Appendix D:

Source Codes

Accelerometer Acquisition program (MPLAB)

```
List      p=16F877a
                include  "p16f877a.inc"
                __config _cp_off & _wdt_off & _xt_osc & _pwrte_on


;Reading Accelerometer duty cycle value

;This subroutine collects and calculates T1X, T1Y and T2
;T1X is represented by registers T1XHi and T1Xlo
;T1Y is represented by registers T1YHi and T1Ylo
;T2 is represented by registers T2Hi and T2lo

T1XEndlo                equ     46h
T1XEndHi                equ     47h
T1Ybeginlo              equ     48h
T1YbeginHi              equ     49h
T1YEndlo                equ     50h
T1YEndHi                equ     55h
T1YHi                   equ     56h
T1YLo                   equ     81h
T1XHi                   equ     82h
T1XLo                   equ     83h
T2Hi                    equ     84h
T2Lo                    equ     85h
ZXcalHi                 equ     86h
ZXcalLo                 equ     87h
ZXActualHi              equ     88h
ZXActualLo              equ     89h
u_term_lo_acce          equ     95h
u_term_hi_acce          equ     96h
KHi                     equ     97h
KLo                     equ     98h

; Start at the reset vector
org     0x000
goto    start

org 0x0004
                        incf            Timer1H
                        bcf             INTCON,T0IF
                        bcf             INTCON,RBIE
                        retfie

Start
                        bcf             STATUS,RP0
                        clrf            PORTA
                        clrf            PORTB
```

```
                bsf     STATUS,RP0                      ;Bank1
                movlw   B’00000011’     ;Set up the I/O ports
                movwf   TRISA
                movlw   B’00010000’
                movwf   TRISB
                movlw   B’00001111’
                movwf   OPTION_REG
                bcf     STATUS,RP0                      ;Bank0
                bsf     INTCON,GIE

                Movlw   b'00100011'
                Movwf   T1CON
                Movlw   b'00000101'
                Movwf   CCP1
                bsf     INTCON,GIE



EdgeA           btfsc   PORTA,0
                Goto    EdgeA

EdgeB           btfss   PORTA,0         ;Look for the high transmission at Ta
                Goto    EdgeB           ;Keep looking for high transmission
                Clrf    TMR1L                           ;Start timing
                Clrf    TMR1H
                Bcf     PIR1,TMR1IF     ;Enabling the timer1 overflow interrupt
                bsf     PIE1,TMR1IE


EdgeC           btfsc   PORTA,0     ;Look for the low transmission at Tb
                Goto    EdgeC       ;Keep looking for low transmission
                Movf    TMR1L,w     ;Record and save the time in register T1X
                MovwfT1XEndlo
                Movf    TMR1H
                MovwfT1XEndHi


EdgeD           btfsc   PORTB,2
                goto    EdgeD

EdgeE           btfsc   PORTB,2     ;Look for the high transmission at Tc
                Goto    EdgeE       ;Keep looking for high transmission
                Movf    TMR1L,w     ;Record and save the time in T1Ybeginlo
                Movwf   T1Ybeginlo
                Movf    TMR1H,w
                Movwf   T1YbeginHi

EdgeF           btfsc   PORTB,2         ;Look for the low transmission at Td
                Goto    EdgeF           ;Keep looking for low transmission
```

```
                Movf   TMR1L,w          ;Record and save the time in
                Movwf   T1YEndlo        ; T1YEndlo
                Movf    TMR1H,w
                Movwf   T1YEndHi

                Movf    T1YEndHi,w
                Movwf   Arg_hi
                Movf    T1YEndlo,w
                Movwf   Arg_lo
                Movf    T1YbeginHi,w
                Movwf    Sum_Hi
                Movf    T1YbeginLo,w
                Movwf   Sum_Lo
                call    Subtract
                Movf    Sum_Hi,w
                Movwf   T1YHi
                Movf    Sum_Lo,w
                Movwf   T1YLo


;CALCULATE T2
;2*(T2Hi,T2Lo) = (T1YEndHi:T1YEndLo)+
;(T1YStartHi:T1YStartLo)-(T1XHi:T1XLo)

                movf    T1YEndHi,w
                movwf   Arg_Hi
                movf    T1YEndLo,w
                movwf    Arg_Lo
                movf    T1YbeginHi,w
                movwf   Sum_Hi
                movf    T1YbeginLo,w
                movwf   Sum_lo
                call    add
                        ;Sum_hi,Sum_lo=(T1YEndHi:T1YEendLo)+
                movf    T1XEndHi,w      ; (T1YBeginHi:T1YBeginLo)
                movwf   Sum_Hi
                movf    T1XEndLo,W
                movwf   Sum_lo
                call    Subtract        ;Sum_hi:Sum_lo = 2*T2
                bcf     STATUS,C
                rrf     Arg_hi,F        ;rotate one bit means multiply
                rrf     Arg_lo,F        ; by two
                movf    Arg_hi,W
                movwf   T2Hi
                movf    Arg_lo,W
                movwf   T2Lo
                return
```

```
; Calulation of the Z value based on the formula
; Zactual = (Zcal * T2actual)/T2cal

ZActual_value   movf    ZXcalHi,w
                Movwf   Arg_Hi
                Movf    ZXcalLo,w
                Movwf   Arg_Lo
                Movf    T2Hi,w
                Movwf   Sum_Hi
                Movf    T2Lo,w
                Movwf   Sum_Lo
                Call    Mul

                Movf    T2calHi,w
                Movwf   Divisor1
                Movf    T2calLo,w
                Movwf   Divisor0
                Call    Division
                Movf    Quo_1,w
                Movwf   ZXActualHi
                Movf    Quo_0,w
                Movwf   ZXActualLo


; The x-axis acceleration value is programmed based on the formula
; Acceleration = K*(T1-Zactual)/T2actual


X_Accel_value   movf    ZXActualHi,w ; This is to check whether the
                Subwf   T1XHi,w      ; numerator  is positive or negative
                Btfss   STATUS,c
                Goto    Num_negx
                Btfss   STATUS,z
                Goto    Num_posx
                Movf    ZXActualLo,w
                Subwf   T1XLo,w
                Btfss   STATUS,c
                Goto    Num_posx

;This subroutine  is chosen if the x-axis acceleration value is negative

Num_negx        movf    ZXActualHi,w
                Movwf   Arg_Hi
                Movf    ZXActualLo,w
                Movwf   Arg_Lo
                Movf    T1XHi,w
                Movwf   Sum_hi
                Movf    T1XLo,w
```

```
                Movwf   Sum_lo
                Call    Subtract
                Movlw   KHi
                Movwf   Arg_Hi
                Movlw   KLo
                Movwf   Arg_Lo
                Call    Mul

                Movf    T2Hi,w
                Movwf   Divisor1
                Movf    T2Lo,w
                Movwf   Divisor0
                Call    Division

                Movf    T2Hi,w
                Movwf   Divisor1
                Movf    T2Lo,w
                Movwf   Divisor0
                Call    Division
                movf    Quo_0,w
                movwf   u_term_hi_acce
                movf    Quo_1,w
                movwf   u_term_lo_acce


                movf    u_term_hi_acce,w
                sublw   b'00000010' ; Upper byte for analog value 3V
                call    no_drive
                movwf   temp_lo
                btfsc   STATUS,c
                call    ccw
                call    cw


no_drive        movwf   temp_lo     ;No Signal is output to the h-bridge
                btfsc   STATUS,z
                call    next_byte3
                return

;This section is to determine which direction the motor should turn
next_byte3
                bcf     STATUS,c
                bcf     STATUS,z
                bsf     STATUS,RP0
                movf    u_term_lo_acce,w
                bcf     STATUS,RP0
                sublw   b'00000001'     ;lower byte for analog value 3V
                call    no_drive_test2  ;This is the balanced state value
                btfsc   STATUS,c
```

```
                call    ccw     ;If  no carry then go to ccw subroutine
                call    cw      ;If carry then go to cw subroutine

no_drive_test2  movwf   temp_lo
                btfsc   STATUS,z
                call    clr_drive       ;No Signal is output to the h-bridge
                return

;This ccw subroutine contains a few individual error values, which in turn will call the
;appropriate duty cycle subroutines.

ccw
                movf    u_term_hi_acce,w
                sublw   b'00000000'     ; upper byte error value (3 – 1.8)v
                btfsc   STATUS,z
                call    upper_byte

valtest1        movf    u_term_hi_acce,w
                sublw   b'00000000'     ; upper byte error value (3-1.9)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte2
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle1


valtest2        movf    u_term_hi_acce,w
                sublw   b'00000000'     ; upper byte error value (3-2)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte3
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle2


valtest3        movf    u_term_hi_acce,w
                sublw   b'00000000'     ; upper byte error value (3-2.1)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte4
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle3
```

```
valtest4        movf    u_term_hi_acce,w
                sublw   b'00000000'    ; upper byte error value(3-2.2)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte5
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle4

valtest5        movf    u_term_hi_acce,w
                sublw   b'00000000'    ; upper byte error value (3-2.3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte6
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle5

valtest6        movf    u_term_hi_acce,w
                sublw   b'00000000'    ; upper byte error value (3-2.4)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte7
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle6

valtest7        movf    u_term_hi_acce,w
                sublw   b'00000000'    ; upper byte error value (3-2.5)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte8
                movwf   test_bytelo
