ServoWire S2D Drives

Installation and Operation Manual

SAC-S2D 01c

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Table of Contents

Appendix G: Tech Notes

List of Tables

List of Figures

Chapter 1
Welcome

1 Welcome

This manual provides information about ORMEC's ServoWire S2D servodrives, H-Series, G-Series and D-Series Servomotors--- providing both technical descriptions and information required for their installation, operation and maintenance.

The manual is divided into the following chapters:

Chapter 1	**Welcome** introduces you to this manual.
Chapter 2	**General Description** gives an overview of the ServoWire S2D Drive product family.
Chapter 3	**Installation** provides instructions on how to install your ServoWire S2D Drive(s), including a complete hardware description.
Chapter 4	**Operation** documents the power up and initial configuration approach for the ServoWire S2D Drive.
Chapter 5	**Getting Started** provides detailed instructions on how to run your ServoWire S2D Drive system for the first time.
Chapter 6	**Specifications** provides a detailed list of performance specifications for ServoWire S2D Drives.
Chapter 7	**Maintenance and Troubleshooting** documents the various status and fault indicators.
Appendix	**Appendixes** contain a detailed drawing set **.**

Chapter 2
General Description

2 General Description

This manual covers ServoWire S2D Drives, which operate with SMLC or Orion Motion Controllers. The drives control a wide variety of AC Servomotors, including ORMEC H-Series, G-Series and D-Series Servomotors.

This manual generically identifies the drive as an S2D drive. However, there are two possible part numbers depending on the controller, SAC-S2DM when configured for use with an SMLC controller and SAC-S2D when configured for use with an Orion controller. Unless detailed otherwise items apply to both configurations.

2.1 ServoWire S2D Drive Capabilities and Features

2.1.1 Digital Network Interface

- **ServoWire Interface**: The IEEE 1394 ServoWire interface to the SMLC or Orion Motion Controller or Host PC simplifies panel wiring and reduces cabling cost.
- **Simple Setup**: The drive's axis ID is programmed via a pushbutton on the top of the drive; all other drive configuration settings are set by the user's application software using the ServoWire interface. This eliminates drive jumpers, address switches, and potentiometers.

2.1.2 Easy Installation and Configuration

- **Standard Line Voltage Input**: ServoWire S2D200 V Drive Series (SAC-S2D_**2**__) are available for operation directly on commercial power lines supplying 100- 240 (+10%, -10%) VAC for the main power. Control power can be supplied as either AC or DC. AC control power is supplied as 100-240 (+10%, -10%) VAC. DC control power is supplied as 24 VDC. The selection must be made when the drive is ordered.

  ServoWire S2D 400 V Drive Series (SAC-S2D_**2**__) are available for operation directly on commercial power lines supplying 100- 480 (+10%, -10%) VAC for the main power. Control power can be supplied as either AC or DC. AC control power is supplied as 100-240 (+10%, -10%) VAC. DC control power is supplied as 24 VDC. The selection must be made when the drive is ordered. Some restrictions apply.

- **Fault Detection and Protection against**:
  Motor short
  Peak & RMS drive current limit
  Peak & RMS motor current limit
  ServoWire network communications errors
  Encoder open wire detection
  Hall sensor phasing error
  Motor over temperature

- **Diagnostics**: A 2-digit 7-segment display shows the servodrive identification (ID) number, enabled status and fault status, 11 LEDs indicating I/O status and I/O power.

- **Small Size**: ServoWire S2D Drives have a small footprint to conserve panel space.

2.1.3 General Purpose I/O and High Speed Sensor Inputs

- **Software Configurable General Purpose I/O**: ServoWire S2D Drives have general purpose I/O which can be software configured to provide an emergency stop or quick stop input and drive ready and fail-safe brake control outputs.

- **High Speed Sensor Inputs**: There are two high speed sensor inputs connected to special circuitry within the drive to address applications that require registration. The operational characteristics of these inputs are software configurable as well.

2.1.4 Feedback Interfaces

- **Serial Encoder**: The motor encoder interface supports several serial encoder types.
  - Yaskawa Sigma II 13 and 17-bit incremental and 16, 17 and 20-bit absolute encoders.
  - EnDat versions 2.1 and 2.2 serial communications.
  - The Tamagawa TS56xx series of absolute encoders.
  - An external battery is required to maintain multiturn information for many absolute encoders. It can be ordered as CBL-HBAT/n.
- **Resolver Support**: The motor resolver interface provides the following characteristics.
  - Exicitation frequency control to match interface signals with resolver characteristics.
  - Transformation ratio control.

2.1.5 Feedback Groups

Drive options provide a grouping of feedback interfaces

- **S option**:
  - Standard Quadrature Encoders (A quad B) up to 12 MHz. Differential or single-ended.
  - Yaskawa Sigma 1 quadrature

  - Yaskawa Serial Encoders (Sigma II)
  - Tamagawa TS56xx serial
- **R option**:
  - Resolver Interface.
  - Yaskawa Serial Encoders (Sigma II)
  - EnDat Serial Encoders with digital 2.1 or 2.2 protocols
- **D option**:
  - Delay Counter Interface
  - Standard Quadrature Encoders (A quad B) up to 12 MHz. Differential or single-ended.
  - Yaskawa Sigma 1 quadrature
  - Yaskawa Serial Encoders (Sigma II)

2.1.6 Motor Control Features

- **All Digital**: High-speed DSP-controlled current loops provide precise torque, velocity and position mode operation.
- **Variety of Commutation Options**: ServoWire S2D Drives can be software configured for sinusoidal or trapezoidal commutation for AC brushless motors or DC commutation to control DC motors, voice coils and other single phase actuators.
- **Soft Start**: Circuitry is provided on all S2D Drives to reduce servodrive in-rush current.
- **Torque Mode Operation**: When combined with velocity and position loops in high performance Host PC's or Orion Motion Controller, torque mode operation allows extremely high load inertia to motor inertia ratios.
- **Velocity Mode Operation**: Velocity mode operation provides fast and precise velocity control. By closing the velocity loop on the S2D Drive the computing burden on the SMLC or Orion Controller is reduced compared to torque mode operation.
- **Position Mode Operation**: Position mode operation provides precise motion control with the minimum computing burden on the SMLC or Orion Controller by closing the velocity and position loops in the S2D Drive.
- **Wide Current Loop Bandwidth**: For high positioning accuracy and response.
- **Velocity and Torque Monitor**: High quality velocity monitor and torque monitor signals are provided to simplify system testing.

- **Shunt Regulation**: All Models have shunt regulation circuitry. If an application requires regenerative operation, regenerative discharge resistors can be mounted external to the servodrive. On models 203 – 215 the circuitry is optional and must be specified in the model number when ordered.

2.2 Differences between SAC-SD and SAC-S2D Drives.

The S2D line of ServoWire drives has enhanced features and functionality from the SD series of drives.

Feature		**SD Servodrive**	**S2D Servodrive**
Power connections		Fixed terminal block on all models.	Pluggable terminal blocks models 203-215, 403-405.
Control power		120/230 VAC only	100-240 VAC or 24 VDC
24 VDC output power		Not available	Available when using AC control power
Regen control circuitry		Available on all models except 203 and 205.	Available on all models. Optional on models 203-215.
Peak current		2 times continuous rating	3 times continuous rating on models 203-215, 403-410
Absolute encoder battery		Optional inside drive	External to drive, use cable part CBL-HBAT/n
Safety circuit		Not available	Available option on all models.

Table 1*, Differences between SAC-SD _ and SAC-S2D_ Drives.*

2.2.1 Considerations when Replacing a SAC-SD with a SAC-S2D Drives.

In most applications the SAC-S2D series of servodrives can be used as a direct substitution for the SAC-SD drives. Considerations to review:

1. **Current capabilities.** The S2D series, models 203-215 and 403-410, have 3x peak capability versus 2x peak capability in the SD series. In all cases except model 220, the S2D current capabilities are superior. Due to the difference in peak capabilities, the 215 will substitute for the 220 in nearly all applications.

Drive model	**Current**		**Replace with**	**Current**	
	Cont	**Peak**		**Cont**	**Peak**
SAC-SDx203	2.4	4.8	SAC-S2Dx203	3.0	9.0
SAC-SDx205	4.2	8.4	SAC-S2Dx205	5.0	15
SAC-SDx210	8.4	17.2	SAC-S2Dx210	10	30
SAC-SDx217	14.2	28	SAC-S2Dx215	15	45
SAC-SDx220	17	34	SAC-S2Dx215	15	45
SAC-SDx225	25	50	SAC-S2Dx225	25	50

SAC-SDx235	35	70	SAC-S2Dx235	35	70
SAC-SDx260	60	120	SAC-S2Dx260	60	120
			SAC-S2Dx403	3.0	9.0
SAC-SDx405	5.0	10.0	SAC-S2Dx405	5.0	10.0
SAC-SDx410	10	20	SAC-S2Dx410	10	30
SAC-SDx417	17	34	SAC-S2Dx417	17	34
SAC-SDx425	25	50	SAC-S2Dx425	25	50
SAC-SDx435	35	70	SAC-S2Dx435	35	70
SAC-SDx450	50	100	SAC-S2Dx450	50	100

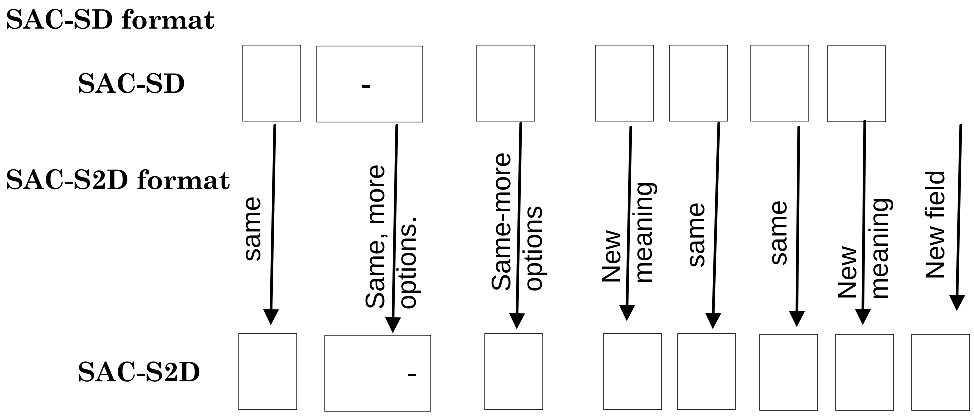
2. **Project Definition**. The project definition in ServoWire Pro or MotionDesk does not require a change. The new S2D drive will function as the old SD drive did. However, the drive will have only 2x peak current capability. To use the full 3x peak capability you must upgrade your ServoWire Pro to revision 3.4.0 or later and then select a S2D drive in your project. Sync the project to the SMLC to complete the upgrade. The 3x peak capability is not available in an Orion system.

3. **Mounting**. The mounting hole spacings are identical in all 200 V drives. In the 400 V series the 403-410 are smaller and the 417-450 are identical. The S2D will mount using the same holes in most cases. There are minor differences in the width of the drives as shown.

Original model	Width	Replacement	Width
SAC-SDx203	2.6”	SAC-S2Dx203	2.2”
SAC-SDx205	2.6”	SAC-S2Dx205	2.2”
SAC-SDx210	2.6”	SAC-S2Dx210	2.73”
SAC-SDx217	3.8”	SAC-S2Dx215	4.18”
SAC-SDx220	3.9”	SAC-S2Dx215	4.18”
SAC-SDx405	4.3”	SAC-S2Dx405	3.95”
SAC-SDx410	4.3”	SAC-S2Dx410	4.18”

4. **Firmware**. The S2D drives firmware is different than the SD drive series. .

5. **Model Numbers**. The S2D_ drives have slightly different options than the equivalent SD_ drive. The options are defined in **ServoWire S2D Drive Model Number** Description. The differences are noted here. Contact ORMEC for assistance.



Same – indicates options letters that position have same meaning in SD and S2D drives.

2.3 ServoWire S2D Drive Model Number Description

ORMEC's S2D drives can be ordered in many configurations. This chart details the meaning of the model number characters, indicating which features are included.

Standard features include 2 high speed sensors, digital I/O, diagnostic LEDs and 1394 Firewire communications. Configurable options and model number are indicated.

Example: SAC-S2DM210-SA00R0 denotes a 200V, 10A drive with AC control power, the encoder feedback group and regen support circuitry. The analog I/O, pacer feedback and Safety circuit options are not installed.

Rated Power		Series	Motor Voltage	Output Current	Feedback	Control Power[1]	Analog I/O	Pacer (Aux) Feedback	Regen[3]	Safety Circuit
		SAC-S2D or SAC-S2DM	V	AA	- F	C	A	P	R	S
KW	HP									
0.7	1.0		2 (200V)	03	S (quad encoder, serial) R (Resolver, EnDat) D (quad encoder, serial, delay counter)	D A	0 (none) A (analog installed)	0 (none) P (incremental encoder)	0 R	0 (none) S (STO)
1.2	1.6			05		D A			0 R	
2.4	3.2			10		D A			0 R	
3.6	4.8			15		D A			0 R	
6.0	8.0			25		D A			R	
8.4	11			35		D A			R	
14.0	19			60		D A			R	
1.4	2.0		4 (400V)	03		D			R	
2.4	3.2			05		D			R	
4.8	6.4			10		D			R	
8.1	10.9			17		D A			R	
12	16			25		D A			R	
17	22			35		D A[2]			R	
24	32			50		D A[2]			R	

Notes:

[1] Control power: D = 24 VDC, A=115-240 VAC

[2] AC Control power this model limited to A=208-240 VAC

[3] Regen: R = Regen support circuit present. External resistor required. 0 = no circuitry installed.

ServoWire Drive logo's	Model Number
Yellow Logo	**S2D.....** Used with ORION Motion Controller. **MotionDESK** is used to upgrade the drive firmware.
Blue Logo	**S2DM..** Used with SMLC &MotionObjects applications. **ServoWire Pro** is used to upgrade the drive firmware.

2.4 Certifications and safety markings

ORMEC's S2D drives are designed and built to meet many US and international standards for safety and operation. Drives meeting such standards will be marked with the appropriate marks.

2.4.1 UL and CSA

The S2D drives which meet requirements of UL 508C and CSA C22.2 No. 14-95 are marked with the following

C UL US LISTED

When used in an application or on a panel certain information is needed for the correct application, ratings and approvals. The information can be found throughout this manual. A concise list of the required UL information is provided here for your quick reference. For complete details and operation please refer to the correct section of this manual or contact ORMEC support.

UL File: E158657

This device is to be installed in a pollution degree 2 environment.

For 200V drives: The Drives are suitable for motor group installation on a on a circuit capable of delivering not more than 200kA RMS symmetrical amperes, 240 VAC maximum when protected by class RK5 fuses or 200 kA rated circuit breakers.

For 400v drives: The Drives are suitable for motor group installation on a on a circuit capable of delivering not more than 200kA RMS symmetrical amperes, 480 VAC maximum when protected by class RK5 fuses or 200 kA rated circuit breakers.

This drive provides solid state motor overload protection at 105% of motor FLA.

These drives are intended to be used with motors which have integral thermal protection in or on the motor. Contact ratings 12 VDC, 2.5 mA.

Ambient temperature 0 to 50^{o}C

Maximum surrounding air temperature 50^{o}C

This servodrive uses solid state short circuit protection on the motor outputs. Integral short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.

WARNING: The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. To reduce the risk of fire or electric shock, current-carrying parts and other components of the controller should be examined and replaced if damaged. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced.

CAUTION – Risk of Electric Shock. After disconnecting power wait 5 minutes to discharge capacitor to 50 VDC.

Electrical ratings: see label on side of drive.

2.4.2 CE

The S2D drives have been tested to meet requirements the Low Voltage Directive, 2006/95/EC and the Electromagnetic Compatibility Directive, 2004/108/EC.

Drives meeting the requirements will be marked with a CE mark.

2.4.3 Safe Torque Off

The S2D drives can be optionally ordered with a Safe Torque Off feature. This feature provides redundant control inputs and redundant methods to disable the motor outputs. The circuit has been evaluated to:
PL rating: PL d

PFH: 1.5 E-7 (1/h)

Chapter 3
Installation

3 Installation

3.1 Receiving and Inspection

ORMEC Servodrives and their associated accessories are put through rigorous tests at the factory before shipment. After unpacking, check for damage, which may have been sustained in transit. The bolts and screws should all be tight, and motor output shafts should rotate freely by hand. Check the servodrive and any accessories for bent or broken components or other physical damage before installation.

3.2 ServoWire S2D Drive Panel and Environment Considerations

ServoWire S2D Drives are designed for panel mounting, with the panel in turn mounted in a metallic enclosure (supplied by the machine builder). For optimal EMC (Electromagnetic Compatibility) shielding, the enclosure should have continuous ground continuity maintained between all metal panels.

For high quality servo performance, proper wiring, grounding and shielding techniques must be considered.

- Refer to the "Shielding, Grounding and Design Techniques for Motion Control Servo Systems" Application Note, which is included as an Appendix to this manual and can also be downloaded from ORMEC's website at http://www.ormec.com/Portals/0/files/Services/Applications/ApplicationNotes/Shielding_and_Grounding.pdf
- .

The servodrive environment should be maintained as follows:

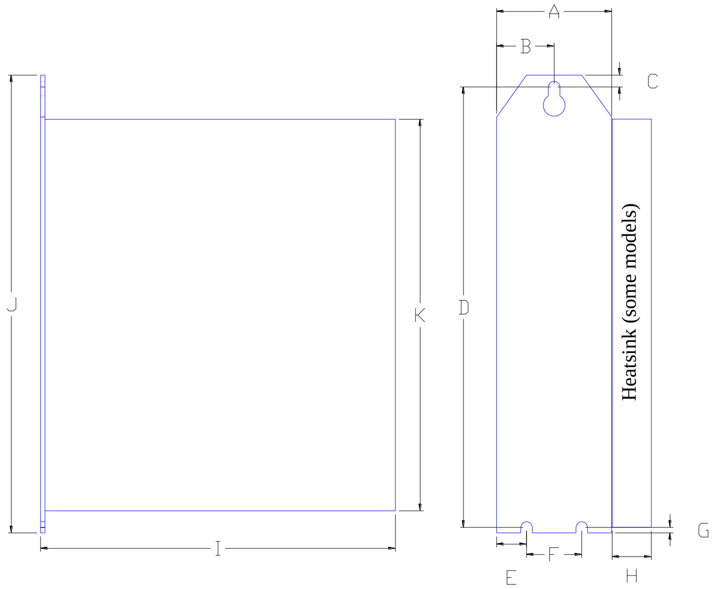
- Ambient operating temperature should be between 0^{o}C & and 50^{o}C.
- If the electrical panel is subjected to vibration, mount the units on shock absorbing material. Be sure to maintain a good electrical connection.
- Avoid use in corrosive atmospheres, which may cause damage over time.
- Select a location with minimum exposure to oil, water, hot air, high humidity, excessive dust, or metallic particles.

- The proper mounting orientation for the servodrive is vertical on a panel using the mounting holes on the base plate.

- Allow sufficient clearance around servodrive for airflow, and provide proper ventilation. Section **3.3** shows the minimum clearance between drives.
- If possible, external regenerative discharge resistors should be mounted in an enclosure separate from the ServoWire S2D Drive enclosure. Regenerative discharge resistors can become extremely hot, so proper ventilation must be provided.

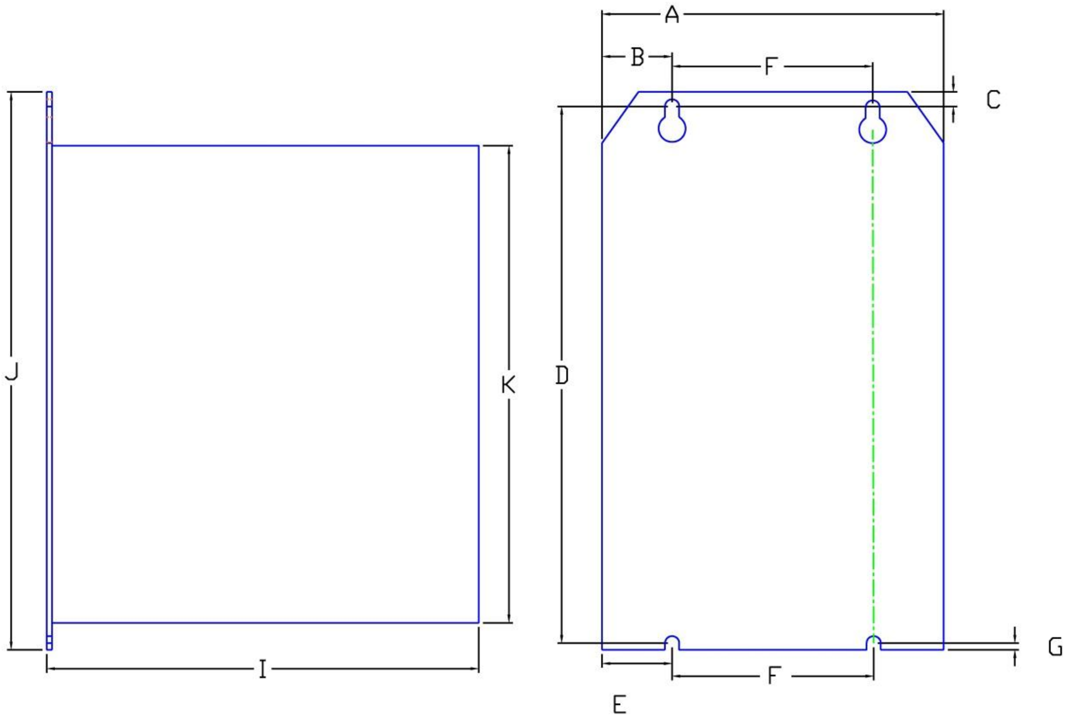
3.3 ServoWire S2D Drives Outline Drawings

3.3.1 Mounting Information for SAC-S2D_203, 205, 210, 215



Dimension Ref.	Model						
	S2D 203-S2D 205	S2D 210	S2D 210H	S2D 215	S2D 403	S2D 405	S2D 410
A	2.15	2.73	2.73	2.73	2.73	2.73	2.73
B	1.11	1.38			1.38		
C	0.22						
D	8.68				8.68		
E	0.35	0.6			0.60		
F	1.5						
G	0.1						
H	None		1.2	1.45	None	1.22	1.45
I	7.4						
J	9						
K	7.8						
All dimensions in inches							

Figure 1, *ServoWire S2D Drives 203 – 215, 403-410 Dimensions*



	Model		
Dimension	**S2D 225 S2D 235 S2D260**	**S2D 417 S2D 425**	**S2D 435 S2D 450**
Ref.			
A	6.8		7.8
B	1.44		1.96
C	0.22		
D	11.68		13.68
E	1.44		1.92
F	4.0		
G	0.1		
H			
I	8.22		9.23
J	12.0		14.0
K	10.85		12.85
All dimensions in inches.			

Figure 2, *ServoWire S2D Drives 225 – 260, 417-450 Dimensions*

Additional clearance above, below and to the sides of the ServoWire S2D Drives is required for heat dissipation. Required space depends on application load, duty cycle, ambient temperature in cabinet and air flow at drive.

SAC-S2D_203, SAC-S2D_205 and SAC-S2D_210
Add 1.5” (38 mm) clearance top and bottom.
Add .5” (12.5 mm) clearance each side.

SAC-S2D_210H
Add 1.5” (38 mm) clearance top and bottom.
Add .5” (12.5 mm) left side, .75” (19 mm) right side clearance.

SAC-S2D_215
Add 1.5” (38 mm) clearance top and bottom.
Add .5” (12.5 mm) clearance each side.

SAC-S2D_225, SAC-S2D_235, SAC-S2D_260,
SAC-S2D_417, SAC-S2D_425, SAC-S2D_435, SAC-S2D_450
Add 1.5” (38 mm) clearance top and bottom.
Add .5” (12.5 mm) clearance each side.

3.4 Software Configuration Setup

Software configurable motor parameters and drive settings include:

- **Motor Model Number / name**
- **Continuous Stall Current**
- **Peak Current**
- **Motor Torque** (Peak, Continuous, Rated)
- **Maximum Speed** of motor
- **Resistance** measured phase-to-phase
- **Inductance** measured phase-to-phase
- **Inertia** of motor
- **Number of Poles** of motor
- **Feedback Offset** in degrees (Hall or Resolver offset)
- **Maximum Drive Input Voltage** based on motor's rating
- **Commutation Type:** (Sine-Brushless/Trap-Brushless/DC-Brush)
- **Commutation Feedback Type:**
  Incremental encoder with separate U,V,W hall inputs -or-
  Yaskawa Sigma I incremental encoder –or-
  Yaskawa Sigma II Serial encoder-or-
  Resolver
- **Feedback Resolution** (Counts per revolution)
- **Thermal Switch** in motor is present/not present
- **Thermal Time Constant** of motor.
- **Motor Over Temperature Handling** (Ignore/Error/Drive Fault)
- **Hardware Travel Limit Inputs** (Enable/Disable)
- **Input Voltage for Drive** (115/230/460 VAC)
- **Pull-up Resistors for ASEN & BSEN**:
  2.7 KΩ (8.9 mA at 24 VDC) for NPN sensor –or-
  No pull-up resistor for PNP sensor
- **ASEN & BSEN** gating (Enable/Disable)
- **ASEN, BSEN, ZREF** trigger (Rising/Falling/High/Low)
- **ZOUT** (primary or auxiliary axis)
- **Regen Resistor Resistance** (Ohms)
- **Regen Resistor Rated Power** (Watts)

The ServoWire icon, shown at the left, will be displayed in this manual wherever one of these drive parameters is discussed, to indicate that the functionality of the drive will depend on the Software Configuration setting.

SAC-S2DM...........................used with **SMLC** or **MotionObjects** software.

These configuration settings are stored as part of your ServoWire Pro software project file (*filename***.SwSetup**), and are downloaded to the drive by the application program.

SAC-S2D...............................used with **ORION** Motion Controller.

These configuration settings are stored as part of your MotionDESK software project file (*filename***.MTD**), and are downloaded to the drive by the Orion MotionBASIC application program.

3.5 ServoWire S2D Drives Power Considerations

3.5.1 Control Power for 200 V (SAC-S2D_2__) Drives

ServoWire S2D 200 V Drives (SAC-S2D_**2**__) control power can be operated from AC or DC supplies. When ordered configured for AC control power the drive will provide a 24 VDC output at 1A, suitable for use as an I/O device power supply.

When ordered for AC input the drive should be operated, through line filters or an isolation transformer, on commercial power lines supplying 100-240 (+10%, -10%) VAC, 50/60 Hz.

When ordered for DC input a 24 VDC power supply must be supplied. The ground (low side) of the power supply output should be referenced to frame or safety ground. The controller must be referenced to the same ground. Floating power supplies are not recommended.

To prevent power line accidents due to grounding error, contact error, or to protect the system from a fire, circuit breakers or fuses must be installed according to the number and size (current capacity) of ServoWire S2D Drives used. Slow-blow circuit breakers or fuses should be used because the servodrive draws substantial inrush current at power up.

3.5.2 Main Supply Power for 200 V (SAC-S2D_2__) Drives

ServoWire S2D 200 V Drives (SAC-S2D_**2**__) can be operated, through line filters or an isolation transformer, on commercial power lines supplying 100-240 (+10%, -10%) VAC, 50/60 Hz. The Drives are suitable for motor group installation on a on a circuit capable of delivering not more than 200kA RMS symmetrical amperes, 240 VAC maximum when protected by class RK5 fuses or 200 kA rated circuit breakers.

To prevent power line accidents due to grounding error, contact error, or to protect the system from a fire, circuit breakers or fuses must be installed according to the number and size (current capacity) of ServoWire S2D Drives used. Slow-blow circuit breakers or fuses should be used because the servodrive draws substantial inrush current at power up.

This servodrive uses solid state short circuit protection on the motor outputs. Integral short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.

3.5.3 Control Power for 400 V (SAC-S2D_4__) Drives

ServoWire S2D 400 V Drives (SAC-S2D_4__) have different limits for control power and motor power. This section deals with control power.

ServoWire S2D 400 V Drives (SAC-S2D_**4**__) control power can be operated from AC or DC supplies. When ordered configured for AC control power the drive will provide a 24 VDC output at 1A, suitable for use as an I/O device power supply.

- Exception 1, models 403-410 are 24 VDC control power only.

When ordered for DC input a 24 VDC power supply must be supplied. The ground (low side) of the power supply output should be referenced to frame or safety ground. The controller must be referenced to the same ground. Floating power supplies are not recommended.

When ordered for AC input the drive should be operated, through line filters or an isolation transformer, on commercial power lines supplying:

Models 417-425	100-240 (+10%, -10%) VAC, 50/60 Hz.
Models 435-450	200-240 (+10%, -10%) VAC, 50/60 Hz.

To prevent power line accidents due to grounding error, contact error, or to protect the system from a fire, circuit breakers or fuses must be installed according to the number and size (current capacity) of ServoWire SD Drives used. Slow-blow circuit breakers or fuses should be used because the servodrive draws substantial inrush current at power up.

3.5.4 Main Supply Power for 400 V (SAC-S2D_4__) Drives

ServoWire S2D 400 V Drives (SAC-S2D_4__) can be operated, through line filters or an isolation transformer, on commercial power lines supplying 100-480 (+10%, -10%) VAC, 50/60 Hz. The Drives are suitable for motor group installation on a on a circuit capable of delivering not more than 200kA RMS symmetrical amperes, 480 VAC maximum when protected by class RK5 fuses or 200 kA rated circuit breakers.

To prevent power line accidents due to grounding error, contact error, or to protect the system from a fire, circuit breakers or fuses must be installed according to the number and size (current capacity) of ServoWire S2D Drives used. Slow-blow circuit breakers or fuses should be used because the servodrive draws substantial inrush current at power up.

This servodrive uses solid state short circuit protection on the motor outputs. Integral short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the National Electrical Code and any additional local codes.

3.5.5 Shielding, Power Line Filtering & Noise Suppression

The Servodrive uses high voltage switching power transistors in the main DC Bus circuit. When these transistors are switched, the $^{di}/_{dt}$ or $^{dv}/_{dt}$ switching noise could prove objectionable depending on the wiring and/or grounding method. The Servodrive utilizes a DSP, which can be susceptible to power line interference caused either by the output switching transistors or other equipment on the power line, such as welders, electrical discharge machines, induction heating equipment, etc. Careful layout of wiring and power line filtering will help prevent noise interference. Recommendations with respect to wiring and grounding are described later in this section.

- Further information is available in the "Shielding & Grounding Electrical Panels" Application Note, which is included as an Appendix to this manual and can also be, downloaded at ORMEC's Web Site (http://www.ORMEC.com).

It is recommended that line filters be installed to eliminate electro-magnetic interference coming into the system from the power line, as well as block switching noise from being transmitted back out to the power line from the servodrives.

3.5.6 Sizing Fuses, Line Filters, and Transformers

To determine current requirements for fuses, line filters and transformers for main power, use the following conservative formulas:

$$\textbf{Required Power} \text{ (in KVA)} = \frac{1.1 * \textbf{Rated Power of Motor} \text{ (in Watts)}}{1000}$$

$$\textbf{Required Current} \text{ (in Amps)} = \frac{1.1 * \textbf{RatedPower of Motor} \text{ (in Watts)}}{\textbf{Incoming LineVoltage} \text{ (in Volts AC)}}$$

Note: **Rated Power of Motor** can be found in Chapter 6, Specifications.

In cases where the motor is substantially over-sized for an application, consider substituting the actual power required by the application into the above formulas instead of the motor's rated power.

3.5.7 Power Dissipation for cabinet cooling

Use the following table to determine cabinet cooling requirements:

	Dissipated Power (Watts)			
	Control Power			**External** Regen Resistor (if used)
	Max	Typical	Main Power	
SAC-S2D_203	45	20	55	700 max.
SAC-S2D_205	45	20	90	700 max.
SAC-S2D_210	45	20	180	1000 max.
SAC-S2D_215	45	20	300	1000 max.
SAC-S2D_225	45	30	360	3000 max.
SAC-S2D_235	45	30	490	4175 max.
SAC-S2D_260	45	30	830	7100 max.
SAC-S2D_403	40	20	80	700 max.
SAC-S2D_405	40	20	130	1000 max.
SAC-S2D_410	42	20	264	1000 max.
SAC-S2D_417	45	30	405	4000 max.
SAC-S2D_425	45	30	600	5970 max.
SAC-S2D_435	45	30	835	8350 max.
SAC-S2D_450	45	30	1200	12000 max.

***Table 2**, Power Dissipation*

Main power dissipation is shown for the rated output power of the drive. The actual dissipated main power may be lower, depending on the motor and/or application requirements. To more closely estimate main power dissipation, use the conservative formula: 0.07*(rated power of the motor). In cases where the motor is substantially oversized for the application, use 0.1*(the power required by the application).

Actual power dissipated in the regen resistor is dependent on the application requirements. Table 2, column “External Regen Resistor” shows the rated regen capacity of the ServoWire S2D Drive.

3.5.8 Line Filters

Once the incoming power service is determined, the appropriate main power line filter can be selected from Table 3. When a system uses multiple ServoWire S2D Drives, they may share one line filter per cabinet.

<table>
<tr><th>ServoWire S2D Drive</th><th>Main Power Input Voltage</th><th>Total Continuous Current</th><th>Main Power Line Filter</th></tr>
<tr><td rowspan="2">SAC-S2D_203
SAC-S2D_205</td><td rowspan="2">Single phase</td><td>Up to 15 Amps</td><td>SAC-LF215U</td></tr>
<tr><td>Up to 30 Amps</td><td>SAC-LF230U</td></tr>
<tr><td rowspan="3">SAC-S2D_210
SAC-S2D_215
SAC-S2D_225
SAC-S2D_235
SAC-S2D_260
SAC-S2D_403
SAC-S2D_405
SAC-S2D_410
SAC-S2D_417
SAC-S2D_425
SAC-S2D_435
SAC-S2D_450</td><td rowspan="3">Three-phase</td><td>Up to 30 Amps</td><td>SAC-LF30C</td></tr>
<tr><td>30 – 55 Amps</td><td>SAC-LF55C</td></tr>
<tr><td>55 – 100 Amps</td><td>SAC-LF100C</td></tr>
</table>

***Table 3**, Line Filter Recommendations*

The following methods are recommended for proper installation of line filters:

1. The filter must be mounted on the same panel, and as close as possible to the ServoWire S2D Drive(s).
2. Paint or other panel covering material should be removed before mounting the filter.
3. All SAC-LF___C line filter ground connections should be tied to earth ground with a single wire (preferably braid), and **the filter must be grounded before connecting the ServoWire S2D Drives.**
4. Line filters should not be touched for a minimum of 10 seconds after removal of the supply power.
5. Separate the input and output leads by a minimum of 10 inches (250 mm). Do not bundle or run them in the same duct or wireway.

Do not bundle the ground lead with the filter output lines or other signal lines and do not run them in the same duct.

3.5.9 Terminal Block Wiring Guidelines

All ServoWire S2D terminal block wiring should be UL listed copper wire with at least an 80°C-temperature rating (wiring to regen resistors should be heat resistant, non-combustible insulation). The maximum wire gauge and screw terminal torque for each terminal block is indicated in **Table 4**. Wiring for TB1 should be twisted pair, shielded with the drain wire connected to earth ground (NOTE: the SHIELD connections at various points on the ServoWire S2D Drive are connected to the frame ground).

	Wire Gauge (AWG) [mm^2]	**Screw Torque** (in-lb) [N-m]
Terminal Block – **TB3 – Analog I/O**	30 to 14 [0.14 to 1.5]	1.95 [.22]
Terminal Block – **TB4 – Drive I/O**	30 to 14 [0.14 to 1.5]	1.95 [.22]
Terminal Block – **TB5 – Drive I/O**	30 to 14 [0.14 to 1.5]	1.95 [.22]
Terminal Block - **TB6 – DC Power**	28 to 16 [0.14 to 1.3]	1.95 [.22]
Terminal Block - **TB7 – AC Power**	22 to 12 [0.64 to 2.1]	7.0 [0.8]
Terminal Block - **TB8 – Regen**	22 to 12 [0.64 to 2.1]	7.0 [0.8]
Terminal Block - **TB9 – Motor**	22 to 12 [0.64 to 2.1]	7.0 [0.8]
Terminal Block - **TB10 – Safety Circuit**	28 to 16 [0.14 to 1.3]	1.95 [.22]
Terminal Block - **TB11 – Power & Motor**	22 to 12 [0.64 to 2.1]	7.0 [0.8]

***Table 4**, Terminal Block Wiring Gauge and Screw Torque*

NOTE: **Install all power wiring (including ground wiring) according to NEC (National Electric Code) or UL (Underwriters Laboratories) specifications and in compliance with local ordinances.**

3.6 ServoWire S2D Drive Connections

The complete family of S2D drives are designed to provide an optimized tradeoff in power density and cost effectiveness. The drives are designed with three connector arrangements. An overview of each follows in the next few pages. Links to the applicable sections are provided.

Quick links can also be found here.

Table 12, Drive Analog I/O (TB3) Connections
Table 4, Terminal Block Wiring Gauge and Screw Torque
Table 5, Drive Sensor (TB4) Connections
Table 6, Drive Input / Output (TB5) Connections
Table 7, ServoWireDCPower Connections (TB6)
Table 8, ServoWire AC Power Connections (TB7)
Table 9, ServoWireRegen Resistor Connections (TB8)
Table 10, ServoWire Motor Connections (TB9)
Table 11, ServoWire Power & Motor Connections (TB11)
Table 13, Encoder Motor Feedback Connector (J4) Descriptions
Table 14, Resolver Motor Feedback Connector (J4) Descriptions

Detailed electrical specs are in Section **6.1, ServoWire S2D Drive** Specifications. Part numbers for these and mating connectors are in Section**6.1.11** (**page92**).

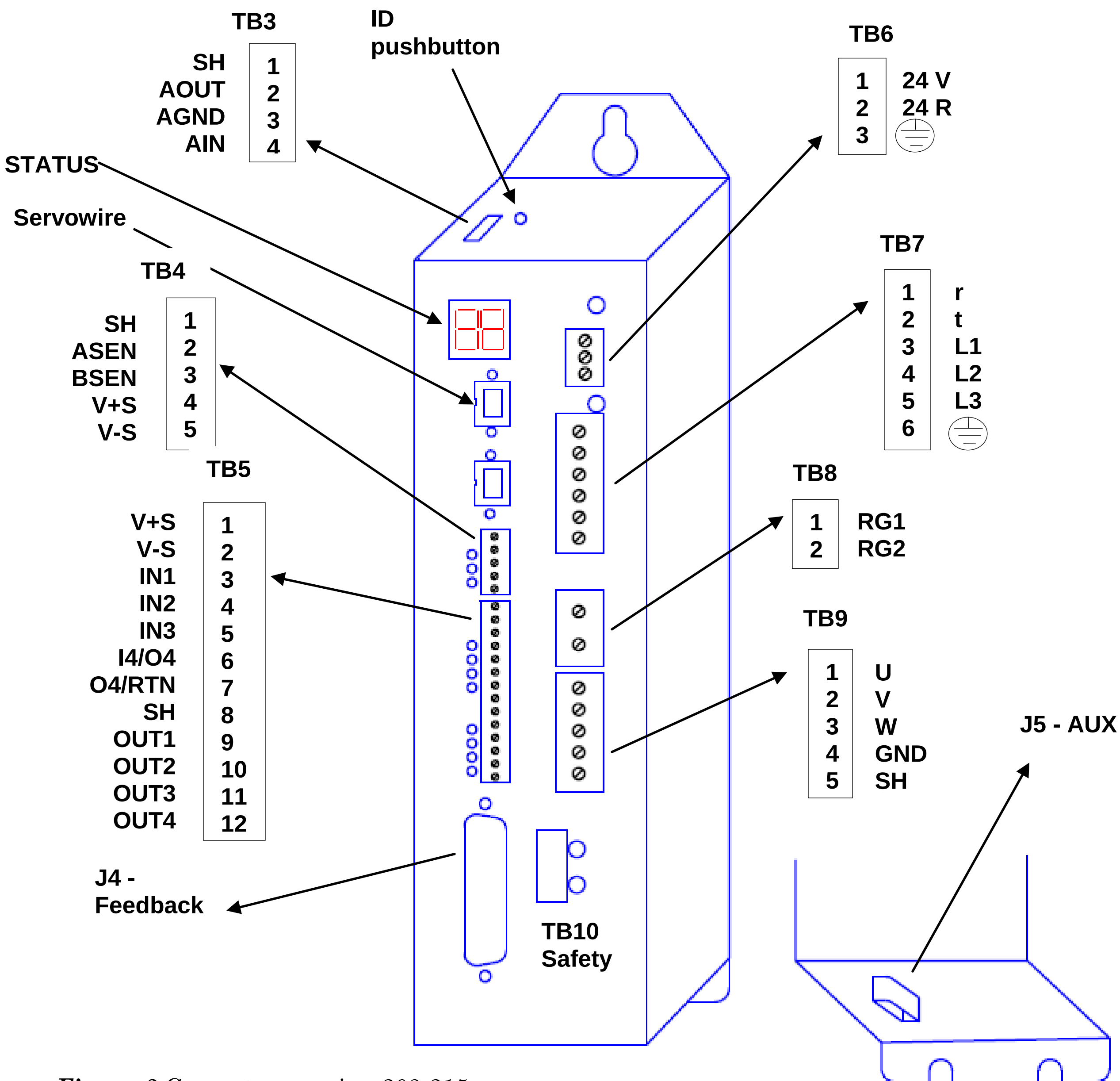


Figure 3 *Connector overview 203-215*

Connection information:

TB3: Table 12, Drive Analog I/O (TB3) Connections
TB4: Table 5, Drive Sensor (TB4) Connections
TB5: Table 6, Drive Input / Output (TB5) Connections
TB6: Table 7, ServoWireDCPower Connections (TB6)
TB7: Table 8, ServoWire AC Power Connections (TB7)
TB9: Table 9, ServoWireRegen Resistor Connections (TB8)
J4: Table 13, Encoder Motor Feedback Connector (J4) Descriptionsor Table 14, Resolver Motor Feedback Connector (J4) Descriptions
J5: Table 15, Pacer Feedback Connector Descriptions

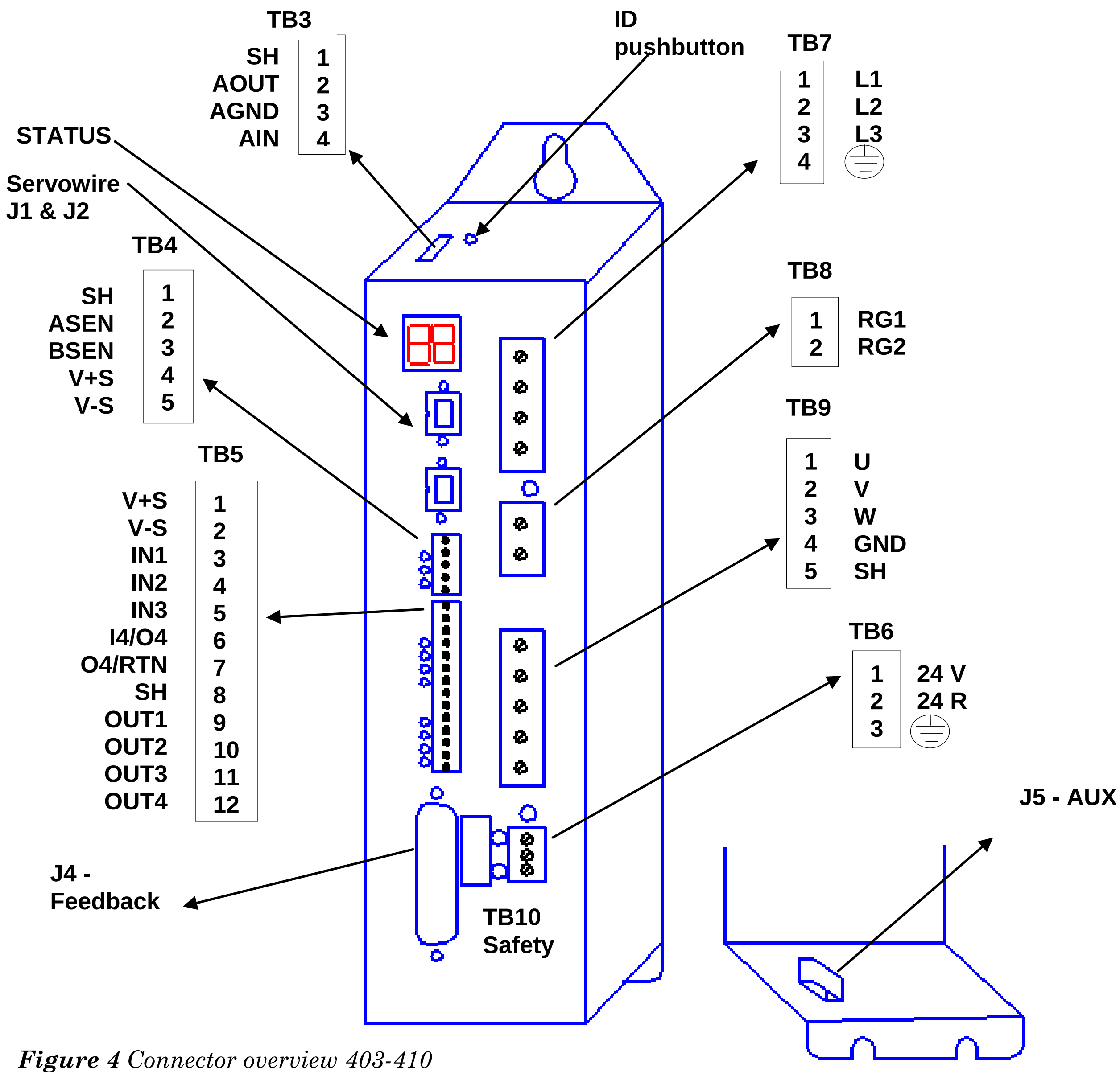


Figure 4 *Connector overview 403-410*

Connection information:

TB3: Table 12, Drive Analog I/O (TB3) Connections
TB4: Table 5, Drive Sensor (TB4) Connections
TB5: Table 6, Drive Input / Output (TB5) Connections
TB6: Table 7, ServoWireDCPower Connections (TB6)
TB7: Table 8, ServoWire AC Power Connections (TB7)
TB9: Table 9, ServoWireRegen Resistor Connections (TB8)
J4: Table 13, Encoder Motor Feedback Connector (J4) Descriptions or Table 14, Resolver Motor Feedback Connector (J4) Descriptions
J5: Table 15, Pacer Feedback Connector Descriptions

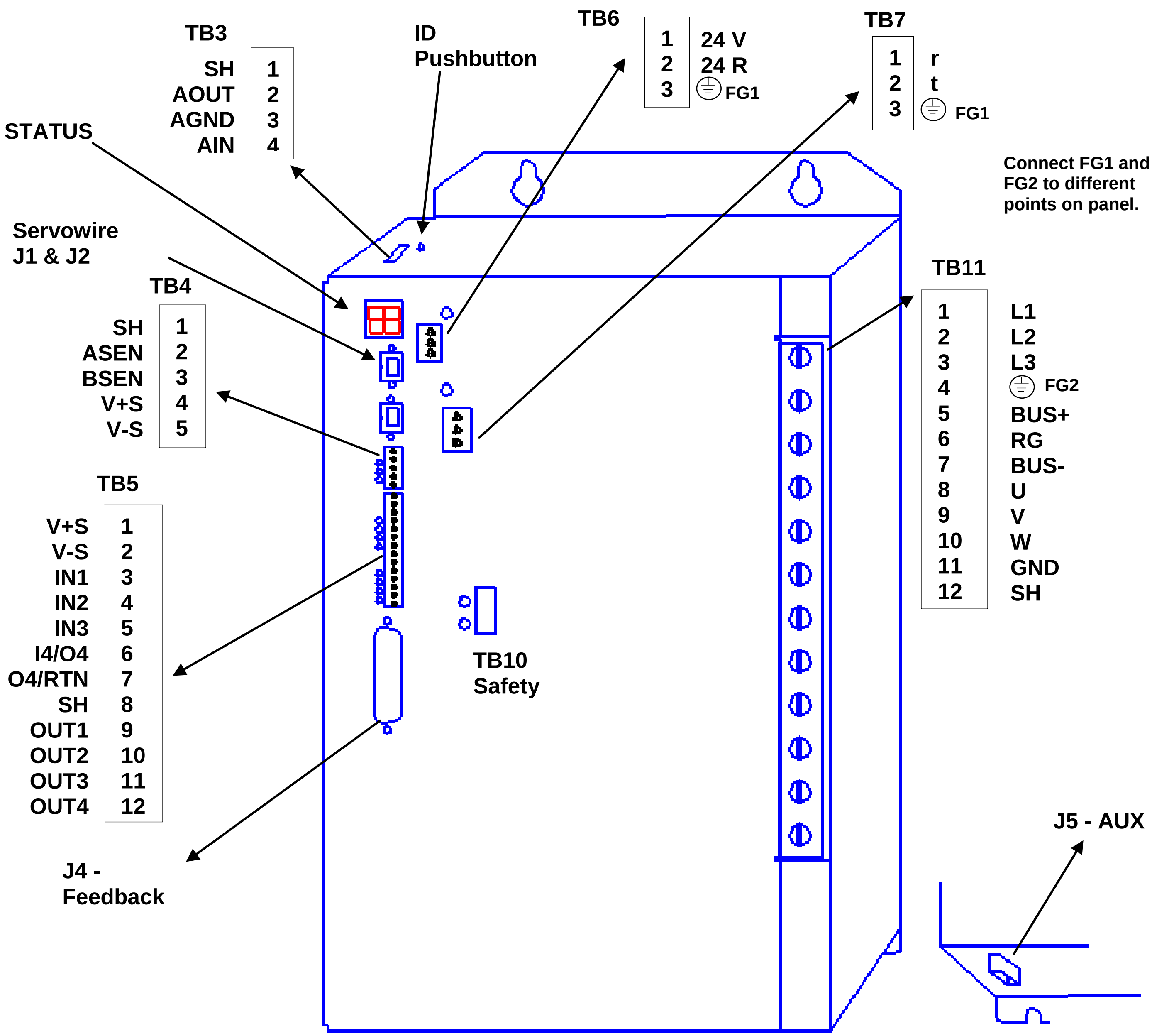


Figure 5 *Connector overview 225-260, 417-450*

Connection information:

TB3: Table 12, Drive Analog I/O (TB3) Connections
TB4: Table 5, Drive Sensor (TB4) Connections
TB5: Table 6, Drive Input / Output (TB5) Connections
TB6: Table 7, ServoWireDCPower Connections (TB6)
TB7: Table 8, ServoWire AC Power Connections (TB7)
TB9: Table 9, ServoWireRegen Resistor Connections (TB8)
J4: Table 13, Encoder Motor Feedback Connector (J4) Descriptions or Table 14, Resolver Motor Feedback Connector (J4) Descriptions
J5: Table 15, Pacer Feedback Connector Descriptions

3.6.1 Drive Sensor Connections for All Models (TB4)

Refer to the **Table 39, I/O Specifications (TB4 and TB5)** section (page **88**) of the Specifications chapter for further information.

