REF _{OUT} Current Sink Capability	—	10	—	μA	
REF _{SRC}	REF _{OUT} Current Source Capability	300	—	—	μA	

- Note 1:** Differential input voltage defined as (V_{IN+} – V_{IN-}).
Note 2: Resistance from INn+ to INn- or INn to GND.
Note 3: @ V_{DD} = 1.8V, I_{SOURCE} ≤ 200μA.

TC3402

TC3402 DC ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: $T_A = 25^\circ\text{C}$ and $V_{DD} = 2.7\text{V}$, unless otherwise specified. **Boldface** type specifications apply for temperatures of 0°C to 85°C . $V_{REF} = 1.25\text{V}$, Internal Clock Frequency = 520kHz

Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
SCLK, A0, A1						
V_{IL}	Input Low Voltage	—	—	$0.3 \times V_{DD}$	V	
V_{IH}	Input High Voltage	$0.7 \times V_{DD}$	—	—	V	
I_{LEAK}	Leakage Current	—	1	—	μA	
SDAT						
V_{OL}	Output Low Voltage	—	—	0.4	V	$I_{OL} = 1.5\text{mA}$
V_{OH}	Output High Voltage (SDAT)	$0.9 \times V_{DD}$	—	—	V	$I_{SOURCE} = 400\mu\text{A}$ (Note 3)

- Note 1:** Differential input voltage defined as $(V_{IN+} - V_{IN-})$.
Note 2: Resistance from $INn+$ to $INn-$ or INn to GND.
Note 3: @ $V_{DD} = 1.8\text{V}$, $I_{SOURCE} \leq 200\mu\text{A}$.

TC3402 AC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: $T_A = 25^\circ\text{C}$ and $V_{DD} = 2.7\text{V}$, unless otherwise specified. **Boldface** type specifications apply for temperatures of 0°C to 85°C . $V_{REF} = 1.25\text{V}$, Internal Clock Frequency = 520kHz

Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
t_1	Resolution Reduction Clock Width	1	—	—	μsec	Width of SCLK (Negative)
t_2	Resolution Reduction Clock Width	1	—	—	μsec	Width of SCLK (Positive)
t_3	Conversion Time (15-bit Plus Sign)	—	125	—	msec	16-bit Conversion, $T_A = 25^\circ\text{C}$ (Note 1)
	Conversion Time (14-bit Plus Sign)	—	$t_3/2.0$	—	msec	15-bit Conversion
	Conversion Time (13-bit Plus Sign)	—	$t_3/4.0$	—	msec	14-bit Conversion
	Conversion Time (12-bit Plus Sign)	—	$t_3/7.8$	—	msec	13-bit Conversion
	Conversion Time (11-bit Plus Sign)	—	$t_3/15.1$	—	msec	12-bit Conversion
	Conversion Time (10-bit Plus Sign)	—	$t_3/28.6$	—	msec	11-bit Conversion
	Conversion Time (9-bit Plus Sign)	—	$t_3/51.4$	—	msec	10-bit Conversion
t_4	Resolution Reduction Window	—	$t_3/85.7$	—	msec	Width of SCLK
t_5	SCLK to Data Valid	1000	—	—	nsec	SCLK Falling Edge to SDAT Valid
t_6	Address Setup	0	—	—	nsec	Address Valid to SCLK
t_7	Address Hold	1000	—	—	nsec	SCLK to Address Valid Hold
t_8	Acknowledge Delay	—	—	1000	nsec	SCLK to SDAT Delay

- Note 1:** Nominal temperature drift is $-2830\text{ppm}/^\circ\text{C}$ for temperature less than 25°C and $-1340\text{ppm}/^\circ\text{C}$ for temperatures greater than 25°C .

