OVERVIEW

Since most detectors are analog type, an analog to digital converter (ADC) is needed to measure its data by the digital device. ADC discussed in this application note is designed to measure slowly changing voltage in the range from 1.4 to 2.55 Volts with 0.01 Volts accuracy (if table is changed, other ADC ranges are possible using the PIC12C508) and outputs data through it's four digital outputs. Input is used to activate ADC measure (active low) and can be activated through a button, or a switch, or may be used as a digital line in terminal. With a few components added it could measure voltage, temperature, volume or any other condition with a proper analog detector. With a simple amplifier added ADC may be used as a peak meter in a sound system. And, of course, ADC may be used as a digital comparator to keep some parameters in certain limits through ADC's digital outputs.

FIGURE 3: SCHEMATIC DIAGRAM
THE ADC PARTS LIST

Capacitors:  
- C1 - 0.1µF  
- C2 - 47µF electrolytic

Diodes:  
- D1 – D4 – Any type red light emitting diodes  
- D5 – Zener diode 4.7 Volts (1N4734A) It is needed to measure voltages higher than 5.0 Volts. If the voltage will not exceed 5.0 Volts it is better to remove this diode.

Resistors:  
- R1 – 1.0 MOhm  
- R2 – 1.0 MOhm variable (adjustment)  
- R3 – 30 kOhm variable (fine adjustment)

Miscellaneous:  
- U1 – PIC12C508 programmed with ADC code  
- S1 – Normally open push-button switches

Measuring mechanism is shown in Figure 2.

FIGURE 4: MEASURING MECHANISM

First, the PIC12C508 pin connected to Line In is set to be output and is driven low to discharge the capacitor. Then this pin becomes input and the counter starts. The counter increases while the Line In pin is low. The pin changes its state from low to high when the pin voltage is about 1.25 Volts (this voltage strongly depends on the PICmicro™ supply voltage (5 volts), the leakage current and the chip itself. When the pin is raised high, the counter stops. I assume that the capacitor discharge voltage difference is almost zero (if not then the pin state change may be assumed slightly smaller). Since there wouldn’t be two identical PICmicros, I use the voltage of 1.25 volts as average with minimal voltage of about 1.15 volts and the maximum of 1.35 volts. The variable resistor is used to adjust the timing for voltage pin state change and the capacitor difference.

The formula I used to calculate the time when the state of the pin changes is:

\[ U = E(1 - e^{-t/T}) \]

Where:

\[ U = \text{The voltage when the pin changes its state} \]
\[ E = \text{Input voltage (1.4 to 2.55 volts)} \]
\[ t = \text{Time (t<T)} \]

\[ T = RC \]

\[ U/E = 1 - e^{-t/T} \]

\[ e^{t/T} = 1 - U/E \]

\[ \ln e^{t/T} = \ln (1 - U/E) \]

\[ t = -T \ln (1 - U/E) \]

\[ t = -RC \ln (U/E) \]
I used this formula to build a table. But first I have to calculate the resistance for a particular capacitor for the highest counter (lowest voltage equals 1.395 Volts in my case). This is needed to fully utilize the table format.

\[ R = \frac{-t}{(C \ln(1 - U/E))} = 1.477 \text{ Mohms} \]

(with a capacitor of 0.1 \( \mu \)F)

where

\[ t = MHC (5 \text{ MLC}+2) \text{ uS} \]

\[ MHC = \text{measure high counter byte} \]
\[ MLC = \text{measure low counter byte} \]

When the circuit is ready, connect GP3 to ground and turn ADC on. Supply Line In terminal with 2.00 Volts and adjust the circuit until D3 lights up (Be patient while doing this!). LEDs will light up on the following voltage:

- D1 = 1.39 Volts or less
- D2 = 1.50 Volts
- D3 = 2.00 Volts
- D4 = 2.56 Volts or higher

**QUICK CODE IDEAS**

I wrote the measuring algorithm as a macro because there can be more than one analog input in microcontroller. Another macro to compare two 16-bit values. With some improvement, these values may be 24 or 32 bits wide. Depending on the results, it branches to three different places.

**MICROCHIP TOOLS USED**

This code was written and debugged with MPLAB for Windows/16 Version 3.22.02

Assembler/Compiler version: MPASM v01.50 using P12C508.inc
APPENDIX B: SOURCE CODE

;ADC
;Author: Kirill Yelizarov

LIST P=PIC12C508, R=DEC
INCLUDE <p12c508.inc>

__CONFIG _IntRCOSC & _WDT_OFF & _CP_OFF & _MCLRE_OFF

V_Low equ 0 ;Low voltage indicator
V_1_5 equ 1 ;1.5 Volts indicator
V_2_0 equ 2 ;2.0 Volts indicator
Button equ 3 ;Enable measure button
V_High equ 4 ;High voltage indicator
LineIn equ 5 ;ADC line in GPIO pin

