UNIVERSITY OF FLORIDA

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

EEL 5666C
INTELLIGENT MACHINES DESIGN LAB

Final Report

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I. ABSTRACT

The importance of having a good robot design is whether or not it can be practically feasible, while at the same time resourceful. In the course of determining basic functions for my robot, first, I had to figure out all of the possible limitations that could obstruct my goals. However, the biggest constraints for most peoples' projects always seem to arrive in the forms of time, energy and/or money; three of which I have neither of. Therefore, reusing old parts and implementing pre-built parts seemed the most cost/time effective method.

The idea of a "Fire-fighting" robot, with the capability of intelligent decision-making, sparked an interest in me as early as a year ago. Over the course of this summer semester, my goal is to make this "idea" a practical reality. Many attempts have been previously made upon this similar concept, and I plan to conduct improvements where I see fit. My overall goal is to basically develop a more flexible model that will conduct the same old routines in a more effective manner.

II. EXECUTIVE SUMMARY

Over the summer (2004), I was part of the IMDL group, directed by Drs. Eric Schwartz and Antonio Arroyo. I was actually able to design and create an autonomously moving and "fire-detecting" robot that doused flames (…or anything in its path). Throughout the summer, I encountered plenty of setbacks and suffered from quite a few "explosions" (human-error of course). But, that was all done in the process of learning and at a price ($$$). Additionally, I got the chance to interface several different hardware platforms, and integrated them into one package. Prior to this experiment, an application of this type seemed a little difficult. Now, however, I feel I should and will improve upon this design in the months ahead. Overall, my robot design functioned "mediocre". I think it basically did the job, but nothing else. There was room for several improvements to be made. First and foremost, was the lack of power and calibration from my "driving" motors. They were simply not designed for the purpose I had in mind. Second, the chassis could not provide enough cabinet space for all of the necessary components to work "error-free". After these two, there were several others to follow. In contrast, there were actually some positive things that came out of this whole project. First, my programming code is pretty much universal, and I had the opportunity to create some very efficient and useful functions (assembly language). These can be used in future applications and/or versions of this project. Also, I got the opportunity to learn about PICs. Actually, these microprocessors are incredible, and I highly recommend becoming familiar in their broad range of uses, and their simple register space and instruction set.

III. INTRODUCTION

A problem that exists to this day is that people directly interact with fires in the process of extinguishing them. A large number of injuries and fatalities occur every year because of this interaction. A solution to this problem is to allow an intelligent robot to complete this risky task for them. However, due to practical reasons and particular time constraints (being a student and employed), I will be limited to a less flexible robot (in terms of its intelligence and ability to navigate through "rough" environments).

My "Fire-fighting" robot is dubbed "FLAME"; an acronym that stands for: ***F****ire* ***L****ocator* ***A****nd* ***M****echanical* ***E****xtinguisher*. The very nature of this robot is pretty much self-explanatory. It will roam around a small-sized arena and avoid obstructions in its path, while simultaneously reading its environment for an open flame. If and when an open flame has been detected, it will try to align itself so an extinguishing mechanism can be activated. Then, (business as usual) the robot will continue its search for another flame.

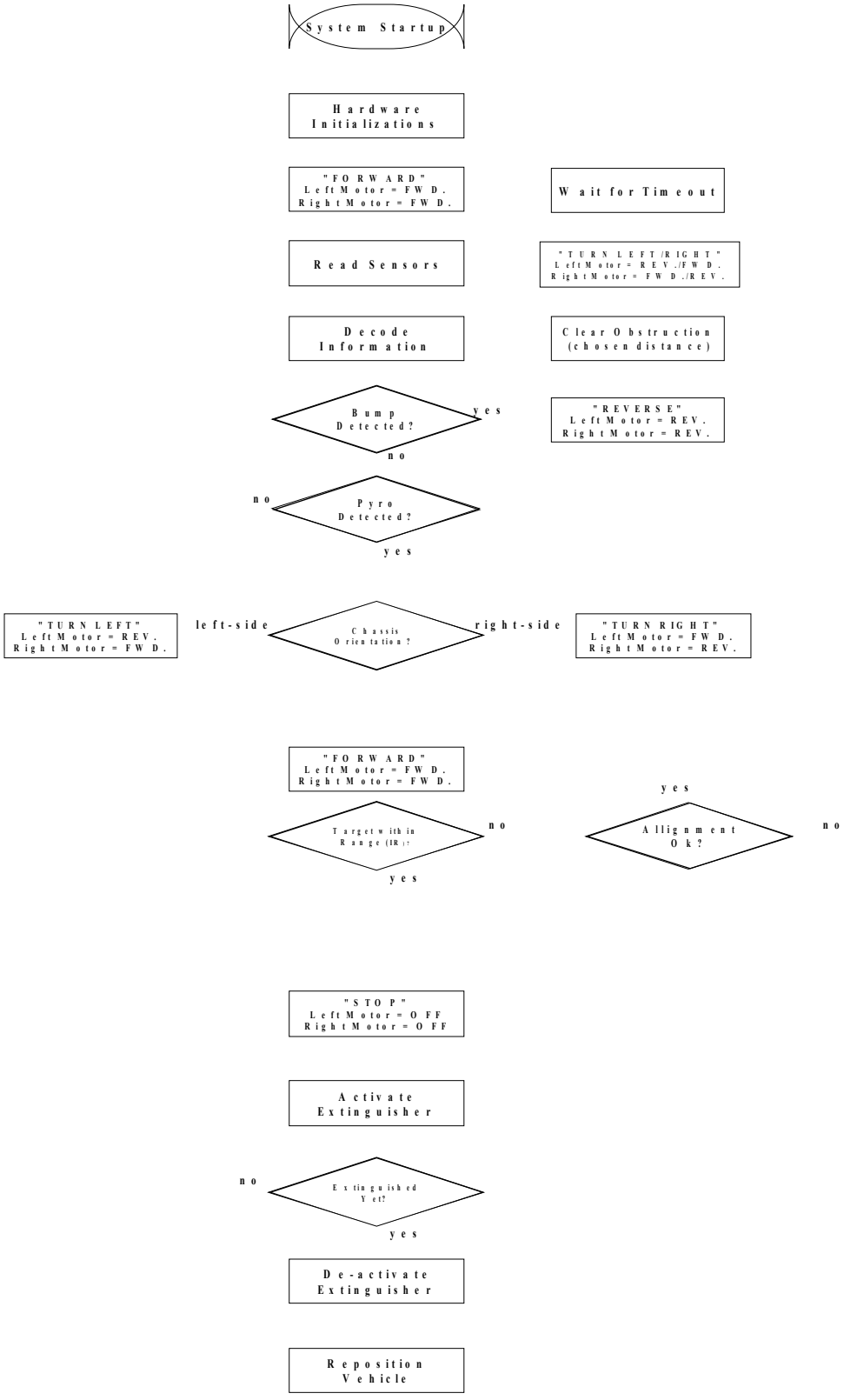
In the course of reading this report, I definitely plan to inform the viewer of the details in my designing of this autonomous "Fire-fighting" robot. The report is broken down into several sections regarding the required hardware and software (code) and experimental results that concluded. A "walk-through" of the steps and building process will be fully provided to allow for easy duplication and/or upgrading for future projects. Specifically, these steps include sections from: Integrated System, Mobile Platform, Actuation, Sensors, Behaviors, and

Experimental Layout/Results. Most likely though, this report will only serve one purpose: as a reference to the "work-arounds" for many of the problems I encountered throughout the experiment.

