Stepper and Servo Motors

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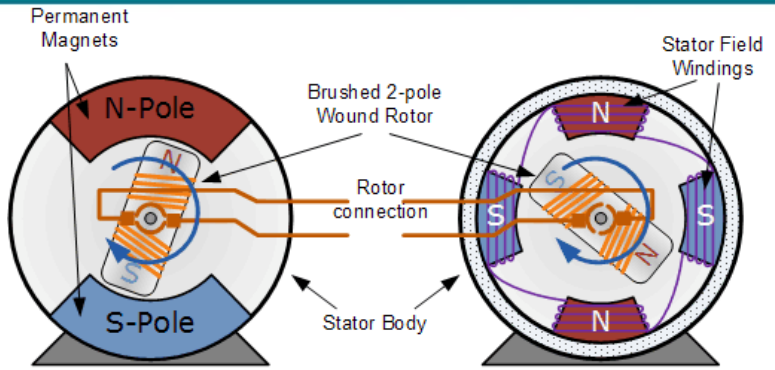
Outline

- In this module, the students will learn the following
  - Understand the working and control of stepper and servo motors
  - Control speed and direction of stepper motor using AVRs
  - Control position of servo motor using AVRs

Types of Motors

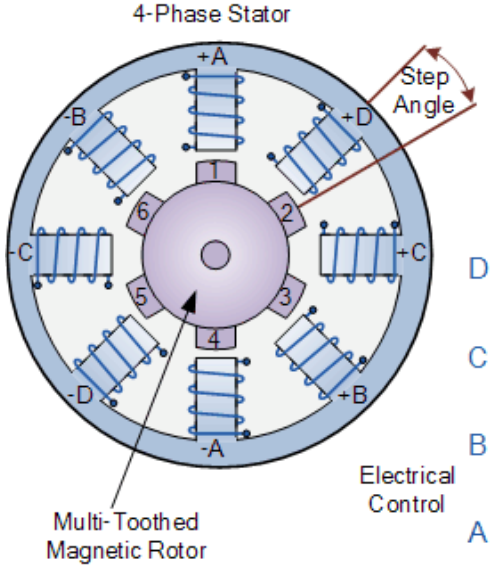
- DC Motors
- Stepper Motors
- Servo Motors

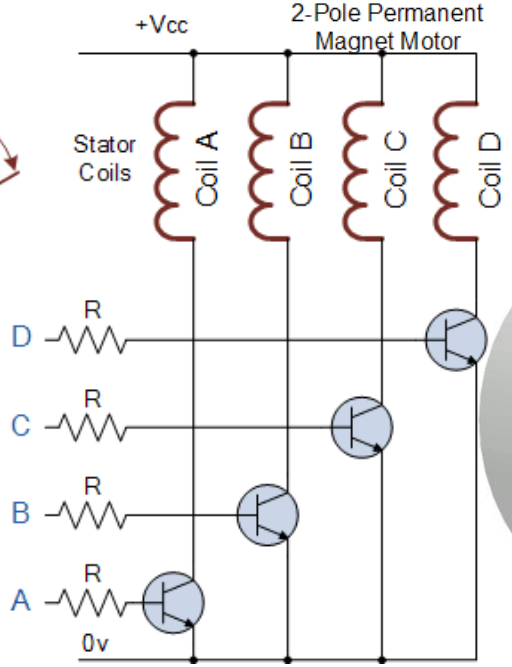


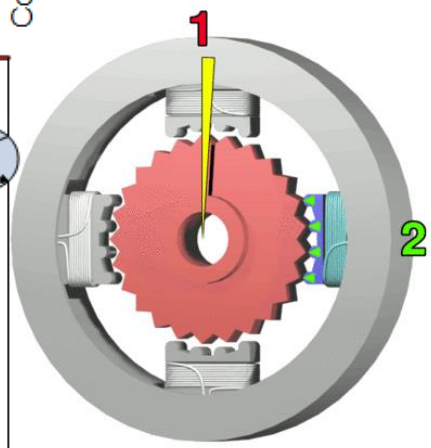
2-Pole Permanent Magnet Motor

4-Pole Wound Field Motor

DC motor







Stepper motor

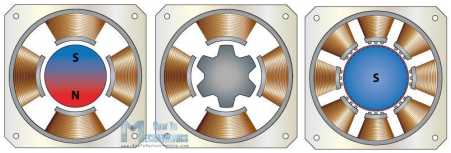
Servo

Types & Characteristics of Stepper Motor

- **Types of Stepper Motor**
- Unipolar Stepper Motors
  - Needs 0/+ signals to control the motor
- Bipolar Stepper Motor
  - Needs -/+ signals to control the motor

