

Danaher Motion  
Dual-Axis Drive

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# Installation and User Manual

**KOLLMORGEN**

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giving our customers freedom of design

Firmware Version 0.5.6  
M-SS-014-2063

# Record of Manual Revisions

Issue No.	Date	Brief Description of Revision
01	10/31/01	Initial Release
03	12/31/01	Description of Position Loop
04	02/05/02	PGEAR and UVIGNORE
05	20 February, 2002	I/O Electrical specifications Direction of Motion Complete System I/O description
06	April 28, 2002	Updated description of Absolute Position and Zeroing

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# Safety Instructions

Only qualified personnel are permitted to transport, assemble, commission, and maintain this equipment. Properly qualified personnel are persons who are familiar with the transport, assembly, installation, commissioning and operation of motors, and who have the appropriate qualifications for their jobs. The qualified personnel must know and observe the following standards and regulations:

IEC 364 resp. CENELEC HD 384 or DIN VDE 0100

IEC report 664 or DIN VDE 0110

National regulations for safety and accident prevention or VBG 4

Read all available documentation before assembling and using. Incorrect handling of products in this manual can result in injury and damage to persons and machinery. Strictly adhere to the technical information regarding installation requirements.

It is vital to ensure that all system components are connected to earth ground. Electrical safety is provided through a low-resistance earth connection.

The Dual-Axis Drive product contains electro-statically sensitive components that can be damaged by incorrect handling. Avoid contact with high insulating materials (artificial fabrics, plastic film, etc.). Place the product on a conductive surface. Ground yourself (discharge any possible static electricity build-up) by touching an unpainted, metal, grounded surface before touching the equipment.

Keep all covers and cabinet doors shut during operation. Otherwise, potential hazards could cause severe personal injury or damage to the product.

Be aware that during operation, the product has electrically charged components and hot surfaces. Control and power cables can carry a high voltage, even when the motor is not rotating.

Never disconnect or connect the product while the power source is energized to avoid electric arcing and hazards to personnel and electrical contacts.

After removing the power source from the equipment, wait at least 10 minutes before touching or disconnecting sections of the equipment that normally carry electrical charges (e.g., capacitors, contacts, screw connections). To be safe, measure the electrical contact points with a meter before touching the equipment.

Safety-alert symbols indicate a potential for personal injury or equipment damage if the recommended precautions and safe operating practices are not followed. Read and be familiar with the safety notices in this manual before attempting installation, operation, or maintenance to avoid serious bodily injury, damage to the equipment, or operational difficulty. The symbols are:



**Warning** identifies hazards that could result in personal injury or death.



**Caution** identifies hazards that could result in personal injury or equipment damage.



**Note** identifies information critical to the user's understanding or use of the equipment.

# Product Description

The Dual-Axis Drive incorporates two independent servo drives in a single enclosure and provides high performance with fully digital current, velocity and position loop control. Digital control brings with it all the advantages of ease of use, eliminating the need adjusting potentiometers. Since the control loop parameters are stored digitally, there is no drift in performance over time. Commutation is sinusoidal from a  $\pm 10\text{VDC}$  command.

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## Operational Modes

- Current Mode:  $\pm 10\text{VDC}$  analog command
- Velocity Mode:  $\pm 10\text{VDC}$  analog command
- Position Mode: Pulse and direction

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## Robust Design

- Fully isolated electronics
- Fault Protection against output phase to phase short circuit, over-voltage, under-voltage, over-current, over-temperature (motor and drive), feedback loss
- Current foldback ( $I^2t$ ) provides protection against over-heating of the drive

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## Motor Feedback

- Heidenhain EnDat<sup>®</sup> sine encoder
- 2048 sine cycles per revolution
- Interpolation x256 for 524,288 equivalent lines per revolution and 2,097,152 counts per revolution after quadrature

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## Amplifier Configuration

- Use MOTIONLINK<sup>®</sup> to configure the amplifier

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## Protection

- Hardware faults: Over-current, over-voltage, under-voltage, feedback loss, Drive over-temperature, Motor over-temperature
- Application protection: Overspeed limit, velocity and current saturation, current foldback ( $I^2t$ ), position following error
- Fatal and non-fatal error coding with text explanation (FLTHIST, FLTCLR) and a run-time counter (TRUN) that records the time the fault occurred
- Configurable drive thermal protection through the foldback feature (FOLD, FOLDMODE). It sets the maximum time limit the drive can provide peak current (3:1) to the motor
- Active enable indicator through the status display decimal point

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## General

- Flash firmware memory for easy field upgrade installation
- Kollmorgen's patented "Torque Angle Control" for buried magnet motor designs (MTANGLC, MTANGLP, MVANGLF, MVANGLH - defined as speed and torque optimization through commutation angle advancing of the drive's output current waveform with respect to the motor's back EMF waveform
- Firmware and serial number information (VER, MOTOR) via terminal

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## Electrical Interface

- Bus Power: derived from 100-220VAC
- Logic Power: Separate 24VDC input

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## Control Specifications

- Current loop closure rate: 62.5 $\mu$ sec (16kHz)
- Velocity loop closure rate: 250  $\mu$ sec (4kHz)
- Position loop closure rate: 500 $\mu$ sec (2kHz)

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## Input/Output

- Individual Enable signals
- Individual  $\pm 10$ VDC reference command
- Individual Pulse & Direction command
- Individual InPosition indicator
- Ready: Set active when both drives are enabled without faults
- Alarm: Set active if either of the drives has faulted
- Clear: Toggling this signal low to high clears the faults

# Read Before Installing



*High voltage can present dangerous and hazardous conditions if not performed by a qualified electrician. Be certain to follow all national and local codes during installation. Follow all safety precautions outlined in the front of this documentation.*

1. Open the box(es) and remove all the contents. Check to ensure there is no visible damage to any of the equipment.
2. Mount the Dual-Axis Drive to the back panel. Refer to the appropriate Outline Dimensions for additional details. Metal-to-metal contact is important for electrical noise control!
3. Wire the Dual-Axis Drive according to the Connector Pin-outs.
4. Connect solid earth ground to frames of all components.
5. Wire the main AC power.
6. A 24VDC is needed for the logic power. This must be supplied through pins 40 and 41 (24V and 24V return respectively) of the I/O connector.
7. Wire user I/O and Encoder equivalent output at connector C250.
8. Wire the motor (Ma, Mb, Mc) and feedback.
9. Verify that all wiring is correct. Verify that earth grounds are connected. Verify all electrical and safety codes are met.
10. Connect the RS232 serial cable from the PC to connector C1.



# Unpacking and Inspecting

Open the box and remove all the contents. Check to ensure there is no visible damage to any of the equipments or parts.



*Electronic components in this amplifier are design-hardened to reduce static sensitivity. Proper procedures should be used when handling this equipment.*



*Remove all packing material and equipment from the shipping container. Be aware that some connector kits and other equipment pieces may be quite small and can be accidentally discarded if care is not taken when unpacking the equipment. Do not dispose of shipping materials until the packing list has been checked.*



*Upon receipt of the equipment, inspect components to ensure that no damage has occurred in shipment. If damage is detected, notify the carrier immediately. Check all shipping material for connector kits, manuals, diskettes, and other small pieces of equipment.*

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## Warranty Information

All products covered in this manual are warranted to be free of defects in material and workmanship and to conform to the specifications stated either in this document or product catalog description. All Kollmorgen brushless motors and electronics are warranty for a period of 12 months from the time of shipment. There are no other warranties, expressed or implied (including the warranty of merchantability and fitness for a particular purpose) which extends beyond this warranty. Kollmorgen warrants that the products covered in the manual are free from patent infringement when used for normal purposes.

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## Use as directed

Kollmorgen guarantees the conformance of the servo amplifiers with the standards for industrial areas stated in this manual, only if Kollmorgen delivers the components (motors, cables, amplifiers etc). The following guidelines describe the restrictions for proper use of the Dual-Axis Drive system:

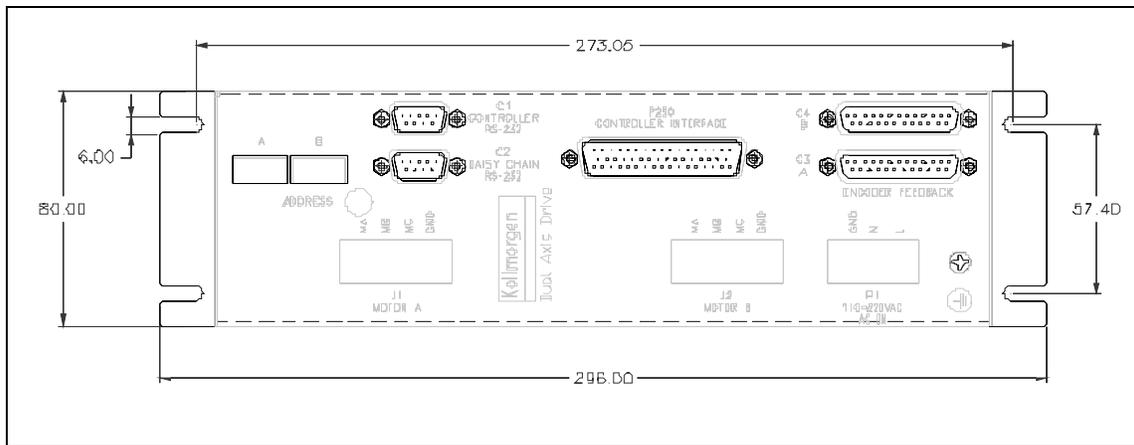
- The amplifiers are components built into electrical equipment or machines and can only be commissioned as integral components of such equipment.
- The servo amplifiers are to be used only on earthed three-phase industrial mains supply networks (TN-system, TT-system with earthed neutral point).
- The servo amplifiers must not be operated on power supply networks without an earth or with an asymmetrical earth.
- If the servo amplifiers are used in residential areas or in business or commercial premises, the user must implement additional filter measures.
- The servo amplifiers are only intended to drive specific brushless synchronous servomotors from Kollmorgen with closed-loop control of torque, speed, and position. The rated voltage of the motors must be at least as high as the DC-link voltage of the servo amplifier.
- The servo amplifiers may only be operated in a closed switchgear cabinet, taking into account the ambient conditions defined in the environmental specifications.

# Mounting

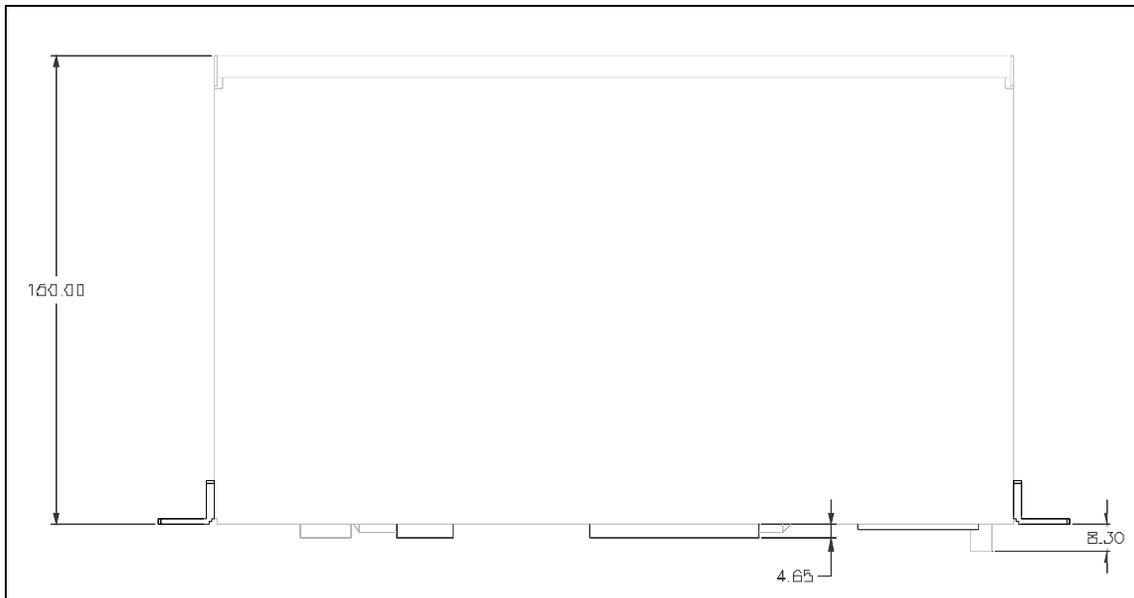
For proper ventilation, the Dual-Axis Drive *must* be mounted vertically. This product is designed for mounting in an electrical enclosure to protect it from physical and environmental damage.

## Outline Dimensions

### Front View



### Top View



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## Installation

The environment that any electronic control system ‘lives’ in can effect its operation. Kollmorgen recommends that the Dual-Axis Drive system be operated and stored under the environmental conditions stated in the product specification tables. The system may be operated in higher temperature ambient conditions with a derating applied. Please check with the factory for derating information.



