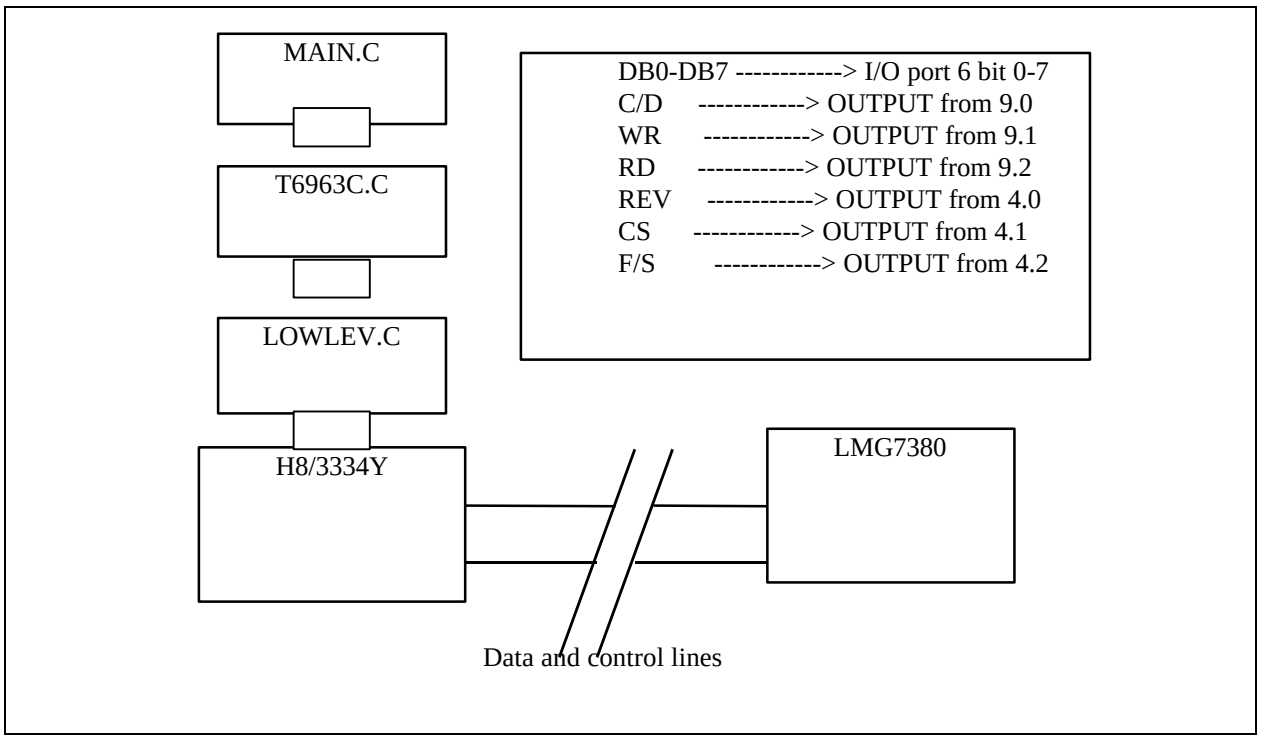
APPLICATION NOTE **DATE : 19/11/96**

Text and Graphics using C and the T6963c

The following application note shows how to connect to a T6963C (as used on the Hitachi LMG738X,LMG742Xetc..) and provides high level C routines such as plot and print to produce text and graphics on screen simultaneously. The above display panels also include 8K bytes (0x1FFF) of SRAM which provides the user with a complete graphics subsystem. The interface between the host processor and the T6963C is PORT BASED which means the code is easily portable between microcontrollers. The code was developed and tested using a 16Mhz H8-3334Y. This application note is intended to be used in conjunction with the T6963C datasheet and the Hitachi LCD Graphics databook.

