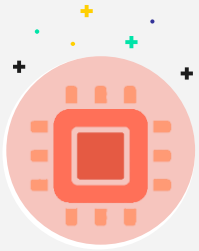
1402/11/22



Microcontrollers

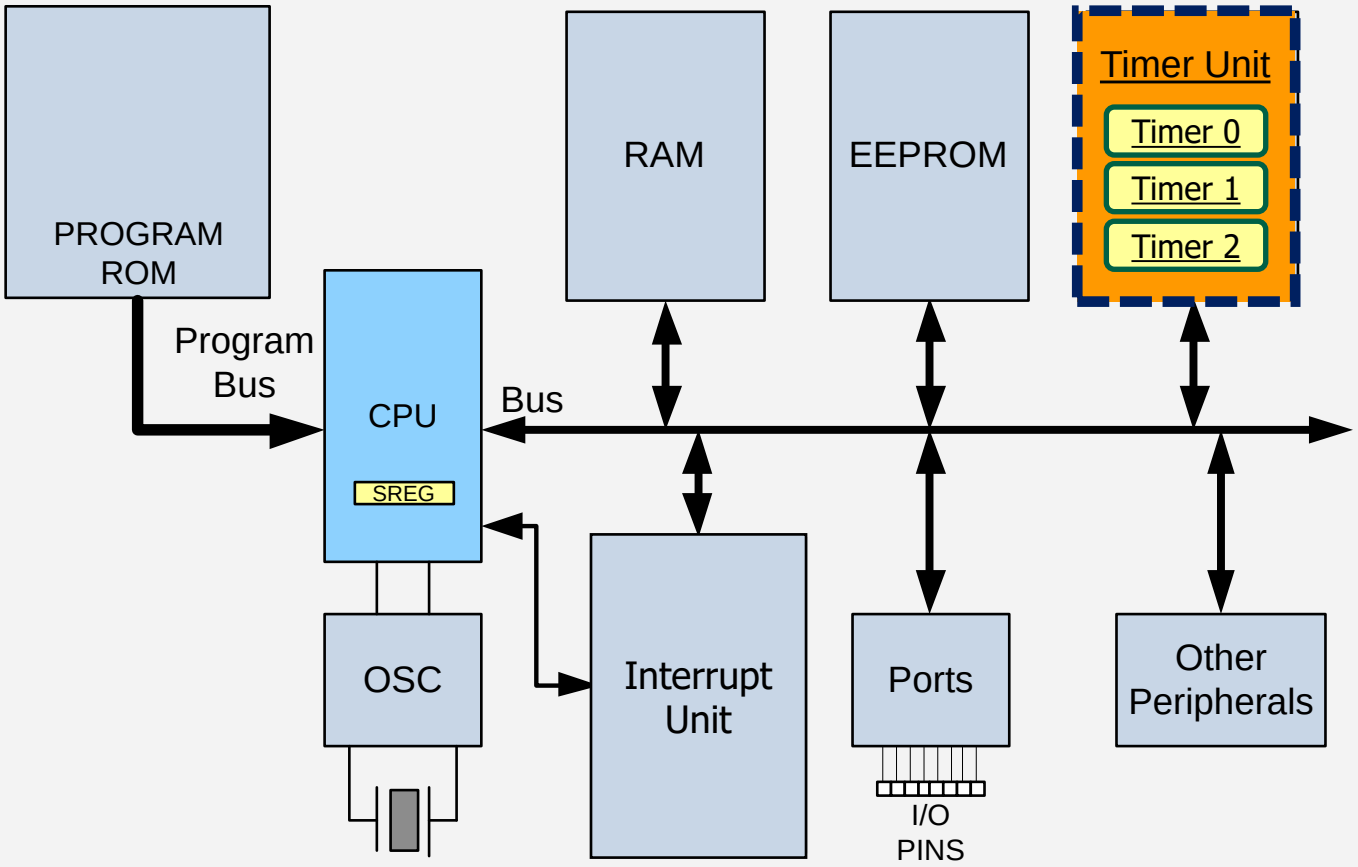
Lecture 5:

Timer/counter (Normal,CTC Modes)

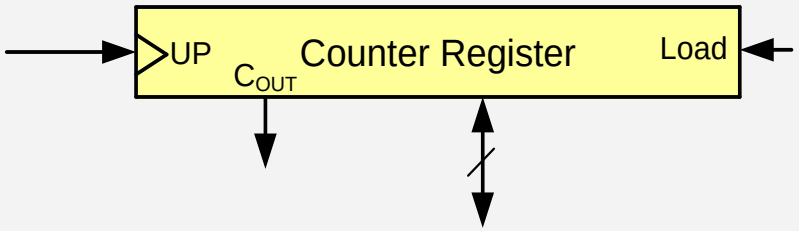
By: M.Razeghizadeh

Start now!

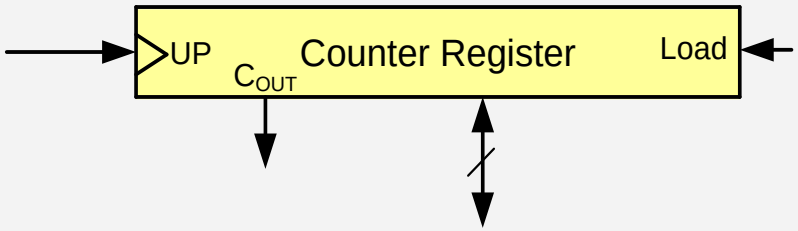
Overview


PROGRAM ROM
Program Bus
CPU
SREG
OSC
RAM
EEPROM
Timer Unit
Timer 0
Timer 1
Timer 2
Bus
Interrupt Unit
Ports
I/O PINS
Other Peripherals

A counter register



A counter register



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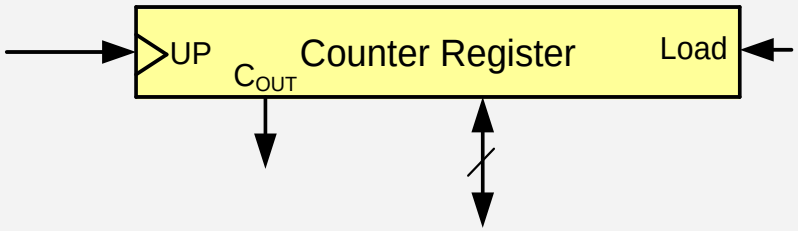

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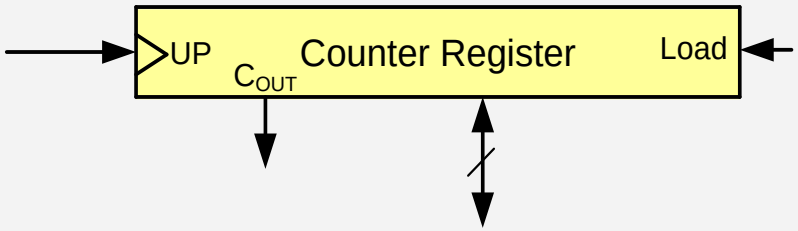

A counter register - First design

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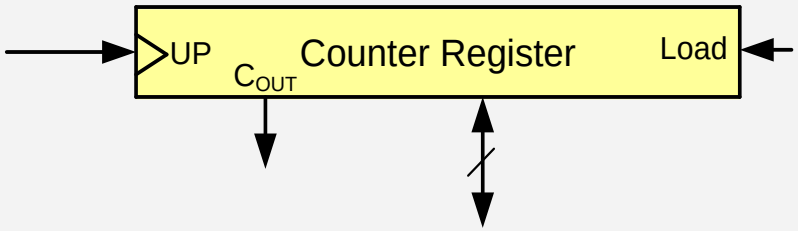

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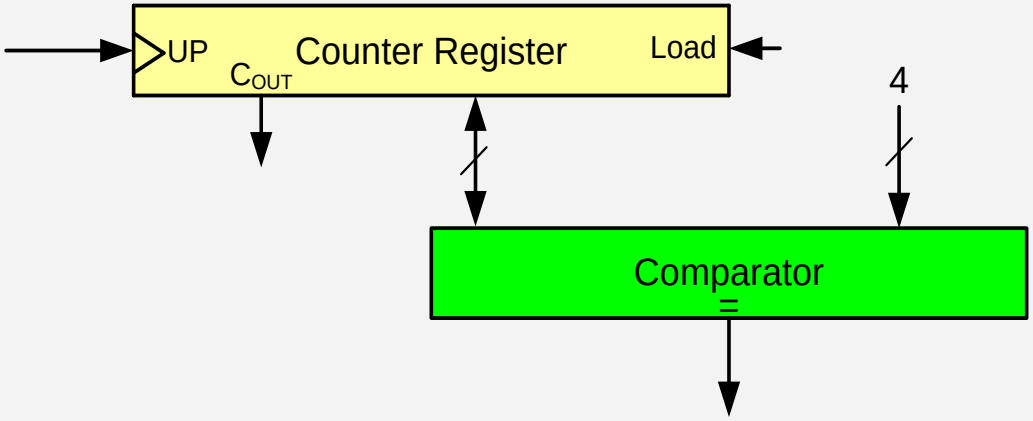
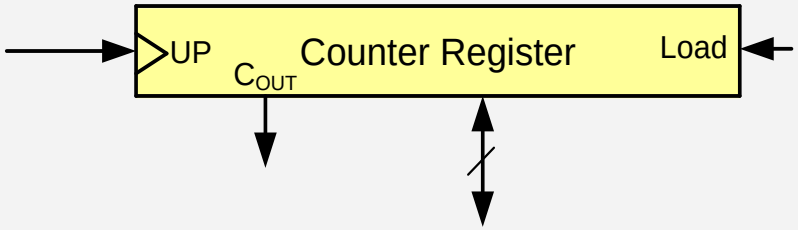


A counter register



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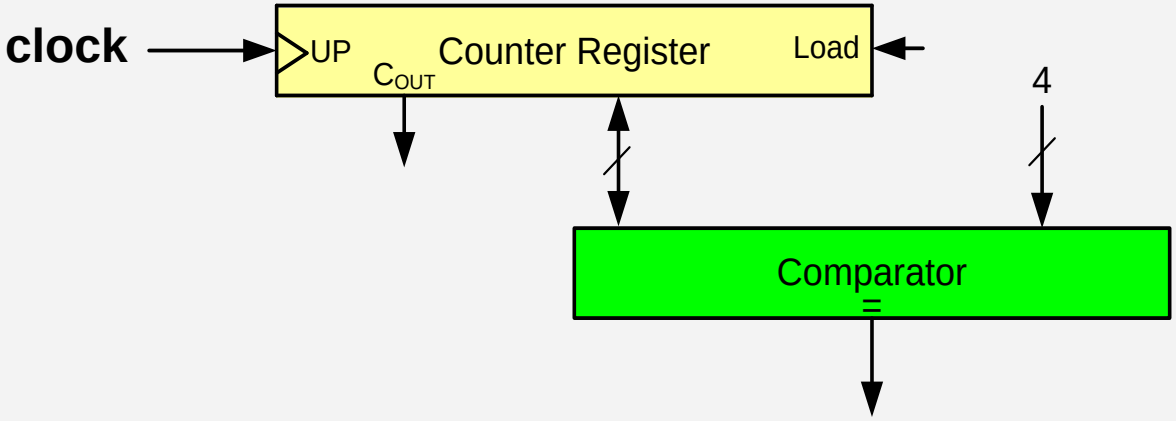

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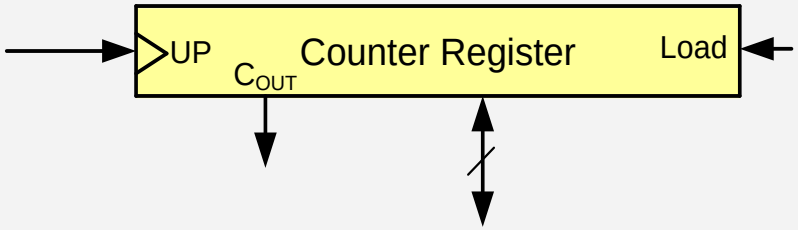

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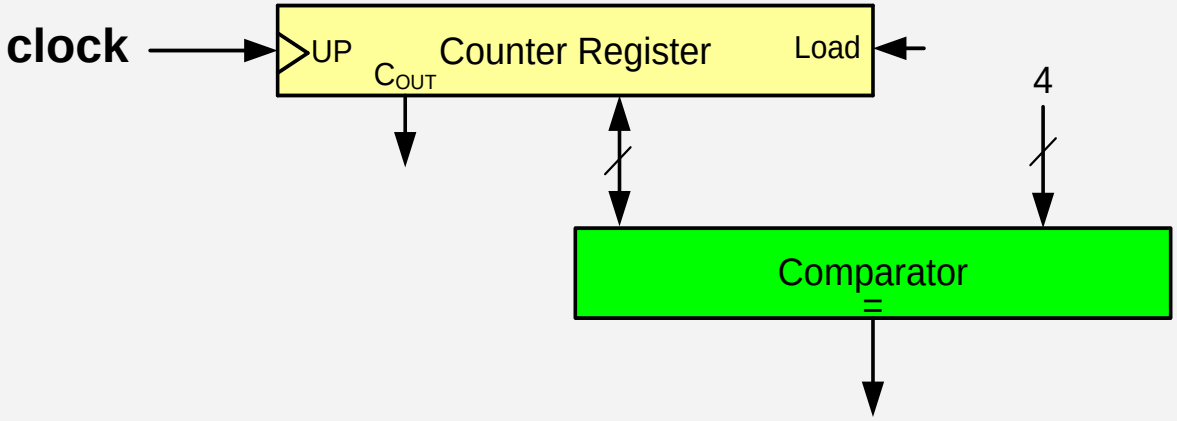

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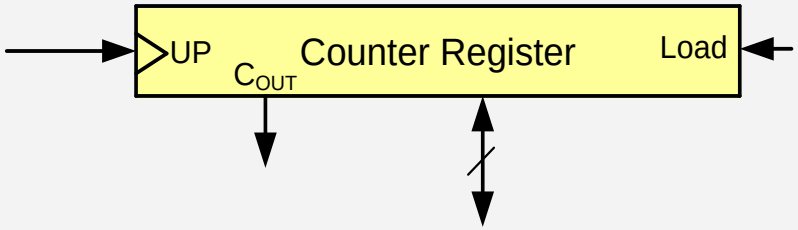

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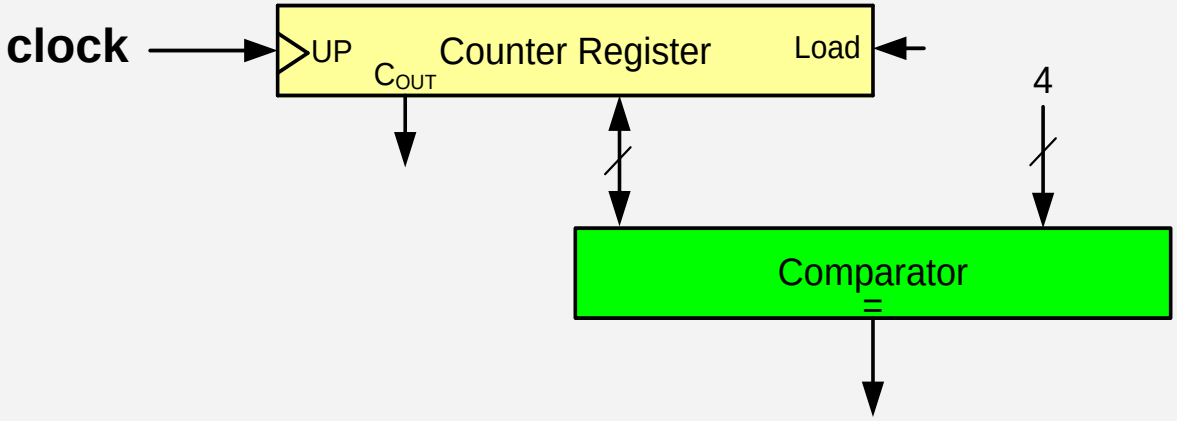

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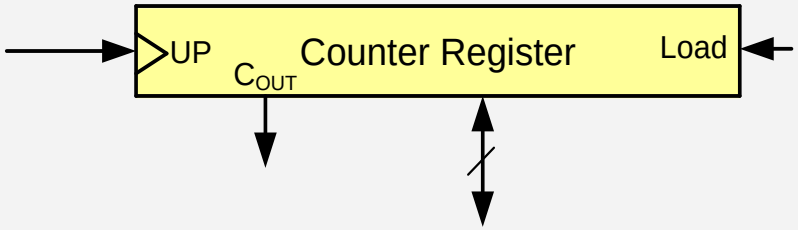

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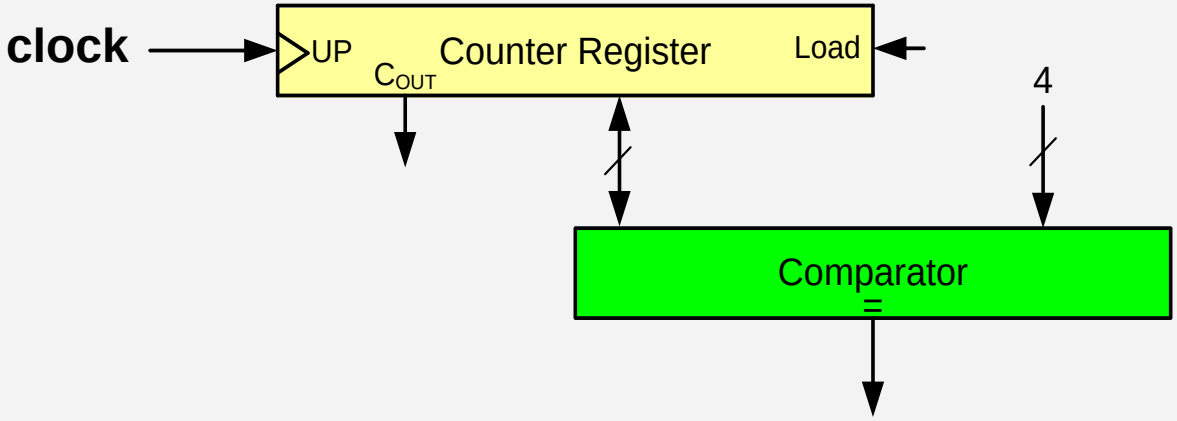

A counter register - Second design

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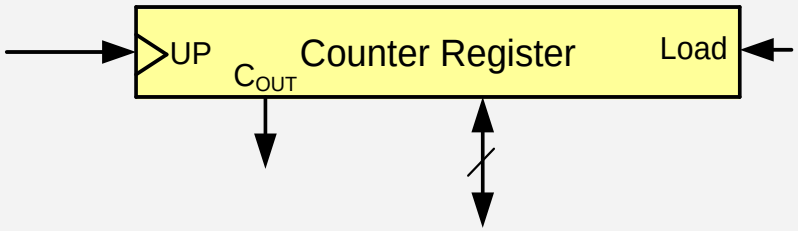

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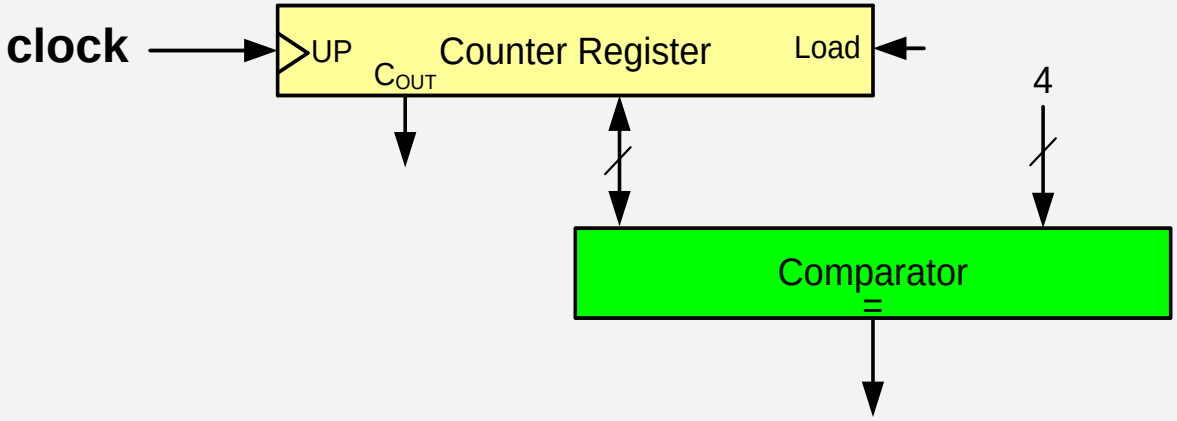

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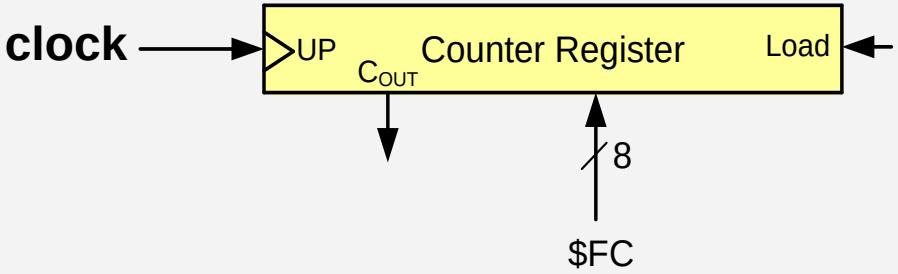

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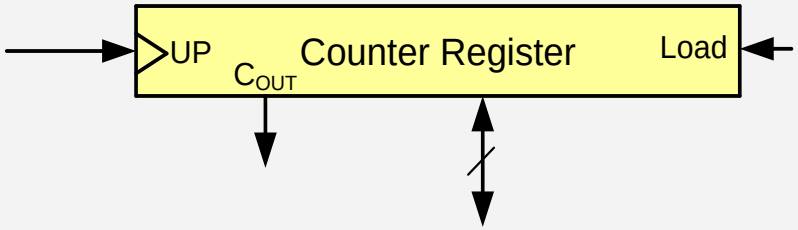

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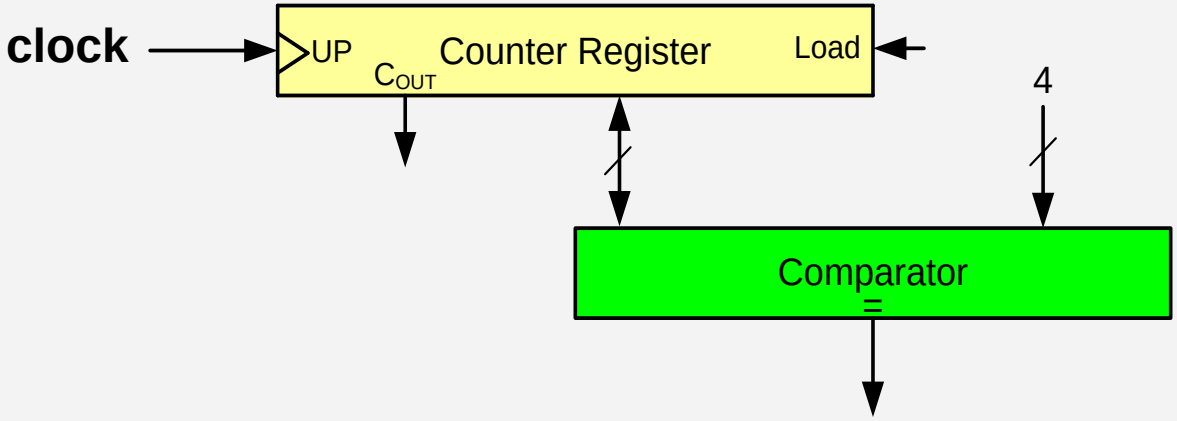

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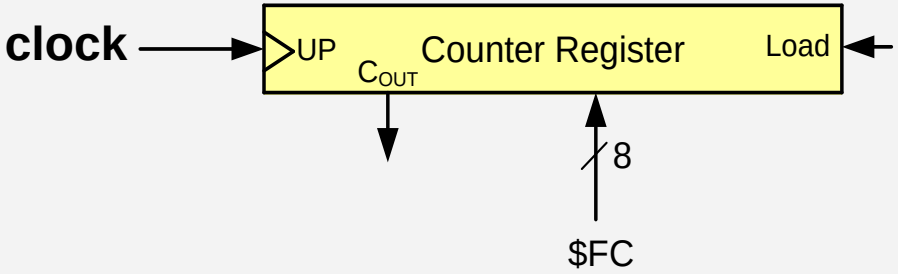
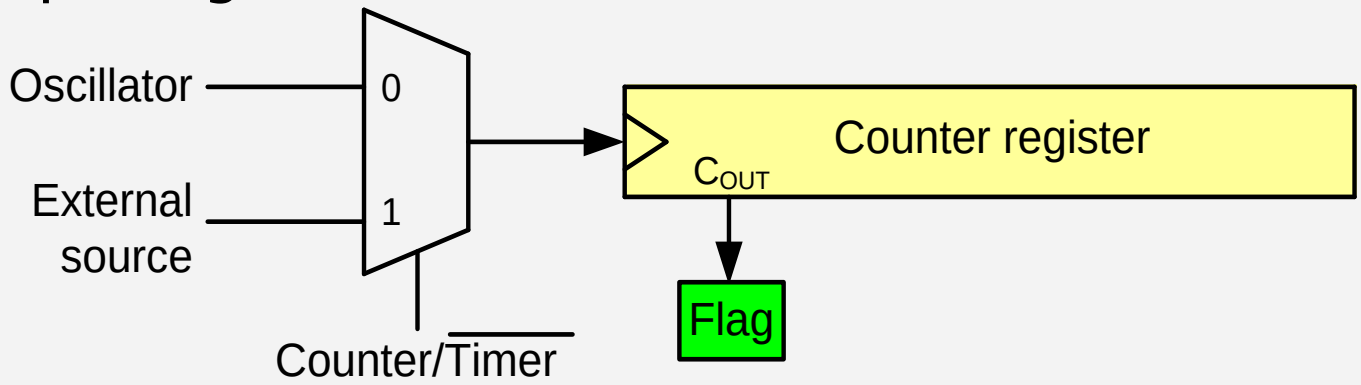


A generic timer/counter

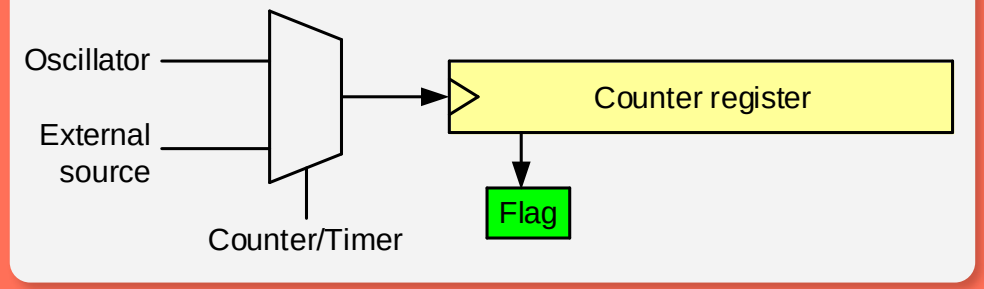
- Delay generating
- Counting
- Wave-form generating
- Capturing



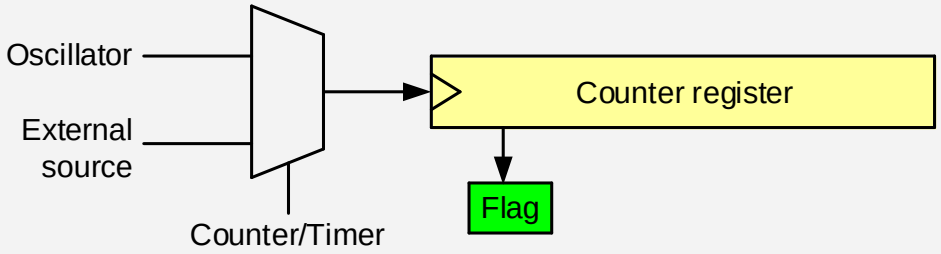
A generic timer/counter

- 1 to 6 timers
  - 3 timers in ATmega328
- 8-bit and 16-bit timers
  - two 8-bit timers and one 16-bit timer in ATmega328

Timer in AVR


Oscillator
External source
Counter/Timer
Counter register
Flag

Timer in AVR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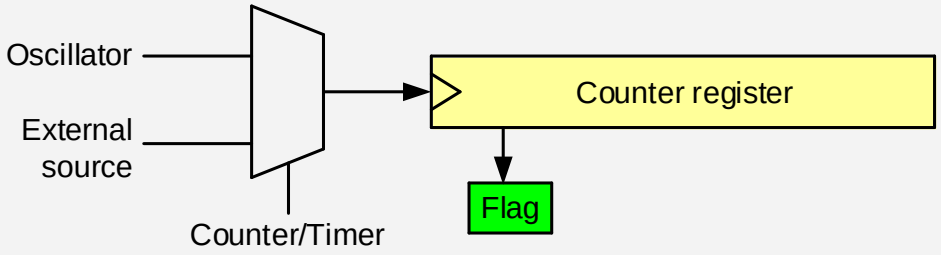
Oscillator
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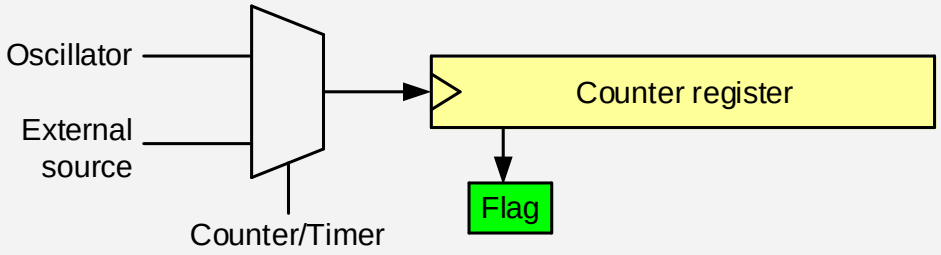

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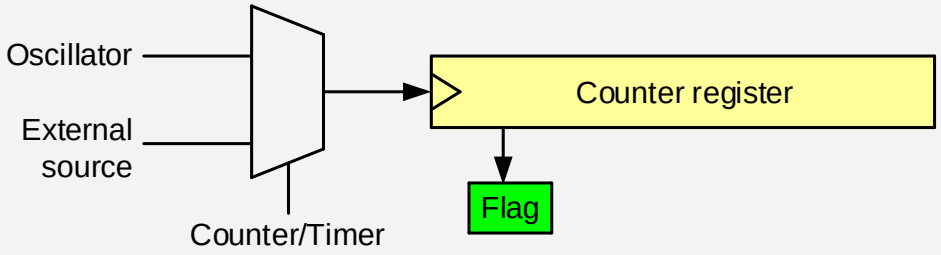

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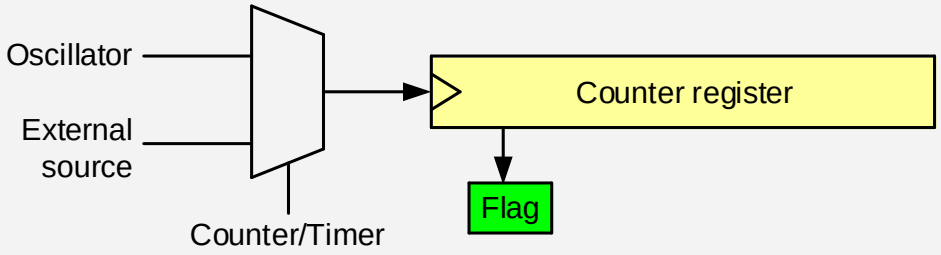

note

Timer in AVR

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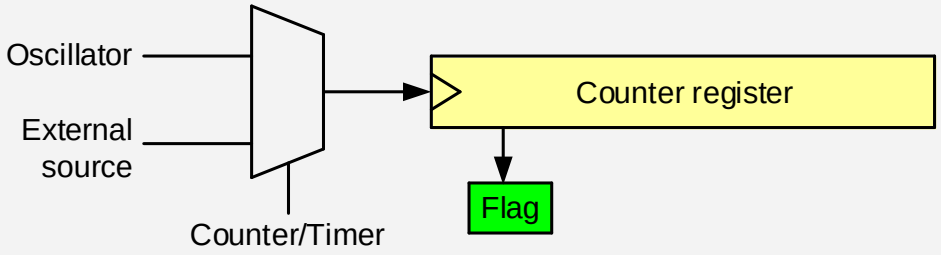

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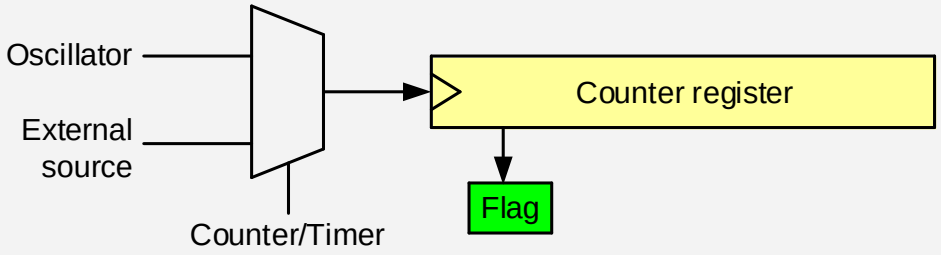


note

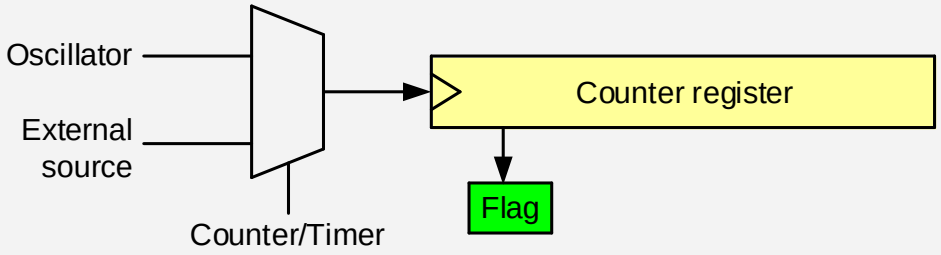
All of the timer registers are byte-addressable registers

Timer in AVR

Timer in AVR

TCNTn

Timer in AVR



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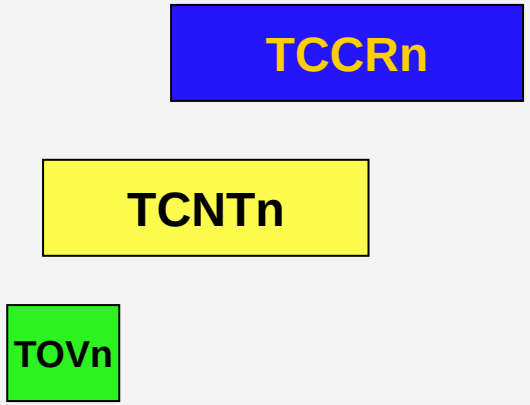

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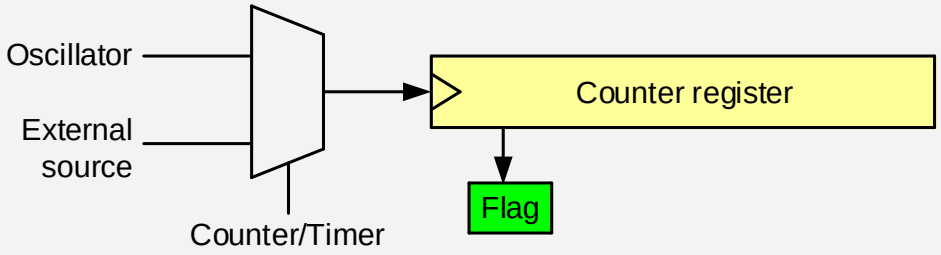

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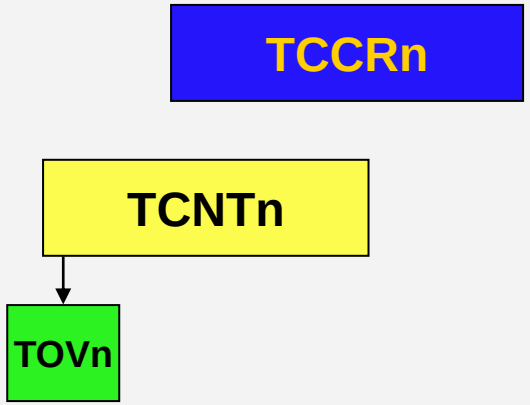

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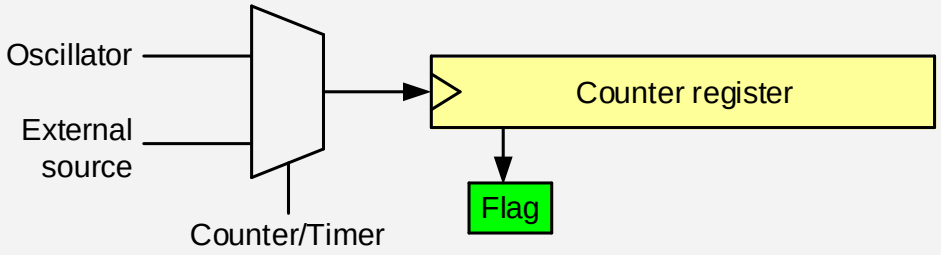

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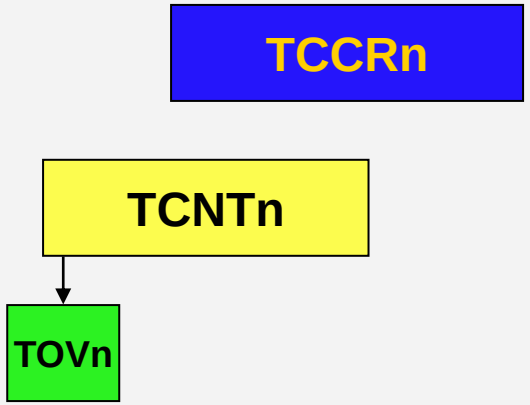

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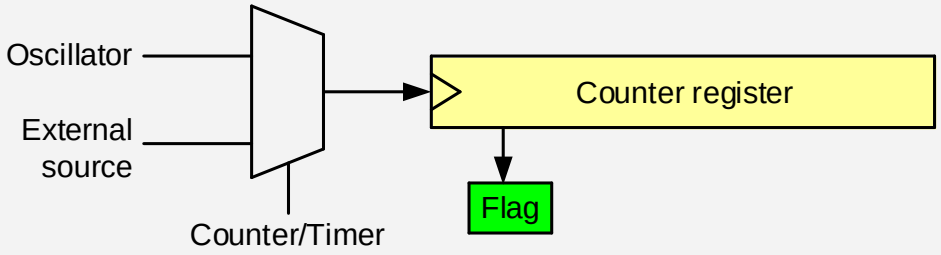

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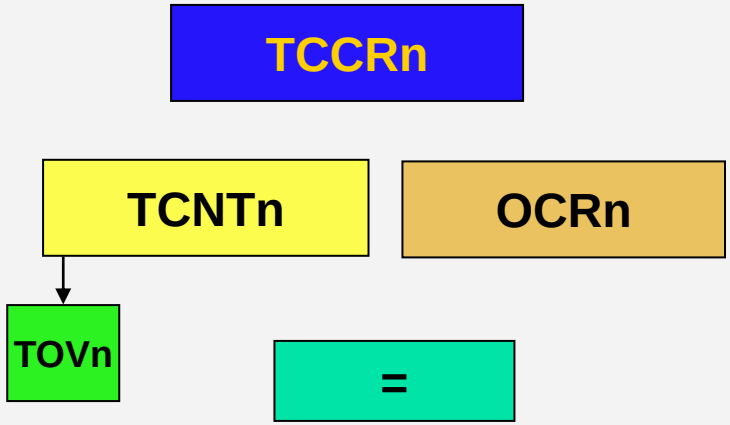

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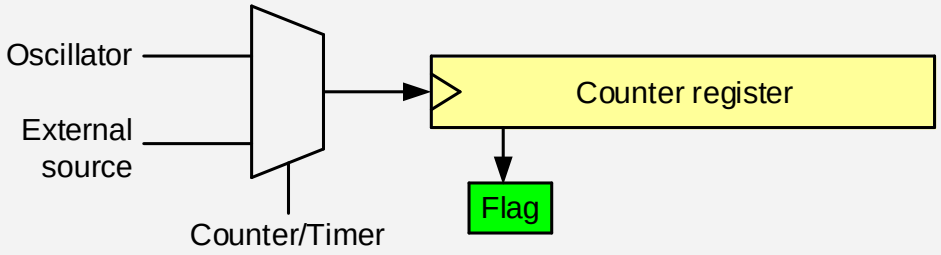

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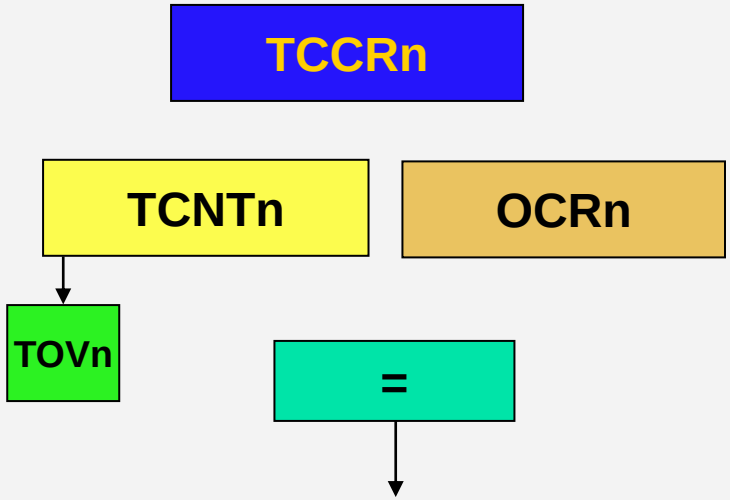

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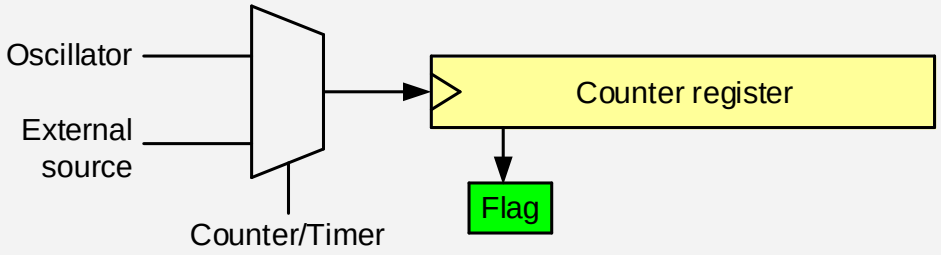

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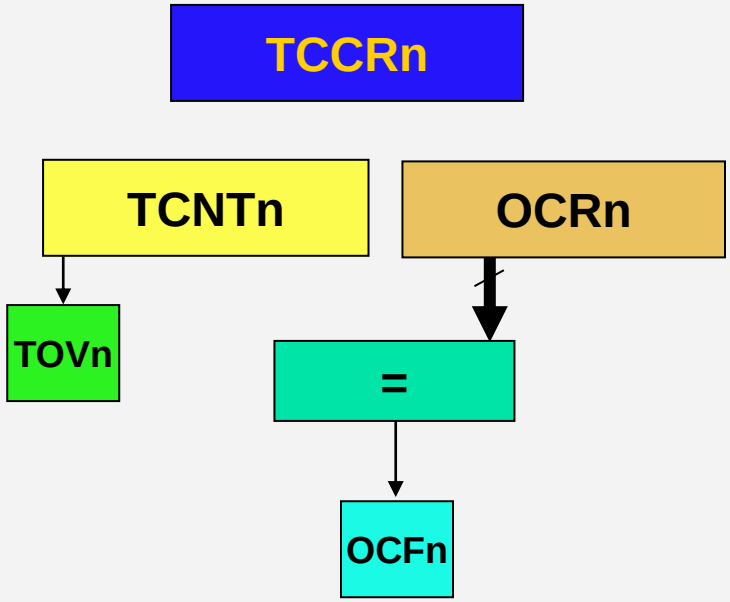

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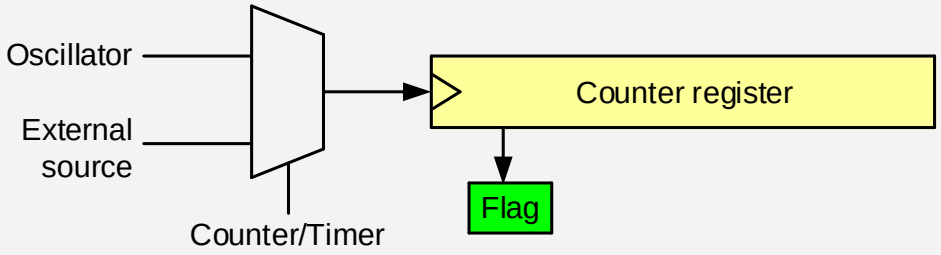

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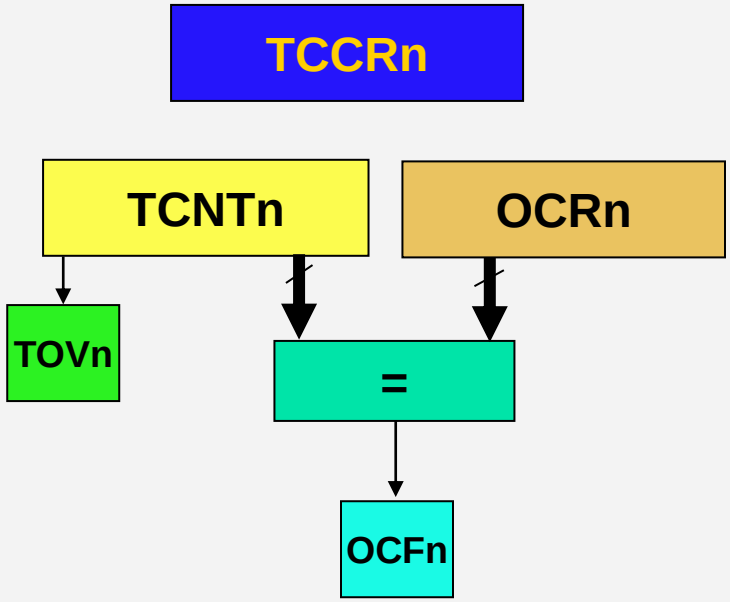

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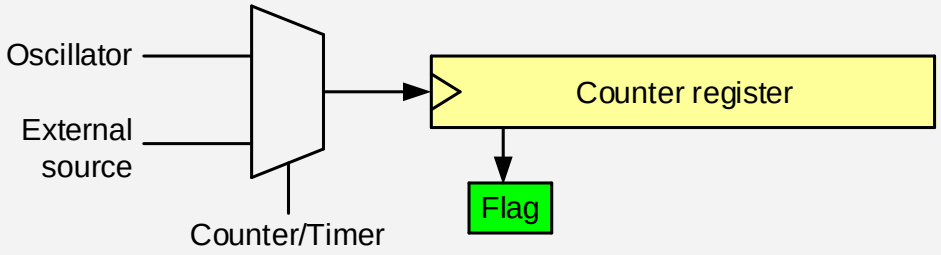

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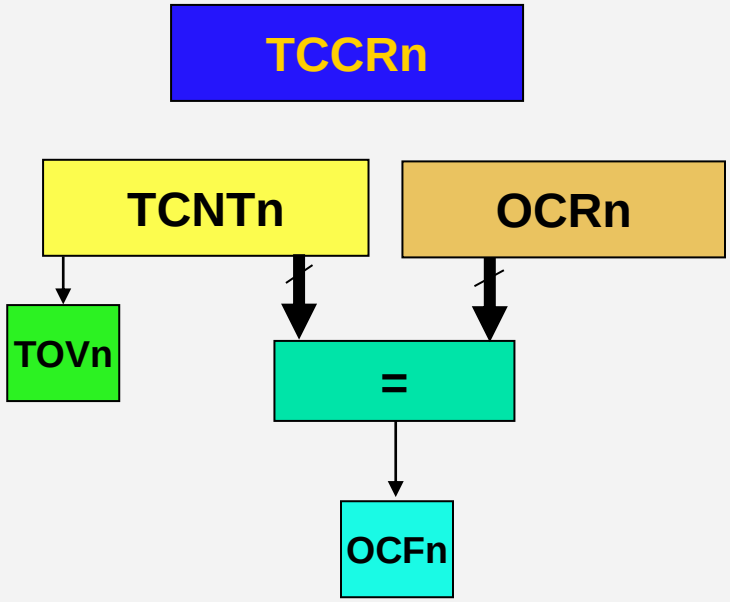

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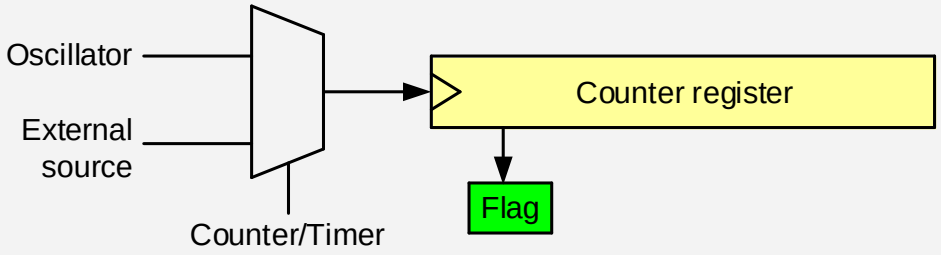

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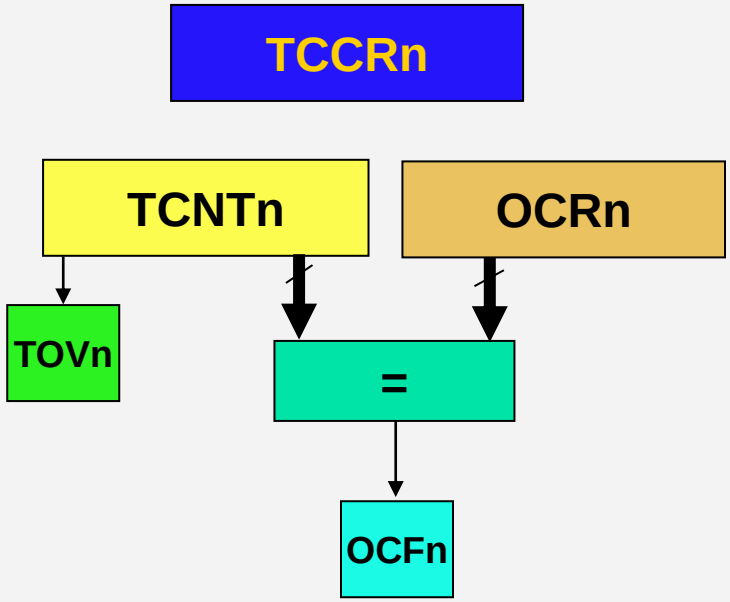

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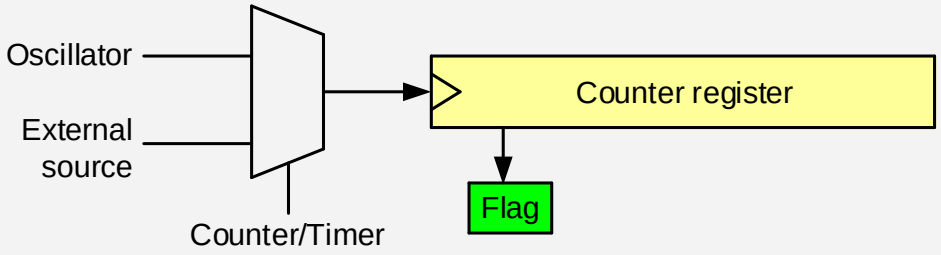

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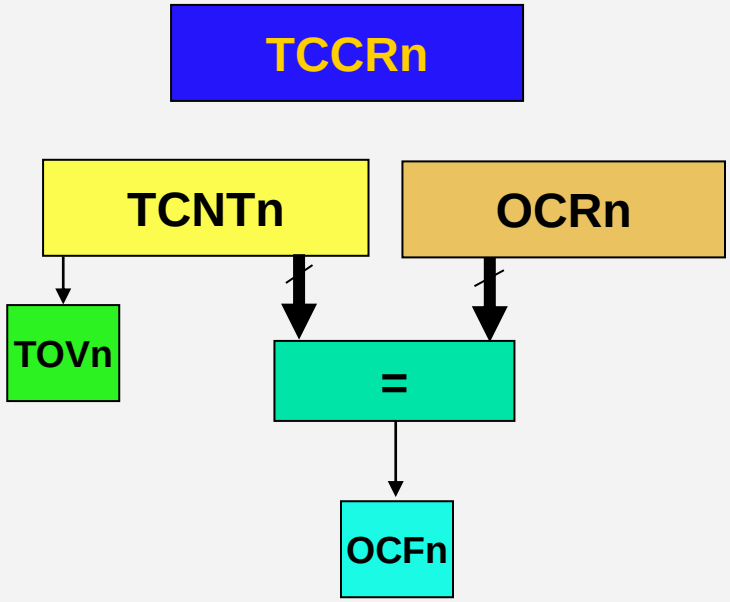

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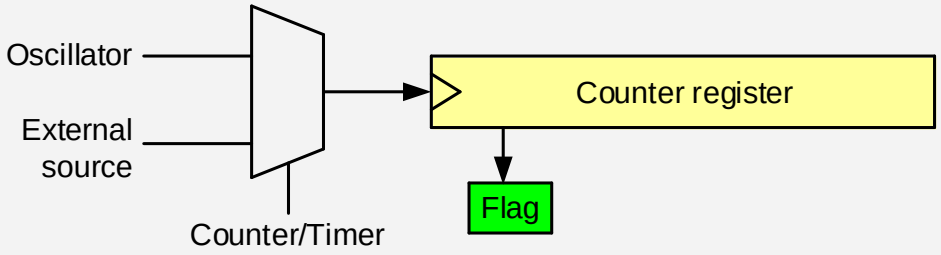


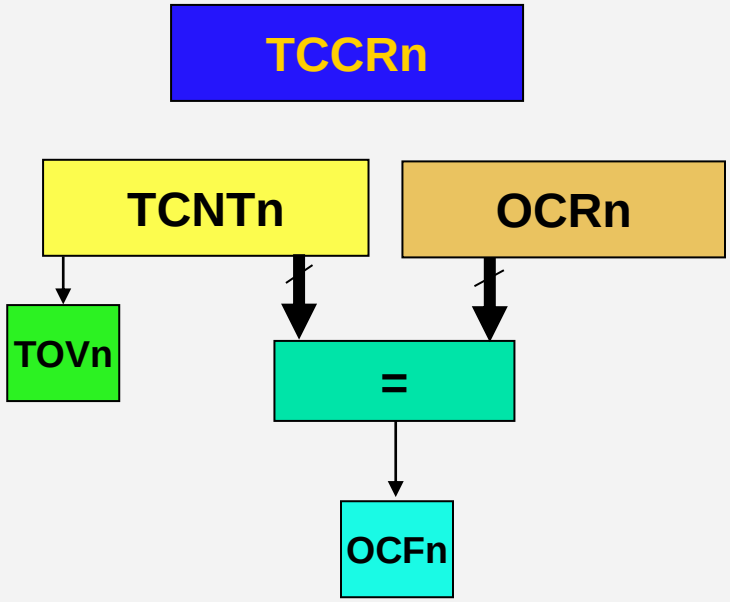
note

All of the timer registers are byte-addressable registers

Timer in AVR

- TCNTn (Timer/Counter register)
- TOVn (Timer Overflow flag)
- TCCRn (Timer Counter control register)
- OCRn (output compare register)
- OCFn (output compare match flag)

Timer in AVR



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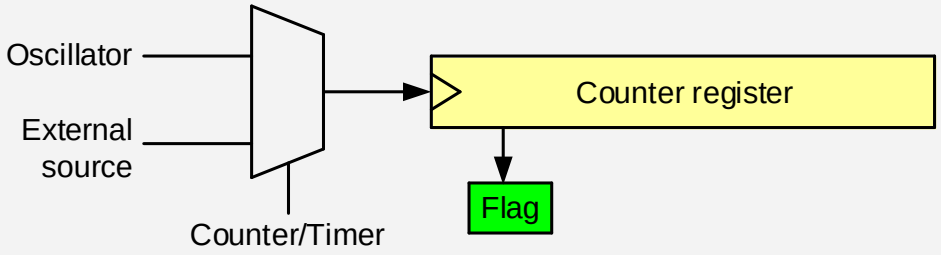

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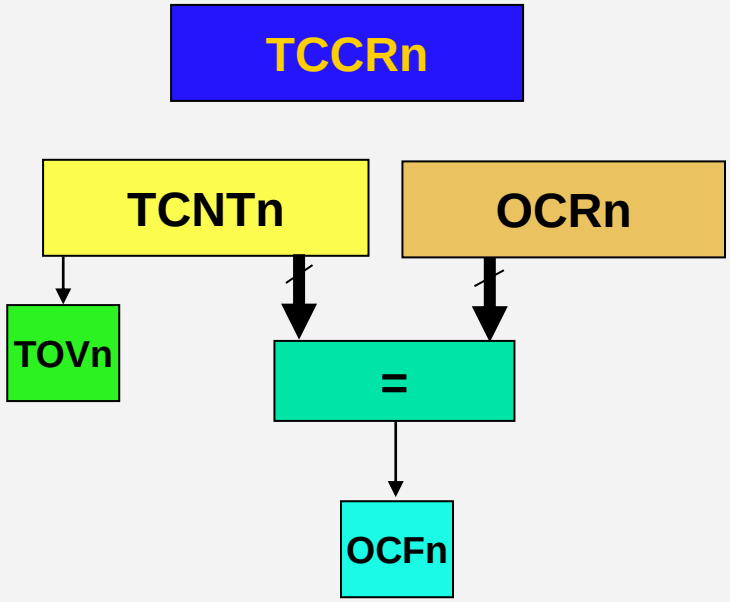

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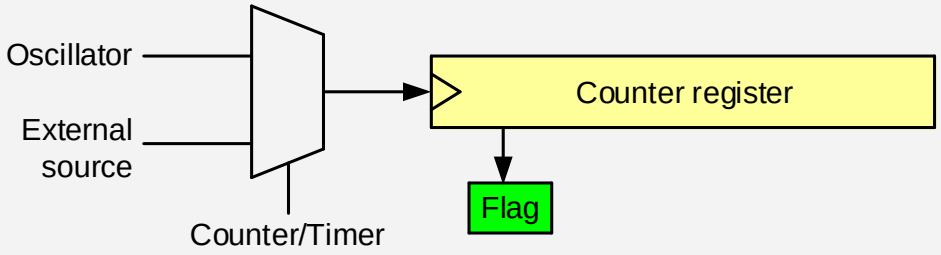

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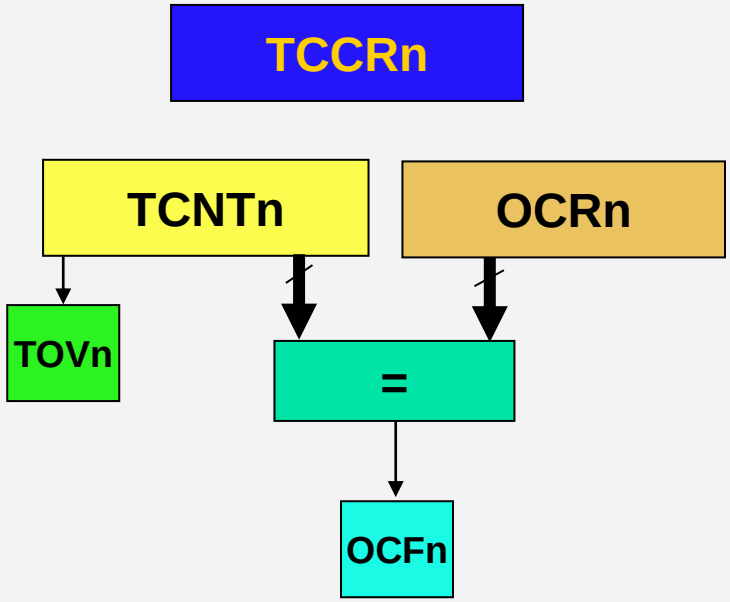
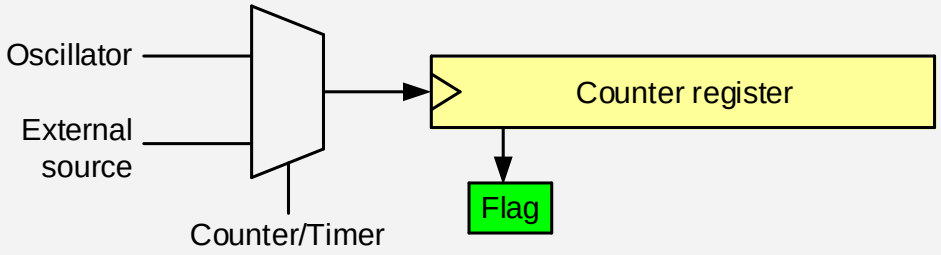


