MICROCHIP

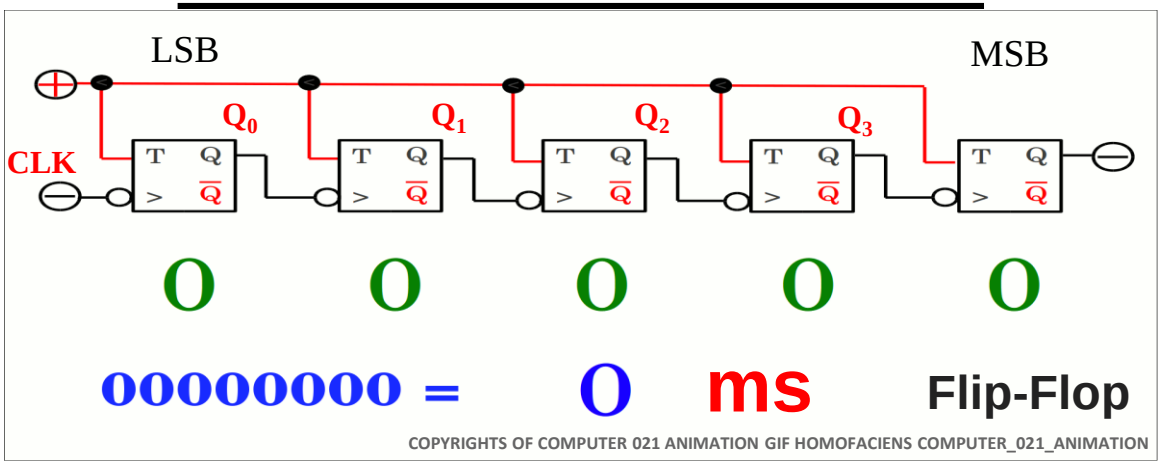
Regional Training Centers

Section 6
Timer/Counter, TC Architecture

Timer or Counter?

- **Counter or Timer is a clock counter, use to count how many clock into module after start.**
- **There are two kinds of generally called Timer or Counter. In fact, it's same.**
  - The Input Clock unknown : Just know how many count, called Counter.
  - The Input Clock known : Can use count and clock period to calculate time, called Timer.
- **Timer can set a notify condition, like overflow, equal some value etc.**
  - If interrupt disable : user must check flag, as soon as possible.
  - If interrupt enable : Timer will notify CPU, if condition is true.

Timer or Counter?



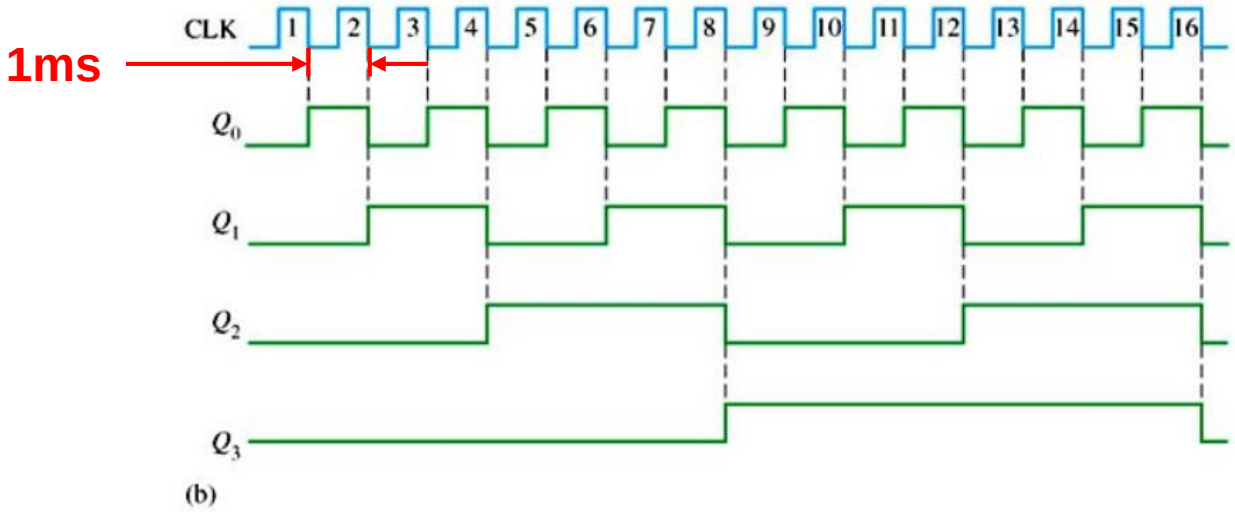


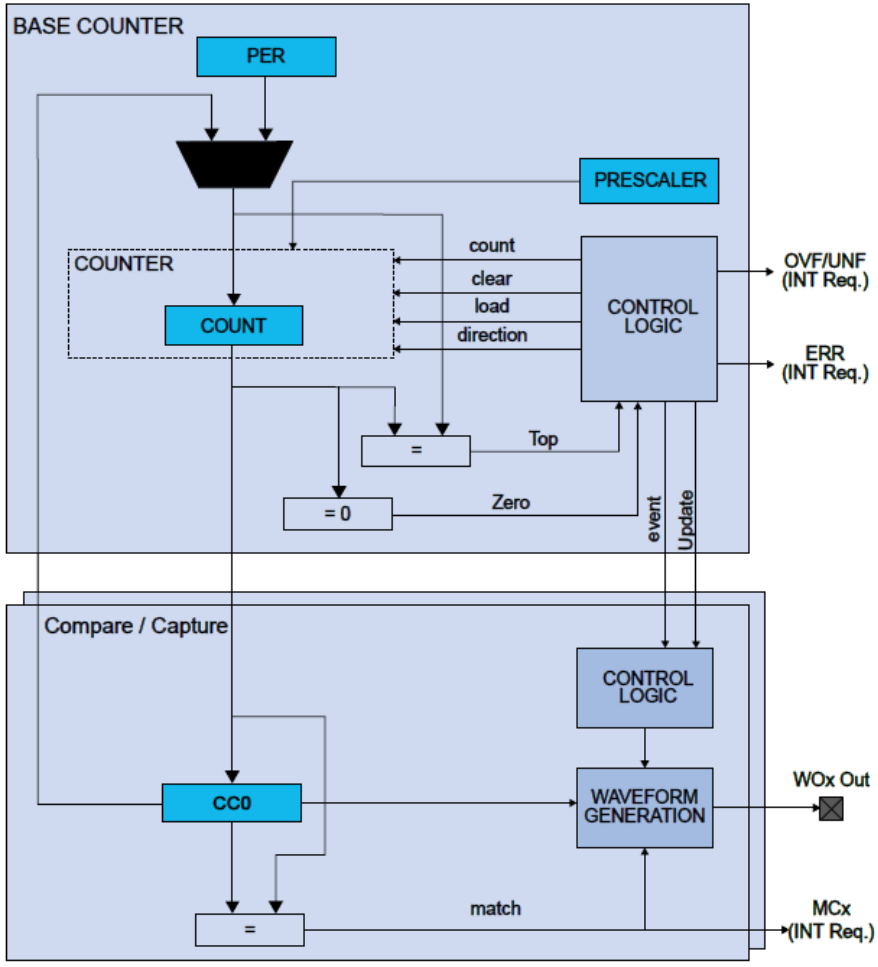
Figure 9--5 Four-bit asynchronous binary counter and its timing diagram.

SAMD21 Timer/Counter

- The SAMD21 Timer/Counter, TC module consists 3 function Counter, Compare and Capture.
- The counter can be set to count events, or it can be configured to count clock pulses. The counter, together with the compare/capture channels, can be configured to timestamp input events, allowing capture of frequency and pulse width.
- It can also perform waveform generation, such as frequency generation and pulse-width modulation (PWM).

