# MODEL ACE120X-XXX-XYZX
# MODEL ACE130X-XXX-XYZX

Hardware User's Manual

Digital Velocity/Torque/Position Mode Servo Drive

**This manual covers the use and maintenance of the models ACE120X and ACE130X series Torque, Velocity and Position mode brushless motor control product family.**

**READ ENTIRE USER MANUAL FIRST BEFORE ATTEMPTING TO USE THIS PRODUCT. DO NOT RETURN PRODUCTS WITHOUT OBTAINING PRIOR AUTHORIZATION DIRECT FROM AUTOMOTION.**

This manual describes the installation and operation of the ACE1000 series of digital high voltage servo-amplifiers manufactured by Automotion, Inc.

This document applies to serial numbers ending with xxxx0105.

We reserve the right to modify our products at any time. Information, specifications, and material data that appear within this user manual are subject to change without notice. For the latest revision of this manual please check our web site at www.automotioninc.com or contact Automotion.

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Revision History

| Release Number | Date | Product | Comments |
|---|---|---|---|
| 0.0 | 12/10/04 | ACE1000 firmware ver. XXXX | Creation Date |
| 1.0 | 1/1/05 | ACE1000 Main Processor Ver. 50013505<br>ACE1000 I/O Processor Ver. 50011201 | Initial Release Date |
| 1.1 | 1/23/06 | ACE1000 Main Processor Ver. 50013505<br>ACE1000 I/O Processor Ver. 50011201 | Added Auto-Phase<br>Added Function Gen. |

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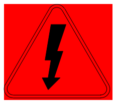
# Table of Contents

# Table of Figures

# 1 Product Safety Precautions

Read this section and Section 1 before using the ACE1000 series drive.



# WARNING!

## THIS PRODUCT USES HIGH VOLTAGE ELECTRICAL POWER. IT POSES A SHOCK HAZARD TO THE USER.

To operate your control successfully, these minimum safety precautions MUST be followed to insure proper performance without injury to the operator and damage to motor or control. **FAILURE TO OBSERVE THESE SAFETY PRECAUTIONS COULD RESULT IN SERIOUS BODILY INJURY, INCLUDING DEATH IN EXTREME CASES.**

1. DO NOT touch any of the output connector pins in connectors P1, P2, or P6 when power is applied. The voltages at these connector pins are dangerous and can produce an electric shock. Bare wires from adjacent connector pins must never be allowed to touch one another. P1, pin 1, must be connected to an external earth ground. Follow wiring procedures carefully. Know and understand which connectors are NOT electrically (galvanically) isolated from the AC/DC voltages within the drive.

2. Always operate the control within the prescribed voltage limits.

3. Each model has dangerous voltages on the circuit boards and stores a high voltage charge after being disconnected. **DO NOT REMOVE THE COVER IF ONE IS IN PLACE. DO NOT ATTEMPT TO SERVICE THIS PRODUCT IF A PROBLEM OCCURS**.

4. Do not parallel multiple motors off of the same control.

5. Under no circumstances must a phase output from the control be connected to anything other than a passive inductive/resistive motor load. See manual for minimum inductance requirements. Short circuit protection for the drive is limited to momentary conditions only! Repetitive short circuits on any of the output pins for P6 will likely cause permanent damage to the ACE.

6. Excessive speed and current can destroy some DC brushless motors and possibly injure the user. Check the motor manufacturer's specifications to ensure the maximum current and voltage output for your control model does not exceed their limitations.

7. External methods are advisable to limit both the top speed and travel motion of the motor and its load. Whenever the ACE drive is disabled for any reason, the motor is placed into a free/spinning coast mode.

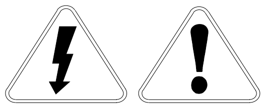
8. Do not remove the connectors on ports J5, J8, J9, P1, P2, or P6 from the control while the motor is operating.

9. Read Automotion's Life Support Policy in Section 1.1 for application limitations.

10. To avoid a shock hazard always wait at least 5 minutes after disconnecting power from P1 before physically handling or touching any internal circuit boards. Use a voltmeter to be certain that all high voltage capacitors inside the ACE are fully discharged before physically handling or touching the internal circuit boards.

11. Follow precautionary guidelines in this manual with regard to proper installation of an external shunt resistor. See Sections 1.0 and 4.1.6.

12. Do NOT operate the ACE in the vicinity of flammable or explosive materials.  Do NOT use the ACE in environments where it is likely to be exposed to strong and/or frequent static discharge. See Section 1.0 for additional details.



**READ THIS ENTIRE SECTION BEFORE ATTEMPTING TO USE THE ACE1000 SERVO DRIVE!  GIVE SPECIAL ATTENTION TO ALL BOLD PRINT ITEMS.**

To operate the ACE1000 successfully, these safety precautions MUST be followed to reduce the risk of injury to the operator and damage to motor or ACE1000 control.
**Failure to observe all safety precautions could result in serious bodily injury, including death in extreme cases.**

## 1.1 LIFE SUPPORT POLICY

**Automotion's products are not authorized for use as critical components in life support devices or systems without the express written approval of the President of Automotion Incorporated.**

As described herein:

Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the User's Manual and in the labeling, can be reasonable expected to result in a significant injury to the user.

A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

## 1.2 Other safety issues

1.2.1 The ground on P1, pin 1, MUST always be connected to an appropriate external earth ground during use of the ACE.   There is also a chassis ground stud located on the lower end of the ACE.  This must be connected to a appropriate external earth ground.

1.2.2 If the ACE does not seem to function correctly, first consult section titled ``Troubleshooting." If this fails to solve the problem, call AUTOMOTION.

1.2.3 Always operate the ACE within the prescribed voltage limits. Any attempt to operate outside these bounds may result in damage to the ACE control.

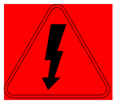
1.2.4 DO NOT LOCATE ANY ACE IN A POSITION WHERE IT WOULD HAVE CONTACT WITH LIQUIDS,  WATER CONDENSATION, CORROSIVE CHEMICALS OR WHERE FOREIGN MATERIALS WOULD BE ALLOWED TO FALL INTO AND COLLECT INSIDE THE ACE.

1.2.5 DO NOT MOUNT THE ACE DIRECTLY UPON OR NEAR FLAMMABLE MATERIALS.

1.2.6 DO NOT OPERATE THE ACE IN AN EXPLOSIVE ATMOSPHERE OR IN THE VICINITY OF EXPLOSIVE MATERIALS. KEEP THE INSTALLATION VENTILATED SO THAT CLEAN FRESH AIR CAN MOVE FREELY THROUGH AND AROUND THE ACE ENCLOSURE.

1.2.7 Avoid frequently plugging connector P1 into the control while live power is applied to the connecting cables.  Ignoring this precaution will cause electrical arcing at the connector pins which can cause permanent connector damage. AUTOMOTION recommends using a disconnect switch ahead of P1 to minimize contact arcing if the ACE must be disconnected often.

1.2.8 Keep external shunt resistor far away from flammable materials. Read Sections 4.1.6 and 11 carefully for more shunt installation details.



# WARNING!

## HIGH VOLTAGE MAY BE PRESENT AT THIS CONNECTOR.

1.2.9 If the user adds supplemental external capacitance via terminal P2 provisions should be made by the user to rapidly bleed this high voltage energy down to safe levels whenever the user's power source is disconnected from the system. Bleeder resistors are frequently used for this purpose. It will be necessary for the user to size this discharge method appropriately. The objective is to reduce the motor rail voltage down to safe levels (generally below +40 Volts DC) within an acceptable time period after the user's external power source is turned off or disconnected.

**The remainder of this page is intentionally left blank.**

# 2 Unpacking and Repacking the ACE1000

When your package arrives, inspect the shipping box and the unit carefully, and save ALL packing materials. Contact the carrier promptly if damage is discovered. Your ACE1000 has arrived carefully packaged from Automotion in an antistatic bag. As you unseal this bag inspect the contents carefully. There should not be any loose or damaged parts inside.

Compare the packing slip against all items included in the box. Any shortages or other inspection problems should be reported to AUTOMOTION immediately.

Never attempt to operate or power-up the ACE1000 if there is any visible external damage or if it sounds as though there are loose materials inside the chassis. While unpacking, if you discover any loose or damaged parts, notify AUTOMOTION within two working days.

AUTOMOTION recommends that all packing materials be saved in case the ACE1000 ever needs to be shipped again. Always place the ACE1000 in the same antistatic bag used in the original shipment. Abundant anti-static filler material should always be placed around the ACE1000 bag so that it cannot shift inside the box. Extreme care should be exercised when placing packing material around all external connectors to prevent mechanical stress damage.

All material to be returned to AUTOMOTION must have a Return Material Authorization (RMA) tracking number assigned before shipment. This may be obtained by contacting the AUTOMOTION Service Dept. Any product returned without this number will be rejected by AUTOMOTION.

Always insure your shipment for the proper replacement value of its contents. AUTOMOTION will not assume responsibility for any returned goods that have been damaged outside of our factory because of improper packaging or handling. All goods shipped to AUTOMOTION must be shipped FREIGHT PREPAID.

# 3 ACE1000 Introduction

## 3.1 Amplifier

The ACE1000 is fully digital servo amplifier that uses DSP technology to provide a powerful feature set that is fully configurable by means of a RS232 serial port. The ACE1000 servo drive is configurable as a Torque, Velocity, or Position mode servo amplifier. The ACE1000 is designed to operate a single 3 phase Brushless DC or AC, permanent magnet motor. The motor may have either a WYE or Delta wound stator. The ACE1000 provides commutation using Hall sensors or encoder feedback.

Principal features of this product:

- User configurable operation modes: Torque, Velocity, Position.
- Selectable BLAC (sine wave, flux vector) or BLDC (Six step, trapezoidal) commutation.
- 4 Quadrant performance.
- 3 Phase output, PWM controlled output.
- Full digital control of all loops
- Variable servo rate from up to 10 kHz.
- Loop tuning via serial interface (No pots!).
- Drive setup & status information available serially via RS232 link.
- 60 – 264 VAC input power supply range.
- Output current of 10 or 18 Amp continuous, 20 or 30 Amp peak, depending upon model selected.
- Compact package size.
- ***AutoMotionPLUS©*** Graphical Windows Interface for Set-up, Configuration and Tuning.

The ACE1000 current, velocity or Position modes accept +/- 10 volt DC analog or digital PWM.

## 3.2 Theory of operation

The ACE1000 operates as a "mode configurable" digital servo amplifier. This product is typically applied as a component within an end use industrial application. Within industry, application requirements for servo amplifiers vary widely. For example, one application may require an amplifier with an analog input reference for speed. Another application may require an amplifier that offers torque control and Hall sensor commutation only. For this reason the ACE1000 offers a choice of many different servo-operating modes. This flexibility is made possible because all of the control functions within the ACE1000 are implemented in software. The ACE1000 physical I/O and closed loop functionality are selected using the *AutoMotionPLUS* Windows Setup utility. See Section 4, Introduction to the *AutoMotionPLUS* software, and the *AutoMotionPLUS* software User Manual for additional information on using this software.

The internal firmware architecture of the ACE1000 is modular. ACE1000 software is built as a series of components (or modules) that are linked together to form an ACE1000 servo-operating mode. ACE1000 software components are stored in ROM memory as a run time library. These components exist as Reference input modules, Feedback modules, PI (D) control modules, commutation modules and firmware extension modules. A detailed list of these components is found in Section 4 of this manual.

## 3.3 ACE1000 Architecture

An internal digital signal processor (ASIC) is used to read I/O signals, motor feedback signals and to process serial communication messages. ROM memory inside the ACE1000 is used to store a library of modular software components. RAM memory is used for data logging and graphical tuning of the ACE1000. The serial EEPROM provides nonvolatile memory for retention of user-configured parameters and operating mode. EEPROM memory is also used to extend the program functionality of the ACE1000.

## 3.4 ACE1000 I/O

Drive specific I/O operates independent of the user selected operating mode. Dive specific I/O signals have fixed functionality. These signals are used to interface the ACE1000 to an outside control system. They provide "hand shaking" signals for enabling, disabling, and monitoring the status of the ACE1000. For physical reference to the ACE hardware see Figure 2 below.

### Connector J5 – User I/O Control, DB25 Plug with metal shell

| Pin | I/O | Description |
|---|---|---|
| 1 | Input | + 5 volts DC Power. User supplied regulated +5VDC power. |
| 2 | | COMMON Return |
| 3 | Input | + 5 volts DC Power. User supplied regulated +5VDC power. |
| 4 | Input | Unipolar Analog Signal Input. 0 – 10 volt signal amplitude. +24 Volt max./ -0.5 Volt min. |
| 5 | Input | Enable/Reset Control Signal Input. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. Positive true logic. Forces a master hardware reset for entire drive on a falling edge. Drive recovers beginning after rising edge. Drive remains disabled while a logic "0" is applied to this input.<br><br>When Enabled (logic "1" applied), the active inrush current limit relay will close after a 3 second delay. After this delay, the drive will be allowed to enter Run Mode as commanded by the Run Command Signal Input on pin 6. |
| 6 | Input | Run Command Signal Input. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. Positive true logic. A logic "1" state will allow motor commutation once some level of current is commanded. A logic "0" state places motor into a coast state. |
| 7 | Input | Dynamic Brake Command Signal Input. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. Positive true logic. A logic "1" state will suspend motor commutation and current delivery from drive. It shorts all three motor phases together to cause the motor's BEMF to generate a dynamic braking torque within the motor. |
| 8 | Input | General Purpose Digital Input. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. This input function is application specific.<br>*Or*<br>I2C Clock Input. 0V - +5V input signals |
| 9 | Input | General Purpose Digital Input. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. This input function is application specific.<br>*Or*<br>I2C Data Input. 0V - +5V input signals |
| 10 | | COMMON Return. |

| | | |
|---|---|---|
| 11<br> | Input | Dual purpose Input. Software configured.<br>+ Differential Command Signal Analog Input. Zero to ±10 Volt external command signal input. The polarity of this signal controls the relative applied direction of output motor torque, velocity, or position. Input is protected to ±24 Volt maximum.<br>*Or*<br>PWM Control Input. Zero to +5 Volt logic signal. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. Positive true logic. Weighting of PWM On-time Vs Off-time controls the amount of commanded torque, velocity, or position. 0% PWM = 0 current output. 100% PWM = Max. rated output.<br><br>**NOTE: When using a single ended analog input signal to this input Pin 11 (rather than a differential analog signal) be certain to ground pin 12 to the Analog common, Pin 13.** |
| 12 | Input | Dual purpose Input. Software configured.<br>- Differential Command Signal Analog Input. Zero to ±10 Volt external command signal input. The polarity of this signal controls the relative applied direction of output motor torque, velocity, or position. Input is protected to ±24 Volt maximum.<br>*Or*<br>Direction Input. Zero to +5 Volt logic signal. TTL compatible. +24 VDC maximum signal amplitude. 0 Volts minimum. 10K Ohm input impedance. Selects relative direction of current flow into motor to control direction of applied torque, velocity, or position. |
| 13 | | Analog COMMON. |
| 14 | Output | Encoder "A" Signal Output. Zero to +5 Volt logic signal. |
| 15 | Output | Encoder "!A" Signal Output. Zero to +5 Volt logic signal. |
| 16 | Output | Encoder "B" Signal Output. Zero to +5 Volt logic signal. |
| 17 | Output | Encoder "!B" Signal Output. Zero to +5 Volt logic signal. |
| 18 | Output | Encoder "Z" Marker Signal Output. Zero to +5 Volt logic signal. |
| 19 | Output | Encoder "!Z" Marker Signal Output. Zero to +5 Volt logic signal. |
| 20 | | COMMON Return. |
| 21 | Output | Tachometer Signal Output. 250 Ohm output impedance. Zero to +5 Volt logic signal. |
| 22 | Output | Motor Overtemp Signal Output. 250 Ohm output impedance. Zero to +5 Volt logic signal. Positive true output signal. Logic "1" state indicates the motor is in an overtemp condition. |
| 23 | Output | !Fault Signal Output. 250 Ohm output impedance. Zero to +5 Volt logic signal. Negative true output signal. Logic "1" state indicates drive is NOT in a Fault mode. |
| 24 | | No Connect |
| 25 | | Frame Ground (OPTIONAL). Factory option to connect to servo drive frame. Its configuration for this purpose may violate certain safety agency requirements. Consult Automotion. |
| Shell | | J1 Connector Frame. Connector shell is connected to servo frame ground. |

### Connector J9 – Motor Feedback Signals, DB15 receptacle type with metal shell

| Pin | I/O | Description (for Hall based system) |
|---|---|---|
| 1 | Input | Hall signal Input S1. |
| 2 | Input | Hall Signal Input S2. |
| 3 | Input | Hall Signal Input S3. |
| 4 | | +5 Volt DC Hall/Encoder supply voltage. |
| 5 | | COMMON. |
| 6 | Input | A Encoder Signal Input. |
| 7 | | !A Encoder Signal Input. |
| 8 | | COMMON. |
| 9 | Input | B Encoder Signal Input. |
| 10 | Input | !B Encoder Signal Input. |
| 11 | | Factory Optional Servo Frame Ground. Normally this pin is not connected. |
| 12 | Input | Z Encoder Signal Input. |
| 13 | Input | !Z Encoder Signal Input. |
| 14 | | PTC/thermal switch contact for motor temp sensing. |
| 15 | | PTC/thermal switch contact for motor temp sensing. |
| Shell | | J2 Connector Frame. Connector shell is connected to servo frame ground. |

# WARNING!

**THIS PRODUCT USES HIGH VOLTAGE ELECTRICAL POWER. IT POSES A SHOCK HAZARD TO THE USER. A SHOCK FROM HIGH VOLTAGE ELECTRICAL POWER MAY CAUSE SEVERE INJURY AND/OR DEATH IN EXTREME CIRCUMSTANCES.**

The connectors shown below have High Voltage power applied to several of the associated pins. Use extreme care when making wire connections to them. All external electrical power should be OFF whenever wiring to these connectors to avoid a shock hazard.

### Connector P1 – AC/DC Power Input, Phoenix type plug-able connector, Part #18 04 92 0

| Pin | Description |
|---|---|
| 1 | Frame GROUND. |
| 2 | AC Input. 90 to 254 VAC, 50/60 Hz, 1 Phase AC or ±120 to 360 Volts DC.* |
| 3 | AC Input. 90 to 254 VAC, 50/60 Hz, 1 Phase AC or ±120 to 360 Volts DC.* |
| 4 | AC Input. 90 to 254 VAC, 50/60 Hz, 1 Phase AC or ±120 to 360 Volts DC.* |

* These are UL operating voltage ranges at peak currents. Contact Automotion for application assistance for operating outside these specified ranges.

### Connector P6 – Motor Phase Output, Phoenix type plug-able connector, Part #18 04 92 0

| Pin | Description |
|---|---|
| 1 | Frame GROUND. |
| 2 | Motor Phase 1 Output. Peak voltage out of this terminal is dependant upon the incoming crest voltage on connector P1. Peak amperage is model dependant. |
| 3 | Motor Phase 2 Output. Peak voltage out of this terminal is dependant upon the incoming crest voltage on connector P1. Peak amperage is model dependant. |
| 4 | Motor Phase 3 Output. Peak voltage out of this terminal is dependant upon the incoming crest voltage on connector P1. Peak amperage is model dependant. |

# WARNING!

**WHEN THIS PRODUCT USES AN INTERNAL OR EXTERNAL SHUNT RESISTOR, PRECAUTIONS MUST BE FOLLOWED TO PREVENT A POSSIBLE FIRE HAZARD.**

The use of shunt resistor, either internal or external, requires careful placement to avoid a possible fire hazard. Never place the shunt resistor in the vicinity of flammable or explosive materials. See this manual for further precautionary details.