                btfss   STATUS,c
                call    set_cycle7

valtest8        movf    u_term_hi_acce,w
                sublw   b'00000000'    ; upper byte error value (3-2.6)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upper_byte9
                movwf   test_bytelo
                btfss   STATUS,c
```

```
                call        set_cycle8

valtest9        movf        u_term_hi_acce,w
                sublw       b'00000000'    ; upper byte error value (3-2.7)v
                movwf       test_bytelo
                btfsc       STATUS,z
                call        upper_byte8
                movwf       test_bytelo
                btfss       STATUS,c
                call        set_cycle9

valtest10       movf        u_term_hi_acce,w
                sublw       b'00000000'    ; upper byte error value (3-2.8)v
                movwf       test_bytelo
                btfsc       STATUS,z
                call        upper_byte9
                movwf       test_bytelo
                btfss       STATUS,c
                call        set_cycle10

valtest11       movf        u_term_hi_acce,w
                sublw       b'00000000'    ; upper byte error value (3-2.9)v
                movwf       test_bytelo
                btfsc       STATUS,z
                call        upper_byte10
                movwf       test_bytelo
                btfss       STATUS,c
                call        set_cycle11
                call        clr_drive


upper_byte      movf        u_term_lo_acce,w
                sublw       b'11110110'    ; lower byte error value (3 – 1.8)v
                movwf       test_bytelo
                btfss       STATUS,c
                call        set_cycle1

upper_byte2     movf         u_term_lo_acce,w
                sublw       b'11100010'    ; lower byte error value  (3 – 1.9)v
                movwf       test_bytehi
                btfss       STATUS,c
                call        set_cycle1
                call        valtest2

upper_byte3     movf         u_term_lo_acce,w
                sublw       b'11001101'    ; lower byte error value  (3 – 2.0)v
                movwf       test_bytehi
                btfss       STATUS,c
                call        set_cycle2
```

```
                    call        valtest3

upper_byte4         movf        u_term_lo_acce,w
                    sublw       b'10111001'    ; lower byte error value (3 – 2.1)v
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle3
                    call        valtest4

upper_byte5         movf        u_term_lo_acce,w
                    sublw       b'10100100'    ; lower byte error value  (3 – 2.2)v
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle4
                    call        valtest5


upper_byte6         movf        u_term_lo_acce,w ;lower byte error value (3 – 2.3)v
                    sublw       b'10010000'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle5
                    call        valtest6


upper_byte7         movf        u_term_lo_acce,w ;lower byte error value (3 – 2.4)v
                    sublw       b'01111011'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle6
                    call        valtest7

upper_byte8         movf        u_term_lo_acce,w ;lower byte error value  (3 – 2.5)v
                    sublw       b'01100111'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle7
                    call        valtest8

upper_byte9         movf        u_term_lo_acce,w ;lower byte error value (3 – 2.6)v
                    sublw       b'01010010'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle8
                    call        valtest9

upper_byte10        movf        u_term_lo_acce,w ;lower byte error value  (3 – 2.7)v
                    sublw       b'00111110'
                    movwf       test_bytehi
```

```
                    btfss       STATUS,c
                    call        set_cycle9
                    call        valtest10

upper_byte11        movf        u_term_lo_acce,w ;lower byte error value (3 – 2.8)v
                    sublw       b'00101001'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle10
                    call        valtest11


upper_byte12        movf        u_term_lo_acce,w ;lower byte error value  (3 – 2.9)v
                    sublw       b'00010101'
                    movwf       test_bytehi
                    btfss       STATUS,c
                    call        set_cycle11
                    goto        $-1

;The duty cycle values based on ON and OFF Pulse Width Modulation

set_cycle1          movlw       h'E5'           ; 100% duty cycle
                    movwf       fr_cnt
                    movlw       h'FE'
                    movwf       fr_cnt2
                    call        dir_chg
                    call        ramp_rou

set_cycle2          movlw       h'E7'           ;95% duty cycle
                    movwf       fr_cnt
                    movlw       h'FD'
                    movwf       fr_cnt2
                    call        dir_chg
                    call        ramp_rou

set_cycle3          movlw       h'E8'           ;90% duty cycle
                    movwf       fr_cnt
                    movlw       h'FC'
                    movwf       fr_cnt2
                    call        dir_chg
                    call        ramp_rou

set_cycle4          movlw       h'E9'           ;85% duty cycle
                    movwf       fr_cnt
                    movlw       h'FB'
                    movwf       fr_cnt2
                    call        dir_chg
                    call        ramp_rou
```

```
set_cycle5      movlw   h'EA'        ;80% duty cycle
                movwf   fr_cnt
                movlw   h'FA'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle6      movlw   h'EC'        ;75% duty cycle
                movwf   fr_cnt
                movlw   h'F9'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle7      movlw   h'ED'        ;70% duty cycle
                movwf   fr_cnt
                movlw   h'F7'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle8      movlw   h'EE'         ;65% duty cycle
                movwf   fr_cnt
                movlw   h'F6'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle9      movlw   h'EF'        ;60% duty cycle
                movwf   fr_cnt
                movlw   h'F5'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle10     movlw   h'F1'        ;55% duty cycle
                movwf   fr_cnt
                movlw   h'F4'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set_cycle11     movlw   h'F2'        ;50% duty cycle
                movwf   fr_cnt
                movlw   h'F2'
                movwf   fr_cnt2
```

```
                call        dir_chg
                call        ramp_rou


clr_drive       bcf         PORTB,5
                bcf         PORTB,7
                bcf         PORTB,1
                bcf         PORTB,2
                movlw       h'e5'
                movwf       fr_cnt
                call        delay1
                call        dir_chg2


; Time delay in ensuring the current is fully flowed to ground before
; Starting to turn the other direction of motor. This is to prevent short circuit from
happening. The delay is about 500ms

dir_chg2        movlw       h'FF'
                movwf       cnt4
Con2            movlw       h'FF'
                Movwf       cnt5
                decfsz      cnt5,1
                goto        $-1
                decf        cnt4,1
                movf        cnt4,w
                sublw       h'be'
                btfss       status,z
                goto        Con2
                incf        num_times
                movf        num_times,w
                subwf       fr_cnt1,w

                btfss       status,z
                goto        dir_chg2
                call        EdgeA


;The other time delay for motor to turn the other direction. The function is same as above
;subroutine

dir_chg         movlw       h'FF'
                movwf       cnt4
Con3            movlw       h'FF'
                movwf       cnt5
                decfsz       cnt5,1
                goto        $-1
                decf        cnt4,1
                movf        cnt4,w
```

```
                sublw       h'be'
                btfss       status,z
                goto        Con3
                incf        num_times
                movf        num_times,w
                sublw       d'20'

                btfss       status,z
                goto        dir_chg
                return

; Thie Ramp_rou subroutine is to start the ramping up of motor voltage
ramp_rou        movlw       h'fc'
                movwf       ramp_cnt
                movlw       h'ea'
                movwf       ramp_cnt2
                call        PWM_ramp
                decf        ramp_cnt
                movf        fr_cnt,w
                subwf       ramp_cnt,w
                btfss       STATUS,c
                call        PWMbegin
                incf        ramp_cnt2
                call        PWM_ramp
                goto        ramp_rou

PWM_ramp        bcf         PORTB,7
                bsf         PORTB,4
                call        delay1
                bcf         PORTB,2
                bsf         PORTB,1
                call        delay2
                bcf         PORTB,7
                bcf         PORTB,4
                call        delay1
                bcf         PORTB,2
                bcf         PORTB,1
                call        delay2
                return

; Output the PWM signal to respective PORTS

PWMbegin        bcf         PORTB,7
                bsf         PORTB,4
                call        delay1
                bcf         PORTB,2
                bsf         PORTB,1
                call        delay2
                bcf         PORTB,7
```

```
                bcf     PORTB,4
                call    delay1
                bcf     PORTB,2
                bcf     PORTB,1
                call    delay2
                incf    cnt3
                movf    cnt3,w
                sublw   d'50'
                btfss   status,z
                goto    PWMbegin
                clrf    cnt3
                clrf    num_times
                 call   EdgeA
```

