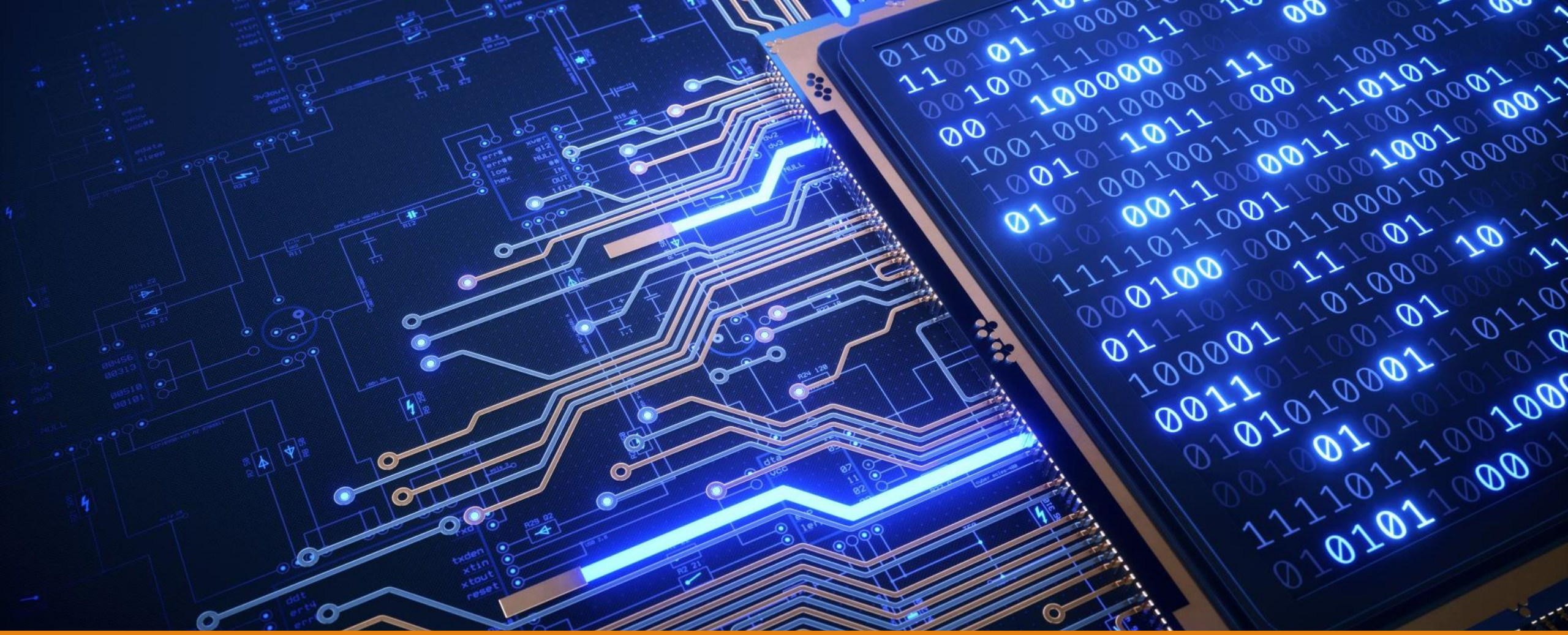

Embedded Systems

Dr. Abdelhay Ali

Lecture 4

Timer

Outlines

1. Introduction
2. Basic registers and flags of the Timers
3. Timer0
4. Normal Mode: Delay using Timer0
5. Timer Interrupt
6. Project

Introduction

- Generally, we use a timer/counter to generate time delays, waveforms, or to count events.
- Also, the timer is used for PWM generation, capturing events, etc.

- In AVR ATmega16 / ATmega32, there are three timers:
  - **Timer0**: 8-bit timer
  - **Timer1**: 16-bit timer
  - **Timer2**: 8-bit timer

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Basic registers and flags of the Timers

- **TCNTn: Timer / Counter Register**

  Every timer has a timer/counter register. It is zero upon reset. We can access value or write a value to this register. It counts up with each clock pulse.

