4020 Linear Servo Amplifier

P/N: EDA105 (Revision: 1.02.00)

Dedicated to the Science of Motion

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CHAPTER 1: DESCRIPTION

The Aerotech Model 4020 (40-volt, 20-amp) Linear Servo Controller (Figure 1-1) provides a unique combination of high reliability, compact design, high output power, high power dissipation, noiseless performance, and ease of operation. The power output stage contains all linear NPN power transistors for reliable, second-breakdown-free operation.

The servo controller consists of a 741-type pre-amplifier with rate and position loop compensation, driving a power amplifier configured in a current feedback mode.

The pre-amplifier has three adjustable scale factors for the inverting input, a non-inverting input, balance adjustment and a gain adjustment for the lag-lead compensation. The lag-lead network, along with the three inverting input resistors, are mounted on stand-offs for quick easy replacement.

The power stage operates in the linear mode (Class B) for wide bandwidth and quiet, reliable operation.

Figure 1-1: The 4020-LS Amplifier

Adjustable current limiting prevents motor demagnetization and directional current limits, initiated by limit switch or relay closures, decrease the torque available in only one direction for limited travel motor loads.

The fused, isolated, power supply operates from 115 VAC (or optional 230 VAC) and provides all necessary operating voltages, in addition to regulated ±15 volts for external use.

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CHAPTER 2: SPECIFICATIONS

2.1. Maximum Ratings and Electrical Characteristics

Table 2-1: 4020-LS Amplifier Ratings and Characteristics

Specifications	Units	4020
Peak Output Current (2 sec)	Amps	± 20
Continuous Output Current	Amps	± 5
Output Fuse (3AG, slow blow)	Amps	5
Peak Output Voltage	Volts	± 40
Peak Power Dissipation	Watts	1000
Continuous Power Dissipation(1)	Watts	250
Voltage Gain (max open loop)	dB	100
Drift (referred to input)	µV/°C	10
Offset	Volts	Adjustable to Zero
Operating Temperature	°C	0 to 50
Storage Temperature	°C	-30 to 80
Weight	kg (lb)	6.4 (14)
Power Amplifier		
Gain	Amps/Volt	2
Bandwidth	Hz	500
Peak Power Output	Watts	500
Continuous Power Output	Watts	160
Current Limit(2)	Amps (max)	2
Shutdown(2)	Amps (max)	1
Minimum Load Inductance	mH	0
Dimensions (L x W x H)	mm (in)	238.1 (9.38) x 185.6 (7.3) x 152.4 (6)

1. Derate at 2.0 watts per °C above 25°C.
2. Requires a closure with current handling capability of 20 mA.
3. Unless otherwise stated, ratings are at 25°C.

2.2. Outline Drawings

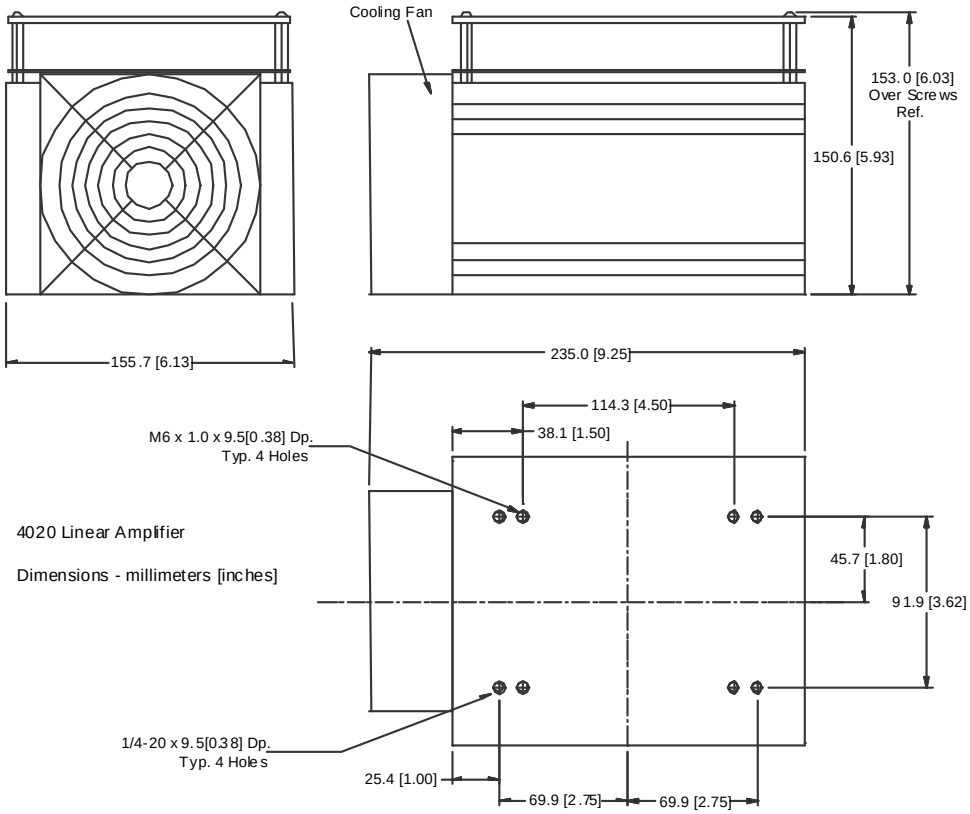

Figure 2-1: 4020-LS Amplifier Outline Drawing

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CHAPTER 3: INSTALLATION and OPERATION

3.1. Input/Output Connections

3.1.1. AC Power Input

The input power required is 115 VAC, 5 amp (optional wiring: 230 VAC, 2.5 amp). The fan requires a 50/60 Hz source. AC input terminals are TB2-15 and 16. TB2-15 is fused with a 5 amp (3 amp for optional 230 V wiring) slow blow 3AG fuse.

