Basic and Finite State Machine LED and Switch I/O Programming

6th Laboratory Report for ECE 383

Microcomputers

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Abstract

Lab 6 was an introduction to using the basic I/O ports associated with the PIC24 to create a switch-based input and LED-based output. A program was created using the C language to create a software-based finite state machine to solve a basic I/O problem. During the lab, we expanded the system schematic and printed circuit board for the PIC24, created a software-based finite state machine to solve a simple LED/switch I/O problem, and created C code to solve a multicolor LED problem involving binary to gray code conversions.

For task 1, we expanded the PIC24 system schematic based on a given design, to include pushbuttons, resistors, and LEDs using PCB Artist. In task 2, we converted the new schematic created in task 1 to a printed circuit board layout and controlled and noted the locations of the components on the board. In task 3, a simple LED problem was solved using C code and the PIC24 hardware. For task 4, a software-based finite state machine was created to solve a given LED problem using two LEDs and a given circuit involving the PIC24 on a breadboard. In task 5, a multicolored RGB LED was used in a circuit with the PIC24, and C code was written to involve pushbuttons and conversion from binary codes to gray codes.

In Lab 6, we became familiar with involving the PIC24 in a breadboard layout, and how to write code to involve the I/O ports of the PIC24, and we verified the success of our programs with a demo using our implementations on the PIC24 hardware.

Introduction

The objective of this lab is to become more familiar with PIC24 I/O and how to configure and use pins for input and output. Task one has us creating a system schematic for the PIC24 that includes resistors, switches and LEDs. Task two has us taking the system schematic created in task one and converting it into a printed circuit board schematic. Task three has us taking a given piece of code, running it on the PIC24, and then modifying the code and running it on the PIC24. Task four is the most complicated and involves creating a finite state machine that solves a basic I/O LED and switch button problem. Task five involves writing C code to run a program that turns on a RGB LED based on what switches are being held down. This code also converts binary codes to gray codes.

Prelab

Task 1. Expanding the PIC24 Reference System Schematic

In the first task, we create the new schematic circuit based on the previous lab. The figure of schematic circuit is Fig.1

