PRIMENA MIKROKONTROLERA-MS1PMK

5. deo

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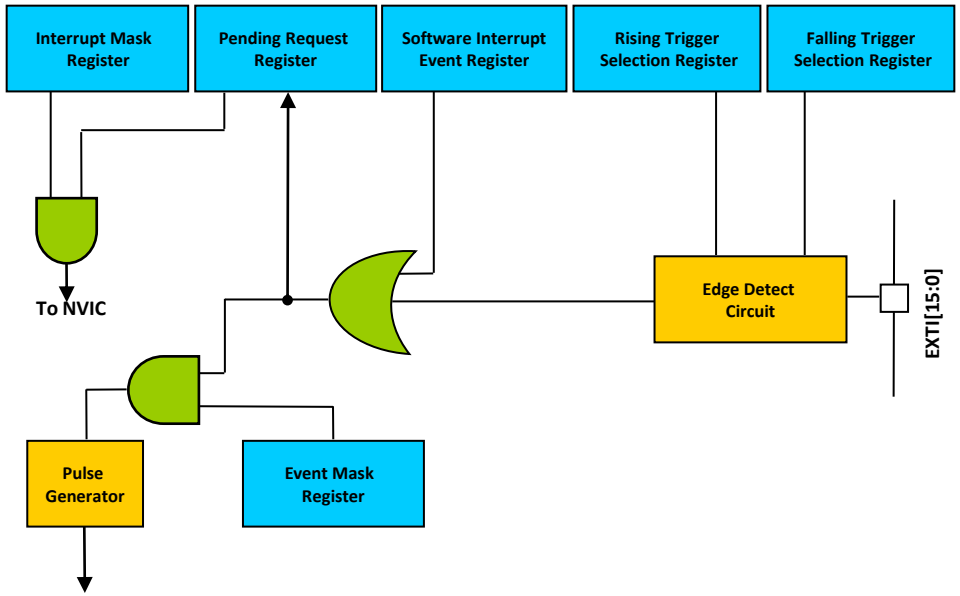
EXTI Spoljašnji prekidi

- Do 40 Interrupt/Events zahteva
  - Do 80 pinova se može koristiti kao EXTI ulaz.
  - 16 linija povezanih na GPIO pinove
  - Ostale linije poveyane na specificne periferije



- Dva konfiguraciona moda:
  - Interrupt mode: generisanje prekida
  - Event mode: generisanje buđenja sistema koji je u SLEEP modu.

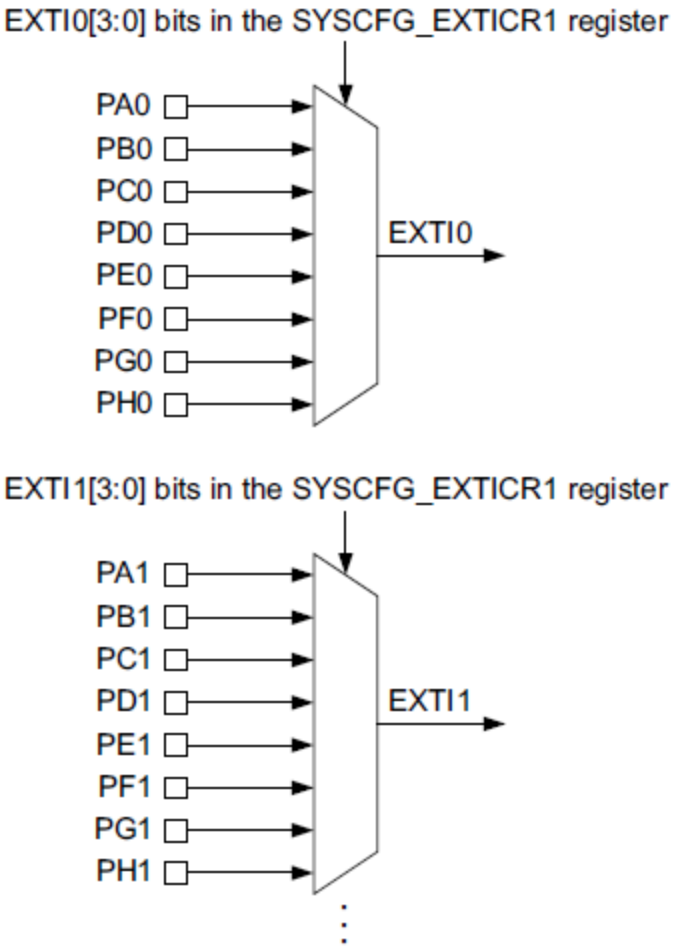
- Nezavisni trigeri (rastuća, opadajuća ili obe ivice)

- Status bit svake linije

- Mogućnost softverskog forsiranja bilo kog prekida/događaja.

- EXTI periferija je povezana na APB2 da bi se skratilo vreme ragovanja (APB2 je u opštem slučaju brža od APB1 magistrale)

EXTI prekidi




```
DCD     PVD_IRQHandler              ; PVD through EXTI Line detect
DCD     TAMPER_IRQHandler           ; Tamper
DCD     RTC_IRQHandler              ; RTC
DCD     FLASH_IRQHandler            ; Flash
DCD     RCC_IRQHandler              ; RCC
DCD     EXTI0_IRQHandler            ; EXTI Line 0
DCD     EXTI1_IRQHandler            ; EXTI Line 1
DCD     EXTI2_IRQHandler            ; EXTI Line 2
DCD     EXTI3_IRQHandler            ; EXTI Line 3
DCD     EXTI4_IRQHandler            ; EXTI Line 4
DCD     DMA1_Channel1_IRQHandler    ; DMA1 Channel 1
DCD     DMA1_Channel2_IRQHandler    ; DMA1 Channel 2
DCD     DMA1_Channel3_IRQHandler    ; DMA1 Channel 3
DCD     DMA1_Channel4_IRQHandler    ; DMA1 Channel 4
DCD     DMA1_Channel5_IRQHandler    ; DMA1 Channel 5
DCD     DMA1_Channel6_IRQHandler    ; DMA1 Channel 6
DCD     DMA1_Channel7_IRQHandler    ; DMA1 Channel 7
DCD     ADC1_IRQHandler             ; ADC1
DCD     0                           ; Reserved
DCD     0                           ; Reserved
DCD     0                           ; Reserved
DCD     0                           ; Reserved
DCD     EXTI9_5_IRQHandler          ; EXTI Line 9..5
DCD     TIM1_BRK_TIM15_IRQHandler   ; TIM1 Break and TIM15
DCD     TIM1_UP_TIM16_IRQHandler    ; TIM1 Update and TIM16
DCD     TIM1_TRG_COM_TIM17_IRQHandler ; TIM1 Trigger and Commutation and TIM17
DCD     TIM1_CC_IRQHandler          ; TIM1 Capture Compare
DCD     TIM2_IRQHandler             ; TIM2
DCD     TIM3_IRQHandler             ; TIM3
DCD     TIM4_IRQHandler             ; TIM4
DCD     I2C1_EV_IRQHandler          ; I2C1 Event
DCD     I2C1_ER_IRQHandler          ; I2C1 Error
DCD     I2C2_EV_IRQHandler          ; I2C2 Event
DCD     I2C2_ER_IRQHandler          ; I2C2 Error
DCD     SPI1_IRQHandler             ; SPI1
DCD     SPI2_IRQHandler             ; SPI2
DCD     USART1_IRQHandler           ; USART1
DCD     USART2_IRQHandler           ; USART2
DCD     USART3_IRQHandler           ; USART3
DCD     EXTI15_10_IRQHandler        ; EXTI Line 15..10
DCD     RTCAlarm_IRQHandler         ; RTC Alarm through EXTI Line
DCD     CEC_IRQHandler              ; HDMI-CEC
```

External interrupt configuration register 1 (2,3,4) (SYSCFG_EXTICR1 (2,3,4))

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res	EXTI3[2:0]			Res	EXTI2[2:0]			Res	EXTI1[2:0]			Res	EXTI0[2:0]		
	rw	rw	rw		rw	rw	rw		rw	rw	rw		rw	rw	rw

Bits 31:15 Reserved, must be kept at reset value.

Bits 14:12 **EXTI3[2:0]**: EXTI 3 configuration bits

These bits are written by software to select the source input for the EXTI3 external interrupt.

000: PA[3] pin
001: PB[3] pin
010: PC[3] pin
011: PD[3] pin
100: PE[3] pin
101: PF[3] pin
110: PG[3] pin
111: Reserved

Na EXTIx ide uvek pinx

Ostale EXTI konekcije

Table 43. EXTI lines connections

EXTI line	Line source[1]	Line type
0-15	GPIO	configurable
16	PVD	configurable
17	OTG_FS wakeup event[2]	direct
18	RTC alarms	configurable
19	RTC tamper or timestamp or CSS_LSE	configurable
20	RTC wakeup timer	configurable
21	COMP1 output	configurable
22	COMP2 output	configurable
23	I2C1 wakeup[2]	direct
24	I2C2 wakeup[2]	direct
25	I2C3 wakeup	direct
26	USART1 wakeup[2]	direct
27	USART2 wakeup[2]	direct
28	USART3 wakeup[2]	direct
29	UART4 wakeup[2]	direct
30	UART5 wakeup[2]	direct
31	LPUART1 wakeup	direct
32	LPTIM1	direct
33	LPTIM2[2]	direct
34	SWPMI1 wakeup[2]	direct
35	PVM1 wakeup	configurable
36	PVM2 wakeup	configurable
37	PVM3 wakeup	configurable
38	PVM4 wakeup	configurable
39	LCD wakeup	direct

Interrupt mask register (EXTI_IMR)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IM31	IM30	IM29	IM28	IM27	IM26	IM25	IM24	IM23	IM22	IM21	IM20	IM19	IM18	IM17	IM16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IM15	IM14	IM13	IM12	IM11	IM10	IM9	IM8	IM7	IM6	IM5	IM4	IM3	IM2	IM1	IM0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **IMx:** Interrupt Mask on line x (x = 31 to 0)

0: Interrupt request from Line x is masked

1: Interrupt request from Line x is not masked

Interrupt mask register 2 (EXTI_IMR2)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IM39	IM38	IM37	IM36	IM35	IM34	IM33	IM32
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:8 Reserved, must be kept at reset value

Bits 7:0 **IMx:** Interrupt mask on line x (x = 39 to 32)

0: Interrupt request from line x is masked

1: Interrupt request from line x is not masked

Rising trigger selection register (EXTI_RTSR)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RT22	RT21	RT20	RT19	RT18	Res.	RT16
									rw	rw	rw	rw	rw		rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RT15	RT14	RT13	RT12	RT11	RT10	RT9	RT8	RT7	RT6	RT5	RT4	RT3	RT2	RT1	RT0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:23 Reserved, must be kept at reset value.

Bits 22:18 **RTx:** Rising trigger event configuration bit of line x (x = 22 to 18)

0: Rising trigger disabled (for Event and Interrupt) for input line
1: Rising trigger enabled (for Event and Interrupt) for input line

Bit 17 Reserved, must be kept at reset value.

Bits 16:0 **RTx:** Rising trigger event configuration bit of line x (x = 16 to 0)

0: Rising trigger disabled (for Event and Interrupt) for input line
1: Rising trigger enabled (for Event and Interrupt) for input line

Wakeup event mask register (EXTI_EMR)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EM31	EM30	EM29	EM28	EM27	EM26	EM25	EM24	EM23	EM22	EM21	EM20	EM19	EM18	EM17	EM16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EM15	EM14	EM13	EM12	EM11	EM10	EM9	EM8	EM7	EM6	EM5	EM4	EM3	EM2	EM1	EM0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **EMx:** Event mask on line x (x = 31 to 0)

0: Event request from line x is masked

1: Event request from line x is not masked

Falling trigger selection register (EXTI_FTSR)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	FT22	FT21	FT20	FT19	FT18	Res.	FT16
									rw	rw	rw	rw	rw		rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FT15	FT14	FT13	FT12	FT11	FT10	FT9	FT8	FT7	FT6	FT5	FT4	FT3	FT2	FT1	FT0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:23 Reserved, must be kept at reset value.

Bits 22:18 **FTx:** Falling trigger event configuration bit of line x (x = 22 to 18)
0: Falling trigger disabled (for Event and Interrupt) for input line
1: Falling trigger enabled (for Event and Interrupt) for input line

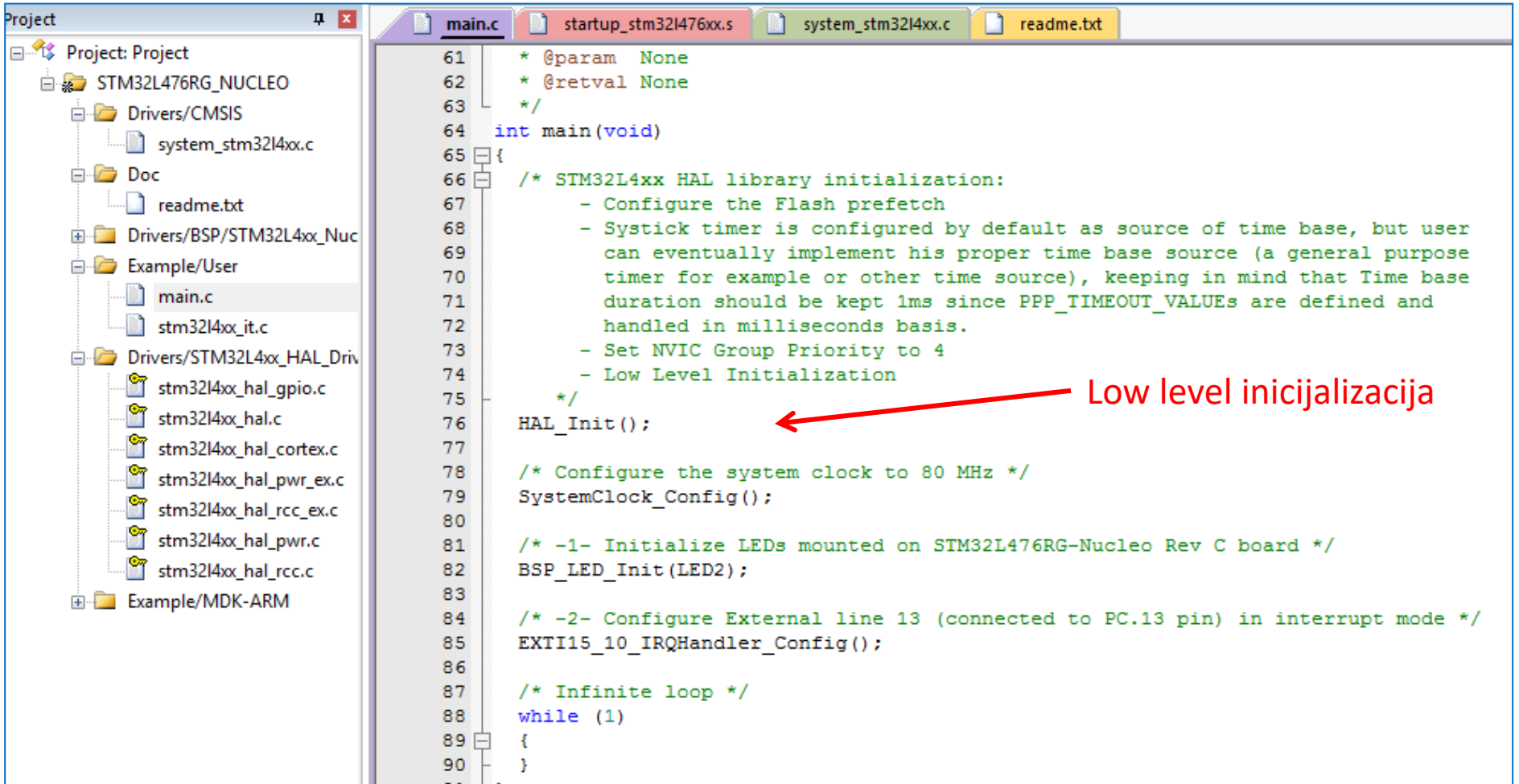
Bit 17 Reserved, must be kept at reset value.

