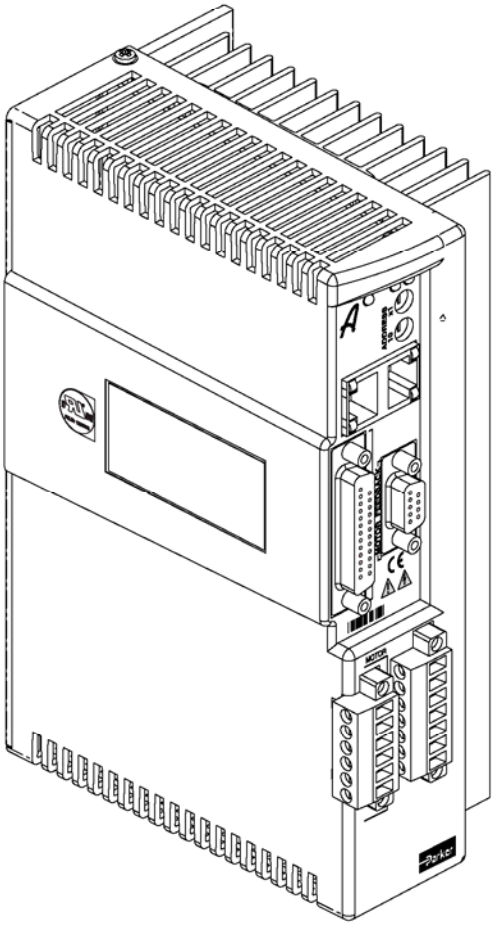
ACR Motion Controllers

88-028786-01B

Aries Controller Hardware Installation Guide

Effective: October 2008



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User Information

Warning — Aries Controller series products are used to control electrical and mechanical components of motion control systems. Test your motion system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

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Product Type..... Aries Controller Family AR-04CE, AR-08CE, and AR-13CE

The above product complies with the requirements of directives:

- EMC Directive 89/336/EEC;
- Low Voltage Directive 73/23/EEC; and
- CE Marking Directive 93/68/EEC

provided the installation requirements described in this guide are met, and there are no special requirements of the installation and operating environment so that the application may be considered typical.

The above equipment conforms with the protection requirements of Council Directive 89/336/EEC as amended by Directive 92/31/EEC on the approximation of the laws of the Member States relating to Electromagnetic Compatibility when installed, operated and maintained as intended. Also: - The above equipment conforms with the requirements of Council Directive 73/23/EEC (Low Voltage Directive) as amended by Directive 93/68/EEC (CE Marking Directive), when installed, operated, and maintained as intended.

In accordance with IEC 61800-3:1997 (Adjustable speed electrical power drive systems) this product is of the restricted sales distribution class which meets the needs of an industrial environment when installed as directed. However, further measures may need to be taken for use of the product in a domestic environment.

The installation requirements are detailed in the Information supplied with the equipment. The equipment is sold only to competent system builders.

Compliance is demonstrated by the application of the following standards:

- BS EN 61800-3 (1997) including Amendment A11 Adjustable speed electrical Power drive systems Part 3. EMC product standard including specific test methods.
- BS EN 50081-2 (1994) Electromagnetic compatibility—Generic emission standard Part 2. Industrial Environment.
- BS EN 61000-6-2 (1999) Electromagnetic compatibility Part 6-2: Generic Standards – Immunity for industrial environments.
- BS EN 61010-1 (1993) including Amendment A2. Safety requirements for electrical equipment for measurement, control, and laboratory use. Part 1 General Requirements.

Warning — Risk of damage and/or personal injury

The Aries Controllers described in this guide contain no user-serviceable parts. Attempting to open the case of any unit, or to replace any internal component, may result in damage to the unit and/or personal injury. This may also void the warranty.

Symbols	Description
	Protective Earth Ground
	Functional Earth (Ground) Terminal
	Shield, Frame, or Chassis Terminal
	Caution Risk of Electrical Shock
	Caution, Refer to Accompanying Documentation

Important Safety Information

It is important that motion control equipment is installed and operated in such a way that all applicable safety requirements are met. It is your responsibility as an installer to ensure that you identify the relevant safety standards and comply with them; failure to do so may result in damage to equipment and personal injury. In particular, you should study the contents of this user guide carefully before installing or operating the equipment.

The installation, set up, test and maintenance procedures given in this user guide should only be carried out by competent personnel trained in the installation of electronic equipment. Such personnel should be aware of the potential electrical and mechanical hazards associated with mains-powered motion control equipment—please see the safety warnings below. The individual or group having overall responsibility for this equipment must ensure that operators are adequately trained.

Under no circumstances will the suppliers of the equipment be liable for any incidental, consequential or special damages of any kind whatsoever, including but not limited to lost profits arising from or in any way connected with the use of the equipment or this guide.

Warning — High-performance motion control equipment is capable of producing rapid movement and very high forces. Unexpected motion may occur especially during the development of controller programs. **KEEP WELL CLEAR** of any machinery driven by stepper or servo motors. Never touch any part of the equipment while it is in operation.

This product is sold as a motion control component to be installed in a complete system using good engineering practice. Care must be taken to ensure that the product is installed and used in a safe manner according to local safety laws and regulations. In particular, the product must be positioned such that no part is accessible while power may be applied.

This and other information from Parker Hannifin Corporation, its subsidiaries, and authorized distributors provides product or system options for further investigation by users having technical expertise. Before you select or use any product or system, it is important that you analyze all aspects of your application and review the information concerning the product in the current product catalog. The user, through its own analysis and testing, is solely responsible for making the final selection of the system and components and assuring that all performance, safety, and warning requirements of the application are met.

If the equipment is used in any manner that does not conform to the instructions given in this user guide, then the protection provided by the equipment may be impaired.

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Change Summary

Revision B Changes

This document, 88-028786-01B, supersedes 88-028786-01A. Changes associated with Aries Controller User Guide revisions, and document clarifications and corrections are as follows:

Topic	Description
Electrical Installation	Removed Diode across motor cables in drawing in Brake Relay to Motors with Full Wave Rectifiers.
Troubleshooting	Added E28 to Error Codes table; added the word “Warning” to error name for E10, E11, and E12 because they are not faults.

CHAPTER ONE

1 Introduction

IN THIS CHAPTER	
• Aries Controller—Overview	13
• Checking Your Shipment	14
• Illustrations in this Installation Guide	15
• Assumptions of Technical Experience	15
• Technical Support	15

Aries Controller—Overview

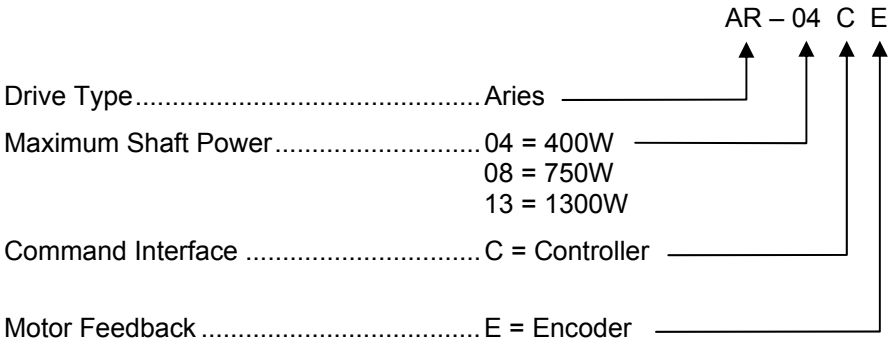
The Aries Controller is a single-axis drive/controller based on the Aries drive platform. Setup and programming is accomplished using the AcroBASIC language within the ACR-View programming environment.

Aries Controller Product Description

The Aries Controller is a single-axis digital servo drive with controller capability. The drive closes position, velocity, and torque loops, receiving its position setpoints from an internal servo controller. ACR-View is used to configure and program the Aries Controller. There are three models with a maximum continuous shaft power of 400, 750, or 1300 watts.

Aries Controller Part Numbers

The following diagram explains the Aries Controller part numbers:



Input Power Level

Motor Input Power

AR-04CE, AR-08CE, AR-13CE ..... 120/240 VAC single-phase mains motor input power

Control Input Power

AR-04CE, AR-08CE, AR-13CE ..... 120/240 VAC single-phase mains control input power

Output Power Level

Servo Motor Drives

In Table 1, the maximum current is given at 120/240 VAC input, which equates to a motor bus voltage of 170/340 VDC.

Drive	Continuous Current (RMS)	Peak Current (RMS)	Continuous Shaft Output Power
AR-04CE	3A	9A	400W, 0.53 hp*
AR-08CE	4.50A	13.5A	750W, 1.0 hp*
AR-13CE	6.3A	14.07A	1300W, 1.75 hp*
* Maximum rating at 240 VAC, single-phase			

Table 1 Output Power Level

Components

For information about cables, motors, and other motion-control-system components see *Chapter 2 Mechanical Installation*.

Options

For the latest additions, see our website at www.parkermotion.com.

Checking Your Shipment

Inspect your shipment carefully. You should have received the corresponding ship kit along with your drive.

Ship Kit Items

The following items ship with the AR-04CE, AR-08CE, and AR-13CE drives.

Part	Part Number
Aries Controller Quick Reference Guide	88-028905-01
R-Clamp	52-019734-01
Screw (8-32 $^{3}/_{8}$ inch)	51-006055-01
Compact disc containing the following: • Aries Controller Hardware Installation Guide	88-028786-01

Table 2 Ship Kit Items

Motors

You may have ordered a motor from one of the following families of compatible Parker motors:

- BE Series
- LXR Series
- MPP Series
- SM Series
- SME Series
- SMN Series
- I Linear Series
- SL Linear Series
- T Linear Series
- K Frameless Series

Illustrations in this Installation Guide

Typically, the illustrations in this guide show the Aries AR-08CE, which is representative of all Aries Controller models. All models have the same external features and housing, although the power level and height of the heat sink fins differ.

Assumptions of Technical Experience

The Aries Controller is designed for industrial applications. To effectively install and troubleshoot the drive, you must have a fundamental understanding of the following:

- Motion control applications
- Electromechanical actuators
- Voltage, current, switches, and other electrical concepts

Technical Support

For solutions to questions about implementing the drive, first refer to this manual. If you cannot find the answer in this documentation, contact your local Automation Technology Center (ATC) or distributor for assistance.

If you need to talk to our in-house Application Engineers, please contact us at the telephone numbers listed on page 2.

CHAPTER TWO

2 Mechanical Installation

IN THIS CHAPTER

- Environment & Drive Cooling 17
- Dimensions 21
- Weight 22
- Mounting Guidelines 22

Environment & Drive Cooling

The Aries Controller drive operates in an ambient temperature range of 0°C (32°F) to 50°C (120°F) ambient air temperature. The drive can tolerate atmospheric pollution degree 2. Only dry, non-conductive pollution is acceptable. Therefore, it is recommended that the drive be mounted in a suitable enclosure.

For drive cooling, you must install the drive so that the heat sink fins are vertical. Figure 4 on page 23 shows the mounting orientation, as well as the minimum top, bottom, and side installation clearances.

Notes

- Avoid installing heat-producing equipment directly below a drive.
- Make sure the ambient air temperature entering the drive or rising up to the drive is within acceptable ambient temperature limits. Under normal use, the temperature of air leaving the drive and heat sink may be 25°C (45°F) above ambient temperature.
- After installation, verify that the ambient air temperature directly below the top-most drive does not exceed the maximum Ambient Air Operating Temperature shown below. In addition, make sure that nothing obstructs the circulating airflow.

	Environmental Specifications
Operating Temperature, Ambient Air	Maximum 50°C (120°F) Minimum 0°C (32°F)
Storage Temperature	–40°C to 85°C (–40°F to 185°F)
Humidity	0 to 95%, non-condensing
Shock:	15g, 11 ms half-sine
Vibration	10 to 2000 Hz at 2g
Pollution Degree	2 (per IEC 61010)
Installation Category	2 (per IEC 61010)

Table 3 Environmental Specifications

Cabinet Cooling

Use the cabinet loss and power dissipation values in this section along with the formula in “Cabinet Cooling Calculations” on page 20 to calculate cabinet cooling for each installation. Following are graphs showing cabinet losses and tables showing power dissipation for each drive/controller model.

AR-04CE Model

The following values have been measured using the Parker BE344J motor.

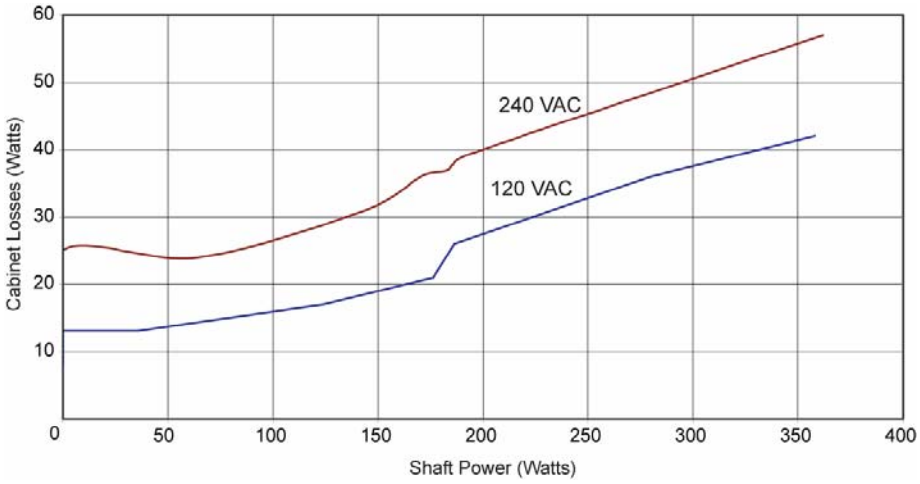


Figure 1 Cabinet Losses: AR-04CE (400 Watt) Connected to Parker BE344J Motor

	Shaft Power		
Voltage	**0W***	**200W**	**350W**
120 VAC	13W	28W	42W
240 VAC	25W	40W	57W
* Drive enabled, zero torque.			

Table 4 Power Dissipation for AR-04CE (400 Watt Model)

AR-08CE Model

The following values have been measured using the Parker BE343J motor.

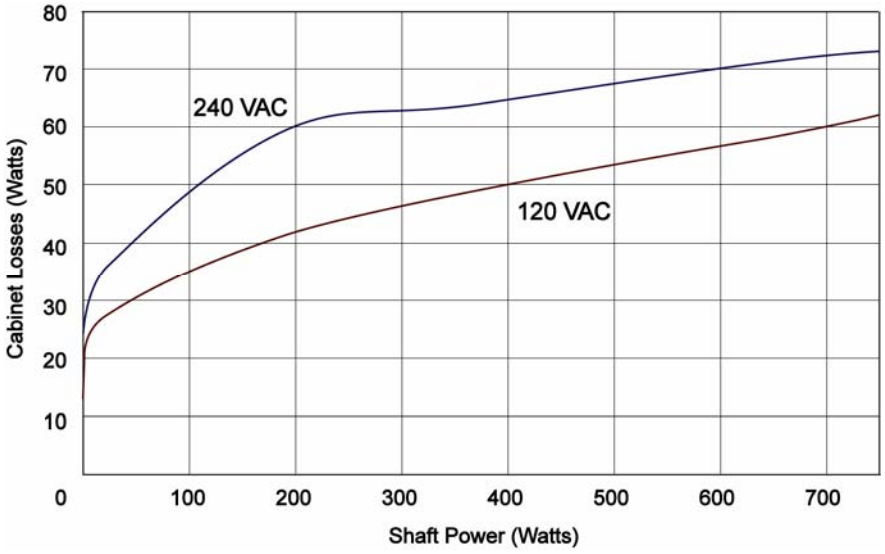


Figure 2 Cabinet Losses: AR-08CE (750 Watt) Connected to Parker BE343J Motor

	Shaft Power		
Voltage	**0W***	**200W**	**700W**
120 VAC	13W	42W	60W
240 VAC	24W	60W	73W
* Drive enabled, zero torque.			

Table 5 Power Dissipation for AR-08CE (750 Watt Model)

AR-13CE Model

The following values have been measured using the Parker MPM1421CSJXXXN motor.

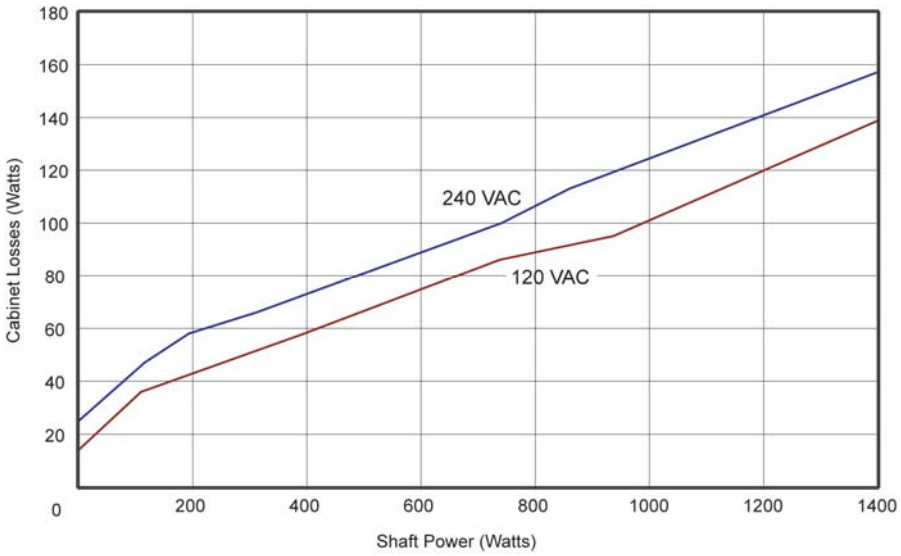


Figure 3 Cabinet Losses: AR-13CE (1300 Watt) Connected to Parker MPM1421CSJ Motor

	Shaft Power		
Voltage	**0W***	**700W**	**1300W**
120 VAC	14W	82W	130W
240 VAC	25W	95W	146W
* Drive enabled, zero torque.			

Table 6 Power Dissipation for AR-13CE (1300 Watt Model)

Cabinet Cooling Calculations

Use the motor's speed torque curve to determine the torque when the motor is at running speed for your application. If the torque is not known, use the "knee" of the graphed motion (where the peak-torque curve intersects the continuous-torque curve)—this assumes the worst-case scenario for continuous motion.

$$P_{LOSS} = \frac{P_{MOTOR}}{E_{MOTOR}} * \left(1 - E_{DRIVE}\right)$$

P_{LOSS} = power dissipated to cabinet (Watts)

P_{MOTOR} = shaft power of the motor (Watts)

E_{MOTOR} = efficiency of motor, approximately 0.85

E_{DRIVE} = efficiency of drive, approximately 0.90

Dimensions

There is one basic housing size, although the height of the heat sink fins varies with each model. This section contains the dimensions of all models.

Drive Dimensions

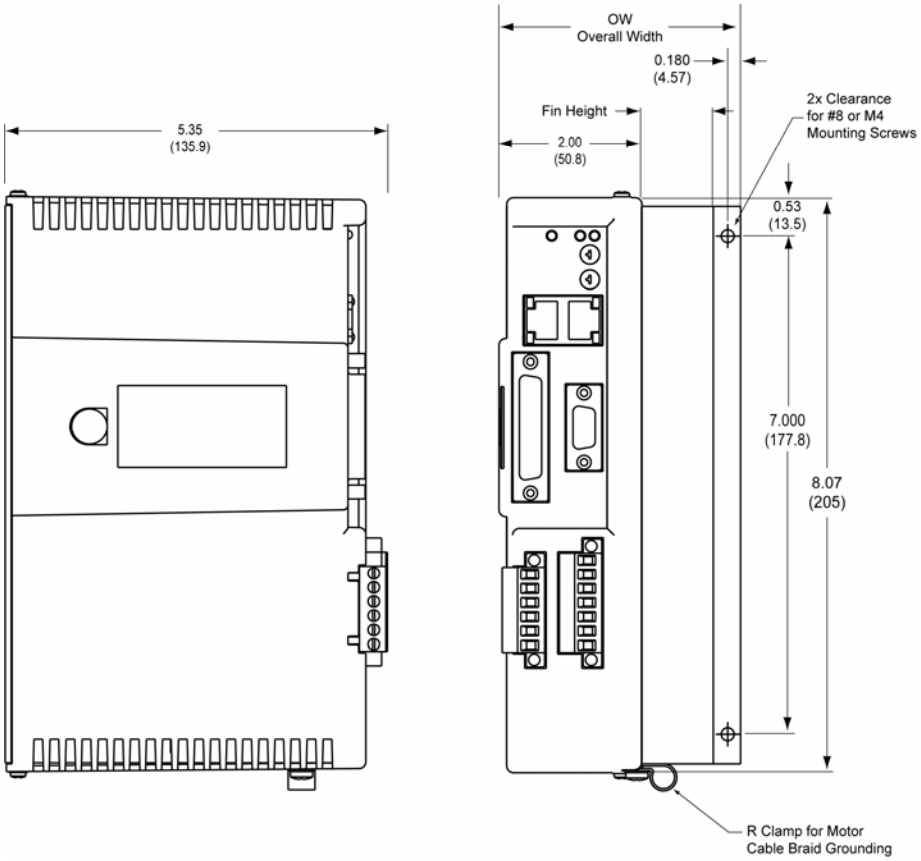


Figure 4 Drive Mounting for All Aries Controllers

Drive	Fin Height *in (mm)*	Overall Width (OW) *in (mm)*	Overall Depth with Cables *in (mm)*
AR-04CE	0.625 (15.9)	3.01 (78.3)	7.90 (200.7)
AR-08CE	1.00 (25.4)	3.38 (85.9)	7.90 (200.7)
AR-13CE	2.00 (50.8)	4.38 (111.3)	7.90 (200.7)

Table 7 Drive Dimensions

Weight

Table 8 lists the weight of each drive/controller model.

Drive/Controller	Weight *pounds (kg)*
AR-04CE	2.9 (1.32)
AR-08CE	3.3 (1.50)
AR-13CE	4.2 (1.91)

Table 8 Drive/Controller Weights

Mounting Guidelines

The Aries Controller is a vented product. To prevent material spilling into the drive, mount it under an overhang or in a suitable enclosure.

Aries products are made available under “Restricted Distribution” for use in the “Second Environment” as described in the publication EN 61800-3: 1996.

Cable Routing

Route high power cables (motor and mains) at right angles to low power cables (communications and inputs/outputs). Never route high and low power cables parallel to each other.

Panel Mounting

The minimum clearance between Aries Controllers is 0.62 inches (15.75 mm). The minimum clearance above and below a drive is 1 inch (25.4 mm). Figure 5 on page 23 demonstrates these clearance requirements.

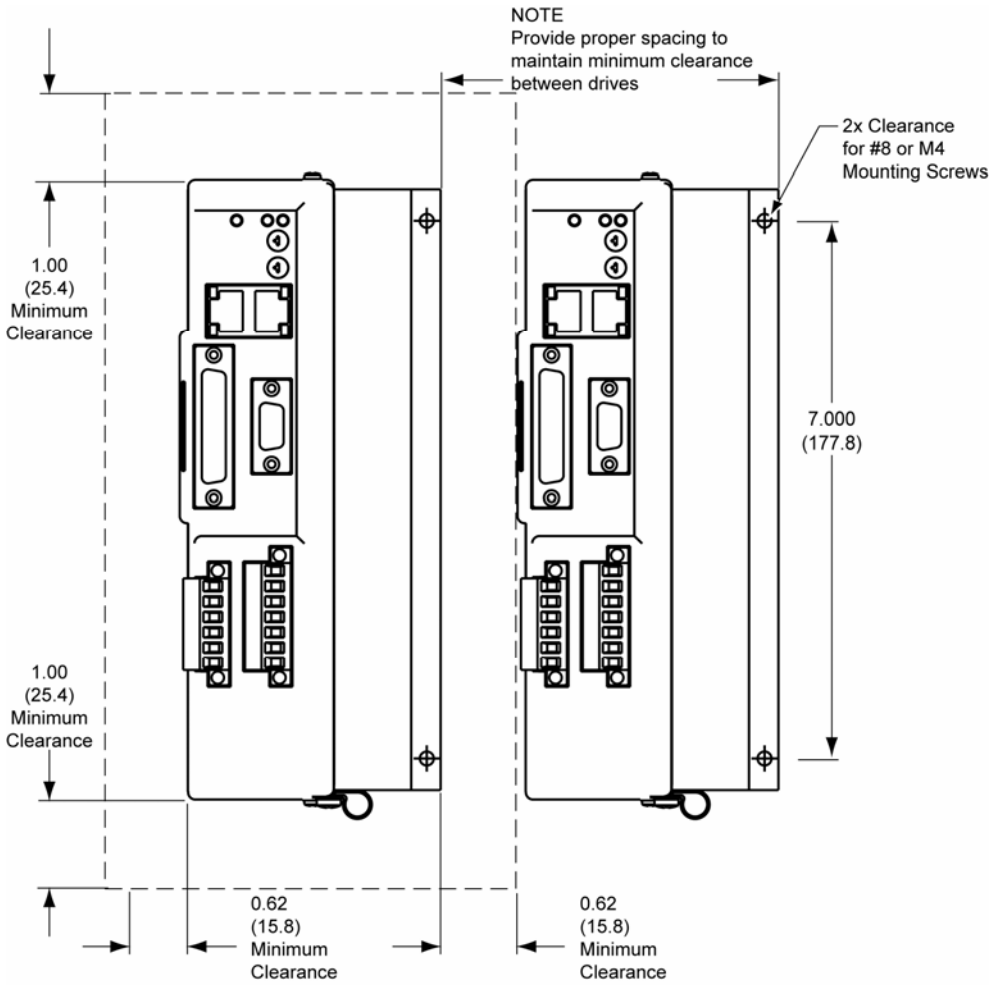


Figure 5 Panel Layout Dimensions for All Aries Controller Models

CHAPTER THREE

3 Electrical Installation

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- Installation Safety Requirements 25
- System Installation Overview 26
- Connectors 27
- Output (Motor) Power 38
- Power Supply 40
- Multiple Drive/Controller Installations 44
- Brake Relay (Optional) 45
- Regeneration Protection 48

Installation Safety Requirements

Aries Controllers meet the requirements of both the European LVD (Low Voltage Directive) and EMC (Electromagnetic Compliance) directives when installed according to the instructions given within “Appendix C Regulatory Compliance–UL and CE.”