IV. INTEGRATED SYSTEM

The system consists of a set number of routines or patterns to carry out the tasks of a simple "Fire-fighting" robot. Figure 1.1 shows a general flowchart of the entire procedure. A run-through of the procedure illustrates a maximum of seven decision-making blocks to test different types of sensors and drive motors. Depending on each of their outcomes, different parameters will be set. As a result, the robot should be able to accomplish its task, and continue in an endless loop cycle.

Figure 1.1



V. MOBILE PLATFORM

The chassis to "FLAME" has been built several times, through the use of the T-tek machine and CAD software. The framework is built from 1/8th inch wood, and the motors, wheels and tracks can be mounted easily. The entire chassis is actually quite small, and the guts of it are packed (stuffed) with wires. Basically, it could have been slightly larger to aid better debugging/testing. At the end of the semester (3rd build), the chassis cabinet had all sorts of wires dangling and interfering with each other. It did not look very cosmetic at all! Figures 1.2a and 1.2b below, will give you the dimensions of the chassis.

Figure 1.2a

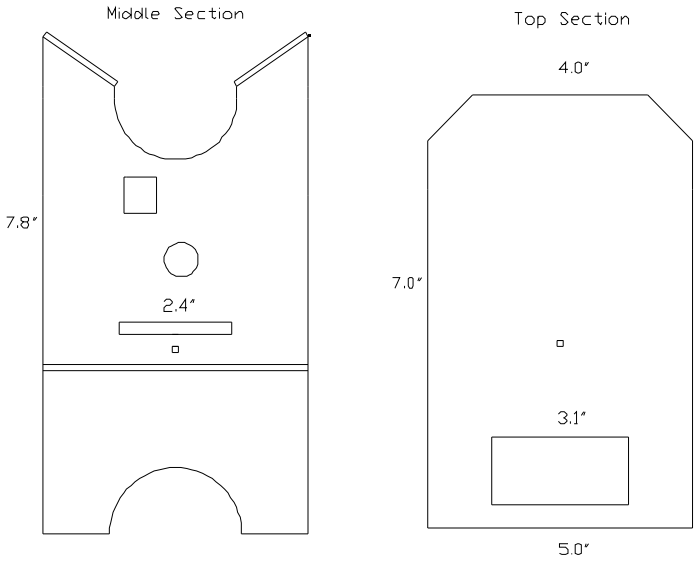
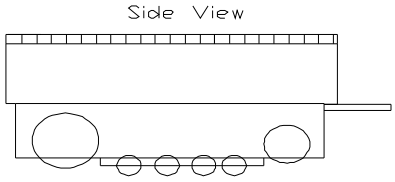


Figure 1.2b



VI. ACTUATION

F.L.A.M.E.'s internals consist of a many components: the chassis, microcontroller, battery packs, water reservoir and crank. The chassis will have two tracks for mobility (similar to a tank's design). Two motors mounted in the rear will control both tracks independently (to allow for all possible movement). These motors will drive two wheels, and those wheels will drive their corresponding tracks. Stationary wheels (placed slightly lower than the "driving wheels") should make clean traction with the surface. The microcontroller and battery packs are physically located on the rear or the top to prevent water damage. The water reservoir and crank are fitted to the center of the chassis (located more towards the front). Three IR cans were mounted on the front. The risk of water damage to electrical components must definitely be considered.

The majority of my design has probably been in implementing control over the motors. Originally software control in the microcontroller's memory would make it possible to move the chassis, via Pulse Width Modulation. However, after several motors were stripped due to current overloads, that design had to be

scrapped. Basically, the H-Bridge (originally intended for use with these motors), had to be supplied with at least (10V to 12V) for those chips (LMD18200) to even operate. A duty cycle could reduce the voltage requirement on the load. However, the problem was not that the voltage could not be stepped-down. The problem stemmed from the current that was generating from my power source. As a result, an alternate "relay" system (not recommended) was improvised. Each motor would be connected to a bus-line, where several relay outputs would be fed into. Voltages on those relays were actually +3.0V (fast-forward), +1.5V (slow-forward) and -1.5V (slow-reverse). Then, it was basically up to software to set/clear the necessary port-C bits to enable directions and speeds. Speeds were basically preset, and only the power-sources could change them. Also, it would probably be good to include a transition delay period to allow any relays to be shut down before turning on any others (power-source collision).

VII. SENSORS

The main sensor in detecting fire in a small room will be a "Pyro-Electric" sensor. Hamamatsu's "UVTron" is a recommended choice for this purpose. It comes complete with a bulb and a processor board for filtering pulses. I got the idea to use this device from a previous students' "Fire-fighting" robot design. For application purposes, an interrupt system will sample and record the number of pulses generated during a period of time (Timer-0). If the number of pulses exceeds the desired level, then a special register bit will be set (cleared if pulses generated is insufficient).

The only other sensors in my system are the IR cans (Sharp GP2Y0A02YK). These must be configured with the A/D subsystem on Port-A of my processor. The analog values can be recorded once the initializations (delay-time needed) are complete. Then, it is just up to software to enable/disable channels to read from. In my particular design, I am using three IR cans. Therefore, in code I must set the correct configuration (for each channel) before reading from any of them.

VIII. BEHAVIORS

The central "initial" behavior for my "Fire-fighting" robot is to circle a path while detecting fire. Then, when a fire has been detected, it should maneuver itself toward the target (repositioning in the case of going off-course). Finally, when the target has reached certain proximity, the robot should come to a halt and the extinguishing system should take over. The robot can accomplish this by setting or clearing flags in memory with an interrupt system. Significant overhead can be reduced from this method by limiting the bulk of the code to subroutines from "main( )". A particular register in memory (Pyro-bit0) was actually used for my fire detection process. Setting or clearing this register-bit communicates an "on/off" state, which will allow selected subroutines to be called-up. The entire code (roughly 1500 including several unused functions) can be viewed in the Appendix of this report.

IX. EXPERIMENTAL LAYOUT AND RESULTS

Typical interface data for my pyro-sensor (Hamamatsu UVTron) consists of a set number of pulses, given the proximity of an open flame to the sensor. For example, a higher number of pulses suggest an open flame is nearer to the sensor, and a lower number for a farther distance. Actual data is given below for this device (Table 1.1). Note that the actual number of counted pulses will depend on the Timer-0 delay time (threshold). The IRs (Sharp GP2Y0A02YK) operated differently than the pyro-sensor, in that the interrupt system was not relied upon. The IRs utilized the A/D subsystem (input capture) and gave the proximity of an object relative to a magnitude. For example, a higher magnitude represented a "closer" object, and a small magnitude for a "farther" object. This information is available in Table 1.2. Note that a linear representation of (magnitude vs. distance) varies, and may become unstable at very close proximities (resulting in a non-linear curve). This can be viewed in Figure 1.3.