Bits 16:0 **FTx:** Falling trigger event configuration bit of line x (x = 16 to 0)
0: Falling trigger disabled (for Event and Interrupt) for input line
1: Falling trigger enabled (for Event and Interrupt) for input line

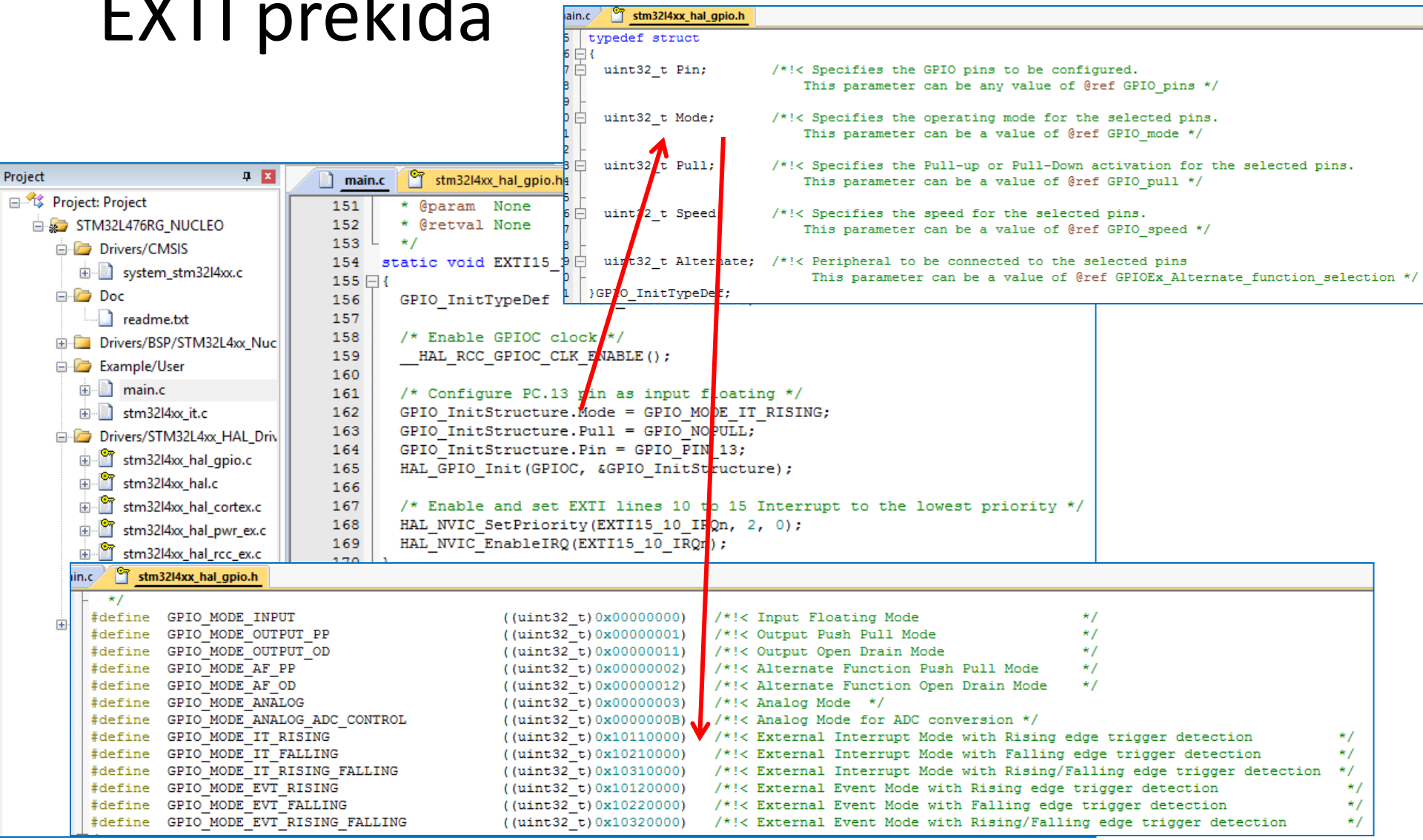
STM CUBE

Projekat GPIO_EXTI

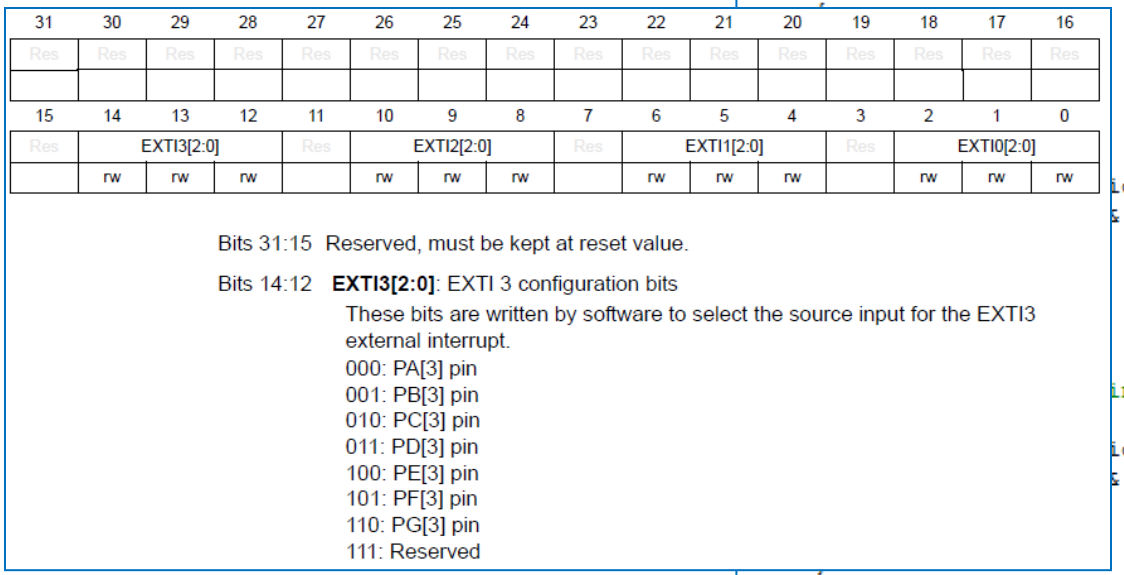
- …\STM32Cube_FW_L4_V1.4.0\Projects\STM32L476RG-Nucleo\Examples\GPIO\GPIO_EXTI\MDK-ARM



Inicijalizacija EXTI prekida



HAL_GPIO_Init()



31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res	EXTI3[2:0]			Res	EXTI2[2:0]			Res	EXTI1[2:0]			Res	EXTI0[2:0]		
	rw	rw	rw		rw	rw	rw		rw	rw	rw		rw	rw	rw

Bits 31:15 Reserved, must be kept at reset value.

Bits 14:12 **EXTI3[2:0]**: EXTI 3 configuration bits

These bits are written by software to select the source input for the EXTI3 external interrupt.

000: PA[3] pin
001: PB[3] pin
010: PC[3] pin
011: PD[3] pin
100: PE[3] pin
101: PF[3] pin
110: PG[3] pin
111: Reserved

it.c | main.c | stm32l4xx_hal_gpio.h | stm32l4xx_hal_gpio.c

```
/*---------------------- EXTI Mode Configuration ------------------------*/
/* Configure the External Interrupt or event for the current IO */
if((GPIO_Init->Mode & EXTI_MODE) == EXTI_MODE)
{
  /* Enable SYSCFG Clock */
  __HAL_RCC_SYSCFG_CLK_ENABLE();

  temp = SYSCFG->EXTICR[position >> 2];
  temp &= ~(((uint32_t)0x0F) << (4 * (position & 0x03)));
  temp |= (GPIO_GET_INDEX(GPIOx) << (4 * (position & 0x03)));
  SYSCFG->EXTICR[position >> 2] = temp;

  /* Clear EXTI line configuration */
  temp = EXTI->IMR1;
  temp &= ~((uint32_t)iocurrent);
  if((GPIO_Init->Mode & GPIO_MODE_IT) == GPIO_MODE_IT)

                                    iocurrent);
                                    & GPIO_MODE_EVT) == GPIO_MODE_EVT)

                                    ing edge configuration */

                                    iocurrent);
                                    & RISING_EDGE) == RISING_EDGE)

  EXTI->RTSR1 = temp;
```

Reakcija na prekid!

startup_stm32l476xx.s | stm32l4xx_it.c | main.c | stm32l4xx_hal_gpio.h | stm

```
273         EXPORT      I2C1_ER_IRQHandler              [WEAK]
274         EXPORT      I2C2_EV_IRQHandler              [WEAK]
275         EXPORT      I2C2_ER_IRQHandler              [WEAK]
276         EXPORT      SPI1_IRQHandler                 [WEAK]
277         EXPORT      SPI2_IRQHandler                 [WEAK]
278         EXPORT      USART1_IRQHandler               [WEAK]
279         EXPORT      USART2_IRQHandler               [WEAK]
280         EXPORT      USART3_IRQHandler               [WEAK]
281         EXPORT      EXTI15_10_IRQHandler            [WEAK]
282         EXPORT      RTC_Alarm_IRQHandler            [WEAK]
283         EXPORT      DFSDM3_IRQHandler               [WEAK]
284         EXPORT      TIM8_BRK_IRQHandler             [WEAK]
```

Drajverske funkcije – korisnik ne menja

startup_stm32l476xx.s | stm32l4xx_it.c | main.c | stm32l4xx_hal_gpi

```
167  /**************************************************
168
169  /**
170    * @brief  This function handles external lines 10
171    * @param  None
172    * @retval None
173    */
174  void EXTI15_10_IRQHandler(void)
175  {
176    HAL_GPIO_EXTI_IRQHandler(USER_BUTTON_PIN);
177  }
178
```

Korisničke funkcije

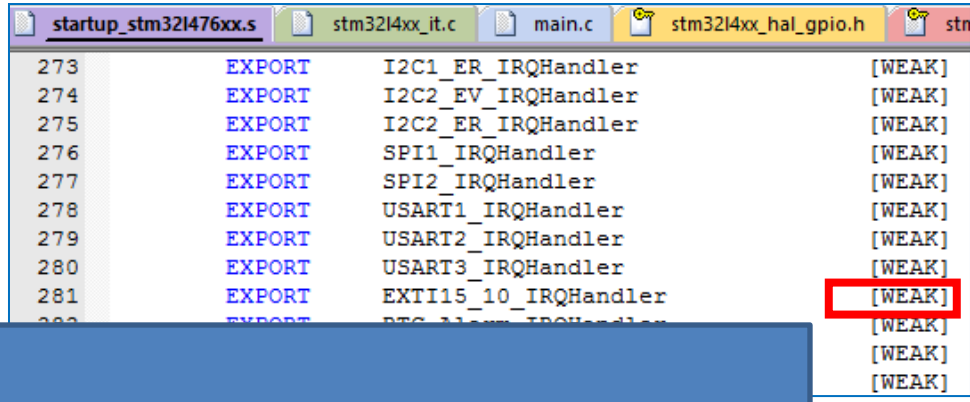
artup_stm32l476xx.s | stm32l4xx_it.c | main.c | stm32l4xx_hal_g

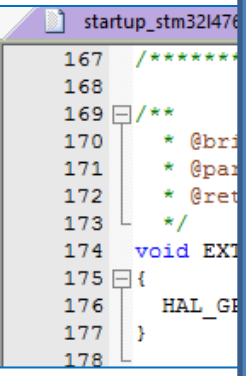
```
/**
  * @brief EXTI line detection callbacks
  * @param GPIO_Pin: Specifies the pins connected
  * @retval None
  */
void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
  if (GPIO_Pin == GPIO_PIN_13)
  {
    /* Toggle LED2 */
    BSP_LED_Toggle(LED2);
  }
}
```

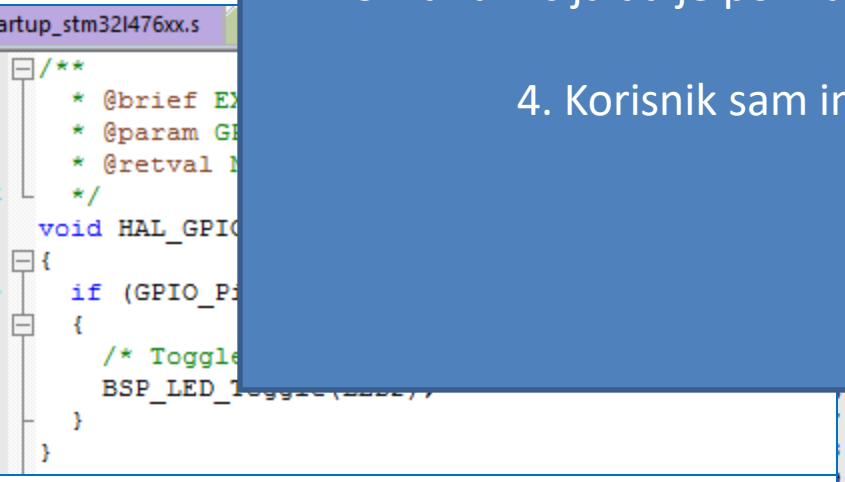
artup_stm32l476xx.s | stm32l4xx_it.c | main.c | stm32l4xx_hal_gpio.h | stm32l4xx_hal_gpio.c

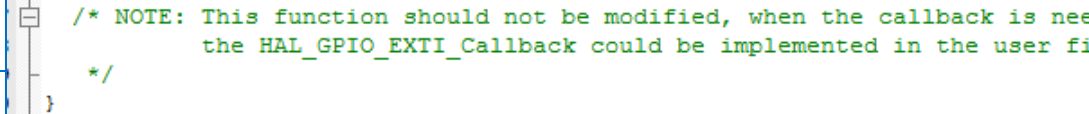
```
  * @brief  Handle EXTI interrupt request.
  * @param  GPIO_Pin: Specifies the port pin connected to corresponding E
  * @retval None
  */
void HAL_GPIO_EXTI_IRQHandler(uint16_t GPIO_Pin)
{
  /* EXTI line interrupt detected */
  if(__HAL_GPIO_EXTI_GET_IT(GPIO_Pin) != RESET)
  {
    __HAL_GPIO_EXTI_CLEAR_IT(GPIO_Pin);
    HAL_GPIO_EXTI_Callback(GPIO_Pin);
  }
}

/**
  * @brief  EXTI line detection callback.
  * @param  GPIO_Pin: Specifies the port pin connected to corresponding E
  * @retval None
  */
__weak void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
  /* Prevent unused argument(s) compilation warning */
  UNUSED(GPIO_Pin);

  /* NOTE: This function should not be modified, when the callback is nee
           the HAL_GPIO_EXTI_Callback could be implemented in the user fi
   */
}
```

Reakcija na prekid!







