DC Motor Velocity Control Using Pulse Width Modulation (PWM)

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Agenda for Discussion

1. Introduction
   - Pulse Width Modulation
   - Duty Cycle
2. PWM Generation in AVR
   - Timers in AVR
   - Timer/Counter 5 (TCNT5)
   - Output Compare Register
   - TCCR5A
   - TCCR5B
   - Summary
   - Program

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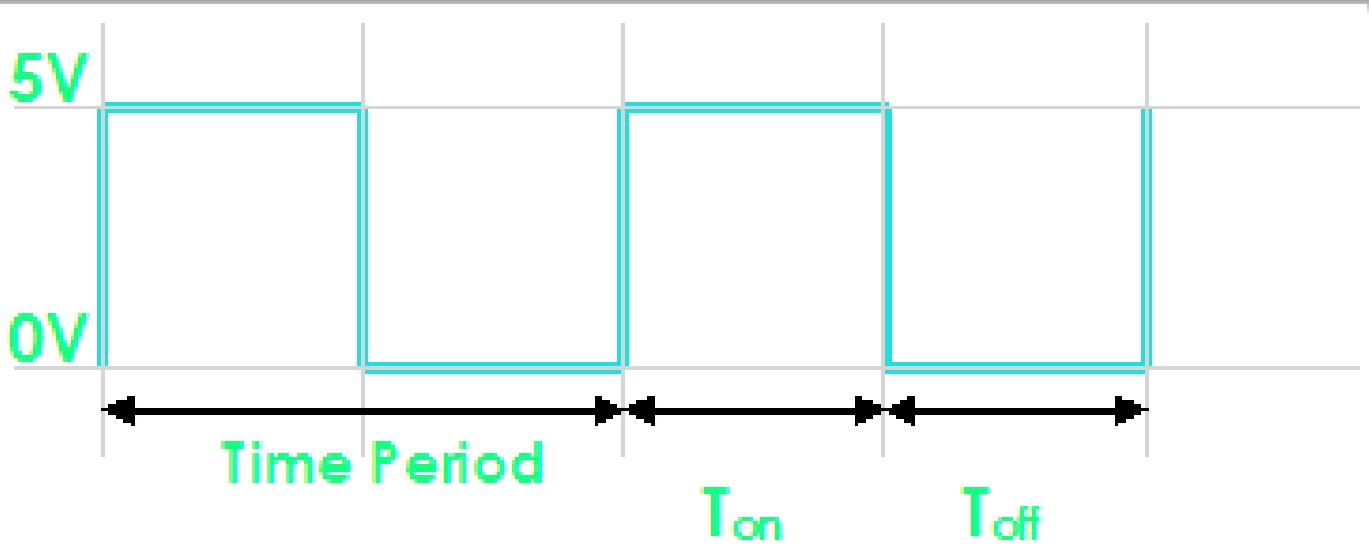

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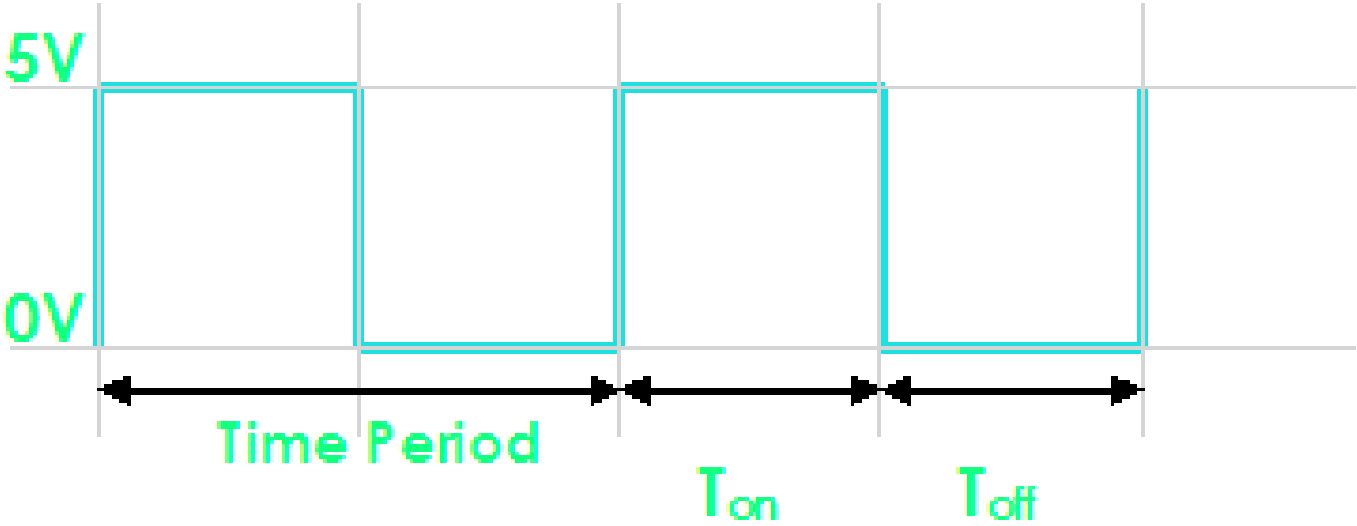

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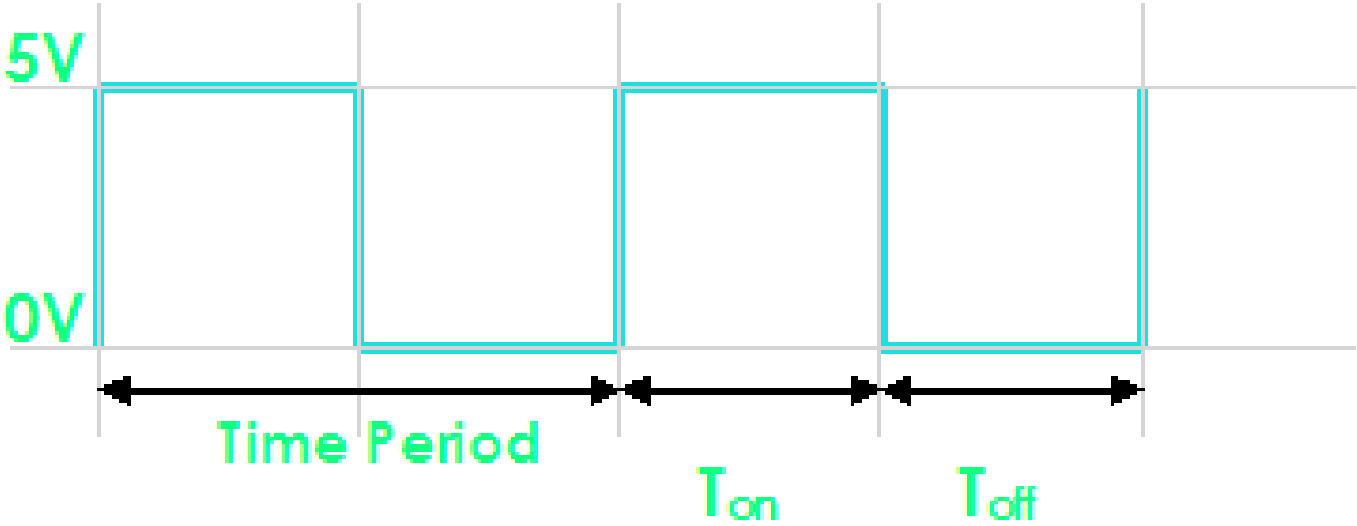

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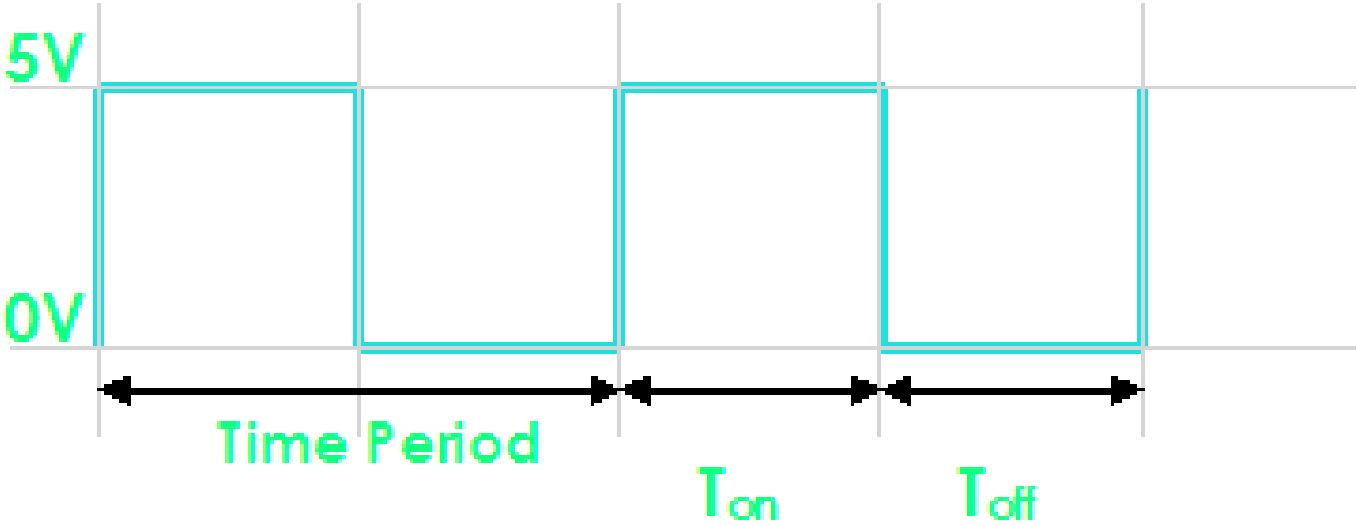