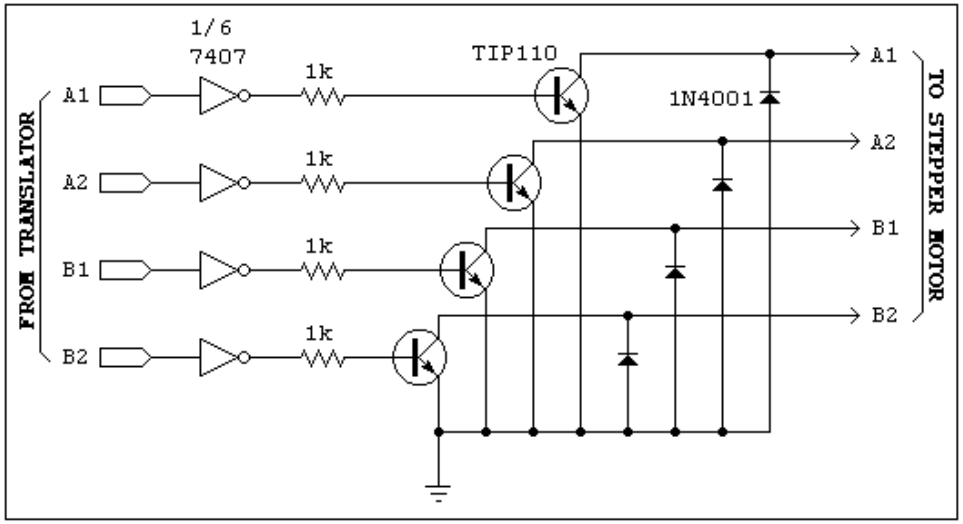
Types of Stepper Motor (based on construction)

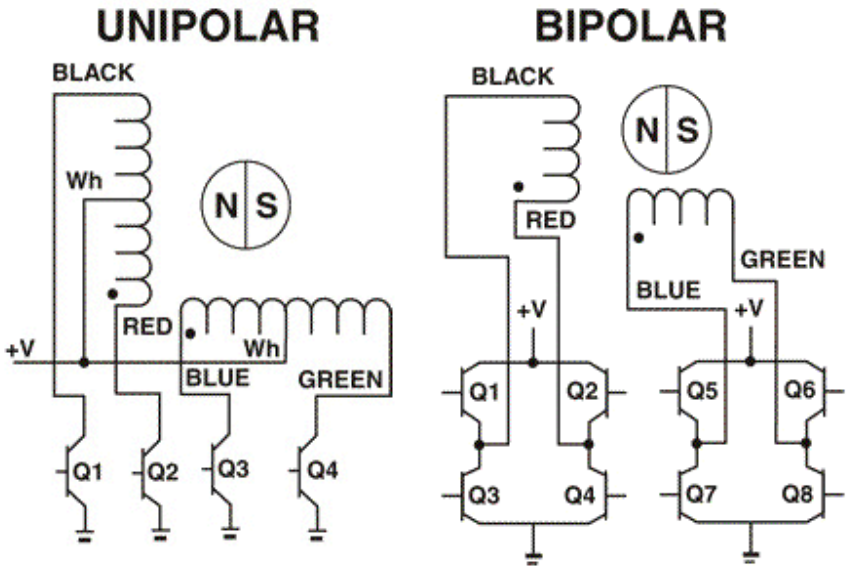
1. Permanent magnet
2. Variable reluctance
3. Hybrid



- The following elements **characterize a given stepper motor**:
- Voltage
  - Stepper motors usually have a voltage rating.
- Resistance
  - Resistance-per-winding is another characteristic of a stepper motor. Affect the motor's torque curve and maximum operating speed.
- Degrees per step
  - Common degree/step numbers include: 0.72, 1.8, 3.6, 7.5, 15, and even 90. Degrees per step is often referred to as the *resolution* of the motor.

