Motion control using Pulse Width Modulation in Firebird V

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Agenda for Discussion

1. Pulse Width Modulation
   - Duty Cycle
   - Motion Control Using Pulse Width Modulation in Firebird V
2. Registers
   - Timer/Counter 5(TCNT5)
   - Output Compare Register 5
   - Timer/Counter Control Register (TCCR5A and TCCR5B)
     - TCCR5A
     - TCCR5B
3. Summary
4. Program

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Duty Cycle

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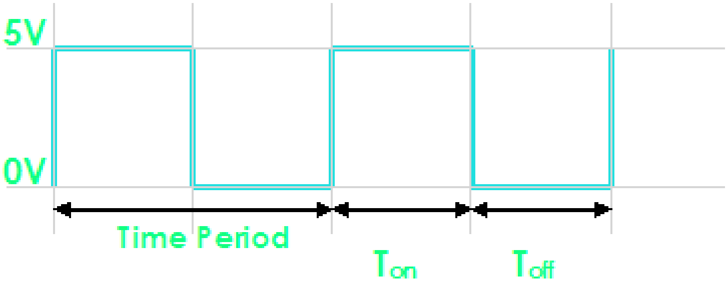

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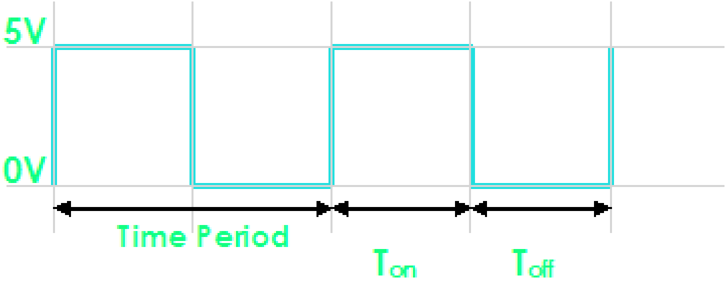

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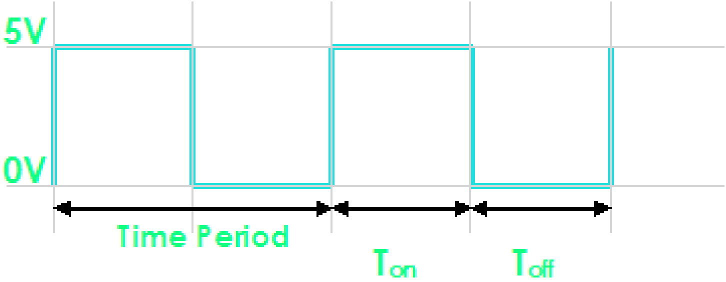

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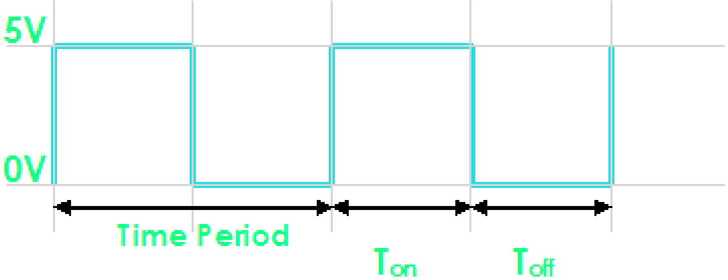
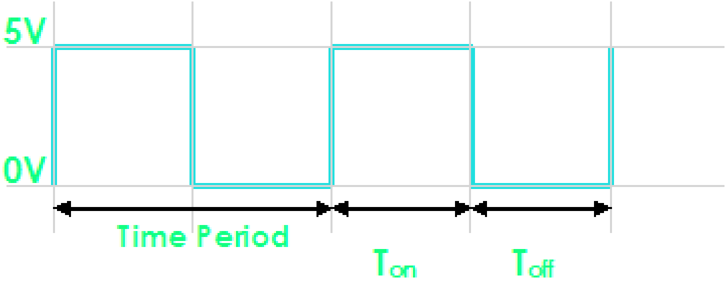


- ✓ The signal remains "ON" for some time and "OFF" for some time.
- ✓ Ton = Time the output remains high.
- ✓ Toff = Time the output remains Low.