### Connector P2 – External Shunt Resistor/External Supplemental Capacitors, Phoenix type plug-able connector, Part #18 04 91 7

| Pin | Description |
|---|---|
| 1 | B+ Motor Rail. High Voltage DC positive rail for motor power. This terminal is used for connecting external supplemental capacitance and/or an external user supplied shunt resistor. |
| 2 | Shunt Resistor. Connection for external user supplied shunt resistor. The other side of the external shunt resistor connects to terminal #1. |
| 3 | B- Motor Rail. High Voltage DC negative rail for motor power. This terminal is used for connecting external supplemental capacitance supplied by user. |

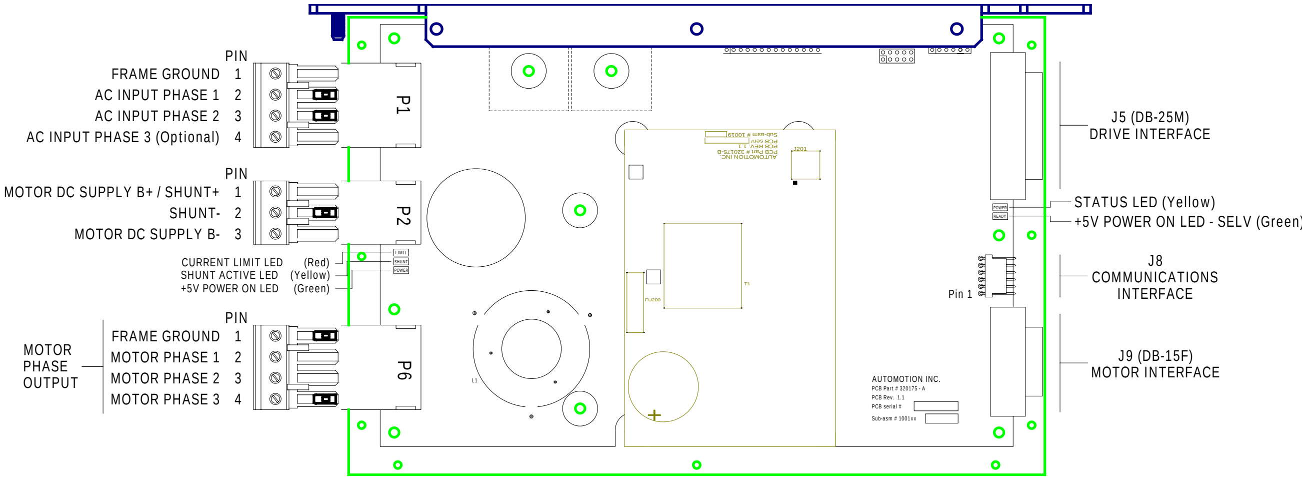



**Figure 1: Drive Connector Layout**

# ACE1000 Status LEDs

In normal operation, the ACE1000 is either in a “Ready” state or in and “Error” state, meaning that one, or the other LED is on. If both LEDS are “ON”, this indicates that the ACE1000 has been powered or reset with the Mode input floating. The Mode input is used to update ACE1000 program memory. See section 4, “Introduction to the *AutoMotionPLUS* software”, and section 5, Working with the ACE1000- Helpful Notes and Procedures” for additional information.

## 3.5.1 Ready LED (User side - Yellow)

| FLASH CODE | DESCRIPTION | POSSIBLE CAUSE | RESULT | RECOVERY METHOD |
|---|---|---|---|---|
| ON Steady | ACE1000 is in RUN mode. | • User commanded RUN mode via user interface | • Clear all faults and STATUS flags<br>• Enable three-phase PWM | • Toggle the DRIVE ENABLE signal |
| OFF | Processor is inoperable. | • Drive is in reset<br>• Processor fault<br>• Improper user supplied +5Volts | • ACE1000 will stay in a DISABLED mode<br>• Processor code branches to dead-end program loop in order to prevent any ACE1000 operation | • Disconnect power from the ACE1000 for 1 min to reset the microprocessor. Then re-apply power to allow microprocessors to operate |
| 1 | Drive is in Standby mode | • The user commanded standby mode from the user interface | • The drive is placed in standby mode | • Command run mode |
| 2 | Power Module Fault | • Short circuit<br>• Over temp fault<br>• Improper power module logic control voltage | • The drive is placed in standby mode | • Toggle the run line, see Note 1 |
| 3 | Shunt over stressed | • Shunt is turned on continuously for more | • The drive is placed in standby mode | • Toggle the run line, see Note 1 |

| | | | | |
|---|---|---|---|---|
| | B+ rail voltage to high | than five seconds<br>• The B+ rail greater than fixed 450-Volt limit | | |
| 4 | B+ rail to low | • B+ rail is less than the B+ rail low limit | • The drive is placed in standby mode | • Toggle the run line, see Note 1 |
| 5 | User +5volt Logic supply fault | • User supplied SELV +5Volt out of spec. (4.75-5.25 Volts) | • The drive is placed in standby mode | • Toggle the run line, see Note 1<br>• Check supply voltage |
| 6 | SPI communica-tions timeout detected | • DSP Lost SPI synchronization from communication processor | • The drive is placed in the disabled mode. (hard fault) | • Toggle the DRIVE ENABLE signal. |
| 7 | Locked rotor fault | • Supplied current is greater than user specified time with no hall transitions | • The drive is placed in standby mode | • Toggle the run line, see Note 1 |
| 8 | Logic supply fault | • Line side logic power supplies out of spec (+/-15V and +5V) | • The drive is placed in standby mode | • Toggle the run line, see Note 1 |
| 9 | EEPROM Fault<br><br>Check sum fault | • The user EEPROM has a checksum error<br><br>• DSP program memory error | • The drive is placed in standby mode<br><br>• The drive is placed in disabled mode (hard fault) | • Toggle the run line, see Note 1<br><br>• Reprogram DSP,<br>➢ Warning: This will reset all drive parameters to default state |
| 10 | SPI communications timeout detected | • Communication processor lost SPI communications from the DSP | • The drive is placed in standby mode | • Toggle the RUN line, see Note 1 |

Note 1: To toggle the run command set the Run/! Standby signal logic '0' state for 100mS, then back to a logic '1'.

### 3.5.2 Power LED (User side - Green)

| LED | Description | Possible Cause | Result | Recovery Method |
|---|---|---|---|---|
| ON | +5 VDC Power Indicator | • On if user power is on | • Required to Run | • N/A |
| OFF | +5 VDC Power Indicator | • No user supplied +5 volts | • Drive will not Run | • Apply +5volts |

### 3.5.3 Power LED (Line side - Green)

| LED | Description | Possible Cause | Result | Recovery Method |
|---|---|---|---|---|
| ON | +5 VDC Power Indicator | • Logic power is on | • Required to Run | • N/A |
| OFF | +5 VDC Power Indicator | • Logic power is not on | • Drive will not Run | • Check AC power |

### 3.5.4 Current limit status LED (Line side – Red)

| LED | Description | Possible Cause | Result | Recovery Method |
|---|---|---|---|---|
| ON | Steady State | • Drive in Reset | • | • Toggle the DRIVE ENABLE signal |
| ON | During Power Up | • Soft Charge (Relay Opened) | • | • Allow 5 second power-up delay to allow internal capacitors to charge. |
| OFF | | • N/A | • Soft Charge Complete (Relay Closed) | • N/A |
| DIM | Flickering – Drive current limit | • Current is sensed to be more than the calibrated drive capacity | • | • N/A |

### 3.5.5 Shunt status LED (Line side -Yellow)

| LED | Description | Possible Cause | Result | Recovery Method |
|---|---|---|---|---|
| ON | | • B+ Rail is high above the Shunt turn on limit of 437V | • The shunt resistor is turned on | |
| OFF | | • B+ Rail is below the shunt turn off limit of 425V | • The shunt resistor is turned off | |

# 4 Introduction to the *AutoMotionPLUS©* software:

The *AutoMotionPLUS* software can be used to:
- …Configure the Drive's Operation Mode.
- …Configure the Drive for operation of different motors.
- …Tune the Position, Velocity and Current control loops.
- …Save and Load parameter files to and from the drive.
- …Graph application variables like Velocity, Position, Current and Motor Voltage.
- …Update the Drive's internal firmware.

The following sections are intended to familiarize the user with the basic operation of this software only. A complete user manual for the Automotion Plus software is still under development at Automotion.

**About Parameters and Variables:**
Drive parameters are used to configure the drive for different operating modes and to tune the control structure that each operating mode presents. Variables are internal values that change while the Drive is running. For example, "Position Proportional Gain" is a parameter and motor "Position" is a variable. Parameters can be changed using the different parameter screens available in the Automotion Plus program. Variables can NOT be changed. Variables can only be recorded using the Graph Window. Variables are graphed to evaluate the effectiveness of set Parameters.

## 4.1 Getting started:

Connect the Comm Port Cable from your PC to the Drive. Locate the program file named "AutomotionPlus.exe" that you extracted from the supplied zip file and saved on your PC. Double-click on this file to run the program. The following screen will be displayed:

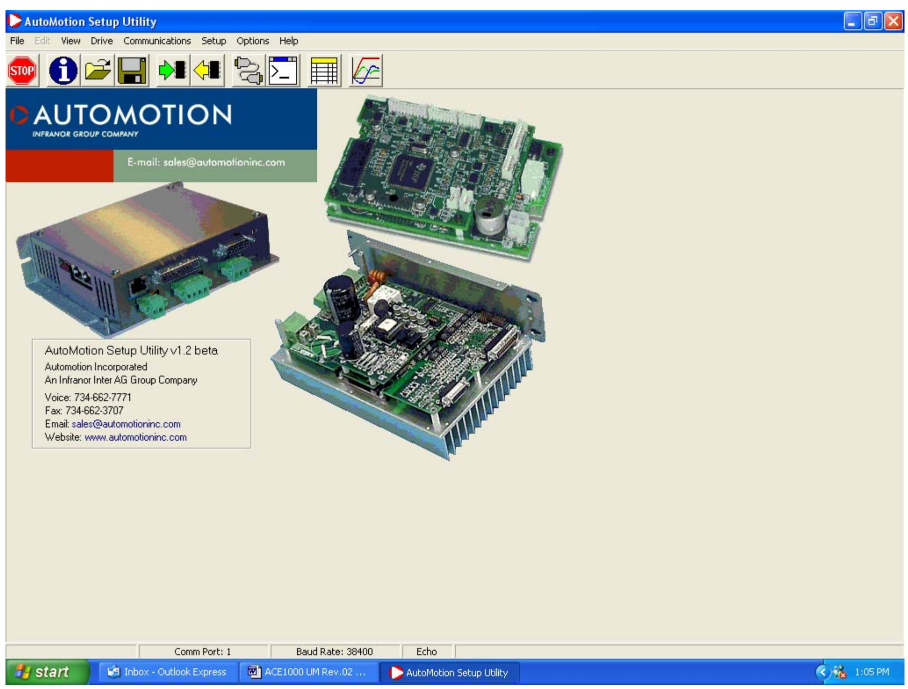



**Figure 2: AutoMotionPLUS™ Screen**

Select the Communications tab from the tool bar, then click on Comm Port Settings.

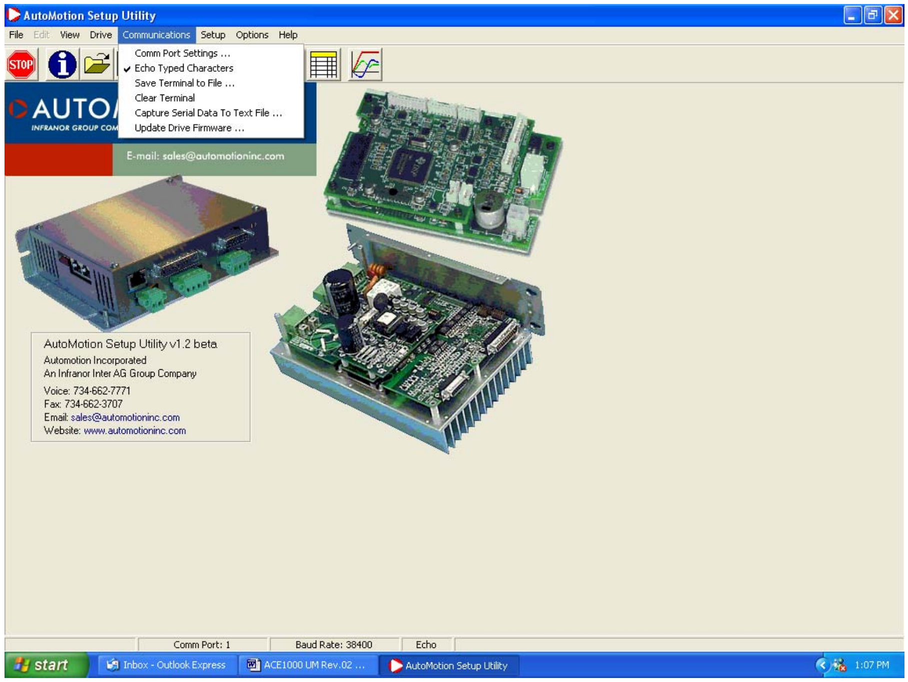



**Figure 3: Communications Tab Screen**

Use the drop box to select an available Com Port on your PC. Typically Com Port 1 or 2 is selected. **Note that for the ACE1000 product line, the required communications Baud Rate is 38,400. If you select any other Baud Rate you will get a communications error message.**

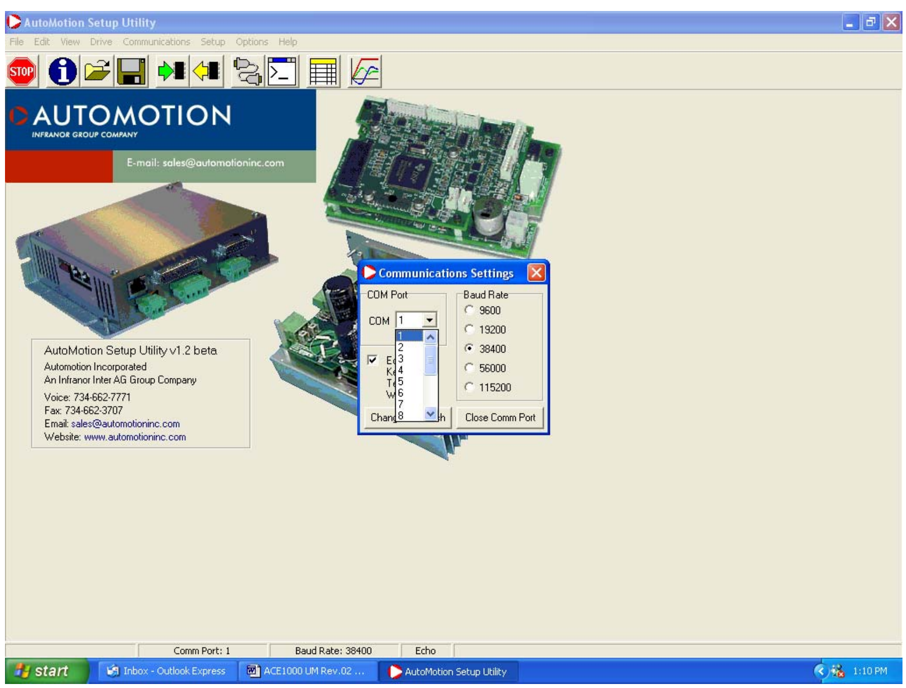



**Figure 4: Communications Drop Down Box**

After establishing communications with the drive, you can now read the existing drive parameters stored in the drive. Click on the “Read Parameters from Drive” icon button on the tool bar, or use the file menu to select “Drive” and then “Retrieve Parameters from Drive” option.

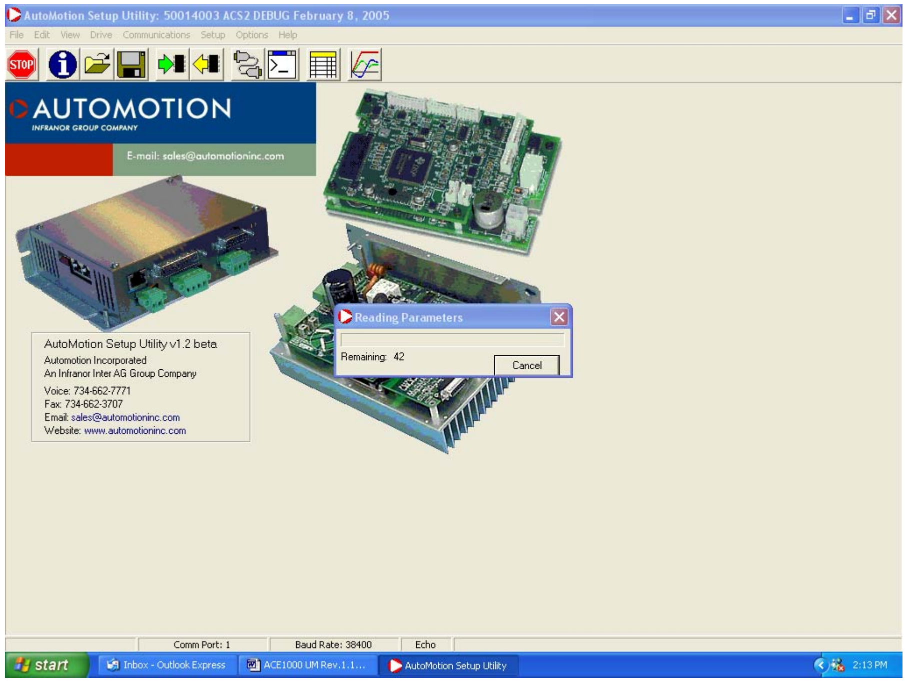



**Figure 5: Read Parameters From Drive**

Alternatively, you can load drive parameters from a file or disk, by clicking on the “Load Parameters from Disk” icon on the tool bar or “File” “Open” from the menu.

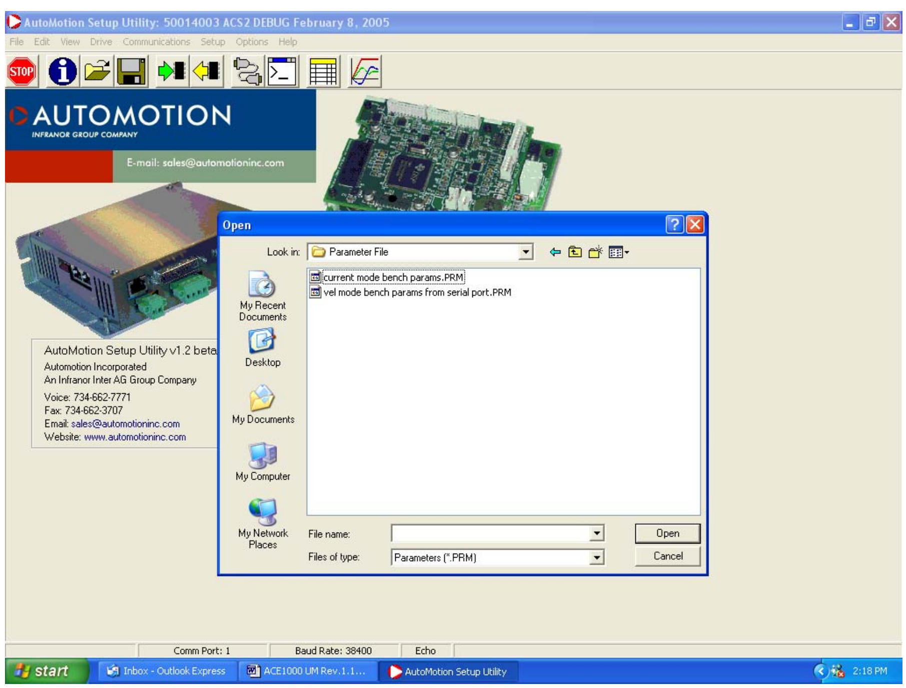
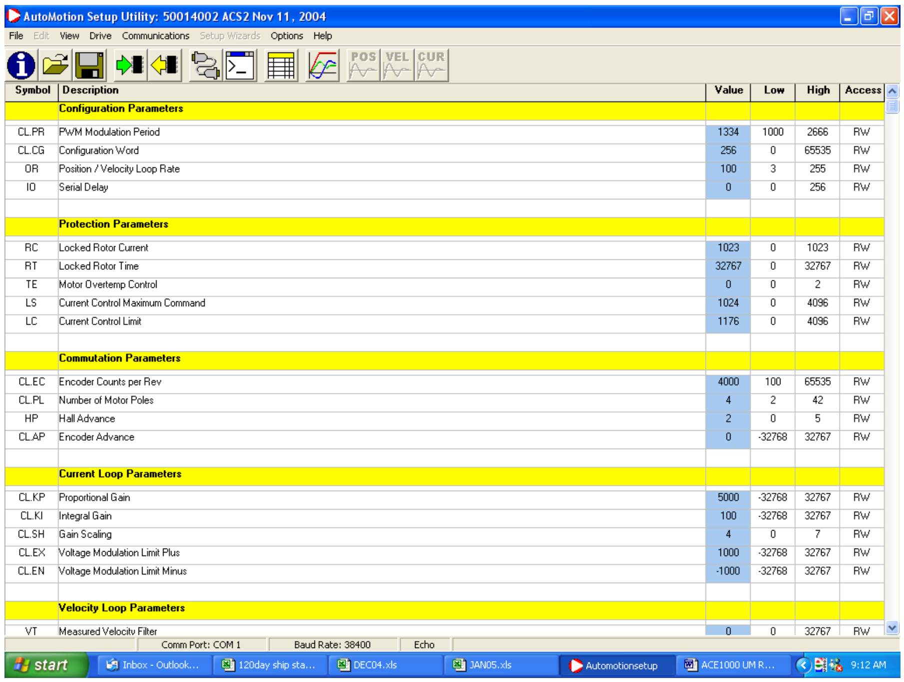



**Figure 6: Load Parameters from File**

In the above file open example, you can select from two pre-loaded parameter file sets that have been established for use with this drive when using the Infranor Mavilor motors.

