
# AX Series

# PWM Servo Amplifier

# OPERATOR’S MANUAL

Motion Control Systems, Inc.
New River, Virginia

http://www.motioncontrol.org/

1404650 Rev. Original

# Table Of Contents

# Part 1

## IMPORTANT SAFETY NOTICES

### 1.1 Safety Notices

The following conventions are used to illustrate important safety information in the manual.

**WARNING: Alerts reader of conditions and/or procedures that could result in personal injury or death**

**CAUTION: Calls attention to conditions and/or procedures which, if not followed, can result in permanent damage to equipment.**

**NOTE: Points out useful or important information to the reader.**

### 1.2 Safety Ground

This product must be grounded. The user must connect a hard wired system ground, having the same conductor size as the incoming AC power, to the Protective Conductor Terminal (PCT, denoted by the symbol ⏚).

In addition, any device (e.g. motor, control device, etc.) that is connected to this system must also be grounded. See "System Wiring" for a schematic of the grounding required for the amplifier.

**WARNING: Operation without proper grounding can result in a potentially fatal electric shock. Any accessible component or peripheral device is to be considered "live" under this condition.**

### 1.3 Hazardous Voltages Warning

**WARNING: Dangerous voltages exist at several places within the enclosure. Disconnect power before and during any disassembly or servicing. Only qualified personnel should service this product.**

**WARNING: Dangerous voltages exist at the motor power terminals when the drive has power applied. Disconnect power and exercise caution when connecting to these terminals.**

## 1.4 Life Support Policy

Motion Control Systems, Inc. products are not authorized for use as critical components in life support systems without the expressed written consent of the President of Motion Control Systems, Inc.

A critical component is any component whose failure or malfunction could result in the failure of the life support system or in the reduction of its safety or effectiveness.

## 1.5 Other Notices

**WARNING: Do not operate this system in explosive atmospheres.**

**CAUTION: The voltages applied to the AX amplifier must not exceed the maximum stated voltages. (See Section 4.1.4)**

**NOTE: This manual uses the terms "Amplifier", "Controller", "Motor Drive", and "Motor Controller" interchangeably.**

# Part 2

# GENERAL

## 2.1 Introduction

The AX series of motor drives are analog-controlled, four quadrant velocity servo amplifiers that are intended to control three phase permanent magnet synchronous motors. These motors are commonly called brushless DC motors, since some of their characteristics are similar to ordinary DC motors. The AX motor drives use a highly efficient Pulse Width Modulated (PWM) control scheme. The PWM scheme is well suited to velocity control of high power motors or where efficiency is important. AX amplifiers have a communications port available for configuration and diagnostic feedback.

Each motor controller is packaged in a standard panel mount enclosure, making it convenient to install these systems with other panel mounted equipment. Connections are at the front, top and bottom of the package.

Under normal operation, a brushless DC motor controller must always "know" the position of the rotor. Position information can be obtained from a quadrature encoder, Hall effect devices, or a resolver. Details concerning the type of commutation that your system is configured for are included with your drive shipment and can be obtained from Motion Control Systems, Inc.

This manual includes sections that discuss each commutation type. Any single system can be configured to work with any feedback device. The amplifier will switch between encoder and Hall effect combinations through the **COMMUT** command. Resolver commutation and Pseudo-sinewave (20-step) commutation must be installed at the factory. See “Software Command Descriptions” in Section 5.3 for details.

## 2.2 Warranty

Motion Control Systems, Inc. (MCS) warrants that all products it manufactures shall be free from defects in materials and workmanship for a period of one (1) year from the date of shipment, provided that such products have been subjected to proper and normal use, and further provided that MCS receives written notice from the purchaser setting forth the nature and extent of the defect within the warranty period. The obligations of MCS under this warranty are limited to, at its option, the repair or replacement, free of charge, of any product covered by this warranty that has been returned with prior written consent to MCS, or as it may direct, transportation charges prepaid by the purchaser.

Motion Control Systems, Inc. (MCS) reserves the right to void this warranty at any time if any product is altered, tampered with, modified, repaired or serviced by any unauthorized person or company, without prior written approval from MCS.

MCS takes no responsibility for any damage to product if unauthorized alterations or modifications were performed without prior written consent from MCS.

MCS shall, in no event, be liable for any breach of warranty in an amount exceeding the purchase price, nor for any special, consequential, or incidental damages.

This warranty is in lieu of any and all other warranties, expressed, implied, or statutory including implied warranties of merchantability or fitness.

## 2.3 Field Service

Normal procedure requires that defective products be shipped prepaid and with prior written consent to MCS for repair. However, under certain extreme circumstances and at the purchaser's request, MCS can provide on site service. Contact the MCS sales department to arrange a service visit. A purchase order must be issued and received by MCS prior to departure of MCS service personnel.

# Part 3

## INSTALLATION

### 3.1 Unpacking

Remove the unit from its shipping container. All units should be lifted and handled from the back (mounting panel surface). Inspect the unit for shipping damage. Do not attempt to operate the unit if it has been damaged, or if it has been configured improperly. Instead, call MCS.

### 3.2 Mounting

Mount the motor controller on a panel using mounting screws (not supplied). Be sure to allow sufficient room at the top, front and bottom of the unit for wiring and ventilation (refer to the mounting diagrams included with this manual). Part 10 contains links to mounting diagrams for each of the AX drives.

### 3.3 Ambient Conditions

Select a location free of excessive dust, coolants, vibration, corrosives, condensation, flammable materials, etc. Select a location having ambient temperature between zero and 40 degrees C, and humidity between 5% and 95% (non-condensing). Although the motor controller is thermally protected, ambient temperature should be kept as low as practical, since high temperatures can degrade performance and reliability. Ambient conditions affect the rating of the drive. The AX drive current will fold back to within safe limits should internal sensors detect elevated temperatures.

### 3.4 Air Flow Requirement

The motor controller has a built-in fan for cooling, which typically exhausts out of the top panel. Do not obstruct the fan, or any other vents, as this will cause the unit to overheat.

### 3.5 Liquid Coolant Requirements

Some higher-power systems may require liquid cooling in addition to air cooling. If liquid coolant is required for the system, refer to the connection diagram for further plumbing information. Appropriate fittings must be installed prior to routing the cooling system. The suggested coolant is a 50/50 mixture of water and glycol.

# Part 4

## ELECTRICAL SYSTEM WIRING

Use the Control level schematic (Section 10.7) included in this manual as a reference when connecting the system.

**CAUTION: Make all connections to the system with the power OFF, unless otherwise instructed.**

### 4.1 Power Wiring

#### 4.1.1 AX Wiring General Information

Refer to the Control level schematic (Section 10.7) for suggested wiring. There is no particular phase rotation required for AC Mains power.

**CAUTION: Logic AC power must always be present at the motor controller whenever main AC power is applied.**

A connector block is located on the unit for the mains and logic AC power, motor power outputs, and external regen loads. There are also grounding lugs or terminal blocks on the unit for connecting the Protective Conductor Terminal (PCT) and motor grounds. Part 10 contains links to wiring diagrams for each AX drive.

#### 4.1.2 Recommended Fuses

Power line fuses are not provided in the AX motor Controllers. The external fusing should be sized to meet the current requirements shown below. If very fast acting circuit breakers are used, higher current ratings may be necessary because of half-cycle inrush currents that occur during power up. All circuit breakers or disconnects should be located near the equipment and within easy reach of the operator. Power cords must meet the voltage and current specifications of the motor controller and must include grounding conductors. See the table in section 4.1.4 on the following page for power requirements and fuse ratings.

There are internal fuses in AX Series Servo Amplifiers for protection of the logic power supply and/or fan power supplies.. This information is provided for reference only. This fuse should be replaced by Qualified Service Personnel Only. Contact MCS if you suspect that a fuse has been opened (because logic power supply or fan power supply fails to operate correctly).

### 4.1.3 Recommended Wire Sizes

AX Drives should be connected in compliance with applicable local codes. The table (see below) is provided as a guideline for selecting wire size. The conductor sizes that are listed below are for PVC jacketed wire in free air and connection lengths of less than 20 ft. For longer connections or non-ideal cooling arrangements, use larger wire to minimize lead resistance.

| | Motor Outputs | Motor Ground | AC Mains AC Ground | Logic Power | Regen Output |
|---|---|---|---|---|---|
| AX 500 | 14-16 AWG | 12-16 AWG | 14-18 AWG | 18-20 AWG | N/A |
| AX 1000 | 12-14 AWG | 12-14 AWG | 12-14 AWG | 18-20 AWG | 12-14 AWG |
| AX 2000 | 10-12 AWG | 8-12 AWG | 10-12 AWG | 18-20 AWG | 10 AWG |
| AX 2500 | 8-10 AWG | 6-10 AWG | 8-10 AWG | 18-20 AWG | 8 AWG |
| AX 3000 | 6-8 AWG | 6-8 AWG | 6-8 AWG | 18-20 AWG | 6 AWG |
| AX 5000 | 4-6 AWG | 4-6 AWG | 4-6 AWG | 18-20 AWG | 4 AWG |
| AX 6000 | 4 AWG | 4-6 AWG | 4 AWG | 18-20 AWG | 4 AWG |
| AX 6000 HV | 6-8 AWG | 6-8 AWG | 6-8 AWG | 18-20 AWG | 4 AWG |
| AX 10000 HV | 4 AWG | 4-6 AWG | 4-6 AWG | 18-20 AWG | 4 AWG |
| AX 20000 HV | 1-1/0 AWG | 1-4 AWG | 2-6 AWG | 18-20 AWG | 2-4 AWG |

### 4.1.4 Mains and Logic AC Power Voltage/Current Requirements

There are different logic AC current draw requirements for each AX amplifier. The table below lists those current draw requirements (in Amps, RMS), allowable input voltage range, and suggested fuse size. Mains and Logic AC power may be 50 Hz or 60 Hz in frequency.

| | LOGIC AC Curr. Draw (RMS Amps) | LOGIC AC Input Voltage Range | LOGIC AC Fuse Rating | MAINS AC Input Voltage Range | MAINS AC Voltage Phasing | AC Mains Fuse |
|---|---|---|---|---|---|---|
| AX 500 | 250 mA | 100 - 240 VAC | 1A, 250 VAC | 100 - 240 VAC | ~1 / ~3 | 10 A |
| AX 1000 | 250 mA | 100 - 240 VAC | 1A, 250 VAC | 100 - 240 VAC | ~3 | 20 A |
| AX 2000 | 250 mA | 100 - 240 VAC | 1A, 250 VAC | 100 - 240 VAC | ~3 | 40 A |
| AX 2500 | 250 mA | 100 - 240 VAC | 1A, 250 VAC | 100 - 240 VAC | ~3 | 50 A |
| AX 3000 | 250 mA | 100 - 240 VAC | 1A, 250 VAC | 100 - 240 VAC | ~3 | 60 A |
| AX 5000 | 550 mA | 100 - 240 VAC | 1.5A, 250 VAC | 100 - 240 VAC | ~3 | 100 A |
| AX 6000 | 550 mA | 100 - 240 VAC | 1.5A, 250 VAC | 100 - 240 VAC | ~3 | 120 A |
| AX 6000 HV | 550 mA | 100 - 240 VAC | 1.5A, 250 VAC | 200 - 480 VAC | ~3 | 60 A |
| AX 10000 HV | 1.25 A | 220 VAC | 2A, 250 VAC | 200 - 480 VAC | ~3 | 100 A |
| AX 20000 HV | 375 mA | 200-240 VAC | 1A, 250 VAC | 200 - 480 VAC | ~3 | 200 A |

### 4.1.5 Analog Interface and Test Point Signal Wiring

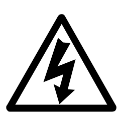
AX amplifiers use pluggable screw-down style connectors for connecting signals to SC1 and TP1. The plugs are designed to accept wires sizes between AWG 28 and AWG 16.

### 4.1.6 External Regen Load Wiring

An external regenerative energy discharge (regen) load is required for most motor-amplifier systems that must actively decelerate inertial loads. The AX1000 and larger drives have terminals for external resistive loads. Connection details are specified in the wiring and connection diagrams found in Part 10. Wire gauge size should follow the suggestions in section 4.1.3. The minimum load resistance for AX amplifiers is shown in the following table:

| | Minimum Load Resistance |
|---|---|
| **AX 500** | No ext. load permitted |
| **AX 1000** | 26 ohms |
| **AX 2000** | 10 ohms |
| **AX 2500** | 7 ohms |
| **AX 3000** | 7 ohms |
| **AX 5000** | 4 ohms |
| **AX 6000** | 3 ohms |
| **AX 6000 HV** | 6 ohms |
| **AX 10000 HV** | 8 ohms |
| **AX 20000 HV** | 4 ohms |

NOTE: **Some parameters must be changed in the AX software when adding an external regen load or when changing the resistance or power rating of the load. The REGENOHM, REGENPOWER, and REGENOVERLOAD commands are described in section 5.3.**



**WARNING: The power rating of the regenerative resistive load must be appropriate for the AX power rating. The load must safely dissipate the energy contained in the rotating mass. An incorrectly sized load could result in damage to the resistive load bank and the possibility of fire and damage to surrounding objects. The power rating of the resistive load must be entered through the control interface using the REGENPOWER and REGENOVERLOAD commands. If the regenerative resistive load opens due to overload conditions, or if the overload circuit is incorrectly configured, the rotating mass will not decelerate quickly and may pose a safety risk.**

### 4.1.7 Motor Connections (*for motors manufactured by MCS*)

Motors manufactured by MCS will have leads that are colored or coded with the following convention:

| Amplifier Label | Wire Color | Phase Name |
|---|---|---|
| W | White | Phase W |
| V | Black | Phase V |
| U | Red | Phase U |

Some motors manufactured by MCS will have all phase windings available for connection. In this case, the motor has six leads; two per phase. This permits the windings to be connected in either wye or delta connection. Such a motor will have its leads labeled as 1F, 1S, 2F, 2S, 3F, and 3S.

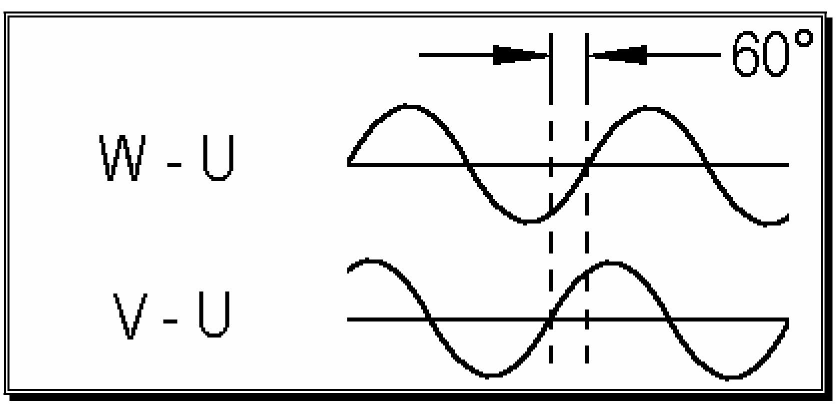
| WYE | |
|---|---|
| AMP | MOTOR |
| W | Phase W: 3S (1F + 2F + 3F |
| V | Phase V: 1S connected together) |
| U | Phase U: 2S |

| DELTA | |
|---|---|
| AMP | MOTOR |
| W | Phase W: 2F + 3S (connect together) |
| V | Phase V: 3F + 1S (connect together) |
| U | Phase U: 1F + 2S (connect together) |

When connecting motor leads to the front panel connector use the silk-screened panel labels to ensure correct motor phasing. For a schematic, please refer to the Control Level Schematic drawing (Section 10.7).

### 4.1.8 Motor Connections (*for motors* not *manufactured by MCS*)

Designate the motor leads as "U," "V," and "W" such that the sequence U-V-W causes CW (clockwise) rotation of the motor shaft when looking at the motor from the non-lead side. The lead side is the side of the motor at which the motor lead wires exit. If you view the motor output voltages (Back-EMF) of the motor while it is disconnected from the controller and being spun clockwise by hand, the output on an oscilloscope should look as follows:



## 4.2 Motor Feedback (Commutation) Wiring

### 4.2.1 6-Step Hall Effect Device Commutation

#### 4.2.1.1 6-Step Hall Effect Device Wiring (*for motors manufactured by MCS*)

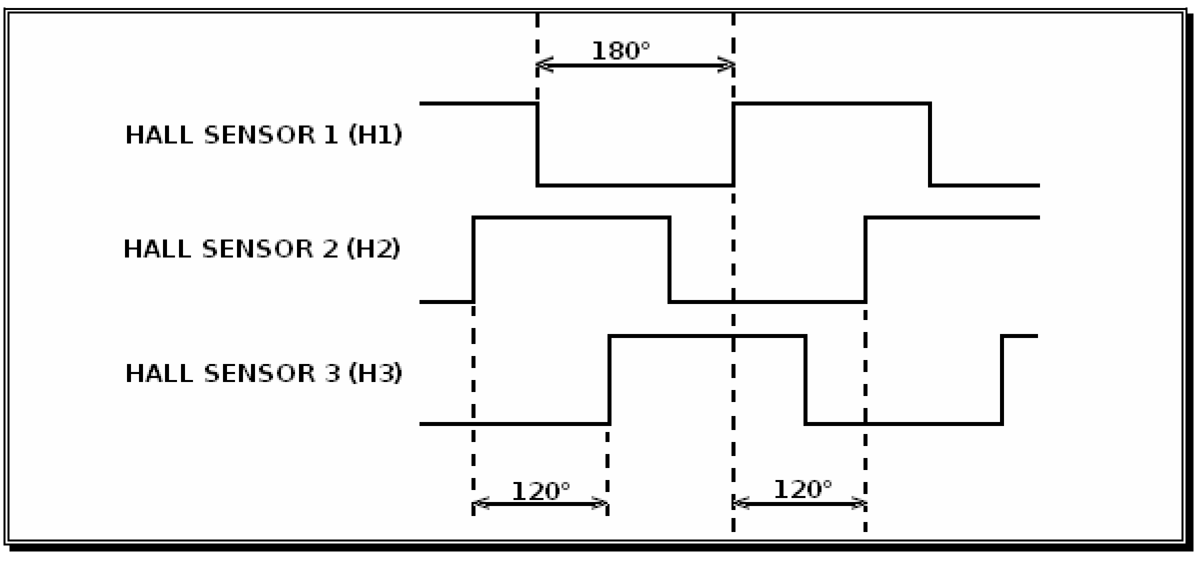
The AX motor controller has a 5 volt, 250mA (max.) power supply available for powering Hall effect sensors. The sensors connect to connector SC-2 (DB25M) on the front panel.

*6 Step Hall Effect Wiring Connections (for MCS motors)*

| DESIGNATION | WIRE COLOR | SC-2 PIN # |
|---|---|---|
| + 5V Supply | Red | 1 |
| Logic Common | Black | 9 |
| Hall Sensor 1 | White | 15 |
| Hall Sensor 2 | Green | 16 |
| Hall Sensor 3 | Yellow | 17 |
| Shield | ---- | 24 |

#### 4.2.1.2 6-Step Hall Effect Convention (*for motors* not *manufactured by MCS*)

Hall Effect devices are used by the controller to determine the position of the rotor with respect to the stator. The proper phasing of the Hall sensors is essential to proper motor operation. To determine the correct phasing, display the waveforms described below on an oscilloscope to determine whether the Hall effect devices are properly phased with respect to one another. The following figure shows the correct Hall effect sensor relationship for CW rotation:

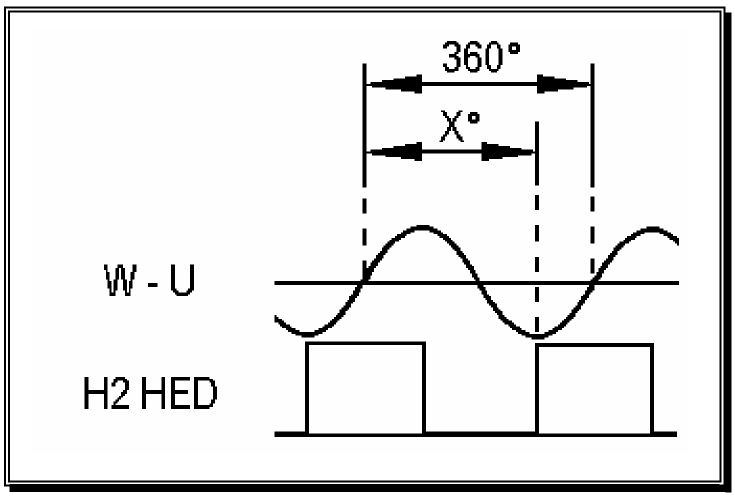



**<u>NOTE:</u> Hall effect devices have open collector outputs and must be connected to a +5VDC power supply through a suitable "pull-up" resistor. AX series drives contain internal pull-up resistors. When disconnected from the drive the Hall effect outputs will not switch. Use 2.2Kohm pull-up resistors to +5VDC to observe device switching.**

#### 4.2.1.3 6-Step Angle Adjustment

Motors not manufactured by MCS may have a different Hall effect placement (with respect to the motor windings) than standard MCS placement. The amplifier must "know" the relationship between the motor Back-EMF (BEMF) and the hall effect devices to optimize torque production. In order for the motor and drive to be phased correctly, a measurement must be made and the drive should be programmed for the correct commutation angle.

To make this measurement, display H2 (SC2-16) and motor phase W with respect to phase U on the oscilloscope display. Turn the motor in the CW direction (as defined in Section 4.1.6 Motor Connection). Measure the angle from the positive zero crossing transition of W-U to the rising edge of H2. Take this number and use the RS232 interface to program the drive with the correct commutation angle using the **ANGLE** command. An example of the measurement and the standard for MCS motors is shown in the following figure:




For Example: If, in this display X=270 degrees, then you would issue the command "**ANGLE270**". After the ready light becomes green, enter a **SAVE** command in order for the drive to power up with the correct setting.

### 4.2.2 20-Step (Pseudo-Sinewave) Hall Effect Device Commutation

#### 4.2.2.1 20-Step (Pseudo-Sinewave) Hall Effect Device Wiring

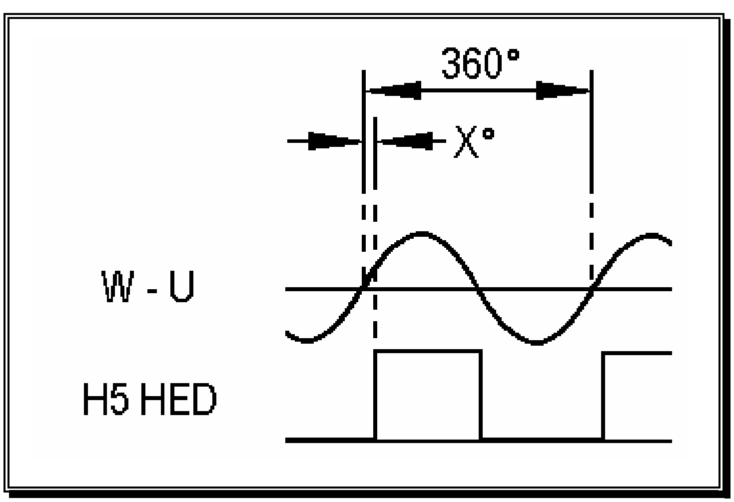
The AX motor controller has a 5 volt, 250mA (max.) power supply available for powering Hall effect sensors. The sensors connect to connector SC-2 on the front panel.

*Pseudo-Sinewave Wiring Connections*

| DESIGNATION | WIRE COLOR | SC-2 PIN # |
|---|---|---|
| + 5V Supply | Brown | 1 |
| Logic Common | Black | 9 |
| Hall Sensor 1 | Red | 15 |
| Hall Sensor 2 | Violet | 16 |
| Hall Sensor 3 | Orange | 17 |
| Hall Sensor 4 | Gray | 2 |
| Hall Sensor 5 | Yellow | 3 |
| Hall Sensor 6 | White | 4 |
| Hall Sensor 7 | Green | 20 |
| Hall Sensor 8 | Tan | 21 |
| Hall Sensor 9 | Blue | 12 |
| Hall Sensor 10 | Pink | 10 |
| Shield | --- | 24 |

#### 4.2.2.2 20-Step (Pseudo-Sinewave) Angle Adjustment

Integral Hall effect sensors are placed in the motor to within +/- 10 electrical degrees, however, it is sometimes necessary to fine-tune the placement through internal software. To do this, disconnect the motor power leads from the AX amplifier and use an oscilloscope to view the Hall effect outputs with respect to the motor phase voltages (Back-EMF). Place one scope probe on Phase W (white) with respect to Phase U (red). Attach the other scope probe to H5 (yellow), which should be connected to SC2-3. Hall effect devices are open collector so they must be connected to the amplifier or use a 2.2K pull up resistor to 5VDC on their output. Rotate the motor in the CW direction (as viewed from the non-lead side of the motor) and measure the angle between the positive-going zero crossing of W-U and the rising edge of H5. This measured number should be the **ANGLE** for the drive.



### 4.2.3 Resolver Commutation

#### 4.2.3.1 Resolver Wiring

The AX motor controller has a built in reference oscillator that has been adjusted for resolvers having transformation ratios between 0.45 and 0.50. The resolver connects to SC2 (DB25M) on the front panel. Most resolvers will have wire leads that are color-coded.

*Resolver Wiring Connections*

| DESIGNATION | WIRE COLOR | SC-2 PIN # |
|---|---|---|
| R1 | Red/White | 9 |
| R2 | Yellow/White | 10 |
| S1 | Red | 3 |
| S2 | Yellow | 4 |
| S3 | Black | 1 |
| S4 | Blue | 2 |
| Shield | ---- | 24 |

**<u>NOTE:</u> The resolver is assumed to be mounted at the rear (leaded end of the motor) and turning in the same direction as the motor. For installation of geared resolvers, or reverse-mounted resolvers, in which the resolver and the motor turn in opposite directions, swap S1 and S3.**

Make sure the resolver is phased correctly by spinning the motor by hand in the CW direction when viewed from the non-lead end. Use the **SPDQ** command to verify that the speed read back is a positive number.

#### 4.2.3.2 Resolver Commutation Adjustment

The commutation adjustment for a resolver requires either moving the resolver or making an electrical adjustment through software. When properly adjusted, the motor-controller system will use the least amount of current to provide a maximum torque.

**<u>CAUTION</u>: Operating the motor controller with motor commutation that has not been optimized will result in excessive motor and amplifier heating along with a marked decrease in system performance.**

**<u>NOTE:</u> If the motor and resolver were shipped as a completely assembled system, this adjustment has already been made by MCS. In this case, further adjustments will not be necessary.**

##### 4.2.3.2.1 Mechanical Adjustment for Resolver Systems

This adjustment method is achieved by locking the rotor into a set position and then moving the resolver. The procedure is achieved by first issuing the **SETZEROPOS** command which locks the rotor into the zero position. After this command is issued, apply a negative (-) voltage to

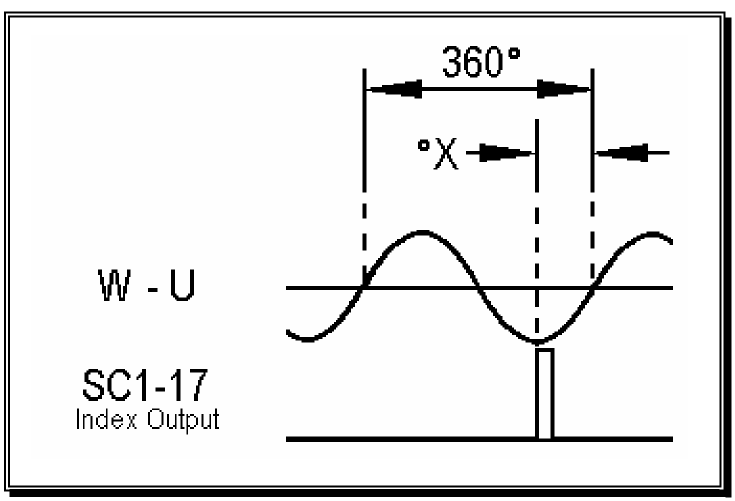
SC1 (velocity request) and enable the amplifier in order to lock it into position. When going through this sequence it is usually easier to apply –10V from SC1-6 to the velocity request and control the current going to the motor by using the Torque Limit input on pins SC1-3 and SC1-4. Using no more than 5V of torque command should provide a sufficient rotor lock and reduce motor heating during this procedure.

**CAUTION: This command will cause the motor to oscillate until it reaches a locked position. Use a low torque limit setting when first enabling the drive in order to reduce motor vibration. When the motor is at the lock position, increase the Torque Limit voltage to obtain a better lock.**

Use the **RESOLVERQ** command to view the current position word. The returned value is a 16-bit, 14-bit, 12-bit, or a 10 bit signed integer, depending on the selected resolver resolution bits (see **RESOLVERRES** command). Adjust the resolver until the value returned is 0. Tighten the resolver and disable the drive. Issue the **CLEARZEROPOS** command again and wait for the ready light to turn green, the system is now ready to run. This setting has a commutation **ANGLE** of 0. Make sure that the setting is zero by typing "**ANGLE**" and looking at the returned parameter.