Pin	Signal	Function	Description
1	Shield	Cable shield connection	Connect the cable shield at one end only.
2 3	ASEN BSEN	High Speed Sensor Inputs	Software configurable for: • **2.7KΩ** pull-up resistor for NPN sensor (8.9 mA @ 24VDC) • **No** pull-up resistor for PNP sensor See***Figure 10*** (page **36**)for a simplified schematic. **V+S** and **V-S** must be connected to a DC Power Supply (5 – 24 VDC) in order to use these inputs.
4 5	V+S V-S	I/O Power Supply Input Common for I/O Power	Inputs for 5-24 VDC power supply used for: • High Speed Sensor inputs ASEN, BSEN • Discrete Inputs IN1' – IN4' • Discrete Outputs OUT1' – OUT5' Note that V-S must be referenced to FG somewhere in the system.

Table 5*, Drive Sensor (TB4) Connections*

3.6.2 Drive Input / Output Connections for All Models (TB5)

Refer to the **Table 39, I/O Specifications (TB4 and TB5)** section (page **88**) of the Specifications chapter for further information.

Pin	Signal	Function	Description
1 2	V+S V-S	I/O Power Supply Input Common for I/O Power	Inputs for 5-24 VDC power supply used for: • High Speed Sensor inputs ASEN, BSEN • Discrete Inputs IN1' – IN4' • Discrete Outputs OUT1' – OUT5'
3 4 5	IN1' IN2' IN3'	General Purpose Input 1 General Purpose Input 2 General Purpose Input 3	Software configurable for operation as general-purpose inputs, or Hardware Travel Limit switch inputs, an E-Stop/Quick Stop input. Refer to the Discrete Inputs section (page 50) for further information. See Figure 11 (page 38) for a simplified schematic. **V+S** and **V-S** must be connected to a DC Power Supply (5 – 24 VDC) in order to use these inputs.
6 7	IN4'/ OUT4' OUT4 RTN	General Purpose Input 4 or General Purpose Output 4 IN4/OUT4 Return	Usable as either a general purpose input or output and ServoWire Pro software-configurable for operation as a Drive Ready indicator. Refer to the Discrete Outputs section (page 51) for further information. See Figure 11 (page 38) for a simplified schematic.
8	Shield	Cable shield connection	Connect the cable shield at one end only.
9 10 11 12	OUT1' OUT2' OUT3' OUT5'	General Purpose Output 1 General Purpose Output 2 General Purpose Output 3 General Purpose Output 5	Software configurable for operation as general purpose outputs, as a Brake control output, isolated motor encoder reference or isolated feedback option module output. Refer to the Discrete Outputs section (page 52) for further information. See (page40) for a simplified schematic. **V+S** and **V-S** must be connected to a DC Power Supply (5 – 24 VDC) in order to use these inputs.

***Table 6**, Drive Input / Output (TB5) Connections*

3.6.3 ServoWire S2D Drive DC Power Terminal Block (TB6)

Pin	Signal	Function	Description
The drive can be ordered with DC or AC control power. **When ordered with DC control power this terminal block is an input.**			
1 2	**24V** **24R**	Input Control Power	24 VDC control logic input power. Once the ServoWire S2D Drives in a network have control power applied, it is best to leave their control power on continuously, while any of the drives is torque-producing.
3	⏚	Ground	Ground for input power. **Must be connected to input power ground.**
When ordered with AC control power this terminal block is an output.			
1 2	**24V** **24R**	OutputDC power	24 VDC output power available for I/O. Do not use for inductive loads.
3	⏚	Ground	Connection to TB7 ground point.

***Table 7**, ServoWireDCPower Connections (TB6)*

3.6.4 ServoWire S2D DriveAC Power Terminal Block (TB7)

Pin	Signal	Function	Description
The drive can be ordered with DC or AC control power. **When ordered with AC control power that control power is provided on terminals r and t.** **When ordered with DC control power terminals r and t do not need connection.**			
1 2	**r** **t**	Input Control Power	Single phase 100 – 240 VAC, 50/60 Hz control logic input power. Needed only when drive ordered as AC control power. 200 – 240 VAC required on models 435 and 450. Before any drive is placed in a torque-producing mode it is best to have control power applied to all ServoWire S2D Drives in the network. Control power should remain for all drvies.
3 4 5	**L1** **L2** **L3**	Input Main Bus Power	**200 V Series** Three phase 100 to 240 VAC, 50/60 Hz**.** Single phase 100 to 240 VAC on models 203 and 205. **400 V Series Drives** Three phase 100 to 480 VAC, 50/60 Hz To ensure proper operation of low bus voltage faults and inrush current limiting, the input voltage should match the configuration software setting.
6	⏚	Ground	Ground for input power. **Must be connected to input power ground.**Preferred connection is to the panel, close to

			the drive.

***Table 8**, ServoWire AC Power Connections (TB7)*

3.6.5 ServoWire S2D Regen Terminal Block (TB8)

Pin	Signal	Function	Description
1 2	**RG1** **RG2**	Regen Resistor	If an external regen resistor is used it is connected between **RG1** and **RG2**. See Section 4.11, External Regen Resistor Wiring (RG1, RG2 or BUS+, RG)(page 39).

***Table 9**, ServoWireRegen Resistor Connections (TB8)*

3.6.6 ServoWire S2D Motor Connection Terminal Block (TB9)

Pin	Signal	Function	Description
1 2 3	**U** **V** **W**	Motor Power	Single or Three-phase power to the motor. See: • H-Series Servomotor Connections (page 46) • Servomotor Connections (page 45) • DE/DA/DB-Series Servomotor Connections (page 46) • DC Servomotor Connections (page 46). To ensure proper operation the motor type must match the configuration software setting.
4	**GND**	Ground	Ground connection for motor frame ground
5	**SH**	Shield Connection	Connection for motor shield drain

***Table 10**, ServoWire Motor Connections (TB9)*

3.6.7 ServoWire S2D Power& Motor Connection Terminal Block (TB11)

Pin	Signal	Function	Description
1 2 3	**L1** **L2** **L3**	Input Main Bus Power	**200 V Series** Three phase 100 to 240 VAC, 50/60 Hz. Single phase 100 to 240 VAC on models 203 and 205. **400 V Series Drives** Three phase 100 to 480 VAC, 50/60 Hz To ensure proper operation of low bus voltage faults and inrush current limiting, the input voltage should match the configuration software setting.
4	⏚	Ground	Ground for input power. **Must be connected to input power ground.** Preferred connection is to the panel, close to the drive. DO NOT connect to same point as TB7 panel connection.

5 6 7	**BUS+** **RG** **BUS-**	Regen Resistor	If an external regen resistor is used it is connected between **Bus+** and **RG**. See Section 4.11, External Regen Resistor Wiring (RG1, RG2 or BUS+, RG) (page 39).
8 9 10	**U** **V** **W**	Motor Power	Single or Three-phase power to the motor. See: • H-Series Servomotor Connections (page 46) • Servomotor Connections (page 45) • DE/DA/DB-Series Servomotor Connections (page 46) • DC Servomotor Connections (page 46). To ensure proper operation the motor type must match the configuration software setting.
11	**GND**	Ground	Ground connection for motor frame ground
12	**SH**	Shield Connection	Connection for motor shield drain

***Table 11**, ServoWire Power & Motor Connections (TB11)*

3.6.8 Drive Analog I/O Connections for All Models (TB3)

Refer to the Table 42, Analog I/O Specifications (TB3) section (page 91) of the Specifications chapter for further information.

Pin	Signal	Function	Description
1	Shield	Cable shield connection	Connect the cable shield at one end only.
2	AOUT	Analog Output	Provides an analog output from the drive. The signal output is Software configurable. Torque command, Velocity Monitor, Position Error, Bus Voltage, Phase U, V or W current or a manual value can be selected.
3	AGND	Analog Ground	Ground reference for AOUT and AIN
4	AIN	Analog Input	Provides an analog input. This input can be used to close a feedback loop in the drive when in tension mode or can be used by the host controller. The input has a Software configurable low pass filter.

***Table 12**, Drive Analog I/O (TB3) Connections*

3.6.9 ServoWire Connectors for All Models (J1 & J2)

The S2D Drives are enhanced with 1394b capabilities. They utilize bilingual connectors and interface chips which allow communication in either 1394b or 1394a protocols. The 1394b protocol is an improvement over the 1394a protocol, offering more digital communication, better noise immunity and the possibility for faster communication.

The ServoWire bilingual connector has 9 pins: two for power, four for communications and three additional shield pins. The connectors are available only as an integral part of an IEEE 1394 or ServoWire cable.

There is no ‘in’ or ‘out’ distinction between the J1 and J2 connectors. Each ServoWire network can be thought of as a bus.

The SAC-S2D series drives use locking ServoWire 1394 connectors. To take full advantage of the locking cables order cables CBL-SW-BL-x, where the L specifies the locking screws. The locking cables are only available for 1394 b to 1394 b connections. Such connections are available on the SAC-S2D servodrives and the SMLC controller. Connections between the SMLC and the SAC-S2DM drive and from SAC-S2DM drive to SAC-S2DM drive can use the locking cables. ORMEC’s Orion controller uses 1394a style connectors which are not supported with locking cables. A system with an Orion and multiple SAC-S2D drives must use a CBL-SW-BA for the Orion to drive connection and then can use CBL-SW-BL locking cables from drive to drive.

3.6.10 ServoWire Cable for All Models

With the addition of 1394b and the bilingual connectors care must be made in the selection of ServoWire cables. It is necessary to match the cable to the connector on both ends. There are four choices available.

- **1394b – Cabling differences**

  ServoWire Cables

  CBL-SW-A-x
  - 6 pin to 6 pin
  - 1394a to 1394a
  - SW or SM drive to SW or SM drive

  CBL-SW-BA-x
  - 9 pin to 6 pin
  - 1394b to 1394a
  - SMLC (30, 80, 160) to SW or SM drive
  - Orion to S2D drive
  - S2D drive to SW or SM drive

  CBL-SW-B-x
  - 9 pin to 9 pin
  - 1394b to 1394b
  - SMLC (30, 80, 160) to S2DM drive
  - S2DM drive to S2DM drive
  - S2D drive to S2D drive

  CBL-SW-BL-x
  - 9 pin to 9 pin, with locking screws
  - 1394b to 1394b
  - SMLC (30, 80, 160) to S2DM drive
  - S2DM drive to S2DM drive
  - SMLC version 2.0 or later support locking cables

Figure 6, CBL-SW-A-*x*

Figure 7, CBL-SW-BA-x

Figure 8, CBL-SW-B-x

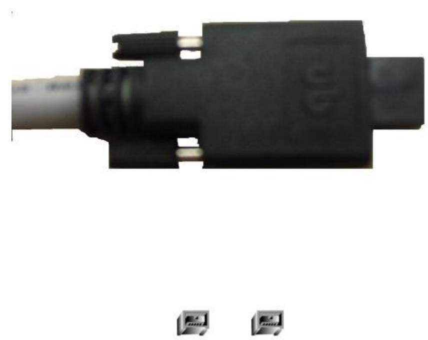


Figure 9, CBL-SW-BL-x

3.6.11 1394 network topology restrictions:

- Never exceed 63 nodes per bus
- Never create a loop in the ServoWire network
- Maximum of 16 cables between any 2 nodes
- Maximum of 72 meters (accumulated cable length) between any 2 nodes
- Maximum single cable length of 10 m. Use a repeater to span a greater distance. (Repeater counts as a node.)
- SM, SD and S2D drives can be mixed on the same network. This requires a mix of cables.

3.6.12 Motor Feedback Connector for Serial Encoder Models SAC-S2Dxxxx-S (J4)

*Refer to the **Table 40, SAC-S2Dxx-S version Motor Encoder Specifications (J4)** section (page 90) of the Specifications chapter for further information*

.

Note: This table applies to the –S and –D version drives with Quadrature and Serial Encoder support		
Pin	**Signal**	**Description**
1 2	ENCA ENCA'	Differential input, quadrature feedback channel A from the motor encoder.
3 4	ENCB ENCB'	Differential input, quadrature feedback channel B from the motor encoder.
		Single ended quadrature encoders use ENCA and ENCB pins 1 & 3 only. With an SMLC configure using ServoWire Pro and select feedback type "single ended quadrature". Not available in Orion configurations.
5 6	ENCZ ENCZ'	Differential input, "once per revolution" marker signal from the motor encoder.
7 8 9 10 11 12	U U' V V' W W'	Differential or single-ended input, commutation feedback channels U, V and W from the motor encoder. Use pin pairs for differential inputs. The U, V and W (pins 7, 9 & 11) inputs are intended for use with single ended commutation feedback. If the feedback signals are open collector outputs, external-biasing hardware may be required. The U', V' and W' (pins 8, 10 & 12) inputs are internally biased and no connection or external circuitry is required for use with single ended feedback. Refer to Appendix B-4 for further information.
13,24,25	ENC PWR1	+5.25VDC power supply output for the motor encoder (450 mA max). This power is derived from the input control power.
16,17,18	DGND	Common for the +5.25 VDC supply (ENC PWR1).
19 20	TEMP' TEMP RET	Motor Over Temperature input. Configuration software settings determine the usage of this input. **Normally closed Contact** wired to the ServoWire S2D Drive: • Open contact causes drive fault ***F4***. (Immediately disables motor torque). • or – Open contact causes application program error. • or – Open contact is ignored. No fault or error occurs. **No Sensor exists at motor**. Leave TEMP & TEMP RETURN unconnected. • Contact is normally open. (This setting will cause an application program configuration error if there is a closed contact). See Section **4.11.6** (page Error! Bookmark not defined.) for a detailed explanation.
21	SHIELD	Motor encoder shield termination point
22 23		Reserved. Do not connect.
14 15	SDATA SDATA'	Bi-directional differential signal pair for serial encoder communications. Used with Yaskawa and Tamagawa serial encoders.

***Table 13**, Encoder Motor Feedback Connector (J4) Descriptions*

(also see cable drawings in Appendix E)

3.6.13 Motor Feedback Connector for Resolver Models SAC-S2Dxxxx-R (J4)

Refer to the Table 40, SAC-S2Dxx-S version Motor Encoder Specifications (J4) section (page 90) for further information

Note: This table applies to the –R version drives with Resovler Feedback support

Pin	Signal	Description
5, 7, 9	SHIELD	Resolver shield termination points.
17 18	REF- REF+	Differential output, resolver excitation frequency. Resolver excitation parameters are specified in the configuration software settings: • Excitation Frequency: 2.5, 5.0 (default) & 10.0 kHz • Excitation Amplitude: 0 to 6.5V RMS, 6V RMS at 100% set in the configuration software. (The default is set for a transformation ratio of .5 with 100% indicating the default setting.) Due to variations in resolver transformation ratios, the excitation amplitude may require adjustment to meet the sine and cosine input voltage.
19 20	COS- COS+	Differential Input, resolver feedback cosine channel from the motor resolver. • Feedback Amplitude: 3V RMS, +/-15%
21 22	SIN- SIN+	Differential Input, resolver feedback sine channel from the motor resolver. • Feedback Amplitude: 3V RMS, +/-15%
3 16 6 8 11 24	U U' V V' W W'	Differential or single-ended input, commutation feedback channels U, V and W from the motor encoder. Use pin pairs for differential inputs. The U, V and W (pins 3, 6 & 11) inputs are intended for use with single ended commutation feedback. If the feedback signals are open collector outputs, external-biasing hardware may be required. The U', V' and W' (pins 16, 8 & 24) inputs are internally biased and no connection or external circuitry is required for use with single ended feedback. Refer to Appendix B-4 for further information.
4	5.3v	+5.25VDC power supply output for the motor encoder (450 mA max). This power is derived from the input control power.
25	GND	Common for the encoder power, +5.25 VDC or +12 VDC supply.
12	+12v	Encoder power – provides power for encoder, +12v, 400 mA maximum.This power is derived from the input control power.
10 23	TEMP' TEMP RET	Motor Over Temperature input. Configuration software settings determine the usage of this input. **Normally closed Contact** wired to the ServoWire S2D Drive: • Open contact causes drive fault ***F4***. (Immediately disables motor torque). • or – Open contact causes application program error. • or – Open contact is ignored. No fault or error occurs. **No Sensor exists at motor**. Leave TEMP & TEMP RETURN unconnected. • Contact is normally open. (This setting will cause an application program configuration error if there is a closed contact). See Section 4.11.6 (page Error! Bookmark not defined.) for a detailed explanation.
13	V+S	Parallels V+S pins from TB5. Used to power additional devices.
2 1	SDATA SDATA'	Serial Data. Bi-directional differential signal pair for serial encoder communications. Used with EnDat serial encoders.

15 14	SCLK SCLK'	Serial Clock. Differential CLOCK pair for serial encoder communications. Used with EnDat serial encoders.

***Table 14**, Resolver Motor Feedback Connector (J4) Descriptions*
(also see cable drawings in Appendix E)

3.6.14 Pacer Feedback Connector for All Models (J5 – mounted on bottom of drive)

*Refer to the **Table 40, SAC-S2Dxx-S version Motor Encoder Specifications (J4)** section (page 90) for further information*
.

Pin	Signal	Description
1 14	ENCA ENCA'	Differential input, quadrature feedback channel A from the pacer encoder.
2 15	ENCB ENCB'	Differential input, quadrature feedback channel B from the pacer encoder.
3 16	ENCZ ENCZ'	Differential input, "once per revolution" marker signal from the pacer encoder.
5, 6, 18	ENC PWR1	+5.25 VDC power supply output for the pacer encoder (450 mA max). This power is derived from the input control power.
7, 19, 20	DGND	Common for the +5.25 VDC supply (ENC PWR1).
9	SHIELD	Pacer encoder shield termination point

***Table 15**, Pacer Feedback Connector Descriptions*
(also see cable drawings in Appendix E)

3.6.15 High Speed Sensor Inputs (ASEN, BSEN)

High speed sensor inputs ASEN and/or BSEN are individually software configurable for:

- NPN sensor: 2.7K pull-up resistor (8.9 mA @ 24 VDC)
- PNP sensor: pull-up resistor removed from circuit.

V-S from external power supply must be referenced to FG

Figure 10on the following page shows sensor wiring for types NPN (top) and PNP (bottom).

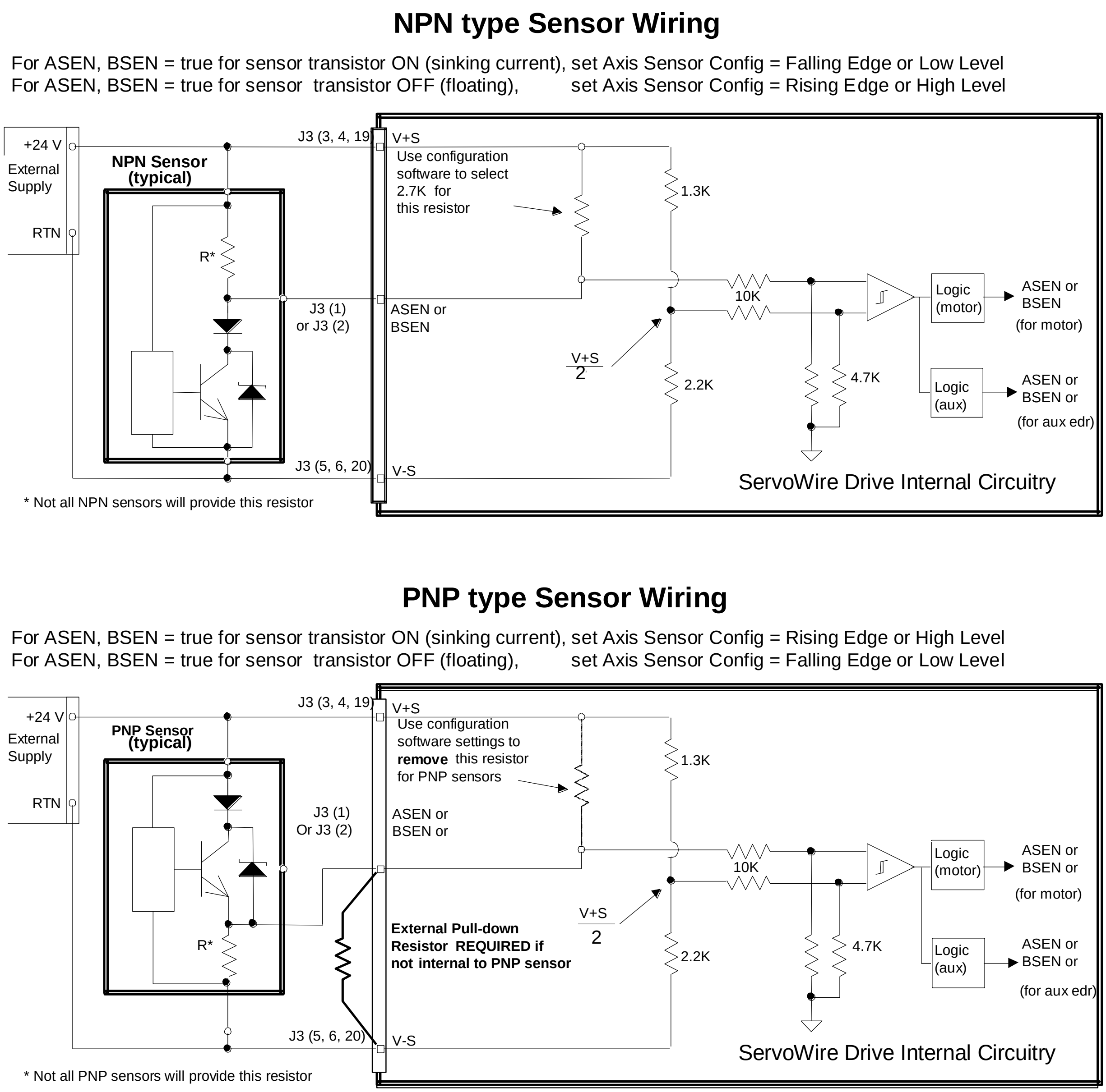


Figure 10, Schematic of ASEN and BSEN wiring for NPN and PNP sensors

3.6.16 High Speed Sensor Inputs (ASEN, BSEN) (continued)

NOTE: ASEN and BSEN wiring should be shielded twisted pair cable, with a foil shield. The DC Power Supply V-S connection should be connected to the same ground as the ServoWire S2D Drive frame ground (TB6, ground pin).

Configuration software is used to configure ASEN and BSEN for edge- or level-sensitive triggering. **Using level-sensitive (high or low) triggering increases the susceptibility of your sensor inputs to noise.**

ASEN and/or BSEN inputs can be software configured to operate in a gated (masked) behavior by the ServoWire S2D Drive outputs OUT1 and OUT2.

3.6.17 Discrete Inputs (IN1', IN2', IN3', IN4'/OUT4')

* Note: Input # 4 is Bi-directional & shares the same pin with Output # 4.

The four discrete inputs on the ServoWire S2D Drive can be software configured as general purpose inputs for use by the application program, or as Hardware Travel Limits inputs and E-Stop/Quick Stop input.

	SAC-S2DM	SAC-S2D MotionBASIC required.
Hardware Travel Limit Forward **Hardware Travel Limit Reverse** Refer to the Hardware Travel Limits (IN1', IN2') page 50	IN1' IN2'	IN1' IN2'
E-Stop / Quick Stop Refer to the Quick Stop Input (IN3') page 50	IN3'	Not Available

Figure 11 shows a simplified schematic of the Discrete Inputs, TB5 pins 3, 4, 5 and 6 (IN1' – IN4') connected to a limit switch. Refer to the Hardware Travel Limits (page 50) and Quick Stop Input (page 51) information.

The IN4'/OUT4' pin is shared, with IN4' indicating the state of the I/O point. If OUT4' is disabled, then this pin can be used as an input. If OUT4' is enabled, then this pin cannot be used as an input, though the state of IN4' will still correctly indicate the state of the I/O point.

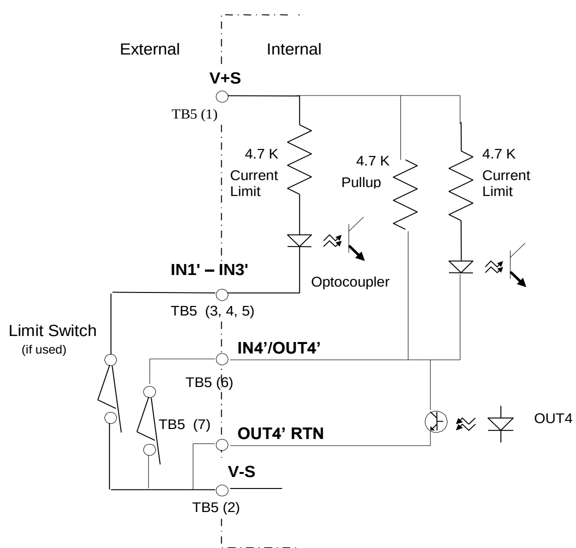


***Figure 11**, Schematic of IN1', IN2', IN3' and IN4'/OUT4' Inputs*

3.6.18 Discrete Outputs (OUT1'-OUT5')

* Note: Output # 4 is Bi-directional & shares the same pin with Input # 4.

A ServoWire S2D Drive provides five optically isolated general-purpose digital outputs. By default these are controlled by the application program, but can be software configured as hardware status and control signals.

Software configurable, OUT1' through OUT5' can be configured as general purpose.

	SAC-S2DM	**SAC-S2D** MotionBASIC required.
Brake control or Delay Counter Refer to the Brake Control or Phased Sensor (Delay counter) Output (OUT3') page 52	OUT3'	OUT3' (Delay counter not available)
Drive Ready Refer to the If the Sensor Phasing option is installed, this output can be used to signal external circuitry that a delay counter terminal count has been reached. See 4.9 Sensor Phasing Option for details. Drive Ready Output (OUT4') page 52	OUT4'	Not Available
Zero Reference Refer to the Encoder Feedback Zero Reference Output (OUT5') page 52	OUT5'	OUT5'

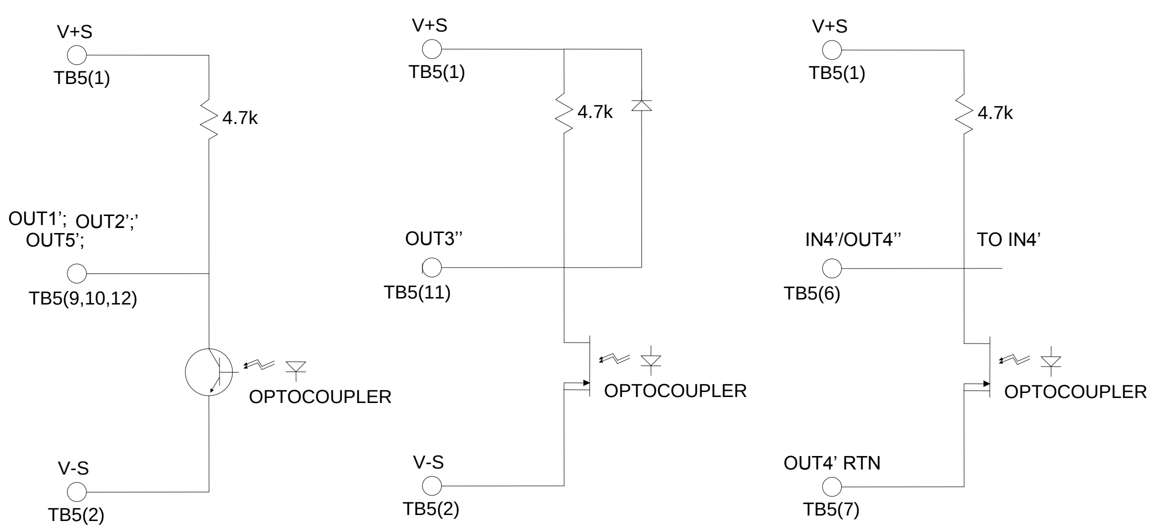


Figure 12, *Schematic of Discrete Outputs OUT1'-OUT5', -R version and –S version*

3.6.19 External Regen Resistor Wiring (RG1, RG2 or BUS+, RG)

Regenerative (regen) shunt circuitry, for use with external regen resistors, is available or provided on ServoWire S2D drives. The circuitry is optional on models 203-215 and standard on all others. Regen resistors are connected between the **RG1** and **RG2** terminals on TB8 (models 203-215) and **Bus +** and **RG** terminals on TB11 (all other models), (refer to Figure 13).

Recommended methods for proper installation of regen resistors:

1. **Regen resistors can become very hot as part of normal operation and should be mounted in a ventilated, "touch safe" enclosure.** ORMEC SAC-SMRR/0700, SAC-SMRR/0845, SAC-SMRR/0846, and SAC-SMRR/1700 regen resistors are supplied with enclosures. Mounting enclosures for the SAC-SMRR/0055 and SAC-SMRR/0095 regen resistors are not included and must be supplied by the user.
2. Regen resistor wiring should have heat resistant, non-combustible insulation.
3. Regen resistor and other system wiring should be routed so that it is not in contact with the regen resistors.
4. **Switching voltages exceeding 400 VDC (230 V drives) may be present on the RG1, RG2 terminals (and across the regen resistor).** Use appropriate high voltage safety wiring methods.
5. Mounting and wiring practices should be in accordance with NEC (National Electric Code) or UL (Underwriters Laboratories) specifications and in compliance with local ordinances.

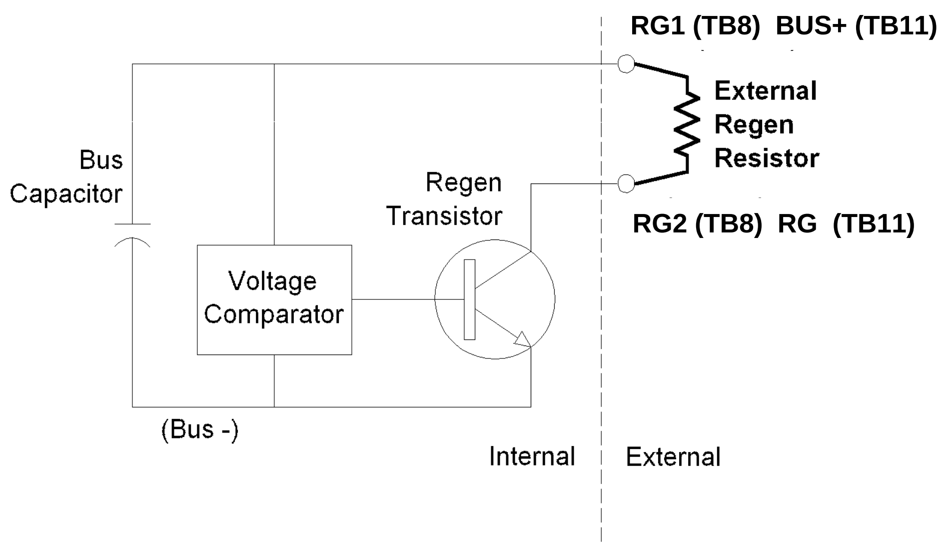
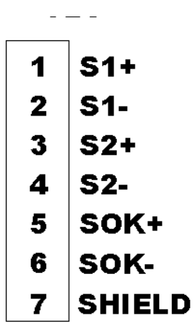


***Figure 13**, Regen Resistor Connection*

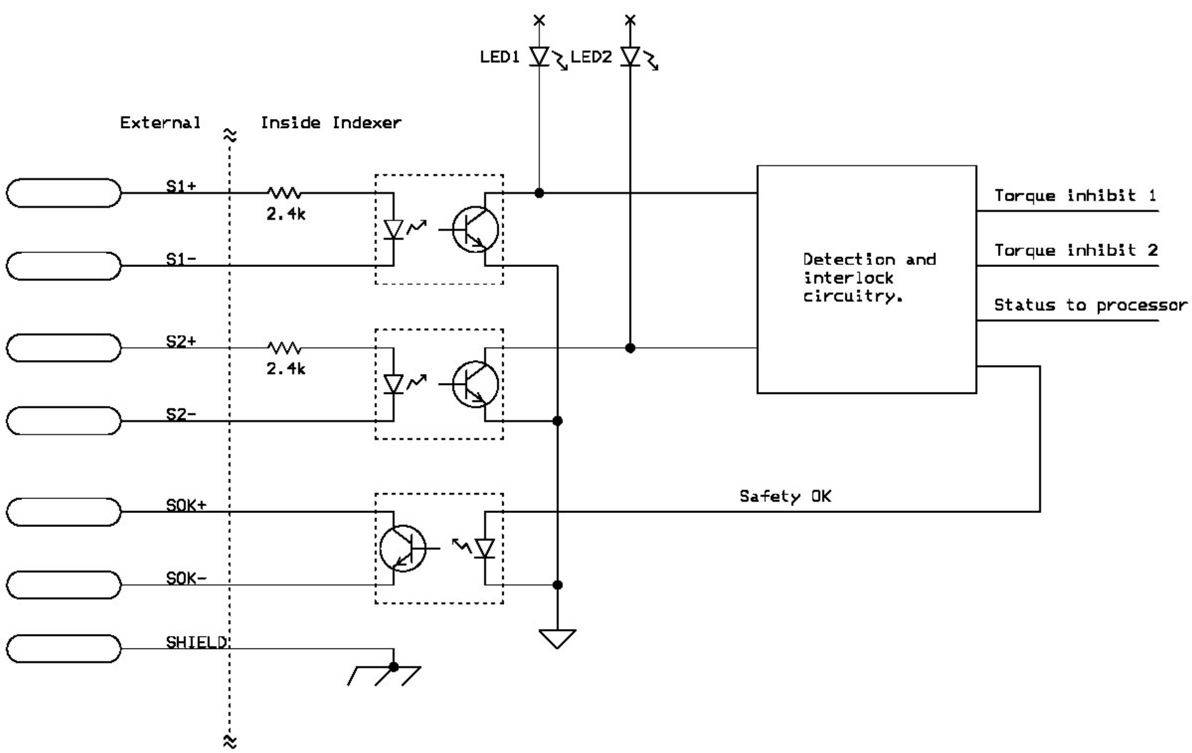
For information on how the shunt circuitry operates, as well as information on sizing regen resistors, see Section 4.11, Regenerative Loads (page 64).

3.6.20 STO – Safte Torque Off Wiring

The STO safety interface provides a redundant hardware torque interlock. The interlock is generally used as part of a machine safety system. No configuration is needed to activate the feature. This feature becomes active when installed and cannot be over-ridden by software.



TB10 – STO Safety connections			
Pin	Signal	Typical	Comment
1	S1+	24 VDC from interlock 1	Current is required to enable the drive.
2	S1-		
3	S2+	24 VDC from interlock 2	Current is required to enable the drive.
4	S2-		
5	SOK+	18 mA status output	Transistor output available to monitor status of the safety inputs. Conducts when both inputs are satisfied. EXTERNAL CURRENT LIMITING DEVICE REQUIRED.
6	SOK-		
7	SH	SHIELD	



3.7 ServoWire S2D Drive ID

Each ServoWire S2D Drive has a Drive Identification (ID) number, which is shown on the ID/Status LED display on the front of the unit. ServoWire S2D Drives are shipped from the factory with Drive ID number set to 1.

The Drive ID is important because it establishes the axis ID of the motor being controlled by the ServoWire S2D Drive.

A push-button on the top of the ServoWire S2D Drive allows setting of the Drive ID. Once the Drive ID is being displayed, pressing the push-button will increment the Drive ID by 1 each time it is pushed. The maximum value for an S2D drvie is 32, for an S2DM drive is 16. Pressing and holding down the push-button will cause the Drive ID to continue incrementing. After reaching its maximum value, it will roll over back to 1, and continue increasing again from there. This functionality is available after each power-up, before torque has been enabled at the motor.

***Figure 14**, Drive ID Setup Flowchart*

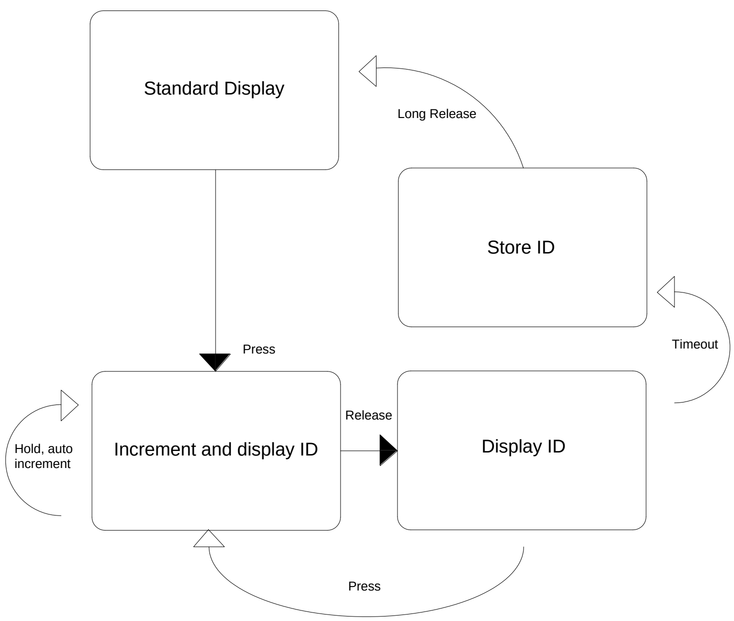
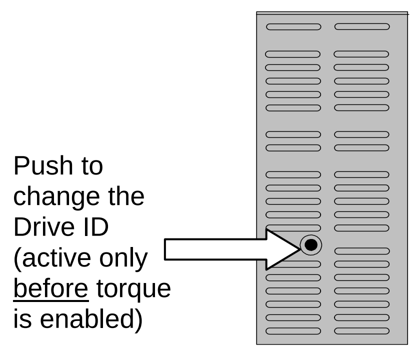


***Figure 15**, Top View of ServoWire S2D Drive showing Drive ID Pushbutton*



3.8 Servomotor Installation

3.8.1 Motor Use and Environment

A *standard* G-Series Servomotor (IP65) is designed for use as:

- Horizontal or vertical mounting orientation
- Indoors, clean, dry environment.
- Free from corrosive and/or explosive gases or liquids
- If the location is subject to excessive water or oil, protect the motor with a cover. The motor can withstand a small amount of splashed water or oil.
- Accessible for inspection and cleaning
- Face mounting: The structural integrity of the mounting can be critical to obtaining the maximum performance from your Servomotor application.
- G-Series Servomotors: Rated Torque's/Currents are for 25°C; for ambient temperatures above 25°C, use the formula given below. Note that $°C_{Max}$ is 100°C for all G-Series Servomotors except models G006, G011, G015, and G019; for these motors, $°C_{Max}$ is 85°C. The motor current is de-rated by the same factor as the torque.

$$\text{Torque}_{\text{Derated}} = \frac{\text{Torque}_{\text{Rated}} * ({}^{o}C_{Max} - {}^{o}C_{Ambient})}{({}^{o}C_{Max} - 25^{o}C)}$$

***Figure 16**, G-Series Torque Derating for High Ambient Temperature*

3.8.2 Recommended Servomotor Wiring Methods

1. When the motor is mounted to the machine and grounded through the machine frame, $^{dv}/_{dt}$ current flows from the ServoWire S2D Drive through the floating capacity of the motor. To prevent the noise effects from this current, and also for safety, the motor housing (terminal D of the motor connector) should be connected to the frame of the ServoWire S2D Drive (TB1 pin FG or TB9 GND depending on model), which should be directly grounded to the control panel frame using copper wire.
2. When motor wiring is contained in metal conduits, the conduits and boxes must be grounded. For ServoWire S2D 115/230 VAC drives, use wires of 12 AWG or heavier for grounding to the case (preferably flat woven silver-plated copper braid).
3. If possible, route motor feedback and motor power cables in separate conduits or ductwork, separated by a minimum of 10 inches (25 cm).

3.8.3 Motors with Integral Fail-Safe Brakes

NOTE: **The integral fail-safe brakes supplied on M-Series , G-Series, H-Series and D-Series motors are intended for holding purposes (preventing the movement of a stopped motor) only and should not be used for braking a motor in motion. Using an integral fail-safe brake to stop a motor in motion may result in damage to the motor-brake unit.** An external brake should be used for fail-safe stopping of a motor in motion.

Motors with brakes require special cables; see **Table 18** (page **45**) for G-Series cable part numbers. Drawings for these cables are shown in Appendix E.

SAC-S2Dx drives have a high current output capability on OUT3’ and can directly drive many 24VDC brakes. IF the brake requires additional current or a different voltage an external relay is needed.

Figure 17 shows the recommended safety and fault interlock wiring for motors with fail-safe brakes when an external relay is required.

Figure 18 shows the recommended safety and fault interlock wiring for motors with fail-safe brakes when no relay is needed.

- When the main power contactor opens, the brake engages.
- When OUT3’ is asserted, the brake disengages. OUT3’ can be software configured to automatically control the brake when it needs to be engaged and disengaged. OUT3’ can also be manually turned on and off to disengage or engage the brake under the control of the application program. Refer to the application software Help and the Brake Output section of the Operation chapter (page 52) for further information.

