

A Comparator Based Slope ADC

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INTRODUCTION

Comparators are used for many things, but many people want to build analog-to-digital converters using a comparator. Comparators are one basic building block of all ADC architectures. A PICmicro[®] microcontroller with internal comparators can become an ADC with the application of some software and a minimum of external hardware. In this application note you will be shown how to build a Slope ADC. This ADC has been used with the digital pins on PICmicro microcontrollers for many years. The addition of a comparator to the circuit improves the results and reduces the power consumption.

A characteristic to measure with a Slope ADC is resistance. By using a thermistor, temperature can be directly converted to a resistance. Measuring a thermistor is a good way to demonstrate the functions of a Slope ADC. Temperature measurement, or control, is one of the more common applications of microprocessor systems. One of the first signs of an illness in a person is a fever. Overheating fuels cause disasters. Food that has not been stored at the proper temperature spoils. Nearly every system or process requires an accurate understanding of the temperature. This application note describes another way to measure the temperature, and a way to build an analog-to-digital converter.

An example of some of the PICmicro microcontrollers that have comparators are:

- PIC12F629
- PIC12F675
- PIC16C620
- PIC16C621
- PIC16C22
- PIC16CE623

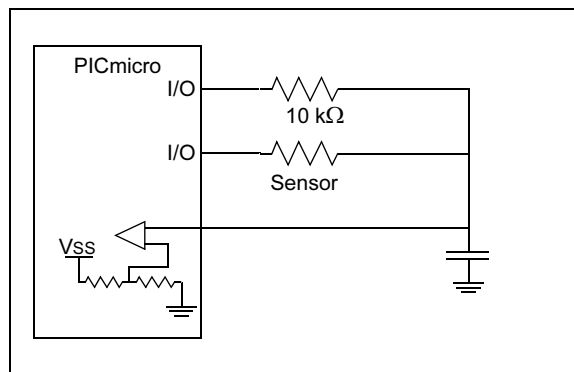
Thermistors

Thermistors are devices that change in resistance with changes in temperature. Thermistors are more properly called RTDs (Resistive Temperature Detectors). An RTD can be made from a variety of substances depending on the desired operation temperature range, the desired operation environment, the required accuracy and the cost. Platinum RTDs can achieve an accuracy of much less than 1°C. Other low cost RTDs achieve an accuracy of just a few degrees.

Slope ADC

Analog-to-digital converters can be created in a variety of ways. For this application note, we will build a slope converter. The slope converter works by timing the rate that a capacitor charges to a specified voltage. This is done twice, once with a reference source and once with a sensor. By performing the operation twice, variations in capacitor values or timing accuracy can be minimized. The reference source for this application note was simply a 10 kΩ resistor. The sensor was a 10 kΩ thermistor. See Figure 1.

FIGURE 1: SENSOR SCHEMATIC



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To make a measurement, the following steps are taken:

1. Activate the comparator & voltage reference.
2. Clear the timer.
3. Activate the thermistor.
4. Wait for the comparator to trip.
5. Multiply the timer value by the value of the reference resistor.
6. Discharge the timing capacitor.
7. Clear the timer.
8. Activate the reference.
9. Wait for the comparator to trip.
10. Divide the result of step 5 by the new timer value.
11. Shutdown the comparator and voltage reference.
12. Return with the result of step 10 stored as the thermistor resistance.

Scaling the Data

One advantage of using RTD is that the response is nearly linear. Most RTDs are specified with an R_{25}/R_{50} value. This is the ratio of the 25°C , with the 25°C value. The ratio is a linear relationship that can be coded to convert the ADC values to temperature. The Multiple and Divide code is located in Appendix C.

Using the Data

How an application will use the data from a sensor will depend on the function. For this application note, the data is simply displayed on a 3-digit, 7-segment LED display. The segments are driven by PORTB on an 18-pin PICMicro microcontroller. The digits are selected by a second 8-pin PICmicro microcontroller (See Figure 2). The digit selection was performed by the second PICmicro microcontroller to demonstrate a simple I/O expander.

The software for the PIC12F629 is located in Appendix B. The master sends the pulse train to select the correct digit while driving the segment lines. See Figure 4 for a scope capture of the pulse train.

