Tolomatic™
EXCELLENCE IN MOTION

AXIOM DV and AXIOM DB Brushless and Brushed Servo Drives are DISCONTINUED. Replacements are not available. For legacy AXIOM drives use this manual for reference only.

USER GUIDE

AXIOM DV AND AXIOM DB BRUSHLESS AND BRUSHED SERVO DRIVES

3600-4603_09

Product and Safety Notice

Use of Axiom Servo Drives

Axiom servo drives are intended to be used as amplifiers driving brush or brushless motors, depending on model of drive. They are intended to be part of a controlled system and not to operate as stand alone motor drives. Installation and operating instructions for all of the system components must be observed.

Unless otherwise specified, Axiom servo drives are intended for use in a normal industrial environment. Installation is to be in a suitable electrical cabinet capable of protecting the drive from exposure to excessive moisture, corrosive agents or excessive ambient temperatures. Installation of this drive must only be attempted by skilled personnel and with adherence to the installation instructions in this manual. This drive does not contain any user serviceable components. Should repair or replacement of a drive become necessary, please contact the place of purchase for instructions.

Safety Notes

As with any electrical equipment, there are some possible hazards associated with the installation and use of this drive. Please observe the following precautions. Further specific Warnings and Cautions are listed throughout this manual.

Installation and Maintenance: All installation and maintenance must be carried out by qualified personnel.

Generation: A motor driven mechanically will act as a generator. Because dangerous voltage levels may be generated, motor to drive connections must be suitably guarded to protect against electrical shock hazards.

Cables: Use only Tolomatic supplied cables, or cables deemed suitable for use by a competent person familiar with the electrical and mechanical requirements of a given application.

Supply: Drives must be connected to a permanent power source and fused according to the instructions in this manual, in accordance with all local and national electrical codes.

Safety Requirements: The safe and proper installation and operation of this motor drive into a machine system is the responsibility of the machine designer and should comply with all applicable local and national safety requirements. In Europe, this is likely to include the Machinery Directive, the ElectroMagnetic Compatibility Directive and the Low Voltage Directive. In the United States this will likely include the National Electrical Code.

Mechanical Installation: Drives must be installed inside an appropriate electrical cabinet providing environmental controls and protection. The minimum requirements are outlined in this manual.

WARNING! A SEVERE MOTOR JUMP WILL OCCUR IF THE DRIVE IS ENABLED WITH A LARGE ERROR BETWEEN THE POSITION COMMANDED BY THE CONTROLLER AND THE ACTUAL MOTOR POSITION.
To prevent this from occurring, make sure the Axiom servo drive and controller are energized with the drive in the disabled position. Before sending any commands from the controller to the Axiom servo drive, make sure the Axiom servo drive is enabled. When powering units down, disable the Axiom servo drive prior to powering down the controller and the drive. If the actuator is to be moved while the drive and controller are powered up for manual position correction, disable the Axiom servo drive, manually position the actuator, and then reset or re-zero the controller prior to re-enabling the Axiom servo drive.

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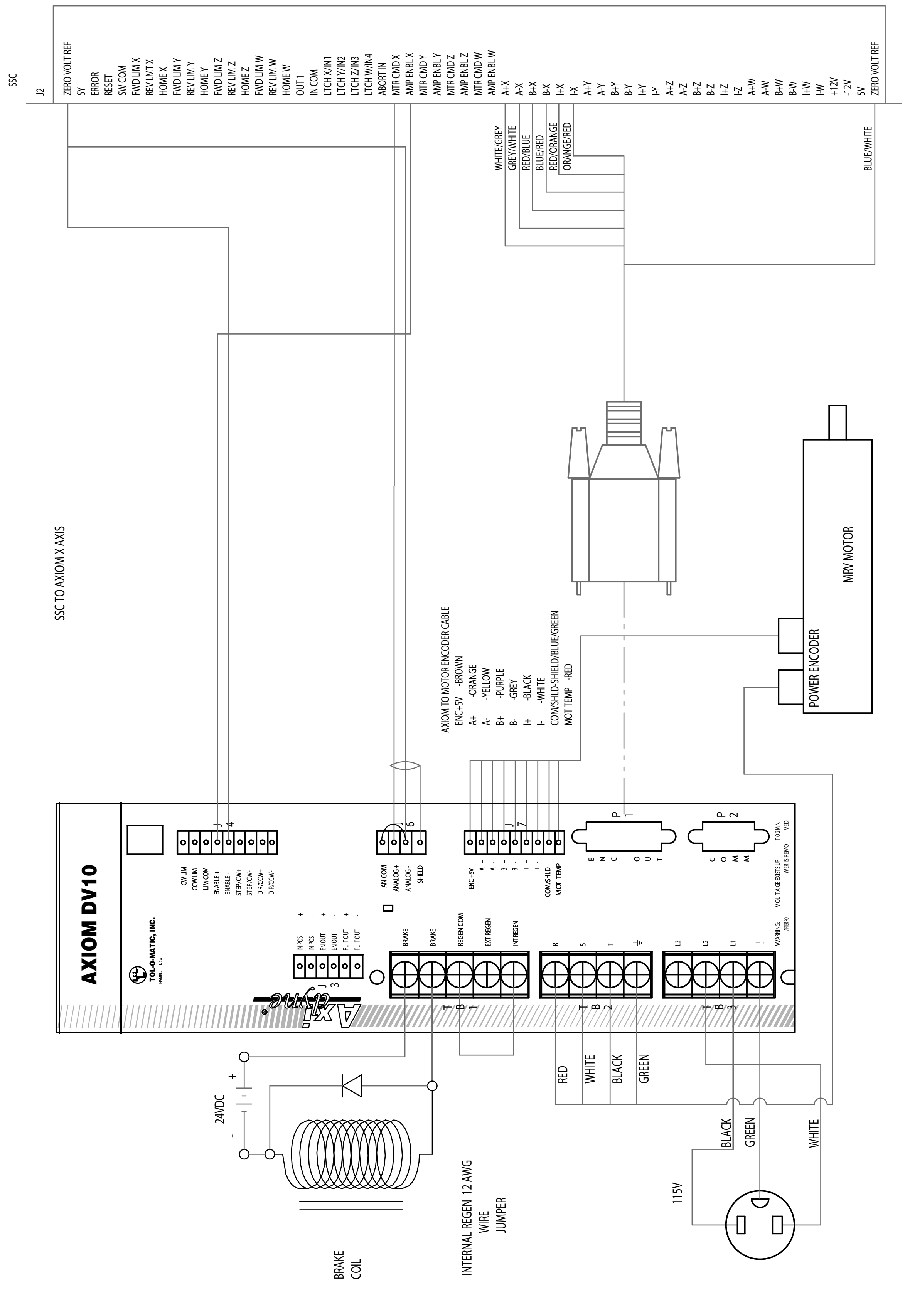
SSC
J2
ZERO VOLT REF
5Y
ERROR
RESET
SW COM
FWD LIM X
REV LMT X
HOME X
FWD LIM Y
REV LIM Y
HOME Y
FWD LIM Z
REV LIM Z
HOME Z
FWD LIM W
REV LIM W
HOME W
OUT 1
IN COM
LTCH X/IN1
LTCH Y/IN2
LTCH Z/IN3
LTCH W/IN4
ABORT IN
MTR CMD X
AMP ENBL X
MTR CMD Y
AMP ENBL Y
MTR CMD Z
AMP ENBL Z
MTR CMD W
AMP ENBL W
A+X
A-X
B+X
B-X
I+X
I-X
A+Y
A-Y
B+Y
B-Y
I+Y
I-Y
A+Z
A-Z
B+Z
B-Z
I+Z
I-Z
A+W
A-W
B+W
B-W
I+W
I-W
+12V
-12V
5V
ZERO VOLT REF
WHITE/GREY
GREY/WHITE
RED/BLUE
BLUE/RED
RED/ORANGE
ORANGE/RED
BLUE/WHITE
SSC TO AXIOM X AXIS
MRV MOTOR
POWER ENCODER
AXIOM TO MOTOR ENCODER CABLE
ENC+5V -BROWN
A+ -ORANGE
A- -YELLOW
B+ -PURPLE
B- -GREY
I+ -BLACK
I- -WHITE
COM/SHLD-SHIELD/BLUE/GREEN
MOT TEMP -RED
AXIOM DV10
TOL-O-MATIC, INC.
CW LIM
CCW LIM
LIM COM
ENABLE +
ENABLE -
STEP/CW+
STEP/CW-
DIR/CCW+
DIR/CCW-
J4
AN COM
ANALOG +
ANALOG -
SHIELD
J6
ENC +5V
A +
A -
B +
B -
I +
I -
COM/SHLD
MOT TEMP
J7
P1
ENC OUT
P2
COMM
IN POS
ENOUT
FL TOUT
J3
BRAKE
BRAKE
REGEN COM
EXT REGEN
INT REGEN
TB1
R
S
T
TB2
L3
L2
L1
TB3
WARNING
Axidyne
24VDC
+
-
RED
WHITE
BLACK
GREEN
BLACK
GREEN
WHITE
115V
BRAKE COIL
INTERNAL REGEN 12 AWG WIRE JUMPER