*Attention to proper installation and field wiring are imperative to ensure long-term and trouble-free operation. Users should familiarize themselves with and follow the installation and wiring instructions listed in this section. In addition to these practices, some localities and industries may require applicable electrical and safety codes, laws, and standards.*

## Enclosure

The Kollmorgen SERVOSTAR series of electronic system components are designed for panel assembly. This panel assembly should be mounted in a metallic enclosure. ***Metal-to-metal contact is important for electrical noise control!*** Enclosures are supplied by the manufacturers of the final product and must meet the environmental IP rating of the end product. To ensure proper grounding (and to optimize EMC), the enclosure should have continuous ground continuity maintained between all metal panels. This ground continuity is intended to be both a safety ground and a high frequency ground. The units should be mounted on a back plane, which is installed into the enclosure. Ideally, the back plane should be an unpainted metallic surface to optimize electrical bonding of the frame and provide the lowest possible impedance path to earth ground. These enclosures also provide added safety.

# Wiring

## Electrical Specifications

<b>Main Input Power (both axes)</b>	Voltage (VAC <sub>L-L</sub> ) Nominal $\pm 10\%$	110 – 230
	Connection	Single Phase
	Line Frequency (Hz)	47 – 63
	KVA at 115	0.89
	KVA at 230	1.8
	Continuous current (Amps)	10
	Peak Current (Amps) for 500 msec	30
	Peak Current (Amps) for 2 sec	20
	Line fuses	20
<b>Rated Output Power (Per Axis)</b>	Continuous Power (KVA) at 115 VAC Line Input (45C (113F) Ambient)	0.35
	Continuous Power (KVA) at 230 VAC Line Input (45C (113F) Ambient)	0.7
	Continuous Current (Arms)	3 (6A with additional cooling)
	Peak Current (Arms) for 500 mSec	9 (18A for additional cooling)
	Peak Current (Arms) for 2 Sec	6
	PWM Frequency (kHz) PWM	16
	Motor Current Ripple (kHz)	32
<b>Protective Functions</b>	Under Voltage trip	75VDC
	Over Voltage Trip	450VDC
	Over Temperature Trip	80°C (176°F)
<b>Environment</b>	Operating Temperature	5°C (41°F) to 45°C (113°F)
	Storage Temperature	0°C (32°F) to 70°C (158°F)
	Ambient Humidity	10% to 90%
<b>Analog Input</b>	Maximum Voltage	$\pm 12.5$ V differential
	Operating Voltage Range	$\pm 10$ V differential
	Input Resolution	12 bit
	Sensitivity	4.9mV @12Bit
	Input Impedance/CMR	> 10 K ohms/50 dB
<b>Digital Inputs</b> (AlarmClear, ServoOn)	Input voltage	5-24Vdc $\pm 10\%$
	Maximum current	10mA per input

<b>Pulse Train Input</b>	Input voltage	5Vdc ± 10%
	Maximum current	25mA
	Maximum frequency	2.5MHz
<b>Digital Outputs</b> (DriveReady, InPosition, Alarm)	Maximum load capacity	24Vdc / 50mA
	Maximum saturated voltage	2V
<b>Equivalent Encoder Output</b>	Output format	Differential line driver
	Recommended line driver	TI SN75ALS193 or AM26LS32 equivalent
	Maximum frequency	2.5MHz

## Connector Pin-outs

The following section provides connector information.

### Connector C1: Host Communications

Connector Specification	9-pin D-Sub Male <b>Manufacturer:</b> CONNEC <b>Part Number:</b> 163A 20009X <b>Description:</b> DUAL D-T 9P MALE TOP/FEMALE BOTTOM; 4-40THD W/CLIP
Mating Connector Specification	9-pin D-Sub Female

Pin Number	Functionality
1	N/A
2	DUAL-AXIS DRIVE Rx
3	DUAL-AXIS DRIVE Tx
4	N/A
5	DGND
6	N/A
7	N/A
8	N/A
9	N/A

### Connector C2: Daisy Chain Communications

Connector Specification	9-pin D-Sub Female <b>Manufacturer:</b> CONNEC <b>Part Number:</b> 163A 20009X <b>Description:</b> DUAL D-T 9P MALE TOP/FEMALE BOTTOM; 4-40THD W/CLIP
Mating Connector Specification	9-pin D-Sub Male

Pin Number	Functionality
1	N/A
2	DUAL-AXIS DRIVE Tx
3	DUAL-AXIS DRIVE Rx

4	N/A
5	DGND
6	N/A
7	N/A
8	N/A
9	N/A

**Connector P250: Controller Interface**

Connector Specification	50-pin D-Sub Male <b>Manufacturer:</b> CONNEC <b>Part Number:</b> 163A 18709 X <b>Description:</b> D-TYPE CONN. 50 PIN MALE 0.370", 4-40 Thread
Mating Connector Specification	50-pin D-Sub Female

Pin Number	Name	I/O	Function
1	DC5V	Input	External 5VDC power supply or 5-24VDC common.
2	-	-	No connection
3	CLR	Input	Alarm Clear
4	-	-	No connection
5	-	-	No connection
6	ALM+	Output	Alarm +
7	ALM -	Output	Alarm -
8	COM	Output	Output common
9	-	-	No connection
10	CWP+ A	Input	Axis A direction +
11	CWP- A	Input	Axis A direction -
12	CCWP- A	Input	Axis A pulse -
13	CCWP+ A	Input	Axis A pulse +
14	CWP+ B	Input	Axis B direction +
15	CWP- B	Input	Axis B direction -
16	CCWP- B	Input	Axis B pulse -
17	CCWP+ B	Input	Axis B pulse +
18	SVON B	Input	Axis B servo on (enable)
19	-	-	No connection
20	-	-	No connection
21	-	-	No connection
22	IPOS B	Output	Axis B In Position
23	-	-	No connection
24	-	-	No connection
25	RDY	Output	Drive ready
26	CHA B	Output	Axis B position feedback phase A
27	* CHA B	Output	Axis B position feedback phase A complement
28	CHB B	Output	Axis B position feedback phase B
29	* CHB B	Output	Axis B position feedback phase B complement
30	CHZ B	Output	Axis B position feedback phase Z (index)
31	* CHZ B	Output	Axis B position feedback phase Z (index) complement
32	ANIN+ B	Input	Axis B analog input +
33	ANIN- B	Input	Axis B analog input -
34	SVON A	Input	Axis A servo on (enable)
35	-	-	No connection
36	-	-	No connection
37	-	-	No connection
38	IPOS A	Output	Axis A In Position
39	-	-	No connection
40	24V	Power	24V Supply
41	24V_RET	Power	24V Return
42	CHA A	Output	Axis A position feedback phase A
43	* CHA A	Output	Axis A position feedback phase A complement
44	CHB A	Output	Axis A position feedback phase B

Pin Number	Name	I/O	Function
45	* CHB A	Output	Axis A position feedback phase B complement
46	CHZ A	Output	Axis A position feedback phase Z (index)
47	* CHZ A	Output	Axis A position feedback phase Z (index) complement
48	-	-	No connection
49	ANIN+ A	Input	Axis A analog input +
50	ANIN- A	Input	Axis A analog input -

### Connector C3: Motor A Feedback

Connector Specification	25-pin D-Sub Female <b>Manufacturer:</b> CONNEC <b>Part Number:</b> 164A20429X <b>Description:</b> DUAL PORT D-TYPE CONN. 4x40 THREAD
Mating Connector Specification	25-pin D-Sub Female

Pin Number	Functionality
1	Sine Enc A
2	Sine Enc A\
3	No connection
4	Sine Enc B
5	Sine Enc B\
6	No connection
7	DGND
8	DGND
9	SSI Data\
10	SSI Clock\
11	No connection
12	No connection
13	Motor Temperature
14	No connection
15	No connection
16	No connection
17	No connection
18	E5V
19	E5V
20	E5V
21	No connection
22	SSI Data\
23	SSI Clock\
24	No connection
25	Motor Temperature\

**Connector C4: Motor B Feedback**

Connector Specification	25-pin D-Sub Female <b>Manufacturer:</b> CONNEC <b>Part Number:</b> 164A20429X <b>Description:</b> DUAL PORT D-TYPE CONN. 4x40 THREAD
Mating Connector Specification	25-pin D-Sub Female

Pin Number	Functionality
1	Sine Enc A
2	Sine Enc A\
3	No connection
4	Sine Enc B
5	Sine Enc B\
6	No connection
7	DGND
8	DGND
9	SSI Data\
10	SSI Clock\
11	No connection
12	No connection
13	Motor Temperature
14	No connection
15	No connection
16	No connection
17	No connection
18	E5V
19	E5V
20	E5V
21	No connection
22	SSI Data\
23	SSI Clock\
24	No connection
25	Motor Temperature\

**Connector J1: Motor A**

Connector Specification	AMP 193839-3
Mating Connector Specification	Housing: AMP P/N 770019 Pins (12-14 AWG): AMP 193841-1 Strain relief: AMP P/N 641945-1

Pin Number	Functionality
1	Chassis
2	Phase C1
3	Phase B1
4	Phase A1

**Connector J2: Motor B**

Connector Specification	AMP 193839-3
Mating Connector Specification	Housing: AMP P/N 770019 Pins (12-14 AWG): AMP 193841-1 Strain relief: AMP P/N 641945-1

Pin Number	Functionality
1	Chassis
2	Phase C2
3	Phase B2
4	Phase A2

**Connector P1: AC Input**

Connector Specification	AMP 193839-2 (3 pin)
Mating Connector Specification	Housing: AMP 770018 Pins (12-14 AWG): AMP 193841-1 Strain relief: AMP 641776-1

Pin Number	Functionality
1	Line
2	Neutral
3	Chassis

**Wiring Notes**

- Note 1** Allow 30 seconds after turning power off before reapplying power.
- Note 2** All AC Line wires should be twisted pair.
- Note 3** The ground of the drive and motor best minimizes ground currents and noise when connected in a “star point” configuration.
- Note 4** Cables should be properly bonded to the back panel and implemented as close to the drive side of the cable as possible for effective grounding. If bonding is installed, the shield on the cable end need not be connected to the “star point” configuration. Only connect the shield on one end of the cable; preferably on the drive side.
- Note 5** Do not connect unused pins on C1 connector. Some manufacturers’ cables connecting all pins may give unpredictable operation.

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## Filtering and Bonding Notes

- Note 1:** Input power - Enters enclosure from metal conduit.
- Note 2:** Single point ground. A bus bar (ground bus) is an excellent way to achieve this.
- Note 3:** High frequency ground between conductive back panel and enclosure. Also, a high frequency ground is required between the enclosure and earth ground.
- Note 4:** EMI filter grounding. Safety grounds must be provided on the filters. Potentials can exist even when the power is off because of the capacitors internal to the filters.
- Note 5:** Bonding of motor cables. The use of armored (screened) motor cables that are bonded as close to the drive as possible are essential for CE compliance and strongly recommended to better the overall performance and reliability of the system.
- Note 6:** Feedback cable bonding is required for CE compliance. As with the motor cables, the feedback cables should be bonded to the back panel. This bonding will do two things. First it will cut down radiation from the drive. This radiation may be in the form of high frequency energy resulting from internal processor clocks. The second thing this bonding effort does is provide immunity for the drive. Since the feedback device is located internal to the motor it is going to pick up some noise currents and transmit them along the feedback cable. The bonding will direct the currents from the shield of the feedback cable to back panel ground. This will reduce the amount of noise entering the drive.
- Note 7:** AC power lines that must be routed past other lines (such as motor cables or I/O lines) should cross at a 90° angle. This will minimize the coupling effect. Additionally, the power lines should be routed as close to the back panel as possible. Any noise currents on the lines may then be capacitively coupled to the ground plane and not to other lines.
- Note 8:** Control (I/O) signals should be kept separate from all power and motor cables if possible. Keep control wiring as short as possible and use screened wire. Bonding is also recommended but not required for CE compliance. Separation distance of 20cm (8 in) should be sufficient in most cases. Where control cables must cross power cables, they should cross with an angle of 90 degrees.
- Note 9:** Motor cables and feedback cables exiting the cabinet going to the motor should be separated as much as possible. Ideally, the use of separate conduits will provide good isolation, which can limit coupling of noise from motor to feedback cables.

## Grounding

System grounding is essential for proper performance of the drive system. A ground bus bar may be used as a single point ground for the system. Safety grounding should be provided to all pieces of the system from a “star point”. In addition to the safety grounding, a high frequency ground must be provided that connects the back panel to the enclosure, and ultimately to earth ground. The objective is to provide an extremely low impedance path between the filters, drives, power supplies, and earth ground. This high frequency ground can be accomplished with the use of a flat braid or copper bus bar. It is important not to rely on a standard wire for the high frequency ground. In general, a wire has an inductance of 8nH/in regardless of diameter. At higher frequencies, this unwanted inductance between grounds equates to limited filter performance. When connecting high frequency grounds, use the shortest braid possible.

## Bonding

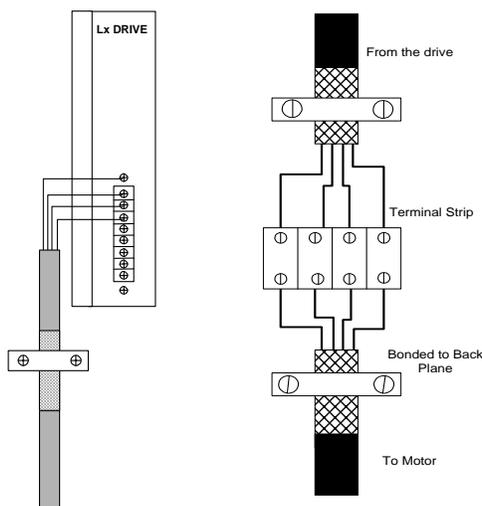
The proper bonding of shielded cables is *imperative* for minimizing noise emissions and increasing immunity levels of the drive system. Its effect is to reduce the impedance between the cable shield and the back panel. Kollmorgen recommends that all shielded cables be bonded to the back panel.

Power input wiring does not require shielding (screening) if the power is fed to the cabinet (enclosure) via metallized conduit. If the metallized conduit is used with proper high frequency grounds, bonding technology, and recommended wire routing, then power input wire shielding will have no affect. In the event that metallized conduit is not implemented into the system, shielded cable will be required on the power input wires and proper bonding technologies should be implemented.

The motor and feedback cables should have the shield exposed as close to the drive as possible. This exposed shield can be bonded to the back panel using one of the two suggested methods below:

## NON-INSULATED CABLE CLAMP

The following figures shows how cable bonding can be implemented using non-insulated metallic cable clamps. The first figure demonstrates clamping to the back panel in the vicinity of the drive. The second shows a technique for bonding a terminal strip (for best results, it is recommended not to break the shielding of the cable).



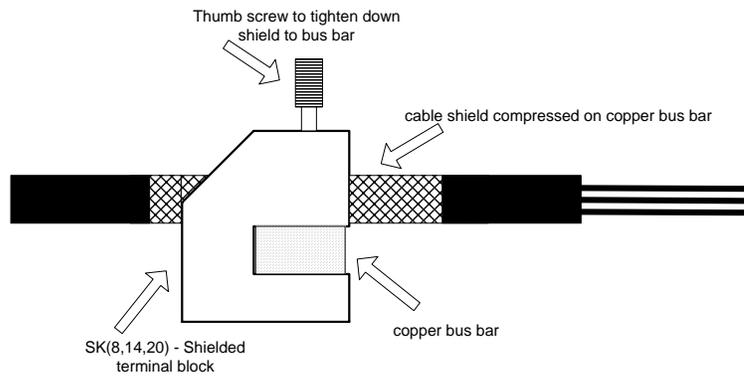
*Lx Drive Clamp and Terminal Clamp*

## ALTERNATIVE BONDING METHODS

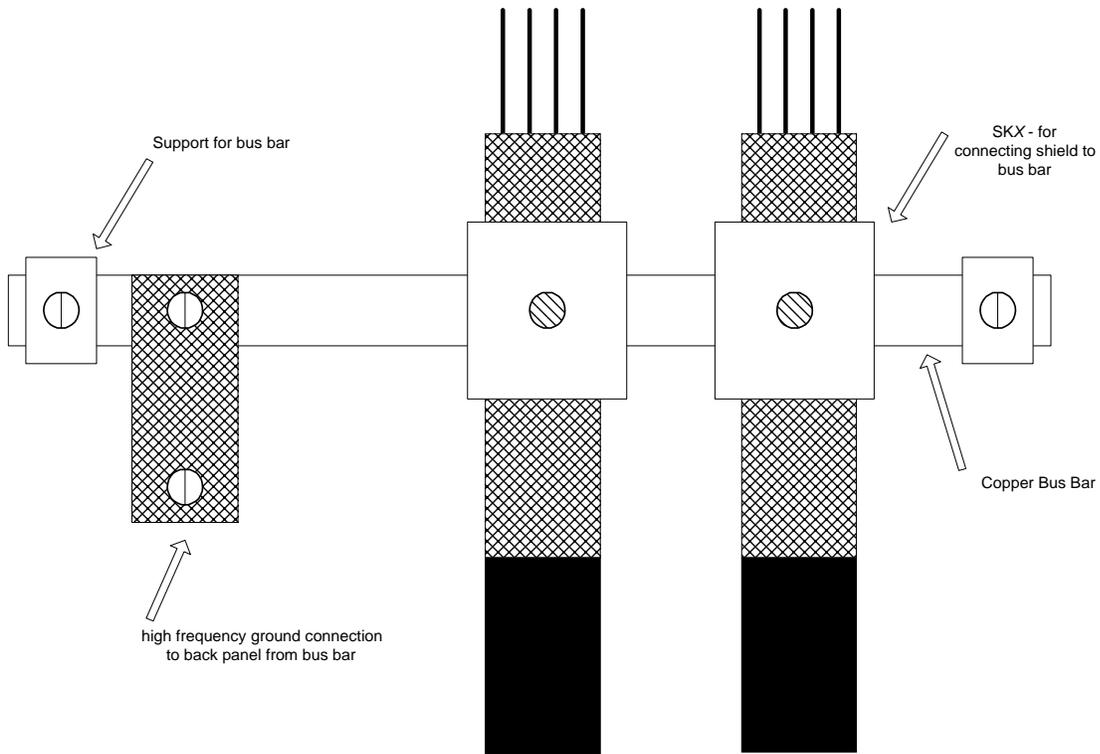
Another option is to use cable bonding clamps offered by Phoenix Contact (and others). When using the Phoenix Contact parts, make sure that a low impedance (high frequency) ground is connected from the ground bus bar to the back panel. This can be done with a flat braid or a copper bus bar. The SK parts from Phoenix (SK8, SK14, & SK20) slide onto the bus bar. The cable (with exposed shield) is inserted through the SK piece and the thumbscrew on top of the SK piece is used to tighten the connection between the cable shield and the bus bar.

Phoenix Contact Part #	Description	Cable Diameter Range
3025163 Type SK8	Shielded terminal block - for placing the shield on bus bars.	SK8 up to 8mm or 0.315 inches
3025176 Type SK14	Shielded terminal block - for placing the shield on bus bars.	SK14 8mm to 14mm or 0.551 inches
3025189 Type SK20	Shielded terminal block - for placing the shield on bus bars.	SK20 14mm to 20mm or 0.787 inches
0404428 Type AB/SS	Support for bus bar. 2 needed to mount ground bus.	N/A
0402174 Type NLS-CU 3/10	Bus bar material - 10mm x 3mm copper at varying lengths.	N/A

The next two figures represent a side and top view of the SK device that clamps down on the shield of the cable. The use of the Phoenix SK device is an excellent method for providing a low impedance path between cable shield and the back panel.



*Phoenix Contact -Side View*



*Phoenix Contact -Top View*

## ***CE Filtering Techniques***

The Dual-Axis Drive system (drive and motor) meets the CE Mark standards stated in the front of this manual. It is imperative for the user to apply proper bonding and grounding techniques, described earlier in this section, when incorporating EMC noise filtering components for the purpose of meeting this standard.

Noise currents often occur in two types. The first is conducted emissions that are passed through ground loops. The quality of the system grounding scheme inversely determines the noise amplitudes in the lines. These conducted emissions are of a common-mode nature from line to neutral (or ground). The second is radiated high-frequency emissions that are usually capacitively coupled from line-to-line; therefore, they are differential in nature.

To properly mount the filters, the enclosure should have an unpainted metallic surface. This will allow for more surface area to be in contact with the filter housing and provide a lower impedance path between this housing and the back plane. The back panel should in turn have a high frequency ground strap connection to the enclosure frame and/or earth ground.

## **INPUT POWER FILTERING**

The Dual-Axis Drive electronic system components require EMI filtering in the input power leads to meet the conducted emission requirements for the industrial environment. This filtering will block conducted-type emissions from exiting onto the power lines and/or provide a barrier for EMI that might be present on the power lines.

Care must be taken to adequately size the system. The type of filter must be based on the voltage and current rating of the system and whether the incoming line is single or three-phase. One input line filter may be used for multi-axis control applications. These filters should be mounted as close to the incoming power as possible so noise is not capacitively coupled into other signal leads and cables. These lines may be noisy and should be separated from other sensitive cabling to avoid unwanted coupling of noise. Several manufacturers of these filters are listed below.

They should be able to recommend the best filter design for most typical motor control applications. Kollmorgen has also provided specific filters recommendations that will adequately attenuate the conducted noise to levels well below the CE limits. The implementation of the EMI filter should be done in accordance with the following guidelines:

- Filter should be mounted as close as possible to incoming cabinet power.
- When mounting the filter to the panel, remove any paint or material covering. Use an unpainted metallic back panel if possible.
- Filters are provided with an earth connection. All ground connections should be tied to ground.
- Filters can produce high leakage currents. Filters must be earthed before connecting the supply!
- Filters should not be touched for a period of 10 seconds after removal of the supply.

## MOTOR LINE FILTERING

Motor filtering may not be necessary for CE compliance of SERVOSTAR systems. However, this additional filtering may increase the reliability of the system. Poor non-metallic enclosure surfaces and lengthy, unbonded (or unshielded) motor cables that couple noise line-to-line (differential) are just some of the factors that may lead to the necessity of motor lead filtering.

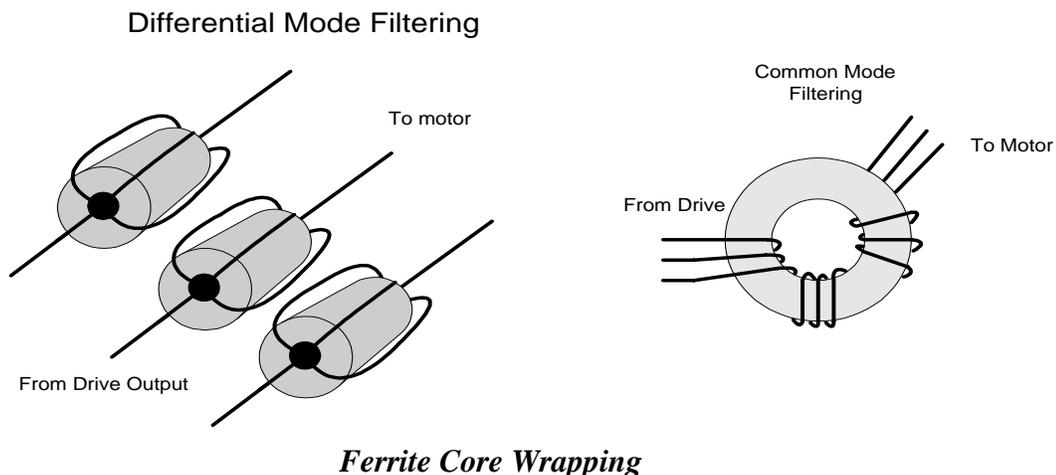
Motor lead noise may be either common-mode or differential. The common-mode conducted currents occur between each motor lead and ground (line-to-neutral). Differential radiated currents will exist from one motor lead to another (line-to-line). The filtering of the lines feeding the motor will provide additional attenuation of noise currents that may enter surrounding cables and equipment I/O ports that are in close proximity.

Differential mode currents commonly occur with lengthy motor cables. As the cable length increases, so does its capacitance and its ability to couple noise from line-to-line. While every final system is different and every application of the product may cause a slightly different emission profile, it may become necessary to use differential mode chokes to provide additional noise attenuation to minimize the radiated emissions. The use of a ferrite core (placed at the drive end) on each motor lead, as shown in the diagram below, can attenuate differential mode noise and lower frequency (30-60 MHz) broadband emissions to within specifications.

Kollmorgen recommends a Fair-Rite P/N 263665702 (or equivalent) ferrite core. You should wrap each motor lead through the core several times as shown in the Ferrite Core Wrapping figure below.



*Never wrap a ground lead through a core.*



Common mode currents commonly occur from noise spikes created by the PWM switching frequency of the drive. The use of a ferrite or iron-powder core toroid will place common mode impedance in the line between the motor and the drive. The use of a common mode choke on the motor leads may increase signal integrity of encoder outputs and associated I/O signals. The Toroidal Core Recommendations table lists the toroidal and ferrite cores that can be used to make common mode chokes.

Manufacturer	Manufacturer Part #	Size		
Micrometals	T400-26D	OD 4in (102mm)	ID 2.25in (57.2mm)	HT 1.3in (33mm)
Micrometals	ST102-267	OD 1.025 in (26mm)	ID .6 in (15.2mm)	HT .475 in (12.1mm)
Micrometals	ST150-275B	OD 1.52 in (38.6mm)	ID .835 in (21.2mm)	HT .825 in (21mm)
Micrometals	ST200-275B	OD 2.01 in (51.1mm)	ID 1.24 in (31.5mm)	HT 1.025 in (26mm)
Magnetics	77930-A7	OD 1.09 in (27.7mm)	ID .555in (14.1mm)	HT .472in (11.99mm)
Fair-Rite	2643803802	OD 2.4in (61mm)	ID 1.4in (35.55mm)	HT .5in (12.7mm)

### *Toroidal Core Recommendations*

Manufacturer	Manufacturer Part #	Kollmorgen Part #	Description
Schaffner	RD7137-36-0m5	A-96843-005	500 $\mu$ H 3 phase common mode choke. 36 amps continuous.
Schaffner	RD8137-64-0m5	A-96843-010	500 $\mu$ H 3 phase common mode choke. 64 amps continuous.

### *Pre-wound Common-Mode Chokes*

## I/O FILTERING

I/O filtering, while not a necessity for CE compliance, may be desired depending on system installation, application, and integration with other equipment. It may be necessary to place ferrite cores on I/O lines to avoid unwanted signals entering and disturbing the drive system or other associated equipment. The following chart lists some ferrite parts that may be used for I/O filtering and noise attenuation. These parts are ideal for providing in-line common mode impedance for I/O lines (Fair-Rite Products Corporation also has a varied selection, which can suit most any application).