;Below are the subroutines to select the appropriate duty cycle values based on the on and
;off time of pulses.

```
set2_cycle1     movlw   h'E5'
                movwf   fr_cnt
                movlw   h'FE'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set2_cycle2     movlw   h'E7'
                movwf   fr_cnt
                movlw   h'FD'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set2_cycle3     movlw   h'E8'
                movwf   fr_cnt
                movlw   h'FC'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set2_cycle4     movlw   h'E9'
                movwf   fr_cnt
                movlw   h'FB'
                movwf   fr_cnt2
                call    dir_chg
                call    ramp_rou

set2_cycle5     movlw   h'EA'
                movwf   fr_cnt
                movlw   h'FA'
                movwf   fr_cnt2
```

```
                call        dir_chg
                call        ramp_rou

set2_cycle6     movlw       h'EC'
                movwf       fr_cnt
                movlw       h'F9'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou


set2_cycle7     movlw       h'ED'
                movwf       fr_cnt
                movlw       h'F7'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou

set2_cycle8     movlw       h'EE'
                movwf       fr_cnt
                movlw       h'F6'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou

set2_cycle9     movlw       h'EF'
                movwf       fr_cnt
                movlw       h'F5'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou

set2_cycle10    movlw       h'F1'
                movwf       fr_cnt
                movlw       h'F4'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou

set2_cycle11    movlw       h'F2'
                movwf       fr_cnt
                movlw       h'F2'
                movwf       fr_cnt2
                call        dir_chg
                call        ramp_rou


delay1          movlw       h'FF'    ; PWM modulation based on the
                movwf       cnt2     ;values given by fr_cnt and fr_cnt2
```

```
Con             movlw   h'FF'
                movwf   cnt1
                decfsz  cnt1,1
                goto    $-1
                decf    cnt2,1
                movf    cnt2,w
                subwf   fr_cnt,w
                btfss   status,z
                goto    Con
                return

delay2          movlw   h'FF'
                movwf   cnt2
Con5            movlw   h'FF'
                movwf   cnt1
                decfsz  cnt1,1
                goto    $-1
                decf    cnt2,1
                movf    cnt2,w
                subwf   fr_cnt2,w

                btfss   status,z
                goto    Con5
                return


cw
                comf    u_term_hi_acce,f
                comf    u_term_lo_acce,f
                movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.1-3)v
                btfsc   STATUS,z
                call    upperbyte


val_test1       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.2-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte9
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle11


val_test2       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.3-3)v
                movwf   test_bytelo
```

```
                btfsc   STATUS,z
                call    upperbyte11
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle10

val_test3       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value  (3.4-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte10
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle9

val_test4       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.5-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte9
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle8

val_test5       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.6-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte8
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle7

val_test6       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.7-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte7
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle6

val_test7       movf    u_term_hi_acce,w
```

```
                sublw   b'00000000'    ;Upper byte error value (3.8-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte6
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle5

val_test8       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (3.9-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte5
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle4

val_test9       movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (4.0-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte4
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle3

val_test10      movf    u_term_hi_acce,w
                sublw   b'00000000'    ;Upper byte error value (4.1-3)v
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte3
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle2

val_test11      movf    u_term_hi_acce,w ;Upper byte error value (4.2-3)v
                sublw   b'00000000'
                movwf   test_bytelo
                btfsc   STATUS,z
                call    upperbyte2
                movwf   test_bytelo
                btfsc   STATUS,c
                call    set2_cycle1
                call    clr_drive
```

```
upperbyte       movf    u_term_lo_acce,w
                sublw   b'00010100'    ;lower byte error value (3.1-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle11

upperbyte2      movf    u_term_lo_acce,w
                sublw   b'00101001'    ;lower byte error value (3.2-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle11
                call    val_test11

upperbyte3      movf    u_term_lo_acce,w
                sublw   b'00111101'    ;lower byte error value (3.3-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle10
                call    val_test10

upperbyte4      movf    u_term_lo_acce,w
                sublw   b'01010010'    ;lower byte error value (3.4-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle9
                call    val_test9

upperbyte5      movf    u_term_lo_acce,w
                sublw   b'01100110'    ;lower byte error value (3.5-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle8
                call    val_test8

upperbyte6      movf     u_term_lo_acce,w
                sublw   b'01111011'    ;lower byte error value (3.6-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle7
                call    val_test7

upperbyte7      movf     u_term_lo_acce,w
                sublw   b'10001111'    ;lower byte error value (3.7-3)v
                movwf   test_bytehi
                btfsc   STATUS,c
                call    set2_cycle6
```

```
                call        val_test6

upperbyte8      movf        u_term_lo_acce,w ;lower byte error value (3.8-3)v
                sublw       b'10100100'
                movwf       test_bytehi
                btfsc       STATUS,c
                call        set2_cycle5
                call        val_test5

upperbyte9      movf        u_term_lo_acce,w ;lower byte error value  (3.9-3)v
                sublw       b'10111000'
                movwf       test_bytehi
                btfsc       STATUS,c
                call        set2_cycle4
                call        val_test4


upperbyte10     movf         u_term_lo_acce,w     ;lower byte error value (4-3)v
                sublw       b'11001101'
                movwf       test_bytehi
                btfsc       STATUS,c
                call        set2_cycle3
                call        valtest3

upperbyte11     movf        u_term_lo_acce,w;lower byte error value (4.1-3)v
                sublw       b'11100001'
                movwf       test_bytehi
                btfsc       STATUS,c
                call        set2_cycle2
                call        valtest2

upperbyte12     movf        u_term_lo_acce,w ;lower byte error value (4.2-3)v
                sublw       b'11110110'
                movwf       test_bytehi
                btfsc       STATUS,c
                call        set2_cycle1
                call        valtest1
```

