

## Intelligent Remote Positioner (Motor Control)

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### INTRODUCTION

The excellent cost/performance ratio of the PIC16C5X makes it well suited as a low-cost proportional D.C. actuator controller. This application note depicts a design for a remote intelligent positioning system using a D.C. motor (up to 1/3 hp) run from 12V to 24V. The position accuracy is one in eight bits or 0.4%. The PIC16C5X receives its command and control information via a Microwire<sup>®</sup> serial bus. However, any serial communication method is applicable.

### IMPLEMENTATION

The PIC16C5X based controller receives movement commands from a host, compares them to the actual position, calculates the desired motor drive level and then pulses a full H-bridge (Figure 2). In this way it serves as a remote intelligent positioner, driving the load until it has reached the commanded position. It can be used to control any proportional D.C. actuator (i.e., D.C. motor or proportional valve).

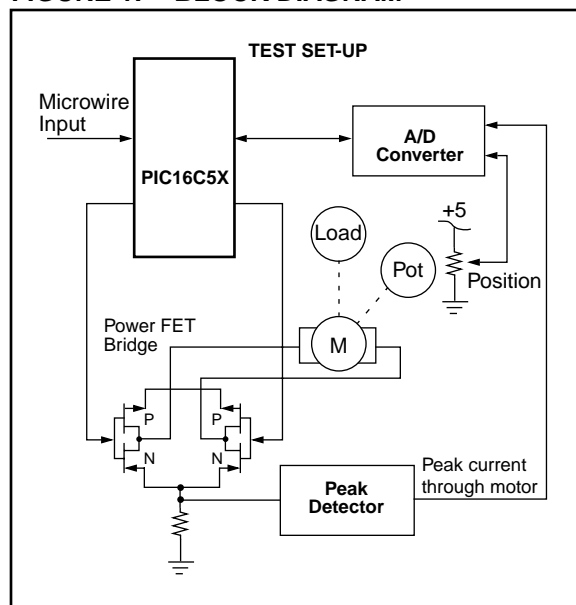
This system is ideally suited for remotely positioned valves and machinery. It can be used with D.C. motors to easily automate manual equipment. Because of the 5-wire serial interface, the positioner can be installed near its power supply and load. The remote intelligent positioner can then be linked to the central control processor by a small diameter easily routed cable. Since the positioner is running its own closed-loop PID algorithm (Figure 3), the host central processor needs only to send position commands and is therefore free to service the user interface, main application software and command multiple remote positioners.

The limit switch inputs provide a safety net which keeps the system from destroying itself in the event that the feedback device is damaged. The optional current sense input can be used to determine if the load has jammed and prevent overheating of the actuator and drive electronics.

The commanded positions are presented to the PIC16C5X via a microwire type protocol at bit-rates of up to 50 Kbs for a 4 MHz part. As currently implemented in this application note, the position request is the only communication. There are several variable locations available which could be used to down-load the loop gain parameters, read positioner information, or set a current limit. The host that is sending the position request must set the chip select low, and wait for the PIC16C5X to raise the "busy" (DO) line high. At this point, eight data bits can be clocked into the PIC16C5X. The requested position is sent most significant bit first and can be any 8-bit value. Values 1 through 255 represent valid positions with 0 being reserved for drive disable.

The PIC16C5X acquires its data by way of a Microwire<sup>®</sup> A/D converter. This part was chosen for low cost while providing adequate performance. In Figure 1 the second channel of the A/D converter is shown connected to a peak current detector. If the user desires, the PIC16C5X could monitor and protect the motor from overcurrent conditions by monitoring the second channel.

**FIGURE 1: BLOCK DIAGRAM**



The H-bridge power amplifier will deliver 10 or more amps at up to 24V when properly heat-sinked. It is wired for a modified 4-quadrant mode of operation. One leg of the bridge is used to control direction and the other leg pulses the low FET and the high FET alternately to generate the desired duty-cycle. In this way the system will operate well to produce a desired "speed" without the use of a separate speed control loop. This allows use of the PIC16C5X to control the PID algorithm for position directly while having reasonable speed control. The capacitance at the gates of the FETs combined with the impedance of the drive circuits provides for turn-off of the upper FET before the lower FET turns on... an important criteria.

The PID algorithm itself is where most of the meat of this application note is located so let's look at it more closely. The algorithm is formed by summing the contribution of three basic components. The first calculation is the error upon which the other terms are based.

The **error** is the requested position minus the actual position. It is a signed number whose magnitude can be 255. In order not to lose resolution, the error is stored as an 8-bit magnitude with the sign stored separately in the FLAGS register under ER\_SGN. This allows us to resolve a full signed 8-bit error with 8-bit math.

The **proportional term** is merely the algebraic difference of the requested position minus the actual position. It is scaled by a gain term ( $K_P$ ) called the "proportional gain". The sign (+,-) of this term is important for it tells the system which direction it must drive to correct the error. The proportional term is limited to  $\pm 100$ . Increasing the proportional gain term will improve the dynamic and static accuracy of the system. Increasing it too much will cause oscillations.

The next term that gets calculated is the **integral term ( $K_I$ )**. This term is traditionally formed by integrating the error over time. In this application it is done by integrating the  $K_I$  term over time. When the error is zero, no integration is performed. This is a more practical way to handle a potentially large number in 8-bit math. By increasing the  $K_I$  term the D.C. or static gain of the system is improved. Increasing the integral gain too much can lead to low frequency oscillations.

The **differential term ( $K_D$ )** is a stabilizing term that helps keep the integral and proportional terms from overdriving the system through the desired position and thus creating oscillations. As you use more proportional and integral gain you will need more differential gain as well. The differential gain is calculated by looking at the rate of change of the positional error with respect to time. It is actually formed as "delta error/delta time" with the delta time being a program cycle.

The three terms (proportional, integral, differential) are summed algebraically and scaled to produce a percentage speed request between 0 and 100%. The sign of the sum is used to control the direction of the H-bridge. The loop calculations run approximately 20 times per second on a 4 MHz part. This yields sufficient gain-bandwidth for most positioning applications. If higher system performance is desired, the number of pulses can be reduced to 20 and a 16 MHz PIC16C5X can be used. Your loop gains ( $K_P$ ,  $K_I$ ,  $K_D$ ) will have to be recalculated, but the system sample rate will be increased to 400 Hz. This should be sufficient to control a system that has a response time of 20 milliseconds or more.

The key to using the PIC16C5X series parts for PID control and PWM generation is to separate the two into separate tasks. There simply is not the hardware support or the processing speed to accurately do both concurrently. It is fortunate therefore that it is not necessary to do both concurrently. Most systems can be stabilized with a much lower information update rate than the PWM frequency. This supports the approach of calculating the desired percentage, outputting the PWM for a period of time and then recalculating the new desired percentage. Using this technique, the inexpensive PIC16C5X can implement PID control, PWM generation, and will still have processing time left over for monitor or communication functions.

## **About the Author:**

Steven Frank has been designing analog and digital control systems for ten years. His background is in medical and consumer electronics. He has received numerous patents in control systems and instrumentation. At Vesta Technology Inc., Mr. Frank works with a number of engineers on custom embedded control systems designs. Vesta Technology Inc. is a provider of embedded control systems from an array of standard products and designs. Vesta offers custom design services and handles projects from concept to manufacturing.