2.0 PIN DESCRIPTIONS

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

TABLE 2-1: PIN FUNCTION TABLE

Pin No. (16-Pin PDIP) (16-Pin QSOP)	Symbol	Description
1	IN1+	Analog Input. This is the positive terminal of a true differential input consisting of IN1+ and IN1-. $V_{IN1} = (IN1+ - IN-)$. See Section 1.0, Electrical Characteristics.
2	IN1-	Analog Input. This is the negative terminal of a true differential input consisting of IN1+ and IN1-. $V_{IN1} = (IN+ - IN-)$ IN1- can swing to, but not below, ground. See Section 1.0, Electrical Characteristics.
3	IN2+	Analog Input. This is the positive terminal of a true differential input consisting of IN2+ and IN2-. $V_{IN2} = (IN2+ - IN-)$. (See Section 1.0, Electrical Characteristics.)
4	IN2-	Analog Input. This is the negative terminal of a true differential input consisting of IN2+ and IN2-. $V_{IN2} = (IN+ - IN-)$ IN2- can swing to, but not below, ground. See Section 1.0, Electrical Characteristics.
5	IN3+	Analog Input. This is the positive terminal of a true differential input consisting of IN3+ and IN3-. $V_{IN3} = (IN3+ - IN-)$. See Section 1.0, Electrical Characteristics.
6	IN3-	Analog Input. This is the negative terminal of a true differential input consisting of IN3+ and IN3-. $V_{IN3} = (IN+ - IN-)$ IN3- can swing to, but not below, ground. See Section 1.0, Electrical Characteristics.
7	REF _{IN}	Analog Input. The converter's reference voltage is the differential between this pin and ground times two. It may be tied directly to REF _{OUT} or scaled using a resistor divider. Any user supplied reference voltage less than 1.25V may be used in place of REF _{OUT} .
8	GND	Ground Terminal.
9	REF _{OUT}	Analog Output. The internal reference connects to this pin. It may be scaled externally and tied to the REF _{IN} input to provide the converter's reference voltage. Care must be taken in connecting external circuitry to this pin.
10	SDAT	Digital Output (push-pull). This is the microPort™ serial data output. SDAT is driven low while the TC3402 is converting data, effectively providing a "busy" signal. After the conversion is complete, every high to low transition on the SCLK pin puts a bit from the resulting data word on the SDAT pin (from MSB to LSB).
11	IN4-	Analog Input. This is the negative terminal of a true differential input consisting of IN4+ and IN4-. $V_{IN4} = (IN+ - IN-)$ IN4- can swing to, but not below, ground. See Section 1.0, Electrical Characteristics.
12	IN4+	Analog Input. This is the positive terminal of a true differential input consisting of IN4+ and IN4-. $V_{IN4} = (IN4+ - IN-)$. See Section 1.0, Electrical Characteristics.
13	A1	Digital Input. Controls analog multiplexer in conjunction with A0 to select one of the four Input channels. This address is latched at the falling edge of the SCLK, which starts an A/D conversion. A1, A0 = 00 = Input 1; 01 = Input 2; 10 = Input 3; 11 = Input 4.
14	A0	Digital Input. Controls analog multiplexer in conjunction with A1 to select one of four Input channels. This address is latched at the falling edge of the SCLK, which starts an A/D conversion. A1, A0 = 00 = Input 1; 01 = Input 2; 10 = Input 3; 11 = Input 4.
15	SCLK	Digital Input. This is the microPort™ serial clock input. The TC3402 comes out of Sleep mode and a conversion cycle begins when this pin is driven low. After the conversion starts, each additional falling edge (up to six) detected on SCLK for t_4 seconds reduces the A/D resolution by one bit. When the conversion is complete, the data word can be shifted out on the SDAT pin by clocking the SCLK pin.
16	V _{DD}	Power Supply Input.

3.0 DETAILED DESCRIPTION

The TC3402 has a 16-bit sigma-delta A/D converter. It has four differential inputs and an analog multiplexer. See the Typical Application circuit and the Functional Block diagram. The key components of the TC3402 are described below.

Also refer to Figure 3-4, A/D Operational Flowchart and the Timing Diagrams, Figure 3-1, Figure 3-2 and Figure 3-3.

3.1 A/D Converter Operation

When the TC3402 is not converting, it is in Sleep mode with both the SCLK and SDAT lines high. An A/D conversion is initiated by a high to low transition on the SCLK line, at which time the internal clock of the TC3402 is started and the address value (A0 and A1) is internally latched. The address value steers the analog multiplexer to select the input channel to be converted. Each additional high to low transition of SCLK (following the initial SCLK falling edge) during the time interval t_4 , will decrement the conversion resolution by one bit and reduce the conversion time by one half. The time interval t_4 is referred to as the resolution reduction window. The minimum conversion resolution is 10-bits so any more than 6 SCLK transitions during t_4 will be ignored.

