TRƯỜNG ĐẠI HỌC BÁCH KHOA – TP. HỒ CHÍ MINH

KHOA KHOA HỌC VÀ KỸ THUẬT MÁY TÍNH

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Lab 3 - Buttons - Switchs

Microcontroller - Microprocessor (Lab)

COURSE ID: CO3010 - HK251

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1 Exercises and Report

1.1 Specifications

You are required to build an application of a traffic light in a cross road which includes some features as described below:

- The application has 12 LEDs including 4 red LEDs, 4 amber LEDs, 4 green LEDs.
- The application has 4 seven segment LEDs to display time with 2 for each road. The 2 seven segment LEDs will show time for each color LED corresponding to each road.
- The application has three buttons which are used

  - to select modes,

  - to modify the time for each color led on the fly,

  - to set the chosen value.

- The application has at least 4 modes which is controlled by the first button. Mode 1 is a normal mode, while modes 2 3 4 are modification modes. You can press the first button to change the mode. Modes will change from 1 to 4 and back to 1 again.

  Mode 1 - Normal mode:

  - The traffic light application is running normally.

  Mode 2 - Modify time duration for the red LEDs: This mode allows you to change the time duration of the red LED in the main road. The expected behaviours of this mode include:

  - All single red LEDs blink at 2 Hz.
  - Two seven-segment LEDs display the time value.
  - The other two seven-segment LEDs display the mode.
  - The second button increases the time duration value for the red LEDs.
  - The time duration value ranges from 1 to 99.
  - The third button sets the value.

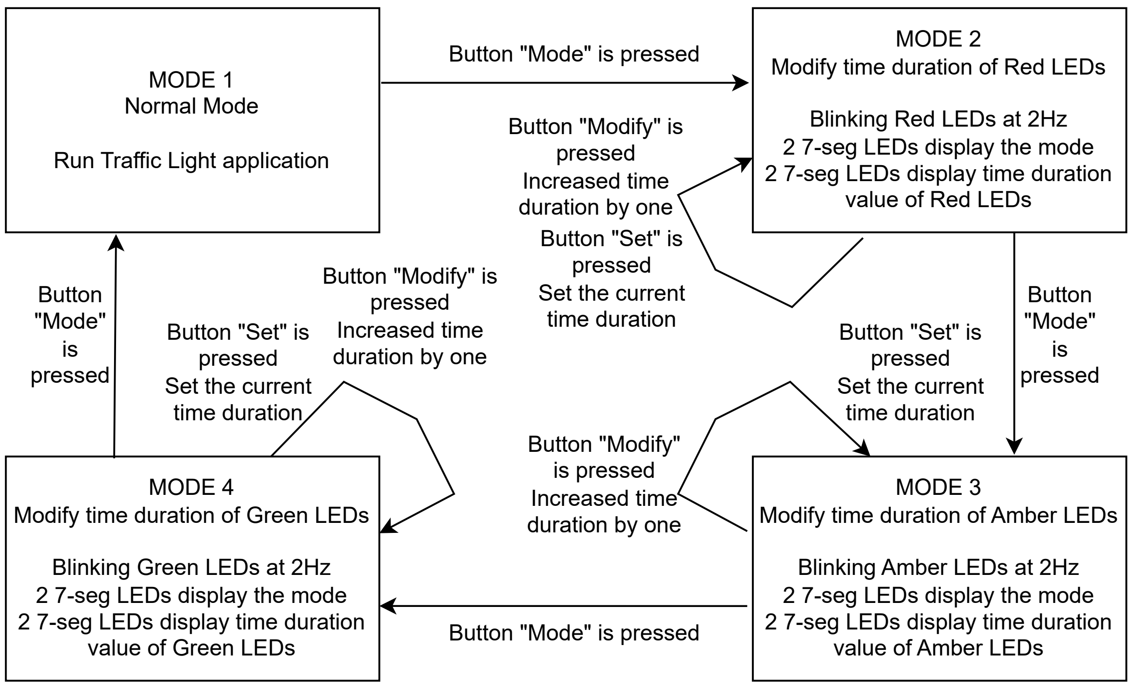
  Mode 3 - Modify time duration for the amber LEDs: Similar for the red LEDs described above with the amber LEDs.

  Mode 4 - Modify time duration for the green LEDs: Similar for the red LEDs described above with the green LEDs.