Once communications have been established and the drive parameters have been retrieved, they can be displayed by clicking the “Parameters” icon on the tool bar, or selecting the “View” and then “Parameters” selection from the menu.

The following table of drive parameters will then be displayed.




| Symbol | Description | Value | Low | High | Access |
|---|---|---|---|---|---|
| | **Configuration Parameters** | | | | |
| CL.PR | PWM Modulation Period | 1334 | 1000 | 2666 | RW |
| CL.CG | Configuration Word | 256 | 0 | 65535 | RW |
| OR | Position / Velocity Loop Rate | 100 | 3 | 255 | RW |
| IO | Serial Delay | 0 | 0 | 256 | RW |
| | **Protection Parameters** | | | | |
| RC | Locked Rotor Current | 1023 | 0 | 1023 | RW |
| RT | Locked Rotor Time | 32767 | 0 | 32767 | RW |
| TE | Motor Overtemp Control | 0 | 0 | 2 | RW |
| LS | Current Control Maximum Command | 1024 | 0 | 4096 | RW |
| LC | Current Control Limit | 1176 | 0 | 4096 | RW |
| | **Commutation Parameters** | | | | |
| CL.EC | Encoder Counts per Rev | 4000 | 100 | 65535 | RW |
| CL.PL | Number of Motor Poles | 4 | 2 | 42 | RW |
| HP | Hall Advance | 2 | 0 | 5 | RW |
| CL.AP | Encoder Advance | 0 | -32768 | 32767 | RW |
| | **Current Loop Parameters** | | | | |
| CL.KP | Proportional Gain | 5000 | -32768 | 32767 | RW |
| CL.KI | Integral Gain | 100 | -32768 | 32767 | RW |
| CL.SH | Gain Scaling | 4 | 0 | 7 | RW |
| CL.EX | Voltage Modulation Limit Plus | 1000 | -32768 | 32767 | RW |
| CL.EN | Voltage Modulation Limit Minus | -1000 | -32768 | 32767 | RW |
| | **Velocity Loop Parameters** | | | | |
| VT | Measured Velocity Filter | 0 | 0 | 32767 | RW |

**Figure 7: Drive Parameter Table**

The parameter table lists all of the user accessible drive parameters, grouped by function type. The current drive parameter value is displayed along with the range of acceptable values, Low to High, and the parameter’s access level, i.e. R/W stands for Read/Write. For R/W access parameters the user can both read the value as well as write a new value.

## 4.2 How to Save and Load Drive Parameter Files

Before you change any parameters, it is recommended that you first save the original parameters to a file so that you can restore them if needed at a later time. Notice the menu bar located on the top of the window. Either click the Diskette icon shown for “Save Parameters to Disk”, or click the File menu, then “Save Parameters”. Either selection will bring up a Windows “Save as” dialog box. If a “Parameter File” does not already exist on your PC, create one, and then name your file, i.e. “default.prm”, and save it. The file will be saved on your PC.

To open this saved “default.prm” file from your PC, or any previously saved parameter files already on your PC or on a separate diskette, click the File Folder (Load Parameters from Disk) icon from the top of your Windows screen, or select the File menu, then “Open” and search for the desired parameter file on your PC or diskette.

Note: Opening a file will load the parameters from your PC or diskette to the ***AutoMotionPLUS***™Windows program only. It does not automatically change the parameter values stored in the drive itself.

A pop-up dialog box will appear any time you open a new parameter file from your PC or diskette that will ask if you wish to write the parameters to the drive. See example below.

If you are not certain that you want to replace the drive parameters with the new parameters just opened, select No. The new parameters will be loaded into the Windows program where you can refer them and change them if desired, but will not be uploaded to the drive.

When you are ready to upload the new parameters, you can then use the "write Parameters to Drive icon on the Tool bar, or select "Drive", "Write Parameters to Drive", from the menu line.

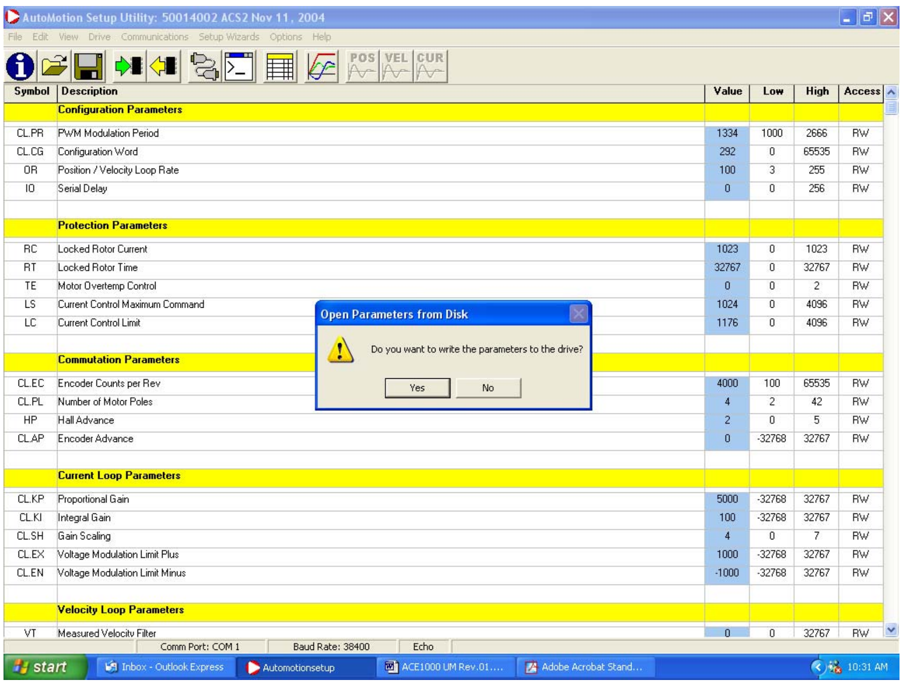



**Figure 8: Uploading New Drive Parameters**

## 4.3 How to Change Individual Drive Parameters

Some Drive parameters can be changed while the Drive is running the motor. For example, Proportional, Integral and Derivative Gain parameters in any control loop may be changed at any time, and will take immediate effect.

However, some Drive parameters, if changed, will require you to reset the drive before proceeding. For example, the "Position/Velocity Loop Rate" parameter on this page is used to set the processing frequency for these control loops. The Drive must be placed into "Stop" using the Run/Stop! Switch when changing this parameter. After this parameter is changed, the drive must be Reset to function properly.

For example, to change the "Velocity Proportional Gain" parameter (VLKP) found under the "Velocity Loop Parameters" section, move your mouse pointer over the displayed value box and then click on it. This will bring up a pop-up dialog box as shown in the next frame.

To change the value simply type in the new value and hit OK. When the OK key is pressed the new parameter value will be uploaded to the drive immediately, so that the value shown on the Windows Parameter table is always the same as it is in the drive.

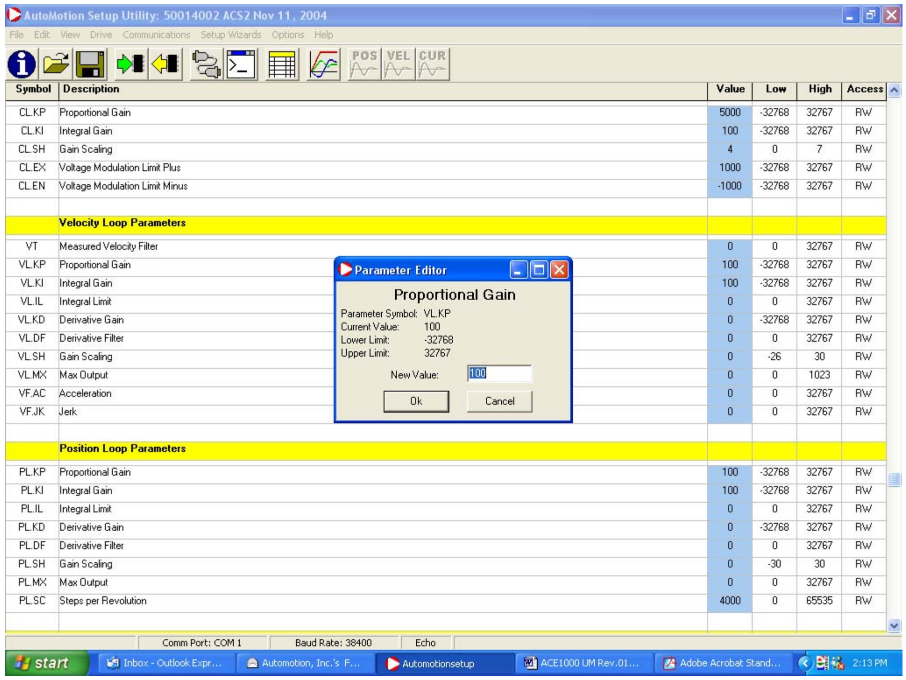



**Figure 9: Changing Drive Parameter Values**

Note: When parameters are stored or written to the Drive, they are automatically saved in nonvolatile memory. If power is removed and re-applied, the Drive will retain any changed values. To restore the default drive values, Open and load the “default.prm”. See 3.6.2 How to Save and Load Parameter files.

## 4.4 Drive Configuration

The ACE1000 drive can be configured in one of three operational servo modes, torque, velocity, or position.

To determine the default configuration of the current drive select the “Configuration Word” CLCG value from the Configuration Parameters section of the Parameter table. The Configure Dialog pop-up box will appear. See Windows screen below.

You will use this Configure Dialog box to set up the drive for the desired operational mode, as well as to define the motor feedback, analog feedback, and position and auxiliary command feedback.

The torque mode of servo operation is the most basis set-up for this servo and it is set as the default drive mode. Torque mode is also required for operation of the other two servo modes, velocity and position mode.

The commutation mode can be one of three choices. The first, Trapezoidal, uses Hall feedback only. The other two, Sine, which operate the drive in Sinusoidal mode, offer operation with either “Sine with Halls Synchronized” or “Sine with Encoder Synchronized”.

Sine commutation modes require “Halls and Encoder” commutation signals.

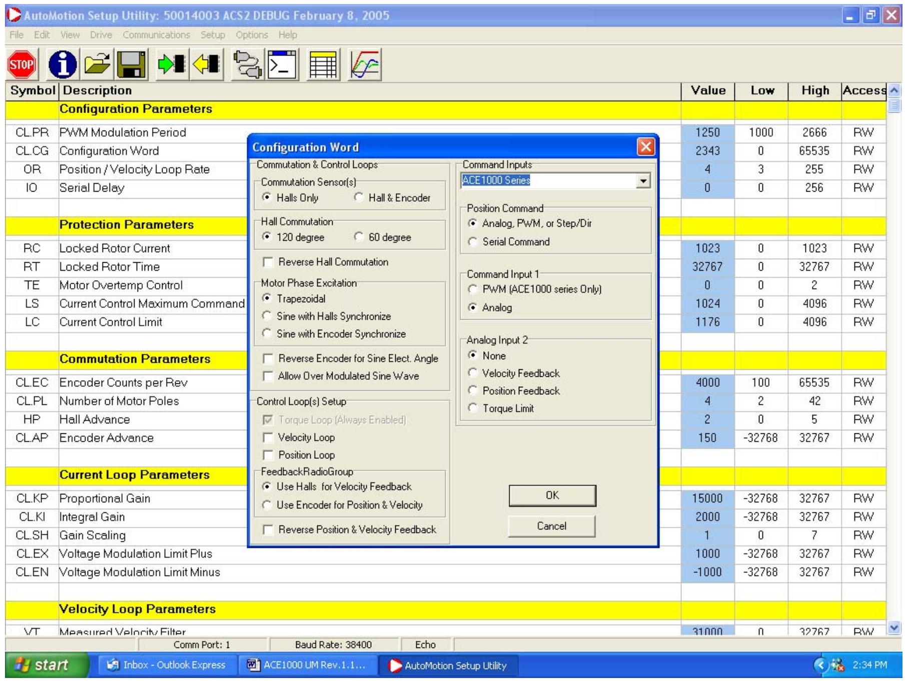



**Figure 10: Drive Configuration Set-up**

### 4.4.1 Requirements for Torque Mode Operation

To properly set up the ACS1000 drive's operating mode, for all possible operating configurations, you will use the "Configuration Word" (CL.CG) found under "Configuration Parameters" section of the main "Parameter Page" of the Windows program.

If you click on the “Value” figure in the right hand column of this "Configuration Word" parameter, a pop up "Configuration Dialog" box will appear on the screen, as explained under section 4.4, and shown in Figure 10, above.

Note, for the drive to be configured properly with a new motor you will need to run the Auto-Phasing tool found under "Motor Setup", described in section 5.2.

However, before you run the "Motor Setup" routine, which determines the proper phasing for the commutation and the encoder feedback relationship, you first should set up the "Configuration Word".

### 4.4.1.1 Setting up for Torque Mode with Halls Only (no Encoder)

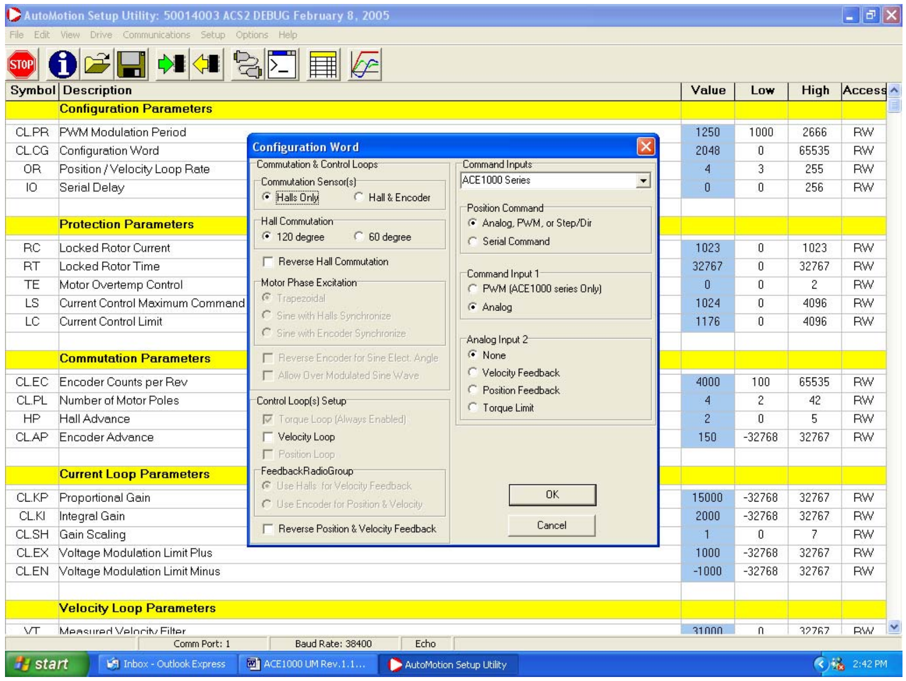



**Figure 11: Set-up for Torque Mode with Halls**

In this Torque Mode only configuration example (Figure 11), the motor does not have an encoder, so the “Halls Only” box is checked. Hall Commutation is set for 120 degree.

Reverse Hall Commutation is unchecked. After the Motor Phasing is run this box may be checked automatically if the direction of rotation of the motor needs to be changed.

Motor Phase Excitation is set for Trapezoidal, as the drive can only run in trapezoidal mode with Halls only for feedback.

Control Loop(s) Setup is set for Torque Loop (always enabled).

The Velocity Loop option is unchecked, as we are planning to run in Torque Mode only.

Feedback is selected for “Use Halls for Velocity Feedback” since we are only running Halls at this time.

“Command Inputs” have been selected for the ACS1000 drive product.

The Position Command is defaulted to Analog Input.

Command Input #1 is set for Analog. Other alternate is PWM command input.

Analog Input #2 is selected for “None” as we are not planning to use this auxiliary analog input. An example of where we could use this additional analog input is as a master/slave application.

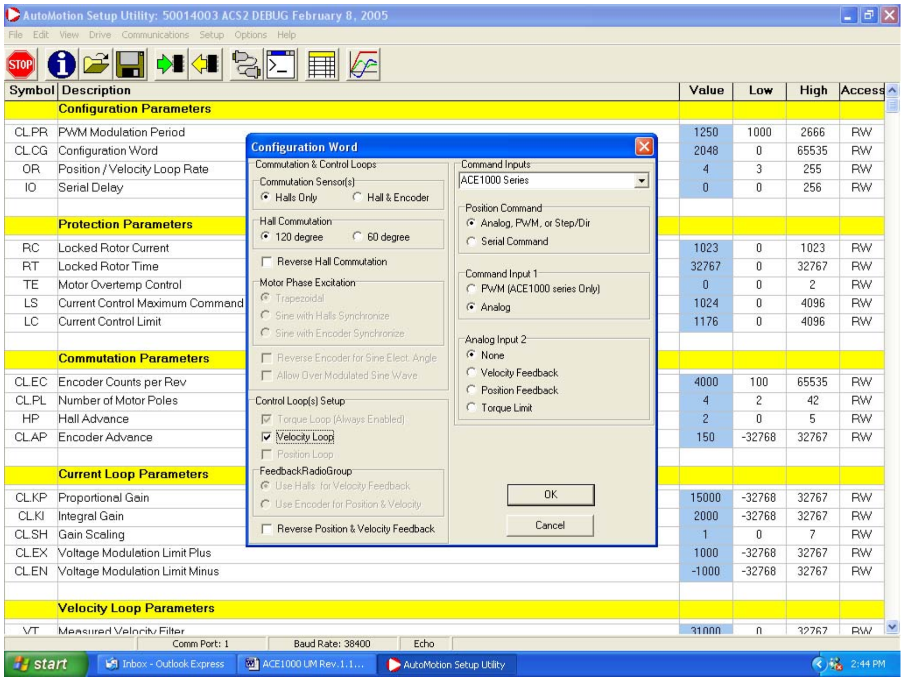


**Figure 12: Set-up for Sine Velocity Mode with Halls**

### 4.4.2 Requirements for Velocity Mode Operation

#### 4.4.2.1 Velocity Mode Operation Using Halls Only

In this example we desire to run the drive in a closed loop Velocity mode using the Halls as our velocity feedback device. See Figure 12.

The “Halls Only” box is still checked. Hall Commutation is still set for 120 degree.

Reverse Hall Commutation is unchecked. After the Motor Phasing is run this box may be checked automatically if the direction of rotation of the motor needs to be changed.

Motor Phase Excitation is set for Trapezoidal and grayed out, as the drive can only run in trapezoidal mode with Halls only for feedback.

Control Loop(s) Setup is set for Torque Loop (always enabled).

The Velocity Loop option is now checked, as we are planning to run in Velocity Mode.

Feedback is selected for “Use Halls for Velocity Feedback” and grayed out since we are only running Halls at this time.

“Command Inputs” have been selected for the ACS1000 drive product.

The Position Command is defaulted to Analog Input.

Command Input #1 is set for Analog. Other alternate is PWM command input.

