Laboratory Manual

Semester: VI
Course Code: ECL68
Course Name: Embedded System Design Lab
Ramaiah Institute of Technology

Ramaiah Institute of Technology
(Autonomous Institute, Affiliated to VTU)
Department of Electronics and Communication Engineering
VI Semester Microcontroller Lab (ECL68)

Embedded C programming

1. Bit manipulation
2. Device driver for reading from stdin (keyboard) and writing to stdout (monitor) using system calls

RTOS Programs (System level programming by Linux API)

1. Creation of processes using fork()
2. Usage of "Signal" function calls–when DEL key or CTRL C is pressed, this sends a signal for abrupt termination
3. Multithreading – One thread reads the input from the keyboard and another thread converts to uppercase. This is done until 'Stop" is pressed. Number of threads can be running sharing same CPU.
4. Intertask communication using semaphore and pipes – Two threads, one for reading the input and one for converting the text to upper case letters, converting thread will wait for a semaphore to be released before it starts the operation and also pipes can be used to share the data from one thread toanother

Interfacing programs

1. Familiarize I/O ports of a controller – on/off control of LEDs using switches.
2. Display a given string using the LCD display interface.
3. Interface keypad and display the key pressed on 7 segment LED.
4. Waveform generation using the internal DAC of LPC2148
5. Design and display a two-digit counter

COURSE DESIGN, DELIVERY AND ASSESSMENT

Course code and Title : ECL68 Embedded System Design Lab	Course Credits :0:0:1
CIE : **50 Marks**	SEE : **50 Marks**
Total No of Theory / Tutorial / Lab Hours : 14	

Prerequisites

Prerequisite Courses with codes : Microprocessor Lab ECL48

LIST OF EXPERIMENTS

Part A: Embedded C programming

1. Bit manipulation
2. Calculation of Cyclic Redundancy Code
3. Device driver for reading from stdin (keyboard) and writing to stdout (monitor) using system calls

Part B: RTOS Programs (System level programming by Linux API)

4. Creation of processes using fork()
5. Usage of "Signal" function calls – when DEL key or CTRL C is pressed, this sends a signal for abrupt termination
6. Multithreading – One thread reads the input from the keyboard and another thread converts to upper case. This is done until „Stop" is pressed. Number of threads can be running sharing same CPU.
7. Intertask communication using semaphore and pipes – Two threads, one for reading the input and one for converting the text to upper case letters, converting thread will wait for a semaphore to be released before it starts the operation and also pipes can be used to share the data from one thread to another

Part C: Interfacing programs

8. Familiarize I/O ports of a controller – on/off control of LEDs using switches.
9. Display a given string using the LCD display interface.
10. Interface keypad and display the key pressed on 7 segment LED.
11. Waveform generation using the internal DAC of LPC2148
12. Design and display a two-digit counter

Textbooks:

1. Dr. K. V. K. K. Prasad, "Embedded Real-Time Systems: Concepts, Design & Programming", Reprint Edition, Dreamtech Press, 2013.
2. Shibu K. V, "Introduction to Embedded Systems", 2nd Edition, Tata McGraw Hill Education, 2017.
3. James K. Peckol, "Embedded Systems – A Contemporary Design Tool", Student Edition, John Wiley and Sons, 2014.

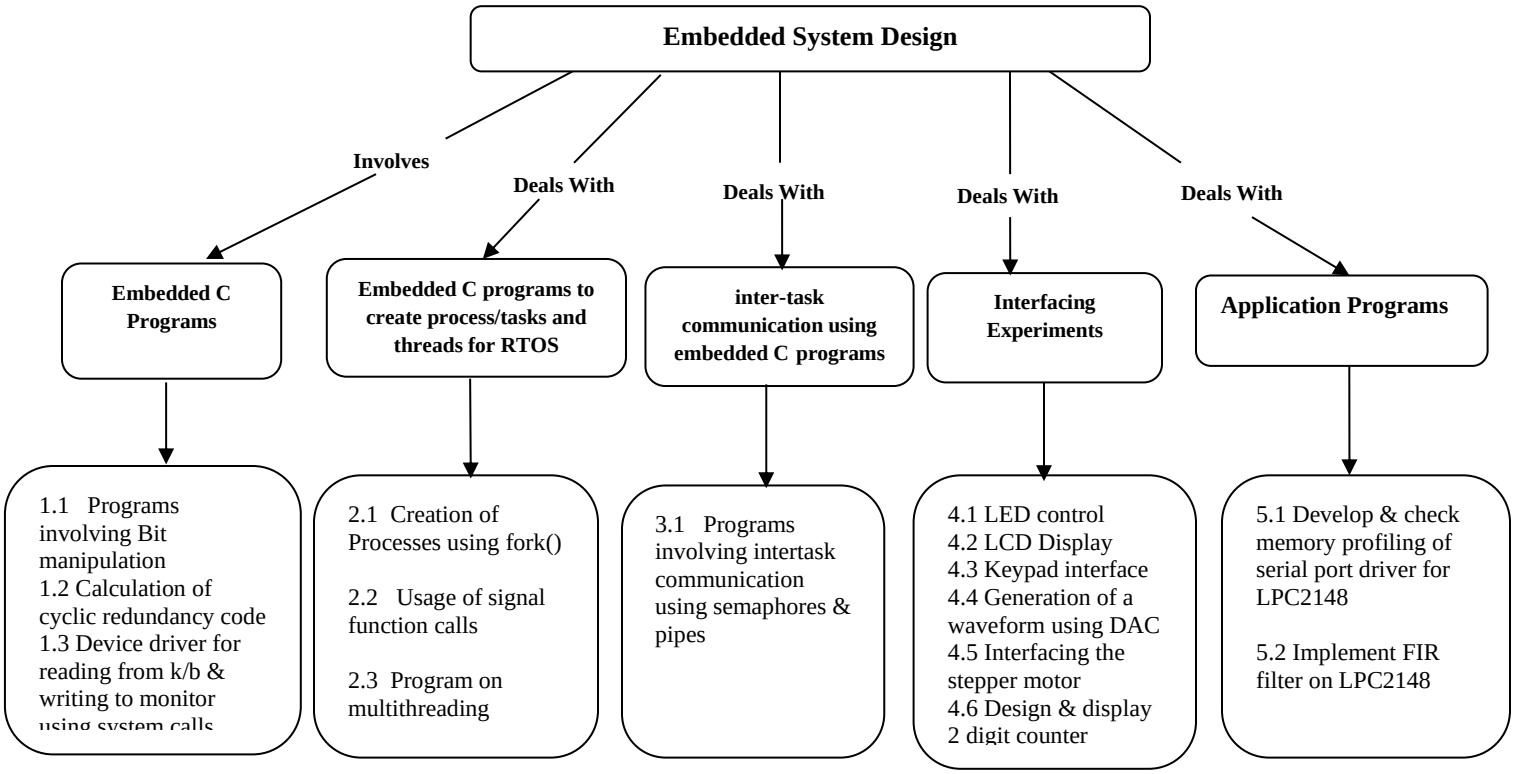
References:

1. Steve Heath, “Embedded System Design”, 2nd Edition, Newnes Publishers, 2003.
2. LPC 2148 user manual.

Course Outcome (COs):

1. Develop embedded C programs (POs – 1, 2, 5, 9, 10, 12, PSO – 2)
2. Demonstrate embedded C programs to create process/tasks and threads for RTOS (POs – 1, 2, 5, 9, 10, 12, PSO – 2)
3. Illustrate inter-task communication using embedded C programs (POs – 1, 2, 5, 9, 10, 12, PSO – 2)
4. Design embedded C programs to interface data converters with a microcontroller (POs – 1, 2, 3, 5, 9, 10, 12, PSO – 2)
5. Interface different types of I/O peripherals using a microcontroller for a typical application (POs – 1, 2, 3, 5, 9, 10, 12, PSO – 2)

Concept Map:


Embedded System Design
Involves
Deals With
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Deals With
Embedded C Programs
Embedded C programs to create process/tasks and threads for RTOS
inter-task communication using embedded C programs
Interfacing Experiments
Application Programs
1.1 Programs involving Bit manipulation
1.2 Calculation of cyclic redundancy code
1.3 Device driver for reading from k/b & writing to monitor
2.1 Creation of Processes using fork()
2.2 Usage of signal function calls
2.3 Program on multithreading
3.1 Programs involving intertask communication using semaphores & pipes
4.1 LED control
4.2 LCD Display
4.3 Keypad interface
4.4 Generation of a waveform using DAC
4.5 Interfacing the stepper motor
4.6 Design & display 2 digit counter
5.1 Develop & check memory profiling of serial port driver for LPC2148
5.2 Implement FIR filter on LPC2148

Introduction to Software IAR embedded workbench.

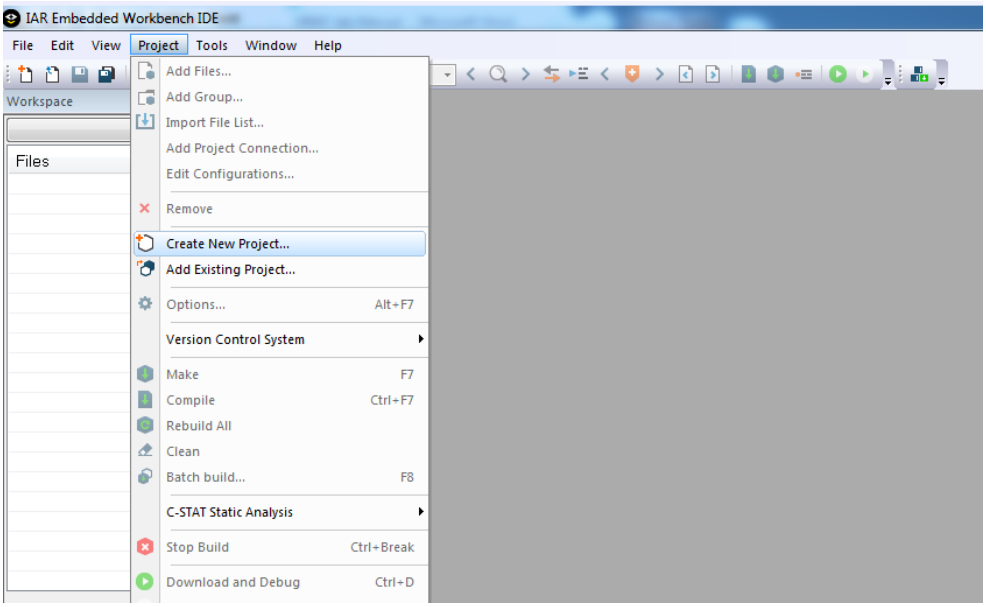
CREATION OF NEW PROJECT and SIMULATING:

The **IAR** compiler is used to create,compile& simulate the projects for ARM family micro-controllers. The procedure to create projects is as follows

Step 1:Create a folder with the name related to the project in any drive.

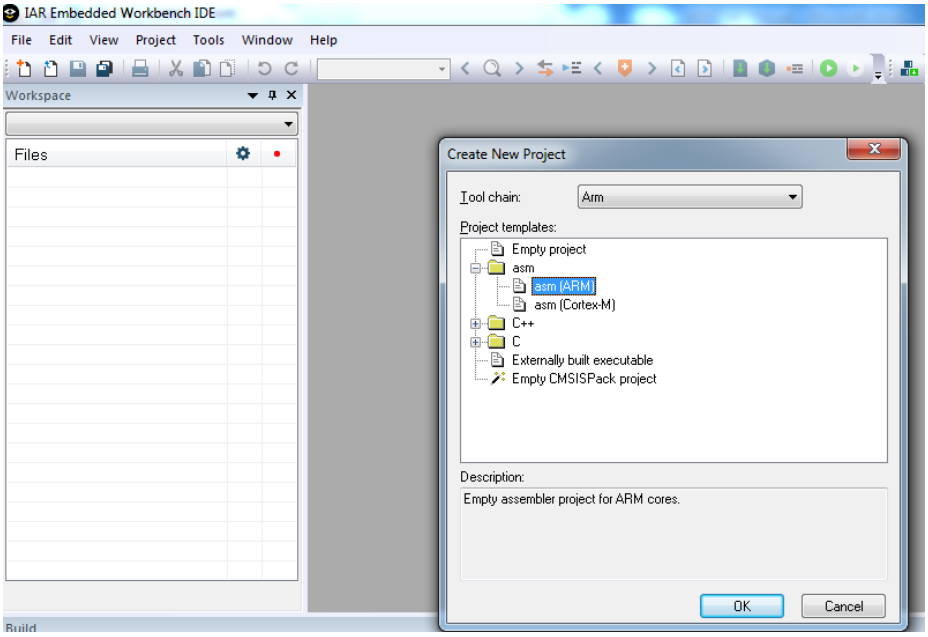
Step 2: Open **IAR Embedded Workbench** software. A new workspace launcher will open.

Step 3: Go to **Project** click "**CreateNewProject".**



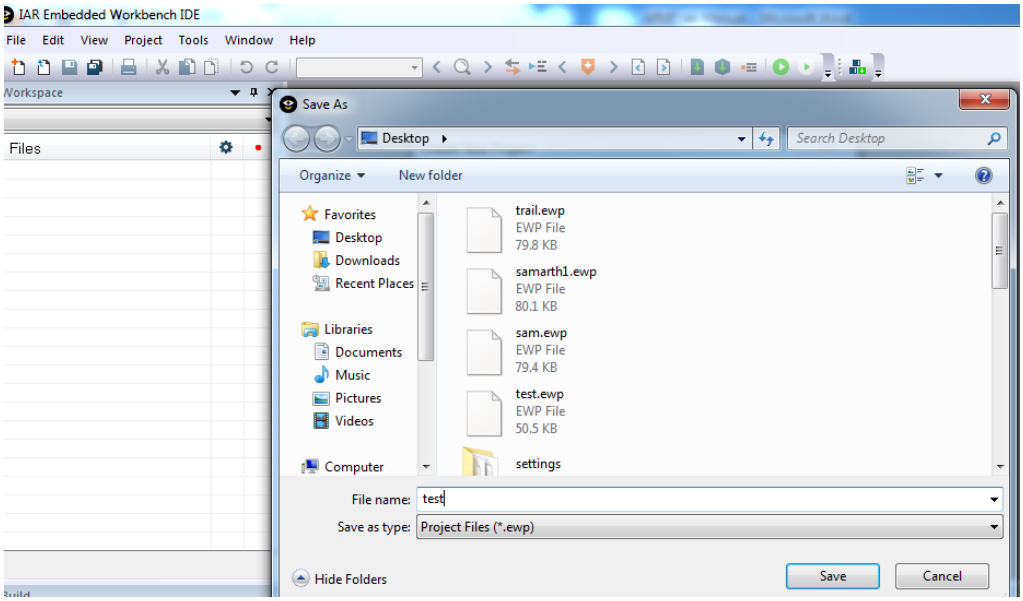
Step 4: Tool chain:Select**ARM**

Project templates : select **asm (ARM)** if assembly code you would like write, else you would like to write **C** then select **main**

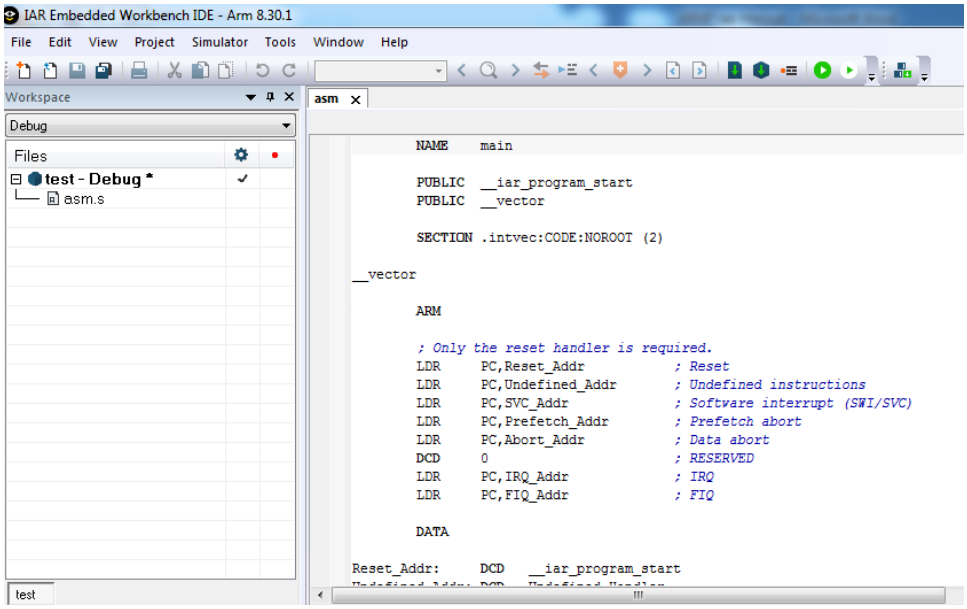


Step 5: select **asm** and click **OK.**

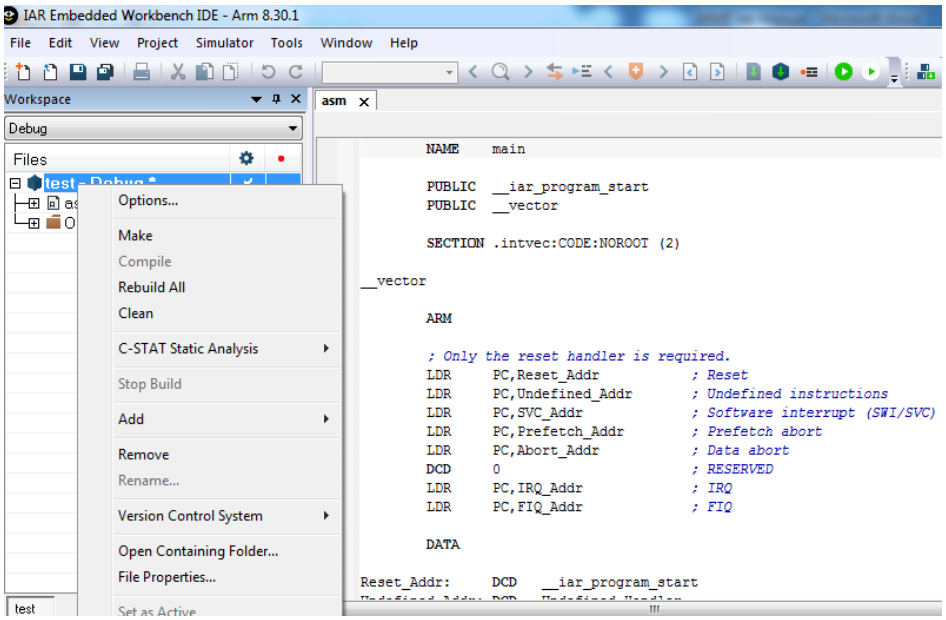
Step 6: Give project name and save the file name in corresponding folder.



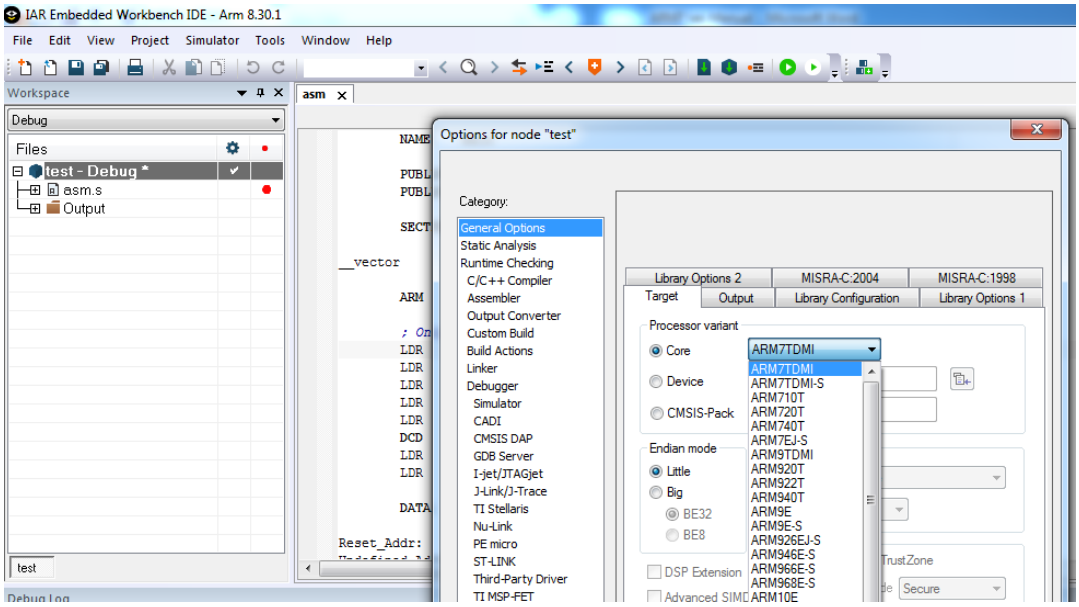
Step7: The window you can see after step6**.**



Step 8:Go to project name, right click and select **options.**

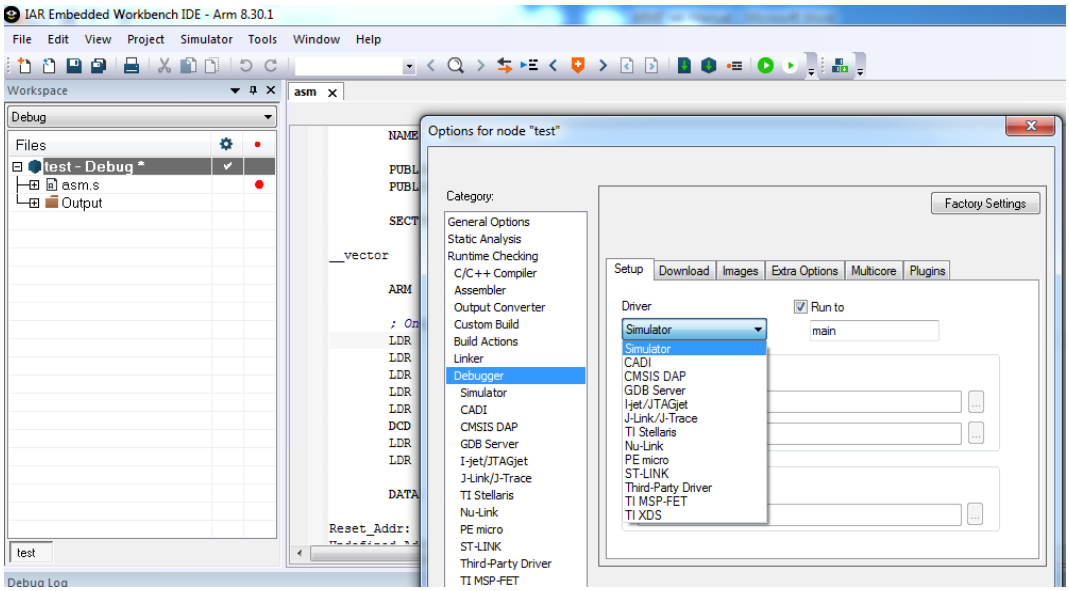


Step 9: Go to **generaloptions**>**targettab**>**core**> ARM7TDMI



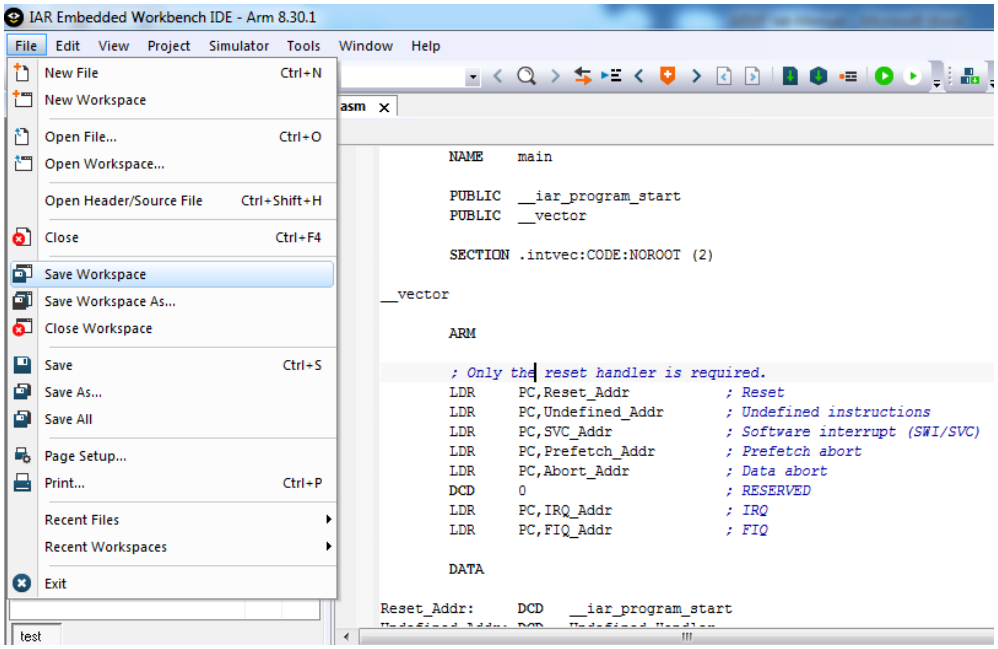
Step 10: Select device **ARM7TDMI** and click **OK.**

Step 11: Go to **debugger**>**setup** tab > select **simulator**> click **OK**

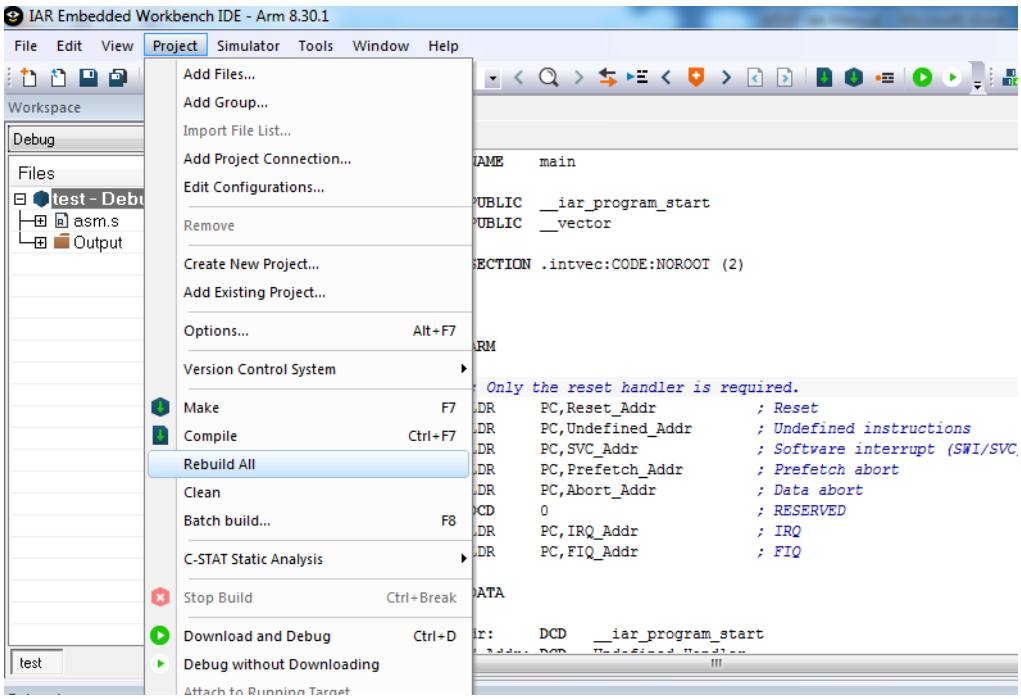


Step 12: Type program in editor window.

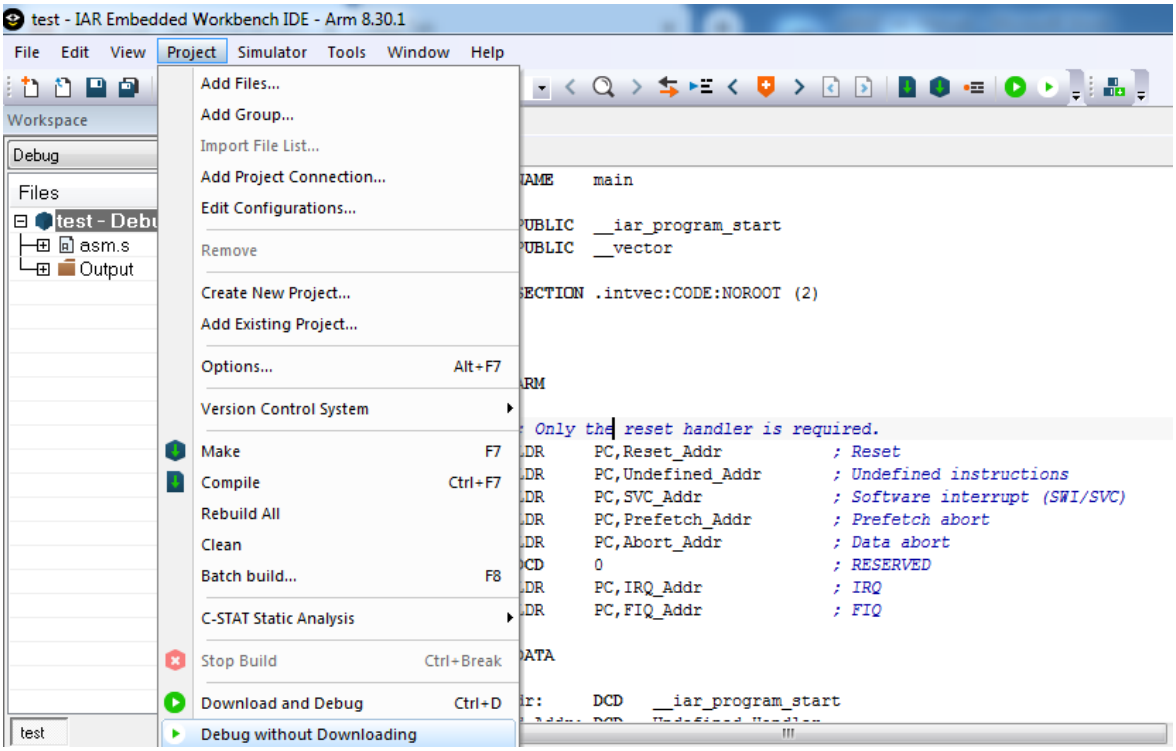
Step 13: Go to **file** ->**SaveWorkspace**, save the workspace in corresponding folder, Click **ok.**



Step 14: Go to project->**RebuildAll,**if any **errors** or **warnings** you will get the result in **build** console



Step 15: To **simulate** the program: Go to **Project→ Debug without Downloading**



Step 16: PC points to the initial point of the program.

Step 17:

1) If you want to see the memory then go to **view->memory.**
2) If you want to see the resistor then go to **view->register.**
3) Any resistor you can add to the watch window. Just right click on the register and click **add to watch.**
4) If you need to perform **Run**, **step over**, **step into**,**step out** and **next statement**
   Then go to the **Debug** and click your option.

Commands for Linux:

gedit filename.c	**// to edit file**
gcc –o filename filename.c	**// to compile the file**
./filename	**// to run the executable file**

C Programs involving Bit manipulation

(i) Perform logical operations on two given values.

```
#include <stdio.h>
int
main ()
{
  int a = 7;
  int b = 3;
printf ("\n The value of a AND b: %d \n", a & b);
printf ("\n The value of a OR b: %d \n", a | b);
printf ("\n The value of a XOR b: %d \n", a ^ b);
printf ("\n The value of ~a: %d \n", ~a);
printf ("\n The value of a>>1: %d \n", a >> 1);
printf ("\n The value of a>>2: %d \n", a >> 2);
printf ("\n The value of b<<1: %d \n", b << 1);
printf ("\n The value of b<<2: %d \n", b << 2);
}
```

(ii) Set the 5^{th} bit in a given value

```
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char *argv[])
{
int value;
if (argc> 1)
{
value = atoi(argv[1]);
value |= (1<<5);
printf ("value = %d \n", value);
//}
return 0;
}
```

C Program involving Device driver for reading from stdin (keyboard) and writing to stdout (monitor) using system calls

(i) Read from keyboard and write into monitor

```
#include <unistd.h>
#include <stdlib.h>
#include <stdio.h>

int main()
{
char letters[50];
int input;
input = read(0,letters,50);
printf("%d \n", input);
write(1,letters,input);
return(0);
}
```

(ii) Copy text from out.txt to out1.txt

```
//#include <stdio.h>
#include<fcntl.h>
//#include <stdlib.h>
#include <unistd.h>
//#include <string.h>
int main ()
{
  char* c;
  int n;
  int fin, fout;
  fin = open ("out.txt", O_RDONLY);
fout = open ("out1.txt", O_WRONLY|O_CREAT,0777);
while(read (fin, &c, 1)==1)
  write (fout, &c, 1);
return 0;
}
```

(iii) Enter data from keyboard and echo into monitor and also text file

```
#include<fcntl.h>
#include <unistd.h>
int main ()
{
  char c[50];
  int n;
  int f1
f1 = open ("out.txt", O_RDWR | O_CREAT, 0777);
    n =  read (0, c, 50);
      write(1,c,n);
      write (f1, c, n);
  close(f1);
  return 0;
}
```

RTOS Programs (System level programming by Linux API)

Write a C program to demonstrate usage of fork.

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
int main() {

   fork();
   printf("Fork testing code\n");
   return 0;
}
```

Write a C program to demonstrate usage of fork with child and parent process ID is printed and parent waits for child process to terminate.

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
#include <stdlib.h>
#include <sys/wait.h>
int
main (void)
{
  pid_t pid;
  char *message;
  int no, NO1 = 1;
  int i, l;
  printf ("calling fork \n");
  pid = fork ();

   switch (pid)
    {
    case -1:
      printf ("fork failed \n");
      exit (1);

    case 0:
      message = "Child Process";
      i = 1;
      no = getpid ();
      NO1 = getppid ();
      break;

    default:
      message = "Parent Process";
      i = 1;
```

```
    no = getpid ();
    NO1 = getppid ();
    break;
   }


   if(pid !=0) {
   printf("HP: hello from parent\n");
      wait(NULL);
      printf("CT: child has terminated\n");
   }

  for (l = i; l > 0; l--)
   {
    puts (message);
    printf ("My ID is %d \n", no);
    printf ("My parent ID is %d \n", NO1);
       }
  return (0);
}
```

Usage of "Signal" function calls–

Write a C program to demonstrate usage of signal function calls: when CTRL C is pressed a signal is sent for abrupt termination.

```
#include <signal.h>
#include <stdio.h>
#include <unistd.h>
void my_handler(int signal)
{
printf("Problem encountered %d \n", signal);
}
int main()
{
(void) signal (SIGINT,my_handler);
while(1)
{
printf("Hello \n");
sleep(2);
}
}
```

Write a C program to demonstrate usage of signal function calls: when CTRL C is pressed a signal ignore the signal.

```
#include <signal.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
(void) signal (SIGINT,SIG_IGN);
while(1)
{
printf("%d \n", getpid());
sleep(1);
}
}
```

Multithreading

gcc –o filename filename.c -lpthread // to compile the file

Write a C program for : One thread reads the input from the keyboard and another thread converts to upper case. This is done until Stop‟ is pressed. Use concept of multithreading

```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include<string.h>
#include<ctype.h>
#include <pthread.h>

#define BUFFER_SIZE 1024

char buffer[BUFFER_SIZE];

void *read_thread (void *arg)
{
  while (strncmp ("stop", buffer, 4) != 0)
    {
      printf ("Enter text:  ");
      fgets (buffer, BUFFER_SIZE, stdin);
      sleep (1);
    }

  pthread_exit ("read_thread exit successful");
```

```
}

void *convert_thread ()
{
  int i;
  while (strncmp ("stop", buffer, 4) != 0)
    {
      sleep (1);
      printf ("Converted text:  ");
      for (i = 0; i < strlen (buffer); i++)
           printf ("%c", toupper (buffer[i]));
    }
  pthread_exit ("convert_thread exit successful");
}

int main ()
{
  int result;
  pthread_t rthread, cthread;
  void *thread_result;
  printf("Enter text, the program will convert it into upper case, \n To stop enter 'stop' \n");
  pthread_create (&rthread, NULL, read_thread, NULL);
  pthread_create (&cthread, NULL, convert_thread, NULL);

  pthread_join (rthread, &thread_result);
  printf("read_thread joined, %s\n",(char *)thread_result);
  pthread_join(cthread, &thread_result);
  printf ("convert_thread joined, %s\n", (char *) thread_result);
return(0);
}
```

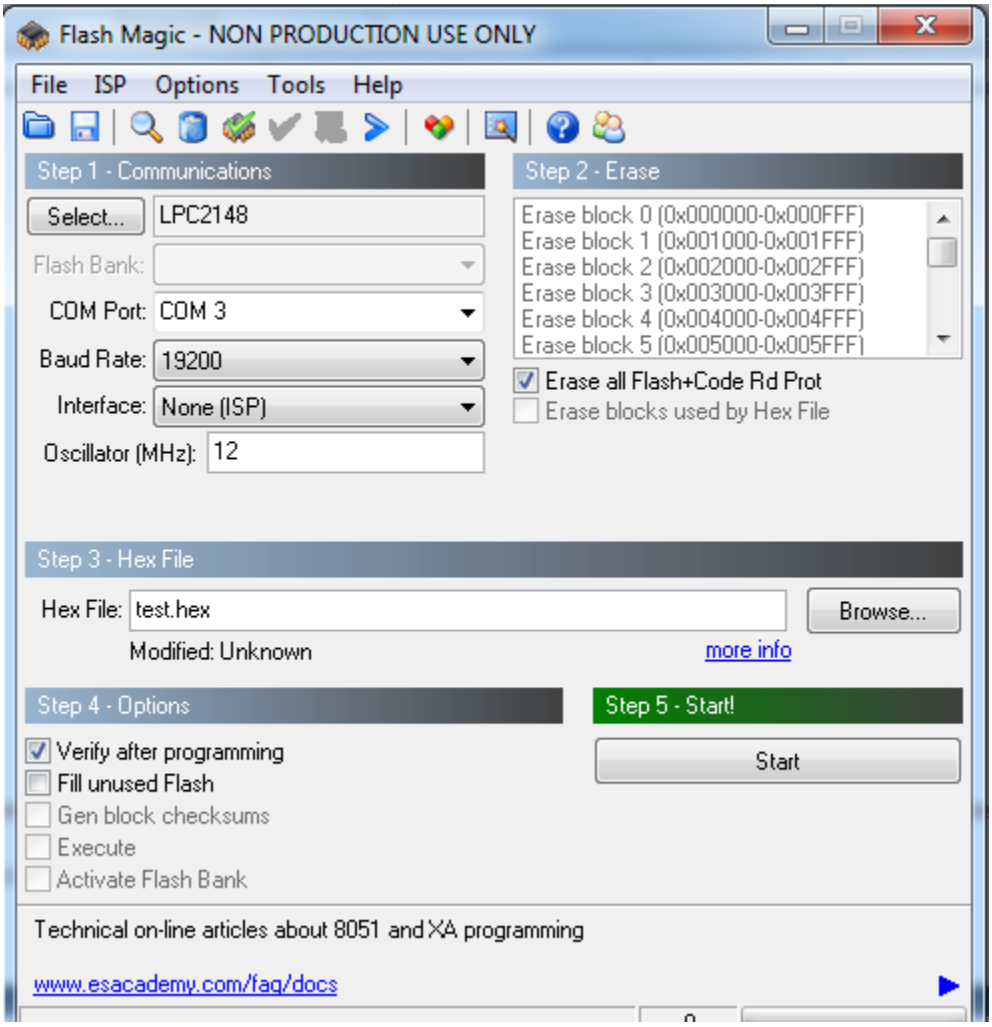
Write a C program for : One thread reads the input from the keyboard and another thread converts to upper case. This is done until Stop" is pressed. Use concept of semaphore, so that multiple printing is avoided.

```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include<string.h>
#include <ctype.h>
#include <pthread.h>
#include <semaphore.h>


#define BUFFER_SIZE 1024
sem_t sem;
```

```
char buffer[BUFFER_SIZE];

void *read_thread(void *arg)
{
while(strncmp("stop",buffer,4) != 0)
{
printf("Enter text:  ");
fgets(buffer, BUFFER_SIZE, stdin);
sem_post(&sem);
printf("%d \n",sem);
sleep(2);

}

pthread_exit("read_thread exit successful");
}

void *convert_thread()
{
int i;
sem_wait(&sem);
while(strncmp("stop", buffer, 4) != 0)
{
printf("Converted text:  ");
for(i=0; i<strlen(buffer); i++)
printf("%c", toupper(buffer[i]));
sem_wait(&sem);
}
pthread_exit("convert_thread exit successful");
}

int main()
{
int result;
pthread_t rthread, cthread;
void *thread_result;
sem_init(&sem, 0, 1);
printf("Enter text, the program will convert it into upper case, \n To stop enter 'stop' \n");
pthread_create(&cthread, NULL, convert_thread, NULL);

pthread_create(&rthread, NULL, read_thread, NULL);

result = pthread_join(rthread, &thread_result);

printf("read_thread joined, %s\n",(char *)thread_result);

pthread_join(cthread, &thread_result);
```

```
printf("convert_thread joined, %s\n",(char *)thread_result);
sem_destroy(&sem);
exit(0);
}
```

Steps for hardware Interfacing using Flashmagic



Familiarize I/O ports of LPC 2148 – on/off control of LEDs using switches.

```
#include "lpc214x.h"
#include "stdint.h"
unsignedintdelay_ms,led_val;
unsigned char index;
unsigned
intmvright[]={0x80808080,0x40404040,0x20202020,0x10101010,0x08080808,0x04040404,0x02
020202,0x01010101,0x00};
voidInitLPC(void)
{
        PINSEL0 = 0x00L;
        IODIR = 0XFFFFFFFF;
}
void Delay(unsigned intdms)
{
        delay_ms = dms;
        while(delay_ms> 0)
                delay_ms--;
}
main()
{
        index=0;
        InitLPC();
        while(1)
        {
        index&= 0x7;
        led_val = mvright[index++];
        IOSET =led_val;
        Delay(20000);
        IOCLR=0xFFFFFFFF;
        }
}
```

Interface keypad and display the key pressed on 7 segment LED display.

```
#include "lpc214x.h"
#include "stdint.h"
unsignedinti,delay_ms,segval;
unsigned char index, lcdval,row,keyscan,keyret,keynum=0, keypress,scanret = 0xFF;
unsigned char seg7[] =
{0x3f,0x06,0x5b,0x4f,0x66,0x6d,0x7d,0x07,0x7f,0x67,0x77,0x7c,0x39,0x5e,0x79,0x71,0x00,0x0
0,0x0};
unsigned char scan[]    = {0xEF,0xDF,0xBF,0x7F,0x00} ;
unsigned char keycode[]  =
{0xEE,0xED,0xEB,0xE7,0xDE,0xDD,0xDB,0xD7,0xBE,0xBD,0xBB,0xB7,0x7E,0x7D,0x7B,0x7
7,0x00};
voidInitLPC(void)
{
        PINSEL0 = 0x00L;
        IO0DIR = 0XFFFFFFF0;
}
void Delay(unsigned intdms)
{       delay_ms = dms;
        while(delay_ms> 0)
                delay_ms--;
}
voidGetKey()
{
      row=0;
      while(1)
      {
            IO0CLR = 0xFF;
            row&= 0x3;
            keyscan=scan[row];
            IO0SET = keyscan;
            Delay(2);
            keyret = IO0PIN;
           if (keyscan != keyret)
              break;
            row++;
      }
for(i=0;i<0x10;i++)
      {
            if(keycode[i]==keyret)
                  keynum=i;
      }
      IO0CLR = 0xFF00;
      segval = seg7[keynum];
      segval<<= 8;
      IO0SET = segval;
```

```
}
void main(void)
{
        InitLPC();
        index=0;
           while(1)
           GetKey();
}
```