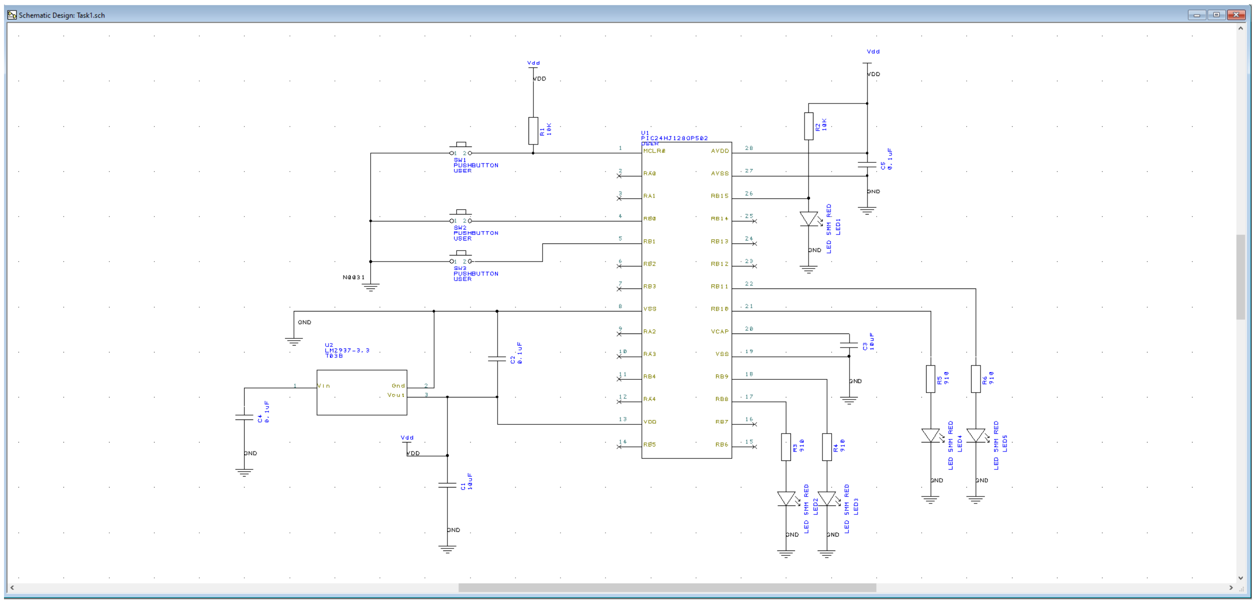


Figure 1. Schematic Circuit of Task 1

Task 2. Expand the PIC24 System Printed Circuit Board Layout

Task two had us take the system schematic created in Task one and convert it to a printed circuit board (Fig.2) and note where the components are on the board from the list of and y coordinates. We also created mounting holes to the printed circuit board design. To verify that our circuit board passed basic electrical design rules, we clicked Tools->Design Rule Check, checking both the Spacing, Nets, and Manufacturing boxes. This rule check reported that no errors were found in our designs. Finally, we generated two different reports on our printed circuit board. The first of these reports was a bill of materials CSV file. The second of these reports was a component positions report CSV file. They are both in the Appendix A as Bill of Materials CSV File and Components Position CSV File.

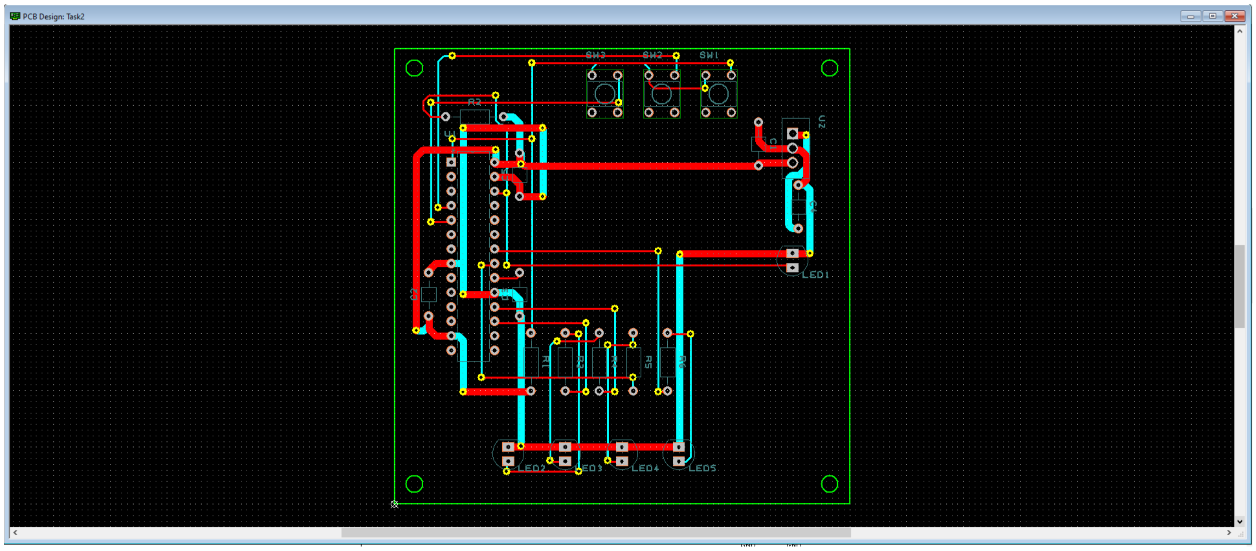


Figure 2 PCB Layout

Procedure/Results

Task 3. A Basic LED Problem

Task three was broken into two parts, 3a and 3b. 3a included creating a new project, and copying code to a file in the project, and then downloading the code to the PIC24 and running the code to verify it is working properly. The program from 3a blinked an onboard LED at a constant rate. 3b included creating a new project and taking the code from 3a and modifying it to blink the LED at two different rates, one fast and one slow. The code for 3b was then downloaded to the PIC24 and verified to work properly. The source code will be shown in Appendix B.

Task 4. Software-Based Finite State Machine for LED/Switch I/O

Task four was the most complex of the tasks for this lab and involved creating a software-based finite state machine to implement a simple LED problem using the PIC24 I/O ports on a breadboard configuration. This task also implemented the use of pushbuttons which were used a source of input to the program. The finite state machine solved a given problem and was implemented using C code. The code was then downloaded to the PIC24 and tested in the breadboard circuit. Fig.3 is the layout of bread board and the source code and ASM chart will be shown in Appendix C.

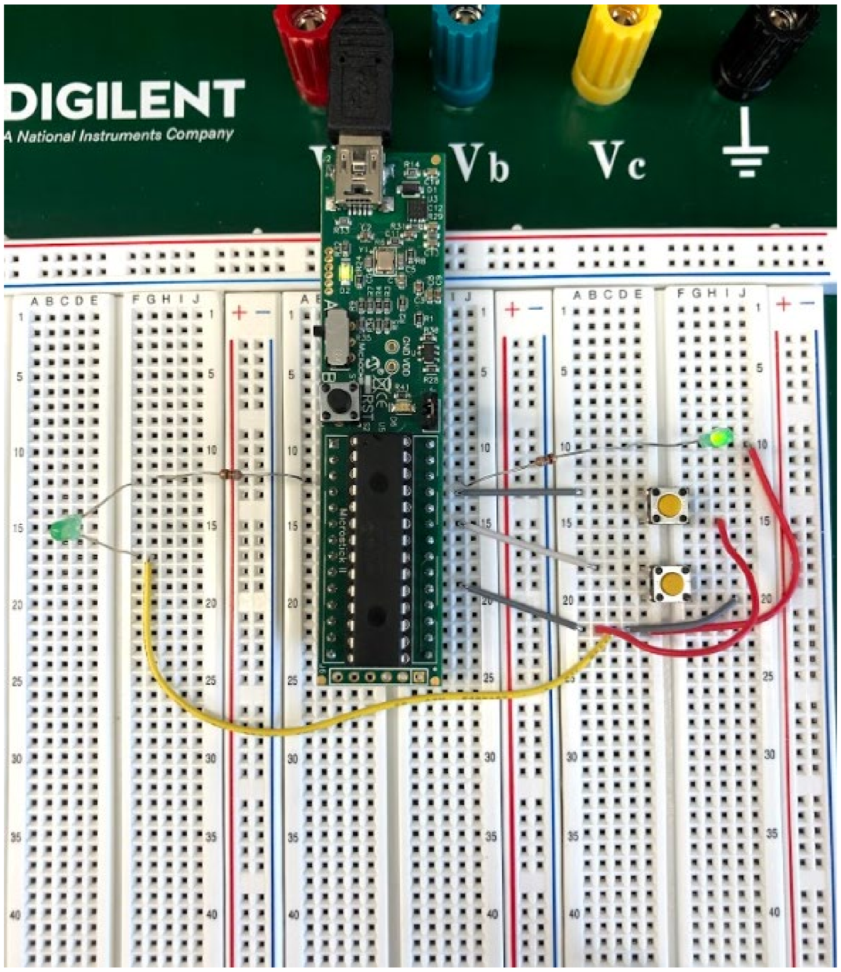


Figure 3. Layout of bread board for Task4

Task 5. Variable Rotating LED

Task 5 implemented the use of RGB LED in a circuit with the PIC24 on the Microstick II. A C program was written to solve a given problem, and the code would display different binary or gray codes and convert between them based on what pushbuttons were being pushed or released. The C code was then downloaded to the PIC24 and tested in the breadboard circuit. The source code and answers of questions will be shown in Appendix D. Fig.4 is the breadboard layout of Task5.

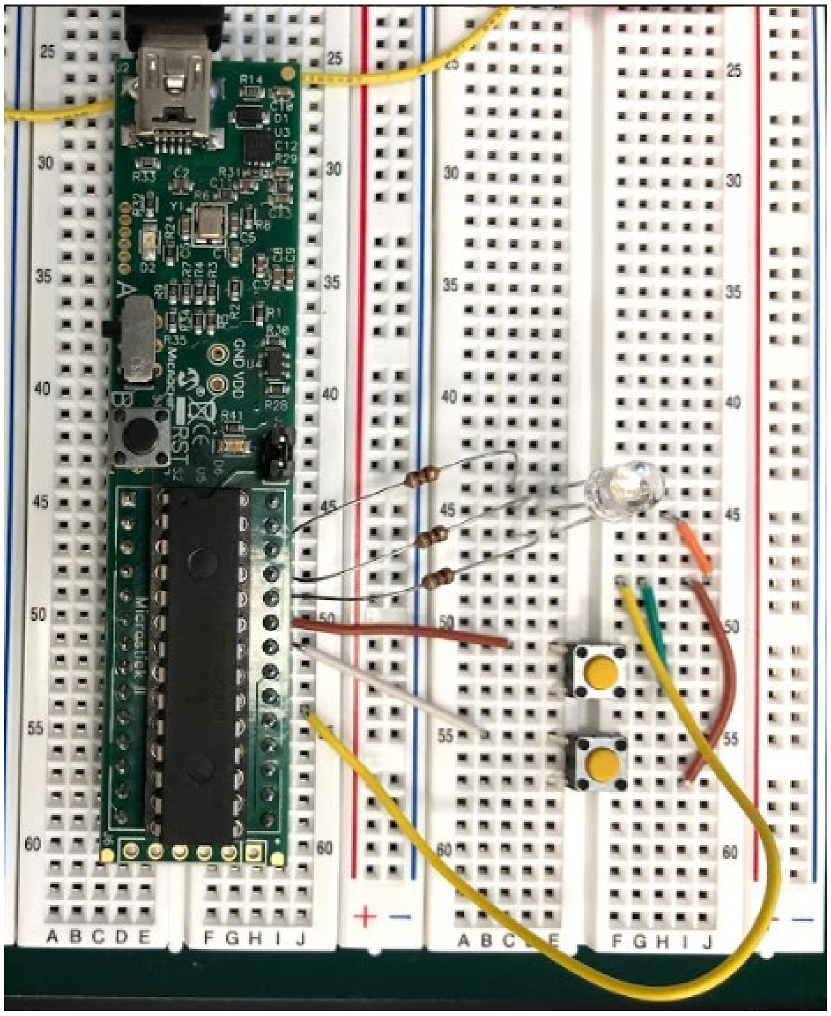


Figure 4. Breadboard layout of Task5

Conclusion

This sixth lab was a learning experience for the use of the PIC24 I/O ports. We were taught how to implement and run programs that used and configured some of the PIC24 I/O ports on a breadboard. We now know how to properly interlay the PIC24 on a breadboard to take full advantage of its I/O ports. We also know how to develop and write C code that can control the PIC24 ports, and solve problems using both onboard and external devices. Overall, we now have a much better understanding of the PIC24 I/O systems.

Appendixes

Appendix A – Reports of Task 2

Bill of Material Report

Component	Package	Value	Manuf	Manuf Part No	Distrib	Distrib Part No	Ref Name	Qty
C	DSC	0.1uF					C2 C4 C5	3
C	DSC	10uF					C1 C3	2
LED	DSC	LED 5MM RED					LED1 LED4 LED5 LED2 LED3	5
LM2937-3.3	T03B			LM2937ET-50			U2	1
PIC24HJ128GP502	USER						U1	1
PUSHBUTTON	USER						SW1 SW2 SW3	3
R	DSC	10K					R1 R2	2
R	DSC	910					R3 R4 R5 R6	4
								21
PCB Artist Bill of Materials is provided for reference only and must be verified by the user.								

Position Report

Name	Component	Side	Centre X	Centre Y	Rotation
C1	C	Top	64	63.2	270
C2	C	Top	6	36.8	90
C3	C	Top	22	36.8	90
C4	C	Top	71	52.2	270
C5	C	Top	22	57.8	90
LED1	LED	Top	70	42.6	0
LED2	LED	Top	20	8.6	0
LED3	LED	Top	30	8.6	0
LED4	LED	Top	40	8.6	0
LED5	LED	Top	50	8.6	0
U2	LM2937-3.3	Top	70.5	62.5	270
U1	PIC24HJ128GP502	Top	13.8	43.5	0

SW1	PUSHBUTTON	Top	57	72	0
SW2	PUSHBUTTON	Top	47	72	0
SW3	PUSHBUTTON	Top	37	72	0
R1	R	Top	24	24.9	270
R2	R	Top	14.1	68	0
R3	R	Top	30	24.9	270
R4	R	Top	36	24.9	270
R5	R	Top	42	24.9	270
R6	R	Top	48	24.9	270

Appendix B – Source code of Task 3

Task 3a

Source code

```
#include "pic24_all.h"

#if __PIC24HJ128GP502__

#define LED1 _LATA0 // MicroStick II definitions

#define CONFIG_LED1() CONFIG_RA0_AS_DIG_OUTPUT()

#endif

int main(void) { CONFIG_LED1(); LED1=0;

while (1) { // Infinite while loop

LED1 = !LED1; // Toggle LED1

DELAY_MS(100); // Delay 100ms

}

return 0;

}
```