Timer in AVR



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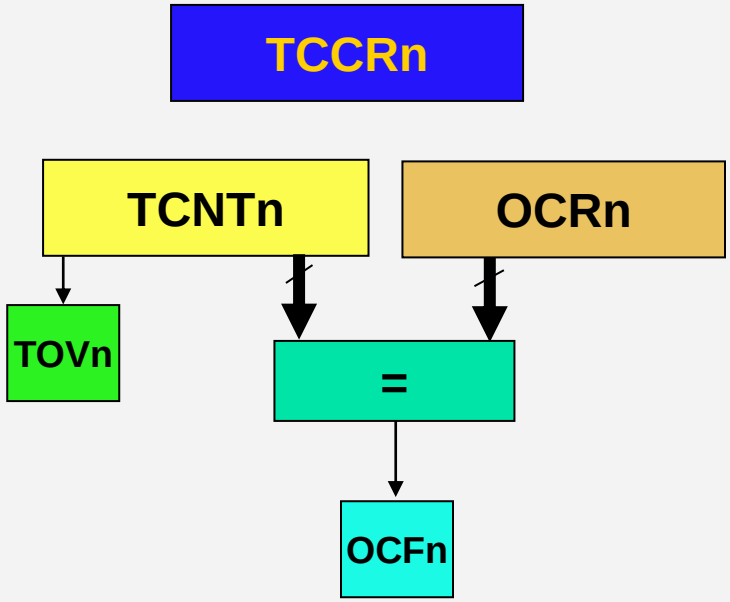
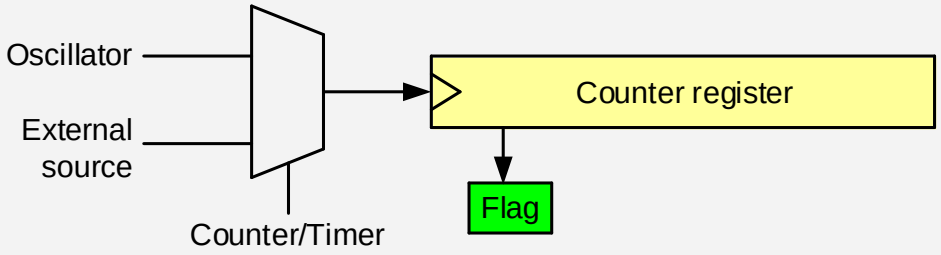


Timer in AVR



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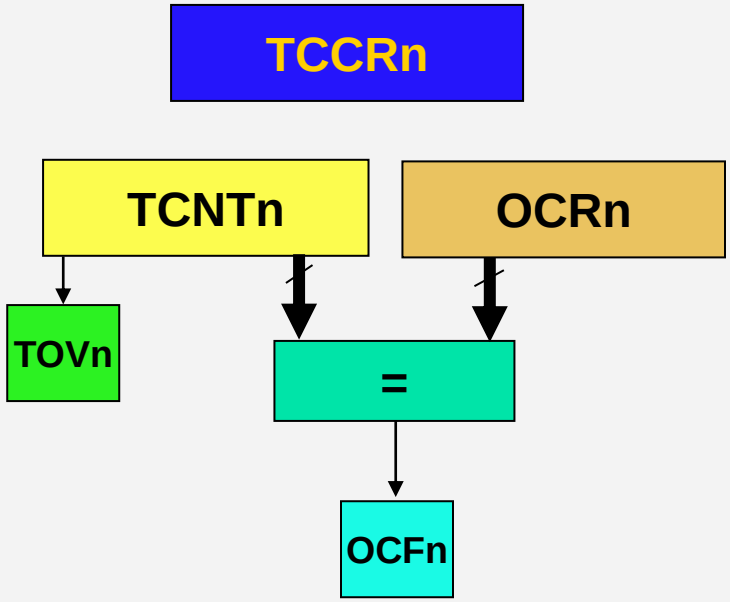
Timer in AVR



Timer 0 (8-bit timer)

–	–	–	–	–	OCIE0B	OCIE0A	TOIE0

TIMSK0

Timer 0 (8-bit timer)

TCNT0

-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)

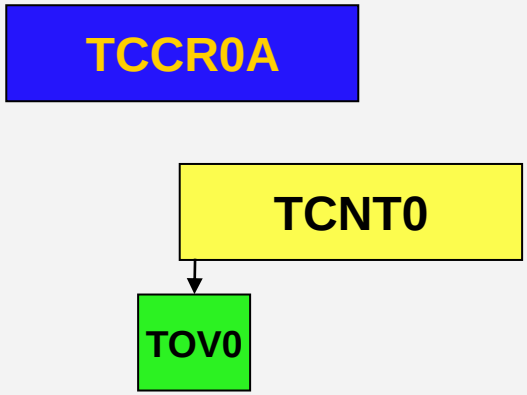
TCCR0A

TCNT0

TOV0

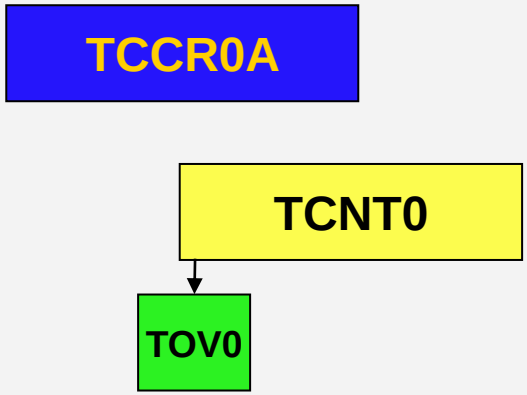
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



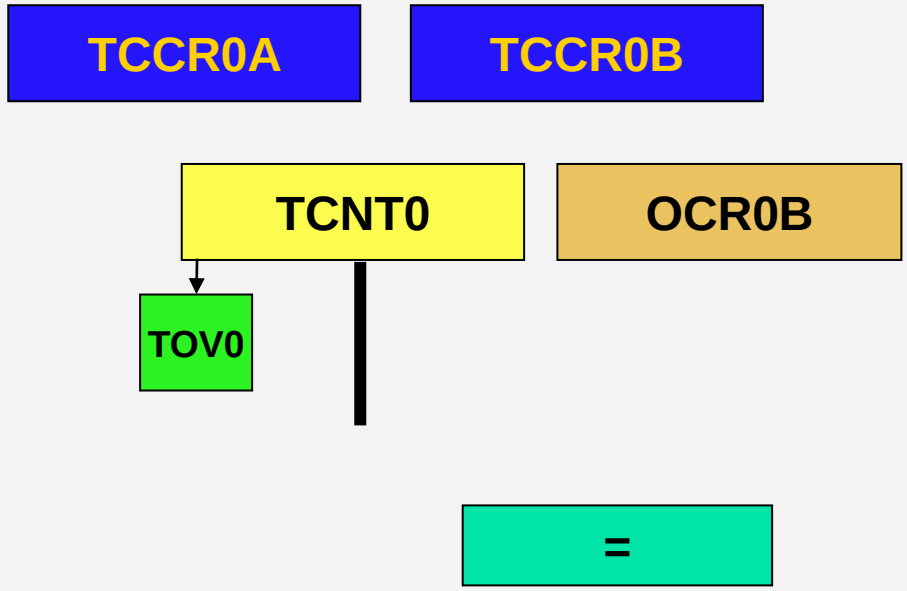
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



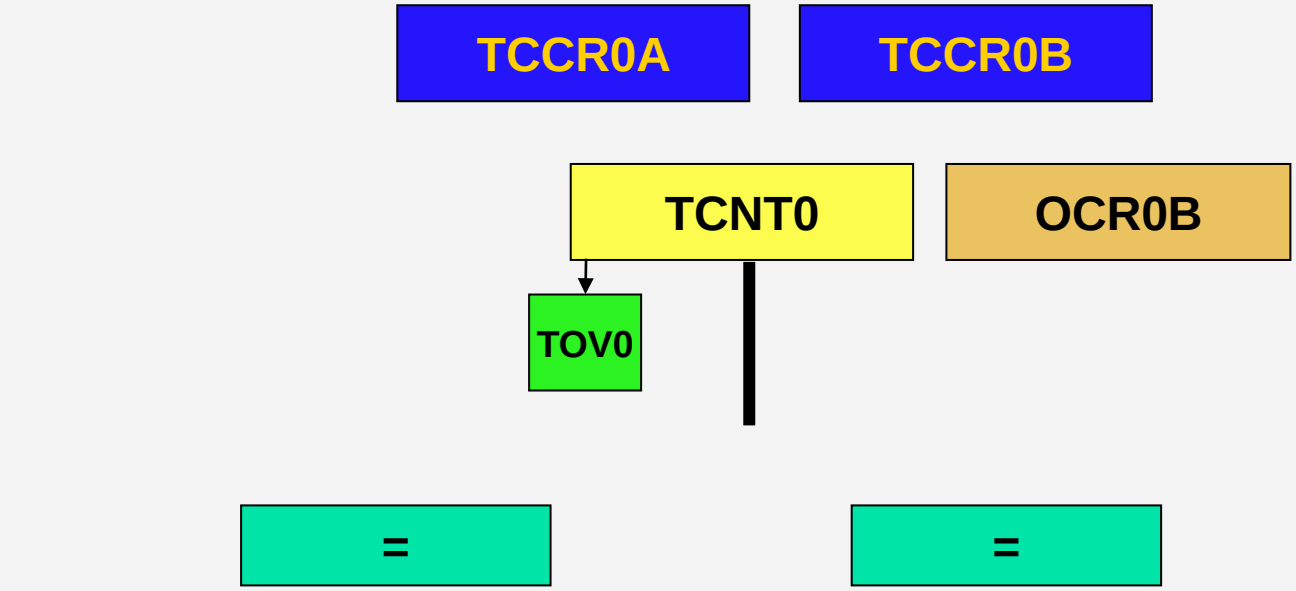
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



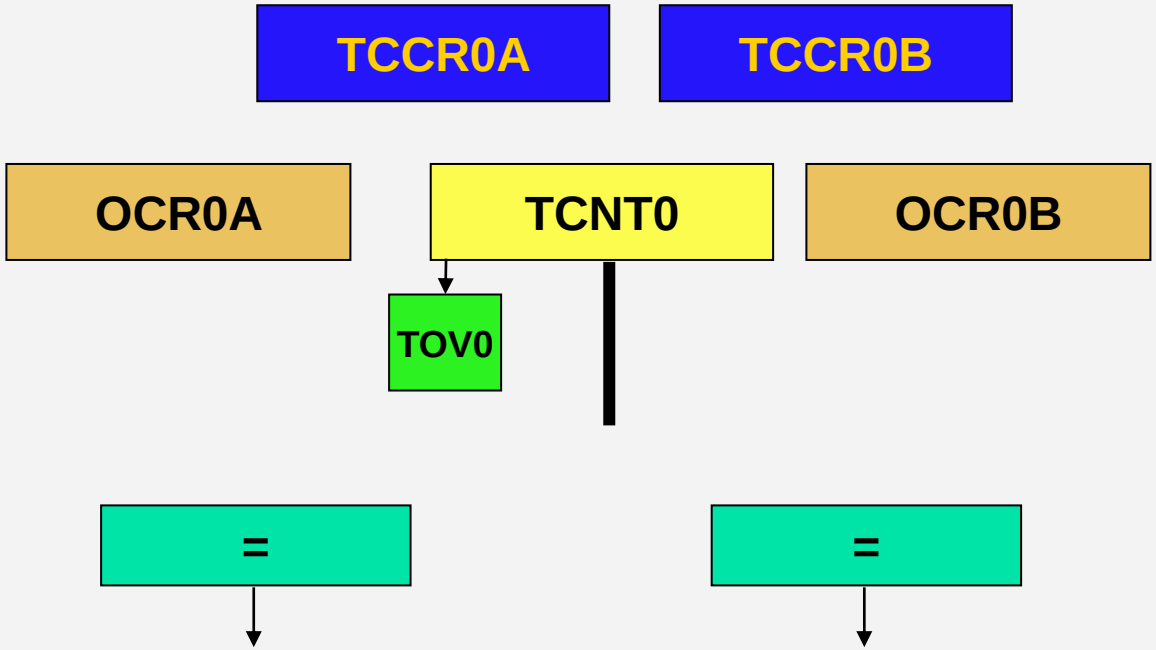
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



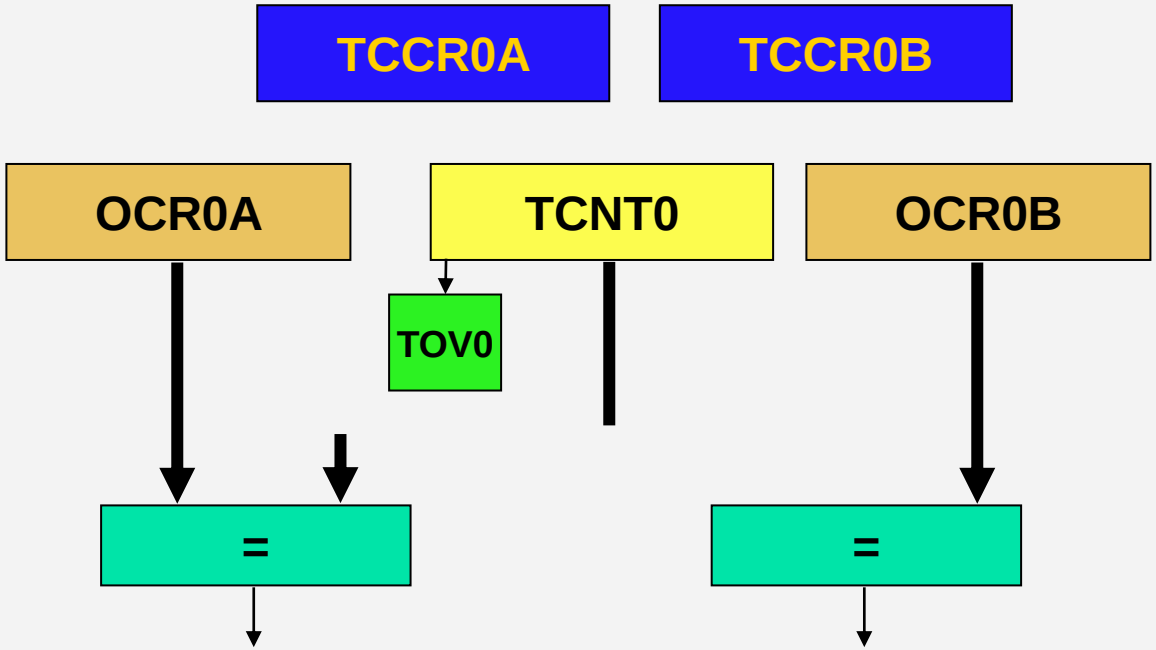
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



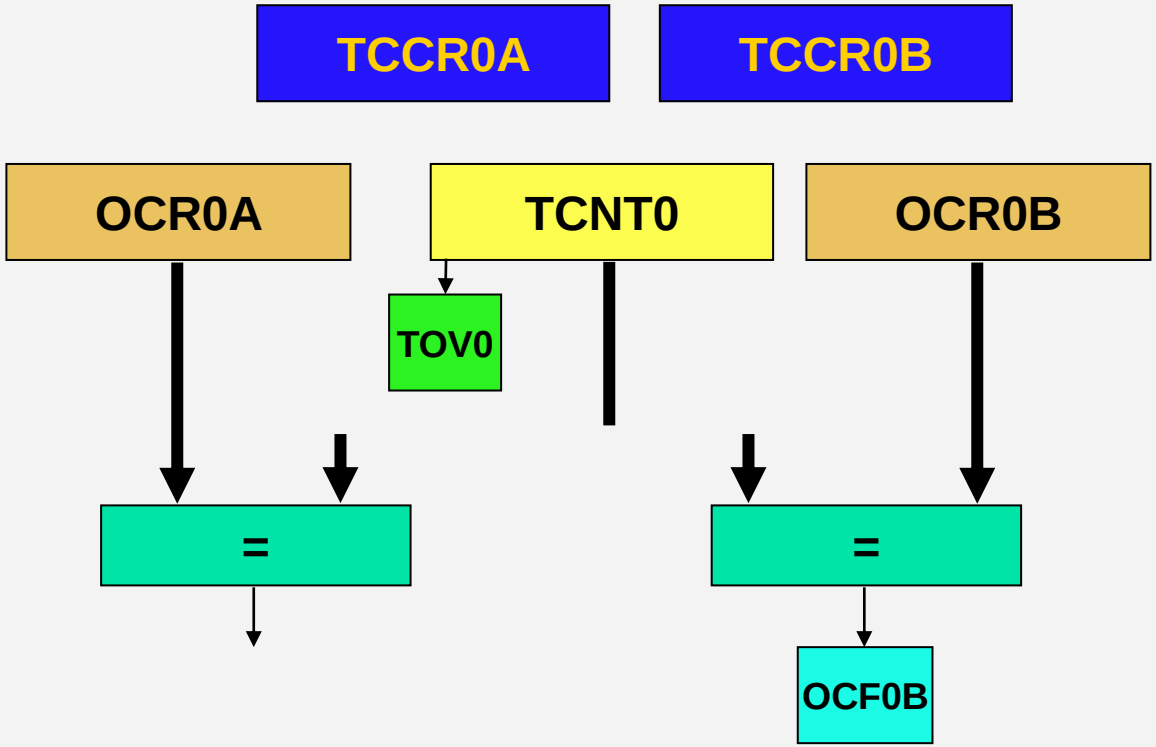
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



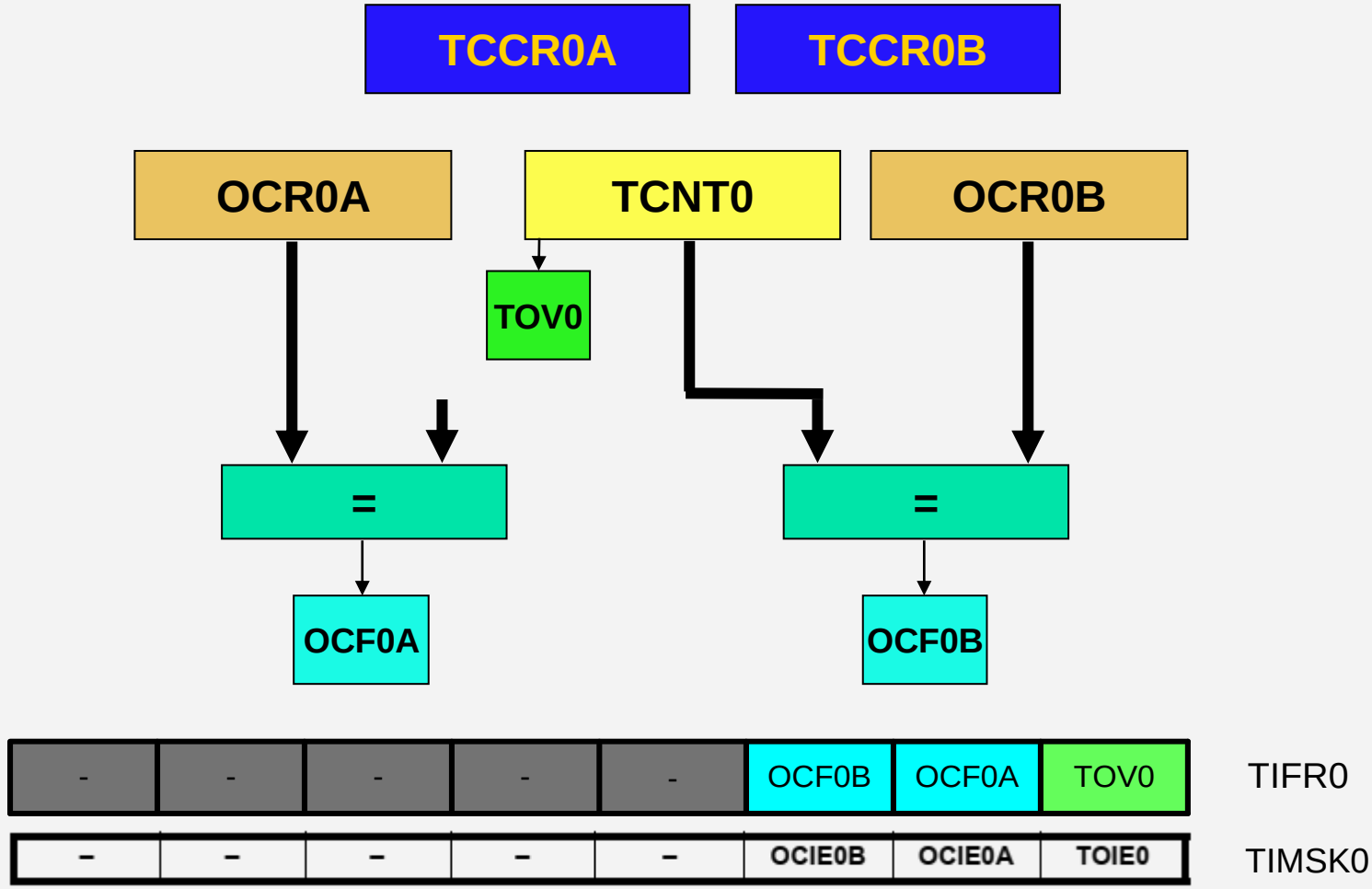
-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)

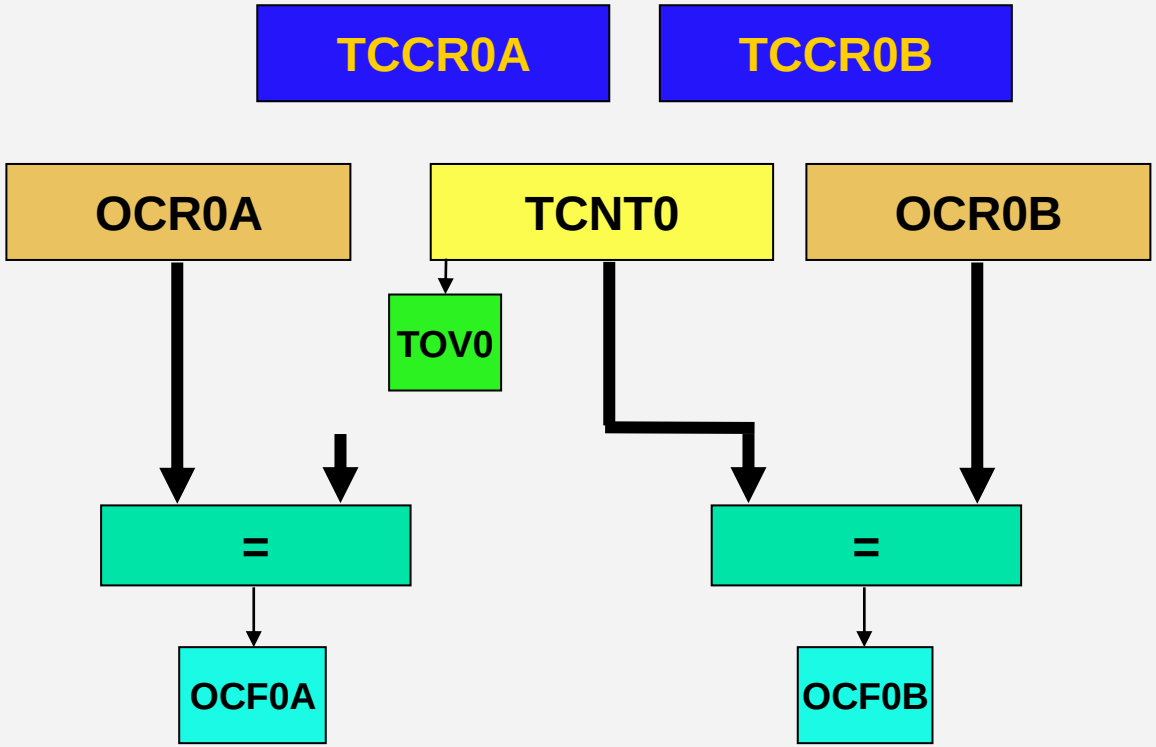


-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)

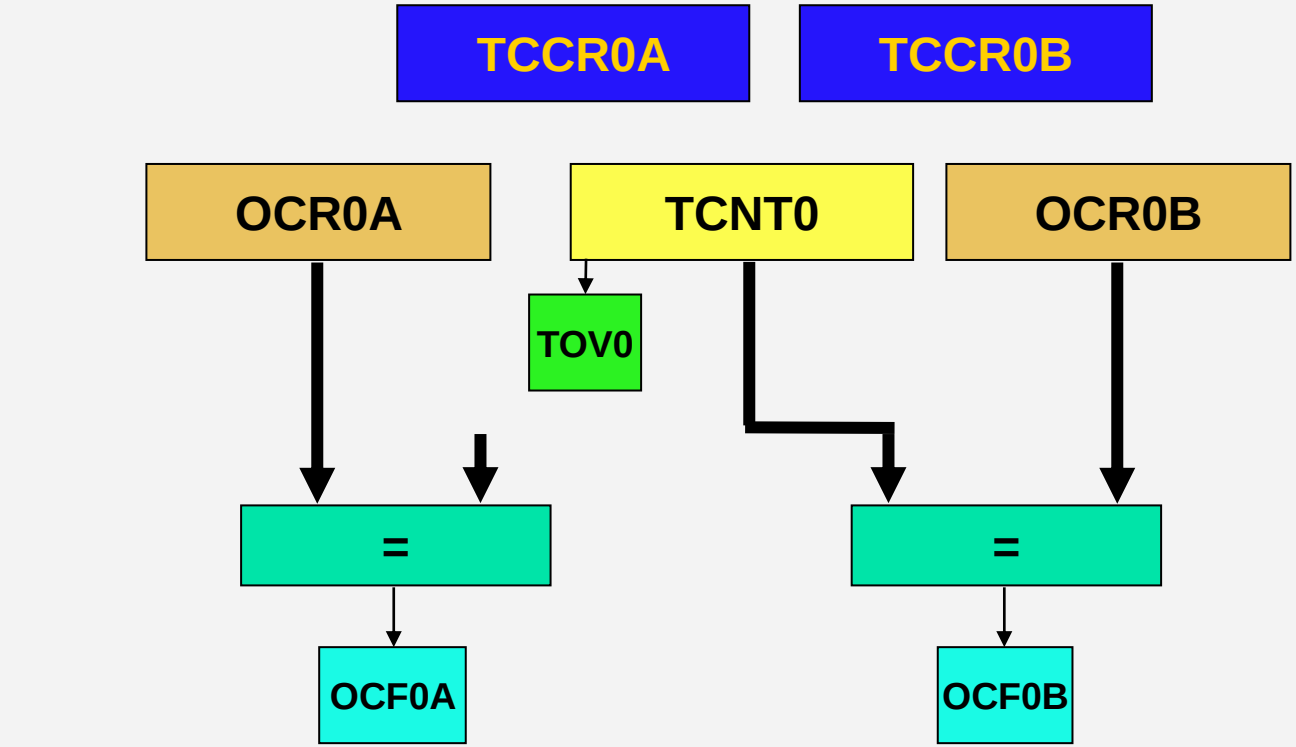


Timer 0 (8-bit timer)



-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0

Timer 0 (8-bit timer)



-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
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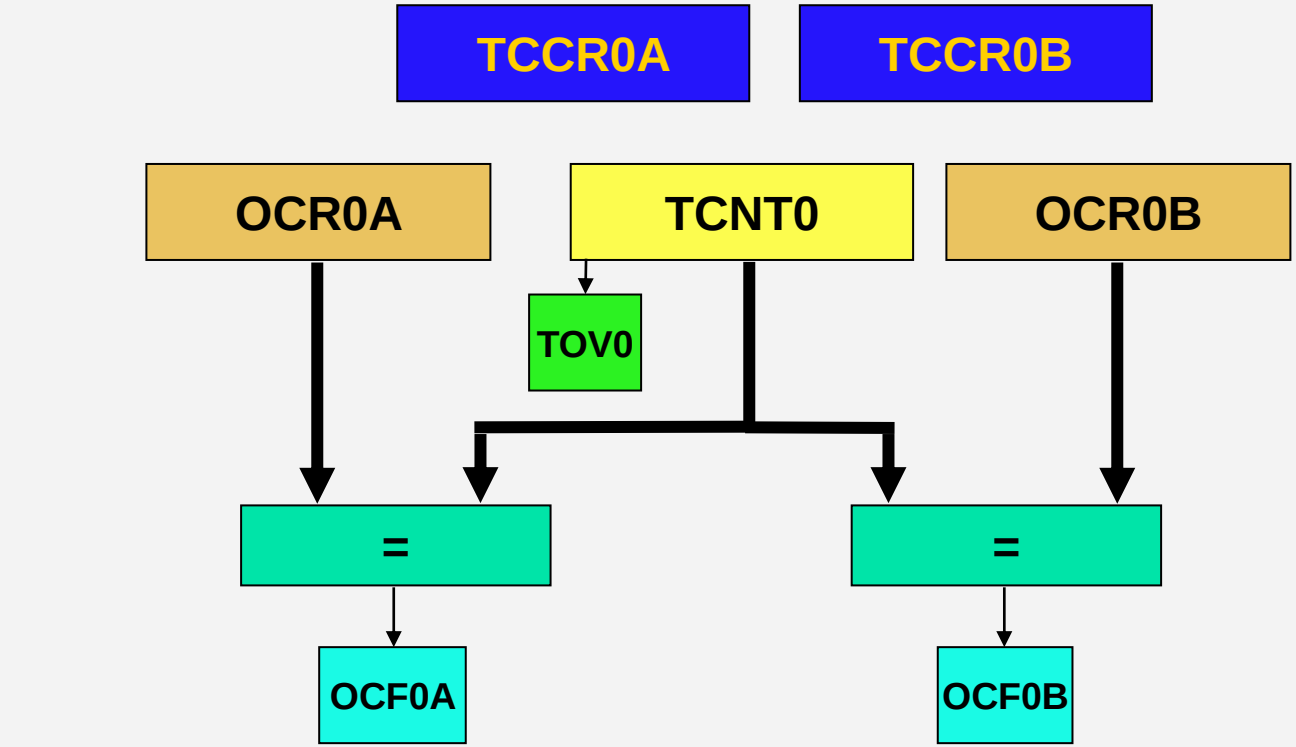

-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
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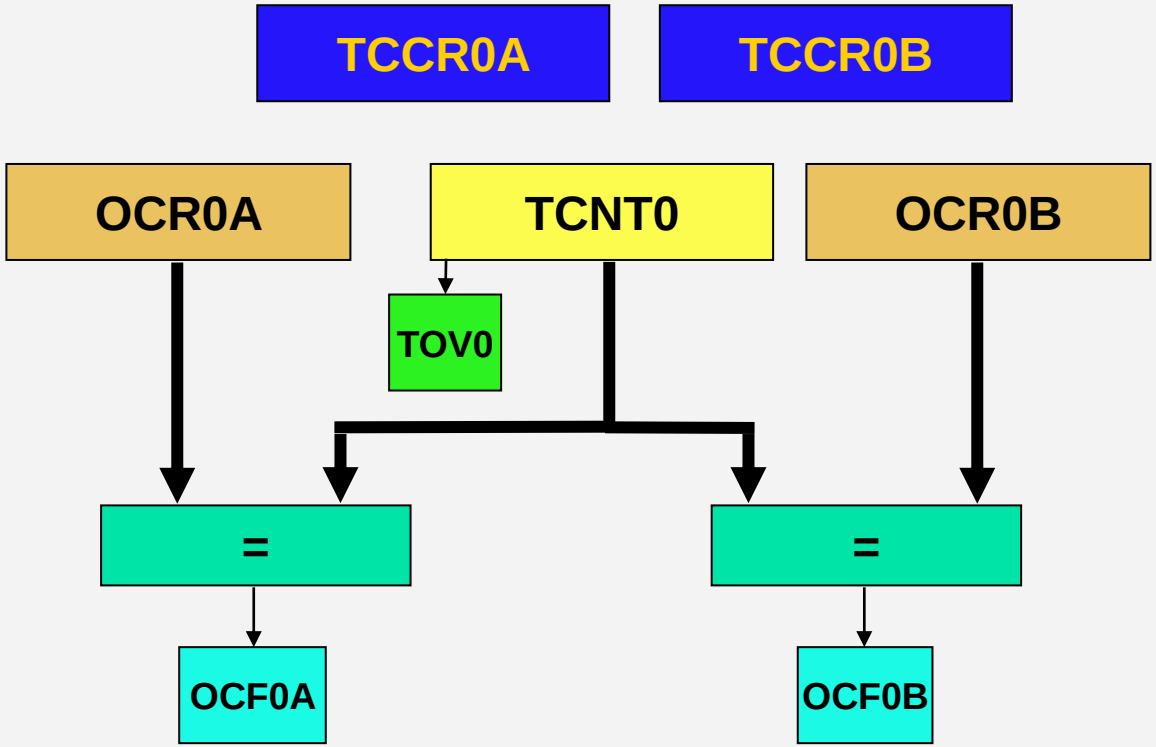
Timer 0 (8-bit timer)



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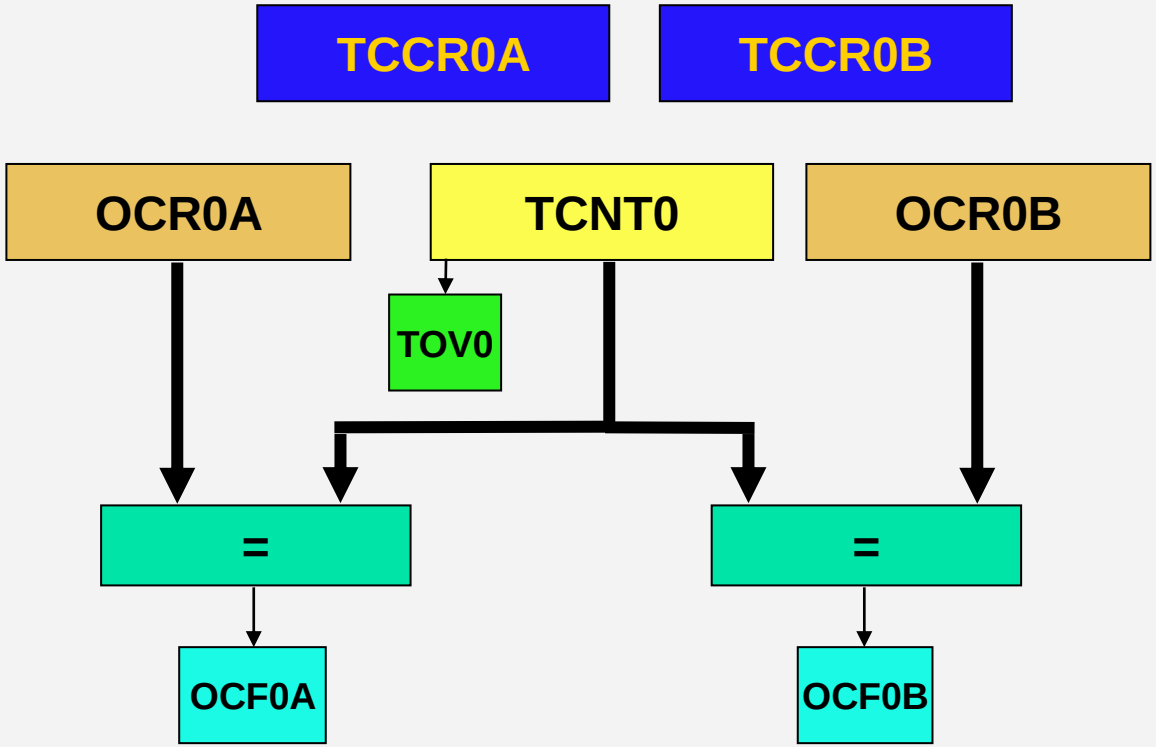

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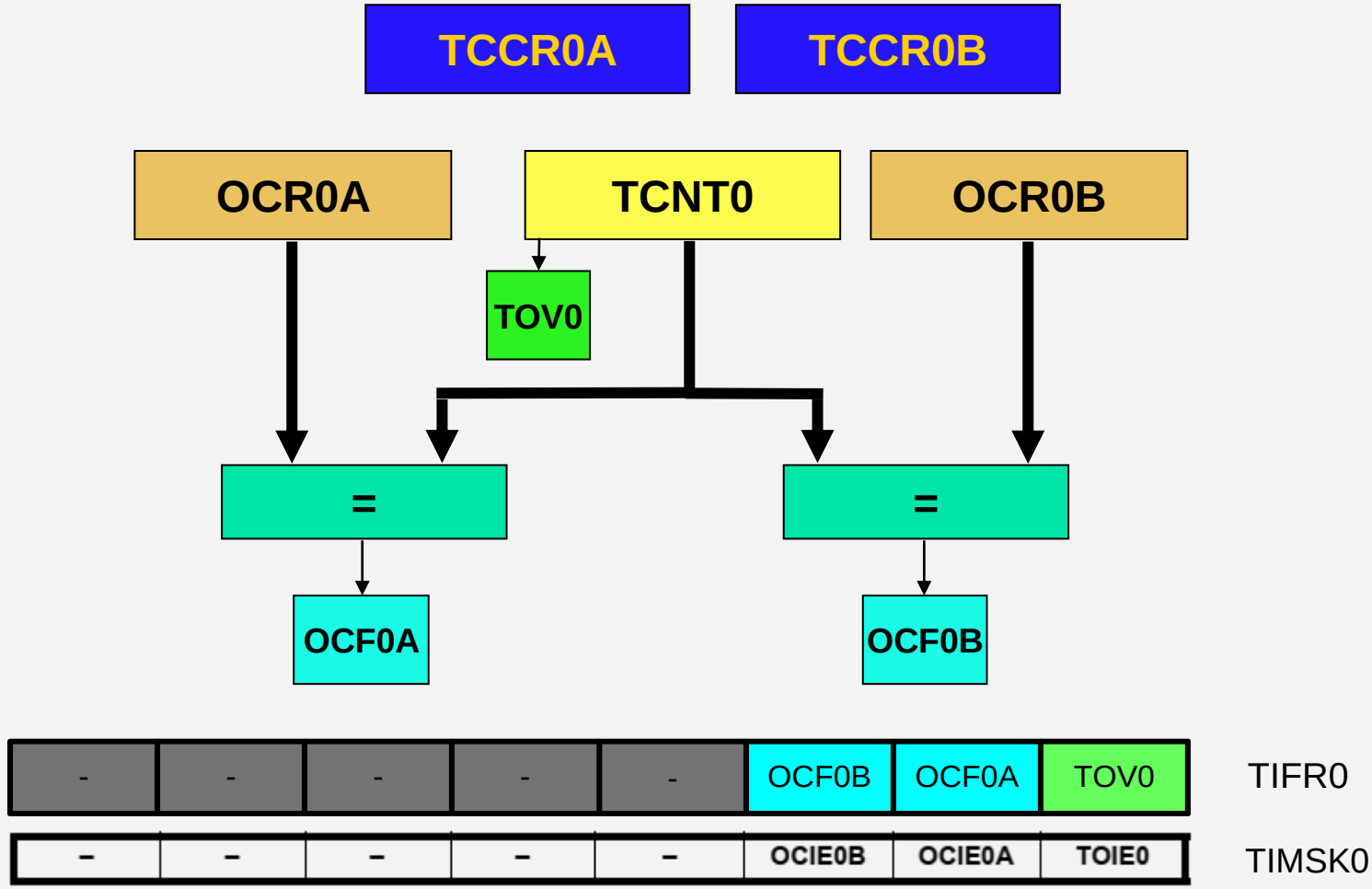

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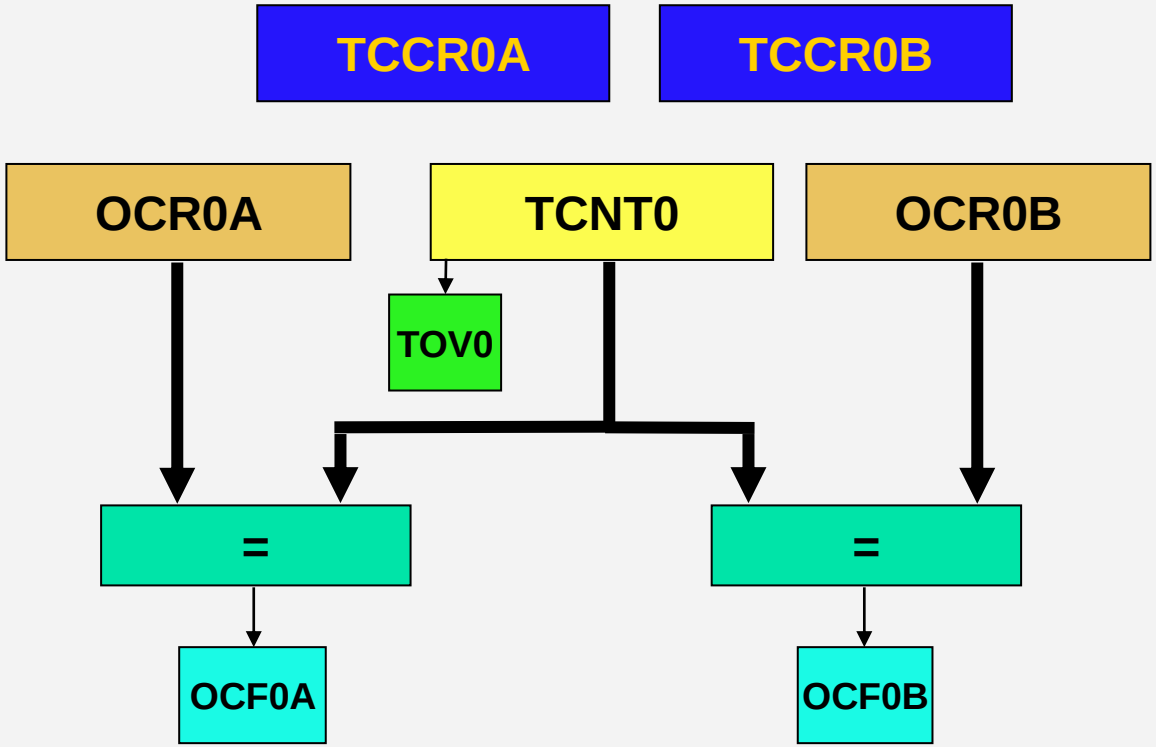

-	-	-	-	-	OCF0B	OCF0A	TOV0	TIFR0
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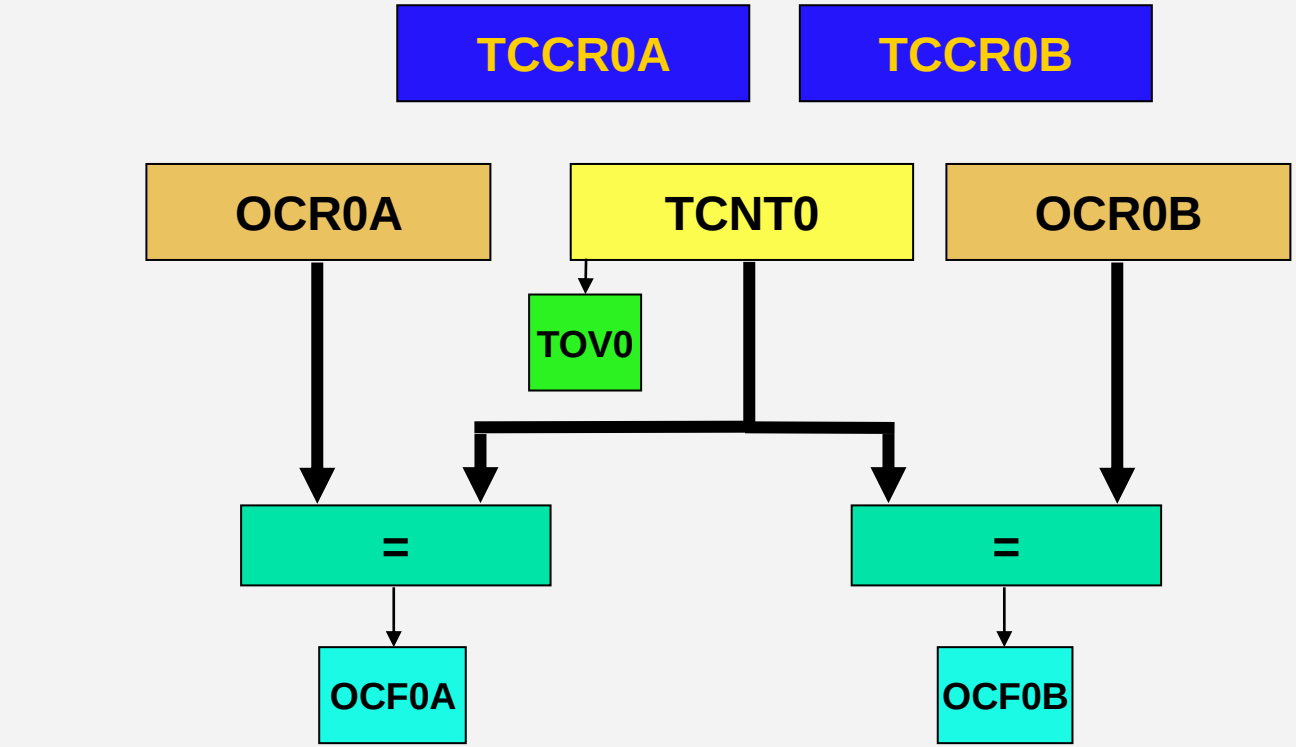

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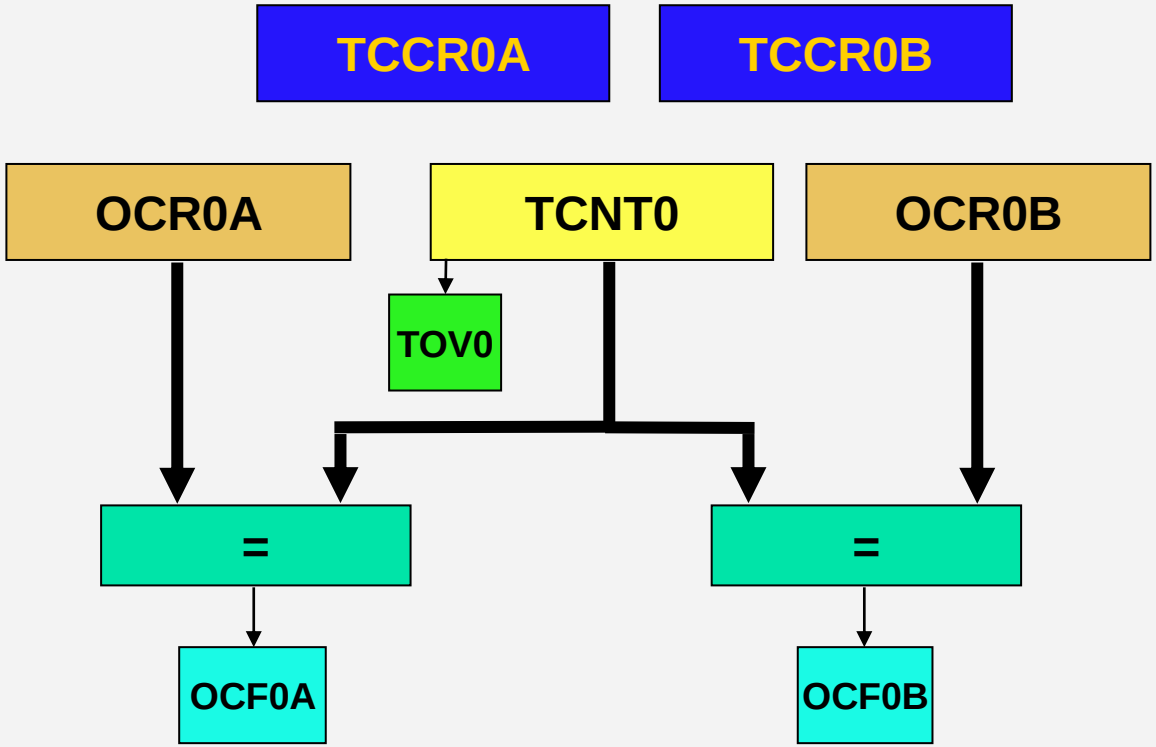

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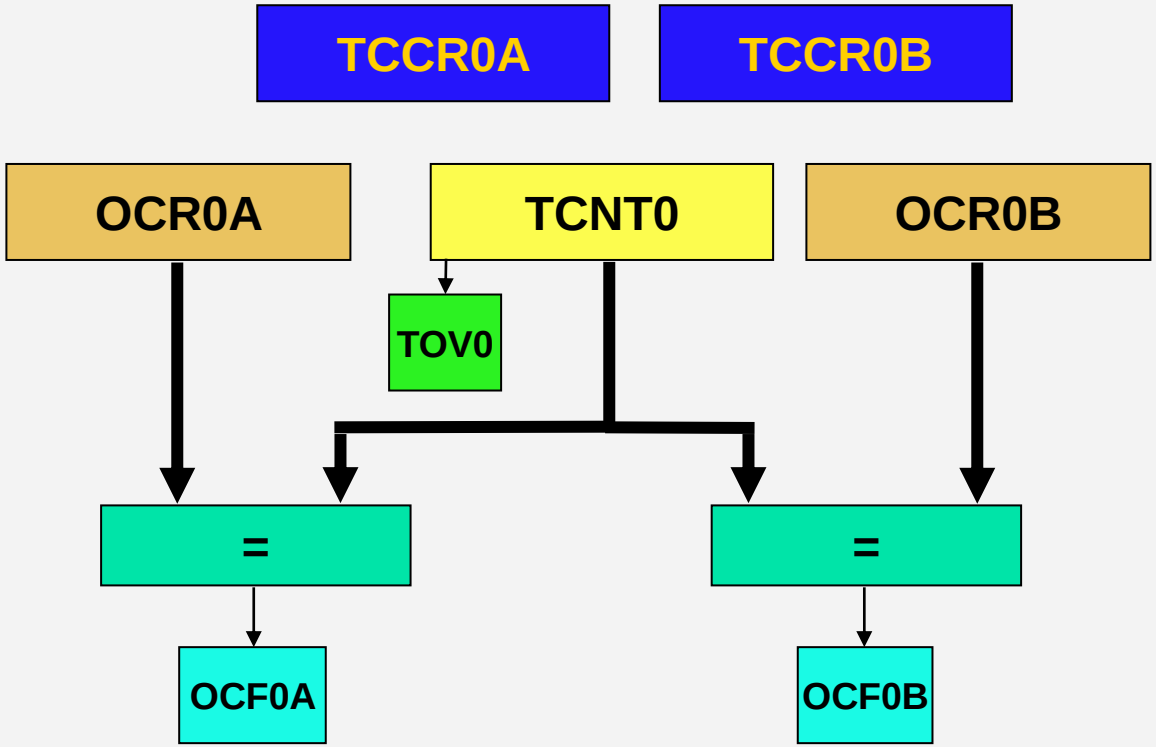

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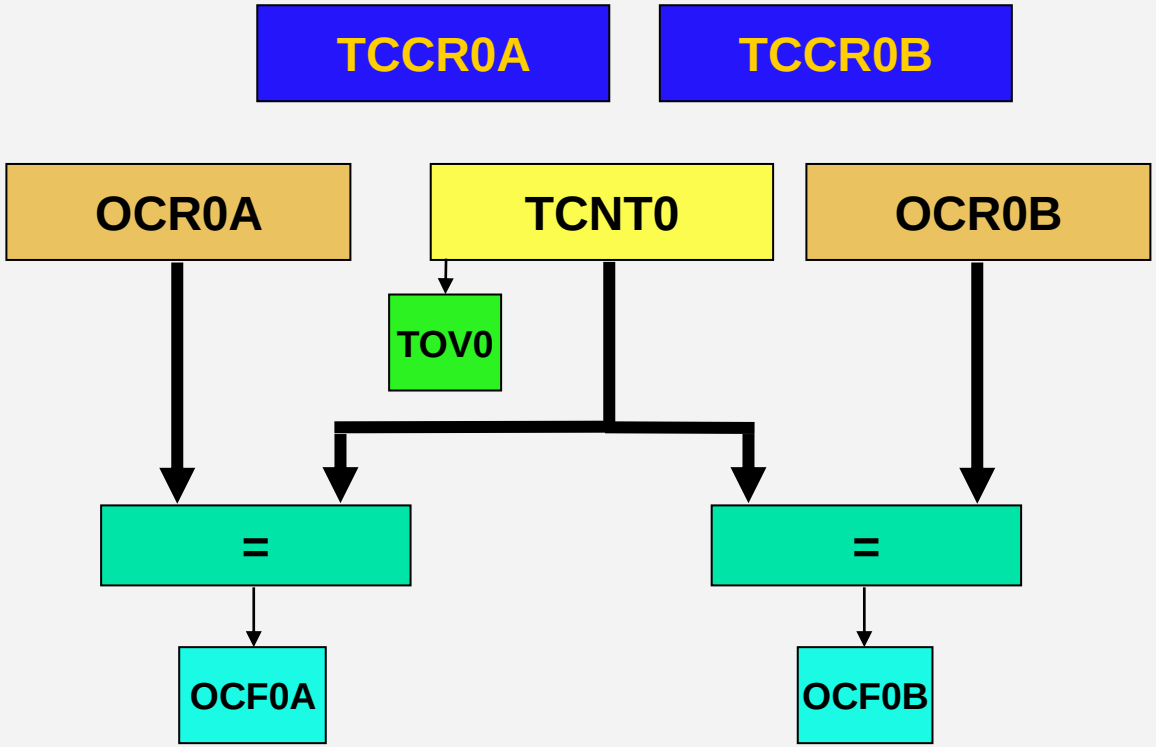

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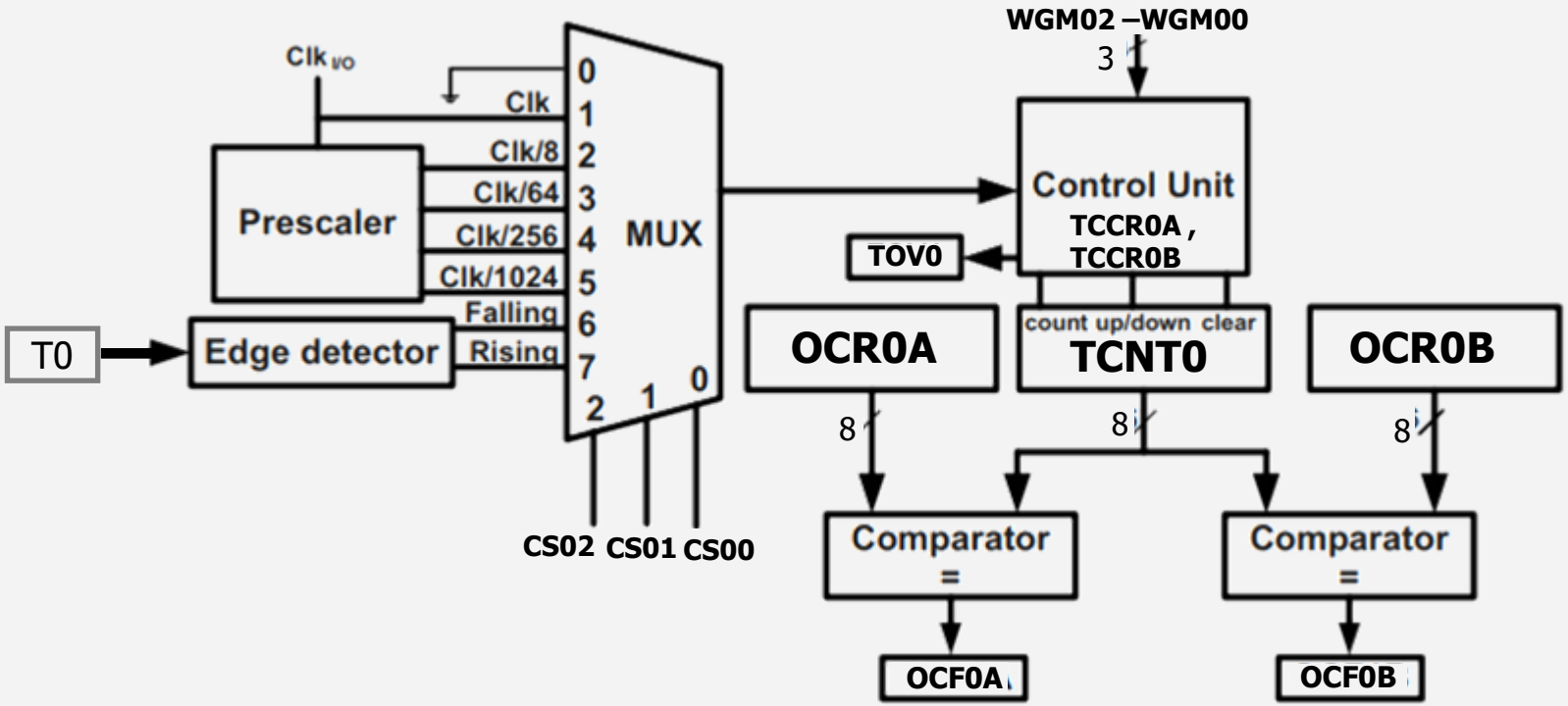

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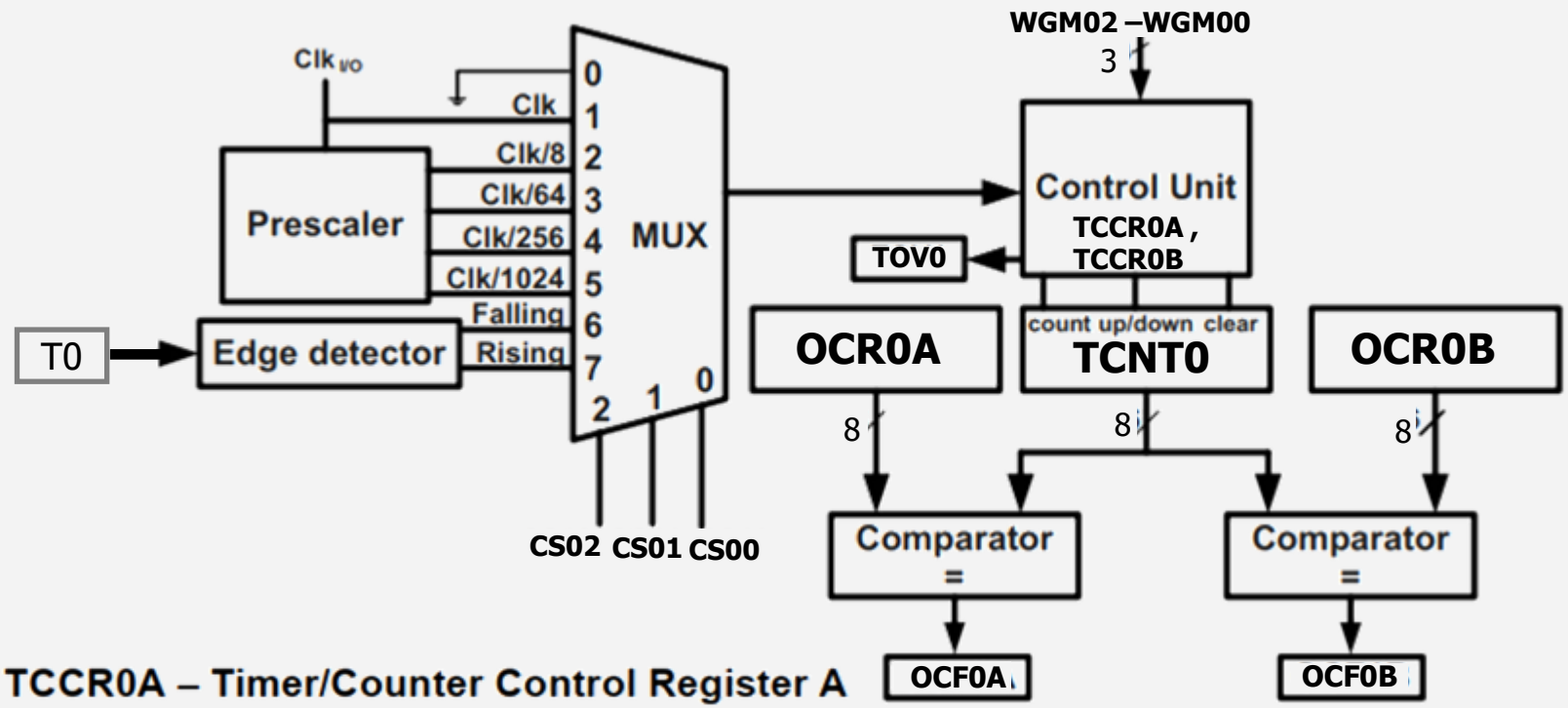


