Motion Control Glossary

This section contains a description of many of the terms used in the design and application of motion control products and programmable devices. Although other reference books and definitions exist, these should serve reference for most needs.

Absolute Position. Position referenced to a fixed zero position.

Absolute Positioning. Refers to a motion control system employing position feedback devices to maintain a given mechanical location.

Acceleration. Acceleration is the time rate of change of velocity with respect to a fixed reference frame. Angular acceleration is the time rate of change of angular displacement with respect to a fixed rotational reference axis. For step motor systems, the commanded step rate is started at a base velocity and accelerated to the slew velocity at a defined and controlled rate or rate of changes.

Acceleration (Linear). Linear acceleration is the most commonly utilized form of accelerating the commanded pulse rate, and is expressed mathematically as:

a = dv/dt (constant)

For rotating bodies the angular acceleration is the ratio of torque to inertia, and is expressed mathematically as:

a **= dw/dt = Torque/J_{system}** (constant)

Acceleration (Nonlinear). Nonlinear acceleration is a constantly changing acceleration of the commanded step rate and can be customized to reflect and "S-Curve" acceleration or any other required shape to provide control of the step motor system. The Optimal Nonlinear acceleration technique utilized in some API Motion controller designs allows for the high acceleration rates at low commanded pulse rates where steppers exhibit high torque capabilities, and a reduced acceleration rate as the slew speed commanded pulse rate is achieved. Optimal nonlinear ramping techniques allow for greater torque utilization and a "faster" point-to-point positioning than with linear acceleration techniques.

Accuracy. A measure of the difference between expected position and actual position of a motor or mechanical system. Motor accuracy is usually specified as an angle representing the maximum deviation from expected position.

AC Servo Drive. A servo drive used to control either a synchronous or induction type AC motor.

Actuator. A device that creates mechanical motion by converting various forms of energy to mechanical energy.

Adaptive Control. A technique to allow a control to automatically compensate for changes in system parameters, such as load variations.

Air Gap (Brake/Clutch). The physical axial space between rotor and armature that is overcome when the magnet body is energized, engaging the clutch, or brake.

Ambient Temperature. The temperature of the cooling medium, usually air, immediately surrounding a motor or other device.

Amplifier. Electronics that convert low level command signals to high power voltages and currents to operate a motor, also called a Drive.

Armature (Brake/Clutch). The output component in a clutch that is attracted to the rotor by the magnetic field created by the case assembly, effecting the coupling of motor and load.

ASCII. American Standard Code for Information Interchange. This code assigns a number to each numeral and letter of the alphabet. In this manner, alphanumeric information can be transmitted between machines as a series of binary numbers.

Back-EMF. The voltage generated when a permanent magnet motor's rotor is rotated. This voltage is proportional to motor speed and is present regardless of whether the motor winding(s) are energized or un-energized.

Base Speed. The command pulse range over which an unloaded step motor can accelerate to command pulse rate from standstill, decelerate from command pulse rate to standstill, and reverse direction (on command) without loss of synchronism.

Bifilar Winding. Refers to the winding configuration of a step motor where each stator pole has a pair of windings, (4 electrical phases), the motor will have either 6 or 8 lead wires depending on termination. This winding configuration can be driven from a unipolar or bipolar drive design.

Bipolar Drive. The term bipolar refers to specific type of drive that is connected to a step motor configured for 2-phase operation, unifilar connected motor. The 4 electrical cycles required for operation are generated when the direction of current is reversed in each motor phase. A bipolar drive can be utilized with a 4, 6 or 8 lead motor.

Block Diagram. A simplified representation of a system, with each component represented by a block, and each block typically positioned in order of signal flow through the system.

Brush. Conducting material that passes current from terminals of a DC motor to the rotating commutator.

Brushless Servo Drive. A servo drive used to control a permanent magnet synchronous AC motor. May also be referred to as an AC Servo Drive.

Burnishing (Brake/Clutch). A process of running in a clutch or a brake, so as to reach full potential torque. All standard catalog values of torque are indicated as burnished. Generally, any unit will become burnished during the first few cycles of normal operation at the customer's site. **Pre-burnishing** at the factory is normally an additional operation required only by those customers needing immediate out-of-box torque prior to the normal application run-in period.

Bus. A group of parallel connections carrying pre-assigned digital signals. Buses usually consist of address and data information and miscellaneous control signals for the interconnection of microprocessors, memories, and other computing elements.

Case Assembly (Brake/Clutch). The fixed component in a clutch or brake that is energized, creating a magnetic field, effecting the engagement of rotor and armature.

Class B Insulation. A NEMA insulation specification. Class B insulation is rated to an operating temperature of 130 degrees centigrade.

Class H Insulation. A NEMA insulation specification. Class H insulation is rated to an operating temperature of 180 degrees centigrade.