1.2 Report

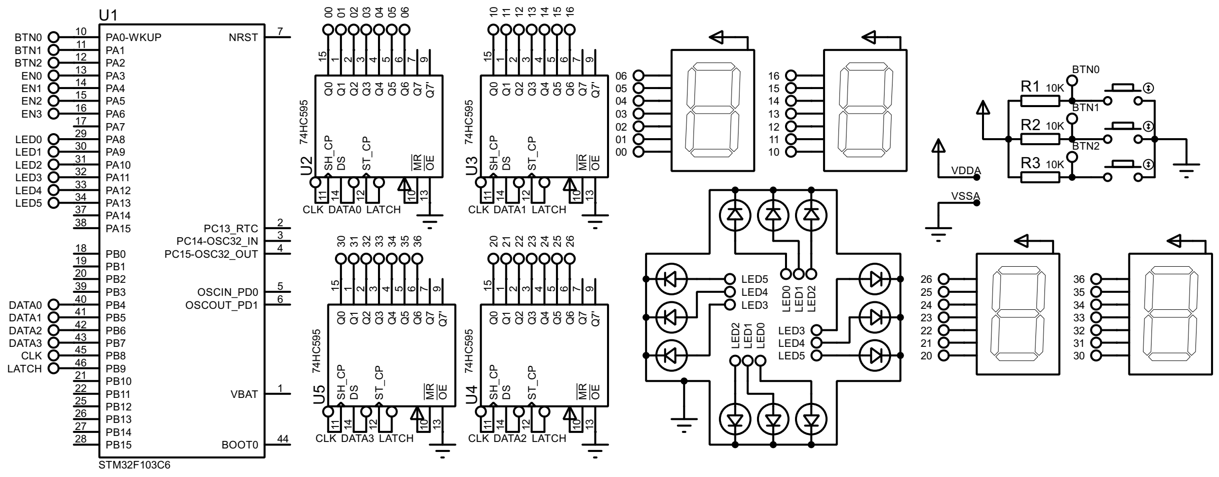
The GitHub link for the lab files: https://github.com/hygameo/VXL-VDK_2352458

