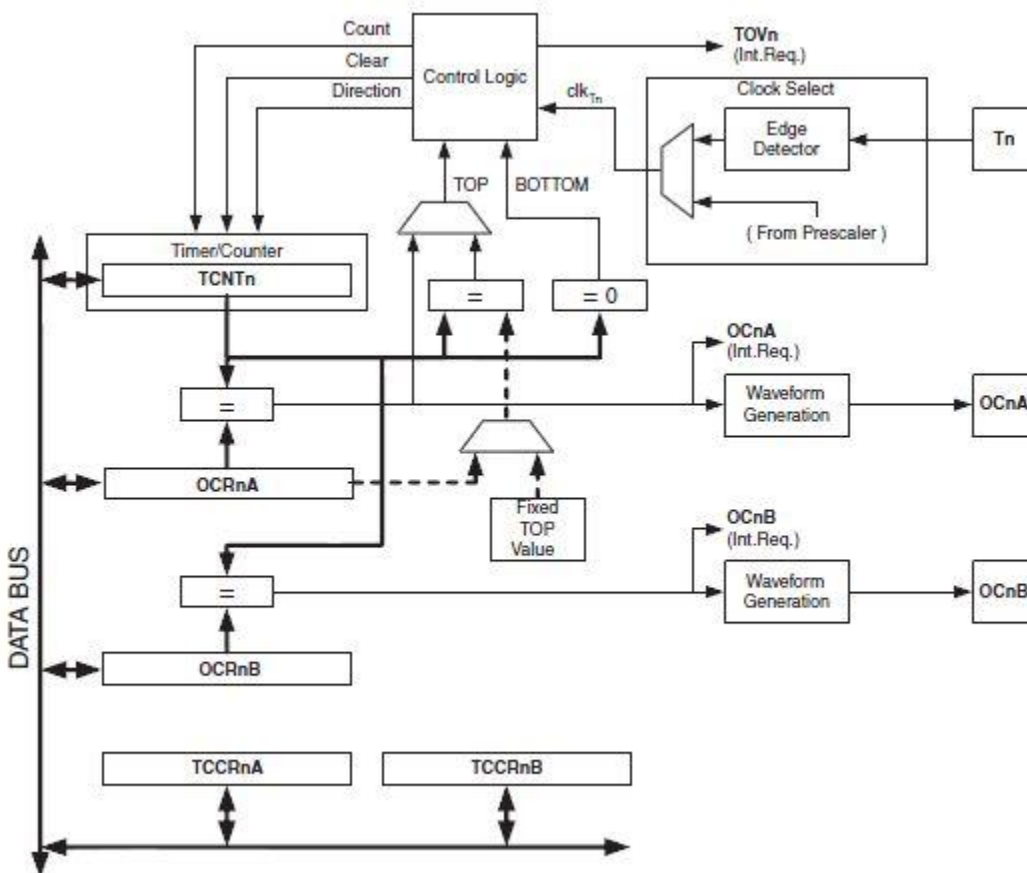


Timer/Counter PWM Subsystem

Reference:

1. Timer with PWM
2. Adafruit Motor Shield - Part 2 Timer PWM
3. Section 17. "8-bit Timer/Counter2 with PWM and Asynchronous Operation" of the ATmega328P datasheet

Figure 17-1. 8-bit Timer/Counter Block Diagram



1. For Timer/Counter 2, which waveform modes implement pulse width modulation?

ANSWER: Modes 1, 3, 5, 7

2. Which mode(s) instructs the timer to count up to a specified value and then restart from the BOTTOM (0x00). What is this mode(s) named?

ANSWER: Modes 3 and 7 Fast PWM

For more on the Fast PWM Mode read Section 17.7.3 "Fast PWM Mode" in the datasheet.

3. Which mode(s) instructs the timer to count up to a specified value and then counts down to BOTTOM (0x00)? What is this mode(s) named?

ANSWER: Modes 1 and 5 Phase-Correct PWM

4. What modes restrict the frequency of the PWM to one of five (5) values defined by (a) the clock frequency (fclk) (b) a prescale value (1, 8, 64, 256, 1024), and (c) the value of TOP?

ANSWER: Modes 3 and 1

5. What values would needed to be saved in registers TCCR2A and TCCR2B so Timer/Counter 2 operates in Mode 3 Fast PWM, OC2A non-inverted output and OC2B off, with a clock prescaler of $clk_{I/O}/32$. Hint: Review Section 17.11 Register Description in the ATmega datasheet or Section 7.3 Pertinent Register Descriptions in your textbook. Hint: read the Adafruit Motor Shield - Part 2 pdf document and Section 17.7.3 "Fast PWM Mode" in the ATmega datasheet.

ANSWER:

In fast PWM mode, the compare unit allows generation of PWM waveforms on the OC2A pin. Setting the COM2A1 and COM2A0 bits to two (10_2) will produce a non-inverted PWM TOP is defined as 0xFF when WGM2:0 = 3 (See Table 17-3 on page 158). The actual OC2A value will only be visible on the port pin if the data direction for the port pin is set as output.

Bit	7	6	5	4	3	2	1	0	
(0xB0)	COM2A1 COM2A0 COM2B1 COM2B0 – – WGM21 WGM20								TCCR2A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	
Bit	7	6	5	4	3	2	1	0	
(0xB1)	FOC2A FOC2B – – WGM22 CS22 CS21 CS20								TCCR2B
Read/Write	W	W	R	R	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Table 17-3. Compare Output Mode, Fast PWM Mode⁽¹⁾

COM2A1	COM2A0	Description
0	0	Normal port operation, OC2A disconnected.
0	1	WGM22 = 0: Normal Port Operation, OC0A 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).

Table 17-8. Waveform Generation Mode Bit Description

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

- Notes: 1. MAX= 0xFF
2. BOTTOM= 0x00

Table 17-9. Clock Select Bit Description

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)

TCCR2A = 0b10000011 = 0x83
TCCR2B = 0b00000011 = 0x03

6. Using the `_BV(bit)` macro, write the C code to configure TCCR2A without modifying any other bits. Specifically do not modify the configuration of the output OC2B. Hint: read the Adafruit Motor Shield - Part 2 pdf document

```
TCCR2A |= _BV(COM2A1) | _BV(WGM20) | _BV(WGM21); // fast PWM, turn on oc0
```

7. Write the C code to configure bit 3 of PORT B as an output so you can see the PWM output.

ANSWER: `DDRB |= _BV(3);`

8. Assuming that Timer/Counter 2 is configured in FAST PWM mode as described in the last question, what frequency would be generated on output OC2A given the 16 MHz clock of the Arduino.

ANSWER: $f_{OC2APWM} = 1.953 \text{ KHz}$

DISCUSSION:

For our 8-bit counter/timers the PWM frequency is given by the equation:

$$f_{OCnxPWM} = \frac{f_{clk} / 10}{N \cdot 256}$$

The N variable represents the prescale factor (1, 8, 32, 64, 128, 256, or 1024).

9. Given Adafruit method call `motor.setSpeed(200)`; what hexadecimal number would be loaded into Output Compare Register A (OCR2A).

ANSWER: `OCR2A = 0xC8`

10. Again assuming the call `motor.setSpeed(200)`; what duty cycle would be generated on the OC2A pin?

ANSWER: $\text{Duty Cycle} = 200/255 = 78 \%$