**TC3402**

+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 250µA; Sleep: 0.75µA
- 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**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC3402VPE</td>
<td>16-Pin PDIP (Narrow)</td>
<td>0°C to +85°C</td>
</tr>
<tr>
<td>TC3402VQR</td>
<td>16-Pin QSOP (Narrow)</td>
<td>0°C to +85°C</td>
</tr>
</tbody>
</table>

**Package Type**

<table>
<thead>
<tr>
<th>IN1+</th>
<th>1</th>
<th>VDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN1-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>IN2+</td>
<td>3</td>
<td>A0</td>
</tr>
<tr>
<td>IN2-</td>
<td>4</td>
<td>A1</td>
</tr>
<tr>
<td>IN3+</td>
<td>5</td>
<td>IN4+</td>
</tr>
<tr>
<td>IN3-</td>
<td>6</td>
<td>IN4-</td>
</tr>
<tr>
<td>REFIN</td>
<td>7</td>
<td>SDAT</td>
</tr>
<tr>
<td>GND</td>
<td>8</td>
<td>REFOUT</td>
</tr>
</tbody>
</table>

**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 \( t_x \) 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.
Typical Application

![Typical Application Diagram]

Functional Block Diagram

![Functional Block Diagram]
1.0  ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage .......................................................... 6.0V
Input Voltage .......................................................... GND – 0.3V to (VDD + 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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>Supply Voltage</td>
<td>1.8</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>IDD</td>
<td>Supply Current, During Data Conversion</td>
<td>—</td>
<td>250</td>
<td>—</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>IDD(S)</td>
<td>Supply Current, Sleep Mode</td>
<td>—</td>
<td>0.75</td>
<td>1.5</td>
<td>μA</td>
<td>TA = +25°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>1.8</td>
<td>3.0</td>
<td>μA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES</td>
<td>Resolution</td>
<td>—</td>
<td>16</td>
<td>—</td>
<td>Bits</td>
<td></td>
</tr>
<tr>
<td>INL</td>
<td>Integral Non-Linearity</td>
<td>—</td>
<td>.0038</td>
<td>—</td>
<td>%FSR VDD = 2.7V</td>
<td></td>
</tr>
<tr>
<td>VOS</td>
<td>Offset Error</td>
<td>—</td>
<td>—</td>
<td>±0.9</td>
<td>%FSR IN+, IN- = 0V</td>
<td></td>
</tr>
<tr>
<td>VNOISE</td>
<td>Referred to input</td>
<td>—</td>
<td>60</td>
<td>—</td>
<td>μVrms</td>
<td></td>
</tr>
<tr>
<td>CMR</td>
<td>Common Mode Rejection</td>
<td>—</td>
<td>75</td>
<td>—</td>
<td>dB</td>
<td>At DC</td>
</tr>
<tr>
<td>FSE</td>
<td>Full Scale Error</td>
<td>—</td>
<td>0.4%</td>
<td>—</td>
<td>%FS</td>
<td></td>
</tr>
<tr>
<td>PSRR</td>
<td>Power Supply Rejection Ratio</td>
<td>—</td>
<td>75</td>
<td>—</td>
<td>dB</td>
<td>VDD = 2.5V to 3.5V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIN±</td>
<td>Differential Input Voltage</td>
<td>—</td>
<td>—</td>
<td>VDD</td>
<td>V</td>
<td>Note 1</td>
</tr>
<tr>
<td></td>
<td>Absolute Voltage Range on IN+n, IN+n- INn</td>
<td>—</td>
<td>—</td>
<td>VDD</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input Bias Current</td>
<td>—</td>
<td>1</td>
<td>100</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>CIN</td>
<td>Input Sampling Capacitance</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>pF</td>
<td></td>
</tr>
<tr>
<td>RIN</td>
<td>Differential Input Resistance</td>
<td>—</td>
<td>2.0</td>
<td>—</td>
<td>MΩ</td>
<td>Note 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>VREF</td>
<td>REFIN Voltage Range</td>
<td>0</td>
<td>—</td>
<td>1.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>IREF</td>
<td>REFIN Input Current</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>VREFOUT</td>
<td>REFOUT Voltage</td>
<td>—</td>
<td>1.93</td>
<td>—</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>REF SINK</td>
<td>REFOUT Current Sink Capability</td>
<td>—</td>
<td>10</td>
<td>—</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>REF SRC</td>
<td>REFOUT Current Source Capability</td>
<td>300</td>
<td>—</td>
<td>—</td>
<td>μA</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Differential input voltage defined as \(V_{IN+} - V_{IN-}\).
2: Resistance from IN+n+ to IN+n- or INn to GND.
3: @ VDD = 1.8V, ISOURCE ≤ 200μA.
## TC3402 DC ELECTRICAL SPECIFICATIONS (CONTINUED)