Analog Input #2 is selected for “None” as we are not planning to use this auxiliary analog input. An example of where we could use this additional analog input is as a master/slave application.

## 4.4.2.2 Sine Wave Velocity Mode Operation Using Encoder Feedback

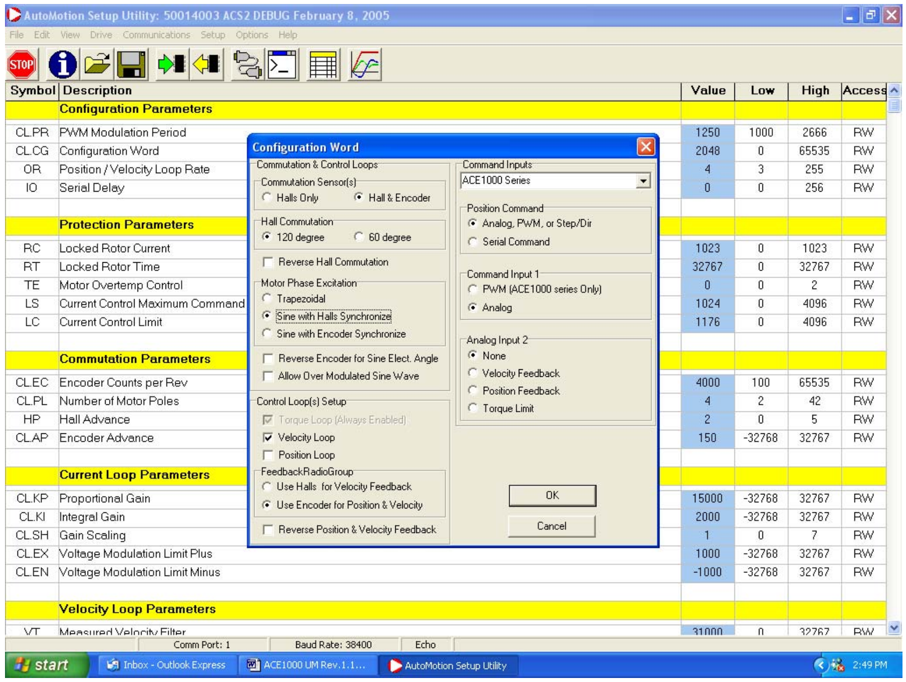



**Figure 13: Set-up for Sine Velocity Mode with Encoder**

In this Velocity Mode with Encoder Feedback example (Figure 13), the motor is equipped with an encoder, so the “Halls & Encoder” box is checked. Hall Commutation is still set for 120 degree.

Reverse Hall Commutation is unchecked. After the Motor Phasing is run this box may be checked automatically if the direction of rotation of the motor needs to be changed.

Motor Phase Excitation is set for “Sine with Halls Synchronized” so that we can run in sine wave commutation. As an alternate, if desired, we could also run the Velocity Loop closure using encoder feedback in a Trapezoidal excitation mode only.

Control Loop(s) Setup is set for Torque Loop (always enabled).

The Velocity Loop option is checked, as we are planning to run in Velocity Mode.

Feedback is now selected for “Use Encoder for Position & Velocity”.

“Command Inputs” have been selected for the ACS1000 drive product.

The Position Command is defaulted to Analog Input.

Command Input #1 is set for Analog. Other alternate is PWM command input.

Analog Input #2 is selected for “None” as we are not planning to use this auxiliary analog input. An example of where we could use this additional analog input is as a master/slave application.

### 4.4.3 Requirements for Position Mode Operation

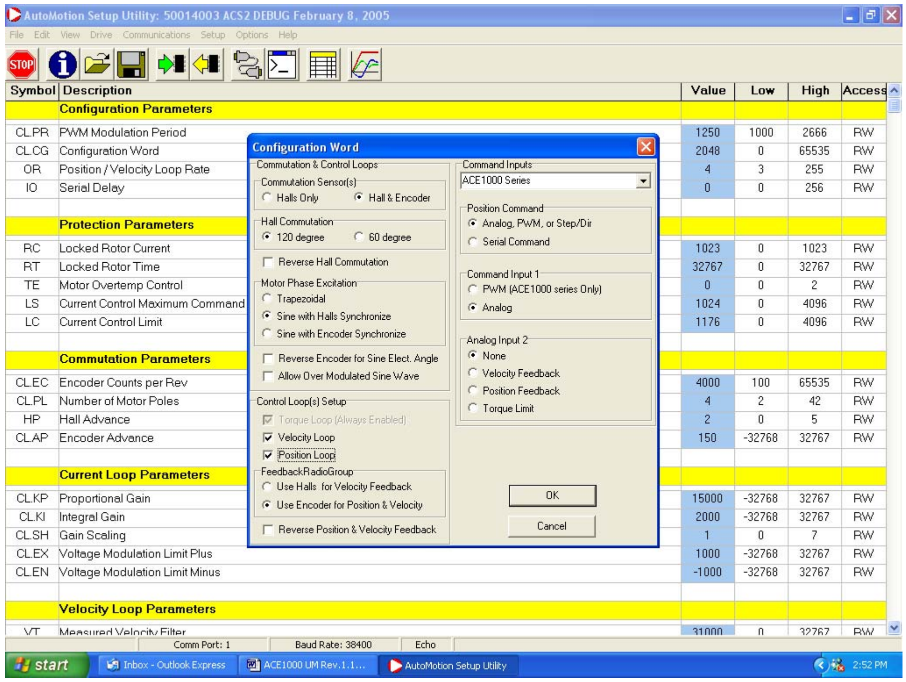



**Figure 14: Set-up for Position Mode with Encoder**

In this final example (Figure 14), we are setting the drive up for Position Mode with Step & Direction input.

For this mode the motor must have an encoder for position feedback. “Halls & Encoder” box is checked. Hall Commutation is still set for 120 degree.

Reverse Hall Commutation is unchecked. After the Motor Phasing is run this box may be checked automatically if the direction of rotation of the motor needs to be changed.

Motor Phase Excitation is set for “Sine with Halls Synchronized” so that we can run in sine wave commutation. As an alternate, if desired, we could also run the Position Loop using encoder feedback in a Trapezoidal excitation mode only.

Control Loop(s) Setup is set for Torque Loop (always enabled), and the Velocity Loop option is checked.

In additon, the Position Loop is now checked and enabled.

Feedback is selected for “Use Encoder for Position & Velocity”.

“Command Inputs” have been selected for the ACS1000 drive product.

The Position Command is set up for Analog, PWM, or Step & Direction Input.

Command Input #1 is set for Analog. Other alternate is PWM command input.

Analog Input #2 is selected for “None” as we are not planning to use this auxiliary analog input. An example of where we could use this additional analog input is as a master/slave application.

## 4.5 How to Graph Drive Variables

All of the variables discussed in the preceding section can be captured and displayed graphically using the Graph screen. In this way, control loop tuning can be evaluated.

### 4.5.1 Initial Graph Channel Set-up

Select “View->Graph” from the AutomotionPlus menu bar. The following screen will be displayed:

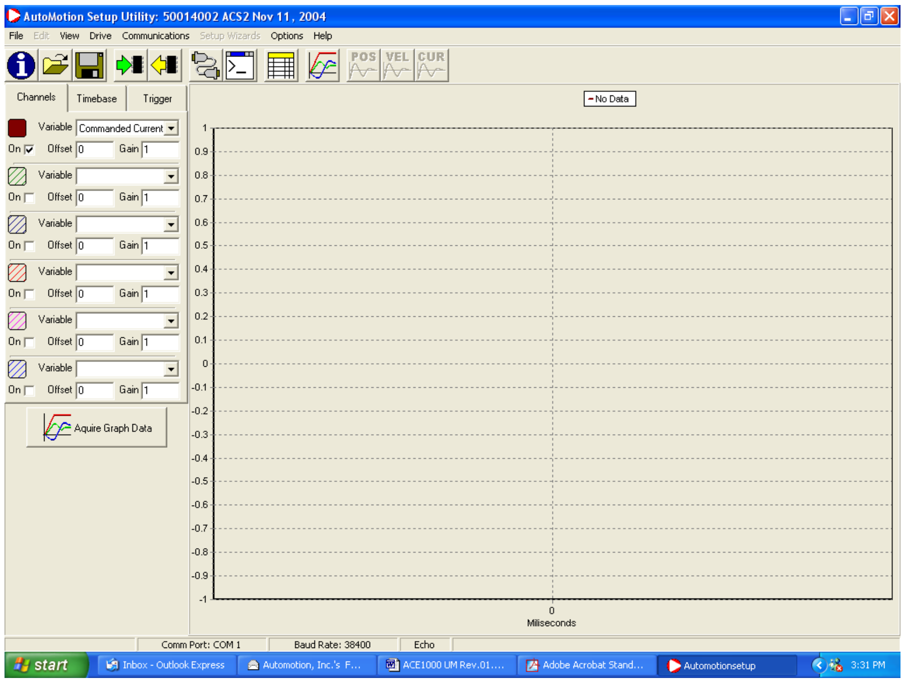



**Figure 15: Graph Channel Set-up**

Use the drop down list box in the upper left corner of this screen to select a variable to be graphed. For example select the variable named "Position Error" by scrolling down with your

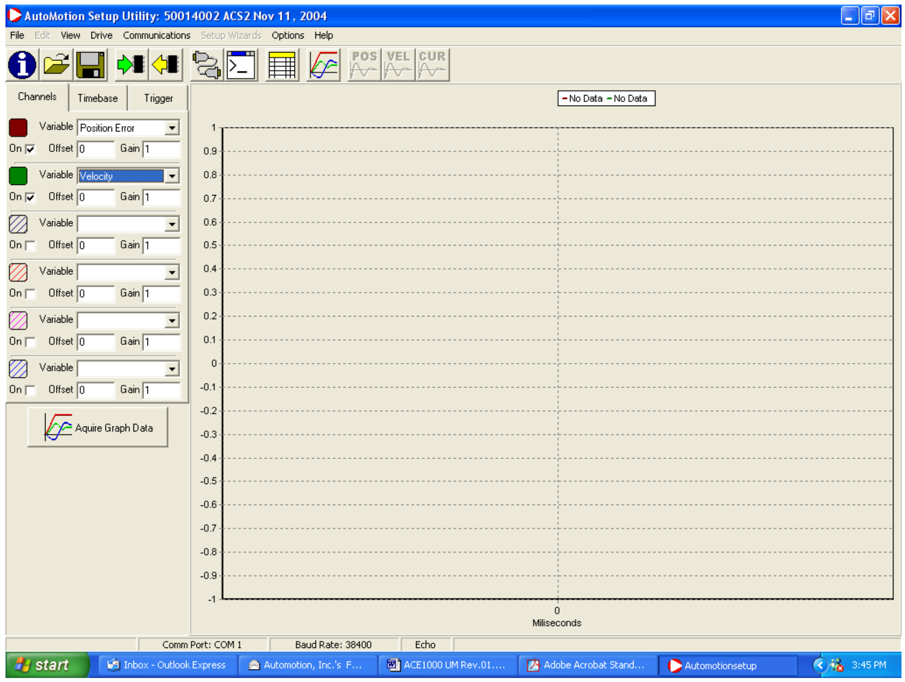



**Figure 16: Selecting Variables to Graph**

mouse and then clicking on it. You can then click on the second drop down box to select a second variable to graph, such as "Velocity". Additional variables of interest can be selected in a similar fashion.

Note that a check mark appears in the "On" box located just below both selected variables. This means that both variables are enabled for data collection. You can disable a variable by clicking on this box.

You can also enter a number in the "Offset" box adjacent to each variable, to scale each variable as desired. This feature is useful for displaying variables in user units, or to display variables of different numerical ranges on a single graph.

If we leave the Offset for these two variables set at 1, the collected Velocity data will be displayed in units if rpm and the collected Position Error data will be displayed in units of encoder counts.

You can also change the color of the Data being displayed on the graph by clicking on the color box associated with each variable for easier viewing.

Click in the Graph window and drag a box from the upper left, to the lower right. A zoomed view of the graph will appear. To zoom out, click and drag a box from the lower right, to the upper left. Click and hold the right mouse button to PAN the graph. Additional view functions are also available by right clicking on the graph.

### 4.5.2 Graph Timebase Set-up

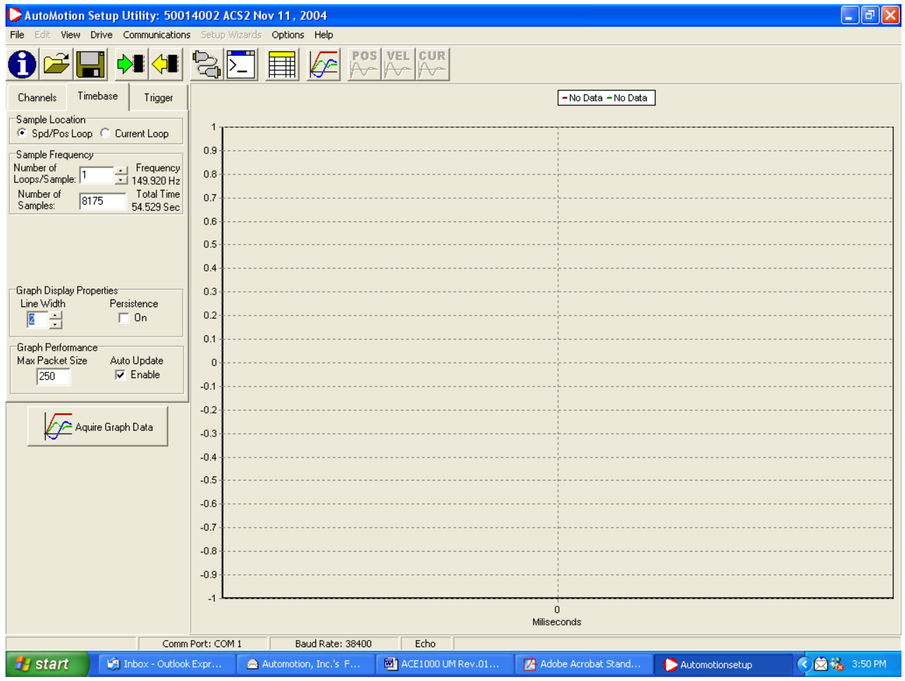



**Figure 17: Graph Timebase Set-up**

After selecting the initial variables to include in your graph, you will need to select the timebase for your data collection.

Within the Timebase set-up you first must select your Sample Location, either from within the Speed/Position Loop, or from within the Current Loop.

Next you determine your Sample Frequency. This is influenced by your Sample Location selection above, and is determined by both the number of loops per sample used, as well as the number of sample points desired.

Note that as the “Number of loops per sample” figure is adjusted, both the frequency as well as the total time for the samples to be collected will change. When just the “Number of Samples” is adjusted after setting the number of loops per sample, just the “Total Time” required to collect the sample data will change.

In the Graph Display Properties box you can select the thickness of the graph display lines, and also determine if you will retain the last graph data to be overlaid by the next graph run using the “Persistence On” feature. This feature is useful when wishing to compare two consecutive data runs results on the same graph.

Finally, the “Graph Performance” box allows the user to adjusted the maximum data packet size from 20 to 500 for best upload performance, while the Auto Update Enable allows incoming data to be displayed as it is received, rather than waiting until all data is collected. This can be turned off when desirable.

### 4.5.3 Graph Trigger Set-up

The ***AuotMotionPLUS***™ graphing utility is supplied with an additional data trigger feature to allow the user to more easily capture specific events of interest.

While data can be captured any time that the drive is in Run mode, by clicking on the “Acquire Graph Data” button at the bottom left of any graph screen, this special trigger feature allows the user to start data capture upon a particular event or action.

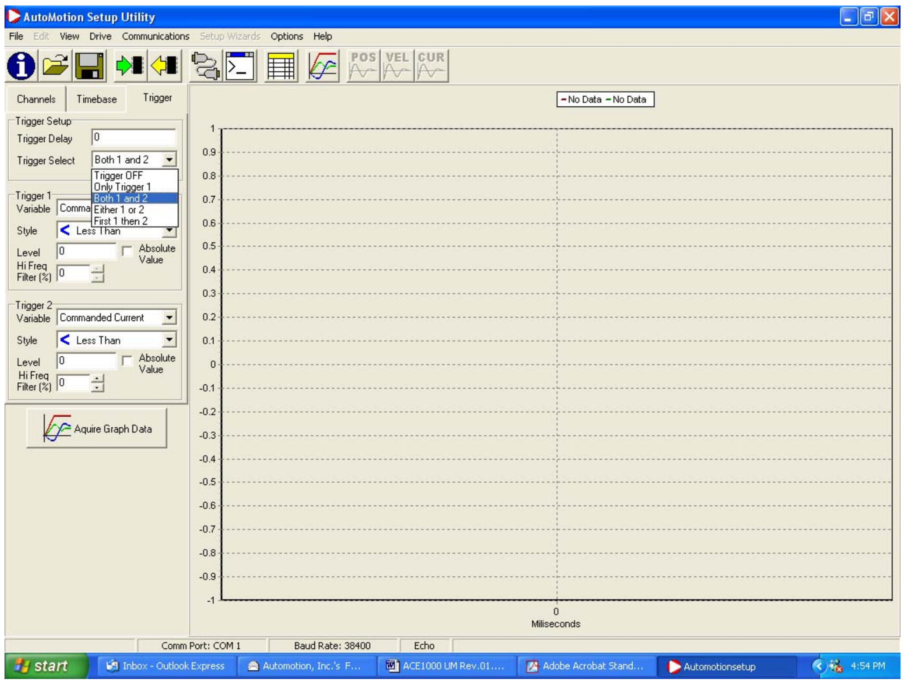



**Figure 18: Graph Trigger Set-up**

The first step in using the graph trigger function is to turn on the trigger function by selecting one of the five options in the drop down box. In the example above, Both 1 and 2 trigger functions has been selected, activating the Trigger 1 and Trigger 2 set-up boxes.

At the same time the “Trigger Delay” function can be selected to better capture the exact moment of the event you are looking for. The figures inserted into this box are in “number of samples”, not time. This figure can be either positive or negative. A negative number would be used in the case where it was desirable to capture some data ahead of the event you are looking for. S an example, if 500 samples had been selected in the Timebase set-up (see section 4.2 Graph Timebase Set-up) and you chose to collect 100 samples prior to your trigger event, you would insert a minus 100 (-100) into the Trigger Delay box. In this case the total of 500 samples would be spread over the selected tripper event with 100 samples displayed before the event took place, and 400 samples displayed after the trigger event occurred. The actual amount of time that elapses over the 100-sample size will be dependent upon the sample location and the number of loops per sample as explained in section 4.2.

In each Trigger box a desired Variable to trigger the graph on can be selected from among the 27 variables offered in the drop down display box.

