ROBOTICS

Robot Actuators and Drive Systems

Joint Drive Systems

- Electric
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots

- Hydraulic
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity
- Pneumatic
  - Typically limited to smaller robots and simple material transfer applications

Actuators

- Actuator is the term used for the *mechanism that drives* the robotic arm.
- There are 3 main types of Actuators
  1. Electric motors
  2. Hydraulic
  3. Pneumatic cylinder
- *Hydraulic* and *pneumatic* actuators are generally suited to driving *prismatic joints* since they produce *linear* motion directly
- Hydraulic and pneumatic actuators are also known as *linear actuators.*
- *Electric motors* are more suited to driving *revolute joints* as they produce rotation

Electric Drives

Servomotor type	*Max. Performance*	*Features*
Step Motor	1 kW	• Open control circuit • Heating during standstill • Poor dynamics
DC-Brush	5 kW	• Good controllability by armature current • High starting torque • Wear by brushing
DC-Brushless	10 kW	• Maintenance • Communication by resolvers, Hall-Effect or the optical sensor • High power with the permanent magnet
AC-Synchronous	20 kW	
AC-Asynchronous	80 kW	• Maintenance • Very robust •High Speed Expensive control

- A modern motion control system typically consists of a motion controller, a motor drive or amplifier, an electric motor, and feedback sensors.
- The system might also contain other components such as one or more belt-, ballscrew-, or leadscrew-driven linear guides or axis stages.
- A motion controller can be a standalone programmable controller, a personal computer containing a motion control card, or a programmable logic controller (PLC).
- All of the components of a motion control system must work together seamlessly to perform their assigned functions.
- Their selection must be based on both engineering and economic considerations.

Figure 1-1 illustrates a typical multiaxis X-Y-Z motion platform that includes the three linear axes required to move a load, tool, or end effector precisely through three degrees of freedom.

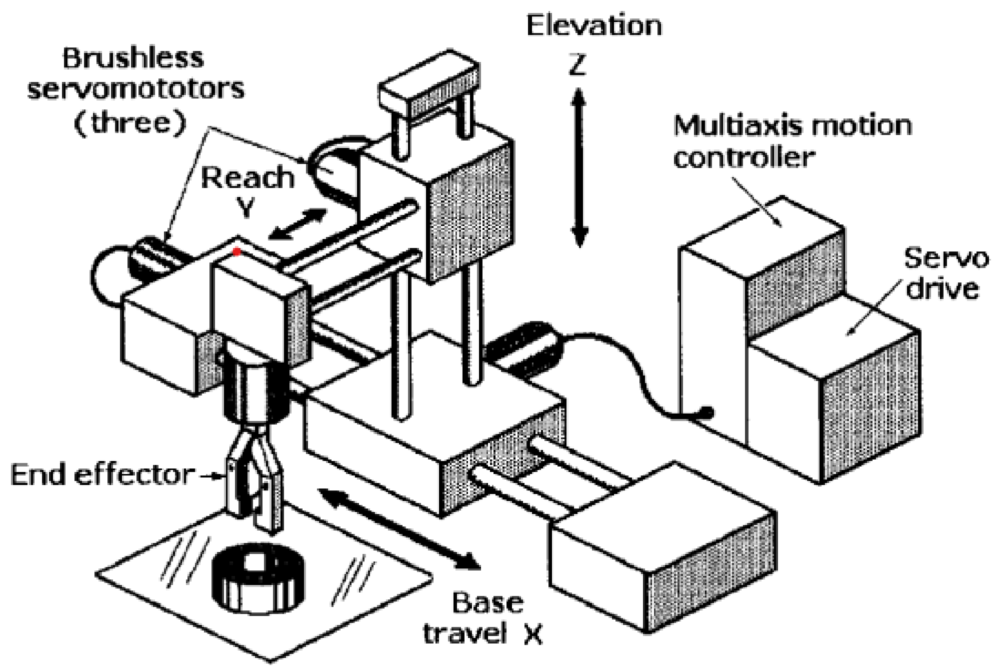


Figure 1-1 This multiaxis X-Y-Z motion platform is an example of a motion control system.

- With additional mechanical or electro mechanical components on each axis, rotation about the three axes can provide up to **six degrees of freedom**
- As shown in Figure 1-2. Motion control systems can be found in such diverse applications as materials handling equipment, machine tool centers, chemical and pharmaceutical process lines, inspection stations, robots, and injection molding machines.

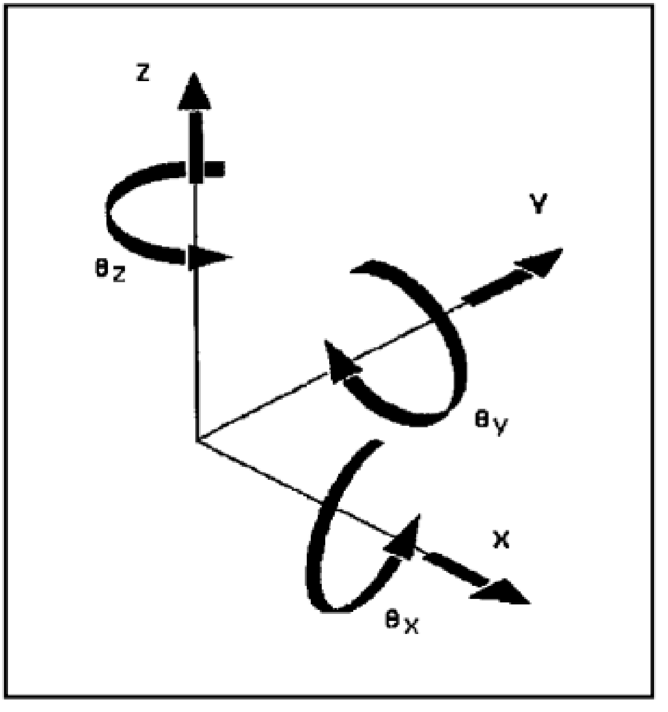


Figure 1-2 The right-handed coordinate system showing six degrees of freedom.

Merits of Electric Systems

- Most motion control systems today are powered by electric motors rather than hydraulic or pneumatic motors or actuators because of the many benefits they offer:
  - More precise load or tool positioning, resulting in fewer product or process defects and lower material costs.
  - Quicker changeovers for higher flexibility and easier product customizing.
  - Increased throughput for higher efficiency and capacity.
  - Simpler system design for easier installation, programming, and training.
  - Lower downtime and maintenance costs.
  - Cleaner, quieter operation without oil or air leakage

Electric-powered motion control systems do not require pumps or air compressors, and they do not have hoses or piping that can leak hydraulic fluids or air.
This discussion of motion control is limited to electric-powered systems.

Motion Control Classification Motion control systems can be classified as open-loop or closed-loop.

- An open-loop system does not require that measurements of any output variables be made to produce error-correcting signals
- by contrast, a closed-loop system requires one or more feedback sensors that measure and respond to errors in output variables

Closed-Loop System

- A closed-loop motion (Fig.1.3)control system has one or more feedback loops that continuously compare the system's response with input commands or settings to correct errors in motor and/or load speed, load position, or motor torque.
- Feedback sensors provide the electronic signals for correcting deviations from the desired input commands.
- Closed-loop systems are also called **servosystems.**
- Each motor in a servosystem requires its own feedback sensors, typically encoders, resolvers, or tachometers that close loops around the motor and load.
- Variations in velocity, position, and torque are typically caused by variations in load conditions, but changes in ambient temperature and humidity can also affect load conditions.

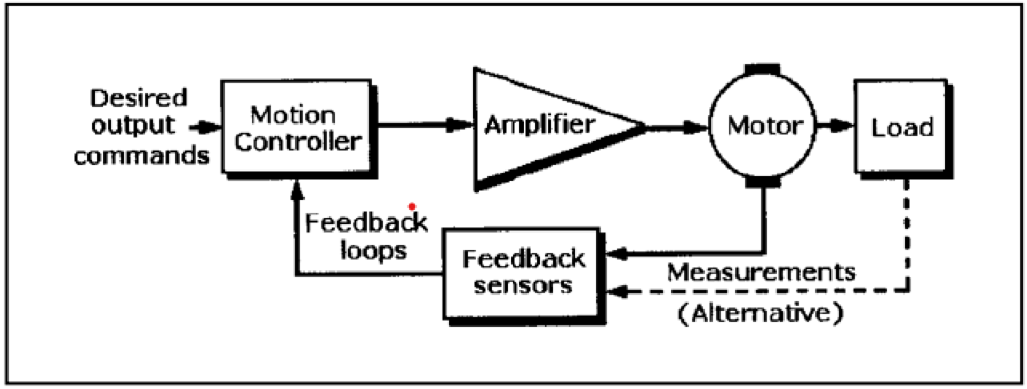


Figure 1-3 Block diagram of a basic closed-loop control system.

- A **velocity control loop**, as shown in block diagram Figure 1-4, typically contains a **tachometer** that is able to detect changes in **motor speed**.
- This sensor produces error signals that are proportional to the positive or negative deviations of motor speed from its preset value.
- These signals are sent to the **motion controller so that it can compute a corrective signal** for the amplifier to keep motor speed within those preset limits despite load changes

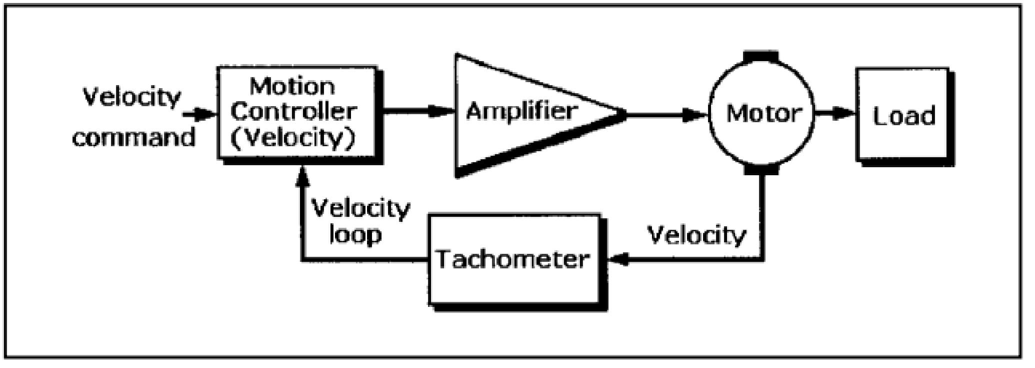


Figure 1-4 Block diagram of a velocity-control system.

- A **position-control** loop, as shown in block diagram Figure 1-5, typically contains either an encoder or resolver capable of direct or indirect measurements of load position.
- These sensors generate error signals that are sent to the motion controller, which produces a corrective signal for amplifier.
- The output of the amplifier causes the motor to speed up or slow down to correct the position of the load.
- **Most position control closed-loop systems also include a velocity-control loop**

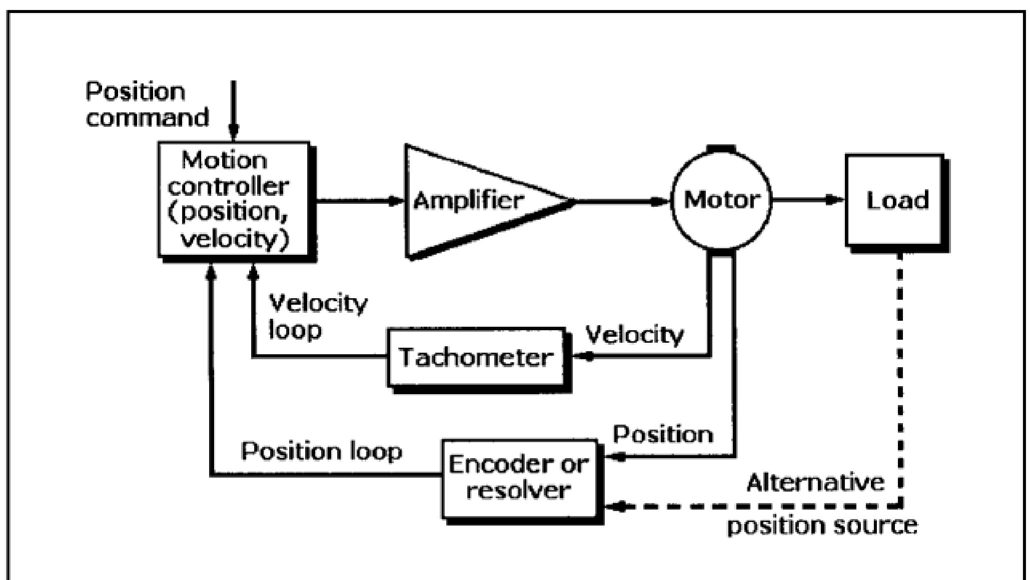


Figure 1-5 Block diagram of a position-control system.

- The ballscrew slide mechanism, shown in Figure 1-6, is an example of a mechanical system that carries a load whose **position must be controlled** in a closed-loop servosystem because it is not equipped with position sensors.

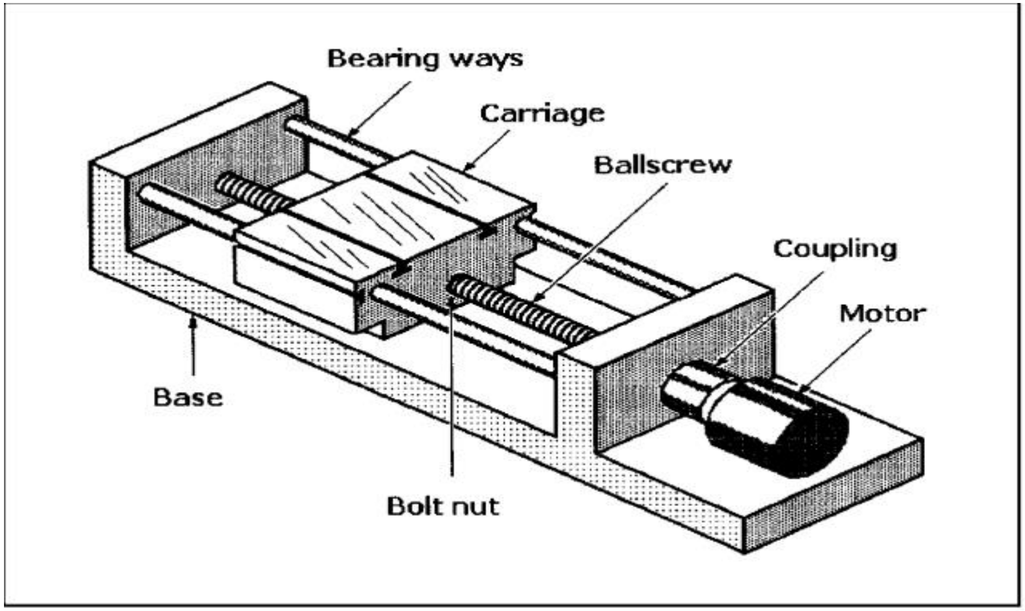


Figure 1-6 Ballscrew-driven single-axis slide mechanism without position feedback sensors.