FIGURE 2: PROGRAM FLOWCHART

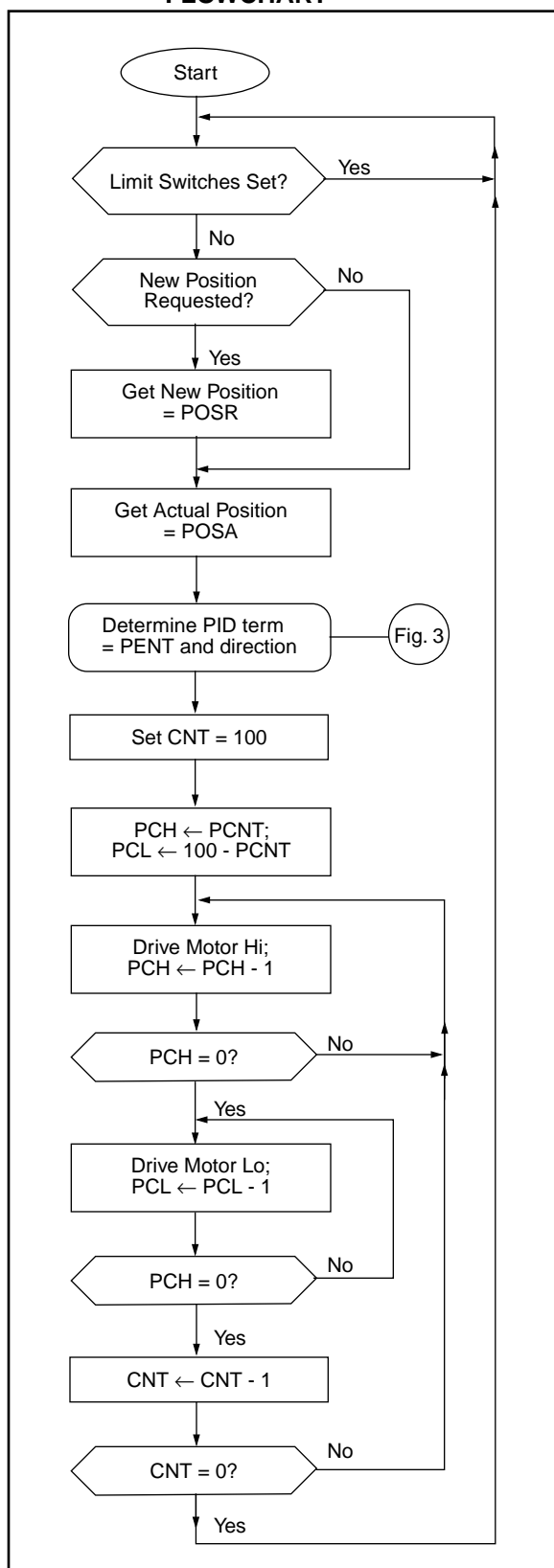
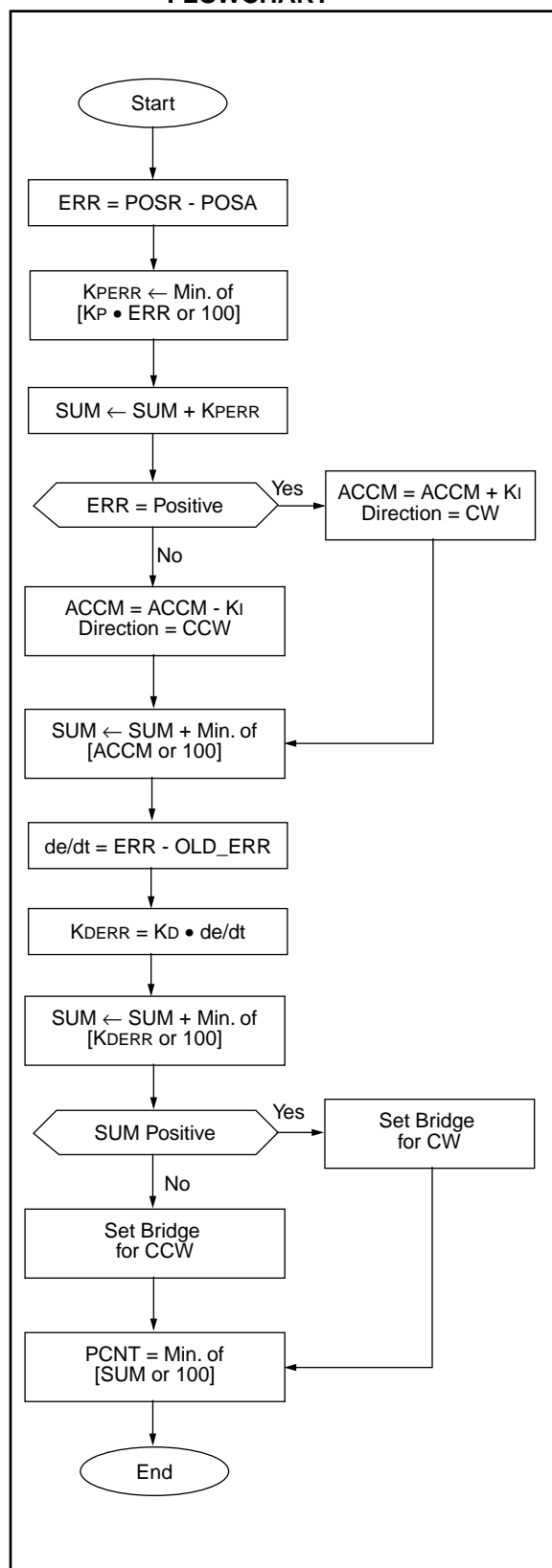


FIGURE 3: PID ALGORITHM FLOWCHART





Please check the Microchip BBS for the latest version of the source code. Microchip's Worldwide Web Address: [www.microchip.com](http://www.microchip.com); Bulletin Board Support: MCHIPBBS using CompuServe® (CompuServe membership not required).

## APPENDIX A: MWPOS.ASM

MPASM 01.40 Released

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LOC  OBJECT CODE      LINE SOURCE TEXT
VALUE

00001      TITLE " MicroWire Positioner "
00002 ;
00003 ;          mw8pos.asm
00004 ;
00005          LIST P=16C56
00006 ;
00007 ;*****
00008 ;
00009 ;          Program:          MWPOS.ASM
00010 ;          Revision Date:    1/10/92 srf    REV. A
00011 ;                               1-13-97      Compatibility with MPASMWIN 1.40
00012 ;
00013 ;*****
00014 ;
00015 ;REGISTER EQUATES
00016 ;
00000000    00017 PNTR      EQU      00H          ; CONTENTS OF POINTER
00000019    00018 FLAGS     EQU      19H          ; USE THIS VARIABLE LOCATION AS FLAGS
00019          ; 0 BIT IS SIGN OF ERROR 1 IS NEGATIVE
00020          ; 1 BIT IS SIGN OF ERROR ACCUMULATOR
00021          ; 2 BIT IS SIGN OF THE DE/DT TERM
00022          ; 3 BIT IS DIRECTION 0 IS CW
00023          ; 4 BIT IS SIGN OF THE OLD ERROR
00000003    00024 STATUS   EQU      03H
00000001    00025 F        EQU      1
00000000    00026 W        EQU      0
00000003    00027 SWR      EQU      03H          ; STATUS WORD REGISTER
00028          ; 0 = CARRY
00029          ; 1 = DC
00030          ; 2 = Z, SET IF RESULT IS ZERO
00000004    00031 FSR      EQU      04H          ; FILE SELECT REGISTER
00000005    00032 PORTA     EQU      05H          ; I/O REG (A0-A3), (A4-A7 DEF=0)
00000006    00033 PORTB     EQU      06H          ; I/O REGISTER(B0-B7)
00000007    00034 HI        EQU      07H          ; NUMBER OF HIGH MICROSECONDS
00000008    00035 LO        EQU      08H          ; NUMBER OF LOW MICROSECONDS
00000009    00036 PCNT      EQU      09H          ; PERCENT DUTYCYCLE REQUEST
0000000A    00037 HI_T      EQU      0AH          ; COUNTER FOR USECONDS LEFT/PULSE HI
0000000B    00038 LO_T      EQU      0BH          ; COUNTER FOR USECONDS LEFT/PULSE LO
0000000C    00039 ERR1      EQU      0CH          ; HOLDER FOR THE POSITIONAL ERROR
00040          ; THIS IS AN 8 BIT MAGNITUDE WITH THE SIGN
00041          ; KEPT IN THE FLAG REGISTER (9BIT SIGNED)
0000000D    00042 SUMLO     EQU      0DH          ; PROGRESSIVE SUM OF THE PID TERMS
0000000E    00043 ACCUM     EQU      0EH          ; ERROR ACCUMULATOR
0000000F    00044 ERR_O     EQU      0FH          ; ERROR HISTORY USED FOR de/dt
00045          ; THIS IS AN 8 BIT MAGNITUDE WITH THE SIGN
00046          ; KEPT IN THE FLAG REGISTER (9BIT SIGNED)
00000010    00047 POSR      EQU      10H          ; POSITIONAL REQUEST
00000011    00048 POSA      EQU      11H          ; ACTUAL POSITION
00000012    00049 CYCLES    EQU      12H          ; COUNTER FOR CYCLES OUT
00050
00000013    00051 mulcnd     equ      13H          ; 8 bit multiplicand
00000013    00052 ACCaLO     EQU      13H          ; same location used for the add routine
00000014    00053 mulplr     equ      14H          ; 8 bit multiplier
00000014    00054 ACCbLO     EQU      14H          ; same location used for the add routine
00000015    00055 H_byte     equ      15H          ; High byte of the 16 bit result
00000015    00056 ACCaHI     EQU      15H          ; same location used for the add routine
00000016    00057 L_byte     equ      16H          ; Low byte of the 16 bit result
00000016    00058 ACCbHI     EQU      16H          ; same location used for the add routine
00000017    00059 count      equ      17H          ; loop counter
00000018    00060 SUMHI      EQU      18H          ; HIGH BYTE OF THE LOOP SUM
00061
00062
00063 ; PORT ASSIGNMENTS AND CONSTANTS
00064
00000000    00065 PWMCW      EQU      0          ; CLOCKWISE PWM OUTPUT BIT
00000001    00066 PWMCCW     EQU      1          ; COUNTERCLOCKWISE PWM OUTPUT BIT
00000000    00067 CARRY      EQU      0          ; CARRY BIT IN THE STATUS REGISTER
00000002    00068 Z          EQU      2          ; THE ZERO BIT OF THE STATUS REGISTER
00000001    00069 Same       equ      1          ;
00000000    00070 ER_SGN     EQU      0          ; SIGN BIT FOR THE ERROR IN FLAG REGISTER