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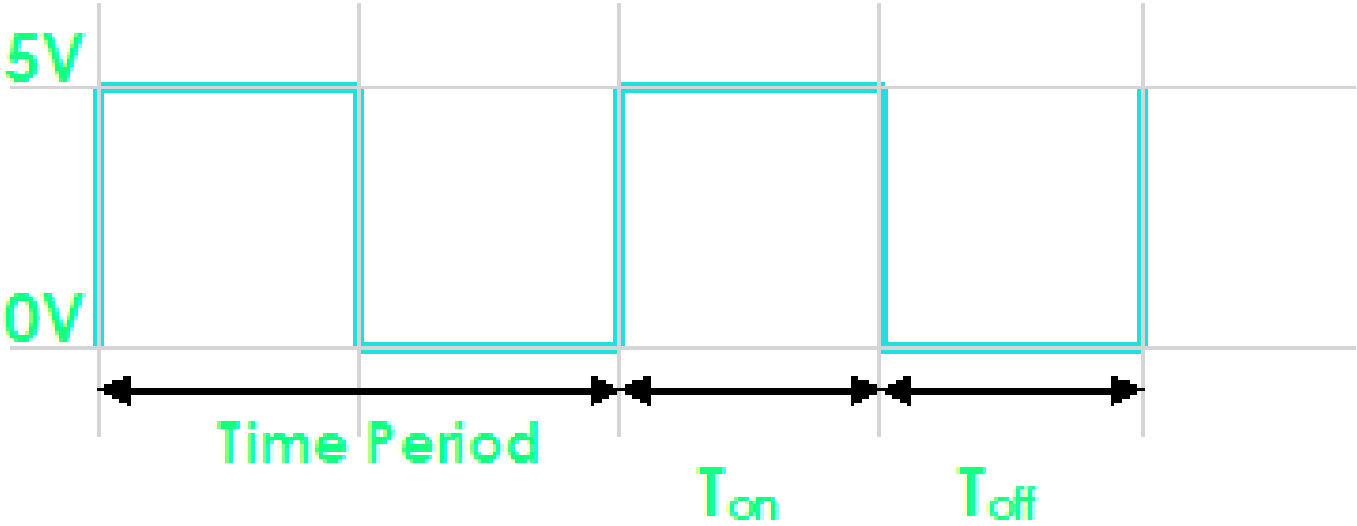

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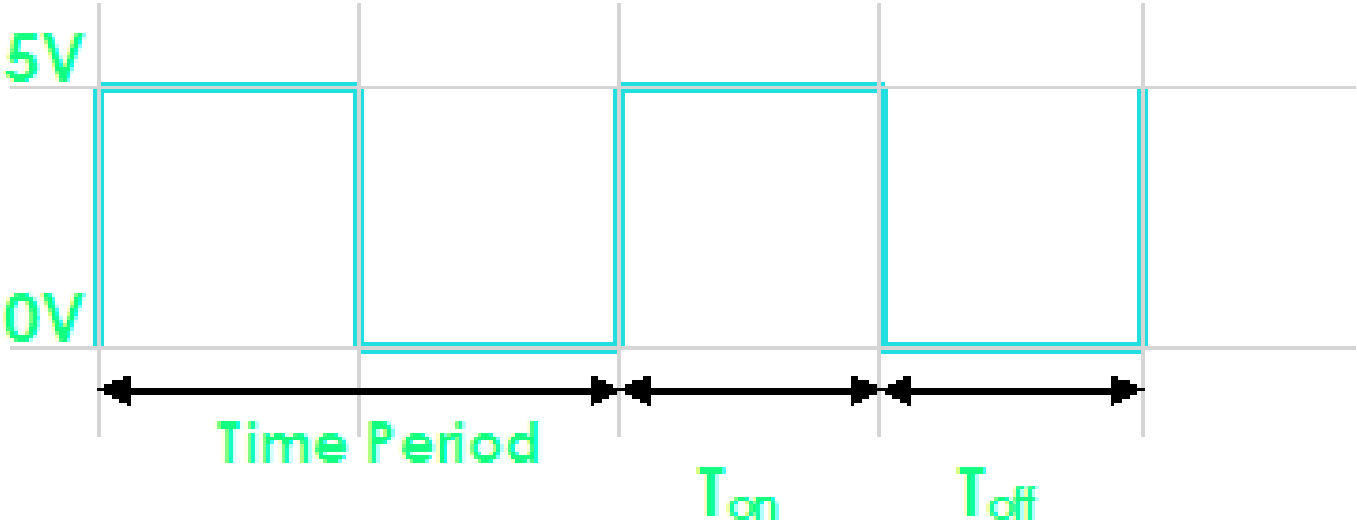

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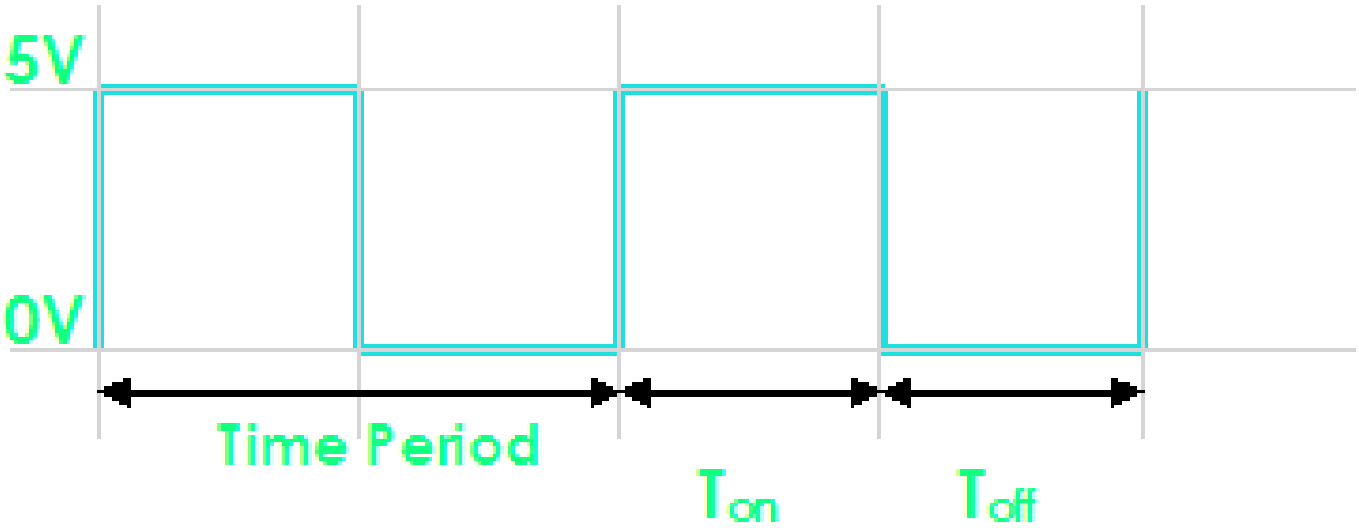

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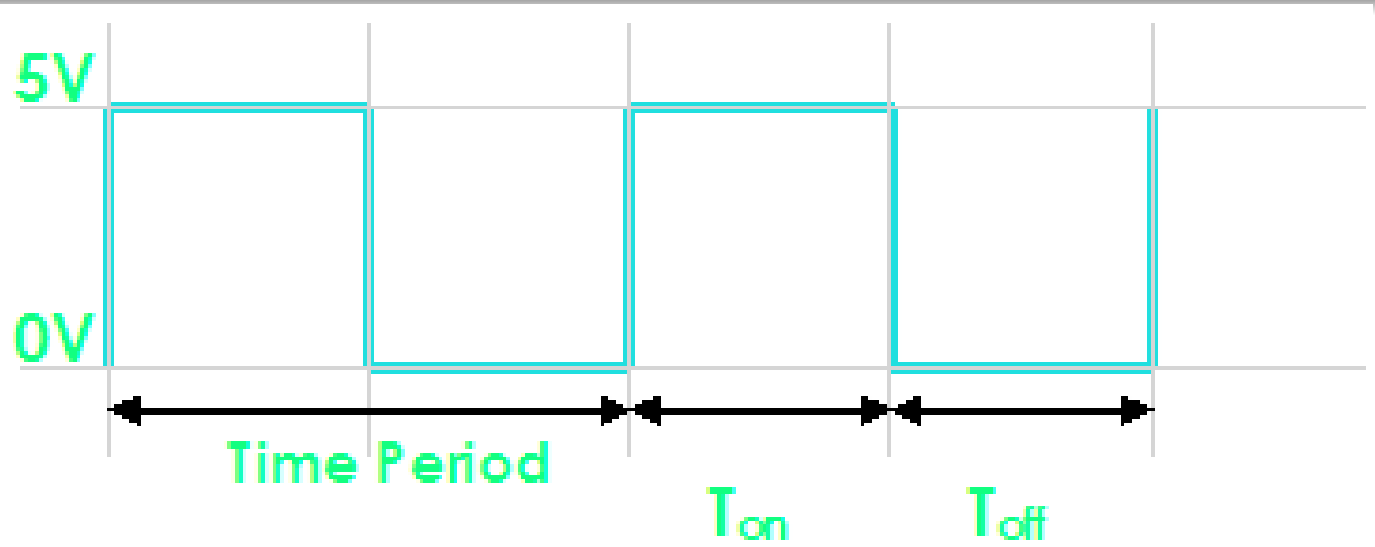
Duty Cycle



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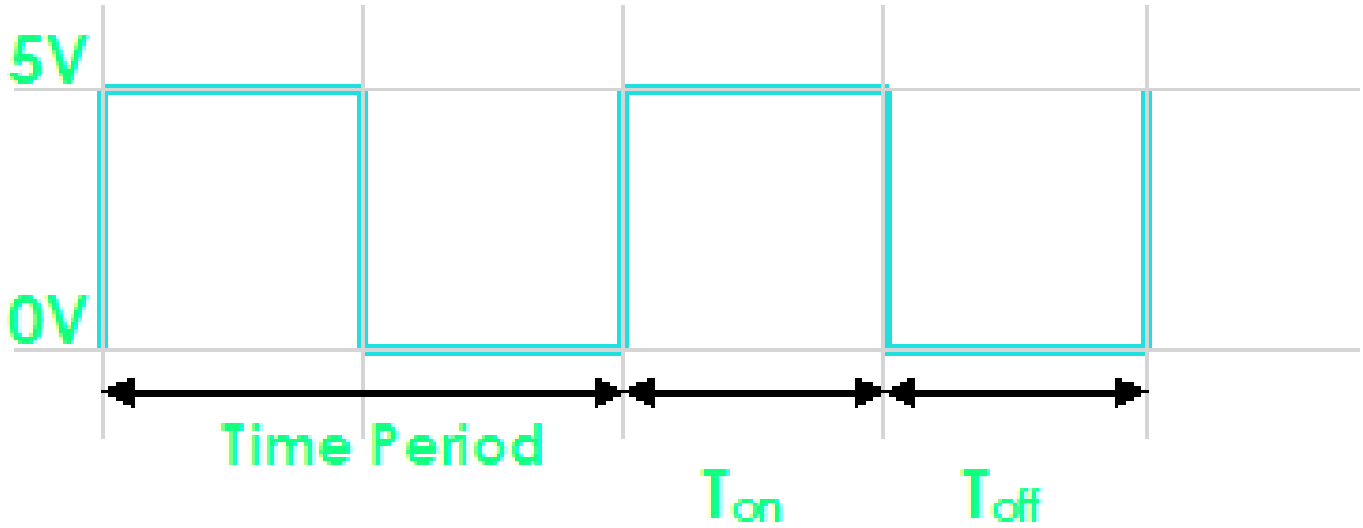

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- Ton = Time the output remains high.
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- When output is high the voltage is 5v
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- Time Period(T) = Ton + Toff
- Duty Cycle = Ton*100/(Ton + Toff)
- Duty Cycle = 50%

Duty Cycle (Contd..)

