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ACS Tech80

REDEFINING MOTION CONTROL

SB1391

Single-Axis Universal Motion Control Module

Hardware and Setup Guide

Document part no. TM-01391-000
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Dangerous voltages are present in this equipment!
Contact with live parts could cause serious injury or death!
Refer connection, installation, maintenance, adjustment, servicing and operation to qualified personnel.

RECENT CHANGES TO THIS GUIDE

Ver.	Date	Section	Change	ECR
1-11	Sept./00	4.5.1	Description of CAN indicator LED states improved.	
1-11	Sept./00	4.4.5 and 7.5.1.1	Warning added: Controller does not provide hardware facilities for hardware Emergency Stop or Safety Interlock.	
1-11	Sept./00	4.4.5 and 7.5.1.1	Warning added: E-STOP input is only for indicating that an emergency situation exists. It cannot be used as the Emergency Stop for the entire system.	
1-11	Sept./00	4.4.3, 4.4.4, and 7.3	Warning added: Encoder support does not include facilities for over-speed protection.	
1-12	Oct./00	4.3.3.1	Added replacement instructions for regeneration resistor fuse.	
1-12	Oct./00	4.4.6	Corrected TABLE 4-22, connection pins for the HSSI/PEG connector (J5).	296
1-13	Oct./00	7.5.4	Updated description of ACSPL analog output parameters.	
1-13	Dec./00	4.3.1.1	Warning added for drive supply: If using secondary circuit to supply the SB1391, supply must be suitably European Approved.	
1-13	Dec./00	4.3.1.1.3	Warning added for control supply: If using secondary circuit or DC direct to supply the SB1391, supply must be suitably European Approved.	
1-13	Dec./00	4.4.5	Warning added for I/O supply: If using secondary circuit or DC direct to supply the SB1391, supply must be suitably European Approved.	
1-13	Dec./00	4.3.2	Warning added for motor connection: Wiring and output must be in accordance with the relevant safety requirements of the EN 60204-1 standard (latest version).	
1-13	Dec./00	4	Warning added for mounting (installation): The SB1391 must be enclosed or incorporated into an end-product in accordance with the EN 60204-1 standard (latest version) for electrical shock, environmental (IP), and earthing requirements.	
1-13	Jan./01	4.3.3.1	Description of internal fuses and external regeneration resistor fuse added.	
1-13	Jan./01	4.3.1.2	Control supply must be minimum 1.5A.	
1-13	Jan./01	4.3.1.1.3	Description of phase-loss detection for three-phase drive connection added.	
1-13	Jan./01	Cover	Copyright, area code, and disclaimer updated.	

Ver.	Date	Section	Change	ECR
1-13	Jan./01	5.3.2	Screen shots updated & new debugger disable function added	
1-13	Jan./01	All	16-bit, RS-232, Stand-Alone, and all ACS-Tech80 SB…..	
1-13	Feb./01	4.4.6	Maximum PEG delay & Minimum Pulse width added	
1-13	Feb./01	3	Section 3 information updated to match Data Sheet	
1-13	Feb./01	2	General Safety and EMC Guidelines section added	
1-13	Feb./01	8	Other Topics section changed to Vector control and motors, EMC section moved to Chapter 2.	
1-13	Feb./01	5.2.6	Warning that motors are activated and ACScope output is mirrored at the analog output added	
1-13	Feb./01	5.2.10	Feedback sensor counting direction corrective measures added	
1.14	Aug/01	4-24	Encoder 2 pins 2-7 are “Master Encoder...”	Ltd33
1.14	Nov/01	2.1	UL compliance for section 508c.	Ltd48
1.14	Nov/01	Cover &9	Update cover page, trademark/contact info, and warranty pages. New template added.	

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PREFACE

The *SB1391 Hardware and Setup Guide* describes how to mount, connect, tune, and operate the SB1391 motion control module. Regarding operation, only an introduction to the ACS-Tech80, programming language, ACSPL, is provided. For a detailed description of ACSPL, refer to the *ACSPL Software Guide*.

The information in this guide is organized sequentially according to the steps involved in installing and setting up the control module. An index is included.

Conventions

Visual cues are used in this guide in an attempt to make it easier to absorb the information.



Note
A note box is used for information of special interest or importance.



Caution

A caution box is used when an action must be done with care. Otherwise minor equipment damage or loss of data could occur.



Warning

A warning box is used when an action must be done with great care. Otherwise personal injury or significant equipment damage can occur.

ACSPL terms appearing in the text are presented in **bold** style.

ACSPL program fragments are presented in **`bold Courier New`** typeface.

Guide Outline

Chapter 1 INTRODUCTION. Introduction to the control module.

Chapter 2 SAFETY AND EMC GUIDELINES. Basic precautions and UL requirements.

Chapter 3 FEATURES & SPECIFICATIONS. Primary features of the control module and specification.

Chapter 4 MOUNTING AND WIRING. Mounting information and electrical interface.

Chapter 5 WORKING WITH THE CONTROL UNIT. Setting up, tuning, and programming the control module.

Chapter 6 TUNING THE CONTROL LOOPS. Detailed description of the control loops, how to fine tune them, and how to implement dual loop control.

Chapter 7 HARDWARE INTERFACE PARAMETERS. Motion monitoring and other programming guidelines for the communication, feedback, and I/O.

Chapter 8 VECTOR CONTROL AND MOTORS. Specialized topics for vector control for DC brushless (AC servo/AC synchronous) and AC induction motors, and multiprogramming.



Note

For information developed after this guide was published, please refer to the ACS-Tech80 web site (http://www.acs-tech80.com/) or contact ACS-Tech80.

Related Documentation

Programming the control module is covered in the *Software Guide*.

1. INTRODUCTION

The SB1391 is a powerful and cost effective combination of an advanced programmable controller, an all-digital drive, and a power supply (with a separate, backup input for the control section).

The universal drive is software configurable for the any of the following types of rotary or linear motor: DC Brushless (AC servo/AC synchronous) (with sinusoidal s/w commutation), AC induction, and DC Brush. Three power levels are available: 5A (10A peak), 10A (20A), and 15A (30A). The bus voltage range is 120Vdc up to 370Vdc (= AC input x 1.41).

The SB1391 supports encoder (+ Hall) or resolver (12-bit resolution) as primary feedback and encoder as secondary feedback or master. In addition to dedicated safety inputs, it has eight isolated inputs, eight isolated outputs, an analog input, and an analog output.

1.1. About ACS-Tech80 Motion Control Modules

ACS-Tech80 control modules are based on state of the art, proprietary technology that is used in thousands of demanding systems, such as, semiconductor assembly and testing, electronic assembly and inspection, digital printing, medical imaging, and packaging. Built-in capabilities simplify programming common applications, such as advanced pick & place, master/slave, and electronic gearing and cam.

The modules can be programmed to handle motion, time, and I/O events. They can operate stand-alone, without a PLC or a PC. RS-232/422/485 serial communications is standard and CAN with CANOPEN protocol is optional. Every module meets stringent safety and EMC standards and is CE compliant.

Windows tools are provided for setting up and tuning the modules and for developing application programs. C/C++ (Microsoft® and Borland) and Visual Basic® libraries are available for DOS, Windows® 3.11/95/98/2000/NT, and Linux. The libraries support multithreading in Windows 95/98/2000/NT.

ACS-Tech80 is certified compliant with the ISO 9001 quality management standard.

2. SAFETY AND EMC GUIDELINES

TABLE 2-1 Topics covered in this chapter

Topic	Description
UL® Compliance	Section 508c compliance requirements
General Electrical Safety Guidelines	End-user installed protective devices and safety precautions
General wiring and electromagnetic compatibility (EMC) guidelines	Suggestions for proper wiring and shielding

2.1. UL Compliance Section 508c


UL Listed

TABLE 2-2 UL Compliance Label for SB1391

SB1391	-A		-B		-C
Model Input Voltage	85-265Vac (50/60 Hz, 1θ)		85–265Vac (50/60 Hz, 1θ)		5-265Vac (50/60 Hz, 1θ)
Model Input Current	6.54A (rms)		14.5A (rms)		14.0A (rms)
Motor Type	**DC**	**AC or DC Brushless**	**DC**	**AC or DC Brushless**	**AC or DC Brushless**
Output Voltage	208Vdc	147.5Vac (rms)	264.6Vdc	187.6Vac (rms)	170.2Vac (rms)
Output Current per axis	5.0Adc	3.9A (rms)	10.0Adc	7.0A (rms)	9.5A (rms)
Output Current per Module	5.0Adc	3.9A (rms)	10.0Adc	7.0A (rms)	9.5A (rms)
Control Input Voltage	24Vdc		24Vdc		24Vdc

2.1.1. Overload, Over-current, and Over-speed Protection

Section 54.1: Degree of protection

Refer to TABLE 5-7 Detailed guidelines for calculating protective parameters.

Section 54.2: Thermal motor protectors

Refer to Section 4.4.3.5 Motor Temperature, for thermal switch and sensor specifications.

Section 54.3: Equipment employing ventilation

The following table outlines all external, user replaceable fuses.

TABLE 2-3 External, user replaceable fuse for Regen Termination Resistor

Fuse	Size	Type	Manufacturer	Part Number
Located in holder on top of unit	1.5 Amp Fast-Acting	600Vac/dc	LittleFuse®	KLKD001.5

Section 54.4: Supply source with specific over-current protective device

A recommended maximum input current protection device must be specified for each product. This value should be equal to the specified input current rating of the module. Properly sized circuit breakers shall be used for over-current and short-circuit protection.

Section 54.5: **Not incorporating over-speed protection**



Warning

Facilities for over-speed protection are not provided in the control unit. Therefore, when facilities for over-speed protection are required for the end-product, they will have to be provided separately by the end-user.

2.1.2. Branch Circuit Short Circuit Protection

Section 55.1: Short circuit rating and fuse information

Suitable for use on a circuit capable of delivering not more than 5,000 rms symmetrical amperes, 250 volts maximum.

2.1.3. Wiring Terminal Markings

Section 57: Wire Terminal Markings

Refer to FIGURE 4-2 Wiring diagram, for correct terminal connections. Chapter 4 MOUNTING AND WIRING, also contains all needed specifications regarding proper wire type and size.

2.2. General Safety Guidelines

Under certain circumstances it is not enough to just power off the unit. For instance under emergency situations the unit should be completely disconnected from any power supply. The E-Stop and Left/Right Limits on ACS-Tech80 products are designed for use in conjunction with customer installed devices to protect driver load. The end user is responsible for complying with all Electrical Codes.

2.2.1. Emergency Stop

An emergency stop device shall be located at each operator control station and other operating stations where an emergency stop may be required. The emergency stop device shall disconnect any electrical equipment connected to the unit from the power supply. It will not be possible to restore the circuit until the operator manually resets the emergency stop. In situations with multiple emergency stop devices the circuit shall not be restored until all emergency stops devices are manually reset.

2.2.2. Electrical Separation

Electrical separation is required between the control and power supply cables to prevent electrical shock or damage to the equipment.

2.2.3. Over-Current Protection

Properly sized circuit breakers shall be used for over-current protection.

2.2.4. Power Supply and Motor Cable Ground

The power supply cable and the motor cable must have a ground wire that is connected to the protective earth terminal located on the motor and power connectors. A connection must also be made between the protective earth screw (located on the top of the unit) and the equipotential bar inside electrical enclosure.

2.2.5. Thermal Detection

Suitable thermal detection shall be installed to interrupt the power circuit where abnormal temperatures can cause a hazardous condition.

2.2.6. Over-Travel Protection

Over-travel limit protection shall be provided where over-travel is hazardous. The over-travel limiting device shall be installed to interrupt the power circuit.

2.3. General Wiring and Electromagnetic Compatibility (EMC) Guidelines

2.3.1. Routing Signal and Power Cables

Power cables (to the motor, mains outlet, etc.) and signal cables (to I/O, encoder, RS-232, etc.) must be kept as far apart as possible. Keep at least an inch (~2.5 cm) for each 3 feet (~1 m) of parallel run.

For example, if the motor and encoder cables run parallel for 6 feet (~2 m), maintain a 2 inch (~5 cm) separation between them.

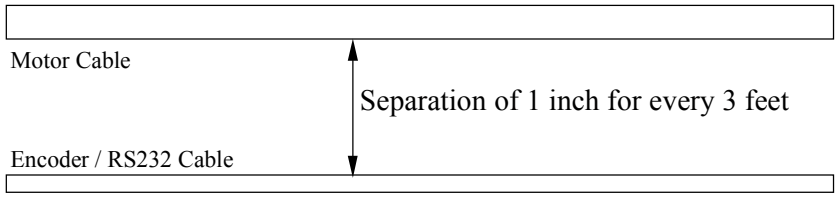


FIGURE 2-1 Cable Spacing

It is recommended to use cables that are completely shielded.

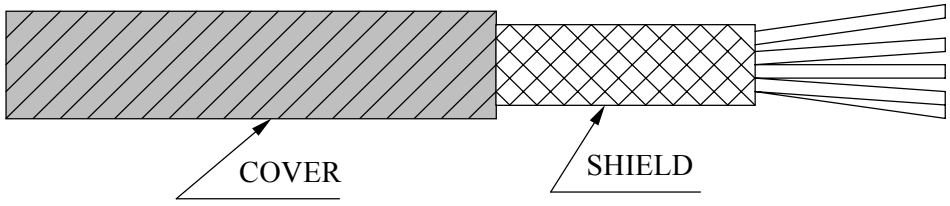


FIGURE 2-2 Shielded Cable

2.3.2. Cable Lengths

Use short cables as much as possible, and route cables as far from other EMI sources as possible.

2.3.3. Shielding

To reduce EMI radiation, do the following:

- Attach the cable shield with a 180° metal clamp to a dedicated paint-free area around the unit.
- Install a ferrite core around the cable as close to the unit as possible to reduce.

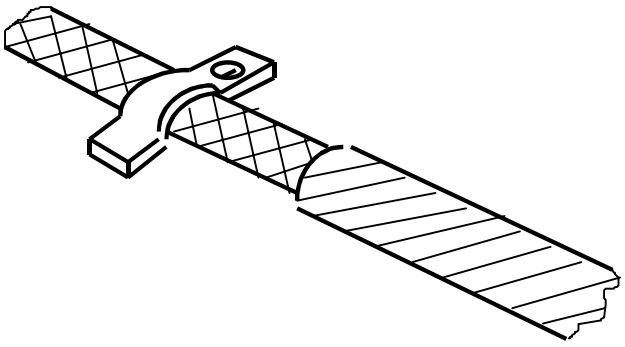


FIGURE 2-3 Improved Shielding

2.3.4. Grounding the Control Module Box

1. Connect the control module box's ground point (PE screw) to the nearest machine chassis ground point.
2. Connect the motor chassis to the machine chassis ground.
3. Avoid ground loops.

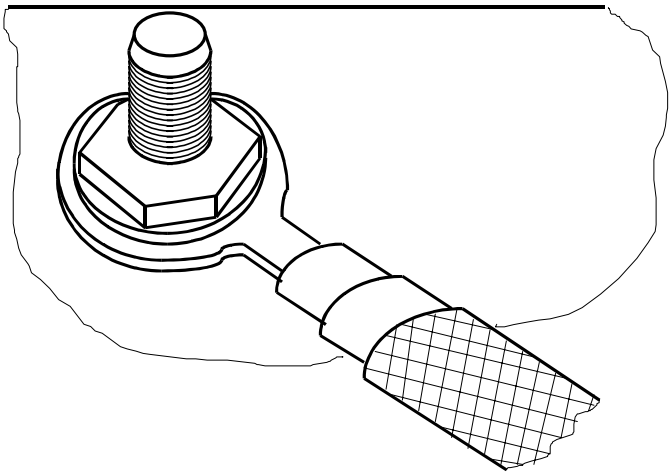


FIGURE 2-4 Case shielding (top of control module)

3. FEATURES & SPECIFICATIONS

3.1. Main Features

3.1.1. Fully Programmable Stand-Alone and Host-Interfaced Operation

- Easy to program using ACSPL, a powerful high level language common to all ACS-Tech80 SB control modules
- 32k of user-programmable memory
- General Purpose I/O: 8 inputs and 8 outputs, all opto-isolated
- One 12-bit analog input that can be used for feedback, such as, force and position control
- One 10-bit analog output for monitoring and auxiliary control functions
- Powerful I/O handling with advanced PLC capabilities
- Teach & Go for up to 1,024 points
- Built-in smart joystick interface
- RS-232/422/485 high-speed serial communications interface, up to 57,600 baud rate

3.1.2. Special Features for Demanding Applications

3.1.2.1. Master/Slave

This mode is characterized by its following accuracy, superimposed move capability, ability to switch "on-the-fly" from slave mode to velocity mode and vice versa through comprehensive software support. This feature has proven itself in challenging applications such as industrial flying shears, coil winding, multi-color printing and high-accuracy scanning and plotting.

3.1.2.2. Registration

This feature allows the destination position of the axis to be changed on-the-fly based on the position of an external sensor captured during a move. Registration has a variety of uses including labeling and high-speed printing. The 'Search-For-Contact' registration mode is specifically designed for pick and place applications, such as wire bonding, die attachment and SMD assembly.

3.1.2.3. Position Event Generator (PEG)

The PEG function generates real time, position-triggered output to activate external events based on position. It has a position compare accuracy of ±1 count at up to 5 million counts/second, and is designed for such demanding applications as high accuracy laser cutting and automatic optical inspection (AOI) and scanning systems.

3.1.3. Universal Digital Drives

- 5A to 15A continuous (10A to 30A peak), up to 370Vdc
- Software configurable for AC servo (AC synchronous), DC brush and AC induction motors
- High performance digital current control
- State of the art 20kHz PWM power bridge with optimized current ripple and efficiency
- Sinusoidal commutation with automatic setup for three-phase motors

3.1.4. Outstanding Performance and Capabilities

- Fully digital position, velocity, and current control at 20kHz sampling rate, for excellent dynamic and tracking performance
- Special built-in features and support for AC servo (AC synchronous) linear motor applications
- Dual loop capability supports two encoders, one mounted on the motor and one on the load, for accurate belt-driven and lead-screw based applications

3.1.5. Comprehensive Safety, Diagnostics, and Protection

- Programmable automatic routine for each fault, error, and exception
- Real-time data collection of one or two variables, programmable sampling rate up to 1kHz.
- Two separate power supplies: 24Vdc backup supply for the control section, 85 to 265Vac for the power section
- 7-Segment display for error, status, and programmable messages
- CE marked, meets European safety standard EN60204-1 and EMC standards EN50081-2 (emission) and EN50082-2 (immunity)

3.1.6. Powerful Programming and Support Tools

- ACS Adjuster for Windows: Interactive tool for setting up and tuning
- ACS Debugger for Windows: Development environment for ACSPL applications
- ACS Saver/Loader for Windows: Tool for copying system setup and application data from one controller to another
- ACSLIB C Libraries: Comprehensive C, C++, and Visual Basic libraries for DOS, Windows 3.11/ 95/ 98/ 2000/ NT and Linux

3.2. Product Specifications

3.2.1. Position Control

Sampling Rate: 20kHz
Control Algorithms: Pgain, acceleration feed-forward, automatic velocity feed-forward, anti-reset windup
Trajectory Calculation Rate: 1kHz
Range: ±999,999,999 counts
Accuracy: ±1 encoder count
Position Feedback:
Primary: Incremental encoder (+ Hall) or resolver
Secondary: Incremental encoder only
Encoder: Incremental, 3 channel (A, B, I), differential line drivers, 0-5V
Supply Voltage: 5V
Maximum current consumption from onboard supply: 100mA per encoder (200mA total) (Use external supply if higher current is needed)
Hall: 3 channel, 0-5V or equivalent commutation tracks
Resolver (option must be specified with order):
Onboard RDC: 12-bit resolution (4096 counts/rev), 1kHz bandwidth
Reference Frequency: 5-7kHz
Reference voltage: 4V ±20% rms
Reference current (@5kHz): <25mA rms
Transformation Ratio: 0.5
DC Resistance: Rotor >15Ω
Stator>40Ω
Pole Pairs: 1
Dual Loop Capability: Primary feedback (encoder only) for velocity and commutation, secondary feedback (encoder only) for position
Position Registration Delay: <1µsecond
Position Event Generator (PEG™):
Output: Differential line driver, 0-5V
Delay: <0.2µsecond
Position Compare Accuracy: ±1 count at up to 5,000,000 counts/second
Repetition Rate:
Random Mode: 5 events/0.001second
Incremental Mode: Up to 1MHz

3.2.2. Velocity Control:

Sampling Rate: 20kHz
Control Algorithm:
PI + second order low pass filter
Range: Up to 128,000,000 counts/second
Resolution: 1 count/second
Incremental Encoder Count Rate:
Up to 32,000,000 counts/second
Velocity Accuracy:
Long Term: 0.005%
Short Term: 0.01%-0.5% (system-dependent)
Acceleration Range: Up to 2,000,000,000 counts/second^2
Acceleration build-up time (Smooth Factor): 1-255 millisecond

3.2.3. Communications

Standard:
RS-232/422/485, up to 57,600 baud

3.2.4. Drive

Type: PWM, digital current control
PWM Frequency: 20kHz
Motor Types: AC induction, DC brush, AC servo/synchronous (DC brushless)
Current Loop Sampling Rate: 20kHz.
Control Algorithm: PI
Current Resolution: 12-bit
Bus Voltage: 120-370Vdc (85-265Vac)
Phase Current
(Sine Wave Amplitude):
SB1391A: 5A Continuous, 10A Peak (1 sec.)
SB1391B: 10A Continuous, 20A Peak (1 sec.)
SB1391C: 15A Continuous, 30A Peak (1 sec.)
Minimum Inductance: 0.5mH
Current Ripple:
<0.25A (320Vdc, 6A, L=2mH)

3.2.5. I/O

Safety Inputs:
Left limit, right limit, E-stop
General Purpose Inputs: Eight
General Purpose Outputs:
Eight, 50mA/output, maximum total current 350mA, fully protected against overloads
Features Common to Safety & General Purpose I/O:
Fed by common external supply via the I/O connector
Type: Source, opto-isolated (contact factory for other configurations)
Response Time: <1msecond
External Supply Range: 5Vdc (±10%) or 24Vdc (±20%), detected automatically
Analog Input:
Differential, ±10V, 12-bit resolution
Analog Output:
Single ended, ±10V, 10-bit resolution

3.2.6. Power

Separate Supplies: Drive and Control (For I/O supply, see I/O section above)
Drive: 85-265Vac, single phase or three phase
Control (Backup): 24Vdc (±20%), 1.5A, 30W
Regeneration:
Built-in: R = 150 (±10Ω), 100W
External: Power resistor with R>15Ω
Recommended Power: >200W

3.2.7. Controller

Dual Processor Architecture:
• 20MHz Intel 80C196KD for high-level tasks and management
• 80MHz SB2500 ACS Servo Processor for real-time control tasks
Memory:
Firmware: 256k
RAM: 256k
Nonvolatile Memory:
128k, 100,000 write cycles
User Program Memory: 32k

3.2.8. Dimensions

Size: H 272mm x W 106.5mm x D 168mm (H 10.7" x W 4.2" x D 6.6"

4. MOUNTING AND WIRING

TABLE 4-1 Topics covered in this chapter

Topic	Description
Mounting	Mounting guidelines, operating temperatures, front and side view of the control unit, dimensions, and recommended clearances
Wiring diagram	For quick understanding of the control unit connections
Power connections	Wiring details for power connections (Drive supply, Control supply, Motor, Regen, and Fan 24Vdc)
Control connections	Wiring details for control connections (RS-232/433, CAN, Encoder1+Hall/Resolver, Encoder2, I/O + Safety. and HSSI/PEG)
Indicators, Switches, and Test Points	Functional description of the other elements of the control unit front panel

4.1. Mounting

Mounting guidelines:

- Mount only on a well grounded surface.
- Do not mount units on top of each other.
- The support surface should be a rigid, non-vibrating object, such as, a wall or rack.
- Keep the environment free from corrosive chemical vapors, oil, steam, metal particles, moisture, or dust.

The ambient temperature must be maintained between +5 C and +45 C.

If the heat sink temperature reaches 70º C, the over-temperature protection is activated and the motor is shut down. To prevent overheating, an external fan must be used. The control module has a (fused) fan supply output. For information about the fan supply connection, refer to Section 4.3.4, "Fan 24Vdc Connector."

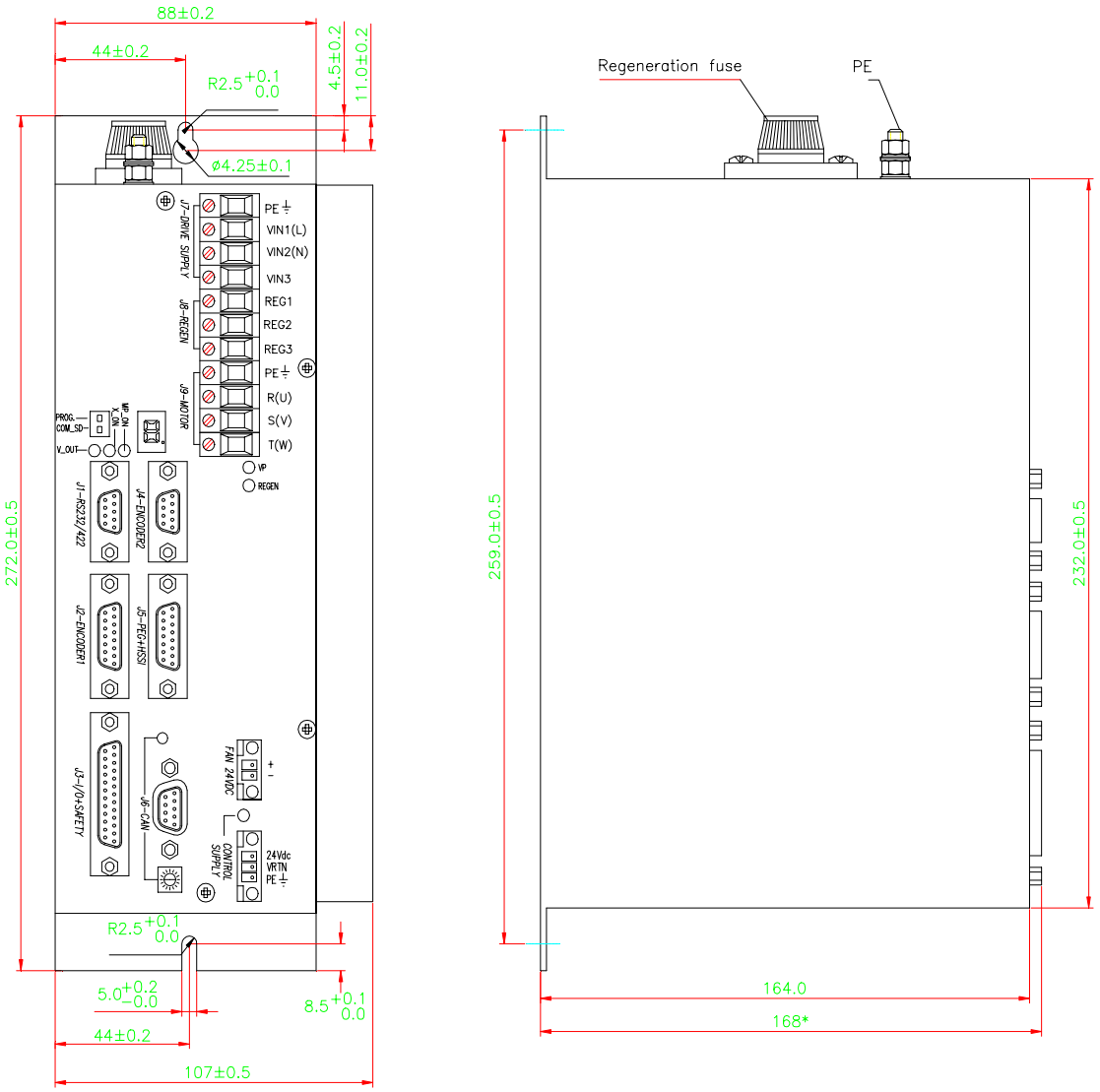


FIGURE 4-1 SB1391 mounting dimensions



Warning

The SB1391 must be enclosed or incorporated into an end-product in accordance with the EN 60204-1 standard (latest version) for electrical shock, environmental (IP), and earthing requirements.

TABLE 4-2 Minimum recommended clearances

Location	Clearance
Each side	10 mm (A in FIGURE 4-1)
Top and bottom	15 mm (B in FIGURE 4-1).

4.2. Wiring Diagram

Note

Note

Connection to any other equipment (e.g., for supply, communications, data processing, etc.) must be only to either Class III Type equipment or to equipment that is approved for an applicable Low Voltage Directive standard.



Warning

Do not turn on the power while making connections. Doing so could result in severe bodily injury or damage to the unit.

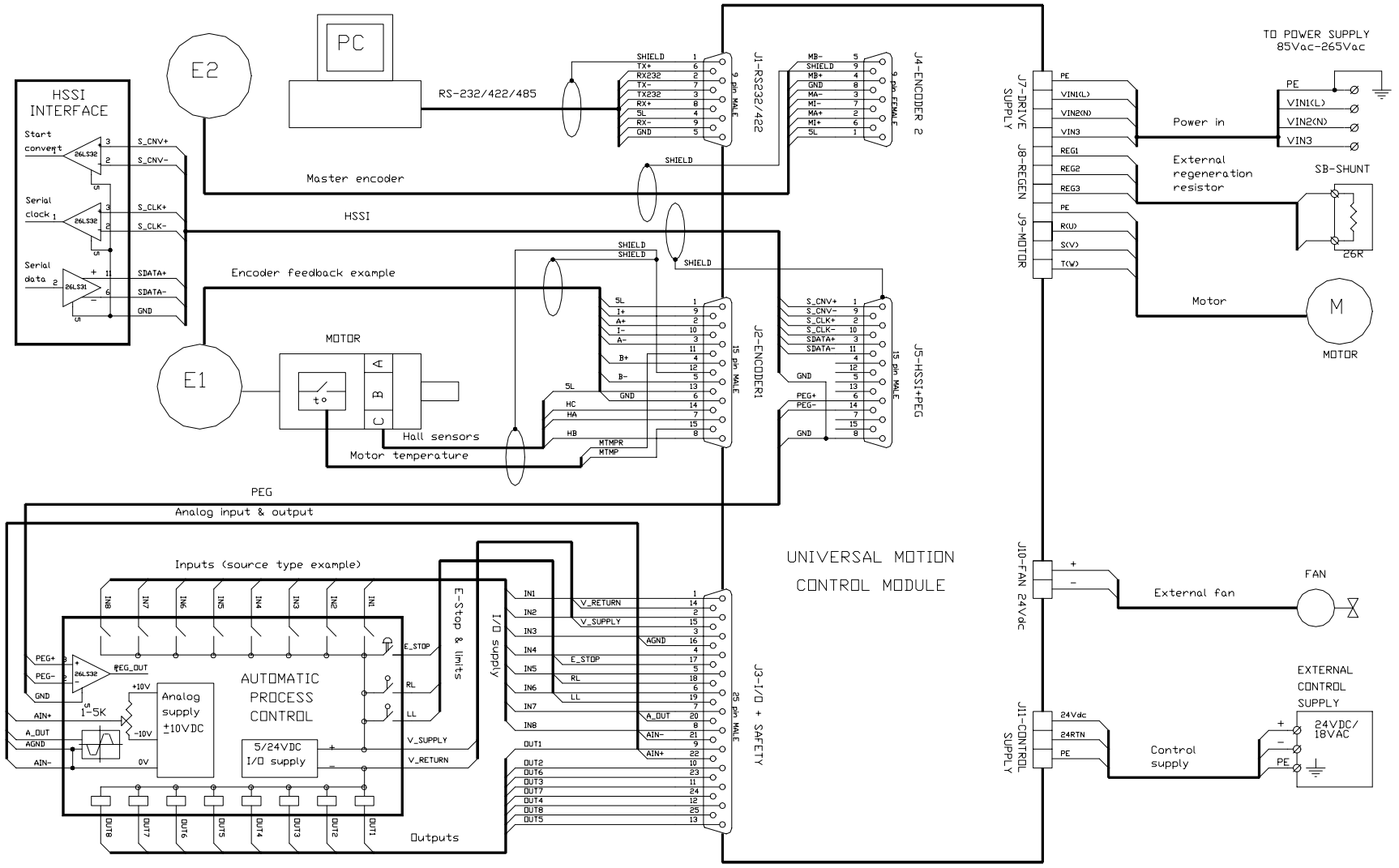


FIGURE 4-2 Wiring diagram

4.3. Power Connectors



Warning

Do not turn on the power while making connections. Doing so could result in severe bodily injury or damage to the unit.

TABLE 4-3 Power connectors

Power Connectors
Drive Supply
Control
Motor
Fan 24Vdc
Regen (external regeneration resistor)
Power Supply



Warning

Do not solder wires before insertion into the connector. Solder will contract and cause a loose connection over time.

Wire should be stripped 7mm (as shown in FIGURE 4-3).

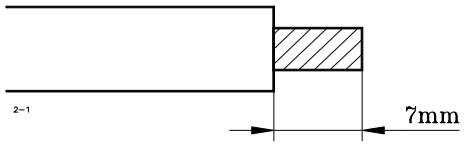


FIGURE 4-3 Wire stripping dimension for terminal block connections

4.3.1. Drive Supply and Control Supply Connectors

The supply to the drive power section is separate from the supply to the control section. This separation makes it possible to maintain position information, communication, and ACSPL program execution in the event that power must be removed for safety reasons.

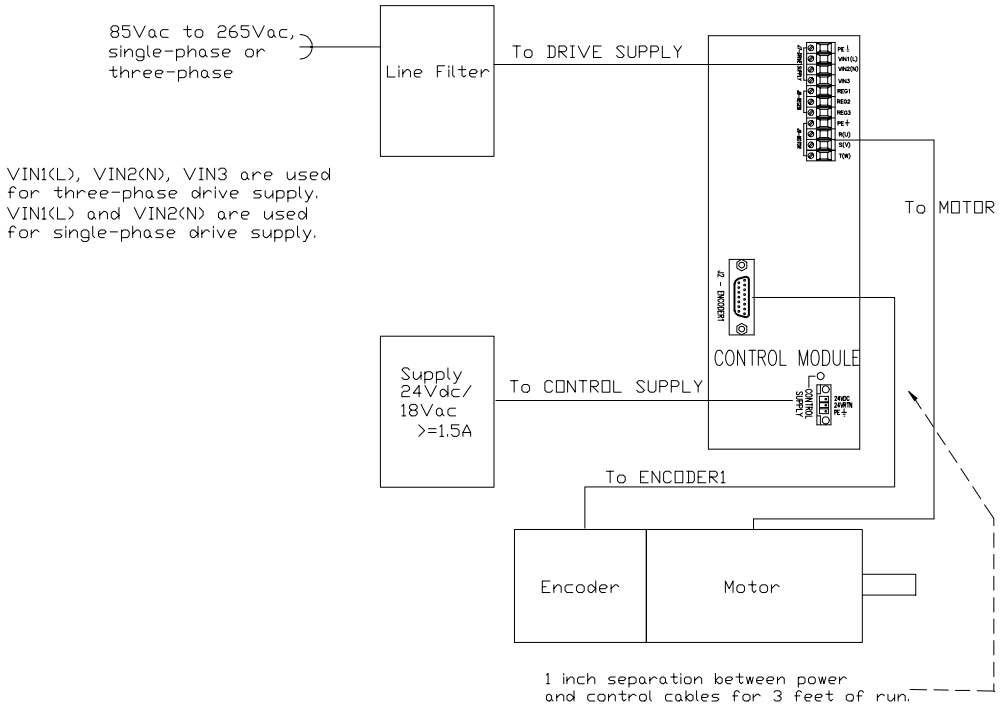


FIGURE 4-4 Power supplies and suggested use of line filter

Further information

More guidelines for grounding and shielding can be found in Section 2 SAFETY AND EMC GUIDELINES.

4.3.1.1. Drive Supply Connector (J7)

Warning

The SB1391 is designed to run directly off single-phase or three-phase 85Vac to 265Vac. DO NOT use 380/400 Vac supply. It will destroy the unit!

Warning

If the SB1391 is intended to be used with a secondary supply circuit, the supply must be a suitably European Approved power supply.

The Drive Supply connector is a terminal block connector (accepts wires directly).

Use 16 to 14 AWG wire for the Drive Supply connector.

The AC input to the power section can be single-phase or three-phase. Use 85Vac to 265Vac supply voltage.

VIN1(L), VIN2(N), VIN3 are used for three-phase drive supply.

VIN1(L) and VIN2(N) are used for single-phase drive supply.

Internal protection against over-current and short circuit make it unnecessary to use expensive external over-current protection devices, such as breakers with adjustable current protection.

Therefore standard external breakers are recommended for drive supply. Ratings are in TABLE 4-4.

TABLE 4-4 Single-phase drive supply current level

Model	Input current at nominal load [A_{rms}]	Circuit breaker current rating [A_{rms}]
SB1391A	7	10
SB1391B	14	20
SB1391C	22	25

TABLE 4-5 Three-phase drive supply current level

Model	Input current at nominal load [A_{rms}]	Circuit breaker current rating [A_{rms}]
SB1391A	5.5	10
SB1391B	10.5	16
SB1391C	16	20

TABLE 4-6 Drive supply connection pins

Pin	Description
PE	Protective Earth.
VIN1(L)	Power input 1
VIN2(N)	Power input 2
VIN3	Power input 3

4.3.1.1.1. Line Filter

To meet CE requirements, a line filter is required between the AC power supply and the Drive Supply connector (see FIGURE 4-4). Suitable filters are manufactured by Corcom™ (http://www.corcom.com/).

TABLE 4-7 Corcom line filters for single-phase power supply

Controller model	Input current at nominal load [Arms]	Corcom part no.
SB1391A	7	12FC10
SB1391B	14	16FC10
SB1391C	22	25FC10

If a single-phase line filter from a different manufacturer is used, it should have a circuit similar to the Corcom line filters shown in the following figures.

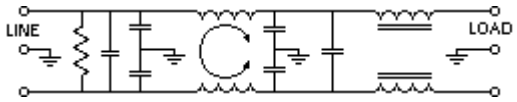


FIGURE 4-5 Electrical schematic of 12A, and 16A line filter for single-phase

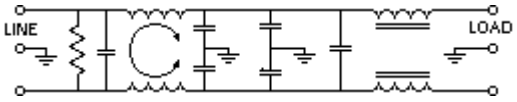


FIGURE 4-6 Electrical schematic of 25A line filter for single-phase

Suitable three-phase line filters available from Corcom are listed in the following table.

TABLE 4-8 Corcom line filters for three-phase power supply

Controller model	Input current at nominal load [Arms]	Corcom part no.
SB1391A	5.5	6FCD10
SB1391B	10.5	12FCD10
SB1391C	16	16FCD10

If a three-phase line filter from a different manufacturer is used, it should have a circuit similar to the Corcom line filters shown in the following figures.

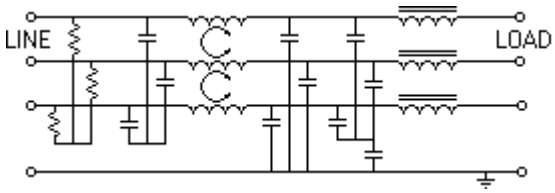


FIGURE 4-7 Electrical schematic of 6A line filter for three-phase

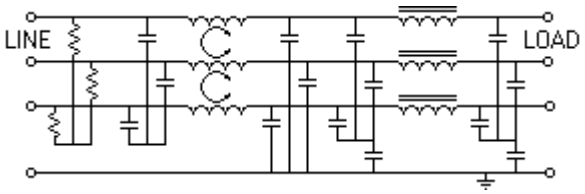


FIGURE 4-8 Electrical schematic of 12A and 16A line filter for three-phase

4.3.1.1.2. Drive Supply Fuses

There are three internal fuses for drive supply protection and one internal fuse for VP bus circuit protection.



Warning

Only ACS-Tech80 authorized service personnel are permitted to replace internal fuses or perform any other servicing operations.

4.3.1.1.3. Phase-Loss Protection Mechanism

When three-phase drive supply is used, phase-loss protection is available by removing jumper JP2 from the driver board. Note, however that the driver cannot be operated in single-phase until the jumper is reinstalled. This is because the control module will interpret the lack of a third wire (only two are used for single phase) as a phase-loss.

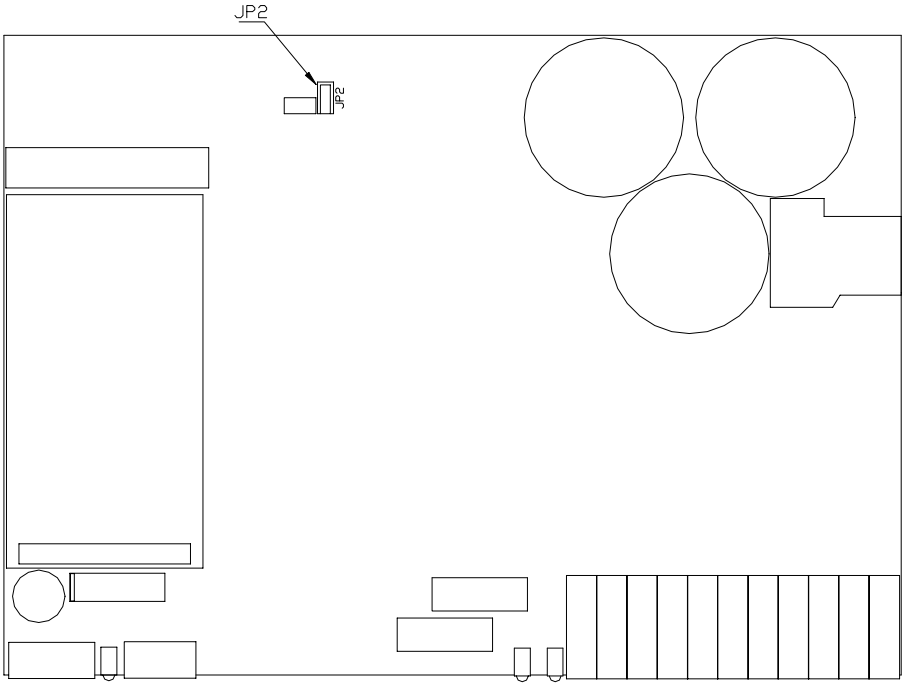


FIGURE 4-9 Jumper JP2 (factory default: installed) on driver board

4.3.1.2. Control Supply Connector (J11)

The Control Supply is a header plug-in connector manufactured by Phoenix Contact™ (http://www.phoenixcontact.com/), part number MC 1,5/3-GF-3,81. It mates to plug part number MC 1,5/3-STF-3,5.



Warning

If the SB1391 is intended to be used with a secondary supply circuit or DC supply, the supply must be a suitably European Approved supply.

Use 22 to 18 AWG wire for the Control Supply connector.

Use 24Vdc or 18Vac supply, minimum 1.5A.

The logic and control are powered through this connector. In an emergency, when the high power to the motor has to be cut off, control supply can remain alive. This means the position feedback is not lost and the ACSPL program execution is not interrupted.

TABLE 4-9 Control supply connection pins

Pin	Description
+24VDC	24 Vdc ±10% or 18 Vac ±10%
-24vrtn	24 Vdc return or 18 Vac return
PE	Protective earth

4.3.2. Motor Connector (J9)

The Motor connector is a terminal block connector (accepts wires directly).



Warning

Motor connector wiring and output must be in accordance with the relevant safety requirements of the EN 60204-1 standard (latest version).

Use 16 to 14 AWG wire for the Motor connector.

The unit works with the following types of motor:

- Three-phase DC brushless (AC servo/AC synchronous) with sinusoidal commutation
- Three-phase AC induction.
- DC brush

The connection procedure for each type of motor is described later in this section.



Warning

It is important to record the motor phase connection order. If the motor or controller is replaced, make the connection in the same order. Otherwise the motor will not function properly and a new commutation setup will be necessary.

TABLE 4-10 Motor connection pins

Pin	Description
PE	Protective Earth. Motor should be grounded via this pin. In addition, it must be grounded locally.
R(U)	Motor phase R.
S(V)	Motor phase S.
T(W)	Motor phase T.

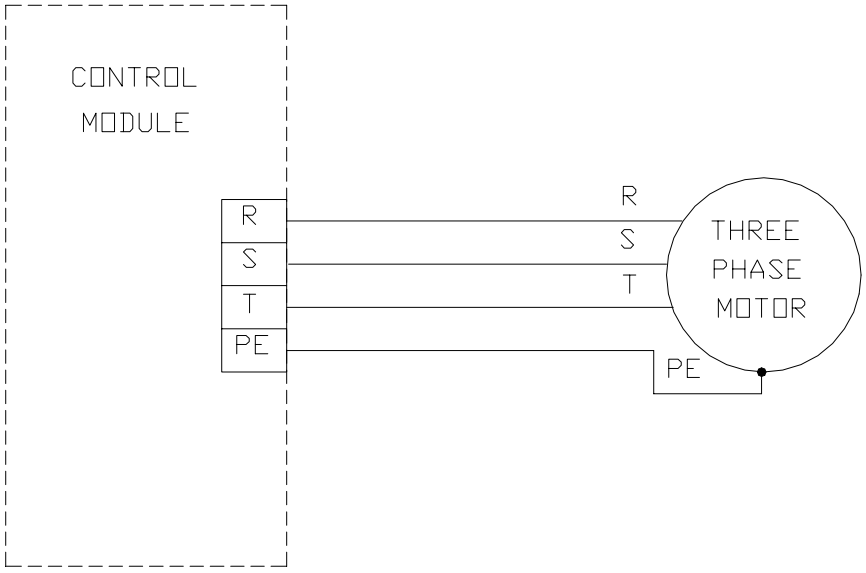


FIGURE 4-10 Three-phase motor connection

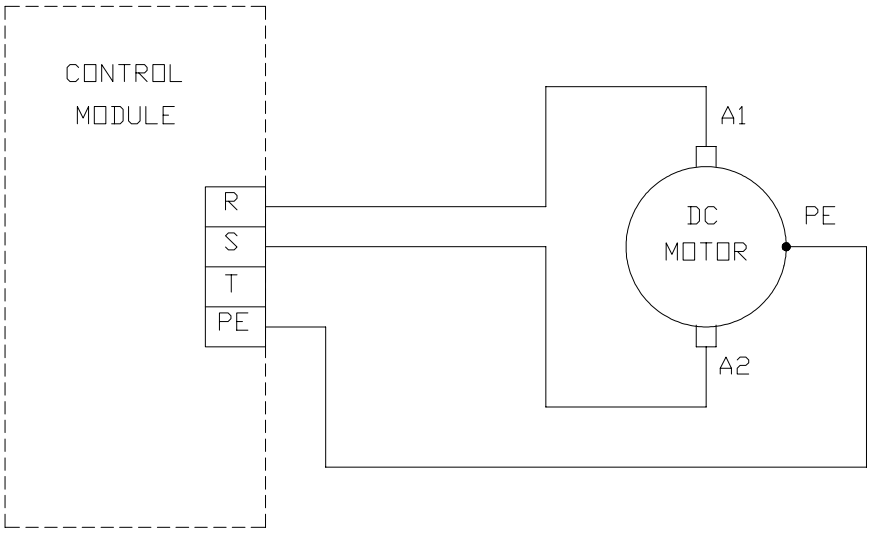


FIGURE 4-11 Single-phase (DC brush) motor connection

4.3.3. Regen Connector (J8)

The Regen connector is a terminal block connector (accepts wires directly).