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00000001    00071 AC_SGN EQU    1           ; SIGN BIT FOR THE ERROR ACCUMULATOR
00000002    00072 DE_SGN EQU    2           ; SIGN BIT FOR DE/DT
00000004    00073 OER_SGN EQU    4           ; SIGN BIT FOR THE OLD ERROR
00000030    00074 KP EQU    30           ; PROPORTIONAL GAIN
00000002    00075 KI EQU    2           ; INTEGRAL GAIN
00000020    00076 KD EQU    20           ; DIFFERENTIAL GAIN
00000003    00077 DIR EQU    3           ; THE DIRECTION FLAG
00000007    00078 CSN EQU    7           ; CHIP SELECT NOT ON A/D
00000006    00079 BV EQU    6           ; DATA LINE FOR THE A/D
00000005    00080 CK EQU    5           ; CLOCK LINE FOR THE A/D
00000002    00081 MWDO EQU    2           ; MICROWIRE DATA OUT FROM POSITIONER
00000001    00082 MWDI EQU    1           ; MICROWIRE DATA IN TO POSITIONER
00000000    00083 MWCS EQU    0           ; MICROWIRE CHIP SELECT TO POSITIONER
00000003    00084 MWCK EQU    3           ; MICROWIRE CLOCK IN TO POSITIONER
00085
00086
00087 ;**** MACROS *****
00088 ;
00089 CLKUP MACRO                ; clock up macro for the microwire
00090     BSF    PORTB,CK          ; data acquisition from the a/d
00091     NOP
00092     ENDM
00093
00094 CLKDN MACRO                ; clock down macro for the microwire
00095     BCF    PORTB,CK          ; data acquisition from the a/d
00096     NOP
00097     ENDM
00098
00099 GET_BIT MACRO                ; ** FOR RECEIVING A/D DATA **
00100     BCF    SWR,CARRY
00101     BSF    PORTB,CK          ; SET CLOCK BIT HIGH
00102     BTFSC   PORTB,BV          ; LOOK AT DATA COMING IN
00103     BSF    SWR,CARRY          ; SET THE CARRY FOR A 1
00104     RLF    POSA, F           ; ROTATE THE W REG LEFT
00105     BCF    PORTB,CK          ; SET THE CLOCK LOW
00106     NOP                      ; DELAY
00107     ENDM
00108
0000 0B88    00109 GOTO    CLRREG
00110
00111 ;**** MATH ROUTINES *****
00112 ;
00113
00114 ; **** 8 BIT MULTIPLY *****
00115 ; ***** Begin Multiplier Routine
0001 0075    00116 mpy_S  clrf    H_byte
0002 0076    00117         clrf    L_byte
0003 0C08    00118         movlw   8
0004 0037    00119         movwf   count
0005 0213    00120         movf    mulend,W
0006 0403    00121         bcf     STATUS,CARRY    ; Clear the carry bit in the status Reg.
0007 0334    00122 loop   rrf     mulplr, F
0008 0603    00123         btfsc   STATUS,CARRY
0009 01F5    00124         addwf   H_byte,Same
000A 0335    00125         rrf     H_byte,Same
000B 0336    00126         rrf     L_byte,Same
000C 02F7    00127         decfsz  count, F
000D 0A07    00128         goto    loop
000E 0800    00129         retlw   0
00130
00131 ; *****
00132 ; DOUBLE PRECISION ADD AND SUBTRACT ( ACCb-ACCa->ACCb )
00133
000F 0917    00134 D_sub   call    neg_A          ; At first negate ACCa, then add
00135
00136 ;*****
00137 ; Double Precision Addition ( ACCb+ACCa->ACCb )
00138
0010 0213    00139 D_add   movf    ACCaLO,W
0011 01F4    00140         addwf   ACCbLO, F      ; add lsb
0012 0603    00141         btfsc   STATUS,CARRY    ; add in carry
0013 02B6    00142         incf    ACCbHI, F
0014 0215    00143         movf    ACCaHI,W
0015 01F6    00144         addwf   ACCbHI, F      ; add msb
0016 0800    00145         retlw   00
00146 ;
00147 ;
0017 0273    00148 neg_A   comf    ACCaLO, F      ; negate ACCa
0018 02B3    00149         incf    ACCaLO, F
0019 0643    00150         btfsc   STATUS,Z
001A 00F5    00151         decf    ACCaHI, F
001B 0275    00152         comf    ACCaHI, F
001C 0800    00153         retlw   00