After each high to low transition of SCLK, in the t_4 interval, the SDAT output is driven high by the TC3402 to acknowledge that the resolution has been decremented. When the SCLK returns high or the t_4 interval ends, the SDAT line returns low (see Figure 3-2). When the conversion is complete SDAT is driven high. The TC3402 now enters Sleep mode and the conversion value can be read as a serial data word on the SDAT line.

3.2 Reading the Data Word

After the conversion is complete and SDAT goes high, the conversion value can be clocked serially onto the SDAT line by high to low transitions of the SCLK. The data word is in two's complement format with the sign bit clocked onto the SDAT line, first followed by the MSB and ending in the LSB. For a 16-bit conversion the data word would consist of a sign bit followed by 15 magnitude bits, Table 3-1 shows the data word versus input voltage for a 16-bit conversion. Note that the full scale input voltage range is $\pm(2 \text{ REF}_{IN} - 1\text{LSB})$. When REF_{OUT} is fed back directly to REF_{IN} , an LSB is $73\mu\text{V}$ for a 16-bit conversion, as REF_{OUT} is typically 1.193V.

Figure 3-3 shows typical SCLK and SDAT waveforms for 16, 12 and 10-bit conversions. Note that any complete convert and read cycle requires 17 negative edge clock pulses. The first is the convert command. Then, up to six of these can occur in the resolution reduction window, t_4 , to decrement resolution. The remaining pulses clock out the conversion data word.

TABLE 3-1: DATA CONVERSION WORD VS. VOLTAGE INPUT ($\text{REF}_{IN} = 1.193\text{V}$)

Data Word	INn+ – INn- (Volts)
0111 1111 1111 1111	2.38596 (Positive Full Scale)
0000 0000 0000 0001	72.8 E -6
0000 0000 0000 0000	0
1111 1111 1111 1111	-72.8 E -6
1000 0000 0000 0001	-2.38596 (Negative Full Scale)
1000 0000 0000 0000	Reserved Code

The SCLK input has a filter which rejects any positive or negative pulse of width less than 50nsec to reduce noise. The rejection width of this pulse can vary between 50nsec and 750nsec depending on processing parameters and supply voltage.

Figure 3-1 and Table 3-2 show information for determining the mode of operation for the TC3402 part by recording the value of SDAT for SCLK in a high, then low, then high state. For example, if SCLK goes through a 1-0-1 transition and the corresponding values of SDAT are 1-1-0, then the SCLK falling edge started a new data conversion. A 0-1-0 for SDAT would have indicated a resolution reduction had occurred. This is useful if the microcontroller has a Watchdog Reset or otherwise loses track of where the TC3402 is in the conversion and data readout sequence. The microcontroller can simply transition SCLK until it "finds" a Start Conversion condition.

FIGURE 3-1: SCLK, SDAT LOGIC STATE DIAGRAM

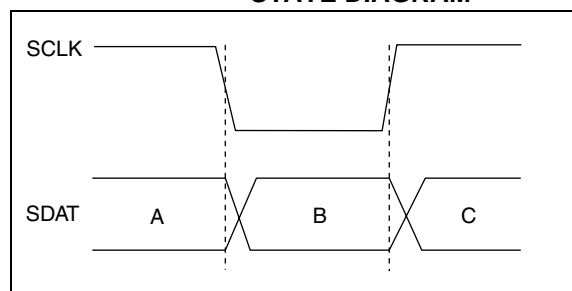


TABLE 3-2: SCLK, SDAT LOGIC STATE

A	B	C	Status
1	1	0	Start Conversion
0	1	0	Resolution Reduction
x	1	1	Data Transfer
x	0	0	Data Transfer or Busy*

***Note:** The code X00 has a dual meaning: Data Transfer or Busy converting. To avoid confusion, the user should send only the required number of pulses for the desired resolution, then wait for SDAT to rise to 1, indicating conversion is complete before clocking SCLK again to read out data bits.

