The Timers of the STM32 Microcontrollers

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L.A.P. 1 Course

What is a “timer”?

- A **TIMER** is a circuit that enables the software to have the “knowledge of time”
- It is basically a **global variable** (timer counter) that **increments** (or **decrements**) on the basis of a **programmable clock source**
- The **global variable** (timer counter) can be read or written by the software
- A timer can generate **interrupts**
- A timer can be used by a **slave circuit**:
    - to generate particular periodic signals
    - to measure the period or pulse of input signals

Basics of timers

- The hardware of **TIMER** is composed by three basic programmable parts:
  - The **clock source**, the circuit that generates the clock tick for the timer
  - The **time base**, the circuit that derive the *time granularity* from the clock source and contains the **timer counter variable**
  - The **slave circuits**, that provide additional functions (pulse measure, signal generation, etc.) by exploiting the timer variable

The Timers of the STM32 MCUs

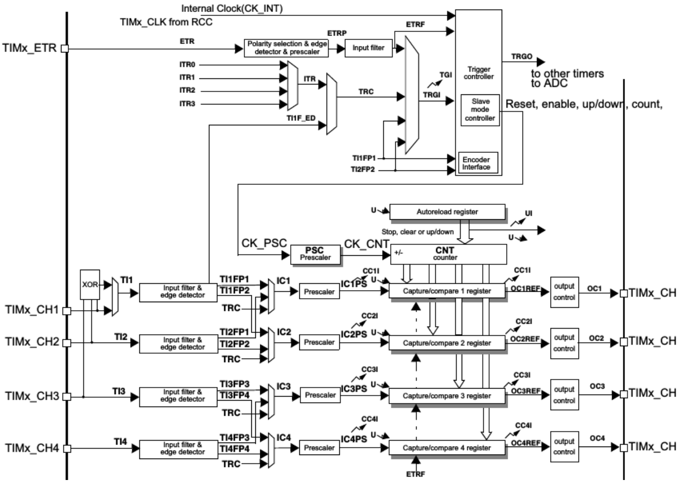
STM32 MCUs offer up to 11 different **timer/counters** with the following features:

- Clock selection (internal, external, other)
- 16/32-bit counter resolution
- Programmable prescaler
- Four independent channels configurable as:
  - Input Capture
  - Output Compare
  - PWM Mode
  - One-pulse Output
- Interrupt generation on the basis of the various events that can occur

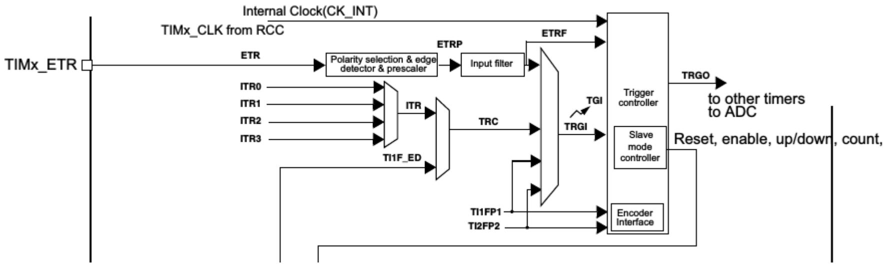
The Software interface of Timers

- Each timer has several special function registers
- All of them are accessible by means of global variables called **`TIMx`**, where **`x`** is the number of the timer (**`TIM1`**, **`TIM2`**, ...)
- The type of these variables is **`TIM_TypeDef *`**, i.e. pointers to a structure whose field are the SFR of the timer

Block Schematics of the Timers



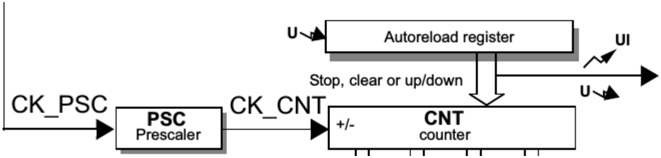
Timer Clock Source



Clock source can be:

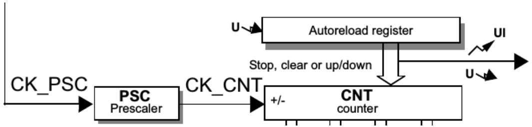
- Internal (System Peripheral Clock, default setting)
- External (External Pin)
- External in QEI mode (Quadrature-encoder interface)
- Several Gate/Trigger inputs can be configured in order to start/stop the clock on the basis of events

Time-Base Part



Counting is handled in the time-base by the following registers:

- **`TIMx->PSC`**: the prescaler register, it directly specified the **division factor**
- **`TIMx->CNT`**: the counter register, it holds the counter value and increments (or decrements) according to the input clock
- **`TIMx->ARR`**: the auto-reload register, **`CNT`** counts from 0 to **`ARR`**, then **`CNT`** is set to 0 again
- When **`CNT`** is **reloaded** an **update event** is generated (the "**U**" in figure), that can trigger **interrupt generation**



Note: Timer functions of stm32_unict_lib currently support timers from TIM2 to TIM5 (but TIM5 is also used by the display)

- Initialize a TIMER:

```
void TIM_init(TIM_TypeDef * timer);
```

- Configure the timebase:

```
void TIM_config_timebase(TIM_TypeDef * timer,
                         uint16_t prescaler,
                         uint16_t autoreload);
```

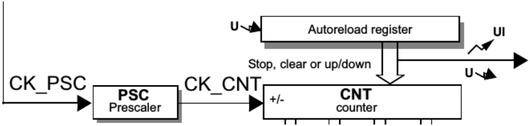
- Start a timer:

```
void TIM_on(TIM_TypeDef * timer);
```

- Stop a timer:

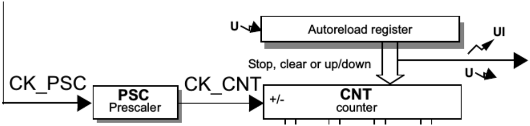
```
void TIM_off(TIM_TypeDef * timer);
```

stm32_unict_lib Functions for Timers



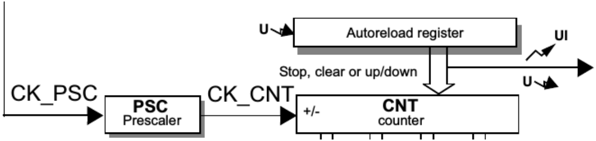
- Read the counter:
  `int16_t TIM_get(TIM_TypeDef * timer);`
- Write the counter:
  `void TIM_set(TIM_TypeDef * timer, int16_t value);`
- Check if an update event occurred:
  `int TIM_update_check(TIM_TypeDef * timer);`
- Clears the update event notification:
  `void TIM_update_clear(TIM_TypeDef * timer);`

Example: let's flash a LED at 500 ms



- Default clock source **`CK_PSC`** is at 84 *MHz* (about 19 *ns*)
- We must derive a period of 500 *ms*
- We could use a **division factor** of 84000 in order to have a clock count signal (**`CK_CNT`**) at 1 *ms*, but the PSC register has only 16 bits...
- Let's used instead a **division factor** of 8400 in order to have a clock count signal (**`CK_CNT`**) at 0.1 *ms*
- So we must have 5000 counts in order to have a period of 500 *ms*

Example: let's flash a LED at 500 ms



- Let's configure the timebase with **prescaler=8400** and **autoreload=5000**
- Then poll the **"update event"**
- When it occurs, toggle the led and **clear the event**

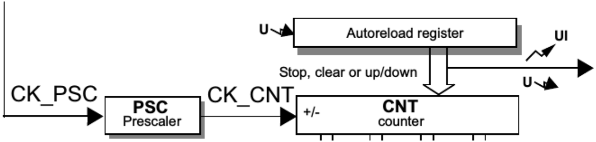
First Example: flashing using timer

```
#include "stm32_unict_lib.h"

int main()
{
    // LED at PC3
    GPIO_init(GPIOC);
    GPIO_config_output(GPIOC, 3);

    // init the timer
    TIM_init(TIM2);

    // Configure the timebase
    // Counter clock set to 0.1 ms
    TIM_config_timebase(TIM2, 8400, 5000);

    TIM_set(TIM2, 0); // resets the counter
    TIM_on(TIM2); // starts the timer

    // infinite loop
    for (;;) {
        // check the update event
        if (TIM_update_check(TIM2)) {
            GPIO_toggle(GPIOC, 3);
            // clear the update event
            TIM_update_clear(TIM2);
        }
    }
}
```