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00154
00155 ; *****
00156 ; divide by 16 and limit to 100 Decimal
00157
00158 SHIFT    MACRO
00159         BCF    SWR,CARRY
00160         RRF    L_byte, F
00161         BCF    SWR,CARRY
00162         RRF    H_byte, F
00163         BTFSC  SWR,CARRY
00164         BSF    L_byte,7
00165     ENDM
00166
00167 DIV_LMT
00168     SHIFT
001D 0403    M        BCF    SWR,CARRY
001E 0336    M        RRF    L_byte, F
001F 0403    M        BCF    SWR,CARRY
0020 0335    M        RRF    H_byte, F
0021 0603    M        BTFSC  SWR,CARRY
0022 05F6    M        BSF    L_byte,7
00169     SHIFT
0023 0403    M        BCF    SWR,CARRY
0024 0336    M        RRF    L_byte, F
0025 0403    M        BCF    SWR,CARRY
0026 0335    M        RRF    H_byte, F
0027 0603    M        BTFSC  SWR,CARRY
0028 05F6    M        BSF    L_byte,7
00170     SHIFT
0029 0403    M        BCF    SWR,CARRY
002A 0336    M        RRF    L_byte, F
002B 0403    M        BCF    SWR,CARRY
002C 0335    M        RRF    H_byte, F
002D 0603    M        BTFSC  SWR,CARRY
002E 05F6    M        BSF    L_byte,7
00171     SHIFT
002F 0403    M        BCF    SWR,CARRY
0030 0336    M        RRF    L_byte, F
0031 0403    M        BCF    SWR,CARRY
0032 0335    M        RRF    H_byte, F
0033 0603    M        BTFSC  SWR,CARRY
0034 05F6    M        BSF    L_byte,7
00172
0035     LMT100
00173
0036 0095    00174    MOVLW    1H                ; SUBTRACT 1 FROM THE HIGH BYTE TO SEE
0037 0703    00175    SUBWF    H_byte,0          ; IF THERE IS ANYTHING THERE, IF NOT,
0038 0A3C    00176    BTFSS    SWR,CARRY          ; THEN LEAVE THE LOW BYTE ALONE
0039 0C64    00177    GOTO     L8_E              ; OTHERWISE GIVE THE LOW BYTE A FULL
003A 0036    00178    MOVLW    64H                ; COUNT AND IT WILL HAVE BEEN LIMITED
003B 0A42    00179    MOVWF    L_byte             ; TO 100
003C         00180    GOTO     LMT_EXIT
003C 0C64    00181    L8_E
003D 0096    00182    MOVLW    64H                ; LIMIT THE MAGNITUDE OF THE VALUE TO
003E 0703    00183    SUBWF    L_byte,0          ; 100 DECIMAL
003F 0A42    00184    BTFSS    SWR,CARRY
0040 0C64    00185    GOTO     LMT_EXIT
0041 0036    00186    MOVLW    64H
0042         00187    MOVWF    L_byte
0042 0800    00188    LMT_EXIT
00189    RETLW    00
00190 ;
00191 ;THE ROUTINE CALCTIMES DOES THE FOLLOWING: PCNT = DUTY CYCLE IN %
00192 ; 100 - PCNT --> LO AND PCNT --> HI. ZERO VALUES IN EITHER LO OR HI
00193 ;ARE FORCED TO 1.
0043     CALCTIMES
00194
0043 0209    00195    MOVF     PCNT,W                ; PUT REQUESTED % INTO W REGISTER
0044 0027    00196    MOVWF    HI                    ; COPY ON MICROSECONDS IN TO HI TIME
0045 0C64    00197    MOVLW    64H
0046 0028    00198    MOVWF    LO
0047 0209    00199    MOVF     PCNT,0
0048 00A8    00200    SUBWF    LO,1                    ; LEAVE 100-HI TIME IN LO TIME
0049 0207    00201    MOVF     HI,0                    ; INSPECT THE HIGH TIME
004A 0643    00202    BTFSC    SWR,2                    ; IF ITS IS ZERO
004B 02A7    00203    INCF     HI,1                    ; INCREMENT IT
004C 0208    00204    MOVF     LO,0                    ; INSPECT THE LO TIME
004D 0643    00205    BTFSC    SWR,2                    ; IF ITS ZERO
004E 02A8    00206    INCF     LO,1                    ; INCREMENT IT
004F 0800    00207    RETLW    00
00208
00209
00210 ; *****
0050     BEGIN
0050 0000    00212    NOP                        ; STUBBED BEGINNING

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00213
00214
00215 ;****CHECKING THE LIMIT SWITCHES AND CHECKING FOR MW*****
00216 ; This will check the switch inputs for closure and will terminate
00217 ; pulsing if one is closed. It doesn't distinguish between the switches
00218 ; so they are not dedicated to cw end and ccw end.
00219
0051 00220 SW_TRAP
0051 0004 00221 CLRWDT
0052 0746 00222 BTFSS PORTB,2 ; THIS WILL TEST ALL THREE OF THE
0053 0A51 00223 GOTO SW_TRAP ; SWITCH INPUTS. IF ANY ONE IS
0054 0766 00224 BTFSS PORTB,3 ; SET THEN EXECUTION OF THE CODE
0055 0A51 00225 GOTO SW_TRAP ; WILL BE LIMITED TO LOOKING FOR
0056 0786 00226 BTFSS PORTB,4 ; IT TO BE CLEARED
0057 0A51 00227 GOTO SW_TRAP
00228
00229
00230 ;****RECEIVING THE POSITIONAL REQUEST*****
00231 ; The host system that wishes to send positional requests to the positioner
00232 ; servo makes its desire known by setting the chip select to the positioner
00233 ; low. It then monitors the busy (Data Out) line from the positioner. When
00234 ; the positioner sets the busy line high, the host may begin sending its 8 bit
00235 ; request. The data bits should be valid on the rising edge of the clock.
00236 ; After 8 bits have been received by the positioner it will begin operation
00237 ; to send the system to the received position. It can be interrupted at any
00238 ; point during the positioning process by the host sending a new command. The
00239 ; opportunity to update the command is issued every 100 pwm pulses (every 50
00240 ; milliseconds).
00241 ; If the host sends a zero positional command the positioner will stop the
00242 ; system and remain inactive.
00243 ; If the host does not successfully complete a microwire transmission of 8
00244 ; data bits the watchdog timer will trip and reset the system to an inactive
00245 ; "stopped" state.
00246
00247
0058 00248 REC_MW
0058 0C0B 00249 MOVLW 0BH ; RESET THE PORT FOR THREE INPUTS
0059 0005 00250 TRIS PORTA ; AND ONE OUTPUT
005A 0445 00251 BCF PORTA,MWDO ; SET THE DATA OUT LOW FOR BUSY
005B 0C20 00252 MOVLW 20H
005C 0037 00253 MOVWF count
005D 00254 WATCH_CS
005D 0705 00255 BTFSS PORTA,MWCS ; CHECK FOR INCOMING REQUESTS
005E 0A62 00256 GOTO REC_CMD ; RECEIVE A NEW POSITION REQUEST
005F 02F7 00257 DECFSZ count,1
0060 0A5D 00258 GOTO WATCH_CS
0061 0A71 00259 GOTO REC_EXIT ; NO REQUEST WAS MADE IN THE TIME ALLOTTED
0062 00260 REC_CMD
0062 0545 00261 BSF PORTA,MWDO ; SET THE DATA OUT HIGH FOR "OK TO SEND"
0063 0C08 00262 MOVLW 8H ; SET TO RECEIVE 8 BITS
0064 0037 00263 MOVWF count
0065 00264 WAIT_UP
0065 0765 00265 BTFSS PORTA,MWCK ; WAIT FOR A RISING EDGE
0066 0A65 00266 GOTO WAIT_UP
0067 0403 00267 BCF SWR,CARRY ; RESET THE CARRY TO A DEFAULT ZERO
0068 0625 00268 BTFSC PORTA,MWDI ; READ THE DATA IN
0069 0503 00269 BSF SWR,CARRY ; SET THE CARRY FOR A ONE
006A 0370 00270 RLF POSR,1 ; ROTATE THE BIT INTO THE POSITION REQ.
006B 02F7 00271 DECFSZ count,1 ; DECREMENT THE BIT COUNTER
006C 0A6E 00272 GOTO WAIT_DN ; WAIT FOR THE FALLING EDGE
006D 0A71 00273 GOTO REC_EXIT ; LAST BIT RECEIVED
006E 00274 WAIT_DN
006E 0665 00275 BTFSC PORTA,MWCK ; CHECK THE INCOMING CLOCK
006F 0A6E 00276 GOTO WAIT_DN ; IF IT IS STILL HIGH WAIT FOR IT TO GO LOW
0070 0A65 00277 GOTO WAIT_UP ; IF IT GOES LOW GO BACK TO RECEIVE NEXT BIT
00278
0071 00279 REC_EXIT
0071 0445 00280 BCF PORTA,MWDO ; SET THE BUSY FLAG
00281
00282
00283 ;***** CHECK FOR THE DISABLE REQUEST *****
00284 ; Position 0 is considered a request to not drive the system. In this way
00285 ; the positioner will come up from a reset in a safe state and will not
00286 ; try to move the system to some arbitrary location.
00287
0072 00288 MOVE
0072 0210 00289 MOVF POSR,W ; CHECK THE REQUESTED POSTION
0073 0643 00290 BTFSC SWR,Z ; IF IT IS ZERO THEN WAIT FOR A NON-ZERO
0074 0A50 00291 GOTO BEGIN ; REQUEST BY BRANCHING BACK TO THE BEGINNING
00292
00293 ;****READING THE A/D VALUES*****
00294 ;
00295 ; Read the positional a/d channel (1) and store the value in the actual