As a rule, it is recommended that you install the drive/controller in an enclosure to protect it from atmospheric contaminants and to prevent operator access while power is applied. Metal equipment cabinets are ideally suited for housing the equipment because they provide operator protection and EMC screening, and can be fitted with interlocks arranged to remove all hazardous motor and drive power when the cabinet door is opened.

Do not arrange the interlocks to open circuit the motor phase connections while the system is still powered as this could damage the drive/controller.

Precautions

During installation, take the normal precautions against damage caused by electrostatic discharges.

- Wear earth wrist straps.
- Include a mains power switch or circuit breaker within easy reach of the machine operator. Clearly label the switch or breaker as the disconnecting device.

Warning — High-performance motion control equipment is capable of producing rapid movement and very high forces. Unexpected motion may occur especially during the development of controller programs. **KEEP WELL CLEAR** of any machinery driven by stepper or servo motors. Never touch any part of the equipment while it is in operation.

Auto-Configuration for Encoders

The drive/controller recognizes “smart encoders” attached to Parker motors. You can apply power to the drive/controller, and it reads all necessary motor parameters from the motor. The drive/controller and motor are then ready to use.

If a drive/controller is swapped out for any reason, the replacement Aries Controller automatically reads the motor parameters.

System Installation Overview

This section details the components and configuration necessary for electrical installation of all models of the Aries Controller.

Installation of a motion control system requires an Aries Controller, a compatible motor (listed on page 15), and access to a computer. See Figure 6 for a diagram of this system.

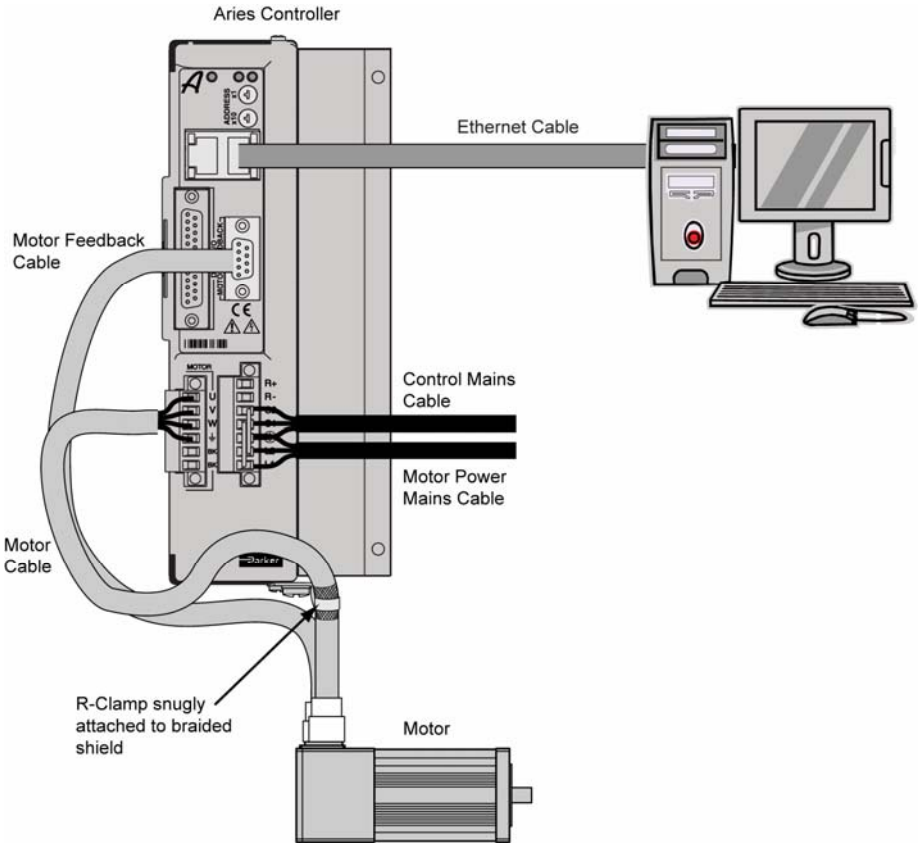


Figure 6 System Installation Overview

Warning — This product has been developed for industrial environments. Due to exposed high voltage terminals, this product must not be accessible to users while under normal operation.

Important — An R-clamp must be connected to the drive and snugly attached to the exposed braided shield of the motor cable in order to control electrical noise.

Connectors

All Aries Controller models have the same set of connectors. Connector specifications are in this section and also “Appendix A Additional Specifications.”

Figure 7 shows the name and location of the connectors.

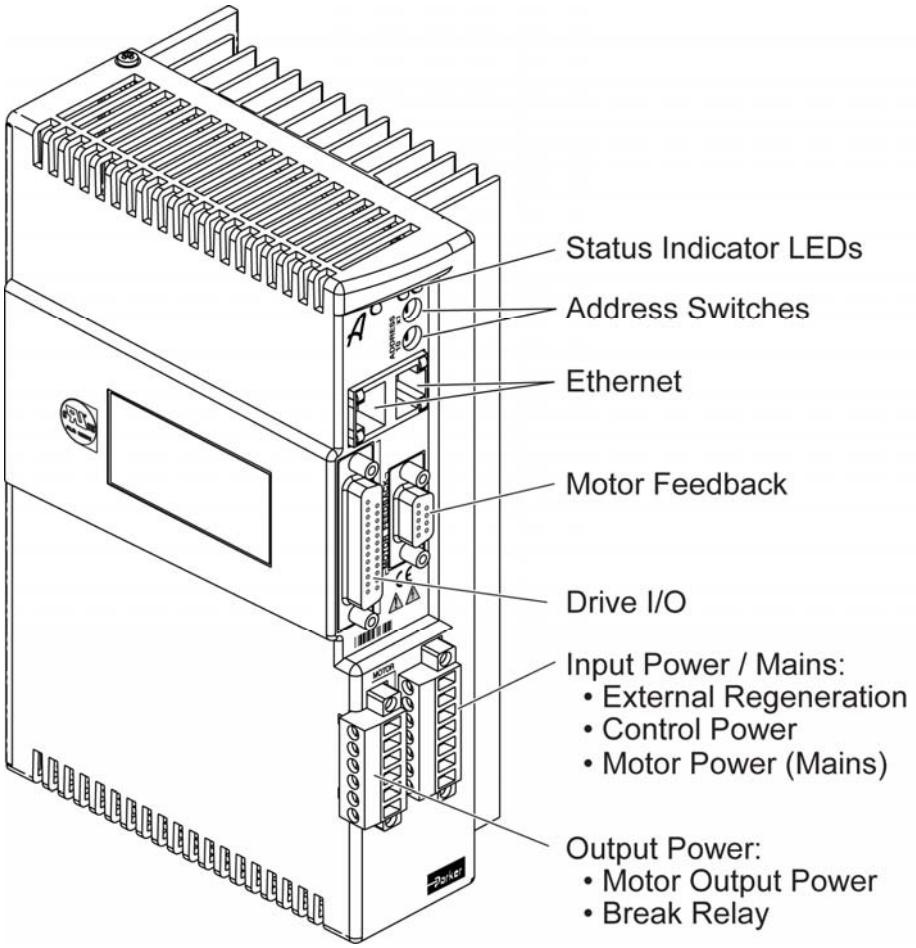


Figure 7 Aries Controller Connectors

Output Power Connector

The drive's Motor screw terminal connector provides output power to the motor. [For connection information, see *Output (Motor) Power* on page 38.]

The drive's Motor connector provides terminals U, V, W and ⏚ for connecting output power to the motor. It also serves to connect an external motor brake to the drive's internal solid-state relay on the two BK terminals. This connector is removable.

Connector Type	Removable screw terminal
Terminals	6
Pitch	0.200 in (5.08 mm)
Wire range	12-26 AWG
	14-27 SWG
	(0.12-3.30 mm^2)
Wire strip length	0.310 in (8 mm)
Torque	7.0 in–lbs nom. (0.79 N-m)

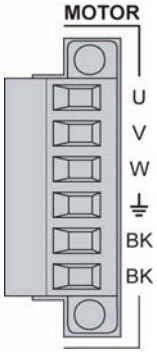


Figure 8 Output Power Connector

Input Power / Mains Connector

The Input Power / Mains connector contains terminals for external regeneration, control power, and motor power. Do not connect power to this connector before reading the section *Power Supply* on page 40.

The Input Power / Mains connector provides terminals L1, L2, and ⏚ for connecting motor mains power. It also serves to connect Control power through terminals C1 and C2, and a power dissipation resistor on terminals R+ and R–. The connector is removable.

Connector Type	Removable screw terminal
Terminals	7
Pitch	0.200 in (5.08 mm)
Wire Range	12-26 AWG
	14-27 SWG
	(0.12-3.30 mm^2)
Wire Strip length	0.31 in (7.87 mm)
Torque	7.0 in–lbs nom. (0.79 N-m)

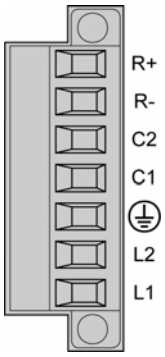


Figure 9 Input Power / Mains Connector

Important — Power to the Aries Controller can be supplied in two ways. See the section *Power Supply* on page 40 before proceeding with connecting the unit to power.

Factory Installed Jumpers

The Aries Controller comes with external jumpers installed in the Input Power / Mains connector from C1 to L1, and C2 to L2. Figure 10 shows the location of the factory installed jumpers.

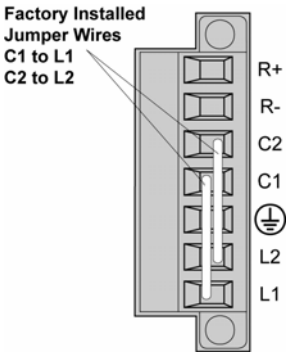


Figure 10 Factory-Installed Jumpers on Input Power / Mains Connector

Motor Feedback Connector

Inputs for the encoder feedback, motor thermal switch, and hall effects are located on the 15-pin Motor Feedback connector.

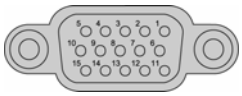


Figure 11 Motor Feedback Connector, Female

Motor Feedback Connector Specification

Connector Type..... 15-Pin High Density D-Subminiature (female socket)

Manufacturer..... KYCON or equivalent

KYCON Part Number..... K66-E15S-NR

Motor Feedback Connector Specification—Mating Connector

Mating connectors are not provided with the drive. Parker cables are available with mating connectors attached.

Connector Type..... 15-Pin High Density D-Subminiature (male connector)

Manufacturer..... AMP or equivalent

Cable Kit	AMP Part Number 748473-1 Includes: 748364-1 connector, shield, enclosure, and two jack screws (does not include contacts or ferrules)
Contacts	Crimp style 30µ" Gold—AMP Part Number 748333-4 Gold Flash—Amp Part Number 748333-7

Important — Encoder inputs use a DS26LV32 differential line receiver. Parker Hannifin recommends 26LS31 (or compatible) differential line driven encoders. Single-ended encoders are *not* compatible with the drive/controller.

Motor Feedback Connector Pinout

Pinout configuration for the Motor Feedback connector is listed in Table 9. A box surrounding pins indicates a requirement for twisted pair wiring.

Signal	Pin	Description
ENC Z+ / DATA+	1	Encoder Z Channel in
ENC Z– / Data–	2	Encoder Z Channel in
DGND	3	Encoder power return
+5 VDC	4	+5 VDC Encoder power
+5 VDC	5	+5 VDC Hall power
DGND	6	Hall power return
ENC A– / SIN–	7	Encoder A Channel in
ENC A+ / SIN+	8	Encoder A Channel in
Hall 1 / SCLK+ *	9	Hall 1 input
Thermal+	10	Motor thermal switch/thermistor
Thermal–	15	Motor thermal switch/thermistor
ENC B–/ COS–	11	Encoder B Channel in
ENC B+ / COS+	12	Encoder B Channel in
Hall 2 / SCLK– *	13	Hall 2 input
Hall 3	14	Hall 3 input
* When using the SinCos protocol, pins 9 and 13 require twisted pair wiring. NOTE: Twisted pairs are outlined by a box.		

Table 9 Motor Feedback Connector Pinout

Internal Connections

A schematic diagram of the internal connections for the Motor Feedback connector is shown in Figure 12.

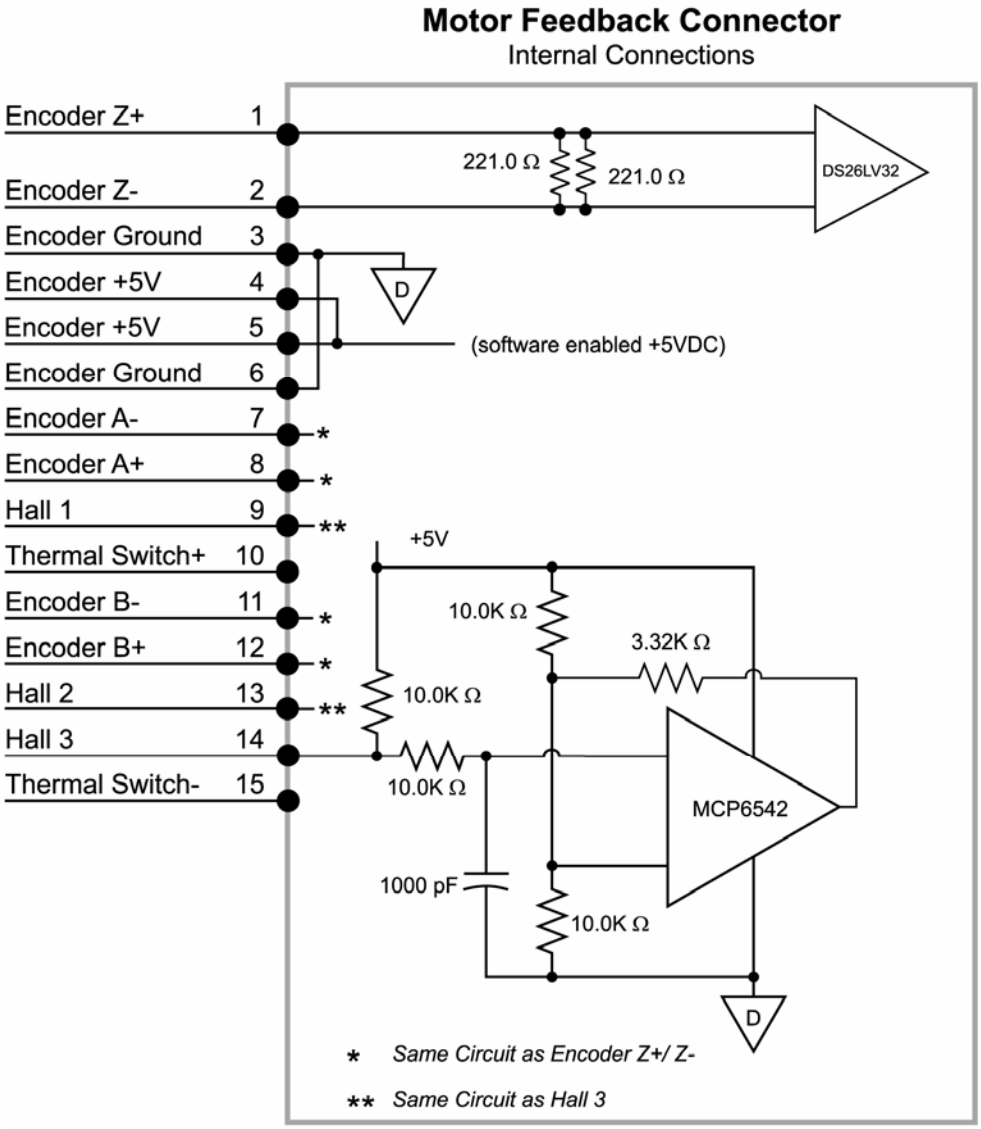


Figure 12 Internal Circuit Diagram for the Motor Feedback Connector

Encoder Inputs

Encoder input requirements are listed in Table 10.

Description	Min	Typical	Max	Units
Common Mode Range	-7		+7	V
Current—Encoder			250	mA
Current—Hall			250	mA
Differential Threshold Voltage	-200		+200	mV
Differential Termination Impedance		120		ohms
Thermal Switch Current			2	mA
Thermal Switch Voltage Maximum (supplied)			15	V
Primary Encoder Input Frequency (pre-quadrature)			1.6	MHz
Note: All parameters are at the connector pin.				

Table 10 Electrical and Timing Characteristics for the Encoder Inputs

Drive I/O Connector

The 25-pin Drive I/O connector has seven inputs and four outputs, which are described below. All drive input and output signals are optically isolated.

- Four general purpose inputs with both Anodes (+) and Cathodes (–) available
- Three high-speed inputs with both Anodes (+) and Cathodes (–) available
- Four General Purpose outputs

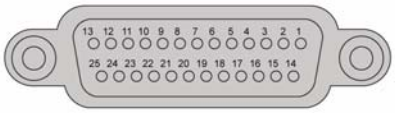


Figure 13 Drive I/O Connector

Cable

For preparing your own cable, use differential pair wiring with a minimum of three turns-per-inch (3 TPI).

Drive I/O Connector Specification

Connector Type	25-Pin D-Subminiature (female socket)
Manufacturer	KYCON or equivalent
KYCON Part Number	K22-B25S-NR

Drive I/O Connector Specification—Mating Connector

Mating connectors are not provided with the drive.

Connector Type	25-Pin D-Subminiature (male connector)
Manufacturer	AMP or equivalent
Cable Kit	AMP Part Number 748474-1 Includes: 1658648-1 connector, shield, enclosure, and two jack screws (does not include contacts or ferrules)
Contacts	Crimp style 30µ" Gold—AMP Part Number 748333-4 Gold Flash—Amp Part Number 748333-7

Drive I/O Connector Pinout

Pinout configuration for the Drive I/O connector is listed in Table 11. A box surrounding pins indicates a requirement for twisted pair wiring.

Signal	Pin
Input 0+	1
Input 0–	14
Input 1+	2
Input 1–	15
Input 2+	3
Input 2–	16
High-Speed Input 4+	4
High-Speed Input 4–	17
High-Speed Input 5+ (or Auxiliary Encoder A+) *	5
High-Speed Input 5– (or Auxiliary Encoder A-) *	18
High-Speed Input 6+ (or Auxiliary Encoder B+) *	6
High-Speed Input 6– (or Auxiliary Encoder B-) *	19
Input 3+	7
Input 3–	20
Reserved (future 5 V)	8
Reserved (future GND)	21
Output 32+	9
Output 32–	22
Output 33+	10
Output 33–	23
Output 34+	11
Output 34–	24
Output 35+	12
Output 35–	25
Not used	13

* Can be used as a high-speed input or an auxiliary encoder.

Table 11 Drive I/O Connector Pinout

Internal Connections

A schematic diagram of the internal connections for the Drive I/O connector is shown in Figure 14.

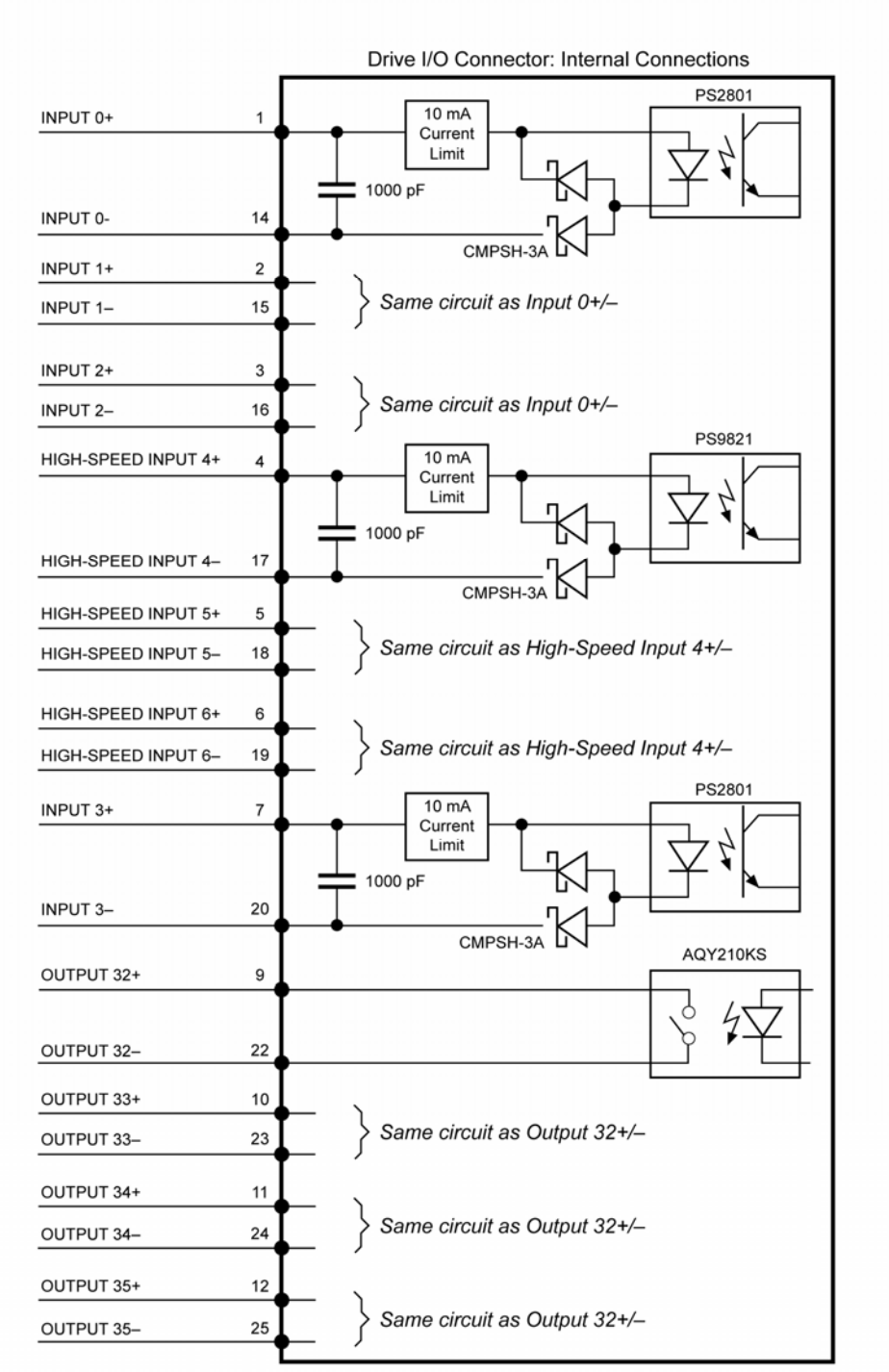


Figure 14 Internal Circuit Diagram for the Drive I/O Connector

Inputs—High-Speed

The high-speed inputs are optically isolated inputs. Current is limited internally for input voltage control of 5 to 24 volt logic. The Anode (+) and Cathode (−) optocoupler inputs are on separate connector pins to allow significant flexibility in wiring to different styles of interface.

Description	Min	Max	Units
Turn-on time	–	200	ns
Turn-off time	–	400	ns
Guaranteed on voltage	4	–	VDC
Guaranteed off voltage	–	2	VDC
Maximum forward voltage	–	30	VDC
Maximum reverse voltage	−30	–	VDC
Forward current	3	12	mA
Note: All parameters are at the connector pin.			

Table 12 Inputs—Trigger and Home Electrical/Timing Characteristics

Inputs—General Purpose

These slow inputs are optically isolated. Current is limited internally for input voltage control of 5 to 24 volt logic. The Anode (+) and Cathode (−) optocoupler inputs are on separate connector pins to allow significant flexibility in wiring to different styles of interface.

Description	Min	Max	Units
Turn-on time	–	1	ms
Turn-off time	–	2	ms
Guaranteed on voltage	4	–	VDC
Guaranteed off voltage	–	2	VDC
Maximum forward voltage	–	30	VDC
Maximum reverse voltage	−30	–	VDC
Forward current	3	12	mA
Note: All parameters are at the connector pin.			

Table 13 Additional Inputs—Electrical/Timing Characteristics

Outputs—General Purpose

The general purpose outputs are optically isolated and current limited. Both sides of the MOSFET output structure are brought to the pins to allow significant flexibility in wiring to different styles of interface.

Description	Min	Typical	Max	Units
Turn-on time	–	–	2	ms
Turn-off time	–	–	1	ms
Working voltage	−30	–	30	VDC
On-time voltage drop IL ≤ 10 mA	–	–	0.4	VDC
On-time voltage drop 10 mA < IL ≤ 100 mA	–	–	4.0	VDC
Load current, IL (TA ≤ 35C)	–	–	100	MA
Load current, IL (35C < TA ≤ 50C)	–	–	80	MA
Short circuit trip current	–	200	–	mA
Note: All parameters are at the connector pin.				

Table 14 Outputs—General Purpose Outputs Electrical/Timing Characteristics

Output (Motor) Power

Output Power Ratings

Continuous and peak output power ratings for all Aries Controller models are listed in Table 15.

	Continuous Output		Peak Output	
Drive	**Current (Amps, RMS)**	**Shaft Power* (Watts, max)**	**Current (Amps, RMS)**	**Shaft Power (Watts, max)**
AR-04CE	3.0	400	9.0	1200
AR-08CE	4.5	750	13.5	2250
AR-13CE	6.3	1300	14.1	3900
* Maximum shaft power rating at 240 VAC				

Table 15 Output Power, Continuous and Peak

Output (Motor) Power Connections

Figure 15 shows how to connect the motor cable to the Output Power connector.