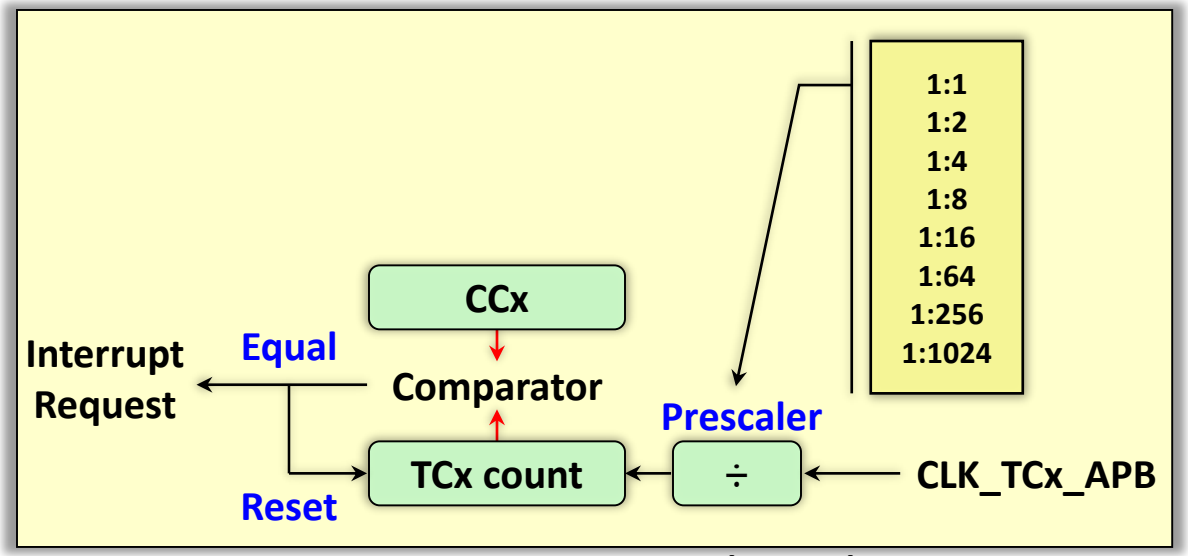
TC Block Diagram

- **SAMD21G18A TC Block Diagram**



SAMD21 Timer/Counter

- Please refer to the block diagram, Just a concept. The real and detail block diagram please refer to the following slide.
- Clock into TCx after prescaler. Comparator continuously compares the values of TCx and CCx. Asserts a into the an interrupt request when equal, and resets TCx to zero.
- You can fill a value to CCx to determine period you want.



Match Frequency Generation (MFRQ), 16Bit, Up count

Prescaler

- TC is 16 Bits counter , counting range from 0 to 65,535. If you need more than the count. You must adjust prescaler to expand the count range.
- For example:
  if the clock in is 0.25uS, to reach a 500mS period, the CC0 must be set to 2,000,000 (2,000,000 * 0.25uS = 500mS).
  However, this value has exceeded the acceptable range of CC0.
  At this point you can set the prescaler to reduce the count value to expand the count range.

$$\left(2^n - 1\right) \leq CC0 = \frac{Peroid}{Clock \times Scale}$$

2,000,000

✗ $CC0 = \frac{500mS}{0.25uS \times 1} \quad CC0 > 65{,}535$

31,250

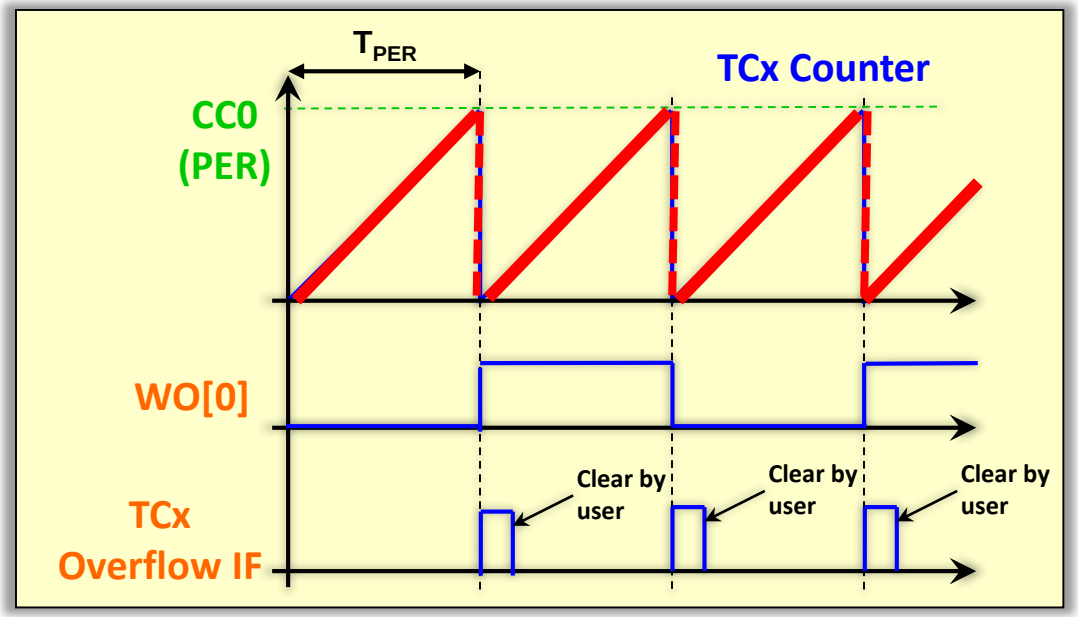
✓ $CC0 = \frac{500mS}{0.25uS \times 64} \quad CC0 < 65{,}535$

Timer/Counter

- **TC provide 4 difference for Timer, Counter and Compare operation mode**
  - **Normal Frequency Generation (NFRQ)**
    toggled on each compare match
  - **Match Frequency Generation (MFRQ)**
    toggles on each update condition
  - **Normal Pulse-Width Modulation Operation (NPWM)**
    toggles on each match & update condition
  - **Match Pulse-Width Modulation Operation (MPWM)**
    toggles on each match & update condition, Count direction reverse.

Match Frequency Generation (MFRQ) Mode

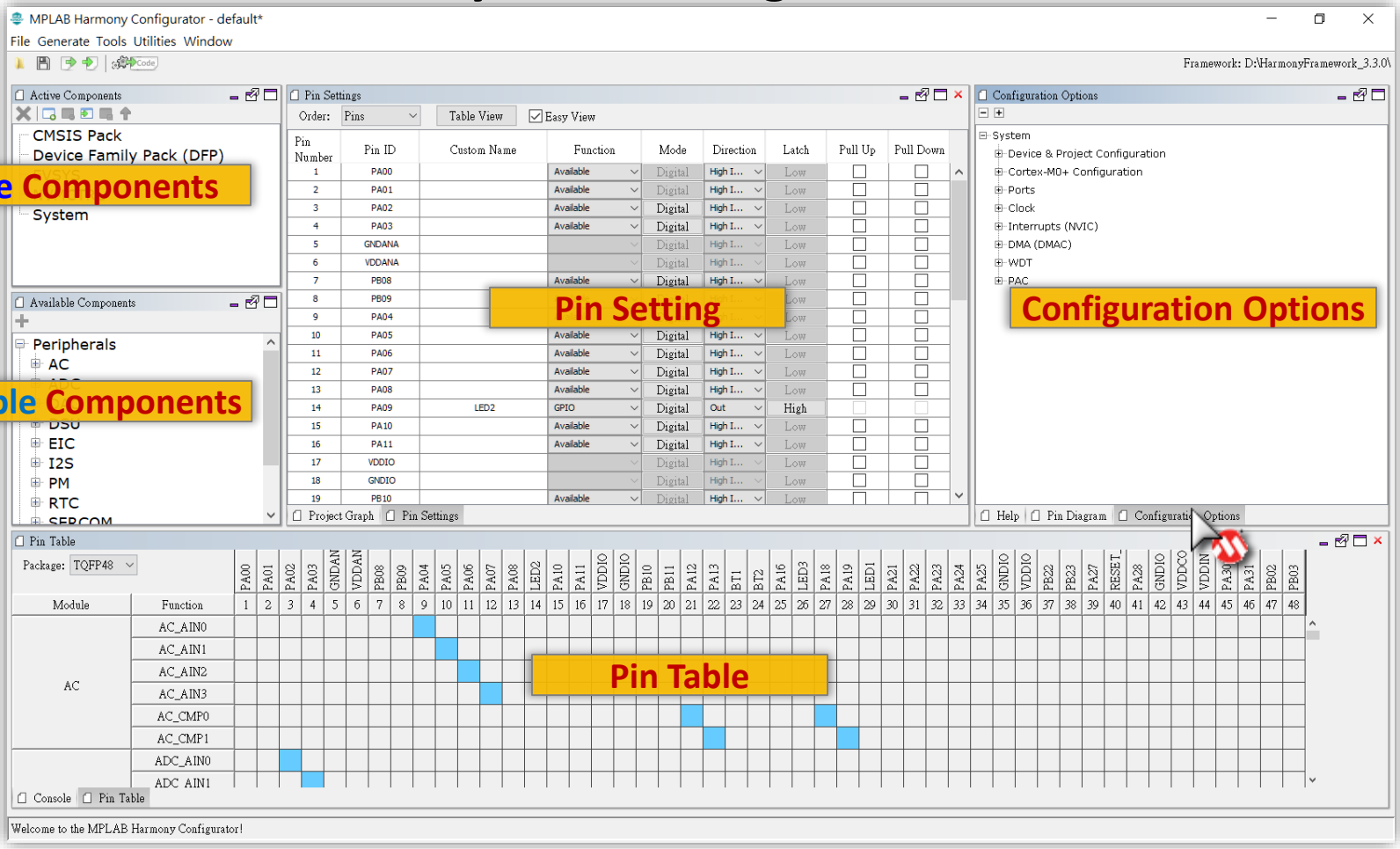
- For Match Frequency Generation, the period time (T_{PER}) is controlled by the CC0 register instead of PER.
  WO[0] toggles on each update condition.



