PRIMENA MIKROKONTROLERA-MS1PMK

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MBED

Sistemski časovnik

http://mbed.org/handbook/Ticker

- Klasa Ticker daje jednostavan način realizacije periodičnog poziva korisničke funkcije, što praktično predstavlja sistemski časovnik.

Ticker Class Reference

`#include <Ticker.h>`

Inherits mbed::TimerEvent.

Inherited by Timeout.

Public Member Functions

void attach (void(*fptr)(void), float t)
Attach a function to be called by the **Ticker**, specifiying the interval in seconds.

template<typename T >
void attach (T *tptr, void(T::*mptr)(void), float t)
Attach a member function to be called by the **Ticker**, specifiying the interval in seconds.

void attach_us (void(*fptr)(void), unsigned int t)
Attach a function to be called by the **Ticker**, specifiying the interval in micro-seconds.

template<typename T >
void attach_us (T *tptr, void(T::*mptr)(void), unsigned int t)
Attach a member function to be called by the **Ticker**, specifiying the interval in micro-seconds.

void detach ()
Detach the function.

Static Public Member Functions

static void irq (uint32_t id)
The handler registered with the underlying timer interrupt.

Ticker - primer programa

```
#include "mbed.h"
Ticker flipper;
DigitalOut flash(LED2);
void flip() {
     flash = !flash;
}
int main() {
       flash = 1;
       flipper.attach(&flip, 0.5);              // the address of the function to be attached
           (flip)
                                        //and the interval (0.5 seconds)
                                        // spin in a main loop. flipper will interrupt it to call flip
       while(1) ;
}
```

Povezivanje sa funkcijom članicom neke klase

```
#include "mbed.h"

// A class for flip()-ing a DigitalOut
class Flipper {
public:
    Flipper(PinName pin) : _pin(pin) {
        _pin = 0;
    }
    void flip() {
        _pin = !_pin;
    }
private:
    DigitalOut _pin;
};

Flipper f(LED2);
Ticker t;

int main() {
    t.attach(&f, &Flipper::flip, 0.5); // the address of the object, member function,
    and interval
                                // spin in a main loop. flipper will interrupt it to call
    flip
    while(1) ;
}
```

Klasa Timeout

http://mbed.org/handbook/Timeout

- Klasa Timeout se koristi kada je potrebno generisati akciju nakon isteka određenog vremena.
- Praktično ima isti interfejs kao klasa Ticker, ali se izvršava samo jedan interval.

Timeout Class Reference

`#include <Timeout.h>`

Inherits mbed::Ticker.

Public Member Functions

void attach (void(*fptr)(void), float t)
Attach a function to be called by the Ticker, specifiying the interval in seconds.

template<typename T >
void attach (T *tptr, void(T::*mptr)(void), float t)
Attach a member function to be called by the Ticker, specifiying the interval in seconds.

void attach_us (void(*fptr)(void), unsigned int t)
Attach a function to be called by the Ticker, specifiying the interval in micro-seconds.

template<typename T >
void attach_us (T *tptr, void(T::*mptr)(void), unsigned int t)
Attach a member function to be called by the Ticker, specifiying the interval in micro-seconds.

void detach ()
Detach the function.

Static Public Member Functions

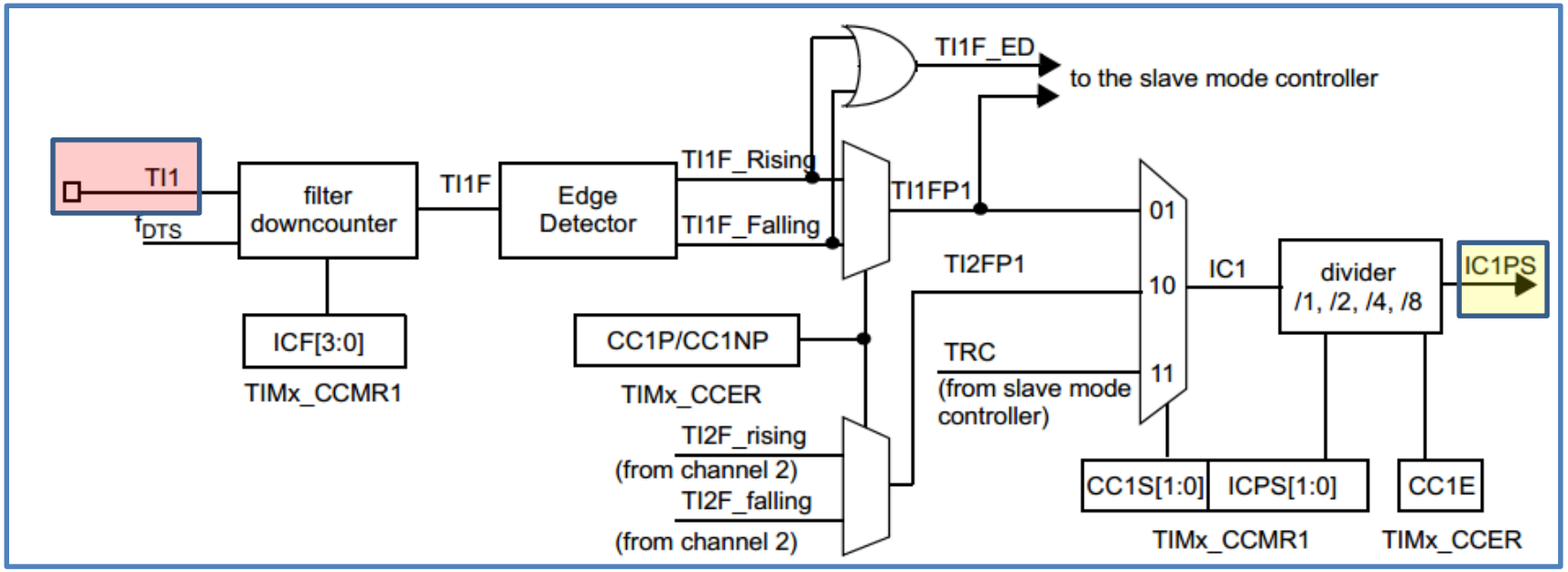
static void irq (uint32_t id)
The handler registered with the underlying timer interrupt.

Timeout

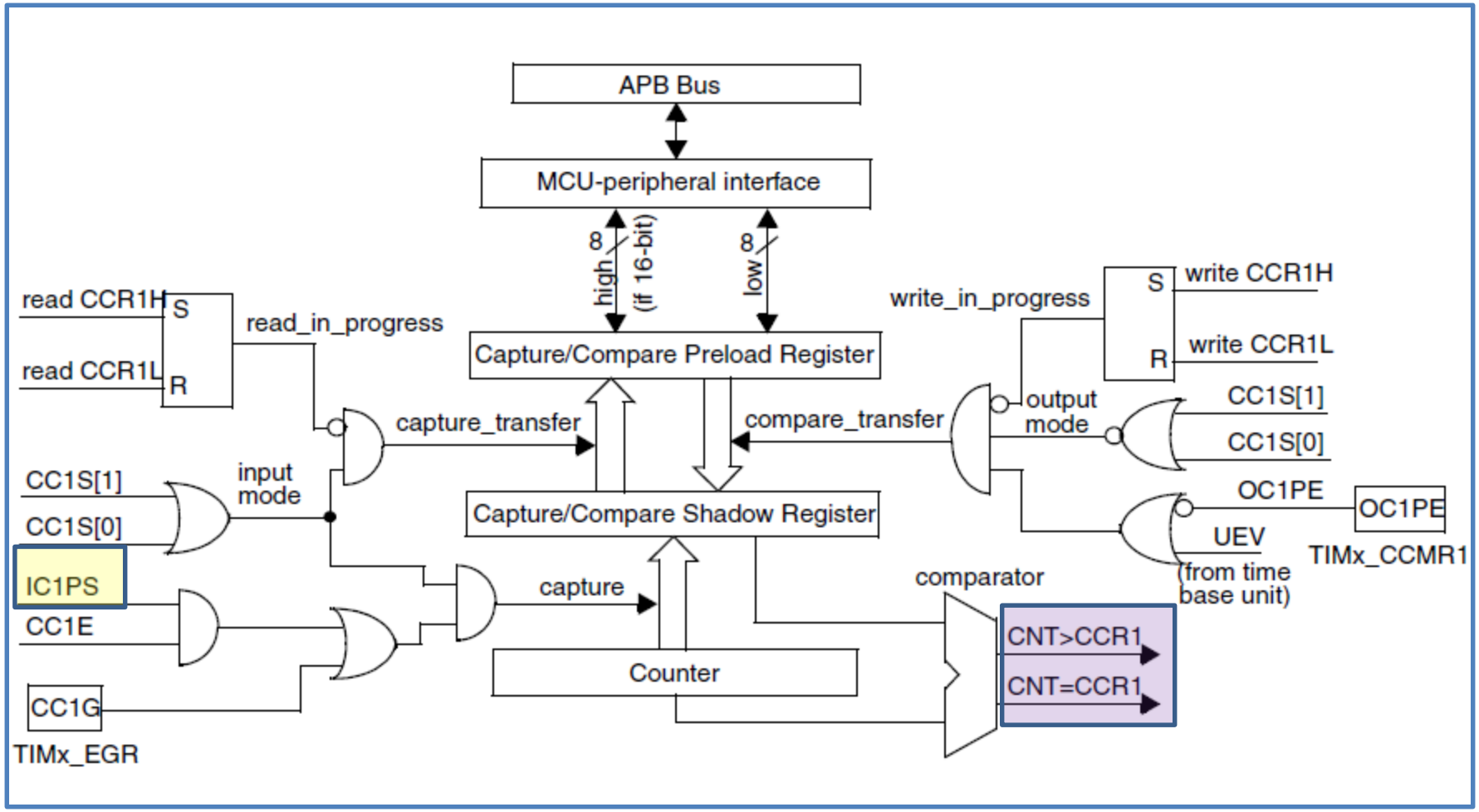
```
#include "mbed.h"

Timeout flipper;
DigitalOut led2(LED2);

void flip() {
    led2 = !led2;
}

int main() {
    led2 = 1;
    flipper.attach(&flip, 2.0); // setup flipper to call flip after 2
   seconds

    // spin in a main loop. flipper will interrupt it to call flip
    while(1) ;
}
```

Capture/compare jedinica input capture deo

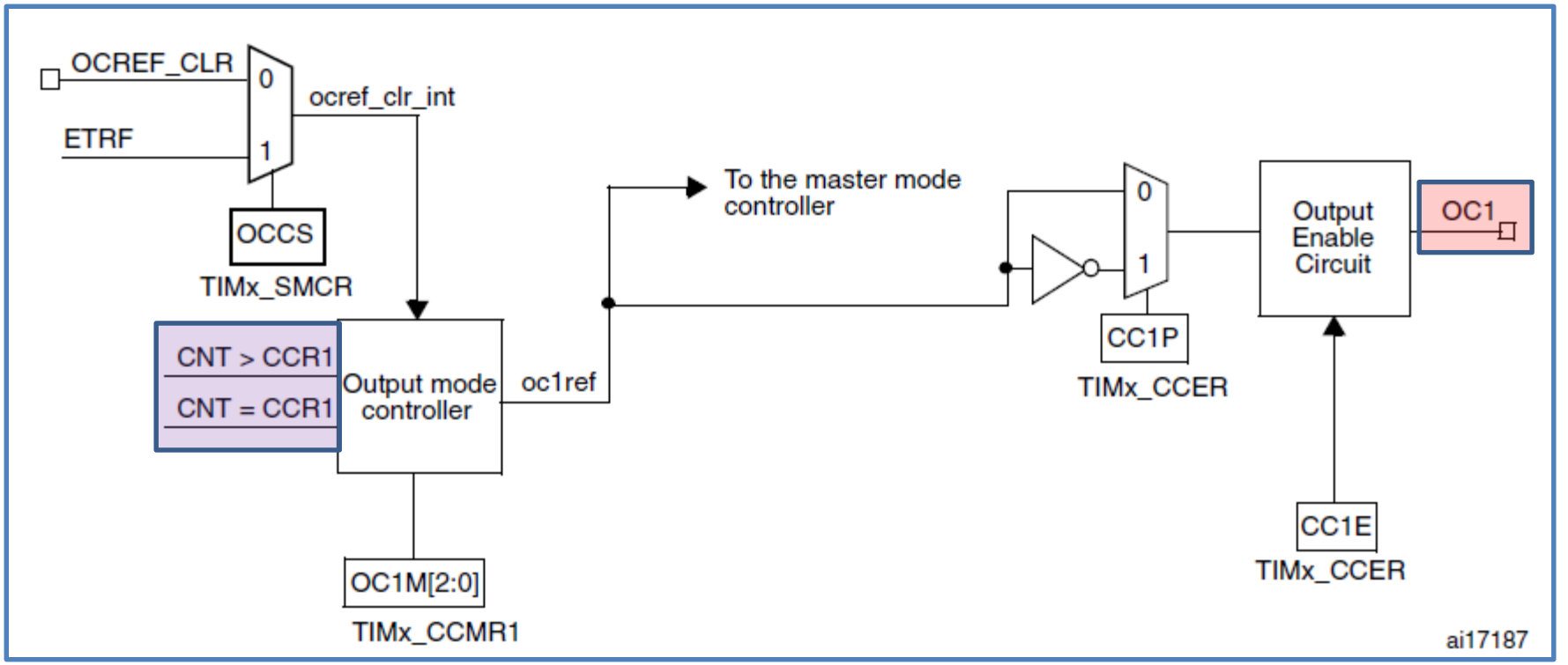
- Svaki capture događaj može da generiše prekid ili DMA zahtev.