Closed Loop System. A broadly applied term relating to any system where the output is measured and compared to the input. The output is then adjusted to reach the desired condition. In motion control the term is used to describe a system where a velocity or position (or both) transducer is used to generate correction signals by comparison to desired parameters.

Closed Loop (Step System). A step motor system can be operated in a closed loop application where the output is measured and compared to the input. The output is then adjusted to reach the desired input condition. In motion control the term is used to describe a system wherein a velocity or position sensor is used to generate signals for comparison to desired parameters. For cases where loads are not predictable the closed loop feedback from an external encoder to the controller may be used for stall detection, position verification or position maintenance.

Cogging. A term used to describe nonuniform angular velocity. Cogging appears as jerkiness especially at low speeds.

Commutation. A term that refers to the action of steering currents or voltage to the proper motor phases so as to produce optimum motor torque. In brush type motors, commutation is done electromechanically via the brushes and commutator. In brushless motors, commutation is done by the switching electronics using rotor position information, typically obtained by Hall sensors, a resolver or an encoder.

Commutator. A mechanical cylinder consisting of alternating segments of conductive and insulating material. This cylinder used in DC motors passes currents from the brushes into the rotor windings and performs motor commutation as the motor rotates.

Compensation. The corrective or control action in a closed loop system that is used to improve system performance characteristics such as accuracy and response time.

Compensation, Feed-forward. A control action that depends on the command only, and not the error, to improve system response time.

Compensation, Integral. A control action that is proportional to the integral or accumulative time error value of the feedback loop error signal. It is usually used to reduce static error.

Compensation, Lag. A control action which causes a lag at low frequencies and tends to increase the delay between the input and output of a system while decreasing static error.

Compensation, Lead. A control action that causes the phase to lead at high frequencies and tends to decrease the delay between the input and output of a system.

Compensation, Lead-Lag. A control action that combines the characteristics of lead and lag compensations.

Compensation, Proportional. A control action that is directly proportional to the error signal of a closed loop system. It is used to improve system accuracy and response time.

Compliance. The amount of displacement per unit of applied force.

Compliant Coupling. The limited motion of one coupled shaft without causing motion of the other coupled shaft, that does not permit permanent displacement of one shaft with respect to the other.

Computer Numerical Control (CNC). A computer-based motion control device programmable in a numerical word address format. A computer numerical control typically includes a CPU section, operator interface devices, input/output signal and data devices, software and related peripheral apparatus.

Control Systems or Automatic Control Systems. An engineering or scientific field that deals with controlling or determining the performance of dynamic systems such as servo systems.

Coordinated Motion. Multi-axis motion where the position of each axis is related to the other axes, such that the path and velocity of a move can be accurately controlled. (Requires coordination among axes.)

Coupling Ratio. The ratio of motor velocity to load velocity for a load coupled to a motor through a gear or similar mechanical device.

Critical Damping. A system is critically damped when the response to an incremental change in desired velocity or position is achieved in a minimum possible time with little or no overshoot.

Daisy Chain. A term used to describe the linking of several RS232C devices in sequence such that single data stream flows through one device and on to the next. Daisy-chained devices usually are distinguished by device addresses that serve to indicate the desired destination for data in the stream.

Damping. An indication of the rate of decay of a signal to its steady state value. Related to setting time.

Damping (Step Motor). The reduction or elimination of step overshoot is defined as damping. It is used in application where settling time is important. Types of damping are mechanical, electronic and viscous (fluid). The electronic method includes series resistance, capacitance, back-phasing, delayed last-step excitation, and others. Mechanical damping is accomplished by adding friction in various schemes including fluid dampers.

Damping Ratio. Ratio of actual damping to critical damping. Less than one is an under-damped system and greater than one is an over-damped system.

DC Adjustable-Speed Drive. All equipment required to adjust the speed or torque of DC motor(s) by controlling the voltages applied to the armature and/or field of the motors.

DC Drive. An electronic control unit for running DC motors. The DC drive converts AC line current to a variable DC current to control a DC motor. The DC drive has a signal input that controls the torque and speed of the motor.

Dead Band. A range of input signals for which there is no system response.

Deceleration. See Acceleration.

Decibel (db). A logarithmic measurement of gain. If G is a systems gain (ratio of output to input), then 20 log G = gain in decibels (db)

Demag Current. The current level at which the motor magnets will be demagnetized. This is an irreversible effect that will alter the motor characteristics and degrade performance.

Detent Position. The static angular position which the shaft of an unloaded stepping motor assumes when it is energized as specified.

Detent Torque. Sometimes noted as "Cogging Torque" is the periodic torque ripple resulting from the tendency of magnetic rotor poles and stator poles to align themselves to positions of minimal reluctance. The measurement is taken with all phases de-energized.