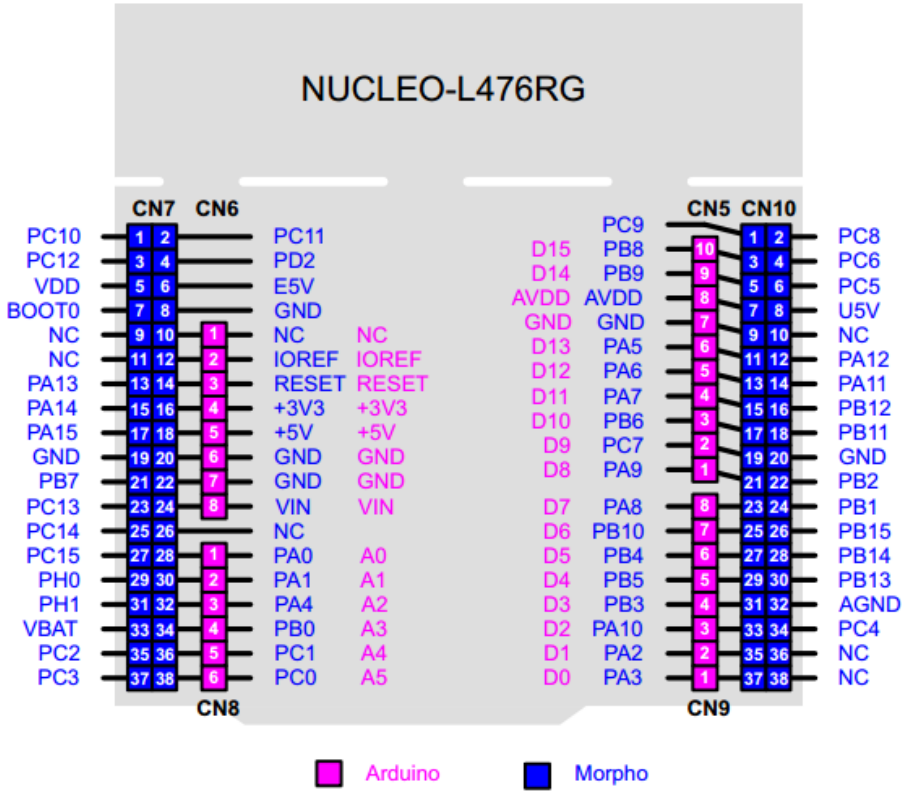


Principi HAL drajvera kada su u pitanju prekidi su sledeći:

1. Uvek postoji default handler u startup fajlu
2. Korisnik sam piše svoju prekidnu funkciju i u njoj poziva HAL_PPP_IRQHandler() funkciju u kojoj se “servisira” prekid
3. Ta funkcija dalje poziva HAL_PPP_Callback() funkciju koja ustvari “reaguje” na prekid
4. Korisnik sam implementira tu Callback funkciju.

ZADATAK 1

- Napisati program koji obezbeđuje promenu stanja diode LED2 na prekid na pinu PA_8.
- Problem 1 – PA_8 je floating
- Rešenje – aktivirati pull-up
- Problem 2 – PA_8 ima drugi prekidni vektor
- Rešenje – Identifikovati koji je to drugi prekidni vektor i na osnovu toga izvršiti adekvatna prilagođenja.



MBED

Prekidi digitalnih portova

- Klasa InterruptIn implementira na jednostavan način odavno prisutnu funkcionalnost digitalnih ulaza mikrokontrolera

InterruptIn Class Reference

```
#include <InterruptIn.h>
```

Public Member Functions

InterruptIn (PinName pin)
Create an **InterruptIn** connected to the specified pin.

void rise (void(*fptr)(void))
Attach a function to call when a rising edge occurs on the input.

template<typename T >
void rise (T *tptr, void(T::*mptr)(void))
Attach a member function to call when a rising edge occurs on the input.

void fall (void(*fptr)(void))
Attach a function to call when a falling edge occurs on the input.

template<typename T >
void fall (T *tptr, void(T::*mptr)(void))
Attach a member function to call when a falling edge occurs on the input.

void mode (PinMode pull)
Set the input pin mode.

void enable_irq ()
Enable IRQ.

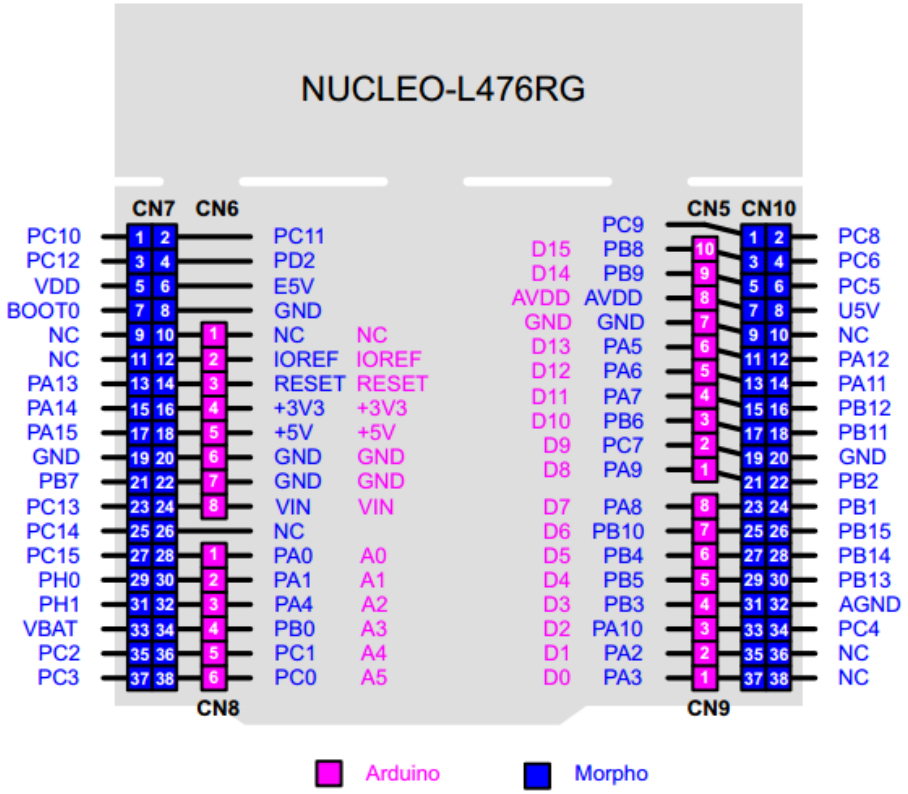
void disable_irq ()
Disable IRQ.

Klasa InterruptIn

```
#include "mbed.h”
InterruptIn button(USER_BUTTON);
DigitalOut led(LED2);

void flip() {
   led = !led;
}

int main() {
   button.fall(&flip);  // attach the address of the flip function to the rising
     edge
   while(1);
}
```

ZADATAK 2

- Napisati program koji obezbeđuje promenu stanja diode LED2 na prekid na pinu PA_8.
- Problem – PA_8 je floating
- Rešenje – aktivirati pull-up



STM32Fxx - Tajmeri

- STM32 ahitektura poseduje nekoliko vrsta tajmera:
  - Tajmeri opšte namene koji se koriste iz generisanje običnih PWM signala (output comapre), pojedinačnih impulsa (one-pulse), hvatanje ulaznih signala (input capture), specifični senzorski iterfejsi (enkoder, hall-effect senzor)
  - Napredni tajmeri (advanced timers) koji osim opštih funkcija imaju neke prednosti za generisanje signala koji se koriste u motornim pogonima ili digitalnom upravljanju pretvaračima. Primer: komlementarni izlazi sa regulisanjem mrtvog vremena, automatski isključivanje svih kanali i slično.
  - N-kanalni tajmeri (N-channel timer), koji imaju karakteristike tajmera opšte namene ali imaju ograničen broj kanala.
  - N-kanalni tajmeri tajmeri sa komplementarnim izlazima, i sa regulacijom mrtvog vremena samo na jednom kanalu.
  - Osnovni tajmer (basic timer), koji nema izlaze i ulaze već se koristi za generisanje vremenske baze, ili periodično trigerovanje DAC periferije.

Tajmeri – pregled po STM32 familiji

Timer type		STM32F0 series	STM32F101 /102/103/ 105/107 lines	STM32F100 value line	STM32L1 series	STM32F2 and STM32F4 series	STM32F30x and STM32F3x8	STM32F37x lines
Advanced		TIM1	TIM1	TIM1	-	TIM1	TIM1	-
		-	TIM8	-	-	TIM8	TIM8	-
							TIM20(1)	
General purpose	16-bit	-	TIM2	TIM2	TIM2	-	TIM2	TIM2
		TIM3	TIM3	TIM3	TIM3	TIM3	TIM3	TIM3
		-	TIM4	TIM4	TIM4	TIM4	TIM4	TIM4
		-	TIM5	TIM5	-	-	-	TIM5
		-	-	-	-	-	-	TIM19
	32-bit	TIM2	-	-	-	TIM2	TIM2	TIM2
		-	-	-	-	TIM5		TIM5
Basic		TIM6	TIM6	TIM6	TIM6	TIM6	TIM6	TIM6
		-	TIM7	TIM7	TIM7	TIM7	TIM7	TIM7
		-	-	-	-	-	-	TIM18
1-channel		-	TIM10	-	TIM10	TIM10	-	-
		-	TIM11	-	TIM11	TIM11	-	-
		-	TIM13	TIM13		TIM13	-	TIM13
		TIM14	TIM14	TIM14		TIM14	-	TIM14
2-channel		-	TIM9		TIM9	TIM9	-	-
		-	TIM12	TIM12	-	TIM12	-	TIM12
1-channel with one complementary output		TIM15	-	TIM15	-	-	TIM15	TIM15
		-	-	-	-	-	-	-
2-channel with one complementary output		TIM16	-	TIM16	-	-	TIM16	TIM16
		TIM17	-	TIM17	-	-	TIM17	TIM17

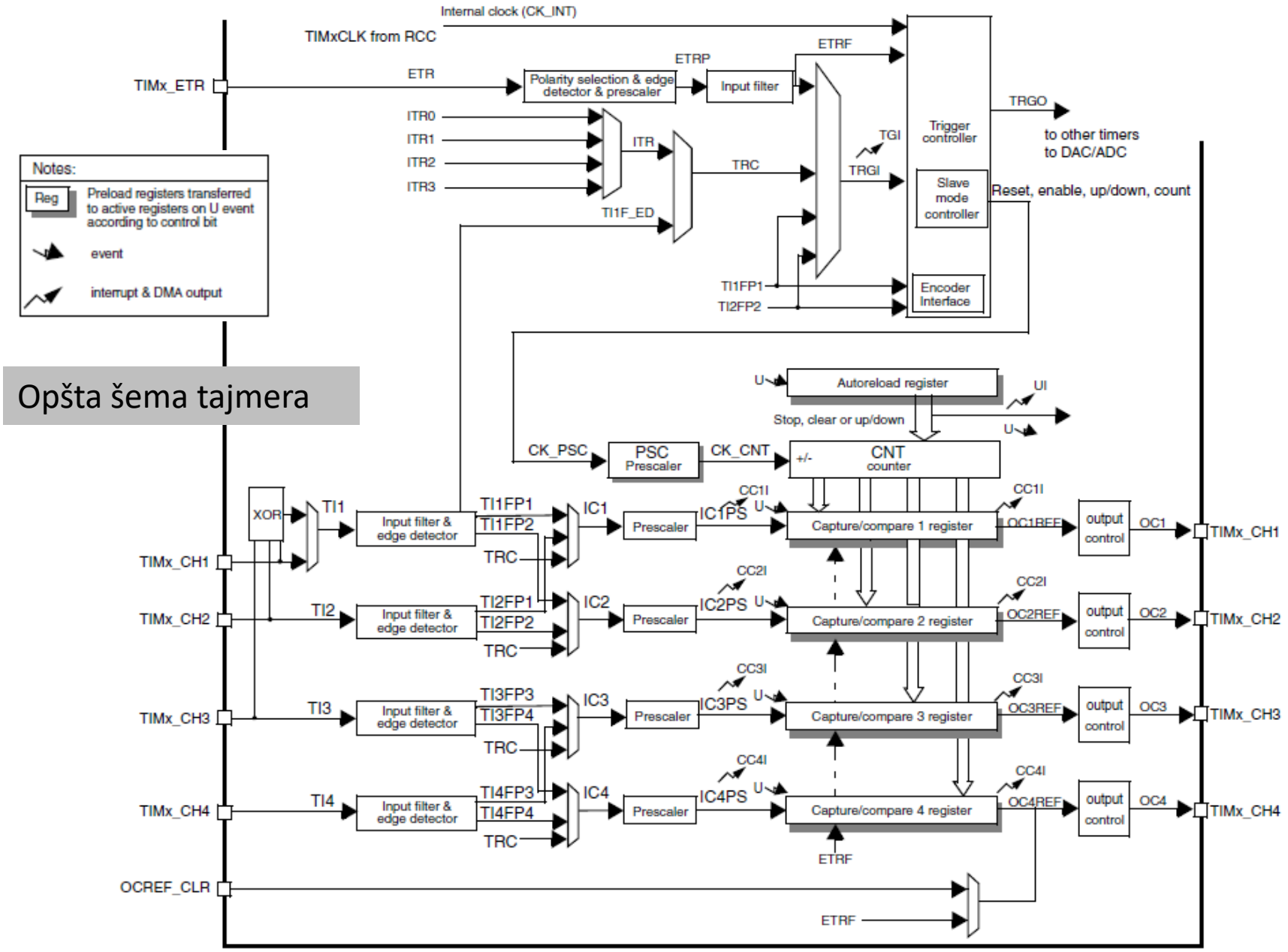
STM32L476 tajmeri

Timer type	Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/ compare channels	Complementary outputs
Advanced control	TIM1, TIM8	16-bit	Up, down, Up/down	Any integer between 1 and 65536	Yes	4	3
General-purpose	TIM2, TIM5	32-bit	Up, down, Up/down	Any integer between 1 and 65536	Yes	4	No
General-purpose	TIM3, TIM4	16-bit	Up, down, Up/down	Any integer between 1 and 65536	Yes	4	No
General-purpose	TIM15	16-bit	Up	Any integer between 1 and 65536	Yes	2	1
General-purpose	TIM16, TIM17	16-bit	Up	Any integer between 1 and 65536	Yes	1	1
Basic	TIM6, TIM7	16-bit	Up	Any integer between 1 and 65536	Yes	0	No

Tajmeri opšte namene TIMx (x=2,3,4,5)

- 16-bitni (TIM3 i TIM4) ili 32-bitni brojač (TIM2 i TIM5) na gore, dole ili gore/dole.
- 16-bitni preskaler za ulazni takt
- Do 4 nezavisna kanala koji mogu da rade u izlaznom (output comapre), ulaznom (input capture), PWM ili pojedinačnom impulsnom modu.
- Mogućnost sinhronizacije sa ostalim tajmerima.
- Prekid/DMA zahtev za sledeće događaje:
  - Input capture
  - Output compare
  - Reload tajmera, inicijalizacija (softverska ili spoljašnja)
- Podržavaju kvadraturne inkrementalne enkodere i hall-effect senzore.

