Kollmorgen **SILVER**LINE®

S/O Manual

Kollmorgen **SILVER**LINE® **Product Series**
S/O Installation Manual
Old Number M-SL-000-H
New Number MSO000H

Record of Manual Revisions

ISSUE NO.	DATE	BRIEF DESCRIPTION OF REVISION
1	8/96	M96104 - Initial Product Launch
2	5/97	M96104 - Update of previous Issue
3	11/98	MSL000H - Model Number change and rearrangment of previous Issue. No content change

Copyright Information

Printed in the United States of America.

Contents Overview

Table of Contents

Safety Instructions

Only qualified personnel are permitted to transport, assembly, commission, and maintenance 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 assembly and commissioning. Incorrect handling of products in this manual can result in injury and damage to persons and machinery. Strictly adhere to the technical information on the installation requirements.
- It is vital to ensure that all system components are connected to earth ground. Electrical safety is impossible without a low-resistance earth connection.
- The Kollmorgen **SILVER**LINE product series contains electrostatically sensitive components which can be damaged by incorrect handling. Discharge yourself before touching the product. Avoid contact with high insulating materials (artificial fabrics, plastic film, etc.). Place the product on a conductive surface.
- During operation keep all covers and cabinet doors shut. Otherwise, there are deadly hazards that could possibility cause severe damage to health or the product.
- In operation, depending on the degree of enclosure protection, the product can have bare components which are live or have hot surfaces. Control and power cables can carry a high voltage even when the motor is not rotating.
- Never pull out or plug in the product while the system is live. There is a danger of electric arcing and danger to persons and contacts.
- After powering down the product, wait at least 10 minutes before touching live sections of the equipment or undoing connections (e.g. contacts, screwed connections). Capacitors can store dangerous voltages for long periods of time after power has been switched off. To be safe, measure the contact points with a meter before touching.
- The safety-alert symbols are illustrated as follows:

Safety-Alert Symbols

When these symbols are seen in this manual, be alert to the potential for personal injury. Follow the recommended precautions and safe operating practices included with the alert symbols. Safety notices in this manual provide important information. Read and be familiar with these instructions before attempting installation, operation, or maintenance. The purpose of this section is to alert users to possible safety hazards associated with this equipment and the precautions that need to be taken to reduce the risk of personal injury and damage to the equipment. Failure to observe these precautions could result in serious bodily injury, damage to the equipment, or operational difficulty.

"**Warning**" alerts users to potential danger or harm. Failure to follow warning notices could result in personal injury or death.

"**Caution**" directs attention to general precautions, which if not followed, could result in personal injury and/or equipment damage.

"**Note**" highlights information critical to the users understanding or use of these products.

Directives and Standards

The product has not be tested for any UL or European CE standards.

Section 1 General Information

1.1 HOW TO USE MANUAL

This manual is designed to lead the user through proper installation, setup, and understanding of a SERVO**STAR**® servo system. The user does not have to be an expect in motion control to install and operate. The manual was developed with the assumption that there is a fundamental understanding of basic electronics, computers, mechanics, and proper safety practices. It is recommended that the entire manual be read completely before installation and operation is attempted.

The layout of material in this manual is designed to guide the user through the following process:

- Product description and features (Section 2)
- System hardware installation (Section 3)
- System startup through a host communicator (Section 4)
- The system's various modes of operation (Section 5)
- System troubleshooting and customer support (Section 6)

Included along with this hardcopy installation portion is a Quick Reference Guide (QRG) and two floppy disks. The QRG provides information on the Variable and Command set. An 8½ x 11 electronic copy in .PDF format of the QRG is provide on disk 2 of 2 for easy notebook insertion. The floppy disks contain the MotionLink® software program and other SERVO**STAR**® technical information and theory in PDF format.

1.2 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 a product catalog description. All Kollmorgen brushless motors and electronics are warranty for a period of 24 months from the time of installation or 30 months from time of shipment, which ever comes first. There are no other warranties, expressed or implied (including the warranty of merchantability and fitness for a particular purpose, which extend beyond this warranty. Kollmorgen warrants that the products covered in the manual are free from patent infringement when used for normal purposes.

1.3 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 our customers the most effective way, Kollmorgen offers a one-stop service center to answer all our customer's product needs. This one number provides order status and delivery information, product information and literature, and application and field technical assistance:

Kollmorgen Customer Support Network
203 Rock Road Suite A
Radford, VA 24141
Phone: (800) 774-KCSN (5276)
Fax: (540) 639-1640 Inside Sales
Fax: (540) 639-1574 Technical Support
Email: KMTG@Kollmorgen.com
Http://www.KMTG.Kollmorgen.com

Note! If you are unaware of your local sales representative, please contact us at the number above. Visit our web site for MotionLink® software upgrades, technical articles, and the most resent version of our product manuals.

1.4 ABBREVIATIONS

A/D or ADC	Analog-to-Digital Converter
CCW	Counter Clockwise*
CMR	Common Mode Rejection
CW	Clockwise*
CR-LF	ASCII Carriage Return, Line Feed
D/A or DAC	Digital-to-Analog Converter
EMF	Electro-Motive Force
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
Hz	Hertz
I	Current
I/O	Input / Output
kHz	KiloHertz
KCSN	Kollmorgen Customer Support Network
KW	KiloWatts
LED	Light Emitting Diode
NEC	National Electrical Code
PC	Personal Computer
P/N	Part Number
PWM	Pulse Width Modulation
QRG	Quick Reference Guide
R/D	Resolver-to-Digital
Regen	Regeneration
RMS	Root Mean Square
UL	Underwriters Laboratories

* Clockwise and counterclockwise reference as viewing the motor output shaft.

1.5 LIST OF FIGURES

Section 2 System Description

2.1 INTRODUCTION

The Kollmorgen S/O-series amplifiers are six-step modules designed to bring high performance to cost-sensitive applications. S/O amplifiers have these important features:

High linearity

- Minimal dead band
- No heatsink required
- Full-differential ±10 volt input
- Field configurable without special tools or soldering
- No crimping tools or special wire preparation required
- User Selectable Operation Modes:
  - High performance current-loop mode
  - Simple open-loop mode
  - Optional velocity loop
- Velocity loop option provides encoder power
- Jumper selectable 60° or 120° commutation
- Overcurrent protection
- Overvoltage protection
- Continuous current limit
- ESD protection on all inputs
- Optical isolation for ENABLE input and AMP OK output
- Reverse polarity protection on ENABLE and AMP OK
- Surge suppression on the DC bus input
- Up to 40 volt input
- Up to 8 amp continuous (16 amp peak) output
- Two mounting options

This manual provides information for installation and operation.

2.2 PART NUMBER DESCRIPTION

A model number is printed on a tag on the front of your S/O and SPS/R. The model number identifies how the equipment is configured. Each component is described in Figure 2-1 and Figure 2-2. Verify that the model numbers represent the equipment desired for your application.

Current Loop

The S/O has analog current loops which are tuned with one capacitor (CL in J3) and one resistor (RL in J4). The values of these components vary depending on the motor and amplifier models. Failure to install the correct values can result in damage to the motor and amplifier. See Chapter 2 for more information.

CAUTION

Failure to install the proper compensation components in RL/CL can cause damage to the S/O, the motor, or both.

2.2.1 S/O Model Number

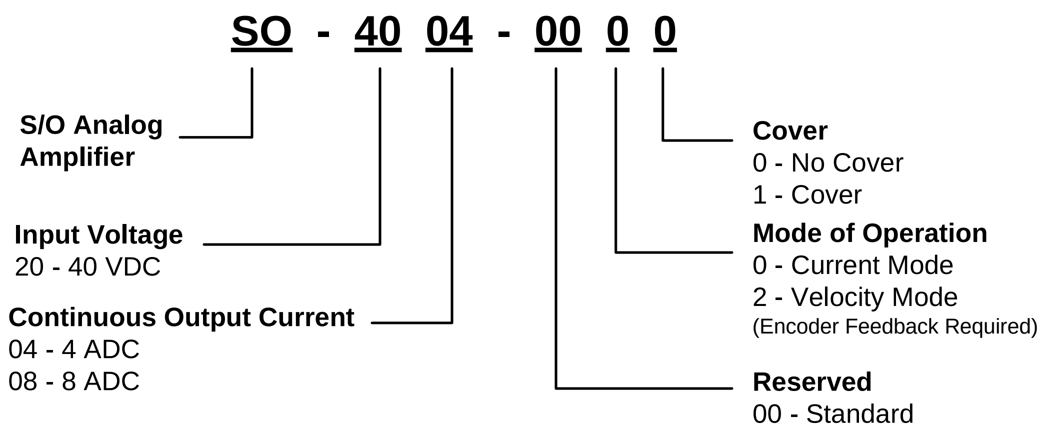


Figure 2-1 S/O Model Number Scheme

2.2.2 SPS/R Model Number

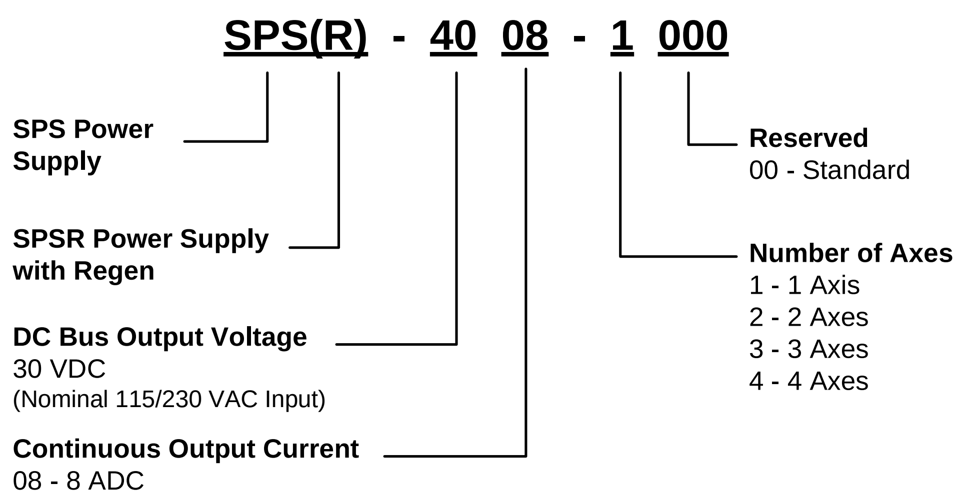


Figure 2-2 SPS/R Model Number Scheme

Note: specifying a larger number of axes does not increase the electrical ratings. It only provides space to mount more S/O units.

2.3 SYSTEM TOPICS

2.3.1 Specifications and Ratings

Control Inputs	ANALOG Command (Analog) ENABLE (Digital)
Control Method	Jumper selectable for high-performance current loop or open loop. Current loop provides high-response for servo applications. Open loop controls speed by using the natural regulation of the motor. Velocity control is provided optionally.
Control Outputs	AMP OK (Digital)
Input Power Protection	Transient Protectors (1500 watts for 1 msec)

ESD Protection	ANALOG CMD inputs resistor/diode protected. ENABLE input opto-isolated. AMP OK output opto-isolated and buffered. Hall sensor inputs resistor / diode protected.
Current Overload	Monitor Current
Analog Input	Full Differential, ±10 volts Impedance: Approximately 40 kohm
AMP OK	Max Current sink:24 mA (Customer must supply impedence) Voltage Range: 5-26V, impedance limited by customer
ENABLE	Voltage Range: 5-26V Maximum Load for 12 mA @ 26V (2.5 mA @ 5V)

Table 2-1 Specifications

SO-40XX		
DESCRIPTION	**SO-4004**	**SO-4008**
Main DC Bus: Minimum Maximum	20 VDC 40 VDC	20 VDC 40 VDC
Output Current (40°C Ambient) Continuous Peak (2.0 sec)	 4 ADC 8 ADC	 8 ADC 16 ADC
Output VA (@ 40 V BUS & 40°C Ambient) Continuous Peak (2.0 sec) (RMS)	 160 VA 320 VA	 320 VA 640 VA
PWM Switching Frequency	18 kHz	18 kHz
Overvoltage Trip	43 VDC	43 VDC

Table 2-2 Specifications

Velocity Loop Option	
Encoder Supply Max	250 mA
Linearity	0.2% Full Scale
Velocity Range	2000:1
Differential Input	±10 VDC
Max Frequency	384 kHz

Table 2-3 Specifications

SPS/R - 4008	
DESCRIPTION	**RATING**
Main AC Line Input Voltage (short term 2-3) (short terms 1-2 & 3-4)	207-264 VAC 104-132 VAC
Phase	1
Frequency	57-63 Hz
Current Cont. (DC)	8 ADC
Peak (2.0 sec)	16 ADC
Peak (50.0 msec)	24 ADC
Main DC Bus Output Voltage (Nominal 115/230 VAC Input/Full Load)	30 VDC
Shunt Regulator Current (PK)	16 ADC
Regen Power Dissipation (Cont.)	25 WATTS
Regen Power Dissipation (PK)	250 WATTS
Internal Heat Dissipation	25 WATTS
Regen Trip voltage	41-43 VDC

Table 2-4 Environmental Specifications

Operating Temperature*	0°C to 40°C
Storage Temperature	-20°C to 70°C
Humidity (Non-Condensing)	10% to 90%

Note: For operation ambients above 40°C, consult the Kollmorgen Customer Support Network

2.3.2 Physical Deminsions

MODEL NUMBER	WIDTH		HEIGHT		DEPTH	
	MM	IN.	MM	IN.	MM	IN.
SO 40XX	42	1.62	204	8	92	4
SPS/R-4008-0	150	5.9	241	9.5	108	4.25
SPS/R-4008-1	213	8.4	241	9.5	108	4.25
SPS/R-4008-2	297	11.7	241	9.5	108	4.25
SPS/R-4008-3	381	15.0	241	9.5	108	4.25
SPS/R-4008-4	463	18.3	241	9.5	108	4.25

