ENGINE

Teaching online electronics, microcontrollers and programming in Higher Education

Programing of embedded systems

3. Timers and counters

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Declaration

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Programing of embedded systems

3. Timers and counters

I. System Timer

1. Create a new project for the *LPCXpresso804* board as in the previous manual and name the project eg *Lab02*.
2. Configure three GPIO lines to control the RGB LEDs. From the Functional Group menu, select the *BOARD_InitLEDsPins* preset, then activate it by selecting the flag icon on the left, as in the previous manual. Select *Update Code* to generate the code based on the entered configuration.
3. Modify the program code by adding system timer support:

```
#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"

bool g_pinState = false;

void SysTick_Handler(void)
{
   GPIO_PinWrite(BOARD_INITLEDSPINS_LED_RED_GPIO, BOARD_INITLEDSPINS_LED_RED_PORT, BOARD_INITLEDSPINS_LED_RED_PIN,
g_pinState^=true);
}
/*
 * @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

          SysTick_Config(SystemCoreClock / 10U); // 10 Hz

          while(1) {

          }
          return 0 ;
}
```

Build a project, program the microcontroller and check the operation. The led should change state 10 times per second (5 flashes per second).

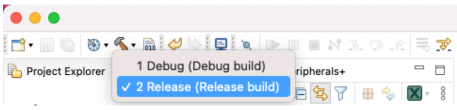
II. Delay function

1. Create a new project for the *LPCXpresso804* board and name it eg *Lab02_2*.
2. *As before, configure three GPIO lines to control the RGB LEDs*. Modify the program code as in the example 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"

bool g_pinState = false;
uint32_t g_systickCounter;

void SysTick_Handler(void) {

          if (g_systickCounter)
              g_systickCounter--;
}

void delay_ms(uint32_t n) {

          g_systickCounter = n;
          while (g_systickCounter);
}

/*
 * @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


          SysTick_Config(SystemCoreClock / 1000U); // 1 ms

          while(1) {

                    GPIO_PinWrite(BOARD_INITLEDSPINS_LED_RED_GPIO,
                                              BOARD_INITLEDSPINS_LED_RED_PORT,
                                              BOARD_INITLEDSPINS_LED_RED_PIN,
                                              g_pinState ^= true);

