TRƯỜNG ĐẠI HỌC BÁCH KHOA – TP. HỒ CHÍ MINH
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Lab 2
Timer Interrupt and LED Scanning

Microcontroller - Microprocessor (Lab)

COURSE ID: CO3010 - HK251

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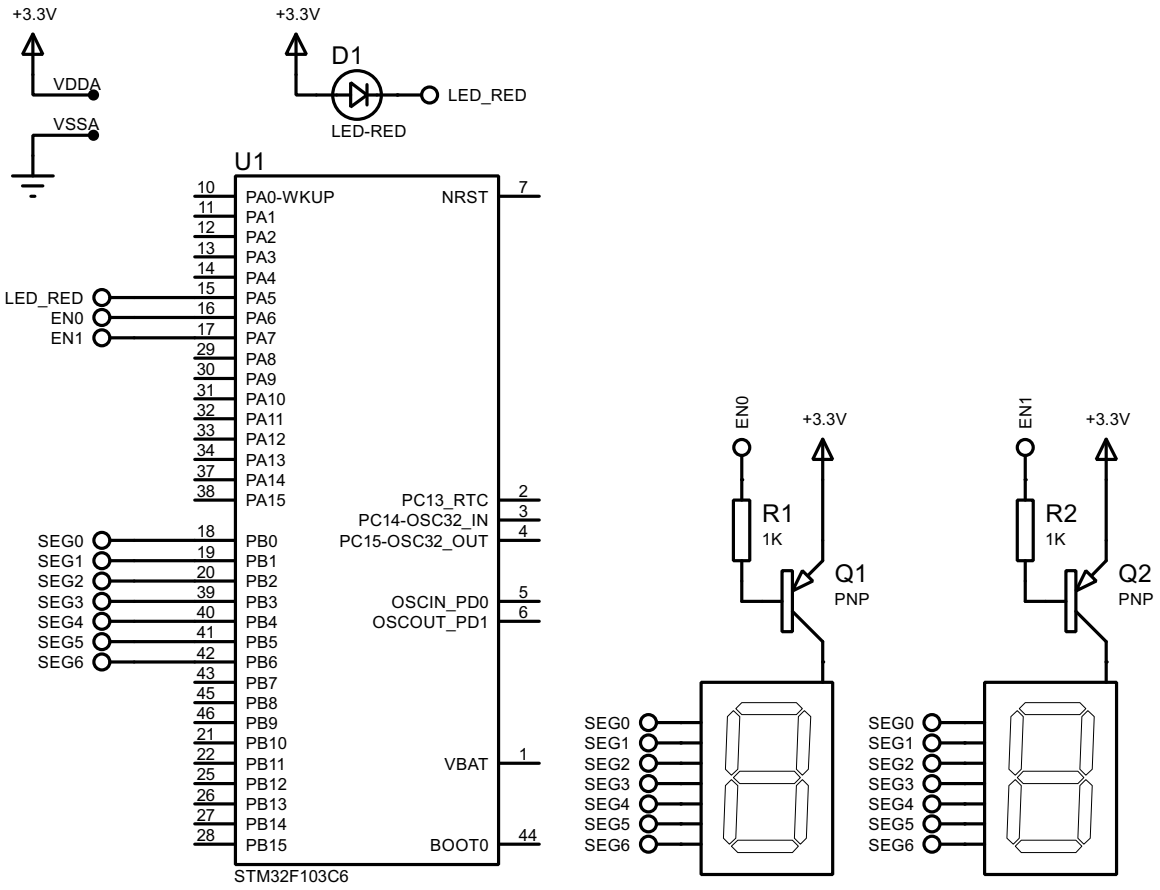
1 Exercise

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

1.1 Exercise 1

1.1.1 Report 1: Capture your schematic from Proteus and show in the report.



1.1.2 Report 2: Present your source code.

```
uint8_t segmentMap[10] = {
    0b1111110, 0b0110000,
    0b1101101, 0b1111001,
    0b0110011, 0b1011011,
    0b1011111, 0b1110000,
    0b1111111, 0b1111011
};

uint8_t SegPin[7] = {
    SEG_A_Pin, SEG_B_Pin,
    SEG_C_Pin, SEG_D_Pin,
    SEG_E_Pin, SEG_F_Pin,
    SEG_G_Pin
};

int counter = 0;
```