### 4.2.3.2.2 Electrical Adjustment for Resolver Systems

This method allows for the mounting of the resolver with no mechanical adjustment. To use this method view the index output from the drive SC1-17 and motor phase W with respect to phase U on an oscilloscope. Measure the angle from the rising edge of the index to the positive zero crossing transition of W-U. Take this number and use the RS232 interface to program the drive with the correct commutation angle using the **ANGLE** command. An example of the measurement is shown below. For this measurement X= 90 degrees, so you would type "**ANGLE90**" for the drive to be phased correctly.



**CAUTION: Electrical adjustments must be repeated whenever substituting another motor or controller. The measured angle must be programmed into the new controller. A different motor requires that a new measurement be programmed in the controller.**

### 4.2.4 Encoder Commutation

#### 4.2.4.1 Encoder Wiring

The AX motor controller has a 5 volt, 250 mA (max.) power supply available for powering an encoder. AX series amplifiers accept differential TTL level inputs for encoder signals. The encoder connects to connector SC- 2 (DB25M).

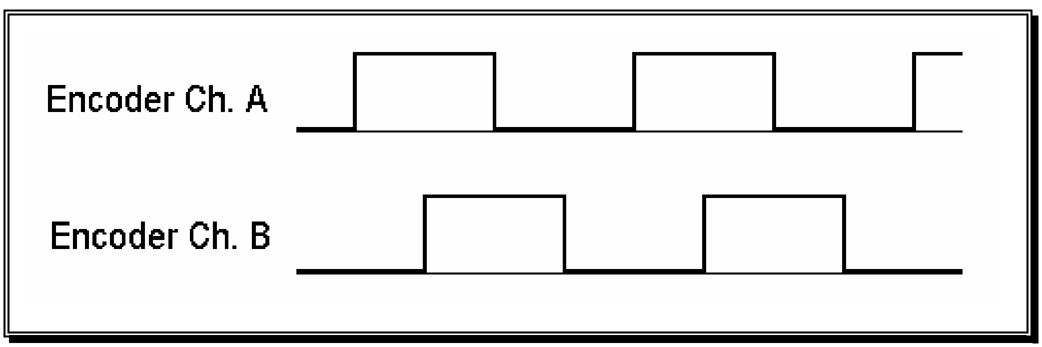
*Encoder Wiring Connections*

| DESIGNATION | SC-2 PIN # |
|---|---|
| + 5V Supply | 1 |
| Encoder Channel A+ | 2 |
| Encoder Channel B+ | 3 |
| Encoder Index + | 4 |
| Encoder Common | 9 |
| Encoder Index - | 12 |
| Encoder Channel A- | 20 |
| Encoder Channel B- | 21 |
| Shield | 24 |

#### 4.2.4.2 Encoder Input Convention

To determine the correct convention of the A and B inputs, apply power to the encoder and rotate the shaft or rotor in the CW direction. The A input should lead the B input by transitioning from 0 to 1 while B is at 0. To determine whether the system is set up properly, rotate the motor in the CW direction and compare the A and B signals to the drawing below. To view both the A and B inputs, use the encoder outputs on SC1-13 (Ch. A) and SC1-15 (Ch. B). For more information on these outputs, see section 4.5 - Digital Outputs.

Correct encoder phasing for CW rotation



### 4.2.4.3 Commutation Adjustment for Encoder Systems

Commutation adjustment requires either a mechanical alignment of the encoder index to an optimal angular location with respect to the motor or an electrical adjustment to ensure proper drive phasing. This adjustment allows the system to use the minimum current to produce a given torque. Make initial adjustments only if the unit is configured to use the encoder index as the source of commutation (**COMMUT** modes 0 and 5).

**CAUTION: Use care when making this adjustment, since encoders are delicate instruments. A mis-adjustment of the index could cause reduced torque and motor heating.**

**NOTE: If the motor and encoder were shipped as a completely assembled system, MCS has already made the adjustment. In this case, further adjustments will not be necessary.**

**NOTE: A connector "breakout fixture" (which makes signals easily accessible for scope probing) on connector SC2 is helpful for this adjustment.**

The index input is edge-sensitive and will detect active-high or active-low index pulses. The index input will detect the falling edge for CW motor rotation or the rising edge for CCW rotation.

#### 4.2.4.3.1 Mechanical Commutation Adjustment for Encoder Systems

To set the index, power up the system and rotate the motor shaft (or rotor) in the CW direction. You should observe a once-per-revolution index pulse on SC1 Pin 17. Set the motor shaft position near the present index. This will minimize the adjustment required.

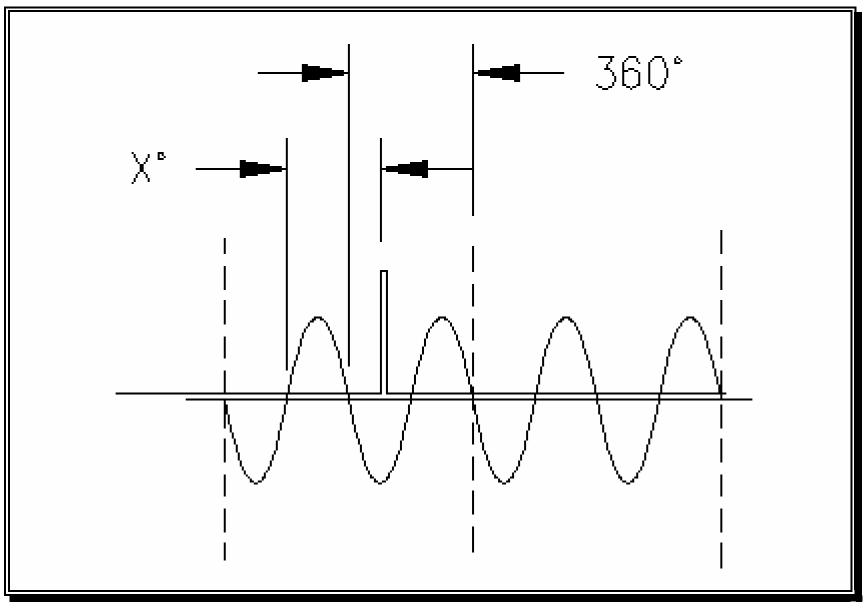
Connect the SETUP pin (SC2-10) to ground (SC2-9). This will hold the system in its power up state. Reduce the torque limit to below +5VDC (SC1-3) and apply a negative (-) velocity request (SC1-1). Monitor the index at the index output from the drive (SC1-17).

**WARNING: If the SETUP pin becomes disconnected during the following steps, the motor could start to move unexpectedly.**

The motor will seek a position and lock there. Rotate the encoder body until the index is displayed on the oscilloscope and fix the encoder body in place. Test the adjustment by manually turning the motor a few degrees, and see that it returns to the index position. Power off and disconnect the SETUP pin (SC2 pin 10). Power up and verify operation.

### 4.2.4.3.2 Electrical Commutation Adjustment for Encoder Systems

This method allows for the mounting of the encoder with no mechanical adjustment. To use this method view the index output from the drive SC1-17 and motor phase W with respect to phase U on an oscilloscope. Spin the motor shaft by hand *clockwise* (viewed from non-lead side of motor) and measure the angle from the positive zero crossing transition of W-U to the rising edge of the index. Take this number and use the RS232 interface to program the drive with the correct commutation angle using the **ENCODERANGLE** command. An example of the measurement is shown below. For this measurement, X=270 degrees and you would type "**ENCODERANGLE270**" for the drive to be phased correctly.




**<u>CAUTION</u>: Changing the motor requires that the procedure be repeated. When changing the controller, you must program the encoder angle determined above into the new controller.**

**<u>NOTE:</u> The index signal from encoders are very short pulses and when using a digital scope to do these measurement it is convenient to put the scope in peak detect mode so that the encoder edges are captured.**

**<u>NOTE:</u> When in COMMUT mode 5, the ANGLE of the system should be determined by the hall effect phasing. To determine this angle see section 4.2.1.3.**

### 4.2.5 10-Step (Odd/Even Pseudo-Sinewave) Hall Effect Device Commutation

This is a subset of 20-step commutation which only uses either the even-numbered or odd-numbered HEDs. Contact MCS for applications information if there are special requirements.

## 4.3 Serial (RS-232) Communications Wiring

The serial interface conforms to EIA RS-232C specifications, using a DB-9 (female) connector on the bottom of the unit. Communication parameters for the system are 9600 baud, 8 data bits, 1 stop bit, and no parity. AX series amplifiers do not use any type of hardware or software handshaking. If hardware handshaking is enabled on the host system, those pins must be disabled. The amplifier requires a null modem cable in order to communicate. If one is not available, Pins 2 and 3 should be crossed in the cable.

| Amp DB9 Female Connector | Signal Name | Connect To Terminal Standard Serial Port | | Serial Port Function |
|---|---|---|---|---|
| | | DB9 | DB25 | |
| 1 | Ground | - | 1 | Shield |
| 2 | Receive | 3 | 3 | Transmit |
| 3 | Transmit | 2 | 2 | Receive |
| 4 | Shield | - | - | Not Used |
| 5 | Ground | 5 | 7 | Ground |
| 6 | Reserved | - | - | Reserved |
| 7 | +5V | - | - | +5V |
| 8 | Reserved | - | - | Reserved |
| 9 | Reserved | - | - | Reserved |

9600 Baud, 8 Data Bits, 1 Stop Bit, No Parity

A reference is available in Part 5 that details the controller command protocol. The command update rate is a minimum of 10 Hz (typically over 30Hz for most commands).

## 4.4 Analog Interface Wiring

### 4.4.1 Standard VELOCITY or TORQUE Mode Control

The Analog Control Connector (SC1) is a block connector located on the front of the amplifier. Pins 1-10 control the analog interface to the drive. Analog inputs have a minimum input impedance of 20 kohm.

*SC1 Analog Interface Signal Definition For VELOCITY or TORQUE Mode Control*

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 1 | Velocity Command + | 0.5 mA (sink) |
| 2 | Velocity Command - | 0.5 mA (sink) |
| 3 | Torque Limit + | 0.5 mA (sink) |
| 4 | Torque Limit Reference | 0.5 mA (sink) |
| 5 | + 10 VDC Reference Output | 15 mA (source) |
| 6 | - 10 VDC Reference Output | 15 mA (source) |
| 7 | Enable Input + | 5 mA (source) |
| 8 | Enable Input Reference (Logic Common) | 100 mA (sink) |
| 9 | Amp Ready Output (HI = Ready, LOW = Not Ready) | 0.25 mA (sink) |
| 10 | Velocity/Torque Mode Select (HI or OPEN = Vel, LOW = Torq) | 5 mA (sink) |

**Pins 1 and 2** are the differential input for the velocity command or for the torque mode input. The full-scale input range is typically + or - 10 VDC with a 0 VDC input commanding zero speed for velocity mode or zero torque when in torque mode. The standard is that a positive voltage causes a CW rotation. If a CCW rotation for a positive voltage is desired, switch the wires going to pins 1 and 2. For velocity mode, + or - 10V = CW or CCW maximum speed. When in torque mode, (see Pin 10) inputs to Pins 1 and 2 request motor torque as a percentage of full-scale phase current to the motor. + or - 10V = + or - 100% of full-scale motor phase current. Maximum allowable voltage between pins 1 and 2 is 10VDC in magnitude.

**Pins 3 and 4** are differential inputs that control the torque limit to the drive. This input at SC1-3 limits the maximum current that the drive will provide to the motor. The input range is 0 to +10VDC. A 10VDC input allows the drive to deliver full current to the motor. Use SC1-4 as a reference or common input to help reduce differential mode noise. When not using SC1-3 and SC1-4 as a differential input, connect 0V to SC1-4.

**Pin 5** is a + 10 VDC (15mA max.) output (referenced to SC1-8) that can be used to derive the input voltage for the velocity and torque request inputs.

**Pin 6** is a -10 VDC (15mA max.) output (referenced to SC1-8) that can be used to derive the input voltage for the velocity request input.

**Pin 7** is the ENABLE COMMAND input. In order to enable the amplifier, short this pin to (SC1-8) or apply 0V (referenced to SC1-8) to the input. Opening pin 7 or pulling it up to any voltage from 5-24VDC will disable the drive. Opening pin 7 or pulling it high clears faults from the system. See section 6.5 for more details about amplifier faults and how they are cleared.

**Pin 8** is tied internally to logic common and is normally used as a logic common connection for the ENABLE input.

**Pin 9** is the READY output and can be used to determine when the drive is able to be enabled and is ready for a command input after a power up or a change in the commutation configuration.

**Pin 10** selects between TORQUE mode and VELOCITY mode of operation. The TTL signal is pulled up internally to select the default VELOCITY mode. Opening pin 10 or pulling it up to any voltage from 5-24VDC will allow VELOCITY mode of operation. Pulling this pin to logic common (SC1-8) changes from VELOCITY mode to TORQUE mode operation.

### 4.4.2 Sine & Sine+120 Control

Sine and Sine +120 operation occurs when the sinusoidal current requests are directly sent to the amplifier in the form of differential sine waves. The differential inputs are not isolated, however, and therefore the amplifier LOGIC COMMON must be connected to the common ground (not chassis ground) of the Sine & Sine+120 generating source.

*SC1 Analog Interface Signal Definition for Sine & Sine +120 systems*

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 1 | Sine (+) Input | 0.5 mA (sink) |
| 2 | Sine (-) Input | 0.5 mA (sink) |
| 3 | Sine+120 (+) Input | 0.5 mA (sink) |
| 4 | Sine+120 (-) Input | 0.5 mA (sink) |
| 5 | + 10 VDC Reference Output | 15 mA (source) |
| 6 | - 10 VDC Reference Output | 15 mA (source) |
| 7 | Enable Input + | 5 mA (source) |
| 8 | Enable Input Reference (Logic Common) | 100 mA (sink) |
| 9 | Amp Ready Output (HI = Ready, LOW = Not Ready) | 0.25 mA (sink) |
| 10 | Reserved | N/A |

**CAUTION: An amplifier configured for Sine & Sine+120 operation may not be used for standard VELOCITY or TORQUE mode control (as shown in 4.4.1). Contact MCS if operation in both Sine & Sine+120 and VELOCITY/TORQUE mode is required.**

**CAUTION: The Sine & Sine+120 signals must be sinusoidal and be phased properly for predictable amplifier operation. Failure to ensure these two conditions may result in unpredictable amp behavior and potential amplifier damage.**

**NOTE: This is an option and should be requested from the factory if needed. Check your configuration sheet in the manual to determine if Sine & Sine +120 inputs are available on your system.**

## 4.5 Digital Outputs

Some digital outputs are included on the SC1 connector. The encoder outputs on this connector are non-isolated and TTL level. The fault enable outputs are by default non-isolated and TTL, however 5V and 24V opto-isolated outputs are available as an option. Check the configuration sheet shipped with the drive to determine if this option is installed on the unit. If this option is installed, 5V or 24V and the supply's common reference must be connected to pins 12 and 21 respectively for the outputs to be active.

