Embedded systems lab

Lab # 8

Analog to Digital conversions

Objectives

- To be familiar with analog to digital converter module in PIC18F4550.

Theory

Analog to digital conversion

Signals in the real world are analog: light, sound, etc. So, real-world signals must be converted into digital, using a circuit called ADC (Analog-to-Digital Converter), before they can be manipulated by digital equipment such as microcontroller.

Let's say you have a sound wave, and you wish to sample it with an ADC. Here is a typical wave

When you sample the wave with an analog-to-digital converter, you have control over two variables:

- **The sampling rate**
  - Controls how many samples are taken per second

- **The sampling precision (resolution)**
  - Controls how many different gradations (quantization levels) are possible when taking the sample

- **The reference voltages**
  - The VREF + represents the maximum analog value that can be converted by the Analog to Digital converter
  - The VREF - represents the minimum analog value that can be converted by the Analog to Digital converter

You can see that as the sampling rate and precision (resolution) increase, the similarity between the original wave and the ADC's output improves.
PIC Internal Analog to Digital Converter

A number of microcontrollers have built in Analog to Digital Converter (ADC). Commonly, these AD converters have 8-bit or 10-bit resolution allowing them voltage sensitivity of 19.5mV or 4.8mV, respectively.

PIC18F4550 Analog to Digital Converter module

![PIC18F4550 Pinout](image)

The ADC for PIC 18F4550 module has the following characteristics

- Number of analog channels
  - The Analog-to-Digital (A/D) Converter module has 13 inputs for PIC18F4550 (AN0 – AN12) which corresponds to (RA0-RA5 & RE0-RE2 &RB0-RB4) as indicated on PIC18F4550 pins.
  - The analog channels can be configured as digital input/output pins by configuring ADCON1

- Resolution (precision)
  - The conversion of an analog input signal results in a corresponding 10-bit digital number this means the conversion result has 1024 levels
  - The lower 8 bits of the result are stored at ADRESL register, the upper 2-bits are stored at ADRESH register

- VRef+ / Vref- Configured by ADCON1 register such that
  - Vref + is determined by RA3 voltage level pin or by VDD
  - Vref- is determined by RA2 voltage level or by VSS

- The module has five registers:
  - A/D Result High Register (ADRESH)
  - A/D Result Low Register (ADRESL)
  - A/D Control Register 0 (ADCON0)
  - A/D Control Register 1 (ADCON1)
  - A/D Control Register 2 (ADCON2)

The configuration of ADC module can be determined by configuring ADCON0, ADCON1 and ADCON2 register
ADCON0, ADCON1 and ADCON2 from PIC18f4550 Data sheet

1. **ADCON0** (mainly Select A/D input channel)

   **REGISTER 21-1: ADCON0: A/D CONTROL REGISTER 0**

<table>
<thead>
<tr>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>CHS3</td>
<td>CHS2</td>
<td>CHS1</td>
<td>CHS0</td>
<td>GO/DONE</td>
<td>ADCN</td>
</tr>
</tbody>
</table>

   bit 7

   bit 5-2

   CHS3:CHS0: Analog Channel Select
   - 0000 = Channel 0 (AN0)
   - 0001 = Channel 1 (AN1)
   - 0010 = Channel 2 (AN2)
   - 0011 = Channel 3 (AN3)
   - 0100 = Channel 4 (AN4)
   - 0101 = Channel 5 (AN5[1,2])
   - 0110 = Channel 6 (AN6[1,2])
   - 0111 = Channel 7 (AN7[1,2])
   - 1000 = Channel 8 (AN8)
   - 1001 = Channel 9 (AN9)
   - 1010 = Channel 10 (AN10)
   - 1011 = Channel 11 (AN11)
   - 1100 = Channel 12 (AN12)

2. **ADCON1** (Configure analog pins, voltage reference and digital I/O)

   **REGISTER 21-2: ADCON1: A/D CONTROL REGISTER 1**

<table>
<thead>
<tr>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>VCFG0</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
</tr>
</tbody>
</table>

   bit 7

   bit 5

   VCFG0: Voltage Reference Configuration bit (VREF- source)
   - 1 = VREF- (AN2)
   - 0 = VSS

   bit 4

   VCFG0: Voltage Reference Configuration bit (VREF+ source)
   - 1 = VREF+ (AN3)
   - 0 = VDD
3. **ADCON2 (Select A/D conversion clock)**

### REGISTER 21-3:  **ADCON2: A/D CONTROL REGISTER 2**

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADFM</td>
<td>—</td>
<td>ACQT2</td>
<td>ACQT1</td>
<td>ACQT0</td>
<td>ADCS2</td>
<td>ADCS1</td>
<td>ADCS0</td>
</tr>
</tbody>
</table>

bit 7

bit 2-0

**ADCS2:ADCS0: A/D Conversion Clock Select bits**

- 111 = FRC (clock derived from A/D RC oscillator)\(^{(1)}\)
- 110 = FOSC/64
- 101 = FOSC/16
- 100 = FOSC/4
- 011 = FRC (clock derived from A/D RC oscillator)\(^{(1)}\)
- 010 = FOSC/32
- 001 = FOSC/8
- 000 = FOSC/2
Mikrobasic ADC library

Adc_Read

<table>
<thead>
<tr>
<th>Prototype</th>
<th>sub function Adc_Read(dim channel as byte) as word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns</td>
<td>10-bit unsigned value read from the specified channel.</td>
</tr>
<tr>
<td>Description</td>
<td>Initializes PIC's internal ADC module to work with RC clock. Clock determines the time period necessary for performing AD conversion (min 12TAD). Parameter channel represents the channel from which the analog value is to be acquired. Refer to the appropriate datasheet for channel-to-pin mapping.</td>
</tr>
<tr>
<td>Requires</td>
<td>Nothing.</td>
</tr>
<tr>
<td>Example</td>
<td>tmp = Adc_Read(1) ' Read analog value from channel 1</td>
</tr>
</tbody>
</table>

Lab Exercise:

Digital voltmeter

Build a basic program for the simplified digital voltmeter circuit shown that works as follows
- The program should read the analog voltage on AN2 & AN3 and then displays the voltage on LCD