- **TIFR: The Timer/Counter Interrupt Flag Register**

  TOVn: Timer Overflow Flag :Each timer has a Timer Overflow flag. When the timer overflows, this flag will get set.

Basic registers and flags of the Timers

- **TCCRn: Timer Counter Control Register**

  This register is used for setting the modes of timer/counter.

- **OCRn: Output Compare Register**

  The value in this register is compared with the content of the TCNTn register. When they are equal, the OCFn flag will get set.

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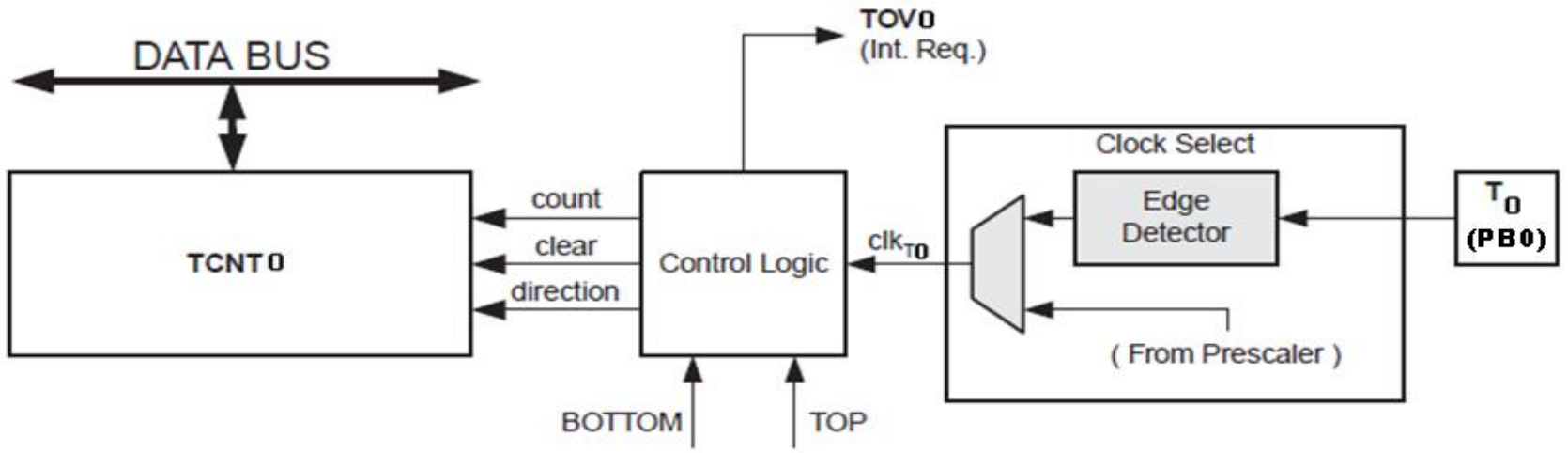
Timer 0



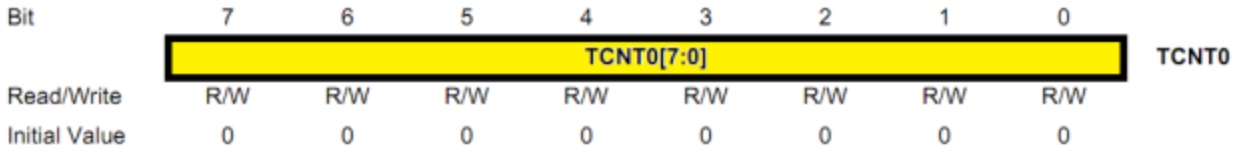
►By Timers 0,1 external clock sources are synchronous produced by edge detection of input signals on pins T0 (PB0), and T1 (PB1) sampled once every system clock cycle.

Timer 0

First, we need to understand the basic registers of the Timer0

1. **TCNT0: Timer / Counter Register 0**

   It is an 8-bit register. It counts up with each pulse.



