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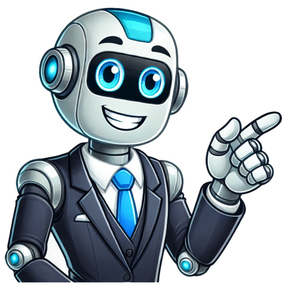

A Direct Current Motor, DC is named according to the connection of the field winding with the armature. Mainly there are two types of DC Motors. One is Separately Excited DC Motor and other is Self-excited DC Motor. The self-excited motors are further classified as Shunt wound or shunt motor, Series wound or series motor and Compound wound or compound motor. The dc motor converts electrical power into mechanical power. The construction of the dc motor and generator are the same. But the dc motor has a wide range of speed and good speed regulation in electric traction. The working principle of the dc motor is based on the principle that the current-carrying conductor is placed in the magnetic field and a mechanical force is experienced by it. The DC motor is generally used in the location that requires a protective enclosure, for example, drip-proof, the fireproof, etc. according to the requirements. The detailed description of the various types of motor is given below. Contents: Separately Excited DC Motor As the name signifies, the field coils or field windings are energised by a separate DC source as shown in the circuit diagram shown below: Separately Excited DC Motor Self Excited DC Motor As the name implies self-excited, hence, in this type of motor, the current in the windings is supplied by the machine or motor itself. Self-excited DC Motor is further divided into shunt wound, and series wound motor. They are explained below in detail. Shunt Wound Motor This is the most common types of DC Motor. Here the field winding is connected in parallel with the armature as shown in the figure below: Shunt Wound DC Motor The current, voltage and power equations for a shunt motor are written as follows. By applying KCL at junction A in the above figure. The sum of the incoming currents at A = Sum of the outgoing currents at A. Where, I is the input line current Ia is the armature current Ish is the shunt field current Equation (1) is the current equation. The voltage equations are written by using Kirchhoff's voltage law (KVL) for the field winding circuit. For armature winding circuit the equation will be given as: The power equation is given as: Power input = mechanical power developed + losses in the armature + loss in the field. Multiplying equation (3) by Ia we get the following equations. Where, VIa is the electrical power supplied to the armature of the motor. Series Wound Motor In the series motor, the field winding is connected in series with the armature winding. The connection diagram is shown below: Series Wound Motor By applying the KCL in the above figure: Where, Ise is the series field current The voltage equation can be obtained by applying KVL in the above figure. The power equation is obtained by multiplying equation (8) by I we get Power input = mechanical power developed + losses in the armature + losses in the field Comparing the equation (9) and (10), we will get the equation shown below: Compound Wound Motor A DC Motor having both shunt and series field windings is called a Compound Motor. The connection diagram of the compound motor is shown below: Compound Motor The compound motor is further subdivided as Cumulative Compound Motor and Differential Compound Motor. In a cumulative compound motor the flux produced by both the windings is in the same direction, i.e. In differential compound motor, the flux produced by the series field windings is opposite to the flux produced by the shunt field winding, i.e. The positive and negative sign indicates that the direction of the flux produced in the field windings. In this article, we will discuss different types of DC motors, their definitions, applications, and characteristics equations.An electric motor is an electromechanical energy conversion device that converts electrical energy into mechanical energy. Therefore, the input of an electric motor is electricity, while the output is mechanical energy in the form of the shaft's rotation.Depending on the type of electricity input, electric motors are classified into two major types, namely,DC Motor or Direct Current MotorAC Motor or Alternating Current MotorAn AC motor operates using alternating current, whereas a DC motor requires direct current. However, in this article, we will only consider DC motors.An electrical machine that converts direct current electricity into mechanical energy in the form of rotation of the shaft is called a DC motor. A typical DC motor consists of two main parts: the field system and the armature. The armature is the one that produces the required operating torque to drive the mechanical load, while the field system produces the working magnetic flux in the motor.Depending on the method of excitation used, the DC motors are classified into two types, viz.Separately Excited DC MotorSelf-Excited DC MotorA type of DC motor in which the required excitation to the field winding is provided using an external supply is known as a separately excited DC motor.A circuit diagram of a typical separately excited DC motor is shown in the figure. It consists of an armature that carries the armature winding that is directly supplied from the DC mains. The field winding of the motor is supplied by a DC battery to produce the required working flux in the motor.The separately excited motors are rarely used in practice due to some technical and economic reasons. From the circuit diagram of the motor, we may write the following important expression representing the different electrical characteristics of the motor.(1). Armature current of the motor:(2). Field current of the motor:(3). Supply voltage given to the motor:Where Eb is the back emf, and Ra is the armature resistance.The self-excited DC motor is the one in which the current required to excite the field winding is supplied by the motor itself. Therefore, these motors are very popular over separately excited DC motors in practical applications.Depending on the connection of the field winding of the motor with the armature winding, the self-excited DC motors are further classified into three main types:Series DC MotorShunt DC MotorCompound Wound DC MotorThe series DC motor is the one in which the field winding is connected in series with the armature winding, as shown in the figure.From the above circuit, it is clear that the series field winding of the motor carries the entire armature current; therefore, it is designed to have low resistance. In practice, the series field winding is made of fewer turns of thick wire.By referring to the circuit diagram, the important characteristic equations of a series DC Motor can be written as,(1). Armature current of series DC motor:(2). Voltage equation of the DC series motor:In the case of DC series motors, the change in the supply current causes a change in the magnetic field, which in turn causes variation in the speed of the motor. Therefore, series DC motors are variable-speed DC motors.One of the most important characteristics of a DC series motor is that it produces very high torque at low speeds and vice-versa. It is always taken into care while using a series DC motor that it attains a dangerously high speed at no load or light load.Hence, series DC motors are used in applications where high starting torque is required, such as electric traction, cranes, lifts, elevators, sewing machines, air compressors, etc.A shunt DC motor is a type of DC motor in which the armature winding and field winding are connected in parallel. The circuit diagram of a shunt DC motor is shown in the following figure.In the case of the shunt DC motor, the field winding is designed to have high resistance. For that, it is made with a large number of turns of thin wire. So that it carries only a small fraction of the total supply current, the rest of the current flows through the armature winding to produce the working torque.We can write the following characteristics equations for the shunt DC motor by referring to its circuit diagram.(1). Armature current of the shunt DC motor:(2). The field current in the shunt winding:(3). Voltage equation of the shunt DC motor:Shunt motors are considered constant-speed DC motors. Hence, they are used in applications such as lathes, drill machines, spinning machines, weaving machines, etc.As its name implies, the compound DC motor is the compound (combination) of both series and shunt DC motors. A type of DC motor that consists of both series field winding and shunt field winding to produce the required magnetic flux in the machine is called a compound DC motor.Depending on the series and shunt field winding arrangement in the motor circuit, the compound DC motors are further classified into the following two types.Short-Shunt Compound DC MotorLong-Shunt Compound DC MotorThe type of compound DC motor in which the parallel combination of shunt field winding and the armature winding is connected in series with the series field winding is known as a short-shunt compound DC motor.The circuit diagram of the short-shunt compound DC motor is shown in the figure. From this circuit diagram, we can write the following expressions describing the motor characteristics:(1). Armature current of the short shunt DC motor:(2). Voltage equation of the short shunt DC motor:A compound wound DC motor in which the series combination of armature winding and the series field winding is connected in parallel with the shunt field winding is known as a long-shunt compound DC motor.The circuit diagram of a long shunt compound DC motor is shown in the figure. By referring to this circuit, we can write the following characteristics equations of the long shunt DC motor:(1). Armature current of long shunt DC motor:(2). Voltage equation of the long shunt motor:DC compound motors have a high starting torque (series field) and a finite speed at no load or light load (shunt field). Hence, they are extensively used in cutting tools, rolling mills, etc.Both short-shunt and long-shunt compound DC motors are classified into two types, namely, cumulatively compound motors and differentially compound motors. In the cumulatively compound motor, the fluxes of both series and shunt field windings assist each other, while in the differentially compound motor, the fluxes of both series and shunt field windings oppose each other. For this reason, the performance of differentially compound DC motors is poor; hence, they are not suitable for practical applications.Author: Satyadeo Vyas Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. In a DC motor, when the armature rotates under the influence of the driving torque, the armature conductors move through the magnetic field, and therefore an EMF is induced in them by the generator action. This induced EMF in the armature conductors acts in opposite direction to the applied voltage $\mathit{V_{s}}$ and is known as the back EMF or counter EMF. The magnitude of the back EMF is given by, $$\mathrm{\mathit{E_{b}}\:=\:\frac{\mathit{NP\phi Z}}{\mathrm{60}\mathit{A}}\:\cdot \cdot \cdot (1)}$$ The back EMF $\mathit{E_{b}}$ is always less than the applied voltage $\mathit{V_{s}}$. However, this difference is small when the DC motor is running under normal conditions. In DC motors, the back EMF $\mathit{E_{b}}$ induced in the armature opposes the applied voltage, thus the applied voltage has to overcome this EMF $\mathit{E_{b}}$ to force a current $\mathit{I_{a}}$ in the armature circuit for motor action. The required power to overcome this opposition is given by, $$\mathrm{\mathit{P_{m}}\:=\:\mathit{E_{b}I_{a}}\:\cdot \cdot \cdot (2)}$$ The power $\mathit{P_{m}}$ is one which actually converted into mechanical power. For this reason, the power $\mathit{P_{m}}$ is also called as electrical equivalent of mechanical power developed. Consider a shunt DC motor whose electrical equivalent circuit is shown in Figure-1. When a DC voltage $\mathit{V_{s}}$ is applied across terminals of the motor, the field electromagnets are excited and armature conductors are supplied with current. Hence, a driving torque acts on the armature which begins to rotate. When the armature rotates, a back EMF is induced in the armature conductors that opposes the applied voltage $\mathit{V_{s}}$. This applied voltage has to force a current through the armature conductors against the back EMF. The voltage equation of the dc motor can be expressed as, $$\mathrm{\mathit{V_{s}\:=\:E_{b}+I_{a}R_{a}}\:\cdot \cdot \cdot (3)}$$ Where,$\mathit{R_{a}}$ is the resistance of the armature circuit. Then, the armature current of the DC motor is given by, $$\mathrm{\mathit{I_{a}}\:=\:\frac{\mathit{V_{s}-E_{b}}}{\mathit{R_{a}}}\:\cdot \cdot \cdot (4)}$$ Since the applied voltage $\mathit{V_{s}}$ and armature resistance $\mathit{R_{a}}$ are usually fixed for a given motor, then the value of $\mathit{E_{b}}$ will determine the current drawn by the DC motor. If the speed of the DC motor is high, then the value of back EMF is large and hence the motor will draw less armature current and vice-versa. Significance of Back EMF in DC Motor The back EMF in a DC motor makes it a self-regulating machine, which means it makes the motor to draw a sufficient amount of armature current to develop the torque required by the mechanical load. Now, from Equation-4, we may explain the importance of back EMF in the DC motor as − Case 1 − Motor running on no load In this case, the dc motor requires a small torque to overcome the frictional and windage losses. Thus, the armature current $\mathit{I_{a}}$ drawn by the motor is small and the back EMF is nearly equal to the supply voltage. Case 2 − Motor load is changed suddenly In this case, when load is suddenly attached to the motor shaft, the armature slows down. Consequently, the speed at which the armature conductors move through the magnetic field is decreased and hence the back EMF decreases. This decreased back EMF allows a larger current to pass through the armature conductors, and larger armature current means high driving torque. Hence, it is clear that the driving torque increases as the motor speed decreases. The reduction in motor speed stops when the armature current is sufficient to produce the increased torque required by the mechanical load. Consider another situation, where the load on the motor is decreased. In this case, the driving torque is momentarily more than the requirement so that the armature is accelerated. The increase in the armature speed increases the back EMF, and causes the armature current to decrease. Once the armature current is just sufficient to produce the reduced driving torque required by the load, the motor will stop accelerating. This discussion clears that the back EMF in a dc motor automatically regulates the flow of armature current to meet the load requirements. Your browser does not support the video tag. At Motor Specialty Inc. we design and manufacture custom universal, shunt wound, permanent magnet fractional & integral horsepower electric motors, gearmotors and armatures & fields up to 2 HP, 12 volts to 240 volts. We can design or modify existing models to your specifications with various mounting options available to meet your needs. Motor Specialty Inc. has been serving OEMs with quality motors for over 75 years. Company History " - Elliot Snyder, Ridge Tool Co. In this article, you'll learn what is DC motor? How does it work? and different types of DC motors explained with parts, construction detail, applications, and more.You can also download the PDF file of this article at the end.What is a DC motor?An electrical motor is a machine that mainly converts electrical energy into mechanical energy. A DC motor is an electrical machine that converts mechanical energy into direct current and vice-versa.Direct current (DC) motors are widely used in today's manufacturing industries. Due to their extensive functionality, DC motors are frequently used in small and medium-sized motoring applications, including robotics and automobiles.There are various types of DC motors suitable for various tasks across the manufacturing industry because DC motors are used in such a wide range of applications.You might want to read this: 12 Basic Parts of DC Generator & Their Functions [PDF]How does DC Motor Works?Consider a part of a multipolar DC motor, as shown in the figure. When the main supply is applied to the armature conductors and field magnets are excited, the conductors experience a force that tends to rotate the armature.Armature conductors under N-pole are assumed to carry current downwards, and the S-poles carry upwards. Now by applying Fleming's Left-hand rule, the direction of the force on each conductor can be found. This is shown by small arrow marks in the figure in each conductor. The force 'F' experienced by each conductor tends to rotate the armature in the anti-clockwise direction. The continuous and unidirectional torque is developed by a commutator which reverses the current in each conductor as it passes from one pole to another.Read also: A.C Motors: Types, Working, Construction, Applications and MoreThe operation of D.C. The motor is based on the working principle that when a current-carrying conductor is located in a magnetic field, it undergoes a mechanical force, guided by Fleming's left-hand rule and whose magnitude is given by:F = BIl newtons.Where,B = Flux density in cub/$m^2$I = Current through the conductor in amperes.l = Length of the conductor in meters.Read also: Resistors: Types of Resistor and Their Symbols, and Selection of ResistorsThe construction of the D.C. motor is the same as D.C. Generator.Following are the parts of a DC motor:Yoke or frameField polesField windingBrushesEnd shieldsArmature coreArmature windingCommutatorShaft1) Yoke or Frame: It is a stationary part called a starter. The functions of Yoke are:It supports the field poles and field winding.Provides a magnetic path to the main field flux.Protects armature from mechanical injury.2) Field Poles: The main functions of poles are :Provides support to the field winding.Provide a slow reactance path to the main field flux.Distributes the main field flux uniformly all around the periphery of the armature.3) Field Windings: They produce a magnetic field when D.C. is passed through them.4) Brushes: They receive D.C. from the main and supply it to the armature winding through a commutator.5) End Shields: The main functions are:Supports the bearings in which the armature rotates.It covers the armature and protects it.6) Armature Core: It houses the windings in the slot and provides a low reactance path to the main field flux and the armature flux.7) Armature Windings: It produces armature flux when current is passed through them. This flux reacts with the main field flux and produces rotation or torque.8) Commutator: It collects D.C. from brushes, converts it into A.C., and supplies it to the armature windings.9) Shaft: The main functions are :It provides support to the armature, windings, and commutator.It helps the armature to rotate.Checkout this article: What Are The Fundamental Parts of Transformer?Following are the three main types of DC motors:Separately excited dc motorPermanent magnet dc motorSelf excited dc motorShunt-wound dc motorsSeries wound dc motorsCompound wound dc motorsCumulative compound DC motorDifferential compound DC motorShort shunt DC motorLong shunt DC motorIn this type of dc motor, the electrical supply is given separately to the field and armature winding. In this, the armature current does not flow through the field winding, as the field winding is powered by a separate external source of DC current.So from the torque equation of the dc motor, we getTg = Ka φ IaIn this case, the torque is varied by varying field flux φ, and it is independent of the armature current Ia.A permanent magnet DC motor has armature winding like a usual motor, but it does not have field winding. In this type of dc motor, the radially magnetized permanent magnets are placed inside the stator core to generate flux. At the same time, the rotor consists of a conventional DC armature with a commutator segment and brushes.By applying the torque equation of the DC motor,Tg = Ka φ IaThe value of φ is constant because permanent magnets of the required flux density are selected at the time of manufacture and cannot be changed thereafter.For permanent magnet DC motor,Tg = Ka1 IaWhere Ka1 = Ka.φ is constant.In this case, the torque of the DC motor can be adjusted by controlling the armature supply.Read Also: Different Types of Essential Electrician Tools [Names & Uses]In a self-excited type DC motor, the field winding is connected in series or in parallel, partly in series or partly in parallel with the armature winding. Self-excited DC motors are then divided into three types:These types of dc motors are characterized by the connection of field winding in relation to the armature namely.Shunt-wound motor: in which field winding is connected in parallel with the armature.Series wound motor: in which the field winding of the motor is connected in series with the armature.Compound wound motor: which has two field windings: one connected in parallel with the armature and the other in series with it.A DC shunt motor (also known as a shunt wound DC motor) is a type of self-excited DC motor, where field winding is shaken or connected parallel to the armature winding of the motor. Because they are connected in parallel, the armature and field winding are exposed to the same supply voltage.But, there are separate branches for the flow of armature current and field current, as shown in the figure above.The construction of a DC shunt motor is similar to other types of DC motors, as shown in the figure. This motor can consist of basic parts such as field windings (stator), a commutator, and an armature (rotor).The working principle of a DC shunt motor is whenever a DC motor is turned ON. Suddenly, DC flows across the entire stator as well as the rotor. This current flow will create two fields, particularly the pole as well as the armature.In the air distance between the armature and the field shoes, there are two magnetic fields, and they will react with each other to rotate the armature. The commutator reverses the current flow direction of the armature at ordinary intervals.Therefore the armature field, as opposed to the pole field at all times, keeps rotating the armature in an equal direction.The following are the advantages of a shunt-wound motor:DC shunt motors can be used for heavy industrial applications where torque and speed are a wide range.A shunt-wound motor capable of running at a predetermined speed.The power supply of a DC motor is inexpensive.The following are the disadvantages of shunt-wound motor:Installation of DC shunt-wound motors is expensive compared with other types of motors.Because shunt motors are constant-speed motors, this would be a disadvantage where it is necessary to operate under variable speeds.The shunt-wound motors are inaccurate in low-speed operation.Read Also: Different Types of Insulators: Their Working and ApplicationsA DC series motor is similar to any other motor because the main function of this motor is to convert electrical energy into mechanical energy. The operation of the series motor essentially depends on the electromagnetic principle.Whenever the magnetic field is approximately formed, a current-carrying conductor cooperates with the external magnetic field, and then a rotating motion can be produced.The D.C series motor is consists of a rotor (armature), commutator, stator, axle, field windings, and brushes. The fixed component of the motor is the stator and is constructed with two or more electromagnet pole parts.The rotor consists of the armature and windings at the associated core for the armature. The power source in the brush array associated with the commutator can be connected to the armature winding.The rotor includes a central axle for rotating, and due to a large amount of current in the entire winding the field winding should be able to hold the higher current, the larger will be the torque produced with the motor.An external voltage source is applied in a series configuration of field winding and armature. So one end of the voltage source is attached to the winding and the other end is attached to the armature through the brush.Initially at the motor starts with a voltage source attached to the motor, it forms a large amount of current because both the winding and the armature of the motor are made up of large conductors, providing minimal resistance to the current path. The large current through the winding produces a strong magnetic field.This strong magnetic field gives high torque to the armature shaft, thus exerting the spinning action of the armature. Hence the motor starts rotating at its maximum speed in the beginning. A rotating armature in the presence of a magnetic field occurs in a counter EMF, limiting the current build-up in a series combination of armature and winding.Thus the series motors will offer maximum speed and torque once started but with increasing speed gradually, its torque will come down due to its low current. In practice, this is required from motors. Due to the high torque provided by the armature, the load on the shaft is initially set to rotate.Consequently, the low torque will drive the load forward. This further helps to increase the heat dissipation of the motor. But, the amount of torque generated by the motor is directly proportional to the winding current.The following are the advantages of a series wound motor:The starting torque of a DC series motor is relatively high compared to other motors, so such motors are widely used for traction applications.It can be used for AC or DC supply; therefore, it is also known as a universal motor.A Shunt motor develops more power for the same construction size than a DC shunt motor.The following are the disadvantages of a series wound motor:The speed control and regulation of the DC series motor are not good enough.DC series motors need to be loaded before starting. Therefore the DC series motors are not good to use, where the load is not applied in the initial stage.Read Also: 9 Different Types of Batteries & Their ApplicationsA compound wound DC motor is a type of self-excited motor and consists of both series of field coils and shunt field coils attached to the armature winding. Both field coils provide for the expected amount of magnetic flux, which links with the armature coil and delivers about the torque required to facilitate rotation at the desired speed.As we know, a compound wound motor is basically formed by the amalgamation of a shunt wound DC motor and a series wound DC motor to obtain better closure properties of both these types.Like a shunt wound, a DC motor is offered with a highly efficient speed regulation characteristic, while a DC series motor has high starting torque. So the compound wound DC motor makes a compromise in terms of both these characteristics and has a good combination of proper speed regulation and high starting torque.However, its initial torque is not as high as in the case of a DC motor, nor is its speed regulation as good as a DC shunt motor. The overall characteristics of a DC shunt motor come in between these two extreme limits.The following are the advantages of a compound wound motor:The motor can quickly start and stop.The reversing and acceleration of the motor can do fast.The following are the disadvantages of a compound wound motor:The operation and maintenance costs of compound wound motors are expensive.DC motors cannot operate in a dangerous situation where there is a spark in the brush of the motor.The compound DC motor can be classified into two types according to the nature of compounding.Read Also: What Are Circuit Breakers? Their Types, Working & ApplicationsIf the shunt field flux assists, the main field flux, which is produced by the main field connected in series to the armature winding, is called a cumulative compound DC motor.If the shunt and series winding are arranged so that the field flux generated by the shunt field winding reduces the effect of flux by the main series field winding, then it is called a differential compound DC motor.Both types of compound DC motors can be of short or long shut type according to the nature of the arrangement.You may like this: Working Principle of Servo Motor: Diagram, Types, ApplicationsWhen the shunt field winding of the motor is connected in parallel to the armature winding, it is known as a short shunt DC motor. The diagrammatic representation of the short shunt motor is shown in the figure above.When the shunt field winding of the motor is connected parallel to both armature winding and series field winding, then it is known as a long shunt DC motor. The diagrammatic representation of the long shunt motor is shown in the figure above.Read Also: Types of Electric Motors: Their Working and ApplicationsSeries motor: It is used where very high starting torque and variable speed are required, such as electrical fraction work, electric locomotives, trolleys, cranes, hoists, and conveyors. Air compressors, vacuum cleaners, hair dryers, sewing machines, etc.Shunt motors: It is where constant speed is required with low starting torque, such as for lathes, centrifugal pumps, fans, reciprocating pumps, drilling machines, and boring machines. Spinning and weaving machines etc.Compound motor: It is used where sudden loads are applied or removed, such as for shears, punches, coal-cutting machines, elevators, conveyors, heavy planners, rolling mills, ice machines, printing presses, air compressors etc.That's it; thanks for reading. If you have any questions about "types of DC motors" ask us in the comments. If you found this article helpful, then please share it with your friends.Subscribe to our newsletter to get notifications of new articles:Download the Pdf of this article from here:Check out the topics listed below as well if you're interested!Capacitors: Types, Definition, Specifications, and Application of CapacitorElectric Circuit: Types of circuits, Kirchhoff's Law and Its ClassificationA.C Motors: Types, Working, Construction, Applications, and More16 Different Types of Transformers and Their Working [Explained]What is Resistance Welding? Types, Working, Applications, & Advantages Characteristics of DC motor is crucial for us electricians to learn because of how vast their applications are in various purposes.Almost every mechanical action we witness in our environment is powered by an electric motor. Electric machines are a type of energy converter. Electrical energy is converted into mechanical energy by motors.Hundreds of items that we use every day are powered by electric motors. Motors are available in a variety of sizes. In the industry, massive motors capable of carrying loads of 1000s of Horsepower are commonly used.Elevators, electric trains, hoists, and heavy metal rolling mills are all examples of huge motor usage. Automobile motors, robotics, hand power tools, and food blenders are all examples of small motor applications.Micro Machines are electric machines with parts the size of red blood cells that have a wide range of medical applications.Electric motors are divided into two categories: DC (Direct Current) and AC (Accurate Current) (Alternating Current). There are various varieties within these categories, each with its own set of capabilities that are well suited to specific applications.Electric motors, regardless of type, are made up of a stator (stationary field) and a rotor (rotating field or armature) that produce rotational speed and torque through the interplay of magnetic flux and electric current. DC motors differ from other types of motors in that they may run on direct current.Different types of D.C. motors exist, however they all operate on the same principles. We'll look at their essential principles of operation and characteristics in this chapter.It's critical to comprehend motor properties so that we may select the best one for our needs.Make sure you also read the parts of a DC motor to understand fully what parts we are talking about. There are two properties of this type of dc motor:The armature and field windings are separated from each other, electrically.Both armature and field windings are supplied by separated DC sources.The electrical circuit of this DC motor is shown below:Where:Vf = voltage applied to the field windingIf = current flowing in the field windingLf = inductance of field winding coilsRf = resistance of field winding coilsVT = voltage applied to the armature windingIa = current flowing in the armature windingLa = inductance of the armature winding coilsRa = resistance of the armature winding coilsEa = induced voltage in the armatureTm = torque of the motorNow we are analyzing the circuit in steady-state, thus the d/dt for inductance is zero.In steady state, the voltage in the stator (field):In steady state, the voltage in the rotor (armature):In DC motor, induced voltage Ea is also known as back-emf because it is affected by the speed of the motor (⍵r),WhereK1 = armature constant⍵r = speed of the motorSubstitute (1.3) to (1.2) producesIf the value of Ra is small enough to be ignored, thenThe torque needed to rotate the rotor can be calculated from:Where:Tm = torque of the motor (N-m)Pout = output power of the motor (watt)⍵r = speed of the motor (rad/s)DC motor can also act as a DC generator if the armature is moved by external energy, producing electricity in the process. This one can be called a prime mover. There are two types of DC motors:Separately excited DC motorSelf excited DC motorThe separately excited DC motor is shown above along with its equation. As its name implies, this motor has two voltage sources to supply the armature and field windings separately.We will learn about it again further in the next section.The self excited DC motor, the other way, only has one voltage source to supply both armature and field windings. This type can be divided further into:Shunt DC motorSeries DC motorCompound DC motorThis motor has characteristics of:The armature (rotor) and field (stator) windings have to be supplied by voltage separately, thus we need two DC voltage sources electrically separated from each other.The armature and field windings are separated electrically.Torque Speed CharacteristicsBefore jumping into the characteristic curve, there is step-to-step calculation.The induced voltage is given by:The torque generated in the armature can be calculated from:From the Equation.(2.2) ,the armature current is:Substituting Ia in the Equation.(2.1) producesThus, the torque generated in the armature can be found fromFrom the equation below we can draw the characteristic curve below with torque speed relationship. If we constantly maintaining the terminal voltage (VT) and the flux () values then we will get linear dropping line.From the torque speed characteristics curve above, we can list some important notes about separately excited DC motor:The torque is inversely proportional to the speed of the rotor.Stall torque is the maximum torque but the rotor is not rotating.No-load speed is the maximum speed of the rotor when there is no torque applied to the rotor. This motor has characteristics of:The armature and field windings are connected in parallel.Only one voltage source is needed to supply both armature and field windings.The total current drawn from the supply will be, IT = If + Ia.The total input power is VTITTorque Speed CharacteristicsThis motor relatively has constant torque in a wide range of speed.The torque speed characteristics and equation for shunt DC motor is the same with the separately excited DC motor.Help yourself to scroll up a bit.This motor has characteristics of:The armature and field windings are connected in series.Only one voltage source is needed to supply both armature and field windings.The current in the field winding is the same as the current in the armature winding.Series motor has a special trait that we can apply AC or DC voltage to it. Even if we reverse the supply's polarity, the motor will always rotate in the same direction.This is why a series motor is called a universal motor. Of course we will use DC voltage here.Torque Speed CharacteristicsThe series DC motor can be analyzed with the same approach as the shunt motor.The torque generated by the rotor isAssume that the flux is proportional to the field current,In series motor, If = IaWhere Kf is a constant (depending on the number of turns of the field winding, geometry of magnetic circuit, B-H characteristics of an iron).Thus, the motor generate the torque asWe will ignore the Lf in the steady-state condition, then we use KVL to the equivalent circuit,And we have induced voltage:Substituting this equation to the Equation.(3.3)The torque generated:From the equations above, we can draw the torque speed characteristics curve for a series DC motor.From the curve above, the series DC motor is capable of moving a heavy load with low speed. This motor has high torque at low speed and low torque at high speed. Compound DC motors use both series and shunt field windings. Just like stated above, the one field winding is connected in series to the armature, and another one field winding is connected in parallel to the armature.We will have two types of compound DC motor:Cumulative compound : the produced flux from both series and shunt windings have the same direction.Differential compound : the produced flux from both series and shunt windings have different directions. Posted: May 20, 2021 What is a DC (Direct Current) Motor? A DC motor is any class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The history of DC motors goes as far back as the 19th century. In 1832, a British scientist, William Sturgeon, created the first DC motor that had the ability to power machinery. Sturgeon's initial development was further expanded upon by an American scientist, Thomas Davenport. Davenport is known for creating the first working DC motor, which he patented in 1837. However, Davenport ran into some issues with the cost of battery power while the motors were running. This made the motors ineffective to stand up over time. After the initial invention, created by Davenport, many other inventors began developing concepts. In 1834, Moritz von Jacobi, a Russian engineer, invented the first rotating DC motor. Jacobi's motor became well known for its power, which would later set a world record. Jacobi went on to create an even more powerful motor, thus breaking his own record for power in 1838. The invention of this motor, by Jacobi, went on to further inspire others to expand and produce more DC motors of the same power. Antonio Pacinotti made a breakthrough in 1864 with the development of the ring armature. This piece has become crucial in the design of the DC motor; the ring armature carries the current through the grouped coils. Even with all of the developments throughout the 19th century, possibly the most important came in 1886. An inventor named Julian Sprague invented a DC motor that was capable of maintaining a constant speed under variable loads. Sprague's invention would lead to the commercial use of the DC motor. This would include early variations of the electric elevator and electric trolleys. These developments led to high demand of the motors, for both commercial & residential usage. Today, DC motors are widely used in many industries, such as healthcare, food service and many industrial settings. The use of DC motors has made industry work far more efficient, with machines able to function with a dependable source of power and speed. DC motors have made many other industries far easier to function in their day to day faculties, by taking a lot of manual power off of humans or animals, and replacing it with motorized equipment. Many of us wouldn't know how to function in our everyday lives without DC motors. From dishwashers, to blenders, to medical equipment at the doctor's office, many of us don't know just how ingrained DC motors are in our everyday life. We help provide the motors that you need for the equipment that you use or manufacture. If you are having any issues with your machinery or your current DC motor provider, please contact our experts today at Motor Specialty! 4-Channel ReDriver™ Boosts Signal Quality for High-Speed PCIe 5.0, SAS4, and CXL Interfaces June 17, 2025 High-Speed 4-Channel ReDriver™ Supports PCIe® 6.0, 64GT/s, PAM4 in Latest Computing and Communication Systems June 11, 2025 6.5GHz Double-Pole-Triple-Throw Mux/DeMux with OVT for USB 2.0 and MHL Switching in Portable Applications May 6, 2025 Motor which works on direct current Workings of a brushed electric motor with a two-pole rotor (armature) and permanent magnet stator. "N" and "S" designate polarities on the inside axis faces of the magnets; the outside faces have opposite polarities. The + and - signs show where the DC current is applied to the commutator which supplies current to the armature coils Electromagnetism Electricity Magnetism Optics History Computational Textbooks Phenomena Electrostatics Charge density Conductor Coulomb law Electret Electric charge Electric dipole Electric field Electric flux Electric potential Electrostatic discharge Electrostatic induction Gauss's law Insulator Permittivity Polarization Potential energy Static electricity Triboelectricity Magnetostatics Ampère's law Biot–Savart law Gauss's law for magnetism Magnetic dipole Magnetic field Magnetic flux Magnetic scalar potential Magnetic vector potential Magnetization Permeability Right-hand rule Electrodynamics Bremsstrahlung Cyclotron radiation Displacement current Eddy current Electromagnetic field Electromagnetic induction Electromagnetic pulse Electromagnetic radiation Faraday's law Jefimenko equations Larmor formula Lenz's law Liénard–Wiechert potential London equations Lorentz force Maxwell's equations Maxwell tensor Poynting vector Synchrotron radiation Electrical network Alternating current Capacitance Current density Direct current Electric current Electric power Electrolysis Electromotive force Impedance Inductance Joule heating Kirchhoff's laws Network analysis Ohm's law Parallel circuit Resistance Resonant cavities Series circuit Voltage Watt Waveguides Magnetic circuit AC motor DC motor Electric machine Electric motor Gyrator–capacitor Induction motor Linear motor Magnetomotive force Permeance Reluctance (complex) Reluctance (real) Rotor Stator Transformer Covariant formulation Electromagnetic tensor Electromagnetism and special relativity Four-current Four-potential Mathematical descriptions Maxwell equations in curved spacetime Relativistic electromagnetism Stress–energy tensor Scientists Ampère Biot Coulomb Davy Einstein Faraday Fizeau Gauss Heaviside Helmholtz Henry Hertz Hopkinson Jefimenko Joule Kelvin Kirchhoff Larmor Lenz Liénard Lorentz Maxwell Neumann Ohm Ørsted Poisson Poynting Ritchie Savart Singer Steinmetz Tesla Thomson Volta Weber Wiechert vte The Pennsylvania Railroad's class DD1 locomotive running gear was a semi-permanently coupled pairing of third rail direct current electric locomotive motors built for the railroad's initial New York-area electrification when steam locomotives were banned in the city (locomotive cab removed here). A DC motor is an electrical motor that uses direct current (DC) to produce mechanical force. The most common types rely on magnetic forces produced by currents in the coils. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor. DC motors were the first form of motors to be widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor, a lightweight brushed motor used for portable power tools and appliances can operate on direct current and alternating current. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications. A coil of wire with a current running through it generates an electromagnetic field aligned with the center of the coil. The direction and magnitude of the magnetic field produced by the coil can be changed with the direction and magnitude of the current flowing through it. A simple DC motor has a stationary set of magnets in the stator and an armature with one or more windings of insulated wire wrapped around a soft iron core that concentrates the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be several parallel current paths. The ends of the wire winding are connected to a commutator. The commutator allows each armature coil to be energized in turn and connects the rotating coils with the external power supply through brushes. (Brushless DC motors have electronics that switch the DC current to each coil on and off and have no brushes.) The total amount of current sent to the coil, the coil's size, and what it is wrapped around decide the strength of the electromagnetic field created. The sequence of turning a particular coil on or off dictates what direction the effective electromagnetic fields are pointed. By turning on and off coils in sequence, a rotating magnetic field can be created. These rotating magnetic fields interact with the magnetic fields of the magnets (permanent or electromagnets) in the stationary part of the motor (stator) to create a torque on the armature which causes it to rotate. In some DC motor designs, the stator fields use electromagnets to create their magnetic fields which allows greater control over the motor. At high power levels, DC motors are almost always cooled using forced air. Different number of stator and armature fields as well as how they are connected provide different inherent speed and torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature. Variable resistance in the armature circuit or field circuit allows speed control. Modern DC motors are often controlled by power electronics systems which adjust the voltage by "chopping" the DC current into on and off cycles which have an effective lower voltage. Since the series-wound DC motor develops its highest torque at low speed, it is often used in traction applications such as electric locomotives, and trams. The introduction of DC motors and an electrical grid system to run machinery starting in the 1870s started a new second Industrial Revolution. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles and today's hybrid cars and electric cars as well as driving a host of cordless tools. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines. Large DC motors with separately excited fields were generally used with winder drives for mine hoists, for high torque as well as smooth speed control using thyristor drives. These are now replaced with large AC motors with variable frequency drives. If external mechanical power is applied to a DC motor it acts as a DC generator, a dynamo. This feature is used to slow down and recharge batteries on hybrid and electric cars or to return electricity back to the electric grid used on a street car or electric powered train line when they slow down. This process is called regenerative braking on hybrid and electric cars. In diesel electric locomotives they also use their DC motors as generators to slow down but dissipate the energy in resistor stacks. Newer designs are adding large battery packs to recapture some of this energy. Main article: Brushed DC electric motor A brushed DC electric motor generating torque from DC power supply by using an internal mechanical commutation. Stationary permanent magnets form the stator field. Torque is produced by the principle that any current-carrying conductor placed within an external magnetic field experiences a force, known as Lorentz force. In a motor, the magnitude of this Lorentz force (a vector represented by the green arrow), and thus the output torque, is a function for rotor angle, leading to a phenomenon known as torque ripple) Since this is a two-pole motor, the commutator consists of a split ring, so that the current reverses each half turn ( 180 degrees). The brushed DC electric motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary magnets (permanent or electromagnets), and rotating electromagnets. Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the carbon brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor. Brushes are usually made of graphite or carbon, sometimes with added dispersed copper to improve conductivity. In use, the soft brush material wears to fit the diameter of the commutator, and continues to wear. A brush holder has a spring to maintain pressure on the brush as it shortens. For brushes intended to carry more than an ampere or two, a flying lead will be molded into the brush and connected to the motor terminals. Very small brushes may rely on sliding contact with a metal brush holder to carry current into the brush, or may rely on a contact spring pressing on the end of the brush. The brushes in very small, short-lived motors, such as are used in toys, may be made of a folded strip of metal that contacts the commutator. Main articles: Brushless DC electric motor and Switched reluctance motor Typical brushless DC motors use one or more permanent magnets in the rotor and electromagnets on the motor housing for the stator. A motor controller converts DC to AC. This design is mechanically simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. The motor controller can sense the rotor's position via Hall effect sensors or similar devices and can precisely control the timing, phase, etc., of the current in the rotor coils to optimize torque, conserve power, regulate speed, and even apply some braking. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors. Other types of DC motors require no commutation. Homopolar motor – A homopolar motor has a magnetic field along the axis of rotation and an electric current that at some point is not parallel to the magnetic field. The name homopolar refers to the absence of polarity change. Homopolar motors necessarily have a single-turn coil, which limits them to very low voltages. This has restricted the practical application of this type of motor. Ball bearing motor – A ball bearing motor is an unusual electric motor that consists of two ball bearing-type bearings, with the inner races mounted on a common conductive shaft, and the outer races connected to a high current, low voltage power supply. An alternative construction fits the outer races inside a metal tube, while the inner races are mounted on a shaft with a non-conductive section (e.g. two sleeves on an insulating rod). This method has the advantage that the tube will act as a flywheel. The direction of rotation is determined by the initial spin which is usually required to get it going. Main article: Permanent-magnet electric motor A permanent magnet (PM) motor does not have a field winding on the stator frame, instead relying on PMs to provide the magnetic field against which the rotor field interacts to produce torque. Compensation windings in series with the armature may be used on large motors to improve commutation under load. Because this field is fixed, it cannot be adjusted for speed control. PM fields (stators) are convenient in miniature motors to eliminate the power consumption of the field winding. Most larger DC motors are of the "dynamo" type, which have stator windings. Historically, PMs could not be made to retain high flux if they were disassembled; field windings were more practical to obtain the needed amount of flux. However, large PMs are costly, as well as dangerous and difficult to assemble; this favors wound fields for large machines. To minimize overall weight and size, miniature PM motors may use high energy magnets made with neodymium or other strategic elements; most such are neodymium-iron-boron alloy. With their higher flux density, electric machines with high-energy PMs are at least competitive with all optimally designed singly fed synchronous and induction electric machines. Miniature motors resemble the structure in the illustration, except that they have at least three rotor poles (to ensure starting, regardless of rotor position) and their outer housing is a steel tube that magnetically links the exteriors of the curved field magnets. A field coil may be connected in shunt, in series, or in compound with the armature of a DC machine (motor or generator) Main article: universal motor See also: Excitation (magnetic) There are three types of electrical connections between the stator and rotor possible for DC electric motors: series, shunt/parallel and compound (various blends of series and shunt/parallel) and each has unique speed/torque characteristics appropriate for different loading torque profiles/signatures.[1] A series DC motor connects the armature and field windings in series with a common D.C. power source. The motor speed varies as a non-linear function of load torque and armature current; current is common to both the stator and rotor yielding current squared (I^2) behavior[citation needed]. A series motor has very high starting torque and is commonly used for starting high inertia loads, such as trains, elevators or hoists.[2] This speed/torque characteristic is useful in applications such as dragline excavators, where the digging tool moves rapidly when unloaded but slowly when carrying a heavy load. A series motor should never be started at no load. With no mechanical load on the series motor, the current is low, the counter-Electro motive force produced by the field winding is weak, and so the armature must turn faster to produce sufficient counter-EMF to balance the supply voltage. The motor can be damaged by overspeed. This is called a runaway condition. Series motors called universal motors can be used on alternating current. Since the armature voltage and the field direction reverse at the same time, torque continues to be produced in the same direction. However they run at a lower speed with lower torque on AC supply when compared to DC due to reactance voltage drop in AC which is not present in DC.[3] Since the speed is not related to the line frequency, universal motors can develop higher-than-synchronous speeds, making them lighter than induction motors of the same rated mechanical output. This is a valuable characteristic for hand-held power tools. Universal motors for commercial utility are usually of small capacity, not more than about 1 kW output. However, much larger universal motors were used for electric locomotives, fed by special low-frequency traction power networks to avoid problems with commutation under heavy and varying loads. A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor.[4] It is typically used for industrial, adjustable speed applications, such as machine tools, winding/unwinding machines and tensioners. A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor.[5] This motor is used when both a high starting torque and good speed regulation is needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation. Differential compound DC motors have good speed regulation and are typically operated at constant speed. Cogging torque Ward Leonard control Torque and speed of a DC motor Armature Controlled DC Motor ^ Herman, Stephen. Industrial Motor Control. 6th ed. Delmar, Cengage Learning, 2010. Page 251. ^ Ohio Electric Motors. DC Series Motors: High Starting Torque but No Load Operation Ill-Advised. Ohio Electric Motors, 2011. Archived October 31, 2011, at the Wayback Machine ^ "Universal motor", Construction and working characteristics, Retrieved on 27 April 2015. ^ Laughton M.A. and Warne D.F., Editors. Electrical engineer's reference book. 16th ed. Newnes, 2003. Page 19-4. ^ William H. Yeadon, Alan W. Yeadon. Handbook of small electric motors. McGraw-Hill Professional, 2001. Page 4-134. Wikimedia Commons has media related to DC motors. Make a working model of dc motor at sci-toys.com How to select a DC motor at MICROMO (archived page) DC motor model in Simulink at File Exchange - MATLAB Central Retrieved from " Thomas Davenport invented the first real motor later Micheal Faraday and Joseph supported his work. Micheal Faraday did his work mostly related to the working of electromagnetic fields. This invention became the basic principle behind the working of an electrical motor. Beyond the invention of motor further investigations have been done to study the different types of motors such that different motor operations have been discovered. The operation of these different kinds of motors has been further investigated by determining the characteristics in order to know the performance. In this article, we shall discuss the basics of DC motor, and characteristics of different self-excited motors like DC shunt, series, and Compound motor.Basics of DC MotorA DC motor is a device that works on the principle of Faraday's law of electromagnetic induction. It generally converts electrical energy into mechanical energy. It is commonly used in household appliances and also in large industries for the operating heavy loads. A normal DC type motor is shown in the figure below.Basic DC motorCharacteristics of DC MotorThe characteristics of any motor are determined to know the performance. By this, we can conclude where it can be applied and the necessary precautions can also be taken to avoid any damages. For instance, a series motor should not be started directly by applying load because heavy currents flow to the windings which in fact damages the winding. So, this type of damages can be avoided by knowing its performance characteristics such that we can take necessary precautionary methods to avoid such instances.Torque and speed play a vital role in the operation of the motor. Generally, torque is produced by the flux which gets interacted with the armature flux. The interaction of these two fluxes develops a unidirectional torque that enables the motor to rotate. Now, the speed with which the rotor should rotate comes into the picture. The speed of the rotor generally depends on the back emf and flux produced inside the motor. The relation between the torque and speed explains to us how we can draw a characteristic curve between them. Based on the arrangement of the winding, these different types have been classified and accordingly, the characteristics also differ.The voltage equation of a motor is represented as Eb = V – Ia RaThe speed of the motor mainly depends upon the value of back emf and flux. The relationship between speed and back emf is given by N ∝ Eb/ϕTorque Speed Characteristics of Shunt MotorBasically, in a shunt motor, the field winding is connected in parallel to the armature winding. Whenever a current is supplied by means of a DC source, flux is produced which in turn interacts with the armature flux to produce a unidirectional torque. As φ flux is constant in the case of a shunt motor. The speed of the motor is directly proportional to the back emf.The relationship between torque and speed of a shunt motor is given by T α φ Ia. (φ) flux is constant in the case of a shunt motor. So, torque is directly proportional to the armature current. The torque and speed characteristics are similar to that of the characteristics of speed vs armature current. But a slight decrease in the value because the back emf decreases slightly practically.The characteristic curve drawn between the torque and speed is shown in the figure below.Torque Vs speed characteristics DC shunt motorTorque Speed Curve of Series MotorBasically, in a series motor, the field winding is connected in series to the armature winding. Whenever a current is supplied by means of a DC source, flux is produced which in turn interacts with the armature flux to produce a unidirectional torque. The relationship between the torque and armature current is given by T α φ IaPlease refer to this link to know more about DC Motor MCQs. The relationship between speed and flux is given by N ∝ Eb/ϕ. The flux is inversely proportional to the speed and directly proportional to the armature current. Now, T α (Ia )2 torque varies directly proportional to the square of the current. The relationship between the torque and speed also remains the same I,e torque and the speed are inversely proportional to each other. The figure that depicts the characteristics of DC shunt motor is shown in the figure below.Torque Vs speed characteristics DC shunt motorTorque Speed of Compound MotorDC compound Motor is classified into two kinds such as long shunt and short shunt depending upon the winding placement. It is also a kind self-excited motor and it uses the advantages of both shunt and series DC motors. It uses the good speed regulation property of shunt motor and high starting torque capability of a series motor. The compound wound circuit diagram is shown in the figure below.compound wound circuit diagramCharacteristics of Compound MotorThe torque-speed characteristics of DC compound motor are shown in the figure below.speed torque characteristics DC compound motorThus, in this article, we had discussed the basics of DC motor. The DC motor is a type of machine that transitions the form of input electrical energy to output mechanical energy. Apart from the basics, we had also studied the characteristics of different types of motors such as shunt, series, and compound motor. Here is a question for the readers, what are the applications of the DC shunt, series, and compound motor? DC motor is a machine that converts electrical energy of direct current into mechanical energy. In a DC motor, the input electrical energy is direct current which is converted into mechanical rotation. In this article, we will learn what is DC motor, its Diagram, Construction, Working, types, and applications. We will also compare DC and AC Motors based on various parameters.What is DC Motor?DC Motor is an electrical machine which, when provided with direct current electrical energy, converts it into mechanical energy. It is based on electromagnetic induction, where a conductor carrying current (normally a coil of wire) placed in a magnetic field experiences force to rotate. This rotation is used to perform mechanical work.There are many applications for DC motors, they can be used in robotics; electric vehicles, and some industrial machinery as well as household devices. DC motor can be used at such places where speed control is required. That is why DC motors are often used in trolleys, electric train production systems, elevators, etc.DC Motor DefinitionDC motor, also known as a direct current motor, is an electric motor that converts mechanical energy from the electrical energy of direct current.DC Motor DiagramDiagram of Direct Current Motor is shown below:Construction of DC MotorDC motor has such basic components, as a stator (stationary part of the element producing magnetic field) and a rotor part that rotates carrying winding or coil. When a DC voltage is connected to the coil, current flows through it and generates an electromagnetic field. When the magnetic field of this rotor interacts with that produced by the stator, a torque is induced which causes this piece to start spinning.DC Motor PartsDC achine has the following main parts:Field System or StatorArmatureCommutatorBrushesField Coil or StatorAs the name suggests, the field coil or stator is the non moving or the stationary part of the DC motor around which coil is wounded and produce magnetic fieldThe stator consists of various parts:YokePole CorePole BodyShoe for the poleField WindingEnd PlatesYoke: The structure of a DC machine works to create the magnetic circuit between the poles.Pole Core: Pole Core is usually of laminated iron or other magnetic material. Its function is to serve as a passage for the magnetic flux generated by the field winding.Pole Body: Pole body works with the pole core. When an electric current passes through the field winding, a magnetic flux is established not only in the pole core but also around it. The poles and their bearings are known as the pole body.Shoe: Shoe is a synonym for one of the brushes inside an electric motor. DC motors have brushes to make contact with the rotating armature, and typically they are sodded.Field Winding: Field winding is on the pole core next to the stator. Field winding uses insulated copper wire. An insulated copper coil is wound round the pole core. If this coil on the pole core is excited with direct current, we get magnetic flux.End Plates: End plates encapsulate the entire motor. They provide a casing for all of the internal parts--the armature, commutator and brushes as well sometimes also including field windingsArmatureArmature is the rotating part of the motor which generates mechanical energy. Armature core has windings. The armature core is made of 0.3 to 0.5 mm thick high magnetic strength (silicon steel lamination) and a thin layer of varnish is applied on each sheet.CommutatorCommutators are used in DC appliances such as DC Motors and DC Generators. It periodically reverses the current between the armature and the circuit and produces steady torqueBrushesBrushes or often called Carbon Brushes are made up of graphite. In DC Motors, brushes supplies current to the winding of the armature. DC Motor Working PrincipleWhen a current carrying conductor is placed in a magnetic field, a mechanical force acts on it, which can be determined by Fleming's left hand rule. Due to this force the conductor becomes mobile in the direction of the force.DC Motor WorkingImagine that a current-free conductor (which is not connected to the supply) is placed in the main magnetic field the and without the magnetic field flowing through the conductor. Assume, there is an air gap from N pole to S pole.Current is flowing in the conductor but the magnetic effect of N pole and S pole has been removed. In this situation the conductor will maintain its own magnetic field. The magnetic field lines of force of the conductor will be clockwise according to the cork screw rule.Current is flowing in the conductor and main magnetic field is also present. The magnetic field produced due to the current in the conductor acts along with the main field above the conductor but opposes the main field below the conductor. The result is that flux accumulates in the region above the conductor and flux density reduces in the region below.From this it is clear that when the force is acting on the conductor, it works to push the conductor downwards. If the direction of current in the conductor is changed, the flux will accumulate downwards and will try to move the conductor upwards.DC Motor CharacteristicsIf length of conductor = L meter, field intensity = B weber per square meter (Bwb/m2) and current flowing in the conductor = i ampere, then the force experienced by the conductor will be F = iBL Newton.F= B.L.I.Sinθwhere,B = flux density (in Tesla).L = length of conductor (in meters).I = current flowing in the conductor.Sinθ = angle between the conductor and magnetic lines of force.DC Motor Torque FormulaTorque, also known as moment or moment of force, is the force that tends to rotate or move an object around a central axis. A force is a push or pull, similarly, torque creates twisting to an object. Mathematically, torque is given as T = F × r. For DC Motor, the torque is given asT = (0.159PΦNZ/A)Iawhere,T is Torque of ArmatureIa is the armature currentP is Number of PolesΦ is Flux per poleN is Speed of motor in (RPM)Z is Number of conductorsA is Number of parallel paths DC Motor EMF EquationEMF or the electromotive force is responsible for flow of current in the electrical appliances. EMF is not an force but the electric potential. In case of DC Motor, a back EMF is produced which counters the armature current. The direction of this back EMF is

given by Lenz Law. The formula of back emf is given as Eb = PΦNZ/60Awhere,P is Number of PolesΦ is Flux per poleN is Speed of motor in (RPM)Z is Number of conductorsA is Number of parallel pathsDC Motor SpeedThe formula for DC Motor speed is given as:N = KEb/Φwhere,N is speed in RPMK is constant proportionality which is equal to 60A/ZPTypes of DC MotorsDC Motors can be classified into various categories based on the application and winding connections. Based on the winding of armature DC Motor is of two typesSelf Excited DC MotorsSeparately Excited DC MotorsSelf Excited DC MotorDC motors that excite themselves have a part and coil of field connected in series or partly so, same for parallel connection. They can also have combination of series and Parallel connections. They also get power from only one place. Three types of self-excited DC motors exist:Series DC motorShunt DC motor Compound DC MotorSeries DC MotorIt is a motor in which the field is in series with the armature and its starting torque is very high. This means that the same flow of current goes through both the coil and armature. Series motors always go in one direction and their speed is affected by the physical load.Shunt DC MotorShunt motor is a DC motor in which the field is jointed in parallel to the armature and its starting torque is less than that of series motor. Inside the shunt motor the field winding is connected parallel to the armature winding. The field winding is made of more turns of thin wire. Shunt motors are used in applications where continuous speed is required.Compound DC MotorCompound Motor is a Motor in which both series and parallel fields are added. Compound DC motors use both parallel and connected field windings. In the armature winding, everything is in series. However, field coils can be shunt or series types.Separately Excited DC MotorIn DC motors with a separate excite, field coil to make permanent magnets. But, the armature and field coils are not connected electrically to each other. They work separately and do not bother the other. But, the result of the engine is added up with both.More Types of DC MotorSome more types of DC Motor on the various parameters are discussed below:1. Based on Commutation:Brushed Motors: Use brushes and a commutator for current reversal.Brushless Motors: Switch currents in the windings by electronic commutation.2. Based on Application:DC Servo Motors: Exact control of position and speed. Applied in robotics, CNC machine tools and automation.Stepper Motors: Take small steps, accurate position control. Widely employed in printers and CNC machines.Hysteresis Motors: The materials 'motion makes use of their magnetic hysteresis. Used in devices such as record players, rather simple.Brushed DC Gear Motors: Have a gearbox for high torque at low speeds. Applied in robotics, electric vehicles and automation.DC Traction Motors: Intended for use in traction devices, including electric vehicles and trains.3. Based on Speed-Torque Characteristics:High-Speed DC Motors: Designed for uses involving high rotational speeds. Examples include tools and appliances.Low-Speed DC Motors: Offer high torque at low speeds. Commonly used in industrial machinery.4. Based on Size and Shape:Micro DC Motors: Applications such as consumer electronics call for very small motors.Large DC Motors: As used in industrial purposes such as steel mills, paper industries and ship propulsion.5. Based on Control System:Closed-Loop DC Motors: Feedback mechanisms can be employed for more precise control. Applications where precision control is important.Open-Loop DC Motors: Control without feedback, simpler design. In applications where control is not so critical.Difference between DC Brushed Motor and DC Brushless MotorThe difference between DC Brushed Motor and DC Brushless Motor is given below:DC Brushed Motor vs DC Brushless MotorComparison DC Brushed MotorDC Brushless MotorConstructionConsists of a stator and rotor with windings. Uses brushes and a commutator to switch current.Consists of a stator with permanent or electromagnetic magnets and rotor windings. Electronic commutation is achieved without the use of brushes and commutators.MaintenanceRequires frequent maintenance because of brush and commutator wear.Brushes may have to be changed and commutators need cleaning.Generally requires less maintenance because no brushes or commutators to wear outLifespanTypically runs out faster due to the wear and tear in brushes, commutators.It usually has a longer life since there are no brushes and commutators to wear off.EfficiencyMay have reduced efficiency due to friction and wear in brushes, commutators.Usually, more effective since there are no brush-related losses.Noise and VibrationMay generate additional noise and vibration resulting from physical interaction of brushes with the commutator.Generally less noisy and smoother in operation.CostGenerally less expensive upfront.Normally costlier as they require electronic controllers.AC and DC MotorsAC and DC Motors are two types of motors based on the input of the type of current. As the name suggests AC Motor uses AC Current produce mechanical energy while DC Motor produces mechanical energy from Direct CurrentDifference Between AC And DC MotorThe difference between AC and DC Motor are discussed below:AC Motor vs DC Motor AC MotorDC MotorAC motor runs on alternating current. DC motors operate on direct current.There is no need for conversion of current in AC motors. Like AC.There is no need for conversion of current in AC motors. Like AC.AC motors are used where power performance is demanded for extended periods of time. DC motors are used where the speed of the motor needs to be controlled externally.AC motors can be single-phase or three-phase. All DC motors are single phase.In an AC motor the armature does not rotate while the magnetic field keeps rotating continuously. In a DC motor, the armature rotates while the magnetic field rotates.Repairing AC motors is not expensive.DC motors are very expensive to repair.Brushes are not used in AC motor.Brushes are used in DC motor.AC motors have a very long life spanDC motors do not have a very long life span.The speed of AC motors can be controlled by simply changing the frequency of the current. The speed of DC motors can be controlled by changing the current of the armature winding.Application of DC Motor'DC motor' is used to refer to any rotary electrical machine that converts direct current electrical energy into mechanical energy. DC motors can vary in size and power, ranging from small motors in toys and appliances to large mechanisms that power vehicles.DC motor is used at the following places.DC motor is used in traction work, machine tools, industry, elevators etc.DC motors have the widest variation in speed (compared to other motors).DC series motor has very high starting torque and is commonly used to start high inertia loads such as trains, elevators or hoists.Shunt DC Motors are used in drilling machines, centrifugal machines etc.Also, CheckDifference Between AC and DC MotorDifference between Motor and Generator Download the Testbook APP & Get Pass Pro Max FREE for 7 Days10,000+ Study NotesRealtime Doubt Support71000+ Mock TestsRankers Test Series+ more benefitsDownload App Now Coding Ground For Developers Code, Edit, Run and Share Ignite your coding potential on Coding Ground - an immersive online platform for hands-on learning, collaboration, and skill development. Java Compiler Python Compiler C++ Compiler HTML Editor Types of DC Motors are classified into four major categories. The three types of DC Motors are: Separately Excited DC Motor Self-Excited DC Motor Permanent Magnet A DC motor can be defined as a class of electrical motors which helps to convert direct current electrical energy to mechanical energy. The different types of DC motors are further classified based on the electrical connection between the rotor and stator and their ability to create field reflux. DC Motors have unique speeds and hence find varied applications in the fields of Engineering. These motors employ DC current to transform electrical energy into mechanical energy. The major advantage of using DC motors is their compact design and ability to control speed. Read More: Types of Motors Key Terms: Direct Current Motor, DC, Self-Excited, Separately Excited, Permanent Magnet, Shunt, Compound Excited, Long Shunt, Short Shunt [Click Here for Sample Questions] Direct Current Motor or DC Motor is a type of electric machine which converts electrical input into mechanical output. The Magnetic fields created by electrical currents are used in DC motors to power the movement of a rotor located within the output shaft. The output torque and speed are determined by the electrical input as well as the motor's design. The types of DC Motors are given below: Classification of DC Motors The types of DC motor, if listed sequentially, can be expressed as: Permanent Magnet DC Motor Shunt Motor Series Motor Compound Motor is again classified into Short Shunt Motor Long Shunt Motor Differentially Compound Cumulative Compound DC Motor Function According to the DC motor definition, a direct current source generates mechanical energy from an input of electrical energy. These devices typically possess magnetic devices, which are either permanent or electromagnetic. They also include a stator, armature, rotor, and commutator containing brushes. When an electric current is supplied via the armature or coil, a magnetic field jumps into action. In turn, this field is then seen to react with the installed magnet, producing a specific torque. Thus, a rotation in the motors can be observed. The commutator, here, regulates the current flow among the coils. Read Also: Conversion of Mechanical Energy Self-Excited DC Motor [Click Here for Previous years Questions] In Self-Excited DC Motors, the field winding is linked to the armature winding in series, parallel, partly in series, or partly in parallel. It is further divided into 3 categories which are- Shunt-wound DC motor Series wound DC motor Compound wound DC motor Shunt Wound DC Motor In Shunt Wound DC Motors, the field windings are connected in parallel to the armature winding and are exposed to the entire terminal voltage in a DC motor. The field winding in a shunt-wound motor is linked parallel to the armature. Due to the fairly constant speed and medium starting torque, the shunt DC motors are usually used in industrial applications as machine tools, winding or unwinding machines, and tensioners. Shunt Wound DC Motor Series Wound DC Motor In the series wound DC motor, the field winding is connected in series to the armature winding and the entire armature current passes through it. A series DC motor has a strong starting torque and is frequently used to start high-inertia loads like trains, elevators, and hoists. Series Wound DC Motor Compound Wound DC Motor The compound wound DC motor is the compound or the mixture of the shunt and the series field winding. This type of DC motor is used when high-speed torque and good speed regulation both are needed. It's further subdivided into four groups: Cumulative Compound Motor The flux produced by the shunt field windings decreases the effect of the main series windings in this type of compound wound DC motors. Here, \(\phi_{total} = \phi_{series} + \phi_{shunt}\). Cumulative Compund Motor Differential Compound Motor The flux generated by the shunt field windings increases the effect of the main field flux generated by the series winding in differential compound motors. Here, \(\phi_{total} = \phi_{series} - \phi_{shunt}\). Differential Compound Motor Short Shunt DC Motor In this, the shunt field winding is parallelly connected to the armature winding. And before being split up into the armature, the field coil, which is in series, is completely exposed to current. Short Shunt DC Motor Long Shunt DC Motor In this, the shunt field winding is connected in parallel with both the series field coil and armature which are again connected in series.Compound DC motors are usually used in Rolling mills, Heavy Planers, Elevators, Shears, etc. Long Shunt DC Motor Read More: Separately Excited DC Motor [Click Here for Sample Questions] In separately excited DC motors, the supply is given to the field and armature windings separately. The main feature of this type of DC motor is that the current through the armature doesn't flow through the field windings because the field winding is energized by a separate DC source. This can be understood in a better way through the diagram given below. Separately Excited DC Motor As determined from the torque equation of DC motor, we are aware that Tg = Ka φ Ia. Thus, the torque, here, can vary by a variable field flux φ, independent of the armature current Ia. Some key features and applications include: In a separately excited DC motor, the field coils are energized by an external source of DC supply. Separately Excited DC motor is best suited for applications that require speed variation from extremely low to very high values. These motors are utilized in steel rolling mills, paper machines, ship propulsion, and other applications. Ques. What happens when the speed of a DC motor increases? Ans. The back emf increases with a fall in the line currents when the speed of a DC motor increases. It is due to the speed being proportional to the back emf. In case there is a series motor, the armature current will be equivalent to the load current. Ques. How to find the direction of rotation of the motor? Ans. The direction of rotation of the motor can be decided on the basis of Fleming's left-hand rule. It claims that when the current-carrying conductor is set in the magnetic field, a force acts on the conductor. And the other side of the given conductor which is forcefully kept under a magnetic field will produce an induced current in the conductor. Permanent Magnet DC Motor [Click Here for Previous years Questions] The permanent magnet DC Motors includes armature winding but not necessarily field windings. These DC motors are constructed in such a way that the radially magnetized permanent magnets are positioned on the inner periphery of the stator core for the production of the field winding. The rotor uses a standard DC armature with commutator segments and brushes. A PMDC motor's operating voltage is 6 volts, 12 volts. It is otherwise a 24 volts DC supply acquired from the voltage sources. For a permanent magnet DC motor, Tg = Ka1Ia. Permananet Magnet DC Motor These types of DC motors offer good starting torque and good speed regulation. They are typically used in low-horsepower applications as the torque is limited in these types of DC Motors. Some PMDC Motor applications are: PMDC motors are used in automobile windshield wipers and washers. PMDC motors are used in computer drives and in toy industries. PMDC motors are also utilised in electric toothbrushes. Read More: Power of AC Things to Remember DC Motors converts electrical energy into mechanical energy. There are mainly three types of DC motors- Self Excited, Separately excited, and Permanent magnet DC motors In the Self Excited DC Motors, the field winding is linked to the armature winding in series, parallel, partly in series, or partly in parallel. Self Excited Motors are of four types- Shunt Wound, Series Wound, and Compound Wound. Shunt-wound is a type of DC motor in which the field windings are connected in parallel to the armature winding and are exposed to the entire terminal voltage in a DC motor. In a series-wound DC motor, the field winding is connected in series to the armature winding and the entire armature current passes through it. The compound wound DC motor is the compound or the mixture of the shunt and the series field winding. In separately excited DC motors, the supply is given to the field and armature windings separately. The permanent magnet DC motor includes armature winding but not necessarily field windings Also Check: Previous Year Questions Ques. To what polarity do the interpoles are excited in DC motors? (1 Mark) Ans. For motor operation, the polarity of the interpoles must be similar to the previous main pole. The direction of rotation should also be similar to that of the main poles. Ques. Why DC motors are not operated to develop maximum power in practice? (1 Mark) Ans. DC motors are not operated to develop maximum power in practice because the current obtained will be much higher than the rated current and due to this the efficiency of operation will be below 50%. Ques. What type of DC motors are suitable for various torque operations? (2 Marks) Ans. DC motors that are suitable for various torque operations are: DC series motor DC cumulatively compound motor Ques. What are the types of DC Motors? (2 marks) Ans. DC motors are divided into three types. They are: Separately Excited DC Motors Self-Excited DC Motors Permanent Magnet DC Motors Ques. Which DC motor is the best? (2 marks) Ans. Series wound DC Motors are the best owing to their high initial torque that can be generated wothout any sort of speed regulation. The increased voltage causes the armature and field current to rise which allows extremely high start-up torque for short periods of time. Ques. What is the application of DC motors? (2 marks) Ans. Electric tractions are the most vividly applied application of DC Motors.They have excellent torque properties and because of this they are widely used in traction applications. The square of the armature current is directly proportional to torque, resulting in a high starting torque. Ques. A 10 kW DC shunt motor has the following losses at full load: Mechanical Losses = 300 W, Iron Losses = 400 W, Shunt field Cu loss = 100 W, Armature cu loss = 500 W. Calculate the full-load efficiency of the motor and armature current corresponding to maximum efficiency if the armature resistance is 0.25 Ω. (3 Marks) Ans. Constant Losses, Wc = 300+400+100 = 800W Variable losses = Armature culoss = 500W Total Losses = 800+500 = 1300W Thus, Power input, Pin = 10000+1300 = 11300W Efficiency, η = Pout/Pin×100 = 10000/11300×100 ⇒ η = 88.49% Ques. What is the principle behind the direction of rotation of the DC motor? (3 marks) Ans. Fleming's right-hand rule is the principle nehind the rotation of the DC Motor. Faraday's law of induction causes an electric current to be induced in a current-carrying conductor, such as a wire attached to a circuit, when it moves in a magnetic field. The thumb, first finger, and second finger of the right hand are all perpendicular to each other. The thumb is pointing in the direction of the conductor's motion relative to the magnetic field, i.e. the force direction. The forefinger is pointing in the magnetic field's direction. The direction of the induced or generated current within the conductor is represented