Use 16 to 14 AWG wire for the Regen connector.

TABLE 4-11 Regen Connector

Pin	Description
REG1	For the internal regeneration resistor option, connect via external jumper to REG3. For external regeneration resistor option, not used.
REG2	For internal regeneration resistor option, not used. For external regeneration resistor option, connect to a lead of the external regeneration resistor.
REG3	For internal regeneration resistor option, connect via external jumper to REG1. For external regeneration resistor option, connect to the other lead of the external regeneration resistor.

The power supply unit is fitted with an internal 140Ω, 100W regeneration resistor.

In applications with very high inertia loads, the internal regeneration resistor sometimes can't absorb all the motor's regeneration energy, causing over-voltage protection to be activated. In such cases, the internal resistor must be bypassed using an external resistor with a higher power rating. The resistance of the external resistor must be >= 15Ω.

Further Information

More detailed information about the external regeneration resistor calculation is contained in Chapter4.3.3.

A 26Ω, 600 W external regeneration resistor is available from ACS-Tech80. The part number is SB-SHUNT.

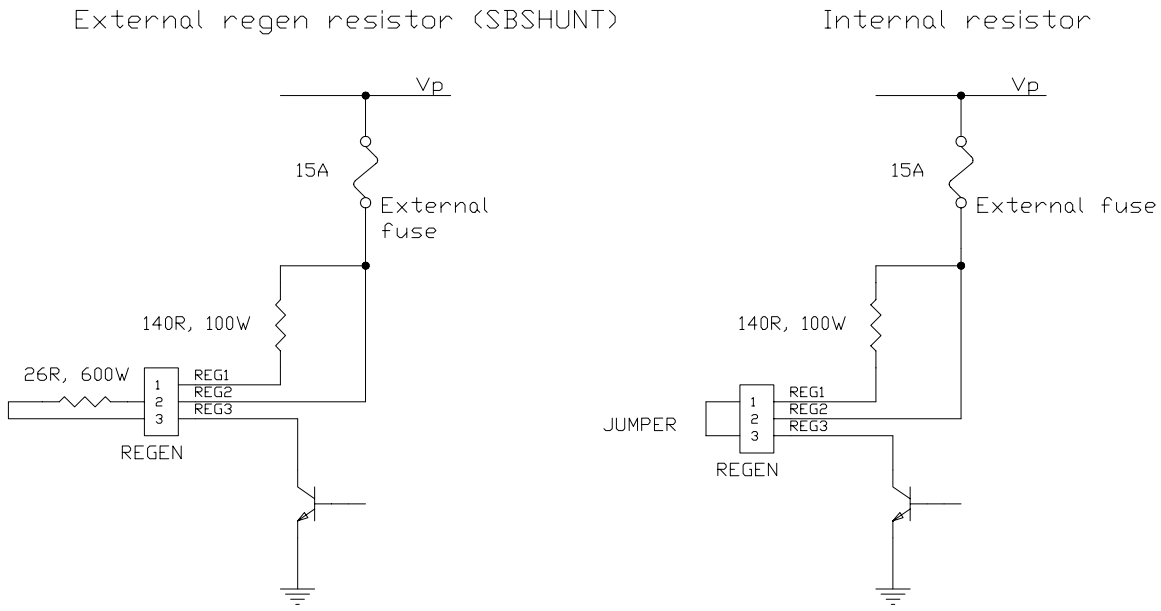


FIGURE 4-12 Regeneration resistor - external and internal

To connect the external resistor, do the following:

- 1. Disconnect the unit and wait until the Vp LED goes out.
- 2. Remove the (factory installed) short wire from the Regen connector to disconnect the internal regeneration resistor.
- 3. Connect the external resistor between the REG2 terminal and the REG3 terminal of the Regen connector.

4.3.3.1. Regeneration Resistor Fuse

There is an external fuse for regeneration circuit protection. The external fuse is in a fuse holder located at the top of the control module.

The recommended fuse specifications are:

Fast-acting

Current rating: 15A

Voltage rating: 600Vac/dc

Interrupting rating:

AC: 100,000 amperes rms symmetrical

DC: 10,000 amperes

Dimensions: 13/32" diameter x 1-1/2" length (10mm x 38mm)

Fuses meeting this specification are available from Bussmann (http://www.bussmann.com/) part number KLM-15 and from Littelfuse (http://www.littelfuse.com/), product no. KLKD-15.

TABLE 4-12 Fuse replacement procedure

Step	Name
1.	Power off the control module.
2.	Remove fuse holder (threaded cap located on top of the control module).
3.	Remove old fuse from fuse holder. Old fuse can be discarded.
4.	Insert new fuse into fuse holder.
5.	Insert fuse holder into control module and thread into place.
6.	Power on the control module.

4.3.4. Fan 24Vdc Connector (J10)

The Fan 24 Vdc is a header plug-in connector manufactured by Phoenix Contact, part no. MC 1,5/2-GF-3,81. It receives plug part number MC 1,5/2-STF-3,5.

Use 24 to 18 AWG wire for the Fan connector.

When the ambient temperature is above 25° C and the control module is operated at full power, the heat sink temperature can reach 75 ° C, which will shut off the power stage. To prevent this, forced air cooling is required.

It is recommended to use a 24 Vdc fan, which can be supplied from this connector. The fan wires should be 24 to 18 AWG.

4.4. Control Connectors



Further information

An overview of ACSPL parameters for programming the hardware interface (serial connection, I/O, display, etc.) can be found in Chapter 6, "Hardware Interface Parameters." More detailed information can be found in the *ACS Software Guide*.

TABLE 4-13 Control connectors

Control Connectors
RS-232/422
CAN
Encoder 1+Hall / Resolver
Encoder 2
HSSI / PEG
I/O + Safety

Use 24 to 20 AWG wire with the control connectors.

4.4.1. RS-232/422 Connector (J1)

The serial connector is D-type, 9 pin, male.

TABLE 4-14 Serial connector pins

Pin	Name	Description
1	SHIELD	RS-232/422/485 shield
2	RX232	RS-232 receive signal
3	TX232	RS-232 transmit signal
4	5L	+5Vdc supply
5	GND	RS-232 ground
6	TX+	RS-422/485 positive transmit signal
7	TX-	RS-422/485 negative transmit signal
8	RX+	RS-422/485 positive receive signal
9	RX-	RS-422/485 negative receive signal

When making the serial connection, verify that the PC receive is wired to the control module transmit and the PC transmit is wired to the control module receive.

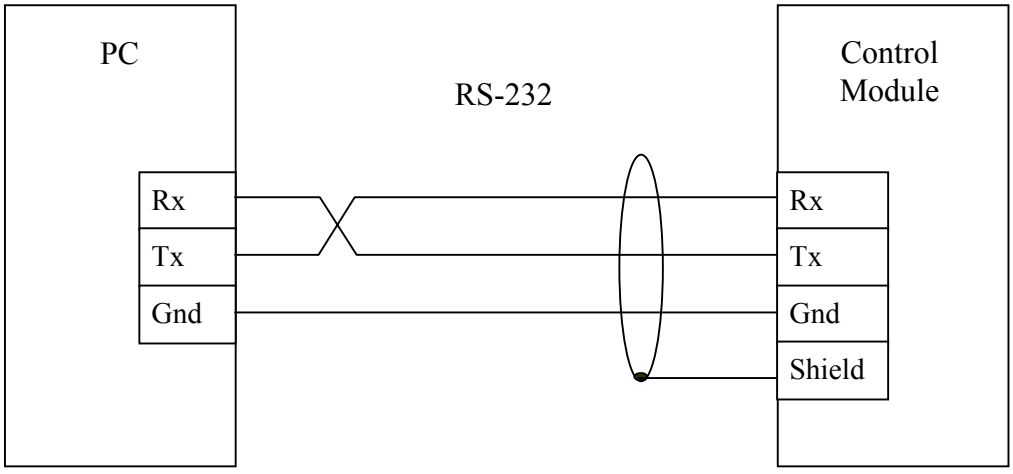


FIGURE 4-13 RS-232 connection

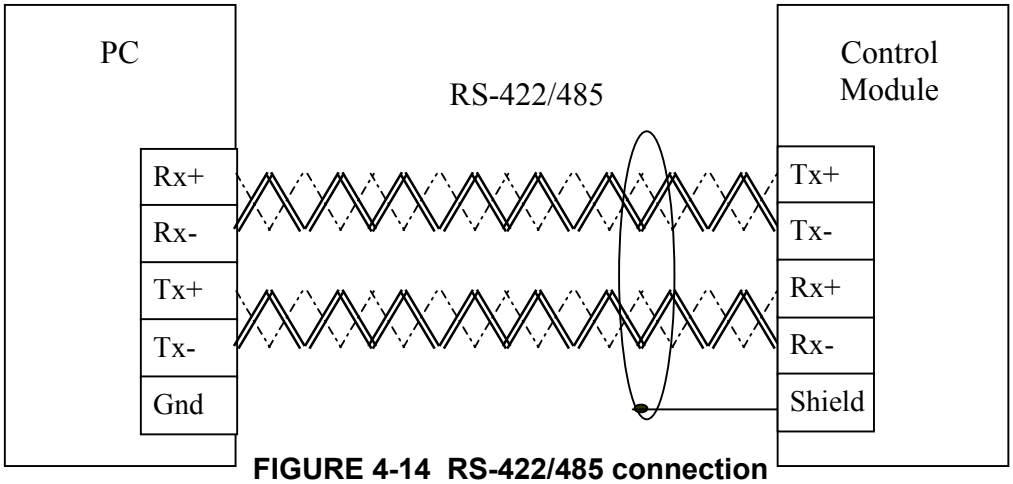


FIGURE 4-14 RS-422/485 connection

4.4.1.1. Partial Communications Shutdown

To prevent unauthorized interference with the operation of the controller, turn on the **COM_SD** DIP switch on the front panel of the control module.



Warning

For CAN communication, COM_SD must be OFF.

4.4.2. CAN Connector (J6)

The optional CAN bus connector is D-type, 9 pin, male.

The CAN support option must be specified in the product order.

Up to 127 devices can be connected on the same CAN line.

TABLE 4-15 CAN connector pins

Pin	Name	Description
1	NU	Reserved
2	CANL	CAN bus negative signal
3	CGND	CAN bus supply ground
4	NU	Reserved
5	SHIELD	Cable shield / screen
6	CGND	CAN bus supply ground
7	CANH	CAN bus positive signal
8	NU	Reserved
9	VCAN+	CAN bus supply 9Vdc to 28Vdc

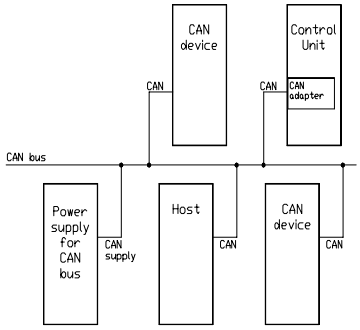


FIGURE 4-15 CAN bus

4.4.2.1. CAN Connection Troubleshooting

If a fault occurs with the CAN communication, the CAN indicator lights turns red. Proceed as follows:

TABLE 4-16 CAN connection troubleshooting

Possible Cause	Corrective Action
1. Incorrect mode	Check the CAN rotary switch.
2. CAN communication problem	Verify that the RS-232/422/485 baud rate is one of the following: • 9,600 • 19,200 • 38,400 • 57,600
3. CAN bus supply not reaching CAN connector	Check pins 3 and 9.
4. COM_SD DIP switch on front panel is not OFF.	Turn COM_SD switch OFF.

4.4.3. Encoder 1 Connector (J2)

The Encoder 1+Hall / Resolver connector is D-type, 15 pin, male.



Warning

Facilities for overspeed protection are not provided in the control unit. Therefore, when facilities for overspeed protection are required for the end-product, they will have to be provided separately by the end-user.

The connector supports either encoder (+ Hall) feedback (TABLE 4-17) or resolver feedback (TABLE 4-18), according to the factory configuration. The encoder and resolver interfaces are described separately below.

The connector also supports a motor temperature sensor (MTMP).

4.4.3.1. Incremental Encoder Feedback

TABLE 4-17 Encoder 1 (+ Hall) connection pins

Pin	Name	Description
1	+5L	5V supply to the encoder and Hall
2	A+	Encoder A+
3	A-	Encoder A-
4	B+	Encoder B+
5	B-	Encoder B-
6	GND	Ground for +5L
7	HA	Motor Hall A
8	HB	Motor Hall B
9	I+	Encoder I+
10	I-	Encoder I-
11	MTMPR	A return for temperature sensor. (Internally connected to GND)
12	SCRN	Screen (shield)
13	+5L	5V supply to the encoder and Hall
14	HC	Motor Hall C
15	MTMP	Motor temperature input. A normally-closed sensor must be connected between MTMP pin 15 and pin 11. If no sensor is used, pin 15 must be shorted to pin 11 for proper operation.

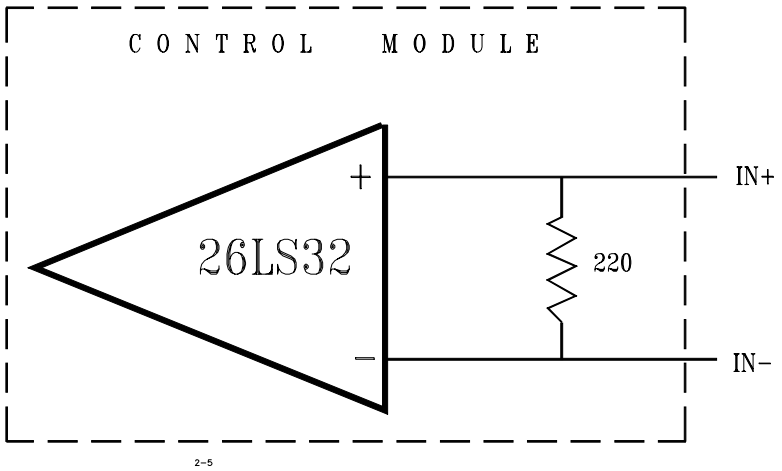


FIGURE 4-16 Encoder interface

Each encoder feedback interface (primary and master) accepts three-channel, differential, TTL level signals.

The input buffer is built around 26LS32 line receivers.

It is recommended to use encoders with built-in line drivers, AM26LS31 or similar.

4.4.3.2. Sensor Inputs

There are three Hall sensors (in motors that include Hall sensors): A, B, and C. The connection for each Hall sensor is shown in FIGURE 4-17.

Instead of Hall sensors, some motors are supplied with encoders that have special commutation tracks. Those tracks can be connected instead of the Hall connection signals.

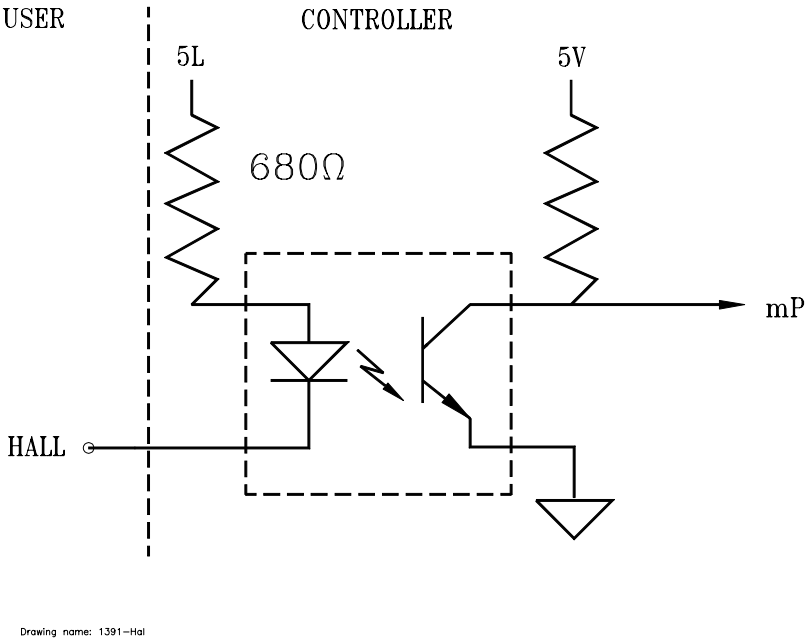


FIGURE 4-17 Hall sensors connection

4.4.3.3. Supply for Encoder and Hall

The encoder and the Hall sensors can be powered by the on-board +5L (5V). The total current consumption must not exceed 0.75A. If the total +5L current consumption (all encoders + Hall) exceeds 0.75A, then an external supply must be used. In such a case, the return of the supply must be connected to GND pin.

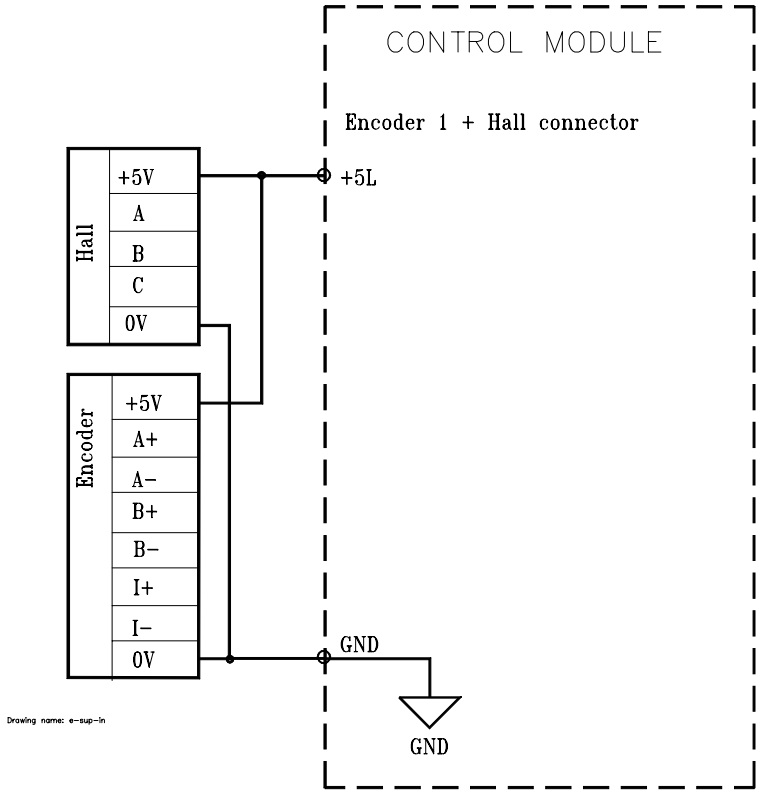


FIGURE 4-18 Internal 5Vdc supply connection for encoder and Hall

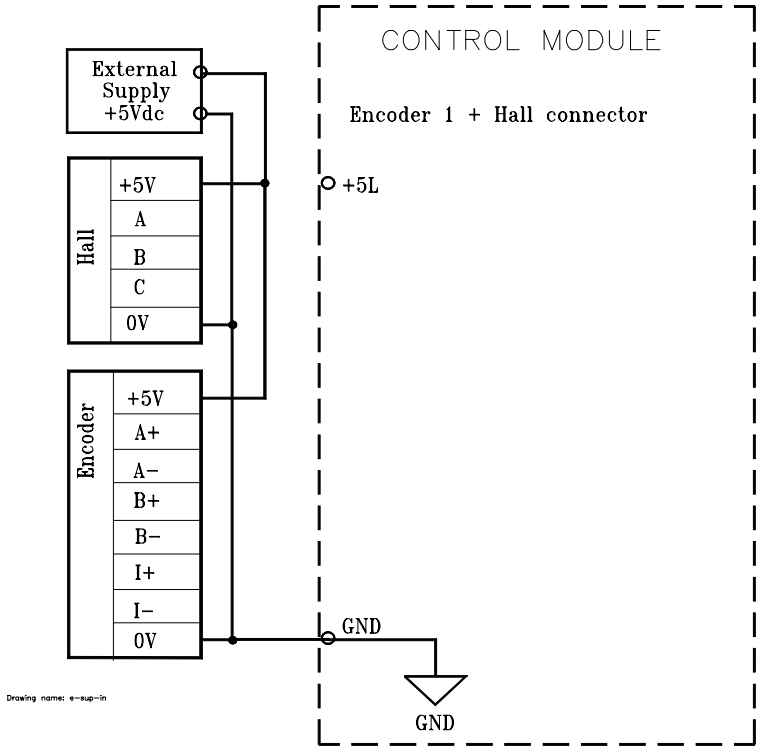


FIGURE 4-19 External 5Vdc supply connection for encoder and Hall

4.4.3.4. Resolver Feedback

TABLE 4-18 Resolver connection pins

Pin	Name	Description
1	+5L	Not used
2	A+	Resolver Cos
3	A-	Resolver Cos L
4	B+	Resolver Sin
5	B-	Resolver Sin L
6	GND	Not used
7	HA	Not used
8	HB	Not used
9	I+	Resolver reference
10	I-	AGND (analog ground) for resolver reference
11	MTMPR	A return for temperature sensor. (Internally connected to GND)
12	SCRN	Screen (shield)
13	+5L	Not used
14	HC	Not used
15	MTMP	Motor temperature input. A normally closed sensor must be connected between MTMP pin 15 and pin 11. If no sensor is used, pin 15 must be shorted to pin 11 for proper operation.

Control unit parameters:

- Reference signal from controller to resolver reference coil: sinusoidal wave, 4V±20% rms, 5kHz to 7kHz.
- Reference current (@5kHz): <25mA rms.
- Cos and Sin inputs to controller from resolver: 0V to 2V ±10% rms.
- Onboard resolver to digital converter (RDC): 12-bit resolution (4096 counts/rev), 1kHz bandwidth.

Resolver parameters:

- Transformation ratio: 0.5.
- DC resistance: rotor >15Ω, stator >40Ω.
- Pole pairs: 1.

Resolver connection:

Cable for resolver connection must be shielded, twisted, triple pair, as shown in FIGURE 4-20.

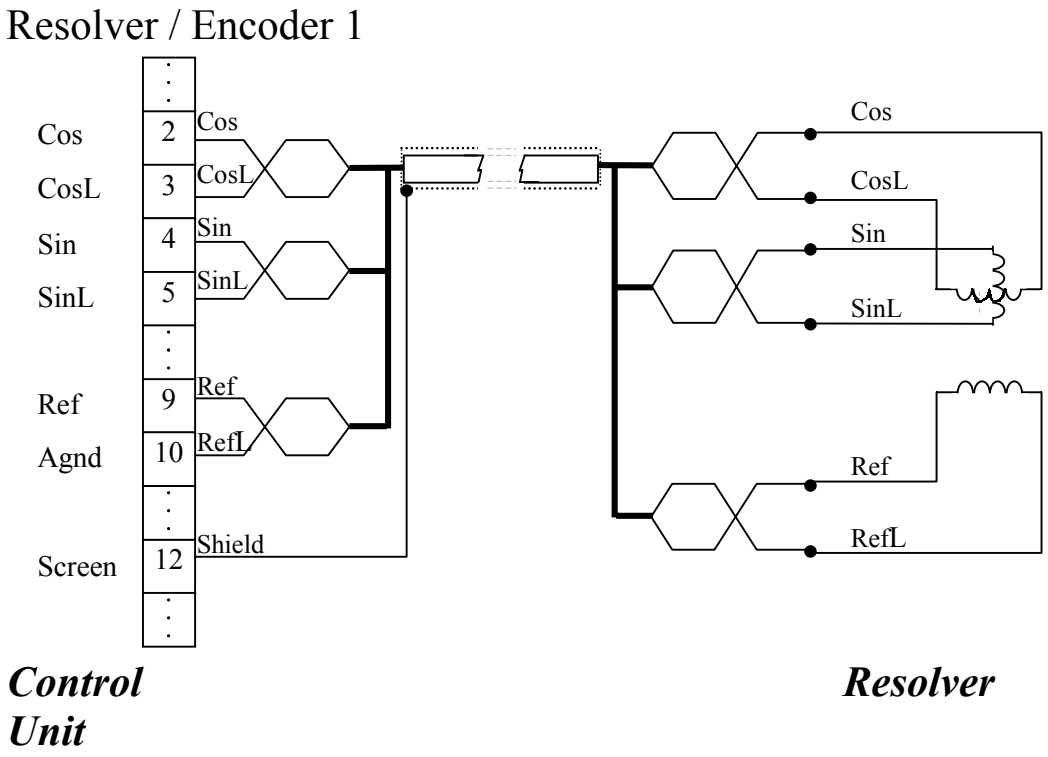


FIGURE 4-20 Resolver connection

4.4.3.5. Motor Temperature

A normally closed switch should be connected between the MTMP pin 15 and the MTMPR pin 11. When the temperature of the motor exceeds the limit, the switch must open (FIGURE 4-21).

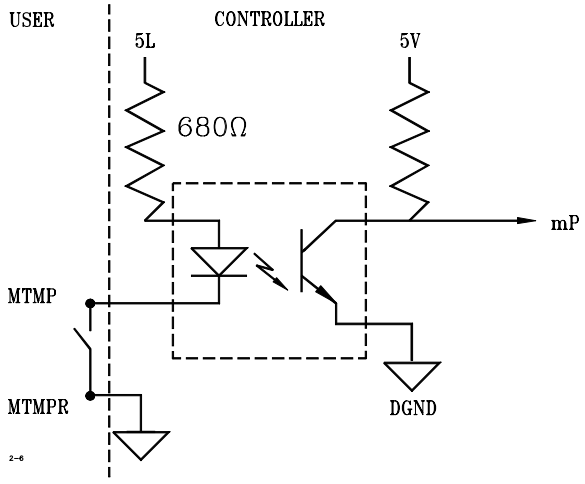


FIGURE 4-21 Switch connection for temperature protection

4.4.4. Encoder 2 Connector (J4)

The Encoder 2 connector is D-type, 9-pin, female.



Warning

Facilities for overspeed protection are not provided in the control unit. Therefore, when facilities for overspeed protection are required for the end-product, they will have to be provided separately by the end-user.

The interface of the Encoder 2 connector is identical to the interface of Encoder 1 connector.

Common uses for the Encoder 2 connection are master/slave and dual-loop control.

The Encoder 2 can be powered by the on-board +5L (5V). The total current consumption must not exceed 0.5A. If the +5L current consumption exceeds 0.5A, an external supply must be used. In such a case, the return of the supply must be connected to GND pin.

TABLE 4-19 Encoder 2 connection pins

Pin	Name	Description
1	+5L	5V supply to the master encoder
2	MA+	Master Encoder A+
3	MA-	Master Encoder A-
4	MB+	Master Encoder B+
5	MB-	Master Encoder B-
6	MI+	Master Encoder I+
7	MI-	Master Encoder I-
8	GND	5L ground
9	SCRN	Cable shield

4.4.5. I/O + Safety Connector (J3)

The I/O + Safety connector is D-type, 25 pin, male.

There are 8 digital inputs, 8 digital outputs, two limit inputs, one E_STOP input, one analog input, and one analog output.

All the digital I/O are isolated.



Warning

The Emergency Stop and Safety Interlock means provided with the controller are software-based only. Therefore, if the end product requires facilities for hardware-based Emergency Stop and/or Safety Interlock, these must be provided separately by the end user.

The digital I/O supply can be either an external supply (factory default configuration) or the internal 5Vdc (non-isolated). The source of the I/O supply is jumper-configured (see table below).

Warning

If the SB1391 is intended to be used with a secondary supply circuit or DC supply, the supply must be a suitably European Approved power supply.

If an external supply is used, the voltage level can be either 5Vdc (±10%) or 24Vdc (±20%), with the voltage level detected automatically.

Warning

To change the jumper position it is necessary to open the control module. This voids the product warranty. Therefore it is recommended to order the required jumper configuration from the factory.

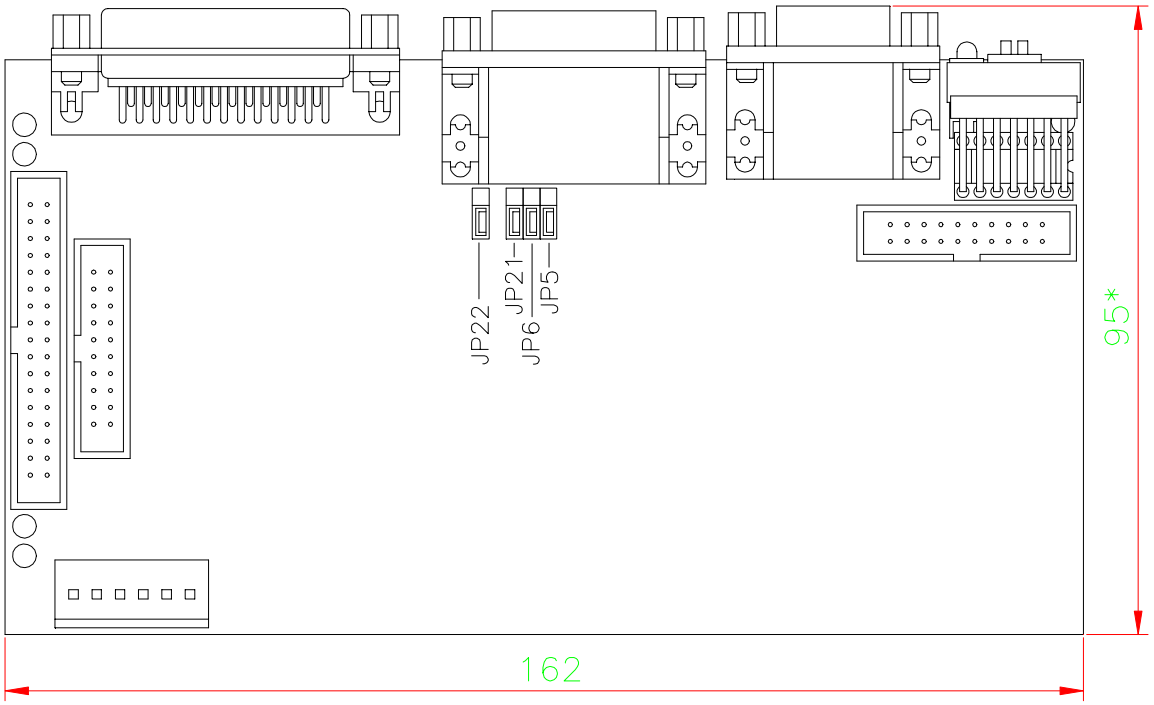


FIGURE 4-22 Jumpers for selecting I/O supply source and for selecting input type

TABLE 4-20 Digital input/output supply selection

Input supply source	Output supply source	JP5 on pins	JP6 on pins	JP21 on pins	JP22 on pins
External 5Vdc/24Vdc (***Factory default***)	External 5Vdc/24Vdc (***Factory default***)	2 -3	2 -3	2 -3	2 -3
External 5Vdc/24Vdc	Internal 5Vdc (non-isolated)	1 - 2	2 -3	1 - 2	2 -3

Input supply source	Output supply source	JP5 on pins	JP6 on pins	JP21 on pins	JP22 on pins
Internal 5Vdc (non-isolated)	External 5Vdc/24Vdc	2 -3	1 - 2	2 -3	1 - 2
Internal 5Vdc (non-isolated)	Internal 5Vdc (non-isolated)	1 - 2	1 - 2	1 - 2	1 - 2

TABLE 4-21 Input/output connection pins

Pin	Name	Description
1.	IN1	Digital input 1
2.	IN2	Digital input 2
3.	IN3	Digital input 3
4.	IN4	Digital input 4
5.	IN5	Digital input 5 (fast input: propagation delay less then 0.2µsecond)
6.	IN6	Digital input 6 (fast input: propagation delay less then 0.2µsecond; can also be used as fast registration mark input)
7.	IN7	Digital input 7
8.	IN8	Digital input 8
9.	OUT1	Output 1
10.	OUT2	Output 2
11.	OUT3	Output 3
12.	OUT4	Output 4
13.	OUT5	Output 5
14.	V_RETURN	I/O supply return
15.	V_SUPPLY	I/O supply
16.	AGND	Analog I/O ground
17.	E_STOP	Emergency stop input.  **Warning: The E-STOP input must <u>not</u> be used as the Emergency Stop for the entire system. Its sole use is to indicate to the control unit that an emergency situation exists.**
18.	RL	Right limit switch input
19.	LL	Left limit switch input

Pin	Name	Description
20.	A_OUT	Analog output, ±10Vdc. Can be programmed to represent **XD4** (**analog output**) (±511) or for monitoring motion variables. For more information see Chapter 6, "Hardware Interface Parameters."
21.	AIN-	Analog inverted input. ±10V can be applied between AIN+ and AIN-. The input is converted by a 12-bit A-to-D converter and is represented by **XA0** (-2,048. +2,047)
22.	AIN+	Analog noninverted input
23.	OUT6	Output 6
24.	OUT7	Output 7
25.	OUT8	Output 8

4.4.5.1. Digital Inputs

There are 8 non-dedicated, isolated digital inputs. An external supply must be connected between the V_SUPPLY and V_RETURN pins.

External supply range: 5Vdc (±10%) or 24Vdc (±20%), detected automatically.

The factory default configuration of the digital inputs is source-type but can be changed to sink-type (FIGURE 4-24). If sink-type inputs are specified in the purchase order, the configuration will be done at the factory.

To change from source- to sink-type inputs, move jumper JP12 on controller board to pins 1 and 2.



Warning

To change the jumper position it is necessary to open the control module. This voids the product warranty. Therefore it is recommended to order the required jumper configuration from the factory.

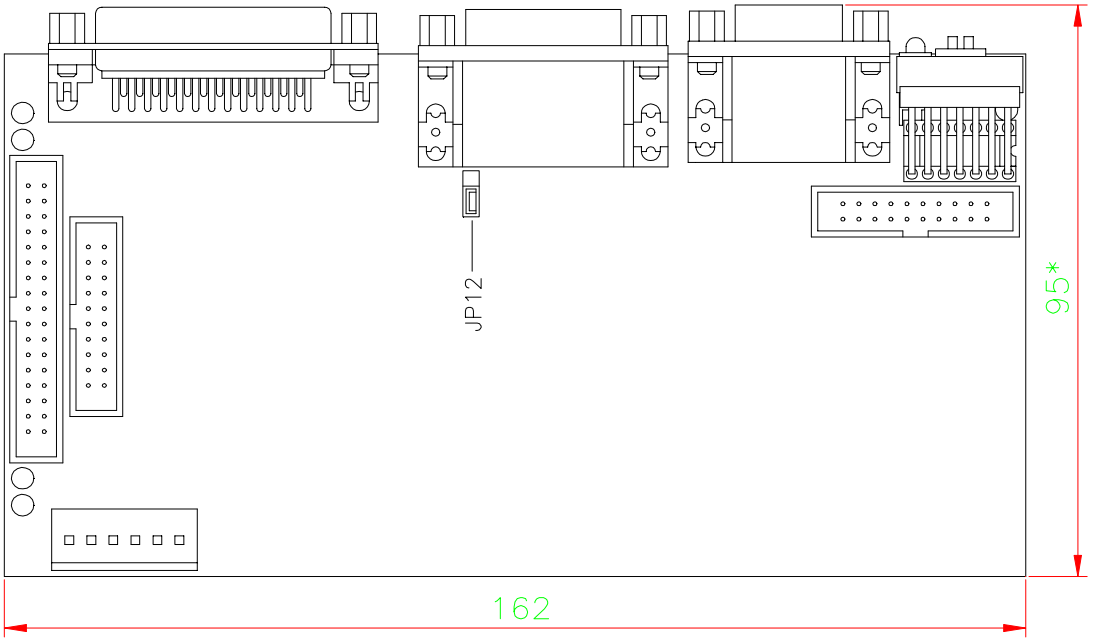


FIGURE 4-23 Jumper 12 for digital input-type selection

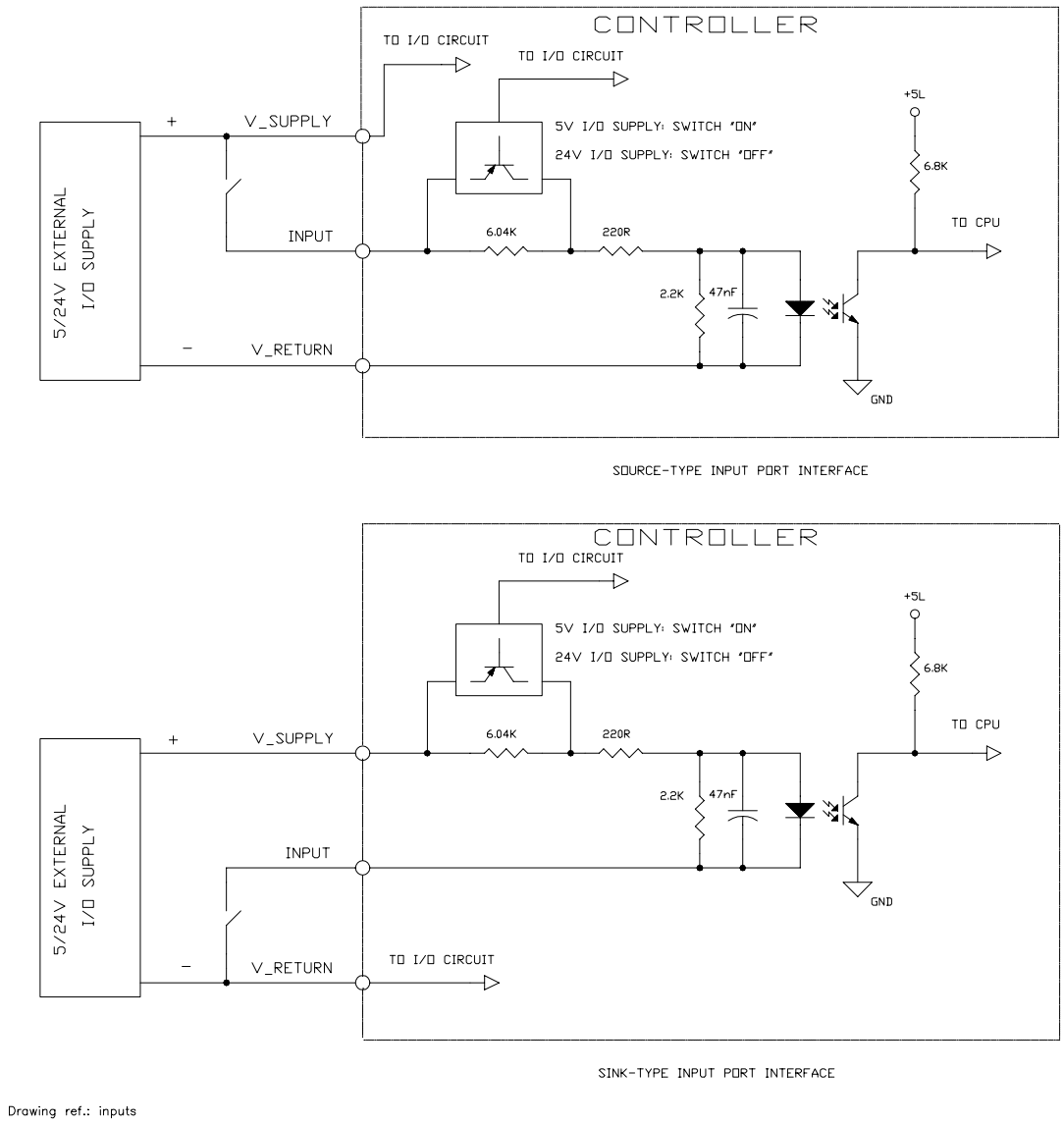


FIGURE 4-24 Input port interface

4.4.5.2. Digital Outputs

There are 8 non-dedicated, isolated outputs. An external supply must be connected between the V_SUPPLY and V_RETURN pins.

External supply range: 5Vdc (±10%) or 24Vdc (±20%).

All the output circuits are protected by an internal automatic fuse. The V_OUT LED indicates that the external supply is connected and the output circuits are working properly.

The maximum current for each output is 50mA (FIGURE 4-25). The maximum total current for all eight outputs is 350 mA.

The digital outputs are protected against overloads (if one or several output currents exceed more then 400mA) and against short circuits

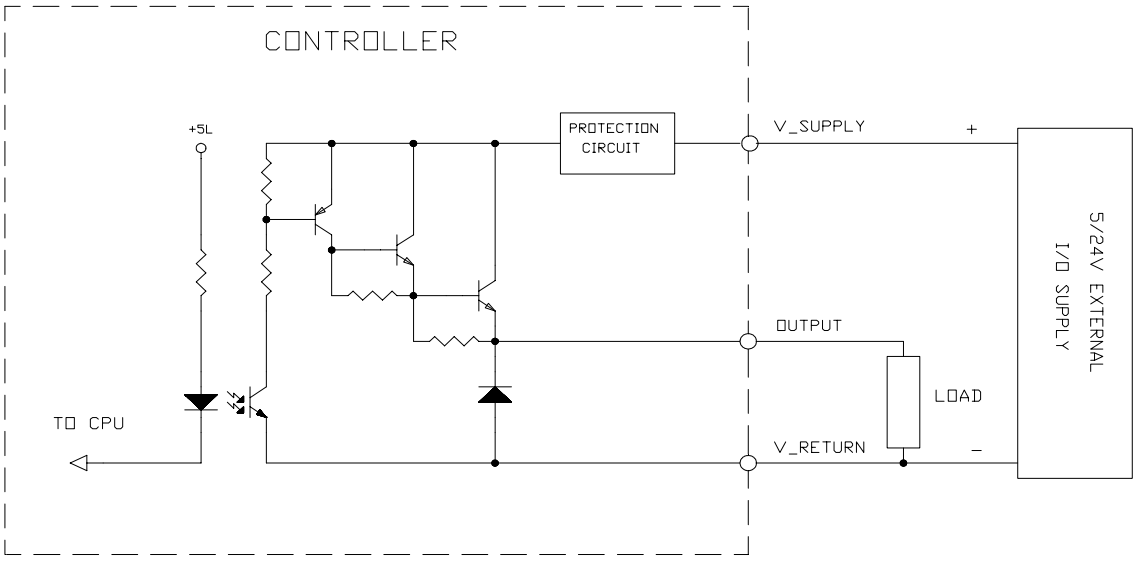


FIGURE 4-25 Output port interface

4.4.5.3. Analog Input

There is one differential analog input, which also acts as joystick input. The voltage range of the analog input is ±10V. The potentiometer output must be connected to AIN1+. AIN1- must be connected to the supply ground pin (FIGURE 4-26).

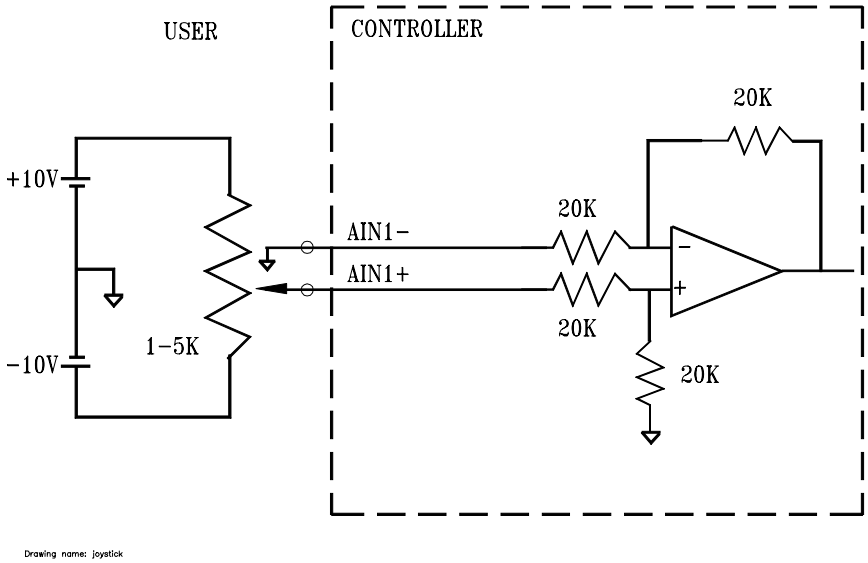


FIGURE 4-26 Joystick connection

4.4.6. HSSI + PEG Connector (J5)

The optional HSSI + PEG connector is D type, 15 pin, male

The PEG option must be specified in the product order.

Maximum PEG delay<0.2µsec

Minimum Pulse width>100nsec

The high-speed serial interface (HSSI) can serve as a general purpose means for adding external extensions. These can include: SSI-type encoder; another A to D converter, temperature sensor, etc.

All the HSSI signals are differential, non-isolated.



Warning

To enable maximum speed, the PEG outputs are not isolated from the 5V logic supply.



Note

Physically the PEG outputs and the corresponding digital outputs have the same source but different output levels. The PEG connector outputs are differential with respect to digital ground (DGND) whereas the equivalent digital outputs are isolated with respect to the I/O return (V_RETURN).



Further information

More detailed information about the PEG function is contained in Chapter 7, "HARDWARE INTERFACE PARAMETERS," and in the *ACS Software Guide*.