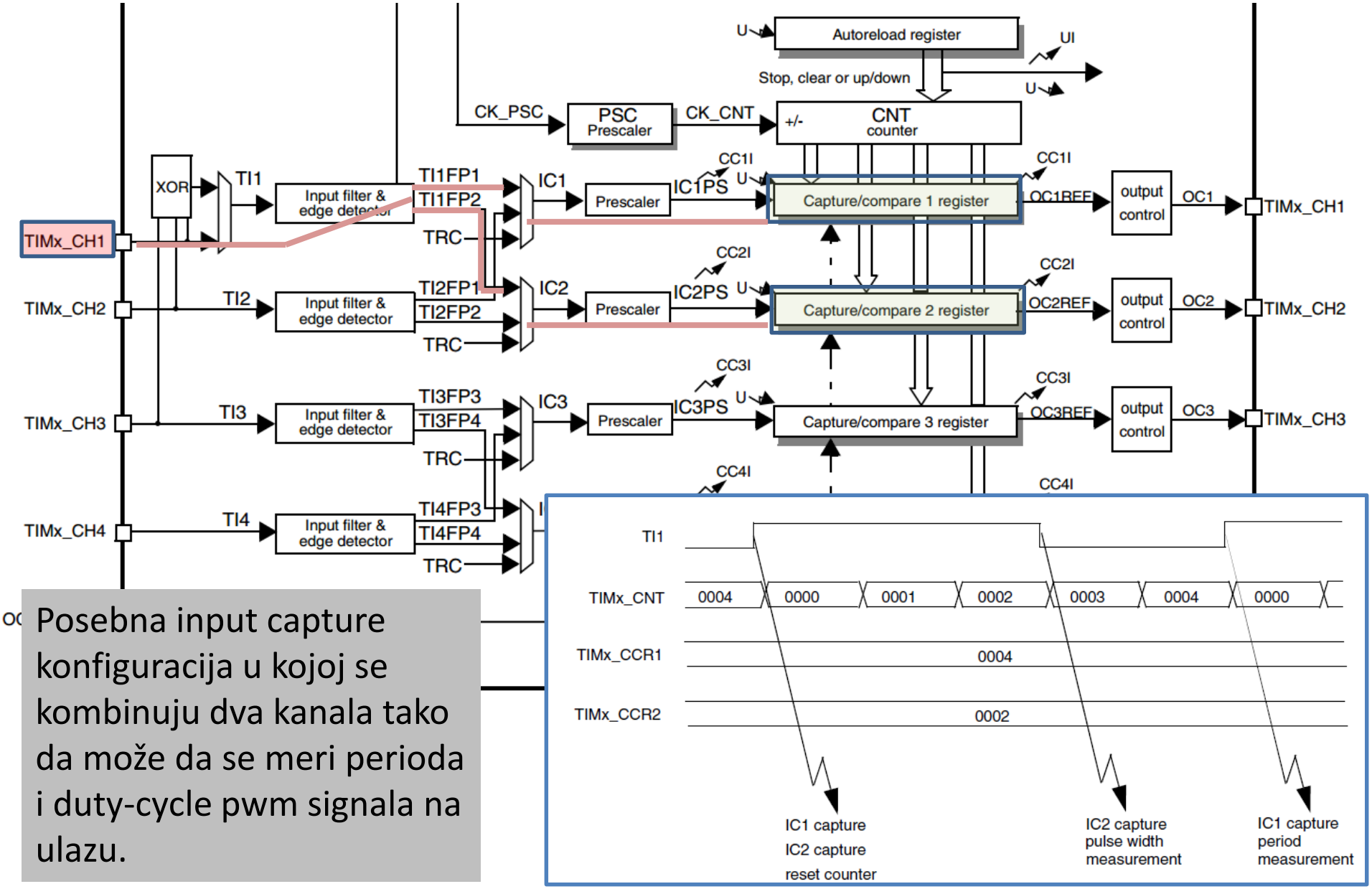
Capture/compare jedinica centralni deo



Capture/compare jedinica output compare deo



PWM input capture

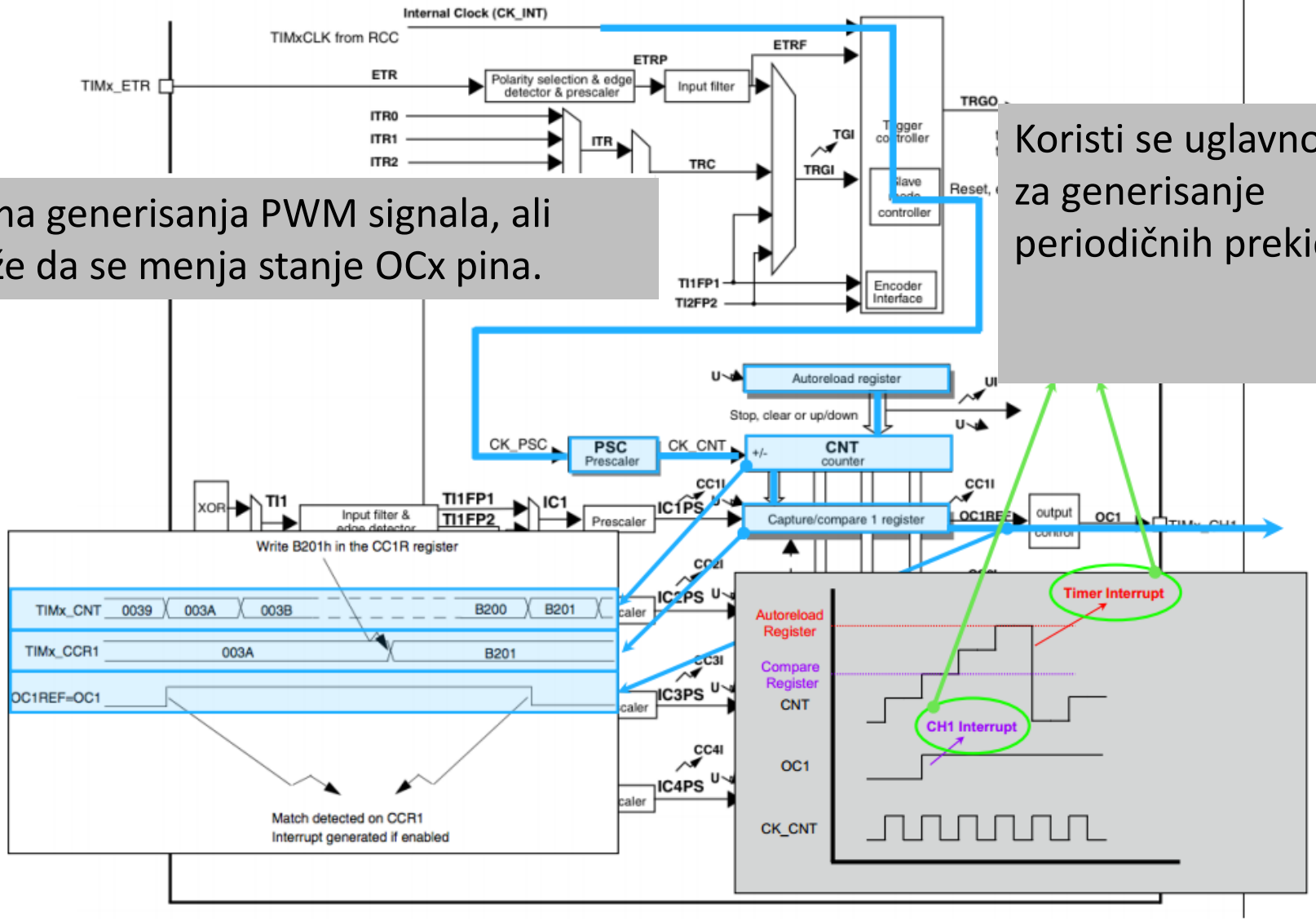


Posebna input capture konfiguracija u kojoj se kombinuju dva kanala tako da može da se meri perioda i duty-cycle pwm signala na ulazu.

Output compare mod

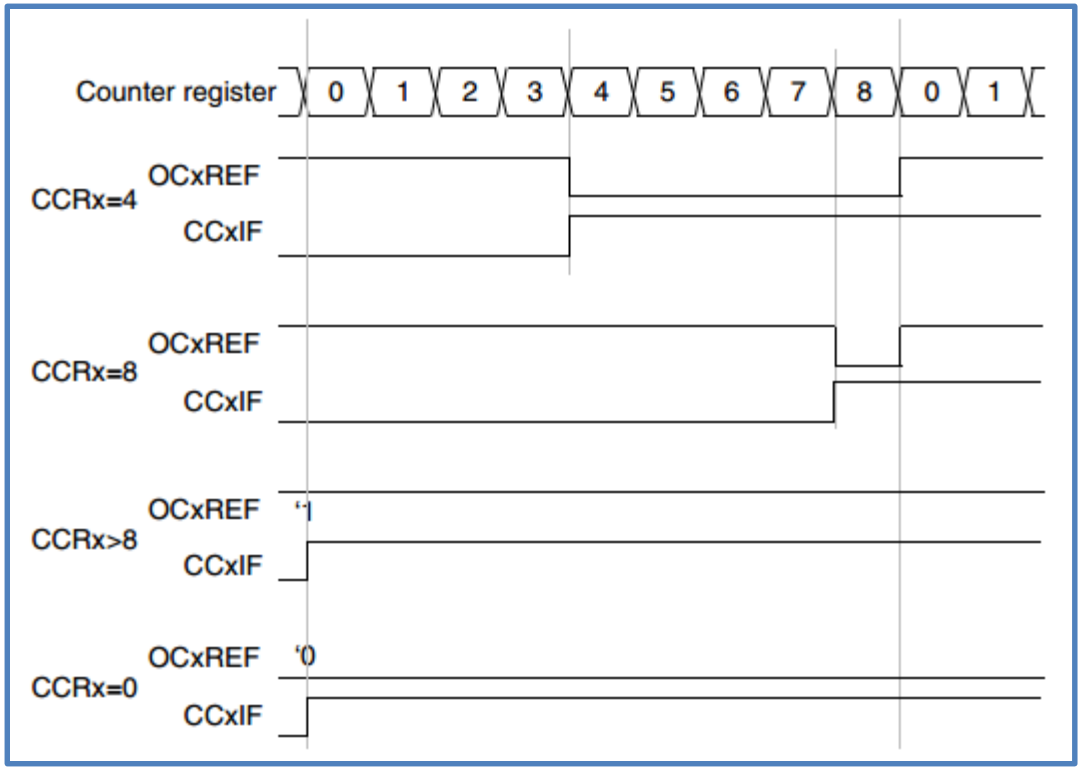
Nema generisanja PWM signala, ali može da se menja stanje OCx pina.

Koristi se uglavnom za generisanje periodičnih prekida.



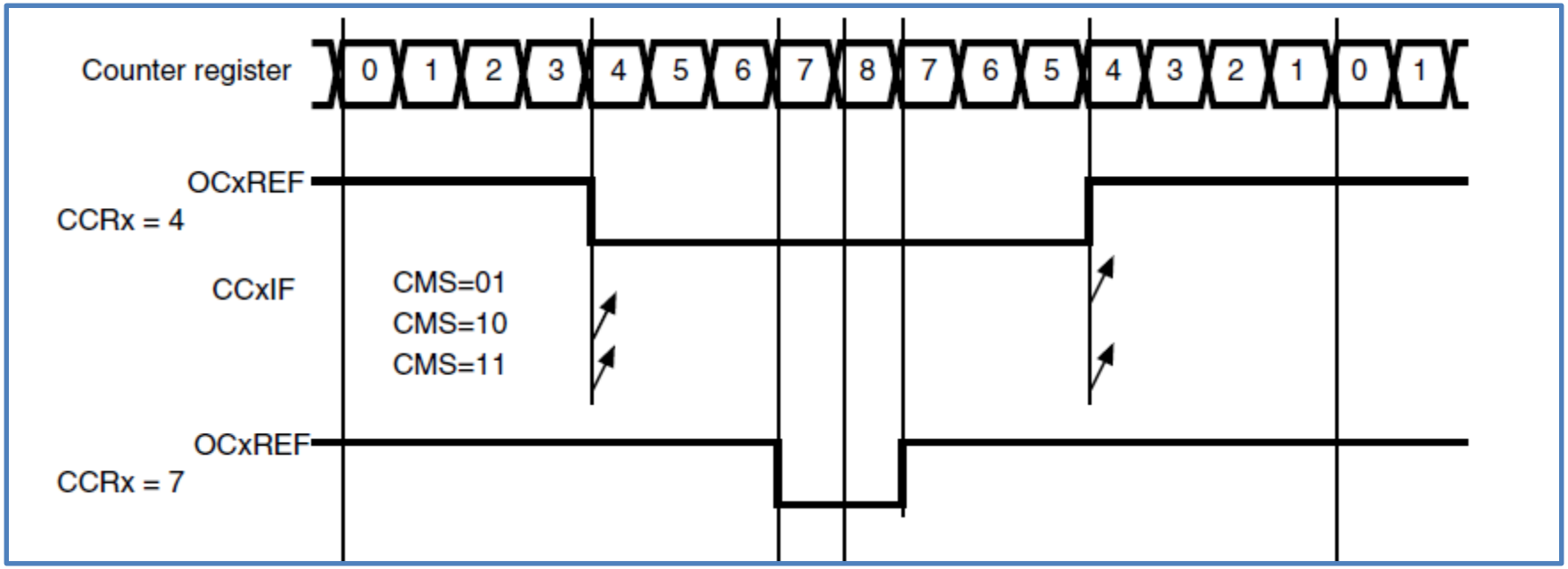
Edge-aligned PWM

- U ovom modu brojač može da radi ili u UP ili u DOWN modu.



Center-aligned PWM

- Slično onome što se kod MSP-a zove phase-correct PWM mod.
- Brojač radi u up/down modu.



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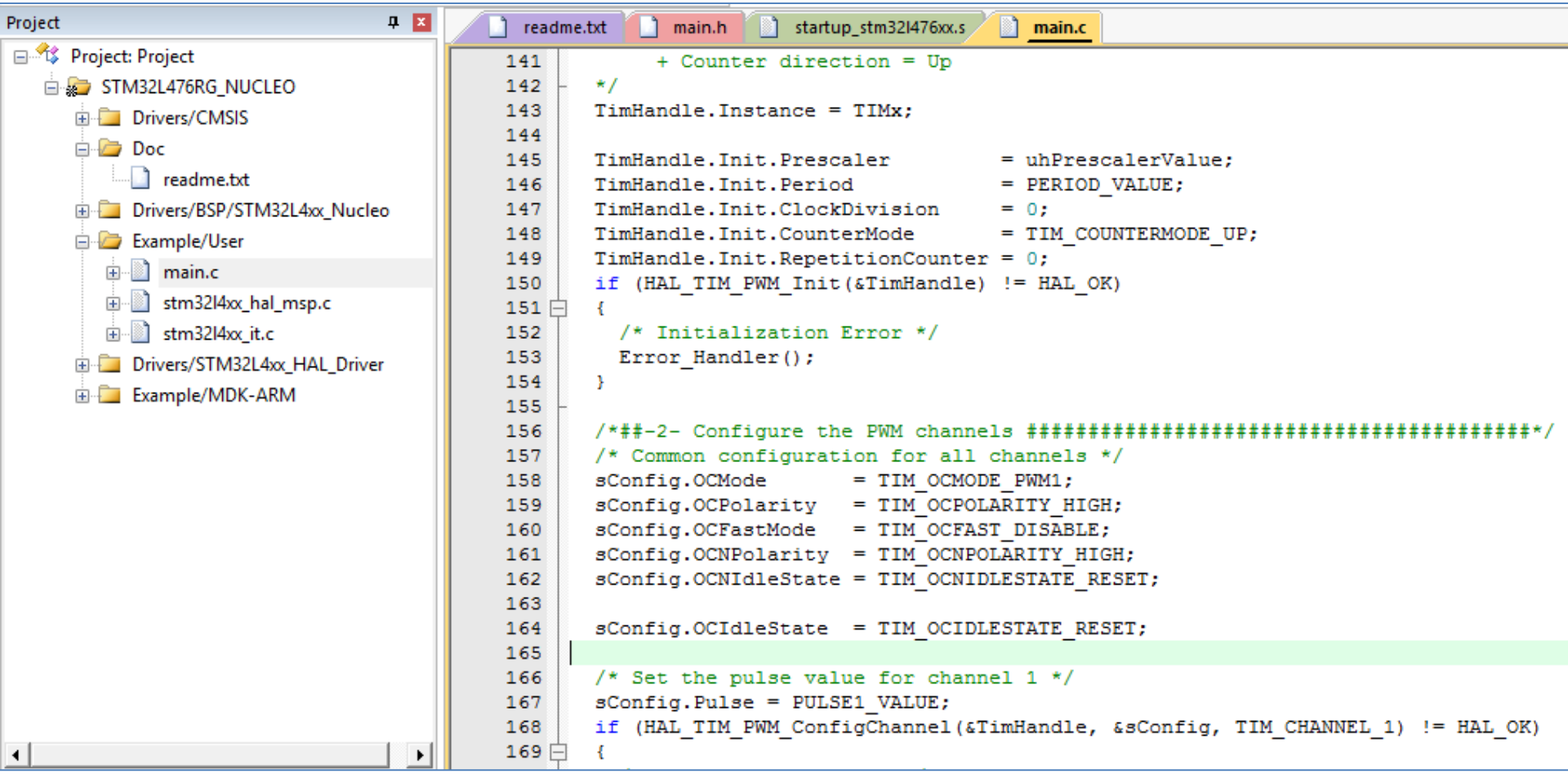
Projekat TIM_PWmOutput



Struktura **TIM_OC_InitTypeDef**

readme.txt | main.h | startup_stm32l476xx.s | main.c | stm32l4xx_hal_tim.h

```
46 /** @addtogroup TIM_PWMOutput
47   * @{
48   */
49
50 /* Private typedef -----------------------------------------------------------*/
51 #define  PERIOD_VALUE       (uint32_t)(666 - 1)  /* Period Value  */
52 #define  PULSE1_VALUE       (uint32_t)(PERIOD_VALUE/2)        /* Capture Compare 1 Value  */
53 #define  PULSE2_VALUE       (uint32_t)(PERIOD_VALUE*37.5/100) /* Capture Compare 2 Value  */
54 #define  PULSE3_VALUE       (uint32_t)(PERIOD_VALUE/4)        /* Capture Compare 3 Value  */
55 #define  PULSE4_VALUE       (uint32_t)(PERIOD_VALUE*12.5/100) /* Capture Compare 4 Value  */
56
57 /* Private define ------------------------------------------------------------*/
58 /* Private macro -------------------------------------------------------------*/
59 /* Private variables ---------------------------------------------------------*/
60 /* Timer handler declaration */
61 TIM_HandleTypeDef    TimHandle;
62
63 /* Timer Output Compare Configuration Structure declaration */
64 TIM_OC_InitTypeDef sConfig;
```

readme.txt | main.h | startup_stm32l476xx.s

```
92   */
93 typedef struct
94 {
95   uint32_t OCMode;         /*!< S
96                                T
97
98   uint32_t Pulse;          /*!< S
99                                T
100
101  uint32_t OCPolarity;     /*!< Specifies the output polarity.
102                                This parameter can be a value of @ref TIM_Output_Compare_Polarity */
103
104  uint32_t OCNPolarity;    /*!< Specifies the complementary output polarity.
105                                This parameter can be a value of @ref TIM_Output_Compare_N_Polarity
106                                @note This parameter is valid only for TIM1 and TIM8. */
107
108  uint32_t OCFastMode;    /*!< Specifies the Fast mode state.
109                                This parameter can be a value of @ref TIM_Output_Fast_State
110                                @note This parameter is valid only in PWM1 and PWM2 mode. */
111
112
113  uint32_t OCIdleState;    /*!< Specifies the TIM Output Compare pin state during Idle state.
114                                This parameter can be a value of @ref TIM_Output_Compare_Idle_State
115                                @note This parameter is valid only for TIM1 and TIM8. */
116
117  uint32_t OCNIdleState;  /*!< Specifies the TIM Output Compare pin state during Idle state.
118                                This parameter can be a value of @ref TIM_Output_Compare_N_Idle_State
119                                @note This parameter is valid only for TIM1 and TIM8. */
120 } TIM_OC_InitTypeDef;
```

Bits 6:4 **OC1M**: Output Compare 1 mode

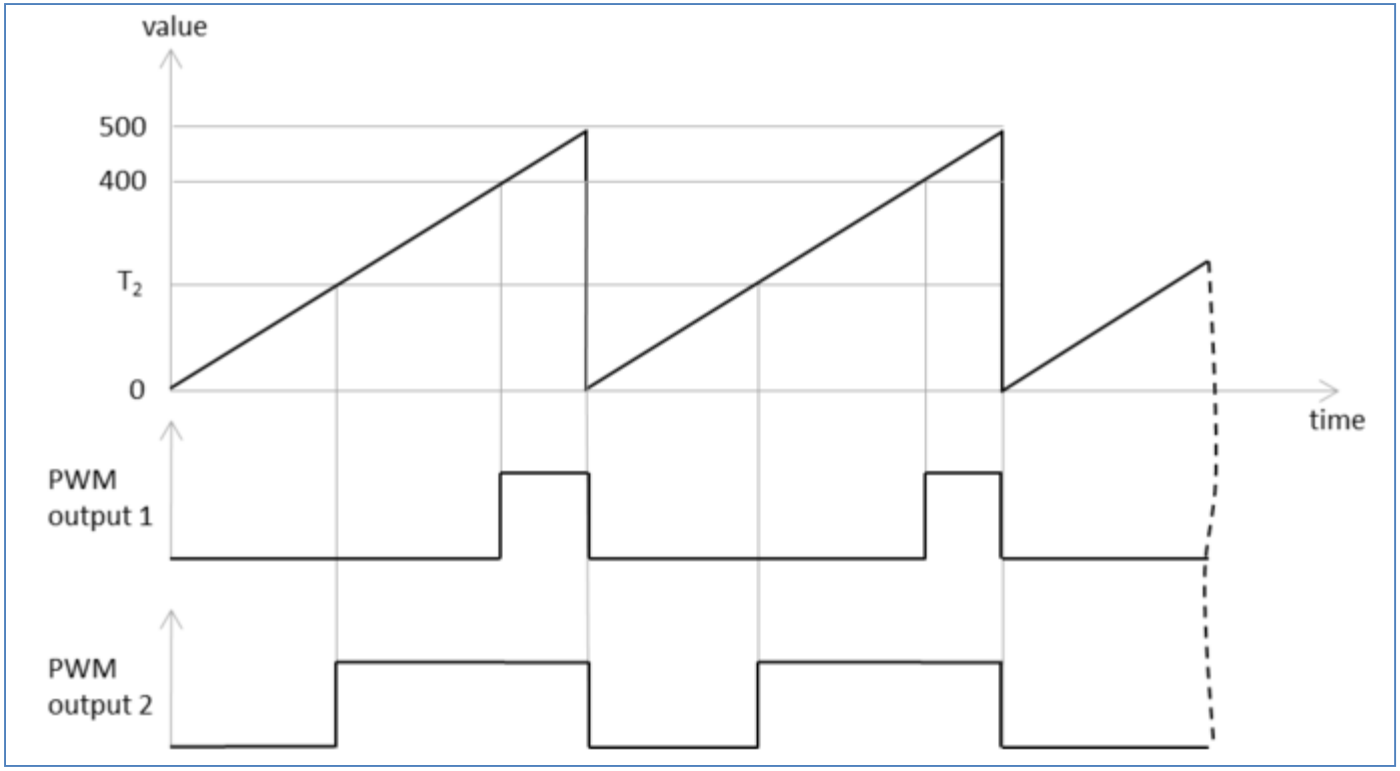
These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

0000: Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.(this mode is used to generate a timing base).
0001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).
0010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).
0011: Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.
0100: Force inactive level - OC1REF is forced low.
0101: Force active level - OC1REF is forced high.
0110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF='1').
0111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active. In downcounting, channel 1 is active as long as TIMx_CNT>TIMx_CCR1 else inactive.
1000: Retriggerrable OPM mode 1 - In up-counting mode, the channel is active until a trigger

readme.txt | main.h | startup_stm32l476xx.s | main.c | stm32l4xx_hal_tim.h

```
860 /** @defgroup TIM_Output_Compare_and_PWM_modes TIM Output Compare and PWM Modes
861   * @{
862   */
863 #define TIM_OCMODE_TIMING                   ((uint32_t)0x0000)
864 #define TIM_OCMODE_ACTIVE                   ((uint32_t)TIM_CCMR1_OC1M_0)
865 #define TIM_OCMODE_INACTIVE                 ((uint32_t)TIM_CCMR1_OC1M_1)
866 #define TIM_OCMODE_TOGGLE                   ((uint32_t)TIM_CCMR1_OC1M_1 | TIM_CCMR1_OC1M_0)
867 #define TIM_OCMODE_PWM1                     ((uint32_t)TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1)
868 #define TIM_OCMODE_PWM2                     ((uint32_t)TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1 | TIM_CCMR1_OC1M_0)
869 #define TIM_OCMODE_FORCED_ACTIVE            ((uint32_t)TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_0)
870 #define TIM_OCMODE_FORCED_INACTIVE          ((uint32_t)TIM_CCMR1_OC1M_2)
871
872 #define TIM_OCMODE_RETRIGERRABLE_OPM1       ((uint32_t)TIM_CCMR1_OC1M_3)
873 #define TIM_OCMODE_RETRIGERRABLE_OPM2       ((uint32_t)TIM_CCMR1_OC1M_3 | TIM_CCMR1_OC1M_0)
874 #define TIM_OCMODE_COMBINED_PWM1            ((uint32_t)TIM_CCMR1_OC1M_3 | TIM_CCMR1_OC1M_2)
```

Što se u suštini svodi na ovo



Podešavanje svakog OC kanala

readme.txt | main.h | startup_stm32l476xx.s | main.c

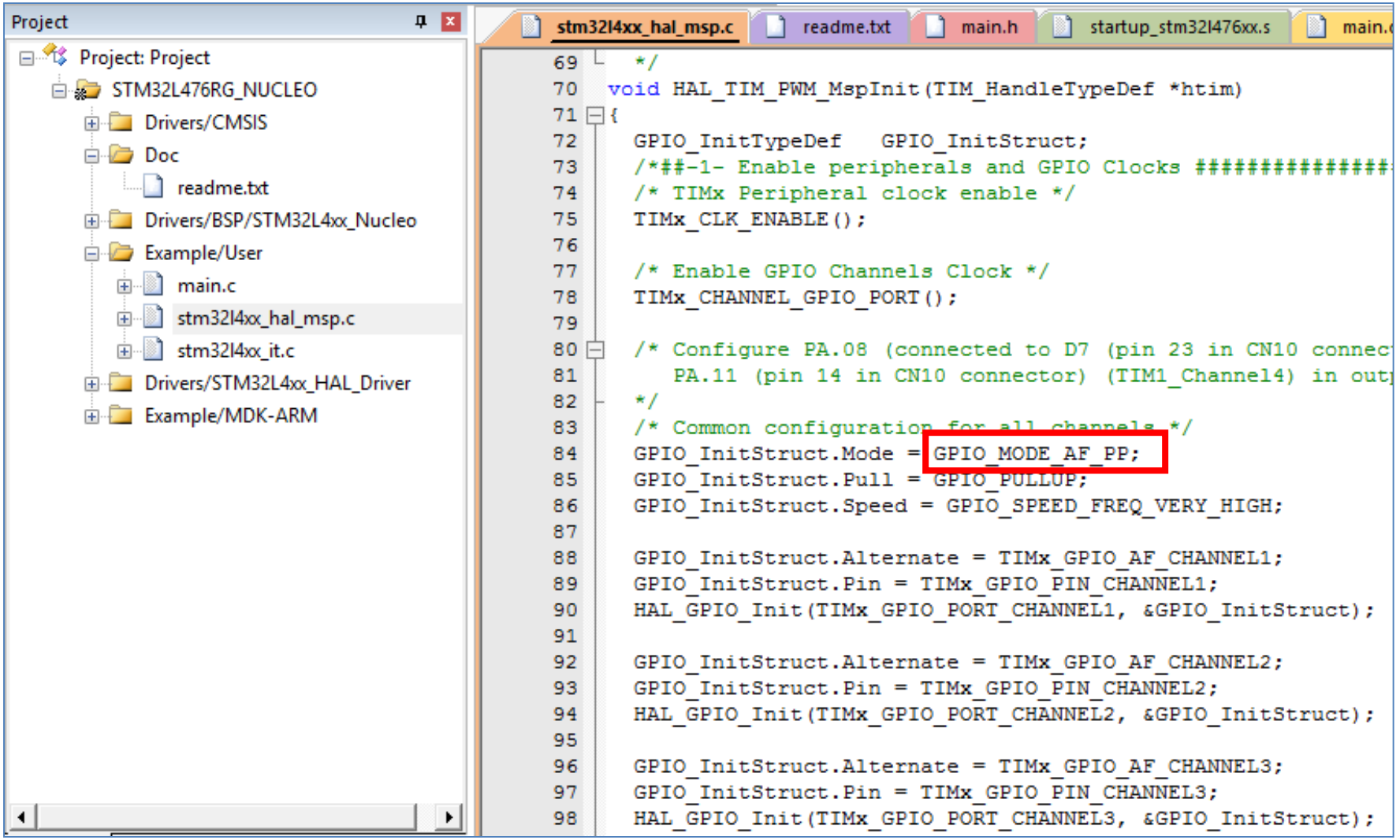
```
166   /* Set the pulse value for channel 1 */
167   sConfig.Pulse = PULSE1_VALUE;
168   if (HAL_TIM_PWM_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_1) != HAL_OK)
169   {
170     /* Configuration Error */
171     Error_Handler();
172   }
173
174   /* Set the pulse value for channel 2 */
175   sConfig.Pulse = PULSE2_VALUE;
176   if (HAL_TIM_PWM_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_2) != HAL_OK)
177   {
178     /* Configuration Error */
179     Error_Handler();
180   }
181
182   /* Set the pulse value for channel 3 */
183   sConfig.Pulse = PULSE3_VALUE;
184   if (HAL_TIM_PWM_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_3) != HAL_OK)
185   {
186     /* Configuration Error */
187     Error_Handler();
188   }
189
190   /* Set the pulse value for channel 4 */
191   sConfig.Pulse = PULSE4_VALUE;
192   if (HAL_TIM_PWM_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_4) != HAL_OK)
193   {
194     /* Configuration Error */
195     Error_Handler();
196   }
```

Startovanje OC kanala

readme.txt | main.h | startup_stm32l476xx.s | main.c

```
197
198   /*##-3- Start PWM signals generation ########################
199   /* Start channel 1 */
200   if (HAL_TIM_PWM_Start(&TimHandle, TIM_CHANNEL_1) != HAL_OK)
201   {
202     /* PWM Generation Error */
203     Error_Handler();
204   }
205   /* Start channel 2 */
206   if (HAL_TIM_PWM_Start(&TimHandle, TIM_CHANNEL_2) != HAL_OK)
207   {
208     /* PWM Generation Error */
209     Error_Handler();
210   }
211   /* Start channel 3 */
212   if (HAL_TIM_PWM_Start(&TimHandle, TIM_CHANNEL_3) != HAL_OK)
213   {
214     /* PWM generation Error */
215     Error_Handler();
216   }
217   /* Start channel 4 */
218   if (HAL_TIM_PWM_Start(&TimHandle, TIM_CHANNEL_4) != HAL_OK)
219   {
220     /* PWM generation Error */
221     Error_Handler();
222   }
223
224   while (1)
225   {
226   }
227
```

A šta je sa low level inicijalizacijom?



life.augmented

STM32L476xx

Ultra-low-power ARM® Cortex®-M4 32-bit MCU+FPU, 100DMIPS, up to 1MB Flash, 128 KB SRAM, USB OTG FS, LCD, analog, audio

Datasheet - production data

Features

- Ultra-low-power with FlexPowerControl
  - 1.71 V to 3.6 V power supply
  - -40 °C to 85/105/125 °C temperature range
  - 300 nA in V_{BAT} mode: supply for RTC and

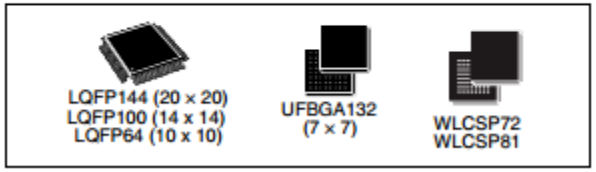


Table 15. STM32L476xxSTM32L476xx pin definitions (continued)

Pin Number						Pin name (function after reset)	Pin type	I/O structure	Notes	Pin functions	
LQFP64	WLCSP72	WLCSP81	LQFP100	UFBGA132	LQFP144					Alternate functions	Additional functions
41	E2	E2	67	D11	100	PA8	I/O	FT_l	-	MCO, TIM1_CH1, USART1_CK, OTG_FS_SOF, LCD_COM0, LPTIM2_OUT, EVENTOUT	-
42	E3	E3	68	D10	101	PA9	I/O	FT_lu	-	TIM1_CH2, USART1_TX, LCD_COM1, TIM15_BKIN, EVENTOUT	OTG_FS_ VBUS
43	D2	D2	69	C12	102	PA10	I/O	FT_lu	-	TIM1_CH3, USART1_RX, OTG_FS_ID, LCD_COM2, TIM17_BKIN, EVENTOUT	-
44	D1	D1	70	B12	103	PA11	I/O	FT_u	-	TIM1_CH4, TIM1_BKIN2, USART1_CTS, CAN1_RX, OTG_FS_DM, TIM1_BKIN2_COMP1, EVENTOUT	-

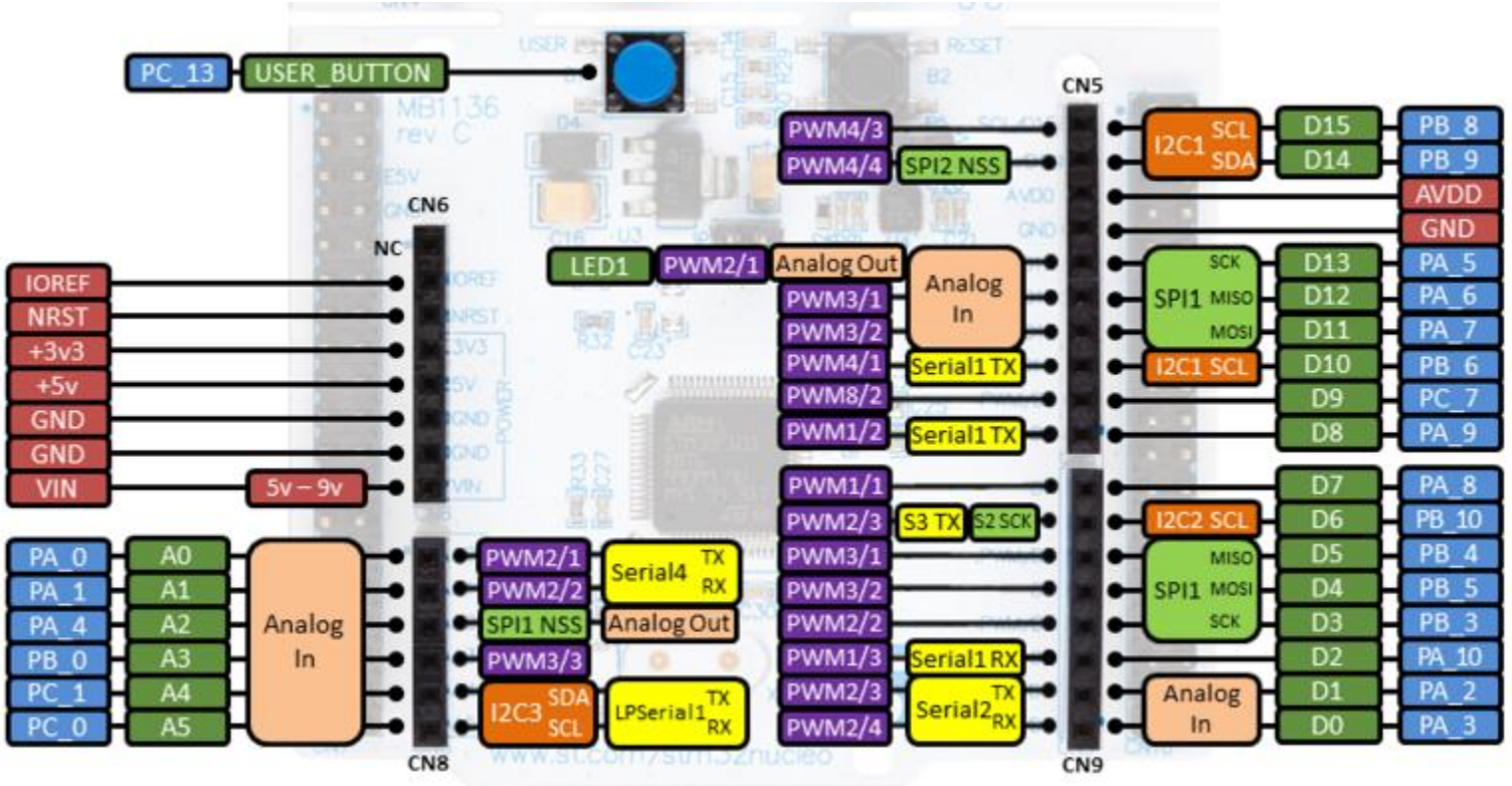
MBED

Digitalni izlazi sa mogućnošću generisanja PWM signala

- Pristup preko MBED biblioteke je brutalno jednostavan i intuitivan.

```
#include "mbed.h"
PwmOut led(LED2);
int main() {
        while(1) {
                for(float p = 0.0f; p < 1.0f; p += 0.1f) {
                        led = p; wait(0.1);
                }
        }
}
```