Duty Cycle



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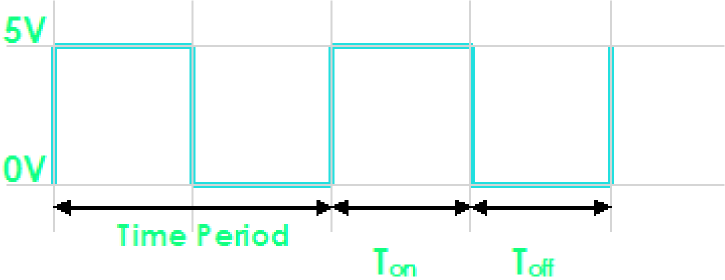
- ✓ When output is high the voltage is 5v

Duty Cycle



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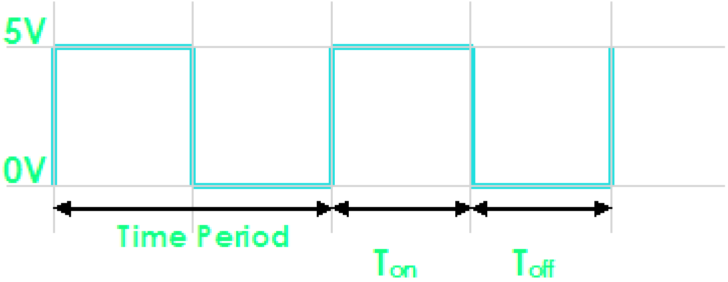
Duty Cycle



- ✓ The signal remains "ON" for some time and "OFF" for some time.
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- ✓ Time Period(T) = Ton + Toff

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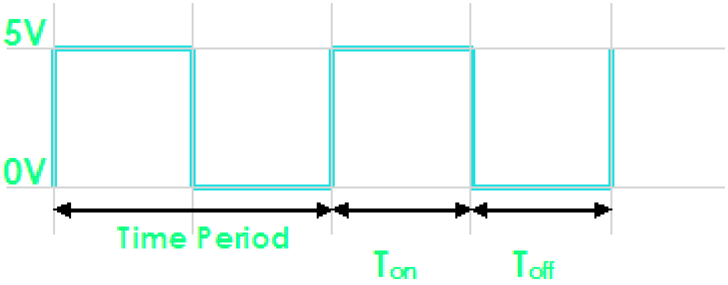

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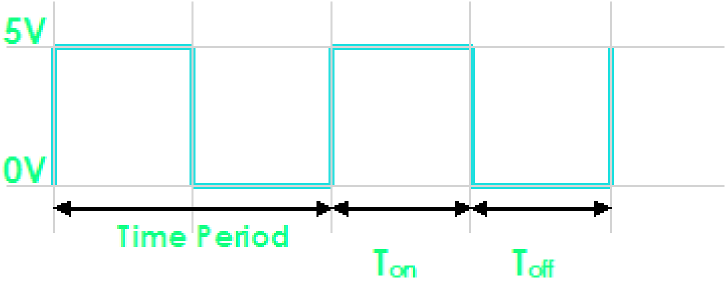
Duty Cycle



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- ✓ When output is high the voltage is 5v
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- ✓ Time Period(T) = Ton + Toff
- ✓ Duty Cycle = Ton/(Ton + Toff)
- ✓ Duty Cycle = 50%

Duty Cycle (Contd..)

