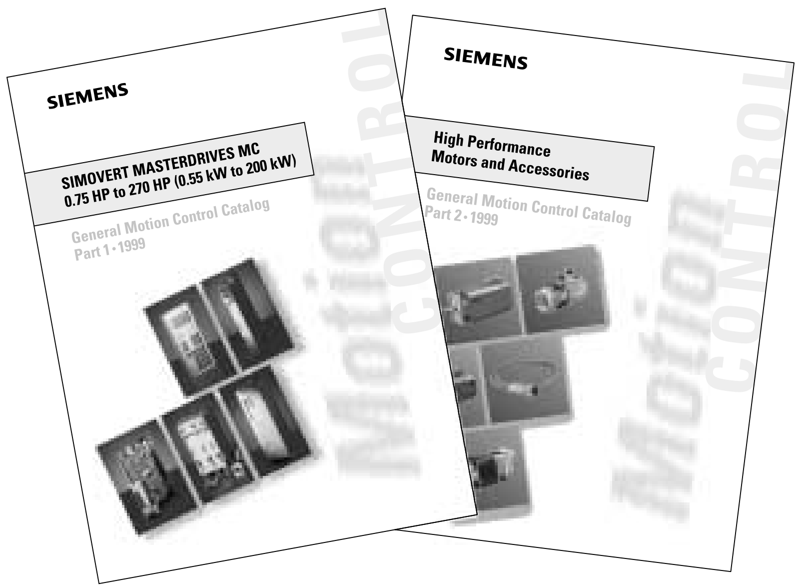
Siemens Servomotors

Siemens manufactures asynchronous and synchronous servomotors for virtually every motion control application. Selection and ordering information, as well as configuration aids such as speed-torque curves for specific motors, can be found in Part 2 of the General Motion Control Catalog. This is available from your local Siemens sales representative.

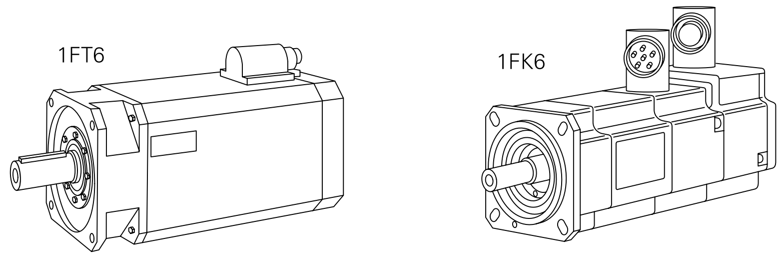


Synchronous Servomotors

Siemens manufactures two models of permanent-magnet synchronous servomotors. The 1FK6 is a standard servomotor. The 1FT6 is a performance servomotor.

Motor	Protection	Cooling	Power Range kW (HP)	Rated Torque Nm (lb-in)
1FK6	IP64 (IP65)*	Natural	0.5 - 5.2 (0.7 -7.0)	0.8 - 16.5 (7 - 148)
1FT6	IP64 (IP65, IP67)*	Natural	0.5 - 15.5 (0.7 - 20.7)	0.8 - 88 (7 - 779)
		Blower Vent	6.9 - 34.6 (9.2 - 46.4)	17 - 160 (150 - 1416)
		Water	11 - 27.6 (14.7 - 37)	34 - 78 (300 - 690)

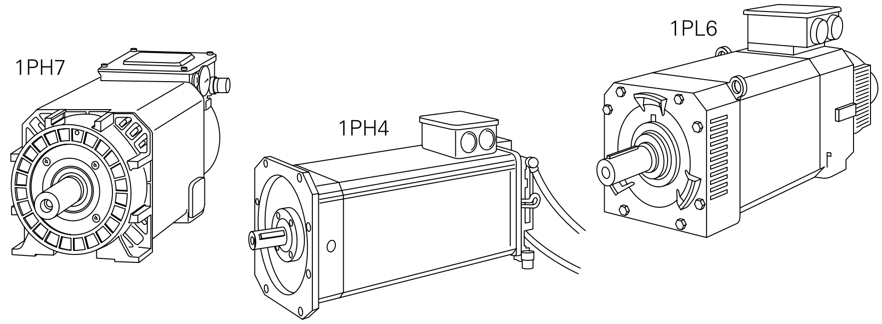
* Optional



Asynchronous Servomotors

Siemens manufactures three models of squirrel-cage asynchronous servomotors: 1PH7, 1PL6, and 1PH4.

Motor	Protection	Cooling	Power Range kW (HP)	Rated Torque Nm (lb-ft)
1PH7	IP 55	Blower Vent Surface	3.7 - 215 (5 - 288)	22 - 1145 (16 - 844)
1PL6	IP23	Blower Vent	24.5 - 300 (32.8 - 400)	370 - 1720 (273 - 1268)
1PH4	IP65	Water	7.5 - 61 (10 - 81)	48 - 330 (35 - 243)



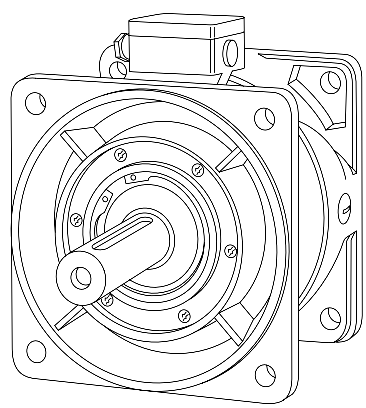
Servomotor Accessories

Holding brakes, built-on gears, and encoders are typical accessories for use with servomotors and motion control systems. Holding brakes and built-on gears will be covered in this section. Encoders will be covered in a separate section.

