Analog Input Through One Digital Pin

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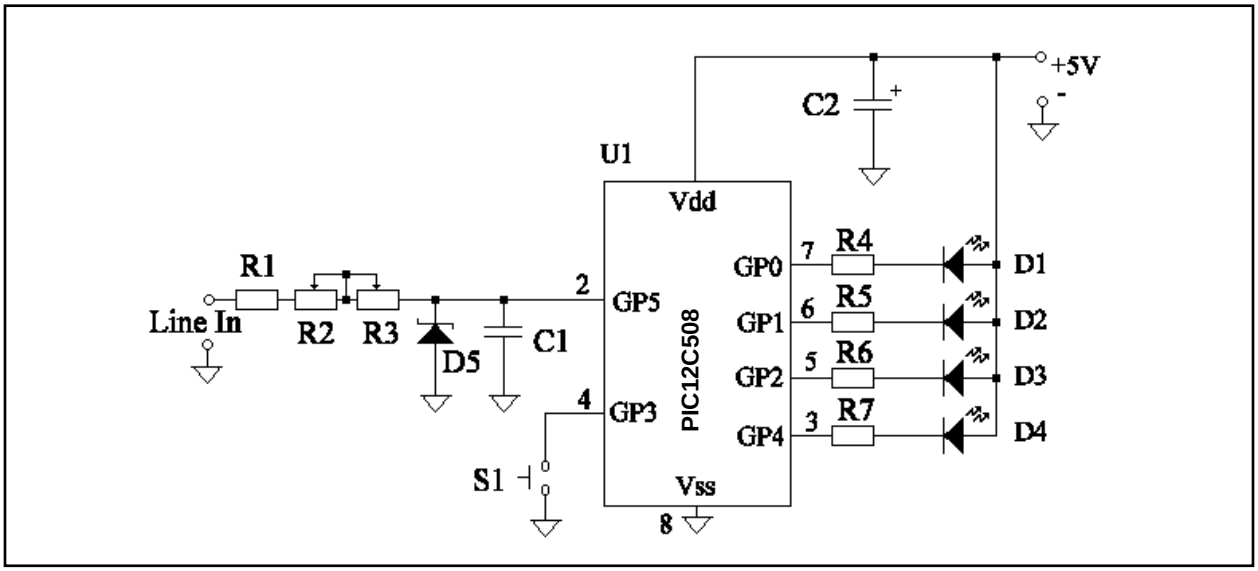
OVERVIEW

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

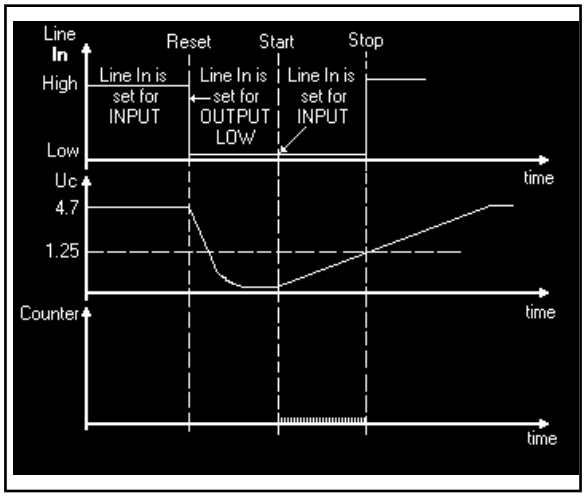


THE ADC PARTS LIST

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 it's 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	=	The voltage when the pin changes its state
E	=	Input voltage (1.4 to 2.55 volts)
t	=	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.

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

(with a capacitor of 0.1 µF

where

t = MHC (5 MLC+2) uS

MHC = measure high counter byte

MLC = 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 _IntRC_OSC & _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        ;Multiporpose register

;                       ------------ M A C 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

                        clrf        dh          ;wait 1 ms
next:
                        nop
                        decfsz      dh,F
                        goto        next

                        clrf        dh          ;Reset counter
                        clrf        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
                        incfsz      dl,F
                        goto        nextm
                        incfsz      dh,F
                        goto        nextm
                        comf        dh,F        ;An overflow occures
```

```
                    comf        dl,F        ;Voltage is too low if got here
out:
                    endm

;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
                                            ;if got here they are equal
                    endm

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

             org           0x00
             goto          Start

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
```

```
;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       102
;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:
            btfsc       GPIO,Button
            goto        NextMeasure
            movlw       0xE0
            movwf       MHC
            clrf        MLC
Wait:
            incfsz      MLC,F
            goto        Wait
            incfsz      MHC,F
            goto        Wait
            btfsc       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
            btfsc       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
            btfsc       STATUS,Z
            bcf         GPIO,V_Low
            movlw       150             ;test 1.5 Volts
            subwf       Voltage,W
            btfsc       STATUS,Z
            bcf         GPIO,V_1_5
            movlw       200             ;test 2.0 Volts
            subwf       Voltage,W
            btfsc       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
```

NOTES: