ENGINE

Teaching online electronics, microcontrollers and programming in Higher Education

Programing of embedded systems

6. Neopixels driver

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Declaration

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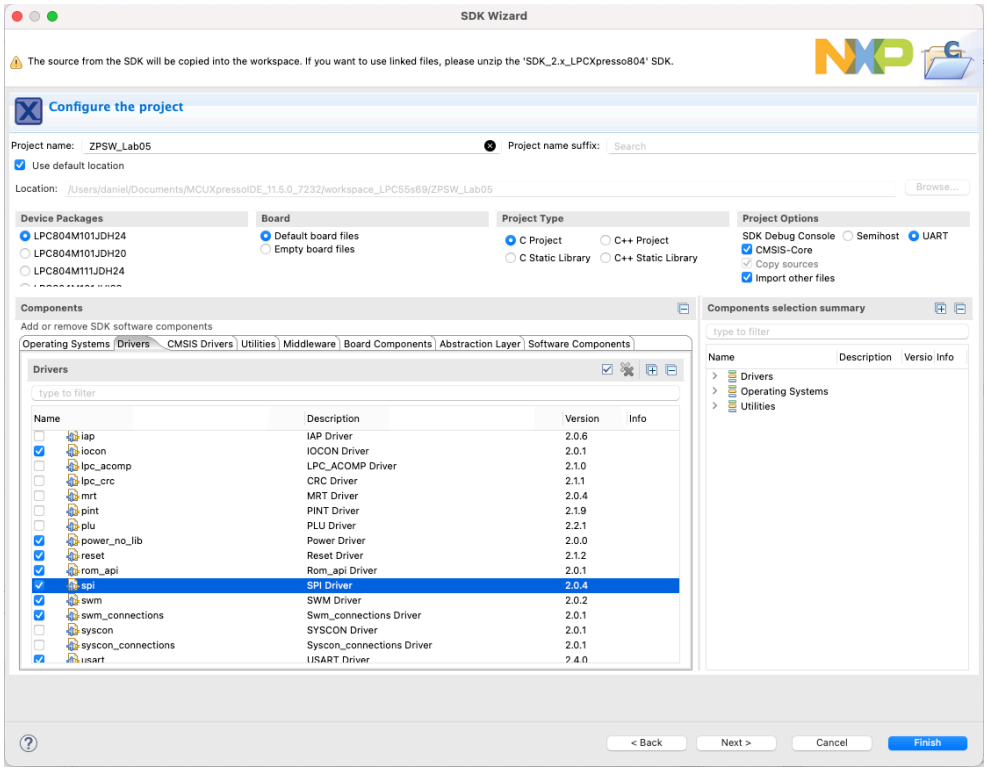
Programing of embedded systems