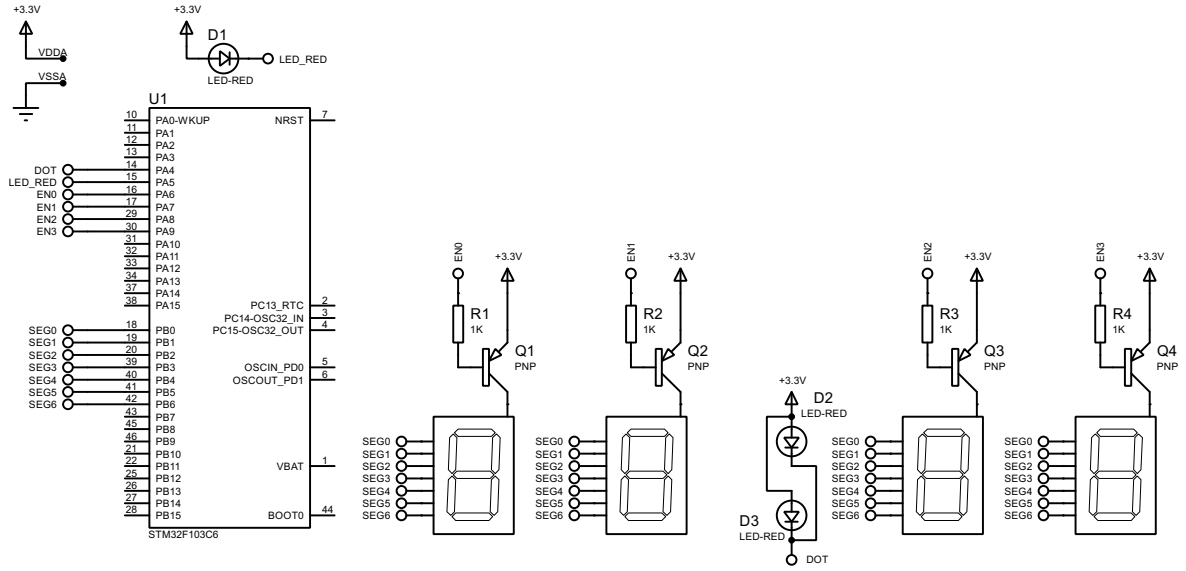
```
int DisplayNum = 0;

void display7SEG(int num) {
    uint8_t bitmask = segmentMap[num];

    for(int i = 0; i < 7; i++) HAL_GPIO_WritePin(GPIOB, SegPin[i], (
       bitmask & (1 << (6 - i))) ? RESET : SET);
}

void HAL_TIM_PeriodElapsedCallback ( TIM_HandleTypeDef * htim )
{
    counter++;
    if(counter >= 50){
        counter = 0;

        HAL_GPIO_WritePin(GPIOA, EN0_Pin | EN1_Pin, GPIO_PIN_SET);

        if(DisplayNum == 0){
            HAL_GPIO_WritePin(GPIOA, EN0_Pin, GPIO_PIN_RESET);
            display7SEG(1);
        }
        if(DisplayNum == 1){
            HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin);
            HAL_GPIO_WritePin(GPIOA, EN1_Pin, GPIO_PIN_RESET);
            display7SEG(2);
        }

        DisplayNum = (DisplayNum + 1) % 2;
    }
}
```

1.1.3 Question: What is the frequency of the scanning process?

The frequency of the scanning process is 1 Hz, as the switching time between the two seven-segment displays is half a second (0.5 seconds), resulting in one complete cycle (switching from the first to the second and back) every 1 second.

1.2 Exercise 2

1.2.1 Report 1: Capture your schematic from Proteus and show in the report.



1.2.2 Report 2: Present your source code.

```
void HAL_TIM_PeriodElapsedCallback ( TIM_HandleTypeDef * htim )
{
    counter++;
    if(counter >= 50){
        counter = 0;

        HAL_GPIO_WritePin(GPIOA, EN0_Pin | EN1_Pin | EN2_Pin | EN3_Pin
           , GPIO_PIN_SET);

        if(DisplayNum == 0){
            HAL_GPIO_WritePin(GPIOA, EN0_Pin, GPIO_PIN_RESET);
            display7SEG(1);
        }
        if(DisplayNum == 1){
            HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin | DOT_Pin);
            HAL_GPIO_WritePin(GPIOA, EN1_Pin, GPIO_PIN_RESET);
            display7SEG(2);
        }
        if(DisplayNum == 2){
            HAL_GPIO_WritePin(GPIOA, EN2_Pin, GPIO_PIN_RESET);
            display7SEG(3);
        }
        if(DisplayNum == 3){
            HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin | DOT_Pin);
            HAL_GPIO_WritePin(GPIOA, EN3_Pin, GPIO_PIN_RESET);
            display7SEG(0);
        }
        DisplayNum = (DisplayNum + 1) % 4;
    }
}
```

1.2.3 Question: What is the frequency of the scanning process?

The frequency of the scanning process is 0.5 Hz. This is because each seven-segment LED is displayed for 500ms (0.5 seconds), and the system cycles through all 4 LEDs, completing one full scan every 2 seconds (4 x 0.5s = 2s). The frequency is calculated as $\frac{1}{2}$ Hz.