1.2.1 Exercise 1: Sketch an FSM

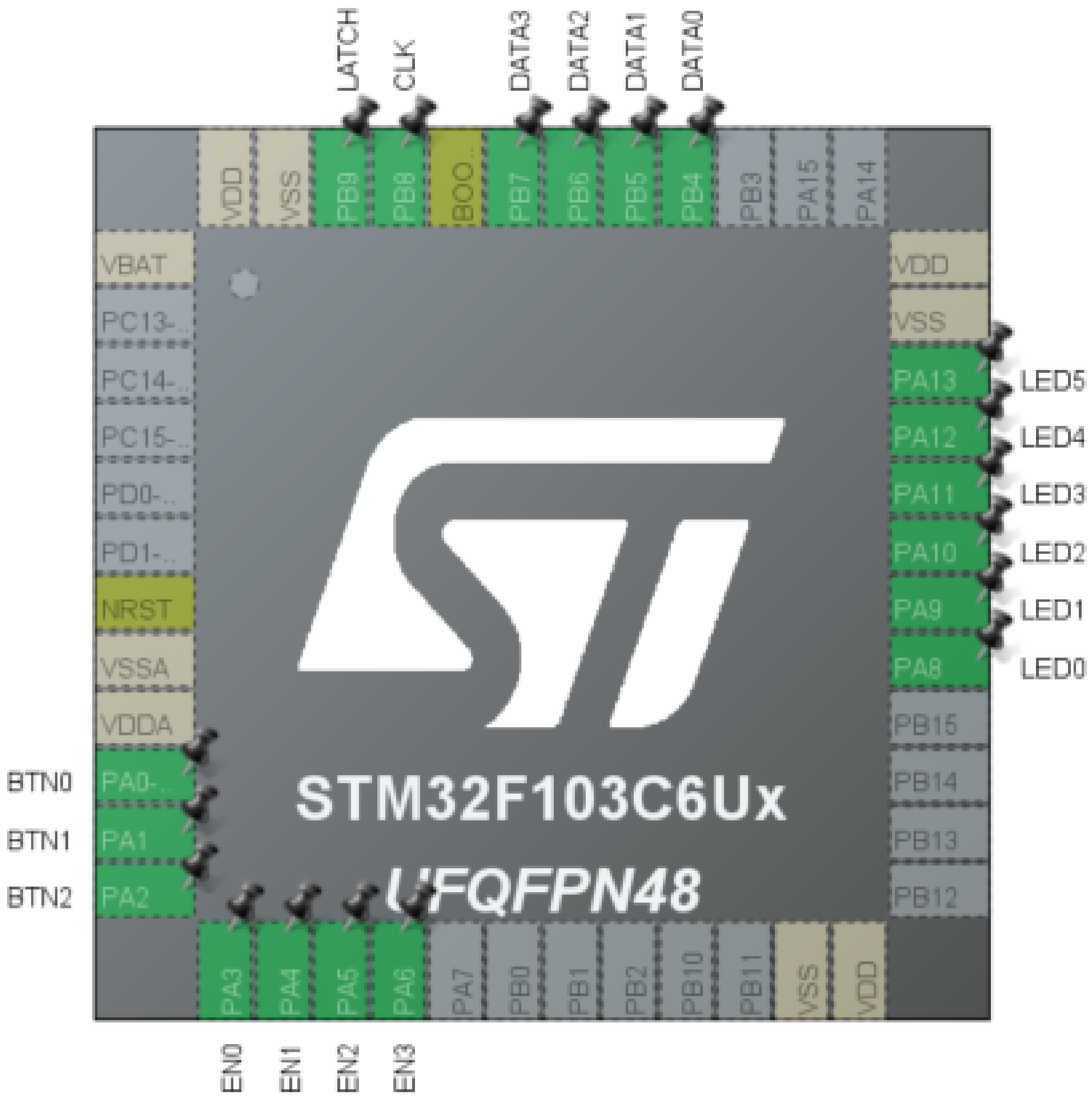

MODE 1
Normal Mode
Run Traffic Light application
Button "Mode" is pressed
MODE 2
Modify time duration of Red LEDs
Blinking Red LEDs at 2Hz
2 7-seg LEDs display the mode
2 7-seg LEDs display time duration value of Red LEDs
Button "Modify" is pressed
Increased time duration by one
Button "Set" is pressed
Set the current time duration
Button "Mode" is pressed
MODE 3
Modify time duration of Amber LEDs
Blinking Amber LEDs at 2Hz
2 7-seg LEDs display the mode
2 7-seg LEDs display time duration value of Amber LEDs
Button "Set" is pressed
Set the current time duration
Button "Modify" is pressed
Increased time duration by one
Button "Mode" is pressed
MODE 4
Modify time duration of Green LEDs
Blinking Green LEDs at 2Hz
2 7-seg LEDs display the mode
2 7-seg LEDs display time duration value of Green LEDs
Button "Set" is pressed
Set the current time duration
Button "Modify" is pressed
Increased time duration by one
Button "Mode" is pressed

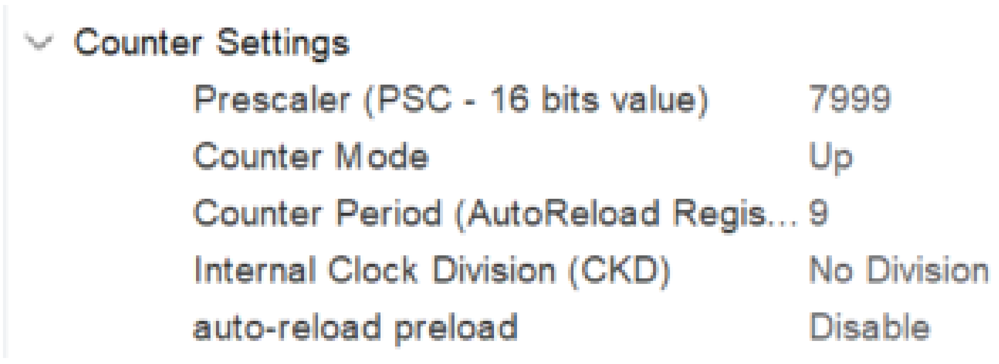
1.2.2 Exercise 2: Proteus Schematic

I used the 74HC595 IC to control the 4 seven-segment LEDs, replacing the LED scanning method from previous labs.