Use a separate +24 VDC power supply for coil power from the machine I/O power supply!

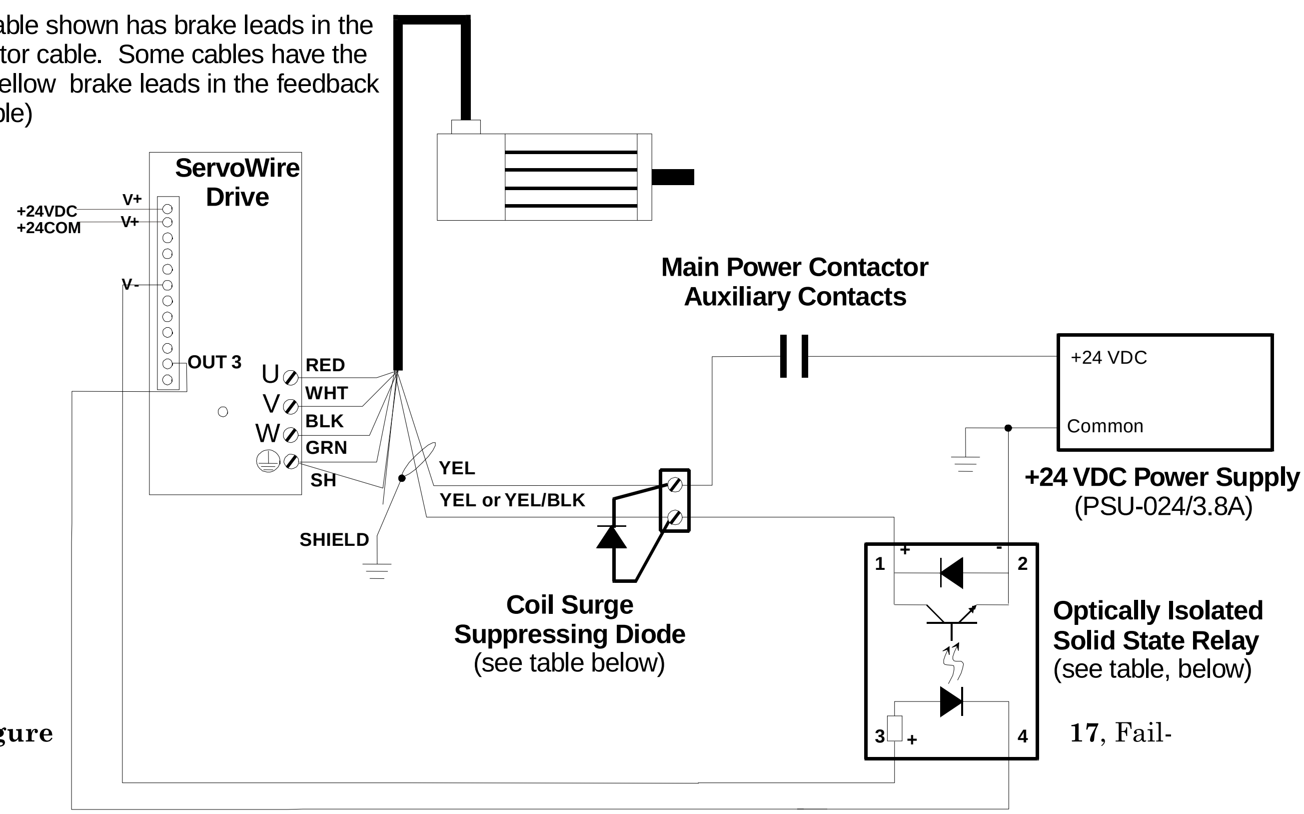


Figure **17**, Fail-

Safe Brake Interlock Circuit – with external relay.

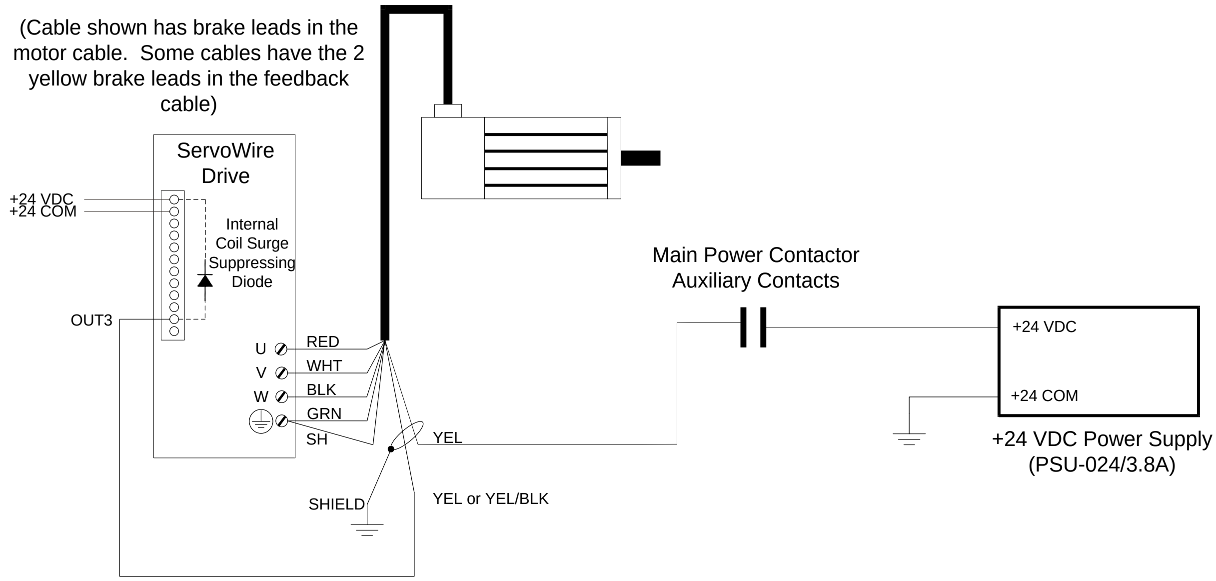


Figure 18, Fail-Safe Brake Interlock Circuit – no external relay required.

	ORMEC P/N	Manufacturer, P/N
Optically-IsolatedSolidState Relay	MIO-DC60S-3	Opto-22, DC60S-3
Coil Surge Suppressing Diode	SEM029	Motorola, MUR410

***Table 16**, Additional Components for use with Fail-Safe BrakeServomotor Connections*

3.8.4 G-Series Servomotor Connections

For G-Series motors without brakes, refer to the appropriate cable drawing(s) in Appendix E. The motor and encoder cable part numbers and page numbers are shown in **Table 17** (motors without brakes) and **Table 18** (motors with brakes).

MAC-G Motors Without Brakes	Motor Power Cable	Motor Encoder Cable
G005, G010, G006, G011, G015,G019 with SAC- S2D_203 – S2D_215	CBL-GMSW1 (p D-3)	
G016, G030, G040, G055, G080, G115 with SAC-S2D_203 – S2D_215	CBL-GMSW2 (p D-4)	CBL-GMSW (1-50 ft: p D-1) (51-150 ft: p D-2)
G130 & G210 with SAC-S2D_210 – S2D_215	CBL-GMSW3 (p D-6)	

***Table 17,** Cable Drawings for G-Series Motors **Without** Brakes*

For G005, G006, G010, G011, G015 and G019 motors, the brake leads are in the combined power/feedback cable.
For G016, G030, G040, G055, G080, and G115 motors, the brake leads are in the motor power cable.
For G130, G210, G280, G400 and G640 motors, the brake leads are in the motor feedback cable.

MAC-G Motors With Brakes	Motor Power Cable	Motor Encoder Cable
G005, G010, G006, G011, G015,G019 with SAC-S2D_203 – S2D_215	CBL-GMSWB1 (p D-3)	

G016, G030, G040, G055, G080, G115 with SAC-S2D_203 – S2D_215	CBL-GMSWB2 (p D-10)	CBL-GMSW (1-50 ft: p D-1) (51-150 ft: p D-2)
	CBL-GMSWBT2 (p D-11)	
G130 & G210 with SAC-S2D_210 – S2D_215	CBL-GMSW3 (p D-6)	CBL-GMSWB (1-50 ft: p D-8) (51-150 ft: p D-9)

Table 18*, Cable Models for G-Series Motors* ***With*** *Brakes*

3.8.5 D-Series Servomotor Connections

For D-Series motors without brakes, refer to the appropriate cable drawing(s) in Appendix E. The motor and encoder cable part numbers and page numbers are shown in **Table 19** (motors without brakes) and **Table 20** (motors with brakes).

MAC-D Motors Without Brakes	**Motor Power Cable**	**Motor Encoder Cable**
DE003, DE006, DE008, DE011, DE021, DE042 with SAC- S2D_203 – S2D_215	CBL-DEMSW1 (p E-1)	CBL-DMSW (1-50 ft: p F-1) (51-150 ft: p F-12)
DA030, DA055, DB025, DB055, DB080 with SAC-S2D_210 – S2D_215	CBL-DMSW1 (p F-3)	

Table 19, *Cable Models for D-Series Motors* ***Without*** *Brakes*

MAC-D Motors With Brakes	**Motor Power Cable**	**Motor Encoder Cable**
DE003, DE006, DE008, DE011, DE021, DE042 with SAC- S2D_203 – S2D_215	CBL-DEMSWB1 (p E-1)	CBL-DMSW (1-50 ft: p F-1) (51-150 ft: p F-2)
DA030, DA055, DB025, DB055, DB080 with SAC-S2D_210 – S2D_215	CBL-DMSWB1 (p F-5)	

Table 20*, Cable Models for D-Series Motors* ***With*** *Brakes*

3.8.6 H-Series Servomotor Connections

Serial encoder support requires S2D Servo Drive with the “S” option.

MAC-D Motors Without Brakes	**Motor Power Cable**	**Motor Encoder Cable**
HA003, HA055, HB025, HB055, HB080, HB100	CBL-HMSW1	CBL-HMSW (1-50 ft: p G-1) (51-150 ft: p G-5)
HA110, HA140, HB200	CBL-HMSW2	
HB300	CBL-HMSW3	
HA90	CBL-HMSW4	
HB330, HB465	CBL-HMSW5	
HB700	CBL-HMSW6	
HE003, HE006, HE011, HE021, HE042	CBL-HEMSW1	CBL-HEMSW (1-50 ft: p G-3) (51-150 ft: p G-2)

Table 21, *Cable Drawings for H-Series Motors* ***Without*** *Brakes*

3.8.6.1 H-Series Motor Encoder Resolutions

Model numder		Raw encoder resolution	Motor Resolution using ORION	Motor Resolution using SMLC
MAC-HE003A/	2.8 lb-in, 5000 RPM max, 115 VAC	**13-bit**	8,192	8,192
MAC-HE006A/	5.6 lb-in, 5000 RPM max, 115 VAC			
MAC-HE003B/	2.8 lb-in, 5000 RPM max, 230 VAC			
MAC-HE006B/	5.6 lb-in, 5000 RPM max, 230 VAC			
MAC-HE011B/	11 lb-in, 5000 RPM max, 230 VAC			
MAC-HE021B/	21 lb-in, 5000 RPM max, 230 VAC			
MAC-HE042B/	42 lb-in, 5000 RPM max, 230 VAC			
MAC-HA030B/	28 lb-in, 5000 RPM max, 230 VAC	**17-bit**	32,768 **	131,072 (17 bit)
MAC-HA055B/	56 lb-in, 5000 RPM max, 230 VAC			
MAC-HA090B/	87 lb-in, 5000 RPM max, 230 VAC			
MAC-HA110B/	112 lb-in, 5000 RPM max, 230 VAC			
MAC-HA140B/	140 lb-in, 5000 RPM max, 230 VAC			
MAC-HB025B/	25 lb-in, 3000 RPM max, 230 VAC	**17-bit**	32,768 **	131,072 (17 bit)
MAC-HB055B/	48 lb-in, 3000 RPM max, 230 VAC			
MAC-HB080B/	74 lb-in, 3000 RPM max, 230 VAC			
MAC-HB100B/	102 lb-in, 3000 RPM max, 230 VAC			
MAC-HB200B/	177 lb-in, 3000 RPM max, 230 VAC			
MAC-HB300B/	305 lb-in, 3000 RPM max, 230 VAC			
MAC-HB330B/	345 lb-in, 3000 RPM max, 230 VAC			
MAC-HB465B/	465 lb-in, 3000 RPM max, 230 VAC			
MAC-HB700B/	700 lb-in, 2000 RPM max, 230 VAC			

Note: **** Orion's MotionBASIC limits the counts per revolution to 32,768.
The full 17-bit resolution is unattainable when using an Orion Motion Controller.

3.8.7 DC Servomotor Connections

DC motors, voice coils and other actuators requiring single phase current output can be connected to pins U and V on the High Power Terminal Block (TB6 or TB11). The Custom Motor editor can be used to configure the Drive for use with a DC motor or single phase actuator, as well as for configuring the Low Bus Voltage fault trip point.

3.8.8 Coupling the Servomotor to the Load

Good alignment of motor and the driven machine is essential to prevent vibration, increase bearing and coupling life, and to prevent shaft and bearing failures.

With a direct drive application a torsionally rigid flexible coupling should be used. Timing belts and gearboxes are also commonly used in servo applications. Shaft loading should be kept to a minimum. The allowable shaft bearing loading is listed in the Specifications Section.

In either case, it is preferable to attach the coupling or pulley to the shaft with a clamping arrangement rather than transmit torque through the keyway, because of the reversing shock torque, which the Servomotor can generate. A number of mechanical approaches afford this type of attachment including tapered hubs, split hubs, ringfeder devices, etc.

Further information is available in ORMEC Tech Note #27 – Coupling High Performance Servos to Mechanical Loads, which is available from the ORMEC Web Site (www.ORMEC.com).

Chapter 4
Operation

4 Operation

4.1 Power On and Off Sequencing

Appendix A shows the recommended interlock approaches for both single and multiple axes. Features:

1) E-Stop interlocks

a) The recommended E-Stop switch is a maintained-contact red mushroom head push-button. This must be manually pulled out (reset) after it has been pressed (asserted). It should be powered by 115 or 230 VAC and must conduct current for the Servomotor to provide output torque.

b) The E-Stop Reset should be a momentary contact pushbutton. It must be asserted after all power is applied and the E-Stop switch is closed. It must be closed long enough for the Main Power contactor auxiliary contact (MP-AUX) to “pull-in”, so that the main power contactor coil circuit is energized.

c) If the E-Stop Switch is pressed (asserted), the main circuit power is disconnected and torque is prevented at the motor(s).

2) ServoWire Drive faults

a) If any fault condition occurs within a ServoWire S2D Drive, the main circuit power is disconnected because the Drive Ready (OUT4’) signal is unasserted and the customer supplied relay contact in the main power contactor coil circuit opens. In this case, the ServoWire S2D Drive ID/Status display will indicate the fault code. **For the operation described above, OUT4 must be configured for operation as the Drive Ready output in the configuration software.** Refer to 4.3.2 for further information.

To reset a High Bus Voltage Fault, the main input power must be disabled long enough for the power capacitors to discharge to a level below the High Bus Voltage Fault limit.

To reset a Motor Over Temperature Fault, the motor must be sufficiently cool. The application program can clear all other fault conditions.

All fault conditions, including E-Stop, must be cleared before motor power can be restored. The E-Stop Reset push-button must be depressed long enough for all the drive power supplies to charge and the Drive Ready (OUT4') Relays to pull-up again.

b) If the E-Stop switch is pressed or another ServoWire S2D Drive in the system experiences a fault, the drive discrete input IN3 will be unasserted. This will cause the drive to either disable the output or command zero utput (hold position, zero velocity or zero torque), depending on how the drive is configured. **For the operation described above, IN3 must be software configured for E-Stop or Quick Stop operation.**

4.2 Discrete Inputs (IN1', IN2', IN3', IN4'/OUT4')

There are four optically isolated discrete inputs, IN1' through IN4'.

* Note: Input # 4 is Bi-directional and shares the same pin with Output # 4. See: I/O Schematic, Figure 11 (Page 38).

These inputs are available for use by the application program as general-purpose inputs, or can be configured as Hardware Travel Limits inputs and/or E-Stop/Quick Stop input. Refer to your application program documentation to determine how the Discrete Inputs are being used.

4.2.1 Hardware Travel Limits (IN1', IN2')

Discrete input IN1' and/or IN2' can be software configured to operate as Hardware Travel Limits (HTL). IN1' is assigned HTL Forward. IN2' is assigned HTL Reverse.

If a servo is in position, velocity or output mode and its Hardware Travel Limit is asserted, then its commanded motion will be stopped, and a motion error will be generated. The HTL must be reset before any motion can be commanded to move off and away from the limit. Once the limit hardware has cleared and the HTL input is conducting current, then the software variable can be successfully cleared. Motion is then allowed in the direction of the HTL.

4.2.2 E-Stop Input (IN3')

Using ServoWire Pro, Discrete input IN3' can be software configured to operate as an E-Stop input. When unasserted, this input causes the servodrive to generate a drive fault and disable output power to the motor, as well as generating a fault callback in the application program. Refer to Appendix A-1 for a diagram of how this input is connected to the machine E-Stop interlock circuit.

4.2.3 Quick Stop Input (IN3')

Using ServoWire Pro, Discrete input IN3' can be software configured to operate as a Quick Stop input. Unasserting IN3' in this mode generates an alarm callback in the application program and has the effects indicated in Table 22. They are dependent on the axis mode (torque, velocity or position), as configured in ServoWire Pro (Axis Settings, Drive Input). Refer to Appendix A-1 for diagram of how this input is connected to the machine E-Stop interlock circuit.

Drive Input (Mode)	Quick Stop Operation
Torque	Generates an alarm callback in the application program. Output remains enabled and the drive continues to receive torque commands. This allows the motion controller to decelerate the load under control.
Velocity/Position	Generates an alarm callback in the application program. Output remains enabled; zero speed is commanded[1]. Commanding zero speed may result in a commanded current to bring the motor to a stop. When the drive is configured to use IN3 as a Quick Stop input, missing phase detection is disabled when IN2 is unasserted.

***Table 22**, Quick Stop Operation*

4.3 Discrete Outputs (OUT1' – OUT5')

* Note: Output # 4 is Bi-directional and shares the same pin with Input # 4. See: I/O Schematic, Figure 11 (Page 38).

There are five optically isolated discrete outputs, OUT1' through OUT5'. These outputs are available for use by the application program as general-purpose outputs, or

(OUT3') can be configured as a Brake Control Output,

(OUT4') can be configured as a Drive Ready Output,

(OUT5') can be configured as a Feedback Encoder Reference Output.

Refer to your application program documentation to determine how the Discrete Outputs are being used.

[1] The drive may command current as necessary to maintain zero velocity.

4.3.1 Brake Control or Phased Sensor (Delay counter) Output (OUT3')

Discrete output OUT3' can be software configured to operate as a Brake Output for controlling a motor fail-safe brake. When asserted, this output can be used to supply power to the coil of a motor fail-safe brake, keeping the brake disengaged and allowing motor motion. Figure 17 is a diagram of how this output is connected to a fail-safe brake interlock circuit.

The user can configure the delay time between enabling motor power and releasing the fail-safe brake, as well as the delay time between engaging the fail-safe brake and disabling motor power. This is a very useful feature when controlling vertical loads, it allows holding torque to be enabled before the brake is released and vice versa. Figure 19 is a diagram of the Brake Output sequence of operation and the configurable delay parameters.

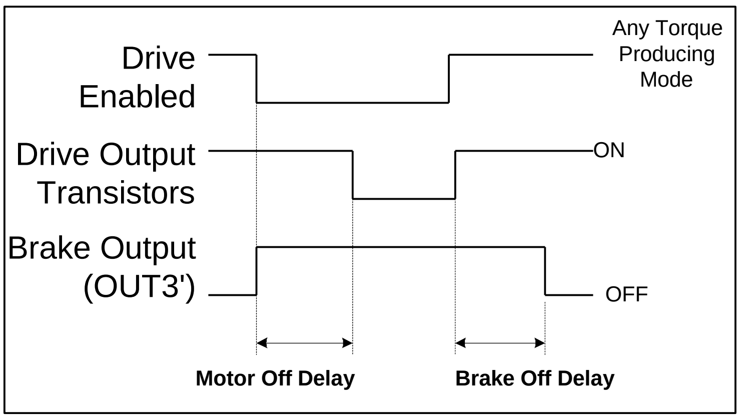


***Figure 19**, Brake Output Sequence of Operation*

If the Sensor Phasing option is installed, this output can be used to signal external circuitry that a delay counter terminal count has been reached. See 4.9 Sensor Phasing Option for details.

4.3.2 Drive Ready Output (OUT4')

Discrete output OUT4' can be software configured to operate as a Drive Ready Output. When asserted, this output indicates that the servodrive is operating without any faults and the main bus is charged. Appendix A-1 is a diagram of how this output is connected to the machine E-Stop interlock circuit.

A limit of 32 drives can be connected in series when configured as Drive Ready.

4.3.3 Encoder Feedback Zero Reference Output (OUT5')

Discrete output OUT5' can be software configured to operate as a buffered feedback encoder/resolver zero reference output. If no feedback option module is present on the drive, the state of this output corresponds to the state of the feedback (J4) zero reference signal. If one or more feedback option modules is present, the configuration software can be used to specify which reference signal's state will be indicated by OUT5'.

4.4 Status Indications

The servodrive status indication consists of a 2-digit 7-segment LED display (ID/Status), several individual LEDs indicating the status of the I/O points and a yellow LED indicating bus power.

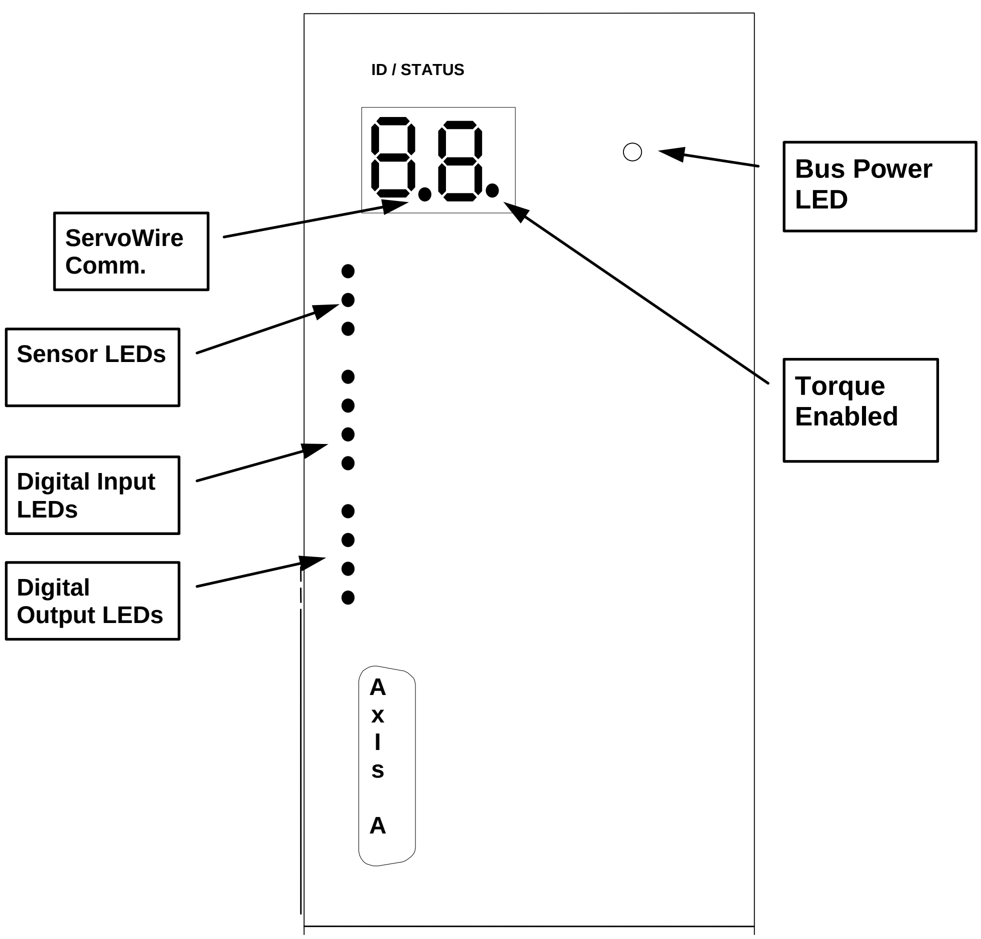
If a fault condition (except for auxiliary encoder open wire ***F2***) is present on the ServoWire S2D Drive, the output transistors are disabled. An appropriate fault code is displayed on the ID / Status display. The control power should be maintained in case of a servodrive fault. This allows the status indicators to display the unit's status until the cause of the fault is determined.

If any wiring changes are necessary, turn off the control and main power circuits to avoid possible shock then wait for the BUS POWER LED to go completely off.

Notes:

1. After the servodrive fault conditions have been corrected, the application program must reset the drive fault.
2. If the fault is due to the motor or drive being over temperature, the servodrive fault will not reset until the component has cooled down.

Figure 20*, ID/Status Indications*



4.4.1 ServoWire Communications (Middle Dot of ID/Status Display)

During normal operation (e.g. when there are no faults), the middle dot of the ID/Status Display flashes to indicate the state of ServoWire Network.

Slow Flash: (on for 1 second, off for 1 second) indicates that the drive is functional. ServoWire power is detected on the ServoWire cable, but there is no ServoWire communications.

Moderate Flash: (on for ½ second, off for ½ second) indicates that 1394 (ServoWire) communications are beginning and the drive is seeing cycle start activity on the Network.

Rapid Flash: (on for 1/8 second, off for 1/8second) indicates that ServoWire communications is functioning normally and the drive is sending and receiving Isochronous communications.

Solid On or Off: indicates a drive failure that is recoverable only by cycling control power. This should be reported to the ORMEC Customer Service Dept.

4.4.2 Torque Enabled (Right lower dot of ID/Status Display)

Off: indicates that torque is not enabled at the motor.
On: indicates that torque is enabled at the motor.

4.4.3 24VDC Power (Yellow LED above TB6)

Illuminates to indicate 24VDC power is present. For drives ordered with AC control power it indicates that the drive is on and that 24 VDC output power is available. On drives ordered with DC control power the LED indicates that 24V is applied to the drive.

4.4.4 Bus Power (Yellow LED above TB7 or TB1)

Illuminated to indicate that the bus power supply voltage is greater than approximately 24 VDC.

4.4.5 Sensor Status LED (to the side of TB4)

Illuminates to indicate that the sensor connection is sinking current. In the case of a sensor configured for PNP operation illumination does not indicate that the sensor is active. The third LED in this section indicates that Sensor/IO power is applied (i.e. a voltage is applied between V+S and V-S).

4.4.6 Digital Input LEDs (to the side of TB5 Inx positions)

Illuminated to indicate that there is current in the digital input. For most operation this indicates that the input is on.

4.4.7 Digital Output LEDs (to the side of TB5 OUTx positions)

Illuminated to indicate that the digital output is turned on.

4.4.8 Axis ID and Fault ID

When no drive alarms exist, the ID/Status will display the Drive ID, e.g. 1, 2, etc. When a drive alarm exists, the ID/Status display will alternate between the

Drive ID and the alarm code (shown on the next page in **Table 23, ServoWire S2D Drive Fault** Codes.

Some errors have extended codes consisting of the general number followed by an _n (underscore <value>). Extended error codes aid in diagnosing a problem and are listed and explained in Section **7.2**, **ServoWire S2D Drive Troubleshooting** Guide (page **94**).

There is a more detailed table of fault codes, which shows cause-and-effect for many of these faults in Section **7.2**, **ServoWire S2D Drive Troubleshooting** Guide (page **94**).

A Drive ID that is flashing alone (no alarm code) indicates two ServoWire Drives with duplicate axis IDs on the same Controller. If the controller is an Orion controller then the duplicate axis ID may belong to a pacer axis (ID = one less than the displayed Drive ID).

With one exception(fault ***F2***, Auxiliary Encoder Open Wire), all drive faults cause torque to be disabled at the motor.

Drive faults ***90 – 99*** and ***9A-9F*** may require cycling control power to clear the fault. The application program can clear all other faults (after the cause of the fault has been cleared).

Drive faults ***C0-CF*** are generated by the motion engine in the SMLC and then displayed on the drive. Refer to the online help accessed from ServoWire Pro Help for help in identifying and resolving these fault conditions.

Drive Fault Indicator[1] [1]	**Fault Code**	**Condition**	**Description**
70-7F *90-9F*	112-159	Internal Drive Error	Internal errors may require cycling the drive control power to clear the fault. If the problem recurs or does not clear, contact ORMEC Support at **(585) 385-3520** or via e-mail at **support@ormec.com**. Please have your Support ID available when you call or reference it in your e-mail message.
90	144	Internal Drive Error	This fault is normal during ServoWire 1394 network cable pulls.
9C	156	Power board support Error	Indicates that the firmware loaded does not support the power level of the drive. Load newer firmware to correct.
70	112	Axis offline	The drive has lost communications
71	113	Reference generation conflict	Internal error
72		*Not used*	
73		*Not used*	
74	116	Unsupported feedback device	The drive firmware does not support this feedback device type
75	117	Tension Max	Tension has reached the OP_TEN_MAX limit
76	118	Tension Min	Tension has reached the OP_TEN_MIN limit
77-7F		*Not used*	
A0	160	Drive RMS Over Current	The actual RMS current has exceeded the drives rated continuous current longer than the allowed time (2 seconds at peak current).
A1	161	Peak Over Current	The peak current rating for the drive was exceeded.
A2	162	Power Module Fault	The Power Module's self-protection has detected a short circuit, over current, over temperature or control supply under voltage. – **or-** An SCR soft-start circuit error has been detected (SAC-S2D_225, S2D_235 &S2D_260 only).
A3	163	Low Bus Voltage	The bus voltage is below the low voltage limit, which is calculated based on the Drive Input Voltage specified in the configuration software.
A4	164	High Bus Voltage	The bus voltage is above the high voltage limit, which is calculated based on the lessor of the motor rated voltage (as specified in software) and the drive maximum voltage.
A5	165	Drive hardware and configuration software mismatch.	The drive type or drive options does not match the software configuration settings. The application program has detected that the drive hardware does not match software configuration settings.
A6	166	Drive Not Configured	An attempt was made to enable torque before the drive's setup parameters have been configured. The drive setup parameters must be configured each time the drive's control power cycles on, before the drive can be enabled.
A7	167	Illegal While Drive Enabled	An attempt was made to configure a drive parameter while the drive was enabled.

[1]*Also see Section 7.2, ServoWire SD Drive Troubleshooting*

Drive Fault Indicator[1] [1]	Fault Code	Condition	Description
A8	168	Invalid Commutation Position	An invalid commutation position was detected, possibly due to a discharged absolute encoder, or an encoder failure encoder. (See **ServoWire S2D Drive Troubleshooting** Guide, Fault Code ***A8***)
A9	169	Phase Loss	The drive detected the loss of a main power phase or a soft-start error.
AA	170	Soft Start Error	Inrush current greater than 0.5 amps or a low bus voltage (<50 VDC) was detected when attempting to enable the drive (this is only checked when enabling a drive).
Ab		*Not Used.*	
AC	172	Drive Over Temperature	An over-temperature condition was detected in the drive powerblock, or a failure of the inrush current resistor.
Ad	173	E-Stop	A drive emergency stop was detected. This requires that the drive be configured to use one of the general-purpose inputs as E-Stop input.
AE	174	Software upgrade.	**SAC-S2DM Drive**, SMLC or MotionObjects fault: Host PC driver software upgrade is required.
AF		*Not Used.*	
B0	176	Checksum error	The checksum on the downloaded code was incorrect. The download has been aborted. Try again.
B1	177	Bad file	The download code was not recognized. The wrong file was used. The drive firmware may be too old to recognize this format.
B2	178	Firmware not compatible	The downloaded code is not designed for this drive hardware, but rather for different drive hardware. Obtain the correct file and try again.
B3	179	Firmware Checksum error	Internal firmware program checksum error. Reload drive firmware.
C0	192	Lag Fault	The position following error exceeded the maximum amount configured using ServoWire Pro.
C1	193	Command Overspeed	The commanded speed exceeded the software configured axis speed limit.
C2	194	Actual Overspeed	The actual (feedback) speed exceeded the software configured axis speed limit.
C3	195	Hardware Travel Limit	Motion was commanded into a hardware travel limit while the limit was still active.
C4		*Not used*	
C5	197	Loop Rate Exceeded	The available loop update time was insufficient to complete the loop processing
C6	198	Missing MotionData	The MotionData from the master axis is not available.
C7	199	Motion Segment overflow	
C8	200	Missing Motion table	
C9	201	Unexpected Offline	The SMLC is not receiving isochronous feedback from the drive.
CA	202	1394 Driver failure	The 1394 driver is no receiving its once-per-looprate update information from the 1394 bus driver.
Cb	203	Pacer Backup Overflow	The pacer axis backed up far enough to overflow the backup compensation.
CC	204	Invalid MotionDataConfig.	The MotionData is configured in a loop, which is not valid.
CD-CF		*Not used*	
D0-DF		*Not used*	

Drive Fault Indicator[1] 1	Fault Code	Condition	Description
E0	224	ServoWire Protocol Incompatibility	The ServoWire communications protocol in the drive is not compatible with the one used by the motion controller or PC.
E1	225	ServoWire Timeout	1394 network power loss (Host PC power lost or PC re-booted) or isochronous communications were lost. Example: Torque commands from the Orion Motion Controller or Host PC are missing.
E2	226	Isochronous Arbitration Failure	One possible cause is that the Loop Rate is set too high to allow all the drives on the 1394 network to send their isochronous data packets. Lower the Loop Rate.
E3	227	ServoWire Watchdog Timeout	The ServoWire isochronous communications watchdog bit has not changed state within the allotted time.
E4	228	ServoWire Initialization Error	A hardware error was detected when initializing the IEEE 1394 communications controller circuitry.
E5	229	Drive Watchdog Timeout	The drive internal watchdog has timed out due to either the loss of ServoWire network power (usually due to loss of PC power) or an unexpected failure.
E6	230	No ServoWire Network Power	The drive is not detecting the 8-40 VDC on the ServoWire cable. No communication is possible until this is corrected. The error will automatically clear itself when ServoWire power is applied.
E7		*Not Used*	
E8	232	Duplicate Drive ID	The host has detected more than one drive with the same Axis ID. All the drives with duplicate IDs should be displaying this error.
F0	240	Motor RMS Over Current	The motor's rating for continuous current has been exceeded by the actual RMS current for longer than allowed by the thermal time constant of the motor. (Software configuration setting)
F1	241	Motor Encoder Open Wire	At least one motor encoder feedback channel (ENCA, ENCA', ENCB, ENCB') is not connected properly. (J4 pins 1,2,3,4)
F2	242	Auxiliary Encoder Open Wire	At least one channel (AUXENCA, AUX ENCA', AUXENCB, AUXENCB') is not connected properly.
F3	243	InvalidHallState	The hall track feedback from the motor is improperly wired. This fault can also occur if the feedback type in the drive configuration software has been improperly identified.
F4	244	Motor Over Temperature	Open contact at J4 pins 19-20. See Section**4.11.6**, page Error! Bookmark not defined. or **Table 13**
F5	245	Unknown Option Board	The drive has detected an option board installed, but does not recognize or support this board.
F6	246	OvertempConfig. Error.	The motor configuration indicates that there is no over temperature sensor, but an over temperature sensor was detected by the drive.
F7	247	Serial Encoder Alarm.	An alarm bit has been returned by the Sigma 2 encoder.
F8	248	Unsupported Serial Encoder detected.	Unsupported encoder feedback type **- or –** Not supported by the drive firmware

***Table 23**, ServoWire S2D Drive Fault Codes (continued from previous page)*

4.5 Commutation Modes

By default, ServoWire S2D Drives are configured to control permanent magnet brushless DC servomotors using sine wave commutation. A commutation signal is needed at initial startup to determine motor orientation. Serial encoders have this information in serial data. With absolute encoders and resolvers the information is derived from the absolute position and the Hall Offset value. Quadrature encoders must provide the commutation information using the Hall inputs, U, U', V, V' and W, W'.

4.6 Commutation Feedback Signals – Quadrature Feedback sources

With quadrature feedback sources the drive can be configured for trapezoidal commutation of brushless motors or DC output for brush motors using the configuration software. This can be useful when integrating third party motors or when controlling motors other than DC brushless servomotors.

Commutation position signals are illustrated below.

The U, V and W signals are "on" for 180° spaced 120° apart and allow the Drive to determine motor position for commanding current. These signals are used to determine rotor position whenever the Drive is operating in trapezoidal commutation mode.

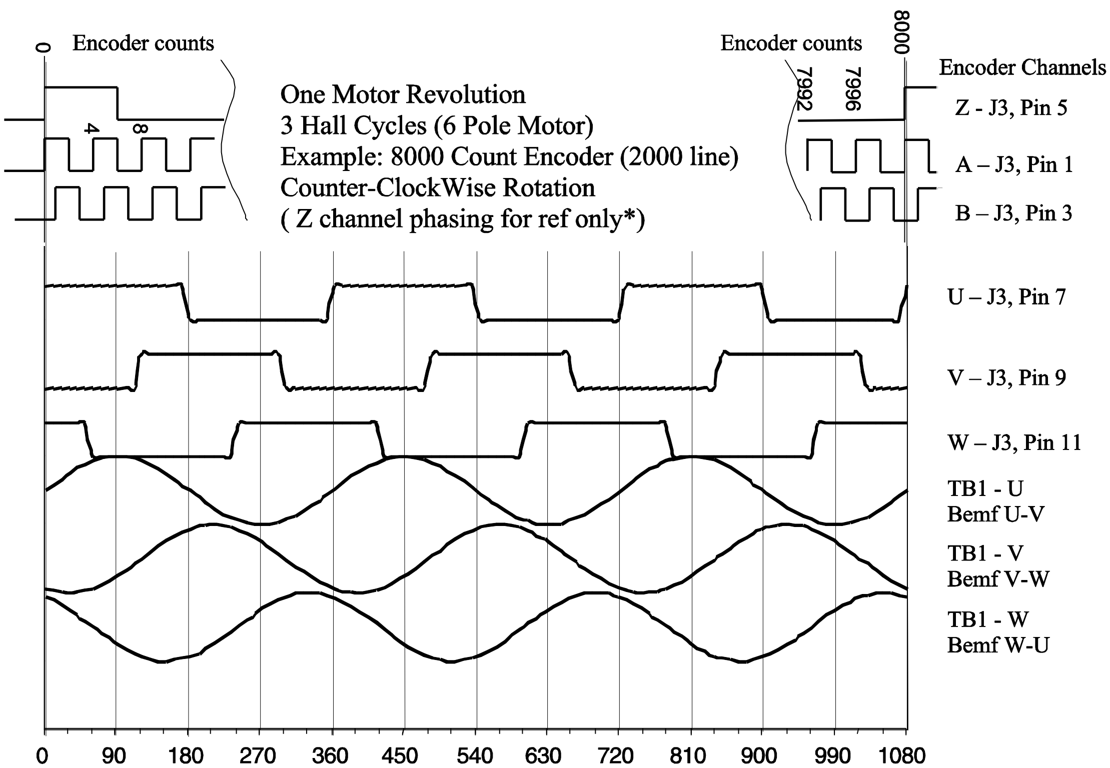


Figure 21, Hall signals and Motor Back EMF waveforms

If the motor's back EMF and commutation signals are not directly in phase, the Hall Offset parameter can be used to compensate for the offset.

4.7 ServoWire Drive Commutation Feedback (HallSignals)

NOTE: For the below procedure to work, the encoder must have hall support by providing integrated HALL data tracks. Resolver motors & Serial encoders (Sigma II) do not have hall support.

Using ServoWire Pro (SMLC)

The state of the commutation signals can be displayed using the Monitor utility in ServoWire Pro. To verify that the commutation feedback is correct, rotate the motor shaft clockwise or counter-clockwise and confirm that the Hall sensors proceed through the sequence indicated in this table.

Counter Clockwise Rotation			Clockwise Rotation		
W	V	U	W	V	U
1	0	1	1	0	0
0	0	1	1	1	0
0	1	1	0	1	0
0	1	0	0	1	1
1	1	0	0	0	1
1	0	0	1	0	1
Note: Clockwise and Counter Clockwise shaft rotation refers to rotation when viewing the end of the motor shaft					

***Table 24**, Valid Hall Signal Sequences*

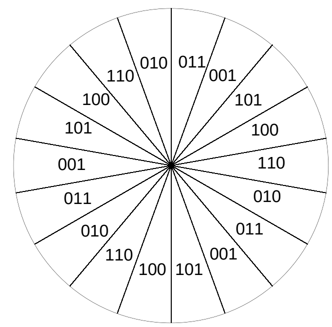


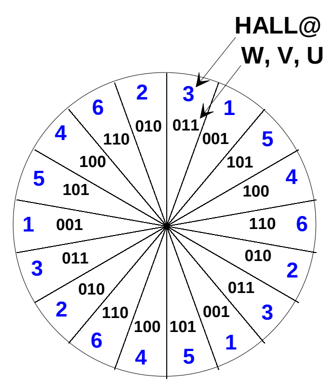
***Figure 22**, ValidHallStates (6 Pole Motor Example diagram)*

Using MotionDESK (Orion)

The state of the commutation signals can be displayed using the HALL@ MotionBASIC variable and the table below. To verify that the commutation feedback is correct, " **REPEAT PRINT HALL@(*AxisNumber~*)** ", rotate the motor shaft clockwise or counter-clockwise and confirm that the HALL@ value proceeds through the sequence indicated below. Refer to the MotionBASIC Help HALL@ variable section for further details.

Counter Clockwise Rotation		Clockwise Rotation	
W, V, U	HALL@	W, V, U	HALL@
101	5	100	4
001	1	110	6
011	3	010	2
010	2	011	3
110	6	001	1
100	4	101	5
Note: Clockwise and Counter Clockwise shaft rotation refers to rotation when viewing the end of the motor shaft			

Valid HALL@ Sequence



Valid Hall States (6 Pole Motor Example diagram)

4.8 Quadrature Feedback Signals

Quadrature position signals for "Forward" and "Reverse" travel are illustrated in **Figure 23**.

Channel A and Channel B are phase quadrature signals, which allow the Servodrive and associated digital positioning electronics to determine both travel distance and direction. The S2D drive decodes each transition of both encoder channels, yielding a resolution of four times the linecount specification per revolution e.g. A position encoder with 4096 linecount, when decoded by a ServoWire S2D drive yields a positioning resolution of 16,384 cnts/rev.

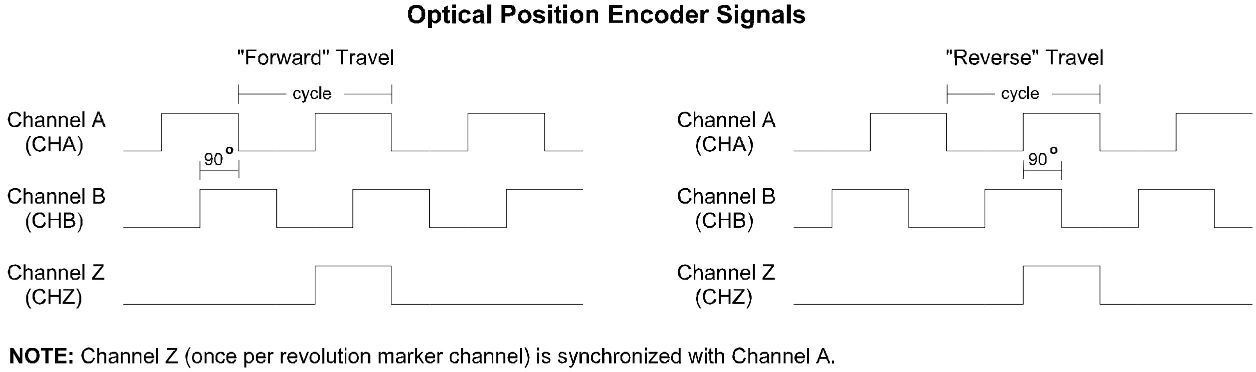


***Figure 23**, Quadrature Encoder Channel Description*

4.9 Sensor Phasing Option

Many applications trigger a motion on a sensor input. Typically detecting a mark on a web or the presence of a portion of the mechanism and then moving. Timing is dependent on the physical location of the sensor, which can be a challenge to mount. Fine mechanical adjustments can be difficult to achieve.

This drive option provides an electronic method to adjust the phasing of the sensor input. Extremely fine adjustments of the sensor input to action are possible without any mechanical changes, without physically moving the sensor. This makes it practical to fine tune machine registration or adjust for changes over time with ease.

In operation the sensor is received and the selected edge triggers a counter. The counter down counts to 0 and outputs a pulse which is directed to the internal sensor circuitry or can be brought to one of the drive outputs. The counter can be configured to count motion of the main motor, the pacer input or time. **Figure 24** shows a block diagram of the sensor phasing unit. This counter is labeled Delay Counter in the diagram and in references to phasing operation.

4.9.1 Operating Modes

Configuration is done using a function block in the SMLC. Once configured the output is used by selecting Delay as the start or stop condition on a motion definition. Sensor phasing modes include:

1. **One shot delay of sensor**. Delay output happens once for each execution of the configuration function block.
2. **Repeated delay of sensor**. Delay counter is automatically reloaded and rearmed when selected sensor occurs. Only one execution of the

function block is needed. Note: if the delay count is not reached before another sensor occurs there will be no output from the previous sensor. The delay counter is reloaded and begins counting down again when the second sensor occurs.

3. **Measure distance between 2 sensors**. Configure for sensor 1 to load a large count and begin counting. Configure stop counting on sensor 2. After sensor 2 occurs the delay counter value can be read and the distance calculated.
4. **Measure width of a sensor**. This is similar to measuring the distance between 2 sensors. Configure start on one edge of a sensor and stop on the other edge of the same sensor.
5. **Count the number of sensors**.
6. **Timed delay of sensor**. This is the same as other modes except delay is in usec rather than distance. Note: time delay is generally not used with variable speed webs because a fixed time results in a different distance as web speed changes.