1.3 Exercise 3

1.3.1 Report 1: Present the source code of the update7SEG function.

```
void update7SEG(int index){
    HAL_GPIO_WritePin(GPIOA, EN0_Pin | EN1_Pin | EN2_Pin | EN3_Pin,
       GPIO_PIN_SET);

    switch (index){
        case 0:
        HAL_GPIO_WritePin(GPIOA, GPIO_PIN_6, GPIO_PIN_RESET);
        display7SEG(led_buffer[0]);
        break;
        case 1:
        HAL_GPIO_WritePin(GPIOA, GPIO_PIN_7, GPIO_PIN_RESET);
        display7SEG(led_buffer[1]);
        break;
        case 2:
        HAL_GPIO_WritePin(GPIOA, GPIO_PIN_8, GPIO_PIN_RESET);
        display7SEG(led_buffer[2]);
        break;
        case 3:
        HAL_GPIO_WritePin(GPIOA, GPIO_PIN_9, GPIO_PIN_RESET);
        display7SEG(led_buffer[3]);
        break;
        default:
        break;
    }
}
```

1.3.2 Report 2: Present the source code.

```
void HAL_TIM_PeriodElapsedCallback ( TIM_HandleTypeDef * htim )
{
    counter++;
    if(counter0 >= 50){
        counter = 0;

        if(index_led == 1 || index_led == 3) HAL_GPIO_TogglePin(GPIOA,
            LED_RED_Pin | DOT_Pin);
        update7SEG(index_led++);
        if(index_led >= 4) index_led = 0;
    }
}
```

1.4 Exercise 4

1.4.1 Report 1: Present the source code.

```
void HAL_TIM_PeriodElapsedCallback ( TIM_HandleTypeDef * htim )
{
    counter++;
    if(counter >= 25){
        counter = 0;

        if(index_led == 3) HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin |
           DOT_Pin);
        update7SEG(index_led++);
        if(index_led >= 4) index_led = 0;
    }
}
```

1.5 Exercise 5

1.5.1 Report 1: Present the source code in the updateClockBuffer function.

```
void updateClockBuffer() {
    led_buffer[0] = hour / 10;
    led_buffer[1] = hour % 10;
    led_buffer[2] = minute / 10;
    led_buffer[3] = minute % 10;
}
```

1.6 Exercise 6

1.6.1 Report 1: if in line 1 of the code above is miss, what happens after that and why?

If the line setTimer0(1000) is removed before the while (1) loop, the global variable timer0_counter will remain at its default value of 0. As a result, when timer_run() is called, the condition if (timer0_counter > 0) will be false, and timer0_counter will not decrement. Consequently, timer0_flag will stay at 0 and never be set to 1. In the while (1) loop, the condition if (timer0_flag == 1) will never be true, so HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin) and setTimer0(2000) will not execute.

Since LED_RED is connected with one pin to 3.3V and the signal pin to PA5, and PA5 remains in its initial state (GPIO_PIN_RESET), the LED will turn on continuously. This happens because the timer mechanism does not start without initializing timer0_counter with a positive value.

1.6.2 Report 2: if in line 1 of the code above is changed to setTimer0(1), what happens after that and why?

If setTimer0(1000) is changed to setTimer0(1), the LED_RED will not toggle at all, and the program will remain in an idle state within the while (1) loop. This occurs because timer0_counter is set to 0 due to integer division, preventing the timer_run function from decrementing it or setting timer0_flag to 1, thus blocking the intended logic from executing. The LED will stayed active like Report 1.

1.6.3 Report 3: If in line 1 of the code above is changed to setTimer0(10), what is changed compared to 2 first questions and why?

Compared to first question (setTimer0(1000)): The initial delay changes from 1 second to 10ms, making the first LED toggle occur much sooner, though subsequent toggles remain on a 2-second interval.

Compared to second question(setTimer0(1)): The system now functions instead of being stuck, because timer0_counter is 1 rather than 0, allowing the timer to run.

