PICDEM™ MSC1 Delta-Sigma Analog-to-Digital Converter Daughter Board User’s Guide
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INTRODUCTION

The PICDEM™ MSC1 Delta-Sigma ADC Daughter Board, in combination with the PICDEM MSC1 Demonstration Board, serves as a demonstration and evaluation kit for designing high resolution Delta Sigma Analog-to-Digital Converters using the PIC16C781/782. The Daughter Board has the following features:

- All the components required to implement an 8 to 16-bit Delta-Sigma ADC
- An RCA connector for connecting an external sensor
- A generous prototyping area for building signal-conditioning circuitry
- An on-board temperature sensor for a demonstration input to the ADC

UNPACKING YOUR PICDEM MSC1 DAUGHTER BOARD

Supplied Items

The items contained in the box are:

- PICDEM MSC1 Delta-Sigma ADC Daughter Board
- PIC16C781/782 programmed with the Delta-Sigma ADC firmware
- PICDEM MSC1 Delta-Sigma ADC Daughter Board User's Guide

Required Items

Additional items required are:

- PICDEM MSC1 Demonstration Board Kit
- PC running Windows® 95 or newer operating system
- 9 VDC Power Supply
- 9-pin RS-232 Cable
INSTALLING THE HARDWARE

Complete the following steps to install the PICDEM MSC1 Delta-Sigma ADC Daughter Board:

1. Install the PICDEM MSC1 Demonstration Board using the installation instructions and verify its operation.
2. Remove the power from the PICDEM MSC1.
3. Remove the PIC16C781/782 (U2) from the PICDEM MSC1 board.
4. Remove the two shorting jumpers from the 40-pin header located at the center of the PICDEM MSC1.
5. Install the PIC16C782 supplied with the Delta-Sigma ADC Daughter Board into the U2 socket of the PICDEM MSC1. Be certain pin 1 is in the correct position.
6. Install the Delta-Sigma ADC Daughter Board onto the PICDEM MSC1 40-pin header, with the Daughter Board covering the prototype area of the PICDEM MSC1. Be certain the 40-pin connector on the Daughter Board is correctly aligned with the 40-pin header.
7. Install the 9-pin RS-232 cable between the 9-pin connector on the PICDEM MSC1 and the serial port of the PC.

CONFIGURING THE DELTA-SIGMA ADC DAUGHTER BOARD

The Delta-Sigma ADC Daughter Board is designed to operate in a continuous conversion mode, repeatedly performing a conversion and transmitting the result serially to a PC. Complete the following steps to configure the Daughter Board and start the conversion sequence.

1. Select the desired ADC input using one of the three options provided in this section.
2. Connect the 9 VDC power supply to the PICDEM MSC1.
3. Load a serial communications program on the PC (Hyper-Terminal or equivalent).
4. Configure the serial communications program for the appropriate serial port.
5. Configure the serial communications program to transmit and receive 8 bits of data, no parity, no flow control and one-stop bit.
6. Send a '!' character to the PICDEM MSC1.
7. The PICDEM MSC1 and Daughter Board should respond with a string of 5 digit numeric values, repeating on a new line every 10 values. (Note: Leading zeros are replaced with blank spaces.)
Overview and Installation

Selecting the On-Board Temperature Sensor Input
To configure the Delta-Sigma ADC Daughter Board to use the on-board temperature sensor, position the shorting jumper in the center of the Daughter Board to match Figure 1-1.

FIGURE 1-1: ON-BOARD TEMPERATURE SENSOR JUMPER POSITION

Selecting the On-Board Prototyping Area Input
To configure the Delta-Sigma ADC Daughter Board to use the analog input from the prototyping area, position the shorting jumper in the center of the Daughter Board to match Figure 1-2.

FIGURE 1-2: ON-BOARD PROTOTYPING AREA INPUT JUMPER POSITION

Selecting the External Sensor Input
To configure the Delta-Sigma ADC Daughter Board to use an external sensor, position the shorting jumper in the center of the Daughter Board to match Figure 1-3.

FIGURE 1-3: ON-BOARD EXTERNAL SENSOR INPUT JUMPER POSITION
FIGURE 1-4: ON-BOARD PROTOTYPING AREA INPUT ADDITIONAL SIGNALS

Note: Figure 1-4 shows all connections available in the prototyping area of the Daughter Board.
A Delta-Sigma ADC is composed of two sections, a Delta-Sigma modulator and a digital filter. The Delta-Sigma ADC Daughter Board implements a simple first order Delta-Sigma ADC using Comparator C2, the Op Amp, Timer1 and Timer2 in the PIC16C782. The Op Amp and Comparator are used to create the modulator, while Timer1 and Timer2 form the Digital Filter or Decimator.