1.2.3 Exercise 3: Create STM32 Project




Counter Settings

Prescaler (PSC - 16 bits value)	7999
Counter Mode	Up
Counter Period (AutoReload Regis...	9
Internal Clock Division (CKD)	No Division
auto-reload preload	Disable

1.2.4 Exercise 4: Modify Timer Parameters

To easily and efficiently modify the timer interrupt duration to 1 ms or 100 ms while keeping the system simple, we can retain the prescaler at 7999 and adjust the ARR (Counter Period) to 0 for 1 ms or 99 for 100 ms. In the code, we calculate the TIMER_CYCLE based on the prescaler and ARR values and update the TIMER_CYCLE variable in timer.c accordingly to maintain the 2 Hz LED blinking frequency and other system functionalities.

Updating TIMER_CYCLE: In timer.c, the TIMER_CYCLE variable is set to 1 (for 1 ms interrupts) or 100 (for 100 ms interrupts) to ensure the soft timer logic correctly scales the duration (e.g., 500 ms for 2 Hz LED blinking) without affecting the system's overall behavior, such as the LED blinking frequency.

This approach minimizes changes to the system by keeping the prescaler constant and only modifying the ARR and TIMER_CYCLE, ensuring simplicity and compatibility with the traffic light application's requirements.

```c
# * timer.c

#include "main.h"
#include "input_reading.h"

#define MAX_SOFT_TIMER 3

int TIMER_CYCLE = 10;

int timer_counter[MAX_SOFT_TIMER];
int timer_flag[MAX_SOFT_TIMER];

void setSoftTimer(int index, int duration) {
    if (index < MAX_SOFT_TIMER) {
        timer_counter[index] = duration / TIMER_CYCLE;
        timer_flag[index] = 0;
    }
}

void softTimer_run() {
    for (int i = 0; i < MAX_SOFT_TIMER; i++) {
        if (timer_counter[i] > 0) {
            timer_counter[i]--;
            if (timer_counter[i] == 0) timer_flag[i] = 1;
        }
    }
}

void HAL_TIM_PeriodElapsedCallback ( TIM_HandleTypeDef * htim )
{
    if(htim -> Instance == TIM2 ){
        softTimer_run();
        button_reading();
    }
}
```

1.2.5 Exercise 5: Adding code for button debouncing

Button debouncing

Two buffers (debounceButtonBuffer1 and debounceButtonBuffer2) store consecutive readings of each button.

At every sampling cycle (for example, every 10ms), the program reads the button state again:

If the two consecutive readings are the same, the signal is considered stable, and the confirmed state is stored in buttonBuffer.

If the readings are different, it means the button is bouncing, so the program ignores the change.

This way, only a stable press or release is accepted as a valid input, effectively filtering out noise and mechanical bouncing.

```c
# * input_reading.c

#include "main.h"

#define NO_OF_BUTTONS 3

#define DURATION_FOR_AUTO_INCREASING 100

#define BUTTON_IS_PRESSED GPIO_PIN_RESET
#define BUTTON_IS_RELEASED GPIO_PIN_SET

static GPIO_PinState buttonBuffer [NO_OF_BUTTONS];

static GPIO_PinState debounceButtonBuffer1[NO_OF_BUTTONS];
static GPIO_PinState debounceButtonBuffer2[NO_OF_BUTTONS];

static uint8_t flagForButtonPress1s [ NO_OF_BUTTONS ];
static uint8_t flagForButtonPressedOnce[NO_OF_BUTTONS];

static uint16_t counterForButtonPress1s [ NO_OF_BUTTONS ];

GPIO_TypeDef* buttonPort[NO_OF_BUTTONS] = {BTN0_GPIO_Port, BTN1
    _GPIO_Port, BTN2_GPIO_Port};
uint16_t buttonPin[NO_OF_BUTTONS] = {BTN0_Pin, BTN1_Pin, BTN2_Pin};

void button_reading ( void ){
    for ( int i = 0; i < NO_OF_BUTTONS ; i ++){
        debounceButtonBuffer2 [i] = debounceButtonBuffer1 [i];
        debounceButtonBuffer1 [i] = HAL_GPIO_ReadPin ( buttonPort[i] ,
            buttonPin[i] );
        if( debounceButtonBuffer1 [i] == debounceButtonBuffer2 [i]){
            if (buttonBuffer[i] == BUTTON_IS_RELEASED &&
               debounceButtonBuffer1[i] == BUTTON_IS_PRESSED)
               flagForButtonPressedOnce[i] = 1;
            else flagForButtonPressedOnce[i] = 0;
            buttonBuffer [i] = debounceButtonBuffer1 [i];
        }
        if( buttonBuffer [i] == BUTTON_IS_PRESSED ){
            if( counterForButtonPress1s [i] < DURATION_FOR_AUTO_INCREASING ) counterForButtonPress1s [ i ]++;
            else flagForButtonPress1s [i] = 1;
        } else {
            flagForButtonPressedOnce[i] = 0;
            counterForButtonPress1s [i] = 0;
            flagForButtonPress1s [i] = 0;
        }
    }
}

unsigned char is_button_pressed ( uint8_t index ){
    if( index >= NO_OF_BUTTONS ) return 0;
    return ( buttonBuffer [ index ] == BUTTON_IS_PRESSED );
}

unsigned char is_button_pressed_once(uint8_t index) {
    if(index >= NO_OF_BUTTONS) return 0;
    if(flagForButtonPressedOnce[index] == 1) {
        flagForButtonPressedOnce[index] = 0;
        return (flagForButtonPressedOnce[index] == 0);
    }
    return (flagForButtonPressedOnce[index] == 1);
}

unsigned char is_button_pressed_1s ( uint8_t index ){
    if( index >= NO_OF_BUTTONS ) return 0;
    return ( flagForButtonPress1s [ index ] == 1);
}
```

