MSYS

Microcontroller Systems

Lektion 15: Timers i PWM mode
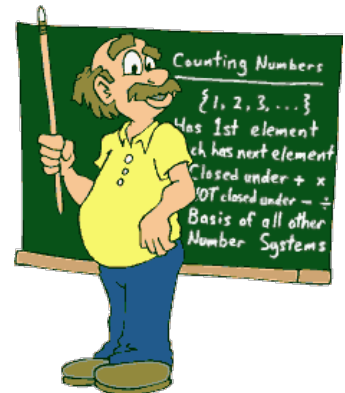
Timer i PWM mode (<u>ikke "fast mode"</u>)

TOP   **TOP**

OCRn

0   **0**

| "Match" | "Match" | | "Match" | "Match" |

Port ben OCn

$$\text{Duty cycle} = 1 - (OCRn\ /\ TOP)$$

$$\text{Frekvens} = f_{cpu}\ /\ (N * 2 * TOP)$$

Output Compare og PWM (ikke "fast")
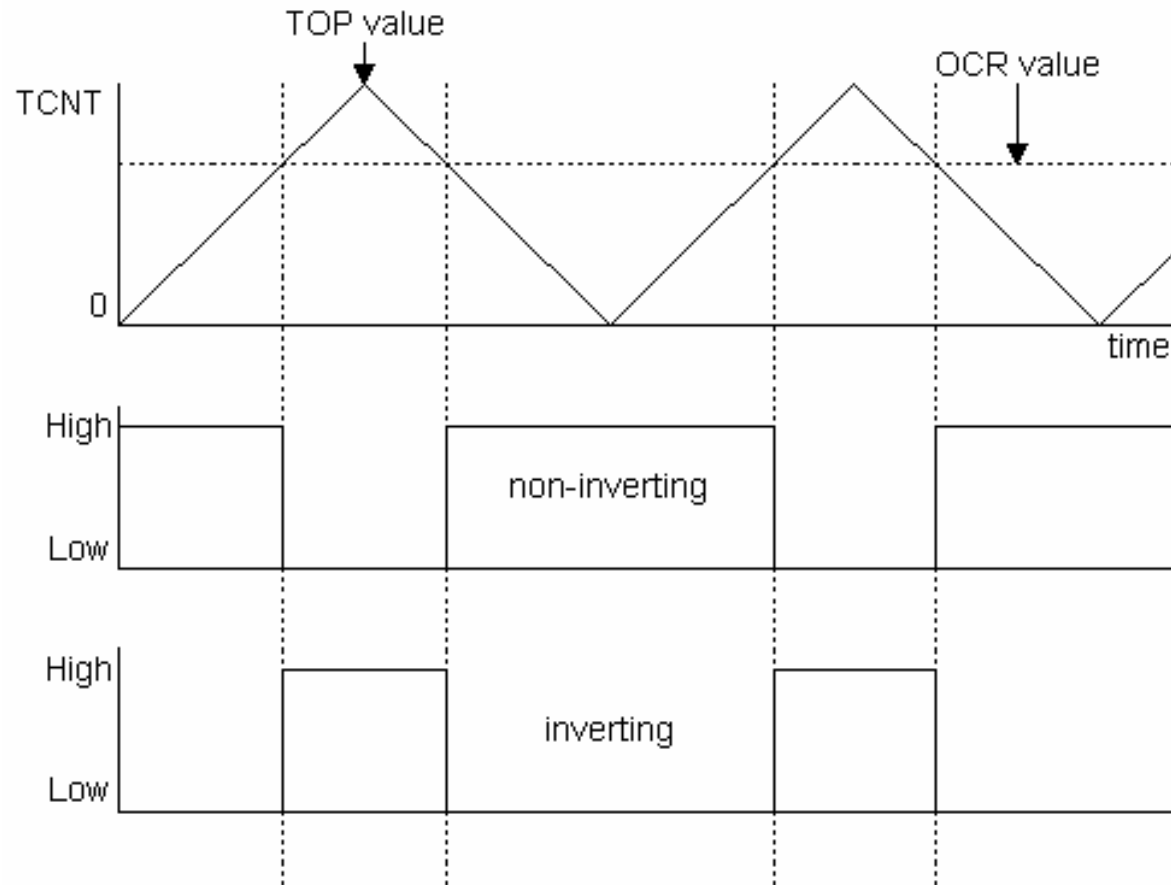
Timer i <u>fast</u> PWM mode

OCRn

TOP   **TOP**   **TOP**

0   **0**   **0**   **0**

"Match"   "Match"   "Match"