### 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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IL}$</td>
<td>Input Low Voltage</td>
<td>—</td>
<td>—</td>
<td>$0.3 \times V_{DD}$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>Input High Voltage</td>
<td>$0.7 \times V_{DD}$</td>
<td>—</td>
<td>—</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_{LEAK}$</td>
<td>Leakage Current</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>$\mu$A</td>
<td></td>
</tr>
<tr>
<td>SDAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Output Low Voltage</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
<td>V</td>
<td>$I_{OL} = 1.5mA$</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>Output High Voltage (SDAT)</td>
<td>$0.9 \times V_{DD}$</td>
<td>—</td>
<td>—</td>
<td>V</td>
<td>$I_{SOURCE} = 400\mu$A (Note 3)</td>
</tr>
</tbody>
</table>

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

## TC3402 AC 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

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

**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

<table>
<thead>
<tr>
<th>Pin No. (16-Pin PDIP) (16-Pin QSOP)</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN1+</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>IN1-</td>
<td>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.</td>
</tr>
<tr>
<td>3</td>
<td>IN2+</td>
<td>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.)</td>
</tr>
<tr>
<td>4</td>
<td>IN2-</td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td>IN3+</td>
<td>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.</td>
</tr>
<tr>
<td>6</td>
<td>IN3-</td>
<td>Analog Input. This is the negative terminal of a true differential input consisting of IN3+ and IN3-. $V_{IN3} = (IN+ - IN-)$. IN1- can swing to, but not below, ground. See Section 1.0, Electrical Characteristics.</td>
</tr>
<tr>
<td>7</td>
<td>REF_IN</td>
<td>Analog Input. The converter’s reference voltage is the differential between this pin and ground times two. It may be tied directly to REFOUT or scaled using a resistor divider. Any user supplied reference voltage less than 1.25V may be used in place of REFOUT.</td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td>Ground Terminal.</td>
</tr>
<tr>
<td>9</td>
<td>REFOUT</td>
<td>Analog Output. The internal reference connects to this pin. It may be scaled externally and tied to the REFIN input to provide the converter’s reference voltage. Care must be taken in connecting external circuitry to this pin.</td>
</tr>
<tr>
<td>10</td>
<td>SDAT</td>
<td>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).</td>
</tr>
<tr>
<td>11</td>
<td>IN4-</td>
<td>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.</td>
</tr>
<tr>
<td>12</td>
<td>IN4+</td>
<td>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.</td>
</tr>
<tr>
<td>13</td>
<td>A1</td>
<td>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.</td>
</tr>
<tr>
<td>14</td>
<td>A0</td>
<td>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.</td>
</tr>
<tr>
<td>15</td>
<td>SCLK</td>
<td>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.</td>
</tr>
<tr>
<td>16</td>
<td>VDD</td>
<td>Power Supply Input.</td>
</tr>
</tbody>
</table>
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 compliment 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 \( \pm (2 \cdot \text{REF}_{\text{IN}} - 1 \text{LSB}) \). When REFOUT is fed back directly to REFIN, an LSB is 73\( \mu \)V for a 16-bit conversion, as REFOUT 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>
<thead>
<tr>
<th>Data Word</th>
<th>( I_{n+} - I_{n-} ) (Volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0111 1111 1111 1111</td>
<td>2.38596 (Positive Full Scale)</td>
</tr>
<tr>
<td>0000 0000 0000 0000</td>
<td>72.8 E-6</td>
</tr>
<tr>
<td>0000 0000 0000 0000</td>
<td>72.8 E-6</td>
</tr>
<tr>
<td>1111 1111 1111 1111</td>
<td>-72.8 E-6</td>
</tr>
<tr>
<td>1000 0000 0000 00001</td>
<td>-2.38596 (Negative Full Scale)</td>
</tr>
<tr>
<td>1000 0000 0000 0000</td>
<td>Reserved Code</td>
</tr>
</tbody>
</table>