2.3.2 Current Control Wiring Diagram

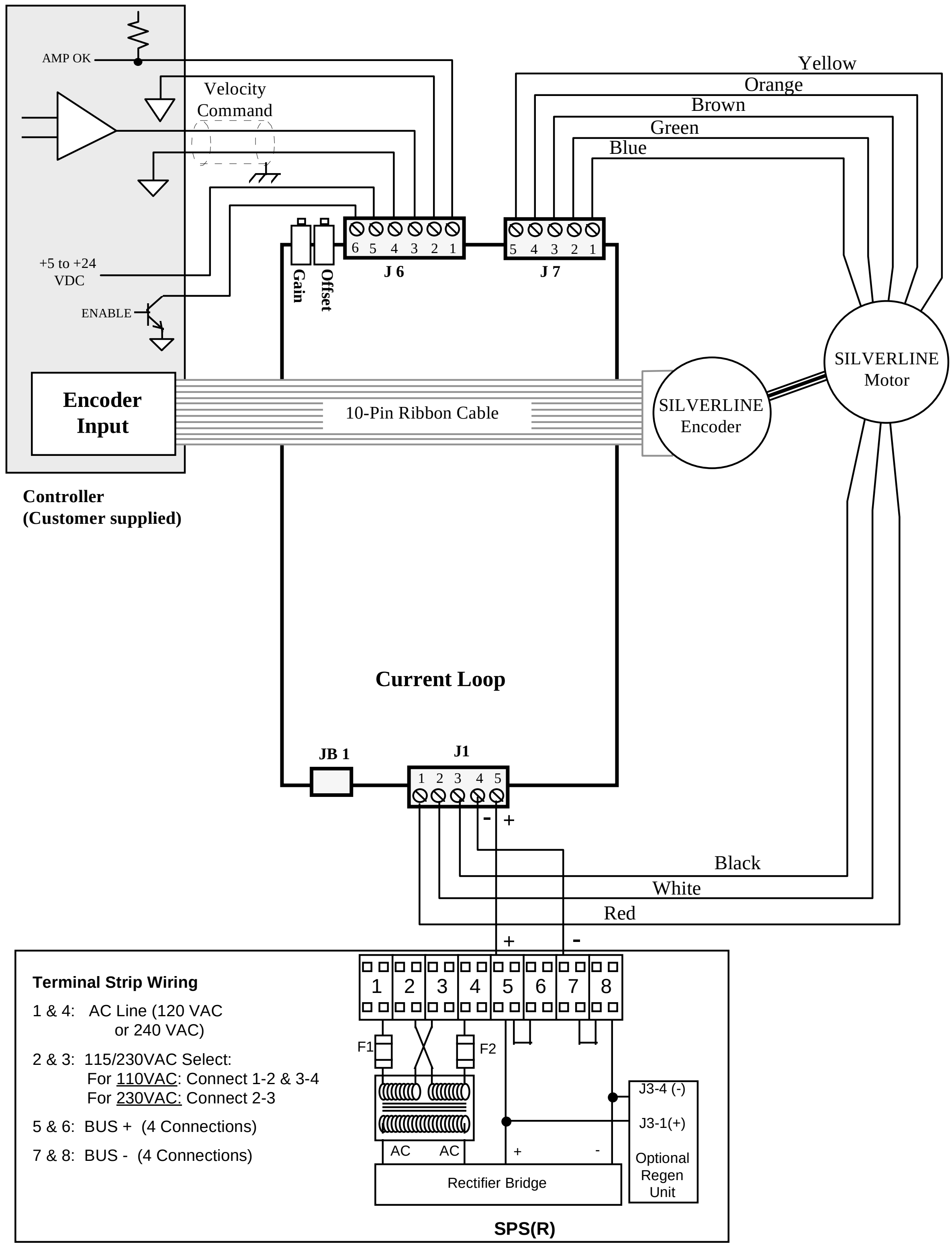


Figure 2-3 SO System Wiring Diagram

2.3.3 Velocity Control Wiring Diagram

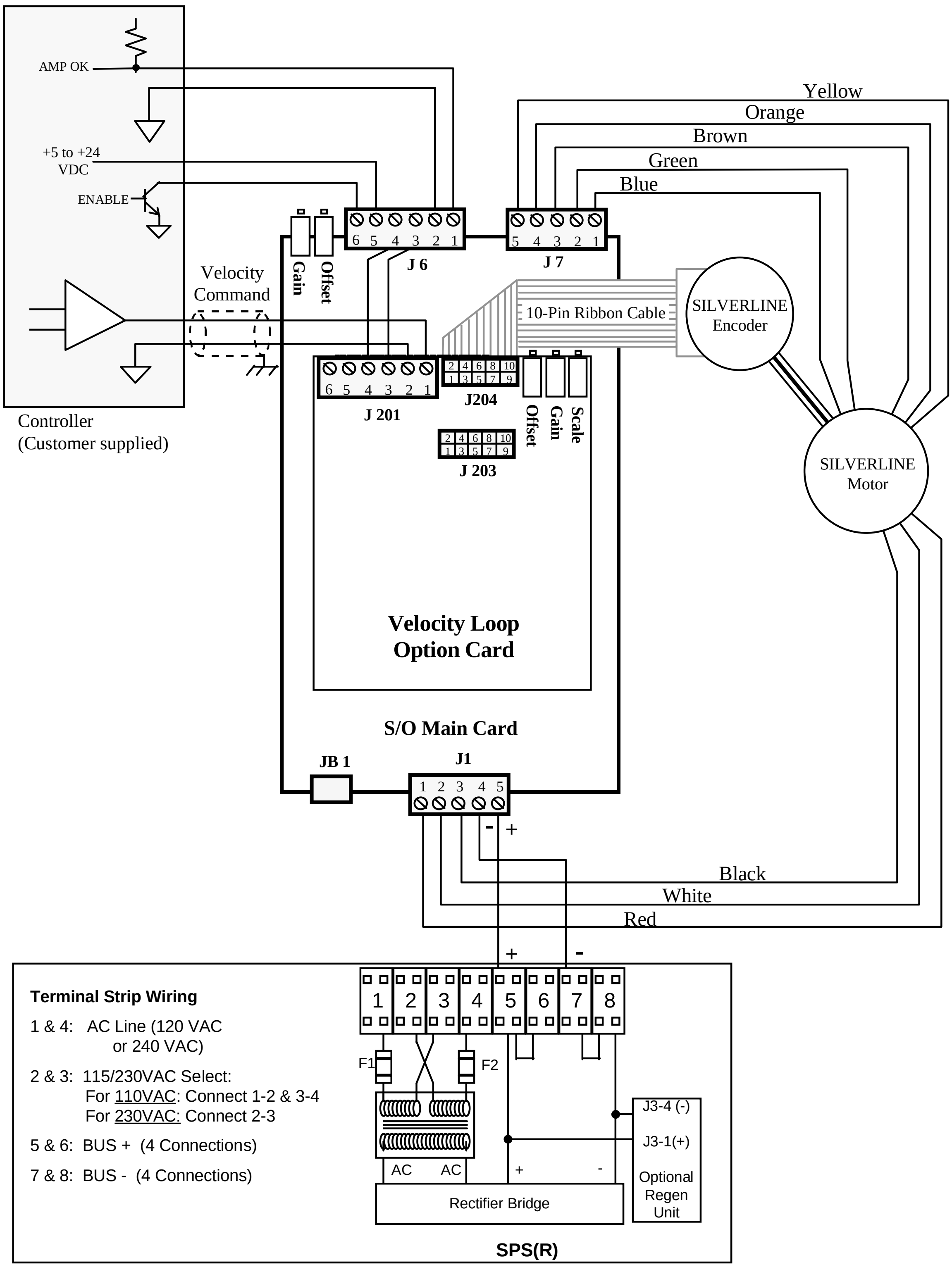


Figure 2-4 SP System Wiring Diagram, Velocity Loop

Section 3 Outline Drawings

OUTLINE DRAWINGS

The following system outline drawings include the following:

Kollmorgen **SILVER**LINE® SPS/R-4008

Kollmorgen **SILVER**LINE® SO-400x

Kollmorgen **SILVER**LINE® H-23x Motor:

Kollmorgen **SILVER**LINE® H-34x Motor:

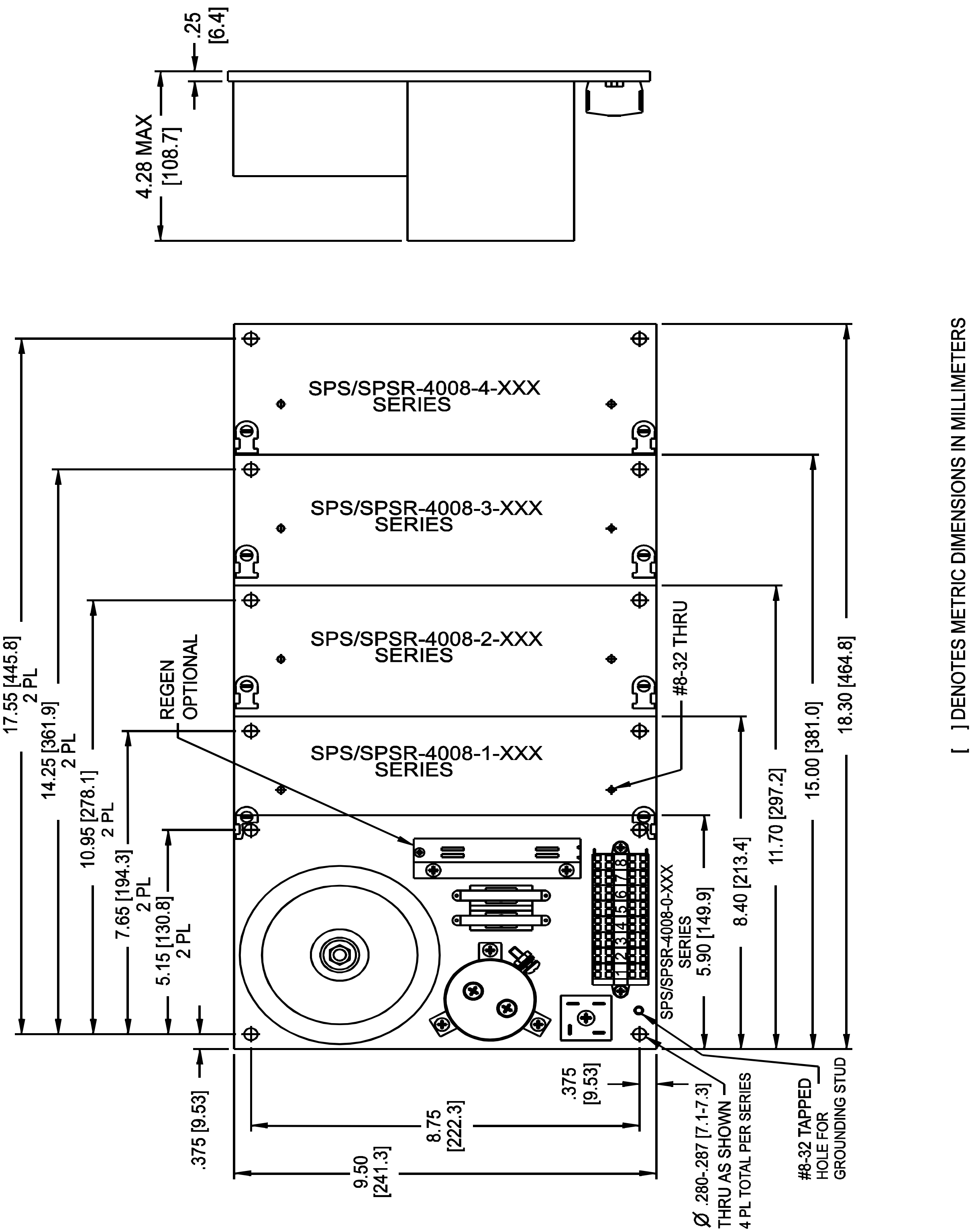


Figure 3-1 SPS/R-4008 Outline

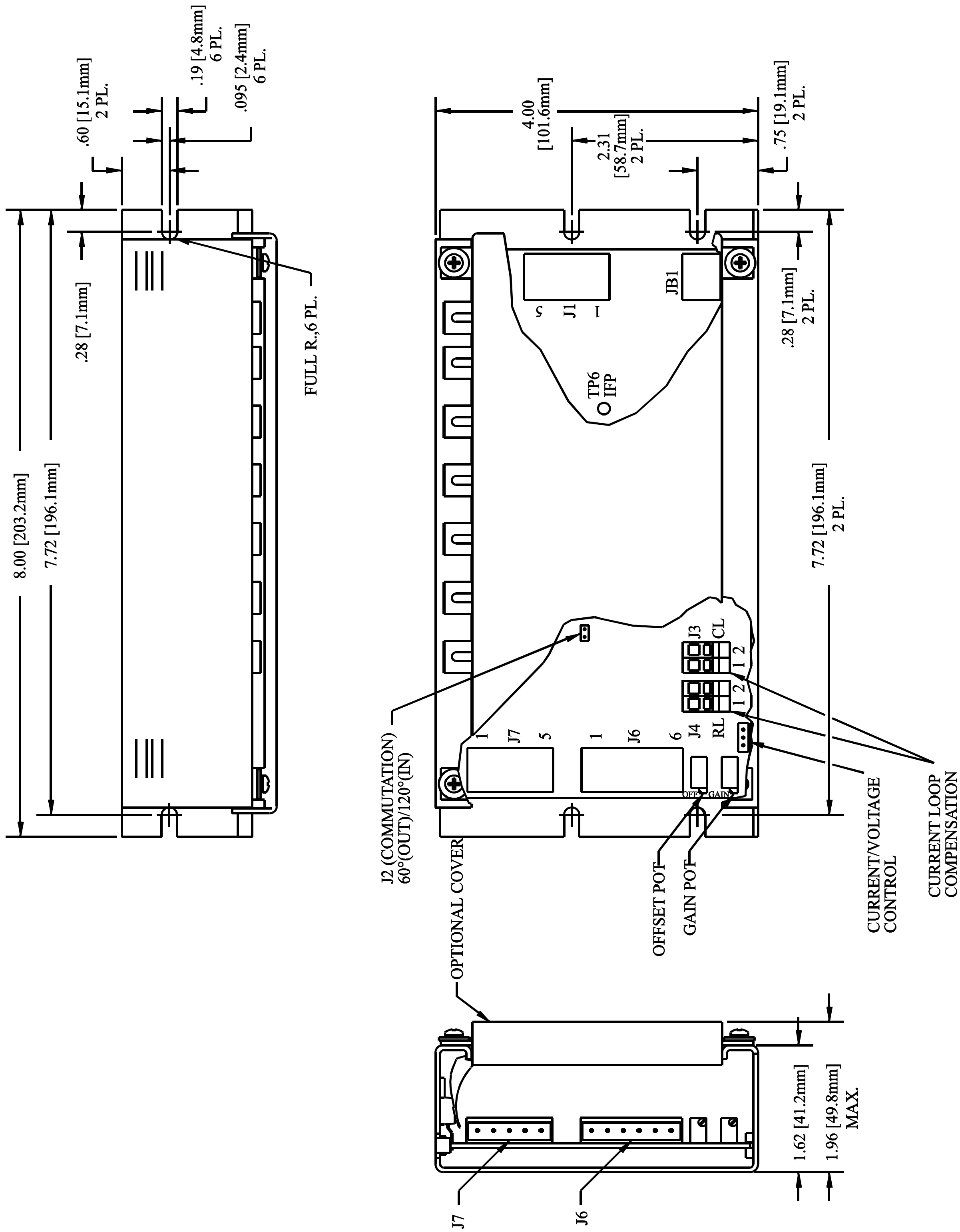
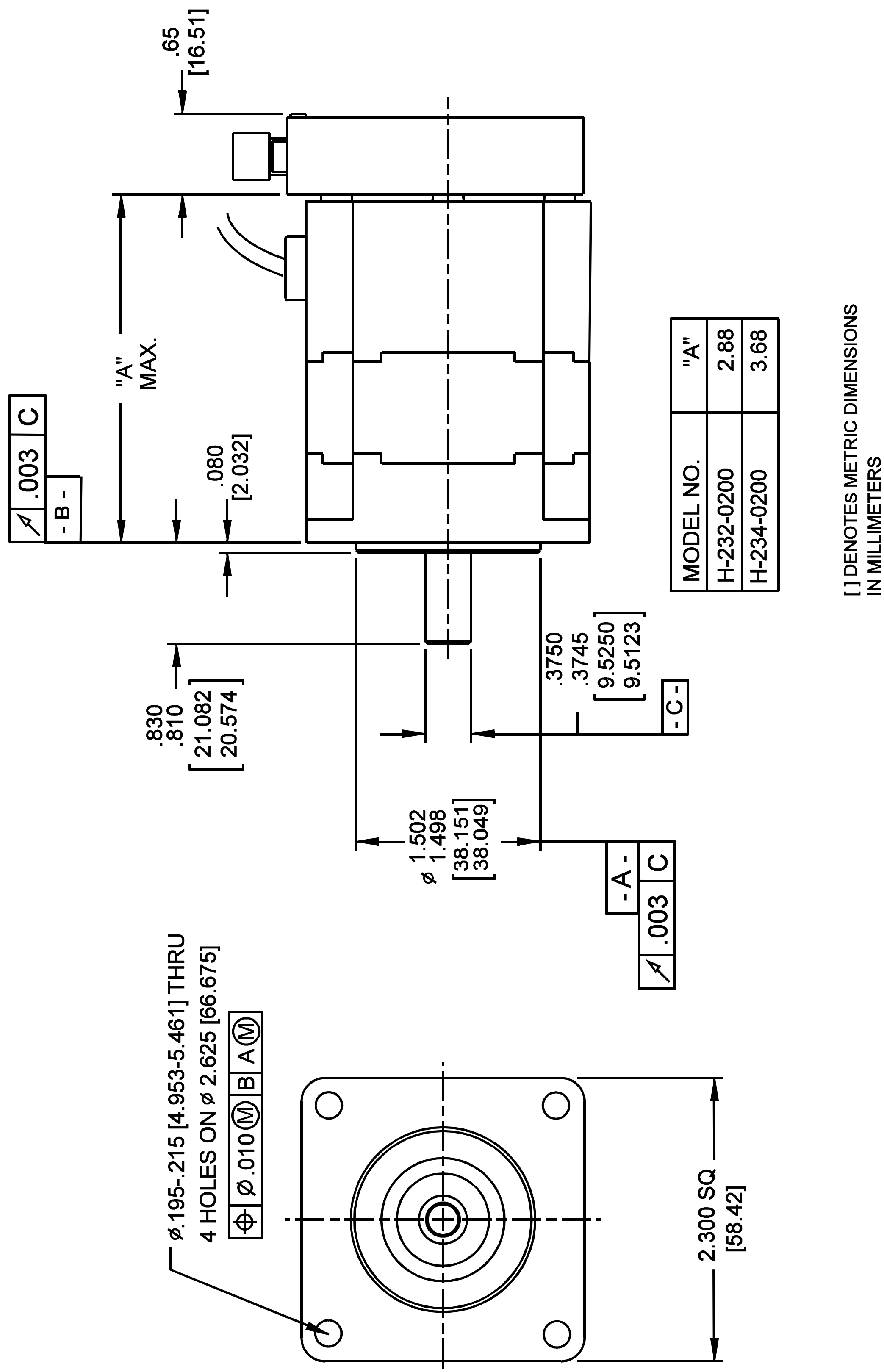


Figure 3-2 SO-400x Outline



MODEL NO.	"A"
H-232-0200	2.88
H-234-0200	3.68

Figure 3-3 Size 23 Outline

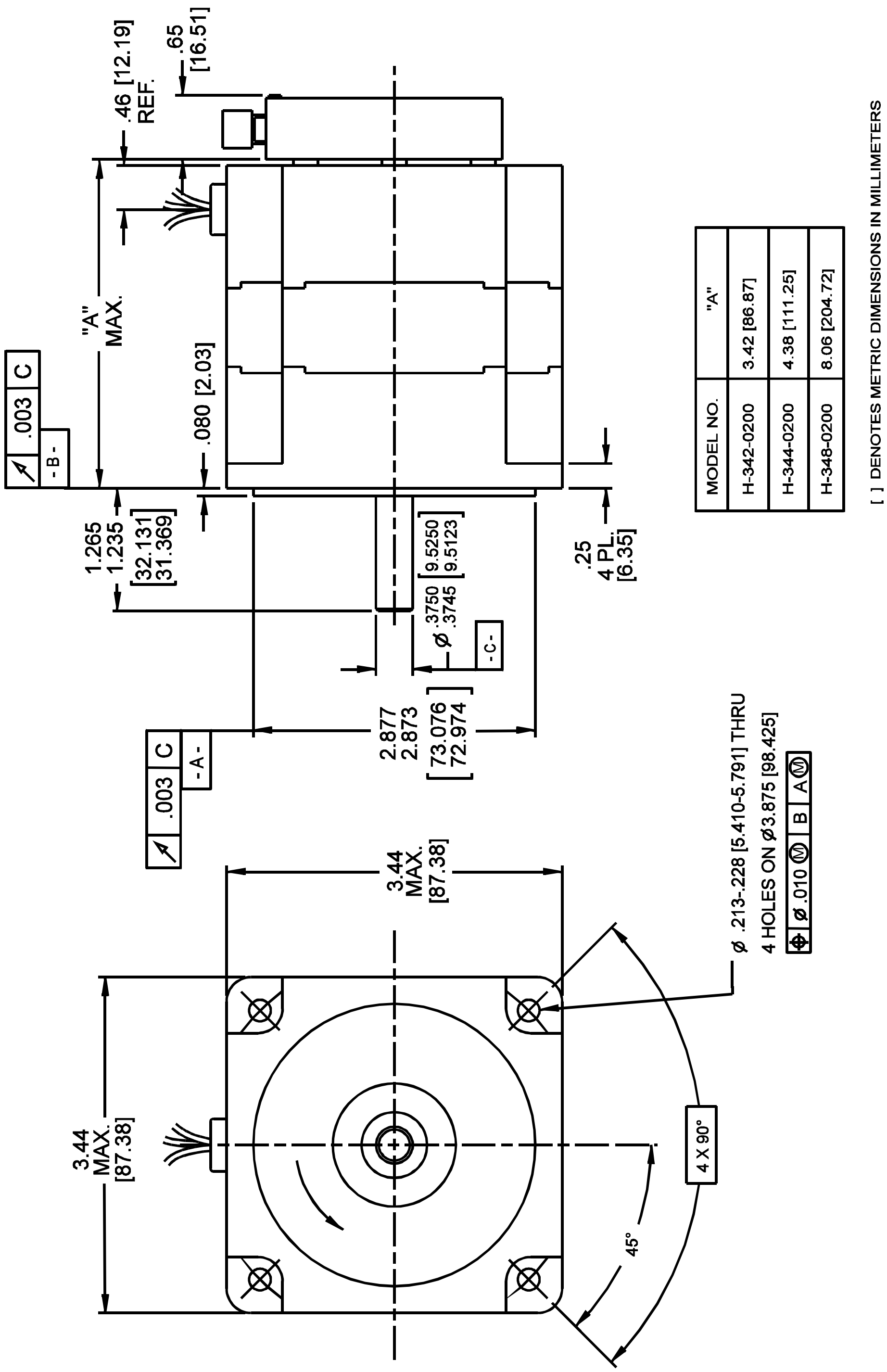


Figure 3-4 Size 34 Outline

Section 4 Mounting and Wiring

4.1 INTRODUCTION

This chapter provides information concerning safety, unpacking, inspection, and installation for the S/O and the SPS/R. Read the entire chapter carefully. **Most installation problems are caused by incorrect wiring or poor wiring practices.**

4.2 SAFETY INFORMATION

This section will alert you to possible safety hazards associated with this equipment and the precautions you can take to reduce the risk of personal injury and damage to the equipment.

Safety notices in this manual provide important information. Read and be familiar with these instructions before attempting installation, operation, or maintenance. Failure to observe these precautions could result in serious bodily injury, damage to the equipment, or operational difficulty.

The safety-alert symbols are illustrated above. When you see these symbols in this manual, be alert to the potential for personal injury. Follow the recommended precautions and safe operating practices included with the alert symbols.

WARNING refers to personal safety and alerts you to potential danger or harm. Failure to follow warning notices could result in personal injury or death.

CAUTION directs attention to general precautions which, if not followed, could result in personal injury and/or equipment damage.

NOTE highlights information critical to your understanding or use of these products.

4.3 UNPACKING AND INSPECTION

CAUTION

Electronic components in this amplifier are static sensitive. Use proper procedures when handling component boards.

Upon receipt of the equipment, closely inspect components to ensure that no damage has occurred in shipment. If damage is detected, notify the carrier immediately.

Carefully remove packing material and remove the equipment from the shipping container. Do not dispose of shipping materials until the packing list has been checked. Parts contained within the shipment but not physically attached to the equipment should be verified against the packing list. If any parts are missing notify Kollmorgen at once.

4.4 INSTALLATION REQUIREMENTS

Proper installation and field wiring are of prime importance in the application of servo amplifiers. Many problems will be avoided if installation is done properly. Users should familiarize themselves with and follow these instructions in addition to all applicable codes, laws, and standards. Pay special attention to the following topics when installing Kollmorgen equipment.

4.4.1 Environmental Considerations

The environment in which this equipment is placed can dramatically affect its operation. Kollmorgen recommends that the S/O and SPS/R be operated and stored under the following conditions:

- Operating Temperature: 0°C to 40°C
- Storage Temperature: -20°C to 70°C
- Humidity: 10% to 90%   (Non-Condensing)

4.4.2 Ventilation

The SPS/R and S/O should be mounted vertically to allow maximum ventilation of the components. This configuration allows the heat generated by the components to vent through the top and draft in cooler air through the bottom. The top and bottom of the components are vented to allow this drafting to occur. Check ventilation paths to ensure they are not constricted by accumulation of contaminants.

4.5 MOUNTING

The S/O and SPS/R should be mounted in a cabinet or other suitable enclosure to protect them from physical and environmental damage.

4.5.1 Mounting the SPS/R

The SPS/R power supply and mounting bracket must be mounted so the S/O units are vertical. These units are convection cooled and require that a 25mm (1") clearance be maintained on all four sides. Refer to the SPS/R Outline Drawing in Section 3 for more information.

4.5.2 Mounting S/O Units on an SPS/R

SPS/Rs include mounting holes for up to four S/O units. The number of S/O units that can be mounted is specified when you order your units. See the SPS/R outline drawing in Section 3 for more information.

4.5.3 Mounting S/O Units without an SPS/R

S/O units must be mounted vertically. These units are convection cooled and require 6mm (0.25") clearance on both sides, as well as at least 25mm (1") above and below. See the S/O outline drawing in Section 3 for more information.

4.6 WIRING OVERVIEW

The customer is responsible for providing proper circuit breaker or fuse protection. The customer is responsible for providing proper wire gauge and insulation rating for all wiring, including motor, AC line, and DC bus. The customer is responsible for making sure that all system wiring and electrical protection comply with all applicable national and local electric codes.

When wiring your S/O system, observe the following guidelines:

- Twist all AC leads to minimize electromagnetic emissions (noise).
- Avoid running signal leads in close proximity to power leads, motor stator leads, or other sources of electromagnetic noise. Run signal leads in separate conduit from power leads. Shields are recommended for signal leads.
- Minimize lead lengths.
- Provide adequate strain relief for all cables and wires.

4.7 WIRING GROUND AND BUS

4.7.1 Wiring the Ground with an SPS/R

To prevent shock hazard and to ensure proper operation of the system, the bus- and the motor must be grounded. The S/O is not isolated from bus-; therefore, grounding bus- will ground the S/O.

WARNING

GROUND bus- and motor PROPERLY! Failure to provide proper grounding can result in a shock hazard.

4.7.2 Providing the DC Bus

The S/O is configured at the factory for operation from a 40-volt DC (max) bus. Regulated supplies may provide up to 40 volts, providing that regulation is within 2% over all line and load conditions.

The maximum allowed nominal bus voltage varies with the power supply line/load variation. Better regulation allows higher nominal bus voltage. However, the nominal value must be selected so that in no case will the bus voltage exceed 40 VDC.

CAUTION

The maximum bus voltage must be 40 volts or less under all conditions.

4.7.2.1 Providing DC Bus Using an SPS/R

Refer to Figure 3-1 (page 3-2). Note that SPS/Rs are unregulated supplies and provide a nominal voltage of 75% of the rated voltage. This limits the actual supplied voltage to be no more than the rated voltage under reasonable line variation.

The SPS/R provides field terminations for DC bus connections for up to 4 S/O units. The terminations are WAGO 264 Series cage clamp connectors and are detailed in Figure 3-1. Each terminal has four internally connected "insertion points." The lower two are provided for customer connections; the upper two are reserved for the factory.

The SPS/R provides wire tie receptacles above and below each S/O unit. These receptacles allow for proper strain relief of all cables and wires entering and exiting the S/O units.

4.7.2.2 SPS/R Wire Preparation and Insertion

SPS/R field terminations accept 16-28 AWG wire. Wire should be stripped 6mm (0.25"). Normally, wires need not be tinned or crimped with a wire ferrule. To insert wires, place a small screw driver fully into the opening just above the insertion point and rotate upward slightly. The metal clamp will open; insert wire and remove the screw driver. Ensure that the clamp is in contact with the conductor, not the insulation. Ensure that no bare wire is exposed outside the insertion point. Gently pull the wire to ensure that it is fully inserted.

4.7.2.3 Wiring SPS/R A/C Line

Configure the SPS/R for the appropriate voltage (115 or 230 volts AC) according to Figure 3-1. Use small jumpers prepared according to instructions in "SPS/R Wire Preparation and Insertion" above. Four connections are provided for bus+ (two from each of terminals 5 and 6) and four are provided for bus- (two from each of terminals 7 and 8).

4.7.2.4 Fusing

If you are not using an SPS/R, you must fuse the incoming power (J1, pin 5). Use a slo-blow fuse. For the SO-4004, the fuse should be no larger than 6 amps. For the SO-4008, the fuse should be no larger than 12 amps. These values (6 and 12 amps) are larger than the nominal value of the amplifier (4 and 8 amps, respectively) because the amplifiers can produce peak currents which are double the continuous current.

4.7.2.5 Motor Protection

Be aware that fusing the power supply input lines does not necessarily limit current in the individual motor leads, especially when the motor is stalled or rotating slowly. The pulse-width modulation (PWM) topology used in this amplifier can produce large motor currents from much smaller line currents. Do not rely on power-supply fusing to limit current in the motor leads. If motor leads must be current limited, then protect the motor leads with motor overload relays or fuses in addition to fusing the power supply input lines.

4.8 WIRING THE ENCODER

The standard **SILVER**LINE encoder uses a 10-pin ribbon cable connector. It is wired according to the HEDL ® standard from Hewlett-Packard. Refer to Figure 4-2 (page 4-17). If you are using a standard **SILVER**LINE encoder or any encoder compatible with the HEDL standard, you may connect the encoder directly to the S/O velocity-loop option PCB with a ribbon cable. If your environment requires discrete wires in place of ribbon cable, substitute appropriate connectors such as AMP 102387-1 shells.

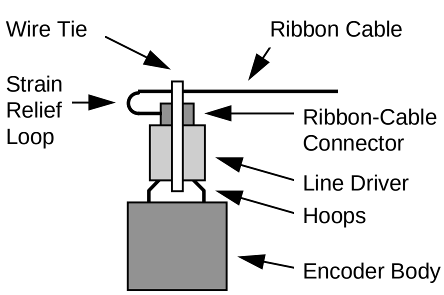
Table 4-1 SILVERLINE **Encoder**

Pin	Signal Name
1	Not Used
2	+5
3	Common
4	Not Used
5	Channel A-
6	Channel A+
7	Channel B-
8	Channel B+
9	Index-
10	Index+

Always strain relieve the encoder cable. If the encoder cable is disconnected or cable connections are broken, the motor will run away. Strain relieve at the connectors and along the length of the cable if necessary. Be particularly thorough when providing strain relief in environments with significant vibration.

On **SILVER**LINE motors, strain relief for the encoder cable is provided with a wire tie which secures the ribbon cable connector and line driver to the encoder body. Use a 0.1" wide, 4.5" long wire tie such as Richo WIT-18R. This wire tie fits securely in notches of the standard **SILVER**LINE encoder ribbon-cable connector (Amp 746285-1). Two steel hoops are attached to the encoder body through which the wire tie is threaded. Note that the connector does not have an integral strain relief as the version with strain relief cannot be fastened reliably with a wire tie. Do not interchange the black encoder connector with blue connectors which are provided for the S/O velocity loop option card.

As the connector does not provide strain relief for the cable, this function is also provided by the wire tie. Assemble as shown below: fold the ribbon cable across the back of the connector to form a small loop and install the wire tie securely, preferably with a wire-tie gun or similar device.



Side View: Application of wire tie to secure and strain relieve ribbon cable

If the encoder cable is disconnected, the motor will run away!

Vibration can loosen and disconnect this cable!

Secure the encoder cable to the Encoder using a wire tie. Use Amp 746285-1 connector.

Strain relieve the encoder cable at both ends.

WARNING

4.9 WIRING THE AMPLIFIER

Refer to Figure 4-3 and Figure 4-4 (pages 4-18 and 4-19) for an overview of all S/O connectors. Connectors J1-J7 are on the main PCB. J200-J205 are located on the optional velocity loop PCB.

4.9.1 Strain Relief

All cables that connect to the S/O must be properly strain relieved. Excessive strain causes damage to the PCB and may result in failure or unreliable operation. Ribbon cables must be properly strain relieved. Absent or inadequate strain relief of insulation displacement connector (IDC) systems causes unreliable interconnects.

Strain relieve all cables leading to the S/O. Excessive strain may cause damage to the PCB and may result in failure or in unreliable operation.

CAUTION

4.9.2 Wiring J1, BUS Power and Motor Leads

J1 is a 5-pin pluggable screw-terminal with connections on 5mm (0.2") centers. Note that in high-vibration environments, it is often preferable to crimp a ferrule onto each connection of J1.

Table 4-2 Connector J1: Power

Pin	Signal Name	Color
1	Motor A	Red
2	Motor B	White
3	Motor C	Black
4	BUS (-) (Common)	N/A
5	BUS (+)	N/A

4.9.2.1 Wiring Bus Leads

Connect bus+ to J1-5; connect bus- to J1-4. The bus must be 20-40 volts DC.

WARNING

Observe proper ESD protection procedures when handling encoder and hall sensor leads.

4.9.2.2 Wiring Motor Leads for Kollmorgen BLDC Motors

Connect the three motor leads according to the color code shown on Figure 4-5. This figure shows the color code for both Kollmorgen **SILVER**LINE® and RBE motors.

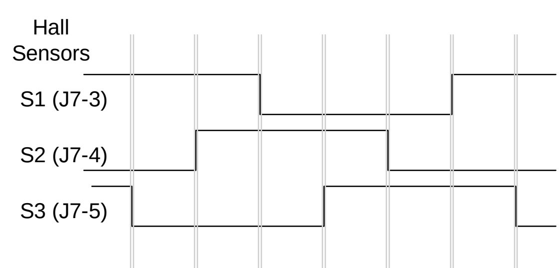
4.9.2.3 Wiring Motor Leads for Kollmorgen VMG Motors

Connect the three motor leads according to the color code shown in Figure 4-6 (page 4-21). This figure shows the color code for Kollmorgen VMG Brushless DC motors. Remove Jumper J2 (discussed later).

4.9.2.4 Wiring Motor Leads for Other BLDC Motors

The graphs below show the commutation sequence for 120° commutation (J2 installed) and 60° commutation, respectively. Match the commutation of your motor as specified by the manufacturer to these graphs.

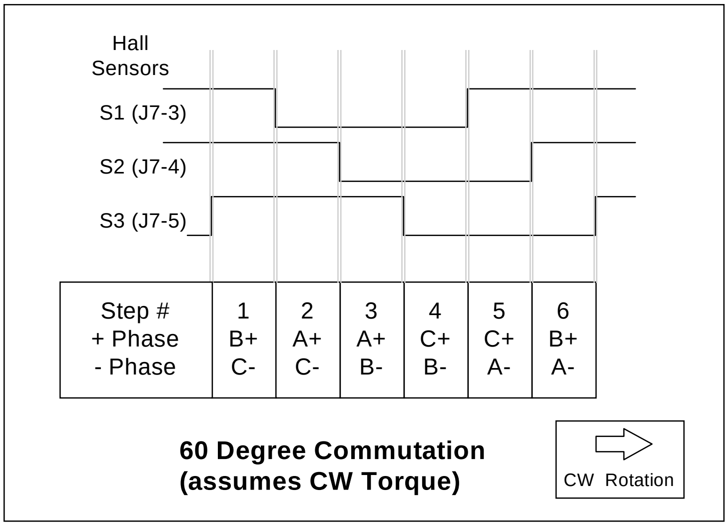
Be aware that phasing depends also on the encoder; if phasing of the encoder or the motor is reversed, the motor may run away.



Step #	1	2	3	4	5	6
+ Phase	B+	C+	C+	A+	A+	B+
- Phase	A-	A-	B-	B-	C-	C-

120 Degree Commutation (assumes CW Torque)

CW Rotation



WARNING

Motor may run away if motor or encoder leads are connected incorrectly.

WARNING

Failure to observe polarity of the DC bus can result in personal injury and damage to the SPS/R and S/O.

4.9.4.4 Wiring Motor Leads for Brush Motors

For brush motors, remove Jumper J2. Connect motor leads to J1-1 and J1-2. For SERVOLINE Brush Motors from Kollmorgen, connect motor lead A to J1-2, and motor lead B to J1-1. Note that phasing of non-SERVOLINE brush motors is often a matter of trial-and-error.

4.9.5 Installing J2, 120° Commutation

Installing J2 selects 120° commutation type. For **SILVER**LINE motors, RBE motors, and most other BLDC motors, install J2. Some BLDC motors, such as Kollmorgen VMG motors, are commutated with 60° sensors. In this case, remove J2. For Brush Motors remove J2.

If the S/O amplifier has a velocity loop option card, you must remove this card to change J2. J2 is shipped installed from the factory.

Installing C_L in J3

CAUTION

Failure to install the correct value for C_L may result in damage to the amplifier or significant loss of performance.

J3 is a 2-pin cage clamp connector that accepts the current loop tuning capacitors. The value of C_L depends on the amplifier model number, the applied voltage, and the motor line-to-line inductance (L). You can measure the value of L, check the data sheets, or contact your Regional Office for assistance in determining this value.

Calculate the value of the capacitor according to Equation 4.1 or 4.2, depending on the model number of your unit:

SO-4004 $$C_L = \frac{2}{V \times L}$$ Equation 4.1

SO-4008 $$C_L = \frac{1}{V \times L}$$ Equation 4.2

where: C_L is the value of the capacitor in μF
V is the applied voltage (volts)
L is the line-to-line inductance (mH).

You can round these values to the nearest 20% so you can use a standard capacitor value. Use multilayer ceramic capacitors such as Panasonic ECU series. Do not use polarized capacitors such as electrolytic or tantalum capacitors.

CAUTION

Use multilayer ceramic capacitors for C_L. Do not use polarized capacitors. Failure to use the correct type of capacitor may lead to unpredictable performance or damage to the system.

Prepare the capacitor by clipping the leads to 12mm (0.5") and bending the leads out so they are approximately 5mm (0.2") apart.

4.9.6 Installing R_L in J4

CAUTION

Failure to install the correct value for R_L may result in damage to the amplifier or significant loss of performance.

J4 is a 2-pin cage clamp connector that accepts the current loop tuning resistor. The value of R_L depends on the amplifier model number, the applied voltage, and L, the motor line-to-line inductance. You can measure the value of L or contact your Regional Office for assistance in determining this value.

Calculate the value of the resistor according to Equation 4.3 or 4.4, depending on the model number of your unit:

SO-4004 $$R_L = 0.5 \times V \times L$$ Equation 4.3

SO-4008 $R_L = V \times L$ Equation 4.4

where: R_L is the value of the resistor in kohm
V is the applied voltage (volts)
L is the line-to-line inductance of your motor (mH).

You can round these values to the nearest 20% so you can use a standard value. Use 1/8 or 1/4 watt resistors.

Prepare the resistor by clipping the leads to 12mm (0.5") and bending the leads out so they are approximately 5mm (0.2") apart.

4.9.7 Installing J5, Current-Loop Mode Select

Current loop provides superior control in positioning systems but is more complex to configure. Many less demanding applications use open-loop control, often referred to as duty-cycle control. In addition, open-loop control is used for system set-up since the amplifier can control speed adequately during the first phases of installation.

- To run in current-loop mode, install Jumper J5 in **position 1-2** (marked "C").
- To run in open-loop mode, install Jumper J5 in **position 2-3** (marked "O").
- When using the optional velocity loop, always install J5 in position 1-2 ("C") for current-loop mode.

NOTE

Jumper J5 must always be installed in one position or the other.

4.9.8 Wiring J6, Amplifier Status and Control

J6 is a 6-pin pluggable screw-terminal with connections on 5mm (0.2") centers. See Figure 4-7 (page 4-22). Note that in high-vibration environments, it is often preferable to crimp a ferrule onto each connection of J6. J6 provides connections to AMP OK output, ANALOG-CMD input, and ENABLE input.

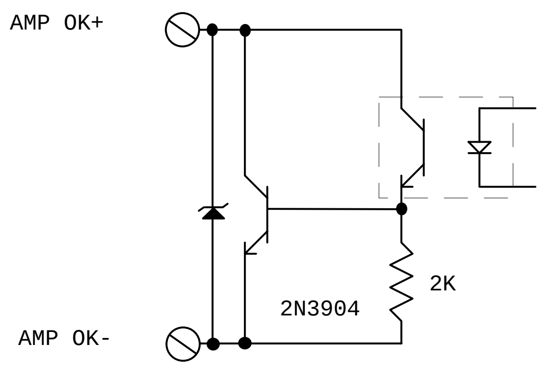
Table 4-3 Connector J6: Customer Input Wiring

Pin	Signal Name
1	AMP OK (+)
2	AMP OK (-)
3	ANALOG CMD (-)
4	ANALOG CMD (+)
5	ENABLE (+)
6	ENABLE (-)

4.9.8.1 AMP OK Output

The AMP OK output indicates that the S/O amplifier is ready to be enabled. It means that the bus voltage is currently applied and that the unit has not exceeded continuous current. It also means that the voltage is below the overvoltage limit (normally about 42 volts). If any of these conditions is not true, the S/O-series amplifier will be forced off and the AMP OK output will turn off. If you exceed continuous current or voltage limits, you must disable and then re-enable to reset the fault condition. The AMP-OK LED indicates the state of AMP OK.

To use AMP OK, connect an impedance limited source from pin 1 (+) to pin 2 (-). Impedance should limit current draw to 24 mA (max); for example, for a 24-volt source, impedance must be no less than 1 kohms. The voltage for AMP OK on all S/O-series units ranges from 5 to 26 volts. If AMP OK is on , its output will be less than 2 volts under full current load (24 mA). When off, the output will draw less than 100 µA under full voltage. The following diagram shows the connections of the AMP OK output.



4.9.8.2 ANALOG-CMD Input (non-Velocity Loop Only)

Apply ANALOG CMD from pin 4 (+) to pin 3 (-). This voltage normally ranges over ±10 volts. If the motor is unloaded, positive voltage normally causes clockwise rotation as viewed from the output-shaft end of the motor. This input is full differential-input. To reverse the direction of rotation, reverse the connections to pins 3 and 4. For velocity loop option, pins 3 and 4 are wired at the factory.

4.9.8.3 ENABLE Input

To energize ENABLE, apply voltage from pin 5 (+) to pin 6 (-). This appears as a 2-kohm load. For example, 24 volts applied to ENABLE will draw approximately 12 mA under full power. You may apply any voltage from 5 to 26 VDC. Less than 5 volts will not provide reliable enabling. More than 26 volts may damage the amplifier. This input is protected from reverse polarity, although the unit will enable only if the polarity of ENABLE is correct.

4.9.9 Wiring J7, Hall Sensors Input

J7 is a 5-pin pluggable screw-terminal with connections on 5mm (0.2") centers. Note that in high-vibration environments, it is often preferable to crimp a ferrule onto each connection of J7.

Table 4-4 Connector J7: Hall Sensor

Pin	Signal Name	Color
1	Hall Sensor Power	Blue
2	Hall Sensor Common	Green
3	Sensor S1	Brown
4	Sensor S2	Orange
5	Sensor S3	Yellow

Connect the Hall sensors from your motor according to Figure 4-5 (page 2-2). Note that color codes are shown for Kollmorgen **SILVER**LINE® and RBE motors. (For Kollmorgen VMG motors, see Figure 4-6 on page 4-21.) Motors from other manufacturers can be used. If you are connecting a brush motor, leave J7 open and remove J2; there is no need to jumper any sensor lines.

4.9.10 Wiring JB1, Bus Power Out

JB1 is a 2-pin pluggable screw terminal. Pin 1 is ground; Pin 2 is bus.

Table 4-5 Connector JB1: Bus Out (low Power)

Pin	Signal Name
1	BUS (-) (Common)
2	BUS (+)

JB1 is designed to provide control power for option cards. Do not use JB1 for bus power.

CAUTION

JB1 provides limited power for option cards. Do not use JB1 for bus power.

4.9.11 Wiring JL1, Logic Out

JL1 is a 4-pin crimp connector. JL1 provides logic power for the velocity loop option card. It is only for factory connections.

Table 4-6 Connector JL1: Logic Out

Pin	Signal Name
1	Common
2	+5
3	+15
4	-15

CAUTION

JL1 is for factory connections only.

4.9.12 Wiring J200, Power (Velocity Loop Only)

J200 is a 3-pin crimp style connector. It is provided as part of the velocity loop option and must be specified at the time of ordering. J200 is wired to JB1 at the factory as follows: JB1-1 to J200-1, and JB1-2 to J200-2.

Table 4-7 Connector J200: Vel Loop Power

Pin	Signal Name
1	Common
2	Bus (+)
3	Common

4.9.13 Wiring J201, Control (Velocity Loop Only)

J201 is a 6-pin pluggable screw-terminal with connections on 5mm (0.2") centers. Note that in high-vibration environments, it is often preferable to crimp a ferrule onto each connection of J7.

Table 4-8 Connector J201: Control

Pin	Signal Name
1	Velocity Command In (-)
2	Velocity Command In (+)
3	Current Command Out (+)
4	Current Command Out (-)
5	Common
6	Tach

Connect the velocity command to J201-1 (-) and -2 (+) as shown in Figure 4-8 (page 4-23). You can monitor the velocity signal on pins J201-5 and -6. The velocity loop option card outputs a current command signal which is connected to J6 on the main PCB at the factory (J201-3 to J6-3, and J201-4 to J6-4).

4.9.14 Wiring J203 and 204, Feedback Encoder (Velocity Loop Only)

J203 and J204 are 10-pin ribbon cable connectors. Note that J203 and J204 are electrically identical. Normally, you should connect the encoder to J204 as it provides positive locking and is more easily accessed. J203 is provided to "daisy-chain" the encoder connection to other components such as a positioner. These connectors are provided as part of the velocity loop option which must be specified at the time of ordering. J203/204 are wired according to the HEDL ® standard from Hewlett-Packard. Refer to Figure 4-4 (page 4-19) and Figure 4-9 (page 4-24). If you are using a standard **SILVER**LINE encoder or any encoder compatible with the HEDL standard, you may connect the encoder directly to the S/O with a single ribbon cable. If you are using an encoder other than a standard **SILVER**LINE encoder, or if the distance or environment is inappropriate for ribbon cable, you can connect J203/204 to the BJ-BKO-10, a 10-pin ribbon-cable DIN-rail mounted breakout from Kollmorgen. The breakout provides screw-terminal connectors for conventional field wiring.

