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# Introduction

Welcome to another course in the STEP series, Siemens Technical Education Program, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers Basics of DC Drives and related products.

Upon completion of Basics of DC Drives you will be able to:

Explain the concepts of force, inertia, speed, and torque

- Explain the difference between work and power
- Describe the operation of a DC motor
- Identify types of DC motors by their windings
- Identify nameplate information on a DC motor necessary for application to a DC drive
- Identify the differences between a power module and a base drive
- Explain the process of converting AC to DC using thyristors
- Describe the basic construction of a DC drive
- Explain the significant differences between 1- and 4-quadrant operation in a DC drive
- Describe features and operation of the Siemens 6RA70 DC MASTER
- Describe the characteristics of constant torque, constant horsepower, and variable torque applications

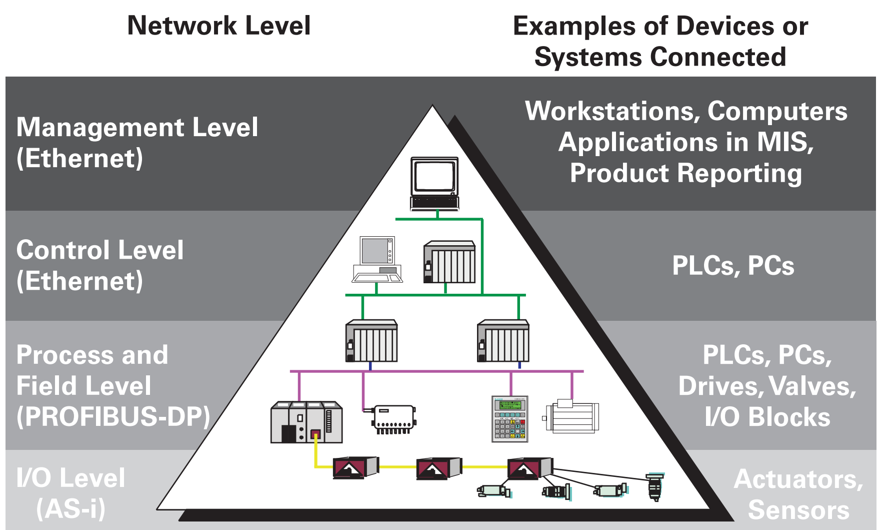
This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

# Totally Integrated Automation and DC Drives

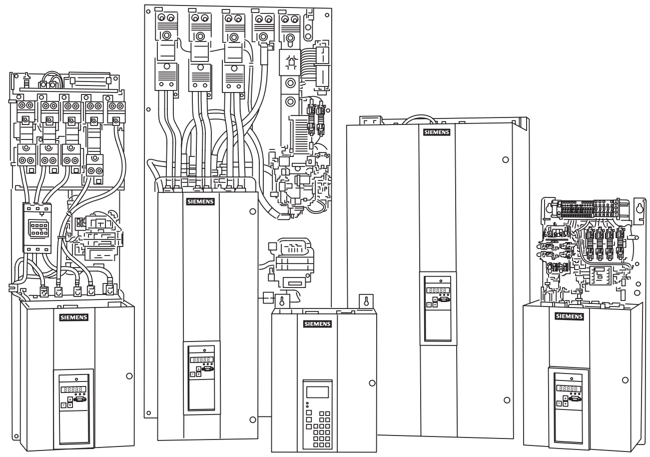
## Totally Integrated Automation

Totally Integrated Automation (TIA) is a strategy developed by Siemens that emphasizes the seamless integration of automation products. The TIA strategy incorporates a wide variety of automation products such as programmable controllers, computer numerical controls, Human Machine Interfaces (HMI), and DC drives which are easily connected via open protocol networks. An important aspect of TIA is the ability of devices to communicate with each other over various network protocols such as PROFIBUS-DP.

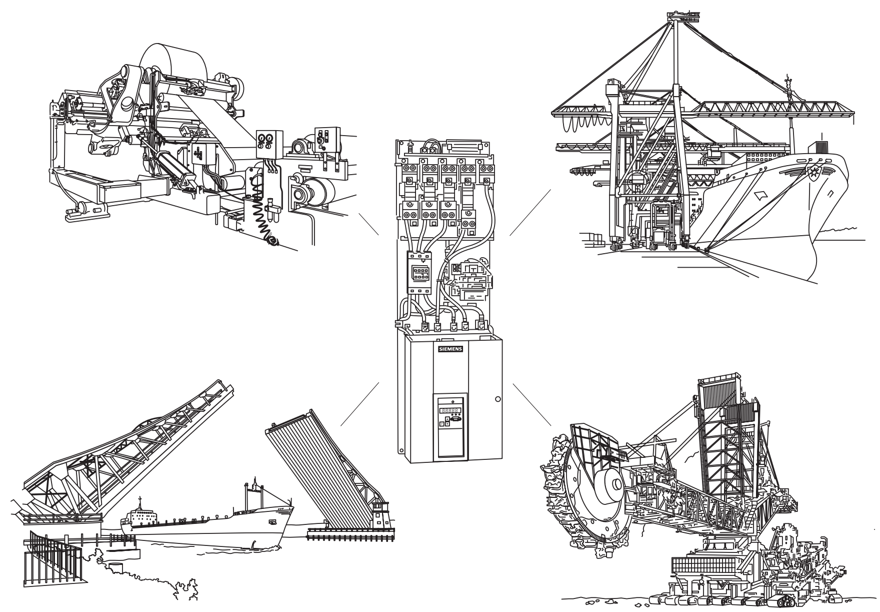



## Siemens DC Drives

SIMOREG® is the trade name for Siemens adjustable speed DC Drives. SIMOREG stands for SIemens MOtor REGulator. Siemens DC drives are an important element of the TIA strategy. DC motors were the first practical device to convert electrical energy into mechanical energy. DC motors, coupled with DC drives such as the Siemens SIMOREG 6RA70, have been widely used in industrial drive applications for years, offering very precise control.



Although AC motors and vector-control drives now offer alternatives to DC, there are many applications where DC drives offer advantages in operator friendliness, reliability, cost effectiveness, and performance. We will discuss applications later in the course.



# Mechanical Basics

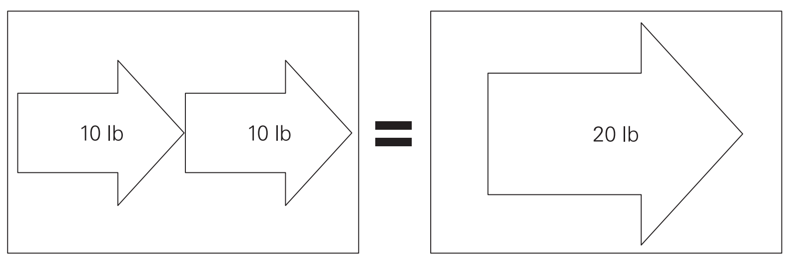
Before discussing Siemens DC drives it is necessary to understand some of the basic terminology associated with the mechanics of DC drive operation. Many of these terms are familiar to us in some other context. Later in the course we will see how these terms apply to DC drives.

**Force**

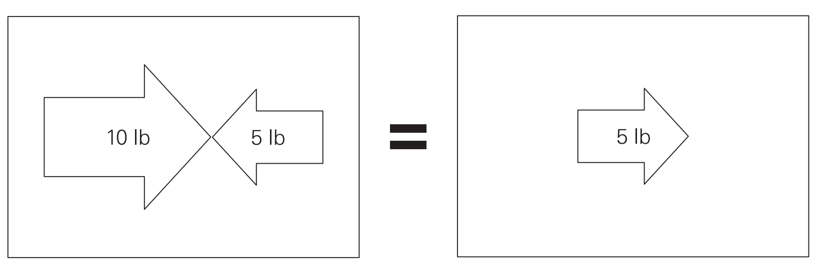
In simple terms, a force is a push or a pull. Force may be caused by electromagnetism, gravity, or a combination of physical means. The English unit of measurement for force is pounds (lb).

**Net Force**

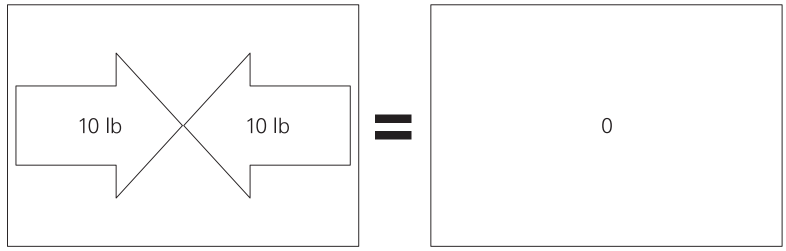
Net force is the vector sum of all forces that act on an object, including friction and gravity. When forces are applied in the same direction they are added. For example, if two 10 lb forces were applied in the same direction the net force would be 20 lb.




If 10 lb of force were applied in one direction and 5 lb of force applied in the opposite direction, the net force would be 5 lb and the object would move in the direction of the greater force.




If 10 lb of force were applied equally in both directions, the net force would be zero and the object would not move.



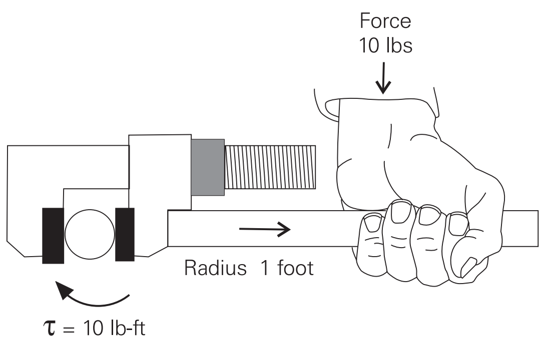

**Torque**

Torque is a twisting or turning force that tends to cause an object to rotate. A force applied to the end of a lever, for example, causes a turning effect or torque at the pivot point.

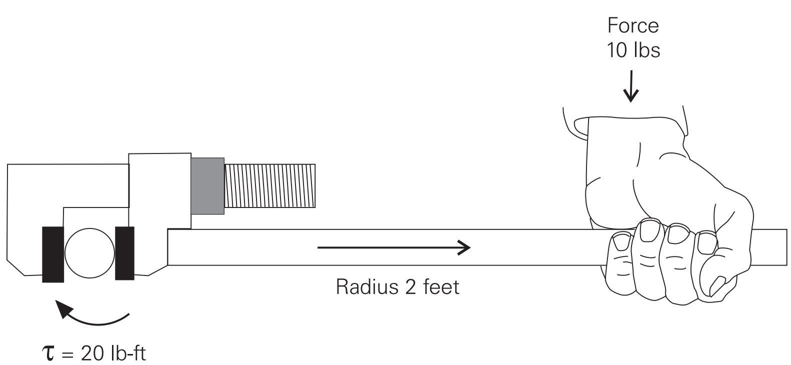
Torque ($\tau$) is the product of force and radius (lever distance).

Torque ($\tau$) = Force x Radius

In the English system torque is measured in pound-feet (lb-ft) or pound-inches (lb-in). If 10 lbs of force were applied to a lever 1 foot long, for example, there would be 10 lb-ft of torque.




An increase in force or radius would result in a corresponding increase in torque. Increasing the radius to 2 feet, for example, results in 20 lb-ft of torque.



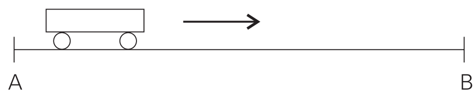

**Speed**

An object in motion travels a given distance in a given time. Speed is the ratio of the distance traveled to the time it takes to travel the distance.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

**Linear Speed**

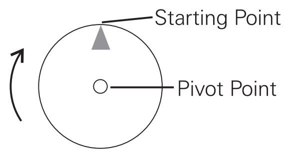
The linear speed of an object is a measure of how long it takes the object to get from point A to point B. Linear speed is usually given in a form such as feet per second (f/s). For example, if the distance between point A and point B were 10 feet, and it took 2 seconds to travel the distance, the speed would be 5 f/s.




Linear Motion

**Angular (Rotational) Speed**

The angular speed of a rotating object is a measurement of how long it takes a given point on the object to make one complete revolution from its starting point. Angular speed is generally given in revolutions per minute (RPM). An object that makes ten complete revolutions in one minute, for example, has a speed of 10 RPM.




Rotational Motion

**Acceleration**

An object can change speed. An increase in speed is called acceleration. Acceleration occurs when there is a change in the force acting upon the object. An object can also change from a higher to a lower speed. This is known as deceleration (negative acceleration). A rotating object, for example, can accelerate from 10 RPM to 20 RPM, or decelerate from 20 RPM to 10 RPM.

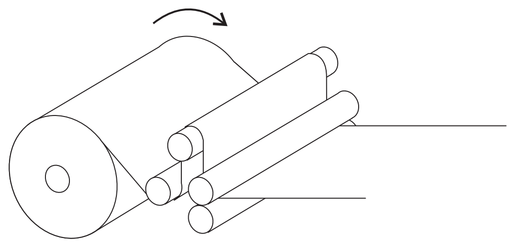

Acceleration

Deceleration

**Law of Inertia**

Mechanical systems are subject to the law of inertia. The law of inertia states that an object will tend to remain in its current state of rest or motion unless acted upon by an external force. This property of resistance to acceleration/deceleration is referred to as the moment of inertia. The English system of measurement is pound-feet squared (lb-ft$^2$).

If we look at a continuous roll of paper, as it unwinds, we know that when the roll is stopped, it would take a certain amount of force to overcome the inertia of the roll to get it rolling. The force required to overcome this inertia can come from a source of energy such as a motor. Once rolling, the paper will continue unwinding until another force acts on it to bring it to a stop.



**Friction**

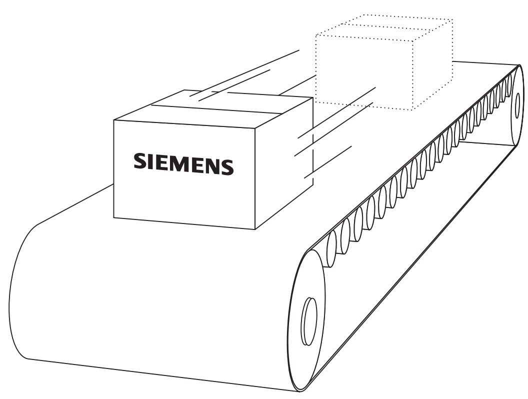
A large amount of force is applied to overcome the inertia of the system at rest to start it moving. Because friction removes energy from a mechanical system, a continual force must be applied to keep an object in motion. The law of inertia is still valid, however, since the force applied is needed only to compensate for the energy lost.

Once the system is in motion, only the energy required to compensate for various losses need be applied to keep it in motion. In the previous illustration, for example: these losses include:

- Friction within motor and driven equipment bearings
- Windage losses in the motor and driven equipment
- Friction between material on winder and rollers

**Work**

Whenever a force of any kind causes motion, work is accomplished. For example, work is accomplished when an object on a conveyor is moved from one point to another.



Work is defined by the product of the net force (F) applied and the distance (d) moved. If twice the force is applied, twice the work is done. If an object moves twice the distance, twice the work is done.

$$W = F \times d$$

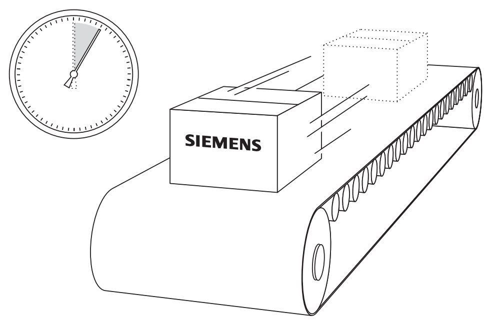
**Power**

Power is the rate of doing work, or work divided by time.

$$\text{Power} = \frac{\text{Force x Distance}}{\text{Time}}$$

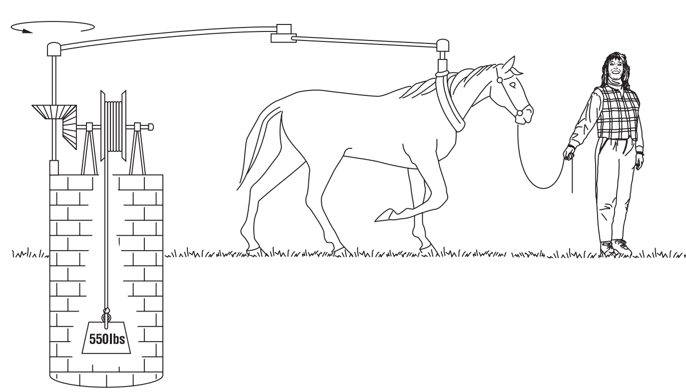
$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

In other words, power is the amount of work it takes to move the package from one point to another point, divided by the time.




**Horsepower**

Power can be expressed in foot-pounds per second, but is often expressed in horsepower (HP). This unit was defined in the 18th century by James Watt. Watt sold steam engines and was asked how many horses one steam engine would replace. He had horses walk around a wheel that would lift a weight. He found that each horse would average about 550 foot-pounds of work per second. One horsepower is equivalent to 500 foot-pounds per second or 33,000 foot-pounds per minute.



The following formula can be used to calculate horsepower when torque (lb-ft) and speed (RPM) are known. It can be seen from the formula that an increase of torque, speed, or both will cause a corresponding increase in horsepower.

$$HP = \frac{\text{Torque x RPM}}{5250}$$

Power in an electrical circuit is measured in watts (W) or kilowatts (kW). Variable speed drives and motors manufactured in the United States are generally rated in horsepower (HP); however, it is becoming common practice to rate equipment using the International System of Units (SI units) of watts and kilowatts.

**Review 1**

1. ____________ is the trade name for Siemens motor generators (DC drives).

2. If 20 lb of force where applied in one direction and 5 lb of force applied in the opposite direction, the net force would be ____________ lb.

3. If 5 lb of force were applied to a radius of 3 feet, the torque would be ____________ lb-ft.

4. Speed is determined by ___________ .

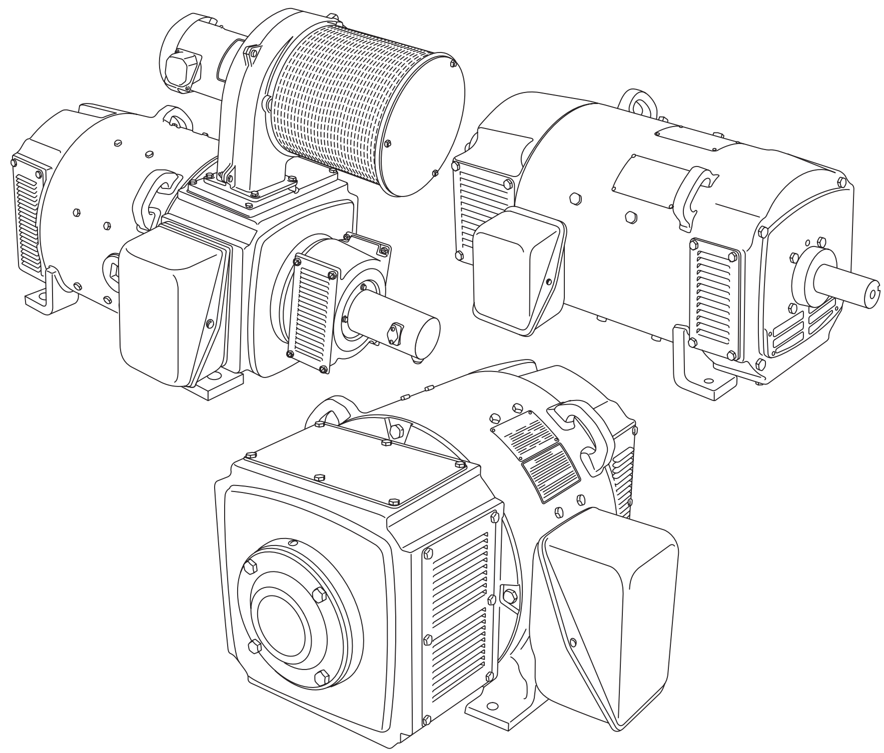
   a. dividing Time by Distance
   b. dividing Distance by Time
   c. multiplying Distance x Time
   d. subtracting Distance from Time

5. Work is accomplished whenever ____________ causes motion.

6. The law of inertia states that an object will tend to remain in its current state of rest or motion unless acted upon by an ____________ ____________ .

# DC Motors

DC motors have been used in industrial applications for years. Coupled with a DC drive, DC motors provide very precise control. DC motors can be used with conveyors, elevators, extruders, marine applications, material handling, paper, plastics, rubber, steel, and textile applications to name a few.

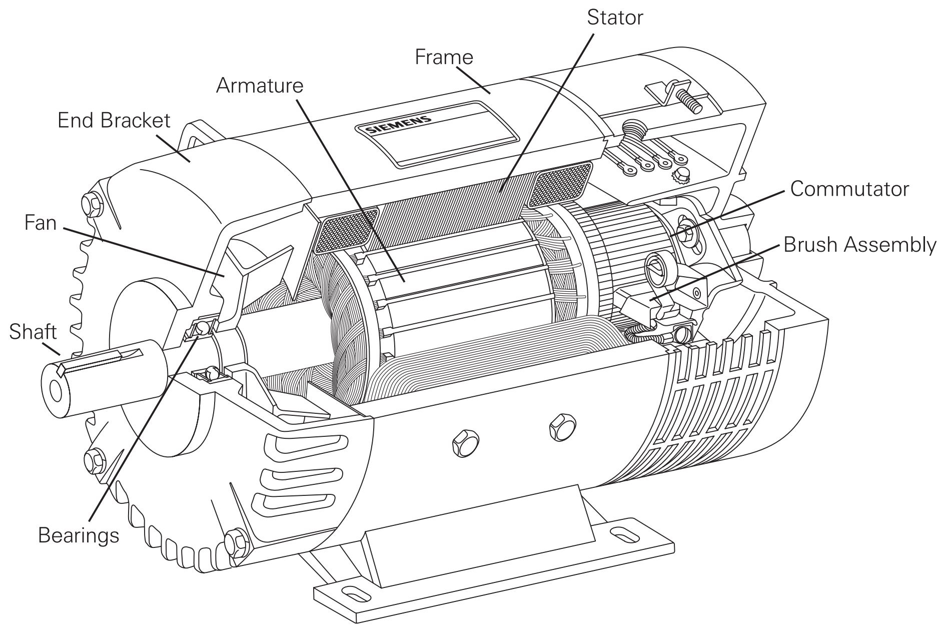


**Construction**

DC motors are made up of several major components which include the following:

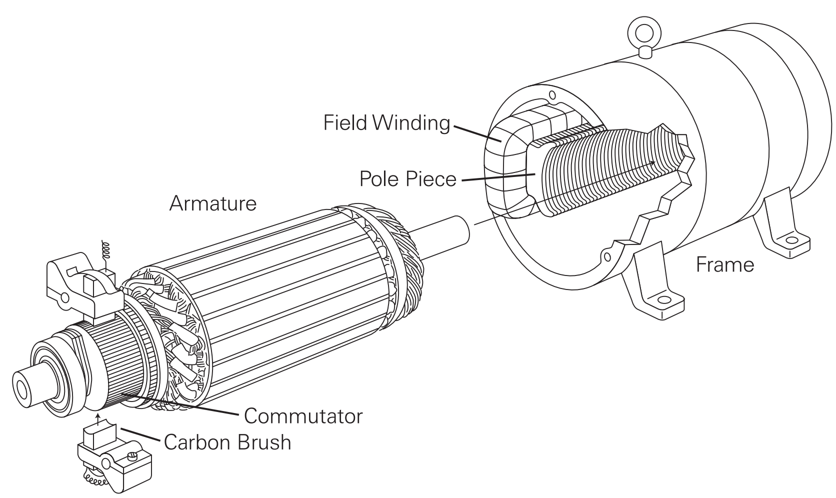
- Frame
- Shaft
- Bearings
- Main Field Windings (Stator)
- Armature (Rotor)
- Commutator
- Brush Assembly

Of these components, it is important to understand the electrical characteristics of the main field windings, known as the stator, and the rotating windings, known as the armature. An understanding of these two components will help with the understanding of various functions of a DC Drive.