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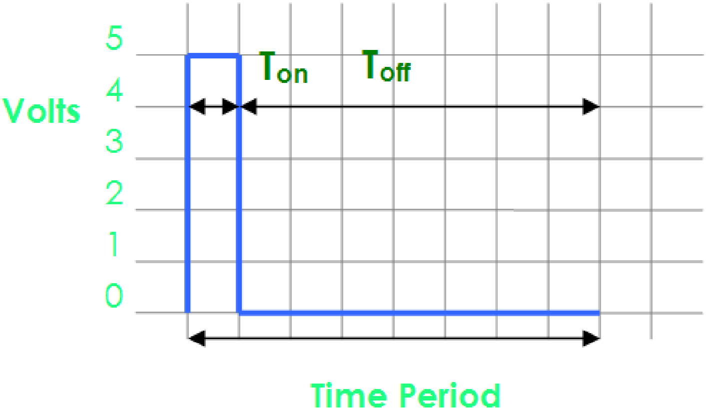

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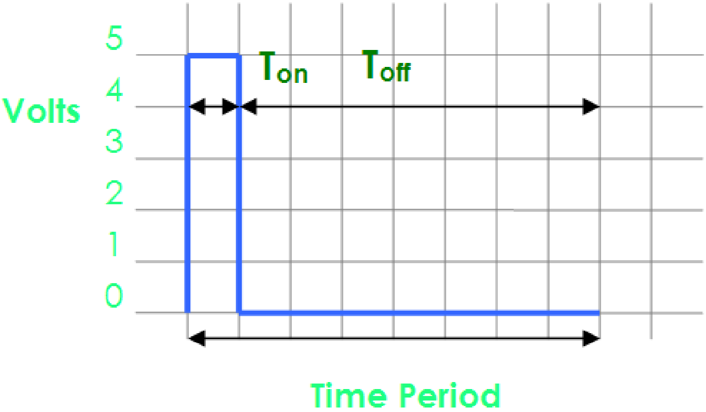
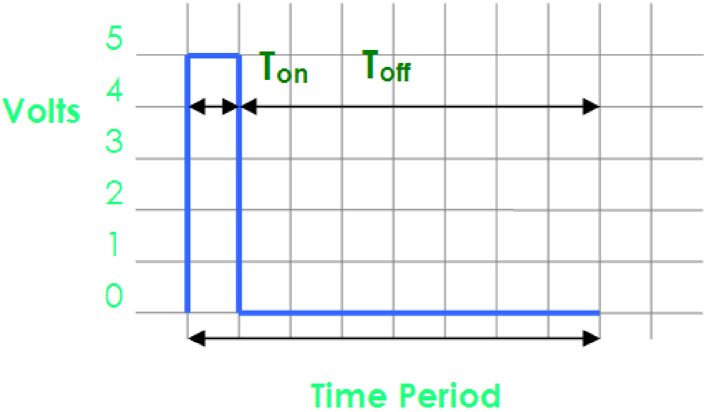


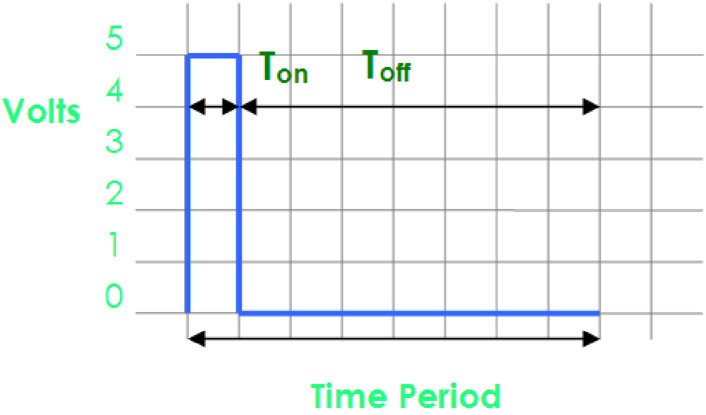
✓ Ton = Time the output remains high = 1

Duty Cycle (Contd..)



- ✓ Ton = Time the output remains high = 1
- ✓ Toff = Time the output remains Low = 7

Duty Cycle (Contd..)



- ✓ Ton = Time the output remains high = 1
- ✓ Toff = Time the output remains Low = 7
- ✓ Duty Cycle = 12.5%

Duty Cycle (Contd..)