Rule
TCx Counter == CC0 -> WO[0] Toggle

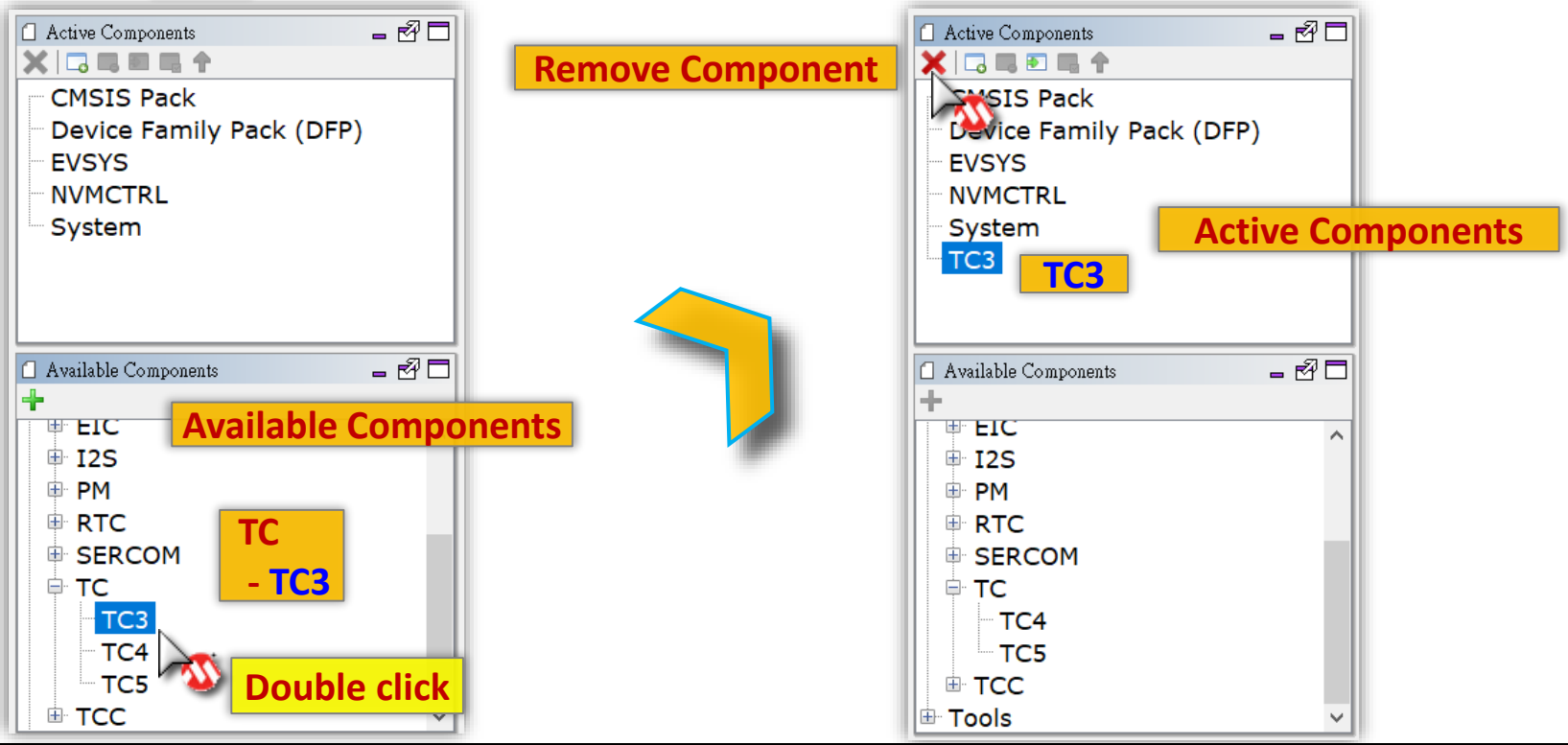
Docking MHC windows

- Return to Harmony and docking windows as below.

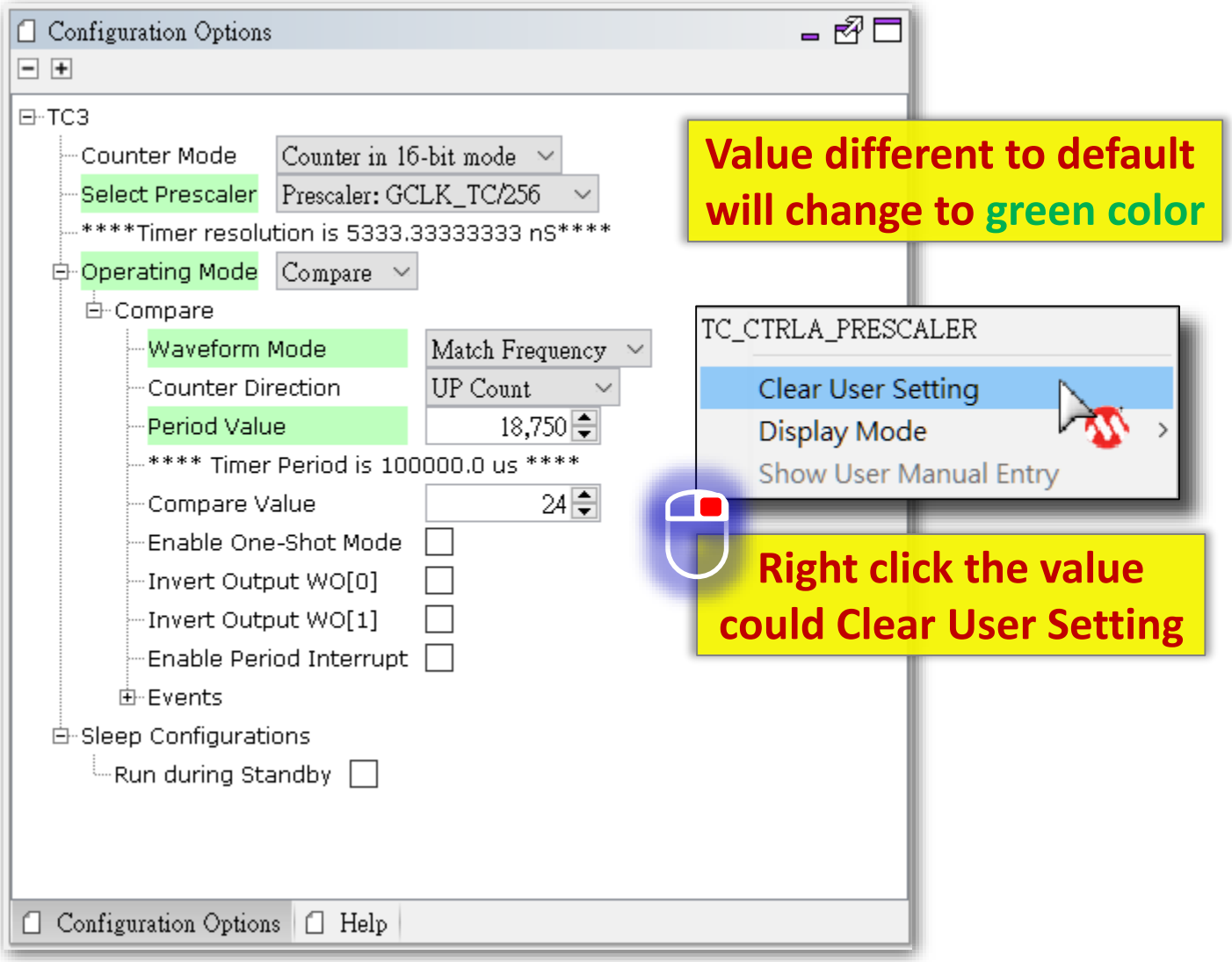


Add TC Function using MHC

- Find TC3 component in Available Components window.
- Double click TC3 to add to Active Components window.
- Click  could remove component from Active window.