Timer 0

2. **TCCR0: Timer / Counter Control register 0**

This is an 8-bit register used for the operation mode and the clock source selection.

7	6	5	4	3	2	1	0
FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00

Bit 7- FOC0: Force compare match

Write only a bit, which can be used while generating a wave. Writing 1 to this bit causes the wave generator to act as if a compare match has occurred.

Timer 0

2. **TCCR0: Timer / Counter Control register 0**

This is an 8-bit register used for the operation mode and the clock source selection.

7	6	5	4	3	2	1	0
FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00

Bit 6, 3 - WGM00, WGM01: Waveform Generation Mode

Normal Mode: Count from BOTTOM (0x00)to MAX (0xFF)
Take an action when overflow

CTC (Clear Timer of Compare Match): Count from bottm to a specific value stored in OCR register

WGM00	WGM01	Timer0 mode selection bit
0	0	Normal
0	1	CTC (Clear timer on Compare Match)
1	0	PWM, Phase correct
1	1	Fast PWM

Timer 0

2. **TCCR0: Timer / Counter Control register 0**

This is an 8-bit register used for the operation mode and the clock source selection.

7	6	5	4	3	2	1	0
FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00

Bit 5:4 - COM01:00: Compare Output Mode

These bits control the waveform generator. We will see this in the compare mode of the timer.

Timer 0

2. **TCCR0: Timer / Counter Control register 0**

7	6	5	4	3	2	1	0
FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00

Bit 2:0 - CS02:CS00: Clock Source Select

These bits are used to select a clock source.

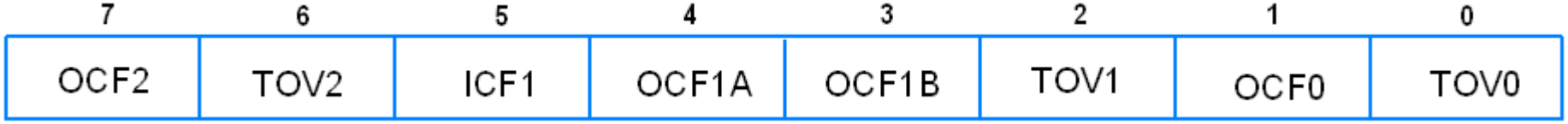
When CS02: CS00 = 000, then timer is stopped.

As it gets a value between 001 to 101, it gets a clock source and starts as the timer.

CS02	CS01	CS00	Description
0	0	0	No clock source (Timer / Counter stopped)
0	0	1	clk (no pre-scaling)
0	1	0	clk / 8
0	1	1	clk / 64
1	0	0	clk / 256
1	0	1	clk / 1024
1	1	0	External clock source on T0 pin. Clock on falling edge
1	1	1	External clock source on T0 pin. Clock on rising edge.

Timer 0

3. **TIFR: Timer Counter Interrupt Flag register**

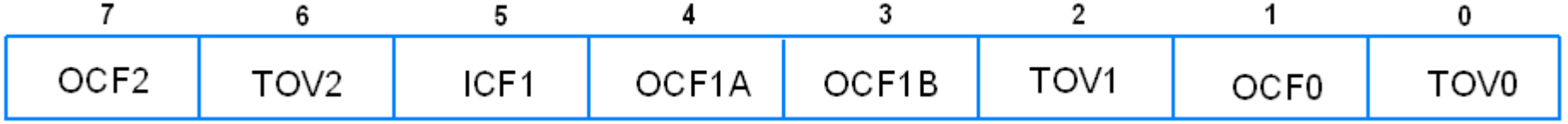


Bit 0 - TOV0: Timer0 Overflow flag
0 = Timer0 did not overflow
1 = Timer0 has overflown (going from 0xFF to 0x00)

Bit 1 - OCF0: Timer0 Output Compare flag
0 = Compare match did not occur
1 = Compare match occurred