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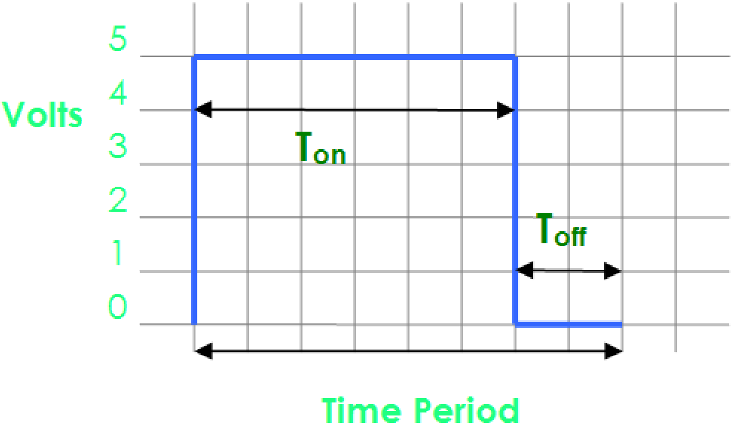

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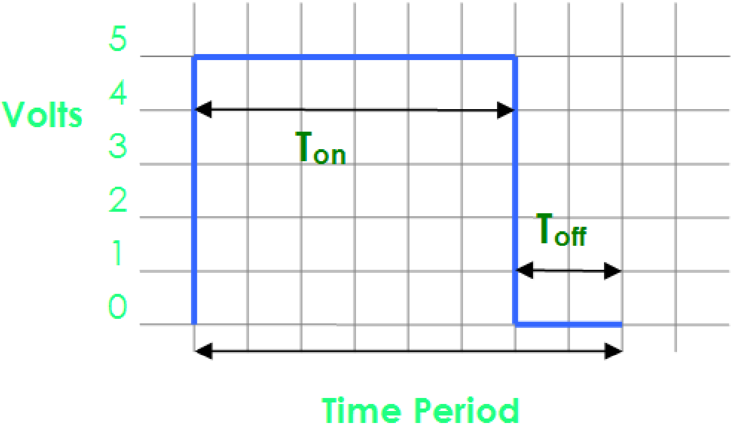
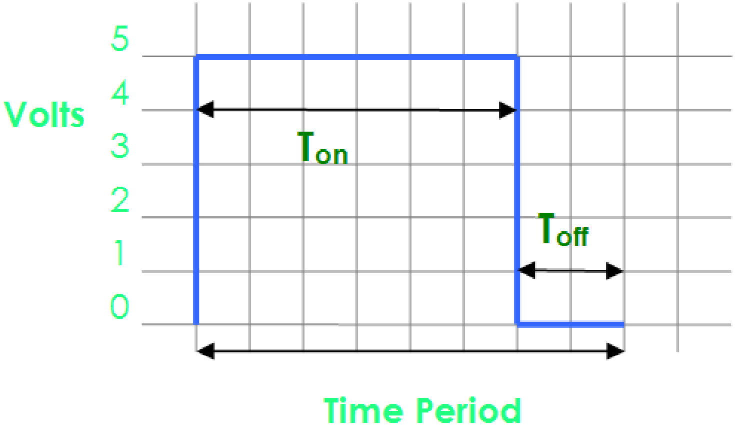


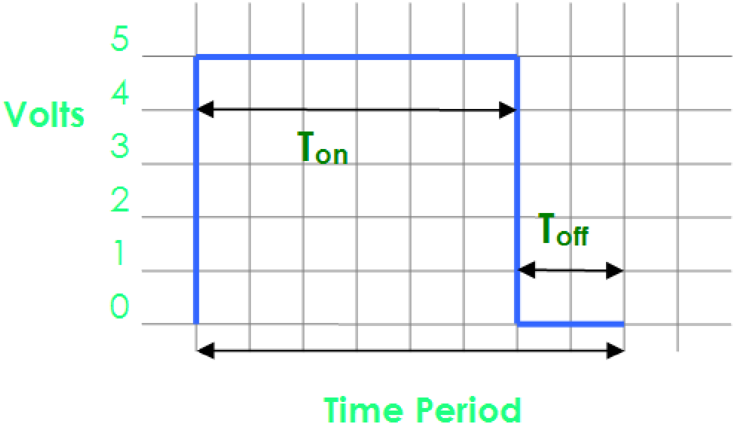
✓ Ton = Time the output remains high = 6

Duty Cycle (Contd..)