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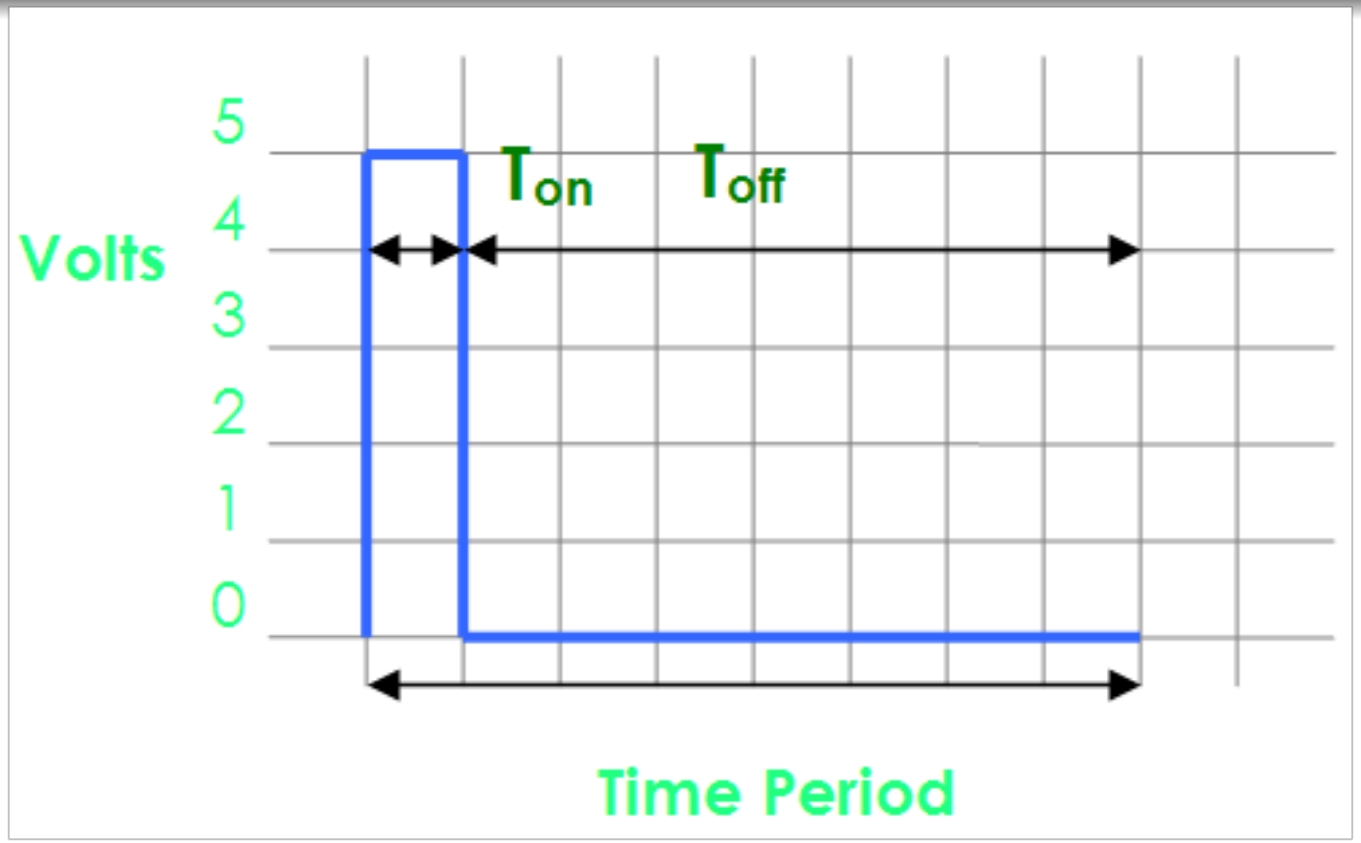
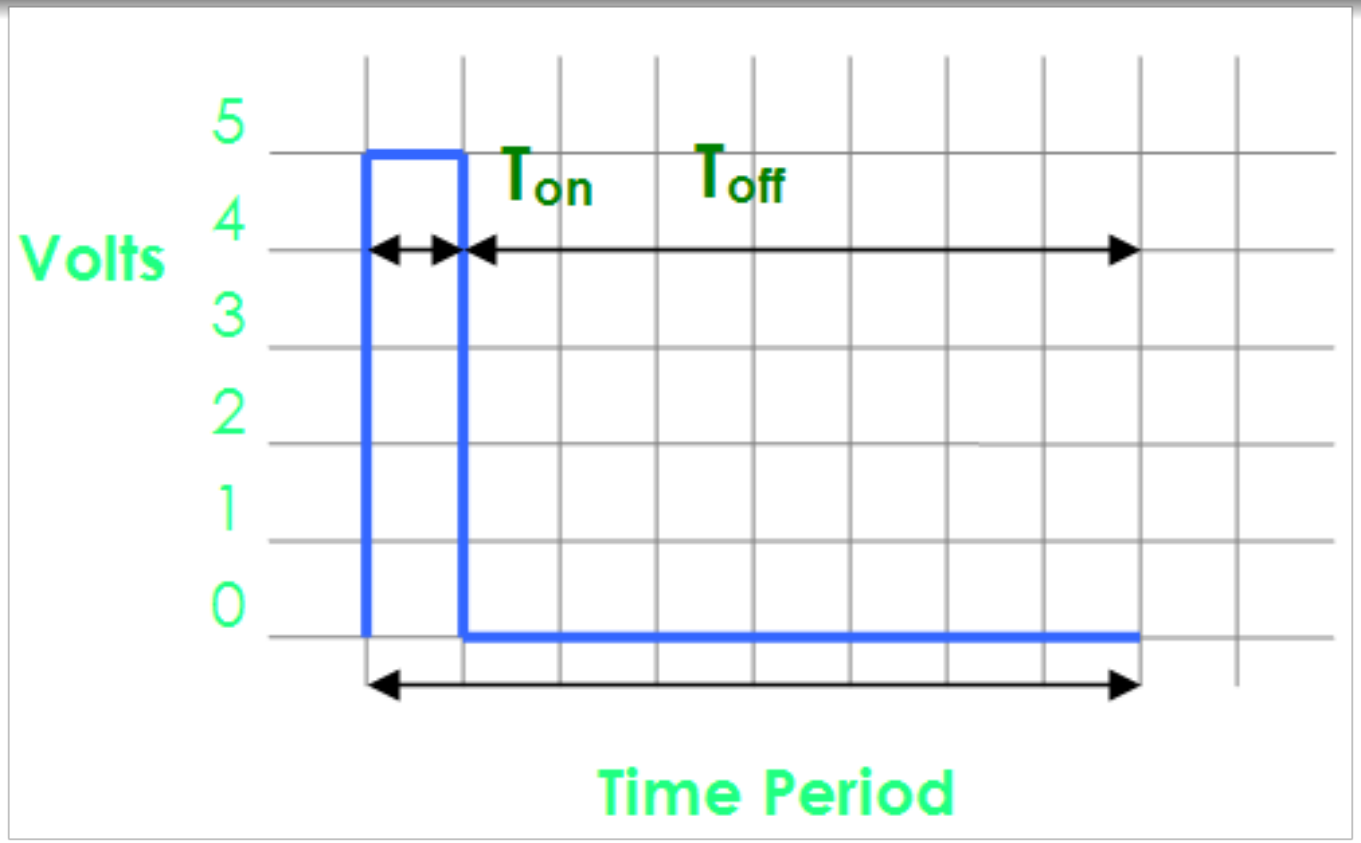
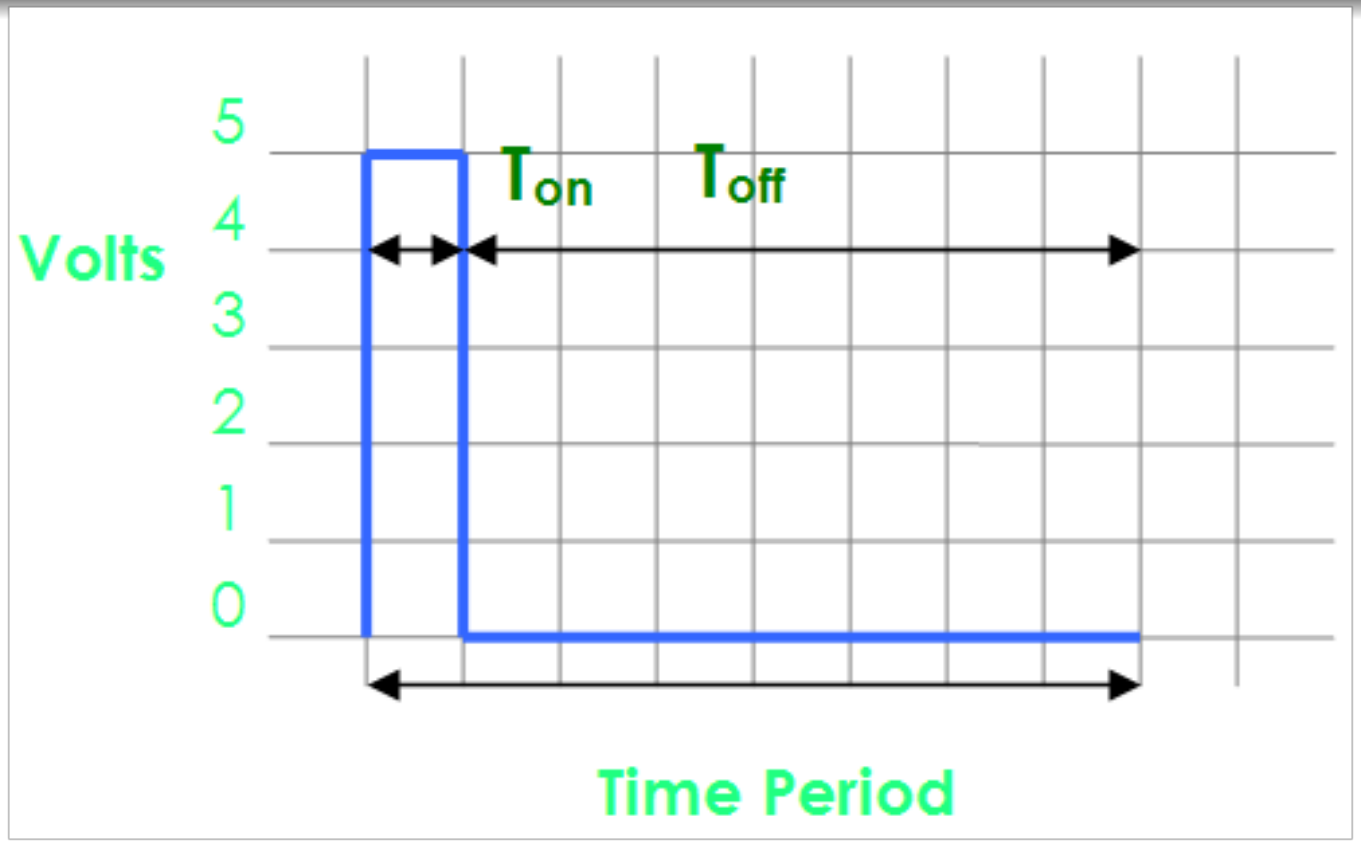