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Introduction

This manual provides step by step instructions for installing, controlling, tuning and maintaining a state-of-the-art Tolomatic Axiom servo motor drive. It details the hardware connections necessary to operate this drive in each of its operating modes.

The Axiom series drives are set up using Axiom setup software. This software runs on a personal computer running Microsoft Windows® 95, 98 or NT operating system. This software uses a graphical user interface and allows point and click setup and tuning of this drive when used with Tolomatic servo motors.

Graphic Symbols and Warning Classifications

Protective Conductor terminal (Earth ground)

Chassis terminal (Not a protective ground)

Risk of Electrical Shock symbol

The use of the following symbols and signal words is based on an estimation of the likelihood of exposure to the hazardous situation and what could happen as a result of exposure to the hazard. DANGER, WARNING or CAUTION require accompanying information notices to prevent potential personal injury and equipment damage.

Classifications include:

DANGER! Indicates a very hazardous situation which, if not avoided, could result in death or serious injury. This signal word is limited to the most extreme situations.

WARNING! Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION! Indicates a potentially hazardous situation which, if not avoided, this situation may result in property damage or minor or moderate injury.

NOTICES

Danger Notices

DANGER! Adjustment, operation and service of this equipment should only be performed by qualified electrical personnel familiar with its operation and hazards. Read and understand this manual before attempting installation or operation of this equipment. Failure to observe this precaution could result in serious bodily injury or loss of life.

DANGER! The user of this equipment is responsible for observing all local, national and international codes. Proper grounding, wiring practice, disconnects and overcurrent protection are of particular importance. Failure to observe this precaution could result in serious bodily injury or loss of life.

DANGER! Any shielded power cables must be grounded in at least one place for safety. Failure to ground the shield of a shielded power cable could result in potentially lethal voltages being present on the shield and anything connected to it.

DANGER! The DC bus capacitors may retain a hazardous voltage level for a period of time after input power has been removed. After disconnecting power, wait for the time period listed on the front of the drive before servicing drive. This allows the bus capacitors time to bleed down to a safe voltage level. Failure to observe this precaution could result in serious bodily injury or loss of life.

Warning Notices

WARNING! Always perform initial drive and motor checkout with the motor disconnected from the load. Remove keys or loose couplings from the motor shaft to prevent injury from flying metal parts. Improper wiring could result in unexpected motor movement. Be prepared to remove power if improper motor movement occurs.

WARNING! Full DC bus voltage is present at the regeneration resistor terminals. Treat them with the same respect and practice as the power and motor drive connections.

WARNING! Large leakage currents exist in AC line filters. They must be grounded properly before applying power. Filter capacitors retain high voltages after power removal. Before handling the equipment, voltages should be measured to determine safe levels prior to handling the equipment. Failure to observe this precaution could result in severe bodily injury.

WARNING! A severe motor jump will occur if the drive is enabled with a large error between the position commanded by the controller and the actual motor position.

WARNING! The circuits in the drive are potential sources of severe electrical shock. Follow the safety guidelines to avoid shock.

WARNING! Rotating motor shafts can cause extensive damage and injury. Motors must be properly guarded during testing and in the final installation.

WARNING! The user must provide an external, hard wired emergency stop circuit in addition to the controller circuitry. This circuit must remove power from the system in case of improper operation. The drive enable is not adequate for this purpose as it does not remove supply voltage from the drive and may not disable the system in all circumstances. Uncontrolled machine operation may result if this procedure is not followed. Failure to observe this precaution could result in severe bodily injury.

WARNING! High voltage may be present on the terminals of the drive. Remove power and disconnect the power cable before making or removing any connection.

Caution Notices

CAUTION! Do not tin (solder) the exposed leads on cables. Tinned leads will loosen in time and may come loose from their screw terminal connections.

CAUTION! Ensure that encoder signals are connected properly. Incorrect connection of encoder signals will result in a “run away” motor condition and/or incorrect commutation.

CAUTION! Electronic components are subject to damage by static electricity. Follow Electrostatic Discharge (ESD) practices while handling components.

CAUTION! If the cabinet is ventilated, use filtered or conditioned air to prevent the accumulation of dust and dirt on electronic components. The air should be free of oil, corrosives, or electrically conductive contaminates.

Axiom Brushed and Brushless Servo Motor Drive Overview

The Axiom series drives use a high speed Digital Signal Processor (DSP) to perform all calculations necessary for high bandwidth digital control of traditional brush and three-phase brushless servo motors in torque, velocity or position modes. All tuning parameters are set and stored digitally using the Axiom setup software.

With brushless motors, the drive incorporates state-of-the-art Space Vector Commutation to give 12.5% better bus voltage utilization than traditional sinusoidal commutation drives. This allows for improved motor speed/torque performance over older technology trapezoidal or sinusoidal motor drives.

In addition, the drive implements a Flux Vector current control algorithm in the brushless motor drive versions. This allows for precise, high bandwidth current control in each individual motor phase. This minimizes torque variations due to slight phase-to-phase differences within a motor's windings. It also minimizes non-torque producing motor current for less motor heating and better speed/torque performance than with traditional trapezoidal and sinusoidal control algorithms.

BRUSHLESS MOTOR DRIVE POWER RATINGS

Three power levels of Axiom brushless servo motor drives are available.

- Axiom DV10 with a continuous current rating of 5A and a peak rating of 10A from a single or three phase power source.
- Axiom DV20 with a continuous current rating of 10A and a peak rating of 20A from a single or three phase power source.
- Axiom DV30 with a continuous current rating of 15A and a peak rating of 30A from a single or three phase power source.

BRUSHED MOTOR DRIVE POWER RATINGS

One power level of Axiom brush servo motor drive is available.

- Axiom DB20 with a continuous current rating of 15A and a peak rating of 20A from a single phase power source. This drive has built in transformer isolation and provides an 80 Vdc nominal bus voltage.