Table 1.1

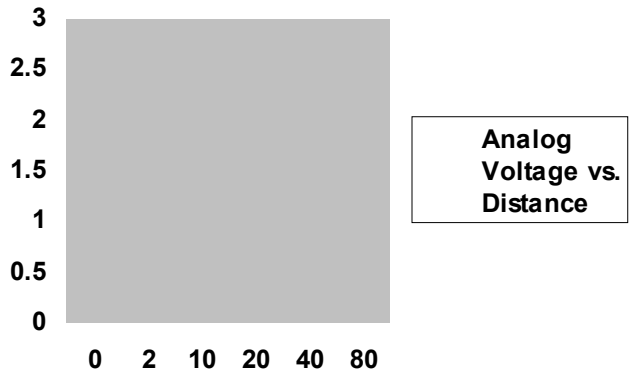
Degrees from Center	UVTron (# pulses)	Timer-0 Delay time	Proximity
0	12	1.0 s	10"
+/- 45	12	1.0 s	10"
+/- 90	11	1.0 s	10"
0	12	1.0 s	24"
+/- 45	11	1.0 s	24"
+/- 90	8	1.0 s	24"
0	12	1.0 s	72"
+/- 45	11	1.0 s	72"

+/- 90	7	1.0 s	72”

Table 1.2

Distance (cm)	Voltage (V)	Hex value
2	0.70	h’7C’
10	2.60	h’209’
20	1.40	h’1A7’
40	0.75	h’97’
80	0.50	h’5F’

Figure 1.3



X. CONCLUSIONS

Over the course of this semester I have reached two conclusions. One is that my robot did work. Second is that there is much needed room for improvement. Much of my problems resulted from incompatibilities with parts. The motors on my vehicle could definitely be upgraded. They were just not acceptable in order

to provide a sustained and accurate means of mobility. On the other end, there was some careless human-error that could have saved me some extra money in the long run. I burned quite a few PIC chips, simply by connecting ports incorrectly. A good bit of advice is to spend some extra time just reviewing a circuit. It will save time and money in the long run. On a different note, future work on this application is a most likely consideration. I think that in the spring of 2005, I could have a much better design functioning to show off at the next media day for IMDL.

XI. DOCUMENTATION

Programming and Customizing PICmicro Microcontrollers. Predko, Mike. 2nd Edition. McGraw-Hill. c.2001.

Online Website: <http://www.microchip.com> . "PIC (16f877/16f877a) documentation and code examples".