FIGURE 2: DISPLAY SCHEMATIC

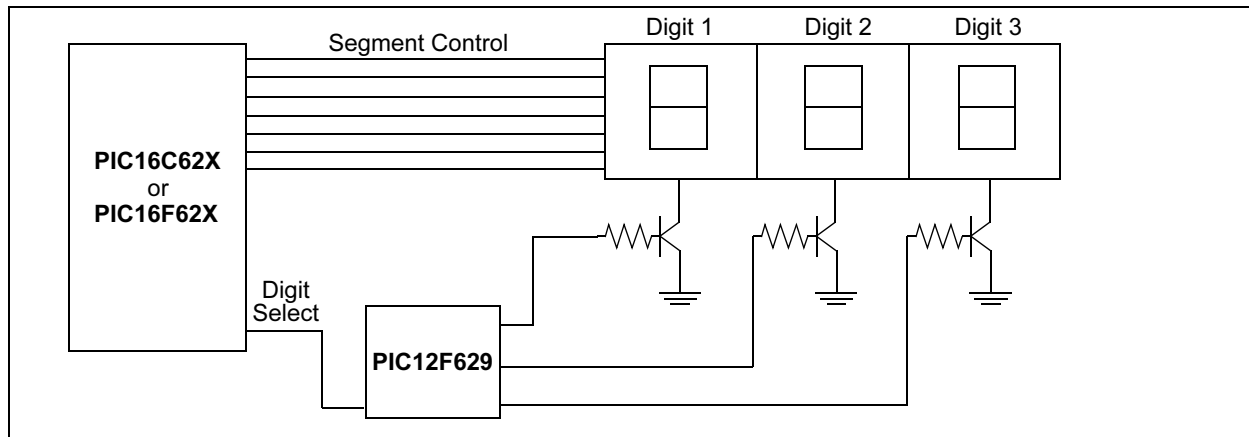


FIGURE 3: CAPACITOR CHARGE GRAPH

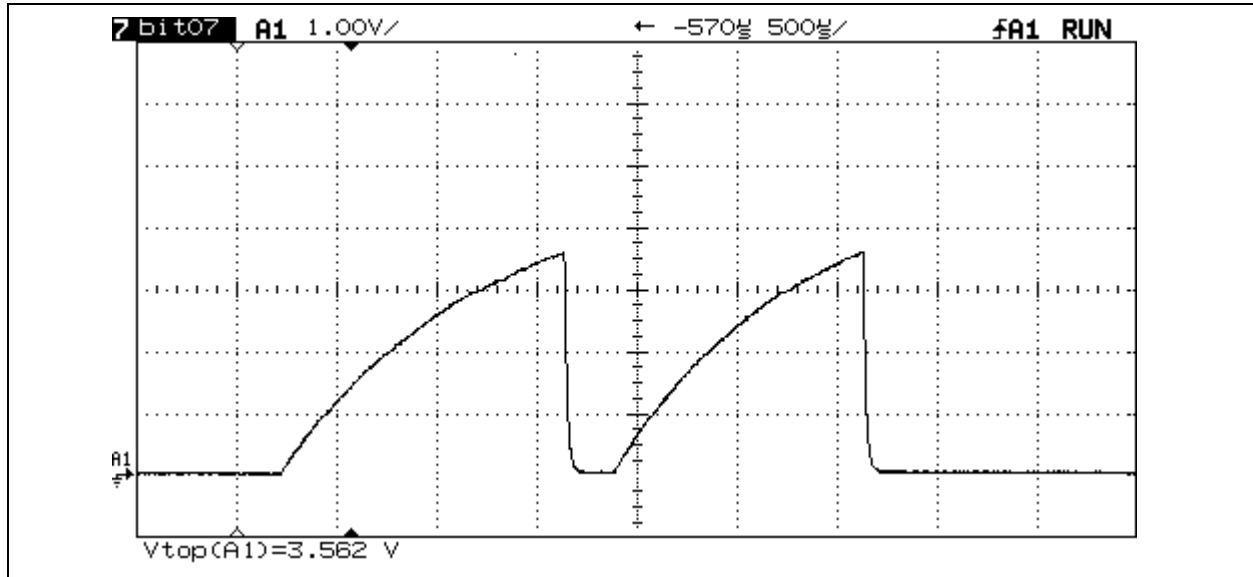
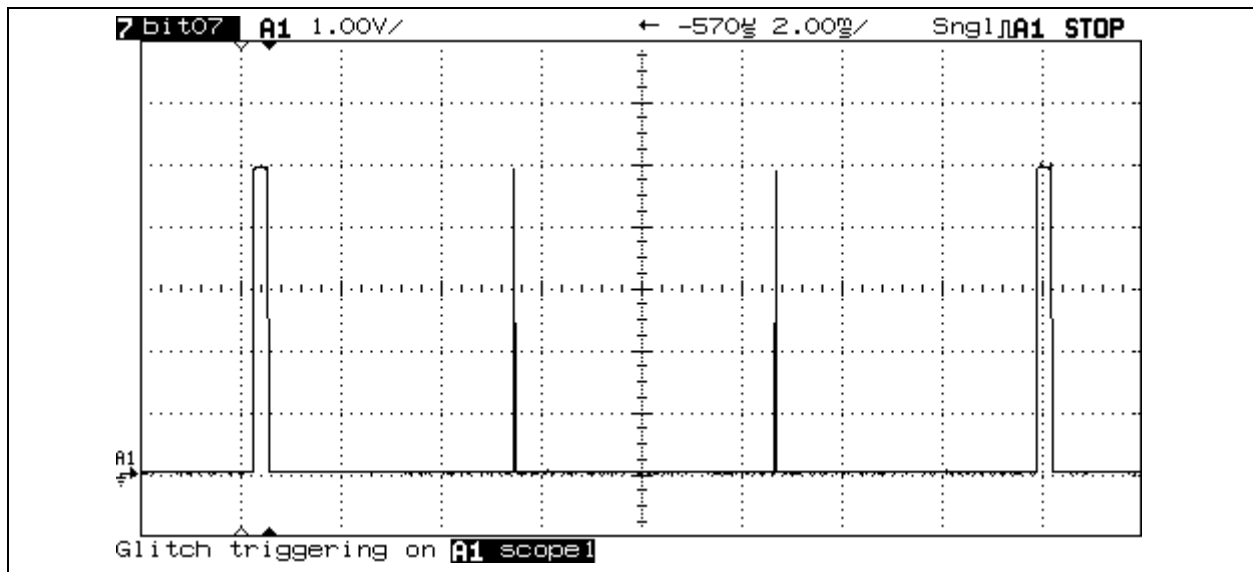


FIGURE 4: DIGIT SELECT SIGNAL TO PIC12F629



Conclusion

Using a comparator to read analog's voltage is a straight-forward process combining a small amount of discrete circuitry with a small piece of firmware. Other ADCs can also be built in this manner. See AN700 for directions on how to build a delta sigma ADC using comparators and a few inexpensive discrete components.

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APPENDIX A: SLOPE CODE

```

;*****
; Perform Slope Conversion
; Uses a0,a1,b0,b1
; result is the unknown resistance in Ohms stored at c0,c1,c2,c3
;*****
reference_value      equ          .10000 ; reference resistance
Measure_Resistance

        banksel TRISA
        movlw    0x27          ;          76543210
        movwf   TRISA        ; PortA is OOIOOIII
        banksel PORTA
        movf    CMCON,W

        bsf     PORTA,3      ; start current through the reference
        call    TOTiming

        movwf   a0
        movf    TO_HIGH,W
        movwf   a1          ; store timer value

        clrf   PORTA

; clearing the Capacitor
        banksel TRISA
        movlw    0x2D          ;          76543210
        movwf   TRISA        ; PortA is OOIOIIOI

        banksel b0
        movlw    high reference_value
        movwf   b1
        movlw    low reference_value
        movwf   b0

        call    multiply

        banksel TRISA
        movlw    0x2E          ;          76543210
        movwf   TRISA        ; PortA is OOIOIIIO
        banksel CMCON
        movf    CMCON,W

        bsf     PORTA,0      ; start current through the sensor
        call    TOTiming

        movwf   a0
        movf    TO_HIGH,W
        movwf   a1
        clrf   PORTA

```

```
banksel    TRISA
movlw     0x2D          ;          76543210
movwf     TRISA        ; PortA is 00101101
banksel    PORTA

call      divide

return
```