Waveform generation using the internal DAC of LPC 2148.

```
//triangle

#include "lpc214x.h"
#include "stdint.h"
voiddelay_ms(uint16_t j)
{
uint16_tx,i;
        for(i=0;i<j;i++)
        {
for(x=0; x<6000; x++);    /* loop to generate 1 milisecond delay with Cclk = 60MHz */
        }
}

int main (void)
{
uint16_t value;
uint16_ti = 0;
PINSEL1 = 0x00080000;       /* P0.25 as DAC output */
        IO0DIR = 0xFFFFFFFF; /* Input pins for switch. P0.8 sine, P0.9 triangular, P0.10
sawtooth, P0.11 square */
        while(1)
        {
        i=0;
        while(i!=1023)
        {
        DACR=i<<6;
        i++;
        }
        i=1023;
        while(i!=0)
        {
        DACR=i<<6;
        i--;
        }
        }
}



//SQUARE
#include "lpc214x.h"
#include "stdint.h"


voiddelay_ms(uint16_t j)
```

```
{
uint16_tx,i;
        for(i=0;i<j;i++)
        {
for(x=0; x<6000; x++);    /* loop to generate 1 milisecond delay with Cclk = 60MHz */
        }
}

int main (void)
{
uint16_t value;
uint16_ti = 0;

        PINSEL1 = 0x00080000;       /* P0.25 as DAC output */
        IO0DIR = 0xFFFFFFFF; /* Input pins for switch. P0.8 sine, P0.9 triangular, P0.10
sawtooth, P0.11 square */
        while(1)
{
DACR=1023<<6;
delay_ms(10);
DACR=0;
delay_ms(10);

        }
}
```

Design and display a 4-digit counter.

```
#include "lpc214x.h"
#include "stdint.h"
#define IO1     0x10000
#define IO2     0x20000
#define IO3     0x40000
#define IO4     0x80000
#define IOX     0xF0000
#defineIOXcl  0xFFFFF

//Multiplexed 7segment Display
int count=0x0000;
unsigned int d0,d1,d2,d3;
unsigned char seg[] =
{0x3f,0x06,0x5b,0x4f,0x66,0x6d,0x7d,0x07,0x7f,0x67,0x77,0x7c,0x39,0x5e,0x79,0x71,0x00};

voidinit_gpio()
{
          PINSEL0 = 0x00000000;
          PINSEL1 = 0x00000000;
       PINSEL2 = 0x00000000;

          IO0DIR = 0XFFFFFFFF;
          IO1DIR = 0XFFFFFFFF;
}

void delay()
{
int c = 100000;
while(c)  //while count is more than zero loop
  {
c--;
  }
}
voidshow_disp()
{
       //Digit 3
          d3 = count & 0x0F000;
          d3 >>= 12;
       IO0CLR = IOXcl;
          IO0SET= seg[d3];       //Willdisplay data 1 on 7seg
          IO1SET = IOX;                  //ALL display are OFF
          IO1CLR = IO4;                  //Display1 is made on
          delay();
```

```
    IO1SET = IOX;            //ALL display are OFF

      //Digit 2
      d2 = count & 0x0F00;
      d2 >>= 8;
    IO0CLR = IOXcl;
      IO0SET= seg[d2];      //Willdisplay data 2 on 7seg
      IO1SET = IOX;               //ALL display are OFF
      IO1CLR = IO3;               //Display1 is made on
      delay();
    IO1SET= IOX;            //ALL display are OFF
      //Digit 1
      d1 = count & 0x00F0;
      d1 >>= 4;
    IO0CLR = IOXcl;
      IO0SET = seg[d1];     //Willdisplay data 3 on 7seg
      IO1SET = IOX;               //ALL display are OFF
      IO1CLR = IO2;               //Display1 is made on
      delay();
      IO1SET = IOX;               //ALL display are OFF
      //Digit 0
    d0 = count & 0x000F;
    IO0CLR = IOXcl;
      IO0SET = seg[d0];     //Will display data 4 on 7seg
      IO1SET = IOX;               //ALL display are OFF
      IO1CLR = IO1;               //Display1 is made on
      delay();
    IO1SET = IOX;            //ALL display are OFF
}
int main( void )
{

init_gpio();
while(1)
  {
        show_disp();
        count++;
        count&= 0xFFFF;
  }
}
```

Display message on LCD

//SINGLE LINE

```
#include "lpc214x.h"
#include "stdint.h"
unsignedint cmd8[] = {0X38,0x38,0x0E,0x02,0x01,0x00};
unsigned intmsg[] = {'H','e','l','l','o',0x20,'R','I','T',0x20,0x00};
unsignedintlcdval,index,delay_ms;
voidInitLPC(void)
{
PINSEL0 = 0x00L;
IO0DIR = 0XFFFFFFFF;
}
void Delay(unsigned intdms)
{
delay_ms = dms;
while(delay_ms> 0)
{
delay_ms--;
}
}
Void InitLCD()
{
index=0;
lcdval=cmd8[index];
while(lcdval !=0x0)
{
IO0SET = lcdval;
lcdval |= 0x400;
IO0SET = lcdval;
Delay(500);
IO0CLR=0xFFFF;
index++;
lcdval=cmd8[index];
}
}
voidShowMsg()
{
index=0;
lcdval=msg[index];
while(lcdval !=0x0)
{
IO0SET = lcdval;
lcdval |= 0x500;
IO0SET = lcdval;
Delay(500);
```

```
IO0CLR=0xFFFF;
index++;
lcdval=msg[index];
}
}
void main(void)
{
InitLPC();
while(1)
{
InitLCD();
ShowMsg();
Delay(5000);
}
}
```