The amplifier must be installed in an earth grounded enclosure. Operator access to the amplifier must be prevented while the unit is connected to the mains power source.

3.1.2. Input Commands

Four inputs are available for input and feedback signals. Inputs TB1-1, 2, and 3 sum to the inverting input of the preamplifier, and TB1-5 enters the non-inverting input. Any of the inputs can be used for command or feedback signals. Aerotech drive systems usually connect tachometer feedback to 3, and velocity commands or position feedback to input 1. The input resistance ranges from about 6.5K to 18K ohm. Input signal commons should be connected to TB1-4, 6, or 9. These commons are connected on the card to power ground, TB1-12.

3.1.3. Directional Current Limits

TB1-7 and 8 are available to inhibit current flow of a specific polarity for limited travel motor loads. If TB1-7 is connected to TB1-6, current flow is inhibited from TB1-11 to 10 but not from TB1-10 to 11. If TB1-7 is connected to TB1-8, current flow is inhibited from TB1-10 to 11 but not from TB1-11 to 10. If TB1-6 is connected to TB1-8, all current flow is inhibited.

3.1.4. Load Connections

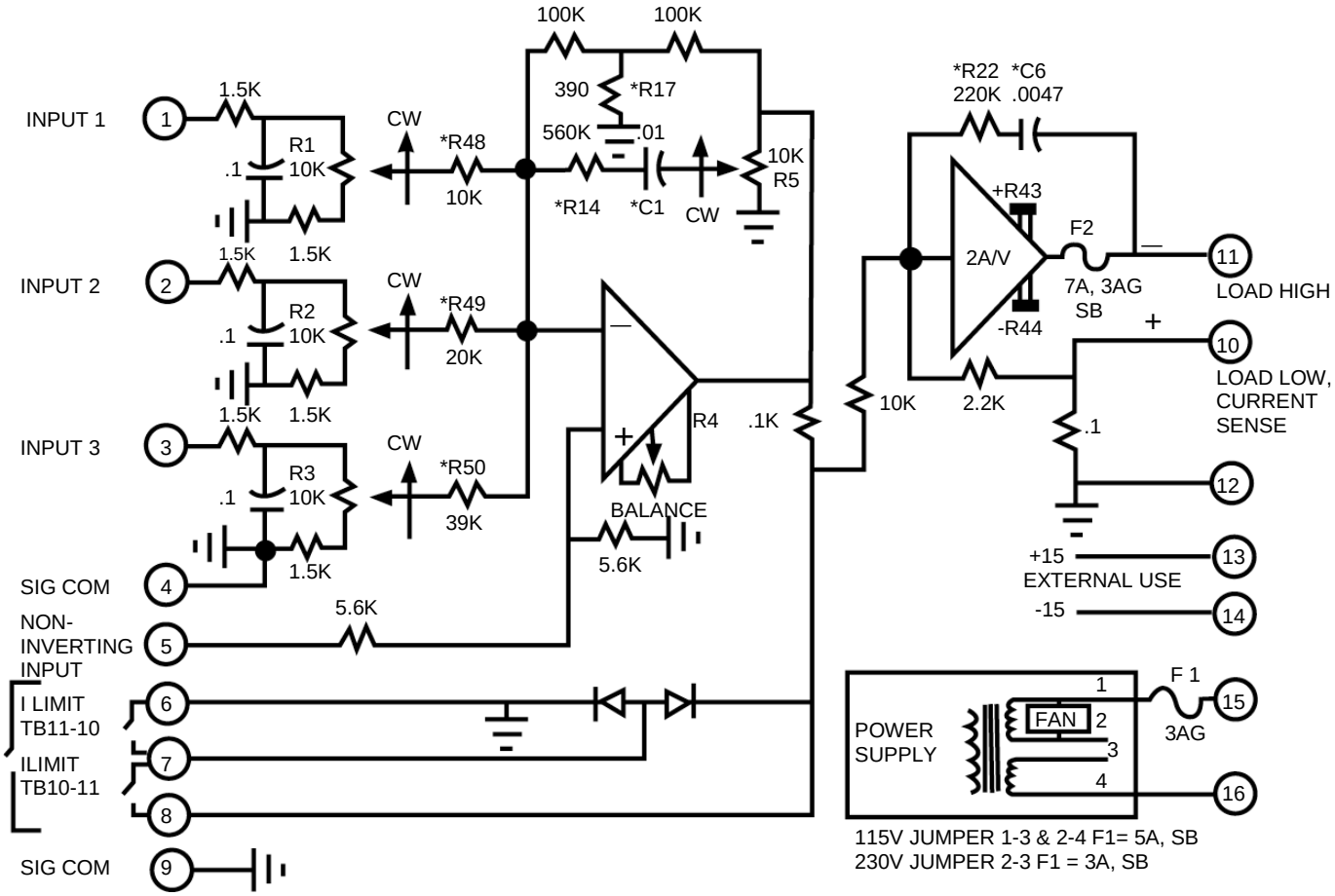
The load is connected from TB1-10 to 11 and “floats”. Connecting either TB1-10 or 11 to ground can damage the power stage.