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APPENDIX B: DIGIT MULTIPLEXING CODE

```
main
    call        0x3FF                ; retrieve factory calibration value
    bsf        STATUS,RP0            ; set file register bank to 1
    movwf     OSCCAL                 ; update register with factory cal value
    bcf        STATUS,RP0            ; set file register bank to 0

    ; time the input
    movlw     reset_time

time_loop
    addlw     0xFF
    btfss     STATUS,Z                ; countdown the reset time
    goto      time_loop

    btfsc     GPIO,3
    goto      reset_return

    incf     state,w
    andlw     0x03
    addwf     PCL,F
    goto     state0
    goto     state1
    goto     state2
    goto     state3

state0
state1
    movlw    .1
    movwf   state
    movlw   .4
    goto    update

state2
    movlw   .2
    movwf   state
    movlw   .2
    goto    update

state3
    movlw   .3
    movwf   state
    movlw   .1

update
    movwf   GPIO
    goto    normal_return
```

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APPENDIX C: MULTIPLE AND DIVIDE ROUTINES

```

;*****
; Unsigned Divide Routine 32/16=32
; c3:c2:c1:c0 / a1:a0 = c3:c2c1:c0
;*****

divide
    ; Test for zero division
    movf    a0,W
    iorwf   a1,W
    btfsc   STATUS,Z
    retlw   0x00

    ; prepare used variables
    clrf    tmp
    clrf    tmp1

    clrf    tmp2

    movlw   D'32'           ; initialize bit counter
    movwf   bcnt

DIVIDE_LOOP_32by16
    rlf     c0,F
    rlf     c1,F
    rlf     c2,F
    rlf     c3,F
    ; shift in highest bit from dividend through carry in temp
    rlf     tmp1,F
    rlf     tmp,F

    rlf     tmp2,F

    movf    a0,W           ; get LSB of divisor
    btfsc   tmp2,7
    goto    Div32by16_add

    ; subtract 16 bit divisor from 16 bit temp
    subwf   tmp1,F        ; subtract

    movf    a1,W           ; get top byte
    btfss   STATUS,C      ; if overflow ( from prev. subtraction )
    incfsz  a1,W          ; increase source
    subwf   tmp,F        ; and subtract from dest.

    movlw   1
    btfss   STATUS,C
    subwf   tmp2,F
    goto    DIVIDE_SKIP_32by16 ; carry was set, subtraction ok, continue with next bit

```

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```
Div32by16_add
    addwf    tmp1,F          ; result of subtraction was negative restore temp
                                ; add it to the lsb of temp

    movf    a1,W            ; MSB byte
    btfsc   STATUS,C        ; check carry for overflow from previous addition
    incfsz  a1,W
    addwf   tmp,F           ; handle overflow

    movlw   1
    btfsc   STATUS,C
    addwf   tmp2,F
```

```
DIVIDE_SKIP_32by16
    decfsz  bcnt,F          ; decrement loop counter
    goto    DIVIDE_LOOP_32by16 ; another run
    ; finally shift in the last carry
    rlf    c0,F
    rlf    c1,F
    rlf    c2,F
    rlf    c3,F
    retlw  0x01            ; done
```

```
*****
; Unsigned Multiply 16x16
; a1:a0 * b1:b0 = c3:c2:c1:c0
;*****
```

```
multiply
    clrf    c3
    clrf    c2
    clrf    c1
    clrf    c0
    bsf    c1, 7

multiply_lp1
    rrf    a1, f
    rrf    a0, f
    btfss  STATUS,C
    goto   multiply_lp2
    movf   b0, w
    addwf  c2, f
    movf   b1, w
    btfsc  STATUS,C
    incfsz b1, w
    addwf  c3, f

multiply_lp2
    rrf    c3, f
    rrf    c2, f
    rrf    c1, f
    rrf    c0, f
    btfss  STATUS,C
    goto   multiply_lp1
    return
```

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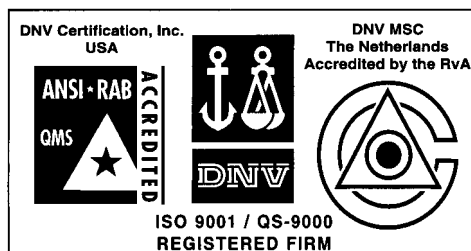
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