Holding Brakes

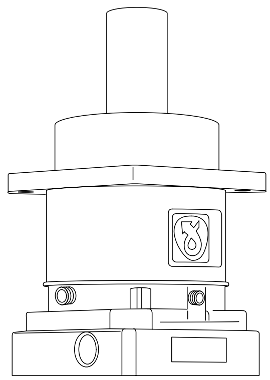
Many systems need a holding brake as part of an emergency-stop function, or for other reasons related to safety. These brakes are electromagnetic brakes. When voltage is applied to the brake, the brake is released and the motor is free to be turned by the AC drive. In the event of a power loss, such as a power interruption caused by initiating an emergency stop, the brake is engaged. This will bring the motor to a standstill.

Holding brakes are available for the 1FK6, 1FT6, and 1PH7 motors.

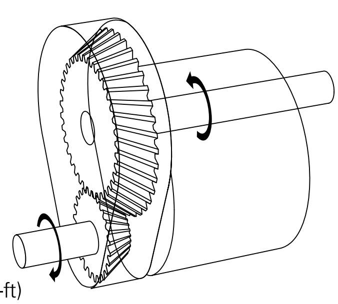


Gear Reducer

In drive systems servomotors are frequently combined with planetary gear reducers. Planetary gears designed for use with Siemens servomotors provide a compact unit with low torsional play, high torsional rigidity, and low running noise.



Earlier in the course we discussed some basic mechanical concepts which include power, torque, and speed. One way to see the relationship of these concepts is through a gear reducer. Power is a function of speed, and directly proportional to both speed and torque. If torque and speed are increased, power would also increase. However, if torque is increased and speed is decreased by a proportionate amount, power remains constant. This is exactly what happens in a gear reducer. The following drawing illustrates a 30:1 gear reducer. The input is driven by a servomotor with 4.068 Nm (3 lb-ft) of torque at 1750 RPM. Output speed is reduced by the gear reducer to 58.3 RPM. Output torque, however, increases to 103.73 Nm (76.5 lb-ft) for use by the connected system.



Output Torque = Input Torque x Ratio x Efficency
Output Torque = 4.068 x 30 x .85
Output Torque = 103.73 Nm

Output Speed = Input Speed / Ratio
Output Speed = 1750 / 30
Output Speed = 58.3 RPM

SPG, LP, and PG Series

Siemens uses SPG and LP series planetary gears made by Alpha Geardrives, Elk Grove Village, IL, for 1FK6, 1FT6, and some 1PH7 motors. Siemens uses PG series planetary gears manufactured by ZF Friedrichshafen, Florence, KY, for 1FK6 and 1FT6 motors.

	SPG Gears	LP Gears	PG Gears
Transmission Ratios, single-stage	4, 5, 7, 10	5, 10	4, 5, 7, 10
Transmission Ratios, 2-stage	16, 20, 28, 40, 50, 70, 100	25, 50, 100	16, 20, 25, 35, 40, 49, 50, 70, 100
Efficiency	up to 97%	>95%	>95% single-stage, >97%, 2-stage
Torsional Play	up to under 2 arc min	<10 arc min	<6 arc min single-stage, <10 arc min 2-stage

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1. ___________ is the duty cycle designation for continuous running duty.

2. If no time is given for a duty cycle a ___________ minute time is assumed.

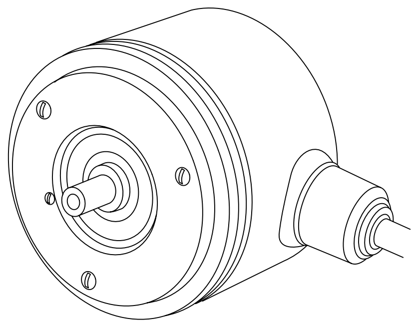
3. The speed-torque curve for specific servomotors show speed-torque ratings for ___________ and ___________ operating regions.

4. The maximum rated torque of a 1PH4 asynchronous servomotor is ___________ HP.

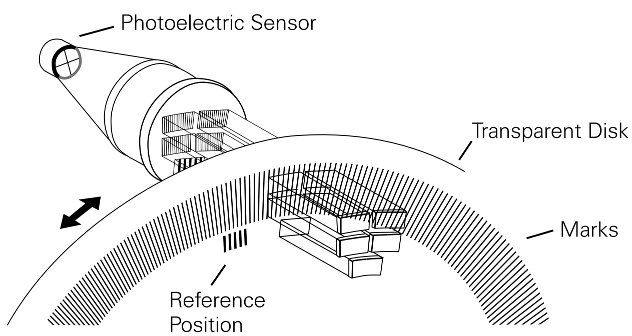
5. 1PH7, 1PL6, and 1PH4 are examples of ___________ servomotors.

Encoders and Resolvers

Siemens encoders and resolvers are designed for use with the Siemens servomotors discussed in previous sections. Encoders and resolvers allow the MASTERDRIVE MC to determine speed, position, and direction of shaft rotation.