Port ben OCn

Duty cycle = 1 – (OCRn / TOP)
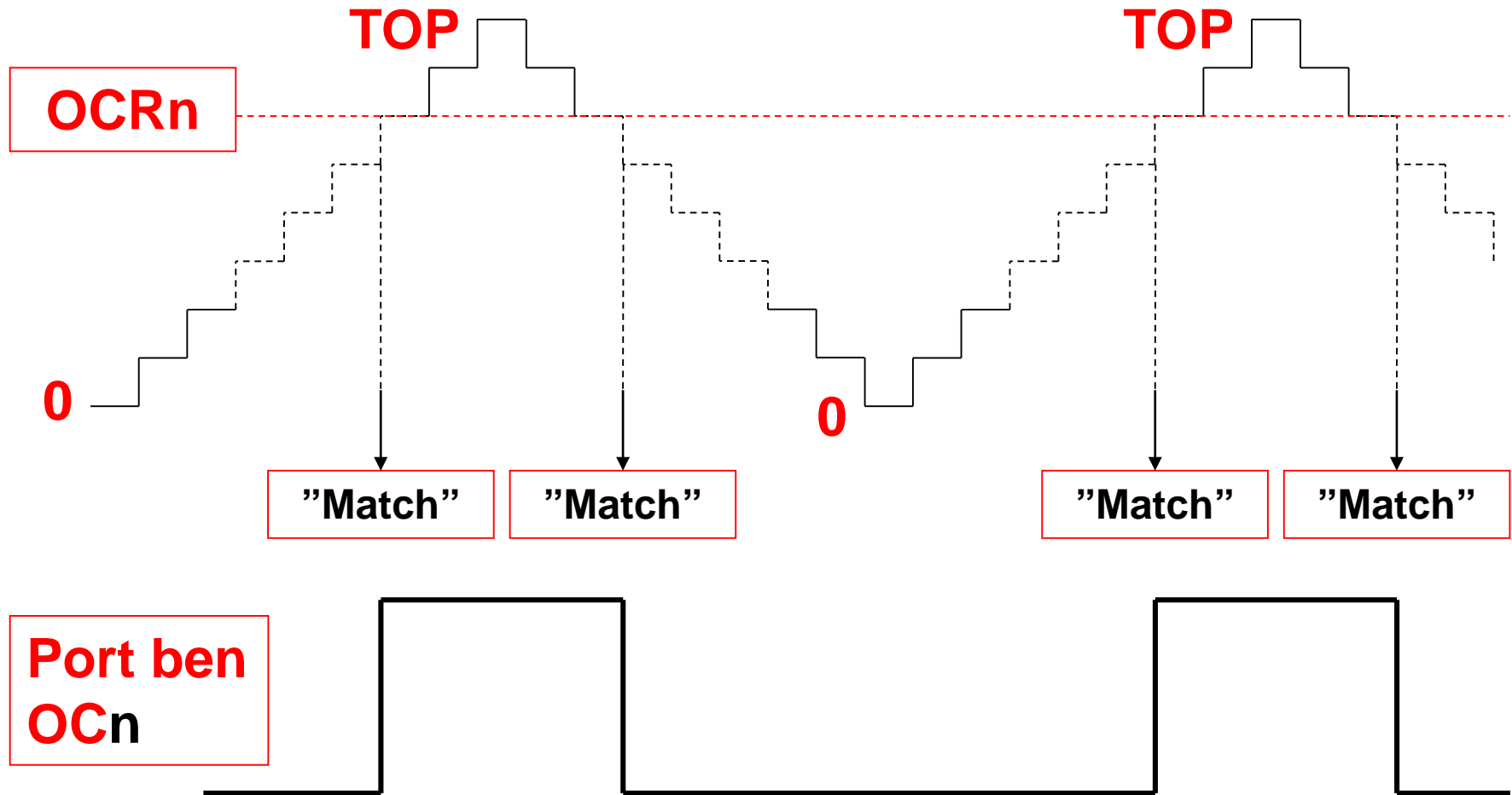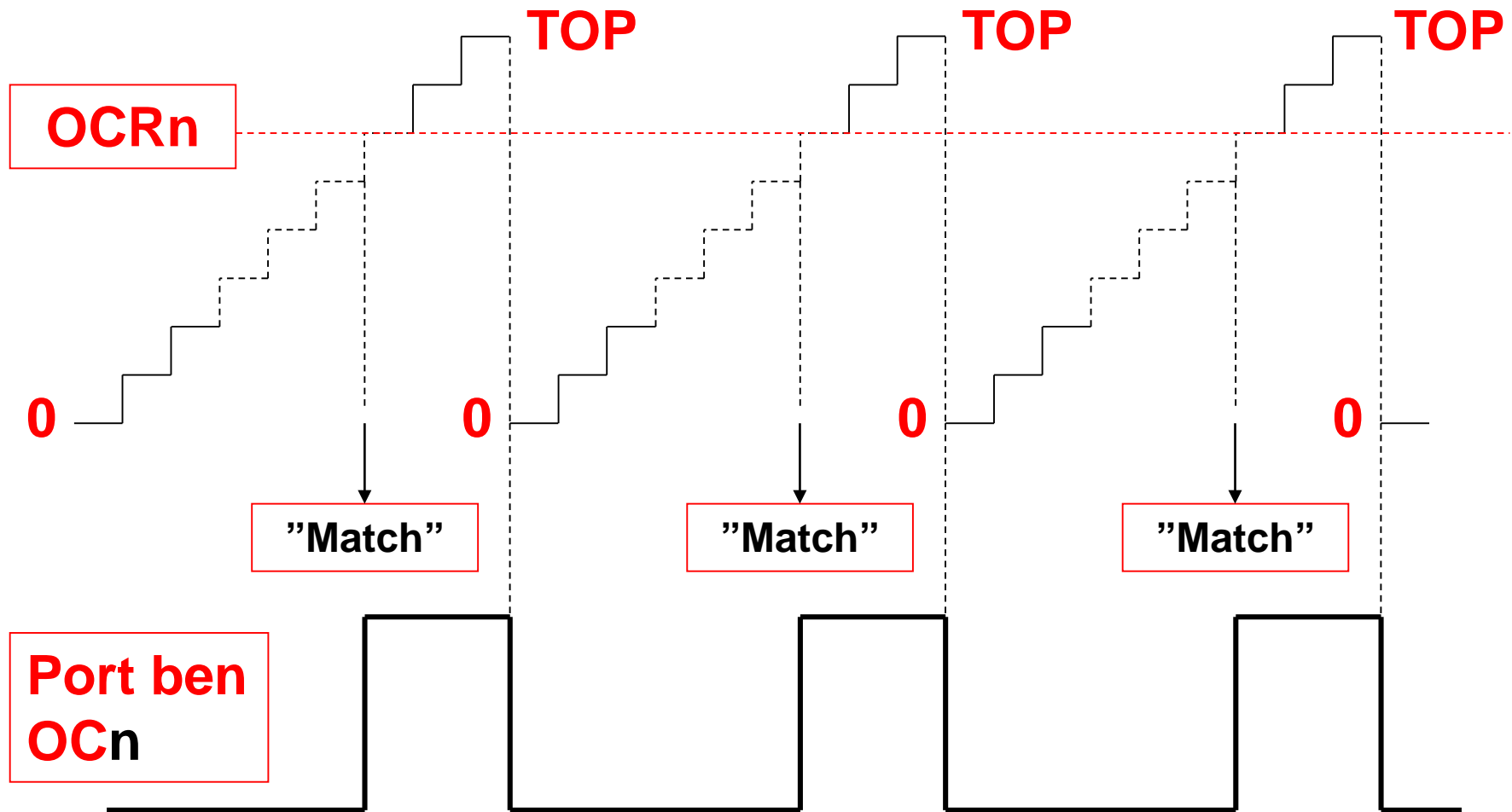
Frekvens = f_{cpu} / (N * (1+TOP))

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Output Compare Unit

Tælleregister TCNTn	Compare Register OCRn

Hardware sammenligner (=?)