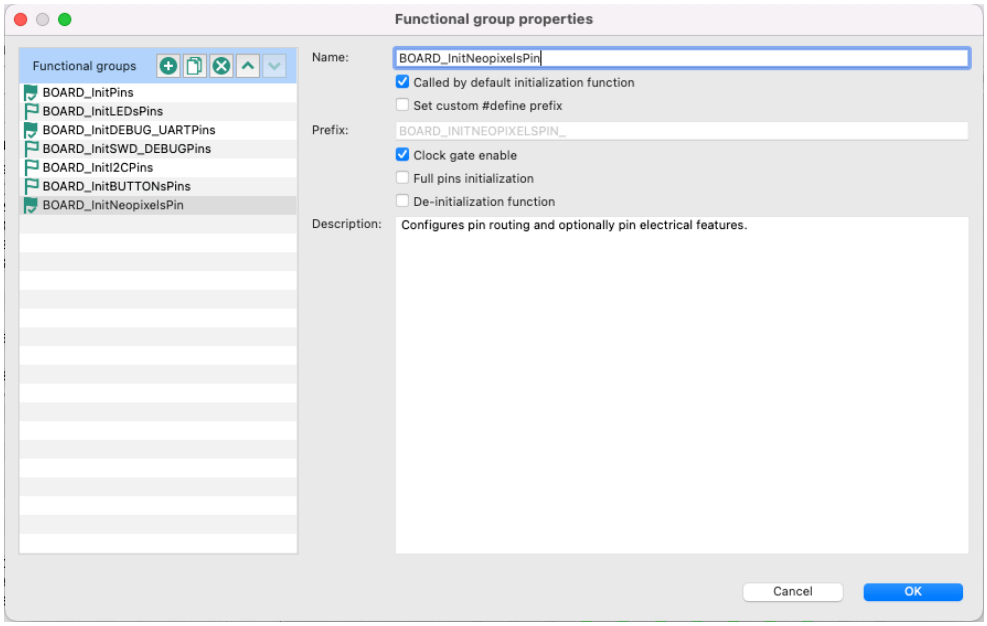
6. Neopixels driver

I. Using the SPI interface

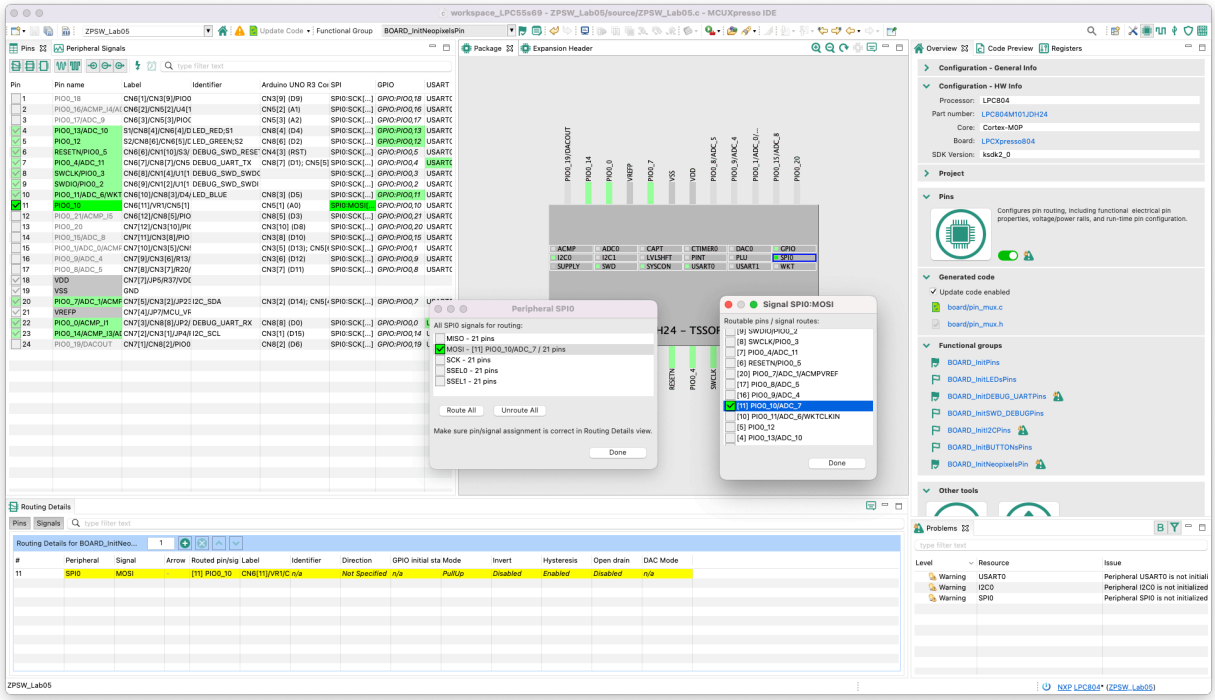
1. Create a new project for the *LPCXpresso804* board and name it eg *Lab06*.
2. Add *SPI* driver:



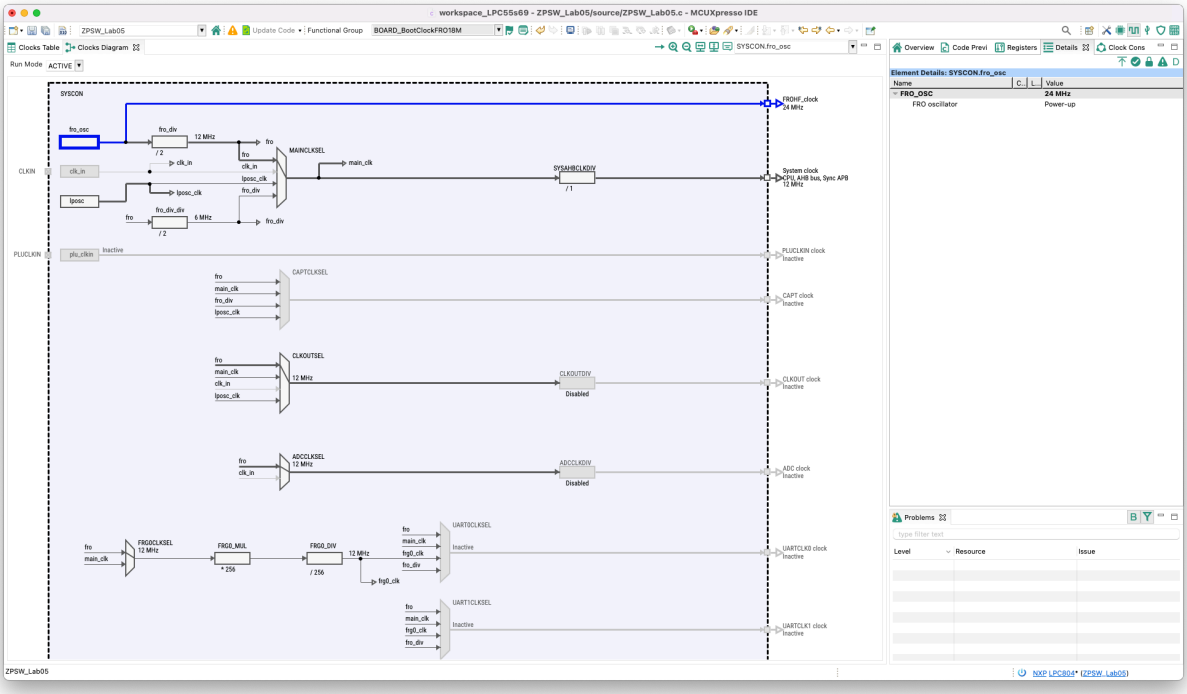
3. Go to *Config Tool -> Pins* and then in the *Functional group* create a new preset *BOARD_InitNeopixelsPin*:



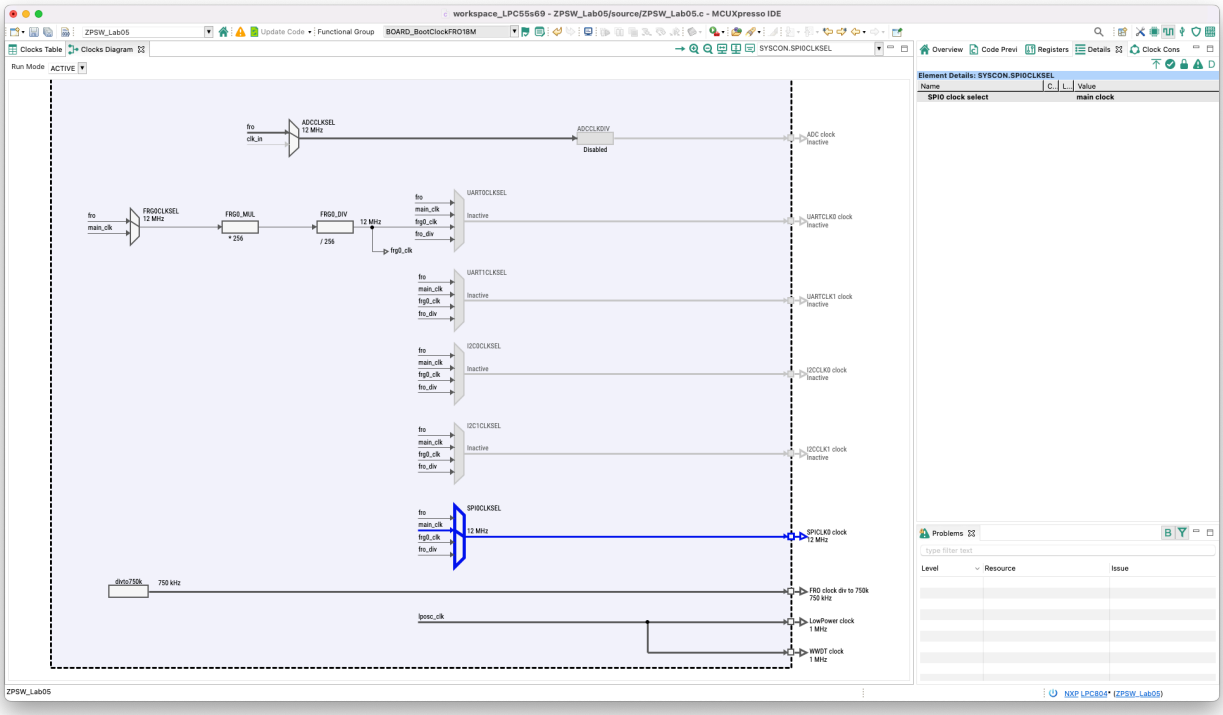
4. Connect the *MOSI* line of the *SPI0* interface to the *PIO_010* pin of the microcontroller:



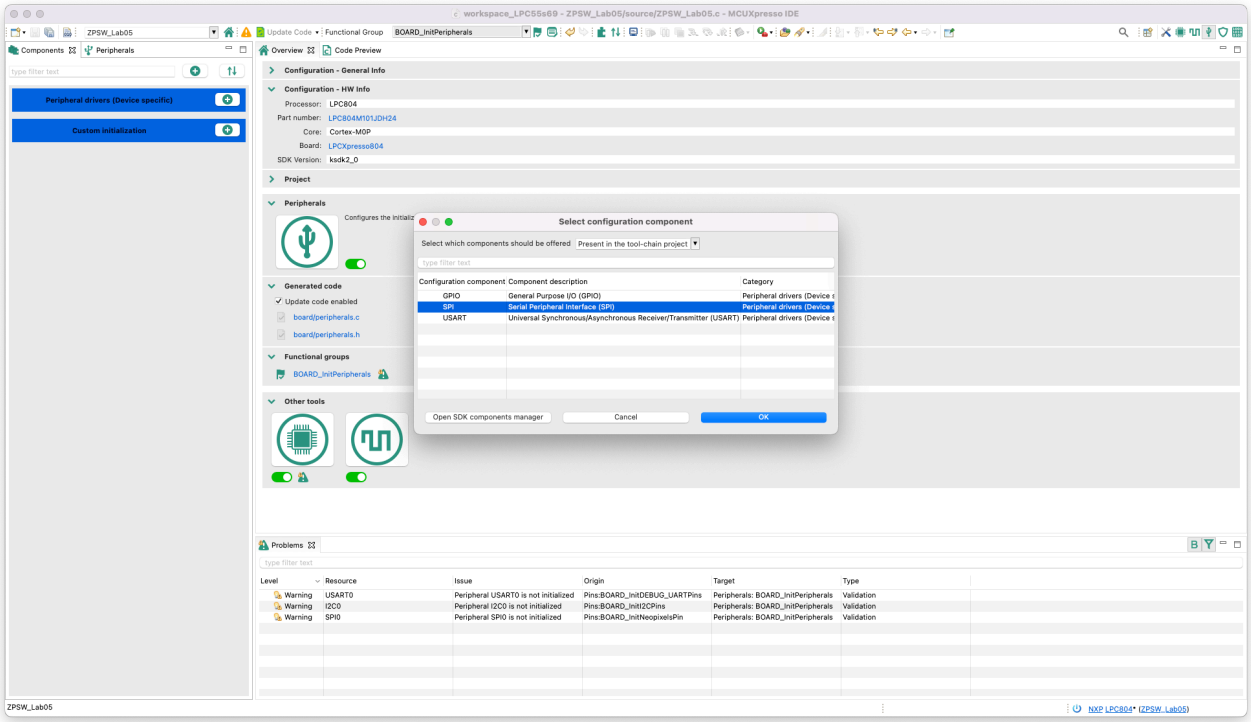
5. In the Clocks tab, click on the *FRO_OSC* oscillator block and change its frequency to 24 MHz:



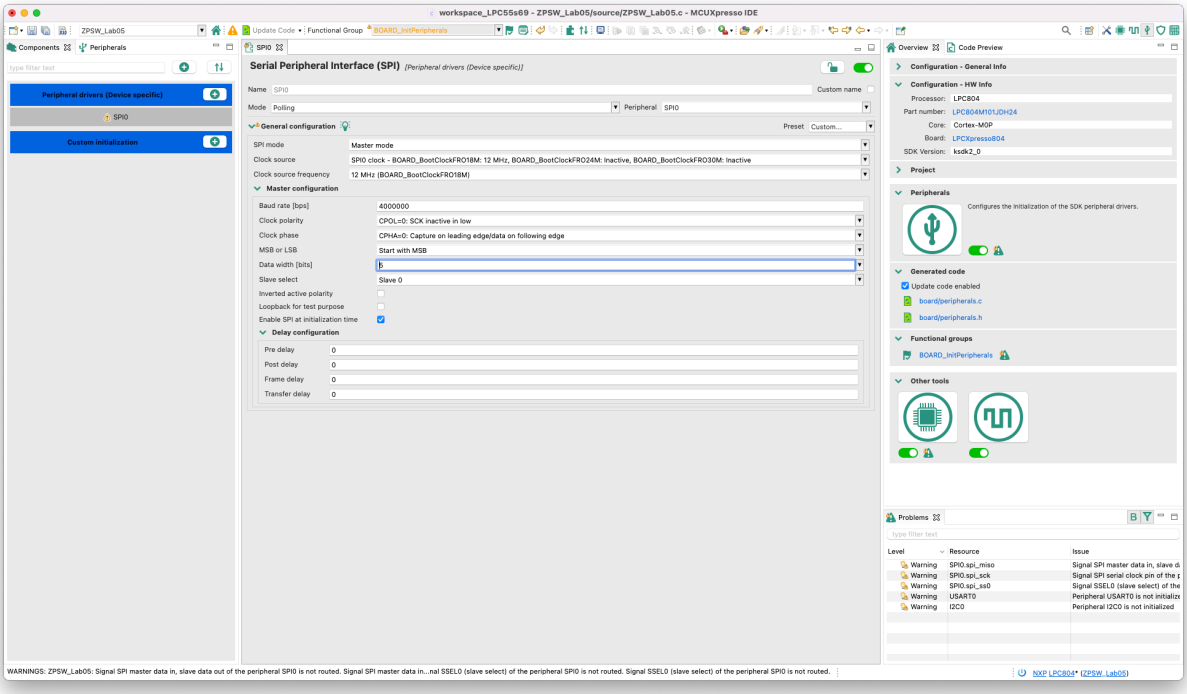
6. Then bring the 12 MHz clock signal to the *SPI0* interface by selecting *main_clk* in the *SPI0CLKSEL* block:



7. In the *Peripherals* tab, select the *SPI driver*:



8. Configure *SPI* transmission parameters in *Polling mode* for the *SPI0* interface:



9. Go to the main project file and modify the code as below:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                  0b10000
#define CODE_1                                  0b11100

uint32_t colors[LEDS]={0};