                    delay_ms(500);
          }

          return 0 ;
}
```

Build a project, program the microcontroller and check the operation. The led should change state 2 times per second (1 flash every second).

3. Rebuild the project in the *Release* configuration by changing the settings in the drop-down menu next to the Build icon:



Build a project, program the microcontroller and check the operation. Due to compiler optimization, the *g_systickCounter* variable is not "refreshed" in the while loop inside the *delay_ms* function. Hence, the LED will stop flashing.

4. To force the value of the *g_systickCounter* variable to "refresh" each time, add the *volatile* modifier:

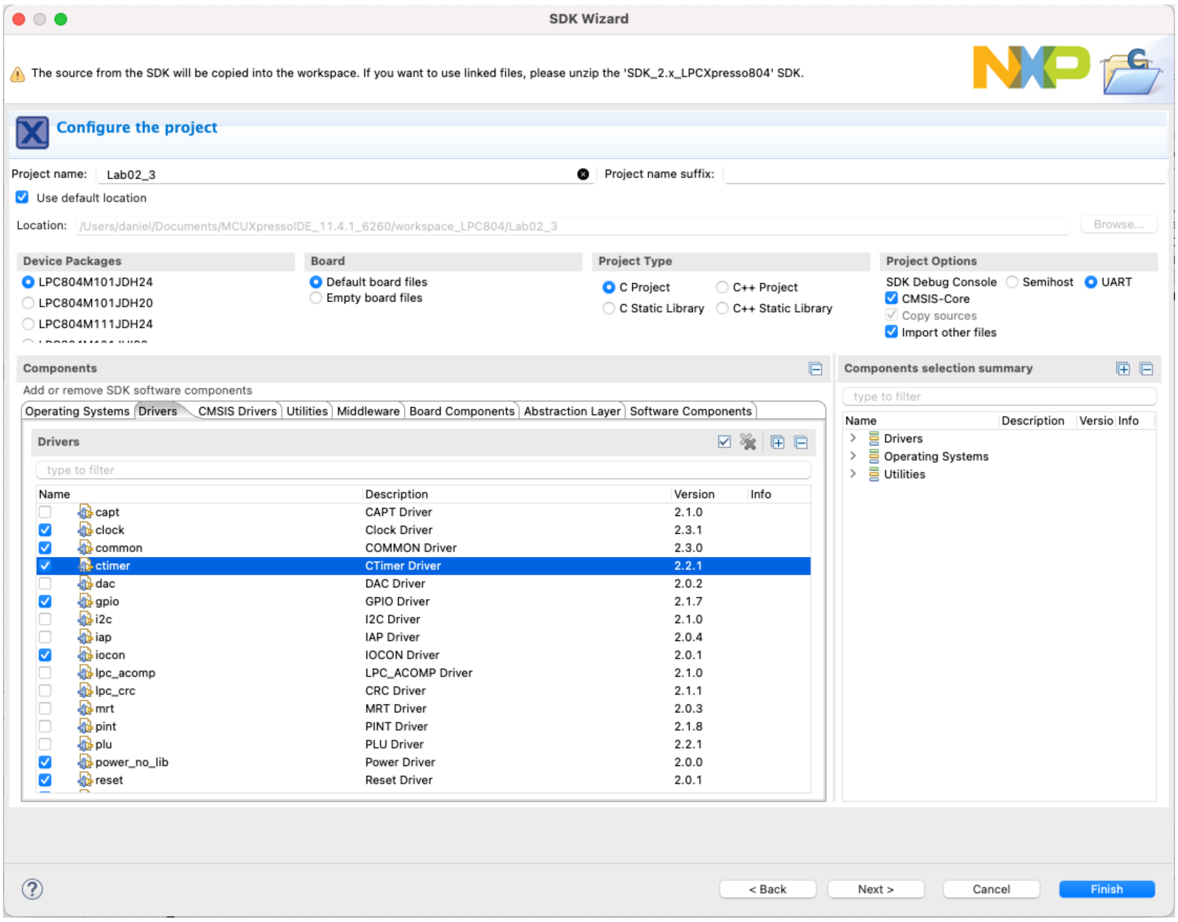
```
#include <stdio.h>
#include "board.h"
#include "peripherals.h"
#include "pin_mux.h"
#include "clock_config.h"
#include "LPC804.h"
#include "fsl_debug_console.h"

bool g_pinState = false;
volatile uint32_t g_systickCounter;

void SysTick_Handler(void) {

          if (g_systickCounter)
              g_systickCounter--;
}

void delay_ms(uint32_t n) {

          g_systickCounter = n;
          while (g_systickCounter);
}
/*
 * @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

          SysTick_Config(SystemCoreClock / 1000U); // 1 ms
```

```
        while(1) {

                GPIO_PinWrite(BOARD_INITLEDSPINS_LED_RED_GPIO,
                              BOARD_INITLEDSPINS_LED_RED_PORT,
                              BOARD_INITLEDSPINS_LED_RED_PIN,
                              g_pinState ^= true);