TABLE 4-22 HSSI + PEG connection pins

Pin	Name	Description
1.	S_CNV+	HSSI start convert (read) output (noninverted)
2.	S_CLK1+	HSSI clock output 1 (noninverted)
3.	S_DATA1+	HSSI data input 1 (noninverted)
4.	X_STA+	X status output (noninverted)
5.	NC	Not connected
6.	X_PEG+	X PEG output (noninverted)
7.	NC	Not connected
8.	DGND	Return +5V
9.	S_CNV-	HSSI start convert (read) output (inverted)
10.	S_CLK1-	HSSI clock output 1 (inverted)

Pin	Name	Description
11.	S_DATA1-	HSSI data 1 input (inverted)
12.	X_STA-	X status output (inverted)
13.	NC	Not connected
14.	X_PEG-	X PEG output (inverted)
15.	NC	Not connected

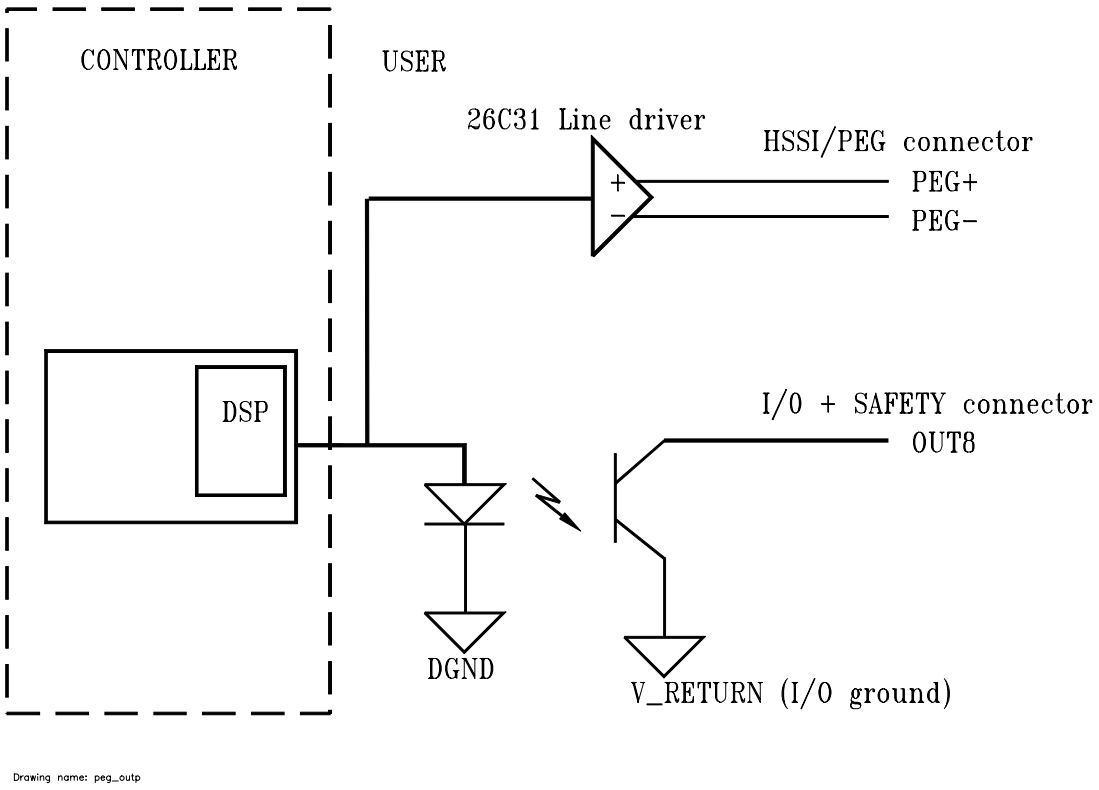


FIGURE 4-27 PEG outputs and corresponding digital outputs

4.5. Indicators, Switches, Display, and Test Points

4.5.1. Indicator LEDs

The locations of the indicator LEDs are shown in FIGURE 4-1.

TABLE 4-23 Indicator LEDs

LED	Description and function
V_OUT	On: 24Vdc (user-supplied) for the outputs is present. Off: 24V is either not connected or the internal automatic fuse is off because of overload.
X_ON	On: Motor enabled. Off: Motor disabled.
MP_ON	On: Control unit working properly. When the control unit detects a receive message, this LED goes off for a fraction of a second. This indicates that the processor and communications are functioning properly.
VP	On: Fused power stage DC bus is present. Off: If AC power is present, indicates that the internal fuse failed and the unit requires service.
REGEN	On: Regeneration circuit is OK and in standby mode. Flash: Regeneration circuit is active. Off: If Vp LED is on, the regeneration circuit is faulty.
CONTROL SUPPLY	On: Fused control voltage is present. Off: Fused control voltage absent.
CAN (optional)	Green and red LED. When the CAN switch is set to CAN mode (positions 0, 3, 7 - E), the LED blinks red until communication is established between the CAN adapter and the control unit's CPU. The CAN turns steady green once communication is successfully established. When the CAN switch is in other modes, the condition of the LED is irrelevant.

4.5.2. Display

The 7-segment display is shown in FIGURE 4-28.

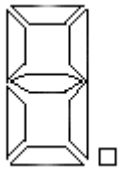


FIGURE 4-28 The 7-segment display

The display can transmit alphanumeric characters (A to Z, 0 to 9) and several punctuation marks (question mark "?," exclamation point "!," and hyphen "-").

During control unit startup, the 7-segment display goes on (i.e., displays an "8") for a few seconds to show it is functioning properly and then goes off.

For information about programming the 7-segment display, to display system and ACSPL program messages, refer to Chapter 7, "HARDWARE INTERFACE PARAMETERS."

4.5.3. DIP Switches

Two DIP switches are located on the front panel of the control module. The **Prog** switch is reserved and the **COM_SD** switch disables communication.

When the **COM_SD** switch is ON, the following limitations apply:

- Control module receives (accepts) only responses to ACSPL **input** statements and user defined function keys (**FKEY_#**).
- Control module transmits only messages generated by ACSPL **disp** statements.

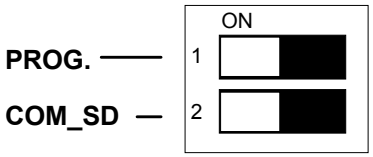


FIGURE 4-29 DIP switches (off)

TABLE 4-24 DIP switches

Switch	ON
PROG.	For future use. **Must always be set to ON**.
COM_SD	Partial communication shutdown.

Note

Note
For CAN communication, the COM_SD switch must be OFF.

4.5.4. Test Points

The test points are located on the bottom of the control module.

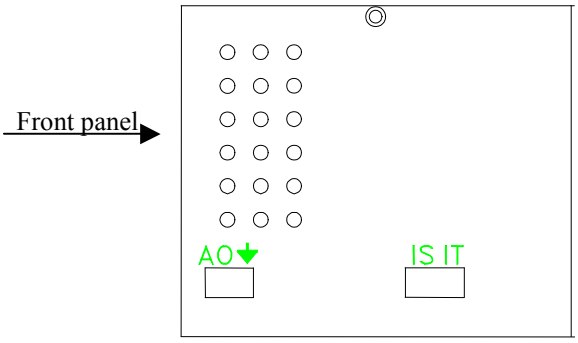


FIGURE 4-30 Location of current test points

TABLE 4-25 Current test points

Test point	Use
A_OUT	Analog output with respect to GND. ±10V.
GND	Ground for analog input.
IS	Phase S current sensing. The scale factor is 8V per Ipeak.
IT	Phase T current sensing. The scale factor is 8V per Ipeak. Example: For the SB1391A (10A peak current), scale factor is 0.8V/A.

5. WORKING WITH THE CONTROL UNIT

TABLE 5-1 Topics covered in this chapter

Topic	Description
Getting started	Equipment requirements, power on, installing the ACS software tools for Windows
Adjusting the unit	An overview of using ACS Adjuster to setup and tune the control unit.
ACSPL programming with ACS Debugger	An introduction to ACSPL, the programming language for the control module, and ACS Debugger, the ACSPL development environment
Direct mode	Description and working examples of direct mode programming
Programming mode	Description and working example of an ACSPL program
Saving and loading control unit memory	Overview of the ACS Saver and ACS Loader for saving and loading control unit memory contents

Note

Note

This chapter and the one that follows are generic descriptions of how to setup and tune an ACS-Tech80 control unit. Not every control unit has every component mentioned in these chapters. For example, not every unit supports encoder + Hall feedback or resolver feedback; not every control unit supports stepper motors, etc.

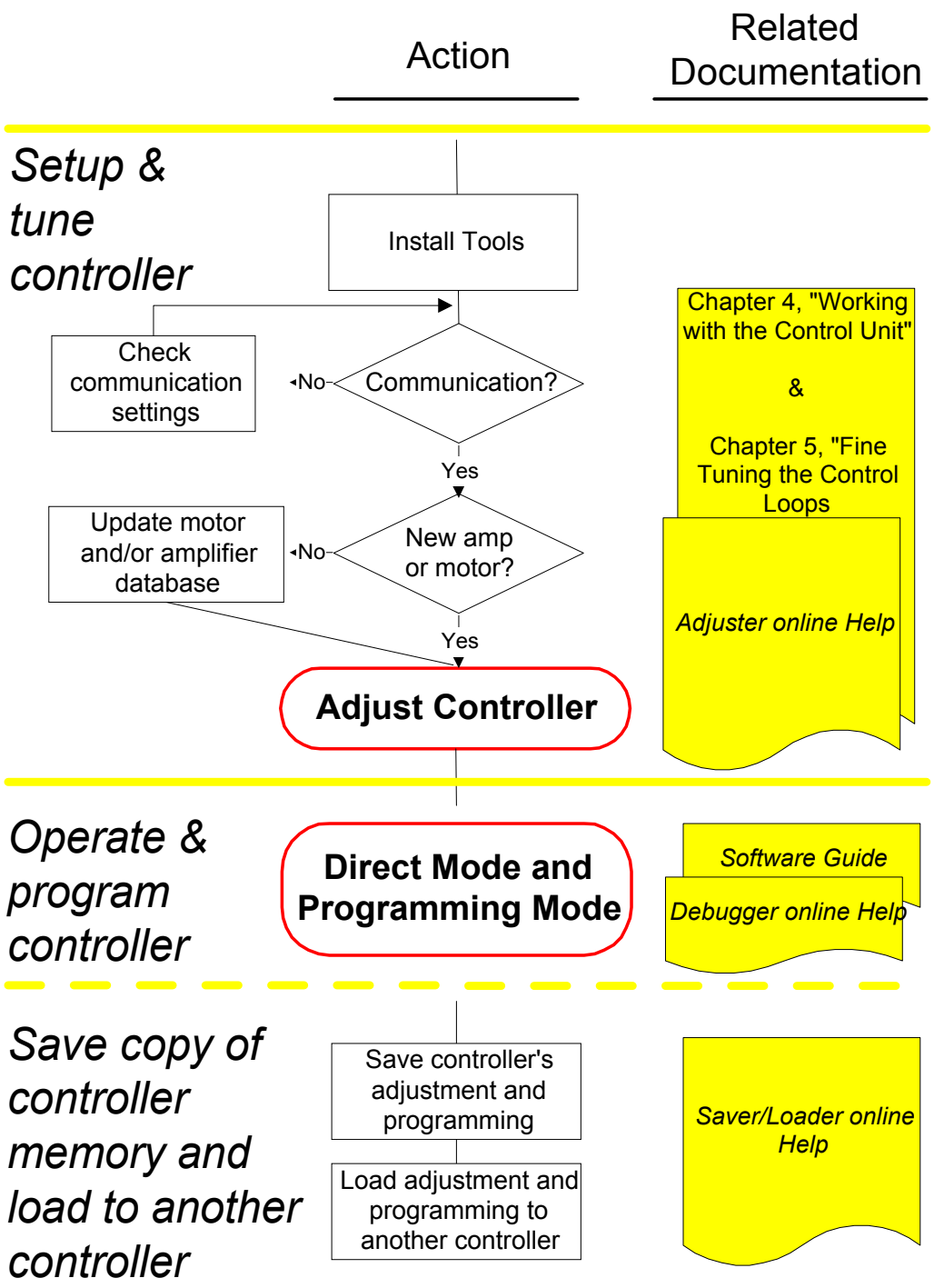


FIGURE 5-1 Working with the controller

TABLE 5-2 Resources for more information about topics covered in this chapter

Required information	Documentation resource
Fine tuning the module's control loops.	Chapter 5, "Adjusting the Control Loops" & ***ACS Adjuster online Help***
ACS Adjuster - Tool for setting up and adjusting the control module.	***ACS Adjuster online Help***
ACSPL motion programming language reference for operating the control unit in direct mode and programming mode.	*ACS Software Guide*
ACS Debugger - ACSPL development and debugging environment	***ACS Debugger online Help***
ACSLIB libraries for C, C++ and Visual Basic programs.	*ACSLIB Library Reference Guide*
ACS Saver/Loader - Application for saving and loading the entire memory contents from one control unit to another.	***ACS Saver/Loader online Help***

5.1. Getting Started

5.1.1. Equipment Requirements

The following additional equipment should be connected to the control module, as described in Chapter 4 MOUNTING AND WIRING.

- Appropriate motor with a position feedback device (encoder, resolver, etc. depending on the control unit factory configuration).
- External amplifier if the control unit is a model that does not have an internal amplifier.
- PC with a communication link (serial port or CAN depending on the control unit factory configuration).
- Power source (or sources depending on the control unit model).
- I/O and safety switches (optional).
- Connection cables.

5.1.2. Power On



Warning

The control unit's power requirements are stamped on the nameplate. Failure to connect the control unit to the correct voltage could result in serious damage to the control unit.



Warning

It is recommended when activating the motor for the first time to disconnect it from external loads and verify that the area is clear of any object that might be hit by the moving motor.

Action	Effect of action
Power on the unit.	During power up, the MP_ON indicator flickers as the control processors communicate with each other. The 7-segment goes on (i.e., displays an "8") for a few seconds to show it is functioning properly and then goes off. Once power up is complete, the MP_ON indicator remains on, showing that the control processors are functioning properly. The VP indicator remains on, showing that the power supply is functioning properly. If the I/O supply has been connected, the V_OUT indicator remains on, showing that the output power is present.

5.1.3. Installing ACS Software Tools

The unit comes with installation diskettes for ACS Tools, a suite of Windows applications for setting up, adjusting, and programming.

TABLE 5-3 ACS Tools

Tool	Description
ACS Adjuster	Interactive tool for setting up and tuning.
ACS Debugger	Development environment for ACSPL applications.
ACS Saver/Loader	Tool for copying system setup and application data from one controller to another.



Note

There are two sets of installation diskettes, one for ACS Adjuster and ACS Debugger and one for ACS Saver/Loader.

	Action	Effect of action
1.	Insert disk 1 of the ACS Tools in the PC disk drive.	
2.	Double-click on Setup and follow the onscreen instructions.	The following ACS software tools will be installed in the ACS Tools program group. • ACS Adjuster • ACS Debugger

	Action	Effect of action
3.	Insert disk 1 of the Saver/Loader in the PC disk drive.	The following ACS software tools will be added to the ACS Tools program group. • ACS Saver • ACS Loader

5.2. Adjusting the Unit

The purpose of adjustment is to setup the module and to tune the control loops. The process is carried out using ACS Adjuster.

An adjustment session consists of the following activities:

- 1. Establish communication with the unit.
- 2. Define amplifier and motor parameters for the specific motion application, set protection parameters, and verify that the feedback subsystem is operating.
- 3. Tune the control loops through a series of interactive steps where the system is excited by a signal and the response is monitored.

The order of operation is summarized in TABLE 5-4.

TABLE 5-4 Adjustment steps

	Step	Description
Setup		
1.	**Amplifier parameters**	Select amplifier from database list. Edit as necessary.
2.	**Motor parameters**	Select motor from database list. Edit as necessary.
3.	**Protection parameters**	Define limits. There are two sets. One for adjustment purposes and one for regular operation.
4.	**Feedback verification**	Verify that the feedback device and safety inputs are functioning properly.
Tuning		
5.	**Current loop adjustment**	Tune the current filter while monitoring the current step response.
6.	**Commutation adjustment**	Identify the relation between the position feedback device's reading and the orientation of the magnetic field.
7.	**Velocity loop adjustment**	Tune the velocity loop filters and parameters while monitoring the velocity step response.
8.	**Position loop**	Tune the position loop gain while monitoring the response to a third

	Step	Description
	adjustment	order point to point move.
9.	**Polishing**	Optimize acceleration feed forward and AC induction motor control parameters.
Review		
10.	**Review parameters**	View all the results of the previous steps. Edit as necessary.

5.2.1. Working with the Adjuster

The overall adjustment procedure is illustrated in FIGURE 5-2. It is as follows:

1. Start ACS Adjuster (if it is not already running).
2. Set the control unit parameter values.
3. Save the application to the control unit nonvolatile memory.
4. Save the application to the PC hard disk.

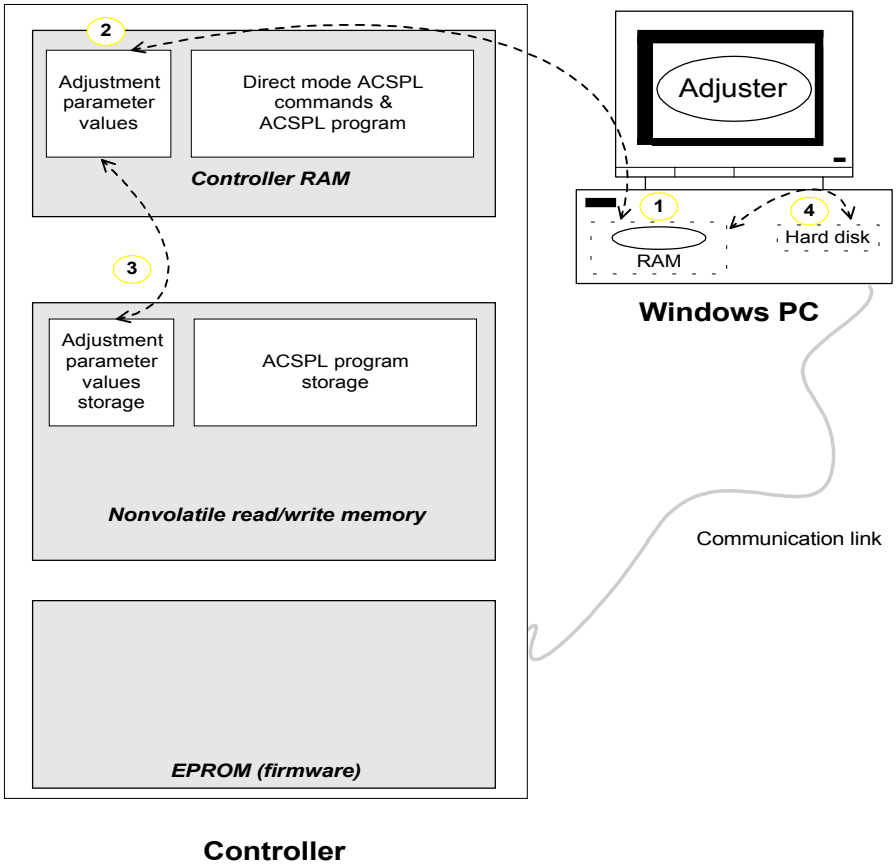


FIGURE 5-2 Adjustment procedure The adjustment procedure affects both the volatile and nonvolatile memory of the control module. The Adjuster keeps the control module's memory in

sync with the application database (on the PC). If the control module is shut off during an adjustment session and the data was not saved to the module's nonvolatile memory, that synchronization will be lost and the adjustment session must be repeated.

5.2.2. Starting ACS Adjuster



Further information

This guide does not cover Microsoft Windows, the PC environment in which ACS software tools run. For more detailed information about MS Windows, consult the appropriate user documentation.

Action	Effect of action
On the Windows **Start** menu, point to the **ACS Tools** program group and click **ACS Adjuster**.	The main **Adjuster** window opens, as shown in FIGURE 5-3.

5.2.3. Establishing Communication

After ACS Adjuster starts up, it attempts to communicate with the control unit. If it succeeds, the **Communication** parameter in the Adjuster status bar will read ON, as in FIGURE 5-3.

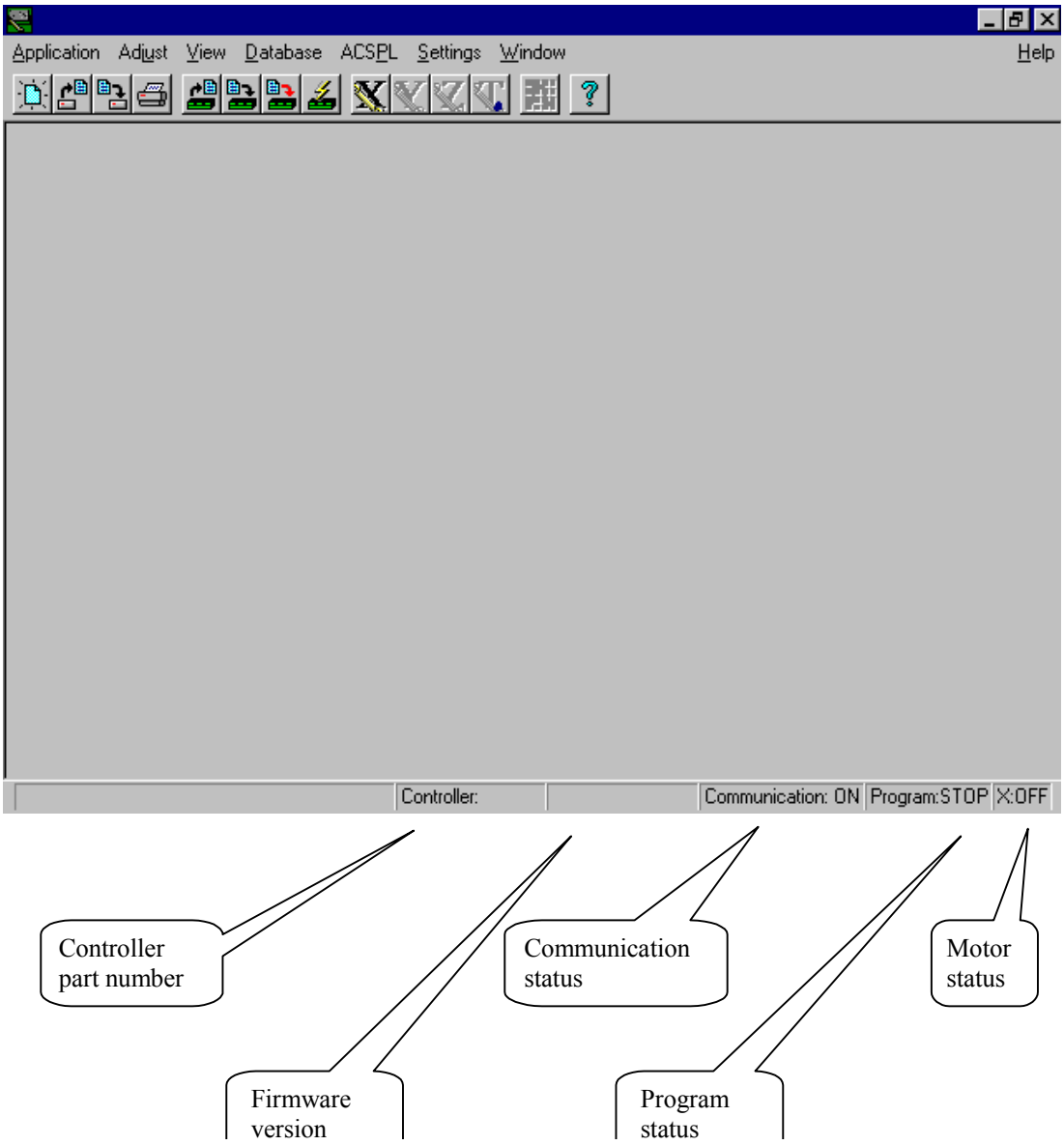


FIGURE 5-3 Adjuster status bar

If communication fails, the **Communication error** message appears, as in FIGURE 5-4.



FIGURE 5-4 "Communication error" message

If there is a communications error, verify that the communication parameters are set correctly by doing the following (does not apply for CAN bus):

	Action	Effect of action
1.	Clicking **Communication** on the **Settings** menu.	The **Communications settings** dialog box opens, as shown in FIGURE 5-5.

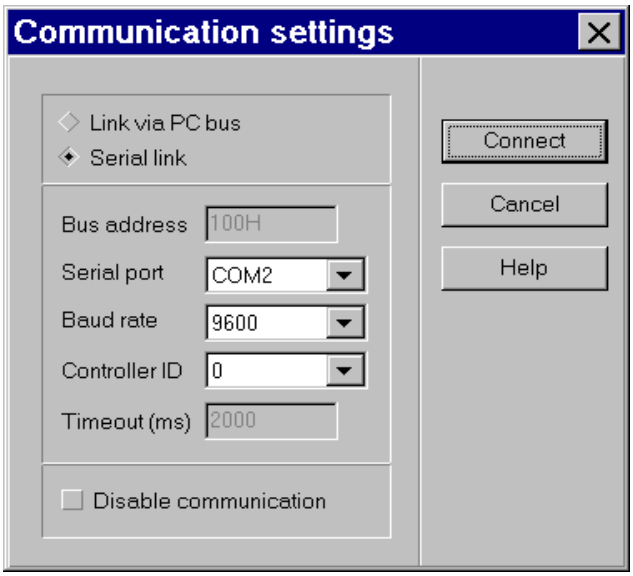


FIGURE 5-5 Communications settings

	Action	Effect of action
2.	Set the **baud rate** to 9600 (control unit default).	
3.	Click OK to save the new baud rate.	If communication is successful, as indicated in the status bar, the process is complete.

	Action	Effect of action
4.	If still not successful, then reopen the **Communications settings** dialog box and check the other serial port parameters in Windows.	If communication is successful, as indicated in the status bar, the process is complete.
5.	If still not successful, then check the serial connection wiring.	

Once Adjuster has established communication, it checks the version number of the firmware running on the control unit. If it recognizes the firmware version, the number is displayed in the status bar as shown in FIGURE 5-3.

If the controller firmware release is newer than the Adjuster release, then Adjuster may not recognize the firmware and will display the **Choose version** dialog box (FIGURE 5-6).

In such a case it is recommended to get a new Adjuster release that supports the firmware. As a temporary measure, select the latest firmware version in the list.

For example, if the control module's firmware version is 29-20, and the most recent version listed is version 21-19, choose that.

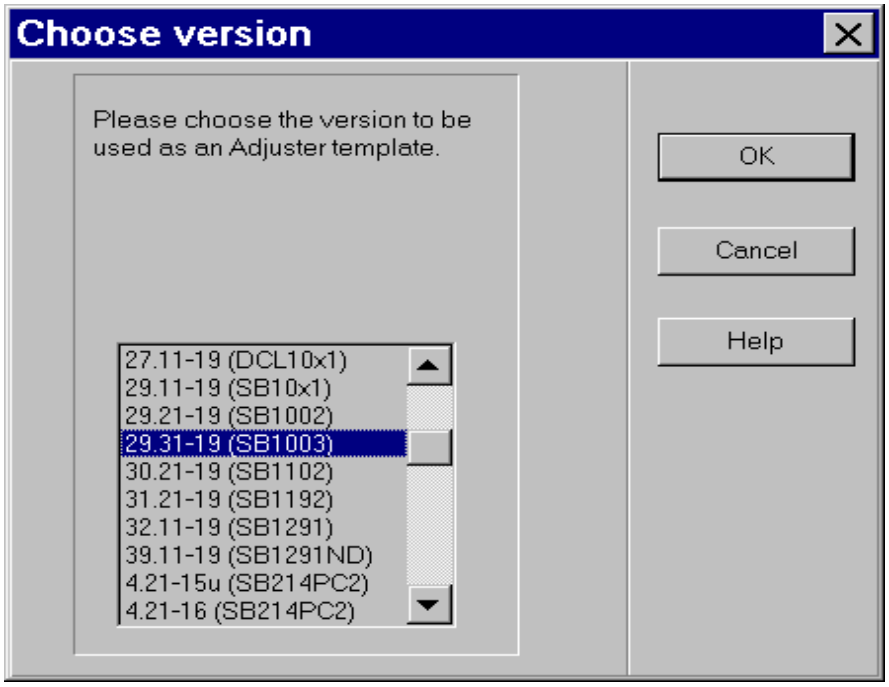


FIGURE 5-6 Choose version dialog box

Note

Note

Once the firmware has been recognized or chosen, if the control unit has been used before, it is recommended to reset it before proceeding with adjustment. To do so, on the Application **menu choose** Reset control unit**.**

5.2.4. Adding an Amplifier to the Adjuster Database

ACS Adjuster maintains two databases, one for amplifiers and one for motors. Adjuster accesses the databases during the adjustment process (for the **Amplifier parameters** and **Motor/feedback parameters** steps, which are described later).

The database comes with some third-party amplifiers already defined. If the system's amplifier is not in the database yet, it should be added now.

	Action	Effect of action
1.	On the **Database** menu, point to **Amplifiers,** and then click **Add item**, as shown in FIGURE 5-7.	The first time that the amplifier database is accessed, the message in FIGURE 5-8 appears, to prevent the default amplifier database from being overwritten.

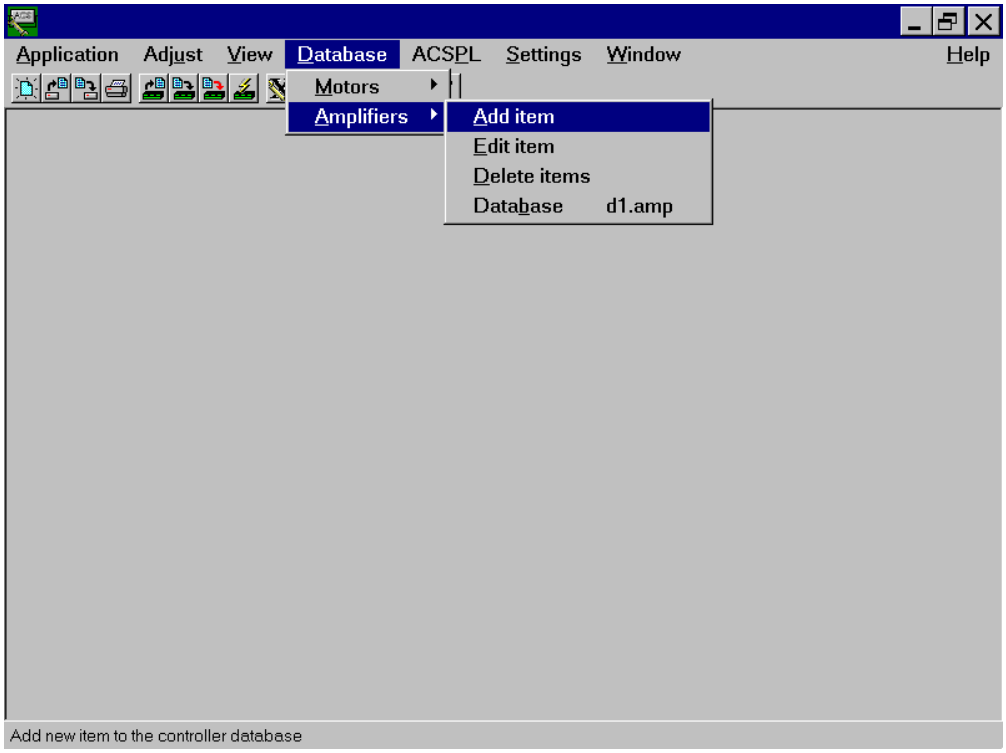


FIGURE 5-7 Add amplifier command

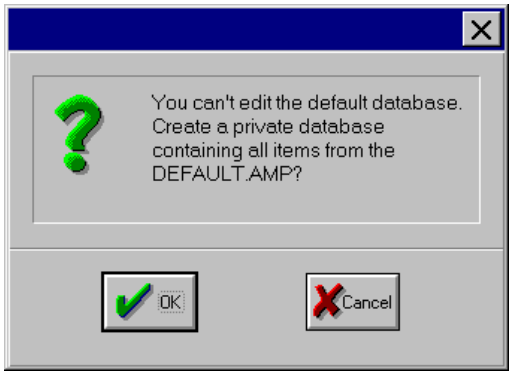


FIGURE 5-8 "Create a new amplifier database" message

	Action	Effect of action
2.	Click **OK** in the message box and save the amplifier database with a new name.	This creates a new amplifier database, which includes copies of all the ACS-Tech80 amplifier definitions in the default database, and opens the **Amplifier database** (create new item) dialog box (FIGURE 5-8).

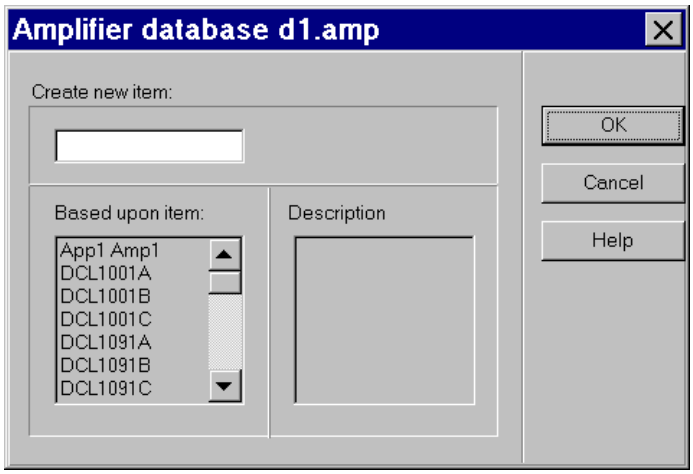


FIGURE 5-9 Add new amplifier item dialog box

	Action	Effect of action
3.	Enter the name of the new amplifier and click **OK**.	The new record dialog box opens with the new item name displayed in the **Amplifier** field (FIGURE 5-10).

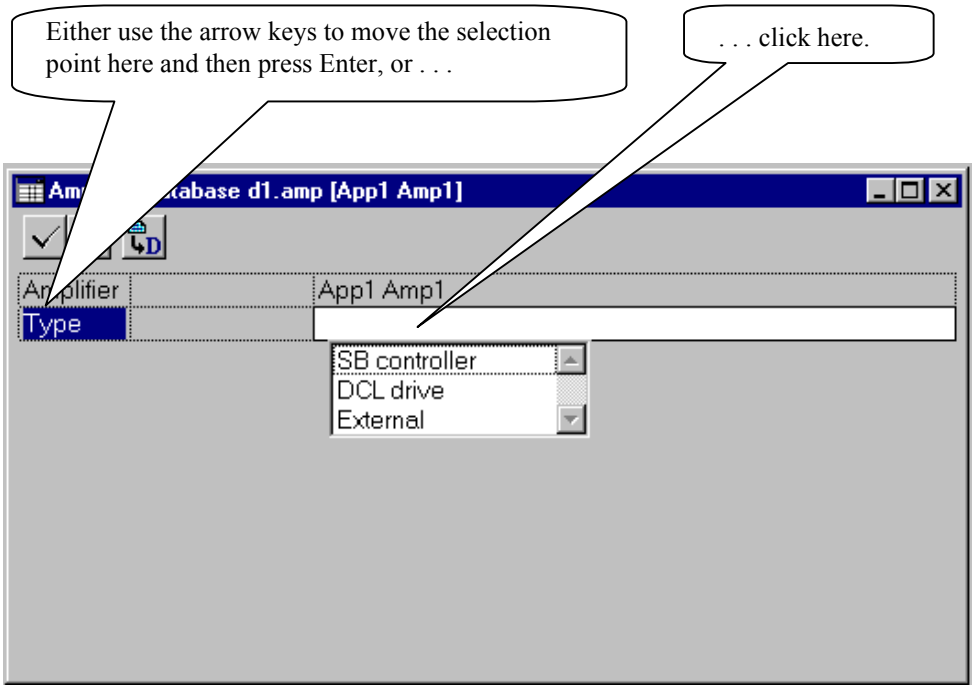


FIGURE 5-10 Opening the amplifier list

	Action	Effect of action
4.	Open the **Type** list by either moving the selection point with the arrow keys to the **Type** box label and then pressing Enter or by clicking in the list (last column), as shown in FIGURE 5-10.	The list of amplifier types opens.

Select this type	when using a/an
SB controller	SB10XX control module
DCL drive	DCL10X1 digital amplifier
External	third-party amplifier

5.	Select the amplifier type by clicking on it, then press ENTER.	The specification fields for the selected amplifier type appear, as shown in FIGURE 5-11. (The fields will vary depending on the motor type).

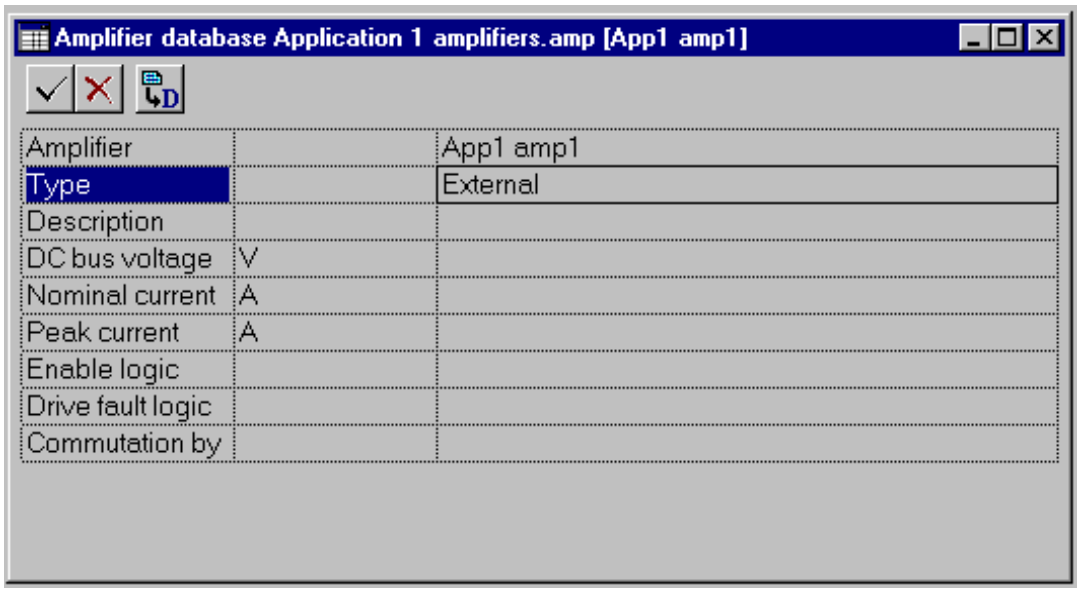


FIGURE 5-11 Amplifier specification (varies by type)

Action
6. Edit the fields based on the manufacturer's specifications. The fields displayed depend on the amplifier type. Fields common to most amplifier types are described in TABLE 5-5. Currently, only some fields are mandatory. However, it is recommended to fill in all the fields for future compatibility.

TABLE 5-5 Amplifier record fields

Field	Amplifier type	Description
Nominal current	All	Nominal continuous phase current amplitude of the amplifier.
Peak current	All	Peak phase current amplitude of the amplifier.
Bus voltage	All	Amplifier's bus voltage. Usually equal to Vac*1.41, where Vac is the line voltage. If the internal voltage is generated by a built-in transformer, then the value is different.
Drive mode	DCL drive	Amplifier's operating mode. Options: • torque • velocity • pulse
Enabled by	DCL drive	Signal that enables amplifier. Options: • Control unit's enable input • Control unit's enable input and **SXMO1** command (disable is by control unit disable input or **SXMO0** command)

Enable signal	External amplifier	Polarity of amplifier's enable signal
Commutation by	External amplifier	**Controller** - the commutation is done by the control unit. The control unit generates a two-phase current reference. The amplifier generates the third phase reference. **Amplifier** - the commutation is done by the amplifier. The control unit outputs a single current command.

	Action	Effect of action
7.	Click the **OK** tool button .	The new amplifier is added to the amplifier database.

5.2.5. Adding a Motor to the Adjuster Database



Note

Some types of motors have more than one name. ACS-Tech80 uses the following motor terminology:

Term used	Alternative name
AC induction	Three-phase AC asynchronous, squirrel cage
DC brushless	Three-phase AC servo, AC synchronous

If the system's motor is not in the database yet, it should be added now.

	Action	Effect of action
1.	On the **Database** menu, point to **Motors,** and then click **Add item** as shown in FIGURE 5-12.	The first time that the motor database is accessed, the message in FIGURE 5-13 appears, to prevent the default motor database from being overwritten.

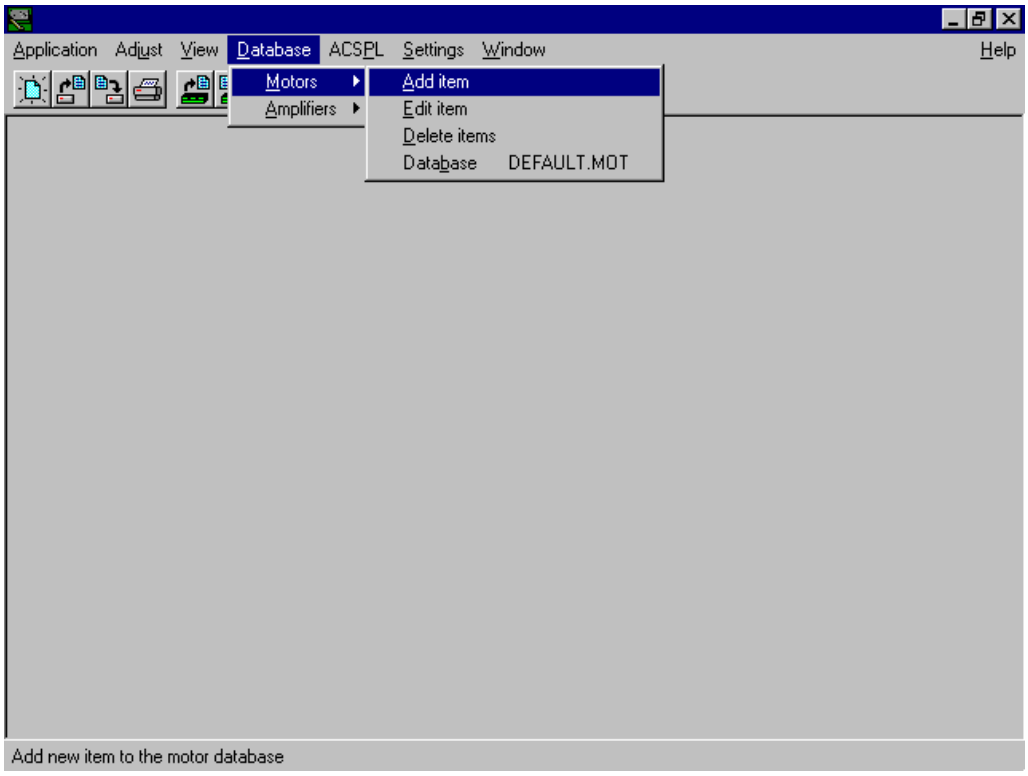


FIGURE 5-12 Add motor command

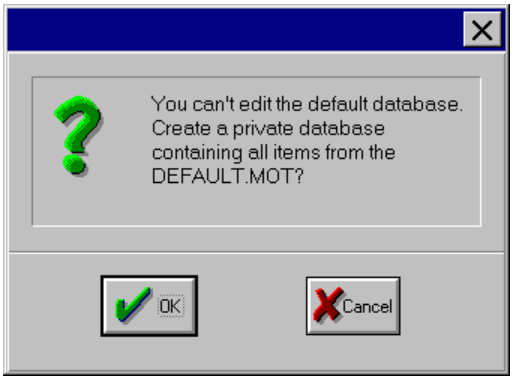


FIGURE 5-13 "Create a new motor database" message

	Action	Effect of action
2.	Click **OK** in the message box and save the motor database with a new name.	This creates a new motor database and opens the **Motor database** (create new item) dialog box (FIGURE 5-14).

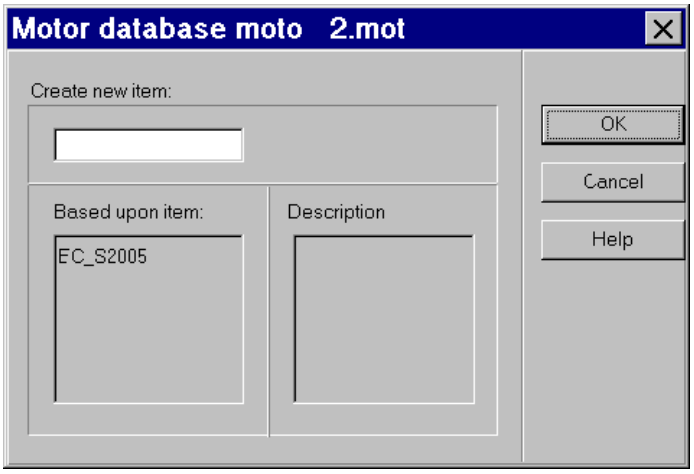


FIGURE 5-14 Add new motor item dialog box

	Action	Effect of action
3.	Enter the name of the motor and click **OK**.	The new motor record dialog box opens with the new item name displayed in the Motor field (FIGURE 5-15).

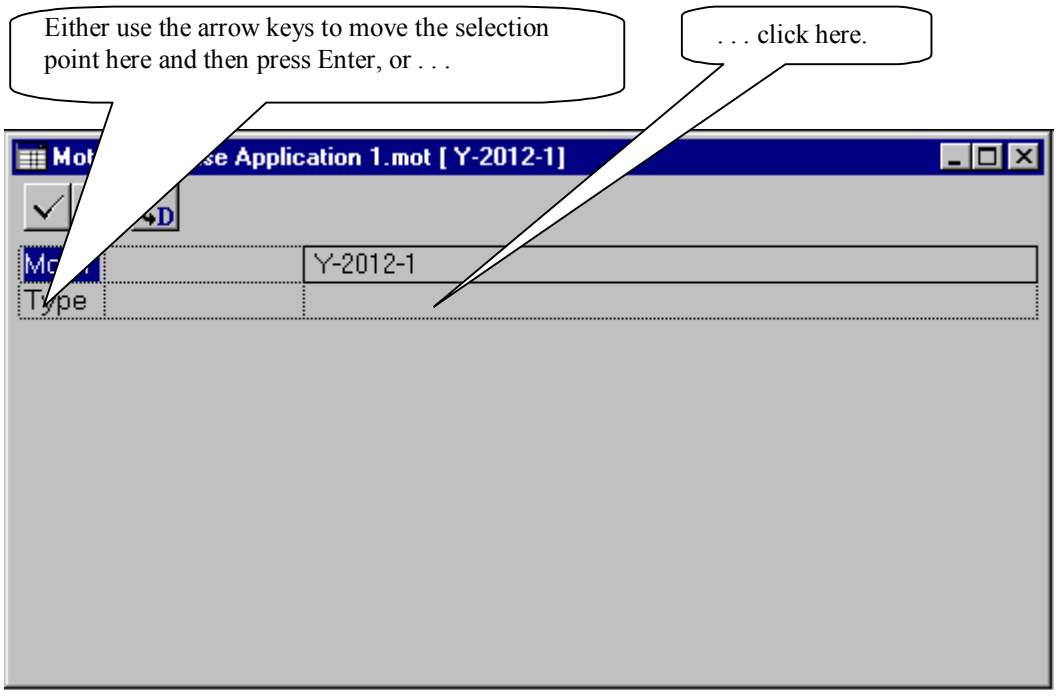


FIGURE 5-15 New motor record dialog box

	Action	Effect of action
4.	Open the **Type** list by either moving the selection point with the arrow keys to the **Type** box label and then pressing Enter or by clicking in the list (last column), as shown in FIGURE 5-15.	The list of motor types opens, as shown in FIGURE 5-16.