Overall balancing program (Gyro only) (MPLAB)

```
        List    p=16F877a
                include  "p16f877a.inc"
                __config _cp_off & _wdt_off & _xt_osc & _pwrte_on



cnt1                            equ     2AH
cnt2                            equ     2CH
cnt3                            equ     2DH
cnt4                            equ     2EH
cnt5                            equ     3BH
num_times                       equ     3DH
fr_cnt                          equ     3FH
fr_cnt2                         equ     7AH
fr_cnt1                         equ     7BH
test_bytehi                     equ     6AH
test_bytelo                     equ     6CH
gy_calc_angle_vel_new_hi        equ     20H
gy_calc_angle_vel_new_lo        equ     21H
gy_calc_angle_new_hi            equ     22H
gy_calc_angle_new_lo            equ     23H
tilt_temp_hi                    equ     24H
tilt_temp_lo                    equ     25H
Kt_tilt_hi                      equ     26H
Kt_tilt_lo                      equ     27H
Kv_tilt_hi                      equ     28H
Kv_tilt_lo                      equ     29H
Ka_tilt_hi                      equ     30H
Ka_tilt_lo                      equ     31H
tilt_rate_hi                    equ     32H
tilt_rate_term_lo               equ     33H
gy_calc_angle_old_hi            equ     34H
gy_calc_angle_old_lo            equ     35H
gy_calc_angle_vel_old_hi        equ     36H
gy_calc_angle_vel_old_lo        equ     37H
u_term_hi                       equ     38H
u_term_lo                       equ     39H
Time_lo                         equ     40H
Time_hi                         equ     41H
set_point_lo                    equ     43H
set_point_hi                    equ     45H
prod_res0                       equ     54H
prod_res1                       equ     53H
prod_res2                       equ     52H
prod_res3                       equ     51H
Arg_hi                          equ     57H
```

```
Arg_lo                  equ     58H
Sum_hi                  equ     59H
Sum_lo                  equ     60H
var_hi                  equ     61H
var_lo                  equ     62H
pwm_bit_cnt             equ     63H
pwm_bit                 equ     64H
pwm_bit_cnt2            equ     65H
pwm_bit2                equ     66H
count                   equ     67H
TILT_RATE_LO            equ     68H
tilt_term_hi            equ     69H
tilt_term_lo            equ     70H
tilt_rate_term_hi       equ     71H
temp_lo                 equ     72H
gy_temp_angle_old_hi    equ     73H
gy_temp_angle_old_lo    equ     74H
tilt_hi                 equ     75H
tilt_lo                 equ     76H
ramp_cnt                equ     77H
ramp_cnt2               equ     78H



        ; Start at the reset vector
    org     0x000
    goto    start

Start
        bsf         STATUS,RP0          ;Bank 1
        bcf         STATUS,RP1
        clrf        TRISB               ;PORTB [7-0] outputs
        movlw       b'10000000'
        movwf       ADCON1              ;Right justified, all A/D
        movlw       b'00000000'
        movwf       OPTION_REG
        bcf         STATUS,RP0      ;Bank 0
        movlw       B'01011001'     ;Fosc/8 [7-6], A/D ch3 [5-3], A/D on [0]
        movwf       ADCON0
        clrf        PORTB
        clrf        cnt3
        clrf        num_times
        movlw        d'8'
        movwf       num_samples

Main
        call    ad_portb
        goto    Main
```

```
ad_portb
                                ;wait for acquision time (20uS)
        bsf     ADCON0,GO       ;Start A/D conversion
Wait
        btfsc   ADCON0,GO       ;Wait for conversion to complete
        goto    Wait


;tilt error value = (ADC(x)-3.0)

comp_ute
                        movwf   Arg_lo
                        movf    ADRESH,w ; Store in ADC 10-bit result
                        movwf   Arg_hi      ; register
                        movf    temp_acchi,w
                        movwf   Sum_hi
                        movf    temp_acclo,w
                        movwf   Sum_lo

                        call    add
                        movf    Sum_hi,w
                        movwf   gy_calc_angle_new_hi
                        movf    Sum_lo,w
                        movwf   gy_calc_angle_new_lo
                        decfsz  num_samples
                        call    wait
                        movlw   d'8'                ;Averaging of 8 samples
                        movwf   num_samples

                        movf    gy_calc_angle_new_hi,w
                        movwf   Arg_hi
                        movf    gy_calc_angle_new_lo,w
                        movwf   Arg_lo
                        movlw   b'00000010'
                        movwf   Sum_hi
                        movlw   b'00000001'
                        movwf   Sum_lo
                        call    substract
                        movf    Sum_hi,w
                        movwf   tilt_temp_hi
                        movf    tilt_temp_hi,w
                        movwf   Arg_hi
                        movf    Sum_lo,w
                        movwf   tilt_temp_lo
                        movf    tilt_temp_lo,w
                        movwf   Arg_lo

                        movlw   b'00000000'
```

```
movwf   Kt_tilt_hi
movf    Kt_tilt_hi,w
movwf   var_hi
movlw   b'00000001'
movwf   Kt_tilt_lo
movf    Kt_tilt_lo,w
movwf   var_lo
call    mul
movf    prod_res1,w
movwf   tilt_hi
movf    prod_res0,w
movwf   tilt_lo


movlw   b'00000000'
movwf   Kv_tilt_hi
movlw   b'00000001'
movwf   Kv_tilt_lo
movf    Kv_tilt_hi,w
movwf   Arg_hi
movf    Kv_tilt_lo,w
movwf   Arg_lo
movf    tilt_hi,w
movwf   var_hi
movf    tilt_lo,w
movwf   var_lo
call    mul
movf    prod_res1,w
movwf   u_term_hi
movf    prod_res0,w
movwf   u_term_lo

movf    ADRESH,w
sublw   b'00000010' ; Upper byte for analog value 3V
call    no_drive
movwf   temp_lo
btfsc   STATUS,c
call    ccw
call    cw
```