Tajmer opšte namene

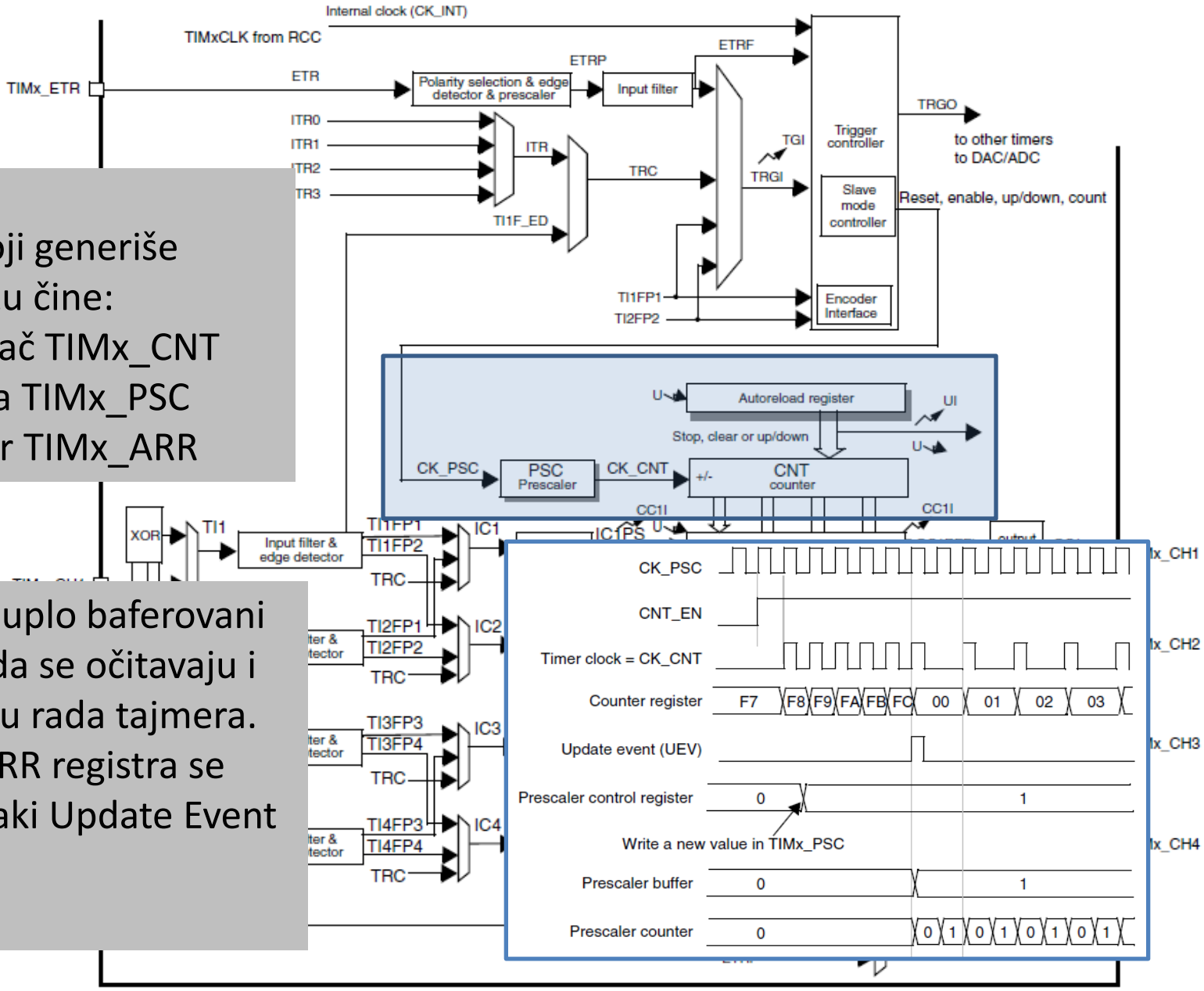


Opšta šema tajmera

Vremenska baza

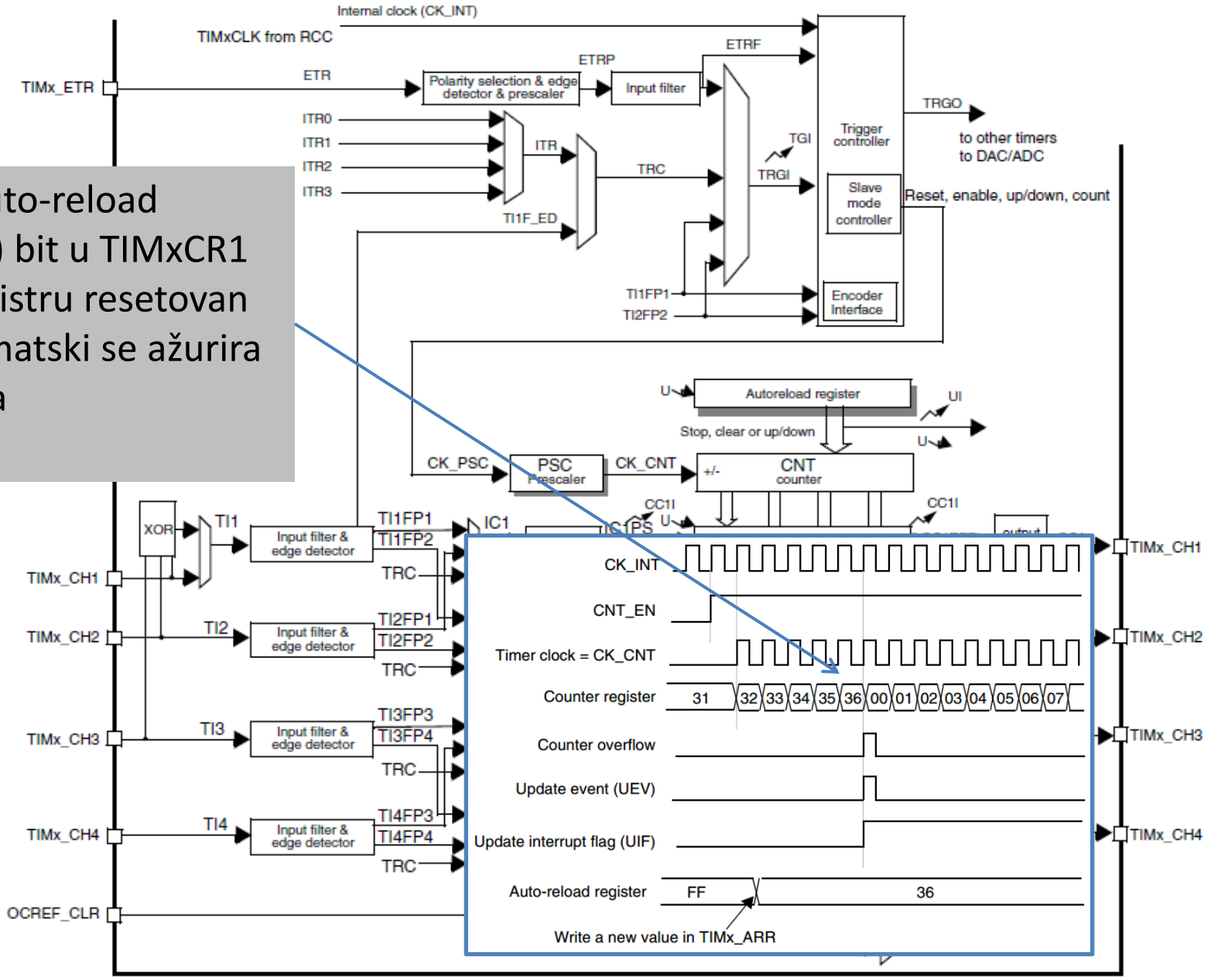
Vremenska baza
Deo tajmera koji generiše vremensku bazu čine:
-Tajmerski brojač TIMx_CNT
-Preskaler takta TIMx_PSC
-Reload registar TIMx_ARR

Svi registri su duplo baferovani tako da mogu da se očitavaju i menjaju i u toku rada tajmera. Izmene PSC i ARR registra se dešavaju na svaki Update Event UEV



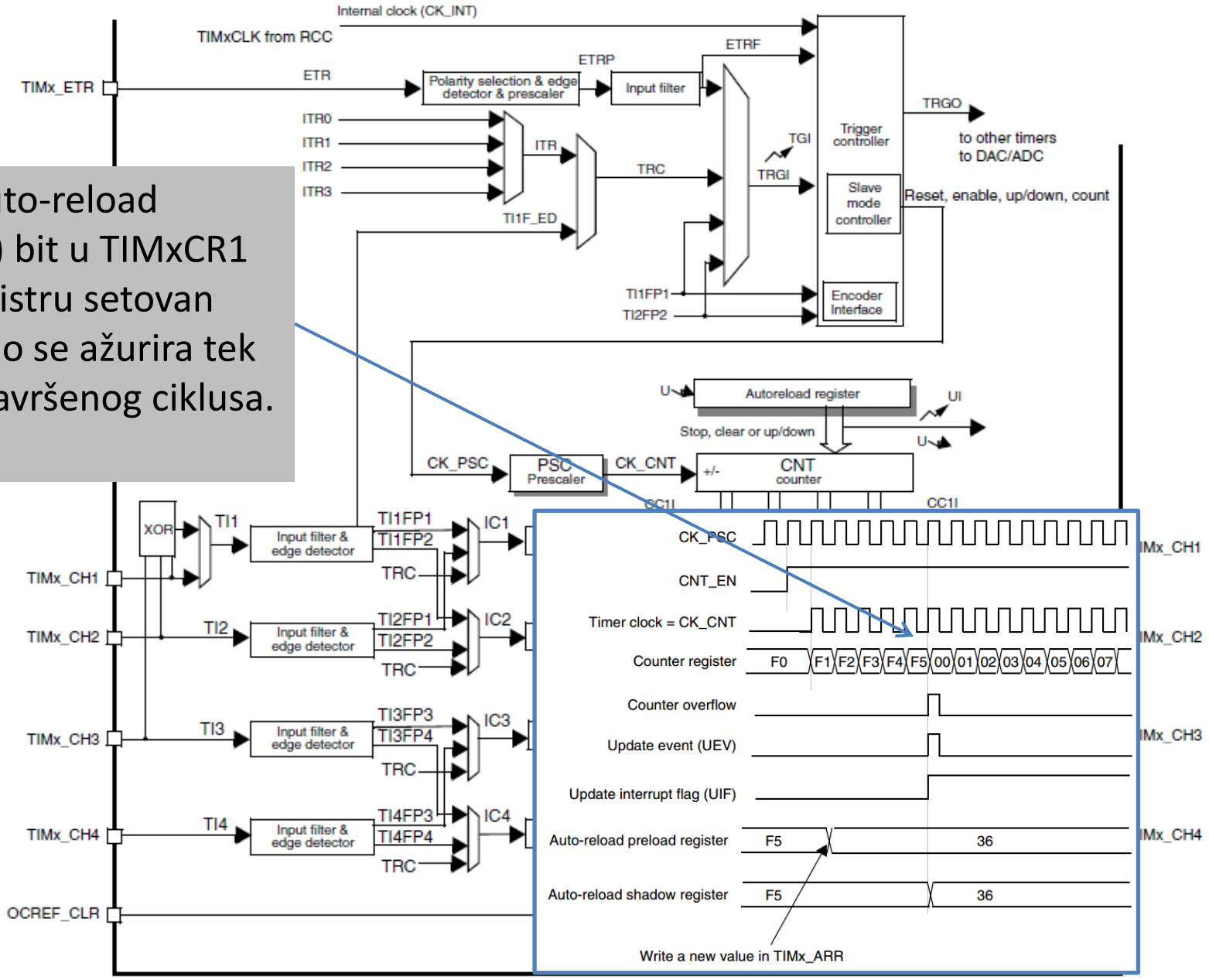
Brojač na gore – UP counting

Ako je ARPE (auto-reload preload enable) bit u TIMxCR1 kontrolnom registru resetovan (ARPE=0) automatski se ažurira moduo brojanja