Table 4-9 Connectors 203 and 204

Pin	Signal Name
1	Not Used
2	+5
3	Common
4	Not Used
5	Channel A-
6	Channel A+
7	Channel B-
8	Channel B+
9	Index-
10	Index+

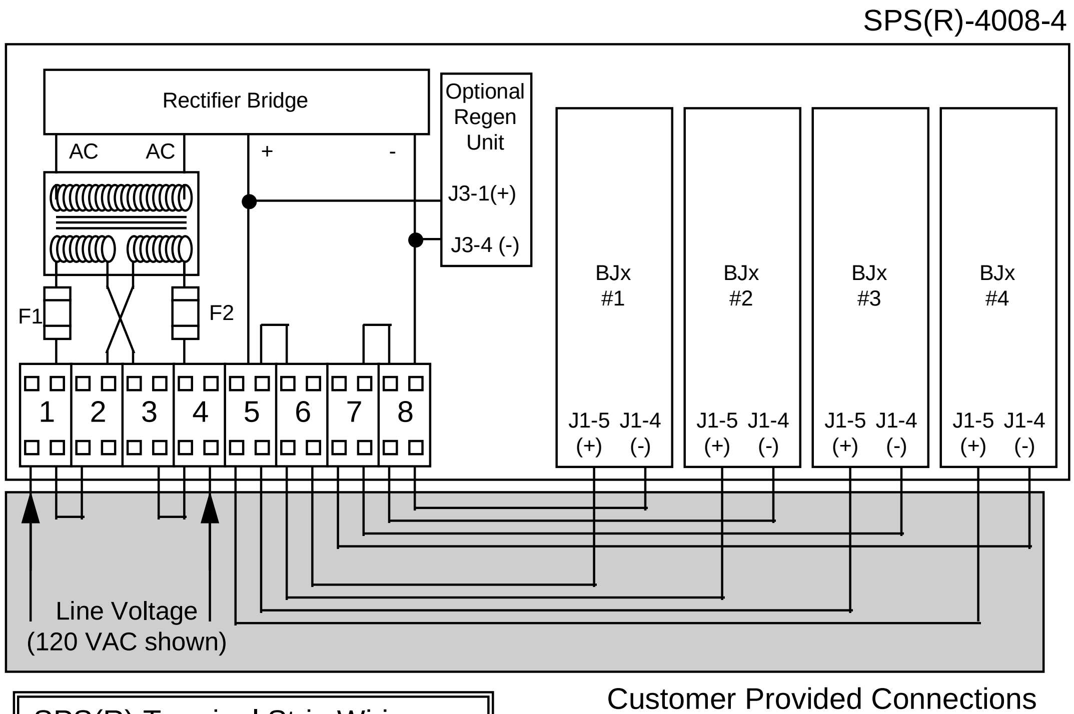
If your encoder supplies single-ended signals, connect these signals to J203/204 -6 (Channel A) and -8 (Channel B). Note, however, that Kollmorgen highly recommends differential signals because of superior noise rejection.

4.9.15 Wiring J205, ±15V Input (Velocity Loop Only)

J205 is a 4-pin crimp style connector. This connector provides ±15 VDC to the velocity loop option card. Pins 1, 3, and 4 of J205 and JL1 are interconnected at the factory.

Table 4-10 Connector JL1: Logic Out

Pin	Signal Name
1	Common
2	+5
3	+15
4	-15



SPS(R) Terminal Strip Wiring	
1 & 4:	AC Line (120 VAC or 240 VAC)
2 & 3:	115/230VAC Select: For <u>110VAC</u>: Connect 1-2 and 3-4 For <u>230VAC:</u> Connect 2-3
5 & 6:	Bus + (4 Connections)
7 & 8:	Bus - (4 Connections)

Note: F1 and F2 are 250V, 1.5 A, 3AG Fuses.

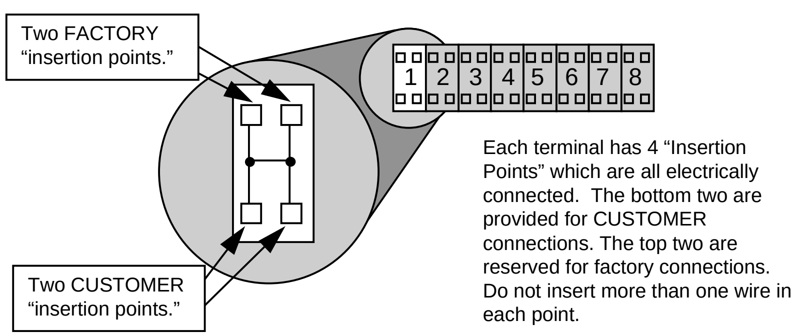


Figure 4-1 SPS/R-4008-4 Field Wiring with Detail of Terminal Strip

Table 4-11 S/O Connector Function

	Name	Location	Type	Description
J1	Power	Main PCB	5- Pin Screw Terminal	Connections for power bus and motor leads.
J2	120°	Main PCB	Jumper	120° select. Install for **SILVER**LINE BLDC motors and other 120° BLDC Motors. Remove for Brush and 60° BLDC Motors.
J3	CL	Main PCB	2-pin WAGO cage clamp	Install current loop compensation capacitor.
J4	RL	Main PCB	2-pin WAGO cage clamp	Install current loop compensation resistor.
J5	Current/ Voltage Mode	Main PCB	Two position jumper	Install in "C" for current-loop and velocity-loop modes. Install in "O" for open loop.
J6	Status and Control	Main PCB	6-pin Screw Terminal	Current command, Enable, AMP OK
J7	Hall Sensor	Main PCB	5-pin Screw Terminal	Connect to Hall sensor cable from motor.
JB1	Bus Out	Main PCB	2-pin Screw Terminal	Bus power for velocity loop option.
JL1	±15 VDC Output (5mA)	Main PCB	4-pin crimp Connector	±15 VDC for Velocity Loop Option Card.
J200	Logic Power	Velocity Loop Option PCB	3-pin crimp connector	Logic Power for Velocity Loop Option. Installed at factory. Wired to JB1 at factory.
J201	Control	Velocity Loop Option PCB	6-pin Screw Terminal	Analog I/O for Velocity Loop Option.
J203	Feedback Encoder	Velocity Loop Option PCB	10-pin Ribbon Cable Connector	Identical to J204. Provided for convenience.
J204	Feedback Encoder	Velocity Loop Option PCB	10-pin Ribbon Cable Connector	Feedback Encoder connection for Velocity Loop.
J205	±15 VDC Input	Velocity Loop Option PCB	4-pin crimp Connector	±15 VDC for Velocity Loop Option Card. Wired to JL1 at factory.

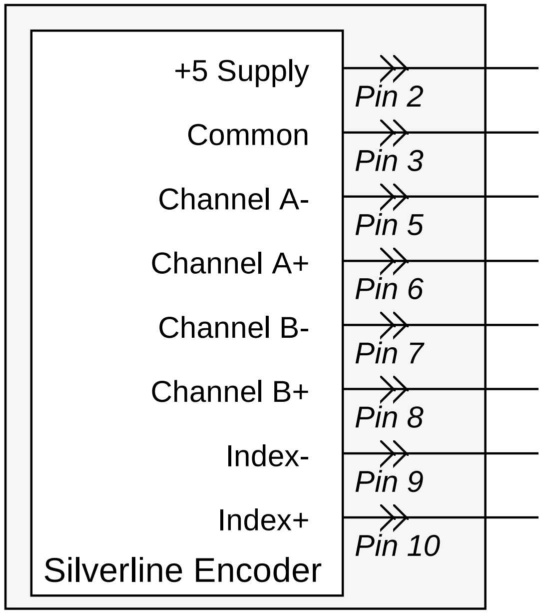


Figure 4-2 SILVERLINE **Encoder**

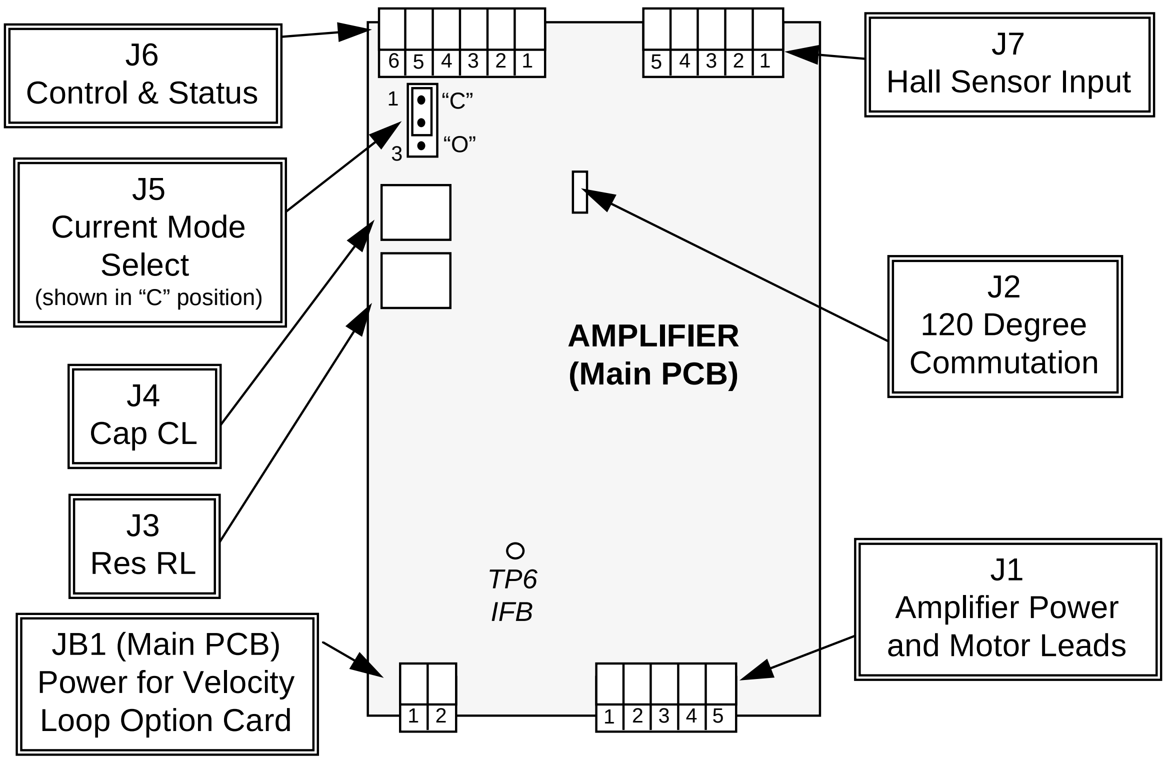


Figure 4-3 S/O Connector Layout-Main PCB

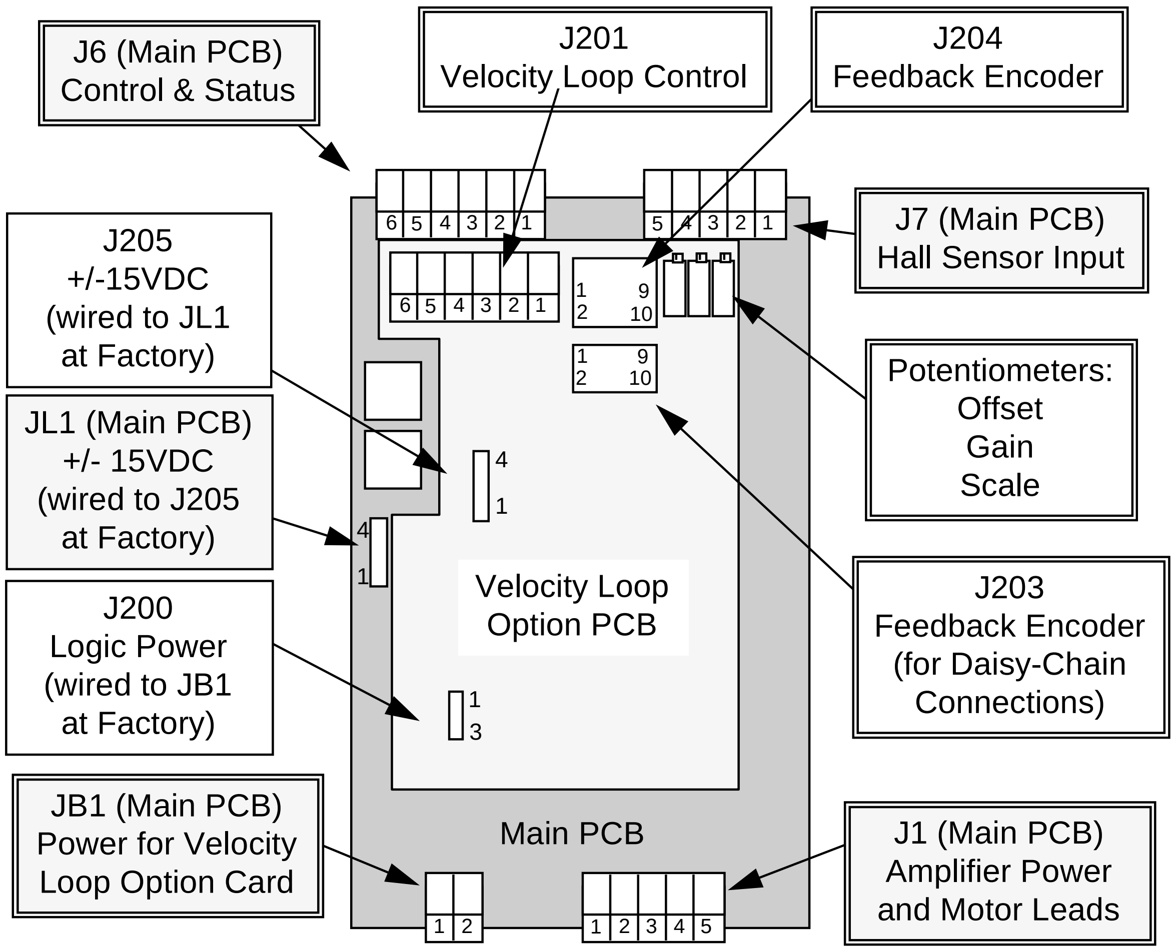


Figure 4-4 S/O Connector Layout-Velocity Loop Option PCB

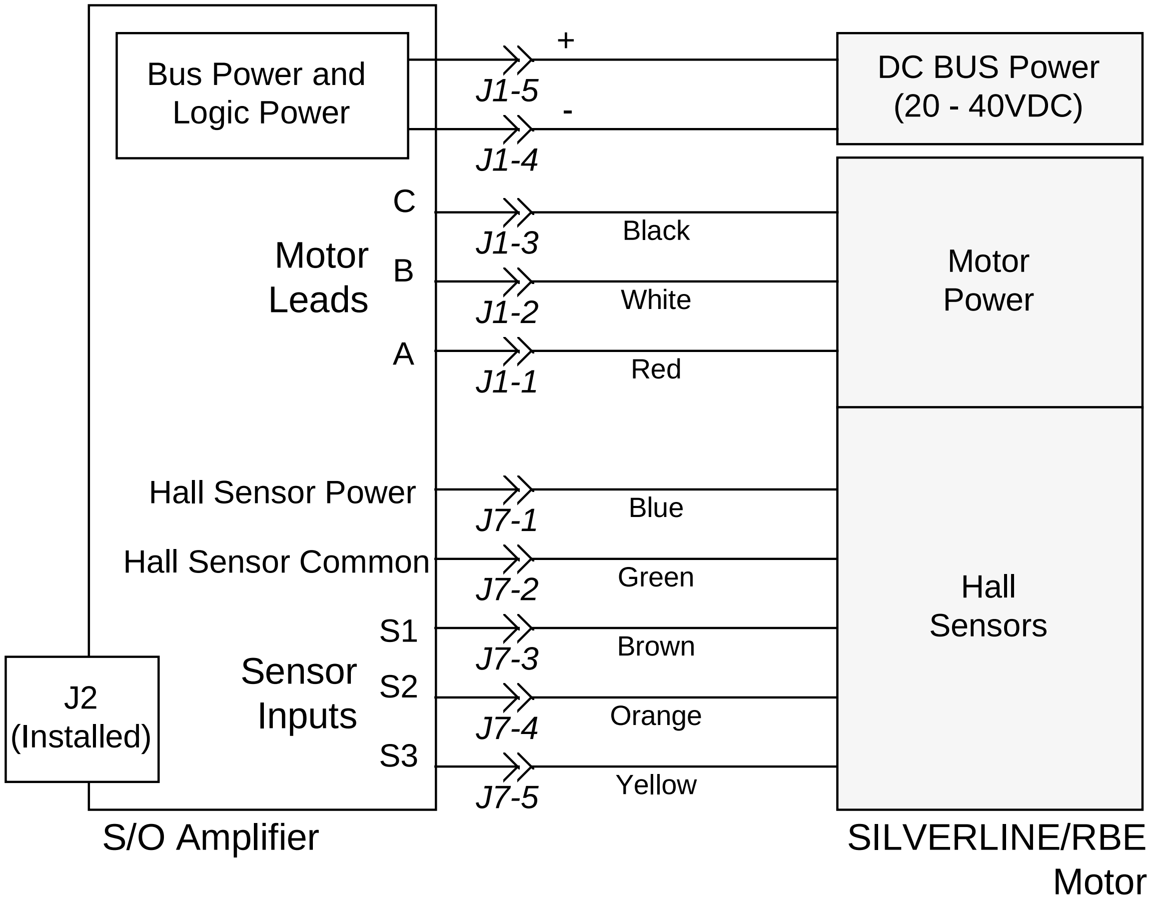


Figure 4-5 Connectors J1 and J7 (SILVERLINE Motors)