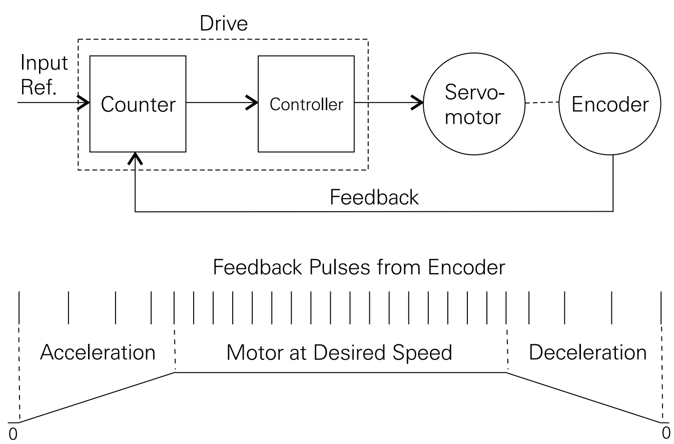
One type of encoder available for use with Siemens servomotors is an incremental encoder. An incremental encoder consists of a transparent disk marked with lines around the radius. A photoelectric scanning device is located near the disk. The output of an incremental encoder is either a series of pulses or a series of sinusoidal waveforms.



Closed-Loop Control

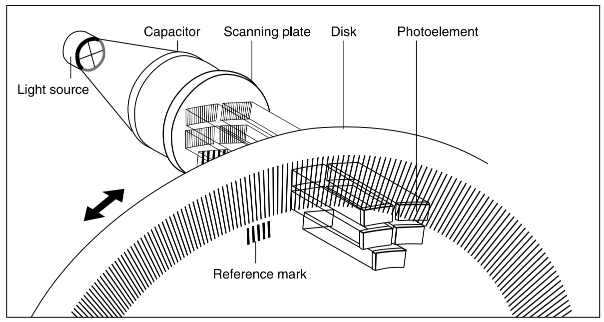
In a motion control system, precise control must be maintained over acceleration, deceleration, velocity, and position. This requires that the drive or other controlling device be provided with commands associated with these items. The drive determines the signal to provide to the servomotor by comparing the actual values with the command values. The actual values are calculated based upon feedback received from the encoder. This is an example of closed-loop control.

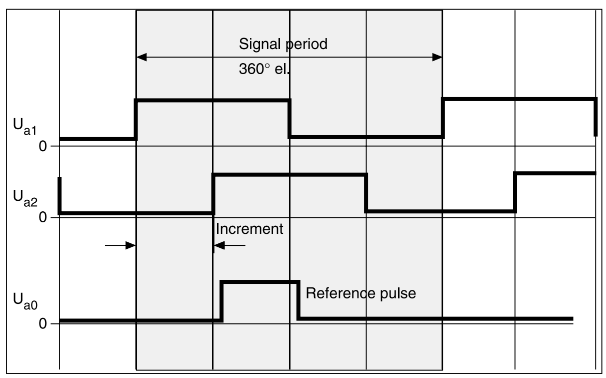
In the following illustration an input reference signal, indicating the position the load is to be moved to, is applied to a counter in the motion control drive. As the motor is accelerated pulses from an encoder are returned to the counter at an increasing rate. Once the motor has reached the desired running speed the pulses are returned at a constant rate. The drive can keep track of the rotor's position and number of rotations by counting these pulses. When the load approaches the desired location the drive slows the motor to a stop. The load is now in the desired location.



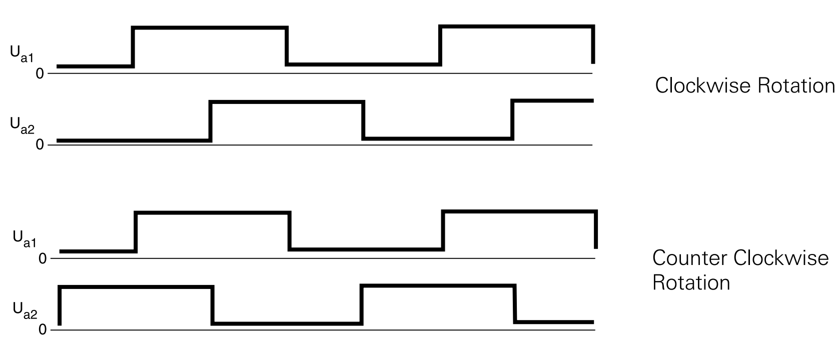
Rod 431 Rotary Pulse Encoder

This encoder has two output channels (U_{a1} and U_{a2}) which are phase shifted by 90°. The encoder has 1024 increments per revolution. Channel U_{a0} is a reference pulse which occurs once per revolution. When power is initially applied to the servomotor the drive will not know the exact position of the rotor. Rotor position can only be calculated within one revolution once the zero reference mark has been crossed the first time. Because synchronous servomotors must know rotor position within one revolution this encoder can only be used with 1PH7, 1PL6, and 1PH4 asynchronous servomotors.





By comparing channel U_{a1} and U_{a2} the drive can determine which direction the motor is running.