Na kojim to pinovima može da se generiše PWM



Klasa PwmOut

PwmOut Class Reference

```
#include <PwmOut.h>
```

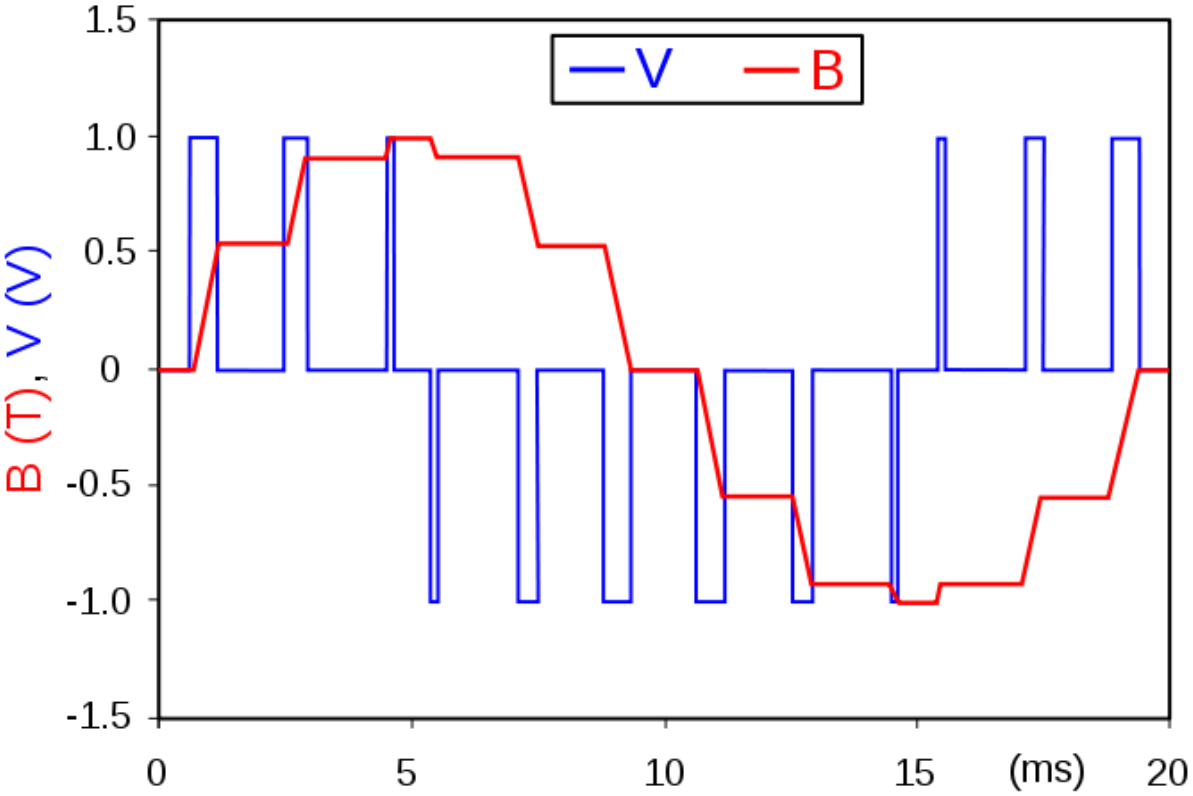
Public Member Functions

	PwmOut (PinName pin) Create a **PwmOut** connected to the specified pin.
void	write (float value) Set the ouput duty-cycle, specified as a percentage (float)
float	read () Return the current output duty-cycle setting, measured as a percentage (float)
void	period (float seconds) Set the PWM period, specified in seconds (float), keeping the duty cycle the same.
void	period_ms (int ms) Set the PWM period, specified in milli-seconds (int), keeping the duty cycle the same.
void	period_us (int us) Set the PWM period, specified in micro-seconds (int), keeping the duty cycle the same.
void	pulsewidth (float seconds) Set the PWM pulsewidth, specified in seconds (float), keeping the period the same.
void	pulsewidth_ms (int ms) Set the PWM pulsewidth, specified in milli-seconds (int), keeping the period the same.
void	pulsewidth_us (int us) Set the PWM pulsewidth, specified in micro-seconds (int), keeping the period the same.
PwmOut &	operator= (float value) A operator shorthand for write() operator float () An operator shorthand for read()

STM CUBE

Projekat TIM_PWmInput

- Merenje karakteristika PWM signala uz pomoć tajmera



Prametri za IC

main.c | stm32l4xx_hal_msp.c | stm32l4xx_hal_tim.c | startup_stm32l476xx.s

```
49
50  /* Private typedef -----------------------------------------------------------*/
51  /* Private define ------------------------------------------------------------*/
52  /* Private macro -------------------------------------------------------------*/
53  /* Private variables ---------------------------------------------------------*/
54  /* Timer handler declaration */
55  TIM_HandleTypeDef    TimHandle;
56
57  /* Timer Input Capture Configuration Structure declaration */
58  TIM_IC_InitTypeDef       sConfig;
59
60  /* Slave configuration structure */
61  TIM_SlaveConfigTypeDef   sSlaveConfig;
62
63  /* Captured Value */
64  __IO uint32_t            uwIC2Value = 0;
65  /* Duty Cycle Value */
66  __IO uint32_t            uwDutyCycle = 0;
67  /* Frequency Value */
68  __IO uint32_t            uwFrequency = 0;
```

in.c | stm32l4xx_hal_msp.c | stm32l4xx_hal_tim.c | stm32l4xx_hal_tim.h

```
/**
  * @brief  TIM Input Capture Configuration Structure definition
  */
typedef struct
{
  uint32_t  ICPolarity;   /*!< Specifies the active edge of the input signal.
                               This parameter can be a value of @ref TIM_Input_Capture_Polarity */

  uint32_t ICSelection;  /*!< Specifies the input.
                              This parameter can be a value of @ref TIM_Input_Capture_Selection */

  uint32_t ICPrescaler;  /*!< Specifies the Input Capture Prescaler.
                              This parameter can be a value of @ref TIM_Input_Capture_Prescaler */

  uint32_t ICFilter;     /*!< Specifies the input capture filter.
                              This parameter can be a number between Min_Data = 0x0 and Max_Data = 0xF */
} TIM_IC_InitTypeDef;
```

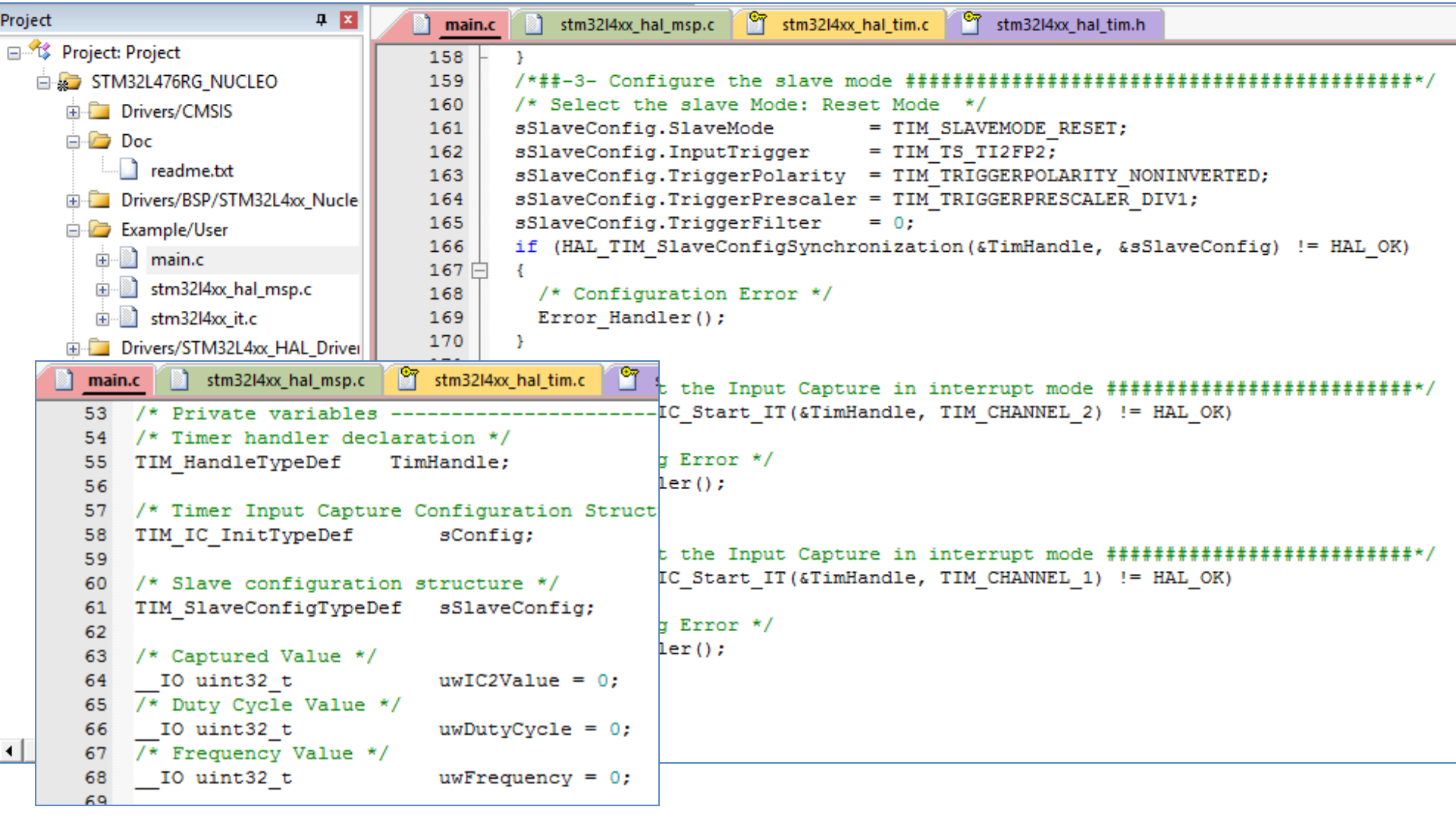
Podešavanje svakog kanala

```
/*##-2- Configure the Input Capture channels ##################################*/
/* Common configuration */
sConfig.ICPrescaler = TIM_ICPSC_DIV1;
sConfig.ICFilter = 0;

/* Configure the Input Capture of channel 1 */
sConfig.ICPolarity = TIM_ICPOLARITY_FALLING;
sConfig.ICSelection = TIM_ICSELECTION_INDIRECTTI;
if (HAL_TIM_IC_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_1) != HAL_OK)
{
  /* Configuration Error */
  Error_Handler();
}

/* Configure the Input Capture of channel 2 */
sConfig.ICPolarity = TIM_ICPOLARITY_RISING;
sConfig.ICSelection = TIM_ICSELECTION_DIRECTTI;
if (HAL_TIM_IC_ConfigChannel(&TimHandle, &sConfig, TIM_CHANNEL_2) != HAL_OK)
{
  /* Configuration Error */
  Error_Handler();
}
```

Posebna podešavanja za PWM input



Slave mode konfiguracija

main.c | stm32l4xx_hal_msp.c | stm32l4xx_hal_tim.c | stm32l4xx_hal_tim.h

```
260 typedef struct {
261   uint32_t  SlaveMode;       /*!< Slave mode selection
262                                 This parameter can be a value of @ref TIM_Slave_Mode */
263   uint32_t  InputTrigger;    /*!< Input Trigger source
264                                 This parameter can be a value of @ref TIM_Trigger_Selection */
265   uint32_t  TriggerPolarity; /*!< Input Trigger polarity
266                                 This parameter can be a value of @ref TIM_Trigger_Polarity */
267   uint32_t  TriggerPrescaler; /*!< Input trigger prescaler
268                                 This parameter can be a value of @ref TIM_Trigger_Prescaler */
269   uint32_t  TriggerFilter;   /*!< Input trigger filter
270                                 This parameter can be a number between Min_Data = 0x0 and Max_Data = 0xF  */
271
272 }TIM_SlaveConfigTypeDef;
```

main.c | stm32l4xx_hal_msp.c | stm32l4xx_hal_tim.c | stm32l4xx_hal_tim.h

```
46
47 /** @defgroup TIM_Slave_Mode TIM Slave mode
48   * @{
49   */
50 #define TIM_SLAVEMODE_DISABLE                ((uint32_t)0x0000)
51 #define TIM_SLAVEMODE_RESET                  ((uint32_t)(TIM_SMCR_SMS_2))
52 #define TIM_SLAVEMODE_GATED                  ((uint32_t)(TIM_SMCR_SMS_2 | TIM_SMCR_SMS_0))
53 #define TIM_SLAVEMODE_TRIGGER                ((uint32_t)(TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1))
54 #define TIM_SLAVEMODE_EXTERNAL1              ((uint32_t)(TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1 | TIM_SMCR_SMS_0))
55 #define TIM_SLAVEMODE_COMBINED_RESETTRIGGER  ((uint32_t)(TIM_SMCR_SMS_3))
56 /**
```

Neki slave modovi

Figure 245. Control circuit in reset mode

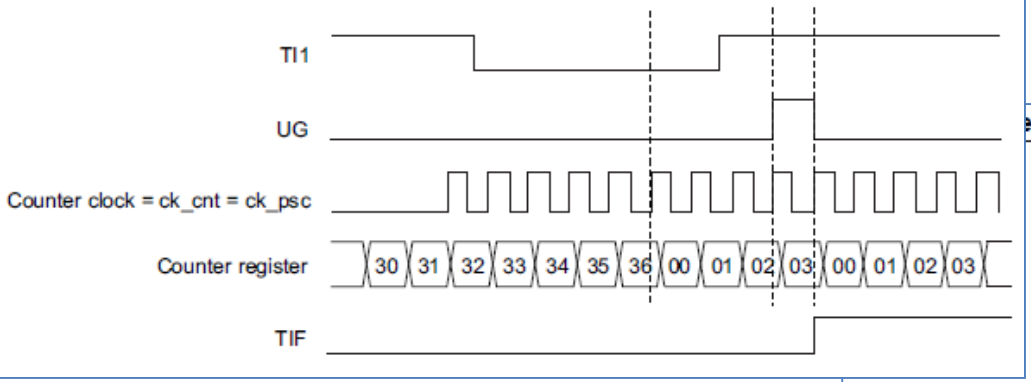
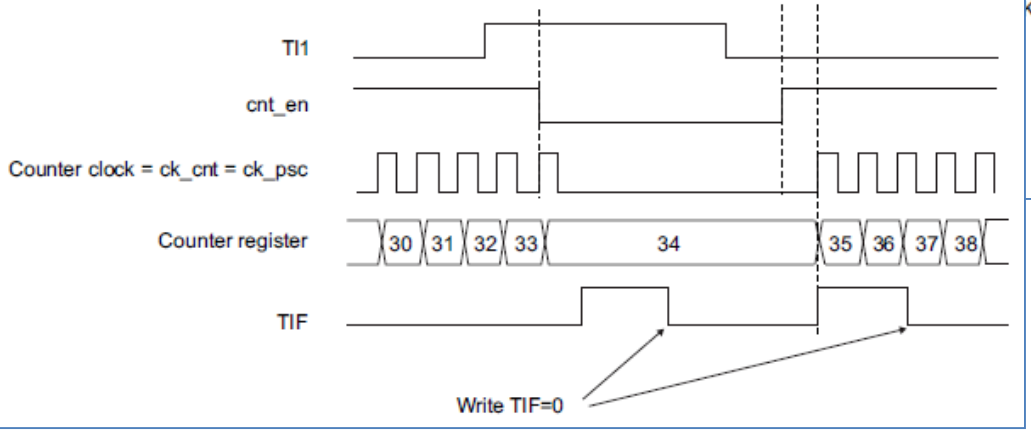
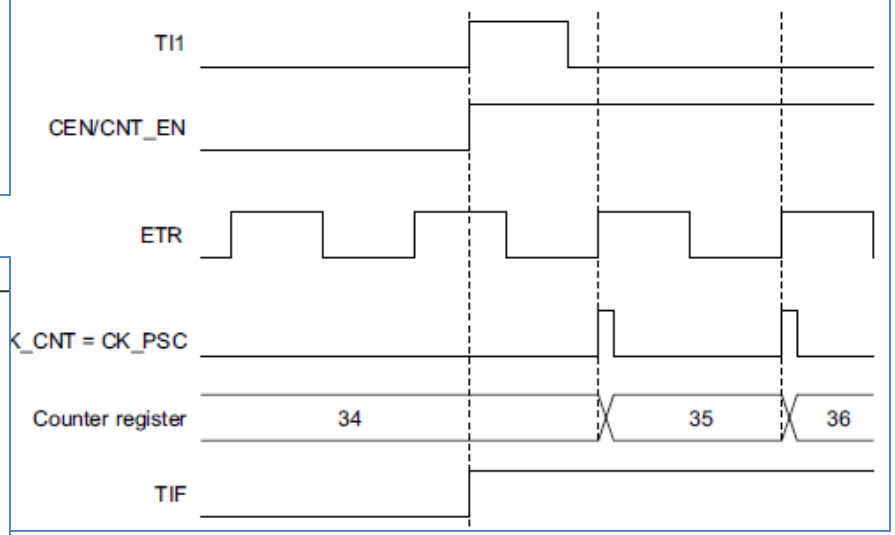


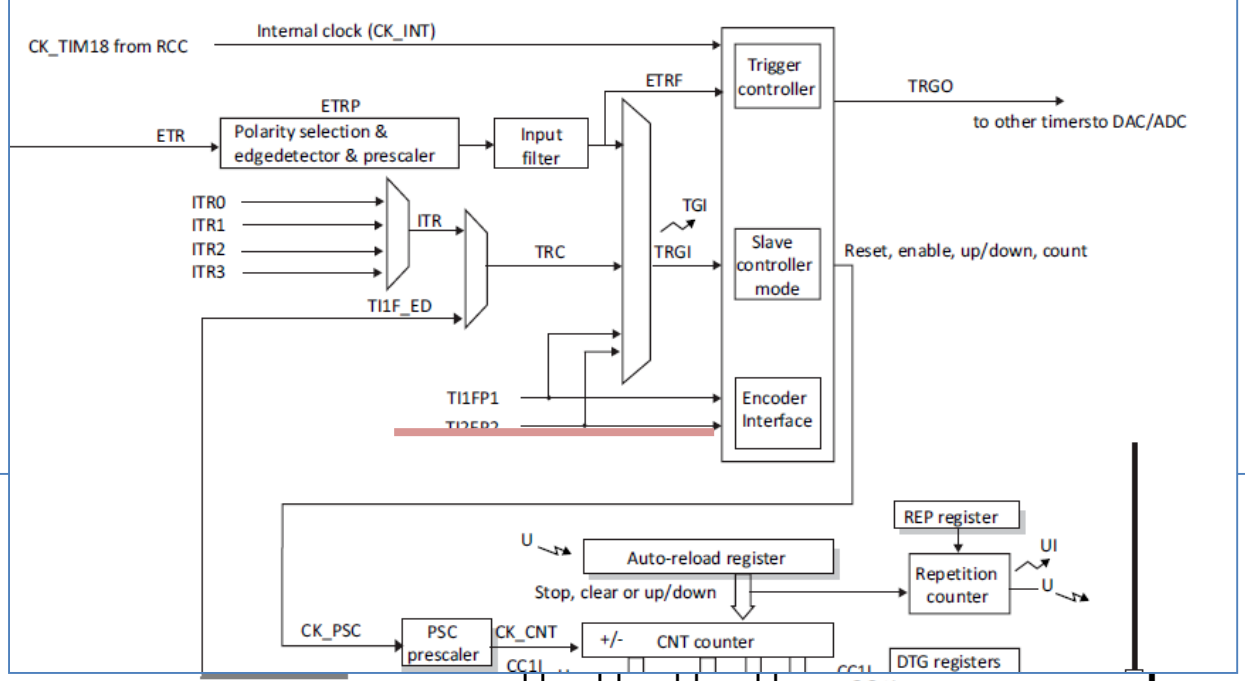
Figure 246. Control circuit in Gated mode