Unipolar & Bipolar Stepper Motors





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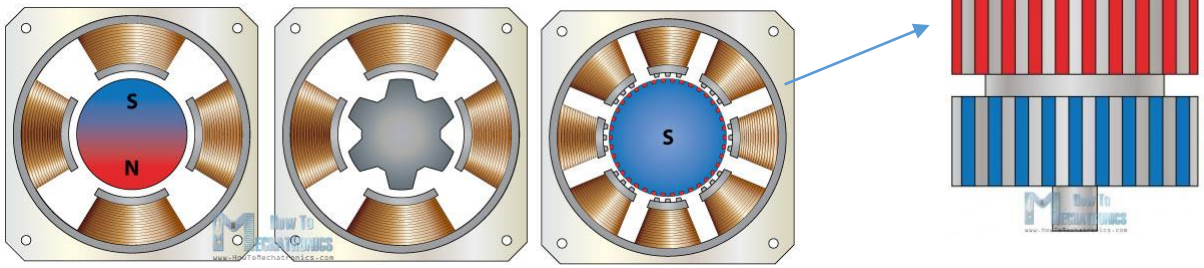
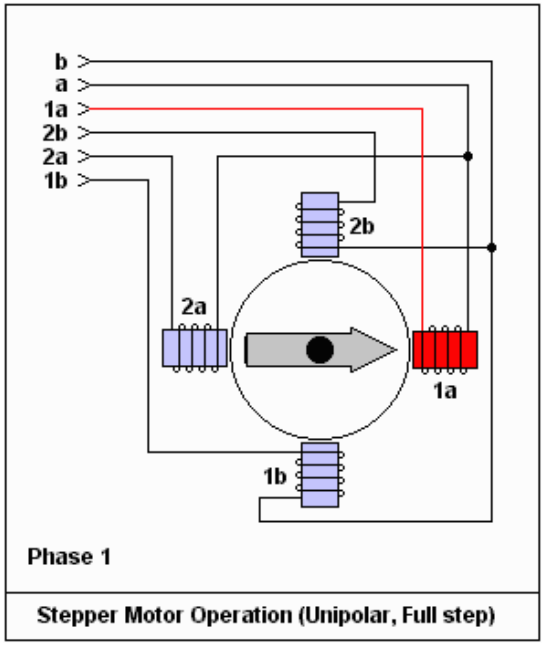
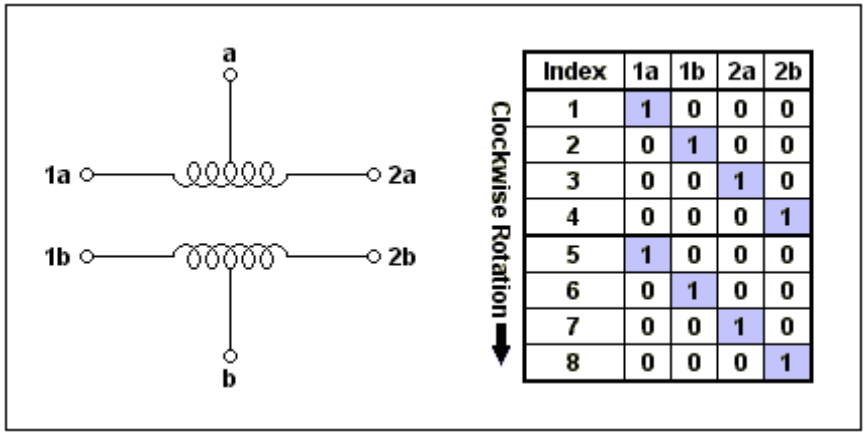


Unipolar Stepper Motors

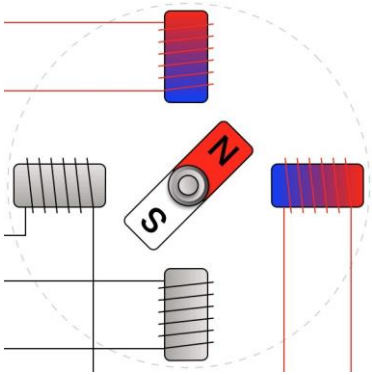


Stepper Motor Operation (Unipolar, Full step)