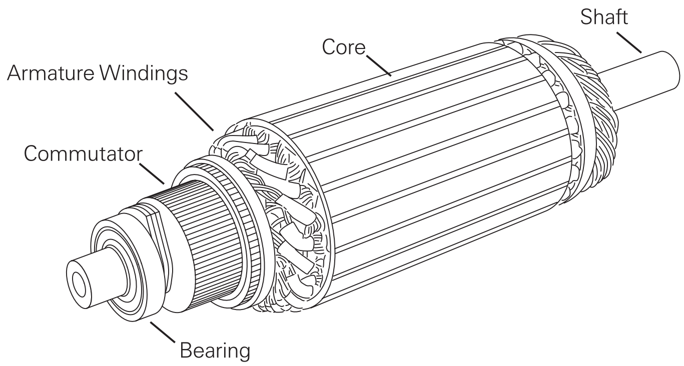

## Basic Construction

The relationship of the electrical components of a DC motor is shown in the following illustration. Field windings are mounted on pole pieces to form electromagnets. In smaller DC motors the field may be a permanent magnet. However, in larger DC fields the field is typically an electromagnet. Field windings and pole pieces are bolted to the frame. The armature is inserted between the field windings. The armature is supported by bearings and end brackets (not shown). Carbon brushes are held against the commutator.



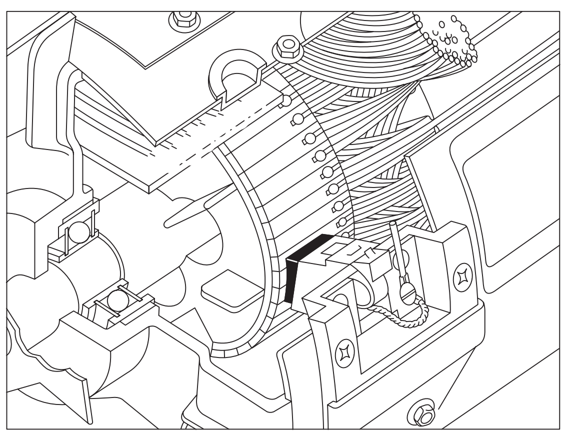
**Armature**

The armature rotates between the poles of the field windings. The armature is made up of a shaft, core, armature windings, and a commutator. The armature windings are usually form wound and then placed in slots in the core.




**Brushes**

Brushes ride on the side of the commutator to provide supply voltage to the motor. The DC motor is mechanically complex which can cause problems for them in certain adverse environments. Dirt on the commutator, for example, can inhibit supply voltage from reaching the armature. A certain amount of care is required when using DC motors in certain industrial applications. Corrosives can damage the commutator. In addition, the action of the carbon brush against the commutator causes sparks which may be problematic in hazardous environments.

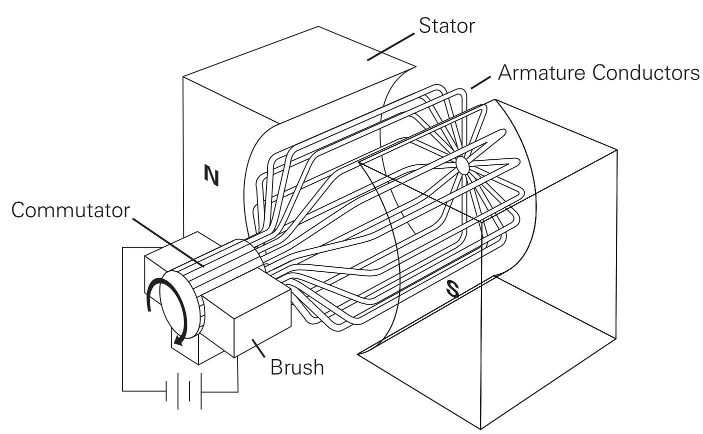


# Basic DC Motor Operation

**Magnetic Fields**

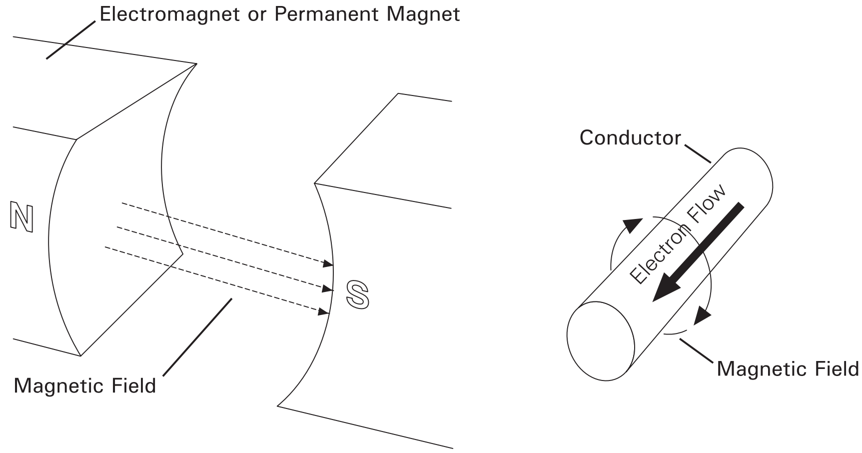
You will recall from the previous section that there are two electrical elements of a DC motor, the field windings and the armature. The armature windings are made up of current carrying conductors that terminate at a commutator. DC voltage is applied to the armature windings through carbon brushes which ride on the commutator.

In small DC motors, permanent magnets can be used for the stator. However, in large motors used in industrial applications the stator is an electromagnet. When voltage is applied to stator windings an electromagnet with north and south poles is established. The resultant magnetic field is static (non-rotational). For simplicity of explanation, the stator will be represented by permanent magnets in the following illustrations.



## Magnetic Fields

A DC motor rotates as a result of two magnetic fields interacting with each other. The first field is the main field that exists in the stator windings. The second field exists in the armature. Whenever current flows through a conductor a magnetic field is generated around the conductor.

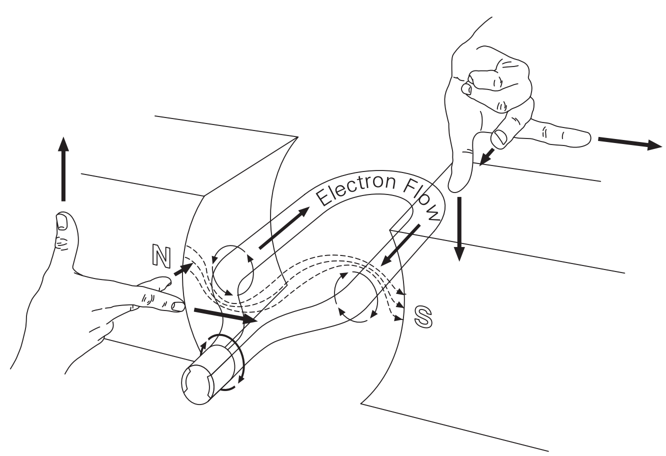



**Stator** **Armature Conductor**

## Right-Hand Rule for Motors

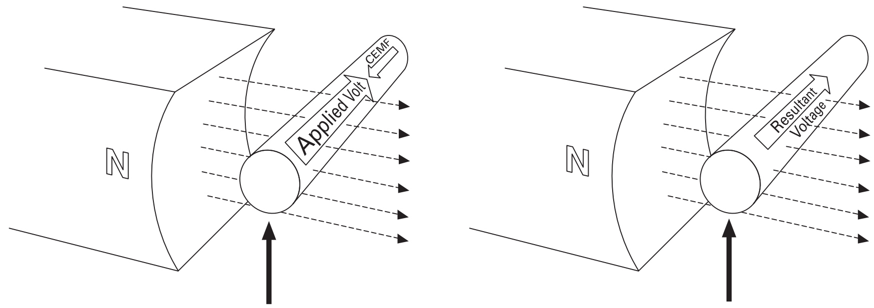
A relationship, known as the right-hand rule for motors, exists between the main field, the field around a conductor, and the direction the conductor tends to move.

If the thumb, index finger, and third finger are held at right angles to each other and placed as shown in the following illustration so that the index finger points in the direction of the main field flux and the third finger points in the direction of electron flow in the conductor, the thumb will indicate direction of conductor motion. As can be seen from the following illustration, conductors on the left side tend to be pushed up. Conductors on the right side tend to be pushed down. This results in a motor that is rotating in a clockwise direction. You will see later that the amount of force acting on the conductor to produce rotation is directly proportional to the field strength and the amount of current flowing in the conductor.



**CEMF**

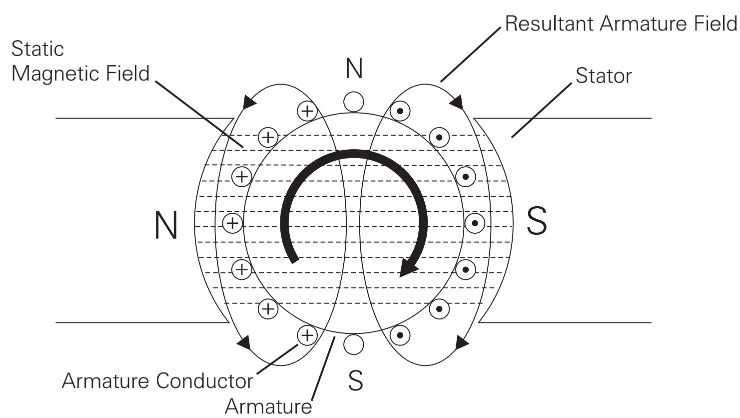
Whenever a conductor cuts through lines of flux a voltage is induced in the conductor. In a DC motor the armature conductors cut through the lines of flux of the main field. The voltage induced into the armature conductors is always in opposition to the applied DC voltage. Since the voltage induced into the conductor is in opposition to the applied voltage it is known as CEMF (counter electromotive force). CEMF reduces the applied armature voltage.




The amount of induced CEMF depends on many factors such as the number of turns in the coils, flux density, and the speed which the flux lines are cut.

**Armature Field**

An armature, as we have learned, is made up of many coils and conductors. The magnetic fields of these conductors combine to form a resultant armature field with a north and south pole. The north pole of the armature is attracted to the south pole of the main field. The south pole of the armature is attracted to the north pole of the main field. This attraction exerts a continuous torque on the armature. Even though the armature is continuously moving, the resultant field appears to be fixed. This is due to commutation, which will be discussed next.

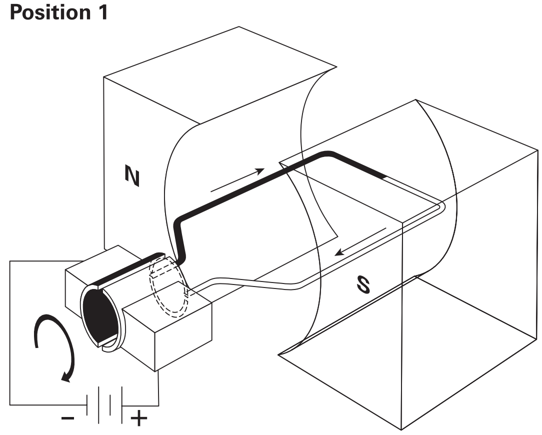


## Commutation

In the following illustration of a DC motor only one armature conductor is shown. Half of the conductor has been shaded black, the other half white. The conductor is connected to two segments of the commutator.

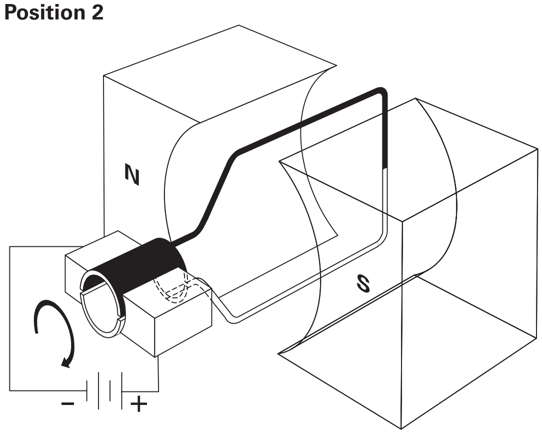
In position 1 the black half of the conductor is in contact with the negative side of the DC applied voltage. Current flows away from the commutator on the black half of the conductor and returns to the positive side, flowing towards the commutator on the white half.

**Position 1**



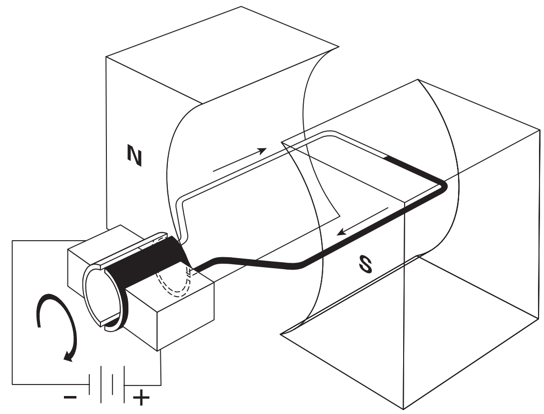

In position 2 the conductor has rotated 90°. At this position the conductor is lined up with the main field. This conductor is no longer cutting main field magnetic lines of flux; therefore, no voltage is being induced into the conductor. Only applied voltage is present. The conductor coil is short-circuited by the brush spanning the two adjacent commutator segments. This allows current to reverse as the black commutator segment makes contact with the positive side of the applied DC voltage and the white commutator segment makes contact with the negative side of the applied DC voltage.

**Position 2**



As the conductor continues to rotate from position 2 to position 3 current flows away from the commutator in the white half and toward the commutator in the black half. Current has reversed direction in the conductor. This is known as commutation.

**Position 3**

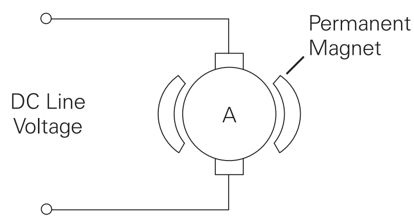


# Types of DC Motors

The field of DC motors can be a permanent magnet, or electromagnets connected in series, shunt, or compound.

**Permanent Magnet Motors**

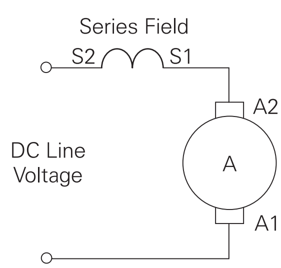
The permanent magnet motor uses a magnet to supply field flux. Permanent magnet DC motors have excellent starting torque capability with good speed regulation. A disadvantage of permanent magnet DC motors is they are limited to the amount of load they can drive. These motors can be found on low horsepower applications. Another disadvantage is that torque is usually limited to 150% of rated torque to prevent demagnetization of the permanent magnets.




**Series Motors**

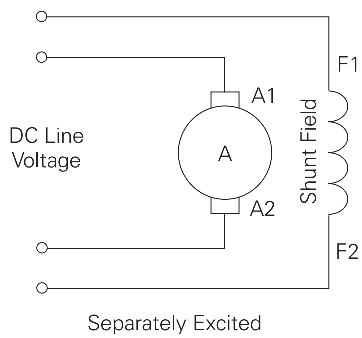
In a series DC motor the field is connected in series with the armature. The field is wound with a few turns of large wire because it must carry the full armature current.

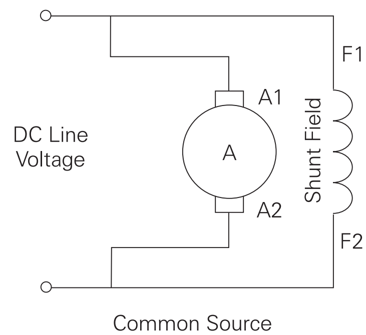
A characteristic of series motors is the motor develops a large amount of starting torque. However, speed varies widely between no load and full load. Series motors cannot be used where a constant speed is required under varying loads. Additionally, the speed of a series motor with no load increases to the point where the motor can become damaged. Some load must always be connected to a series-connected motor. Series-connected motors generally are not suitable for use on most variable speed drive applications.



## Shunt Motors

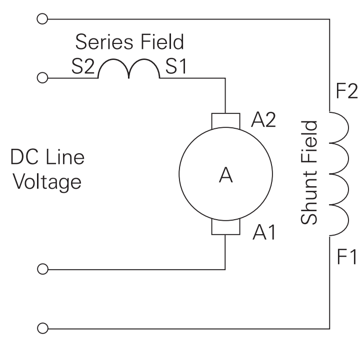
In a shunt motor the field is connected in parallel (shunt) with the armature windings. The shunt-connected motor offers good speed regulation. The field winding can be separately excited or connected to the same source as the armature. An advantage to a separately excited shunt field is the ability of a variable speed drive to provide independent control of the armature and field. The shunt-connected motor offers simplified control for reversing. This is especially beneficial in regenerative drives.



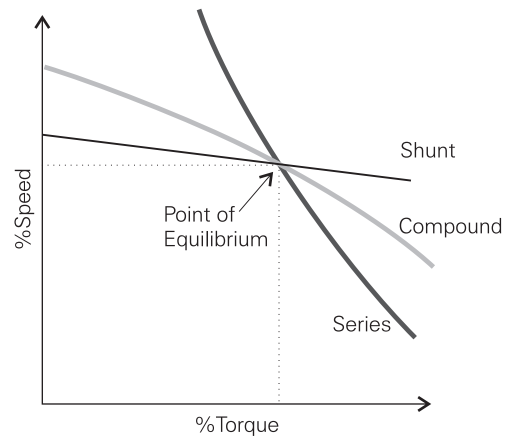

## Compound Motors

Compound motors have a field connected in series with the armature and a separately excited shunt field. The series field provides better starting torque and the shunt field provides better speed regulation. However, the series field can cause control problems in variable speed drive applications and is generally not used in four quadrant drives.



**Speed/Torque Curves**

The following chart compares speed/torque characteristics of DC motors. At the point of equilibrium, the torque produced by the motor is equal to the amount of torque required to turn the load at a constant speed. At lower speeds, such as might happen when load is added, motor torque is higher than load torque and the motor will accelerate back to the point of equilibrium. At speeds above the point of equilibrium, such as might happen when load is removed, the motor's driving torque is less than required load torque and the motor will decelerate back to the point of equilibrium.




**Review 2**

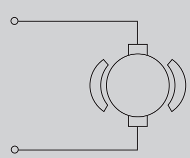
1. The field in larger DC motors is typically an ___________ _ .

2. Whenever ____________ flows through a conductor a magnetic field is generated around the conductor.

3. Voltage induced into the conductors of an armature that is in opposition to the applied voltage is known as ____________ .