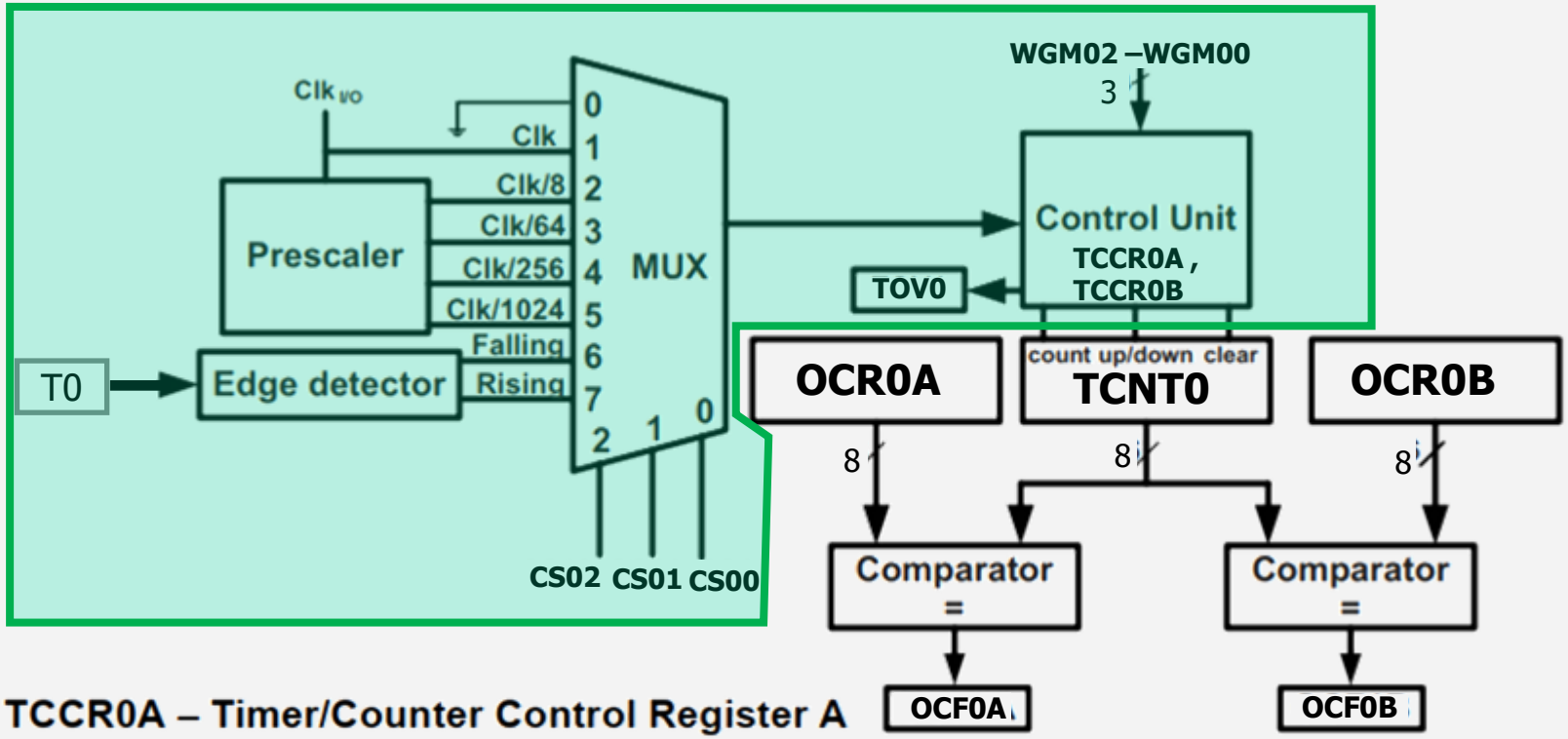
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



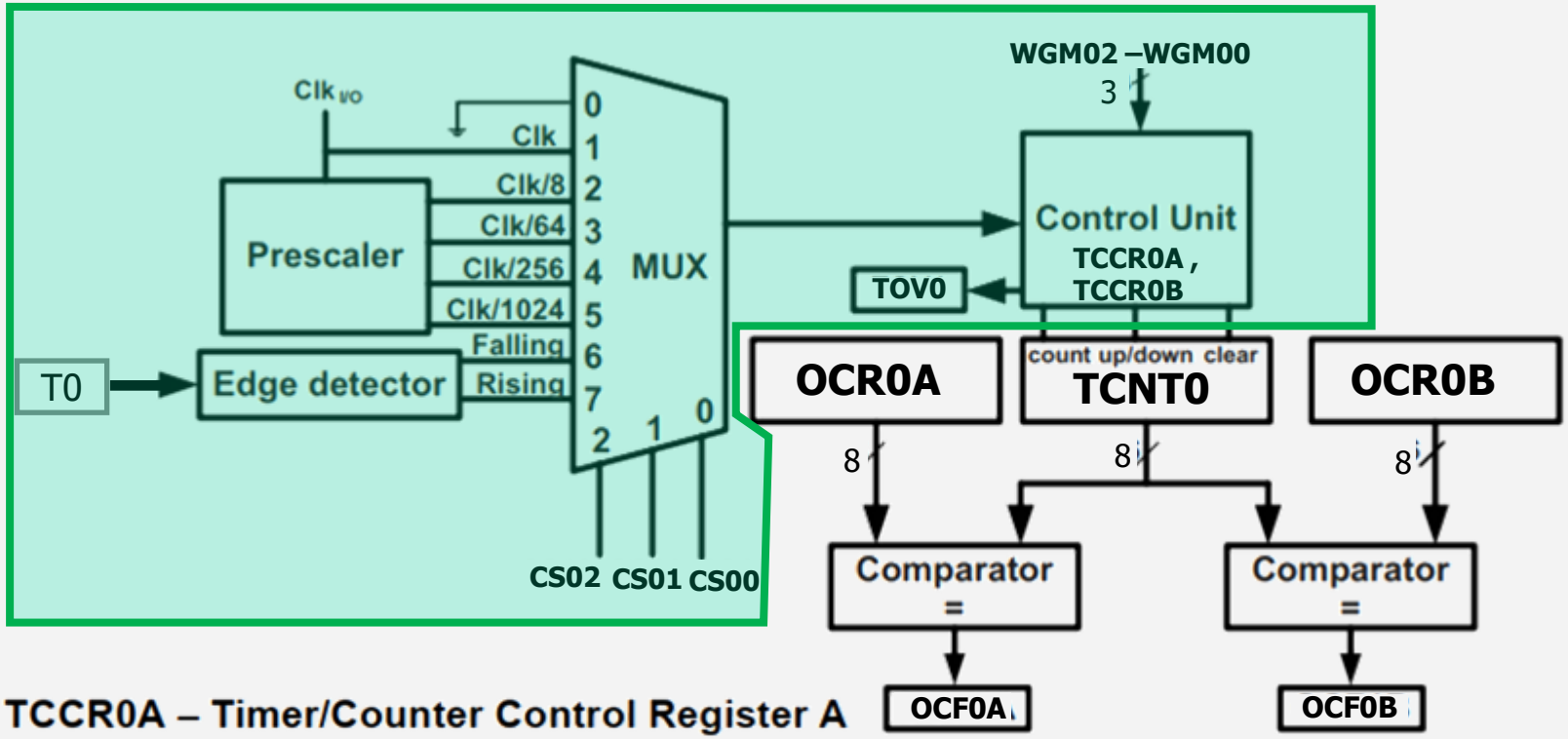
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



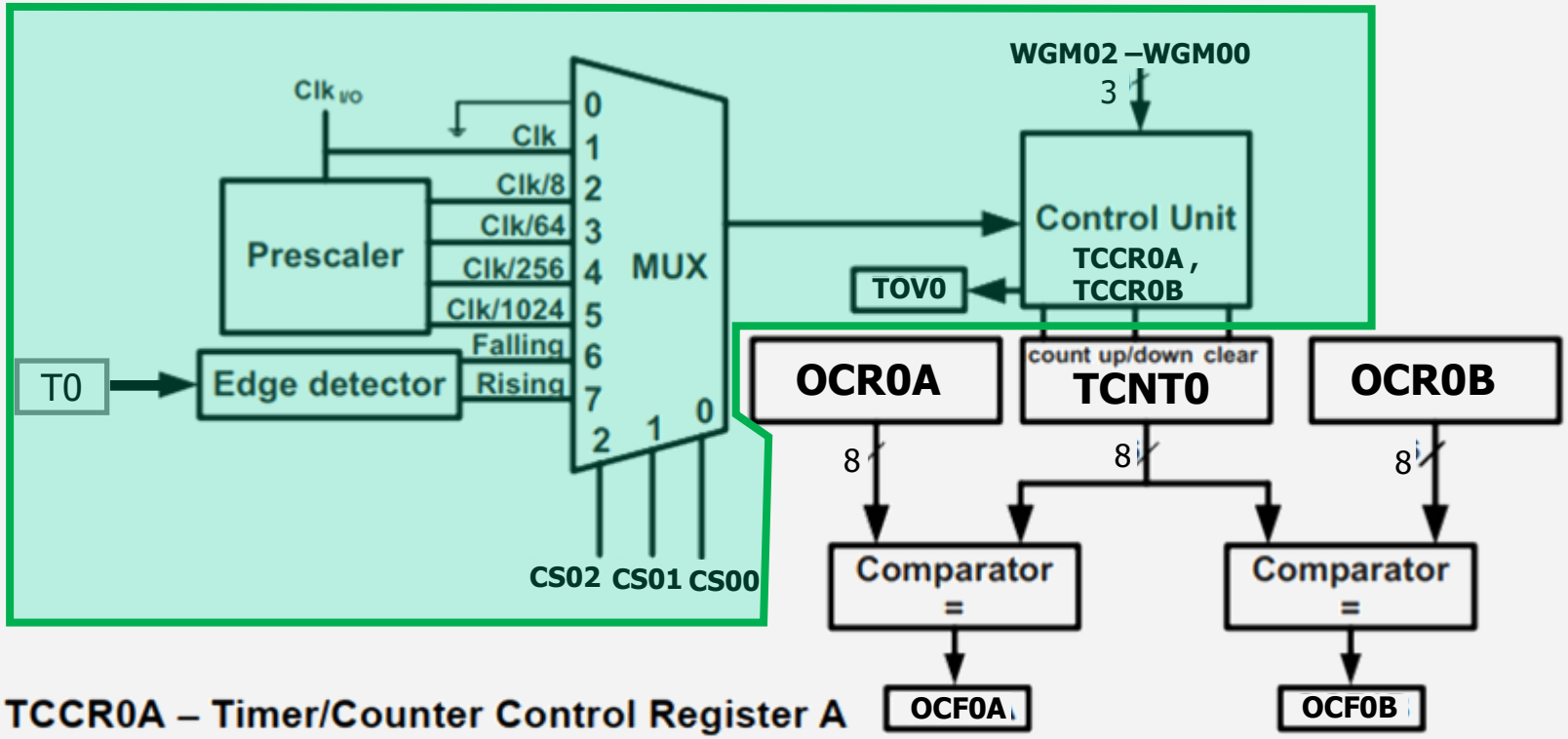
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



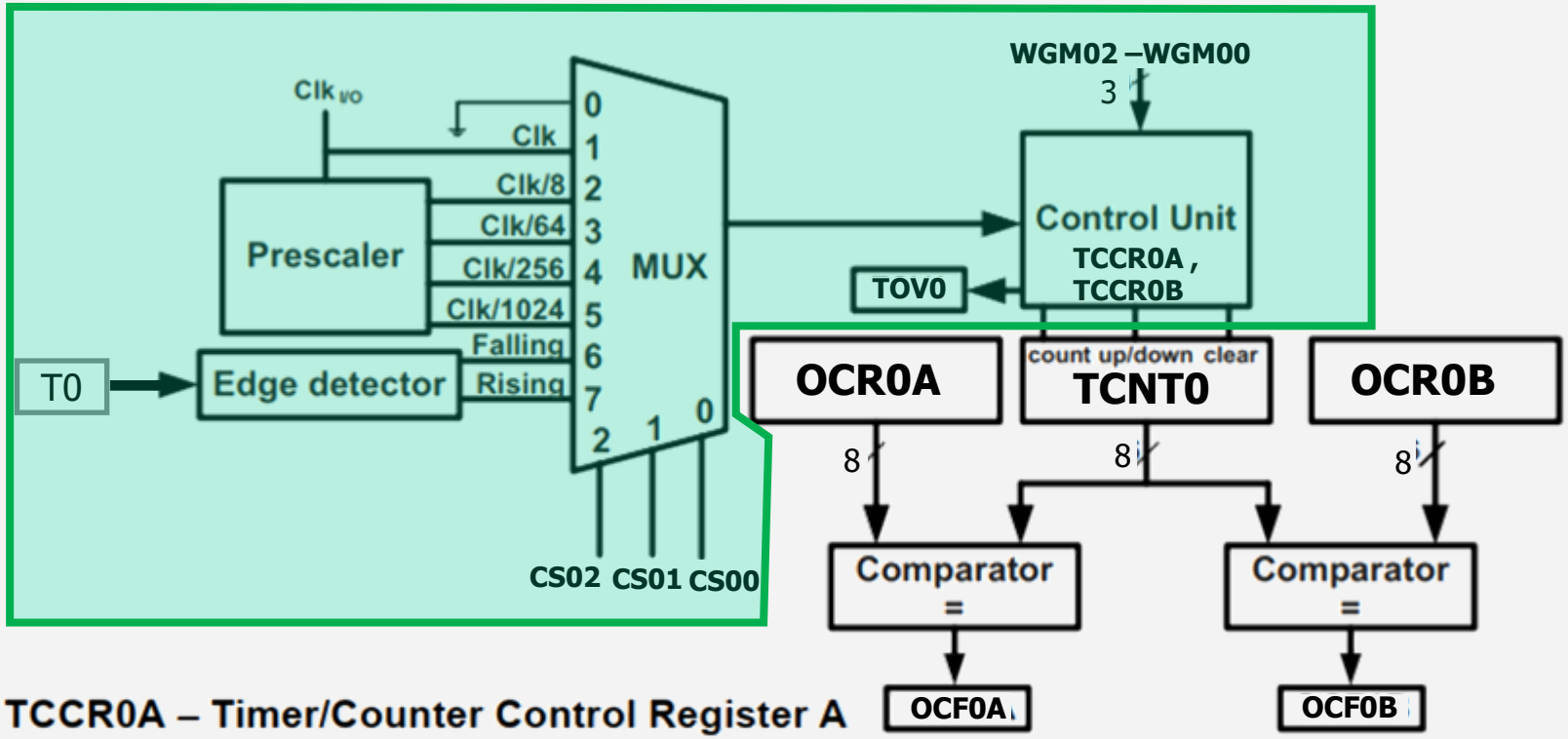
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



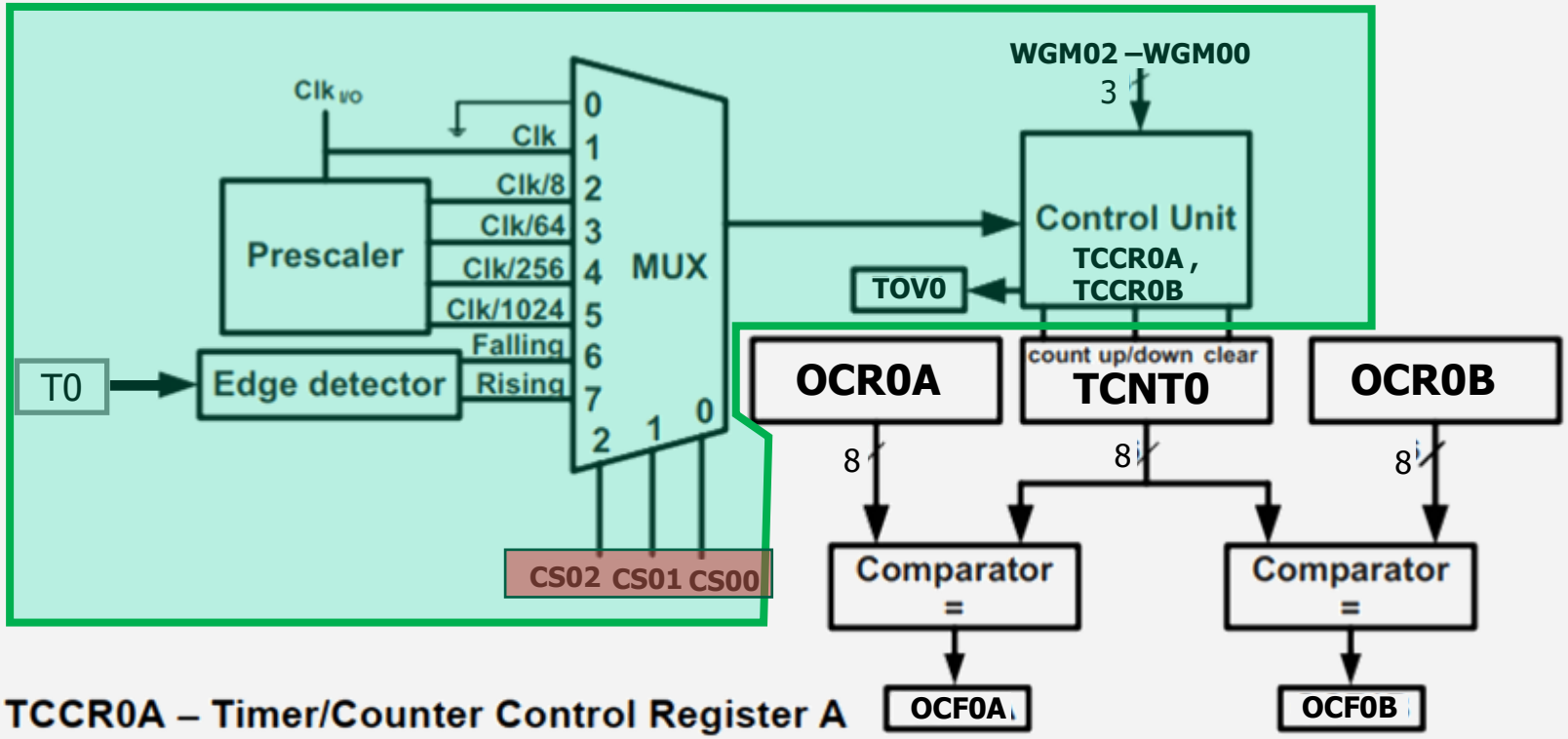
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



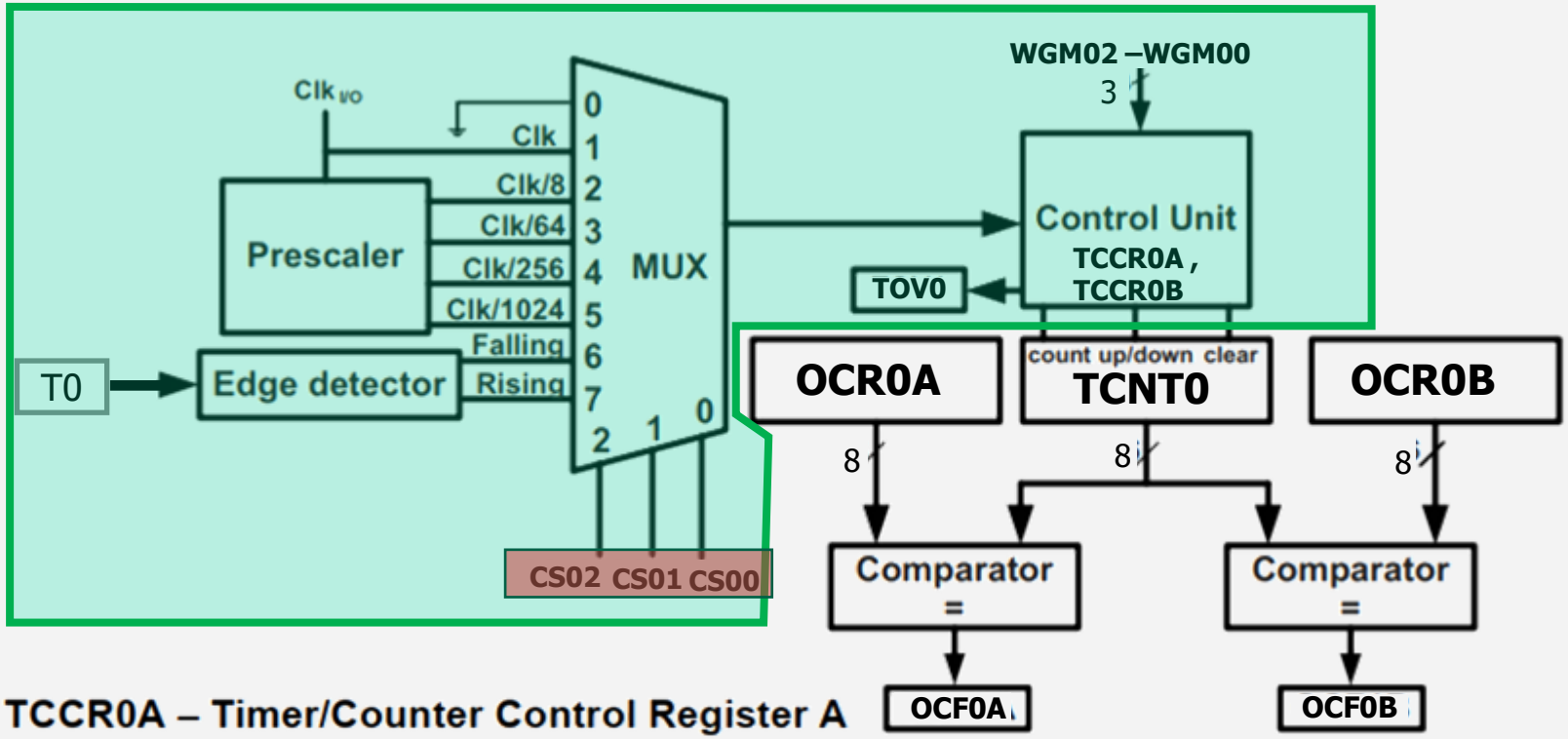
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



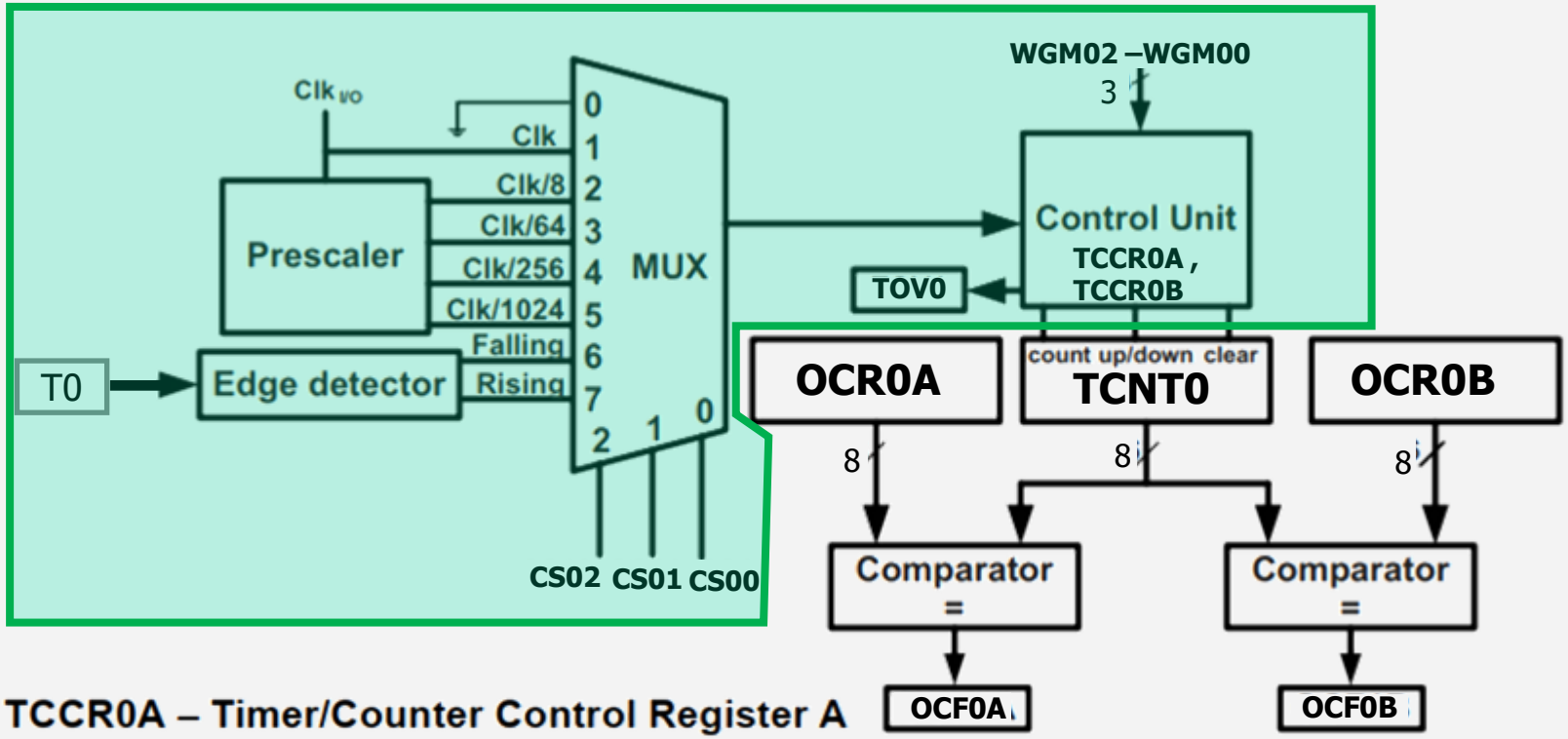
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



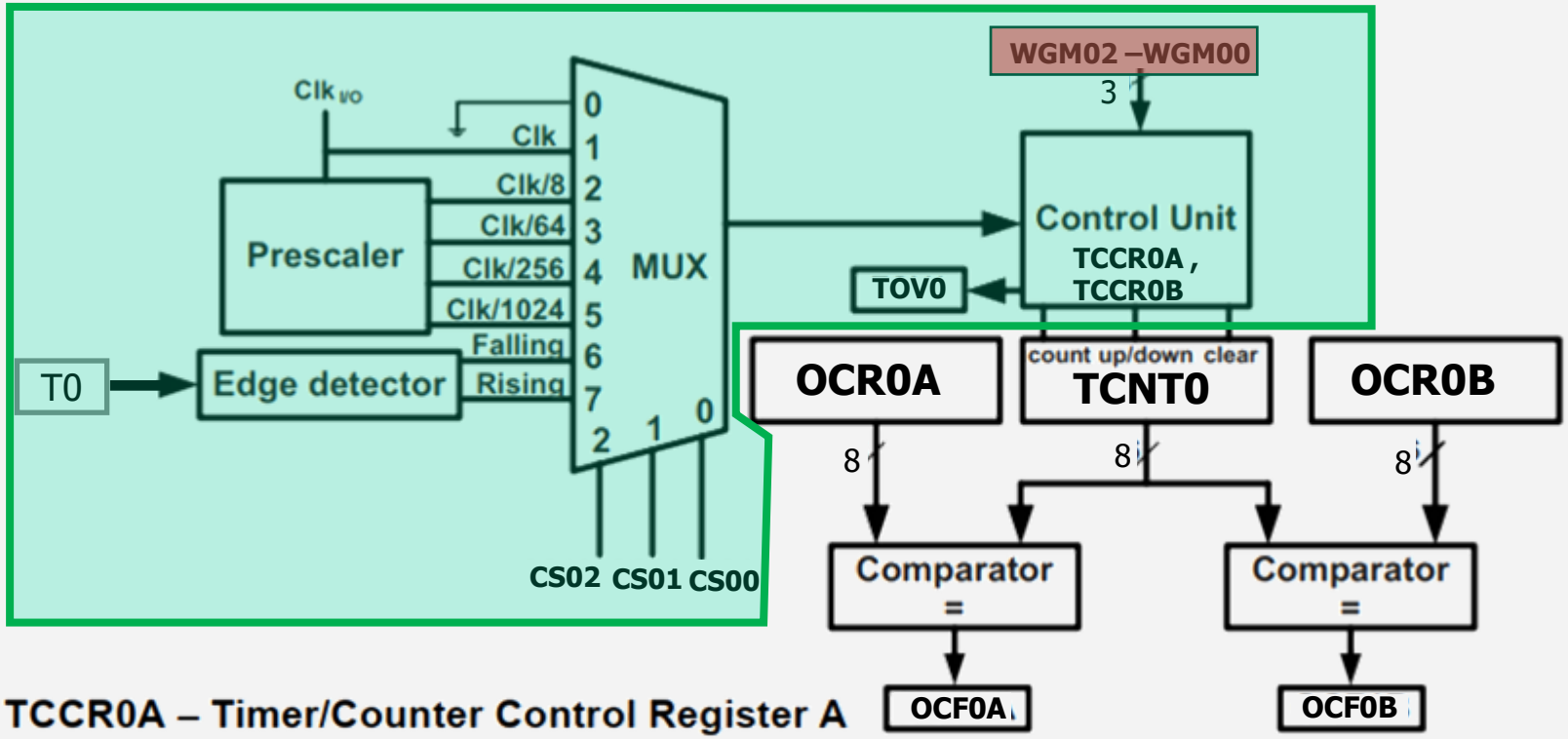
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



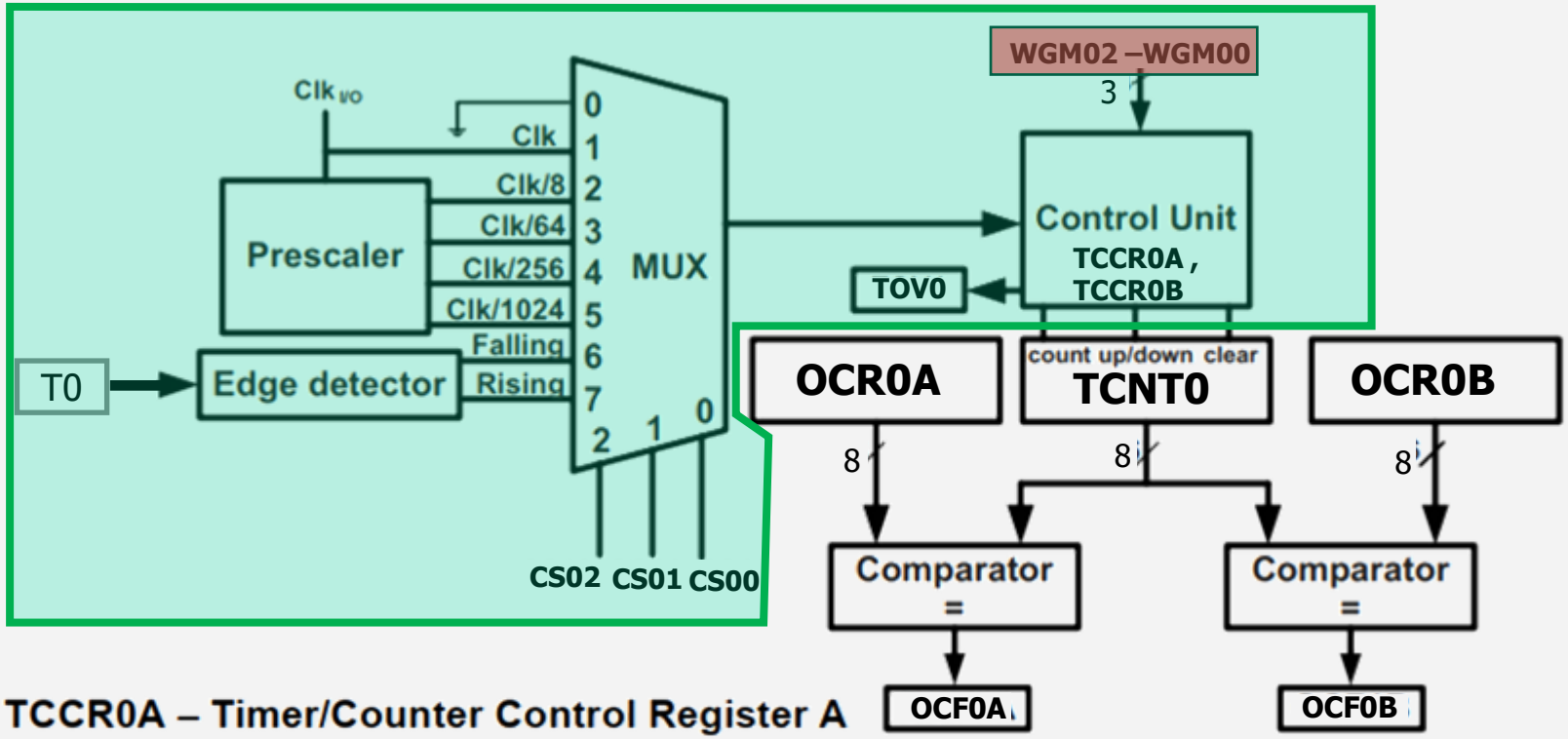
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



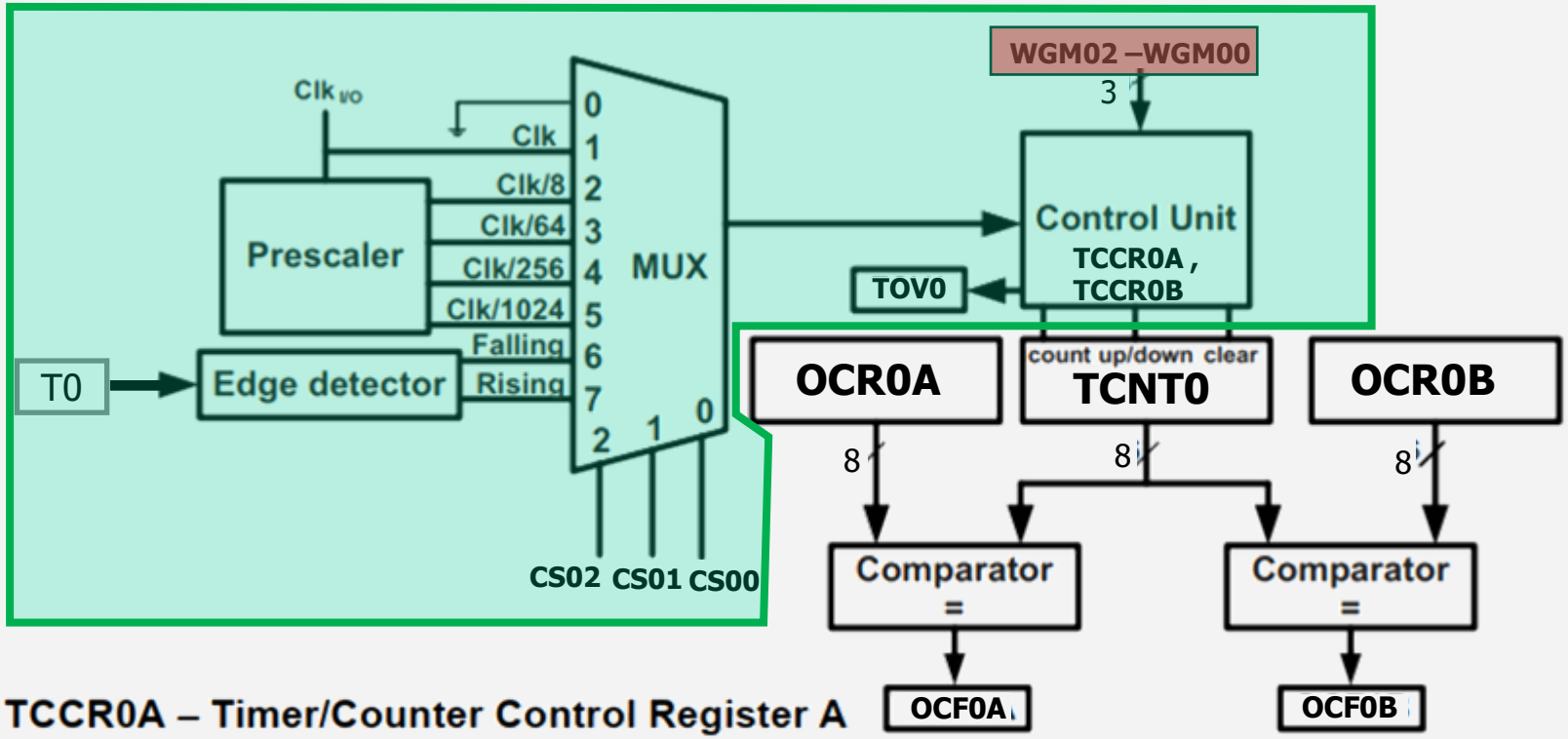
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



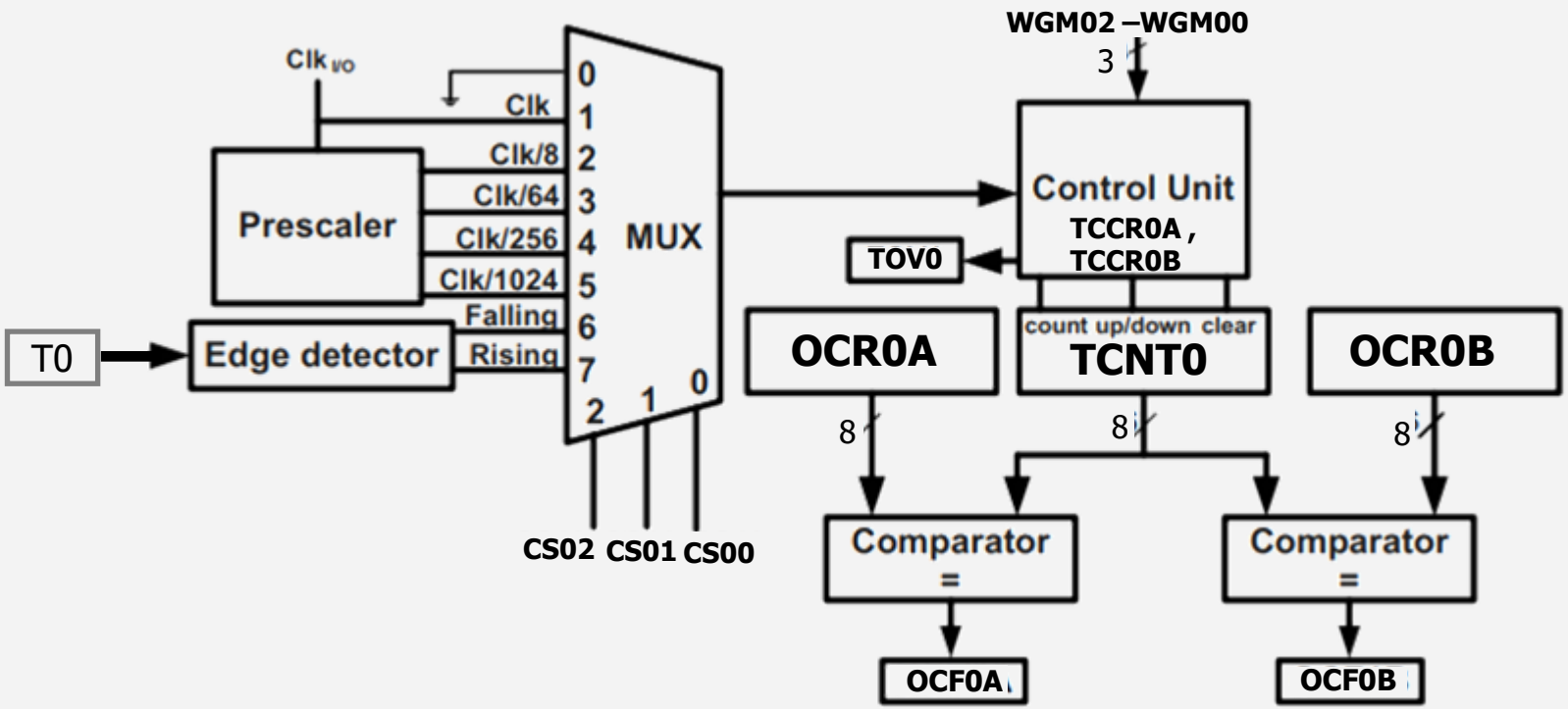
TCCR0A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W

TCCR0B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W

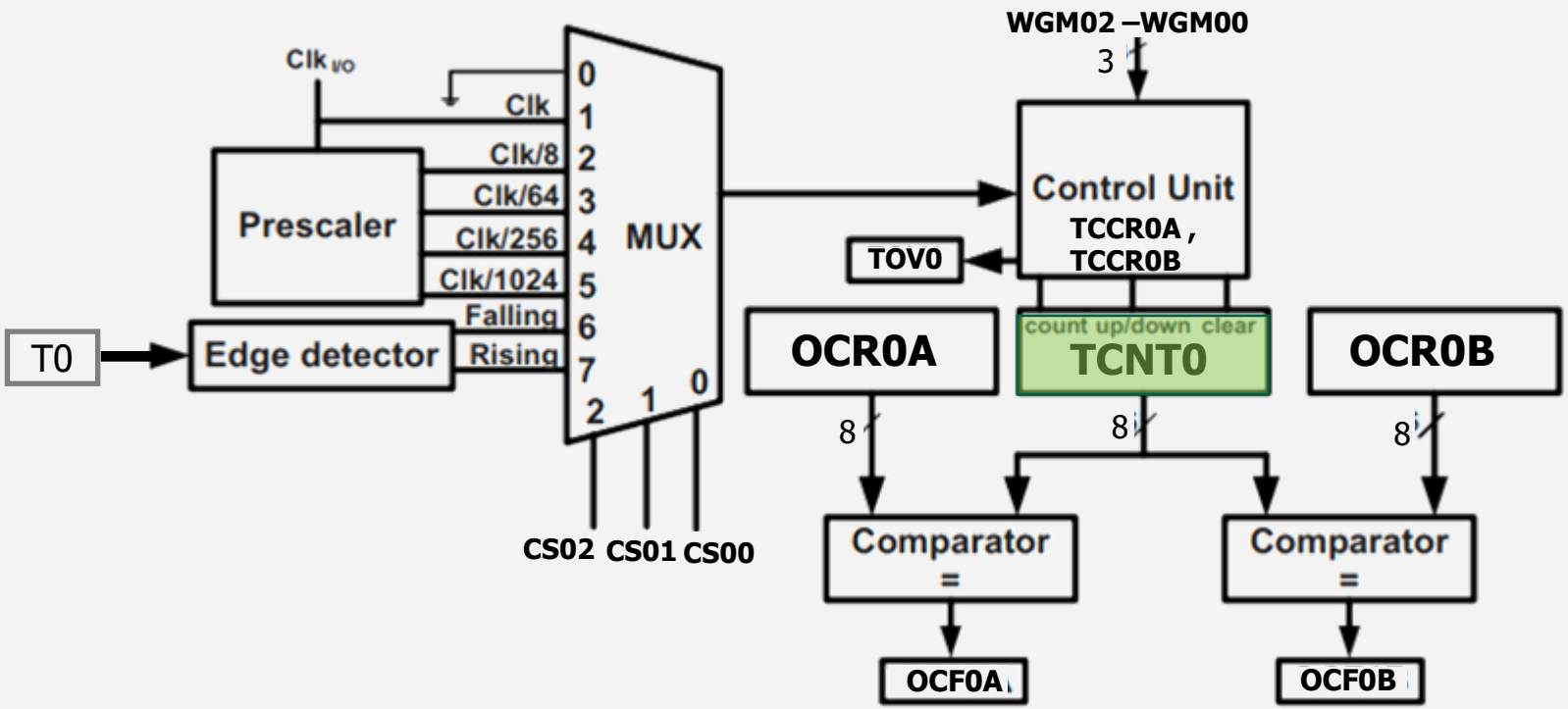
Timer 0 (8-bit timer)



TCNT0 – Timer/Counter Register

Bit	7	6	5	4	3	2	1	0
0x26 (0x46)	TCNT0[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

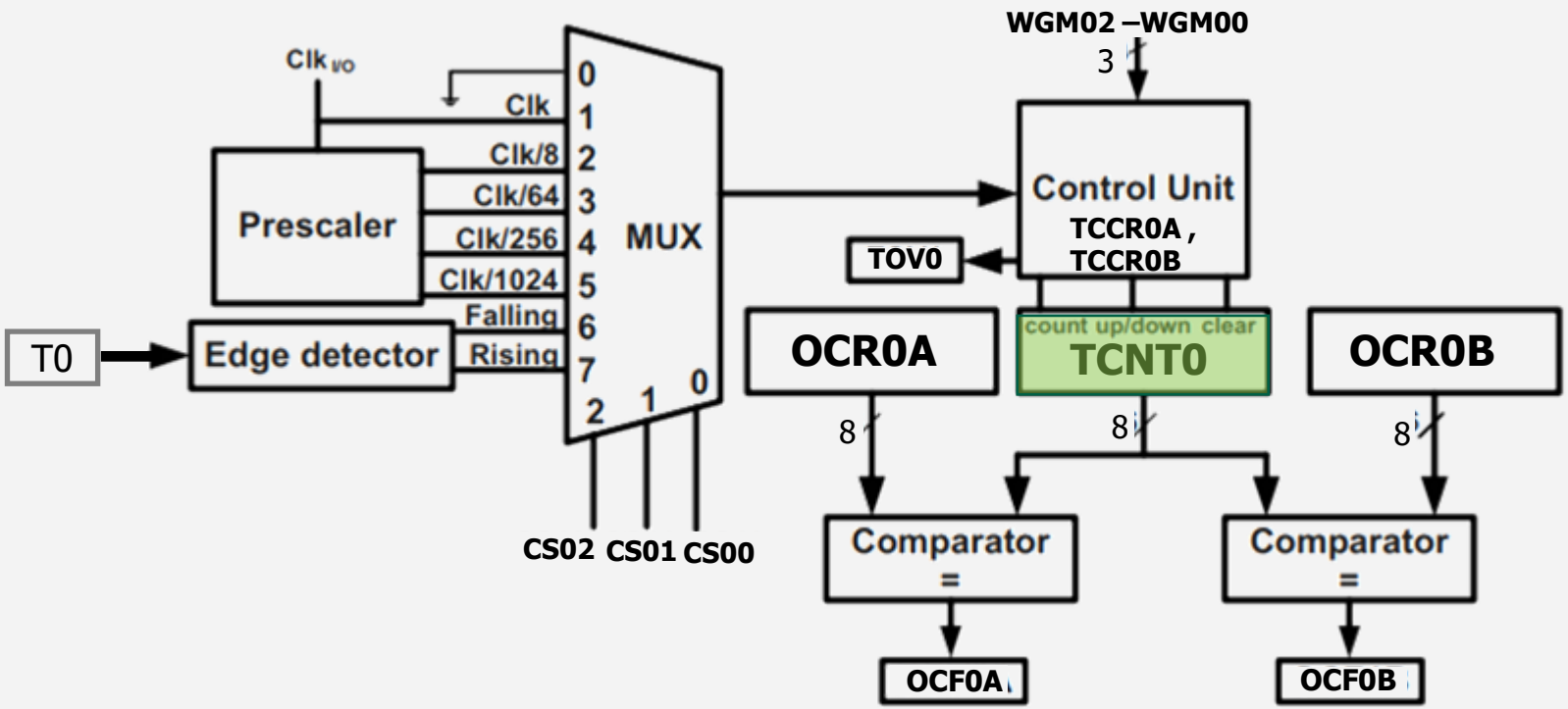
Timer 0 (8-bit timer)



TCNT0 – Timer/Counter Register

Bit	7	6	5	4	3	2	1	0
0x26 (0x46)	TCNT0[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

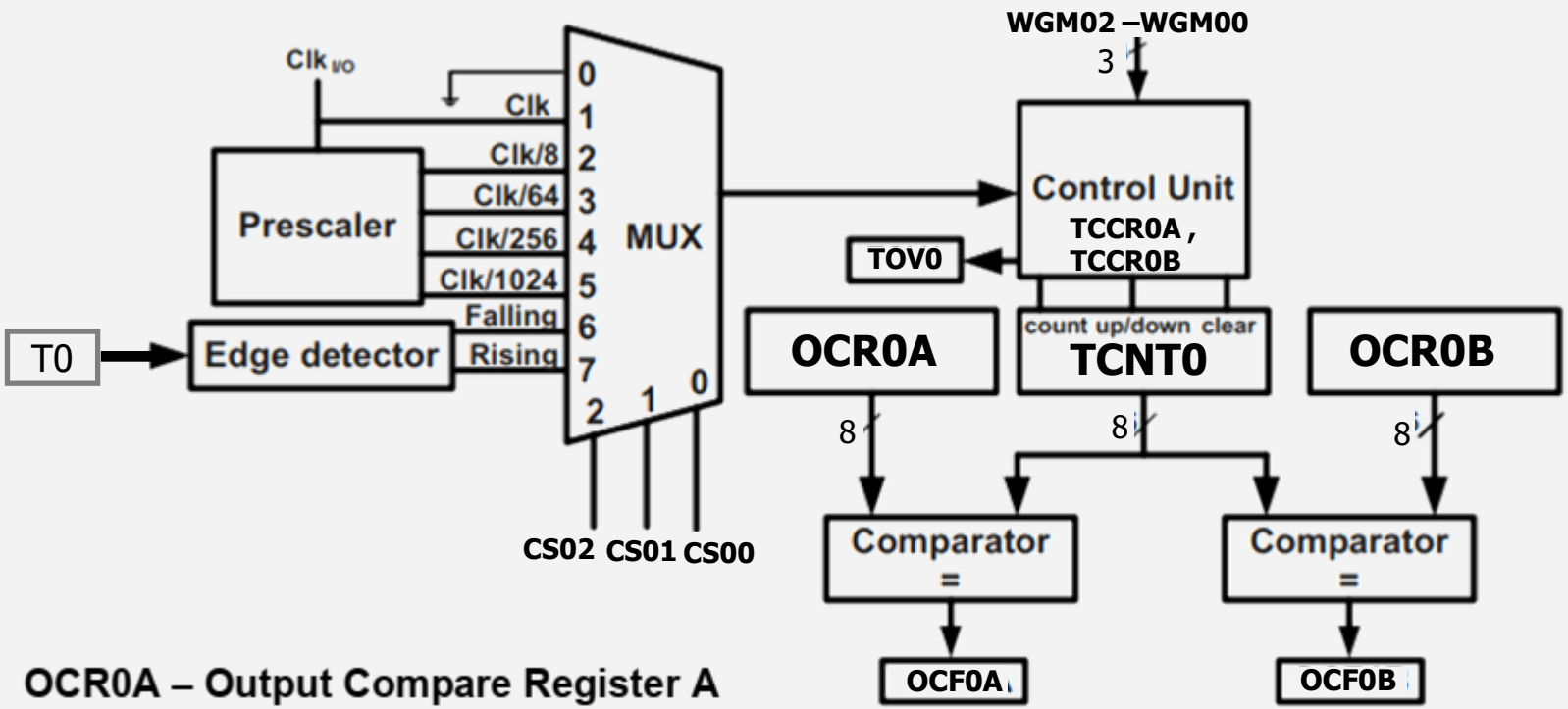
Timer 0 (8-bit timer)



TCNT0 – Timer/Counter Register

Bit	7	6	5	4	3	2	1	0
0x26 (0x46)	TCNT0[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



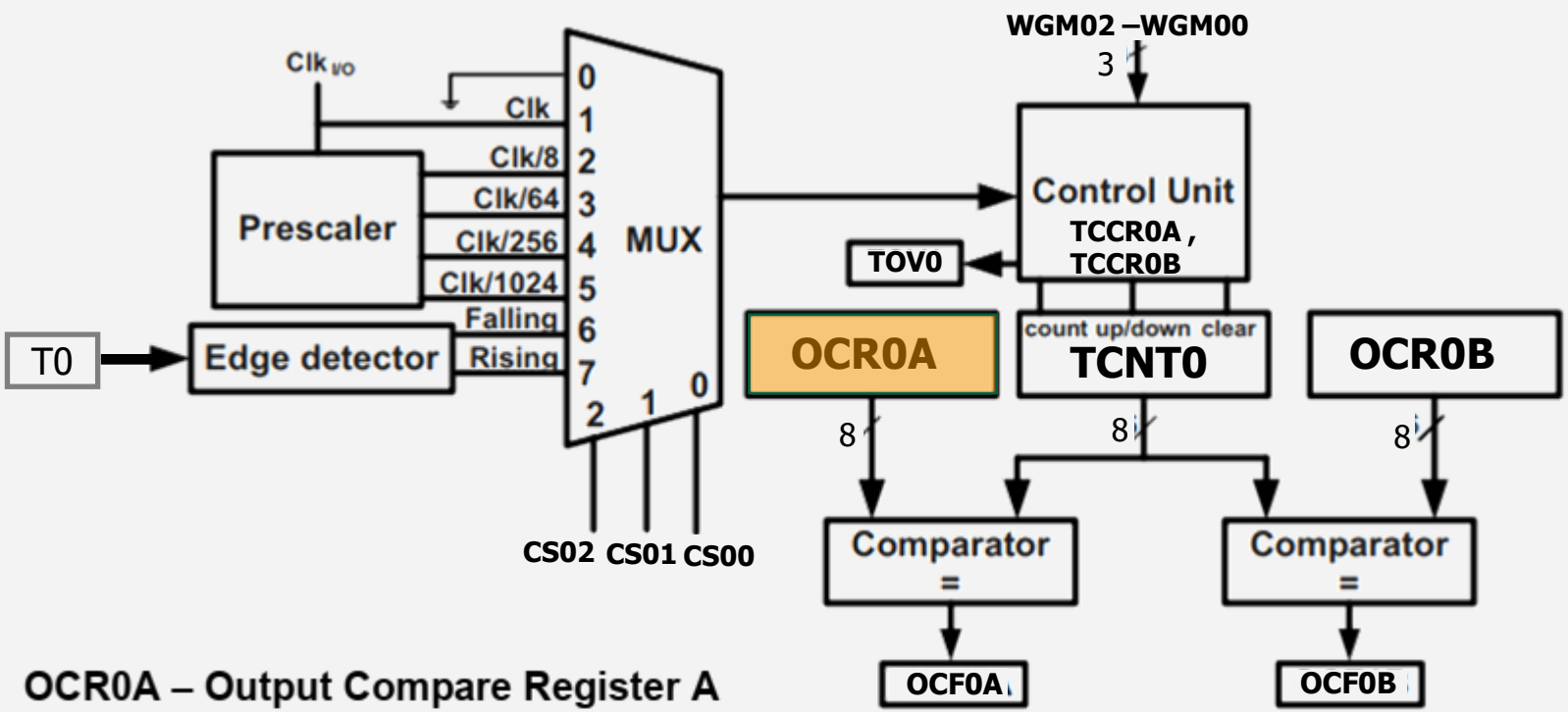
OCR0A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0
0x27 (0x47)	OCR0A[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCR0B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0
0x28 (0x48)	OCR0B[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



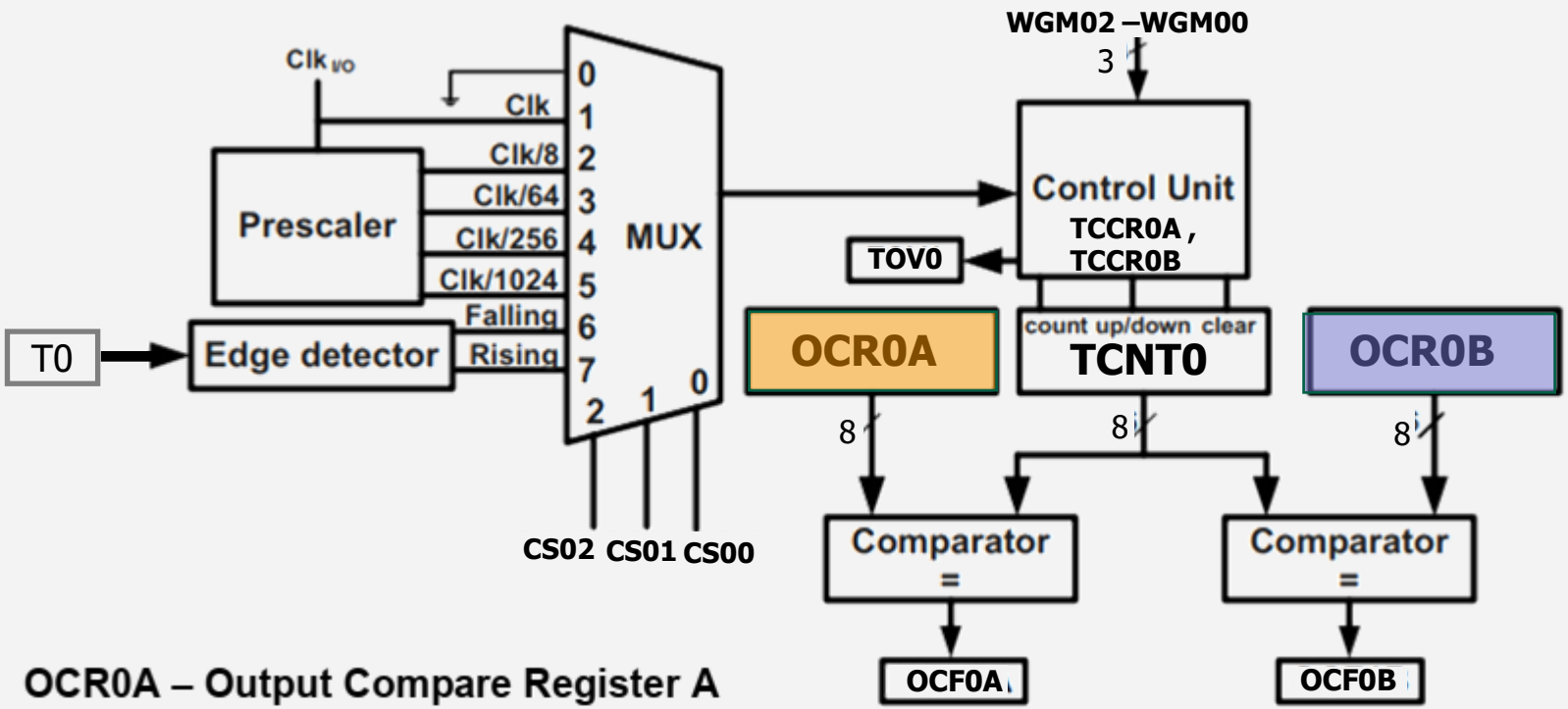
OCR0A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0
0x27 (0x47)	OCR0A[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCR0B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0
0x28 (0x48)	OCR0B[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