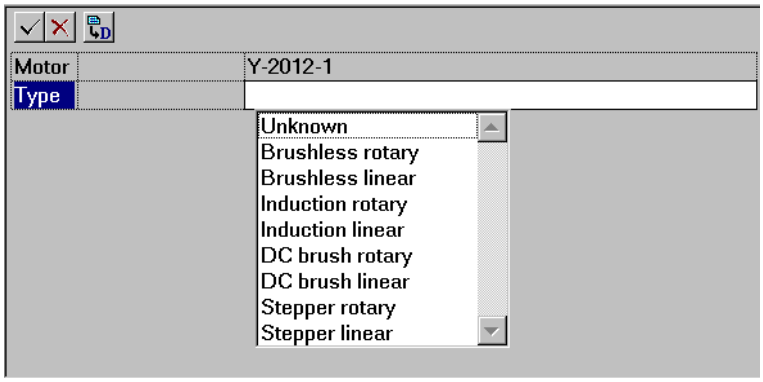


FIGURE 5-16 Motor type list

	Action	Effect of action
5.	Select the motor type by clicking on it, then press ENTER.	The specification fields for the selected motor type appear, as shown in FIGURE 5-17. (The fields will vary depending on the motor type).

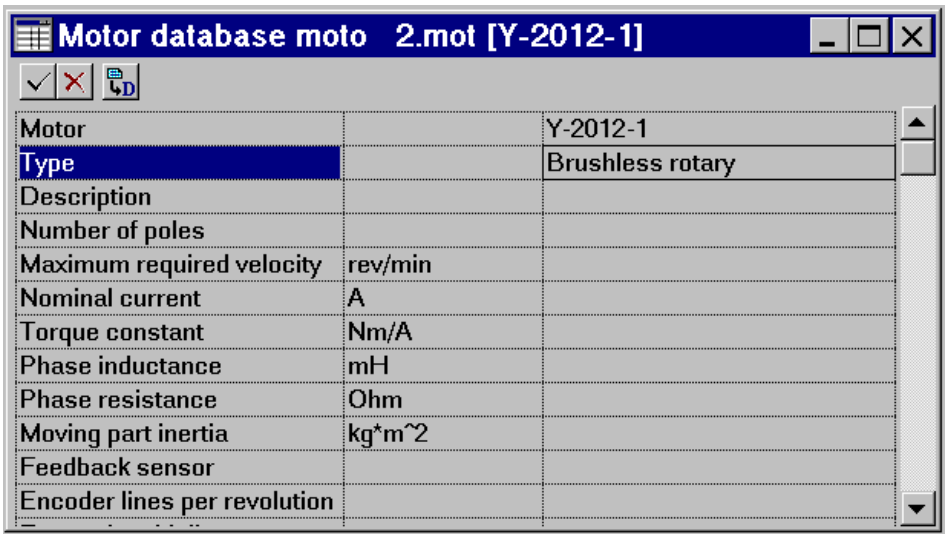


FIGURE 5-17 Motor specification (varies by type)

Action
6. Edit the fields based on the manufacturer's specification. The specific fields depend on the motor type selection. The fields are described in TABLE 5-6.



Warning

Failure to specify correct values for critical fields such as Nominal current, could result in damage to the motor.

TABLE 5-6 Motor record fields

Field	Motor type	Description
Number of poles	All except DC brush	Must be specified for DC brushless (AC servo/AC synchronous) and AC induction motors.
Maximum required velocity	All	The maximum speed that the motor will be run. **Required.**
Nominal current	All	Required to protect the motor from overcurrent. This is the maximum amplitude of the continuous phase current. Some manufacturers specify the rms phase current. To calculate the nominal current from the rms phase current, multiply by 1.41. **Required.**
Magnetic pitch	Linear only	Distance between two adjacent magnets. The magnetic field changes by 180 electrical degrees along one magnetic pitch.
Nominal velocity	AC induction only	This parameter is used for initial calculation of the **SK** (slip constant) parameter.
Torque constant (Kt)	Rotary only	The amount of torque that the motor generates for 1A of phase current.
Force constant (Kf)	Linear only	The amount of force that the motor generates for 1A of phase current
Phase inductance (Lmotor) [mH]	All	Phase to phase inductance. The inductance measured between any two terminals of the motor.
Phase resistance (Rm) [Ohm]	All	Phase to phase resistance. The resistance measured between any two terminals of the motor.

Field	Motor type	Description
Peak current		Maximum current for acceleration/deceleration. Can be derived from Tp/Kt (Tp is peak torque and Kt is torque constant).
Stall current		Maximum continuous current allowed during a stall. If this value is not known, use the nominal current.
Moving part inertia	Rotary only	Total inertia of the motor's moving part and the load.
Moving part mass	Linear only	Total mass of the motor's moving part and the load.
Feedback sensor	All	Commutation and position feedback sensor. Options: Resolver Encoder Encoder + Hall (***DC brushless (AC servo/AC synchronous) motor only***) **Required.**
Encoder lines per revolution	Rotary only	If the **Feedback sensor** selection is "Resolver," Adjuster ignores any values entered here and sets LR=4096, LF=0. The total Counts per Revolution. = 4 x (**Encoder lines per revolution**) x (**External multiplier**), where 4 is an internal multiplier provided by control unit. Example: For a 1000 line encoder (**Encoder lines per revolution** = 1000) and no external multiplier (**External multiplier** = 1), the Counts per Revolution = 4000 (because of the internal 4x multiplier). Based on the value of the **Encoder lines per revolution** and the **External multiplier** defined here, Adjuster calculates the internal controller parameters, **LR** and **LF**. For rotary motors, the Total Number Of Counts per Revolution = **LR** x 2^{LF}. **Required.**
Encoder lines per mm/inch	Linear only	If the **Feedback sensor** selection is "Resolver," Adjuster ignores any values entered here and sets LR=4096, LF=0. The total number of counts per mm/inch = **Encoder lines per mm/inch**) x (**External multiplier**) x 4. **Required.**
External multiplier		If the encoder does not have an external multiplier (interpolator), select 1. The external multiplier is used in the calculation of the Encoder Counts Per Revolution and the Encoder Counts per mm/inch.

Field	Motor type	Description
Dual loop	All	When improved velocity and position loop bandwidth is required, two encoders can be used. Dual loop control is described in Section 6.9, "Dual Loop Control."
Dual loop ratio	All	The ratio of the encoder one to encoder two. This ratio is described in Section 6.9, "Dual Loop Control."

	Action	Effect of action
7.	Click the **OK** tool button .	New motor record dialog box closes.

5.2.6. Adjustment Session



During the Adjustment session, motors are activated and ACScope output is mirrored at the analog output.

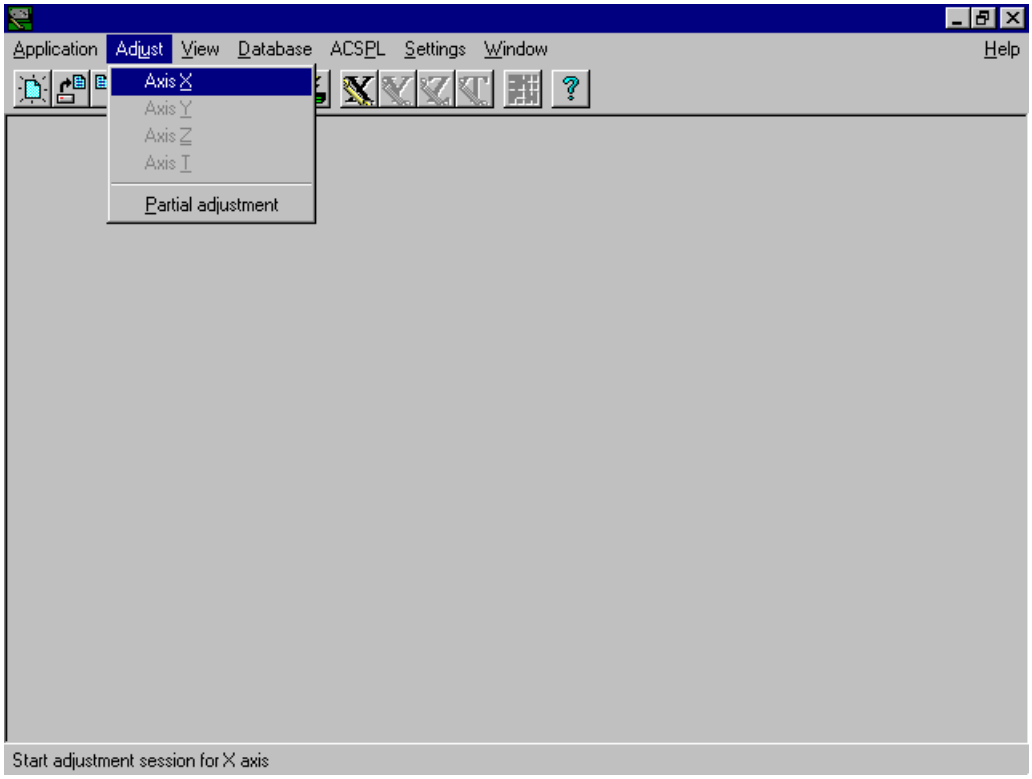


FIGURE 5-18 Starting adjustment session

	Action	Effect of action
1.	From the **Adjust** menu, select the axis to adjust, for example, **Axis X** (FIGURE 5-18)**.**	Adjuster displays a warning that some of the values in the control unit RAM may change (FIGURE 5-19). (Leave the **Partial adjustment** option unchecked.)

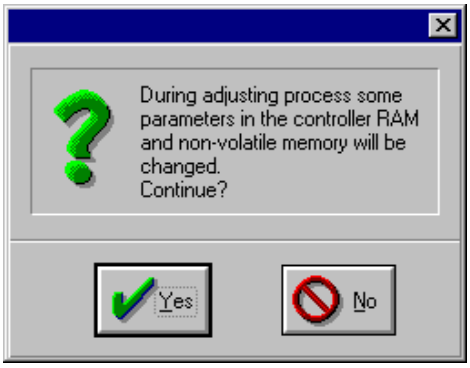


FIGURE 5-19 Control unit warning before adjustment session

2.	Click **Yes**.	Adjuster sets the control module parameters to default values. The **Axis Adjustment** dialog box appears, as in FIGURE 5-20.

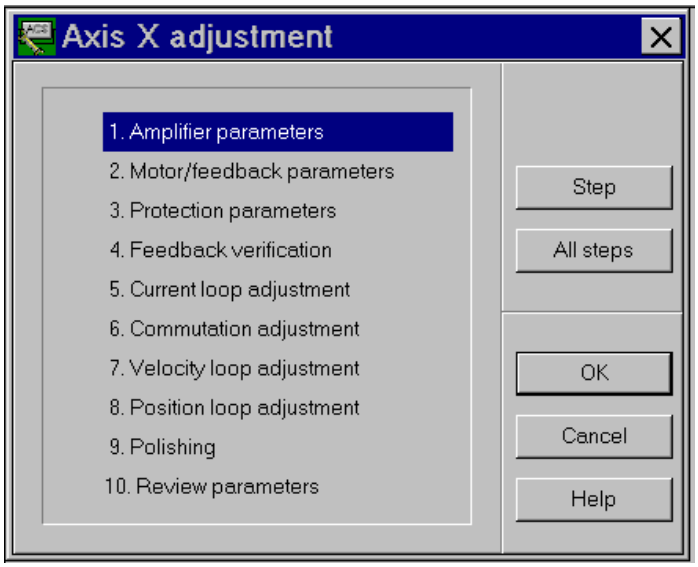


FIGURE 5-20 Adjustment steps

The **Axis adjustment** dialog box is the starting point for each adjustment step.

Selecting a step and clicking **Step** (or double-clicking the step) opens a dialog box. In the loop adjustment steps (steps 5, 7, and 8), a "soft oscilloscope" window also opens, displaying the control unit response as parameters are changed.

5.2.7. Step 1 - Amplifier

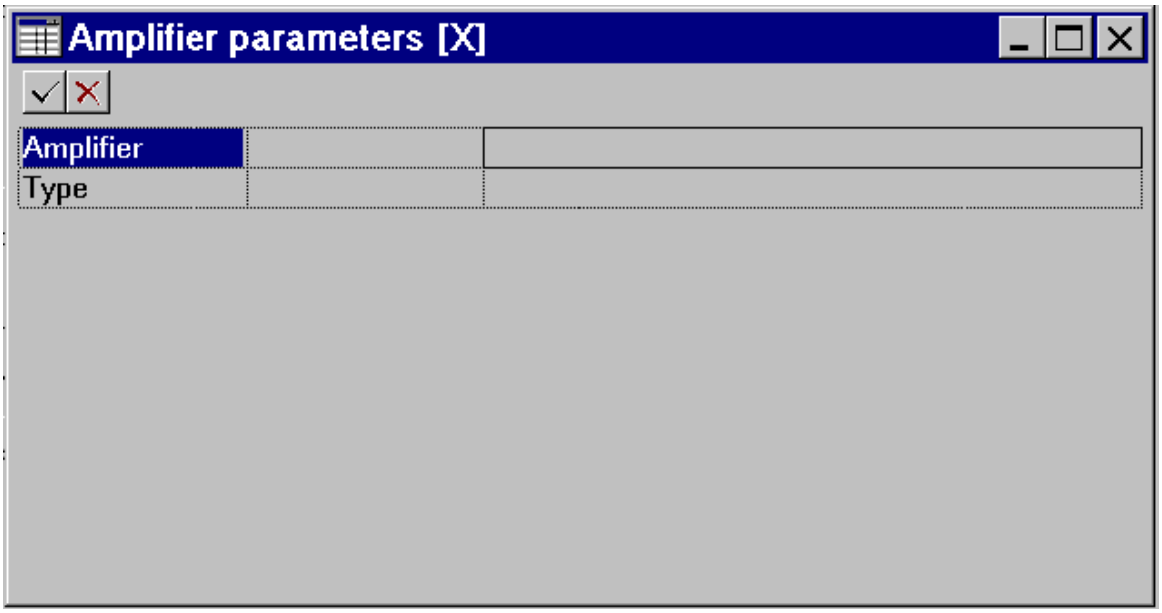


FIGURE 5-21 Amplifier parameters step

The first adjustment step, defining the **amplifier parameters**, is similar to adding an amplifier to the database, which was explained in Section 5.2.4, "Adding an Amplifier to the Adjuster Database". If the unit includes an ACS-Tech80 amplifier, that amplifier is already be in the database and the parameters should be left unchanged.

	Action	Effect of action
1.	Select **1. Amplifier parameters** and click **Step.**	The **Amplifier parameters** dialog box opens FIGURE 5-21.
2.	Open the **Amplifier** list by either clicking on the list cell (FIGURE 5-22) or, with the insertion point on **Amplifier**, by pressing ENTER.	The list is based on the contents of the Adjuster database. If the amplifier for the current application is not in the list, close the **Amplifier parameters** dialog box and add the amplifier to the database, as described in Section 5.2.4, "Adding an Amplifier to the Adjuster Database".

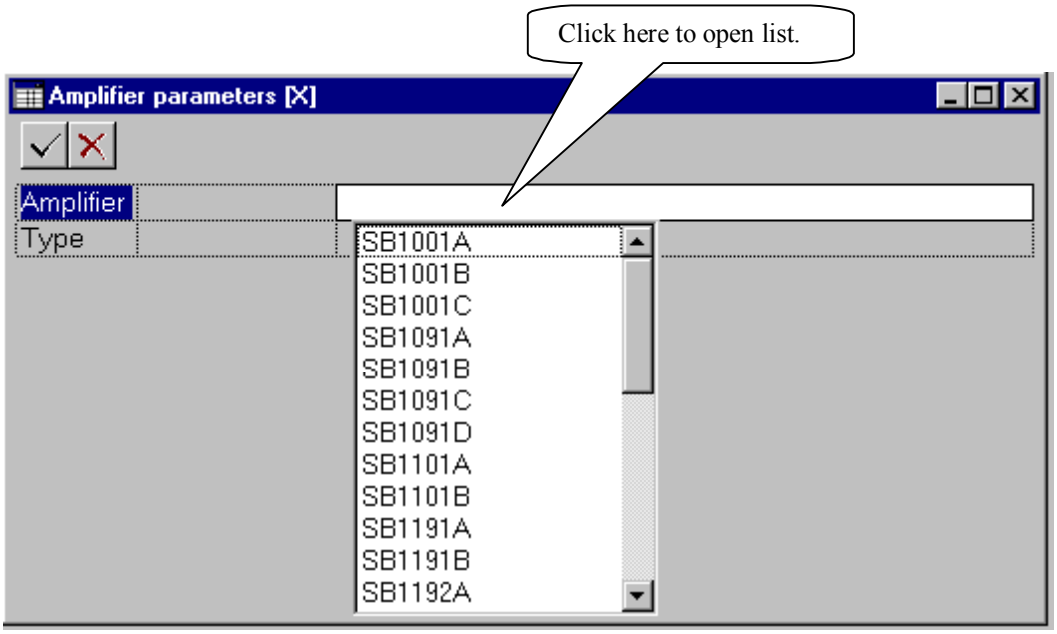


FIGURE 5-22 Selecting the amplifier type

	Action	Effect of action
3.	Select an amplifier from the list by clicking on it once and pressing ENTER or by double clicking on it.	The parameters for the selected amplifier are displayed, as shown in FIGURE 5-23.

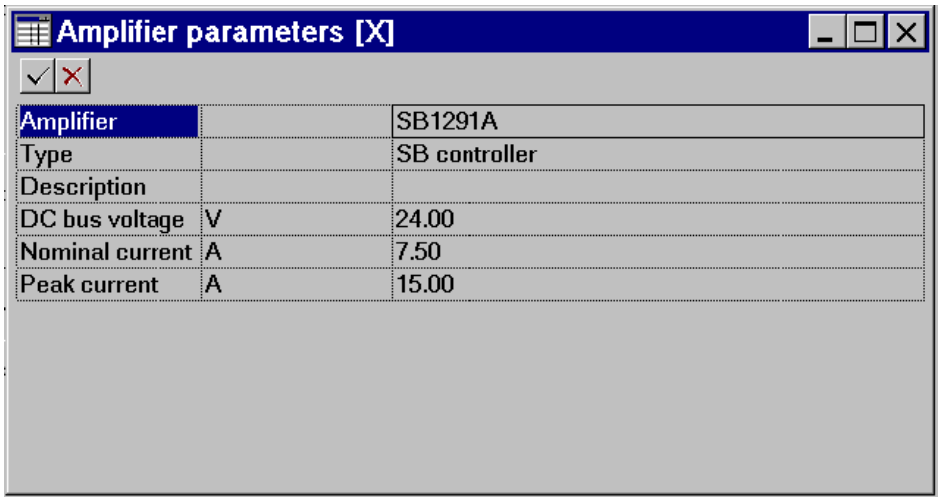


FIGURE 5-23 Amplifier parameters

	Action	Effect of action
4.	Edit the amplifier information, as necessary.	The fields are explained in Section 5.2.4, "Adding an Amplifier to the Adjuster Database".

	Action	Effect of action
5.	Click the OK button .	The **Amplifier parameters** dialog box closes.



Warning

Failure to select the amplifier parameters correctly can result in damage to the motor.

5.2.8. Step 2 - Motor/Feedback

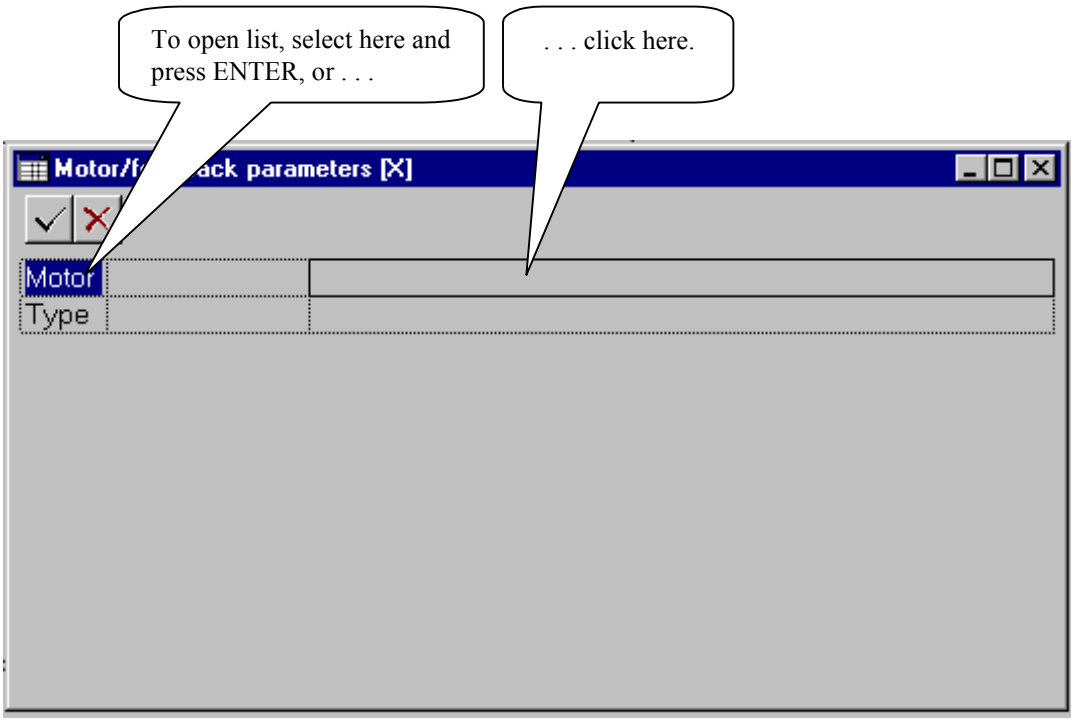


FIGURE 5-24 Selecting the motor type

This step is for defining the motor and the feedback device.

	Action	Effect of action
1.	Select **2. Motor/feedback parameters** and click **Step**.	The **Motor/feedback parameters** dialog box opens (FIGURE 5-24).
2.	Select the **Motor** and **Type** from the list.	The parameters for the selected **Motor** and **Type** are displayed, including the feedback sensor type (FIGURE 5-25).

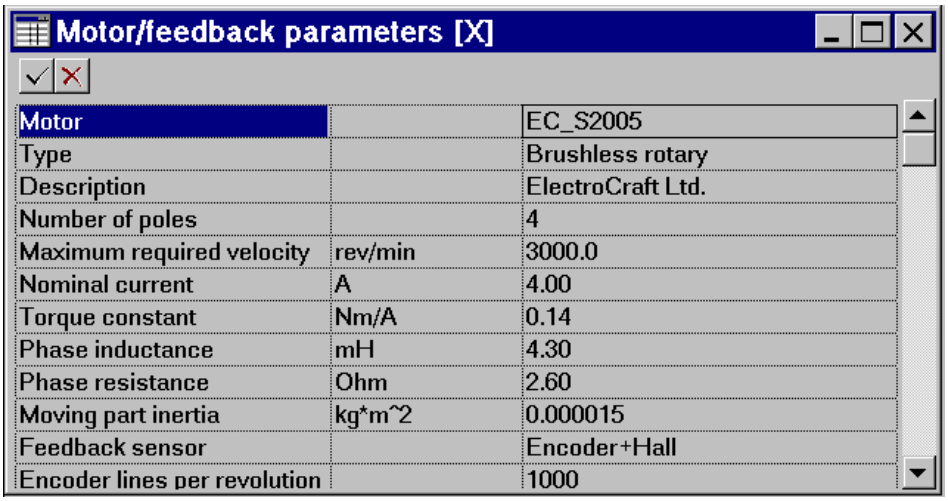


FIGURE 5-25 Motor/feedback parameters

	Action	Effect of action
3.	Edit the motor information.	The fields are explained in Section 5.2.5, "Adding a Motor to the Adjuster Database".
4.	Click the **OK** button.	The **Motor/feedback parameters** dialog box closes.

5.2.9. Step 3 - Protection



Further information

More detailed information about setting protection parameters is contained in Chapter 5, "Adjusting Control Loops."

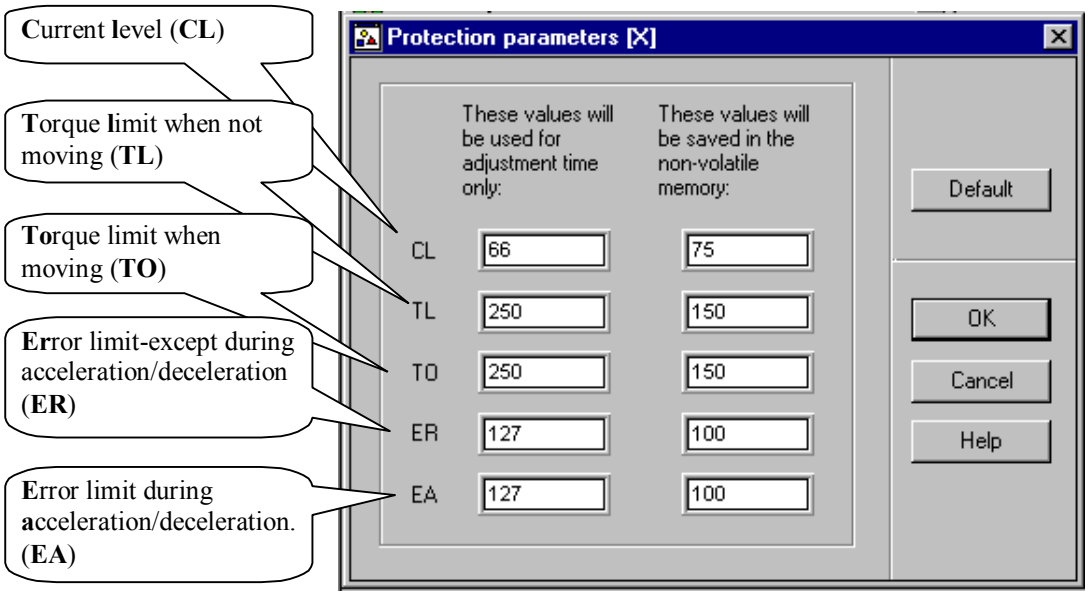


FIGURE 5-26 Protection parameters

The purpose of the protection parameters is to protect the system from misuse, overcurrent, overheat, and other mistakes. For each parameter there are two columns. The left column applies during the adjustment session only. The right column applies during normal operation.

	Action	Effect of action
1.	Select **3. Protection parameters** and click **Step**.	The **Protection parameters** dialog box opens (FIGURE 5-26).
2.	Set the protective parameters. Refer to TABLE 5-7 for more information.	



Warning

Failure to set the correct current limit can result in damage to the motor. For more information about the current limit, refer to Chapter 5, "Adjusting Control Loops."

TABLE 5-7 Detailed guidelines for calculating protective parameters

Parameter	Description
Current level (CL)	**CL** sets the limit for the actual RMS current of the motor. When the RMS current exceeds that limit, the amplifier is disabled, generating error message 27. Set **CL** as a percentage of the motor continuous current and the amplifier nominal current. **CL** is specified as a percentage of the nominal current of the amplifier. For example, if the nominal continuous current of the amplifier is 25A, and the maximum continuous current of the motor is 15A, set **CL** to 60 (**SXCL60<cr>**). If the maximum current of the motor is 10.0A, set **CL** to 40 (**SAXCL40<cr>**). In summary: $CL[\%] = \frac{I_{continuous-motor}}{I_{nominal-amplifier}} \times 100$
Torque limit low (TL)	The **TL** parameter limits the maximum value of the current command (Torque) when the motor is not moving. (When the motor moves, **TO** is used.) A value of 1638 allows for twice the nominal current of the amplifier (I_{peak} = 2 x $I_{nominal}$). A value of 819 allows for 50% of the peak. During the setup procedure it is recommended to set **TL** to 820 or higher. During normal operation it is recommended to set **TL** to a value that is 20%-30% above the maximum anticipated torque disturbance when not moving. Thus, providing a protection to the system if the axis is stacked. **TD** milliseconds after switching from moving to non-moving state, **TL** becomes effective. As soon as motion starts, **TO** becomes effective.
Torque limit (TO)	The **TO** parameter limits the maximum value of the current command while moving. A value of 1638 allows for the nominal peak current of the amplifier. A value of 819 allows for 50% of the nominal peak.
Error limit (ER)	**ER** specifies the maximum position error allowed during periods of constant velocity (otherwise **EA** is used). When the error value exceeds **ER**, the motor is automatically disabled and an error massage 25 is generated. During the initial set-up it is recommended to use a large **ER** value (32000), to prevent false error situations. Afterwards, when moving a large distance back and forth, using the maximum required velocity and acceleration, it is recommended to reduce the **ER**ror limit gradually until the motor traps on error. Then, to increase the value by 100%. Such a value provides a good protective measure against any malfunction.
Error limit during accel./decel. (EA)	**EA** specifies the maximum position error allowed during acceleration and deceleration. When the error value during acceleration exceeds **EA**, the motor is automatically disabled and an error massage 25 is generated. During the initial set-up it is recommended to use a large **EA** value (32,000), to prevent false error situations. Afterwards, when moving a large distance back and forth, using the maximum needed velocity and acceleration, it is recommended to reduce **EA** gradually until the motor traps on error. Then, to increase the value by 100%. Such a value provides a good protective measure against any malfunction.

	Action	Effect of action
3.	Click **OK**.	The **Protection parameters** dialog box closes.

5.2.10. Step 4 - Feedback

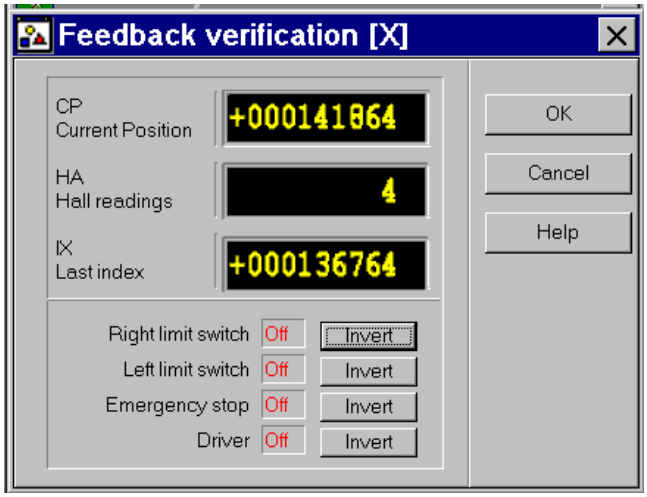


FIGURE 5-27 Feedback verification step

	Action	Effect of action
1.	Select **4. Feedback Verification** and click **Step**.	The **Feedback Verification** dialog box opens (FIGURE 5-27).
2.	Manually move or rotate the motor and verify that the displayed feedback values increase and decrease as expected according to the needed.	When **Current position** (**CP**) counts up, the **Hall reading** (**HA**) (if there are Hall sensors) should display: 0, 1, 2, 3, 4, 5, 0, 1, 2, etc. If it doesn't, try swapping two of the Hall wires.
3.	Activate the safety switches: **Right limit switch, Left limit switch**, and **Emergency stop**.	Verify for each switch that the parameter value changes to ON, when the switch is activated. If the reverse is true (turning the switch on changes the parameter value to OFF), click the appropriate **Inverse** button to ensure that the parameter reflects the actual state of the switch.
4.	Click **OK**.	The **Feedback verification** dialog box closes.

When the position feedback sensors are counting in opposite directions, an error message will occur suggesting that you rotate the axis more slowly or check the wiring. The following is a list of corrective measures:

- Slowly rotate the axis
- Make sure all cables are firmly secured
- Confirm connectivity and polarity (pin assignment)

- Confirm that the proper feedback sensor type has been selected during the Motor Adjustment step
- The following wire swaps may be necessary to match encoder and Hall direction:
  - A+ and A-, or
  - B+ and B-, or
  - 2 pins on Hall

Note

Note
If any safety devices are turned off during the adjustment session, they should be turned back on upon session completion.

5.2.11. Step 5 - Current Loop

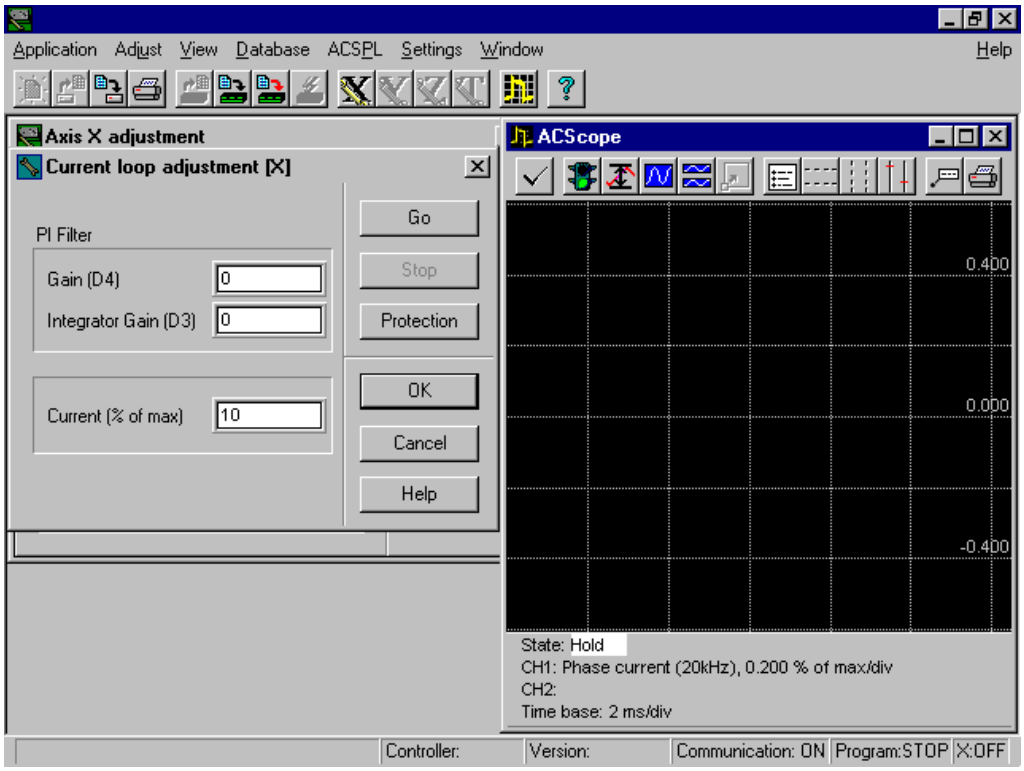


FIGURE 5-28 Current loop adjustment step

	Action	Effect of action
1.	Select **5. Current loop adjustment** and click **Step**.	The **Current loop adjustment** dialog box and the **ACScope** window open (FIGURE 5-28).
2.	Click the Start button (green light) in the **ACScope** window.	The button function changes to **Stop** (red light). The **ACScope** is now active.

	Action	Effect of action
3.	Click the **Go** button in the **Current loop adjustment** dialog box.	A waveform of the current response to a step command appears in the window.
4.	Set the **Integrator Gain (D3)** to 2000 and the **Gain** (**D4**) to 100.	An initial profile is displayed, similar to the following figure. (If the profile extends out of view, click the **Adjust vertical scale** button in the **ACScope** toolbar.)

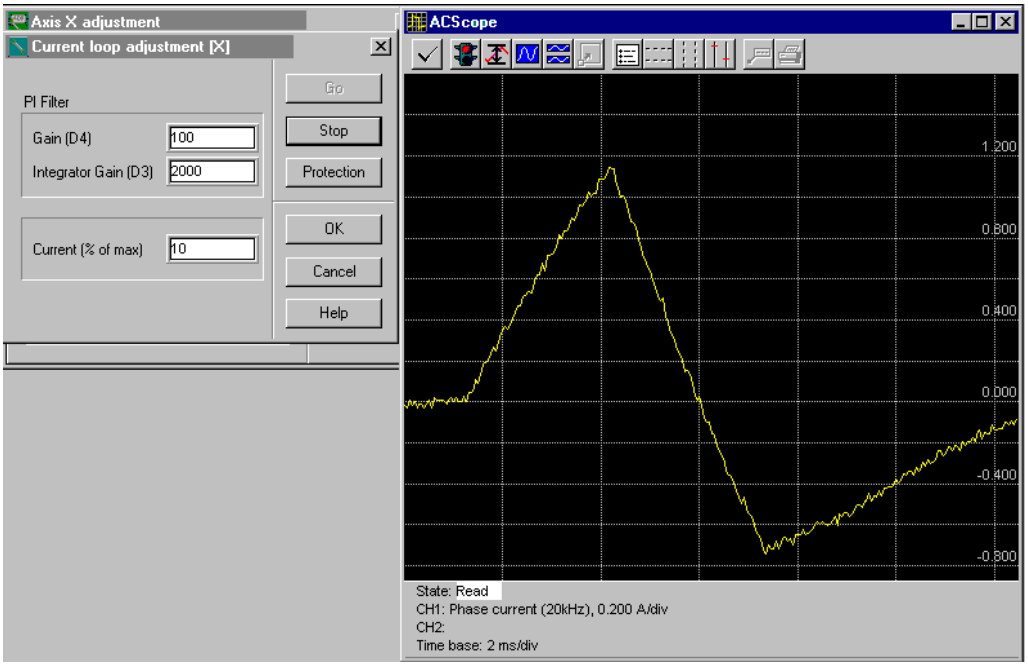


FIGURE 5-29 Initial current loop profile

5.	Increase/decrease the **Gain** (**D4**) to 200. Continue to increment by 200 (example, 400, 600, 800, etc.) until the profile is similar to the following figure.	

Action	Effect of action

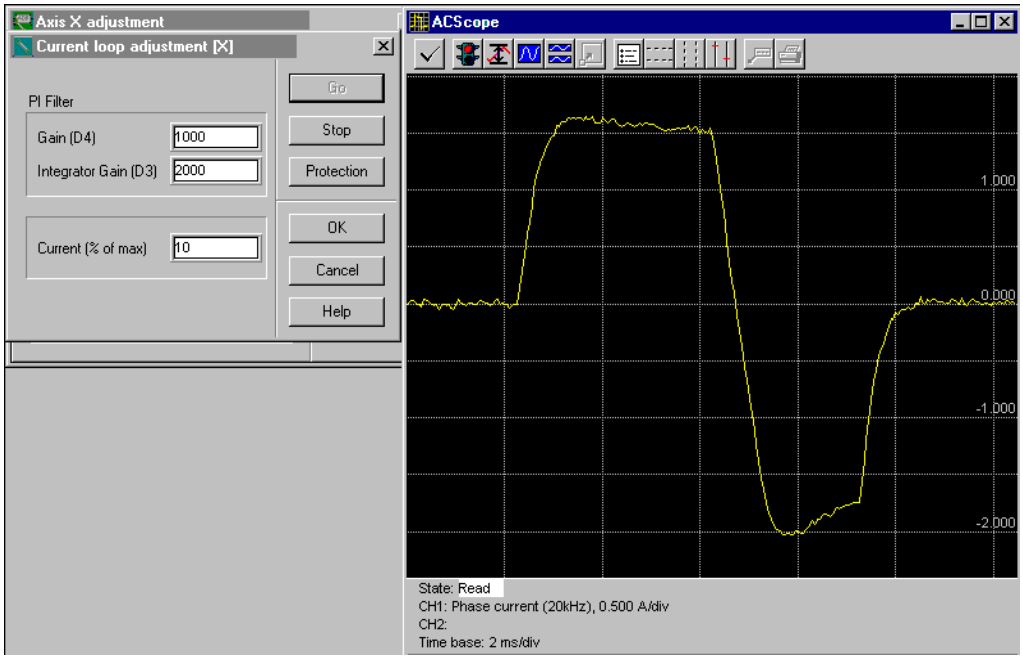


FIGURE 5-30 Final current loop profile

6.	Click **OK**.	The **Current loop adjustment** dialog box and the **ACScope** window close.



Caution

Avoid setting the **Current** parameter outside the range 10% to 30%.

5.2.12. Step 6 - Commutation

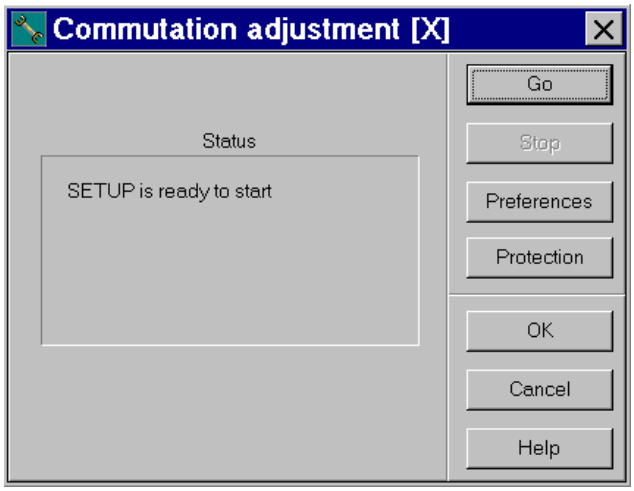


FIGURE 5-31 Commutation adjustment step



Warning

During commutation, the motor physically moves.



Warning

At this point, the phase order of the wiring is fixed. Remember to note at this point how the motor and encoder are wired, to use as a future reference.

	Action	Effect of action
1.	Select **6. Commutation adjustment** and click **Step.**	The **Commutation adjustment** dialog box opens (FIGURE 5-31).
2.	Click **Preferences**.	**The Commutation preferences dialog box opens.**

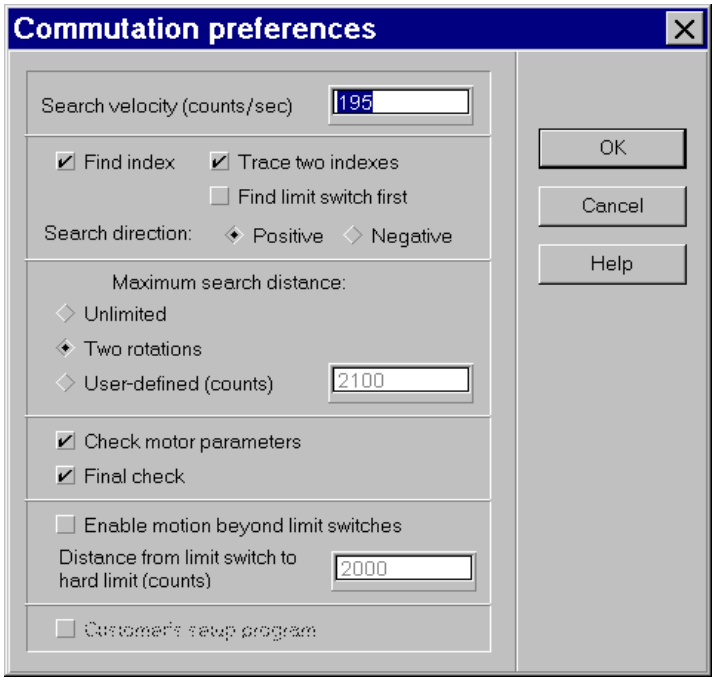


FIGURE 5-32 Commutation preferences dialog box

	Action	Effect of action
3.	Select the following check boxes: - **Find index** - **Trace two indexes** - **Search direction: Positive** - **Maximum search distance:** **Two rotations** **Check motor parameters** **Final check**	
4.	Click **OK**.	The **Commutation preferences** dialog box closes.
5.	Click **Go**.	The following message is displayed.

Action	Effect of action

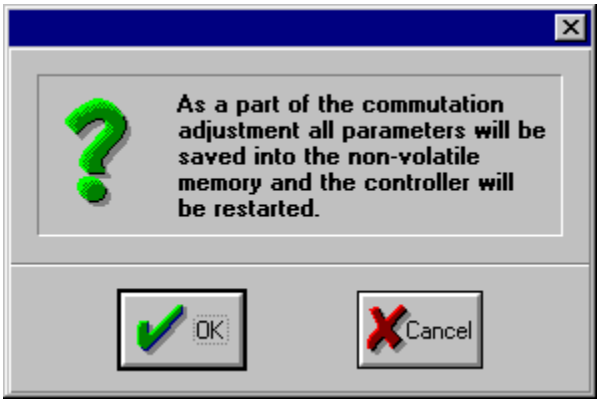


FIGURE 5-33 Prompt to write parameters to nonvolatile memory

6.	Click **OK**.	The values of the control unit's parameters are saved to the control unit's nonvolatile memory. The **Adjuster** initiates commutation adjustment. The process can take up to several minutes. When the process is complete, the status message should read "Setup finished successfully."

Action	Effect of action

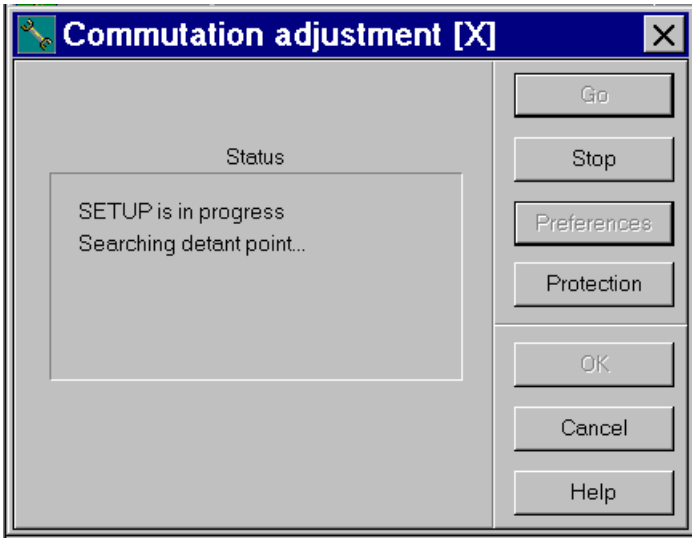


FIGURE 5-34 Adjustment in progress

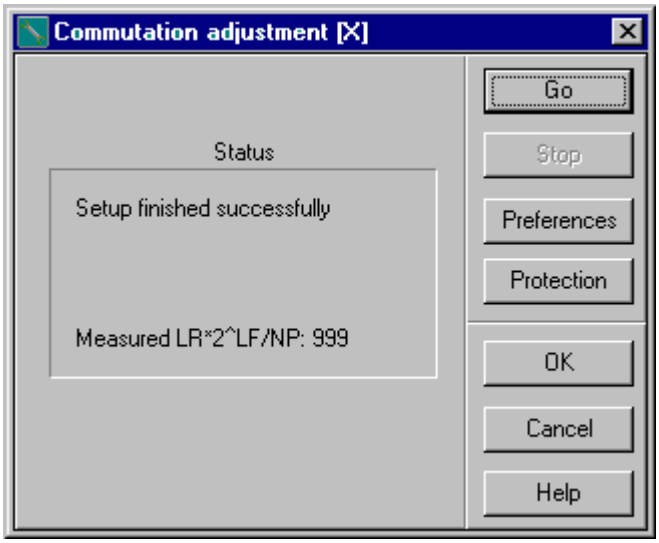


FIGURE 5-35 Successful completion of commutation

7.	Click **OK**.	The **Commutation adjustment** dialog box closes.



Warning

Commutation adjustment MUST complete successfully. Do not proceed further until this has been accomplished. For more information about commutation adjustment, see Chapter 5, "Adjusting the Control Loops."