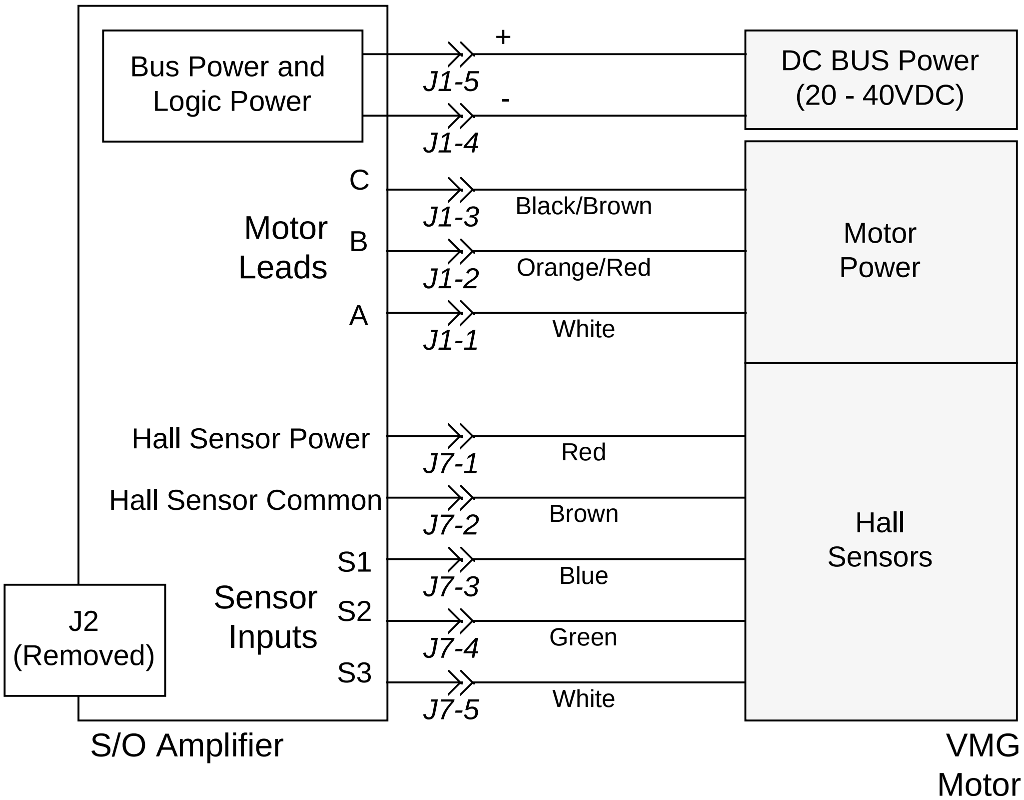


Figure 4-6 Connectors J1 and J7 (VMG Motor)

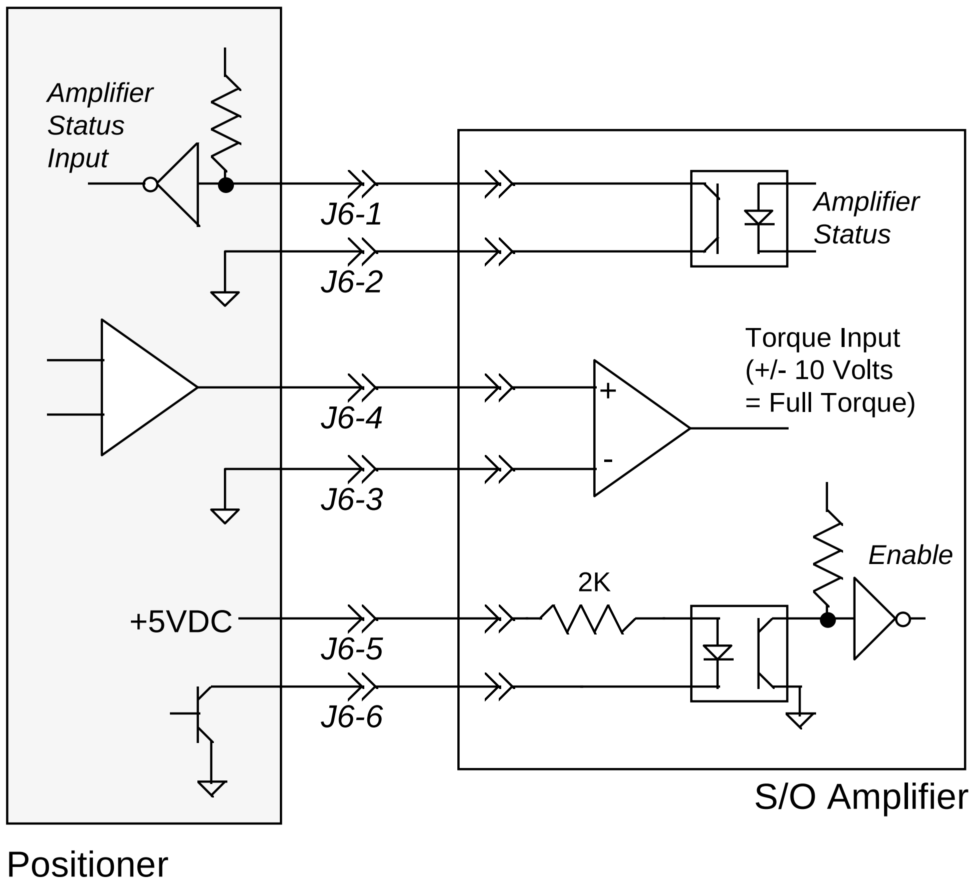
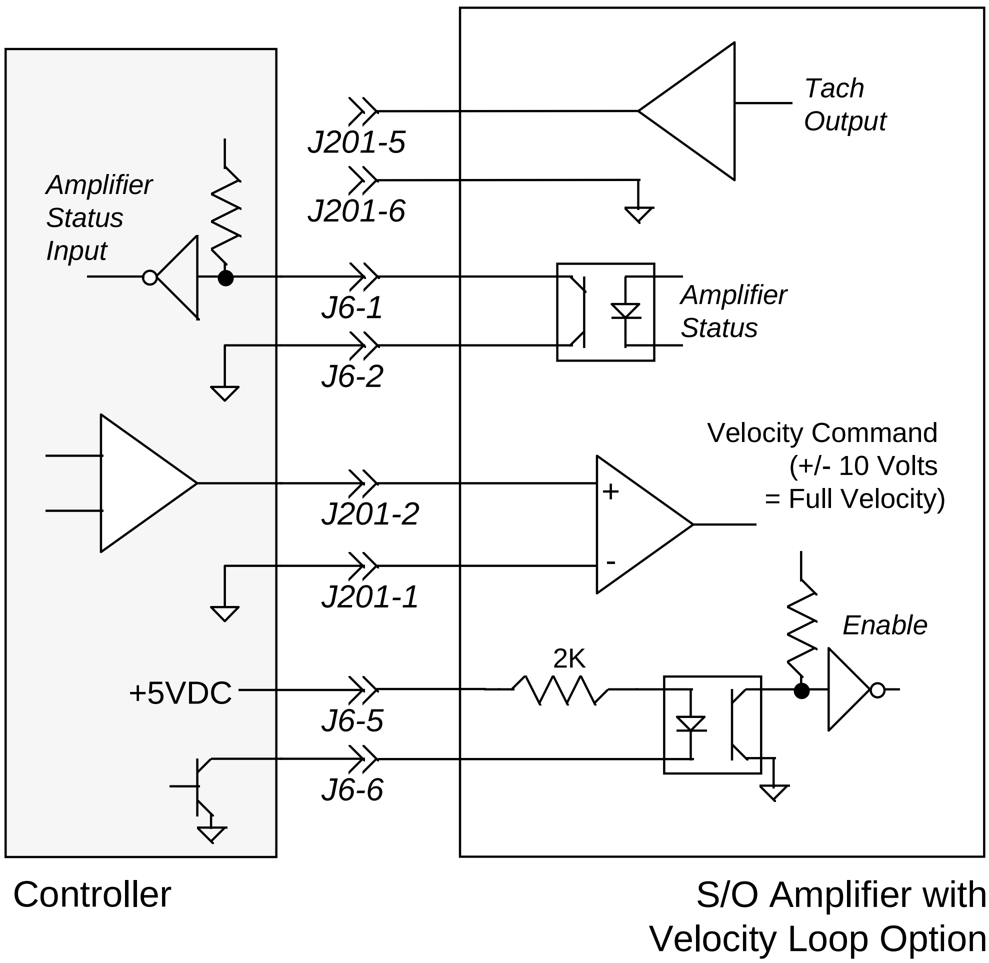


Figure 4-7 Connector J6 Amplifier Enable, Command and Status

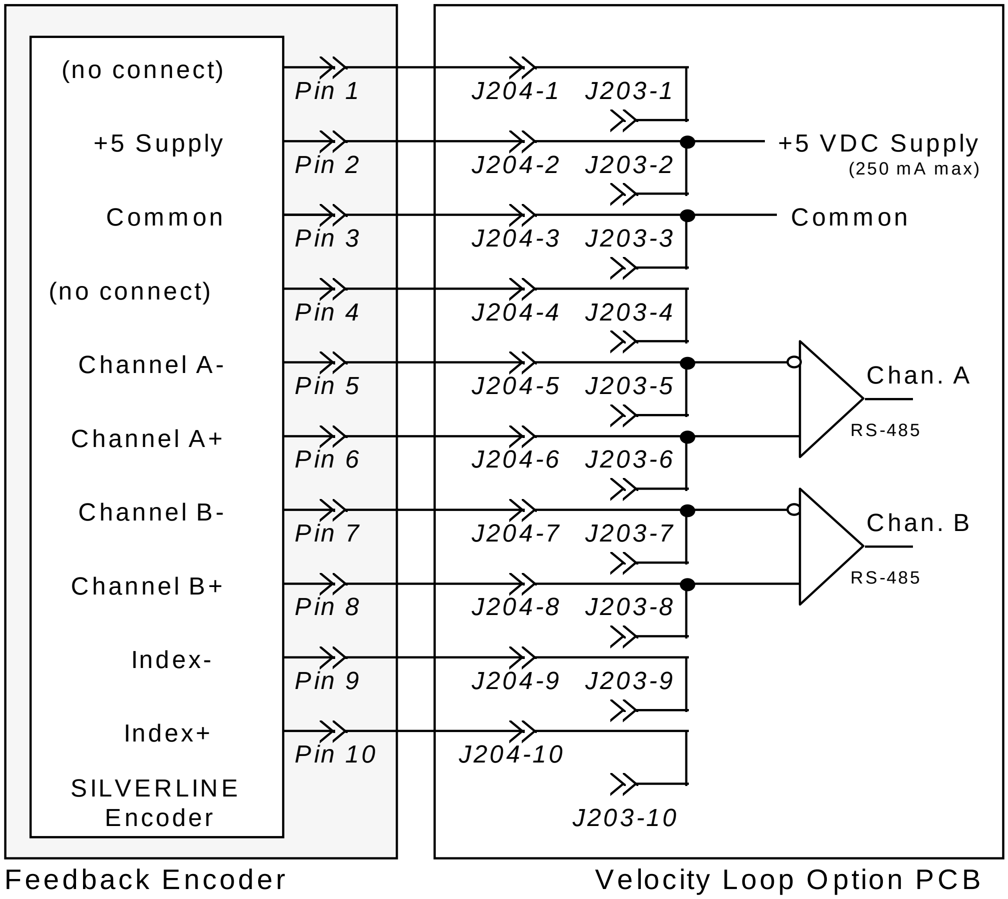


Factory connections in this configuration include:

J200-1 to JB1-1	J205-1 to JL1-1
J200-2 to JB1-2	J205-3 to JL1-3
J201-3 to J6-3	J205-4 to JL1-4
J201-4 to J6-4	

Figure 4-8 Connectors J6 and J201

Velocity Loop Option PCB



Notes: If encoder supplies single-ended signals, connect to pins 6 and 8 on the Velocity Loop PCB; leave pins 5 and 7 open.

Figure 4-9 Connectors J203 and J204

Feedback Encoder (Velocity Loop Option Only)

Section 5 Commissioning

5.1 START UP AND CHECK OUT

You should now be ready to test your system functions. Be prepared to disable the S/O amplifier by opening the enable signal (J6-5 and J6-6). Limit switches and safety devices should be operational. In multi-axis systems, work with one axis at a time.

5.1.2 Start up the Current Controller

This section starts up the current controller. If your S/O has a velocity loop option, disconnect J6-3 and -4 for these tests. This places your S/O in current-loop mode; the voltage applied to J6-3 and -4 is a current command. After completing this section, continue in "Start up the Velocity Controller" below.

WARNING

The amplifier will be enabled and the motor will turn. Make sure the motor is secured.

WARNING

THE MOTOR MAY MOVE UNEXPECTEDLY!

BE PREPARED TO REMOVE POWER FROM THE S/O!

The procedure in this section will enable the S/O. The system may be unstable. The motor may begin oscillating or it may run away.

5.1.2.1 Apply Power and Enable

Apply bus power to your S/O. (If you are using an SPS power supply, apply line voltage.) To enable the S/O, apply logic power to the enable input (J6-5 and -6).

5.1.2.2 Running the Motor

Apply 1 VDC to J6-3 and -4. If the S/O is in current mode, an unloaded motor should rotate at near full speed. If the S/O is in open-loop mode, the motor will rotate slowly. In either case, rotation should be smooth. Reverse polarity of the command. The motor should rotate in the opposite direction at approximately the same speed.

If the motor does not turn, or does not turn smoothly, the hall sensors or motor leads may be connected improperly. Verify motor wiring according to Figure 4-5 on page 4-20 (Figure 4-6, page 4-21 for VMG Motors). If the motor has positions where there is no torque ("dead spots"), verify that J2 is properly installed. (J2 is installed for **SILVER**LINE and RBE motors; it is removed for VMG motors.) If you are using a non-Kollmorgen motor, refer to the "Non-Kollmorgen Motor Phasing" section at the end of this chapter.

5.1.2.3 Offset Adjustment

To adjust offset, short the command (J6-3 and -4) and adjust trimpot R57 ("OFF") until motor torque is minimized. An unloaded motor should not turn. Optionally, you can monitor current on TP-IFB (Figure 4-3 on page 4-18 shows the location) using a digital volt meter. Adjust for minimal voltage on TP-IFB.

NOTE

When using the velocity loop option, be aware that both cards have an <u>offset</u> pot. This section refers to the pot on the bottom (main) board.

5.1.2.4 Command Scaling Adjustment

Command scaling is adjusted at the factory so that 10 volts generates peak current (or peak voltage if the S/O is in open-loop mode). You can reduce the output by adjusting trimpot R71 (GAIN). You can monitor current on TP-IFB; this signal is scaled so that 0.2V = continuous current.