FIGURE 3-2: CONVERSION AND DATA OUTPUT TIMING

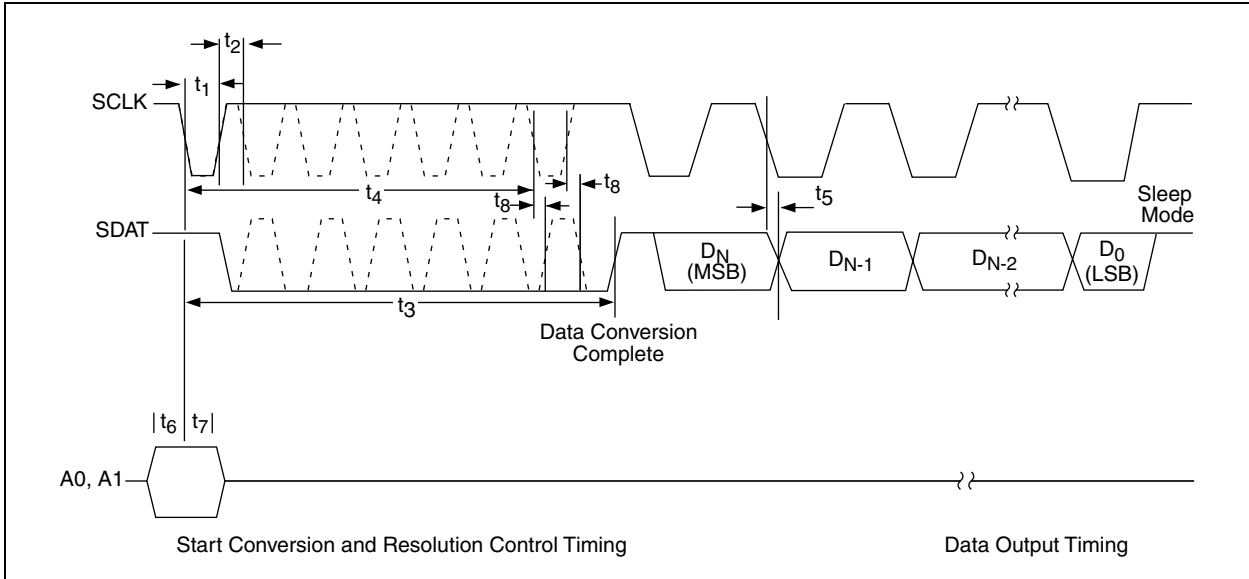


FIGURE 3-3: SCLK AND SDAT WAVEFORMS