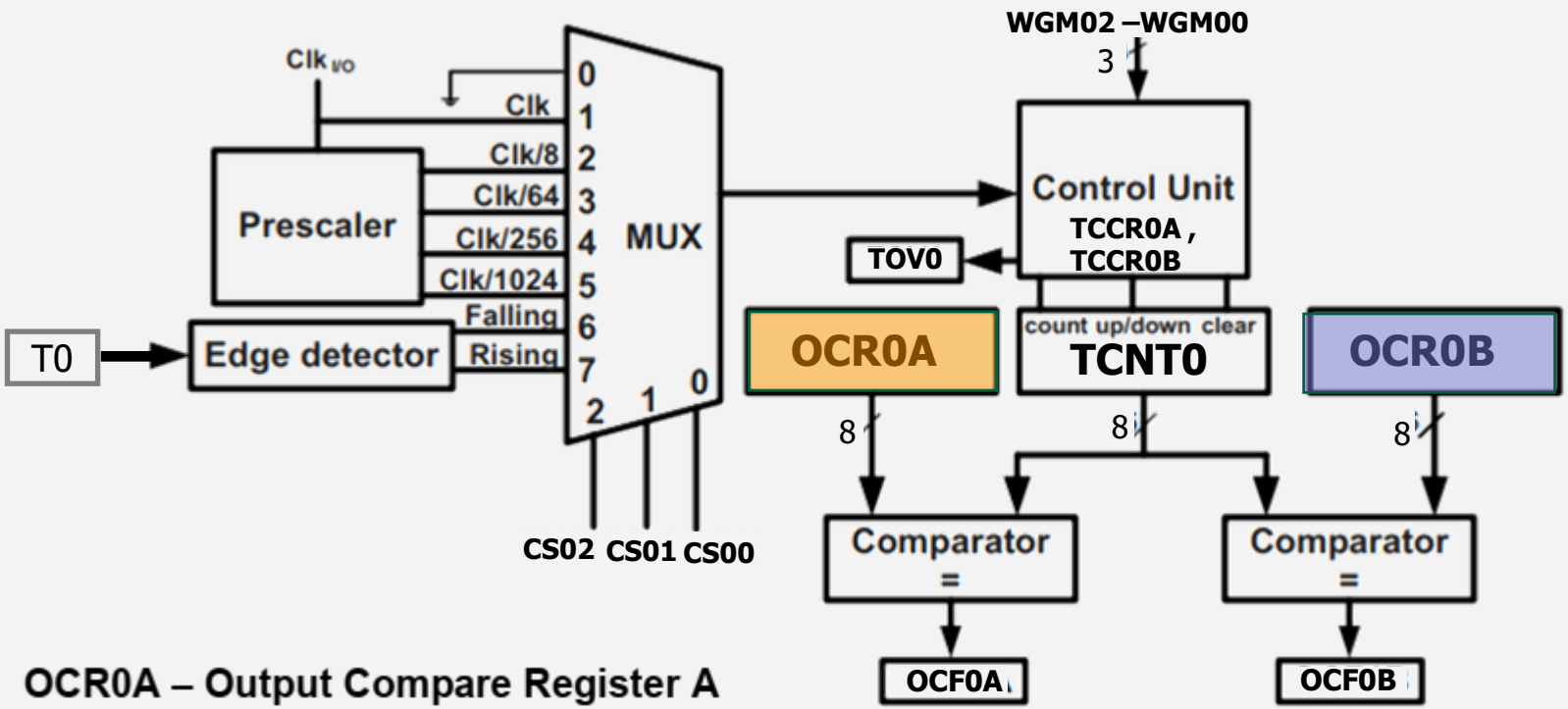
OCR0A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0
0x27 (0x47)	OCR0A[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCR0B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0
0x28 (0x48)	OCR0B[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



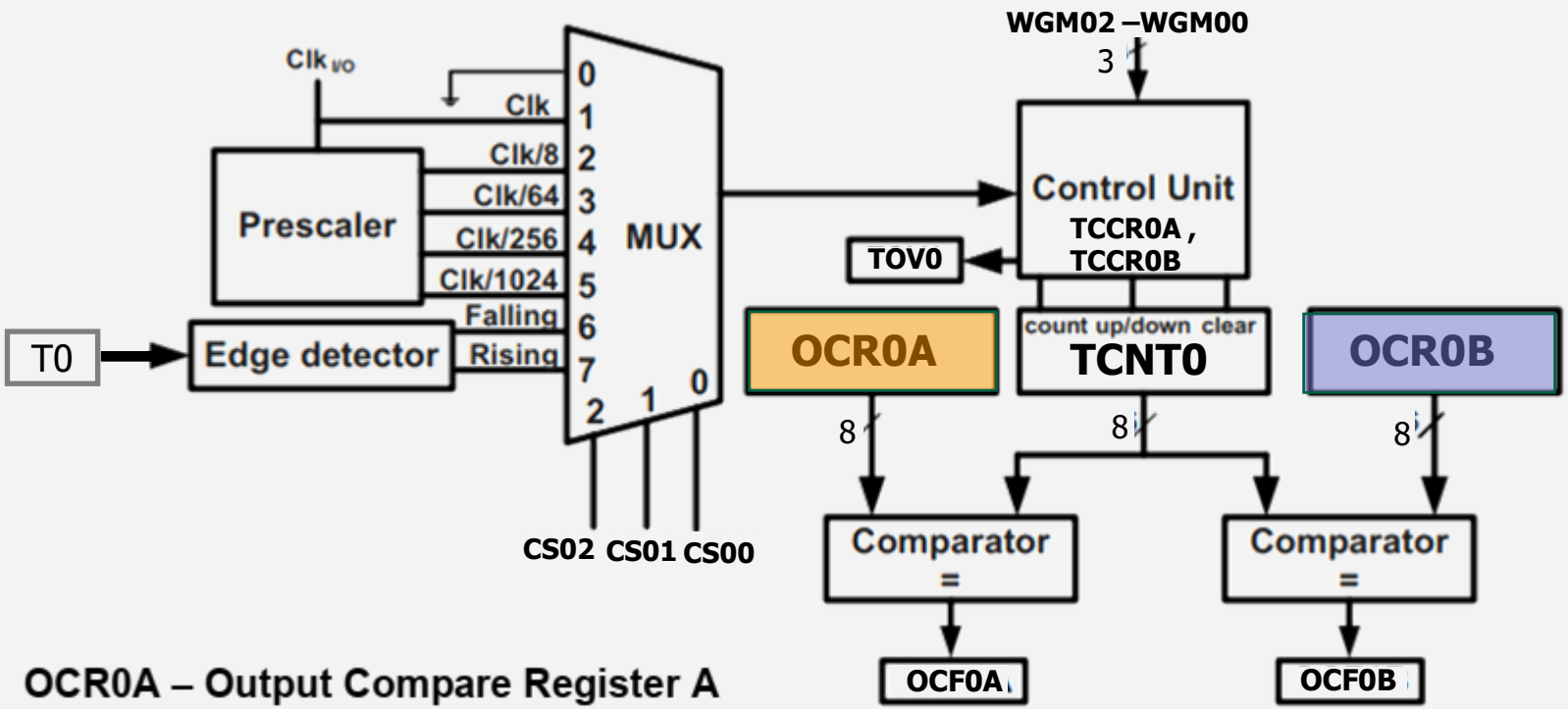
OCR0A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0
0x27 (0x47)	OCR0A[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCR0B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0
0x28 (0x48)	OCR0B[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Timer 0 (8-bit timer)



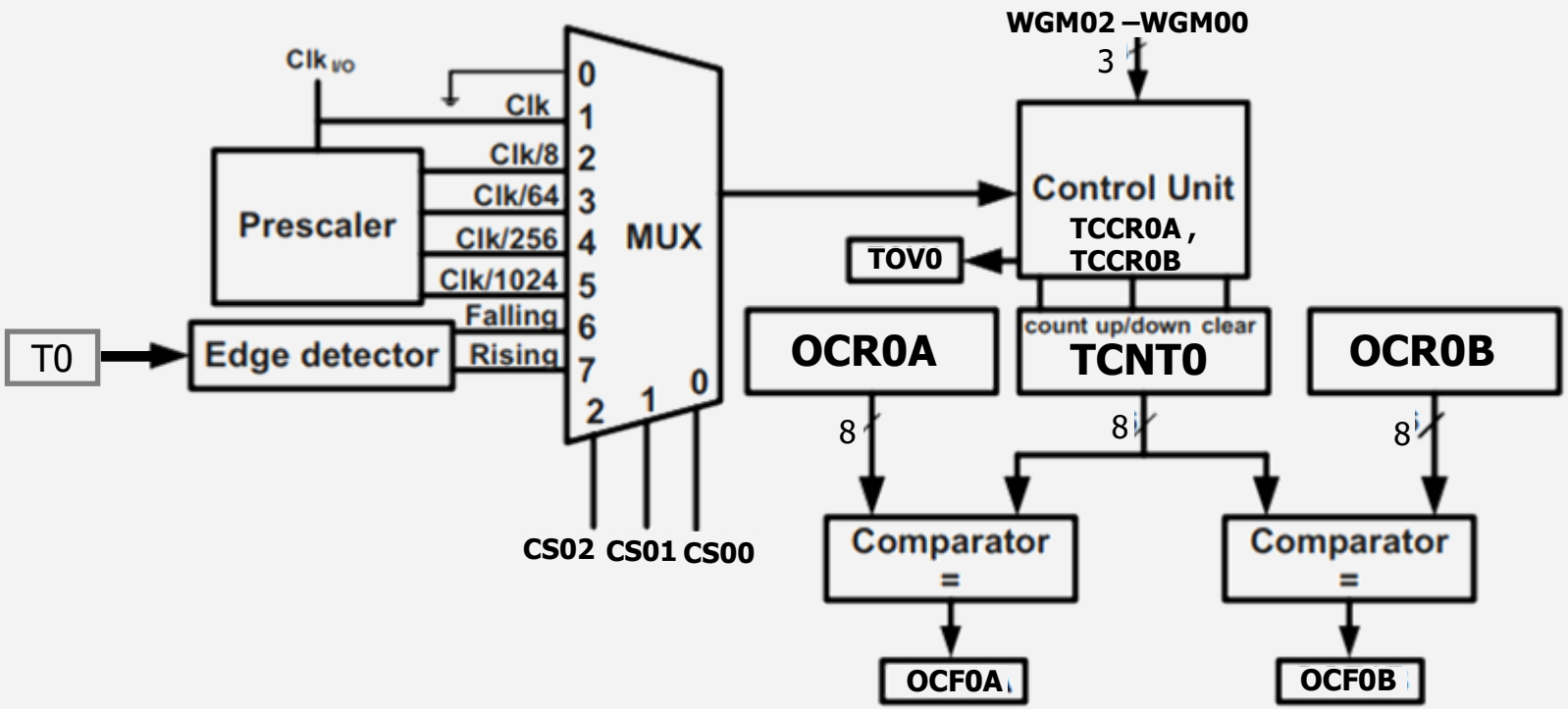
OCR0A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0
0x27 (0x47)	OCR0A[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCR0B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0
0x28 (0x48)	OCR0B[7:0]							
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

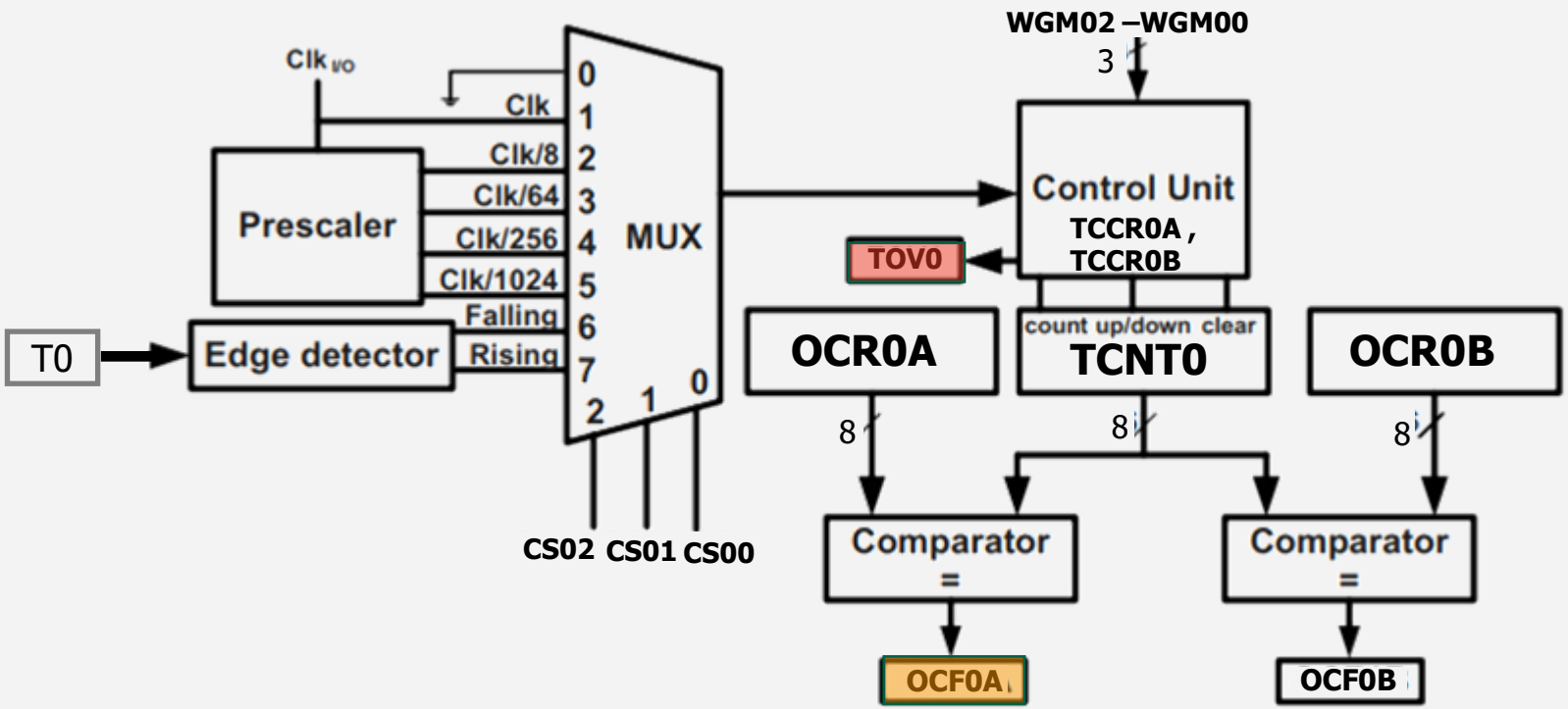
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

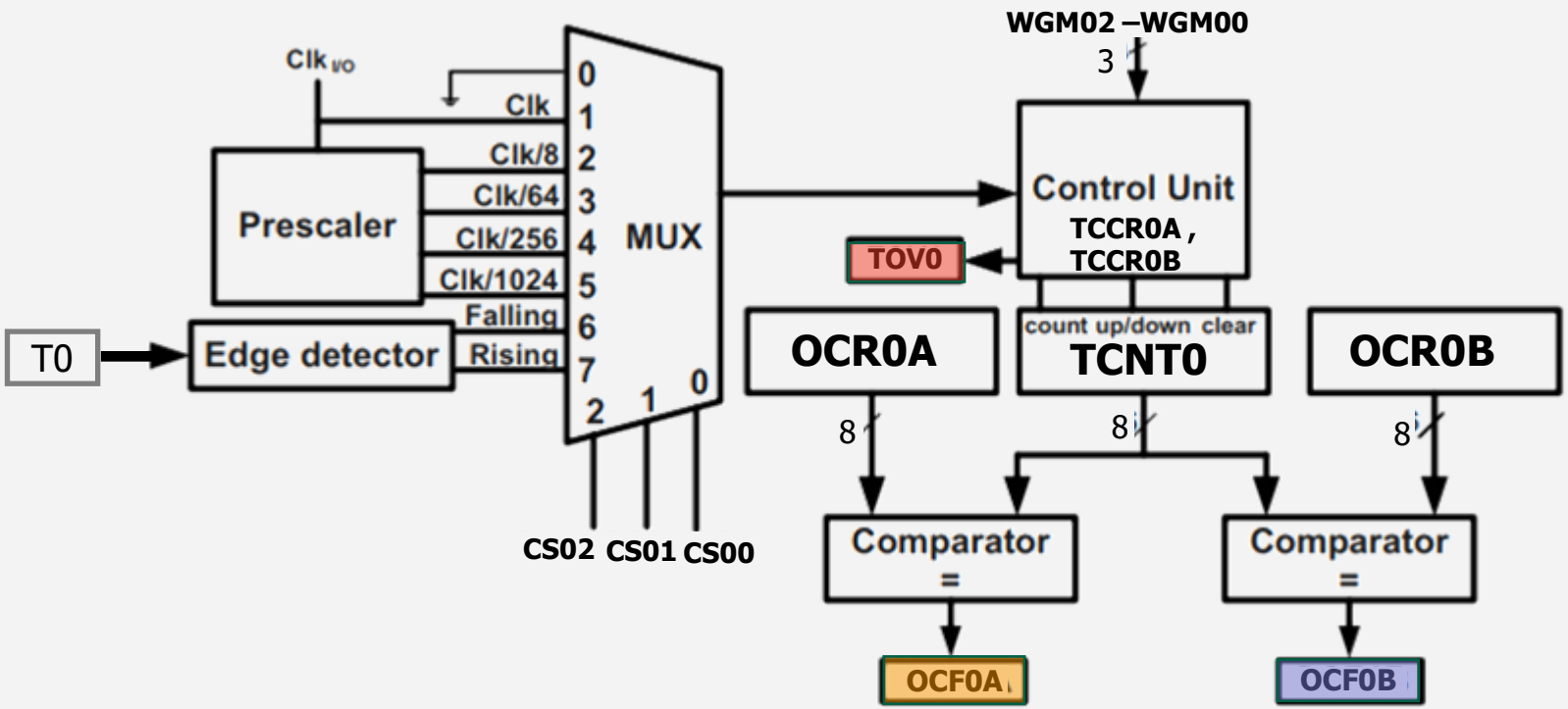
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

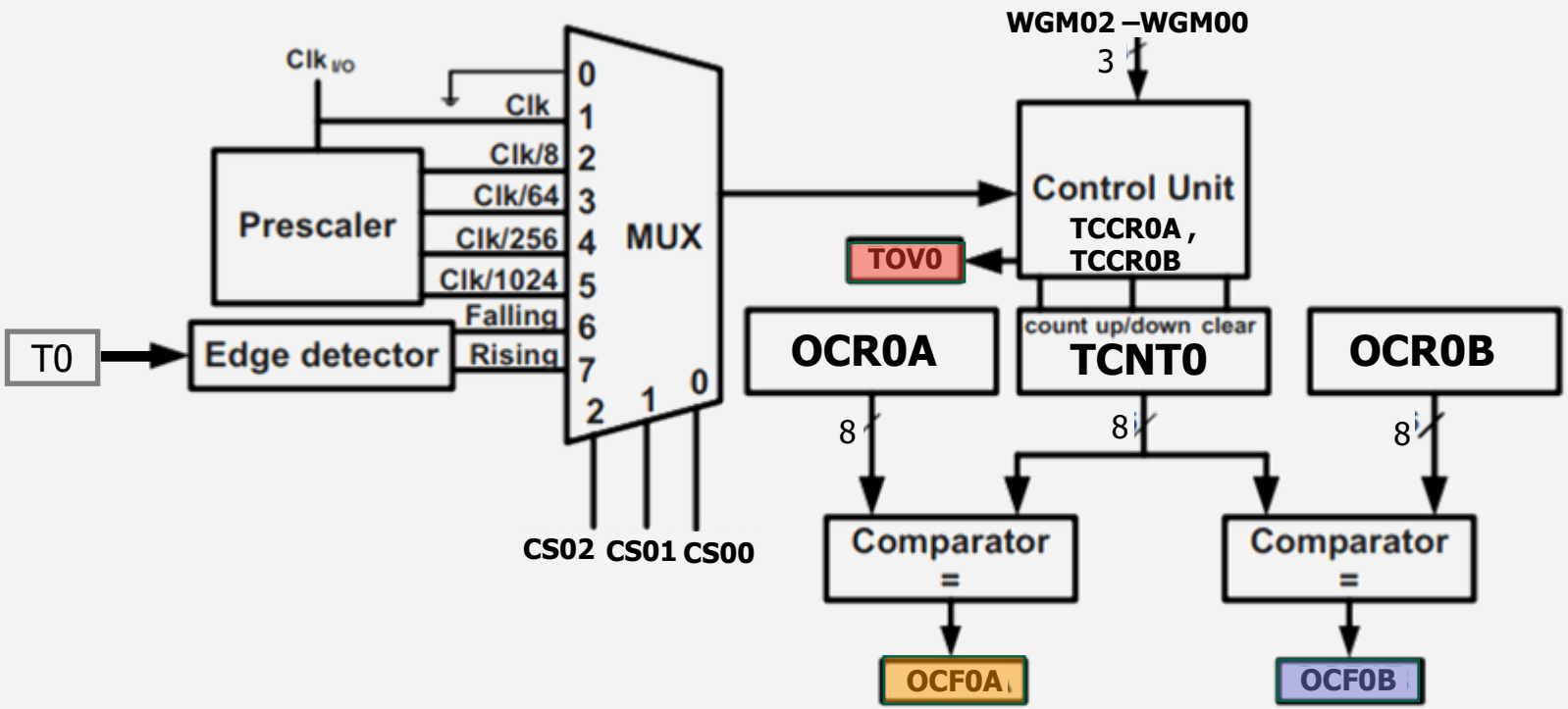
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

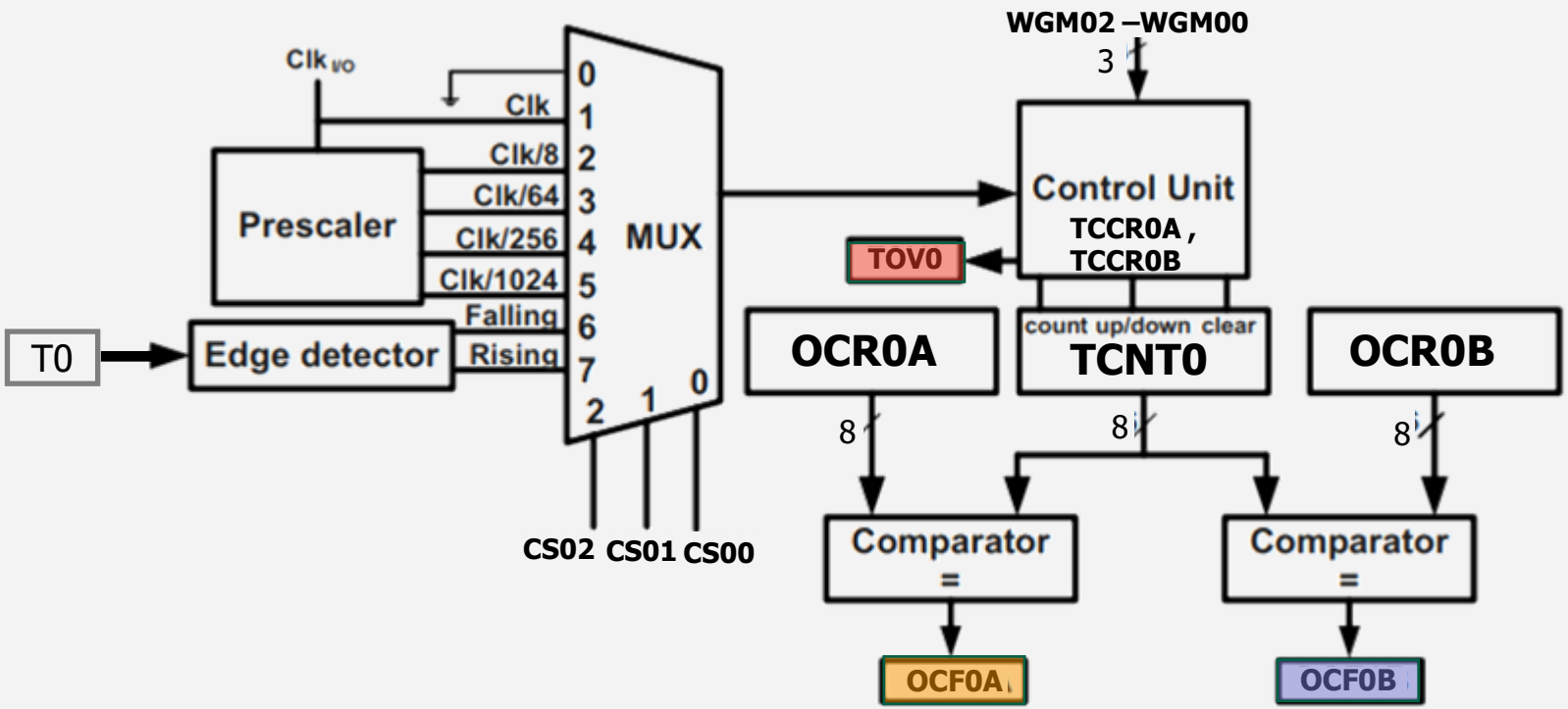
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

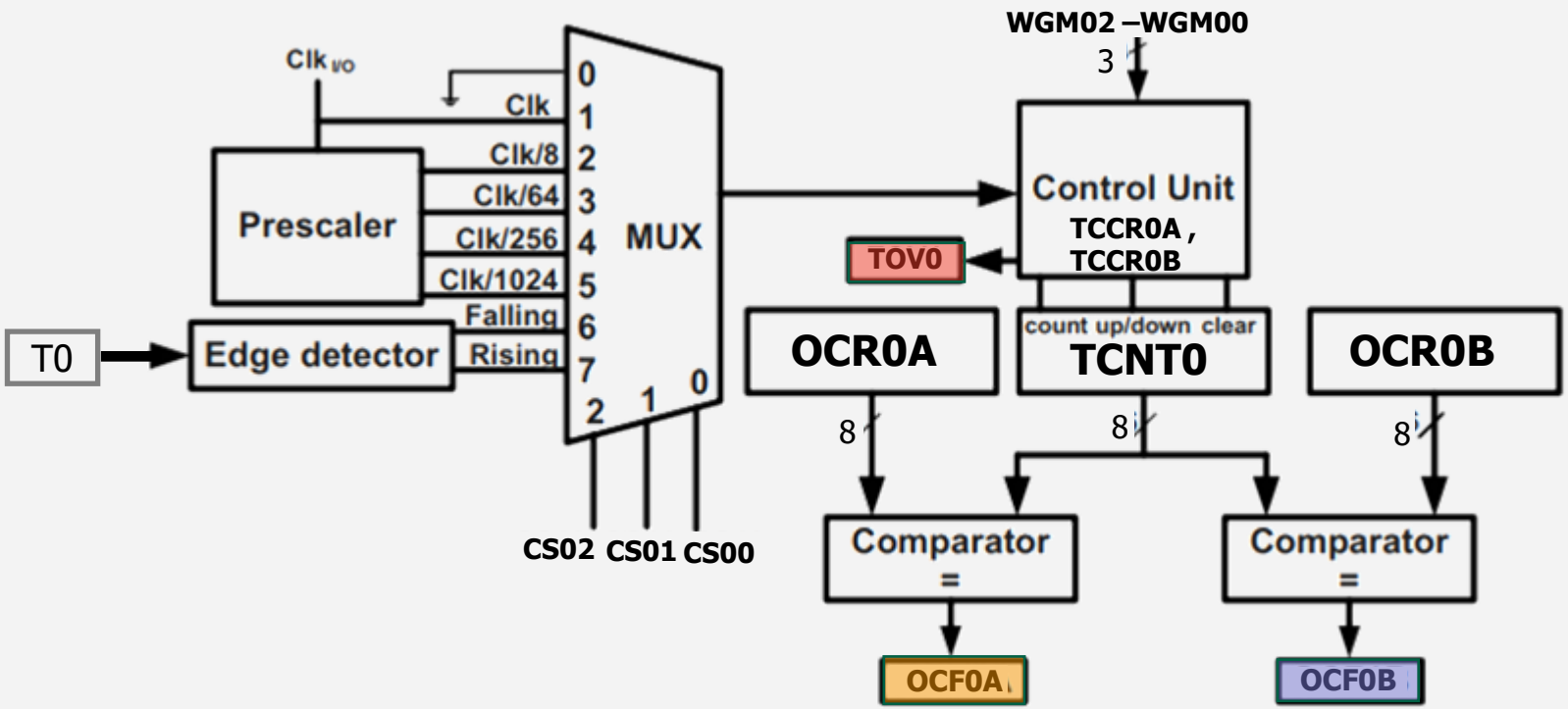
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

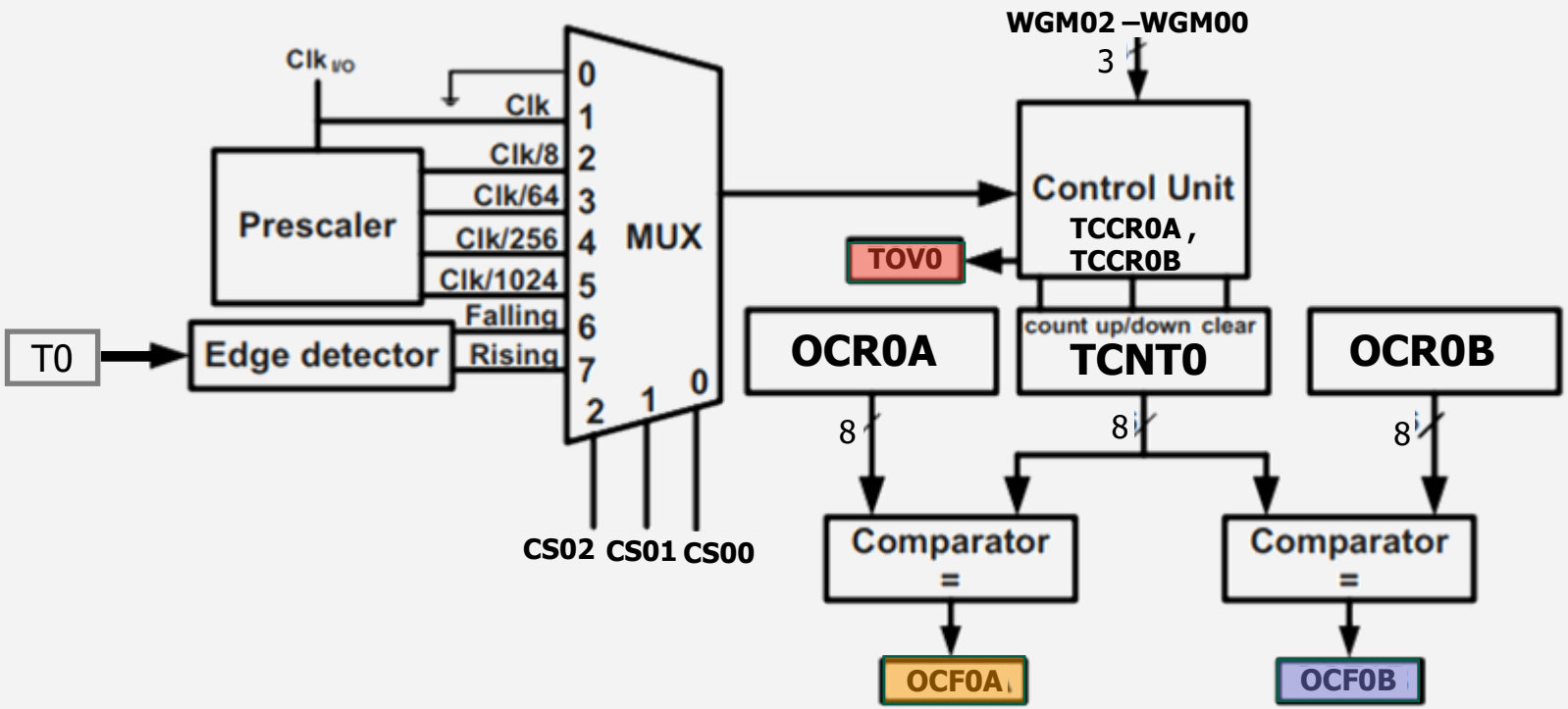
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

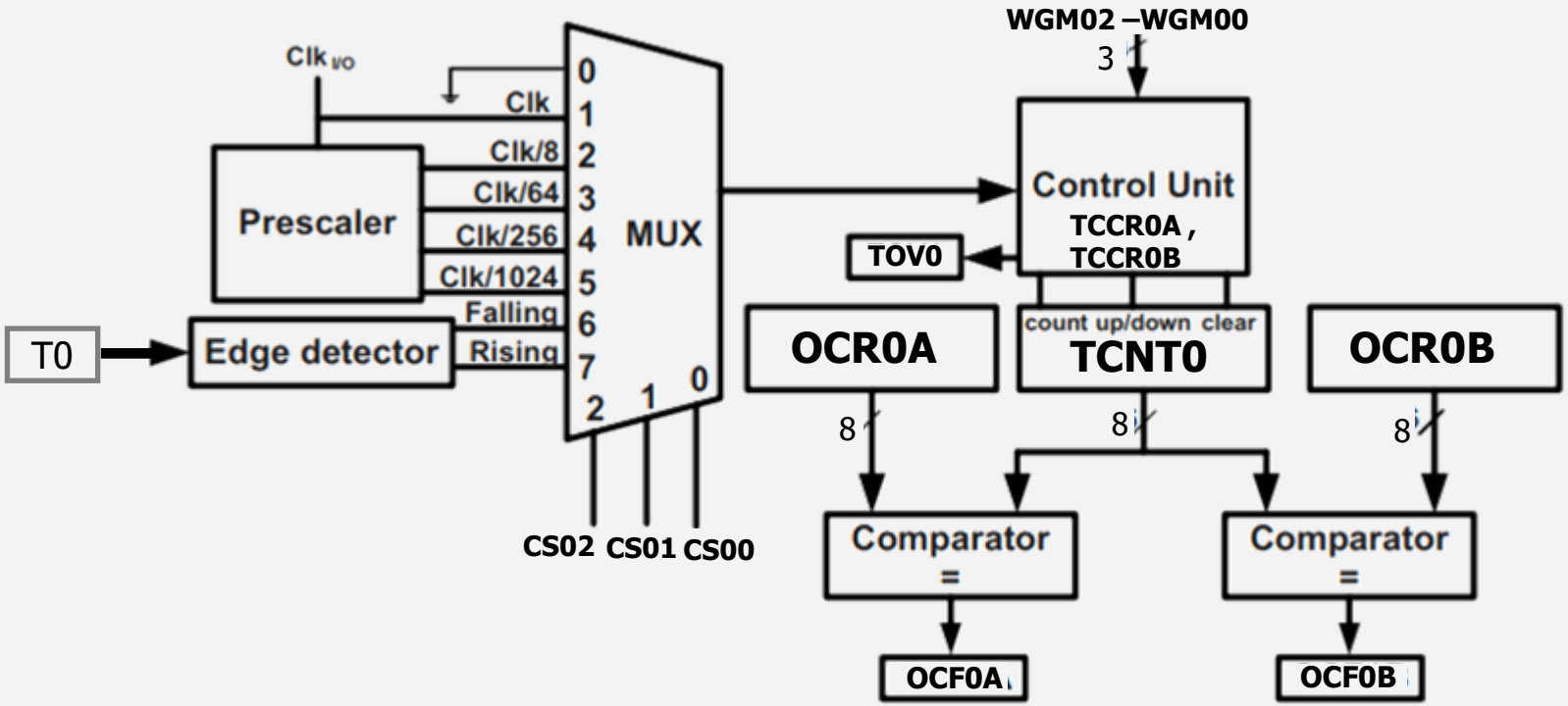
Timer 0 (8-bit timer)



TIFR0 – Timer/Counter 0 Interrupt Flag Register

Bit	7	6	5	4	3	2	1	0
0x15 (0x35)	–	–	–	–	–	OCF0B	OCF0A	TOV0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

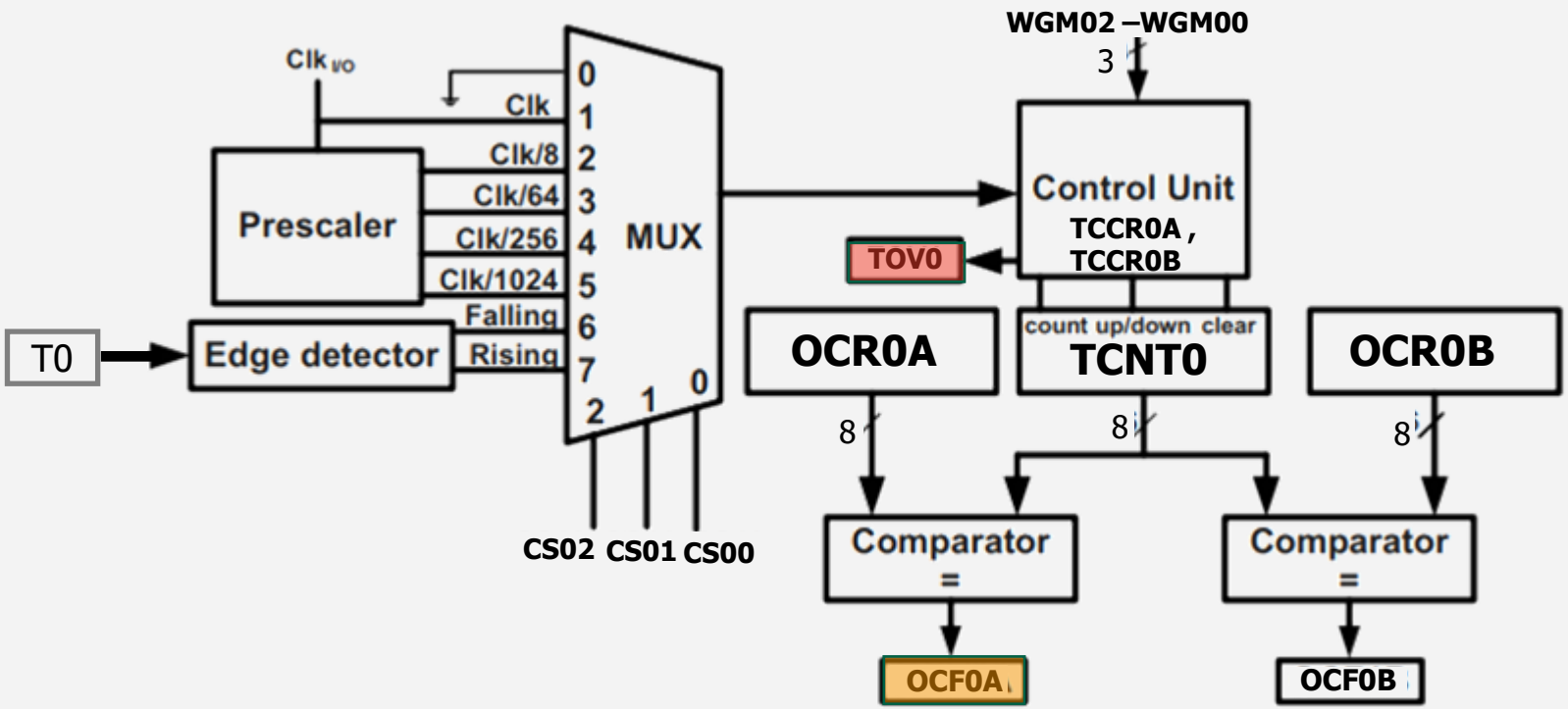
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

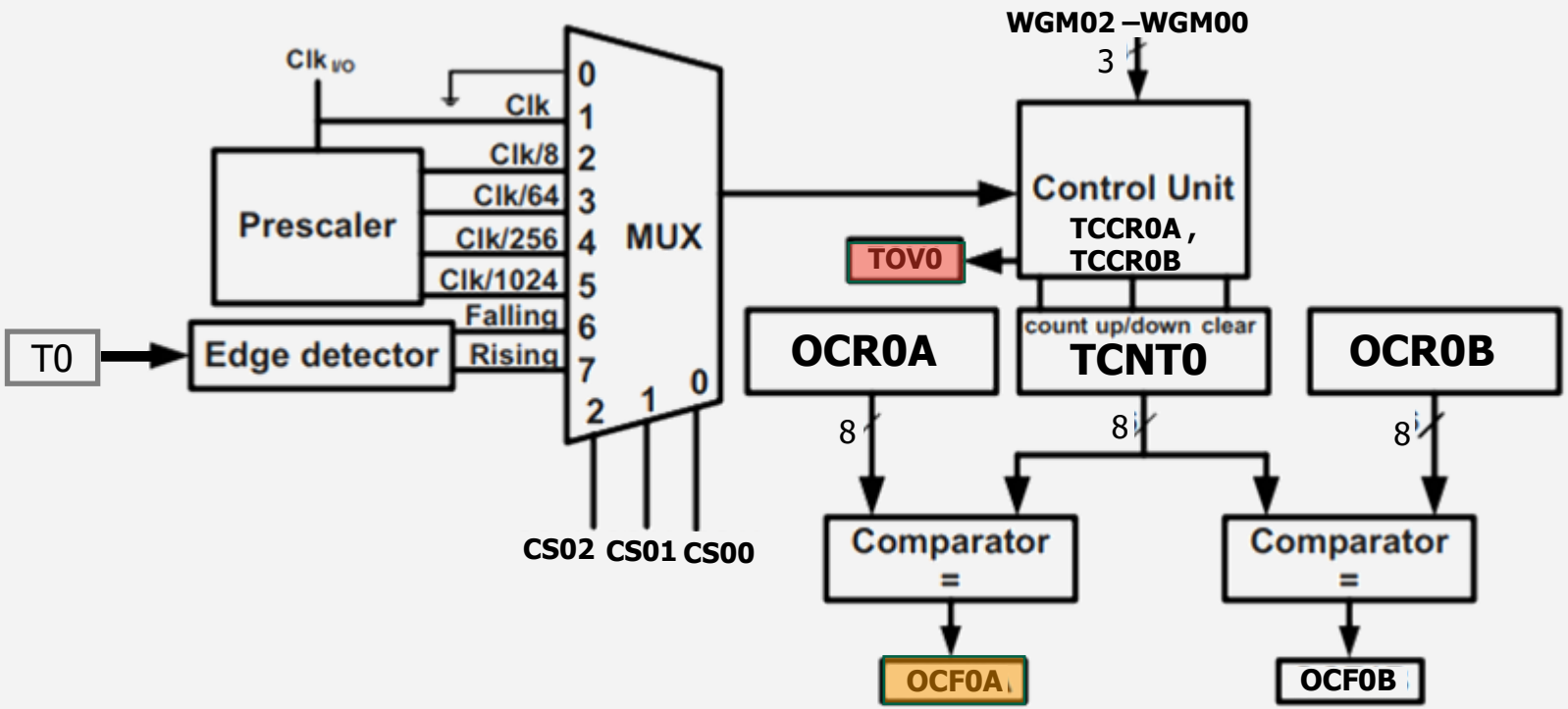
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

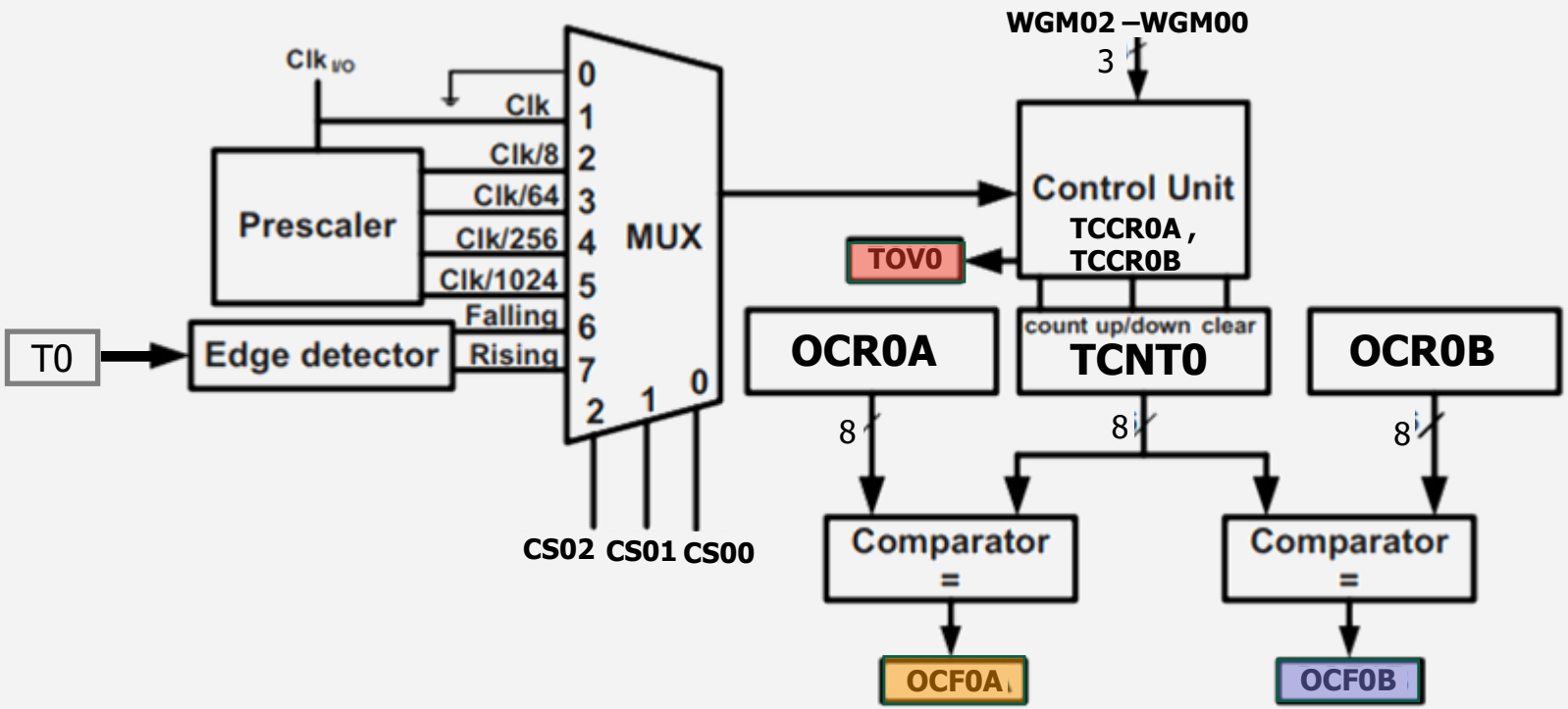
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

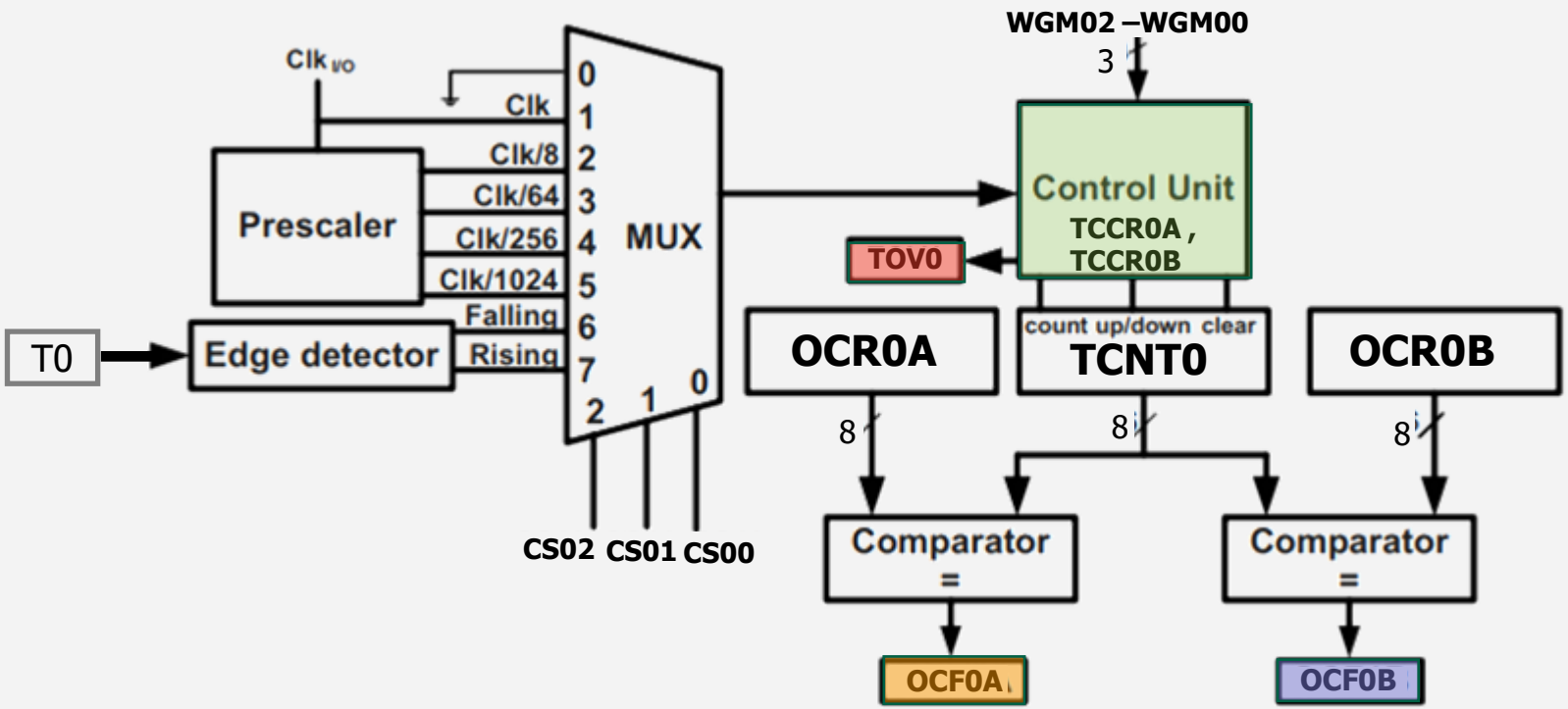
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

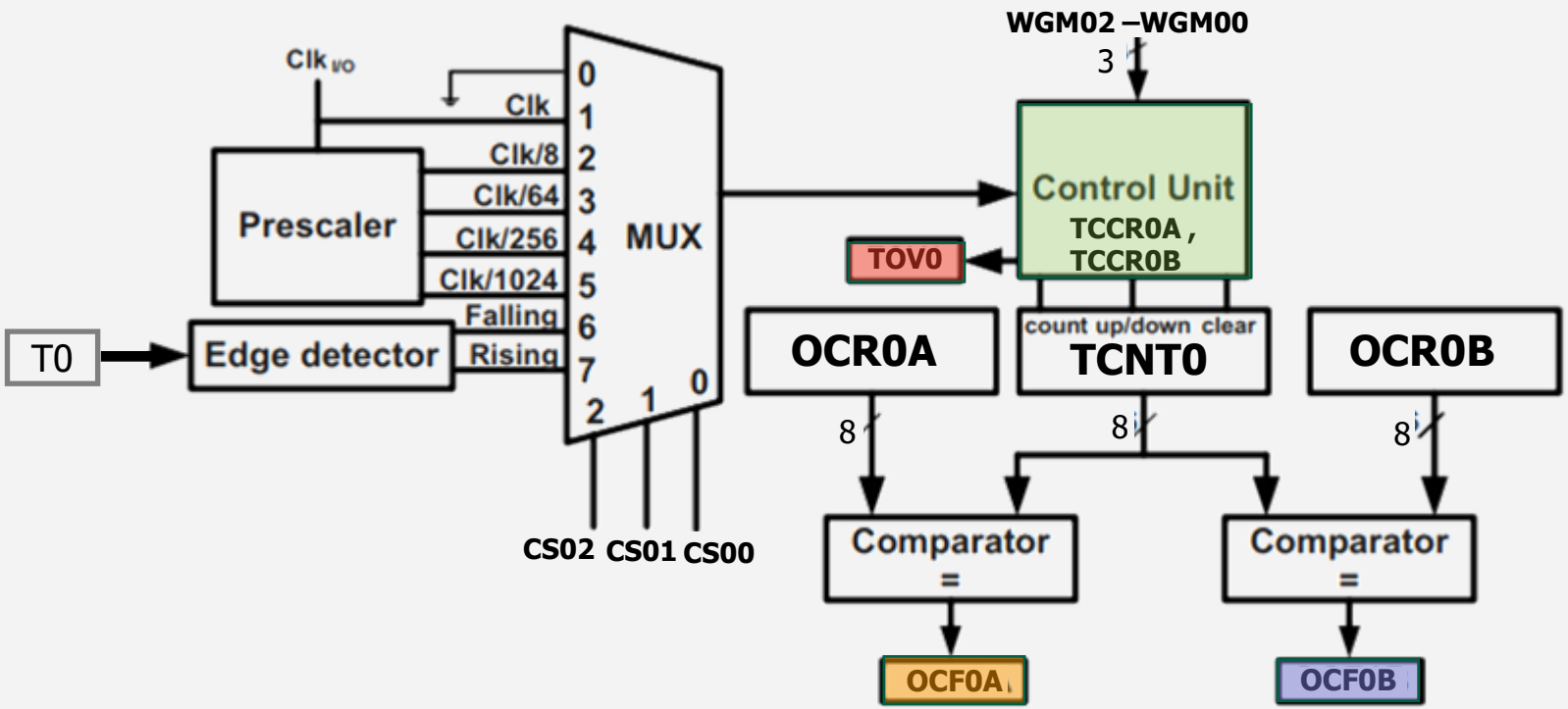
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

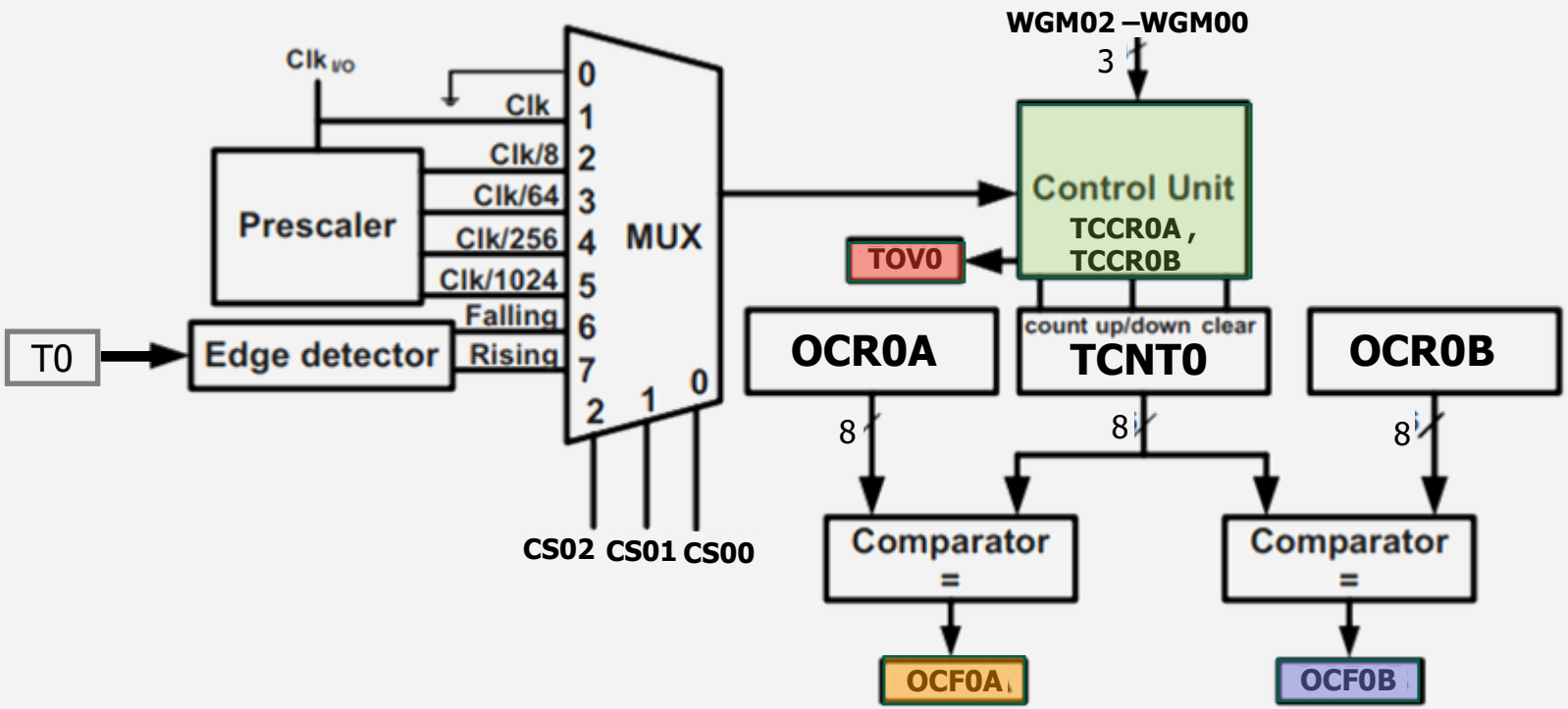
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

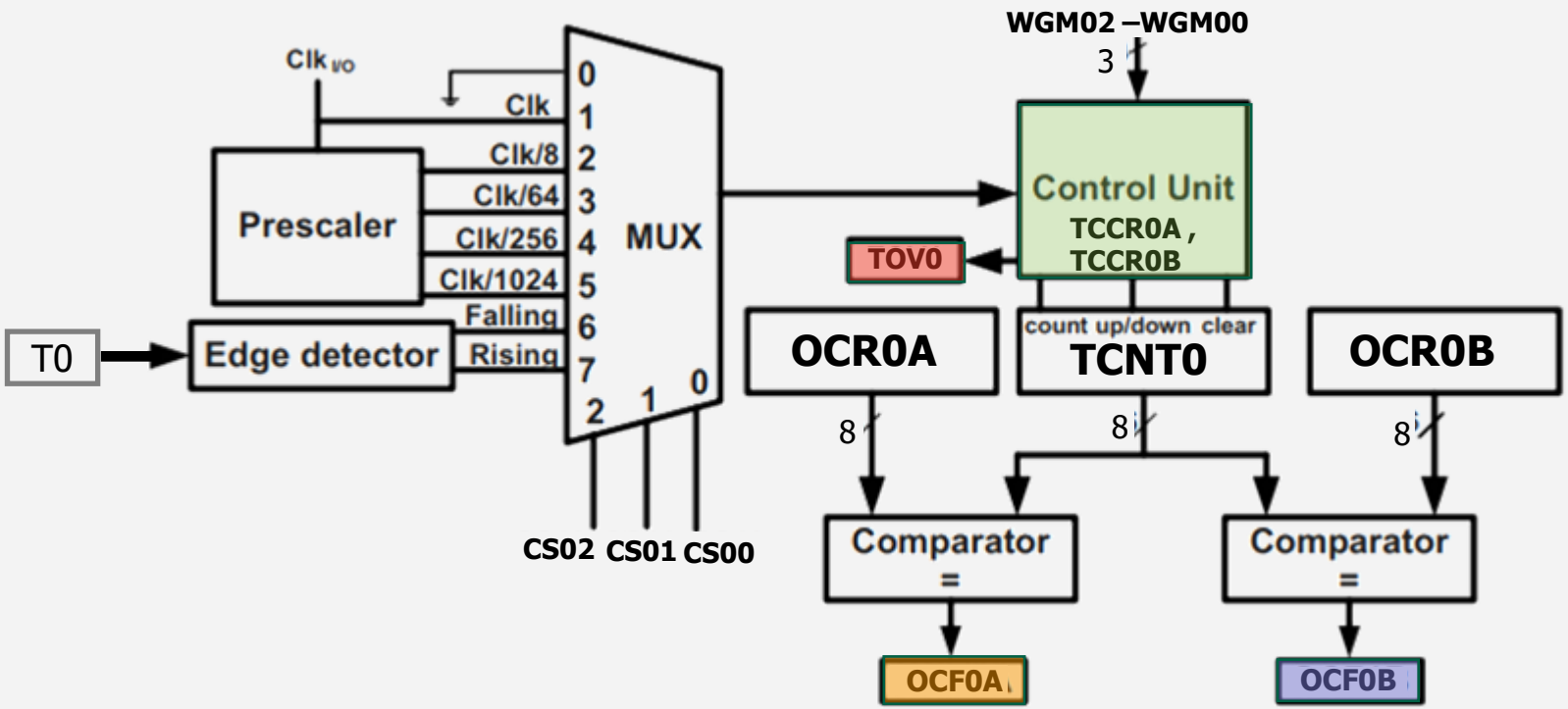
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