The Axiom servo motor drives, when combined with Tolomatic brush and brushless servo motors, provide continuous torque up to 75 lb-in (10.7 Nm) and peak torque up to150 lb-in (21.4 Nm) and speeds up to 6000 RPM.

INTERFACE CABLES

Standard motor power and encoder feedback cables, as well as communications cables, are available to complete the motion control system and provide reliable, trouble free start-up. For a description of optional equipment, refer to *Appendix A: Options and Accessories*.

Axiom Brushless Motor Drive Features

AXIOM BRUSHLESS SERVO DRIVES

State-of-the-Art Space Vector Commutation - Provides 12.5% better bus voltage utilization than traditional sinusoidal commutation drives.

State-of-the-art Flux Vector Motor Current Control - Allows higher bandwidth control of torque producing current than traditional Sinusoidal approach. Flux Vector control also improves overall efficiency by reducing harmonic currents in motor windings.

High Performance Digital Signal Processor (DSP) Technology - Allows for the implementation of advanced brushless motor control algorithms.

Digital Current, Velocity and Position Calculations - Provide for high bandwidth motor control while minimizing drift and aging problems inherent in traditional analog drives.

Standard Features:

1. Designed for use with Tolomatic MRV series brushless motors.
2. Pluggable terminal block connections for ease of Installation.
3. Accepts analog torque, analog velocity or step/direction command signals.
4. Continuous output ratings of 5A, 10A and 15A.
5. Peak output ratings of 10A, 20A and 30A.
6. Buffered encoder output.
7. 115/208/230VAC input, 50/60Hz, single or three phase.
8. Short circuit protection.
9. Overcurrent protection.
10. Bus over-voltage shutdown.
11. Internal bus current regeneration.
12. Connection for additional external regeneration capacity.
13. Motor and Drive thermal protection.
14. Auto-Phasing: Requires no Hall Effect switches for phasing or commutation.

15. RS-232 communications.
16. Point and click software for setup, tuning and diagnostics.
17. 3A brake relay.
18. Front panel status and fault display indicator.

AXIOM BRUSHED SERVO DRIVES

The same High Performance Digital Signal Processor (DSP) technology found in Axiom brushless motor drives can also be applied to provide high bandwidth digital control of brush servo motors.

All current, velocity and position calculations are performed digitally to provide for high bandwidth motor control while minimizing drift and aging problems inherent in traditional analog drives.

Other Features:

1. Designed for use with Tolomatic MRB series brush motors.
2. Pluggable terminal block connections for ease of installation.
3. Accepts analog torque, analog velocity or step/direction command signals.
4. Continuous output rating of 15A.
5. Peak output rating of 20A.
6. Buffered encoder output.
7. 115VAC input, 50/60Hz, single phase.
8. Short circuit protection.
9. Overcurrent protection.
10. Bus over-voltage shutdown.
11. Internal bus current regeneration.
12. Motor and drive thermal protection.
13. RS-232 communications.
14. Point and click software for setup, tuning and diagnostics.
15. 3A brake relay.

ANALOG AND DIGITAL INPUT COMMAND INTERFACES

All Axiom servo drives allow the user to select one of the following analog or digital command interfaces:

- ±10 Volt Analog Interface - This input can be programmed for either velocity or torque mode. The ±10V signal can be scaled to represent 50% to 200% of full rated drive current or velocity.
- Step/Direction or Step CW/Step CCW Digital Interface - Provides position control allowing a step motor type indexer to control a high performance servo motor system. Step/Direction or Step CW/Step CCW mode selected through the Axiom setup software. This is a 5Vdc optically isolated input.

ENCODER INPUT

A single, motor mounted optical encoder provides complete commutation information as well as position and velocity feedback. The input can accept a wide range of encoder line counts at quadrature rates up to 4MHz.

ENCODER OUTPUT

The Axiom drive incorporates a buffered encoder output signal for connection to a motion controller. This is a 5Vdc differential signal.

DEDICATED DIGITAL I/O

The Axiom servo drive incorporates several dedicated digital I/O connections.

- Brake Relay Output - A 3A relay contact for connection to an actuator or motor shaft-mounted, energize to release type brake.
- Fault Output - An optically isolated output that goes active anytime the drive is in any fault state.
- In-Position Output - An optically isolated output that goes active anytime the drive is “In Position” as defined in the setup software.
- Motor Temp Input - Connection for a motor’s internal temperature switch. This requires a normally closed (N.C.) connection. If this connection is broken, the drive shuts down and displays the appropriate fault on the fault indicator.
- CW Limit - Optically isolated input for connection to a CW end of travel

limit switch. This input disables any further CW input command when active.

- CCW Limit - Optically isolated input for connection to a CCW end of travel limit switch. This input disables any further CCW input command when active.
- Enable Input - This optically isolated input enables the drive when activated and disables the drive when inactive.

AC INPUT POWER

Axiom brushless servo drives are powered directly from single or three phase ac mains. The drive accepts nominal input voltages of 115Vac, 208Vac or 230Vac. The input range is switch selectable. The 115V selection is for 115Vac operation. The 230V selection is for 208Vac or 230Vac operation. Failure to make the correct switch selection will result in the drive entering a fault condition when power is applied. The drive will not operate until powered down and switched correctly.

Axiom brush servo drives are powered from single phase, 115VAC, 50/60Hz power. These drives are transformer-isolated and provide an 80Vdc nominal motor bus voltage.

DRIVE AND MOTOR PROTECTION CIRCUITRY

- Seven-segment LED display provides drive status and fault codes at a glance
- Overtemperature, short circuit and overcurrent protection for the power output
- Peak and continuous current limits
- Bus overvoltage and undervoltage
- Motor overspeed protection

- Watchdog timers provide fail-safe operation

AGENCY APPROVALS

Axiom Brushless Servo Drive

UL, cUL	UL508C	File E207326

CE

Tolomatic, Inc. Axiom series drives have been tested to the following standards.

Low Voltage Directive and Electromagnetic Compatibility Directive (see page B.1)

Axiom Brushed Servo Drive

Refer to approval agency marks on drive or contact Tolomatic for latest information on agent approvals.

Axiom Software

All drive setup and tuning is accomplished with the setup software. This is a Windows based graphical software program that communicates through the drive's RS-232 serial communications port. Windows 95, 98 and NT are supported. (For software to support Windows 3.1 please contact Tolomatic.)

- The software allows selection of any Tolomatic MRV or MRB servo motor with simple point-and-click commands.
- The software provides a user friendly "on screen" oscilloscope and diagnostic screen for quick and easy tuning and troubleshooting.

AUTOTUNING

Digital auto tuning allows easy setup. All adjustments are made in software which immediately sets the servo system compensation parameters thus eliminating the time-consuming adjustments required by potentiometers.

Safety 1

Before you begin...

Please read this manual in its entirety before attempting to install or operate the drive. In this way, risk of injury, damage or wasted time and effort can be minimized.

Potential Hazards

The equipment described in this manual is intended for use in industrial drive systems. This equipment can endanger life through rotating machinery and high voltages, therefore it is essential that guards for both electrical and mechanical parts are not removed.

Hazards which can be encountered in the use of this equipment include:

- Electric Shock
- Electric Fire
- Mechanical
- Stored Energy

These hazards must be controlled by suitable machine design, using the safety guidelines which follow. There are no chemical or ionizing radiation hazards.