Mode Switching

Each time the button is pressed once (is_button_pressed_once(0)), the value of mode increases by 1.

When mode exceeds 4, it returns to 1, allowing the user to cycle through four modes in sequence.

There are two switch(mode) structures in the code, and each has a different purpose:

Initialization switch

It updates last_mode and calls an initialization function corresponding to the selected mode.

These functions are used to reset variables, timers, or LEDs so the new mode starts in a defined state.

Continuous execution switch

This part executes repeatedly inside the main while(1) loop while the mode remains the same.

It calls the finite state machine (FSM) function for the current mode, allowing the system to continuously perform its tasks — for example, controlling the traffic lights or updating the modification timing logic.

```c
# * part of main.c

int last_mode = 1;
int mode = 1;

while (1)
{
    fsm_for_input_processing();
    fsm_for_led_display();

    if(is_button_pressed_once(0)) mode++;
    if(mode > 4) mode = 1;

    if (mode != last_mode) {
        last_mode = mode;
        switch(mode) {
            case 1: traffic_Init(); break;
            case 2: modifySec_Init(0); break;
            case 3: modifySec_Init(1); break;
            case 4: modifySec_Init(2); break;
        }
    }
    else {
        switch(mode){
            case 1: fsm_for_trafic_light(); break;
            case 2: fsm_for_traffic_modifySec(0); break;
            case 3: fsm_for_traffic_modifySec(1); break;
            case 4: fsm_for_traffic_modifySec(2); break;
        }
    }
}
```

1.2.6 Exercise 6: Adding code for displaying modes

Display mode on seven-segment LEDs

The function update7SEG() controls four seven-segment displays using a shift register mechanism.

Each segment pattern is defined in the segmentMap[] array, where each bit represents one segment of a digit (from 0 to 9).

The current values to be shown on the displays are stored in the seg_buffer[4] array.

During each update cycle, update7SEG() shifts out the bit patterns of all four digits (using DATAx and CLK pins), and finally sends a latch pulse (LATCH pin) to update the output of the shift registers.

By modifying the values in seg_buffer[], the program can display numbers or mode indicators on the seven-segment LEDs.

Blinking LEDs depending on the mode that is selected

The array led_buffer[6] stores the ON/OFF states of six indicator LEDs.

The function updateLED() writes these states to the physical GPIO pins connected to each LED.

The finite state machine function fsm_for_led_display() is called continuously in the main loop.

A software timer (timer_flag[0]) is used to trigger periodic updates — every 100ms.

The timer ensures that LED updates happen at regular intervals, producing a stable and visible blinking effect.

```c
# * led_display.c

#include "main.h"
#include "timer.h"

#define SEG_HIGH GPIO_PIN_RESET
#define SEG_LOW  GPIO_PIN_SET
#define LED_HIGH GPIO_PIN_SET
#define LED_LOW  GPIO_PIN_RESET

uint8_t segmentMap[11] = {
    0b0000001, 0b1001111,
    0b0010010, 0b0000110,
    0b1001100, 0b0100100,
    0b0100000, 0b0001111,
    0b0000000, 0b0000100,
    0b1111111
};

uint16_t ENPin[4] = {
    EN0_Pin, EN1_Pin,
    EN2_Pin, EN3_Pin
};