3.1.5. Supplies for External Use

Regulated + and – 15 VDC at .03 amp is available at TB1-13 and 14 for customer use. The 15V common can be pin 4, 6, 9, or 12.

3.2. Compensation

The pre-amplifier compensation consists of a lag-lead network shown in Figure 3-1, with the frequency response shown on the pre-amplifier transfer function graph of Figure 3-2. The lag is caused by C1 and the lead results from R14. An additional lag at about 1000 Hz results from the 1.5K/.1uf input filter on each of the three inverting inputs. The DC gain is determined by the input resistance and potentiometer setting (R48 and pot R1 for input 1) along with R17 and the two 100K ohm resistors on either side. For example, with R1 maximum CW, the pre-amplifier DC gain would be about 2500V/V (68 dB); since the power amplifier is 2 amp/volt, overall DC gain is 5000 amp/volt. The AC gain is a function of frequency, R1 and R5 potentiometer settings, as shown on the pre-amplifier transfer action graph (Figure 3-2).



* INDICATES COMPONENTS MOUNTED ON STAND-OFFS: R IN OHMS, C IN MICROFARADS

R43 CW DECREASES OUTPUT CURRENT FORM TB1-11 TO 10 (+AT TB1-10)
R44 CW DECREASES OUTPUT CURRENT FORM TB1-10 TO 11 (-AT TB1-10)

Figure 3-1: Functional Schematic

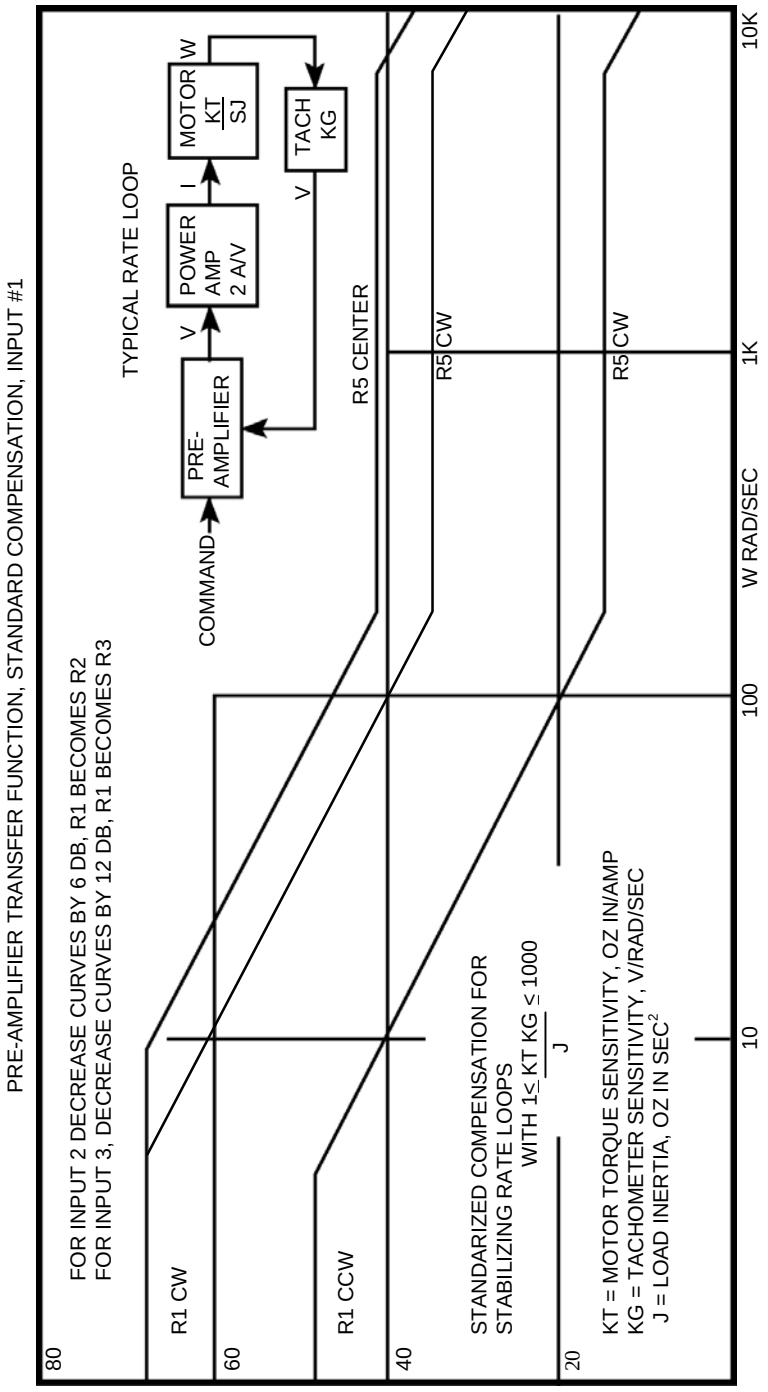


Figure 3-2: Pre-Amplifier Transfer Function Graph

3.3. Adjustments

3.3.1. Current Limit Adjustments

The current can be measured by monitoring TB1-10 (.1 volts/amp) with an oscilloscope. Turn R43 and R44 maximum CW (minimum current limit). Since there is a continuous output current limit of 5 amps, apply a square wave input command to make peak currents above the continuous rating. When the square wave is commanding a positive current (positive voltage to non-inverting input or negative voltage to inverting input, current flow from the TB1-10 to TB1-11, negative current sense voltage at TB1-10) adjust R44 until the desired positive current limit is obtained. When the square wave is commanding a negative current (negative voltage to non-inverting input or positive voltage to inverting input, current flow from TB1-11 to TB1-10, positive current sense voltage at TB1-10) adjust R43 until the desired negative current limit is obtained.