"Match"

Mulighed for
"Compare interrupt"

Port ben

Kontrol via SW
(2 bit i I/O-registre) → **Waveform generator** → **OCn**
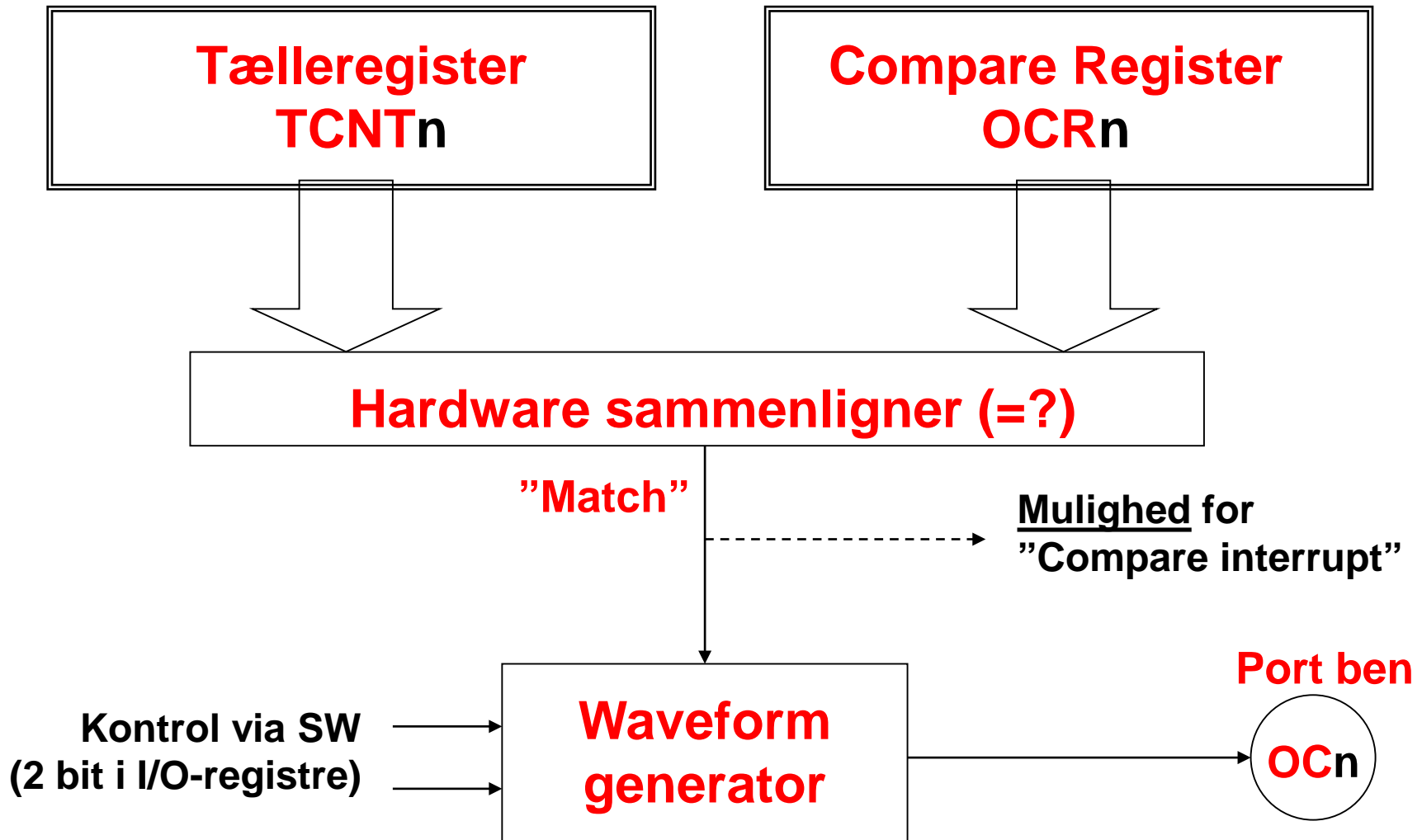
Speciel funktion i PWM modes !

Blokdiagrammer

- De næste slides er de samme som fra "CTC mode".

- Gentaget for overskuelighedens skyld.

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Mega32: 3 timere

- **Timer 0 :
  8 bit (MAX = 255).**
  Normal, **CTC** og PWM modes.

- **Timer 1 :
  16 bit (MAX = 65535).**
  Normal, **CTC**, <u>mange</u> PWM modes.
  (Mulighed for "Input Capture")

- **Timer 2 :
  8 bit (MAX = 255).**
  Normal, **CTC** og PWM modes.
  Asynkron mode (Real Time Clock).

Mega2560: 6 timere

- **Timer 0 :
8 bit (MAX = 255).**
Normal, **CTC** og PWM modes.

- **Timer 1, Timer 3, Timer 4 og Timer 5 :
16 bit (MAX = 65535).**
Normal, **CTC**, mange PWM modes.
(Mulighed for "Input Capture")

- **Timer 2 :
8 bit (MAX = 255).**
Normal, **CTC** og PWM modes.
Asynkron mode (Real Time Clock).