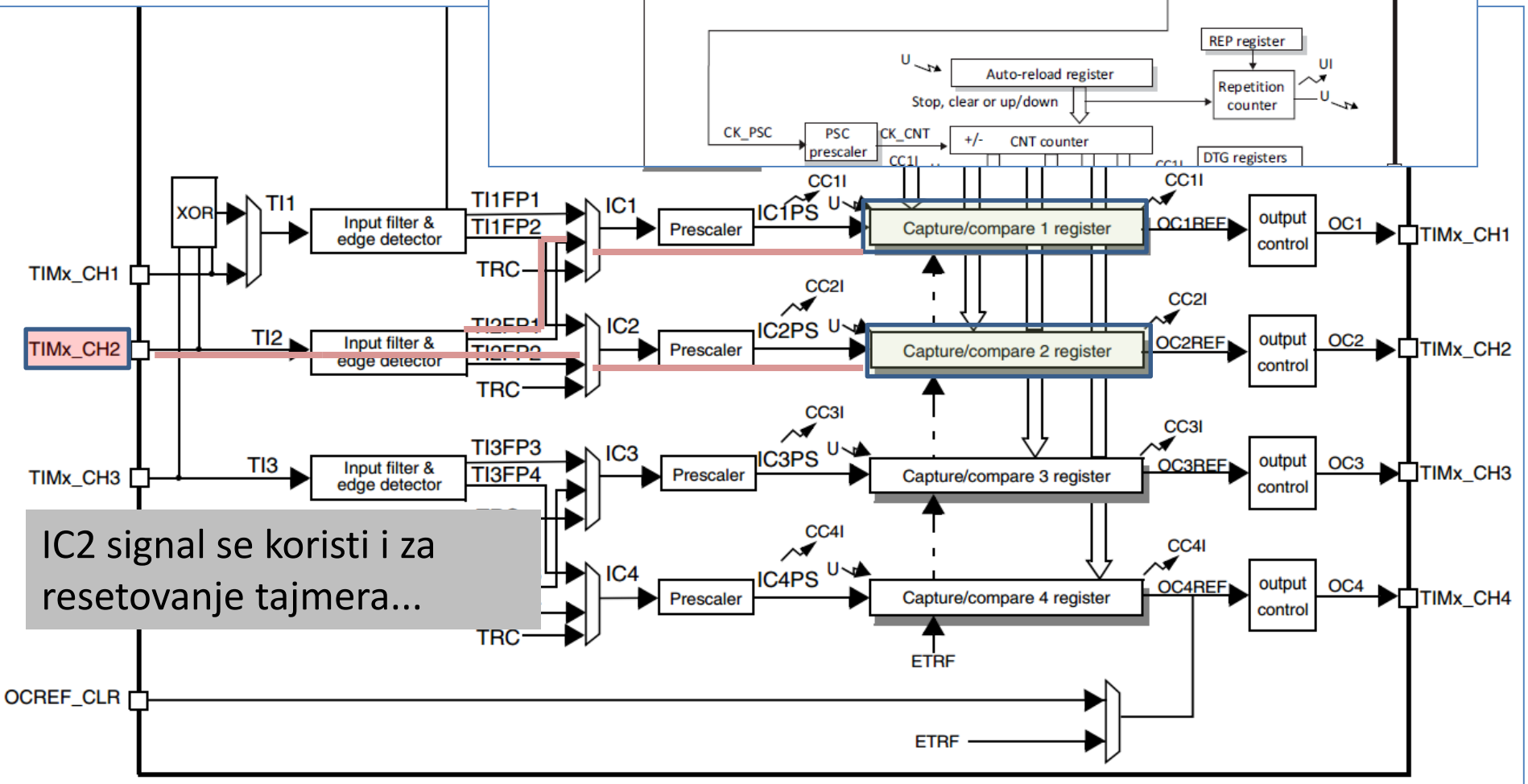


e 248. Control circuit in external clock mode 2 + trigger mode



PWM input capture





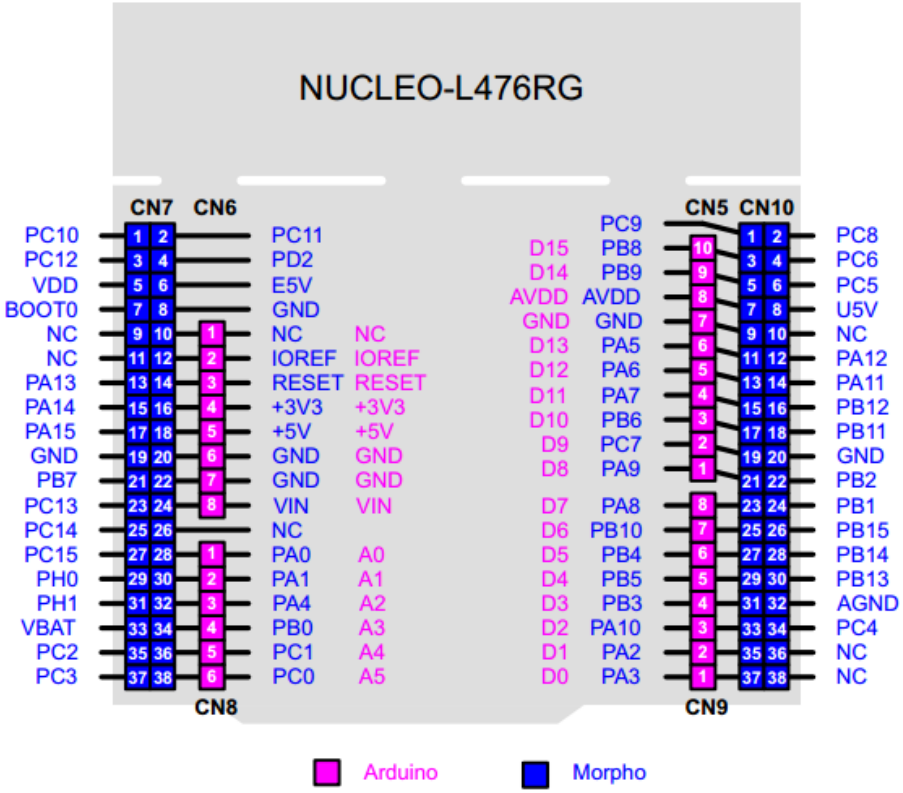
IC2 signal se koristi i za resetovanje tajmera...

I na kraju to sve treba startovati

stm32l4xx_it.c | readme.txt | main.c* | stm32l4xx_hal_msp.c | stm32l4xx_hal_tim.c | stm32l4xx_hal_tim

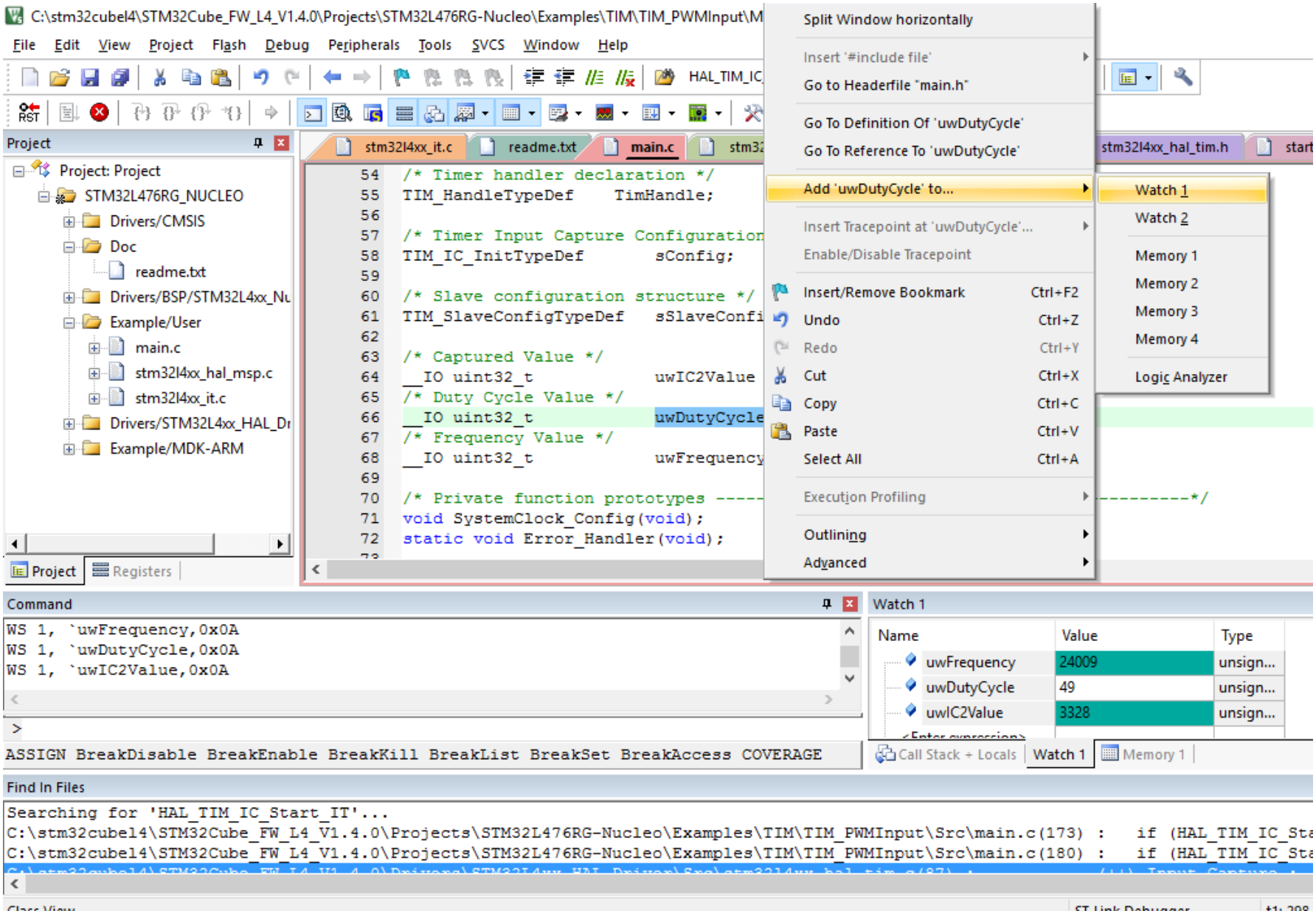
```
163   sSlaveConfig.TriggerPolarity  = TIM_TRIGGERPOLARITY_NONINVERTED;
164   sSlaveConfig.TriggerPrescaler = TIM_TRIGGERPRESCALER_DIV1;
165   sSlaveConfig.TriggerFilter    = 0;
166   if (HAL_TIM_SlaveConfigSynchronization(&TimHandle, &sSlaveConfig) != HAL_OK)
167   {
168     /* Configuration Error */
169     Error_Handler();
170   }
171
172   /*##-4- Start the Input Capture in interrupt mode ##########################*/
173   if (HAL_TIM_IC_Start_IT(&TimHandle, TIM_CHANNEL_2) != HAL_OK)
174   {
175     /* Starting Error */
176     Error_Handler();
177   }
178
179   /*##-5- Start the Input Capture in interrupt mode ##########################*/
180   if (HAL_TIM_IC_Start(&TimHandle, TIM_CHANNEL_1) != HAL_OK)
181   {
182     /* Starting Error */
183     Error_Handler();
184   }
185
186   while (1)
187   {
188   }
189 }
```

Zadatak



- Jedna kontroler izvršava projekat PWMOutput, a druga grupa izvršava projekat PWMInput
- Povezati dva kontrola pomoću dva provodnika – masa i signal.
- Pitanje: Gde se računaju parametri ulaznog PWM signala?
- Da li će projekat PMWInput korektno da radi ako se CH1 inicijalizuje bez prekidne funcije tj. sa: HAL_TIM_IC_Start(&TimHandle, TIM_CHANNEL_1)?

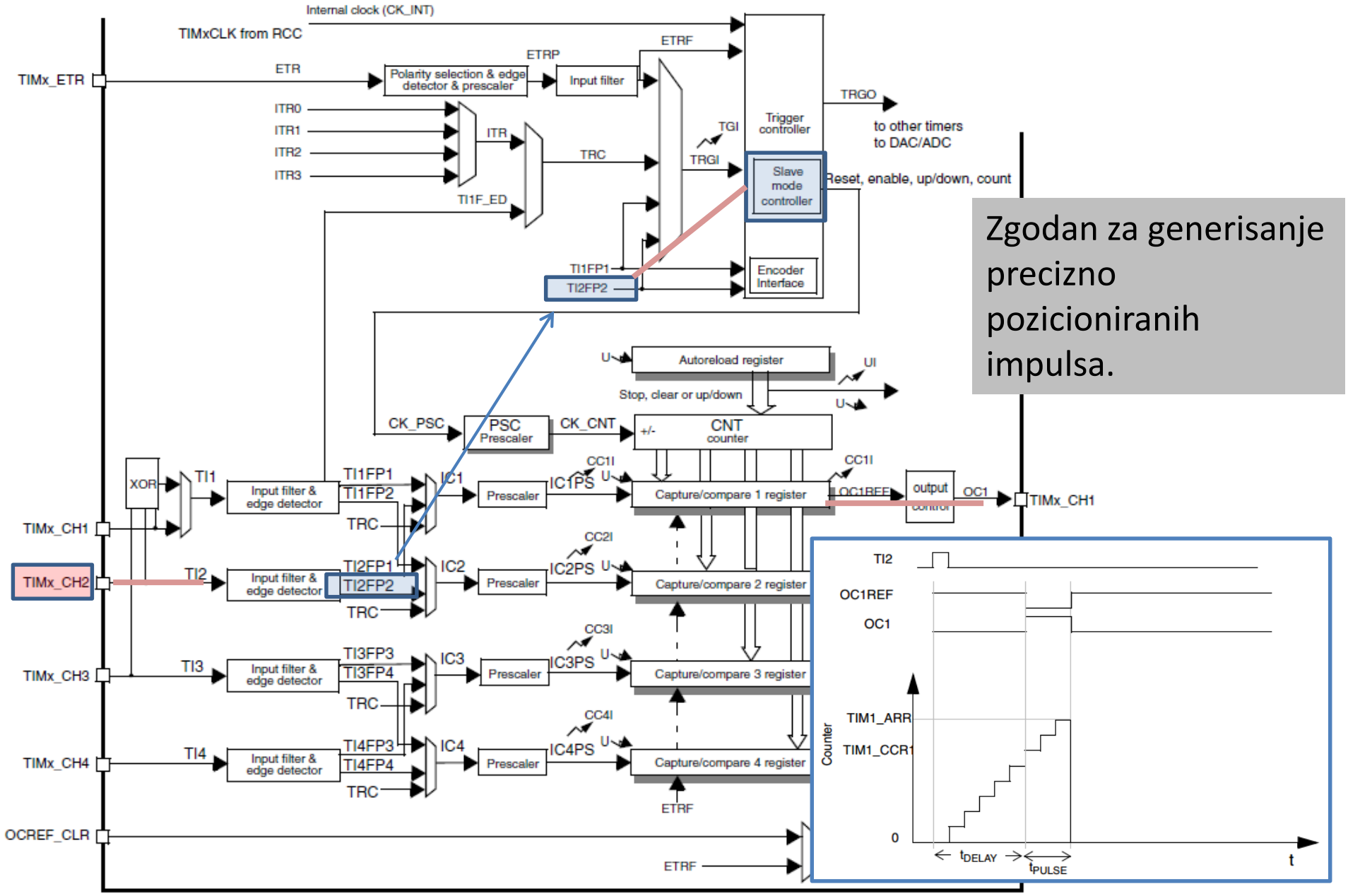
KEIL Osvežava promenljive u realnom vremenu