3.3.2. Gain and Scale Factor Adjustments

Scale factor adjustments are R1, R2, and R3 for inputs 1, 2, and 3 respectively. The GAIN adjustment is R5. Connect the tachometer to input 3, turn R3 and R5 max CW, connect the motor and apply AC power. If the system runs away when AC power is applied, reverse the motor or tach connections. If the motor rotates slowly in either direction, adjust the balance, R4. Adjust R5 CCW until the motor oscillates, then adjust CW until oscillation ceases – continue 1/8 to 1/16 turn further. Apply velocity commands or position feedback to input 1 or 2 and adjust scale factor for that input to obtain proper speed or response.

Input 1 will command greater speed than input 2 because R48 is smaller than R49. If the speed is too fast with the scale factor full CCW, increase R48 or R49. If the speed is too slow with the scale factor full CW, R3 can be adjusted CCW – if R3 is adjusted, R5 will require readjustment.

3.3.3. Balance Adjustment

The pre-amplifier balance (R4) should be adjusted so that with zero input command, the tach voltage, or current monitor voltage is minimal. Or visually observe the motor and adjust R16 until the motor does not rotate. If it is determined that the balance is difficult to adjust and DC gain can be sacrificed, R17 can be increased.

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CHAPTER 4: MAINTENANCE

This solid state servo controller requires no maintenance. If it is desired, the balance can be checked as mentioned in Section 3.3.3. at three or six month intervals; and the PC card and heat sinks for an accumulation of dirt if operated in a dirty environment.

4.1. Troubleshooting

Troubleshooting will be aimed at determining whether the unit is defective and needs to be returned to the factory for repair. The symptoms will be those for a motor/tach system.

4.1.1. Motor Runs Away

If the motor runs away at maximum speed with no input commands, the problem can be an open tach, wrong tach phasing, or power amplifier failure.

Table 4-1: Motor Runs Away

Open Tachometer	Measure the tachometer input terminals and verify that tachometer feedback voltage is being returned.
Tach Phasing	If the tachometer phasing is questioned, the simplest check is to reverse motor or tach leads.
Power Amplifier Latched-up	To verify that the 4020 or 2020 power stage is not latched-up, suort TB1-8 to 6. This will command zero current out and TB1-11 should be near 0 volts; if TB1-11 is near ± 40 volts, the power stage has failed.
Pre-Amplifier Latch-up	To verify that the pre-amplifier is not at fault, remove all input signals and lift one side of R17 (this places the pre-amplifier in a low DC gain). The voltage at TB1-8 should be less than 1 volt.

4.1.2. Blown Fuse

Table 4-2: Blown Fuse

AC Fuse (F1) Open	The AC fuse open usually indicates a power supply failure or power stage short. To test for a short in the power stage, remove AC power, the load and ohmmeter the power stage by: 1. Replace F2 if it is open 2. Place the + lead of the ohmeter (X1 scale) on +40 volts (see Figure 4-1) and the – lead to TB1-11. If the reading is under 100 ohms, the power stage has failed. 3. Place the – lead on –40 volts (see Figure 4-1, below) and the + lead to TB1-11. If the reading is under 30 ohms, the power stage has failed. (1) 4. If the above reading does not fail, check the load for a short to ground.
DC Fuse (F2) Open	The load fuse opening usually indicates a shored (to ground) load or a current demand greater than the continuous capability. Check for motor shorts to ground. Before replacing fuse, remove AC power and the load, replace F2 and check the power stage with an ohmmeter by performing steps 1 through 4 from the section above.

1. Resistance readings are taken with a Simpson 260 or equivalent multimeter. If ohmmeter polarities are not observed, low resistance readings will be measured…even for a good power stage.

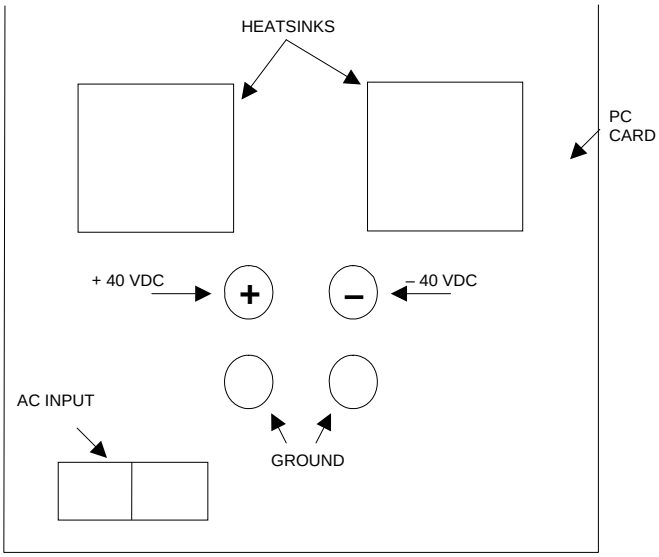

Figure 4-1: Test Procedure for a Short in a Power Stage

4.1.3. Poor Servo Response or Regulation

Poor servo response usually results from improper servo compensation (not enough gain) or adjustment (see Sections 3.2. and 3.3.), or failure to replace R17.