Task 3b

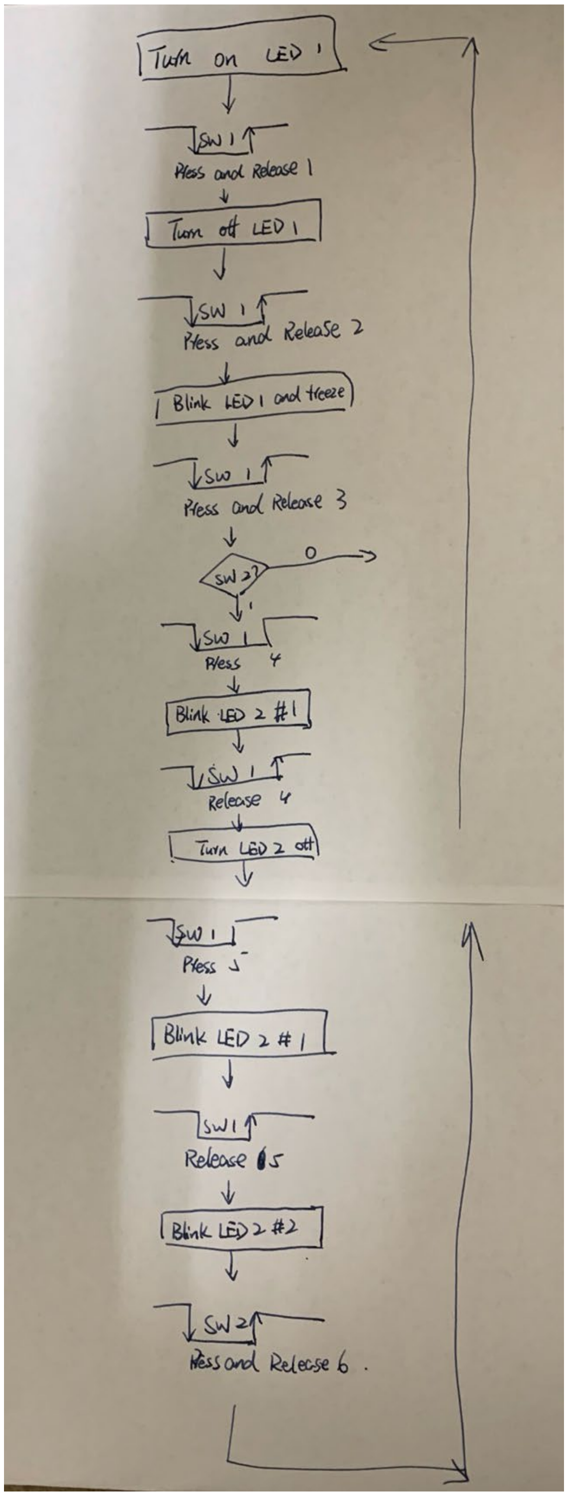
Source code

```
#include "pic24_all.h"
#if __PIC24HJ128GP502__
#define LED1 _LATA0 // MicroStick II definitions
#define CONFIG_LED1() CONFIG_RA0_AS_DIG_OUTPUT()
#endif
int main(void) { CONFIG_LED1(); LED1=0;
        int i;
        while (1) { // Infinite while loop
                i = 0;
                while(i <= 50) {
                        LED1 = !LED1; // Toggle LED1
                        DELAY_MS(100); // Delay 100ms
                        i++;
                }
                i = 0;
                while(i < 25) {
                        LED1 = !LED1; // Toggle LED1
                        DELAY_MS(200); // Delay 200ms
                        i++;
                }

        }
        return 0;
}
```