The code described here is split into 3 'C' files which divides the functions up as follows:-

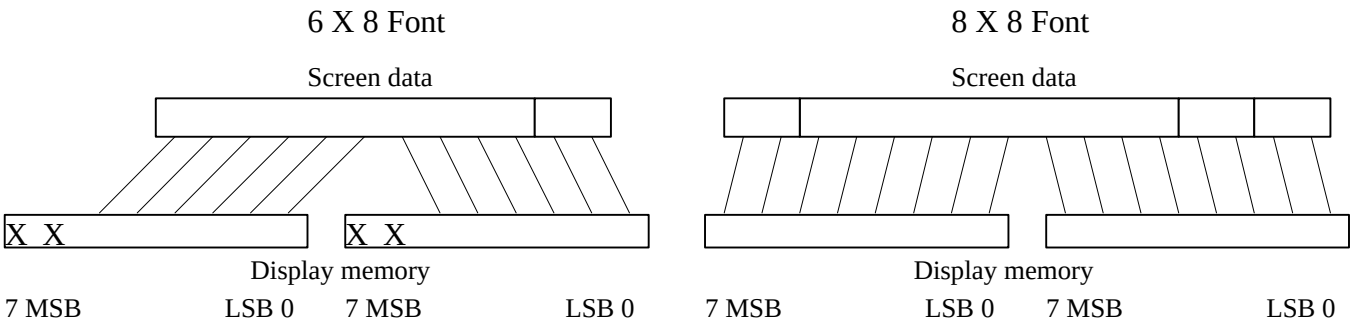
1. LOWLEV.C
   This file contains the basic command write, status check and data read and write cycles as described in the T6963C. The functions toggle the port lines to re-create the timing diagrams required by the T6963C. It is designed to act as the bottom layer of the software dealing with the physical levels on the port lines.
2. T6963C.C
   All of the high level routines that perform the useful graphics functions such as PRINTF, CLRLCD and display initialisation are contained in this file. This file does not contain any functions that directly manipulate the ports. Instead it calls the LOWLEV.C functions to talk to the T6963C. The functions contained in this file are the ones that should be called from your own code. Any further routines written by the user (eg. CIRCLE) should be added to this file.
3. MAIN.C
   This program is a simple demo to show the use of a couple of the functions provided in T6963C.C. It initialises the display to Mixed Text and Graphics mode, clears the screen, prints some text and then bounces a ball shaped sprite around the screen.



Hardware Specification

The hardware used to produce this application note consisted of a +12V supply for the INVC191 CFL backlight inverter, -13V for the LCD bias voltage and a 5V supply for the display and EVB3334Y logic. A power up delay and fast switch off circuit should be implemented for the LCD bias voltage as recommended in the LCD Graphics databook to avoid damaging the LCD when the bias voltage is present but the T6963C controller is not operational.
The connection between the H8/3334Y on the evaluation board and the LMG7380 LCD is via the port lines. All of Port 6 is used as the databus, with a total of 6 other lines used to provide the control signals. The actual number of lines used can be reduced by not using a separate WR line and supplying it from an inverted RD line. Also the REV (display invert) line may be hardwired high to provide the standard black pixel on white background mode. CS (chip select), C/D (command/data) and at least one line to control Read/Write are essential.
If required font select FS, Display Off and the CFL on/off line on the inverter may also be controlled directly from additional ports.
It should be noted that for the graphics routines described in this note to work properly, it is necessary to run the display in 8x8 font mode (See diagram below). The character font used in the two modes is exactly the same except that on 8 x 8 mode 2 blank pixels are inserted to bring the character spacing up to 8 pixels.

Diagram showing correspondence between Font Select and graphics display



Software Specification

Generation of code

The tools that were used for the code generation are that of the IAR compiler/linker system. As shown in the first diagram the code is split into three layers which interact with each other. This corresponds to three source files T6963.C, LOWLEV.C & MAIN.C. These are compiled in turn and then linked together using XLINK. The batch file used to do this is as follows:-

COMPILE / LINK Batch file BUILD.BAT

```
icch83 main.c -o main.r20 -P -g -ml -e -K -C -q -l main.lst -1id -v0 -s0 -r
icch83 lowlev.c -o lowlev.r20 -P -g -ml -e -K -C -q -l lowlev.lst -1id -v0 -s0 -r
icch83 t6963.c -o t6963c.r20 -P -g -ml -e -K -C -q -l t6963c.lst -1id -v0 -s0 -r


xlink main lowlev t6963c  -f link.xcl -l out.map -xsme -o out -r
```

```
rem produce debug .d20 file with source info
```

The above batch file produces a .D20 file (UBROF format) used by IAR C-Spy and Hitachi CIDE windows based debuggers for the 300 series. Removing the -r switch from the link command line will cause a S-record to be produced which is suitable for blowing a PROM.