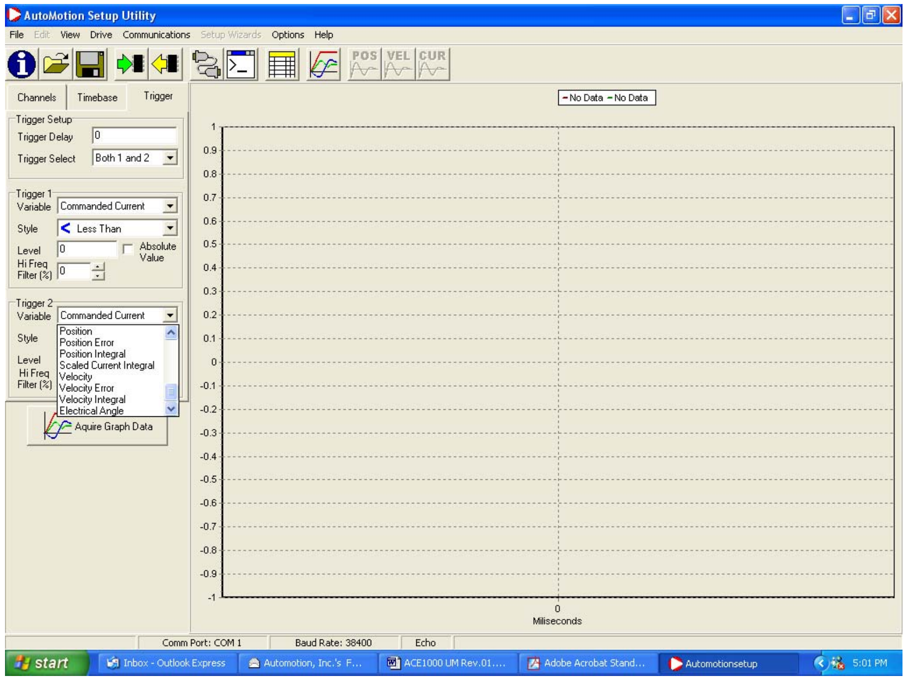



**Figure 19: Selecting Trigger Variable to Graph**

# 5 Working with the ACE1000 – Helpful Notes and Procedures

## 5.1 Recommended hookup

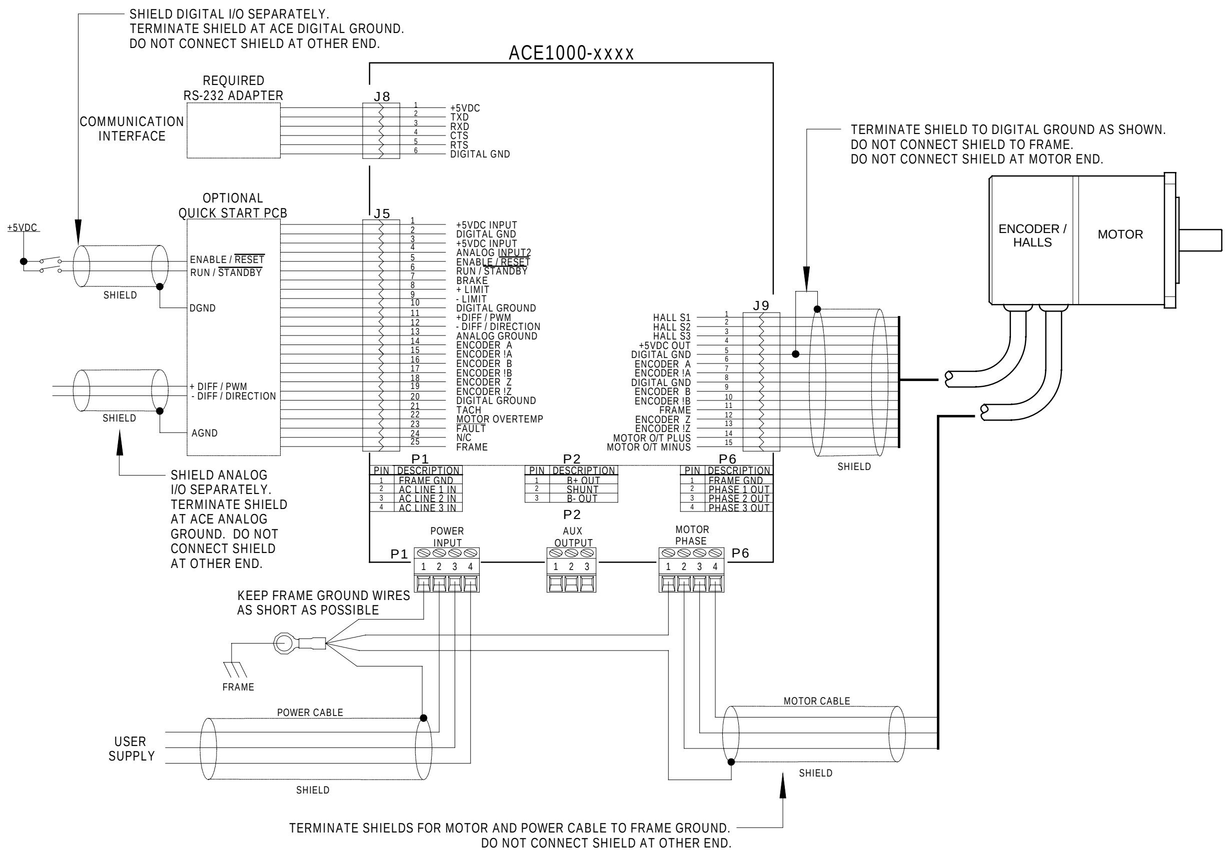



**Figure 20: Drive Motor Set-up**

## 5.2 First time operation

### 5.2.1 Phasing the Motor

Automotion has determined the correct motor phasing for all Mavilor motors sold by Infranor Inter AG. If your drive was ordered with a Mavilor motor specified, the correct parameter set for the mating Mavilor motor in your system was loaded into your drive at the factory prior to shipment.

Alternate Mavilor motor parameters can be selected from the motor selection file on the software disk supplied with your drive, or you can contact Automotion for these files.

In addition, Automotion has established the correct motor phasing relationships for many other popular US and foreign motor manufacturers. A listing of these additional motor manufacturers may be obtained from Automotion upon request.

### 5.2.2 Using *AutoMotionPLUS*™ Auto-Phasing Tool

Please refer to the *AutoMotionPLUS*™ Windows Motor Set-up screen, figure 21 below. To establish the correct motor phasing for a new or unknown motor Automotion has provided a new feature called Auto-Phasing. To make use of this feature proceed as follows:

1. Connect all phase and hall wires to the drive.
2. Place drive into standby
3. Connect power and establish communications (38400 baud rate required)
4. Load a starting parameter set (select from Automotion motor tables, use default already in drive, or contact Automotion for assistance)
5. On the ***AutoMotionPLUS***™ Windows menu, select "Setup" -> "Motor setup"
6. Select "Start Auto Config" button in lower right corner of "Motor Setup" window.
7. When the “Auto Config” is complete, place drive in standby
8. Select "close" button in lower right corner of "Motor Setup" window
9. The motor should now be properly phased for the ACE1000. You can now proceed with drive loop tuning.

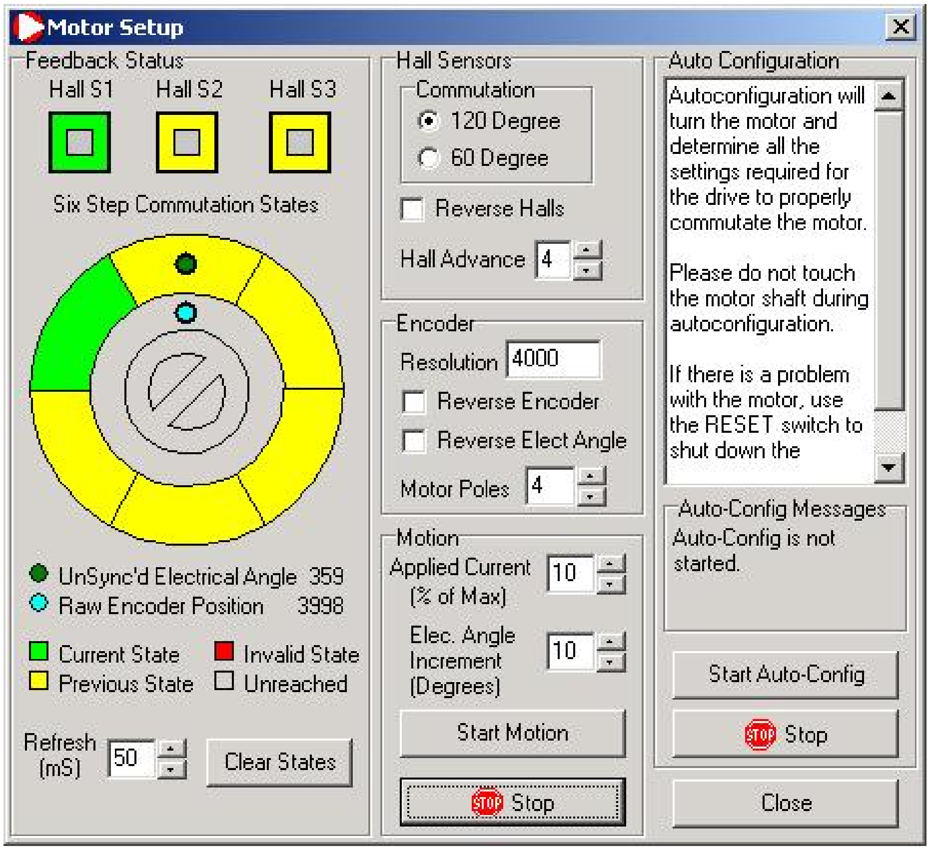



**Figure 21: Motor Set-up Screen**

### 5.2.3 Scaling the Analog Inputs

To properly adjust the analog inputs to match the desired input analog command voltage range with the desired output (i.e. Current, Velocity, etc.) you must first calculate the proper analog gain and offset values for entry into the drive's parameter page, under "I/O Configuration".

To assist you in this conversion Automotion has developed an Excel spread sheet which will automatically convert your calculated or measured analog input values to the required analog gain and offset values to achieve the desired ranges.

#### 5.2.3.1 Analog Input for Current Mode Operation – Primary Analog Input

For ACE +/- Analog In for Current Mode operation, using the Primary Analog Input, first detemine your actual High and Low analog values that will be used for the Analog input reading.

Note – to read the +/- Analog Input voltages (High & Low) from you're an input device, such as a pot, you can use the Windows terminal program. With the drive in standby, go to the Terminal window and after setting the Analog input at its minimum value, read this value by typing in the terminal command VF.VA.
Then set the Analog input at its maximum value, and again read the value by typing in the VF.VA command.
Note that to measure VF.VA via the Terminal window you must first have the Analog gain value VF.GN on the drive's Parameter page set to some value other than zero (0).

Place these High and Low Analog Input values into the spreadsheet.

Enter the desired output current range (Maximum and Minimum) that correspond to the High and Low Analog inputs you just measured.

The Spreadsheet will then calculate the required I/O Command Gain (VF.GN) and Command Offset (VF.OF) required to achieve the span of Analog control desired.

Enter these values into the drive's Parameter page, under the I/O Configuration" section.

Reset drive. Now initiate RUN command to control current from your Analog Input source.

#### 5.2.3.2 Analog Input for Current Mode Operation – Auxiliary Analog Input

To set up and scale the Aux Analog Input for the ACS200 follow the same procedures as outlined above for the Primary Analog Input.

### 5.2.4 Scaling the Primary Velocity Input

#### 5.2.4.1 Hall Based Velocity Control

Using the Automotion Excel spreadsheet section for Hall Based Velocity Control, enter your calculated or measured High and Low analog input values. See previous section 5.2.3 for instructions on determining these values using the VF.VA command in the Terminal window.

Then enter the desired corresponding High and Low RPM speed range you wish these Analog inputs to represent.

The spreadsheet will calculate the Velocity Gain (VF.GN) and Offset (VF.OF) values. Enter these values into the drive's Parameter page, under the I/O Configuration" section.

#### 5.2.4.2 Encoder Based Velocity Control

Contact Automotion for assistance in setting up the Analog Input for encoder based velocity control.

## 5.3 Initial Parameter Calculations

If your drive was supplied with a Mavilor motor initial parameters for that motor may already be loaded in the ACS1000 drive, or a set of factory default parameters may be loaded.

From assistance in determining an initial set of drive parameters to begin your evaluation please contact Automotion applications support.

## 5.4 Manually Tune the Current Loop

To tune the current loop, apply square-wave excitation from a function generator to the current loop and adjust current loop proportional gain (CL.KP) and current loop integral gain (CL.KI) to obtain desired wave form.

You can use the scope function contained within the Graphing window of the AutoMotionPLUS™ set-up and utility software to perform this task.

Set the excitation of the function generator to Square Wave. Set the frequency to 100 Hz.

Set the amplitude of the applied current to no more than 10% of the drives continuous current rating. Verify that the amplitude of the applied current is not excessive for the motor.

On the parameter screen adjust the current loop proportional gain (CL.KP) found under the Current Loop Parameters section of the Parameters page by first:

a) setting the current loop integral gain (CL.KI) to zero.

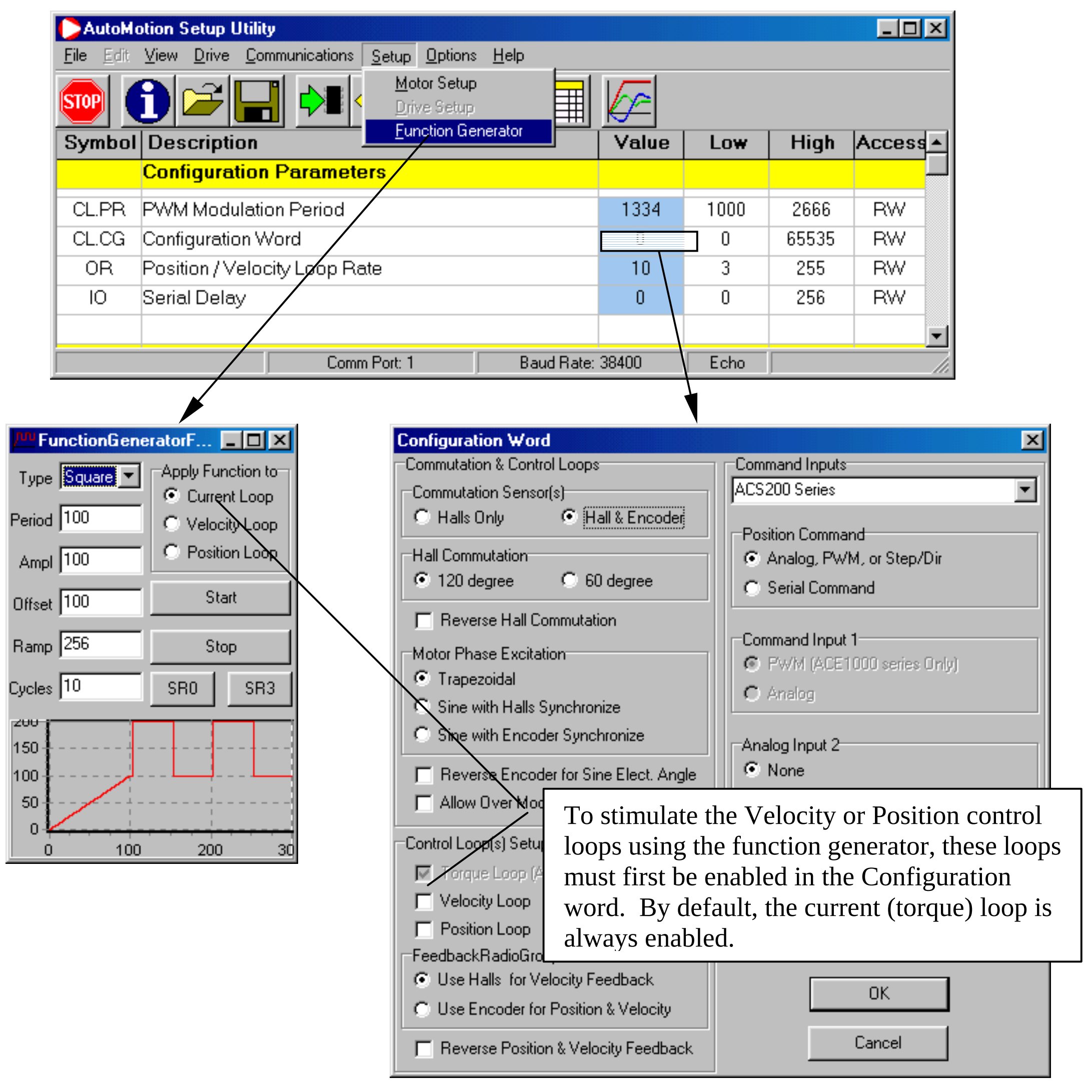
b) Increase or decrease the proportional gain (CL.KP) until the desired step response is obtained. Typically, the desired result is little or no overshoot with a 100 Hz, low-current square wave applied.

c) If the proportional gain (CL.KP) is too large, ringing may occur. If the proportional gain is set too low, the response bandwidth will suffer, i.e. decrease.

Next, adjust the current loop integral gain (CL.KI) from zero until the desired settling time is obtained.

Once the desired current step response is obtained for the selected motor, save the values of CL.KI and CL.KP before proceeding to the next step, velocity loop tuning. If the amplifier is to be used in current mode only, you can skip the velocity and position loop manual tuning steps, sections 5.5 and 5.6.

### 5.4.1 Function Generator Overview



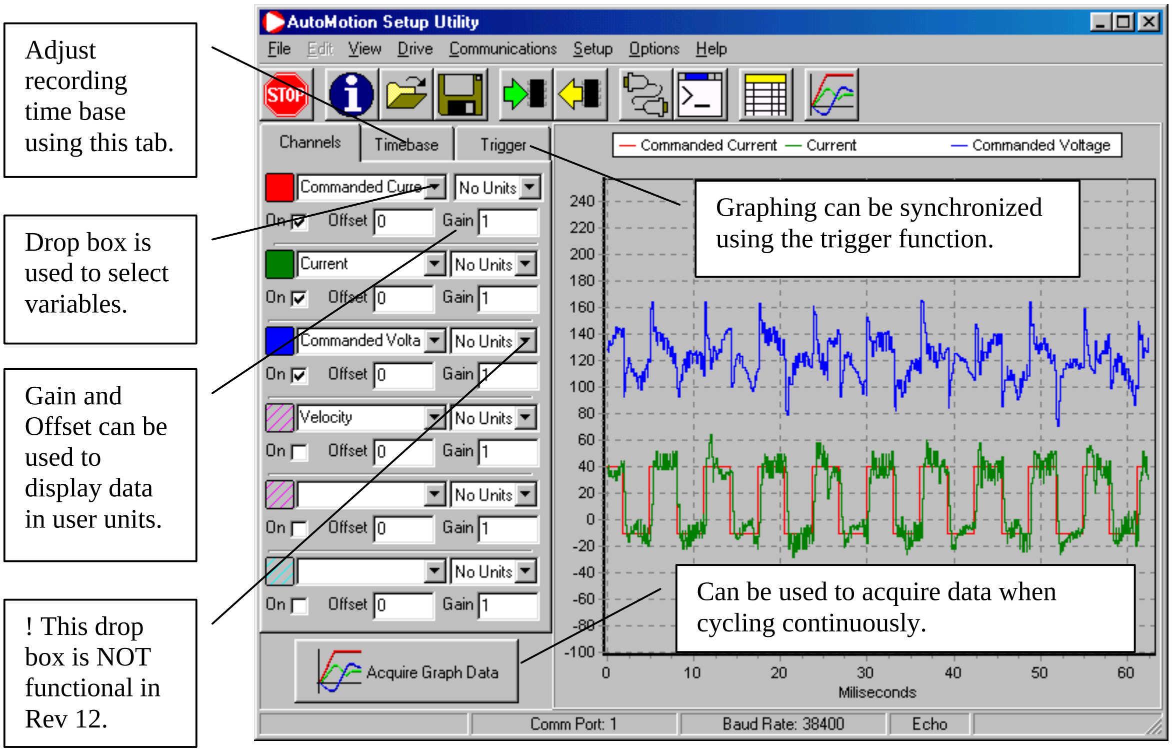
#### 5.4.1.1 Enabling the function generator

Place the ACE/ACS unit into standby. Select "Setup> Function generator" from the main menu bar to enable the function generator. The function generator floats in a separate window that can be positioned away from the Automotion Plus window for convenience. The function generator is used to output a user configured reference signal to either the current, velocity or position control loops. To stimulate the Velocity or Position control loops using the function generator, these loops must first be enabled in the Configuration word. (Hint: The drive must be reset for any changes to the configuration word to take effect)

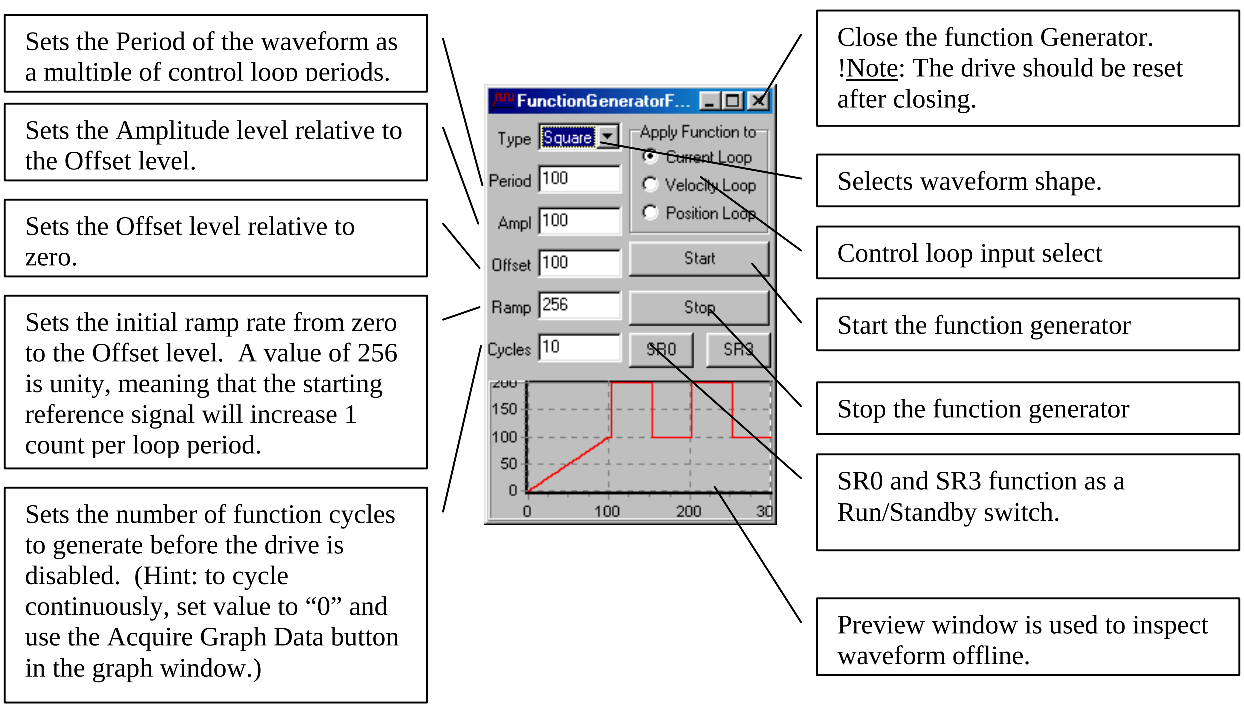
When the "Start" button is pressed in the function generator window, the drive's Command input signal (as determined by the configuration word) is replaced with the function generator signal, the drive is enabled in software and graphing begins automatically. (Hint: Before pressing the start button, loop variables and other recording options should first be selected in the graph window.)