*SC1 Digital Output Interface Signal Definition*

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 11 | +5V Output (Referenced to Logic Common) | 250 mA (source) |
| 12 | +5 to +24V Isolated Supply Input | 250 mA (sink) |
| 13 | A Differential Encoder Signal Output | 20 mA (source) |
| 14 | !A Differential Encoder Signal Output | 20 mA (source) |
| 15 | B Differential Encoder Signal Output | 20 mA (source) |
| 16 | !B Differential Encoder Signal Output | 20 mA (source) |
| 17 | I Differential Encoder Signal Output | 20 mA (source) |
| 18 | !I Differential Encoder Signal Output | 20 mA (source) |
| 19 | Amp Fault Status Output (HI = Fault, LOW = OK) | 50 mA (source) |
| 20 | Amp Enable Status Output (HI = Enabled, LOW = Disabled) | 50 mA (source) |
| 21 | Isolated Supply Reference Input | 250 mA (source) |
| 22 | Logic Common | 250 mA (sink) |

When in resolver mode, the encoder outputs simulate a 16384 (16 bit), 4096 (14 bit), 1024 (12 bit), or 256 (10 bit) line encoder. These resolutions are programmable through the RS232 interface using the **RESOVLERRES** command. For Hall effect only operation, either 6 or 20 step, the encoder outputs simulate an encoder whose line number is a function of the number of hall effects and the number of poles in the motor. The function is 0.75 * motor pole count for 6-Step, and 2.5 * motor pole count for 20-step systems.

## 4.6 User-accessible Test Point Outputs

Access to several commonly required analog servo signals is provided at TP1 on the amplifier near the RS232 serial interface. Refer to section 9.3.4 for details on this connector. Each test point is scaled for -10V to +10V, where 10V (either polarity) is 100% value of the signal being measured. All signals are referenced to "Logic Common", available on TP1-10.

Velocity Request is used to measure the "scaled" speed request voltage. The velocity request is input to the drive on SC1-1 and SC1-2, but may be scaled using the SPAN potentiometer on the front of the drive (in Velocity Loop mode only). Velocity loop amplifiers are scaled so that on SC1-1, 10V = positive maximum system speed, and -10V = negative maximum system speed. The SPAN pot allows 10 Volts to equal a lower speed, if required. For example, if the maximum motor speed is 1000 RPM, then a voltage of 2.5V measured on this test point will equate to (2.5V / 10V) * 1000 RPM = 250 RPM (assuming SPAN is not used). Torque mode amplifiers are scaled so that 10V = positive maximum torque and -10V = negative maximum torque (Note that SPAN has no effect in Torque mode). Each AX amplifier has a different maximum current output. See section 9.2.4 for a list of amplifier current scalings. Section 6.4 discusses potentiometer adjustments.

Velocity Error displays the velocity loop error signal, after it has gone through the torque limiting circuit. This means that the torque limit input (SC1-3) will influence the maximum voltage that may appear on this test point. This signal is a roughly DC voltage which is proportional to the peak motor current. In other words, 5V of velocity error equals 50% of amplifier peak current output.

Current Request shows the actual sinusoidal (or "trapezoidal") motor current requests that are fed into the current loops. The amplitudes of these signals are equal to the magnitude of the Velocity Error. A peak waveform value of 10V (or -10V) equals maximum current output scaling of the amplifier.

Current Feedback displays a true representation of the actual motor current as sensed by the current sensors.

Current Error shows the error signal generated by the current loop which is amplified by the power stage.

The only exception to the 10V = maximum rule is TP1-9 (Tachometer Output) which will usually be scaled somewhat lower than 10V maximum amplitude. This test point shows an analog representation of the actual motor speed. The scaling can be determined (in Volts / RPM) by spinning the motor at some speed, measuring the voltage at TP1-9, then dividing the voltage measured by the actual motor speed.

## 4.7 External Tachometer Wiring

In some systems, especially where very precise low speed control is required, an external tachometer may be used to provide feedback to the velocity control loop. The tachometer connects to the DB25 connector SC2 on the front panel. Jumper J12 on the control PC card must be in the "A" position for the external tachometer to provide feedback to the velocity servo loop.

*External Tachometer Connection*

| Designation | SC2 pin # |
|---|---|
| Tach + | 13 |
| Tach - (Logic Common) | 14 |

The plus and minus signs indicate the polarity of the tachometer voltage for positive (CW) rotation of the motor.

## 4.8 Interlock Wiring

Some amplifier interlocks are provided for customer use. The interlocks drive the system into a fault state under certain conditions. A fault state is indicated by a red front panel FAULT LED, and by the fault status output on SC1-19. When using the RS232 interface, the **STAT** and **FLT** commands will also give specific fault indications.

**1.** Motor Temperature: SC2 pins 5, 6. Intended for sensing excessive motor temperature using a PTC thermistor mounted in the motor and connected between these pins. The system will go into a fault state when resistance between these terminals rises above approximately 825 ohms. Short these pins together if a motor thermistor is not used.

**2.** SC2 Aux. Interlock: SC2 pins 7, 8. These two pins are normally short circuited together; the system will go into a fault state if the connection is opened. The normal use for this interlock is to run wires from these pins out along any cable connected to SC2 and connect the wires after the last connector. Thus, the system will fault if the motor feedback cable is disconnected.

If there is no requirement to use an interlock, it may be disabled using the **DISFLT** command. See Part 5 for more details on this and other software commands.

## 4.9 EMI/EMC Compliance Wiring

The AX Series PWM Servo Amplifier meets the requirements set forth by the European Community for Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) as of the date of certification only when installed according to the instructions below.

To reduce the electromagnetic energy emitted and absorbed by the amplifier the power, control, and feedback wiring must have ferrite chokes of the snap-on or tubular variety attached as listed. The manufacturer and part numbers listed below are for reference and any suitable equivalent may be used. In addition, a line filter capable of passing full load current and having 25 dB or more of roll off at 1MHZ is recommended in the input power circuit and should be located near the amplifier.

Input power:
Steward 28A2024.0A0 one at the amplifier, one at the line filter.

Motor power:
Steward 28A2029.0A0 one at the amplifier, one at the motor.

Motor feedback:
Steward 28A2024.0A0 one at the amplifier, one at the motor.

Control wiring:
Steward 28B2024.0A0 at the amplifier.

# Part 5

## SOFTWARE USER INTERFACE

### 5.1 Command Definition

A command consists of any number of letters from ‘A’ through ’Z’ followed by zero or more delimiters, sometimes followed by a + or - character, and an integer decimal number. A maximum of twenty characters (including the sign character) are allowed following the delimiters. The occurrence of the first digit character indicates the start of a decimal number. The decimal number terminates on the first occurrence of a non-digit character such as a decimal point. If a sign character is not followed by a decimal digit, then a zero decimal number is assumed. To initiate action, the command string must be terminated by a carriage-return character (ASCII 13).

A command string may contain one or more commands, separated by semicolons. The maximum length of a command string is 1024 characters. There are a maximum of fifty characters for each command segment. Characters after the fifty-character maximum are ignored until another carriage-return character or a semicolon is entered. Any ASCII characters other than A...Z, 0...9, backspace (ASCII 8), delete (ASCII 127), and + or – character, are defined as delimiters. A character entered before the backspace and the “delete” character are removed from the command word. The commands are not case sensitive.

After a valid command is received and processed, the system responds with a carriage-return and a line feed (ASCII 10). For some commands, before the carriage-return and the line feed, the system returns certain information in the form of ASCII strings. For invalid commands, the system responds with a message code followed by a question mark (ASCII 63) and a carriage-return and a line feed. If a command consists of only a carriage return, then it is ignored by the drive and no response is returned.

### 5.2 Command Types

#### 5.2.1 Input Commands

The Input and Output commands write and read the system parameters. If a decimal number is included in the command, then that number is an input to the system. Otherwise, the present value of the parameter affected by the command will be returned. All input and output data are in decimal numbers, and any input data that are outside the indicated ranges (see descriptions below) are invalid requests and are rejected by the system with an error message.

### 5.2.2 Output Commands

The output commands return the system status and diagnostics. In the following descriptions, only the alphabetic parts of the commands are shown. All other optional parts described earlier are ignored by the system.

## 5.3 Software Command Descriptions

This section lists each of the commands, available to the user, that are required for system operation and status queries. Each command description gives the command name in **bold** type, a command description, and some additional information that is important to know when using the command.

*Input Commands:* A command that is used to view or change certain drive parameters. If the command is issued with a decimal number, the system changes that parameter's value. If no additional numbers are provided after the command, the system responds with the current value of that parameter. Some input commands do not require additional input. The system will also respond with carriage-return and line feed characters at the end of the line.

*Output Commands:* A command that is used to view drive status or diagnostics. These commands are issued without any other numbers, and the system responds with the current information about that command followed by carriage-return and line feed characters.

*Operating Commands:* A command which accepts no input nor returns any output. The command is used to perform a specific drive operation. The system responses are the carriage-return and line feed characters.

*Range:* The valid range of input values for INPUT COMMANDS is shown here.

*Saved in EEPROM:* Certain INPUT COMMAND values may be saved in EEPROM. These values are not erased when the drive is powered down and back up again. "Yes" means the value can be saved to EEPROM. "No" means it cannot. "N/A" means the command is an output command. See the **SAVE** command description for more details.

*Enabled or Disabled (En/Dis):* Certain INPUT COMMAND values cannot be changed while the drive is enabled. "Disabled" means drive must be disabled prior to changing the command. "Either" means the system does not care whether the drive is enabled or disabled when changing the command. The system will return an error message if a command is entered that cannot be processed due to the enable status of the drive.

*String Length:* All numeric responses are returned as a character string of 4 to 71 characters. When the response displays fewer characters than the "string length" indicates, it is padded with spaces on the left. The string may be repeated several times depending on the length of the returned data. Each string is followed by the two additional characters, carriage-return and the linefeed.

**ANGLE**
*Input Command*
*Range: 0 to 359*
*EEPROM: Yes*
*En/Dis: Disabled*

Sets the motor commutation angle to a number from 0 to 359 in electrical degrees. This command can be used to optimize the commutation angle without having to mechanically adjust the feedback device.

**NOTE: There may be a short delay where the amplifier is in a "not ready"state while the commutation mode is updated in software.**

**CLEARZEROPOS**
*Operating Command*
*EEPROM: N/A*
*En/Dis: Disabled*

This command returns the system to normal operation after a **SETZEROPOS** command has been issued. (See section 4.2.3.2.1)

**COMMUT**
*Input Command*
*Range: 0 to 7*
*EEPROM: Yes*
*En/Dis: Disabled*

Selects the motor commutation type using a number from 0 to 7, where

0 = Encoder only ("Lock-and-go")
1 = Six step
2 = Twenty step (Pseudo-Sinewave)
3 = Resolver (Optional only)
4 = Encoder with six-step start and six-step reset
5 = Encoder with six-step start and index reset
6 = Ten step (even twenty step HEDs)
7 = Ten step (odd twenty step HEDs)

**NOTE: There may be a short delay where the amplifier is in a "not ready" state while the commutation mode is updated in software.**

**CONFIG**
*Output Command*
*En/Dis: Either*
*String Length: 10*

Requests the MCS configuration code of the amplifier. This parameter cannot be changed by the user.

**CONFIGREV**
*Output Command*
*En/Dis: Either*
*String Length: 10*

Requests the revision number of the amplifier configuration code. This parameter cannot be changed by the user.

**CONTROLLER**
*Output Command*
*En/Dis: Either*
*String Length: 10*

Requests the amplifier model number. This parameter cannot be changed by the user.

**DISFLT**
*Input Command*
*Range:0 to 4096*
*EEPROM: Yes*
*En/Dis: Either*

Determines which faults are active. Sets the DISFLT parameter to a number from 0 to any sum of one or more numbers below, to disable any selected faults. A fault is disabled if its weight is included in the number. ***The faults labeled "RESERVED" are not permitted to be disabled.*** To view what faults are disabled, use the **DISFLTQ** command.

**DISFLTQ**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 38 per line*

Requests a list of which faults have been enabled or disabled using the **DISFLT** command.

| Fault Name | DISFLT Decimal Weight | DISFLTQ Current Status |
|---|---|---|
| Motor Over Temperature | 1 [reserved] | ENABLED / DISABLED |
| Amp Over Voltage | 2 [reserved] | ENABLED / DISABLED |
| Logic Power Fault | 4 [reserved] | ENABLED / DISABLED |
| Auxiliary Fault | 8 | ENABLED / DISABLED |
| IPM Fault | 16 [reserved] | ENABLED / DISABLED |
| Regen Overload | 32 [reserved] | ENABLED / DISABLED |
| HED Fault | 64 | ENABLED / DISABLED |
| Resolver/Encoder Fault | 128 | ENABLED / DISABLED |
| Heatsink Overtemperature | 256 [reserved] | ENABLED / DISABLED |
| Overspeed Fault | 512 [reserved] | ENABLED / DISABLED |
| Short Circuit Fault | 2048 [reserved] | ENABLED / DISABLED |
| Tempsensor Fault | 4096 [reserved] | ENABLED / DISABLED |

**ENCODER**
*Input Command*
*Range: 0 to 999,999*
*EEPROM: YES*
*En/Dis: Disabled*

Sets the encoder line count to a number from 1 to 999999. Value is only Used when **COMMUT** is set to 0, 4, or 5. For other **COMMUT** values this parameter is ignored.

**ENCODERANGLE**
*Input Command*
*Range: 0 to 359*
*EEPROM: YES*
*En/Dis: Disabled*

This commands sets the phasing for the sinusoidal current requests with respect to the encoder index signal. See section 4.2.4.3.2 (*Commutation Adjustment for Encoder Systems*) for more information on this command.

**FLT**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length:*
*38 per line*

Requests system fault status in the following form:

| Fault Name | Current Status |
|---|---|
| Motor Over Temperature (1)* | FAULT / OK |
| Amplifier Over Voltage (2) | FAULT / OK |
| Logic Power Fault (4) | FAULT / OK |
| Auxiliary Fault (8) | FAULT / OK |
| IPM Device Fault (16) | FAULT / OK |
| Regen Overload Fault (32) | FAULT / OK |
| HED Fault (64) | FAULT / OK |
| Resolver/Encoder Fault (128) | FAULT / OK |
| Heatsink Over Temperature (256) | FAULT / OK |
| Overspeed Fault (512) | FAULT / OK |
| Short Circuit Fault (2048) | FAULT / OK |
| Tempsensor Fault (4096) | FAULT / OK |

* (weight, see **FLTX** command)

The unit is disabled, the fault output line remains high and the fault LED remains red as long as there is any fault in the system.

**FLTA**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 2*

Requests system fault status. Similar to **FLTX** command, except that the four digit hex number returned in **FLTX** command is returned here as two ASCII characters. The last two hex characters form the first ASCII character, and the first two hex characters form the second ASCII character (see **FLTX** command).