Timer 0

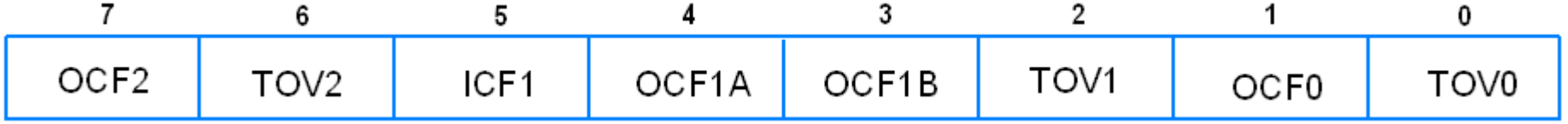
3. **TIFR: Timer Counter Interrupt Flag register**



Bit 2 - TOV1: Timer1 Overflow flag
Bit 3 - OCF1B: Timer1 Output Compare B match flag
Bit 4 - OCF1A: Timer1 Output Compare A match flag
Bit 5 - ICF1: Input Capture flag
Bit 6 - TOV2: Timer2 Overflow flag
Bit 7 - OCF2: Timer2 Output Compare match flag

Timer 0

3. **TIFR: Timer Counter Interrupt Flag register**



Bit 2 - TOV1: Timer1 Overflow flag
Bit 3 - OCF1B: Timer1 Output Compare B match flag
Bit 4 - OCF1A: Timer1 Output Compare A match flag
Bit 5 - ICF1: Input Capture flag
Bit 6 - TOV2: Timer2 Overflow flag
Bit 7 - OCF2: Timer2 Output Compare match flag

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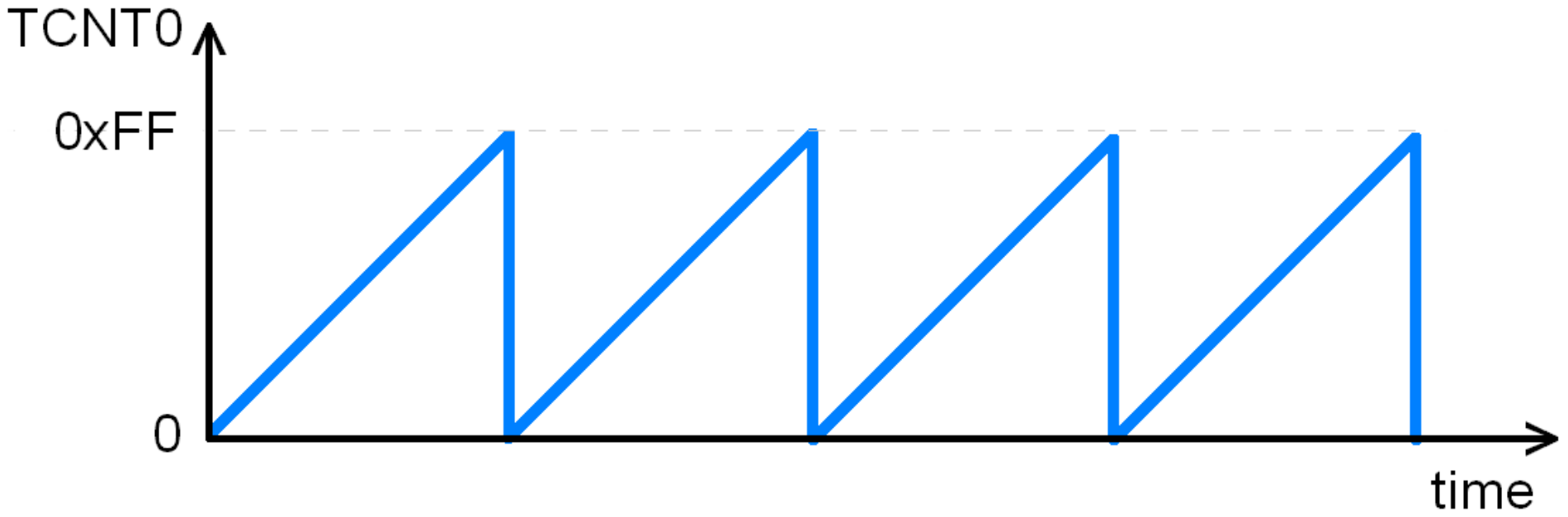
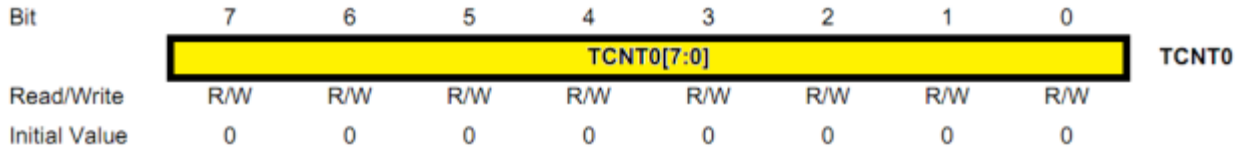
Normal Mode