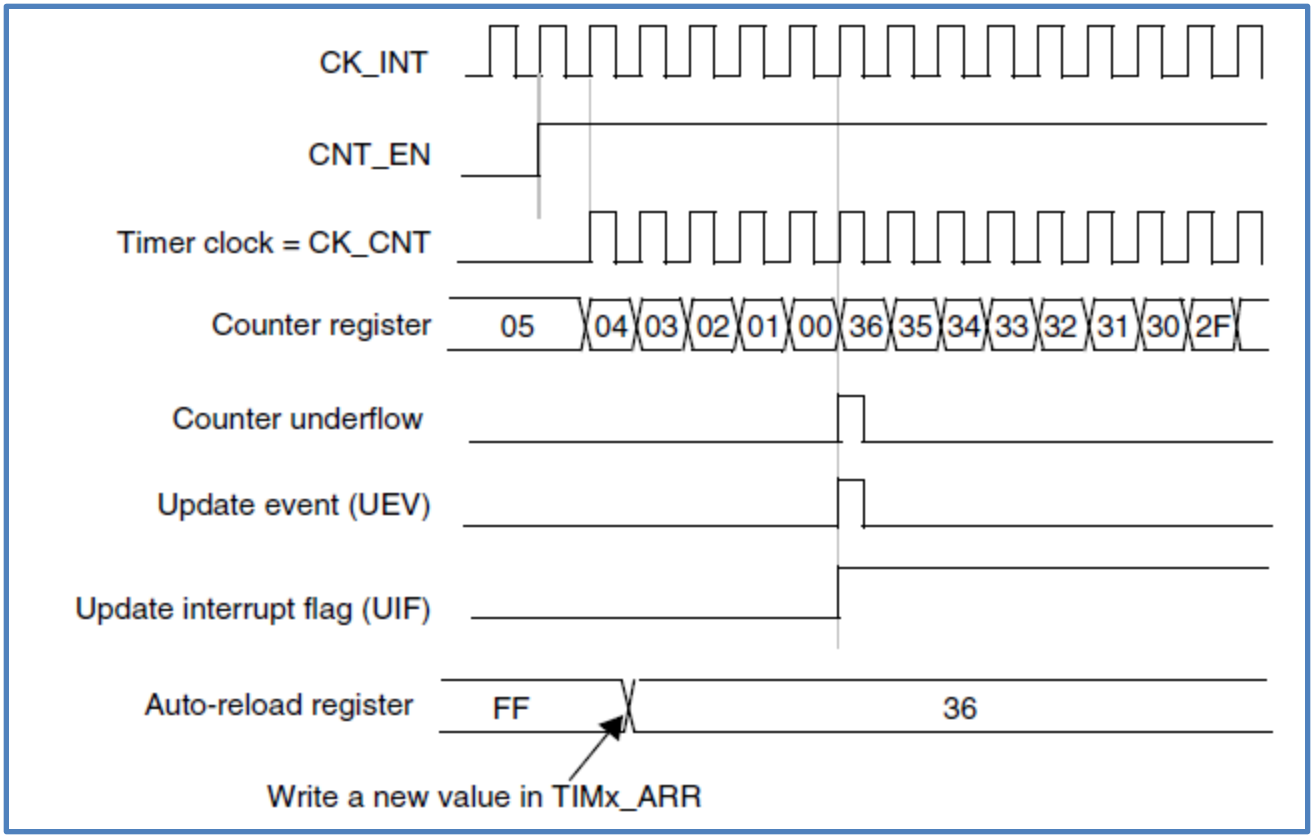


Brojač na gore – UP counting

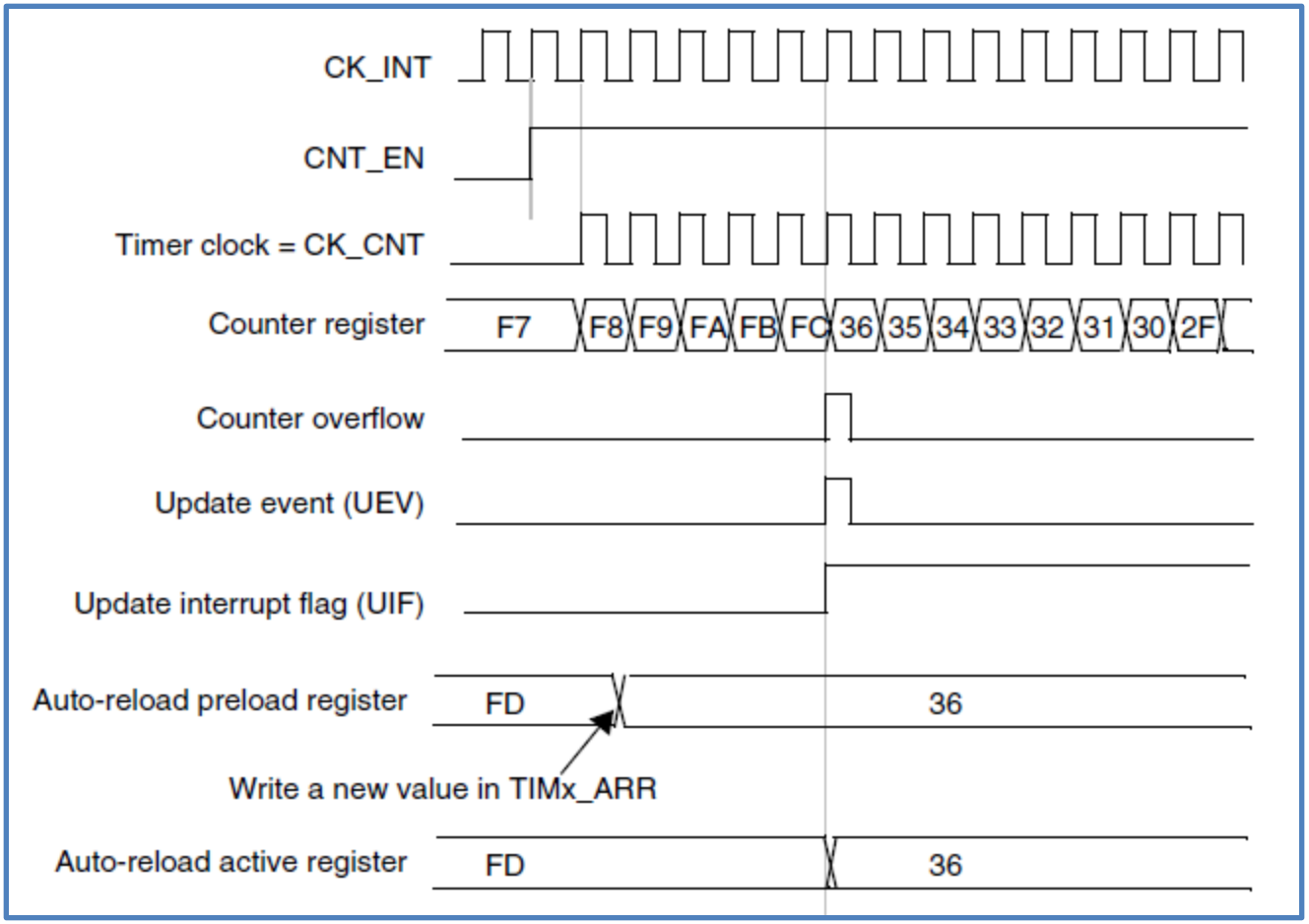
Ako je ARPE (auto-reload preload enable) bit u TIMxCR1 kontrolnom registru setovan (ARPE=1) moduo se ažurira tek nakon jednog završenog ciklusa.



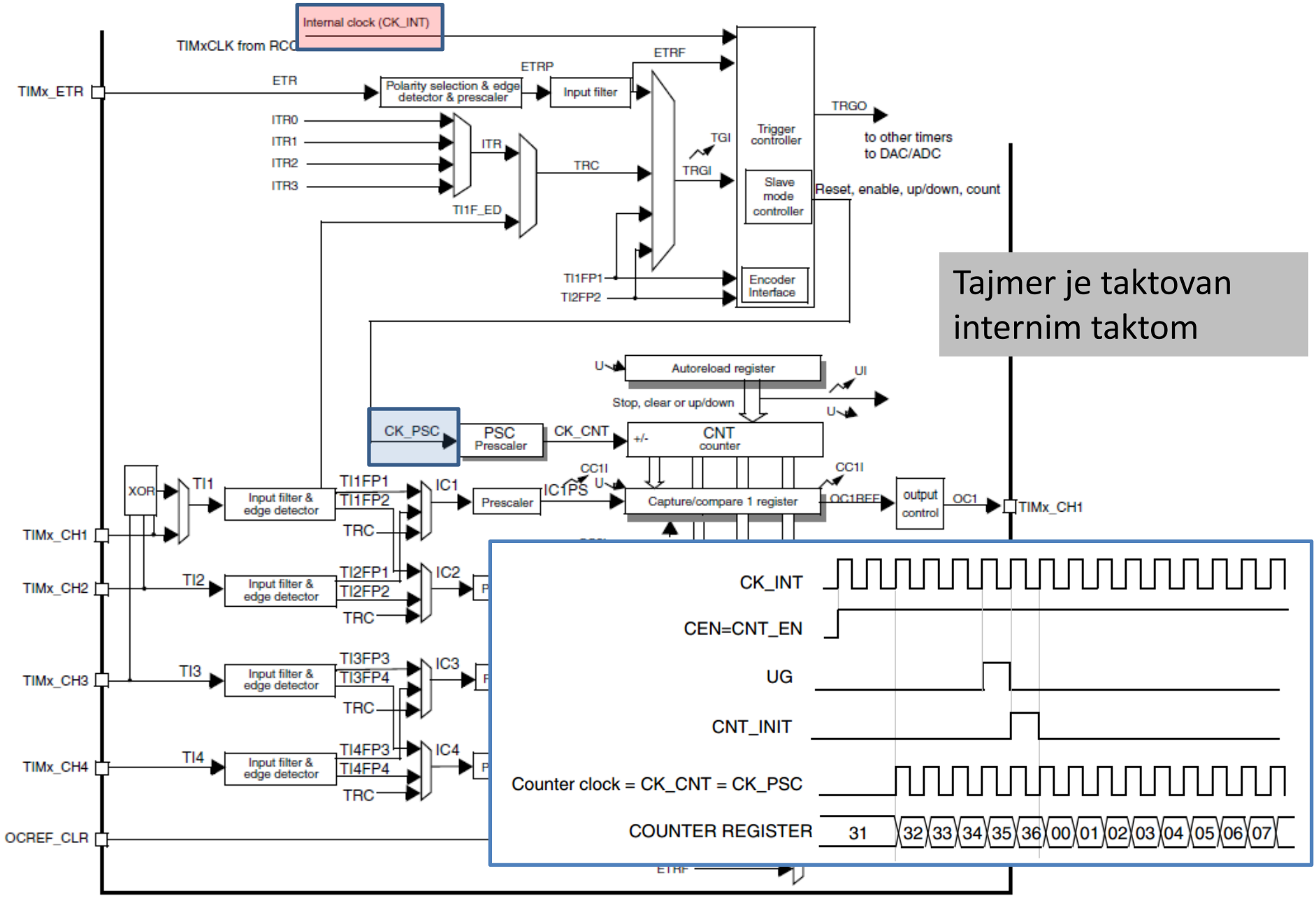
Downcounting mode



Brojač gore-dole
(Center-aligned / Up-down counting mode)