                delay_ms(500);
        }

        return 0 ;
}
```

Build a project, program the microcontroller and check the operation. The led should change state 2 times per second (1 flash every second) as it did in *Debug* mode.

III. CTIMER - Match mode

1. Create a new project for the *LPCXpresso804* board and name it eg *Lab02_3*. Add the *ctimer* driver:



SDK Wizard

⚠ The source from the SDK will be copied into the workspace. If you want to use linked files, please unzip the 'SDK_2.x_LPCXpresso804' SDK.

Configure the project

Project name: Lab02_3 Project name suffix:

☑ Use default location

Location: /Users/daniel/Documents/MCUXpressoIDE_11.4.1_6260/workspace_LPC804/Lab02_3

Device Packages: ● LPC804M101JDH24 ○ LPC804M101JDH20 ○ LPC804M111JDH24

Board: ● Default board files ○ Empty board files

Project Type: ● C Project ○ C++ Project ○ C Static Library ○ C++ Static Library

Project Options: SDK Debug Console ○ Semihost ● UART; ☑ CMSIS-Core; ☑ Copy sources; ☑ Import other files

Components

Add or remove SDK software components

Operating Systems | Drivers | CMSIS Drivers | Utilities | Middleware | Board Components | Abstraction Layer | Software Components

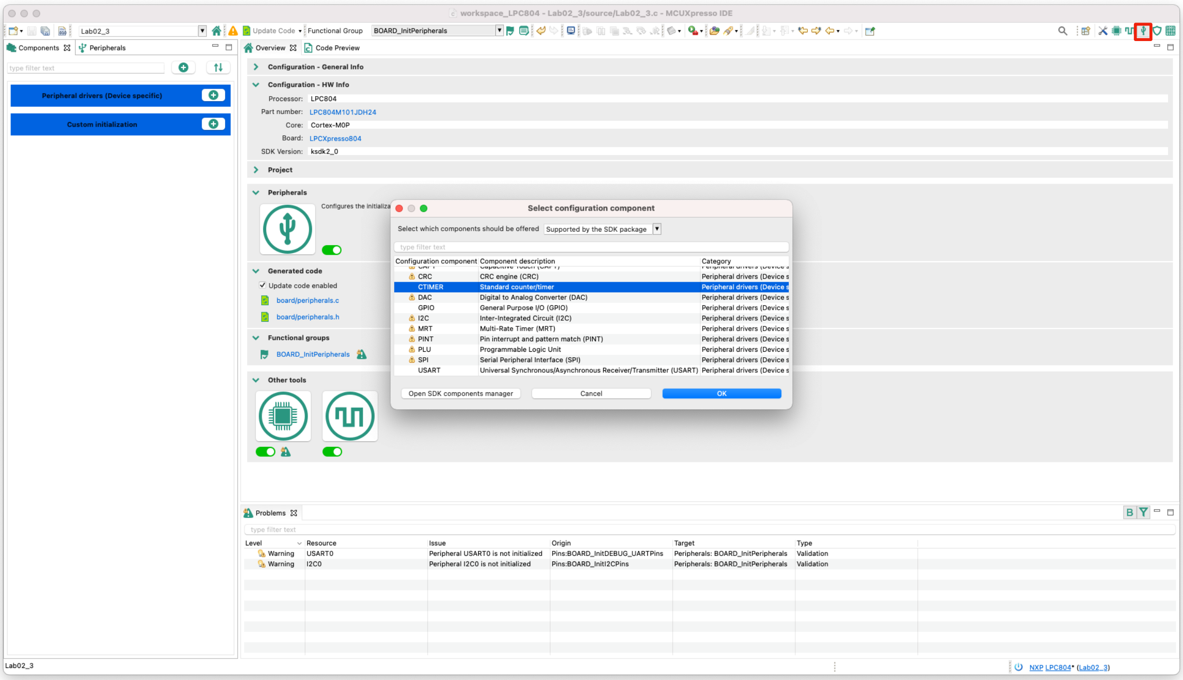
Drivers

	Name	Description	Version	Info
□	capt	CAPT Driver	2.1.0	
☑	clock	Clock Driver	2.3.1	
☑	common	COMMON Driver	2.3.0	
☑	ctimer	CTimer Driver	2.2.1	
□	dac	DAC Driver	2.0.2	
☑	gpio	GPIO Driver	2.1.7	
□	i2c	I2C Driver	2.1.0	
□	iap	IAP Driver	2.0.4	
☑	iocon	IOCON Driver	2.0.1	
□	lpc_acomp	LPC_ACOMP Driver	2.1.0	
□	lpc_crc	CRC Driver	2.1.1	
□	mrt	MRT Driver	2.0.3	
□	pint	PINT Driver	2.1.8	
□	plu	PLU Driver	2.2.1	
☑	power_no_lib	Power Driver	2.0.0	
☑	reset	Reset Driver	2.0.1	

Components selection summary

Name	Description	Versio	Info