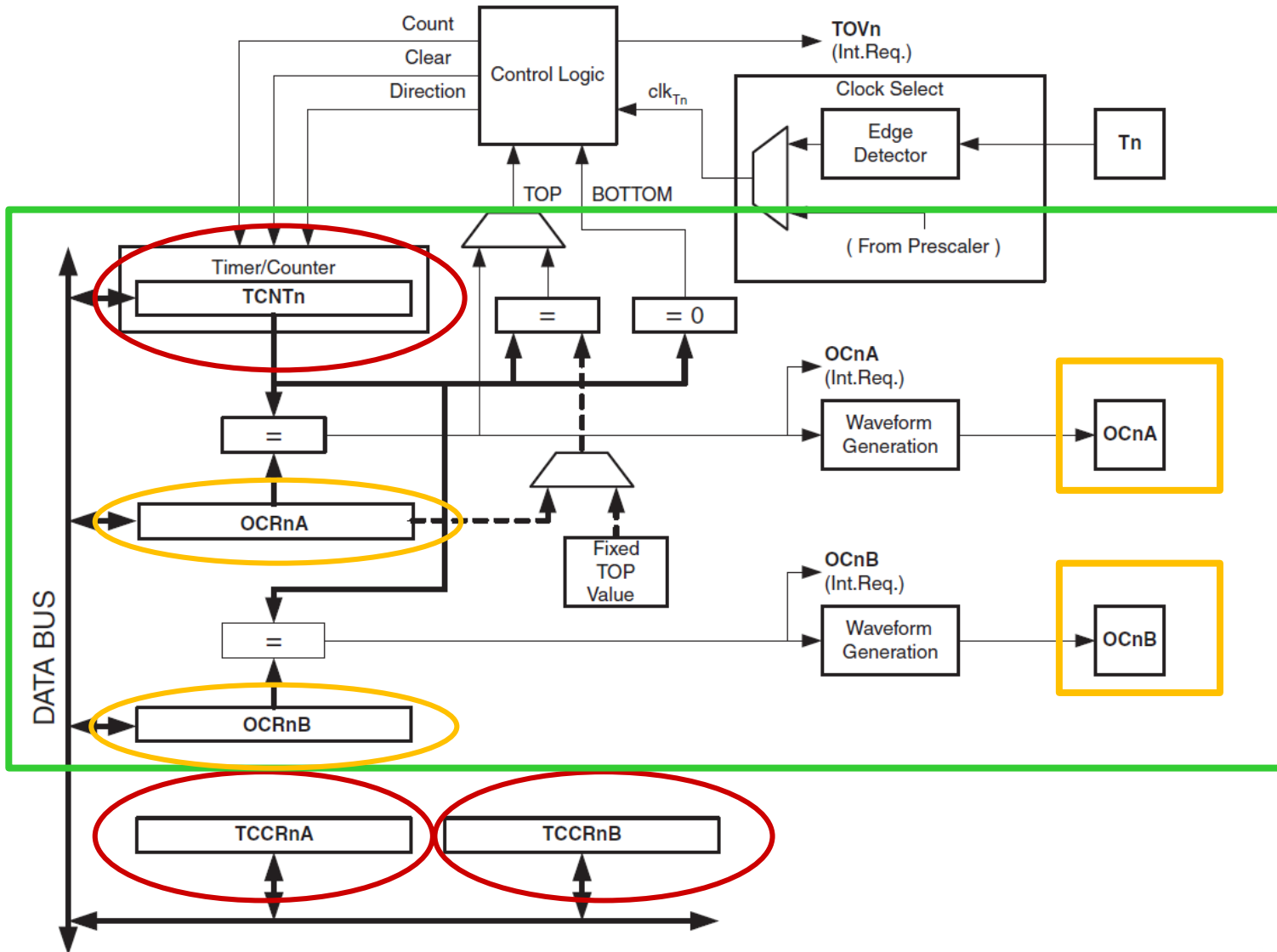AARHUS UNIVERSITY
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Mega2560: Timer 0 (8 bit)

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Mega2560: Timer 1,3,4,5 (16 bit)

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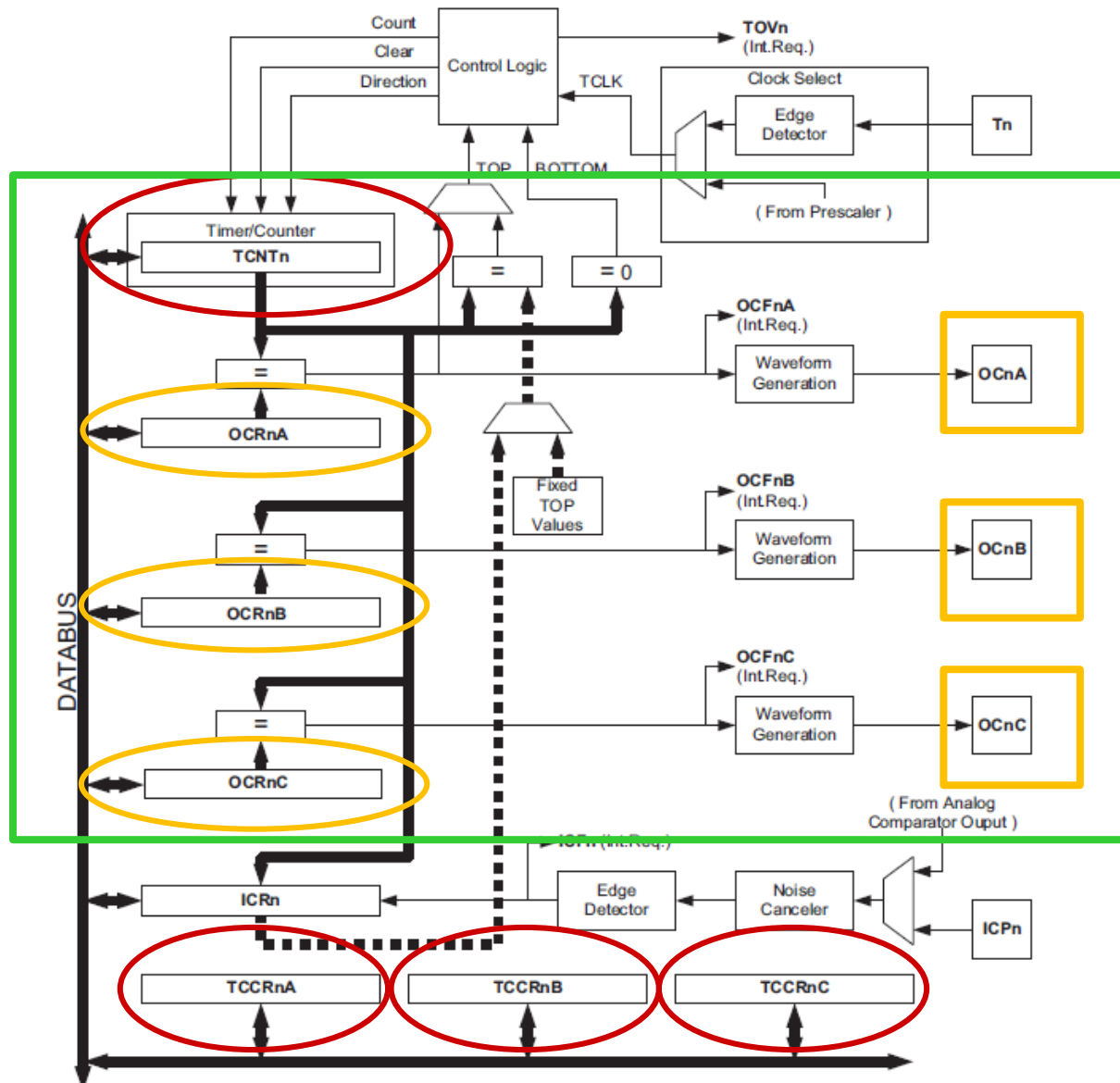
Mega2560: Timer 2 (8 bit)
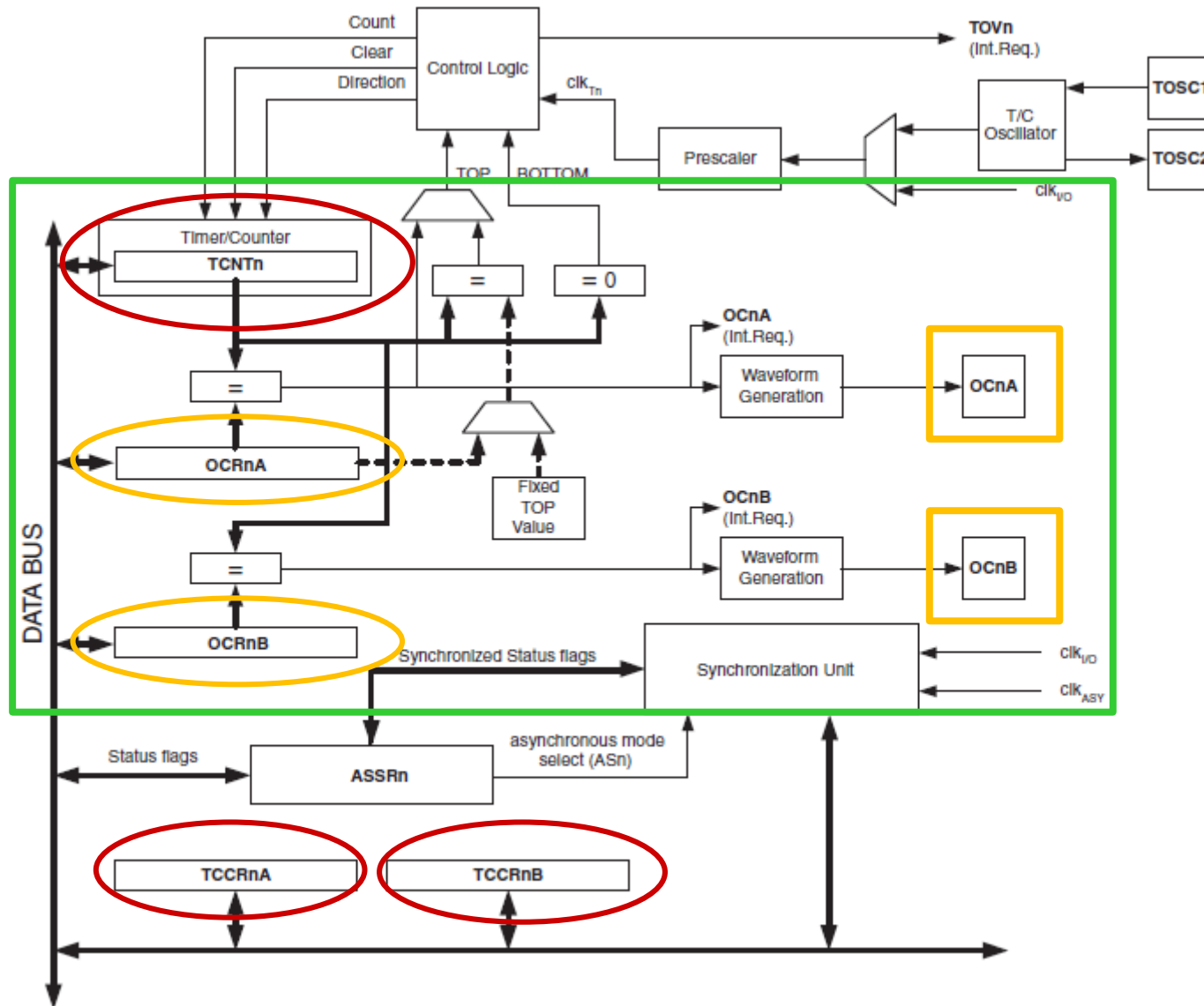
NYT: Valg af PWM Mode