5.2.13. Step 7 - Velocity Loop

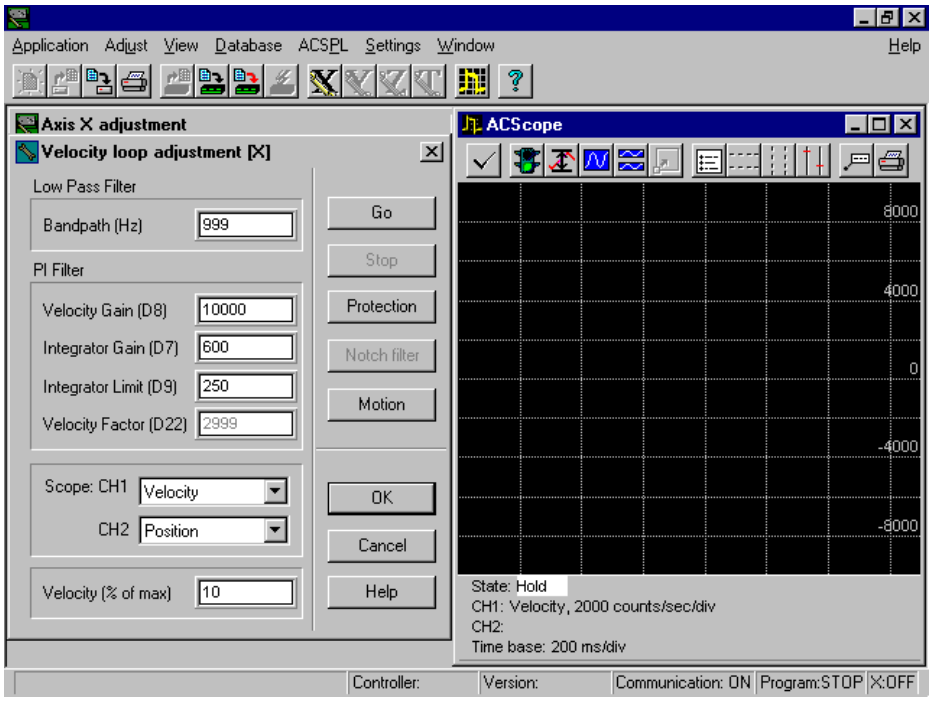


FIGURE 5-36 Velocity loop adjustment step

	Action	Effect of action
1.	Select **7. Velocity loop adjustment** and click **Step.**	The **Velocity loop adjustment** dialog box and **ACScope** window open (FIGURE 5-36).
2.	First set the motion parameters for the velocity loop adjustment. To do so, click **Motion**.	The **Motion parameters** dialog box is displayed (FIGURE 5-37).

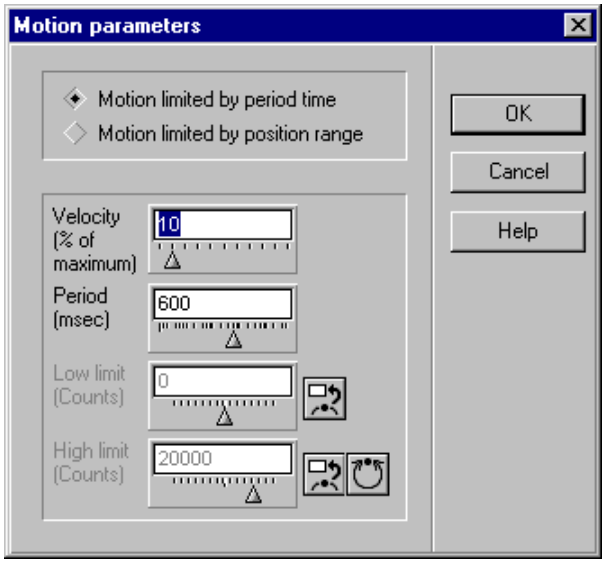


FIGURE 5-37 Motion parameters (for velocity loop)

	Action	Effect of action
3.	Change the **Period** to 600msec. Click OK.	The **Motion parameters** dialog box closes.
4.	Click the **Start** button (green light) in the **ACScope** window.	The button function changes to **Stop** (red light). The soft oscilloscope is now active.
5.	Click **Go** in the **Velocity loop adjustment** dialog box.	A waveform of the velocity response appears in the **ACScope** window.

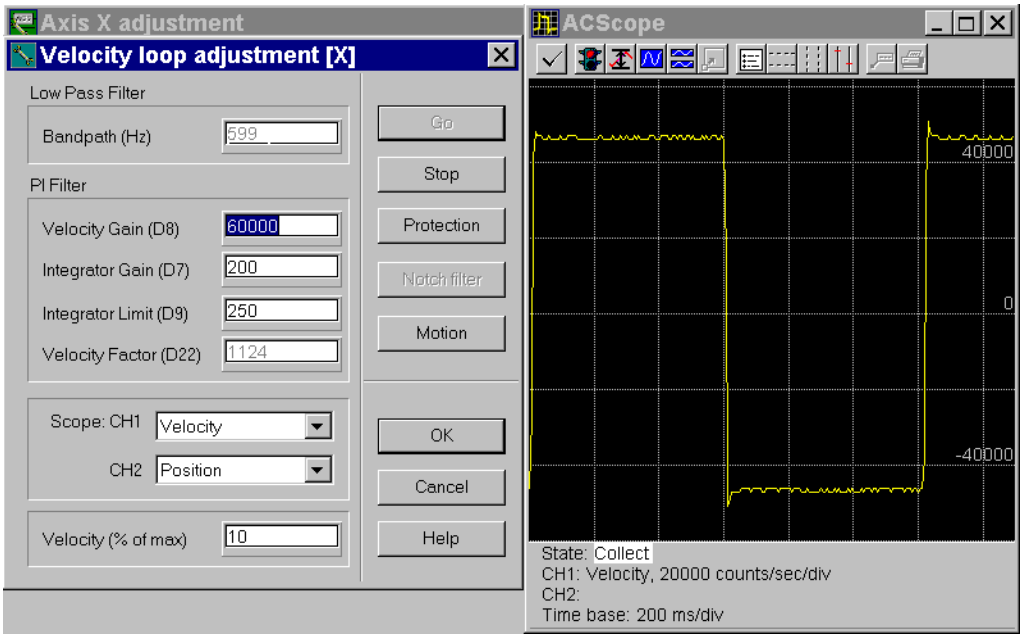


FIGURE 5-38 Typical velocity loop step response

	Action	Effect of action
6.	Set the **Integrator Gain** (**D7**) to 200.	
7.	Increase/decrease the **Velocity Gain** (**D8**) until a good step response profile is achieved.	A typical step profile for the velocity loop is shown in FIGURE 5-38. (If the profile extends out of view, click the **Adjust vertical scale** button in the **ACScope** toolbar.)

Note

Note
Avoid setting Vel (% of max) **higher than 10%.**

	Action	Effect of action
8.	Click **OK**.	The **Velocity loop adjustment** dialog box and the **ACScope** window close.

5.2.14. Step 8 - Position Loop

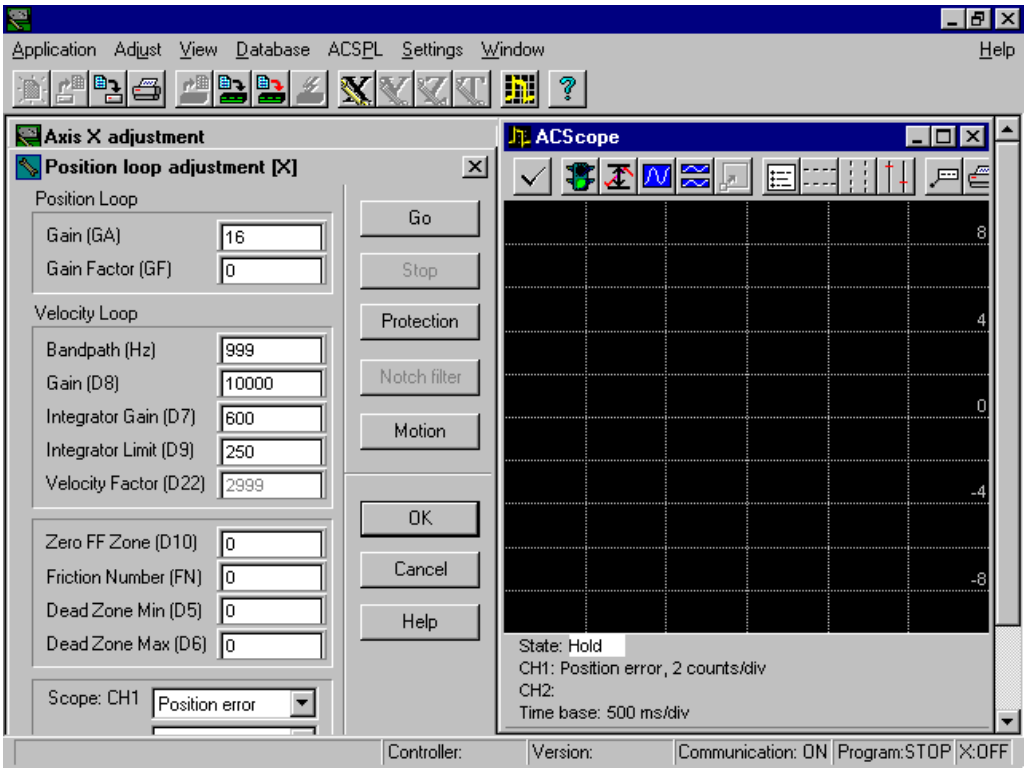


FIGURE 5-39 Position loop adjustment step

	Action	Effect of action
1.	Select **8. Position loop adjustment** and click **Step**.	The **Position loop adjustment** dialog box and the **ACScope** window open (FIGURE 5-39).
2.	First set the motion parameters for the position loop adjustment. To do so, click **Motion**.	The **Motion parameters** dialog box opens (FIGURE 5-40).

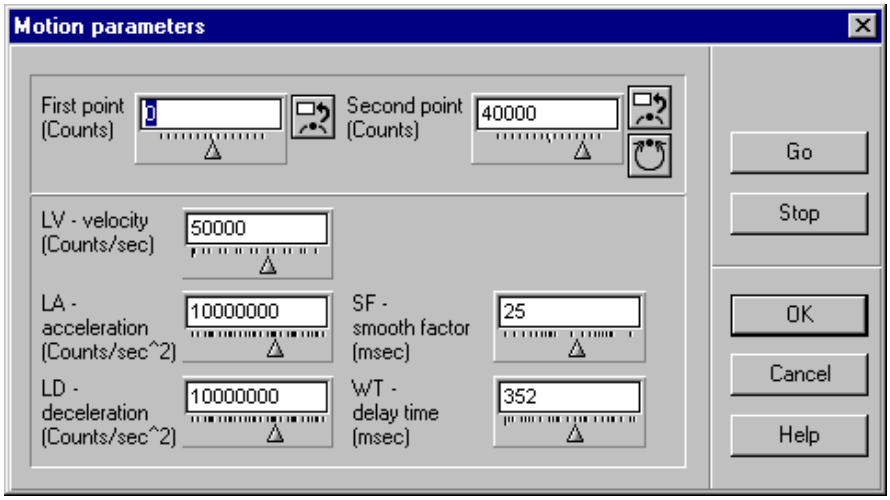


FIGURE 5-40 Motion parameters (for position loop)

	Action	Effect of action
3.	Set the **Velocity** (**LV**), **Acceleration** (**LA**), and **Deceleration** (**LD**) to 50% of the maximums required for the motion control application. Make the distance between the first and second point large enough that the motor will reach the constant velocity region.	
4.	Click **OK**.	The **Motion parameters** dialog box closes.
5.	Click the **Start** button (green light) in the **ACScope** window.	The button function changes to **Stop** (red light). The soft oscilloscope is now active.
6.	Click **Go** in the **Position loop adjustment** dialog box.	A waveform of the position response appears in the **ACScope** window.

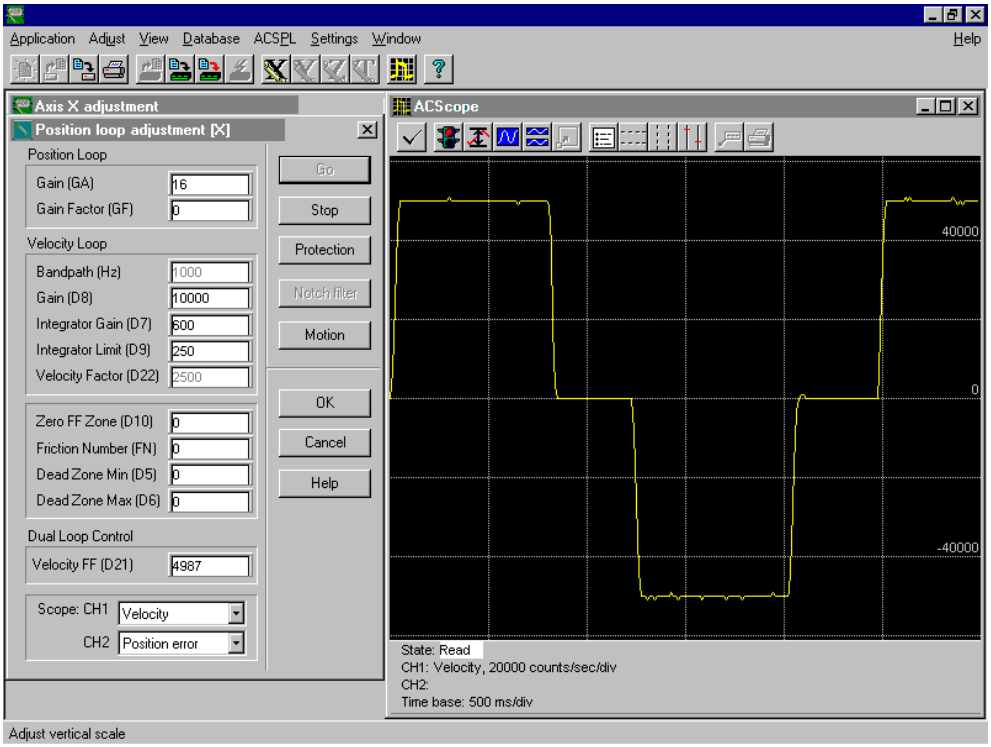


FIGURE 5-41 Typical velocity profile

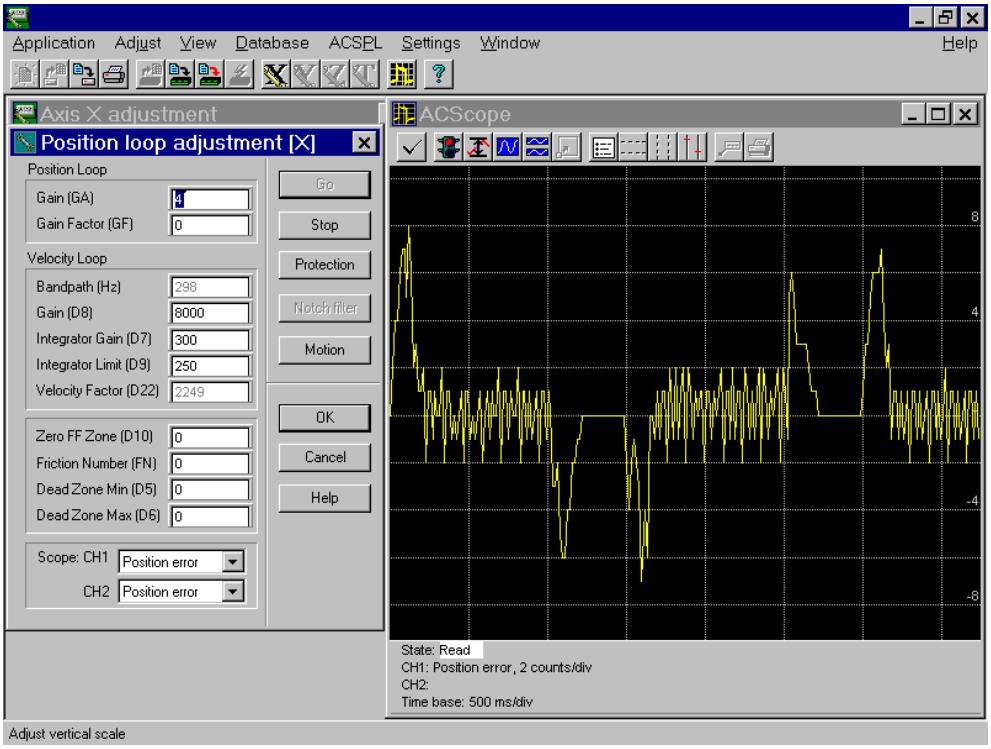


FIGURE 5-42 Typical position error profile

	Action	Effect of action
7.	Increase/decrease the **Gain** (**GA**) until a good response profile is achieved.	Typical velocity and position error profiles for the position loop are shown in FIGURE 5-41 and FIGURE 5-42. (If the profile extends out of view, click the **Adjust vertical scale** button in the **ACScope** toolbar.)

Note

Note

If the protection parameters are too restrictive, it can cause position error failures. To correct this, click Protection **to open the** Protection parameters **dialog box, then increase the value of the limiting parameter.**

	Action	Effect of action
8.	Click **OK**.	The **Position loop adjustment** dialog box and the **ACScope** window close.

5.2.15. Step 9 - Polishing

Further information

More detailed information about polishing is contained in Chapter 5, "Adjusting Control Loops"

The **Polishing** step is for final optimization of the system performance. Polishing is not required at this time.

5.2.16. Step 10 - Reviewing Parameters

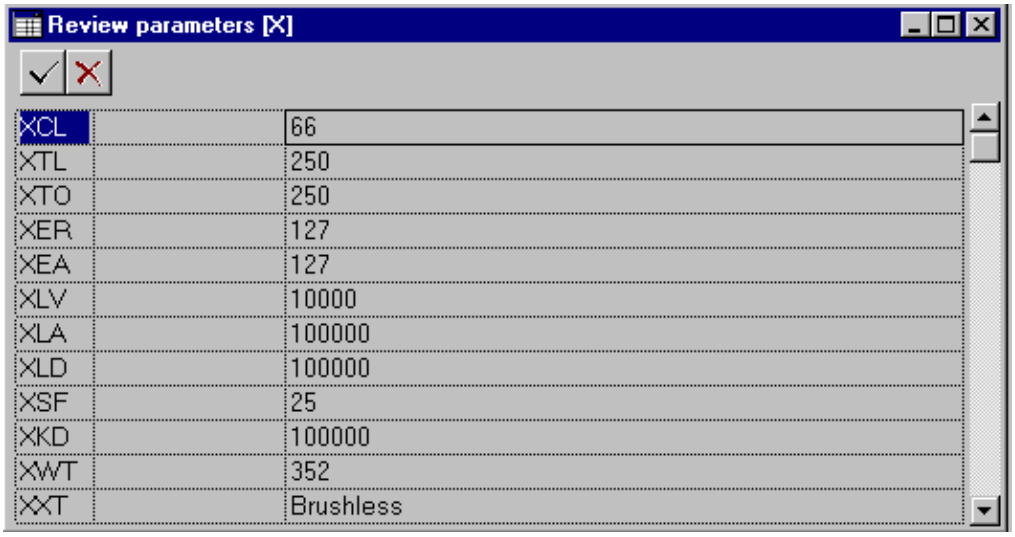


FIGURE 5-43 Review parameters step

This is the last stage of the adjustment session. The parameter values set during the adjustment session (steps 1 through 9) are accessible here. If it is necessary to change a parameter value, it can be done here directly or, if preferred, by closing the **Review parameters** step going back to the step containing the parameter.

	Action	Effect of action
1.	Select **10. Review parameters** and click **OK**.	The **Review parameters** dialog box opens (FIGURE 5-43). The results of the nine previous steps are organized in an expandable tree format (FIGURE 5-44).

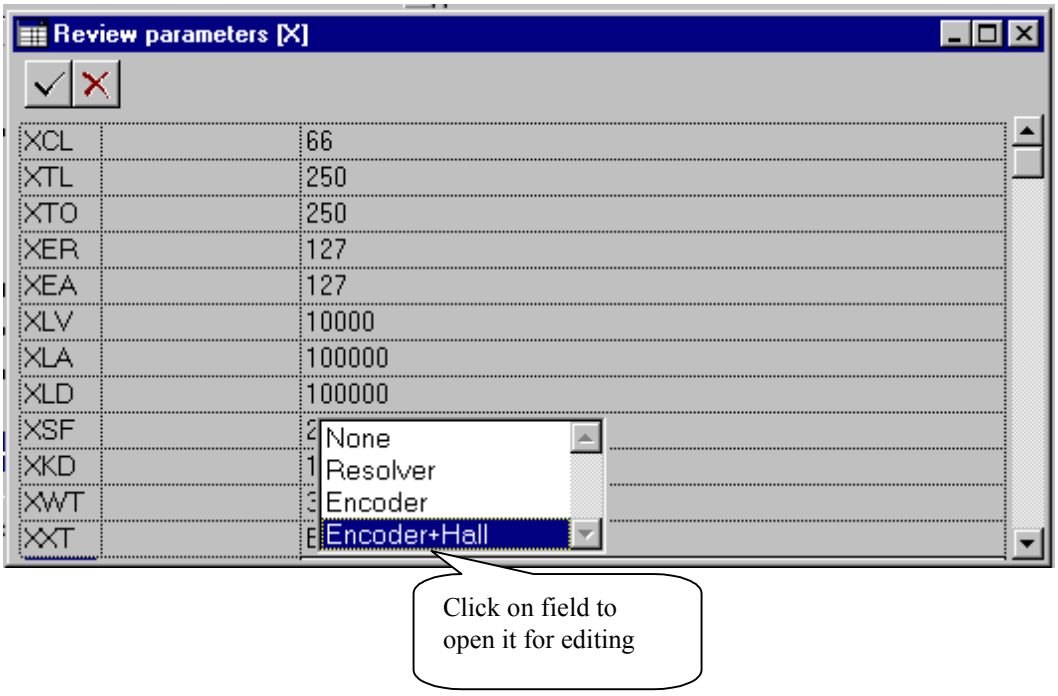


FIGURE 5-44 Editing parameters

	Action	Effect of action
2.	When done click **OK**.	The **Review parameters** dialog box closes.

5.2.17. Saving the Adjustment Application

	Action	Effect of action
1.	Click **OK**.	The **Review parameters** dialog box closes. The **Axis Adjustment** dialog box becomes the focus.
2.	Click **OK**.	A message appears asking whether to save the new application to the control unit's nonvolatile memory and restart the control unit (FIGURE 5-45).

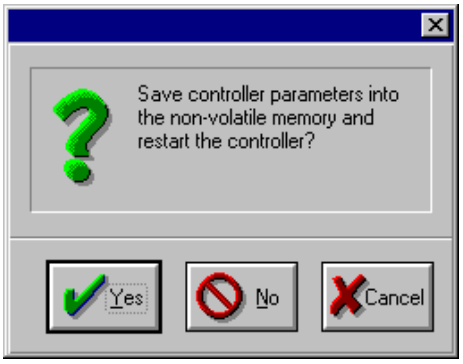


FIGURE 5-45 "Save to controller nonvolatile memory" query

	Action	Effect of action
3.	Click **Yes**	Adjuster performs the actions stated and the **Axis Adjustment** dialog box closes.
4.	On the **Application** menu, click **Save**.	The Application is written to the PC hard disk. This is recommended as a backup precaution. Upon successful save, a confirmation box is displayed (FIGURE 5-46).

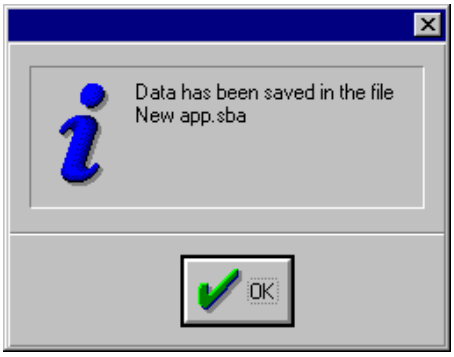


FIGURE 5-46 "Application saved to PC hard disk" confirmation

	Action	Effect of action
5.	Click Yes.	The confirmation box closes.
6.	On the **Application** menu, click **Exit.**	Adjuster closes.



Warning

If any safety devices were turned off during the adjustment session, they should be turned back on upon session completion.

5.3. ACSPL Programming with ACS Debugger



Note

In the examples in this chapter, user input is shown as text in bold capitals, for example, `SXMO1`**. Input must be followed by pressing the ENTER (or Carriage Return) key, which is indicated in the examples by** `<cr>`**.**

5.3.1. About ACSPL

ACSPL is the programming language for operating all ACS-Tech80, SB controllers and control modules. ACSPL provides powerful, high-level motion control capabilities in a straightforward, easy to use syntax. There are two modes for working with ACSPL:

- **Direct mode:** Commands are issued to the control module for immediate execution.

- **Program mode**: A program (sequence of commands) is stored in the control module's nonvolatile memory for later execution.

ACS Debugger is a comprehensive ACSPL development environment. It enables both direct mode and program mode operation.



Further information

More detailed information about ACSPL is contained in the *ACSPL Software Guide*.

To illustrate the relationship between the ACSPL operation modes, TABLE 5-8 shows two different ways to accomplish the following task:

Read the unit's current level, then set the current level to 55%.

TABLE 5-8 Two ways to read and set an ACSPL parameter

Method	Report current level	Set current level to 55%
Direct mode	Type **RXCL** and press carriage return (Enter)	Type **SXCL55** and press carriage return (Enter)
Programming mode	Add to program: `disp XCL`	Add to program: `let XCL=55`

5.3.2. Starting ACS Debugger



Note

It is recommended to use ACS Debugger's terminal for direct communication with the control unit. However, any Windows terminal application can also be used.

	Action	Effect of action
1.	From the Windows Start menu, point to the **ACS Tools** program group and click **ACS Debugger**	The ACS Debugger window opens. Debugger attempts to communicate with the control unit. If it succeeds, the **Communication** parameter in the status bar will read `ON` (FIGURE 5-47). If it fails, verify that the communication parameters are set correctly by clicking **Communication** on the **Settings** menu.

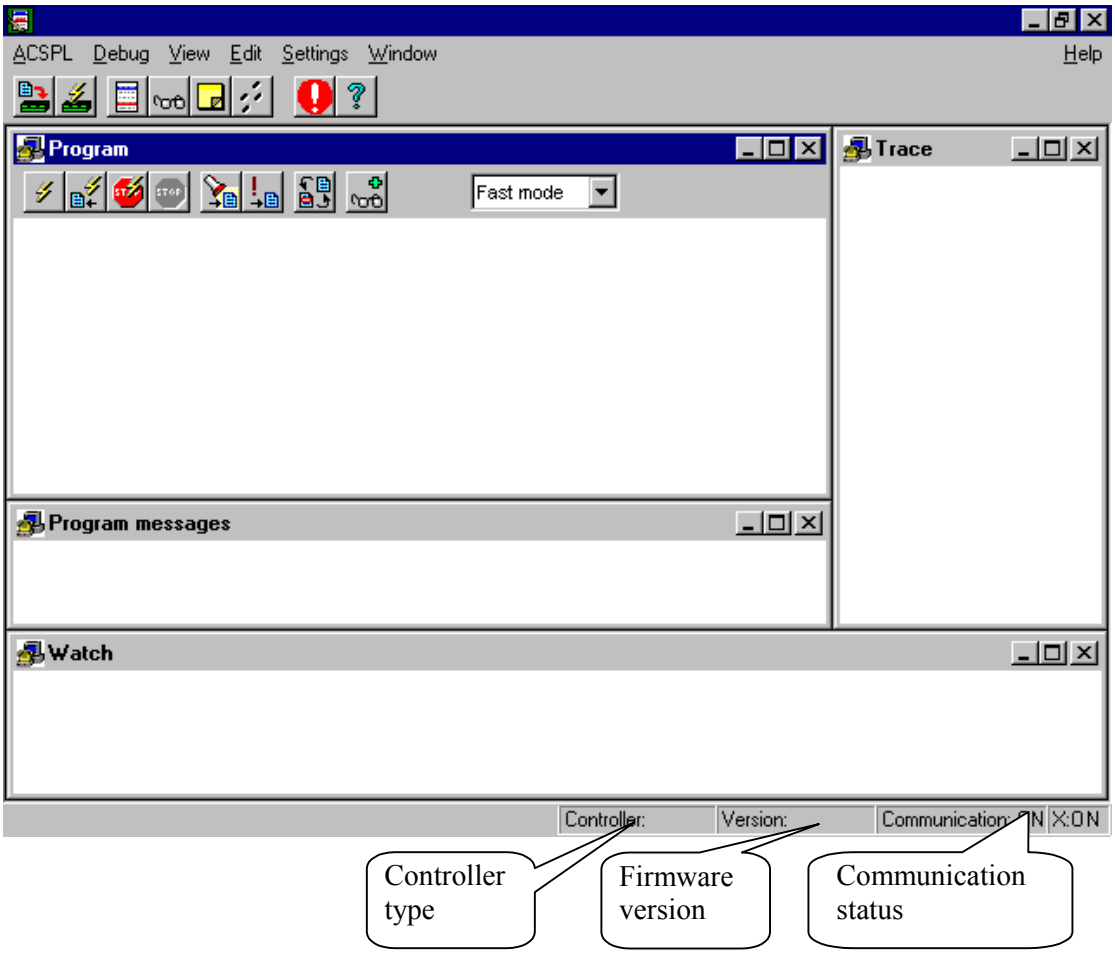


FIGURE 5-47 Debugger status bar - successful communication with control unit

	Action	Effect of action
2.	Once communication is established, click **Communication Terminal** on the **View** menu (FIGURE 5-48).	The Debugger's **Terminal** window comes up. The **Terminal** is in indirect communications mode: messages from the control unit arrive periodically but the terminal can't send commands (FIGURE 5-49).

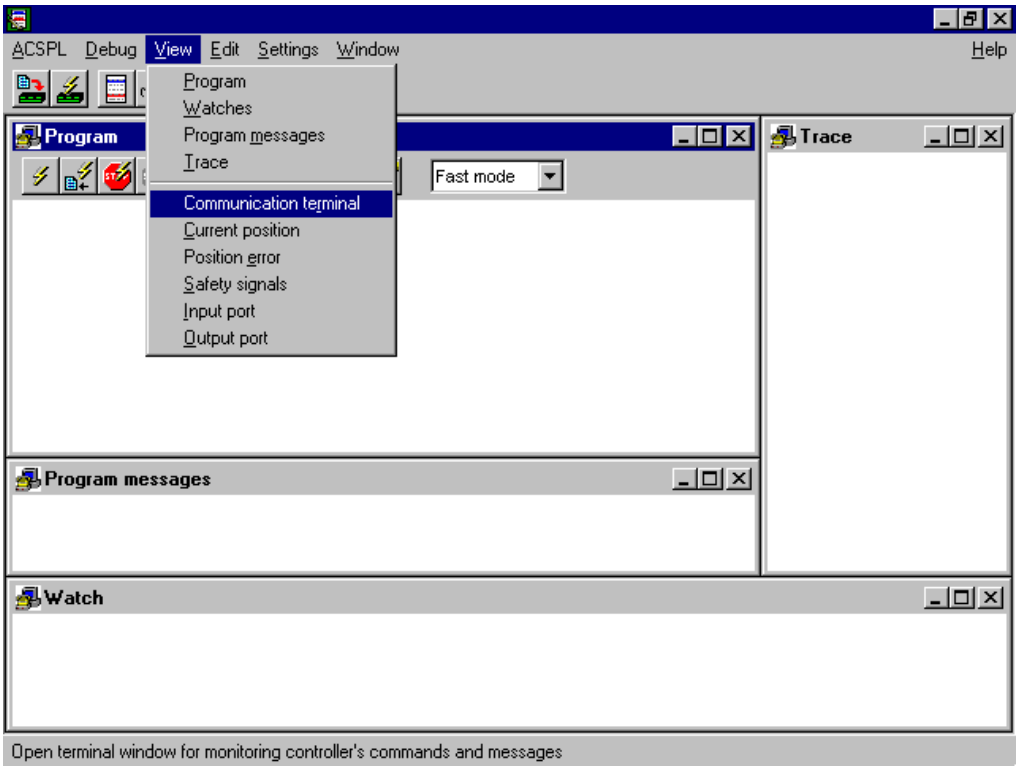


FIGURE 5-48 Opening the Debugger terminal

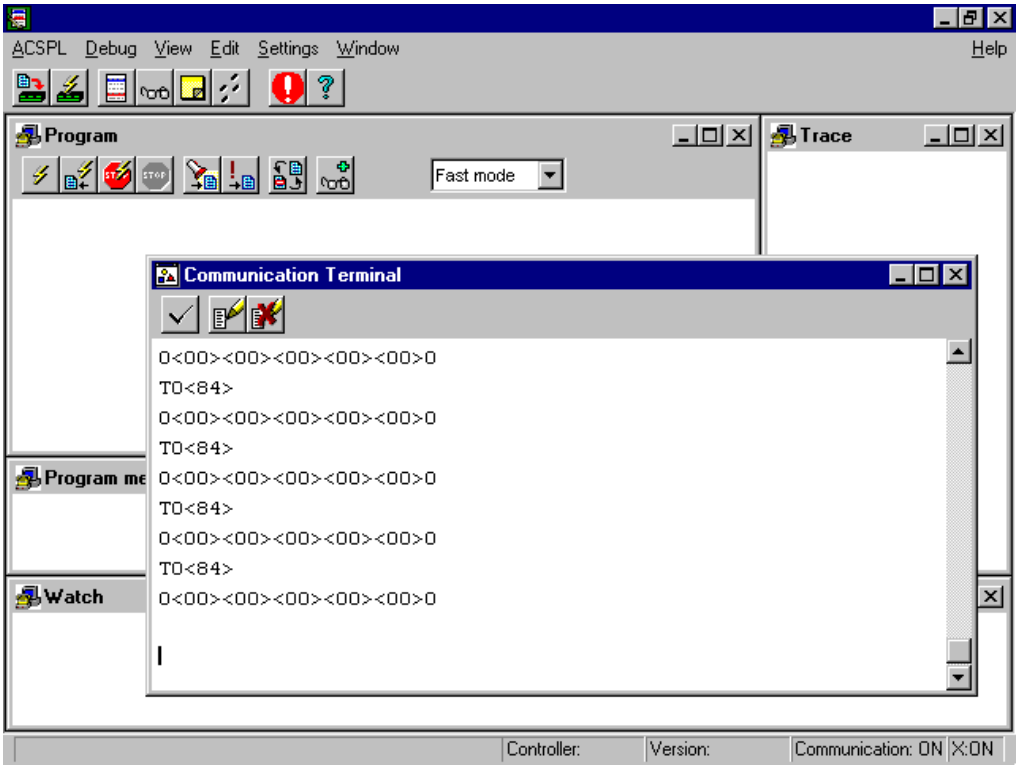


FIGURE 5-49 Debugger terminal

	Action	Effect of action
3.	Click the **Enable Direct Communication** tool button .	The **Terminal** is ready to use for programming the control unit using direct mode (FIGURE 5-50).

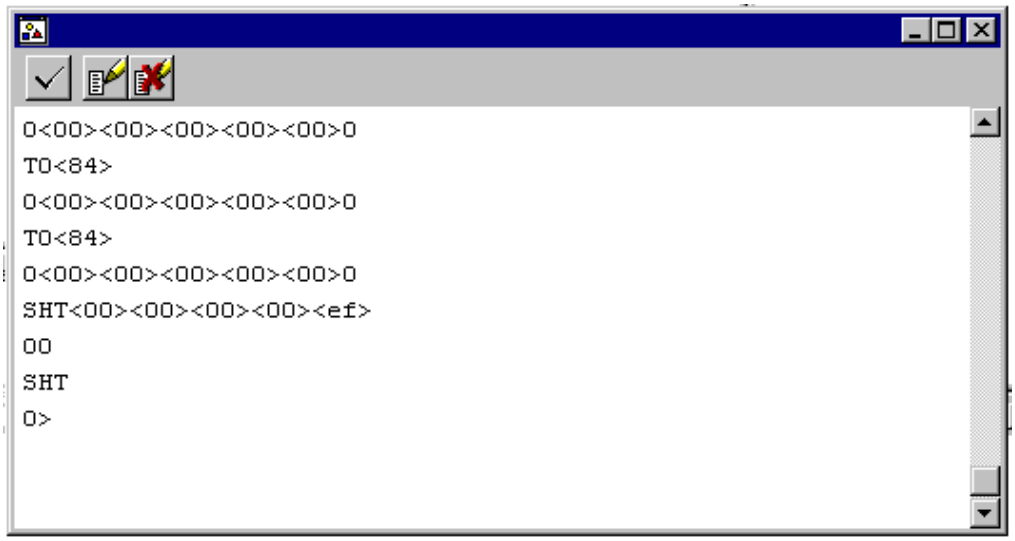


FIGURE 5-50 Direct mode prompt

5.3.3. Disable Function

(Kill All) button added to main toolbar. Kills the running ACSPL program including any autoroutines and disables all motors. After a Kill All command, no autoroutines can be invoked until you run the ACSPL program again. You do not need to restart ACS Debugger.

5.4. Direct Mode

In this mode, the host terminal communicates with the control unit via the serial communication link. The control unit interprets and executes each command as it receives it. The procedure is as follows:

	Action	Effect of action
1.	Type in each command and press ENTER.	The command is downloaded to the control unit where it is immediately interpreted and executed.

5.4.1. Point to Point Move

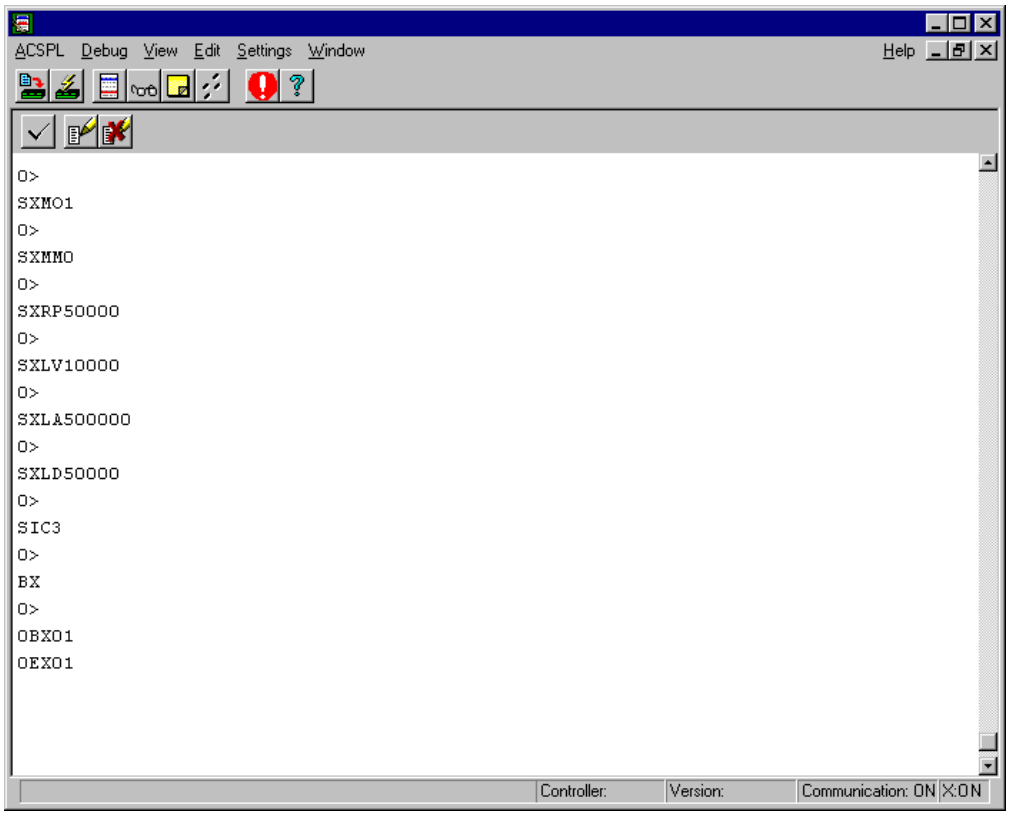


FIGURE 5-51 Point to point move

Type in the following command sequence, as shown in FIGURE 5-51. The motor will move to the specified point.

	Command` mnemonic	Meaning	Effect of command
1.	`SXMO1<cr>`	**S**et **X** axis **Mo**tor enable to **1**	Enable the amplifier.
2.	`SXMM0<cr>`	**S**et **X** axis **M**otion **M**ode to **0**	Set the motion mode to repetitive point-to-point (PTP).
3.	`SXRP50000<cr>`	**S**et **X** axis **R**elative **P**osition to **50000**	Set a relative position move of 50,000 counts
4.	`SXLV10000<cr>`	**S**et **X** axis **L**inear **V**elocity to **10000**	Specify the linear velocity.
5.	`SXLA500000<cr>`	**S**et **X** axis **L**inear **A**cceleration to **500000**	Specify the linear acceleration.

	Command` mnemonic	Meaning	Effect of command
6.	`SXLD50000<cr>`	**S**et **X** axis **L**inear **D**eceleration to **50000**	Specify the linear deceleration.
7.	`SIC3<cr>`	**S**et **I**nitiate **C**ommunication to **3**	Set initiate communication to 3. When IC=3, the control unit prompts each time that a move is requested or terminated.
8.	`BX<cr>`	**B**egin **X** axis	"Start move" command The control unit should reply with the following message: **0BX01** **0-** The ID number **BX-** Response to a **BX** command **01-** The result code. 01 means a successful operation. If the move is executed successfully, the control unit prompts with the following **E**nd message: **0EX01**

An End message of 01, indicates successful completion. The most recent Begin and End messages can be retrieved using the T1 and T2 commands. Type: `T1 T2<cr>` to see the result.

5.4.2. Repetitive Point To Point Move

The result of the following command sequence is that the motor runs back and forth between two points:

	Command mnemonic	Meaning	Effect of command
1.	`SXMO1<CR>`	**S**et **X** axis **Mo**tor enable to **1**	Enable the amplifier.
2.	`SXMM1<cr>`	**S**et **X** axis **M**otion **M**ode **1**	Choose motion mode 1 - repetitive point to point.
3.	`SXZP0<cr>`	**S**et **X** axis **Z**ero **P**osition to **0**	Set the current position counter to 0.

	Command mnemonic	Meaning	Effect of command
4.	`SXWT500`	**S**et **X** axis **W**ait **T**ime to **500**	Define a dwell between moves (in msec).
5.	`SXRP50000<cr>`	**S**et **X** axis **R**elative **P**osition to **50000**	Set a Relative Position move of 50,000 counts.
6.	`BX<cr>`	**B**egin **X** axis	Send a Begin command. The motor will move back and forth between point 0 and 50,000 with a 0.5 second dwell between moves.

5.4.3. Move By Sequence

The result of the following command sequence is that the motor runs through five predefined points:

	Command mnemonic	Meaning	Effect of command
1.	`SXMO1<cr>`	**S**et **X** axis **Mo**tor enable to **1**	Enable the amplifier.
2.	`AXSE0 5000 10000 20000 -20000 50000<cr>`	**A**rray **X** axis **Se**t to **5000 10000 20000 -20000 50000**	Define 5 points in the X target array.
3.	`SXUI4<cr>`	**S**et **X** axis **U**pper **I**ndex to **4**	Sets the upper limit of the X target array. This ensures that the controller will not read values out of the upper range.
4.	`SXLI0<cr>`	**S**et **X** axis **L**ower **I**ndex to **0**	Sets the lower limit of the X target array. **Note:** UI >= LI.
5.	`SXMM3<cr>`	**S**et **X** axis **M**otion **M**ode to **3**	Choose motion mode 3 - move by sequence.
6.	`SXZP0<cr>`	**S**et **X** axis **Z**ero **P**osition to **0**	Set the current position counter to 0. **Note:** This command applies only if the encoder has found the index at least once. Otherwise a controller error no. 15 will result. The error can be ignored and the next command entered.
7.	`SXWT400`	**S**et **X** axis **W**ait **T**ime to **400**	Define a dwell between moves (in msec).

	Command mnemonic	Meaning	Effect of command
8.	BX<cr>	**B**egin **X** axis	Issue a Begin command. The motor will run through the 5 point with a 0.5-second delay between the moves.

5.4.4. Constant Velocity

The result of the following command sequence is that the motor turns at a constant velocity.

	Command mnemonic	Meaning	Effect of command
1.	SXMO1<cr>	**S**et **X** axis **Mo**tor enable to **1**	Enable the amplifier.
2.	**SXMM10 LV25000<cr>**	**S**et **X** axis to **M**otion **M**ode **10** and the **L**inear **V**elocity to **25000**	Switch to motion mode 10 and set the required velocity to 25,000 counts/sec. (***This line demonstrates how more than one parameter can be set in the same command line.***)
3.	**BX<cr>**	**B**egin **X** axis	Start to move. The motor accelerates to the desired speed.
4.	**RXAV<ENTER>**	**R**eport **X axis** **A**ctual **V**elocity	Find out what is the actual speed by sending a Report Actual Velocity command - The control unit measures the actual distance passed during 0.01 second, multiplies it by 100, and prompts with that value.
5.	**SXLV-20000<cr>**	**S**et **X** axis **L**inear **V**elocity to **-20000**	Switch to a speed of 20,000 counts/sec, in the opposite direction The motor decelerates down to the required velocity.
6.	**T0<cr>**	**T**ell **0**	To find out the status of the motor(s), use Tell 0 command
7.	**EX<cr>**	**E**nd **X** axis	To stop the motor, send an End command

5.4.5. Manual Control Using a Joystick

Attach a joystick to the analog input.