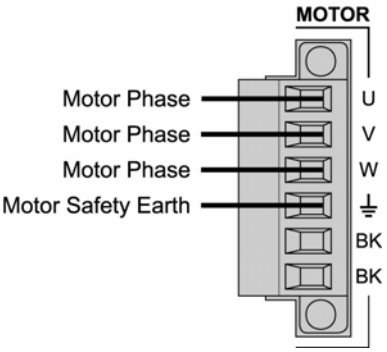


Figure 15 Output Power Connection

Current Parker motor cables are marked with white numbers (1,2, or 3) to indicate the phase. Connect Motor Phase 1 to U, 2 to V, and 3 to W, and Motor Safety Earth to the Protective Earth ground connector.

Warning — You must connect the Motor Safety Earth conductor terminal, marked with the earth symbol ⏚, to the motor cable's motor-safety-earth wire (green/yellow).

Table 16 contains wiring information for making connections with various Parker Hannifin motors.

Phase	Hi-Flex/ PS/ Gemini	Legacy Parker Hannifin	Legacy MaxPlus
U	1	Red/Yellow	Red
V	2	White/Yellow	Black
W	3	Black/Yellow	Blue
⏚	Green/Yellow	Green/Yellow	Green

Table 16 Wiring to Parker Motors

Power Supply

Important — Power to the Aries Controller can be supplied in two ways. Completely read this section and comply with all safety measures before proceeding with connecting the unit to power.

Input Power

The mains Motor Power supply and the optional Control Power supply for the drive/controller must meet the requirements listed in Table 17.

Input Power	Requirements
Motor Input Power (L1, L2)	120/240 VAC, 50/60 Hz, single phase
Control Input Power (C1, C2)	120/240 VAC, single phase

Table 17 Input Power Requirements

Fuse Requirements

Aries Controllers have no user-serviceable internal fuses. For safety, the user must provide a fuse in each of the mains input lines.

Motor Power Fuse Information

Select the proper Motor Power input fuse for your specific application using Table 18.

Drive	AC Voltage	Fuse Style	Rating	Fuse Type
AR-04CE	120 VAC	125 VAC Time Delay	20A	RK5 or better
	240 VAC	250 VAC Time Delay	20A	RK5 or better
AR-08CE	120 VAC	125 VAC Time Delay	20A	RK5 or better
	240 VAC	250 VAC Time Delay	20A	RK5 or better
AR-13CE	120 VAC	125 VAC Time Delay	30A	RK5 or better
	240 VAC	250 VAC Time Delay	30A	RK5 or better

Table 18 Motor Power Fuse Information

Table 19 lists part numbers (at time of publication) for suitable fuses from several manufacturers. These fuses are type RK5 (time delay fuses).

Amps	Bussmann	Ferraz Shawmut (formerly Gould)	Littelfuse
10	FRN-R-10	TR10R	FLNR10
20	FRN-R-20	TR20R	FLNR20
30	FRN-R-30	TR30R	FLNR30
40	FRN-R-40	TR40R	FLNR40

Table 19 Fuse Part Numbers

Control Power Fuse Information

Each Control Power input line must be protected by the following fuse:

Fuse Rating	1 Amp
Fuse Type	Class CC (Bussmann KTK-R-1 or equivalent UL listed fuse)
Input Voltage Range	120/240 VAC, 50/60 Hz
Input Current	0.2 Amps RMS
Control Power Functions	Communications Diagnostics Motor position feedback Brake relay in brake mode Drive I/O signals

Drive Inrush Current

The drive inrush current is limited by an internal thermistor that changes value with the ambient temperature. Drive inrush current is therefore dependent upon the temperature of the surrounding environment (T_{amb}). To determine the drive inrush current for your drive, see Table 20.

Drive Type	AC Voltage	Drive Inrush at T_{amb} = 25°C	Drive Inrush at T_{amb} = 50°C
AR-04CE	120 VAC	17A	36A
	240 VAC	34A	73A
AR-08CE	120 VAC	17A	36A
	240 VAC	34A	73A
AR-13PE	120 VAC	17A	36A
	240 VAC	34A	73A

Table 20 Drive Motor Power Inrush Current

Power Supply Connections

Power to the Aries Controller may be supplied in one of two ways: a single-source to the Motor Input Power (Mains) screw terminals with the factory-installed jumpers in place; or removal of the jumpers and application of separate sources to the Motor Power terminals and to the Control Power terminals.

When a separate mains power is applied to the drive/controller, the internal control board remains powered when the primary Motor Power source is disconnected. When operated in this configuration, the Control Power input performs a “keep-alive” function. The keep-alive circuit maintains several important functions, including the following:

- Communications
- Diagnostics
- Motor position feedback
- Brake relay in brake mode
- Drive I/O signals

Earth Ground

Under normal operation, no current should flow through the Protective Earth connection.

Important — Make the Protective Earth ground connection directly by means of a low-impedance path less than or equal to 0.1 ohm (with no fuses or other devices).

Single-Source (Motor Input Power) Connections

Figure 16 shows how to connect the external 120/240 VAC Motor Power single-source to the Input Power connector.

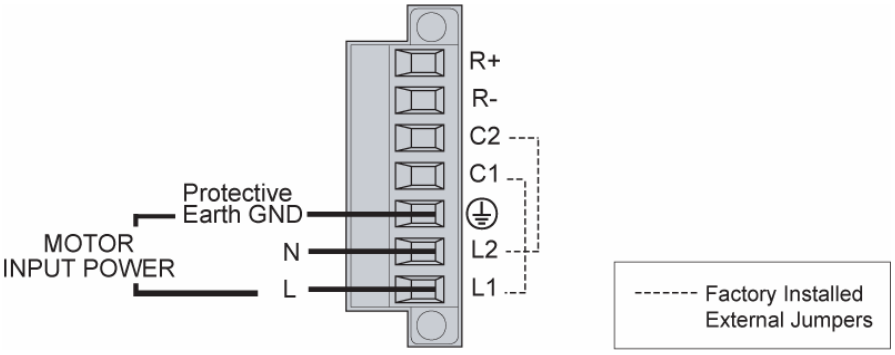


Figure 16 Motor and Control Power Supply Connection, Single Source

Single input (with factory-installed jumpers)	Connections
Connect *Motor Input Power* only.	L1, L2, Gnd

Separate Sources Connections

Figure 17 shows how to connect separate external Motor and Control Power sources to the terminal connector installed in the drive.

Note: *You must remove the factory installed jumper wires to use separate power sources.* For more information on the jumpers, see *Factory Installed Jumpers* on page 30.

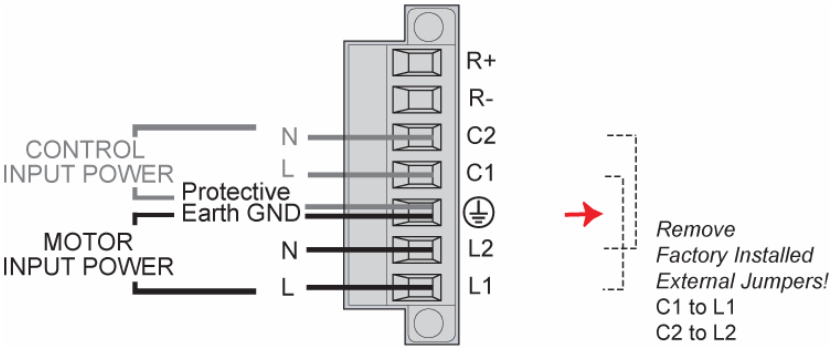


Figure 17 Motor and Control Power Supply Connection, Separate Sources

Multiple inputs (remove jumpers)	Connections
connect *Motor Input Power*	L1, L2, Gnd
- and -	
connect *Control Input Power.*	C1, C2, Gnd

Warning — You must connect the drive's protective conductor terminal, marked with the earth symbol ⏚, to a reliable system Protective Earth.

Warning — The drive's connector strip terminals have hazardous voltages when power is applied to the drive, *and up to several minutes after power is removed*. Lower voltages may still be present for several minutes after power is removed. During normal operation, these high voltage terminals must not be accessible to the user.

Multiple Drive/Controller Installations

In a typical cabinet installation, a single mains line connects to a terminal bus inside the cabinet. From the terminal bus, make individual connections for Mains and Control Power to the corresponding connector(s) on each drive/controller. Be sure to install fuses for each drive between the terminal bus and the drive.

Tie each drive's Protective Earth ⏚ conductor terminal directly to the system safety earth location as shown in Figure 18. Under normal operation, no current should flow through the Protective Earth ground.

Safety Earth Connection

For multiple drive installations, Parker Hannifin recommends a single point or "star" safety earth configuration. Figure 18 represents a typical star safety earth connection .

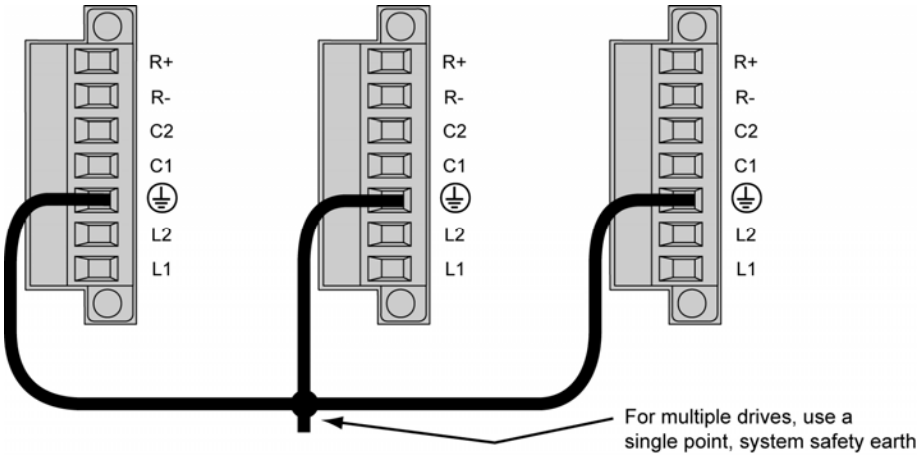


Figure 18 Multiple Drives Safety Earth Connection

Brake Relay (Optional)

The Brake Relay connection (on the Output Power connector) provides a safety feature for your motion control system, particularly for vertical applications. The drive/controller acts as a control switch for the motor brake (if a brake is present). When 24V is applied from an outside power supply through the drive's Brake Relay (BK) terminals, the motor brake is disabled. When the power supply is interrupted, or the drive/controller faults or is disabled, the brake is enabled and stops shaft rotation.

Brake Relay Connector (on Output Power Connector)

AR-04CE, AR-08CE, & AR-13CE

Connector Type..... Removable screw terminal
Terminals 6
Pitch ..... 0.200 in (5.08 mm)
Wire range .....12-26 AWG
.....14-27 SWG
.....(0.12-3.30 mm^2)
Wire strip length..... 0.310 in (8 mm)
Torque....7.0 in–lbs nom. (0.79 N-m)

Brake Relay Operation

Drive Condition	Relay State
Enabled	Closed (conducting)
Faulted	Open
No AC power on L1 and L2* or drive not enabled	Open

* Mains Control power on C1 and C2 does not affect the relay. With mains power applied to C1 and C2, the relay remains open if AC power is *not* applied to the L1 and L2 terminals.

Table 21 Brake Relay Operation

Brake Relay Specifications

Relay Type..... Solid State Relay
Normally open

Relay Maximum Rating..... 1 Amp at 24 VDC

Warning — Do not exceed the ratings of the brake relay. If required, control a suitable external relay with this relay to meet your power requirements.

Brake Relay Connection

On all models, the two BK terminals are optically isolated from the drive/controller's internal logic.

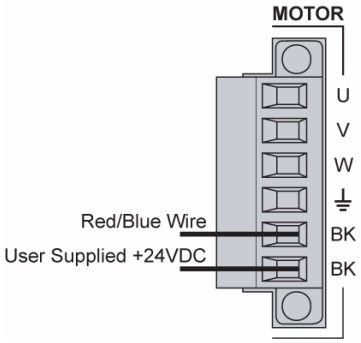


Figure 19 Typical Brake Relay Connection on the Output Power Connector

Warning — You must connect the drive/controller's protective conductor terminal, marked with the earth symbol ⏚, to a reliable system Protective Earth.

Warning — The drive/controller's connector strip terminals have hazardous voltages when power is applied, *and up to several minutes after power is removed*. Lower voltages may still be present for several minutes after power is removed. During normal operation, these high voltage terminals must not be accessible to the user.

Brake Relay to Motors with Full Wave Rectifiers

Some Parker brake motors (BE, SM, SE, NeoMetric, MPP, and J series motors, serial numbers 010904xxxxx and greater) contain full wave rectifiers, so connection polarity is not an issue during installation.

1. Connect one red/blue brake wire (Parker Motor cable or equivalent) to one BK terminal.
2. Connect the second red/blue brake wire (Parker Motor cable or equivalent) to the 24V return on the power supply.
3. Connect the +24 VDC power supply to the second BK terminal.

Figure 20 shows a typical application.

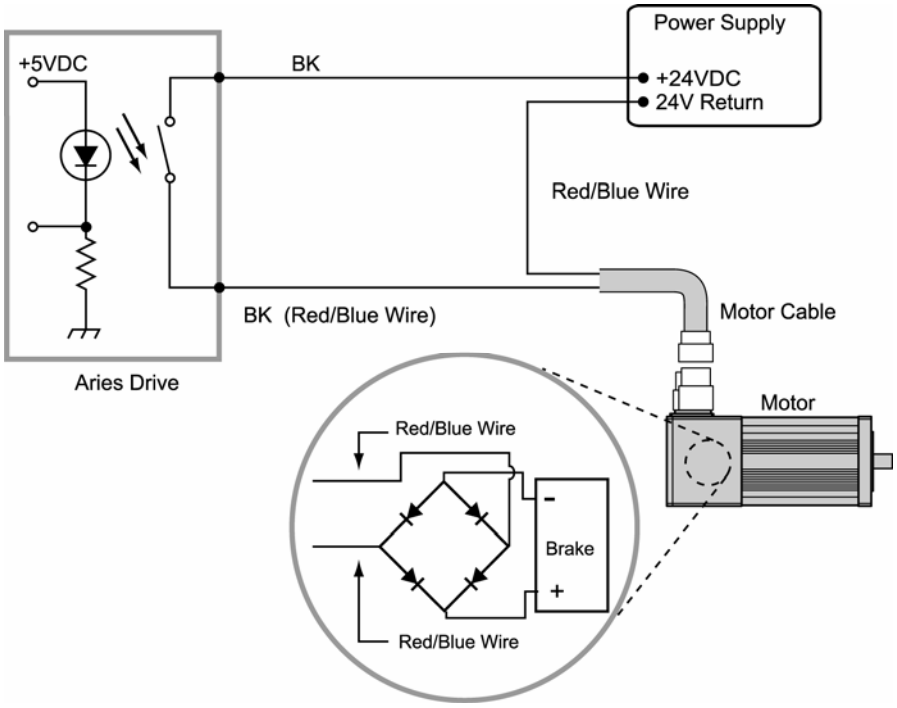


Figure 20 Brake Relay Connection for Motor with Full Wave Rectifiers

Brake Relay to Motors Without Full Wave Rectifiers

When using Parker MaxPlus motors, Parker motors with serial numbers less than 010904xxxxx, or non-Parker motors, you must install a fly-back diode. Consult the specifications or the manufacturer of your motor.

1. Connect one red/blue brake wire (Parker Motor cable or equivalent) to one BK terminal (located on the Motor connector.
2. Connect the second red/blue brake wire (Parker Motor cable or equivalent) to the 24V return on your power supply.
3. Between the two red/blue wires, connect the fly-back diode.
4. Connect the +24 VDC power supply to the second BK terminal.

Figure 21 shows a typical installation.

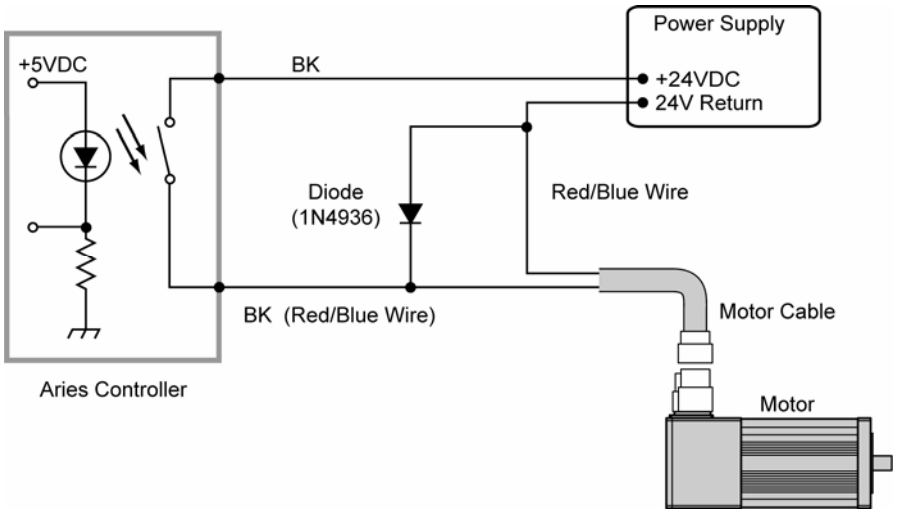


Figure 21 Brake Relay Connection for Motor without Full Wave Rectifiers

Regeneration Protection

Drive/controller models AR-04CE, AR-08CE, and AR-13CE do not have internal regeneration resistors for power dissipation; however, an external regeneration resistor can be used for this purpose. For information on selecting a suitable external regeneration resistor, see “Appendix B External Power-Dump Resistor Selection.”

Regeneration Connection

To use an external regeneration resistor, connect your external resistor to the R+ and R- terminals located on the Control Power connector.

Figure 22 illustrates the external regeneration resistor connections.

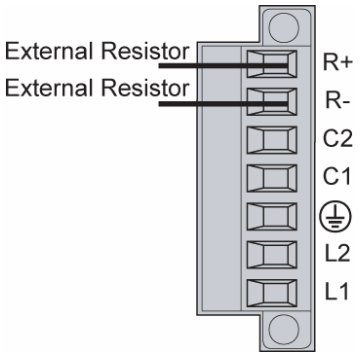


Figure 22 External Regeneration Connection

Warning — The drive/controller's connector strip terminals are at hazardous voltages when power is applied, and up to several minutes after power is removed. Lower voltages may still be present for several minutes after power is removed.

During normal operation, these high voltage terminals must not be accessible to the user.

Internal Regeneration Capability

The drive/controller may experience an over-voltage fault if the regeneration exceeds the absorbent capacity of the drive/controller's internal bus capacitors, as shown in Table 22.

The available absorption varies, based on mains voltage and the drive/controller's internal capacitance. The various drives can absorb the following amounts of regenerated energy in its internal capacitors.

Drive	Absorbs (Joules) 120 VAC	Absorbs (Joules) 240 VAC
AR-04CE	57	19
AR-08CE	72	24
AR-13CE	104	35

Table 22 Regeneration Absorption

For more specifications about energy absorption by the drive/controller's capacitors, see Table 39 Drive Capacitor Absorption.

For more information about selecting an external power-dissipation resistor, see "Appendix B External Power-Dump Resistor Selection".

CHAPTER FOUR

4 Communications

IN THIS CHAPTER

- Overview 51
- Ethernet Specifications 51
- Assigning IP Address 53
- Connecting to a PC 57
- Verifying the IP Address 57
- LED Status Indicators 58

Overview

The Aries Controller drive communicates in a standard Ethernet network, thereby providing a direct link for sending commands through the ACR-View online help system installed on a PC. This chapter describes how to establish the standard Ethernet connection.

All models of the drive/controller have a dual-stack, standard RJ-45 connector, which provides two communications ports.

Ethernet Specifications

Ethernet Cable Specification

Use a braid over foil twisted pair cable (straight or crossover) for connection to a PC. An example of this type of cable is L-COM TRD855SIG-XX. The maximum cable length is 100m, as defined by Ethernet 100Base-TX standards.

Ethernet Connector

A dual-stack, standard RJ-45 socket connector, located on the front panel of the drive/controller, provides two communication ports that accommodate ETHERNET connections. The two sockets of the connector are identical and either may be used for direct connection to a PC network card.

To provide top noise performance, the connector contains isolation transformers and common mode chokes for both the transmit and receive signal pairs.

Figure 23 shows the plug and socket connectors and their features.

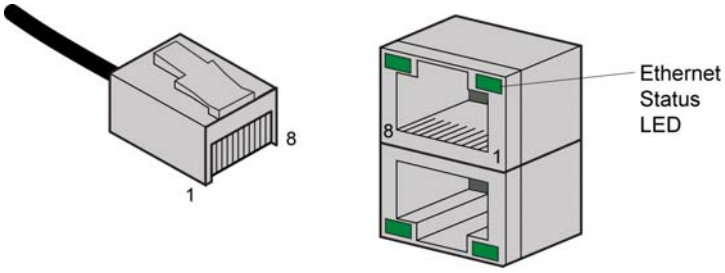


Figure 23 RJ-45 Connectors

Connector Specifications

Manufacturer ..... Bel or equivalent

Connector Type..... 8-Pin, RJ-45 (female socket)

Bel Part Number..... 0845-2D1T-H5

Ethernet Connector Pinout

Table 23 contains the Ethernet connector pinout.

Signal	Pin	Wire Color	Description
RX+	1	White/orange	Differential Receive positive side
RX–	2	Orange	Differential Receive negative side
TX+	3	White/green	Differential Transmit positive side
	4	Blue	Not used
	5	White/blue	Not used
TX–	6	Green	Differential Transmit negative side
	7	White/brown	Not used
	8	Brown	Not used
Note: Pin assignment follows EIA/TIA T568B guidelines.			

Table 23 RJ-45 Connector Pinout

RJ-45 LED Ethernet Status Indicators

LEDs located on the RJ-45 socket connector indicate Ethernet status. Table 24 describes the LED states and their meanings.

LED	Steady	Flash	Description
Ethernet Link/Activity	Off	—	No Ethernet link detected
	Yellow	—	Ethernet link established, no activity
	—	Yellow	Ethernet link established and active
Ethernet Speed	Off	—	Ethernet 10Mbps
	Green	—	Ethernet 100Mbps

Table 24 RJ-45 Ethernet Status LED Indications

Assigning IP Addresses

Communication between the Aries Controller and your PC must be set up before connecting over the Ethernet network. Do this by first setting the IP address of the Aries Controller, and then setting the IP address and subnet mask for the PC.

Setting the IP Address—Aries Controller

The factory assigns the following to each Aries Controller:

IP Address
192.168.100.01

Subnet Mask (fixed)
255.255.255.0

Before adding the Aries Controller to the network, complete its IP address by setting the last octet (digits) of the IP address on the rotary decimal switches. The last octet can be any number from 01 through 99 (00 is not valid).

One rotary switch is marked X1 and the other X10. X1 is the “ones” position and X10 is the “tens” position. For example, to set the address to 14, turn the pointer of the X10 switch to 1, and the X1 switch to 4 (10 + 4 = 14). See Figure 24. This IP address is now set to 192.168.100.14.

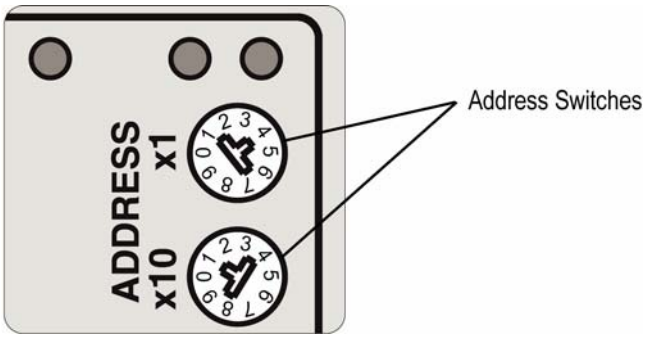


Figure 24 IP Address Switches (Set to 14)

Setting the IP Address and Subnet Mask—PC

Now set the IP address and Subnet mask for your PC. (These instructions are for Windows XP users. If you have another Windows version, the steps may vary. Please consult your Network Administrator.)