- PWM mode vælges normalt under opstart (initiering).

- Hvilke registre, der skal skrives til, afhænger af, om vi bruger Mega32 eller Mega2560.

  Desuden afhænger det af, hvilken timer, der drejer sig om.

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Mega2560: Timer 0. PWM modes

7	6	5	4	3	2	1	0	
COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	TCCR0A
R/W	R/W	R/W	R/W	R	R	R/W	R/W	
0	0	0	0	0	0	0	0	

7	6	5	4	3	2	1	0	
FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00	TCCR0B
W	W	R	R	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

Mode	WGM2	WGM1	WGM0	Timer/Counter Mode of Operation	TOP	Update of OCRx at	TOV Flag Set on[1][2]
0	0	0	0	Normal	0xFF	Immediate	MAX
1	0	0	1	PWM, Phase Correct	0xFF	TOP	BOTTOM
2	0	1	0	CTC	OCRA	Immediate	MAX
3	0	1	1	Fast PWM	0xFF	TOP	MAX
4	1	0	0	Reserved	–	–	–
5	1	0	1	PWM, Phase Correct	OCRA	TOP	BOTTOM
6	1	1	0	Reserved	–	–	–
7	1	1	1	Fast PWM	OCRA	BOTTOM	TOP

OBS : TOP er afhængig af mode !

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Mega2560: Timer 1,3,4,5. PWM modes

7	6	5	4	3	2	1	0	
COM1A1	COM1A0	COM1B1	COM1B0	COM1C1	COM1C0	WGM11	WGM10	**TCCRnA**
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

7	6	5	4	3	2	1	0	
ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	**TCCRnB**
R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	
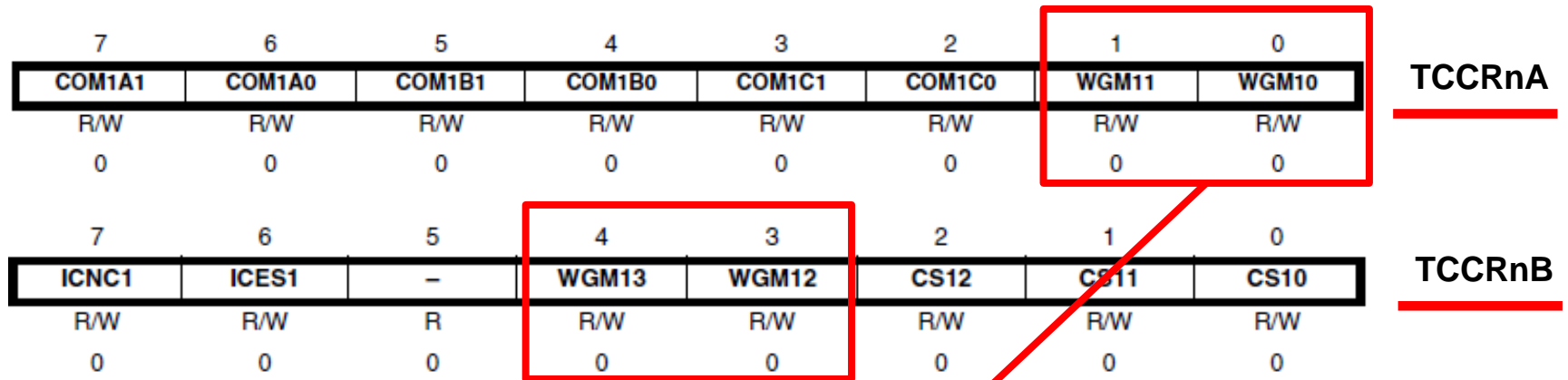
Se næste slide !