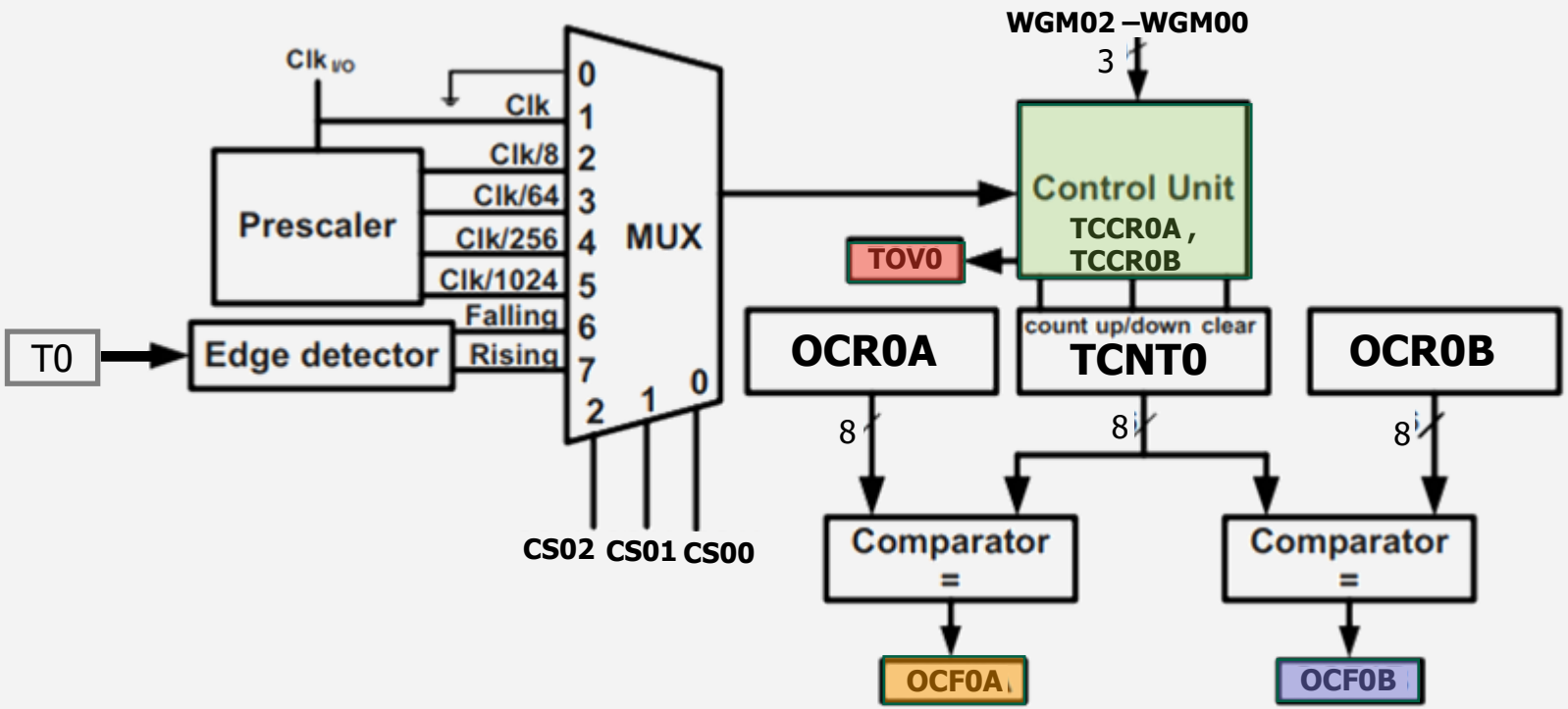
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

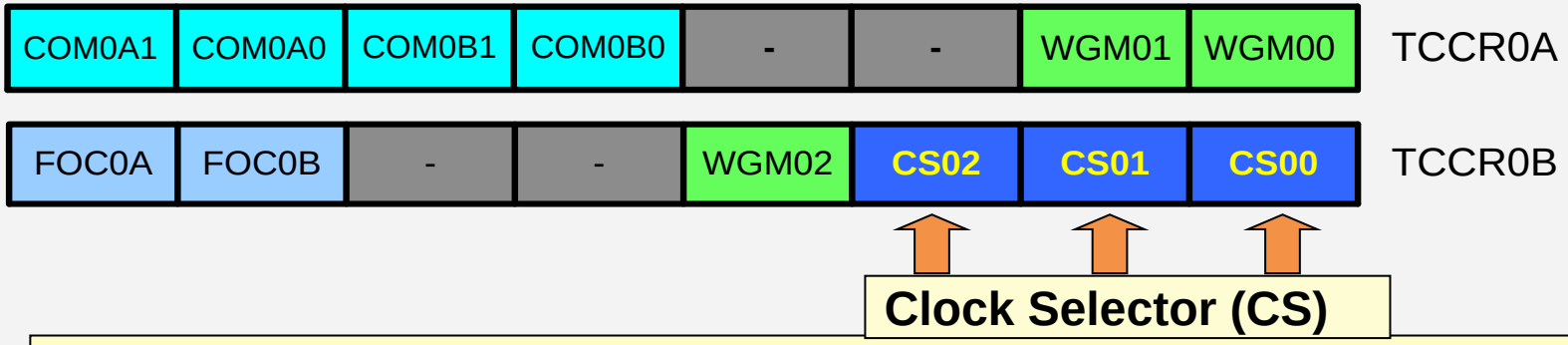
Timer 0 (8-bit timer)



TIMSK0 – Timer/Counter Interrupt Mask Register

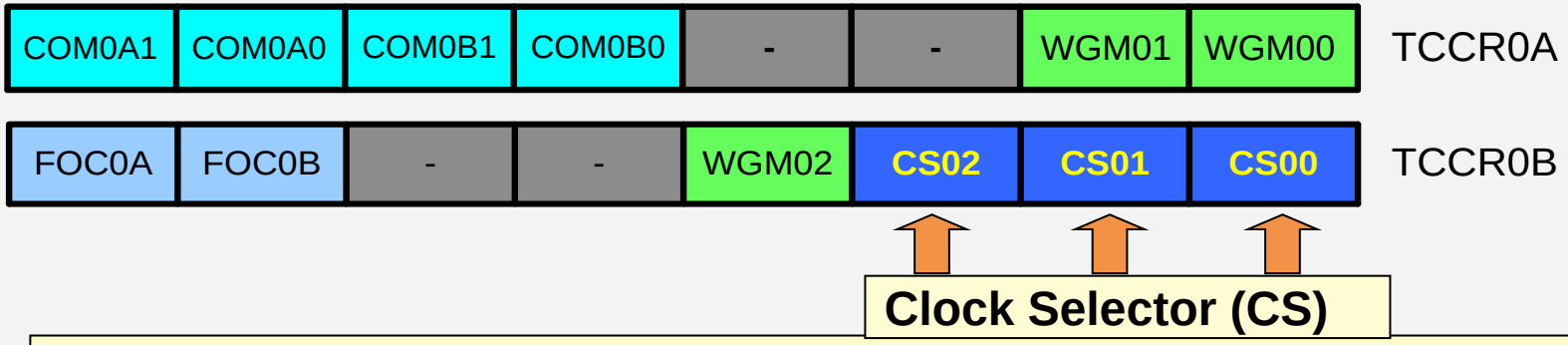
Bit	7	6	5	4	3	2	1	0
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0
Read/Write	R	R	R	R	R	R/W	R/W	R/W

Timer 0 (8-bit timer)



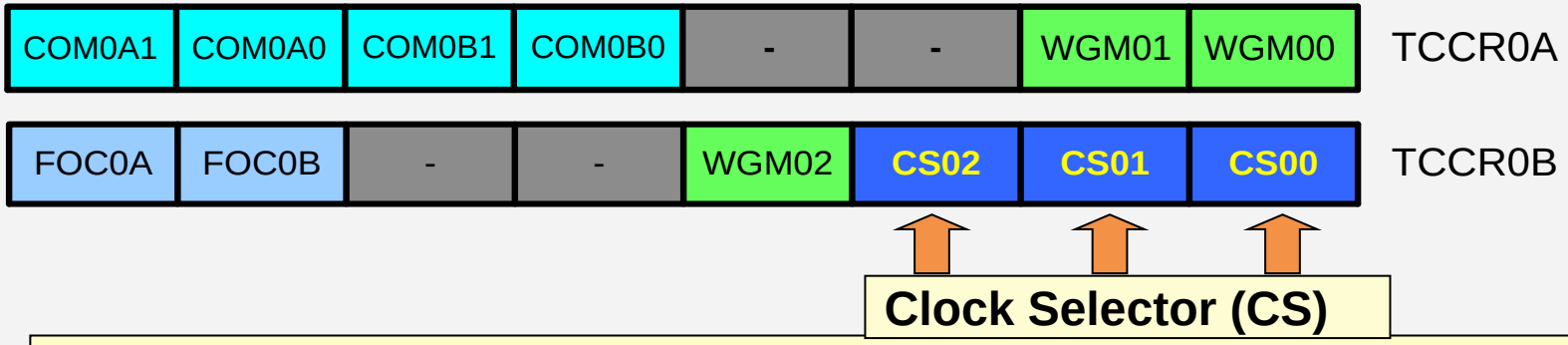
CS02	CS01	CS00	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
0	1	0	clk / 8
0	1	1	clk / 64
1	0	0	clk / 256
1	0	1	clk / 1024
1	1	0	External clock source on T0 pin. Clock on falling edge
1	1	1	External clock source on T0 pin. Clock on rising edge

Timer 0 (8-bit timer)



CS02	CS01	CS00	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
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

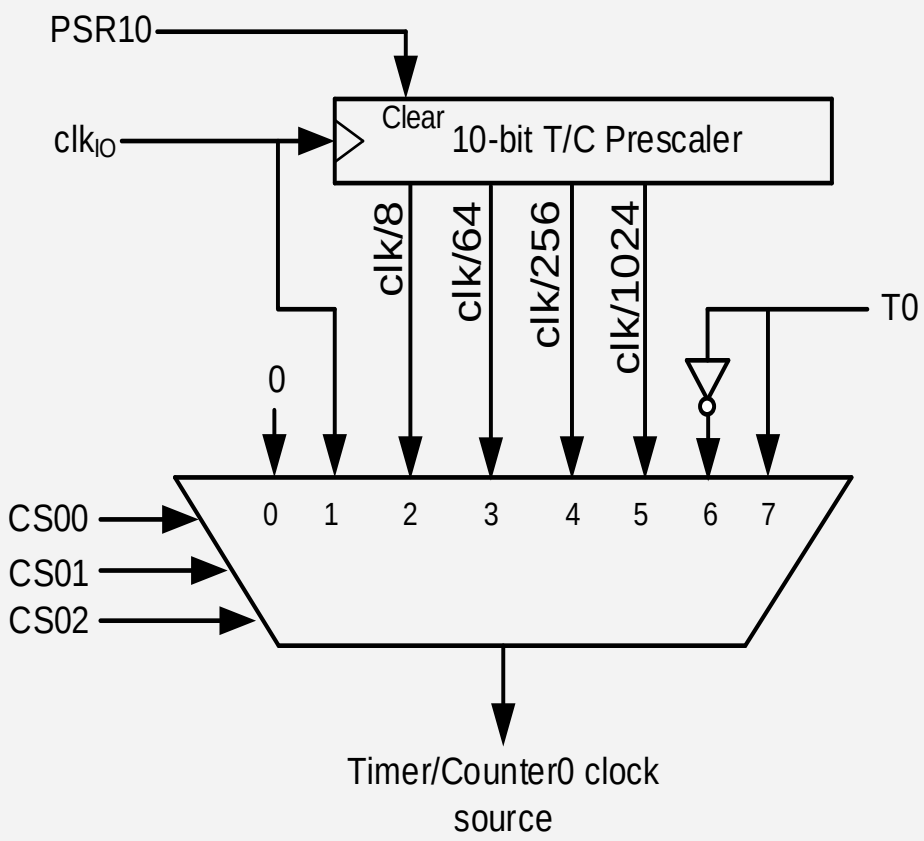
Timer 0 (8-bit timer)



CS02	CS01	CS00	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
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 (8-bit timer)

COM0A1	COM0							TCCR0A
FOC0A	FOC							TCCR0B



CS02	CS01
0	0
0	0
0	1
0	1
1	0
1	0
1	1
1	1

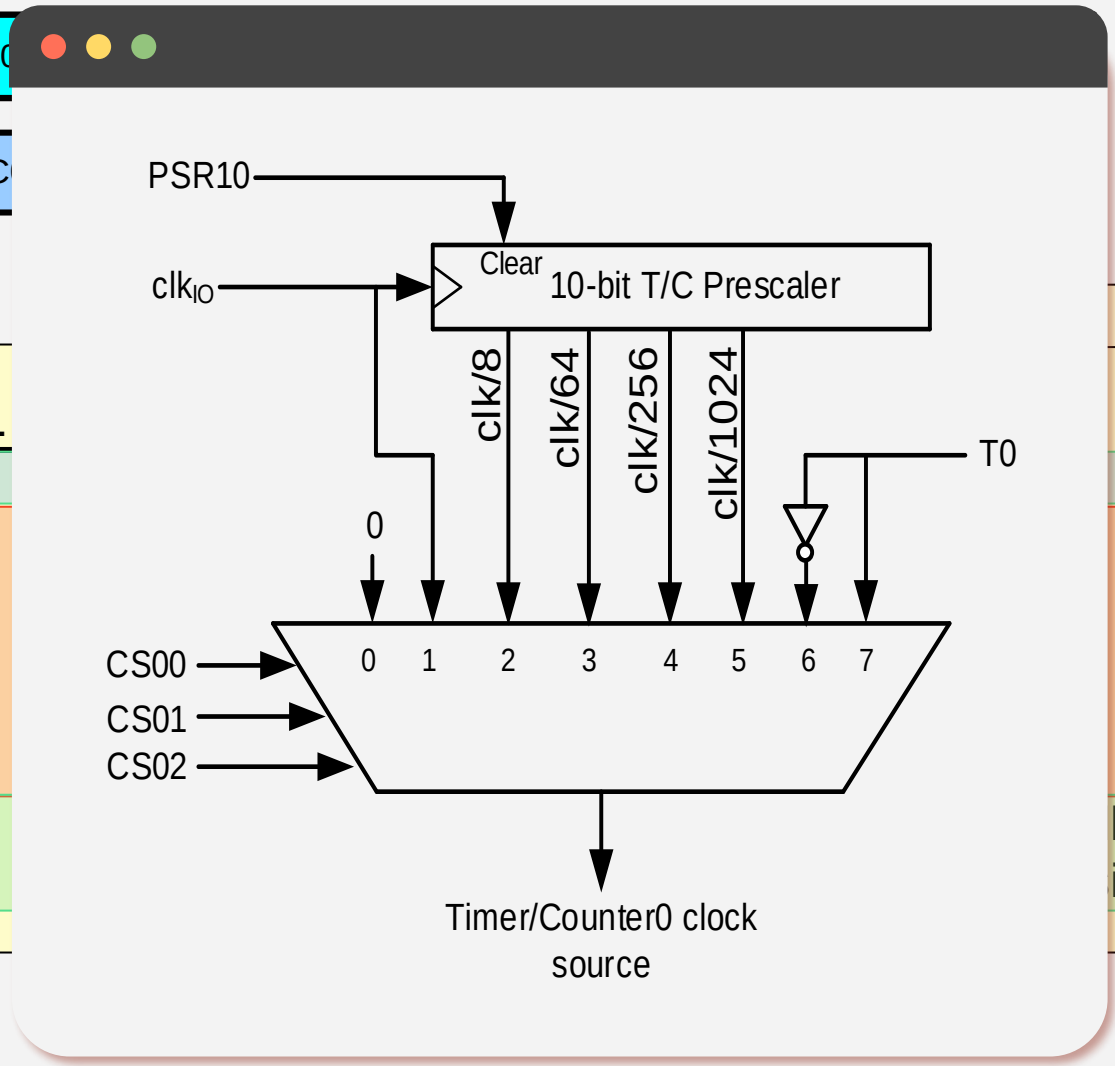
ling edge
ing edge

Timer 0 (8-bit timer)

COM0A1	COM0
FOC0A	FOC

TCCR0A

TCCR0B



CS02	CS01
0	0
0	0
0	1
0	1
1	0
1	0
1	1
1	1

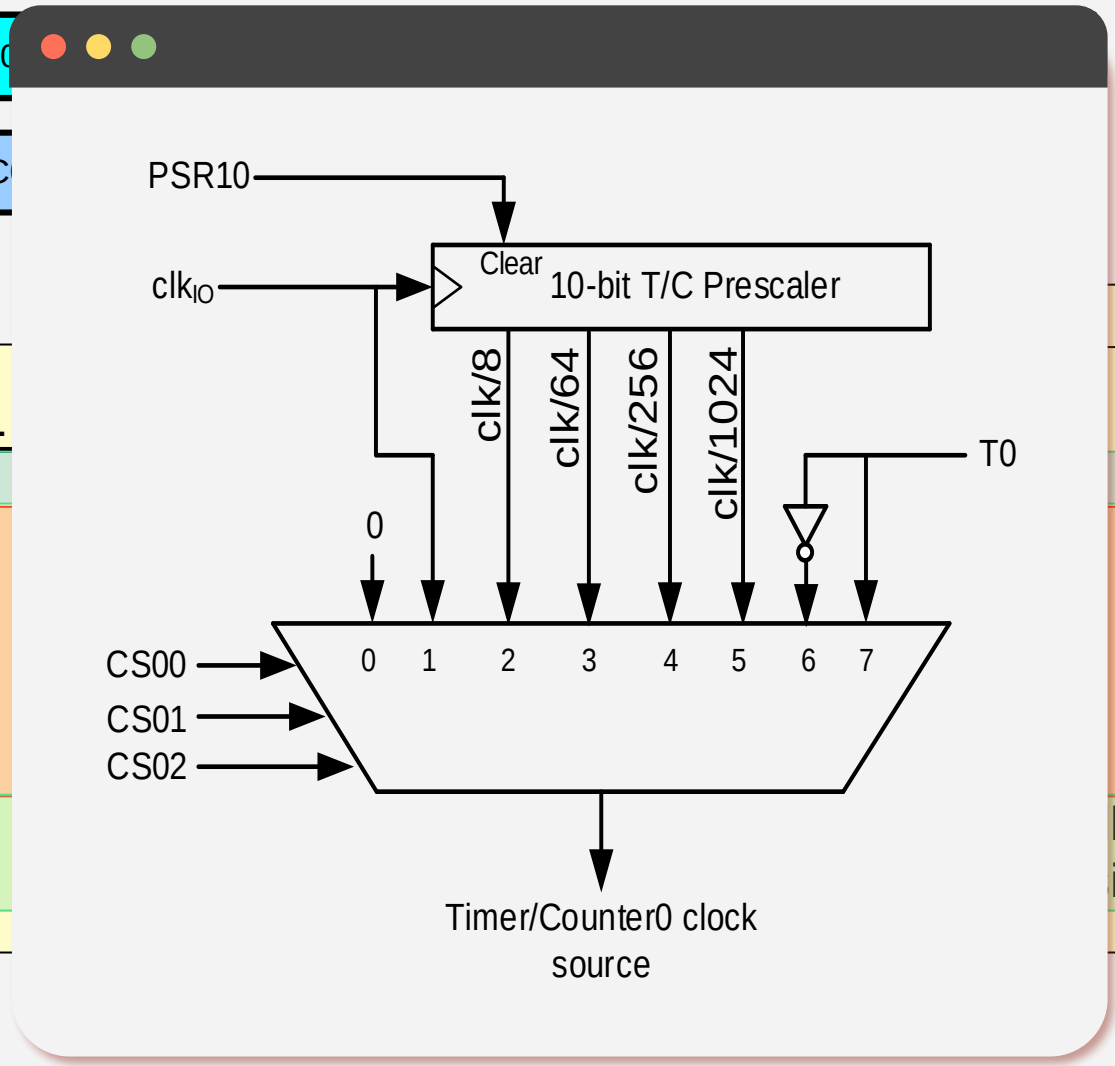
ling edge
ing edge

Timer 0 (8-bit timer)

COM0A1	COM0
FOC0A	FOC

TCCR0A

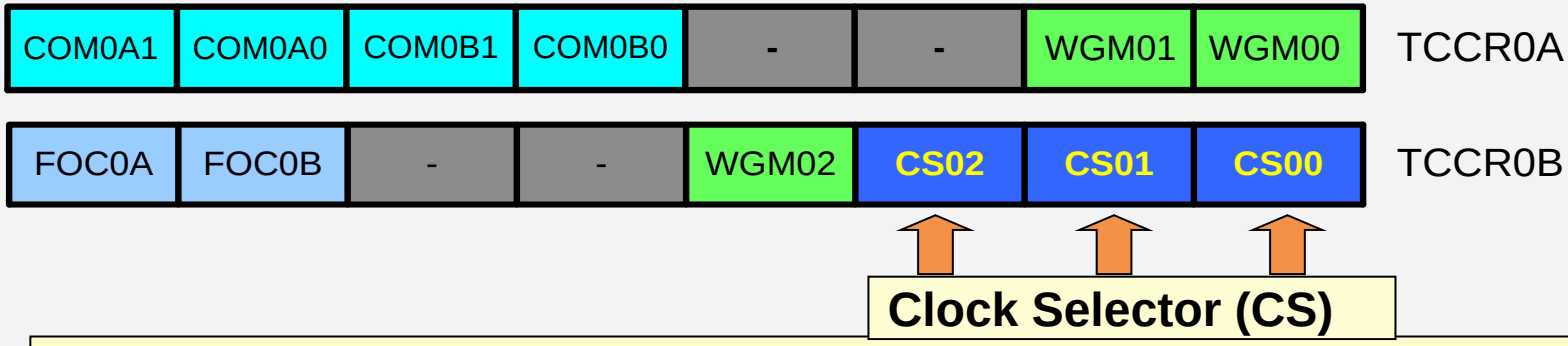
TCCR0B



CS02	CS01
0	0
0	0
0	1
0	1
1	0
1	0
1	1
1	1

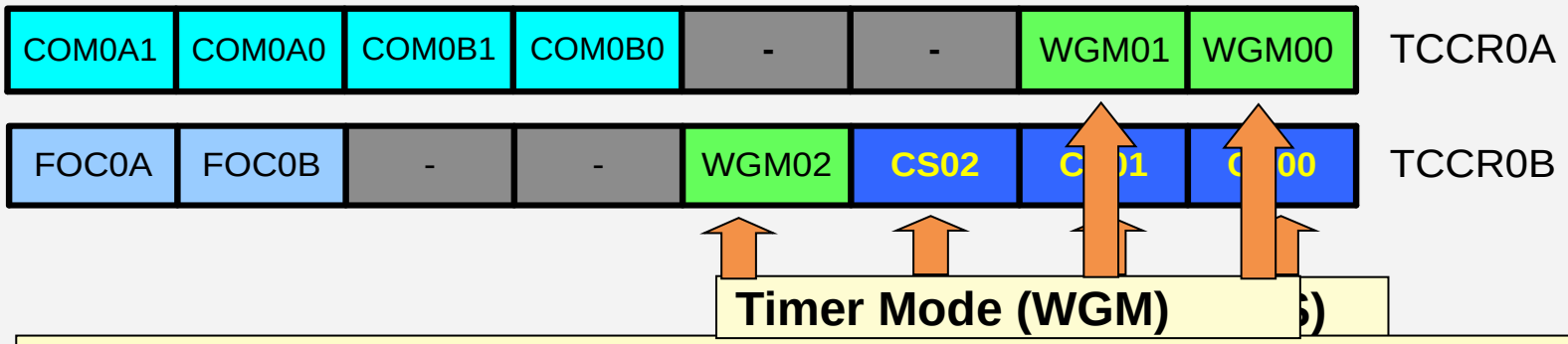
ling edge
ing edge

Timer 0 (8-bit timer)



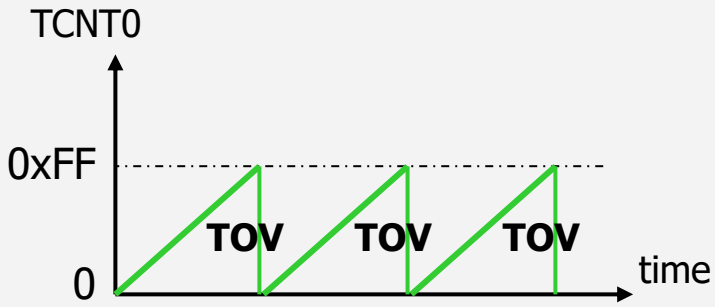
CS02	CS01	CS00	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
0	1	0	clk / 8
0	1	1	clk / 64
1	0	0	clk / 256
1	0	1	clk / 1024
1	1	0	External clock source on T0 pin. Clock on falling edge
1	1	1	External clock source on T0 pin. Clock on rising edge

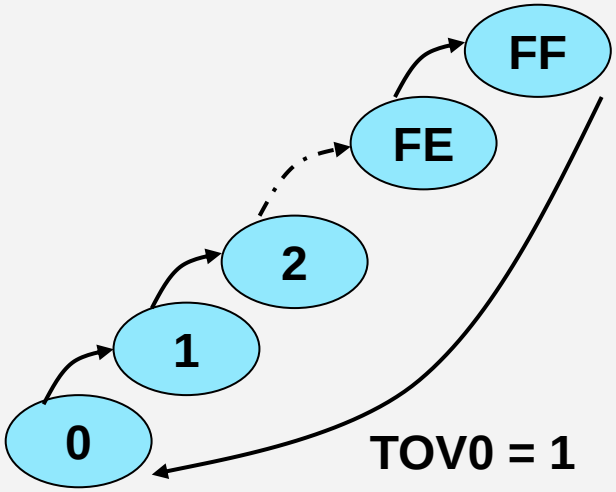
Timer 0 (8-bit timer)



WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC (Clear Timer on Compare Match)
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM

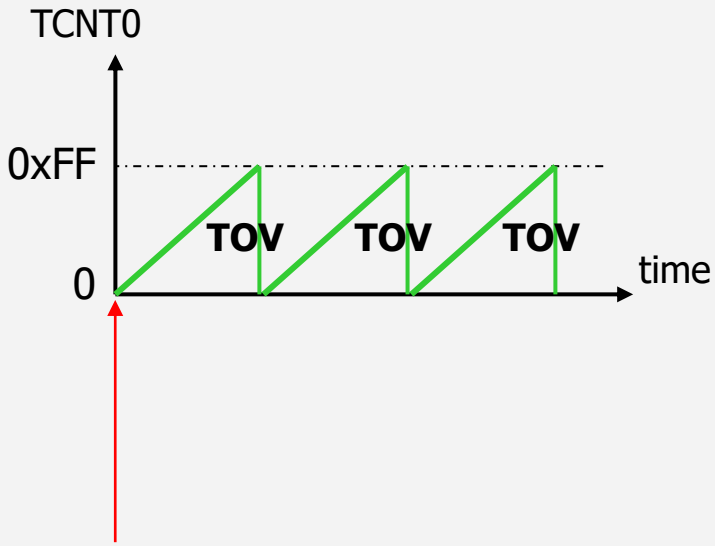
Normal mode

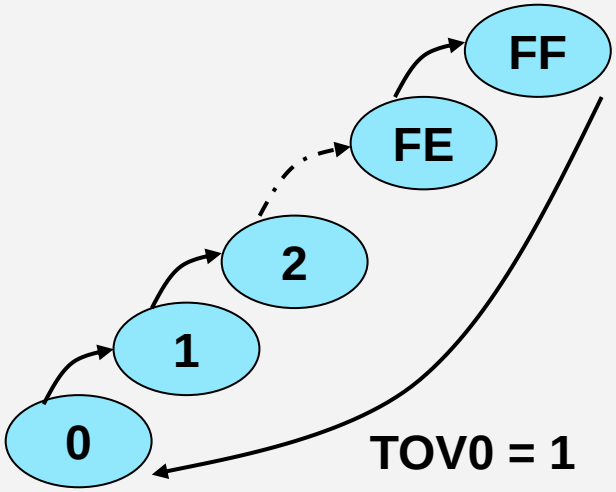




TOV0: 0

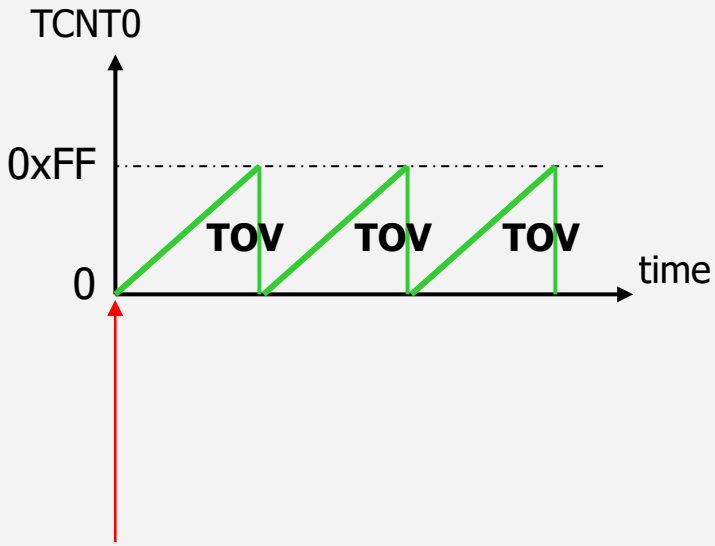
Normal mode

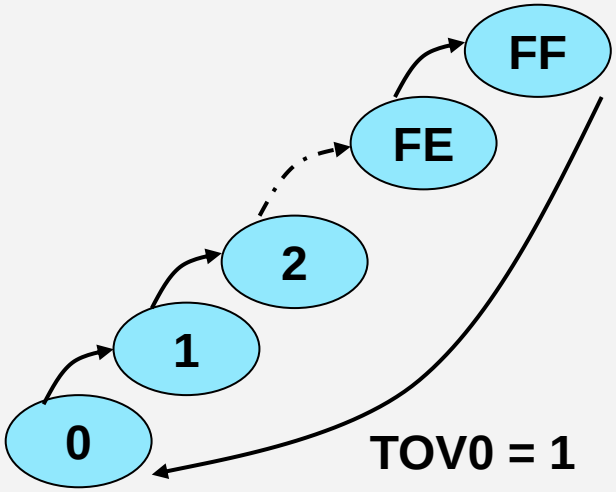




TOV0: **0**

Normal mode

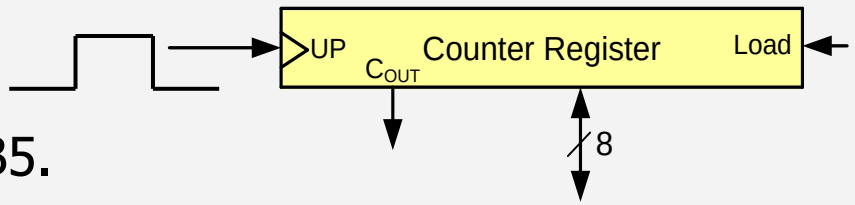




TOV0: **1**

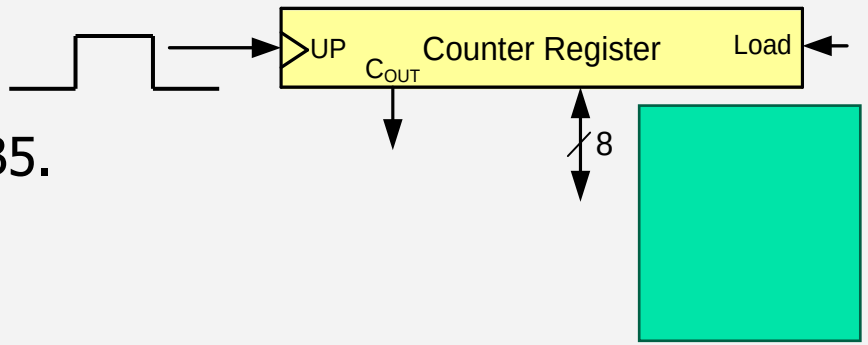
Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



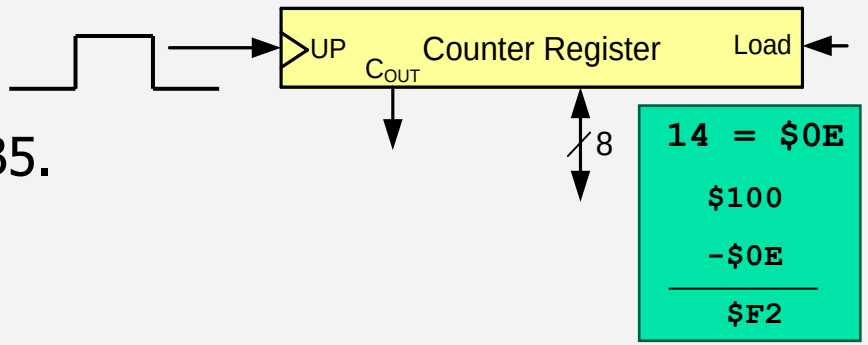
Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



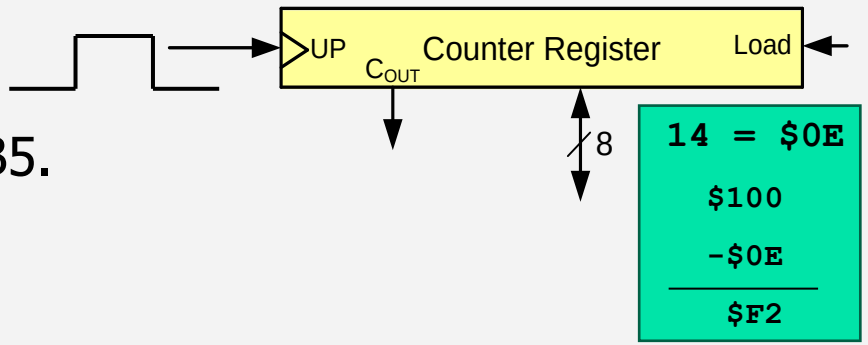
Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



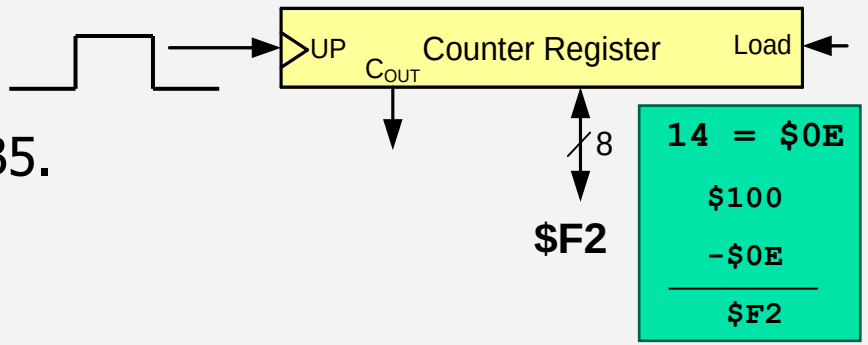
Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



Normal mode

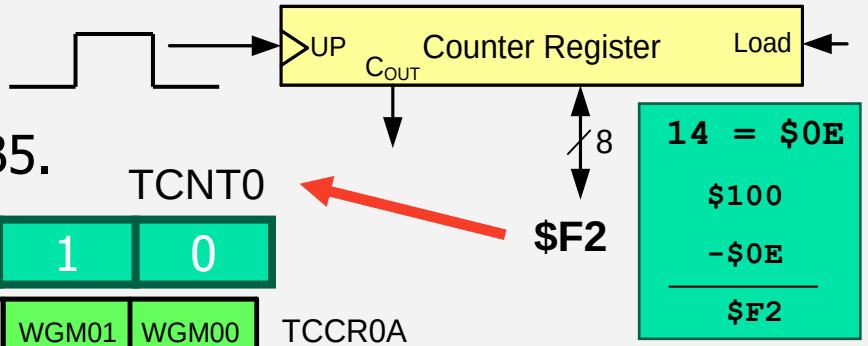
Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



0 0 1

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



TCNT0

1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

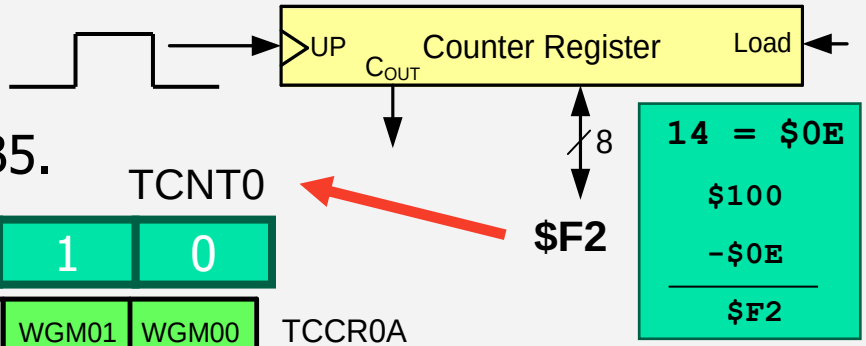
TCCR0A

FOC0A	FOC0B	-	-	WGM02	CS02	CS01	CS00
					0	0	1

TCCR0B

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



TCNT0

1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

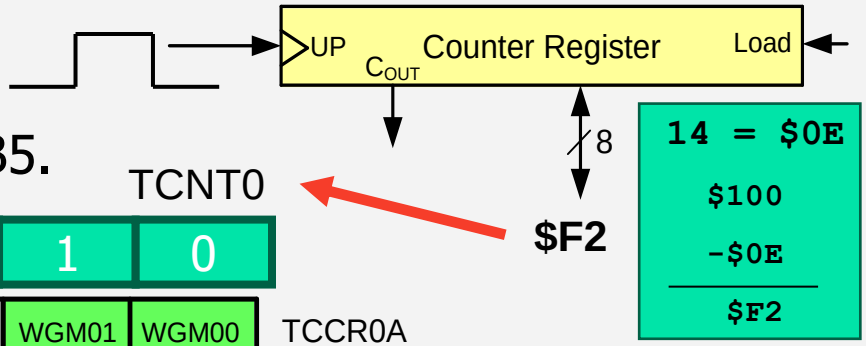
TCCR0A

FOC0A	FOC0B	-	-	WGM02	CS02	CS01	CS00
					0	0	1

TCCR0B

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



TCNT0

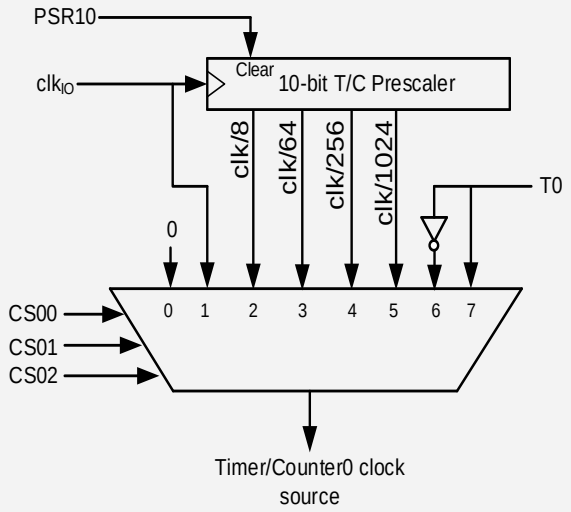
1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

TCCR0A

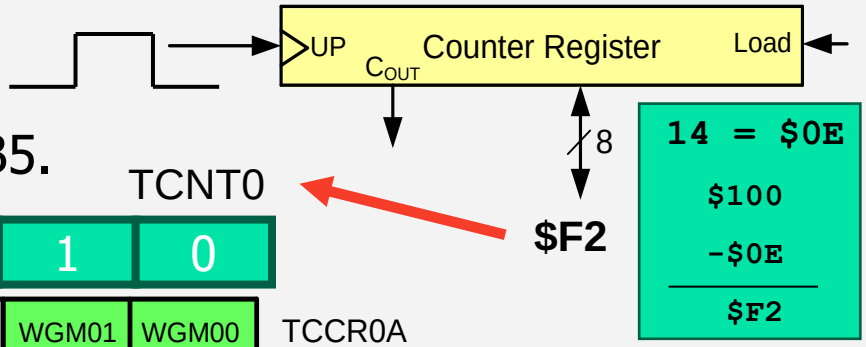
FOC0A	FOC0B	-	-	WGM02	CS02	CS01	CS00
					0	0	1

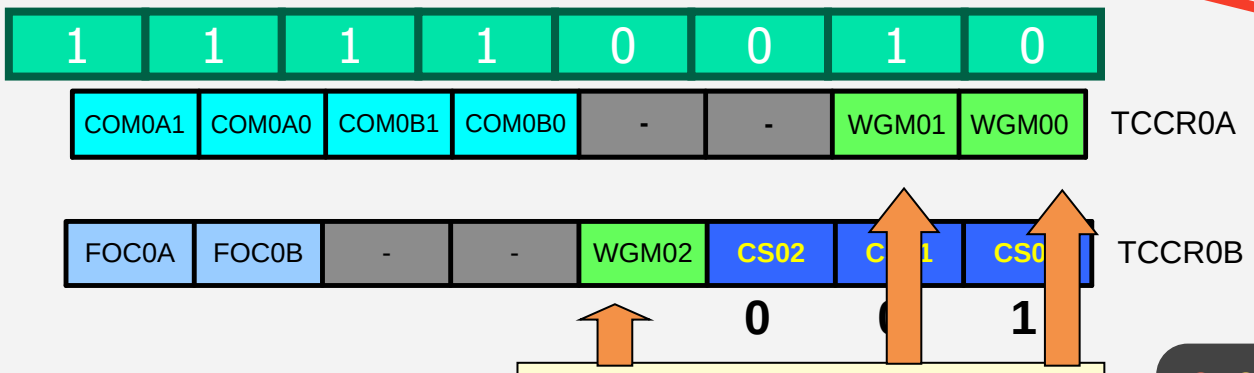
TCCR0B



Normal mode

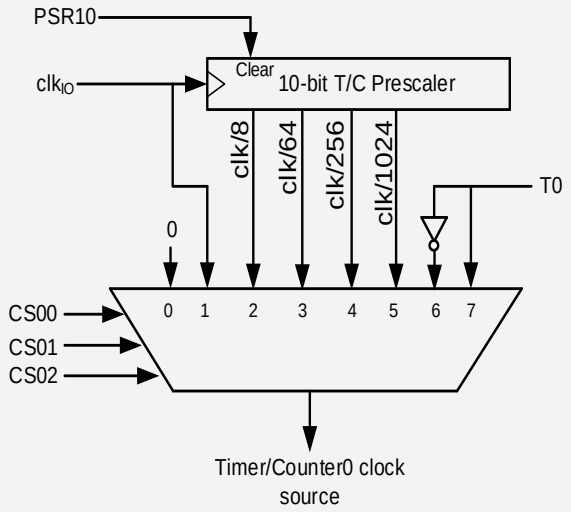
Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.





Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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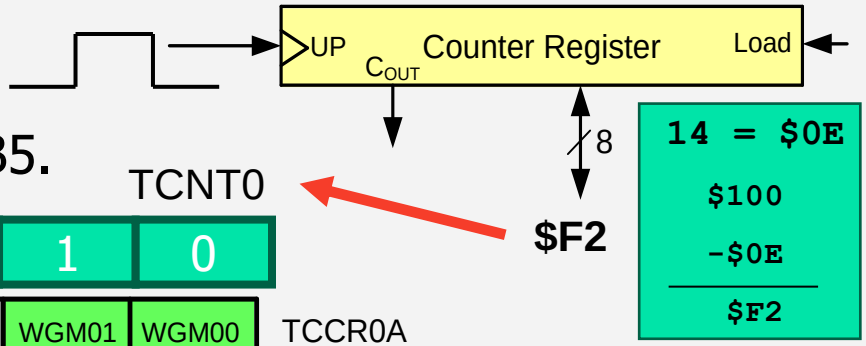


TCNT0

1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

TCCR0A

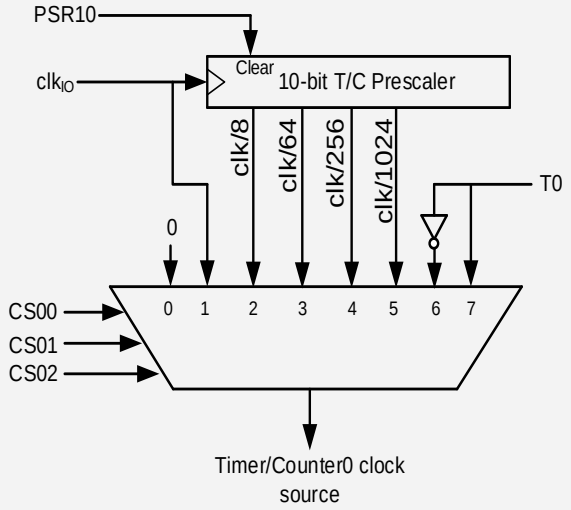
FOC0A	FOC0B	-	-	WGM02	CS02	C 1	CS0

TCCR0B

0 0 0 1

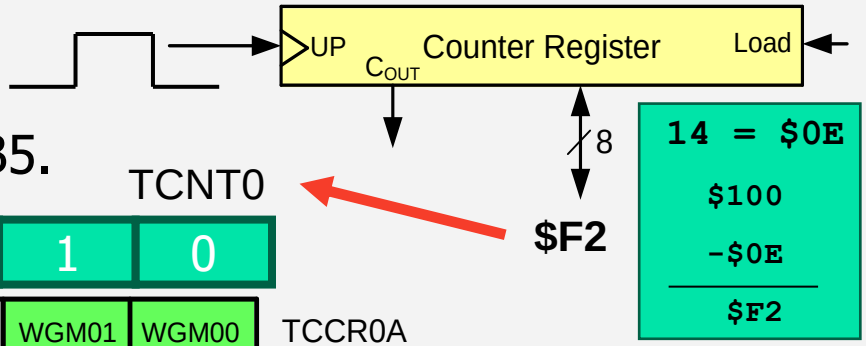
Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



TCNT0

1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

TCCR0A

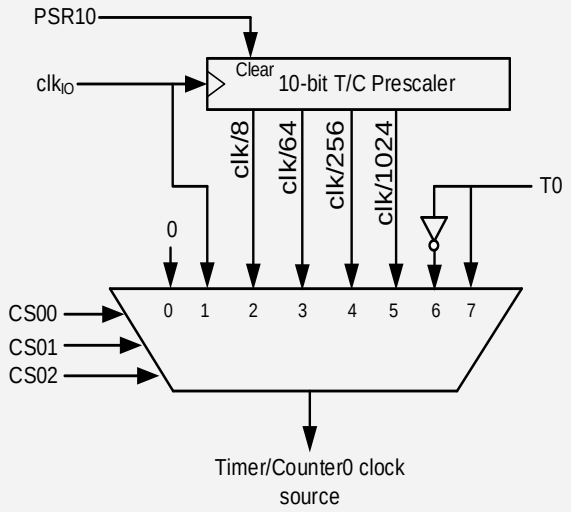
FOC0A	FOC0B	-	-	WGM02	CS02	C 1	CS0

TCCR0B

0 0 0 1

Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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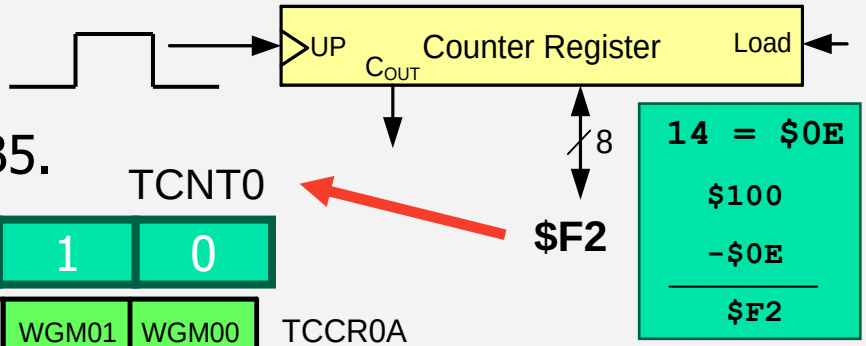
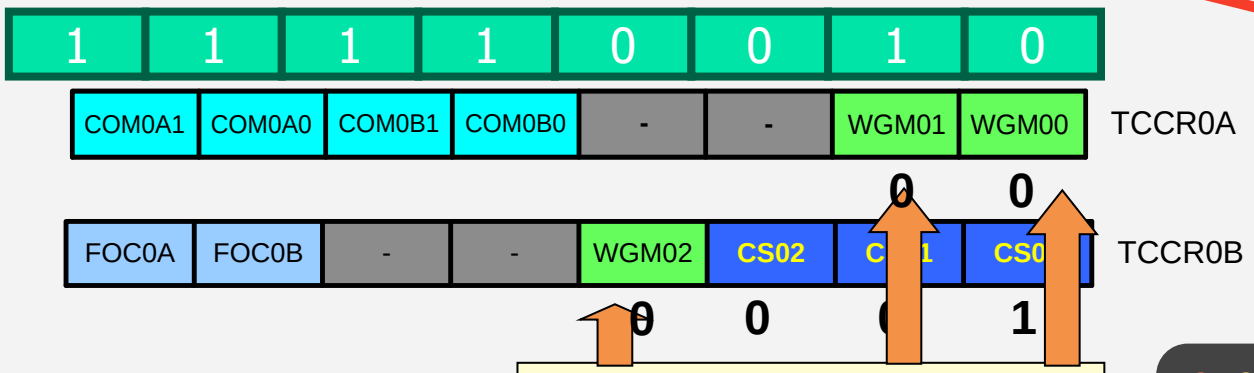
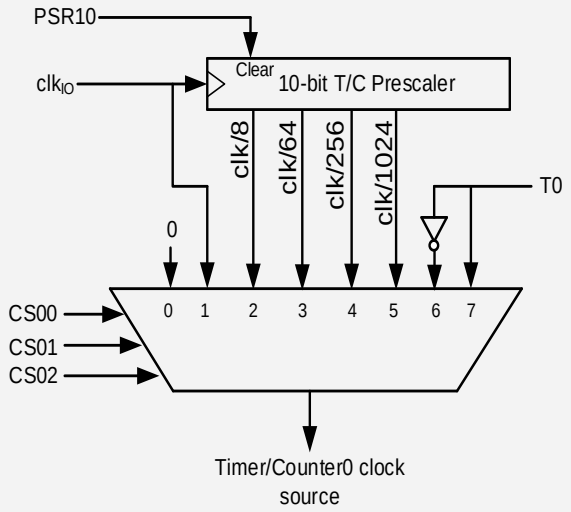




Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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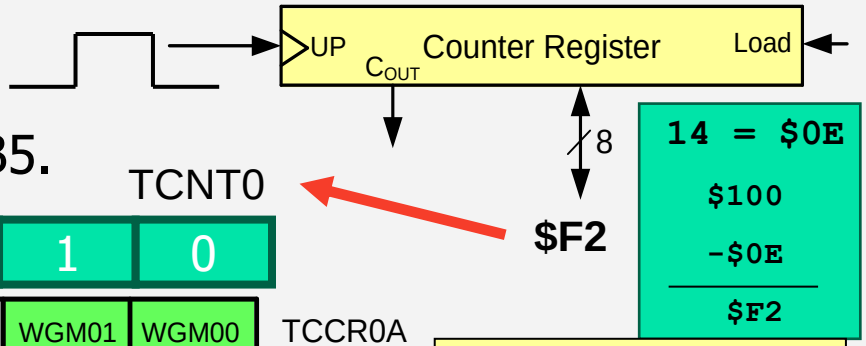
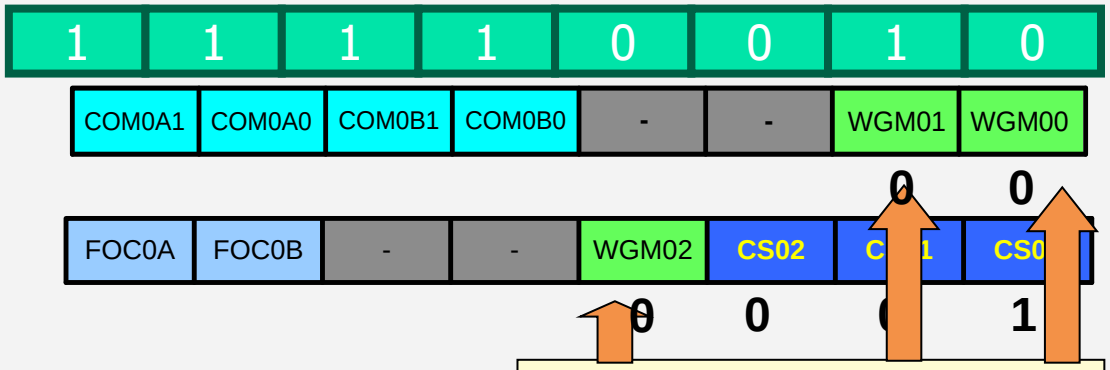
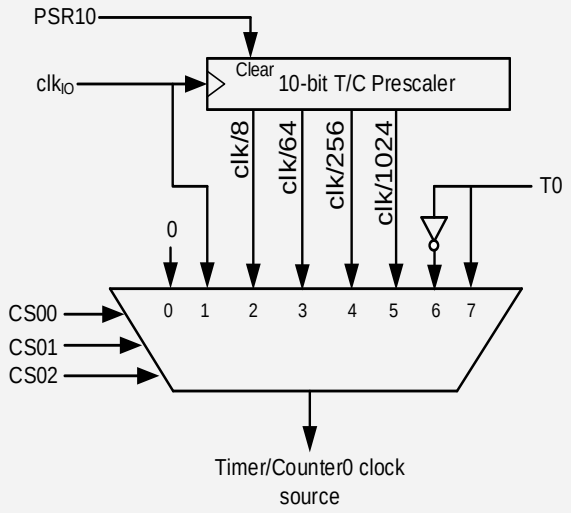





```
TCCR0A = 0x00;
TCCR0B = 0x03;
```

Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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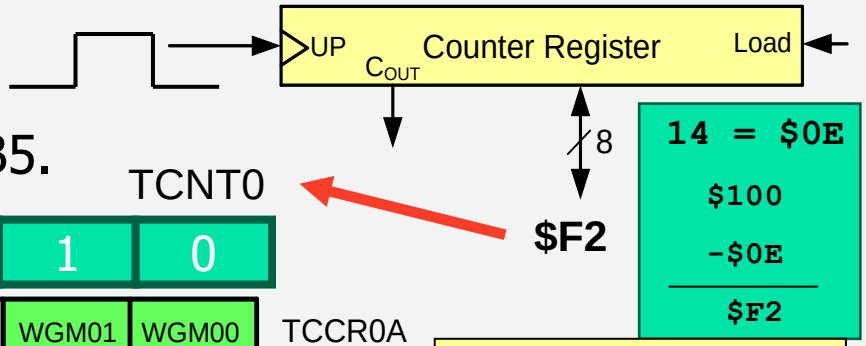

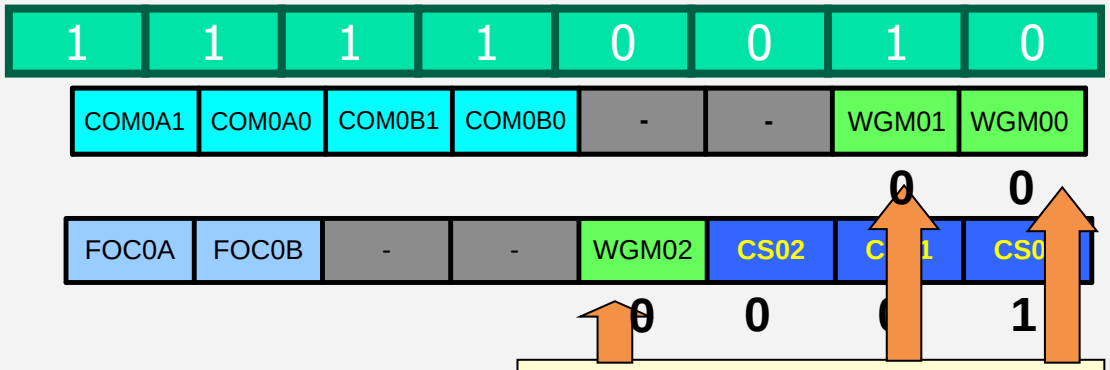


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Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
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0	1	1	Fast PWM
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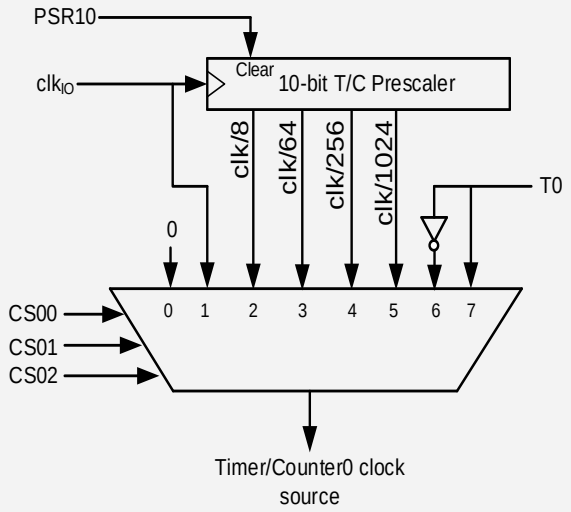
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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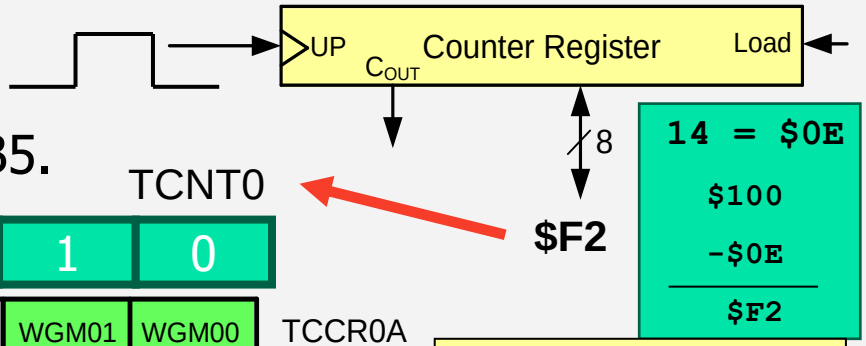

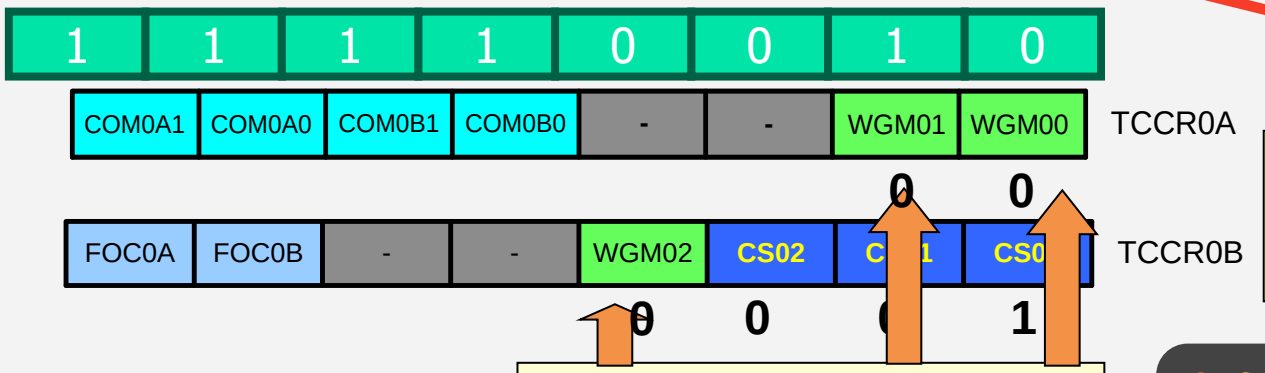


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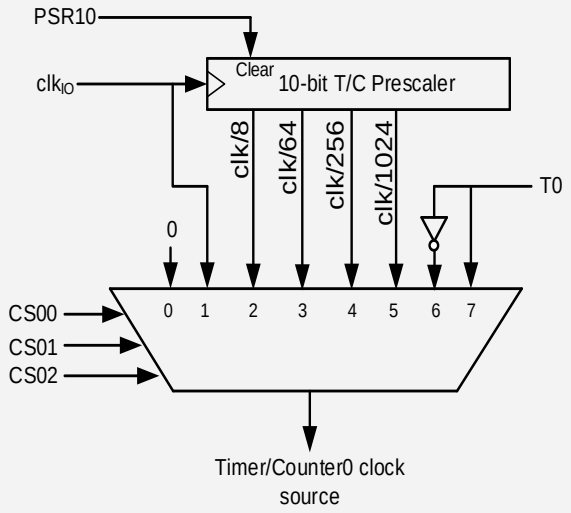
TCCR0A = 0x00;
TCCR0B = 0x03;
```

Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

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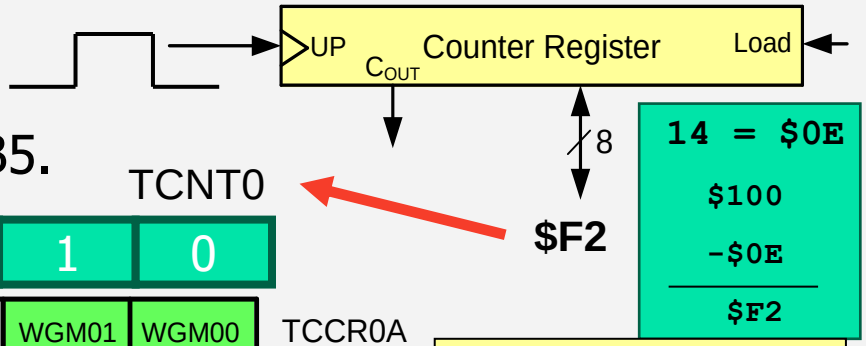


TCNT0

1	1	1	1	0	0	1	0

TCCR0A

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

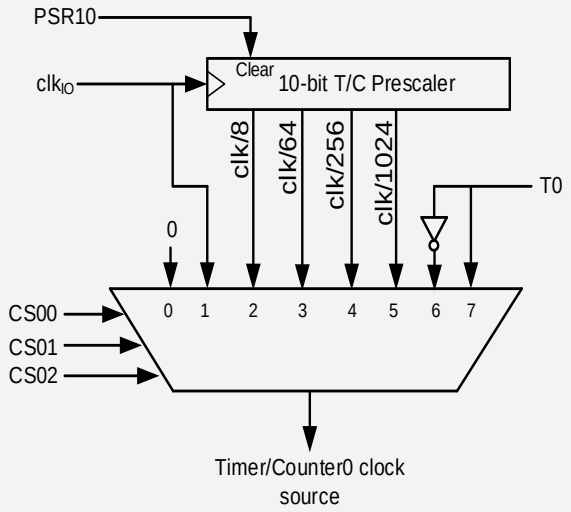
TCCR0B

FOC0A	FOC0B	-	-	WGM02	CS02	C 1	CS0
				0	0	0	1