The link file used to build the code was set up for the EVB3334Y evaluation board which uses the H8/3334Y 16Mhz 8 bit microcontroller.
The link file is shown below:-

```
-!          -link.xcl-

 First define CPU  -!
-cH8300

-!  Allocate segments which should be loaded -!
-Z(BIT)BITVARS=0

-!  First allocate the read only segments . -!
-Z(CODE)INTVEC,IFLIST,FLIST=0-FF
-Z(CODE)CDATA0,CDATA1,RCODE,CODE,CDATA2,CDATA3,ZVECT,CONST,CSTR,CCSTR=100-3fff

-!  Then the writeable segments which must be mapped to a RAM area
    C000 was here supposed to be start of RAM -!
-
Z(DATA)DATA1,IDATA1,UDATA1,DATA2,DATA3,IDATA2,IDATA3,UDATA2,UDATA3,ECSTR,WCSTR,TE
MP,CSTACK+140=fb80-ff40
-Z(DATA)DATA0,IDATA0,UDATA0,SHORTAD=Ff41-Ff7F

-! See configuration section concerning printf/sprintf -!
 -e_medium_write=_formatted_write

-! See configuration section concerning scanf/sscanf -!
 -e_medium_read=_formatted_read

-!  Now load the 'C' library -!
clh83sf0
```

Software functionality

1. LOWLEV.C
    - short_delay - provides a small delay (a few tens of machine cycles) to slow LCD access cycles down
    - status_read - performs a read of the t6963c status register and returns it to the calling function
    - status_checkx - calls the status_read function to check the presence of a 1 in specific bits of the status register STA
    - command_write - send a command instruction to the t6963c. The command value is passed to the function as an unsigned char. Available commands are defined in the file command.h
    - data_write - used to send data to a display memory location. Note it is necessary to issue a data write command before this is used.
    - data_read - same as above except used to fetch data from the display memory location.

When customising this file for your host processor please note the interface timing specification of the LCD display as specified in the LCD Graphics Databook.

1. T6963C.C

Note all of the functions here when called first check the appropriate busy flags in the STA register before attempting to read or write commands or data.

- addr_set - this function sets the address pointer in the t6963c. It should be set before reading or writing to the display memory unless the value of the pointer is known. By adding the offset of the

graphics start address for example, it is possible to easily select a specific set of pixels on the screen. When addressing the character memory a specific character on the screen can be accessed as follows:-

Character to be addressed = X,Y with the origin (0,0) being the top left hand corner,
use... addr_set(character memory address start + (Y * number of columns) + X);

- plot - This function uses the bit set function of the t6963c to manipulate a single bit of graphics memory. You should pass three unsigned characters to it, the first being the x co-ordinate in pixels, the second being the y co-ordinate and the third being 1 or 0 depending on whether you want to set or reset that pixel.
- sprite - 8 x 8 sprites can be displayed on the screen using this function and can be placed to pixel resolution. The parameters to passed to this function are:-
    - 1 - the address of the 8 byte array containing the sprite information (unsigned char *)
    - 2 - the x position of the sprite in pixels
    - 3 - the y position of the sprite in pixels
    - 4 - The writing method used. 0 will AND with existing display data, 1 will OR with the existing display data and 2 will perform an EXOR. 2 is particularly useful for sprites as calling the function twice will first display the sprite and then remove it leaving the screen with the original display data.
- lcd_putchr - this function should be used following an addr_set command to tell the t6963c whereabouts in character memory a character should be placed. The functioned calling lcd_putchr should pass the character to be displayed and a null. An ASCII translation is performed to allow normal use of this function. See t6963c user manual for the character set. The address pointer is incremented after lcd_putchr to allow continuous characters to be sent
- lcd_printf - This function uses the IAR formatting library to provide a standard printf function. It calls lcd_putchr to display the characters after they have been formatted. Use this function exactly the same way as you would use printf whilst bearing in mind the restrictions on formatters used according to which write library is specified in the link file. (formatted write)
- clr_lcd - This function provides a block erase function on the display memory. Simply pass two integer values to this function specifying the start and end address of the block to be erased and all values in that range will be set to 0x00. The Auto write mode is used for speed, where the t6963c address pointer is automatically incremented after each write.
- set_up_lcd - The address map used by the t6963c is set up here which specifies the location of text and graphics memory within the 8K available. Other parameters such as number of columns, offset register value (start of custom character memory) are also set up here. Note that the actual values written depend on the pre-processor defines specified in LMG7380.H. When using different size displays it is necessary only to adjust the values in this include file as the other files take their values form here.