XII. APPENDICES

Code for this experiment (below):

```
;*****************************************************************
;PROG:          "FLAME.asm"
;VERSION:       1.0
;AUTHOR:        Robert Lee
;DATE:          08/09/04

;Function:
;       This code will provide drivers + a set routine for "FLAME ver.1.0".
;       IRs, an LCD, 1.5-3V motors, and pyro-sensor are included to allow
;       for a "fire-fighting" robot design.  Presently, the code only
```

```
;               allows minimal functioning.  Limitations to the design are "mostly"
;               in the motors and small chassis design.  This robot will search for
;               candle-light, manuever toward the target and then extinguish it
;               with a water-cannon.  Then, it will just idle and wait for "reset".


;Modifications:
;               This code is remodified from the original.  The original
;               had PWM channels enabled, and was optimized for "heavier-duty"
;               motors.  The present motors in this design (version 1.0), has
;               very little tolerance for the current requirements of the
;               h-bridge previously fitted.  However, in this software design
;               relays have been implemented to provide "set" movements.
;               ~ (+3.0V,+1.5V).
;*****************************************************************
#include    <f877a.inc>             ; processor specific variable definitions

;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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;-------------------------------
;* * * * * VARIABLES * * * * *
;-------------------------------
TIME_H:             EQU             h'20'               ;Timer-0 delay counter (high byte)
TIME_L:             EQU             h'21'               ;Timer-0 delay counter (low byte)
PULSE_H:            EQU             h'22'               ;pyro's pulses (high byte ~ "spill register")
PULSE_L:            EQU             h'23'               ;pyro's pulses (low byte)
PYRO:               EQU             h'24'               ;pyro-sensor flag (set=on;clear=off)
TEMP1:              EQU             h'25'               ;
COUNT1:             EQU             h'26'               ;delay-counter value #1
COUNT2:             EQU             h'27'               ;delay-counter value #2
COUNT3:             EQU             h'28'               ;delay-counter value #3
ON:                 EQU             h'29'               ;display-bit(on) to limit display overhead
OFF:                EQU             h'2A'               ;display-bit(off) to limit display overhead
TEMP_H:             EQU             h'2B'               ;
TEMP_L:             EQU             h'2C'               ;
NUM:                EQU             h'2D'               ;used with "WRITE_NUM_WORD"
TEMP2:              EQU             h'2E'               ;
AD_COUNT0:          EQU             h'2F'               ;
AD_H:               EQU             h'30'               ;A/D value (high byte) ~ used with "WRITE_AD"
AD_L:               EQU             h'31'               ;A/D value (low byte) ~ used with "WRITE_AD"
TEMP3:              EQU             h'32'               ;
AD_H_TEMP:          EQU             h'33'               ;A/D value (high byte) ~
AD_L_TEMP:          EQU             h'34'               ;A/D value (low byte) ~
AD_BIT0:            EQU             h'35'               ;test bits for all 3 AD_channels
AD_BIT1:            EQU             h'36'               ;
AD_BIT2:            EQU             h'37'               ;
AD_COUNT1:          EQU             h'38'               ;
AD_COUNT2:          EQU             h'39'               ;
PY_COUNT:           EQU             h'3A'               ;
AD_TEMP:            EQU             h'3B'               ;
AD_L_TEMP2:         EQU             h'3C'               ;

;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

;-------------------------------
;* * * * * CONSTANTS * * * * *
;-------------------------------
TIME_INIT:          EQU             d'100'              ;Timer-0 delay value (both high/low regs)
P_MIN:              EQU             d'2'                ;minimum # pulses to set pyro-bit
PY_INIT:            EQU             d'100'
AD_TMP:             EQU             d'5'

;Motor/Relay "Bit Values":
R_30:               EQU             0           ;+3.0V-forward
L_30:               EQU             1           ;+3.0V-forward
R_15:               EQU             2           ;+1.5V-forward
L_15:               EQU             3           ;+1.5V-forward
;R_N15:             EQU             4           ;-1.5V-reverse          ;"NOT IMPLEMENTED IN THIS
VERSION 1.0 SOFTWARE"
;L_N15:             EQU             5           ;-1.5V-reverse
```

```
;------------------------------
;* * * * * * MAIN * * * * * *
;------------------------------

                        org     h'0'                    ;"RESET VECTOR"
                        goto    MAIN

                        org     h'4'                    ;"INTERRUPT VECTOR"
                        goto    ISR

                        org     h'5'                    ;"START OF USER-CODE"
MAIN:

;Initializations:
                        call    MOTOR_INIT      ;enable Port_C relay control
                        call    LCD_INIT        ;enable data-writes to LCD
                        call    AD_INIT         ;enable I/R cans
                        call    TIMER_INIT      ;enable 'Timer-0' subsystem
                        call    INTR_INIT       ;enable global interrupts

;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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START:
                        call    SPLASH_VER              ;display general information
                        call    DELAY_1SEC
                        call    CLEAR_HOME
                        call    RIGHT_1                 ;initialize system for pyro-detection
CHK1:
                        btfsc   PYRO,0                  ;check pyro-bit for response
                        goto    PY1                             ;branch when set
                        goto    CHK1                    ;do-nothing if clear

PY1:
                        call    FORWARD_2               ;manuever toward target (once detected)

DEBUG1:
                        call    AD_CH0                  ;check "center-IR" for object
                        call    AD0_READ_FAR
                        btfsc   AD_BIT0,0
                        goto    RESPONSE_0

                        call    AD_CH1                  ;check "left-IR" for object
                        call    AD1_READ
                        btfsc   AD_BIT1,0
                        goto    RESPONSE_1

                        call    AD_CH2                  ;check "right-IR" for object
                        call    AD2_READ
                        btfsc   AD_BIT2,0
                        goto    RESPONSE_2

                        goto    DEBUG1                  ;continuous "checking" loop


RESPONSE_0:
                        call    FORWARD_1
                        call    AD_CH0
                        call    AD0_READ
                        btfsc   AD_BIT0,0
                        goto    DEBUG2          ;Bingo!     "FOUND TARGET -> PROCEED TO
NEXT SEQUENCE"
                        goto    DEBUG1          ;Try Again "KEEP ALLIGNING"

RESPONSE_1:
                        call    RIGHT_1
                        call    DELAY_TICK
                        call    STOP
                        call    AD_CH0
                        call    AD0_READ_FAR
                        btfsc   AD_BIT0,0
```

```
                        goto    DEBUG1          ;Bingo! "REPEAT ALLIGNMENT PHASE"
                        goto    RESPONSE_1      ;Try Again "KEEP ALLIGNING"

RESPONSE_2:
                        call    LEFT_1
                        call    DELAY_TICK
                        call    STOP
                        call    AD_CH0
                        call    AD0_READ_FAR
                        btfsc   AD_BIT0,0
                        goto    DEBUG1          ;Bingo! "REPEAT ALLIGNMENT PHASE"
                        goto    RESPONSE_2      ;Try Again "KEEP ALLIGNING"


DEBUG2:
                        call    STOP            ;stop motors
                        call    SPLASH_FOUND    ;print result to display
                        call    DC_MOTOR        ;start "extinguisher" motor
                        goto    here            ;done!....(for this project)
;)))))))))))))))))))))))))))))))))))))))))))))))))))))))
;)))))))))))))))))))))))))))))))))))))))))))))))))))))))
;)))))))))))))))))))))))))))))))))))))))))))))))))))))))


here:           goto    here            ;Safety Loop (no entry into subroutines)

;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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;--------------------------------
;* * *INT. SERVICE ROUTINES* * *
;--------------------------------

ISR:

                        btfsc   INTCON,T0IF     ;time-out has occurred for Timer-0 int.
                        goto    ISR_TIMER0

                        btfsc   INTCON,RBIF     ;pulse has been detected for Port-B (change) int.
                        goto    ISR_PULSE

                        goto    end_isr         ;Nevermind...It was nothing!

;- - - - - - - - - - - - - - - - - -

ISR_PULSE:
                        bcf             INTCON,RBIF     ;clears RB.interrupt flag
                        incf    PULSE_L         ;increments the counter (pulses)
                        btfsc   STATUS,Z
                        goto    inc_pul2
done_pb:                goto    end_isr
inc_pul2:
                        incf    PULSE_H
                        goto    done_pb

;- - - - - - - - - - - - - - - - - -

ISR_TIMER0:

                        tstf    TIME_L          ;check if TIME1 is 'zero' or not
                        skpz                            ;if not zero, then decrement
                        goto    dec1            ;otherwise skip the 'goto'
                        goto    test2
dec1:
                        decf    TIME_L,F
                        goto    end_timer
test2:
                        tstf    TIME_H
                        skpz
                        goto    dec2
                        goto    pulse_out  ;if both registers are 'clear', then pulse!
dec2:
```

```
                                decf     TIME_H,F
                                movlw    TIME_INIT
                                movwf    TIME_L
                                goto     end_timer
pulse_out:
                                movlw    P_MIN              ;check if pulse-count is great enough
                                subwf    PULSE_L,W
                                btfss    STATUS,C           ;if negative, then output; otherwise skip
                                goto     not_met
;*********************************
                                bsf             PYRO,0              ;SET THE 'PYRO' BIT (ON)
;*********************************
                                goto     default
not_met:
;*********************************
                                bcf             PYRO,0              ;CLEAR THE 'PYRO' BIT (OFF)
;*********************************
default:
                                banksel  PORTD
                                clrf     PULSE_L            ;clear pulse count
                                clrf     PULSE_H

                                movlw    TIME_INIT          ;(140 clocks)
                                movwf    TIME_L
                                movwf    TIME_H             ;re-initialize timer registers
end_timer:
                                bcf             INTCON,T0IF         ;clear Timer-0 int. flag
                                goto     end_isr

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end_isr:
                                retfie                              ;SERVICES ROUTINES ARE
COMPLETE!!!

;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

;-----------------------------
;* * * * *SUBROUTINES* * * * *
;-----------------------------

FORWARD_2:      ;+3.0V to motors (forward motion)

                                banksel  PORTC
;********************************
                                bCf             PORTC,R_15                  ;turn-off +1.5V
                                bCf             PORTC,L_15

                                call     DELAY_1SEC                 ;TRANSITION...(needed!!!)

                                bSf             PORTC,R_30                  ;turn-on +3.0V
                                bSf             PORTC,L_30
;********************************
                                return

;- - - - - - - - - - - - - - - - -

FORWARD_1:      ;+1.5V to motors (forward motion)

                                banksel  PORTC
;********************************
                                bCf             PORTC,R_30                  ;turn-off +3.0V
                                bCf             PORTC,L_30

                                call     DELAY_1SEC                 ;TRANSITION...(needed!!!)

                                bSf             PORTC,R_15                  ;turn-on +1.5V
                                bSf             PORTC,L_15
;********************************
                                return
```

```
;- - - - - - - - - - - - - - - - -

STOP:       ;0V to motors (no movement)
                        banksel     PORTC
;*********************************
                        bCf         PORTC,L_30          ;turn everything "off"
                        bCf         PORTC,R_30
                        bCf         PORTC,L_15
                        bCf         PORTC,R_15
;*********************************
                        return

;- - - - - - - - - - - - - - - - -

LEFT_1:   ;+1.5V to motors (left direction)
                        banksel     PORTC
;*********************************
                        bCf         PORTC,R_30          ;turn-off +3.0V
                        bCf         PORTC,L_30

                        call        DELAY_1SEC          ;TRANSITION...(needed!!!)

                        bSf         PORTC,R_15          ;turn-on +1.5V
                        bCf         PORTC,L_15
;*********************************
                        return

;- - - - - - - - - - - - - - - - -

RIGHT_1: ;+1.5V to motors (right direction)
                        banksel     PORTC
;*********************************
                        bCf         PORTC,R_30          ;turn-off +3.0V
                        bCf         PORTC,L_30

                        call        DELAY_1SEC          ;TRANSITION...(needed!!!)

                        bCf         PORTC,R_15          ;turn-on +1.5V
                        bSf         PORTC,L_15
;*********************************
                        return

;- - - - - - - - - - - - - - - - -

LEFT_2:   ;+3.0V to motors (left direction)
                        banksel     PORTC
;*********************************
                        bCf         PORTC,R_15          ;turn-on +1.5V
                        bCf         PORTC,L_15

                        call        DELAY_1SEC          ;TRANSITION...(needed!!!)

                        bSf         PORTC,R_30          ;turn-on +1.5V
                        bCf         PORTC,L_30
;*********************************
                        return

;- - - - - - - - - - - - - - - - -

RIGHT_2: ;+3.0V to motors (right direction)
                        banksel     PORTC
;*********************************
                        bCf         PORTC,R_15          ;turn-on +1.5V
                        bCf         PORTC,L_15

                        call        DELAY_1SEC          ;TRANSITION...(needed!!!)

                        bCf         PORTC,R_30          ;turn-on +1.5V
                        bSf         PORTC,L_30
;*********************************
                        return
```

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;@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
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AD0_READ:		;Reads A/D-bit0 (SHORT DISTANCE) -> sets/clears bit accordingly

			banksel	PORTA
			bsf		ADCON0,GO_DONE		;set "go-bit" to begin the
conversion
ad_wait0:
			btfsc	ADCON0,GO_DONE		;wait for "complete-flag" to be set
			goto	ad_wait0		;....then proceed.