- ✓ Ton = Time the output remains high = 6
- ✓ Toff = Time the output remains Low = 2

Duty Cycle (Contd..)



- ✓ Ton = Time the output remains high = 6
- ✓ Toff = Time the output remains Low = 2
- ✓ Duty Cycle = 75%

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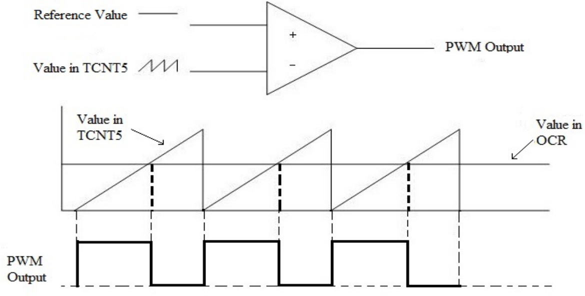

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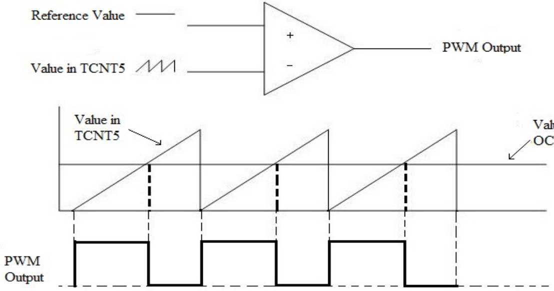

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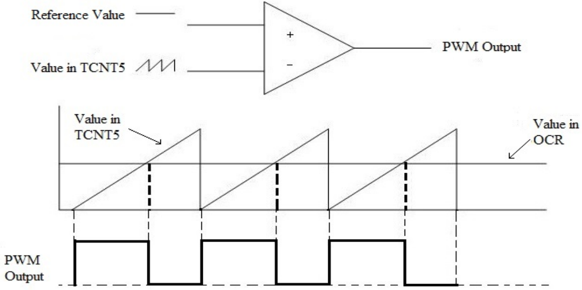

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  - ✓ Timer/Counter register 5(TCNT5)

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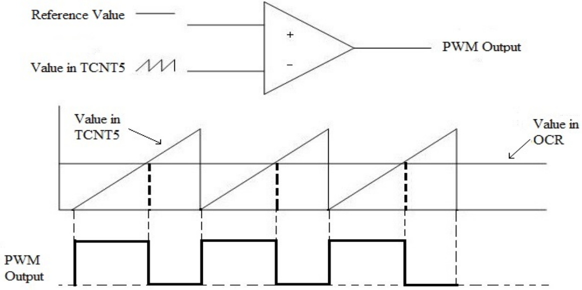

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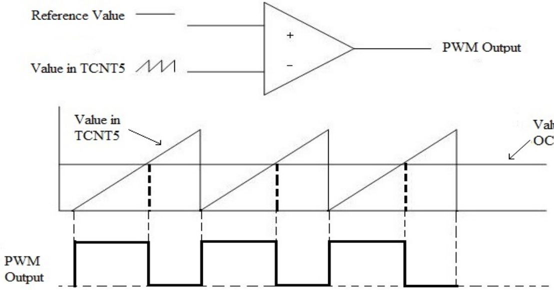

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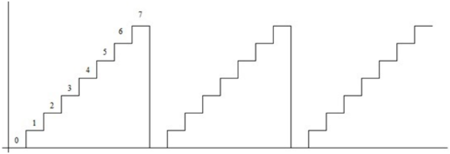

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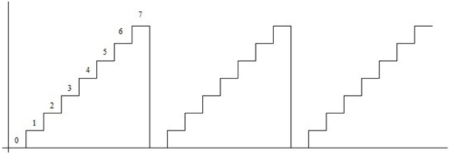

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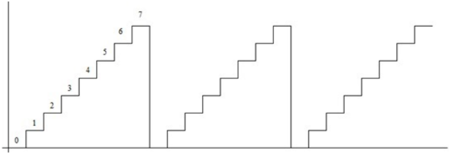

- For n-bit counter, maximum value $= 2^n - 1$.
- The Timer/Counter 5 is a 16 bit register.
- We use it in 8-bit mode, for PWM generation.