NOTE

When using the velocity loop option, be aware that both cards have a <u>gain</u> pot. This section refers to the pot on the bottom (main) board.

5.1.2.5 Improving Current Loop Performance

For current loop and velocity loop systems, Equations 4.1 through 4.4 (see Section 4) provide suitable performance for most systems. The current loop is stable and should have a bandwidth well in excess of 1000 Hz. If you wish to modify the loop performance, please refer to discussions on tuning theory (page 5-10).

5.1.2.6 LEDs

Two green, light-emitting diodes (LEDs) are provided on the front of the S/O, placed one above the other. The bottom LED indicates that bus power is applied. The top LED indicates that the amplifier is OK. Overvoltage and overcurrent faults disable the amplifier and turn off the amplifier-OK LED. Disabling the S/O resets the fault condition and turns the LED on.

5.1.2.7 Faults

The S/O includes protection against excessive voltage and excessive current. If you exceed the S/O bus voltage (J1-4 and -5), the amplifier will fault. The enable signal (J6-5 and -6) must be removed and reapplied to reset the unit. The most common cause of this fault is bus voltage elevation due to regenerative energy. The SPSR power supply provides a "REGEN" unit which can dissipate up to 20 watts of regenerative energy. If you are using an SPSR and you are still experiencing this fault, the regen fuse (located in the regen unit) may have opened. Replace this fuse with the rating specified in Chapter 4. If this fuse opens regularly, your system is probably overloading the regen unit.

If you need to add a regen unit to your system, Kollmorgen supplies the SPSR-4008-RGN, a stand-alone regenerative dissipation unit. If you are already using an SPS power supply, the SPSR-4008-RGN can be mounted directly to the SPS. (This effectively converts the SPS to an SPSR.) If you are using the stand-alone regen unit, that unit can be converted to run on a 24 VDC system by removing jumper W1. This changes the regen trip level to approximately 28 volts.

CAUTION

Removing W1 reduces the regen trip voltage to 28 VDC. Do not remove W1 if the bus voltage is greater than 28 VDC. Doing so will overload the regen unit.

If you exceed the S/O continuous current rating (for example, 8 ADC for an SO-4008) for more than a few seconds, the amplifier will fault. The enable signal (J6-5 and -6) must be removed and reapplied to reset the unit. If this happens regularly, your amplifier may be too small for the application.

5.1.3 Start up the Velocity Controller

This section describes how to start up the velocity controller. Before proceeding in this section, you should have completed the "Start up the Current Controller" section above. Disable the S/O. Reconnect J6-3 and -4 to the option PCB (these were disconnected in the procedure above).

5.1.3.1 Check-out the Encoder

Connect a meter to Tach Monitor (J201-5, -6). Rotate the motor by hand. Verify that the tach changes as you rotate the motor. Rotate the motor both directions and verify that the tach changes sign. Do not proceed until your system passes this test. Running a velocity loop system with the encoder disconnected or improperly connected may cause the motor to "run away," a condition where the motor accelerates to full speed without control.

WARNING

Do not proceed until the encoder checks out properly.

Running a system with a disconnected or improperly connected encoder may cause the motor to run away.

5.1.3.2 S1 DIP Switch Settings

S1 is used to set the maximum encoder frequency. Setting this switch correctly will improve the low speed performance. Maximum encoder frequency is affected by the maximum velocity the motor needs to run in your application and the number of encoder lines. The frequency can be calculated as follows:

Max Frequency = (Max velocity in RPM) * (lines per rev) / 60

Set S1 so that the frequency supported is at least 50% higher than calculated to allow for overshoot and other conditions that may cause the motor to go faster than expected. If S1 scales the signal for too low a frequency or if the motor goes faster than planned even for a short time, the velocity monitor may saturate, causing the motor to run away.

WARNING

Scaling the velocity incorrectly may cause the motor to run away!

Use Table 3.1 to set S1. Allow at least 50% margin when selecting the maximum frequency.

Table 5-1 S1 vs. Maximum Frequency

Max Frequency Range	S1	S2	S3	S4
32 kHz - 64 kHz	OFF	ON	ON	OFF
64 kHz - 96 kHz	ON	OFF	ON	OFF
96 kHz - 128 kHz	OFF	OFF	ON	OFF
128 kHz - 192 kHz	ON	ON	OFF	OFF
192 kHz - 256 kHz	OFF	ON	OFF	OFF
256 kHz - 320 kHz	ON	OFF	OFF	OFF
320 kHz - 384 kHz	OFF	OFF	OFF	OFF

S1 sets the tach monitor (J201-5 and -6) scaling. The values in Table 3.1 provide settings that scale the tach monitor to approximately ±10 VDC at full speed.

5.1.3.3 S2 DIP Switch Settings

Switches S2-1 to S2-3 are used to set the velocity loop integrator value. The more switches set, the lower the loop response will be. See Figure 5-1 on page 5-8 for detail of the switch circuit.

For demanding applications, you may need performance beyond that attainable by adjusting S2 and the GAIN pot. In this case, the velocity loop option card provides positions for a user-installed integrator capacitor (C7) and lead capacitor (C28). These components are rarely used and determining their values is beyond the scope of this manual. Refer to Figure 5-1 for more detail.

NOTE

If C7 is left empty, at least one switch in S2-1 to S2-3 must be on.

5.1.4 Velocity Loop Tuning

To start, turn S2-1 on, and S2-2 and -3 off. This selects the highest velocity loop response. (S2-4, the test-mode switch, should also be off).

Be prepared for the motor to run away when you enable the system. If the encoder or amplifier are wired incorrectly, the motor will run full speed. If this happens, it may be because the system is phased backwards. If so, reversing J201-3 and -4 will correct this problem.

WARNING

If the encoder or amplifier are wired improperly, the motor may run away.

Be prepared for the motor to run full speed.

To reverse direction of rotation, exchange J201-3 and -4.

CAUTION

The velocity loop may be unstable.

If the velocity controller is unstable, reduce the velocity loop GAIN pot by turning it clockwise.

5.1.4.1 Setting Velocity Loop Gain

Adjust the velocity command reference until the motor speed is approximately 300-400 RPM. If an adjustable command reference is not available, the OFFSET pot (R20) can be used as a command. Turning S2-4 on will raise the sensitivity to the offset pot, allowing a much greater range than normal for offset adjustment.

Turn the velocity loop GAIN pot (R21) CCW until the motor is unstable or undesirably "noisy." Back off approximately one turn, or until the motor is stable again.

NOTE	**When using velocity loop option, be aware that both cards have a <u>gain</u> pot. This section refers to the pot on the top (option) board.**

5.1.4.2 Detuning the Velocity Loop

Detuning reduces the velocity loop response. This can be accomplished two ways: 1) reducing GAIN pot, and 2) slowing the velocity loop integrator. The GAIN pot (R21) can be manually adjusted by the user (CW for less gain), while the velocity loop integrator value is set by adjusting S2-1 through S2-3. Softer response is achieved by setting more switches ON. Refer to Figure 5-1.

5.1.4.3 Checking the Velocity Loop Response

The response can be monitored on the TACH monitor (J201-5 and -6). Attach an oscilloscope and monitor the motor velocity feedback. Velocity loop response should be tested by monitoring the TACH feedback on large velocity transitions. Quickly switch the velocity command from 0 to max. Observe the motor velocity feedback for overshoot and ringing. Adjust the GAIN pot or change the integrator value by turning additional S2 switches ON (S2-1 to S2-3).

5.1.4.4 Setting Velocity Offset

Short the velocity command (short J201-1 and -2.) Verify S2-4 is off. Enable the S/O amplifier. The motor should not be moving but should have holding torque. If the motor is rotating slowly, adjust the OFFSET pot (R20) until motion ceases.

NOTE	**When using velocity loop option, be aware that both cards have an <u>offset</u> pot. This section refers to the pot on the top (option) board.**

5.1.4.5 Check Velocity Command Scaling

Attach velocity command reference to J201-1 and J201-2. Apply the maximum velocity command which is to be used. Adjust SCALE pot (R19) until motor velocity is at the maximum velocity desired. This sets the ratio between RPM and velocity command voltage

5.2 STABILITY AND PERFORMANCE

Feedback systems such as motor controllers require tuning to attain high performance. Tuning can be a laborious procedure requiring an experienced person. The S/O simplifies this by providing equations 4.1 through 4.4 (see Section 4) for current loop tuning.

If you want to modify the standard current loop performance, or if you are tuning the optional velocity loop, you will need to determine loop gains according to a three-part criterion:

- Noise Susceptibility

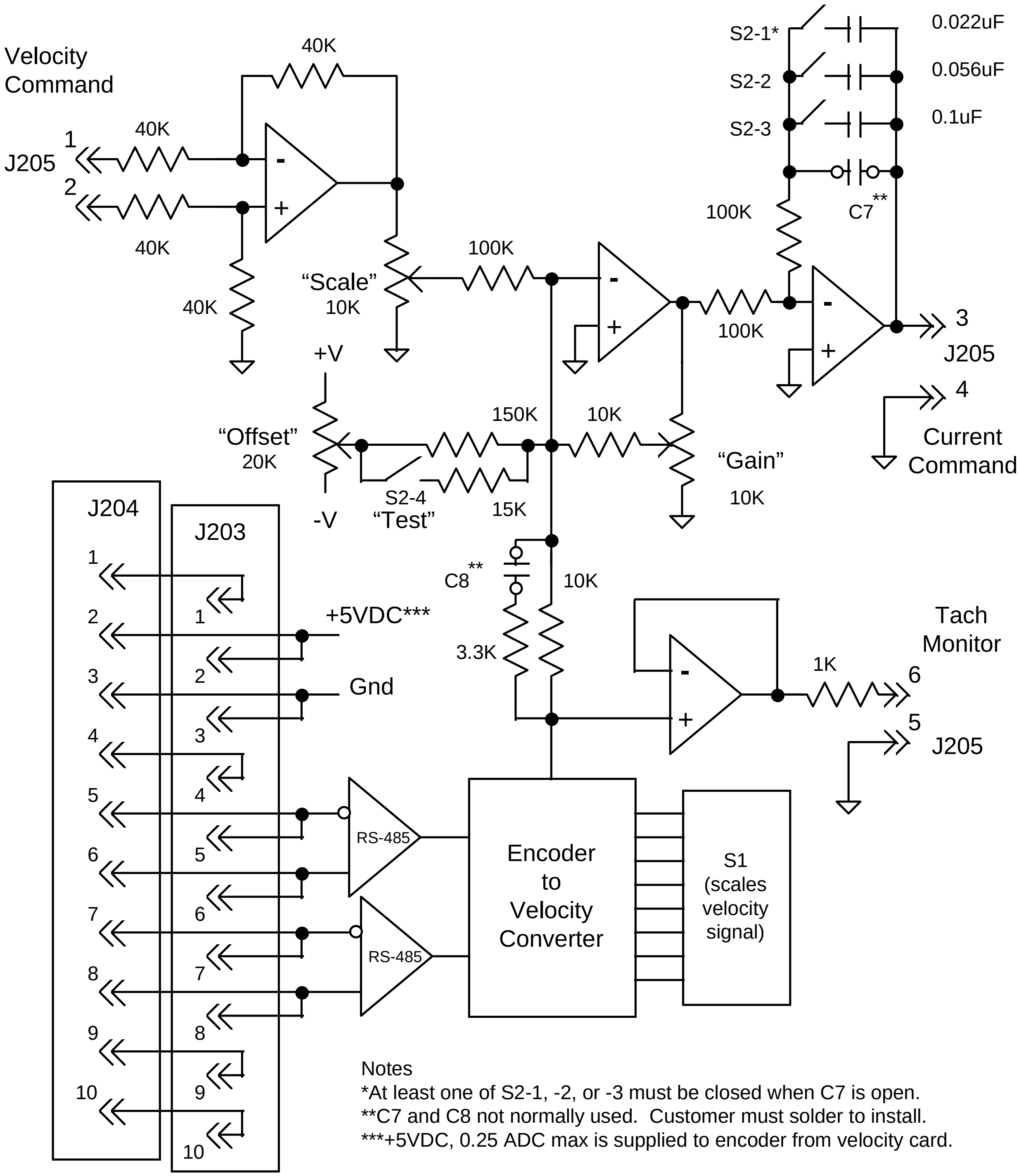
- Response
- Stability

In a broad sense, the performance of a system is characterized by its noise susceptibility, response, and stability. These quantities tend to be mutually exclusive. The system designer must decide what noise susceptibility (in the form of a "busy" motor) is acceptable.

"Busyness" is random activity in the motor and can often be felt on the motor shaft. Busyness in a motor should not be confused with PWM noise. PWM noise is high pitched, relatively constant noise and cannot be felt on the motor shaft.

Response is a measure of the system's quickness. Response can also be characterized by bandwidth and by rise time in response to a step command. Normally, designers want high bandwidth, though sometimes the response is purposely degraded to reduce stress on mechanical components. This is called *detuning*. Typical current loop bandwidths range from 1000 to 2500 Hz. Typical velocity loop bandwidths range from 20 to 60 Hz.

Stability measures the level of control in the system. Stability can be measured with damping ratio or with overshoot in response to a step command. A discussion of different levels of stability follows.



Notes
*At least one of S2-1, -2, or -3 must be closed when C7 is open.
**C7 and C8 not normally used. Customer must solder to install.
***+5VDC, 0.25 ADC max is supplied to encoder from velocity card.

Figure 5-1 Velocity Loop Option

5.2.1 Critical Damping

Generally, the most desirable amount of damping is Critical Damping. Critically damped systems respond as fast as possible with little or no overshoot. The graph in Figure 5-2 shows the velocity response of a system to a square wave input when the system is critically damped.

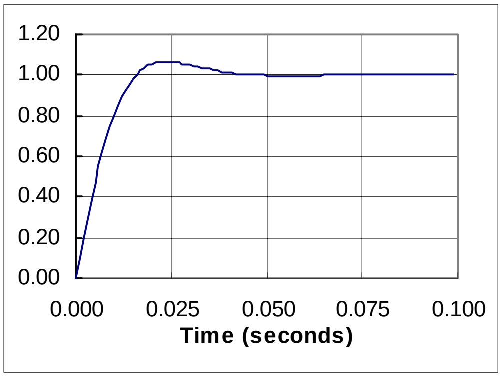


Figure 5-2 Critical Damping

5.2.1 Underdamping

Sometimes the system is tuned for critical damping and the system is still too slow. In these cases, you may be willing to accept less than critical damping. For applications that can work properly with a slightly underdamped system, you may reduce the stability to improve the response. The graph in Figure 5-3 shows a slightly underdamped system.

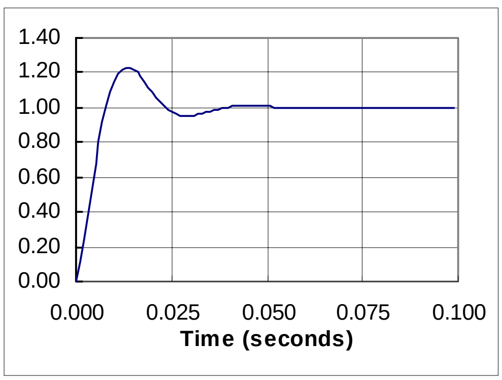


Figure 5-3 Underdamping

5.2.2 Overdamping

An overdamped system is very stable but has a longer response time than critically damped or underdamped systems. Also, overdamped systems are noisier than less damped systems with the same response rate. The graph in Figure 5-4 shows an overdamped system.