Dielectric Test. A high voltage breakdown test of insulation's ability to withstand an AC voltage. Test criterion limits the leakage current to a specified magnitude and frequency, applied between the specified test points.

Differential: An electrical input or output signal which uses two lines of opposite polarity referenced to the legal signal ground.

Distributed Processing. A technique to gain increased performance and modularity in control systems utilizing multiple computers or processors.

DNC, Direct Numerical Control. Technique of transforming part program data to a numerical control system via direct electrical connection in place of paper tapes.

Drive, Analog. Usually referring to any type of motor drive in which the input is an analog signal.

Drive, Digital. Usually referring to any type of motor drive in which the tuning or compensation is done digitally. Input may be an analog or digital signal.

Drive, Linear. A non-switching type motor drive in which the output is directly proportional to either a voltage or current input. Normally both inputs and outputs are analog signals. This is a relatively inefficient drive type.

Drive, PWM. A motor drive utilizing Pulse-Width Modulation techniques to control power to the motor. Typically a high efficiency drive that can be used for high response applications.

Drive, SCR. A DC motor drive that utilizes silicon controlled rectifiers as the power control elements. Usually used for low bandwidth, high power applications.

Drive, Servo. A motor drive that utilizes feedback for accurate control of motor current and/or velocity.

Duty Cycle. For repetitive cycle, the ratio of on time to total cycle time.

Duty cycle = On time X 100% /
(On time + Off time)

Dynamic Braking. A passive technique for stopping a permanent magnet brush or brushless motor. The motor windings are shorted together through a resistor that results in motor braking with an exponential decrease in speed.

Efficiency. The ratio of output power to input power.

Electrical Time Constant. the ratio of armature inductance to armature resistance.

Electronic Damping. A means of suppressing oscillation of a step motor output by switching the motor winding in sequence such that the motor and load have come to rest when the final step position has been reached.

EMI (Electro-Magnetic Interference). EMI is noise which, when coupled into sensitive electronic circuits, may cause problems.

Encoder. A type of feedback device that converts mechanical motion into electrical signals to indicate actuator position. Typical encoders are designed with a printed disc and a light source. As the disc turns with the actuator shaft, the light source shines through the printed pattern onto a sensor. The light transmission is interrupted by the patterns on the disc. These interruptions are sensed and converted to electrical pulses. By counting these pulses, actuator shaft position is determined.

Encoder, Absolute. A digital position transducer in which the output is representative of the absolute position of the input shaft within one (or more) revolutions. Output is usually a parallel digital word.

Encoder, Incremental. A position encoding device in which the output represents incremental changes in position.

Encoder, Linear. A digital position transducer that directly measures linear position.

Encoder, Marker. A once-per-revolution signal provided by some incremental encoders to specify a reference point within that revolution. Also known as Zero Reference signal or index pulse.

Encoder Resolution. A measure of the smallest positional change that can be detected by the encoder.

Engagement Time (Brake/Clutch). The time required, from the moment the clutch receives the appropriate electrical signal, for the magnet to attract the armature and the clutch faces are engaged.

Explosion-proof. A motor classification that indicates a motor is capable of withstanding internal explosions without bursting or allowing ignition to reach beyond the confines of the motor frame.

Fall Time. The time for the amplitude of system response to decay to 37% of its steady-state value after the removal of a steady-state input signal.

Feedback. A signal that is transferred from the output back to the input for use in a closed loop system.

Feed Forward. A technique used to pre-compensate a control loop for known errors due to motor, drive, or load characteristics. Provides improved response.

Filter (control systems). A transfer function used to modify the frequency or time response of a control system.

Flutter. Flutter is an error of the basic cycle of an encoder per one revolution.

Following Error. The positional error during motion resulting from use of a position control loop with proportional gain only.

Form Factor. The ratio of RMS current to average current. This number is a measure of the current ripple in a PWM or other switch mode type of controller. Since motor heating is a function of RMS current while motor torque is a function of average current, a form factor greater than one means some fraction of motor current is producing heat but not torque.

Four Quadrant. Refers to a motion system which can operate in all four quadrants i.e. velocity in either direction or torque in either direction. This means that the motor can accelerate, run, and decelerate in either direction.

Friction. Friction is defined as the resistance to motion caused by surfaces rubbing together. Friction can be a constant with varying speed (Coulomb) or proportional to speed (Viscous).

Full Load Current. The armature current of a motor operated at its full load torque and speed with rated voltage applied.

Full Load Speed. The speed of a motor operated with rated voltage and full load torque.

Gain. The ratio of system output signal to system input signal. The control loop parameter that determines system performance characteristics.

Hall Sensors. A feedback device, sensitive to magnetic fields, that is used in brushless servo motors to provide information for the amplifier to electronically commutate the motor. The device uses a magnetized wheel and Hall effect sensors to generate the commutation signals.

Home Position. A reference position for all absolute positioning movements. Usually defined by a home limit switch and/or encode marker. Normally set at power up and retained for as long as the control system is operational.

HP (Horsepower). One horsepower is equal to 746 watts. Since Power = Torque X Speed, horsepower is a measure of a motor's torque and speed capability (e.g. a 1 HP will produce 35 lb-in. at 1800 RPM).

Holding Torque (Step Motor). Sometimes called static torque, holding torque specifies the maximum external torque that can be applied to a stopped, energized motor without causing the rotor to rotate continuously. Generally used as a figure of merit when comparing motors.

Host Computer. A computer system that is connected to a controller or controllers. The host computer in distributed control systems is frequently involved with controlling many remote and distributed motion control devices. It may also by used for off-line tasks such as program preparation, storage, and supervisory control and evaluation.

Hunting. The oscillatory response of a system response about a theoretical steady-state value.

Hybrid Step Motor. A motor designed to move in discrete increments or steps. The motor has a permanent magnet rotor and a wound stator. Such motors are brushless. Phase currents are commutated as a function of time to produce motion.

Hysteresis. The difference between the position when approached from one direction and the same position when approached from the opposite direction.

I/O (Input/Output). The reception and transmission of information between control devices. In modern control systems, I/O has two distant forms: switches, relays, etc., which are either an on or off state; or analog signals that are continuous in nature such as speed, temperature, flow, etc.

Idle Current Reduction. A stepping motor driver feature that reduces the phase current to the motor when no motor motion (idle) is commanded for a specified period of time. This reduces motor heating and allows higher machine throughput to be obtained from a given motor.

Incremental Motion. Incremental motion is motion which is characterized by a series of discrete steps. It is the type of motion produced by a step motor system. The motion may have an acceleration phase, a deceleration phase, and it may also have a constant velocity phase.

Inductance (mutual). The property that exists between two current carrying conductors or coils when magnetic lines of force from one link with those of the other.

Inductance (self). The self-inductance of a coil is the constant by which the time rate of change of the current in the coil must be multiplied to give the self-induced counter EMF.

Inertia. A measure of an object's resistance to a change in velocity. The larger an object's inertia, the greater the force or torque required to accelerate or decelerate it. Inertia is a function of an object's mass and shape. For the most efficient operation of rotary systems, the system coupling ratio should be selected so that the reflected inertia of the load is equal to or greater than 10 times the rotor inertia of the motor.

Inertial Match. An inertial match between motor and load is obtained by selecting the coupling ratio such that the load moment of inertia referred to the motor shaft is equal to the motor moment of inertia.

Inner & Outer Pole (face) (Brake/ Clutch). Areas of the rotor that form the magnetic flux path and torque carrying friction within a clutch. In a brake the case assembly forms these poles.

In-rush Current. The current surge generated when a piece of equipment such as a servo amplifier is connected to an AC line. This surge is typically due to the impulse charging of a large capacitor located in the equipment.

Instability. Undesirable motion of an actuator that is different from the command motion. Instability can take the form or irregular speed or hunting of the final rest position.

Intelligent Drive. An Intelligent Drive is a processor-based, programmable control and driver unit with built-in network communications. A unique feature of this device is that by design, it eliminates the need for pulse generation and interpretative circuitry, resulting in a complete control system for essentially the same cost as most stand-alone drives.

Lead Screw. A device for translating rotary motion into linear motion, consisting of an externally threaded screw and an internally threaded carriage (nut).

Lead Ball Screw. A lead screw that has its threads formed as a ball bearing race; the carriage contains a circulating supply of balls for increased efficiency.

Limits. A properly designed system has sensors called limits that alert the control electronics that a physical end of travel is being approached and that the motion is not allowed in a specific direction.

Linear Coordinated Move. A coordinated move where the path between endpoints is a line.

Linearity. For a speed control system it is the maximum deviation between actual and set speed expressed as a percentage of set speed.

Load. Any external static or dynamic resistance to motion that is applied to the motor. The characteristics of the load can be defined as: Coulomb Friction, Viscous Friction, Inertial, etc.

Load Angle (Step Motor)

Static Load Angle. Static Load Angle is the angle through which the rotor is displaced from its energized stable equilibrium position by a given applied torque at a specified current.

Dynamic Load Angle. The Dynamic Load Angle is the angle between the loaded and unloaded position (theoretical zero) of the rotor at a given instant under otherwise identical conditions at a specified command pulse rate, mode of winding excitation and phase current.

Logic Ground. The logic ground is the reference “zero” voltage to which a group of control signals in a particular system are referenced.

Loop Gain, Open. The product of the forward path and feedback path gains.