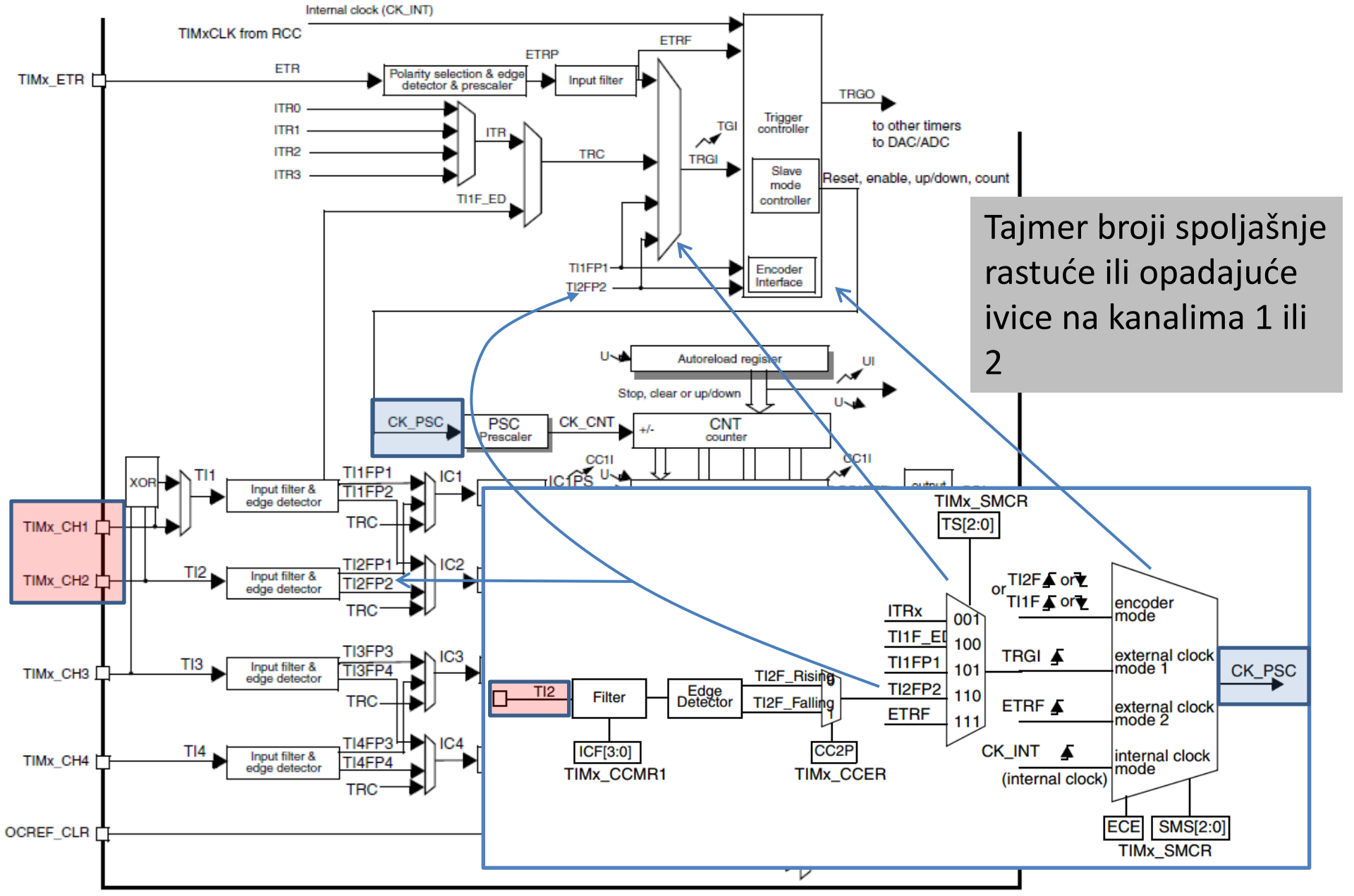


Taktovanje - Internal mode



Tajmer je taktovan internim taktom

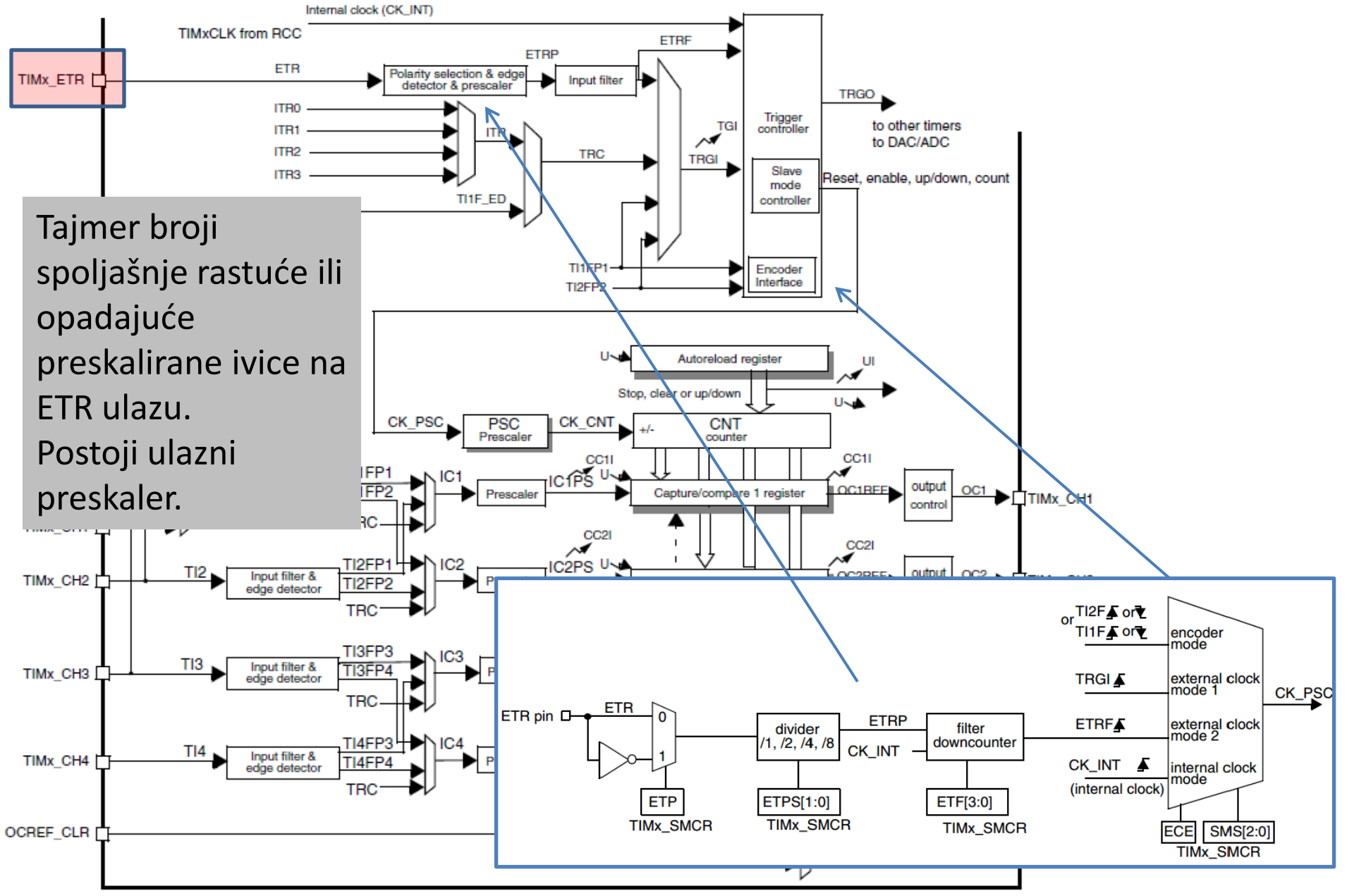
External mode 1



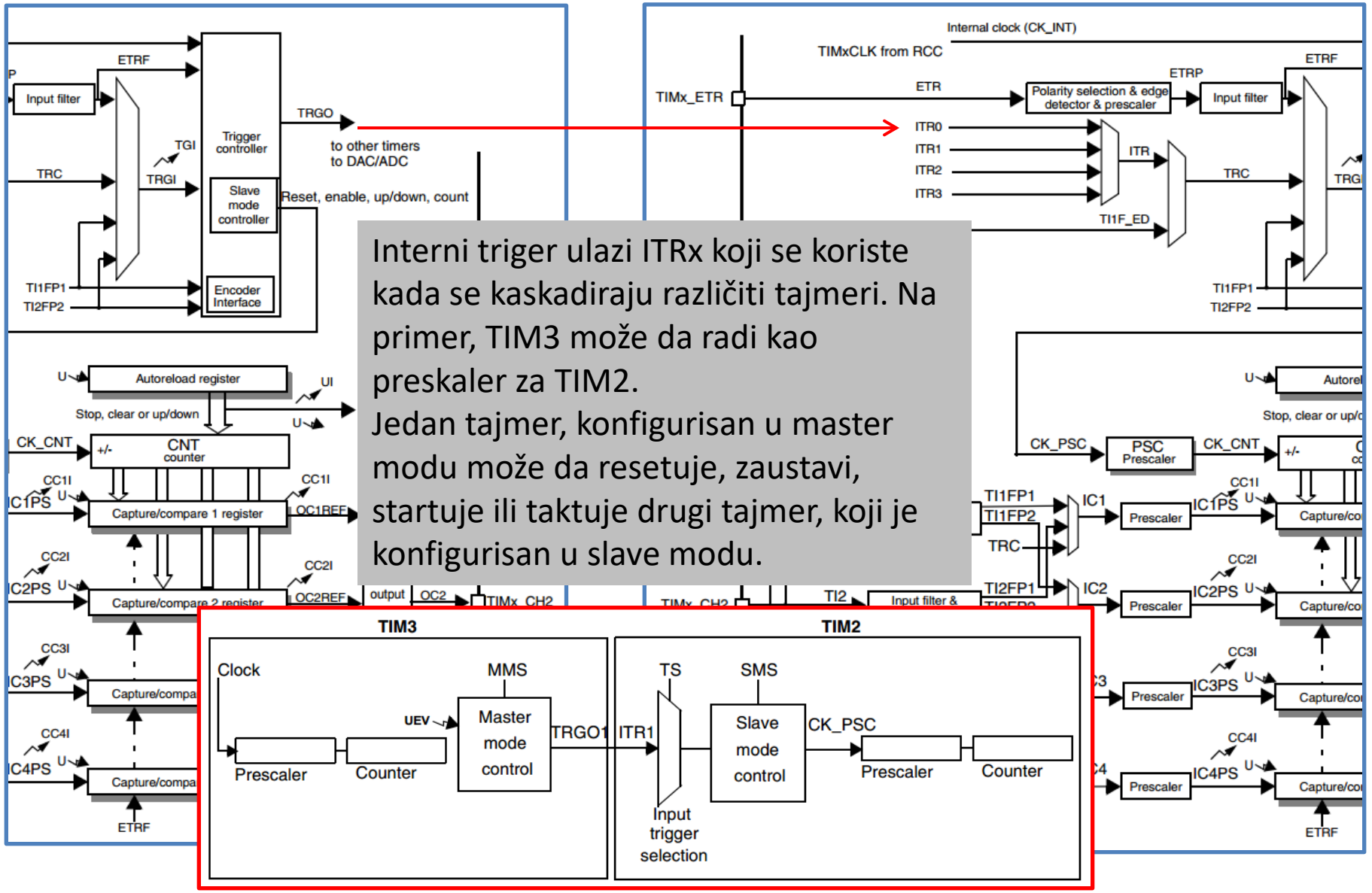
Tajmer broji spoljašnje rastuće ili opadajuće ivice na kanalima 1 ili 2

External mode 2

Tajmer broji spoljašnje rastuće ili opadajuće preskalirane ivice na ETR ulazu.
Postoji ulazni preskaler.



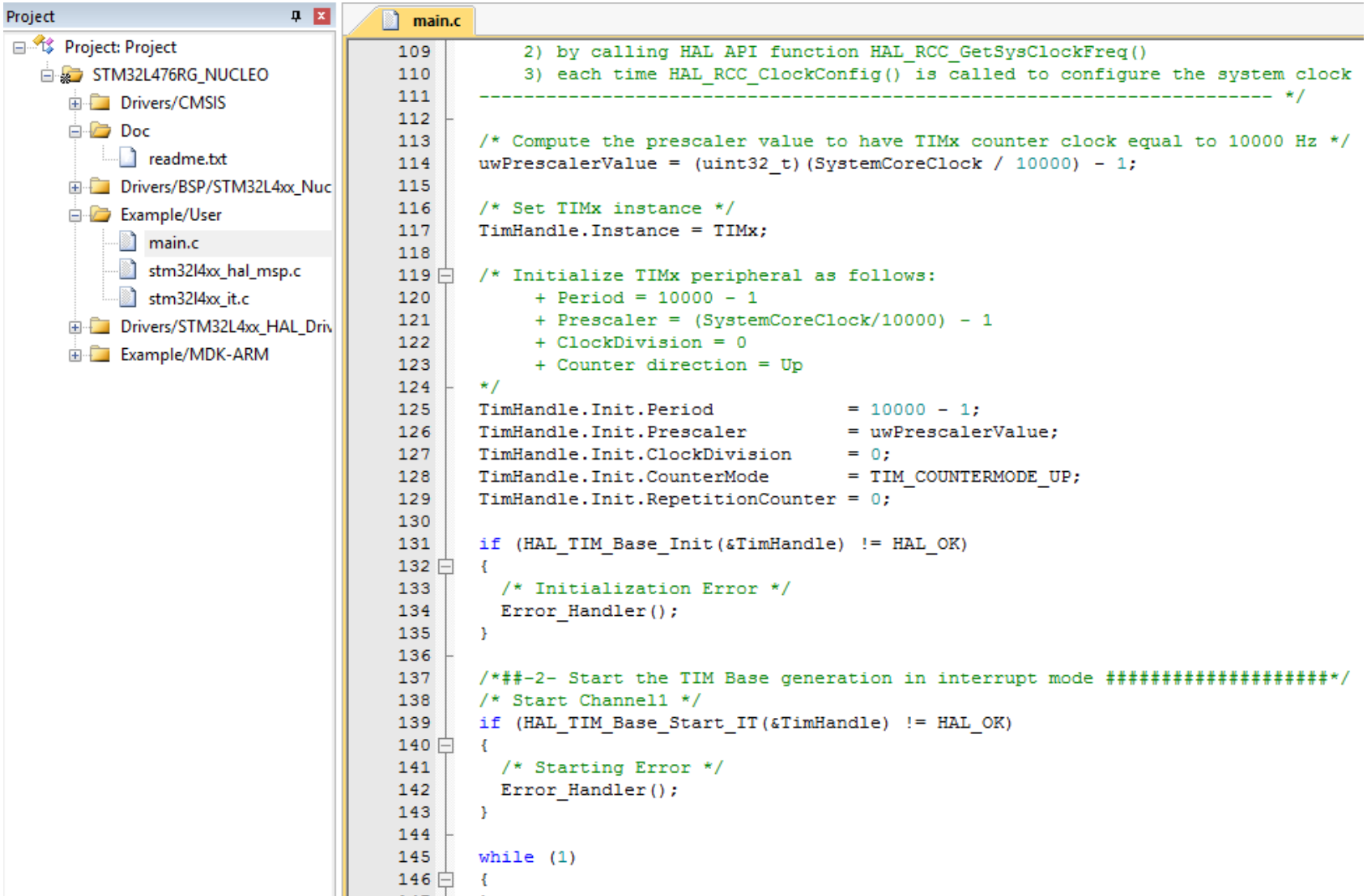
Kaskadna veza tajmera



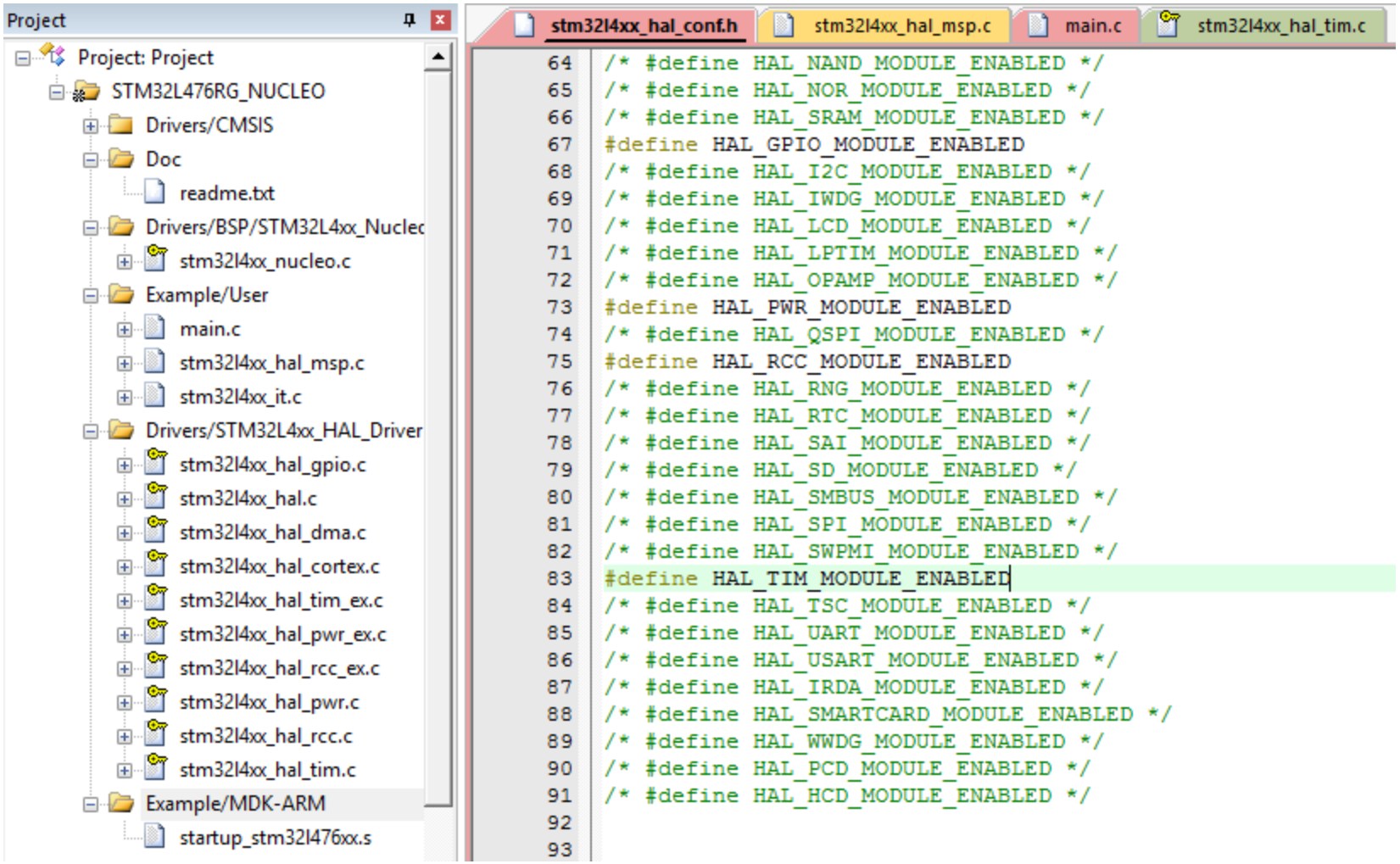
Interni triger ulazi ITRx koji se koriste kada se kaskadiraju različiti tajmeri. Na primer, TIM3 može da radi kao preskaler za TIM2.
Jedan tajmer, konfigurisan u master modu može da resetuje, zaustavi, startuje ili taktuje drugi tajmer, koji je konfigurisan u slave modu.

STM CUBE

Projekat TIM_TimeBase



Ako koristimo periferije potrebno je to da označimo u .conf fajlu



Šta to piše u drajverskim fajlovima?