```

```
GPIO_TypeDef* ENPort[4] = {
    EN0_GPIO_Port, EN1_GPIO_Port,
    EN2_GPIO_Port, EN3_GPIO_Port
};

uint16_t LEDPin[6] = {
    LED0_Pin, LED1_Pin,
    LED2_Pin, LED3_Pin,
    LED4_Pin, LED5_Pin
};

GPIO_TypeDef* LEDPort[6] = {
    LED0_GPIO_Port, LED1_GPIO_Port,
    LED2_GPIO_Port, LED3_GPIO_Port,
    LED4_GPIO_Port, LED5_GPIO_Port
};

int led_buffer[6] = {0, 0, 0, 0, 0, 0};
int seg_buffer[4] = {0, 0, 0, 0};

void updateLED(){
    for(int i = 0; i < 6; i++) HAL_GPIO_WritePin(LEDPort[i], LEDPin[i
       ], led_buffer[i] ? LED_HIGH : LED_LOW);
}

void update7SEG() {
    for (int i = 7; i >= 0; i--) {
        HAL_GPIO_WritePin(DATA0_GPIO_Port, DATA0_Pin, (segmentMap[
           seg_buffer[0]] >> i) & 1);
        HAL_GPIO_WritePin(DATA1_GPIO_Port, DATA1_Pin, (segmentMap[
           seg_buffer[1]] >> i) & 1);
        HAL_GPIO_WritePin(DATA2_GPIO_Port, DATA2_Pin, (segmentMap[
           seg_buffer[2]] >> i) & 1);
        HAL_GPIO_WritePin(DATA3_GPIO_Port, DATA3_Pin, (segmentMap[
           seg_buffer[3]] >> i) & 1);

        HAL_GPIO_WritePin(CLK_GPIO_Port, CLK_Pin, GPIO_PIN_SET);
        HAL_Delay(1);
        HAL_GPIO_WritePin(CLK_GPIO_Port, CLK_Pin, GPIO_PIN_RESET);
    }

    HAL_GPIO_WritePin(LATCH_GPIO_Port, LATCH_Pin, GPIO_PIN_SET);
    HAL_Delay(1);
    HAL_GPIO_WritePin(LATCH_GPIO_Port, LATCH_Pin, GPIO_PIN_RESET);
}

void resetBuffer(void){
    for(int i = 0; i < 6; i++) led_buffer[i] = 0;
    for(int i = 0; i < 4; i++) seg_buffer[i] = 0;
    updateLED();
    update7SEG();
}

void led_display_Init(){
    setSoftTimer(0, TIMER_CYCLE);
}

void fsm_for_led_display()
{
    if (timer_flag[0] == 1) {
        timer_flag[0] = 0;
        setSoftTimer(0, 100);

        updateLED();
        update7SEG();
    }
}
```

1.2.7 Exercise 7-8-9: Adding code for increasing time duration value for the red LEDs, amber LEDs and green LEDs

second button to increase the time duration value

The second button (is_button_pressed_once(1)) is used to increase the current time value (tempSec) of the selected light.

Each press increases the temporary time by one second, and this value is shown on the 7-segment display.

third button to set the value

The third button (is_button_pressed_once(2)) is used to confirm and save the new duration value.

When pressed, it updates the corresponding variable (redSec, yellowSec, or greenSec) using trafficSecCompute().