4.1.4. System Oscillation

An unstable system usually results from too much loop gain or mechanical resonances. Scope the tach and observe the frequency of oscillation. If mechanical resonances are suspected, remove the tach feedback, lift one end of R17, turn R5 full CCW, and apply a variable frequency sine wave to a command input. The sine wave magnitude should be low enough so that the current capability of the amplifier is not exceeded. Vary the sine wave frequency through the range of the oscillation that was observed with the tach connected. A mechanical resonance will be indicated by a sizable increase (factor of 10) in tach voltage as the frequency increased)

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APPENDIX A: GLOSSARY OF TERMS

Abbe Error	The positioning error resulting from angular motion and an offset between the measuring device and the point of interest.
Abbe Offset	The value of the offset between the measuring device and the point of interest.
Absolute Move	A move referenced to a known point or datum.
Absolute Programming	A positioning coordinate reference where all positions are specified relative to a reference or “home” position.
AC Brushless Servo	A servomotor with stationary windings in the stator assembly and permanent magnet rotor. AC brushless generally refers to a sinusoidally wound motor (such as BM series) to be commutated via sinusoidal current waveform. (see DC brushless servo)
Acceleration	The change in velocity as a function of time.
Accuracy	An absolute measurement defining the difference between actual and commanded position.
Accuracy Grade	In reference to an encoder grating, accuracy grade is the tolerance of the placement of the graduations on the encoder scale.
ASCII	American Standard Code for Information Interchange. This code assigns a number to each numeral and letter of the alphabet. Information can then be transmitted between machines as a series of binary numbers.
Axial Runout	Positioning error of the rotary stage in the vertical direction when the tabletop is oriented in the horizontal plane. Axial runout is defined as the total indicator reading on a spherical ball positioned 50 mm above the tabletop and centered on the axis of rotation.
Axis of Rotation	A centerline about which rotation occurs.
Back emf, Kemf	The voltage generated when a permanent magnet motor is rotated. This voltage is proportional to motor speed and is present whether or not the motor windings are energized.
Backlash	A component of bidirectional repeatability, it is the non-responsiveness of the system load to reversal of input command.
Ball Screw	A precision device for translating rotary motion into linear motion. A lead screw is a low-cost lower performance device performing the same function. Unit consists of an externally threaded screw and an internally threaded ball nut.
Ball Screw Lead	The linear distance a carriage will travel for one revolution of the ball screw (lead screw).
Bandwidth	A measurement, expressed in frequency (hertz), of the range which an amplifier or motor can respond to an input command from DC to -3dB on a frequency sweep.
Baud Rate	The number of bits transmitted per second on a serial communication channel such as RS-232 or modem.
BCD	Binary Coded Decimal - A number system using four bits to represent 0-F (15).

Bearing	A support mechanism allowing relative motion between two surfaces loaded against each other. This can be a rotary ball bearing, linear slide bearing, or air bearing (zero friction).
Bidirectional Repeatability	See Repeatability.
CAM Profile	A technique used to perform nonlinear motion that is electronically similar to the motion achieved with mechanical cams.
Cantilevered Load	A load not symmetrically mounted on a stage.
Closed Loop	A broad term relating to any system where the output is measured and compared to the input. Output is adjusted to reach the desired condition.
CNC	Computer Numerical Control. A computer-based motion control device programmable in numerical word address format.
Coefficient of Friction	Defined as the ratio of the force required to move a given load to the magnitude of that load.
Cogging	Nonuniform angular/linear velocity. Cogging appears as a jerkiness, especially at low speeds, and is due to magnetic poles attracting to steel laminations.
Commutation	The action of steering currents to the proper motor phases to produce optimum motor torque/force. In brush-type motors, commutation is done electromechanically via the brushes and commutator. A brushless motor is electronically commutated using a position feedback device such as an encoder or Hall effect devices. Stepping motors are electronically commutated without feedback in an open-loop fashion.
Commutation, 6-Step	Also referred to as trapezoidal commutation. The process of switching motor phase current based on three Hall effect signals spaced 120 electrical degrees beginning 30 degrees into the electrical cycle. This method is the easiest for commutation of brushless motors.
Commutation, Modified 6-Step	Also referred to as modified sine commutation. The process of switching motor phase current based on three Hall effect signals spaced 120 electrical degrees beginning at 0 electrical degrees. This method is slightly more difficult to implement than standard 6-step, but more closely approximates the motor's back emf. The result is smoother control and less ripple. Aerotech's BA series self-commutate using this method.
Commutation, Sinusoidal	The process of switching motor phase current based on motor position information, usually from an encoder. In this method, the three phase currents are switched in very small increments that closely resemble the motor's back emf. Sinusoidal commutation requires digital signal processing to convert position information into three-phase current values and, consequently, is most expensive to implement. The result, however, is the best possible control. All Aerotech controllers, as well as the BAS series amplifiers, commutate using this method.
Coordinated Motion	Multi-axis motion where the position of each axis is dependent on the other axis, such that the path and velocity of a move can be accurately controlled. Drawing a circle requires coordinated motion.
Critical Speed	A term used in the specification of a lead screw or ball screw indicating the maximum rotation speed before resonance occurs. This speed limit is a function of the screw diameter, distance between support bearings, and bearing rigidity.