			BANKSEL		TRISC
			movfw	ADRESL			;move A/D result into 'WREG'
			BANKSEL		PORTC
			movwf	AD_L			;RESULT(LOW)
			movwf	AD_L_TEMP
			movfw	ADRESH
			andlw	b'00000011'
			movwf	AD_H			;RESULT(HIGH) for "WRITE_AD"
subroutine
			movwf	AD_H_TEMP		;result for testing distance of IR to target (2
= 4 inches)

;*********************************************************
; "USE FOR DEBUGGING PURPOSES - ONLY!"

;			call	WRITE_AD		;write result to LCD
;*********************************************************

			movlw	h'2'
			subwf	AD_H_TEMP
			skpc
			goto	bad_dist0
			goto	good_dist0

bad_dist0:
			bCf		AD_BIT0,0
			goto	done_a0
good_dist0:
			bSf		AD_BIT0,0		;OUTPUT-BIT IS NOW SET,
B/C ALL CONDITIONS ARE TRUE!

done_a0:
			return

;- - - - - - - - - - - - - - - - -

AD0_READ_FAR:	;Reads A/D-bit0 (LONG DISTANCE) -> sets/clears bit accordingly

			banksel	PORTA
			bsf		ADCON0,GO_DONE		;set "go-bit" to begin the
conversion
ad_wait0far:
			btfsc	ADCON0,GO_DONE		;wait for "complete-flag" to be set
			goto	ad_wait0far		;....then proceed.

			BANKSEL		TRISC
			movfw	ADRESL			;move A/D result into 'WREG'
			BANKSEL		PORTC
			movwf	AD_L			;RESULT(LOW)
			movwf	AD_L_TEMP
			movfw	ADRESH
			andlw	b'00000011'
			movwf	AD_H			;RESULT(HIGH) for "WRITE_AD"
subroutine
			movwf	AD_H_TEMP		;result for testing distance of IR to target (2
= 4 inches)

;*********************************************************
```

```
; "USE FOR DEBUGGING PURPOSES - ONLY!"

;                               call    WRITE_AD                ;write result to LCD
;*************************************************************

                                movlw   h'1'
                                subwf   AD_H_TEMP
                                skpc
                                goto    next_far
                                goto    good_dist0far

next_far:
                                movlw   h'50'                   ;DEBUGGER-USE ONLY!!!
                                subwf   AD_L_TEMP
                                skpc
                                goto    bad_dist0far
                                goto    good_dist0far

bad_dist0far:
                                bCf             AD_BIT0,0
                                goto    done_a0far
good_dist0far:
                                bSf             AD_BIT0,0               ;OUTPUT-BIT IS NOW SET,
B/C ALL CONDITIONS ARE TRUE!

done_a0far:
                                return

;- - - - - - - - - - - - - - - - -

AD1_READ:       ;Reads A/D-bit1 (LEFT) -> sets/clears bit accordingly

                                banksel PORTA
                                bsf             ADCON0,GO_DONE          ;set "go-bit" to begin the
conversion
ad_wait1:
                                btfsc   ADCON0,GO_DONE          ;wait for "complete-flag" to be set
                                goto    ad_wait1        ;....then proceed.

                                BANKSEL         TRISC
                                movfw   ADRESL                  ;move A/D result into 'WREG'
                                BANKSEL         PORTC
                                movwf   AD_L                    ;RESULT(LOW)
                                movwf   AD_L_TEMP
                                movfw   ADRESH
                                andlw   b'00000011'
                                movwf   AD_H                    ;RESULT(HIGH) for "WRITE_AD"
subroutine
                                movwf   AD_H_TEMP               ;result for testing distance of IR to target (2
= 4 inches)

;*************************************************************
; "USE FOR DEBUGGING PURPOSES - ONLY!"

;                               call    WRITE_AD                ;write result to LCD
;*************************************************************

                                movlw   h'1'
                                subwf   AD_H_TEMP
                                skpc
                                goto    next_1
                                goto    good_dist1

next_1:
;                               movlw   h'10'
                                MOVLW   H'50'           ;DEBUGGER-USE ONLY!!!
                                subwf   AD_L_TEMP
                                skpc
                                goto    bad_dist1
                                goto    good_dist1

bad_dist1:
```

```
                        bCf             AD_BIT1,0
                        goto    done_a1
good_dist1:
                        bSf             AD_BIT1,0               ;OUTPUT-BIT IS NOW SET,
B/C ALL CONDITIONS ARE TRUE!

done_a1:
                        return

;-----------------------------------------

AD2_READ:       ;Reads A/D-bit2 (RIGHT) -> sets/clears bit accordingly

                        banksel PORTA
                        bsf             ADCON0,GO_DONE          ;set "go-bit" to begin the
conversion
ad_wait2:
                        btfsc   ADCON0,GO_DONE          ;wait for "complete-flag" to be set
                        goto    ad_wait2                ;....then proceed.

                        BANKSEL         TRISC
                        movfw   ADRESL                  ;move A/D result into 'WREG'
                        BANKSEL         PORTC
                        movwf   AD_L                    ;RESULT(LOW)
                        movwf   AD_L_TEMP
                        movfw   ADRESH
                        andlw   b'00000011'
                        movwf   AD_H                    ;RESULT(HIGH) for "WRITE_AD"
subroutine
                        movwf   AD_H_TEMP               ;result for testing distance of IR to target (2
= 4 inches)

;*************************************************************
; "USE FOR DEBUGGING PURPOSES - ONLY!"

;                       call    WRITE_AD                ;write result to LCD
;*************************************************************

                        movlw   h'1'
                        subwf   AD_H_TEMP
                        skpc
                        goto    next_2
                        goto    good_dist2

next_2:
;                       movlw   h'10'
                        MOVLW   H'50'           ;DEBUGGER-USE ONLY!!!
                        subwf   AD_L_TEMP
                        skpc
                        goto    bad_dist2
                        goto    good_dist2

bad_dist2:
                        bCf             AD_BIT2,0
                        goto    done_a2
good_dist2:
                        bSf             AD_BIT2,0               ;OUTPUT-BIT IS NOW SET,
B/C ALL CONDITIONS ARE TRUE!

done_a2:
                        return

;- - - - - - - - - - - - - - - - - -

DC_MOTOR:       ;Drives "Extinguisher" motor for a few seconds

                        banksel PORTC
                        bsf             PORTC,5
                        call    DELAY_1SEC
                        call    DELAY_1SEC
                        bcf             PORTC,5
                        call    DELAY_1SEC
```

```
                        return

;- - - - - - - - - - - - - - - - - -

MOTOR_INIT:     ;Initialization of PORTC (motor bits)

                        banksel TRISC           ;PortC will be outputs for "motor relays"
                        clrf    TRISC
                        banksel PORTC
                        movlw   PY_INIT
                        movwf   PY_COUNT

                        return

;- - - - - - - - - - - - - - - - - -


AD_INIT: ;Initialization of PORTA + A/D subsystem (default=channel0)