**FLTQ**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 38*

Requests the first system fault status of a queue. The queue stores up to twenty previous system faults. Each system fault may contain one or more of the above listed faults, and is stored in the queue only if it is different from the previous system fault or the fault was cleared and it occurred again. At each request, the oldest system fault in the queue is removed and is returned as the string names of the faults with the faulted status (see **FLT** command). When the queue is empty, there are no system faults. The FLT command will return "*No Faults Waiting for Print*."

**FLTQA**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 2*

Requests the first system fault status of a queue. The response is returned in the same form as the **FLTA command.**

**FLTQX**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 4*

Requests the first system fault status of a queue. The response is returned in the same form as the **FLTX command.**

**FLTX**
*Output Command*
*EEPROM: N/A*
*String Length: 4*

Requests the system fault status. The weights of all faults are added up (See **FLT** command) and the result is returned as a four-digit hex number. This is an exception to the minimum eight-character response rule.

**HEATSINKT**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 8*

Requests the heatsink temperature and displays in degrees Celsius. The temperature is displayed with a 1°C resolution.

**ID**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 71*

Requests the drive software version, controller type, serial number, configuration code, and configuration revision number. The response is 71-character string.

**LACOMPATIBLE**
*Input Command*
*Range: 0 or 1*
*EEPROM: YES*
*En/Dis: Disabled*

Command allows AX series drives to accept the LA series drive wiring standard for 6-step Hall effect commutators. LA series standard Hall effect wiring has H1 and H3 reversed from the AX wiring standard.

**LACOMPATIBLE**=1 turns on the compatibility mode
**LACOMPATIBLE**=0 turns off the compatibility mode

**LOCKCOUNT**
*Input Command*
*Range: 1 to 200*
*EEPROM: YES*
*En/Dis: Disabled*

Sets the time that the motor locks into a known position when first enabled. This command is only valid when **COMMUT** is set to 0 (Encoder Only). Each **LOCKCOUNT** step is equal to 100ms, therefore the parameter can be set to a minimum of 100ms and a maximum of 20 seconds.

**MAXSPD**
*Input Command*
*Range: 0 to freq limit*
*EEPROM: YES*
*En/Dis: Either*

Sets the maximum motor speed. Speed is entered in RPM. The maximum value is frequency limited depending on the settings of other parameters. **MAXSPD * ENCODER**. = 1.25 MHz maximum.

**MENU**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 70 per line*

Requests the alphabetical list of all commands. Each line in the response contains 70 characters.

**OVERSPEED**
*Input Command*
*Range:*
*0 to 110% MAXSPD*
*EEPROM: YES*
*En/Dis: Either*

Sets the speed threshold for an OVERSPEED fault. **OVERSPEED** is set to a positive speed value that is no greater than a speed 10% above the **MAXSPD** value. When the velocity feedback exceeds this value the drive faults and disables. OVERSPEED fault status is displayed using the **FLT** commands.

**PLIST**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 68 per line*

Requests the alphabetical list of all system parameters and their current values. This command may be issued before the **SAVE** command to review what data will be stored in memory.

**POLES** Sets the motor pole count to an even integer.
*Input Command*
*Range: Even Integers 2 to 128*
*EEPROM: YES*
*En/Dis: Disabled*

**REGENOHM** Inputs the resistance of the external load bank in ohms. This parameter is used in conjunction with **REGENPOWER** and **REGENOVERLOAD** commands to help protect the external load bank from a power overload. See Appendix A for more information.
*Input Command*
*Range: 2 to 360*
*EEPROM: YES*
*En/Dis: Disabled*

**REGENOVERLOAD** Inputs the short-duration overload factor (peak energy) rating of the external load bank. This parameter is used in conjunction with **REGENPOWER** and **REGENOHM** commands to help protect the external load bank from a power overload. See Appendix A for more information.
*Input Command*
*Range: 1 to 100*
*EEPROM: YES*
*En/Dis: Disabled*

**REGENPOWER** Inputs the continuous power rating of the external load bank in Watts. This parameter is used in conjunction with **REGENOHM** and **REGENOVERLOAD** commands to help protect the external load bank from a power overload. See Appendix A for more information.
*Input Command*
*Range: 100 to 36000*
*EEPROM: YES*
*En/Dis: Disabled*

**RESOLVERQ** Requests the current resolver position. The returned value is a 16, 14, 12, or 10 bit signed integer, depending on the selected resolver resolution (See **RESOLVERRES** command for more details.)
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length:*

**RESOLVERRES** Sets the resolution of the resolver to a number from 0 to 3, where:
*Input Command*
*Range: 0 to 3*
*EEPROM: YES*
*En/Dis: Disabled*

| | | |
|---|---|---|
| 0 = 10 bit | Max Speed* = 69120 RPM | Sim Encoder Out** = 256 |
| 1 = 12 bit | Max Speed = 17280 RPM | Sim Encoder Out = 1024 |
| 2 = 14 bit | Max Speed = 4320 RPM | Sim Encoder Out = 4096 |
| 3 = 16 bit | Max Speed = 1080 RPM | Sim Encoder Out = 16384 |

*The max speed limitation is due to the R/D converter.
**See section 4.5 for more details on simulated encoder outputs.

**SAVE** Stores current values of all commands for future power up. A save failure will return the response “write failed” which is 12 characters long.
*Operating Command*
*EEPROM: N/A*
*En/Dis: Either*

**SERIAL**
*Output Command*
*En/Dis: Either*
*String Length: 10*

Requests the serial number assigned to the amplifier. This parameter cannot be changed by the user.

**SETZEROPOS**
*Operating Command*
*EEPROM: N/A*
*En/Dis: Disabled*

Locks the rotor into a known position. The system is put in a special mode and the rotor remains locked until the **CLEARZEROPOS** command is issued. This command is useful for mechanically setting resolver commutation. (See section 4.2.3.2.1)

**SPDQ**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 8*

Requests the current motor speed in RPM. The motor direction is indicated by the **STAT** command and the polarity of the **SPDQ** response. Positive (+) speed is *clockwise* (looking at non-lead side) and negative (-) speed is *counterclockwise*.

**STAT**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 38*

Request system status in the following form:

| | | WEIGHT* |
|---|---|---|
| Speed | (the current speed) | |
| Direction | CW / CCW | (CCW = 1) |
| Enable Status | Enabled / Disabled | (Enabled = 2) |
| Ready | Yes / No | (Yes = 4) |
| Faulted | Yes / No | (Yes = 8) |
| Temperature Foldback | Yes / No | (Yes = 16) |
| Energy Foldback | Yes / No | (Yes = 32) |

(*WEIGHTS not returned by AX. See **STATX** for use of weights)

**STATA**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 4*

Requests the system status in the form of ASCII characters. The weights of the six system status (listed in **STAT** command) are added together and the result is returned as two ASCII characters. Note that the speed does not appear in the weight of this output.

**STATX**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 4*

Requests the system status. The weights of the six system status (listed in **STAT** command) are added together and the result is returned as a four-digit hex number. This is an exception to the minimum eight-character response rule. Note that the speed does not appear in the weight of this output.

**VERSION**
*Output Command*
*EEPROM: N/A*
*En/Dis: Either*
*String Length: 18*

Requests the drive software firmware version.

## 5.4 Error Messages And Their Meanings

When entering commands, the system may not be able to process the command for various reasons. The table below describes the error codes and the probable cause of the error.

| Error code | Error message | Possible Cause |
|---|---|---|
| 0? | Unrecognized command | Spelling of command incorrect |
| 2? | Invalid request | Input data out of acceptable range |
| 3? | Unable to change setup | Drive needs to be disabled |
| 4? | EEPROM Failure | EEPROM could not be read |
| 5? | Decimal number length exceeds limit | |
| 6? | Command string too long | Too many commands on one line |
| 7? | Index not found | Encoder index wire(s) broken |
| 8? | Max Commut Frequency Exceeded | 1.25 MHz encoder freq. exceeded* |
| 9? | Ext. Regen Overload Value Out-Of-Range | REGENOVERLOAD value too high |

*The error is generated when the product of MAXSPD and the encoder line count exceeds a frequency of 1.25MHz. This applies primarily to encoder-commutated systems.

# Part 6

## OPERATION

### 6.1 Power Up

**<u>CAUTION</u>: Before powering up for the first time, ensure that the system has Been installed and wired correctly. Refer to Part 3: Installation.**

At initial power up the drive logic voltage stabalize and the front panel LEDs begin to glow. (2-3sec). After initial configuration (3-10sec), the READY light will go green and the drive will be ready to accept commands. If the enable line is closed on power up, the READY light will stay red until the enable switch is opened. See Appendix A for a more detailed description of power up scenarios. In encoder only systems (**COMMUT 0**), when the unit is first enabled, it goes into an encoder initialization state. In this state, the motor is locked in a known position, and the position counter is initialized. The length of time that the rotor is locked is dependent on **LOCKCOUNT**.

### 6.2 Power Down

AX amplifiers contain internal bus capacitor bleeders which discharge the main bus capacitors after removal of Mains AC power. While the actual bleed-down time varies from drive to drive, all AX amplifiers bleed the main bus capacitors down to 60VDC or less within 5 seconds of removing Mains AC power assuming no other energy sources are present delivering energy to the amplifier (a spinning motor inertia, for example)

### 6.3 Normal Operation

#### 6.3.1 Torque Mode

In torque mode the amplifier controls the amount of current (torque) going to the motor. It uses the differential voltage at SC1-1 and SC1-2 for the torque request. This request is scaled into current determined by the rating of the amplifier, with +10V equal to full current in the CW direction and -10V equal to full current in the CCW direction. If this polarity needs to be changed, either adjust the ANGLE command by 180 degrees, or switch the inputs at SC1-1 and SC1-2. In this mode, the RDC (see the control level schematic) on the compensation header is set to 20.0K (unity gain). There is no tachometer feedback in the system.

#### 6.3.2 Velocity Mode

AX series amplifiers external velocity mode requires that the user input an analog signal at the differential analog input, SC1-1 and SC1-2. Positive voltage causes CW rotation, while negative voltage causes CCW rotation. An input of 10V will request to the top speed of the system. This mode is primarily used when there is an external controller that is either closing the position loop or commanding a velocity.

### 6.3.3 Velocity and Torque Mode Select

The AX amplifier can be configured to allow a controller to switch between torque mode and velocity mode through a digital input on SC1-10. The TTL signal is pulled up internally to select the default velocity mode. Velocity mode is the default setting and is selected by opening pin 10 or pulling it up to any voltage from 5-24VDC. When pin 10 is pulled down to logic common (SC1-8), the drive switches from velocity mode to torque mode operation.

## 6.4 Potentiometer Adjustments

Only two potentiometer adjustments are necessary on the motor controller: the speed scaling and the speed balance adjustment (zero speed offset). The speed scaling sets the top speed for the motor and the speed balance adjustment eliminates creep of the motor when requesting zero speed. It is best to perform the speed balance adjustment first.

Being analog adjustments, these potentiometers may need to be readjusted over time.

### 6.4.1 Speed Balance Adjustment

The zero speed balance adjustment is used to set the motor speed to zero when zero motor speed is requested. In analog command systems this is done by applying 0 VDC to the velocity request SC1-1. (shorting SC1-1 to SC1-2 or SC1-24) Adjust the "BALANCE" potentiometer, by inserting a small bladed screwdriver through the front panel and rotate the screw until the motor slows and then stops rotating.

In most Hall effect commutated systems, some encoder commutated systems, and some resolver commutated systems the motor may "hunt" back and forth when zero speed is requested. In these systems, the potentiometer should be adjusted to remove any net rotation.

### 6.4.2 Speed Scaling Adjustment

The speed scaling adjustment is used to vary the ratio of the command voltage to motor speed. (i.e. volts/RPM) In analog control systems, this is done by applying a voltage to the velocity request SC1-1, normally 10 VDC and measuring the speed of the motor. Adjust the "SPAN" potentiometer, by inserting a small bladed screwdriver through the front panel and turning the potentiometer until the speed of the motor matches the expected speed of the request voltage. Testpoint connector TP1-1 can be used to measure the “SPANNED” voltage.

## 6.5 Interlock Operation

**NOTE:** **When a fault occurs, the drive will stay in the faulted state until the enable line is opened. If the fault is no longer present, the drive will exit the fault state. If the fault is still present, the drive will stay faulted until the fault is cleared.**

The amplifier is well protected by a system of interlocks that continually monitor certain conditions that are external and other conditions that are internal to the unit. In addition to the internal interlocks, the auxiliary interlock input SC2-7 and the motor thermistor input, can be configured as external interlocks. Fault conditions are those that require immediate attention. These conditions cause the amplifier to automatically disable itself, as a protective mechanism, and go into a fault state. Faults will be indicated by a red front panel FAULT LED, the digital outputs connector, as well as over the RS232 interface (use commands **FLT** or **FLTQ**). Power supply interlocks monitor logic voltages and add power stage protection. The fault state is latching which means that the unit will remain faulted and disabled, even after the fault-causing condition is removed. The fault is cleared by disabling the drive if the drive was enabled when the fault occurred. If the fault occurs while the drive is disabled and the fault condition has been subsequently removed, the drive will enable the next time requested to do so.

**NOTE: Faults will only clear if they are no longer valid.**

A fault can be triggered by the following conditions:

**Motor Over- Temperature** - SC2-5 and SC2-6 are used to monitor resistance of a PTC thermistor embedded in the motor. A fault will occur when the resistance between SC2-5 and SC2-6 rises above approximately 825 ohms.

**Amplifier Over-Voltage Fault** - The amplifier has a bus over-voltage condition. This usually means that the external regen resistors are mis-sized or missing.

**Logic Power Supply Fault** - Occurs when the logic power supplies are missing or out of tolerance. Can also occur if +5 or +/- 15V outputs (encoder power, etc) are overloaded. This fault will also occur when trying to apply main AC power when the drive is already enabled.

**Auxiliary Fault*** - SC2-7 is open or pulled up to 5-24V.

**IPM Fault** - The IGBT IPM fault signal is active. An overtemperature or overload condition is a probable cause for this fault. If the IPM fault cannot be cleared, contact MCS.

**Regen Overload Fault –** The maximum peak or continuous power ratings of the internal or external resistive load ratings have been exceeded.