Current Command	Motor driver or amplifier configuration where the input signal is commanding motor current directly, which translates to motor torque/force at the motor output. Brushless motors can be commutated directly from a controller that can output current phase A and B commands.
Current, Peak	An allowable current to run a motor above its rated load, usually during starting conditions. Peak current listed on a data sheet is usually the highest current safely allowed to the motor.
Current, rms	Root Mean Square. Average of effective currents over an amount of time. This current is calculated based on the load and duty cycle of the application.
Cycle	When motion is repeated (move and dwell) such as repetitive back-and-forth motion.
DC Brushless Servo	A servomotor with stationary windings in the stator assembly and permanent magnet rotor. (See AC Brushless Servo)
Deceleration	The change in velocity as a function of time.
Duty Cycle	For a repetitive cycle, the ratio of “on” time to total cycle time used to determine a motor’s rms current and torque/force.
Dwell Time	Time in a cycle at which no motion occurs. Used in the calculation of rms power.
Efficiency	Ratio of input power vs. output power.
Electronic Gearing	Technique used to electrically simulate mechanical gearing. Causes one closed loop axis to be slaved to another open or closed loop axis with a variable ratio.
Encoder Marker	Once-per-revolution signal provided by some incremental encoders to accurately specify a reference point within that revolution. Also known as Zero Reference Signal or Index Pulse.
Encoder Resolution	Measure of the smallest positional change which can be detected by the encoder. A 1000-line encoder with a quadrature output will produce 4000 counts per revolution.
Encoder, Incremental	Position encoding device in which the output is a series of pulses relative to the amount of movement.
Feedback	Signal that provides process or loop information such as speed, torque, and position back to the controller to produce a “closed loop” system.
Flatness (of travel)	Measure of the vertical deviation of a stage as it travels in a horizontal plane.
Force, Continuous	The value of force that a particular motor can produce in a continuous stall or running (as calculated by the rms values) condition.
Force, Peak	The maximum value of force that a particular motor can produce. When sizing for a specific application, the peak force is usually that required during acceleration and deceleration of the move profile. The peak force is used in conjunction with the continuous force and duty cycle to calculate the rms force required by the application.
Friction	The resistance to motion between two surfaces in contact with each other.
G.P.I.B.	A standard protocol, analogous to RS-232, for transmitting digital information. The G.P.I.B. interface (IEEE-488) transmits data in parallel instead of serial format. (See IEEE-488)

Gain	Comparison or ratio of the output signal and the input signal. In general, the higher the system gain, the higher the response.
Grating Period	Actual distance between graduations on an encoder.
Hall Effect Sensors	Feedback device (HED) used in a brushless servo system to provide information for the amplifier to electronically commutate the motor.
HED	Hall Effect Device. (See Hall Effect Sensors)
HMI	Human Machine Interface. Used as a means of getting operator data into the system. Also, refered to as an MMI.
Home	Reference position for all absolute positioning movements. Usually defined by a home limit switch and/or encoder marker.
Home Switch	A sensor used to determine an accurate starting position for the home cycle.
Hysteresis	A component of bidirectional repeatability. Hysteresis is the deviation between actual and commanded position and is created by the elastic forces in the drive systems.
I/O	Input / Output. The reception and transmission of information between control devices using discrete connection points.
IEEE-488	A set of codes and formats to be used by devices connected via a parallel bus system. This standard also defines communication protocols that are necessary for message exchanges, and further defines common commands and characteristics. (See G.P.I.B.)
Incremental Move	A move referenced from its starting point (relative move).
Inertia	The physical property of an object to resist changes in velocity when acted upon by an outside force. Inertia is dependent upon the mass and shape of an object.
Lead Error	The deviation of a lead screw or ball screw from its nominal pitch.
Lead Screw	A device for translating rotary motion into linear motion. Unit consists of an externally threaded screw and an internally threaded carriage (nut). (See Ball Screw)
Life	The minimum rated lifetime of a stage at maximum payload while maintaining positioning specifications.
Limit Switch	A sensor used to determine the end of travel on a linear motion assembly.
Limits	Sensors called limits that alert the control electronics that the physical end of travel is being approached and motion should stop.
Linear Motor	A motor consisting of 2 parts, typically a moving coil and stationary magnet track. When driven with a standard servo amplifier, it creates a thrust force along the longitudinal axis of the magnet track.
Load Carrying Capability	The maximum recommended payload that does not degrade the listed specifications for a mechanical stage.
Master-Slave	Type of coordinated motion control where the master axis position is used to generate one or more slave axis position commands.