Normal mode: When the counter overflows i.e. goes from 0x00 to 0xFF, the TOV0 flag is set.



Normal Mode: Steps to Program Delay Timer0

1. Load the TCNT0 register with the initial value (let's take 0x25).

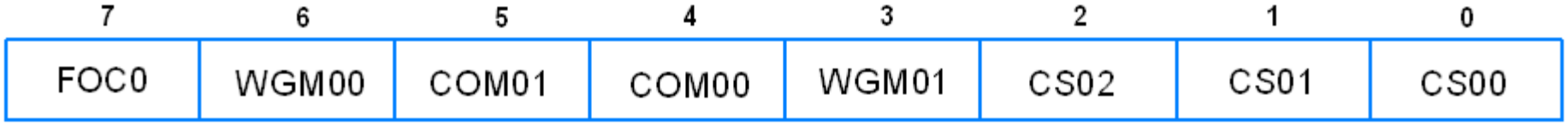



```
TCNT0 = 0x25; /* Load TCNT0*/
```

Normal Mode: Steps to Program Delay Timer0

2- For normal mode and the pre-scaler option of the clock, set the value in the TCCR0 register.

As soon as the clock Prescaler value gets selected, the timer/counter starts to count, and each clock tick causes the value of the timer/counter to increment by 1.



7	6	5	4	3	2	1	0	
FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00	
0	0	0	0	0	0	0	1	= 0x01

```
TCCR0 = 0x01; /* Timer0, normal mode, no pre-scalar */
```

Normal Mode: Steps to Program Delay Timer0

3.Timer keeps counting up, so keep monitoring for timer overflow i.e. TOV0 (Timer0 Overflow) flag to see if it is raised.

```
while((TIFR&0x01)==0); /* Wait for TOV0 to roll over */
```

4. Stop the timer by putting 0 in the TCCR0 i.e. the clock source will get disconnected and the timer/counter will get stopped.

```
TCCR0 = 0;
```

5. Clear the TOV0 flag. Note that we have to write 1 to the TOV0 bit to clear the flag.

```
TIFR = 0x1; /* Clear TOV0 flag*/
```

Normal Mode: Steps to Program Delay Timer0

1. Load the TCNT0 register with the initial value (let's take 0x25).

2. For normal mode and the pre-scaler option of the clock, set the value in the TCCR0 register. As soon as the clock Prescaler value gets selected, the timer/counter starts to count, and each clock tick causes the value of the timer/counter to increment by 1.

3.Timer keeps counting up, so keep monitoring for timer overflow i.e. TOV0 (Timer0 Overflow) flag to see if it is raised.

4. Stop the timer by putting 0 in the TCCR0 i.e. the clock source will get disconnected and the timer/counter will get stopped.

5. Clear the TOV0 flag. Note that we have to write 1 to the TOV0 bit to clear the flag.

6. Return to the main function.

Program for Timer Delay

As *Fosc = 8 MHz*
T = 1 / Fosc = 0.125 µs

Therefore, the count increments by every **0.125 µs**.