› Drivers			
› Operating Systems			
› Utilities			

2. To do this, right-click on the project name and select *MCUXpresso Config Tools -> Open Pheriperals*:



workspace_LPC804 - Lab02_3/source/Lab02_3.c - MCUXpresso IDE

Processor: LPC804
Part number: LPC804M101JDH24
Core: Cortex-M0P
Board: LPCXpresso804
SDK Version: ksdk2_0

☑ Update code enabled
board/peripherals.c
board/peripherals.h
BOARD_InitPeripherals

Select configuration component

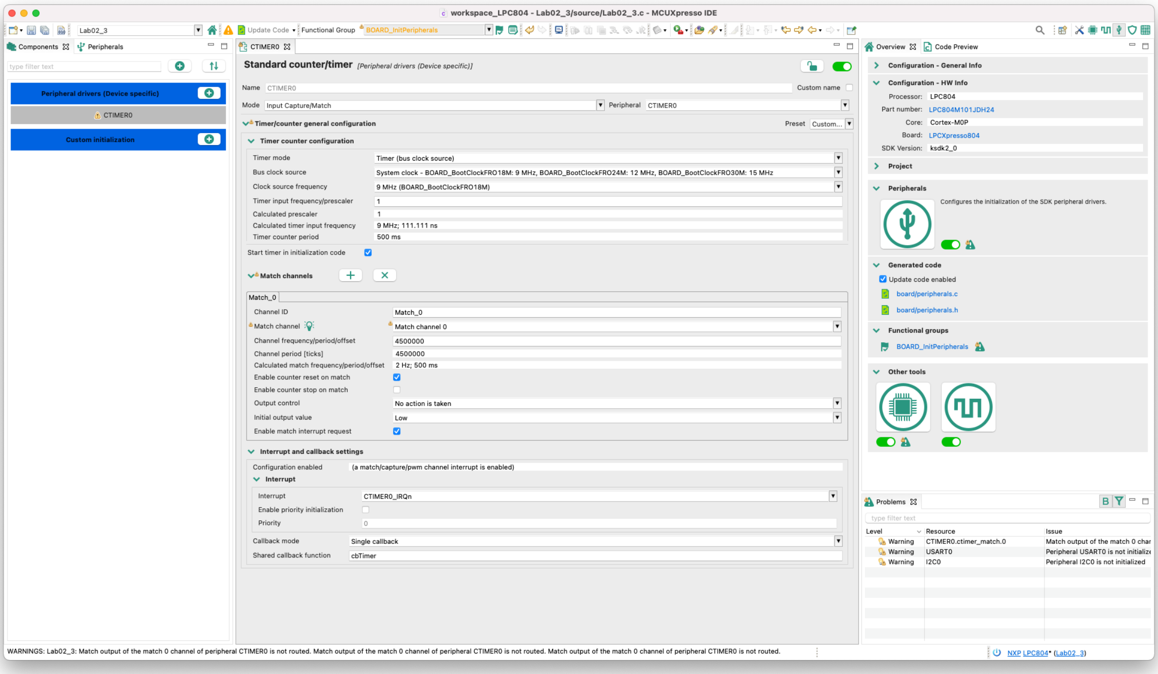
Select which components should be offered: Supported by the SDK package

Configuration component	Component description	Category
CRC	CRC engine (CRC)	Peripheral drivers (Device s
CTIMER	Standard counter/timer	Peripheral drivers (Device s
DAC	Digital to Analog Converter (DAC)	Peripheral drivers (Device s
GPIO	General Purpose I/O (GPIO)	Peripheral drivers (Device s
I2C	Inter-Integrated Circuit (I2C)	Peripheral drivers (Device s
MRT	Multi-Rate Timer (MRT)	Peripheral drivers (Device s
PINT	Pin interrupt and pattern match (PINT)	Peripheral drivers (Device s
PLU	Programmable Logic Unit	Peripheral drivers (Device s
SPI	Serial Peripheral Interface (SPI)	Peripheral drivers (Device s
USART	Universal Synchronous/Asynchronous Receiver/Transmitter (USART)	Peripheral drivers (Device s

Level	Resource	Issue	Origin	Target	Type
Warning	USART0	Peripheral USART0 is not initialized	Pins:BOARD_InitDEBUG_UARTPins	Peripherals: BOARD_InitPeripherals	Validation
Warning	I2C0	Peripheral I2C0 is not initialized	Pins:BOARD_InitI2CPins	Peripherals: BOARD_InitPeripherals	Validation

Lab02_3 NXP LPC804* (Lab02_3)

3. Configure the *CTIMER0* pheriperal:



workspace_LPC804 - Lab02_3/source/Lab02_3.c - MCUXpresso IDE

Standard counter/timer *[Peripheral drivers (Device specific)]*

Name: CTIMER0 Custom name □