Loop, PID (Proportional, Integral, and Derivative Loop). Specialized very high performance control loop that gives superior response.

Loop, Position. A feedback control loop in which the controlled parameter is motor position.

Loop, Velocity. A feedback control loop in which the controlled parameter is mechanical velocity.

Master Slave Motion Control. A type of coordinated motion control where the master axis position is used to generate one or more slave axis position commands.

Matched Load. A load inertia equal to the driving element (motor rotor) inertia.

Maximum Reversing Rate (Step Motor). The maximum pulse rate at which an unloaded step motor is able to reverse and remain in synchronism.

Maximum Slew Rate (Step Motor). The Maximum Slew Rate is the maximum velocity at which an unloaded stepping motor can remain synchronous with the command pulses under the specified drive conditions. This velocity is usually defined in the full step mode of 1.8º steps or as shaft speed in revolutions per second.

Mechanical Damper. A device of known inertia that attaches to a step motor shaft for damping step oscillations and preventing resonance.

Mechanical Time Constant. The time for an unloaded motor to reach 63.2% of its final velocity after the application of a DC armature voltage.

Microstepping. Microstepping refers to a control technique that proportions the current in a step motor’s windings to provide additional intermediate positions between poles. The advantage of microstepping is the smooth rotation with a reduction of system resonances over a wide speed range and high positional resolution.

Motor, AC. A device that converts electrical alternating current into mechanical energy. Requires no commutation devices such as brushes. Normally operated off commercial AC power. Can be single or multiple phases.

Motor, AC Asynchronous or Induction. An AC motor in which speed is proportional to the frequency of the applied AC. Requires no magnets or field coil. Usually used for non-precise constant speed applications.

Motor, AC Synchronous. Another term for brushless DC motor.

Motor Constant. The ratio of the motor torque to motor input power.

Motor, DC. A device that converts electrical direct current into mechanical energy. It requires a commutating device, either brushes or electronic. Usually requires a source of DC power.

Motor, DC Brushless. A type of direct current motor that utilizes electronic commutation rather than brushes to transfer current.

Motor, DC Permanent Magnet. A motor utilizing permanent magnets to produce a magnetic field. Has linear torque speed characteristics.

Motor, DC Wound Field. A direct current utilizing a coil to produce a magnetic field. Usually used in high power applications where constant horsepower operation is desired.

NC, Numerical Control. Usually refers to any type of automated equipment or process used for contouring or positioning.

Negative Feedback. The type of feedbacks used in a closed loop system where the output value is inverted and combined with the input to be used to stabilize or improve system characteristics.

No Load Speed. Motor speed with no external load.

Open Collector. A term used to describe a signal output that is performed with a transistor. An open collector output acts like a switch closure with one end of the switch at ground potential and the other end of the switch accessible.

Open Loop System. An open loop motor system is a system where no external sensors are used to provide position or velocity feedback signals, such as encoder feedback of position. Step motor systems are typically open loop systems.

Operator Interface. A device that allows the operator to communicate with a machine. This device typically has a keyboard or thumbwheel to enter instructions into the machine. It also has a display device that allows the machine to display messages.

Optically Isolated. A system or circuit that transmits signals with no direct electrical connection. Used to protectively isolate electrically noisy machine signals from the low-level control logic.

Oscillation. An effect that varies periodically between two values.

Overshoot (Transient). The Overshoot (transient) is the peak angular distance the shaft of a motor rotates beyond the final position under the specified drive and load conditions.

Phase (Step Motor). A motor phase is a set of electrically excited stator poles, consisting of one or more pairs of oppositely polarized poles. Step motor manufactures provide 4 lead motors with bifilar ratings and 6 or 8 lead motors with unifilar ratings.

Phase-Locked Servo System. A hybrid control system in which the output of an optical tachometer is compared to a reference square wave signal to generate a system error signal proportional to both shaft velocity and position errors.

Phase Margin. The difference between 180 degrees and the phase angle of a system at the frequency where the open loop gain is unity.

PID. Proportional-Integral-Derivative. An Acronym that describes the compensation structure that can be used in a closed-loop system.

PLC. Programmable Logic Controller. Also known as a programmable controller, these devices are used for machine control and sequencing.

PMDC Motor. A motor consisting of a permanent magnet stator and a wound iron-core rotor. These are brush type motors and are operated by application of DC current.

Point-to-Point Move. A multi-axis move from one point to another where each axis is controlled independently. (No coordination between axes is required.)

Pole Pair, Electromechanical. The number of cycles of magnetic flux distribution in the air gap of an electromechanical device.

Position Error. The difference between the present actuator (feedback) value and the desired position command for a position loop.

Position Feedback. Present actuator position as measured by a position transducer.