4. Identify the following motor types.

a



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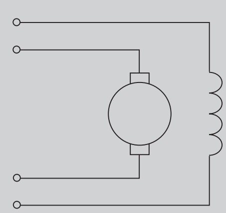

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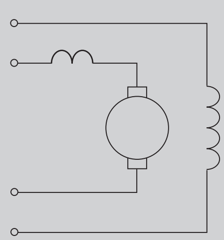

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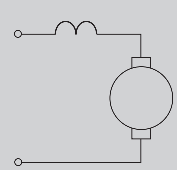
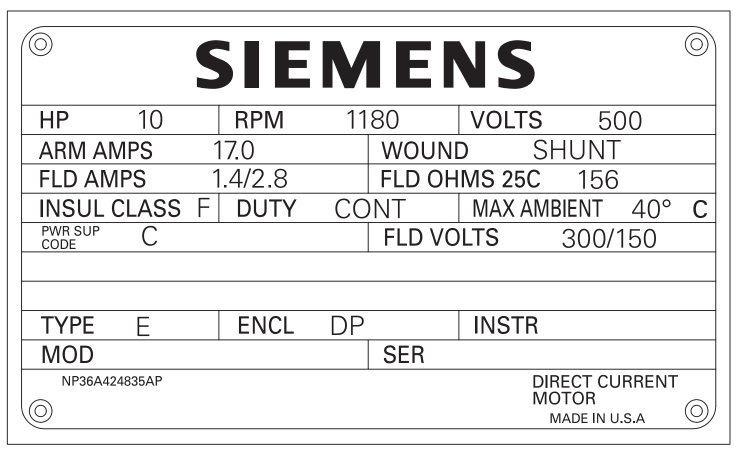


# DC Motor Ratings

The nameplate of a DC motor provides important information necessary for correctly applying a DC motor with a DC drive. The following specifications are generally indicated on the nameplate:

- Manufacturer's Type and Frame Designation
- Horsepower at Base Speed
- Maximum Ambient Temperature
- Insulation Class
- Base Speed at Rated Load
- Rated Armature Voltage
- Rated Field Voltage
- Armature Rated Load Current
- Winding Type (Shunt, Series, Compound, Permanent Magnet)
- Enclosure



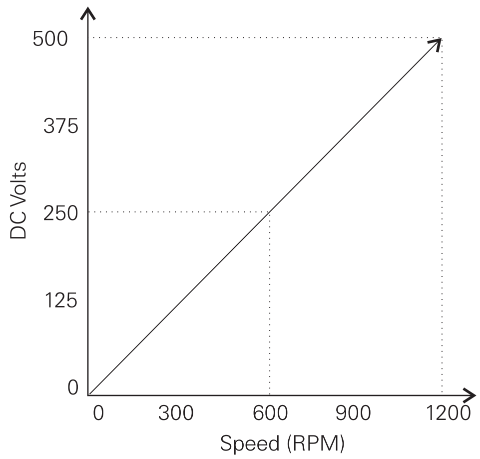

**HP**

Horsepower is a unit of power, which is an indication of the rate at which work is done. The horsepower rating of a motor refers to the horsepower at base speed. It can be seen from the following formula that a decrease in speed (RPM) results in a proportional decrease in horsepower (HP).

$$HP = \frac{\text{Torque x RPM}}{5250}$$

## Armature Speed, Volts, and Amps

Typically armature voltage in the U.S. is either 250 VDC or 500 VDC. The speed of an unloaded motor can generally be predicted for any armature voltage. For example, an unloaded motor might run at 1200 RPM at 500 volts. The same motor would run at approximately 600 RPM at 250 volts.




$$\text{Speed (n)} = \frac{Va - (IaRa)}{Kt\Phi}$$

or

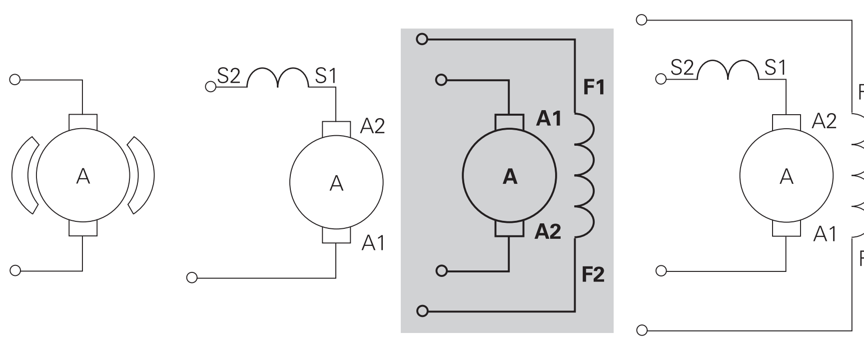
$$\text{Speed (n)} \approx \frac{CEMF}{\Phi}$$

The base speed listed on a motor's nameplate, however, is an indication of how fast the motor will turn with rated armature voltage and rated load (amps) at rated flux ($\Phi$).

The maximum speed of a motor may also be listed on the nameplate. This is an indication of the maximum mechanical speed a motor should be run in field weakening. If a maximum speed is not listed the vendor should be contacted prior to running a motor over the base speed.

## Winding

The type of field winding is also listed on the nameplate. Shunt winding is typically used on DC Drives.




Permanent Magnet

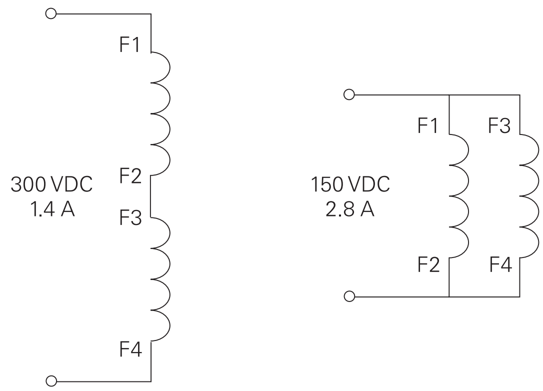
Series

Shunt

Compound

**Field Volts and Amps**

Shunt fields are typically wound for 150 VDC or 300 VDC. Our sample motor has a winding that can be connected to either 150 VDC or 300 VDC.



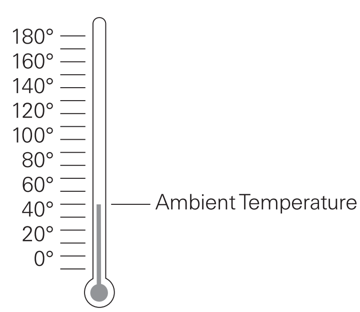

**Field Economizing**

In many applications it may be necessary to apply voltage to the shunt field during periods when the motor is stationary and the armature circuit is not energized. Full shunt voltage applied to a stationary motor will generate excessive heat which will eventually burn up the shunt windings. Field economizing is a technique used by DC drives, such as the SIMOREG® 6RA70, to reduce the amount of applied field voltage to a lower level when the armature is de-energized (standby). Field voltage is reduced to approximately 10% of rated value. A benefit of field economizing over shuting the field off is the prevention of condensation.

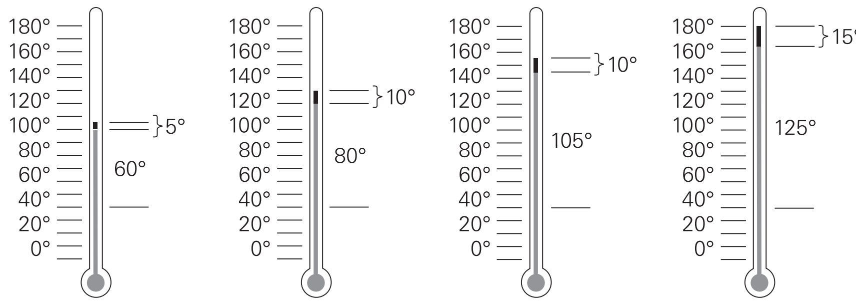
**Insulation Class**

The National Electrical Manufacturers Association (NEMA) has established insulation classes to meet motor temperature requirements found in different operating environments. The insulation classes are A, B, F, and H.

Before a motor is started the windings are at the temperature of the surrounding air. This is known as ambient temperature. NEMA has standardized on an ambient temperature of 40°C (104°F) for all classes.



Temperature will rise in the motor as soon as it is started. The combination of ambient temperature and allowed temperature rise equals the maximum winding temperature in a motor. A motor with Class F (commonly used) insulation, for example, has a maximum temperature rise of 105°C. The maximum winding temperature is 145°C (40°C ambient + 105°C rise). A margin is allowed to provide for a point at the center of the motor's windings where the temperature is higher. This is referred to as the motor's hot spot.




Class A
60° C Rise
5° C Hot Spot

Class B
80° C Rise
10° C Hot Spot

Class F
105° C Rise
10° C Hot Spot

Class H
125° C Rise
15° C Hot Spot

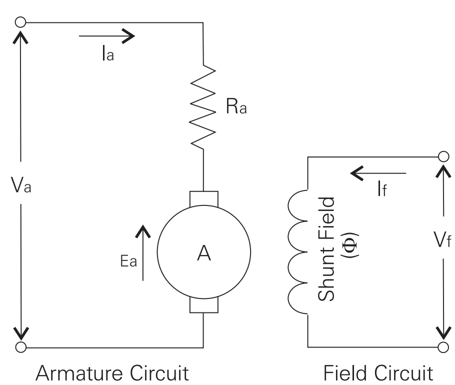
The operating temperature of a motor is important to efficient operation and long life. Operating a motor above the limits of the insulation class reduces the motor's life expectancy. A 10°C increase in the operating temperature can decrease the life expectancy of a motor by as much as 50%. In addition, excess heat increases brush wear.

# Speed/Torque Relationships of Shunt Connected Motors

An understanding of certain relationships within a DC motor will help us understand the purposes of various the functions in a DC drive discussed later in the course. The formulas given in the following discussion apply to all three types of DC motors (series, shunt, and compound). However, The focus will be on shunt connected DC motors because these motors are more commonly used with DC drives.

**DC Motor Equations**

In a DC drive, voltage applied ($V_a$) to the armature circuit is received from a variable DC source. Voltage applied to the field circuit ($V_f$) is from a separate source. The armature of all DC motors contains some amount of resistance ($R_a$). When voltage is applied ($V_a$), current ($I_a$) flows through the armature. You will recall from earlier discussion that current flowing through the armature conductors generates a magnetic field. This field interacts with the shunt field ($\Phi$) and rotation results.




**Armature Voltage**

The following armature voltage equation will be used to demonstrate various operating principles of a DC motor. Variations of this equation can be used to demonstrate how armature voltage, CEMF, torque, and motor speed interact.

$V_a = (K_t\Phi n) + (I_aR_a)$

Where:
$V_a$ = Applied Armature Voltage
$K_t$ = Motor Design Constants
$\Phi$ = Shunt Field Flux
n = Armature Speed
$I_a$ = Armature Current
$R_a$ = Armature Resistance

## CEMF

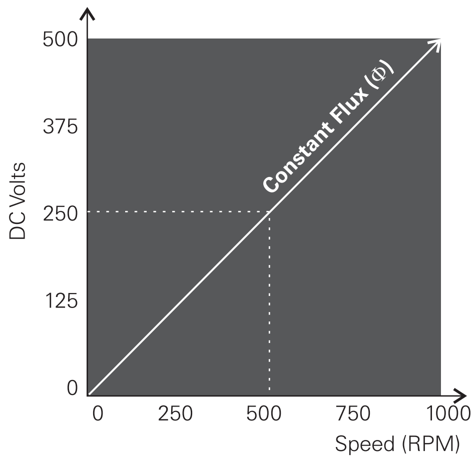
As previously indicated, rotation of the armature through the shunt field induces a voltage in the armature ($E_a$) that is in opposition to the armature voltage ($V_a$). This is counter electromotive force (CEMF).

CEMF is dependent on armature speed (n) and shunt field ($\Phi$) strength. An increase in armature speed (n) or an increase of shunt field ($\Phi$) strength will cause a corresponding increase in CEMF ($E_a$).

$E_a = K_t\Phi n$ or $E_a = V_a - (I_aR_a)$

## Motor Speed

The relationship between $V_A$ and speed is linear as long as flux ($\Phi$) remains constant. For example, speed will be 50% of base speed with 50% of $V_A$ applied.




$$\text{Speed (n)} = \frac{Va - (IaRa)}{Kt\Phi}$$

or

$$\text{Speed (n)} \approx \frac{CEMF}{\Phi}$$

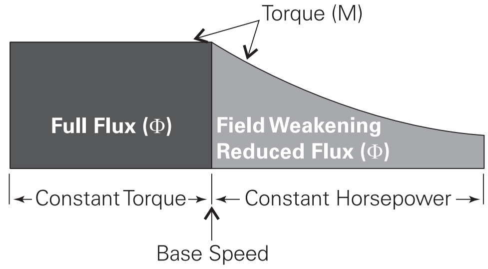
## Motor Torque

The interaction of the shunt and armature field flux produces torque (M). An increase in armature current ($I_a$) increases armature flux, thereby increasing torque. An increase in field current ($I_f$) increases shunt field flux ($\Phi$), thereby increasing torque.

$M \approx I_a\Phi$

## Constant Torque

Base speed corresponds to full armature voltage ($V_a$) and full flux ($\Phi$). A DC motor can operate at rated torque (M) at any speed up to base speed,  by selecting the appropriate value of armature voltage. This is often referred to as the constant torque region. Actual torque (M) produced, however, is determined by the demand of the load ($I_a$).




$$\text{Speed (n)} = \frac{Va - (IaRa)}{Kt\Phi}$$

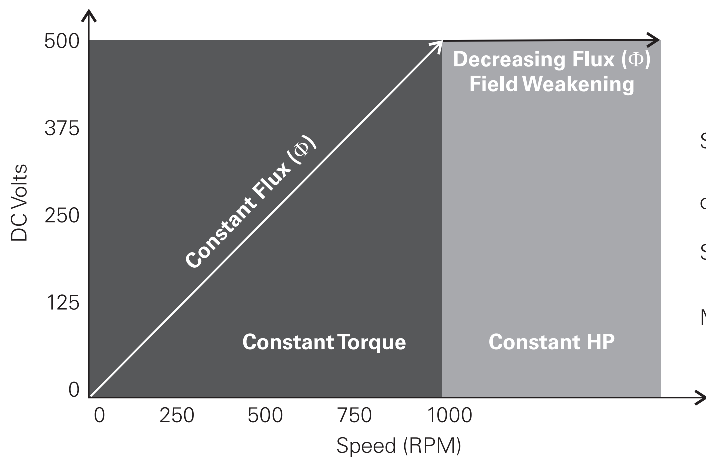
or

$$\text{Speed (n)} \approx \frac{CEMF}{\Phi}$$

$$M \approx I_a\Phi$$

**Constant Horsepower**

Some applications require the motor to be operated above base speed. Armature voltage ($V_a$), however, cannot be higher than rated nameplate voltage. Another method of increasing speed is to weaken the field (Φ). Weakening the field reduces the amount of torque (M) a motor can produce. Applications that operate with field weakening must require less torque at higher speeds.




$$\text{Speed (n)} = \frac{Va - (IaRa)}{Kt\Phi}$$

or

$$\text{Speed (n)} \approx \frac{CEMF}{\Phi}$$

$$M \approx I_a\Phi$$

Horsepower is said to be constant because speed (N) increases and torque (M) decreases in proportion.

$$\text{Horsepower (HP)} = \frac{\text{Torque (M) x Speed (N)}}{5250}$$

$$\text{HP (Remains Constant)} = \frac{\text{M (Decreases) x N (Increases)}}{5250}$$

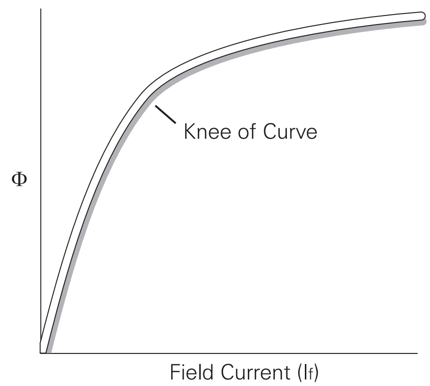
**Field Saturation**

It can be seen from the speed (n) and torque (M) formulas that field flux (Φ) density has a direct effect on motor speed and available torque. An increase in field flux (Φ), for example, will cause a decrease in speed (n) and an increase in available motor torque (M).

$$\text{Speed (n)} \approx \frac{CEMF}{\Phi} \qquad M \approx Ia\Phi$$

The relationship between field current ($I_f$) and flux ($\Phi$) is not as directly proportional as it may appear. As flux density increases the field's ability to hold additional flux decreases. It becomes increasingly difficult to increase flux density. This is known as saturation.

A saturation curve, such as the example shown below, can be plotted for a DC motor. Flux ($\Phi$) will rise somewhat proportionally with an increase of field current ($I_f$) until the knee of the curve. Further increases of field current ($I_f$) will result in a less proportional flux ($\Phi$) increase. Once the field is saturated no additional flux ($\Phi$) will be developed.




## Review 3

1. One way to increase motor speed is to ____________ armature voltage.

   a. increase
   b. decrease

2. CEMF is zero when the armature is ____________ .

   a. turning at low speed
   b. turning at max speed
   c. not turning
   d. accelerating

3. A ____________ - connected motor is typically used with DC drives.

4. A DC motor, operating from zero to base speed, can be said to be operating in the constant ____________ range.

   a. horsepower
   b. torque

5. No additional ____________ can be developed once the field becomes saturated.

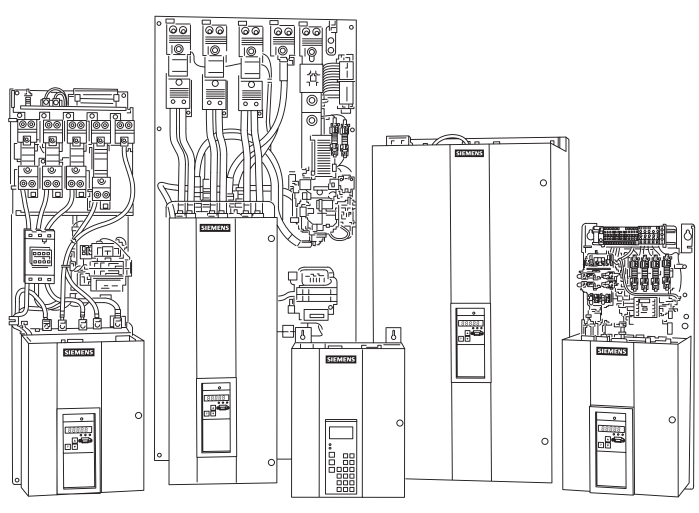
# Basic DC Drives

The remainder of this course will focus on applying the SIMOREG DC MASTER® 6RA70, to DC motors and associated applications. The SIMOREG DC MASTER 6RA70 drives are designed to provide precise DC motor speed control over a wide range of machine parameters and load conditions. Selection and ordering information, as well as engineering information can be found in the SIMOREG 6RA70 DC MASTER catalog, available from your Siemens sales representative.

SIMOREG drives are designed for connection to a three-phase AC supply. They, in turn, supply the armature and field of variable-speed DC motors. SIMOREG drives can be selected for connection to 230, 400, 460, 575, 690, 830, and 950 VAC, making them suitable for global use.

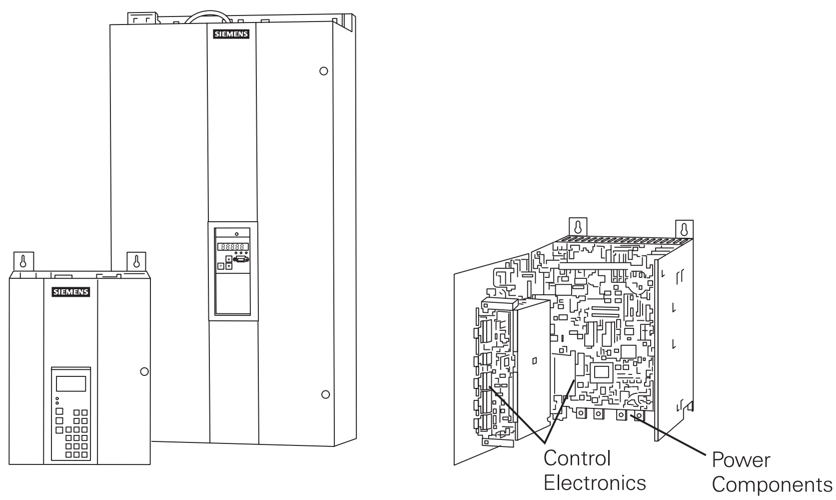
Siemens SIMOREG DC MASTER 6RA70 drives are available up to 1000 HP at 500 VDC in standard model drives. In addition, drives can be paralleled, extending the range up to 6000 HP.

Siemens SIMOREG drives have a wide range of microprocessor-controlled internal parameters to control DC motor operation. It is beyond the scope of this course to cover all of the parameters in detail, however; many concepts common to most applications and drives will be covered later in the course.



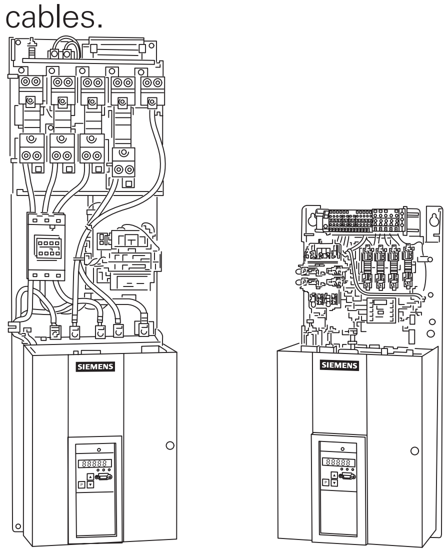
**Power Modules**

The SIMOREG 6RA70 is available in a power module and base drive panels. The power module contains the control electronics and power components necessary to control drive operation and the associated DC motor.




**Base Drive Panels**

The base drive panel consists of the power module mounted on a base panel with line fuses, control transformer, and contactor. This design allows for easy mounting and connection of power cables.



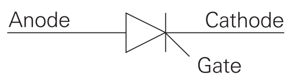
## High Horsepower Designs

High horsepower designs are also available with ratings up to 14,000 amps. These drives have input ratings up to 700 VAC and can operate motors with armature ratings up to 750 VDC. For additional information on high horsepower design SIMOREG 6RA70 DC MASTER drives, contact your Siemens sales representative.

# Converting AC to DC

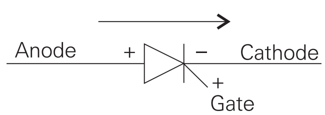
**Thyristor**

A primary function of a DC drive, such as the SIMOREG 6RA70 DC MASTER, is to convert AC voltage into a variable DC voltage. It is necessary to vary to DC voltage in order to control the speed of a DC motor. A thyristor is one type of device commonly used to convert AC to DC. A thyristor consists of an anode, cathode, and a gate.



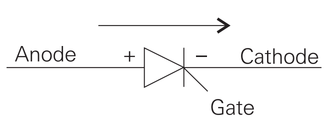

**Gate Current**

A thyristor acts as a switch. Initially, a thyristor will conduct (switch on) when the anode is positive with respect to the cathode and a positive gate current is present. The amount of gate current required to switch on a thyristor varies. Smaller devices require only a few milliamps; however, larger devices such as required in the motor circuit of a DC drive may require several hundred milliamps.

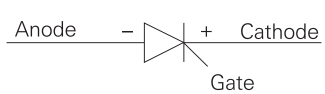



**Holding Current**

Holding current refers to the amount of current flowing from anode to cathode to keep the thyristor turned on. The gate current may be removed once the thyristor has switched on. The thyristor will continue to conduct as long as the anode remains sufficiently positive with respect to the cathode to allow sufficient holding current to flow. Like gate current, the amount of holding current varies from device to device. Smaller devices may require only a few milliamps and larger devices may require a few hundred milliamps.

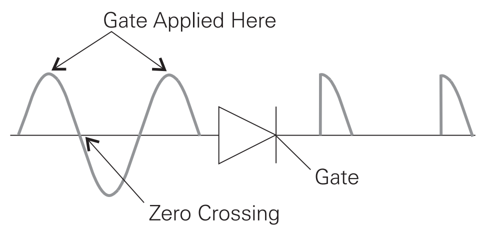



The thyristor will switch off when the anode is no longer positive with respect to the cathode.