void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif
```

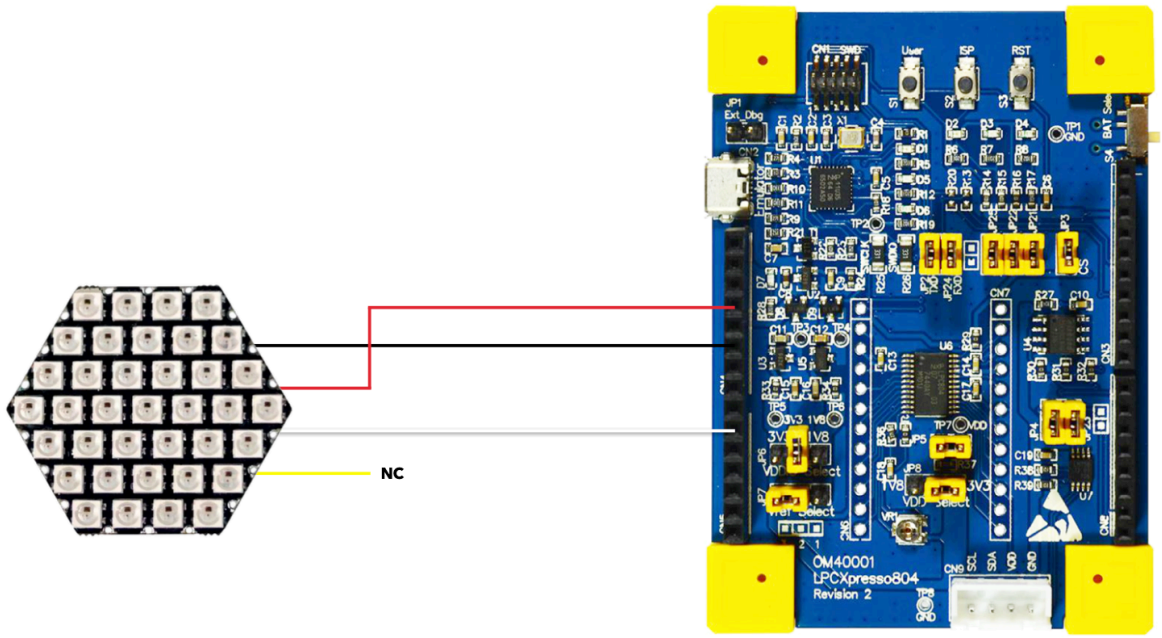
```
        SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);

        while(1) {

                colors[18] = 0x00000F;
                Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);

        }
        return 0 ;
}
```

10. Connect the LED module to the prototype board according to the diagram below:



11. Build the project in the ***Release*** configuration, program the microcontroller and check the program operation.

ATTENTION! Do not turn on all the LEDs with full brightness without additional power supply to the module - it may damage the on board stabilizer. The prototype board is able to power the entire LED module with approx. 1/16 brightness - the maximum value for the white color: **HEX 0x0F0F0F.**
DEC R: 15, G: 15, B: 15

II. Function *setRGB*

1. Write a function that sets the color in RGB 888 format.
2. Add a system timer and check the brightness adjustment of individual RGB components:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                  0b10000
#define CODE_1                                  0b11100

uint32_t colors[LEDS]={0};
uint8_t k=0;


void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

inline uint32_t setRGB(uint8_t r, uint8_t g, uint8_t b) {

          return ((g<<16) | (r<<8) | b);
}


void SysTick_Handler(void) {

          colors[18] = setRGB(k++, 0,   0);
          //colors[18] = setRGB(0,   k++, 0);
          //colors[18] = setRGB(0,   0,   k++);
          Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);

          SysTick_Config(SystemCoreClock / 100); // 100 Hz

          while(1) {

          }
          return 0 ;
}
```

3. Build a project, program the layout and test the program.

II. Function *setBrightness*

1. Write a function that sets the brightness of a given color:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                  0b10000
#define CODE_1                                  0b11100

uint32_t colors[LEDS]={0};
uint8_t k=0;


void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

inline uint32_t setRGB(uint8_t r, uint8_t g, uint8_t b) {

          return ((g<<16) | (r<<8) | b);
}

uint32_t setBrightness(uint32_t color, uint8_t level) {

          uint8_t b = level *  (color & 0x0000FF)        / 255;
          uint8_t r = level * ((color & 0x00FF00) >> 8)  / 255;
          uint8_t g = level * ((color & 0xFF0000) >> 16) / 255;

          return ((g<<16) | (r<<8) | b);
}

void SysTick_Handler(void) {

          colors[18] = setRGB(255, 0, 128);
          colors[18] = setBrightness(colors[18], k++);

          Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);