Positional Error (Step Motor). Position error (sometimes designated “Absolute Accuracy”) is the deviation from the theoretically correct angular position of any step position in a complete revolution. The zero position used in determining the theoretically correct angular position is the midpoint between the two extremes of position error. It is expressed as either percentage of the nominal full step or as an angular measure and is noncumulative. It is measured under rated motor conditions.

Power Dissipation (Step Motor). The heat generated by a step motor during standstill operation or while responding to a command pulse rate is expressed by the mathematical equation:

$P \text{ (watts)} = I^2 * R$ for single phase operation

$P \text{ (watts)} = I^2 * R * 2$ for dual phase or microstep operation

Where the square of the drive output current (I) times the motor resistance (R) is the dissipated heat generated in the motor.

Process Control. A term used to describe the control of machine or manufacturing processes, especially in continuous production environments.

Pull-In Step Rate. The pull-in step rate or error-free start speed for a step motor is the maximum command pulse rate (constant) at which the energized stepping motor can accelerate an applied load from standstill to command pulse step rate, synchronously without missing steps.

Pull-In Torque. The pull-in torque for a step motor is the maximum positive coulomb friction torque which an energized stepping motor will accelerate to command pulse rate, and run synchronously with the command pulse rate without losing steps, under specified conditions.

Pull-Out Step Rate. The pull-out step rate is the maximum command pulse rate (constant) at which an energized step motor can run synchronously with the command pulse rate under specified conditions.

Pull-Out Torque. Pull-out torque is the maximum positive coulomb friction torque which can be applied to the rotating shaft of a step motor (already running in synchronism with the command pulse rate at a given command

pulse rate and conditions of drive circuit without missing a step, under specified conditions.

Pulse Width Modulation (PWM). Pulse width modulation. An acronym that describes a switch-mode control technique used in amplifiers and drivers to control motor voltage and current. This control technique is used in contrast to linear control and offers the advantages of greatly improved efficiency.

Quadrature. Refers to signal characteristics of interfaces to positioning devices such as encoders or resolver's. Specifically, that property of position transducers that allows them to detect direction of motion using the phase relationship of two signal channels.

Ramping (Step Motor). The process of controlling the rate of change of pulse frequency to accelerate or decelerate the rotor from one speed to another. Ramping increases the capability of driving the motor and load to higher speed levels.

Rated Torque. The torque producing capacity of a motor at a given speed. This is the maximum continuous torque the motor can deliver to a load and is usually specified with a torque/speed curve.

Regeneration. The action during motor braking in which the motor acts as a generator and takes kinetic energy from the load, converts it to electrical energy, and returns it to the amplifier.

Repeatability. The degree to which the positioning accuracy for a given move performed repetitively can be duplicated.

Residual Magnetism. The condition in electromagnets where low level magnetism remains after the electrical current is removed.

Resolution. The smallest positioning increment that can be commanded. Frequently, resolution is defined as the number of increments per one complete revolution of the motor's shaft.

Resolver. A position transducer utilizing magnetic coupling to measure absolute shaft position over one revolution.

Resonance. The effect of a periodic driving force that causes large amplitude increases at a particular frequency. (Resonance frequency.)

Resonance (Step Motor). Since a step motor system is a discrete incremental positioning system, it is subject to the effects of resonance, where the system is operated at this given frequency it may begin oscillating. Primary resonance frequency occurs at about one revolution per second. This oscillating will cause a loss of effective torque and may result in loss of synchronism. When an application is being considered the design should allow for working outside the primary resonance frequency or by utilizing half step or microstepping techniques to reduce or shift the resonance frequency. The Resonance Frequency may also be shifted by changing the system friction or inertia.

Response Range (Step Motor). The frequency range over which the motor can start, stop or reverse at fixed frequency without missing steps.

Response Rate (Step Motor). The pulse rate an unloaded motor can follow from a standing start without missing steps.

Response Time (Step Motor). The time a step motor will require to move a load a specified distance. This is usually defined as that time from switching the winding "on" until the load comes to rest at the end of the motion.

Restoring Torque (Step Motor). The maximum torque that can be externally applied to the shaft without causing continuous rotation when one phase of the motor is energized. Sometimes referred to as the stall torque.

RFI. Radio frequency interference.

Ringing. This term refers to the oscillation that may occur in a system following a sudden change in velocity or position state.

Rise Time. The time required for a signal to rise from 10% of its final value to 90% of its final value.

RMS Current. Root mean square current. In an intermittent duty cycle application, the RMS current is equal to the value of steady state current which would produce the equivalent resistive heating over a long period of time.