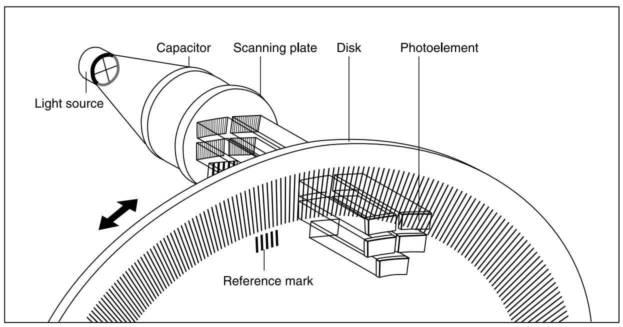


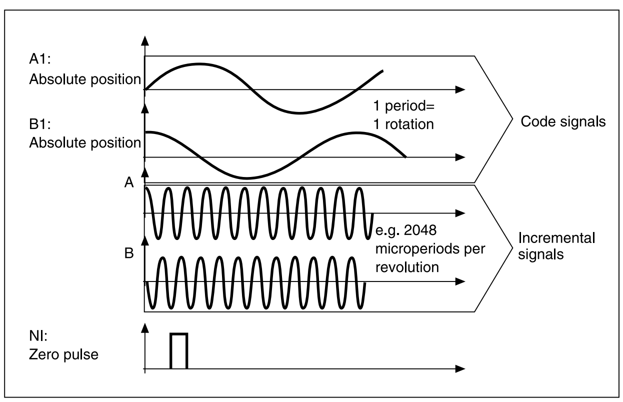
ERN 1387/1381 Encoders

The ERN 1387 encoder has four tracks and a reference pulse. A1 channel produces one sine signal per revolution and B1 channel produces one cosine signal. These signals are used to determine exact rotor position from initial power up within one revolution. After each revolution the calculated position is adjusted to the position indicated by the reference pulse position, if necessary. This encoder is suitable for use with all Siemens synchronous and asynchronous motors.

The 1381 encoder is a two-channel device which does not produce A1 and B1 signals. The 1381should be used only with asynchronous servomotors.

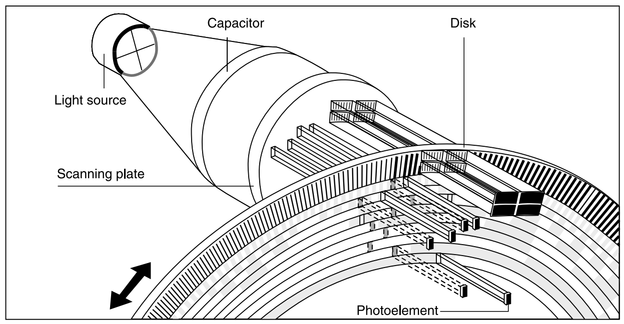
Tracks A and B on both encoders produce a sinewave output of 2048 microperiods per revolution. Evaluation electronics within the MASTERDRIVE MC can increase the resolution to 16.8 x 10^6 periods per revolution (ppr).

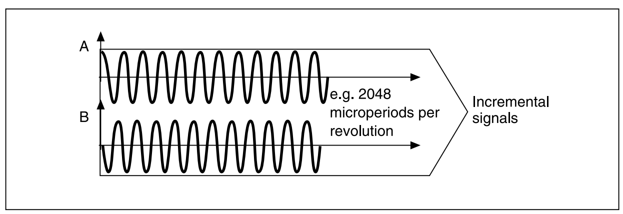




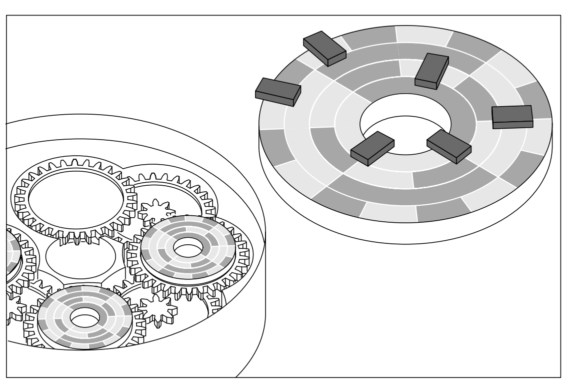
EQN 1325 Absolute-Value Encoder

The EQN 1325 absolute value encoder is made up of two sections. The outer ring is identical to the ERN 1387 and is used to provide speed and direction information. Two output channels, A and B, produce 2048 periods per revolution. Channel B is offset from channel A by 180 degrees. The drive can determine which direction the motor is running by comparing channel A with channel B. A second feature of the EQN 1325 is the coded inner rings. These provide a unique code for 8192 positions. This unique code is sent to the drive via an EnDat interface. The drive uses this unique code number to determine rotor positon.





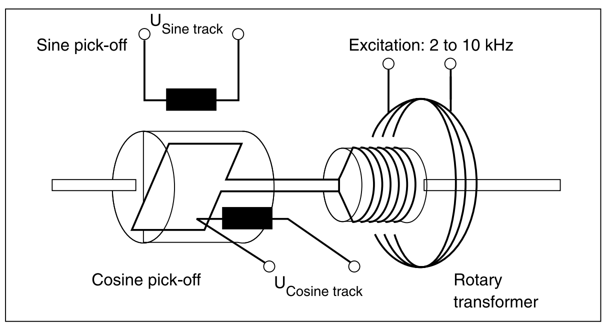
In addition, the encoder uses a mechanical gear sequence to count up to 4096 revolutions and store them. As long as the distance the application moves is less than 4096 revolutions there is no need to "home" the application as the absolute position is always known by the encoder count. As soon as it counts 4096 revolutions the encoder starts counting again from zero. These encoders are designed for use with synchronous and asynchronous servomotors.