1. Open the Control Panel on your PC by clicking on **START**, selecting **Settings**, and clicking on **Control Panel**.
2. Double-click on **Network Connections**. Your screen should look similar to this:

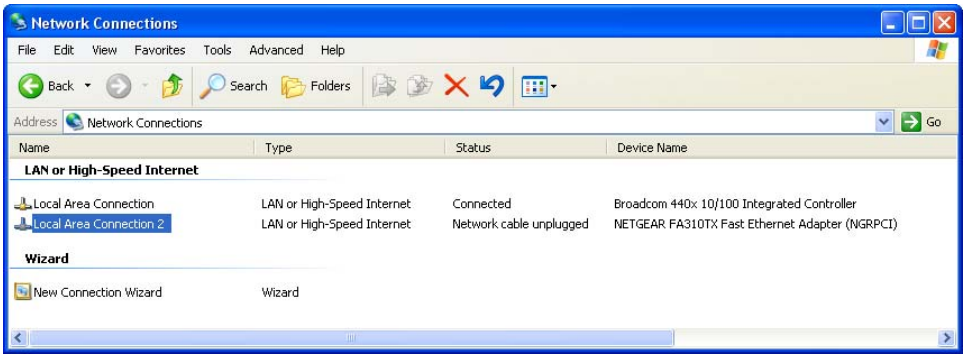


Figure 25 Network Connections Screen

3. Select the LAN or High-Speed Internet connection that you want to use for the Aries Controller network. In the example above, it is **Local Area Connection 2**.
4. Click **File>Properties** to open the Local Area Connection Properties window similar to the one below:

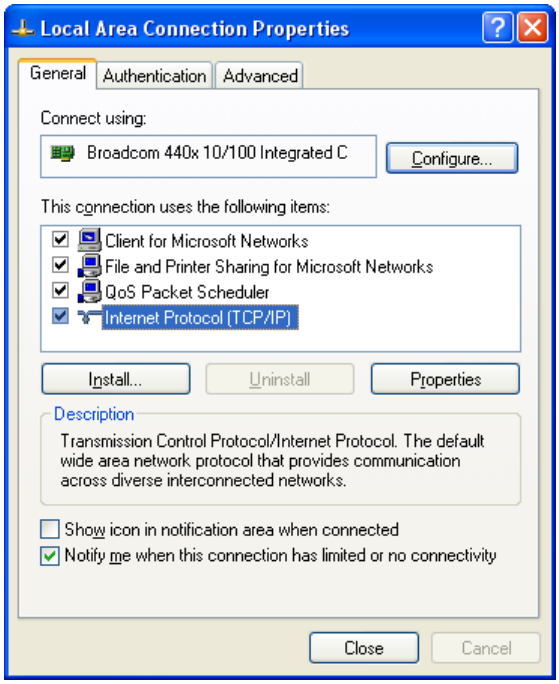


Figure 26 Local Area Connection Properties Screen

5. Select Internet Protocol (TCP/IP) and click on the Properties button. You should get a window similar to this:

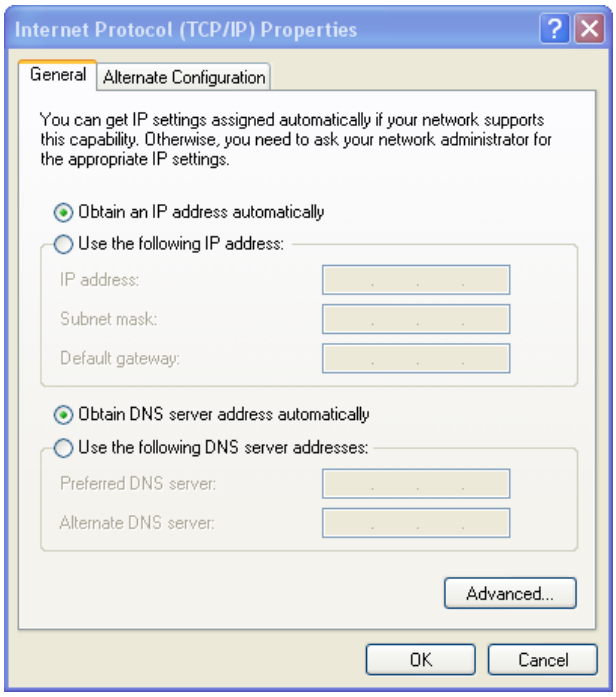


Figure 27 Internet Protocol (TCP/IP) Properties Screen

6. Click on the radio button next to “Use the following IP address:” and type in an IP address with the same first three octets as the default Aries Controller IP address (192.168.100). Set the last octet to a number different from the number you set with the Address Switches on the faceplate of the Aries Controller. (See the section Setting the IP Address—Aries Controller.) Making the last octet different gives the Aries Controller and your PC different IP addresses in the Ethernet network. The valid range is 1 to 254. Using 000 or 255 is not valid.

   In the example in the next step, the IP address is set to 192.168.100.25.

7. Set the Subnet mask value to 255.255.255.0. Your window should look similar to the following:

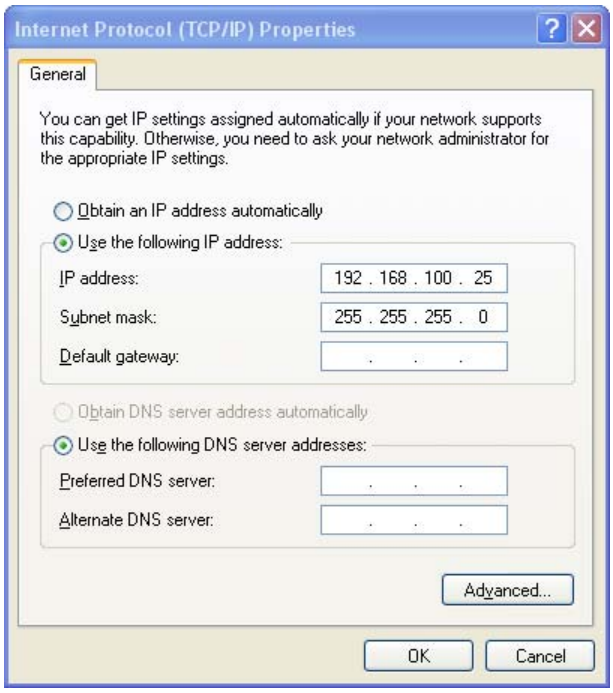


Figure 28 Internet Protocol Properties Screen Completed

8. Click OK twice to close the windows and save your changes.
9. It might be necessary to reboot your PC before you can connect to the Aries Controller.

Important — It is good practice to isolate the Aries Controller and related devices on their own subnet so that their performance is not affected by high-volume network traffic.

Connecting to a PC

After assigning the IP address for the Aries Controller, and the Subnet mask and a different IP address for your PC, connect one end of an Ethernet cable to the PC. Connect the other end to one of the Aries Controller's two RJ-45 socket connectors. See Figure 29. The two RJ-45 sockets can be used interchangeably.

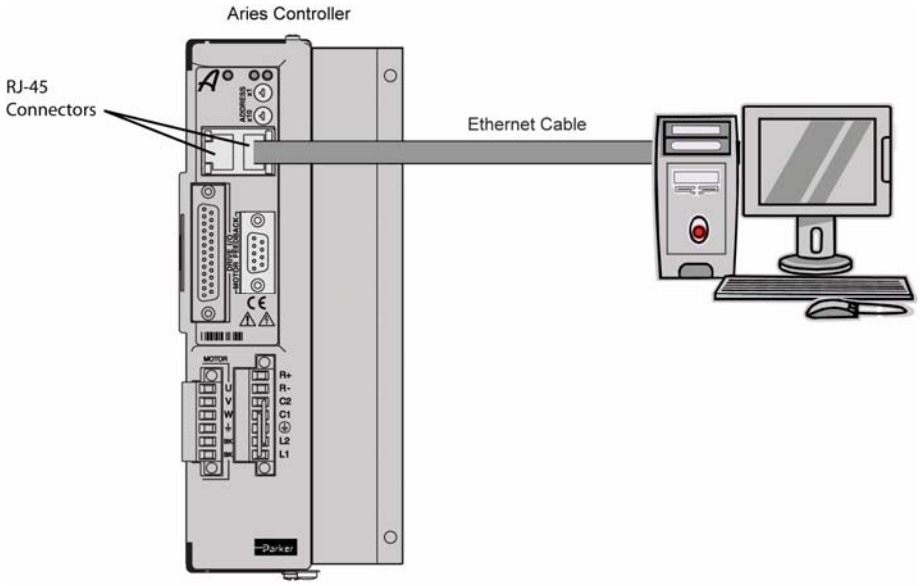


Figure 29 Ethernet Connection

Verifying the IP Address

The following verifies the Ethernet is set up correctly.

1. In ACR-View, under **ARxxCE** and **Communications**, click **Ethernet**. Then enter the IP address in the box to the right.
2. In the dialog box, click **Connect**.
3. In the Terminal Emulator, type VER. If the Ethernet is set up correctly, the terminal emulator reports the firmware version information for the Aries Controller.

See Communications on page 78 for help troubleshooting Ethernet problems.

LED Status Indicators

Ethernet Network Status

The drive has one bi-color LED on the left of the front panel that indicates Ethernet status. It displays green or yellow colors. Figure 30 shows the location of the LED on the unit.

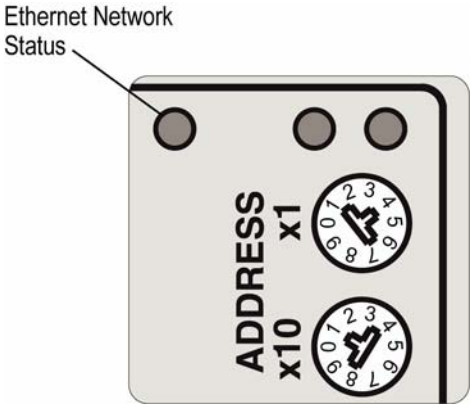


Figure 30 Ethernet Network Status LED

Table 25 describes the states and meanings of the Ethernet Network LED. (For additional information on verifying communication, see Chapter 6 Troubleshooting.)

Ethernet Status LED Illumination States	
LED State	**Description**
Off	Powering up; no connection on port 5002/5006 or 5003
Green	TCP connection on port 5002 or 5006
Red	UDP connection on port 5003
Red/Green (alternating)	UDP and TCP connection active

Table 25 Ethernet Network Status Indicator LED Descriptions

Drive/Controller Status

The Aries Controller has two bi-color Drive/Controller Status LEDs on the right of the front panel that indicate operating status of the controller. The LED on the left displays green or yellow colors. The LED on the right displays green or red colors. Figure 31 shows the location of the LEDs. Table 26 contains their states and meanings.

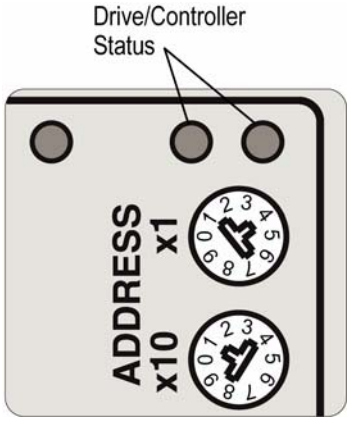


Figure 31 Drive/Controller Status Indicator LEDs

Drive/Controller Status LED Illumination States		
LED Left	**LED Right**	**Description**
Drive/Controller Enabled		
Off	Green	Enabled
Yellow (flashes during Regeneration)	Green	Enabled, Regeneration active
Yellow/Green (alternating)	Green	Enabled, Autorun mode
Drive/Controller Disabled		
Off	Red	Disabled, no faults or Ethernet boot, 8-second process
Yellow	Off	Motor control boot, 4-second process
Yellow	Red	Disabled, no bridge power
Yellow & 1 Green (flashing)	Red	Disabled, Bridge fault
Yellow & 2 Green (flashing)	Red	Disabled, Feedback fault (Hall error or Encoder loss)
Yellow & 3 Green (flashing)	Red	Disabled, Thermal fault
Yellow & 4 Green (flashing)	Red	Disabled, other fault (Undervoltage, Overvoltage, Motor Configuration error, Motor Regeneration fault, or Network Loss fault)
Yellow & 5 Green (flashing)	Red	Disabled, Drive Parameter fault

Table 26 Drive Status Indicator LED Descriptions

CHAPTER FIVE

5 Tuning

IN THIS CHAPTER

- Servo Tuning Overview 61
- Position Variable Overview 62
- Servo Response Overview 63
- Servo System Gains 66
- Servo Tuning—Tutorial 69
- Auto-Tuning 75

Servo Tuning Overview

The Aries Controller uses a *digital control algorithm* to control and maintain position and velocity. The digital control algorithm consists of a set of numerical equations used to periodically (once every servo sampling period) calculate the value of the control output.

The numerical terms of the equations consist of the current commanded and actual position values (including a few from the previous sampling period), and a set of control parameters. Each control parameter, commonly called a *gain*, has a specific function (for more information, see *Servo System Gains* on page 66). In addition, *tuning* is the process of selecting and adjusting gains to achieve optimal servo performance.

When using the control algorithm described above, the whole servo system acts as a closed-loop system (see Figure 32). It is called closed loop because the control algorithm accounts for both the command (position, velocity, tension, etc.) and the feedback data from the encoder. Therefore, it forms a closed loop of information. When all gains are set to zero, the digital control algorithm is disabled.

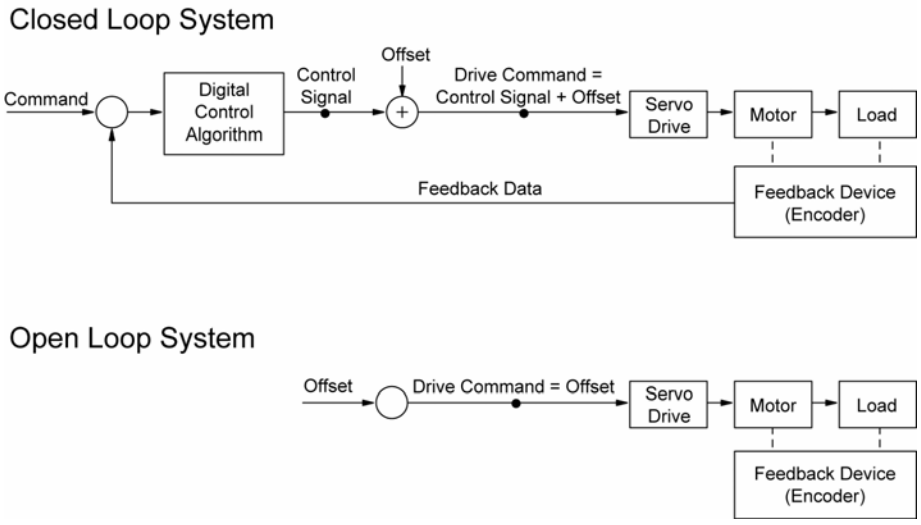


Figure 32 Closed Loop and Open Loop System Comparison

Position Variable Overview

In a servo system, the controller uses two types of position information: commanded position and actual position. As these positions change with time, you can use the position values to determine if the system is positioning as you expect.

Commanded Position

The commanded position is calculated by the motion profile routine from the controller and it is updated every servo sampling period. Therefore, the commanded position is the intended position at any given point of time.

To view the current commanded position, open the numeric status panel in ACR-View, select Axis Parameters, then Current Position. The instantaneous commanded position is shown for all axes.

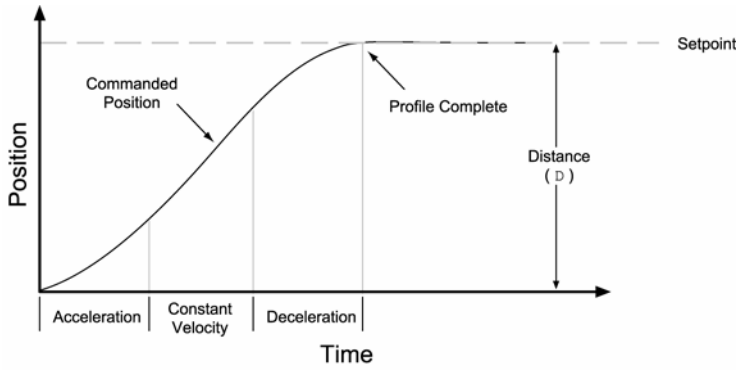


Figure 33 Commanded Position

Actual Position

The actual position of the motor/load is the drive's response to the commanded position, and is measured with the feedback device. The profile resulting from the actual position across time is the *position response* (for more information, see *Servo Response Overview* on page 63).

To view the actual position, open the numeric status panel in ACR-View, select Axis Parameters, then Actual Position. The actual encoder position is shown for all axes

The difference between commanded and actual positions is called a *following error*. To view the following error, open the numeric status panel in ACR-View, select Axis Parameters, then Following Error. The following error is shown for all axes.

If the motor is not moving, the position error is called a *steady-state position error*. If a position error occurs when the motor is moving, it is called a *position tracking error*.

Even when the system is properly tuned, the position error can still be quite significant due to a combination of factors such as the desired profile, the motor's limitation, or the dynamic characteristics of the system. For example, if the commanded velocity is higher than the maximum velocity the motor can physically achieve, the actual position will always lag behind the commanded position. Under these circumstances, a position error will accumulate no matter how high the gains are set.

Servo Response Overview

Stability

The first objective of tuning is to stabilize the system. The formal definition of system stability is when a bounded input is introduced to the system, the output of the system is also bounded. What this means to a motion control system is if the system is stable, and the position setpoint is a finite value, the final actual position of the system is also a finite value.

In contrast, if the system is unstable, no matter how small the position setpoint or how little a disturbance the system receives (such as motor torque variation, load change, or noise from the feedback device), the position error will increase exponentially in almost all cases. In practice, when the system experiences instability, the actual position will oscillate in an exponentially diverging fashion as shown in Table 27.

One common misperception is that whenever there is oscillation, the system is unstable. It is important to recognize that a system is considered stable if the oscillation finally diminishes (damps out), even if it takes a long time.

Position Response Types

Table 27 identifies the six basic types of position responses. The primary difference among these responses is due to *damping*—the suppression (or cancellation) of oscillation.

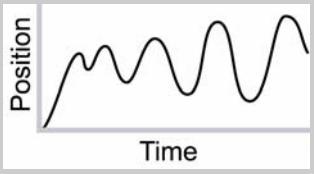
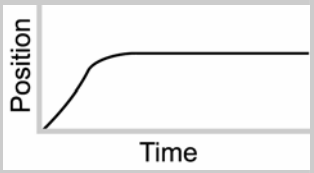
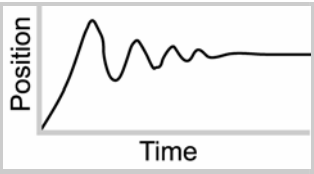
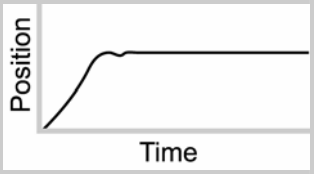
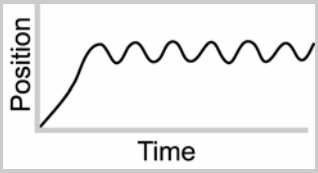
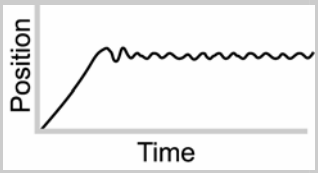
Response	Description	Profile (position/time)
Unstable	Instability causes the position to oscillate in an exponentially diverging fashion.	
Over-damped	A highly damped, or over-damped, system gives a smooth but slower response.	
Under-damped	A slightly damped, or under-damped, system gives a slightly oscillatory response.	
Critically damped	A critically-damped response is the most desirable because it optimizes the trade-off between damping and speed of response.	
Oscillatory	An oscillatory response is characterized by a sustained position oscillation of equal amplitude.	
Chattering	Chattering is a high-frequency, low-amplitude oscillation that is usually audible.	

Table 27 Position Response Types

Performance Measurements

If you plot of the position response versus time, you can make a few measurements to quantitatively assess the performance of the servo. These three measurements are made before or shortly after the motor stops moving:

- **Overshoot**—The measurement of the maximum magnitude that the actual position exceeds the position setpoint. It is usually measured in terms of the percentage of the setpoint value.
- **Rise Time**—The time it takes the actual position to pass the setpoint.
- **Settling Time**—The time between when the commanded position reaches the setpoint and the actual position settles within a certain percentage of the position setpoint. (Note the settling time definition here is different from that of a control engineering text book, but the goal of the performance measurement is still intact.)

Servo System Gains

Proportional Feedback Control (PGAIN)

Proportional feedback is the most important feedback for stabilizing a servo system. When the controller uses proportional feedback, the control signal is linearly proportional to the position error (the difference between the commanded position and the actual position—"following error"). The proportional gain is set by the **PGAIN** command. Proportional feedback can be used to make the servo system more responsive (stiff), as well as reduce the steady state position error.

Because the control is proportional to the position error, whenever there is any disturbance (such as torque ripple or a spring load) forcing the load away from its commanded position, the proportional control can immediately output a signal to move it back toward the commanded position. This function is called *disturbance rejection.*

If you tune your system using only the proportional feedback, increasing the proportional feedback gain (**PGAIN** value) too much will cause the system response to be oscillatory, under-damped, or in some cases, unstable.

Note: Do not set the proportional feedback gain (**PGAIN**) to zero, except when open-loop operation is desired.

Derivative Feedback Control (DGAIN)

Using *derivative feedback control*, the control signal is proportional to the rate of change of the position error. The derivative feedback gain (**DGAIN**) command sets the gain, which is in turn multiplied by the feedback device's rate of change of position error to produce the control signal derivative rate of change of position error. Such control tends to increase damping and improve the stability of the system.

A high **DGAIN** can also increase the position tracking error when traveling at constant velocity. In addition, setting the derivative feedback gain too high tends to slow down (over-damp) the response to a commanded position change.

Integral Feedback Control (IGAIN)

Using *integral feedback control*, the value of the control signal is integrated at a rate proportional to the feedback device position error. The rate of integration is set by the **IGAIN** command.

The primary function of the integral control is to overcome friction and/or gravity and to reject disturbances so that steady state position error is minimized or eliminated. This control action is important for achieving high system accuracy. However, if you can achieve acceptable position accuracy by using only the proportional feedback (**PGAIN**), then there is no need to use the integral feedback control.

Controlling Integral Windup

If you are using integral control (**IGAIN**) and there is an appreciable position error that persists long enough during the transient period (time taken to reach the setpoint), the control signal generated by the integral action can end up too high; this saturates to the maximum level of the controller's analog control signal output. This phenomenon is called *integrator windup* (see Figure 34.)

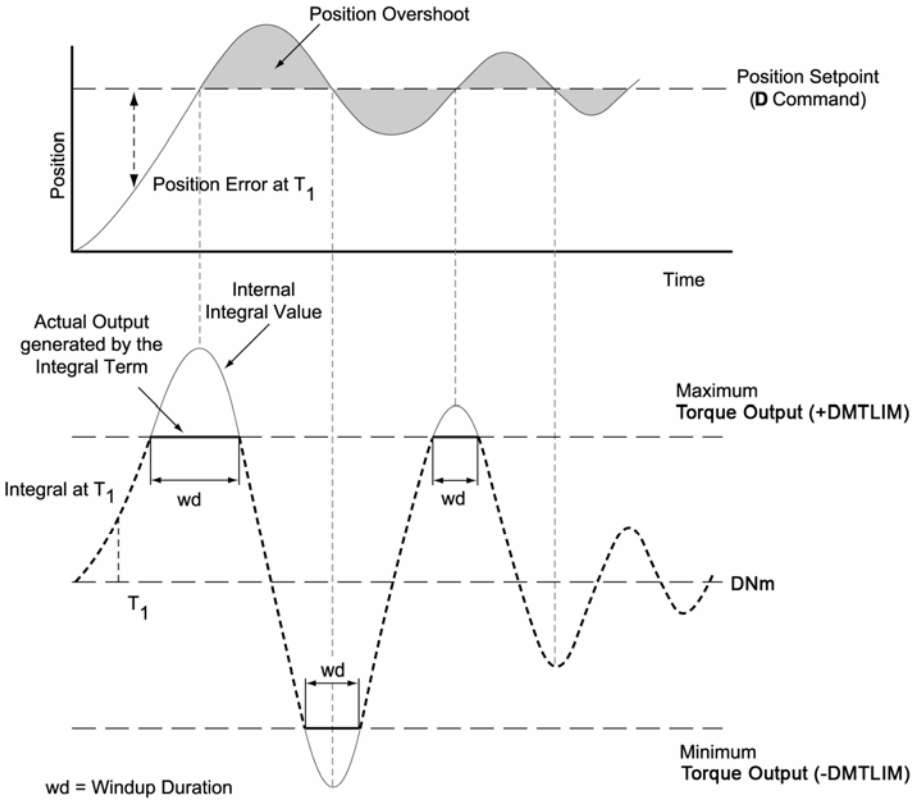


*Figure 34 Integrator Windup (Without Using **ILIMIT**)*

After windup occurs, it takes time before the integrator output returns to a level within the limit of the controller's output. Such a delay causes excessive position overshoot and oscillation.

The integral windup limit (**ILIMIT**) command allows you to set the absolute limit of the integral. The commanded limit, in essence, turns off the integral action as soon as it reaches the limit; consequently, position overshoot and oscillation can be reduced (see Figure 35.)

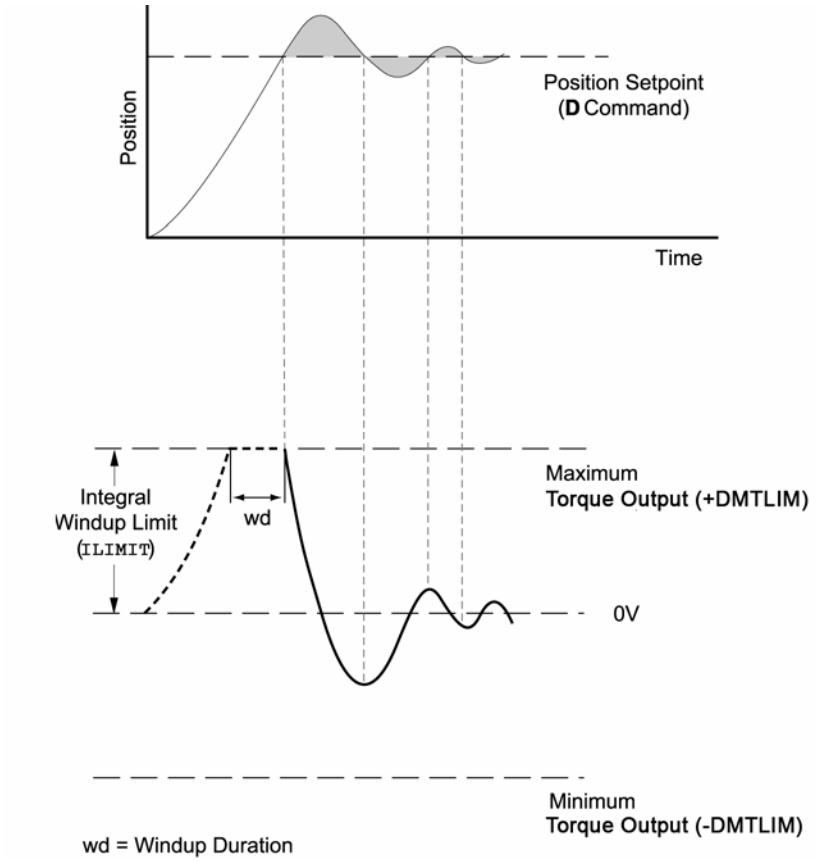


*Figure 35 Integrator Windup (Using the **ILIMIT**)*

Servo Tuning—Tutorial

The tuning process lets you hone the servo response and settling for your particular system.

Settling and responsiveness are the main components that determine performance. Generally, the goal of servo tuning is good settling, with a secondary goal of good responsiveness. Ultimately, only you can determine which aspect is of prime importance, and when the tuning is acceptable for your application.

Warning — When tuning a servo motor, remove all loads from the motor to prevent personal injury or mechanical destruction. Once tuning provides a stable and responsive servo motor, you can attach the load and start the tuning process again.

Note: Because the differences between systems are wide, the following are provided only as guidelines.

Proportional and derivative gains work against each other—an increase to one gain affects the other. With this in mind, treat tuning as an iterative process; alternate between adjusting proportional and derivative gains.

- **PGAIN:** Adjusts servo response. You can always try to increase responsiveness, though mechanics ultimately limit response time.
- **DGAIN:** Adjusts settling time. The goal is always good settling.
- **IGAIN:** Adjusts steady-state errors (not discussed in this tutorial). Adding integral gain also increases responsiveness, though the increase might not be noticeable.

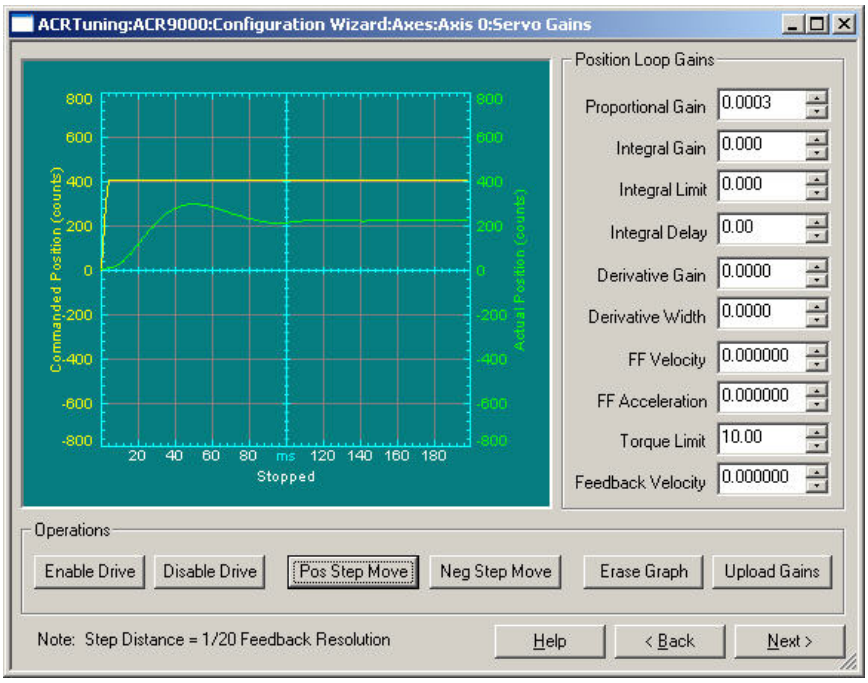
Tuning Example

The tuning example assumes the following:

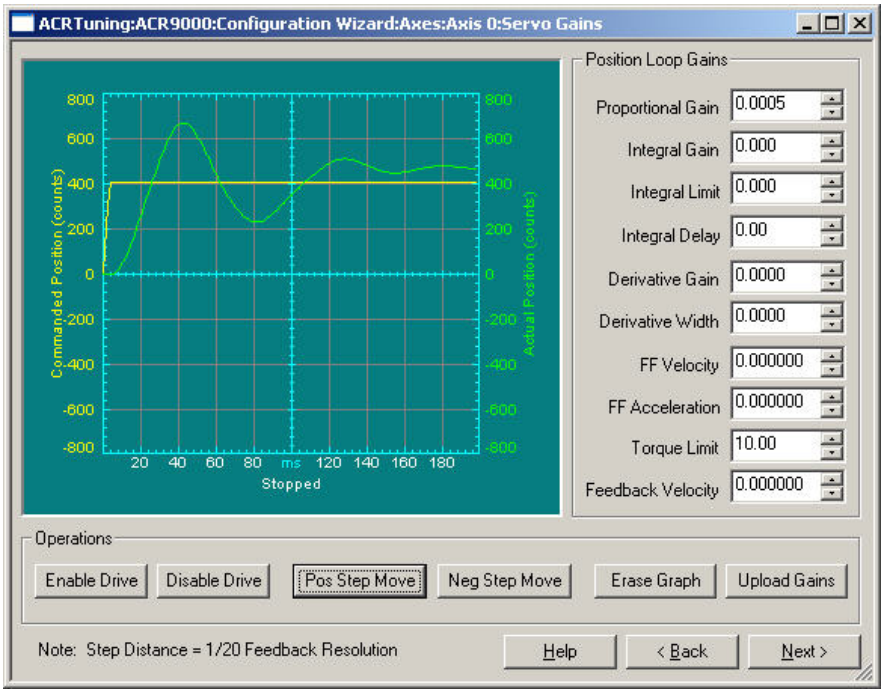
- Parker BE 231 motor.
- 9 to 1 load-to-rotor inertia ratio.

Illustration Legend	
Color	**Position**
Green	Commanded
Yellow	Actual

1. As a starting point, the **PGAIN** is set to 0.0003; no **DGAIN** is set at this time. The following figure shows that the motor is under responsive.

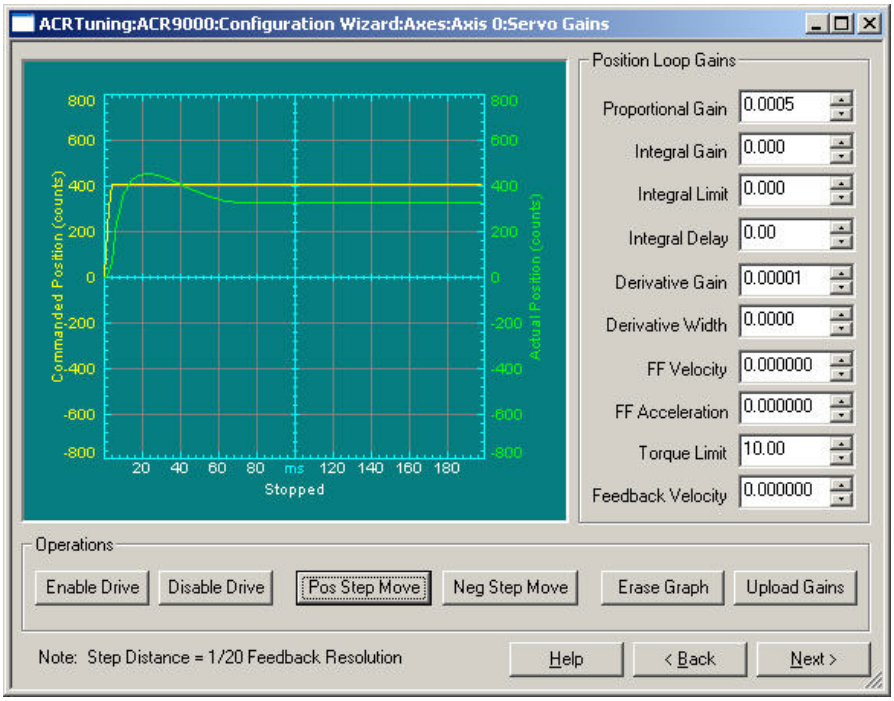


2. The **PGAIN** is increased to 0.0005 to increase the response. As the next figure illustrates, the motor response increased significantly, the motor is under-damped. Before continuing with adjusting the motor response, it is important to compensate for the under-damping by adding **DGAIN**.

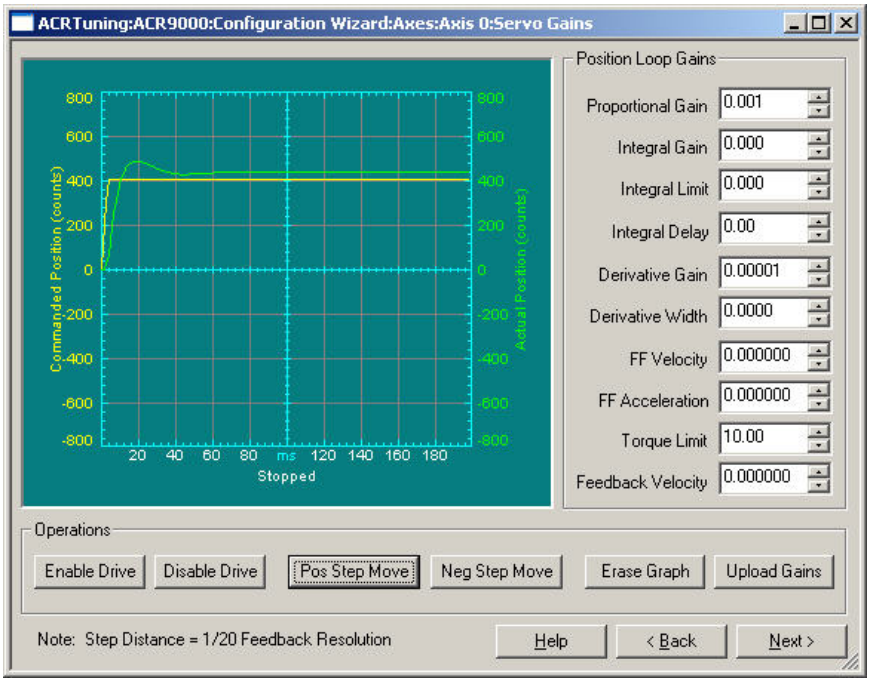


3. Setting the **DGAIN** to 0.00001 slightly over-damps the response, as shown in the following figure. Now you can return to adjusting the motor response by increasing the **PGAIN**.

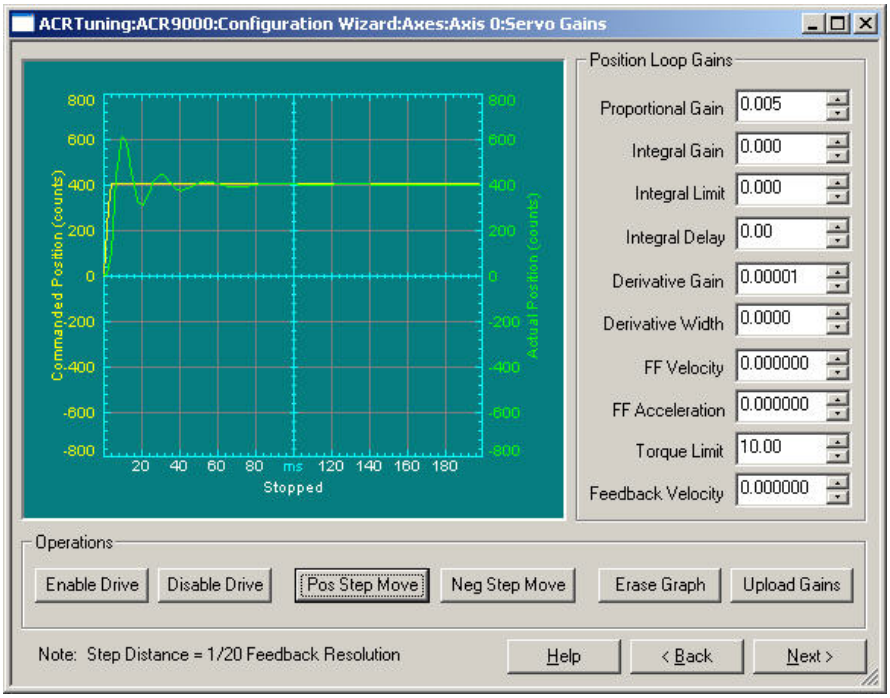
   If you were to increase the proportional gain without adjusting the derivative gain, the oscillations would increase and possibly create motor instability.



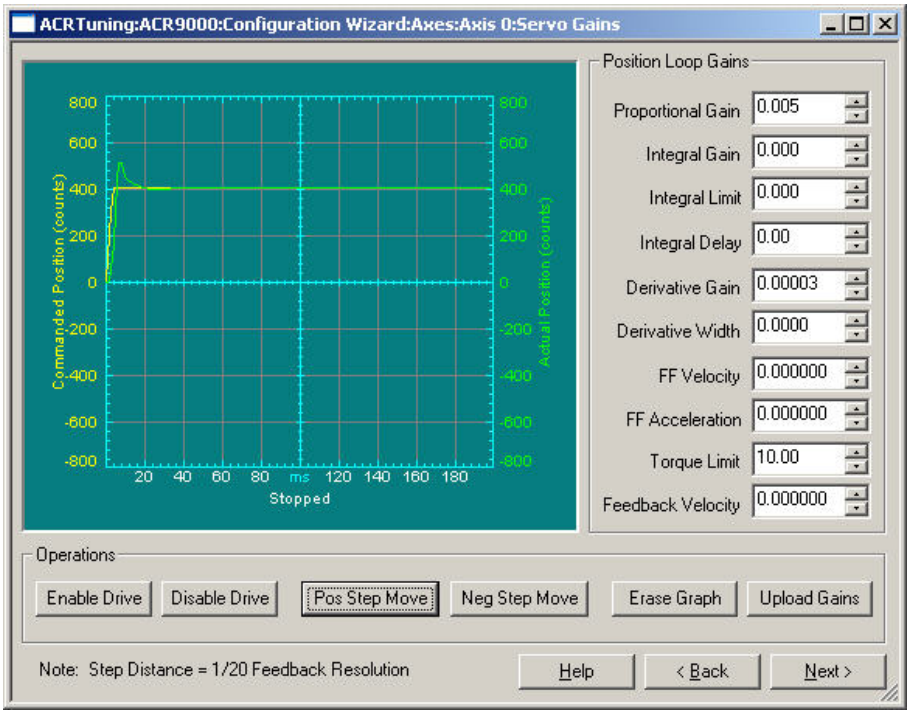
4. With **PGAIN** increased to 0.001, motor responsiveness has increased and the over-damping has decreased slightly. As there is no significant change to the settling, there is no need to adjust the **DGAIN**. However, there is still room for improvement on motor response.



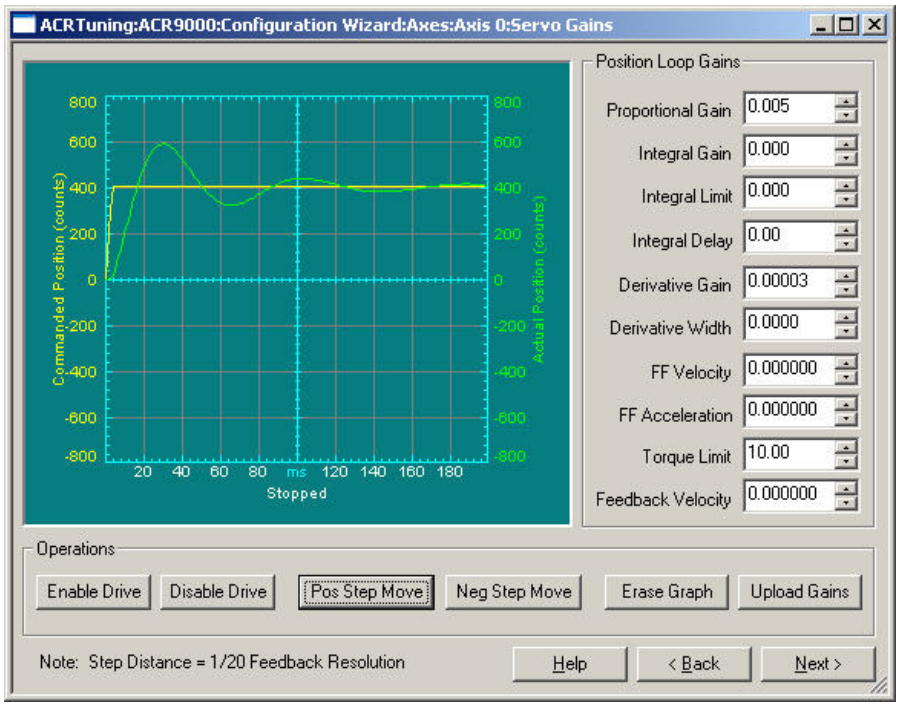
5. The **PGAIN** is increased to 0.005, resulting again in increased responsiveness, as seen in the following figure. But with increased oscillations, due to under-damping, **DGAIN** needs to be adjusted again.



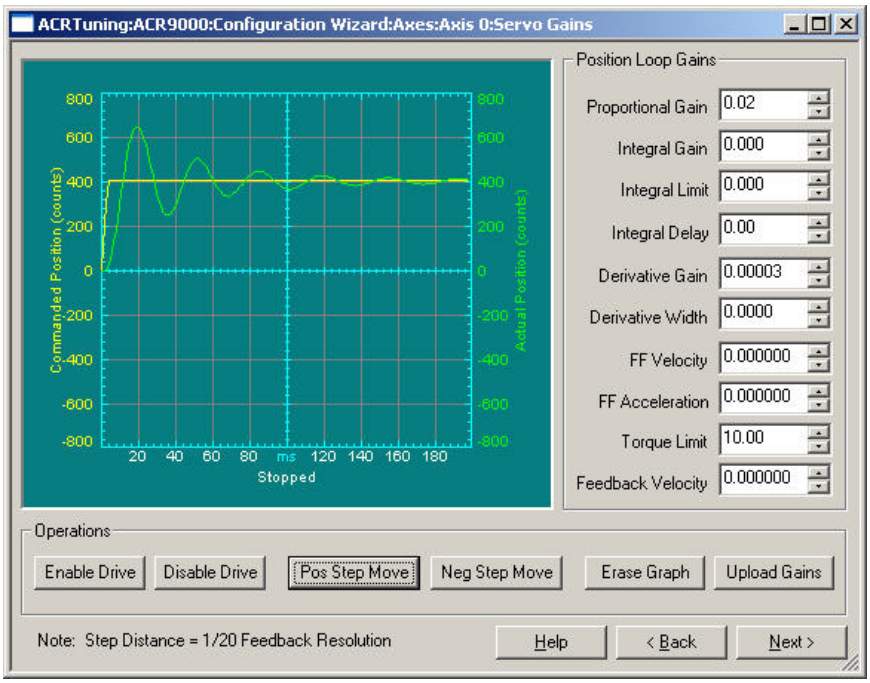
6. Increasing the **DGAIN** to 0.00003 damps the oscillation. As the next figure illustrates, both motor response and damping look good. You are ready to add a load to the motor.



7. With a loaded motor, the response has slowed and the damping is weaker. Like before, you can increase the **PGAIN** for a better response.

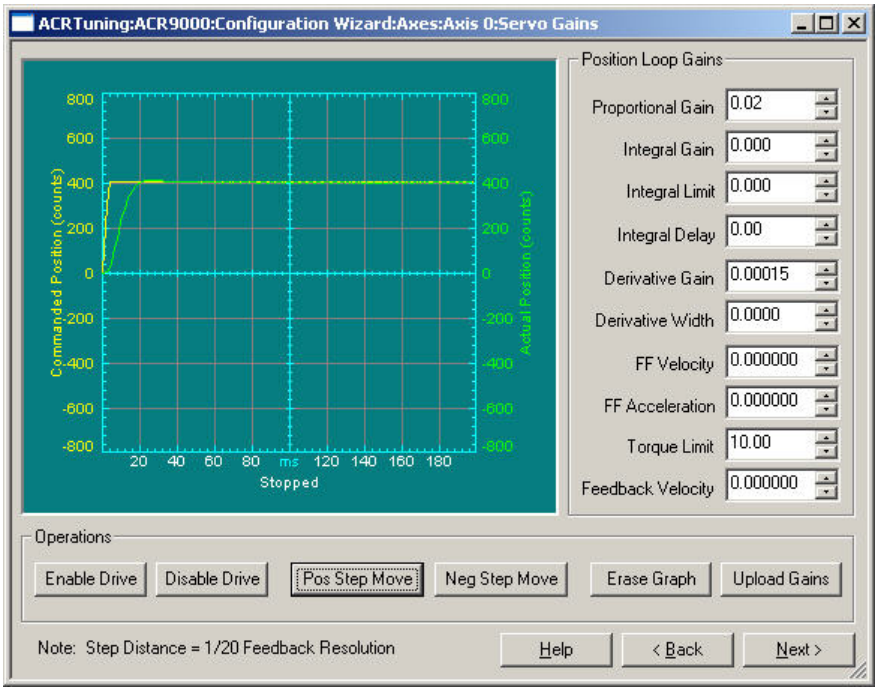


8. The **PGAIN** is increased to 0.02, and you can see better response from the motor. But there is still some oscillation from the motor, so increase the damping.



9. With **DGAIN** increased to 0.00015, the chattering is significantly reduced—both motor response and damping look good.

   With a load attached, the motor is now fast and stable; no more tuning is necessary.



Warning — When tuning a servo motor, remove all loads from the motor to prevent personal injury or mechanical destruction. Once tuning provides a stable and responsive servo motor, you can attach the load and start the tuning process again.

Auto-Tuning

The Aries Controller can automatically determine the inertia of the load attached to the motor. This is performed by applying a specified torque to the motor and measuring the acceleration and deceleration of the motor. From this, the drive/controller can calculate the load inertia and multiply the position loop gains to allow for the change in inertia. The calculated inertia can be observed using the **LJRAT** parameter.

Note: Excess friction can affect the measured inertia, thereby estimating the value higher than the actual inertia. While the drive/controller can compensate for some friction, it may not compensate for all. If the estimated load inertia seems overly high, this may be the cause.

The Auto-Tune process should only last a few seconds, during which time the motor will rotate about one-quarter of a turn in each direction. Use the following method to start Auto-Tune mode:

1. In ACR-View, select the Servo Tuner window and select an axis.
2. Click on Auto Inertia Detection. The motor will move and the new gains will be shown in the Position Loop Gains box.

CHAPTER SIX

6 Troubleshooting

IN THIS CHAPTER

- General Troubleshooting Guidelines 77
- Power 77
- Power-Up Sequence 78
- Communications 78
- Motor Control 82
- Fault Correction 83

General Troubleshooting Guidelines

The Aries Controller design features easy connectivity, auto-detect functions, and reliability. In addition, LEDs on the front panel of the unit provide quick identification of AC power, drive, and Ethernet status. If, after following the installation guidelines in Chapter 2, 3, and 4, your drive/controller does not function properly, use the guidelines and procedures in this chapter to troubleshoot. These guidelines also apply to troubleshooting a malfunction during normal operation of the drive.

A problem with the drive typically can be traced to one of four areas: power, power-up sequence, communications, and motor control. If your system is not functioning properly, follow the steps indicated for each of these areas.

Power

Check the status LEDs (Figure 36).

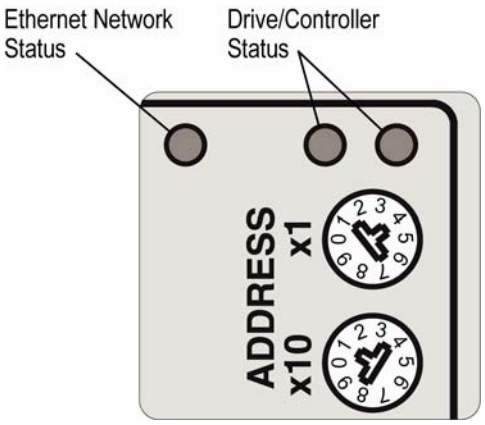


Figure 36 Ethernet Network and Drive/Controller Status LEDs

If neither the Ethernet Network Status LED nor the Drive/Controller Status LEDs are illuminated, do the following:

1. Look for problems with AC power. Check the AC power source(s). Also check Input Power / Mains connections (L1, L2, and ⏚ earth ground terminals for Motor Input Power, and C1, C2, and ⏚ earth ground terminals for Control Input Power).
2. If the AC wiring is correct but no LEDs illuminate, remove all connections to the unit (Ethernet cables, Drive I/O, Motor Feedback, Motor Input Power, and Output Power), leaving the Control Input Power C1, C2, and ⏚ earth ground terminals connected. Apply power to the drive. If any LEDs illuminate, there is a short in one of the disconnected cables.

Power-Up Sequence

Observing the power-up sequence may help identify defective hardware or software issues. Any deviation from the following power-up sequence may indicate the need for additional technical resources. Please see “Technical Assistance” on page 2 for contact information.

1. Cycle power to the unit and observe the right and left Status Indicator LEDs and the Ethernet Status LED. (See Figure 36 for LED locations.)
2. When power is first applied, the right Status Indicator LED turns RED. This is the default hardware state and simply indicates that power is applied.
3. After approximately 8 seconds, the right Status Indicator LED turns off and the left Status Indicator LED changes from off to yellow. This indicates the Ethernet processor has booted and is now in the process of booting the motor control processor.
4. After approximately 4 more seconds, the right Status Indicator LED changes from off to RED again, indicating that the motor control processor has completed the boot process.
5. The left Status Indicator LED changes states depending on conditions described in the section *Motor Control* on page 82.
6. The Ethernet Status LED changes states depending on the status of the Ethernet network as described in the section *Communications* on page 78.

Communications

All drive/controller communications are based on Ethernet. The Aries Controller may be connected directly to any appropriately configured Ethernet port. The drive IP address will be 192.168.100.xx, where xx is defined by the address selection switches on the unit’s front panel.

RJ-45 Ethernet Status LEDs

The first step in troubleshooting communications is to observe the state of the RJ-45 Ethernet Status LEDs. (Figure 37 shows their location on the drive’s dual-stack RJ-45 socket.) These LEDs indicate any Ethernet connection, as described in Table 28. Note that for a standard 100Mbps connection, both the yellow and green LED should be illuminated. For a 10Mbps Ethernet connection, the Yellow LED should be illuminated and the Green LED off.

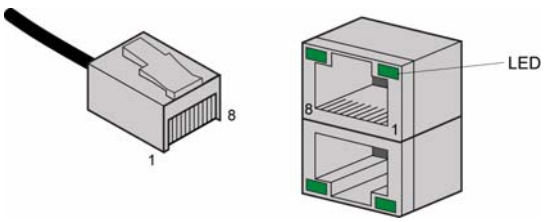


Figure 37 RJ-45 Ethernet Status LEDs

LED	Steady	Flash	Description
Ethernet Link/Activity	Off	—	No Ethernet link detected
	Yellow	—	Ethernet link established, no activity
	—	Yellow	Ethernet link established and active
Ethernet Speed	Off	—	Ethernet 10Mbps
	Green	—	Ethernet 100Mbps

Table 28 Ethernet Status LED Descriptions

If neither RJ-45 Ethernet Status LED is illuminated, the physical Ethernet connection is faulty.