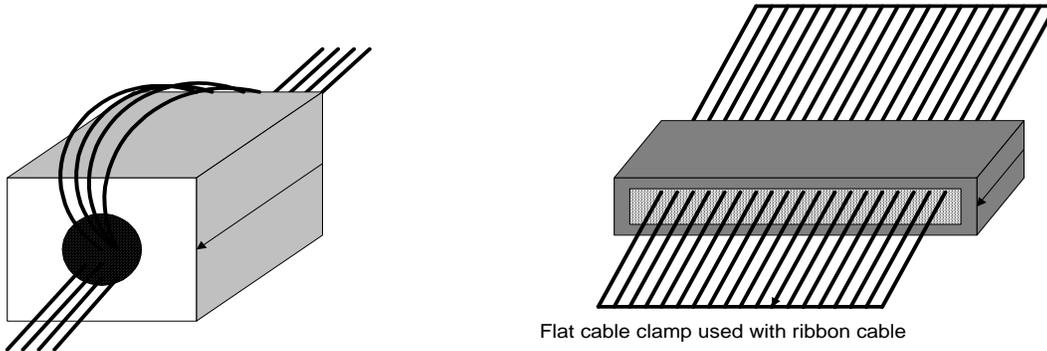
Manufacturer	Manufacturer's Part #	Kollmorgen Part #	Description
Ferrishield	SS33B2032	A-96770-003	Clamp on core
Ferrishield	SS33B2036	A-96769-005	Clamp on core
Ferrishield	FA28B2480	A-96771-003	Clamp on core - flat cable clamp
Ferrishield	SA28B4340	A-96772-009	Clamp on core - flat cable clamp
* Fair-Rite	2643167251		

### *I/O Filter Recommendations*



*\* This core must be used with the drives for CE compliance. It should be applied to the 24V input power lines and the Remote Enable lines (7 & 8 on C3 connector) with approximately 3 turns through the core.*

The following figure illustrates the use of multiple turns through a clamp-on core. The more turns created, the more impedance is added to the line. Avoid putting the shield in a clamp-on core. It is undesirable to place an impedance in-line with the shield. The use of ribbon cable may be common in many cabinets. Some ferrite clamps are designed just for ribbon cable use as shown below.



### *I/O Filtering Techniques*

# System Communication

You communicate with the Dual-Axis Drive through the serial port. The Dual-Axis Drive comes with its own software interface, **MOTIONLINK**. **MOTIONLINK** is a Windows-based program designed to effectively assist you in setting up and controlling the drive's operation. It is highly intuitive in nature and contains an extensive context-sensitive on-line Help (F1) tool. The on-line Help describes how to use the program in detail and serves as a valuable reference for the drive's variable and command set, setup process, and troubleshooting techniques. This software package can be downloaded from the Product Support Package CD-ROM or from the Kollmorgen website (<http://www.MotionVillage.com>). The complete variable and command set for the Dual-Axis Drive is described in the *Dual-Axis Drive VarCom* document.

Since the software is designed to guide you through the operation process of the drive, this section will cover only general steps of use. A "dumb terminal" can also be used to communicate to the drive. You may find this method of communication very awkward until a certain level of familiarity with the drive's operation is achieved. **MOTIONLINK** also provides a terminal emulation feature that contains many useful editing tools.

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## Computer Requirements

**MOTIONLINK** requires an IBM-PC or compatible computer with the following features:

- IBM-compatible, Pentium or higher computer.
- 16 M RAM.
- Windows 95, Windows98, WindowsNT 4.0 with Service Pack 3, Windows 2000.
- CD-ROM player.
- Standard Video Adapter (CGA, MDA, EGA, MCGA, VGA, or SVGA).
- Serial Port (for communication link with Dual-Axis Drive). The serial communications port may be COM1, COM2, COM3, or COM4. COM1 is the normal configuration:

COM1: Address 3F8h, Interrupt Request #4

COM2: Address 2F8h, Interrupt Request #3

COM3: Address 3E8h, Interrupt Request #4

COM4: Address 2E8h, Interrupt Request #3

## Address for Communications

A 16-pole rotary switch is assembled on the Dual-Axis Drive. The address of each axis is derived from the switch setting, with address being calculated according to

Address of axis 1 = Switch setting (i.e. 1, 2, 3, ..., F)

Address of axis 2 = Switch setting + F in ASCII (i.e. G, H, I, ..., U)

The address is necessary for the motion controller to be able to differentiate between the axes. The following table shows the axis addresses of a series of Dual-Axis Drives with different address settings:

DIP switch setting	Axis Address	
	Axis A	Axis B
1	1	G
2	2	H
3	3	I
4	4	J
5	5	K
6	6	L
7	7	M
8	8	N
9	9	O
A	A	P
B	B	Q
C	C	R
D	D	S
E	E	T
F	F	U



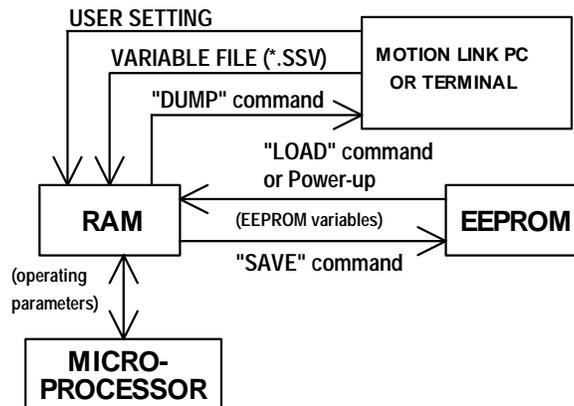
*A switch setting of 0 is reserved for use when updating drive firmware (Ember). If the switch is set to zero, the drive cannot be enabled.*

## Drive Communication Protocol

The communications link between the drives and a host computer is full duplex, using an RS-232 connection. The signaling lines (CTS, RTS, etc.) are not used. Data are transmitted asynchronously, using 8 data bits, no parity, and 1 stop bit. The data rate is fixed at 19200 BPS.

## Sending and Retrieving System Data

The following chart shows the flow of data between the PC and the Dual-Axis Drive. When logic power is applied to the drive, it loads the variable parameters stored in non-volatile memory into the dynamic RAM for fast and easy access. You can read (and write) these variable parameters to (and from) the PC by one of several methods described in the INITIAL STARTUP section below.



*Memory Flow Chart*

The PC transmits serial data to the drive and stores it in dynamic RAM. However, any variable data changed from the PC is lost when logic power is lost, if it is not saved (using the SAVE command) into non-volatile memory. If you configure the same system on similar applications, the variables can be saved on disk in an .SSV file for convenient downloading into other drives.

## Installing MOTIONLINK From CD-ROM

1. Insert the SERVOSTAR PSP CD-ROM to load **MOTIONLINK** for Windows.
2. The CD-ROM should AUTORUN. If not, select Start | Run (or browse your CD-ROM drive).
3. Type "D:AUTORUN.EXE" and press the Enter key (this assumes your CD player has a D: letter designation).
4. Select a product and follow the instructions on the screen.

To run the program, go to your Start/Programs listing and select **SERVOSTAR MOTIONLINK** from the menu (or click on the **SERVOSTAR MOTIONLINK** icon if loaded on the desktop).

## Using MOTIONLINK

**MOTIONLINK** gives you three methods to configure the drive. The first uses a Startup Wizard. This is the easiest and most highly recommended approach. Its main purpose is for initial startups.

The second allows you to more indirectly perform the same configuration as the first using the Main **MOTIONLINK** screen. This method is most convenient when corrections to an existing configuration are required.

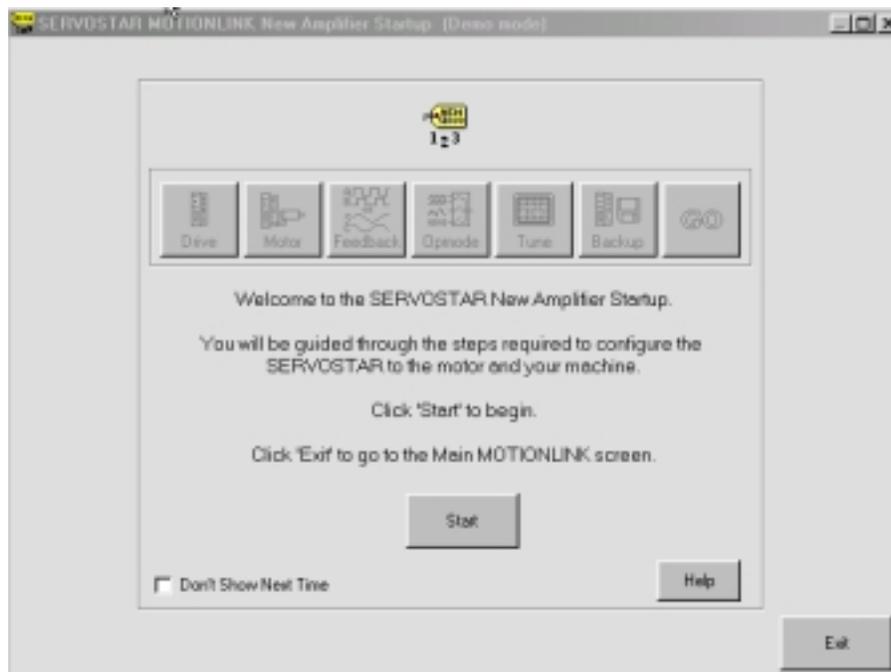
The third uses the Terminal Mode screen to directly set (or monitor) values for the same variables and commands that the other two methods configure through a more friendly user interface. You can gain a more thorough understanding of the Dual-Axis Drive, **MOTIONLINK**, and its variable and command set by using the context-sensitive Help (F1) provided in **MOTIONLINK**.

### **MOTIONLINK Startup Wizard**

This screen (shown below) appears the first time (and any time after should you choice not to deselect it) **MOTIONLINK** is run on a PC. It is designed to guide you through a step-by-step approach to configure a drive. Click the “START” button on the first user screen and walk through the complete sequence of buttons provided to set the drive, motor, and application (Opmode, Tune, Backup, Go) variable parameters.



*Should you de-activate this screen, it can be reactivated by going to the Main MOTIONLINK screen, pulling down the Configuration menu, and selecting the New Drive (123) option.*



- **Setting Drive Variable Parameters:** Click the Drive button. This screen allows you to select a BUS value that corresponds to the incoming line voltage. This selection actually determines the setting of the variable VBUS. Also included is a real-time monitoring of the DIP switch on top of the drive so you can verify the proper setting for the drive address, baud rate, and various other parameters. Click Exit to return to the Startup Wizard screen.
- **Setting Motor Variable Parameters:** Click the Motor button. This screen allows you to access the **MOTIONLINK** motor database. Select a motor family and then a model within that family. Information will appear in the blank parameter fields on the right. Click on the “To Drive” button beneath the fields to send the variable parameters to the drive. Click “Exit” to return to the Startup Wizard screen.



*For you that has a configured drive, a “From Drive” button is provided to retrieve the motor data already in the drive. Retrieving this data will not erase it from the drive.*

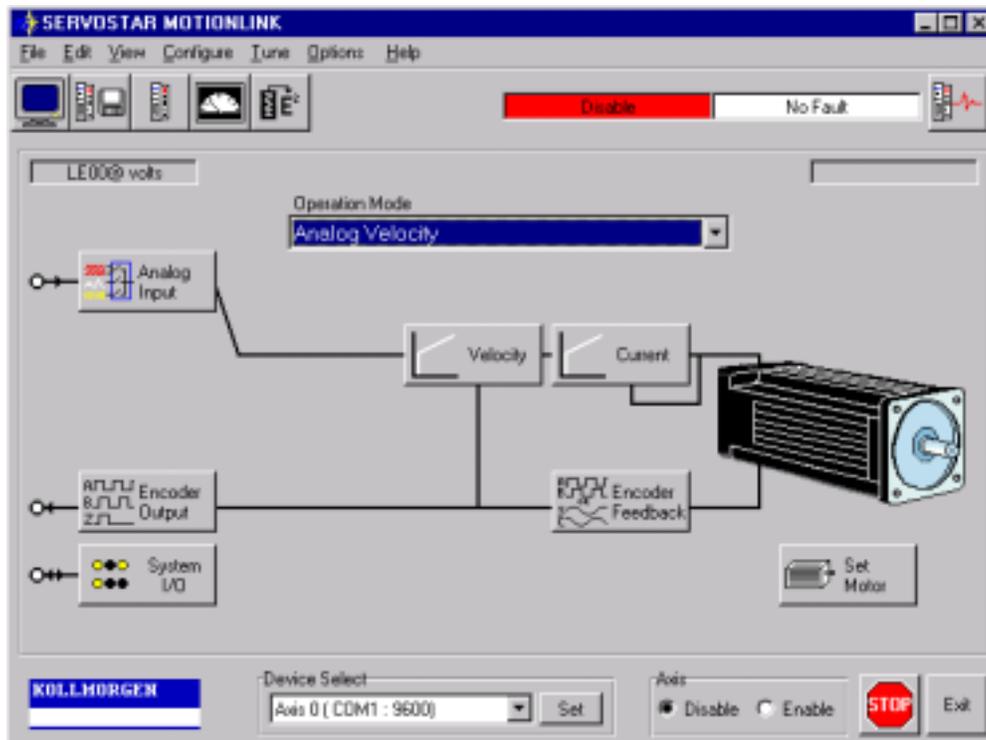


*If the motor cannot be found in the database, click on you Define tab. Contact the Kollmorgen Customer Support Network for detailed instructions.*

- **Customizing to Application:** Click the “Opmode” button in the Startup Wizard screen to select the mode of loop control desired; position, velocity, or torque. Click Exit to return to the Startup Wizard screen.
- **Setup Complete:** Click EXIT to go to the Main **MOTIONLINK** screen.