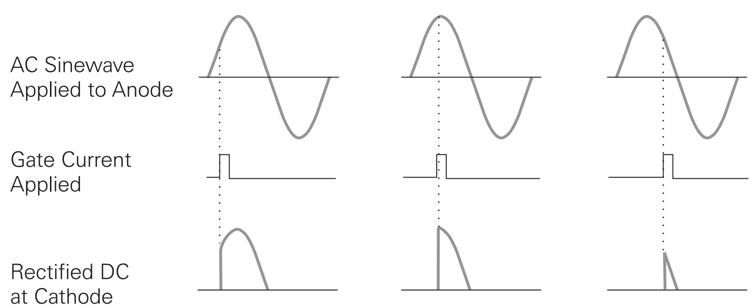


## AC to DC Conversion

The thyristor provides a convenient method of converting AC voltage to a variable DC voltage for use in controlling the speed of a DC motor. In this example the gate is momentarily applied when AC input voltage is at the top of the sinewave. The thyristor will conduct until the input's sinewave crosses zero. At this point the anode is no longer positive with respect to the cathode and the thyristor shuts off. The result is a half-wave rectified DC.

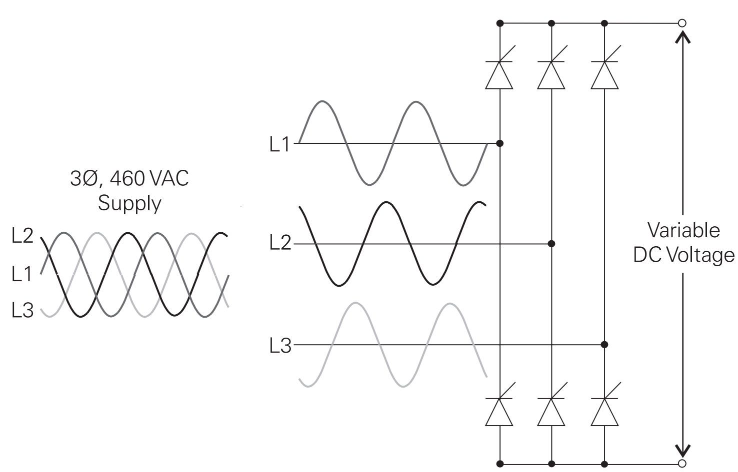



The amount of rectified DC voltage can be controlled by timing the input to the gate. Applying current on the gate at the beginning of the sinewave results in a higher average voltage applied to the motor. Applying current on the gate later in the sinewave results in a lower average voltage applied to the motor.




## DC Drive Converter

The output of one thyristor is not smooth enough to control the voltage of industrial motors. Six thyristors are connected together to make a 3Ø bridge rectifier.



## Gating Angle

As we have learned, the gating angle of a thyristor in relationship to the AC supply voltage, determines how much rectified DC voltage is available. However, the negative and positive value of the AC sine wave must be considered when working with a fully-controlled 3Ø rectifier.

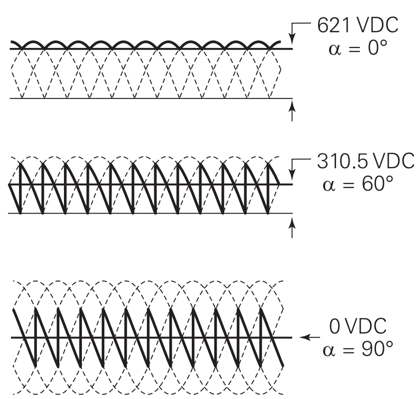
A simple formula can be used to calculate the amount of rectified DC voltage in a 3Ø bridge. Converted DC voltage ($V_{DC}$) is equal to 1.35 times the RMS value of input voltage ($V_{RMS}$) times the cosine of the phase angle ($\cos\alpha$).

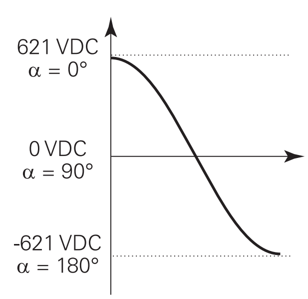
$$V_{DC} = 1.35 \times V_{RMS} \times \cos\alpha$$

The value of DC voltage that can be obtained from a 460 VAC input is -621 VDC to +621 VDC. The following table shows sample values of rectified DC voltage available from 0° to 180°. It is important to note that voltage applied to the armature should not exceed the rated value of the DC motor.

| Volts RMS | a | Cosine | Formula | VDC |
|---|---|---|---|---|
| 460 VAC | 0 | 1.00 | VDC = 460 x 1.35 x 1 | 621 |
| 460 VAC | 30 | 0.87 | VDC = 460 x 1.35 x 0.87 | 538 |
| 460 VAC | 60 | 0.50 | VDC = 460 x 1.35 x 0.50 | 310.5 |
| 460 VAC | 90 | 0.00 | VDC = 460 x 1.35 x 0 | 0 |
| 460 VAC | 120 | -0.50 | VDC = 460 x 1.35 x (-0.50) | -310.5 |
| 460 VAC | 150 | -0.87 | VDC = 460 x 1.35 x (-0.87) | -538 |
| 460 VAC | 180 | -1.00 | VDC = 460 x 1.35 x (- 1) | -621 |

The following illustration approximates the output waveform of a fully controlled thyristor bridge rectifier for 0°, 60°, and 90°. The DC value is indicated by the heavy horizontal line. It is important to note that when thyristors are gated at 90° the DC voltage is equal to zero. This is because thyristors conduct for the same amount of time in the positive and negative bridge. The net result is 0 VDC. DC voltage will increase in the negative direction as the gating angle (α) is increased from 90° to a maximum of 180°.




Average DC Voltage
as a Function of α

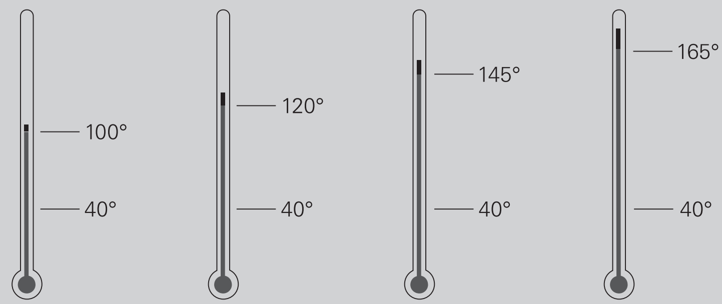
## Review 4

1. An increase of torque causes a corresponding ____________ in horsepower

   a. increase
   b. decrease

2. Typically, DC motor armature voltage is either rated for ____________ VDC or ____________ VDC.

3. Identify the following insulation classes.




   a. _____ b. _____ c. _____ d. _____

4. The SIMOREG 6RA70 DC MASTER ____________ drive consists of the power module mounted on a panel with line fuses, control transformer, and a contactor.

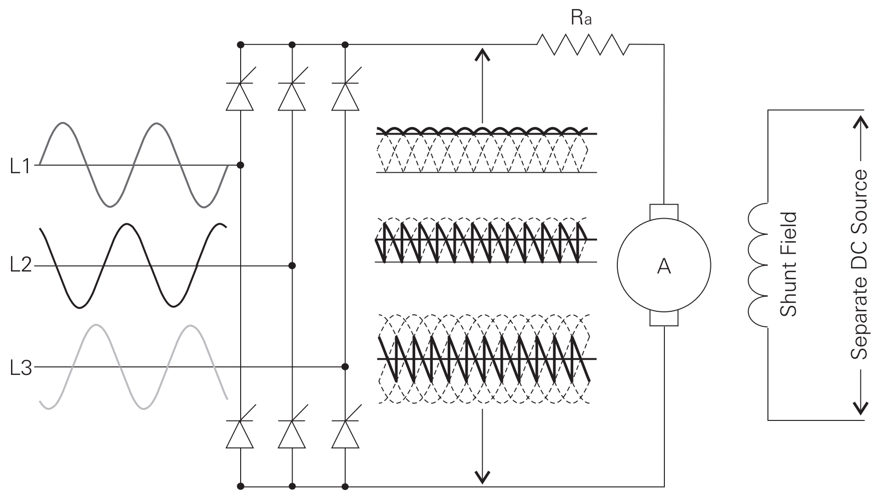
5. A thyristor is one type of device commonly used to convert ____________ .

   a. DC to AC
   b. AC to DC

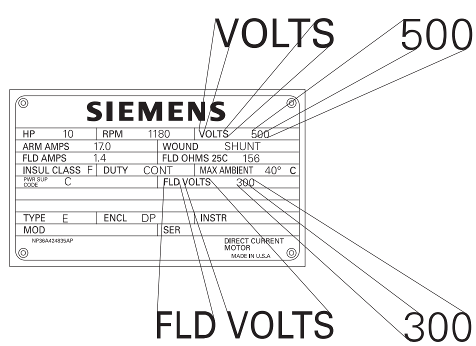
6. The approximate converted DC voltage of a six-pulse converter when the thyristors are gated at 30° is ____________ VDC.

**Controlling a DC Motor**

A thyristor bridge is a technique commonly used to control the speed of a DC motor by varying the DC voltage. Examples of how a DC rectifier bridge operates are given on the next few pages. Voltage values given in these examples are used for explanation only. The actual values for a given load, speed, and motor vary.

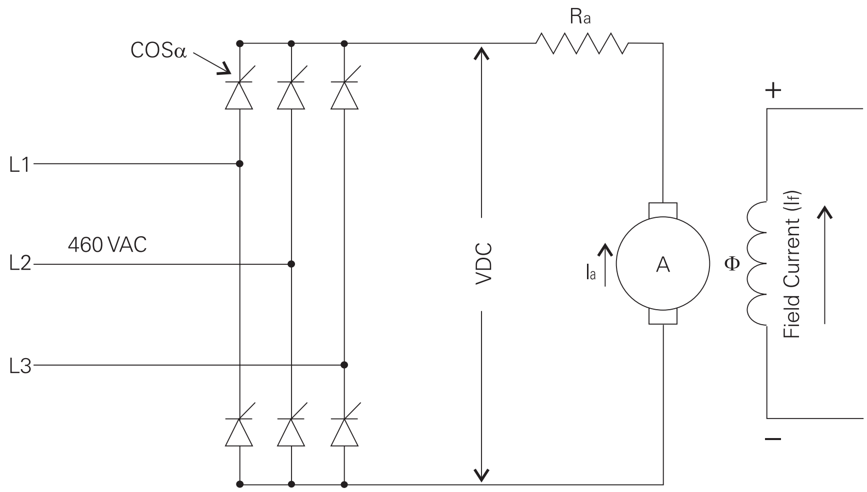



It is important to note that the voltage applied to a DC motor be no greater than the rated nameplate. Armature windings are commonly wound for 500 VDC. The control logic in the drive must be adjusted to limit available DC voltage to 0 - 500 VDC. Likewise, the shunt field must be limited to the motor's nameplate value.



## Basic Operation

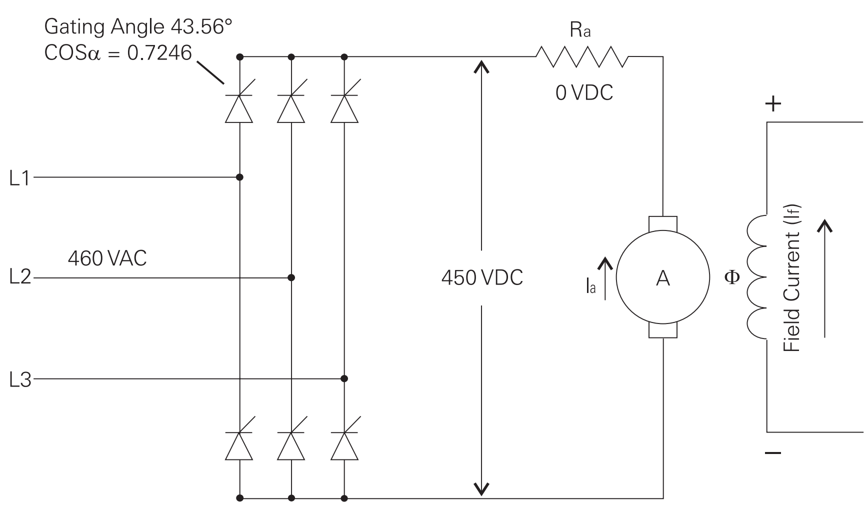
A DC drive supplies voltage to the motor to operate at a desired speed. The motor draws current from this power source in proportion to the torque (load) applied to the motor shaft.




## 100% Speed, 0% Load

In this example an unloaded motor connected to a DC drive is being operated at 100% speed. The amount of armature current ($I_a$) and unloaded motor needs to operate is negligible. For the purpose of explanation a value of 0 amps is used.

The DC drive will supply only the voltage required to operate the motor at 100% speed. We have already learned the amount of voltage is controlled by the gating angle (COSα) of the thyristors. In this example 450 VDC is sufficient. The motor accelerates until CEMF reaches a value of $V_a - I_aR_a$. Remember that $V_a = I_aR_a + \text{CEMF}$. In this example $I_aR_a$ is 0, therefore CEMF will be approximately 450 VDC.



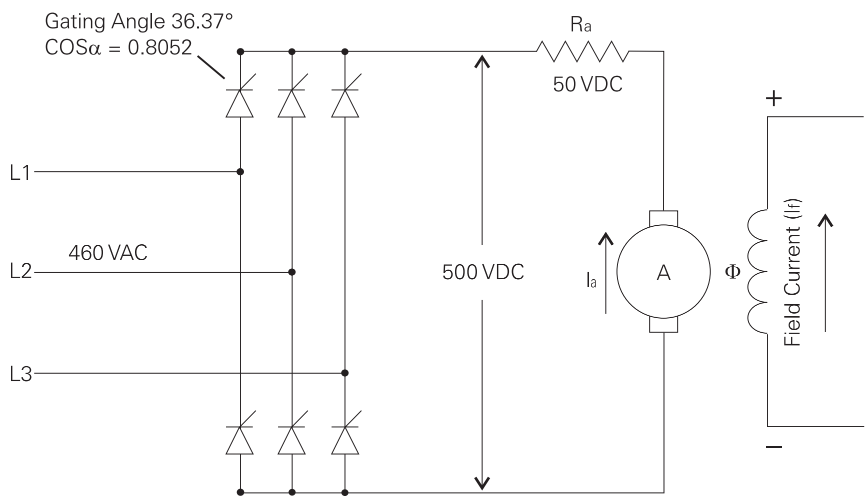

$V_a = 1.35 \times \text{VRMS} \times \text{COS}\alpha$
$V_a = 1.35 \times 460\ \text{VAC} \times 0.7246$
$V_a = 450\ \text{VDC}$

$V_a = I_aR_a + \text{CEMF}$
$V_a = 0 + 450$
$V_a = 450\ \text{VDC}$

## 100% Speed, 100% Load

A fully loaded motor requires 100% of rated armature current at 100% speed. Current flowing through the armature circuit will cause a voltage drop across the armature resistance ($R_a$). Full voltage (500 VDC) must be applied to a fully loaded motor to operate at 100% speed. To accomplish this, thyristors are gated earlier in the sine wave (36.37°).

The DC drive will supply the voltage required to operate the motor at 100% speed. The motor accelerates until CEMF reaches a value of $V_a - I_aR_a$. Remember that $V_a = I_aR_a +$ CEMF. In this example armature current ($I_a$) is 100% and $R_a$ will drop some amount of voltage. If we assume that current and resistance is such that $R_a$ drops 50 VDC, CEMF will be 450 VDC.



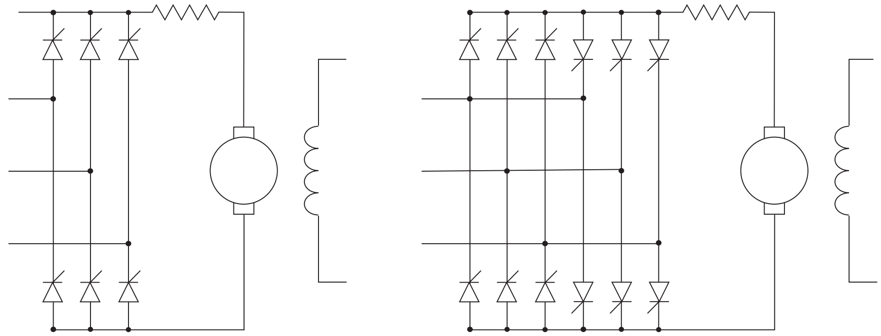

$V_a = 1.35 \times VRMS \times COS\alpha$
$V_a = 1.35 \times 460\,VAC \times 0.8052$
$V_a = 500\,VDC$

$V_a = I_aR_a + CEMF$
$V_a = 50 + 450$
$V_a = 500\,VDC$

**1 Quad, 4 Quad**

Up to this point we have only looked at a drive in single-quadrant operation. A single-quadrant DC drive will have six thyristors.

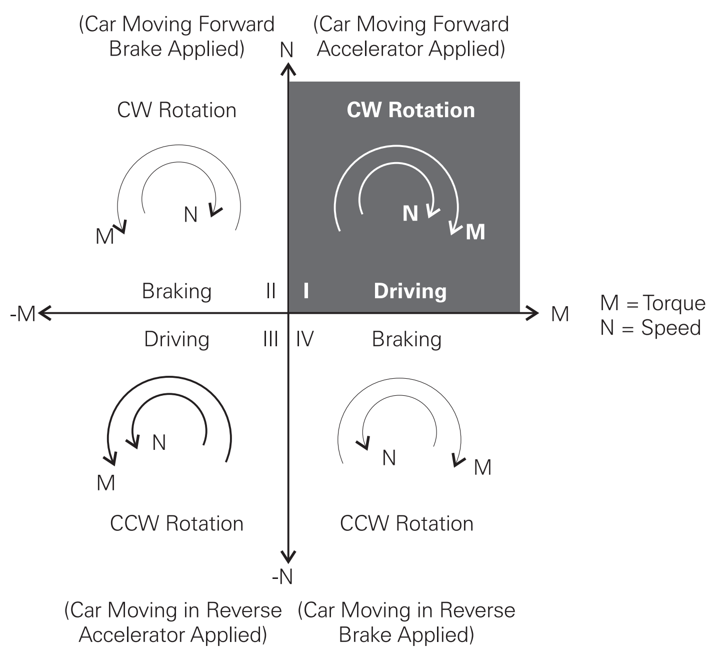
In the speed-torque chart there are four quadrants of operation according to direction of rotation and direction of torque. A four-quadrant DC drive will have twelve thyristors.



1 Quadrant - 6 SCRs    4 Quadrant - 12 SCRs

**Single-Quadrant Operation**

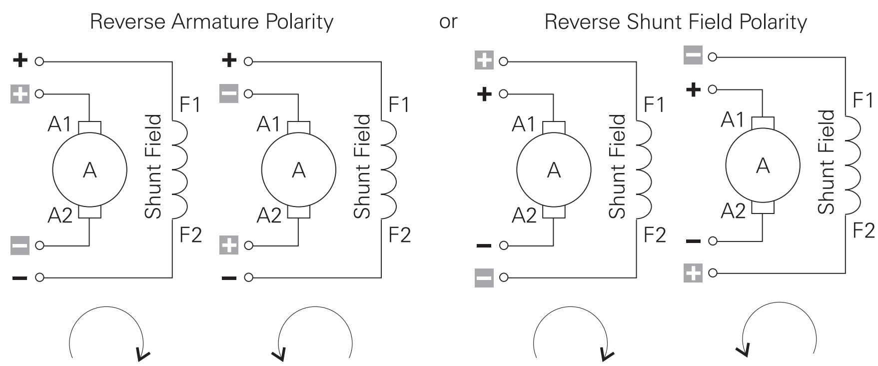
Single-quadrant drives only operate in quadrant I. Motor torque (M) is developed in the forward or clockwise (CW) direction to drive the motor at the desired speed (N). This is similar to driving a car forward on a flat surface from standstill to a desired speed. It takes more forward or motoring torque to accelerate the car from zero to the desired speed. Once the car is at desired speed your foot can be let off the accelerator a little. When the car comes to an incline a little more gas, controlled by the accelerator, maintains speed. To slow or stop a motor in single-quadrant operation the drive lets the motor coast.



## Changing Direction of a DC Motor

There are two ways to change the direction a DC motor rotates.

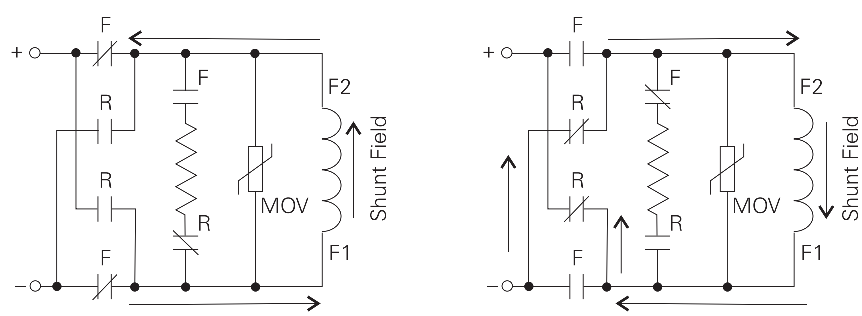
1. Reverse Armature Polarity
2. Reverse Field Polarity




## Reversing in Single-Quadrant Operation

Field contactor reverse kits can be used to provide bidirectional rotation from a single-quadrant drive. To turn the motor in the forward direction the "F" contacts are closed, applying DC voltage in one polarity across the shunt field. Simply reversing the polarity of the field, by opening the "F" contacts and closing the "R" contacts, will reverse direction of a DC motor.

It is important to note that field reversal will only work when a quick reversal is not required. The field circuit is inductive and must be brought to 0 current before opening the contacts.




Forward Direction (Quadrant I)

Reverse Direction (Quadrant III)

## Stopping a Motor

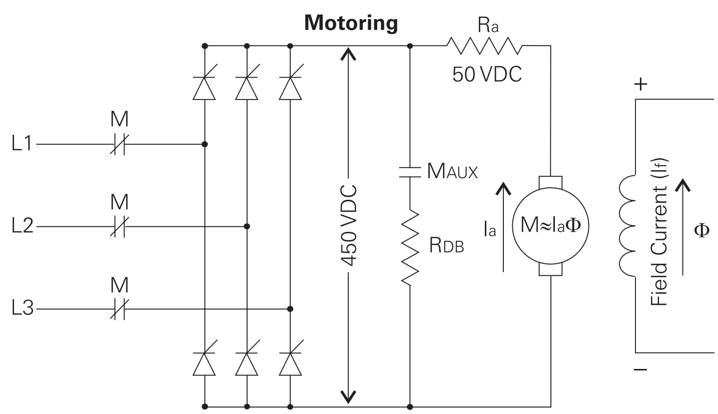
Stopping a motor in single-quadrant operation can be done by simply removing voltage to the motor and allowing the motor to coast to a stop. Alternatively, voltage can be reduced gradually until the motor is at a stop. The amount of time required to stop a motor depends on the inertia of the motor and connected load. The more inertia the longer the time.