1. Verify that you are using the correct type of cable. See *Ethernet Cable Specification* on page 51.
2. Verify that the cable pin out matches the drive's connector pin out. See *Ethernet Connector* on page 51.
3. Try swapping cables with Ethernet cables you know to be good. Even cables that do not meet the Ethernet cable specification should cause the LEDs to illuminate.
4. If the LEDs still do not illuminate, look for Ethernet hardware problems.

Ethernet Network Status LED

If the Ethernet Network Status LED is off, there is no valid Ethernet communication.

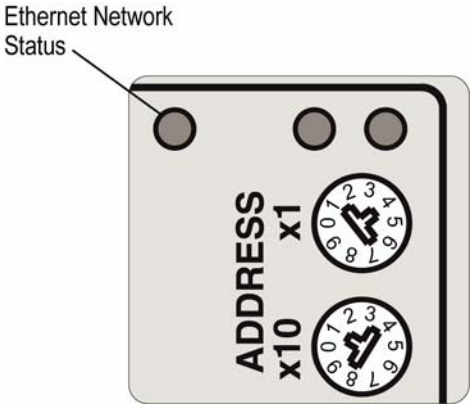
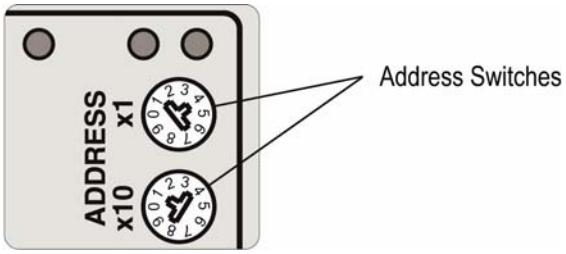


Figure 38 Ethernet Network Status LED

Ethernet Status LED Illumination States	
LED State	**Description**
Off	Powering up; no connection on port 5002/5006 or 5003
Green	TCP connection on port 5002 or 5006
Red	UDP connection on port 5003
Red/Green (alternating)	UDP and TCP connection active

Table 29 Ethernet Status Indicator LED Descriptions

1. Verify that no two drive/controllers on the network have the same IP address. The IP address is determined by the Address Switch settings on the front panel of the unit.



2. Using a standard Ethernet connection, test the IP assignment. At a DOS or command prompt, type “ping 192.168.100.xx”, where xx is the setting of the Aries Controller address switches on the front panel.
    a. If you receive a “reply from” message, do the following: disconnect the Ethernet cable and type the ping command again.
        1. If you see “reply from” message, then another device or computer has already been assigned the same IP address. Change the IP address of the Aries Controller to one that is unique in the network.
        2. If you see a “timeout” message, then the unit is properly configured and is network accessible. Re-attach the Ethernet cable.
    b. If a “timeout” message is seen, the Aries Controller has an invalid IP address. Determine the correct setting and assign it to the unit.

ACR-View

The ACR-View software is a user-friendly interface for verifying status of and commanding the Aries Controller. Use ACR-View to perform additional troubleshooting of your network and drive/controller.

Once you have established an Ethernet connection as indicated by the Ethernet Network Status LED, launch ACR-View on the computer system connected to your drive/controller.

1. Open the Configuration Wizard. Select Axes, then select the desired axis (drive).
2. Set the drive motor combination used, then check the box next to “I want to edit the mechanical/electrical parameters for my motor (Advanced).”
3. Click Next and verify that the motor parameters are correct.
4. Continue through the configuration wizard and verify that all the parameters for the axis are correct.

Terminal Emulator (Hyper Terminal)

A terminal emulator such as Hyper Terminal will allow basic access to the Aries Controller’s native commands. This may be connected directly to the drive/controller via a standard Ethernet port, using TCP/IP and the IP address of the Aries Controller. The unit’s IP address is 192.168.100.xx, where xx is the front panel Address Switch settings.

Set the communication port in Hyper Terminal to `5002`, and click **OK**.

At this point the terminal emulator should be communicating directly with the Aries Controller, and all native drive commands should function. The Ethernet communications LED should light up green. For example, the following command should elicit a response:

`?TDTEMP`	(drive temperature query)
`26.000`	(drive/controller will respond with the temperature)

Motor Control

The first step in troubleshooting motor-control issues is to examine the Drive/Controller Status LEDs (Figure 39). Use Table 30 to determine the indicated condition. Use the additional information in this section to take corrective action.

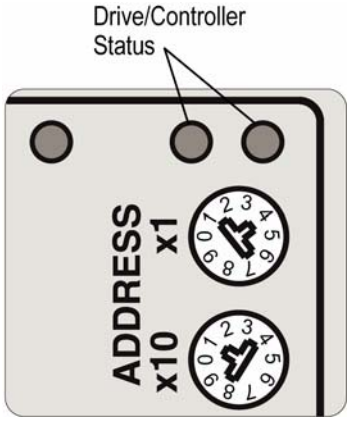


Figure 39 Drive/Controller Status LEDs

Drive/Controller Status LED Illumination States		
LED Left	**LED Right**	**Description**
Drive/Controller Enabled		
Off	Green	Enabled
Yellow (flashes during Regeneration)	Green	Enabled, Regeneration active
Yellow/Green (alternating)	Green	Enabled, Autorun mode
Drive/Controller Disabled		
Off	Red	Disabled, no faults or Ethernet boot, 8-second process
Yellow	Off	Motor control boot, 4-second process
Yellow	Red	Disabled, no bridge power
Yellow & 1 Green (flashing)	Red	Disabled, Bridge fault
Yellow & 2 Green (flashing)	Red	Disabled, Feedback fault (Hall error or Encoder loss)
Yellow & 3 Green (flashing)	Red	Disabled, Thermal fault
Yellow & 4 Green (flashing)	Red	Disabled, other fault (Undervoltage, Overvoltage, Motor Configuration error, Motor Regeneration fault, or Network Loss fault)
Yellow & 5 Green (flashing)	Red	Disabled, Drive Parameter fault

Table 30 Drive Status Indicator LED Descriptions

Fault Correction

To access further information on the drive status and fault conditions, use ACR-View on the computer system connected to your Ethernet network.

1. Open a terminal connection to the drive using one of the methods described under *Terminal Emulator (Hyper Terminal)* on page 81.
2. Enter the **DRCONFIG** command to see a list of drive configuration editors.
3. Enter the **DRERROR** command to see a list of drive error messages.

Pay particular attention to faults that need to be fixed. Refer to Table 31 for corrective action suggestions.

Error Codes

Table 31 below contains a list of error messages and a brief description of corrective action.

Error	Resolution
E0 Motor Configuration Warning	The motor rating is too high for the drive/controller, and the drive/controller is using its own limits for safety reasons.
E1 Motor Configuration Error	One of the motor parameters is set to zero (0). Look at the additional errors to find which parameters are set at zero (0). Refer to your motor specifications for the correct value.
E3 Max Inductance = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C4 Motor Inductance)
E4 Rated Speed = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C8 Motor Rated Speed)
E5 C9 = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C9 Number of Motor Pole Pairs)
E6 Resistance = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C7 Motor Winding Resistance)
E7 Ke = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C15 Motor Ke)
E8 Continuous Current = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C1 Continuous Current)
E9 Peak Current = 0	This parameter is set to zero (0). To correct the error, you must set a non-zero value. Refer to your motor specifications for the correct value. (C3 Peak Current)
E10 Used Drive Continuous Current Warning	The continuous current of the motor is higher than the continuous current rating of the drive/controller. Use the continuous current rating for the drive/controller.
E11 Torque Rating > Peak Power Rating Warning	The motor's torque rating is too high for the power level of the drive/controller. Use the drive/controller's torque rating.
E12 Used Drive Peak Current Warning	The peak current of the motor is higher than the peak current rating of the drive/controller. Use the drive/controller's value for peak current.
E13 Inertia = 0	This parameter is set to zero (0). The drive/controller will not enable Velocity or Position Modes. To correct the error, you must set to a non-zero value. Refer to your motor specifications for the correct value. (C11 Motor Rotor Inertia / Forcer Mass)
E14 Damping = 0	This parameter is set to zero (0). The drive/controller will not enable Velocity or Position Modes. To correct the error, you must set to a non-zero value. Refer to your motor specifications for the correct value. (C10 Motor Damping)
E26 Drive Faulted	The drive/controller is faulted.
E27 Bridge Hardware Fault	Excessive current or short on the H-bridge.
E28 Bridge Temperature Fault	Excessive current being commanded: 1. If the application is operating in the peak range, limiting the peak current setting with DMTLIM can limit the current commanded and lower the bridge temperature. Default DMTLIM is 3 x continuous current, perhaps lowering it to 2.5 x continuous current or 2 x continuous current can help. This, however, will limit the motor's available torque, which may increase position error and possibly cause a position error fault. 2. Issue a DIFOLD 1 command. This command enables the "current foldback" feature in the drive. However, a drive in "foldback" mode can limit the motor's available torque, which may increase position error

Error	Resolution
	and possibly cause a position error fault. 3. Use a larger Aries amplifier, which would be capable of higher current outputs.
E29 Drive Over-Voltage	The bus voltage is too high (>410 VDC). Lower AC Mains voltage (Motor Input Power) and check for excessive regeneration power. (**S22** Transfer Bus Voltage)
E30 Drive Under-Voltage	The bus voltage is too low (<85 VDC) or there is overly aggressive acceleration or deceleration. Raise AC Mains voltage (Motor Input Power). (**S22** Transfer Bus Voltage)
E31 Bridge Foldback	Drive/controller current was limited to prevent overheating (warning only).
E32 Power Regeneration Fault	Check the Regeneration resistor for a short.
E34 Drive Temperature Fault	Wait for the drive/controller to cool down.
E35 Motor Thermal Model Fault	The motor thermal model has determined the motor is too hot. Wait for the motor to cool, and then re-enable the drive/controller. (**S21** Transfer Mode Temperature)
E36 Motor Temperature Fault	Motor thermal switch has tripped. Wait for the motor to cool, then re-enable the drive/controller. (**S21** Transfer Mode Temperature)
E37 Bad Hall State	A problem with the Hall sensors exists. Check the Hall state wiring. (**S27** Transfer Hall State)
E38 Feedback Failure	Feedback not present or the signal level is incorrect. (**S16** Transfer Position of Encoder; **S27** Transfer Hall State)
E39 Drive Disabled	The drive/controller is disabled.
E40 PWM Not Active	The H-bridge is not switching.
E41 Power Regeneration Warning	The drive/controller regenerated (warning only).
E42 Shaft Power Limited Warning	Shaft power is limited to the rated output to protect the drive/controller (warning only).
E43 Excessive Speed at Enable	The motor was turning too fast when the drive/controller was enabled.
E47 Low Voltage Enable	No motor power was present when the drive/controller was enabled.
E48 Control Power Active	The drive/controller is in Control power mode. No motor power is present.
E49 Alignment Error	The ALIGN command did not complete successfully. (**S16** Transfer Position of Encoder; **S27** Transfer Hall State)
E52 Encoder Read Fault	The drive/controller determined there was loss of feedback. Check the feedback wiring. (**S16** Transfer Position of Encoder; **S27** Transfer Hall State)
E54 Encoder Loss Fault	The Aries Controller could no longer detect the encoder. Check the encoder connections. Check/modify the value of **C137** or set to zero (0) to disable this error.
E56 Factory Programming Error	Factory parameters have been corrupted. Contact the factory for repair.

Table 31 Error Messages

Drive Configuration

Some fault conditions or incorrect motor operation may require changes to the drive/controller configuration. Change the configuration of the Aries Controller using ACR-View.

1. Open a terminal connection to the Aries Controller using one of the methods described under *Terminal Emulator (Hyper Terminal)* on page 81.

2. Enter the **DRCONFIG** command to see a list of drive configuration errors.
3. Enter the **DRERROR** command to see a list of drive error messages.

Important! — Further troubleshooting steps can change the drive/controller configuration. Upload the current configuration file and save it as a backup before proceeding.

Smart Encoders

This troubleshooting procedure assumes a terminal emulator connection is established with the Aries Controller.

If the drive/controller does not initialize correctly when connected to a Smart Encoder (Parker motors only), check the following:

1. Verify the motor phases are wired correctly. Incorrectly wired motor phases can produce any combination of the following symptoms in the motor; runs backwards, produces low torque, or gets warm.
2. Check that the feedback cables are wired correctly.
3. Apply power to the drive/controller.
    a. Send the **SFB** command. It should report 4. If the response is not **<*>4**, then check the feedback cable (if using a non-Parker cable, check that it is correctly wired). If the cable is correctly wired and connected, the problem might be the encoder.
    b. Send the **THALL** command. It should report a number in the range of 1–6, which indicates the phase wires are connected correctly. If the response is **Ø** or **7**, a fault exists, check the motor phase wiring.
    c. Send the **TPE** command and turn the motor shaft. Verify the encoder is counting in the correct direction. Turning the shaft clockwise results in positive encoder counts when Bit 8455 is set to zero (Ø). If not, check the encoder feedback wires and reset the drive.

Hall Sensors

The troubleshooting procedures in this section assume that a terminal emulator connection is established with the Aries Controller. The procedures assist you in resolving a Hall fault (**ERROR** bit **E37-Bad Hall State**). Several problems can cause a Hall fault; the following checklist will help identify these problems.

Troubleshooting Checklist

1. Does **?THALL** report either 0 or 7?
   If yes, see Problem 1 or Problem 2, below.
2. Does **?THALL** change if you move the motor by hand?
   If no, see Problem 2, below.

3. Does **?THALL** have six distinct Hall states from 1 to 6? (No numerical order is necessary.)
   If no, see Problem 2, below.
4. Does **?THALL** report the six distinct Hall states *n* times as the rotor turns one revolution, where *n* is equal to the number of pole-pairs (**DPOLE**)? (Linear motors: *n* = pitch)
   If no, see Problem 2 or Problem 3, below.
5. Does **?THALL** report the Hall state sequence [1, 5, 4, 6, 2, 3, 1...] as the motor turns clockwise? (Clockwise means **?TPE** is increasing when Bit 8455 set to zero (Ø); it is also the direction the motor turns in **?DMODE1**.)
   If no, see Problem 4, below.
6. Does **DRERROR** report a Hall fault each time the drive is enabled (**DRIVEON AXIS0**), even though the Hall state sequence is correct?
   If yes, see Problem 4, below.
7. Does the Hall fault occur irregularly?
   If yes, see Problem 6, below.

Possible Problems

Problem 1

No Hall states are seen by the drive/controller.

Problem 2

The cable is not connected, or is connected incorrectly (incorrectly wired).

Problem 3

DPOLE or **DMEPIT** is not set correctly.

Problem 4

Either the motor wires or the Hall wires are connected incorrectly.

- Use *Procedure 1—Motor Wires* to fix this problem by changing the motor wires.
- Use *Procedure 2—Hall Wires* to fix this problem by changing the Hall wires.

Problem 5

The Hall wires or the encoder wires may have loose connections, causing intermittent faults.

Problem 6

Noise induced on the Hall signals from routing the motor feedback cable next to high-voltage cables (for example, strapped to motor input power cables).

Procedures

Procedure 1—Motor Wires

Use this procedure to connect your motor wires to the Aries Controller.

1. With the motor's feedback cable connected to the drive/controller, randomly connect two motor input power wires and slowly apply a positive voltage with respect to the third. See Figure 40 on page 88.

   Note: A variable low voltage (5 to 24V) current limiting power supply (less than continuous current rating of motor) is preferred.

Warning — This procedure could damage the motor. Slowly increase the voltage until the motor moves. Do not exceed the rated current.

Safety Warning — High-performance motion control equipment is capable of producing rapid movement and very high forces. Unexpected motion may occur especially during the development of controller programs. **KEEP WELL CLEAR** of any machinery driven by stepper or servo motors. Never touch any part of the equipment while it is in operation.

2. If **?THALL** reports a 1, 2, or 4, change **SHALL** from either 0 to 1 or from 1 to 0. After you change **SHALL**, reset the drive/controller.
3. Repeat step 1 until **?THALL** reports a value of 6.
4. The wire on the negative voltage or ground is motor wire W. The two wires at the positive voltage are U and V.

   Now there are two possibilities:

   a. Connect the motor wires to the terminals. Operate the drive in **DMODE1**. If the motor does not turn in the clockwise direction, exchange motor wires U and V. Verify that the Bit 8455 command is set to zero (Ø).

   b. Put positive voltage on motor wire W together with either U or V and put negative voltage or ground on the remaining wire. If **?THALL** reports a value of 3, the wire at the negative voltage is V. If **?THALL** reports a value of 5, the wire at the negative voltage is U.

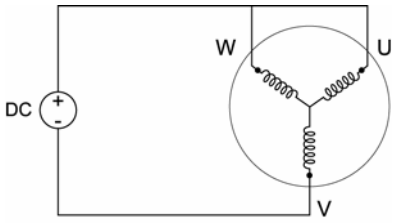


Figure 40 Hall Connection Diagram

Procedure 2—Hall Wires

Use this procedure to connect your *Hall wires* to the Aries Controller.

1. First operate the Aries Controller in **DMODE1** and verify that the motor turns clockwise. If not, swap any two motor wires.
2. Remove the motor input power leads, leaving the feedback cable connected to the drive/controller. Connect motor input power wires U and V and slowly apply a positive voltage with respect to W. (See Figure 40.)

   Note: A variable low voltage (5-24V) current limiting power supply (less than continuous current rating of motor) is preferred.

Warning — This procedure could damage the motor. Slowly increase the voltage until the motor moves. Do not exceed the rated current.

Safety Warning — High-performance motion control equipment is capable of producing rapid movement and very high forces. Unexpected motion may occur especially during the development of controller programs. **KEEP WELL CLEAR** of any machinery driven by stepper or servo motors. Never touch any part of the equipment while it is in operation.

3. If **?THALL** reports a value of 1, 2 or 4, change **SHALL** from either 0 to 1 or from 1 to 0. After you change **SHALL**, reset the drive/controller.
4. Change the Hall wires until **?THALL** reports a value of 6.
5. Connect motor wires U and W and slowly apply a positive voltage with respect to V.
6. If **?THALL** does not report a value of 3, change Hall wires B and C. If **?THALL** reports a value of 3, the wires are connected correctly.

Table 32 summarizes phase voltages and their corresponding Hall states. Starting with **SHALL=Ø** and the phase voltages as shown, the **THALL** command should report the Hall states that match the “Correct” column. If instead **THALL** reports Hall states that match the “Use **SHALL=1**” column, enter **SHALL=1** and reset the drive/controller. The Hall states should now match the “Correct” column. For more information, see Figure 41 on page 90.

Phase			Hall State	
U	**V**	**W**	**Correct**	**Use** SHALL=1
–	–	+	1	6
–	+	+	5	2
–	+	–	4	3
+	+	–	6	1
+	–	–	2	5
+	–	+	3	4

Table 32 Configuring Hall Sensors

Figure 41 illustrates the alignment of phases U, V, and W with Halls 1, 2, and 3 as viewed from the front of the shaft. The illustration assumes the following:

- Hall signals that are High equal TRUE signals.
- Hall 1 is the least significant bit (LSB).
- Hall 3 is the most significant bit (MSB).
- There is one hall cycle and one electrical cycle per pole pair on the motor.

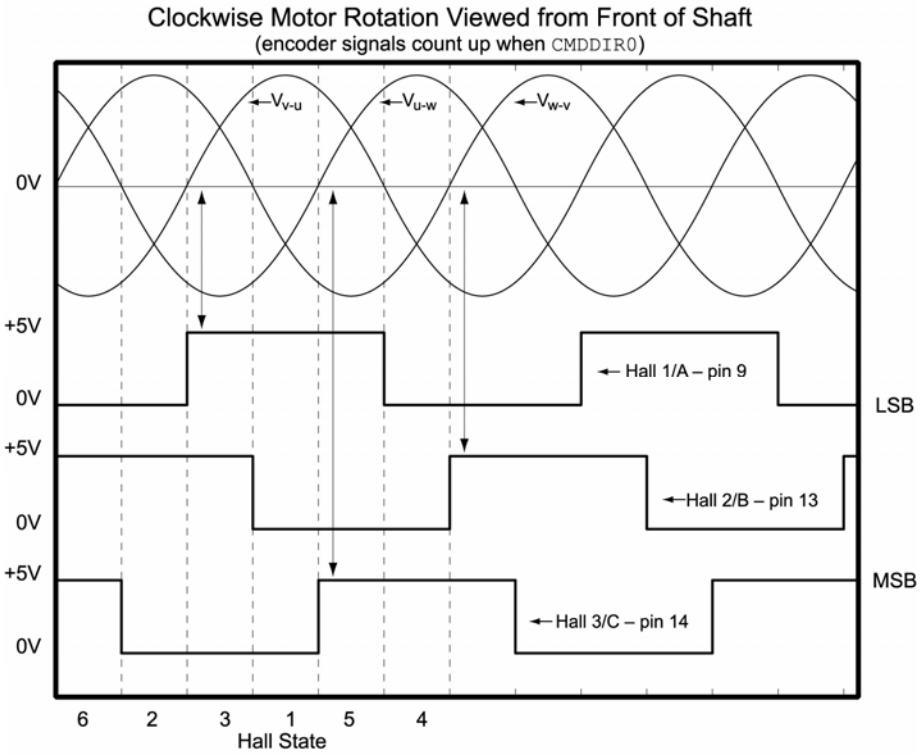


Figure 41 Motor Terminal Voltages (back EMF) and Hall Sensor Signals

APPENDIX A

Additional Specifications

IN THIS CHAPTER	
• Amplifier	92
• Performance	92
• Protective Circuits	93
• Cables	96

Amplifier

Control Power: all models	120/240 VAC Single Phase Mains Control Power
AR-04CE, AR-08CE, and AR-13CE	Single Phase AC Input, 120/240 VAC 16 or 32 kHz switching frequency (motor dependant), pulse-width modulated (PWM) with 3-phase motor output
Current Loop Update Rate	31.25 µs
Velocity and Position Loop	125 µs

Performance

Accuracy	±1 encoder count; encoder dependent
Maximum Primary Encoder Input Freq. (pre-quadrature)	1.6 MHz
Maximum Secondary Encoder Input Freq. (pre-quadrature)	1 MHz

Protective Circuits

Short Circuit Protection

The Aries Controller drive has an internal circuit that protects it from short circuits between one motor terminal to another (phase to phase), or from any motor terminal to earth.

Short Circuit Fault—Cause ..... Phase-to-phase short circuit
Phase-to-earth short circuit

Results of Fault ..... Power to motor is turned off
Drive status word is updated via Ethernet to the PC

LED Left	LED Right
Yellow & 1 Green (blinking)	Red

Table 33 LED Short Circuit Fault

Resetting the fault

To clear the latched fault, choose one of the following methods:

Cycle power to the drive/controller.

–or–

Open ACR-View and issue the **DRIVE RES AXIS0** command to the Aries Controller.

Drive/Controller Over-Temperature Protection

The Aries Controller over-temperature circuit monitors the drive/controller's internal temperature. If the sensors exceed the threshold temperature, the unit issues an over-temperature fault.

Threshold Temperature
AR-04CE, AR-08CE, and AR-13CE 80°C (176°F)

Results of Fault ..... Power to motor is turned off
Drive status word is updated via Ethernet to the PC

LED Left	LED Right
Yellow & 3 Green (blinking)	Red

Table 34 LED Drive Over-Temperature Fault

Resetting the Fault

After the internal temperature has dropped below the values shown in Table 35, you can clear the latched fault. There are two methods available:

Cycle power to the drive/controller.

–or–

Open ACR-View and issue the **DRIVE RES AXIS0** command to the Aries Controller.

Model	Reset Temperature
AR-04CE, AR-08CE, and AR-13CE	75°C (167°F)

Table 35 Reset Temperature Values

Under-Voltage Protection

The unit's under voltage protection circuit monitors AC input voltage. If the voltage falls below a specific value while the Aries Controller is operating, the unit issues an under-voltage fault and turns off power to the motor output terminals (Output Power connector). This allows the motor to freewheel to a stop.

Warning — When an under-voltage protection fault occurs, the Aries Controller disables power to its motor output terminals on the Output Power connector. This cuts all control to the motor and allows the load to freewheel to a stop.

Threshold Voltage

AR-04CE, AR-08CE, and AR-13CE ..... Voltage below 70 VAC trips fault

Results of Fault ..... Power to motor is turned off
Drive status word is updated
via Ethernet to the PC

LED Left	LED Right
Yellow	Red

Table 36 LED Under-Voltage Fault

Resetting the Fault

To clear the latched fault, choose one of the following methods:

Cycle power to the drive/controller.

–or–

Open ACR-View and issue the **DRIVE RES AXIS0** command to the Aries Controller.

Over-Voltage Protection

The Aries Controller over-voltage circuit protects the drive from excessive regeneration. If the voltage on the motor output terminals rises above the threshold voltage, the drive/controller issues an over-voltage fault and turns off power to the motor output terminals (Output Power connector). This allows the motor to freewheel to a stop.

Warning — When an over-voltage protection fault occurs, the Aries Controller disables power to its motor output terminals on the Output Power connector. This cuts all control to the motor and allows the load to freewheel.

Threshold Voltage

All Models..... 410 VDC

Results of Fault ..... Power to motor is turned OFF
Drive status word is updated via Ethernet to the PC

LED Left	LED Right
Yellow & 4 Green (blinking)	Red

Table 37 LED Over-Voltage Fault

Resetting the Fault

To clear the latched fault, choose one of the following methods:

Cycle power to the drive/controller.

–or–

Open ACR-View and issue the **DRIVE RES AXIS0** command to the Aries Controller.

Warning — Over-voltage protection monitors only the motor output terminals (DC motor bus). It does not protect against an over voltage on the AC input terminals, which can permanently damage the drive/controller.

Current Foldback

The Aries Controller's current foldback circuit helps to protect the unit from damage due to prolonged high currents.