```
TCCR0A = 0x00;
TCCR0B = 0x03;
```

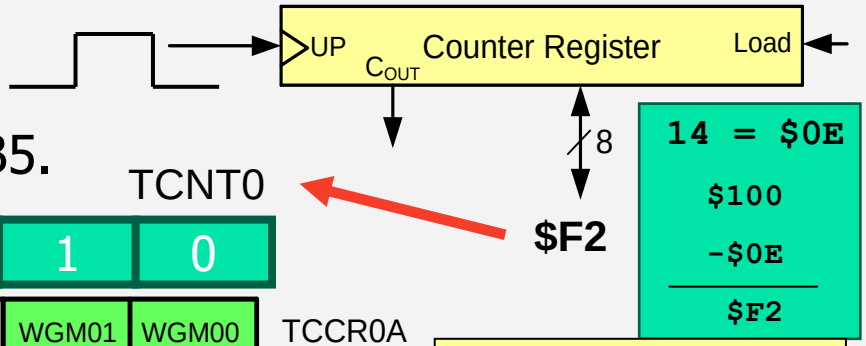
Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



TCNT0

1	1	1	1	0	0	1	0

COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00

TCCR0A

FOC0A	FOC0B	-	-	WGM02	CS02	C 1	CS0

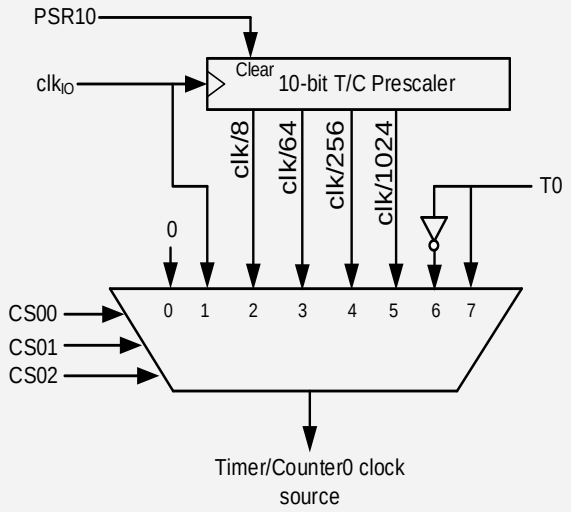
TCCR0B

0 0 0 1

```
TCCR0A = 0x00;
TCCR0B = 0x03;
```

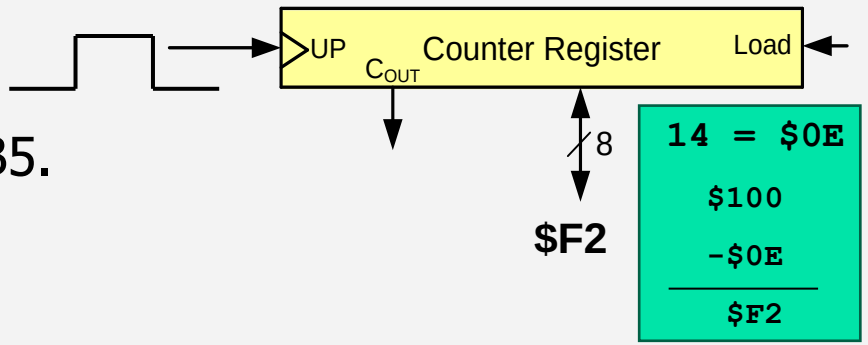
Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM



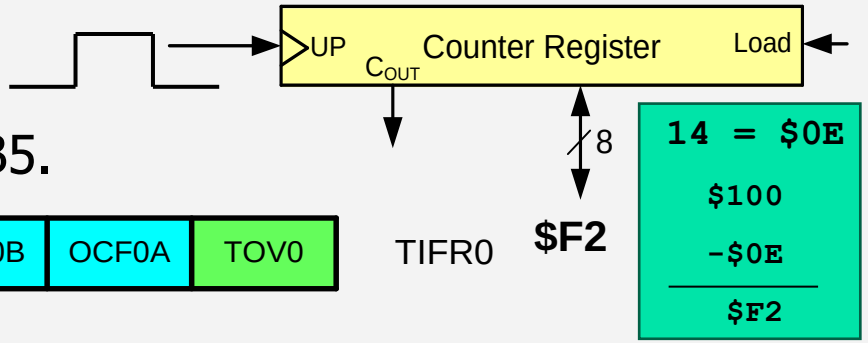
Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.

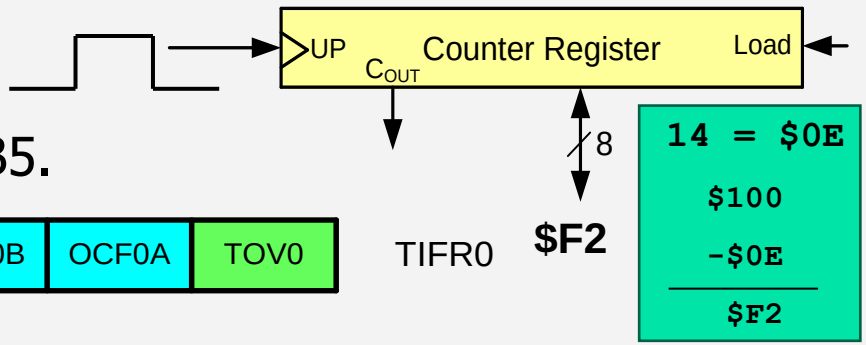


-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



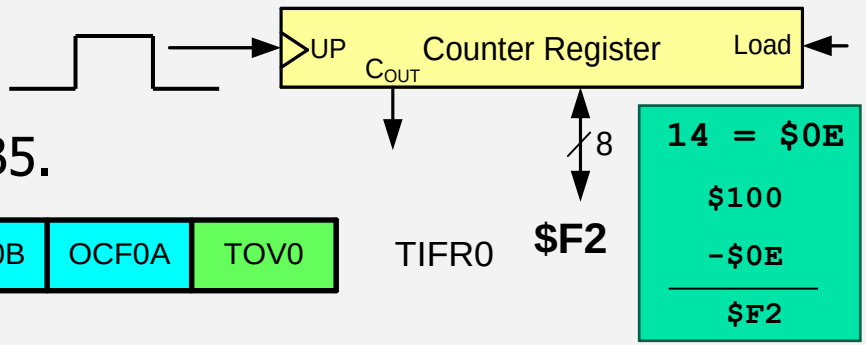
-	-	-	-	-	OCF0B	OCF0A	TOV0

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS   TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



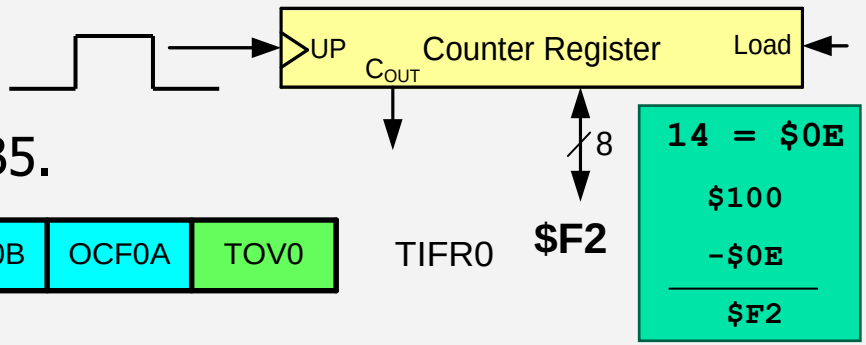
-	-	-	-	-	OCF0B	OCF0A	TOV0

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



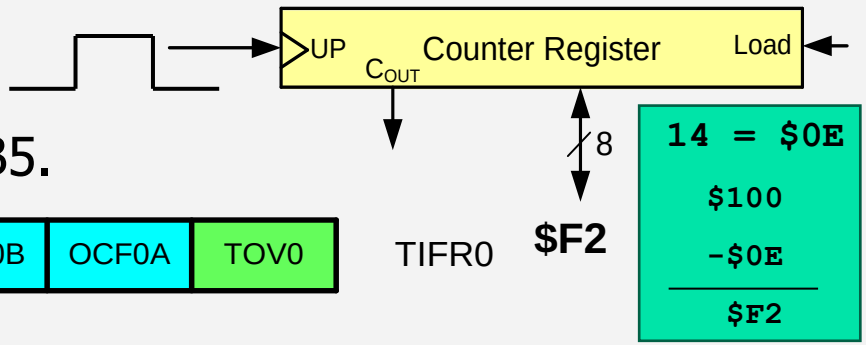
-	-	-	-	-	OCF0B	OCF0A	TOV0

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

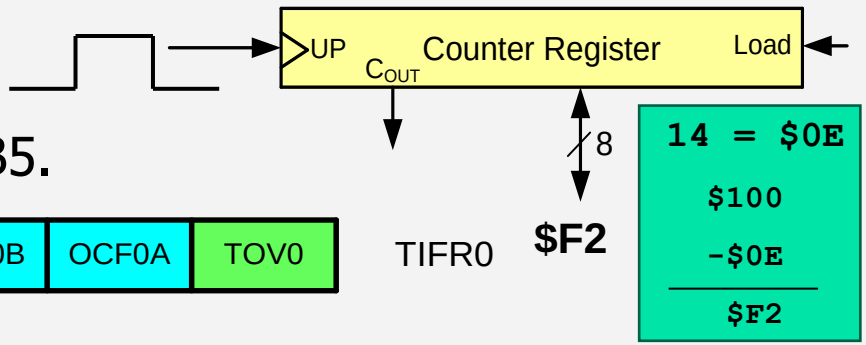
```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

```
DDRB = 1<<5;
PORTB &= ~(1<<5);  //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

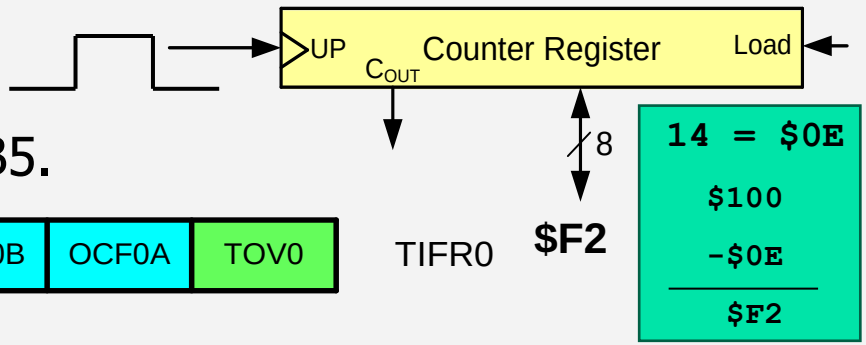
```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

```
DDRB = 1<<5;
PORTB &= ~(1<<5);   //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS  TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

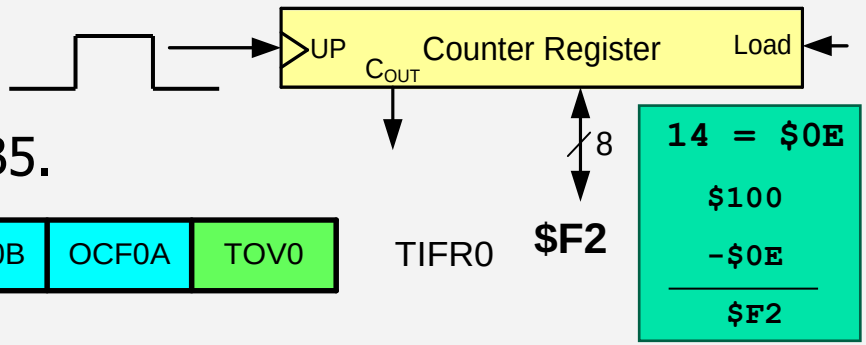
        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1<<5;
PORTB &= ~(1<<5);  //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

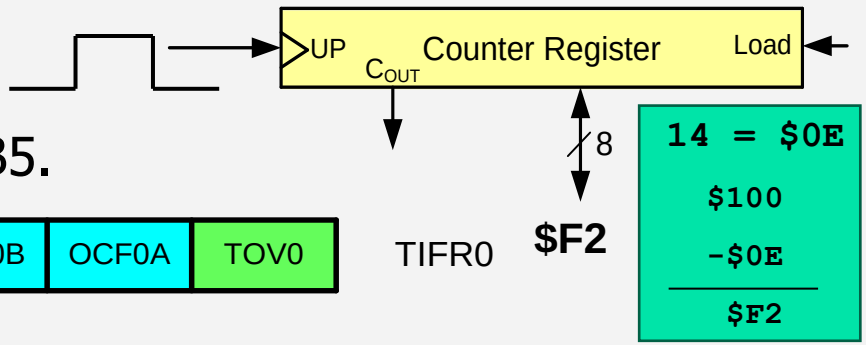
        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1<<5;
PORTB &= ~(1<<5);   //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

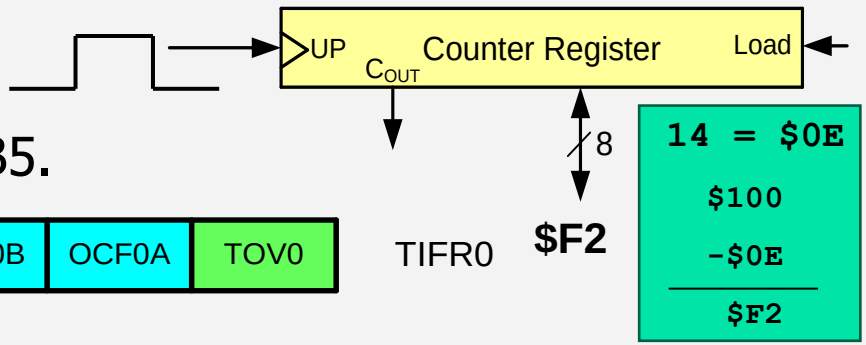
        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1<<5;
PORTB &= ~(1<<5);   //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

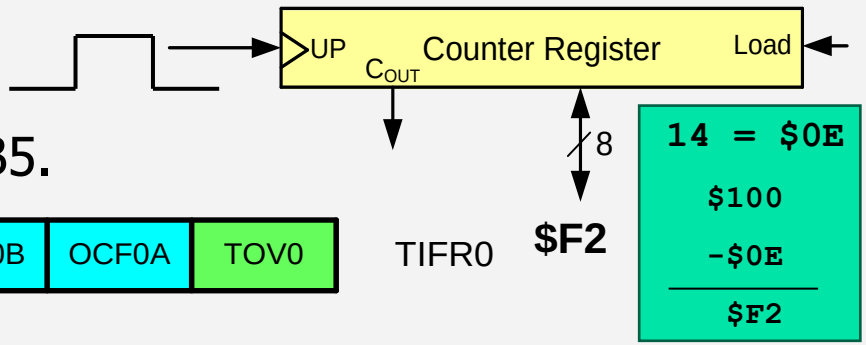
C

```
DDRB = 1<<5;
PORTB &= ~(1<<5);  //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

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

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



-	-	-	-	-	OCF0B	OCF0A	TOV0

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

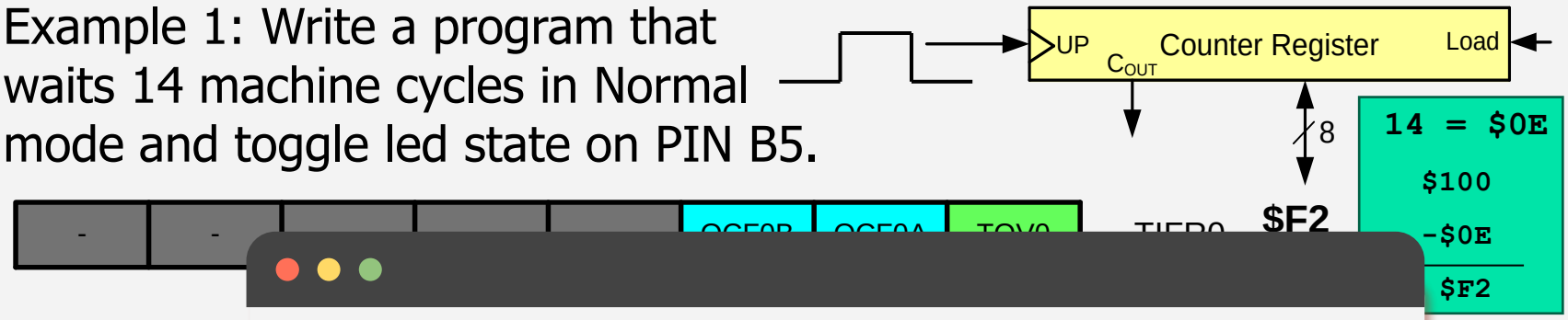
        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1<<5;
PORTB &= ~(1<<5);   //PB5=0
while (1)
{
  TCNT0 = 0xF2;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&(1<<TOV0))==0)
  {}
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



How to calculate the delay generated by the timer?

Answer:

1) Calculate how much a machine clock lasts.
   T= 1/f
2) Calculate how many machine clocks it waits.
3) Delay = T * number of machine cycles

Assembl

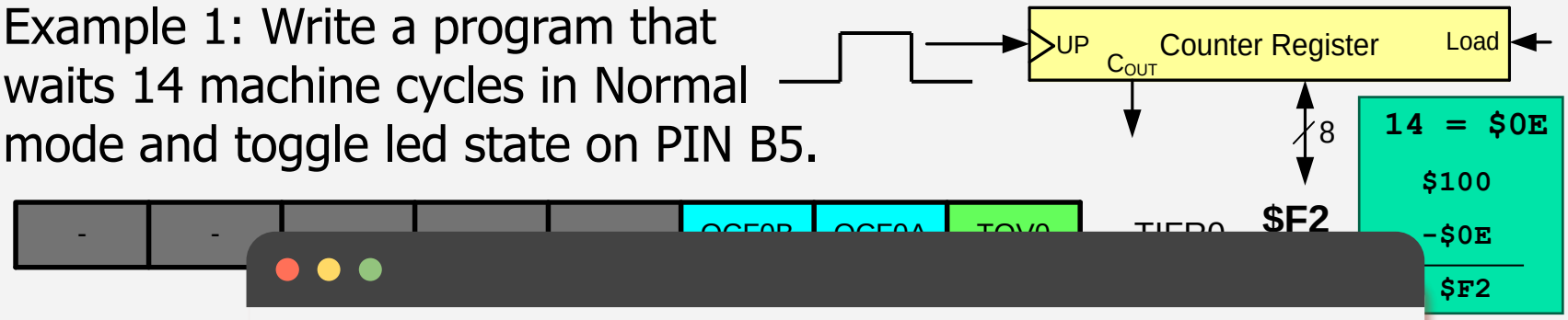
```
          LDI
          SBI
          LDI
          OUT
BEGIN:    LDI
          OUT
          LDI
          OUT
          LDI
          OUT
AGAIN:    SBIS
          RJMP      AGAIN
          LDI       R20,0x0
          OUT       TCCR0B,R20          ;stop Timer0
          LDI       R20,(1<<TOV0)       ;R20 = 0x01
          OUT       TIFR0,R20 ;clear TOV0 flag

          EOR       R17,R16             ;toggle D5 of R17
          OUT       PORTB,R17 ;toggle PB5
          RJMP      BEGIN
```

```
PB5=0
V0))==0)
  TCCR0B = 0;
  TIFR0 = (1<<TOV0);
  PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



How to calculate the delay generated by the timer?

Answer:

1) Calculate how much a machine clock lasts.
   T= 1/f
2) Calculate how many machine clocks it waits.
3) Delay = T * number of machine cycles

Assembl

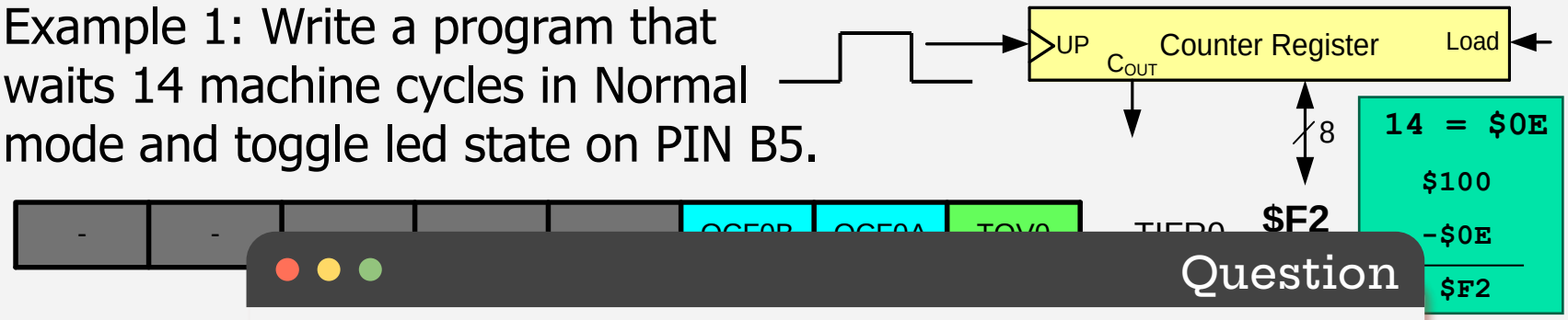
```
        LDI
        SBI
        LDI
        OUT
BEGIN:  LDI
        OUT
        LDI
        OUT
        LDI
        OUT
AGAIN:  SBIS
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

```
PB5=0
V0))==0)
    TCCR0B = 0;
    TIFR0 = (1<<TOV0);
    PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



Question

How to calculate the delay generated by the timer?

Answer:

1) Calculate how much a machine clock lasts.
   T= 1/f
2) Calculate how many machine clocks it waits.
3) Delay = T * number of machine cycles

Assembl

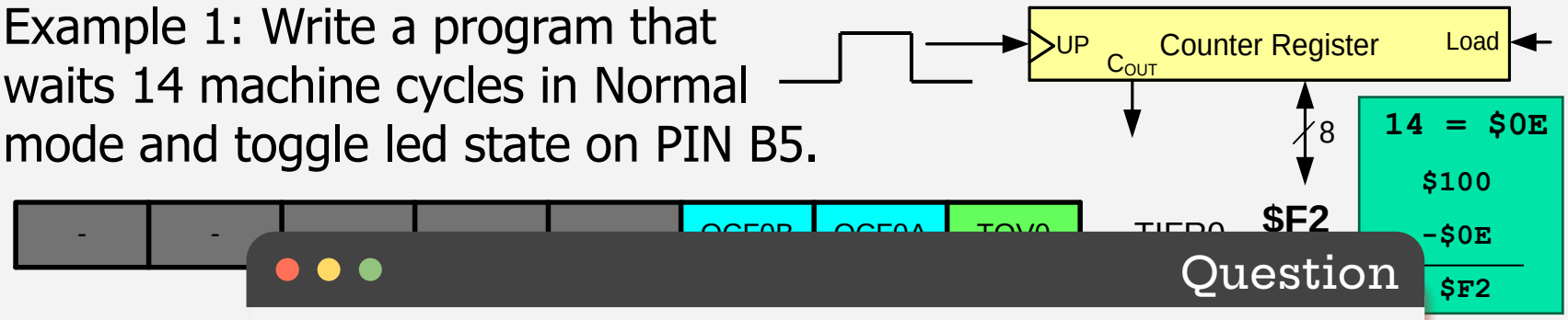
```
        LDI
        SBI
        LDI
        OUT
BEGIN:  LDI
        OUT
        LDI
        OUT
        LDI
        OUT
AGAIN:  SBIS
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

```
PB5=0
V0))==0)
    TCCR0B = 0;
    TIFR0 = (1<<TOV0);
    PORTB ^= (1<<5);
}
```

Normal mode

Example 1: Write a program that waits 14 machine cycles in Normal mode and toggle led state on PIN B5.



Question

How to calculate the delay generated by the timer?

Answer:

1) Calculate how much a machine clock lasts.
   T= 1/f
2) Calculate how many machine clocks it waits.
3) Delay = T * number of machine cycles

```
Assembl
        LDI
        SBI
        LDI
        OUT
BEGIN:  LDI
        OUT
        LDI
        OUT
        LDI
        OUT
AGAIN:  SBIS
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16             ;toggle D5 of R17
        OUT     PORTB,R17 ;toggle PB5
        RJMP    BEGIN
```

```
PB5=0
V0))==0)
    TCCR0B = 0;
    TIFR0 = (1<<TOV0);
    PORTB ^= (1<<5);
}
```

Solution

In example 1 calculate the delay. XTAL = 10 MHz.

Solution 1 (inaccurate)

1) Calculating T:

T = 1/f = 1/10M = 0.1µs

2) Calculating num of machine cycles:

```
 $100
-$F2
 ----
  $0E = 14
```

3) Calculating delay

14 * 0.1µs = 1.4 µs

Assembly

```
          LDI     R16,(1<<5) ;R16=0x20
          SBI     DDRB,5     ;PB5 as an output
          LDI     R17,0
          OUT     PORTB,R17
BEGIN:    LDI     R20,0xF2
          OUT     TCNT0,R20 ;load timer0
          LDI     R20,0x0
          OUT     TCCR0A,R20
          LDI     R20,0x01
          OUT     TCCR0B,R20 ;Normal mode, inter. clk
AGAIN:    SBIS   TIFR0,TOV0 ;if TOV0 is set skip next
          RJMP    AGAIN
          LDI     R20,0x0
          OUT     TCCR0B,R20          ;stop Timer0
          LDI     R20,(1<<TOV0)       ;R20 = 0x01
          OUT     TIFR0,R20 ;clear TOV0 flag

          EOR     R17,R16             ;toggle D5 of R17
          OUT     PORTB,R17 ;toggle PB5
          RJMP    BEGIN
```

Accurate calculating

Other than timer, executing the instructions consumes time; so if we want to calculate the accurate delay a program causes we should add the delay caused by instructions to the delay caused by the timer

```
        LDI     R16,0x20
        SBI     DDRB,5
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0xF2        1
        OUT     TCNT0,R20       1
        LDI     R20,0x00        1
        OUT     TCCR0A,R20      1
        LDI     R20,0x01        1
        OUT     TCCR0B,R20      1
AGAIN:  SBIS    TIFR0,TOV0      1 / 2
        RJMP    AGAIN           2
        LDI     R20,0x0         1
        OUT     TCCR0B,R20      1
        LDI     R20,0x01        1
        OUT     TIFR0,R20       1
        EOR     R17,R16         1
        OUT     PORTB,R17       1
        RJMP    BEGIN           2
                                18
```

Delay caused by timer = 14 * 0.1µs = 1.4 µs **Delay caused by instructions = 18 * 0.1µs = 1.8**

Total delay = 3.2 µs ➔ wave period = 2*3.2 µs = 6.4 µs ➔ wave frequency = 156.25 KHz

Finding values to be loaded into the timer

1. Calculate the period of clock source.
   - Period = 1 / Frequency
     - E.g. For XTAL = 16 MHz ➔ T = 1/16MHz
2. Divide the desired time delay by period of clock.
3. Perform 256 - n, where n is the decimal value we got in Step 2.
4. Set TCNT0 = 256 - n

Example 2

Question: Assuming that XTAL = 10 MHz, write a program to generate a square wave with a period of µ10 s on pin PORTB.3.

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. 256 - 50 = 206.

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,206
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, int. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1<<3;
PORTB &= ~ (1<<3);
while (1)
{
  TCNT0 = 206;
  TCCR0A = 0x00;
  TCCR0B = 0x01;
  while((TIFR0&0x01) == 0)
  {}
  TCCR0B = 0;
  TIFR0 = 1<<TOV0;
  PORTB = PORTB ^ (1<<3);
}
```

Example 3

Question: Modify TCNT0 in Example 2 to get the largest time delay possible with no prescaler. Find the delay in µs. In your calculation, do not include the overhead due to instructions.

- To get the largest delay we make TCNT0 zero. This will count up from 00 to 0xFF and then roll over to zero.

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R17,0
        OUT     PORTB,R17
BEGIN:  LDI     R20,0
        OUT     TCNT0,R20 ;load timer0
        LDI     R20,0x0
        OUT     TCCR0A,R20
        LDI     R20,0x01
        OUT     TCCR0B,R20 ;Normal mode, int. clk
AGAIN:  SBIS    TIFR0,TOV0 ;if TOV0 set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,(1<<TOV0)       ;R20 = 0x01
        OUT     TIFR0,R20 ;clear TOV0 flag

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1 << 3;
PORTB &= ~(1<<3);
while (1)
{
  TCNT0 = 0x00;
  TCCR0A = 0x00;
  TCCR0B = 0x01;

while((TIFR0&(1<<TOV0))==0)
{}
  TCCR0B = 0;
  TIFR0 = 0x01;
  PORTB = PORTB^(1<<3);
}
```

Example 3

Question: Modify TCNT0 in Example 2 to get the largest time delay possible with no prescaler. Find the delay in µs. In your calculation, do not include the overhead due to instructions.

- To get the largest delay we make TCNT0 zero. This will count up from 00 to 0xFF and then roll over to zero.

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R
        OUT     P
BEGIN:  LDI     R
        OUT     T
        LDI     R
        OUT     T
        LDI     R
        OUT     T
AGAIN:  SBIS    T
        RJMP    A
        LDI     R
        OUT     T
        LDI     R
        OUT     T

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1 << 3;
= ~(1<<3);
1)

 = 0x00;
A = 0x00;
B = 0x01;

TIFR0&(1<<TOV0))==0)

B = 0;
 = 0x01;
 = PORTB^(1<<3);
}
```

Example 3

Question: Modify TCNT0 in Example 2 to get the largest time delay possible with no prescaler. Find the delay in µs. In your calculation, do not include the overhead due to instructions.

- To get the largest delay we make TCNT0 zero. This will count up from 00 to 0xFF and then roll over to zero.

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R
        OUT     P
BEGIN:  LDI     R
        OUT     T
        LDI     R
        OUT     T
        LDI     R
        OUT     T
AGAIN:  SBIS    T
        RJMP    A
        LDI     R
        OUT     T
        LDI     R
        OUT     T

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1 << 3;
= ~(1<<3);
1)

 = 0x00;
A = 0x00;
B = 0x01;

TIFR0&(1<<TOV0))==0)

B = 0;
 = 0x01;
 = PORTB^(1<<3);
}
```

Question

Example 3

Question: Modify TCNT0 in Example 2 to get the largest time delay possible with no prescaler. Find the delay in µs. In your calculation, do not include the overhead due to instructions.

- To get the largest delay we make TCNT0 zero. This will count up from 00 to 0xFF and then roll over to zero.

Assembly

```
        LDI     R16,(1<<5) ;R16=0x20
        SBI     DDRB,5     ;PB5 as an output
        LDI     R
        OUT     P
BEGIN:  LDI     R
        OUT     T
        LDI     R
        OUT     T
        LDI     R
        OUT     T
AGAIN:  SBIS    T
        RJMP    A
        LDI     R
        OUT     T
        LDI     R
        OUT     T

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1 << 3;
= ~(1<<3);
1)

 = 0x00;
A = 0x00;
B = 0x01;

TIFR0&(1<<TOV0))==0)

B = 0;
 = 0x01;
 = PORTB^(1<<3);
}
```

Question

Example 3

Question: Modify TCNT0 in Example 2 to get the largest time delay possible with no prescaler. Find the delay in µs. In your calculation, do not include the overhead due to instructions.

- To get the largest delay we make TCNT0 zero. This will count up from 00 to 0xFF and then roll over to zero.

Assembly

```
        LDI     R16,(1<<5)  ;R16=0x20
        SBI     DDRB,5      ;PB5 as an output
        LDI     R
        OUT     P
BEGIN:  LDI     R
        OUT     T
        LDI     R
        OUT     T
        LDI     R
        OUT     T
AGAIN:  SBIS    T
        RJMP    A
        LDI     R
        OUT     T
        LDI     R
        OUT     T

        EOR     R17,R16     ;toggle D5 of R17
        OUT     PORTB,R17   ;toggle PB5
        RJMP    BEGIN
```

C

```
DDRB = 1 << 3;
= ~(1<<3);
1)

 = 0x00;
A = 0x00;
B = 0x01;

TIFR0&(1<<TOV0))==0)

B = 0;
 = 0x01;
 = PORTB^(1<<3);
}
```

Question

Solution

1) Calculating T:

T = 1/f = 1/10MHz = 0.1µs

2) Calculating delay

256 * 0.1µs = 25.6µs

Generating Large Delays

- Using loop
- Prescaler
- Bigger counters

Generating Large Delays

- Using loop
- Prescaler
- Bigger counters

Generating Large Delays

- Using loop
- Prescaler
- Bigger counters

Generating Large Delays

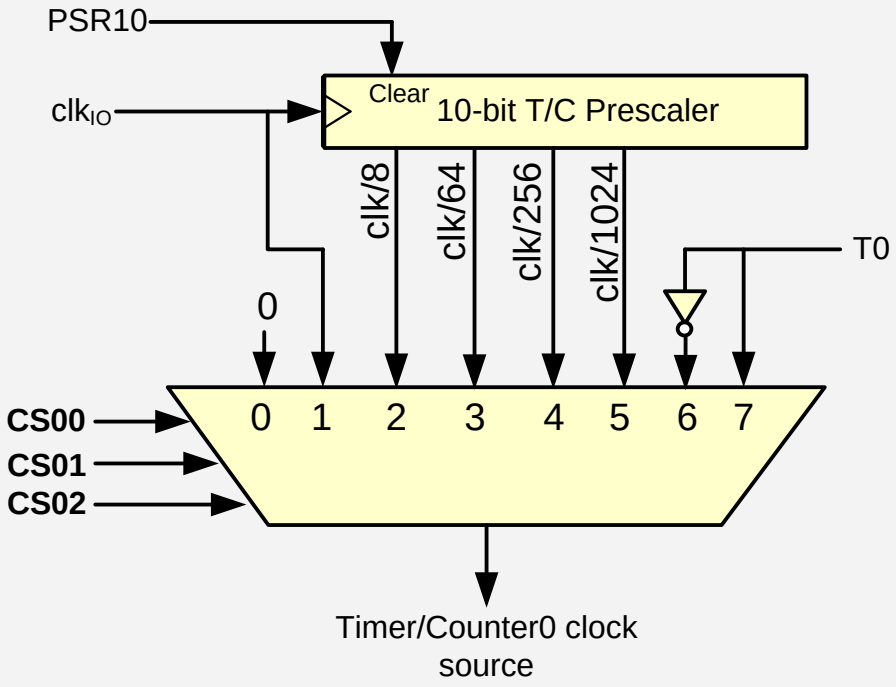
- Using loop
- Prescaler
- Bigger counters

Prescaler and generating a large time delay

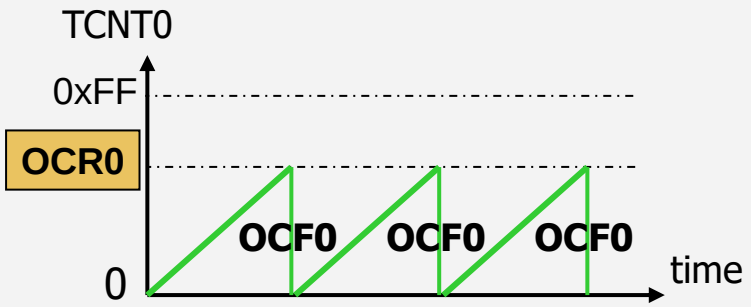
Generating Large Delays

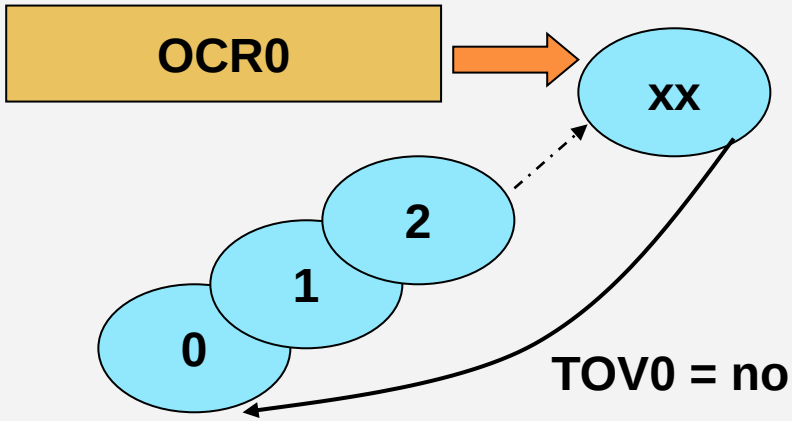
- Using loop
- Prescaler
- Bigger counters

Prescaler and generating a large time delay



CTC (Clear Timer on Compare match) mode





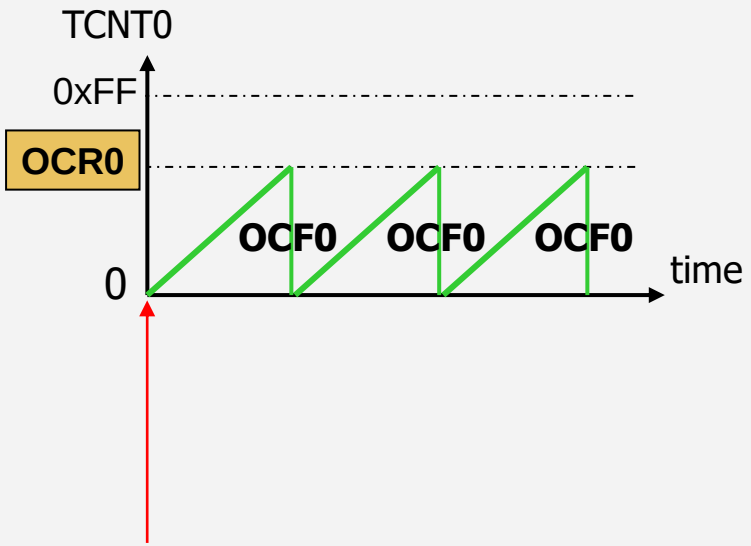
TOV0 = no change

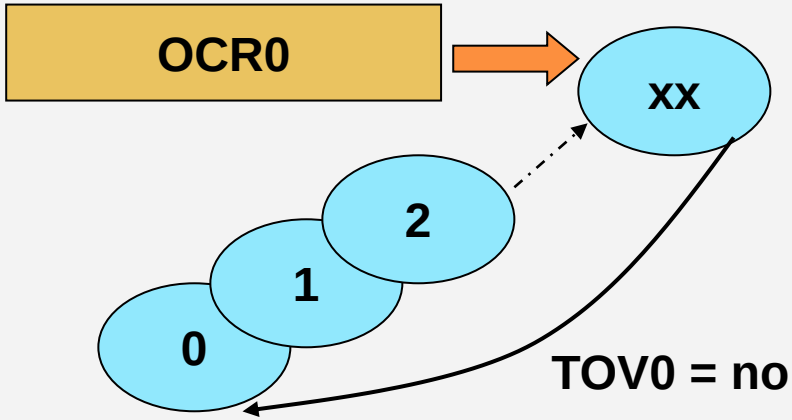
OCF0 = 1

TOV0: 0

OCF0: 0

CTC (Clear Timer on Compare match) mode





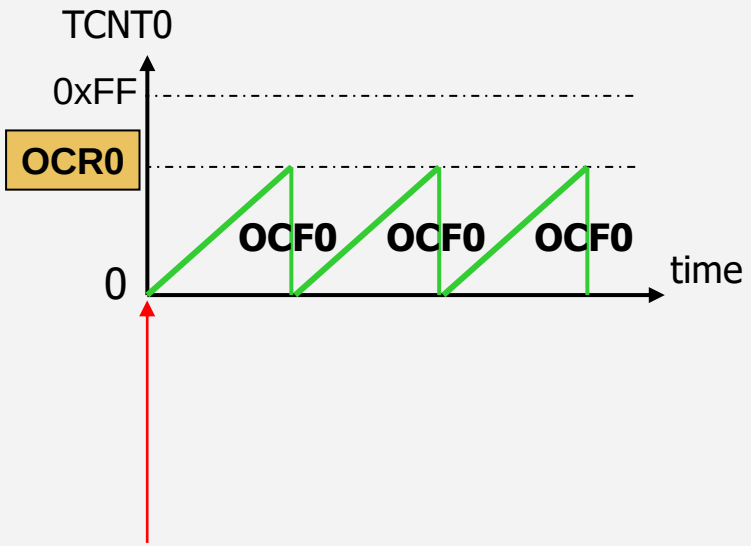
TOV0 = no change

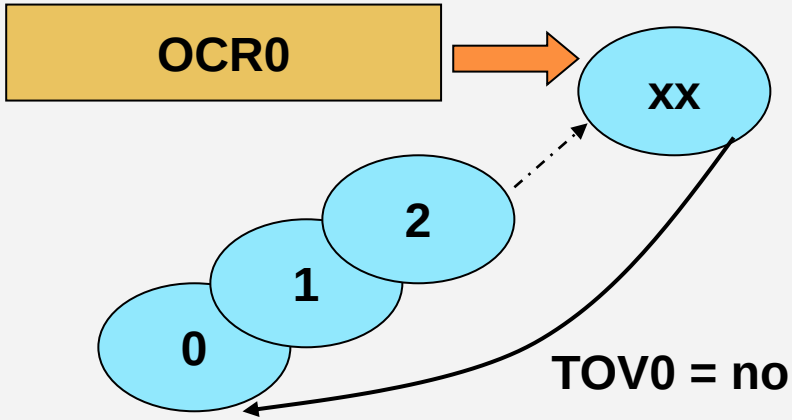
OCF0 = 1

TOV0: 0

OCF0: 0

CTC (Clear Timer on Compare match) mode





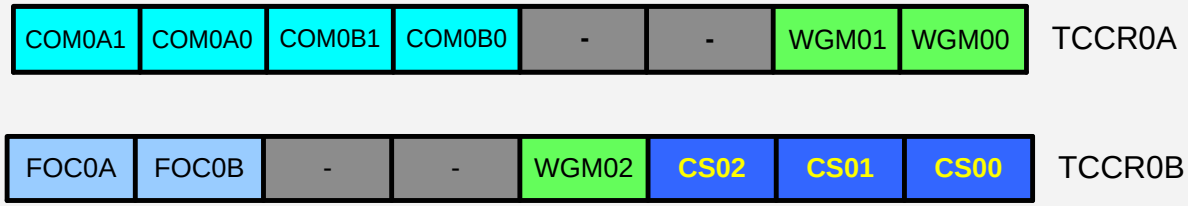
TOV0 = no change

OCF0 = 1

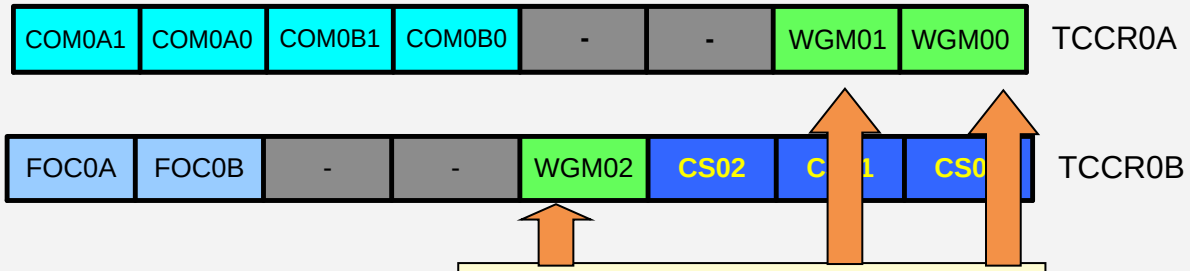
TOV0: 0

OCF0: 1

CTC mode (Cont.)



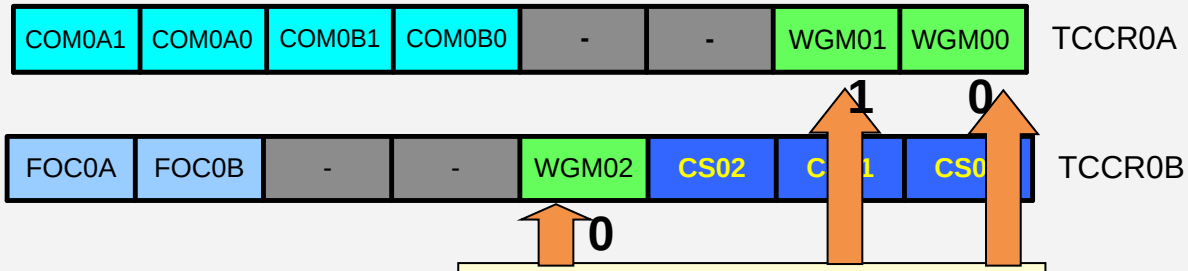
CTC mode (Cont.)



Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM

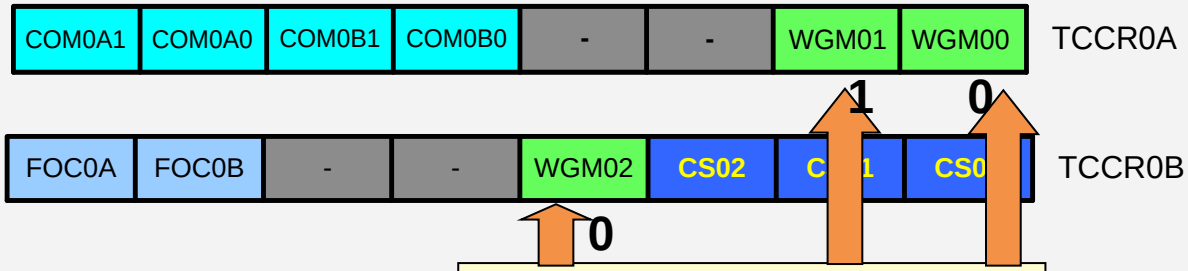
CTC mode (Cont.)



Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM

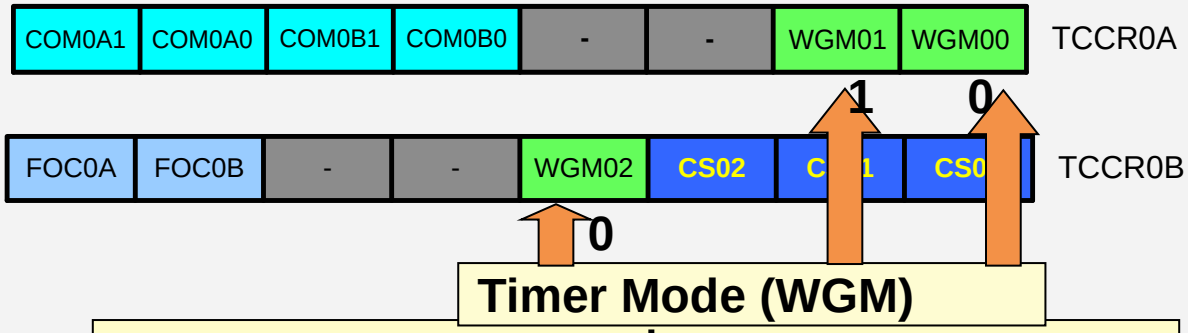
CTC mode (Cont.)



Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM

CTC mode (Cont.)



Timer Mode (WGM)

WGM02	WGM01	WGM00	Comment
0	0	0	Normal
0	0	1	Phase correct PWM
0	1	0	CTC
0	1	1	Fast PWM
1	0	0	Reserved
1	0	1	Phase correct PWM
1	1	0	Reserved
1	1	1	Fast PWM

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 μs.)

- For a square wave with T = 10 μs we must have a time delay of 5 μs. Because XTAL = 10 MHz, the counter counts up every 0.1 μs. This means that we need 5 μs / 0.1 μs = 50 clocks. Therefore, we have OCR0A= 49.

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 μs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 μs we must have a time delay of 5 μs. Because XTAL = 10 MHz, the counter counts up every 0.1 μs. This means that we need 5 μs / 0.1 μs = 50 clocks. Therefore, we have OCR0A= 49.

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

```
        LDI     R16,(1<<3)          ;R16 = 0x08
        SBI     DDRB,3              ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)      ;TCCR0A=0x02
        OUT     TCCR0A,R20  ;CTC mode, int. clk
        LDI     R20,1               ; TCCR0B = 1
        OUT     TCCR0B,R20          ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16             ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

```
        LDI     R16,(1<<3)          ;R16 = 0x08
        SBI     DDRB,3              ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)      ;TCCR0A=0x02
        OUT     TCCR0A,R20  ;CTC mode, int. clk
        LDI     R20,1               ; TCCR0B = 1
        OUT     TCCR0B,R20          ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16             ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

```
        LDI     R16,(1<<3)          ;R16 = 0x08
        SBI     DDRB,3              ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)      ;TCCR0A=0x02
        OUT     TCCR0A,R20  ;CTC mode, int. clk
        LDI     R20,1               ; TCCR0B = 1
        OUT     TCCR0B,R20          ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20          ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16             ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

Assembly

```
        LDI     R16,(1<<3)              ;R16 = 0x08
        SBI     DDRB,3                  ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)          ;TCCR0A=0x02
        OUT     TCCR0A,R20   ;CTC mode, int. clk
        LDI     R20,1                   ; TCCR0B = 1
        OUT     TCCR0B,R20              ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20              ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16                 ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

```
DDRB |= 1<<3;
while (1)
{
  OCR0A = 49;
  TCCR0A = (1<<WGM01); //CTC
  TCCR0B = 1;  //N = 1
 while((TIFR0&(1<<OCF0A))==0)
  { }
  TCCR0B = 0; //stop timer0
  TIFR0 = 1<<OCF0A;
  PORTB ^= 1<<3; //toggle PB3
}
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

Assembly

```
        LDI     R16,(1<<3)              ;R16 = 0x08
        SBI     DDRB,3                  ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)          ;TCCR0A=0x02
        OUT     TCCR0A,R20   ;CTC mode, int. clk
        LDI     R20,1                   ; TCCR0B = 1
        OUT     TCCR0B,R20              ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20              ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16                 ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

```
DDRB |= 1<<3;
while (1)
{
  OCR0A = 49;
  TCCR0A = (1<<WGM01); //CTC
  TCCR0B = 1;  //N = 1
 while((TIFR0&(1<<OCF0A))==0)
  { }
  TCCR0B = 0; //stop timer0
  TIFR0 = 1<<OCF0A;
  PORTB ^= 1<<3; //toggle PB3
}
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

Assembly

```
        LDI     R16,(1<<3)              ;R16 = 0x08
        SBI     DDRB,3                  ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)          ;TCCR0A=0x02
        OUT     TCCR0A,R20   ;CTC mode, int. clk
        LDI     R20,1                   ; TCCR0B = 1
        OUT     TCCR0B,R20              ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20              ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16                 ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

C

```
DDRB |= 1<<3;
while (1)
{
  OCR0A = 49;
  TCCR0A = (1<<WGM01); //CTC
  TCCR0B = 1;  //N = 1
 while((TIFR0&(1<<OCF0A))==0)
  { }
  TCCR0B = 0; //stop timer0
  TIFR0 = 1<<OCF0A;
  PORTB ^= 1<<3; //toggle PB3
}
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

Assembly

```
        LDI     R16,(1<<3)              ;R16 = 0x08
        SBI     DDRB,3                  ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)          ;TCCR0A=0x02
        OUT     TCCR0A,R20   ;CTC mode, int. clk
        LDI     R20,1                   ; TCCR0B = 1
        OUT     TCCR0B,R20              ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20              ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16                 ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

C

```
DDRB |= 1<<3;
while (1)
{
  OCR0A = 49;
  TCCR0A = (1<<WGM01); //CTC
  TCCR0B = 1;  //N = 1
 while((TIFR0&(1<<OCF0A))==0)
  { }
  TCCR0B = 0; //stop timer0
  TIFR0 = 1<<OCF0A;
  PORTB ^= 1<<3; //toggle PB3
}
```

Example 4: Rewrite example 2 using CTC

(Assuming XTAL = 10MHz, write a program to generate a square wave with a period of 10 µs.)

-	-	-	-	-	OCF0B	OCF0A	TOV0

TIFR0

- For a square wave with T = 10 µs we must have a time delay of 5 µs. Because XTAL = 10 MHz, the counter counts up every 0.1 µs. This means that we need 5 µs / 0.1 µs = 50 clocks. Therefore, we have OCR0A= 49.