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- Similarly, OCR5B is associated with the OC5B pin (PORTL.4), This pin is connected to the enable(EN1) pin of motor driver, which is associated with the right motor.

Timer/Counter Control Register (TCCR5A and TCCR5B)

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  2. The type of PWM Signal to be generated.
  3. The Frequency of the PWM signal.

Timer/Counter Control Register 5A(TCCR5A)

Bit	Symbol	Description	Bit Value
7	COM5A1	Compare Output Mode for Channel A bit 1	1
6	COM5A0	Compare Output Mode for Channel A bit 0	0
5	COM5B1	Compare Output Mode for Channel B bit 1	1
4	COM5B0	Compare Output Mode for Channel B bit 0	0
3	COM5C1	Compare Output Mode for Channel C bit 1	1
2	COM5C0	Compare Output Mode for Channel C bit 0	0
1	WGM11	Waveform Generation Mode bit 1	0
0	WGM10	Waveform Generation Mode bit 0	1

- There are 2 types of bits in TCCR5A: Compare output mode bit & waveform generation mode bit.

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3	COM5C1	Compare Output Mode for Channel C bit 1	1
2	COM5C0	Compare Output Mode for Channel C bit 0	0
1	WGM11	Waveform Generation Mode bit 1	0
0	WGM10	Waveform Generation Mode bit 0	1

- There are 2 types of bits in TCCR5A: Compare output mode bit & waveform generation mode bit.
- Compare Output Mode bits decide the action to be taken when counter(TCNT5) value matches reference value in Output Compare Register(OCR5).

Timer/Counter Control Register 5A (TCCR5A) (...contd)

- In the given table:

Timer/Counter Control Register 5A (TCCR5A) (...contd)

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  - ✓ COM5A1 AND COM5A0 bits are used to control the output on left motor.

Timer/Counter Control Register 5A (TCCR5A) (...contd)

- In the given table:
  - ✓ COM5A1 AND COM5A0 bits are used to control the output on left motor.
  - ✓ COM5B1 and COM5B0 bits are used to control the output on right motor.

TCCR5A: Compare Output Mode Bits

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).

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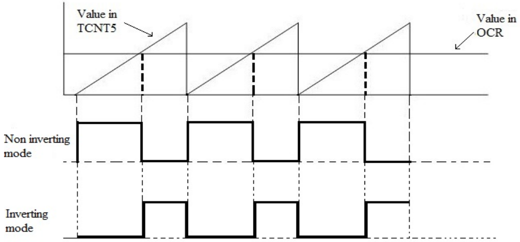
1	0	Clear OCnA/OCnB/OCnC on compare match, set OCnA/OCnB/OCnC at BOTTOM (non-inverting mode).
1	1	Set OCnA/OCnB/OCnC on compare match, clear OCnA/OCnB/OCnC at BOTTOM (inverting mode).

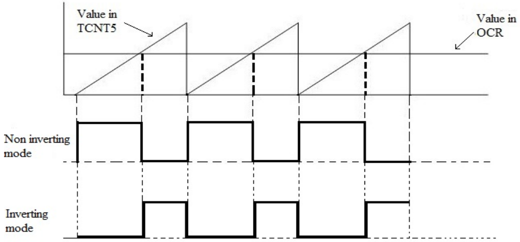
- We are using non-inverting mode for PWM generation.

Inverting and Non-inverting mode



- There are two modes of pwm waveform generation:

Inverting and Non-inverting mode



- There are two modes of pwm waveform generation:
- Non-inverting mode and inverting mode

TCCR5A: Waveform Generation Mode Bits

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

- The Waveform Generation Mode bits are used to generate the type of PWM signal needed.