If your unit is operating above its continuous current rating, see Figure 42 to predict the number of seconds until foldback will occur. For example, the figure shows that at the drive/controller's peak current rating (250% of continuous), foldback will occur after six seconds. After operating at the its peak current, the Aries Controller will reduce the drive/controller current to 80% of the its continuous rating for 60 seconds. This is to ensure the unit's average continuous current rating is not exceeded.

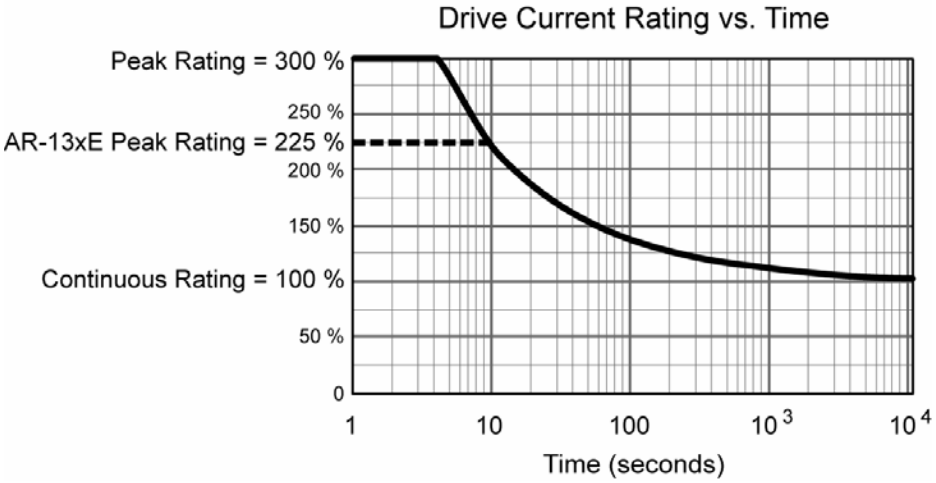


Figure 42 Time Until Current Foldback Occurs

Cables

EMC Ready Cables

Many Parker cables are EMC installation ready. If installed according to instructions provided under *A Highly-Immune, Low-Emission Installation—Meeting the Requirements of the Electromagnetic Compatibility (EMC) Directive* on page 115, these cables are designed to aid the user in gaining European Compliance, and are thus an integral part of a CE system solution. EMC cables add RF screening and bonding to reduce emissions, increase immunity, and provide high integrity safety Earth bonding. They also help to reduce problems in high electrical noise environments.

Non-EMC Cables

Parker also offers non-EMC cables, for applications where CE compliance is not required, and where ambient electrical noise does not cause problems. Because these cables are either unshielded, or contain simple foil shielding terminated by a drain wire, they do not provide significant shielding of electrical noise at high frequencies.

APPENDIX B

External Power Dump Resistor Selection

IN THIS CHAPTER

- External Power Dump 98
- Simplified Resistor Selection 99
- Calculating Resistance—Rotary Motors 100
- Resistor Specifications—Rotary Motors 104
- Calculating Resistance—Linear Motors 106
- Resistor Specifications—Linear Motors 109

External Power Dump

Deceleration generates excess kinetic and potential energy. You can remove the energy through regeneration—a process where the motor acts as generator. Regeneration allows you to transfer the excess energy from the motor and load back to the power supply.

When the drive/controller and assorted losses cannot remove all the stored kinetic energy, you must connect an external power-dump resistor. Connecting an external power-dump resistor to the drive/controller helps dissipate the excess kinetic and potential energy.

While the drive/controller contains circuitry to control an external power dump resistor, resistor selection depends on the requirements of your particular application.

There are two methods for selecting the appropriate external power-dump resistor:

- In this appendix, the section *Simplified Resistor Selection* provides quick recommendations for Parker drive and motor combinations.
- The sections *Resistor Specifications—Rotary Motors* and *Resistor Specifications—Linear Motors* step you through the relevant formulas to determine the needs of your particular application.

Note: Both methods assume regeneration occurs during a trapezoidal move.

Important — It is possible to overload a drive/controller or the combination of a drive/controller and power dump resistor.

If, at the end of the calculations, you find the required resistor is less than allowed for your specific Aries Controller model, or requires a wattage rating greater than the rated resistors available, do not use the unit in your application.

Drive/controller models AR-04CE, AR-08CE, and AR-13CE require external resistance values of 22 Ohms or greater.

Simplified Resistor Selection

Many applications do not require a power-dump resistor because the drive/controller can absorb or dissipate the regenerative deceleration energy. However, if a drive/controller faults from over-voltage during a deceleration event, an external power dump resistor is probably required.

Table 38 contains recommended power-dump resistors for specific drive/controller and Parker Hannifin motor combinations. The recommendations are based on the calculations presented in the section *Calculating Resistance—Rotary Motors*. These recommendations assume a worst-case load-to-rotor inertia ratio of 10 to 1, maximum duty cycle and maximum deceleration from maximum velocity for that specific motor/drive pairing.

These are recommendations only—while not optimized for your particular application, they will work in most situations.

Drive/ Controller	AC Voltage	Motor	Resistor Rating (Resistance —Ohms)	Resistor Rating (Continuous Power—Watts)	Isotek Part Number
AR-04CE	240	SM233A	47	200	BRM-47R0-10-L[2, 4]
		BE232D			See note 1
		BE233D			See note 1
		BE233F			See note 1
AR-08CE	120	BE230F			See note 1
		BE231F			See note 1
		BE232F			See note 1
	240	BE341F			See note 1
		BE342H			See note 1
		NO702F	22	300	BRQ-22R0-10-L[2, 4]
		NO703F	22	300	BRQ-22R0-10-L[2, 4]
		NO704F	22	300	BRQ-22R0-10-L[2, 4]
AR-13CE	240	BE344L	22	300	BRQ-22R0-10-L[2,3,4]
		MPM1141ASG	22	300	BRQ-22R0-10-L[2,3,4]
		SMN1002S2F-KPN	22	300	BRQ-22R0-10-L[2,3,4]

1. External power dump resistor not needed. However, higher operating voltage, higher load to rotor inertia ratio, and higher duty cycles can increase the need.
2. Higher friction loads, lower speeds, lower deceleration rates, lower load to rotor inertia ratio, and lower duty cycles can decrease the need for this resistor.
3. Minimum resistance allowed for AR-13 is 22 Ohms, therefore the maximum deceleration rate and/or duty cycle may need to be reduced.
4. Isotek resistor or equivalent

Table 38 Simplified Selection of External Power-Dump Resistor

Calculating Resistance—Rotary Motors

Because there are different types of motion profiles and application-specific conditions, you may need to modify the results to suit your particular application. To keep it simple, the formulas assume a trapezoidal move profile in which the deceleration event is a single constant deceleration to zero (Ø) velocity. For other motion profiles, you can modify the basic concepts presented below.

Calculating the amount of energy to dissipate requires the motion profile parameters, and the motor, drive/controller, and load information. While significantly more information is required, the calculations help tailor the size of power-dump resistor to your application.

This is a multi-step process:

1. Calculate the motor's kinetic energy.
2. Calculate the motor's potential energy—vertical applications only.
3. Calculate the energy that can be absorbed by the drive/controller capacitors.
4. Calculate energy dissipated in the motor winding resistance.
5. Calculate energy dissipated in the load.
6. Using the results from the previous calculations, calculate the amount of energy to dissipate through an external power-dump resistor.

With that result, you can then calculate the resistor necessary to dissipate the excess energy.

Total Kinetic Energy

A body in motion produces energy. To stop motion, that energy must be absorbed or dissipated elsewhere.

That energy can be defined in terms of inertia and velocity.

$$E_K = \tfrac{1}{2}\left(J_M + J_L\right)\omega^2$$

Where

E_K = rotational kinetic energy (Joules)

J_M = rotor inertia in kilogram meter squared ($kg \cdot m^2$)

J_L = load inertia in kilogram meter squared ($kg \cdot m^2$)

ω = rotational speed in radians per sec (1 revolution/sec = $2 \cdot \pi \cdot$radians/sec)

Total Potential Energy

A body at rest stores energy relative to the position of the body. When the body moves, the potential energy is released and translated into kinetic energy.

For purely horizontal applications, potential energy is negligible and therefore not necessary for inclusion in your calculations. However, for vertical applications, potential energy can greatly affect the selection of power dump resistor. Regardless of whether the incline is gentle or steep, it is important to

calculate the potential energy that must be absorbed or dissipated elsewhere.

$$E_p = mgh$$

Where

E_p = potential energy (Joules)

m = mass of forcer and load (kg)

g = gravitational constant (9.81 m/s^2)

h = vertical height change during deceleration (m)

Energy Absorbed by Drive Capacitors

The Aries Controller drive capacitors absorb some of the kinetic and potential energy. While the capacitors absorb energy, the bus voltage increases. Later, the capacitors release that potential energy in subsequent accelerations, or into typical drive losses.

If too much energy is absorbed by the capacitors, the drive/controller faults from over-voltage. Under these circumstances, an external power dump resistor is required.

That ability to absorb energy can be defined in terms of capacitance and voltage.

$$E_C = \frac{1}{2} C (V_{TRIP}{}^2 - V_{NOM}{}^2)$$

Where

E_C = energy that can be absorbed by the drive capacitors (Joules)

C = drive capacitance (Farads)

V_{TRIP} = power dump trip DC voltage (400 VDC)

V_{NOM} = nominal DC motor voltage (typically AC mains voltage at $\sqrt{2}$; for example, 120 VAC * $\sqrt{2}$ = 170 VDC)

Fortunately, for a given drive/controller, the capacitance and voltages are fixed. Table 39 provides the necessary information and results from the above calculation.

Drive/ Controller	Capacitance (uF)	V_{TRIP} (VDC)	E_C (120 VAC) Joules	E_C (240 VAC) Joules
AR-04CE	880	400	57	19
AR-08CE	1100	400	72	24
AR-13CE	1590	400	104	35
When the voltage drops below 385 VDC, the drive stops dissipating power through the power dump resistor.				

Table 39 Drive Capacitor Absorption

Energy Dissipated in Motor Winding Resistance

Some energy is dissipated in the motor windings. Because the energy is converted to wasted heat in the motor, it is referred to as *copper losses*.

The energy during deceleration can be derived from the inertia, deceleration rate, motor resistance, and motor torque constant. If some of the parameters are not known, the energy dissipated in the motor windings (E_W) can conservatively be assumed zero (Ø).

This is based on current and motor winding resistance.

$$E_W = \frac{1}{2} I^2 R_M \cdot t_D = \frac{1}{2} \cdot \left(\frac{\left(J_M + J_L\right) \cdot \omega}{k_T \cdot t_D} \right)^2 \cdot R_M \cdot t_D$$

Where

- E_W = energy dissipated in the motor windings (Joules) – copper losses
- I = current through the windings ($Amps_{rms}$)
- R_M = line to line motor resistance (Ohms)
- t_D = deceleration time (Seconds)
- J_M = rotor inertia ($kg \cdot m^2$)
- J_L = load inertia ($kg \cdot m^2$)
- k_T = motor torque constant (Nm/Amp_{rms})
- ω = rotational speed in radians per sec (1 revolution/sec = $2 \cdot \pi \cdot$radians/sec)

Energy Dissipated in Load

The load dissipates energy through friction losses, viscous damping, and other motor/load related losses. These losses are known as load losses. If some of the parameters are not known, the energy dissipated in the load (E_L) can conservatively be assumed zero (Ø).

This can be derived from the torque required during the constant velocity portion of the move profile, either measured or calculated.

$$E_L = \frac{1}{2} T \omega \cdot t_D$$

Where

- E_L = energy dissipated by the load (Joules) – load losses
- T = torque at constant velocity (Nm)
- ω = rotational speed in radians per sec (1 revolution/sec = $2 \cdot \pi \cdot$radians/sec)
- t_D = deceleration time (Seconds)

Energy to Dissipate in the External Power-Dump Resistor

To stop a motor, kinetic and potential energy must go somewhere. Through the previous calculations, you have determined the total kinetic and potential energy, and the energy lost to various paths.

From the total kinetic and potential energy, subtract the energy dissipated through the drive capacitors, motor windings, and load loss. If the copper losses (E_W) or load losses (E_L) are not easily determined, you can conservatively assume they are zero (Ø).

The resulting sum represents the power for dissipation in an external power dump resistor.

$$E_R = E_K + E_P - E_C - E_W - E_L$$

Where

- E_R = energy to be dissipated in the external resistor (Joules)
- E_K = rotational kinetic energy (Joules)
- E_P = potential energy (Joules)
- E_C = energy that can be absorbed by the drive capacitors (Joules)
- E_W = energy dissipated in the motor windings (Joules) – copper losses
- E_L = energy dissipated by the load (Joules) – load losses

Resistor Specifications—Rotary Motors

Having determined the amount of energy to dump (E_R), you can then calculate the resistor specifications.

- Maximum resistance
- Peak dissipation
- Average dissipation

Maximum Resistance

This calculation determines the maximum value of resistance needed for the external power-dump resistor. We recommend that you select a lower value resistance, typically in the 22 to 100 ohm range.

Important — It is possible to overload a drive/controller or the combination of a drive/controller and power dump resistor.

If, at the end of the calculations, you find the required resistor is less than allowed for your specific Aries Controller model, or requires a wattage rating greater than the rated resistors available, do not use the unit in your application.

Drive/controller models AR-04CE, AR-08CE, and AR-13CE require external resistance values of 22 Ohms or greater.

$$R_R = \frac{V}{I} = \frac{V_{TRIP} \cdot k_T \cdot t_D}{(J_M + J_L) \cdot \omega}$$

Where

R_R = maximum external power dump resistance (Ohms)

V = voltage across the resistor (V_{TRIP})

I = current through the resistor (drive current required to decelerate the load)($Amps_{rms}$)

V_{TRIP} = power dump trip DC voltage (400 VDC)

k_T = motor torque constant (Nm/Amp_{rms})

J_M = rotor inertia ($kg \cdot m^2$)

J_L = load inertia ($kg \cdot m^2$)

t_D = deceleration time (Seconds)

ω = rotational speed in radians per sec (1 revolution/sec = $2 \cdot \pi \cdot$radians/sec)

Peak Dissipation

During a single deceleration, all the calculated power-dump energy (E_R) must dissipate in the external resistor. The external power-dump resistor then slowly dissipates that energy as heat. This peak power must not exceed the capabilities of the resistor, which is typically 10 times the average power rating.

$$P_{PEAK} = \frac{E_R}{t_D}$$

Where

P_{PEAK}= peak power into the external power dump resistor (Watts)

E_R = energy to be dissipated in the external resistor (Joules)

t_D = deceleration time (Seconds)

Average Dissipation

Repetitive moves need to dump the energy each time the deceleration occurs. The duty cycle of this repetition determines the average power the resistor must dissipate. This average power must not exceed the capabilities of the resistor.

Power resistors are rated based on ideal heat sink and airflow conditions, and are therefore often over-rated by the manufacturers. To ensure the average energy dissipation of the resistor exceeds the average power dump for the application, the regenerative power should never exceed 50% of the resistor's average power rating.

$$P_{AVG} = P_{PEAK} \cdot \frac{t_D}{t_C}$$

Where

P_{AVG} = average power into the external power dump resistor (Watts)

P_{PEAK} = peak power into the external power dump resistor (Watts)

t_D = deceleration time (Seconds)

t_C = cycle time or time between each deceleration event (Seconds)

Important — Under normal operation the external power-dump resistor could operate in excess of 200 °C. Keep the resistor away from thermally sensitive components, such as cables or plastic hardware.

Proper installation may require the use of thermal compound and proper thermal connection to a heat absorbing metal surface.

Calculating Resistance—Linear Motors

Because there are different types of motion profiles and application-specific conditions, you may need to modify the results to suit your particular application. To keep it simple, the formulas assume a trapezoidal move profile in which the deceleration event is a single constant deceleration to zero (Ø) velocity. For other motion profiles, you can modify the basic concepts presented below.

Calculating the amount of energy to dissipate requires the motion profile parameters, and the motor, drive/controller, and load information. While significantly more information is required, the calculations help tailor the size of power-dump resistor to your application.

This is a multi-step process:

1. Calculate the motor's kinetic energy.
2. Calculate the motor's potential energy—vertical applications only.
3. Calculate the energy that can be absorbed by the drive/controller capacitors.
4. Calculate energy dissipated in the motor winding resistance.
5. Calculate energy dissipated in the load.
6. Using the results from the previous calculations, calculate the amount of energy to dissipate through an external power-dump resistor.

With that result, you can then calculate the resistor necessary to dissipate the excess energy.

Total Kinetic Energy

A body in motion produces energy. To stop motion, that energy must be absorbed or dissipated elsewhere.

That energy can be defined in terms of mass and velocity.

$$E_K = \tfrac{1}{2}\left(M_F + M_L\right)v^2$$

Where

E_K = rotational kinetic energy (Joules)

M_F = mass of forcer in kilograms (kg)

M_L = mass of load in kilograms (kg)

v = velocity in meters per second (m/s)

Total Potential Energy

A body at rest stores energy relative to the position of the body. When the body moves, the potential energy is released and translated into kinetic energy.

For purely horizontal applications, potential energy is negligible and therefore not necessary for inclusion in your calculations. However, for vertical applications, potential energy can greatly affect the selection of power dump resistor. Regardless of whether the incline is gentle or steep, it is important to calculate the potential energy that must be absorbed or dissipated elsewhere.

$$E_p = mgh$$

Where

E_p = potential energy (Joules)

m = mass of forcer and load (kg)

g = gravitational constant (9.81 m/s^2)

h = vertical height change during deceleration (m)

Energy Absorbed by Drive Capacitors

The Aries Controller drive capacitors absorb some of the kinetic and potential energy. While the capacitors absorb energy, the bus voltage increases. Later, the capacitors release that potential energy in subsequent accelerations, or into typical drive losses.

If too much energy is absorbed by the capacitors, the drive/controller faults from over-voltage. Under these circumstances, an external power dump resistor is required.

That ability to absorb energy can be defined in terms of capacitance and voltage.

$$E_C = \frac{1}{2} C (V_{TRIP}{}^2 - V_{NOM}{}^2)$$

Where

E_C = energy that can be absorbed by the drive capacitors (Joules)

C = drive capacitance (Farads)

V_{TRIP} = power dump trip DC voltage (400 VDC)

V_{NOM} = nominal DC motor voltage (typically AC mains voltage at $\sqrt{2}$; for example, 120 VAC * $\sqrt{2}$ = 170 VDC)

Fortunately, for a given drive the capacitance and voltages are fixed. The table below provides the necessary information and results from the above calculation.

Drive	Capacitance (uF)	V_{TRIP} (VDC)	E_C (120 VAC) Joules	E_C (240 VAC) Joules
AR-04CE	880	400	57	19
AR-08CE	1100	400	72	24
AR-13CE	1590	400	104	35

Note: When the voltage drops below 385 VDC, the drive stops dissipating power through the power dump resistor.

Energy Dissipated in Motor Winding Resistance

Some energy is dissipated in the motor windings. Because the energy is converted to wasted heat in the motor, it is referred to as *copper losses*.

The energy during deceleration can be derived from the mass, deceleration rate, motor resistance, and motor force constant. If some of the parameters are not known, the energy dissipated in the motor windings (E_W) can conservatively be assumed zero (Ø).

This is based on current and motor winding resistance.

$$E_W = \frac{1}{2} I^2 R_M \cdot t_D = \frac{1}{2} \cdot \left(\frac{(M_F + M_L) \cdot v}{k_F \cdot t_D} \right)^2 \cdot R_M \cdot t_D$$

Where

- E_W = energy dissipated in the motor windings (Joules) – copper losses
- I = current through the windings ($Amps_{rms}$)
- R_M = line to line motor resistance (Ohms)
- t_D = deceleration time (Seconds)
- M_F = mass of forcer in kilograms (kg)
- M_L = mass of load in kilograms (kg)
- k_F = motor force constant (N/Amp_{rms})

Energy Dissipated in Load

The load dissipates energy through friction losses, viscous damping, and other motor/load related losses. These losses are known as load losses. If some of the parameters are not known, the energy dissipated in the load (E_L) can conservatively be assumed zero (Ø).

This can be derived from the force required during the constant velocity portion of the move profile, either measured or calculated.

$$E_L = \frac{1}{2} F \cdot v \cdot t_D$$

Where

- E_L = energy dissipated by the load (Joules) – load losses
- F = force at constant velocity in Newtons (N)
- v = velocity in meters per second (m/s)
- t_D = deceleration time (Seconds)

Energy to Dissipate in the External Power-Dump Resistor

To stop a motor, kinetic and potential energy must go somewhere. Through the previous calculations, you have determined the total kinetic and potential energy, and the energy lost to various paths.

From the total kinetic and potential energy, subtract the energy dissipated through the drive capacitors, motor windings, and load loss. If the copper losses (E_W) or load losses (E_L) are not easily determined, you can conservatively assume they are zero (Ø).

The resulting sum represents the power for dissipation in an external power dump resistor.

$$E_R = E_K + E_P - E_C - E_W - E_L$$

Where

E_R = energy to be dissipated in the external resistor (Joules)

E_K = rotational kinetic energy (Joules)

E_P = potential energy (Joules)

E_C = energy that can be absorbed by the drive capacitors (Joules)

E_W = energy dissipated in the motor windings (Joules) – copper losses

E_L = energy dissipated by the load (Joules) – load losses

Resistor Specifications—Linear Motors

Having determined the amount of energy to dump (E_R), you can then calculate the resistor specifications.

- Maximum resistance
- Peak dissipation
- Average dissipation

Maximum Resistance

This calculation determines the maximum value of resistance needed for the external power-dump resistor. We recommend that you select a lower value resistance, typically in the 22 to 100 ohm range.

Important — It is possible to overload a drive/controller or the combination of a drive/controller and power dump resistor.

If, at the end of the calculations, you find the required resistor is less than allowed for your specific Aries Controller model, or requires a wattage rating greater than the rated resistors available, do not use the unit in your application.

Drive/controller models AR-04CE, AR-08CE, and AR-13CE require external resistance values of 22 Ohms or greater.

$$R_R = \frac{V}{I} = \frac{V_{TRIP} \cdot k_F \cdot t_D}{(M_F + M_L) \cdot v}$$

Where

R_R = maximum external power dump resistance (Ohms)

V = voltage across the resistor (V_{TRIP})

I = current through the resistor (drive current required to decelerate the load)($Amps_{rms}$)

V_{TRIP} = power dump trip DC voltage (400 VDC)

k_F = motor force constant (N/Amp_{rms})

M_F = mass of forcer in kilograms (kg)

M_L = load mass in kilograms (kg)

t_D = deceleration time (Seconds)

v = velocity in meters per second (m/s)

Peak Dissipation

During a single deceleration, all the calculated power-dump energy (E_R) must dissipate in the external resistor. The external power-dump resistor then slowly dissipates that energy as heat. This peak power must not exceed the capabilities of the resistor, which is typically 10 times the average power rating.

$$P_{PEAK} = \frac{E_R}{t_D}$$

Where

P_{PEAK}= peak power into the external power dump resistor (Watts)

E_R = energy to be dissipated in the external resistor (Joules)

t_D = deceleration time (Seconds)

Average Dissipation

Repetitive moves need to dump the energy each time the deceleration occurs. The duty cycle of this repetition determines the average power the resistor must dissipate. This average power must not exceed the capabilities of the resistor.

Power resistors are rated based on ideal heat sink and airflow conditions, and are therefore often over-rated by the manufacturers. To ensure the average energy dissipation of the resistor exceeds the average power dump for the application, the regenerative power should never exceed 50% of the resistor's average power rating.

$$P_{AVG} = P_{PEAK} \cdot \frac{t_D}{t_C}$$

Where

P_{AVG} = average power into the external power dump resistor (Watts)

P_{PEAK} = peak power into the external power dump resistor (Watts)

t_D = deceleration time (Seconds)

t_C = cycle time or time between each deceleration event (Seconds)

Important — Under normal operation the external power-dump resistor could operate in excess of 200 °C. Keep the resistor away from thermally sensitive components, such as cables or plastic hardware.

Proper installation may require the use of thermal compound and proper thermal connection to a heat absorbing metal surface.

APPENDIX C

Regulatory Compliance UL and CE

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System Installation Overview

This appendix contains information related to installation methods and practices that can be used to aid the systems integrator or machine builder in designing a compliant installation, meeting the needs of global regulatory agencies.

The installation overview is divided in to two general sections—Safety and Electromagnetic Compatibility (EMC).

It is recommended that the installer *read this entire overview* prior to taking any action, as some of the required installation methods can be leveraged across both Safety and EMC installations.

Although this product is technically considered a motion control component and is therefore not within the scope of the European Union's CE (Conformité Européenne) directives, Parker has taken the initiative to provide its customers with easy-to-integrate motion control products that meet global requirements.

The following information describes the measures typically required to install this product in a CE compliant system. Additional installation measures may be required at some locations. The machine builder has the ultimate responsibility for machine compliance.

General Safety Considerations

This drive/controller is intended for installation according to the appropriate safety procedures, including those laid down by the local supply authority regulations. The recommendations provided in this guide are based on the requirements of the Low Voltage Directive and specifically on EN61010. Remember, never compromise safety to achieve EMC compliance. Therefore, in the event of a conflict between safety regulations and the following EMC recommendations, *safety regulations always take precedence*.

General EMC Considerations

This drive/controller is a motion control component, and as such, will be built in to another machine that will in turn be required to comply with the relevant directives of the marketplace.

It is important to remember that for specific installations, the full protection requirements of the EMC directive 89/336/EEC need to be met before the system is taken in to service. This must be verified either by inspection or by testing. The following EMC installation recommendations are intended to assist in ensuring that the requirements of the EMC directive are met. It may be necessary to take additional measures in certain circumstances and at specific locations.

It should be stressed that although these recommendations are based on the expertise acquired during the design and development of the drive/controller, and on tests carried out on similar products, it is impossible for Parker to guarantee compliance of any particular installation. This will be strongly influenced by the physical and electrical details of the installation and the performance of other system components. Nevertheless, it is important to follow *all* the installation recommendations if an adequate level of compliance is to be achieved.