TrisReg equ 0x07 ;Tris register
MLC equ 0x08 ;Measure low time
MHC equ 0x09 ;Measure high time
TLC equ 0x0a ;Table low time
THC equ 0x0b ;Table high time
Voltage equ 0x0c ;Voltage on line in
Value equ 0x0d ;Multipurpose register

;------------------------- MAC R O -------------------------

; This macro will perform a measuring method described in the document
Measure macro reg,pin,trisr,dh,dl
; reg - register (GPIO for 12C508)
; pin - microcontroller's pin assigned for line in
; trisr - Tris register local data
; dh - counter high byte
; dl - counter low byte

local next
local nextm
local out

bcf trisr,pin ;set line in for output
movf trisr,W
tris reg

bcf reg,pin ;set line in pin low
clrdf dh ;wait 1 ms

next:
	nop
decfsz dh,F
goto next

crclf dh ;Reset counter
crclf dl

bsf trisr,pin ;set line in for input
movf trisr,W
tris reg

nextm:

btfsc reg,pin ;time=MHC(5MLC+2) us
goto out
infsz dl,F
goto nextm
infsz dh,F
goto nextm
comf dh,F ;An overflow occurs
; This macro can compare two 16 bit digits and it do not change them
; Uses W register and flags
; If dh(high),dl(low) is smaller than th(high),tl(low) it branches to slab
; If dh,dl is larger than th,tl it branches to llab
; If dh,dl is equal to th,tl it goes to the end of macro
Compare macro th,tl,dh,dl,slab,llab

movf th,W
subwf dh,W
btfss STATUS,C
  goto slab ; if result is negative then go to SMALLER label
btfss STATUS,Z
  goto llab ; if not zero then go to LARGER label
movf tl,W
subwf dl,W
btfss STATUS,C
  goto slab ; if result is negative then go to SMALLER label
btfss STATUS,Z
  goto llab ; if not zero then go to LARGER label
endm

; ------------------------- C O D E -------------------------

org 0x00

VoltageTable

movwf PCL
Voltage too low
retlw 255
retlw 136
; 1.40
retlw 248
retlw 207
; 1.41
retlw 242
retlw 142
; 1.42
retlw 236
retlw 181
; 1.43
retlw 231
retlw 57
; 1.44
retlw 226
retlw 17
; 1.45
retlw 221
retlw 51
; 1.46
retlw 216
retlw 153
; 1.47
retlw 212
retlw 59
; 1.48
retlw 208
retlw 22
; 1.49
retlw 204
retlw 36
;1.50           retlw 200
               retlw 97
;1.51           retlw 196
               retlw 201
;1.52           retlw 193
               retlw 88
;1.53           retlw 190
               retlw 13
;1.54           retlw 186
               retlw 229
;1.55           retlw 183
               retlw 220
;1.56           retlw 180
               retlw 241
;1.57           retlw 178
               retlw 33
;1.58           retlw 175
               retlw 109
;1.59           retlw 172
               retlw 209
;1.60           retlw 170
               retlw 76
;1.61           retlw 167
               retlw 221
;1.62           retlw 165
               retlw 130
;1.63           retlw 163
               retlw 59
;1.64           retlw 161
               retlw 6
;1.65           retlw 158
               retlw 227
;1.66           retlw 156
               retlw 208
;1.67           retlw 154
               retlw 205
;1.68           retlw 152
               retlw 217
;1.69           retlw 150
               retlw 243
;1.70           retlw 149
               retlw 27
;1.71           retlw 147
               retlw 80
<table>
<thead>
<tr>
<th>Line</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 1.72 | retlw 145  
     | retlw 145 |
| 1.73 | retlw 143  
     | retlw 222 |
| 1.74 | retlw 142  
     | retlw 54  |
| 1.75 | retlw 140  
     | retlw 154 |
| 1.76 | retlw 139  
     | retlw 7   |
| 1.77 | retlw 137  
     | retlw 127 |
| 1.78 | retlw 135  
     | retlw 255 |
| 1.79 | retlw 134  
     | retlw 138 |
| 1.80 | retlw 133  
     | retlw 29  |
| 1.81 | retlw 131  
     | retlw 185 |
| 1.82 | retlw 130  
     | retlw 93  |
| 1.83 | retlw 129  
     | retlw 8   |
| 1.84 | retlw 127  
     | retlw 188 |
| 1.85 | retlw 126  
     | retlw 118 |
| 1.86 | retlw 125  
     | retlw 56  |
| 1.87 | retlw 124  
     | retlw 0   |
| 1.88 | retlw 122  
     | retlw 208 |
| 1.89 | retlw 121  
     | retlw 165 |
| 1.90 | retlw 120  
     | retlw 128 |
| 1.91 | retlw 119  
     | retlw 98  |
| 1.92 | retlw 118  
     | retlw 73  |
| 1.93 | retlw 117  
     | retlw 54  |
; 1.94
retlw 116
retlw 40
; 1.95
retlw 115
retlw 31
; 1.96
retlw 114
retlw 28
; 1.97
retlw 113
retlw 29
; 1.98
retlw 112
retlw 35
; 1.99
retlw 111
retlw 46
; 2.00
retlw 110
retlw 61
; 2.01
retlw 109
retlw 81
; 2.02
retlw 108
retlw 105
; 2.03
retlw 107
retlw 132
; 2.04
retlw 106
retlw 164
; 2.05
retlw 105
retlw 200
; 2.06
retlw 104
retlw 240
; 2.07
retlw 104
retlw 27
; 2.08
retlw 103
retlw 74
; 2.09
retlw 102
retlw 124
; 2.10
retlw 101
retlw 178
; 2.11
retlw 100
retlw 235
; 2.12
retlw 100
retlw 39
; 2.13
retlw 99
retlw 99
; 2.14
retlw 98
retlw 168
; 2.15
retlw 97
retlw 238
; 2.16
  retlw 97
  retlw 54
; 2.17
  retlw 96
  retlw 129
; 2.18
  retlw 95
  retlw 207
; 2.19
  retlw 95
  retlw 31
; 2.20
  retlw 94
  retlw 115
; 2.21
  retlw 93
  retlw 200
; 2.22
  retlw 93
  retlw 32
; 2.23
  retlw 92
  retlw 123
; 2.24
  retlw 91
  retlw 217
; 2.25
  retlw 91
  retlw 56
; 2.26
  retlw 90
  retlw 154
; 2.27
  retlw 89
  retlw 254
; 2.28
  retlw 89
  retlw 100
; 2.29
  retlw 88
  retlw 204
; 2.30
  retlw 88
  retlw 55
; 2.31
  retlw 87
  retlw 163
; 2.32
  retlw 87
  retlw 17
; 2.33
  retlw 86
  retlw 130
; 2.34
  retlw 85
  retlw 245
; 2.35
  retlw 85
  retlw 105
; 2.36
  retlw 84
  retlw 223
; 2.37
  retlw 84
  retlw 87
;2.38    retlw  83
         retlw  209
;2.39    retlw  83
         retlw  76
;2.40    retlw  82
         retlw  201
;2.41    retlw  82
         retlw  72
;2.42    retlw  81
         retlw  200
;2.43    retlw  81
         retlw  74
;2.44    retlw  80
         retlw  206
;2.45    retlw  80
         retlw  83
;2.46    retlw  79
         retlw  218
;2.47    retlw  79
         retlw  98
;2.48    retlw  78
         retlw  236
;2.49    retlw  78
         retlw  119
;2.50    retlw  78
         retlw  3
;2.51    retlw  77
         retlw  145
;2.52    retlw  77
         retlw  32
;2.53    retlw  76
         retlw  176
;2.54    retlw  76
         retlw  66
;2.55    retlw  75
         retlw  213
;Voltage too high