### 5.4.1.2 Configuring the Graph window:

In the example below, Commanded Current, Current and Commanded Voltage are recorded in the current loop. The variable "Command current" has been replaced with the function generator.

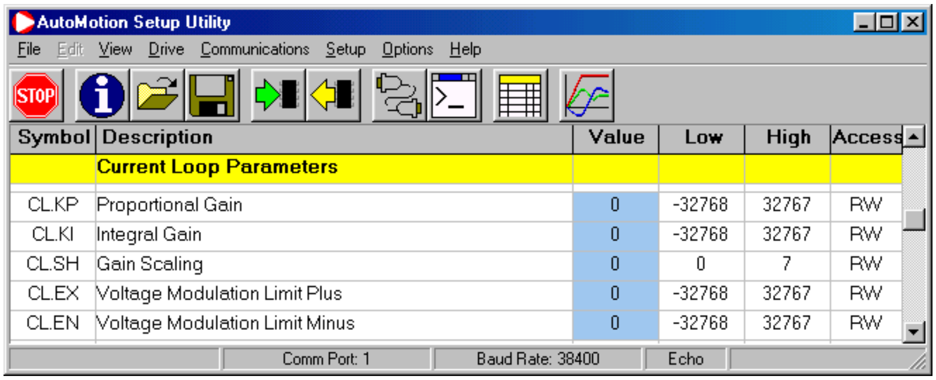



### 5.4.1.3 Configuring the Function Generator



### 5.4.2 Adjusting Current loop gains:

Proportional and Integral gains operate on the variable *Current Error*. Proportional and Integral gain are integer values between 0 and +32767, representing 0 to 100% gain. (Note: gains can be set to negative values but this practice is not recommended)




The gain scaling parameter, CL.SH, is a binary multiplier applied to both the Proportional (KP) and Integral (KI) gain values. For example, If CL.SH=1 then KP & KI range of 0 to 32767 represents 0 to 200% gain. If CL.SH=2 then the KP & KI range of 0 to 32767 represents 0 to 400% gain, etc.

When adjusting current loop gain values, Automotion recommends using the lowest possible value for CL.SH. For example, use KP=10000, Ki=2000 and SH=0, rather than KP=5000, Ki=1000 and SH=1. The variable *commanded voltage* is the output signal of the current control loop. This signal is compared to an internal modulator to produce applied motor PWM (i.e. voltage). CL.EX and CL.EN can be used to limit the maximum PWM (i.e. voltage) applied to the motor.

Automotion recommends initially setting CL.EX and CL.EN to +32767 and –32767 respectively. Internal firmware will then automatically limit the maximum and minimum values to the numerical limit of the internal modulating signal. This internal limit can then be determined by typing “CL.MX<enter>” at the terminal window. The returned value can then be used to scale CL.EX and CL.EN parameters. For example, if CL.MX<enter> returns a value of “642” then scaling is calculated as follows:

CL.EX = [(Desired +Limit) / (Supply Voltage)] * 642.
CL.EN = [(Desired -Limit) / (Supply Voltage)] * 642.

One the CL.MX value is determined, the variable *Commanded voltage* can also be displayed in the graph window in units of volts. For example, if CL.MX returns a value of 642, then the “variable gain” in graph window is calculated as follows:

*Commanded voltage* Gain $_{\text{(located in graph window)}}$ = (Supply Voltage ) / 642

Note: Gain and Offset values in the Graph window are not stored in the drive. These values are only used in the windows interface to manipulate displayed data.

## 5.5 Manually Tune the Velocity Loop

To tune the velocity loop, apply square-wave excitation from a function generator to the velocity loop and adjust the velocity loop proportional gain (VL.KP) and the velocity loop integral gain (VL.KI) to obtain the desired waveform.

You can use the scope function contained within the Graphing window of the AutoMotionPLUS™ set-up and utility software to perform this task.

Set the excitation of the function generator to Square Wave. Set the frequency to 5 Hz.

Set the amplitude of the applied voltage command to no more than 10% of the drives maximum velocity value. Verify that the amplitude of the applied velocity value is not excessive for the motor.

On the parameter screen adjust the velocity loop proportional gain (VL.KP) found under the Velocity Loop Parameters section of the Parameters page by first:

a) setting the velocity loop integral gain (VL.KI) to zero.

b) Increase or decrease the velocity loop proportional gain (VL.KP) until the desired step response is obtained. Typically, the desired result is little or no overshoot with a 5 Hz, slow-speed square wave applied.

Next, adjust the velocity loop integral gain (VL.KI) from zero until the desired settling time is obtained.

Once the desired velocity step response is obtained for the selected motor, save the values of VL.KI and VL.KP before proceeding to the next step, position loop tuning. If the amplifier is to be used in velocity mode only, you can skip the position loop manual tuning step 5.6.

## 5.6 Manually Tune the Position Loop

To tune the position loop, minimize the following error and any oscillations by running profiles and adjusting the position proportional gain (PL.KP), position integral gain (PL.KI), and position derivative gain (PL.KD), and other settings to obtain the desired performance.

5.6.1 You can use the scope function contained within the Graphing window of the AutoMotionPLUS™ set-up and utility software to perform this task.

5.6.2 Set up your profile generator to perform a relative trapezoidal move within an appropriate distance. Set up a trapezoidal profile by setting the trajectory limits and distance.
Note- the profile may not reach constant velocity during a short move.

5.6.3 Set values for Maximum Velocity, Maximum Acceleration, and Maximum Deceleration that are typical of those that you expect to use in the application.

5.6.4 Set the move distance to produce a complete trajectory profile.
Caution – make certain that the selected distance does not exceed any mechanical limitations of the system.

5.6.5 Adjust the position proportional gain (PL.KP) to minimize position following error by first:
a) Setting the position integral gain (PL.KI) and position Derivative gain (PL.KD) to zero.
b) Adjust the position loop proportional gain (PL.KP) and repeat move to obtain best results. Caution – too much proportional gain (PL.KP) can cause instability and oscillation.

5.6.6 Adjust velocity feed forward (VL.FF) to reduce the following error in the constant velocity portion of the move profile. Typically a velocity feed forward (VL.FF) value of 100% or 1023 will provide a good starting point. Repeat moves after each adjustment to obtain best results.

5.6.7 Adjust the Position Feed Forward (PL.FF) to reduce following error in the acceleration and deceleration portions of the move profile. Repeat moves after each adjustment to obtain best results.

If upon completing the position loop tuning the motor makes an audible noise while enabled but not moving, you may have the velocity proportional and integral loop gains set too high. You can lower these to see if it reduces or eliminates the noise, but be aware that if these gains are set too low, the responsiveness of your system will be reduced in many cases.

For best performance you must repeat the above procedure for all move profiles that are expected to be executed in your final application.

# 6 ACE1000 Hardware Reference

## 6.1 ACE1000 electrical ratings

Ratings at Tamb = 0…50°C, (unless otherwise noted)

| Parameter | Conditions | 20A | 30A | Units |
|---|---|---|---|---|
| ***Supply*** | | | | |
| Supply voltage | Nominal operating | 100 to 240 | | VAC |
| Supply current, surge | Inrush pulse duration <=100mS | | | A |
| Supply current, idle | No load condition. | | | mA |
| Supply current, operating | | | | A |
| Over Voltage protection | Internal peak supply limited. | | | VAC |
| Reversed polarity withstand | Continuous; supply current externally limited to: | | | A |
| +5VDC User Supplied - regulation | Encoder Inputs, Hall Inputs and Digital I/O | 4.75 to 5.25 | | V |
| +5VDC User Supplied - current required | Encoder Inputs, Hall Inputs and Digital I/O | 250 minimum | | mA |
| ***Motor Outputs – P6*** | | | | |
| Output current, continuous | No additional heatsink | 10 | 18 | Arms |
| Output current, peak | | 20 | 30 | A |
| Short circuit withstand | Phase-to-phase, phase-to-ground, phase to- supply threshold. | +/- | +/- | Amp |
| Short circuit protection delay | | to | | uS |
| On state voltage drop | Phase current = +/-5Amp | to | | mV |
| Off-state leakage current | Phase Voltage = +/-48V. | to | | uA |
| PWM frequency | Programmable, PWMPER | 30 | | kHz |
| ***Digital I/O Maximum Ratings – J5*** | | | | |
| Input voltage | All inputs (opto-isolated); referenced to +COM | to | | V |
| Input current | All inputs (opto-isolated); referenced to +COM | to | | mA |
| Output voltage | All outputs | to | | V |
| Output current | All outputs | | | mA |
| ***Digital Inputs – J5*** | | | | |
| On state voltage threshold | Referenced to +com | to | | V |
| Off state voltage threshold | Referenced to +com | to | | V |
| On state current | Input = -5V | to | | mA |
| On state pulse width | Off voltage = 0V , On voltage = -3V | | | uS |
| Off state pulse width | On voltage = -5V , Off voltage = -1V | | | uS |
| ***Digital Outputs) – J5*** | | | | |
| On state current | Referenced to +com | to | | mA |
| On state voltage drop | On state current = 15 mA | to | | V |
| Off state voltage | Sustained | to | | V |
| Off state leakage current | Off state = 5.5V | to | | uA |
| ***Analog Inputs – J5*** | | | | |
| Input voltage Common-mode | Referenced to AGND | to | | V |
| Input voltage differential | Nominal operating | to | | V |
| Input impedance | Differential | | | K Ohm |
| Input impedance | Common mode, referenced to AGND | | | K Ohm |
| Analog ground current | Maximum AGND to GND | to | | mA |

| | | | |
|---|---|---|---|
| ***Encoder Inputs – J9*** | | | |
| Input voltage, Max. | Common-mode, referenced to GND | -25 to +25 | V |
| Input voltage, Max. | Differential peak A to A , B to B , Z to Z | -30 to +30 | V |
| Input voltage, differential | RS422 receiver, A to A , B to B , Z to Z operating. | -5 to +5 | V |
| ***Halls – J9*** | | | |
| Input voltage range | Transient peak | -0.3 to +5.3 | V |
| Low level voltage | Operating | 0 to 1.8 | V |
| Low level input current | Internal 1 K pull up to +5V | 4 to 5 | mA |
| Input hysteresis | | 0.2 to 0.5 | V |
| ***Other*** | | | |
| Thermal resistance | Case to ambient | | °C/W |
| Frame isolation voltage withstand | GND to Frame. | | V |
| Operating temperature | powered | 0 to +50 | °C |
| Storage temperature | Not powered | -20 to +85 | °C |
| Humidity | Non-condensing | 0 to 90 | %RH |
| Weight | | 5.98 / 2.71 | Lb./Kg |

## 6.2 ACE1000 Package Outline

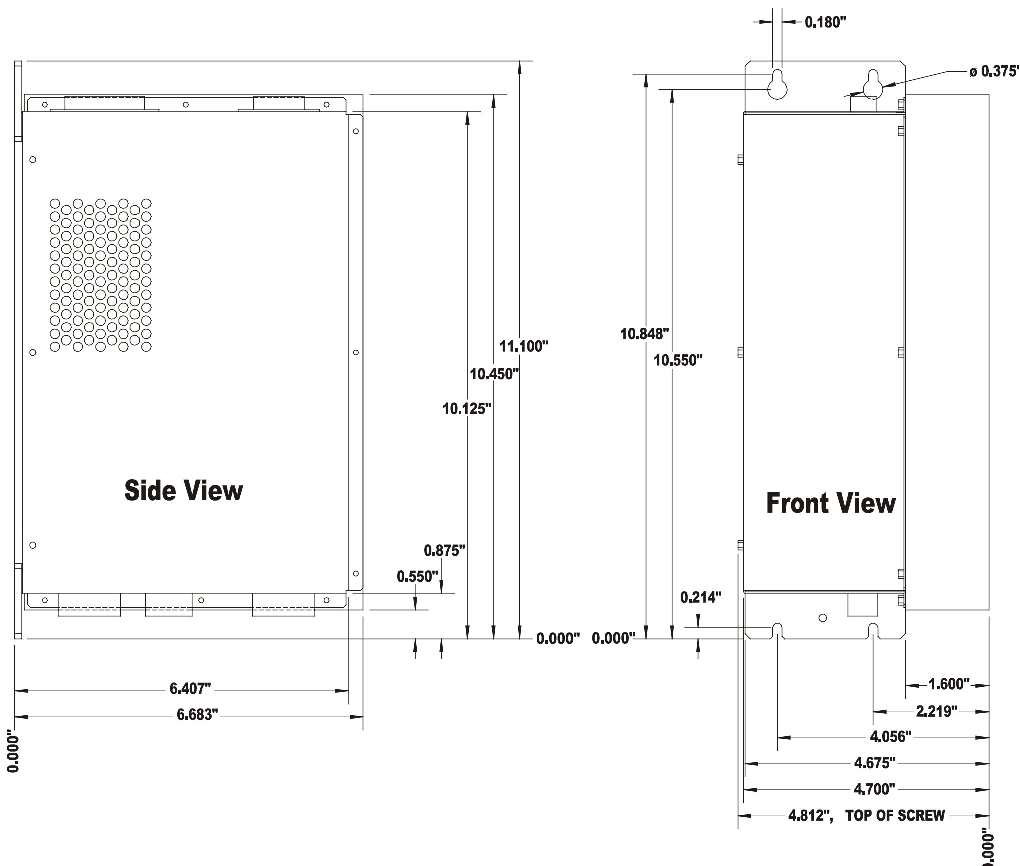



Figure 22: ACE1000 Package Outline

## 6.3 List of ACE1000 mating connectors

| Ref. | Connector name | Manufacturer | P/N |
|---|---|---|---|
| J1 | PWR | PHOENIX CONTACT | MC 1.5/3-ST-3.81 |
| J3 | MOTOR | PHOENIX CONTACT | MC 1.5/4-ST-3.81 |
| J4 | RS-232 | (Generic) | 9 Pin D-Sub, Male |
| J5 | RS-485 | MOLEX | --- |
| J6 | ADDR | (Generic) | --- |
| J7 | ENC. | HARTING | SEK18-0918-510-6803 |
| J8 | HALLS | MOLEX | KK-2,54-22012065 |
| J9 | DIGITAL & ANALOG I/O | HARTING | SEK18-0918-526-6803 |