by the middle finger. That is why Fleming's right-hand rule. Is used to determine the direction of rotation of the DC motor. Ques. For the same percentage increase in torque, which DC motor has the lowest percentage increase in input current for the same percentage increse in torque? (3 marks) Ans. Series motors have the lowest percentage increase in input current. This is because the field and armature windings are connected in series, both carry the same current from the source in a DC series motor. As a result, torque is proportional to the product of field current and armature windings. The torque produced is equal to the square of the source current. So, even though there is a small change in current, the torque change is significant. Ques. Which part helps to identify the Direct Current motor? (3 marks) Ans. The Commutator helps identify the direct current motor. The commutator converts the alternating current generated in armature into the unidirectional current. Since it is a mechanical rectifier, the commutator collects induced EMF or the current developed in the armature. In the DC motor, the commutator is used to alternate the magnetic field created by the DC. For an AC motor the magnetic field is already alternated by the nature of the AC current. Ques. Which DC motor should be used in an elevator? (3 marks) Ans. Cumulative compound motor is used in an elevator. When a high starting torque or pulsating load is required, a compound motor is used. The load in the elevator is constantly pulsing, requiring a high starting torque to operate the elevator. The compound motor's series winding provides this high starting torque, while the shunt winding limits the compound motor's maximum speed at no load. Ques. A shunt generator delivers 450 A at 230 V and the resistance of the shunt field and armature are 50 Ω and 0.03 Ω respectively. Calculate the generated e.m.f? (4 Marks) Ans. The Generator Circuit is as shown below: Current through shunt field winding is: Ish= 230/50= 4.6 A Load current, I = 450 A Thus, Armature Current Ia = I + Ish =450 + 4.6 = 454.6 A Armature Voltage Drop, IaRa = 454.6 x 0.03 =13.6 V Generated Emf, Eg = terminal voltage + armature drop =V + IaRa Therefore, Emf generated in armature Eg = 230 + 13.6 =243.6 V Ques. A 250 volt DC shunt motor has an armature resistance of 0.25 ohm on the load it takes an armature current of 50A and runs at 750rpm. If the flux of the motor is reduced by 10% without changing the load torque, find the new speed of the motor. (4 Marks) Ans. V = 250, Ra = 0.25, Ia = 50, N1 = 750, Φ2 = 90%Φ1 \(\frac {N_2}{N_1} = \frac {E_{b2}}{E_{b1}} = \frac {\Phi_1}{\Phi_2}\) Eb1 = V-Ia1Ra = 250-(50x0.25) = 237.5V Eb2 = V-Ia2Ra Load torque is constant Ta1 = Ta2 Φ1Ia1 = Φ2Ia2 Ia2 = 55.55A Eb2 = 250-55.55X0.25 = 236.12V N2 = 828 rpm Ques. A 4 pole generator with wave wound armature has 51 slots each having 24 conductors. The flux per pole is 10 mWb. At what speed must the armature rotate to give an induced emf of 0.24 kV. What will be the voltage developed, if the winding is lap connected and the armature rotates at the same speed? (4 Marks) Ans. Given data P = 4 No.of slots = 51 No.of conductors/slot = 20 Eg= 0.24 Kv = 240 V Φ = 10 mW= 10/1000 Web Total no. of conductors, Z = 51x20 = 1224 Wave winding, A=2 From EMF equation, N= Eg60A / ΦZP = (240x60x2)/(10/1000x1224x4) = 612.75 rpm Lap winding, A=P=4 Eg = PΦZN/60A = (4x10/1000x1224x612.75)/(60x4) = 0.125 kV Ques. Explain the principle and parts of an electric motor (DC motor) with the help of a diagram. What is the function of a split ring commutator? (5 Marks) Ans. A DC motor converts electrical energy into mechanical energy. It works on the principle that- a current-carrying conductor placed in a magnetic field experiences a force. Parts of a DC Motor- (i) Coil: It is a rectangular coil of insulated copper wire having a large number of turns. (ii) Permanent Magnet: A large permanent magnet provides a strong magnetic field between its pole pieces. The coil rotates between these pole pieces. (iii) Split rings: These are the two halves of Split rings. The two ends of the coil are connected to two split rings. (iv) Brushes: Two carbon brushes are kept in contact with split rings. DC Motor Schematic The split-ring commutator changes direction after every half rotation. The direction of current going in the coil also reverses and the arm of the coil which goes up in the first half now moves down in the second half. Due to this, the coil continues to rotate in one direction. Anything connected to the axis of the coil also rotates. As a result, the electrical energy given to the coil changes into mechanical energy. For Latest Updates on Upcoming Board Exams, Click Here: Do Check Out: By David Birks, Applications Engineer, Diodes IncorporatedDC electric motors have been around for nearly two hundred years, with a steady series of refinements in that time. More recently, brushless DC motors have become increasingly popular but for many applications brushed DC motors are still the right choice. Brushed motors are lower cost and are simpler to drive, so they remain a popular option.In this article, we'll explain the basics of brushed DC motors, and then look at the circuitry required to drive them. We'll also introduce brushless DC motors and their pros and cons.Brushed DC Motor BasicsGoing back to basics, the fundamental principle of an electric motor is, of course, that it converts electricity into motion. It does this through the interaction between magnets, one of which is typically created by passing a current through wire bound around a ferrite core. The current flowing through the wire generates the second magnetic field. This interacts with the primary magnetic field to create an opposing force that moves one part of the motor, usually causing it to rotate around an axle.Brushed DC motors consist of four key components; the stationary magnet (called a stator), the rotor, the commutator and the brushes (see Figure 1). The rotor consists of one or more windings of wire wrapped around a core made of a ferrous metal, usually iron, and connected to power with a metal 'brush'. When we send current through the rotor windings, the field generated interacts with the stator's field and creates the force that turns the rotor. The stator can be a permanent magnet or electromagnet, depending on the requirements of any particular application.That's all very well but if we just used regular wires to connect the rotor windings to the power supply, once the rotor has turned far enough its magnetic force would effectively reverse direction – so the rotor would just move back and forth, instead of rotating in one direction.To fix this we use the commutator, which is a conductive copper sleeve around the axle of the rotor, physically and electrically divided into segments. As the commutator rotates it connects and disconnects these segments through the brushes, applying power to different pairs of segments. This causes the polarity of the magnetic field to reverse each time the motor rotates 180º, resulting in smooth and continuous rotation. Figure 1: Two Pole Brushed Motor The Alternative: Brushless DC MotorsAs its name suggests, a brushless DC motor has no brushes. Instead it uses transistors in the electronic control circuitry to apply and remove power to the rotor's wire, producing an alternating current from a DC supply to reverse the current on each half-cycle, achieving continuous rotation.Brushless DC motors are typically smoother and more efficient than brushed motors, have higher torque-to-power ratios and offer higher speeds with more precise control. With no wear on a brush or commutator, they need less maintenance and have a longer operational life. However, one of the main drawbacks of the brushless motor is cost: of the motor itself, and of the more complex drive circuitry that's needed.To provide continuous motion, the brushless motor's controller reverses the direction, or phase, of the current each time the motor rotates 180 degrees, or another fixed amount such as 120 degrees for a 3-phase motor.Varying the control voltage may be achieved with analog components, or digitally using an FPGA or microcontroller. The control circuitry needs to be aware of the relative angular position of the motor, so it can activate the correct phase at the right time. This can be achieved with sensors, by using an optical encoder or Hall effect sensor, or without sensors by inferring the rotational angle from the back EMF generated by the magnetic field. In either case, an all-in-one motor driver is often used which integrates the required functions into a single chip.Drive Circuits for Brushed MotorsIn principle, as discussed above, a brushed motor does not require an external controller, as the change of magnetic field polarity is implemented through the brushes making and breaking the electrical pathway through the windings, achieving continuous rotation in one direction.For some applications, that's good enough. But if we want to be able to change the speed of the motor, or reverse the direction of rotation, we need a drive circuit. This can be as simple as just reversing the direction of current flow to make the motor turn the other way.To change speed we could alter the voltage, using a potential divider – with speed being proportional to voltage. However, reducing the voltage in this way is inefficient, as a voltage divider does not reduce the total current flowing. To overcome this, pulse width modulation (PWM) is often used, which involves rapidly switching the current off and on to reduce the 'average' voltage across the motor.Let's look at an example of a simple single-direction application, such as a toy. For this, we only need a single transistor and a flyback diode, which provides a route to dissipate the back EMF that could otherwise cause damage (see Figure 2).To enable the speed to be varied, we need a transistor that can deliver the required power and can be switched on and off by a control signal. An example of this is the DMTH4008LFDFWQ from Diodes Incorporated, a rugged MOSFET device that operates at up to 175ºC. The device offers high power density, with up to 40V and 11.6A being handled in a compact 2mm x 2mm package. Figure 2: Single Direction Brushed DC Motor Control If changing the motor's direction of rotation is required, it can be achieved using an 'H-bridge' circuit, so called because it uses four transistors to control the flow of current (see Figure 3). When the two transistors Q1 and Q4 are switched on, current flows through the motor (labelled 'BDC' in Figure 3) from left to right, making it rotate. Switching Q1 and Q4 off, and turning Q2 and Q3 on, causes the current to flow from right to left through the motor, causing it to rotate in the opposite direction. Figure 3 also shows that we still need a flyback diode for each transistor, as in the single-transistor circuit discussed earlier. In practice, the body diode of the transistor provides this functionality. Figure 3: H-Bridge Gate Arrangement There are now devices available that integrate all four transistors of the H-bridge into one package, such as the DMHC4035LSDQ. This forms an H-bridge that can switch up to 3A. It is provided in the SO-8 package and is qualified for automotive applications, based on the rigorous AEC-Q101 standard. This device can also be used to control a single-phase brushless motor.ConclusionBrushed DC motors may seem less glamorous than their brushless cousins but they deliver reliable, proven performance that needs less complicated drive circuitry – keeping overall costs to a minimum.Choosing the right motor for any given application depends on the specific requirements of that application. Is precise control of the motor's position required, with the smoothness of motion offered by brushless motors, or can a simpler, lower cost brushed alternative provide a better solution? Is it important to avoid wear and maintenance, which a brushless motor can deliver, or does the application's motor operate so rarely that deterioration of the brushes and commutator is a low priority?If the application does not justify the higher cost and complexity that come with the features offered by a brushless motor, then a brushed DC motor, coupled with the right drive circuit design, can still provide a very appealing solution.