TC Configuration Options Example



TC polling Interface Routines

```
/*** TC3 Interface Routines***/
void TC3_CompareInitialize( void );
void TC3_CompareStart( void );
void TC3_CompareStop( void );
uint32_t TC3_CompareFrequencyGet( void );
void TC3_Compare16bitPeriodSet( uint16_t period );
uint16_t TC3_Compare16bitPeriodGet( void );
uint16_t TC3_Compare16bitCounterGet( void );
void TC3_Compare16bitCounterSet( uint16_t count );
TC_COMPARE_STATUS TC3_CompareStatusGet( void );
```

TC Interrupt Flag Event

- **The TC has the following interrupt sources:**
  - **Overflow/Underflow (OVF)**
    Counter overflow/underflow
  - **Match or Capture Channel x (MCx)**
    Compare match or capture
  - **Capture Overflow Error (ERR)**
    New capture interrupt
    occurs while interrupt flag is set.
  - **Synchronization Ready (SYNCRDY)**
    Read/Write synchronization ready.
- **How to get and polling TC overflow interrupt flag status ?**

TC Polling Code Example

TC MFRQ Example

```
…
TC3_CompareStart();

while(1)
{
   if ( TC3_REGS->COUNT16.TC_INTFLAG & TC_COMPARE_STATUS_OVERFLOW )
   {
      TC3_REGS->COUNT16.TC_INTFLAG = TC_COMPARE_STATUS_OVERFLOW;

      LED1_Toggle();
   }
}
```

Bit 0 – OVF Overflow Interrupt Flag

Writing a '0' to this bit has no effect.

Writing a '1' to this bit clears the Overflow interrupt flag.

OR

```
…
TC3_CompareStart();

while(1)
{
   if ( TC3_CompareStatusGet() & TC_COMPARE_STATUS_OVERFLOW )
   {
      LED1_Toggle();
   }
}
```

Lab3 TC MFRQ Polling

- Try to use TC3 to replace software delay to control LED1(PA20) continues toggle.
- The TC3 setup to MFRQ, 16 bit mode, Timer period is 100mS.
- Enable waveform output of TC3 on pin PA18 and PA19.

- Let's go!

Lab3 TC MFRQ Polling

Step 1

Configuration Options

- TC3
  - Counter Mode: Counter in 16-bit mode — **16-bit mode**
  - Select Prescaler: Prescaler: GCLK_TC/256 — **GCLK_TC/256**
  - ****Timer resolution is 5333.33333333 nS****
  - Operating Mode: Compare — **Compare**
    - Compare
      - Waveform Mode: Match Frequency — **MFRQ**
      - Counter Direction: UP Count — **UP count**
      - Period Value: 18,750 — **18750 (CC0)**
      - **** Timer Period is 100000.0 us ****
      - Compare Value: 24 — **Unused (CC1)**
      - Enable One-Shot Mode ☐
      - Invert Output WO[0] ☐
      - Invert Output WO[1] ☐
      - Enable Period Interrupt ☐ — **Don't check**
      - Events
  - Sleep Configurations
    - Run during Standby ☐

Configuration Options | Help

System Clock = 48MHz

One second counts of system clock :

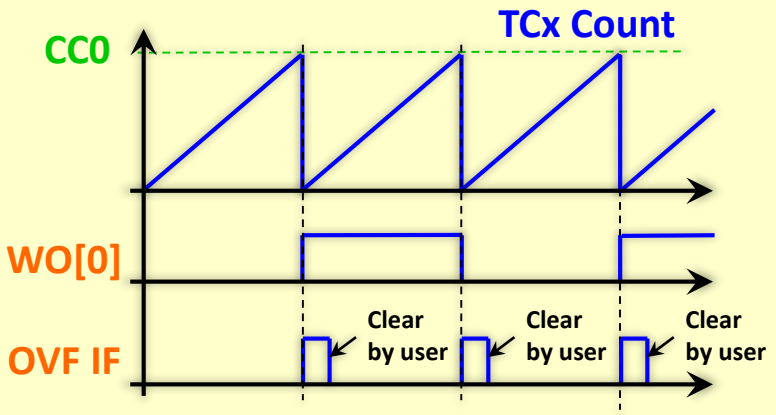
48,000,000 counts

One second counts after Prescaler :

48000000 / 256 **187,500 counts**

100ms counts for LAB3 target :

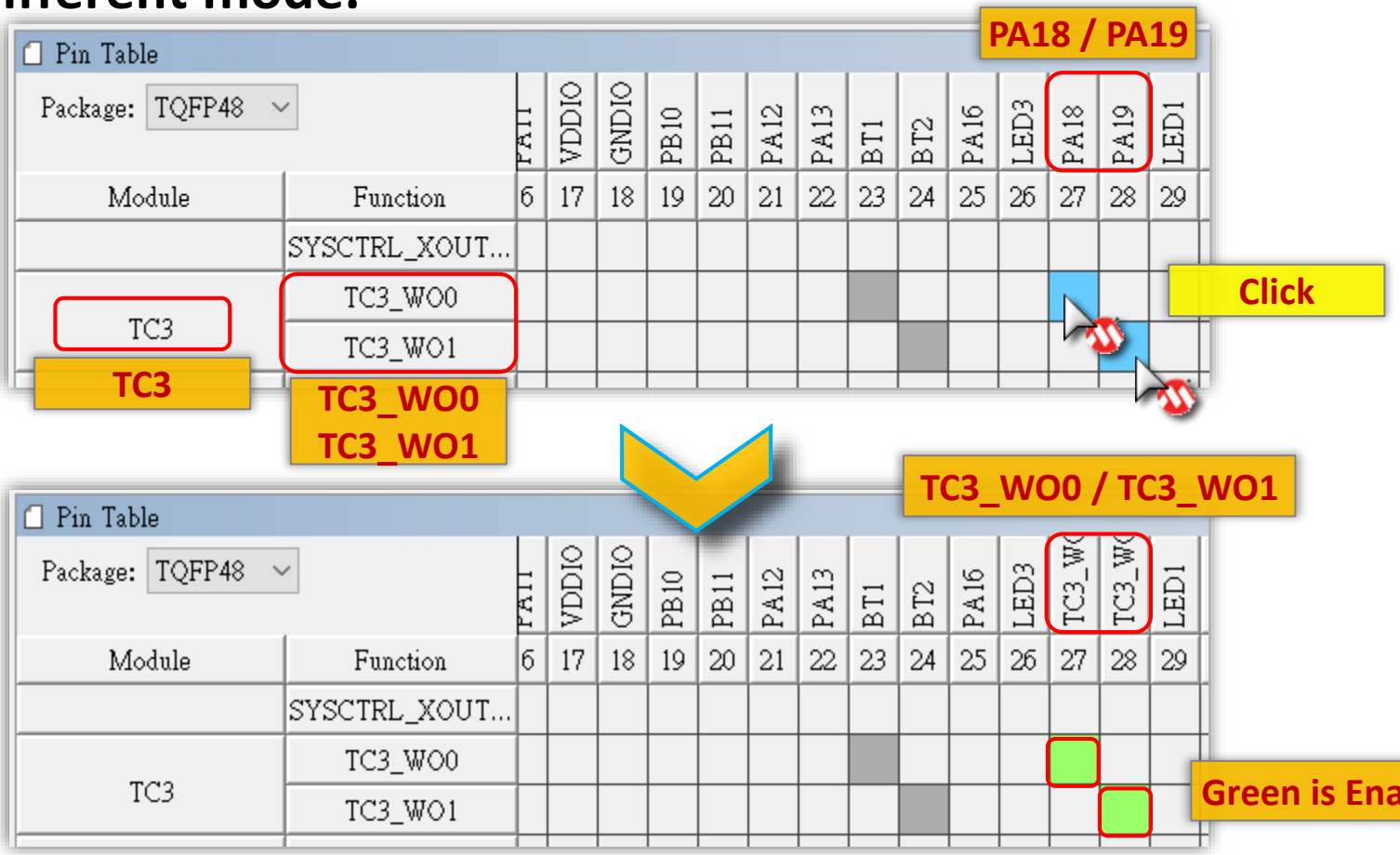
187500 / 10 **18,750 counts**



Lab3 TC MFRQ Polling

Step 2

- TC support waveform output through WO[x] pin depend on different mode.