Mode: Input Capture/Match Peripheral: CTIMER0

Timer/counter general configuration Preset: Custom...

Timer counter configuration

Timer mode	Timer (bus clock source)
Bus clock source	System clock - BOARD_BootClockFRO18M: 9 MHz, BOARD_BootClockFRO24M: 12 MHz, BOARD_BootClockFRO30M: 15 MHz
Clock source frequency	9 MHz (BOARD_BootClockFRO18M)
Timer input frequency/prescaler	1
Calculated prescaler	1
Calculated timer input frequency	9 MHz; 111.111 ns
Timer counter period	500 ms

Start timer in initialization code ☑

Match channels

Match_0

Channel ID	Match_0
Match channel	Match channel 0
Channel frequency/period/offset	4500000
Channel period [ticks]	4500000
Calculated match frequency/period/offset	2 Hz; 500 ms
Enable counter reset on match	☑
Enable counter stop on match	□
Output control	No action is taken
Initial output value	Low
Enable match interrupt request	☑

Interrupt and callback settings

Configuration enabled (a match/capture/pwm channel interrupt is enabled)

Interrupt

Interrupt	CTIMER0_IRQn
Enable priority initialization	□
Priority	0
Callback mode	Single callback
Shared callback function	cbTimer

Level	Resource	Issue
Warning	CTIMER0.ctimer_match.0	Match output of the match 0 char
Warning	USART0	Peripheral USART0 is not initialize
Warning	I2C0	Peripheral I2C0 is not initialized

WARNINGS: Lab02_3: Match output of the match 0 channel of peripheral CTIMER0 is not routed. Match output of the match 0 channel of peripheral CTIMER0 is not routed. Match output of the match 0 channel of peripheral CTIMER0 is not routed.

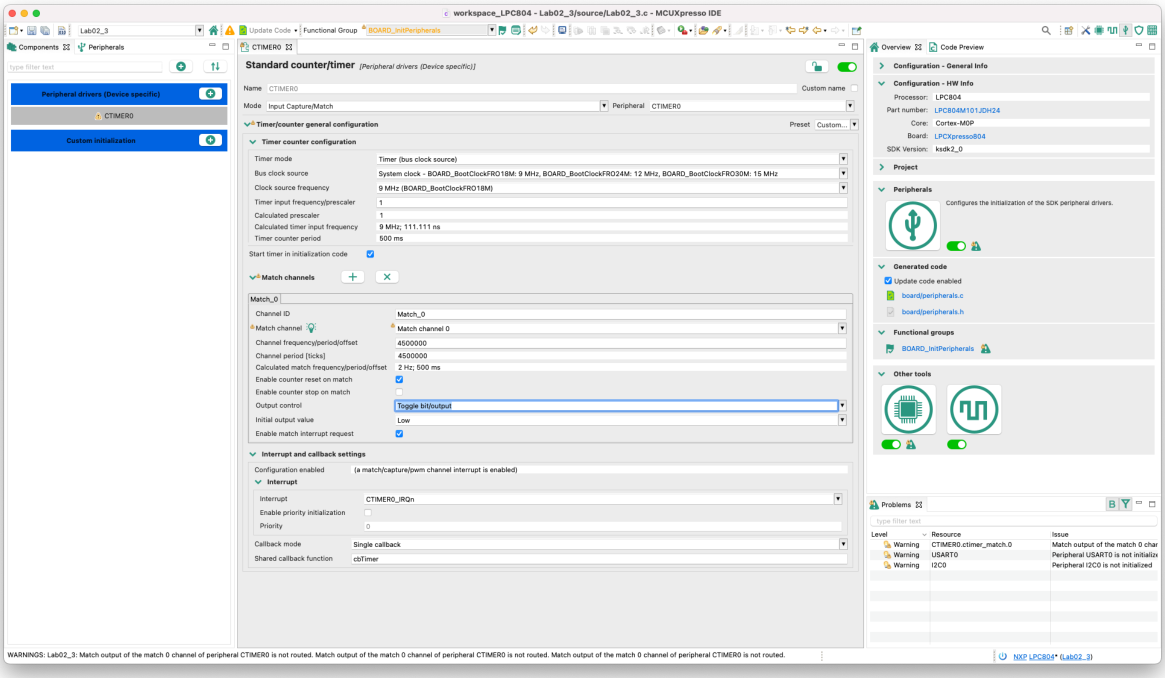
NXP LPC804* (Lab02_3)

4. Press *Update Code* and modify the program code by adding the *cbTimer* function, the definition of which was generated in the file *peripherals.h*:

```
#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"

void cbTimer(uint32_t flags) {

          PRINTF("Timer INT\r\n");
}

/*
 * @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

    PRINTF("Start\n");

    while(1) {

    }
    return 0 ;
}
```

Build a project, program the microcontroller, start the debugger console and check the program operation.

5. Go back to *MCUXpresso Config Tools-> Pheriperals* and activate the hardware output of the *Match* block:



Standard counter/timer *[Peripheral drivers (Device specific)]*

Name: CTIMER0 Custom name □
Mode: Input Capture/Match Peripheral: CTIMER0

Timer/counter general configuration Preset: Custom...

Timer counter configuration

Timer mode: Timer (bus clock source)
Bus clock source: System clock - BOARD_BootClockFRO18M: 9 MHz, BOARD_BootClockFRO24M: 12 MHz, BOARD_BootClockFRO30M: 15 MHz
Clock source frequency: 9 MHz (BOARD_BootClockFRO18M)
Timer input frequency/prescaler: 1
Calculated prescaler: 1
Calculated timer input frequency: 9 MHz; 111.111 ns
Timer counter period: 500 ms

Start timer in initialization code ☑

Match channels

Match_0

Channel ID: Match_0
Match channel: Match channel 0
Channel frequency/period/offset: 4500000
Channel period [ticks]: 4500000
Calculated match frequency/period/offset: 2 Hz; 500 ms
Enable counter reset on match ☑
Enable counter stop on match □
Output control: Toggle bit/output
Initial output value: Low
Enable match interrupt request ☑

Interrupt and callback settings

Configuration enabled: (a match/capture/pwm channel interrupt is enabled)

Interrupt

Interrupt: CTIMER0_IRQn
Enable priority initialization □
Priority: 0

Callback mode: Single callback
Shared callback function: cbTimer

Configuration - General Info

Configuration - HW Info

Processor: LPC804
Part number: LPC804M101JDH24
Core: Cortex-M0P
Board: LPCXpresso804
SDK Version: ksdk2_0

Project

Peripherals

Configures the initialization of the SDK peripheral drivers.

Generated code

☑ Update code enabled
board/peripherals.c
board/peripherals.h

Functional groups

BOARD_InitPeripherals

Other tools

Level	Resource	Issue
Warning	CTIMER0.ctimer_match.0	Match output of the match 0 char
Warning	USART0	Peripheral USART0 is not initialize
Warning	I2C0	Peripheral I2C0 is not initialized

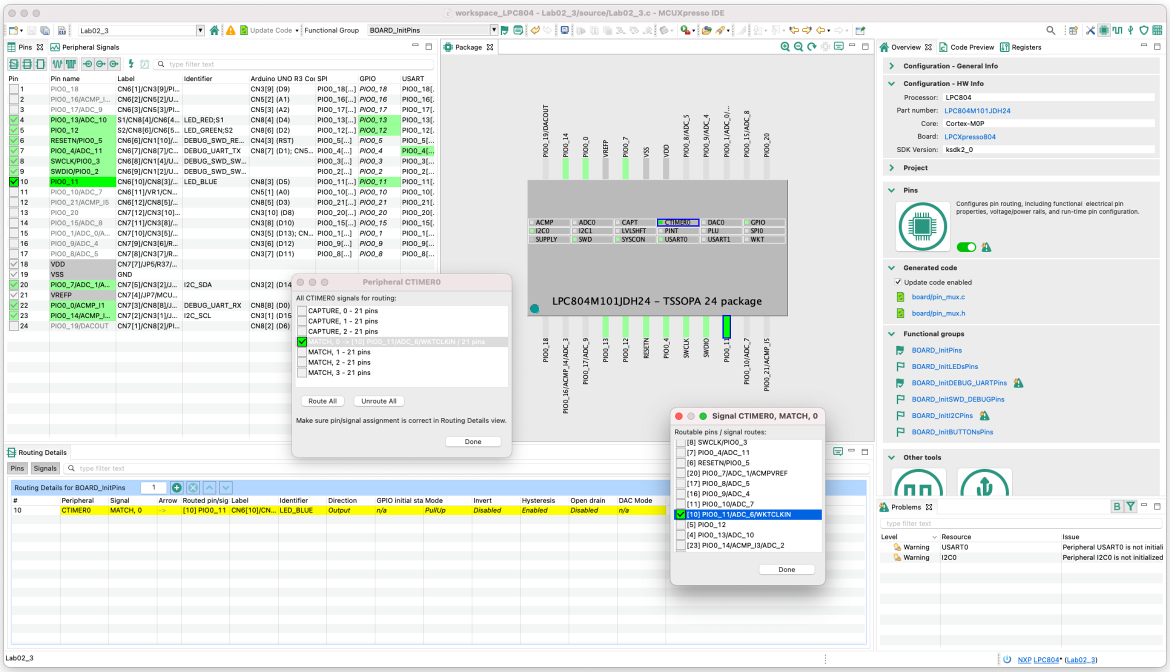
WARNINGS: Lab02_3: Match output of the match 0 channel of peripheral CTIMER0 is not routed. Match output of the match 0 channel of peripheral CTIMER0 is not routed. Match output of the match 0 channel of peripheral CTIMER0 is not routed.

NXP LPC804* (Lab02_3)

Programing of embedded systems

3. Timers and counters

6. In the picture showing the microcontroller, click on *CTIMER*.