Duty Cycle (Contd..)



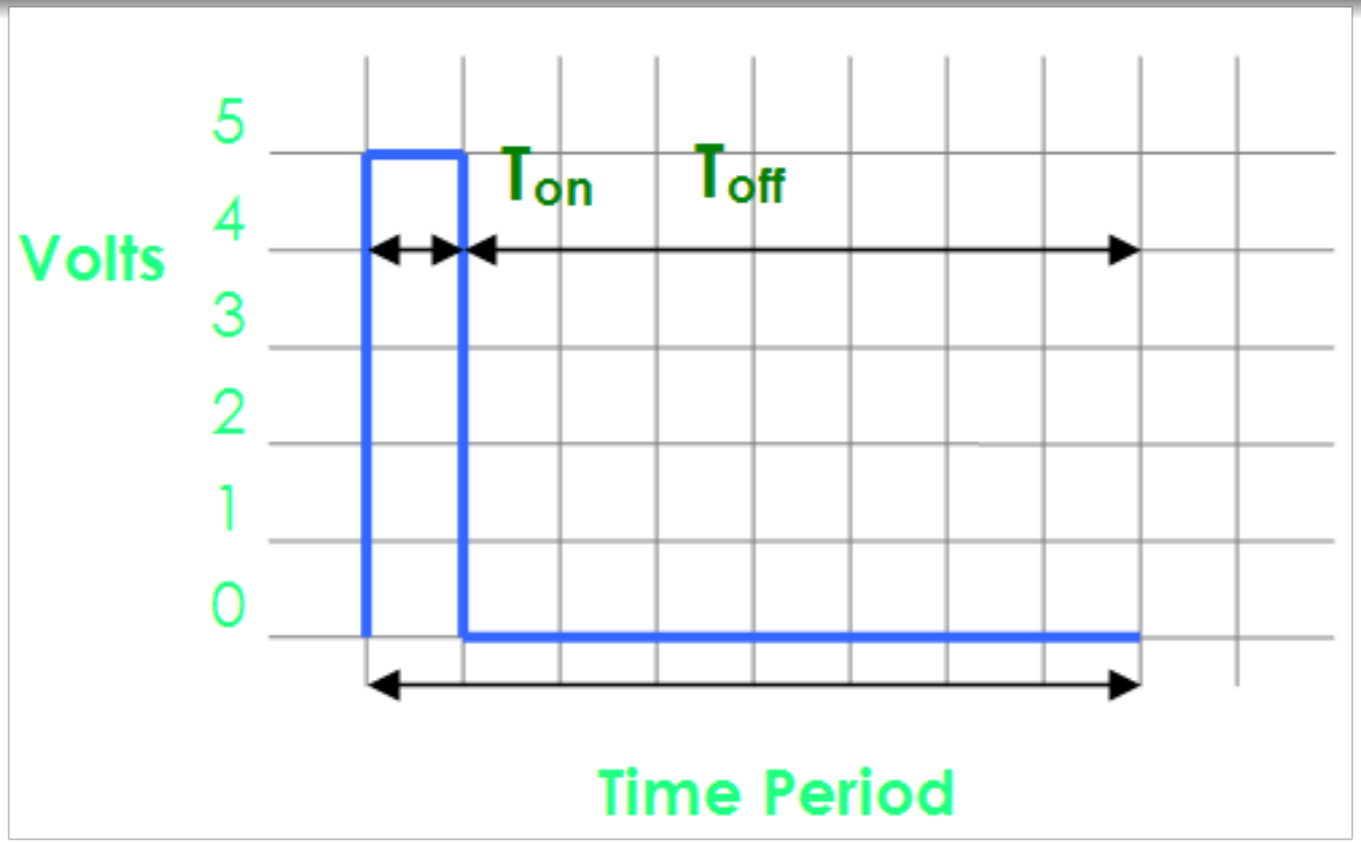
- Ton = Time the output remains high = 1

Duty Cycle (Contd..)



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

Duty Cycle (Contd..)



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- Duty Cycle = 12.5%

Duty Cycle (Contd..)

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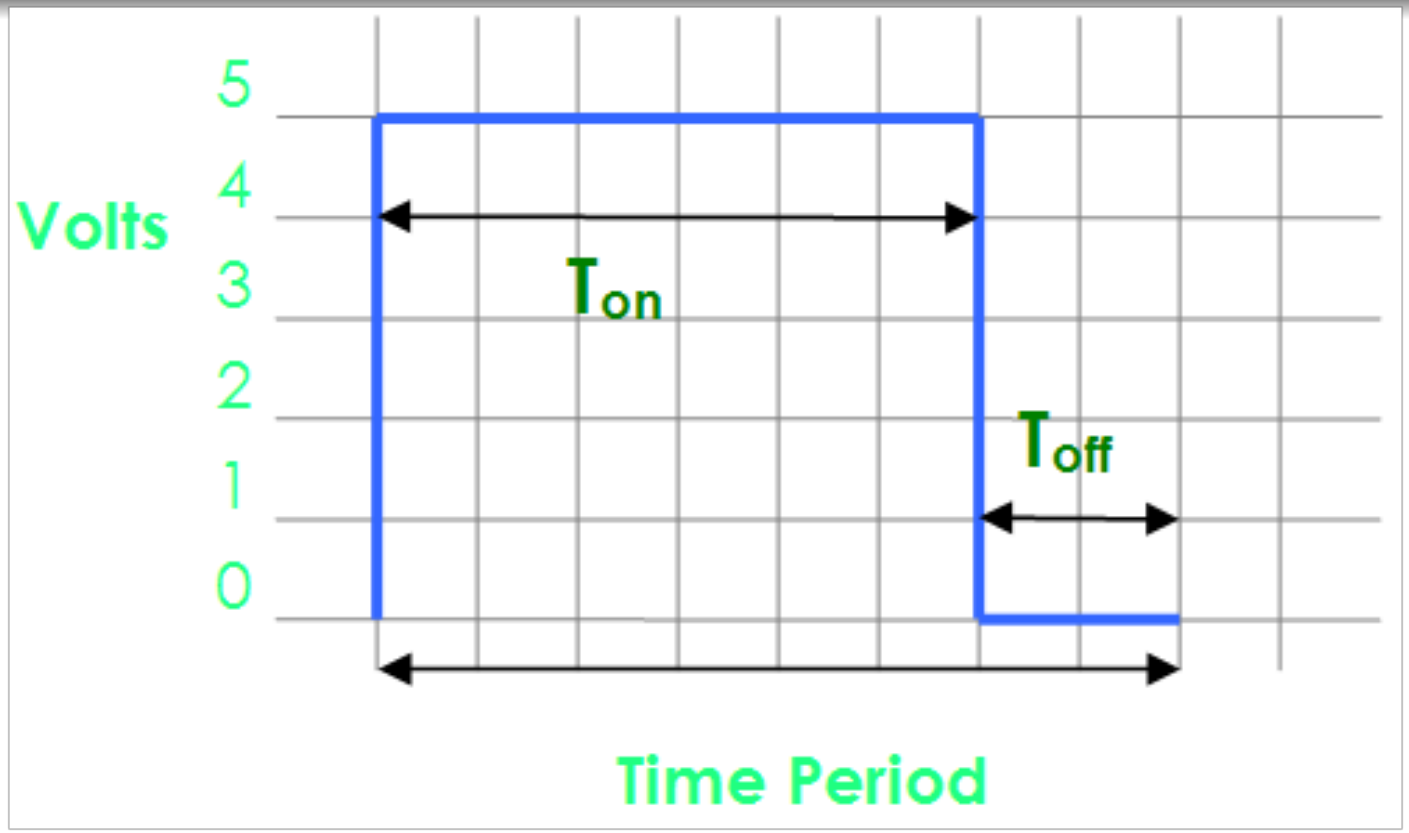