FOR 16, 12 AND 10-BIT CONVERSIONS

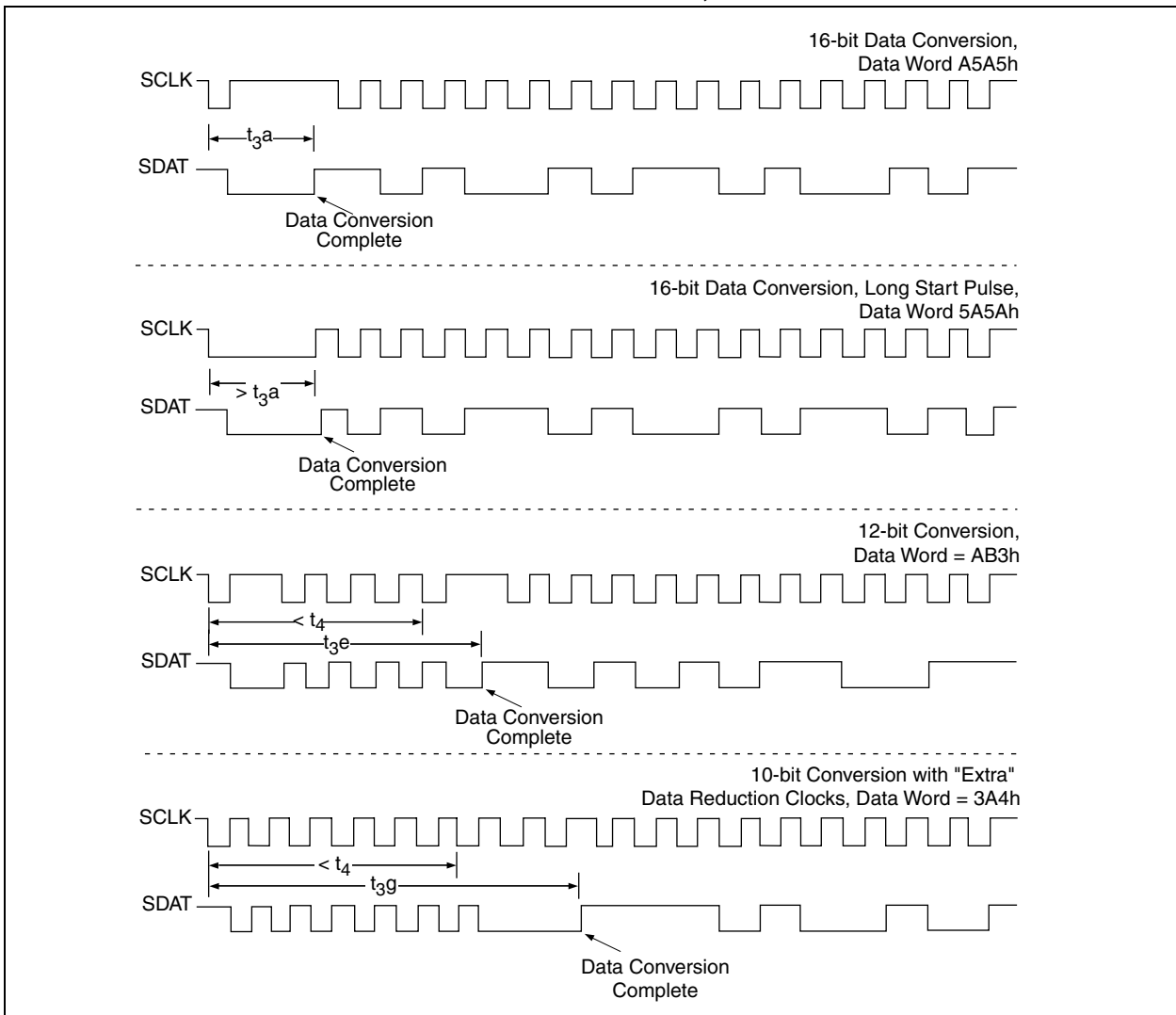
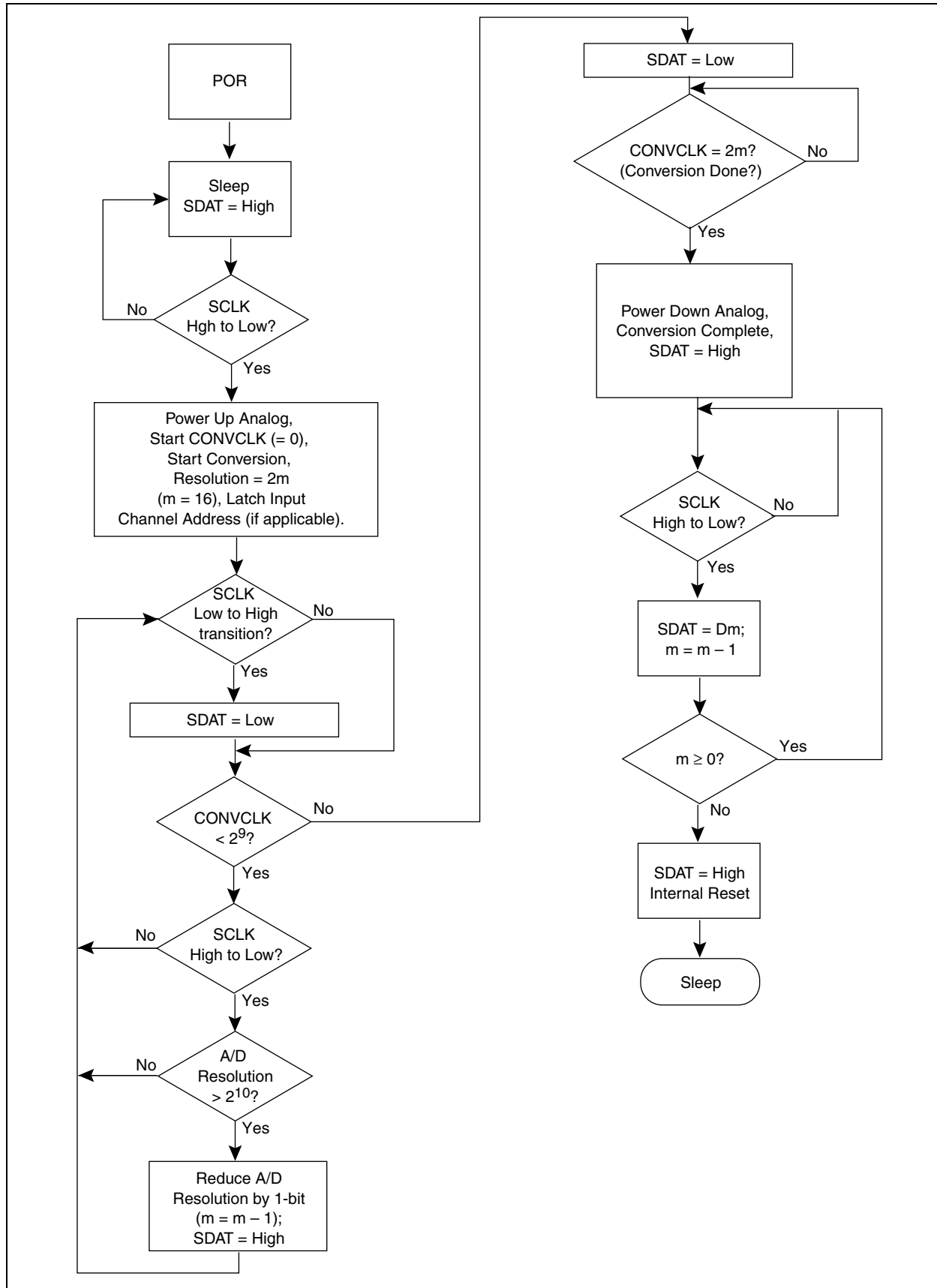