The following program is similar to the list of program from pg 94, no-drive subroutine to pg 109 .

Multiplication program

```
Mul
                ;movlw          b'00010010'
                ;movwf          Arg_lo
                ;movlw          b'00011000'
                ;movwf          Arg_hi
                ;movlw          b'10010100'
                ;movwf          var_lo
                ;movlw          b'01110000'
                ;movwf          var_hi
                clrf        prod_res0
                clrf        prod_res1
                clrf        prod_res2
                clrf        prod_res3
                clrf        count
                movlw       d'17'
                movwf       count

                movf        var_lo,w            ; Place the value from other program
                                                ;loop
movwf           prod_res0           ;into the variable of this
                                    ;multiplication loop.
                btfss       status,z        ;Check whether the product_res0 is zero
                call        Check_n
                movf        var_hi,w            ;the product_res0 is zero
                movwf       prod_res1           ;Check the next upper byte.
                btfsc       status,z
                call        equal_zero

Check_n         btfss       status,c
                Call        add_var
                movf        var_hi,w
                Movwf       prod_res1


Check_Arg       movf        Arg_Lo,f
                btfss       status,z        ;Test if value of Arg_Lo is zero
                call        test_lsb            ;Arg_lo is not zero
                movf        Arg_Hi,w            ;Arg_lo is zero
                btfsc       status,z        ;Test if value of Arg_Hi is zero
                call        equal_zero          ;Arg_Hi is equal to zero
                call    test_lsb

add_var         incf    prod_res1
                movf    var_hi,w
                movwf   prod_res1
```

```
test_lsb    bcf     status,c
            rrf     prod_res3
            rrf     prod_res2
            rrf     prod_res1
            rrf     prod_res0
            btfss   status,c        ;Test if there is carry bit
            call    shift               ; There is no carry
            movf    Arg_lo,w        ;Upper two bytes is added with the bytes
            addwf   prod_res2,f         ;of the Arg_Hi:Arg_Lo.
            Btfsc   status,c
            call    Add_Hi
            movf    Arg_Hi,w
            addwf   prod_res3,f
            call    shift

equal_zero  clrf    prod_res0   ; the multiplication result is zero.
            clrf    prod_res1
            clrf    prod_res2
            clrf    prod_res3
            call    stop            ;Exit from the mul subroutine

Add_Hi      incf    prod_res3
            Movf    Arg_Hi,w
            Addwf   prod_res3


shift       decfsz  count
            call    test_lsb
            goto    stop

stop clrf   count
```