Installing the Drive/Controller

Only qualified, skilled electrical technicians familiar with local safety requirements should install this product. For service, the drive/controller must be returned to an authorized service center. There are no user serviceable parts inside the chassis. In certain circumstances, opening the cover may void the product warranty.

The unit is a vented product. To prevent material spilling into the drive/controller, mount it under an overhang or in a suitable enclosure.

This unit is made available under “Restricted Distribution” for use in the “Second Environment” as described in EN 61800-3 1996, page 9. This means only those individuals familiar with the EMC requirements of power drive systems should install this product and that this product is designed for connection to mains distribution networks other than low-voltage networks, which may supply domestic premises. The product can tolerate atmospheric pollution degree 2, which means only dry, non-conductive pollution is acceptable.

The Aries Controller has been shown to meet the requirements of both the European LVD & EMC directives when installed according to the recommendations given within this section. It is recommended the drive/controller be installed in an enclosure to protect it from atmospheric and industrial process contaminants and to prevent operator access while it has power applied. Metal equipment cabinets are ideally suited for housing the equipment since they can provide operator protection, EMC screening, and can be fitted with interlocks arranged to remove all hazardous motor and drive power when the cabinet door is opened. Do not arrange interlocks to open circuit the motor phase connections while the system is still powered, as this could cause damage to the unit.

Precautions

During installation, take the normal precautions against damage caused by electrostatic discharges. Wear earth wrist straps. A switch or circuit breaker must be included in the installation, which must be clearly marked as the disconnecting device and should be within easy reach of the machine operator.

The drive/controller has exposed high voltage terminals. In order to comply with the safety requirements pertaining to European Compliance, and other authorities, the drive/controller must be mounted in such a way as to restrict access to these terminals during normal operation.

A Safe Installation—Meeting the Requirements of the Low Voltage Directive (LVD)

In order to comply with the requirements of the European Union’s Low Voltage Directive, the following installation measures must be taken.

- *Mains fuses must* be installed on all mains input lines carrying operating current. For more information, see all information in the section *Fuse Requirements* starting on page 40.

- Drive/Controller Protective Earth Conductor must be connected directly to a reliable system safety Earth point. Total resistance from the drive/controller's Protective Conductor Terminal to a Reliable System Safety Earth must not exceed 0.1 Ohm, and must be capable of carrying 25A of Fault Current.
- Motor Safety Earth Conductor (for motor voltages greater than or equal to 75 volts) must be connected to the drive/controller's Motor Earth terminal, marked with ⏚.
- The drive/controller must be installed in a manner that prevents operator access to hazardous, live terminals during normal operation.

Additional safety measures may be required within your particular market, please consult you local regulatory agency for additional requirements.

A Highly-Immune, Low-Emission Installation—Meeting the Requirements of the Electromagnetic Compatibility (EMC) Directive

The following information was compiled to aid the machine builder or systems integrator in gaining EMC compliance. For effective control of Conducted and Radiated Emissions, along with maximizing the drive/controller's inherent noise immunity, the following recommendations should be followed:

- Mount the drive/controller and all components to a common, clean (not painted), earthed, metal panel.

Important! — To reduce the risk of electrical noise entering your system, you must properly earth ground the enclosure and remove all paint and other non-conductive surface coatings from the panel mounting surface and RF earth bonding locations.

- If you mount the drive/controller in an equipment cabinet, *terminate cable braids (screens) as they enter the enclosure*. This can be easily accomplished using the "additional EMC installation hardware" shown Figure 44 on page 120.

  There is only one exception: *the motor braid must return to the drive/controller's R-clamp* (located on the bottom of the drive/controller--see Figure 44 on page 120). *Do not* return the motor braid to any other location; its function is to return high-frequency chopping current back to the drive/controller. This may require mounting the connector on a sub-panel insulated from the main cabinet or using a connector having an insulated internal screen from the connector housing.

  The shields of all other cables that enter or exit the enclosure must be RF-bonded to the enclosure entrance point using an R-clamp, bulkhead clamshell clamp, or other 360° bonding technique. This ensures that no stray noise will enter or exit the enclosure. Figure 43 on page 116 illustrates 360° bonding techniques.

  There must be no break in the 360° coverage that the screen provides around the cable conductors.

All braid termination connections must remain secure. For small diameter cables, it may be necessary to fold back the braid or add additional conductive material, such as conductive, adhesive, copper tape to increase the effective diameter of the cable so that R-clamps are secure.

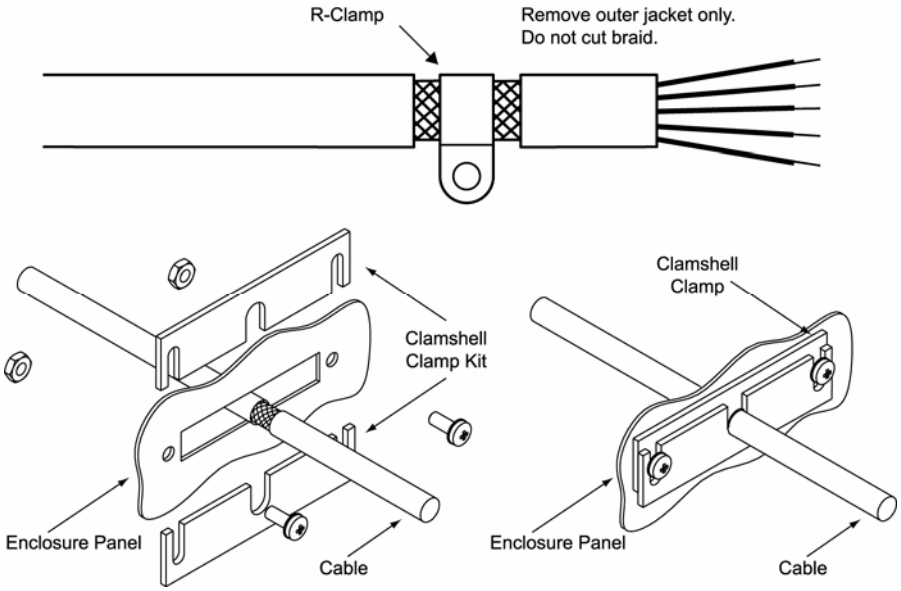

Figure 43 360° Bonding Techniques

- Within the cabinet itself, all the motor cables should lie in the same trunking as far as possible. Keep the cables separate from any low-level control signal cables. This applies particularly where the control cables are unscreened and run close to the drive/controller.
- A steel equipment cabinet will screen radiated emissions provided all panels are bonded to a central earth point. Separate earth circuits are commonly used within equipment cabinets to minimize the interaction between independent circuits. A circuit switching large currents and sharing a common earth return with another low-level signal circuit could conduct electrical noise into the low level circuit, thereby possibly interfering with its operation. For this reason, so called ‘dirty earth’ and ‘clean earth’ circuits may be formed within the same cabinet, but all such circuits will eventually need to be returned to the cabinet’s main star earth point.
- Mount the individual units and EMC filter on a metal earth plane. The earth plane will have its own individual star point earth that should be hard wired (using an insulated copper conductor) back to the cabinet’s ‘clean earth’ connection point.
- Panel mounting can provide a similar measure of EMC performance if strict attention is paid to cable screen termination and cable layout.

Important! — Ensure that all cable shields are properly terminated at both ends of the cable, utilizing 360 degrees of termination either within a metallic connector shell (preferred) or with an R-clamp terminating the shield to Earth ground as close as possible to the end of the cable. In any installation, improperly terminated cable shields will lead to problematic operation in the form of hardware, software, and communication lock-ups and intermittent functioning.

- Again, the machine builder's primary focus should be on ensuring operators are kept safe from all hazards.
- *Install a Mains filter.* The drive/controller requires an EMC mains supply filter to meet EMC emission requirements. It is recommended that the drive/controller be mounted on a conductive panel which is shared with the EMC filters. If the panel has a paint finish, it will be necessary to remove the paint in certain areas to ensure filters and drive/controller make a good large-area metal to metal contact between filter case and panel.

  The EMC Mains filter should be mounted either at the enclosure (preferred) or the power entry point or as close to the drive/controller as possible.

  You must install a filter on both the Motor power mains and Control power mains if both are used. Use Table 40 and Table 41 to determine the correct filter for your specific application.

Control Power

Control power is 1 Amp, maximum. Any of the following filters works with all models of the drive/controller.

Filter	Manufacturer
6EP1 (160937-5)	Corcom
10EP1 (160937-7)[1,]	Corcom
FN2070-10/06	Schaffner
1. Available from Parker:	10 Amp filter—part number 47-016140-01 16 Amp filter—part number 47-017900-01

Table 40 Control Power Filter Selection

Mains Motor Power

Use Table 41 to determine the appropriate mains filter for your drive/controller.

Filter	Continuous Current (Amps)	AR-04CE	AR-08CE	AR-13CE
6EP1 (160937-5)[1]	5 at 240 VAC			
10EP1 (160937-7)[1, 3]	8 at 240 VAC	×	×	x
FN2070-10/06[2]	10 at 240 VAC	×	×	x
FN2070-12/06	12 at 240 VAC	×	×	x
FN2070-16/06[2, 3]	16 at 240 VAC	×	×	x
16FCD10[1]	16 at 240 VAC			
25FCD10[1]	25 at 240 VAC			

Product with applicable mains filter denoted by "×"

1. Corcom (a division of Tyco Electronics)
2. Schaffner
3. Available from Parker: 10 Amp filter—part number 47-016140-01
   16 Amp filter—part number 47-017900-01

Table 41 Mains Motor Power Filter Selection

Follow these requirements for mains power connections:

- Install transient suppressors.

  Single Phase Input
  You must install varistors or other voltage surge-limiting devices in order to meet the requirements of EN61000-4-5. Place a Littelfuse V275LA2ØC, or equivalent varistor, from line to line and from lines to earth before the mains filter, as shown in the *EMC Installation* drawings.
  Note: Intersil, General Electric, and Littelfuse manufacture equivalent varistors.

- Use an EMC-ready motor or a motor that has demonstrated acceptable EMC performance.

  Motors with shielded cabling or pipe thread style cabling options allow the easiest integration into machines required to bear the CE mark for EMC.

  Note: Motors may bear the CE mark. This mark indicates the motor meets the requirements of construction and safety—*not EMC compliance*.

- Use shielded cabling with braided and bonded headshells. Use of Parker CE/EMC-compliant cables is recommended—they are fully shielded and provide the required screening. Parker cabling requires no additional cable preparation.

  All motor connections must be made using a high quality braided-screen cable. Cables using a metalized plastic bandage for an earth screen are unsuitable and in fact provide very little screening. Care must be taken when terminating the cable screen, the screen itself is comparatively fragile; bending it round a tight radius can seriously affect the screening

performance. The selected cable must have a temperature rating that is adequate for the expected operating temperature of the motor case.

All cables must maintain high-integrity 360° shielding. *Do not* use drain wires to terminate shields. If shields cannot be properly terminated within the connector shell, utilize a conductive R-clamp to terminate the shield to chassis ground as close to the cable end as possible. This requires carefully exposing ½ to ¾ inch of the cable shields as shown in Figure 43 on page 116.

When you install limit switches and other inputs/outputs, you must observe these same noise immunity procedures and practices.

- Route cables as shown in Figure 44 on page 120.

  Route high power cables (motor and mains) at right angles to low power cables (communications and inputs/outputs). Never route high and low power cables parallel to each other.

  Mount filters close to the drive/controller and keep the supply wiring as short as practical. Attempt to layout the wiring in a way that minimizes cross coupling between filtered and non-filtered conductors. This means avoiding running wires from the output of a filter close to those connected to its input. Where you wish to minimize the cross coupling between wires avoid running them side-by-side one another, if they must cross, cross them at 90° to each other. Use cable fasteners to keep wiring supported and close to cabinet metalwork.

- Cables may require the use of ferrite core suppressors.

  Some installations may require that you take additional EMC measures. To further increase product immunity and reduce product emissions, you may add clip-on ferrite absorbers to all cables. Parker recommends ferrites with at least 200 ohm impedance at 100 MHz, such as the following:

Make	Part Number
Steward Ferrite	28A2024
Fair-Rite	0443164151
Note: These ferrites are also available from Parker Hannifin, part number 47-015956-01. For larger diameter cables (up to 0.722 in O.D.), Fair-Rite part number 0444176451 is recommended.	

Table 42 Ferrite Core Suppressors

- Your Installation may require additional EMC installation hardware (as shown in illustrations).

  The following clamp kits are available from Parker:

Clamp Type	Parker Part Number
R-Clamp Kit (10 per)	R CLAMP KIT
Clamshell Clamp Kit (2 per)	CLAMSHELL KIT

Table 43 Enclosure Mounting Clamps

Note: The Control power input also requires a mains power line filter, varistors, and fuses in order to comply with the relevant CE directives.

Panel Installation—All Models

Figure 44 illustrates a typical panel installation of the drive/controller that meets LVD and EMC requirements.

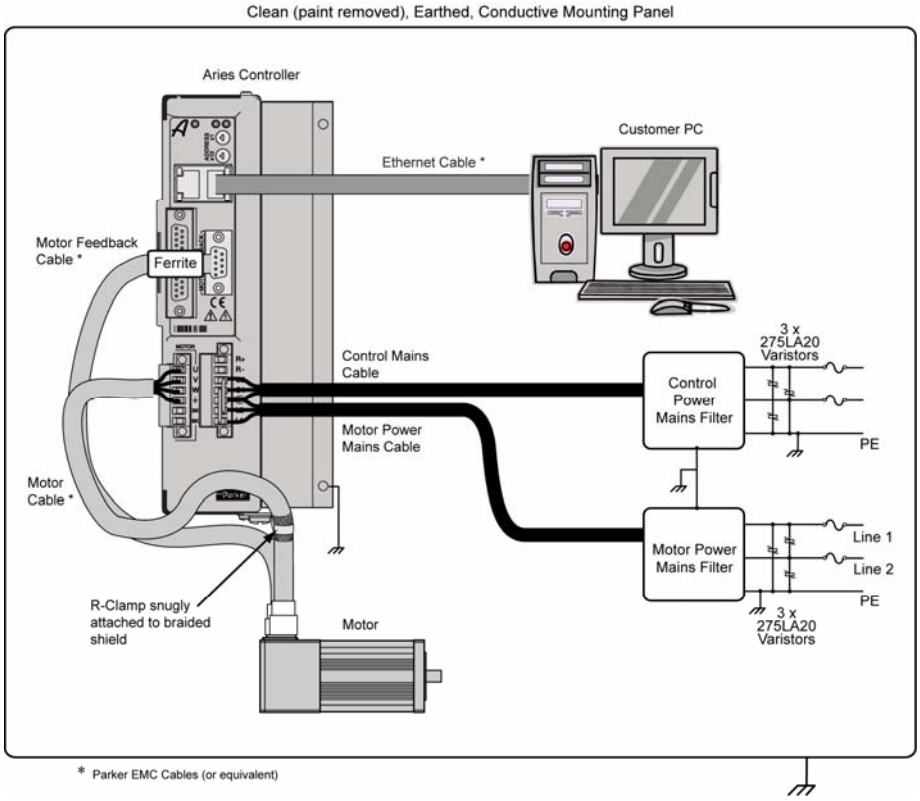

Figure 44 Typical LVD/EMC Installation

Warning — This product has been developed for industrial environments. Due to exposed high voltage terminals, this product must not be accessible to users while under normal operation.

Panel Mounting

The mounting clearance requirements are the same for all drive/controller models, as shown in Figure 45.

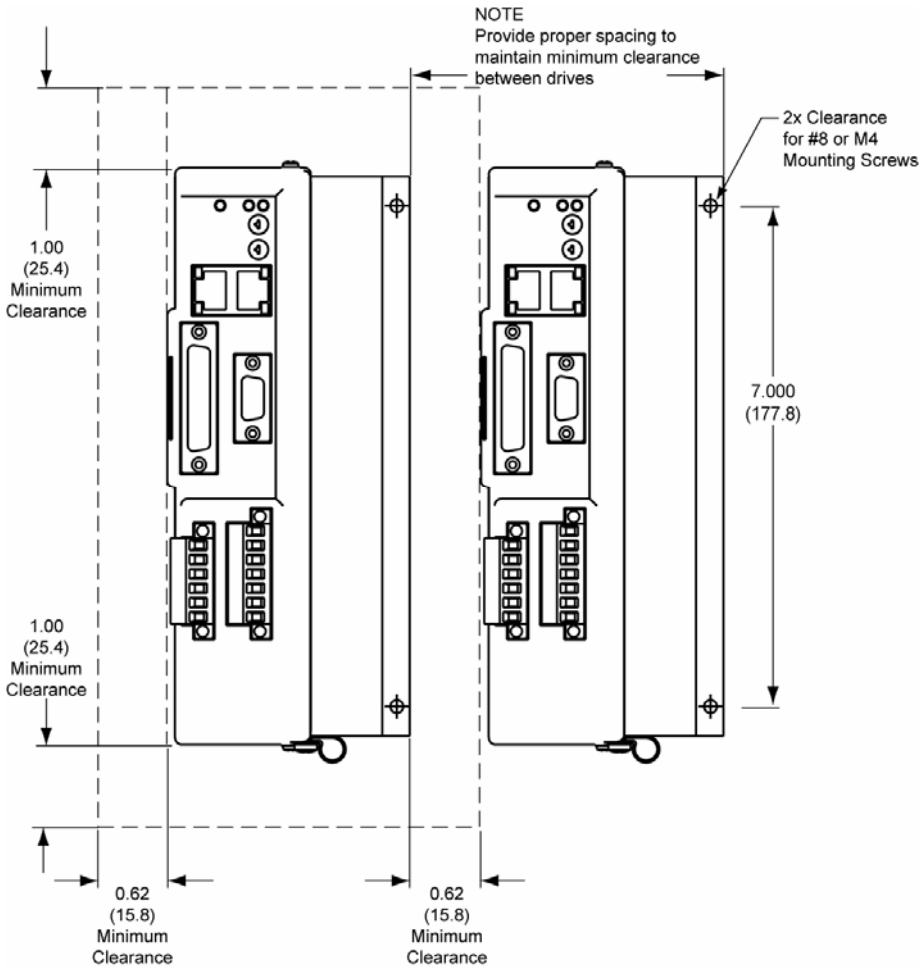

Figure 45 Panel Layout Dimensions

Regulatory Agencies

The Aries Controllers are designed to meet the requirements of global regulatory agencies. The drive/controllers have shown compliance with the regulatory agencies in the following list. The list also shows additional steps that must be taken to ensure compliance.

Agency	Additional Steps User Must Take
UL	Mains fuses
CE (LVD)	Mains fuses; earth connection for drive/controller and motor (if applicable), proper installation
CE (EMC)	Varistors, mains filter, EMC cabling, EMC ready motor, proper installation

Table 44 Regulatory Agencies

Standards of Compliance

UL	508C	
CE for LVD	73/23/EEC	
	BS EN 61010-1 (1993) including Amendment A2.	Safety requirements for electrical equipment for measurement, control, and laboratory use. Part 1. General Requirements.
CE for EMC	89/336/EEC	
	BS EN 61800-3 (1997) including Amendment A11	Adjustable speed electric power drive systems Part 3. EMC product standard including specific test methods.
	BS EN 50081-2 (1994) Electromagnetic compatibility	Generic emission standard Part 2. Industrial Environment.
	BS EN 61000-6-2 (1999) Electromagnetic compatibility Part 6-2: Generic Standards	Immunity for industrial environments.

APPENDIX D

Servo Tuning Flow Diagram

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Servo Tuning Flow Diagram

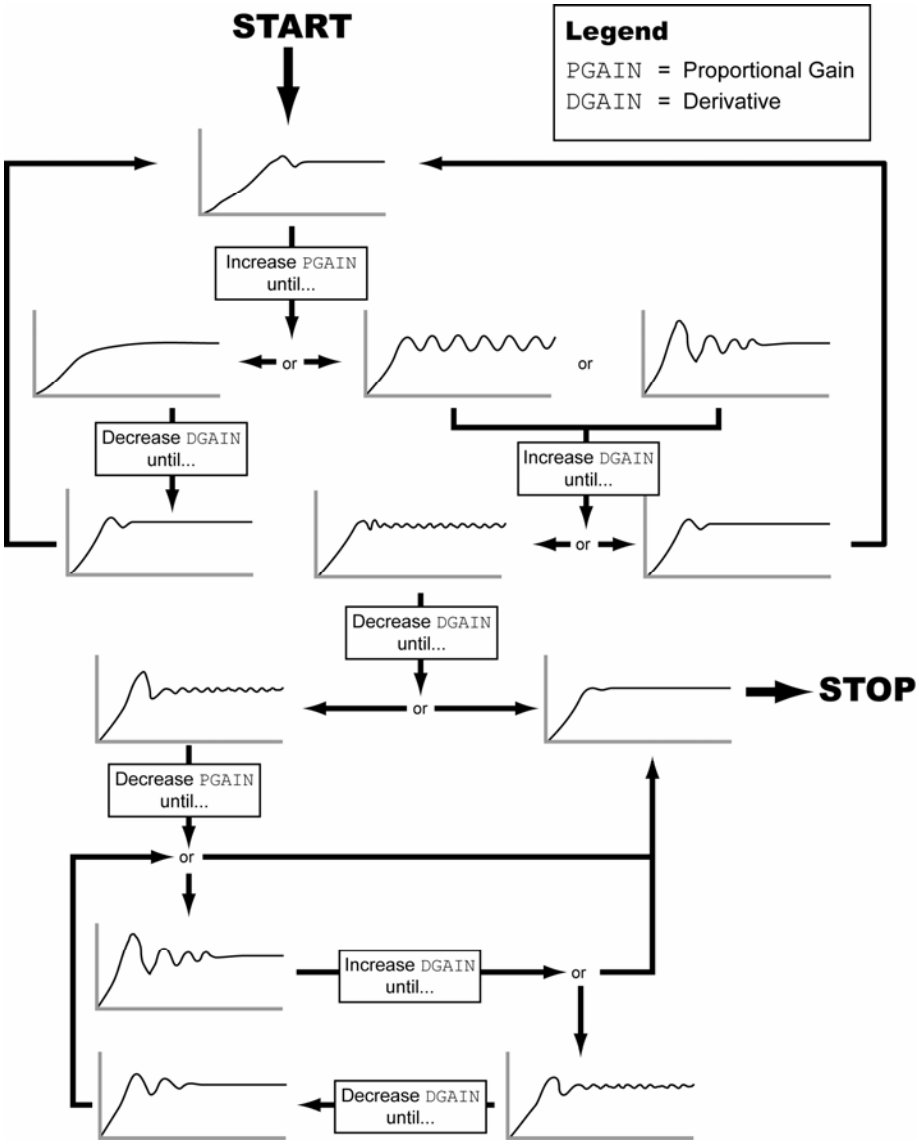

Figure 46 Servo Tuning Flow Diagram

APPENDIX E

VM25 Expansion Module

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Overview

The VM25 Expansion Module provides screw-terminal connections for input/output on the 25-pin Drive I/O connector. The VM25 comes with a 2-foot cable that provides easy connection between the VM25 and the drive's 25-pin connector. The VM25 is ordered separately (part number is "VM25").

Notes

- The VM25 module ships with DIN-rail mounting clips installed.
- The overall cabinet depth with cable-bend radius is 5 inches (127 mm).

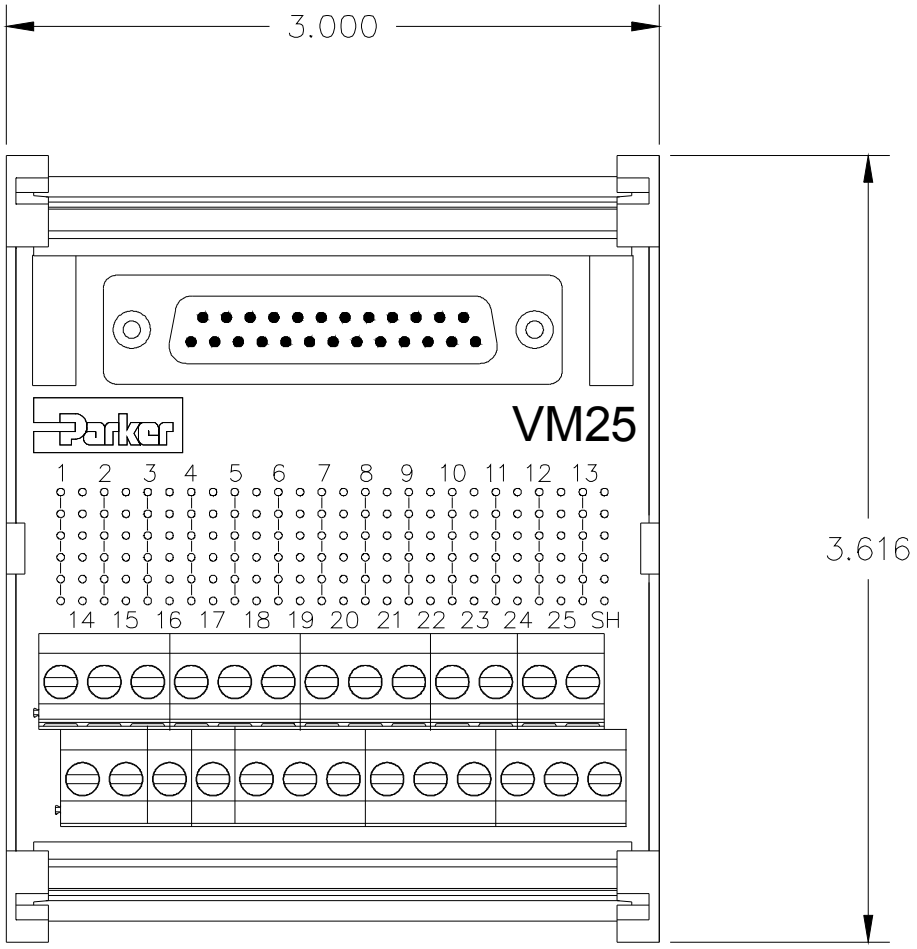

Figure 47 VM25 Expansion Module

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