FIGURE 3-4: A/D OPERATIONAL FLOWCHART



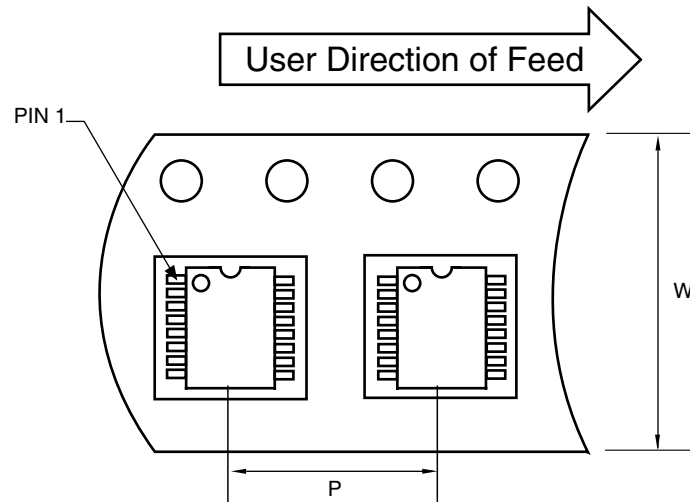
4.0 PACKAGING INFORMATION

4.1 Package Marking Information

Package marking data not available at this time.