- **TCCRnA = TCCR1A, TCCR3A, TCCR4A eller TCCR5A.**
- **TCCRnB = TCCR1B, TCCR3B, TCCR4B eller TCCR5B.**

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Mega2560: Timer 1,3,4,5. PWM modes

Mode	WGMn3	WGMn2 (CTCn)	WGMn1 (PWMn1)	WGMn0 (PWMn0)	Timer/Counter Mode of Operation	TOP	Update of OCRnx at	TOVn 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	OCRnA	Immediate	MAX
5	0	1	0	1	Fast PWM, 8-bit	0x00FF	BOTTOM	TOP
6	0	1	1	0	Fast PWM, 9-bit	0x01FF	BOTTOM	TOP
7	0	1	1	1	Fast PWM, 10-bit	0x03FF	BOTTOM	TOP
8	1	0	0	0	PWM, Phase and Frequency Correct	ICRn	BOTTOM	BOTTOM
9	1	0	0	1	PWM, Phase and Frequency Correct	OCRnA	BOTTOM	BOTTOM
10	1	0	1	0	PWM, Phase Correct	ICRn	TOP	BOTTOM
11	1	0	1	1	PWM, Phase Correct	OCRnA	TOP	BOTTOM
12	1	1	0	0	CTC	ICRn	Immediate	MAX
13	1	1	0	1	(Reserved)	–	–	–
14	1	1	1	0	Fast PWM	ICRn	BOTTOM	TOP
15	1	1	1	1	Fast PWM	OCRnA	BOTTOM	TOP

OBS : TOP er afhængig af mode !

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Mega2560: Timer 2. PWM modes

	7	6	5	4	3	2	1	0	
	COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	TCCR2A
	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
	0	0	0	0	0	0	0	0	

	7	6	5	4	3	2	1	0	
	FOC2A	FOC2B	–	–	WGM22	CS22	CS21	CS20	TCCR2B
	W	W	R	R	R/W	R/W	R/W	R/W	
	0	0	0	0	0	0	0	0	

Mode	WGM2	WGM1	WGM0	Timer/Counter Mode of Operation	TOP	Update of OCRx at	TOV Flag Set on[1][2]
0	0	0	0	Normal	0xFF	Immediate	MAX
1	0	0	1	PWM, Phase Correct	0xFF	TOP	BOTTOM
2	0	1	0	CTC	OCRA	Immediate	MAX
3	0	1	1	Fast PWM	0xFF	BOTTOM	MAX
4	1	0	0	Reserved	–	–	–
5	1	0	1	PWM, Phase Correct	OCRA	TOP	BOTTOM
6	1	1	0	Reserved	–	–	–
7	1	1	1	Fast PWM	OCRA	BOTTOM	TOP

OBS : TOP er afhængig af mode !

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Valg af clock

- De næste slides er de samme som fra "Normal mode" og "CTC mode".

- Gentaget for overskuelighedens skyld.

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Mega2560: Timer 0. Valg af clock

	7	6	5	4	3	2	1	0	
	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00	TCCR0B
	W	W	R	R	R/W	R/W	R/W	R/W	
	0	0	0	0	0	0	0	0	

CS02	CS01	CS00	Description
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	$clk_{I/O}$/(No prescaling)
0	1	0	$clk_{I/O}$/8 (From prescaler)
0	1	1	$clk_{I/O}$/64 (From prescaler)
1	0	0	$clk_{I/O}$/256 (From prescaler)
1	0	1	$clk_{I/O}$/1024 (From prescaler)
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

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Mega2560: Timer 1,3,4,5. Valg af clock

7	6	5	4	3	2	1	0	
ICNC1	ICES1	–	WGM13	WGM12	CSn2	CSn1	CSn0	TCCRnB
R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

- **TCCRnB = TCCR1B, TCCR3B, TCCR4B eller TCCR5B.**

CSn2	CSn1	CSn0	Description
0	0	0	No clock source. (Timer/Counter stopped)
0	0	1	$clk_{I/O}/1$ (No prescaling
0	1	0	$clk_{I/O}/8$ (From prescaler)
0	1	1	$clk_{I/O}/64$ (From prescaler)
1	0	0	$clk_{I/O}/256$ (From prescaler)
1	0	1	$clk_{I/O}/1024$ (From prescaler)
1	1	0	External clock source on Tn pin. Clock on falling edge
1	1	1	External clock source on Tn pin. Clock on rising edge

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Mega2560: Timer 2. Valg af clock

7	6	5	4	3	2	1	0	
FOC2A	FOC2B	–	–	WGM22	CS22	CS21	CS20	TCCR2B
W	W	R	R	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

CS22	CS21	CS20	Description
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	clk_{T2S}/(No prescaling)
0	1	0	clk_{T2S}/8 (From prescaler)
0	1	1	clk_{T2S}/32 (From prescaler)
1	0	0	clk_{T2S}/64 (From prescaler)
1	0	1	clk_{T2S}/128 (From prescaler)
1	1	0	clk_{T2S}/256 (From prescaler)
1	1	1	clk_{T2S}/1024 (From prescaler)

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NYT: Pin styring i PWM Mode

- OC – benene styres af waveform-generatoren i PWM mode.

- Der er forskel på, hvilken "tabel" der skal bruges for "fast PWM mode" og "ikke-fast PWM mode".