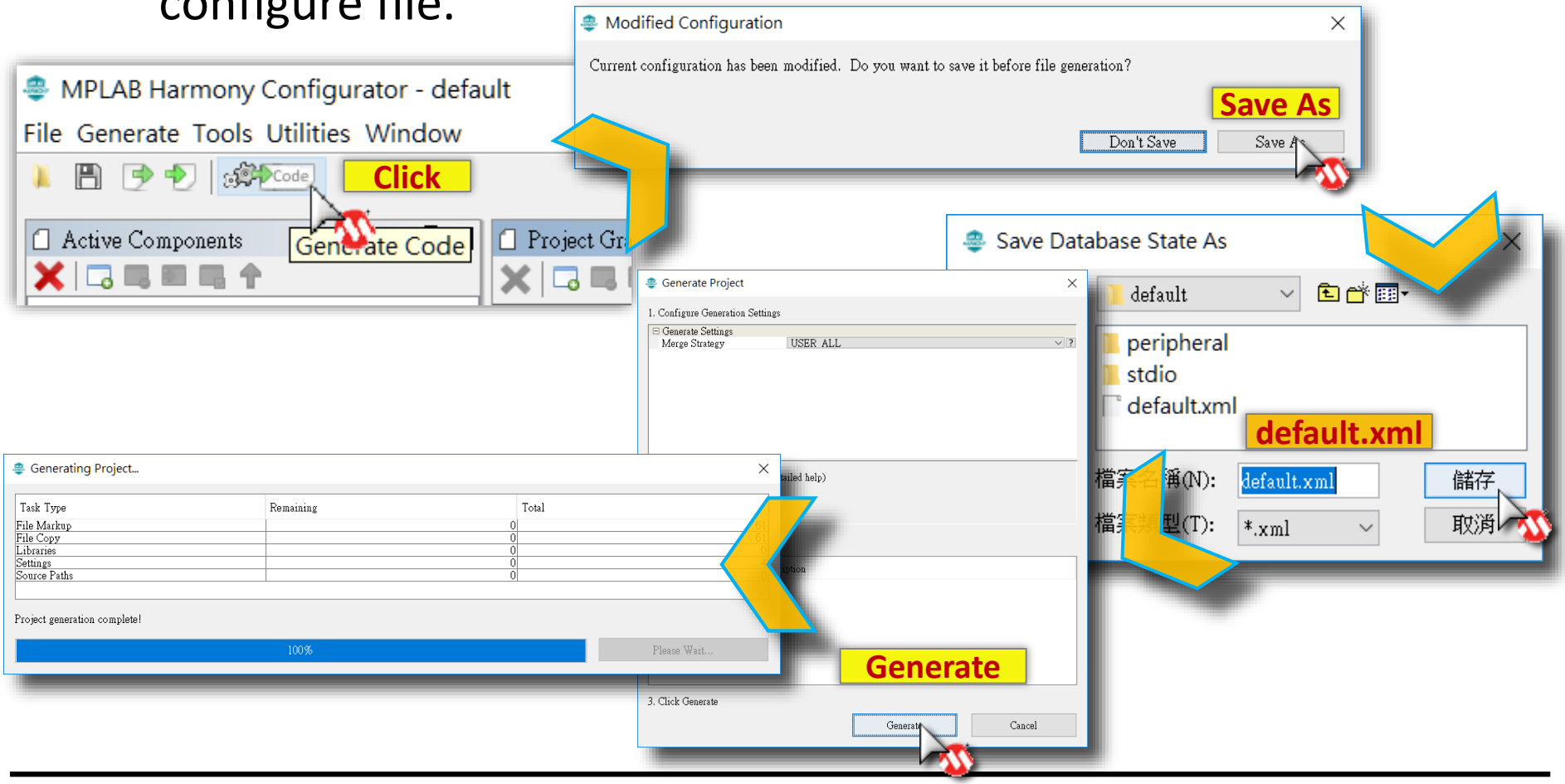


Lab3 TC MFRQ Polling

Step 3

- Click 

to Generate Code and save changes to MHC configure file.



Lab3 TC MFRQ Polling

Step 4

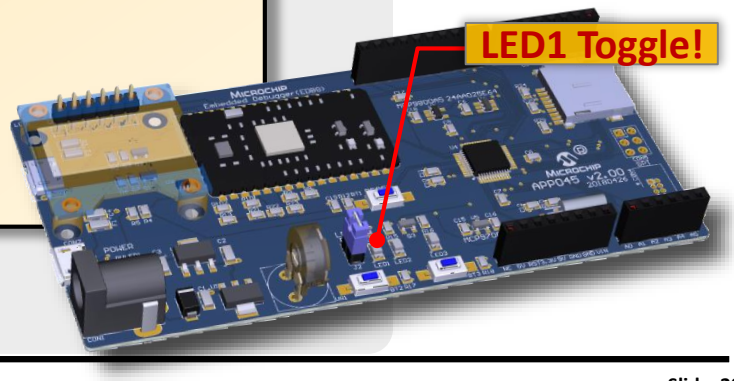
a Add code segment to your main loop

```
…
int main (void)
{
   SYS_Initialize ( NULL );

   // TODO 3.01
   TC3_CompareStart();

   while(1)
   {
      // TODO 3.02
      if ( TC3_CompareStatusGet() &
              TC_COMPARE_STATUS_OVERFLOW )
      {
          LED1_Toggle();
      }
      …
   }
}
```

Period Control



b Program firmware to target board then observe result.