VOLTAGE POTENTIALS

DANGER! DC bus capacitors may retain hazardous voltages after input power has been removed. Before working on the drive, wait the full time interval listed on the warning on the front of the drive. Failure to observe this precaution could result in severe bodily injury or loss of life.

Voltage potentials for the internal drive circuitry vary from 325 Volts above to 325 Volts below earth ground for a 230 Volt input. Voltages can reach 400 Vdc within the drive. All circuits, including the connections on the front panel, should be considered “hot” when power is connected and for the time specified in the warning on the front of the drive after power is removed.

Your Responsibilities

As the user or person installing this drive, you are responsible for determining the suitability of the product for the intended application. Tolomatic is neither responsible nor liable for indirect or consequential damage resulting from the inappropriate use of this product.

A *qualified person* is someone who is familiar with all safety codes and established safety practices, pertaining to the installation, operation and maintenance of this equipment and the hazards involved. For more detailed definitions, refer to IEC 364.

It is recommended that anyone who operates or maintains electrical or mechanical equipment should have a basic knowledge of First Aid. As a minimum, they should know where the First Aid equipment is kept and the identity of the official First Aid personnel.

These safety notes do not represent a complete list of the steps necessary to ensure safe operation of the equipment. For further information, please contact the nearest Tolomatic distributor.

Safety Guidelines

Electrical shock and fire hazards can be avoided by using normal installation procedures for electrical power equipment in an industrial environment. Installation must be undertaken by *suitably qualified personnel.* Note that this amplifier must be installed in an industrial cabinet such that access is restricted to suitably qualified personnel.

Mechanical hazards are associated with potentially uncontrolled movement of the motor shaft. If this imposes a risk in the machine, appropriate precautions must be made to electrically disconnect the motor from the drive when personnel have access to moving parts of the machine. Note also that the motor must be securely mounted at all times.

Stored energy hazards are both electrical and mechanical.

1. Electrical hazards can be avoided by disconnecting the drive from its power source and waiting for the time indicated in the warning on the front of the drive prior to removing the protective covers or touching any connections.

2. Mechanical hazards require a risk analysis on the effects of stored mechanical energy when the machine is running at speed, as well as the potential for the conversion of electrical energy stored in the drive being converted to mechanical energy. Electrical energy may be stored in the drive for the time indicated in the warning on the front of the drive.

   The following points should be observed for the safety of personnel:

- Only qualified personnel familiar with the equipment are permitted to install, operate and maintain the device.
- System documentation must be available and observed at all times.
- All non-qualified personnel should maintain a safe distance from the equipment.
- The system must be installed in accordance with local regulations.
- The equipment is intended for permanent connection to a main power input. It is NOT intended for use with a portable power input.
- DO NOT power up the unit without all guards and covers in place.
- DO NOT operate the unit without connecting the motor conductors to the appropriate terminals on the drive.
- Always remove power before making or removing any connection on the unit. Failure to observe this condition could result in injury or damage to equipment.
- DO NOT remove cover from unit. There are no internal user serviceable parts or adjustments required.
- DO NOT make any connections to the internal circuitry. Connections on the front panel are the only points where users should make connections.
- Be careful of the line voltage input, motor output and shunt terminals. High voltage is present when power is applied to the drive.
- DO NOT use the ENABLE input as a safety shutdown. Always remove power to a drive before maintaining or repairing the unit.

Theory of Operation 2

Discussion of drive technologies.

Axiom DV series brushless motor drives are state-of-the-art Vector drives designed to drive three-phase brushless servo motors. These drives offer several performance improvements over conventional "six-step," "trapezoidal," or "sine" commutation brushless servo drives.

Three-Phase Brushless Motors

Three-phase brushless servo motors employ a three-phase, wye-connected motor winding wound on the stator, or stationary outer part of the motor. The rotor has permanent magnets installed. A two-pole motor has one North-South pole pair (two poles) and a four-pole motor has two North-South pole pairs (four poles).

There are several advantages to this configuration over a conventional DC brush commutated servo motor.

- Because the windings are wound on the stator rather than the rotor (armature), much better heat transfer occurs between the heat generating windings and the outside environment. This allows a more powerful motor to be built in a smaller package without encountering overheating problems.

- Because only the relatively small magnets are mounted on the rotor, brushless servo motors can be built with much lower rotor inertia than brush motors. This facilitates higher bandwidth response and enables motors with much higher maximum speeds to be built economically.

- As the name implies, these motors are brushless. This means there are no motor brushes to wear out. This translates into less maintenance. In fact, there is no reason why a properly sized brushless servo motor cannot provide years of maintenance-free operation.

As with most technological improvements, there are some disadvantages or difficulties inherent in brushless servo motor technology. The primary one is the need for more sophisticated drive technology to electronically commutate the motor.

Commutation

Any time electrical current flows in a wire or coil of wires, a magnetic field is created. In a motor, this magnetic field is used to generate torque at the motor shaft output. In a permanent magnet motor, this occurs when a magnetic field caused by current flowing in the motor windings attracts the permanent magnets in the motor.

Maximum torque is generated when the internal magnet is field generated by the motor windings is at right angles (90°) in relation to the permanent magnet's magnetic field. By controlling the magnitude and direction of the current flowing in the motor windings, the magnetic field generated by them can be made to rotate around the motor axis. The attraction between this rotating field and the permanent magnet's magnetic field is what causes motor shaft rotation.

The necessary switching of current between the motor windings to cause this magnet field rotation is what is referred to as *commutation.* This switching can be done electronically or mechanically.

In a conventional DC brush servo motor, this switching is done mechanically. By incorporating a number of motor windings with their current switched through carbon brushes riding on copper commutation bars, effective commutation is accomplished at speeds (typically) of 4000 RPM or less. The servo drive is only required to control overall current.

Brushless servo motors are a better choice when higher speed, rapid acceleration, higher bandwidth and compact size are needed. They are commutated electronically. By controlling the magnitude and direction of current in the three phase windings, high bandwidth speed and torque control can be accomplished. This means the motor drive must control both the commutation and the motor current to provide servo performance.

BRUSHLESS SERVO DRIVES

In order to provide servo performance with permanent magnet brushless servo motors, several different commutation and current control schemes have been used. These can be grouped into four main types: Six-Step Drives, Trapezoidal Drives, Sine Commutation Drives, and Vector Drives. Axiom drives are vector drives.

Six Step Drives

A six-step drive incorporates the simplest approach to brushless motor commutation. This drive type uses Hall Effect sensors in the motor to trigger one of six commutation states. These states are accomplished by alternately connecting each motor leg to bus positive, off and bus negative. By offsetting the cycle on each leg by 120° electrically (60° of shaft rotation for a four-pole motor), six switching states are generated. These switching states can also be referred to as *voltage vectors.*

This commutation generates the rotating magnetic field necessary for motor shaft rotation. However, since there are only six voltage vectors applied, the field rotates in steps. This means its magnetic field is not at a right angle to the rotor magnet’s field at all times. This causes the torque to vary as the motor rotates. This phenomena is referred to as *torque ripple.*

Because the magnetic fields are not at right angles at all times, some of the motor current does not produce torque. This current still heats the motor windings, causing excess heat to be generated in the motor.

Current control in these drives is closed loop, but only for total motor current. Since current is not controlled in each motor phase, minor winding variations can lead to currents that do not distribute exactly as intended in the three motor phases. This leads to some additional torque ripple.