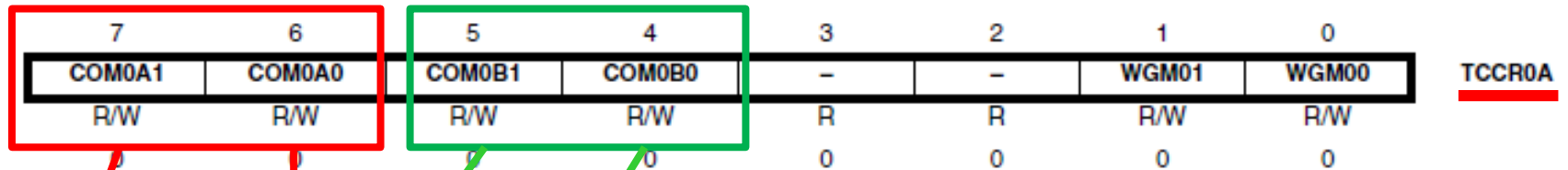- Pas derfor på at anvende den rigtige "tabel" (se de næste slides).
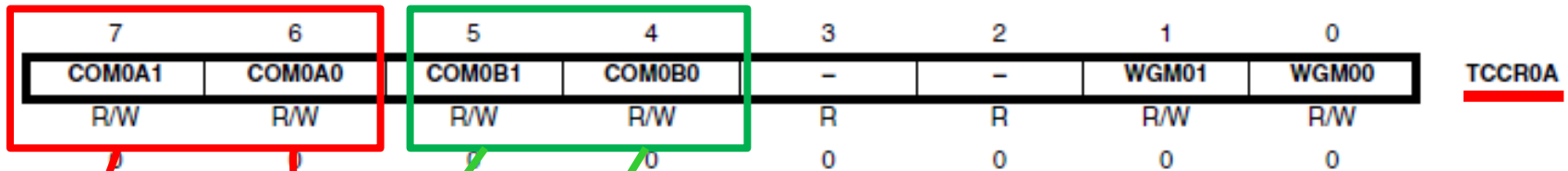
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Mega2560: Timer 0. Pin styring A + B. **Fast** PWM.

	7	6	5	4	3	2	1	0	
	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	TCCR0A
	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
	0	0	0	0	0	0	0	0	

COM0A1	COM0A0	Description
0	0	Normal port operation, OC0A disconnected
0	1	WGM02 = 0: Normal Port Operation, OC0A Disconnected WGM02 = 1: Toggle OC0A on Compare Match
1	0	Clear OC0A on Compare Match, set OC0A at BOTTOM (non-inverting mode)
1	1	Set OC0A on Compare Match, clear OC0A at BOTTOM (inverting mode)

COM0B1	COM0B0	Description
0	0	Normal port operation, OC0B disconnected
0	1	Reserved
1	0	Clear OC0B on Compare Match, set OC0B at BOTTOM (non-inverting mode)
1	1	Set OC0B on Compare Match, clear OC0B at BOTTOM (inverting mode)

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Mega2560: Timer 0. Pin styring A + B. **Ikke-fast** PWM.

	7	6	5	4	3	2	1	0	
	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	TCCR0A
	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
	0	0	0	0	0	0	0	0	

COM0A1	COM0A0	Description
0	0	Normal port operation, OC0A disconnected
0	1	WGM02 = 0: Normal Port Operation, OC0A Disconnected WGM02 = 1: Toggle OC0A on Compare Match
1	0	Clear OC0A on Compare Match when up-counting. Set OC0A on Compare Match when down-counting
1	1	Set OC0A on Compare Match when up-counting. Clear OC0A on Compare Match when down-counting

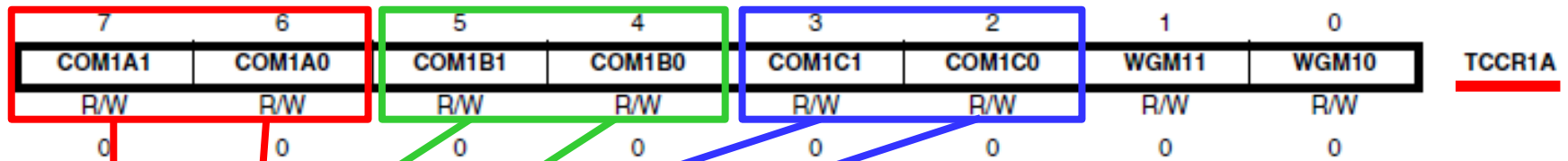| COM0B1	COM0B0	Description
0	0	Normal port operation, OC0B disconnected
0	1	Reserved
1	0	Clear OC0B on Compare Match when up-counting. Set OC0B on Compare Match when down-counting
1	1	Set OC0B on Compare Match when up-counting. Clear OC0B on Compare Match when down-counting

Mega2560: Timer 0. OC pins.

OC0A = PB, ben 7

OC0B = PG, ben 5

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Mega2560: Timer 1,3,4,5. Pin styring A+B+C. **Fast** PWM.

7	6	5	4	3	2	1	0	
COM1A1	COM1A0	COM1B1	COM1B0	COM1C1	COM1C0	WGM11	WGM10	TCCR1A
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

COMnA1 COMnB1 COMnC1	COMnA0 COMnB0 COMnC0	Description
0	0	Normal port operation, OCnA/OCnB/OCnC disconnected
0	1	WGM13:0 = 14 or 15: Toggle OC1A on Compare Match, OC1B and OC1C disconnected (normal port operation). For all other WGM1 settings, normal port operation, OC1A/OC1B/OC1C disconnected
1	0	Clear OCnA/OCnB/OCnC on compare match, set OCnA/OCnB/OCnC at BOTTOM (non-inverting mode)
1	1	Set OCnA/OCnB/OCnC on compare match, clear OCnA/OCnB/OCnC at BOTTOM (inverting mode)

Rød = A-systemet.
Grøn = B-systemet.
Blå = C-systemet.

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Mega2560: Timer 1,3,4,5. Pin styring A+B+C. **Ikke-fast** PWM.

7	6	5	4	3	2	1	0	
COM1A1	COM1A0	COM1B1	COM1B0	COM1C1	COM1C0	WGM11	WGM10	TCCR1A
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

COMnA1 COMnB1 COMnC1	COMnA0 COMnB0 COMnC0	Description
0	0	Normal port operation, OCnA/OCnB/OCnC disconnected
0	1	WGM13:0 =9 or 11: Toggle OC1A on Compare Match, OC1B and OC1C disconnected (normal port operation). For all other WGM1 settings, normal port operation, OC1A/OC1B/OC1C disconnected
1	0	Clear OCnA/OCnB/OCnC on compare match when up-counting Set OCnA/OCnB/OCnC on compare match when downcounting
1	1	Set OCnA/OCnB/OCnC on compare match when up-counting Clear OCnA/OCnB/OCnC on compare match when downcounting

Rød = A-systemet.
Grøn = B-systemet.
Blå = C-systemet.