Zadatak

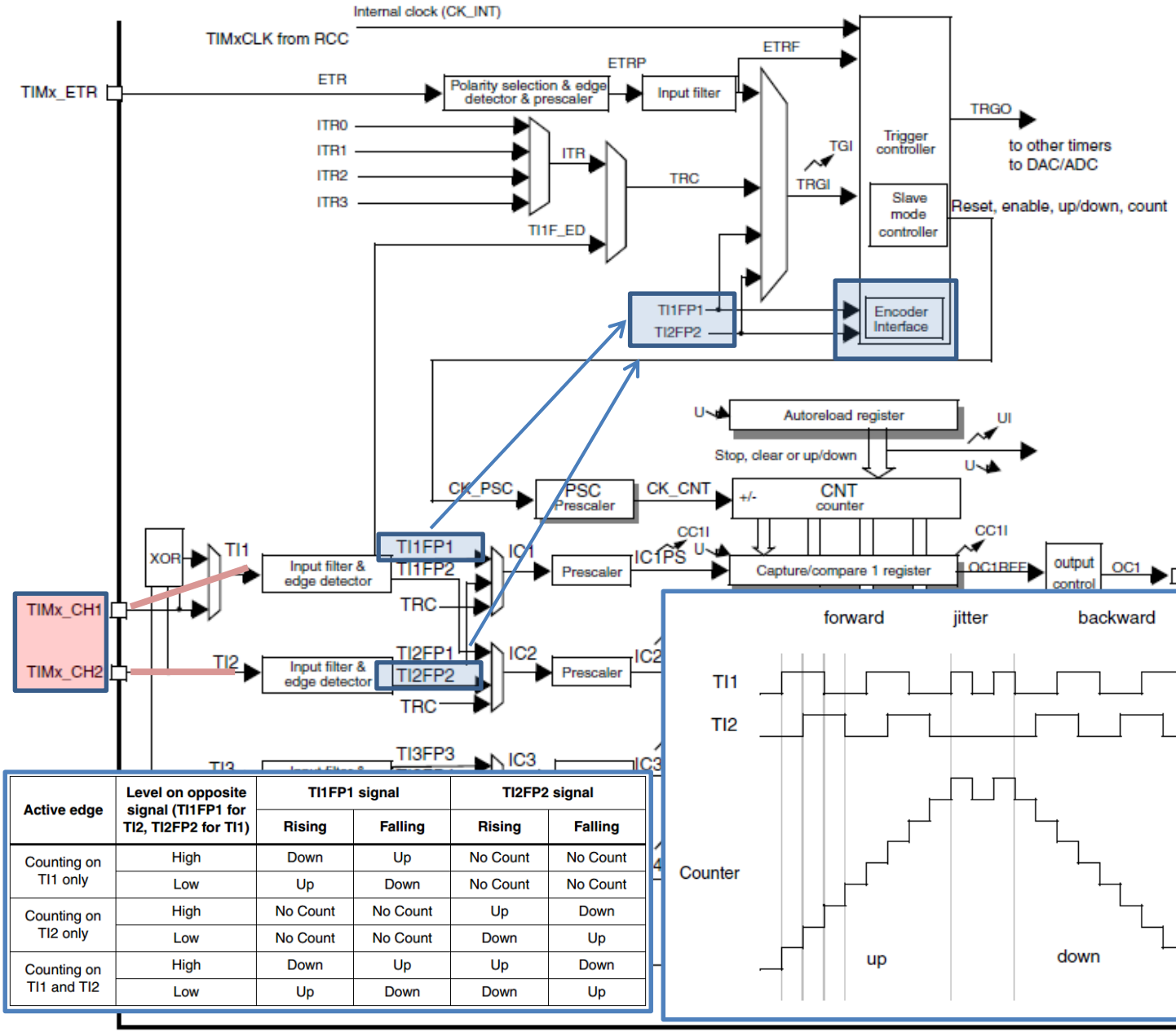
- Implementirati obe funkcionalnosti na MBED platformi.
- PWMOutput je izuzetno lako implementirati.
- PWMInput nema direktnu podršku...
- Ideja za PWMInput:
  a) Uvede se jedan Ticker tajmer koji radi nekom velikom brzinom i inkrementira neku promenljivu *time*.
  b) Ulazni signal se poveže na neka dva InterruptIn ulaza koji generišu prekide na rastuću i opadajuću ivicu.
  c) U prekidima se očitava promenljiva *time* i na osnovu sukcesivnih vrednosti se računaju parametri..

One pulse mod



Zgodan za generisanje precizno pozicioniranih impulsa.

Encoder interface

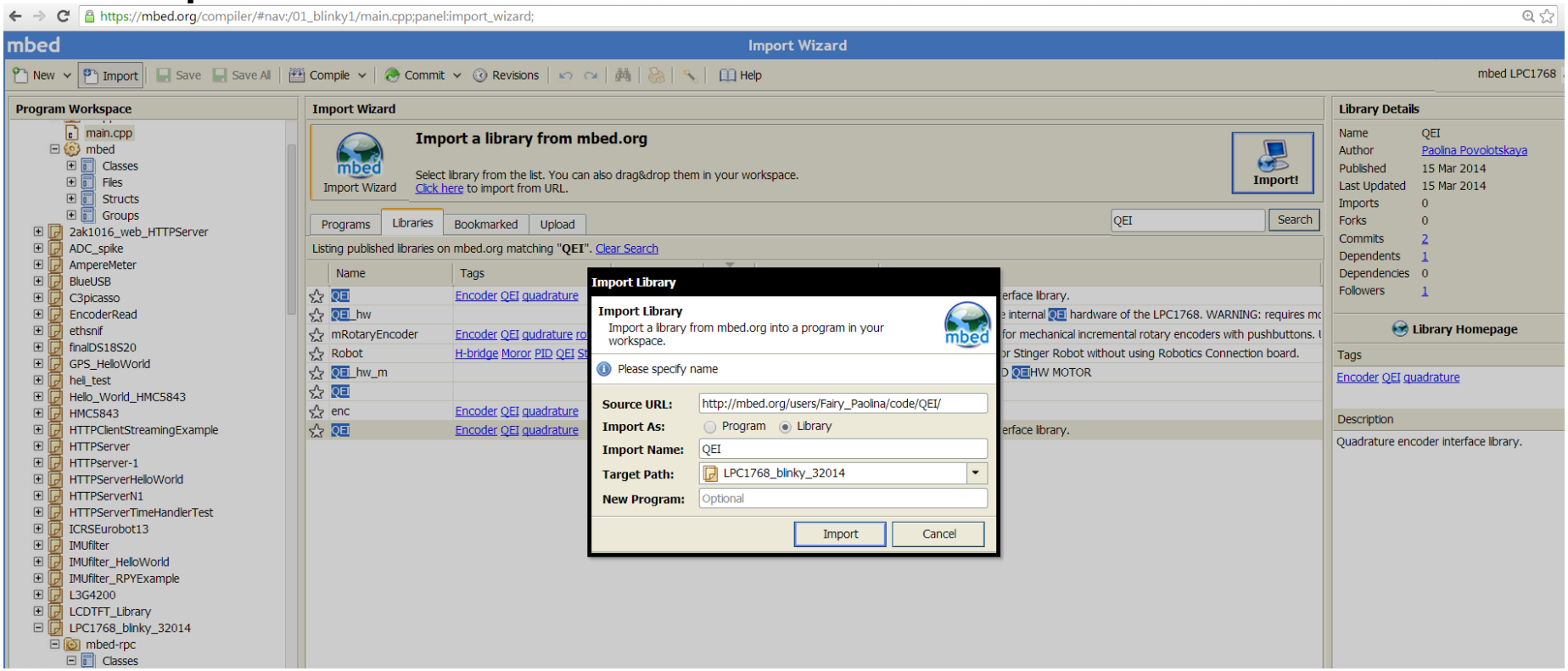


Povezivanje kvadraturnog enkodera na kanalima 1 i 2 u svim modovima brojanja: x1, x2, x4.

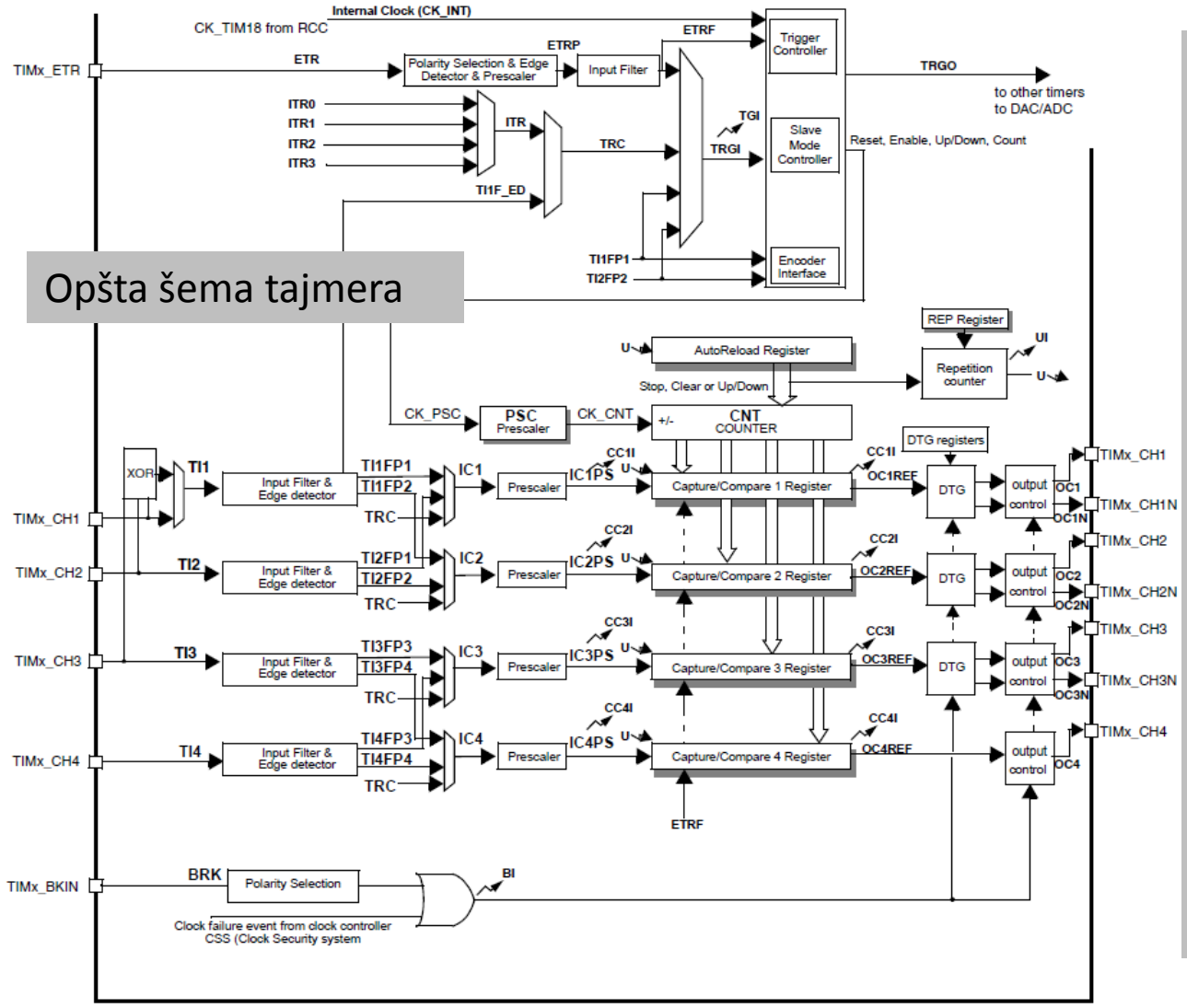
Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No Count	No Count
	Low	Up	Down	No Count	No Count
Counting on TI2 only	High	No Count	No Count	Up	Down
	Low	No Count	No Count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

Encoder i MBED????

- Osnovna MBED biblioteka ne definiše klasu za encoder interfejs, ali postoje projekti i biblioteke u pokviru MBED baze. Doduše za LPC1768...



TIM1– Advanced control timer

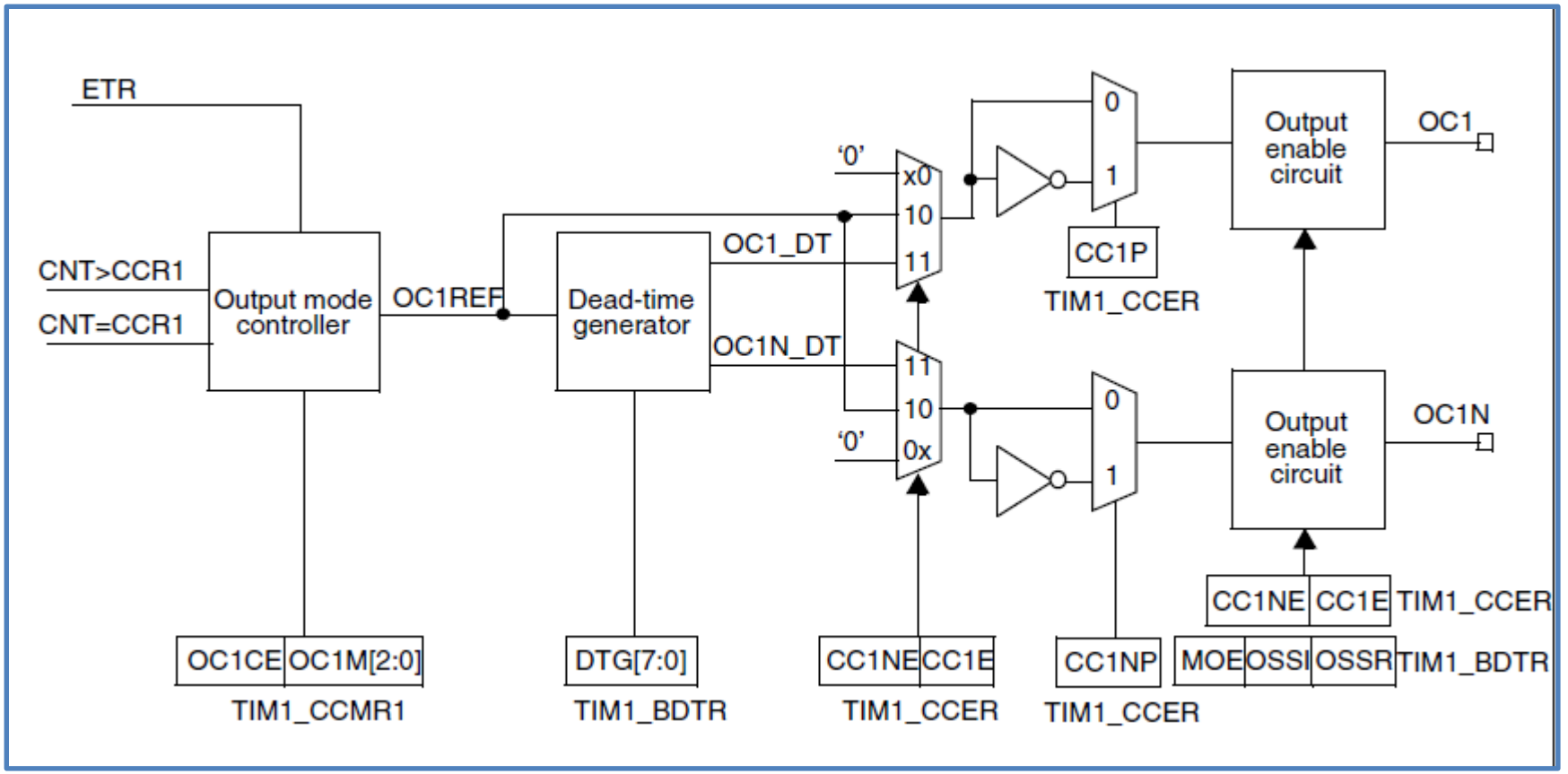


Opšta šema tajmera

Pored osobina tajmera opšte namene poseduje sledeće specifičnosti:

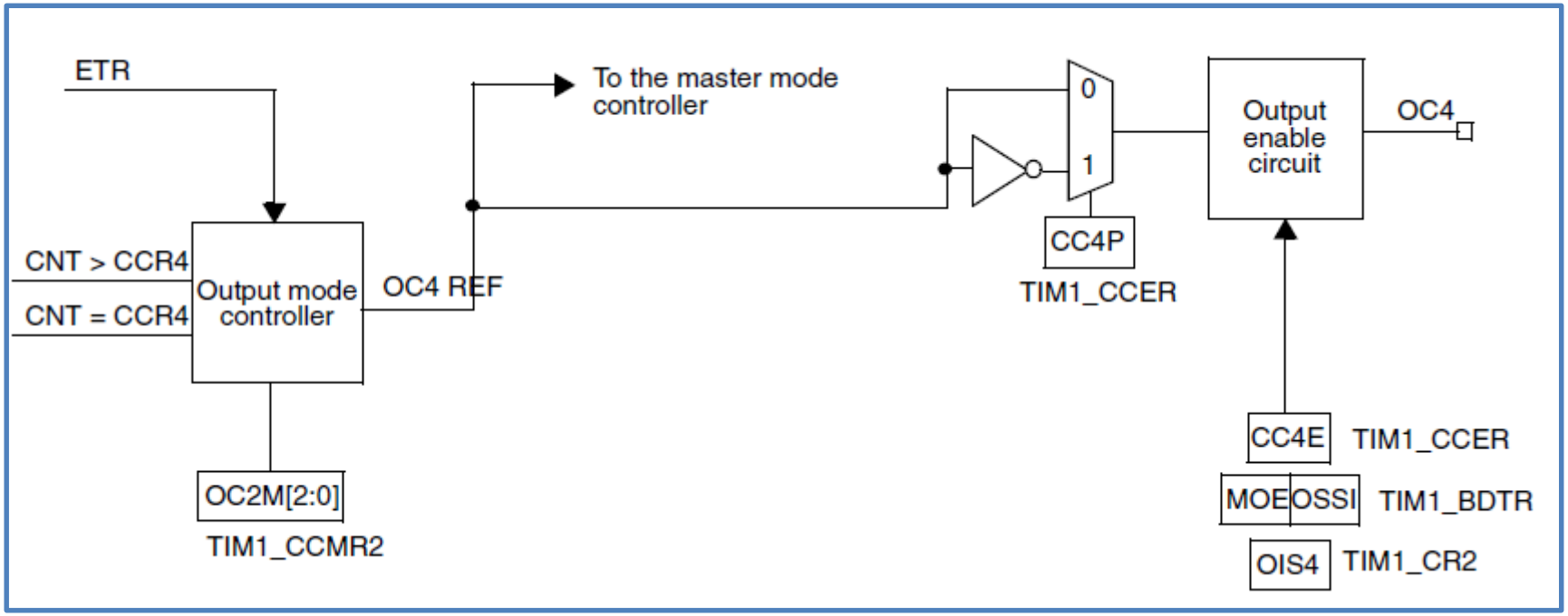
- Komplementarni izlazi sa programabilnim mrtvim vremenom.
- Break signal koji jednovremeno deaktivira sve izlaze.
- Brojač ponavljanja koji obezbeđuje ažuriranje tajmerskih registara tek posle određenog broja ciklusa.
- Interfejs prema trofaznom hall-effect senzoru.