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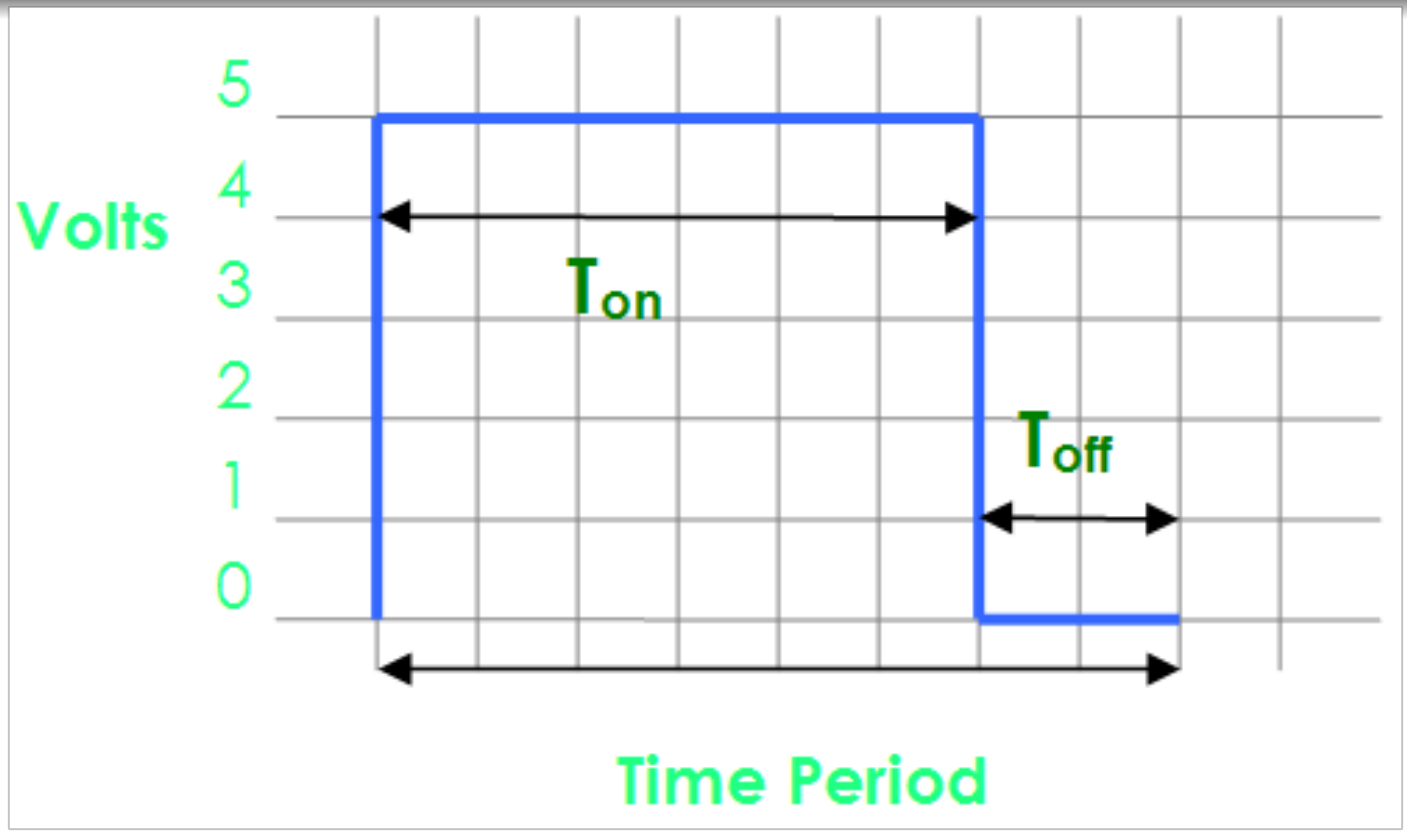
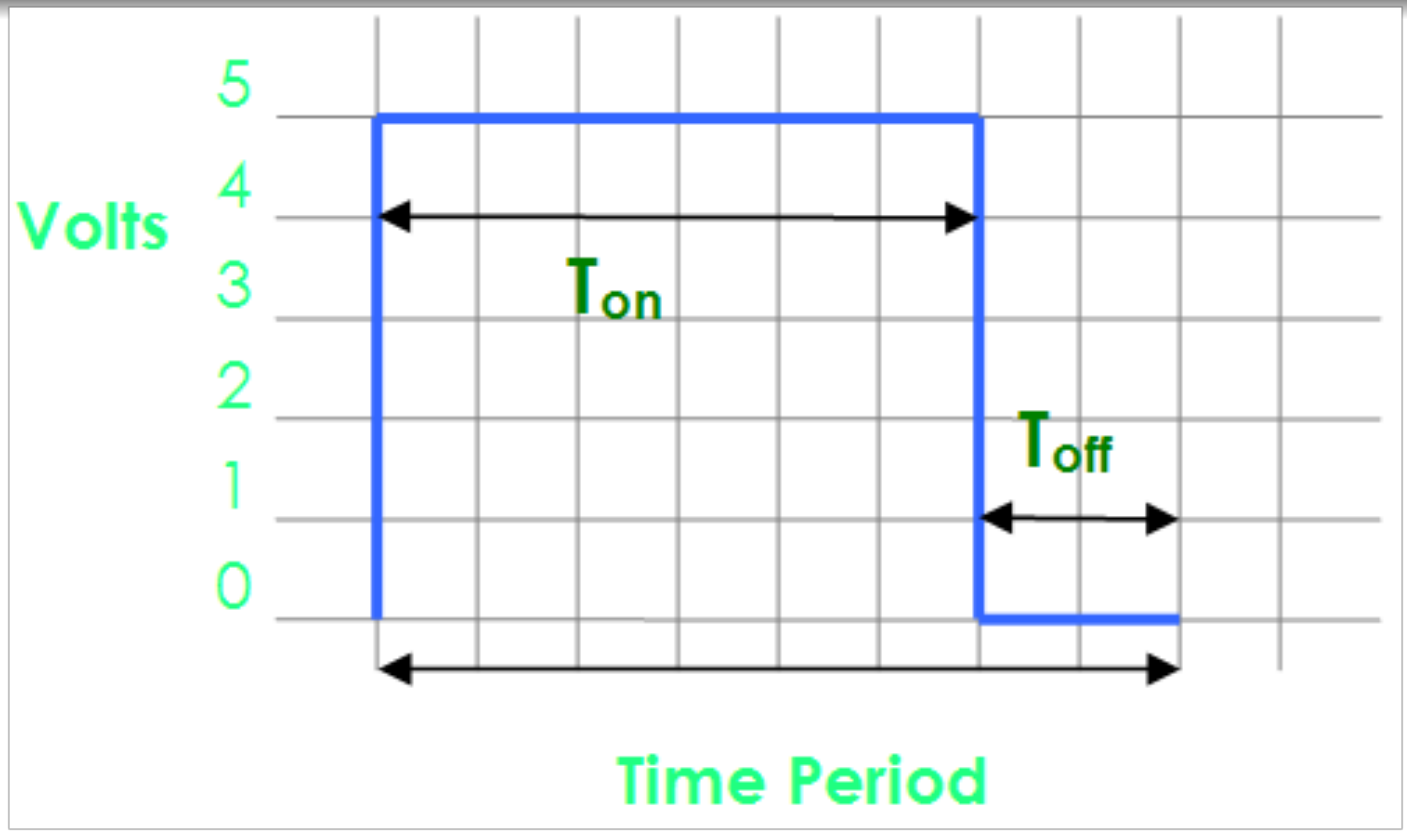


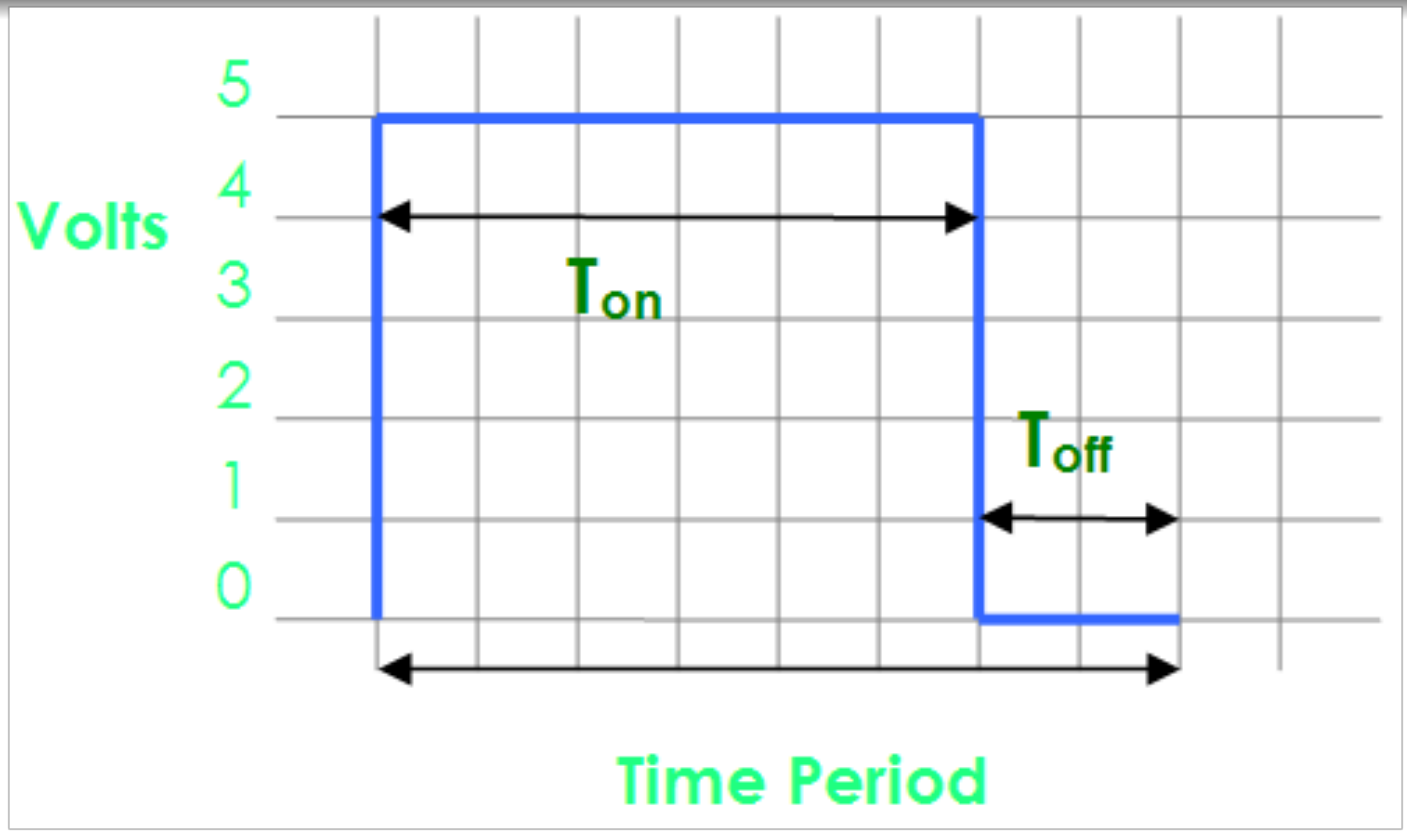
- Ton = Time the output remains high = 6