Division program

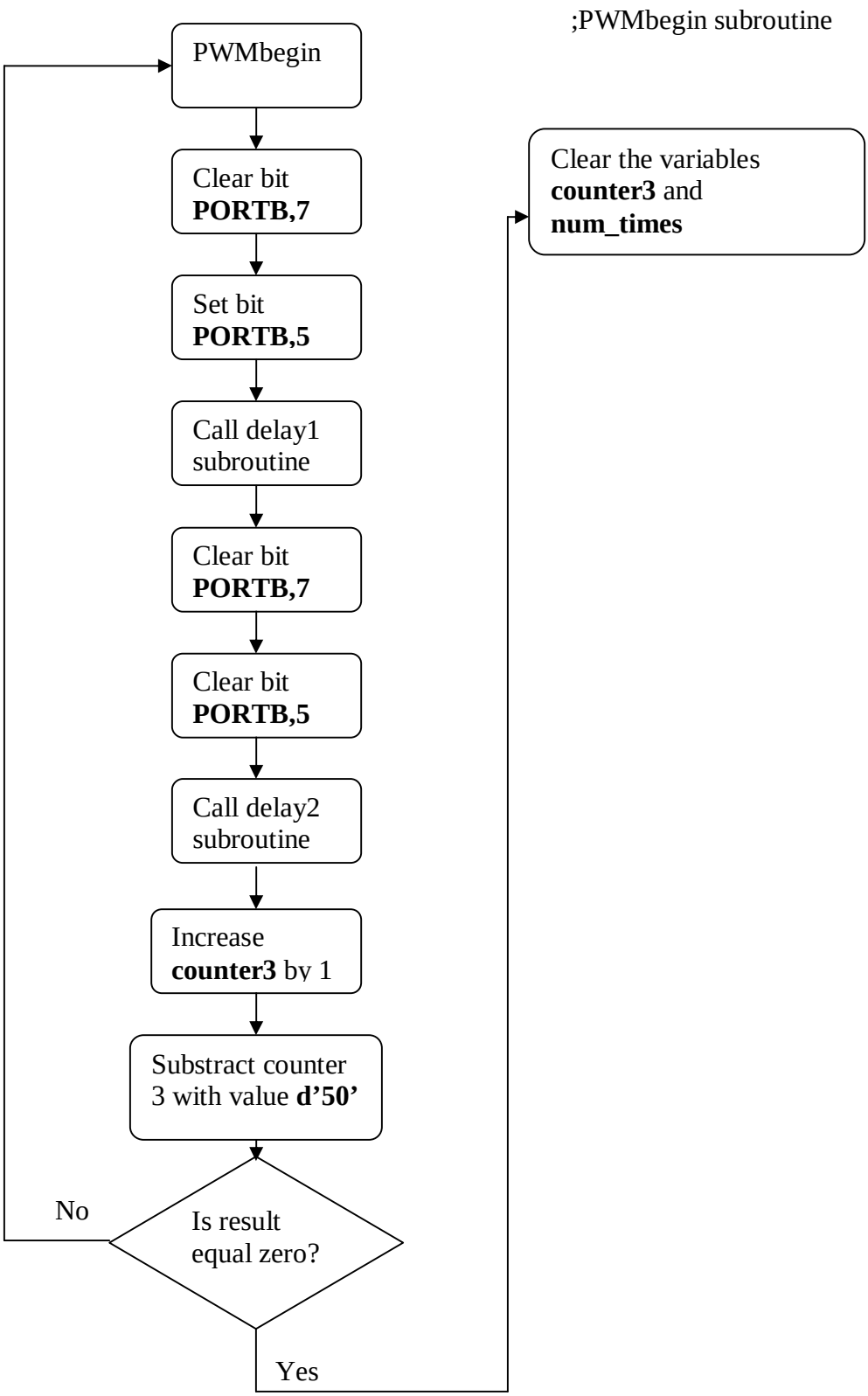
```
Division
                ;movlw      b'00010010'   ;Inserting the values into divisor and the
                ;movwf      divisor0      ;number to be divided.
                ;movlw      b'00011000'
                ;movwf      divisor1
                ;movlw      b'00111000'
                ;movwf      divisor2
                ;movlw      b'01001000'
                ;movwf      divisor3
                ;movlw      b'10010100'
                ;movwf      prod_res0
                ;movlw      b'01110000'
                ;movwf      prod_res1
                ;movlw      b'00000100'
                ;movwf      prod_res2
                ;movlw      b'11100000'
                ;movwf      prod_res3

Clrf            rem_dr0     ;Initialise variables by clearing all the values
                Clrf        rem_dr1
                clrf        rem_dr2
                clrf        rem_dr3
                clrf        Quo_0
                clrf        Quo_1
                clrf        Quo_2
                clrf        Quo_3
                Movlw       32
                Movwf       bitcnt



Loop            rlf         prod_res0     ;Clear the 32 bit result registers
                rlf         prod_res1
                rlf         prod_res2
                rlf         prod_res3
                rlf         rem_dr0
                rlf         rem_dr1
                rlf         rem_dr2
                rlf         rem_dr3



movf            divisor3,w  ;Compare divisor and remainder
```