## **Main MOTIONLINK Screen**

The Main **MOTIONLINK** screen (shown on the next page) appears when you exit out of the **MOTIONLINK** Startup Wizard screen. All the screens mentioned in the method above can be accessed from this screen and should be used to make corrections in the current system configuration.



- ◆ **Setting Drive Variable Parameters:** From the Configure menu, click the Drive option. The same screen appears as described in the Startup Wizard screen section. Click Exit to return to Main **MOTIONLINK** Screen.
- ◆ **Setting Motor Variable Parameters:** Selecting the Motor option under the Configure menu, you can obtain the same parameter screen found in the Startup Wizard screen. Click Exit to return to Main **MOTIONLINK** Screen.
- ◆ **Customizing to Application:** By dropping down the Operational Mode listing, you can select the mode of loop control desired (position, velocity, torque). Clicking the “Tune” button, you can select the system bandwidth, the type of loop control, and the filtering necessary for the application. These are the same parameter screens found in the Startup Wizard screen. Click Exit to return to Main **MOTIONLINK** Screen.
- ◆ **Saving Variable Parameters to EEPROM:** At the top of this screen, you can click the button labeled “RAM/E<sup>2</sup>” to save the modified variables from RAM to EEPROM.
- ◆ **Saving Variable Parameters to .SSV file:** Occasionally, you may desire to backup the variable parameters from one drive for use in another. To do this, you must pull down the Edit menu and select Backup Variables, request the information from the drive (“Receive” button) into the editor, and save (“Save” button) the contents in a .SSV format to a specified disk location.
- ◆ **Restoring Factory Variable Parameters:** To restore the original factory variable parameters, pull down the Configure menu, select Motor, and select the motor family and motor model. Click the “To Drive” button to send the variable parameters to RAM and the “RAM/E<sup>2</sup> SAVE” button to save to EEPROM.

- ◆ **Restoring Custom Variable Parameters:** This process assumes that you saved the custom variable parameters to a .SSV file, as described above. To restore the custom parameters, pull down the Edit menu, select Backup Variables, and click on “Open”. Highlight the custom .SSV file to import variable parameters into editor. Click “Xmit” to send variable parameters to drive.

## Terminal Mode

Use the **MOTIONLINK** Terminal Mode (or any other “dumb” host) to directly monitor or modify the variable set and command the drive. This approach should only be taken when a PC with a Windows operating system is not available and/or you are well-versed with the variable and command set.

Each variable and command are referenced for its syntax and parameter definition. The variables and commands are grouped alphabetically for easy look-up and are found at the end of this manual. Be sure you review this information before you begin.

## Initial Startup

Most drives are shipped from the factory already configured for a particular motor. You can verify this by applying logic power and monitoring the status display. A factory-configured drive goes through a power-up sequence flashing all segments of the display before settling out to a number indicating the mode of operation. If the drive is not configured with a particular motor, the display will flash a minus sign “-”, indicating that you must enter drive, motor, and application variable parameters. The remainder of this section describes the process of setting up a non-configured drive.



***Caution must be taken when applying power to the drive. It is factory-configured to enable upon application of power. Verify that the hardware Remote Enable (REMOTE) enable switch is disabled.***

Upon powering up, the Dual-Axis Drive performs a series of self-tests. If the status display illuminates a solid number, then no errors were found and the EEPROM has loaded its variable parameters (or loaded with default values in case of invalid EEPROM data) into RAM. The Remote Enable switch on the I/O connector (C3) may now be energized, thus enabling the servo loops.

## Enabling the System

The drive enable logic is based on the following variable switches and flags:

**ACTIVE:** This is the overall readiness flag indicating the enable/disable state of the drive. If high (1), the drive is enabled and power is being applied to motor. The following equation must hold true for ACTIVE to go high: **ACTIVE = (READY) AND (REMOTE)**  
*where* **READY = (DRIVEOK) AND (SWEN)**

**READY:** Flag that indicates the drive is free of faults and ready to hardware enable.

**DRIVEOK:** Switch indicates the status of the drive faults.

**SWEN:** Switch indicates the status of the software enable (EN or DIS).

**REMOTE:** Switch indicates the status of the hardware Remote Enable line on the C3 connector. The Remote Enable can be ignored by setting RMTMODE=1.

Ready Flag		
DRIVEOK (fault status)	SWEN (software enable)	READY (drive ready)
0 (fault exists)	0 (disable)	0
0 (fault exists)	1 (enable)	0
1 (no faults)	0 (disable)	0
1 (no faults)	1 (enable)	1

Active Flag		
READY (drive ready)	REMOTE (hardware enable)	ACTIVE (power to the motor)
0	X	0 (no)
X	0	0 (no)
X	X	0 (no)
1	1	1 (yes)

If the drive will not enable, check the state of the switches and flags by clicking the “Status” button in the upper right-hand corner of the Main **MOTIONLINK** screen. If using a terminal, you can query the drive for the value stored in the STATUS variable. The status display indicates an enabled drive when the decimal point is illuminated solid.

In some systems, there is no Remote Enable signal. The servo drives must be configurable such that you can instruct the drive whether ignore the Remote Enable signal or not. To this end, two special drive instructions are defined:

- **Remote Enable Ignore:** When set, this instruction causes the drive to ignore the remote enable. Then, the drive is enabled by a combination of only the Software Enable and the state of the faults. The relevant instruction is RMTMODE, and it may be set to 0 (don’t ignore Remote) or 1 (ignore Remote).
- **Power on Servo State (Software Enable):** Since the drive can be configured to ignore the remote enable, the software enable state needs to be stored in flash memory, so that the user can program the power up enable state of the drive. The relevant instruction is SWENMODE, and it may be set to 0 (SW disable on power-up) or 1 (SW enable on power-up).

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# System Operation

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## Communications Interface

The Dual-Axis Drive has an RS232 interface, through which communications with a terminal or PC is possible. The following table describes the essential elements of the serial communication interface.

<b>Physical layer</b>	RS-232 For ASCII communications: 8 data bits, no parity, 1 stop bit Baud rate: 19200 bps
<b>Data link layer</b>	Drives are individually addressable Up to 15 DUAL-AXIS DRIVES can be accessed. Prompt for flow control Active echoing by drive for error control
<b>Application layer</b>	Firmware Update (Ember). Parameter setting (configuration) – ASCII.

The serial communication link enables the digital drive to be controlled using ASCII-coded messages, transmitted over a serial asynchronous point-to-point link. The drive language includes messages to command and query the drive, as well to set and query variables and parameters. Thus, from the point of view of the messages on the bus, there is no distinction between commands, variables and parameters.

The *Dual-Axis Drive VarCom* document provides further information on each of the instructions recognized by the Dual-Axis Drive.

### ***Physical Layer***

The communications link between the drives and a host computer is full duplex, using an RS-232 connection. The signaling lines (CTS, RTS, etc.) are not used. Data are transmitted asynchronously, using 8 data bits, no parity, and 1 stop bit. The data rate is fixed at 19200 BPS.

### ***Data Link Layer***

The data link layer level governs addressing, flow control, and error control.

## ADDRESSING

A 16-pole rotary switch is assembled on the Dual-Axis Drive. The address of each axis is derived from the switch setting, with address being calculated according to

Address of axis 1 = Switch setting (i.e. 1, 2, 3, ..., F)

Address of axis 2 = Switch setting + F in ASCII (i.e. G, H, I, ..., U)

The address is necessary for the motion controller to be able to differentiate between the axes. The following table shows the axis addresses of a series of Dual-Axis Drives with different address settings.

DIP switch setting	Axis Address	
	Axis A	Axis B
1	1	G
2	2	H
3	3	I
4	4	J
5	5	K
6	6	L
7	7	M
8	8	N
9	9	O
A	A	P
B	B	Q
C	C	R
D	D	S
E	E	T
F	F	U

Drives are addressed using addressing commands that are part of the set of commands recognized by the drive. Addressing one drive automatically un-addresses all the other drives. A special addressing command is used to address all the drives simultaneously and is used by the host to broadcast commands to all the drives. In this case, the drives remain addressed until a regular addressing command is sent. Then, the addressed drive remains addressed and all the other drives are un-addressed. When all the drives are addressed, the drives do not echo characters they receive.

The backslash character (\) is defined as the addressing command. It has the form:

**\x**

where x is {1, 2, 3, ..., 9, A, B, ..., , \*, \}

The '\*' argument to the backslash command is used to globally address the drives. The '\ ' argument is used to globally un-address the drives.

## FLOW CONTROL / PROMPT FUNCTION

The drive returns a prompt to the host after it has finished processing the last command received from the host. The format of this prompt is:

x->

The receipt of the prompt indicates to the host that the drive is ready to receive further commands. There is no prompt when the drive is globally addressed.

## ERROR CONTROL

Simple error control is only implemented using active echoing.

Echoing is only implemented by the drive communication software, not by the host software. With this mechanism, the drive re-transmits each character it receives. The host can then check (with a certain level of reliability) that the data it transmits is being received correctly. There is no echo when the drive is globally addressed.

When the host detects an error using this mechanism, the message being transmitted is aborted by the host. The mechanism for doing this is described in the *Message Processing Protocol* section below.

### ***Message Processing Protocol***

Message Processing Protocol is a set of rules defining how the digital servo drive responds to message sent by the host, and how the host sends information to the drive.

Message termination indicates the end of the message to the receiving station. Messages transmitted by the host must be terminated by the Carriage Return (CR) character (ASCII 0DH), while messages transmitted by the drive are terminated by the Carriage Return / Line Feed (CR/LF) combination (ASCII 0DH / 0AH).

The drive begins processing a message when it detects the <CR> message termination character. It is not be able to process more than one message at a time.

The host aborts message transmission at any point during the transmission by sending an ESCAPE character (ASCII 1BH) to the drive. When active echoing is enabled, the ESC would *NOT* be echoed by the drive. The prompt is returned after the ESC has been processed, if the prompt function is enabled.

In case of an invalid or unknown message, an error message is returned by the drive.

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## Drive Configuration

Dual-Axis Drives contain digital servo drives. The control functionality is set using various drive parameters and instructions communicated over the RS232 serial port. The parameters are stored in non-volatile memory in the drive, to be used on power-up. **MOTIONLINK** is used to configure the drive.

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## Absolute Position and Zeroing

The DAD maintains absolute position within one revolution. The position feedback is given in units of encoder counts, where there are 2,097,152 counts per motor revolution. The value is always positive, and in the range 0 .. 2,097,151. That is, the value is always within one revolution.

The value displayed is modified relative to the value read from the encoder by the Position Offset, which is defined using the PFBOFF variable. The value of PFBOFF is added to the value read from the encoder before PFB is presented to the user.

The value of PFB that is reported by the drive is modified by PFBOFF in the following way:

$$PFB_{User} = PFB_{Internal} + PFBOFF$$

PFBOFF can be used to set the position of the machine zero point. In order to do this, do the following steps:

- Set PFBOFF to 0
- Read PFB
- Set PFBOFF to the negative value of the PFB

The position offset is stored in non-volatile memory in the encoder, and read by the drive at power up.

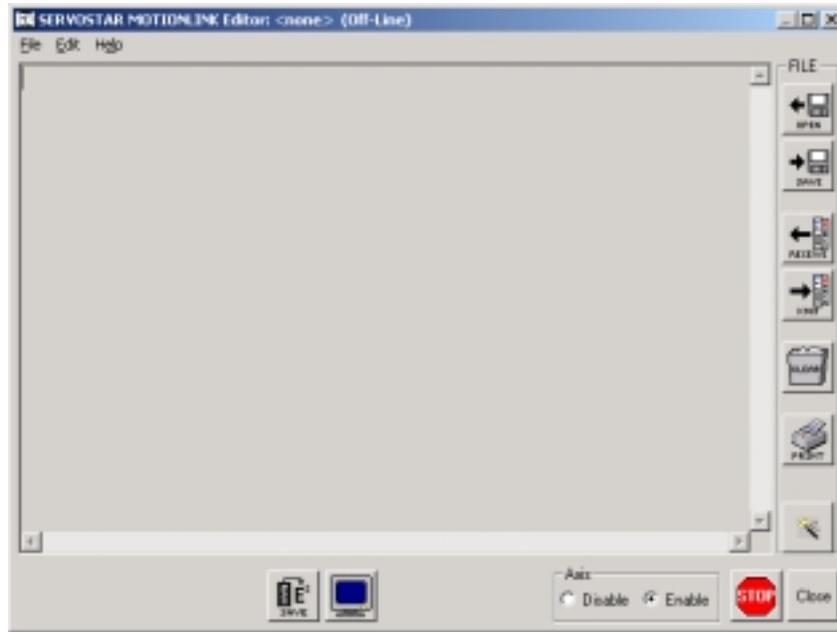
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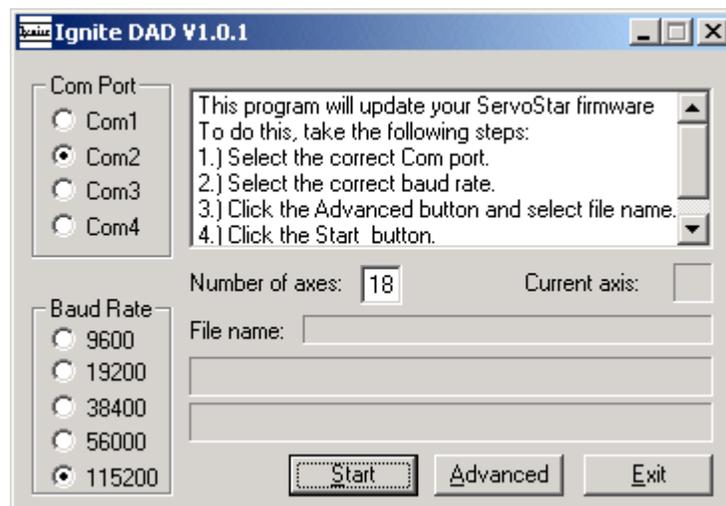
## Firmware Update

Firmware on the Dual-Axis Drive is updated using a process called EMBER. Kollmorgen provides a program that downloads the firmware file over the RS232 link to the drive. Both axes use the same firmware. The address of the Dual-Axis Drive must be set to 0 (zero) to put the unit into the EMBER mode. During the process, the display alternately shows E and ∃. Once the firmware has been downloaded, set the address to a value other than zero and cycle the power. The firmware update process is described below.