Assembly

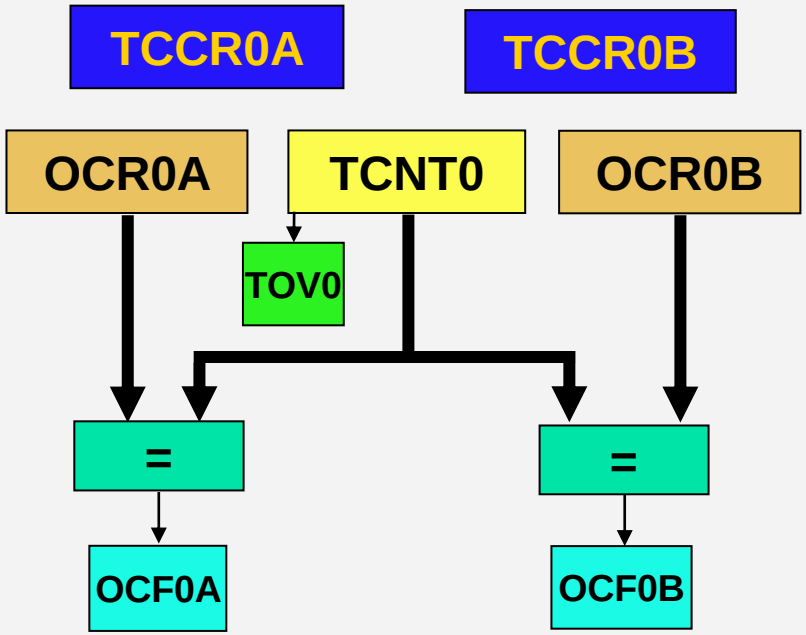
```
        LDI     R16,(1<<3)              ;R16 = 0x08
        SBI     DDRB,3                  ;PB3 as an output
        LDI     R17,0
        OUT     PORTB,R17
        LDI     R20,49
        OUT     OCR0A,R20 ;load OCR0A
BEGIN:  LDI     R20,(1<<WGM01)          ;TCCR0A=0x02
        OUT     TCCR0A,R20   ;CTC mode, int. clk
        LDI     R20,1                   ; TCCR0B = 1
        OUT     TCCR0B,R20              ; N = 1
AGAIN:  SBIS    TIFR0,OCF0A ;if OCF0 is set skip next
        RJMP    AGAIN
        LDI     R20,0x0
        OUT     TCCR0B,R20              ;stop Timer0
        LDI     R20,1<<OCF0A
        OUT     TIFR0,R20 ;clear OCF0A flag
        EOR     R17,R16                 ;toggle D3 of R17
        OUT     PORTB,R17 ;toggle PB3
        RJMP    BEGIN
```

C

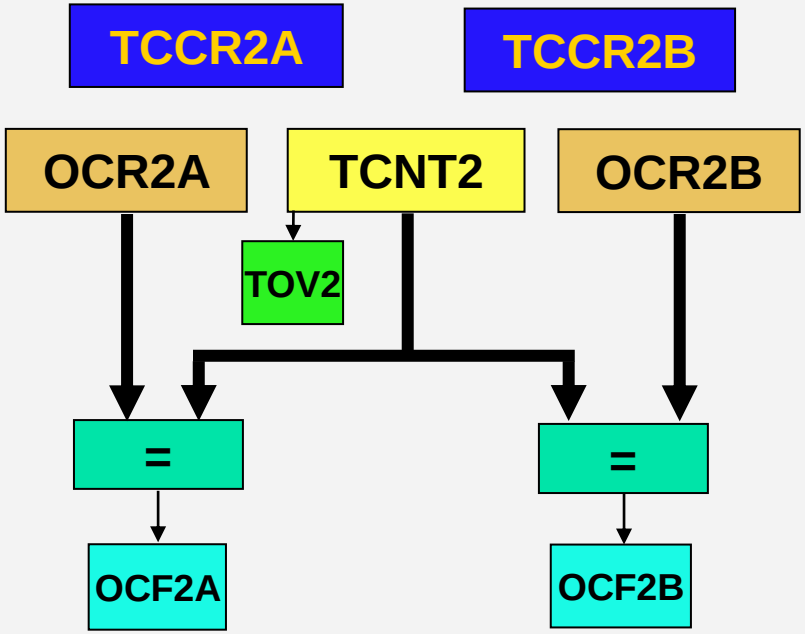
```
DDRB |= 1<<3;
while (1)
{
  OCR0A = 49;
  TCCR0A = (1<<WGM01); //CTC
  TCCR0B = 1;  //N = 1
 while((TIFR0&(1<<OCF0A))==0)
  { }
  TCCR0B = 0; //stop timer0
  TIFR0 = 1<<OCF0A;
  PORTB ^= 1<<3; //toggle PB3
}
```

Timer2 vs. Timer0

- Timer0



- Timer2



The difference between Timer0 and Timer2

- Timer0

CS02	CS01	CS00	Comment
0	0	0	Timer/Counter stopped
0	0	1	clk (No Prescaling)
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 (falling edge)
1	1	1	External clock (rising edge)

- Timer2

CS22	CS21	CS20	Comment
0	0	0	Timer/Counter stopped
0	0	1	clk (No Prescaling)
0	1	0	clk / 8
0	1	1	clk / 32
1	0	0	clk / 64
1	0	1	clk / 128
1	1	0	clk / 256
1	1	1	clk / 1024

Timer 1

Timer 1

TCNT1H TCNT1L

-	-	ICF1	-	-	OCF1B	OCF1A	TOV1

TIFR1

Timer 1

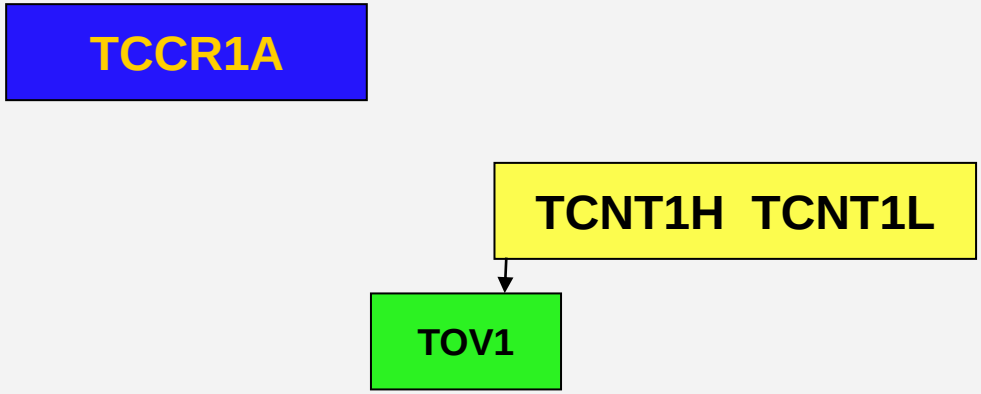
TCCR1A

TCNT1H TCNT1L

TOV1

TIFR1

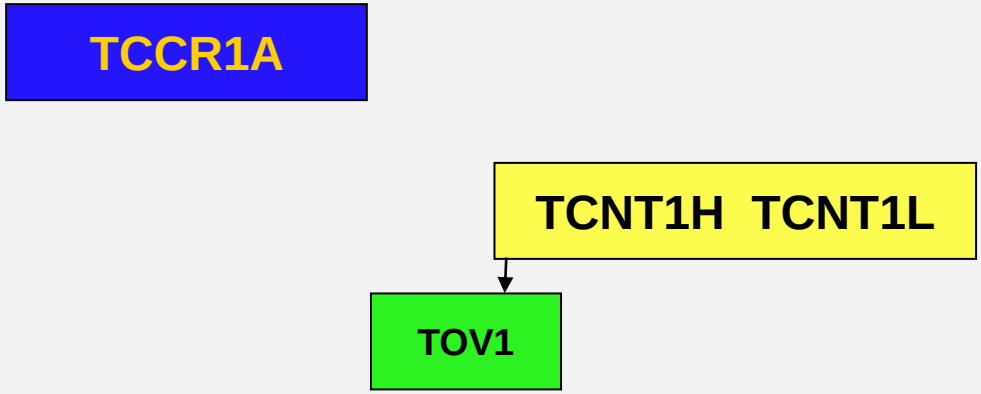
Timer 1



-	-	ICF1	-	-	OCF1B	OCF1A	TOV1

TIFR1

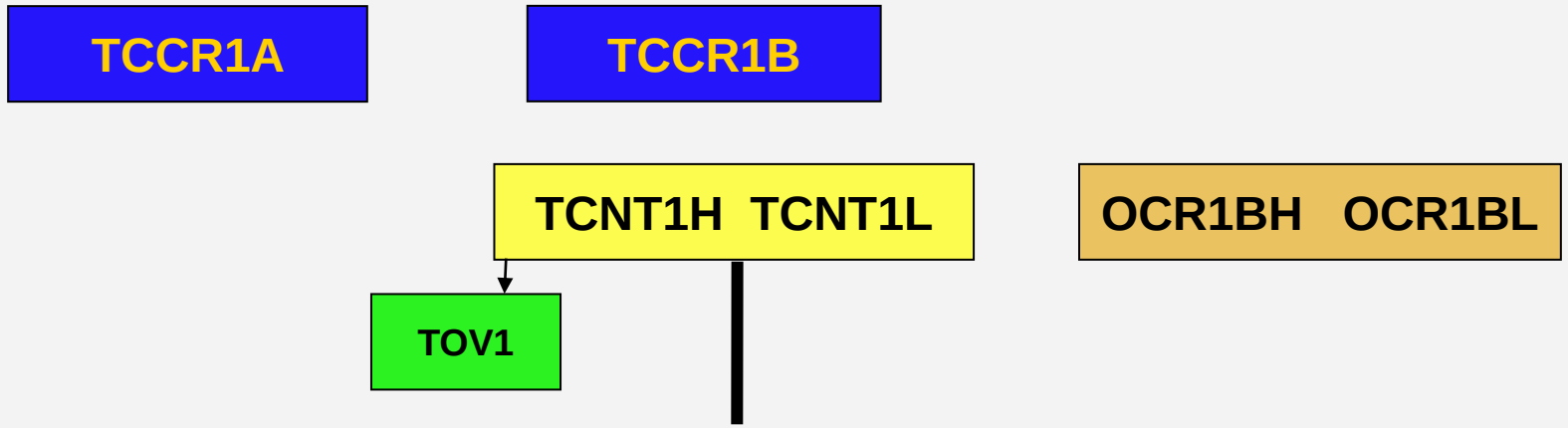
Timer 1



-	-	ICF1	-	-	OCF1B	OCF1A	TOV1

TIFR1

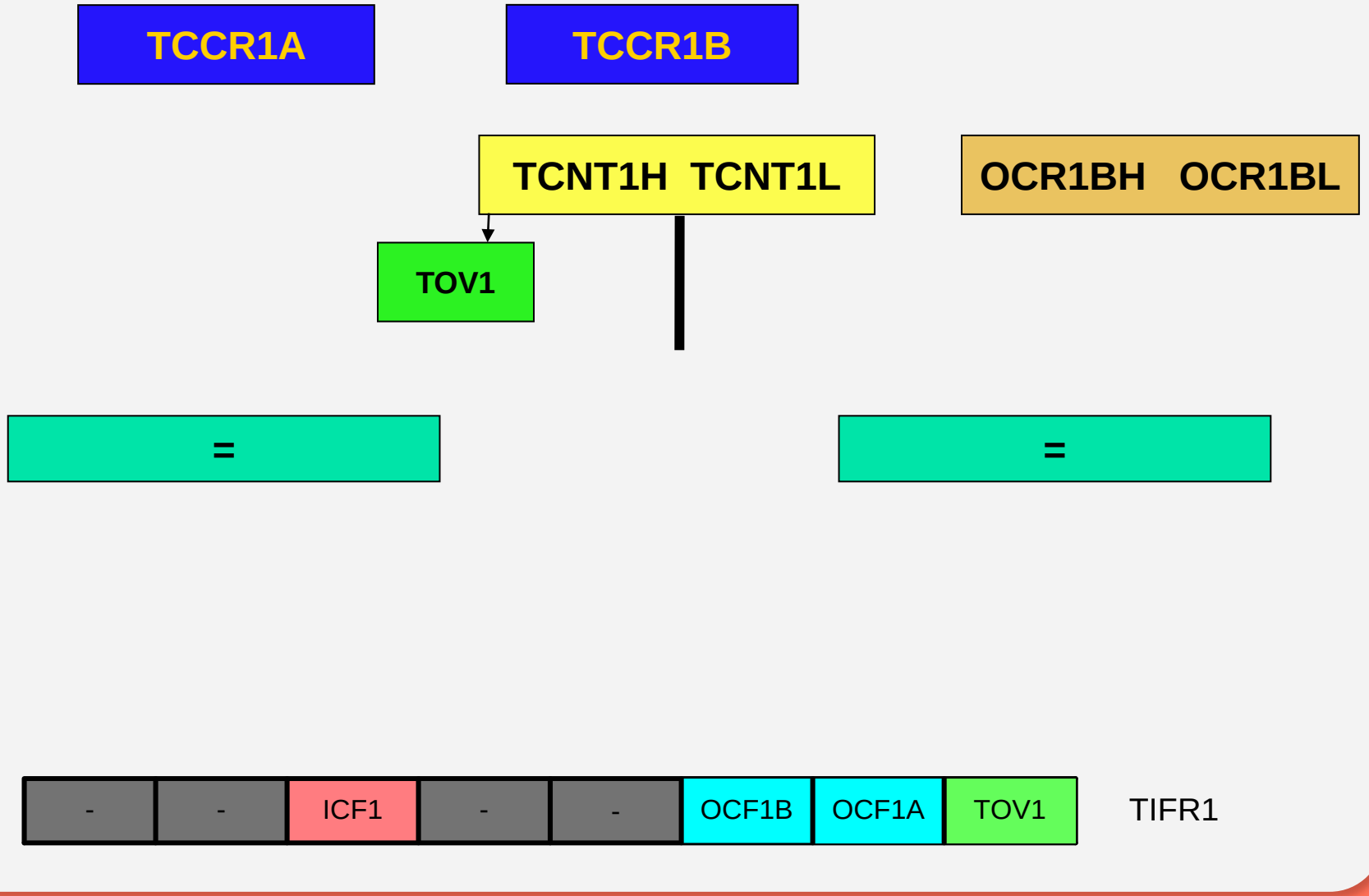
Timer 1



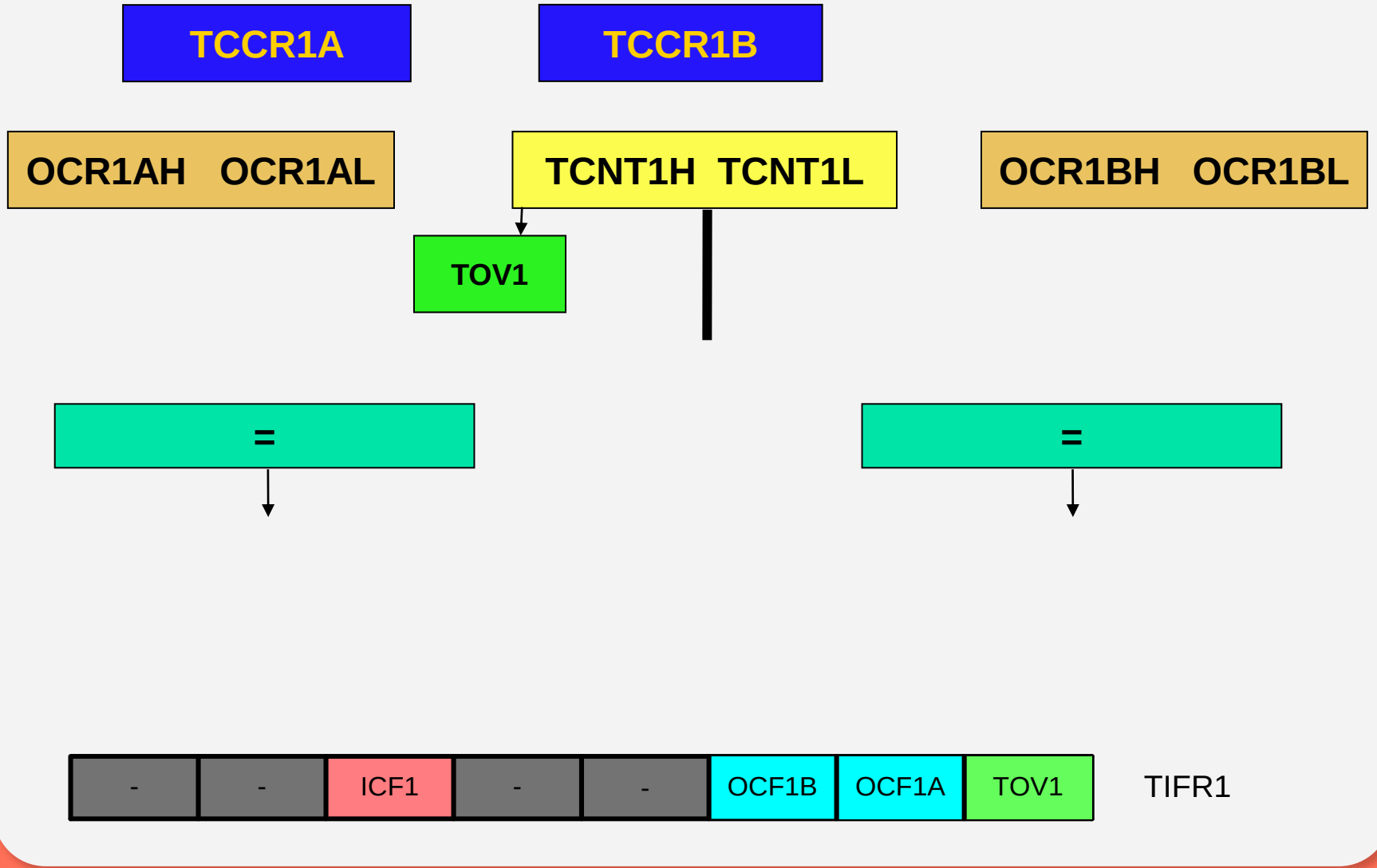
-	-	ICF1	-	-	OCF1B	OCF1A	TOV1

TIFR1

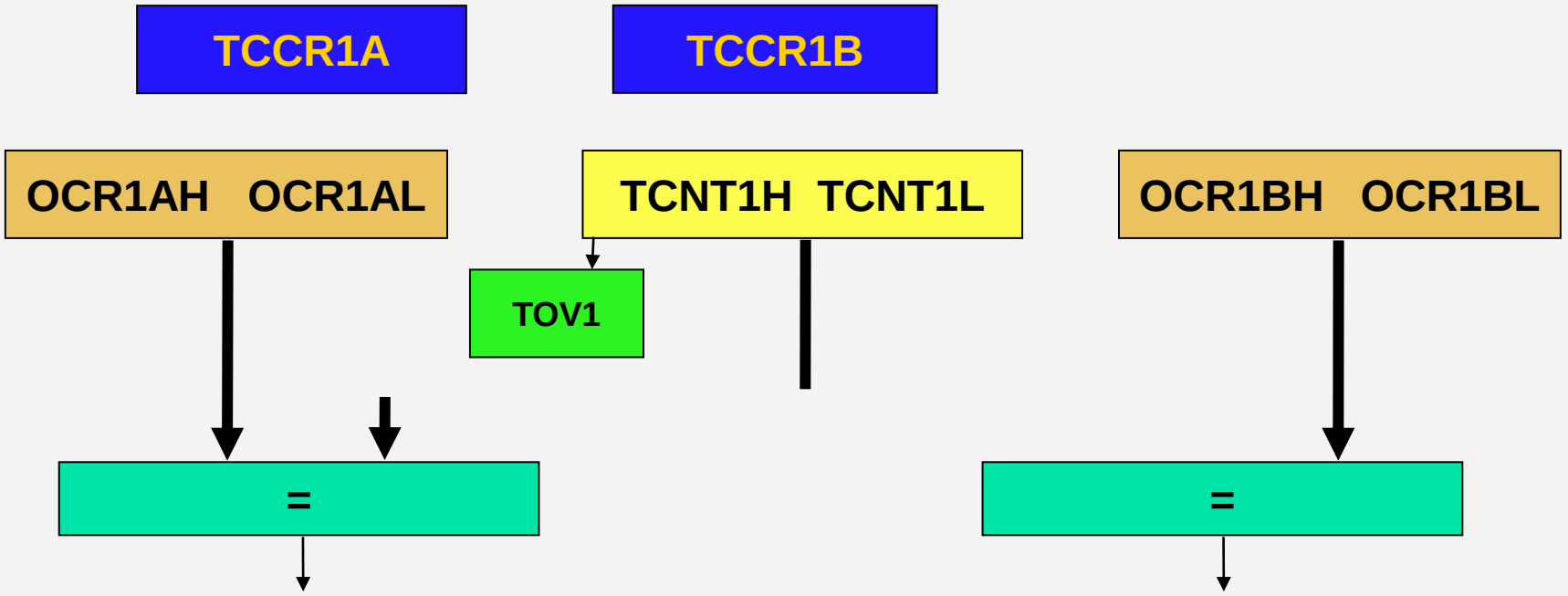
Timer 1


TCCR1A
TCCR1B
TCNT1H TCNT1L
OCR1BH OCR1BL
TOV1
=
=
- - ICF1 - - OCF1B OCF1A TOV1
TIFR1

Timer 1

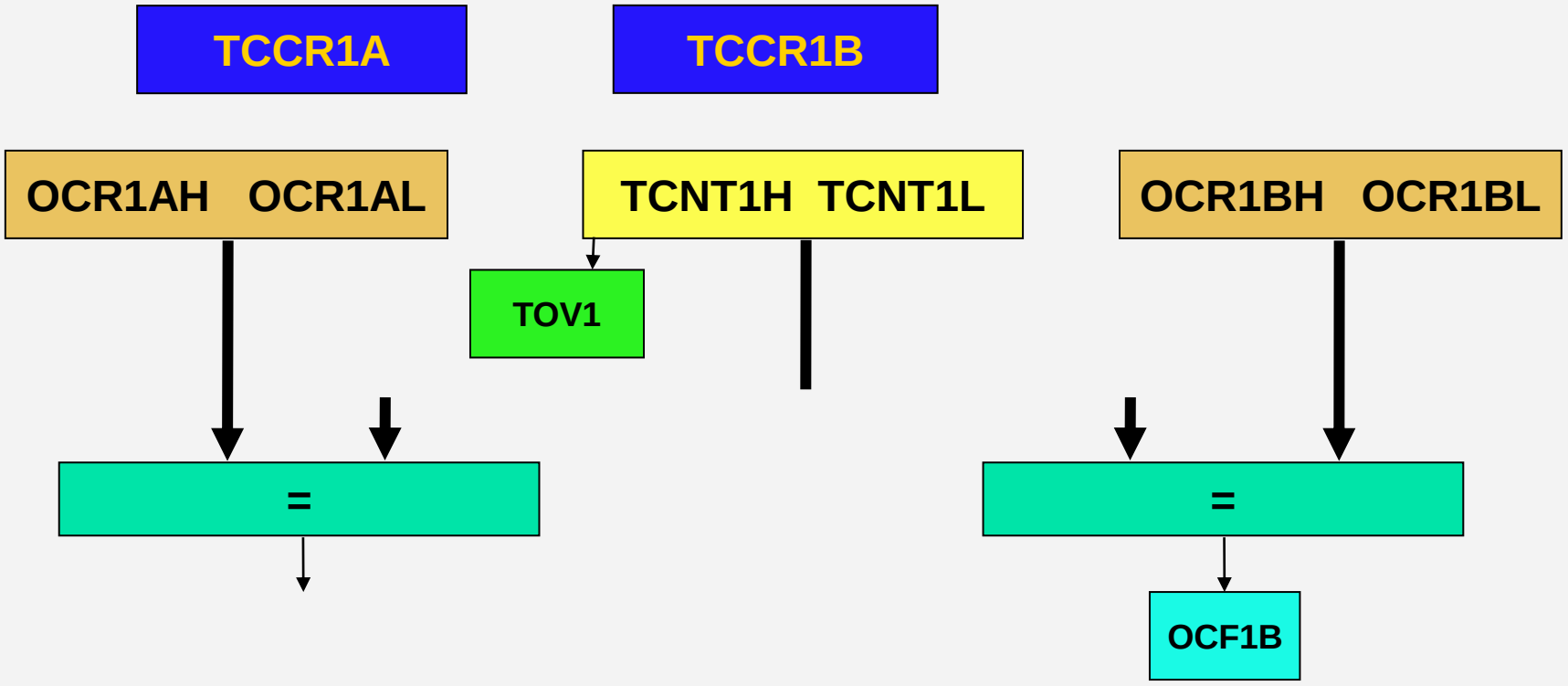

TCCR1A
TCCR1B
OCR1AH OCR1AL
TCNT1H TCNT1L
OCR1BH OCR1BL
TOV1
=
=
- - ICF1 - - OCF1B OCF1A TOV1
TIFR1

Timer 1



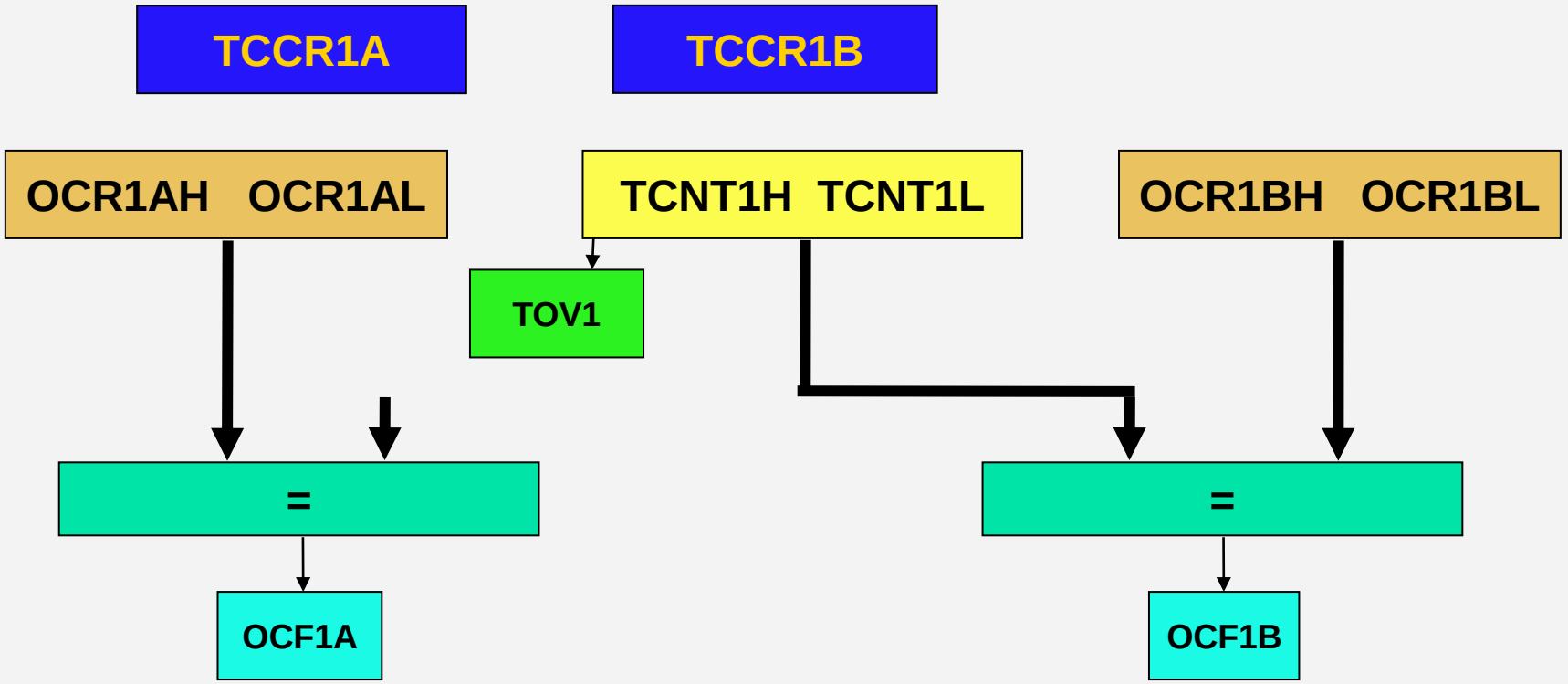
TIFR1

Timer 1



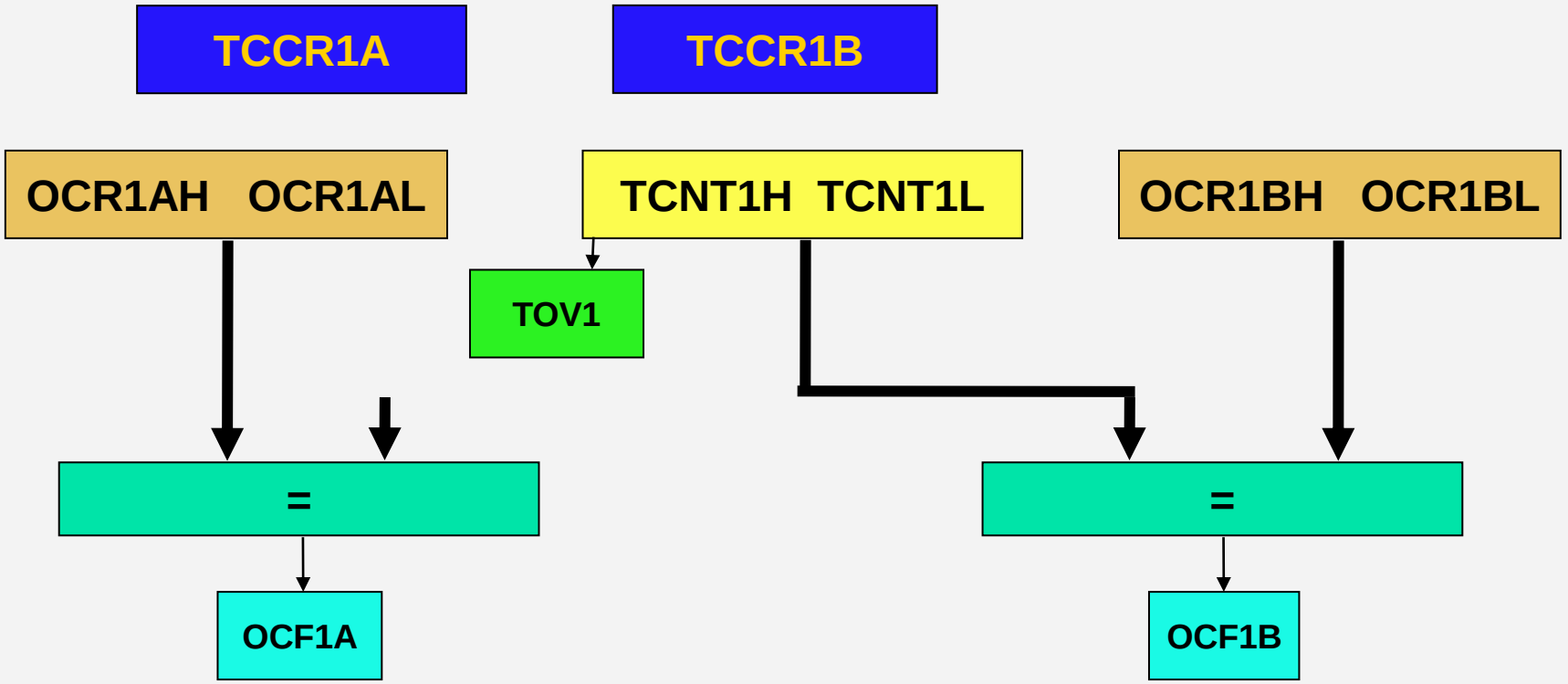
TIFR1

Timer 1



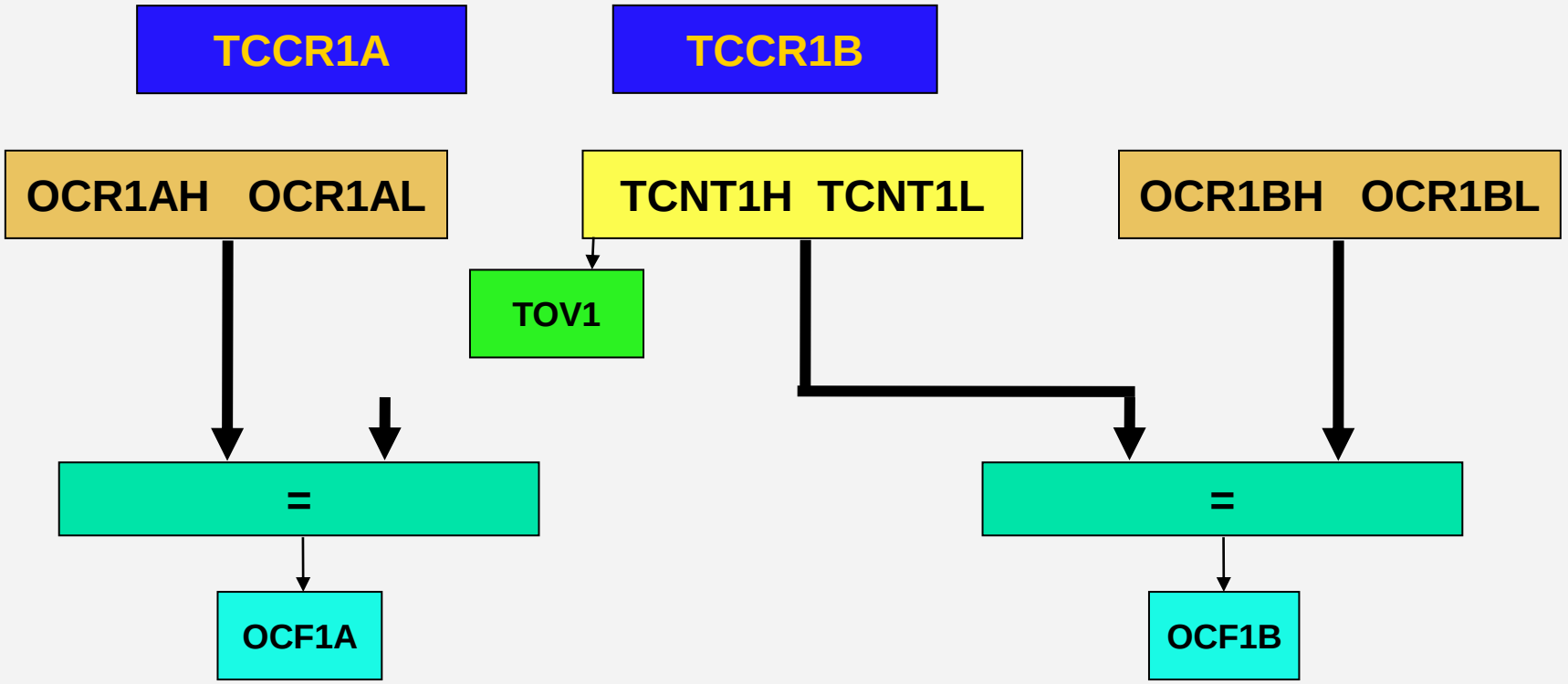
TIFR1

Timer 1



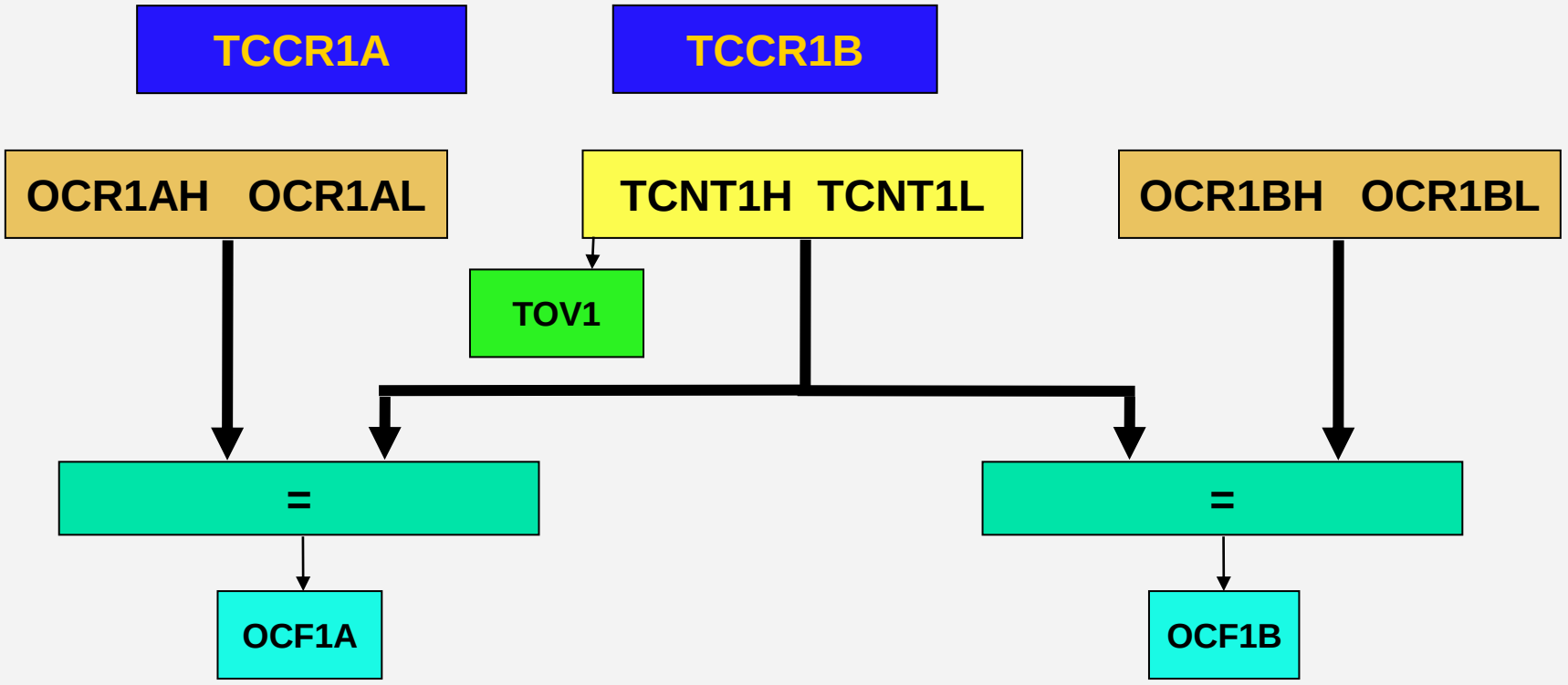
TIFR1

Timer 1



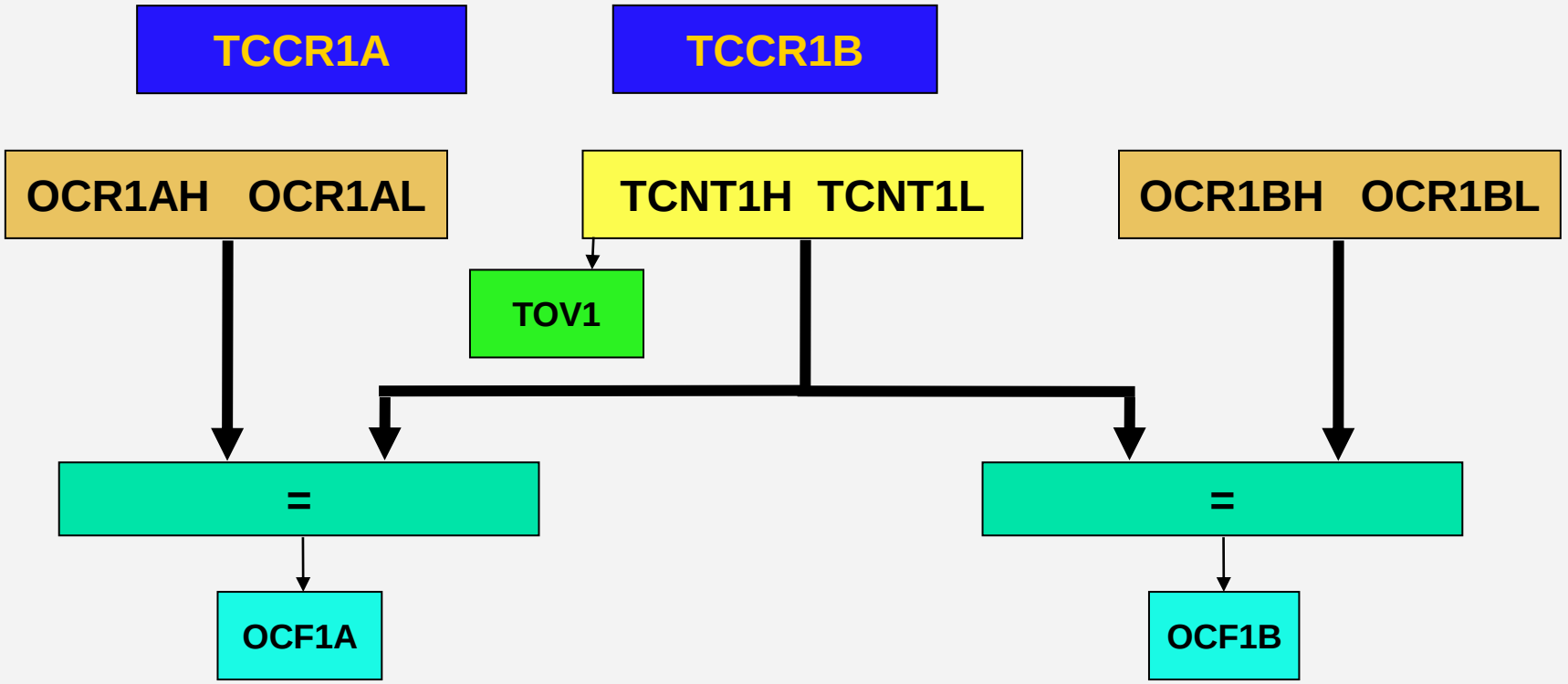
TIFR1

Timer 1



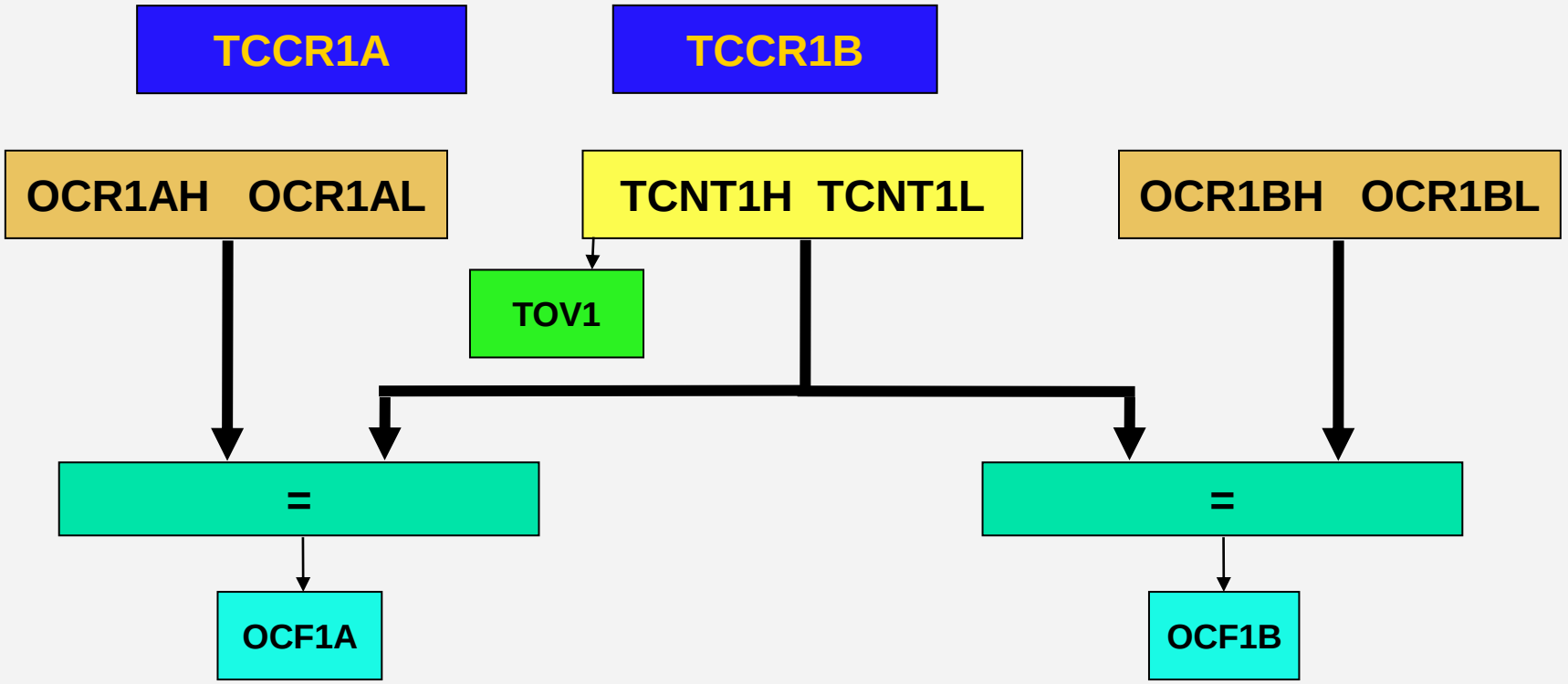
TIFR1

Timer 1



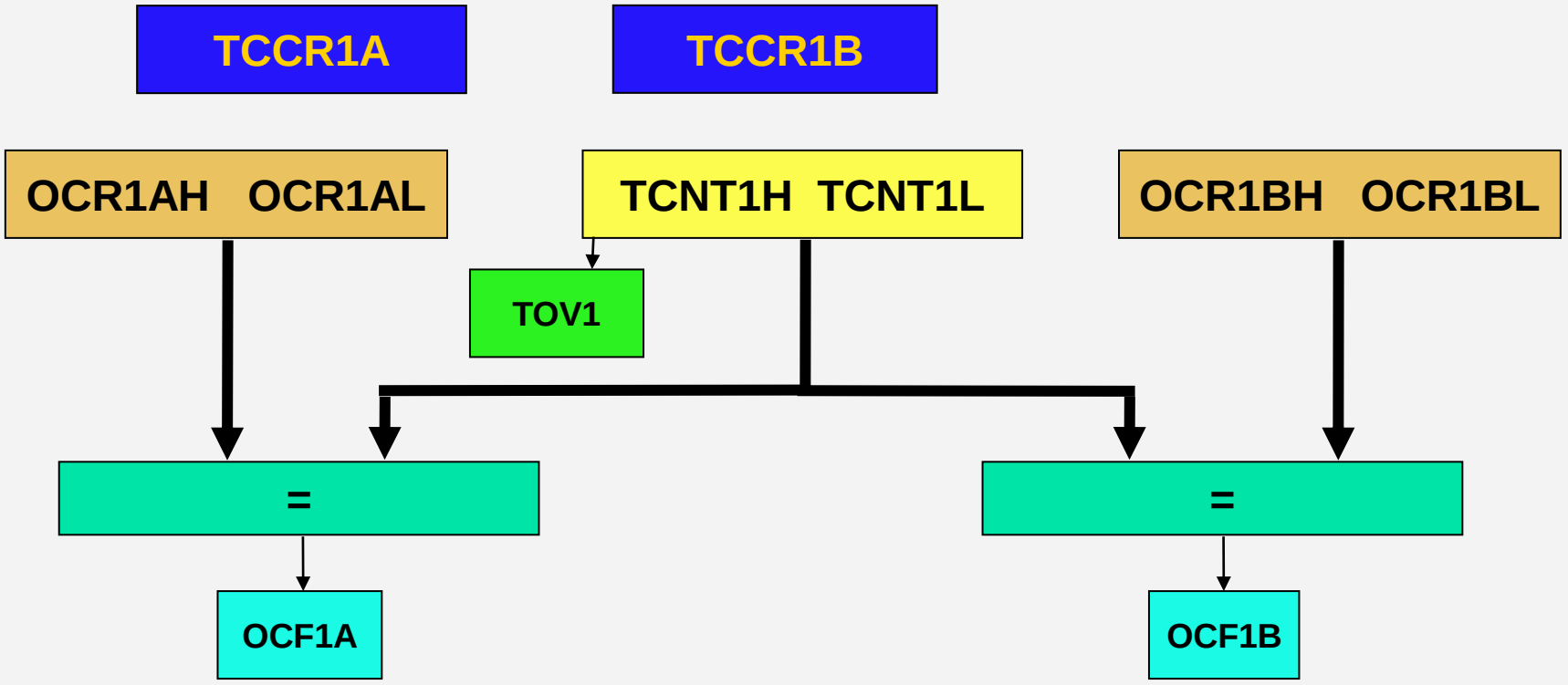
TIFR1

Timer 1



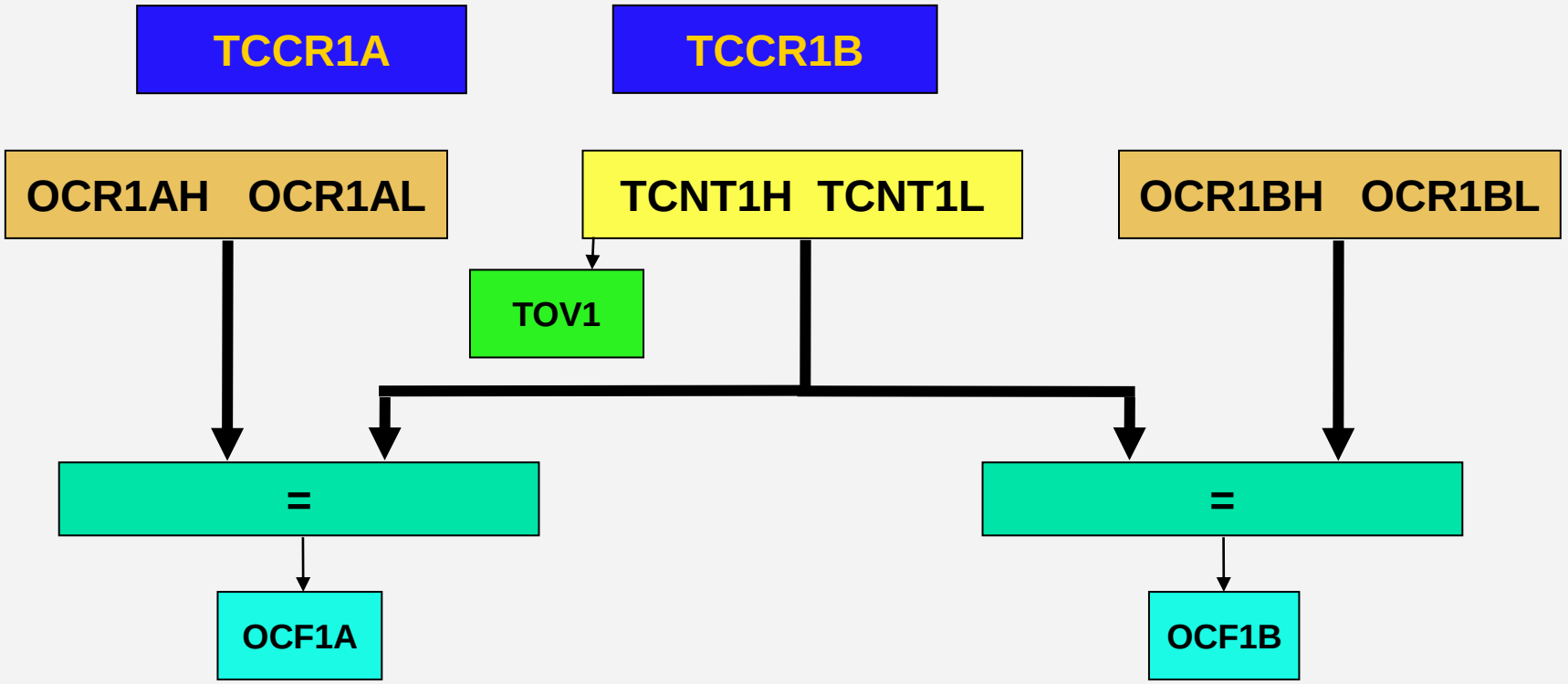
TIFR1

Timer 1



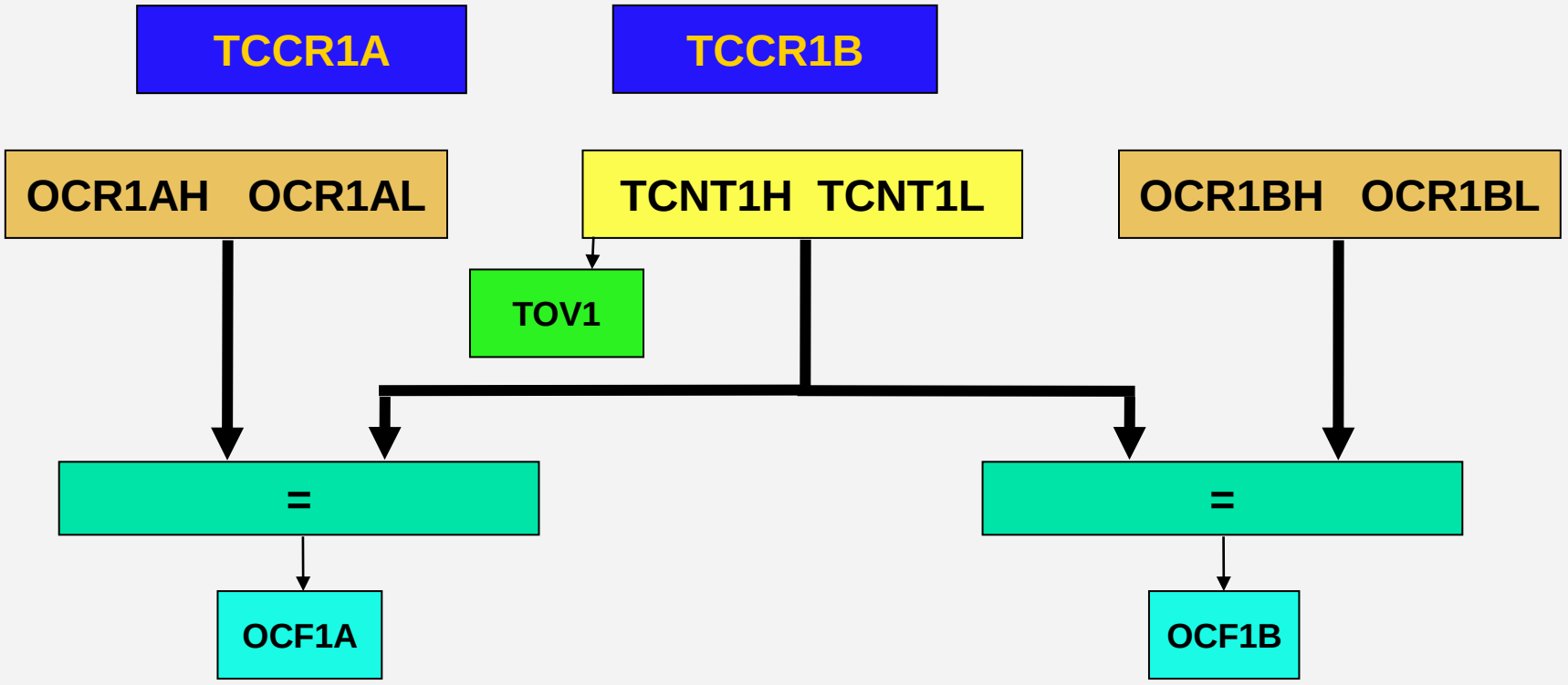
TIFR1

Timer 1



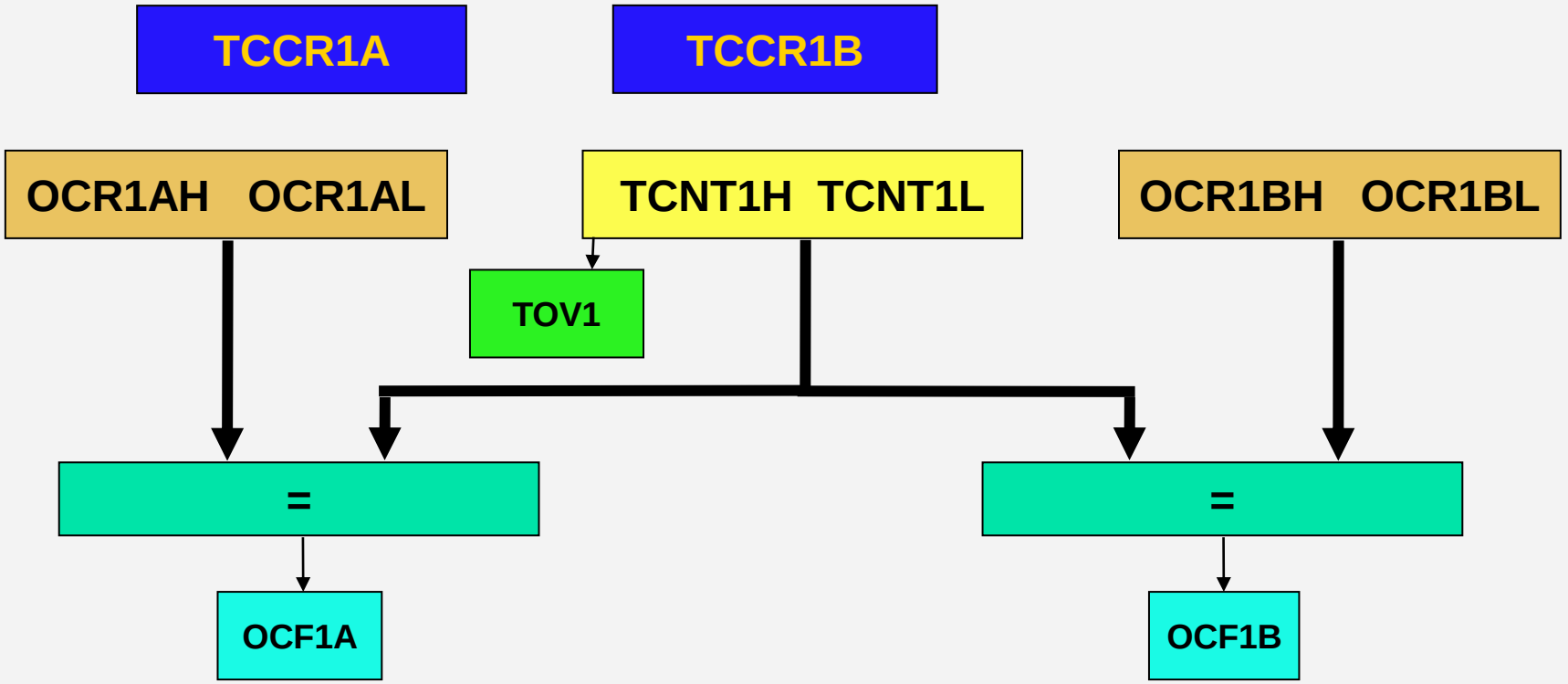
TIFR1

Timer 1



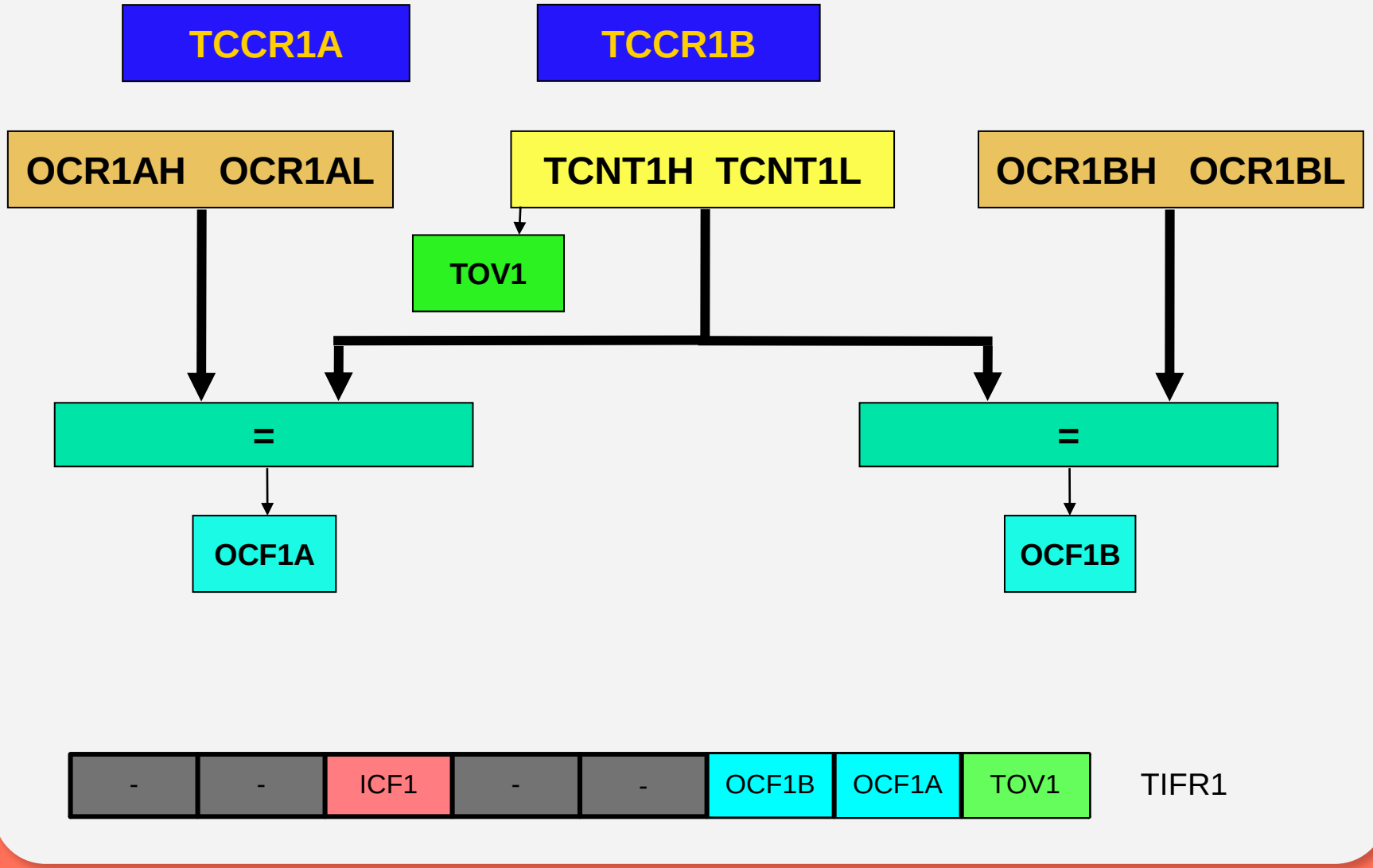
TIFR1

Timer 1

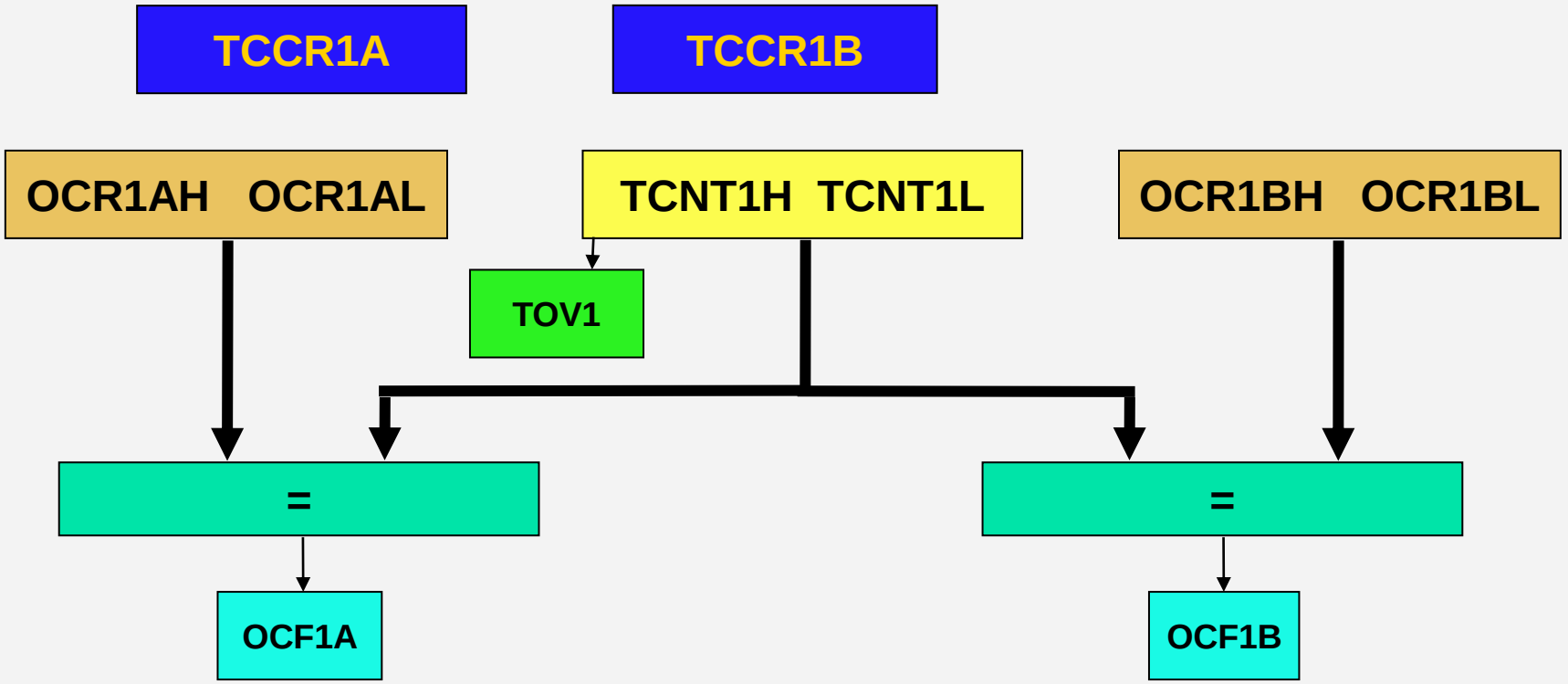


TIFR1

Timer 1

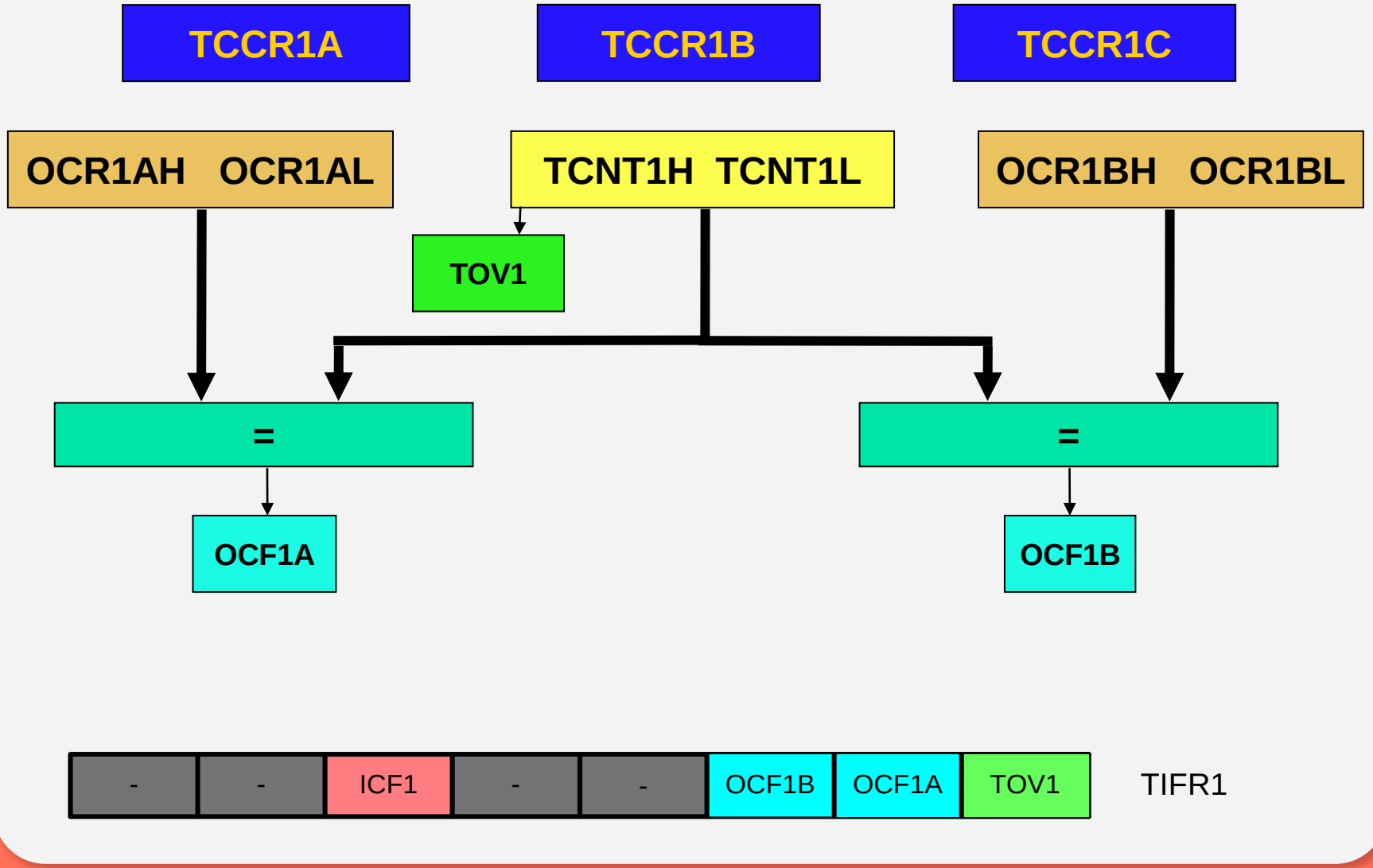

TCCR1A
TCCR1B
OCR1AH OCR1AL
TCNT1H TCNT1L
OCR1BH OCR1BL
TOV1
=
=
OCF1A
OCF1B
- - ICF1 - - OCF1B OCF1A TOV1
TIFR1

Timer 1

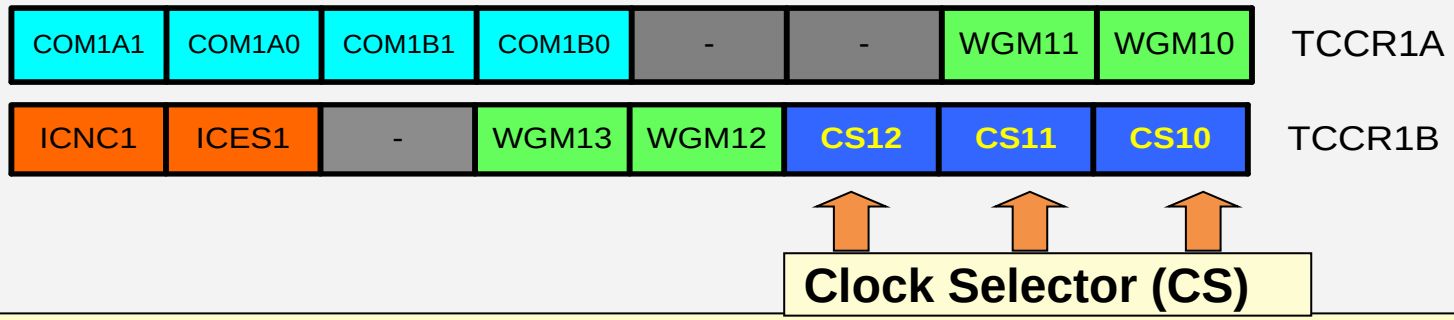


TIFR1

Timer 1

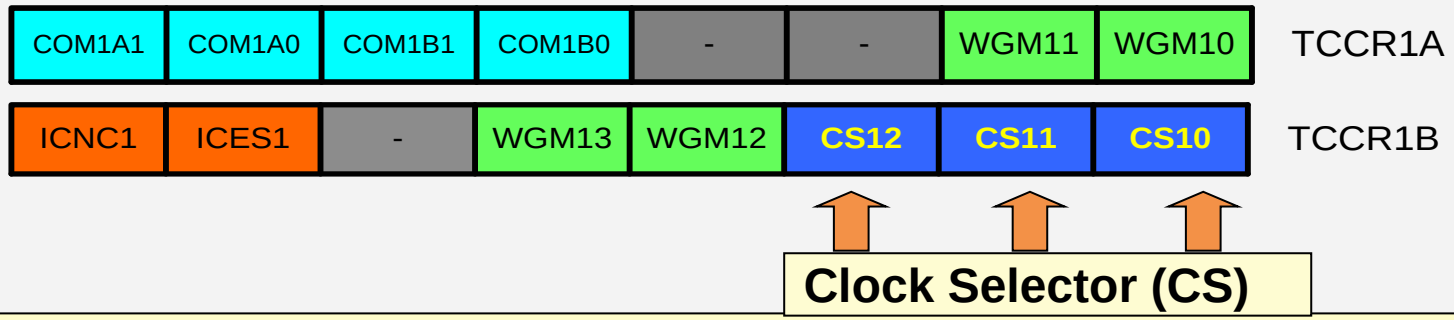

TCCR1A
TCCR1B
TCCR1C
OCR1AH OCR1AL
TCNT1H TCNT1L
OCR1BH OCR1BL
TOV1
=
=
OCF1A
OCF1B
- - ICF1 - - OCF1B OCF1A TOV1
TIFR1

Timer 1



CS12	CS11	CS10	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
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 1