MMI	Man Machine Interface used as a means of getting operator data into the system. (See HMI)
Motion Profile	A method of describing a process in terms of velocity, time, and position.
Motor Brush	The conductive element in a DC brush-type motor used to transfer current to the internal windings.
Motor, Brushless	Type of direct current motor that utilizes electronic commutation rather than brushes to transfer current.
Motor, Stepping	Specialized motor that allows discrete positioning without feedback. Used for noncritical, low power applications, since positional information is easily lost if acceleration or velocity limits are exceeded.
NC	Numerical Control. Automated equipment or process used for contouring or positioning (See CNC). Also, Normally Closed, referring to the state of a switch.
NEMA	National Electrical Manufacturer's Association. Sets standards for motors and other industrial electrical equipment.
Non-Volatile Memory	Memory in a system that maintains information when power is removed.
Open Collector	A signal output that is performed with a transistor. Open collector output acts like a switch closure with one end of the switch at circuit common potential and the other end of the switch accessible.
Open Loop	Control circuit that has an input signal only, and thus cannot make any corrections based on external influences.
Operator Interface	Device that allows the operator to communicate with a machine. A keyboard or thumbwheel is used to enter instructions into a machine. (See HMI or MMI)
Optical Encoder	A linear or angular position feedback device using light fringes to develop position information.
Opto-isolated	System or circuit that transmits signal with no direct electrical connections, using photoelectric coupling between elements.
Orthogonality	The condition of a surface or axis perpendicular (offset 90°) to a second surface or axis. Orthogonality specification refers to the error from 90° from which two surfaces of axes are aligned.
Overshoot	In a servo system, referred to the amount of velocity and/or position overrun from the input command. Overshoot is a result of many factors including mechanical structure, tuning gains, servo controller capability, and inertial mismatch.
PID	A group of gain terms in classical control theory (Proportional Integral Derivative) used in compensation of a closed-loop system. The terms are optimally adjusted to have the output response equal the input command. Aerotech controllers utilize the more sophisticated PID FVFA loop which incorporates additional terms for greater system performance.
Pitch (of travel)	Angular motion of a carriage around an axis perpendicular to the motion direction and perpendicular to the yaw axis.
Pitch Error	Positioning error resulting from a pitching motion.
PLC	Programmable Logic Controller. A programmable device that utilizes "ladder logic" to control a number of input and output discrete devices.

PWM	Pulse Width Modulation. Switch-mode technique used in amplifiers and drivers to control motor current. The output voltage is constant and switched at the bus value (160 VDC with a 115 VAC input line).
Quadrature	Refers to the property of position transducers that allows them to detect direction of motion using the phase relationship of two signal channels. A 1000-line encoder will yield 4000 counts via quadrature.
Radial Runout	Positioning error of the rotary stage in the horizontal direction when the tabletop is oriented in the horizontal plane. Radial runout is defined as the total indicator reading on a spherical ball positioned 50 mm above the tabletop and centered on the axis of rotation.
Ramp Time	Time it takes to accelerate from one velocity to another.
Range	The maximum allowable travel of a positioning stage.
RDC	Resolver to Digital Converter. Electronic component that converts the analog signals from a resolver (transmitter type) into a digital word representing angular position.
Repeatability	The maximum deviation from the mean (each side) when repeatedly approaching a position. Unidirectional repeatability refers to the value established by moving toward a position in the same direction. Bidirectional repeatability refers to the value established by moving toward a position in the same or opposite direction.
Resolution	The smallest change in distance that a device can measure.
Retroreflector	An optical element with the property that an input light beam is reflected and returns along the same angle as the input beam. Used with laser interferometers.
Roll (of travel)	Angular motion of a carriage around an axis parallel to the motion direction and perpendicular to the yaw axis.
Roll Error	Positioning error resulting from a roll motion.
Rotor	The rotating part of a magnetic structure. In a motor, the rotor is connected to the motor shaft.
RS-232C	Industry standard for sending signals utilizing a single-ended driver/receiver circuit. As such, the maximum distance is limited based on the baud rate setting but is typically 50-100 feet. This standard defines pin assignments, handshaking, and signal levels for receiving and sending devices.
RS-274	Industry standard programming language. Also referred to as G-code machine programming. A command set specific for the machine tool industry that defines geometric moves.
RS-422	Industry communication standard for sending signals over distances up to 4000 feet. Standard line driver encoder interfaces utilize RS-422 because of the noise immunity.
Runout	The deviation from the desired form of a surface during full rotation (360 degrees) about an axis. Runout is measured as total indicated reading (TIR). For a rotary stage, axis runout refers to the deviation of the axis of rotation from the theoretical axis of rotation.
Servo System	Refers to a closed loop control system where a command is issued for a change in position and the change is then verified

	via a feedback system.
Settling Time	Time required for a motion system to cease motion once the command for motion has ended.
Shaft Radial Load	Maximum radial load that can be applied to the end of the motor shaft at maximum motor speed.
Shaft Runout	Deviation from straight line travel.
Slotless	Describes the type of laminations used in a motor that eliminates cogging torque due to magnetic attraction of the rotor to the stator slots.
Stator	Non-rotating part of a magnetic structure. In a motor, the stator usually contains the mounting surface, bearings, and non-rotating windings.
Stiction	Friction encountered when accelerating an object from a stationary position. Static friction is always greater than moving friction, and limits the smallest possible increment of movement.
Straightness of Travel	Measure of the side-to-side deviation of a stage as it travels in a horizontal plane.
Torque	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, Continuous	Torque needed to drive a load over a continuous time.
Torque, Peak	Maximum amount of torque a motor can deliver when the highest allowable peak currents are applied.
Torque, rms	Root Mean Square is a mathematical method to determine a steadfast or average torque for a motor.
Torque, Stall	The maximum torque without burning out the motor.
Total Indicated Reading (TIR)	The full indicator reading observed when a dial indicator is in contact with the part surface during one full revolution of the part about its axis of rotation.
Tuning	In a servo system, the process of optimizing loop gains (usually PID terms) to achieve the desired response from a stage or mechanism from an input command.
Unidirectional Repeatability	See Repeatability
Velocity Command	Motor driver or amplifier configuration where the input signal is commanding motor velocity. Motors with analog tachometers are normally driven by this driver configuration.
Wobble	An irregular, non-repeatable rocking or staggering motion of the table top of a rotary stage. Wobble is defined as an angular error between the actual axis of rotation and the theoretical axis of rotation.
Yaw (of travel)	Rotation about the vertical axis, perpendicular to the axis of travel. Angular movement (error) that affects straightness and positioning accuracy.
Yaw Error	Positioning error resulting from a yaw motion.