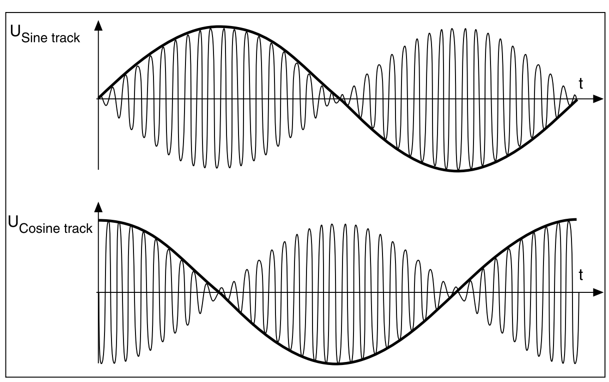


Two-Pole Resolver

A resolver is similar to an encoder, but instead of using a photoelectric sensor a rotating transformer is employed. The primary is located on the rotor of the resolver. Two secondary windings, arranged at right angles to each other, make up the stator. The amplitude of the sinewave induced into each stator winding depends on the angular position of the rotor winding. Since the amplitude variations available at the stator windings are 90° apart, one signal is called a sine signal and the other is called a cosine signal.

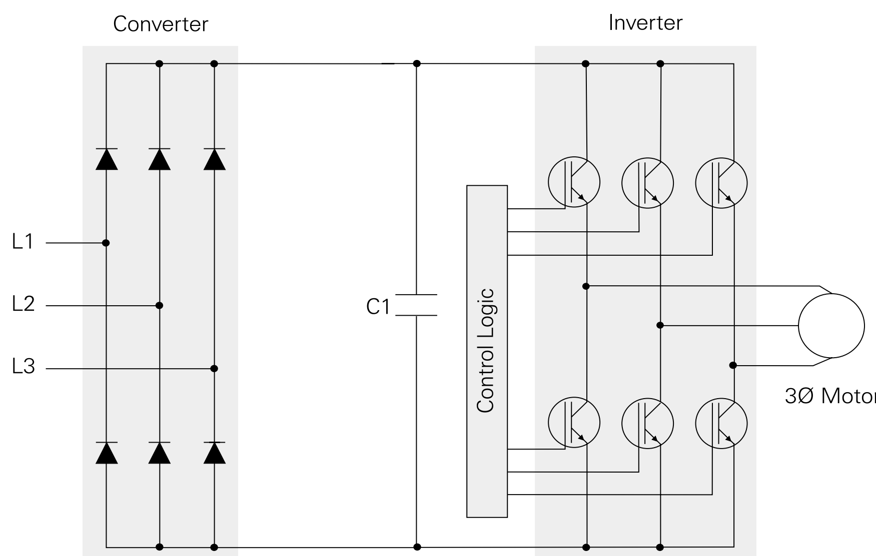
The sine signal and the cosine signal are both applied to the MASTERDRIVE MC. By comparing the two signals, the MASTERDRIVE MC can determine the angular position of the rotor and its direction of rotation. Each revolution of the rotor is divided into 4096 increments. Once the initial position of an axis is determined by finding a home position, exact position of an axis will be tracked by the MASTERDRIVE MC over multiple revolutions of the resolver. Two-pole resolvers are designed for use with synchronous and asynchronous servomotors.





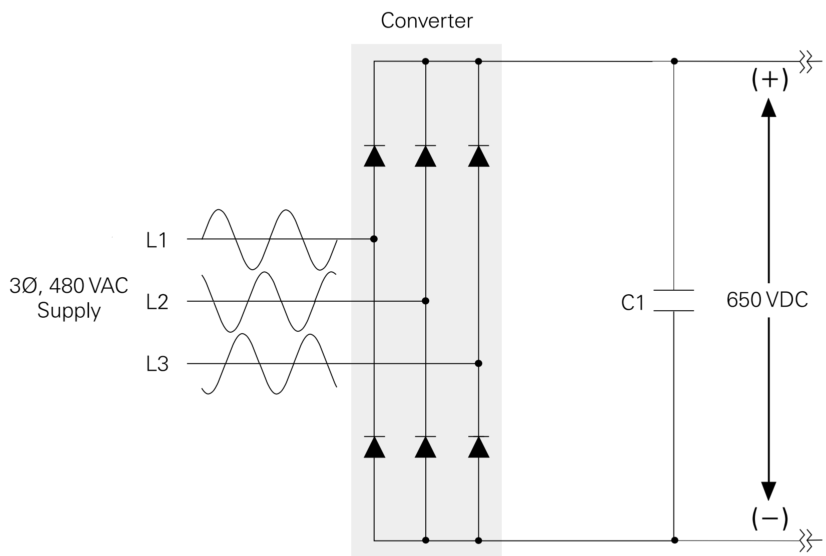
Pulse Width Modulation

Before discussing the MASTERDRIVE MC it is necessary to know something about Pulse Width Modulation (PWM). Pulse width modulation is one type of technology used by AC drives, such as the MASTERDRIVE MC. PWM drives convert a fixed voltage, fixed frequency into a variable voltage, variable frequency output to control the speed of an AC motor. Pulse width modulation provides a more nearly sinusoidal current output to control frequency and voltage supplied to an AC motor than other technologies. PWM drives are more efficient and typically provide higher levels of performance than other drives. A basic PWM drive consists of a converter, control logic, and an inverter.