Clockwise Rotation

Index	1a	1b	2a	2b
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1
5	1	0	0	0
6	0	1	0	0
7	0	0	1	0
8	0	0	0	1



Clockwise Rotation

Index	1a	1b	2a	2b
1	1	0	0	1
2	1	1	0	0
3	0	1	1	0
4	0	0	1	1
5	1	0	0	1
6	1	1	0	0
7	0	1	1	0
8	0	0	1	1

Alternate Full Step Sequence
(Provides more torque)

Clockwise Rotation

Index	1a	1b	2a	2b
1	1	0	0	0
2	1	1	0	0
3	0	1	0	0
4	0	1	1	0
5	0	0	1	0
6	0	0	1	1
7	0	0	0	1
8	1	0	0	1
9	1	0	0	0
10	1	1	0	0
11	0	1	0	0
12	0	1	1	0
13	0	0	1	0
14	0	0	1	1
15	0	0	0	1
16	1	0	0	1

Half Step Sequence

For direction change, simply switch the sequence

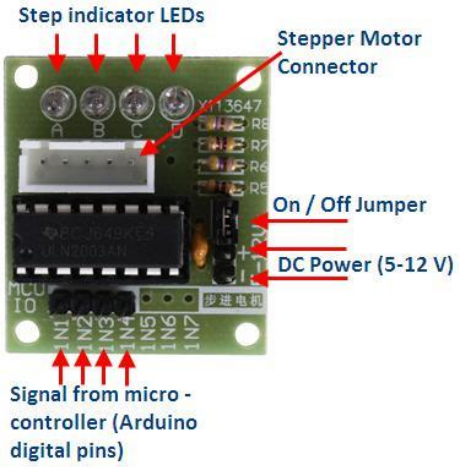
These are cyclic codes

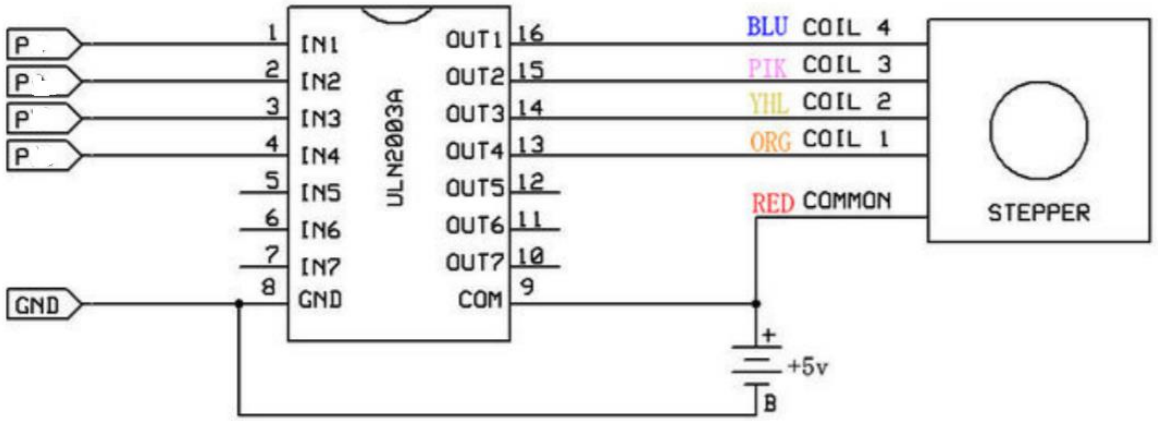
Unipolar Stepper Motor

Model: 35BY48B06 - Unipolar Stepper Motor

Specifications:

- 5 VDC
- 7.5deg. step angle, 48 teeths
- Phase resistance: 10 Ohms
- Current: 500 mA





Stepper Motor (FS) using ULN2003

```
#define F_CPU 16000000UL/* Define CPU Frequency 16MHz */
#include <avr/io.h>/* Include AVR std. library file */
#include <util/delay.h>/* Include delay header file */

int main(void)
{
int period;
DDRD = 0x0F;/* Make PORTD lower pins as output */
period = 100;/* Set period in between two steps */
   while (1)
   {
   /* Rotate Stepper Motor Anticlockwise with Full step sequence */
   PORTD = 0x09;
   _delay_ms(period);
   PORTD = 0x03;
   _delay_ms(period);
   PORTD = 0x06;
   _delay_ms(period);
   PORTD = 0x0C;
   _delay_ms(period);
   }
}
```

Too small or too large will damage the motor

Too small -> switching faster – Motor vibrates and heats up.