1. Preparations
  - A. Retrieve Drive Parameters
    - a. Using **MOTIONLINK**, go the Drive Backup screen (shown below).

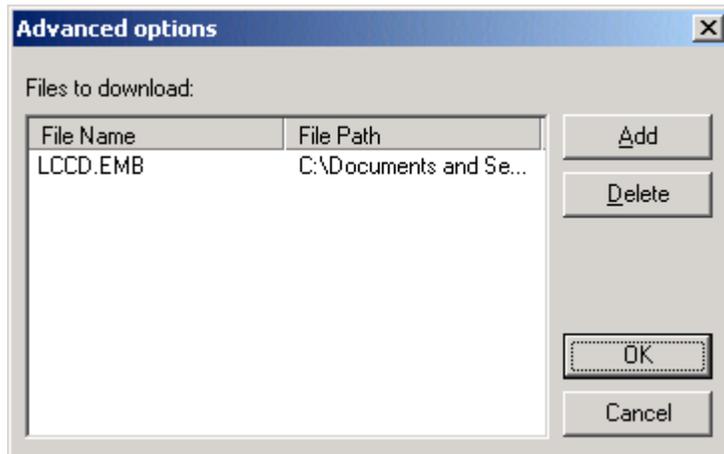


- b. Click on the Receive button to get the parameters from the drive.
  - c. Click on the Save button to save the file to disk.
  - d. Go to the Terminal screen to change the addressed axis.
  - e. Repeat the process for each axis.
- B. Clear the Drive Parameters
- a. Clear the drive parameter memory.
    1. Go to the Terminal.
    2. Enter the instruction, CLREEPROM.
    3. Repeat for all axes.
  - b. Exit from **MOTIONLINK**.
- C. Set the Dual-Axis Drive address to zero
- a. Turn the Dual-Axis Drive off.
  - b. Set the address to zero.
  - c. Turn the Dual-Axis Drive on. The 7-segment display should now show E. If it does not, either the address was not properly set to zero or the drive is faulty and must be returned for repair. Repeat the steps to be sure you correctly set the address to zero.
2. Update Drive Firmware
- A. Use the Dual-Axis DADIGNI0.EXE program to download the new firmware. This is a Windows program. Run the program; the following screen appears:



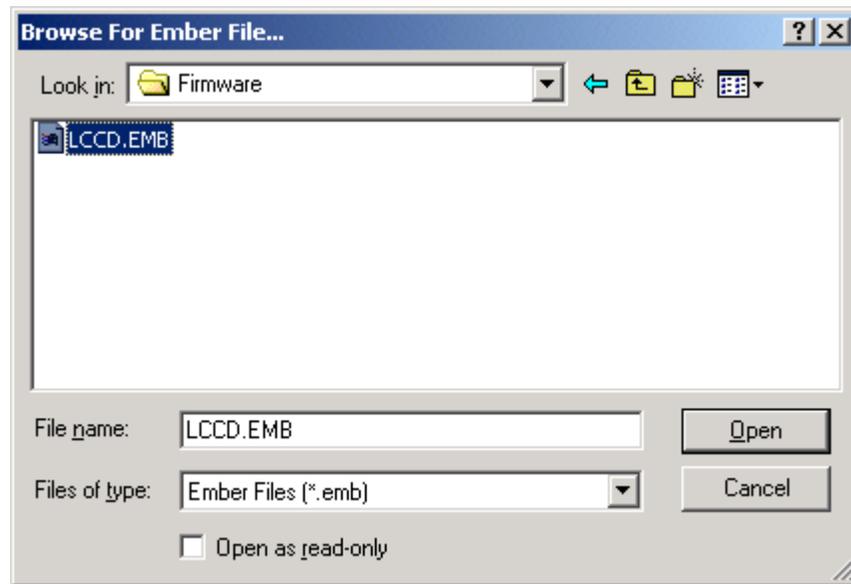
- a. Select the correct Com port.
- b. Select the correct baud rate (use 115,200 so the process is faster).

c. Click on the Advanced button.

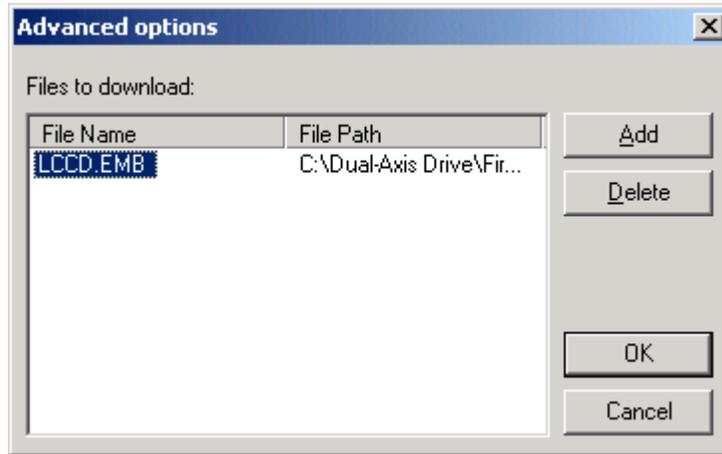


Select any files that appear in the windows and click on Delete. Do this to make sure that you are not downloading the incorrect file.

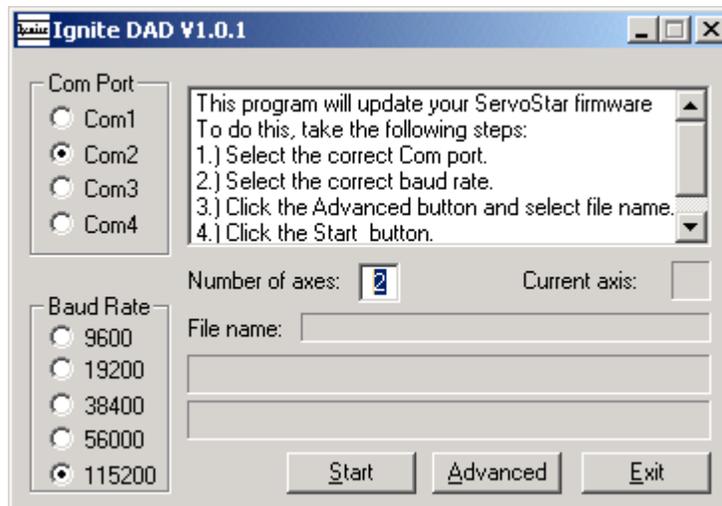
d. Click the Add button to select the file to be downloaded.



- e. Select the relevant \*.EMB file.
- f. Click on Open.
- g. Return to the Advanced Options screen.



- h. Select the LCCD.EMB file.
  - i. Click OK.
- B. Set the number of axes. If only one Dual-Axis Drive is connected to your PC, the number is 2. If you have a number of Dual-Axis Drives daisy-chained, enter the appropriate value.



- C. Click on the Start button to start the firmware download.
3. Cycle Power
    - A. Once the download is finished, turn off the drive.
    - B. Set the Dual-Axis Drive address to the value you want.
    - C. Reapply power to the Dual-Axis Drive.
    - D. Connect to the drive with **MOTIONLINK**.
    - E. From the Terminal screen, type VER to verify that the drive firmware version is as expected.

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## Firmware Version

The firmware version is obtained by entering the VER instruction. In response, the drive returns a string that is similar to:

```
Kollmorgen Motion Technologies  
ServoStar CDL: ENCODER  
6.0 Amp continuous; 18.0 Amp peak rating  
Firmware version A.0.5.6  
Runtime: 0:27:30
```

This response indicates the current rating (in Ampere RMS).



*Always know the firmware version when calling for technical support.*

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## Drive Enable

The drive is enabled by a combination of 3 signals:

- The Remote Enable is the signal generated by the motion controller (Servo on)
- The Software Enable is generated by one of the serial port instructions (EN).
- The drive can be enabled only when no faults exist.

Additionally, the drive address must not be 0.

In some systems, there is no Remote Enable signal. The servo drives must be configurable such that you can instruct the drive whether ignore the Remote Enable signal or not. To this end, two special drive instructions are defined:

- **Remote Enable Ignore:** When set, this instruction causes the drive to ignore the remote enable. The drive is enabled only by a combination of the Software Enable and the state of the faults. The relevant instruction is RMTMODE and may be set to 0 (do not ignore Remote) or 1 (ignore Remote).
- **Power on Servo State (Software Enable):** Since the drive can be configured to ignore the remote enable, the software enable state needs to be stored in flash memory, so you can program the power up enable state of the drive. The relevant instruction is SWENMODE, and may be set to 0 (SW disable on power-up) or 1 (SW enable on power-up).

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## Direction of Motion

By default, a positive motion command will result on clockwise (CW) motion of the motor shaft. However, in some case it may be desirable to be able to reverse the direction of motion with respect to the command. The DIR instruct enables this to be done. When set to 1, this variable inverts the sign of the reference command ( $\pm 10Vdc$  for Torque and Velocity modes, and Direction signal for Pulse & Direction Position mode).

The following table describes the effect of DIR in Torque and Velocity modes:

DIR Value	Reference Command	Direction of Motor Rotation	Equivalent Encoder Output
0	Positive	CW	A lead B
0	Negative	CCW	B lead A
1	Positive	CCW	B lead A
1	Negative	CW	A lead B

The following table describes the effect of DIR in Position mode:

DIR Value	Direction Signal	Direction of Motor Rotation	Equivalent Encoder Output
0	5V	CW	A lead B
0	0V	CCW	B lead A
1	5V	CCW	B lead A
1	0V	CW	A lead B

---

## Operating Modes

The drives operate in one of three operation modes. The operation mode is set by OPMODE. Setting the operation mode determines the servo control loops that will be closed and the source of the reference command. Changing operating modes is only possible when the drive is disabled.

### ***Position Mode: OPMODE 8***

In position mode, the drive responds to the pulse-following reference command. The controller sends out a number of pulses corresponding to the commanded position, and the drive counts only rising edges. In this mode, the display shows the digit, 8, during steady-state operation.

Motor speed can be increased using the PGEAR parameter. This parameter applies a multiplier of 1, 2, or 4 to the position command pulses. Thus, with PGEAR set to 2, for example, the motor will turn twice as fast as if it was set to 1. The equivalent encoder output is scaled in the same way as the position command pulses, resulting in a 1-to-1 relationship between pulses in and encoder counts out.

### ***Velocity Mode: OPMODE 1***

In velocity mode, the analog  $\pm 10$ VDC signal is the velocity reference command. The velocity loop has a PDFF (Pseudo-Derivative Feedback with feed-forward), with proportional, integral and feed-forward terms. In this mode, the display shows the digit, 1 during steady-state operation.

### ***Current Mode: OPMODE 3***

In current mode, the analog  $\pm 10$ VDC signal is the current reference command. In this mode, the display shows the digit, 3, during steady-state operation.

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## Faults

When a fault occurs in either of the drives in the module, the fault output is true. The controller then queries the drives using the communications link to determine which of the drives

encountered the fault. Only the drive which encountered the fault is disabled. The following is a list of faults that are detected by the Dual-Axis Drive:

Fault	Description
Over-current	The amplifier is shut off if the current exceeds 53A. The over-current fault can only be cleared by cycling the power.
Over voltage	The drive is disabled when the bus voltage exceeds 450V.
Under voltage	The drive is disabled when the bus voltage drops below 80VDC and recovers at 120VDC.
Drive over-temperature	Temperature is monitored once on the entire module with the probe assembled on the heat sink. At temperatures exceeding 82°C, the drive is disabled.
Motor over-temperature	The drive is disabled if the motor over-heats. This fault is indicated by a PTC device embedded in the motor.
Current foldback ( $I^2t$ )	$I^2t$ is used for protection of both the motor and the drive with the limit being set for whichever of the devices is weaker. This is only a warning. The drive is not automatically disabled when foldback occurs.
Position following error	When the drive is operating in the position mode, it detects and responds to position following error. The drive is disabled when the maximum allowed position following error (as specified by the user), is exceeded.
Feedback loss	The drive is disabled if the feedback cable is disconnected or if any one of the feedback wires breaks. This is determined in software, so the fault is only detected in some cases if the motor is turning.
Overspeed	Overspeed limit is set by user. The Drive faults out if limit is exceeded.