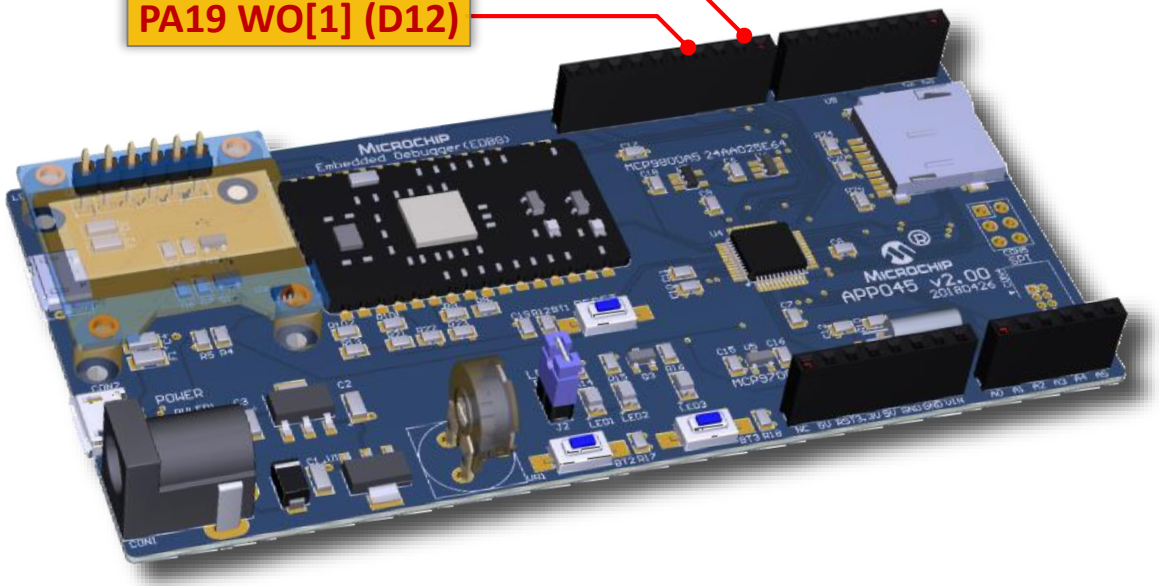
Lab3 TC MFRQ Polling

Waveform Output

PA21		
PA20	29	PA20
PA19	28	EDBG_MISO
PA18	27	EDBG_CS
PA17	26	EDBG_SCK
	25	EDBG_MOSI

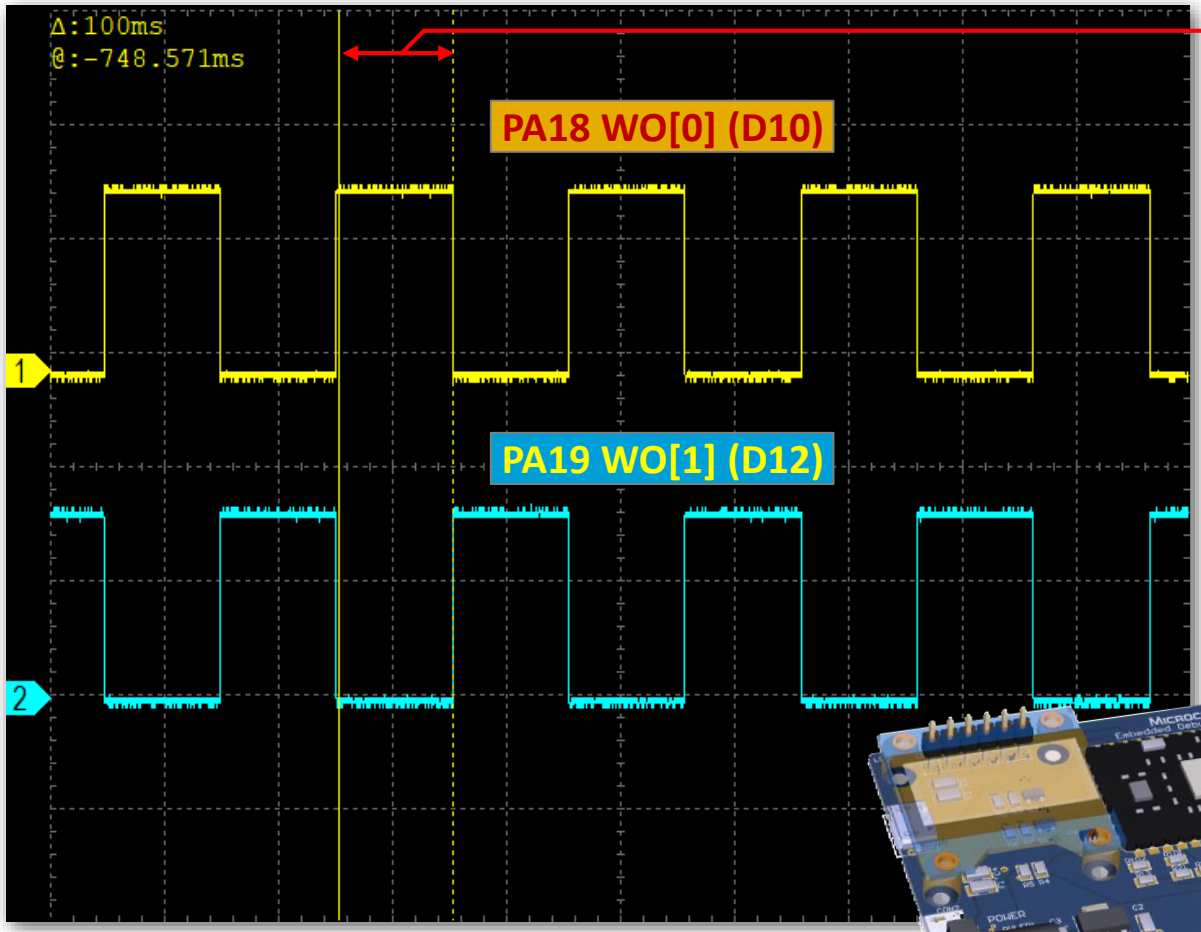
		CON9C Arduino UNO Socket
EDBG_GPIO2	15	D8
EDBG_GPIO3	16	D9/PWM
EDBG_CS	17	D10/PWM/SS
EDBG_MOSI	18	D11/PWM/MOSI
EDBG_MISO	19	D12/MISO
EDBG_SCK	20	D13/SCK
	21	

PA18 WO[0] (D10)
PA19 WO[1] (D12)



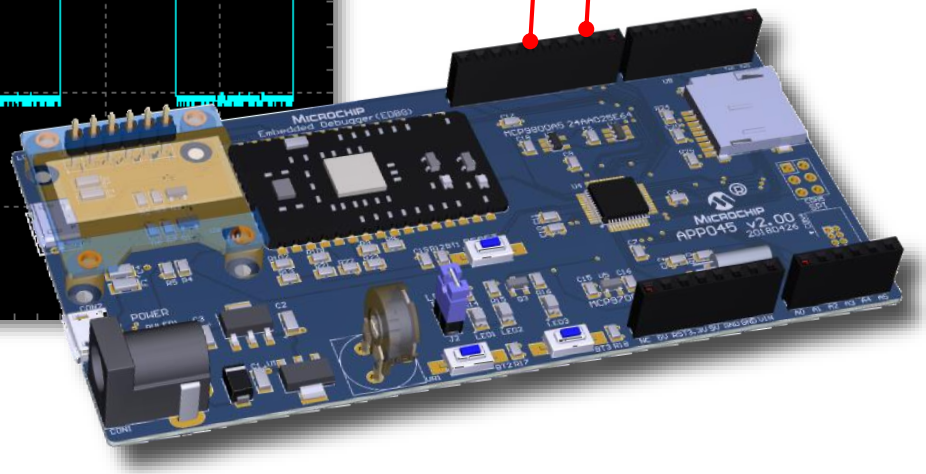
Lab3 TC MFRQ Polling

Waveform Output



Δ:100ms
@:-748.571ms

PA19 WO[1] (D12)
PA18 WO[0] (D10)



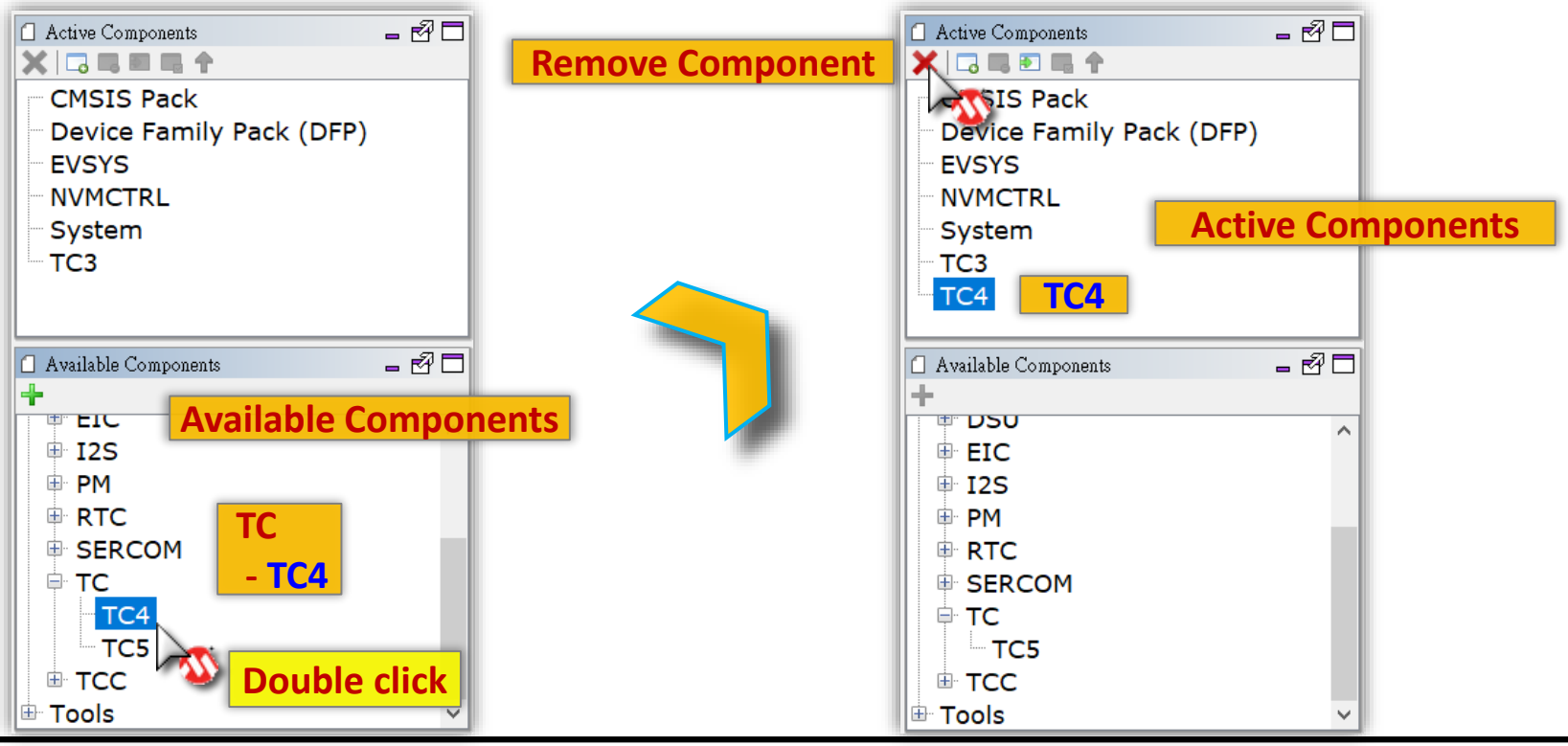
Lab4 TCs MFRQ Polling

- Try to add TC4 to replace software delay to control LED2(PA09) continues toggle.
- All setting same as TC3 except period.
- The TC4 set timer period to 50ms.
- Enable waveform output of TC4 on pin PA22 and PA23. Then you can measure the signal at PA22 and PA23 also.