7. In the open dialog boxes select MATCH, 0 and then PIO0_11, respectively:



Peripheral CTIMER0

All CTIMER0 signals for routing:

- □ CAPTURE, 0 - 21 pins
- □ CAPTURE, 1 - 21 pins
- □ CAPTURE, 2 - 21 pins
- ☑ MATCH, 0 -> [10] PIO0_11/ADC_6/WKTCLKIN / 21 pins
- □ MATCH, 1 - 21 pins
- □ MATCH, 2 - 21 pins
- □ MATCH, 3 - 21 pins

Make sure pin/signal assignment is correct in Routing Details view.

Signal CTIMER0, MATCH, 0

Routable pins / signal routes:

- □ [8] SWCLK/PIO0_3
- □ [7] PIO0_4/ADC_11
- □ [6] RESETN/PIO0_5
- □ [20] PIO0_7/ADC_1/ACMPVREF
- □ [17] PIO0_8/ADC_5
- □ [16] PIO0_9/ADC_4
- □ [11] PIO0_10/ADC_7
- ☑ [10] PIO0_11/ADC_6/WKTCLKIN
- □ [5] PIO0_12
- □ [4] PIO0_13/ADC_10
- □ [23] PIO0_14/ACMP_I3/ADC_2

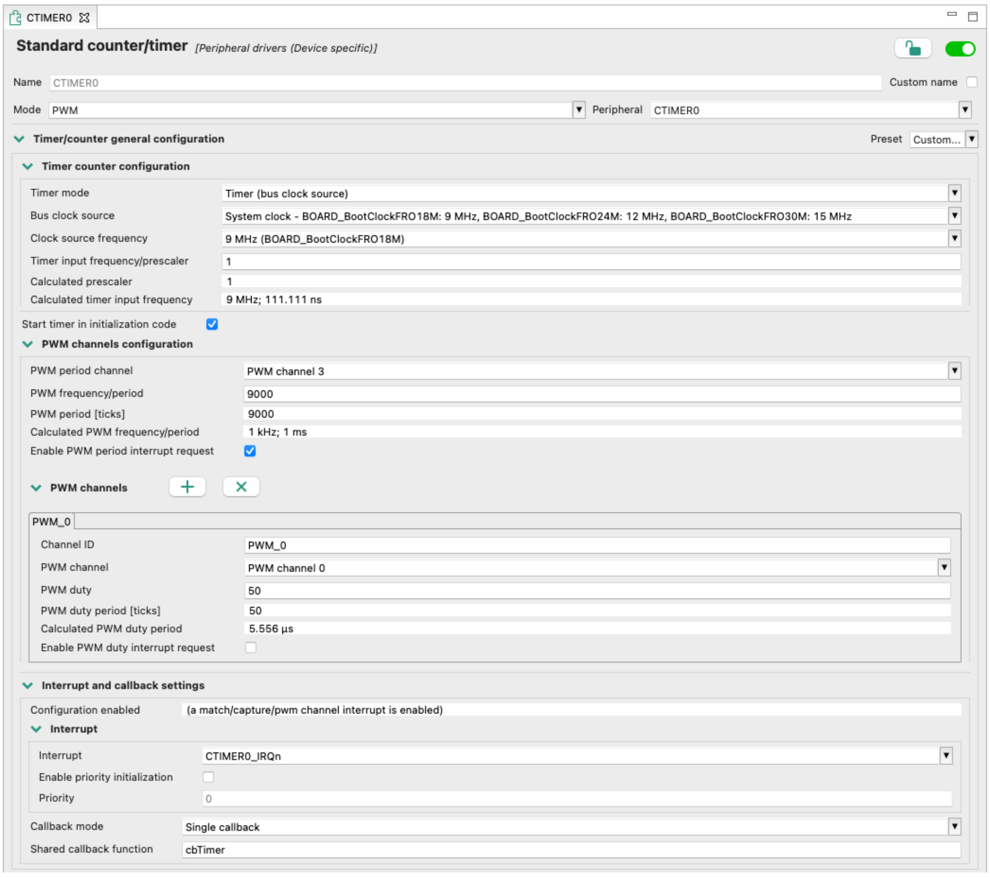
Routing Details for BOARD_InitPins

#	Peripheral	Signal	Arrow	Routed pin/sig	Label	Identifier	Direction	GPIO initial sta	Mode	Invert	Hysteresis	Open drain	DAC Mode
10	CTIMER0	MATCH, 0	->	[10] PIO0_11	CN6[10]/CN...	LED_BLUE	Output	n/a	PullUp	Disabled	Enabled	Disabled	n/a

8. Press *Done* in the individual dialog boxes and then *Update Code*.
9. Build a project, program the microcontroller and check the operation. The LED (blue) should change state 2 times per second (1 flash every second).

IV. CTIMER - PWM mode

1. Go to *Pheriperals* and change the configuration of CTIMER0 to PWM and set the values as below:



CTIMER0

Standard counter/timer *[Peripheral drivers (Device specific)]*

Name: CTIMER0 — Custom name □

Mode: PWM — Peripheral: CTIMER0

Timer/counter general configuration — Preset: Custom...

Timer counter configuration

Timer mode	Timer (bus clock source)
Bus clock source	System clock - BOARD_BootClockFRO18M: 9 MHz, BOARD_BootClockFRO24M: 12 MHz, BOARD_BootClockFRO30M: 15 MHz
Clock source frequency	9 MHz (BOARD_BootClockFRO18M)
Timer input frequency/prescaler	1
Calculated prescaler	1
Calculated timer input frequency	9 MHz; 111.111 ns

Start timer in initialization code ☑

PWM channels configuration

PWM period channel	PWM channel 3
PWM frequency/period	9000
PWM period [ticks]	9000
Calculated PWM frequency/period	1 kHz; 1 ms
Enable PWM period interrupt request	☑

PWM channels

PWM_0

Channel ID	PWM_0
PWM channel	PWM channel 0
PWM duty	50
PWM duty period [ticks]	50
Calculated PWM duty period	5.556 µs
Enable PWM duty interrupt request	□

Interrupt and callback settings

Configuration enabled: (a match/capture/pwm channel interrupt is enabled)

Interrupt

Interrupt	CTIMER0_IRQn
Enable priority initialization	□
Priority	0

Callback mode	Single callback
Shared callback function	cbTimer

2. Press *Update Code* and modify the program code:

```
#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"

volatile uint8_t pwmDuty0=0;

void cbTimer(uint32_t flags) {

          CTIMER_UpdatePwmDutycycle(CTIMER0_PERIPHERAL,
                                    CTIMER0_PWM_PERIOD_CH,
                                    CTIMER0_PWM_0_CHANNEL,
                                    100-pwmDuty0); // Because the LED is active low
}

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

          char c;

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

          EnableIRQ(CTIMER0_TIMER_IRQN); // Fix the BUG in Config Tools

          PRINTF("Start\r\n");

          while(1) {
                c=GETCHAR();
                switch(c) {

                case 'a':
                        if(pwmDuty0<100)
                                pwmDuty0++;
                        PRINTF("PWM0: %d\r\n", pwmDuty0);
                        break;
                case 'z':
                        if(pwmDuty0>0)
                                pwmDuty0--;
                        PRINTF("PWM0: %d\r\n", pwmDuty0);
                        break;
                }
        }
        return 0 ;
}
```

Adding the *EnableIRQ* function is necessary due to a bug in Config Tools (does not set the interrupt activation flag in the generated code).

Build a project, program the microcontroller and check the operation. Open the terminal and check the LED brightness control operation.

V. Exercises

1. Add an additional PWM channels (PWM_1 and PWM_2) to *CTIMER0*, connect its outputs to PIO0_12 (Green LED) and PIO0_13 (Red LED). Write a program to control LEDs brightness using the terminal. Send a mark:
   a: Blue PWM ++
   z: Blue PWM - -
   s: Green PWM ++
   x: Green PWM - -
   d: Red PWM ++
   c: Red PWM - -