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00296 ; position variable (POSA).
00297 ; This is written in line to minimize the use of variables
00298
0075 00299 READ_POS
0075 0071 00300 CLR F POSA ; CLEAN THE POSITION ACTUAL HOLDER
0076 04E6 00301 BCF PORTB,CSN ; SET THE CHIP SELECT LOW TO A/D
0077 0C1C 00302 MOVLW 1CH ; SET THE DATA LINE TO OUTPUT
0078 0006 00303 TRIS PORTB ; FOR SENDING SET-UP BITS
0079 05C6 00304 BSF PORTB,BV ; SET FOR "START" BIT
007A 0000 00305 NOP
00306
007B 05A6 00306 CLKUP ; CLOCK IN THE START BIT
007C 0000 M BSF PORTB,CK ; data acquisition from the a/d
M NOP
00307
007D 04A6 M BCF PORTB,CK ; "
007E 0000 M NOP ; data acquisition from the a/d
00308
007F 05A6 M BSF PORTB,CK ; CLOCK IN SINGLE-ENDED
0080 0000 M NOP ; data acquisition from the a/d
00309
0081 04A6 M BCF PORTB,CK ; "
0082 0000 M NOP ; data acquisition from the a/d
00310
0083 05A6 M BSF PORTB,CK ; CLOCK IN CHANNEL 1
0084 0000 M NOP ; data acquisition from the a/d
00311
0085 04A6 M BCF PORTB,CK ; TO THE MUX
0086 0000 M NOP ; data acquisition from the a/d
00312
0087 0C5C 00312 MOVLW 5CH ; SET THE DATA LINE TO INPUT
0088 0006 00313 TRIS PORTB ; TO RECEIVE DATA BITS FROM A/D
00314
0089 05A6 M BSF PORTB,CK ; CLOCK UP TO LET MUX SETTLE
008A 0000 M NOP ; data acquisition from the a/d
00315
008B 04A6 M BCF PORTB,CK ; CLOCK DN TO LET MUX SETTLE
008C 0000 M NOP ; data acquisition from the a/d
00316
008D 0403 M GET_BIT ; GET BIT 7
008E 05A6 M BCF SWR,CARRY
008F 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
0090 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
0091 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
0092 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
0093 0000 M BCF PORTB,CK ; SET THE CLOCK LOW
M NOP ; DELAY
00317
0094 0403 M GET_BIT ; BIT 6
0095 05A6 M BCF SWR,CARRY
0096 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
0097 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
0098 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
0099 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
009A 0000 M BCF PORTB,CK ; SET THE CLOCK LOW
M NOP ; DELAY
00318
009B 0403 M GET_BIT ; BIT 5
009C 05A6 M BCF SWR,CARRY
009D 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
009E 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
009F 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
00A0 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
00A1 0000 M BCF PORTB,CK ; SET THE CLOCK LOW
M NOP ; DELAY
00319
00A2 0403 M GET_BIT ; BIT 4
00A3 05A6 M BCF SWR,CARRY
00A4 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
00A5 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
00A6 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
00A7 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
00A8 0000 M BCF PORTB,CK ; SET THE CLOCK LOW
M NOP ; DELAY
00320
00A9 0403 M GET_BIT ; BIT 3
00AA 05A6 M BCF SWR,CARRY
00AB 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
00AC 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
00AD 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
00AE 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
00AF 0000 M BCF PORTB,CK ; SET THE CLOCK LOW
M NOP ; DELAY
00321
00B0 0403 M GET_BIT ; BIT 2
00B1 05A6 M BCF SWR,CARRY
00B2 06C6 M BSF PORTB,CK ; SET CLOCK BIT HIGH
00B3 0503 M BTFSC PORTB,BV ; LOOK AT DATA COMMING IN
00B4 0371 M BSF SWR,CARRY ; SET THE CARRY FOR A 1
00B5 04A6 M RLF POSA, F ; ROTATE THE W REG LEFT
M BCF PORTB,CK ; SET THE CLOCK LOW

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00B6 0000          M      NOP                      ; DELAY
                                00322      GET_BIT          ; BIT 1
00B7 0403          M      BCF      SWR,CARRY
00B8 05A6          M      BSF      PORTB,CK          ; SET CLOCK BIT HIGH
00B9 06C6          M      BTFSC     PORTB,BV          ; LOOK AT DATA COMMING IN
00BA 0503          M      BSF      SWR,CARRY          ; SET THE CARRY FOR A 1
00BB 0371          M      RLF      POSA, F            ; ROTATE THE W REG LEFT
00BC 04A6          M      BCF      PORTB,CK          ; SET THE CLOCK LOW
00BD 0000          M      NOP                      ; DELAY
                                00323      GET_BIT          ; BIT 0
00BE 0403          M      BCF      SWR,CARRY
00BF 05A6          M      BSF      PORTB,CK          ; SET CLOCK BIT HIGH
00C0 06C6          M      BTFSC     PORTB,BV          ; LOOK AT DATA COMMING IN
00C1 0503          M      BSF      SWR,CARRY          ; SET THE CARRY FOR A 1
00C2 0371          M      RLF      POSA, F            ; ROTATE THE W REG LEFT
00C3 04A6          M      BCF      PORTB,CK          ; SET THE CLOCK LOW
00C4 0000          M      NOP                      ; DELAY
00C5 05E6          00324      BSF      PORTB,CSN        ; DESELECT THE CHIP
                                00325
                                00326
                                00327 ;***** CALCULATING THE PID TERMS *****
                                00328
                                00329 ;****CALCULATE THE ERROR*****
                                00330 ; The error is very simply the signed difference between where the
                                00331 ; system is and where it is supposed to be at a particular instant
                                00332 ; in time. It is formed by subtracting the actual position from the
                                00333 ; requested position (Position requested - Position actual). This
                                00334 ; difference is then used to determine the proportional,integral and
                                00335 ; differential term contributions to the output.
                                00336
00C6              00337 C_ERR
00C6 0211          00338      MOVF     POSA,0          ; LOAD THE ACTUAL POSITION INTO W
00C7 0090          00339      SUBWF    POSR,0          ; SUBTRACT IT FROM THE REQUESTED POSITION
00C8 0603          00340      BTFSC     SWR,CARRY          ; CHECK THE CARRY BIT TO DETERMINE THE SIGN
00C9 0ACB          00341      GOTO     PLS_ER          ; ITS POSITIVE(POSR>POSA)
00CA 0ACE          00342      GOTO     MNS_ER          ; ITS NEGATIVE (POSA>POSR)
                                00343
00CB              00344 PLS_ER
00CB 002C          00345      MOVWF    ERR1          ; SAVE THE DIFFERENCE IN "ERROR"
00CC 0419          00346      BCF      FLAGS,ER_SGN      ; SET THE SIGN FLAG TO INDICATE POSITIVE
00CD 0AD2          00347      GOTO     CE_EXIT
                                00348
00CE              00349 MNS_ER
00CE 0210          00350      MOVF     POSR,0          ; RE-DO THE SUBTRACTION
00CF 0091          00351      SUBWF    POSA,0          ; ACTUAL - REQUESTED
00D0 002C          00352      MOVWF    ERR1          ; STORE THE DIFFERENCE IN "ERROR"
00D1 0519          00353      BSF      FLAGS,ER_SGN      ; SET THE SIGN FLAG FOR NEGATIVE
                                00354
00D2              00355 CE_EXIT
00D2 006D          00356      CLRF     SUMLO          ; CLEAN OLD VALUES OUT TO PREPARE
00D3 0078          00357      CLRF     SUMHI          ; FOR THIS CYCLES SUMMATION
                                00358
                                00359 ;****CALCULATE THE PROPORTIONAL TERM*****
                                00360 ; The proportional term is the error times the proportional gain term.
                                00361 ; This term simply gives you more output drive the farther away you are
                                00362 ; from where you want to be (error)*Kp.
                                00363 ; The proportional gain term is a signed term between -100 and 100 The
                                00364 ; more proportional gain you have the lower your system following error
                                00365 ; will be. The higher your proportional gain, the more integral and
                                00366 ; differential term gains you will have to add to make the system stable.
                                00367 ; The sum is being carried as a 16 bit signed value.
                                00368
00D4              00369 C_PROP
00D4 020C          00370      MOVF     ERR1,0          ; LOAD THE ERROR TERM INTO W
00D5 0033          00371      MOVWF    mulcnd          ; MULTIPLY IT BY THE PROPORTIONAL GAIN
00D6 0C30          00372      MOVLW    KP              ; KP AND THEN SCALE IT DOWN BY DIVIDING
00D7 0034          00373      MOVWF    mulplr          ; IT DOWN BY 16. IF IT IS STILL OVER
00D8 0901          00374      CALL     mpy_S          ; 255 THEN LIMIT IT TO 255
00D9 091D          00375      CALL     DIV_LMT
                                00376
00DA              00377 RESTORE_SGN
00DA 0719          00378      BTFSS     FLAGS,ER_SGN      ; IF THE ERROR SIGN IS NEGATIVE THEN
00DB 0ADE          00379      GOTO     ADDPROP          ; PUT THE SIGN INTO THE LOW BYTE
00DC 0276          00380      COMF      L_byte,1
00DD 02B6          00381      INCF      L_byte,1
                                00382
00DE              00383 ADDPROP
00DE 0216          00384      MOVF     L_byte,W          ; SAVE THE PROPORTIONAL PART
00DF 01ED          00385      ADDWF     SUMLO,1          ; IN THE SUM
00E0 0603          00386      BTFSC     SWR,CARRY          ; IF THE ADDITION CARRIED OUT THEN
00E1 02B8          00387      INCF      SUMHI,1          ; INCREMENT THE HIGH BYTE
00E2 0C00          00388      MOVLW    0              ; THEN
00E3 06ED          00389      BTFSC     SUMLO,7          ; SIGN EXTEND TO THE UPPER