An over-current fault can only be cleared by cycling power to the drive. All other faults are resettable. The faults are latched when they occur and may be cleared by first removing the source of the fault and then toggling the Alarm Clear signal. The drive clears the fault when it detects a transition from Low to High on the Alarm Clear signal (not active to active transition).

The user can choose to configure the drive to ignore the Under Voltage fault, using the UVIGNORE parameter. When set to 1, the drive will not detect Under Voltage conditions.

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## Diagnostics

The ten most recent faults are stored independently on each axis in a cyclic buffer. This fault log is read over the serial port using the FLTHIST command. The state of all drive parameters can similarly be read over the serial port.

## Disabling an Axis

In some applications, only one of two axes are used. In this case, the drive always indicates a fault, since the feedback for one of the axes is not connected. Since there is only a single Ready and Alarm signal for both axes, the AXISOFF instruction allows one of the axes to be disabled. When AXISOFF is set to 1 (AXISOFF 1), that axis:

- Sets its ready signal to 1 so it does not effect the overall ready signal.
- Sets its Alarm signal to 0 so it does not effect the overall alarm signal.
- Disables the axis so it cannot be enabled.
- Show a flashing 'A-0' on the display.

Set AXISOFF 0 to return the axis to the normal operating state.

## Display

A 7-segment display that shows the drive status for each axis in the Dual-Axis Drive. There are four types of status display: Power-up, Steady State, Flashing State, and Momentary State. The decimal point indicates the drive is enabled.

Status Display	
Drive State	Display Appearance
Power-up	Momentarily illuminates all display segments (forming an 8) and the decimal point.
Steady State (No Faults)	Displays the operational mode (OPMODE) of the drive (1, 3 or 8). OPMODE 1 is Velocity mode (PDFF velocity controller). OPMODE 3 is Current mode (Current loop parameters). OPMODE 8 is Position mode
Flashing State	Used to indicate an abnormal operating state: If a fault was detected, a flashing code is displayed to identify the fault. Some codes consist of a sequence of two or more digits (see Troubleshooting). In general, these faults cause a latched disable (sometimes controllable through software switches). To clear a fault enable (except for over-current), toggle the Alarm Clear signal from low to high. A flashing "A - 0" is not indicative of a fault. This pattern is displayed when the axis is disabled (AXISOFF = 1).
Momentary Fault	Displays a character for 500 ms before returning to the steady state. You can reset the timer. F = Drive is in Foldback mode

Status Display Decimal Point	
Decimal Point State	Drive Status
Steady OFF	No power to the motor
Steady ON	Drive enabled, power to the motor

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## System I/O

This section discusses the I/O features of the P250 connector.

Notes:

- All digital I/O's are optically isolated.
- Digital outputs have an open-collector structure. The maximum output voltage is 28Vdc, and the maximum current is 50mA.
- ServoOn and AlarmClear are referenced to pin 1, which is 5V common. Pin 1 may be at either 5V or at GND, enabling the controller to activate the signal by either switching it to ground or to 5V respectively. The drive can accept 24V Common as well.

### ***Analog Input (ANIN1)***

The velocity or torque loop receives its command from an analog voltage source. The analog input to the Dual-Axis Drive is differential. This means that the signals received at the two inputs are subtracted from each other to create a difference, which is then used to command the rest of the system. This type of input has a high degree of noise immunity and, in many cases, allows for ground isolation between systems. This analog input also has a low pass filter (ANLPPHZ) to prevent high frequency noise from entering the system.

The input voltage from the differential receiver is applied to a precise 12-bit Analog-to-Digital (A/D) conversion system. The A/D conversion system is read by the microprocessor every 250 $\mu$ S for the velocity loop mode, and every 62.5 $\mu$ S for the torque (current) loop mode of operation.

Analog systems often require scaling and offset bias. The Dual-Axis Drive adds an analog offset (ANOFF1) variable to this reading, performs an analog deadband (ANDB) adjustment, and scales it through velocity loop input scaling (VSCALE) or torque loop input scaling (ISCALE) before passing the data to the selected control loop. The analog input (ANIN1) variable indicates the analog reading after the offset (ANOFF1) and the deadband (ANDB) adjustments, but before the loop scaling. The ANIN1 variable range is  $\pm 22500$  mV.

The Dual-Axis Drive also offers an automatic analog input zeroing function. Invoking the ANZERO command while the drive is enabled or disabled samples motor velocity over a 32mSec period and updates ANOFF1 accordingly to cancel analog input offset. This command also incorporates an internal offset mechanism that has finer resolution than ANOFF1 is capable of providing.

### ***Servo On / Remote Enable Input (REMOTE)***

Individual enable signals exist for the two axes of the amplifier module. The signal is active when current is flowing through the optocoupler. Input range is 5 to 24Vdc. When the RMTMODE parameter is set to 1, the drive will ignore the Remote Enable input.

## Alarm

A single fault signal exists for the amplifier module. The signal polarity is Active High. The output stage is an open collector, being driven when there is no fault. This is a differential signal.

## Alarm Clear

A single Alarm Clear signal is used by the controller to clear faults on the amplifier. The signal is active when current is flowing through the optocoupler (see drawing below). A transition from not active to active clears faults. Input range is 5VDC to 24VDC.

## Ready

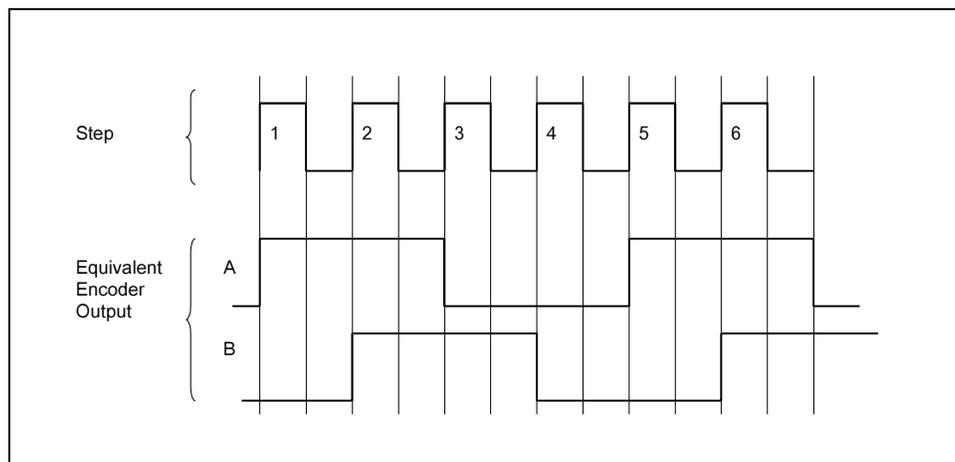
A single drive ready signal indicates when the drive is ready (enabled without faults). In this state, only a Servo On active signal is needed to enable the drives. The signal polarity is Active High: The output stage is an open collector, being driven when the module is ready.

## Equivalent Encoder Output

The drive generates equivalent A/B/I quadrature encoder signals for each axis, for use by the motion controller. These are differential signals, driven by an RS422 driver.

The resolution of the equivalent encoder output is 524,288 LPR (Lines per Revolution) (19 bit resolution before quadrature). If the motor is moving at 2.5RPS, the pulse frequency will be 1,310,720 pulses per second.

The following diagram shows the timing of the controller Step signal and the equivalent encoder output signal.



## InPosition

This signal is set when the motor is determined to be *In Position*. This occurs when the absolute value of the difference between the position command and the position feedback is less than or equal to a user-settable value (PEINPOS). There is an individual *In Position* per axis. This signal is relevant only when drive is operating in position mode.

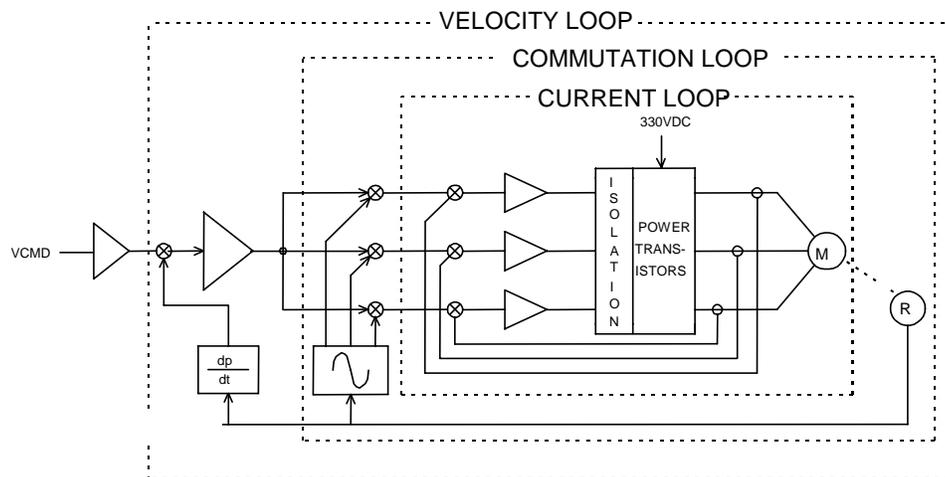
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## Control loops

This section describes the servo control loops, their characteristics, and how to configure them.

### Servo Loop Description

The Dual-Axis Drive provides high performance motor control by controlling up to three distinct closed loop systems within the DSP: the current, commutation, velocity. The figure below depicts the control loops graphically.



### Current Sampling

The current loop receives corrective feedback from the current sampling circuitry. The current sensors use closed-loop hall sampling techniques in all units.

The current sample is used by the current loops to regulate the current in each of the three motor phases. Two phases (A and C) of the current signal are sampled by the microprocessor at a 16kHz rate. The momentary A phase current and C phase current can be monitored by examining the IA and IC variables, respectively. The microprocessor calculates the equivalent absolute current, which is monitored as I.

## ***Current Loop***

Since current and torque are proportional in a Permanent Magnet (PM) motor, the current loop is often referred to as the torque loop. The function of the current loop is to regulate motor current as directed by a current command signal. The current command signal from the microprocessor can either come from a direct user input (OPMODE 3) or from the output of the velocity loop. There are actually three current loops, one for each motor phase. Each current loop receives its own command input from the commutation loop.

The Dual-Axis Drive uses a fully digital, pole placement current loop with high bandwidth and a current loop sampling rate of 16 kHz (62.5  $\mu$ S). All coefficients of the current loop are digitally calculated inside the drive for a given set of motor and drive characteristics. The current loop also includes adaptive gain terms to compensate for some non-linear effects.

The current loop receives its input from the analog-to-digital (A/D) conversion system. After conversion, the input command signal is processed through an algorithm which adjusts the signal (ANOFF1, ANDB, ANZERO), filters it (ANLPHZ) and then scales it (ISCALE), before developing the current command. The current (or torque) command is then checked against peak (IMAX, ILIM) and continuous current clamp limits (Foldback features, ICONT). Sinusoidal commutation modulation is added to the command and then fed to the three-phase current loop regulator, which calculates a current error. This error is then fed through a digital pole-placement compensation algorithm. The output of the compensator is converted to a PWM signal and fed to the power transistor bridge. The PWM center frequency can be 8 or 16 kHz according to the drive size. The power bridge uses the high voltage DC BUS Module (typical 325 VDC bus) to supply the required current to the motor windings. The actual motor current is updated and the process begins again.

## ***Commutation Loop***

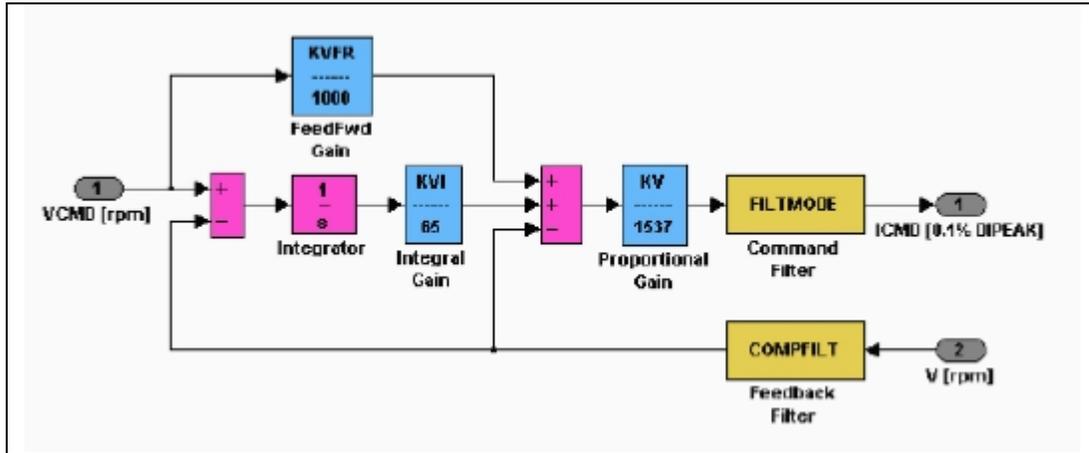
This loop converts a single-phase current command signal into a three-phase, position-modulated sine wave input to the current loops. The Dual-Axis Drive has a patented sinusoidal waveform generator, which uses a technique called Torque Angle Advance to get top performance out of its motors. The waveform generator is part of the microprocessor and is updated at a 16 kHz rate. This provides hi-fidelity sine wave commutation at both low and high velocities. The sine wave output must be aligned to the back EMF characteristics of the motor. This is why encoder alignment to the motor is critical.