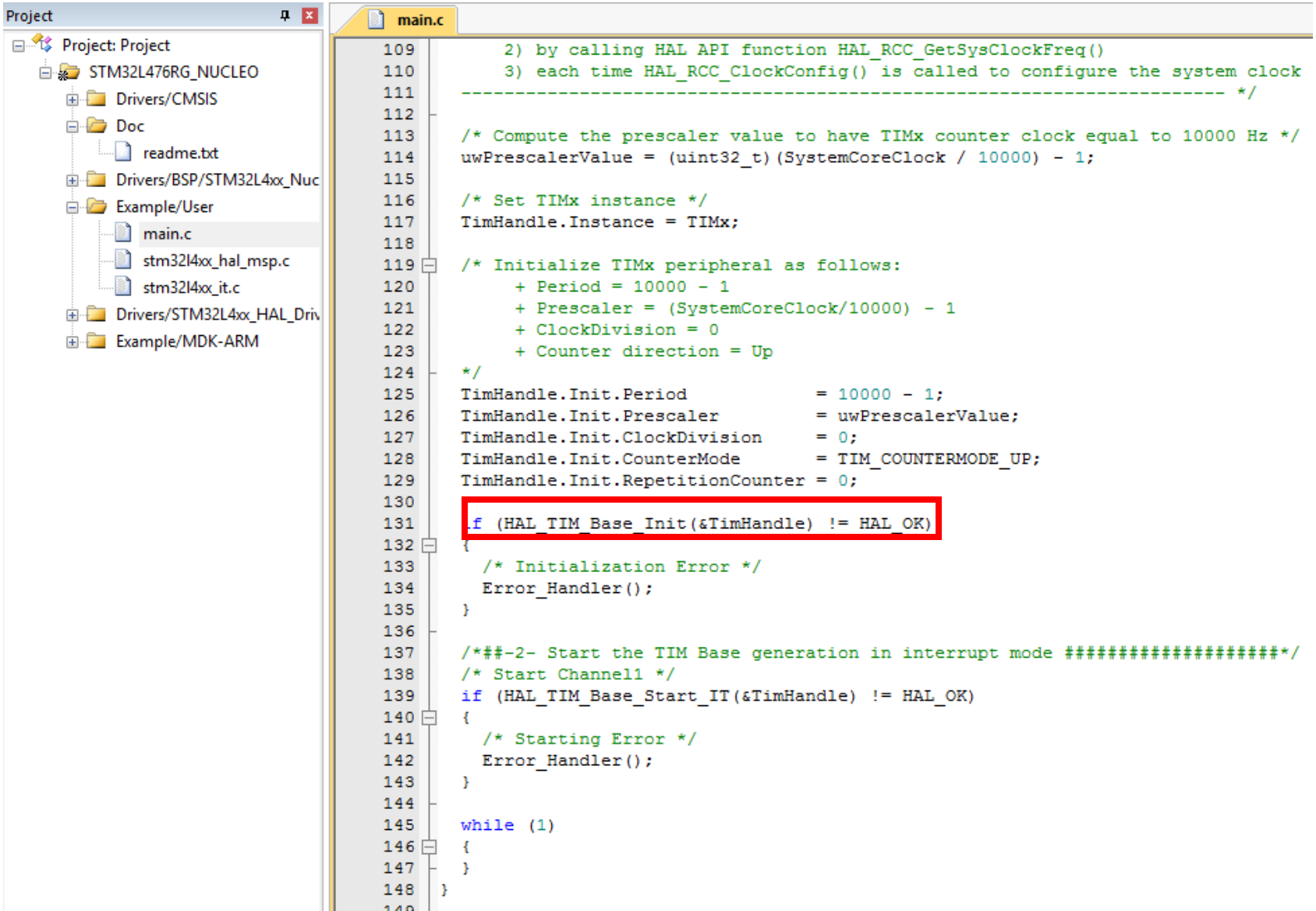
stm32l4xx_hal_tim.c

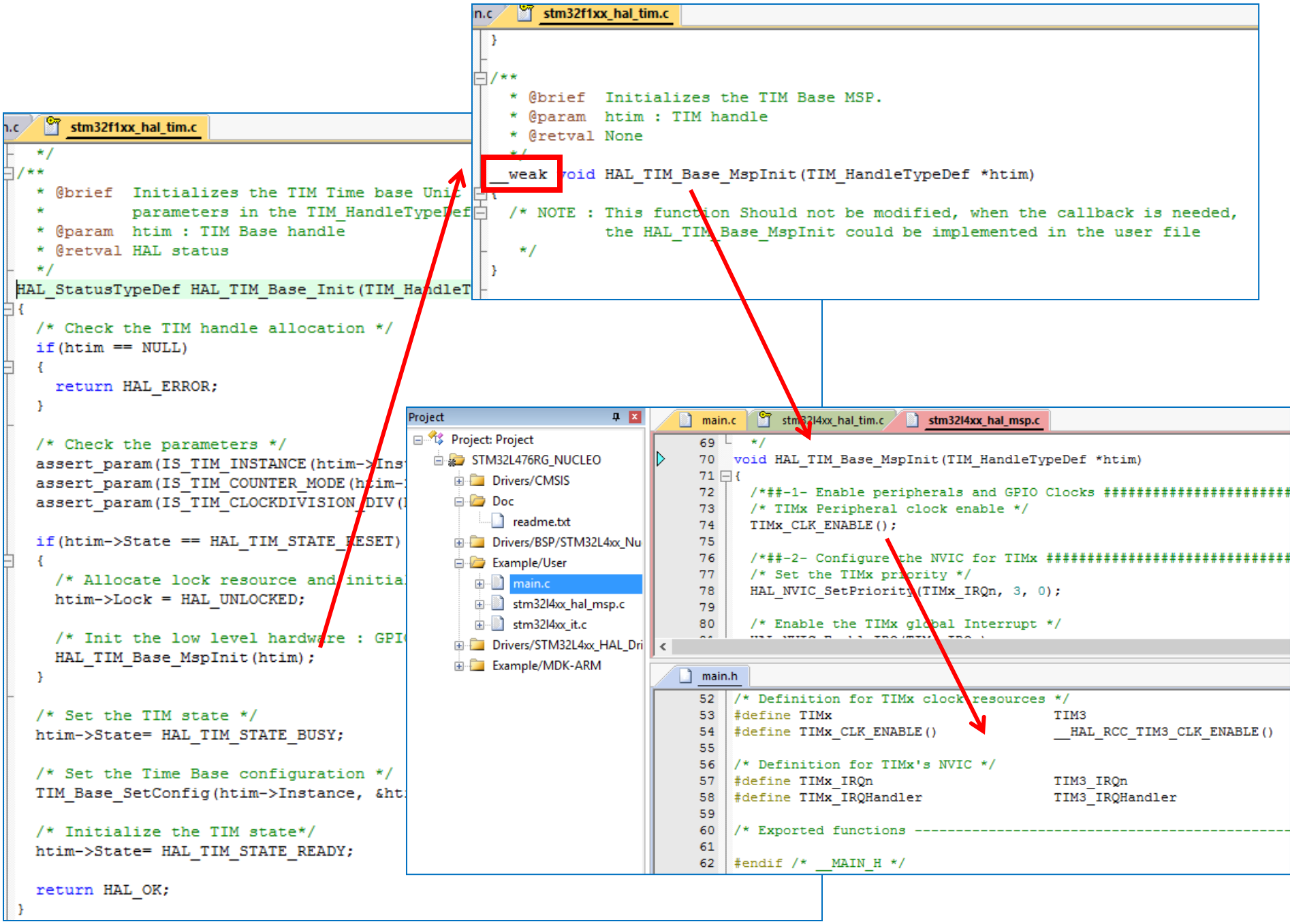
```
/**
  ******************************************************************************
  * @file    stm32l4xx_hal_tim.c
  * @author  MCD Application Team
  * @version V1.4.0
  * @date    26-February-2016
  * @brief   TIM HAL module driver.
  *          This file provides firmware functions to manage the following
  *          functionalities of the Timer (TIM) peripheral:
  *           + Time Base Initialization
  *           + Time Base Start
  *           + Time Base Start Interruption
  *           + Time Base Start DMA
  *           + Time Output Compare/PWM Initialization
  *           + Time Output Compare/PWM Channel Configuration
  *           + Time Output Compare/PWM  Start
  *           + Time Output Compare/PWM  Start Interruption
  *           + Time Output Compare/PWM Start DMA
  *           + Time Input Capture Initialization
  *           + Time Input Capture Channel Configuration
  *           + Time Input Capture Start
  *           + Time Input Capture Start Interruption
  *           + Time Input Capture Start DMA
  *           + Time One Pulse Initialization
  *           + Time One Pulse Channel Configuration
  *           + Time One Pulse Start
  *           + Time Encoder Interface Initialization
  *           + Time Encoder Interface Start
  *           + Time Encoder Interface Start Interruption
  *           + Time Encoder Interface Start DMA
```

```
31    *           + Commutation Event configuration with Interruption and DMA
32    *           + Time OCRef clear configuration
33    *           + Time External Clock configuration
34    @verbatim
35    ==============================================================================
36                        ##### TIMER Generic features #####
37    ==============================================================================
38    [..] The Timer features include:
39         (#) 16-bit up, down, up/down auto-reload counter.
40         (#) 16-bit programmable prescaler allowing dividing (also on the fly) the
41             counter clock frequency either by any factor between 1 and 65536.
42         (#) Up to 4 independent channels for:
43             (++) Input Capture
44             (++) Output Compare
45             (++) PWM generation (Edge and Center-aligned Mode)
46             (++) One-pulse mode output
47
48             ##### How to use this driver #####
49    ==============================================================================
50      [..]
51       (#) Initialize the TIM low level resources by implementing the following functions
52           depending on the selected feature:
53             (++) Time Base : HAL_TIM_Base_MspInit()
54             (++) Input Capture : HAL_TIM_IC_MspInit()
55             (++) Output Compare : HAL_TIM_OC_MspInit()
56             (++) PWM generation : HAL_TIM_PWM_MspInit()
57             (++) One-pulse mode output : HAL_TIM_OnePulse_MspInit()
58             (++) Encoder mode output : HAL_TIM_Encoder_MspInit()
```

```
59
60      (#) Initialize the TIM low level resources :
61         (##) Enable the TIM interface clock using __HAL_RCC_TIMx_CLK_ENABLE();
62         (##) TIM pins configuration
63             (+++) Enable the clock for the TIM GPIOs using the following function:
64              __HAL_RCC_GPIOx_CLK_ENABLE();
65             (+++) Configure these TIM pins in Alternate function mode using HAL_GPIO_Init();
66
67      (#) The external Clock can be configured, if needed (the default clock is the
68          internal clock from the APBx), using the following function:
69          HAL_TIM_ConfigClockSource, the clock configuration should be done before
70          any start function.
71
72      (#) Configure the TIM in the desired functioning mode using one of the
73        Initialization function of this driver:
74         (++) HAL_TIM_Base_Init: to use the Timer to generate a simple time base
75         (++) HAL_TIM_OC_Init and HAL_TIM_OC_ConfigChannel: to use the Timer to generate an
76              Output Compare signal.
77         (++) HAL_TIM_PWM_Init and HAL_TIM_PWM_ConfigChannel: to use the Timer to generate a
78              PWM signal.
79         (++) HAL_TIM_IC_Init and HAL_TIM_IC_ConfigChannel: to use the Timer to measure an
80              external signal.
81           (++) HAL_TIM_OnePulse_Init and HAL_TIM_OnePulse_ConfigChannel: to use the Timer
82                in One Pulse Mode.
83         (++) HAL_TIM_Encoder_Init: to use the Timer Encoder Interface.
84
85      (#) Activate the TIM peripheral using one of the start functions depending from the feature used:
86            (++) Time Base : HAL_TIM_Base_Start(), HAL_TIM_Base_Start_DMA(), HAL_TIM_Base_Start_IT()
87            (++) Input Capture :  HAL_TIM_IC_Start(), HAL_TIM_IC_Start_DMA(), HAL_TIM_IC_Start_IT()
88            (++) Output Compare : HAL_TIM_OC_Start(), HAL_TIM_OC_Start_DMA(), HAL_TIM_OC_Start_IT()
89            (++) PWM generation : HAL_TIM_PWM_Start(), HAL_TIM_PWM_Start_DMA(), HAL_TIM_PWM_Start_IT()
90            (++) One-pulse mode output : HAL_TIM_OnePulse_Start(), HAL_TIM_OnePulse_Start_IT()
91            (++) Encoder mode output : HAL_TIM_Encoder_Start(), HAL_TIM_Encoder_Start_DMA(), HAL_TIM_Encoder_St
92
93      (#) The DMA Burst is managed with the two following functions:
94          HAL_TIM_DMABurst_WriteStart()
95          HAL_TIM_DMABurst_ReadStart()
```