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Mega2560: Timer 1,3,4,5. OC pins

Timer 1
OC1A = PB, ben 5
OC1B = PB, ben 6
OC1C = PB, ben 7

Timer 3
OC3A = PE, ben 3
OC3B = PE, ben 4
OC3C = PE, ben 5

Timer 4
OC4A = PH, ben 3
OC4B = PH, ben 4
OC4C = PH, ben 5

Timer 5
OC5A = PL, ben 3
OC5B = PL, ben 4
OC5C = PL, ben 5
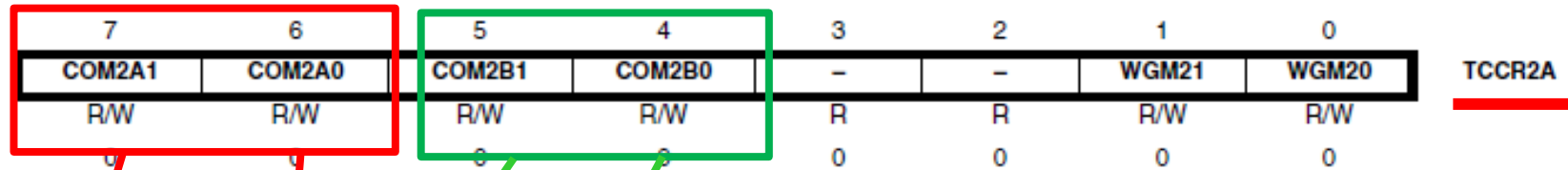
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Mega2560: Timer 2. Pin styring A + B. **Fast** PWM.

7	6	5	4	3	2	1	0	
COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	TCCR2A
R/W	R/W	R/W	R/W	R	R	R/W	R/W	
0	0	0	0	0	0	0	0	

COM2A1	COM2A0	Description
0	0	Normal port operation, OC2A disconnected
0	1	WGM22 = 0: Normal Port Operation, OC2A Disconnected WGM22 = 1: Toggle OC2A on Compare Match
1	0	Clear OC2A on Compare Match, set OC2A at BOTTOM (non-inverting mode)
1	1	Set OC2A on Compare Match, clear OC2A at BOTTOM (inverting mode)

COM2B1	COM2B0	Description
0	0	Normal port operation, OC2B disconnected
0	1	Reserved
1	0	Clear OC2B on Compare Match, set OC2B at BOTTOM (non-inverting mode)
1	1	Set OC2B on Compare Match, clear OC2B at BOTTOM (inverting mode)
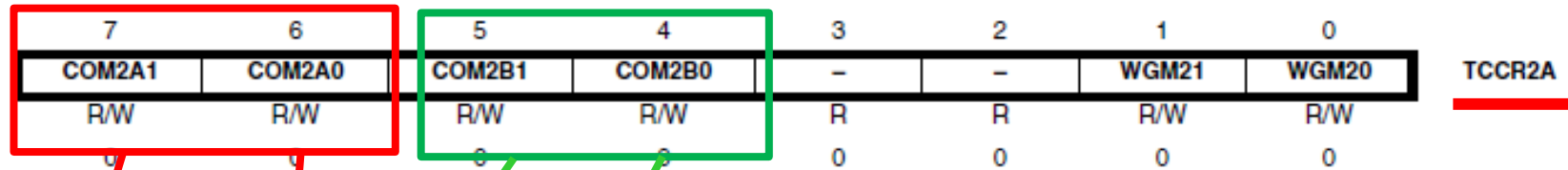
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Mega2560: Timer 2. Pin styring A+B. **Ikke-fast** PWM.

7	6	5	4	3	2	1	0	
COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	TCCR2A
R/W	R/W	R/W	R/W	R	R	R/W	R/W	
0	0	0	0	0	0	0	0	

COM2A1	COM2A0	Description
0	0	Normal port operation, OC2A disconnected
0	1	WGM22 = 0: Normal Port Operation, OC2A Disconnected WGM22 = 1: Toggle OC2A on Compare Match
1	0	Clear OC2A on Compare Match when up-counting Set OC2A on Compare Match when down-counting
1	1	Set OC2A on Compare Match when up-counting Clear OC2A on Compare Match when down-counting

COM2B1	COM2B0	Description
0	0	Normal port operation, OC2B disconnected
0	1	Reserved
1	0	Clear OC2B on Compare Match when up-counting Set OC2B on Compare Match when down-counting
1	1	Set OC2B on Compare Match when up-counting Clear OC2B on Compare Match when down-counting

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Mega2560: Timer 2. OC pins.

OC2A = PB, ben 4

OC2B = PH, ben 6

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Test ("socrative.com": Room = MSYS)

o Denne kode initierer Mega2560's Timer 1:
DDRB = 0xFF;
TCCR1A = 0b11000011;
TCCR1B = 0b00000001;
Hvilken værdi skal herefter skrives til registeret OCR1A for at få et PWM signal på OC1A benet med **50%** duty cycle?

A: OCR1A = 128;

• B: OCR1A = 256;

• C: OCR1A = 512;

• D: OCR1A = 1024;

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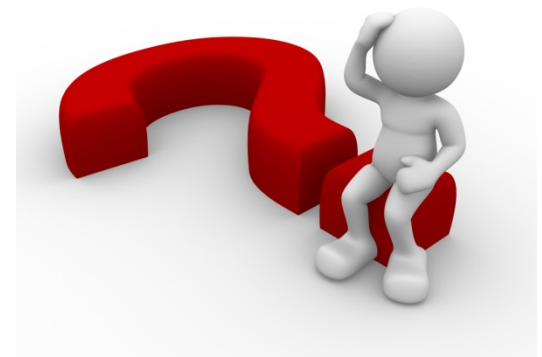
Test ("socrative.com": Room = MSYS)

- Mega2560's Timer 1 er initieret til "**10 bit Phase Correct PWM**".
  CPU clock-frekvens er **3,6864 MHz**.
  Timer 1's clock prescaler er sat til **256**.
  Hvilken <u>frekvens</u> har PWM-signalet ?

- A: Cirka 14 Hz

- B: Cirka 3600 Hz

- C: Cirka 7 Hz

- D: Cirka 1 Hz

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Slut på lektion 15

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