This function also selects EXOR mode (text and graphics information will be exored on screen) and puts the t6963c into mixed text and graphics mode.

1. MAIN.C

   This program is a simple demo to show the use of a couple of the functions provided in T6963C.C. It initialises the display to Mixed Text and Graphics mode, clears the screen, prints some text and displays a wall around the border, then bounces a ball shaped sprite around the screen. It shows how the functions in t6963.c are called.

2. COMMAND.H

All of the commands available with the t6963c are defined in this file. It has the benefit of making code which writes commands to the LCD much more readable.

3. LMG7380.H

   This include file has two purposes:-

   1. It defines the constants of the display such as size and start address of memory areas.
   2. It declares function prototypes for the functions used in the three c source files

LOWLEV.C

```
/*low level routines used to read and write
  data and functions to T6963. Includes wait
  and staus check routines. The functions are designed
  to acurately reflect the timing diagrams given in the
  t6963 datasheet              */
/* the lcd interface is configured as below :-

       DB0-DB7 ------------> I/O port 6 bit 0-7
       C/D     ------------> OUTPUT from 9.0
       WR      ------------> OUTPUT from 9.1
       RD      ------------> OUTPUT from 9.2
       REV     ------------> OUTPUT from 4.0
       CS      ------------> OUTPUT from 4.1
       F/S    ------------> OUTPUT from 4.2
    port 6 is initialsied as inputs and port 9.0-2 4.0,2 as outputs

*/


#include <ioh8337.h>  /*io port & peripheral definitions*/
#include <inh8337.h>  /*interrupt vectors*/
#include <inh83.h>   /*interrupt functions*/
#include <stdlib.h>
#include "command.h" /*t6963 commands*/
#include "lmg7380.h" /*function prototypes*/


void short_delay (void)
{
char count;

count = 3;
while (--count); /* delay */
}



  char status_read (void)
{
char read_val;

P6DDR=0x00;             /* port 6 all inputs */
P9DR=0x03;              /* set wr/cd clear rd */
short_delay();
read_val = P6DR;        /* get status */
P9DR=0x07;              /* set rd/wr and cd */
return (read_val);
}



void status_check ( void )
{
while ( (status_read() & 0x03) != 0x03 ) /* wait for status check STA0,1 = 3 */
{ }
}

void status_check1 ( void )
{
while ( (status_read() & 0x03) != 0x03 ) /* wait for status check STA0,2 = 5 */
{ }
}

void status_check2 ( void )
{
while ( (status_read() & 0x08) != 0x08 ) /* check auto write mode STA2,3 = 8 */
{ }
}
```

```
void command_write (char write_val)
{

P6DDR=0xff;             /* port 6 all outputs */
P6DR=write_val;         /* output the data */
P9DR=0x07;              /* output r/w and rs signals */
short_delay();
P9DR=0x05;              /* output E signal */
short_delay();
P9DR=0x07;              /* output E signal */
short_delay();
P9DR=0x06;              /* output rs and r/w signals */
}



void data_write (char write_val)
{

P6DDR=0xff;             /* port 6 all outputs */
P6DR=write_val;         /* output the data */
P9DR=0x06;              /* output control signals */
short_delay();
P9DR=0x04;              /* output control signal */
short_delay();
P9DR=0x06;              /* output control signal */
short_delay();
P9DR=0x07;              /* output control signal */
}


char data_read (void)
{
char read_val;

P6DDR=0x00;            /* port A all inputs */
P9DR=0x06;              /* output control signals */
short_delay();
P9DR=0x02;              /* set wr, clear cd/rd */
short_delay ();
read_val=P6DR;          /* get data */
P9DR=0x06;              /* set rd/wr clear cd */
short_delay();
P9DR=0x07;               /* set rd/wr and cd */
return (read_val);
}
```

T6963C.C

```
/*****************************************************************************/
/*This  module contains the two essential graphics operations, sprite and plot*/
/*Plot will set a pixel to 1 or 0. Sprite will display a 8x8 pixel sprite     */
/*anywhere on the screen to pixel resolution (unlike using custom characters) */
/*****************************************************************************/

#include <ioh8337.h>
#include <inh8337.h>
#include <inh83.h>
#include <stdio.h>
#include <icclbutl.h>
#include "command.h"
#include "lmg7380.h"

void addr_set(int address)
{
status_check1();
data_write (address%0x100);      /* low order address */
status_check1();
data_write (address/0x100);      /* high order address ie. graphics!!!*/
status_check1();
command_write (APS);   /* address pointer set */
status_check1();
}

void plot(char x,char y,char val)
{
int addr;                /*address offset from start of graphics*/

addr = ((columns) * y) + (x/8); /*calculate addr offset*/
addr += graph;                  /*add on graphics start addr*/
status_check1();
data_write (addr%0x100);      /* low order address */
status_check1();
data_write (addr/0x100);      /* high order address ie. graphics!!!*/
status_check1();
command_write (APS);             /* address pointer set */
status_check1 ();
if (val) command_write (BS + (7-(x%8)));      /*bit set mode*/
else    command_write (BR + (7-(x%8))); /*bit reset mode*/
status_check1 ();
}



void sprite(char *address,char x,char y,char val)
{
int addr;                /*address offset from start of graphics*/
char a,b,temp,shift,sdata;
addr = graph+((columns) * y) + (x/8); /*calculate initial addr offset*/
shift=(x%8);
for (b=0;b<2;b++)
{
 for (a=0;a<8;a++)
       {
       temp = ((char)*address);
       address++;
       if (b==0) temp = (temp >> shift);
       else     temp = (temp << shift);
       addr_set(addr);
       command_write(DRAAN); /*read data from memory*/
       status_check1();
       sdata=data_read();
       status_check1();
       switch(val)
             {
             case 2: data_write(temp^sdata);  /*EXOR with existing data to invert
pixels*/
```

```
              case 1: data_write(temp|sdata);   /*OR with existing data to add
pixels*/
              case 0: data_write(temp&(!sdata));/*AND with NOT value to take away
pixels*/
              }
       status_check1();
       command_write(DWAAN); /*data write with no addr pointer change*/
       addr += columns; /*move down one graphics line*/
       }
  addr-=(columns*8);
  address-=8;
  addr++;
  shift=(8-(x%8));
 }
}

void lcd_putchr(char data, void *ptr)
{
       status_check1();
       command_write (DAWS);   /* auto data write set */
       status_check2 ();
       data_write(data-0x20);  /*print the character*/
       status_check2();        /*need to subtract 20 hex to translate from ASCII*/
       command_write (0xb2); /* auto reset */
       status_check2();
}

int lcd_printf (const char *fmt, ...)
{
    va_list ap;
    int i;
    va_start(ap,fmt);
    i = _formatted_write(fmt, lcd_putchr, (void*)0, ap);
    return(i);
}

void clr_lcd (int start,int finish)
{
int n;
addr_set(start);
command_write (DAWS);  /* auto write mode set */
status_check2();

n=0;
while (n <= finish)
    {
     status_check2();
     data_write (0x00);
     n++;
    }
status_check2();
command_write(AR);
status_check2();
}

void set_up_lcd ( void )
{


/*write_lcd control and data codes for character mode*/

status_check ();
data_write (text%0x100);      /* low order addr */
status_check ();
data_write (text/0x100);      /* high order addr */
status_check ();
command_write (THAS);   /* text home address */
status_check ();
data_write (graph%0x100);      /* low order addr */
status_check ();
data_write (graph/0x100);      /* high order addr */
status_check ();
```

```
command_write (GHAS);   /* graphics home address */
status_check ();
data_write (columns);      /* low order addr */
status_check ();
data_write (0x00);      /* high order addr */
status_check ();
command_write (TAS);   /* text area set ,set columns*/
status_check ();
data_write (columns);      /* low order addr */
status_check ();
data_write (0x00);      /* high order addr */
status_check ();
command_write (GAS);   /* graphic area set ,set columns*/
status_check ();
data_write (0x01);      /* low order addr */
status_check ();
data_write (0x00);      /* high order add */
status_check ();
command_write (ORS);   /* 0800H ~ 0FFFH offset register set */
status_check ();
command_write (EM);     /*exor mode  */
status_check1();
command_write (TONGON);   /* display mode text on graphics on */
status_check ();
}
```

MAIN.C

```
/*****************************************************************/
/* This program is designed to drive the LMG7380 graphics display which
   has the Toshiba T6963C controller built-in. This LCM is driven via an
   H8 microcontroller on an EVB3334Y. It drives the display in mixed text
   and graphics mode. The port lines of the H8/3334Y are used as control*/
/*****************************************************************/

#include <ioh8337.h>
#include <inh8337.h>
#include <inh83.h>
#include <stdlib.h>
#include "command.h"    /*file with T6963 command codes*/
#include "lmg7380.h"    /*contains function prototypes and
                  screen parameters (eg. mem map, columns etc)*/

/************The following parameters are used for collision
detection**********/
#define wall_l 8       /*horizontal position of LHS of wall*/
#define wall_r 248       /*horizontal position of RHS of wall*/
#define wall_t 8      /*vertical position of TOP of wall*/
#define wall_b 56       /*horizontal position of BOTTOM of wall*/
/**********************define sprites*****************************************/

const char ball []= {0x3c,0x7e,0xdb,0xff,0xff,0xdb,0x66,0x3c};
const char brick []= {0xff,0x81,0xbd,0xbd,0xbd,0xbd,0x81,0xff};

/*******************************************************************************
/

extern void init_3334y(void);
char collision_det(char,char);

/*******************************************************************************
/

void main(void)
{
char ballx,oldx,bally,oldy; /*ball position variables*/
signed char spx,spy;   /*horiz and vert. speed of ball*/
char n,m,*util;           /*general purpose variables and pointer
                  for passing to sprite function         */
int count;          /*general purpose counter*/
init_3334y();           /*sets up ports 1,2,4,6,9*/
P4DR=0x01;              /*Chip select Low, enable display access*/
set_up_lcd ();          /*set address of text and graphics,exor mode, display
on*/


clr_lcd(text,text+0x0150);               /* clear text display RAM area */
clr_lcd(graph,graph+0x0b00);             /* clear graphic display RAM area */


addr_set(columns*1);      /*row 1*/
lcd_printf("  The  ");
addr_set(columns*2);      /*row 2*/
lcd_printf("Lmg7380");
addr_set(columns*3);      /*row 3*/
lcd_printf(" from " );
addr_set(columns*4);      /*row 4*/
lcd_printf ("Hitachi");
addr_set(columns*7);      /*row 7*/
lcd_printf ("Mixed text and graphics!");


for(n=0;n<58;n++)
      {
      for(m=8;m<40;m++)     /*black box over text*/
            {
            plot(n,m,1);
```

```
                }
        }

util= &brick[0];    /*select brick as sprite to display*/
/*draw top and bottom of wall border*/
for(n=0;n<32;n++)   /*left to right end of columns*/
        {
        sprite (util,(wall_l + (n*8)),0,1);
        sprite (util,(wall_l + (n*8)),56,1);
        }
/*draw left and right hand side of wall border*/
for(n=0;n<5;n++)    /*top to bottom of screen*/
        {
        sprite (util,0,(n*8),2);
        sprite (util,56,(n*8),2);
        }



/*Game variable initialisation +draw initial bat and ball*/
spx=2,spy=2;            /*initial speed of ball*/
util= &ball[0];           /*select ball as sprite to display*/
sprite(util,oldx,oldy,0);/*draw initial ball*/

while(1)/*MAIN LOOP*/
        {



        for(count=0;count<0xfffe;count++); /*delay*/
                {
                util= &ball[0];        /*select ball as sprite*/
                sprite(util,ballx,bally,2);/*paint new*/
                sprite(util,oldx,oldy,2);/*remove old*/
                ballx+=spx;         /*move ball position*/
                bally+=spy;

                /*collision detection!!*/
                if (bally>wall_b)
                        {
                        spy=-spy; /*bottom bounce*/
                        bally=wall_b;
                        }
                if (bally<=wall_t)
                        {
                        spy=-spy;/*top bounce*/
                        bally=wall_t;
                        }
                if (ballx>wall_r)
                        {
                        spx=-spx; /*righthand bounce*/
                        ballx=wall_r;
                        }
                if (bally<=wall_l)
                        {
                        spx=-spx;/*lefthand bounce*/
                        ballx=wall_l;
                        }


                }

        }

}
/*****************************************************************************/



/*****************************************************************************
/
/*EVB3334Y hardware setup function*/
```

```
 void init_3334y(void)
{

      P4DR = 0x07;    /*set port 4 to 0x07*/
      P4DDR = 0x07;   /* Port 4.0 , 4.1, 4.2 set to outputs */

      P9DR = 0x07;    /*set port 9 to 0x00*/
      P9DDR = 0x07;   /* Port 9.0 , 9.1, 9.2 set to outputs */

      P6DR = 0x00;    /*set port 6 to 0x00*/
      P6DDR = 0xff;   /* Port 6 set to outputs */
      P6DR = 0x00;
}
```