**HED Fault*** - The Hall effect signal inputs to the controller are either missing or mis-phased.

**Resolver/Encoder Fault*** - The resolver or encoder inputs to the controller are missing.

**Heatsink Over-Temperature** - The maximum allowable heatsink temperature has been exceeded.

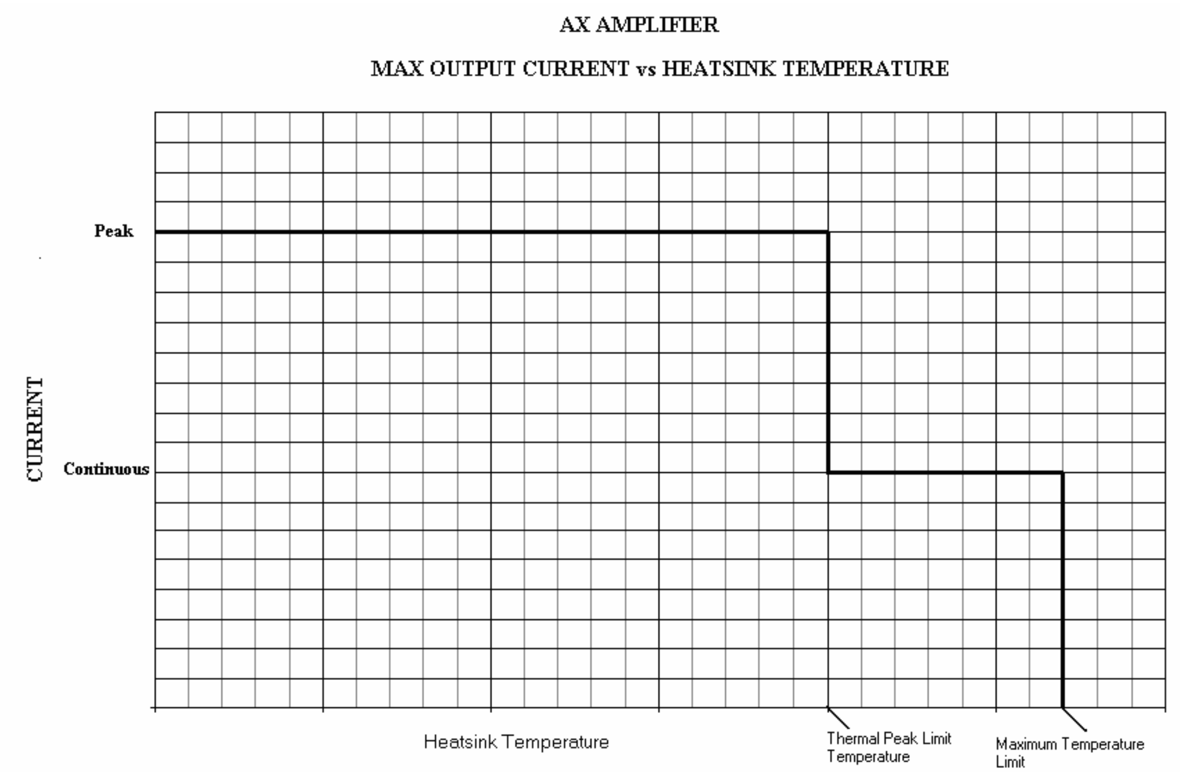
**Overspeed Fault** - The maximum allowable motor speed dictated by the OVERSPEED parameter has been exceeded.

**Short Circuit Fault** - The motor outputs are shorted to each other causing an over-current condition.

**Tempsensor Fault** - Indicates the digital temperature sensor inside the drive is malfunctioning.

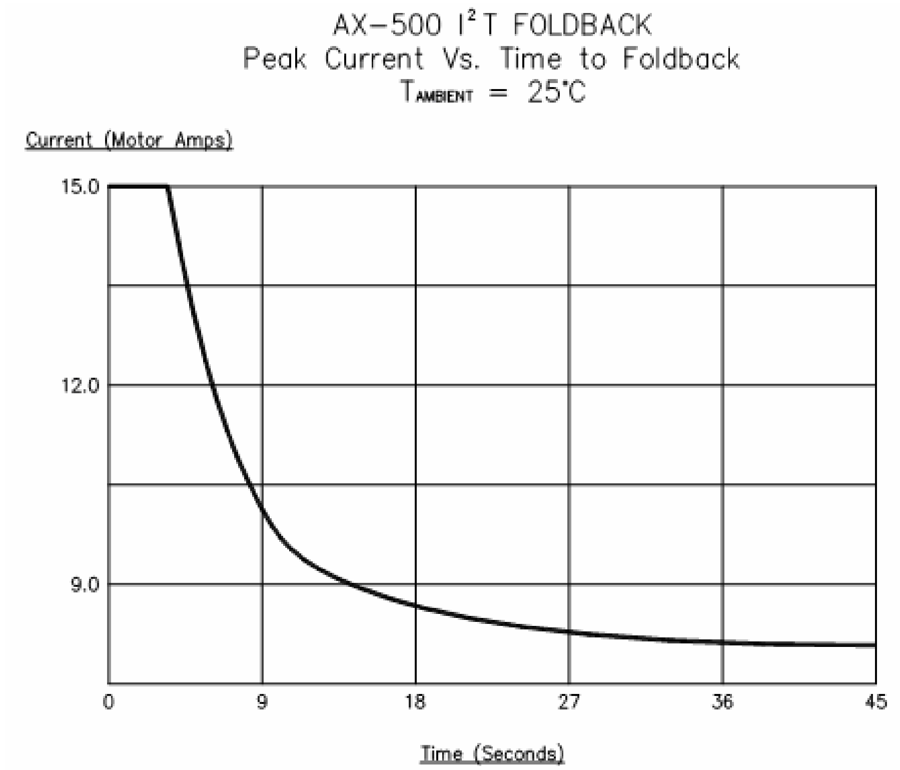
*Indicates faults which may be disabled by the user with the **DISFLT** command
The **DISFLT** command will enable and disable certain system faults. Use the **DISFLTQ** command to determine which faults are enabled/disabled for your system. See section 5.3 for a description of these commands.

## 6.6 I²T Current Foldback Operation




The $I^2T$ protection included in the AX series of amplifiers is used to ensure the reliability of the drive's power electronics in the presence of harsh operating conditions. The software is programmed to approximate the Safe Operating Area (SOA) of the amplifier power stage. Since the SOA is slightly different for each amplifier rating, $I^2T$ works somewhat differently in each case. In general, the protection is accomplished by reducing the allowable torque output to the drive's continuous limit when a foldback condition is exceeded.
The two types of foldback conditions that are implemented are temperature foldback and energy foldback. Temperature foldback is used to limit the drive capacity when the heatsink temperatures become elevated. This can be the result of an elevated ambient temperature, repeated peak torque operation, or a combination of both. The drive will reduce continuous current to the continuous current limit at the first temperature threshold. The drive will resume

normal operation when the temperature has dropped below the foldback threshold. The drive will disable and report an overtemperature fault if the maximum operating temperature is exceeded. Hysteresis is implemented to prevent oscillations in and out of foldback near the transition point. The STAT command displays the foldback status as:




| | |
|---|---|
| Temperature Foldback | YES / NO |
| Energy Foldback | YES / NO |

Energy Foldback is the result of the $I^2T$ integration reaching a defined amplifier limit. A typical overload curve is shown in the following figure. If the drive folds back due to an overload condition, it will resume normal operation in a fixed amount of time (10 seconds for most AX amplifiers).

## 6.7 Regenerative Braking

Regenerative braking is the process that converts the kinetic energy of the spinning rotor to electrical energy. The drive inverter decelerates the motor by producing reverse torque and the regenerated energy from the motor is returned to the DC bus. The AX dissipates the excess energy, as heat, by switching a resistive load (regen load) across the DC bus. The amount of deceleration is controllable through the velocity request/torque command input of the drive.

Dynamic braking converts the kinetic energy of the spinning motor to heat, without inverter control. The motor, acting as a generator, drives through the antiparallel diodes of the inverter and the rectified DC voltage powers the resistive load. The amplitude of the generated voltage (Vemf) determines how fast kinetic energy is removed from the motor and therefore the speed of the motor determines how quickly the motor decelerates. Dynamic braking is not controllable through the velocity request/torque command inputs and braking torque diminishes as the motor speed approaches zero.

The AX series motor drives use both regenerative and dynamic braking to help slow the motor. All AX drives, except for the AX500, have external terminals for connecting an external resistive load. See section 4.1.5 for external load minimum resistances. MCS has off-the-shelf regen solutions for most applications. Contact MCS for help in selecting the power rating for the external load. Regenerative braking requires that the AX drive have control (Logic AC) power and be ENABLED.

*Regenerative Braking*

| Drive Type | Logic AC | Main AC | ENABLED? |
|---|---|---|---|
| All AX series drives | ON | ON or OFF | YES |

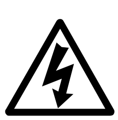
Dynamic braking automatically occurs when main AC power is removed from the drive and the conditions for dynamic braking are shown below:

*Dynamic Braking*

| Drive Type | Logic AC | Main AC | ENABLED? |
|---|---|---|---|
| All AX series drives | ON | OFF | NO |
| | OFF | OFF | X |

X = Does not matter since the drive cannot be ENABLED when logic power is off. The ENABLE status before power loss does not matter.

**CAUTION: Logic AC and Mains AC may be applied and removed together, but Mains AC *should not* be applied while Logic AC is not present.**



**WARNING: The power rating of the regenerative resistive load must be appropriate for the AX power rating. The load must safely dissipate the energy contained in the rotating mass. An incorrectly sized load could result in damage to the resistive load bank and the possibility of fire and damage to surrounding objects. The power rating of the resistive load must be entered through the control interface using the REGENPOWER and REGENOVERLOAD commands. If the regenerative resistive load opens due to overload conditions, or if the overload circuit is incorrectly configured, the rotating mass will not decelerate quickly and may pose a safety risk.**

# Part 7

## THEORY OF OPERATION

### 7.1 Velocity Loop

The velocity loop compares an analog command speed signal that is input through SC1-1 and SC1-2 with a motor speed feedback (tachometer) signal. The loop filter generates a velocity error signal that is proportional to the magnitude of requested motor current. Since motor current is proportional to torque in a DC brushless motor, the AX motor controller can also be operated in a "torquer" mode by removing the velocity feedback and adjusting the gain in the error amplifier to create a transconductance constant that relates command voltage to motor torque.

AX amplifiers use a form of Lead-Lag compensation to tune the response of the velocity loop. The velocity compensator is tuned at the factory prior to shipment and should be sufficient for the majority of applications. However, those who are familiar with tuning analog control loops may contact MCS to request more information to assist them with fine-tuning the response of the loop. MCS should be contacted before attempting to make component level changes within the amplifier as doing so may void the factory warranty.

### 7.2 Commutation Section

The motor controller is a three-phase drive for the sinusoidally wound DC brushless motor. This means that the voltage generated across each phase by turning the rotor at a constant speed will have a sinusoidal wave shape. The magnitude of the generated voltage is proportional to the angular velocity of the rotor. Phase V and phase U voltages lag phase W voltage by 120 and 240 electrical degrees respectively. In order to develop constant torque from the motor, sinusoidal currents must be injected into each motor winding in phase with the generated voltages. To do this the angular position of rotor must be known at all times. The motor controller determines the rotor position by converting the output signals of a shaft mounted resolver or encoder to a digital word that represents the absolute rotor position. This word is converted to three phase words that are each multiplied with the velocity error signal to generate the three-phase current request signals.

### 7.3 Motor Phase Current Control Loop Section

The current control loops compare the three-phase current requests from the velocity loop and commutation section with the actual phase currents to produce three current error signals which are voltage requests to the PWM amplifier stage.

AX amplifier current loops have been tuned, prior to shipment, based on the application data supplied to MCS. Again, for those familiar with tuning analog loops, MCS can supply information and assistance in compensating the current loop. Remember, the MCS factory warranty may be voided by opening the amplifier and making unauthorized changes.

## 7.4 Pulse Width Modulation Amplifier Section

The power stage section consists of the main power supply, the logic power supply, the regenerative discharge circuits, and the output inverter. The function of the power stage is to convert incoming AC power into a DC (350 or 700VDC) bus that is switched at high frequency across the motor phase windings. The pulse width modulation (PWM) section converts the three current error signals from the current loop into three constant frequency square waves that have pulse widths that are proportional to the magnitude of the current error signals. The three PWM pulse trains control the switching of the output inverter. The motor inductance integrates the high voltage pulses to produce smooth sinusoidal motor current. In addition, the power stage section contains current sensors that monitor the phase current and provide feedback signals to the current loops.

# Part 8

## SERVICING

Servicing procedures are not recommended. Do not attempt to service without consulting with MCS first.

**<u>WARNING:</u> Dangerous voltages exist at several places within the enclosure. Disconnect power before and during any disassembly or servicing. Only qualified personnel should service this product.**

### 8.1 Maintenance

AX motor controllers do not require regular maintenance. However, cooling fans and heatsink fins should be inspected for dust accumulation, which interferes with the air-cooling system. Dust can be removed from the AX using a clean pressurized (less than 40psi) air stream. The inspection schedule will depend on the amount of dust in the location of the motor controller.

### 8.2 Troubleshooting

The purpose of this section is to provide a guide for identifying problems related to installation, adjustment, or application of the AX motor controller. The guide is not intended as a service manual for the repair of damaged components. Service procedures should not be attempted without first consulting with MCS.

| ***** The power is turned on but the front panel LED's are not illuminated after applying Logic AC power.** |
|---|
| **<u>Note:</u> During normal operation there is a several second delay before the LED’s will illuminate after applying logic AC power.**<br><br><u>Problem</u> - Logic AC power is not connected.<br><br><u>Solution</u> - Refer to the amplifier connection information in section 10 and the Control Level Schematic |

| ***** The AX controller will not enable or disables when not commanded to do so.** |
|---|
| <u>Problem</u> - The Enable command input has not been opened before attempting to enable the AX.<br><br><u>Solution</u> - Open the connection between SC1-7 and SC1-8 and close the connection to enable. |

Problem - Interlock connections on SC2 (motor feedback connector) have not been made or have opened.

Solution - Refer to the control level schematic and verify that the motor thermistor is connected between SC2-5 and SC2-6. Also, be sure that SC2-7 and SC2-8 have been shorted together. It may be necessary to measure the resistance of the motor thermistor to confirm that its resistance is less than 825 ohms.

***The AX Amplifier has faulted and will not enable or disables when not commanded.***

Problem - Logic power fault as indicated by a **FLT** command..

Solution - Check all of the external wiring to be sure that there are no excessive loads on any of the logic power outputs. Contact Motion Control Systems

Problem - Motor over temperature fault as indicated by a **FLT** command

Solution - The motor thermistor must be connected between pins 5 and 6 of SC2. If the motor is hot, allow it to cool. Each motor thermistor should have a resistance of about 30 ohms when the motor is cool. The total resistance of series connected thermistors must be less than 800 ohms when the motor is cool. Disconnect the motor feedback cable and measure the resistance between pins 5 and 6 on the cable connector. If the resistance is less that 800 ohms and the AX still shows an over temperature fault after the cable is reconnected and an attempt is made to enable the controller, call MCS. If the resistance is greater than 800 ohms and the motor is cool (<25° C ) verify correct wiring to the motor thermistor in the motor feedback cable.