Start:
   IF     Start>0x100
   ERROR  "ADC Message: Voltage Table too large."
   ENDIF
   clrf    GPIO
   comf    GPIO,F        ;Turn OFF all LEDs
   movlw    b'10000000'   ;Enable weak pull-up on Button pin
   option
clrf TrisReg
bsf TrisReg,LineIn ;Set LineIn as analog input
bsf TrisReg,Button ;Set Button as digital input
tris GPIO

NextMeasure:
    btfs R GPIO,Button
go to NextMeasure
movlw 0xE0
movwf MHC
clrf MLC
Wait:
    incfsz MLC,F
    goto Wait
    incfsz MHC,F
    goto Wait
    btfs R GPIO,Button
    goto NextMeasure
Measure GPIO,LineIn,TrisReg,MHC,MLC
    movlw low VoltageTable
    movwf Value
    movlw 138
    movwf Voltage ;First test will be done to 1.39 Volts
NextVoltage:
    incf Voltage,F
    btfs STATUS,Z
    goto Overflow
    incf Value,F
    movf Value,W
    call VoltageTable ;get time high count
    movwf THC ;save time high count
    incf Value,F
    movf Value,W
    call VoltageTable ;get time low count
    movwf TLC ;save time low count
    Compare THC,TLC,MHC,MLC,NextVoltage,SendMessage ;Compare two words
SendMessage:
    movlw b'00010111'
    movwf GPIO ;Turn LEDs off
    movlw 139 ;test low voltage
    subwf Voltage,W
    btfs STATUS,Z
    bcf GPIO,V_Low
    movlw 150 ;test 1.5 Volts
    subwf Voltage,W
    btfs STATUS,Z
    bcf GPIO,V_1_5
    movlw 200 ;test 2.0 Volts
    subwf Voltage,W
    btfs STATUS,Z
    bcf GPIO,V_2_0
    goto NextMeasure
Overflow:
    movlw b'00010111'
    movwf GPIO ;Turn LEDs off
    bcf GPIO,V_High
    goto NextMeasure

org 0x1ff
    movlw b'01110000' ;set OSCCAL
end