Also, since only overall motor current is controlled, there will always be a growing amount of “phase lag” as the motor speed increases. This is due to the fact that each motor leg acts as a series R-L circuit electrically (Resistive-Inductive). Any time voltage is changed in an R-L circuit, the current change lags due to inductive reactance. The effect of this is that, with increasing speed, the generated current vector lags behind the commanded voltage vector by an increasing amount. This causes the torque to roll off with speed, even though the motor current remains constant.

Trapezoidal Drives

In an effort to improve on the limitations of a six-step drive, the trapezoidal drive was developed. It's commutation scheme is improved somewhat by ramping down and ramping up the voltage vectors near the Hall Effect sensor transition points. The current waveform on each leg has a trapezoidal shape, hence the name.

These drives have less torque ripple than six-step drives, especially when used with motors designed for use with trapezoidal drives. Since current control is closed loop on a total motor current basis, the same tolerance and phase lag issues remain.

Sine Commutation Drives

By employing more modern microcontroller technology to brushless servo drives, sine commutation can be achieved. This type of drive uses resolver or encoder feedback to determine the rotor position angle. This information is used to look up sine function values in a lookup table in the drive's microcontroller memory. By applying three 120° spaced sine based voltage vectors to the three motor legs, a rotating voltage vector can be applied at any angle relative to the motor's axis. Ideally, this commutation scheme produces sinusoidal current waveforms on each of the three motor phases. Since this waveform closely matches the motor's back EMF waveform, torque ripple is dramatically reduced.

In addition to better commutation, most sine commutation drives use microcontroller or DSP (Digital Signal Processor) technology to implement their control loop filters digitally. This eliminates potentiometer tuning and problems associated with analog circuit drift and aging. This same technology allows implementation of other features not possible in drives without the computing capability of these more modern drives.

Though these drives are a considerable improvement over older brushless servo drive technologies, they still suffer some limitations. The most significant are reduced bus voltage utilization and lack of individual motor phase current control.

By using the sine table lookup calculation for commutation, only 75% of the available bus voltage can be effectively used. Though no drive can achieve 100% utilization of available bus voltage, a sine commutation drive sacrifices more maximum speed at a given motor torque than other drive technologies. This is the price paid for achieving low ripple motor torque.

The other limitation of these drives is the same as the older drive types. Because the traditional sine drive commutation does not resolve individual motor leg currents, it is subject to the same tolerance-induced torque errors (ripple) and the same phase lag issues.

Since phase lag is such a major problem at higher speeds, many drives attempt to solve the phase lag problem by introducing a "phase advance" factor into their voltage vector calculation. This advances the three rotating voltage vectors by an amount equal to the expected current phase lag for a given speed.

In a perfect world, this voltage vector phase advance would accurately compensate for current phase lag. In the real world, however, factors such as motor winding resistance and inductance tolerances come into play. Also, variations in motor back EMF, cable resistance and winding resistance changes due to temperature all add variability to the actual current vector produced in any given motor at a given speed. Consequently, any phase advance factor is only a "best-guess" value. Due to these tolerance issues, there will still be some phase current error in any real motor drive combination. This will result in some loss of torque at higher speeds, additional motor heating and torque variability with current (ripple).

Some of the most modern sine commutation drives attempt to solve these problems by taking individual current phase readings and running multiple current loops. These drives attain a higher level of performance than traditional sine drives, but still do not provide the full closed loop control of TORQUE PRODUCING current possible with state-of-the-art vector drives which thereby provide higher efficiency and high bandwidth torque response over the full speed range.

Vector Drives

The term *Vector Drive* refers to a class of drives that sense motor current in each individual motor phase and resolves these readings into two current vectors. One vector is the torque producing current (I_q). The other is the waste current (I_d). The current control algorithm then works to drive the non-torque producing component (I_d) to zero. This method gives high bandwidth torque response over the full speed range without the phase lag and tolerance issues that plague older drive technologies.

The technology in these drives is made possible due to the availability of high speed DSP technology. Because the control algorithms necessary for vector drive technology are computationally intense, it was generally not practical to implement them in an affordably priced brushless servo motor drive in the past.

The same DSP technology that makes vector drive technology a reality in all *Axiom* brushless servo drives, makes all digital control loop tuning and other advanced features practical in all *Axiom* brush and brushless servo motor drives. These drives are designed and built to provide enhanced performance and years of dependable service.

The first performance improvement incorporated into *Axiom DV* series drives is an enhanced commutation scheme known as Space Vector Commutation. This commutation scheme is similar to sine commutation except that it uses a more computationally intense algorithm that gains back some of the bus voltage utilization lost in sine commutation. *Axiom DV* series drives will typically provide 12.5% more speed at a given torque than the theoretical maximum possible with sine commutation.

Furthermore, as a *Vector Drive*, all *Axiom DV* series drives provide closed loop motor control of torque producing current. They accomplish this by first accurately measuring motor current in each motor phase leg 10,000 times each second. This information is used to calculate the actual torque producing current vector being produced in the motor.

Because this is a true vectored closed loop current control system, torque errors due to tolerances and R-L time constant induced phase lag are automatically compensated for in the algorithm. All *Tolomatic MRV* motors can be driven from zero speed to full rated speed with negligible torque ripple or loss of torque due to tolerance or current phase lag issues.

Unpacking, Inspection & Storage 3

Unpacking the Drive

Remove the *Axiom* servo drive from the shipping carton. Retain the shipping materials for storage or in case the unit needs to be returned. Check contents against the packing list. Model number, part number and related information appear on a label on the side of the drive.

Inspection Procedure

To protect your investment and ensure applicable warranty rights, Tolomatic recommends the unit be carefully inspected for any signs of physical damage. If any damage is detected, contact the purchasing agent to make a claim with the shipper.

If any improper performance is detected while testing the unit, contact your Tolomatic distributor to obtain a Return Material Authorization (RMA). Do this as soon as possible after receipt of the unit.

For specific warranty information, refer to *Appendix D* in this manual.

Storage

Store in a clean dry place with humidity between 5% and 95%, non-condensing. Make sure the temperature is between -20° and 70° C (-4° and 158° F).

Physical Mounting of the Drive 4

1. This unit must be mounted in a proper electrical enclosure providing protection to IP54 (protected against dust and splashing water), or IP65 (dust free and protected against water jets) where the environment is poor. Many NEMA (national Electrical Manufacturers Association) Type 4 cabinets provide this level of protection.

2. Size enclosure to provide the following spacing around the drive:

Above and Below	5.1 cm (2 in)
Sides:	1.25 cm (0.5 in)
Front:	7.6 cm (3 in)

CAUTION! If the cabinet is ventilated, use filtered or conditioned air to prevent accumulation of dust and dirt inside the drive. The air must be free of oil, corrosives or electrically conductive contaminants.