Appendix C – Source code and ACM chart of Task 3

ACM Chart



Source Code

```
#include "pic24_all.h"

#define CONFIG_LED1() CONFIG_RB15_AS_DIG_OUTPUT()

#define LED1 _LATB15

#define CONFIG_LED2() CONFIG_RB2_AS_DIG_OUTPUT()

#define LED2 _LATB2

inline void CONFIG_SW1() {

        CONFIG_RB14_AS_DIG_INPUT();

        ENABLE_RB14_PULLUP();

}

inline void CONFIG_SW2() {

        CONFIG_RB12_AS_DIG_INPUT();

        ENABLE_RB12_PULLUP();

}

#define SW1                 _RB14

#define SW1_PRESSED()       SW1 == 1

#define SW1_RELEASED()      SW1 == 0

#define SW2                 _RB12

#define SW2_PRESSED()       SW2 == 1

#define SW2_RELEASED()      SW2 == 0


typedef enum {

        STATE_RESET = 0,

        STATE_WAIT_FOR_PRESS1, STATE_WAIT_FOR_RELEASE1,

        STATE_WAIT_FOR_PRESS2, STATE_WAIT_FOR_RELEASE2,

        STATE_WAIT_FOR_PRESS3, STATE_WAIT_FOR_RELEASE3,

        STATE_WAIT_FOR_PRESS4, STATE_WAIT_FOR_RELEASE4,

        STATE_WAIT_FOR_PRESS5, STATE_WAIT_FOR_RELEASE5,

        STATE_WAIT_FOR_PRESS6, STATE_WAIT_FOR_RELEASE6,

        STATE_BLINK1
```

```
}           STATE;


int main(void) {
            configClock();
            STATE e_mystate;
            configBasic(HELLO_MSG);
            CONFIG_SW1(); //configure switch1
            CONFIG_SW2(); //configure switch2
            CONFIG_LED1();          //configure LED1
            CONFIG_LED2();          //configure LED2
            DELAY_US(1);    //give pull-ups time to work

            e_mystate = STATE_WAIT_FOR_PRESS1;
            while(1) {
                        switch (e_mystate) {
                                    case STATE_WAIT_FOR_PRESS1:
                                                LED1 = 1;                               //turn on the LED1
                                                if(SW1_PRESSED()) e_mystate = STATE_WAIT_FOR_RELEASE1;
                                                break;

                                    case STATE_WAIT_FOR_RELEASE1:
                                                if(SW1_RELEASED()) e_mystate = STATE_WAIT_FOR_PRESS2;
                                                break;

                                    case STATE_WAIT_FOR_PRESS2:
                                                DELAY_MS(100);
                                                LED1 = 0;                               //turn off LED1
                                                if(SW1_PRESSED()) e_mystate = STATE_WAIT_FOR_RELEASE2;
                                                break;
```

```
case STATE_WAIT_FOR_RELEASE2:
        if(SW1_RELEASED()) e_mystate = STATE_BLINK1;
        break;

case STATE_BLINK1:
        LED1 = 1;                       //turn on LED1
        DELAY_MS(10);
        LED1 = 0;                       //first blink
        DELAY_MS(10);
        LED1 = 1;                       //turn on LED1
        DELAY_MS(10);
        LED1 = 0;                       //second blink
        DELAY_MS(10);
        LED1  = 1;                      //freeze LED1 on
        e_mystate = STATE_WAIT_FOR_PRESS3;
        break;

case STATE_WAIT_FOR_PRESS3:
        DELAY_MS(100);
        if(SW1_PRESSED()) e_mystate = STATE_WAIT_FOR_RELEASE3;
        break;

case STATE_WAIT_FOR_RELEASE3:
        if(SW1_RELEASED()) {
                if(SW2) {
                        e_mystate = STATE_WAIT_FOR_PRESS4;
                        break;
                }
                else {
                        e_mystate = STATE_WAIT_FOR_PRESS1; // back to start
                        break;
                }
        }
        break;

case STATE_WAIT_FOR_PRESS4:
        DELAY_MS(100);
        if(SW1_PRESSED()) {
                LED2 = 0;
                e_mystate = STATE_WAIT_FOR_RELEASE4;
        }
        else {
                DELAY_MS(10); // Blink LED2 #1
                LED2 = !LED2;
        }
        break;

case STATE_WAIT_FOR_RELEASE4:
        if(SW1_RELEASED()) e_mystate = STATE_WAIT_FOR_PRESS5;
        break;

case STATE_WAIT_FOR_PRESS5:
        DELAY_MS(100);
        if(SW1_PRESSED()) {
                LED2 = 0;
                e_mystate = STATE_WAIT_FOR_RELEASE5;//Second Release
        }
        else {
                DELAY_MS(10);
                LED2 = !LED2;
```

```
                    }
                    break;

                case STATE_WAIT_FOR_RELEASE5:
                    if(SW1_RELEASED()) e_mystate = STATE_WAIT_FOR_PRESS6;
                    break;

                case STATE_WAIT_FOR_PRESS6:
                    DELAY_MS(100);
                    if(SW2_PRESSED()) {
                        LED2 = 0;
                        e_mystate = STATE_WAIT_FOR_RELEASE6;
                    }
                    else {
                        DELAY_MS(5); // Blink LED2 #2
                        LED2 = !LED2;
                    }
                    break;

                case STATE_WAIT_FOR_RELEASE6:
                    if(SW2_RELEASED()) e_mystate = STATE_WAIT_FOR_PRESS1; // Back to
top
                    break;

                default:
                    e_mystate = STATE_WAIT_FOR_PRESS1;
            }
        }
return 0;
}
```