- Three examples of feedback sensors mounted on the ballscrew mechanism that can provide position feedback are shown in Figure 1-7:
- (a) is a rotary optical encoder mounted on the motor housing with its shaft coupled to the motor shaft;
- (b) is an optical linear encoder with its graduated scale mounted on the base of the mechanism; and
- (c) is the less commonly used but more accurate and expensive laser interferometer

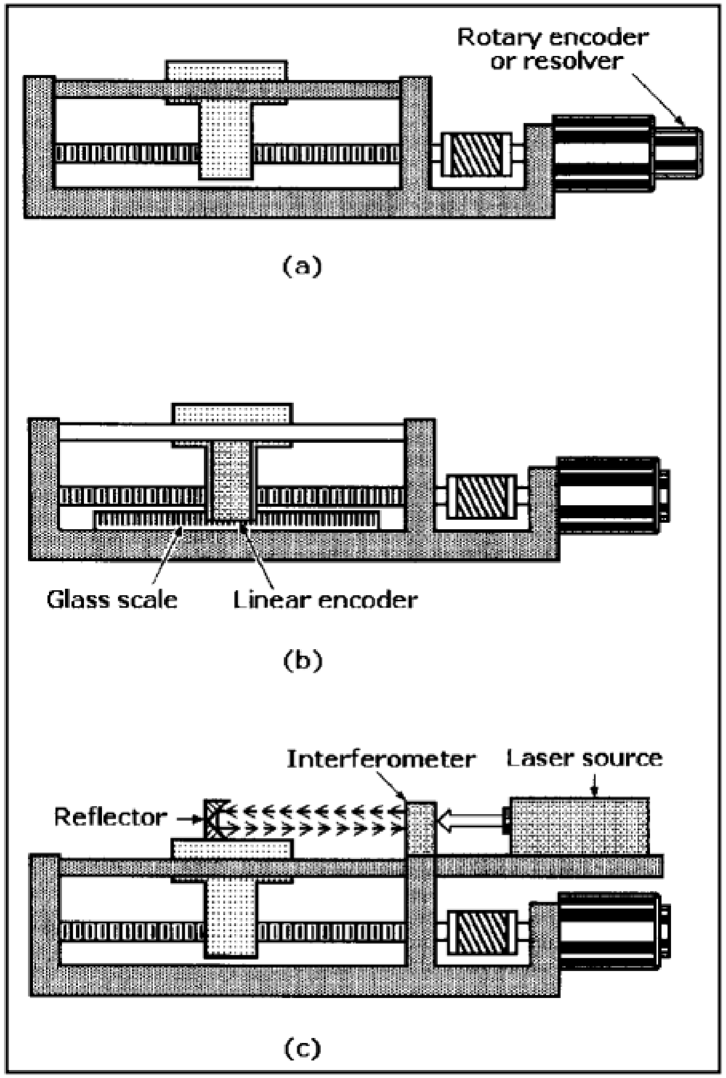
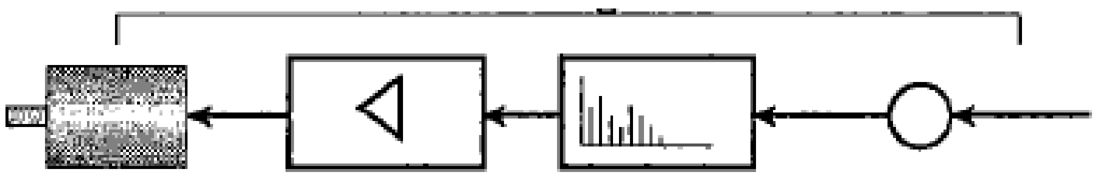


Figure 1-7 Examples of position feedback sensors installed on a ballscrew-driven slide mechanism: (a) rotary encoder, (b) linear encoder, and (c) laser interferometer.

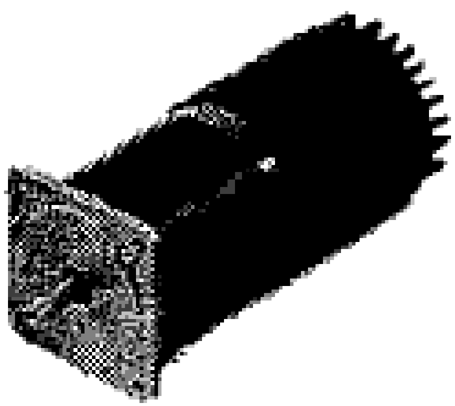
Stepper Motor

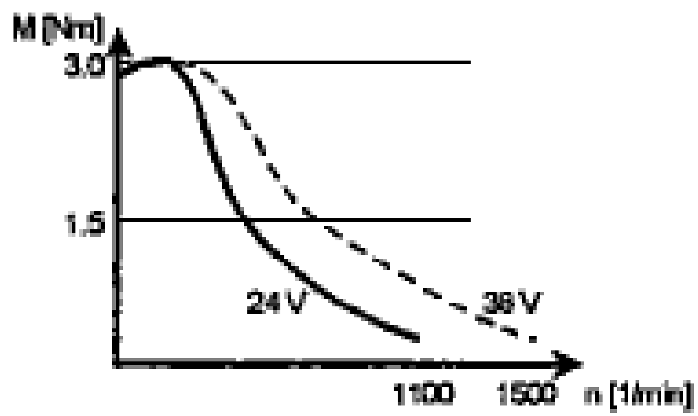
Block scheme:

Open loop



Step Motor Amplifier Pulse Generator Nominal-Position





Stepper Motor - Features

Stepper Motor Type

- Open loop and speed control loop.
- Relatively cheap.
- By turning the control pulse to a drive axle increment (micro step).
- Per rotation are more than 10,000 increments (micro-steps).
- Magnetic rigidity is low in the positioning.
- drive system with the control circuit is not damped and therefore inclined to impulse vibration.
- Mechanical vibrations or of control (closed-loop damped).
- Power-weight ratio is the lowest of all electric motors.

Stepper Motor

- Stepper motors and, in particular, claw pole stepper motors are widely applied in industrial controls.
- In the automotive and robotics industry, these stepper motors, often called tin-can or can-stack motors, have found a variety of applications, such as in the timing of fuel, arc welding.
- Claw pole or interdigitated construction is used for this type of electrical machine.

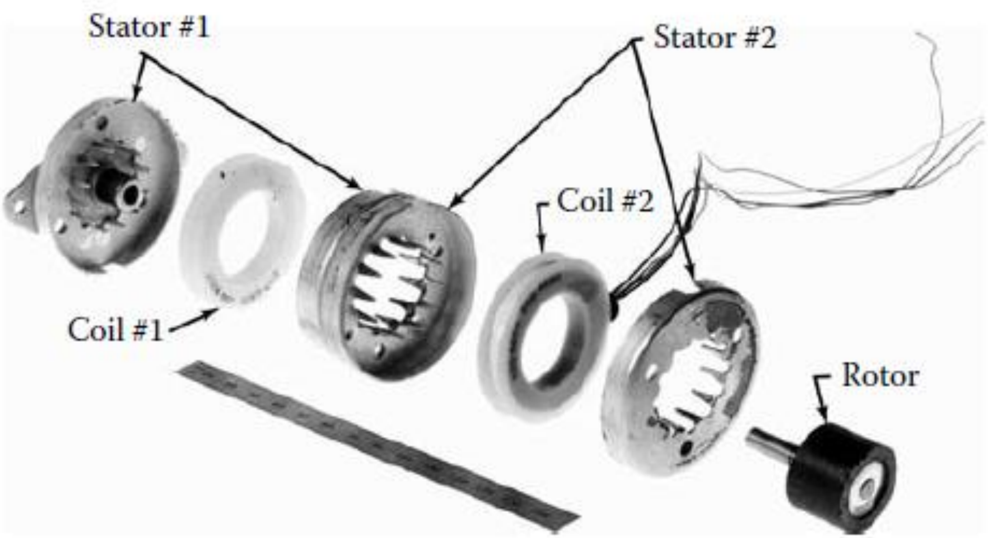


Fig. 1 Claw pole stepper motor with PM

- Figure 1 shows the various motor components necessary to produce a torque.
- There are **two stators,** each consisting of a **north and a south lamination,** with a coil enclosed between them and **one PM rotor having *P* poles along the periphery.**
- Each lamination has *P*/2 teeth which, when assembled, mesh with each other, as shown in Figure 1
- Developed view in Figure 2 shows the same number of teeth and number of magnet poles
- When the **coil is energized** with, say, a **positive current**, all the teeth of the **north lamination will become north poles** and all the teeth of the south lamination south poles.
- Thus, a **torque will be exerted on the rotor** to align its **south poles with the teeth of the north lamination** and its north poles with the teeth of the south lamination, as presented in Figure 2.

- **Reversing the direction of the current reverses** the polarity of the stator teeth and the **resultant torque moves the rotor one step**.
- With only one stator, however, the rotor is as likely to turn backward as forward and so the **second stator** is introduced, physically displaced by 90 electrical degrees (**one fourth of the pole pitch**), as shown in Figure 3.

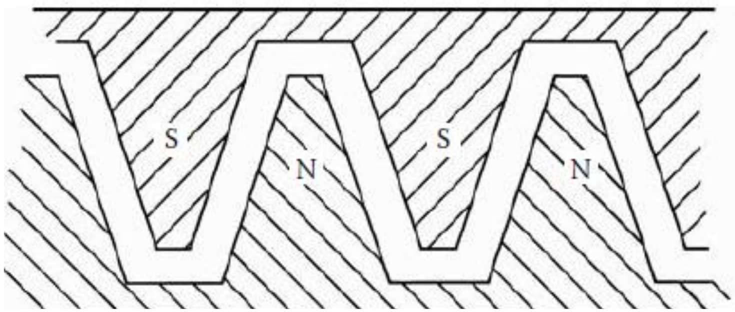


Fig. 2. Cross section of the claw pole stepper motor with PM.

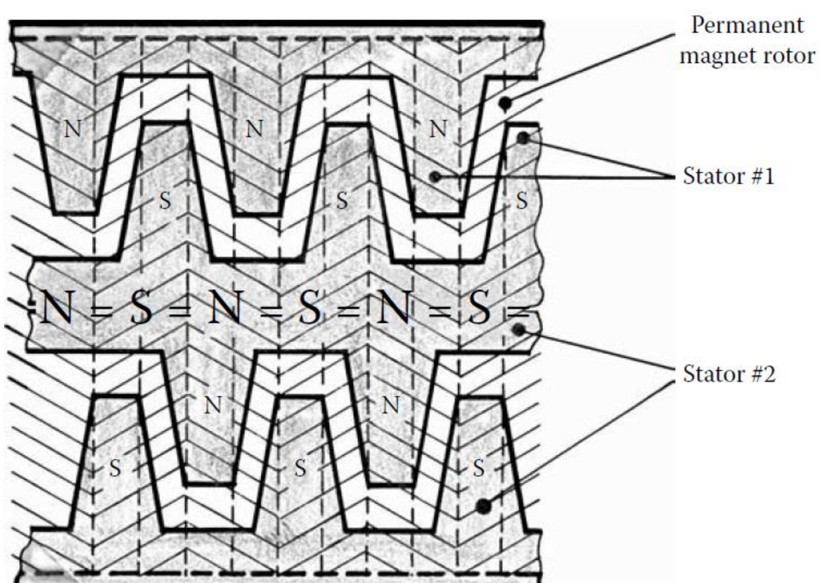


Fig. 3. Production of unidirectional torque energizing two stators.

- Claw pole stepper motors are divided into two types, bipolar and unipolar, depending on the number of coils.
- A **unipolar stepper motor** has **four** coils, and a **bipolar** one has only **two** coils, as shown in the control schematic presented in Figure 4.
- For the unipolar stepper motor, the two windings in each stator are mutually coupled.
- A unipolar **controller driver unit**, in this case, a microcontroller or application specific integrated circuit (ASIC), as shown in Figure 5, **generates a series of pulses** that are organized as a sequence of voltage pulses, as shown in Figure. 6, which indicates that **only two windings can be connected to the voltage pulses at the same time.**
- Because each winding has a free-wheeling **diode connected** across it, **current flows in one winding** while the **other** winding is being **switched off**.

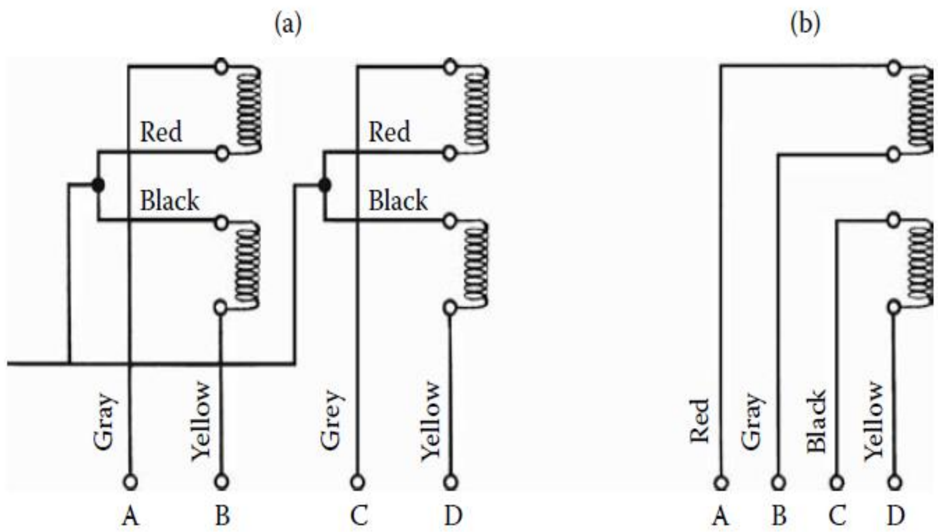


Fig. 4. Schematic of the stepper motor with PM: (a) unipolar with four coils, (b) bipolar with two coils.