	Command mnemonic	Meaning	Effect of command
1.	`SXMO1<cr>`	**S**et **X** axis **Mo**tor enable to **1**	Enable the amplifier.
2.	`SXMM21<cr>`	**S**et **X** axis **M**otion **M**ode to **21**	Change to manual joystick control (motion mode 21).
3.	`BX<cr>`	**B**egin **X** axis	Send a Begin command. The motor is moving at a speed which is relative to the analog input and the value of XLV
4.	`SXLV50000<cr>`	**S**et **X** axis **L**inear **V**elocity **50000**	Now move the joystick. The control unit generates velocity commands that are directly related to the analog voltage output of the joystick potentiometer and the value of **LV**. The maximum velocity is the value of **LV**.
5.	`SXLV10000<cr>`	**S**et **X** axis **L**inear **V**elocity **10000**	If the motor runs too fast, then to achieve better position control with higher resolution, decrease the value of **LV** to a lower value, say 10,000 counts/sec. **Do not make this change when the motor is moving. Doing so could cause the motor to jump.**
6.	`EX<cr>`	**E**nd **X** axis	Terminate the move by an End command.

This "smart joystick's" speed can be adapted to the needs of the application. ACSPL programming, (introduced in the next section), can be used to write a simple program that switches from high speed (for long travel) to low speed, with better position resolution and control, when a switch on one of the inputs is pressed.

In order to prevent axis movement around the stationary point of the joystick, a dead band can be defined via the **L**ower **T**hreshold (**LT**) and **U**pper **T**hreshold (**UT**) parameters. For more information about these parameters, see Chapter 6, "Reference" in the *ACSPL Software Guide*.

5.5. Program Mode

Further information

More detailed information about ACSPL programming is contained in the *ACSPL Software Guide*.

This section shows how to use ACS Debugger to:

- 1. Write a program
- 2. Download the program to the control unit
- 3. Run the program in trace mode
- 4. Run the program in fast mode

FIGURE 5-52 shows the parts of the main Debugger window.

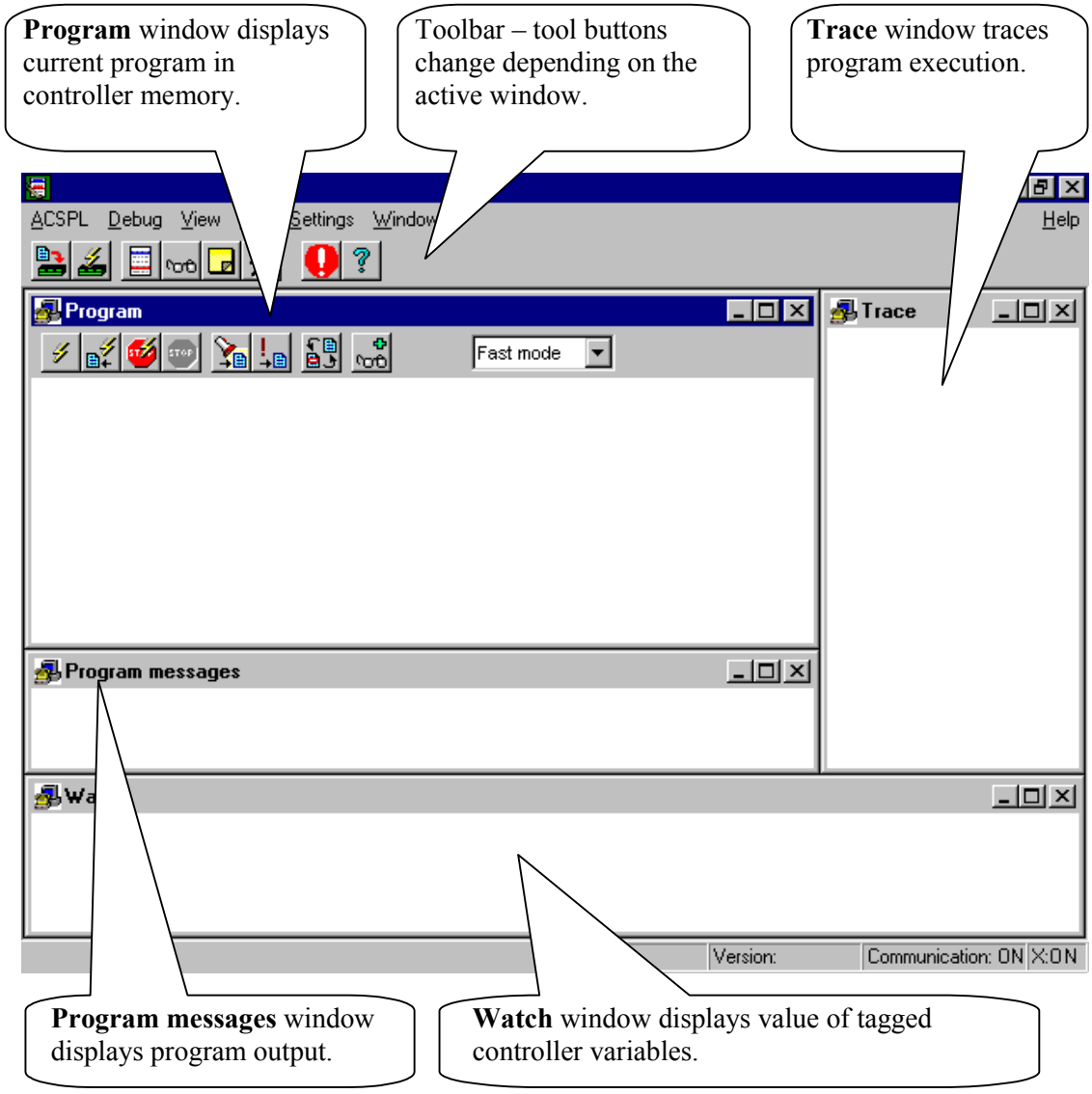


FIGURE 5-52 Debugger main window

5.5.1. Point to Point Move Program

In the following example the motor should make a point to point move and display simple diagnostic messages in the terminal window. The program demonstrates how easy it is to implement an application with built-in diagnostics.

	Action	Effect of action
5.	If the **Communication Terminal** window is still open, click the OK tool button .	The **Communication Terminal** window closes.
6.	On the **Edit** menu, click **Edit file**.	The **File** window opens and the **Open** dialog box displays on top of it (FIGURE 5-53). The **File** window is the program editor.

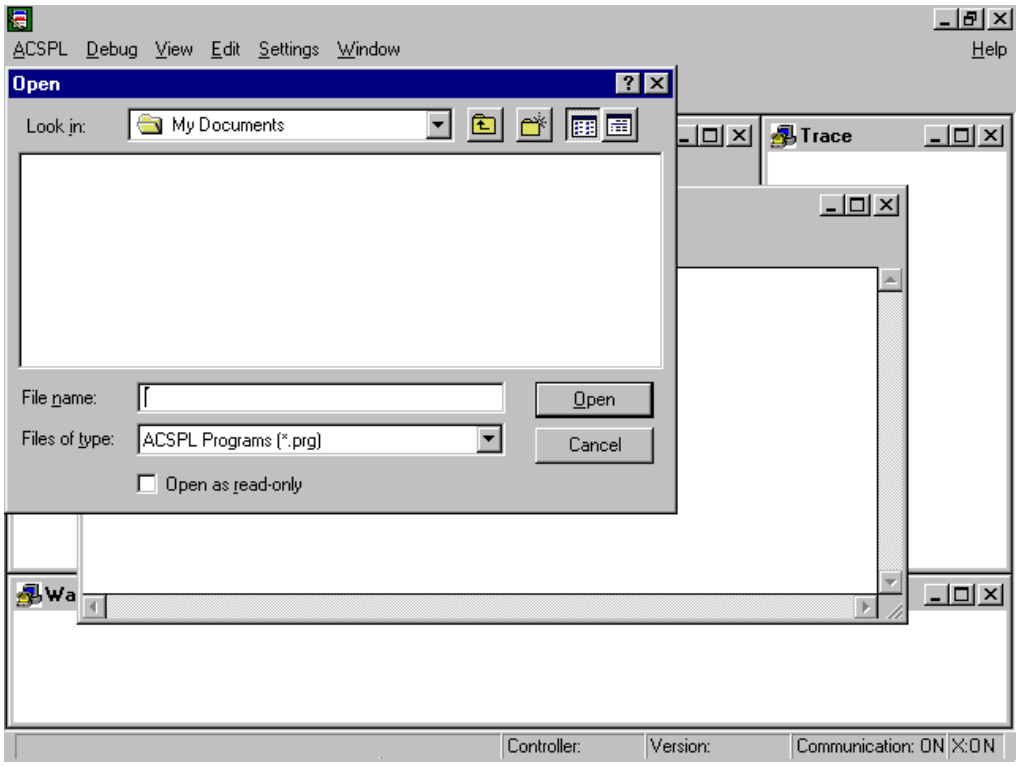


FIGURE 5-53 File window and Open dialog box

	Action	Effect of action
1.	Press ESC (or click **Cancel**).	The **Open** dialog box closes and the **File** window is displayed (FIGURE 5-53).

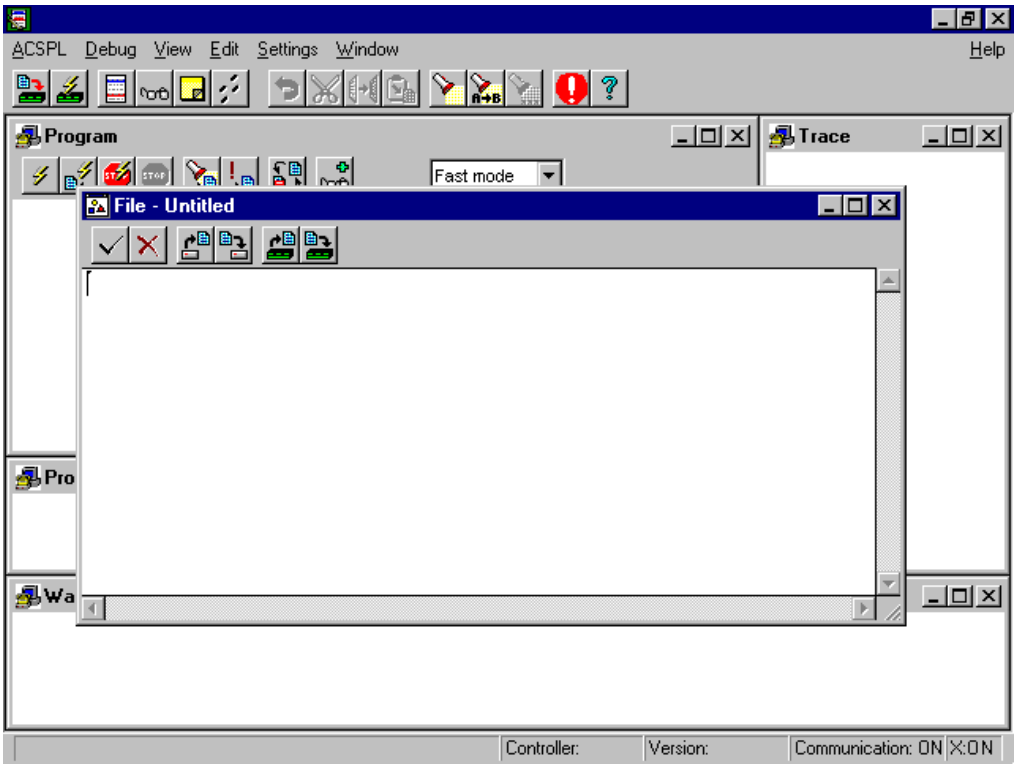


FIGURE 5-54 File window

Action	Effect of action
♦ Type in the program below, pressing ENTER after each line.	The lines are displayed on the editor as they are entered. The completed program is shown in FIGURE 5-55.

	Command mnemonic	Meaning	Effect of command
1.	`Example:`		A label.
2.	`let XMO=1`	**Let X** axis **M**OTOR be **01**	Enable the motor.
3.	`let XMM=0`	**Let X** axis **M**otion **M**ode be **0**	Point to point motion mode.
4.	`let XRP=50000`	**Let X** axis **R**elative **P**osition be **50000**	Relative distance of 50,000 counts.
5.	`exec BX`	**Exec**ute **B**egin **X** axis movement	Begin moving.
6.	`if X_MOVE do`	**If X** axis is **MOV**ING **do** the following	Check if moving.

	Command mnemonic	Meaning	Effect of command
7.	`disp " moving OK.."`	**Disp**lay . . .	Display message in **Program messages** window.
8.	`end`	**End** if … do	End of if-do block
9.	`else do` `disp "Something is wrong."` `disp " press T1T2<cr> to find the reason"` `end`	**Else** . . . **do** the following **Disp**lay … **End** else . . . do	Not moving. Display prompt in **Program messages** window. End of else-do block.
10.	`till ^X_MOVE`	Wait **Till Z** has stopped **Mov**ing	Wait till done.
11.	`if X_END=1 do`	**If** the reason that **X** axis movement **end**ed is status **1**, **do**	Check reason for termination
12.	`disp "Motion completed successfully"`	**Disp**lay …	Display successful completion message in **Program messages** window.
13.	`disp "New location = ", XCP`	**Disp**lay …, **X** axis **C**urrent **P**osition	Display location message in **Program messages** window.
14.	`end`		End of if-do block.
15.	`stop`		End of program.

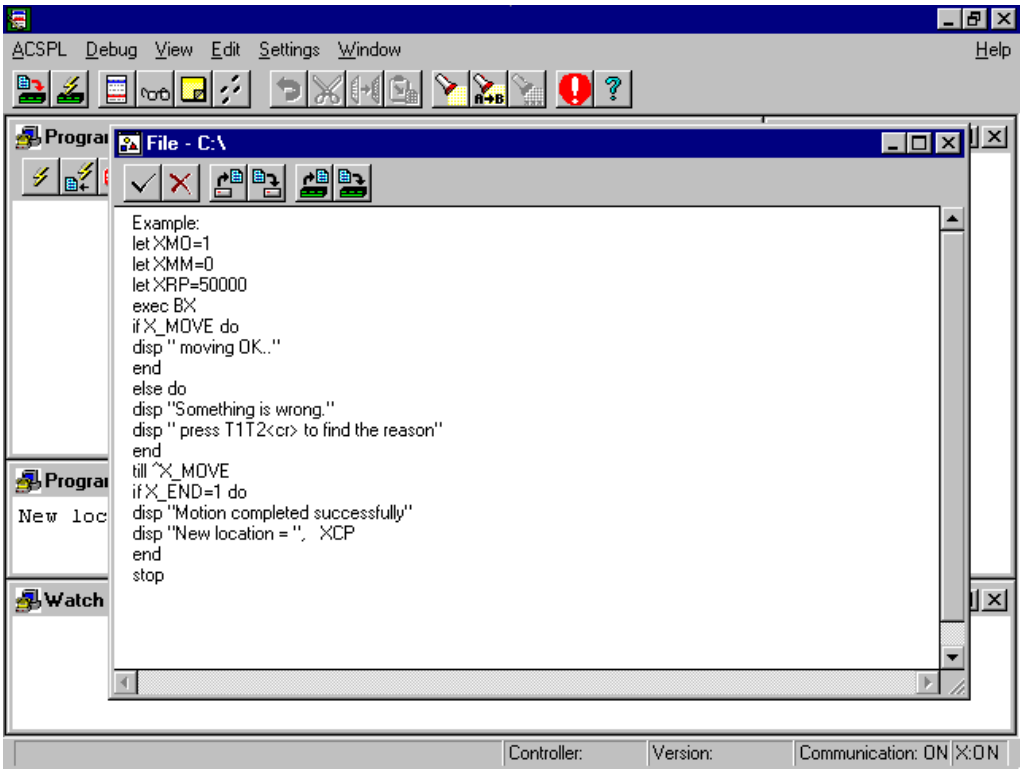


FIGURE 5-55 Program for point to point move

5.5.2. Loading a Program to the Control unit

	Action	Effect of action
1.	Click the **Write Program to Control unit** tool button .	The program is loaded to the control unit RAM. The **Program** window, which displays the control unit RAM contents, now shows the program (FIGURE 5-56).

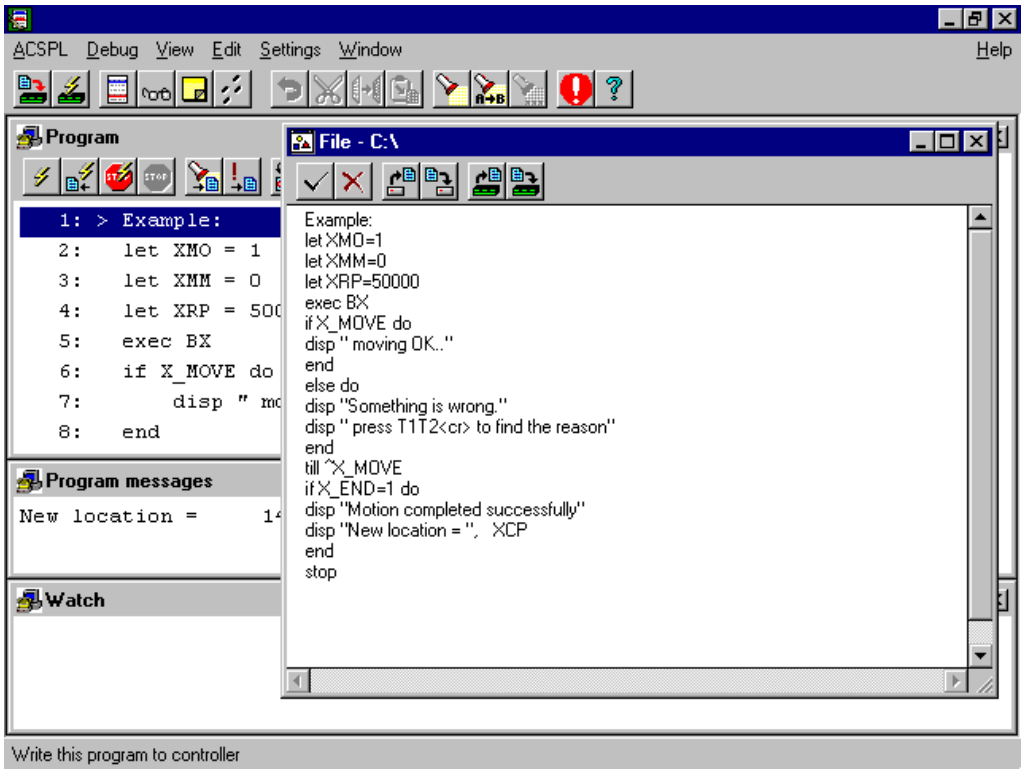


FIGURE 5-56 Program window shows the program in control unit RAM

5.5.3. Execution Modes: Fast and Trace

The ACSPL program can be run from Debugger in either of two modes: Fast or Trace.

In Fast mode, execution continues until one of the following conditions occurs:

- The program encounters one of the breakpoints
- A `Stop` command in the program is executed
- The user issues a `Stop` command from either the toolbar or the ACSPL menu
- A run-time error occurs

In **Trace mode**, as each line of the program is executed, it is highlighted with the selection bar in the **Program** window and the line number is displayed in the **Trace** window.

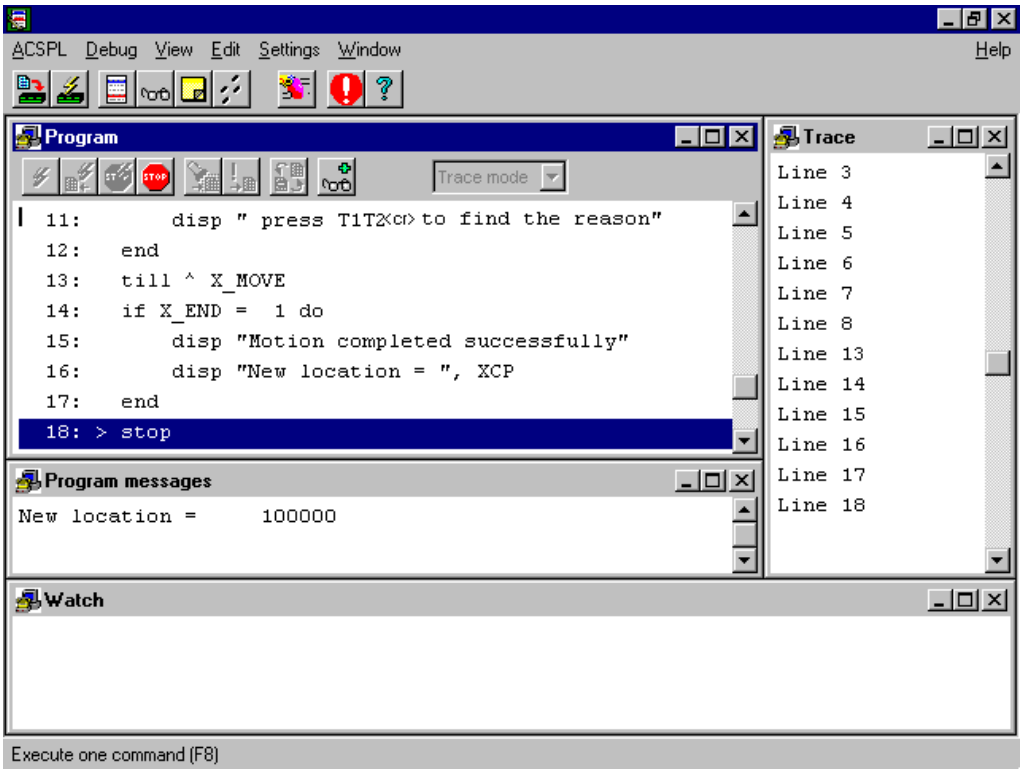


FIGURE 5-57 Trace mode program execution

The execution mode is selected from the **Program** window toolbar. Fast mode is the default.

	Action	Effect of action
1.	On the **View** menu, click **Trace** (FIGURE 5-58).	The **Trace** window opens (FIGURE 5-59).

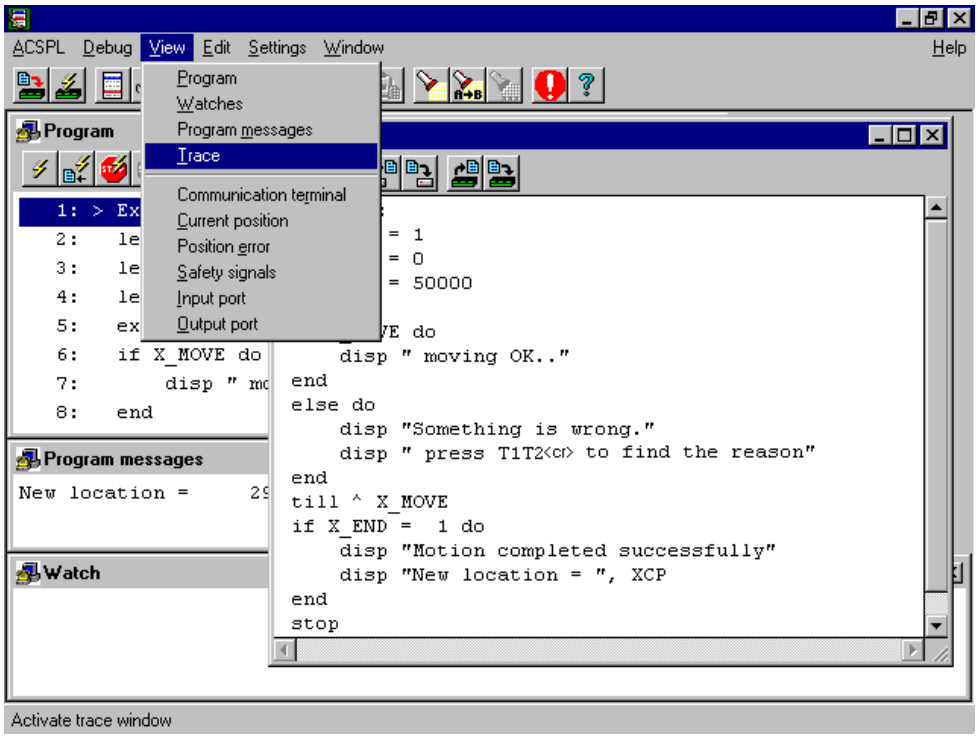


FIGURE 5-58 Opening the Trace window

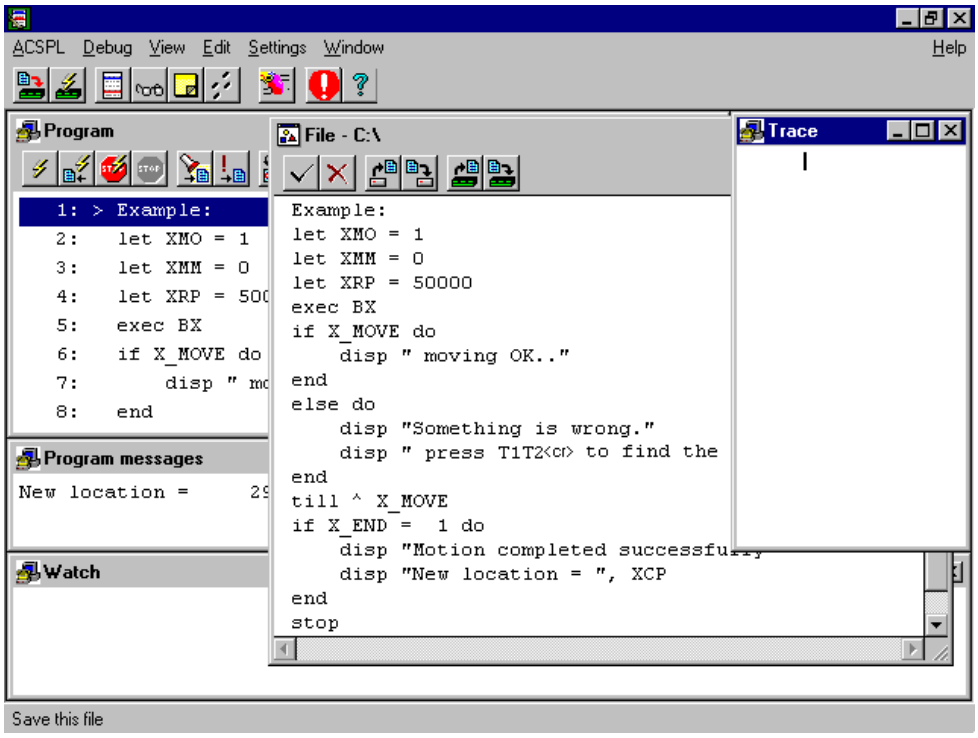


FIGURE 5-59 Trace window

	Action	Effect of action
2.	Click the Run program button.	The program execution can be seen in the **Program** window and the program status in the **Trace** window (FIGURE 5-60).

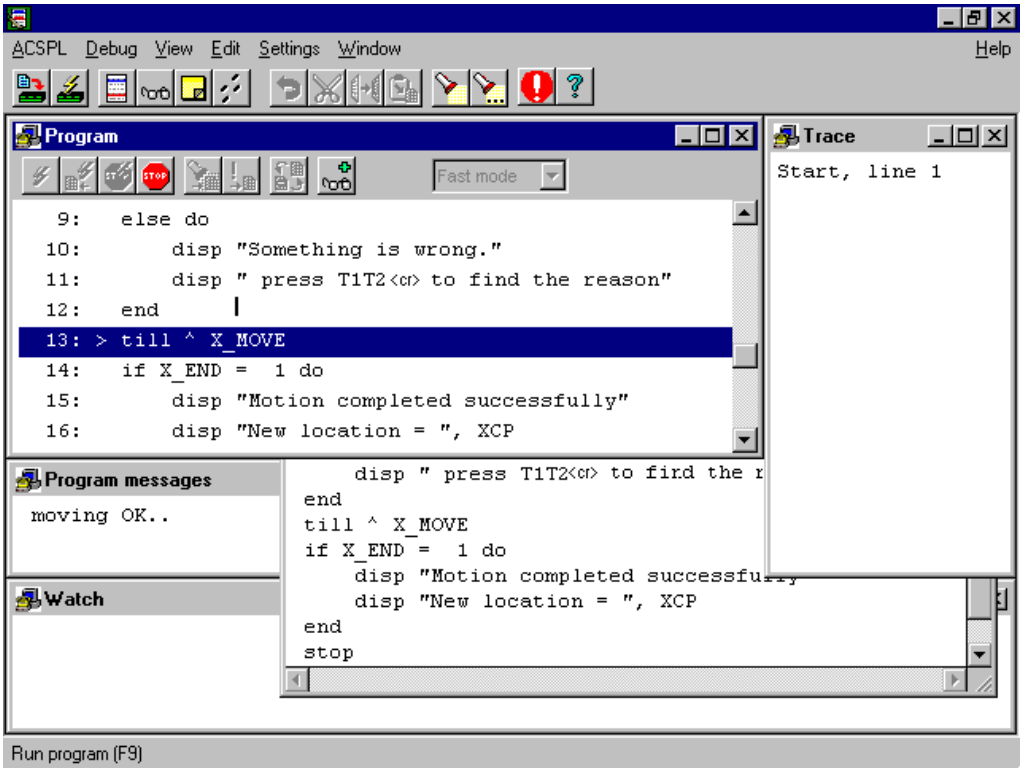


FIGURE 5-60 Program execution and trace messages

5.5.4. More Sample Programs

5.5.4.1. Searching For Index

One of the advanced features of the control unit is its ability to search for the index of the encoder at any speed. In the following example, the X motor is running at constant speed. Each time the index is passed, the position of the index is displayed. For example, with a 2,000-line encoder (8000 counts/rev), there should be an index pulse exactly every 8,000 counts. If a different number of counts appears, it is a strong indication that something is wrong with the encoder feedback path (encoder, connector, and encoder interface).

	Command mnemonic	Meaning	Effect of command
1.	**SearchI:**		Label.
2.	**let XMO=1**	**Let X** axis **M**OTOR be **01**	Enable the motor.

	Command mnemonic	Meaning	Effect of command
3.	**let XLV=50000**	**Let X** axis **L**inear **V**elocity be **01**	Set the velocity.
4.	**exec BX**	**Exec**ute **B**egin **X** axis movement	Begin moving.
5.	**V0=XIX**	Assign variable **V0** the value of the **X** axis **i**nde**x**	Dummy reading of the index to clear the buffer.
6.	**Loop:**	Start **loop**	Loop label.
7.	**till X_INDEX**	Continue loop **till** the **X** axis **index** flag is true	Wait till the index flag is true.
8.	**Disp XIX**	**Disp**lay **X** axis **index**	Display the index position.
9.	**Goto loop**	**Go to** start of **loop**	End of loop.
10.	**Stop**		End of program

5.5.4.2. Working With I/O

The following program reads the status of inputs 1 to 4 and sets outputs 1 to 4 accordingly.

	Command mnemonic	Meaning	Effect of command
1.	**I_O:**		Label.
2.	**V0=IP&15**	Variable **V0** assigned the result of the **I**nput **P**orts parameter **&** the binary representation of **15** (decimal).	Read the input port and ignore the values of inputs 5 to 16.
3.	**let OP=V0**	**Let** the **O**utput **P**ort parameter be assigned the value of **V0**	Set the outputs to the value of the inputs.
4.	**disp "IP = ",IP** **disp "OP =",OP**	**Disp**lay the values of the **I**nput **P**orts and the **O**utput **P**orts.	Display the values of the I/O ports
5.	**Stop**		End of program

To close ACS Debugger, on the **ACSPL** menu, click **Exit.**

5.6. Saving and Loading Control Unit Memory

ACS Saver saves a control unit's memory contents (including the adjustment values, programming, program results, etc.) to a PC file. ACS Loader loads that file to another control unit, ensuring that the two control units operate identically. ACS Saver/Loader greatly simplifies the task of maintaining uniformity between control units.

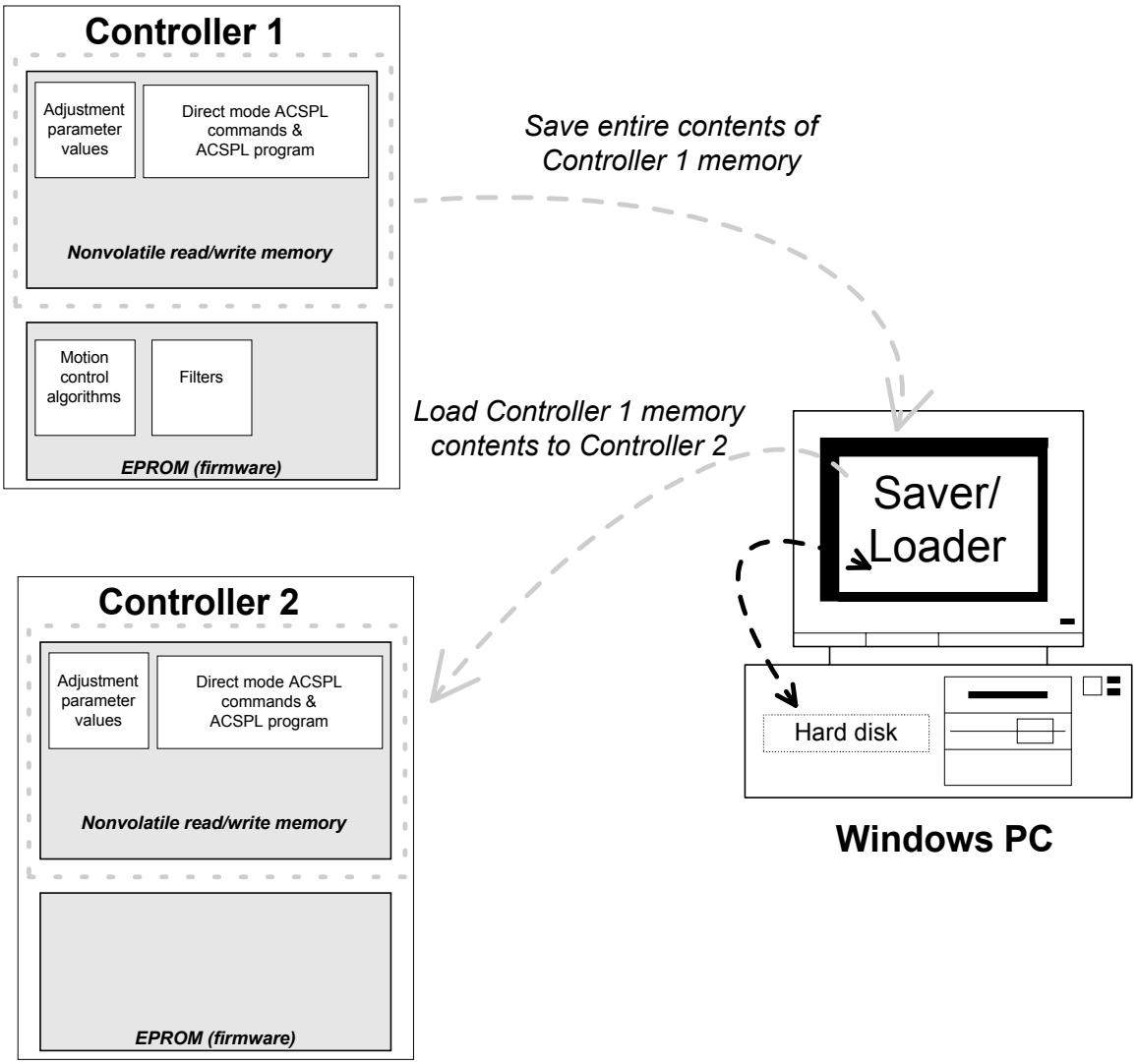


FIGURE 5-61 Saving and loading control unit memory contents

5.6.1. Saving Control Unit Memory Contents

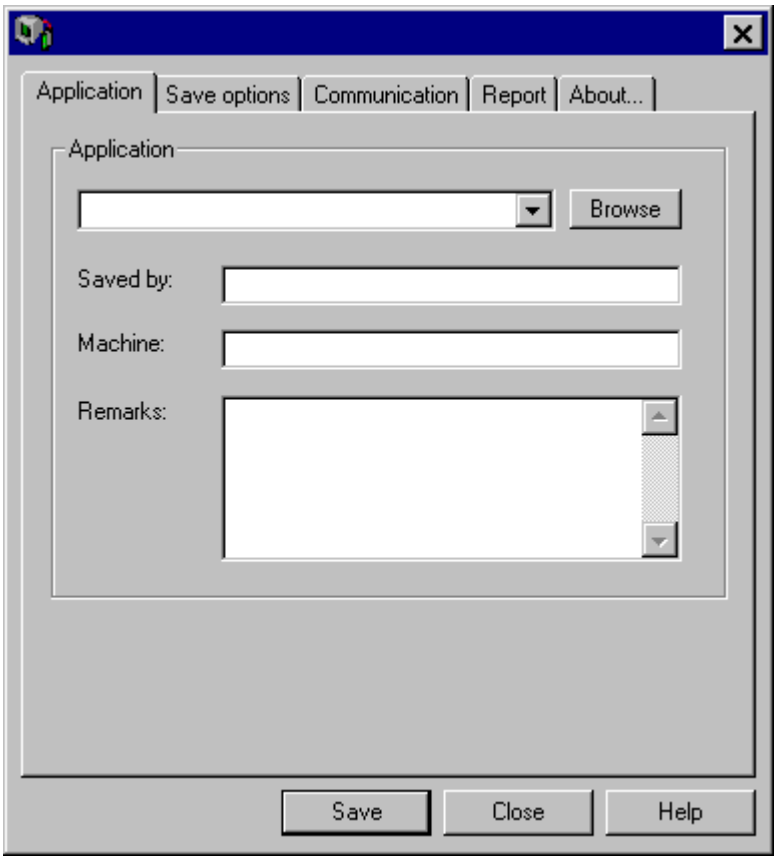


FIGURE 5-62 ACS Saver

	Action	Effect of action
1.	Connect the PC communications channel to the control unit.	
2.	From the Windows Start menu, point to the **ACS Tools** program group and click **ACS Saver**.	The **ACS Saver** window opens (FIGURE 5-62). Saver attempts to communicate with the control unit.
3.	On the **Application** tab, enter a filename for the application to be saved.	The application file will contain a copy of the contents of the control unit's memory.
4.	Click **Save**.	ACS Saver saves the application file.
5.	Click **Close**.	Saver closes.

5.6.2. Loading Control Unit Memory

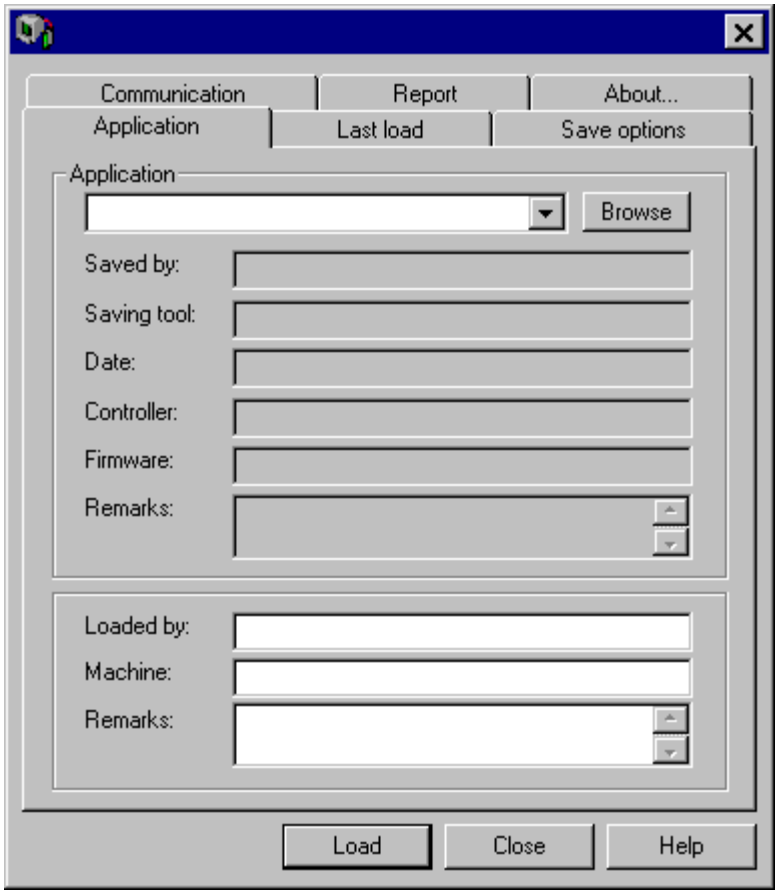


FIGURE 5-63 ACS Loader

	Action	Effect of action
1.	Connect the PC communications channel to the target control unit.	
2.	From the Windows Start menu, point to the **ACS Tools** program group and click **ACS Loader**.	The **ACS Loader** window opens (FIGURE 5-63). Loader attempts to communicate with the control unit.
3.	On the **Application** tab, enter a filename for the application to load.	When the application file is loaded to the control unit, it overwrites the current contents of the control unit's memory.
4.	Click **Load**.	ACS Loader loads the application file to the current control unit.
5.	Click **Close**.	Loader closes.

6. TUNING THE CONTROL LOOPS

TABLE 6-1 Topics covered in this chapter

Topic	Description
About D and K arrays	Description of the controller's **D** and **K** arrays of parameters
Control loop block diagrams	Diagrams of the control loop algorithms
Current loop	Current loop and how to tune it
Commutation	Commutation and commutation process troubleshooting
Velocity loop	Velocity loop, velocity filters, and how to tune the velocity loop
Position loop	Position loop and how to tune it
Slip constant optimization	(Induction motors only) - how to improve the orientation between the magnetic field in the air gap and the current induced into the rotor
Polishing	How to reduce following error during periods of acceleration/deceleration and how to improve the torque-velocity characteristics at high speed (brushless motors only)
Dual loop control	For applications requiring good dynamic performance (wide velocity and position bandwidths)

This chapter starts with a description of the **D** and **K** arrays of control loop parameters. The description also covers how to work with the arrays directly although in most cases it is preferable to work with them using ACS Adjuster.

Block diagrams of the control loops are followed by descriptions and fine tuning instructions. Slip constant optimization and polishing are also covered.

6.1. About D And K Arrays

Some of the control unit parameters are assigned mnemonics, for example, **GA (Gain)** and **GF (Gain Factor)**. The unit also has arrays (**D** and **K**) that are used for communication between the main CPU and the Servo Processor(s).

The **D** array holds some of the control parameters, for example, **D4** is the current loop gain and **D8** is the velocity loop gain.

The **K** array is used for some limitation setups, for example, **K2** limits the velocity loop error to prevent overflow and **K3** limits the current loop errors.

The elements of the D and K arrays are listed in TABLE 6-2.

TABLE 6-2 D and K arrays

Element	Function
D0	Internal use.
D1	Internal use.
D2	Internal use.
D3	Programmable parameter. Used in current loop - integral gain.
D4	Programmable parameter. Used in current loop - current gain.
D5	Programmable parameter.
D6	Programmable parameter
D7	Programmable parameter. Used in velocity loop - integral gain (Ki).
D8	Programmable parameter. Used in velocity loop - velocity gain (Kv).
D9	Programmable parameter. Used in velocity loop -- integrator limit.
D10	Programmable parameter.
D11	Internal use.
D12	Internal use.
D22	Determines the scaling factor for the velocity feedback and the velocity feed forward.
K1	Internal use.
K2	Internal use.
K3	Internal use.
K4	Internal use.

Element	Function
K5	Programmable parameter. **K5 = 0**: Sets the velocity loop output to **DA**. Enables open loop operation: When **GA** is set to zero (which zeroes the position error (**PE**)), the **DA** parameter is used to command the motor. **K5 = 1**: Default. **K5 = 2:** Used only by ACS Adjuster during the commutation setup. **K5 = 3**: Used only by ACS Adjuster in the current loop setup for data collection. **K5 = 4**: Used only by ACS Adjuster in the velocity loop setup for data collection. **NOTE: It is recommended not change K5 (default value is 1).**
K6	Programmable parameter. Commutation indicator - used only by ACS Adjuster (during commutation setup). **K6 = 0**: Positive. **K6 = 1**: Negative. **NOTE: It is recommended not to change K6.**
K7	Programmable parameter. Commutation offset from index - used only by ACS Adjuster (during commutation setup).
K8	Internal use.
K9	Internal use.
K10	Internal use.

6.1.1. D and K Array Protection

Before a **D** and **K** array element value can be changed, the protective mechanism must be removed. Failing to do so will result in a communication error 44 when trying to set a **D** or **K** parameter. The process for removing and restoring array protection is described in TABLE 6-3.

TABLE 6-3 Removing and restoring Z and K array protection

	Mnemonic	Meaning	Effect	Comment
1.	`RXQP<cr>`	**R**eport, for the **X** axis, the value of the **Q**DSPL **p**arameter.	Display the present (default) value of **QP.**	Record this value.
2.	`SXQP0<cr>`	Set, for the **X** axis, the value of the **Q**DSPL **p**arameter to **0**.	Remove the protection by setting **QP** to zero.	Set the array parameters as necessary.

Mnemonic	Meaning	Effect	Comment
`3. SXQP##<cr>`	Set, for the **X** axis, the value of the **Q**DSPL **p**arameter to the number ##.	Restores the protection.	For the number (##) use the value displayed in step 1 (**QP**'s original value).

Restoring the protection prevents unintentional changes to sensitive control parameters held by the arrays.

Manually removing and restoring protection is not required when using ACS Adjuster.

6.1.2. Reporting and Setting D and K Array Values

Examples of reporting and setting array values are given in TABLE 6-4 and TABLE 6-5.

TABLE 6-4 Displaying and setting values of D array elements

Command mnemonic	Meaning	Effect of command
`ADXRE4<cr>`	For **A**rray **D**, for axis **X: re**port the value of element **4**	Display the value of **D4**.
`ADXSE8 50<cr>`	For **A**rray **D**, for axis **X:** set the value of element **8** to 50	Set **D8** to 50.

TABLE 6-5 Displaying and setting values of K array elements

Command mnemonic	Meaning	Effect of command
`AKXRE2<cr>`	For **A**rray **K**, for axis **X: re**port the value of element **2**	Display the value of **K2**.
`AKXSE3 100<cr>`	For **A**rray **K**, for axis **X:** set the value of element **3** to 100	Set **K3** to 1000.

6.2. Control Loop Block Diagrams

FIGURE 6-1 is the control block diagram. The primary control components are shown in greater detail in subsequent figures. These components are

- Plant (motor + load) (FIGURE 6-2)
- Commutation and power amplifier (FIGURE 6-3)
- Velocity loop (FIGURE 6-4)
- Position loop (FIGURE 6-5)

Note

Note

The diagrams in this section are for general description purposes only.