Izlazni stepen Output Capture jedinice – Kanali 1,2,3



TIM1 - Kanal 4

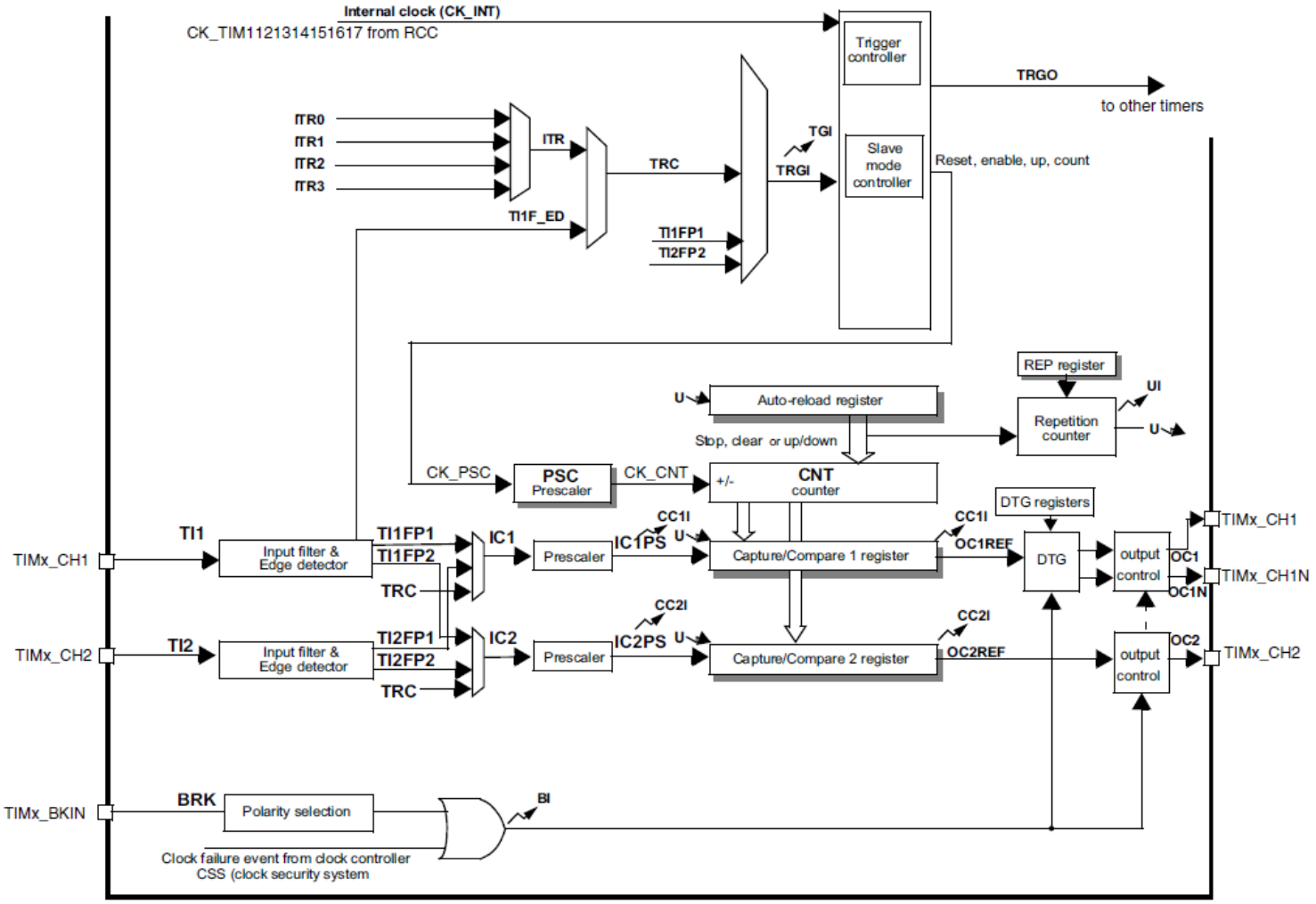
- Kanal 4 je pojednostavljene strukture jer se TIM1 obično koristi u trofaznim PWM generatorima u kojima se sedmi kanal koristi uglavnom za potrebe “kočenja”.



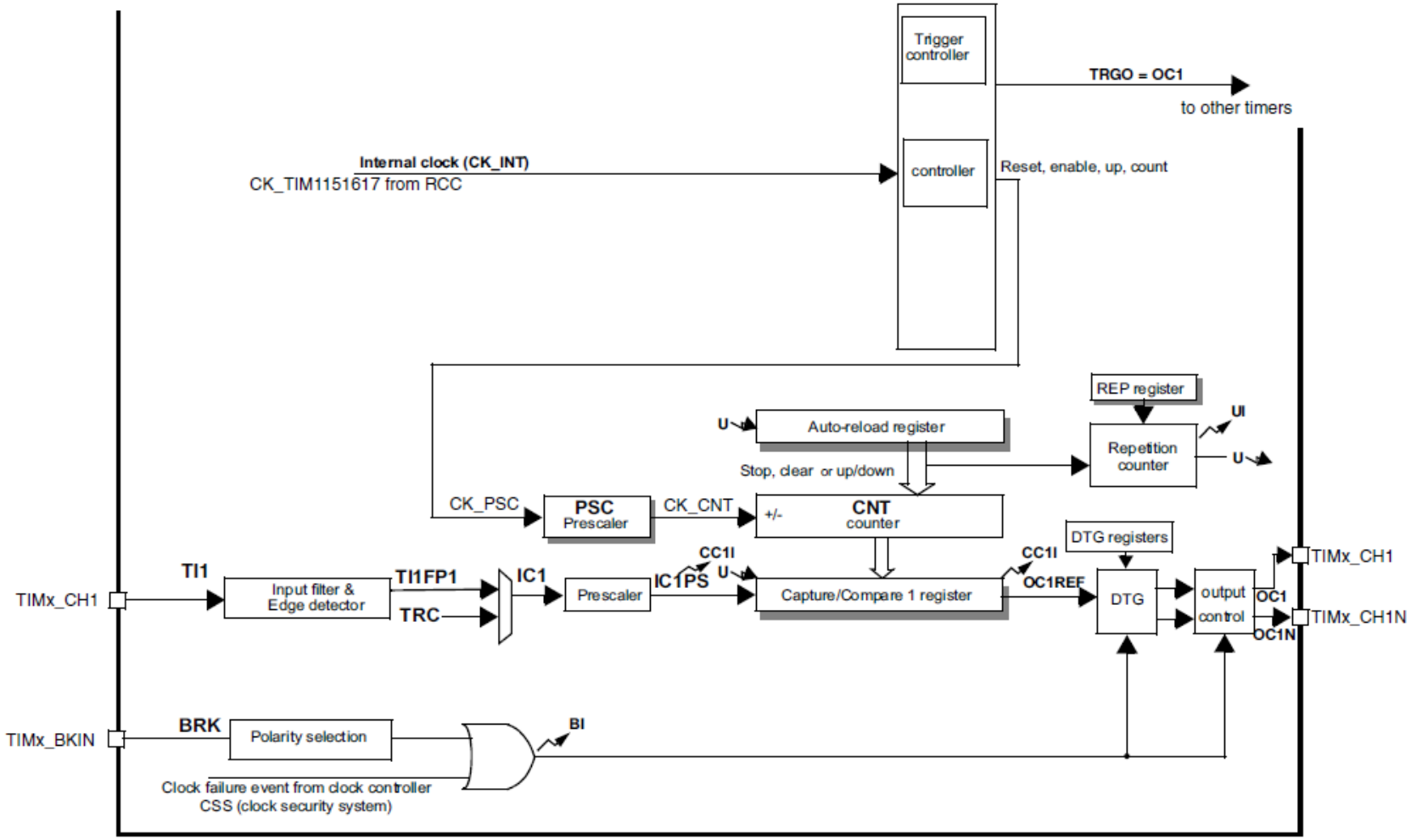
Tajmeri TIM15, TIM16, TIM17

- 16-bitni brojač na gore.
- 16-bitni preskaler za ulazni takt
- 1 (tim15) ili 2 (tim16, tim17) nezavisna kanala koji mogu da rade u izlaznom (output comapre), ulazno (input capture), PWM ili pojedinačnom impulsnom modu.
- Mogućnost sinhronizacije sa ostalim tajmerima.
- Prekid zahtev za sledeće događaje:
  - Input capture
  - Output compare
  - Reload tajmera, inicijalizacija (softverska ili spoljašnja)
- Podržan je DMA prenos
- Uvek postoji jedan komplementarni izlaz.
- Brojač ponavljanja.

TIM15

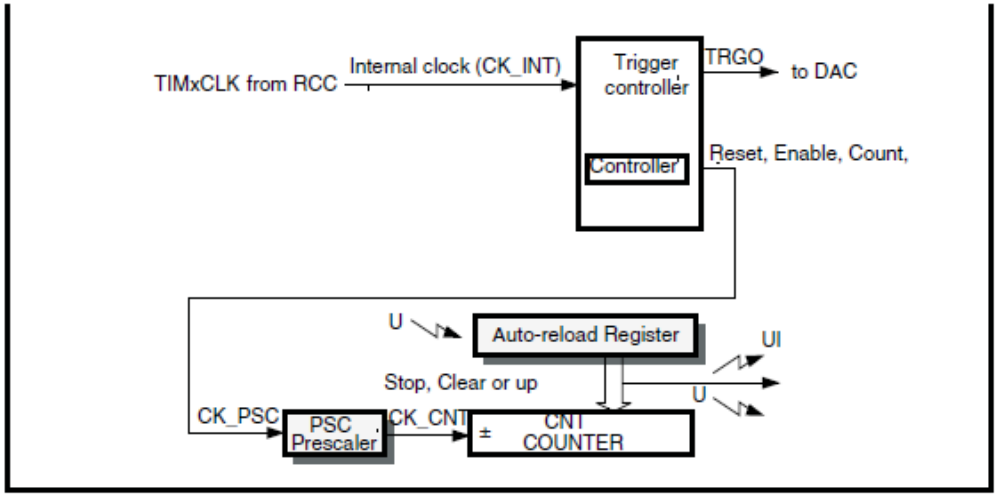

Internal clock (CK_INT)
CK_TIM1121314151617 from RCC
Trigger controller
TRGO
to other timers
ITR0
ITR1
ITR2
ITR3
ITR
TRC
TGI
TRGI
Slave mode controller
Reset, enable, up, count
TI1F_ED
TI1FP1
TI2FP2
REP register
UI
U
Auto-reload register
Repetition counter
Stop, clear or up/down
CK_PSC
PSC Prescaler
CK_CNT
+/-
CNT counter
DTG registers
TI1
TIMx_CH1
Input filter & Edge detector
TI1FP1
TI1FP2
TRC
IC1
CC1I
IC1PS
Prescaler
Capture/Compare 1 register
OC1REF
DTG
output control
OC1
OC1N
TIMx_CH1
TIMx_CH1N
TI2
TIMx_CH2
Input filter & Edge detector
TI2FP1
TI2FP2
TRC
IC2
CC2I
IC2PS
Prescaler
Capture/Compare 2 register
OC2REF
output control
OC2
TIMx_CH2
TIMx_BKIN
BRK
Polarity selection
BI
Clock failure event from clock controller
CSS (clock security system

TIM16, TIM17


Trigger controller
TRGO = OC1
to other timers
Internal clock (CK_INT)
CK_TIM1151617 from RCC
controller
Reset, enable, up, count
REP register
UI
U
Auto-reload register
Repetition counter
U
Stop, clear or up/down
CK_PSC
PSC
Prescaler
CK_CNT
+/-
CNT
counter
DTG registers
CC1I
CC1I
TI1
TIMx_CH1
Input filter & Edge detector
TI1FP1
TRC
IC1
Prescaler
IC1PS
U
Capture/Compare 1 register
OC1REF
DTG
output control
OC1
OC1N
TIMx_CH1
TIMx_CH1N
BRK
TIMx_BKIN
Polarity selection
BI
Clock failure event from clock controller
CSS (clock security system)

Osnovni tajmeri (Basic Timer) TIM6 i TIM7

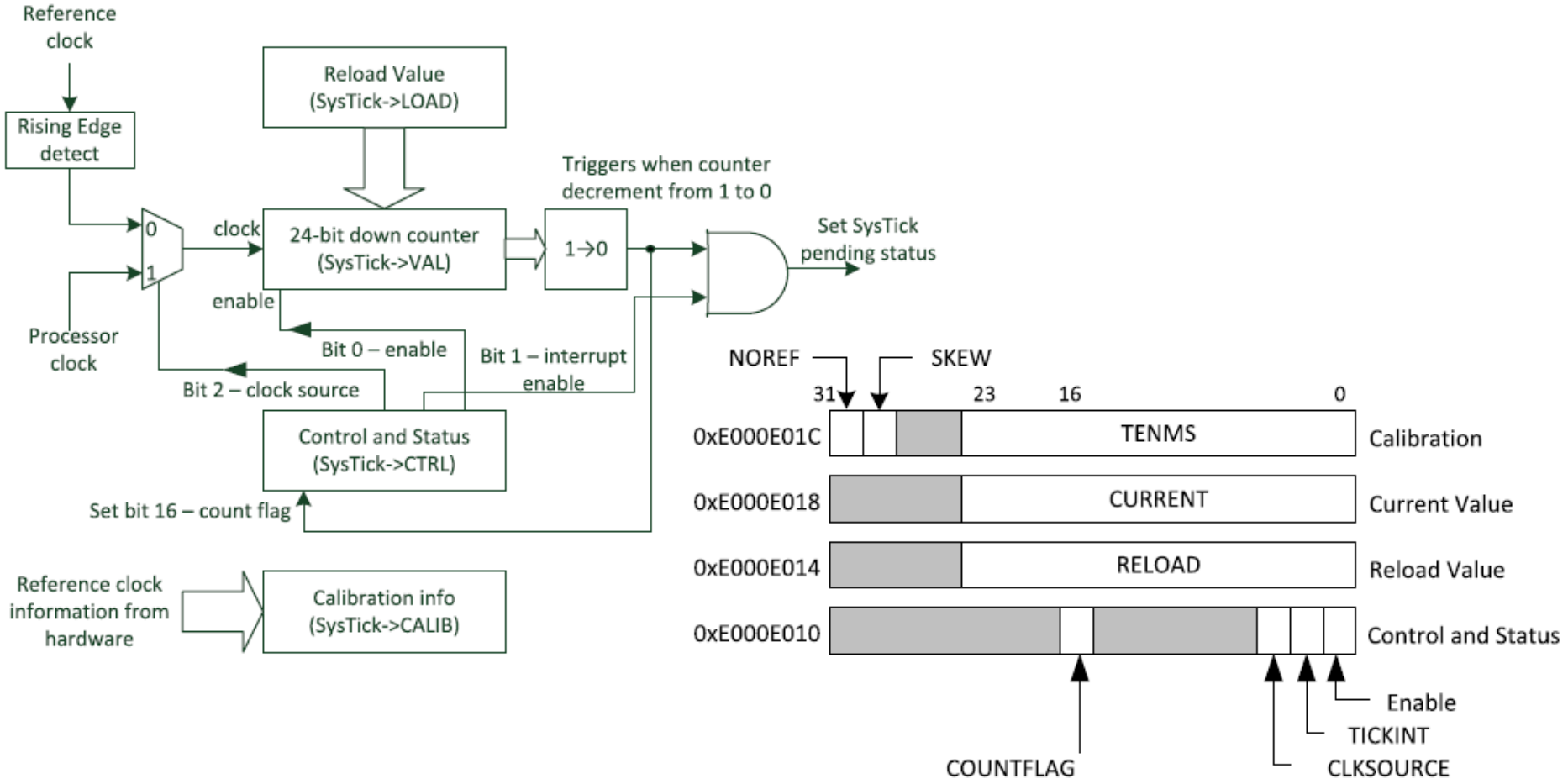
- 16-bitni brojač na gore.
- 16-bitni preskaler za ulazni takt.
- Mogućnost startovanja DAC-a.
- Prekid i DMA zahtev overflow događaj.
- Podržan je DMA prenos.
- Uvek postoji jedan komplementarni izlaz.
- Brojač ponavljanja.



Systick tajmer

- Fleksibilni sistemski tajmer
- Sastavni deo procesorskog CORTEX-M4 jezgra.
- 24-bit auto-reload brojač na dole sa posebnim prekidom.
- 2 konfigurabilna izvora takta
- Pogodan za realizaciju real-time operativnih sistema.
- U STM32L4x5/6 seriji takt za ovu periferiju može bili ili CPU takt ili CPU/8 takt. Ovo se konfiguriše u RCC grupi registara.
- S obzirom da je deo procesorskog jezgra definicije funkcija koje konfigurišu rad časovnika se nalaze u okviru core_cm4.h fajla koji obezbeđuje ARM.
- Neke od high level funkcija može da obezbedi i proizvođač mikrokontrolera i one se nalaze u okviru peripheral drajver biblioteke i to u sastavu misc.h fajla.