RMS Power (Step Motor). The root mean square power of a stepper is the effective value of time varying power consumption of the step motor. A stepper can be driven at a boosted current of up to 30% of rated to generate increased torque, after a limited time and the motor heat dissipation capabilities are exceeded resulting in motor failure. To prevent this failure most drive systems allow for "reduced power" and "no-power" modes. The RMS power is mathematically determined by taking the square root of the summation of the products of the power squared multiplied by the specific time periods of power application divided by the summation of the time periods.

$$P_{RMS} = \sqrt{\frac{\sum P_i^2 * t_i}{\sum t_i}}$$

RMS Torque. Root mean square torque. For an intermittent duty cycle application, the RMS torque is equal to the steady state torque which would produce the same amount of motor heating over long periods of time.

Robot. A re-programmable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

Robot Control. A computer-based motion control device to control the servo-axis motion of a robot.

Rotor. The rotating part of a magnetic structure. In a motor, the rotor is connected to the motor shaft.

Rotor (Brake/Clutch). The rotating component in a clutch that is generally attached (keyed or pinned) to the input (motor) shaft.

Serial Port. A digital data communications port configured with a minimum number of signal lines. This is achieved by passing binary information signals as a timed series of “1”s and “0”s on a signal line.

Servo Amplifiers/Servo Drive. An electronic device that produces the winding current for a servo motor. The amplifier converts a low level control signal into a high voltage and current levels top produce torque in the motor.

Servo System. An automatic feedback control system for mechanical motion in which the controlled or output quantity is position, velocity, or acceleration. Servo systems are closed loop systems.

Settling Time. Settling time is the total time from the application of a stop command signal until the amplitude of any oscillatory motion of the rotor has diminished to a specified level under specified conditions.

Shunt Resistor. A device located in a servo amplifier for controlling regenerative energy generated when braking a motor. This device dissipates or “dumps” the kinetic energy as heat.

Single Point Ground. The common connection point for signal grounds in a control wiring environment.

Slew. Refers to the move profile of a motor operating at a constant non-zero velocity.

Slew Rate (Step Motor). An area of high-speed operation above the pull in curve where the motor can run unidirectional without missing steps. However, it cannot instantaneously start, stop, or reverse.

Speed Regulation. For a speed control system, speed regulation is the variation in actual speed expressed as a percentage of set speed.

Stall Torque. The maximum torque that can be externally applied to a powered motor shaft without causing continuous rotation.

Start-Stop Rate (Step Motor). The maximum switching rate at which an unloaded step motor can run without losing synchronism, or missing steps from a standstill, or stop without taking more steps than pulses.

Static Torque (Step Motor). Static torque is the peak torque that can be applied to the shaft of an energized motor at stand still, also called “holding torque”. The mode of winding excitation and applied current shall be specified.

Stator. The non-rotating part of a magnetic structure. In a motor the stator usually contains the mounting surface, bearings, and non-rotating windings or permanent magnetics.

Step (Step Motor). A full step is the increment in angular position of the rotor between any two adjacent stable equilibrium points, typically 1.8° increments.

Step Angle. The motor shaft rotates a specific angular increment each time the motor receives an electrical step signal. This specific degree of rotation or increment is called the step angle. It is specified in degrees and is determined by the electro-mechanical construction of the motor.

Step Angle Error (Step Motor). (Sometimes designated “Incremental Step Accuracy”) This is the maximum plus or minus deviation from the rated incremental angular motion per step, for any adjacent steps in a complete revolution without reversing direction. It is expressed as a percentage of the angle of the nominal step.

Step Sequence (Step Motor). The sequence of excitation defined by the drive logic, (translator logic), which is the repeatable cyclic pattern by which the windings are energized for unidirectional motion.

Stepping Frequency. The number of steps executed per second by a step motor shaft at a constant control frequency.

Stepping Motor. A stepping motor is a polyphase synchronous inductor motor, the rotor of which rotates in discrete angular increments when the stator windings thereof are energized in a programmed manner either by appropriately timed D.C. states or by a polyphase A.C. Rotation occurs because of the magnetic interaction between the rotor poles and the poles of the sequentially energized stator phases.

Variable Reluctance (VR). A variable reluctance stepping motor utilizes a rotor which has pole salients (soft iron) without magnetic bias in the de-energized state.

Permanent Magnetic (PM). A permanent magnet stepping motor utilizes a rotor which has magnetized poles.

Hybrid (HY). A hybrid stepping motor utilizes a permanent magnetic to polarize soft iron pole pieces.

Steps Per Revolution (Step Motor). This term describes the total number of steps required for the output shaft to rotate 360° or one complete rotation. Steps per revolution are calculated by dividing the step angle into 360°.

Steps Per Second or Pulse Rate. The number of angular movements accomplished by a step motor in one second of time. This figure replaces the RPM figure of a standard drive motor.

Stiffness. Ratio of an applied force or torque to change in position for a mechanical system.