4.2 Taping Forms

Component Taping Orientation for 16-Pin QSOP (Narrow) Devices



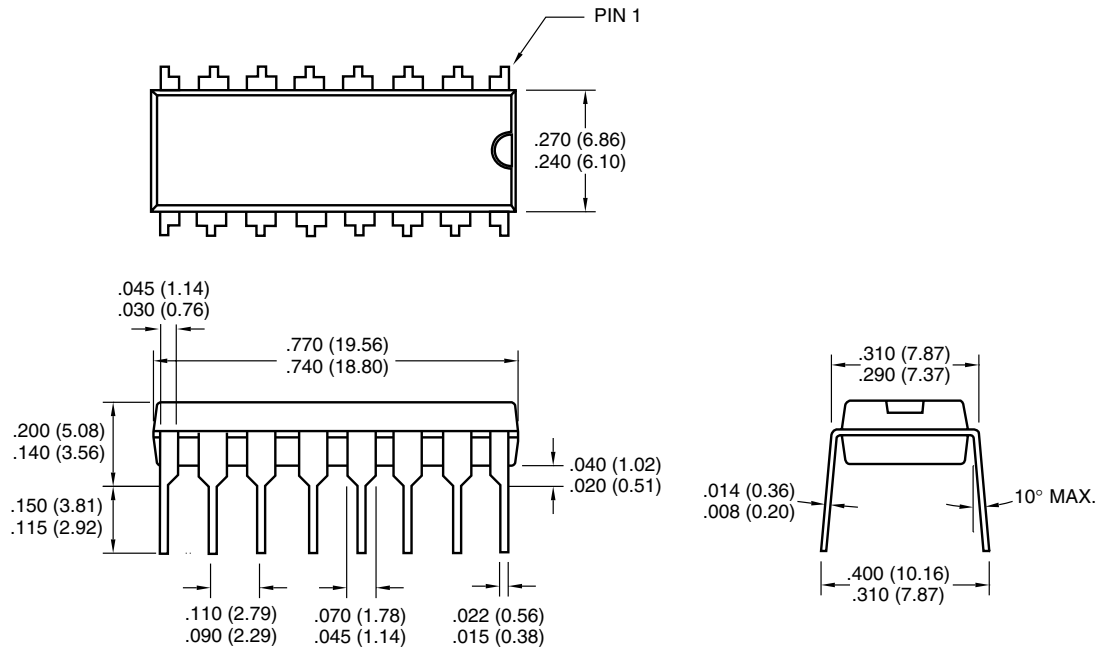
Standard Reel Component Orientation
for TR Suffix Device

Carrier Tape, Reel Size, Number of Components Per Reel and Reel Size

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

4.3 Package Dimensions

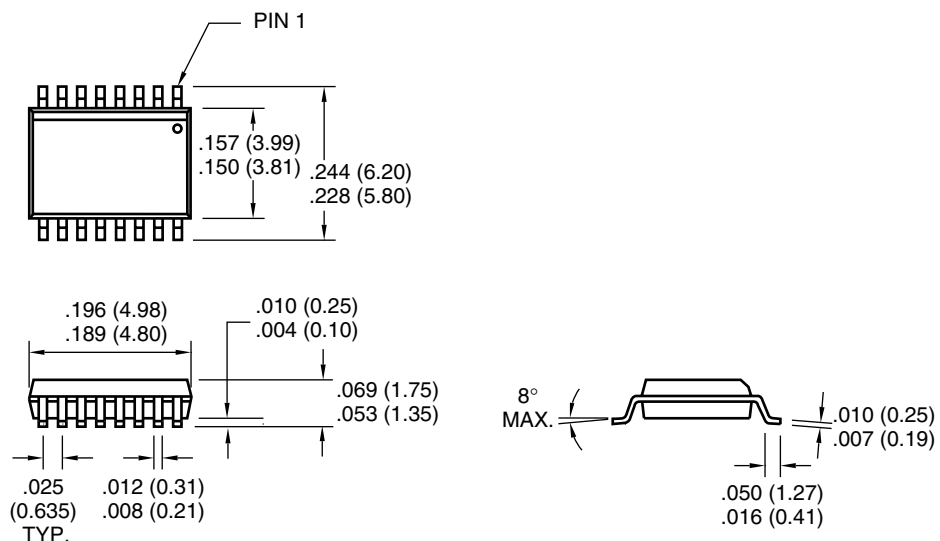
16-Pin PDIP (Narrow)



Dimensions: inches (mm)

1

16-Pin QSOP (Narrow)



Dimensions: inches (mm)

NOTES:

TC3402

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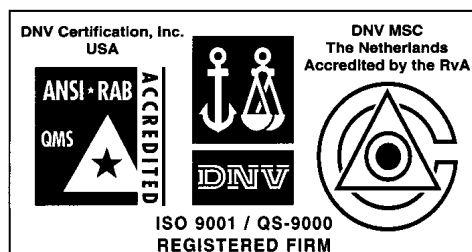
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Detroit

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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: 86-28-86766200 Fax: 86-28-86766599

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

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

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
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Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
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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
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43 Rue du Saule Trapu
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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

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

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