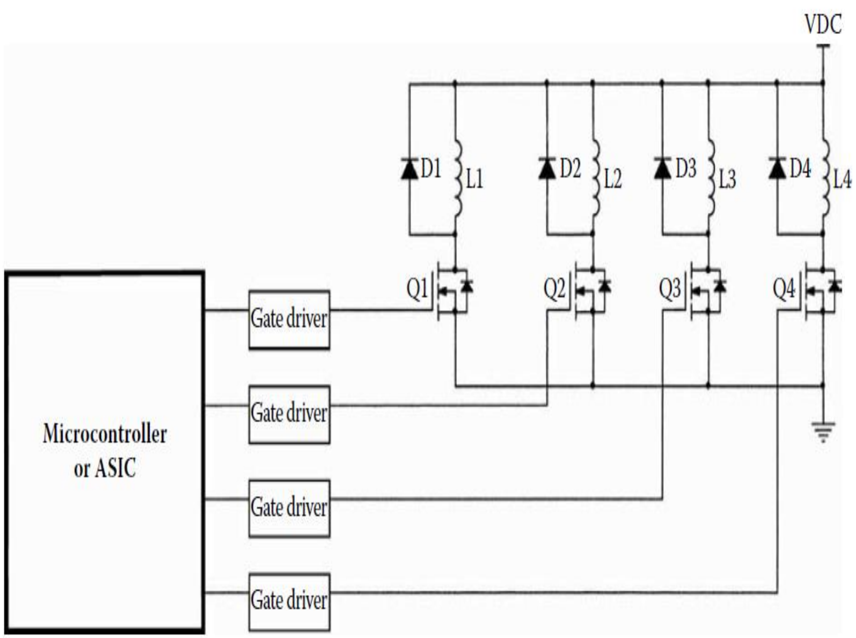


Fig.5. Schematic of the unipolar driver unit with microprocessor and gate drivers: D1, D2, D3, D4 are diodes in each winding from 1 to 4, respectively; L1, L2, L3, L4 are coil inductances from 1 to 4, respectively; Q1, Q2, Q3, Q4 are MOSFET switches in each side of coil 1 and coil 2, respectively; and VDC is battery voltage

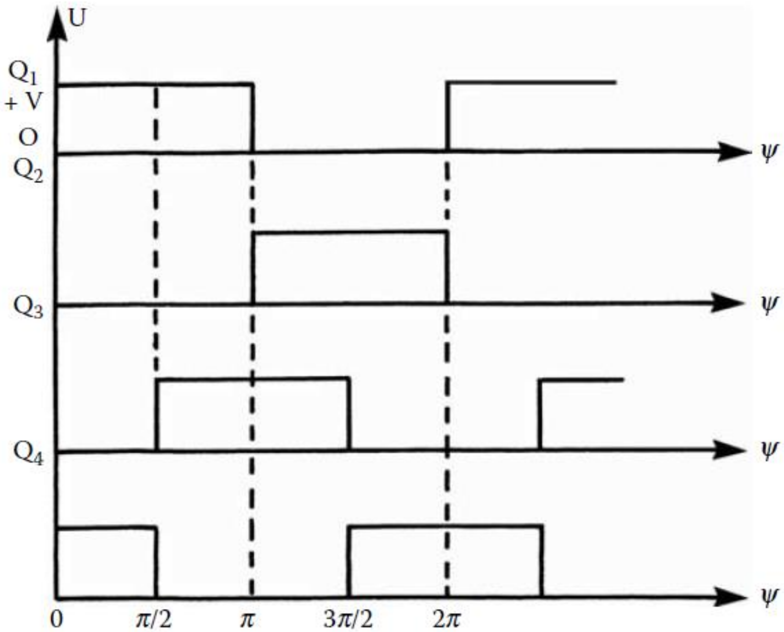


Fig. 6 Voltage waveform for unipolar driver unit

Fig. 7 Excitation Sequence

Excitation Sequence

Positive rotation (left to right, Fig. 5.3)

Stator	Connection	Step 1	2	3	4	5
#1	A	(+)	(–)	(–)	(+)	(+)
#1	B	(–)	(+)	(+)	(–)	(–)
#2	C	(+)	(+)	(–)	(–)	(+)
#2	D	(–)	(–)	(+)	(+)	(–)

Negative rotation (right to left, Fig. 5.3)

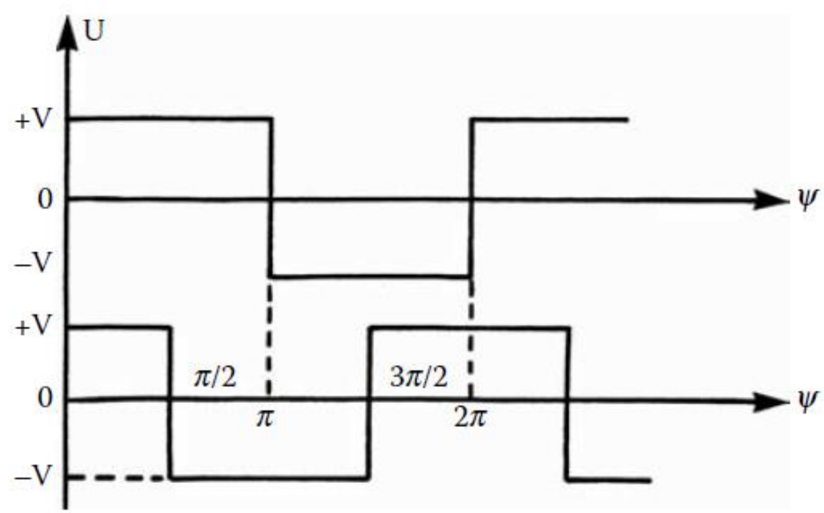
Stator	Connection	Step 1	2	3	4	5
#1	A	(+)	(–)	(–)	(+)	(+)
#1	B	(–)	(+)	(+)	(–)	(–)
#2	C	(–)	(–)	(+)	(+)	(–)
#2	D	(+)	(+)	(–)	(–)	(+)

Source: Courtesy of Delphi Corp.

- The induced current in the **off phase offers** a **damping effect** to the response of the motor, because the **curren**t circulating in the **off phase** provides some **retarding torque**.
- Although this torque is small at low speeds, it becomes significant at high speeds.
- The **circulating energy** is dissipated **as heat in the off phase** winding.
- At high speed the motor heating **increases.**
- A unipolar stepper motor requires a **simple drive** to provide **unidirectional current for its four coils** (two in each stator).
- For the same coil resistance loss in the stator of the unipolar motor peak, the current is only 70% that of the bipolar one.
- Thus, for the **same stator frame and coil resistance loss**, the unipolar stepper motor produces approximately 70% of the static torque in comparison with the bipolar motor.

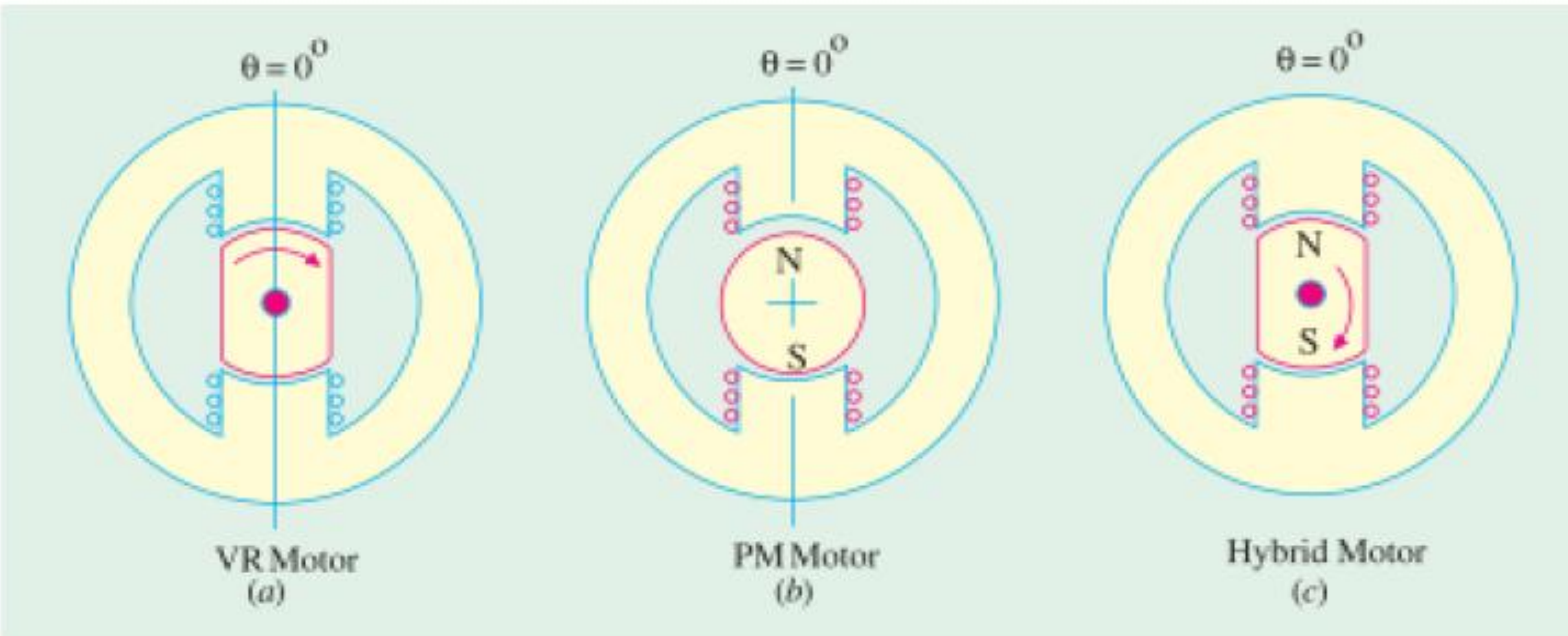
- For the **same torque, it is necessary to increase the stator outer diameter** for the unipolar motor and to use more copper.
- Hence, for the same static conditions, it is less complex and less expensive to produce a **bipolar stepper motor than a unipolar one.**
- However, a **bipolar driver is more complicated** and costly because it requires twice as many metal oxide semiconductor field-effect transistor (MOSFET) switches as the unipolar driver.
- In the off phase of bipolar driver, there is no coupling and the winding current decreases.

Fig. 8 Voltage waveform for bipolar driver unit.



Types of Stepping Motors

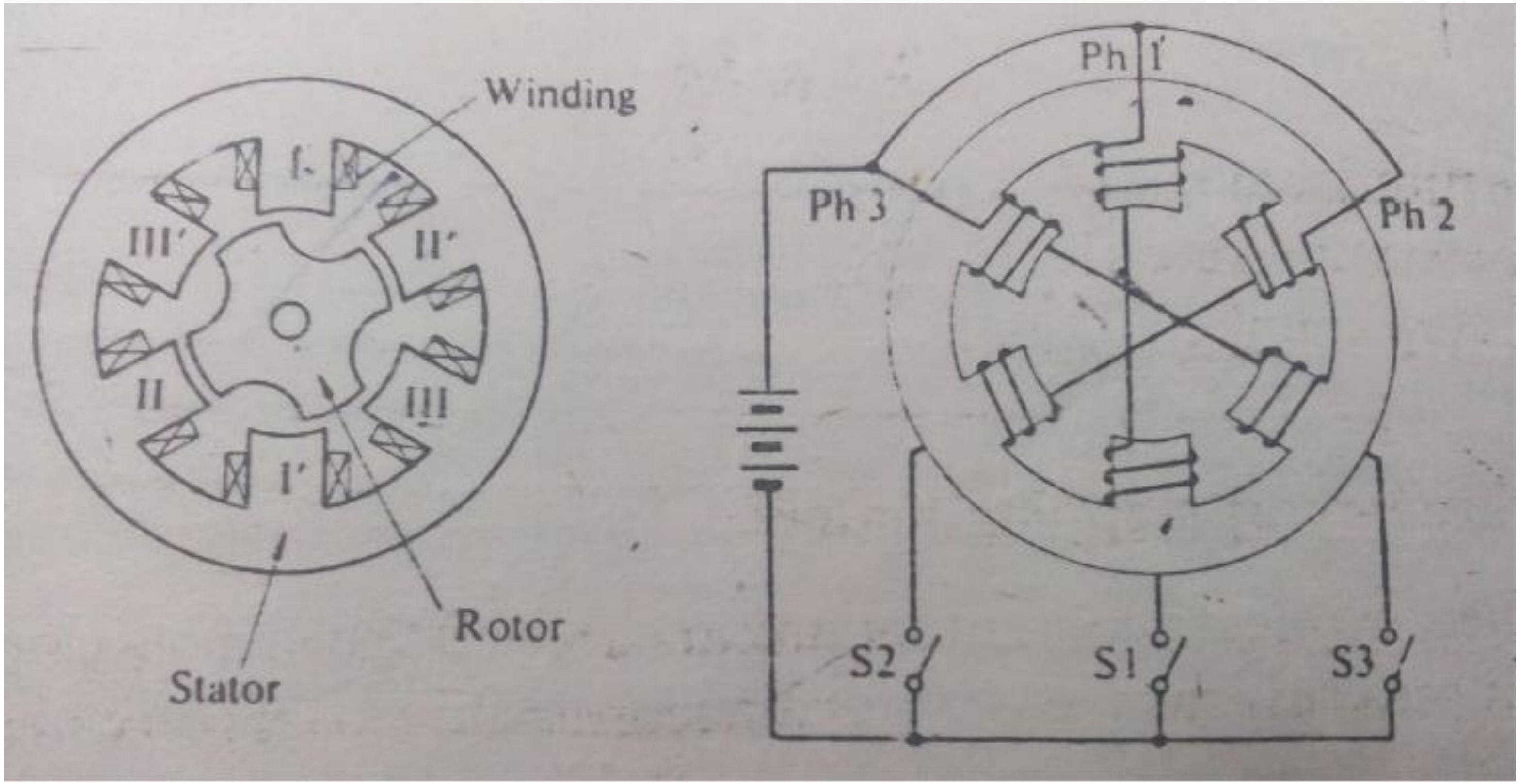
- Permanent Magnet
  - Magnetic rotor
- **Variable Reluctance**
  - Non-magnetic, geared rotor
- Hybrid
  - Combines characteristics from PM and VR
  - Magnetic, geared rotor


θ = 0°
θ = 0°
θ = 0°
N
S
N
S
VR Motor
(a)
PM Motor
(b)
Hybrid Motor
(c)

Variable Reluctance Stepper Motor

- It consists of a wound stator and a soft iron multi-tooth rotor.
- The stator has a stack of silicon steel laminations on which stator windings are wound.
- Usually, it is wound for three phases which are distributed between the pole pairs.
- The rotor carries no windings and is of salient pole type made entirely of slotted steel laminations.
- The rotor pole's projected teeth have the same width as that of stator teeth.
- The number of poles on stator differs to that of rotor poles, which provides the ability to self start and bidirectional rotation of the motor.

Cross section model of 3-ph VR stepper motor and winding arrangement



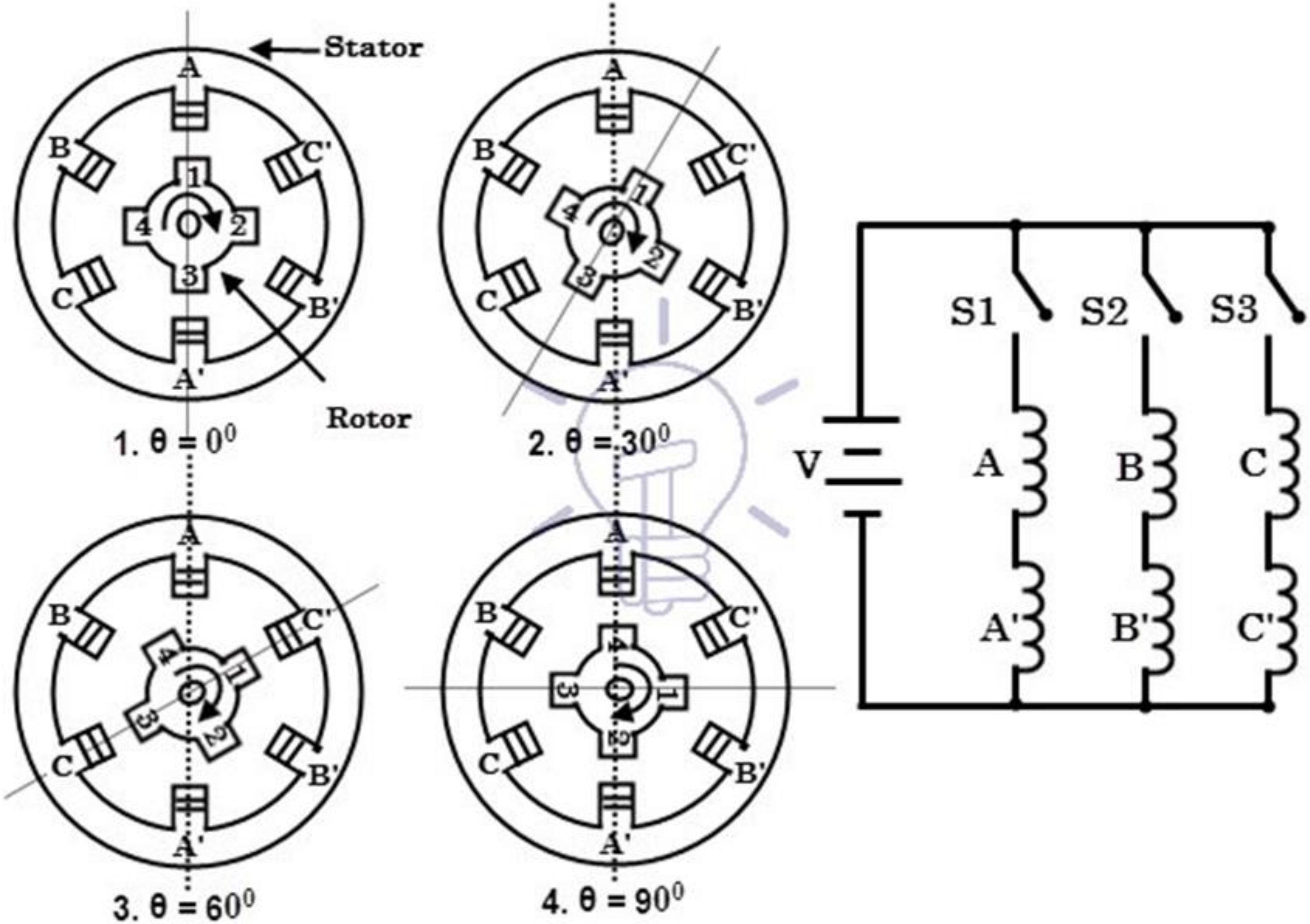
VR Stepper motor has following modes of operation

1. 1 phase ON (or) Full step operation mode
2. 2 phase ON mode
3. Alternate 1 phase ON and 2 phase ON mode (or) Half step operation mode
4. Micro stepping operation mode

Working of Variable Reluctance Stepper Motor

- The stepper motor works on the principle that the rotor aligns in a particular position with the teeth of the excitation pole in a magnetic circuit wherein minimum reluctance path exist.
- Whenever power is applied to the motor and by exciting a particular winding, it produces its magnetic field and develops its own magnetic poles.
- Due to **the residual magnetism in the rotor magnet poles, it will cause the rotor to move in such a position so as to achieve minimum reluctance position and hence one set of poles of rotor aligns with the energized set of poles of the stator.**
- At this position, the axis of the stator magnetic field matches with the axis passing through any two magnetic poles of the rotor.

- When the rotor aligns with stator poles, it has enough magnetic force to hold the shaft from moving to the next position, either in clockwise or counter clockwise direction.
- The stepper motor works on the principle that the rotor aligns in a particular position with the teeth of the excitation pole in a magnetic circuit wherein minimum reluctance path exist.
- Whenever power is applied to the motor and by exciting a particular winding, it produces its magnetic field and develops its own magnetic poles.
- Due to the residual magnetism in the rotor magnet poles, it will cause the rotor to move in such a position so as to achieve minimum reluctance position and hence one set of poles of rotor aligns with the energized set of poles of the stator.
- At this position, the axis of the stator magnetic field matches with the axis passing through any two magnetic poles of the rotor.
- When the rotor aligns with stator poles, it has enough magnetic force to hold the shaft from moving to the next position, either in clockwise or counter clockwise direction.


Stator
Rotor
A
A'
B
B'
C
C'
1. θ = 0⁰
2. θ = 30⁰
3. θ = 60⁰
4. θ = 90⁰
V
S1
S2
S3

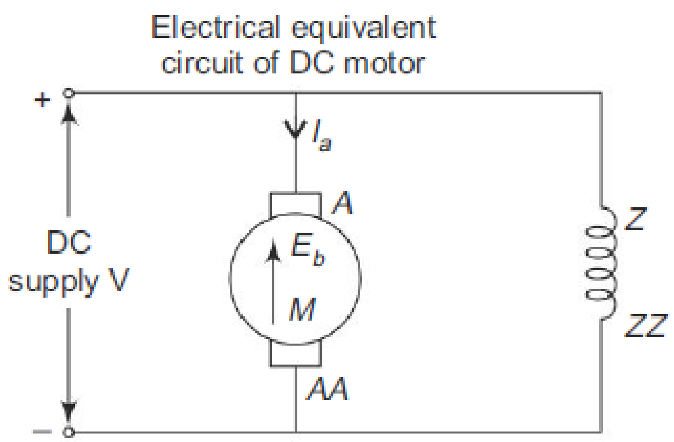
DC MOTOR

Principle

Whenever a current carrying conductor is kept in a stationery magnetic field an electromagnetic force is produced. This force is exerted on the conductor and hence the conductor is moved away from the field. This is the principle used in d.c. motors.

Construction

The construction of dc motor is exactly similar to dc generators. The salient parts of a dc motor are yoke or frame, main field system, brushes, armatures and commutator.



Construction

For the satisfactory operation of a dc generator, it should consists of a stator and a rotor.

The stator accommodates the yoke, the main field system and the brushes. The rotor has the armature and the commutator as its main parts. Figure 6.3 shows these parts. Each of these parts is described as follows:

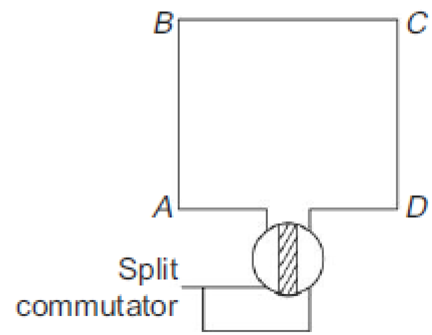
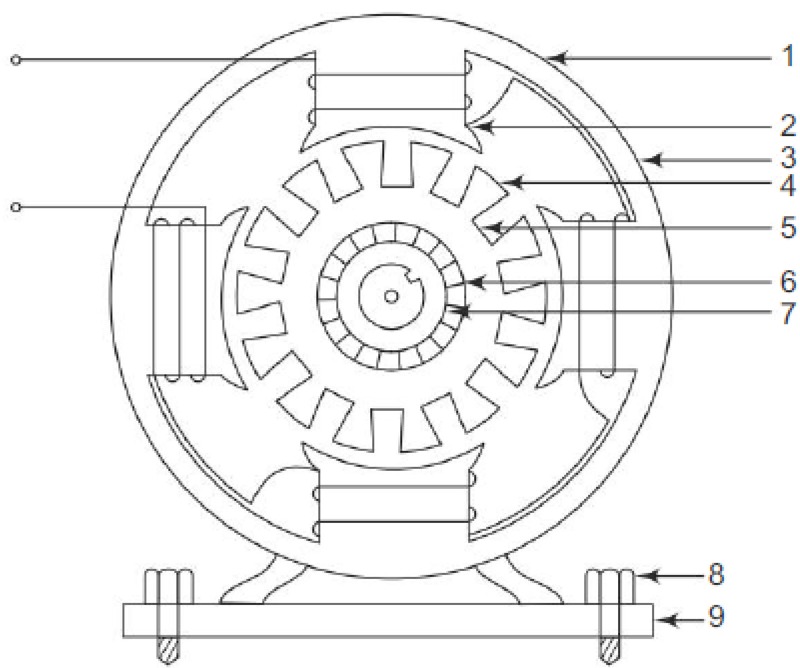


Fig. 6.2



1 Yoke or Frame
2 Main field pole
3 Field winding
4 Armature
5 Slot
6 Commutator
7 Shaft
8 Foundation bolt
9 Bed plate

Working

In a dc motor, both the armature and the field windings are connected to a dc supply. Thus, we have current carrying armature conductors placed in a stationery magnetic field. Due to the electromagnetic torque on the armature conductors, the armature starts revolving. Thus, electrical energy is converted into mechanical energy in the armature. When the armature is in motion, we have revolving conductors in a stationery magnetic field. As per Faraday's Law of electromagnetic induction, an emf is induced in the armature conductors. As per Lenz's law, this induced emf opposes the voltage applied to the armature. Hence, it is called the counter or back emf. There also occurs a potential drop in the armature circuit due to its resistance. Thus, the applied voltage has to overcome the back emf in addition to supplying the armature circuit drop and producing the necessary torque for the continuous rotation of the armature.

Figure gives the electrical circuit of a d.c. shunt motor where

E_b = back EMF

I_a = current flowing in the armature circuit

R_a = resistance of armature circuit

V = applied voltage

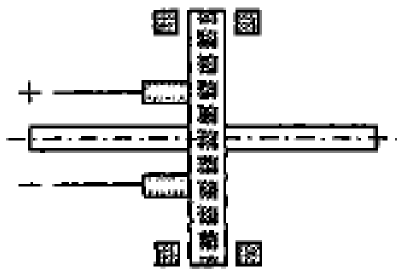
Thus, the characteristics equation of a dc motor is $V = E_b + I_aR_a$, where I_aR_a represents the potential drop in the armature circuit.

DC-motor features (direct current)

→ Mechanical or electronic Commutation
→ Low torque, high speed
→ Transmission is usually necessary
    - Backlash, friction losses
→ Constant velocity at different loads
→ Measurement system is required
→ Simple speed control
→ Dominating the first electrically driven robots
→ Mechanical commutation limits the maximum current transfer
→ Service cycle of the brush is approximately 30,000 hours
→ These engines are increasingly being replaced by AC motors

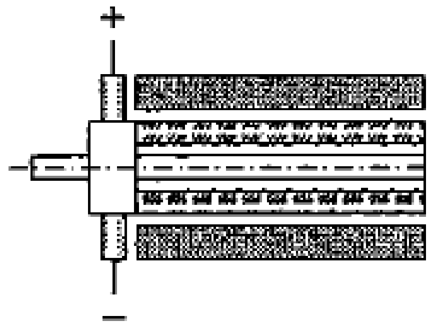
DC Motor Type

DC-Motor Construction



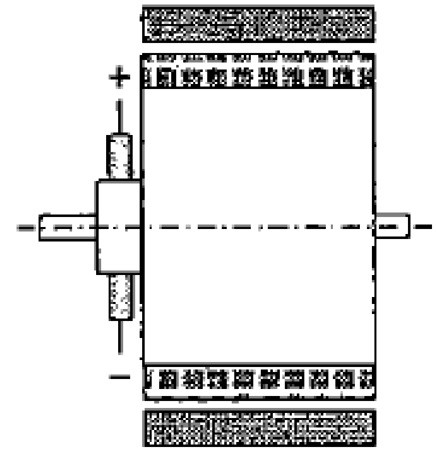
Ring motor

- Low moment
- High rotational speed
- High positioning accuracy
- Narrow execution



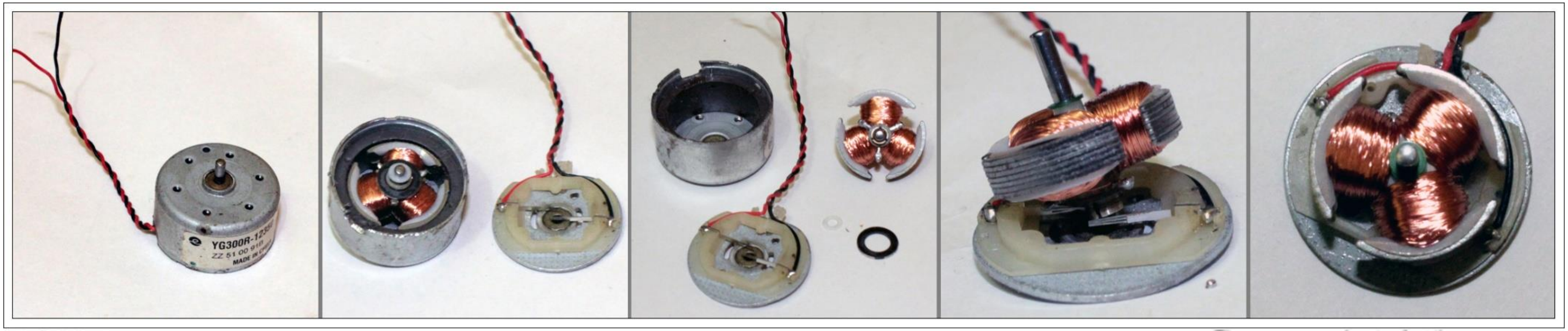
Stabanker motor

- Robust
- Small moment of inertia
- Very high speed

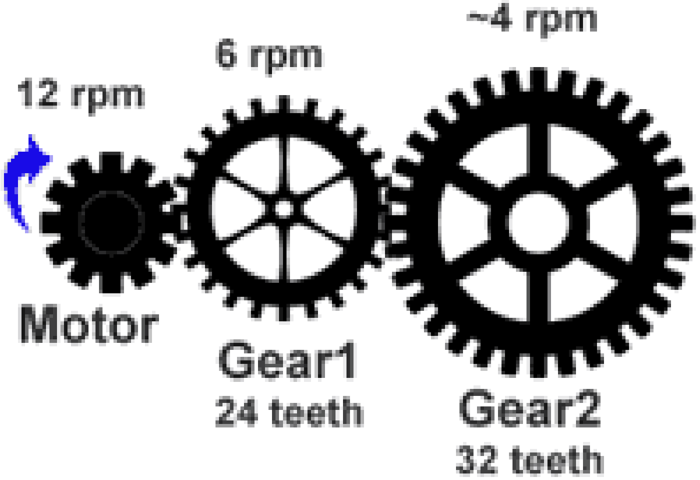


Moment motor

- High torque at lower rotational speed
- Suitable as “Direct drive“ Motor
- High dimensions
- High weight

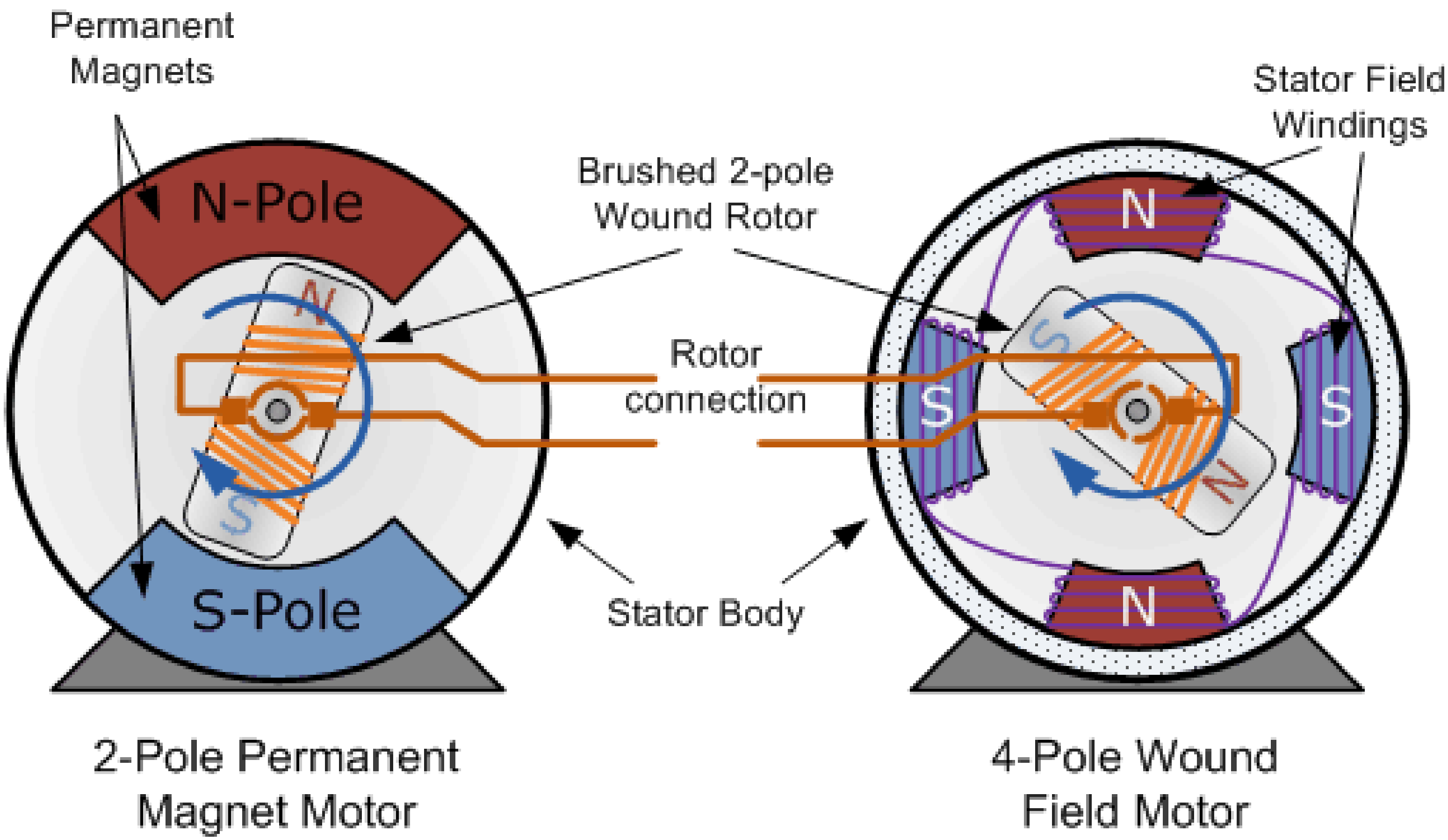


DC Motor © www.robotplatform.com



Gear Motors ©www.robotplatform.com

Conventional (Brushed) DC Motor



Example:

Gearmotor - Brushed geared DC motor GM45 R=642.6 MV1 with Hall sen

Brushed geared DC motor with a GM300AR1 reducer

Position sensor (optionaly): hall type
Supply voltage: from 12-24V DC
Rated rev-per-min: from 4 to 130 min-1
Rated torque: from 0.30 to 1.3Nm
Maximum toque: 1.6Nm
Maximum current: 700mA
Maximum output power: 3W
Temperature working range: from -22°C to +85°C
Gear Type: Conventional evolute gears
Housing type: plastic
Gear ratio: from 47 to 642 (6 gear box combinations)
Estimated life time: 1000 hours
Output shaft dia: Ø4mm
Storage temperature range: -55C~ 85C

DC-Brush Motor:

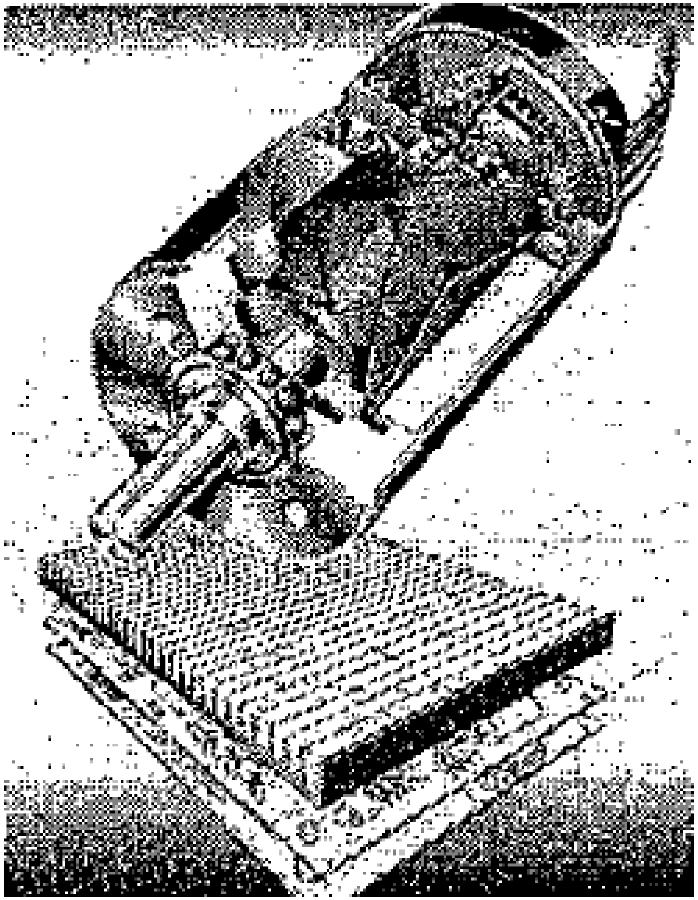
- http://upload.wikimedia.org/wikipedia/commons/7/73/Ejs_Open_Source_Direct_Current_Electrical_Motor_Model_Java_Applet_%28_DC_Motor_%29_80_degree_split_ring.gif

Simple two-pole DC motor Rotation:

- http://en.wikipedia.org/wiki/File:Electric_motor.gif

DC-Motor (electronically commutated)

-Better torque characteristics
- higher power
- higher speed
- maintenance-free



BLDC Motor

Introduction

A brushless DC motor is a poly phase synchronous motor with a permanent - magnet rotor. This motor cannot operate without its electronic controller or electronic commutator. Therefore, a brushless DC motor is motor drive system that combines into one unit an AC motor, solid state inverter and rotor position sensor. The simple block diagram PMBL DC motor.

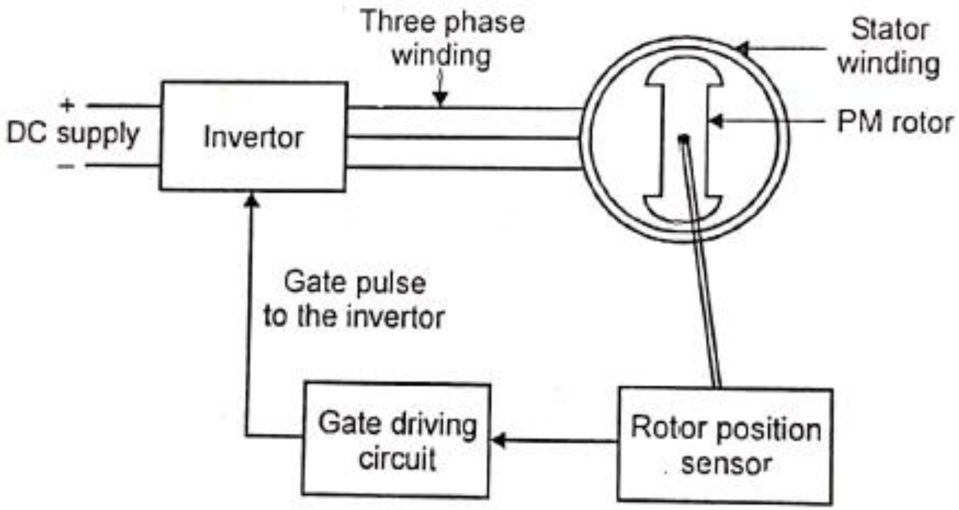


Figure 4.1(e)

The solid state inverter uses transistors, MOSFETs for low and medium power drives and thyristors for high power drives. Here, the rotor position sensor (RPS) monitors the shaft position and sends the contorl signals for turning on the controlled switches of the inverter in an appropriate sequence.

Stator

A brushless DC motor is also viewed as "inside-out" DC motor because its construction is opposite to that of a conventional DC motor.

The stator of the PMBLDC motor is made up of silicen steel stampings with slots its interior surface. There slots are accommodated either in closed or open distrubuted armature winding. This winding is wound for a specified number of poles (even number). This winding is suitable connected to DC supply through a solid state inverter circuit.

Rotor

Rotor accommodates a permanent magnet. The number of poles of the rotor is same as that of stator. The rotor shaft carries a rotor position sensor (RPS). This position sensor provides information about the position of the shaft at any instant to the controller which sends signals to the electronic commutator. This electronic commutator function is similar to the conventional mechanical commutator DC motor.

This motor posses more advantages over conventional DC motor is given below.

1. As no mechanical commutator and brushes are required, it has longer life.
2. Problems relating to radio frequency and electormagnetic interference are minimized.
3. This motor can run at speeds higher than those obtained in a conventional DC motor.
4. This motor is more efficient.

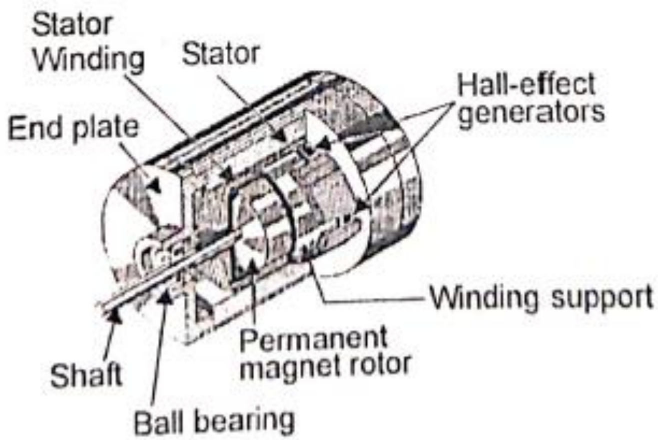


Figure 4.1(f)

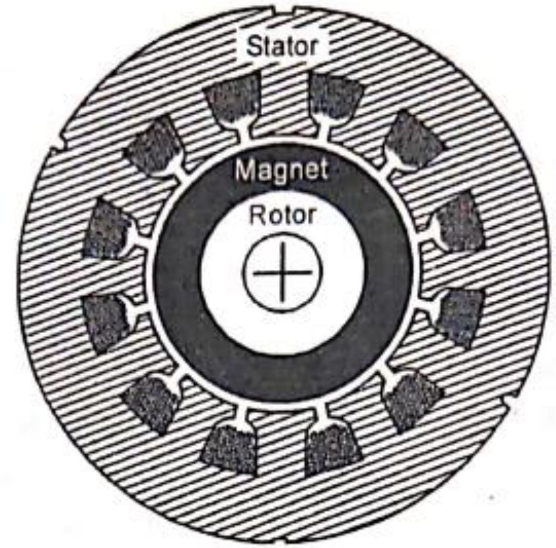


Figure 4.1 (g)

Advantages of PMBL DC Motor

1. There is no field winding so that field copper loss is neglected.
2. Length of the motor is very small as there is no mechanical commutator, so that size becomes very small.
3. Better ventilation because of armature accommodated in the stator
4. Regenerative braking is possible.
5. Speed can be easily controllable.
6. Motor can be designed for higher voltages subjected to the constraint caused by the power semi conductor switching circuit.
7. It is possible to have very high speeds.

Disadvantages

1. Motor field cannot be controlled.
2. Power rating is restricted because of the maximum available size of permanent magnets.
3. It requires a rotor position sensor.
4. It requires a power semi conductor switching circuit.

Applications

1. Automotive applications
2. Verticular electric drive motors
3. Applications in textile and glass industries
4. Computer and Robotics
5. Small appliances such as fans, mixers etc.

Servo Motor

- Servo is an electromagnetic device uses a negative feedback mechanism to converts an electric signal into controlled motion. Basically, servos behave like as actuators which provide precise control over velocity, acceleration, and linear or angular position.
- It consists of four things: DC motor, position sensor, gear train, and a control circuit. The gear mechanism connected with the motor provides the feedback to the position sensor.
- If the motor of the servo is operated by DC then it is called a DC servo motor and if it is operated by AC then it is called as AC servo motor. The gear of the servo motor is generally made up of plastic but in high power servos, it is made up of metal.

Types of Servo Motors on the Basis of Rotation

Positional Rotation Servos: Positional servos can rotate the shaft in about half of the circle. Also, it has the feature to protect the rotational sensor from over-rotating. Positional servos are mainly used in limbs, robotic arms, and in many other places.

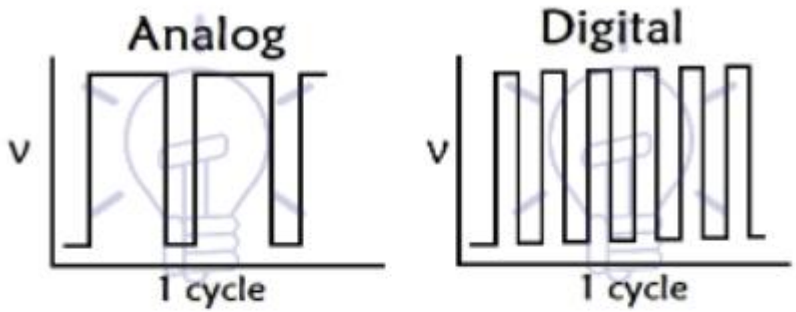
Continuous Rotation Servos: Continuous servos are similar in construction to the positional servo. But, it can move in both clockwise and anticlockwise directions. These types of servos are used in radar systems and robots.

Linear Servos: Again linear servos are also like a positional servo, but with additional gears to the adjust the output from circular to back-and-forth. These type of servos are used in high model airplanes and are rare to find on the stores.

On the Basis of Operating Signal

(i) Analog Servomotors: Analog servos are operated over PWM (Pulse Width Modulation) signals.

(ii) Digital Servomotors: Digital Servo receives signal and acts at high-frequency voltage pulses. Digital servo gives a smooth response and consistent torque, due to faster pulse. Digital servos consume more power than an analog

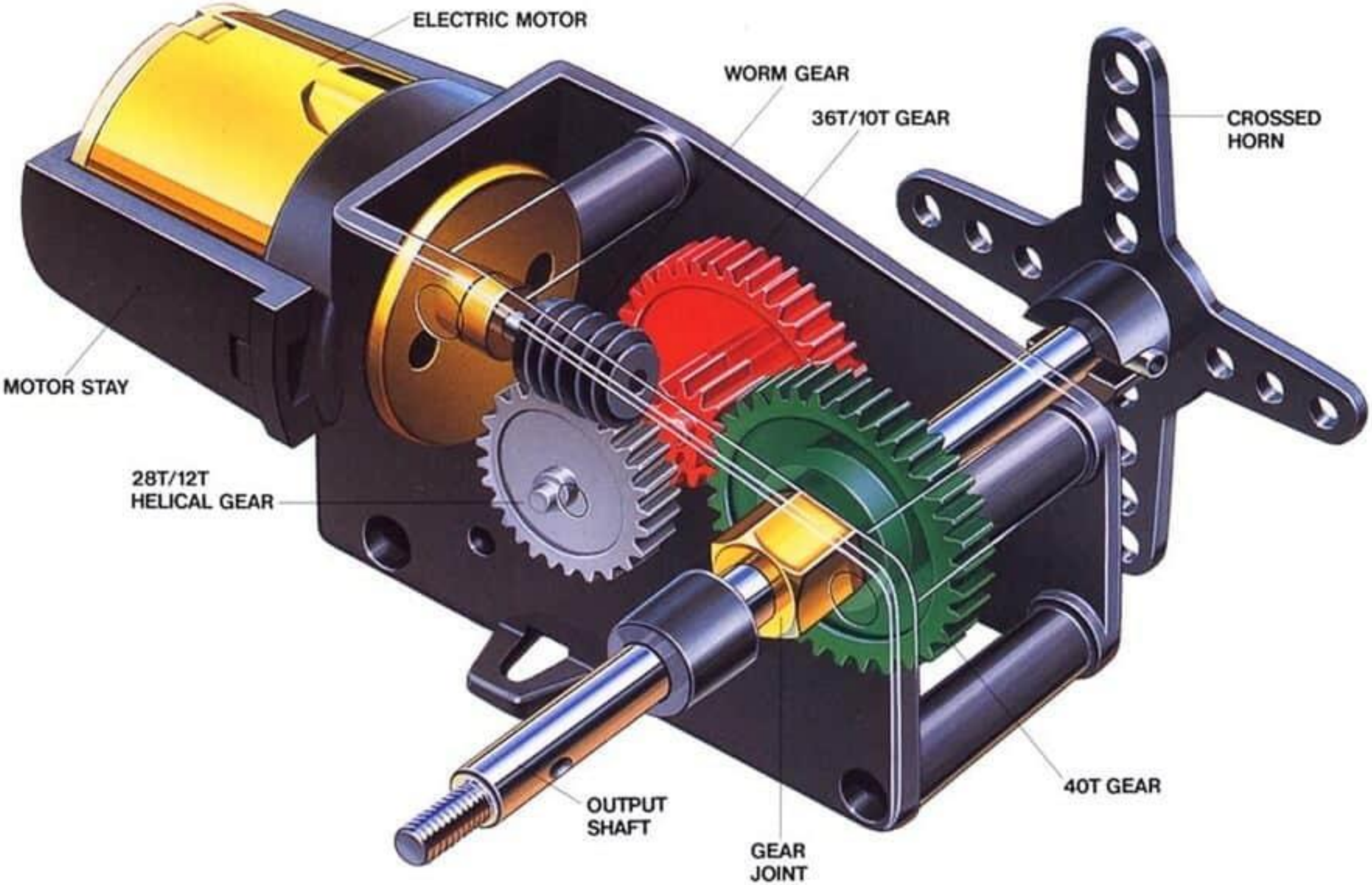


On the Basis of Operating Power

(i) DC Servo Motor

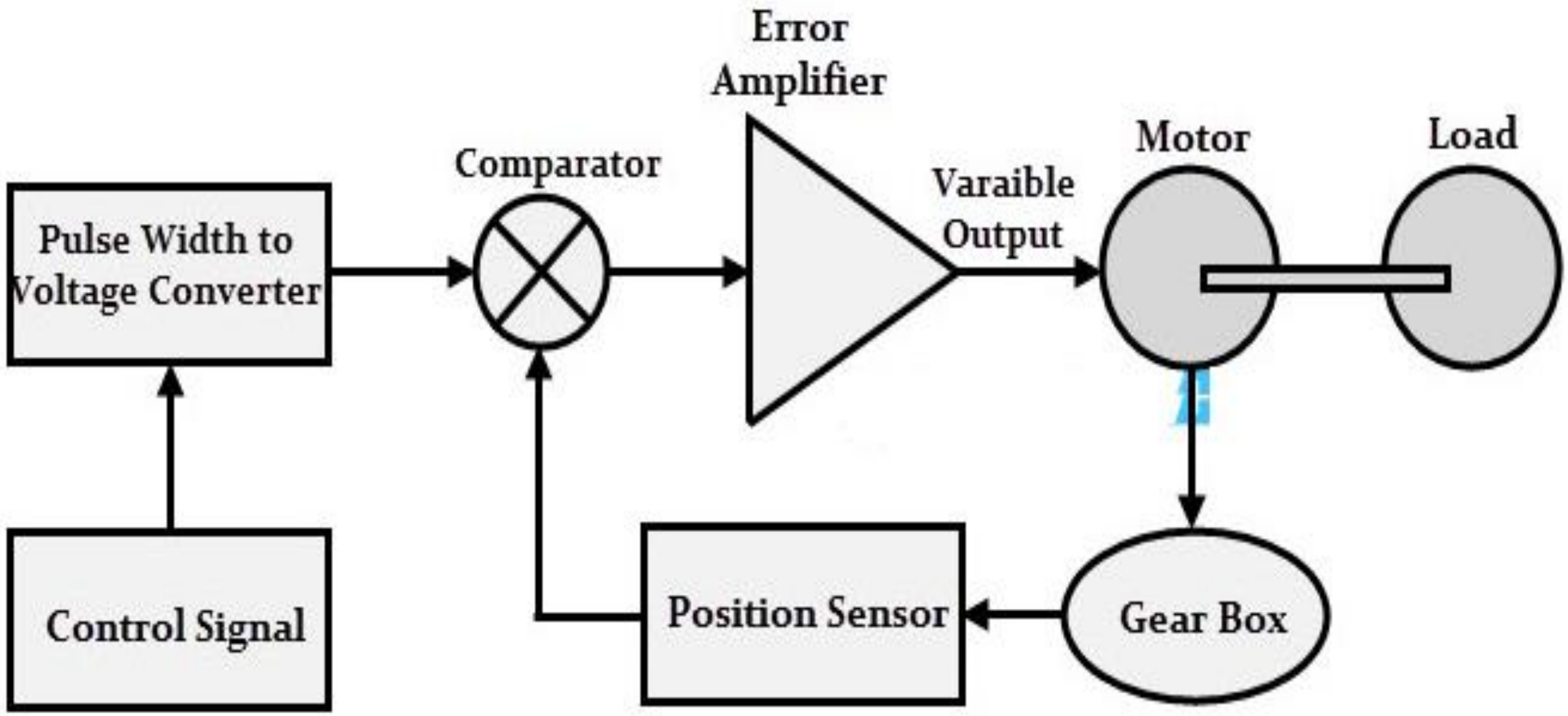
(ii) AC Servo Motor

Construction of Servo Motor:



Construction of Servo Motor

Closed loop system - Servo Motor:



Stator Winding: This type of winding wound on the stationary part of the motor. It is also known as field winding of the motor.

Rotor Winding: This type of winding wound on the rotating part of the motor. It is also known as an armature winding of the motor.

Bearing: These are of two types, i.e, font bearing and back bearing which are used for the movement of the shaft.

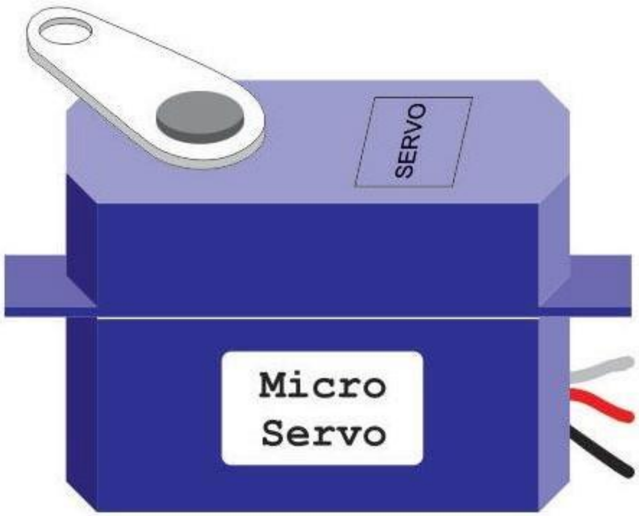
Shaft: The armature winding is coupled on the iron rod is known as the shaft of the motor.

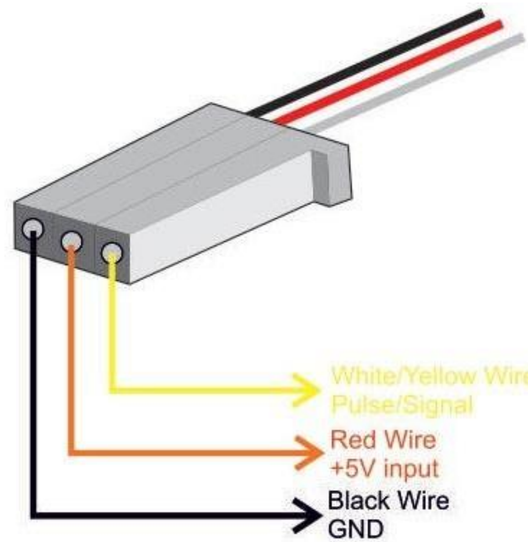
Encoder: It has the approximate sensor which determines the rotational speed of motor and revolution per minute of the motor.

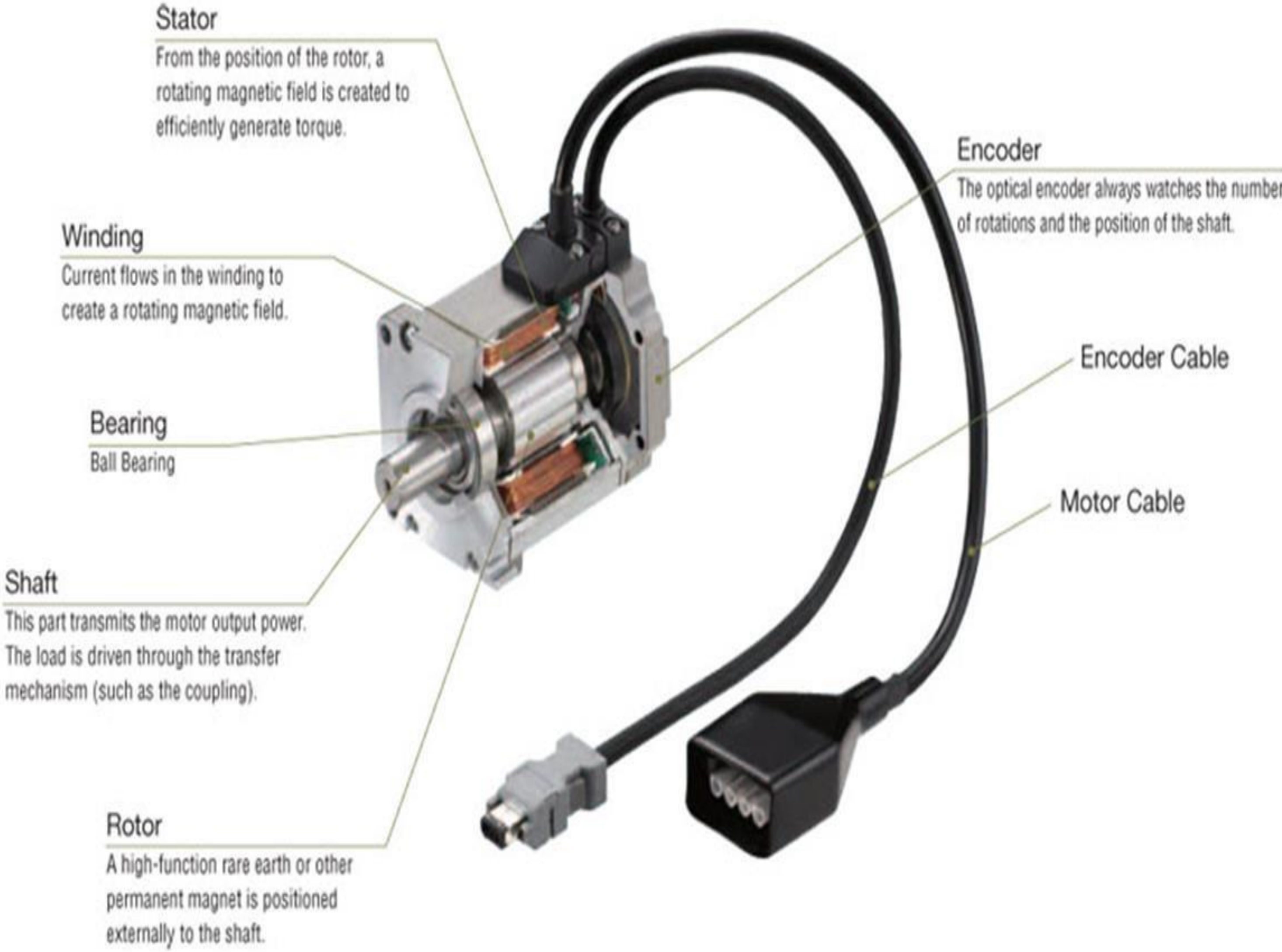
Working of Servo Motors

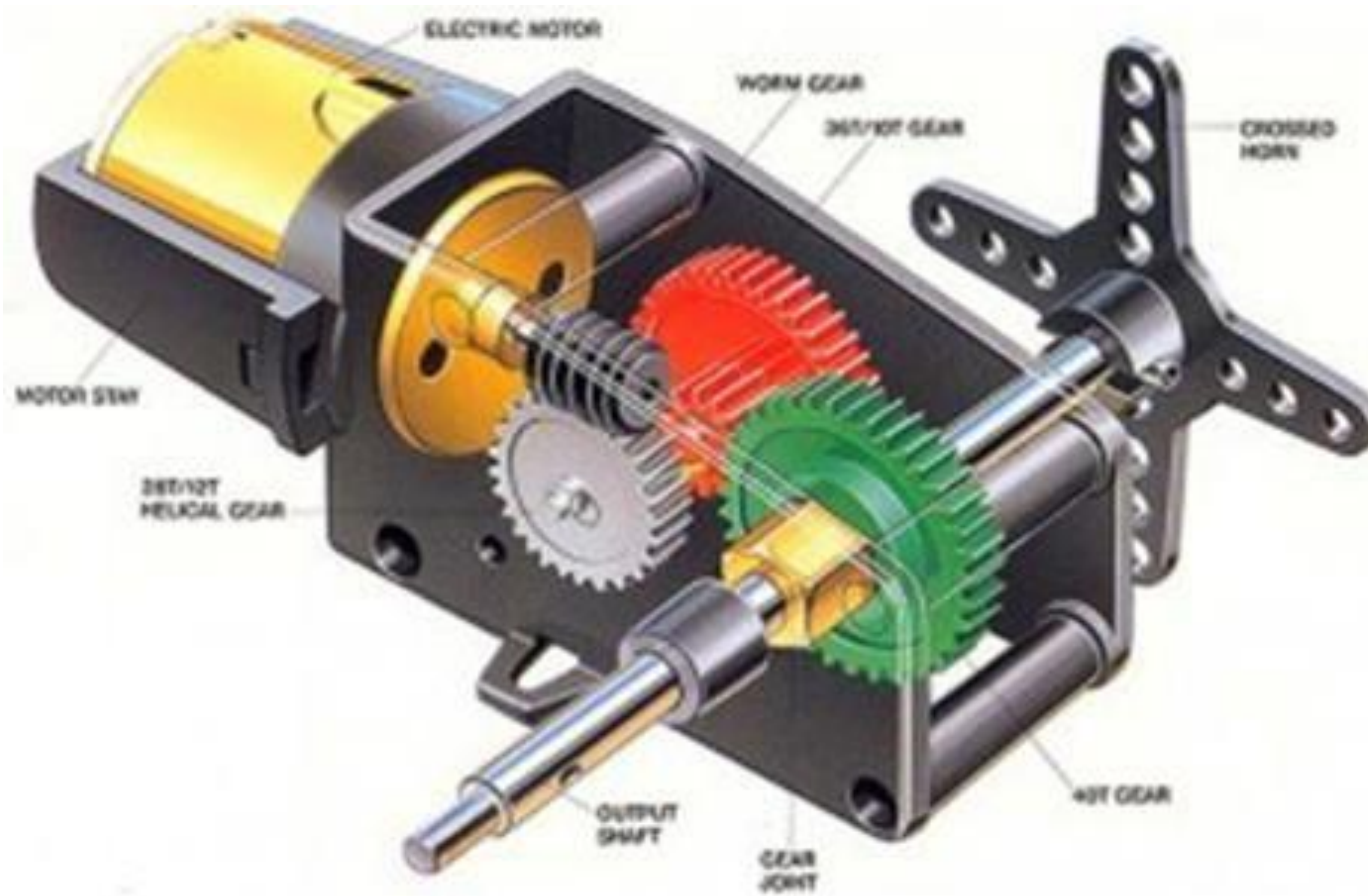
- The servo has a position sensor, a DC motor, a gear system, a control circuit. The **DC motor run at high speed and low torque** when getting power from a battery. The position of shaft sensed by position sensor from its definite position and supply information to the control circuit.
- The **reduction gearbox is connected to a shaft which decreases the RPM of the motor.** The output shaft of the reduction gearbox is the same as of motor which is connected with encoder or potentiometer.
- The output of the encoder is then connected to the control circuit. The wires of the servomotor are also connected to the control circuit.
- The motor control through microcontroller by sending signals in the form of PWM which decodes the control circuit to rotate the motor in required angle the control circuit moves the motor in a clockwise or anticlockwise direction, with this the shaft also rotates in the desired direction.

- More sophisticated servomotors use
- **optical rotary encoders**
  - **to measure the speed** of the output shaft and
- a variable-speed drive
  - to control the motor speed.


SERVO
Micro
Servo


White/Yellow Wire
Pulse/Signal
Red Wire
+5V input
Black Wire
GND


Stator
From the position of the rotor, a rotating magnetic field is created to efficiently generate torque.
Winding
Current flows in the winding to create a rotating magnetic field.
Bearing
Ball Bearing
Shaft
This part transmits the motor output power. The load is driven through the transfer mechanism (such as the coupling).
Rotor
A high-function rare earth or other permanent magnet is positioned externally to the shaft.
Encoder
The optical encoder always watches the number of rotations and the position of the shaft.
Encoder Cable
Motor Cable


ELECTRIC MOTOR
WORM GEAR
36T/10T GEAR
CROSSED HORN
MOTOR STAY
28T/12T HELICAL GEAR
OUTPUT SHAFT
GEAR JOINT
40T GEAR

TYPES OF SERVO MOTORS

- AC servo motor

- Dc servo motor

- Continuous rotation servo motor

- Linear servo motor

- Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at **3kg/cm or 6kg/cm or 12kg/cm**.
- This kg/cm tells you how much weight your servo motor can lift at a particular distance.
- For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity.
- The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

Stepper vs Servo

- The basic difference between a traditional stepper and a servo-based system is the **type of motor and how it is controlled.**
- Steppers don't require **encoders** since they can accurately move between their many poles whereas servos, with few poles, require an encoder to keep track of their position.

- Servo is a **closed loop system** where it uses positive feedback system to control motion and final position of the shaft.
- Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.
- Servomotors are generally used as a high-performance alternative to the stepper motor.

- Stepper motors have some **inherent ability to control position,** as they have built-in output steps.
- This often allows them to be used as an **open-loop position control**, without any feedback encoder, as their drive signal specifies the number of steps of movement to rotate.

- Therefore, on first power up, the controller will have to activate the stepper motor and turn it to a known position, e.g. until it activates an end limit switch.
- This can be observed when switching on **an inkjet printer;** the controller will move the ink jet carrier to the extreme left and right to establish the end positions.
- A **servomotor** will immediately **turn to whatever angle** the controller instructs it to, regardless of the initial position at power up.
- The lack of feedback of a stepper motor limits its performance.

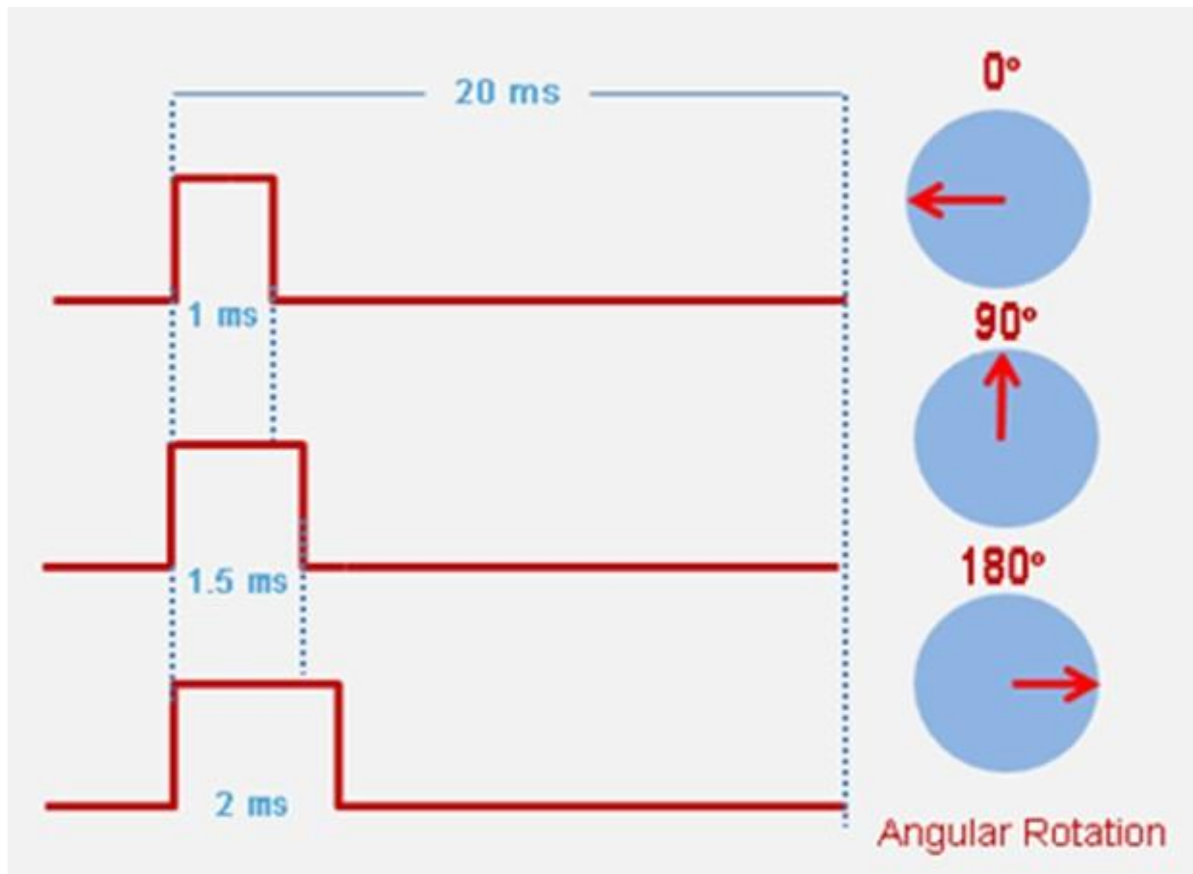
- The lack of feedback of a stepper motor limits its performance.
- The stepper motor can only drive a load that is well within its capacity
- Otherwise missed steps under load may lead to positioning errors and the system may have to be restarted or recalibrated.
- The encoder and controller of a servomotor are an additional cost,
- but they optimise the performance of the overall system.

Controlling Servo Motor

- All motors have three wires coming out of them.
- Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.
- Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires.

- There is a minimum pulse, a maximum pulse and a repetition rate.
- Servo motor can turn 90 degree from either direction form its neutral position.
- The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns.

- For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.



- Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN.
  - Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears.
  - High speed force of DC motor is converted into torque by Gears.

- We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less.
- Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.

- Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing.
- This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin.
- Servo checks the pulse in every 20 milliseconds.

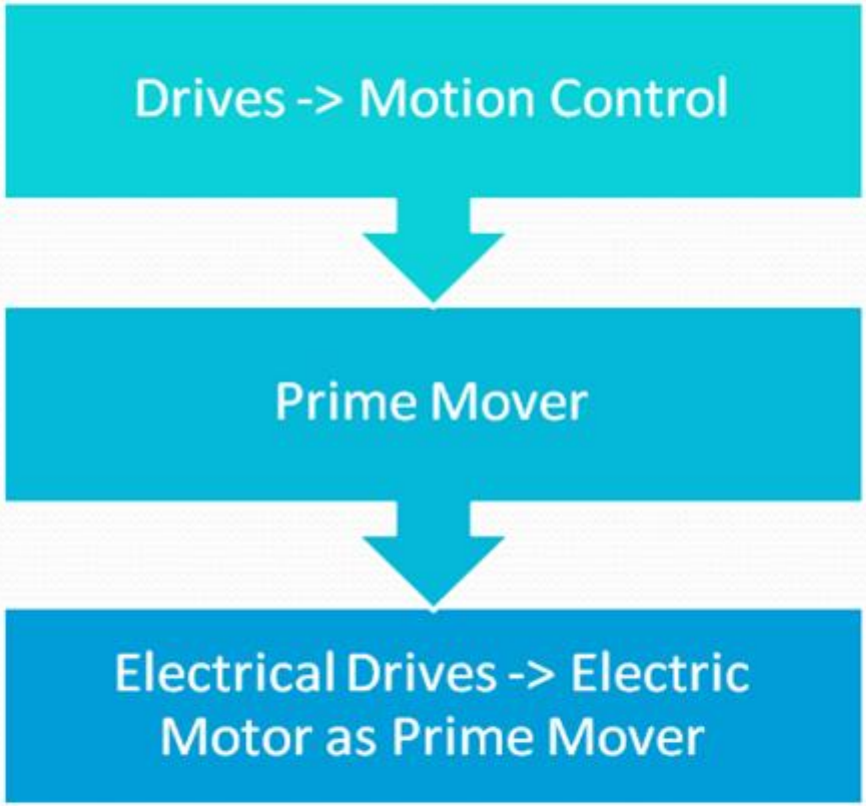
- Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.
- All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume, if you are planning to use more than two servo motors a proper servo shield should be designed.

Applications of Servo Motors

- They are used to control the positioning and movement of elevators in radio controlled airplanes.
- They play an important role in robotics information of robot because of their smooth switching on or off and accurate positioning.
- They are used in hydraulic systems to maintain hydraulic fluid in the aerospace industry.
- In radio controlled toys these are also used.
- They are used to extend or replay the disc trays in electronic devices such as DVDs or Blue-ray Disc players.
- They are used to maintain the speed of vehicles in the automobile industries.

Electrical Drives

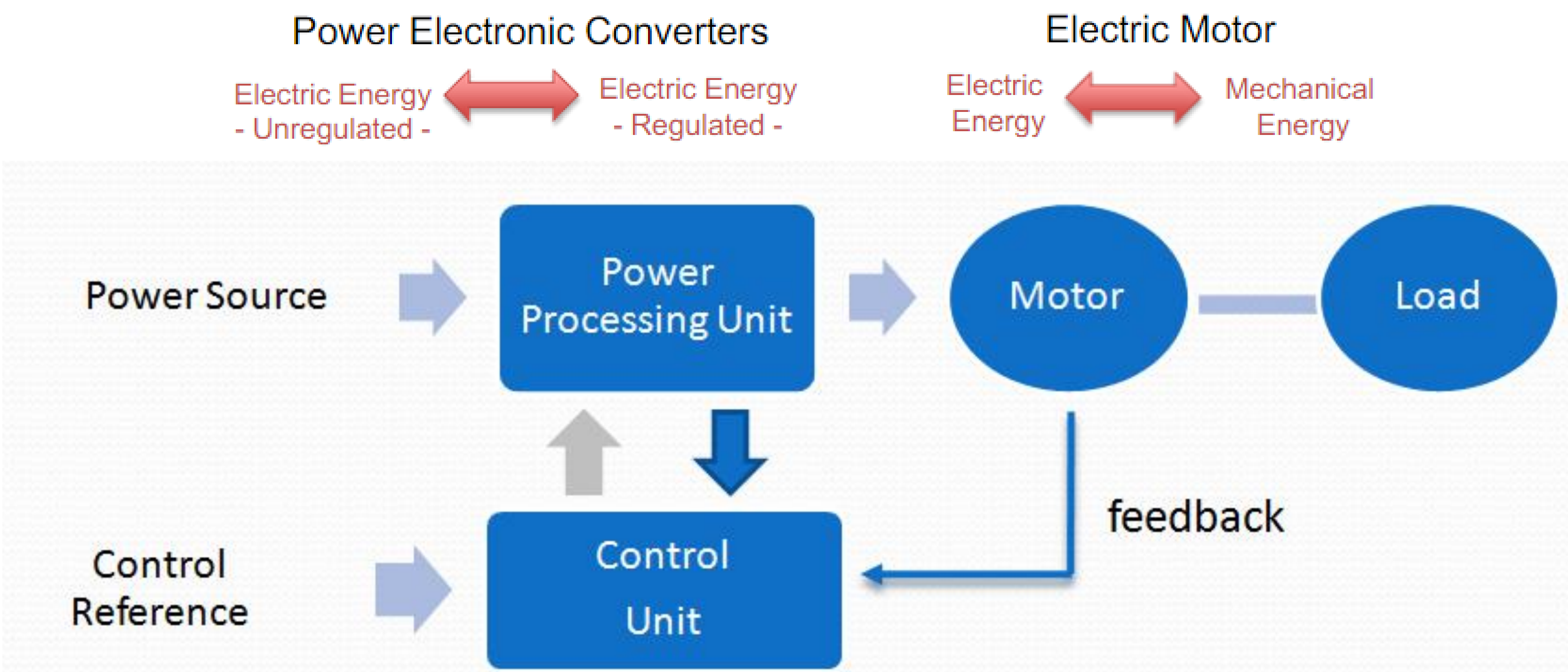
- Drives – system employed for motion control
- Motion control requires prime movers
  Diesel/petrol/gas/stream engines, hydraulic motors, electric motors
- **Electrical Drives** – Drives that employ Electric Motors as prime movers



Advantages of Electrical Drives

- Flexible control characteristic
  - particularly when power electronic converters are employed
- Wide range of speed, torque and power
- High efficiency – low no load losses
- Low noise
- Low maintenance requirements, cleaner operation
- Electric energy easily transported
- Adaptable to most operating conditions
- Available operation in all four torque-speed quadrants

Block Diagram of Electric Drive System



- Power Source
- Motor
- Power Processing Unit (Electronic Converter)
- Control Unit
- Mechanical Load

Components in electric drives

Motors

- DC motors - permanent magnet – wound field
- AC motors – induction, synchronous
- brushless DC
- Applications, cost, environment
- Natural speed-torque characteristic is not compatible with load requirements

Power sources

- DC – batteries, fuel cell, photovoltaic - unregulated
- AC – Single- three- phase utility, wind generator - unregulated

Power processor

- To provide a regulated power supply
- Combination of power electronic converters
    - More efficient
    - Flexible
    - Compact
    - AC-DC, DC-DC, DC-AC, AC-AC

Components in electric drives

Control unit

- Complexity depends on performance requirement
- analog- noisy, inflexible, ideally has infinite bandwidth.
- DSP/microprocessor – flexible, lower bandwidth - DSPs perform faster operation than microprocessors (multiplication in single cycle), can perform complex estimations
- Electrical isolation between control circuit and power circuit is needed:
  - Malfunction in power circuit may damage control circuit
  - Safety for the operator
  - Avoid conduction of harmonic to control circuit

Components in electric drives

Sensors

- Sensors (voltage, current, speed or torque) is normally required for closed-loop operation or protection.
- Electrical isolation between sensors and control circuit is needed.
- The term ‘sensorless drives’ is normally referred to the drive system where the speed is estimated rather than measured.

Applications of Electric Drives

Transportation Systems

Rolling Mills

Paper Mills

Textile Mills

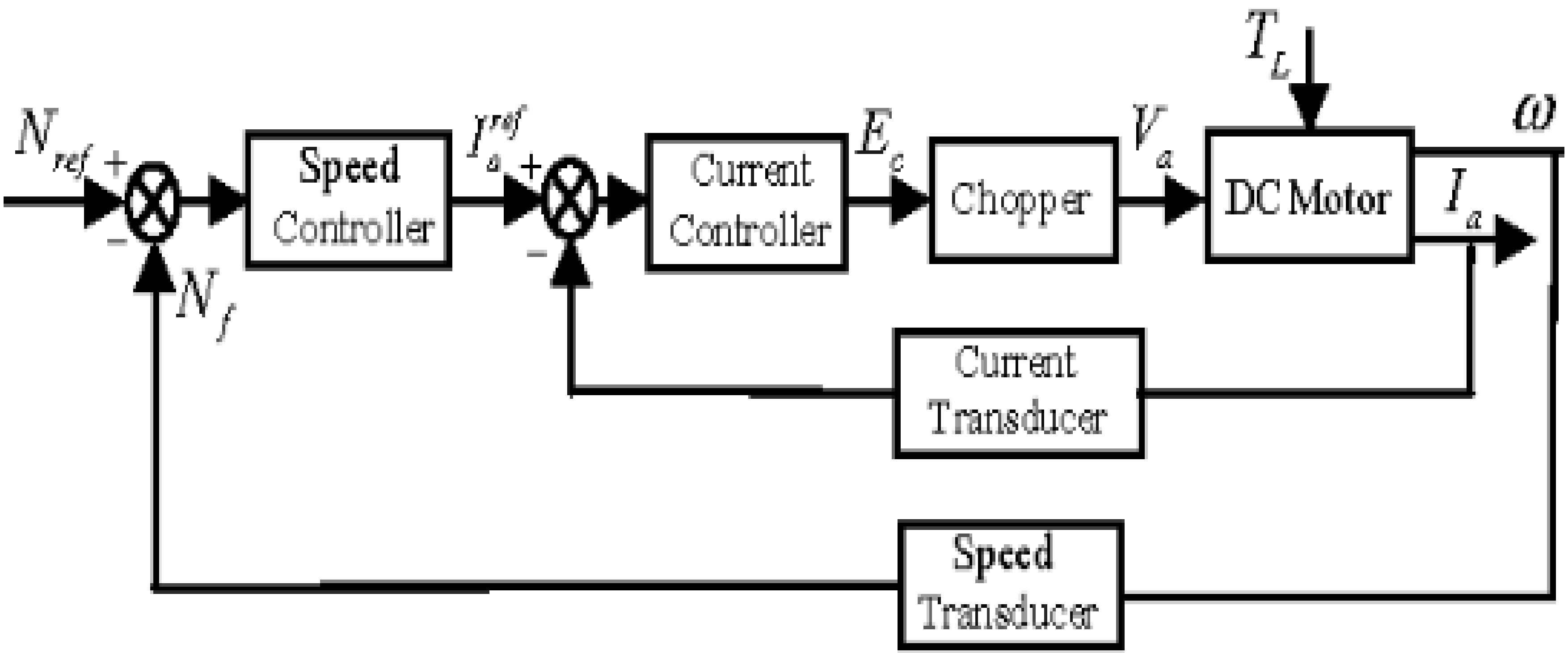
Machine Tools

Fans and Pumps

Robots

Washing Machines etc

Chopper fed dc drive

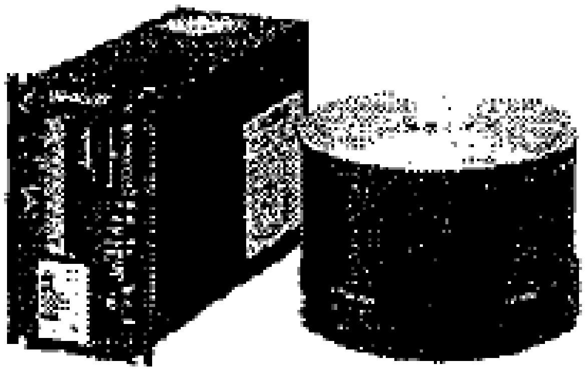


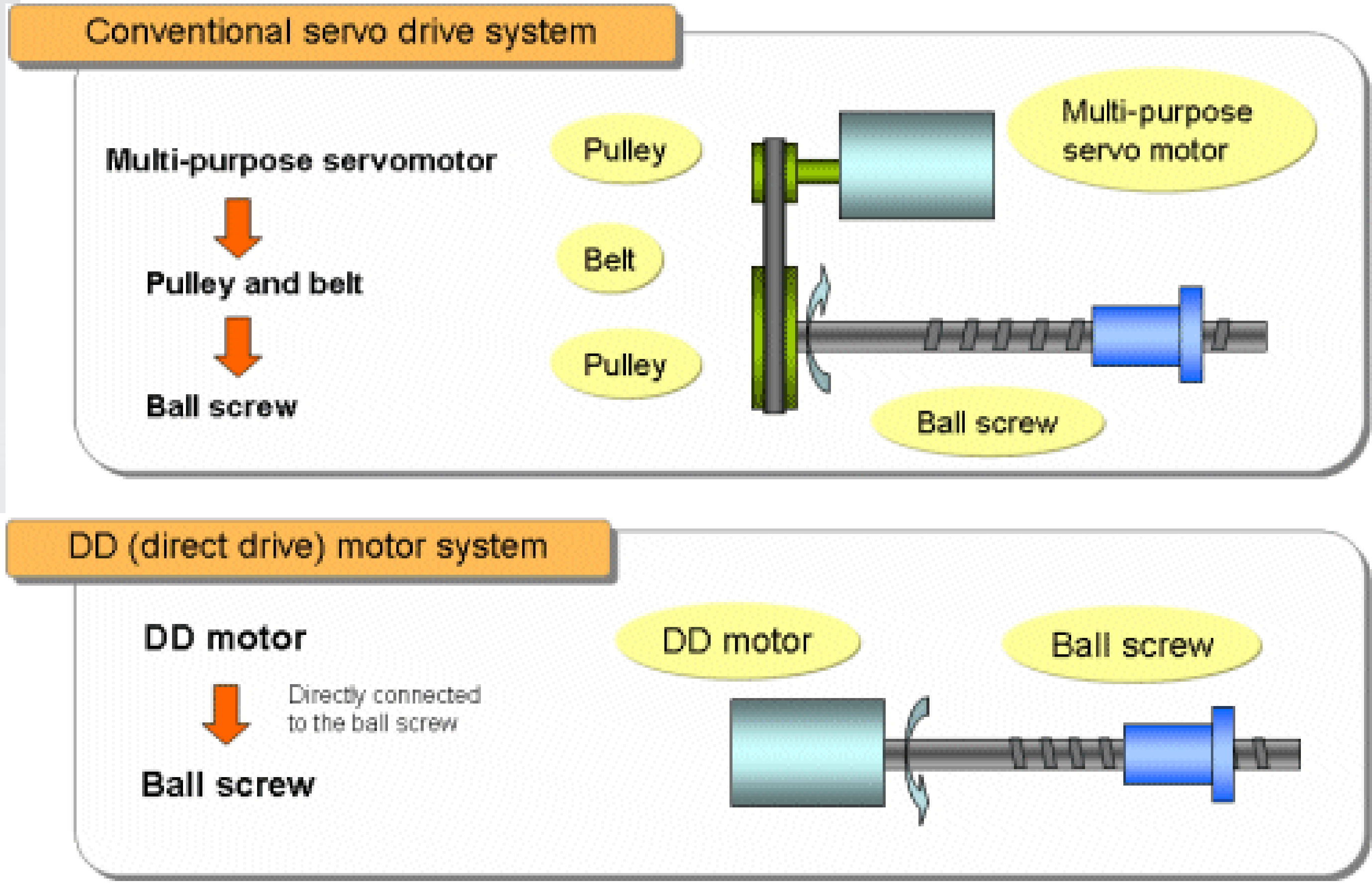
Factors for selection of Electrical Drives

- Several factors affecting drive selection:
  - Steady-state operation requirements
    - nature of torque-speed profile, speed regulation, speed range, efficiency, quadrants of operations, converter ratings
  - Transient operation requirements
    - values of acceleration and deceleration, starting, braking and reversing performance
  - Power source requirements
    - Type, capacity, voltage magnitude, voltage fluctuations, power factor, harmonics and its effect on loads, ability to accept regenerated power
  - Capital & running costs
  - Space and weight restrictions
  - Environment and location
  - Efficiency and reliability

DD-Motor (direct drive)

- Free gear
- Maintenance-free
- Low friction
- High precision positioner
- High repeatability
- high load capacity
- high torque
- computer-controlled
- Application for small robots for assembly purposes
- Strong reaction of the mechanical system on the engine




Conventional servo drive system
Multi-purpose servomotor
Pulley and belt
Ball screw
Pulley
Belt
Pulley
Multi-purpose servo motor
Ball screw
DD (direct drive) motor system
DD motor
Directly connected to the ball screw
Ball screw
DD motor
Ball screw

DD-Motor (direct drive)

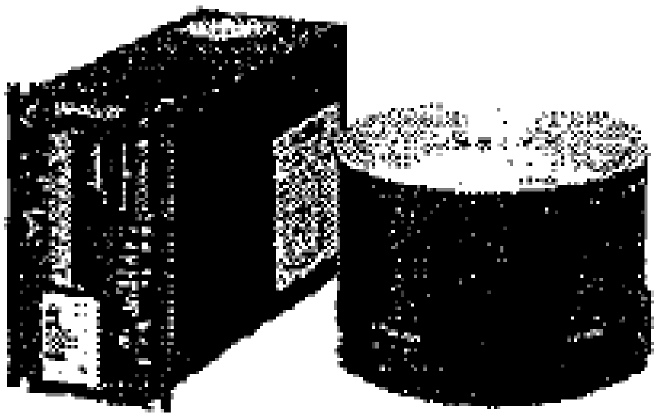
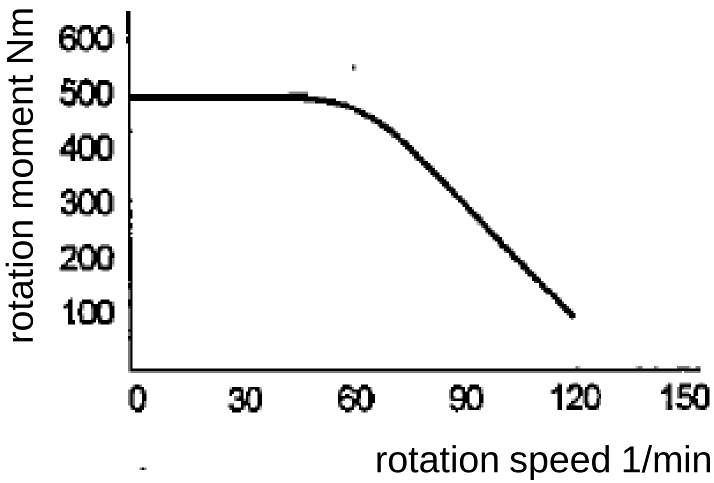
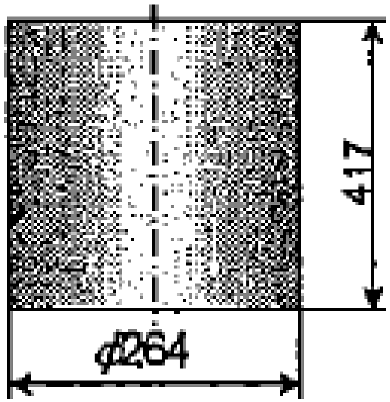


Diagram:



Measuring system:

- Resolver
- Incremental rotary encoder



$J = 0.46$ kgm²

Resolution: 425984 steps/rotation

m = 75 kg

Repeating precision: ±5”

Precision: ±45”

Comparison:
Direct drive - Conventional drive

	Direct drive	conventional drive
Positioning accuracy	Very good for high-resolution measurement system	Extremely low-backlash gear required
maintenance costs	maintenance-free	Regular oil changes on the gear needed.
Motor moment of inertia	$J_m << J_f$	$J_m + J_g >> J_f$ m – Motor g – gears f – foreign load
stiffness	An elastic coupling eliminated, high stiffness can be achieved by technical regulation measures.	Additional elastic coupling due to the gear
parameter fluctuations	large1 : 4	low1 : (1.1 to 2)
warming	Powerful (standstill)	small

Industrial robots drive chain