In above code, the number of cycles required to roll over are:
0xFF - 0x25= 0xDA i.e. decimal 218

Add one more cycle as it takes to roll over and raise TOV0 flag: 219

Total Delay = 219 x 0.125 µs = **27.375 µs**

```
#include <mega16.h>
void T0delay();

int main(void) {
DDRB = 0xFF; /* PORTB as output*/

 while(1) /* Repeat forever*/ {
       PORTB=0x55;
       T0delay(); /* Give some delay */
       PORTB=0xAA;
       T0delay();
}
}

 void T0delay() {
TCNT0 = 0x25; /* Load TCNT0*/
TCCR0 = 0x01; /* Timer0, normal mode, no pre-scalar */
while((TIFR&0x01)==0); /* Wait for TOV0 to roll over */
TCCR0 = 0;
 TIFR = 0x1; /* Clear TOV0 flag*/
}
```

Program for 10 ms Delay Using Timer0

*Fosc = 8 MHz

Use the pre-scalar 1024, so the timer clock frequency :
8 MHz / 1024 = **7812.5 Hz**
Time of 1 cycle = 1 / 7812.5 = **128 µs**

Therefore, for a delay of 10 ms, number of cycles required will be,
10 ms / 128 µs = **78 (approx)**

We need 78 timer cycles to generate a delay of 10 ms.
Value to load in TCNT0 = 256 – 78 (78 clock ticks to overflow the timer)
= **178 i.e. 0xB2 in hex**

Thus, if we load 0xB2 in the TCNT0 register, the timer will overflow after 78 cycles i.e. precisely after a delay of 10 ms.

```
#include <mega16.h>
void T0delay();

int main(void) {
DDRB = 0xFF; /* PORTB as output*/

 while(1) /* Repeat forever*/ {
        PORTB=0x55;
        T0delay(); /* Give some delay */
        PORTB=0xAA;
        T0delay();
}
}

 void T0delay() {
TCCR0 = (1<<CS02) | (1<<CS00); /* Timer0, normal mode,
/1024 prescalar */
TCNT0 = 0xB2; /* Load TCNT0, count for 10ms */
while((TIFR&0x01)==0); /* Wait for TOV0 to roll over */
TCCR0 = 0;
 TIFR = 0x1; /* Clear TOV0 flag*/
}
```

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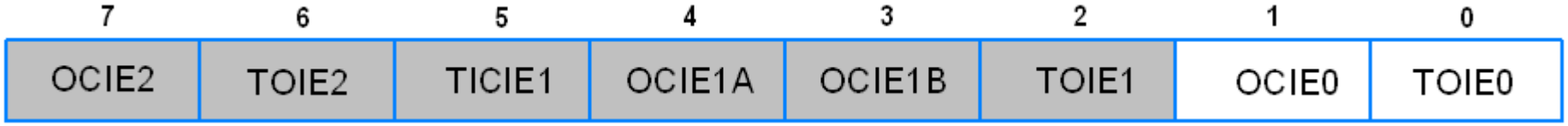
Timer Interrupt

TIMSK: Timer / Counter Interrupt Mask Register



We have to set the **TOIE0** (Timer0 Overflow Interrupt Enable) bit in the TIMSK register to set the timer0 interrupt so that as soon as the Timer0 overflows, the controller jumps to the Timer0 interrupt routine.

Timer0 Interrupt Program

```
#include <mega16.h>

/* timer0 overflow interrupt */
 ISR(TIMER0_OVF_vect) {
PORTB=~PORTB; /* Toggle PORTB */
 TCNT0 = 0xB2;
 }

int main( void ) {
DDRB=0xFF; /* Make port B as output */

sei(); /* Waits for the next instruction to finish before
enabling interrupts *\

TIMSK=(1<<TOIE0); /* Enable Timer0 overflow interrupts */
TCNT0 = 0xB2; /* Load TCNT0, count for 10ms*/

TCCR0 = (1<<CS02) | (1<<CS00); /* Start timer0 with /1024
prescaler*/

while(1);
}
```

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Project

Project submission deadline: 26/12/2021

MAX number of students per project is Five

25 points

Submission Checklist

1- Project Proposal

2- Simulation

3- Circuit

Thanks