Appendix D – Source code and Answer of Task 4

Source code

```
#include "pic24_all.h"

#if __PIC24HJ128GP502__

#define R_LED _LATB15// MicroStick II definitions

#define CONFIG_R_LED() CONFIG_RB15_AS_DIG_OUTPUT()

#define G_LED _LATB14

#define CONFIG_G_LED() CONFIG_RB14_AS_DIG_OUTPUT()

#define B_LED _LATB13

#define CONFIG_B_LED() CONFIG_RB13_AS_DIG_OUTPUT()

#define SW1 _RB12

#define SW2 _RB11

#endif


//Figure (4.1)


//Figure (4.2)


//6


inline void CONFIG_SW1() {

CONFIG_RB12_AS_DIG_INPUT(); // use RB13 for switch input

ENABLE_RB12_PULLUP(); // enable the pullup

}


inline void CONFIG_SW2() {

CONFIG_RB11_AS_DIG_INPUT(); // use RB13 for switch input

ENABLE_RB11_PULLUP(); // enable the pullup
```

```
}

inline char bin2gray(char binNum)
{
char grayNum = binNum;
grayNum = grayNum >> 1;
return (grayNum ^ binNum);
}

int main(void) {
char binNum, grayNum;
CONFIG_R_LED();
CONFIG_G_LED();
CONFIG_B_LED();
CONFIG_SW1();
CONFIG_SW2();
R_LED=0;
G_LED=0;
B_LED=0;
while (1) {

//7

binNum = 0x0;
grayNum = 0x0;
if ((SW1 == 0) && (SW2 == 0)) {R_LED = G_LED = B_LED = 0;}
while ((SW1 == 0) && (SW2 == 0)) //SW1 & SW2 pressed
{
```

```
R_LED = !R_LED; // Toggle LED1
G_LED = !G_LED;
B_LED = !B_LED;
DELAY_MS(10); // Delay 100ms
}
while ((SW1 == 1) && (SW2 == 1))
{
R_LED = 1;
G_LED = 1;
B_LED = 1;
DELAY_MS(15);
}
while ((SW1 == 1) && (SW2 == 0))
{
if (binNum == 8) {binNum = 0x0;}
if ((binNum & 1) == 1) {R_LED = 1;}
else R_LED = 0;
if ((binNum & 2) == 2) {G_LED = 1;}
else G_LED = 0;
if ((binNum & 4) == 4) {B_LED = 1;}
else B_LED = 0;
binNum++;
DELAY_MS(10);
}

//8

while ((SW1 == 0) && (SW2 == 1))
```

```
{
if (grayNum == 8) {grayNum = 0x0;}
if ((bin2gray(grayNum)&1)==1) {R_LED = 1;}
else R_LED = 0;
if ((bin2gray(grayNum)&2)==2) {G_LED = 1;}
else G_LED = 0;
if ((bin2gray(grayNum)&4)==4) {B_LED = 1;}
else B_LED = 0;
grayNum++;
DELAY_MS(10);
}


}
return 0;
}
```

Answers

Question 1. What are the advantages of binary codes and gray code respectively?

Answer:

Advantage of grey code: The difference between two adjacent value is always 1 bit.

Advantage of binary code: Binary code can use in truth tables.

Question 2. Can we convert a gray code value back to binary code? If the answer is yes, please describe one possible method. Otherwise please explain the reason.

Answer: The last digit of gray code is same as the last digit of original binary code. Therefore, we can convert the gray code back to binary code.

Let's suppose the three-digit gray code as g_3 g_2 g_1 and three-digit binary code as b_3 b_2 b_1.

By the conversion from binary code to gray code, g_3 = 0 XOR b_3, g_2 = b_2 XOR b_3, g_1 = b_2 XOR b_1.

If b_3 = 0, then g_3 = 0. If b_3 = 1, then g_3 = 1. So, b_3 = g_3.

Then we can figure out, b_2 = b_3 XOR g_2 and b_1 = b_2 XOR g_1.

In general, to convert gray code to binary code, we can have

b_3 = g_3,

b_2 = b_3 XOR g_2,

b_1 = b_2 XOR g_1.