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%

PWM Generation in AVR

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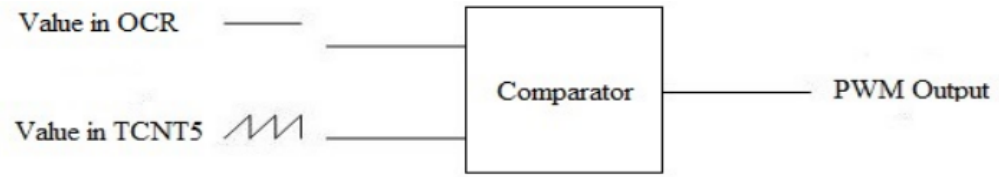
Pulse width waveform generated for motion control of Firebird V is:



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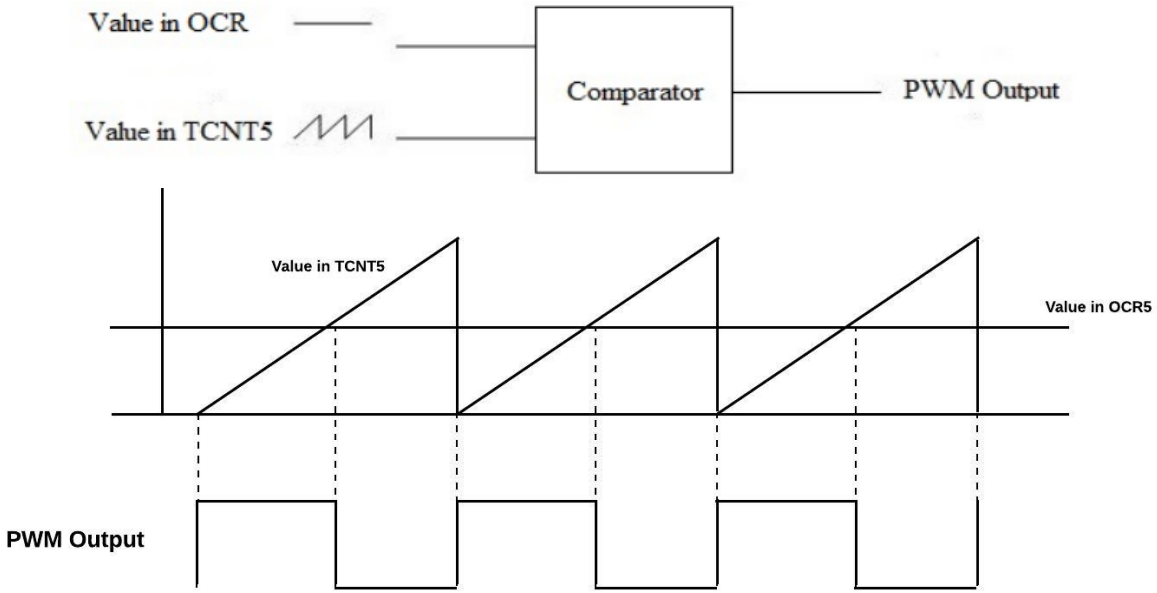

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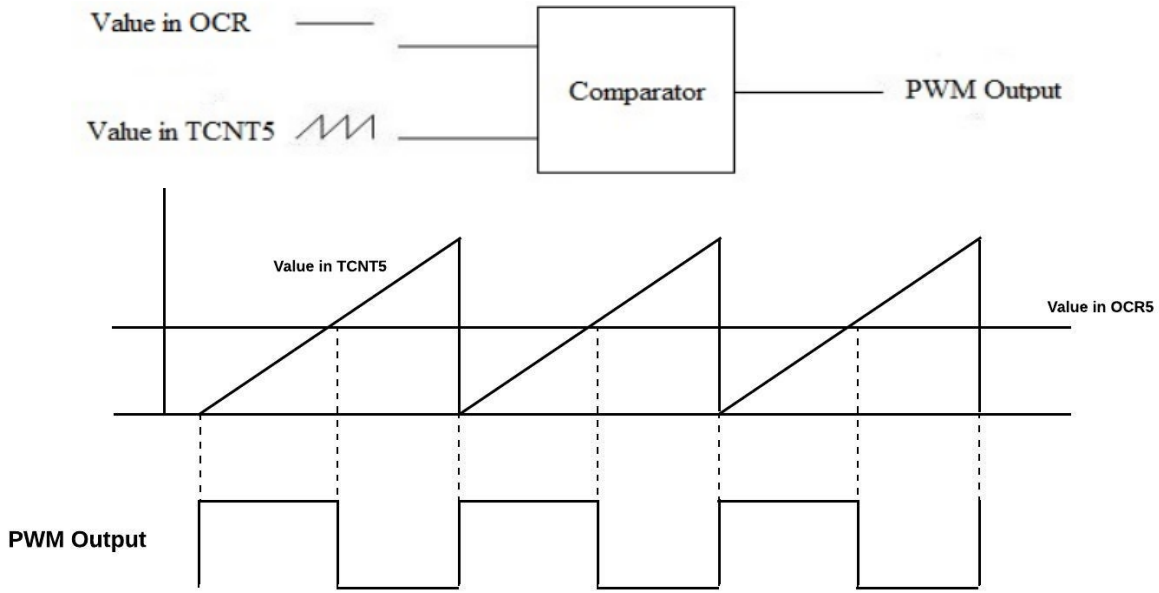

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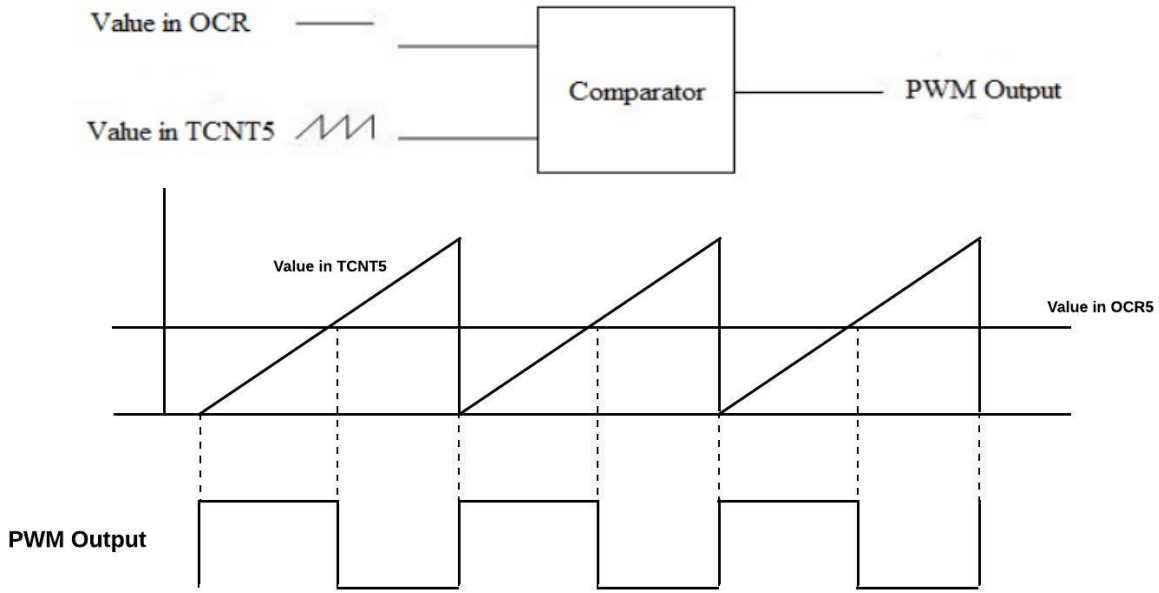

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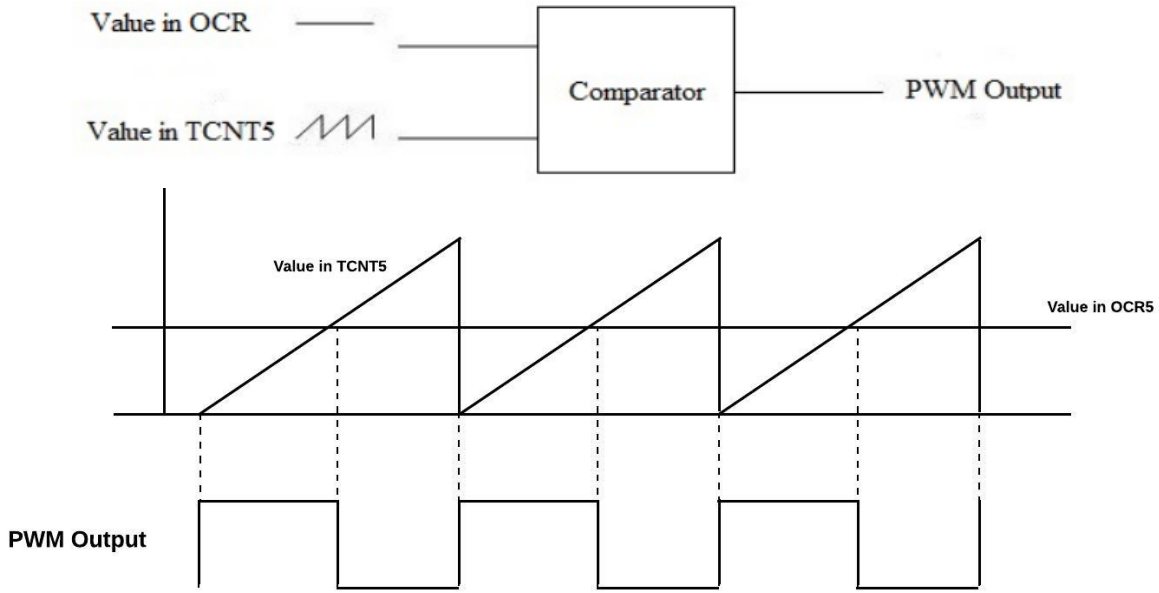