          SysTick_Config(SystemCoreClock / 100); // 100 Hz

          while(1) {

          }
          return 0 ;
}
```

2. Build a project, program the microcontroller and test the program for different RGB colors.

III. Simple animation

1. Write a function that "shifts" the shining point on the matrix:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                  0b10000
#define CODE_1                                  0b11100

uint32_t colors[LEDS]={0};
uint8_t k=0;
uint32_t rgbColor=0;

void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

inline uint32_t setRGB(uint8_t r, uint8_t g, uint8_t b) {

          return ((g<<16) | (r<<8) | b);
}

void Animate(uint32_t color)
{
          for(int j=0;j<LEDS;j++)
                    colors[j]=0x000000;

          colors[k]=color;

          k++;
          if(k>=LEDS)
                    k=0;
}

void SysTick_Handler(void) {

          rgbColor = setRGB(0, 0, 15); // MAX RGB: (15, 15, 15)
          Animate(rgbColor);

          Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);

          SysTick_Config(SystemCoreClock / 10); // 10 Hz

          while(1) {

          }
          return 0 ;
}
```

2. Build a project, program the microcontroller and test the program.

IV. Animation LUT (*lookup table*)

1. Write an animation using the LUT table. They do not exceed the value of 15 for each RGB component!

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                  0b10000
#define CODE_1                                  0b11100

uint32_t colors[LEDS]={0};
uint8_t k=0;
uint32_t rgbColor=0;


const bool pic1[4][LEDS] = {{

                        0,0,0,0,
                      0,0,0,0,0,
                     0,0,0,0,0,0,0,
                    0,0,0,1,0,0,0,
                     0,0,0,0,0,0,0,
                       0,0,0,0,0,
                        0,0,0,0,
},{
                        0,0,0,0,
                      0,0,0,0,0,
                     0,0,1,1,0,0,
                    0,0,1,0,1,0,0,
                     0,0,1,1,0,0,
                       0,0,0,0,0,
                        0,0,0,0,
},{
                        0,0,0,0,
                      0,1,1,1,0,
                     0,1,0,0,1,0,
                    0,1,0,0,0,1,0,
                     0,1,0,0,1,0,
                       0,1,1,1,0,
                        0,0,0,0,
},{
                        1,1,1,1,
                      1,0,0,0,1,
                     1,0,0,0,0,1,
                    1,0,0,0,0,0,1,
                     1,0,0,0,0,1,
                       1,0,0,0,1,
                        1,1,1,1,
}};

void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

inline uint32_t setRGB(uint8_t r, uint8_t g, uint8_t b) {

          return ((g<<16) | (r<<8) | b);
}

void setImage(const bool *image,  uint32_t color) {

          for(int i=0; i<LEDS; i++) {

                    colors[i] = image[i] * color;
          }
}

void SysTick_Handler(void) {
```

```
          rgbColor = setRGB(0, 0, 15); // MAX RGB: (15, 15, 15)
          setImage(pic1[k++ % 4], rgbColor);
          Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);

          SysTick_Config(SystemCoreClock / 5); // 5 Hz

          while(1) {

          }
          return 0 ;
}
```

2. Build a project, program the microcontroller and test the program.
3. Add another board with animation:

```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

#define LEDS 37
#define GET_BIT(k, n)     (k &   (1 << (n)))
#define SET_BIT(k, n)     (k |=  (1 << (n)))
#define CLR_BIT(k, n)     (k &= ~(1 << (n)))

#define CODE_0                                      0b10000
#define CODE_1                                      0b11100

uint32_t colors[LEDS]={0};
uint8_t k=0;
uint32_t rgbColor=0;