                        banksel TRISA
                        movlw   b'11111111'
                        movwf   TRISA           ;configure PortA = "analog input" (low-byte)

                        movlw   b'10000010'
                        movwf   ADCON1

                        banksel PORTA

                        clrf    AD_BIT0
                        clrf    AD_BIT1
                        clrf    AD_BIT2

                        movlw   d'2'            ;initialize the pulse-count for A/D's
                        movwf   AD_COUNT0
                        movwf   AD_COUNT1
                        movwf   AD_COUNT2

                        movlw   b'10000001'     ;INITIALIZE A/D PORT-0
                                                                ;other A/D ports can be initiated
elsewhere in "main()"
                        movwf   ADCON0          ;configure A/D operation
                        call    DELAY_TICK      ;short delay (for boot-up)

                        return

;- - - - - - - - - - - - - - - - - -

AD_CH0:         ;Selects A/D - (channel 0)

                        banksel ADCON0
                        bcf             ADCON0,CHS2
                        bcf             ADCON0,CHS1
                        bcf             ADCON0,CHS0

                        call    DELAY_TICK

                        return

;- - - - - - - - - - - - - - - - - -

AD_CH1:         ;Selects A/D - (channel 1)

                        banksel ADCON0
                        bcf             ADCON0,CHS2
                        bcf             ADCON0,CHS1
                        bsf             ADCON0,CHS0

                        call    DELAY_TICK

                        return
```

```
;- - - - - - - - - - - - - - - - - -

AD_CH2:         ;Selects A/D - (channel 2)

                banksel ADCON0
                bcf             ADCON0,CHS2
                bsf             ADCON0,CHS1
                bcf             ADCON0,CHS0

                call    DELAY_TICK

                return

;- - - - - - - - - - - - - - - - - -

TIMER_INIT:     ;Initializes the Timer-0 Subsystem

                banksel PORTC
                movlw   TIME_INIT               ;(140 clocks)
                movwf   TIME_L
                movwf   TIME_H                  ;TIME_H * TIME_L = 140^2 = (19600
clocks)

                banksel OPTION_REG
                bsf             OPTION_REG,PS0  ;assign prescalar value (~2 seconds)
                bsf             OPTION_REG,PS1
                bsf             OPTION_REG,PS2
                bcf             OPTION_REG,T0CS         ;internal clock cycles
                bsf             OPTION_REG,PSA  ;disables prescalar for Timer-0

                bcf             INTCON,T0IF             ;pre-initialize T0-flag to zero
                bsf             INTCON,T0IE             ;enable Timer-0 system

                return

;- - - - - - - - - - - - - - - - - -

INTR_INIT:      ;Initializes/Enables all interrupt systems

                banksel TRISB
                movlw   b'10000001'             ;PortB (7:0) = "inputs"
                movwf   TRISB
                bcf             OPTION_REG,INTEDG       ;(cleared) ints. to 'falling-edge'

                banksel PORTB
                clrf    PULSE_L
                clrf    PULSE_H
                clrf    PYRO
                bcf             ON,h'0'         ;clear 'ON' (default)
                bcf             OFF,h'0'    ;clear 'OFF' (default)

                bsf             INTCON,INTE     ;enable the RB0/INT external interrupt
                bcf             INTCON,INTF     ;ensures that no external interrupt occurred
yet
                bsf             INTCON,RBIE     ;enable Port-B's interrupt system
                bcf             INTCON,RBIF     ;ensures that no PORTB interrupts occurred
yet
                bsf             INTCON,GIE      ;ENABLE ALL GLOBAL INTERRUPTS!

                return

;- - - - - - - - - - - - - - - - - -

LCD_INIT:       ;Initializes the LCD for 4-bit data format

                banksel TRISD           ;Switch to BANK-1
                clrf    TRISD           ;Initialize Ports (D&C) to "OUTPUT"

                banksel PORTD           ;Switch to BANK-0
                movlw   h'00'           ;Initialize(RS,RW,ECLK == 0)
                movwf   PORTD
;.....................................
```

```
                        movlw   h'33'           ;4-bit mode (enable), part_1
                        call    WRITE_COMM      ;COMMAND ($33)
;.....
                        movlw   h'32'           ;4-bit mode (enable), part_2
                        call    WRITE_COMM      ;COMMAND ($32)
;.....
                        movlw   h'28'           ;2 rows for 4-bit data,(small)
                        call    WRITE_COMM      ;COMMAND ($28)
;.....
                        movlw   h'0C'           ;display(on),cursor and blink(off)
                        call    WRITE_COMM      ;COMMAND ($0F)
;.....
                        movlw   h'01'           ;clear display, cursor to home
                        call    WRITE_COMM      ;COMMAND ($01)
;.....

                        return

;- - - - - - - - - - - - - - - - - -

WRITE_NUM_WORD:         ;Writes a "double" number to the LCD

                        movwf   TEMP_L          ;save data to RAM
                        movwf   TEMP_H
                        swapf   TEMP_H

                        movlw   h'C0'           ;LCD cursor to second line
                        call    WRITE_COMM

                        movfw   TEMP_H          ;check which character to output
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD           ;latch data to LCD
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

                        movfw   TEMP2           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

;.....

                        movfw   TEMP_L          ;check which character to output
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD           ;latch data to LCD
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

                        movfw   TEMP2           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay


                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM
                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM
```

```
                        return

;- - - - - - - - - - - - - - - - - -

NUM_CHECK:      ;Useful function for deciding the ASCII format for "WRITE_NUM_WORD"

chk_0:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'0'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_1

                movlw   h'0'
                movwf   TEMP3
                goto    set_3

chk_1:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'1'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_2

                movlw   h'1'
                movwf   TEMP3
                goto    set_3

chk_2:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'2'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_3

                movlw   h'2'
                movwf   TEMP3
                goto    set_3

chk_3:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'3'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_4

                movlw   h'3'
                movwf   TEMP3
                goto    set_3

chk_4:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'4'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_5

                movlw   h'4'
                movwf   TEMP3
                goto    set_3

chk_5:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'5'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_6

                movlw   h'5'
                movwf   TEMP3
                goto    set_3

chk_6:          bcf     STATUS,Z
                movfw   NUM
                sublw   h'6'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_7
```

```
                movlw   h'6'
                movwf   TEMP3
                goto    set_3

chk_7:          bcf             STATUS,Z
                movfw   NUM
                sublw   h'7'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_8

                movlw   h'7'
                movwf   TEMP3
                goto    set_3

chk_8:          bcf             STATUS,Z
                movfw   NUM
                sublw   h'8'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_9

                movlw   h'8'
                movwf   TEMP3
                goto    set_3

chk_9:          bcf             STATUS,Z
                movfw   NUM
                sublw   h'9'            ;Check for '0'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_a

                movlw   h'9'
                movwf   TEMP3
                goto    set_3

chk_a:
                bcf             STATUS,Z
                movfw   NUM
                sublw   h'A'            ;Check for 'A'
                btfss   STATUS,Z        ;Check the Zero-bit for "a zero number"
                goto    chk_b

                movlw   h'1'
                movwf   TEMP3
                goto    set_4

chk_b:
                bcf             STATUS,Z
                movfw   NUM
                sublw   h'B'            ;Check for 'B'
                btfss   STATUS,Z
                goto    chk_c

                movlw   h'2'
                movwf   TEMP3
                goto    set_4

chk_c:
                bcf             STATUS,Z
                movfw   NUM
                sublw   h'C'            ;Check for 'C'
                btfss   STATUS,Z
                goto    chk_d

                movlw   h'3'
                movwf   TEMP3
                goto    set_4

chk_d:
                bcf             STATUS,Z
                movfw   NUM
                sublw   h'D'            ;Check for 'D'
```