Problem - Amplifier overtemperature fault as indicated by a **FLT** command.

Solution - If the controller has recently faulted, determine whether the exhaust air from the controller is hot or whether the liquid coolant flow has been interrupted for water-cooled units. Verify that the cooling fan is working and is unobstructed. Open the enable input and allow the AX to cool. When the air exiting the AX unit is cool or liquid coolant has been allowed to flow unobstructed for a period of time, try to enable the controller. If the controller begins to operate, verify that the commutation has been adjusted correctly and that the motor turns smoothly. Measure the ambient air temperature and liquid coolant temperature (if used). Record these observations and call MCS.

Problem - Bus Overvoltage fault as indicated by a **FLT** command.

Solution - If this condition occurs on a deceleration make sure that the external regen resistors are attached. Turn off all power to the AX controller and contact MCS.

| ***  The motor will not turn and seems "locked" in position** |
| --- |
| Problem - Motor is wired incorrectly.<br><br>Solution - Verify that the motor is wired correctly according to section 4.1.6 or 4.1.7. |
| Problem - Commutation is incorrect (encoder systems only)<br><br>Solution - Verify the **ENCODER** and **POLES** setting in the amplifier and make sure that the system matches these parameters. |
| Problem - Resolver wired incorrectly or not functioning correctly (resolver commutated systems only)<br><br>Solution - Verify that the resolver is wired to SC2 on the AX according to section 4.2.3.1. Turn logic power on and use an oscilloscope to observe the sinusoidal waveform between pins 1 and 2 of SC2 and then between pins 3 and 4 of SC2. Rotate the motor by hand while observing the waveform. If the resolver is functioning, the oscilloscope should display a sinewave having a frequency between 1000 and 5000 Hz with amplitude that is modulated at a rate of once per motor revolution. |
| Problem - Encoder miswired, quadrature reversed, or not functioning correctly or Hall effect devices miswired, or not functioning. (encoder commutated systems only)<br><br>Solution - Verify that the encoder and Hall effect devices are wired to SC2 according to sections 4.2.1, and 4.2.4. Use an oscilloscope to simultaneously view the encoder signals at SC2-2 and SC2-3 while the motor is rotated in a counterclockwise direction. Be sure that the square wave at SC2-3 leads the squarewave at SC2-2 by about 90 electrical degrees. Refer to Section 4.2.4.2 - Encoder Input Convention for a diagram of the encoder signals. If not, swap the signals at SC2-2 with SC2-3 (and swap SC2-20 with SC2-21. Attempt to operate motor. If the motor is still "locked" into a position, use an oscilloscope to observe the waveforms at SC2-15 (H1), SC2-16 (H2), and SC2-17 (H3). The TTL level square waves should be sequenced in the following order: H1 leads H2 leads H3 when the motor is rotated in the counterclockwise direction. When viewing the Hall effects, make sure either they are connected to the drive or they are attached to a pull-up resistor. |
| Problem - **SETZEROPOS** command was issued but **CLEARZEROPOS** command has not yet been issued.<br><br>Solution - The **CLEARZEROPOS** command must be issued after the resolver has been set to unlock the rotor and allow normal commutation again. |

| ***  The motor turns but rotation is "jerky" or "rough", or the motor reverses direction when not requested to, motor and amplifier may get hot.** |
| --- |
| Problem - Resolver or encoder not coupled securely to the motor shaft.<br><br>Solution - Check couplings or clamps for slip. Tighten if necessary. |

| |
|---|
| Problem - Electrical noise on the encoder or the Hall effect device signals (Encoder commutated systems only).<br><br>Solution - Since high frequency electrical noise and extra edges can be difficult to observe on an oscilloscope, it is best to attempt to fix this problem before proving that noise is present. Read the encoder manufacturers directions and be sure that the encoder has been applied properly. Follow the guidelines in the control level schematic for encoder and Hall effect device wiring and check all connections. Be sure that the cable shields are connected to chassis at SC2-24. The encoder data channels should be connected to the AX using shielded twisted pairs to carry the complementary outputs. |
| Problem - Motor stator slipping in housing or rotor slipping on shaft.<br><br>Solution - Tighten if slip is occurring. |
| Problem - System is tuned incorrectly.<br><br>Solution - Retune until the system is stable. |

| ***  The motor rotates but does not reach speed or produces too little torque.** |
|---|
| Problem - Torque limit command voltage at SC1-3 is too low.<br><br>Solution - Increase the voltage input at SC1-3 (10 VDC max.) or simply connect SC1-3 to SC1-5 for a maximum torque limit setting. |
| Problem - The motor commutation not adjusted properly<br><br>Solution - Refer to sections 4.2.1.3, 4.2.2.2 (hall effects), 4.2.3.2 (resolver), or 4.2.4.3 (encoder only) and repeat the commutation adjustment procedure. |

| ***  The motor rotates but the motor and the AX controller get hot, even with only little motor loading.** |
|---|
| Problem - The motor commutation not adjusted properly<br><br>Solution - Refer to sections 4.2.1.3, 4.2.2.2 (hall effects), 4.2.3.2 (resolver), or 4.2.4.3 (encoder only) and repeat the commutation adjustment procedure. |

# Part 9

## SPECIFICATIONS

### 9.1 General

Operating Temperature: 0°C to +40°C Ambient Air Temperature
Non-Operating Temperature: -10°C to +60°C Ambient Air Temperature
Relative Humidity: 5% to 95%, Non-Condensing
Maximum Input Voltage on SC1: 10 VDC (+ or -) between pins 1 and 2
+10 VDC from pin 3 to pin 4
+5 VDC from pin 12 to pin 21 (for +5V Iso Option)
Or +24 VDC from pin 12 to pin 21 (for +24V Iso Option)

### 9.2 Amplifier Specifications

Details about these specifications are contained in this operator's manual.

### 9.2.1 Logic AC Input [Section 4.1.4]

| | Current Draw (RMS Amps) | Input Voltage Range | Input Voltage Frequency | Fuse Rating |
|---|---|---|---|---|
| **AX 500** | 250 mA | 100 - 240 VAC | 50 - 60 Hz | 1A, 250 VAC |
| **AX 1000** | 250 mA | 100 - 240 VAC | 50 - 60 Hz | 1A, 250 VAC |
| **AX 2000** | 250 mA | 100 - 240 VAC | 50 - 60 Hz | 1A, 250 VAC |
| **AX 2500** | 250 mA | 100 - 240 VAC | 50 - 60 Hz | 1A, 250 VAC |
| **AX 3000** | 250 mA | 100 - 240 VAC | 50 - 60 Hz | 1A, 250 VAC |
| **AX 5000** | 550 mA | 100 - 240 VAC | 50 - 60 Hz | 1.5A, 250 VAC |
| **AX 6000** | 550 mA | 100 - 240 VAC | 50 - 60 Hz | 1.5A, 250 VAC |
| **AX 6000 HV** | 550 mA | 100 - 240 VAC | 50 - 60 Hz | 1.5A, 250 VAC |
| **AX 10000 HV** | 1.25 A | 220 VAC | 50 - 60 Hz | 2A, 250 VAC |
| **AX 20000 HV** | 375 mA | 200-240 VAC | 50 - 60 Hz | 1A, 250 VAC |

*Current measured at 120VAC for AX500 - AX6000HV

### 9.2.2 Mains AC Input [Section 4.1.4]

| | AC Mains Fuse | Input Voltage Range | Input Voltage Phasing | Input Voltage Frequency |
|---|---|---|---|---|
| AX 500 | 10 A | 100 - 240 VAC | ~ 1 / ~ 3 | 50 - 60 Hz |
| AX 1000 | 20 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 2000 | 40 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 2500 | 50 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 3000 | 60 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 5000 | 100 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 6000 | 120 A | 100 - 240 VAC | ~ 3 | 50 - 60 Hz |
| AX 6000 HV | 60 A | 200 - 480 VAC | ~ 3 | 50 - 60 Hz |
| AX 10000 HV | 100 A | 200 - 480 VAC | ~ 3 | 50 - 60 Hz |
| AX 20000 HV | 200 A | 200 - 480 VAC | ~ 3 | 50 - 60 Hz |

### 9.2.3 AC Power and Motor Output Wire Sizes

| | Motor Outputs | Motor Ground | AC Mains AC Ground | Logic Power |
|---|---|---|---|---|
| AX 500 | 14-16 AWG | 12-16 AWG | 14-18 AWG | 18-20 AWG |
| AX 1000 | 12-14 AWG | 12-14 AWG | 12-14 AWG | 18-20 AWG |
| AX 2000 | 10-12 AWG | 8-12 AWG | 10-12 AWG | 18-20 AWG |
| AX 2500 | 8-10 AWG | 6-10 AWG | 8-10 AWG | 18-20 AWG |
| AX 3000 | 6-8 AWG | 6-8 AWG | 6-8 AWG | 18-20 AWG |
| AX 5000 | 4-6 AWG | 4-6 AWG | 4-6 AWG | 18-20 AWG |
| AX 6000 | 4 AWG | 4-6 AWG | 4 AWG | 18-20 AWG |
| AX 6000 HV | 6-8 AWG | 6-8 AWG | 6-8 AWG | 18-20 AWG |
| AX 10000 HV | 4 AWG | 4-6 AWG | 4-6 AWG | 18-20 AWG |
| AX 20000 HV | 1-1/0 AWG | 1-4 AWG | 2-6 AWG | 18-20 AWG |

### 9.2.4 Current Output, PWM Frequency, and Temperature Limits

| | Motor Output Current (Cont) | Motor Output Current (Pk) | Amplifier PWM Freq. | Heatsink Temp Temp Foldback | Heatsink Temp Amp Overtemp |
|---|---|---|---|---|---|
| AX 500 | 7.5A | 15A | 21 kHz | 59 °C | 78 °C |
| AX 1000 | 15A | 30A | 16 kHz | 54 °C | 73 °C |
| AX 2000 | 30A | 60A | 16 kHz | 49 °C | 68 °C |
| AX 2500 | 37A | 75A | 16 kHz | 54 °C | 73 °C |
| AX 3000 | 50A | 100A | 16 kHz | 54 °C | 73 °C |
| AX 5000 | 70A | 140A | 16 kHz | 54 °C | 73 °C |
| AX 6000 | 80A | 160A | 16 kHz | 54 °C | 73 °C |
| AX 6000 HV | 50A | 100A | 12.5 kHz | 50 °C | 60 °C |
| AX 10000 HV | 90A | 180A | 10.5 kHz | 50 °C | 70 °C |
| AX 20000 HV | 200A | 400A | 10.5 kHz | 35 °C | 45 °C |

**NOTE: All motor output current ratings are defined as peak sinewave motor phase current at 25 °C ambient temperature while motoring (not at stall).**

### 9.2.5 Regen Wire Sizes and Load Specifications

| | Minimum Load Resistance | Typical Peak Current At Min Resistance | Recom. Wire Gauge Regen Output |
|---|---|---|---|
| **AX 500** | No ext. load permitted | No ext. load permitted | N/A |
| **AX 1000** | 26 ohms | 14 A | 12-14 AWG |
| **AX 2000** | 10 ohms | 37 A | 10 AWG |
| **AX 2500** | 7 ohms | 53 A | 8 AWG |
| **AX 3000** | 7 ohms | 53 A | 6 AWG |
| **AX 5000** | 4 ohms | 93 A | 4 AWG |
| **AX 6000** | 3 ohms | 124 A | 4 AWG |
| **AX 6000 HV** | 6 ohms | 127 A | 6 AWG |
| **AX 10000 HV** | 6 ohms | 127 A | 4 AWG |
| **AX 20000 HV** | 4 ohms | 190 A | 2-4 AWG |

### 9.2.6 Physical Specifications

| | Height In. [mm] | Width In. [mm] | Depth In. [mm] | Weight Lb [kg] |
|---|---|---|---|---|
| **AX 500** | 13.6 [345.4] | 3.56 [90.5] | 8.84 [224.5] | 11 [5] |
| **AX 1000** | 13.6 [345.4] | 3.56 [90.5] | 8.84 [224.5] | 11 [5] |
| **AX 2000** | 15.35 [389.9] | 6.25 [158.8] | 9.83 [249.6] | 21 [9.5] |
| **AX 2500** | 15.35 [389.9] | 6.25 [158.8] | 9.83 [249.6] | 21 [9.5] |
| **AX 3000** | 15.35 [389.9] | 6.25 [158.8] | 9.83 [249.6] | 21 [9.5] |
| **AX 5000** | 15.35 [389.9] | 9.78 [248.4] | 10.44 [265.2] | 37 [81.5] |
| **AX 6000** | 15.35 [389.9] | 9.78 [248.4] | 10.44 [265.2] | 37 [81.5] |
| **AX 6000 HV** | 15.35 [389.9] | 9.78 [248.4] | 10.44 [265.2] | 37 [81.5] |
| **AX 10000 HV** | 32.25 [819.2] | 16.5 [419.1] | 10.25 [260.4] | 90 [198] |
| **AX 20000 HV** | 27.25 [692.2] | 9.37 [238.0] | 16.59 [421.4] | 88 [193.5] |

## 9.3 Connector Definitions

The connector pin definitions follow. Refer to the sections listed for further information about each connector and signal definitions.