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00E4 0CFF      00390      MOVLW    OFF          ; BYTE
00E5 01F8      00391      ADDWF     SUMHI,1
00392
00393
00394
00395 ;****CALCULATE THE INTEGRAL TERM*****
00396 ; The integral term is an accumulation of the error thus far. Its purpose
00397 ; is to allow even a small error to effect a large change. It does this
00398 ; by adding a small number into an accumulator each cycle through the program.
00399 ; Thusly even a small error that exists for a while will build up to a large
00400 ; enough number to effect an output sufficient to move the system. The effect
00401 ; that this integral accumulator has is modulated by the integral gain term KI.
00402 ; The integral of the error over time is multiplied by KI and the result is its
00403 ; contribution to the final summation for determining the output value. This
00404 ; term helps to insure the long-term accuracy of the system is good. A certain
00405 ; amount is necessary for this purpose but too much will cause oscillations.
00406 ; The integral is bounded in magnitude for two purposes. The first is so that
00407 ; it never rolls over and changes sign. The second is that it may saturate on
00408 ; long moves forcing an excessively large overshoot to "de-integrate" the error
00409 ; accumulated during the first of the moves.
00410
00E6           00411 C_INT
00E6 020C      00412      MOVF     ERR1,W          ; MOVE THE ERROR INTO THE W REG
00E7 0643      00413      BTFSC    SWR,Z          ; AND CHECK TO SEE IF IT IS ZERO
00E8 0AFF      00414      GOTO     ADDINT        ; IF SO THEN DONT CHANGE THE ACCUMULATOR
00E9 0619      00415      BTFSC    FLAGS,ER_SGN    ; TEST THE FLAGS TO FIND THE POLARITY
00EA 0AEE      00416      GOTO     MNS_1          ; OF THE ERROR .. 0 POSITIVE 1 NEGATIVE
00EB
00EB 0C02      00417 PLS_1
00EB 01EE      00418      MOVLW    KI              ; IF POSITIVE ADD ONE TO
00EC 01EE      00419      ADDWF     ACCUM,1        ; THE ERROR ACCUMULATOR
00ED 0AF0      00420      GOTO     LMTACM          ; THEN LIMIT IT TO +/-100
00EE
00EE 0C02      00421 MNS_1
00EE 0C02      00422      MOVLW    KI              ; IF NEGATIVE THEN SUBTRACT ONE
00EF 00AE      00423      SUBWF     ACCUM,1        ; FROM THE ERROR ACCUMULATOR
00F0
00F0 06EE      00424 LMTACM
00F0 06EE      00425      BTFSC    ACCUM,7          ; CHECK THE SIGN BIT OF THE ERROR ACCUMULATOR
00F1 0AF9      00426      GOTO     M_LMT          ; AND DO A POSITIVE OR NEGATIVE LIMIT
00F2
00F2 0C9C      00427 P_LMT
00F2 0C9C      00428      MOVLW    9CH           ; FOR THE POSITIVE LIMIT ADD 156 TO THE
00F3 01CE      00429      ADDWF     ACCUM,0        ; NUMBER AND SEE IF YOU GENERATE A CARRY
00F4 0703      00430      BTFSS    SWR,CARRY      ; BY CHECKING THE CARRY FLAG
00F5 0AFF      00431      GOTO     ADDINT        ; IF NOT THEN ITS O.K.
00F6 0C64      00432      MOVLW    64H           ; IF SO THEN FORCE THE ACCUMULATOR TO
00F7 002E      00433      MOVWF     ACCUM          ; 100 DECIMAL
00F8 0AFF      00434      GOTO     ADDINT
00F9
00F9 0C9C      00435 M_LMT
00F9 0C9C      00436      MOVLW    9CH           ; FOR THE NEGATIVE LIMIT SUBTRACT 156 FROM
00FA 008E      00437      SUBWF     ACCUM,0        ; THE NUMBER AND SEE IF YOU GENERATE A
00FB 0603      00438      BTFSC    SWR,CARRY      ; NON-CARRY CONDITION INDICATING A ROLL-OVER
00FC 0AFF      00439      GOTO     ADDINT        ; IF NOT THEN LEAVE THE ACCUMULATOR ALONE
00FD 0C9C      00440      MOVLW    9CH           ; IF SO THEN LIMIT IT TO -100 BY
00FE 002E      00441      MOVWF     ACCUM          ; FORCING THAT VALUE IN THE ACCUMULATOR
00FF
00FF 020E      00442
00FF 020E      00443 ADDINT
00FF 020E      00444      MOVF     ACCUM,W          ; ADD THE INTEGRAL ACCUMULATOR TO
0100 01ED      00445      ADDWF     SUMLO,1        ; THE LOW BYTE OF THE SUM
0101 0603      00446      BTFSC    SWR,CARRY      ; TEST FOR OVERFLOW, IF SO THEN
0102 02B8      00447      INCF      SUMHI,1        ; INCREMENT THE HI BYTE
0103 0C00      00448      MOVLW    0              ; LOAD 0 INTO THE W REGISTER
0104 06EE      00449      BTFSC    ACCUM,7          ; IF THE INTEGRAL ACCUMULATOR WAS NEGATIVE
0105 0240      00450      COMF      W,W            ; COMPLEMENT THE 0 TO GET SIGN FOR HIGH BYTE
0106 01F8      00451      ADDWF     SUMHI,1        ; ADD INTO THE HIGH BYTE OF THE SUM
00452
00453
0107           00454 U_DEXIT          ; EXIT POINT FOR THE UP/DOWN CONTROL OF ACCUM
00455
00456
00457
00458 ;****CALCULATING THE DIFFERENTIAL TERM*****
00459 ; The differential term examines the error and determines how much
00460 ; it has changed since the last cycle. It does this by subtracting the
00461 ; old error from the new error. Since the cycle time is relatively fixed
00462 ; we can use it as the "dt" of the desired "de/dt". This derivative of the
00463 ; error is then multiplied by the differential gain term KD and becomes the
00464 ; differential term contribution for the final summation.
00465
00466 ; First, create the "de" term by doing a signed subtraction of new error
00467 ; minus the old error. (new_error - old_error)
00468
00469
0107           00470 C_DIFF
0107 020C      00470      MOVF     ERR1,W          ; LOAD THE NEW ERROR INTO REGISTER
0108 0719      00471      BTFSS    FLAGS,ER_SGN
0109 0B0D      00472      GOTO     LO_BYTE