```
                        btfss   STATUS,Z
                        goto    chk_e

                        movlw   h'4'
                        movwf   TEMP3
                        goto    set_4

chk_e:
                        bcf             STATUS,Z
                        movfw   NUM
                        sublw   h'E'            ;Check for 'E'
                        btfss   STATUS,Z
                        goto    chk_f

                        movlw   h'5'
                        movwf   TEMP3
                        goto    set_4

chk_f:
                        bcf             STATUS,Z
                        movfw   NUM
                        sublw   h'F'            ;Check for 'F'
                        btfss   STATUS,Z
                        goto    set_3

                        movlw   h'6'
                        movwf   TEMP3
                        goto    set_4

set_3:                  movlw   h'3'
                        goto    done_num
set_4:                  movlw   h'4'
                        goto    done_num

done_num:
                        return

;- - - - - - - - - - - - - - - - - -

WRITE_COMM:     ;Writes commands to the LCD

                        banksel PORTD
                        movwf   TEMP1           ;saved in location #1

                        swapf   TEMP1,W

                        andlw   h'0F'
                        movwf   PORTD
                        bsf             PORTD,6
                        bcf             PORTD,6         ;toggle PORTD-7; (E-clk)
                        call    DELAY_X                 ;short delay


                        movfw   TEMP1
                        andlw   h'0F'
                        movwf   PORTD
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

                        return

;- - - - - - - - - - - - - - - - - -

WRITE_DATA:     ;Writes data to the LCD

                        banksel PORTD
                        movwf   TEMP1           ;saved in location #1

                        swapf   TEMP1,W
                        andlw   h'0F'
                        movwf   PORTD
```

```
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6         ;toggle PORTD-7; (E-clk)
                        call    DELAY_X         ;short delay


                        movfw   TEMP1
                        andlw   h'0F'
                        movwf   PORTD
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6
                        call    DELAY_X         ;short delay

                        return

;- - - - - - - - - - - - - - - - - -

WRITE_AD:       ;Writes the A/D value (word-length) to the LCD

                        banksel PORTD
;.....
                        movlw   h'02'           ;cursor to home
                        call    WRITE_COMM
;.....
                        movfw   AD_H

                        movwf   TEMP_H          ;save data to RAM
                        movwf   TEMP_L
                        swapf   TEMP_H

                        movfw   TEMP_H
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6
                        call    DELAY_X         ;short delay

                        movfw   TEMP3           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6
                        call    DELAY_X         ;short delay

;.....

                        movfw   TEMP_L
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6
                        call    DELAY_X         ;short delay

                        movfw   TEMP3           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf     PORTD,4
                        bsf     PORTD,6
                        bcf     PORTD,6
                        call    DELAY_X         ;short delay
;;;;;;;;;;;;;;;;
                        movfw   AD_L

                        movwf   TEMP_H          ;save data to RAM
```

```
                        movwf   TEMP_L
                        swapf   TEMP_H

                        movfw   TEMP_H
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

                        movfw   TEMP3           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

;.....................

                        movfw   TEMP_L
                        andlw   h'0F'
                        movwf   NUM
                        call    NUM_CHECK

                        movwf   PORTD
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay

                        movfw   TEMP3           ;return original value to WREG
                        movwf   PORTD           ;place data on PORTD bus
                        bsf             PORTD,4
                        bsf             PORTD,6
                        bcf             PORTD,6
                        call    DELAY_X                 ;short delay


                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM
                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM
                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM
                        movlw   h'10'           ;cursor shift left (non-destructive)
                        call    WRITE_COMM

                        return

;- - - - - - - - - - - - - - - - -

DELAY_X:                ;short delay function for "hardware boot-ups"

;****************************************
; LOOP TIME = (50*50*30) = 75,000 clock cycles (15ms)
; ECLK = [20 MHz]
; MCLK = [5 MHz]
;****************************************
                        movlw   d'50'
                        movwf   COUNT1          ;initialize Counter #1 to d'255'
                        movwf   COUNT2          ;initialize Counter #2 to d'255'
                        movlw   d'30'
                        movwf   COUNT3          ;initialize Counter #3 to (USER DEFINED)

C1:                     decfsz  COUNT1          ;decrement Counter #1 until "time out"
                        goto    C1
                        movlw   d'50'
                        movwf   COUNT1          ;(Refill Counter #1)
```

```
C2:                     decfsz  COUNT2          ;decrement Counter #2 until "time out" occurs
                        goto    C1                      ;Loop back to "START" until "time out"
occurs
                        movlw   d'50'
                        movwf   COUNT2          ;(Refill Counter #2)
C3:                     decfsz  COUNT3          ;decrement Counter #3 until "time out" occurs
                        goto    C1                      ;Loop back to "START" until "time out"
occurs

                        return

;- - - - - - - - - - - - - - - - -

DELAY_1SEC:     ;delay function = "roughly 1 second"....(or so!)

;****************************************
; LOOP TIME = (136^3) = 5/2 Million clock cycles (1s)
; ECLK = [20 MHz]
; MCLK = [5 MHz]
;****************************************
                        movlw   d'136'
                        movwf   COUNT1          ;initialize Counter #1 to d'255'
                        movwf   COUNT2          ;initialize Counter #2 to d'255'
                        movlw   d'136'
                        movwf   COUNT3          ;initialize Counter #3 to (USER DEFINED)

C4:                     decfsz  COUNT1          ;decrement Counter #1 until "time out"
                        goto    C4
                        movlw   d'136'
                        movwf   COUNT1          ;(Refill Counter #1)
C5:                     decfsz  COUNT2          ;decrement Counter #2 until "time out" occurs
                        goto    C4                      ;Loop back to "START" until "time out"
occurs
                        movlw   d'136'
                        movwf   COUNT2          ;(Refill Counter #2)
C6:                     decfsz  COUNT3          ;decrement Counter #3 until "time out" occurs
                        goto    C4                      ;Loop back to "START" until "time out"
occurs

                        return

;- - - - - - - - - - - - - - - - -

DELAY_TICK:     ;short delay function

;****************************************
; LOOP TIME = (y=x^3) = 250,000 clock cycles (10ms)
; ECLK = [20 MHz]
; MCLK = [5 MHz]*[50ms] = 250,000
;****************************************
                        movlw   d'60'
                        movwf   COUNT1          ;initialize Counter #1 to d'255'
                        movwf   COUNT2          ;initialize Counter #2 to d'255'
                        movwf   COUNT3          ;initialize Counter #3 to (USER DEFINED)

C7:                     decfsz  COUNT1          ;decrement Counter #1 until "time out"
                        goto    C7
                        movlw   d'60'
                        movwf   COUNT1          ;(Refill Counter #1)
C8:                     decfsz  COUNT2          ;decrement Counter #2 until "time out" occurs
                        goto    C7                      ;Loop back to "START" until "time out"
occurs
                        movlw   d'60'
                        movwf   COUNT2          ;(Refill Counter #2)
C9:                     decfsz  COUNT3          ;decrement Counter #3 until "time out" occurs
                        goto    C7                      ;Loop back to "START" until "time out"
occurs