Stiffness (Step Motor). (Sometimes called “Torque Gradient”) is the derivative (slope) of the torque verse angle curve. The curve is the sum of the stiffness due to holding torque and detent torque.

Synchronism. Synchronism exists when a step motor’s output is correctly corresponding to the system’s input signals. Load torques exceeding the motor’s capabilities will cause loss of synchronism. This condition is not damaging to the step motor.

Tachometer. An electromagnetic feedback transducer that produces an analog voltage signal proportional to rotational velocity. Tachometers can be either brush or brushless.

Thermal Resistance. Thermal resistance is the opposition to the flow of heat in the materials of which the motor is constructed. It is expressed as degrees Celsius per watt. All measurements are taken after steady state conditions have been achieved with a specified heatsink and in still air.

Thermal Resistance (Winding to Frame). This is the measured difference in temperature between the winding and the specified point on the surface of the motor divided by the total electrical power input to the motor.

Thermal Resistance (Frame to Air). This is the same as Thermal Resistance (Winding to Frame), except that the temperature difference is the temperature at a specified point on the surface of the motor and the ambient air surrounding the motor.

Thermal Time Constant. This is the time required for the winding temperature of a motor to reach 63% of its steady state temperature rise with constant power applied to the motor. It is measured by allowing the motor to reach steady state temperature and then disconnecting the electrical power input. The winding temperature is recorded as a function of time, zero time being the time at which the power source is disconnected. The time required to drop 37% from the steady state temperature rise is the thermal time constant. Usually expressed in minutes.

Time to Speed (Brake/Clutch). The sum of engagement time and acceleration time at which the load is fully engaged and at speed.

Time to Zero (Brake/Clutch). The time required to fully disengage the motor from its load, thus allowing the load to drop to zero speed. **Note:** Factors such as system friction and inertia naturally play an important role in both of these critical measurements.

Torque. The rotary equivalent to force. Equal to the product of the force perpendicular to the radius of motion and distance from the center of rotation to the point where the force is applied.

Torque Constant. A number representing the relationship between input current and motor output torque. Typically expressed in units of torque/amp.

Torque Gradient (Step Motor). The average slope of the torque displacement curve over a specified angle through the origin.

Torque Ripple. The cyclical variation of generated torque given by the product of motor angular velocity and number of commutator segments.

Torque-to-Inertia Ratio. The ratio of rated holding torque of a step motor or the stall torque of a DC or brushless motor to its rotor inertia. The higher the torque-to-inertia ratio, the faster the response with a given drive.

Transducer. Any device that translates a physical parameter into an electrical parameter. Tachometers and encoders are examples of transducers.

Translator Logic. Translator logic (Drive Logic) for step motors converts the signal channel pulse train into multi-channel states to be applied to the power amplifier (Drive) which energizes the step motor.

Transfer Function: The ratio of the Laplace transforms of system output signal and system input signal.

Trapezoidal Profile. A motion profile in which the velocity vs. time profile resembles a trapezoid. Characterized by constant acceleration, constant velocity, and constant deceleration.

Undercut (Brake/Clutch). A process of cutting back one of the pole surfaces in relation to the other. Generally done to reduce any residual magnetism or to derate a device. Also a term used to describe the recessing of friction material so as to effect a more efficient burnished condition.

Unifilar Winding. The term Unifilar winding refers to the winding configuration of a step motor where each stator pole has one set of windings, (4 electrical phases), the motor will have only 4 lead wires. This winding configuration can only be driven from a bipolar drive design.

Unipolar Drive. The term Unipolar refers to a specific type drive that is connected to a step motor configured for 4 phase operation. A unipolar drive can only be utilized with a bifilar wound motor, 6 or 8 leads.

Variable Frequency Drives. An electronic device used to control the speed of a standard AC induction motor. The device controls the speed by varying the frequency of the winding current used to drive the motor.

Vector Control. A method of obtaining servo type performance from an AC motor by establishing a controlled flux vector in the motor's air gap.

Velocity. The change in position as a function of time. Velocity has both a magnitude and a direction.

Viscous Damper. A device containing a fluid that provides a retarding torque during motion. At zero velocity, there is no retarding torque. The higher the velocity, the higher the torque. Normally used with step motos to promote smooth operation and prevent oscillations.

Voltage Constant (or Back-EMF Constant). A number representing the relationship between Back-EMF voltage and angular velocity. Typically expressed as V/kRPM.

Winding Inductance. The winding inductance of a motor. Specified values are typically for each phase of a step motor, the line-to-line value of a brushless motor, or the rotor winding of a DC motor. When a figure for inductance is given, the conditions under which the measurements were taken must be quoted.

Winding Resistance. Winding resistance is the lead-to-lead (terminal-to-terminal) ohmic resistance of a motor's winding measured with the windings at 25°C.