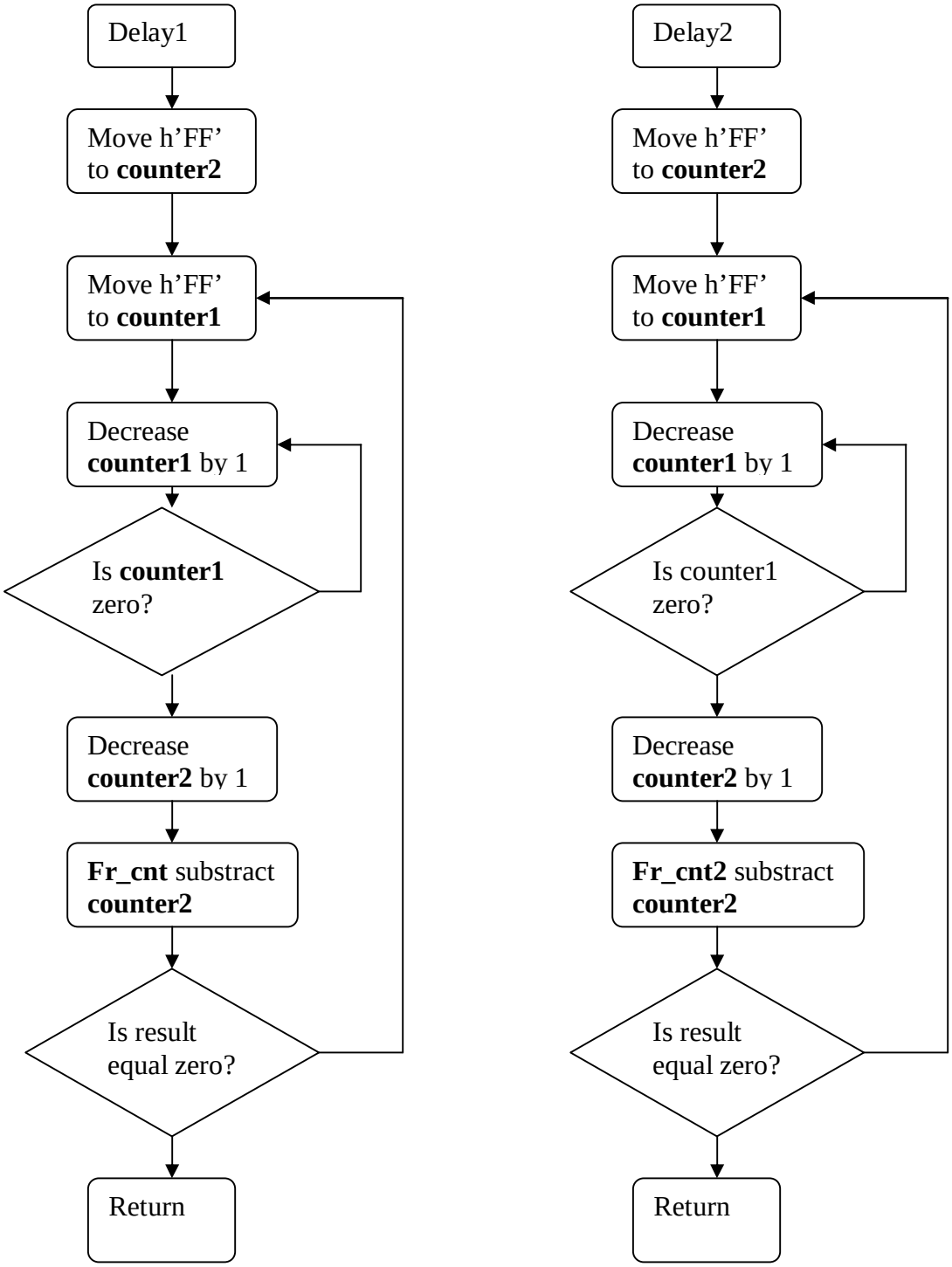
```
                subwf       rem_dr3,w
                btfss       STATUS,z
                call        test_more3      ;test if rem_dr3 is more than divisor if not

equal           movf        divisor2,w      ;High byte is equal, so test the lower byte
                subwf       rem_dr2,w
                btfss       STATUS,z
                call        test_more2
                movf        divisor1,w      ;Test the lower bytes
                subwf       rem_dr1,w
                btfss       STATUS,z
                call        test_more1
                movf        divisor0
                subwf       rem_dr0,w
                call        test_more0

;These sections are to test the result byte whether the divisor value is
;larger or smaller than the rem_dr value.
;If the rem_dr value is larger then the divisor then goto subs subroutine

test_more3      btfss       STATUS,c
                call        last
                call        subs2

test_more2      btfss       STATUS,c
                call        last
                call        subs1

test_more1      btfss       STATUS,c
                call        last
                call        subs0

test_more0      btfss       STATUS,c
                call        last
                bsf         prod_res0,0
                call        last

;These sections subs2, subs1 and subs3 are to compare
;the adjacent bytes on whether there is any carry bits.
;If there is any carry, adjust affected bytes by decresing one
;bit value
```

```
subs2   movf    divisor2,w
        subwf   rem_dr2,w
        btfss   STATUS,c
        decf    rem_dr3
        movf    divisor3,w
        subwf   rem_dr3,w
        movf    divisor1,w
        subwf   rem_dr1,w
        btfss   STATUS,c
        decf    rem_dr2
        movf    divisor2,w
        subwf   rem_dr2,w
        movf    divisor0,w
        subwf   rem_dr0,w
        btfss   STATUS,c
        decf    rem_dr1
        movf    divisor1,w
        subwf   rem_dr1,w
        bsf     prod_res0,0
        call    last

subs1   movf    divisor1,w
        subwf   rem_dr1,w
        btfss   STATUS,c
        decf    rem_dr2
        movf    divisor2,w
        subwf   rem_dr2,w
        movf    divisor0,w
        subwf   rem_dr0,w
        btfss   STATUS,c
        decf    rem_dr1
        movf    divisor1,w
        subwf   rem_dr1,w
        bsf     prod_res0,0
        call    last

subs0   movf    divisor0,w
        subwf   rem_dr0,w
        btfss   STATUS,c
        decf    rem_dr1
        movf    divisor1,w
        subwf   rem_dr1,w
        bsf     prod_res0,0
        call    last


last    decfsz  bitcnt          ;Test whether 32 rotations has been
        Goto    loop            ;executed
```