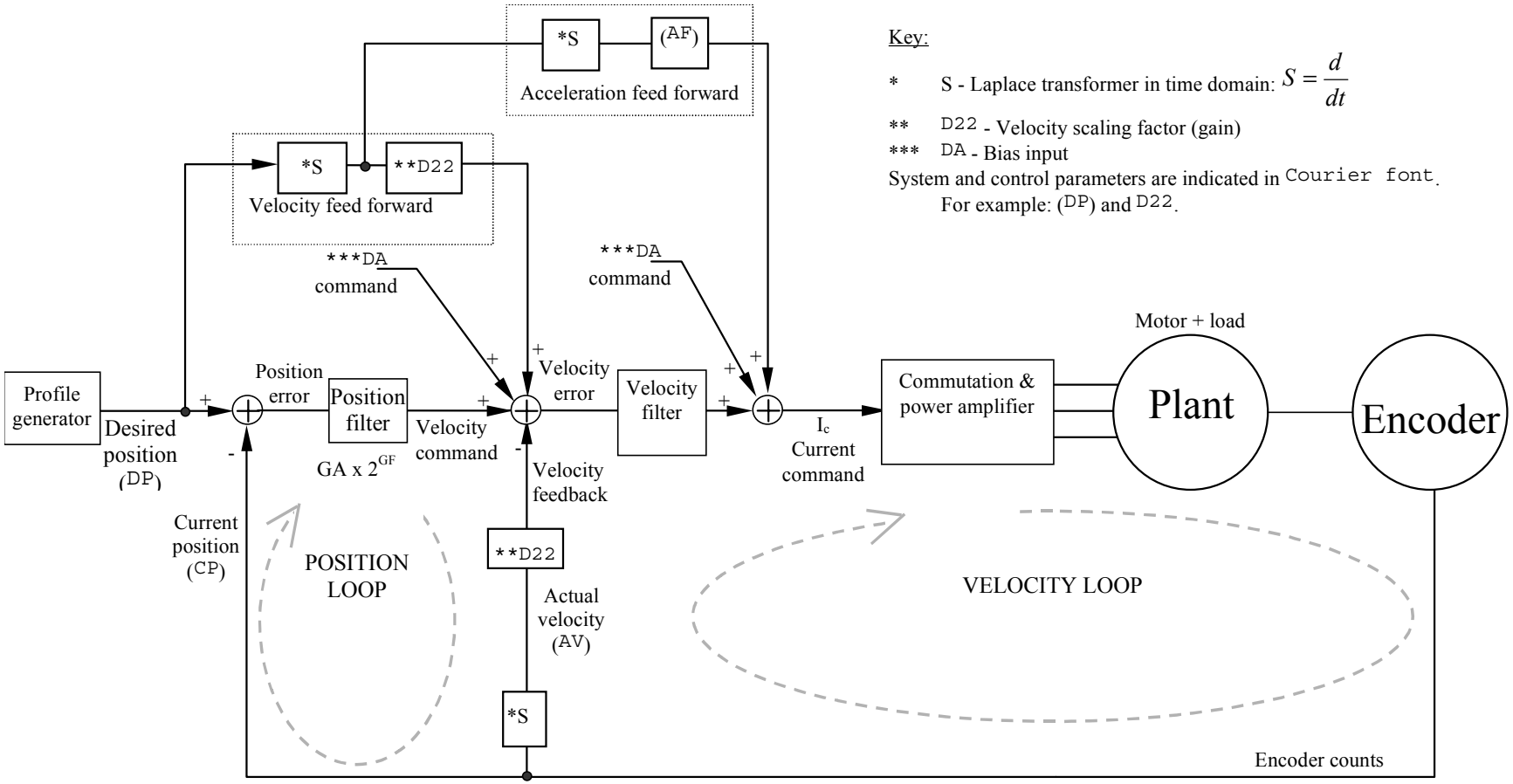


FIGURE 6-1 Control algorithm

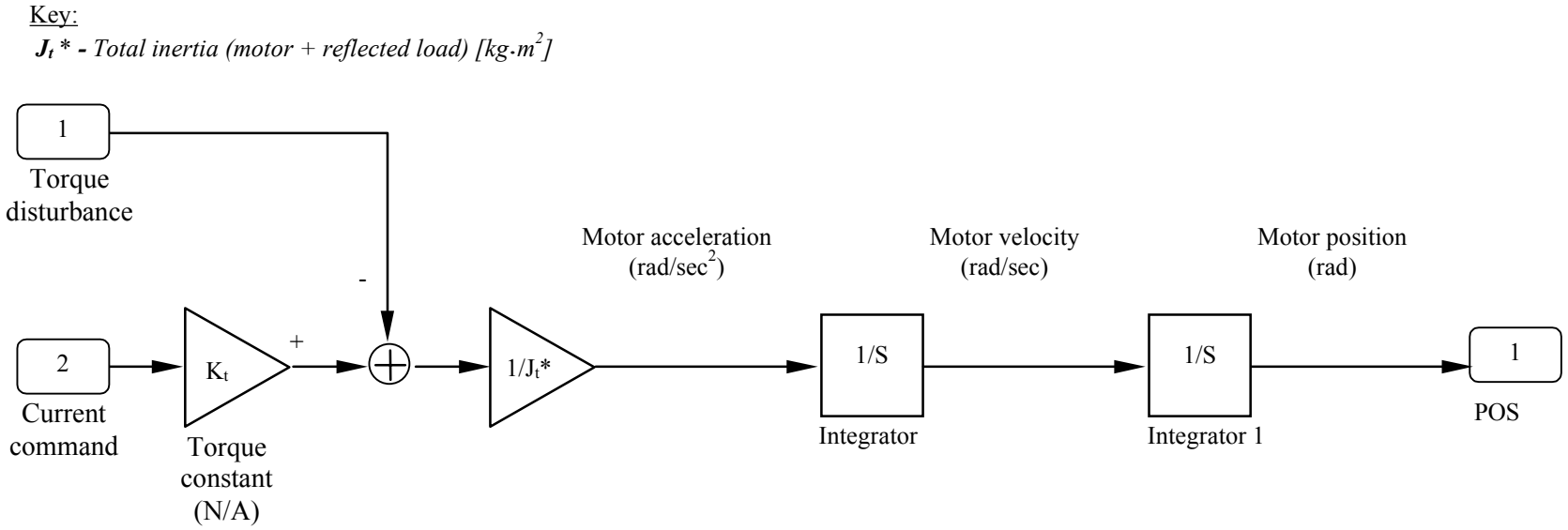


FIGURE 6-2 Plant (motor + load) model

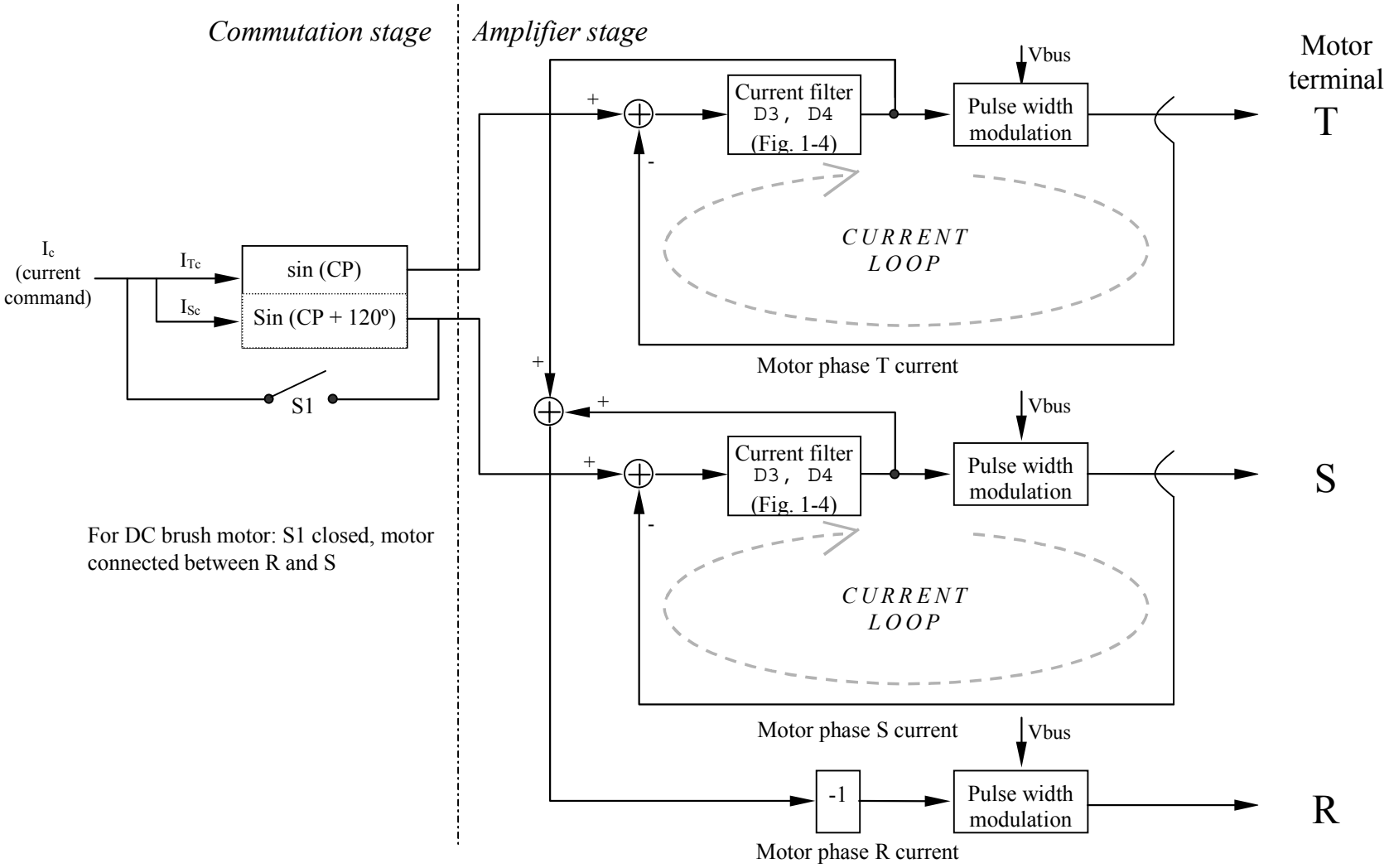
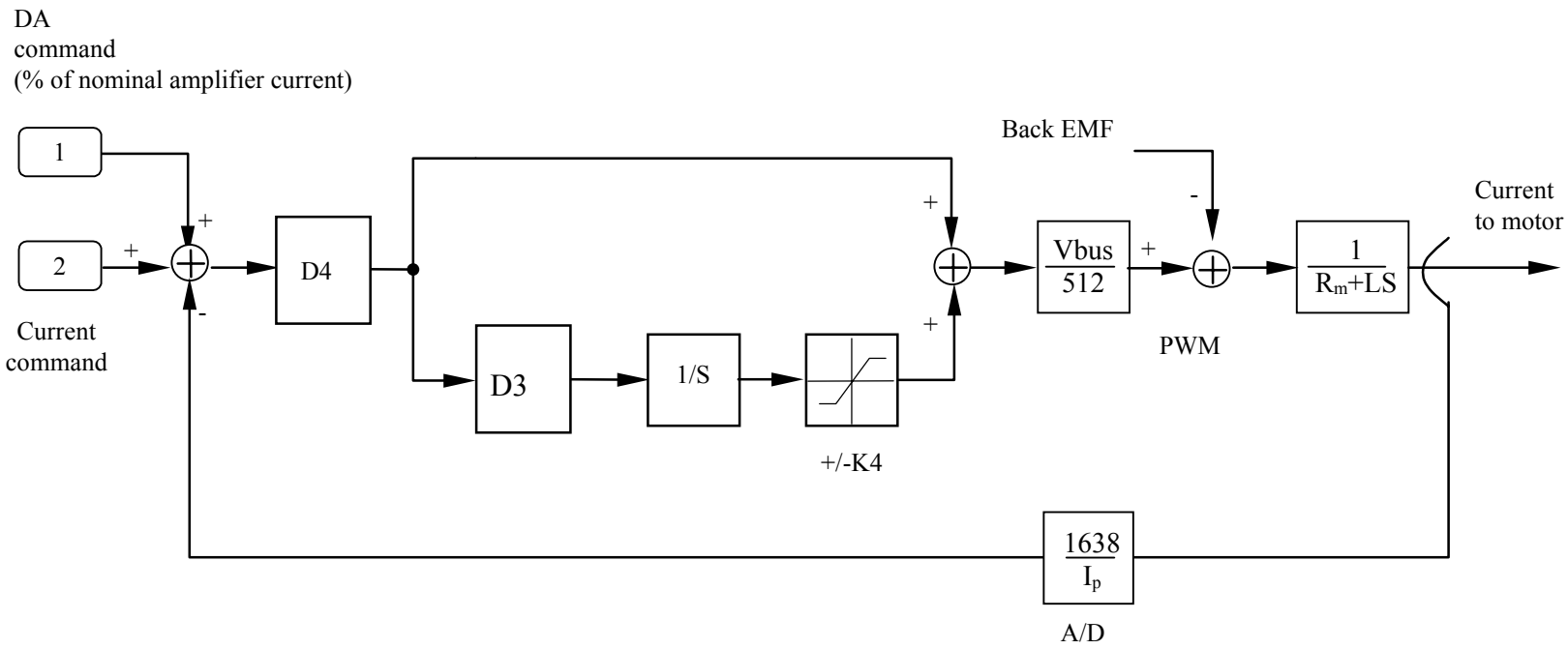


FIGURE 6-3 Commutation and power amplifier stage



Key:

R_m - Motor resistance [Ohm]
L - Motor inductance [Henry]
I_p - Peak current [A]

FIGURE 6-4 Current loop and filter

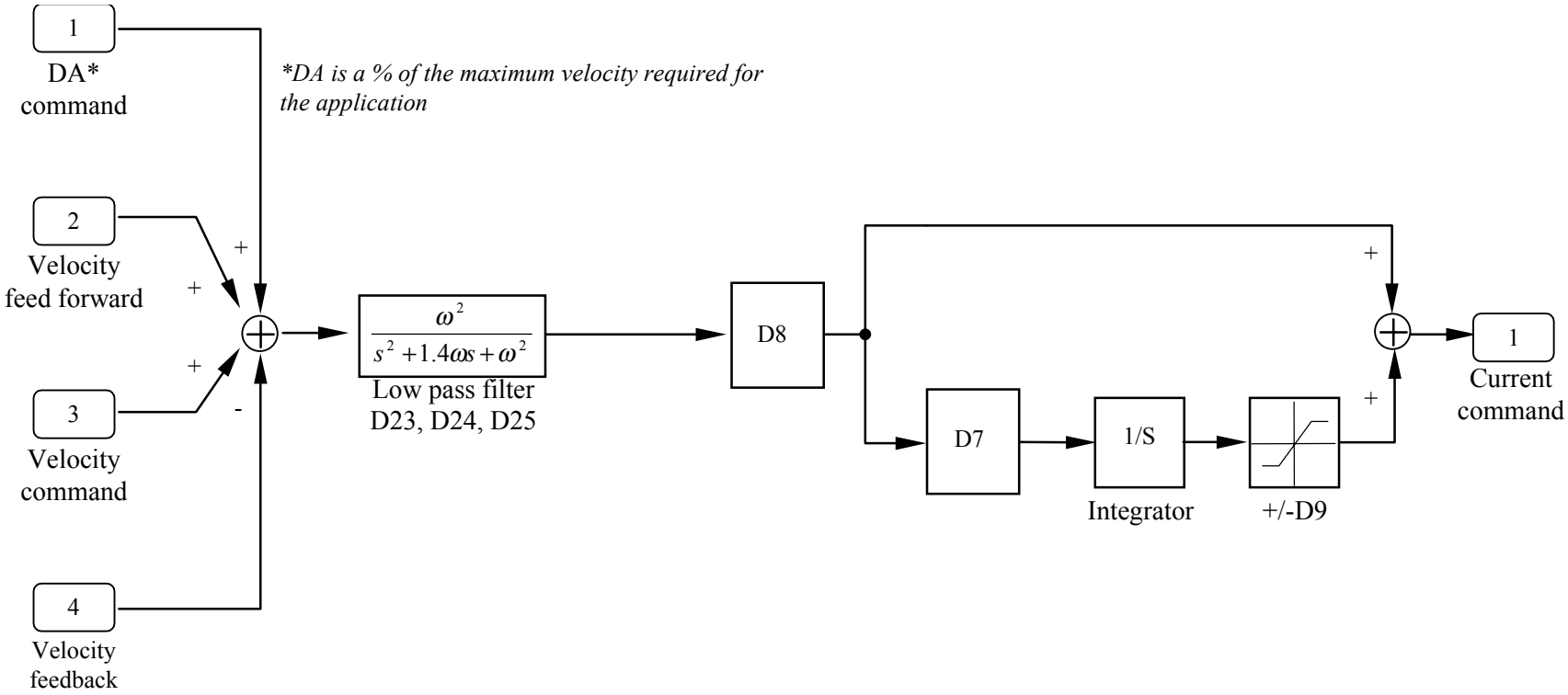


FIGURE 6-5 Velocity loop and filter

6.3. Current Loop

The current control algorithm consists of a proportional-integral (PI) filter, set by the following parameters:

D4 Proportional gain (P). Maximum value is 20,000.

D3 Integral gain (I). Maximum value is 12,000. The integrator bandwidth is equal to D3/20 [Hz].

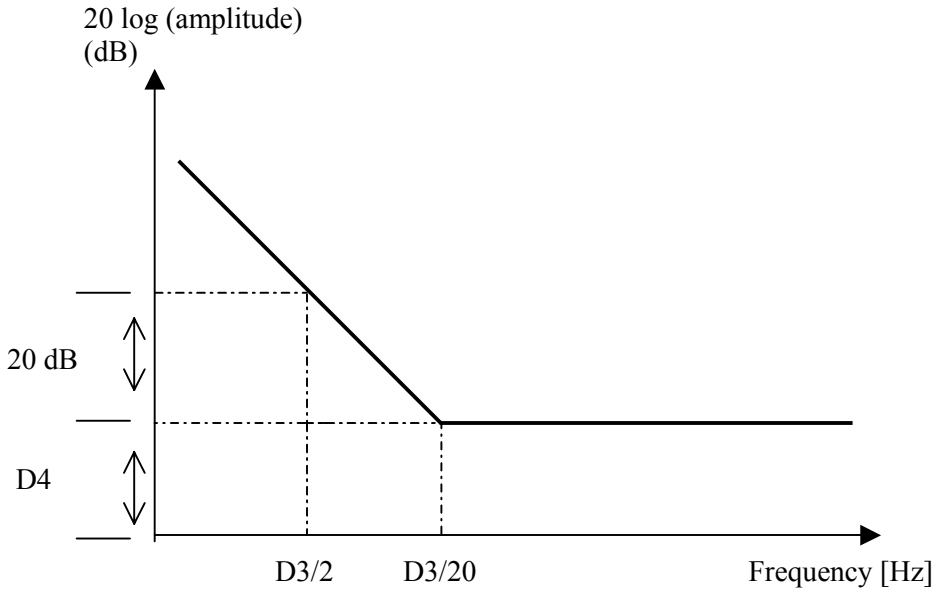


FIGURE 6-6 Current filter Bode diagram

6.3.1. Current Loop Tuning

The following instructions for adjusting the current loop are approximate. The actual values required will depend on the type of amplifier and motor used.

	Action
1.	Set the **Gain (D4)** to 10, the **Integrator Gain (D3)** to 0, and the **Current** (command) to 10% (of the peak value).
2.	Click the start button in the Scope toolbar and the **Go** button in the **Current loop adjustment** dialog box. Wait for the response to be collected and displayed on the scope. To adjust the scale of the signal, click the Adjust Vertical Scale tool button.
3.	Watch the current response. Start increasing or decreasing **D4**, doubling the value each time, (i.e., 20, 40, 80, etc. or -10, -20, -40, etc.) until the response looks similar to FIGURE 6-7.

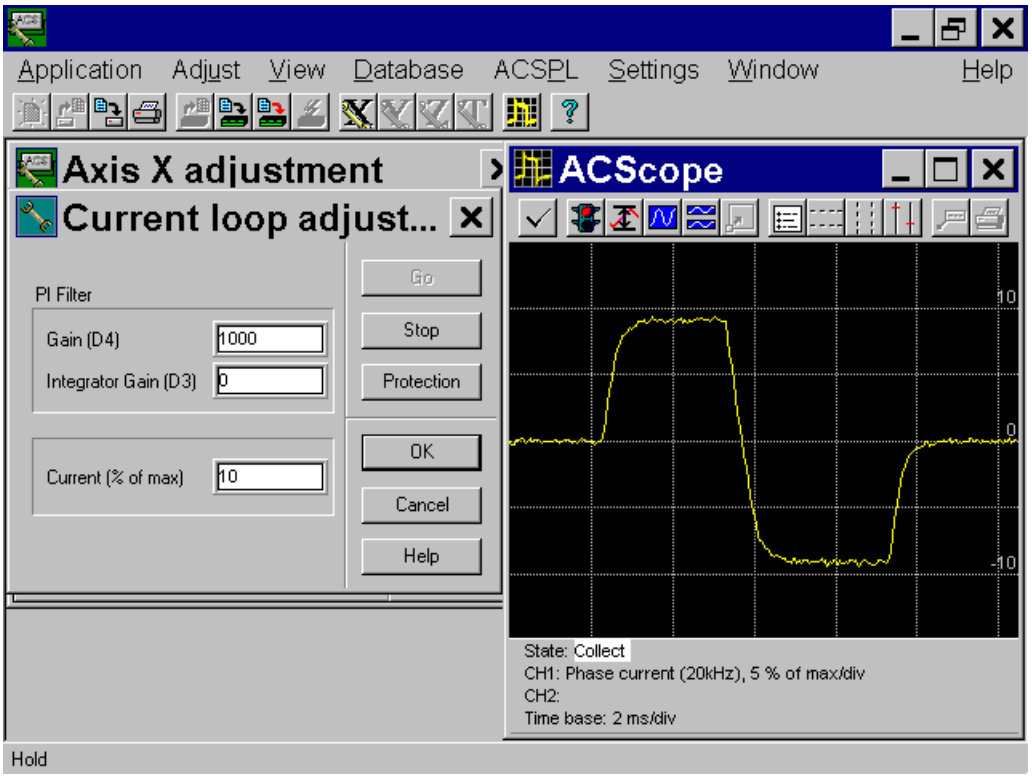


FIGURE 6-7 Current loop response after first Gain (D4) adjustment (step 4).

4. Increase/decrease **D4** by increments of about 20% until the response is similar to that shown in FIGURE 6-8. Note the small overshoot.

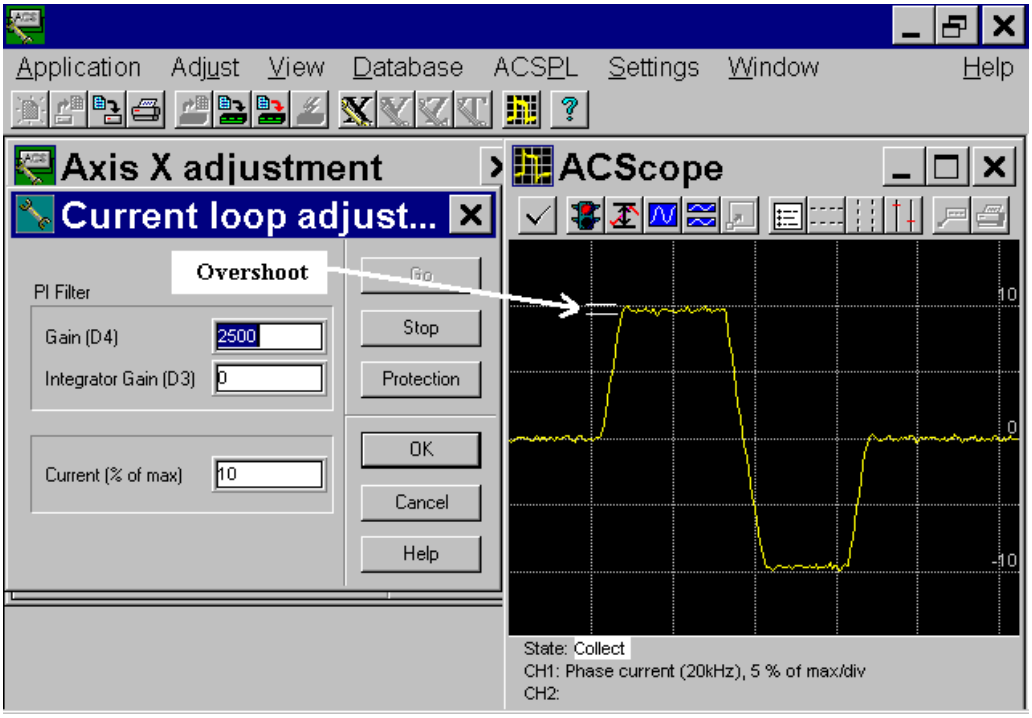


FIGURE 6-8 Current loop response after second Gain (D4) adjustment.

5. Start increasing the **Integrator Gain (D3)** by increments of 1000 till there is a larger overshoot of about 10% as shown in FIGURE 6-9.

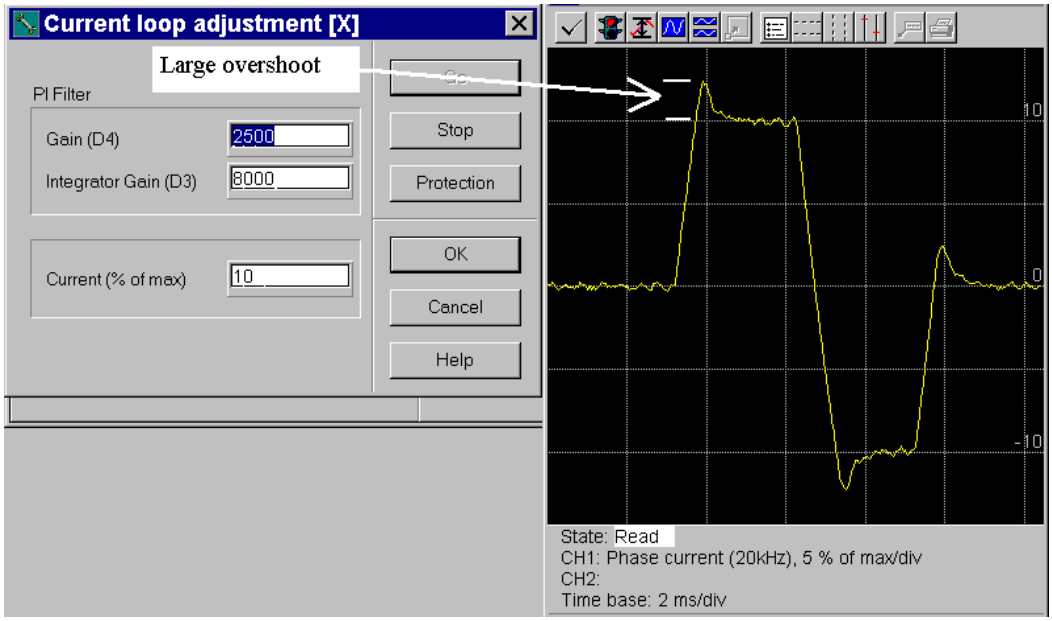


FIGURE 6-9 Current loop response after Integrator gain (D3) adjustment

6. Generally, the **Current (% of max)** can be left at 10%. When the amplifier is relatively oversized for the motor, the **Current (% of max)** can be set lower than 10%. Alternately, if the amplifier is undersized, the **Current (% of max)** can be set higher than 10%. But the value should not be set higher than 50%.
7. Click **OK** to complete the **Current loop adjustment** step.

6.4. Commutation

The **Commutation adjustment** step identifies the correct phasing of the motor in relation to the position feedback reading. It also provides comprehensive testing and verification to ensure accurate phasing.

Commutation is required only for a DC brushless (AC servo/AC synchronous) motor or AC induction motor.

- **For a DC brushless (AC servo/AC synchronous) motor**, the purpose of the commutation adjustment is to align the permanent magnet orientation with the reading of the feedback device (encoder, encoder + Hall, resolver).
- **For an AC induction motor**, the purpose of the commutation adjustment is to align the motor windings orientation with the reading of the feedback device and to properly set the polarity of the Field Current (FC) and Slip Constant (SK) parameters.

It is recommended, if possible, to perform this step without any load attached to the motor.

Action

1. Click the **Preferences** button to open the **Commutation preferences** dialog box.
2. Select the appropriate tests and settings.
3. Click the **OK** button to close the **Commutation preferences** dialog box.
4. Click the **Go** button to start the commutation adjustment.
5. Click **OK** upon successful completion.
6. Click **OK** to complete the **Commutation adjustment** step.

6.4.1. Problems with Commutation

The encoder resolution is incorrect (1000 instead of 1024), therefore the settings of LR and LF are wrong.

- 1. Read the index location in order to clear the index buffer (**`RXIX<cr>`**).
- 2. Manually rotate the motor a little more than one full turn.
- 3. Read the index location (**`RXIX<cr>`**).
- 4. Manually rotate the motor a little bit more than one full turn.
- 5. Read the index location (**`RXIX<cr>`**). The difference between the last two readings is the exact number of counts/rev.

The number of poles is incorrect.

- 1. Open the current position display either by opening step 4, **Feedback verification** or by opening the **View** menu and clicking **Current Position**. Turn the motor manually until the Hall reading (**HA**) is 0.
- 2. Manually rotate the motor slowly one complete turn, while monitoring the Hall reading value.
- 3. For each pair of poles, the Hall should count one complete cycle (0,1,2,3,4,5). For example, for 3 complete Hall cycles, the number of poles is 6 (**NP=6**), for 2 complete cycles, **NP=4,** etc.

When the motor is enabled after power up or after a HWRES command, it jumps. Rotating the motor once before enabling it seems to prevent the problem.

The cause of the problem is most likely that either the control unit is not reading the Hall sensors properly or the Hall counter is not counting in the same direction as the encoder.

- 1. While slowly rotating the motor manually, report the value of **CP** (**RXCP<cr>**). If it counts down, that is the negative direction. Rotate the motor in the positive direction (counts up).
- 2. While rotating the motor in the positive direction, monitor the reading of the Hall counter (**RXHA<cr>**). It should repeatedly count from zero to five, i.e., 0, 1, 2, 3, 4, 5, 0, 1, 2, 3 . . .
  If it does not follow this pattern, it is an indication that there is a fault in the Hall device or in the connection to the unit.

6.5. Velocity Loop

The velocity control algorithm consists of the following:

- Low pass filter
- Proportional-integral (PI) filter with friction compensation

6.5.1. Velocity Low Pass Filter

The low pass filter is a second order filter with damping factor of 0.7 and a bandwidth ω_n [rad/sec]:

$$\text{Fn} = \frac{\omega_n}{6.28} Hz$$

The default bandwidth value for the low pass filter is 637 Hz (4,000 rad/sec). For a system with high inertia and low resonance, it is useful to set the low pass filter to a frequency between 100 Hz and 500 Hz.

The filter is implemented using the following parameters: **D23, D24**, and **D25**.

T_s = 0.00005 [second](sampling time)

F_n - Filter bandwidth (Hz)

$A = 1+1.4*\omega_n* T_s + (\omega_n T_s)^2$

D23 $= (\omega_n T_s)^2 * (2^{16}/A)$

D24 $= (1+0.7*\omega_n * T_s)*2^{16}/A$

D25 $= \frac{2^{16}}{A}$

$\omega_n = 2*3.14* F_n$

Example: For F_n =637Hz: D23 = 1986

D24 = 56599

D24 = 49648

6.5.2. Velocity Proportional-Integral Filter

The proportional-integral (PI) filter is implemented using the following parameters:

D8 Proportional gain

D7 Integrator gain [0, 6000]. The bandwidth of the integrator is D7/20 [Hz].

D9 Integrator limit.

Parameter **D22** determines the scaling factor for the velocity feedback and the velocity feed forward. Adjuster automatically sets **D22** to:

$$D22 = \frac{600\times10^5}{\text{Max velocity}}$$

Max velocity is the maximum velocity [count/sec] that the motor will be running at.

(Max velocity is defined in the **Motor feedback parameters** step of the adjustment session.)

The default value for **D22** is 2000 [maximum value: 30,000].

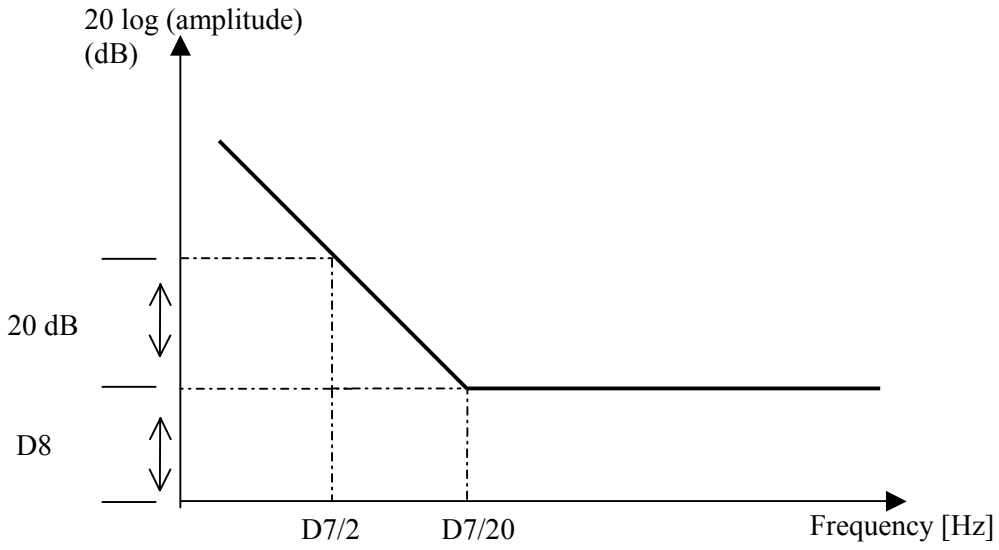


FIGURE 6-10 Velocity proportional-integral filter Bode diagram

6.5.2.1. Friction Compensation

The **FN** (**Friction Number**) parameter sets the initial value of the integrator in the velocity loop (range is 0 to 255). Generally **FN** should be set to zero. For high friction load, increasing **FN** shortens the start motion delay by compensating for the friction torque or force.

6.5.3. Velocity Loop Tuning

The velocity loop can be set in this step and fine tuned in the **Position loop adjustment** step.

	Action
1.	Set the **Bandpath** (bandwidth) of the **Low pass filter** at around 650 Hz.
2.	If the motion system has high inertia and low resonance, it is useful to reduce the **Bandpath** to between 100 Hz and 500 Hz.
3.	Set **D7** (**Integral**) to 0, **D8** (**Proportional Gain**) to 1000, and set **D9** (**Integrator Limit**) to the value of **TL** (the maximum torque when the system is not accelerating). **TL** is set in the **Protection parameters** step, which can be accessed directly from the **Velocity loop adjustment** dialog box by clicking **Protection**.
4.	Click the start button in the Scope toolbar and the **Go** button in the **Velocity loop adjustment** dialog box.
5.	Double **D8** until the response waveform approximates a square.
6.	Increase **D7** by hundreds until the overshoot starts increasing. **D7** should be between 240 (12Hz) and 2000 (100Hz).

	Action
7.	Change **D9** (**Integrator Limit**), until the overshoot is about 10%. A good velocity loop response is shown in FIGURE 6-11.
8.	Click **OK** to complete the **Velocity loop adjustment** step.

Note

Note
The Velocity loop adjustment **step is also affected by the values of the** D5, D6**, and** D10 **parameters. The parameters are accessible later, in the** Position loop adjustment **step.**

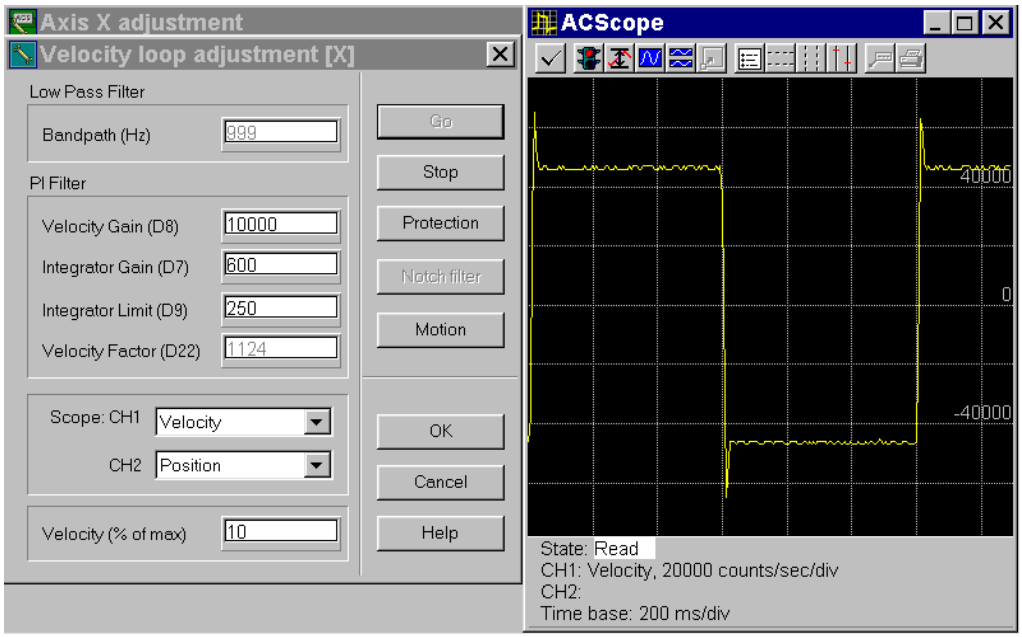


FIGURE 6-11 Velocity loop step response

6.6. Position Loop

The position filter is a pure proportional gain. It is set with the parameters **GA** and **GF**.

The gain value is $GA \times 2^{-GF}$. (**GF** ranges from 0 to 8.)

The bandwidth of the position loop is:

$$\frac{2000 \times GA \times 2^{-GF}}{D22 \times 2 \times 3.14}$$

Note

Note

It is recommended that the bandwidth of the position loop (f_{pc}) be approximately equal to $\frac{\text{D7 (Integrator Gain)}}{\mathbf{2}0}$.

6.6.1. Position Loop Tuning

	Action
1.	Click the **Motion** button to open the Motion parameters dialog box as shown in FIGURE 6-12.

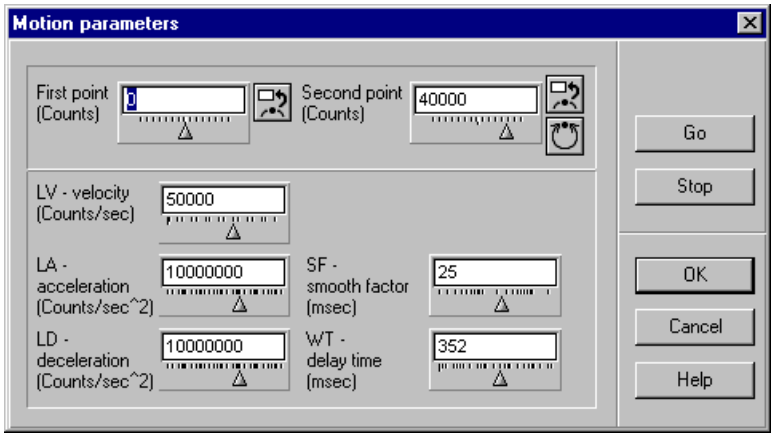


FIGURE 6-12 Motion parameters dialog box

2.	Define the motion profile for the test by setting the **First point** and the **Second point**. To set a point, either enter a number (corresponds to an absolute position of the encoder) or move the motor axis to the desired position and click the **Set From Encoder** button to set the point directly to the value of the current encoder reading. For the second point, there is also a **Set One Revolution** button, which sets the second point exactly one full encoder revolution distant from the first point.
3.	Set other motion parameters as necessary, and click **OK** to close the **Motion parameter** dialog box.
4.	Click the start button in the Scope toolbar and the **Go** button in the **Position loop adjustment** dialog box.
5.	Set **Dead Zone Min (D5)**, **Dead Zone Max (D6)**, and **Zero FF Zone (D10)** to 0. (These parameters are used only with piezoelectric motors.)
6.	Set **FN** to zero. For a high friction load, increase **FN** (range 0 to 255) to overcome friction.

7.	Select Velocity (**Scope CH1**).
8.	Set the **Gain Factor** (**GF)** to 0 and **Gain (GA)** to 1.
9.	Increase **GA** until an overshoot becomes noticeable.
10.	Select Position Error (**Scope CH1**).
11.	Increase/decrease **GA** in order to minimize the position error.
12.	If there is high frequency oscillation, reduce the **Velocity Loop Gain (D8)**. If there is low frequency oscillation, reduce the **Position Loop Gain (GA)**.
13.	Click **OK** to complete the **Position loop adjustment** step.

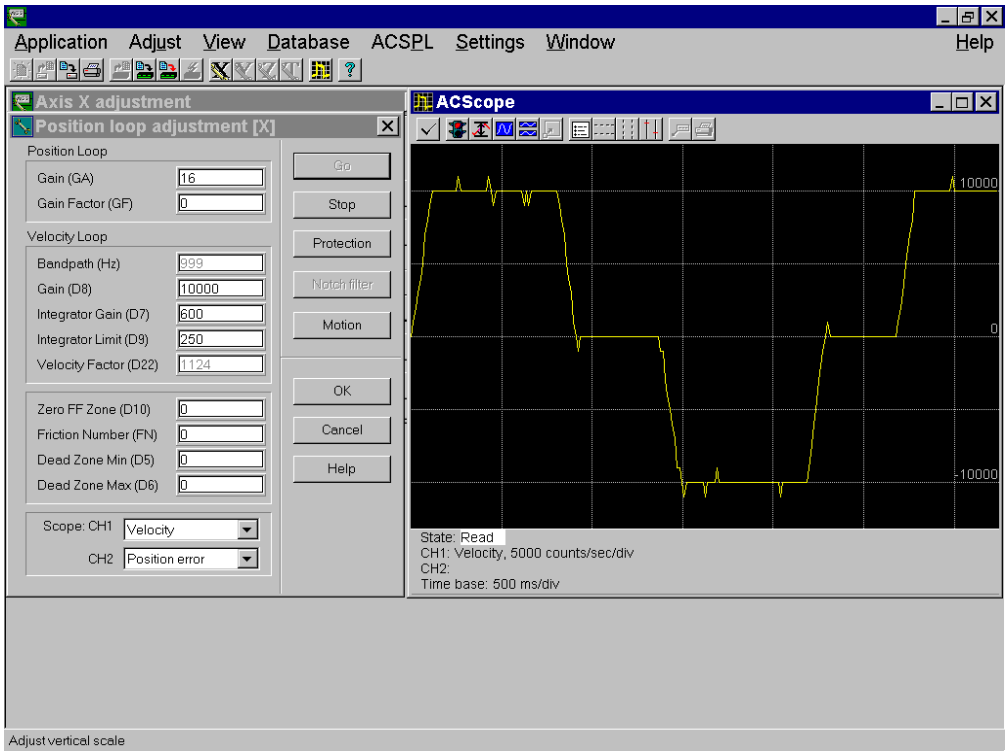


FIGURE 6-13 Position loop velocity response

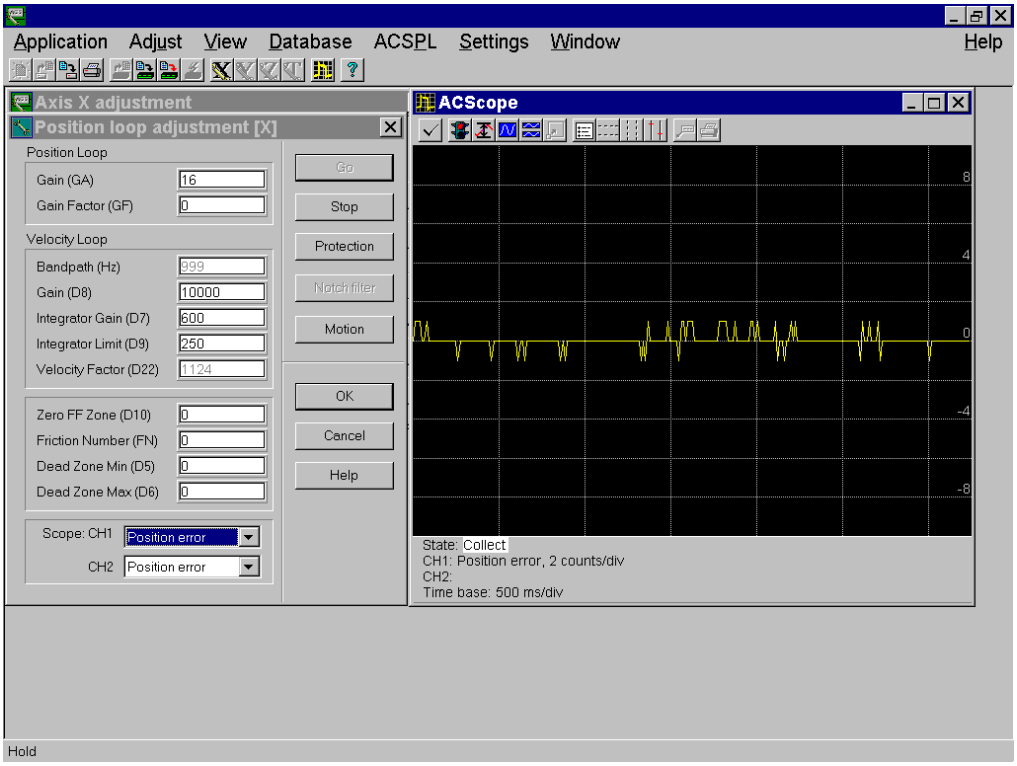


FIGURE 6-14 Position loop error response

6.7. Slip Constant Optimization

(For induction motors only.)

The purpose of setting **SK** (**Slip Constant**) is to improve the orientation between the magnetic field in the air gap and the current induced into the rotor.

While running in repetitive point to point, monitor the error. Increase/decrease the value of **SK** (without changing its polarity!) until the error value is minimized (FIGURE 6-15). The test should be executed while **KZ** is set to 0.