TCCR5A: Waveform Generation Mode Bits

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0	0	0	0	0	Normal	0xFFFF	Immediate	MAX
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4	0	1	0	0	CTC	OCRnA	Immediate	MAX
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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

- The Waveform Generation Mode bits are used to generate the type of PWM signal needed.
- We will be using Fast PWM, 8-bit mode.

Timer/Counter Control Register 5B (TCCR5B)

Bit	Symbol	Description	Bit Value
7	ICNC5	Input Capture Noise Canceller	0
6	ICES5	Input Capture Edge Select	0
5	–	Reserved Bit	0
4	WGM53	Waveform Generation Mode bit 3	0
3	WGM52	Waveform Generation Mode bit 2	**1**
2	CS52	Clock Select	0
1	CS51	Clock Select	**1**
0	CS50	Clock Select	**1**

Timer/Counter Control Register 5B (TCCR5B)

Bit	Symbol	Description	Bit Value
7	ICNC5	Input Capture Noise Canceller	0
6	ICES5	Input Capture Edge Select	0
5	–	Reserved Bit	0
4	WGM53	Waveform Generation Mode bit 3	0
3	WGM52	Waveform Generation Mode bit 2	1
2	CS52	Clock Select	0
1	CS51	Clock Select	1
0	CS50	Clock Select	1

- In the above Table:

Timer/Counter Control Register 5B (TCCR5B)

Bit	Symbol	Description	Bit Value
7	ICNC5	Input Capture Noise Canceller	0
6	ICES5	Input Capture Edge Select	0
5	–	Reserved Bit	0
4	WGM53	Waveform Generation Mode bit 3	0
3	WGM52	Waveform Generation Mode bit 2	1
2	CS52	Clock Select	0
1	CS51	Clock Select	1
0	CS50	Clock Select	1

- In the above Table:
- Input Capture Noise Canceller and Input Capture Edge Select bits are not being used here.

Timer/Counter Control Register 5B (TCCR5B)

Bit	Symbol	Description	Bit Value
7	ICNC5	Input Capture Noise Canceller	0
6	ICES5	Input Capture Edge Select	0
5	–	Reserved Bit	0
4	WGM53	Waveform Generation Mode bit 3	0
3	WGM52	Waveform Generation Mode bit 2	1
2	CS52	Clock Select	0
1	CS51	Clock Select	1
0	CS50	Clock Select	1

- In the above Table:
- Input Capture Noise Canceller and Input Capture Edge Select bits are not being used here.
- WGM bits (WGM52 and WGM53), are used for PWM generation.

Timer/Counter Control Register 5B (TCCR5B)

Bit	Symbol	Description	Bit Value
7	ICNC5	Input Capture Noise Canceller	0
6	ICES5	Input Capture Edge Select	0
5	–	Reserved Bit	0
4	WGM53	Waveform Generation Mode bit 3	0
3	WGM52	Waveform Generation Mode bit 2	1
2	CS52	Clock Select	0
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0	CS50	Clock Select	1

- In the above Table:
- Input Capture Noise Canceller and Input Capture Edge Select bits are not being used here.
- WGM bits (WGM52 and WGM53), are used for PWM generation.
- CS52, CS51, CS50 (Clock select) bits are used to select a frequency at which timer/counter Register will increment its value.

TCCR5B: Clock Select Bits

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.

- Prescalar is used to reduce the frequency of the clock, suitable for the type of PWM being generated.

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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.

- Prescalar is used to reduce the frequency of the clock, suitable for the type of PWM being generated.
- Clock select bits decide the factor with which clock frequency will be divided.

TCCR5B: Clock Select Bits

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.

- Prescalar is used to reduce the frequency of the clock, suitable for the type of PWM being generated.
- Clock select bits decide the factor with which clock frequency will be divided.
- We are using 64 as prescaler so, Clock select bits, we need is 011 .