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010A 026C      00473      COMF      ERR1,1      ; CORRECT THE VALUE TO BE 16 BIT
010B 028C      00474      INCF      ERR1,W
010C 026C      00475      COMF      ERR1,1      ; RESTORE IT FOR FUTURE USE TO 8 BIT MAGNITUDE
010D           00476      LO_BYTE
010D 0034      00477      MOVWF     ACCbLO      ; FOR SUBTRACTION
010E 0C00      00478      MOVLW     00
010F 0619      00479      BTFSC     FLAGS,ER_SGN ; SIGN EXTEND THE UPPER BYTE
0110 0CFF      00480      MOVLW     0FF
0111 0036      00481      MOVWF     ACCbHI
0112 020F      00482      MOVF      ERR_O,W      ; LOAD THE OLD ERROR INTO OTHER REGISTER
0113 0799      00483      BTFSS     FLAGS,OER_SGN
0114 0B17      00484      GOTO      LO_BYTEO
0115 026F      00485      COMF      ERR_O,1      ; CORRECT THE VALUE TO BE 16 BIT
0116 028F      00486      INCF      ERR_O,W
0117           00487      LO_BYTEO
0117 0033      00488      MOVWF     ACCaLO      ; FOR SUBTRACTION
0118 0C00      00489      MOVLW     00
0119 0699      00490      BTFSC     FLAGS,OER_SGN ; SIGN EXTEND THE UPPER BYTE
011A 0CFF      00491      MOVLW     0FF
011B 0035      00492      MOVWF     ACCaHI
011C 090F      00493      CALL      D_sub      ; PERFORM THE SUBTRACTION
011D           00494
011D           00495      STRIP_SGN
011D 06F6      00496      BTFSC     ACCbHI,7      ; TEST THE SIGN OF THE RESULT
011E 0B20      00497      GOTO      NEG_ABS
011F 0B25      00498      GOTO      POS_ABS
0120           00499      NEG_ABS
0120 0559      00500      BSF      FLAGS,DE_SGN ; ITS NEGATIVE SO SET THE FLAG AND
0121 0274      00501      COMF      ACCbLO,1      ; COMPLEMENT THE VALUE
0122 0294      00502      INCF      ACCbLO,W
0123 002F      00503      MOVWF     ERR_O
0124 0B28      00504      GOTO      MULT_KD
0125           00505      POS_ABS
0125 0459      00506      BCF      FLAGS,DE_SGN ; ITS POSITIVE SO SET RESET THE FLAG
0126 0214      00507      MOVF      ACCbLO,W      ; AND SAVE THE VALUE
0127 002F      00508      MOVWF     ERR_O
0127           00509
0127           00510      ; Then multiply by Kd
0127           00511
0128           00512      MULT_KD
0128 020F      00513      MOVF      ERR_O,W
0129 0033      00514      MOVWF     mulcnd      ; MOVE THE DE/DT TERM INTO THE MULCND REG.
012A 0C20      00515      MOVLW     KD      ; MOVE THE DIFFERENTIAL GAIN TERM INTO
012B 0034      00516      MOVWF     mulplr      ; MULPLR TO MULTIPLY THE DE/DT
012C 0901      00517      CALL      mpy_S      ; DO THE MULTIPLICATION
012D 091D      00518      CALL      DIV_LMT      ; SCALE AND LIMIT TO 100
012D           00519
012E           00520      RE_SGN
012E 0759      00521      BTFSS     FLAGS,DE_SGN ; IF THE DE SIGN IS NEGATIVE THEN
012F 0B32      00522      GOTO      SAVE_DIFF      ; PUT THE SIGN INTO THE LOW BYTE
0130 0276      00523      COMF      L_byte,1
0131 02B6      00524      INCF      L_byte,1
0132           00525      SAVE_DIFF
0132 0216      00526      MOVF      L_byte,W
0133 0643      00527      BTFSC     SWR,Z
0134 0B45      00528      GOTO      ROLL_ER
0135 002F      00529      MOVWF     ERR_O
0135           00530
0135           00531      ; ADD THE DIFF TERM INTO THE SUMM *****
0135           00532
0136           00533      ADDDIF
0136 0C00      00534      MOVLW     00
0137 0659      00535      BTFSC     FLAGS,DE_SGN ; PUT THE KD*(DE/DT) TERM INTO THE
0138 0CFF      00536      MOVLW     0FF ; REGISTERS TO ADD. AND
0139 0036      00537      MOVWF     ACCbHI ; SIGN EXTEND THE UPPER BYTE
013A 020F      00538      MOVF      ERR_O,W
013B 0034      00539      MOVWF     ACCbLO
013C 020D      00540      MOVF      SUMLO,W ; LOAD THE CURRENT SUM INTO THE
013D 0033      00541      MOVWF     ACCaLO ; REGISTERS TO ADD
013E 0218      00542      MOVF      SUMHI,W
013F 0035      00543      MOVWF     ACCaHI
0140 0910      00544      CALL      D_add      ; ADD IN THE DIFFERENTIAL TERM
0141 0214      00545      MOVF      ACCbLO,W ; SAVE THE RESULTS BACK
0142 002D      00546      MOVWF     SUMLO ; INTO SUMLO AND HI
0143 0216      00547      MOVF      ACCbHI,W
0144 0038      00548      MOVWF     SUMHI
0144           00549
0145           00550      ROLL_ER
0145 020C      00551      MOVF      ERR1,W ; TAKE THE CURRENT ERROR
0146 002F      00552      MOVWF     ERR_O ; AND PUT IT IN THE ERROR HISTORY
0147 0499      00553      BCF      FLAGS,OER_SGN ; SAVE THE CURRENT ERROR SIGN
0148 0619      00554      BTFSC     FLAGS,ER_SGN ; IN THE OLD ERROR SIGN FOR
0149 0599      00555      BSF      FLAGS,OER_SGN ; NEXT TIME THROUGH