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APPENDIX B: WARRANTY AND FIELD SERVICE

Aerotech, Inc. warrants its products to be free from defects caused by faulty materials or poor workmanship for a minimum period of one year from date of shipment from Aerotech. Aerotech's liability is limited to replacing, repairing or issuing credit, at its option, for any products that are returned by the original purchaser during the warranty period. Aerotech makes no warranty that its products are fit for the use or purpose to which they may be put by the buyer, where or not such use or purpose has been disclosed to Aerotech in specifications or drawings previously or subsequently provided, or whether or not Aerotech's products are specifically designed and/or manufactured for buyer's use or purpose. Aerotech's liability or any claim for loss or damage arising out of the sale, resale or use of any of its products shall in no event exceed the selling price of the unit.

Laser Products

Aerotech, Inc. warrants its laser products to the original purchaser for a minimum period of one year from date of shipment. This warranty covers defects in workmanship and material and is voided for all laser power supplies, plasma tubes and laser systems subject to electrical or physical abuse, tampering (such as opening the housing or removal of the serial tag) or improper operation as determined by Aerotech. This warranty is also voided for failure to comply with Aerotech's return procedures.

Return Procedure

Claims for shipment damage (evident or concealed) must be filed with the carrier by the buyer. Aerotech must be notified within (30) days of shipment of incorrect materials. No product may be returned, whether in warranty or out of warranty, without first obtaining approval from Aerotech. No credit will be given nor repairs made for products returned without such approval. Any returned product(s) must be accompanied by a return authorization number. The return authorization number may be obtained by calling an Aerotech service center. Products must be returned, prepaid, to an Aerotech service center (no C.O.D. or Collect Freight accepted). The status of any product returned later than (30) days after the issuance of a return authorization number will be subject to review.

Returned Product Warranty Determination

After Aerotech's examination, warranty or out-of-warranty status will be determined. If upon Aerotech's examination a warranted defect exists, then the product(s) will be repaired at no charge and shipped, prepaid, back to the buyer. If the buyer desires an airfreight return, the product(s) will be shipped collect. Warranty repairs do not extend the original warranty period.

Returned Product Non-warranty Determination

After Aerotech's examination, the buyer shall be notified of the repair cost. At such time, the buyer must issue a valid purchase order to cover the cost of the repair and freight, or authorize the product(s) to be shipped back as is, at the buyer's expense. Failure to obtain a purchase order number or approval within (30) days of notification will result in the product(s) being returned as is, at the buyer's expense. Repair work is warranted for (90) days from date of shipment. Replacement components are warranted for one year from date of shipment.

Rush Service

At times, the buyer may desire to expedite a repair. Regardless of warranty or out-of-warranty status, the buyer must issue a valid purchase order to cover the added rush service cost. Rush service is subject to Aerotech's approval.

On-site Warranty Repair

If an Aerotech product cannot be made functional by telephone assistance or by sending and having the customer install replacement parts, and cannot be returned to the Aerotech service center for repair, and if Aerotech determines the problem could be warranty-related, then the following policy applies:

Aerotech will provide an on-site field service representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs. For warranty field repairs, the customer will not be charged for the cost of labor and material. If service is rendered at times other than normal work periods, then special service rates apply.

If during the on-site repair it is determined the problem is not warranty related, then the terms and conditions stated in the following "On-Site Non-Warranty Repair" section apply.

On-site Non-warranty Repair

If any Aerotech product cannot be made functional by telephone assistance or purchased replacement parts, and cannot be returned to the Aerotech service center for repair, then the following field service policy applies:

Aerotech will provide an on-site field service representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs and the prevailing labor cost, including travel time, necessary to complete the repair.

Company Address

Aerotech, Inc.
101 Zeta Drive
Pittsburgh, PA
15238-2897

Phone: (412) 963-7470
Fax: (412) 963-7459

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APPENDIX C: TECHNICAL CHANGES

C.1. Current Changes Revision: 1.02.00

Section(s) Affected	Description
Section 3.1.1	Earth ground enclosure information added

C.2. Archived Changes

Version	Section(s) Affected	Description
1.01.00	-	No changes recorded
1.00.00		New manual

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READER'S COMMENTS

4020 Linear Servo Amplifier
P/N: EDA105, January 29, 2008
Revision: 1.02.00

Please answer the questions below and add any suggestions for improving this document.

Is the manual:

	Yes	No
Adequate to the subject		
Well organized		
Clearly presented		
Well illustrated		

How do you use this document in your job? Does it meet your needs? What improvements, if any, would you like to see? Please be specific or cite examples.

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