The SCLK input has a filter which rejects any positive or negative pulse of width less than 50\( \mu \)sec to reduce noise. The rejection width of this pulse can vary between 50\( \mu \)sec and 750\( \mu \)sec 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

- \( \text{SCLK} \)
- \( \text{SDAT} \)
- \( A \)
- \( B \)
- \( C \)

### TABLE 3-2: SCLK, SDAT LOGIC STATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Start Conversion</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Resolution Reduction</td>
</tr>
<tr>
<td>x</td>
<td>1</td>
<td>1</td>
<td>Data Transfer</td>
</tr>
<tr>
<td>x</td>
<td>0</td>
<td>0</td>
<td>Data Transfer or Busy*</td>
</tr>
</tbody>
</table>

*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

![SCLK and SDAT Waveforms Diagram](image)

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

![SCLK and SDAT Waveforms Diagram](image)
FIGURE 3-4: A/D OPERATIONAL FLOWCHART

POR

Sleep
SDAT = High

SCLK
Hgh to Low?

Yes

Power Up Analog,
Start CONVCLK (= 0),
Start Conversion,
Resolution = 2^m
(m = 16), Latch Input
Channel Address (if applicable).

SCLK
Low to High
transition?

Yes

SDAT = Low

CONVCLK
< 2^m?

No

Yes

SDAT = Low

CONVCLK
> 2^{10}?

No

Yes

SCLK
High to Low?

Yes

A/D Resolution
> 2^{10}?

Yes

No

Reduce A/D
Resolution by 1-bit
(m = m – 1);
SDAT = High

SDAT = Low

CONVCLK = 2^m?
(Conversion Done?)

No

Yes

Power Down Analog,
Conversion Complete,
SDAT = High

SCLK
High to Low?

Yes

SDAT = D_m;
m = m – 1

m ≥ 0?

Yes

No

SDAT = High
Internal Reset

Sleep
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

User Direction of Feed

Standard Reel Component Orientation for TR Suffix Device

<table>
<thead>
<tr>
<th>Package</th>
<th>Carrier Width (W)</th>
<th>Pitch (P)</th>
<th>Part Per Full Reel</th>
<th>Reel Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-Pin QSOP (N)</td>
<td>12 mm</td>
<td>8 mm</td>
<td>2500</td>
<td>13 in</td>
</tr>
</tbody>
</table>
4.3 Package Dimensions

16-Pin PDIP (Narrow)

Dimensions: inches (mm)

16-Pin QSOP (Narrow)

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, Keeloo, 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, rPIC, 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.
# WORLDWIDE SALES AND SERVICE

## 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](http://www.microchip.com)

**Rocky Mountain**
2335 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: 972-818-7923 Fax: 972-818-2924

**Detroit**
Tri-Atria Office Building
32265 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
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 Beidaje
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 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., Shanghai Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-2560086 Fax: 86-755-2560086

## EUROPE
**Denmark**
Microchip Technology Nordic ApS
Regus Business Centre
Laurup 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: 49-89-6275-144 0 Fax: 49-89-6275-144-44

**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

**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, 189880
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

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

05/01/02