Inicijalizacija vremenske baze tajmera



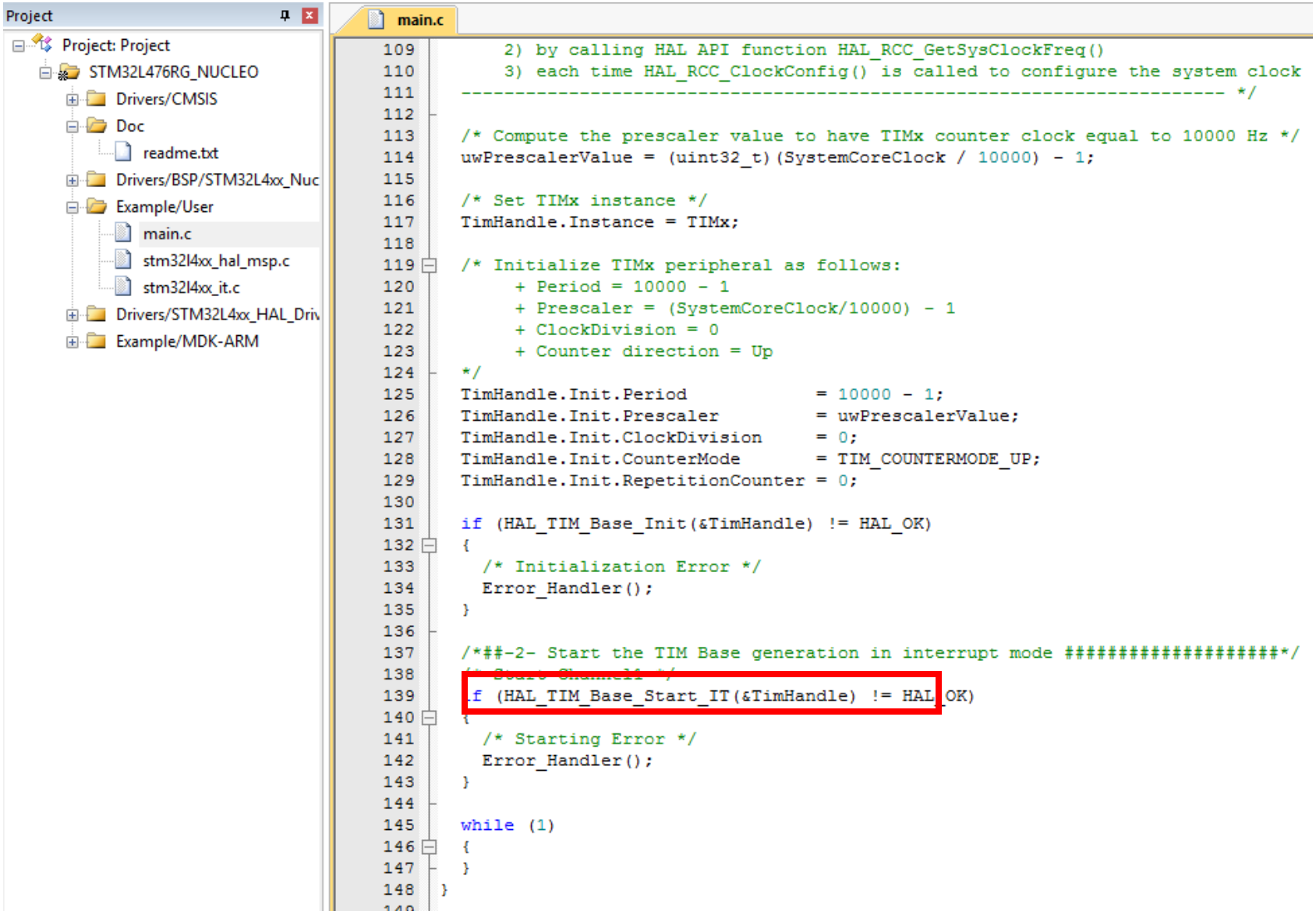

stm32f1xx_hal_tim.c
stm32f1xx_hal_tim.c
__weak void HAL_TIM_Base_MspInit(TIM_HandleTypeDef *htim)
HAL_StatusTypeDef HAL_TIM_Base_Init(TIM_HandleT
HAL_TIM_Base_MspInit(htim);
Project
Project: Project
STM32L476RG_NUCLEO
Drivers/CMSIS
Doc
readme.txt
Drivers/BSP/STM32L4xx_Nu
Example/User
main.c
stm32l4xx_hal_msp.c
stm32l4xx_it.c
Drivers/STM32L4xx_HAL_Dri
Example/MDK-ARM
main.c
stm32l4xx_hal_tim.c
stm32l4xx_hal_msp.c
void HAL_TIM_Base_MspInit(TIM_HandleTypeDef *htim)
TIMx_CLK_ENABLE();
HAL_NVIC_SetPriority(TIMx_IRQn, 3, 0);
main.h
/* Definition for TIMx clock resources */
#define TIMx TIM3
#define TIMx_CLK_ENABLE() __HAL_RCC_TIM3_CLK_ENABLE()
/* Definition for TIMx's NVIC */
#define TIMx_IRQn TIM3_IRQn
#define TIMx_IRQHandler TIM3_IRQHandler
/* Exported functions
#endif /* __MAIN_H */

MspInit()

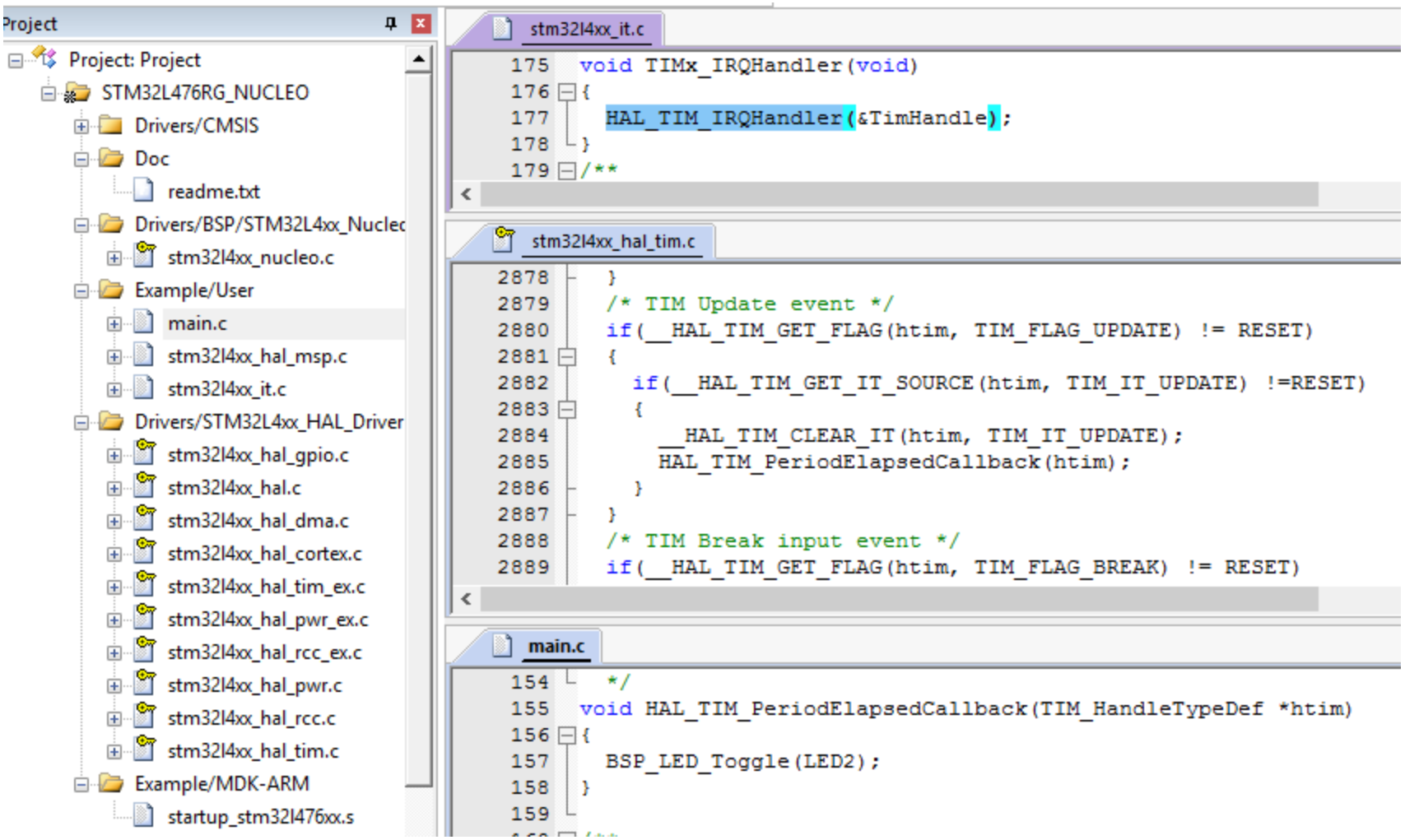
- Dovodimo takt tajmeru (ovakav ili onakav)
- Konfigurišemo prekide
- Dozvoljavamo prekide

```
70  void HAL_TIM_Base_MspInit(TIM_HandleTypeDef *htim)
71  {
72    /*##-1- Enable peripherals and GPIO Clocks #################################*/
73    /* TIMx Peripheral clock enable */
74    TIMx_CLK_ENABLE();
75
76    /*##-2- Configure the NVIC for TIMx #########################################*/
77    /* Set the TIMx priority */
78    HAL_NVIC_SetPriority(TIMx_IRQn, 3, 0);
79
80    /* Enable the TIMx global Interrupt */
81    HAL_NVIC_EnableIRQ(TIMx_IRQn);
82  }
```

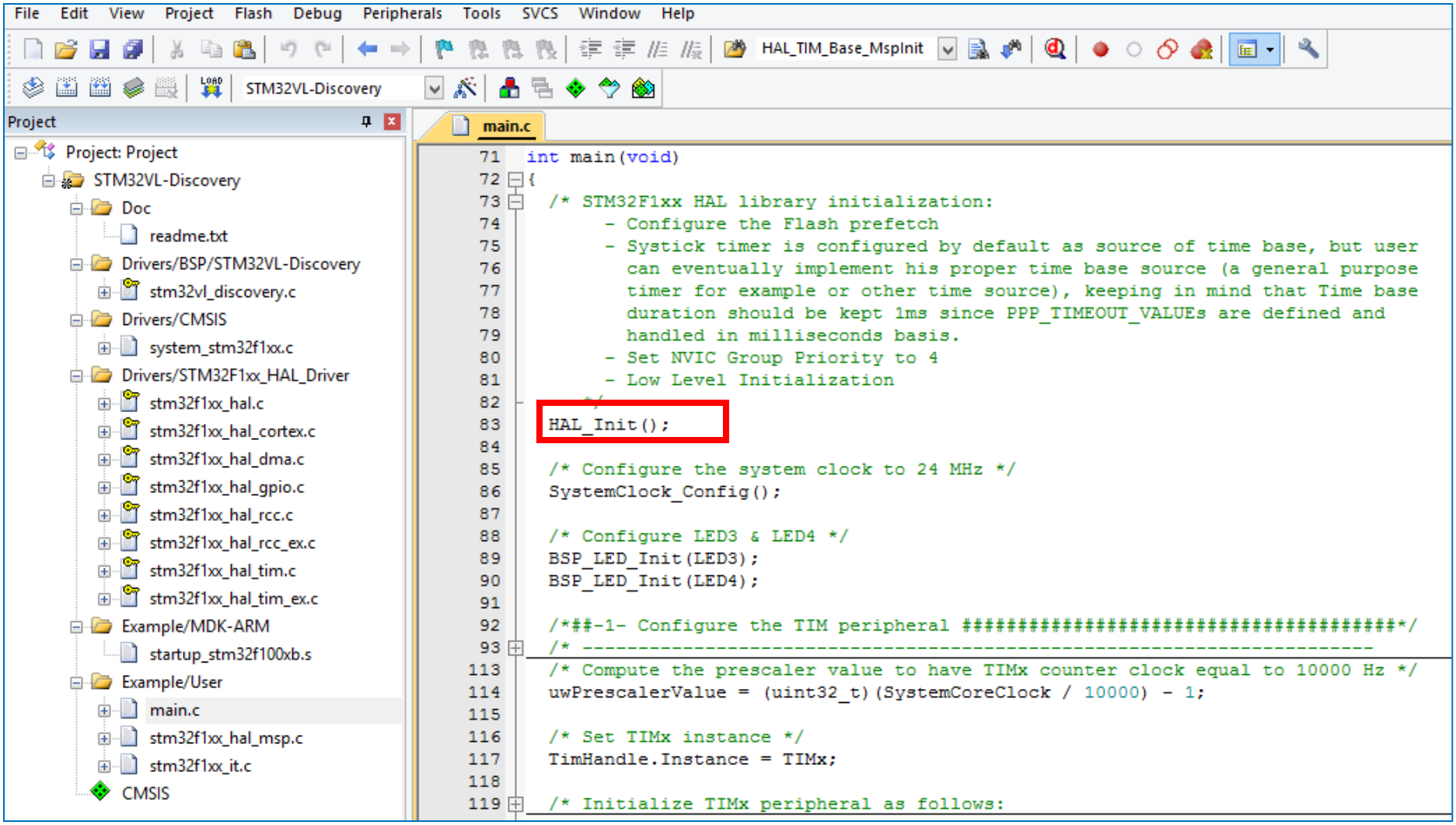
Startujmo tajmer



Imamo i prekid....



Generalna Inicijalizacija hardvera



Generalna Inicijalizacija hardvera

in.c | stm32f1xx_hal.c

```
/**
  * @brief This function configures the Flash prefetch,
  *        Configures time base source, NVIC and Low level hardware
  * @note This function is called at the beginning of program after reset and before
  *       the clock configuration
  * @note The time base configuration is based on MSI clock when exiting from Reset.
  *       Once done, time base tick start incrementing.
  *        In the default implementation,Systick is used as source of time base.
  *       The tick variable is incremented each 1ms in its ISR.
  * @retval HAL status
  */
HAL_StatusTypeDef HAL_Init(void)
{
  /* Configure Flash prefetch */
#if (PREFETCH_ENABLE != 0)
#if defined(STM32F101x6) || defined(STM32F101xB) || defined(STM32F101xE) || defined(STM32F101xG) || \
    defined(STM32F102x6) || defined(STM32F102xB) || \
    defined(STM32F103x6) || defined(STM32F103xB) || defined(STM32F103xE) || defined(STM32F103xG) || \
    defined(STM32F105xC) || defined(STM32F107xC)

  /* Prefetch buffer is not available on value line devices */
  __HAL_FLASH_PREFETCH_BUFFER_ENABLE();
#endif
#endif /* PREFETCH_ENABLE */

  /* Set Interrupt Group Priority */
  HAL_NVIC_SetPriorityGrouping(NVIC_PRIORITYGROUP_

  /* Use systick as time base source and configure
  HAL_InitTick(TICK_INT_PRIORITY);

  /* Init the low level hardware */
  HAL_MspInit();

  /* Return function status */
  return HAL_OK;
}
```

in.c | stm32f1xx_hal.c

```
/**
  * @brief  Initializes the MSP.
  * @retval None
  */
__weak void HAL_MspInit(void)
{
  /* NOTE : This function Should not be modified, when the callback is needed,
            the HAL_MspInit could be implemented in the user file
   */
}
```

Principi HAL drajvera kada su u pitanju kompleksne periferije:

1. Periferiju je najpre potrebno inicijalizovati
2. Inicijalizacija periferije se obavlja u drajveru ali se kao sporedni efekat poziva funkcija HAL_PPP_MspInit() koja inicijalizuje low-level hardverske resurse.
3. Ponekad je potrebno inicijalizovati i neke posebne delove periferije posebni fumkcijama ali to zavisi od aplikacije.
4. Perifereije tipično kreću sa željenim radom tek pošto se pokrenu funkcijom HAL_PPP_start()
5. Ukoliko periferija generiše prekide korisnik sam piše svoju prekidnu funkciju i u njoj poziva HAL_PPP_IRQHandler() funkciju u kojoj se “servisira” prekid.
6. Ta funkcija dalje poziva HAL_PPP_Callback() funkciju koja ustvari “reaguje” na prekid
7. Korisnik sam implementira tu Callback funkciju.

Zadatak

- Najpre pitanje: Koji tajmer je aktivan?
- Zadatak 1: promeniti podešavanja tako da sve ovo radi tajmer 4.
- Zadatak 2: Proširiti projekat tako da rade oba tajmera istovremeno, ali sa neki različitim podešavanjima.
- Problem: MspInit() funkciju će pozvati drajver prilikom inicijalizacije svakog tajmera. Kako da znam za potrebe čije inicijalizacije se poziva MspInit()?

Zato se uvek prosleđuju i pokazivači na objekte koji se inicijalizuju....

- Hint:
  https://my.st.com/public/STe2ecommunities/mcu/Lists/STM32Java/Attachments/1249/tim.c