Reason: The behavior depends on the value of timer0_counter set by duration / TIMER_CYCLE. A value of 1 (from setTimer0(10)) provides a minimal but functional delay, while 100 (from setTimer0(1000)) gives a 1-second delay, and 0 (from setTimer0(1)) disables the timer.

1.7 Exercise 7

1.7.1 Report 1: Present the source code of this function.

```
void clearAllClock(void) {
    for (int i = 0; i < 12; i++) HAL_GPIO_WritePin(GPIOA, ACLOCK_Pins[
       i], GPIO_PIN_RESET);
}
```

1.8 Exercise 8

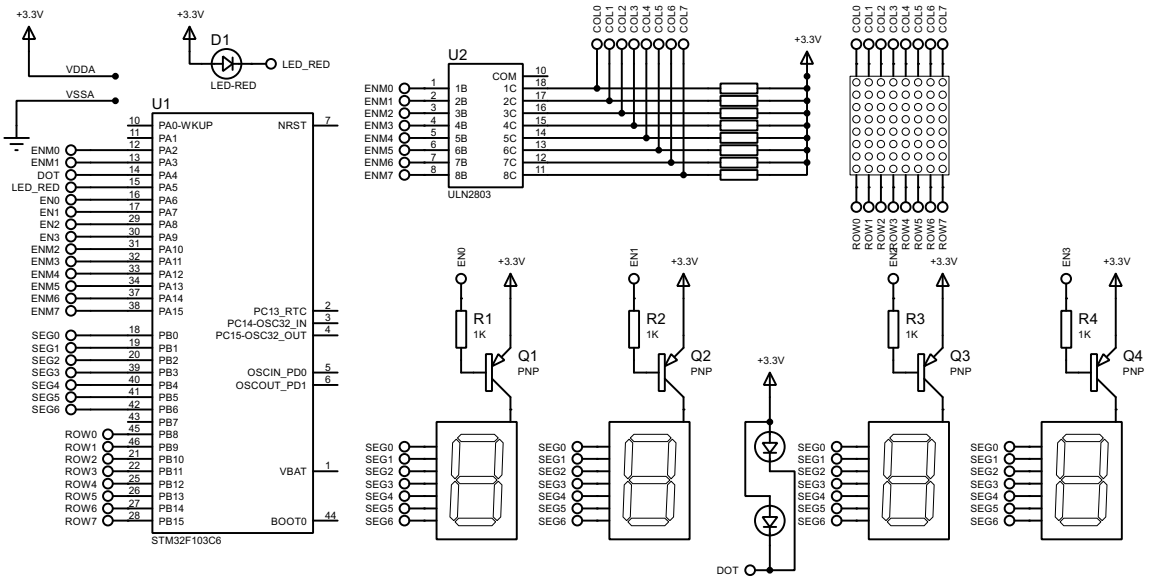
1.8.1 Report 1: Present your source code in the the main function. In the case more extra functions are used (e.g. the second software timer), present them in the report as well.

```
int timer0_counter = 0;
int timer0_flag = 0;
int timer1_counter = 0;
int timer1_flag = 0;
int TIMER_CYCLE = 10;

void setTimer0 ( int duration ){
    timer0_counter = duration / TIMER_CYCLE ;
    timer0_flag = 0;
}

void setTimer1(int duration) {
    timer1_counter = duration / TIMER_CYCLE;
    timer1_flag = 0;
}

void timer_run() {
    if (timer0_counter > 0) {
        timer0_counter--;
        if (timer0_counter == 0) timer0_flag = 1;
    }
    if (timer1_counter > 0) {
        timer1_counter--;
        if (timer1_counter == 0) timer1_flag = 1;
    }
}

int main(void)
{
    setTimer0(1000) ;
    setTimer1(250) ;
    while (1)
    {
        if(timer0_flag == 1){
            if(counter >= 2){
                HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin);
                counter = 0;
            }
```

```
            counter++;
            updateClockBuffer();
            second ++;

            if ( second >= 60) {
                second = 0;
                minute++;
            }
            if( minute >= 60) {
                minute = 0;
                hour++;
            }
            if( hour >= 24){
                hour = 0;
            }

            HAL_GPIO_TogglePin(GPIOA, DOT_Pin);
            setTimer0(1000) ;

        }
        if(timer1_flag == 1){
            update7SEG(index_led++);
            if(index_led >= 4) index_led = 0;
            setTimer1(250) ;
        }
    }
}
```