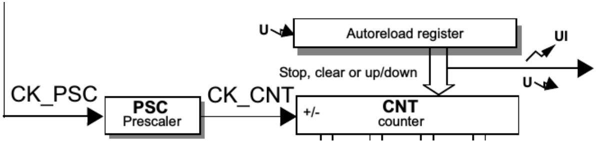
Second Example: flashing controlled by button

```
#include "stm32_unict_lib.h"

int main()
{
    int last_key_state, flashing = 0;
    // LED at PC3
    GPIO_init(GPIOC);
    GPIO_config_output(GPIOC, 3);

    // pushbutton X (PB10)
    GPIO_init(GPIOB);
    GPIO_config_input(GPIOB, 10);

    TIM_init(TIM2);     // init the timer

    // Configure the timebase, counter clock set to 0.1 ms
    TIM_config_timebase(TIM2, 8400, 5000);
    TIM_set(TIM2, 0); // resets the counter
    TIM_on(TIM2); // starts the timer

    last_key_state = GPIO_read(GPIOB, 10);
    for (;;) {
        int current_key_state = GPIO_read(GPIOB, 10);
        if (last_key_state == 1 && current_key_state == 0) flashing = !flashing;
        last_key_state = current_key_state;
        if (TIM_update_check(TIM2)) {
            if (flashing) GPIO_toggle(GPIOC, 3);
            else GPIO_write(GPIOC,3, 0);
            TIM_update_clear(TIM2);
        }
    }
}
```

Using Interrupts



- In a timer, many **events** (apart of the update event) occur
- Any event can be used generate an **IRQ** and thus trigger a proper **interrupt service routine**
- These functionalities are activated by setting proper bits in a timer SFR



- To enable timer IRQ, the following function can be used:

```
void TIM_enable_irq(TIM_TypeDef * timer,
                                           int irq_type);
```

- where `irq_type` is set to the constant `IRQ_UPDATE`
- Once the event is triggered, a specific **interrupt service routine (ISR)** is called, with name `TIMx_IRQHandler`
- The ISR must handle the event and then notify handing via `TIM_update_clear()`

Third Example: flashing using interrupts

```
#include "stm32_unict_lib.h"

int flashing = 0;

int main()
{
    int last_key_state;
    // LED at PC3
    GPIO_init(GPIOC);
    GPIO_config_output(GPIOC, 3);
    // pushbutton X (PB10)
    GPIO_init(GPIOB);
    GPIO_config_input(GPIOB, 10);

    // init the timer
    TIM_init(TIM2);

    // Configure the timebase
    // Counter clock set to 0.1 ms
    TIM_config_timebase(TIM2, 8400, 2500);

    TIM_enable_irq(TIM2, IRQ_UPDATE);
    TIM_set(TIM2, 0); // resets the counter
    TIM_on(TIM2); // starts the timer

    last_key_state = GPIO_read(GPIOB, 10);
    for (;;) {
        int current_key_state = GPIO_read(GPIOB, 10);
        if (last_key_state == 1 && current_key_state == 0) flashing = !flashing;
        last_key_state = current_key_state;
    }
}
```

Third Example: flashing using interrupts (part 2)

```
...
    // Configure the timebase
    // Counter clock set to 0.1 ms
    TIM_config_timebase(TIM2, 8400, 2500);

    TIM_enable_irq(TIM2, IRQ_UPDATE);
    TIM_set(TIM2, 0); // resets the counter
    TIM_on(TIM2); // starts the timer

    last_key_state = GPIO_read(GPIOB, 10);
    for (;;) {
        int current_key_state = GPIO_read(GPIOB, 10);
        if (last_key_state == 1 && current_key_state == 0) flashing = !flashing;
        last_key_state = current_key_state;
    }
}

void TIM2_IRQHandler(void)
{
    if (flashing) GPIO_toggle(GPIOC, 3);
    else GPIO_write(GPIOC,3, 0);
    TIM_update_clear(TIM2);
}
```

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