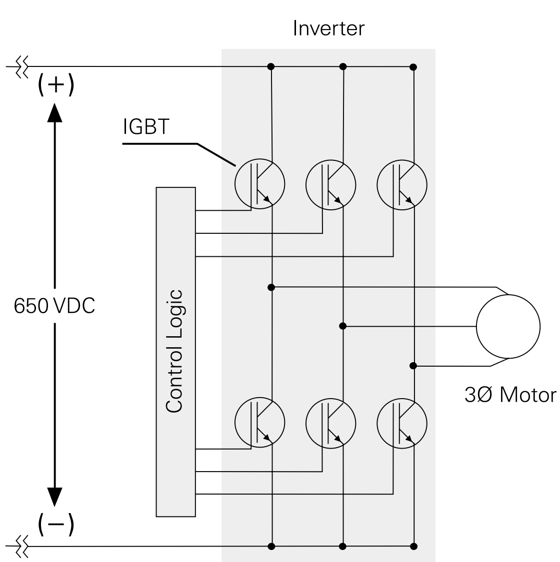
Converter

The converter section consists of a either a fixed diode bridge rectifier or a thyristor bridge rectifier which converts the three-phase power supply to a DC voltage. The C1 capacitor(s) smooths the converted DC voltage by limiting current peaks and reducing harmonics. The rectified DC value is approximately 1.35 times the line-to-line value of the supply voltage. For example, the rectified DC value is approximately 650 VDC for a 480 VAC supply.



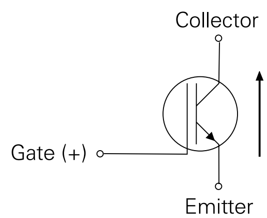
Control Logic and Converter

Output voltage and frequency to the motor are controlled by the control logic and inverter section. The inverter section consists of six switching devices. Various devices can be used such as thyristors, bipolar transistors, MOSFETS and IGBTs. The following schematic shows an inverter that utilizes IGBTs. The control logic uses a microprocessor to switch the IGBTs on and off providing a variable voltage and frequency to the motor.



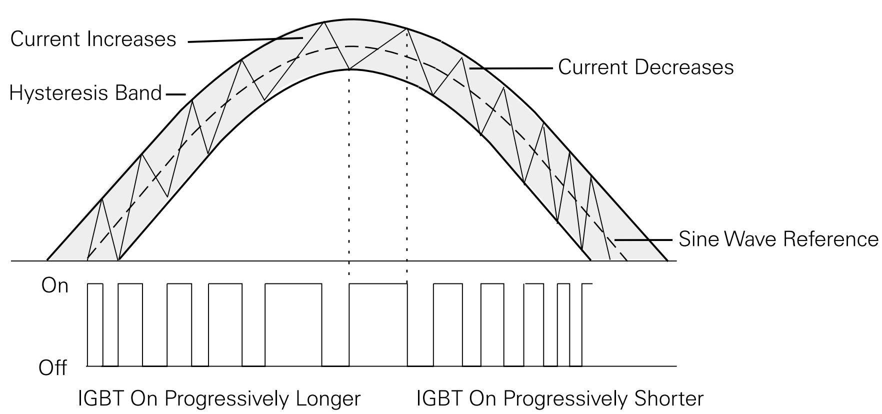
IGBTs

IGBTs (insulated gate bipolar transistors) provide the high switching speed necessary for PWM inverter operation. IGBTs are capable of switching on and off several thousand times a second. An IGBT can turn on in less than 400 nanoseconds and off in approximately 500 nanoseconds. An IGBT consists of a gate, collector and an emitter. When the control circuit applies a positive voltage (typically +15 VDC) to the gate the IGBT will turn on. This is similar to closing a switch. Current will flow between the collector and emitter. An IGBT is turned off by removing the positive voltage from the gate. During the off state the IGBT gate voltage is normally held at a small negative voltage (-15 VDC) to prevent the device from turning on.

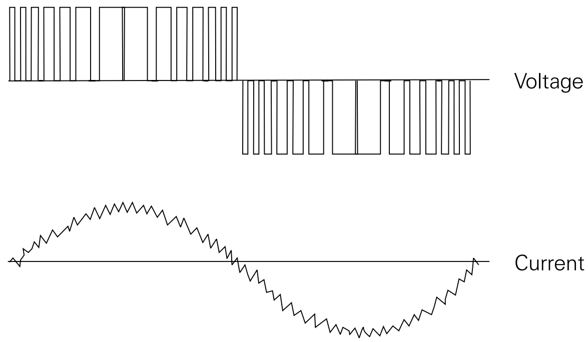


Developing PWM Waveforms

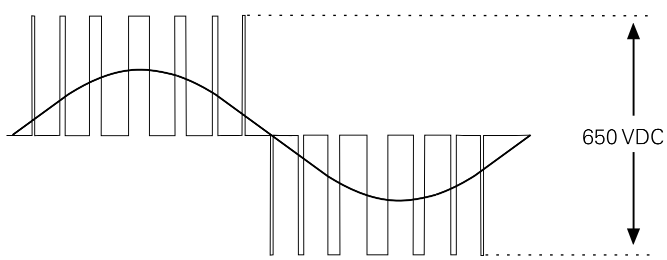
There are several PWM techniques. It is beyond the scope of this book to describe them all in detail. The following text and illustrations describe one method. An IGBT can be switched on, connecting the motor to the positive value of DC voltage (650 VDC from the converter). Current flows in the motor. The IGBT is switched on for a short period of time, allowing only a small amount of current to build up in the motor, and then switched off. The IGBT is switched on and left on for progressively longer periods of time, allowing current to build up to higher levels until current in the motor reaches a peak. The IGBT is then switched on for progressively shorter periods of time, decreasing current build up in the motor.