3. Position the drive vertically on a flat, solid surface capable of supporting the drive's weight.

4. Bolt the unit to the cabinet using the mounting slots on the drive. Use M5 metric (1/4-20) or #10MS bolts.

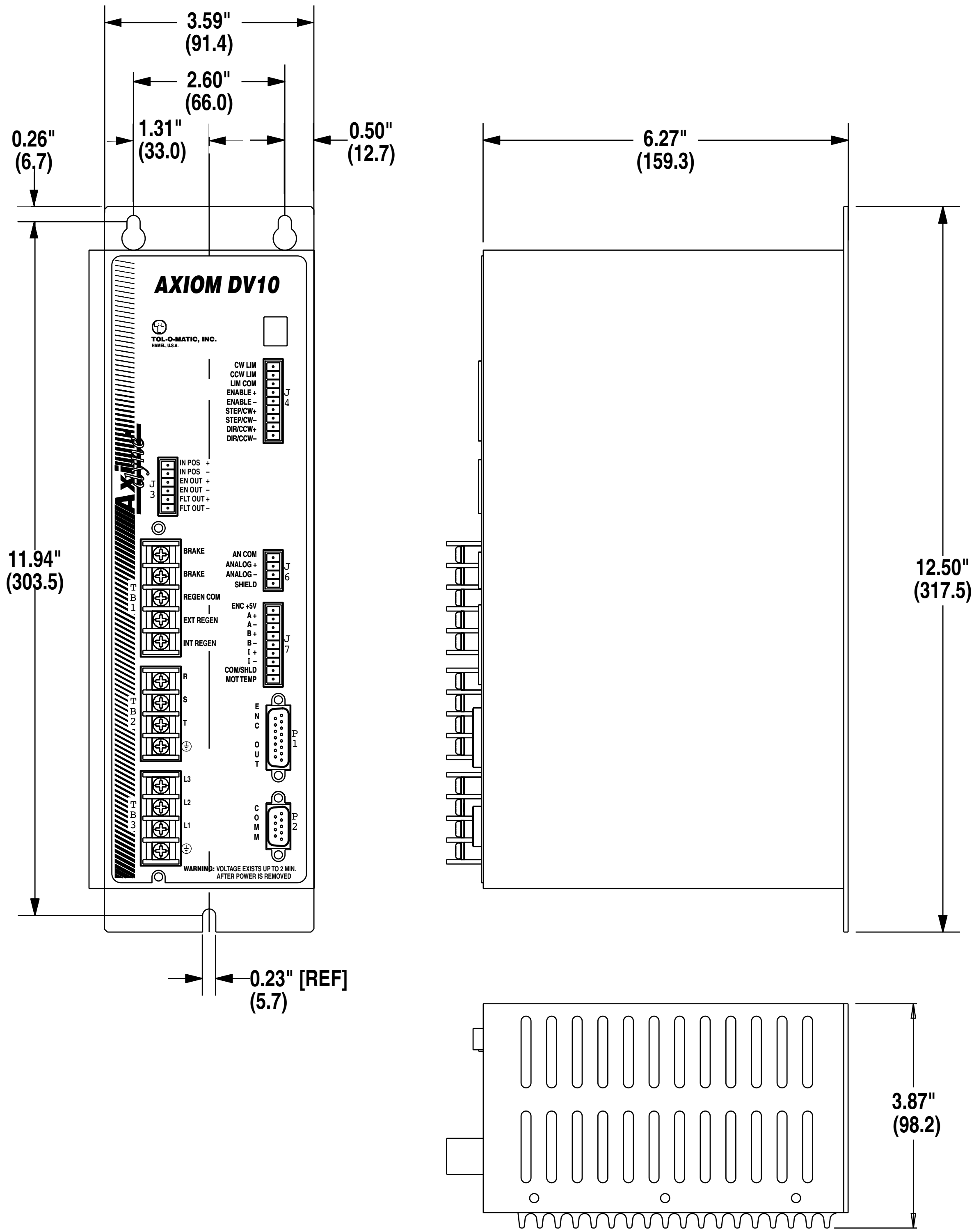


Figure 4.1 - Axiom DV10 Drive Mounting Dimensions

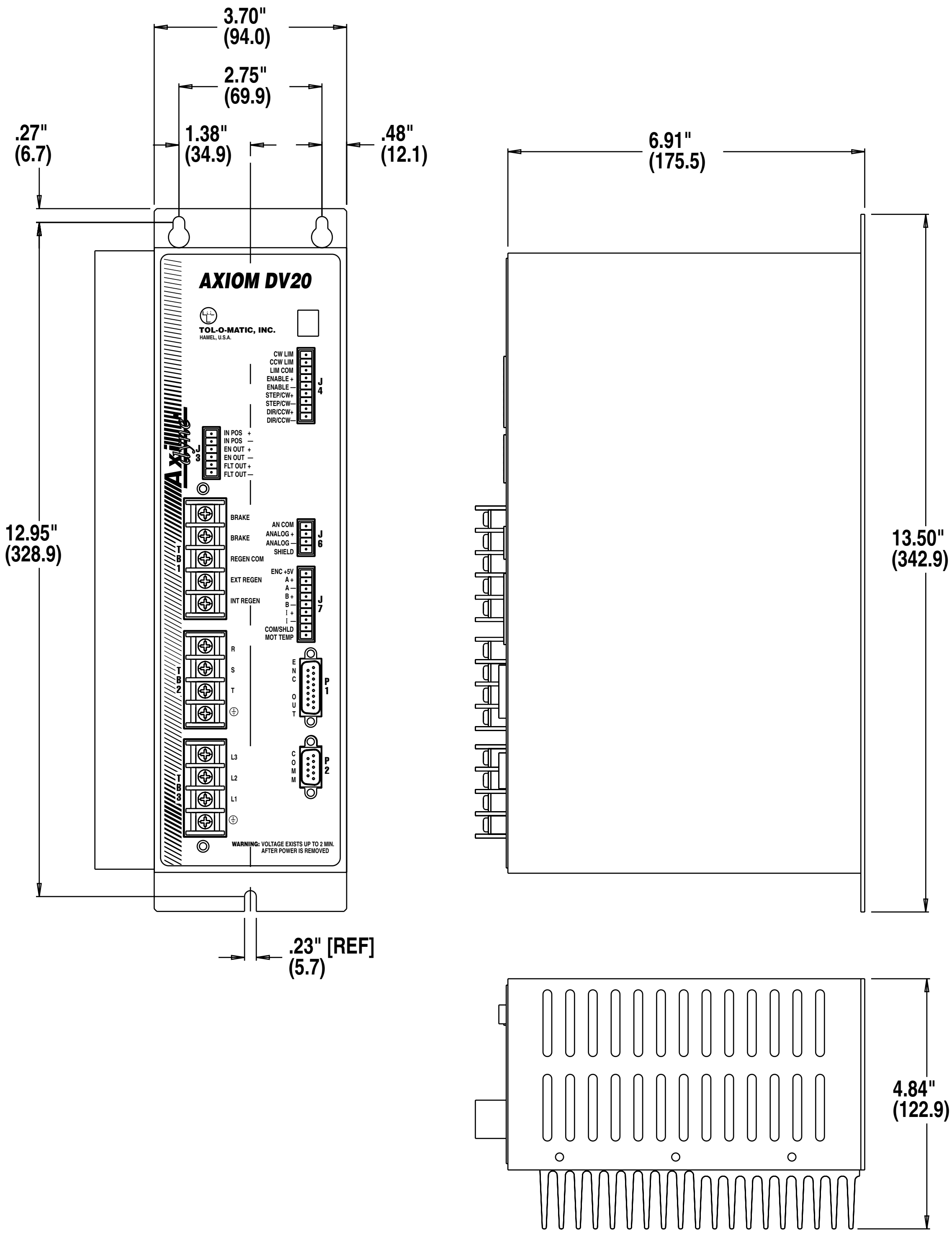


Figure 4.2 - Axiom DV20 and Axiom DV30 Drive Mounting Dimensions

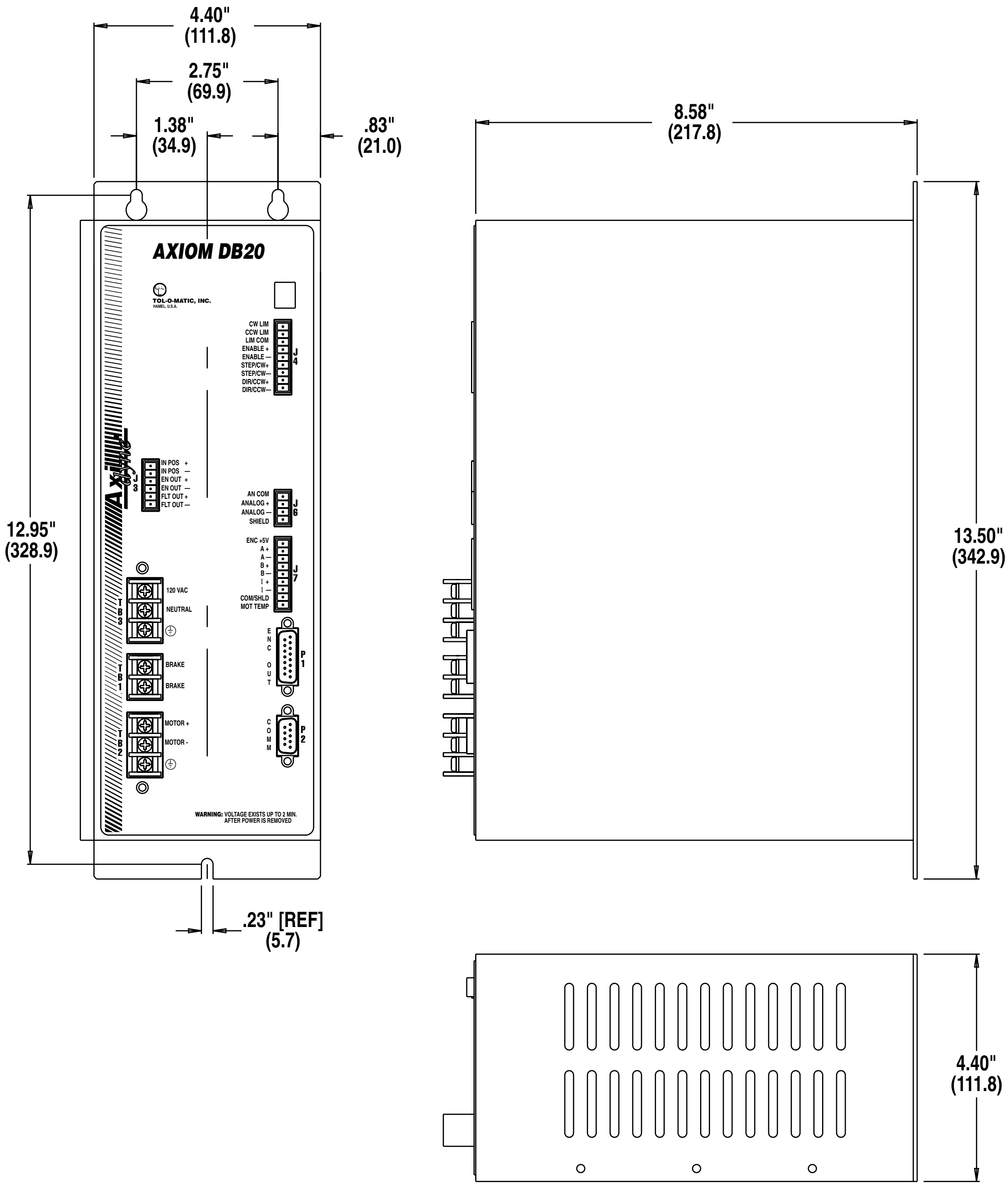


Figure 4.3 - Axiom DB20 Drive Mounting Dimensions

Power Connections & Fusing 5

DANGER! The user is responsible for conforming with all applicable local, national and international codes. Wiring practices, grounding, disconnects and overcurrent protection (fusing) are of particular importance. Failure to observe this precaution could result in severe bodily injury or loss of life.

DANGER! The user is responsible for designing an adequate Emergency Stop (E-Stop) circuit. It is not adequate to depend on the drive enable for an E-Stop. The circuit should remove power from the drive and apply a brake to the motor or load when necessary. Failure to observe this precaution could result in severe bodily injury or loss of life.

CAUTION! Do not tin (solder) the exposed leads on cables. Tinned cables may loosen in screw terminal connections over time.

General Wiring Guidelines

It is always best to keep power wiring separate from control wiring. Properly terminated shielded cables for control wiring will help ensure minimal interference problems, but should be combined with good wire routing practice to ensure optimum results.

Power and control wiring should be run in separate conduit or wiring trays with as much separation as is practical to achieve. When power and control cabling needs to cross, it should be done at right angles.

Analog torque or velocity command signals are the most susceptible to interference from 50/60Hz power wiring. However, encoder and other control wiring can pick up interference from the 50/60Hz power itself or transient energy present on the power lines. This transient energy is most often caused by relays and contactors, other motors and their drives and welders in a typical industrial environment.