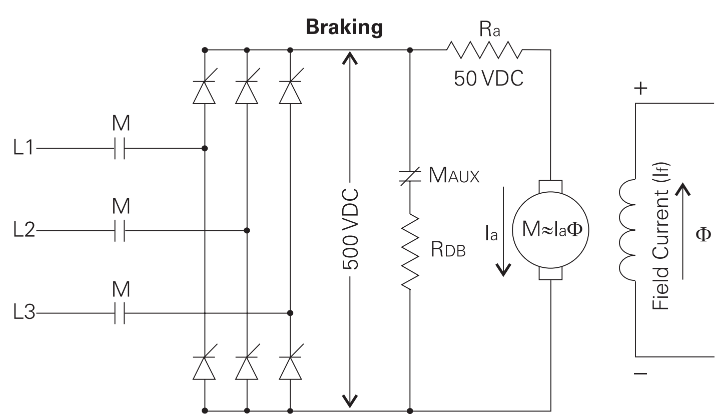
## Dynamic Braking

Dynamic braking is often used on single quadrant drives as a means of stopping a motor quickly. Dynamic braking is not recommended for continuous or repetitive operation. Dynamic braking kits for use with Siemens SIMOREG® drives are typically designed to stop a load operating at base speed a maximum of three consecutive times. After three consecutive stops a waiting period of 15 minutes is required.

Dynamic braking develops stopping torque by using a contact ($M_{AUX}$) to connect a resistor ($R_{db}$) across the armature terminals after the drive controller turns off power to the motor. The field remains energized to supply stopping torque. This is because motor torque (M) depends on armature current ($I_a$) and field flux ($\Phi$).

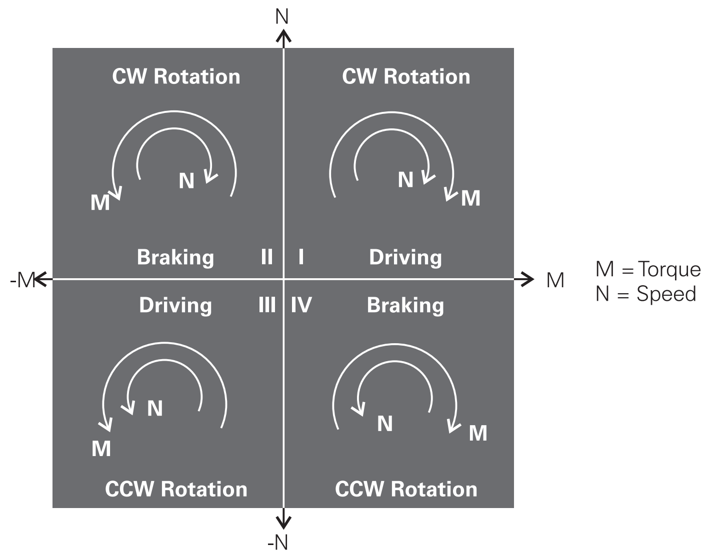
Armature current ($I_a$) reverses direction as the motor now acts like a generator. A reversal in armature current ($I_a$) results in a reversal of torque applied to the motor. Torque, now applied in the opposite direction, acts as a brake to the motor. Stored energy in the rotating motor is applied across the resistor and converted to heat. The resistor is sized to allow 150% current flow initially. Armature voltage decreases as the motor slows down, producing less current through the resistors. The motor is finally stopped due to frictional torque of the connected load.



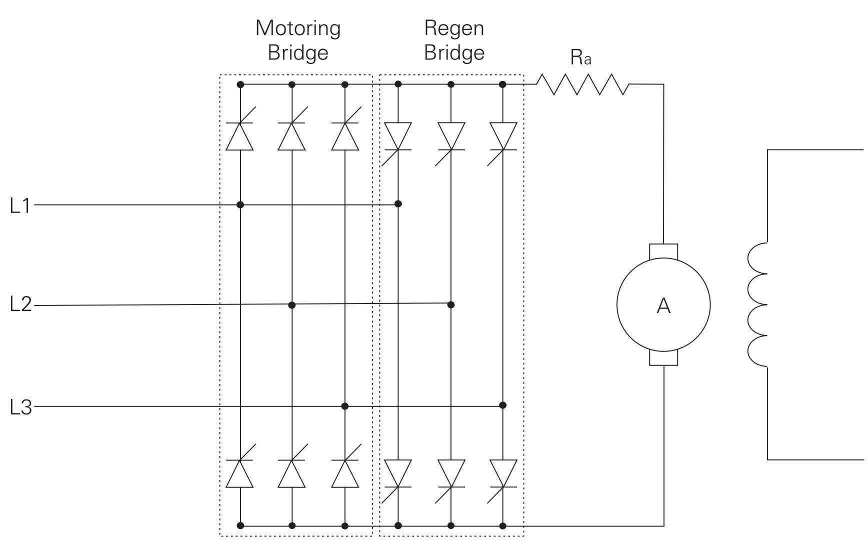
## Four-Quadrant Operation

The dynamics of certain loads require four-quadrant operation. If motor voltage is suddenly reduced, negative torque is developed in the motor due to the inertia of the connected load. The motor acts like a generator by converting mechanical power from the shaft into electrical power which is returned to the drive. This is similar to driving a car downhill. The car's engine will act as a brake. Braking occurs in quadrants II and IV.



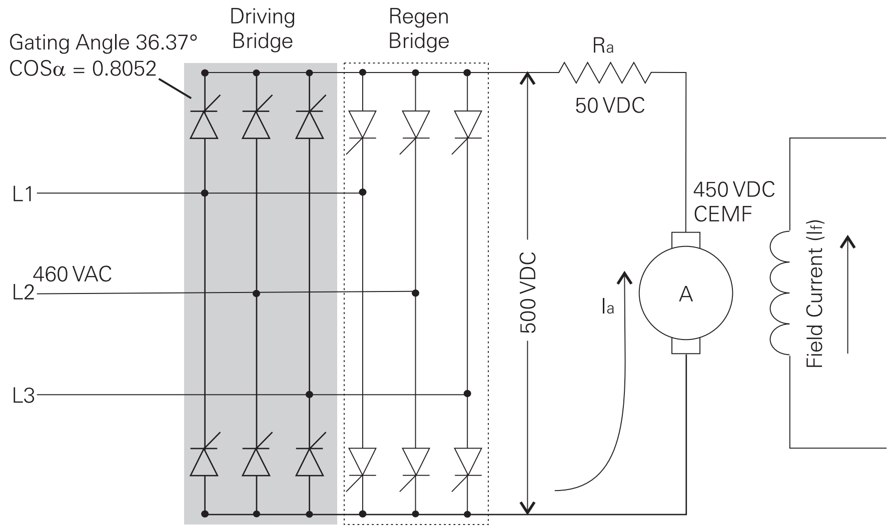

## Regen

In order for a drive to operate in all four quadrants a means must exist to deal with the electrical energy returned by the motor. Electrical energy returned by the motor tends to drive the DC voltage up, resulting in excess voltage that can cause damage. One method of getting four-quadrant operation from a DC drive is to add a second bridge connected in reverse of the main bridge. The main bridge drives the motor. The second bridge returns excess energy from the motor to the AC line. This process is commonly referred to as regen. This configuration is also referred to as a 4-Quad design.



**Motoring**

The motor receives power from the incoming line. In this example the motor is operating at full speed (500 VDC).

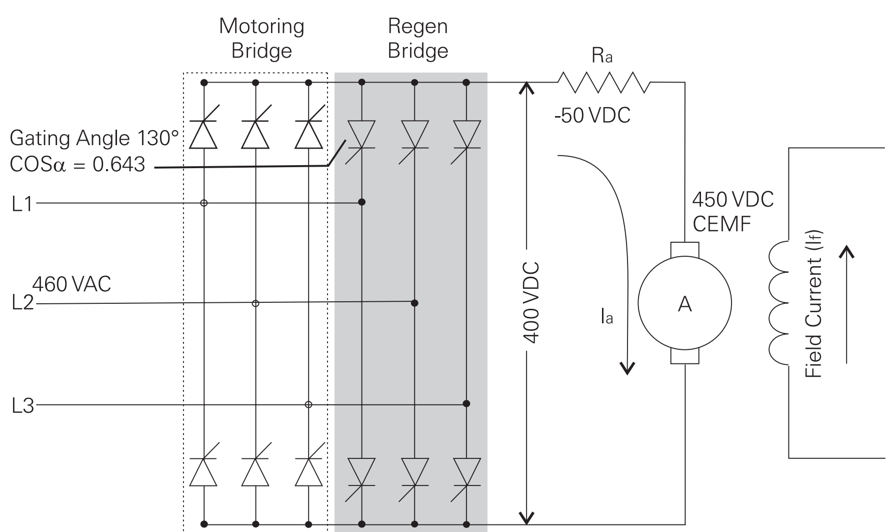



$V_a = 1.35 \times VRMS \times COS\alpha$
$V_a = 1.35 \times 460\ VAC \times 0.8052$
$V_a = 500\ VDC$

$V_a = I_aR_a + CEMF$
$V_a = 50 + 450$
$V_a = 500\ VDC$

**100% Speed, -100% Load**

When the motor is required to stop quickly, the motoring bridge shuts off and the regen bridge turns on. Due to the initial inertia of the connected load the motor acts like a generator, converting mechanical power at the shaft into electrical power which is returned to the AC line. The $I_aR_a$ voltage drop (-50 VDC) is of opposite polarity then when the drive was supplying motoring power. The control logic is gating thyristors in the regen bridge at an angle of 130° and the resultant DC voltage on the bridge is 400 VDC, in the opposite polarity. Because the regen bridge is of opposite polarity, the voltage applied to the motor acts like an electrical brake for the connected load.



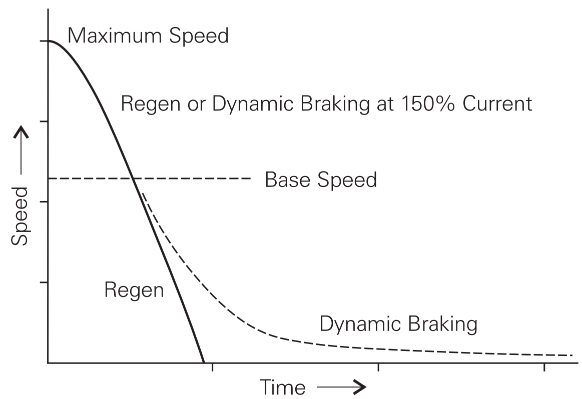

$V_a = 1.35 \times VRMS \times COS\alpha$
$V_a = 1.35 \times 460\ VAC \times 0.643$
$V_a = 400\ VDC$

$V_a = I_aR_a + CEMF$
$V_a = -50 + 450$
$V_a = 400\ VDC$

## Regen vs. Dynamic Braking

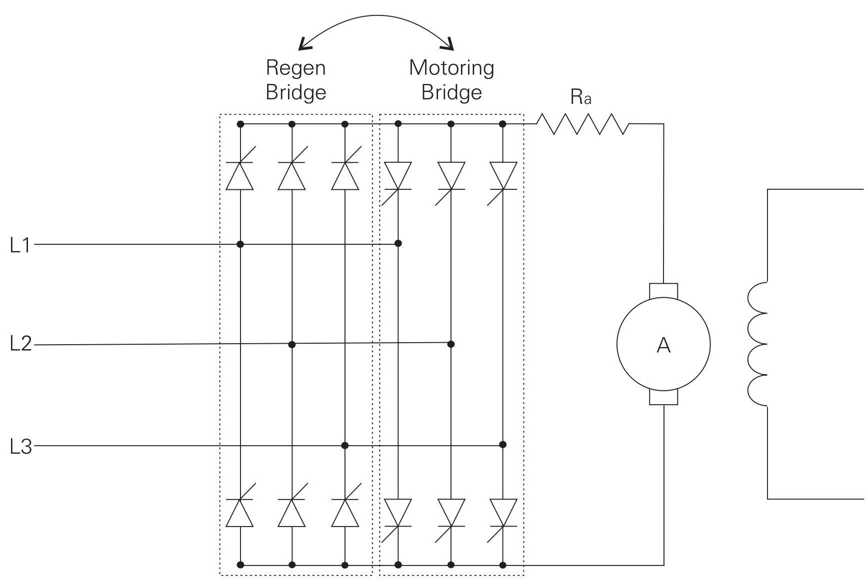
Regen and dynamic braking provide the same amount of braking power to slow a motor from maximum speed in field weakening to base speed. This is because field strength increases until the motor reaches base speed. However, from base speed to stop, regen is capable of slowing a motor at a faster rate. In addition, regen can develop torque at zero speed to bring the motor to a complete stop.

Another advantage of regen is that regen braking is not limited in duty cycle and cool-down periods. Applications that require frequent braking or have overhauling loads should consider four quadrant operation with regen braking.




## Reversing

A four-quadrant drive can easily reverse the direction of rotation of a DC motor simply by applying armature voltage in the opposite polarity. This is accomplished by using what was the regen bridge to motor. The bridge that was used to drive the motor in the forward direction becomes the regen bridge.



## Review 5

1. When torque is developed in the forward direction and the armature is turning in the forward direction, the motor is operating in quadrant ____________ .

2. When the armature is turning in the forward direction but torque is developed in the reverse direction, the motor is operating in quadrant ____________ .

3. The direction of rotation of a DC motor, operated from a 6-pulse converter, can be reversed by reversing the polarity of the DC voltage applied to the ____________ field.

4. ____________ ____________ is a method used to stop a motor quickly by applying a resistor to the armature.

5. Which of the following is an advantage of a 4-quad converter?

   a. Instead of being dissipated in heat, excess energy is returned to the supply line.
   b. From base speed to zero speed a 4-quad converter will stop a motor faster than a 1-quad converter.
   c. A 4-quad converter can reverse motor direction by simply applying voltage in the opposite polarity across the armature.
   d. all of the above.

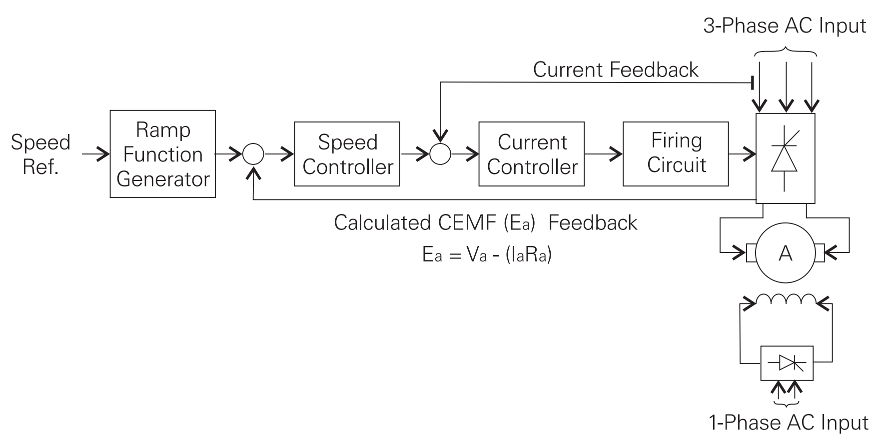
Up to this point we have looked at the power components of a DC Drive necessary to control the speed of a DC motor. The actual control of these components is accomplished with electronic hardware and technology software.

## Speed Control with CEMF Feedback

Speed control is one mode of operation. The drive will attempt to maintain a constant speed regardless of the load's torque. A speed reference is input into a ramp function generator which applies reference voltage to the speed controller over a specified period of time. This allows a smoother acceleration of the motor and connected load. The output of the speed controller is routed to the firing circuit, which controls the amount of voltage applied to the armature.

You will recall that $V_a$ (applied voltage) = $I_aR_a$ + CEMF. $I_aR_a$ is proportional to load and is generally 10% of nameplate armature voltage at 100% load. Therefore, as load torque/current varies between 0 and 100%, $I_aR_a$ varies from 0 to 50 VDC for a 500 VDC armature.

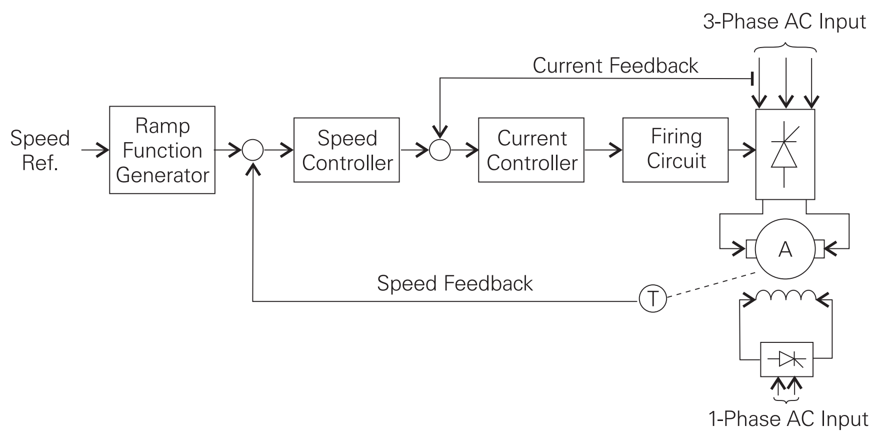
$V_a$ and $I_a$ are constantly monitored. $R_a$ is measured during the comissioning and tuning of the drive. Because $V_a$, $I_a$, and $R_a$ are known values, CEMF ($E_a$) can be precisely calculated. CEMF is proportional to speed and the speed controller uses this value to calculate actual speed. Speed control with CEMF feedback can only be used on applications where the motor operates between zero and base speed. CEMF feedback provides approximately 2-5% speed regulation.



## Speed Control with Tach Feedback

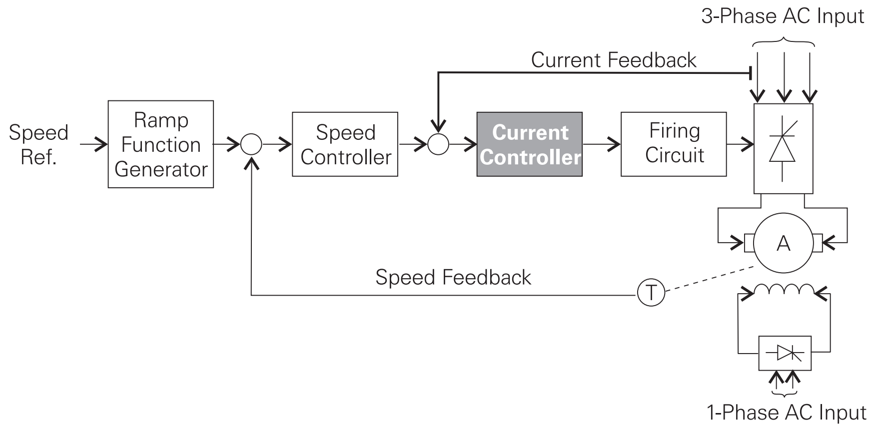
A tachometer can be used when a more accurate measurement of speed is needed, or when the motor will be operated above base speed. A measurement of actual speed is returned to the speed controller. The speed controller will make armature voltage adjustments to maintain constant speed with variations in load. If, for example, load is suddenly increased the motor will slow, reducing speed feedback. The speed controller will output a higher signal to the current controller, which will increase the firing angle of the firing circuit. The resulting increased armature voltage applies more torque to the motor to offset the increased load. Motor speed will increase until it is equal with the speed reference setpoint.

When the motor is rotating faster than desired speed armature voltage is reduced. In a four-quad drive DC armature voltage could momentarily be reversed to slow the motor at a faster rate to the desired speed. Several tachs can be used with the SIMOREG 6RA70. DC tachs provide approximately 0.10 to 2% speed regulation. Digital (pulse) tachs provide at least 0.01% speed regulation. These values vary depending on the tach and the operating conditions.



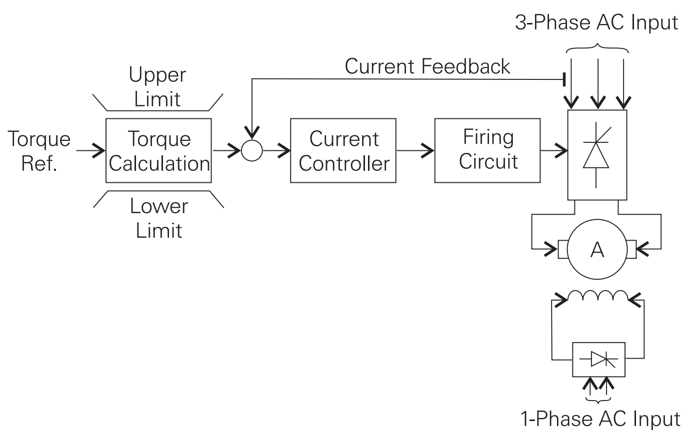
## Current Measurement

The drive monitors current, which is summed with the speed control signal at the current controller. The drive acts to maintain current at or below rated current by reducing armature voltage if necessary. This results in a corresponding reduction in speed until the cause of the overcurrent is removed.



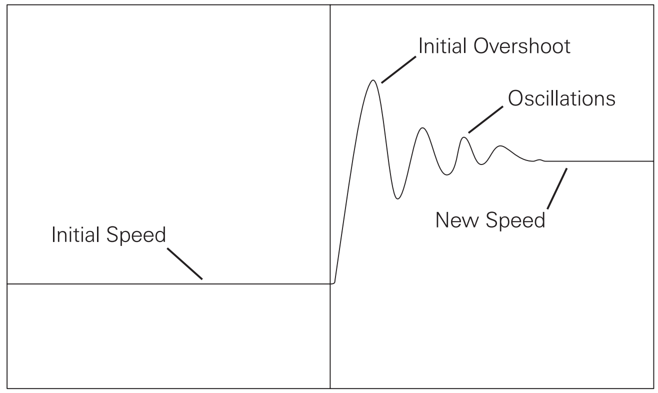

## Torque Control

Some applications require the motor to operate with a specific torque regardless of speed. The outer loop (speed feedback) is removed and a torque reference is input. The current controller is effectively a torque controller because torque is directly proportional to current.