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00556
00557
00558 ;****SET UP THE DIRECTION FOR THE BRIDGE*****
00559 ;
00560 ; After the sum of all the components has been made, the sign of the
00561 ; sum will determine which way the bridge should be powered.
00562 ; If the sum is negative the bridge needs to be set to drive ccw; if the
00563 ; sum is Positive then the bridge needs to be set to drive cw. This
00564 ; is purely a convention and depends upon the polarity the motor and feedback
00565 ; element are hooked up in.
00566
014A 00567 SET_DIR
014A 0479 00568 BCF FLAGS,DIR ; SET FOR DEFAULT CLOCKWISE
014B 06F8 00569 BTFSC SUMHI,7 ; LOOK AT THE SIGN BIT, IF IT IS SET
014C 0579 00570 BSF FLAGS,DIR ; THEN SET FOR CCW BRIDGE DRIVE
00571
00572
00573 ;**** SCALE THE NUMBER TO BETWEEN 0 AND 100% *****
00574
00575 ; After the direction is set the request for duty cycle is limited to between
00576 ; 0 and 100 percent inclusive. This value is passed to the dutycycle setting
00577 ; routine by loading it in the variable "PCNT".
00578
00579
014D 00580 L_SUMM
014D 07F8 00581 BTFSS SUMHI,7 ; CHECK TO SEE IF IT IS NEGATIVE
014E 0B52 00582 GOTO POS_LM
014F 0278 00583 COMF SUMHI,1
0150 026D 00584 COMF SUMLO,1
0151 02AD 00585 INCF SUMLO,1
00586
0152 00587 POS_LM
0152 0C01 00588 MOVLW 1H ; SUBTRACT 1 FROM THE HIGH BYTE TO SEE
0153 0098 00589 SUBWF SUMHI,0 ; IF THERE IS ANYTHING THERE, IF NOT,
0154 0703 00590 BTFSS SWR,CARRY ; THEN LEAVE THE LOW BYTE ALONE
0155 0B59 00591 GOTO LB_L ; OTHERWISE GIVE THE LOW BYTE A FULL
0156 0C64 00592 MOVLW 64H ; COUNT AND IT WILL HAVE BEEN LIMITED
0157 002D 00593 MOVWF SUMLO ; TO 100
0158 0B5F 00594 GOTO LP_EXIT ; GOTO LIMIT PERCENT EXIT
0159 00595 LB_L
0159 0C64 00596 MOVLW 64H ; LIMIT THE MAGNITUDE OF THE VALUE TO
015A 008D 00597 SUBWF SUMLO,0 ; 100 DECIMAL
015B 0703 00598 BTFSS SWR,CARRY
015C 0B5F 00599 GOTO LP_EXIT
015D 0C64 00600 MOVLW 64H
015E 002D 00601 MOVWF SUMLO
00602
015F 00603 LP_EXIT
015F 020D 00604 MOVF SUMLO,W ; STORE THE LIMITED VALUE IN
0160 0029 00605 MOVWF PCNT ; THE PERCENT DUTYCYCLE REQUEST
00606
00607
00608 ;*****
00609 ; PWM GENERATING ROUTINE
00610 ;
00611 ; The important thing here is not to have to do too many decisions or
00612 ; calculations while you are generating the 100 or so pulses. These will
00613 ; take time and limit the minimum or maximum duty cycle.
00614
0161 00615 WHICH_DIR
0161 0679 00616 BTFSC FLAGS,DIR ; CHECK THE DIRECTION FLAG
0162 0B76 00617 GOTO GOCCW ; DO CCW PULSES FOR 1
0163 0B64 00618 GOTO GOCW ; DO CW PULSES FOR 0
00619
00620
0164 00621 GOCW
0164 0426 00622 BCF PORTB,PWMCCW ; SET THE BRIDGE FOR CW MOVE
0165 0C64 00623 MOVLW 64H ;
0166 0032 00624 MOVWF CYCLES ; SET UP CYCLES COUNTER FOR 100 PULSES
0167 0943 00625 CALL CALCTIMES ; CALCULATE THE HI AND LO TIMES
00626
0168 00627 RLDCW
0168 0207 00628 MOVF HI,0 ; RELOAD THE HI TIMER
0169 002A 00629 MOVWF HI_T ; WITH THE CALCULATED TIME
016A 0208 00630 MOVF LO,0 ; RELOAD THE LO TIMER
016B 002B 00631 MOVWF LO_T ; WITH THE CALCULATED TIME
016C 0004 00632 CLRWDW ; TAG THE WATCHDOG TIMER
00633
016D 00634 CWHI
016D 0506 00635 BSF PORTB,PWMCW ; SET THE CLOCKWISE PWMBIT HIGH
016E 02EA 00636 DECFSZ HI_T,1 ; DECREMENT THE HI USEC. COUNTER
016F 0B6D 00637 GOTO CWHI ; DO ANOTHER LOOP
0170 00638 CWLO

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0170 0406      00639      BCF      PORTB,PWMCW      ; SET THE CLOCKWISE PWM BIT LOW
0171 02EB      00640      DECFSZ    LO_T,1          ; DECREMENT THE LO USEC. COUNTER
0172 0B70      00641      GOTO      CWLO           ; DO ANOTHER LOOP
0173 02F2      00642      DECFSZ    CYCLES,1        ; DECREMENT THE NUMBER OF CYCLES LEFT
0174 0B68      00643      GOTO      RLDCW          ; DO ANOTHER PULSE
0175 0A50      00644      GOTO      BEGIN          ; DO ANOTHER MAIN SYSTEM CYCLE
                00645
                00646
0176          00647      GOCCW
0176 0406      00648      BCF      PORTB,PWMCW      ; SET THE BRIDGE FOR CCW MOVE
0177 0C64      00649      MOVLW     64H             ;
0178 0032      00650      MOVWF     CYCLES          ; SET UP CYCLE COUNTER FOR 100 PULSES
0179 0943      00651      CALL     CALCTIMES        ; CALCULATE THE HI AND LO TIMES
017A          00652      RLDCCW
017A 0207      00653      MOVF      HI,0           ; RE LOAD THE HI TIMER
017B 002A      00654      MOVWF     HI_T           ; WITH THE CALCULATED TIME
017C 0208      00655      MOVF      LO,0           ; RE LOAD THE LO TIMER
017D 002B      00656      MOVWF     LO_T           ; WITH THE CALCULATED TIME
017E 0004      00657      CLRWDT      ; TAG THE WATCHDOG
                00658
017F          00659      CCWHI
017F 0526      00660      BSF      PORTB,PWMCCW     ; SET THE COUNTERCLOCKWISE PWM BIT HIGH
0180 02EA      00661      DECFSZ    HI_T,1          ; DECREMENT THE HI USEC. COUNTER
0181 0B7F      00662      GOTO      CCWHI          ; DO ANOTHER LOOP
0182          00663      CCWLO
0182 0426      00664      BCF      PORTB,PWMCCW     ; SET THE COUNTERCLOCKWISE PWM BIT LOW
0183 02EB      00665      DECFSZ    LO_T,1          ; DECREMENT THE LO USEC. COUNTER
0184 0B82      00666      GOTO      CCWLO          ; DO ANOTHER LOOP
0185 02F2      00667      DECFSZ    CYCLES,1        ; DECREMENT THE NUMBER OF CYCLES LEFT
0186 0B7A      00668      GOTO      RLDCW          ; DO ANOTHER PULSE
0187 0A50      00669      GOTO      BEGIN          ; DO ANOTHER MAIN SYSTEM CYCLE
                00670
                00671
                00672
                00673
                00674
00675          ;***** START VECTOR *****
00676
0188          00677      CLRREG                    ;INITIALIZE REGISTERS
                00678
0188 0C0B      00679      MOVLW     0BH             ; SET PORT A FOR 3 INPUTS AND
0189 0005      00680      TRIS      PORTA          ; AN OUTPUT
018A 0C1C      00681      MOVLW     1CH             ; SET PORT B FOR INPUTS AND OUTPUTS
018B 0006      00682      TRIS      PORTB          ; THIS SETTING FOR SENDING TO A/D
018C 0040      00683      CLRW          ; CLEAR THE W REGISTER
018D 0002      00684      OPTION     ; STORE THE W REG IN THE OPTION REG
018E 0C08      00685      MOVLW     08H             ; STARTING REGISTER TO ZERO
018F 0024      00686      MOVWF     FSR            ;
0190          00687      GCLR
0190 0060      00688      CLRF      00             ;
0191 03E4      00689      INCFSZ    FSR, F          ; SKIP AFTER ALL REGISTERS
0192 0B90      00690      GOTO      GCLR           ; HAVE BEEN INITIALIZED
0193 0A50      00691      GOTO      BEGIN          ; START AT THE BEGINING OF THE PROGRAM
                00692
01FF          00693      ORG      01FF             ;
01FF 0B88      00694      GOTO      CLRREG          ; START VECTOR
                00695
                00696
00697      END

```

MEMORY USAGE MAP ('X' = Used, '-' = Unused)

```

0000 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0100 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0140 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0180 : XXXXXXXXXXXXXXXX XXXX-----
01C0 : -----X

```

All other memory blocks unused.

Program Memory Words Used: 405  
Program Memory Words Free: 619

Errors : 0  
Warnings : 0 reported, 0 suppressed  
Messages : 0 reported, 0 suppressed

---

**Note the following details of the code protection feature on PICmicro® MCUs.**

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products of its kind on the market today, when used in the intended manner and under normal conditions.
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- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable”.
- Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

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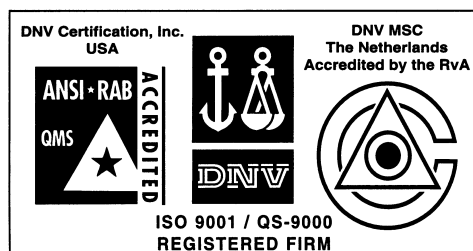
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