4.9.2 Description

The main part of the sensor phasing unit is a Delay Counter. This counter is used to shift the sensor in time or position.

The delay counter is a 24-bit counter, allowing delays up to 16,777,216 units. The counter is loaded with the delay value and always counts down to 0. At 0 an output pulse is generated. The delay counter configuration choices include:

1. **Count source**: quadrature feedback from motor connector (J4), quadrature feedback from pacer connector (J5), sensor A or B and a 1 MHz clock.
2. **Count direction**: count down for forward or reverse motion. This allows the delay counter to work with motion in either direction while the counter is always counting down.
3. **Backup compensation**: The counter will count up for motion in the opposite direction. Then count down when the direction changes back. This prevents double counting of the desired direction. Note, if the backup causes the counter to reach the maximum value and wrap around the output will be incorrect.
4. **Start condition**: start counting on either sensor A or B and either rising or falling edge.
5. **Stop condition**: stop counting on either sensor A or B and either rising or falling edge.
6. **Load or reload condition**: manually load the counter, automatically reload on terminal count or sensor.

The output pulse of the delay counter is always available for motion conditions. In addition the pulse can be directed to OUT3 of the drive. This allows the pulse (the rephrased sensor) to be used by other drives or equipment.

The sensor phasing units are optional in the drive and must be selected when the drive is ordered. Feedback selection D in the model number is required. One phasing unit and one delay counter is included. If the Pacer option is also selected a second sensor phasing unit and delay counter are included.

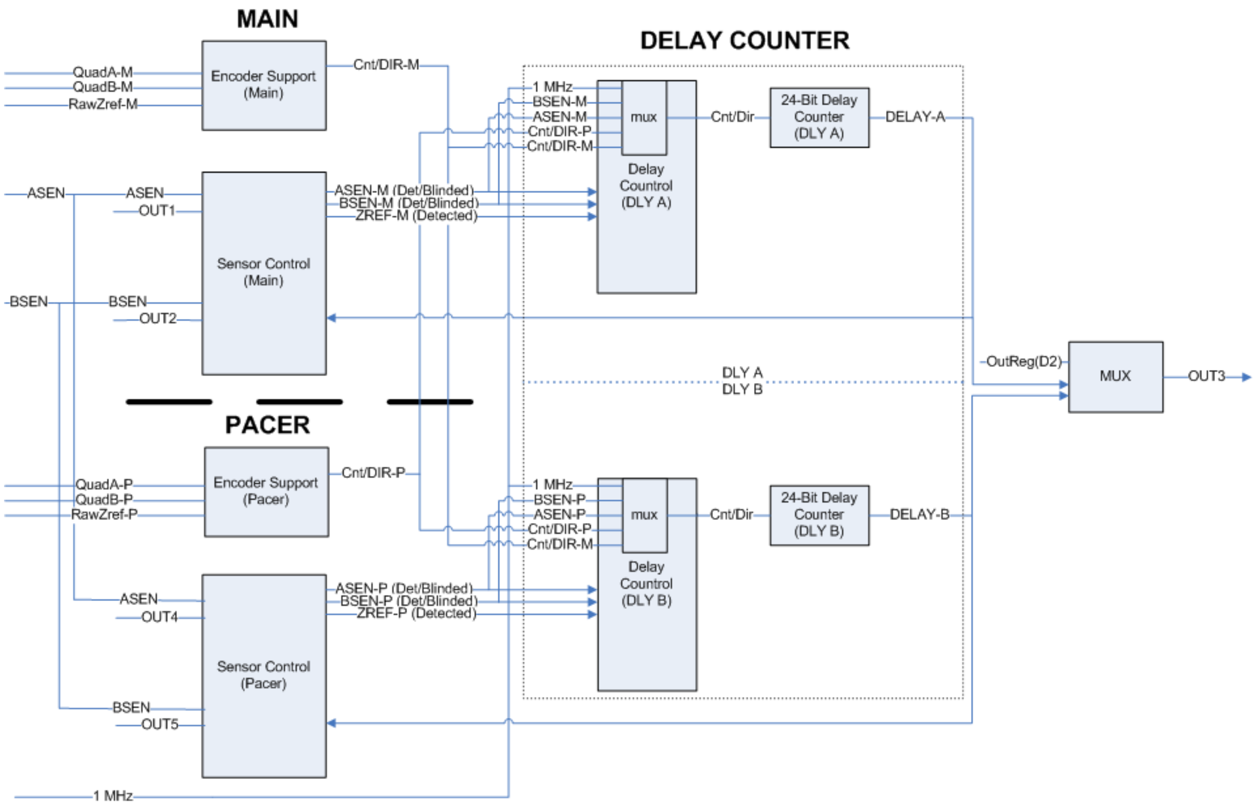


Figure 24, *Sensor phasing – Delay Counter Block Diagram*

4.10 Commutation Feedback Signals – Resolver Feedback drive

Configuration of the drive for a resolver is done using ServoWirePro. Some parameters are motor specific and found in the motor properties definition. Some parameters are drive specific and found on the drive properties page, feedback tab.

A resolver is a position feedback device found on many motors. A resolver works by receiving a reference sine wave of a given frequency and amplitude. The resolver then couples this like a transformer into two other windings, SIN and COS, which are 90 degrees apart. The SIN and COS signals are returned to the drive where they are decoded and the position determined.

There are design variations in resolvers which may need to be compensated. ServoWirePro will help you configure the servodrive for your specific resolver. The servodrive has adjustments for:

- Excitation frequency – the frequency of the reference signal. Some resolvers won't handle high 63requencies. As the frequency changes, the impedance of the resolver changes and the ability of the resolver to couple the signal to the output windings changes. In some cases this becomes so low that the resolver does not output a sufficient signal. As the impedance goes down the current in the reference signal increases. Higher current causes higher voltage drop. As long as it is within the limits of the drive the system works.

- Transformation Ratio – the gain of the resolver reference in to SIN and COS out can vary. This typically ranging from 0.5 to 2. The servodrive expects SIN and COS to be 3 Vrms. The servodrive can be configured to meet this requirement for transformation ratios of 0.25 to 2.

The REF signal is provided by the drive and sent to the resolver. The SIN and COS signals are returned and are spaced 90^{o} apart and allow the drive to determine motor position for commanding current.

If the motor back emf and commutation signals (SIN & COS) are not directly in phase, the feedback offset parameter can be used to compensate for the offset. The drive requires that the SIN and COS signals be phased such that the POS command returns an increasing value when the motor is rotated counter-clockwise as viewed from the shaft end. If the POS value is decreasing, reversing the SIN and COS pairs will usually help. The signals labeled SIN and COS by the motor manufacturer do not always have the same phasing from manufacturer to manufacturer.

4.11 Regenerative Loads

Regenerative loading occurs when the direction of power flow is from the machine to the motor: the motor is acting as a generator. Another way of describing this is that the load torque is acting in a direction to 'help' the motor to move in the commanded direction of motion. This can occur for a variety of reasons including:

1. Decelerating the machine faster than it would coast, especially from high speeds and with large inertial loads;
2. Using the motor to act as a brake on an unwind stand for a roll of material, where the tension in the web causes the motor to brake while moving forward; or
3. Using the motor to lower a vertical load that is not counterbalanced.

In many cases, this extra energy is dissipated by machine friction, or stored temporarily in the drive's power capacitors. However, if the amount of regenerative energy is excessive, it must be shunted to an external regenerative resistor, in order to prevent a high bus voltage condition. For assistance determining if your application has a regenerative load component, contact your ORMEC Sales and Applications Engineer.

4.11.1 Shunt Regulator

ServoWire S2D Drive models have shunt regulator circuitry for dissipating excessive regenerative voltage. The circuitry is optional on models SAC-S2D_203, SAC-S2D_205, SAC-S2D_210, SAC-S2D_215.

The shunt regulator consists of a voltage comparator and a switching transistor. When the voltage comparator detects excess bus voltage, it turns on the shunt regulator transistor, dissipating energy from the servodrive capacitors to the external regen resistor. The ServoWire S2D Drive controls the on-time duty cycle, so that the average current is appropriate for the regen resistor specified in the project software setting.

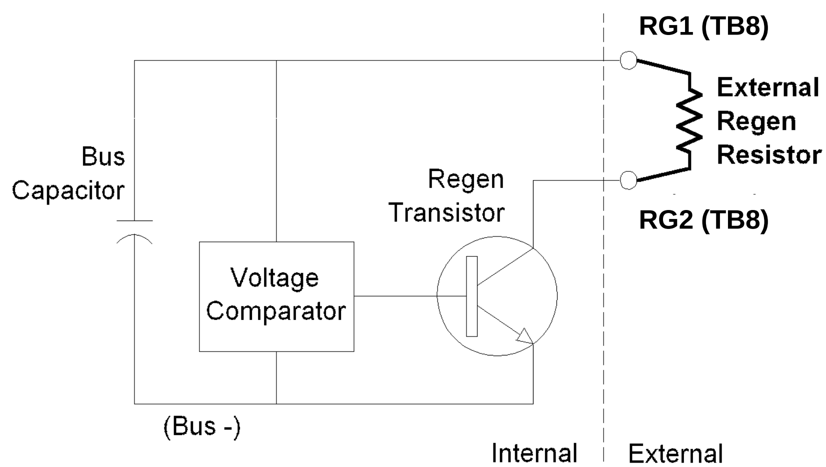


Figure 25, *Simplified Schematic of Shunt Regulator*

4.11.2 Sizing a Regen Resistor: Application-specific Formulas

Regardless the application, the value of interest is **Average Regenerative Power**.

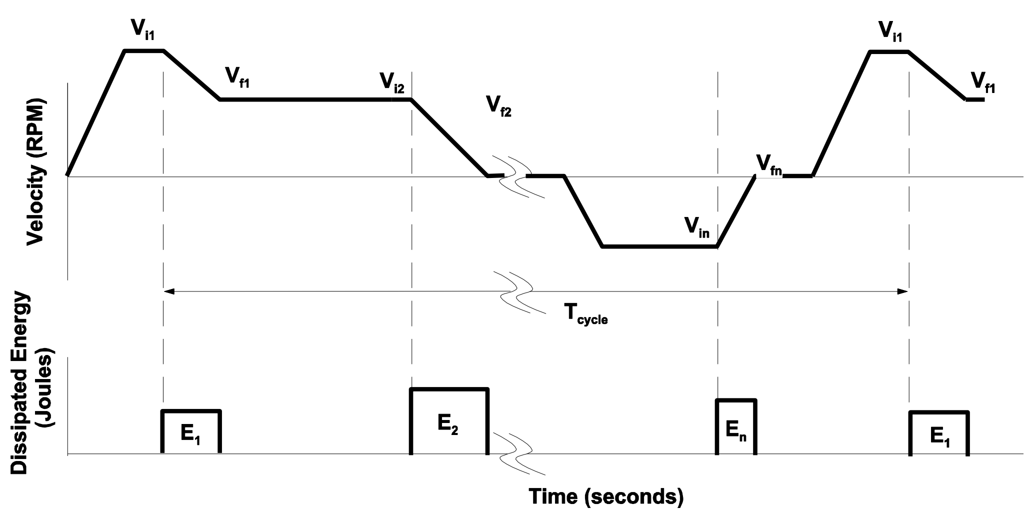


Figure 26, *Regeneration during deceleration.*

4.11.2.1 Sizing a Regen Resistor: Regeneration Due To Decleration

Regeneration during motor deceleration is due to the decreasing kinetic energy of the rotating inertia. Not all of this energy will make it back to the DC bus, some or all of it may be absorbed by machine friction and motor losses. In the case of sizing regen resistors, neglecting frictional losses is a conservative approach to sizing a regen resistor.

Each deceleration in a cycle results in a loss of kinetic energy at the motor. Depending on frictional losses, some or all of this energy may make it back to the drive as **Regenerative Energy**. Rotational kinetic energy at any velocity can be calculated with the general equation $E = \frac{1}{2} I\omega^2$. Applying the appropriate units conversions:

$$E_{regen} = \tfrac{1}{2} I \cdot (V_i^{\,2} - V_f^2) \cdot (0.00124) \qquad \textit{(Equation 1)}$$

where: E_{regen} loss of kinetic energy during a deceleration (Joules)
I total system inertia (motor + load) (in-lb-sec^2)
V_i initial speed of the motor before deceleration (RPM)
V_f final speed of the motor after deceleration (RPM)
(0.00124) is a unit conversion: $\frac{(2\pi rad/rev)^2 (4.448N/lb)(25.4mm/in)}{(60\sec/\min)^2 (1000mm/m)}$

Average Regenerative Power for the total cycle can be calculated as:

$$P_{avg} = \frac{E_1 + E_2 + E_n}{T_{cycle}} \qquad \textit{(Equation 2)}$$

where P_{avg} average dissipated power over the entire cycle (Watts)
E_1 energy dissipated by the 1st decel in the cycle (Joules)
E_2 energy dissipated by the 2nd decel in the cycle (Joules)
E_n energy dissipated by the Nth decel in the cycle (Joules)
N number of decelerations in the cycle
T_{cycle} total repetitive cycle time (seconds)

4.11.2.2 Sizing a Regen Resistor: Regeneration Due To Web Tension (motor acting as brake)

The regeneration in a tensioned web application is due to the web tension pulling the braking motor along in the same direction that it is moving.

Average Regenerative Power is calculated with the general formula: P = Tω. Applying the appropriate unit conversions:

$$P_{avg} = (0.0118) * T * V \qquad \textit{(Equation 3)}$$

where P_{avg} continuous regenerated power (Watts)
T torque at the motor due to web tension (in-lb)
V velocity of the motor shaft (RPM)
(0.0118) is a conversion: $\frac{(2\pi rad/rev)(25.4mm/in)(4.448N/lb)}{(60sec/min)(1000mm/m)}$

4.11.2.3 Sizing a Regen Resistor: Regeneration Due to Vertical Load

In an application where the motor is supporting the weight of a poorly counterbalanced load, regeneration may occur when the load is being lowered. This is due to gravity 'helping' the motor lower the load.

Instantaneous Regenerative Power can be calculated with the formula P = Tω. Applying the appropriate unit conversions:

$P_{instant} = (0.0118) * T * V$ *(Equation 4)*

where $P_{instant}$ instantaneous regenerated power (Watts)
T torque at the motor due to load weight (in-lb)
V speed of the motor during downward motion (RPM)
(0.0118) is a conversion: $\frac{(2\pi rad/rev)(25.4mm/in)(4.448N/lb)}{(60sec/min)(1000mm/m)}$

Average Regenerative Power for the total cycle can be calculated as:

$$P_{avg} = \frac{P_1 * T_1 + P_2 * T_2 + P_n * T_n}{T_{cycle}} \qquad \textit{(Equation 5)}$$

where P_{avg} is the average dissipated power over the entire cycle (Watts)
P_1 power dissipated by the cycle's 1st downward move (Watts)
T_1 time spent in the cycle's 1st downward move (seconds)
P_2 power dissipated by the cycle's 2nd downward move (Watts)
T_2 time spent in the cycle's 2nd downward move (seconds)
…
P_n power dissipated by the cycle's Nth downward move(Watts)
T_n time spent in the cycles Nth downward move (seconds)
n total number of downward moves in the cycle
T_{cycle} total repetitive cycle time (seconds)

4.11.3 Sizing a Regen Resistor: Use Average Regenerative Power

Once Average Regenerative Power has been determined using one of the methods in section 4.11.2, the sizing of the resistor is nearly complete.

The wattage of the regenerative resistor should be greater than or equal to the calculated Average Regenerative Power.

The next section shows the minimum resistance requirements, as well as additional limitations on the regen power that can be shunted. This is based on the ServoWire S2D Drive shunt transistor.

4.11.4 Sizing a Regen Resistor: Regen Transistor and Resistor Limitations

The amount of energy that can be dissipated by an external regen resistor may be limited by the current capability of the switching transistor.

Table 25 shows 1) the mimimumregen resistance allowed, 2) the resulting current at that resistance and 3) the maximum average regen power capability of the drive.

NOTE: **Do not use a lower resistance than shown in the table! Too low a resistance may result in peak currents that are too high for the regen transistor and could result in damage to the transistor.**

	Regen Resistor	**Drive Regen Power Output**	**Regen Transistor**
ServoWire Drive	**Minimum Resistance**(1)	Maximum Average Power(3)	Peak Current(2)
SAC-S2D_203 SAC-S2D_205	50 Ω	700 W	8.5 A
SAC-S2D_210 SAC-S2D_215	40 Ω	1000 W	10.6 A
SAC-S2D_225	7.8 Ω	3000 W	50 A
SAC-S2D_235		4175 W	
SAC-S2D_260	5.0 Ω	7100 W	75 A
SAC-S2D_403	80 Ω	700 W	10 A
SAC-S2D_405		1000 W	
SAC-S2D_410			
SAC-S2D_417	40 Ω	4000 W	20 A
SAC-S2D_425	25 Ω	5970 W	32 A
SAC-S2D_435	20 Ω	8350 W	40 A
SAC-S2D_450	10 Ω	12000 W	53.3 A

	Regen Resistor	Drive Regen Power Output	Regen Transistor
ServoWire Drive	**Minimum Resistance**(1)	Maximum Average Power(3)	Peak Current(2)

1 Minimum resistance – limited by drive transistor.

2 Calculated using minimum resistance at maximum voltage.

3 Average Regen Output Power which the drive can sustain over time without failure

Table 25*, Regen Resistor Selection Requirements*

The actual resistance of the regen resistor determines the current in the resistor. Using Ohms law the current when the regen transistor turns on will be I = V/R. V is 395 V or 775 V depending on the drive bus voltage setting. The table shows what the current will be for the minimum resistance allowed.

When using the minimum resistance value, the power output (dissipated in the resistor) will be much higher than can be sustained by the drive and usually the resistor. Having this peak capability allows the drive to remove a large amount of energy quickly. For example, using the SAC-S2D_425 values: $P = V^2 /R$. With V = 775 V and R = 25 ohms the instantaneous power is $775^2/25$ = 24,025 W. For a short time the drive and resistor (properly sized) can tolerate this power. The column "Maximum Average Power" shows how much average regen power the drive can sustain without damage. Verfying that the Average Power requirements are met is accomplished by analysis of the application.

The resistor current and power ratings may also limit the amount of energy that can be dissipated by a regen resistor. The peak current that will be seen by the resistor is shown in **Table 26**. This current is limited by the regen resistor resistance value. If a higher resistance is used, the peak current will be lower.

The ServoWire S2D Drive using an on-off duty cycle, limits the average current that is seen by the resistor. This limits the average current so that neither the wattage of the resistor (configuration software setting) nor the continuous current of the regen transistor is exceeded on a continuous basis.

Regen Resistor	Resistance	Wattage	Peak Current on 230 V drive (425 VDC max)
SAC-SMRR/0055	50 Ω	55 W	8.5 A
SAC-SMRR/0095	40 Ω	95 W	11 A
SAC-SMRR/0700	54 Ω	700 W	7.9 A
SAC-SMRR/0845	40 Ω	845 W	11 A
SAC-SMRR/0846	10 Ω	846 W	43 A
SAC-SMRR/1700	6.5 Ω	1,700 W	65 A

Table 26*, Standard Regen Resistor Specifications*

The regen resistors are voltage rated for up to 1000 VDC allowing them to be used on both the 200 V and 400 V series drives. When applying the resistor, the minimum resistance supported by the drive must not be exceeded. Table 27 shows which regen resistors are compatible with which drives. Entries with a Pk indicate that the combination provides regen output at or near the peak regen capacity of the drive. However, the power rating of the resistor is not rated for continuous operation at that output level.

Regen Resistor			**Drive Model** SAC-S2D_								
Model Number SAC-	**Resis-tance**	**Power Rating**	**203, 205**	**210, 215**	**225, 235**	**260**	**403 405 410**	**417**	**425**	**435**	**450**
SMRR/0055	50 Ω	55 W	Pk	Y	Y	Y		Y	Y	Y	Y
SMRR/0095	40 Ω	95 W		Pk	Y	Y		Pk	Y	Y	Y
SMRR/0230	81 Ω	230 W	Y	Y	Y	Y	Pk	Y	Y	Y	Y
SMRR/0650	72 Ω	648 W	Y	Y	Y	Y		Y	Y	Y	Y
SMRR/0700	54 Ω	700 W	Pk	Y	Y	Y		Y	Y	Y	Y
SMRR/0825	26 Ω	825 W			Y	Y			Pk	Pk	Y
SMRR/0845	40 Ω	845 W		Pk	Y	Y		Pk	Y	Y	Y
SMRR/0846	10 Ω	846 W			Pk	Y					Pk
SMRR/1650	15 Ω	1650 W			Y	Y					Y
SMRR/1700	6.5 Ω	1,700 W				Pk					
Y = combination acceptable, Pk = acceptable and at or near peak regen output capacity of the drive											

Table 27, *Standard Regen Resistor Drive Compatibility*

The voltage seen by the resistor will range between the Turn-On level and the High-Bus level, as shown below in Table 28.

Nominal Input Voltage (VAC)	**Nominal Bus Voltage (VDC)**	**Turn On Regen Transistor (VDC)**	**High Bus Voltage Fault (VDC)**
230	325	395	425
460	650	775	800

Table 28, *Regen Transistor Turn-On and other Bus Voltage Levels*

4.11.5 Shunt Regulator Overload

If regenerated voltage is excessive, a High Bus Voltage fault (***A4***) may occur. A High Bus Voltage fault will not reset until the voltage level has dropped to an acceptable level. This will occur faster if you disable main power.

If High Bus Voltage faults recur, one of the following actions may resolve the problem:

- Increase the wattage of the external regenerative discharge resistor. **For this change to be effective, you must also change the software configuration settings for the ServoWire S2D Drive: Regen Resistor Power.**
- Reduce the commanded current limit for the Controller.
- Reduce the commanded deceleration.
- Decrease the maximum motor speed.
- Reduce the inertial load seen by the motor, either by removing part of the load, or by increasing the gear ratio (motor-to-load).

4.11.6 Servomotor Temperature Protection

The thermostat contact wiring is part of the Motor Feedback Cable. When the thermal contact opens, the behavior of the ServoWire S2D Drive will depend on the ServoWire S2D Drive software configuration setting:

SMLC		
Motor Thermal Switch state	**ServoWire Pro configuration setting**	**Behavior of ServoWire S2DM Drive & SMLC**
Open Closed	Ignore	An open contact will not cause any error or drive fault. A closed contact will cause an application program, temperature sensor configuration error.
Opens	Generate Alarm	An open contact will cause an OnAlarm callback. **NO Drive Fault will occur.** The motor can still have torque. It is up to the application program to respond to the over temperature warning condition.
Opens	Generate Fault	An open contact will cause an OnFault callback. If the drive torque is enabled, a drive fault ***F4*** will immediately disable torque to the motor.

Orion Motion Controller		
Motor Thermal Switch state	**MotionDesk configuration setting**	**Behavior of ServoWire S2D Drive& MotionBASIC**
Open Closed	Ignore	An open contact will not cause any error or drive alarm. A closed contact will cause the MotionBASIC Configuration Error 1629 = Temperature sensor configuration error.
Open	Generate Motion Error	An open contact will cause MotionBASIC ERR=1628 “Over temperature condition exists”. **NO Drive Alarm will occur.** The motor can still have torque. It is up to the application error handler to respond to the over temperature condition.
Open	Generate Drive Alarm	When the motor is too hot, causing the contact to open, the S2D Drive will generate an alarm. If the drive torque is enabled, a drive alarm ***F4*** will immediately disable torque to the motor. MotionBASIC generates an ALARM@=244 and ERR=1628 “Over temperature condition exists”.
The status of the thermal contact can be monitored with MotionBASIC variable **OVER.TEMP@**.		

Table 29, *Motor Over-Temperature Input*

G-Series Servomotors have embedded thermostats, which open when the motor winding temperature exceeds 155^{o}C.
DE/DA/DB-Series Servomotors do not have embedded thermostats.

4.12 Tuning – Loop Diagram

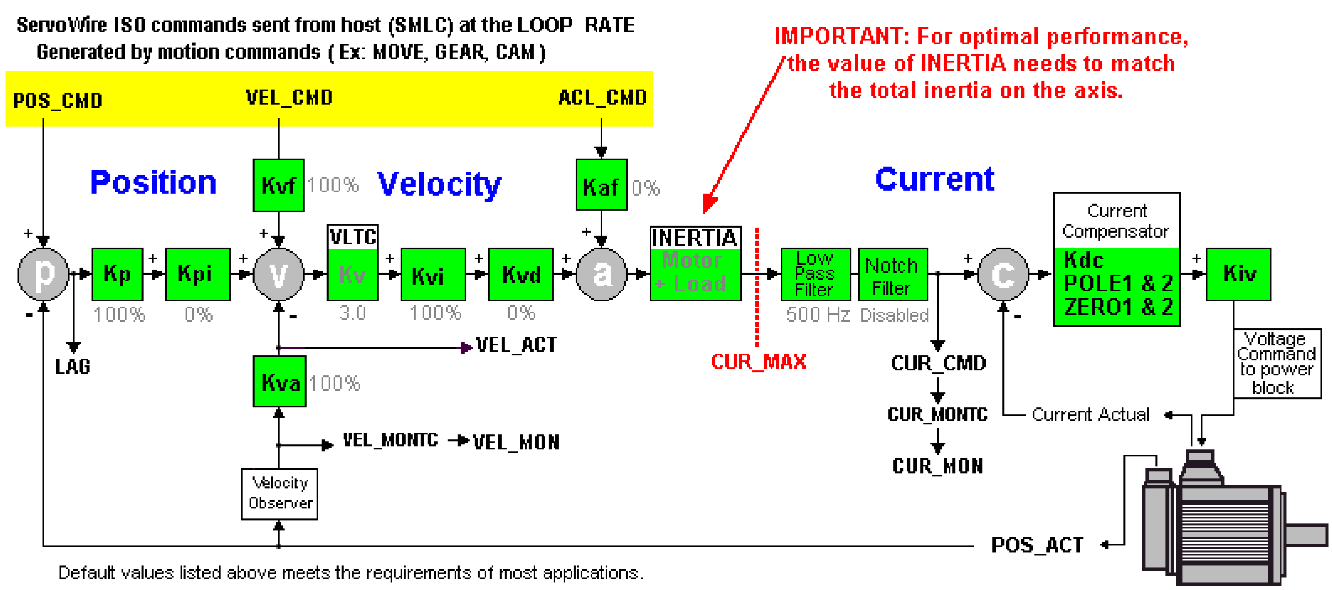


Figure 27 *Tuning Loop Diagram*

Loop Rate
Loop Rate defines the number of times per second (Hz) that the ISO commands will be sent to the drive.

Position Actual

Position Actual (POS_ACT) returns the value of, or assigns a value to, the actual real-time position of an axis feedback device (encoder or resolver in axis position user units). See: Axis Position for more detail.

Position Gain Factor (Kp)
The position loop gain factor (**Kp**) is set by the motion controller as a function of the Velocity Loop Time Constant (VLTC) and Kp. With Kp set to the default 100%, the position loop is adjusted for a critically damped position response. Adjusting this factor higher, results in an under-damped response and adjusting it lower results in an over-damped response.
Default = 100%, range 1 to 500% *(Note: 100% meets the requirements of most applications.)*

Position Integral Factor (Kpi)
The Position Loop Integral gain factor (**Kpi**) is set by the motion controller as a function of the position loop characteristics. Position loop integral gain is normally required only in applications where position error during motion is critical, such as electronic gearing or the control of continuous web systems. It may also be required to eliminate static position errors in applications with analog velocity loops, such as axes using distributed feedback or velocity mode servodrives. With Kpi = 100% and Position Gain Factor (Kp) properly adjusted, the servo axis is adjusted for critically damped position response. Adjusting this factor higher results in an under-damped response and adjusting it lower does not improve the response.
Default = 0%, range 0 to 500%.

Velocity Observer
The velocity observer is software in the drive which derives velocity information from the axis feedback signals (encoder or resolver).

Velocity Feedforward Factor (Kvf)
The Velocity Feedforward Factor (**Kvf**) allows the drive to directly command velocity as well as position in response to a motion command from the motion controller. This enhances servo response and accuracy because the velocity loop has a significantly greater bandwidth than the position loop. The use of velocity feedforward is a major factor in the elimination of position following error while the axis is moving.
Default = 100%, range 0 to 200%.

Velocity Observer Sensitivity (Kva)
The Velocity Observer Sensitivity (**Kva**) determines how the velocity observer responds to changes in motor speed. Lower values smooth low speed motion, but increase settling times on quick stops.
Default = 100%, range 40 to 200%

Velocity Loop Time Constant (VLTC)
The Velocity Loop Time Constant (**VLTC**) is used to indirectly set the velocity proportional gain Kv. The Velocity Loop Proportional Gain (Kv) is not available as a variable. This is set by the motion controller to achieve the velocity loop time constant objective established by VLTC.
The performance characteristics of the servo motion control system are highly dependent on VLTC, This should be set as small as the system dynamics allow. A realistic goal is 0.7 to 3 msec for loads which are tightly coupled to the motor.
Default = 3 milliseconds, range 0.3 to 30 msecs.

Velocity Loop Integral Gain (Kvi)
The velocity loop integral gain factor (**Kvi**) is set by the motion controller as a function of the velocity loop characteristics. With Kvi set to the default 100%, the servo axis is adjusted for a critically damped velocity response. Adjusting this factor higher results in an under-damped response and adjusting it does not improve response.
Default = 100%, range 0 to 1000% *(Note: 100% meets the requirements of most applications.)*

Velocity Derivative Gain (Kvd)
Velocity derivative gain (**Kvd**) sets the gain at which the velocity loop responds to feedback rate changes. Velocity derivative gain is inherently noisy and will increase step-input responsiveness. The default adjustment (0% of nominal) should be satisfactory for achieving stability.
Default = 0%, range 0 to 600%

Velocity Monitor Time Constant
The Velocity Monitor Time Constant (VEL_MONTC) sets the time constant of the filter on the velocity monitor. This filter affects reporting only and not motion performance. VEL_MONTC is a decimal value. A a higher value increases filtering on the velocity-monitoring variable, Velocity Monitor.
Default = 20.0 milliseconds, range 0.0 to 200.0 msecs.

Velocity Monitor
Velocity Monitor(VEL_MON) is a read only variable that returns the filtered observed (actual) velocity of the servo axis in user units. VEL_MONTcontrols the amount of filtering.

Velocity Actual
Velocity Actual (VEL_ACT) is a read only variable, which returns the current real-time instantaneous velocity of the servo axis as determined by the velocity observer, in user units. This filtered value operates internally at the ServoWire Drive, and its resultant filtered value is returned to the velocity-summing junction.

Acceleration Feedforward Factor (Kaf)
Acceleration feedforward(**Kaf**) allows the drive to directly command acceleration (and therefore torque) as well as position in response to a motion command from the application program. This can enhance servo response and accuracy because the current (torque) loop has significantly greater bandwidth than the position and velocity loops. Acceleration feedforward has limited application, and is not used (disabled) in electronic gearing applications. Increasing its value will improve motions that command short, quick acceleration / decelerations.
Default = 0%, range 0 to 200%

Inertia
The total inertia of this axis is the combination of ***Motor and Load Inertia*** at the motor shaft, measured in in-lbs-sec^2. When an assignment is made to the INERTIA value, an additional range check is made to insure that: Axis Peak Torque [in-lbs.] X Torque Gain [%] / OP_LOOP_INERTIA [in-lb-sec^2] >=12800.
If it is less than 12800, an error is generated and the parameters will not be changed in the drive.
Default = Motor Inertia only (in-lb-sec^2), range 0.000001 to 99 in-lb-sec^2

IMPORTANT:
For optimal performance, the value of INERTIA needs to match the total inertia on the axis as seen by the motor.
Use MotionDESK Axis Tune or ServoWire Pro Inertia Calculator to accurately calculate total system Inertia by monitoring successive motor indexes.

Current Maximum
Current maximum (CUR_MAX) is the maximum commanded drive current output. It is expressed as a percent of Peak Current, multiplied by 1000.
Ex: Current Max = 67450 then its value is 67.45% of peak.
Range = 0 to 100,000

Current Command
Current command (CUR_CMD) returns the instantaneous real-time value for the current command output of an axis control loop. The valid range is ± Current Max. The ±100,000 maximum range is expressed as a percent of Peak Current, multiplied by 1000, and is positive for “forward” output. To limit output to values less than ± peak, lower the current max, CUR_MAX.
Range = 0 to 100,000

Current Monitor Time Constant
Current Monitor Time Constant (CUR_MONTC) sets the time constant of the filter on the current command monitor. A higher value increases filtering on the current command monitoring variable. This filter affects reporting and not motion performance.
Default = 4, range 0 to 200 milliseconds.

Current Monitor
Current Monitor (CUR_MON) returns a filtered current value for the current command output of an axis current control loop. The amount of filtering is determined by the value of Current Command Time Constant. The value is positive for "forward" output.
Range -100,000 to 100,000

Current LoopDC Gain (Kdc)
This value is adjusted to the drive's current-loop DC gain. The DC Gain (Kdc) is a function of motor characteristics, impedance, drive bus-voltage, and drive size. This parameter is calculated for a rapid current response with low ringing. In a limited number of cases it is possible to improve current loop response by raising or lowering this value. Doing this in conjunction with the Final Output Stage Gain may provide an improved responsiveness.
Default = 100%, range 0 to 3000%

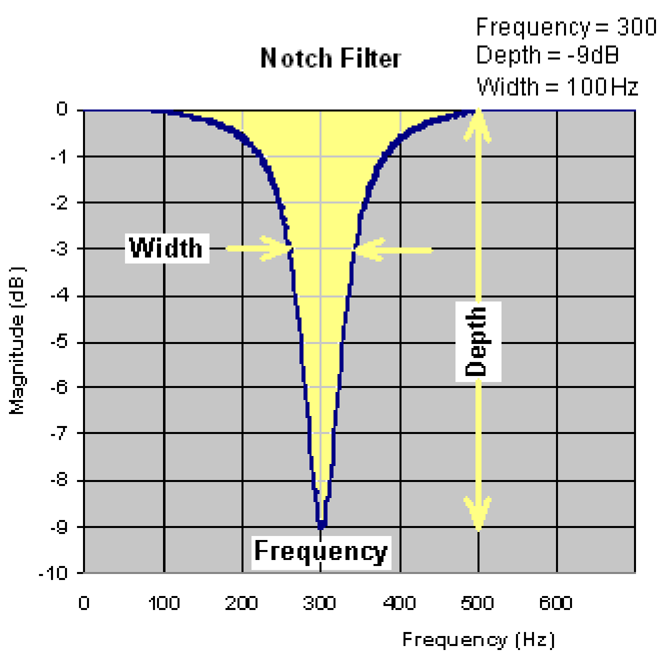
Current to Voltage Gain (Kiv)
This value is adjusted to the drive final output stage gain. The final output stage gain is a function of motor characteristics, impedance, drive bus-voltage, and drive size. This is calculated for a rapid current response with low ringing. In a limited number of cases it is possible to improve current loop response by raising or lowering this value. Doing this in conjunction with the Open-Loop DC Gain may provide an improved responsiveness.
Default = 100%, range 0 to 3000%

4.13 Filter – Low-Pass Current Cutoff

The Current Filter sets the cutoff frequency (Hertz) of a recursive low-pass filter on the Current Command. This digital filter is operates internal to the ServoWire Drive, and the resultant filtered value is not returned to the motion controller current loop. A value of zero (0) disables the filter.
Default = 500 Hz, range 20 to 2500 Hz (In 1 Hertz increments)

4.14 Filter – Digital Notch

The Notch filter is used to reject (remove) one band of frequencies and pass both higher and lower frequencies. This feature is available in SAC-S2D servo drives with firmware version 1.6.0 and later. You must enable the filter.
Default = Disabled



NOTCH FREQUENCY is the center frequency of the current loop's notch filter in Hz. The center frequency of the notch measures the frequency at which the filter's magnitude reaches its minimum value.
Default = 300, range 1 to 2500.

NOTCH DEPTH is the depth of the current loop notch in decibels (dB). The depth of the notch measures the filter minimum magnitude.
Default = -4, range – 4 to – 40.

NOTCH WIDTH is the width of the notch (Hz). The width of the notch measures the distance between the two frequencies where the filter magnitude is –3dB.
Default = 50, range 1 to 1250 Hz

4.15 STO – Safe Torque Off Interface:

The S2D can be ordered with an STO interlock. This option provides redundant inputs and control to safely remove power from the motor. However, fault detection, reporting and feedback associated with Category 3 and above are not present, resulting in a less expensive option.

This STO option uses two redundant inputs to control the torque producing capability of the drive. This reduces the likelihood of a failure of the safety function. Both inputs must be ON (sinking current) for the drive to command torque. Either input will disable the drive. These inputs are designed to react fast and independent of the drive processor. One input will remove torque in 1-5 microseconds, the other in a few milliseconds. A status output is provided that can be used as an interlock to the primary machine controller.

Figure 28 shows the STO functional circuit. The servo drive has two independent optically isolated inputs. A 12-24 VDC voltage is required on each input to allow the torque to be enabled. When allowed, the enable is still controlled by the normal drive enable and other faults. The safety inputs prevent torque regardless of the state of the drive enable input and will not cause torque if the normal drive enable is set to disable. Two LEDs are provided as visual feedback to aid in debugging of the system. An optically coupled output is available for use as feedback to the controller.

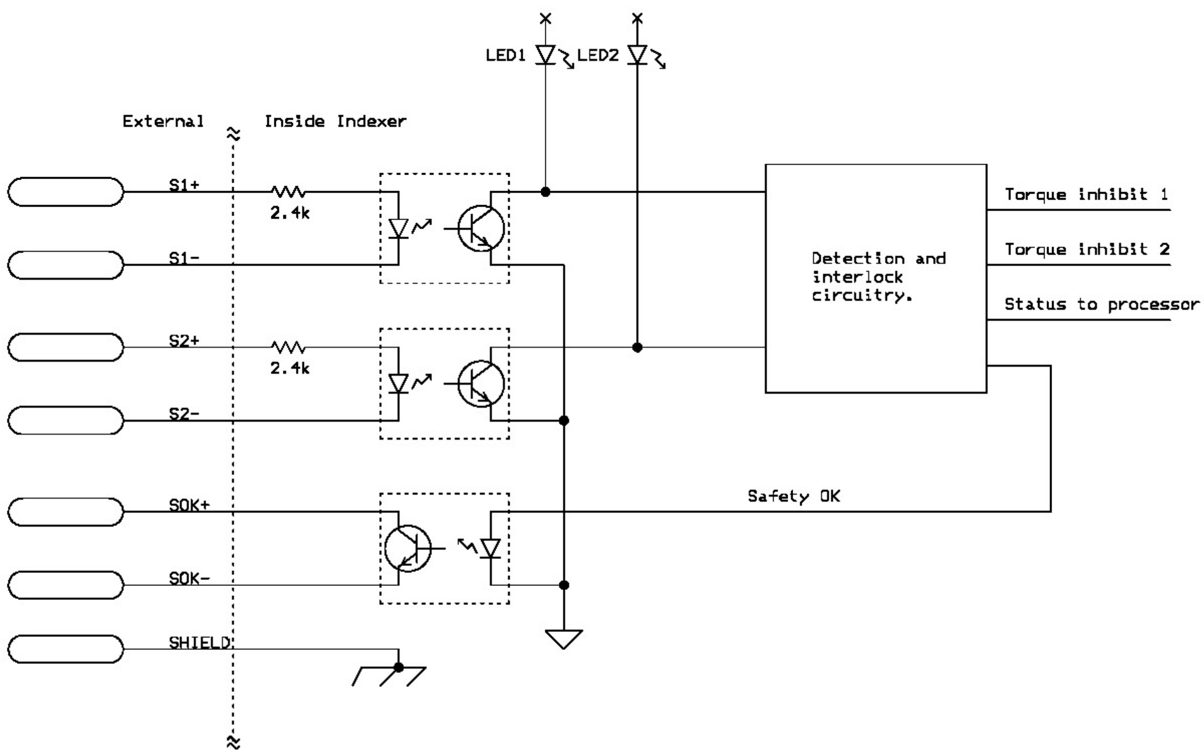


Figure 28 STO Functional Safety Circuit

As shown in Figure 28, STO Functional Safety Circuit, the STO circuitry provides redundant inputs and a redundant torque inhibit. There are two hardware interlocked torque inhibits outputs (Inhibit 1 and Inhibit 2). Either will prevent torque output of the drive to the motor. A status signal is provided to the processor in the servo drive which can then take further action. The processor will disable the drive and issue a fault.

By keeping the drive alive and providing the STO status to the drive processor, the machine controller has additional knowledge that was not available in the old safety model.

Chapter 5
Getting Started

5 Getting Started

5.1 Test Run

Before a test run, perform the following checks. Correct any problems before proceeding.

5.1.1 Servomotor Check

Are motor mounting and grounding correct?
Are bolts and nuts tight?
For motors with oil seals (IP67), are the seals undamaged and properly lubricated?
Are motor power and feedback cables properly attached?

5.1.2 ServoWire S2D 200 V Drive Check (SAC-S2D_2__)

For AC control power, the control power voltage should be 100-240 (+/-10%) VAC, 50/60 Hz.**The absolute maximum is 265 VAC.**

For DC control power, the control should be 24 VDC (+/- 10%). **The absolute maximum is 33 VDC.**

Main power voltage should be 100-240 (+/-10%) VAC, 50/60 Hz. **The absolute maximum is 265 VAC.**

The main power voltage is dependent on the servomotor:
MAC-G005A1, G006A1, G010A1, G010B1, G011A1, G015A1, DE003A1, DE-006B1 and DE008C1 servomotors are rated for 115 VAC – not 230 VAC.

CHECK POWER BEFORE APPLYING TO THE SERVODRIVE.

- Check that feedback connector(s) J4 (and option modules) is(are) firmly seated
- Check that Power terminal block connections r, t, L1, L2, L3, BUS+, RG, BUS-, U, V, W, and ground) are tight.
  Note: The ORMEC standard motor cable is color-coded:
  RED= U, WHITE= V, BLACK= W, Green & Silver= GROUND.
- Motor wiring is correct.
- The main power interlock circuit disables main power under a ServoWire S2D Drive fault condition.

5.1.3 ServoWire S2D 400 V Drive Check (SAC-S2D_4__)

For AC control power, the control power voltage should be 100-240 (+/-10%) VAC, 50/60 Hz.**The absolute maximum is 265 VAC.**

For DC control power, the control should be 24 VDC (+/- 10%). **The absolute maximum is 33 VDC.**

Main power voltage should be 100-480 (+/-10%) VAC, 50/60 Hz. **The absolute maximum is 529 VAC.**

The main power voltage depends on the servomotor. Be sure you are not exceeding the motor's rating.

CHECK POWER BEFORE APPLYING TO THE SERVODRIVE.

- Check that feedback connector(s) J4 (and option modules) is(are) firmly seated
- Check that Power terminal block connections r, t, L1, L2, L3, BUS+, RG, BUS-, U, V, W, and ground) are tight.
  Note: The ORMEC standard motor cable is color-coded:
  RED= U, WHITE= V, BLACK= W, Green & Silver= GROUND. ⏚
- Motor wiring is correct.
- The main power interlock circuit disables main power under a ServoWire S2D Drive fault condition.

5.1.4 Preparation for Test Run

During test run, the driven machine should not be attached to the Servomotor. If it is necessary to start with the driven machine connected to the motor, proceed with great care.

- After verifying all checklist items are corrent, turn on the control power.
- Enable the main power circuit and measure main DC Bus voltage.