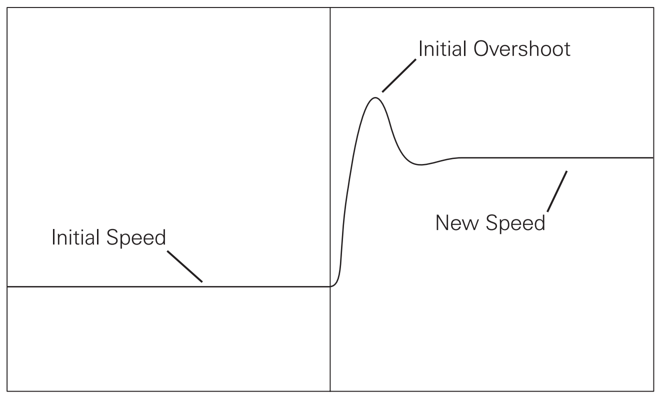



## Tuning the Drive

A feature of the SIMOREG 6RA70 DC MASTER is the ability to self tune for a given motor and associated load. An improperly tuned control may result in an excessive speed overshoot when changing from one speed to another. Oscillations can occur which contribute to system instability.




A properly tuned drive will have an initial overshoot of approximately 43% and settle into a new speed quickly. This provides a stable system with quick response.



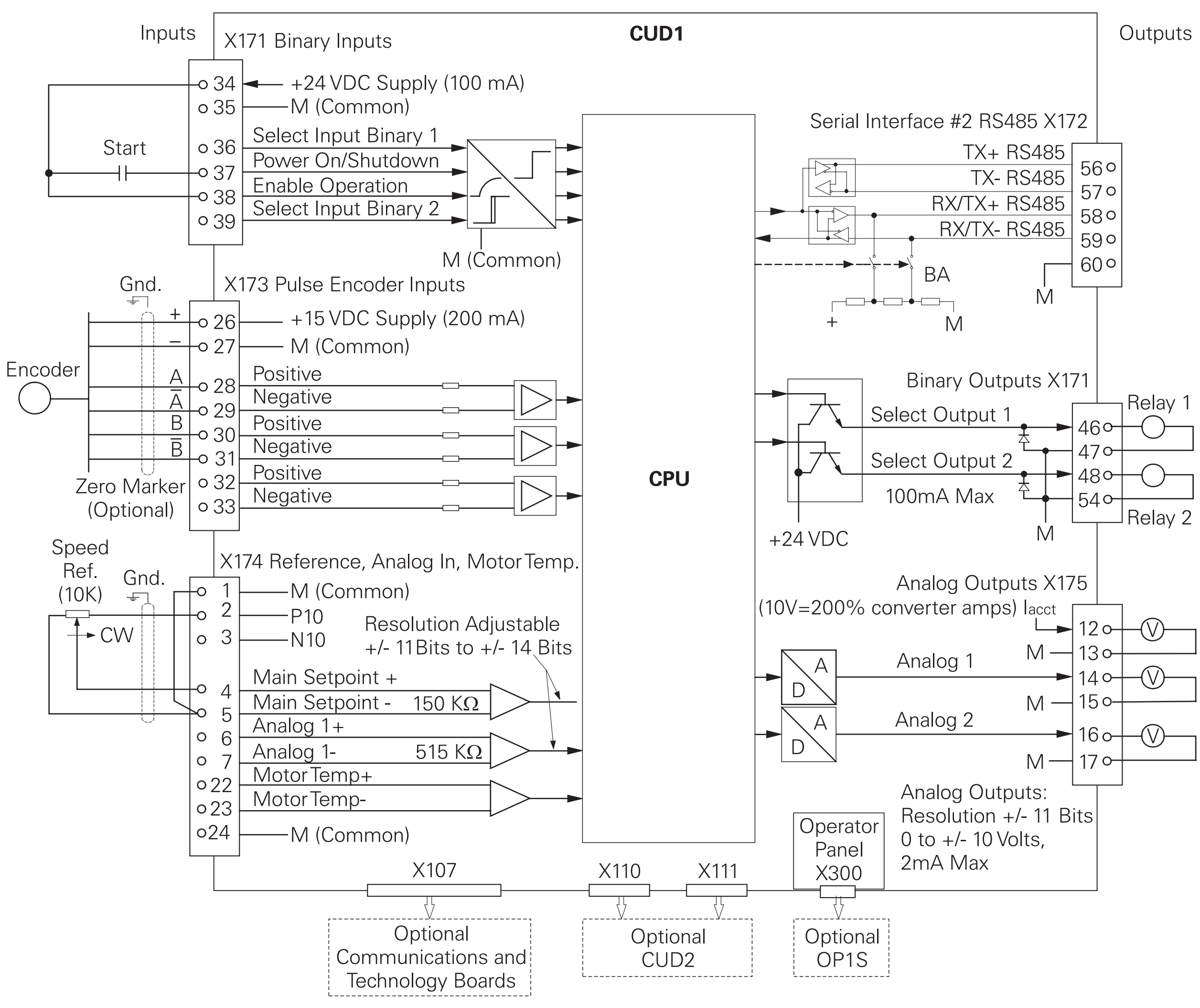

The SIMOREG 6RA70 DC MASTER has five auto tune routines to match the performance of the drive to the controlled motor and associated load.

- Pre-control and current controller for armature and field
- Speed controller for mechanics of the system
- Field weakening
- Friction, windage, and inertia compensation for high intertia loads
- Optimization for drives with oscillating mechanical components

## CUD1 Board

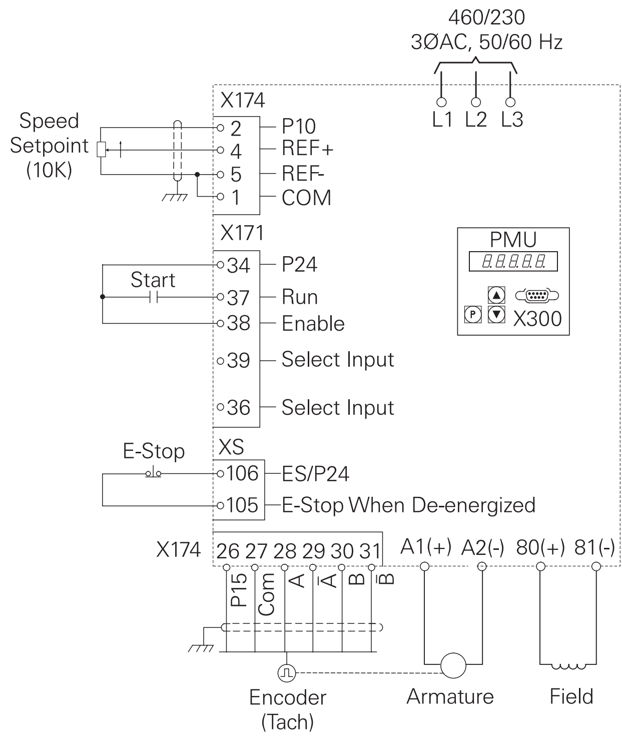
The CUD1 board is the main control board for the SIMOREG 6RA70. This board contains the necessary software and hardware interfaces for operating the drive in speed or torque control. It has input and output connections for wiring the control devices of various functions such as start/stop pushbuttons and speed potentiometer. The CUD1 board has comprehensive diagnostics for troubleshooting. CUD1 also contains the necessary software for self-tuning.

Programmable binary outputs, used to indicate the condition of the drive, are available on X171. Binary inputs are also available to start and stop the drive on X171. In addition, there are two programmable binary inputs for such functions as reverse and jog. The 6RA70 accepts analog inputs for speed control on X174. Programmable analog outputs on X175 provide meter indication of various drive parameters such as current and voltage. A motor temperature switch can be connected to X174 and is used to stop the drive if the motor becomes overheated. Connections are also available on X173 for a digital tach.

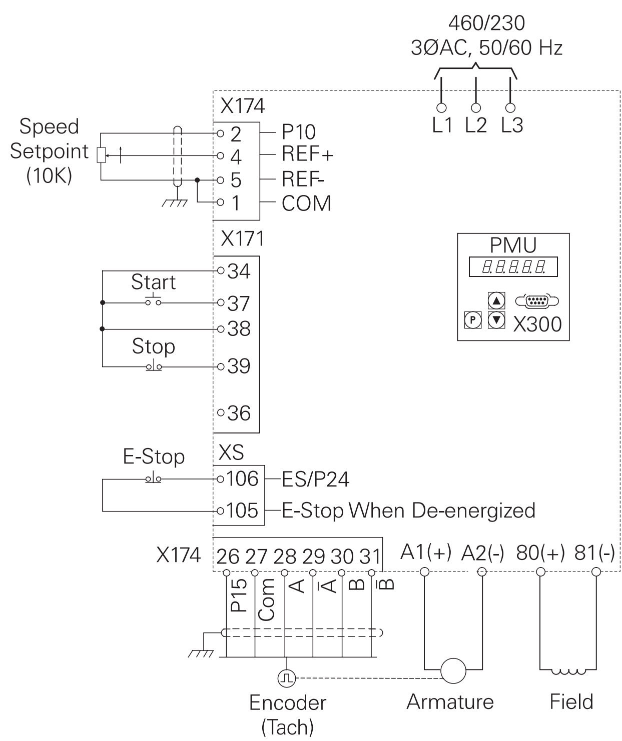


## Typical Connections

The following diagram shows a typical connection used to operate the drive. A normally open (NO) contact is used to start and stop the drive.



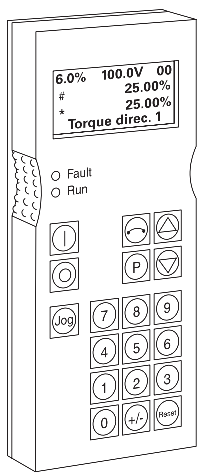

Alternately, pushbuttons can be used to start and stop the drive.



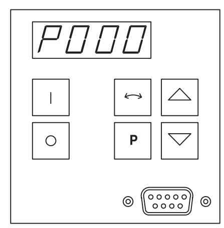
## Programming and Operating Sources

SIMOREG 6RA70 drives can be programmed and operated from various sources, such as the PMU, OP1S, or other SIMATIC® HMI device such as the TP170A, TP170B, OP27, or MP370. In addition to these, various methods of serial communication is available through RS232 or RS485 connections. These will be discussed later in this section with the option boards.

The PMU can be used alone or with the OP1S. The OP1S can be mounted directly on the PMU or up to 200 meters away with an external power supply. Parameters, such as ramp times, minimum and maximum speed, and modes of operation are easily set. The changeover key (“P”) toggles the display between a parameter number and the value of the parameter. The up and down pushbuttons scroll through parameters and are used to select a parameter value, once the “P” key sets the parameter. The OP1S has a numbered key pad for direct entry.



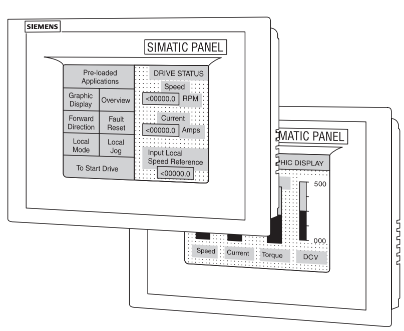

OP1S




PMU

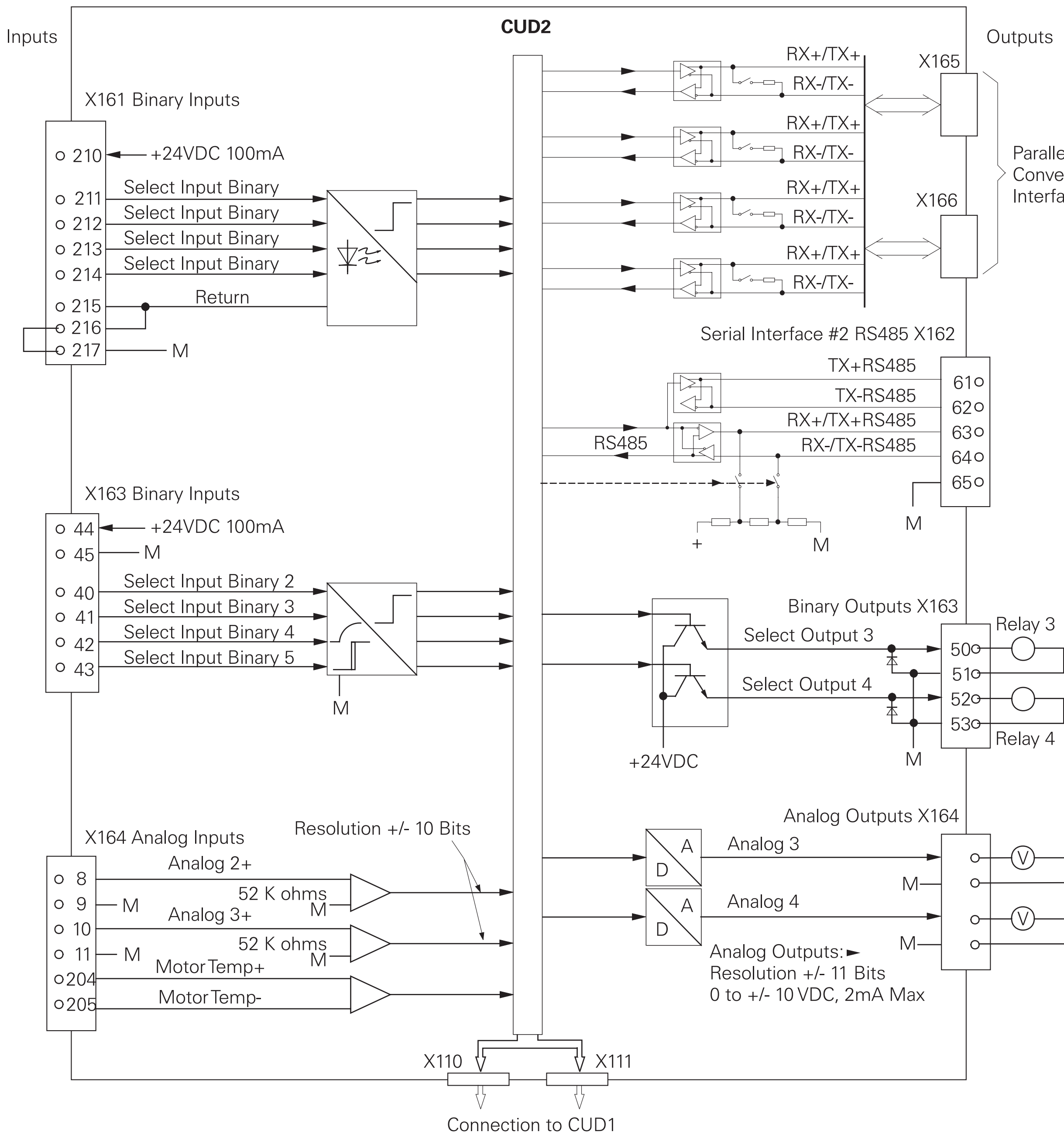
## SIMATIC HMI Devices

Another, more robust option, is a SIMATIC HMI device such as the TP170A. The TP170A uses a touch-sensitive screen for control and monitoring. It is powered from the drive and standard PROFIBUS connections.



## CUD2 Expansion Board

The CUD2 is typically selected when additional inputs and outputs (I/O) are required. CUD2 I/O is selectable. An advantage to the CUD2 expansion board is that it mounts directly on the CUD1 and requires no additional hardware. The CUD2 provides four optically isolated binary inputs, four selectable binary inputs to ground, two analog inputs, one analog input for motor temperature evaluation, two binary outputs, and one serial interface. In addition to the expanded I/O, the CUD2 provides a parallel interface for paralleling up to six power modules.



## EB1 and EB2 Expansion Boards

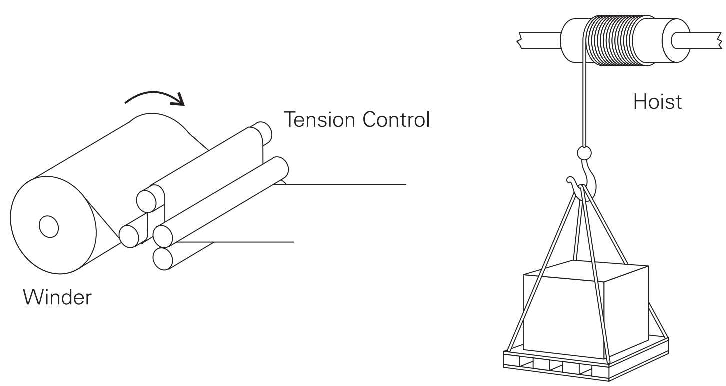
EB1 and EB2 are half-sized expansion boards that provide a number of additional I/O possibilities. EB1 has three binary inputs and four bidirectional binary I/O. Bidirectional I/O can be configured as a binary input or output. One of the analog inputs is used as a voltage or current reference input. Two of the analog inputs can also be configured as binary inputs.

EB2 has two binary inputs, one analog input, one analog output, and four relay contacts. Three of the contacts are normally open (NO) and one of the contacts can be configured as normally open (NO) or normally closed (NC).

| I/O | CUD2 | EB1 | EB2 |
|---|---|---|---|
| Isolated Binary Inputs | 4 | 0 | 0 |
| Binary Inputs | 4 | 3 | 2 |
| Bidirectional Binary I/O | 0 | 4 | 0 |
| Analog Inputs | 2 | 3 | 1 |
| Analog Outputs | 2 | 2 | 1 |
| Relay (Binary) Outputs | 2 | 0 | 4 |
| Serial Interface | 1 | 0 | 0 |
| Parallel Converter Interface | 1 | 0 | 0 |

## T400 Technology Board

The T400 is an option board that is used to provide specialized features for applications, such as winders, tension control, position control, and hoisting gear. In addition to applying built-in technology functions, users familiar with the Siemens PLC software SIMATIC STEP-7 can also implement their own process functions.



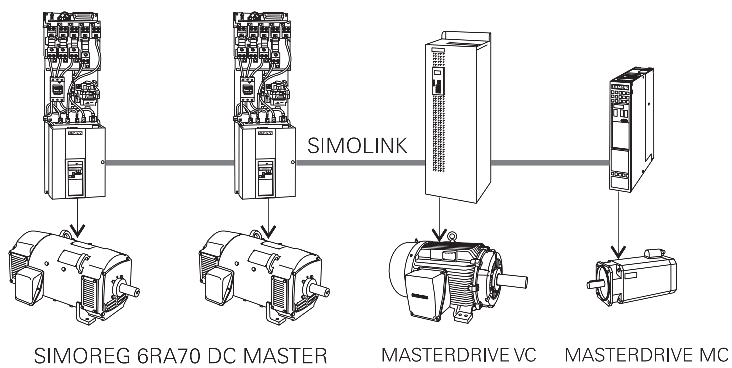

To implement the various control functions required by specific applications the T400 has two analog outputs, five analog inputs, two binary outputs, eight binary inputs, four bidirectional binary inputs/outputs, two incremental encoder inputs, and two serial interfaces.

**Communications**

One of the strong points of the SIMOREG 6RA70 is its serial interface capabilities, which makes it easy to integrate the drive with other automation components. Communication options are available for PROFIBUS-DP, SIMOLINK®, CAN, and DeviceNet communications.

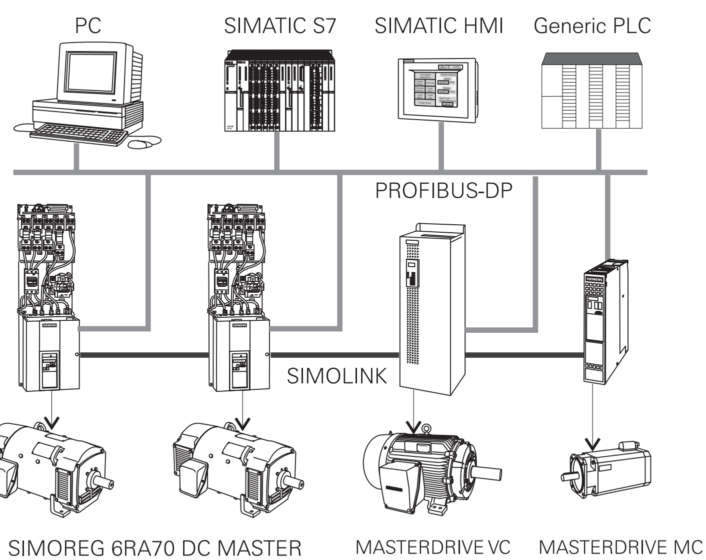
**SLB**

The SLB communication board is used for peer-to-peer communication with other Siemens drives via SIMOLINK. SIMOLINK is a high speed fiber optic ring bus that allows various data to be passed from one drive to the next. Communication is not limited to the SIMOREG 6RA70. SIMOLINK can also communicate between Siemens AC drives such as the MASTERDRIVE MC and MASTERDRIVE VC.




**CBP2**

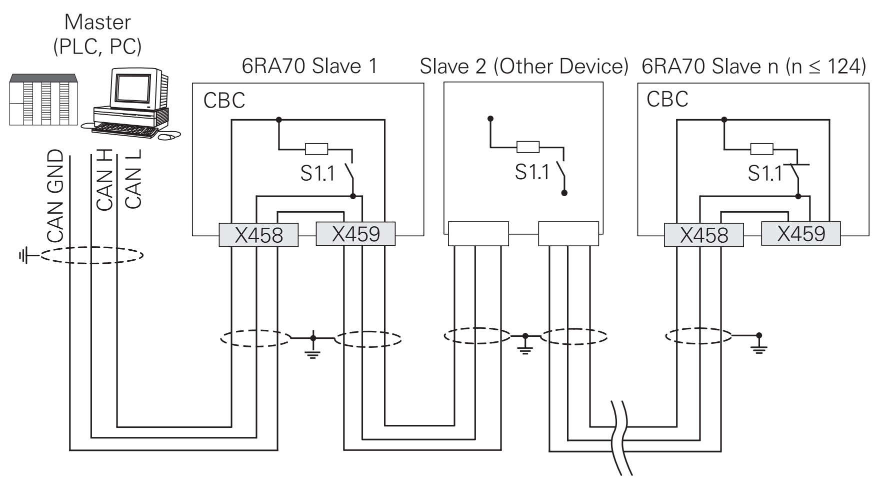
PROFIBUS-DP is an open bus standard for a wide range of applications in various manufacturing and automation applications. Siemens DC drives can easily communicate with other control devices such as programmable logic controllers (PLCs) and personal computers (PCs) through the PROFIBUS-DP communication system and other various protocols. The CBP2 board is required to communicate via PROFIBUS-DP.