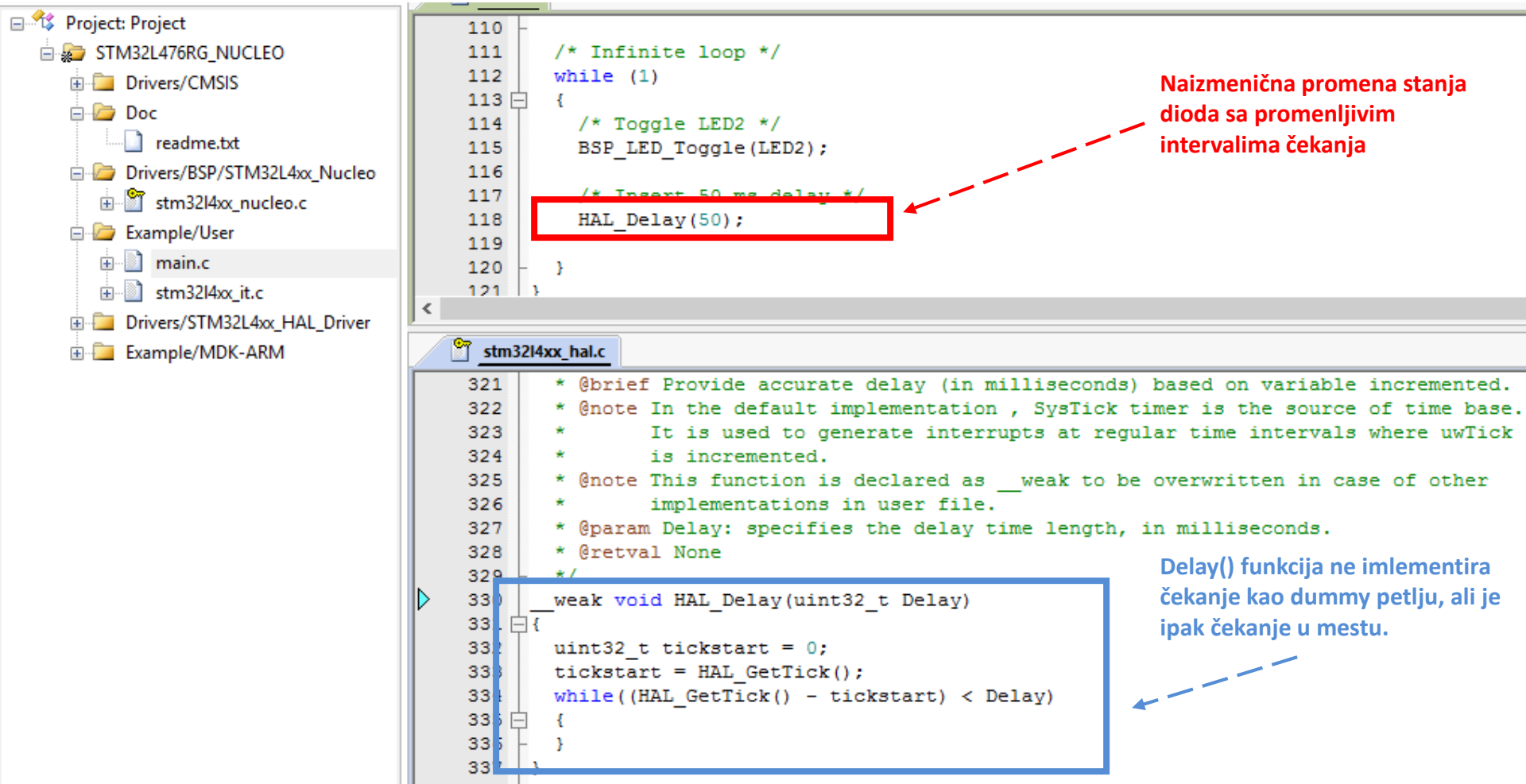
Systick timer



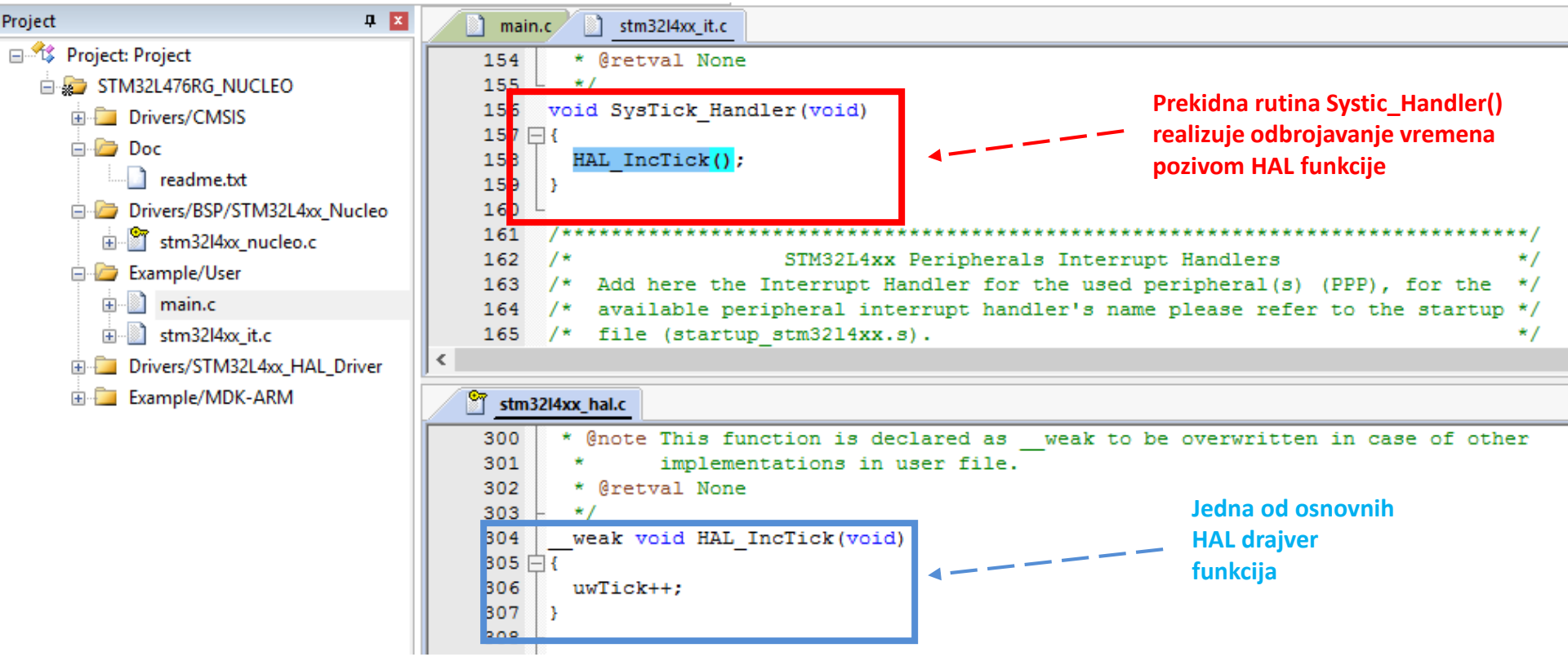
STM CUBE

Projekat CORTEXM_SysTick

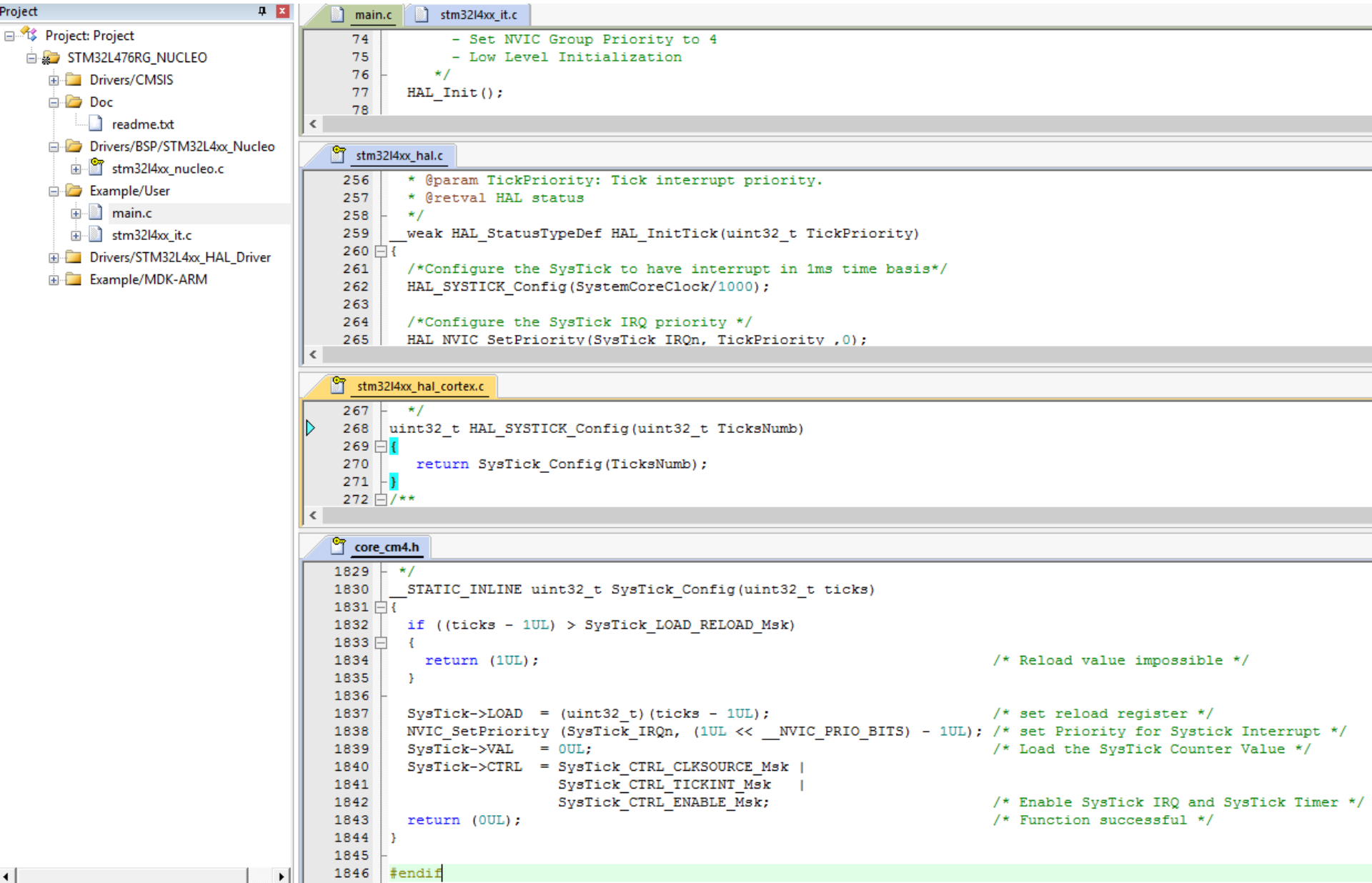
\\stm32cubel4\STM32Cube_FW_L4_V1.4.0\Projects\STM32L476RG-Nucleo\Examples\Cortex\CORTEXM_SysTick\MDK-ARM



Realizacija preko prekida



Inicijalizacija Systick tajmera



Zadatak

- Izmeniti program tako da se prekid sistemskog tajmera generiše sa učestanošću od 500Hz.
- Dakle u pitanju je perioda od 2ms. Gde je najjednostavnije izvršiti izmenu?

Klasa Timer – merenje vremena

http://mbed.org/handbook/Timer

- Klasa koja može da se koristi prilikom testiranja za merenje vremena.

```
#include "mbed.h"

Timer t;

int main() {
    t.start();
    printf("Hello World!\n");
    t.stop();
    printf("The time taken was %f
   seconds\n", t.read());
}
```

Timer Class Reference

`#include <Timer.h>`

Public Member Functions

void start ()
Start the timer.

void stop ()
Stop the timer.

void reset ()
Reset the timer to 0.

float read ()
Get the time passed in seconds.

int read_ms ()
Get the time passed in mili-seconds.

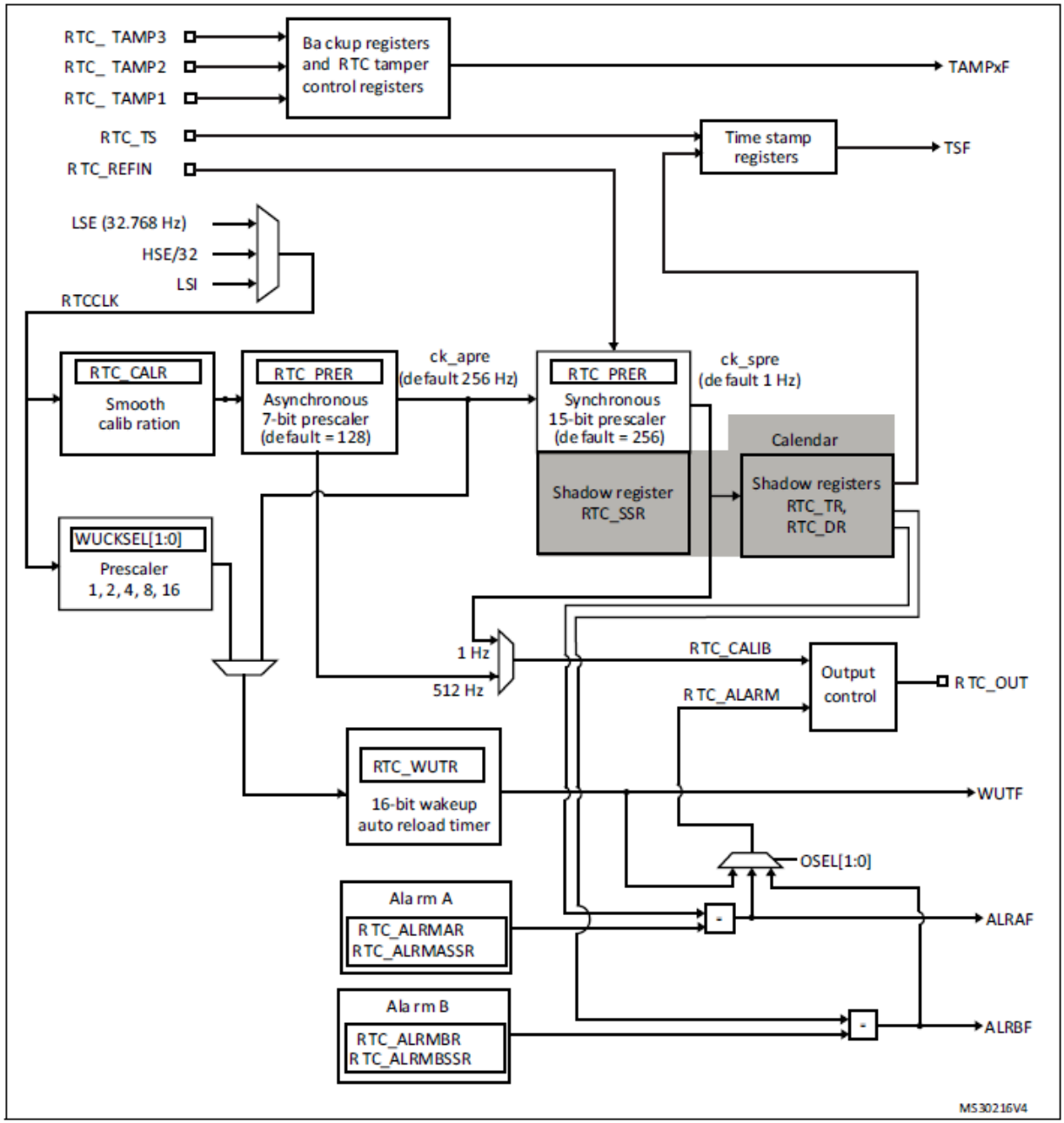
int read_us ()
Get the time passed in micro-seconds.

Real Time Clock - RTC

- The real-time clock (RTC) is an independent BCD timer/counter. The RTC provides a timeof-day clock/calendar with programmable alarm interrupts.
- Two 32-bit registers contain the seconds, minutes, hours (12- or 24-hour format), day (day of week), date (day of month), month, and year, expressed in binary coded decimal format (BCD). The sub-seconds value is also available in binary format.
- Compensations for 28-, 29- (leap year), 30-, and 31-day months are performed automatically. Daylight saving time compensation can also be performed.
- Additional 32-bit registers contain the programmable alarm subseconds, seconds, minutes, hours, day, and date.
- As long as the supply voltage remains in the operating range, the RTC never stops, regardless of the device status (Run mode, low-power mode or under reset).

RTC

- Two alarms
- Three tamper events
- 32 x 32-bit backup registers – The backup registers (RTC_BKPxR) are implemented in the RTC domain that remains powered-on by VBAT when the VDD power is switched off.



Sat realnog vremena – RTC

- Za podršku su kreirane MBED funkcije, ali ne postoji klasa RTC. Funkcije su deklarisane u time.h i rtc_time.h.

time FUNCTIONS	Implementation of the C time.h functions
time	Get the current time
set_time	Set the current time
mktime	Converts a tm structure in to a timestamp
localtime	Converts a timestamp in to a tm structure
ctime	Converts a timestamp to a human-readable string
strftime	Converts a tm structure to a custom format human-readable string

RTC

```
#include "mbed.h"
int main() {
    set_time(1493834400);  // Set RTC time to Wed, 3 May 2017 18:00:00
    while(1) {
        time_t seconds = time(NULL);
        printf("Time as seconds since January 1, 1970 = %d\n", seconds);
        printf("Time as a basic string = %s", ctime(&seconds));
        char buffer[32];
        strftime(buffer, 32, "%I:%M %p\n", localtime(&seconds));
        printf("Time as a custom formatted string = %s", buffer);
        wait(1);
    }
}
```