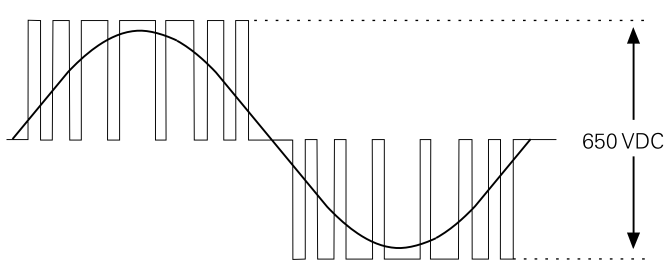
The negative half of the sine wave is generated by switching an IGBT connected to the negative value of the converted DC voltage.



The voltage and frequency are controlled electronically by circuitry within the AC drive. The fixed DC voltage (650 VDC) is modulated, or clipped, with this method to provide a variable voltage and frequency. At low output frequencies a low output voltage is required. The switching devices are turned on for shorter periods of time. Voltage and current build up in the motor is low. At high output frequencies a high voltage is required. The switching devices are turned on for longer periods of time. Voltage and current build up in the motor increases.



Shorter "On" Duration, Lower Voltage

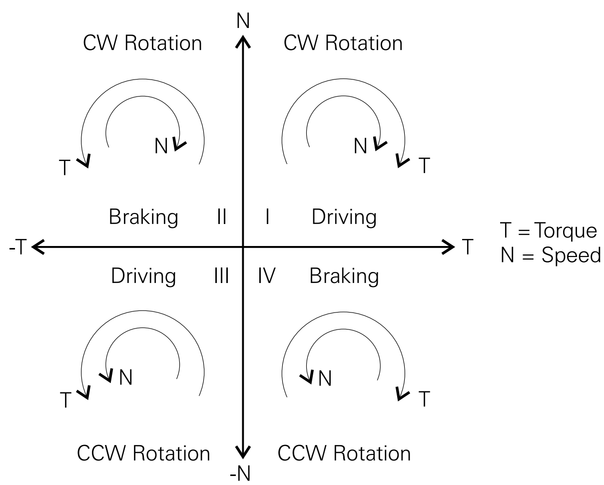


Longer "On" Duration, Higher Voltage

Regeneration and Braking

In the speed-torque chart there are four quadrants according to direction of rotation and direction of torque. Quadrant I is forward motoring or driving (CW). Quadrant III is reverse motoring or driving (CCW). Reverse motoring is achieved by reversing the direction of the rotating magnetic field.

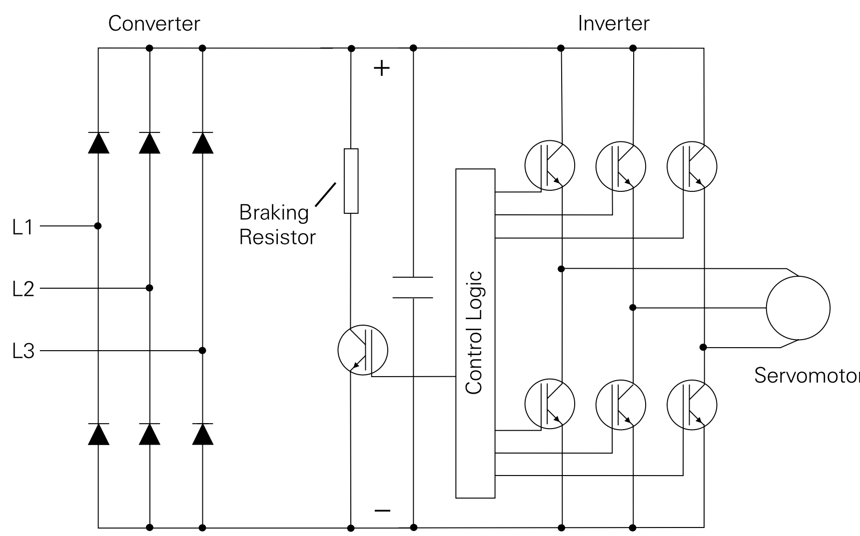
The dynamics of certain loads, such as those associated with many motion control applications, require four-quadrant operation. Torque will always act to cause the rotor to run towards synchronous speed. If the synchronous speed is suddenly reduced, negative torque is developed in the motor. This could occur, for example when a stop command is initiated and the drive tries to slow down to bring the motor to a stop. The motor acts like a generator by converting mechanical power from the shaft into electrical power which is returned to the AC Drive. This is known as regeneration, and helps slow the motor. A similar process occurs when coasting downhill in a car. The car's engine will act as a brake. Braking occurs in quadrants II and IV.



One method of dealing with negative torque and the current it produces is controlled deceleration. Voltage and frequency is reduced gradually until the motor is at stop. This would be similar to slowly removing your foot from the accelerator of a car. Many applications, however, require the motor to stop quicker, and the drive must be capable of handling the excess energy produced by motor when this is done.