const bool pic1[4][LEDS] = {{

                        0,0,0,0,
                      0,0,0,0,0,
                    0,0,0,0,0,0,0,
                  0,0,0,1,0,0,0,
                    0,0,0,0,0,0,0,
                      0,0,0,0,0,
                        0,0,0,0,
},{
                        0,0,0,0,
                      0,0,0,0,0,
                    0,0,1,1,0,0,
                  0,0,1,0,1,0,0,
                    0,0,1,1,0,0,
                      0,0,0,0,0,
                        0,0,0,0,
},{
                        0,0,0,0,
                      0,1,1,1,0,
                    0,1,0,0,1,0,
                  0,1,0,0,0,1,0,
                    0,1,0,0,1,0,
                      0,1,1,1,0,
                        0,0,0,0,
},{
                        1,1,1,1,
                      1,0,0,0,1,
                    1,0,0,0,0,0,1,
                  1,0,0,0,0,0,1,
                    1,0,0,0,0,1,
                      1,0,0,0,1,
                        1,1,1,1,
}};

const bool pic2[6][LEDS] = {{

                        1,1,1,1,
                      0,1,0,1,0,
                    0,0,1,1,0,0,
                  0,0,0,1,0,0,0,
                    0,0,0,0,0,0,0,
                      0,0,0,0,0,
                        0,0,0,0,
```

```
},{
                        0,0,0,1,
                       0,0,0,1,1,
                      0,0,0,1,0,1,
                     0,0,0,1,1,1,1,
                      0,0,0,0,0,0,
                       0,0,0,0,0,
                        0,0,0,0,
},{
                        0,0,0,0,
                       0,0,0,0,0,
                      0,0,0,0,0,0,
                     0,0,0,1,1,1,1,
                      0,0,0,1,0,1,
                       0,0,0,1,1,
                        0,0,0,1,
},{
                        0,0,0,0,
                       0,0,0,0,0,
                      0,0,0,0,0,0,
                     0,0,0,1,0,0,0,
                      0,0,1,1,0,0,
                       0,1,0,1,0,
                        1,1,1,1,
},{
                        0,0,0,0,
                       0,0,0,0,0,
                      0,0,0,0,0,0,
                     1,1,1,1,0,0,0,
                      1,0,1,0,0,0,
                       1,1,0,0,0,
                        1,0,0,0,
},{
                        1,0,0,0,
                       1,1,0,0,0,
                      1,0,1,0,0,0,
                     1,1,1,1,0,0,0,
                      0,0,0,0,0,0,
                       0,0,0,0,0,
                        0,0,0,0,
}};

void Neopixels_Send(SPI_Type *base, uint32_t n, uint32_t *value) {
          uint16_t LED_data=0;


          for(int j=0;j<n;j++) {
                    for(int i=23;i>=0;i--) {
                              LED_data = GET_BIT(value[j], i) ? CODE_1 : CODE_0;

                              while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                              base->TXDAT = LED_data ;
                    }
          }
          // Reset >= 50 us
          LED_data=0;
          for(int j=0;j<50;j++) {
                    while(!(base->STAT & SPI_STAT_TXRDY_MASK));
                    base->TXDAT = LED_data ;
          }
}

inline uint32_t setRGB(uint8_t r, uint8_t g, uint8_t b) {

          return ((g<<16) | (r<<8) | b);
}

void setImage(const bool *image,  uint32_t color) {

          for(int i=0; i<LEDS; i++) {

                    colors[i] = image[i] * color;
          }
}

void SysTick_Handler(void) {

          rgbColor = setRGB(0, 0, 15); // MAX RGB: (15, 15, 15)
          setImage(pic2[k++ % 6], rgbColor);
          Neopixels_Send(SPI0_PERIPHERAL, LEDS, colors);
}

/*
 * @brief   Application entry point.
 */
int main(void) {

          /* Init board hardware. */
          BOARD_InitBootPins();
          BOARD_InitBootClocks();
          BOARD_InitBootPeripherals();
#ifndef BOARD_INIT_DEBUG_CONSOLE_PERIPHERAL
          /* Init FSL debug console. */
          BOARD_InitDebugConsole();
#endif

          SPI_WriteConfigFlags(SPI0_PERIPHERAL,  kSPI_ReceiveIgnore);
```

```
        SysTick_Config(SystemCoreClock / 5); // 5 Hz

        while(1) {

        }
        return 0 ;
}
```

4. Build a project, program the microcontroller and test the program.

V. Exercises

1. Create your own LUT animations
2. Create a color animation (remember not to exceed RGB values: 15, 15, 15 on many LEDs)