PWM Mode selection

- $\text{Component frequency} = \frac{f_{clk_{I/O}}}{N\ x\ prescaler}.............equation(1)$

PWM Mode selection

- Component frequency $= \dfrac{f_{clk_{I/O}}}{N \ x \ prescaler}$ ....$equation(1)$
- Here the component is DC motor whose frequency is 1000Hz

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- Since we are using PWM in 8 bit mode N $= 2^8 = 256$

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- $1000 = \dfrac{14745600}{2^8\ x\ prescaler}$

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- Here the component is DC motor whose frequency is 1000Hz
- $Clockfrequency(f_{clk_{I/O}}) = 14745600Hz$
- Since we are using PWM in 8 bit mode N $= 2^8 = 256$
- Putting all the above values in equation (1), we get
- $1000 = \dfrac{14745600}{2^8\ x\ prescaler}$
- $1000 = \dfrac{14745600}{256\ x\ prescaler}$
- prescaler $= \dfrac{14745600}{256\ x\ 1000}$

PWM Mode selection

- Component frequency $= \dfrac{f_{clk_{I/O}}}{N\ x\ prescaler}$ ....$equation(1)$
- Here the component is DC motor whose frequency is 1000Hz
- $Clockfrequency(f_{clk_{I/O}}) = 14745600Hz$
- Since we are using PWM in 8 bit mode N $= 2^8 = 256$
- Putting all the above values in equation (1), we get
- $1000 = \dfrac{14745600}{2^8\ x\ prescaler}$
- $1000 = \dfrac{14745600}{256\ x\ prescaler}$
- prescaler $= \dfrac{14745600}{256\ x\ 1000}$
- prescaler $= 57.6$

PWM Mode selection

- Component frequency $= \dfrac{f_{clk_{I/O}}}{N \ x \ prescaler}$ .... $equation(1)$
- Here the component is DC motor whose frequency is 1000Hz
- $Clockfrequency(f_{clk_{I/O}}) = 14745600Hz$
- Since we are using PWM in 8 bit mode N $= 2^8 = 256$
- Putting all the above values in equation (1), we get
- $1000 = \dfrac{14745600}{2^8 \ x \ prescaler}$
- $1000 = \dfrac{14745600}{256 \ x \ prescaler}$
- prescaler $= \dfrac{14745600}{256 \ x \ 1000}$
- prescaler $= 57.6$
- Closest value to 57.6 is 64. So, we chose 64 as a prescaler value in 8-bit Fast PWM mode.

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.

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- TCNT5H = 0xFF
- TCNT5L = 0x00

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF
- OCR5BH = 0x00

Summary

- In order to use Fast PWM mode to control dc motors of Firebird V. We have to initialize following registers.
- TCNT5H = 0xFF
- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF
- OCR5BH = 0x00
- OCR5BL = 0xFF

Syntax for C-Program

PWM Initialization

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Port Pin Config

Syntax for C-Program

PWM Initialization

Port Pin Config

```
void motion_pin_config (void)  //Configure Pins as Output
{

Port A for motion control and Port L for Velocity Control must be defined Output
}
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PWM Initialization

Syntax for C-Program
PWM Initialization

Port Pin Config

```
void motion_pin_config (void)  //Configure Pins as Output
{

Port A for motion control and Port L for Velocity Control must be defined Output
}
```

PWM Initialization

```
void timer5_init()  //Set Register Values for starting Fast 8-bit PWM
{
TCCR5A =
   TCCR5B =
   TCNT5H = 0xFF;
   TCNT5L = 0x00;
   OCR5AH = 0x00;
   OCR5AL = 0xFF;
   OCR5BH = 0x00;
   OCR5BL = 0xFF;
}
```

Syntax for C-Program

Program

Syntax for C-Program

Program

Main Program

Syntax for C-Program

Program

Main Program

```
int main(void)
{
  init_devices();
  forward();
  while(1)
  {
    velocity(100,100);
    _delay_ms(500);
    velocity(0,255);
    _delay_ms(500);
  }
}
```

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Velocity Function

Syntax for C-Program

Program

Main Program

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  while(1)
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    velocity(100,100);
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    velocity(0,255);
    _delay_ms(500);
  }
}
```

Velocity Function

```
void velocity (unsigned char left_motor, unsigned char right_motor)
{
OCR5AL = (unsigned char)left_motor;
   OCR5BL = (unsigned char)right_motor;
}
```

Thank You!