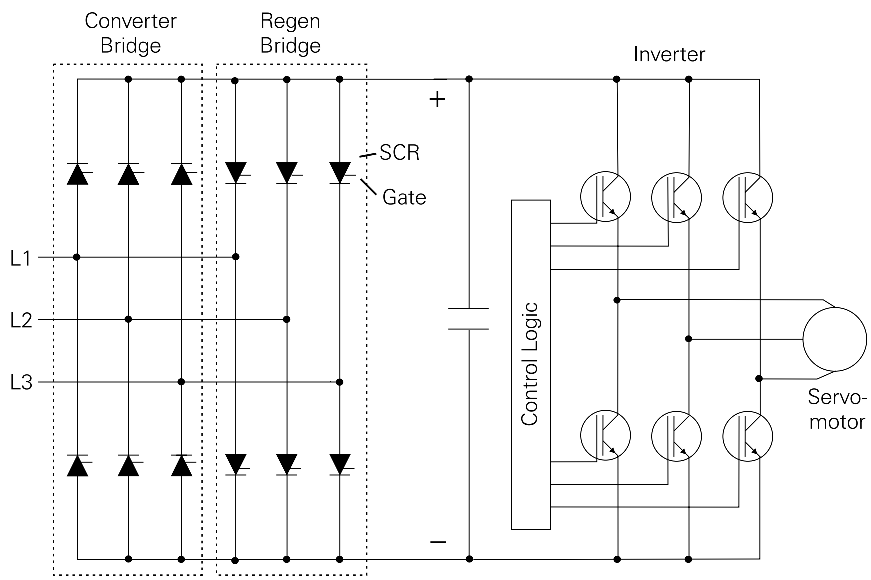
Braking Resistors

Electrical energy returned to the drive from the motor during regeneration can cause the DC link voltage to become excessively high. Braking resistors are one method used to control regeneration during a rapid deceleration. A braking resistor is placed across the DC link, through an IGBT. Energy returned by the motor is seen on the DC link. When the DC link reaches a predetermined limit the control logic switches on the IGBT, completing the path from the negative to the positive DC link through the IGBT and resistor. Excess energy is dissipated by the resistor, reducing bus voltage. When DC link voltage is reduced to a safe level the IGBT is switched off, removing the resistor from the DC link. This process allows the motor to act as a brake, slowing the connected load quickly.

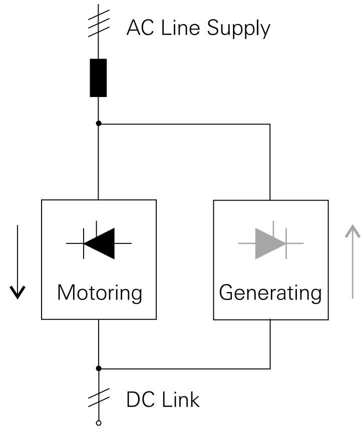


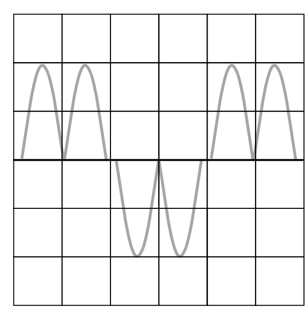
Rectifier Regenerative Front End

Another method of dealing with excessive regeneration is with a rectifier regenerative front end. Diodes in the converter section are replaced with SCRs and a second regen bridge is added. An SCR functions similarily to a dode rectifier, except that it has a gate lead, which is used to turn the SCR on. This allows the control logic to control when the converter bridge and regen bridge are turned on.



A simplified block diagram provides a clearer view of the regen process. When the servomotor needs motoring energy to accelerate or maintain speed against the inertia of a load, the converter bridge is turned on. When the motor is in the regenerative mode, it acts like a generator, supplying electrical energy back to the DC link. When the DC link voltage reaches a predetermined level the motoring SCRs are switched off and the regen (generating) SCRs are switched on. This allows the excess energy to be returned to the AC line in the form of AC current.

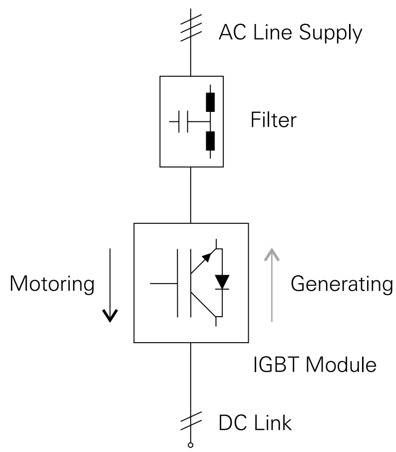


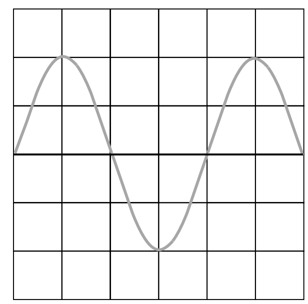


Current Returned to AC Line During Regeneration

ACTIVE FRONT END

An ACTIVE FRONT END (AFE) is another option available to control regenerative voltage. With this option the diodes in the converter bridge are replaced with IGBT modules and a Clean Power Filter. The IGBT, controlled by control logic, operates in both motoring and regenerating modes. In addition, AFE provides low stressing of the line supply. Harmonics are extremely low and the power returned is in the form of sinusoidal current.





Current Returned to AC Line During Regeneration

Review 5

1. The Rod 431 rotary pulse encoder can only be used with ___________ servomotors.

2. The EQN 1325 absolute-value encoder can count up to ___________ revolutions.

3. Braking occurs in quadrants ___________ and ___________ .

4. ___________ ___________ ___________ is one type of regenerative braking that uses IGBTs in the converter section.