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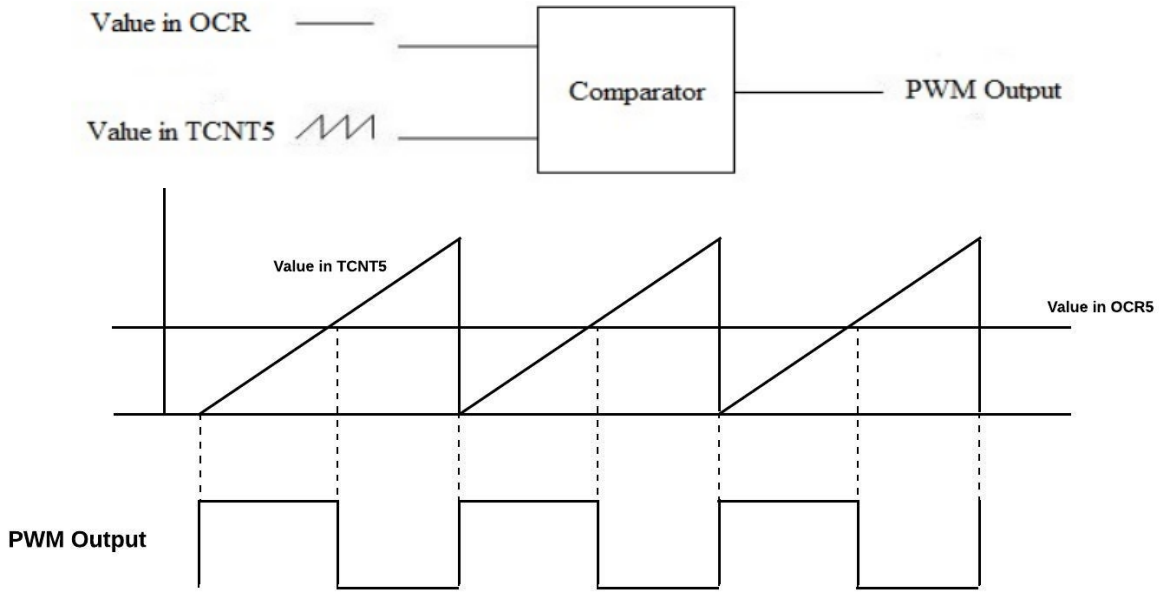

Its generation involves the use of following registers:

- Timer/Counter register 5 (TCNT5)
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- Timer/Counter Control registers (TCCR5A and TCCR5B)

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2. When the counter reaches its maximum count, it rolls over and executes from the start
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   - For 16-bit counter it occurs at 65535 count
3. For speed control of Firebird V, Timer 5 is used.

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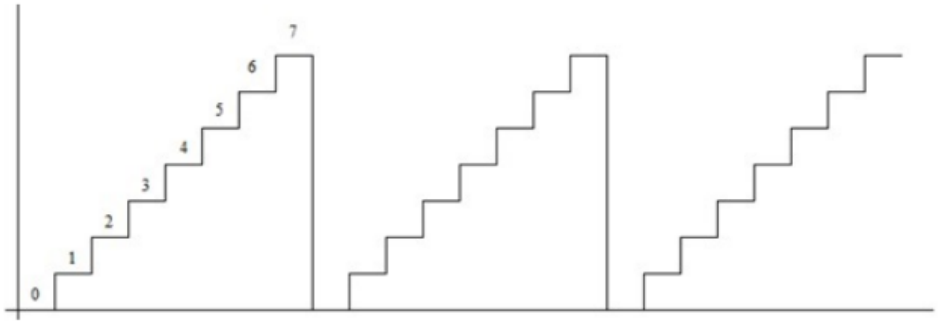
3. For example, a 3 bit counter will have 8 values (i.e. 0-7). Its waveform will be seen as follows:



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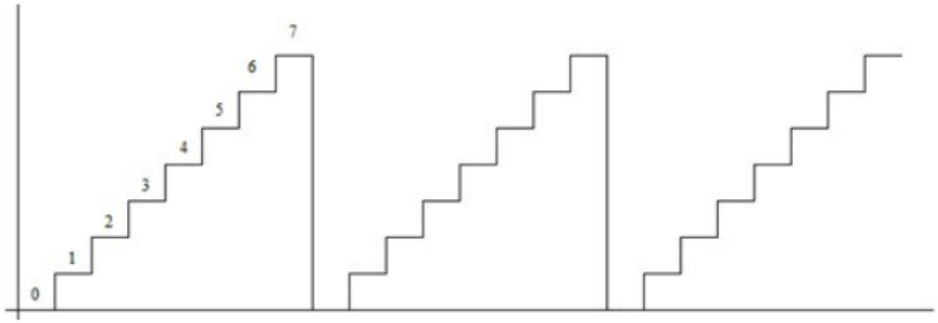

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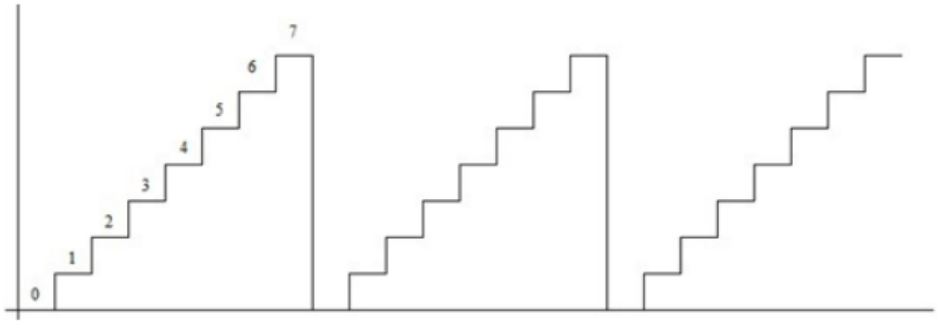

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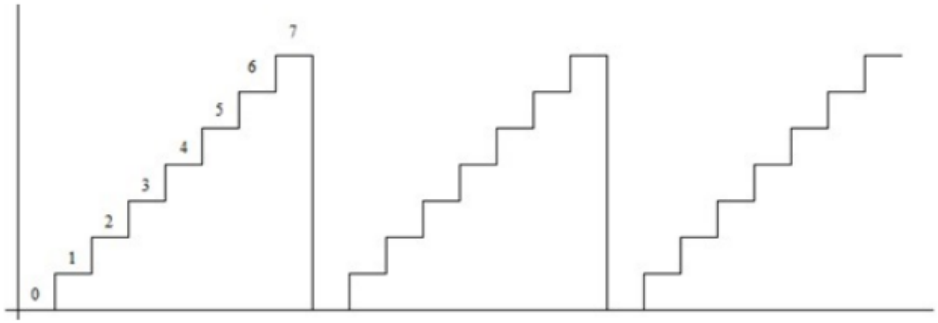

4. For n-bit counter, maximum value $= 2^n - 1$.
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6. We use it in 8-bit mode, for PWM generation.

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4. For motion control of Firebird V, we use OCR5A and OCR5B registers.

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5. OCR5A is associated with the OC5A pin (PORTL3). This pin is connected to the enable(EN2) pin of motor driver, which is associated with the left motor.

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5. OCR5A is associated with the OC5A pin (PORTL3). This pin is connected to the enable(EN2) pin of motor driver, which is associated with the left motor.
6. Similarly, OCR5B is associated with the OC5B pin (PORTL4). This pin is connected to the enable(EN1) pin of motor driver, which is associated with the right motor.