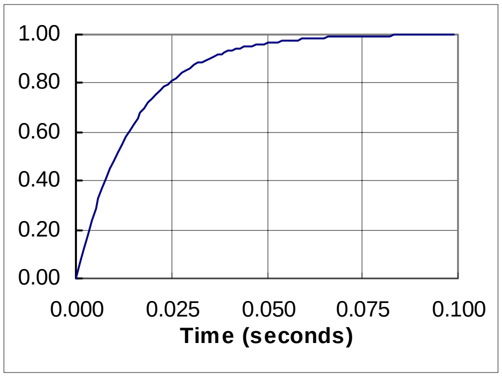


Figure 5-4 Overdamping

5.2.3 Ringing

When you are tuning the S/O you may tune it so that the response rings. Ringing is caused when you attempt to tune the S/O for too rapid response. Normally, the best solution is to reduce the bandwidth. The graph in Figure 5-5 shows a system that rings.

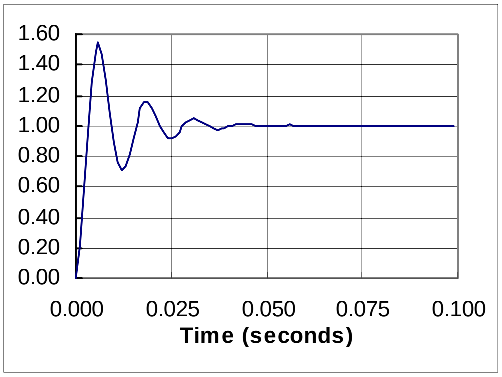


Figure 5-5 Ringing

5.3 CURRENT LOOP TUNING

5.3.1 Theory of Operation

Tuning is the process of optimizing several parameters of operation, including response, bandwidth, and noise. Tuning is based on control theory; the goal is to set loop gains with sufficient gain/phase margin while attaining the required response.

5.3.1.1 The Frequency Domain

A common way to specify response is measuring the response of the current loop to a sinusoidal command over a wide range of frequencies. That is, measuring the loop response in the frequency domain. The response of current loops gets poorer as the command frequency increases. This is expected: when the command is at very low frequencies, below 10 Hz for example, the loop is nearly perfect; that is, the actual current will look very much like the commanded current. At very high frequencies, above 20,000 Hz for example, the system will not be able to respond at all--the command may represent substantial current, but the actual current will be very small.

The basic measure of response is referred to as bandwidth. The bandwidth of a system is defined as the frequency at which the command is attenuated to 70% (-3dB) of its low frequency response. Figure 3.6 shows the response of a properly compensated current loop with a bandwidth of 1000 Hz. This graph illustrates a few key points to understanding response in the frequency domain. The frequency shown here is the -3dB point--the point at which the response is 70% of the command. We assume here that the command and response are scaled the same. However, in an actual system, you will need to adjust your scope so the magnitudes show the same. Do this at a low frequency so you can be sure the loop is responding without attenuation. After adjusting your oscilloscope, you can directly compare the two signals at higher frequencies. Notice also in Figure 5-6 that the feedback (current) is lagging the command. Here, the lag is about 1/8 of a revolution or 45°. This lag is typical for a well-behaved system. A large lag at the -3dB point, especially over 90°, indicates a somewhat unstable system.

Equations 4.1 through 4.4 (see Section 4) were based on this model. In that case, we chose a midrange bandwidth. Using the information provided here, you can select the bandwidth appropriate for your application.

5.3.2 Measurement and Control

To observe current loop operation, lock the shaft. Apply a 10% on-time pulse as command (J6-3, -4). Place a current probe on one of the two leads with current or measure current on TP-IFB (0.2V = continuous current).

If locking the shaft is impractical, configure the drive for a zero-torque position: remove J2 and J7 and move the shaft so current is generated, but without torque. Always apply current in one direction or the shaft will turn. Use very low current rather than zero current.

Observe the response to the pulse; it should be rapid and not over shoot more than 10%. If the response is not as you desire, adjust RL and CL, one at a time and in increments of about 20%, until you achieve the desired response.

5.3.3 Current-Loop Model

For customers who wish to predict the performance of the current-loop operation, Figure 5-7 provides a simplified frequency- domain model. Currently, RS (R69) is 10 kohms, RFB (R55) is 475 ohms, and RSAMPLE is either 0.050 ohms for 4 amp units or 0.025 ohms for 8 amp units. The PWM is a two-state modulator at 18 kHz.

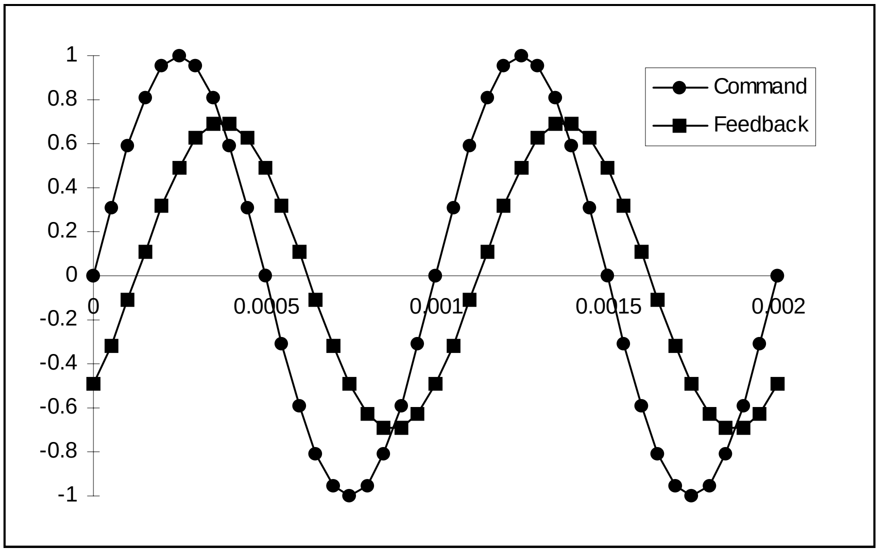


Figure 5-6 -3dB Point: 70% Attentuation

5.4 PROBLEMS

The mechanical construction can limit the performance of your velocity loop. The problems caused by the mechanics fall into three categories:

- Compliance
- Non-Linearities
- Resonance

5.4.1 Compliance

In compliant systems, the load is not tightly coupled to the motor shaft. If you move the load by hand, you can feel springiness. Compliant systems often are very stable when you tune with lower target bandwidths. However, they oscillate vigorously at low frequencies when you try to tune them for higher bandwidths.

A compliant system has the following characteristics:

- There is springiness between the motor and the load or at the motor mounting plate.
- The frequency of oscillation is less than 100 Hz.

Compliance can be corrected by the following actions:

- Reduce the bandwidth of the system.
- Stiffen the machine so the load is not springy.

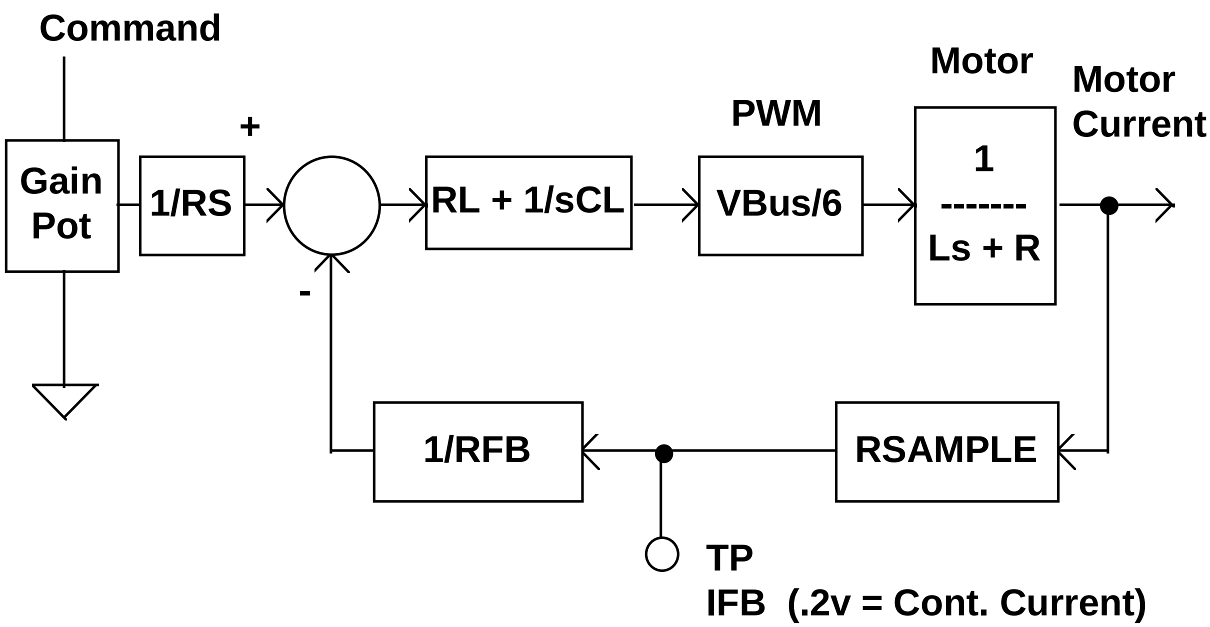


Figure 5-7 Simplified Frequency Domain Model

5.4.2 Non-Linearities

Tuning is based on linear control theory. The most important requirement of a linear controller is that the total reflected inertia should not change substantially during operation. Load inertia includes all the inertia reflected to the motor, such as inertia through gearboxes and leadscrews. Inertia can change in ways that are easy to understand, such as the inertia of a spool of cable decreasing when the cable is unrolled. It can also change in less intuitive ways, such as chain drives (which have load in one direction but are unloaded in the other) and systems with excessive backlash (where there is no load when gear teeth are not touching).

When the inertia changes, the system has the following characteristics:

- System performance is excellent when the motor is in some positions and unacceptable when the motor is in other positions.
- Reducing the bandwidth eliminates the problem.

If the system performance is poor because of changing inertia, you can make the following corrections:

- Correct the system mechanics so that inertia is constant.
- Detune (that is, reduce the bandwidth of) the system.

5.4.3 Resonance

Resonance is a high frequency (> 500 Hz) where the system mechanics oscillate. Normally, systems with resonance will be very stable when you tune with lower target bandwidths. As you increase the target bandwidth, you begin to hear a fairly pure, high pitch. If you want to decrease resonance, use shorter, larger diameter driving shafts.

When your system has a resonance, it will have the following characteristic:

- The system will emit a clear, high pitch (> 500 Hz). Do not confuse this problem with compliance, which has a low pitch.

If the system performance is poor because of resonance, you can make the following corrections:

- Reduce the bandwidth of the system.
- Shorten the length and increase the diameter of shafts and lead screws.

5.5 EMPIRICAL METHOD: PHASING NON-KOLLMORGEN MOTORS

This section discusses how to determine empirical phasing for non-Kollmorgen motors.

Section 4 discussed how to connect non-Kollmorgen motors in the section "Wiring Motor Leads for Other BLDC Motors." That section is based on using sequences for either 60° or 120° commutation. However, if the corresponding information for the motor is not available, use the following trial-and-error procedure.

During this procedure, ensure that the motor does not overheat. Depending on the motor, the specified analog-command voltage may be too large. If the motor frame temperature exceeds 50°C, the command should probably be reduced. If the motor is below 50°C, you should be able to comfortably rest your hand on it.

If your S/O has a velocity loop option, temporarily disconnect J6-3 and -4 from the velocity loop and directly apply the command to those points.

Phasing by Trial and Error:

1. Install J2 if your motor uses 120° commutation. Remove J2 for 60°. Contact the motor manufacturer to determine which is appropriate.
2. Put the amplifier in open-loop (install J5 in position "O").
3. Set ANALOG-CMD for 1.0 volt.
4. Connect the three hall sensor S1, S2, and S3 leads arbitrarily. (Power and Common must be connected correctly.)
5. Enable the amplifier.
6. Try all six combinations of motor lead connections until the motor rotates freely. Always remove power from the amplifier when changing motor lead connections.

Note some incorrect wiring combinations will cause the motor to rotate, but inefficiently and with zero-torque positions (or "dead spots"). Carefully stop the motor by hand and feel torque as you let the motor rotate slowly. If the wiring is correct, torque will be nearly continuous throughout the rotor rotation.

Section 6 Maintenance

6.1 INTRODUCTION

Information in this chapter will enable you to maintain the system components, ensuring smooth, efficient operation of the motor. Preventative maintenance of the equipment is also specified along with periodic maintenance. Follow these practices when operating your servo system.

6.2 SPARE PARTS

6.2.1 S/O Spare Parts List

Connector Kit Series S/O: SO-C100

BJ-BKO-10: J204 (Velocity Loop only)

You can use scissors to cut ribbon cable. A bench vise is necessary to make up ribbon cable connectors.

6.2.2 SPS/R Spare Parts List

1.5 Amp Slow-Blow Glass Fuse	Qty.	2
1.2 Amp Slow-Blow Glass Fuse	Qty.	1

6.2.3 Ordering Information

If you need to order parts for the S/O and/or SPS/R, you can order them through your local distributor. For a complete list of Kollmorgen representatives contact the ICP regional office.

6.3 PREVENTATIVE MAINTENANCE

Preventative maintenance can prevent situations that will damage your equipment. Four types of preventative maintenance are presented below. Following each of the procedures can reduce problems with and add life to your equipment.

CAUTION

Electronic components in this amplifier are static sensitive. Use proper procedures when handling component boards.

Preventative maintenance should be performed with the S/O system out of operation and disconnected from all sources of power.

CAUTION

Preventative maintenance to this equipment must be performed by qualified personnel familiar with the construction, operation, and hazards involved with the application.

Always take equipment out of operation and disconnect it from all power sources before performing maintenance.

6.3.1 Transient Voltages

NOTE

All transient-producing devices must be properly suppressed.

Solid state controls of the S/O may be affected by transient voltages. These voltages may exceed the specified voltage for any given circuit. When these peak voltages occur, even for less than a second, permanent damage can occur.

To help avoid transient voltages that may interfere with electronic circuit functions within the SPS/R and S/O, all switched inductive devices or their wiring (solenoids, relay coils, starter coils, etc.) must be suppressed. A 220 ohm, 1/2 watt resistor in series with a 0.5 micro farad, 600 volt capacitor or equivalent is suggested.

6.3.2 Electrical Noise

The low levels of energy in the S/O control circuits may cause them to be vulnerable to electrical noise. Sources of electrical noise include equipment having large, fast changing voltages and currents when they switch on and off. These devices have the capability of inducing current and voltage transients on their respective power lines. Accommodation must be made for these transients using noise immunity provisions.

Electrical noise is prevented with the same methods as surge current and transient voltages. However, there are other methods of preventing electrical noise, such as:

- Maintain physical separation between electrical noise sources and the S/O amplifier.
- Maintain physical separation between electrical noise sources and the S/O control wiring. This can be accomplished by using separate conduits or wiring trays for control wiring and power wiring.
- Follow good grounding practices when wiring the SPS/R and S/O. Be careful not to create a grounding loop with multiple ground paths. Follow the NEC's provisions on grounding.

6.3.3 Radio Frequency Energy

This equipment is susceptible to, and can radiate, radio frequency energy. It must be installed and used in accordance with this installation manual to prevent possible interference with radio communications or other electronic equipment.

6.4 PERIODIC MAINTENANCE

Periodically you will need to inspect your equipment for possible problems to ensure ongoing safe and efficient operation. Periodic maintenance should be performed at scheduled intervals to ensure proper equipment performance. It must be performed by qualified personnel familiar with the construction, operation, and hazards involved with the S/O and its application. Power should be disconnected during all maintenance procedures.

Periodic maintenance includes the following:

- Check that no screw terminals have vibrated loose.
- Check integrity of wiring.
- Check PCBs for accumulation of contaminants such as fluids, dust, or shavings.
- Check all external circuit breakers to assure that they are within their original ratings as specified by the manufacturer.

6.4.1 Grounding Integrity

The method employed for grounding or insulating the equipment from ground should be checked to assure its integrity on a regular basis. This check should be performed with the power off and the testing equipment grounded.

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