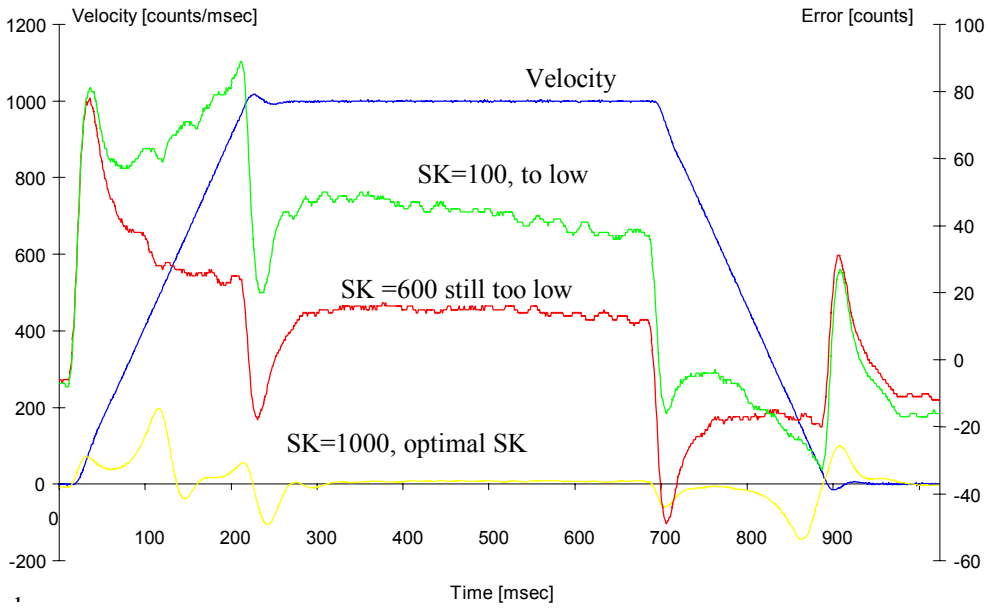


FIGURE 6-15 Position error for various SK values

6.8. Polishing

6.8.1. Acceleration Feed Forward (AF) Setup

The Acceleration Feed forward setup reduces the following error during periods of acceleration/deceleration.

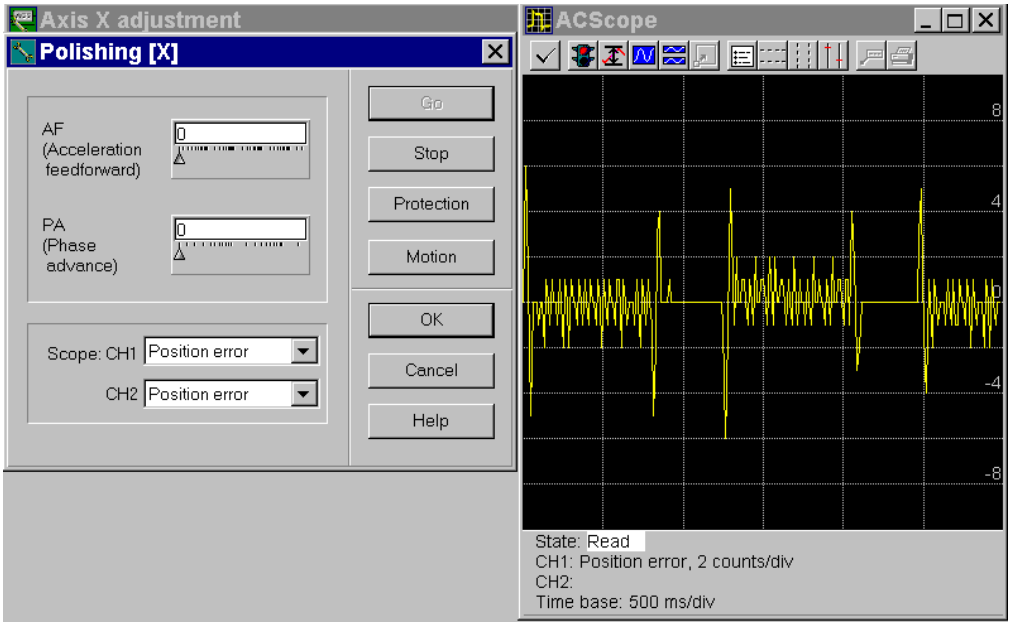


FIGURE 6-16 Position error profile when AF=0

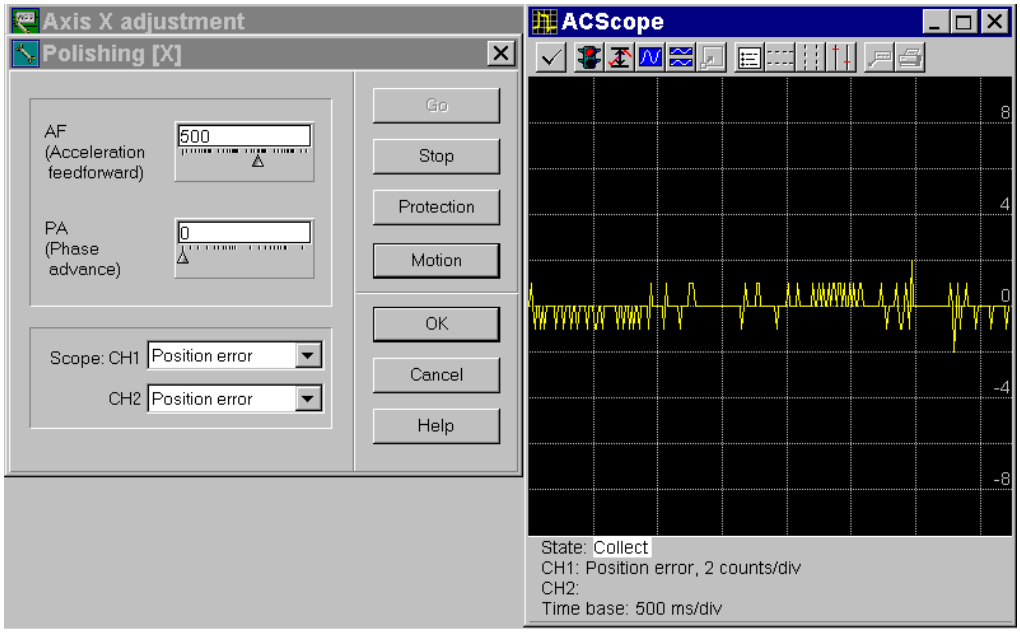


FIGURE 6-17 Position error profile when AF=500

Action

- Increase **AF** until the error is minimized. (If **AF** is too large, the error may be excessive, causing more motor noise.)

6.8.2. Optimizing Torque At High Speed - Phase Advance

For DC brushless (AC servo/AC synchronous) motor only.

The phase advance feature improves the torque-velocity characteristics at high speed. At high speed, the actual current lags behind the command. As a result, the motor either needs more current to produce the required torque, or cannot produce the required torque at all. (FIGURE 6-18)

	Action
1.	Set the velocity to 90% of the maximum velocity that is needed.
2.	While monitoring the phase current at constant speed, increase **PA** as long as the amplitude of the current is reduced.(**SXPA##<cr>).** If the value of **PA** is too high, the control unit might disable the drive.

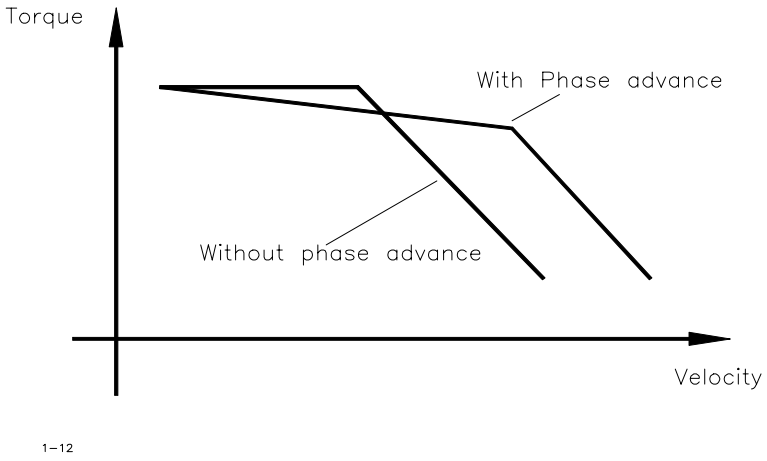


FIGURE 6-18 DC brushless (AC servo/AC synchronous) motor - velocity vs. torque

6.9. Dual Loop Control

Some applications involve positioning a load that is driven by a gear, belt and/or screw. If the driving mechanism (gear etc.) is not accurate enough for the application, a feedback sensor must be mounted directly on the load to provide precise position information. The common practice is to use only this device for feedback. This is called **single loop** control.

Some applications also require good dynamic performance (wide velocity and position bandwidths), which means very short settling time and a very small dynamic error. For such applications, single loop control is inadequate. This is because of the low stiffness between the motor and the load and backlash on the gear.

To achieve good dynamic performance, it is necessary to improve the bandwidth of the velocity and position loops. The recommended way to do so is to use **dual loop** control.

In a dual loop application two encoders are used, one mounted on the motor axis and the other on the load. (The load encoder can be linear for a linear stage application or rotary for a rotary load application).

Examples of applications that benefit from dual loop control:

- Linear stage drive with a screw.
- Printer drum drive with a flexible belt.
- A high-inertia antenna driven by a high-ratio gear motor.

In all these examples, the use of dual loop control will improve the performance of the system. The dual loop control block diagram is shown in FIGURE 6-19.

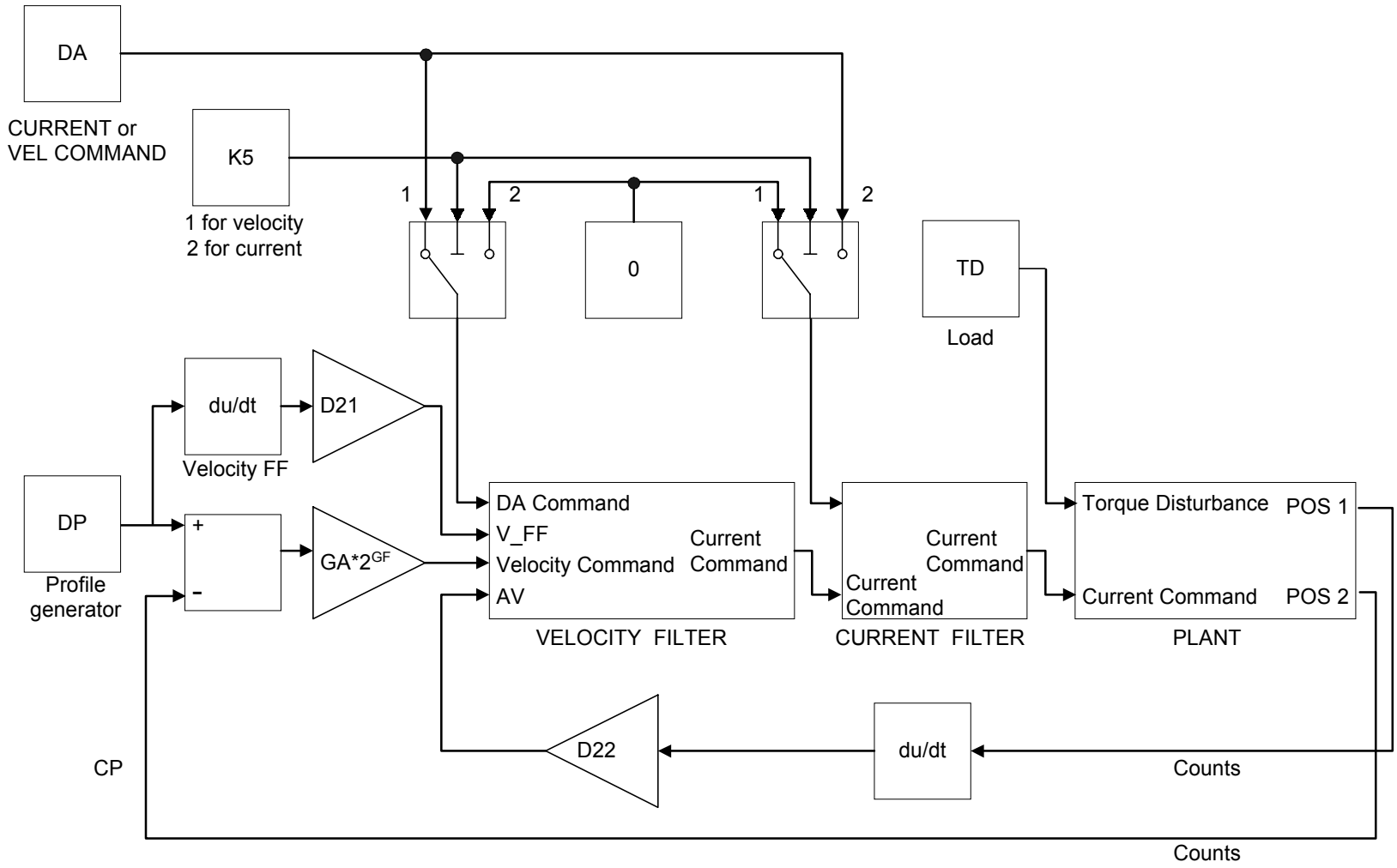


FIGURE 6-19 Dual loop block diagram

6.9.1. Dual Loop Control - Implementation

Encoder 1 (**ENC1**), which is mounted on the motor axis, is used to close the **velocity** loop (and also, in the case of a brushless motor, for software commutation).

Encoder 2 (**ENC2**), which is mounted on the load (the position that is being controlled) is used to closed the **position** loop.

The parameter **$CU ($** stands for the axis, i.e., "x," "y," etc,), which defines the type of commutation feedback device, is also used as the switch for dual loop control. Bit 2 of **$CU** must be always be set to 1 when dual loop control is used.

$CU value (decimal)	**Feedback device(s) and type of control**
$CU = 2	Encoder (no Hall), single loop, for a DC brush, DC brushless (AC servo/AC synchronous), or AC induction motor
$CU = 3	Encoder + Hall, single loop, for a DC brushless (AC servo/AC synchronous) motor.
$CU = 6	Encoder (no Hall), dual loop, for a DC brush, DC brushless (AC servo/AC synchronous), or AC induction motor.
$CU = 7	Encoder + Hall, dual loop, for a brushless or AC induction motor.

$D21, $D22 from the **D** array are used for velocity scaling.

$D22 is determined from the maximum velocity of the motor for the application.

$D21 is determined from the maximum velocity of the load for the application.

$$\mathbf{D22} = \frac{500 \times 10^6}{VMm}$$

Where

VMm - Max velocity of the motor (counts/sec).

$$\mathbf{D21} = \frac{\mathbf{D22} \times \mathbf{ENC1(res)}}{\mathbf{ENC2(res)}}$$

Where

ENC1(res) - Number of counts of **ENC1** per motor revolution ($\mathrm{LR} \times 2^{\mathrm{LF}}$).

ENC2(res) - Number of counts of **ENC2** per motor revolution.

The position loop bandwidth [Hz] **(Fc)** is computed as follows:

$$\mathbf{Fc\ (position)} = \frac{1}{2\pi} \times GA \times 2^{GF} \times \frac{20000}{D21}$$

6.9.2. Adjusting the Dual Loop

- 1. Start to adjust the system with **$CU = 2** or **$Cu = 3** in single loop.
- 2. Set **$CU** bit 2 to 1 **($CU = 6** or **$CU = 7**) and go directly to position loop adjustment.
- 3. Start with very low position gain factor (**GF**) and gain (**GA**): such that **Fc** (position) ~= 1 Hz.
- 4. Example, to reach a position loop gain ($GA \times 2^{GF}$) of 0.75 (i.e., 3/4): **GA** = 3 and **GF** = -2.
- 5. Increase the **GF** and **GA** until a good result is achieved (as with a single loop). If high frequency noise occurs, reduce the velocity gain **D8**.

7. HARDWARE INTERFACE PARAMETERS

This chapter summarizes ACSPL parameters relating to the hardware interface. The interface itself is described in Section 4.4, "Control Connectors."

TABLE 7-1 Topics covered in this chapter

Topic	Description
Serial communications	Changing the baud rate and configuring multiple drop connections
CAN communications (option)	Understanding the CAN switch and parameters
Hall sensors	Using Hall inputs with the control module
Input and output ports	Motion monitoring and other I/O functions



Further information

More detailed information about ACSPL is contained in the *ACSPL Software Guide*

7.1. Serial Communications

7.1.1. Changing the RS-232/422/485 Communication Baud Rate

TABLE 7-2 Changing the baud rate

Mnemonic	Meaning	Result
SBR57600<cr>	**S**et the **b**aud **r**ate to **57600**.	Changes the baud rate to 57600.
SAVE<cr> **SAVE<cr>**	**Save** the change.	Saves the change. (Enter command twice).
HWRES	Perform a **h**ard**w**are **res**et.	Resets the processor (equivalent to power off, power on). The change in the baud rate takes effect upon completion of the hardware reset.

7.1.2. Multiple Drop Configuration for RS-232

Up to 10 control modules can be connected to an RS-232 serial link.

Follow this procedure:

1. Assign a different ID number to each module (factory default ID is 0).
2. Connect the first module to the computer. Run a serial communication program on the computer (for example, ProComm or Windows Terminal) for communicating with the module.
3. Set the unit's ID to 1 (SID1<cr>).
4. Execute a SAVE command (SAVE<cr> twice.)
5. The new ID becomes effective after the next power up.
6. Connect the second unit.
7. Set its ID to 2 (SID2<cr>).
8. Execute a SAVE command (SAVE<cr> twice.).
   The new ID becomes effective after the next power up.
9. Repeat the above for each additional unit up to ID=9. (If there is a 10th unit, just connect it and it will automatically receive the factory default ID: 0.)
10. Connect the TX (Transmit) of all modules in parallel.
11. Connect the RX (Receive) of all modules in parallel.
12. Connect the GND of all modules in parallel as shown in FIGURE 7-1.

Note

Note
Shielding connections will vary according to the installation.

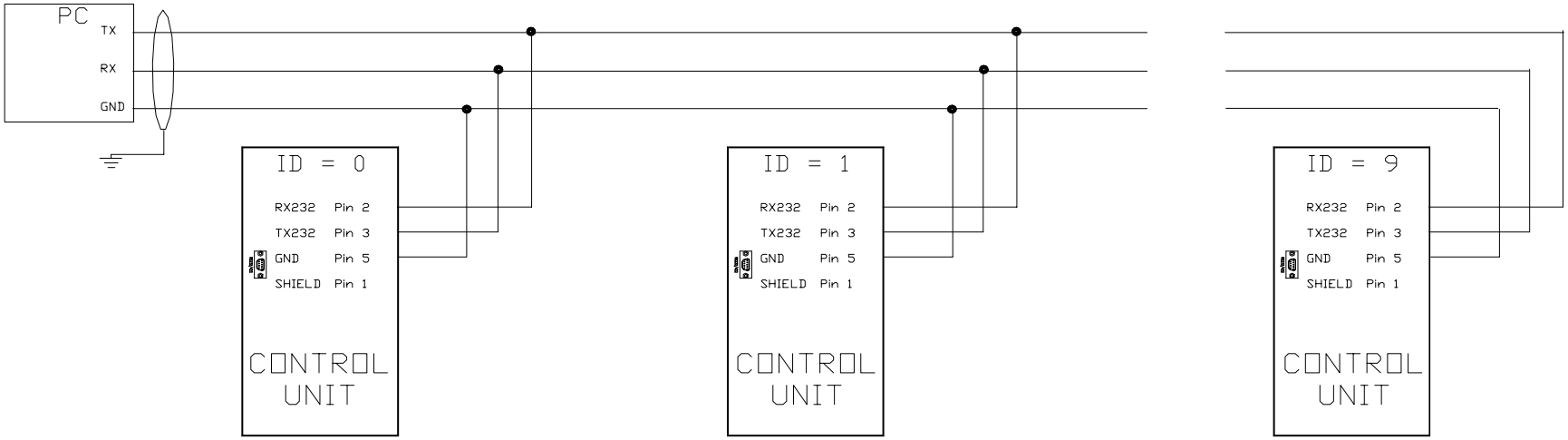


FIGURE 7-1 Multiple drop connections for RS-232

7.1.3. Multiple Drop Configuration for RS-422/485

The multiple drop configuration for RS-422/485 connections is similar to that for RS-232. Connect the following pins in parallel:

- GND
- TX+
- TX-
- RX+
- RX-

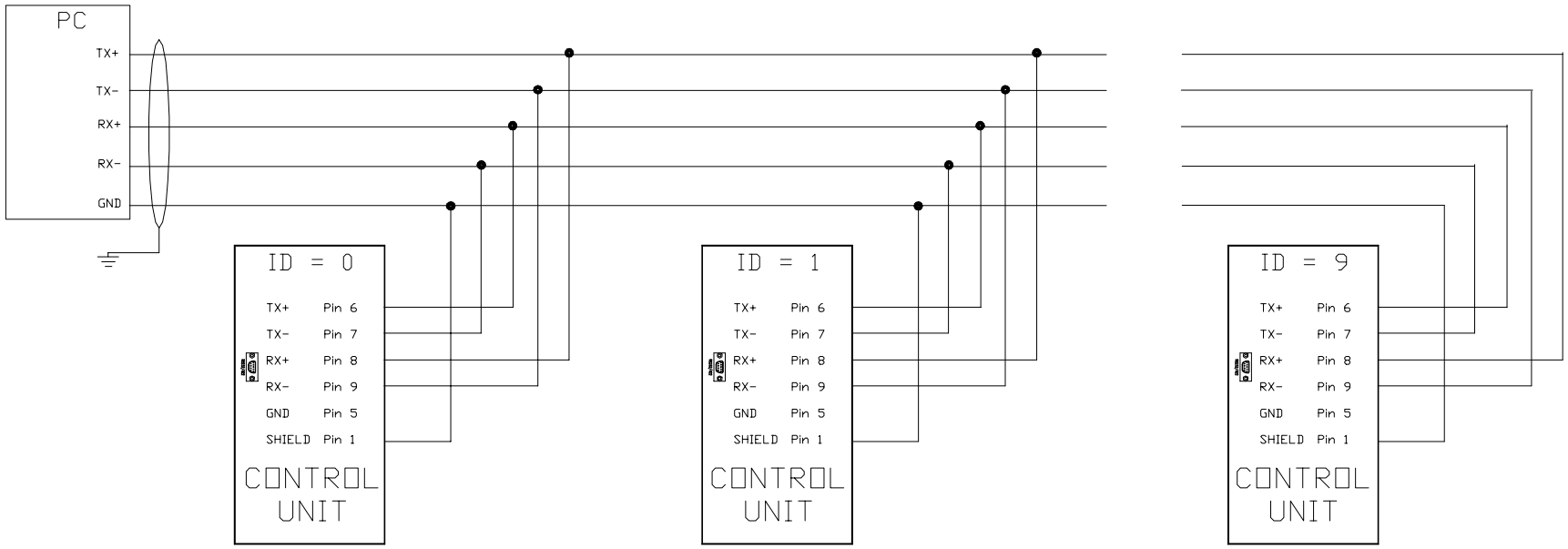


FIGURE 7-2 Multiple drop connections for RS-422/485

7.2. CAN Communications

Note

Note
For CAN communication, the COM_SD switch (on the control unit's front panel) must be OFF.

7.2.1. CAN Rotary Switch

The CAN interface has two parameters:

- **CB** is the CAN baud rate (default CB=500).
- **NI** is the CAN node ID. (default = 1).

The rotary switch on the control module's front panel selects between 16 modes of operation.

TABLE 7-3 CAN rotary switch positions and associated modes

Pos.	Mode	Description
0[1]	CAN	The internal CAN interface attempts to establish communication with the controller. This process can take several seconds. If it succeeds, the CAN LED turns green. From this point on, the controller can communicate with the external CAN bus. The values of the **CB** and **NI** parameters are read from the controller's internal EEPROM (nonvolatile memory).
1[2]	RS-232/422	Set CAN parameters via RS-232/422. Procedure: ♦ 1. Power off the unit (wait until the MP_ON LED goes off). ♦ 2. Set the CAN rotary switch to position 2. ♦ 3. Connect an RS-232 cable between the control module and the PC serial port. ♦ 4. Power on the unit (wait until the MP_ON LED goes on). ♦ 5. Use a terminal program, such as ACS Adjuster's terminal, to change the **CB** and **NI** parameters (see Section 7.2.2, "Setting and Reporting CAN Parameters"). ♦ 6. Power off the unit. ♦ 7. Change the position of the CAN rotary switch to the desired mode. ♦ 8. Power on the unit.

Pos.	Mode	Description
2[2]	RS-232/422	Program CAN firmware via RS-232/422. Procedure: ♦ 1. Power off the unit (wait until the MP_ON LED goes off). ♦ 2. Set the CAN rotary switch to position 2. ♦ 3. Connect an RS-232 cable between the control module and the PC serial port. ♦ 4. Power on the unit (wait until the MP_ON LED goes on). ♦ 5. Use the supplied CAN firmware programming application to download new firmware to the unit's internal CAN interface as follows: ♦ a. Choose option 7. ♦ b. Press F2 to enter a file name (full name with .HEX extension). ♦ c. Wait until the download has completed. ♦ 6. Power off the unit. ♦ 7. Change the position of the CAN rotary switch to the desired mode. ♦ 8. Power on the unit.
3[1]	CAN	Same as position 0, except that parameters **CR** and **NI** are set to default values (**CR** = 500, **NI** = 1)
4	DEBUG	DEBUG mode.
5	NU	Reserved.
6	NU	Reserved.
7 [1]	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 1000k.
8 [1]	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to of 800k.
9 [1]	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 500k.
A [1]	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 250k.
B [1]	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 125k.

Pos.	Mode	Description
C *(1)*	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 50k.
D *(1)*	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 20k.
E *(1)*	CAN	Same as position 0, except that parameter **NI** is read from EEPROM and parameter **CR** is set to 10k.
F *(2)*	RS-232/422	RS-232/422/485 communication, CAN is disabled

(1) -- EEPROM parameters can also be set and reported via CANopen in CAN mode (rotary switch positions 0, 3, or 7 to E).

(2) -- For more information about setting and reporting CAN parameters, see Section, 7.2.2 "Setting and Reporting CAN Parameters."

7.2.2. Setting and Reporting CAN Parameters

The two CAN parameters, (**CB** and **NI**), can be set and verified (reported):

The syntax for **Setting** the **CB** rate parameter is: **`SCB<value><cr>`**.

The syntax for **Reporting** the **CB** rate parameter format is: **`RCB<value>`**.

Value must be one of the following:

10 for 10k

20 for 20k

50 **for 50k**

125 for 125k

250 for 250k

500 for 500k

800 for 800k

1000 for 1000k

Examples:

Set CAN baud rate to 250k: **SCB250`<cr>`**

Report CAN baud rate: **`RCB<cr>`** displays result: `Can Baud rate 250k`

The other CAN-related parameters that can be set and verified is **NI** for the CAN **Node ID** parameter (default **NI**=1).

The syntax for **Setting** the CAN **Node ID** parameter: **`SNI<value><cr>`**.

The syntax for **Reporting** the CAN **Node ID** parameter: **`RNI<value><cr>`**.

Value must be in the range 1 to 127.

Examples:

Set CAN Node ID to 60: **SNI60<cr>**

Report CAN Node ID: **RNI<cr>** displays result: `Can Node ID 60`

7.3. Encoder 1 and Encoder 2



Warning

Facilities for overspeed protection are not provided in the control unit. Therefore, when facilities for overspeed protection are required for the end-product, they will have to be provided separately by the end-user.

The control module supports the following types of incremental encoder signals:

- Two-phase quadrature plus index.
- UP-DOWN plus index.
- CLOCK-DIR plus index.
- Two adjacent bits (C0, C1) of an up-down counter plus index.

The primary encoder feedback type and speed is governed by the **E**ncoder **T**ype (**ET**) parameter. The maximum edge count speed can be up to 20 million counts per second (when **ET** is in the range 1 to 6) or 40 million counts per second (when **ET** is in the range 100 to 106).

The secondary encoder feedback behavior can be programmed with the 2nd **E**ncoder **T**ype (**Et**) parameter.

For more information, see the "Reference" section of the *ACSPL Software Guide*.

7.4. Hall Sensors

When an encoder with Hall sensors (or equivalent) is used for position feedback and commutation, the Hall inputs are used for (trapezoidal) commutation during the first movement of the motor. When the encoder index is passed, the controller automatically switches to full sinusoidal commutation, which is based on the encoder feedback.

The Hall sensor must be connected such that as the encoder counts up, the Hall counter (**$HA**) cycles, i.e., it counts 0, 1, 2, 3, 4, 5, 0, 1, 2 etc.

7.5. Input/Output Ports and Motion Monitoring

This section describes the functions of the control module's input and output ports and how to work with them using ACSPL.



Further information

This section covers the programming interface for I/O. For information about the electrical interface for the I/O, refer to Section 4.4.5, "I/O + Safety Connector."

7.5.1. Digital Inputs

The unit includes eight general-purpose inputs (in addition to safety inputs). Input 6 can serve as a registration input. When the registration input changes its state, the location of the axis is latched into the registration mark position parameter (**$M1**). If **AUTO_M1X** automatic routine exists, it is invoked and executed.

The polarity of the digital inputs is controlled by the **I**nput **L**ogic (**IN**) parameter. When a bit in **IN** is set to 1, it causes the state of the corresponding input to be inverted. For example, if **IN** = 4 (i.e., bit 2 is set to 1), then if input three (IN3) is on, the controller considers it off.

The **IN** parameter does not affect the registration input (or the execution of the **AUTO_M1$** automatic routine). The **IN** parameter can be useful for application debugging.

The **I**nput **S**ource (**IS**) parameter controls execution of a **B**egin on **I**nput (**B$I**) command. When a **B**egin on **I**nput (**B$I**) command is issued, the control unit delays execution until the appropriate input is activated. The **IS** (**I**nput **S**ource) axis parameter defines which input. For example, if **XIS = 1**, then when a **BXI** command is issued, it is not executed until input 1 is high. The default **IS** is input 8.

Each input has a corresponding **ACSPL** state - **IN1, IN2...IN8**.

Inputs 1 to 5 are supported by automatic routines **AUTO_IN1** to **AUTO_IN5**. See ACSPL in the *ACSPL Software Guide* for more details.

7.5.1.1. Safety Inputs



Warning

The E-STOP input must not be used as the Emergency Stop for the entire system. Its sole use is to indicate to the control unit that an emergency situation exists.

The safety inputs comprise left limit and right limit (per axis), and emergency stop.



Warning

The Emergency Stop and Safety Interlock means provided with the controller are software-based only. Therefore, if the end product requires facilities for hardware-based Emergency Stop and/or Safety Interlock, these must be provided separately by the end user.

The limit inputs reduce the motor current to zero in order to avoid axis over-travel by preventing further motion in the inhibited direction. The emergency stop input stops and deactivates the motor instantaneously.

The **SI** (**S**ystem **I**nput Port) parameter holds the status of the safety inputs.

The polarity of the safety inputs can be altered with the **IL** (**I**nput **L**ogic) parameter.

7.5.2. Digital Outputs

The are eight general purpose outputs. Outputs 5 to 8 can be assigned the following predefined motion state functions:

- B/E Motion
- Ready

- Early Ready
- Interpolation Complete.

TABLE 7-4 Predefined motion state functions for digital outputs

Motion state	Description
B/E Motion	Indicates when the axis is in motion ("ON") or not in motion ("OFF"). X: output 5.
Ready	After a **B**egin on **I**nput (BXI), indicates that the calculations are complete and the axis is ready for motion. X uses output 6.
Early Ready	Indicates that the axis is ready to accept a new move command. Also indicates that a superimposed move has been executed. (A superimposed move is initiated by setting the **M**aster-slave relative **D**istance [**MD**] while in Master-Slave Mode [Mode 12]). X: output 7.
Interpolation Complete	Indicates that the axis interpolation (profile generation) for the present move is complete. X: output 8.

The function of each output is controlled by the **O**utput **M**ask (**OM**) and by the **P**eg **M**ask (**PM** parameters. When a **PM** bit is set, the corresponding output serves the **PEG** function and cannot be changed by output handling commands. When the **PM** is cleared and the **OM** bit is set, the appropriate output serves the dedicated function described above. When serving a dedicated function (not the **PEG**), output handling commands can still be used. These commands include the **SHI, SLO** and **SOP** direct mode commands and the **let HI, let LO**, and **let OP** programming mode commands. See the *ACSPL Software Guide* for more details.

TABLE 7-5 Outputs commands

Mnemonic	Meaning	Result
`SOM3<cr>`	**S**et **o**utput **m**ask to 3 (= 00000011 binary).	Enables outputs 1 and 2 for dedicated function
`ROP<cr>`	**R**eport **o**utput **p**ort status.	Displays status of the output ports.

7.5.3. Analog Inputs

The analog input - **AIN1** accept a voltage signal in the range of ±10V. A 12-bit A to D converts the analog input into a binary number in the range ±2,047. The value -2,047 represents -10V, 0 represents 0V and 2,047 represents 9.99V.

AIN1 is also used as the joystick input.

The analog input is accessible via the analog variable **A0** (**AIN1**).

7.5.4. Analog Output

There is one ten bit analog output available - A_OUT. Its value is controlled by the **XD4** axis parameter. The output voltage range is -10V (**XD4= -511**) to +9.99V (**XD4=511**). The analog output can be used to monitor motion and other real time variables.

The analog output is accessible via the I/O connector and via a test point on the bottom of the control module.

The actual velocity, position, position error, master position, and the current (= torque) commands can be monitored via the axis analog parameter **D4**. The analog output is a 10-bit digital to analog converter (DAC). The function of the analog output is controlled by three parameters - **MN** (**Mo**n**i**tor), **DC** (**D**ata **C**ollection), and **MF** (**M**otion **F**actor)**.**

7.5.4.1. Motion Monitoring Parameters

The **MN** (**Mo**n**i**tor) parameter determines the source of the analog output.

TABLE 7-6 MN (Monitor)parameter

MN value	Source of analog output is
MN=0	determined by the **XD4** parameter.
MN=1	velocity signal.
MN=2	drive vector current (torque) signal.
MN=3	determined by the bit assignment of the **DC** (**D**ata **C**ollection) parameter.

When **MN** = 3, it is the **D**ata **C**ollection (**DC**) bit assignment that defines the source of the analog output. If more than one DC bit is set, only the least significant bit is read.

TABLE 7-7 DC (Data Collection) parameter bit assignment

Bit	11 - 15	10	9	8	7	6	5	4	3	2	1	0
Parameter	0	DSP	IO	0	0	A<channel>	MP	D2	DO/D1	PE	CP	LV

For more information about the **DC** parameter, refer to the *ACSPL Software Guide*.

The **MF** (**M**onitor **F**actor) is available for scaling for scaling the internal digital source fed to the analog output's DAC.

Analog output signal = (internal digital source) x 2^{MF} x (10[volts]/512)

To prevent an overflow, **MF** must adhere to the following condition:

$-511 < (\text{internal digital source}) \times 2^{MF} < 511$

7.5.4.2. Monitoring Velocity Profile

The output voltage as a function of the **a**ctual **v**elocity (**AV**) in counts/seconds is:

$$V_{out} = 10 \times \frac{\frac{D22}{20{,}000} \times AV}{512} \times 2^{MF}$$

The velocity scale factor depends on the value of **D22**. Internally, the maximum velocity value is represented by the value 1638.

For example, if **D22** was set according to a maximum velocity of 1,000,000 counts/second, then when the actual velocity is 1,000,000 counts/second, the internal (integer part of the) velocity value is 1638. When the actual velocity is 500,000 counts/second, the internal velocity value is 819.

To monitor the velocity, set **MN** to 1. **MF** must be set to a value that will prevent overflow of the output. In the above example if the actual velocity is getting close to 1,000,000 counts/second (internal velocity of 1638), set **MF** to -2. If the actual velocity is less than 500,000 counts/second (internal velocity of 819) set **MF** to -1. If the actual velocity is 100,000 counts/second (internal velocity of 163), set **MF** to 1. This will provide a better dynamic range for the monitored signal.

7.5.4.3. Monitoring Position Error

Monitoring the position error is useful for improving the tracking quality, for finding the source of torque disturbances, for measuring settling time and for setting the acceleration feed forward (**AF**).

To monitor the position error, reset **MN** to 3 and **DC** to 4. Usually the error value is less than 500, so **MF** should be set to a non-negative value.

TABLE 7-8 Scale factor as a function of MF

MF	VPE [volts/count]
-2	0.00488
-1	0.00976
0	0.0195
1	0.039
2	0.078
3	0.156
4	0.312

7.5.4.4. Monitoring Current Position

Monitoring the **c**urrent **p**osition (**CP)** is a useful tool for measuring settling time. Usually the value of **CP** is large. While moving, the monitor signal will overflow. Ignore it. Just examine the last part, where the axis settles.
The [volts/counts] scale factor is identical to the scale factor for position error monitoring.

Example: Set the system to check whether the axis overshoots the target point by more than 10 counts when moving in **MM1** between **CP=0** and **CP=32768.**

Solution: Set **DC** to 2, **MN** to 3 and **MF** to 3. A 10 count overflow will generate a 1.5V overshoot at the end of the move.

8. VECTOR CONTROL AND MOTORS

8.1. Vector Control for DC Brushless (AC Servo/AC Synchronous)

All ACS-Tech80 digital control modules use the Vector Control method to "convert" a simple low cost DC brushless(AC servo/AC synchronous) motor, equipped with position feedback device, into a high performance servo motor.



Note

The diagrams in this section are for general description purposes only.

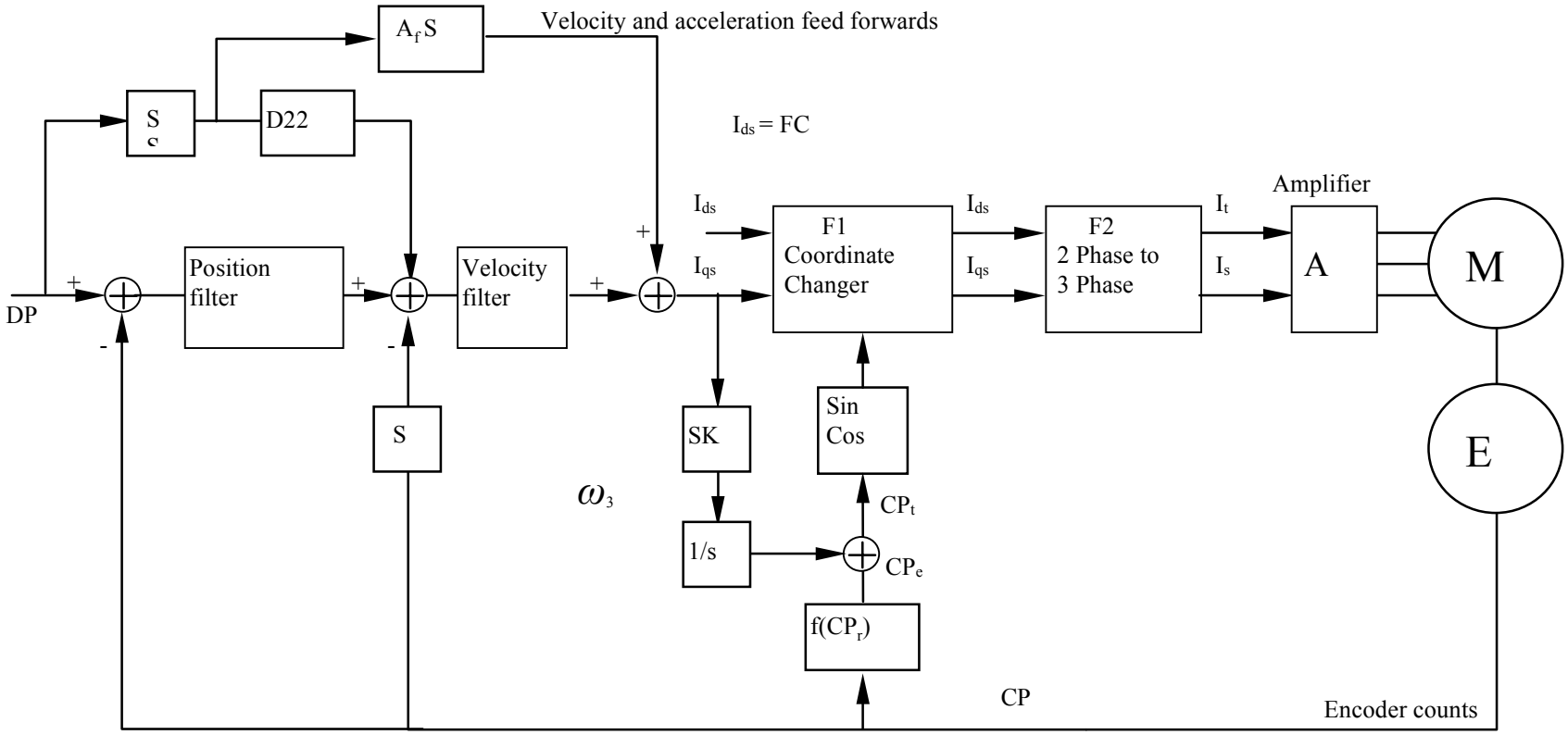


FIGURE 8-1 Vector control

8.1.1. What is Vector Control?

In any electrical motor, to generate torque requires a magnetic field and a current that is perpendicular to it (FIGURE 8-2). The generated torque is related to the vector multiplication of these two vectors.

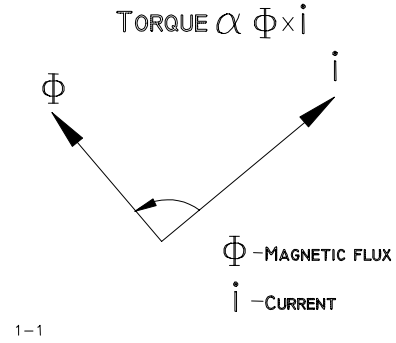


FIGURE 8-2 Current and magnetic field vectors

In the Vector Control method, the AC induction motor is controlled like a separately excited DC motor (FIGURE 8-3).

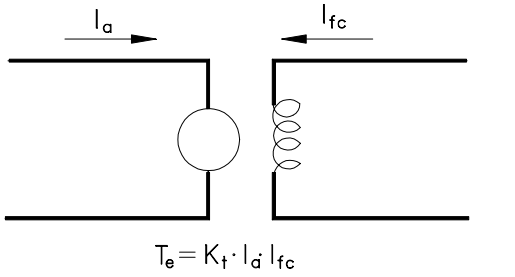
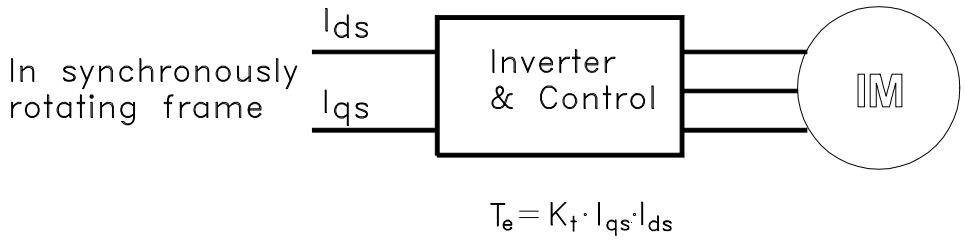


FIGURE 8-3 Model of separately excited DC motor

In a DC motor, the magnetic field is generated by field winding (or by the permanent magnet in a PM motor).

The rotor's current is "always" perpendicular to the magnetic field. Thus, assuming a fixed magnetic field, the torque is proportional to the rotor's current, **which is the basic and most important requirement for high performance servo Action.**

The DC method of control is extended to an AC induction motor by considering the machine operation in a synchronously rotating reference frame where the sinusoidal variables appear as DC quantities (FIGURE 8-4).



$$T_e = K_t \cdot I_{qs} \cdot I_{ds}$$

T_e – Torque

K_t – Constant

I_{qs} – Torque component

I_{ds} – Field component

1-3

FIGURE 8-4 Model of induction motor in synchronously rotating reference frame

I_{ds} - Direct axis component, analogous to the field current of the DC motor. (The Field Current - FC parameter controls the magnitude of I_{ds}.)

I_{qs} - Quadrature axis component, analogous to the armature (torque generating) current of the DC motor.

The synchronously rotating frame is rotating at an angular velocity that is equal to the speed of the rotor (as measured by the encoder) plus the slip speed - W_s. The angle of the rotating frame is CP_t. For a fixed magnetic field the necessary slip speed is directly related to the desired torque/current I_{qs}. (This is the reason that Vector Control is often referred to as Slip Control). The relation constant is defined by the SK parameter.

By fixing I_{ds}, setting I_{qs} to be proportional to the torque command (= velocity loop output), and transforming the two components to the rotating frame (F1 in FIGURE 8-1) according to the instantaneous CPt, the AC motor acts like a DC motor. It is now suitable for servo applications.

The Vector Control method for DC brushless (AC servo/AC synchronous) motors is a private case of the above. All that is required is to set I_{ds} and SK to zero (which the control unit does automatically when the a**x**is **t**ype (**XT**) is changed from AC induction to DC brushless (AC servo/AC synchronous).

8.2. When to Use an AC Induction Motor

The standard AC induction motor is larger and heavier than a permanent magnet DC brushless (AC servo/AC synchronous) motor, and its inertia is higher. Therefore its dynamic characteristics are inferior to that of a DC brushless motor (AC servo/AC synchronous). Its main advantage is its low price. Here are some guidelines for using an AC induction motor:

When already using an AC induction motor and better velocity regulation or more accurate positioning capabilities is required. The ACS-Tech80 control module makes these goals achievable with superb performance at no price penalty (when compared with available vector control based inverters).

If a high performance servo system is required, but not the high dynamic characteristics of a DC brushless (AC servo/AC synchronous) motor. When the inertia of the load is much higher than the inertia of the motor (and it may be difficult to match the inertia of the load to the inertia of the motor). In such cases, a significant cost reduction can be realized by using an AC induction motor.

When high accuracy, low velocity control is required. The high inertia of the AC induction motor and the ability to eliminate most of the magnetic field cogging, will help in overcoming low frequency disturbances, thus achieving a better velocity regulation. Better than an DC brushless (AC servo/AC synchronous) motor based servo!

When motor without brushes is required and there is no budget for a DC brushless (AC servo/AC synchronous) motor. It is surprising what smooth performance and how much torque a small, low cost AC motor can generate. Usually an AC motor is specified by its power level and nominal speed. For example, a 1.1KW motor @ 1500rpm nominal no-load speed. A motor like this (assuming 100% efficiency) is capable of generating rms torque of 7Nm at 1500rpm and 15Nm peak torque at lower speeds!

If using a motor to its full power specifications, make sure that it is cooled by forced air. Otherwise de-rate it by 35-40%.

The motor's windings should be arranged in delta configuration.

The setup procedure for an AC motor differs from the setup procedure for a DC brushless (AC servo/AC synchronous) motor only in the commutation adjustment. All other adjustments are identical. Once the control unit is adjusted properly, it is completely transparent to the user what type of motor is being used.

9. WARRANTY

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