PWM signal for Left and Right motor

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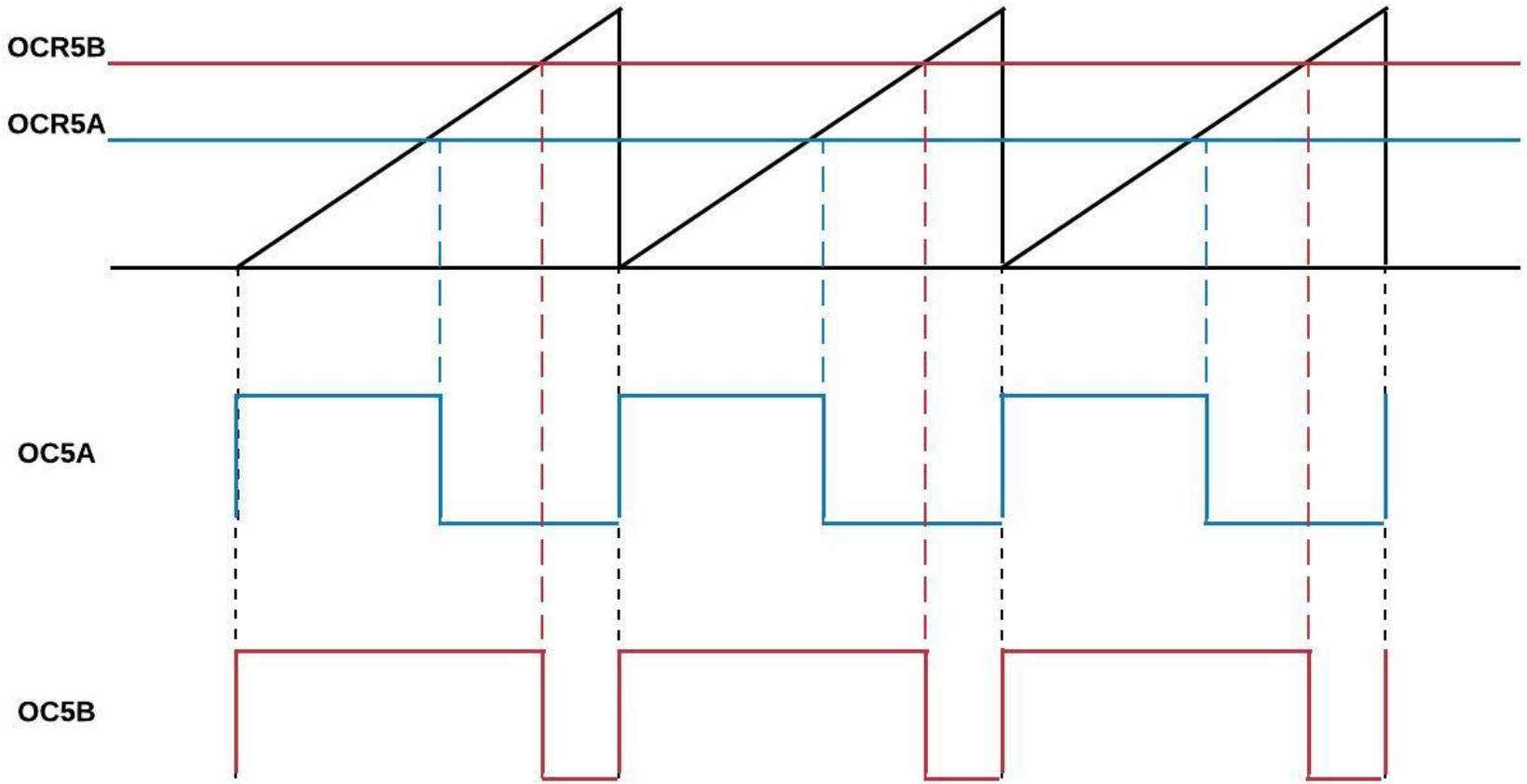

TCCR5A- Timer Counter Control Register A

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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

TCCR5A- Timer Counter Control Register A

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

TCCR5A = 0xA9

TCCR5A- Timer Counter Control Register A

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

TCCR5A = 0xA9

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

TCCR5A- Timer Counter Control Register A

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

TCCR5A = 0xA9

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

Compare Output Mode bits

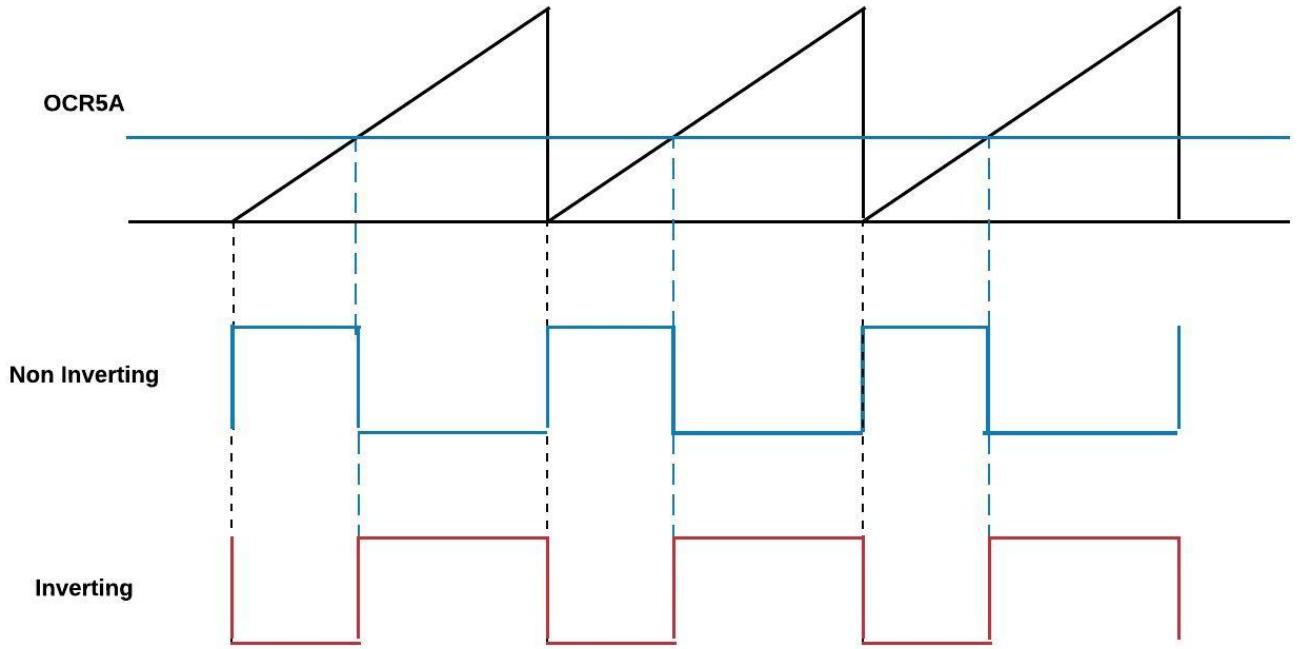
Compare Output Mode bits

Table 17-4. Compare Output Mode, Fast PWM

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).

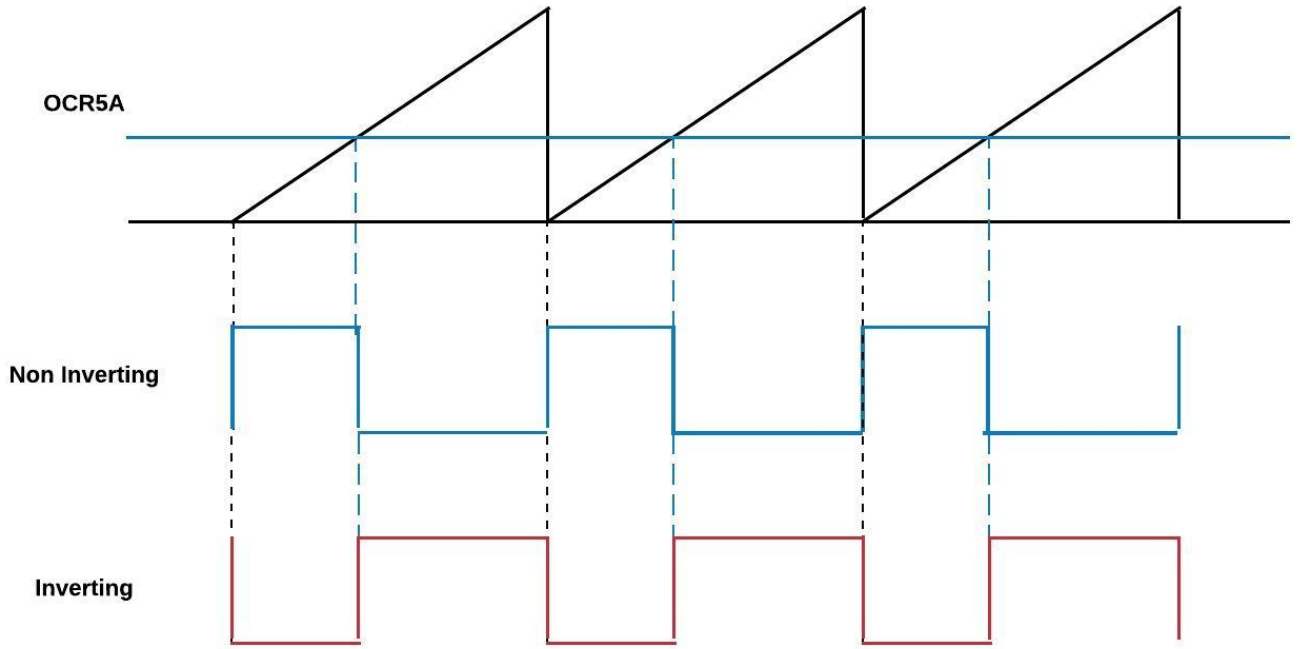
Cont..

Cont..



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

Cont..



1. We are using non-inverting mode for PWM generation.
2. Non-inverting mode and inverting mode

Waveform Generation Bit

Waveform Generation Bit

Table 17-2. Waveform Generation Mode Bit Description[1]

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

TCCR5B- Timer Counter Control Register B

TCCR5B- Timer Counter Control Register B

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

TCCR5B- Timer Counter Control Register B

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**

TCCR5B = 0x0B

Clock Select Bits

Clock Select Bits

Table 17-6. Clock Select Bit Description

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

$PWM_{frequency} = Clock_{frequency}/(N * 255)$

where,

$Clock_{frequency} = 14745600Hz$

N = prescaler factor

Summary

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In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

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- TCNT5L = 0x00

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In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9

Summary

In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B

Summary

In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00

Summary

In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF

Summary

In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF
- OCR5BH = 0x00

Summary

In order to use Fast PWM mode to control the speed of DC motors of Firebird V. We have to initialize following registers with the corresponding values:

- TCNT5L = 0x00
- TCCR5A = 0xA9
- TCCR5B = 0x0B
- OCR5AH = 0x00
- OCR5AL = 0xFF
- OCR5BH = 0x00
- OCR5BL = 0xFF

Syntax for C-Program

PWM Initialization

Syntax for C-Program

PWM Initialization

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


}
```

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

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 = 0xA9;
   TCCR5B = 0x0B;
   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)
{
  motion_pin_config();
  timer5_init();
  forward();
  while(1)
  {
    velocity(100,100);
    _delay_ms(500);
    velocity(0,255);
    _delay_ms(500);
  }
}
```

Syntax for C-Program

Program

Main Program

```
int main(void)
{
  motion_pin_config();
  timer5_init();
  forward();
  while(1)
  {
    velocity(100,100);
    _delay_ms(500);
    velocity(0,255);
    _delay_ms(500);
  }
}
```

Velocity Function

Syntax for C-Program

Program

Main Program

```
int main(void)
{
  motion_pin_config();
  timer5_init();
  forward();
  while(1)
  {
    velocity(100,100);
    _delay_ms(500);
    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!

Post your queries on: support@e-yantra.org