**CBC**

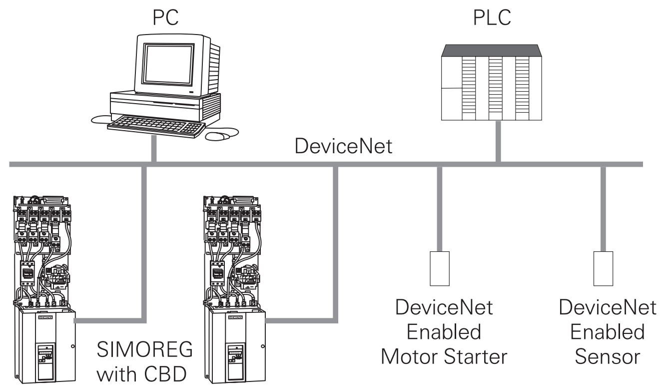
ISO is a federation of standards organizations from over 100 countries that develops voluntary standards for business, science, and technology. The official name is Organization Internationale de Normalisation, also known in the United States as the International Organization for Standardization.

The CBC communication board is used to communicate with CAN protocol, which is an ISO standard (ISO 11898) for serial data communications. CAN protocol was initially developed in 1986 for the automotive industry. Today communication with CAN protocol can also be found in other industrial automation applications. One device, such as a PLC or computer, acts as a master. SIMOREG drives equipped with CBC boards and other controllable devices configured for CAN act as slaves. CAN uses a simple twisted pair of wires for transmission of control and parameter value data between SIMOREG drives with CBC boards.



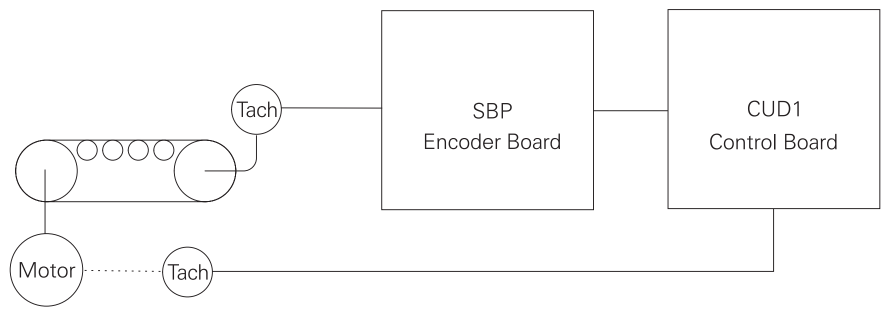

**CBD**

The CBD communication board is used to communicate with DeviceNet. DeviceNet is another communication protocol that was developed based on the CAN technology. DeviceNet provides a low-level network for DeviceNet enabled devices such as sensors, motor starters, and drives to communicate with higher-level devices such as computers and PLCs. DeviceNet can read the state of devices, such as on/off, as well as start and stop motors (motor starters). SIMOREG 6RA70 DC MASTERs equipped with a CBD board can be added to a DeviceNet network. A DeviceNet enabled master device can control the operation, such as start, stop, accel, and decel.




**SBP**

Digital tachometers (encoders) can be used to measure the actual speed of a motor. The SBP encoder board can be also be used to monitor an external encoder, such as might be connected to the driven machine.

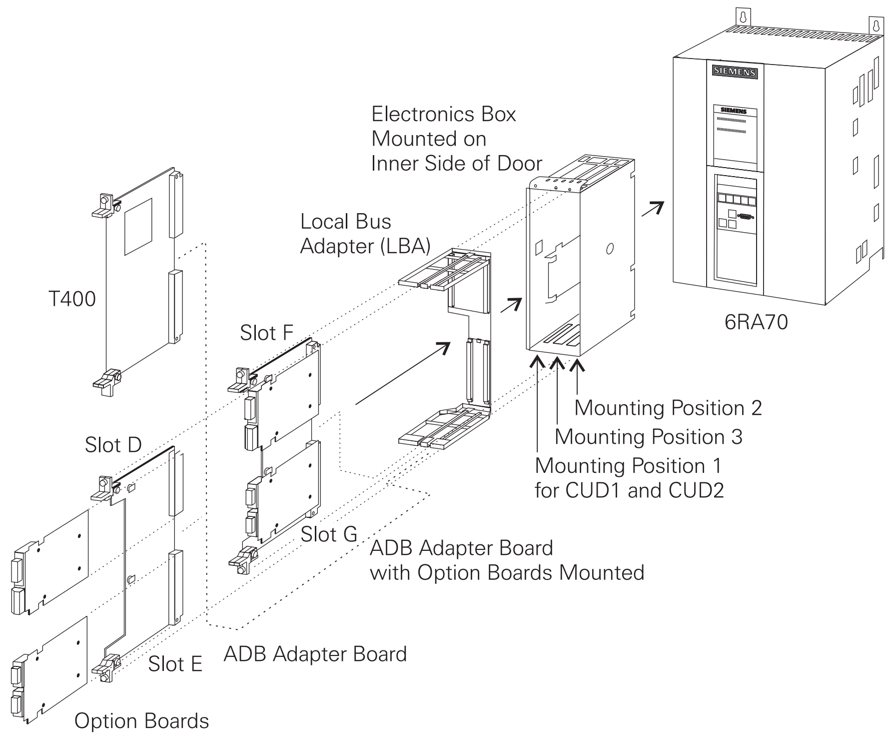



**Electronics Box**

The electronics box contains the CUD1 board (main control board) and option boards. The CUD1 board is plugged into slot 1.

## Mounting Option Boards

There are several option boards available, which will be discussed later in this section. Option boards are automatically recognized by the drive. Up to six boards can be installed in the electronics box. A Local Bus Adapter (LBA) is required if mounting positions 2 or 3 are needed. In addition, adapter boards (ADB) are necessary for slots D, E, F, and G when utilizing the half-size option boards.




There are a few rules that must be followed when mounting option boards:

- Option boards may be plugged into positions 2 or 3, however, position 2 must be filled first.
- When used, a technology board (T400) is always installed in position 2.
- If a communication board (CBP2, CBC. or CBD) is used with a technology board the communication board is placed in slot G.
- It is unnecessary and not possible to use expansion boards EB1 and EB2 in conjunction with the technology board T400. T400 has its own expanded inputs and outputs (I/O).

- It is unnecessary and not possible to use the pulse encoder board (SBP) or the SIMOLINK communication board (SLB) in conjunction with T400. T400 has provision to connect an encoder.

- A maximum of two supplementary boards of the same type may be used in one drive. For example, no more than two communication boards or two expansion boards can be used.

The following chart shows the mounting positions for CUD1 and option boards.

| Board | LBA | ADB | Location 1 | Location 2 | | Location 3 | |
|---|---|---|---|---|---|---|---|
| | | | | D | E | F | G |
| CUD1 | No | No | Yes | No | No | No | No |
| CUD2 | No | No | Yes | No | No | No | No |
| CBP2 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| CBC | Yes | Yes | No | Yes | Yes | Yes | Yes |
| CBD | Yes | Yes | No | Yes | Yes | Yes | Yes |
| SLB | Yes | Yes | No | Yes | Yes | Yes | Yes |
| SBP | Yes | Yes | No | Yes | Yes | Yes | Yes |
| T400 | Yes | No | No | Yes | | No | |
| EB1 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| EB2 | Yes | Yes | No | Yes | Yes | Yes | Yes |

## Review 6

1. __________ is the designation of the main electronic control board in the SIMOREG 6RA70 DC MASTER.

2. A _________ _________ _________ is required when mounting option boards in the electronics box.

3. Position ________ must be filled first when installing option boards.

4. ______ tuning tunes a drive to the motor characteristics.

5. Technology board T400 can be installed in location _______.

6. The CUD2 expansion board mounts directly on _______ and requires no additional hardware.

7. __________ expansion board has the most bidirectional binary I/O.

   a. CUD2 b. EB1 c. EB2

8. _________ is used to communicate with PROFIBUS-DP.

9. __________ is used to communicate with other Siemens drives via SIMOLINK.

10. A second digital tachometer is connected to the drive through an __________ board when T400 is not used.

# Parameters and Function Blocks

The SIMOREG 6RA70 DC MASTER features an extensive parameter set that can easily be adapted to almost any drive task, from simple to complex. A wide scope of parameters include:

- Acceleration/Deceleration Control
- Automatic Restart Function
- Field Reversal
- Various Arithmetic and Boolean Logic Operations
- Technology Controllers
- Velocity/Speed and Diameter Calculators

In addition, the SIMOREG 6RA70 DC MASTER has extensive status indicators and display parameters for monitoring. The SIMOREG 6RA70 DC MASTER also supports a large database of faults and alarms. This provides the operator with a clear indication of what may be needed to correct the problem.

There are numerous parameters within the SIMOREG 6RA70 DC MASTER. It is beyond the scope of this course to cover these in any detail. However, it is important to understand how parameters and function blocks work together.

**Parameters**

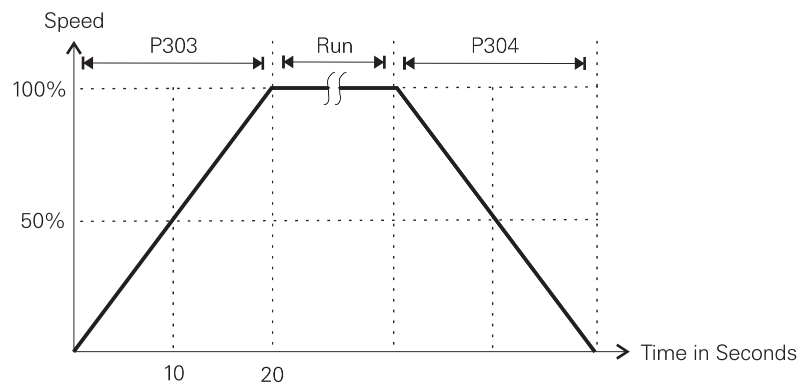
Parameter values are used to provide settings to the drive. In the Siemens SIMOREG 6RA70 DC MASTER each parameter is clearly designated by an assigned number. Parameters are differentiated according to their function:

- Function Parameters (can be read and written)
- Visualization Parameters (can only be read)

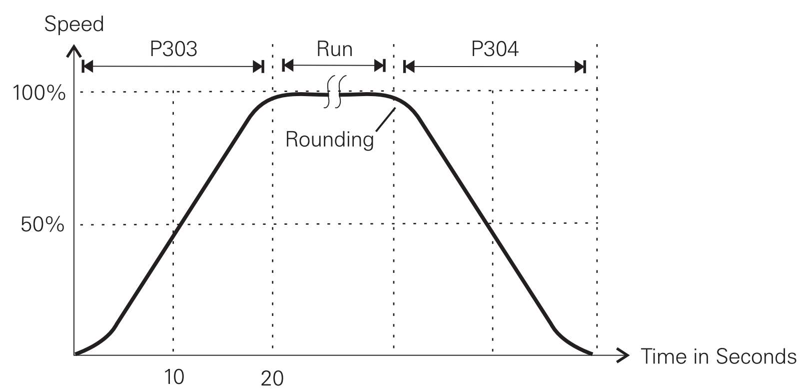
**Function Parameters**

Acceleration or deceleration times are examples of function parameters. A feature of DC drives is the ability to increase or decrease the armature voltage gradually. This accelerates and decelerates the motor smoothly with less stress on the motor and connected load.

Parameters P303 and P304 work together to instruct the SIMOREG 6RA70 DC MASTER how much acceleration/ deceleration time is needed from 0 to 100% speed. P303 and P304 can be set to any value between 0.0 to 650 seconds. If P303 were set to 20.00, for example, the drive would take 20 seconds to accelerate the motor from 0 to 100% speed. Acceleration and deceleration time is linear which means the time speed curve can be accurately tracked. The motor would be at 25% speed after 5 seconds and 50% speed after 10 seconds.

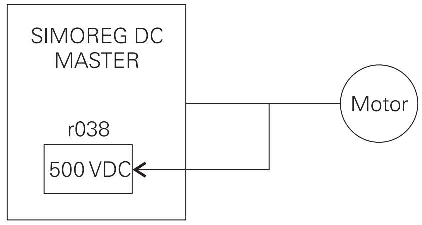



Rounding is a feature that can be added to the acceleration/ deceleration curve. This feature smooths the transition between starting and finishing a ramp.



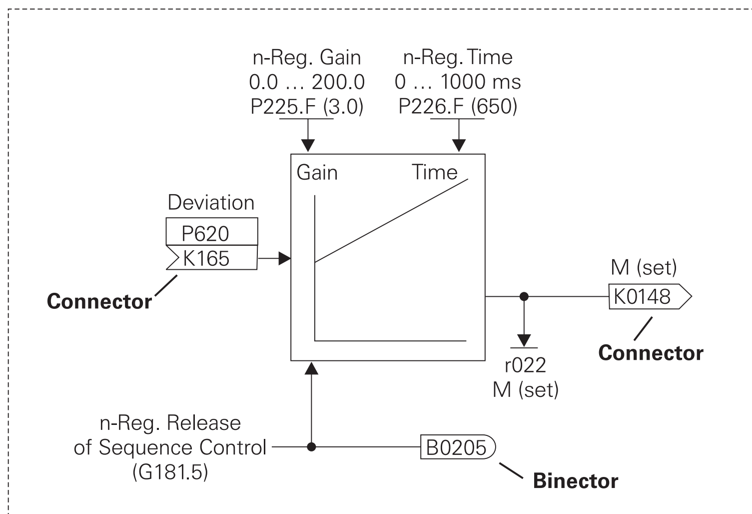
## Visualization Parameters

Visualization parameters are used for visualizing internal quantities. These parameters are only displayed and cannot be changed by the operator. Visualization parameters are distinguished by a lower case "r." Parameter r038, for example, displays the value of voltage output to the motor.



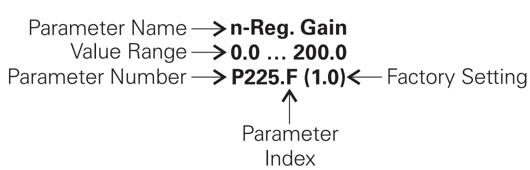

## Function Blocks

A function block consists of several parameters grouped together to perform a specific task. The following function block represents one example of how a proportional/integral (PI) controller can be used in speed control of a SIMOREG 6RA70 DC MASTER.




## Function Parameters

The response of a function block is determined by function parameters. Proportional gain and integral time, for example, determine the response of a PI-controller. Each parameter has a name, identifying number, value range, and a factory setting. Function parameters can be indexed.



## Function and Bico Data Sets

In many applications it may be desirable to configure the SIMOREG 6RA70 DC MASTER for variations in operation. For example, there may be a situation in an application where it is desirable to have different acceleration times. Indexed parameters can have up to four different values stored with them. Each value stored is part of a data set. Parameter P303, acceleration time, is an example of an indexed parameter. P303 can have four different acceleration times stored. P303 could, for example, have the following values:

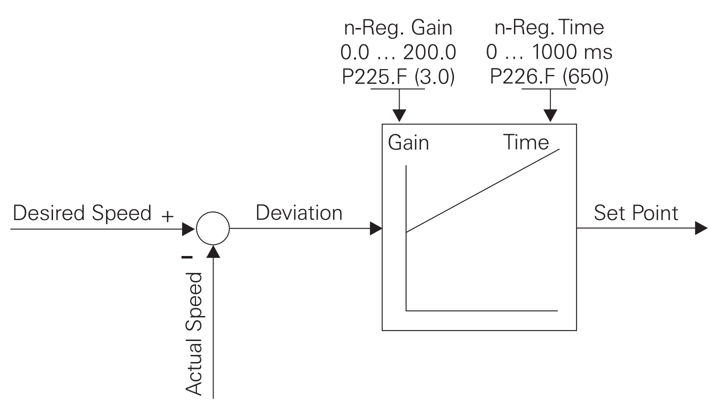
P303.1 = 0.50
P303.2 = 1.00
P303.3 = 3.00
P303.4 = 8.00

If data set 1 is active, the acceleration time is 0.50 seconds. If data set 2 is active, the acceleration time is 1.00 second. Data sets are operator selected and can be changed at any time.

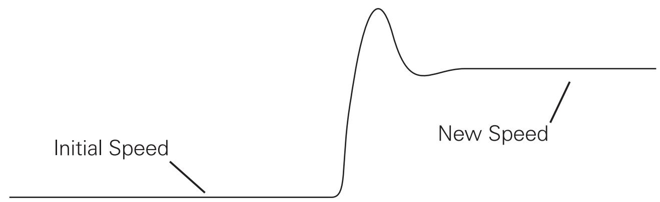
## PI-Controller

PI-controllers are commonly used in drive technology. In our example the desired speed and actual speed are input to a summation point. The two signals are opposite in polarity. When the actual speed is equal to the desired speed the deviation, which is input into the PI-controller, is zero (0). Whenever desired speed and actual speed are different there is a deviation.

Changes in load on the motor, for example, can affect motor speed. A sudden increase in load would cause the motor to slow down. This would decrease the feedback from actual speed and the deviation would become more positive. It is also possible that the application may require the motor to slow down or speed up. Until the motor reaches the new desired speed there will be a deviation.

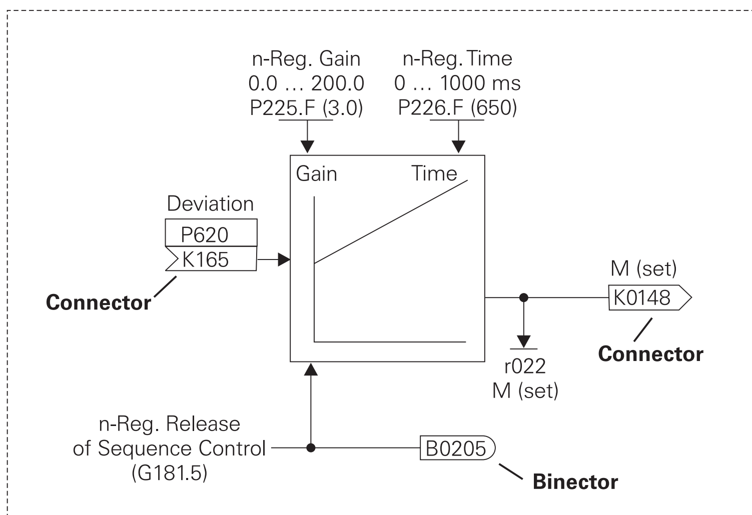


The PI-controller’s job is to make speed corrections quickly a minimal amount of overshoot and oscillation. Parameter P225 (gain) and parameter P226 (time) are used to tune the PI-controller’s performance. The end result should be a fast response time with about a 43% initial overshoot. The motor should then settle in to the new desired speed.




## Connectors and Binectors

Connectors and binectors are elements used to exchange signals between function blocks. Connectors are used to store analog values. Analog values are stored in the form that is represented by 16 bit or 32 bit words. Binectors are used to store binary (digital) information.

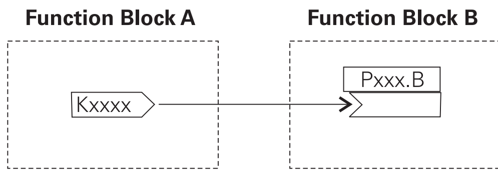



Connectors and binectors are identified by a name and number. Connectors with 16 bit resolution are identified with a “K.” Connectors with 32 bit resolution are identified with a “KK.” Binectors are identified with a “B.”

| | |
|---|---|
| **Connector Name** | M(set, n-Reg) |
| **Connector Number (16 Bit)** | K0148 |
| **Connector Name** | Actual Position Value |
| **Connector Number (32 Bit)** | KK0046 |
| **Binector Name** | Accel active |
| **Binector Number** | B0208 |

**BICO**

BICO is the term used to describe the method of connecting function blocks together. This is performed with BInectors and COnnectors. A connection between two function blocks consists of a connector or binector and a BICO parameter. With BICO parameters you can determine the sources of the input signals of a function block. This allows the user to "softwire" function blocks to meet specific application requirements.




**Engineering Tools**

There are several engineering tools available optionally. These tools aid in programming, operating, troubleshooting, and managing SIMOREG 6RA70 DC MASTER drives.

**Drive Monitor**

?????????