Lab4 TCs MFRQ Polling

Step 1

- Find TC4 component in Available Components window.
- Double click TC4 to add to Active Components window.
- Click  could remove component from Active window.



Lab4 TCs MFRQ Polling

Step 2

Configuration Options

- TC4
  - Counter Mode: Counter in 16-bit mode — **16-bit mode**
  - Select Prescaler: Prescaler: GCLK_TC/256 — **GCLK_TC/256**
  - ****Timer resolution is 5333.33333333 nS****
  - Operating Mode: Compare — **Compare**
    - Compare
      - Waveform Mode: Match Frequency — **MFRQ**
      - Counter Direction: UP Count — **UP count**
      - Period Value: 9,375 — **9375 (CC0)**
      - **** Timer Period is 50000.0 us ****
      - Compare Value: 24 — **Unused (CC1)**
      - Enable One-Shot Mode
      - Invert Output WO[0]
      - Invert Output WO[1]
      - Enable Period Interrupt — **Don't check**
      - Events
  - Sleep Configurations

Help | Configuration Options

System Clock = 48MHz

One second counts of system clock :

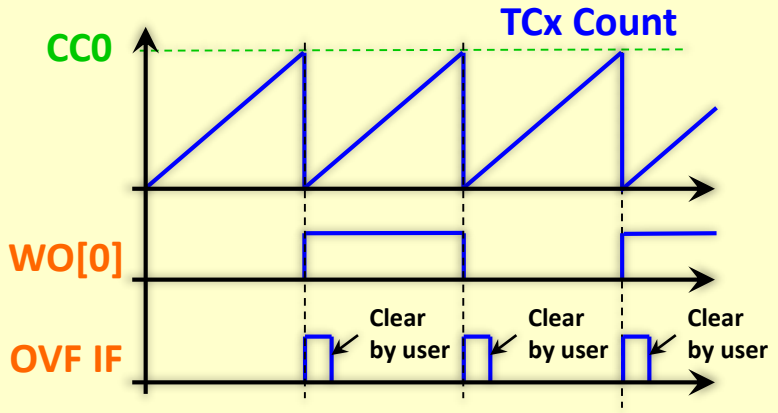
48,000,000 counts

One second counts after Prescaler :

48000000 / 256 187,500 counts

50ms counts for LAB4 target :

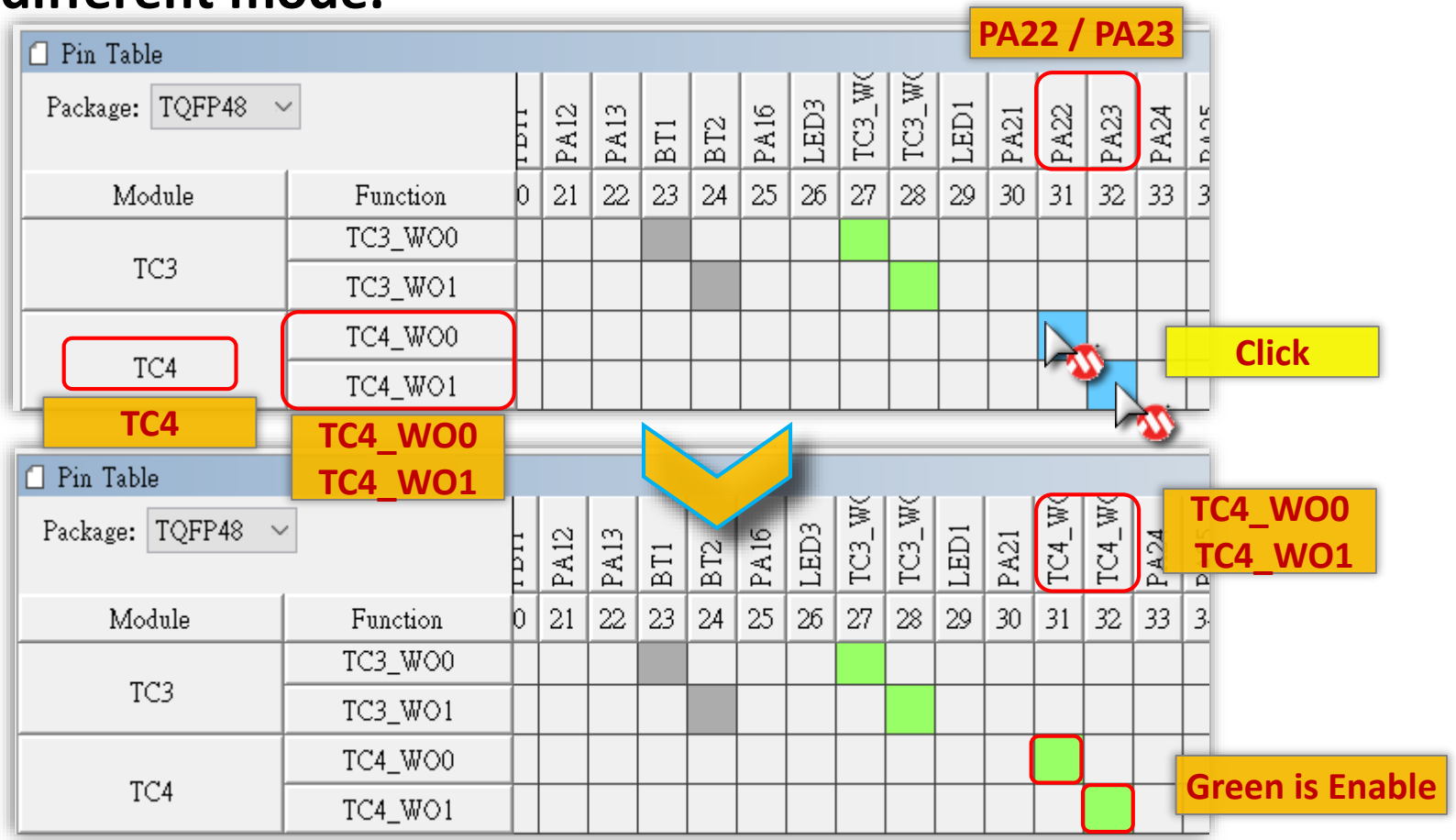
187500 / 20 9,375 counts



Lab4 TCs MFRQ Polling

Step 3

- TC support waveform output through WO[x] pin depend on different mode.



Lab4 TCs MFRQ Polling

Step 4

- Click 

to Generate Code and save changes to MHC configure file.

Lab4 TCs MFRQ Polling

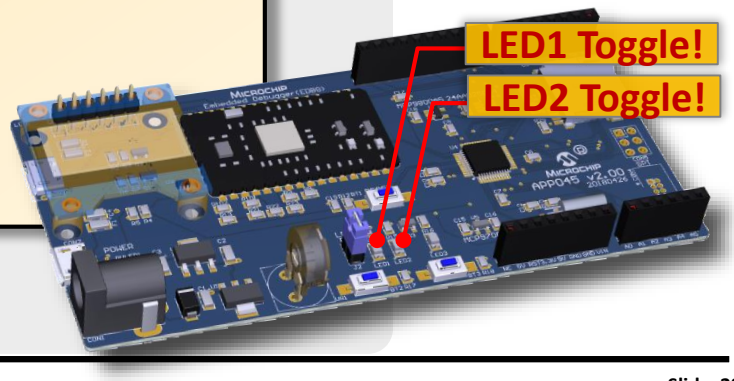
Step 5

a **Add code segment to your main loop**

```
int main (void)
{
   SYS_Initialize ( NULL );
   …
   // TODO 4.01
   TC4_CompareStart();

   while(1)
   {
      …
      // TODO 4.02
      if ( TC4_CompareStatusGet() &
              TC_COMPARE_STATUS_OVERFLOW )
      {
          LED2_Toggle();
      }
      …
   }
}
```