CS12	CS11	CS10	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
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 1

COM1A1	COM1A0	COM1B1	COM1B0	-	-	WGM11	WGM10

TCCR1A

ICNC1	ICES

CR1B

CS12	CS11	CS1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

g edge

edge

Timer 1

CS12	CS11	CS
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

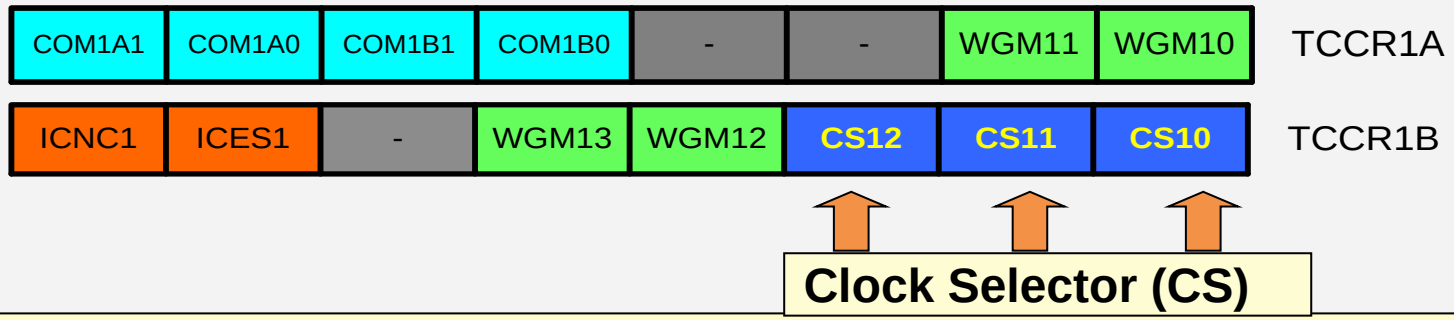
edge
edge

Timer 1

CS12	CS11	CS1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

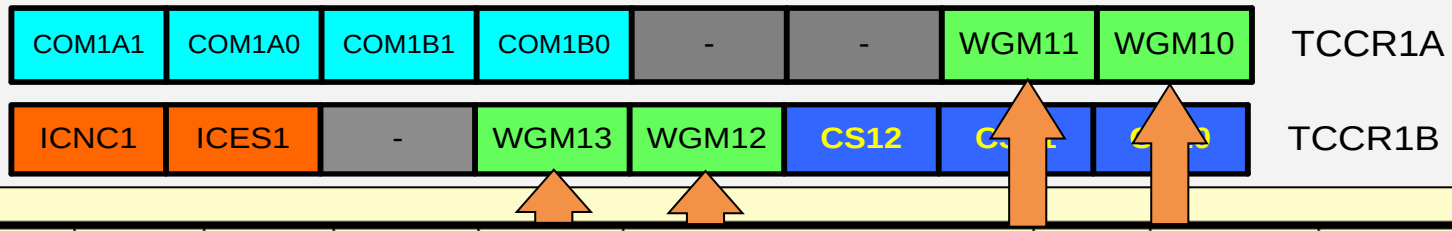
g edge
edge

Timer 1



CS12	CS11	CS10	Comment
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk (No Prescaling)
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 1

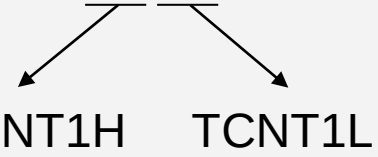


Mode	WGM13	WGM12 (CTC1)	WGM11 (PWM11)	WGM10 (PWM10)	Timer/Counter Mode of Operation	TOP	Update of OCR1x	TOV1 Flag Set on
0	0	0	0	0	Normal	0xFFFF	Immediate	MAX
1	0	0	0	1	PWM, Phase Correct, 8-bit	0x00FF	TOP	BOTTOM
2	0	0	1	0	PWM, Phase Correct, 9-bit	0x01FF	TOP	BOTTOM
3	0	0	1	1	PWM, Phase Correct, 10-bit	0x03FF	TOP	BOTTOM
4	0	1	0	0	CTC	OCR1A	Immediate	MAX
5	0	1	0	1	Fast PWM, 8-bit	0x00FF	TOP	TOP
6	0	1	1	0	Fast PWM, 9-bit	0x01FF	TOP	TOP
7	0	1	1	1	Fast PWM, 10-bit	0x03FF	TOP	TOP
8	1	0	0	0	PWM, Phase and Frequency Correct	ICR1	BOTTOM	BOTTOM
9	1	0	0	1	PWM, Phase and Frequency Correct	OCR1A	BOTTOM	BOTTOM
10	1	0	1	0	PWM, Phase Correct	ICR1	TOP	BOTTOM
11	1	0	1	1	PWM, Phase Correct	OCR1A	TOP	BOTTOM
12	1	1	0	0	CTC	ICR1	Immediate	MAX
13	1	1	0	1	Reserved	–	–	–
14	1	1	1	0	Fast PWM	ICR1	TOP	TOP
15	1	1	1	1	Fast PWM	OCR1A	TOP	TOP

Example

Assuming XTAL = 10 MHz write a program that toggles PB5 once per millisecond, using Normal mode.

XTAL = 10 MHz ➔ 1/10 MHz = 0.1 µs
Num. of machine cycles = 1 ms / 0.1 µs = 10,000
TCNT1 = 65,536 – 10,000 = 55,536 = $D8F0



Example

Assum
millise

XTAL
Num.
TCNT

Solution

```
        LDI    R16,HIGH(RAMEND)     ;init stack pointer
        OUT    SPH,R16
        LDI    R16,LOW(RAMEND)
        OUT    SPL,R16
        SBI    DDRB,5               ;PB5 as an output
BEGIN:SBI  PORTB,5                  ;PB5 = 1
        RCALL  DELAY_1ms
        CBI    PORTB,5              ;PB5 = 0
        RCALL  DELAY_1ms
        RJMP   BEGIN

DELAY_1ms:
        LDI    R20,0xD8
        STS    TCNT1H,R20           ;TEMP = 0xD8
        LDI    R20,0xF0
        STS    TCNT1L,R20           ;TCNT1L = 0xF0, TCNT1H = TEMP
        LDI    R20,0x0
        STS    TCCR1A,R20           ;WGM11:10=00
        LDI    R20,0x1
        STS    TCCR1B,R20           ;WGM13:12=00,CS=CLK
AGAIN:SBIS TIFR1,TOV1               ;if TOV1 is set skip next instruction
        RJMP   AGAIN
        LDI    R20,1<<TOV1
        OUT    TIFR1,R20            ;clear TOV1 flag
        LDI    R19,0
        STS    TCCR1B,R19           ;stop timer
        STS    TCCR1A,R19           ;
        RET
```

Example

Assum
millise

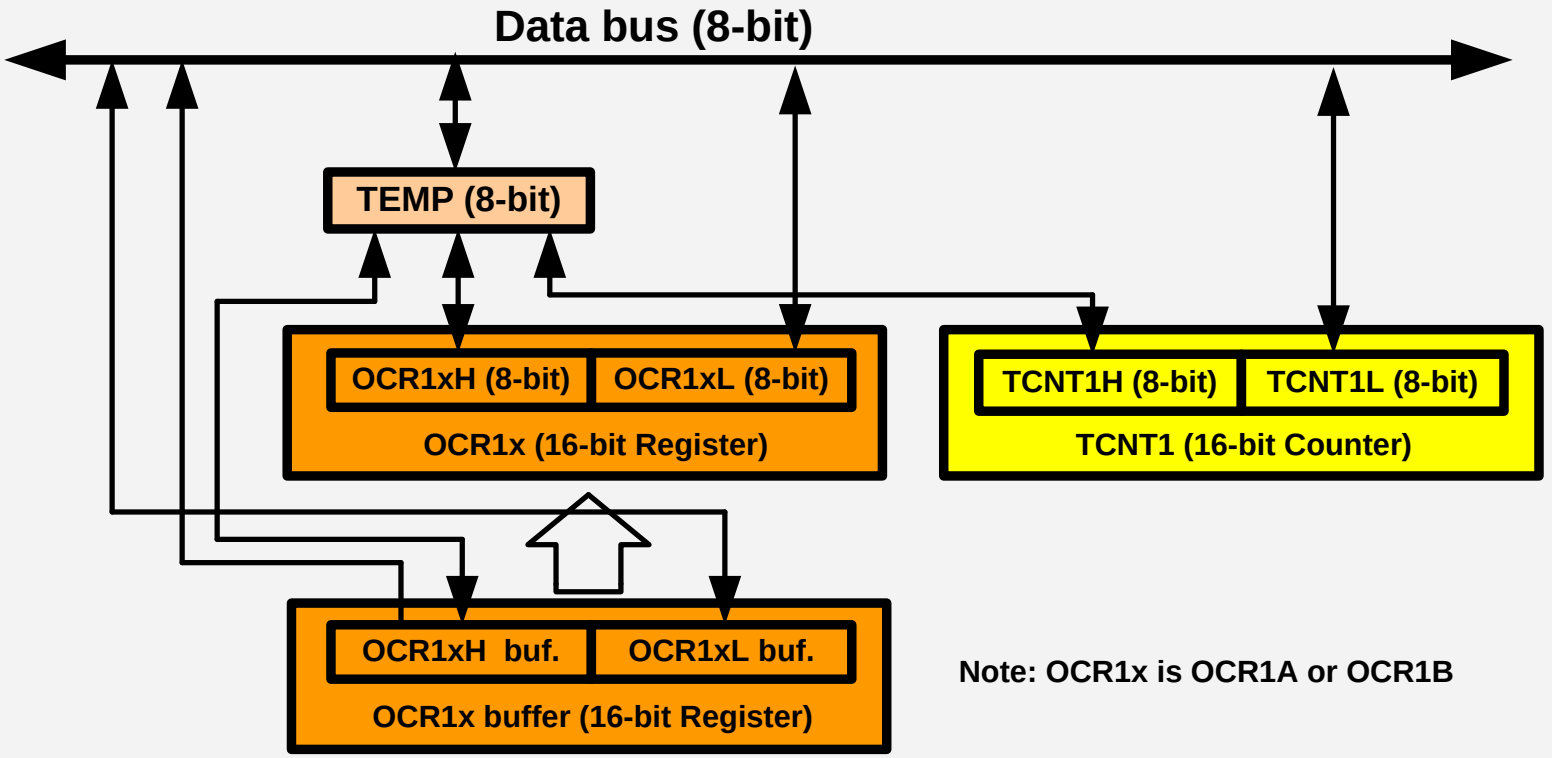
XTAL
Num.
TCNT

Solution

```
        LDI    R16,HIGH(RAMEND)     ;init stack pointer
        OUT    SPH,R16
        LDI    R16,LOW(RAMEND)
        OUT    SPL,R16
        SBI    DDRB,5               ;PB5 as an output
BEGIN:SBI  PORTB,5                  ;PB5 = 1
        RCALL  DELAY_1ms
        CBI    PORTB,5              ;PB5 = 0
        RCALL  DELAY_1ms
        RJMP   BEGIN

    DELAY_1ms:
        LDI    R20,HIGH(-10000)
        STS    TCNT1H,R20
        LDI    R20, ,LOW(-10000)
        STS    TCNT1L,R20           ;Timer1 overflows after 10000 machine cycles
        LDI    R20,0x0
        STS    TCCR1A,R20           ;WGM11:10=00
        LDI    R20,0x1
        STS    TCCR1B,R20           ;WGM13:12=00,CS=CLK
    AGAIN:SBIS TIFR1,TOV1           ;if TOV1 is set skip next instruction
        RJMP   AGAIN
        LDI    R20,1<<TOV1
        OUT    TIFR1,R20            ;clear TOV1 flag
        LDI    R19,0
        STS    TCCR1B,R19           ;stop timer
        STS    TCCR1A,R19           ;
        RET
```

TEMP register

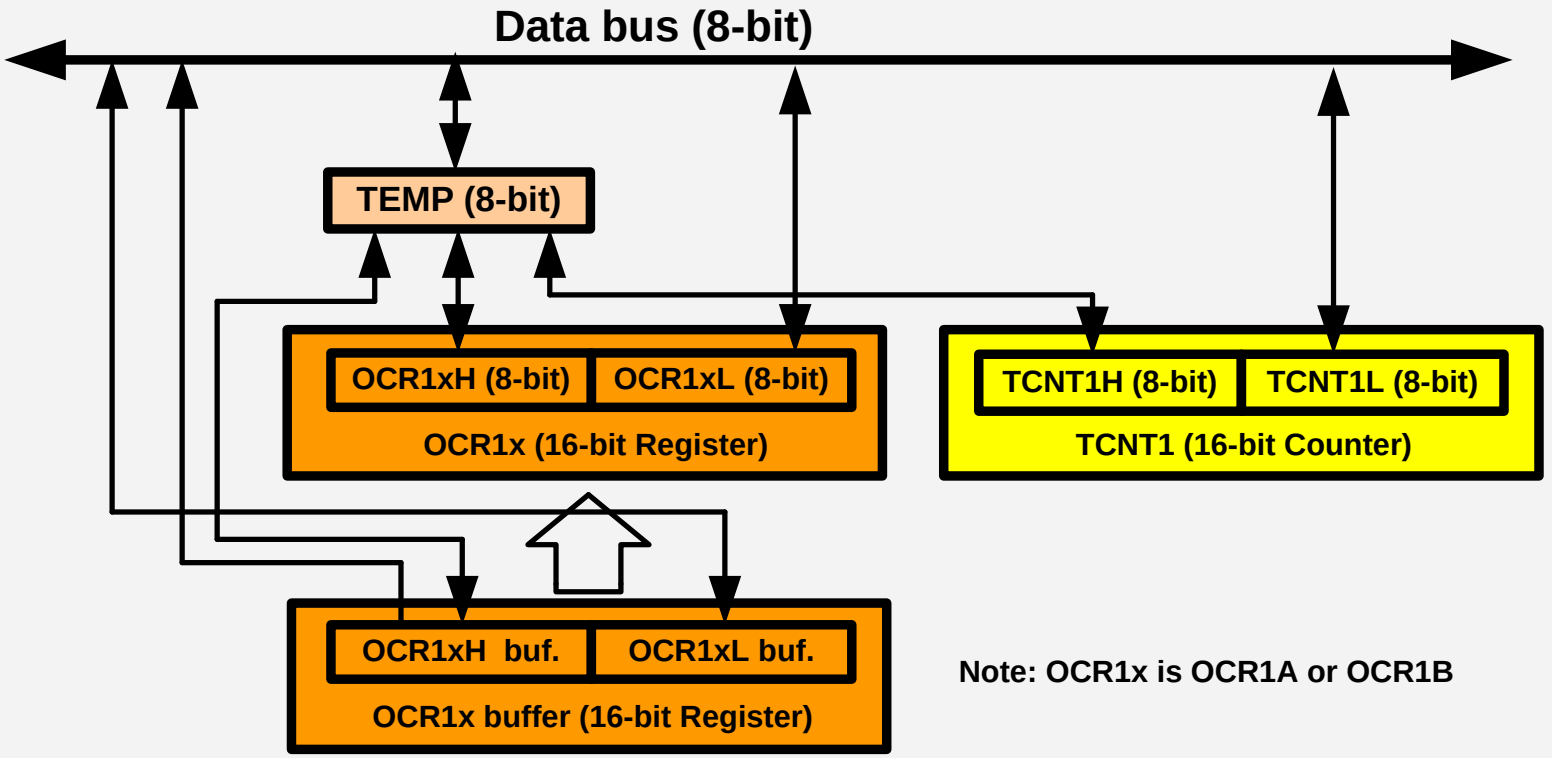


Note: OCR1x is OCR1A or OCR1B

```
LDI   R20,0xF3
STS   TCNT1H,R20
LDI   R20,0x53
STS   TCNT1L,R20
```

```
TCNT1H = 0xF3;
TCNT1L = 0x53;
```

TEMP register

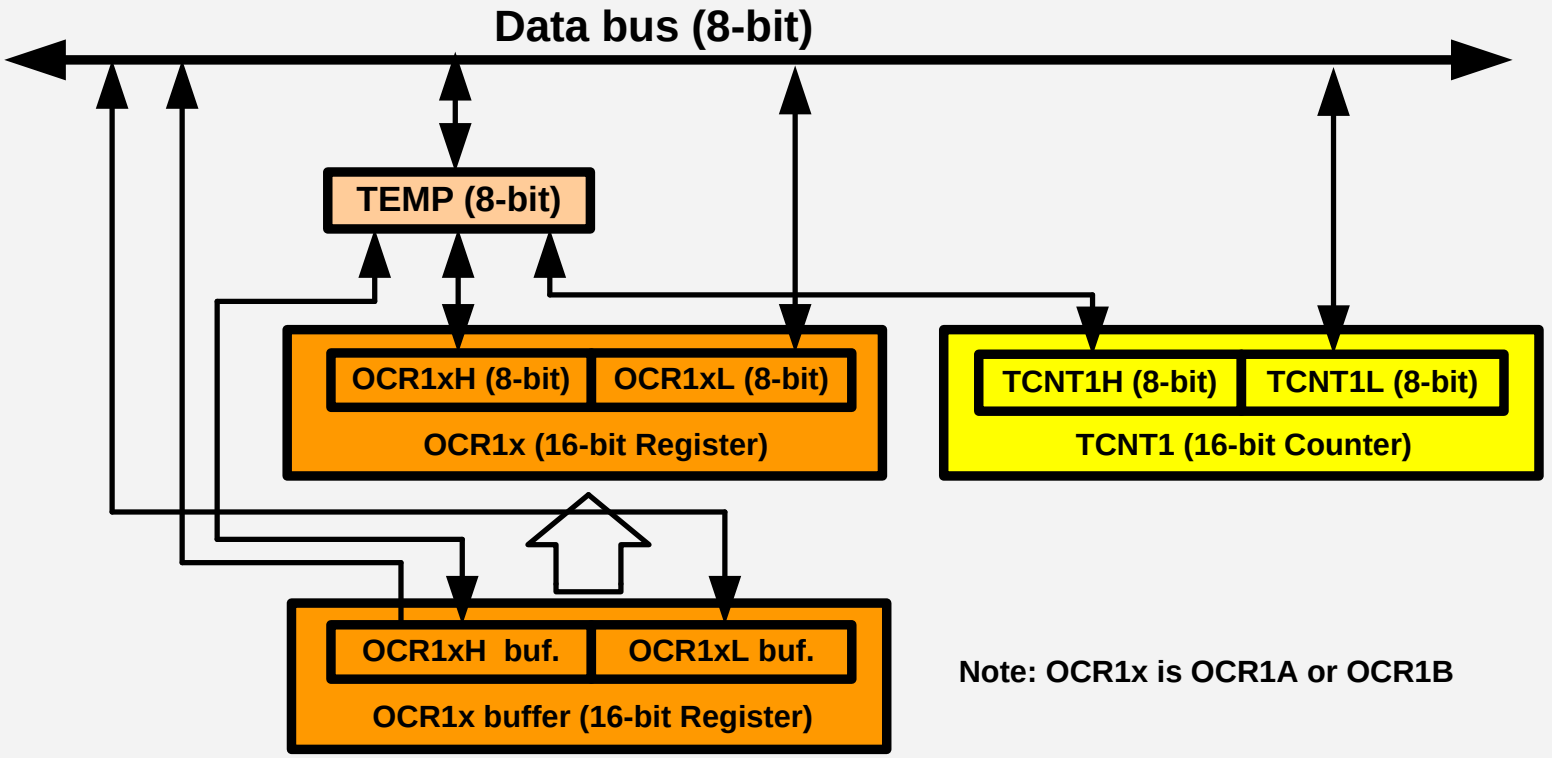


Note: OCR1x is OCR1A or OCR1B

```
LDS   R20,TCNT1L
STS   TCNT1H,R20
LDI   R20,0x53
STS   TCNT1L,R20
```

```
TCNT1H = 0xF3;
TCNT1L = 0x53;
```

TEMP register



Note: OCR1x is OCR1A or OCR1B

```
LDS   R20,TCNT1L
STS   TCNT1H,R20
LDI   R20,0x53
STS   TCNT1L,R20
```

```
TCNT1H=0xF3;
TCNT1L=0x53;
```

Example

Assuming XTAL = 10 MHz, write a program that toggles PB5 once per millisecond, using CTC mode.

Example

...oggles PB5 once per

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

Example

...oggles PB5 once per

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

Example

oggles PB5 once per

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

Example

...oggles PB5 once per

Assembly

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

```
#include <avr/io.h>
void  delay1ms();
int main(){
 DDRB |= 1<<5;
 while (1) {
 delay1ms();
 PORTB ^= (1<<5); //toggle PB5
 }
}
void  delay1ms()
{
 TCNT1 = 0;
 OCR1A = 10000-1;
 TCCR1A = 0;     //WGM=0100 (CTC)
 TCCR1B = 0x09;  //N = 1
 while((TIFR1&(1<<OCF1A))==0)
 { } //wait until OCF1A is set
 TCCR1B = 0; //stop timer1
 TIFR1 = 1<<OCF1A;//clear flag
}
```

Example

...oggles PB5 once per

Assembly

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

```
#include <avr/io.h>
void  delay1ms();
int main(){
 DDRB |= 1<<5;
 while (1) {
 delay1ms();
 PORTB ^= (1<<5); //toggle PB5
 }
}
void  delay1ms()
{
 TCNT1 = 0;
 OCR1A = 10000-1;
 TCCR1A = 0;     //WGM=0100 (CTC)
 TCCR1B = 0x09;  //N = 1
 while((TIFR1&(1<<OCF1A))==0)
 { } //wait until OCF1A is set
 TCCR1B = 0; //stop timer1
 TIFR1 = 1<<OCF1A;//clear flag
}
```

Example

...oggles PB5 once per

Assembly

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

C

```
#include <avr/io.h>
void  delay1ms();
int main(){
 DDRB |= 1<<5;
 while (1) {
 delay1ms();
 PORTB ^= (1<<5); //toggle PB5
 }
}
void  delay1ms()
{
 TCNT1 = 0;
 OCR1A = 10000-1;
 TCCR1A = 0;     //WGM=0100 (CTC)
 TCCR1B = 0x09;  //N = 1
 while((TIFR1&(1<<OCF1A))==0)
 { } //wait until OCF1A is set
 TCCR1B = 0; //stop timer1
 TIFR1 = 1<<OCF1A;//clear flag
}
```

Example

...oggles PB5 once per

Assembly

```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

C

```
#include <avr/io.h>
void  delay1ms();
int main(){
 DDRB |= 1<<5;
 while (1) {
 delay1ms();
 PORTB ^= (1<<5); //toggle PB5
 }
}
void  delay1ms()
{
 TCNT1 = 0;
 OCR1A = 10000-1;
 TCCR1A = 0;     //WGM=0100 (CTC)
 TCCR1B = 0x09;  //N = 1
 while((TIFR1&(1<<OCF1A))==0)
 { } //wait until OCF1A is set
 TCCR1B = 0; //stop timer1
 TIFR1 = 1<<OCF1A;//clear flag
}
```

Example

...oggles PB5 once per

Assembly

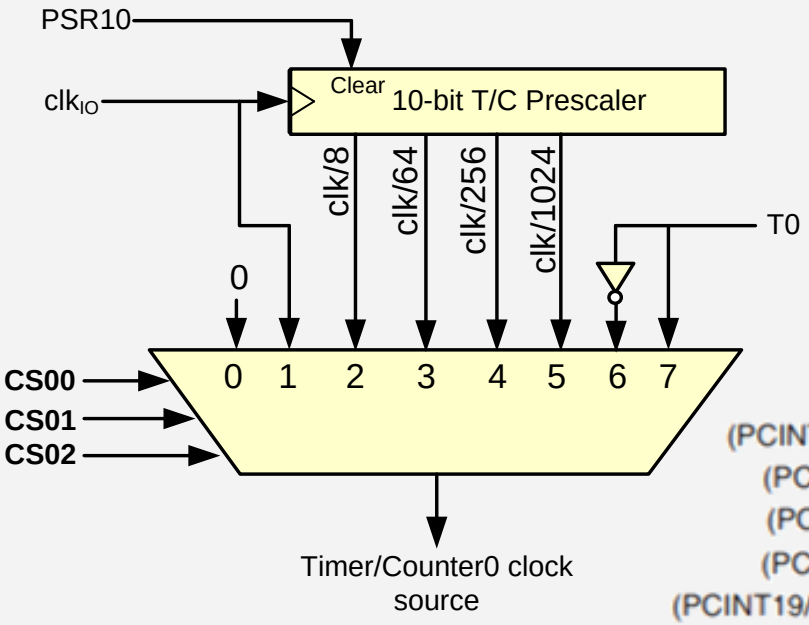
```
          LDI       R16,HIGH(RAMEND)
          OUT       SPH,R16
          LDI       R16,LOW(RAMEND)
          OUT       SPL,R16

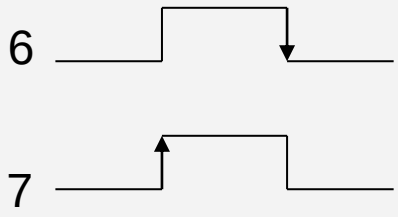
          SBI       DDRB,5     ;PB5 as an output
BEGIN:SBI PORTB,5    ;PB5 = 1
          RCALL     DELAY_1ms
          CBI       PORTB,5    ;PB5 = 0
          RCALL     DELAY_1ms
          RJMP      BEGIN
DELAY_1ms:
          LDI       R20,0x00
          STS       TCNT1H,R20          ;TEMP = 0
          STS       TCNT1L,R20          ;TCNT1L = 0,
TCNT1H = TEMP
          LDI       R20,0x27
          STS       OCR1AH,R20          ;TEMP = 0x27
          LDI       R20,0x0F
          STS       OCR1AL,R20          ;OCR1AL = 0x0F,
OCR1AH = TEMP
          LDI       R20,0x00
          STS       TCCR1A,R20          ;WGM11:10=00
          LDI       R20,0x09
          STS       TCCR1B,R20
          ;WGM13:12=01,CS=CLK
AGAIN:
          SBIS      TIFR1,OCF1A         ;if OCF1A is set
skip next instruction
          RJMP      AGAIN
          LDI       R19,0
          STS       TCCR1B,R19          ;stop timer
          STS       TCCR1A,R19          ;
          LDI       R20,1<<OCF1A
          OUT       TIFR1,R20 ;clear OCF1A flag
          RET
```

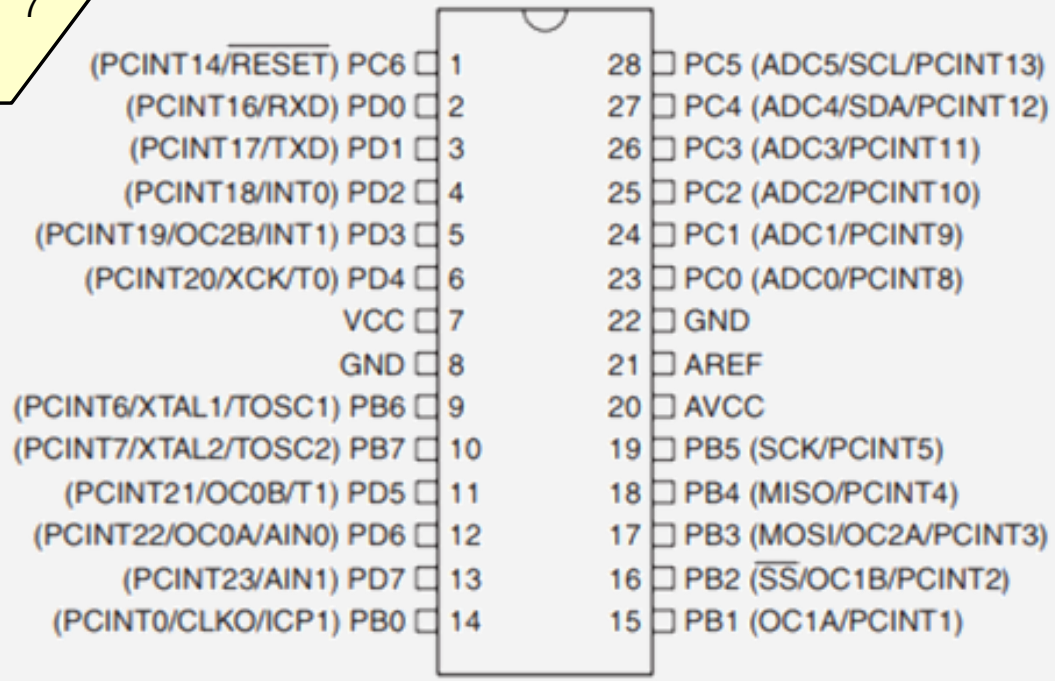
C

```
#include <avr/io.h>
void  delay1ms();
int main(){
 DDRB |= 1<<5;
 while (1) {
 delay1ms();
 PORTB ^= (1<<5); //toggle PB5
 }
}
void  delay1ms()
{
 TCNT1 = 0;
 OCR1A = 10000-1;
 TCCR1A = 0;     //WGM=0100 (CTC)
 TCCR1B = 0x09;  //N = 1
 while((TIFR1&(1<<OCF1A))==0)
 { } //wait until OCF1A is set
 TCCR1B = 0; //stop timer1
 TIFR1 = 1<<OCF1A;//clear flag
}
```

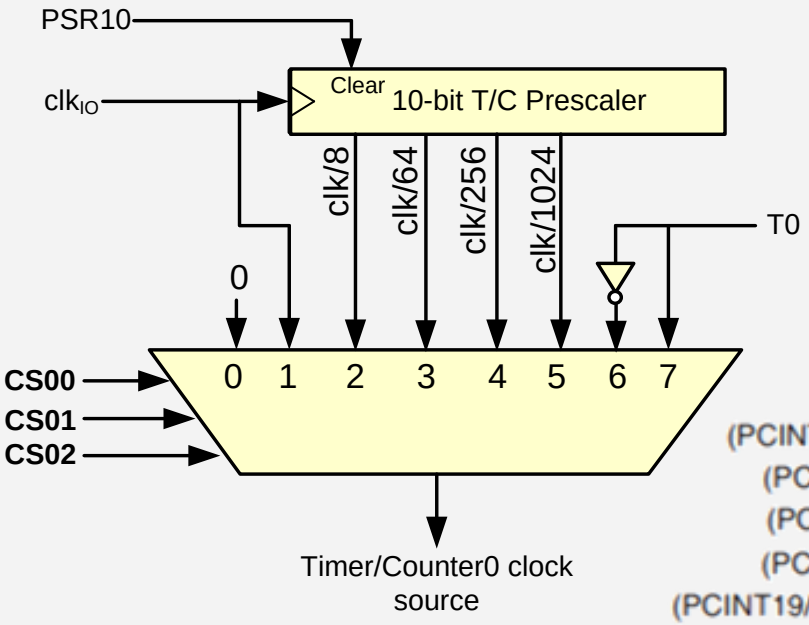
Counting

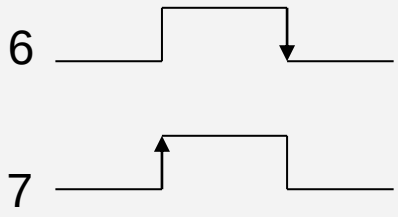

PSR10
clk$_{IO}$
Clear
10-bit T/C Prescaler
clk/8
clk/64
clk/256
clk/1024
T0
0
0 1 2 3 4 5 6 7
CS00
CS01
CS02
Timer/Counter0 clock source

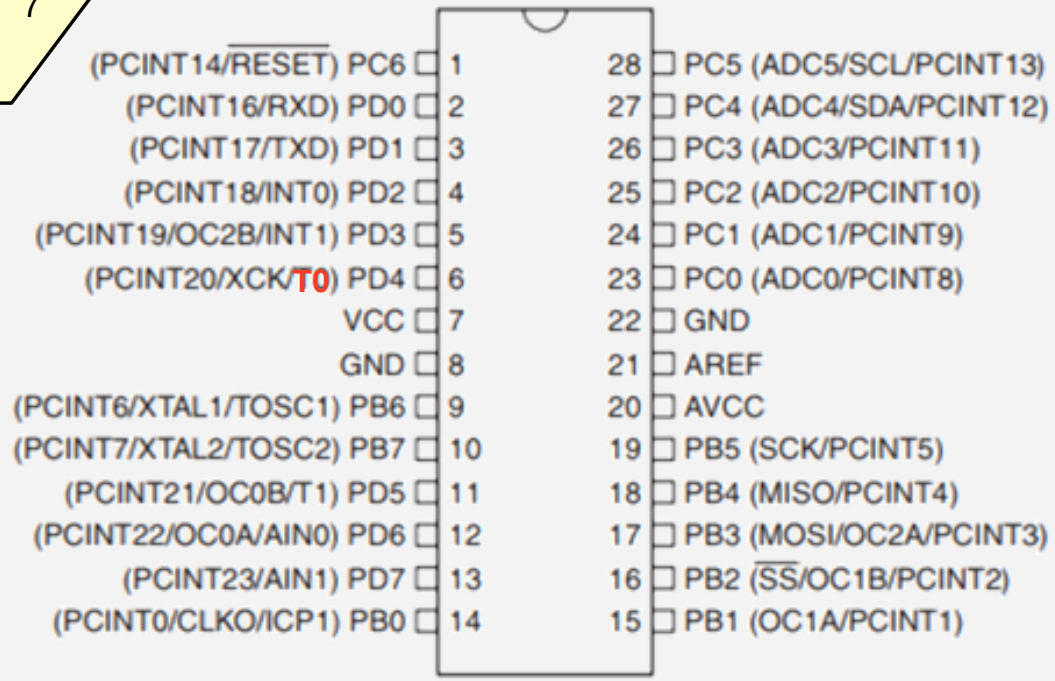

6
7


(PCINT14/RESET) PC6 1
(PCINT16/RXD) PD0 2
(PCINT17/TXD) PD1 3
(PCINT18/INT0) PD2 4
(PCINT19/OC2B/INT1) PD3 5
(PCINT20/XCK/T0) PD4 6
VCC 7
GND 8
(PCINT6/XTAL1/TOSC1) PB6 9
(PCINT7/XTAL2/TOSC2) PB7 10
(PCINT21/OC0B/T1) PD5 11
(PCINT22/OC0A/AIN0) PD6 12
(PCINT23/AIN1) PD7 13
(PCINT0/CLKO/ICP1) PB0 14
28 PC5 (ADC5/SCL/PCINT13)
27 PC4 (ADC4/SDA/PCINT12)
26 PC3 (ADC3/PCINT11)
25 PC2 (ADC2/PCINT10)
24 PC1 (ADC1/PCINT9)
23 PC0 (ADC0/PCINT8)
22 GND
21 AREF
20 AVCC
19 PB5 (SCK/PCINT5)
18 PB4 (MISO/PCINT4)
17 PB3 (MOSI/OC2A/PCINT3)
16 PB2 (SS/OC1B/PCINT2)
15 PB1 (OC1A/PCINT1)

Counting


PSR10
clk_IO
Clear
10-bit T/C Prescaler
clk/8
clk/64
clk/256
clk/1024
T0
0
0 1 2 3 4 5 6 7
CS00
CS01
CS02
Timer/Counter0 clock source


6
7


(PCINT14/RESET) PC6 1
(PCINT16/RXD) PD0 2
(PCINT17/TXD) PD1 3
(PCINT18/INT0) PD2 4
(PCINT19/OC2B/INT1) PD3 5
(PCINT20/XCK/T0) PD4 6
VCC 7
GND 8
(PCINT6/XTAL1/TOSC1) PB6 9
(PCINT7/XTAL2/TOSC2) PB7 10
(PCINT21/OC0B/T1) PD5 11
(PCINT22/OC0A/AIN0) PD6 12
(PCINT23/AIN1) PD7 13
(PCINT0/CLKO/ICP1) PB0 14
28 PC5 (ADC5/SCL/PCINT13)
27 PC4 (ADC4/SDA/PCINT12)
26 PC3 (ADC3/PCINT11)
25 PC2 (ADC2/PCINT10)
24 PC1 (ADC1/PCINT9)
23 PC0 (ADC0/PCINT8)
22 GND
21 AREF
20 AVCC
19 PB5 (SCK/PCINT5)
18 PB4 (MISO/PCINT4)
17 PB3 (MOSI/OC2A/PCINT3)
16 PB2 (SS/OC1B/PCINT2)
15 PB1 (OC1A/PCINT1)

Example 2

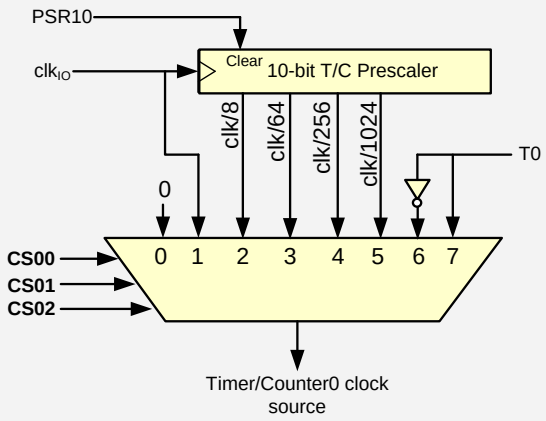
Assuming that clock pulses are fed into pin T0, write a program for counter 0 in normal mode to count the pulses on falling edge and display the state of the TCNT0 count on PORTC.

Assembly

```
        CBI     DDRD,4      ;make T0 (PD4) input
        LDI     R20,0xFF
        OUT     DDRC,R20    ;make PORTC output
        LDI     R20,0x00
        OUT     TCCR0A,R20
        LDI     R20,0x06
        OUT     TCCR0B,R20  ;counter, falling edge
AGAIN:
        IN      R20,TCNT0
        OUT     PORTC,R20   ;PORTC = TCNT0
        RJMP    AGAIN               ;keep doing it
```

C

```
#include <avr/io.h>
int main()
{
 DDRD &= ~(1<<4);
 DDRC = 0xFF;
 TCCR0A = 0;     //WGM=0000
                 (Normal)
 TCCR0B = 0x06; //CS=6
                 (Count on fall)
 while (1)
 {
   PORTC = TCNT0; //read TCNT0
 }
}
```



COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00	TCCR0A
FOC0A	FOC0B	-	-	WGM02	CS02	CS01	CS00	TCCR0B

Example 2

Assuming that clock pulses are fed into pin T1. Write a program for Counter1 in CTC mode to make PORTC.0 high every 100 pulses.

Assembly

```
        CBI     DDRD,5      ;make T1 (PD5) input
        SBI     DDRC,0      ;PC0 as an output

        LDI     R20,0x00
        OUT     TCCR1A,R20
        LDI     R20,0x0E    ;CS=6 (falling edge counter)
        OUT     TCCR1B,R20  ;CTC
AGAIN:
        LDI     R20,0
        OUT     OCR1AH,R20    ;TEMP = 0
        LDI     R20,99
        OUT     OCR1AL,R20    ;ORC1L = R20, OCR1H = TEMP
L1:
        SBRS    TIFR1,OCF1A
        RJMP    L1              ;keep doing it
        LDI     R20,1<<OCF1A    ;clear OCF1A flag
        OUT     TIFR1, R20

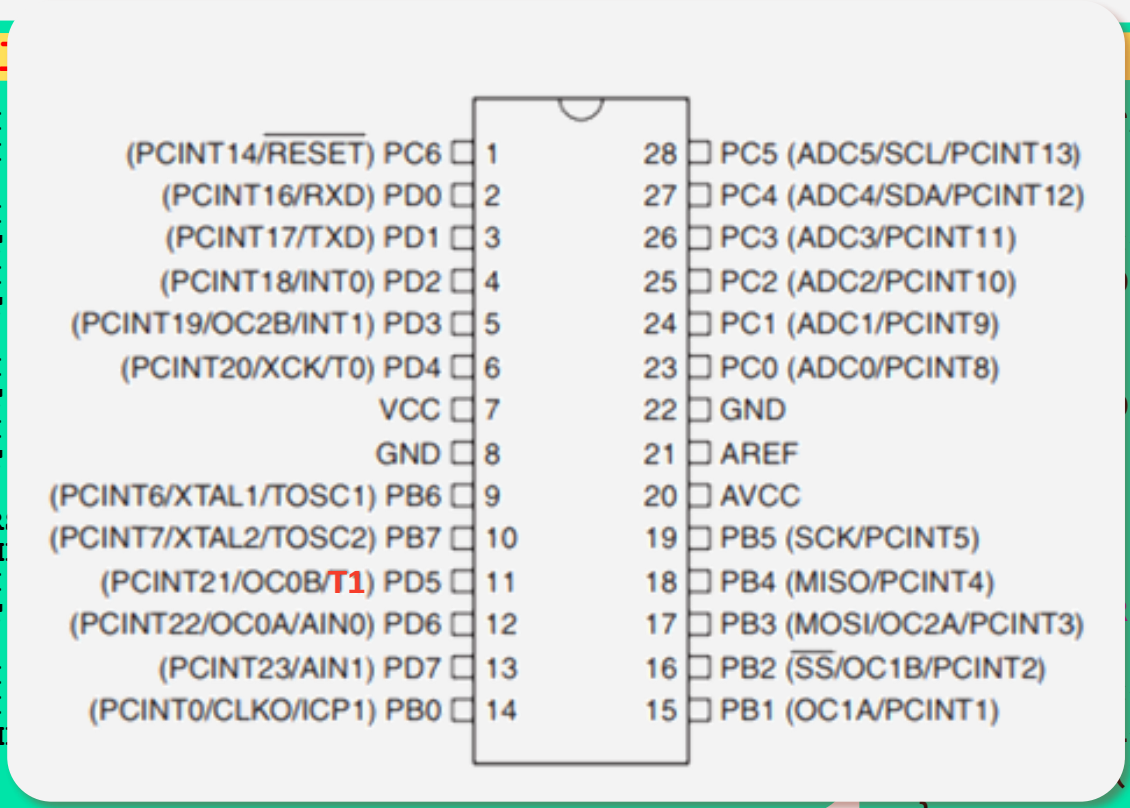
        SBI     PORTC,0             ;PC0 = 1
        CBI     PORTC,0             ;PC0 = 0
        RJMP    AGAIN               ;keep doing it
```

C

```
#include <avr/io.h>
int main()
{
 DDRD &= ~(1<<5);
 DDRC |= 1<<0;
 TCCR1A = 0;     //WGM=0100
                 (CTC)
 TCCR1B = 0x0E;  //CS=6 (Count
                 on fall)
 OCR1A = 99;
 while (1)
 {
  while((TIFR1&(1<<OCF1A)) ==
0);
  TIFR1 = (1<<OCF1A);
  PORTC |= (1<<0);  //PC0 = 1
  PORTC &= ~(1<<0); //PC0 = 0
 }
}
```

Example 2

Assuming that clock pulses are fed into pin T1. Write a program for Counter1 in CTC mode to make PORTC.0 high every 100 pulses.



Assembl

```
        CBI
        SBI

        LDI
        OUT
        LDI
        OUT
AGAIN:
        LDI
        OUT
        LDI
        OUT
L1:
        SBR
        RJM
        LDI
        OUT

        SBI
        CBI
        RJM
```

```
/io.h>


<5);
;
    //WGM=0100
    (CTC)
E;  //CS=6 (Count
    on fall)



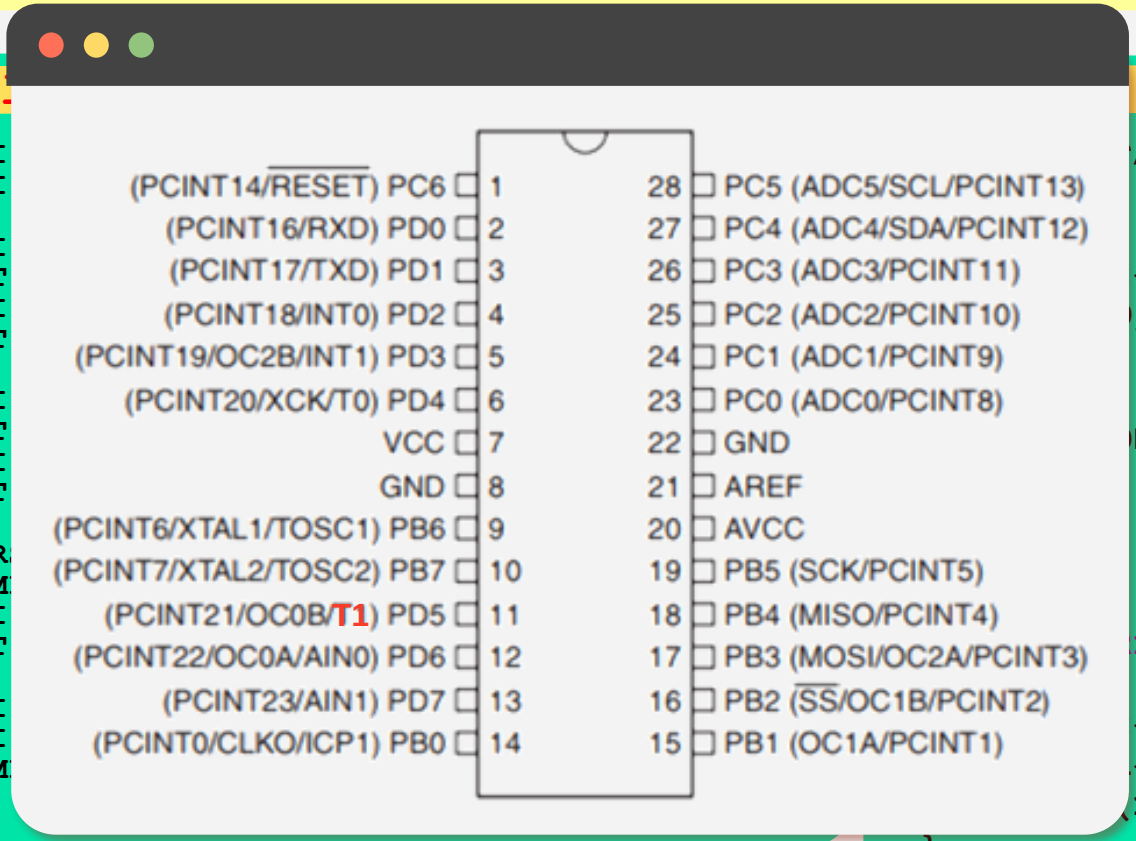
1&(1<<OCF1A)) ==

<OCF1A);
<<0);  //PC0 = 1
1<<0); //PC0 = 0
 }
}
```

Timer 0 | Timer 1 | Timer 2

Example 2

Assuming that clock pulses are fed into pin T1. Write a program for Counter1 in CTC mode to make PORTC.0 high every 100 pulses.



Assemb

```
        CBI
        SBI

        LDI
        OUT
        LDI
        OUT
AGAIN:
        LDI
        OUT
        LDI
        OUT
L1:
        SBR
        RJM
        LDI
        OUT

        SBI
        CBI
        RJM
```

```
/io.h>


<5);
;
    //WGM=0100
    (CTC)
E;  //CS=6 (Count
    on fall)

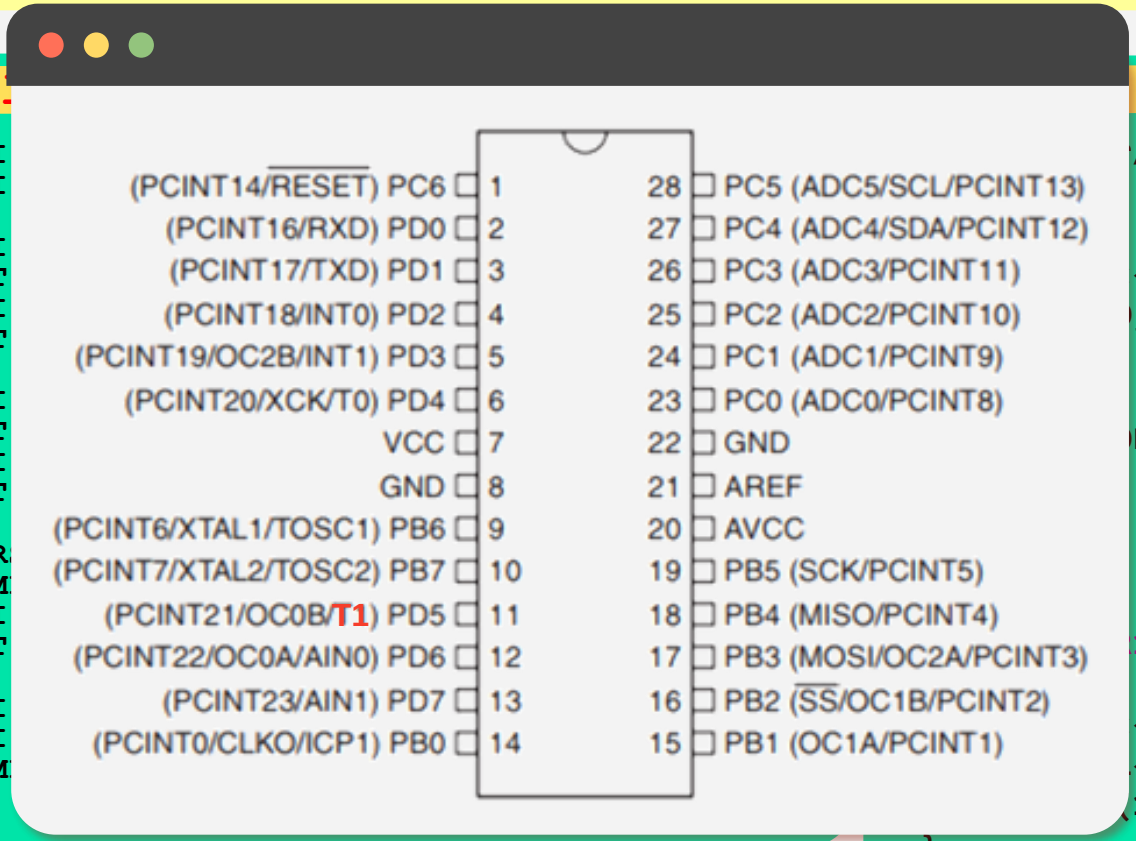


1&(1<<OCF1A)) ==

<OCF1A);
<<0);  //PC0 = 1
1<<0); //PC0 = 0
 }
}
```

Example 2

Assuming that clock pulses are fed into pin T1. Write a program for Counter1 in CTC mode to make PORTC.0 high every 100 pulses.



Assemb

```
        CBI
        SBI

        LDI
        OUT
        LDI
        OUT
AGAIN:
        LDI
        OUT
        LDI
        OUT
L1:
        SBR
        RJM
        LDI
        OUT

        SBI
        CBI
        RJM
```

```
/io.h>


<5);
;
    //WGM=0100
    (CTC)
E;  //CS=6 (Count
    on fall)

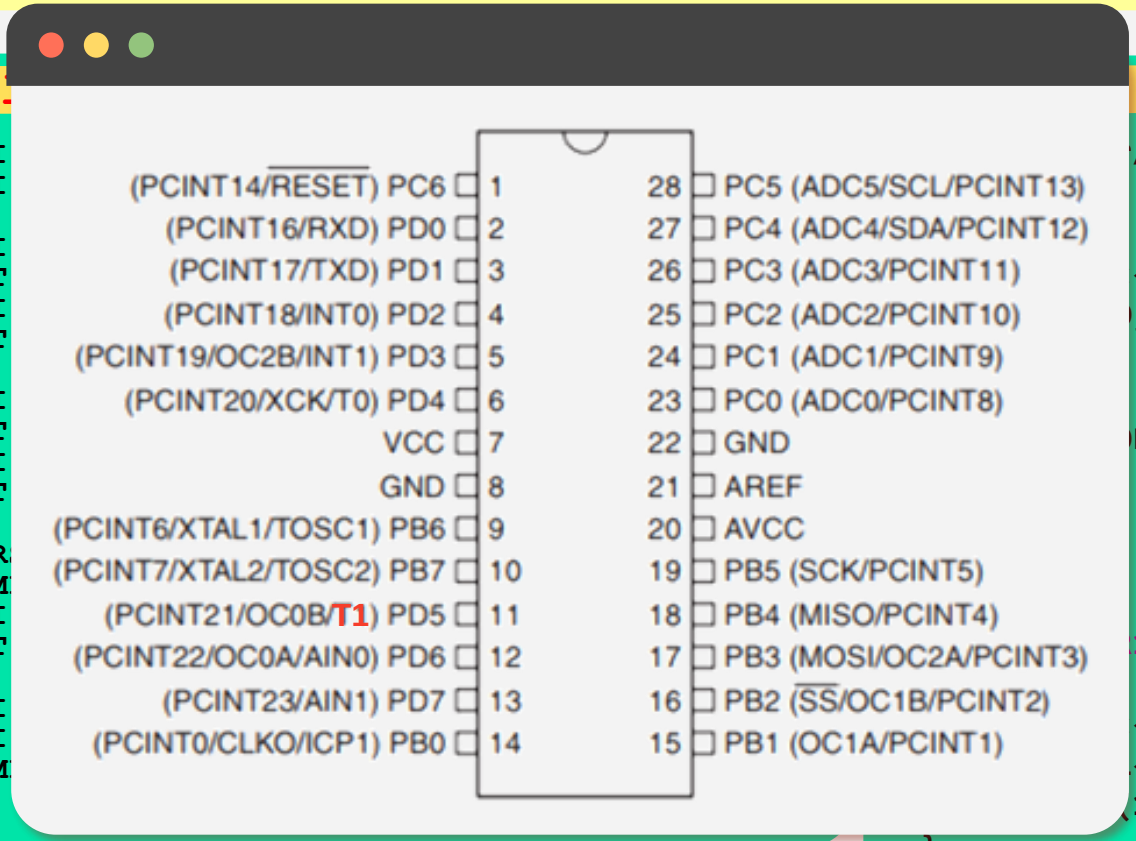


1&(1<<OCF1A)) ==

<OCF1A);
<<0);  //PC0 = 1
1<<0); //PC0 = 0
 }
}
```

Example 2

Assuming that clock pulses are fed into pin T1. Write a program for Counter1 in CTC mode to make PORTC.0 high every 100 pulses.



Assemb

```
        CBI
        SBI

        LDI
        OUT
        LDI
        OUT
AGAIN:
        LDI
        OUT
        LDI
        OUT
L1:
        SBR
        RJM
        LDI
        OUT

        SBI
        CBI
        RJM
```

```
/io.h>


<5);
;
    //WGM=0100
    (CTC)
E;  //CS=6 (Count
    on fall)



1&(1<<OCF1A)) ==

<OCF1A);
<<0);  //PC0 = 1
1<<0); //PC0 = 0
 }
}
```

Thanks!

Do you have any questions?

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