Chapter 6
Specifications

6 Specifications

ORMEC products covered by this manual:

ServoWire S2D Drives			
SAC-S2D_203	SAC-S2D_205	SAC-S2D_210	SAC-S2D_215
SAC-S2D_225	SAC-S2D_235	SAC-S2D_260	
SAC-S2D_403	SAC-S2D_405	SAC-S2D_410	SAC-S2D_417
SAC-S2D_425	SAC-S2D_435	SAC-S2D_450	

6.1 ServoWire S2D Drive Specifications

6.1.1 Environmental Specifications

Operating Temperature:	0 to +50°C
Maximum surrounding Air temperature	+50°C
Storage Temperature:	-20 to +70° C
Operating and Storage Humidity	10 to 90%, non-condensing

***Table 30**, Environmental Specifications*

6.1.2 Mechanical Specifications

Mounting Method: *Also see outline drawings in* **Figure 1, ServoWire S2D Drives 203 –** 215, 403-410 (page 13) or **Figure 2, ServoWire S2D Drives 225 – 260, 417-450 Dimensions** (page 14)	Vertical panel mounting, two, three or four 10-32 (M5) screws.
Dimensions: **SAC-S2D_203, SAC-S2D_205 and SAC-S2D_210** Height: add 2” (51 mm) clearance top and bottom 9.0 inches (229 mm) Width: add 1” (25 mm) clearance each side 2.2 inches (56 mm) Depth: includes clearance for attached cables 10.5 inches (267 mm) Weight: SAC-S2D_203 & SAC-S2D_205 3.7 lbs. (1.7 kg)	

	SAC-S2D_210	4.1	lbs.	(1.9	kg)
SAC-S2D_215					
Height:	add 2” (51 mm) clearance top and bottom	9.0	inches	(229	mm)
Width:	add 1.2” (31 mm) clearance each side	4.2	inches	(107	mm)
Depth:	includes clearance for attached cables	10.5	inches	(267	mm)
Weight:		5.8	lbs.	(2.7	kg)

Table 31*, Mechanical Specifications*

6.1.3 General Electrical Specifications for 200 V Drives (SAC-S2D_2__)

Incoming Main Power Line Voltage –**TB7 or TB11**pins **L1, L2, L3**	
WARNING: Use the servomotor's voltage rating to determine the maximum input voltage for the servodrive. MAC-G005A1, MAC-G006A1, MAC-G010A1, MAC-DE003A1, MAC-DE006B1, and MAC-DE008C1 are rated for 115 VAC, not 230 VAC!	
SAC-S2D_203, SAC-S2D_205:	Single Phase, 50/60 Hz 100 – 240 VAC (+10%, -10%)
SAC-S2D_210, SAC-S2D_215, SAC-S2D_225 SAC-S2D_235, SAC-S2D_260:	Three Phase, 50/60 Hz 100 – 240 VAC (+10%, -10%)
Incoming AC Control Power Line Voltage –**TB7**pins **r, t**	Single Phase, 50/60 Hz 100 – 240 VAC (+10%, -10%)
	0.5A max at 115 VAC, 0.25 A typ
With AC control power 24VDC output available TB6 pins 24V, 24R	24 V, +/- 7% 1A maximum
Incoming DC Control Power – **TB6**	24 VDC, +/- 10% 1.7A maximum, 0.5A typical
MainDC Bus Voltage –	
115 VAC nominal input power: 230 VAC nominal input power:	163 VDC nominal level 325 VDC nominal level
Shunt Regulator Activation DC Bus Voltage[1]:	
115 VAC motors: 230 VAC motors:	207 VDC 395 VDC
High Bus Voltage Fault Activation DC Bus Voltage[1]:	
115 VAC motors: 230 VAC motors:	237 VDC 425 VDC
Low Bus Voltage Fault Activation DC Bus Voltage[2]:	
115 VAC nominal input power: 230 VAC nominal input power:	94 VDC 205 VDC

***Table 32**, General Electrical Specifications for 200 V Drives (SAC-S2D_2__)*

6.1.4 General Electrical Specifications for 400 V Drives (SAC-S2D_4__)

Incoming Main Power Line Voltage –**TB7 or TB11** pins **L1, L2, L3**	
WARNING: Use the servomotor's voltage rating to determine the maximum input voltage for the servodrive.	
SAC-S2D_403, SAC-S2D_405 SAC-S2D_410, SAC-S2D_417, SAC-S2D_425 SAC-S2D_435, SAC-S2D_450:	Three Phase, 50/60 Hz 100 – 480 VAC (+10%, -10%)

AC Control Power	
SAC-S2D_417, S2D_425	Single Phase, 50/60 Hz 100 – 240 VAC (+10%, -10%)
Incoming AC Control Power Line Voltage – **TB7** pins **r, t**	0.5A max at 115 VAC, 0.25 A typ
SAC-S2D_435, S2D_450	
Incoming AC Control Power Line Voltage –**TB7** pins **r, t**	Single Phase, 50/60 Hz 200 – 240 VAC (+10%, -10%) 0.3A max at 230 VAC, 0.2 A typ
Note: AC control power option not available on 403, 405 and 410	
With AC control power 24VDC output available TB6 pins 24V, 24R	24 V, +/- 7% 1A maximum
Incoming DC Control Power – TB6	
SAC-S2D_403, S2D_405, S2D_410 SAC-S2D_417, S2D_425	24 VDC, +/- 10% 1.7A maximum, 0.5A typical
SAC-S2D_435, S2D_450	24 VDC, +/- 10% 3A maximum, 2.2A typical
MainDC Bus Voltage –	
115 VAC nominal input power:	163 VDC nominal level
230 VAC nominal input power:	325 VDC nominal level
460 VAC nominal input power:	650 VDC nominal level
Shunt Regulator Activation DC Bus Voltage[1]:	
115 VAC motors:	207 VDC
230 VAC motors:	395 VDC
460 VAC motors:	775 VDC
High Bus Voltage Fault Activation DC Bus Voltage[1]:	
115 VAC motors:	237 VDC
230 VAC motors:	425 VDC
460 VAC motors:	800 VDC
Low Bus Voltage Fault Activation DC Bus Voltage[2]:	
115 VAC nominal input power:	94 VDC
230 VAC nominal input power:	205 VDC

***Table 33**, General Electrical Specifications for 200 V Drives (SAC-S2D_2__)*

6.1.5 ServoWire S2D Drives Performance Specifications

Drive Model	**PWM Frequency**	**Torque Loop**
SAC-S2D_203 to SAC-S2D_215	20 kHz	10 kHz
SAC-S2D_403 to SAC-S2D_410	10 kHz	10 kHz

***Table 34**, PWM Frequencies and Torque Loop Update Rates*

	SMLC Command Update Rate(s)[1]	**Loop Update Rate**
Position Loop	500 Hz - 2 kHz	Same as command update rate. H Series motors = 2.5kHz (same as Velocity Loop.)
Velocity Loop	500 Hz - 2 kHz	2.5 kHz
Torque Loop	500 Hz - 4 kHz	10 kHz

***Table 35**, SMLC/MotionObjects Command and Loop Update Rates*

6.1.6 Output Specifications for 200 V Drives (SAC-S2D_2__)

	Single Phase 115 VAC Input			**Single Phase 230 VAC Input**		
Drive Model	**Rated Output Power (KVA)**	**Cont. Current (Amps RMS/∅)**	**Peak Current 2 sec (Amps RMS/∅)**	**Rated Output Power (KVA)**	**Cont. Current (Amps RMS/∅)**	**Peak Current 2 sec (Amps RMS/∅)**
SAC-S2D_203	0.29	3.0	9.0	0.59	3.0	9.0
SAC-S2D_205	0.49	5.0	15	0.98	5.0	15
SAC-S2D_210	0.58	10	30	1.17	10	30
SAC-S2D_215	0.98	15	45	1.97	15	45

***Table 36**, Output (TB9 pins U, V, W) Specifications with Single Phase Input Power*

	Three Phase 240 VAC Input			
Drive Model	**Rated Output Power (KVA)**		**Cont. Current (Amps RMS/∅)**	**Peak Current 2 sec (Amps RMS/∅)**
SAC-S2D_203	Three Phase Not Available			
SAC-S2D_205				
SAC-S2D_210	2.5	3.3	10	30
SAC-S2D_215	3.7	5.0	15	45

[1]ServoWire command updates are made at multiples of the 125 usec base network update rate, up to 4 kHz.

SAC-S2D_225	6.2	8.2	25	50
SAC-S2D_235	8.6	11.5	35	70
SAC-S2D_260	14.3	19.2	60	120
Notes: Rated output power requires 240 VAC input and 3-phase input. Consult factory for ratings with other inputs.				

***Table 37**, Output (TB9 or TB11 pins, U, V, W) Specifications with Three Phase Input Power*

	Three Phase 460 VAC Input			
Drive Model	**Rated Output Power** **(KVA)**	**Rated Output Power** **(HP)**	**Cont. Current** **(Amps RMS/∅)**	**Peak Current 2 sec** **(Amps RMS/∅)**
SAC-S2D_403	1.4	1.9	3	9
SAC-S2D_405	2.4	3.2	5	15
SAC-S2D_410	4.8	6.4	10	30
SAC-S2D_417	8.1	10.9	17	34
SAC-S2D_425	11.9	16.0	25	50
SAC-S2D_435	16.7	22.4	35	70
SAC-S2D_450	23.9	32.0	50	100
Notes: Rated output power requires 460 VAC input and 3-phase input. Consult factory for ratings with other inputs.				

***Table 38**, Output (TB9 or TB11 pins, U, V, W) Specifications with Three Phase Input Power*

6.1.7 I/O Specification (TB4 & TB5)

V+S, V-S **TB4 pin 4, TB5 pin 1 (V+S)** **TB4 pin 5, TB5 pin 2 (V-S)**	**I/O Power Supply**
Externally supplied voltage used by: - High speed Sensor Inputs ASEN, BSEN - Discrete Inputs IN1', IN2', IN3', IN4' - Discrete Outputs OUT1'-OUT5'	
Max voltage between V+S and V-S	+27 VDC maximum
Max current V+S	85 mA
SAC-S2Dxx-S versions (Serial Encoder version) Max current V-S (return current on OUTPUTs uses V-S but not V+S)	240 mA
SAC-S2Dxx-R versions (Resolver version) Max current V-S (return current on OUTPUTs uses V-S but not V+S)	1300 mA

ASEN, BSEN **TB4 pins 2, 3**	**High Speed Sensor Inputs**
Input Current depends on software configuration: NPN-type sensor with 2.7K pull-up resistor selected in drive: PNP-type sensor: current depends on pull-down resistance in sensor (or external pull-down).	 8.9 mA @ 24 VDC
Max. voltage	V+S
Minimum acceptance time	1 microsecond
Turn-on voltage $V_{IN} > 0.5 * (V+S) + 0.4$ VDC $V_{IN} < 0.5 * (V+S) + 0.1$ VDC	Receiver Output High Low

IN1', IN2', IN3', IN4' **TB5 pins 3, 4, 5, 6** Note: Input #4 (TB5 pin 6) is Bi-directional and shares the same pin with Output #4.	**Optically-coupled Digital Inputs**
Input should be normally sinking current to prevent an overtravel limit condition.	
Current to turn on	0.7 mA minimum 7.0 mA maximum
Voltage max.	5V + V+S maximum

OUT1'-OUT5' **TB5 pins 9, 10, 11, 6, 12**	**Optically-coupled Digital Outputs**
Note: Output #4 (TB5 pin 6) is Bi-directional and shares the same pin with Input #4. **Applies to –S version drives and –R version drives except as noted below.**	
Max. sink current	33 mA
low level voltage high level voltage	0.7 VDC maximum (Ic = 33 mA) V+S – 0.5 VDC
absolute maximum	27 VDC
max. sink current OUT3' and OUT4' on –R version and –S versions 1.2 and later drives	900 mA

***Table 39**, I/O Specifications (TB4 and TB5)*

6.1.8 SAC-S2Dx-S drive version Motor Encoder Interface Specifications (J4)

This table applies to Quadrature/Serial encoder versions of the drive, identified by –S in part number, SAC-S2Dxx-S.

ENCA, ENCA', ENCB, ENCB' **J4 pins 1, 2, 3, 4** **J5 Pacer pins 1, 2, 14, 15**	**Differential Digital Inputs** **Appendix B-1, B-3**
Common Mode Input	-15 VDC to +15 VDC max.
Absolute Max. Input Voltage	+/-25 VDC
Maximum Encoder Counts per Electrical Cycle	32,768 (after 4x decode) Orion 1,000,000 (after 4x decode) SMLC
Maximum Encoder Data Rate:	12 MHz
Quadrature Specification	90^{o} +/-45^{o}
Differential Turn On Voltage V_{ID}> 0.7 V –0.7 V > V_{ID}> 0.7 V V_{ID}< -0.7 V *Where V_{ID} = (ENCx) – (ENCx')*	Receiver Output H ? L

ENCZ, ENCZ' **J4 pins 5, 6** **J5 Pacer pins 3, 16** **U, U', V, V', W, W'** **J4 pins 7, 8, 9, 10, 11, 12**	**Differential or Single-Ended** **Digital Input** **Appendix B-1, B-3**
Common Mode Input	-12 VDC to +12 VDC max.
Absolute Max. Input Voltage	+/-25 VDC
Differential Turn On Voltage V_{ID}> 0.2 V –0.2 V > V_{ID}> 0.2 V V_{ID}< -0.2 V *Where V_{ID} = (ENCx) – (ENCx')* Single-Ended Turn On Voltage V_{IS}> 3 V 2 V > V_{IS}> 3 V V_{IS}< 2 V	Receiver Output H ? L Receiver Output H ? L

ENC PWR1, DGND **J4 pins 13, 24, 25 (Power)** **J4 pins 16, 17, 18 (Digital Ground)** **J5 Pacer pins 5, 6, 18 (Power)** **J5 Pacer pins 7, 19, 20 (Ground)**	**Encoder Power Supply** **Appendix B-1**
+5 VDC for 115/230 VAC Drives (SAC-S2D_2__)	5.3 VDC, +/-5% 450 mA max.
+5 VDC for Low Power Drives (SAC-S2D_A__)	5.0 VDC, +/- 5% 450 mA max.

TEMP', TEMP RET **J4 pins 19, 20**	**Optically-isolated Digital Input** **Appendix B-1, B-4**
Intended for use with motors having thermal protector in or on the motor. To comply with UL requirements the motor must have integral thermal protection. Protection device should sink current when ok.	
Should be normally sinking current to prevent an over-temperature condition.	
Voltage, nominal	+12 VDC
Current, nominal	2.5 mA
Minimum Current to turn on	2.0 mA
Voltage max.	+13 VDC maximum

***Table 40**, SAC-S2Dxx-S version Motor Encoder Specifications (J4)*

6.1.9 SAC-S2Dx-R drive version Motor Resolver Interface Specifications (J4)

This table applies to Resolver versions of the drive, identified by –R in part number, SAC-S2Dxx-R.

REF+, REF- **J4 pins 18, 17**	**Differential Resolver Reference** **Appendix**
Output Frequency	Configurable to 2441, 4882, 9765 Hz.
Amplitude R_L = 1K Ohms Amplitude R_L = 100 Ohms	0 to 7.5 V RMS 0 to 6.5 V RMS
Output Current	70 mA max

COS+, COS-, SIN+, SIN- **J4 pins 20, 19, 22, 21**	**Differential Resolver Inputs** **Appendix**
Input Voltage	3V RMS +/- 15%

U, U', V, V', W, W' **J4 pins 3, 16, 6, 8, 11, 24**	**Differential or Single-Ended** **Digital Input** **Appendix**
Common Mode Input	-12 VDC to +12 VDC max.
Absolute Max. Input Voltage	+/-25 VDC
Differential Turn On Voltage V_{ID}> 0.2 V –0.2 V > V_{ID}> 0.2 V V_{ID}< -0.2 V *Where V_{ID} = (ENCx) – (ENCx')* Single-Ended Turn On Voltage V_{IS}> 3 V 2 V > V_{IS}> 3 V V_{IS}< 2 V	<u>Receiver Output</u> H ? L <u>Receiver Output</u> H ? L

5.3v Encoder Power, DGND **J4 pins 4 (Power)** **J4 pins 25 (Digital Ground)**	**Encoder Power Supply Appendix**
+5 VDC	5.3 VDC, +/-5% 400 mA max.
12v Encoder Power, DGND **J4 pins 124 (Power)** **J4 pins 25 (Digital Ground)**	**Encoder Power Supply Appendix**
+12 VDC	12 VDC, +/-5% 400 mA max.

TEMP', TEMP RET **J4 pins 10, 23**	**Optically-isolated Digital Input Appendix**
Should be normally sinking current to prevent an over-temperature condition.	
Current to turn on	2.5 mA
Voltage max.	+12 VDC maximum

***Table 41**, SAC-S2Dx-R drive version Motor Encoder Specifications (J4)*

6.1.10 Analog I/O Specificatoins (TB3)

AIN **TB3 pin 4**	**Single Ended Analog Input 3**
Common Mode Input	-10 VDC to +10 VDC max.
Absolute Max. Input Voltage	+/-12 VDC
Native ADC resolution[1]	14 bits
Monotonic	
Sample rate	2500 Hz
Filter – hardware	1 kHz anti-aliasing
Filter – software	0-500 Hz software configurable

AOUT **TB3 pin 2**	**Single Ended Analog Output 3**
Common Mode Output	-10 VDC to +10 VDC max.
Output current drive	+/- 10 mA max
Native DAC resolution[1]	14 bits
Update rate	10,000 Hz

***Table 42**, Analog I/O Specifications (TB3)*

[1] The ADC and DAC have 14-bit resolution. The application quality of these I/O points is determined by the total system, not just the circuitry in the drive. Care should be taken routing signals to and from the drive.

6.1.11 Connector Part Numbers

		Mating Connector[1]			Drive Connector
Drive Label	**Signal**	**Description**	**Manufacturer & Part Number**	**ORMEC P/N**	**Manufacturer & Part Number**
J1/J2	ServoWire	9 pin IEEE 1394	Available only as integral part of IEEE1394 (ServoWire) cable		
TB4	Drive I/O	5-pin terminal block	Phoenix 1803604	CON887	Phoenix 1803303
TB5	Drive I/O	12-pin terminal block	Phoenix 1803675	CON888	Phoenix 1803374
J4 (-S)	Encoder Feedback (-S drive version)	25 pin male D-sub	Amp 207464-1 (conn.) Amp 745254-6 (pin) Amp 206478-3 (shell) Amp 90406-1 (tool)	CON638 CON640 CON641	Kycon K22L-B255N
J4 (-R)	Resolver Feedback (-R drive version)	25 pin female D-sub	Amp 207463-1 (conn.) Amp 745253-6 (pin) Amp 206478-3 (shell) Amp 90406-1 (tool)	CON650 CON649 CON641	Kycon K22B25PN
J5	Pacer Feedback	25 pin female D-sub	Amp 207463-1 (conn.) Amp 745253-6 (pin) Amp 206478-3 (shell) Amp 90406-1 (tool)	CON650 CON649 CON641	Kycon K22B25PN
TB3	Analog I/O (top of drive)	4-pin terminal block	Phoenix 1803594	CON889	Phoenix 1829361

***Table 43**, Connector Part Numbers*

[1] The mating D-sub connectors for J3 and J4 are not provided as part of the ServoWire SD Drive.

Chapter 7
Maintenance and Troubleshooting

7 Maintenance and Troubleshooting

7.1 ORMEC Product Support

- ORMEC Product Support relates to the functionality and proper operation of ORMEC supplied software and equipment
- Product Service is provided by the ORMEC Service Department by phone at (585) 385-3520 or via e-mail at support@ormec.com
- Assistance installing and upgrading ORMEC supplied development software (e.g. CoDeSys), and ServoWire Drive firmware, including necessary third-party supporting files (i.e. Microsoft Windows Dial-Up Networking used for serial communication).
- Assistance configuring ORMEC development software communications.
- Explanation/clarification of the functionality and proper operation of ORMEC supplied hardware and software, as provided in the various documentation available for those products (e.g. Windows Help, Installation & Operation Manuals, Tech and App Notes, etc.)
- Troubleshooting assistance for ORMEC supplied hardware and firmware to insure the proper operation of ORMEC supplied equipment. Assistance troubleshooting third-party equipment connected to ORMEC equipment is not included.
- Providing return authorization (RA) numbers and replacement units (if appropriate) for units needing repair.

Normal Product Support
Phone and e-mail support, available from 8 AM to 5 PM EST.

24-Hour Product Support
Phone support, available 24-hours a day, 7 days a week, 365 days per year.
There is an additional charge for this service.

7.2 ServoWire S2D Drive Troubleshooting Guide

Some of the error codes have been extended to provide additional troubleshooting assistance. The extended error code will display as an _ <number> following the basic error code. For example, F3_4 will display as 4 characters.

This extended code is available on the drive display. ServoWire Pro, MotionDesk and MotionBasic do not report the extended code, yet.

Indication	Code	Status	Description
70	112	Axis off-line	

Indication	Code	Status	Description
71	113	Reference Generation Conflict	Internal error
Defective hardware or software ⇒ Report error to ORMEC Customer Service.			

Indication	Code	Status	Description
74	116	Unsupported Feedback device	The drive firmware does not support this feedback type.
Upgrade the drive firmware to the latest versions			

Indication	Code	Status	Description
75	117	Tension Max	The actual measured tension is greater than OP_TEN_MAX and the application (OP_TEN_LIM_ACTION) is configured to generate a fault if this occurs.
• Check the machine for binding or jamming • Check the tension transducer for failure			

Indication	Code	Status	Description
76	118	Tension Min	The actual measured tension is less than OP_TEN_MIN and the application (OP_TEN_LIM_ACTION) is configured to generate a fault if this occurs.
• Check the machine for binding or jamming • Check the tension transducer for failure			

Indication	Code	Status	Description
90-99	144-153	Internal Drive Error	An unexpected failure has occurred in the ServoWire S2D Drive software or hardware.
9A-9F	154-159		
Failed hardware or software ⇒ Report error to ORMEC Customer Service.			

Indication	Code	Status	Description
A0	160	Drive Over Current (RMS)	The maximum rating for the continuous current output of the drive has been exceeded.
When enabling axis with servomotor connected		• Incorrect servomotor wiring ⇒ See Section 3.5.9 (page 21) for correct wiring. • Defective servomotor ⇒ Replace servomotor	
After applying control power with servomotor disconnected		• Defective servodrive⇒ Replace servodrive	
Under load or during acceleration.		• Drive and/or motor may be undersized for the application.	

Indication	Code	Status	Description
A1	161	Drive Over Current (Peak)	The maximum rating for the peak current output of the drive has been exceeded.
When enabling axis with Servomotor connected		• Incorrect servomotor wiring ⇒ See Section 3.5.9 (page 21) for correct wiring. • Defective Servomotor ⇒ Replace Servomotor	
Under load or during acceleration.		• Drive and/or motor may be undersized for the application. • Wrong motor may be selected in configuration, resulting in poorly tuned current loop.	

Indication	Code	Status	Description
A2	162	Power Module Fault	The Power Module's self-protection has detected a short circuit, over current, over temperature, control supply under voltage. - or- An SCR soft-start circuit error has been detected (SAC-S2D_225, S2D_235, S2D_260, S2D_417, S2D_425, S2D_435 &S2D_450 only). This fault is detected after the drive has been enabled.

Indication	Code	Status	Description
A3 Bus Power LED not on	163	Low Bus Voltage	The bus voltage is below the low voltage limit, which is calculated based on the Drive Input Voltage specified in the configuration software.

When the drive is being or has been enabled	• Input voltage does not match the software setting ⇒ Decrease software setting or increase applied AC input voltage.
	• Main fuses blown or circuit breaker tripped ⇒Correct main input power problem, and replace fuses or reset circuit breaker.
	Defective Servodrive⇒ Replace Servodrive

Indication	Code	Status	Description
A4	164	High Bus Voltage	The bus voltage is above the high voltage limit, which is calculated based on the lessor of the motor rated voltage and the drive maximum voltage.

When power is applied to the main circuit	Applied voltage exceeds the servomotor rating ⇒ Reduce applied voltage. The configuration software settings for ServoWire S2D Drive Input Voltage are lower than desired applied voltage ⇒ Increase setting in the configuration software. Defective Servodrive⇒ Replace Servodrive
While motor is in regeneration, or when drives share bus power, if any of the motors is in regeneration. Regeneration may exist during deceleration, or during downward motion in a non-counterbalanced vertical application, or in a tensioned unwind application.	A regenerative discharge resistor is required by the application but is not present ⇒ Install regen resistor, reduce inertial load, or reduce max speed and/or acceleration. The regenerative resistor installed has been damaged and is no longer fully functional ⇒ Install higher-wattage regenerative resistor, and reduce inertial load, or reduce max speed and/or acceleration.

Indication	Code	Status	Description
A5	165	Configuration Mismatch	The drive type does not match the software configuration settings.

SAC-S2DM Drives: The SMLC or MotionObjects has detected that the drive hardware does not match ServoWire Pro project settings. Either:

- Auxiliary feedback encoder is created in the user program but drive does not have pacer (-P) hardware option. -OR-
- Axis is configured for drive type SAC-SW_ but actual drive type is SAC-S2D_. -OR-
- Axis is configured for drive type SAC-S2D_ but actual drive type is SAC-SW_.

SMLC may also indicate this with exception # 1031,
Error Message = Configured Drive type doesn't match actual drive hardware.

Indication	Code	Status	Description
A6	166	Drive Not Configured	An attempt was made to enable torque before the drive setup parameters have been configured. The drive setup parameters must be configured each time the drive control power cycles on, before the drive can be enabled.

Indication	Code	Status	Description
A7	167	Illegal While Drive Enabled	An attempt was made to write parameters for the 'Number of Poles ' or 'Resolution' to the drive while the drive was enabled. The drive must be disabled before changing these parameters.

Indication	Code	Status	Description
A8	168	Invalid Commutation Position	A Drive configured for a motor with an absolute encoder was commanded to enable when the absolute encoder was discharged, or while the commutation position was invalid, or the ABS output was toggled on a drive configured for an incremental encoder. The commutation position is invalid on a drive *configured for an absolute encodermotor* when: • The drive is powered up, prior to drive configuration • An open encoder line is detected • During trapezoidal commutation • 'Number Of Poles' is written • 'Resolution' is written The commutation position becomes valid when the absolute encoder position is read. Refer to the SMLC/MotionObjects and ServoWire SM RTX documentation for further information regarding reading absolute encoder position.

Indication	Code	Status	Description
A9	169	Phase Loss	The drive detected the loss of a main power phase. L1, L2 and L3 are monitored for AC voltage. This error indicates that no voltage or insufficient voltage is or was not present.

When the drive is being or has been enabled	Main fuses blown or circuit breaker tripped ⇒ Correct main input power problem and replace fuses or reset circuit breaker.
	Loose wire or intermittent contact => Check all wire terminations
	Defective Servodrive⇒ Replace Servodrive

Indication	Code	Status	Description
AA	170	Soft Start Not Complete – general error.	The drive inrush current is greater than 0.5 amps or there is a low bus voltage (<50 VDC). Note: This is only checked when enabling the drive. The hardware switch from soft start mode to full power mode doesn't take place until after startup is complete, as evidenced by low inrush current and sufficient bus voltage. This error may be caused by: • Enabling too soon after applying AC bus power ⇒ Wait longer between disabling and reapplying AC bus power. • Low AC bus power input voltage so that BUS+ never reaches 50 VDC ⇒ Correct the AC bus power input voltage. • The load on BUS+ and BUS- is drawing current as soon as AC bus power is applied ⇒ remove the load from BUS+ and BUS-. There should not be a load on BUS+ and BUS-. Regen resistors are connected to BUS+ and RG.
AA_1	170	Soft Start Not Complete due to low bus voltage.	The drive does not see sufficient bus voltage to switch to full power mode. The minimum is set by host software and is usually about 50% of the expected DC bus voltage.
AA_2	170	Soft Start Not Complete due to phase loss.	The drive does not see all 3 input phases, L1, L2 and L3. One or more may not be working or sufficiently high. Check and correct any conditions found.
AA_3	170	Soft Start Not Complete due to inrush current.	The drive is detecting current in the inrush resistor. The current needs to be less than 0.5 A. This may be because inrush has not completed ~ wait longer after applying bus AC power to enable. Or there is a load on the BUS+ terminal causing a continuous current through the inrush resistor ~ correct the wiring to eliminate this load.
AA_4	170	Soft Start Not Complete due to time delay	The drive waits approximately 750 msec after all of the soft start conditions are satisfied to switch to full power mode. This error indicates that all of the other conditions are ready, however, an attempt was made to enable before the timeout completed. Wait longer. Note, this delay increased significantly in drive firmware version 3.3.2.

Indication	Code	Status	Description
AC	172	Drive Overtemp or Soft Start Error	An over-temperature condition was detected in the drive powerblock or a failure of the inrush current resistor occurred. This fault is detected when the drive is being enabled.

Indication	Code	Status	Description
Ad	173	E-Stop	A drive emergency stop was detected. This requires that the drive be configured to use one of the general purpose inputs as an E-Stop input.

Indication	Code	Status	Description
AE	174	Software upgrade.	**SAC-S2DM Drive**, SMLC fault: SMLC software upgrade is required.

Indication	Code	Status	Description
b0	176	Checksum error	The checksum on the downloaded code was incorrect. The download has been aborted. Try again.

Indication	Code	Status	Description
b1	177	Bad file	The download code was not recognized. The wrong file was used. The drive firmware may be too old to recognize this format.

Indication	Code	Status	Description
b2	178	Firmware not compatible	The downloaded code is not designed for this drive hardware, but rather for different drive hardware. Obtain the correct file and try again.

Indication	Code	Status	Description
b3	179	Firmware Checksum error	Internal firmware program checksum error. Reload drive firmware.

Note: Most of the drive faults are detected and generated in the drive. However, the “C” fault codes are detected by the SMLC and sent via ServoWire to the drive which disables the motor and displays the fault code. Additional documentation and help on the “C” faults can be found in the ServoWire Pro and CoDeSys Help.

Indication	Code	Status	Description
C0	192	Lag Fault	The position following error exceeded the maximum amount configured using ServoWire Pro. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C1	193	Command Overspeed	The commanded speed exceeded the software configured axis speed limit. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C2	194	Actual Overspeed	The actual (feedback) speed exceeded the software configured axis speed limit. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C3	195	Hardware Travel Limit	Motion was commanded further into a hardware travel limit while the limit was still active. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C5	197	Loop Rate Exceeded	The available loop update time was insufficient to complete the loop processing. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C6	198	Missing MotionData	The MotionData from the master axis is not available. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
C9	201	Unexpected Offline	The SMLC is not receiving isochronous feedback from the drive. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
CA	202	1394 Driver failure	The 1394 driver is not receiving its once-per-looprate update information from the 1394 bus driver. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
Cb	203	Pacer Backup Overflow	The pacer axis backed up far enough to overflow the backup compensation. => See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
CC	204	Invalid MotionData Configuration	The MotionData is configured in a loop, which is not valid. See ServoWire Pro or CoDeSys Help for further information.

Indication	Code	Status	Description
E0	224	ServoWire Protocol Incompatibility	The ServoWire communications protocol in the drive is not compatible with the one in the SMLC or Orion.
SMLC controller		Either the drive firmware should be changed to a version that is compatible with the SMLC firmware, or the SMLC firmware must be changed to a version that is compatible with the servodrive firmware. A SAC-S2DM drive is required with an SMLC. Check drive model number.	

Orion Controller	The drive firmware should be changed to a version that is compatible with the Orion controller and MotionBasic version. A SAC-S2D drive is required with an Orion. Check drive model number.

Indication	Code	Status	Description
E1	225	ServoWire Timeout	Isochronous communications (i.e. torque commands, velocity commands, etc.) from the motion controller or PC were lost. The ServoWire dot will indicate if communications has been re-established.
This normally occurs when the drive has control power, but the SMLC loses control power, or the IEEE 1394 interface card fails. In either case, once the cause has been corrected, the fault can be cleared by the application program or by cycling power on the drive.			

Indication	Code	Status	Description
E3	227	ServoWire Watchdog Timeout	The ServoWire Isochronous communications watchdog bit has not changed state within the allotted time.

Indication	Code	Status	Description
E4	228	ServoWire Initialization Error	A hardware error was detected when initializing the IEEE 1394 communications controller circuitry.

Indication	Code	Status	Description
E5	229	Drive Watchdog Timeout	The drive internal watchdog has timed out due to either the loss of ServoWire network power (usually due to loss of motion controller power) or an unexpected failure.

Indication	Code	Status	Description
E6	230	No ServoWire Network Power	The drive is powered up and is not detecting ServoWire network power. Power for the ServoWire interface is supplied by the SMLC or Orion controller (8–40 VDC). Possible causes include: • The ServoWire cable is not connected to the drive and/or the SMLC or Orion controller. Verify that all the cables in the network are properly connected. • The SMLC or Orion controller is off and/or not supplying power to the ServoWire network.

Indication	Code	Status	Description
E8	232	Duplicate Drive ID	The SMLC or Orion has detected more than one drive on the network with same Axis ID.

			Find the other drive with the flashing ID and change one of them to a different value.

Indication	Code	Status	Description
F0	240	Motor Over Current (RMS)	The motor rating for continuous current has been exceeded by the actual RMS current for longer than allowed by the thermal time constant of the motor.

Indication	Code	Status	Description
F1	241	Motor Encoder Open Wire	At least one motor Encoder Feedback channel (ENCA, ENCA', ENCB, ENCB') is not connected properly. (J4 pins 1,2,3,4).

Quadrature Encoder	At least one motor Encoder Feedback channel (ENCA, ENCA', ENCB, ENCB') is not connected properly. (J4 pins 1,2,3,4).
H-Series Motor or other serial encoder	Loss of serial encoder communication or excessive errors. Check wiring and connections. (J4 pins 14, 15)

Indication	Code	Status	Description
F2	242	Auxiliary Encoder Open Wire	At least one auxiliary Encoder Feedback channel (ENCA, ENCA', ENCB, ENCB') is not connected properly. (J4 pins 1,2,3,4)

Indication	Code	Status	Description
F3	243	InvalidHallState	An unexpected combination of Hall inputs has occurred.
F3_1	243	InvalidHallState on Differential Inputs	Drive is configured for differential Hall inputs and an invalid value has been detected. Invalid states detected: Encoder Feedback Connector: U,V,W (J4 pins 7, 9,11) all ON at the same time. U',V',W' (J4 pins 8,10,12) all ON at the same time. U,V,W (J4 pins 7, 9,11) all OFF at the same time. U',V',W' (J4 pins 8,10,12) all OFF at the same time
F3_2	243	InvalidHallState on D-Series Motor interface	Drive is configured for a D-Series motor and an invalid Hall state has been detected.
F3_3	243	InvalidHallState on H-Series Motor interface	Drive is configured for a H-Series motor with a serial encoder and an invalid Hall state has been detected.

When enabling axis	• Bad feedback cable ⇒ Check pins above (see cable diagrams in Appendix E) • Wrong axis feedback type selected in ServoWire Pro or MotionDesk Setup software settings ⇒Correct software.

Indication	Code	Status	Description
F4	244	Motor Over Temperature	The thermal contact has opened indicating that the motor is over temperature. This condition can not be reset until the motor has sufficiently cooled. Encoder connector (J4 pins 19 & 20) Resolver connector (SAC-S2D-RES pins 10 & 23)

When the motor is hot	• Motor is overloaded ⇒ Reduce motor load • Excessive ambient temperature ⇒ Reduce ambient temperature to 25°C
When the motor is cool to the touch	• Faulty motor feedback wiring ⇒ Check cable and all termination points. • Defective thermal switch in motor ⇒ Disconnect motor and test for continuity at motor pins. (See motor pinouts in Appendix E). • Motor has no thermal switch, and ServoWire Setup software settings are configured to expect a closed contact. ⇒ Disable Thermal Contact in ServoWire Setup Axis Configuration. • Defective Servodrive⇒ Replace Servodrive.

Indication	Code	Status	Description
F5	245	Unknown Option Module	The drive has detected an installed option module, but does not recognize and/or support that module type. • Not supported by the drive firmware. ⇒ Verify that the drive firmware revision supports the option module, and update as needed. • Improper option module installation. ⇒ Reinstall the option module and verify it is properly connected to the drive. • Defective option module. ⇒ Replace the option module

Indication	Code	Status	Description
F6	246	OvertempConfig. error.	The motor configuration indicates that there is no over temperature sensor, but an over temperature sensor was detected by the drive.

Indication	Code	Status	Description
F7	247	Serial Encoder Alarm.	When using a H-Series motors. An alarm bit has been returned by the H-Series serial encoder.

			• Check connections and feedback cable for good electrical connection. • Cycle the ServoWire drive control power. • Defective encoder feedback - Replace Servomotor.
F7_1	247	Incremental encoder error	When using a H-Series motor with an incremental encoder the encoder has reported an error. The error is cleared by power cycling the motor which is done by power cycling the drive.
F7_2	247	Absolute encoder overspeed error	When using a H-Series motor, the absolute encoder has reported an overspeed error. The error is cleared by power cycling the motor which is done by power cycling the drive.
F7_3	247	Absolute encoder overspeed error	When using a H-Series motor, the absolute encoder has reported an absolute error. The error is cleared by power cycling the motor which is done by power cycling the drive.
F7_4	247	Absolute encoder backup power error	When using a H-Series motor, the absolute encoder has reported a backup power error. Encoder backup power has failed and absolute position lost. The error can be cleared by issueing an Encoder Reset command, allowing operation to continue without the need for a power cycle. However, absolute position has been lost. This happens when the encoder cable is disconnected for any time or or the CBL-HBAT is disconnected or if the battery has run down.
F7_5	247	Absolute encoder generic error	When using a H-Series motor, the absolute encoder has reported a generic error. The error is cleared by issueing an Encoder Reset command, allowing operation to continue without the need for a power cycle.
F7_6	247	Absolute encoder over temperature error	When using a H-Series motor, the absolute encoder has reported an over temperature error. The error is cleared by issuing an Encoder Reset command, allowing operation to continue without the need for a power cycle. It is recommended that the motor be allowed to cool down before continuing. This error is reported only once per power cycle of the motor.
F7_7	247	Absolute encoder battery low error	When using a H-Series motor, the absolute encoder has reported a battery low error. The error is cleared by issuing an Encoder Reset command, allowing operation to continue without

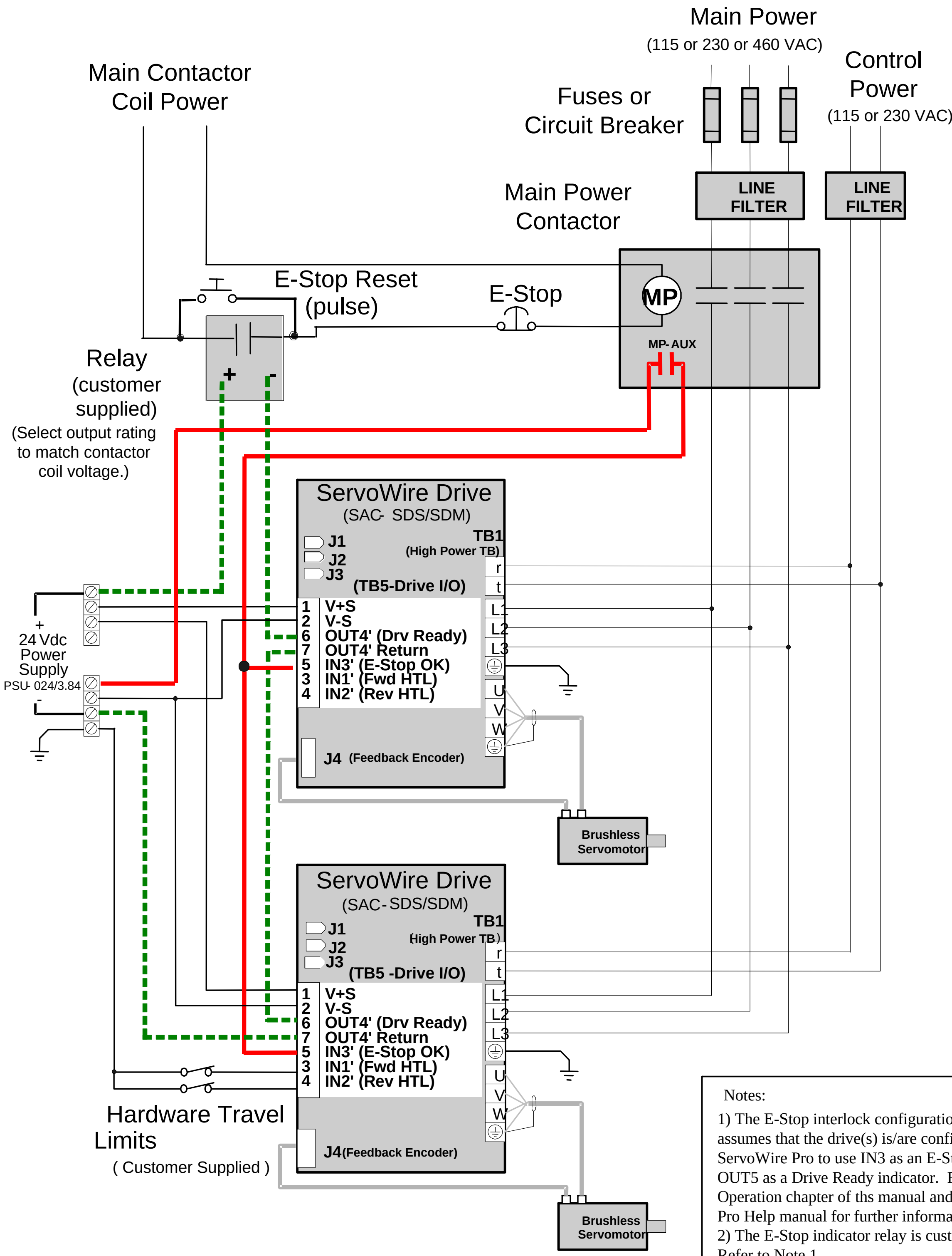
			the need for a power cycle. This error is reported only once per power cycle of the motor.

Indication	Code	Status	Description
F8	248	Unsupported Serial Encoder detected.	• Unsupported encoder feedback type detected - Replace servomotor to a supported type. • Not supported by the drive firmware - Verify that the drive firmware revision supports the Serial Encoder and update as needed.
F8_2	248	Unsupported Serial Encoder detected.	• An operational parameter defined in the encoder makes the encoder incompatible with the drive. Contact ORMEC Service for assistance.

7.3 Servomotor Troubleshooting Guide

Problem	Cause	What to do
WARNING!!! **Turn off power before working on the Servomotor**		
Motor does not start	Loose Connection ⇒ Tighten connection	
	Wrong wiring ⇒ Correct wiring	
	Overload ⇒ Reduce load or use a larger motor	
	Motor defective	Measure voltage across motor terminals U, V, &W on the Servodrive. If correct, replace motor, otherwise replace servodrive.
	Servodrive Defective	
Locked Rotor	Wrong order of U, V, W	Check cabling.
Unstable Operation	Wrong motor selected in the configuration software.	Check and correct that software matches motor.
	Improper Tuning	Check that Inertial load specified in the configuration software is less than or equal to the actual load seen by the motor. Check other tuning parameters.
	Wrong Wiring	Inspect and correct wiring of motor terminals U, V, & W and/or the encoder.
Motor Overheats	Excessive ambient temperature	Reduce ambient temperature below 40°C, or use a larger motor.
	Motor dirty	Clean motor surface.
	Overload	Reduce load or use a larger motor.
Unusual Noise	Motor loosely mounted	Tighten mounting bolts.
	Motor is mis-aligned	Realign.
	Coupling out of balance	Balance coupling.
	Noisy bearing	Check alignment, loading of bearing, lubrication.
	Vibration of driven machine	Check the machine's mechanical operation.
	Improper grounding and/or shielding	Check the servomotor, servodrive, and power supply grounding and shielding.
	Incorrect servo control loop tuning	Check the servo control loop tuning parameters.
Poor Velocity Regulation	Single phase main power (L1 & L2 only) on a drive expecting 3-phase power (SAC-S2D_210, SAC-S2D_215, SAC-S2D_215)	Use 3-phase power.
WARNING!!! **Turn off power before working on the Servomotor**		

115/230/460 VAC System Wiring Diagram



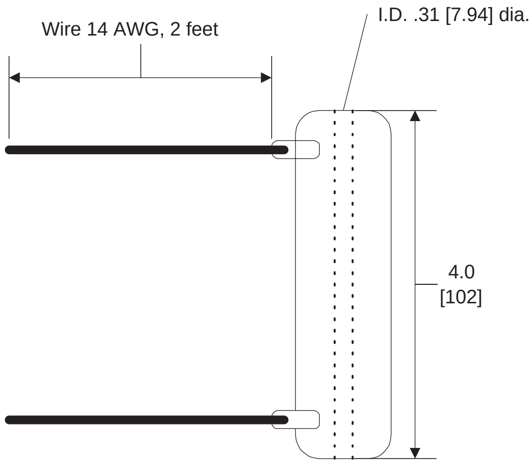
Notes:

1) The E-Stop interlock configuration shown assumes that the drive(s) is/are configured in ServoWire Pro to use IN3 as an E-Stop input and OUT5 as a Drive Ready indicator. Refer to the Operation chapter of ths manual and the ServoWire Pro Help manual for further information.

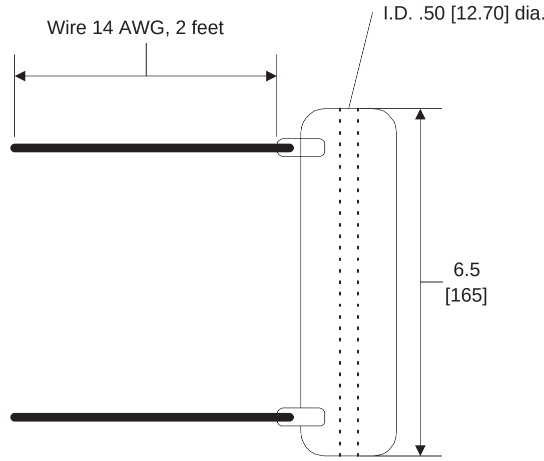
2) The E-Stop indicator relay is customer supplied. Refer to Note 1.