# 6.4 Interface circuitry

## 6.4.1 J5 – Digital & Analog I/O

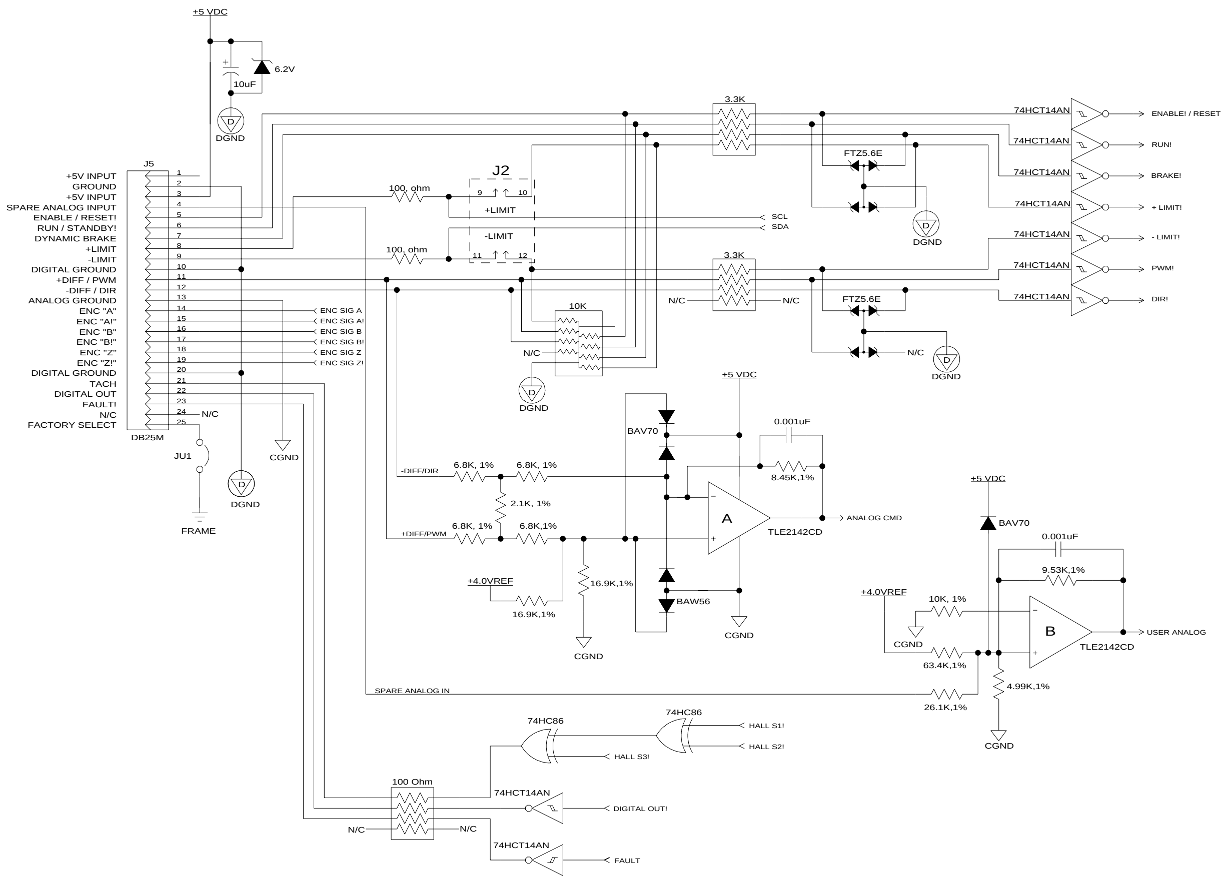


**Figure 23: ACE1000 J5 I/O Interface Circuitry**

### 6.4.2 J9 – Motor Interface

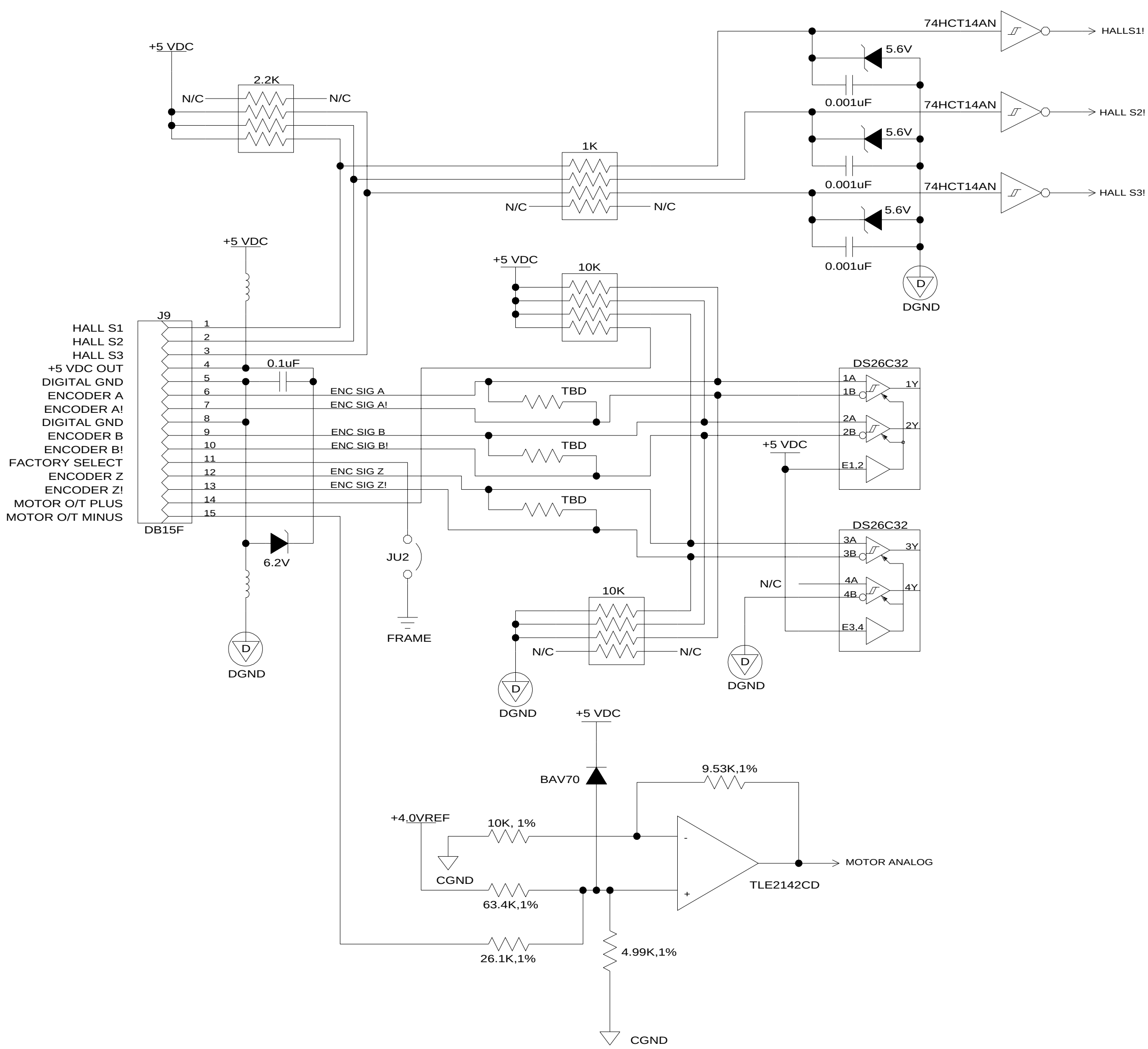



**Figure 24: ACE1000 J9 Motor Interface Circuitry**

### 6.4.3 J8 Communications Interface Requirements

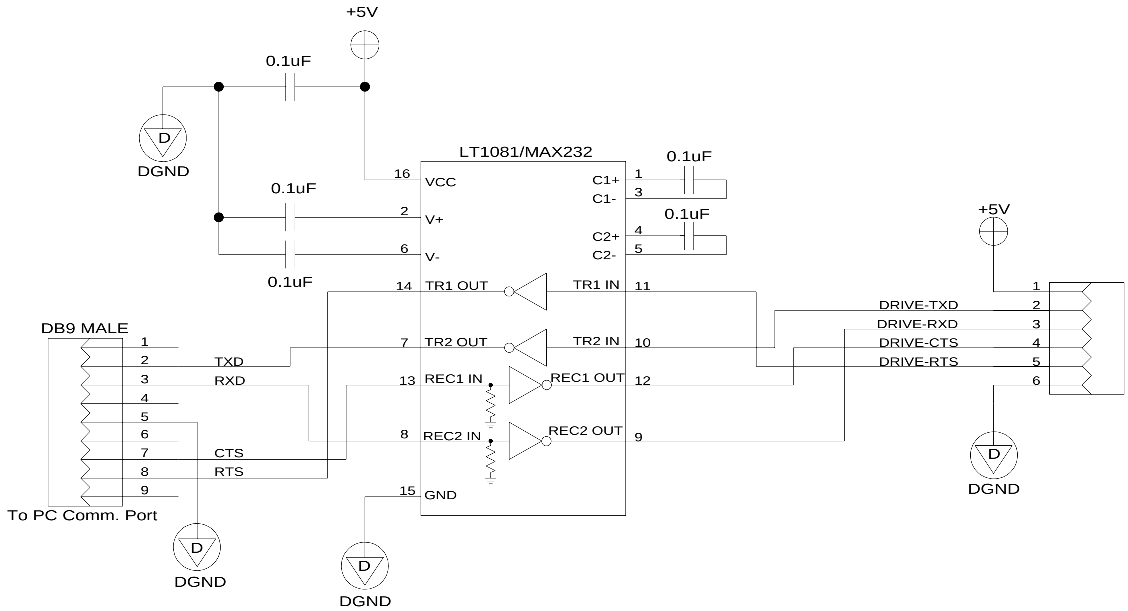



Figure 25: ACE1000 J8 Communications Interface Circuitry

# 6.5 Recommended Cabling and Installation

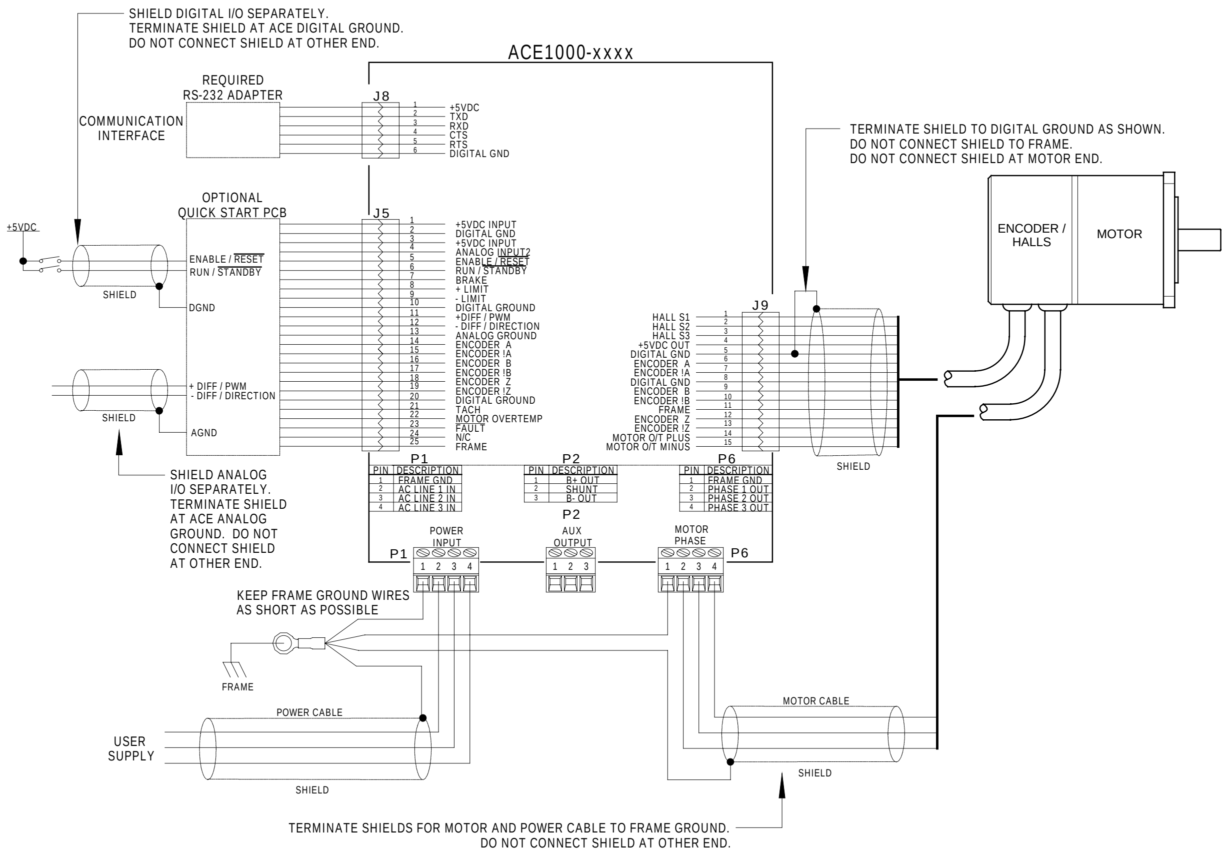



**Figure 26: Recommended Cabling and Installation**

## 6.6 Use & Selection Of The External Shunt Resistor

# CAUTION! SHOCK HAZARD! FIRE HAZARD!

### WHEN THIS PRODUCT USES AN INTERNAL OR EXTERNAL SHUNT RESISTOR, PRECAUTIONS MUST BE FOLLOWED TO PREVENT A POSSIBLE FIRE HAZARD.

**Shunt resistors may function using high voltage electrical power. Avoid physical contact with them whenever the ACE is powered. Shunt resistors can also become extremely hot. Follow the precautions stated below to help prevent a fire hazard.**

In some applications when heavy dynamic braking and/or regenerative braking is involved, the ACE will require a shunt resistor. AUTOMOTION can provide, as one option, an internal shunt resistor up to certain practical limits based upon physical space available and the expected heat generation.

If the application requirements exceed the capability of this optional internal shunt, or the customer wishes to use his own shunt, an external shunt resistor may be added.

If an external shunt resistor is used, this is wired to connector P2. The minimum permissible ohmic value for the external shunt resistor is 50 Ohms. If a lower resistance is needed for any reason, consult AUTOMOTION.

External shunt resistor connections to connector P2 must be made across P2 pin terminals 1 and 2.

- DO NOT CONNECT THE EXTERNAL SHUNT RESISTOR ACROSS PIN TERMINALS 1 AND 3.
- DO NOT SHORT PIN TERMINALS 1, 2 OR 3 TO FRAME GROUND.
- DO NOT USE A SHUNT RESISTOR WITH A VALUE LOWER THAN 50 OHMS AND RATED FOR HIGH MOMENTARY OVERLOADS.

It is important that this external shunt resistor be adequately sized to be reliable. It is also essential that this shunt resistor be located where it cannot cause a fire hazard should it ever overheat. AUTOMOTION recommends that the shunt resistor be placed in a well ventilated location and be kept far away from flammable materials.

The shunt operates in conjunction with a transistor switch that places it across the motor high voltage rail. Should the transistor ever fail in the ON condition the resistor would remain powered continuously. This could result in the shunt resistor becoming very hot. A user-supplied heat shield may be required to limit a possible fire hazard.

# CAUTION! FIRE HAZARD!

**Never mount the external shunt resistor where it can make contact with flammable materials, flammable liquid and/or flammable chemicals. If the ACE contains an optional shunt resistor mounted internal to the chassis, it too must be kept far away from flammable materials, flammable liquid and/or flammable chemicals. Never use the ACE, either with or without a shunt resistor of any type, in an explosive atmosphere. Never place the shunt resistor in the proximity of flammable materials that could melt or drop upon the shunt resistor body or the ACE drive.**

The electrical terminals of this resistor are also a shock hazard. High voltage electricity is present on these terminals whenever the ACE is powered. A safety cover or shield is recommended to avoid a shock hazard.

The selected wattage rating for the shunt resistor is application dependent. Usually a heavy-duty wire wound resistor will work best. However, not all wire wound resistors are suitable for shunt service. Through years of experience, AUTOMOTION has found the Ohmite type 250 series works reliably in many shunt applications.

If the user is supplying their own shunt resistor contact AUTOMOTION for further application advice. Ask for Field Application Bulletin #101-0195.

## 6.7 Model Identification

ACE 1 20 X – X X X – X Y Z X

Model Designator

Base Power Platform
1 = 0.5 to 5Hp.

Power Specifications
20, 30

Drive Customization Code
0 = Standard
1 = Factory Special
2 = Factory Special, 3 Phase

Drive Mounting
0 = Open Frame
1 = Panel Mount
2 = Coldplate

Safety Cover
0 = None
1 = Standard
2 = Special

Supplemental Cooling
0 = None
1 = Heatsink
2 = Heatsink with Fan
3 = Water Cooled Heatsink

Drive Parameters / Configuration
0 = Default
1 = Factory Configured
2 = Factory Configured, On Board RAM

Shunt Regeneration
0 = P2 (Customer External or none)
1= 55 Watt Shunt (Internal)
2= 110 Watt Shunt (Internal)
3= Chassis Mount (External)

Supplemental Capacitance
0 = P2 (Customer External or none)
1 = Factory Installed (2 Caps)
2 = Factory Installed (3 Caps)

Feedback Configuration
0 = Hall
1 = Encoder

# 7 Description of ACE1000 parameters and variables

**General**: Each command entry is headed by the ASCII command followed by its descriptive label. The allowable value range follows. That is followed by the applications that can make use of this parameter or variable. Finally, the scaling and use of the variable follows.

In any formula, the value entered is denoted by 'X'. The parameters are not typically changed once the user has tuned the drive to a specific application.

**To read the value**: From the terminal page type the ASCII command followed by a return.

**To write a new value**: Type the ASCII command followed by the new value (X) and a return.

Backspace allows you to start over in case a mistake is made.

## 7.1 The Parameter Page

### 7.1.1 Configuration Parameters

---

**CL.PR** **PWM (Current) Modulation Period**

**Range**: 1000 (1334 for the ACE1000) to 2666

**Applications**: All

**Use**: The current loop and PWM rates in hertz are $2*10^7$ / X

---

**CL.CG** **Configuration Word**

**Range**: 0 to 65535

**Application**: All DSP based drives.

**Use**: This command is used to specify what servo loops are running and to control other features of the drive. When this field is clicked in the user interface, a popup appears to allow the user to set this configuration word.

| Bits | Usage |
|---|---|
| 0 | On if the position loop is to be used. The position loop will not be used if the velocity feedback is analog. |
| 1 | On if the velocity loop is to be used |
| 2 | On if velocity feedback is to be computed from halls edges or off if velocity is to be computed from encoder edges. On the ACE-1000, this must only be changed if a hardware change is also made. This bit is overridden by analog velocity feedback. |
| 3,12,13 | If these bits are 8 hex (3 on, 12, 13 off), velocity feedback is from analog input (AN2).<br>If these bits are 1000 hex (3 off, 12 on, 13 off), position feedback is from analog input (AN2).<br>If these bits are 1008 hex (3,12 on, 13 off), the torque limit is from analog input. This is not used for a current mode drive. |
| 4 | On if position command is to be supplied from the serial port. |
| 5 | On if sine commutation is to be used synchronized from a halls edge. |

| Bits | Usage |
|---|---|
| 6 | On if sine commutation is to be used synchronized from the encoder index. Bits 4 and 5 cannot both be on. Note that sine mode is available on the ACE1000 only if a hardware change is made. |
| 7 | On to allow sine mode over modulation. |
| 8 and 9 | Halls table to use. These bits can be overridden by the Hall Table command CL.HT.<br>If these bits are 0, use the standard 120 degree table.<br>If these bits are 100 hex, use the 120 degree table with hall S1 and S3 swapped.<br>If these bits are 200 hex, use the standard 60 degree table.<br>If these bits are 300 hex, use the 60 degree table with hall S1 and S3 swapped. |
| 10 | On if encoder direction is reversed. |
| 11 | ACE1000 only. On if command input is analog (AN1). Off for PWM command input. |

---

**OR** **Position/Velocity Loop Rate**

**Range**: 3 to 255

**Application**: Encoder based, velocity mode, or position mode drives.

**Use**: The velocity loop rate is ‘current loop rate’ / X.

---

**IO** **Serial Delay**

**Range**: 0 to 256

**Application**: All

**Use**: For most late model host machines this is typically set to “0”. However, for slower host processors this value inserts a delay in the characters to avoid overflowing the host buffer.

---

### 7.1.2 Protection Parameters

---

**RC** **Locked Rotor Current**

**Range**: 0 to 1023

**Applications**: All

**Use**: Used in conjunction with ‘Locked Rotor Time’ to check for locked rotor. If X is zero, the locked rotor check is not performed. Otherwise, the current is checked at every current loop. If the current level is greater or equal to the current level specified for the amount of time specified by locked rotor current without a halls change, a locked rotor fault occurs. The current level is ‘Rated output’ * X / 1024.

---

**RT** **Locked Rotor Time**

**Range**: 0 to 32767

**Applications**: All

**Use**: Used in conjunction with ‘Locked Rotor Current’ to check for locked rotor. If the current level is greater or equal to the current level specified for the amount of time specified by locked rotor current without a halls change, a locked rotor fault occurs. X is the time in milliseconds.

**TE** **Motor Temp Control**

**Range**: 0 to 2

**Use**: All.

**Application**: This is used to configure and enable the motor over temperature fault.

0 Motor temperature not used
1 PTC motor temperature sensor
2 NTC motor temperature sensor

**LC** **Current Control Limit**

**Range**: 0 to 4096

**Use**: All drives

**Application**: If the current feedback (DI) greater than or equal to LC, then the current control filter multiplies the current error (current command – current feedback) by 4. This gives the effect of increasing the current loop gain by 4 when the current is greater than LC.

### 7.1.3 Commutation Parameters

CL.EC Encoder Counts per Rev

**Range**: 0 to 65535

**Applications**: All applications using an encoder.

**Use**: Used for sine wave modulation. Also used by the PC front end to convert internal velocity to RPM. X is the number of encoder counts per mechanical revolution of the motor. (four times the number of encoder lines)

CL.PL Number of Motor Poles

**Range**: 2 to 42 (must be even)

**Applications**: All applications using an encoder.

**Use**: Used for sine wave modulation. X is the number of motor poles.

**HP** **Halls Advance**

**Range**: 0 to 5

**Applications**: All drives.

**Use**: Advances the 6 step modulation by X states.

**CL.AP** **Encoder Advance**

**Range** –32768 to 32767

**Applications**: Sine mode

**Use**: Advances the electrical angle by X encoder counts. Used to correctly phase the sine wave output to the motor angle.

### 7.1.4 Current Loop Parameters

Note that current is expressed as units of full scale / 1024. However, if the current is commanded through the analog input, the result is divided by 16 before moving it to the current.

---

**CL.KP** **Current Proportional Gain**

**Range**: 0 to 32767

**Use**: All drives.

**Application**: This is performed every current loop. The Proportional portion of the Voltage Modulation output value is set to KP*'Current error.

---

**CL.KI** **Current Integral Gain**

**Range**: 0 to 32767

**Use**: All drives.

**Application**: This is performed every current loop. 'Current error' * KI/32 is added to 'working current integral'.
Note: changing the KI value will not change the 'working current integral'.

---

**CL.KP** **Current Proportional Gain**

**Range**: 0 to 32767

**Use**: All drives.

**Application**: This is performed every current loop.
The Proportional portion of the Voltage Modulation output value is set to KP*'Current error.

---

**CL.SH** **Current Gain Scaling**

**Range**: 0 to 7

**Use**: All drives.

**Application**: This is performed every current loop. The Voltage Modulation output value is multiplied by $2^{SH}$.

---

**CL.EX** **Voltage Modulation Limit Plus**

**Range**: -32768 to 32767

**Use**: All drives.

**Application**: This is an additional restraint to the Voltage Modulation output.
CL.DO<= CL.EX <= CL.MX

---

**CL.EN** **Voltage Modulation Limit Minus**

**Range**: -32768 to 32767

**Use**: All drives.

**Application**: This is an additional restraint to the Voltage Modulation output.
CL.DO>=CL.EN>=CL.EX

### 7.1.5 Velocity Loop Parameters

**Hall based velocity**: The velocity is computed using the 1/T method along with a filter to even out the irregularities in the timing of the halls signals. Internal velocity for halls based is in RPM. Acceleration in RPM per second is ‘internal acceleration’ * ‘velocity loop rate’ / 8. Jerk in RPM per second per second is ‘Jerk’ * ‘velocity loop rate’$^2$ / 2048.