Where a great deal of interference is present on the power lines, a line filter may be necessary. Choose one with the appropriate voltage and current rating for the drive. Also, follow the manufacturer's recommendations for installations. This must include a proper ground. A line filter will also help prevent the motor drive from putting excessive interference back onto the power feed.

Axiom DV10, Axiom DV20 & Axiom DV30 Brushless Servo Motor Drives

Axiom Brushless Servo Motor Drives operate from single or three phase power, 50/60Hz. Nominal input ranges are 115Vac or 208/230Vac. The switch on top of the drive should be set to reflect the proper range. Motor performance is dependent on input voltage. Refer to motor/drive performance curves in *Appendix C* for performance information. Refer to Appendix B for input power requirements and fuse accordingly. The use of properly sized time delay fuses will minimize any nuisance trips due to inrush current at power up.

Axiom Brushless Servo Motor Drives are designed for direct connection to the ac power mains. No isolation transformer is necessary.

NOTE: It is always advisable to use three phase power whenever available. Three phase power will ensure a minimum of motor bus voltage ripple. This will provide for the smoothest possible motor torque and help ensure maximum life of the internal bus capacitors. It may also aid in plant power distribution.

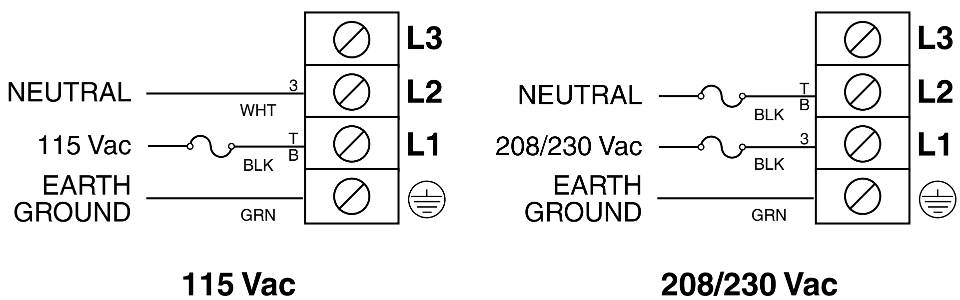


Figure 5.1 - Axiom DV10/20/30 Single-Phase Drive Power Connections

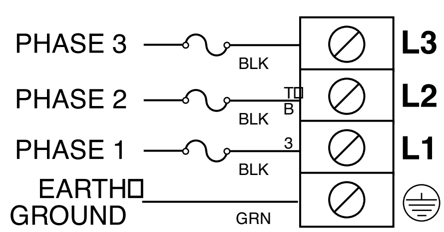


Figure 5.2 - 208/230 Vac Three-Phase; Axiom DV10/20/30 Three-Phase Drive Power Connections

Axiom DB20 Brush Servo Motor Drives

Axiom Brush Servo Motor Drives require single phase power, 50/60Hz. Nominal input voltage is 115Vac. These drives have a self contained isolation transformer to simplify installation and use a minimum of total electrical enclosure space.