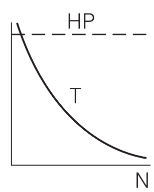
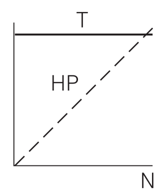
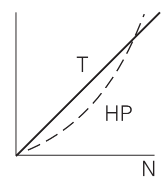
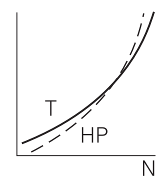
**Drive ES**

Drive ES is used to integrate Siemens drives with the SIMATIC automation world. There are three Drive ES packages available.

| Package | Description |
|---|---|
| Drive ES Basic | Structured similar to SIMOVIS allowing commissioning, parameter handling, oscilloscope readout, and fault evaluation. Based on STEP 7 for integration into SIMATIC. |
| Drive ES Graphic | Provides graphic configuring of BICO function blocks. Requires Drive ES Basic and a SIMATIC programming tool called SIMATIC CFC. |
| Drive ES SIMATIC | Provides function blocks and examples of SIMATIC projects. Requires Drive ES Basic. |

# Applications

When applying a DC drive and motor to an application it is necessary to know the horsepower, torque, and speed characteristics of the load. The following chart shows typical characteristics of various loads.

| $T \approx \frac{1}{N}$ | $T = \text{Constant}$ | $T \approx N$ | $T \approx N^2$ |
|---|---|---|---|
| $HP = \text{Constant}$ | $HP \approx N$ | $HP \approx N^2$ | $HP \approx N^3$ |
|  |  |  |  |
| Winders<br>Facing lathes<br>Rotary cutting machines | Hoisting gear<br>Belt conveyors<br>Process machines involving forming<br>Rolling mills<br>Planers | Calenders with viscous friction<br>Eddy-current brakes | Pumps<br>Fans<br>Centrifuges |

Loads generally fall into one of three categories:

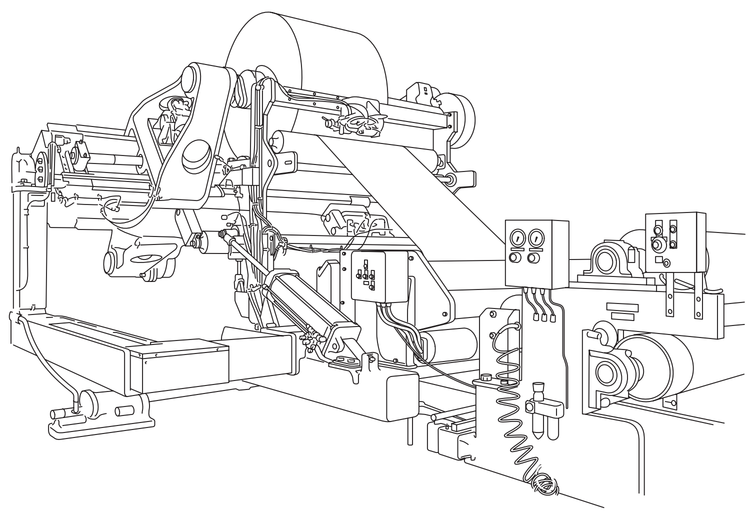
| Category | Description |
|---|---|
| Constant Torque | The load is essentially the same throughout the speed range. Hoisting gear and belt conveyors are examples. |
| Variable Torque | The load increases as speed increases. Pumps and fans are examples. |
| Constant Horsepower | The load decreases as speed increases. Winders and rotary cutting machines are examples. |

# Application Examples

The Siemens SIMOREG 6RA70 DC MASTER drives are designed to handle the most challenging applications. The following examples are just some of applications the SIMOREG can be used on.

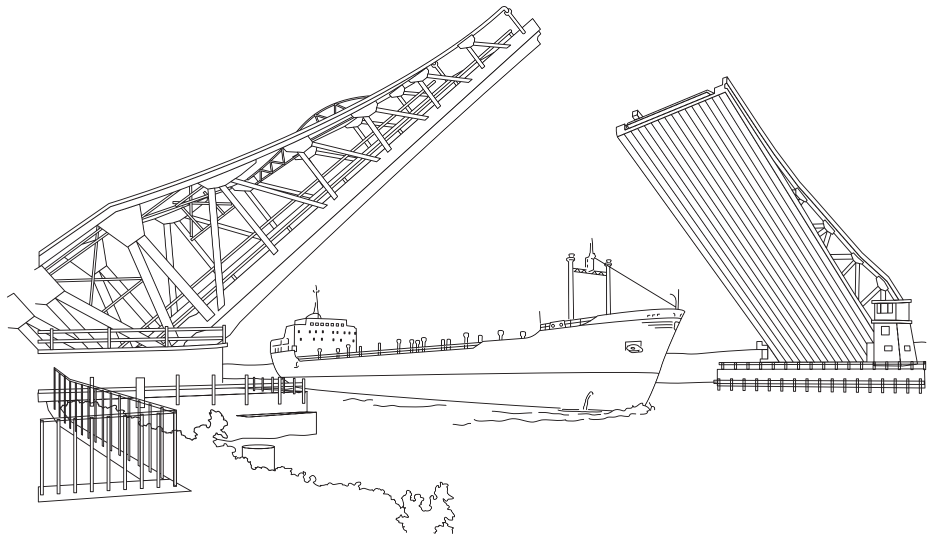
**Winders/Coilers**

DC motors offer superior characteristics at low speed for winder and coiler operation and performance. In winder applications maintaining tension at standstill is a very important operation. DC motors offer a wide speed range at rated torque. On many winder applications that run in an extended speed range a smaller horsepower DC motor could do the same job as a larger horsepower AC motor.



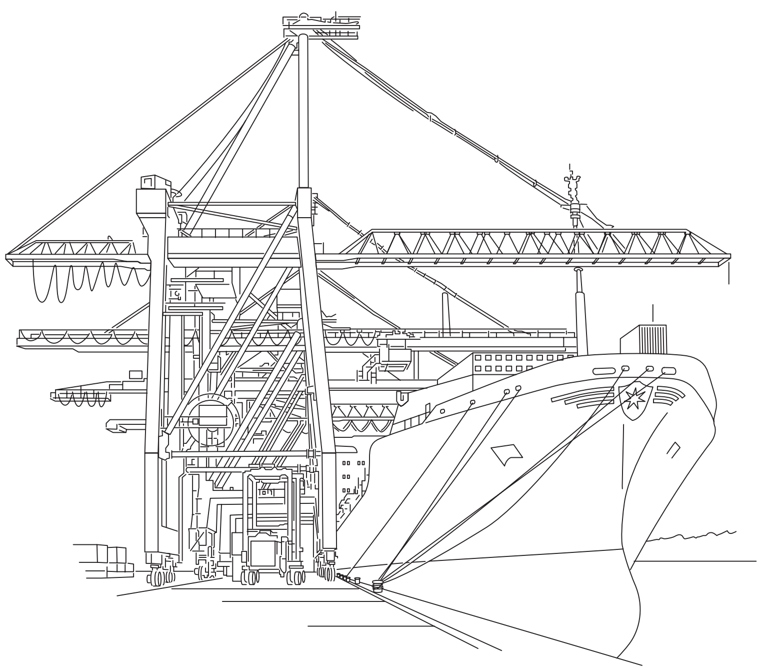
**Marine Applications**

DC drives offer several advantages in marine applications. Compact sizing is one of the biggest advantages. DC drives also adapt well from generator supplies such as found in the marine industry.



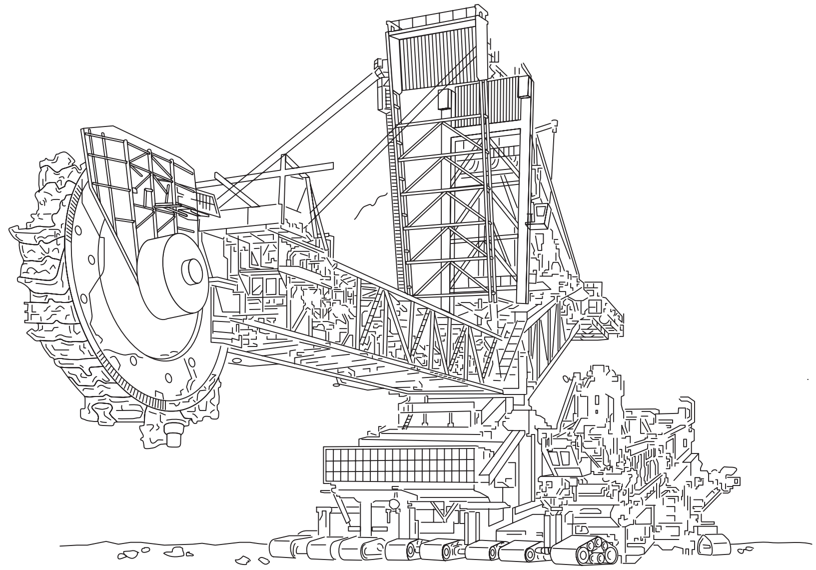
**Crane/Hoist**

DC offers several advantages in applications that operate at low speed, such as cranes and hoists. Advantages include low speed accuracy, short-time overload capability, size, torque proving control, and load sharing.



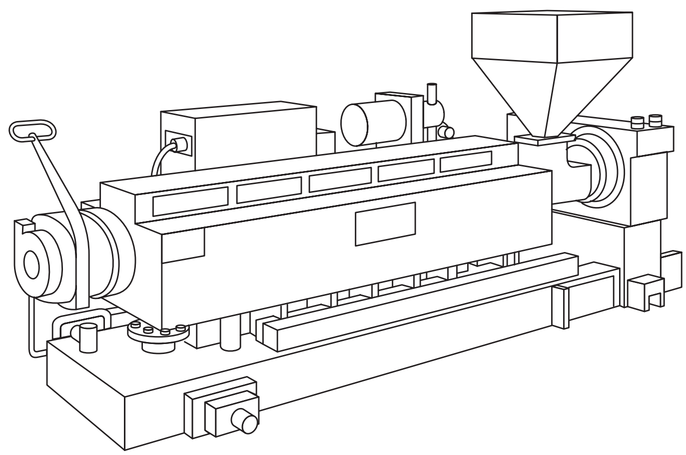
**Mining/Drilling**

DC is often preferred in the high horsepower applications required in the mining and drilling industry. DC drives offer advantages in size and cost. They are rugged, dependable, and proven in the industry.



**Extruding**

Extruding is a price competitive industry. DC offers economical solutions in the 60 to 1000 HP range which is commonly used in extruding applications.



# Selecting a Siemens DC Drive

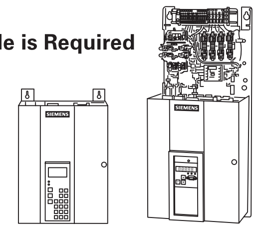
The following flow diagram, along with the selection charts, will help you select the right DC drive for your application.

**Flow Diagram for Selection Process**

**Step 1**

**Determine if Base Drive or Power Module is Required**

A base drive includes the power module along with fuses, control transformer, and contactor all mounted on a backplane for convenient panel installation with a single 3-phase source connection.



**Step 2**

**Verify Supply & Control Voltage Requirements**

Base drives require only a single 3-phase power source to supply the armature, field, control voltage, and fan. On a typical base drive application a 460 VAC 3-phase supply would control a DC motor with a 500 VDC armature and a 300 VDC field.

**Step 3**

**Determine Current Rating**

Current rating is used to determine horsepower.
U.S. current ratings offer a 150% overload for 60 seconds.

**Step 4**

**Determine if Application Requires 1 Quad or 4 Quad Converter**

4 Quad allows the converter to motor and regenerate in both directions. 1 Quad converters only allow armature current flow in the motoring direction and usually coast to decelerate. For a 1 Quad converter to change direction of a DC motor a field reversal circuit is needed.

**Step 5**

**Select Appropriate Model Number from Selection Tables**

Model numbers shown in following tables. For drives larger than 1000 HP consult your Siemens sales representative..

**Step 6**

**Determine if CUD2 Terminal Expansion Board is Needed**

CUD2 includes additional analog and binary I/O along with a paralleling and serial interface. The optional CUD2 mounts directly on CUD1.

**Step 7**

**Determine if Extended Technology Software Option (S00) is Needed**

This onboard software option opens many extended technology functions and applications. In addition to offering a technology regulator, numerous mathematical and Boolean logic function blocks are offered to handle winding and other higher level applications.

**Step 8**

**Determine if Line Reactors are Required**

Line reactors provide the recommended impedance between converter and incoming supply.

**Step 9**

**Determine if Additional System Components are Needed**

Isolation transformers, field reversing kits, starter (blower motor) kits, and dynamic braking are available for loose mounting.

**Flow Diagram for Selection Process**

**Step 10**

**Determine if Alpha-Numeric Operator Panel (OP1S) is Required**

The SIMOREG 6RA70 can be programmed from the built-in operator panel. The OP1S offers ease of commissioning, local control, and an expanded alphanumeric display.

**Step 11**

**Determine if Communication Boards are Required**

USS and peer-to-peer communication with RS485 and RS232 ports are standard. For PROFIBUS, SIMOLINK, and other communication options an appropriate communication board is required.

**Step 12**

**Determine if T400 or Other Option Board is Needed for Application**

The T400 technology board has standard application specific software packages along with the ability to add customized software. Expansion boards, such as EB1 and EB2, are also available to increase the functionality of the SIMOREG 6RA70.

**Step 13**

**If Option Board in Step 11 or 12 is Selected the Following Adapters Apply**

The Local Bus Adapter (LBA) is required if any board other than CUD1 or CUD2 is to be used in the electronics box. The LBA is sold separately and easily installs in the electronics box. The ADB adapter board is necessary if any half-sized option board such as CBP or SLB is to used in the electronics box. The ADB is sold separately.

The following tables provide catalog numbers for SIMOREG DC drives up to 1000 HP. For larger drives consult your Siemens sales representative.

## Power Module

| Horsepower | | Rated Armature (Amps DC) | Catalog Number |
|---|---|---|---|
| 240 VDC | 500 VDC | | |
| 3 | 7.5 | 15 | 6RA7018-6FS22-0Z+X01 |
| 7.5 | 15 | 30 | 6RA7025-6FS22-0Z+X01 |
| 15 | 30 | 60 | 6RA7028-6FS22-0Z+X01 |
| 25 | 60 | 100 | 6RA7031-6FS22-0Z+X01 |
| 40 | 75 | 140 | 6RA7075-6FS22-0Z+X01 |
| 60 | 125 | 210 | 6RA7078-6FS22-0Z+X01 |
| 75 | 150 | 255 | 6RA7082-6FS22-0Z+X01 |
| 125 | 250 | 430 | 6RA7085-6FS22-0Z+X01 |
| 150 | 300 | 510 | 6RA7087-6FS22-0Z+X01 |
| 250 | 500 | 850 | 6RA7091-6FS22-0Z+X01 |
| - | 700 | 1180 | 6RA7093-4GS22-0Z+X01 |
| - | 1000 | 1660 | 6RA7095-4GS22-0Z+X01 |

## Power Module
## Four Quad, Regen

| Horsepower | | Rated Armature (Amps DC) | Catalog Number |
|---|---|---|---|
| 240 VDC | 500 VDC | | |
| 3 | 7.5 | 15 | 6RA7018-6FS22-0Z+X01 |
| 7.5 | 15 | 30 | 6RA7025-6FS22-0Z+X01 |
| 15 | 30 | 60 | 6RA7028-6FS22-0Z+X01 |
| 25 | 60 | 100 | 6RA7031-6FS22-0Z+X01 |
| 40 | 75 | 140 | 6RA7075-6FS22-0Z+X01 |
| 60 | 125 | 210 | 6RA7078-6FS22-0Z+X01 |
| 75 | 150 | 255 | 6RA7082-6FS22-0Z+X01 |
| 125 | 250 | 430 | 6RA7085-6FS22-0Z+X01 |
| 150 | 300 | 510 | 6RA7087-6FS22-0Z+X01 |
| 250 | 500 | 850 | 6RA7091-6FS22-0Z+X01 |
| - | 700 | 1180 | 6RA7093-4GS22-0Z+X01 |
| - | 1000 | 1660 | 6RA7095-4GS22-0Z+X01 |

## Base Drive
## Signle Quad, Non-Regen

| Horsepower | | Rated Armature (Amps DC) | Catalog Number |
|---|---|---|---|
| 240 VDC | 500 VDC | | |
| 3 | 7.5 | 15 | 6RA7013-2FS22-0 |
| 7.5 | 15 | 30 | 6RA7018-2FS22-0 |
| 15 | 30 | 60 | 6RA7025-2FS22-0 |
| 25 | 60 | 100 | 6RA7030-2FS22-0 |
| 40 | 75 | 140 | 6RA7072-2FS22-0 |
| 60 | 125 | 210 | 6RA7075-2FS22-0 |
| 75 | 150 | 255 | 6RA7077-2FS22-0 |
| 125 | 250 | 430 | 6RA7082-2FS22-0 |
| 150 | 300 | 510 | 6RA7083-2FS22-0 |
| 250 | 500 | 850 | 6RA7087-2FS22-0 |
| - | 700 | 1180 | 6RA7091-2FS22-0 |
| - | 1000 | 1660 | 6RA7094-2FS22-0 |

## Base Drive
## Four Quad, Regen

| Horsepower | | Rated Armature (Amps DC) | Catalog Number |
|---|---|---|---|
| 240 VDC | 500 VDC | | |
| 3 | 7.5 | 15 | 6RA7013-2FV62-0 |
| 7.5 | 15 | 30 | 6RA7018-2FV62-0 |
| 15 | 30 | 60 | 6RA7025-2FV62-0 |
| 25 | 60 | 100 | 6RA7030-2FV62-0 |
| 40 | 75 | 140 | 6RA7072-2FV62-0 |
| 60 | 125 | 210 | 6RA7075-2FV62-0 |
| 75 | 150 | 255 | 6RA7077-2FV62-0 |
| 125 | 250 | 430 | 6RA7082-2FV62-0 |
| 150 | 300 | 510 | 6RA7083-2FV62-0 |
| 250 | 500 | 850 | 6RA7087-2FV62-0 |
| - | 700 | 1180 | 6RA7091-2FV62-0 |
| - | 1000 | 1660 | 6RA7094-2FV62-0 |

## Review 7

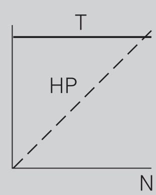
1. Parameters that can be read only are referred to as ____________ parameters.

2. A function block consists of several ____________ grouped together to perform a specific task.

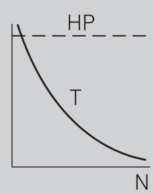
3. ____________ is the term used to describe the method of connecting function blocks together.

4. Winders are examples of ____________ ____________ applications.

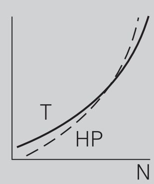
5. Identify the category of the following speed, torque, and horsepower graphs.




a. ____________ ____________




b. ____________ ____________




c. ____________ ____________

# Review Answers

**Review 1**
1) SIMOREG; 2) 15; 3) 15; 4) b. Dividing Distance by Time; 5) force; 6) external force.

**Review 2**
1) electromagnet; 2) current; 3) CEMF; 4) a. Permanent Magnet, b. Compound, c. Shunt, d. Series.

**Review 3**
1) a. increase; 2) c. not turning; 3) shunt; 4) b. torque; 5 flux.

**Review 4**
1) a. increase; 2) 250 VDC or 500 VDC; 3) a. A, b. B, c. F, d. H; 4) base; 5) b. AC to DC; 6) 538.

**Review 5**
1) I; 2) II; 3) shunt; 4) Dynamic Braking; 5) d. all of the above.

**Review 6**
1) CUD1; 2) Local Bus Adapter; 3) 2; 4) Armature; 5) 2; 6) CUD1; 7) b. EB1; 8) CBP2; 9) SLB; 10) SBP.

**Review 7**
1) visualization; 2) parameters; 3) BICO; 4) constant horsepower; 5) a. Constant Torque, Constant Horsepower, Variable Torque.

# Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued. Those receiving a score of less than 70% will be provided a second test.

**Questions**

1. The type of DC motor best suited for use with DC drives is the ____________ wound motor.

   a. series
   b. shunt
   c. compound
   d. series or shunt

2. ____________ is the trade name for Siemens DC drives.

   a. SIMOREG
   b. SIMOVERT
   c. SIMOVIS
   d. SIMOLINK

3. The base speed of a motor is an indication of how fast the motor will turn with rated ____________ and rated load (amps) at rated flux ($\Phi$).

   a. armature voltage
   b. CEMF
   c. field current ($I_f$)
   d. armature resistance ($R_a$)

4. A decrease in field flux strength ($\Phi$) causes a/an ____________ .

   a. decrease in armature voltage
   b. increase in armature voltage
   c. increase in motor torque
   d. decrease in motor torque

5. ____________ is the voltage induced into an armature conductor of a DC motor in opposition to applied voltage.

   a. Armature voltage
   b. Field voltage
   c. CEMF
   d. EMF

6. ____________ current refers to the minimum amount of current flowing from anode to cathode to keep a thyristor turned on.

   a. Armature current
   d. Gating current
   c. Holding current
   d. Field current

7. The value of rectified DC voltage obtained from a 460 VAC 3Ø source when the thyristors are gated at 60° is ____________ VDC.

   a. 0
   b. 310.5
   c. 538
   d. 621

8. A 1-quad drive uses ____________ thyristors to convert AC to a variable voltage DC.

   a. 4
   b. 6
   c. 8
   d. 12

9. ____________ is a method sometimes used on 1-quad drives as a means of stopping a motor quickly by converting mechanical energy to heat.

   a. Regen
   b. Field reversal
   c. Dynamic Braking
   d. Armature reversal

10. Which of the following is <u>not</u> an advantage of regen over dynamic braking?

    a. Regen brakes faster from max speed to base speed
    b. Regen brakes faster from base speed to stop
    c. Regen is not limited to duty cycle and cool-down periods
    d. Regen can develop torque at zero speed

11. ____________ tuning tunes the 6RA70 drive to the motor characteristics.

    a. Speed
    b. Armature
    c. CEMF
    d. Field

12. ____________ is the main control board in the 6RA70 which controls drive operation.

    a. CUD1
    b. CUD2
    c. SLB
    d. CBP2

13. CUD2 requires ____________ to install in the 6RA70.

    a. ADB Adapter Board
    b. LBA Local Bus Adapter
    c. ADB and LBA
    d. No additional hardware

14. If a communication board (CBP2, CBC, or CBD) is used with a technology board, the communication board must be placed in slot ____________ .

    a. D
    b. E
    c. F
    d. G

15. The command to start the 6RA70 drive is received on ____________ of CUD1.

    a. Terminal 106 of XS
    b. Terminal 4 of X174
    c. Terminal 37 of X171
    d. Terminal 14 of X175

16. Hoisting gear is an example of a ____________ load.

    a. constant torque
    b. variable torque
    c. constant horsepower
    d. constant speed

17. ____________ is used to communicate with PROFIBUS-DP.

    a. CBC    c. CBD
    b. CBP2    d. SBP

18. ____________ is the term used to describe the method of connecting function blocks together.

    a. SIMATIC    c. BICO
    b. SIMOVIS    d. QuickStart

19. ____________ is an example of a visualization parameter.

    a. P225    c. K165
    b. r038    d. B0205

20. The correct catalog number for a SIMOREG 6RA70 DC MASTER, base drive, four quad, to be used with armature amps rated for 100 amps is ____________ .

    a. 6RA7031-6FS22-0Z+X01
    b. 6RA7031-6FV62-0Z+X01
    c. 6RA7030-2FS22-0
    d. 6RA7030-2FV62-0

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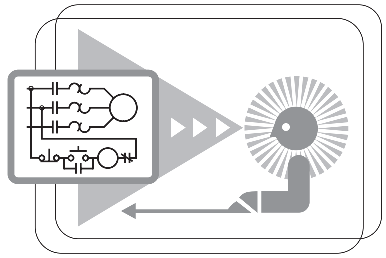

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