### 9.3.1 SC-1: Analog Control & Status Connector

**[From Section 4.4.1 & 4.4.2]**

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 1 | Velocity Command + | 0.5 mA (sink) |
| 2 | Velocity Command - | 0.5 mA (sink) |
| 3 | Torque Limit + | 0.5 mA (sink) |
| 4 | Torque Limit Reference | 0.5 mA (sink) |
| 5 | + 10 VDC Reference Output | 15 mA (source) |
| 6 | - 10 VDC Reference Output | 15 mA (source) |
| 7 | Enable Input + | 5 mA (source) |
| 8 | Enable Input Reference (Logic Common) | 100 mA (sink) |
| 9 | Amp Ready Output (HI = Ready, LOW = Not Ready) | 0.25 mA (sink) |
| 10 | Velocity/Torque Mode Select (HI or OPEN = Vel, LOW = Torq) | 5 mA (sink) |

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 11 | +5V Output (Referenced to Logic Common) | 250 mA (source) |
| 12 | +5 to +24V Isolated Supply Input | 250 mA (sink) |
| 13 | A Differential Encoder Signal Output | 20 mA (source) |
| 14 | !A Differential Encoder Signal Output | 20 mA (source) |
| 15 | B Differential Encoder Signal Output | 20 mA (source) |
| 16 | !B Differential Encoder Signal Output | 20 mA (source) |
| 17 | I Differential Encoder Signal Output | 20 mA (source) |
| 18 | !I Differential Encoder Signal Output | 20 mA (source) |
| 19 | Amp Fault Status Output (HI = Fault, LOW = OK) | 50 mA (source) |
| 20 | Amp Enable Status Output (HI = Enabled, LOW = Disabled) | 50 mA (source) |
| 21 | Isolated Supply Reference Input | 250 mA (source) |
| 22 | Logic Common | 250 mA (sink) |

### 9.3.2 SC-1: Sine/Sine + 120 Connections (Optional)

| SC-1 Pin Number | Signal Definition | I/O Max Current |
|---|---|---|
| 1 | Sine (+) Input | 0.5 mA (sink) |
| 2 | Sine (-) Input | 0.5 mA (sink) |
| 3 | Sine+120 (+) Input | 0.5 mA (sink) |
| 4 | Sine+120 (-) Input | 0.5 mA (sink) |
| 5 | + 10 VDC Reference Output | 15 mA (source) |
| 6 | - 10 VDC Reference Output | 15 mA (source) |
| 7 | Enable Input + | 5 mA (source) |
| 8 | Enable Input Reference (Logic Common) | 100 mA (sink) |
| 9 | Amp Ready Output (HI = Ready, LOW = Not Ready) | 0.25 mA (sink) |
| 10 | Reserved | N/A |

### 9.3.3 SC-2: Commutation (Motor Feedback) Connector

**[From Sections 4.2.1 through 4.2.4]**

| PIN # | RESOLVER | ENCODER / 6-STEP HED | 20-STEP HED |
|---|---|---|---|
| 1 | S3 (Logic Common) | +5V (Red) (250 mA MAX) | +5V (Brown) (250 mA MAX) |
| 2 | S4 (Logic Common) | A Channel Input | H4 (GREY) |
| 3 | S1 (Cosine) | B Channel Input | H5 (YELLOW) |
| 4 | S2 (Sine) | I Channel Input | H6 (WHITE) |
| 5 | Motor Thermistor Input | | |
| 6 | Logic Common | | |
| 7 | Auxiliary Interlock: 0V = OK +5V = Fault | | |
| 8 | Logic Common | | |
| 9 | Logic Common | | |
| 10 | Resolver Oscillator | 6-Step Mode (Setup Pin) | H10 (Pink) |
| 11 | Reserved | Reserved | Reserved |
| 12 | Reserved | !I Channel Input | H9 (Blue) |
| 13 | External Tachometer Input | | |
| 14 | Logic Common | | |
| 15 | Reserved | H1 (White) | H1 (Red) |
| 16 | Reserved | H2 (Green) | H2 (Violet) |
| 17 | Reserved | H3 (Yellow) | H3 (Orange) |
| 18 | Reserved | RESERVED | RESERVED |
| 19 | Reserved | RESERVED | RESERVED |
| 20 | Reserved | !A Channel Input | H7 (Green) |
| 21 | Reserved | !B Channel Input | H8 (Tan) |
| 22 | -15V (150 mA MAX) | | |
| 23 | +15V (150 mA MAX) | | |
| 24 | Chassis Ground (For cable shield drain) | | |
| 25 | Logic Common | | |

*(MCS Wire Colors are given in parentheses)

### 9.3.4 TP-1: User-accessible Test Point Connector

| TP-1 Pin Number | Signal Definition | Output Max Current |
|---|---|---|
| 1 | Torque / Velocity Mode Request | 10 mA |
| 2 | Velocity Error (Torque Limited) | 10 mA |
| 3 | Phase W Current Request | 10 mA |
| 4 | Phase W Current Feedback | 10 mA |
| 5 | Phase W Current Error | 10 mA |
| 6 | Phase V Current Request | 10 mA |
| 7 | Phase V Current Feedback | 10 mA |
| 8 | Phase V Current Error | 10 mA |
| 9 | Tachometer Output | 10 mA |
| 10 | Logic Common | 100 mA |

### 9.3.5 SC-5: RS232 Serial Connector

**[From Section 4.3]**

| Amp DB9 Female Connector | Signal Name | Connect To Terminal Standard Serial Port DB9 | DB25 | Serial Port Function |
|---|---|---|---|---|
| 1 | Logic Common | - | 1 | Reserved |
| 2 | Receive | 3 | 3 | Transmit |
| 3 | Transmit | 2 | 2 | Receive |
| 4 | Shield | - | - | Not Used |
| 5 | Logic Common | 5 | 7 | Ground |
| 6 | Reserved | - | - | Reserved |
| 7 | +5V | - | - | +5V |
| 8 | Reserved | - | - | Reserved |
| 9 | Reserved | - | - | Reserved |

# Part 10

## LIST OF DRAWINGS

The drawings that are referenced in this section are located in the "pdfs" directory on this CDROM manual. Use the following links to jump directly to a specific section.

AX500/1000 Drawings
AX2000/AX2500/AX3000 Drawings
AX5000/AX6000 Drawings
AX6000HV Drawings
AX10000HV Drawings
AX20000HV Drawings
AX Series Control Level Schematic

### 10.1 Outline and Mounting Dimensions

| | |
|---|---|
| AX500/1000 | 1403820 |
| AX2000/AX2500/AX3000 | 1403890 |
| AX5000/6000 | 1404140 |
| AX6000HV | 1404490 |
| AX10000HV | 1404190 |
| AX20000HV | 1404330 |

### 10.2 Connection Diagram - Encoder commutated systems

| | |
|---|---|
| AX500/1000 | 1403780 |
| AX2000/AX2500/AX3000 | 1404280 |
| w/bus output option | 1403960 |
| AX5000/AX6000 | 1404160 |
| w/ bus output option | 1404210 |
| AX6000HV | 1404610 |
| w/bus output option | 1404620 |
| AX10000HV | 1404270 |
| w/bus output option | 1404130 |
| AX20000HV | 1404370 |

### 10.3 Connection Diagram - Resolver commutated systems

| | |
|---|---|
| AX500/1000 | 1403910 |
| AX2000/AX2500/AX3000 | 1404300 |
| w/bus output option | 1403950 |
| AX5000/AX6000 | 1404170 |
| w/ bus output option | 1404220 |

***Resolver commutated systems, continued…***

| | |
|---|---|
| AX6000HV | 1404630 |
| w/bus output option | 1404640 |
| AX10000HV | 1404250 |
| w/bus output option | 1404110 |
| AX20000HV | 1404390 |

## 10.4 Connection Diagram - Sine, Sine + 120 commutated systems

| | |
|---|---|
| AX500/1000 | 1403790 |
| AX2000/AX2500/AX3000 | 1404290 |
| w/bus output option | 1403940 |
| AX5000/AX6000 | 1404150 |
| w/ bus output option | 1404200 |
| AX6000HV | 1404600 |
| w/bus output option | 1404480 |
| AX10000HV | 1404240 |
| w/ bus output option | 1404100 |
| AX20000HV | 1404340 |

## 10.5 Connection Diagram – 20-Step (Pseudo-Sinewave) Commutated systems

| | |
|---|---|
| AX500/1000 | 1403920 |
| AX2000/AX2500/AX3000 | 1404310 |
| w/bus output option | 1403970 |
| AX5000/AX6000 | 1404180 |
| w/ bus output option | 1404230 |
| AX6000HV | 1404560 |
| w/bus output option | 1404590 |
| AX6000HV | 1404260 |
| w/bus output option | 1404120 |
| AX20000HV | 1404410 |

## 10.6 Connection Diagram – Brush DC Motors

| | |
|---|---|
| AX500/1000 | 1404730 |

## 10.7 AX Series Control Level Schematic – 1403900

# Appendix A

## Regeneration and Dynamic Braking

AX amplifiers require external resistor loads for many applications involving rapid acceleration and deceleration of large mechanical loads. Although the drives do contain resistors to assist in light braking and bus capacitor discharging, the internal resistance may be insufficient for some applications. The following discussion explains how to size an external resistor bank and how to configure the AX amplifier to protect against overloading the load bank.

Items required for the calculations:
1. Starting Speed - $N_s$
2. Final Speed - $N_f$
3. Total load inertia as seen by the motor - J
4. Peak Power - $P_{pk}$
5. Operating Bus Voltage - $V_{bus}$ [340VDC for all but HV systems, 680VDC for HV systems]
6. Minimum amplifier load resistance - $R_{min}$ [Refer to Section 4.1.5 or 9.2.5]
7. Maximum amplifier load resistance - $R_{max}$
8. Chosen resistance value - $R_{bank}$
9. Deceleration time between $N_s$ and $N_f$ - $t_d$
10. Peak bus voltage during regen - $V_{regen}$ [385VDC for all but HV, 765VDC for HV systems]

The resistance and power rating of the resistors can be calculated by many methods. In most cases trial and error is required due to the limited selection of sizes of resistors.

**Peak Calculation**

The peak calculation is used to determine the resistance value to use so that the amplifier will not have an overvoltage fault when changing from speed $N_s$ to speed $N_f$.

**Step 1 - Find the peak power point**

From either the torque-speed curve (preferred method) or by using measured torque [T (lb-in)] and speed to find power ( $P_{pk} = 746 * T * N_s / 63024$), determine the peak instantaneous power point for the deceleration. Note that it is possible for power to increase as a deceleration occurs (running against the Back EMF of the motor, for example), however this is not the typical case.

**Step 2 - Determine the peak current and its associated resistance**

Given the operating bus voltage and the peak power, the current and required maximum resistor value can be calculated from:

$I_{required} = P_{pk} / V_{bus}$ [I (Amperes), $P_{pk}$ (Watts), $V_{bus}$ (Volts)]
$R_{max} = V_{bus}^2 / P_{pk}$ [$R_{max}$ (Ohms), $P_{pk}$ (Watts), $V_{bus}$ (Volts)]

**Step 3 - Pick a resistance value**

$R_{max}$ is maximum resistance from which to select a resistor for the regeneration load bank. The minimum resistance $R_{min}$ is predetermined for the amplifier and the final resistance value selected should not be below this value or amplifier damage will occur. Select a value between the minimum and maximum values. Keep in mind that the load bank's resistance will increase as the resistor bank becomes hotter.

**Step 4 - Average Power dissipation**

The average power dissipation by the resistor bank is calculated from the rotational energy equation over the time of the deceleration. The average power calculation is used to size the wattage of the resistor bank.

The average power is given by the following equation:

$P_{avg} = (3.871946*10^{-5}) * J * (N_s - N_f)^2 / t_d$ [N (RPM), J(oz-in-$s^2$), $t_d$ (seconds)]

**Step 5 - Peak Power Dissipation**

The peak power dissipated by the resistor bank must be checked against the manufacturers data. If the power (or the associated current) exceeds the resistor's rated maximum then the resistor must be resized or used in a series and/or parallel connection to bring the power dissipation within rating. The peak power and current is determined from:

$P_{pk} = V_{regen}^2 / R_{bank}$

$I_{pk} = V_{regen} / R_{bank}$

**Configuring the AX for the External Load Bank**

AX amplifiers are designed to help protect the external load bank from an overload (overheating) condition. The drive does this by knowing the size and power capacity of the load bank and knowing when the regen circuit is on or off. From this information, the AX can calculate the power dissipated instantaneously and over a longer period of time. Three software parameters must be configured for the amplifier to correctly perform this calculation. These parameters apply only to the external load bank:

**REGENOHM –** This value represents the total resistance of the external load bank, in ohms. The nominal (room-temperature) value of the bank should be entered here.

**REGENPOWER –** The load bank total average power handling capability, in Watts, should be entered here.

**REGENOVERLOAD –** This parameter represents the "overload" or "peak" factor of the load bank. Typically the manufacturer will indicate a "5 times overload for 5 seconds" type of overload factor. This means the bank can take 5 times the rated power for a duration of 5 seconds without damage to the load. The REGENOVERLOAD parameter is the product of the power overload and the time duration, or a value of "25" for the above example. This example is typical, and in the absence of specified overload factor, a value of "25" may be used.

The AX also protects the resistors within the amplifier with pre-programmed overload parameters which cannot be changed in software. If a combination of REGENOHM, REGENPOWER, AND REGENOVERLOAD were to jeopardize the internal resistors, the AX will respond with an error code 9? to any of the three parameters that exceeded the internal resistor's capability. These three parameters are programmed, by default, to the same value as the internal resistor. When changing these three values, it generally helps to set REGENOVERLOAD to "1" first, then enter the REGENOHM and REGENPOWER values. REGENOVERLOAD can then be increased until the external load bank's overload rating has been reached. If a 9? error occurs while increasing the value of REGENOVERLOAD, that is an indication that the external load bank is sized beyond the power handling capability of the drive's internal resistor.

# Appendix B

## Permanent Magnet Brush DC Motor Control

In addition to brushless motors, the AX amplifier has the ability to be configured to control Brush DC motors. This appendix provides additional information required to connect the motor to the amplifier. See document 1404730 for an AX Connection Diagram for Brush DC Motors.

A brushless amplifier can control a brush motor by fixing the six-step HED states as if a “locked-rotor” six-step motor were connected. This forces the V and W phases into their maximum and minimum points respectively. The amplifier then behaves as a 4 quadrant H-bridge DC motor controller.

The amplifier can be configured as either a torque amplifier or a velocity amplifier. If it is to control velocity a brush tachometer must be used. It can only control permanent magnet motors, not separately excited wound field motors.

**Connections**

On the SC2 connector tie pin 15 to logic common (pin 9 is suggested). Use pins 7 and 5 as suggested in the manual for an auxiliary interlock or a motor over temperature sensor. If not used they must be tied to logic common as well. If a brush tachometer is to be used for velocity feedback, it should be connected to pins 13 and 14 of SC2. The velocity request is connected to pins 1 and 2 of SC1. The torque limit is connected to pins 3 and 4 of SC1 and should be tied to +10 volts if no torque limiting function is to be used. Connect the amplifier enable to pins 7 and 8 of SC1. If the amplifier is to be swapped between velocity mode and torque mode then this signal must be connected to pin 9 of SC1 as described in the manual, otherwise it may be left open. No wires should be connected to the encoder or resolver pins on SC2. The motor itself is wired to the W and V motor terminals on the amplifier.

**Software configuration**

Set the angle to 0 with the **ANGLE 0** command. Set the commutation mode to 1 with the **COMMUT 1** command and save the new configuration with the **SAVE** command

**Operation**

Operation is by supplying positive or negative voltage to pins 1 and 2 of SC1 depending on the direction of rotation desired and enabling the amplifier by shorting pin 7 of SC1 to logic common. The torque output of the motor may be limited by connecting 0 to +10 volts to pins 3 and 4 of SC1 corresponding to 0 to 100 % of torque. Velocity and torque mode may be selected by the use of pin 10 on SC1.

If the system is rotating the wrong direction for a specific velocity voltage request, the direction of rotation may be reversed by swapping the wires in the W and V terminals on the amplifier. If the system is using a brush tach to control velocity and the system runs away, the two brush tach wires should be swapped at pins 13 and 14 of SC2.