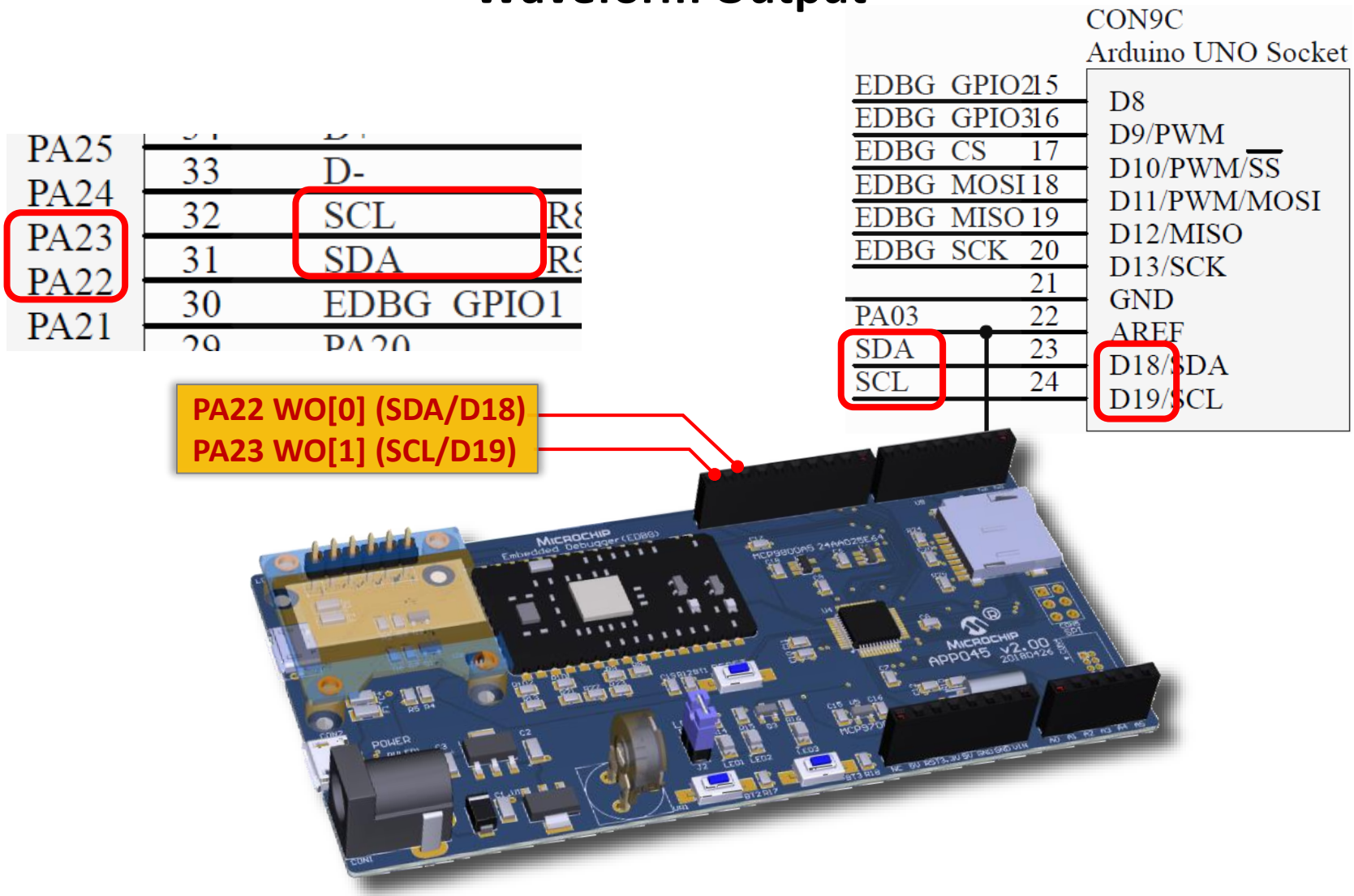
Period Control



b **Program firmware to target board then observe result.**

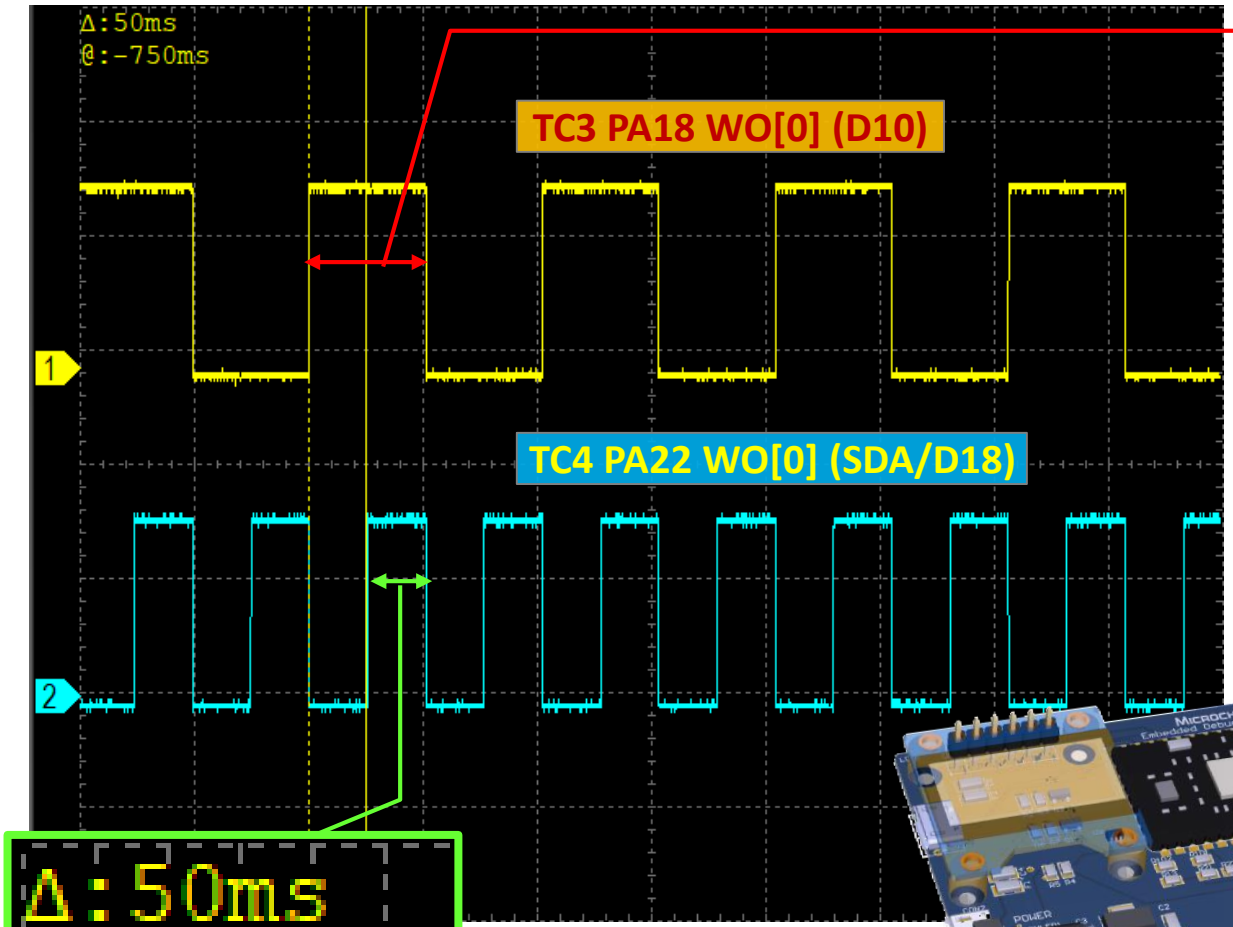
Lab4 TCs MFRQ Polling

Waveform Output



Lab4 TCs MFRQ Polling

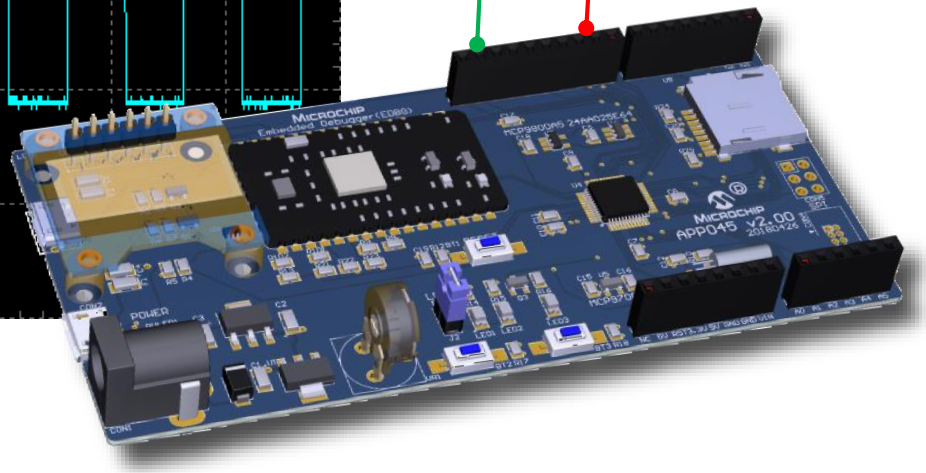
Waveform Output



Δ:100ms
@:-748.571ms

PA22 WO[0] (SDA/D18)

PA18 WO[0] (D10)



Δ:50ms
@:-750ms