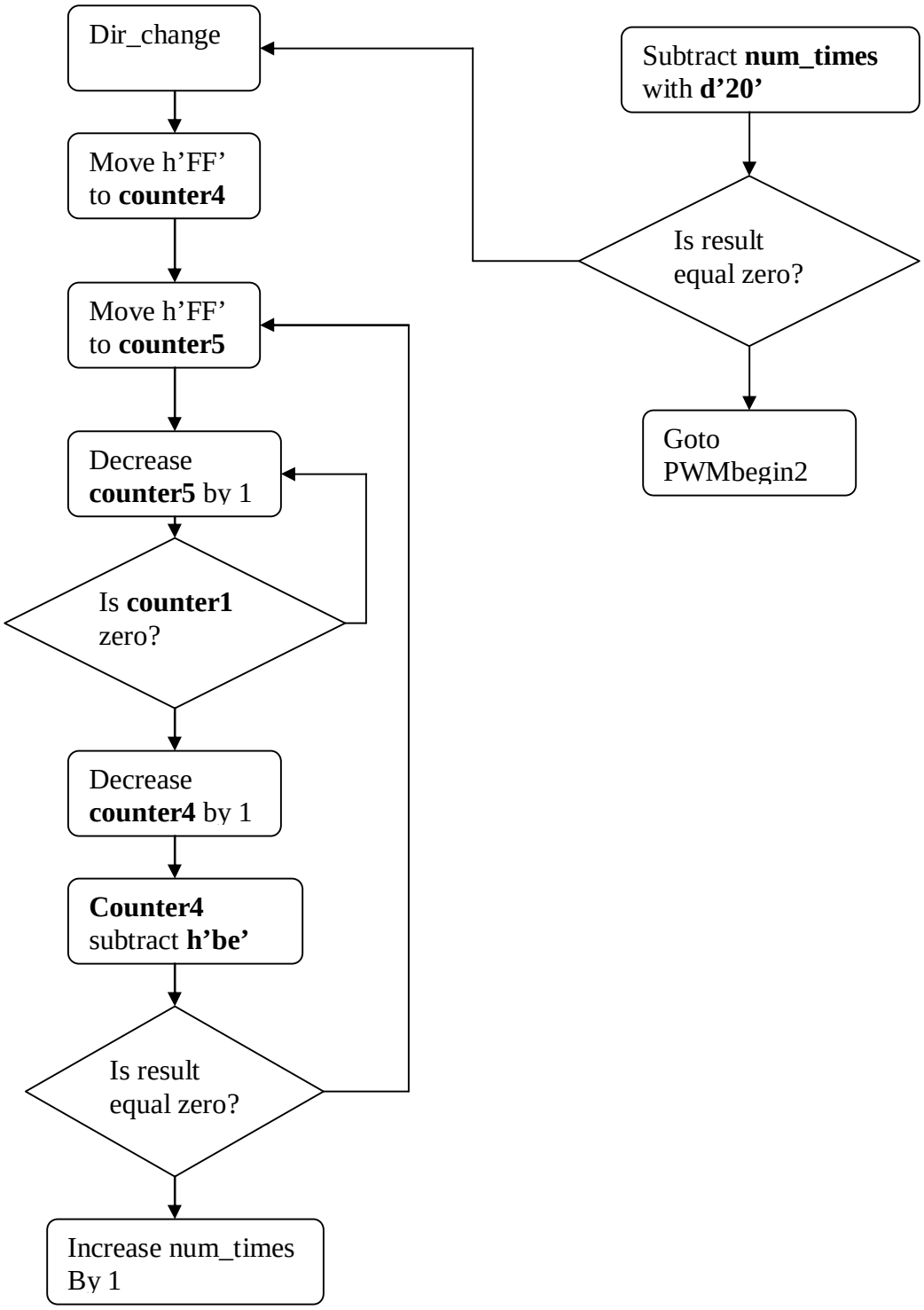
```
Movf        prod_res0,w
Movwf       Quo_0           ;Result is stored in Quo variables
Movf        prod_res1,w             ;The result is 32 bits values
Movwf       Quo_1
Movf        prod_res2,w
Movwf       Quo_2
Movf        prod_res3,w
Movwf       Quo_3

End
```

Programming flow-chart (On h-bridge (bi-direction motor turn))

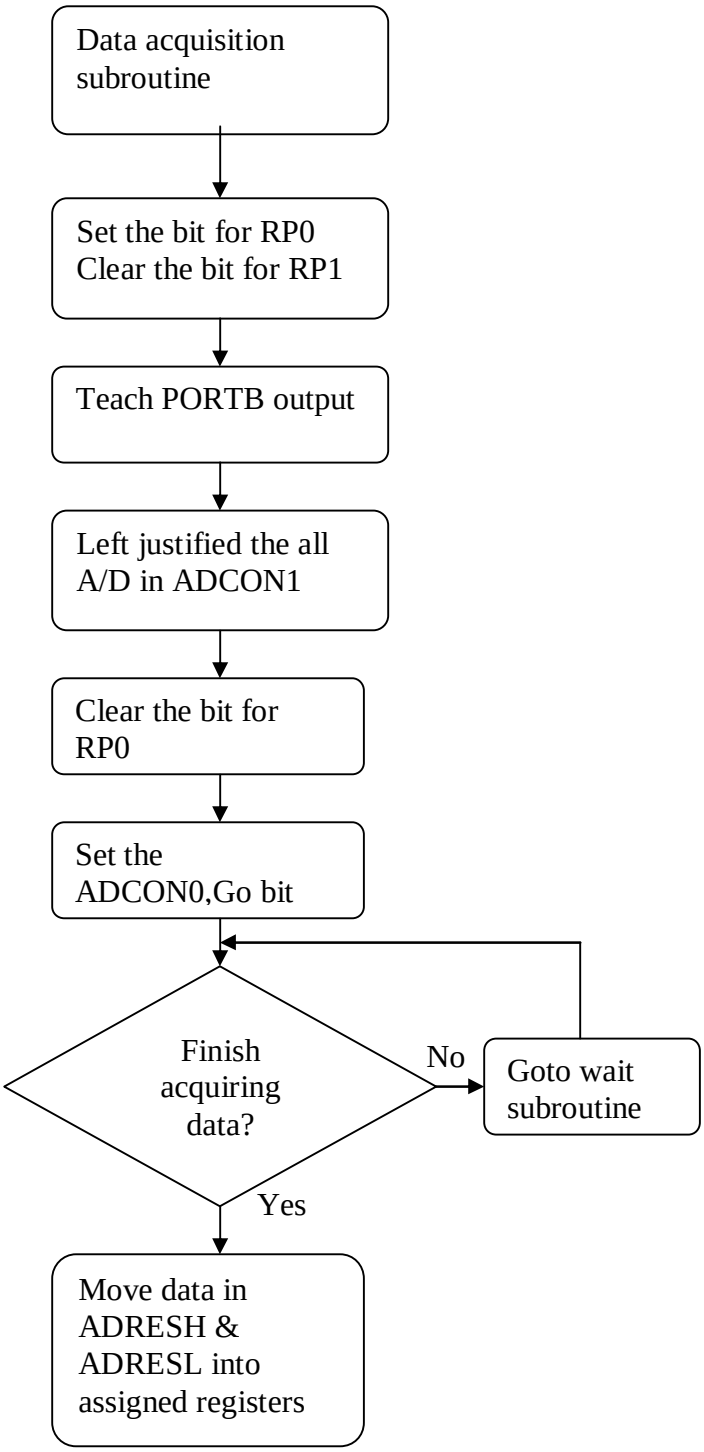




Direction change subroutine



Data Acqusition flow chart



Gyro-Accelerometer

```
;If one of the portc,2 exhibit a 1 signal then use the accelerometer data
;If portc,2 exhibit a 0 signal then use the gyro data
;Both the accelerometer and gyro run simulaneously
;Refer to the CD for more details

Data_chg        btfsc       PORTC,2
                call        acce_data
                call        gyro_data

acce_data       movf        u_term_lo_acce,w
                movwf       u_term_lo
                movf        u_term_hi_acce,w
                movwf       u_term_hi
                return

gyro_data       movf        u_term_lo_gyro,w
                movwf       u_term_lo
                movf        u_term_hi_gyro,w
                movwf       u_term_hi
                return

                end
```