3) The Drive Ready relay is customer supplied. **The Interlock and I/O power should be provided by separate power supplies to prevent inductive in-rush from the Drive Ready relay.**

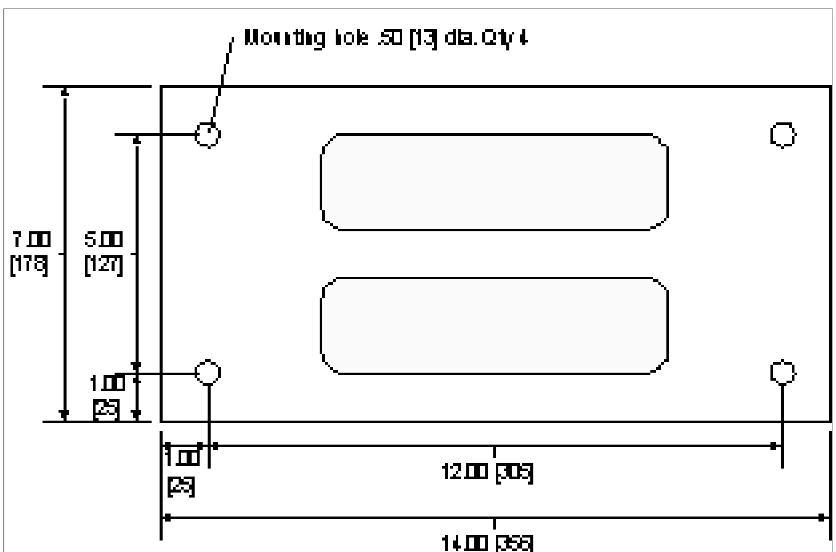
Regen Resistors



SAC-SWRR/0055

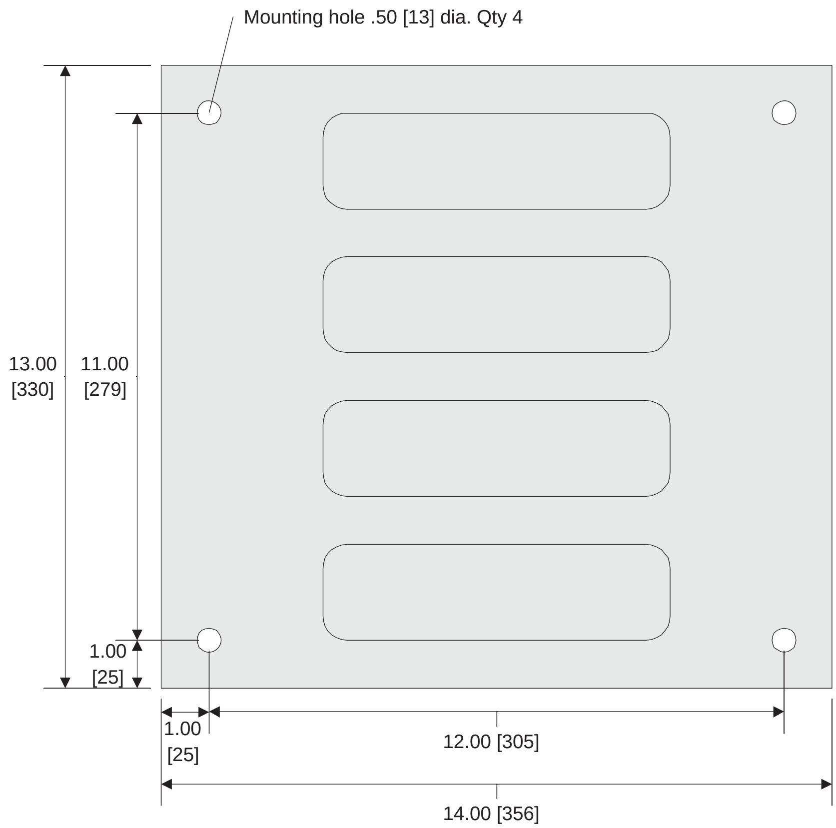


SAC-SWRR/0095



SAC-SWRR/0700, 0845, 0846

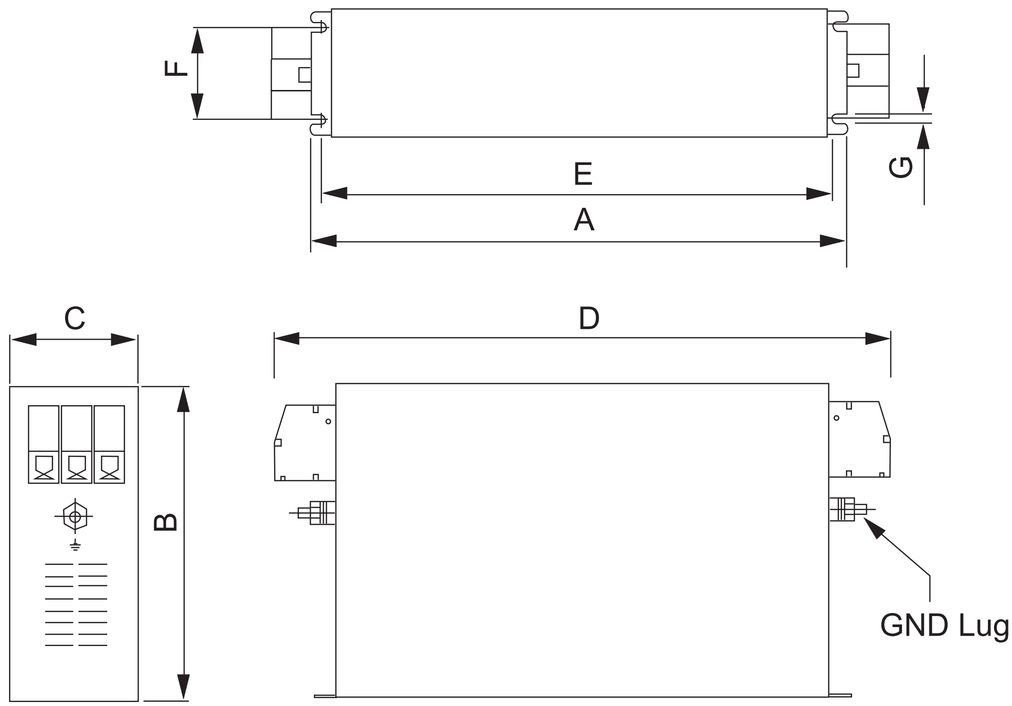
All dimensions in inches [mm]



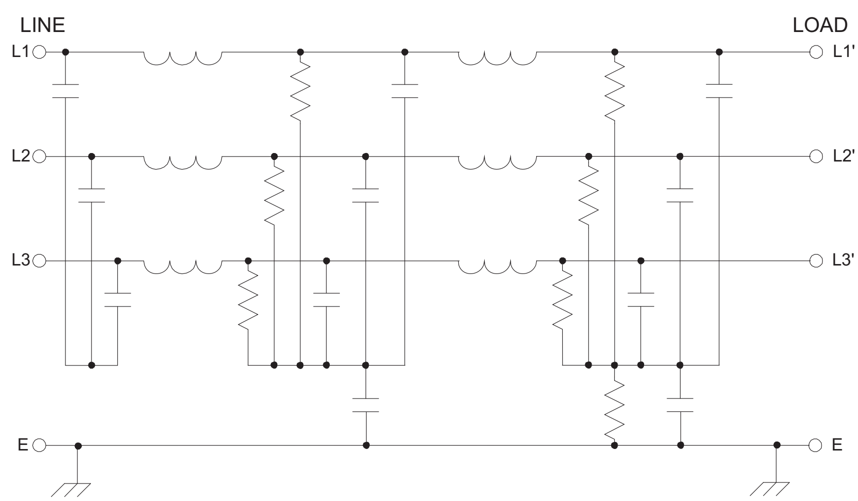
SAC-SWRR/1700

All dimensions in inches [mm]

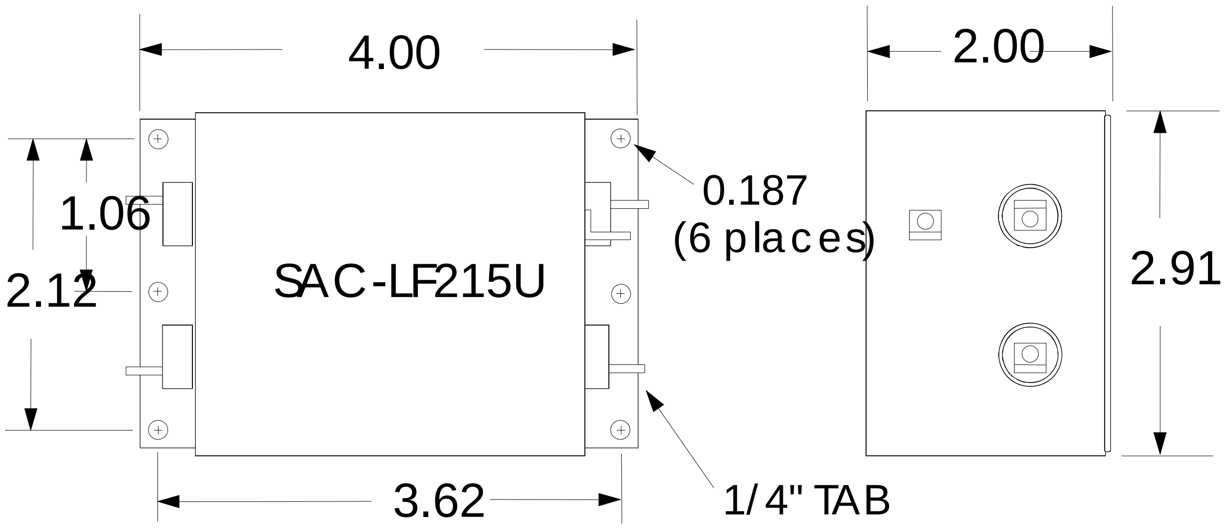
Line Filters: SAC-LF30C, 55C, & 100C



Line Filter	A	B	C	D	E	F	G	Units	GND Lug	Max. Wire Gauge
SAC-LF30C	13.2	5.9	2.4	13.9	12.6	1.4	0.3	inches	M5	6 AWG
	335	150	60	354	320	35	6.5	mm		10 mm2
SAC-LF55C	13.0	7.3	3.1	14.8	12.4	2.2	0.3	inches	M6	3 AWG
	329	185	80	377	314	55	6.5	mm		25 mm2
SAC-LF100C	14.9	8.7	3.5	17.2	14.3	2.6	0.3	inches	M10	1/0 AWG
	379	220	90	436	364	65	6.5	mm		50 mm2