Too large -> switch slower – Motor heats up.

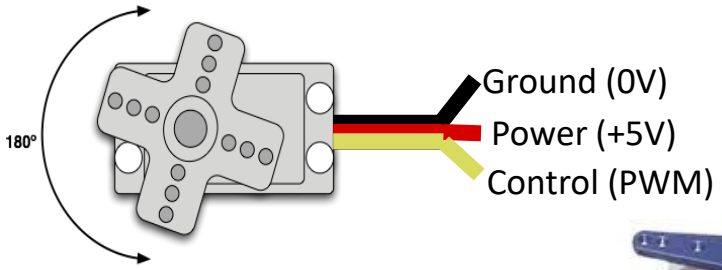
To Switch Directions: -> Switch Sequence

Stepper Motor (HS) using ULN2003

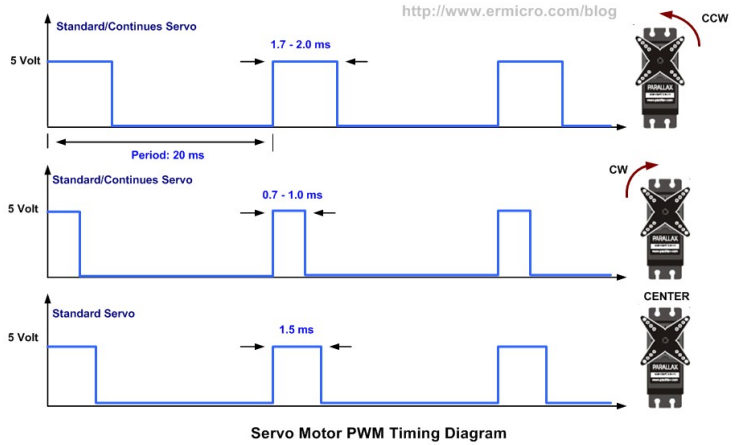
```
    while (1)
    {
    /* Rotate Stepper Motor clockwise with Half step sequence */
    PORTD = 0x09;
    _delay_ms(period);
    PORTD = 0x08;
    _delay_ms(period);
    PORTD = 0x0C;
    _delay_ms(period);
    PORTD = 0x04;
    _delay_ms(period);
    PORTD = 0x06;
    _delay_ms(period);
    PORTD = 0x02;
    _delay_ms(period);
    PORTD = 0x03;
    _delay_ms(period);
    PORTD = 0x01;
    _delay_ms(period);
    }
}
```

Servo Motors

- Can be positioned from 0-180º (usually)*
- Internal feedback circuitry & gearing takes care of the hard stuff
- Easy three-wire PWM 5V interface
- PWM freq is 50 Hz (i.e. every 20 millisecs)
- Pulse width ranges from 1 to 2 millisecs
  - 1 millisec = full anti-clockwise position
  - 2 millisec = full clockwise position