The new values are then applied to the normal traffic mode the next time it runs.

```c
# * traffic_light.c

#include "main.h"
#include "timer.h"
#include "led_display.h"

typedef enum {
    STATE_RED_GREEN = 0,
    STATE_RED_YELLOW = 1,
    STATE_GREEN_RED = 2,
    STATE_YELLOW_RED = 3
} TrafficState;

TrafficState trafficState;

int redSec = 5;
int yellowSec = 2;
int greenSec = 3;

int countdownSec = 0;
int countdownSec7Seg[2] = {0 ,0};

int blinkState = 0;
int tempSec = 0;
int lastPressState0 = 0;
int pressState0 = 0;
int lastPressState1 = 0;
int pressState1 = 0;

void trafficSetLED(){
    for (int i = 0; i < 6; i++) led_buffer[i] = 0;
    switch (trafficState) {
        case STATE_RED_GREEN:
        led_buffer[0] = 1;
        led_buffer[5] = 1;
        break;
        case STATE_RED_YELLOW:
        led_buffer[0] = 1;
        led_buffer[4] = 1;
        break;
        case STATE_GREEN_RED:
        led_buffer[2] = 1;
        led_buffer[3] = 1;
        break;
        case STATE_YELLOW_RED:
        led_buffer[1] = 1;
        led_buffer[3] = 1;
        break;
    }
}

void trafficSet7Seg(){
    int a = countdownSec7Seg[0];
    int b = countdownSec7Seg[1];

    if (a < 0) a = 0;
    if (a > 99) a = 99;
    seg_buffer[0] = (a / 10) % 10;
    seg_buffer[1] = a % 10;

    if (b < 0) b = 0;
    if (b > 99) b = 99;
    seg_buffer[2] = (b / 10) % 10;
    seg_buffer[3] = b % 10;
}

void trafficSecCompute(int redsec, int yellowsec, int greensec){
    if(redsec != 0){
        redSec = redsec;
        greenSec = redsec - yellowSec;
    }
    if(yellowsec != 0){
        yellowSec = yellowsec;
        greenSec = redSec - yellowsec;
    }
    if(greensec != 0){
        greenSec = greensec;
        redSec = greensec + yellowSec;
    }
}

void traffic_Init(){
    resetBuffer();
    trafficState = STATE_RED_GREEN;
    trafficSecCompute(0, 0, 0);
    countdownSec = greenSec;
    countdownSec7Seg[0] = redSec;
    countdownSec7Seg[1] = greenSec;
    setSoftTimer(1, TIMER_CYCLE);
}

void modifySec_Init(int whichsec){
    resetBuffer();
    setSoftTimer(2, TIMER_CYCLE);
    tempSec = whichsec == 0 ? redSec : (whichsec == 1 ? yellowSec :
       greenSec);
}

void fsm_for_trafic_light(){
    if (timer_flag[1]) {
        timer_flag[1] = 0;
        setSoftTimer(1, 1000);

        trafficSecCompute(0, 0, 0);
        countdownSec7Seg[0]--;
        countdownSec7Seg[1]--;

        if (countdownSec == 0) {
            switch (trafficState) {
                case STATE_RED_GREEN:
                trafficState = STATE_RED_YELLOW;
                countdownSec7Seg[1] = yellowSec - 1;
                countdownSec = yellowSec;
                break;
                case STATE_RED_YELLOW:
                trafficState = STATE_GREEN_RED;
                countdownSec7Seg[0] = greenSec - 1;
                countdownSec7Seg[1] = redSec - 1;
                countdownSec = greenSec;
                break;
                case STATE_GREEN_RED:
                trafficState = STATE_YELLOW_RED;
                countdownSec7Seg[0] = yellowSec - 1;
                countdownSec = yellowSec;
                break;
                case STATE_YELLOW_RED:
                trafficState = STATE_RED_GREEN;
                countdownSec7Seg[0] = redSec - 1;
                countdownSec7Seg[1] = greenSec - 1;
                countdownSec = greenSec;
                break;
            }
        }

        countdownSec--;
        if (countdownSec < 0) countdownSec = 0;

        trafficSetLED();
        trafficSet7Seg();
    }
}

```

```
void fsm_for_traffic_modifySec(int whichsec){
    if (timer_flag[2]) {
        timer_flag[2] = 0;
        setSoftTimer(2, 250);

        blinkState = !blinkState;
        for(int i = 0; i < 6; i++) led_buffer[i] = (i == whichsec || i
            == whichsec + 3) ? blinkState : 0;
    }

    seg_buffer[0] = 0;
    seg_buffer[1] = whichsec + 2;
    seg_buffer[2] = (tempSec / 10) % 10;
    seg_buffer[3] = tempSec % 10;

    if(is_button_pressed_once(1)) pressState0 = !pressState0;
    if (pressState0 != lastPressState0) {
        lastPressState0 = pressState0;

        tempSec++;
    }

    if(is_button_pressed_once(2)) pressState1 = !pressState1;
    if (pressState1 != lastPressState1) {
        lastPressState1 = pressState1;

        switch(whichsec) {
            case 0: trafficSecCompute(tempSec, 0, 0); break;
            case 1: trafficSecCompute(0, tempSec, 0); break;
            case 2: trafficSecCompute(0, 0, tempSec); break;
        }
        tempSec = whichsec == 0 ? redSec : (whichsec == 1 ? yellowSec
            : greenSec);
    }
}
```

1.2.8 Exercise 10: To finish the project

The Youtube link for my demo: https://hehehaha.com