1.9 Exercise 9

1.9.1 Report 1: Present the schematic of your system by capturing the screen in Proteus.



1.9.2 Report 2: Display character "A".

```
const int MAX_LED_MATRIX = 8;
int index_led_matrix = 0;
uint8_t matrix_buffer [8] = {0x00, 0x00, 0x7C, 0x12, 0x12, 0x7C, 0x00,
    0x00};

void updateLEDMatrix (int index){
    HAL_GPIO_WritePin(GPIOA, ENM0_Pin | ENM1_Pin | ENM2_Pin | ENM3_Pin
        | ENM4_Pin | ENM5_Pin | ENM6_Pin | ENM7_Pin, GPIO_PIN_SET);

    HAL_GPIO_WritePin(GPIOA, ENMPin[index], GPIO_PIN_RESET);

    for(int i = 0; i < 8; i++) HAL_GPIO_WritePin(GPIOB, ROWPin[i], (
       matrix_buffer[index] & (1 << i)) ? GPIO_PIN_RESET : GPIO_PIN_SET
       );
}

int main(void)
{
    setTimer0(1000) ;
    setTimer1(250) ;
    setTimer2(10) ;
    while (1)
    {
        if(timer0_flag == 1){
            if(counter >= 2){
                HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin);
                counter = 0;
            }
            counter++;
```

```
            updateClockBuffer();
            second ++;

            if ( second >= 60) {
                second = 0;
                minute++;
            }
            if( minute >= 60) {
                minute = 0;
                hour++;
            }
            if( hour >= 24){
                hour = 0;
            }

            HAL_GPIO_TogglePin(GPIOA, DOT_Pin);
            setTimer0(1000) ;

        }
        if(timer1_flag == 1){
            update7SEG(index_led++);
            if(index_led >= 4) index_led = 0;
            setTimer1(250) ;
        }
        if(timer2_flag == 1){
            updateLEDMatrix(index_led_matrix);
            index_led_matrix = (index_led_matrix + 1) % MAX_LED_MATRIX
                ;
            setTimer2(10) ;
        }
    }
}
```