COMMAND.H

```
/*****************************************************************/
/* This file contains definitions for all of the commands in a t6963. */
/*****************************************************************/
/*  Register set    */
#define      CPS    0x21   //Cursor pointer set
#define      ORS    0x22   //Offset register set
#define      APS    0x24   //Address pointer set

#define      THAS   0x40   //Text home address set
#define      TAS    0x41   //Text area set
#define      GHAS   0x42   //Graphic home address set
#define      GAS    0x43   //Graphic area set

#define      OM     0x80   //OR mode
#define      EM     0x81   //EXOR mode
#define      AM     0x83   //AND mode
#define      TAM    0x84   //TEXT ATTRIBUTE mode

#define      DOF    0x90   //Display OFF
#define      CONBOF 0x92   //Cursor ON, Blink OFF
#define      CONBON 0x93   //Cursor ON, Blink ON
#define      TONGOF 0x94   //Text ON, Graphic OFF
#define      TOFGON 0x98   //Text OFF, Graphic ON
#define      TONGON 0x9C   //Text ON, Graphic ON

#define      LC1    0xA0   //1 Line cursor
#define      LC2    0xA1   //2 Line cursor
#define      LC3    0xA2   //3 Line cursor
#define      LC4    0xA3   //4 Line cursor
#define      LC5    0xA4   //5 Line cursor
#define      LC6    0xA5   //6 Line cursor
#define      LC7    0xA6   //7 Line cursor
#define      LC8    0xA7   //8 Line cursor

#define      DAWS   0xB0   //Data auto write set
#define      DARS   0xB1   //Data auto read set
#define      AR     0xB2   //Auto reset

#define      DWAAI  0xC0   //Data write and ADP increment
#define      DRAAI  0xC1   //Data read and ADP increment
#define      DWAAD  0xC2   //Data write and ADP decrement
#define      DRAAD  0xC3   //Data read and ADP decrement
#define      DWAAN  0xC4   //Data write and ADP nonvariable
#define      DRAAN  0xC5   //Data read and ADP nonvariable

#define      SP     0xE0   //Screen PEEK

#define      SC     0xE8   //Screen COPY

#define      BR     0xF0   //Bit RESET
#define      BS     0xF8   //Bit SET
                    //add 3 bit data to these
                    //commands to select bit
```

LMG7380.H

```
#include <inh8337.h>
#include <ioh8337.h>
#include <inh83.h>
/*set up display parameters*/
#define columns 32
#define text 0x0000 /*select text mem start*/
#define graph 0x1000/*select graphics mem start*/
#define font_s 0x08

/*****************************************************************************
*/
/*function prototypes for writing to display*/
extern void set_up_lcd(void);

extern void status_check1(void);
extern void status_check2(void);
extern char status_read (void);
extern void status_check ( void );
extern void short_delay (void);
extern void data_write ( char );
extern char data_read ( void );
extern void command_write ( char );
extern void addr_set(int);

extern void lcd_putchr(char, void *);
extern int lcd_printf(const char *, ...);

extern void sprite(char *,char,char,char);
extern void plot(char,char,char);
```