                        return

;- - - - - - - - - - - - - - - - -
```

```
SPLASH_VER:     ;displays general version/author information

                banksel PORTD

                movlw   "F"
                call    WRITE_DATA
;.....
                movlw   "L"
                call    WRITE_DATA
;.....
                movlw   "A"
                call    WRITE_DATA
;.....
                movlw   "M"
                call    WRITE_DATA
;.....
                movlw   "E"
                call    WRITE_DATA
;.....
                movlw   " "
                call    WRITE_DATA
;.....
                movlw   "("
                call    WRITE_DATA
;.....
                movlw   "v"
                call    WRITE_DATA
;.....
                movlw   "e"
                call    WRITE_DATA
;.....
                movlw   "r"
                call    WRITE_DATA
;.....
                movlw   "1"
                call    WRITE_DATA
;.....
                movlw   "."
                call    WRITE_DATA
;.....
                movlw   "0"
                call    WRITE_DATA
;.....
                movlw   ")"
                call    WRITE_DATA
;.....

                movlw   h'C0'           ;move cursor to beginning of second row
                call    WRITE_COMM
;.....
                movlw   "b"
                call    WRITE_DATA
;.....
                movlw   "y"
                call    WRITE_DATA
;.....
                movlw   ":"
                call    WRITE_DATA
;.....
                movlw   " "
                call    WRITE_DATA
;.....
                movlw   "R"
                call    WRITE_DATA
;.....
                movlw   "."
                call    WRITE_DATA
;.....
                movlw   "E"
                call    WRITE_DATA
;.....
                movlw   "."
```

```
                        call    WRITE_DATA
;.....
                        movlw   "L"
                        call    WRITE_DATA
;.....
                        movlw   "E"
                        call    WRITE_DATA
;.....
                        movlw   "E"
                        call    WRITE_DATA
;.....


                        return

;- - - - - - - - - - - - - - - - - -

SPLASH_ON:      ;displays "on" to the LCD

                        banksel PORTD

                        btfsc   ON,h'0'         ;skip procedure if output already 'exists'
                        goto    end_on

;                       movlw   h'02'           ;move cursor home
;                       call    WRITE_COMM

                        movlw   h'C0'           ;move cursor to beginning of second row
                        call    WRITE_COMM
;.....
                        movlw   "O"
                        call    WRITE_DATA
                        movlw   "n"
                        call    WRITE_DATA
                        movlw   " "
                        call    WRITE_DATA

;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM
;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM
;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM

                        bsf             ON,h'0'         ;set 'ON'
                        bcf             OFF,h'0'    ;clear 'CLEAR'

end_on:
                        return

;- - - - - - - - - - - - - - - - - -

SPLASH_OFF:     ;displays "off" to the LCD

                        banksel PORTD

                        btfsc   OFF,h'0'    ;skip procedure if output already 'exists'
                        goto    end_off

;                       movlw   h'02'           ;move cursor home
;                       call    WRITE_COMM

                        movlw   h'C0'           ;move cursor to beginning of second row
                        call    WRITE_COMM
;.....
                        movlw   "O"
                        call    WRITE_DATA
                        movlw   "f"
                        call    WRITE_DATA
                        movlw   "f"
                        call    WRITE_DATA
```

```
;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM
;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM
;                       movlw   h'10'           ;cursor shift left (non-destructive)
;                       call    WRITE_COMM

                        bcf             ON,h'0'         ;clear 'ON'
                        bsf             OFF,h'0'    ;set 'OFF'

end_off:
                        return

;- - - - - - - - - - - - - - - - - -

SPLASH_FOUND:   ;displays "found" to the LCD

                        banksel PORTD

                        movlw   h'C0'           ;move cursor to beginning of second row
                        call    WRITE_COMM

                        movlw   "F"
                        call    WRITE_DATA
                        movlw   "O"
                        call    WRITE_DATA
                        movlw   "U"
                        call    WRITE_DATA
                        movlw   "N"
                        call    WRITE_DATA
                        movlw   "D"
                        call    WRITE_DATA

                        bcf             ON,h'0'         ;clear 'ON'
                        bcf             OFF,h'0'    ;clear 'OFF'

                        return

;- - - - - - - - - - - - - - - - - -

SPLASH_CLOSE:   ;displays "close" to the LCD

                        banksel PORTD

                        movlw   h'C0'           ;move cursor to beginning of second row
                        call    WRITE_COMM
;.....................................
                        movlw   "C"
                        call    WRITE_DATA
;.....................................
                        movlw   " "
                        call    WRITE_DATA
;.....................................
                        movlw   " "
                        call    WRITE_DATA
;.....................................
                        movlw   " "
                        call    WRITE_DATA
;.....................................
                        movlw   " "
                        call    WRITE_DATA
;.....................................

                        return

;- - - - - - - - - - - - - - - - - -

SPLASH_FAR:     ;displays "far" to the LCD

                        banksel PORTD

                        movlw   h'C0'           ;move cursor to beginning of second row
```

```
                        call    WRITE_COMM
;.....
                        movlw   "F"
                        call    WRITE_DATA
;.....
                        movlw   " "
                        call    WRITE_DATA
;.....
                        movlw   " "
                        call    WRITE_DATA
;.....
                        movlw   " "
                        call    WRITE_DATA
;.....
                        movlw   " "
                        call    WRITE_DATA
;.....

                        return

;- - - - - - - - - - - - - - - - - -

PRINT_AD0:      ;displays "AD-0" to the LCD

                        banksel PORTD

                        movlw   h'01'           ;move cursor home
                        call    WRITE_COMM

                        movlw   "A"
                        call    WRITE_DATA
                        movlw   "D"
                        call    WRITE_DATA
                        movlw   "-"
                        call    WRITE_DATA
                        movlw   "0"
                        call    WRITE_DATA

;.....
                        return

;- - - - - - - - - - - - - - - - - -

PRINT_AD1:      ;displays "AD-1" to the LCD

                        banksel PORTD

                        movlw   h'01'           ;move cursor home
                        call    WRITE_COMM

                        movlw   "A"
                        call    WRITE_DATA
                        movlw   "D"
                        call    WRITE_DATA
                        movlw   "-"
                        call    WRITE_DATA
                        movlw   "1"
                        call    WRITE_DATA

;.....
                        return

;- - - - - - - - - - - - - - - - - -

PRINT_AD2:      ;displays "AD-2" to the LCD

                        banksel PORTD

                        movlw   h'01'           ;move cursor home
                        call    WRITE_COMM

                        movlw   "A"
```

```
                        call    WRITE_DATA
                        movlw   "D"
                        call    WRITE_DATA
                        movlw   "-"
                        call    WRITE_DATA
                        movlw   "2"
                        call    WRITE_DATA

;.....................................
                        return

;- - - - - - - - - - - - - - - - - -

CLEAR_HOME:     ;clears the LCD and moves the cursor to line-1(to the left)

                        banksel PORTD

                        movlw   h'01'           ;move cursor home
                        call    WRITE_COMM
;.....................................
                        return
;- - - - - - - - - - - - - - - - - -

SPLASH_FIRE:    ;displays "fire" to the LCD

                        banksel PORTD

                        movlw   h'01'           ;move cursor home
                        call    WRITE_COMM

                        movlw   "F"
                        call    WRITE_DATA
                        movlw   "I"
                        call    WRITE_DATA
                        movlw   "R"
                        call    WRITE_DATA
                        movlw   "E"
                        call    WRITE_DATA

;.....................................
                        return

;- - - - - - - - - - - - - - - - - -


                        END                                     ;no more code beyond this point!
```