1.10 Exercise 10

1.10.1 Report 1: Present your source code in the report.

```
uint8_t segmentMap[10] = {
    0b1111110, 0b0110000,
    0b1101101, 0b1111001,
    0b0110011, 0b1011011,
    0b1011111, 0b1110000,
    0b1111111, 0b1111011
};

uint8_t SegPin[7] = {
    SEG_A_Pin, SEG_B_Pin,
    SEG_C_Pin, SEG_D_Pin,
    SEG_E_Pin, SEG_F_Pin,
    SEG_G_Pin
};

uint16_t ENMPin[8] = {
    ENM0_Pin, ENM1_Pin,
    ENM2_Pin, ENM3_Pin,
    ENM4_Pin, ENM5_Pin,
    ENM6_Pin, ENM7_Pin
};

uint16_t ROWPin[8] = {
    ROW0_Pin, ROW1_Pin,
    ROW2_Pin, ROW3_Pin,
    ROW4_Pin, ROW5_Pin,
    ROW6_Pin, ROW7_Pin
};

int timer0_counter = 0;
int timer0_flag = 0;
int timer1_counter = 0;
int timer1_flag = 0;
int timer2_counter = 0;
int timer2_flag = 0;
int TIMER_CYCLE = 10;

const int MAX_LED = 4;
int index_led = 0;
int led_buffer [4] = {1, 2, 3, 4};
int hour = 15, minute = 8, second = 50;

const int MAX_LED_MATRIX = 8;
int index_led_matrix = 0;
uint8_t matrix_buffer [8] = {0x00, 0x00, 0x7C, 0x12, 0x12, 0x7C, 0x00,
    0x00};

int counter = 0;

void setTimer0 ( int duration ){
```

```
    timer0_counter = duration / TIMER_CYCLE ;
    timer0_flag = 0;
}

void setTimer1(int duration) {
    timer1_counter = duration / TIMER_CYCLE;
    timer1_flag = 0;
}
void setTimer2(int duration) {
    timer2_counter = duration / TIMER_CYCLE;
    timer2_flag = 0;
}

void timer_run() {
    if (timer0_counter > 0) {
        timer0_counter--;
        if (timer0_counter == 0) timer0_flag = 1;
    }
    if (timer1_counter > 0) {
        timer1_counter--;
        if (timer1_counter == 0) timer1_flag = 1;
    }
    if (timer2_counter > 0) {
        timer2_counter--;
        if (timer2_counter == 0) timer2_flag = 1;
    }
}

void display7SEG(int num) {
    for(int i = 0; i < 7; i++) HAL_GPIO_WritePin(GPIOB, SegPin[i], (
       segmentMap[num] & (1 << (6 - i))) ? RESET : SET);
}

void update7SEG(int index){
    HAL_GPIO_WritePin(GPIOA, EN0_Pin | EN1_Pin | EN2_Pin | EN3_Pin,
       GPIO_PIN_SET);

    switch (index){
        case 0:
        HAL_GPIO_WritePin(GPIOA, EN0_Pin, GPIO_PIN_RESET);
        display7SEG(led_buffer[0]);
        break;
        case 1:
        HAL_GPIO_WritePin(GPIOA, EN1_Pin, GPIO_PIN_RESET);
        display7SEG(led_buffer[1]);
        break;
        case 2:
        HAL_GPIO_WritePin(GPIOA, EN2_Pin, GPIO_PIN_RESET);
        display7SEG(led_buffer[2]);
        break;
        case 3:
        HAL_GPIO_WritePin(GPIOA, EN3_Pin, GPIO_PIN_RESET);
        display7SEG(led_buffer[3]);
        break;
```

```
        default:
        break;
    }
}

void updateClockBuffer() {
    led_buffer[0] = hour / 10;
    led_buffer[1] = hour % 10;
    led_buffer[2] = minute / 10;
    led_buffer[3] = minute % 10;
}

void updateLEDMatrix (int index){
    HAL_GPIO_WritePin(GPIOA, ENM0_Pin | ENM1_Pin | ENM2_Pin | ENM3_Pin
        | ENM4_Pin | ENM5_Pin | ENM6_Pin | ENM7_Pin, GPIO_PIN_SET);

    HAL_GPIO_WritePin(GPIOA, ENMPin[index], GPIO_PIN_RESET);

    for(int i = 0; i < 8; i++) HAL_GPIO_WritePin(GPIOB, ROWPin[i], (
       matrix_buffer[index] & (1 << i)) ? GPIO_PIN_RESET : GPIO_PIN_SET
       );
}

void shiftArray(uint8_t *array, int size) {
    uint8_t temp = array[0];
    for (int i = 0; i < size - 1; i++) array[i] = array[i + 1];
    array[size - 1] = temp;
}

int main(void)
{
    setTimer0(1000) ;
    setTimer1(250) ;
    setTimer2(20) ;
    while (1)
    {
        /* USER CODE END WHILE */

        /* USER CODE BEGIN 3 */
        if(timer0_flag == 1){
            if(counter >= 2){
                HAL_GPIO_TogglePin(GPIOA, LED_RED_Pin);
                counter = 0;
            }
            counter++;
            updateClockBuffer();
            second ++;

            if ( second >= 60) {
                second = 0;
                minute++;
            }
            if( minute >= 60) {
                minute = 0;
```

```
153                 hour++;
154             }
155             if( hour >= 24){
156                 hour = 0;
157             }
158 
159             HAL_GPIO_TogglePin(GPIOA, DOT_Pin);
160             setTimer0(1000) ;
161 
162         }
163         if(timer1_flag == 1){
164             update7SEG(index_led++);
165             if(index_led >= 4) index_led = 0;
166             shiftArray(matrix_buffer, MAX_LED_MATRIX);
167             setTimer1(250) ;
168         }
169         if(timer2_flag == 1){
170             updateLEDMatrix(index_led_matrix);
171             index_led_matrix = (index_led_matrix + 1) % MAX_LED_MATRIX
                ;
172             setTimer2(20) ;
173         }
174     }
175 }
```

1.10.2 Report 2: Briefly describe your solution.

To make the letter "A" displayed on the LED matrix shift to the left, I utilized the shiftArray function in the code. The solution involves updating the matrix_buffer array, which stores the 8-bit patterns representing the LED matrix columns, to shift its contents leftward over time. Specifically, the shiftArray function moves each element one position to the left, with the first element moving to the last position, effectively creating a leftward scrolling effect. In the while (1) loop, the timer1_flag check calls shiftArray(matrix_buffer, MAX_LED_MATRIX) every 250ms (as set by setTimer1(250)), ensuring the pattern shifts incrementally. The initial matrix_buffer is preloaded with a pattern representing the letter "A" (e.g., 0x7C, 0x12, 0x12, 0x7C in the middle), and the continuous shifting moves this pattern left across the 8-column matrix, updating the display via updateLEDMatrix to visually scroll the letter "A" to the left.