**Encoder based velocity**: The velocity is computed using the 1/T method or counting the number of counts in a velocity loop. The method is changed dynamically when it is deemed advantageous. The internal velocity is in units of ‘counts per velocity loop’ * 256. Therefore, velocity in RPM is ‘internal velocity’ * ‘velocity loop rate’ * (60 / 256) / ‘Encoder Counts per Rev’. Acceleration in RPM per second is
‘internal acceleration’ * ‘velocity loop rate’$^2$ * (60 / 32,768) / ‘Encoder Counts per Rev’. Jerk in RPM per second per second is ‘Jerk’ * ‘velocity loop rate’$^3$ * (60 / $2^{23}$) / ‘Encoder Counts per Rev’.

**Analog based velocity**: The velocity is supplied by an analog value which will be filtered and have a gain and offset applied. This value may represent velocity or some other physical value such as pressure.

A serial command, an analog signal, or the output of the position loop can supply ‘velocity command’. If there is no position loop and the command gain is zero, then the velocity command is from a serial command. The velocity loop is also used to control the drive based on an external analog feedback signal.

The ‘velocity error’ is ‘velocity command’ – ‘velocity’.

The ‘velocity integral’ is the sum of the ‘velocity errors’. This value is limited by the
‘Velocity Integral Limit’ * 256. The ‘velocity limit’ is not summed if the current or velocity loops are saturated.

The ‘velocity derivative’ is (‘old velocity derivative’ * ‘Velocity Derivative Filter’ + (32768 – ‘Velocity Derivative Filter) * (‘velocity error’ – ‘old velocity error’)) / 32768.

The output of the velocity loop goes to the current command.

---

**VT** **Measured Velocity Filter**

**Range**: 0 to 32767

**Use**: Halls velocity drives.

**Application**: Every time a new hall based velocity is computed, the result is filtered. The computed velocity is (‘old computed velocity * X + ‘new velocity’ * (32768 – X)) / 32768.
This is also used to filter the velocity command if the position and velocity feedbacks are both encoder, the position command is from step and direction, and both position and velocity loops are active. In this case, the computed velocity command is (‘old velocity command’ * X + ‘new velocity command’ * (32768 – X)) / 32768.

---

**VL.KP** **Velocity Proportional Gain**

**Range**: -32768 to 32767

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop.
‘Working current correction’ is set to ‘velocity error’ * X.

---

---

**VL.KI** — **Velocity Integral Gain**

**Range**: -32768 to 32767

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop.
‘Velocity integral’ * X / 256 is added to ‘working current correction’.

---

**VL.IL** — **Velocity Integral Limit**

**Range**: 0 to 32767

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop. The absolute value of ‘velocity integral’ is limited to 256 * X.

---

**VL.KD** — **Velocity Derivative Gain**

**Range**: -32768 to 32767

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop. ‘Velocity Derivative’ * X is added to ‘working current correction’.

---

**VL.DF** — **Velocity Derivative Filter**

**Range**: 0 to 32767

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop. The ‘velocity derivative is set to (‘old velocity derivative’ * X + (‘velocity error’ – ‘old velocity error’) * (32768 – X)) / 32768.

---

**VL.SH** — **Velocity Gain Scaling**

**Range**: -26 to 30

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop. ‘Working current correction’ is multiplied by $2^{X-4}$.

---

**VL.MX** — **Velocity Max Output**

**Range**: 0 to 1023

**Use**: Velocity mode or position mode drives.

**Application**: This is performed every velocity loop. The absolute value of ‘working current correction’ is limited to X and placed in ‘commanded current’.

---

**VF.AC** — **Acceleration**

**Range**: 0 to 32767

**Application**: All applications for which an analog from AN1 (or PWM for the ACE1000) is used for the command.

**Use**: This command is used every velocity loop unless it is a current mode drive in which case it is used every current loop. If X is zero, then the velocity command is the output of the analog command (if 'Command Gain' is nonzero) or the serial command. Otherwise, if 'Command Gain' is not zero, X/128 is the maximum amount that the absolute value of the velocity command can change in an update cycle. If X is nonzero, 'Command Gain' is zero, and 'Jerk' is zero, X/128 represents the absolute value of the change in command every velocity loop. If X is nonzero, 'Command Gain' is zero, and 'Jerk' is nonzero, X represents the maximum absolute value the internal acceleration can attain. In that case, the internal acceleration divided by 128 represents the change of the velocity command.

---

## VF.JK Jerk

**Range**: 0 to 32767

**Application**: Velocity mode drives.

**Use**: This command is used every velocity loop unless it is a current mode drive in which case it is unused. This command is not used unless 'Command Gain' is zero and 'Acceleration' and 'Jerk' are nonzero. The jerk is used to generate an s-curve velocity command profile. The amount that the absolute value of the internal acceleration changes is X/256.

### 7.1.6 Position Loop Parameters

The position feedback will be from the encoder if the drive is not configured for analog position feedback. The position measurement will then be the number of encoder counts. Otherwise, the position feedback will be from analog.

For the ACE1000 position command may come from a step and direction signal, an analog signal, or a serial command. The command is from step and direction if the drive is not configured for a serial position command and command gain is zero.

The ‘position error’ is ‘position command’ – ‘position’.

The ‘position integral’ is the sum of the ‘position errors’. This value is limited by the ‘Position Integral Limit’ * 256. The ‘position limit’ is not summed if the current loop or the position loop are saturated.

The ‘position derivative’ is (‘old position derivative’ * ‘Position Derivative Filter’ + (32768 – ‘Position Derivative Filter) * (‘position error’ – ‘old position error’)) / 32768.

The output of the position loop goes to the velocity command if there is a velocity loop. Otherwise, it is divided by 16 and put in the current command.

---

**PL.KP** **Position Proportional Gain**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. ‘Working velocity correction’ is set to ‘velocity error’ * X.

---

**PL.KI** **Position Integral Gain**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. ‘Position integral’ * X / 256 is added to ‘working velocity correction’.

---

**PL.IL** **Position Integral Limit**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. The absolute value of ‘position integral’ is limited to 256 * X.

---

**PL.KD** **Position Derivative Gain**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. ‘Position derivative’ * X is added to ‘working current correction’.

---

**PL.DF** **Position Derivative Filter**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. 'Position derivative is set to ('old position derivative' * X + ('position error' – 'old position error') * (32768 – X)) / 32768.

---

**PL.SH** **Position Gain Scaling**

**Range**: -30 to 30

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. 'Working velocity correction' is multiplied by $2^X$.

---

**PL.MX** **Position Max Output**

**Range**: 0 to 32767

**Use**: Position mode drives.

**Application**: This is performed every velocity loop. The absolute value of 'working velocity correction' is limited to X * 16. 'Commanded velocity' is set to ('position command' – 'old position command') * 256 + 'working velocity correction'

---

**PL.SC** **Steps per Revolution**

**Use**: Position mode drives. Command Gain (VF.GN) must be zero and the Configuration word must not be set for serial position command.

**Application**: This is performed every velocity loop. Every step pulse while the drive is in run, the desired position is incremented or decremented (depending on the direction signal) by Encoder Counts per Rev (CL.EC) / Steps per Revolution. The calculation is accurate to within one encoder count both within one revolution and long term. This will try to position the motor as if it were a stepper motor with the correct number of steps for one revolution. Unfortunately, because of an error in the DSP silicon, the first step is always lost. If position feedback is encoder and velocity command is step and direction, the velocity command is incremented by 256 * encoder count difference in addition to the velocity command from the position PID loop.

### 7.1.7 I/O Configuration

**VF.FL** **Command Filter**

**Range**: 0 to 32767

**Application**: All applications for which an analog from AN1 is used for the command.

**Use**: This is used every velocity loop unless the drive is in current mode only in which case it is used every current loop. This is used for the first operation in converting the analog command to an actual command. The output of this command is used as the input to the 'Command Offset'. This command may represent position, current, velocity, or a value represented by the analog feedback signal. The output of the filter is ('Old Value' * X + 'New Value' * (32768 – X)) / 32768. For the ACE200 the input range is 0 to 8191.

---

**VF.OF** **Command Offset**

**Range**: -32768 to 32767

**Application**: All applications for which an analog from AN1 is used for the command.

**Use**: This command is used every velocity loop unless it is a current mode drive in which case it is used every current loop. Used as the second operation in converting the analog command to an actual command. The output of this command is used as the input to the 'Command Gain'. X is added to the input to get the output.

---

**VF.GN** **Command Gain**

**Range**: -32768 to 32767

**Application**: All applications for which an analog from AN1 is used for the command.

**Use**: This command is used every velocity loop unless it is a current mode drive in which case it is used every current loop. Used as the third operation in converting the analog command to an actual command for the outer loop used. If the gain is zero, then there is no analog command and the command must be provided serially or by step and direction for position mode. Note that step and direction is not available on the ACE1000. The output is 'input' * X / 4096 for current command or 'input' * X / 256 for velocity or position command. The output is the command in internal units.

---

CF.FL Aux Analog Filter

**Range**: 0 to 32767

**Application**: All.

**Use**: This is used every velocity loop unless the drive is in current mode only in which case it is used every current loop. This is used for the first operation in converting the analog feedback to an actual feedback. The output of this command is used as the input to the 'Aux Analog Offset'. This feedback may represent position, velocity, or a current limit. The output of the filter is ('Old Value' * X + 'New Value' * (32768 – X)) / 32768. The input range is 0 to 8191.

---

---

## CF.OF Aux Analog Offset

**Range**: -32768 to 32767

**Application**: All.

**Use**: This is used every velocity loop unless it is a current mode drive in which case it is used every current loop. Used as the second operation in converting the analog feedback to an actual feedback. The output of this command is used as the input to the 'Command Gain'. X is added to the input to get the output.

---

## CF.GN Aux Analog Gain

**Range**: -32768 to 32767

**Application**: All applications for which an analog from AN1 (or PWM for the ACE1000) is used for the command.

**Use**: This is used every velocity loop unless it is a current mode drive in which case it is used every current loop. Used as the third operation in converting the analog feedback to an actual feedback. The output is 'input' * X / 256. The output is the feedback in internal units.

## 7.2 Graphing Variables

General: The following are operational variables are used for data gathering and graphing. Any parameter or variable that can be read can be graphed. These are the variables used by the Windows interface.

| | |
|---|---|
| **CL.CC** | **Commanded Current**<br>The commanded current can have values from –1024 to 1023. Units are full scale current / 1024. Commanded current can only be written if there is no position or velocity loop and command gain is zero. |
| **PL.CM**<br>**PL.CH** | **Commanded Position (PL.CM low order, PL.CH high order)**<br><br>The commanded position can have a value from –2147483648 to 2147483647. PL.CM when not used as a data gathering variable returns the value of both words together. Both PL.CM and PL.CH need to be used while setting up data gathering to get both words. Units are encoder counts if serial position command is off and command gain is zero, filtered analog with gain and offset if serial position command is off and command gain is not zero, or a serial command. Commanded position may be written only if there is a position loop and the serial position bit of the configuration is set. |
| **VL.CM**<br>**VL.CH** | **Commanded Velocity (VL.CM low order,VL.CH high order)**<br><br>The commanded velocity can have a value from –2147483648 to 2147483647. VL.CM when not used as a data gathering variable returns the value of both words together. Both VL.CM and VL.CH need to be used while setting up data gathering to get both words. Units are:<br>1 RPM for halls based velocity<br>2 Encoder counts per position servo cycle * 256 for halls based velocity.<br>3 Filtered analog with gain and offset for if there is no position loop, a velocity loop and analog velocity is set in the configuration word. Commanded velocity may be written only if there is no position loop, a velocity loop and the command gain is zero. |
| **CL.DO** | **Commanded Voltage** |
| **DI** | **Current** |
| **CL.ER** | **Current Error**<br><br>This variable is read only. Current error is commanded current – current. |
| **CL.IN**<br>**CL.IH** | **Current Integral (CL.IN low order, CL.IH high order)**<br><br>This variable is read only. The current integral is the sum of the current errors. The integral is not summed if the current loop is saturated. The current integral can have a value between –2147483648 to 2147483647. . IN or CL.IN when not used as a data gathering variable returns the value of both words together. Both IN or CL.IN and IH or CL.IH need to be used while setting up data gathering to get both words. |

| | |
|---|---|
| **VF.VD**<br>**VF.VA** | **Filtered Command (VF.VD low order, VF.VA high order)**<br><br>This variable is read only. See command filter (VF.FL) for details about how the filter operates. When not used as a data gathering variable, VF.VA returns the integer part of the filtered command and VF.VD returns both the integer and fractional parts * 65536. |
| **CF.VD**<br>**CF.VA** | **Filtered Feedback (CF.VD low order, CF.VA high order)**<br><br>This variable is read only. See aux. analog filter (CF.FL) for details about how the filter operates. When not used as a data gathering variable, CF.VA returns the integer part of the filtered feedback and CF.VD returns both the integer and fractional parts * 65536. |
| **PL.DD**<br>**PL.DE** | **Filtered Position Derivative (PL.DD low, PL.DE high order)**<br><br>This variable is read only. See position loop description and position derivative filter (PL.DF) for descriptions of the position derivative. When not used as a data gathering variable, PL.DE returns the integer part of the position derivative and PL.DD returns both the integral and fractional parts * 65536. |
| **VL.DD**<br>**VL.DE** | **Filtered Velocity Derivative (VL.DD low, VL.DE high order)**<br><br>This variable is read only. See velocity loop description and velocity derivative filter (VL.DF) for descriptions of the velocity derivative. When not used as a data gathering variable, VL.DE returns the integer part of the velocity derivative and VL.DD returns both the integral and fractional parts * 65536. |
| **CL.ID** | **Flux Current**<br><br>**Sine mode only**. This variable is read only. The DSP program calculates this value. It is the amount of current that is flowing in the drive that is perpendicular to the torque producing current. Because this current causes the motor to generate heat, the ideal value should be zero. |
| **CL.DV** | **Flux Voltage**<br><br>**Sine mode only**. This variable is read only. The DSP program calculates this value. It is the leading (+) or lagging (-) voltage that the drive is applying to the motor to reduce the flux current. |
| **CH** | **Halls**<br><br>This value is read only. The three hall signals are displayed as 0 or 1 in the order of s3,s2 & s1 and is the actual value of the three halls signals as read at the DSP. |
| **MP** | **Motor Phase**<br><br>This value is read only. Value is from 0 to 5 and is the motor phase derived from the halls. |

| | | |
|---|---|---|
| **DU** | **Phase U Current**<br><br>This value is read only. Value is from –32768 to 32767 and is proportional the phase U current. To calculate the actual current multiply by (IR)* (drive rating in amps)/2017152. |
| **DV** | **Phase V Current**<br><br>This value is read only. Value is from –32768 to 32767 and is proportional the phase V current. To calculate the actual current multiply by (IR)* (drive rating in amps)/2017152. |
| **DW** | **Phase W Current**<br><br>This value is read only. Value is from –32768 to 32767 and is proportional the phase W current. To calculate the actual current multiply by (IR)* (drive rating in amps)/2017152. |
| **PL.AC**<br>**PL.AH** | **Position (PL.AC low order PL.AH high order)**<br><br>This variable is read only. Position can have a value from –2147483648 to 2147483647. PL.AC when not used as a data gathering variable returns the value of both words together. Both PL.AC and PL.AH need to be used while setting up data gathering to get both words. Units are encoder counts if analog position feedback command is off or filtered analog with gain and offset if analog position feedback command is off. |
| **PL.ER** | **Position Error**<br><br>This variable is read only. Position error can have a value of –32768 to 32767. It is commanded position – position. |
| **PL.IN**<br>**PL.IH** | **Position Integral (PL.IN low order PL.IH high order)**<br><br>This variable is read only. Position integral is the sum of the position errors. It is not accumulated if the position loop or current loop is saturated. The position integral can have a value between –8388352 to 8388352. PL.IN when not used as a data gathering variable returns the value of both words together. Both PL.IN and PL.IH need to be used while setting up data gathering to get both words. |
| **CL.DS** | **Scaled Current Integral** |
| **VL.AC**<br>**VL.AH** | **Velocity (VL.AC low order VL.AH high order)**<br><br>This variable is read only. Velocity can have a value from –2147483648 to 2147483647. VL.AC when not used as a data gathering variable returns the value of both words together. Both VL.AC and VL.AC need to be used while setting up data gathering to get both words. Units are:<br>1 RPM for halls based velocity<br>2 Encoder counts per position servo cycle * 256 for halls based velocity.<br>3 Filtered analog with gain and offset for if analog velocity is set in the configuration word. |

| | |
|---|---|
| **VL.ER** | **Velocity Error**<br><br>This variable is read only. Velocity error can have a value of –32768 to 32767. It is commanded velocity – velocity. |
| **VL.IN**<br>**VL.IH** | **Velocity Integral (VL.IN low order VL.IH high order)**<br><br>This variable is read only. Velocity integral is the sum of the velocity errors. It is not accumulated if the velocity loop or current loop is saturated. The velocity integral can have a value between –8388352 to 8388352. VL.IN when not used as a data gathering variable returns the value of both words together. Both VL.IN and VL.IH need to be used while setting up data gathering to get both words. |
| **CL.EA** | **Electrical Angle**<br><br>**Sine mode only**. The electrical angle is a value between 0 and 1535 with 1536 representing 360 degrees. The electrical angle may be set to a value and that value will be held regardless of the position until it is changed by writing a new value or released by writing a negative number to the electrical angle. |

## 7.3 Data Gathering Variables

### 7.3.1 Setting up Triggering:

#### 7.3.1.1 No Trigger:

If there is no trigger, a sample is collected every sample period after a delay of a specified number of sample periods. A sample is a snapshot of the variables specified during the data gathering setup. A sample period is a specified number of current or velocity loops. There are 32768 words available to store the samples. The space required to store all the samples is # of variables * (number of samples + 1). Note that double precision variables such as commanded velocity require two words to store. To set up data gathering, set the start up delay and the sample rate as desired followed by a data specification start, then list the variables in order that you want, then the data specification end.

#### 7.3.1.2 Using Trigger:

If triggering is desired, then a negative sample delay is the number of samples before the trigger event to be displayed and a positive sample delay is the number of samples after the trigger event to delay. No data will be sent until the trigger event occurs.

---

**DG.TC** **Clear trigger table**

This must be the first command before setting up the trigger table if there is to be one. This command clears both the trigger table and the data gathering table.

---

**DG.TR** **Set the trigger control word**

This sets the trigger control word. The trigger control word cannot be read. This command must be directly followed by a command which is the command to read the data variable. The data variable must be followed by a DG.CN command.

---

**Control information format:**

Bits Description
15 Must be set to zero.

13-14 Comparison type which takes one of these four values:
- 0: Variable < constant
- 1: Variable > constant
- 2: Falling edge, Variable was greater or equal to constant, now is less
- 3: Rising edge, Variable was less or equal to constant, now is greater

11-12 Relationship type which takes one of these four values:
- 0: Last entry in table
- 1:Both this comparison and the next one must be true
- 2: Either this comparison or the next must be true
- 3: This comparison must become true and then the next one must become true

9-10 Variable type which takes one of the following three values:
- 0: Variable and constant are unsigned
- 2: Variable is signed, constant is unsigned and comparison is absolute value

- 3: Variable and constant are signed

8 On for double precision variable and constant

0-7 Filter

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## Filter operation:

Let FO be the old filtered value (with fraction), FN be the new filtered value, F be the filter and V be the actual variable value. Then: FN = (V * F + (256 – F) * FO) / 256.

---

**DG.CN** **Set the trigger constant**

This sets the trigger constant. The constant is signed or unsigned and single or double precision depending on the value of the DG.TR command. The trigger constant cannot be read. This command must be directly preceded by a command that specifies the data variable desired.

---