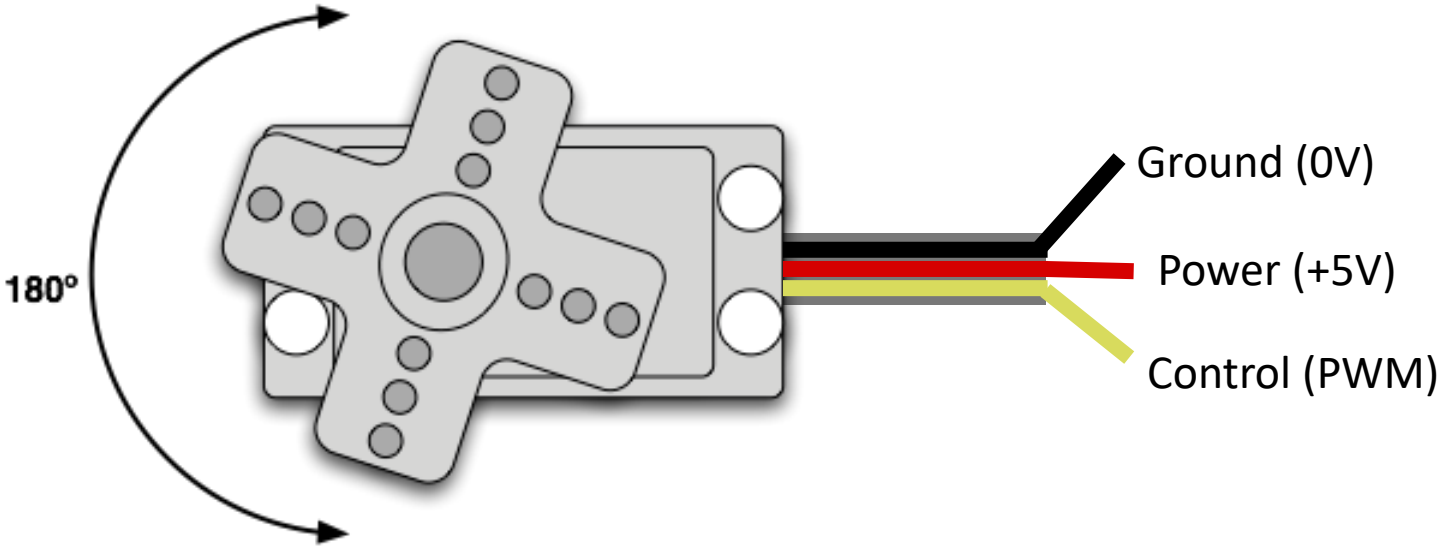


*You can also find 360º continuous servo, 270º servo, smart servo (chain)



Servo Motor PWM Timing Diagram

Servo Control

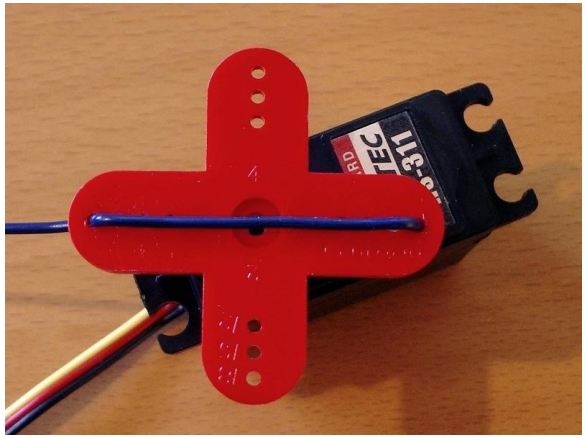


- PWM freq is 50 Hz (i.e. every 20 millisecs)
- Pulse width ranges from 1 to 2 millisecs
  - 1 millisec = full anti-clockwise position
  - 2 millisec = full clockwise position

Servo Movement

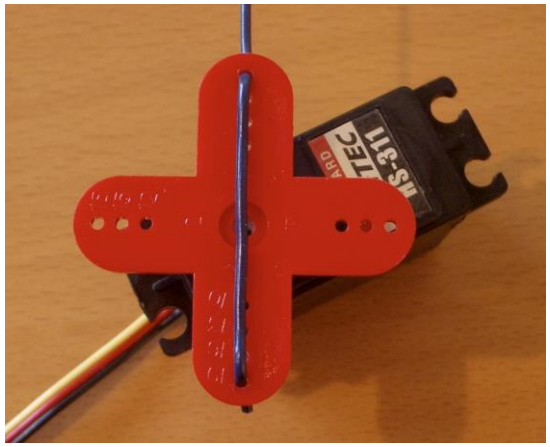
Servo motor is supplied with a PWM period of specific period
Most Servos will work in 50Hz (20 ms period)

