DIGITAL CONTROLLER

3rd STAGE

CHAPTER: 2
ANALOG MODULE

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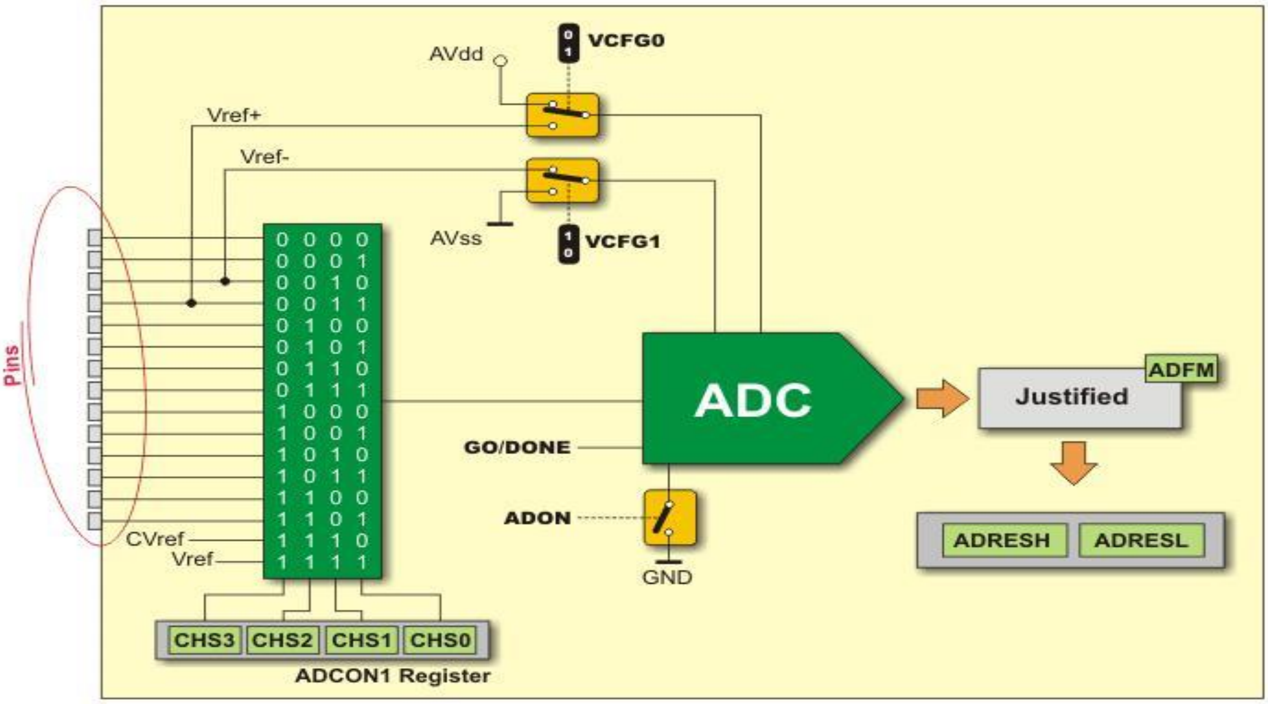
Chapter 2
Analog Module

It is rightly said that we live in Analog World, but we process our information in digital world. Most of the real world data is in Analog form, like temperature, pressure, humidity, altitude, distance, speed, force, voltage, light, radiation, direction, depth and hundreds of more parameters, they are all analog. In order to interact with these analog signals, we have to transform them some how into digital equivalents. The first step in this regards is an appropriate sensor that should be able to detect the particular modality, like temperature and convert the physical world entity into a corresponding electrical signal. The strength of signal in turn corresponds to the measured value.

Most of the sensors return the sensed data as voltage. The strength of physical parameter measured is reflected in the level of voltage returned. In order to use this analog data (voltage) in digital world, it has to be converted into digital equivalent. This process is called Analog to Digital Conversion or ADC. The ADC device has complex design of resistor ladders and networks that sequentially divide the input voltage into discreet levels and then return the value as digital number.

Since interaction with digital world is quite common for microcontrollers, PIC 18F452 has 8 channels of ADC input. The pins associated with analog inputs are also used for other purposes, in order to use them as analog certain registers have to be set. They enable microcontroller to recognize not only whether some pin is driven to logic zero or one (0 or +5V), but to precisely measure its voltage and convert it into numerical value, i.e. digital format. The whole procedure takes place in A/D converter module which has the following features:

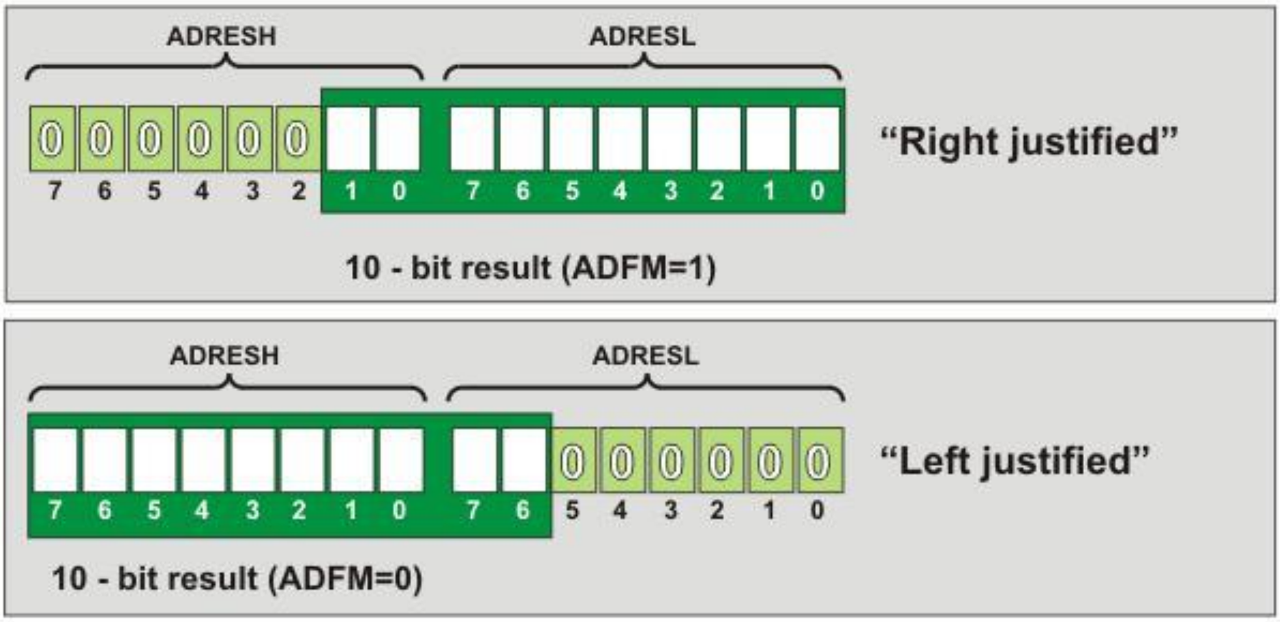
- The converter generates a 10-bit binary result using the method of successive approximation and stores the conversion results into the ADC registers (ADRESL and ADRESH).
- There are 8 separate analog inputs.
- The A/D converter allows conversion of an analog input signal to a 10-bit binary representation of that signal.
- By selecting voltage references Vref- and Vref+, the minimal resolution or quality of conversion may be adjusted to various needs



Although Analog to digital conversion seems to be a difficult task, yet its really simple and easy when working with PIC microcontrollers. The figure shows an overall plan of ADC. In fact there is only one analog to digital converter. The 8 channels are multiplexed, into ADC module one by one. The selection and configuration of channels is determined by ADCON0 and ADCON1 registers whereas the output of ADC module, which is 10 bit number is given in two 8 bit registers ADRESH and ADRESL. The H and L indicate High Byte and Low byte respectively.

ADRESH and ADRESL Registers

Upon converting an analog value into a digital one, the result of 10-bit A/D conversion will be stored in these two registers. In order to deal with this value easier, it can appear in two formats- left justified and right justified. The ADFM bit of the ADCON1 register determines the format of conversion result (see figure). In case the A/D converter is not used, these registers may be used as general-purpose registers.



A/D Acquisition Requirements

For the ADC to meet its specified accuracy, it is necessary to provide certain time delay between selecting specific analog input and measurement itself. That time is called "acquisition time" and mainly depends on the source impedance. There is an equation used for accurate calculating this time which in the worst case amounts to approximately 20uS. Briefly, after selecting (or changing) the analog input and before starting conversion it is necessary to provide at least 20uS time delay to enable the ACD maximal conversion accuracy.

ADCON0 Register & ADCON1 Register

The ADCON0 register selects two main things. First it selects which channel or pin to use to sample the analog signal and secondly the speed of conversion, also called TAD. The TAD depends on the source of clock signals.

ADCON0 REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	—	ADON
bit 7							bit 0

The Chanel Select CHS0 - CHS2 are three bits which select the I/O pin to sample. The ADCS0 and ADCS1 bits determine the TAD. The ADON bit powers up the converting module, GO/DONE bit when set to 1 starts conversion. It remains 1 till conversion is going on, when conversion is complete and data has been transferred to ADRES registers this bit is automatically cleared indicating completion.

In order to avoid damage to the digital circuitry, the analog pins must be set to analog settings before getting analog data.