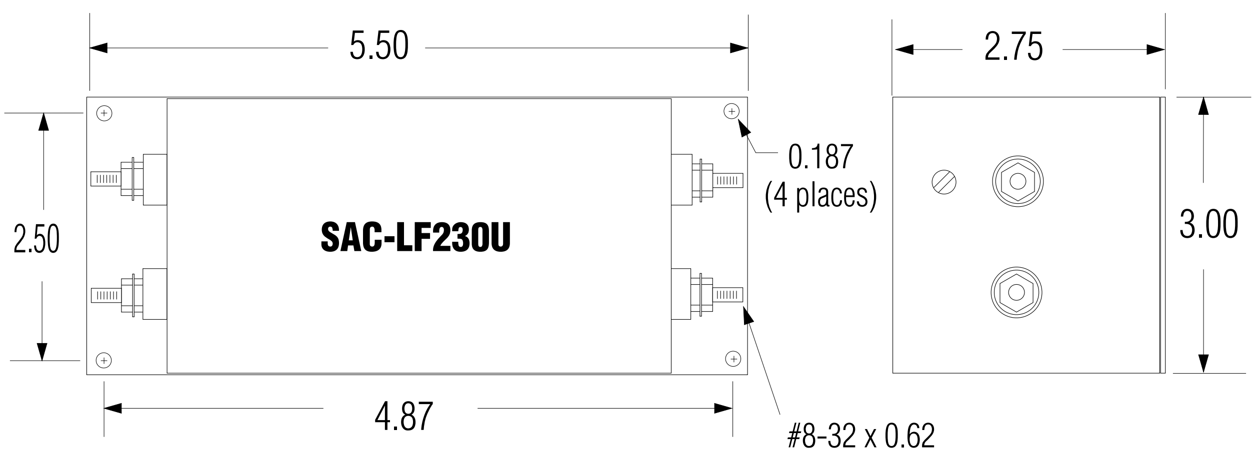


Line Filters: SAC-LF215U



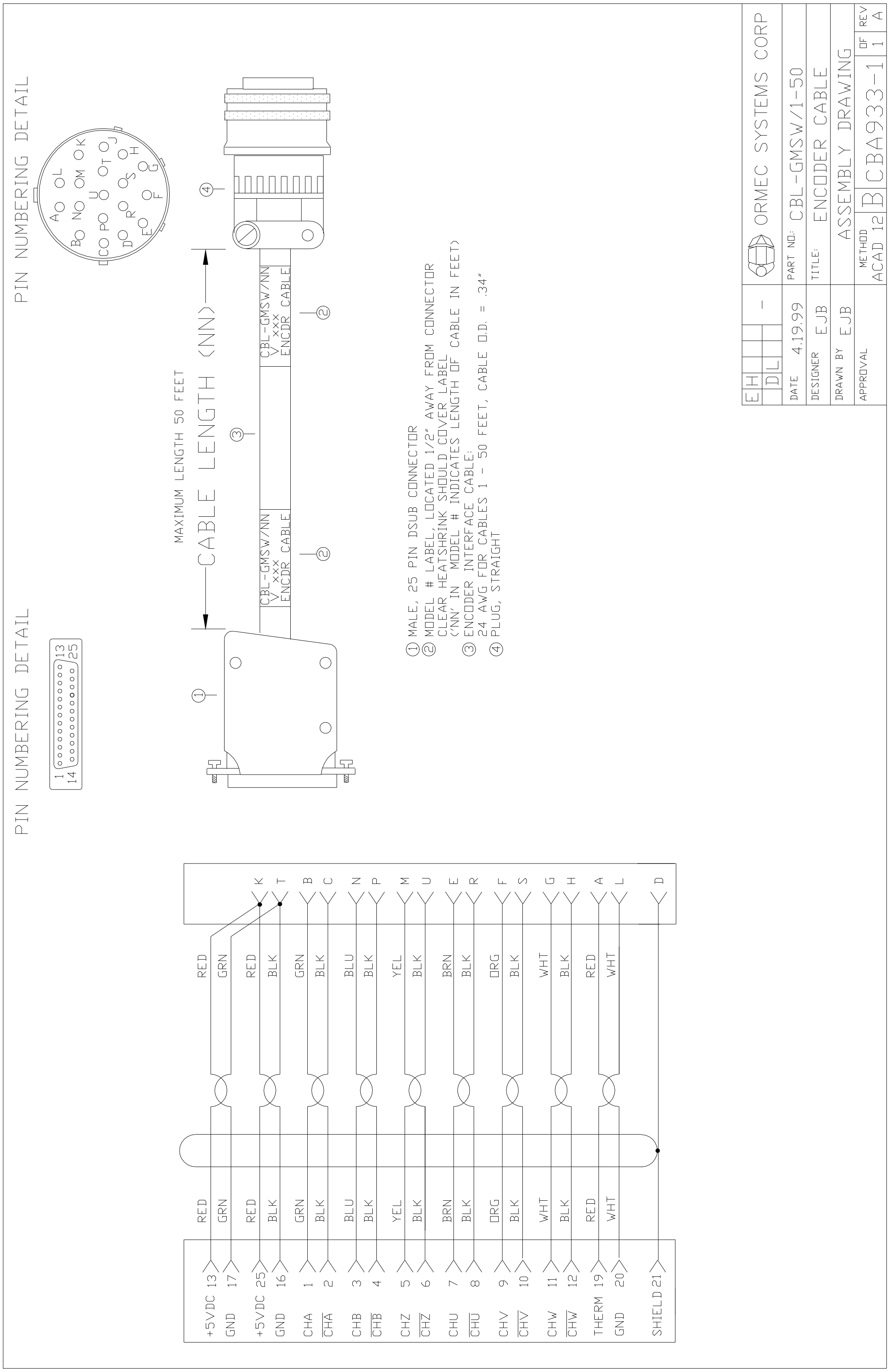
All dimensions in inches

Line Filters: SAC-LF230U

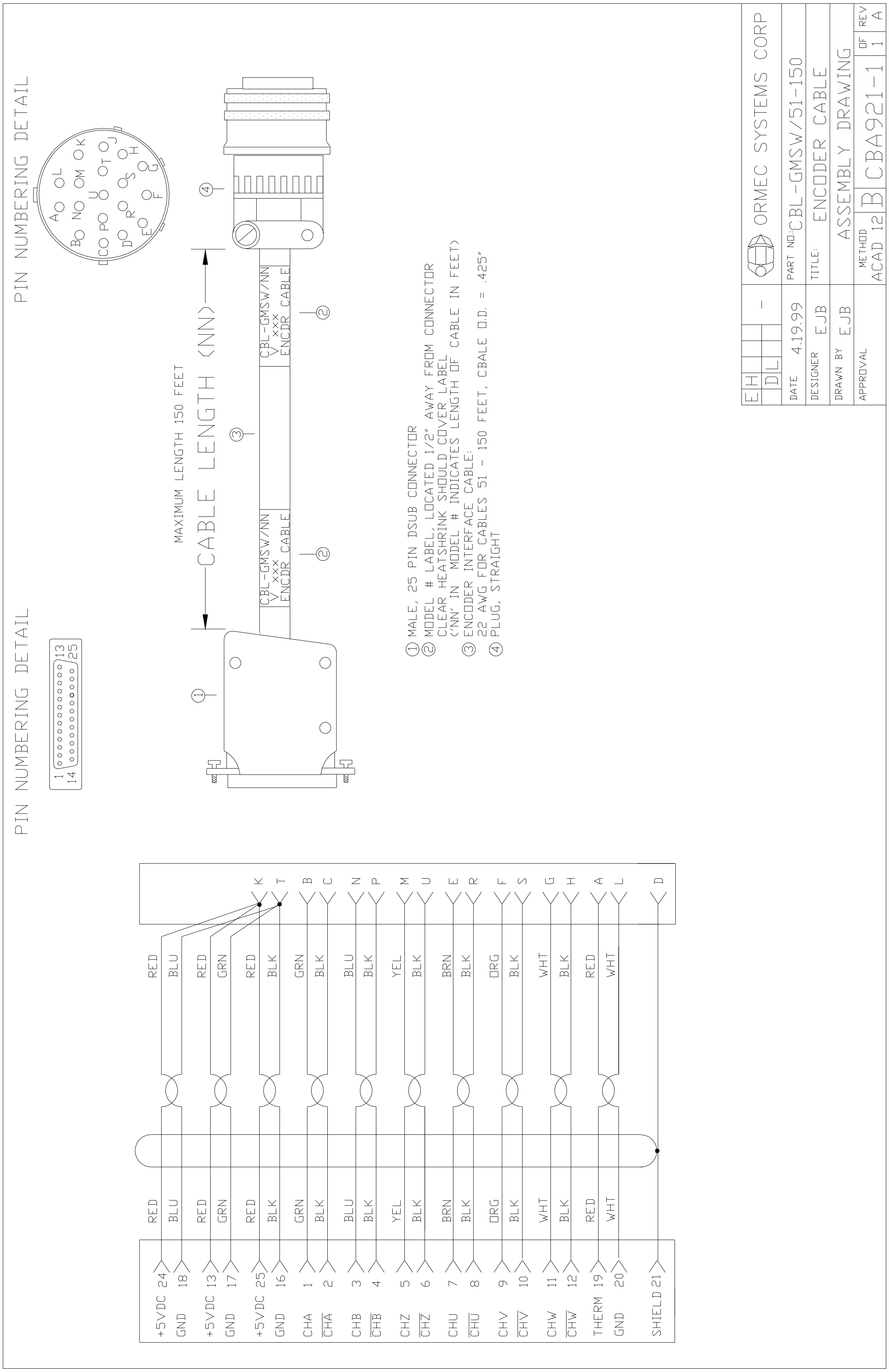


All dimensions in inches

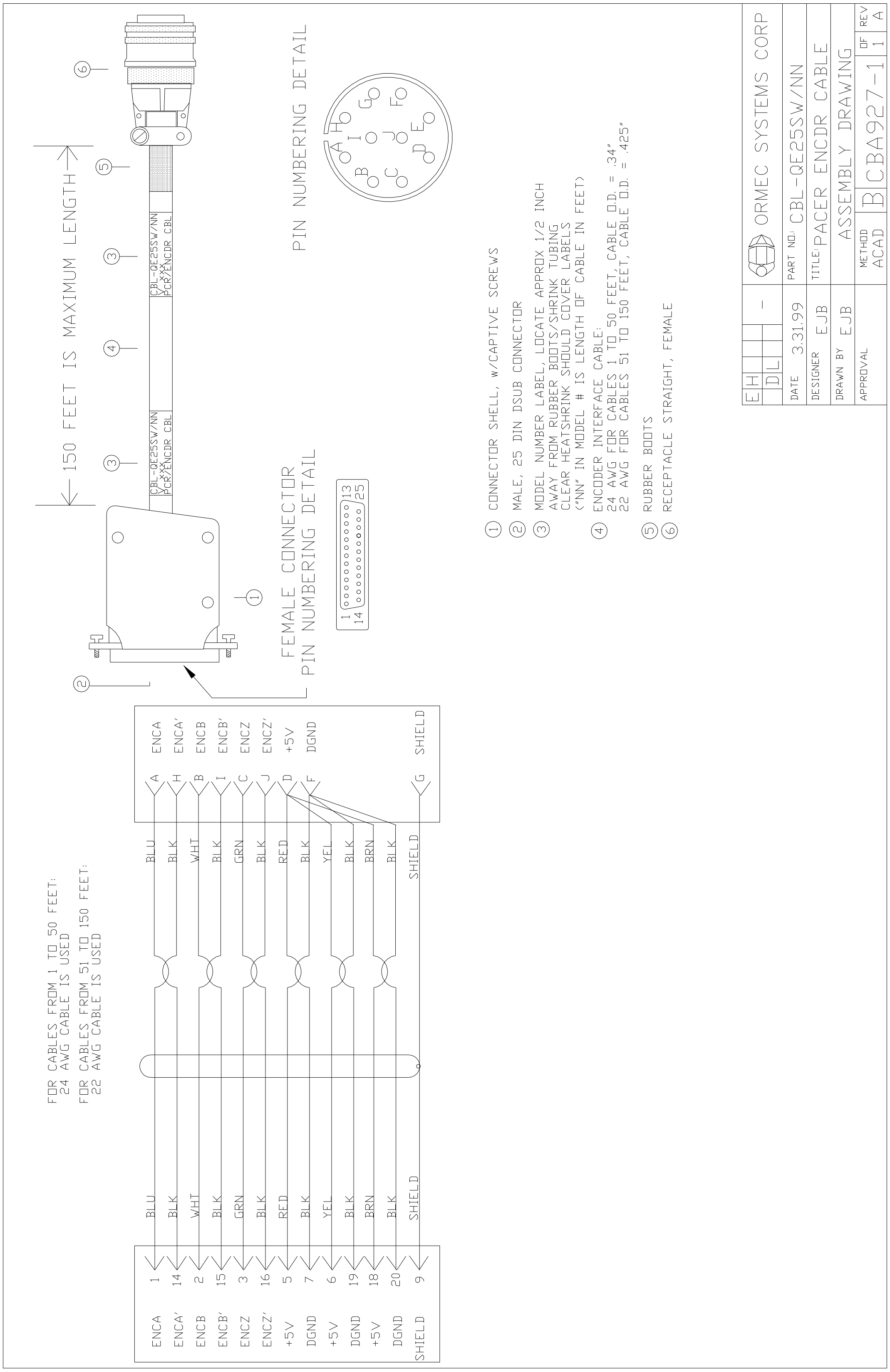
CBL-GMSW (1-50) Encoder Cable



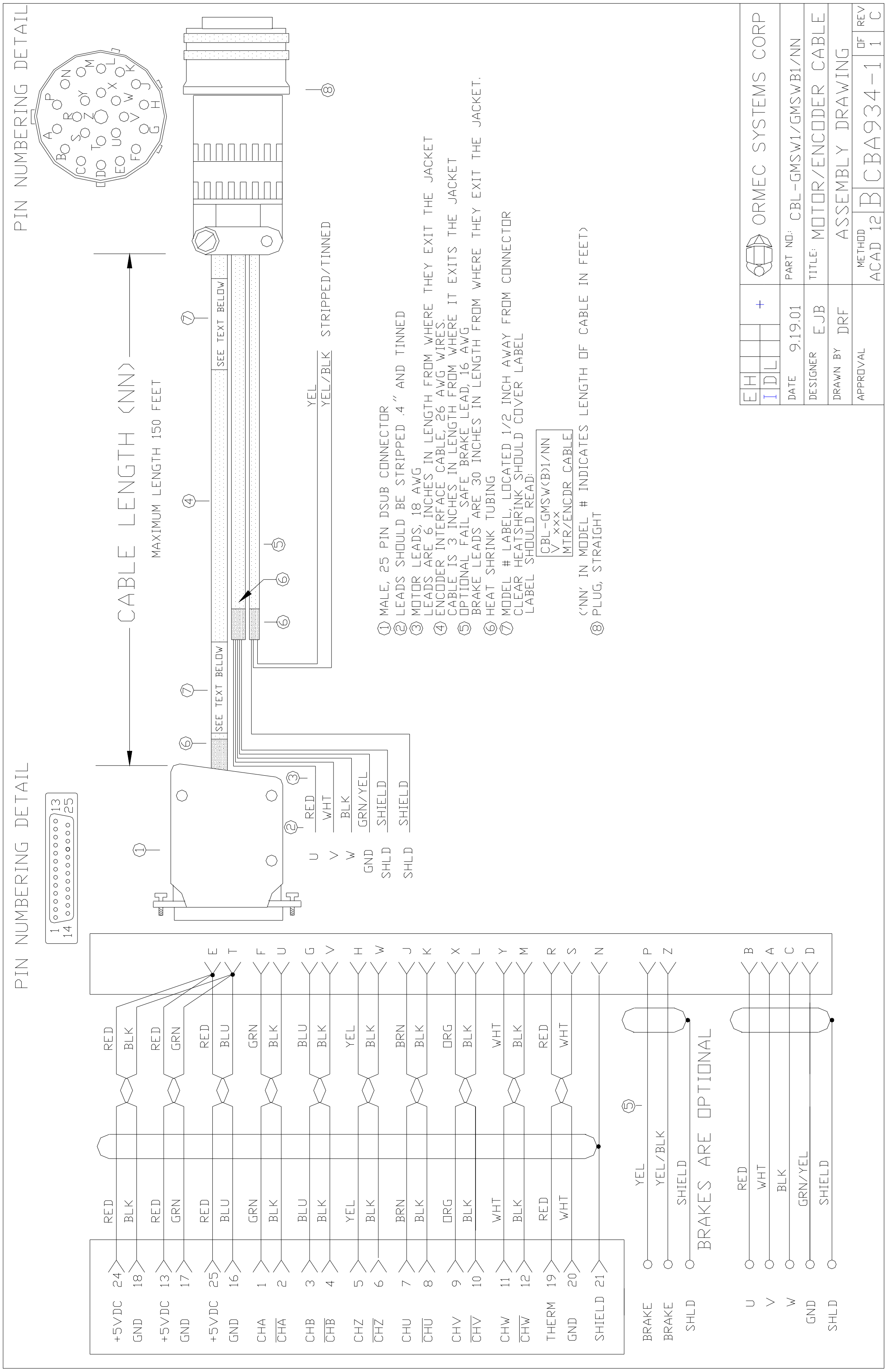
CBL-GMSW (51-150) Encoder Cable



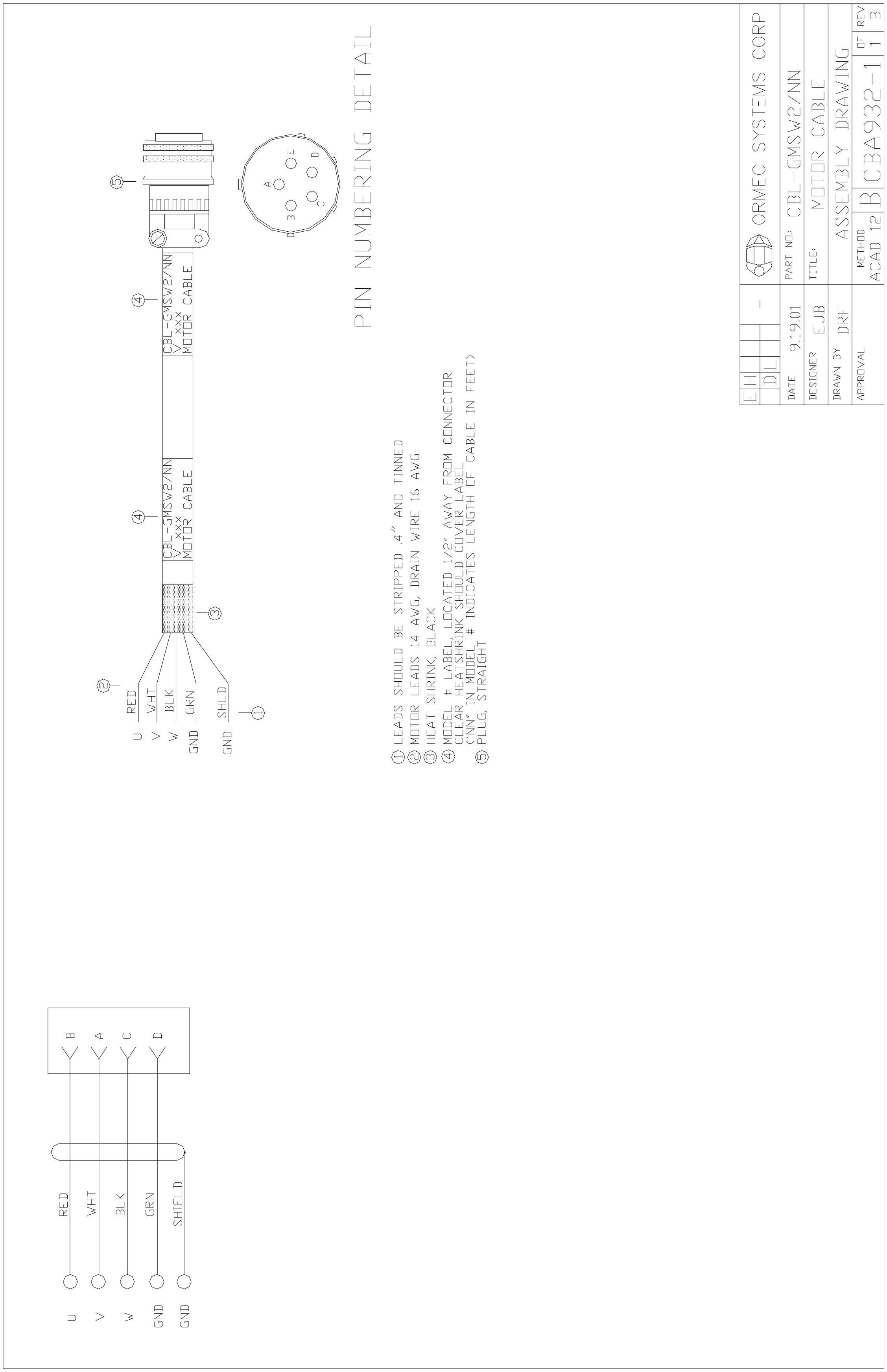
CBL-QE25SW Pacer Encoder Cable



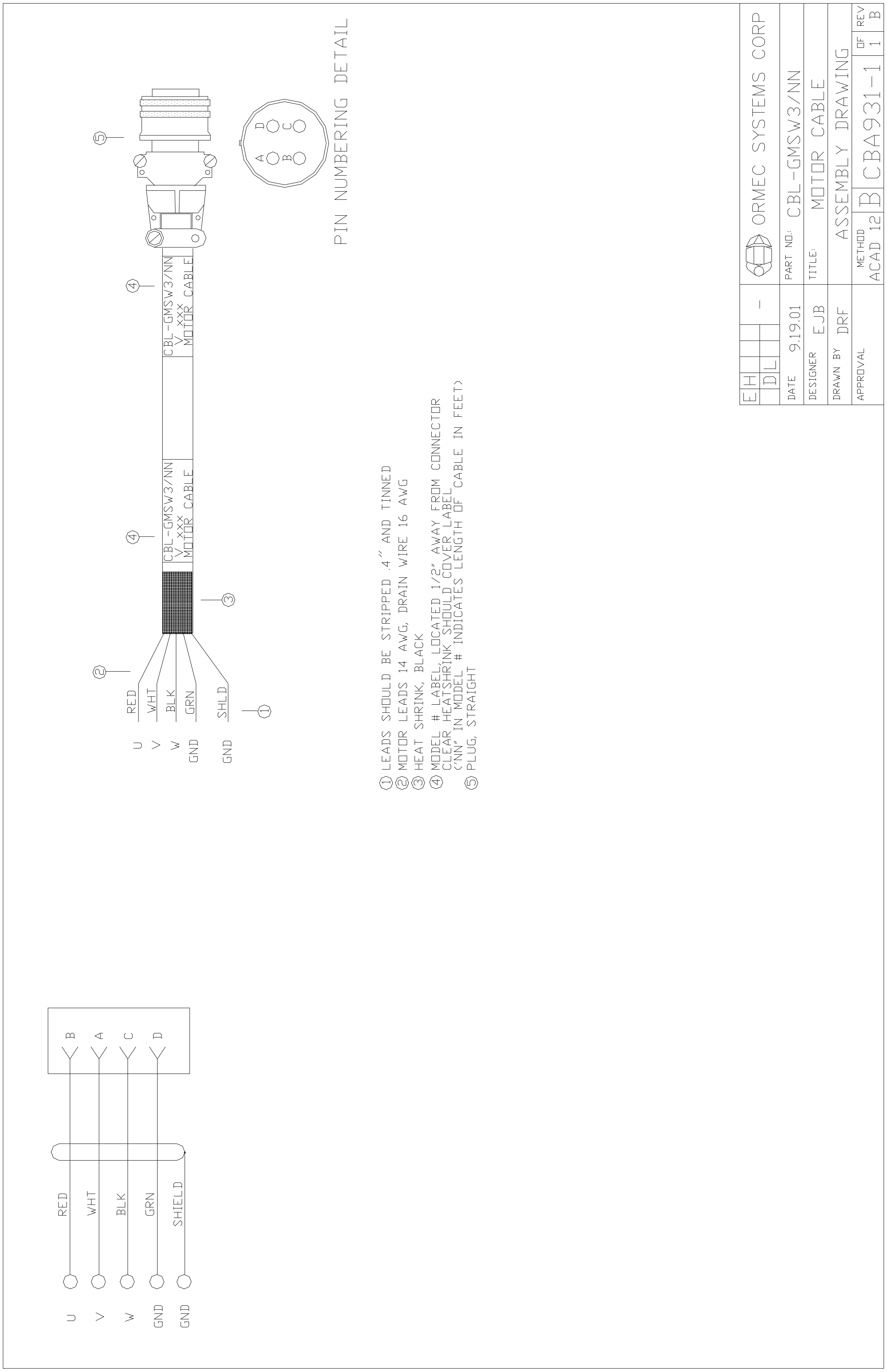
CBL-GMSW1 / GMSWB1 Motor/Encoder Cable



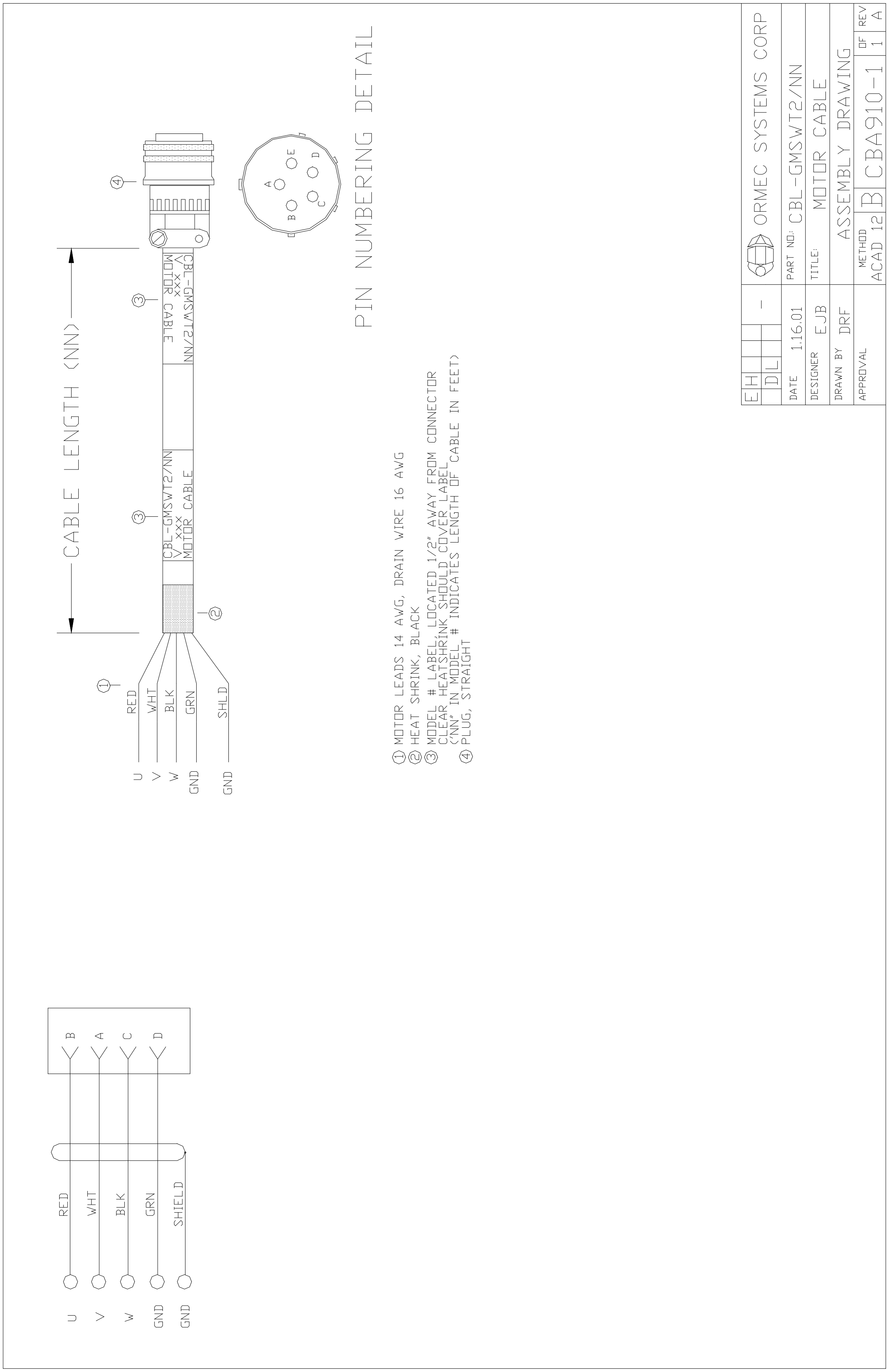
CBL-GMSW2 Motor Cable



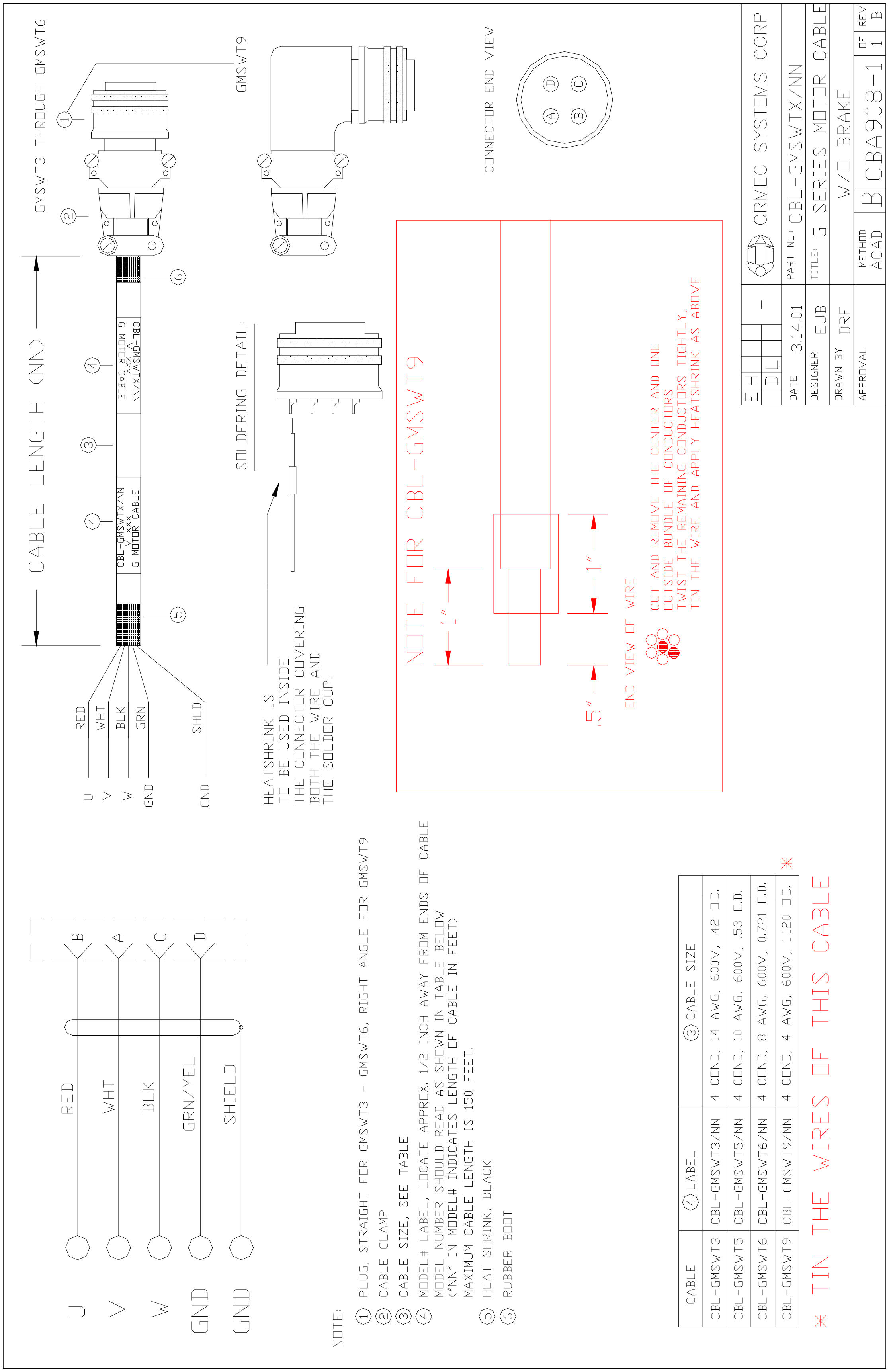
CBL-GMSW3 Motor Cable



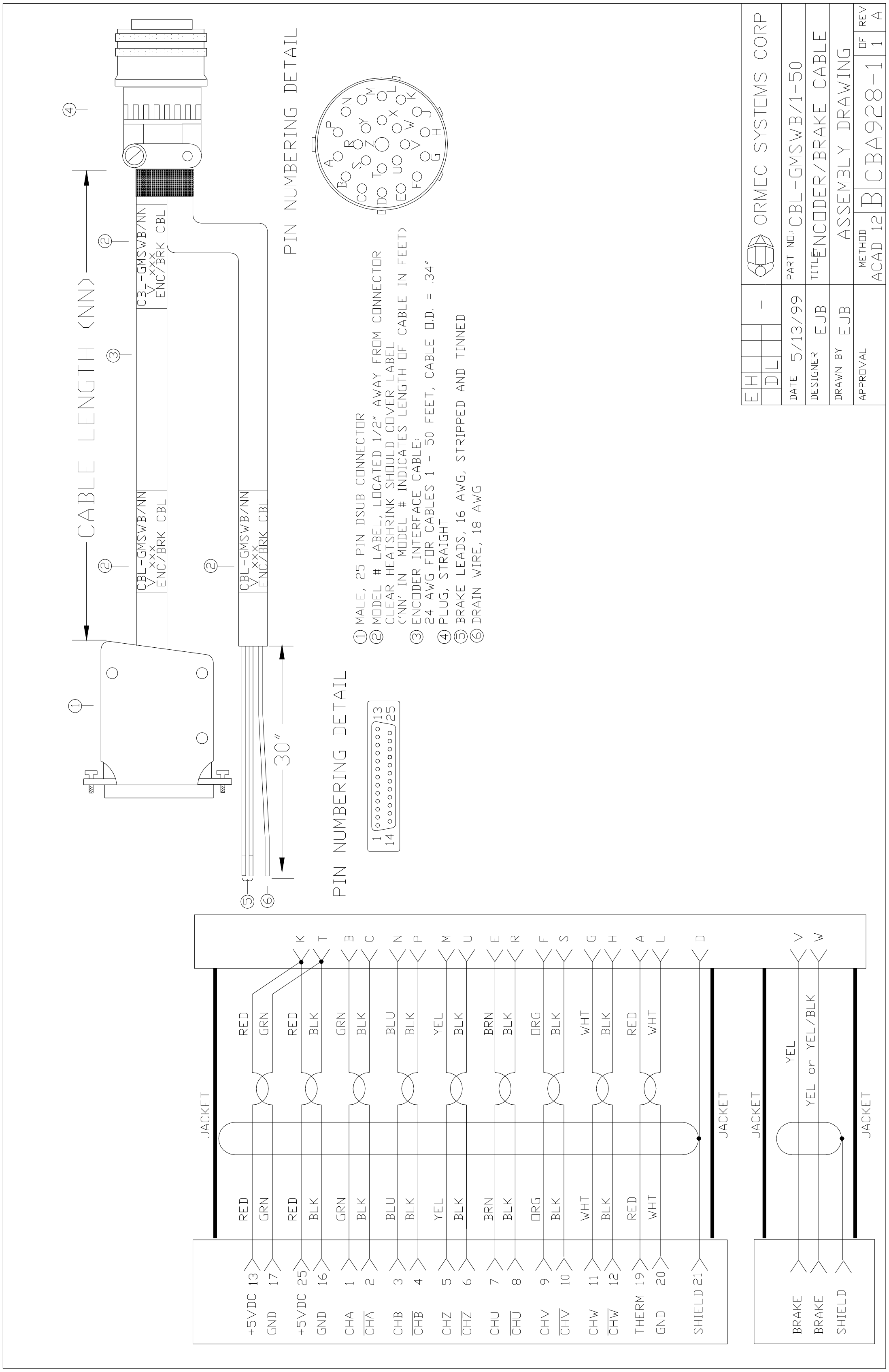
CBL-GMSWT2 Motor Cable



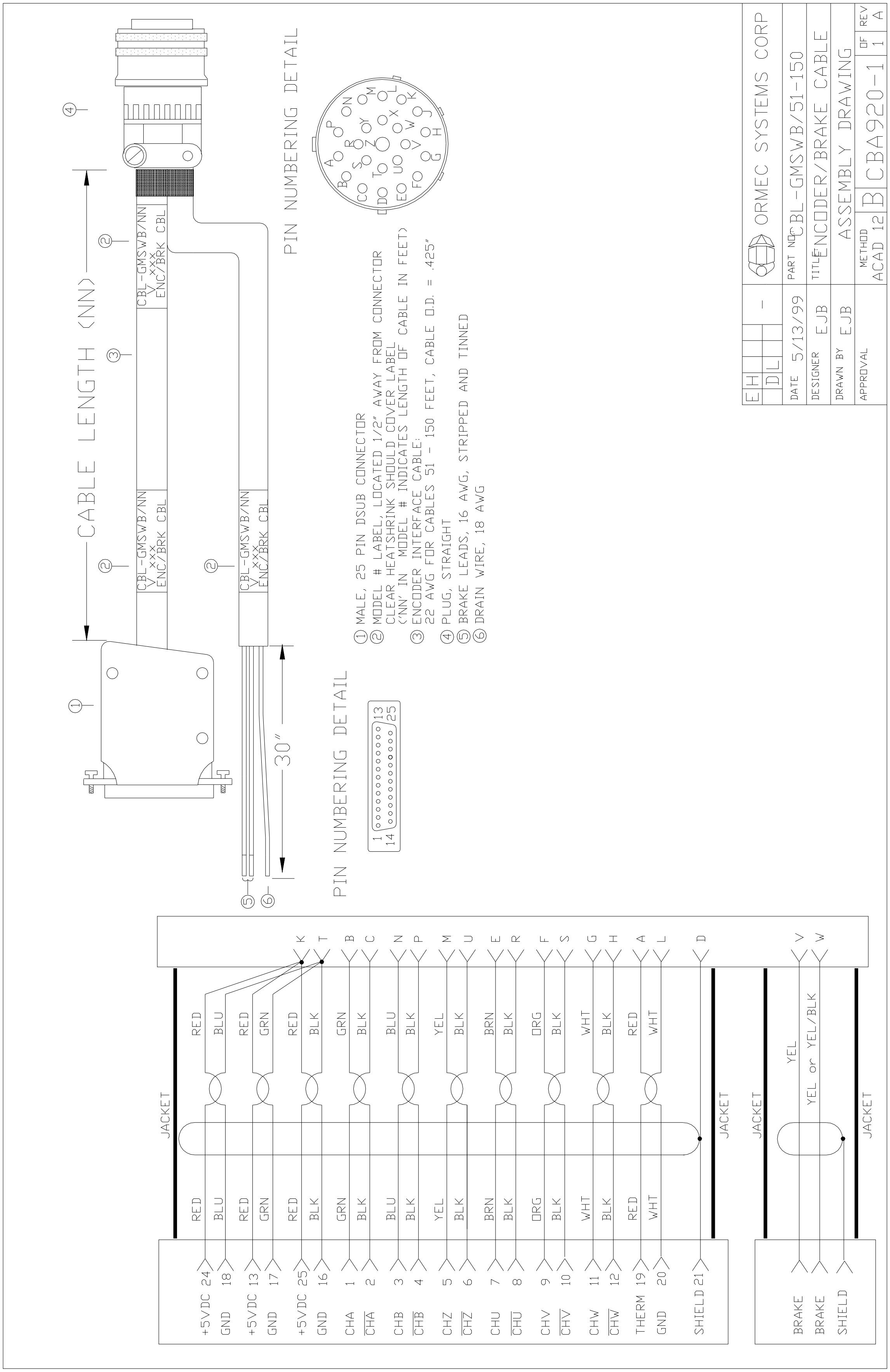
CBL-GMSWTX Motor Cable



CBL-GMSWB Motor Cable

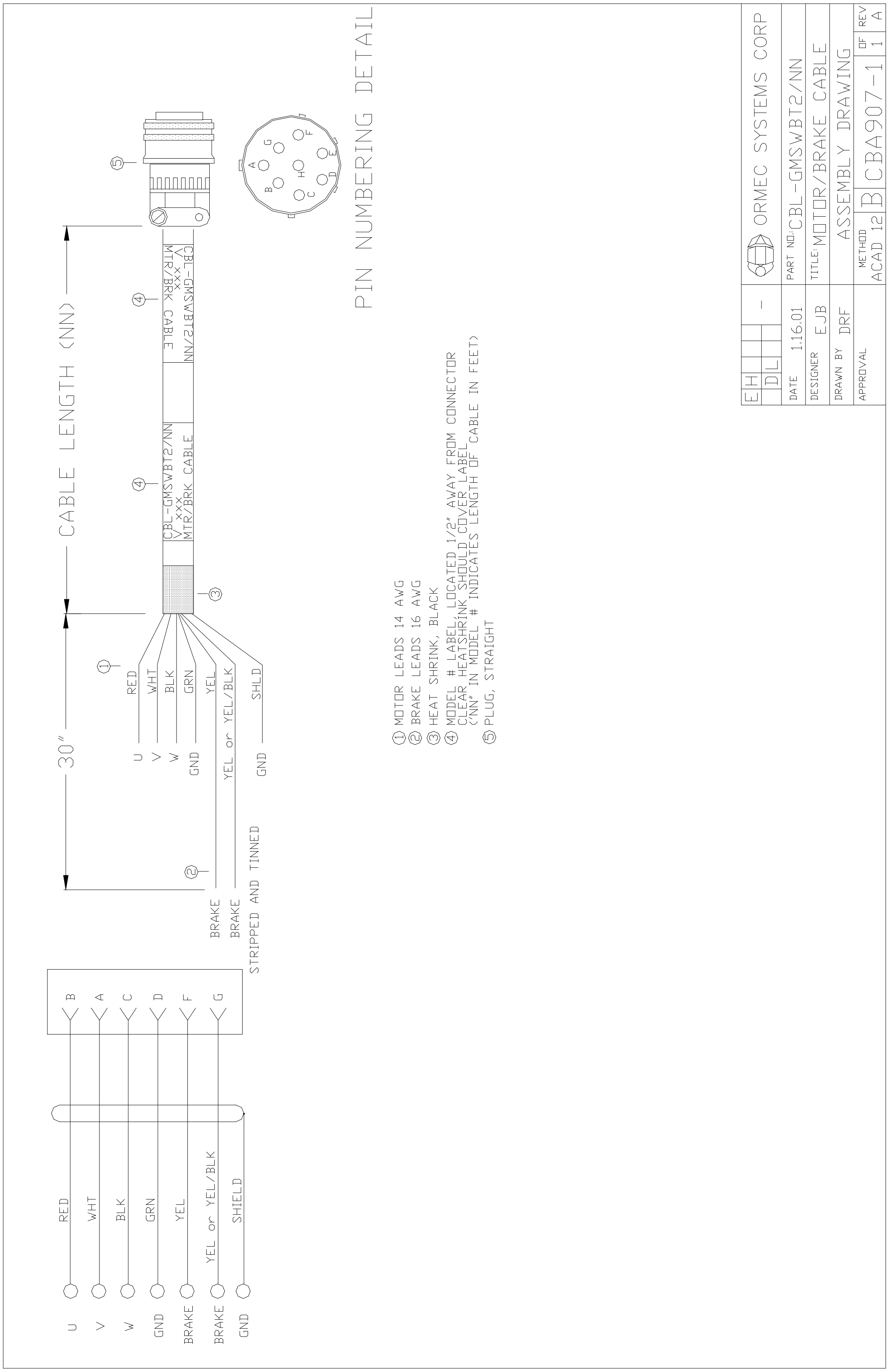


CBL-GMSWB

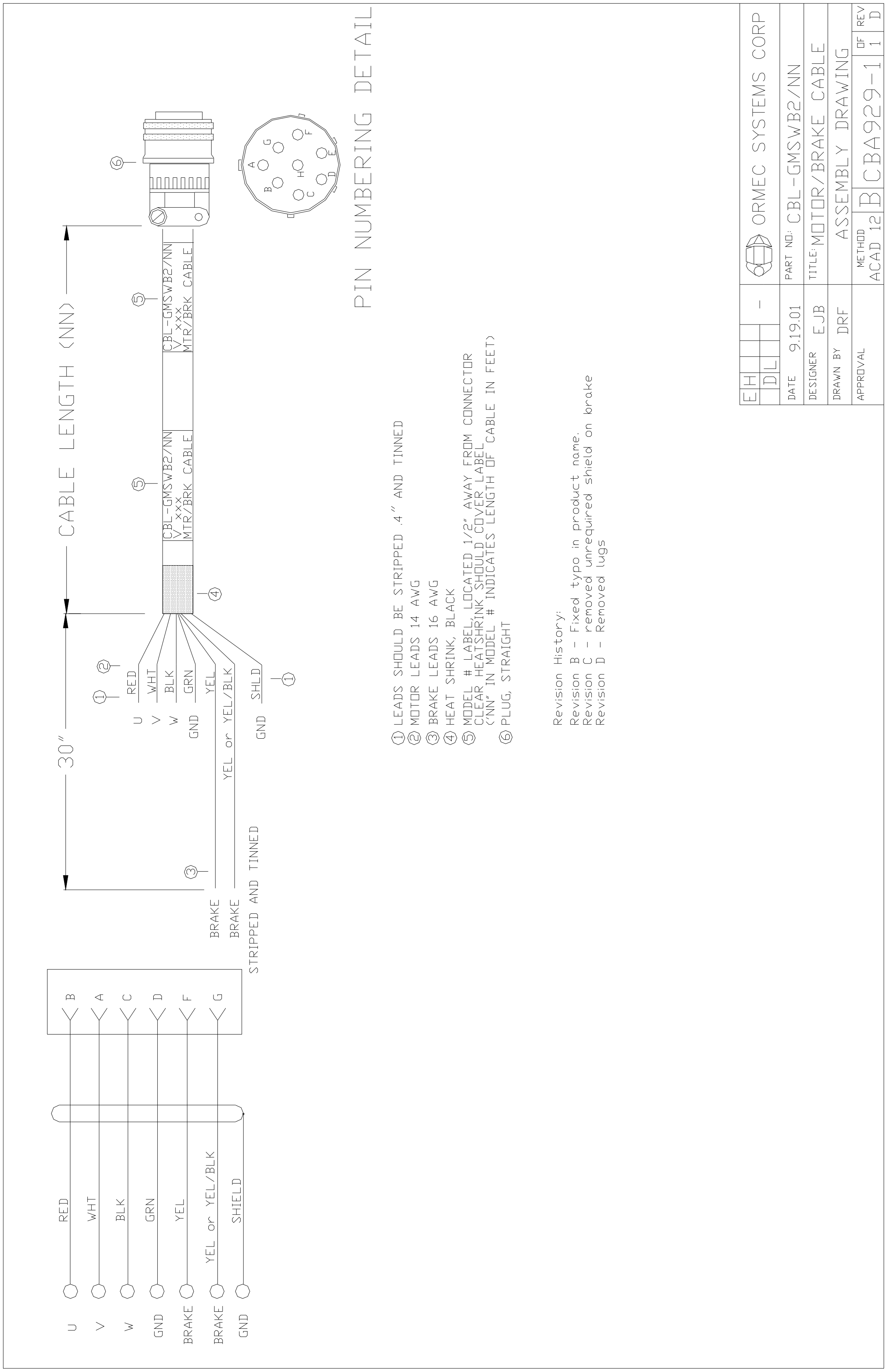


CABLE LENGTH (NN)
30"
PIN NUMBERING DETAIL
PIN NUMBERING DETAIL
CBL-GMSWB/NN
V XX
ENC/BRK CBL
1 MALE, 25 PIN DSUB CONNECTOR
2 MODEL # LABEL, LOCATED 1/2" AWAY FROM CONNECTOR
CLEAR HEATSHRINK SHOULD COVER LABEL
('NN' IN MODEL # INDICATES LENGTH OF CABLE IN FEET)
3 ENCODER INTERFACE CABLE:
22 AWG FOR CABLES 51 - 150 FEET, CABLE O.D. = .425"
4 PLUG, STRAIGHT
5 BRAKE LEADS, 16 AWG, STRIPPED AND TINNED
6 DRAIN WIRE, 18 AWG
ORMEC SYSTEMS CORP
PART NO. CBL-GMSWB/51-150
TITLE ENCODER/BRAKE CABLE
ASSEMBLY DRAWING
DATE 5/13/99
DESIGNER EJB
DRAWN BY EJB
APPROVAL
METHOD ACAD 12
B CBA920-1
OF 1 1
REV A
+5VDC 24
GND 18
+5VDC 13
GND 17
+5VDC 25
GND 16
CHA 1
CHA 2
CHB 3
CHB 4
CHZ 5
CHZ 6
CHU 7
CHU 8
CHV 9
CHV 10
CHW 11
CHW 12
THERM 19
GND 20
SHIELD 21
BRAKE
BRAKE
SHIELD
RED BLU RED GRN RED BLK GRN BLK BLU BLK YEL BLK BRN BLK ORG BLK WHT BLK RED WHT
JACKET
YEL
YEL or YEL/BLK
K T B C N P M U E R F S G H A L D V W

CBL-GMSWBT2 Motor / Brake Cable



CBL-GMSWB2 Motor / Brake Cable



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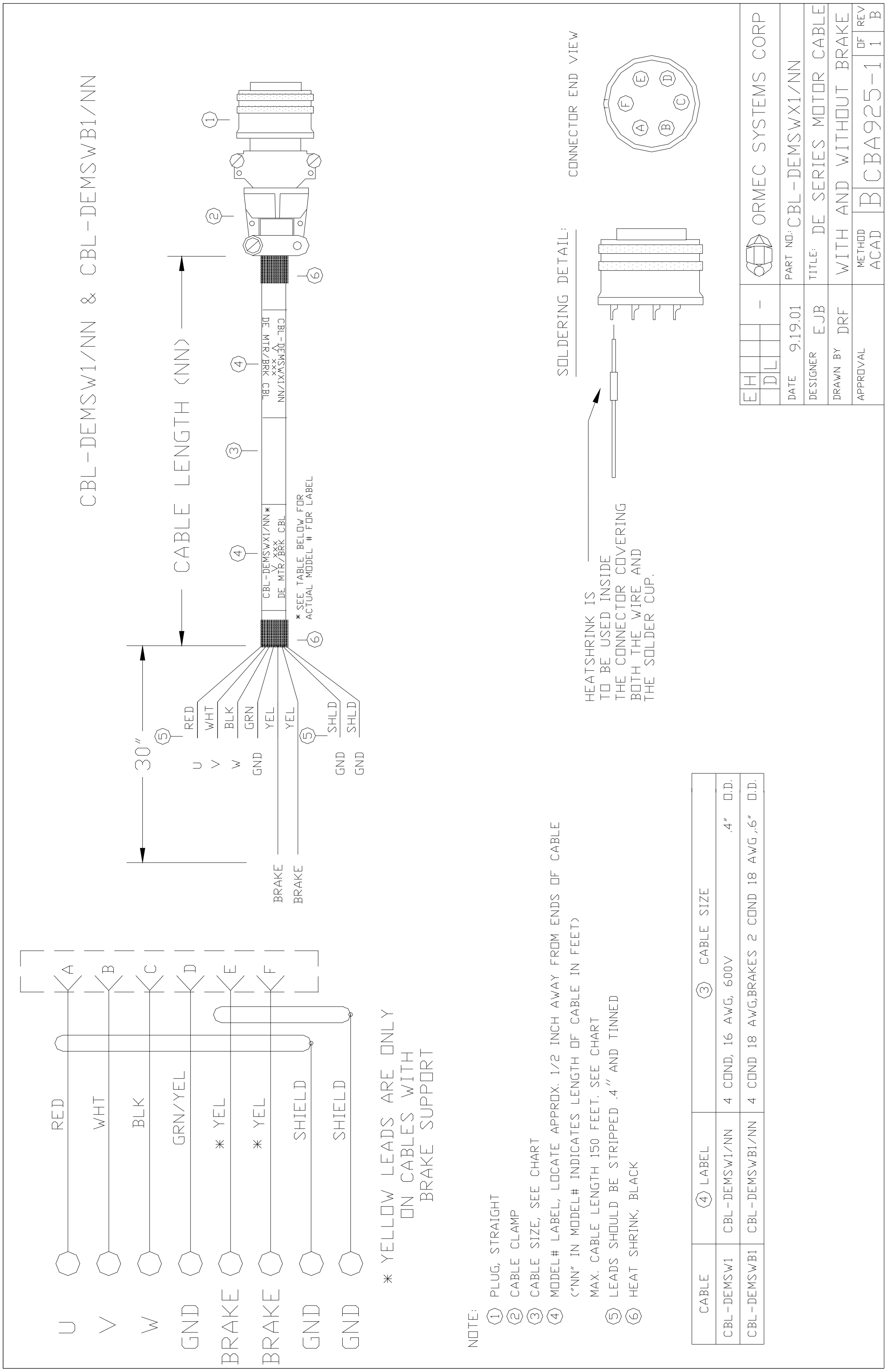
CBL-DEMSW1 Motor Cable



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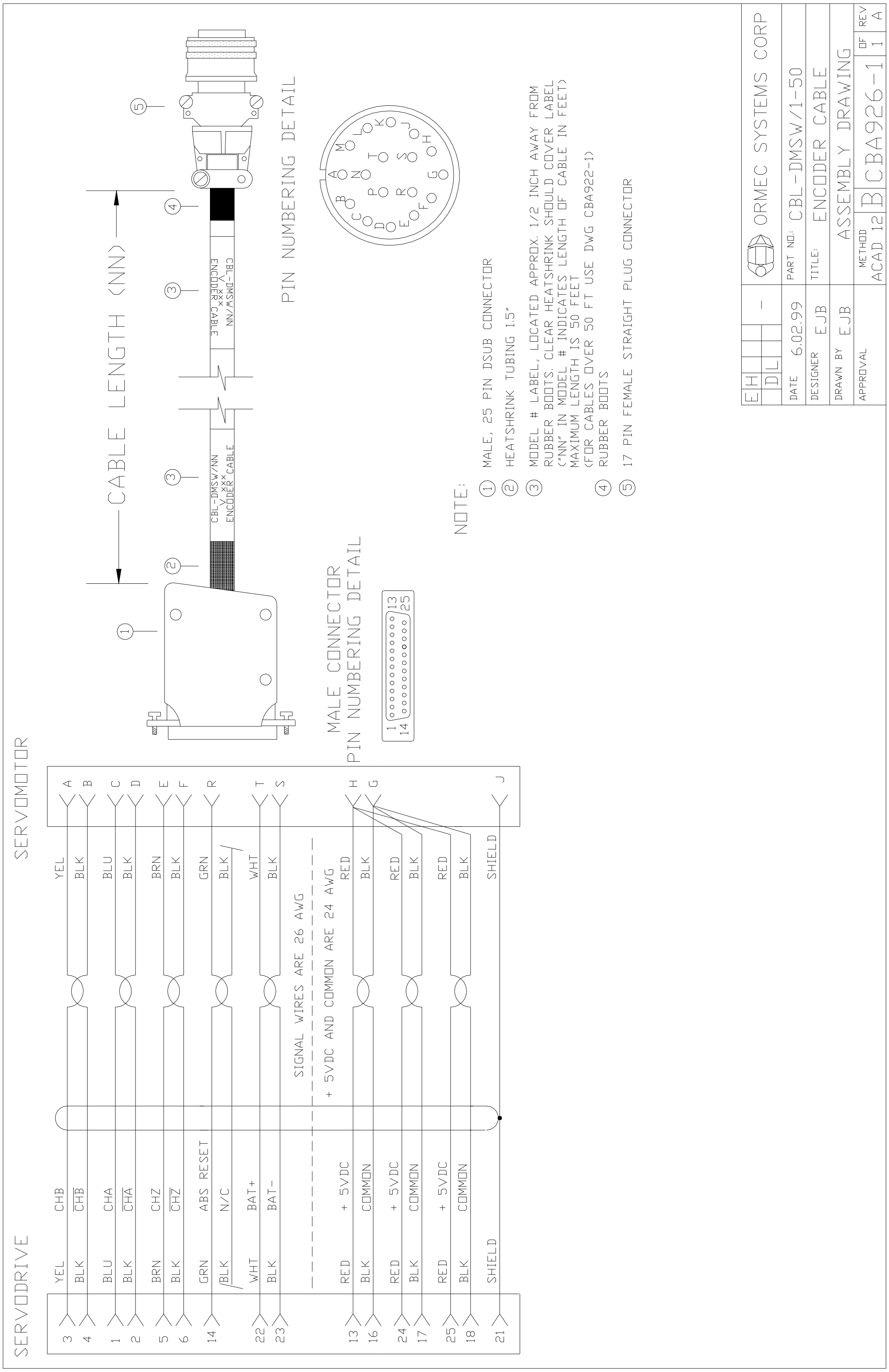
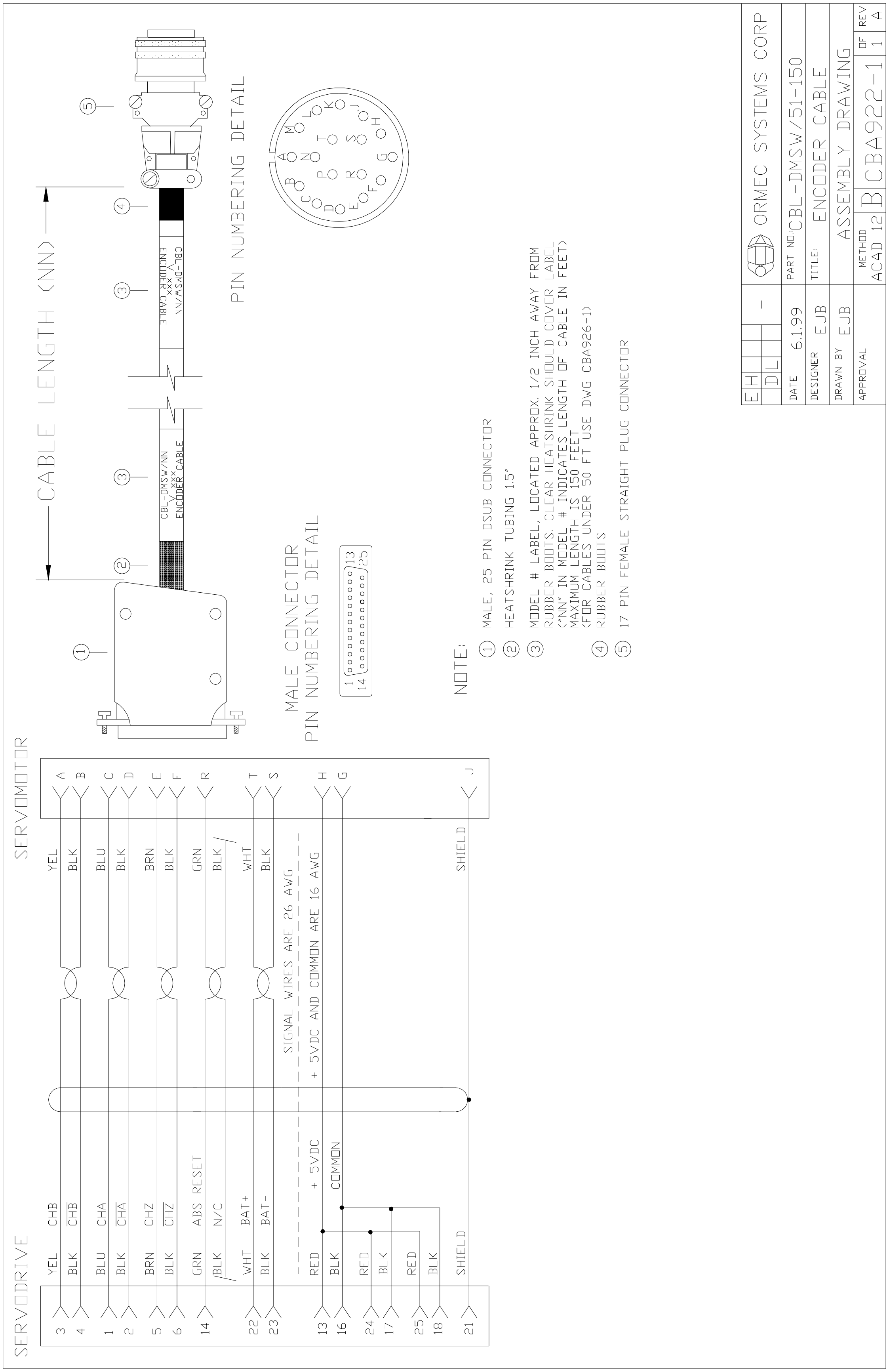
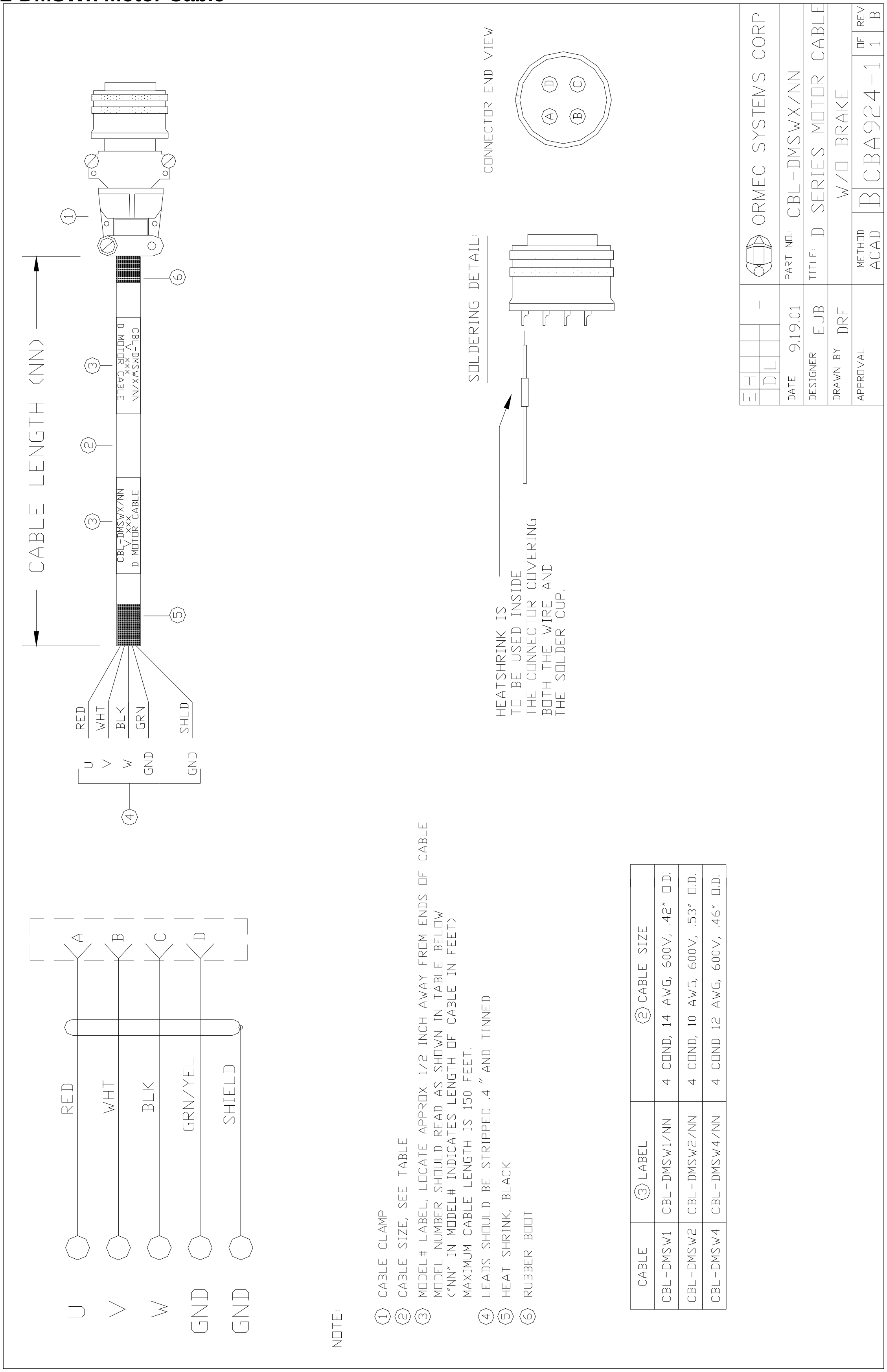
CBL- DMSW Encoder Cable