0 degrees



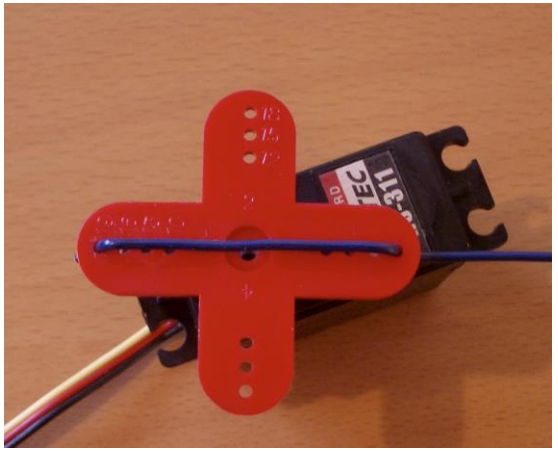
1000 usecs
1ms

90 degrees



1500 usecs
1.5 ms

180 degrees



2000 usecs
2 ms

Pulse width determines the position
If a pulse width of 1.2 ms is given the servo points to 45 deg.

Servos

- EX1: Futaba 3003 servos - rotating between 0 and 180 degrees.
  - 0.388ms = 0 degree.
  - 1.264ms = 90 degrees. (neutral position)
  - 2.14ms = 180 degrees.

- Generating Period
  - The CPU frequency is 16MHz
  - Pre-scalar as 64
  - Timer frequency = 16MHz/64 = 250khz (4uS period).
  - Setup Timer Mode as Mode 14.
    - FAST PWM Mode
    - TOP Value = ICR1
  - Most servo motor will work well on 50 Hz of PWM frequency; this mean the PWM signal should have a period of 20ms.

Servos

- Timer1 PWM
  - $f_{pwm} = f_{ocs} / N(TOP+1)$
  - $f_{pwm} = 50 = 16M/64*(TOP+1)$
  - TOP = 4999
  - ICR1A=4999 = PWM period of 20ms (50 Hz).

- Position Control
  - Servo Angle 0 degrees = pulse width of 0.388ms (388uS) - OCR1A = 388us/4us = 97
  - Servo Angle 90 degrees = pulse width of 1.264ms (1264uS) - OCR1A = 1264us/4us = 316
  - Servo Angle 180 degrees = pulse width of 2.140ms (2140uS) - OCR1A = 2140us/4us = 535

Servo Code

```
void main()
{
  //Configure TIMER1
  TCCR1A|=(1<<COM1A1)|(1<<COM1B1)|(1<<WGM11);   //NON Inverted PWM
 //PRESCALER=64 MODE 14(FAST PWM)
  TCCR1B|=(1<<WGM13)|(1<<WGM12)|(1<<CS11)|(1<<CS10);
  ICR1=4999;  //fPWM=50Hz (Period = 20ms Standard).
  DDRB|=(1<<PB1); //PWM Pins as Out
 while(1)
  {
    OCR1A=97;   //0 degree
    Wait();
    OCR1A=316;  //90 degree
    Wait();
    OCR1A=425;  //135 degree
    Wait();
    OCR1A=535;  //180 degree
    Wait();
  }
}
```

SG90 9G Micro Servo Motor

- EX2: SG90 9G Micro Servo Motor - rotating between 0 and 180 degrees.
  - 1ms = 0 degree.
  - 1.5ms = 90 degrees. (neutral position)
  - 2.0ms = 180 degrees.

- PWM Period:
  - $f_{pwm} = f_{ocs} / N(TOP+1)$
  - $f_{pwm} = 50 = 16M/64*(TOP+1)$
  - TOP = 4999
  - ICR1A=4999 = PWM period of 20ms (50 Hz).

```
while()
{
 if(OCR1A >499) {
  OCR1A = 250;
  _delay_ms(5000);
  }
 else {
   OCR1A = 250 + 25;
   _delay_ms(1000);
  }
```

- Position Control
  - Servo Angle 0 degrees = pulse width of 1ms; OCR1A = 1000us/4us = 250
  - Servo Angle 90 degrees = pulse width of 1.5ms; OCR1A = 1500us/4us = 375
  - Servo Angle 180 degrees = pulse width of 2.0ms; OCR1A = 2000us/4us = 500

Summary

- On completion of this module, the student should be able to
  - Control speed and direction of stepper motor using AVRs
  - Control position of servo motor using AVRs