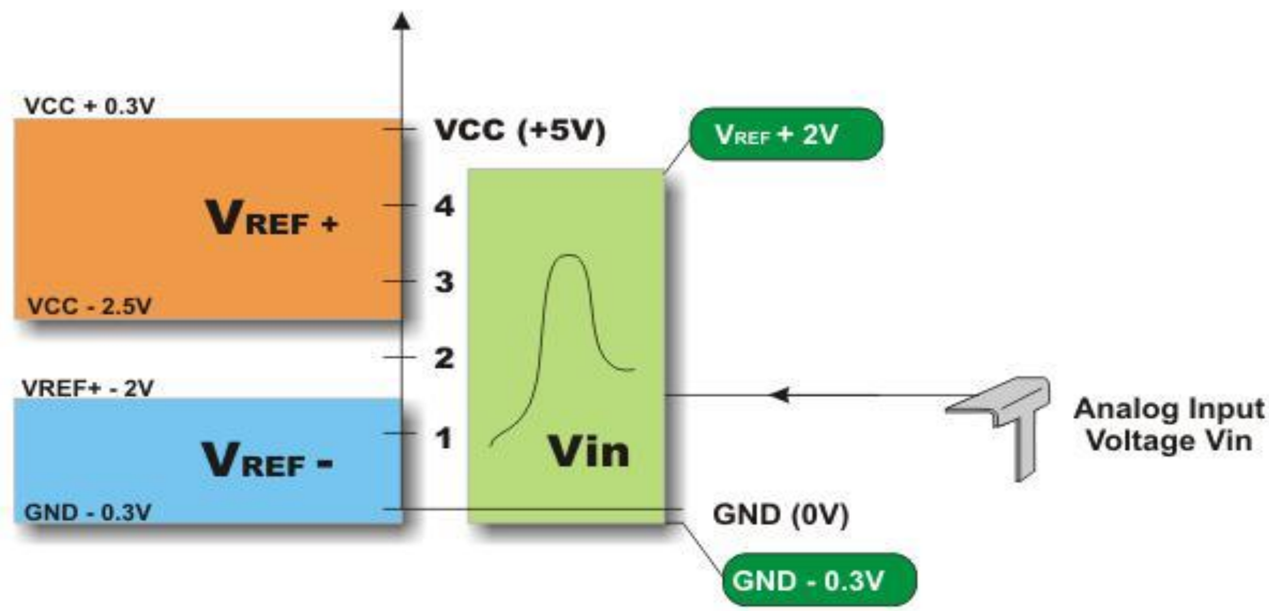
2: ADCON1 REGISTER

R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	ADCS2	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit 7							bit 0

The pins to be used as analog are set by bits PCFG0 - PCFG3 see microcontroller data sheet for details. The ADFM bit sets the output format as already said.

Reference Volts

The ADC of 18F452 has 10 bit resolution. This means it can have a value from 0 to 1023. 0 indicating low-est measurable voltage and 1023 maximum measurable voltage. The output is only a number and has to be converted into actual measure by come calculation. Normally it is assumed that the source voltage which is to be measured will range from 0 to 5V. Thus we can say the lower limit is 0V and highest limit is 5V. These two limits are called reference volts. The low reference is called VREF– and high reference is called VREF+ . Thus in standard practice if nothing is set, the VREF– or lower limit is 0 and VREF+ or upper limit is 5V. This means that the output will be 0 when the pin has 0V and the output will be 1023 (all 10 bits set) when input is 5V.



Therefore a scale of 0-5V has 1023 steps. In other words we say that a value of 1023 indicates 5V and each step indicates 5/1023=0.00488V. This means that ADC will measure in increments of 0.00488V. An output of 0 will indicate 0 input volts and an output of 1 will indicate 0.00488V an output of 2 will indicate 0.00976V and so ON. Until a value of 1023 is reached which would indicate 1023 * 0.00488=4.999 (5V, we truncated the 5/1023 result).

Now consider a device which has a maximum output voltage of 2.5V and minimum 0V. In this case we mean that on reaching 2.5V our output should reach 1023. thus each step in output would indicate a 2.5/1023=0.00244V this gives more precision if we adjust our VREF+ to appropriate level. There are two pins on microcontroller marked as VREF+ and VREF –. The settings on PCFG0- PCFG3 bits determines if VREF to be used or not. If the appropriate bits are set and VREF is selected, then an external source of pre-cise volts must be applied to the VREF+ and VREF– pins these volts will then determine the resolution and step of volts measured and the output in ADRES registers.

LM-35 Temperature Sensor

LM-35 is a precision temperature sensor. This is a small 3 pin IC, in TO-92 package. Remember this is an IC. Its center pin is output and other two are power. PIC -Lab-II comes with LM-35 sensor along with connector cable for easy integration. The LM-35 measures temperature in centigrade. Output of LM35 is analog, uniformly linear over the entire range. It rises by 10.0mV / centigrade. This IC does not require external cali-bration or trimming. Various variants of this commonly used sensor IC are available, which differ in the range of measured temperature.

```
' LM35
temperature
Device = 18F452
XTAL=20
LCD_DTPIN
PORTD.4
LCD_RSPIN
PORTD.3
LCD_ENPIN
PORTD.2
ADIN_RES     10                       ' Set the resolution to 10
ADIN_TAD     FRC                      ' Choose the RC osc for ADC samples
ADIN_STIME   100                      ' Allow 100us for charge time
ADCON1 = %10000010                    ' Set PORTA analog and right justify result
Input PORTA.0
Dim raw As Word
Dim v As Float
Print Cls
Loop:
raw=ADIn 0
Print At 1,1,"Raw:", DEC4 raw
v=(5/1023)* raw
v=v*1000
Print At 2,1, DEC1 v ,"mv"
v=v/10                                '1 degree centigrade for every 10mV
Print At 2,9,"Tem:", Dec v ,"C"
DelayMS 2000

GoTo Loop
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