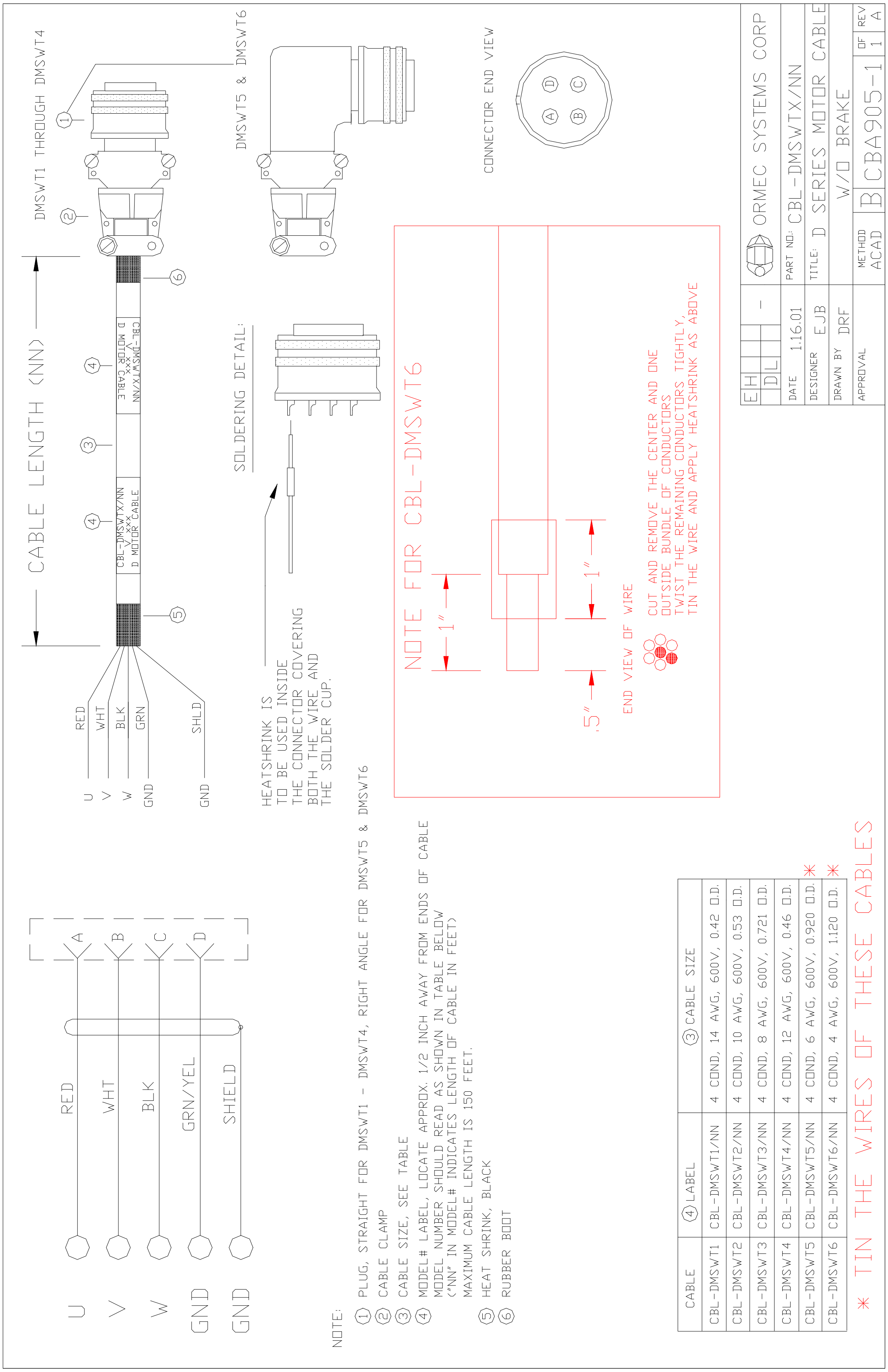
CBL-DMSW Encoder Cable



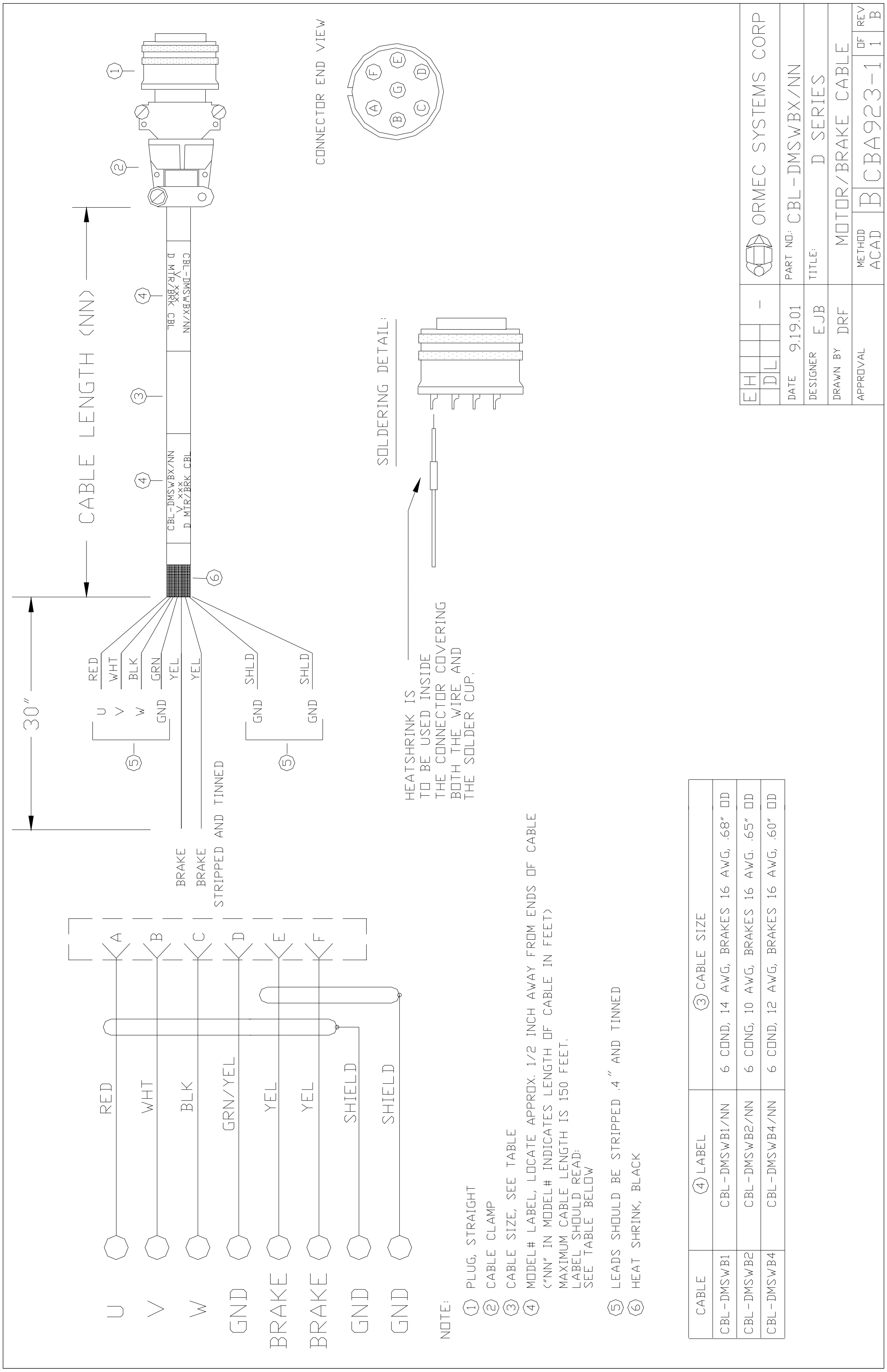
CBL-DMSWn Motor Cable



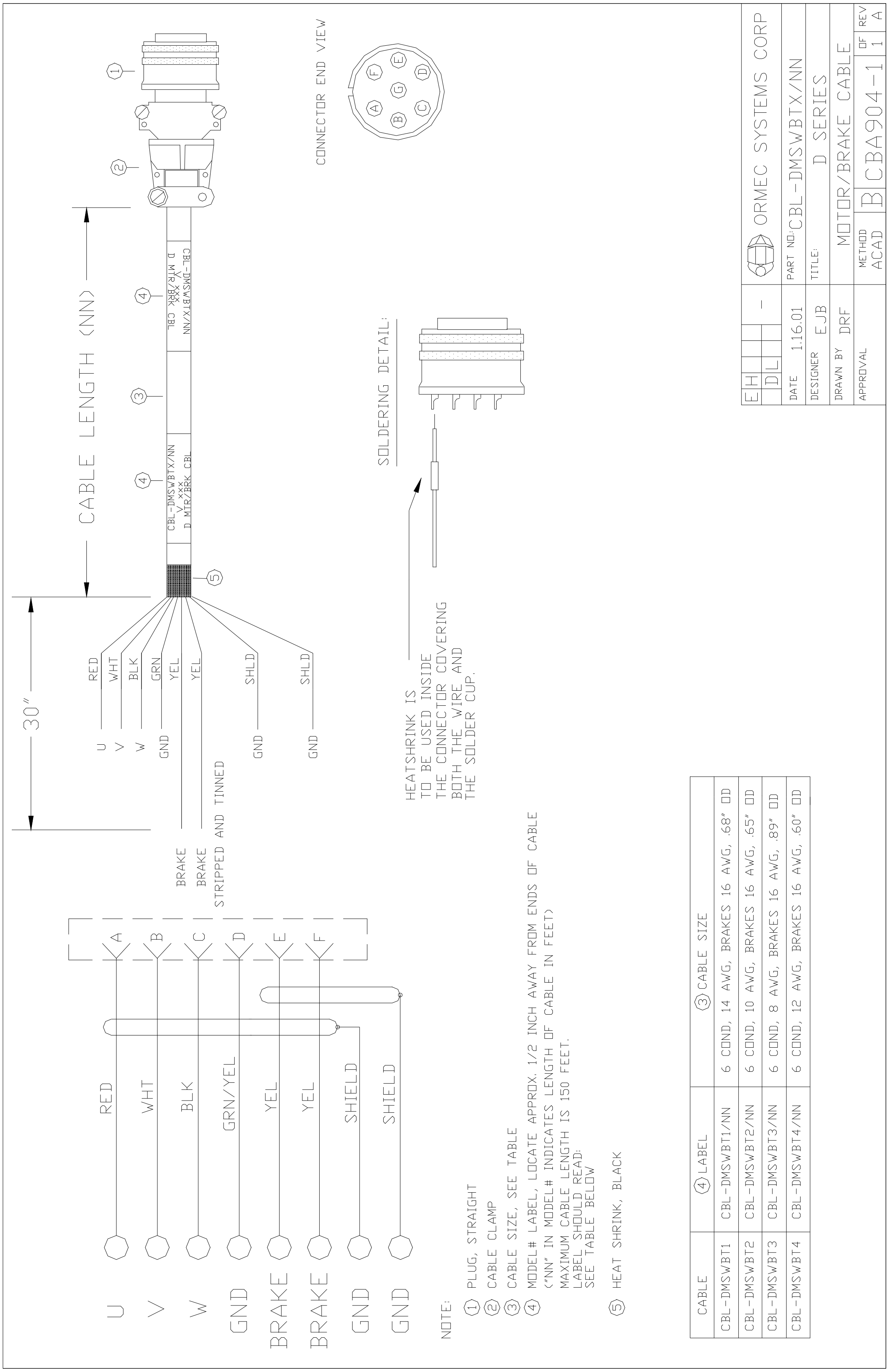
CBL-DMSWTx Motor Cable



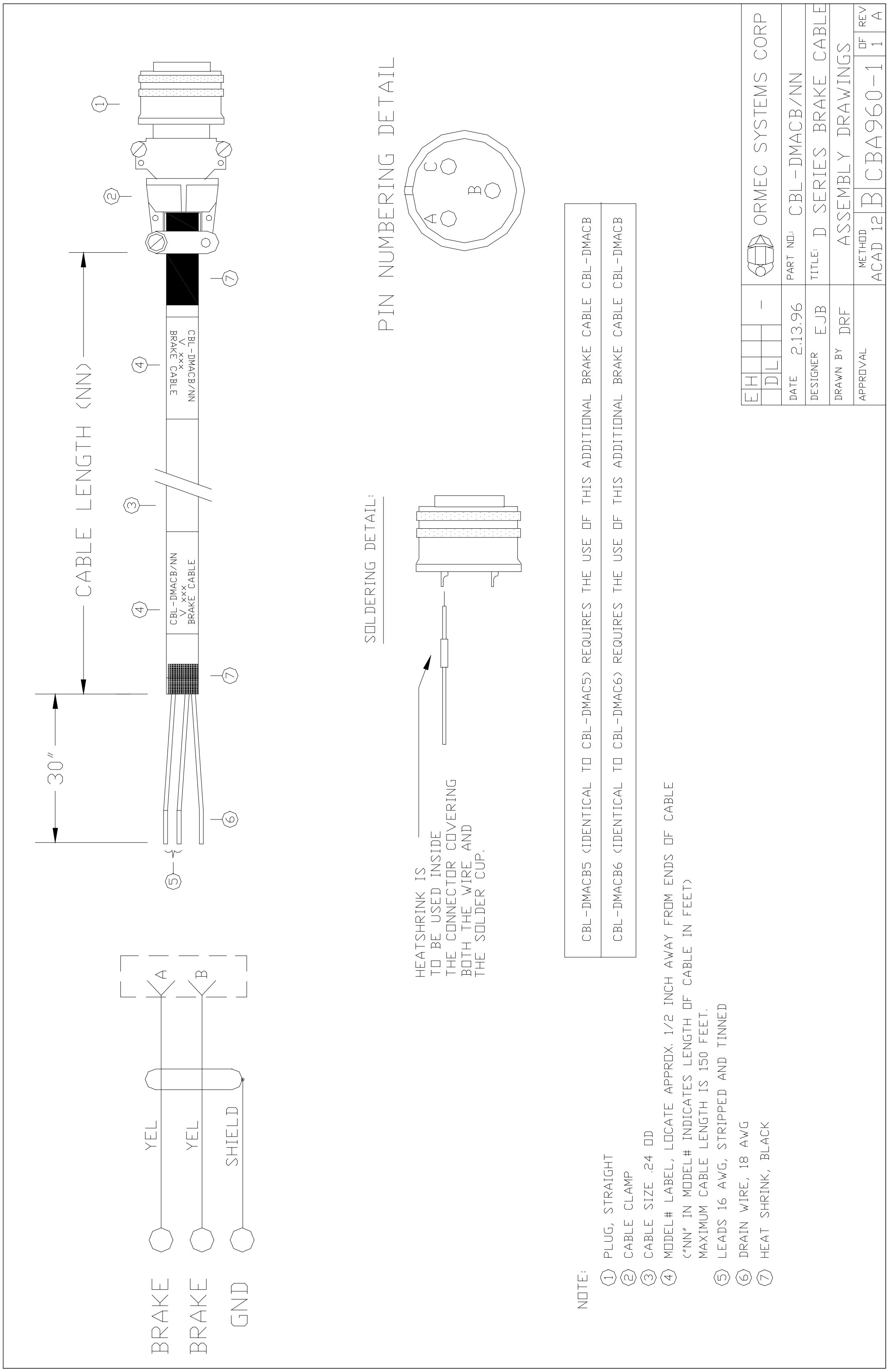
CBL-DMSWBn Motor / Brake Cable



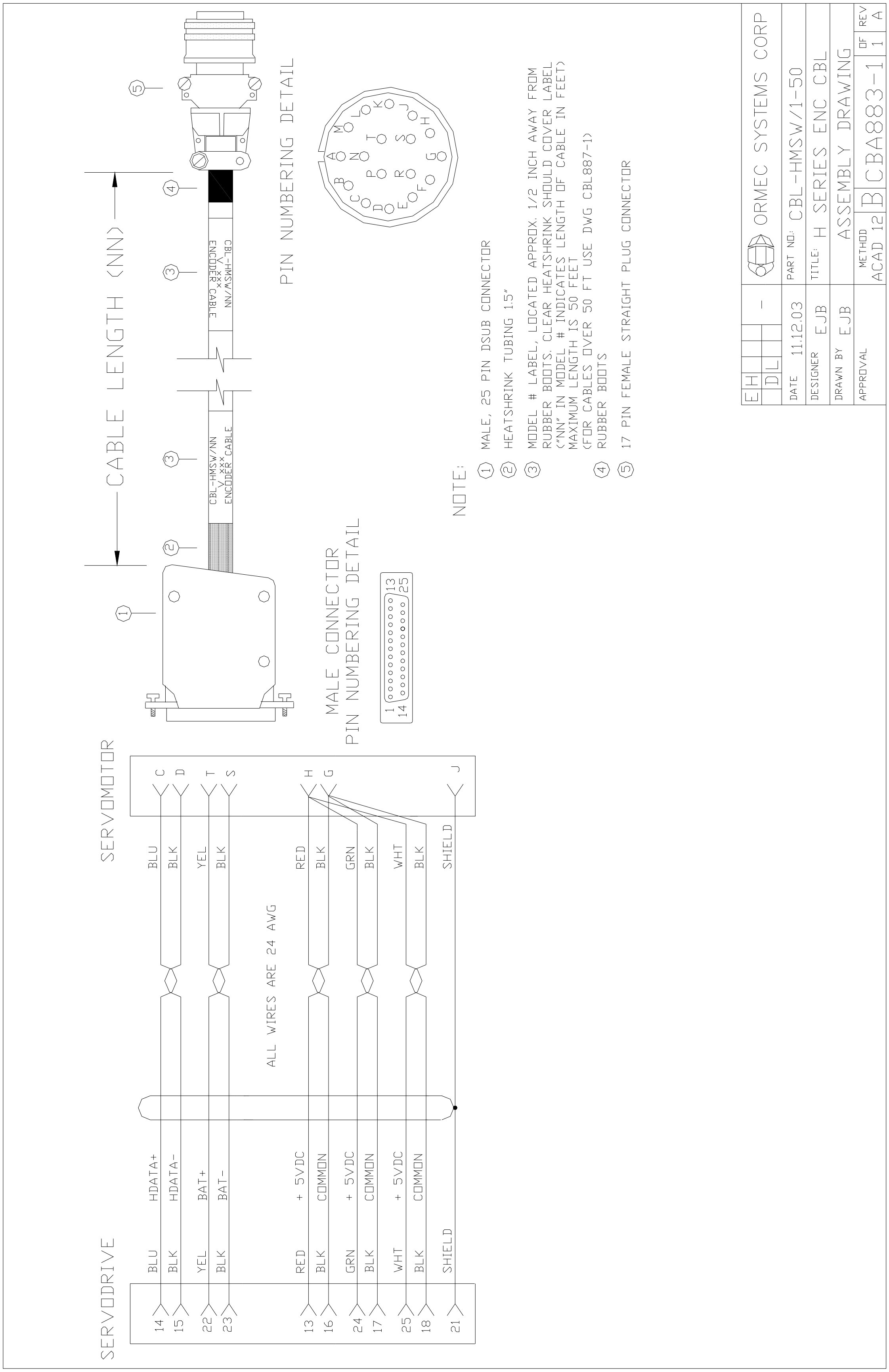
CBL-DMSWBTn Motor / Brake Cable



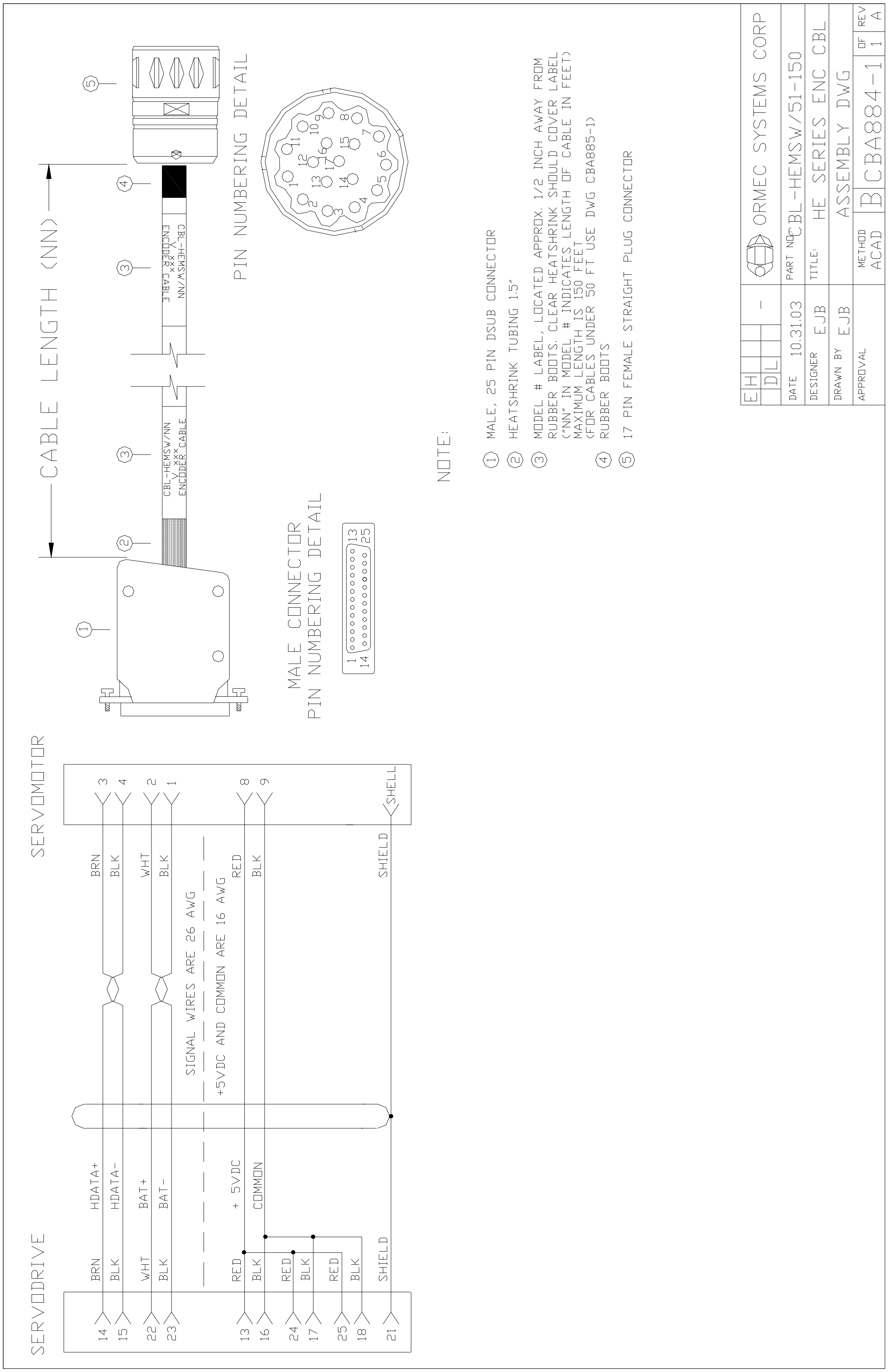
CBL-DMACB Brake Cable



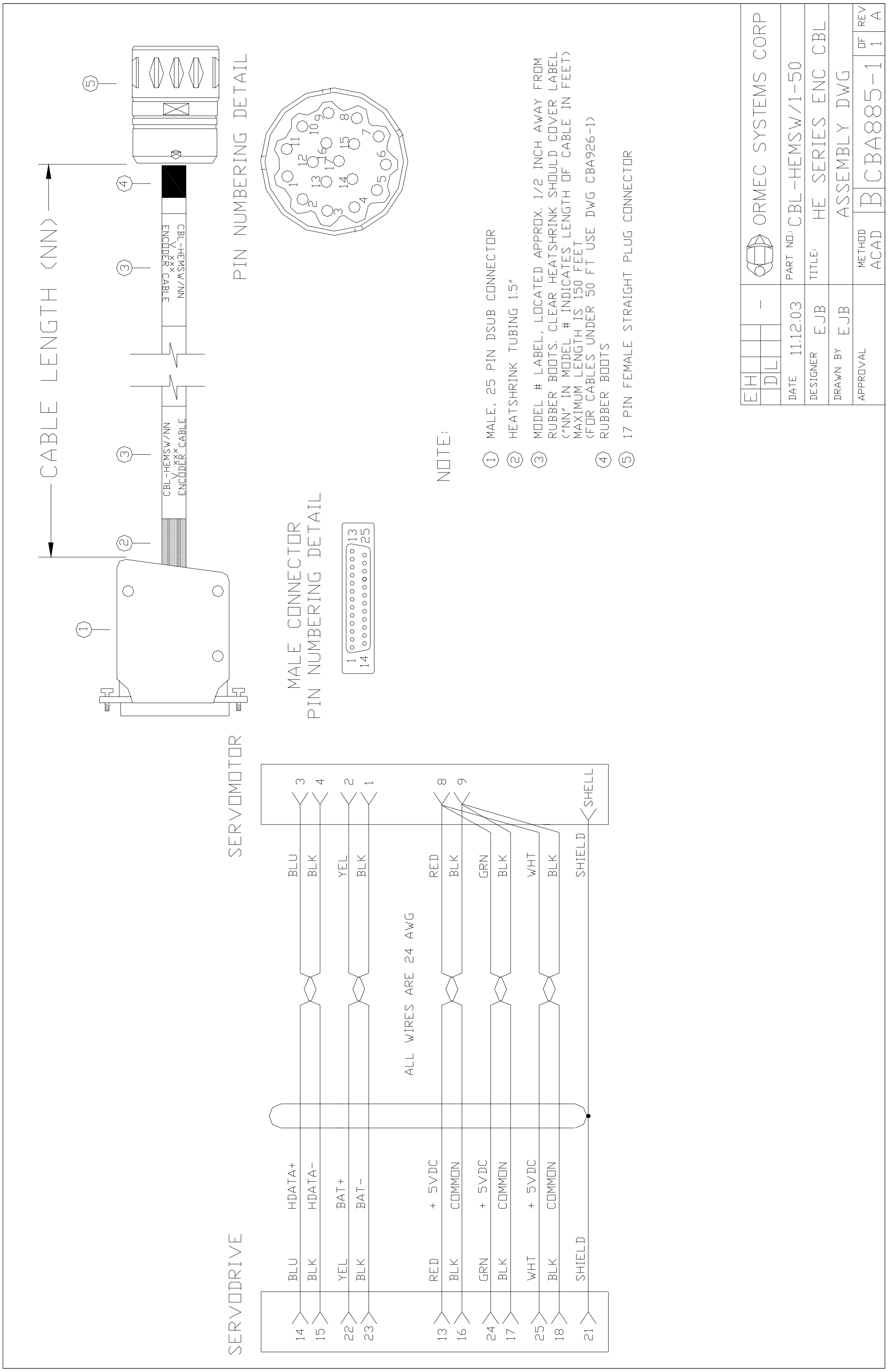
CBL-HMSW Encoder Cable



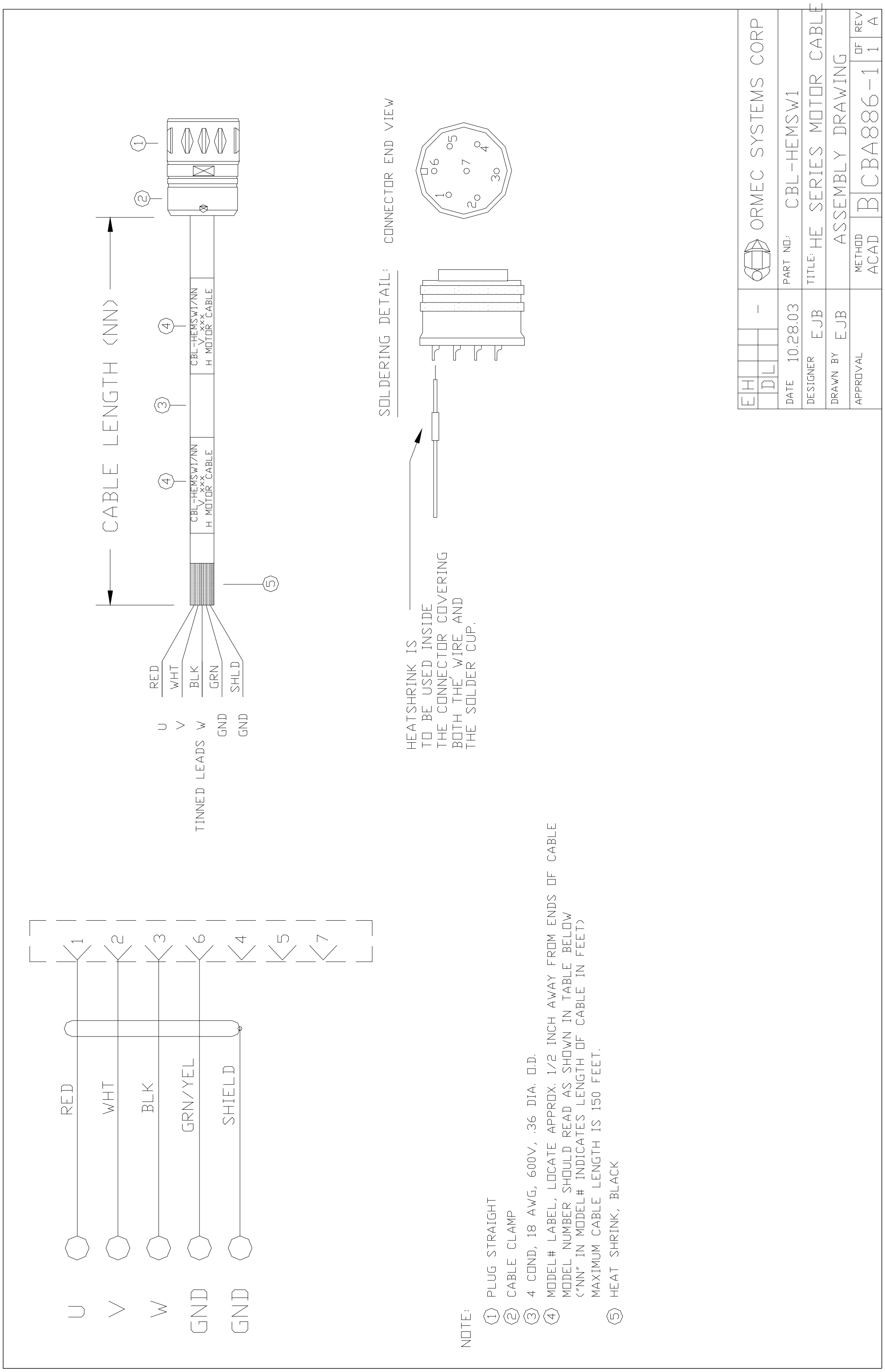
CBL-HEMSW Encoder Cable



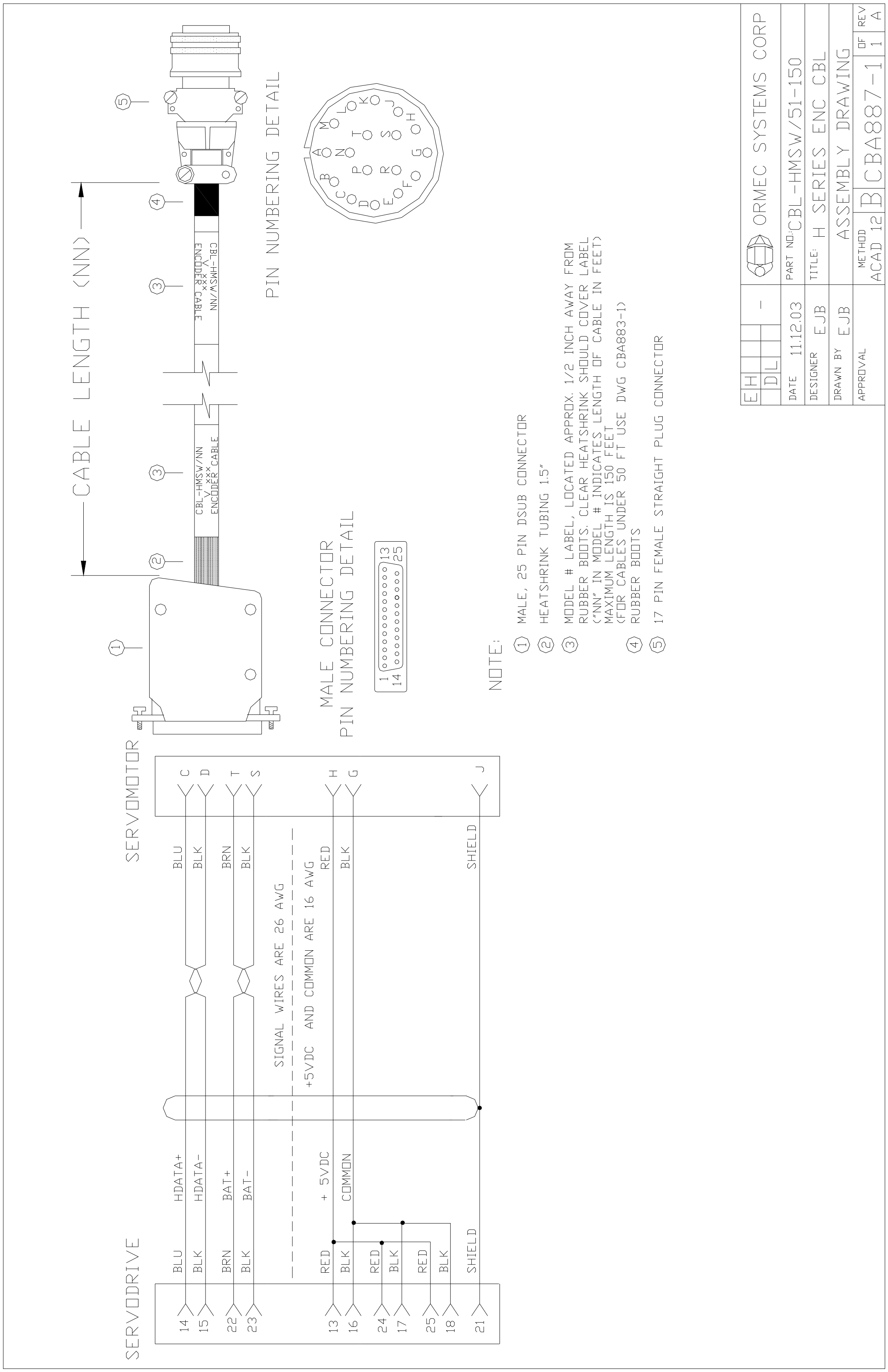
CBL-HEMSW Encoder Cable



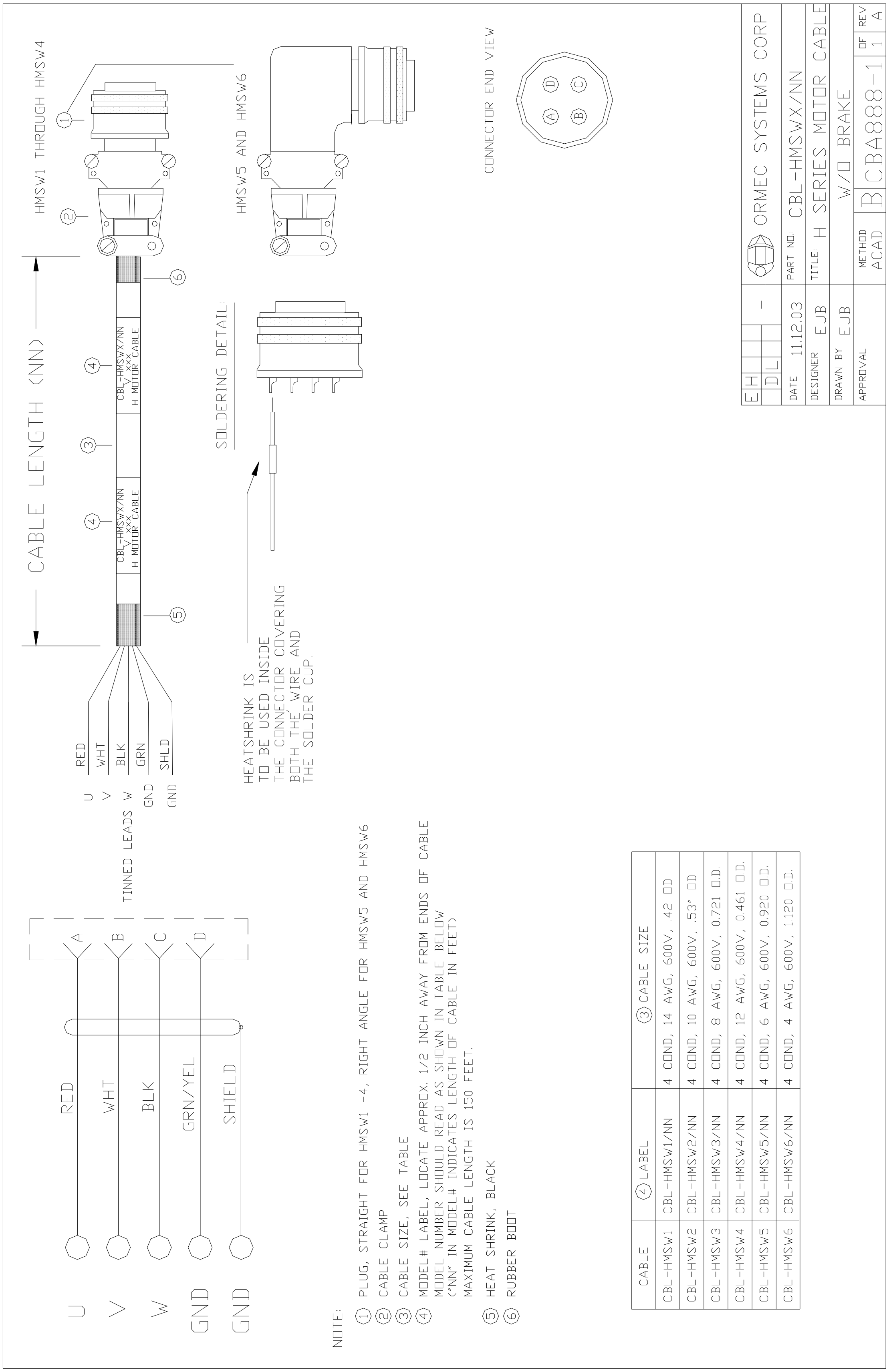
CBL-HEMSW1 Motor Cable



CBL-HMSW Encoder Cable



CBL-HMSWn Motor Cable



Guide to Shielding, Grounding, and Design Techniques for Motion Control Servo Systems used in Factory Automation

Multi-axis motion control servo systems contain digital and micro-processor circuitry that can be affected by Electro-Magnetic Interference (EMI). They also contain high energy switching amplifiers which can generate significant EMI at frequencies from 10MHz to 300MHz. Clearly the potential exists for this switching noise to interfere with correct operation of both the motion controller and any other electronic equipment in the vicinity. While most manufacturers, including ORMEC, are very careful to minimize susceptibility of their products to EMI, complete immunity is not possible. Some responsibility for avoiding EMI problems will inevitably fall to the control system integrator. This guide describes panel layout, wiring, grounding, and shielding techniques that we have found effective in designing and building motion control systems. As in all engineering designs, compromise between the perfect design and what is practical is unavoidable. You may not be able to employ all the suggestions we make. However, careful attention to EMI reduction will minimize startup costs and future operating problems in any system. If you are interested in a more complete understanding of EMI design considerations and techniques, the bibliography at the end of this guide will direct you to authoritative texts on the subject.

Design Goals and Techniques

One of the primary design goals is to keep all signal common return points at the same potential. With the high frequency (up to 300MHz) harmonics generated by switching amplifiers, this is not always easy. At these frequencies, the typical 12 gauge ground wire looks more like a series of inductors and capacitors instead of a low resistance path to ground. Use of silver tinned flat braid and the steel sub-panel itself provide a much better return path than conventional wire. A second, equally important, goal is to minimize the magnetic coupling between circuits. This is generally achieved by minimum separations and wire routing. Radio Frequency coupling is a problem primarily tackled with appropriate shielding and grounding techniques. Protection from and elimination of transient spikes, is achieved with power line filters and appropriate suppressors on relay coils and other inductive loads.

Organization of Guide

The topics in this guide are grouped into related system components and circuitry. Each group requires the designer to employ grounding and shielding techniques appropriate to the type of energy it emits and the type of emissions to which it might be susceptible. This guide includes techniques for the follow topics:

- Motor Cable Installation
- Motor Cable Installation
- Encoder/Resolver Cables
- DC Power Wiring
- DC I/O Wiring
- AC Power Wiring
- AC I/O Wiring
- Communications Cables
- General Placement, Mounting, and Routing Practices
- Cabinet to Machine Grounding

Motor Cable Installation

Both the shield drain wire and the safety ground wire should be terminated at the servo drive ground terminal located next to the motor power terminals.

The unshielded pigtails at the servo drive end of the motor cable, and the shield drain wire should be less than 8 inches (200 mm) long.

Motor cables should be routed in a separate wire-way or secured with tie-downs to ensure proper placement.

If at all possible, do not add terminal blocks between the servo drive and the motor. Doing this will reduce the effectiveness of the high energy noise path back to the servo drive and should be avoided

Encoder/Resolver Cables

Try to keep a minimum of 12 inches (300 mm) separation between encoder or resolver feedback cables and the motor cables or any AC power cables. This is usually more critical with resolver cables than encoder cables due to the analog nature of the signals. We highly recommend placing resolver and encoder feedback cables in separate conduit or wire-ways.

The voltage drop in encoder cables longer than 150 feet (50 meters) reduces the voltage at the encoder below the minimum value. If you must use cables longer than 150 feet (50 meters) you will need to provide a 5VDC power supply located close to the motor/ encoder to power the encoder.

If encoder or resolver cables must cross motor or AC power cables, try to arrange for them to cross at right angles to each other.

If at all possible do not add terminal blocks between the encoder/resolver and the servo drive or controller. Doing this reduces the effectiveness of the high energy noise path back to the servo drive or controller and should be avoided.

DC Power Supply Wiring

All power supply returns (reference common) should be tied to the panel using low impedance ground straps. Silver tinned flat copper braid at least 0.25 inches (6 mm) wide is ideal for this purpose. Use of braid rather than conventional wire is more important on switching power supplies than linear supplies. Such grounding straps should be less than 4 inches (100 mm) long. The ground strap should be used in addition to any safety ground wires required by applicable electrical codes.

In systems with more than one controller tied to a PLC, each controller should have its own 24V DC power supply for DC I/O circuits.

On low voltage DC power supplies used to power semiconductor logic boards containing analog or digital circuits, keep the lead wires lengths to a minimum, preferably 8 inches (200mm) or less.

Where feasible use more than one power supply rather than sharing one power supply between circuits that are far apart.

High voltage DC power supplies used for some servo drives should be placed close to the servo drive according to the directions in the installation manual.

If the servo drive has an external regeneration resistor, the regen wiring should be treated the same as the motor cables. It should have a low impedance braided shield which should be terminated to the panel at the drive end only.

DC Input and Output Wiring

Any connection to an inductive load, including DC electromagnetic relay coils, should be terminated with a high speed flyback-diode to absorb the high energy spikes caused when the load or coil is switched off and its magnetic field collapses. Such diodes should be connected across the coil with the reverse polarity to the voltage that powers the coil. The amount of energy which needs to be absorbed can be considerable and it is important the diode be rated accordingly.

Solid state inputs driven from solid state outputs should have a bleeder resistor across the input to provide a path for the output's leakage current when the output is off. This will help prevent false tripping on the input when the output is off. The size of the resistor depends on the output device's leakage current and the input device's OFF voltage. ORMEC Customer Support Engineering Tech Note #11 and the ORION Model 30/50/70 Manual provide very detailed information on the selection, configuration and wiring of sensors for use with the high speed sensor inputs on the DSP axis cards. Contact ORMEC and ask for a copies of these if you are planning to use high speed sensor inputs.

AC Input and Output Wiring

AC circuits used for relays (solid state or electromechanical), should be powered from a separate control transformer. This is especially true if the associated wiring runs outside of the control cabinet.

Any inductive loads, including all electromagnetic relay coils, should have a "snubber" (typically a 4.7k ohm resistor in series with a 0.1 uF capacitor) wired across the load or coil. These devices absorb the high energy returned to the wiring caused when the load or coil is turned off and its magnetic field collapses. The amount of energy which needs to be absorbed can be considerable and it is important the devices be rated accordingly.

Metal Oxide Varistors (MOVs) are often used in place of R-C "snubbers" however MOVs are designed primarily as safety devices to protect equipment from damage due to transients and are less effective than "snubbers" for noise suppression. Also MOVs tend to degrade with time.

AC Power Wiring

Incoming power brought onto the panel can bring many "dirty" components along with it. This is especially true in facilities that have a large number of SCR controlled devices such as variable speed drives and heating furnaces. Line filters (three phase or single phase as appropriate) should be placed in the incoming power lines immediately after the safety circuits and before any critical control units. ORMEC's controllers do have built-in line filters and transient suppressors to protect them from line induced noise and transients. However, these internal devices cannot prevent such noise from affecting other parts of the system such as high speed sensor inputs and the analog circuits.

Mount filters as close to the incoming power feed as is practical.

High voltage wiring should be as short and direct as possible

Avoid having clean wiring from filtered sources run parallel with dirty unfiltered wiring. If clean and dirty wiring must cross, keep the two sets of wires at right angles to each other.

Constant voltage transformers can be installed if the AC power tends to drop below the specified minimum voltages needed to keep the controllers from resetting.

Where loss of power is critical or an orderly shutdown in the event of a loss of power is required, consider using an uninterruptable power supply (UPS).

Some industrial equipment can "punch holes" in the line causing missed cycles lasting hundreds of milliseconds. Problems caused by this can only be resolved by an active line conditioner such as a UPS or a separate clean feed.
Ground the neutral of any transformer secondary to the panel with a low impedance ground strap made from silver tinned flat copper braid of appropriate width based on the current and voltage in the circuit. The ground strap should be used in addition to any safety ground wires required by applicable electrical codes.

Twisting hot and neutral wires together will help minimize any EMI effects that may be present.

Communications Cables

Cables used for communications are designed to transmit and receive high frequency signals. When placed in the same electrical enclosure with high energy noise sources such as servo drives, any noise coupled to the communications cabling can be similar in frequency to the actual communications signals. It is important to use cable, termination devices, splitters, etc. that conform exactly to the detailed recommendations contained in the applicable communications standard. Inexpensive hardware store or consumer electronics store substitutes can result in problems. Most communications standards define recommended network topography, minimum drop lengths and terminator locations. These recommendations should be followed exactly. Communication cables should be placed in the low voltage DC wire-ways. Keep communication separated from AC power and motor cables. If they must cross such wiring, keep them at right angles to each other.

General Placement, Mounting and Routing Practices

How the parts are placed on the panel and on the enclosure door can play an important role in reducing or worsening the effects of high energy interference. It is good practice to group parts into families of similar components then place these groups according to a pattern of power flow and/or conversion in an effort to minimize wire lengths while maximizing separation.

Avoid running wires from different circuit types (AC/DC, High voltage/Low voltage, Digital/Analog) parallel to each other without at least 12 inches (300 mm) of separation.

When wires from different circuit types must cross, keep the two sets of wires at right angles to each other.
Provide separate wire-ways for high power AC, low power AC, high power DC and low power DC.
When placing components on a cabinet door, make sure that closing the door does not bring the component close to a part of the panel that will cause problems. For example, placing a video terminal too close to a transformer or servo drive.

When mounting any unit, be sure to scrape away any paint on both the unit and the mounting surface to obtain a bare metal-to-metal contact. Use of external toothed washers will improve the connection. If in doubt, use a ground strap made of silver tinned flat copper braid to ensure a good connection between the chassis and the mounting surface.

Use ground straps made from 1 inch (25 mm) silver tinned flat copper braid to connect the cabinet door(s) to the enclosure, the first sub-panel to the enclosure, and from each sub-panel to the next.

Where electrical codes call for the typical green safety ground wires, use them *in addition* to any ground strap suggested in this guide.

Cabinet to Machine Grounding

Do not rely on the ground wires included in the motor cables to provide cabinet to machine grounding. Make sure that the cabinet and machine grounds are always at the same potential.

Provide a ground connection between all major machine sections and the cabinet using #6 or larger ground wire.

Welding cable is ideal for this purpose since a cable made up of many very small cross section conductors is much more effective at high frequencies than conventional wire.

Brief Bibliography

Morrison, Ralph. *Grounding and Shielding Techniques in Instrumentation*, 2nd ed., (Wiley-Interscience 1977).

Ott, Henry W. *Noise Reduction Technique in Electronic Systems*. 2nd ed., (New York: John Wiley & Sons, 1976).

For more information

Contact the motion control experts at ORMEC for further information. Please call us at (585) 385-3520 or email sales@ormec.com
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Coupling High Performance Servos to Mechanical Loads

TECHNICAL NOTE
Best Practices

Mick Oakley, ORMEC Systems Corp.

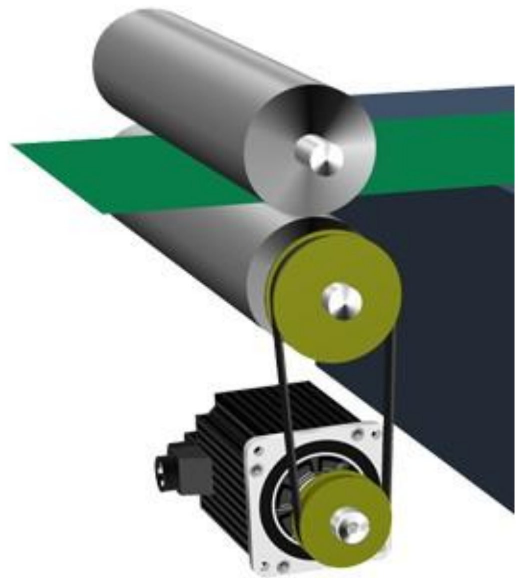
Mechanical design for servos places an additional set of constraints to the design rules normally used for power transmission design. These added constraints relate primarily to the stiffness of the system and inertial matching. Decisions on speed reducers, couplings, shaft configurations and many other critical aspects of the mechanical design are often made very early in the design process. Once made, these decisions can be very expensive and time consuming to change.

The intent of this technical note is to communicate some design information and "rules of thumb" that we at ORMEC have found important in our many years of applying servos to industrial automation. Are these guidelines universal truths? Obviously any set of design rules will from time to time collide with a special case. However, the following guidelines will apply in the vast majority of cases and the prudent designer will only violate them after careful analysis and with a thorough understanding of the risks involved.

Why be concerned about the load?

Knowledgeable servo designers are wary of using a servomotor to drive mechanisms whose moment of inertia is many times that of the motor itself. However, economic pressures and other technical advantages often cause engineers to want to direct drive high inertia loads. The main advantages they seek are to eliminate the cost, the maintenance and the inaccuracy of a reducer. While it is usually easier to avoid large inertia mismatches, with appropriate attention to detail, they can be made to work.

No designer should approach the design of a servo driven mechanism especially one with a significant inertial mismatch, without doing a careful analysis of the natural frequency of the mechanical system. "Seat of the pants" engineering is almost guaranteed to result in problems.



One reason many designers lean towards direct drive, is to avoid the cyclical inaccuracies that gear reducers can introduce. The closed loop servo can monitor its actual speed and position and rapidly adjust for load disturbances. When the load inertia is many times the motor inertia, the motor has only a very small amount of kinetic energy compared to the load. To compensate for a sudden change in load, the servo amplifier must inject a large amount of energy into the servomotor very quickly. This demands a high gain, high bandwidth system. When you combine high gain, high bandwidth and large inertia mismatches, alarm bells should start to sound.

What constitutes a large inertia mismatch? At one time designers strove to achieve a 1:1 inertia match. They considered anything above 5:1 to be a potential problem. The application of digital technology to servo control, digital signal processors in particular, has relaxed that constraint. These days, mismatches of 100:1 or even 1000:1 can be made to work with careful mechanical design. While good mechanical design is always important, inertia mismatches of 10:1 and above, can only work if the mechanical designer has paid careful attention to minimizing backlash and compliance in the design.

Backlash Effects

Backlash, sometimes called "lost motion", is a mechanical effect that allows you to turn the motor shaft without causing any motion at the load. Generally, with the servo drive disabled, you can rotate the motor shaft back and forth over a limited range. If you release the shaft, it will stay where it is. Backlash has the effect of temporarily uncoupling and recoupling the load and the motor with changing speed and direction. When stopped, if there are insufficient external forces acting on the load, the motor may for all intents and purposes be disconnected from the load completely. If the servo is tuned to work well when the load is disconnected, it will have extremely poor performance when the load is connected. Likewise, if the servo is tuned for adequate performance, it will be unstable when the backlash disconnects the load.

The most common symptom of backlash is a "buzz" , often very loud, which occurs primarily when the motor is stopped. Often you can eliminate the "buzz", the system becomes very "soft". Sometimes the gain is so low that it cannot stabilize the position loop and the system may oscillate wildly at a low frequency (1-5Hz). The only way to solve the problem is to mechanically eliminate the backlash. If you do not eliminate the buzz, over time it may overheat the motor or ruin the mechanical system. A common source of backlash is using a keyway or set screw to couple to the motor shaft. While keyways are fine for lawnmowers, they are inadequate for high performance servos! A clamp style coupling, preferably a taper lock bushing, is the only acceptable way to couple to a servomotor shaft.

Another common cause of backlash is improperly adjusted spur gears or using gear reducers that are not designed for servo applications. Properly selected precision planetary gearheads, such as ORMEC GBX Series are generally quite good for servo applications. However, you must make sure the gearhead and primary pinion are mounted and adjusted properly. If you are not careful, improper mounting will introduce backlash into the system and it will deteriorate over time.

Compliance Effects

Compliance also allows you to rotate the input shaft without the load moving. However, with compliance you are actually "winding up" the mechanical system like a spring. When you release the input shaft, it will spring back close to its original position.

Compliance, or wind up, effects show up as a torsional resonant frequency which in turn causes the servo to be unstable. The instability generally shows up as a medium to high frequency oscillation in the order of 100 to 500 Hz. Unlike the "buzz" caused by backlash the sound is often a pure note and does not go away when the motor moves. The frequency does not change as you manipulate the servo tuning however the amplitude may change. Applying a friction load may also reduce the amplitude of the oscillation. As with the buzz caused by backlash, left uncorrected, this resonance will overheat the motor and possibly damage the mechanism.

EQUATIONS FOR SOLID SHAFT RESONANT FREQUENCY

Figure A) **Equations for shaft windup**

Stiffness $$S = \frac{\pi(OD^4 - ID^4)G}{32L} \quad \text{in-lb/rad}$$

Windup $$W = \frac{360T}{2\pi S} \quad \text{degrees}$$

Where:

OD	is shaft outside diameter (inches)
ID	is shaft inside diameter (inches)
L	is shaft length (inches)
T	is applied torque (in-lb)
G	is shaft shear modulus (lb/in^2) [11 x 10^6 for stainless steel]

Figure B) **Equations for natural frequency**

Natural Frequency $$f = \frac{1}{2\pi}\sqrt{S\,\frac{(J_M + J_L)}{(J_M * J_L)}}$$

Where:

J_M	is motor inertia (in-lb-s^2)
J_L	is load inertia (in-lb-s^2)
S	is shaft stiffness (in-lb/rad) [see equations above]

Figure C) **Equation for accumulated stiffness 'S'**

$$S_T = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \cdots \frac{1}{S_n}}$$

Long drive shafts, where the bulk of the load inertia is some distance from the motor, are a common cause of this type of problem. It is often surprising how much windup can exist in what appears to be a rather substantial shaft. Take for example a one inch diameter stainless steel shaft about 18 inches long. When you apply a 500 in-lb load the shaft will wind up almost 0.5 degrees (see equations in Figure A above).

If we take that same shaft and connect an HB200 motor, with a moment of inertia of 0.0407 in-lb-s^2, on one end and a load inertia of 100 times the motor inertia on the other end, the natural frequency of the system will be about 184 Hz (see equations in Figure A above).

If we take that same shaft and connect an HB200 motor, with a moment of inertia of 0.0407 in-lb-s^2, on one end and a load inertia of 100 times the motor inertia on the other end, the natural frequency of the system will be about 184 Hz (*see equations in Figure B. above)*

Generally, if the natural frequency of the system is less than about 500 Hz, you may encounter resonance problems in high performance systems. There is no magic about the number 500, it is simply a rule of thumb. With a mechanical natural frequency above 500 Hz, you are unlikely to have a resonance problem. At frequencies below 500 Hz, the probability of resonance problems increases. In the above example, to achieve a natural frequency of 500 Hz, you would have to increase the shaft diameter to 1.6875 inches or decrease the shaft length to 2.5 inches. The natural frequency will usually be determined by the least stiff portion of the drive train which is often the shaft coupling. Be sure to obtain stiffness specifications for any coupling you expect to use and complete the necessary calculations. If you have more than one “unstiff” component in your drive train, the effects are additive in that the resulting overall stiffness is given by equation in Figure C in the chart on page 2.

If the moment of inertia of components located between these couplings is significant compared to the overall load inertia, the calculations become a lot more complex and usually result in multiple resonant frequencies. Often times, choice of couplings, shaft dimensions and attachment methods have surprising effects. No designer should approach the design of a servo driven mechanism, especially one with a significant inertial mismatch, without doing a careful analysis of the natural frequency of the mechanical system."Seat of the pants" engineering is almost guaranteed to result in problems.

Coupling Selection

In any servo mechanism, selection of mechanical couplings is critical. When there is a large inertia mismatch it is doubly so. Many times it is the choice of coupling that causes the system to have a low resonant frequency. Helical style couplings are almost never stiff enough to avoid problems unless the load inertia is so low as to be insignificant. The best choice is a bellows style coupling with taper lock bushings.

If we take a typical inexpensive helical coupling rated for 500 in-lbs of torque, the stiffness will be approximately $72x10^3$ in-lb/rad. If we use this coupling on the load system described earlier, it will limit the system natural frequency to less than 197 Hz. Clearly this type of coupling would not be adequate. So instead, if we take a similarly rated bellows coupling1 , its stiffness will be $433x10^3$ in-lb/rad. This coupling would have a natural frequency of 480 Hz, which is much less likely to affect operation.

Generally, it is best to avoid helical, disc, oldham, split beam and jaw type couplers. Metal bellows will usually provide the best results. In addition to the coupling type you must also pay careful attention to how it is attached to the shafts. A clamping or taper lock is the best way to go. Always avoid keyways and set screws.

How to Tame Mechanical Load Problems

As said earlier, most mechanical load problems are really backlash and/or compliance problems. The solutions involve changing the mechanical design to eliminate any backlash and to raise the natural frequency above 500 Hz. Increasing the natural frequency can often be accomplished by selecting a stiffer coupling, increasing the diameter of shafts or decreasing the lengths of shafts.

Another way to reduce the possibility of instability is to add a speed reducer. This step can reduce the reflected inertia by the square of the reduction ratio. Adding speed reduction also increases resolution at the motor and improves performance at low load speeds. It also allows the motor to run at a higher speed which gives it more kinetic energy to overcome load disturbances. This in turn can reduce the gain and bandwidth requirements for the servo. Obviously, adding a speed reducer adds the reducer’s efficiency losses, inaccuracies and compliance to the system so careful selection of the reducer type is critical.

Another helpful technique, although one with its own disadvantages, is to add notch filtering in the servodrive command. Ideally, a notch filter exactly counters the effect of the mechanical resonance and eliminates the system’s ability to respond at that frequency. When properly designed and implemented, they work well without requiring mechanical changes. The disadvantages of notch filters are:

- The filter will only work if the mechanism does not undergo significant changes over time. As mechanisms wear or heat up, their natural frequencies can change. The natural frequency will also change as the load inertia changes. A once stable system may become unstable if the natural frequency shifts enough that the notch filter no longer cancels it out.
- Many resonant loads have several natural frequencies. If you design a notch filter with a wide enough notch to cover all of the natural frequencies, you may end up with what is effectively a low pass filter which will reduce servo response considerably.

While many mechanical problems can be resolved using notch filters, they don’t address the root cause of the problem and therefore are not a universal cure all.

Timing Belts

Timing belts are a very economical and surprisingly accurate way to provide modest speed reductions. For servo applications, you should choose a belt with a high tensile stiffness and low backlash. Belts that use an aramid tensile member and a modified curvilinear tooth profile are good in both qualities. Belt selection and design is a fairly specialized process and the reader would be well advised to consult one of the many excellent application guides published by belt manufacturers for assistance in this area. Another advantage of timing belts over other types of reducer is their very high efficiency, 95% or better. A disadvantage of timing belts is the added inertia of the pulleys. However, the added inertia can be minimized by modifying standard pulleys to reduce their mass. Custom pulleys made from light weight materials such as aluminum are available from most belt manufacturers.

Timing belts designed for precise positioning have a tensile member that uses fibers with a very high tensile strength.

TIMING BELT EQUATIONS TO DETERMINE FREQUENCY

Figure D)

$$\text{Mass} \quad M_1 = \frac{J_1}{(R_1)^2} \quad \text{lb}$$

$$\text{Mass} \quad M_2 = \frac{J_2}{(R_2)^2} \quad \text{lb}$$

$$\text{Belt Stiffness} \quad S = \frac{EA * \text{width}}{\text{span}} \quad \text{lb/inch}$$

$$\text{Natural Frequency} \quad F = \frac{1}{2\pi}\sqrt{S\,\frac{(M_1 + M_2)}{(M_1 * M_2)}}$$

Where:

J_1	is the total moment of inertia at the driving pulley (in-lb-s^2). It includes the inertia of the pulley and everything connected to it.
J_2	is the total moment of inertia at the load pulley (in-lb-s^2). It includes the inertia of the pulley and everything connected to it.
R_1	is the radius of the driving pulley (inches).
R_2	is the radius of the driven pulley (inches).
S	is the belt stiffness (lb/inch).
span	is the belt span, which is the distance the belt spans between the initial contact points on the pulleys on the tension side of the belt (inches).
width	is the belt width (inches).
EA	Belt spring rate in (lbs/inch width per unit strain).

These fibers are set at a diameter that is much larger than a typical direct drive shaft. If the belt system has been properly sized the stiffness of the system can be better than a solid steel shaft. In the example shown on page 2, the system had a shaft windup of 0.5 degrees with a 500 in-lb load. If you substitute a 37mm wide timing belt[2] using 6 inch pulleys[3] on 18 inch centers, the windup will be less than 0.25 degrees. When a speed reduction is used rather than 1:1, the windup decreases further. To calculate the natural frequency of a timing belt system, you need to know the spring rate of the belt. This is available from the belt manufacturer and is normally called the EA factor. The EA factor for a belt varies with the tension of the belt and is usually shown on a chart that plots EA (lbs per inch width per unit strain) against belt load (lbs per inch width). The calculations for windup and resonant frequency of a timing belt system can get quite tricky since you must take belt tension and load forces into account when deciding what EA value to use[4]. Unless you are already familiar with the techniques, you should seek the assistance of your belt supplier. For the purpose of this application note it is sufficient to say that it is not difficult to design a timing belt drive that is as stiff or stiffer than a typical direct coupled load. The main advantage of a timing belt system is not that it significantly increases the natural frequency but rather it changes the amplitude of the resonance. A timing belt system adds considerable damping to the system and for a given natural frequency, will allow higher gain settings before resonance becomes a problem. Another advantage is that it allows you to run the motor at a higher speed which, if the motor inertia is small compared to the load, will provide better operation.

One thing to remember is that resonances are usually a greater problem when the system is stopped than when it is moving under load. By reducing belt tension slightly, you can provide a measure of decoupling between the motor and load. This decoupling and the damping provided by the belt will often reduce resonance problems. Be careful not to reduce the tension too much or accuracy will suffer. A good rule of thumb is to make sure the “slack” side of the belt is always under some tension. Another thing to remember is that too much belt tension can easily generate a radial load on the motor shaft which will drastically reduce bearing life. When belt tension must be high, always use a jack shaft with its own bearings to isolate the motor shaft from the radial load.

Summary

If you have a load to motor inertia mismatch greater than 10:1, or have a significant portion of the load inertia coupled through long shafts, you will need to carefully analyze your mechanical design. You will need to make sure there is no backlash and that the natural frequency is higher than 500 Hz. If you cannot achieve that, gear or belt reduction are the best alternatives for making it work. As a last resort, notch filtering may be practical in some special cases.

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2. Gates Rubber Co. Poly Chain GT [Part # 14M-1400-37]
3. Gates Rubber Co. [Part # 14M-34S-37]
4. Selecting Synchronous Belts for Precise Positioning, by A.W. Wallin - Applications Engineer, Synchronous Drives Div., The Gates Rubber Co., Denver CO.

For more information

Contact the motion control experts at ORMEC for further information. Please call us at (585) 385-3520 or email sales@ormec.com Visit our website at www.ormec.com