## ***Velocity Loop***

The purpose of the velocity loop is to regulate motor speed. Like the current and the commutation loops, the velocity loop is fully digital and uses the resolver or the encoder feedback signals to calculate actual motor velocity. The command for the velocity loop can come from a direct user input (OPMODE=1) or from the position loop output. The velocity loop is a digital sampling system operating at 4 kHz.

The difference between actual and desired velocity is filtered through a compensator algorithm and fed to the commutation loop. The Dual-Axis Drive implements a velocity control loop with

Pseudo-Derivative-Feedback with Feed-Forward (PDFF) structure. The loop structure is shown below:



The velocity control structure of the Dual-Axis Drive includes two second order filters applied to the output of the velocity controller. The filter parameters are set using VF and VF2, which have the identical structure. The explanation to follow applies equally for VF and VF2.

VF is a vector variable that defines the filter at the output of the velocity controller. The vector defined by this variable includes five integers that represent the polynomial coefficients, and two shift parameters, one that scales each polynomial. The filter structure is:

$$(b_0 + b_1*z^{-1} + b_2*z^{-2}) / (1 + a_1*z^{-1} + a_2*z^{-2})$$

The instruction syntax is

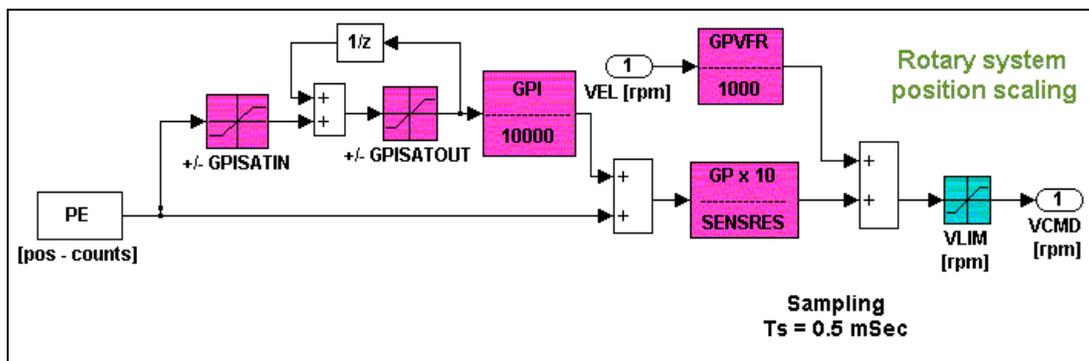
$$VF [b_0] [b_1] [b_2] [bshift] [a_1] [a_2] [ashift]$$

This filter may be programmed either as a Low Pass Filter or a Notch Filter. The filter parameters are calculated with an EXCEL utility that Kollmorgen supplies.

COMPFLT is a 400Hz filter on the velocity feedback. It can be switched On or Off.

## Position Loop

The position loop in the DAD has a PI structure, as shown in the following diagram:



GPISATIN / GPISATOUT are saturation components that control or limit the effect of the integrator. They appear in the integration path in order to maintain integration resolution of error counts. Usually one would like the integrator to operate near the target point to close the error, but one doesn't want the integrator to affect the dynamic behavior during the move. Thus, the limits are set so that the integrator operates only when the position error is within certain limits.

The output saturation, GPISATOUT, sets the maximum command that the integrator can give, while the input saturation, GPISATIN, limits the charging rate of the integrator.

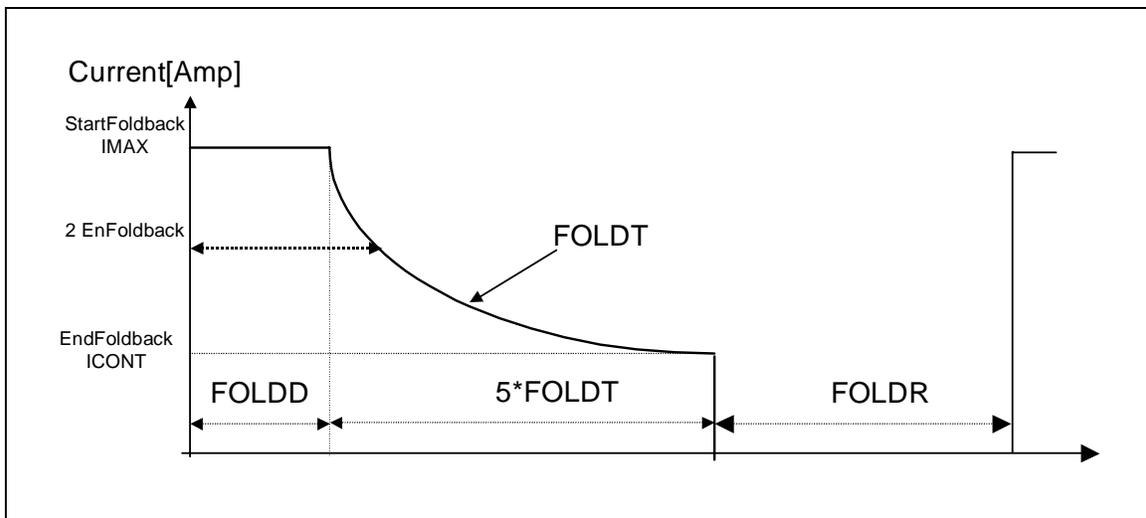
SENSRES is equal to 2,097,152.

---

## Foldback

The Foldback algorithm monitors current feedback, and its purpose is to keep the RMS level of the current below or equal to ICONT. Assuming a "long" time of zero current before applying current step, the current step may exceed ICONT. Still, the current level is limited by ILIM. The algorithm "integrates" the current above ICONT (the delta between the current and ICONT) over time, and when this value exceeds a threshold, the current starts to be reduced exponentially (folds) until limited to the value of ICONT.

When the current level goes below ICONT, the "integrator" is released at a rate proportional to the delta between ICONT and the actual current.



The decay and recovery times are programmable, using the FOLDD, FOLDR and FOLDT instructions. The FOLD query returns the foldback status. The drive can be programmed in various ways to fault during foldback events (FOLDMODE and FOLDTIME).

# Troubleshooting

There are three levels of error handling in the Dual-Axis Drive: errors, faults and fatal faults.

- **Errors** occur when an instruction cannot be executed. The Dual-Axis Drive responds to an erroneous instruction with a text message transmitted over the serial port. The drive is not disabled.
- **Faults** occur in response to the drive's protection mechanisms. The drive is disabled and the fault is recorded in the fault log (accessible using the FLTHIST command). Faults are cleared by removing the source of the fault and toggling the ALARM CLEAR digital input.
- **Fatal Faults** occur in response to the drive's protection mechanisms. These faults result in the drive not only being disabled, but also being non-operational until power is cycled.

Faults and Fatal Faults are shown on the 7-segment display. A table below shows the codes for the faults.

---

## Fault Monitoring System

The Dual-Axis Drive microprocessor is constantly monitoring the status of many different components. In general, the Dual-Axis Drive latches all fault conditions so you can readily determine the source of the problem. When a fault is detected, it is logged in the internal error log, indicated in the Status Display, enunciated over the serial port, and causes a Dual-Axis Drive disable. Many faults are reset by toggling the ALARM CLEAR digital input.

The following provides a list of some of the more frequent faults the Dual-Axis Drive detects in the unit hardware and operating system:

**Motor Over-Temperature:** The Motor's External Thermostat input is monitored for an open circuit condition. This condition is indicated with an 'H' in the status display.

**Drive Over-Temperature:** The internal heatsink temperature is monitored for an unsafe condition. This condition causes a 't' to be displayed and disables the Dual-Axis Drive. The Dual-Axis Drive eventually cools enough to allow reset.

**RMS Over Current (Foldback):** the Foldback detection system can 'clamp' the available output current. This is not a true fault condition, but may cause undesired performance, as the command current is limited below what is required to achieve the desired performance. This condition is indicated with an 'F' in the status display and is detected by monitoring the FOLD switch variable.

**Bus Over-Voltage:** an over-voltage condition shuts down the Dual-Axis Drive and displays a lower-case 'o' in the status display. This fault occurs normally during REGEN operation (sharp deceleration) where the BUS is raised to higher values than that produced by the power supply.

**Bus Under-Voltage:** an under-voltage condition shuts down the Dual-Axis Drive and displays an 'u' in the status display. This fault normally occurs when the incoming line voltage drops out or a fault occurs in the power supply.

**Power Stage Fault (Over-Current):** Hardware circuitry monitors load short-circuit, transistor failure, and instantaneous Over-Current. A power stage fault can only be reset by power cycling. This condition is indicated by a flashing 'P' in the status display.

**Feedback Loss:** Software algorithms are used to detect Sine and Cosine line break and Endat RS485 communication signal break. A flashing 'r4' or a flashing 'r10' respectively are displayed.

**Over-Speed fault:** Software continuously monitors the actual feedback speed. If the motor speed exceeds the VOSPD limit, a 'J' is displayed and the Dual-Axis Drive is disabled. If the motor speed exceeds  $1.8 \cdot \text{VLIM}$  then "J1" is displayed and the Dual-Axis Drive is disabled. This normally occurs when there is an improperly tuned system and the load overshoots its commanded speed.

**No compensator:** In case the Dual-Axis Drive cannot design a compensator, such as after a CONFIG, RSTVAR or CLREEPROM command, a flashing minus sign (-) is displayed and the Dual-Axis Drive is disabled. This display normally indicates that the Dual-Axis Drive does not have a compensation file loaded.

**Memory reliability:** During the initialization process upon power up, the run time, variables memory (RAM - Random Access Memory), and the program memory (Flash Memory) are tested.

If a RAM fault is detected, an 'I' is displayed and the Dual-Axis Drive halts. If a Flash Memory fault is detected, a 'c' is displayed and the Dual-Axis Drive halts.

The user configuration non-volatile memory is also checked for integrity upon power-up. Any discrepancy in this data is noted with an 'e' in the status display. After power-up is successfully completed, any subsequent fault in the operation of the non-volatile memory is noted with an 'E' in the status display.

**Watch Dog:** In addition, the Dual-Axis Drive incorporates a watchdog system to maintain software operation integrity. Failure of the watchdog mechanism displays three bars on the status display and halts the Dual-Axis Drive. This normally indicates serious problems. Contact the factory for support.

## Faults and Fatal Faults

The table below describes the display seen for each of the faults and fatal faults.

Display	Error Message	Possible Cause	Error #
	No fault		0
t	Power stage over temperature	Overload, fan malfunction, power stage failure	1
o	Over voltage	Excessive deceleration rate	2
P	Over current	Power stage surge current*	3
r4	A/B line break	Break in encoder A/B input lines detected	4.4
R10	EnDat communication error	EnDat communication line break	4.10
u	Under voltage	Bus voltage is too low	5
H	Motor over temperature	Motor overload caused overheating	6
J	Over Speed	Velocity $\geq$ VOSPD	8
J1	Over Speed (1.8*VLIM)	Velocity $\geq$ 1.8 x VLIM	8.1
d2	Excessive position deviation	PE > PEMAX	15.2
E	EEPROM failure	Faulty EEPROM	9
e	EEPROM checksum fail	EEPROM checksum invalid on power up	10
F	Foldback	System in foldback mode	12

\*These faults can only be cleared by cycling power

**NOTE:** A flashing “A – 0” is not indicative of a fault. This pattern is displayed when the axis is disabled (AXISOFF = 1).

## Errors

Errors result from attempted execution of invalid instructions.

Error Message	Possible Cause	Error #
Unknown Command	Undefined command	20
Drive Active	Drive needs to be inactive for the requested command or variable	23
Value out of range	Variable value out of range	25
Syntax Error	Communication message syntax error	28
Not Programmable	Variable is read-only	36
Current loop design failed	CONFIG failed due to current loop design failure	37.01
MSPEED out of range	CONFIG failed due to MSPEED	37.04
Vel loop design failed	The velocity loop cannot be configured with given parameters. Check that VLIM is greater than 0.	41
EEPROM is empty	Data cannot be loaded because EEPROM is empty	45
Argument not binary	Argument needs to be an even number	46
Burnin is active	The requested function cannot be executed during Burnin (factory)	47
Burnin is not active	Burnin (factory function) cannot be stopped if it is not active	48
Not available	The requested variable value is not available. Refer to the VarCom.	51

## No Message Faults

These faults do not generate messages; they are only indicated on the display.

Display	Fault Description	Fatal Error	Flashing Display
≡	Watchdog	Y	N
-1	No Compensation	N	Y
-2	Invalid Velocity Control	N	Y
I	RAM failure (during init)	Y	N
c	EPROM checksum (during init)	N	N
8	Test LED	N	N

## Customer Support

Kollmorgen is committed to quality customer service. Our goal is to provide the customer with information and resources as soon as they are needed. In order to serve in the most effective way, contact your local sales representative for order status and delivery information, product information and literature, and application and field technical assistance. If you are unaware of your local sales representative, please contact us at:

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