Figure 1-5 shows the Delta-Sigma Modulator using the PIC16C782. The Op Amp and C10 form a single pole integrator driven by the net current flow at the inverting input to the Op Amp. The output of the integrator drives the comparator, which acts as a 1-bit ADC. The output of the comparator is sampled at a rate set by the Timer1 clock with the output fed back to the input of the integrator.

If the sensor voltage is equal to \( \frac{V_{DD}}{2} \) (reference voltage of the non-inverting Op Amp input), then the output of the comparator will oscillate back and forth at the Timer1 clock frequency with a duty cycle of 50%. If the sensor input voltage is higher than \( \frac{V_{DD}}{2} \) reference, the duty cycle of the comparator output will drop such that the average input to the integrator is equal and opposite to the change in the input. In this manner, the modulator converts an input voltage into a variable duty cycle.

The Digital Filter, or Decimator, takes the variable duty cycle output of the modulator and converts it into a digital value. To do this, both timers and the Timer1 Gate option of Timer1 are used to create an averaging filter. In operation, Timer0 (with its prescaler) counts out a specific number of input samples. While Timer0 is counting out the total number of samples, Timer1, using its gate function, counts the number of input samples that are zero. The result is a measure of the average duty cycle over the sample period and the result of the ADC conversion.
FUTURE EXPANSION

Several modifications can be made to the basic Delta-Sigma ADC converter to modify its configuration and/or performance:

1. To change the input voltage range, change the ratio of the input resistor (R9) to the feedback resistor (R8). If the resistors are equal, the input range is 0-5 VDC (centered at VDD/2). However, enlarging R9 to 10 times R8 will expand the input range to 50 VDC. Reducing R9 to 1/10 will produce an input range of 0.5 VDC. Note that 50 VDC and 0.5 VDC ranges will still be centered at VDD/2. To change the DC offset, see Item 2.

2. To change the DC offset of the ADC converter, place a resistor between the input to the integrator and VDD or VSS. To move the DC offset up in voltage, connect the resistor to VSS. To move the DC offset down, connect the resistor to VDD. The amount of shift will be determined by the value of the resistor according to the following equation. Note: Voltage shift is relative to VDD/2 and R9 input resistor value.

\[ V_{\text{shift}} = \frac{V_{DD} \times R}{R9} \]

3. Using Digi-Pots for both the feedback resistance and a DC offset adjustment would allow the microcontroller to scale both its range and zero for an automated range and calibration converter.

TROUBLESHOOTING

1. The board does not return data to the serial communications program.
   - Check the connections to the serial port and 9 VDC power supply.
   - Verify the serial communication program is configured correctly.
   - Test communications by removing the RS-232 cable from the PICDEM MSC1 and shorting pins 2 and 3. Characters typed on the PC should echo to the screen. If not, try selecting a different serial port and verify the program’s settings.
   - If the previous character echo test works but the board does not communicate, reconnect the serial cable, remove the PIC16C782, short U2 socket pins 11 and 12 together, and connect the 9 VDC power supply. If keys pressed on the PC are not echoed to the screen, the PICDEM MSC1 may be damaged. Contact your local vendor concerning repair or replacement.
   - If both previous tests pass, then verify the code in the PIC16C782 by downloading the HEX file from the Microchip Technology Inc. web site (www.microchip.com) and verify the programming using a PICSTART® Plus or PRO MATE® Programmer.

2. The board always returns a zero.
   - Verify that the ADC input is not shorted.
   - Verify that the Daughter Board is installed correctly on the 40-pin header at the center of the PICDEM MSC1.
   - Verify the code in the PIC16C781/782 by downloading the HEX file from the Microchip Technology Inc. web site (www.microchip.com) and verify the programming using a PICSTART Plus or PRO MATE Programmer.

3. The board always returns a 32768 +/- 20 count.
   - Verify the placement of the input selection jumper is correct.
   - Verify the resistance of the 33KΩ input resistor.
FIGURE 1-6: PICDEM MSC1 DELTA-SIGMA ADC DAUGHTER BOARD SCHEMATIC