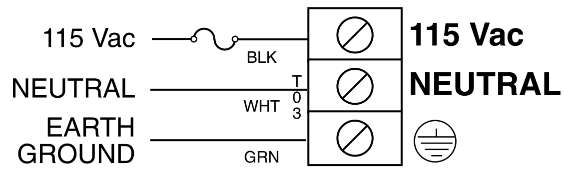


Figure 5.3 - Axiom DB20 Drive Power Connections

Fusing

The value of maximum line-current the drive can draw peaking is important for properly selection of short circuit fuse/breaker selection.

DV10 full-load nominal line current (rms):
- Single-phase: 12.5 amps
- Three-phase: 7.5 amps per phase

DV20 full-load nominal line current (rms):
- Single-Phase: 25.0 amps
- Three-phase: 15.0 amps per phase

DV30 full-Load nominal line current (rms):
- Single-phase: 37.5 amps
- Three-phase: 22.5 amps phase

DB20 full-Load nominal line current (rms):
- Single-Phase: 10 amps

If fuses are used, the fuse class should exhibit a time-delay blow characteristic suitable for high inrush currents and motor-starting loads. If magnetic circuit breakers are used, they must have long trip-delay times.

Motor Encoder & Power Connections 6

This chapter contains information about proper connection of motor power and encoder wiring. For additional information on Tolomatic motor performance specifications please refer to *Appendix C.*

WARNING! Never connect or disconnect motor power connections when power is applied to the drive. To do so could cause electrical shock or result in severe arcing and may damage the motor or drive.

CAUTION! Proper phasing of the drive outputs relative to the motor terminals is critical. Double check the connections after wiring the motor.

CAUTION! Do not tin (solder) the exposed leads on cables. Tinned leads will loosen in time and may come loose from their screw terminal connections.

General Wiring Guidelines

It is always best to keep motor power wiring separate from control wiring. Properly terminated shielded cables for motor power and control wiring will help ensure minimal interference problems, but should be combined with good wire routing practice to ensure optimum results.

Motor power and control wiring should be run in separate conduit or wiring trays with as much separation as is practical to achieve. When motor power and control cabling needs to cross, it should be done at right angles.

All power cables should be copper conductors rated 60°C minimum and should be tightened to the terminal blocks with 9 in.•lbs. of torque.

Axiom Brushless Servo Motor Drives

Axiom brushless servo drives are designed to drive three phase brushless servo motors. For proper operation, the motor must be connected to the drive in the proper phasing sequence.

MRV 1X Motor

MOTOR CONNECTOR PINOUT	
RED	PHASE R
WHT	PHASE S
BLU	PHASE T

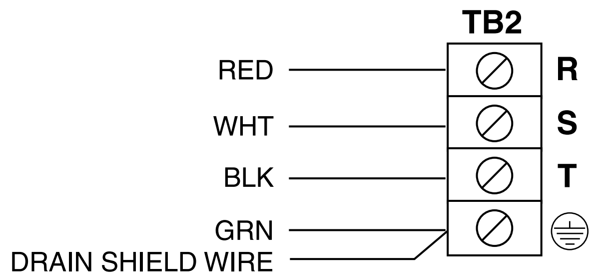


Figure 6.1 - DV10/20/30 Motor Power Cable Connections for MRV 2X, 3X, 5X

Proper encoder phasing is necessary for proper motor operation. The following color codes apply to Tolomatic cables.

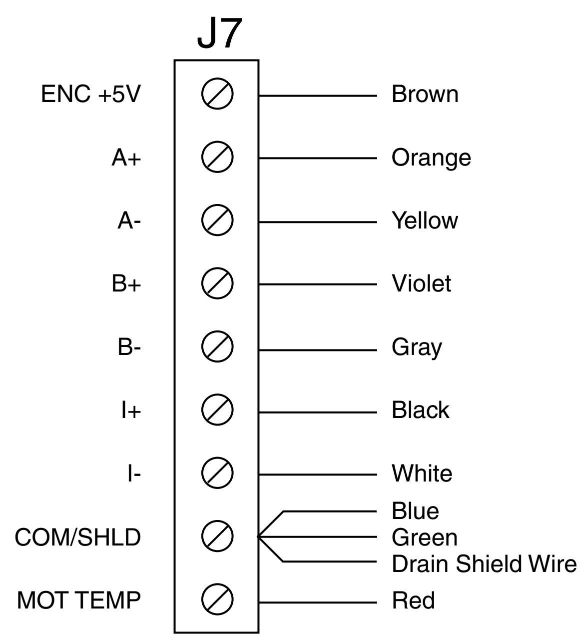


Figure 6.2 - DV10/20/30 Motor Encoder Connections

Axiom Brush Servo Motor Drives

Axiom brush servo motor drives are designed to drive conventional brushed DC permanent magnet motors. For proper operation, the motor must be connected in the correct polarity.

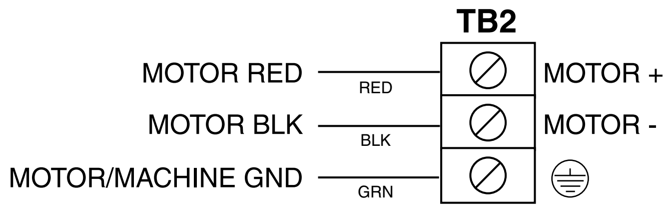
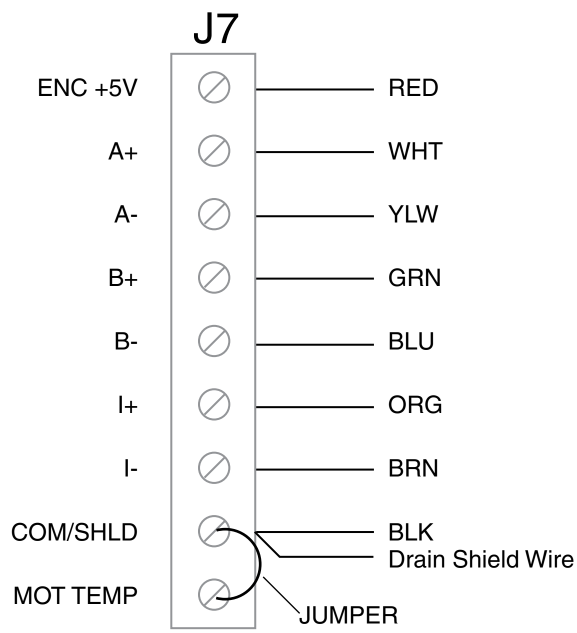


Figure 6.3 - DB20 Motor Power Connections

Proper encoder phasing is necessary for proper motor operation. Figure 6.4 shows the color codes for encoders supplied on Tolomatic MRB series brush motors.



NOTE: Tol-O-Matic MRB brush servo motors do not include a thermal switch. Place wire jumper between COM/SHLD and MOT TEMP terminals. The drive's I^2T motor protection is still active to provide motor over-heating protection.

Figure 6.4 - DB20 Motor Encoder Connections

Emergency Stop Connection

Emergency stop can be implemented in a number of ways depending on the application requirements. In most cases, the best method is to simply break power to the drive.

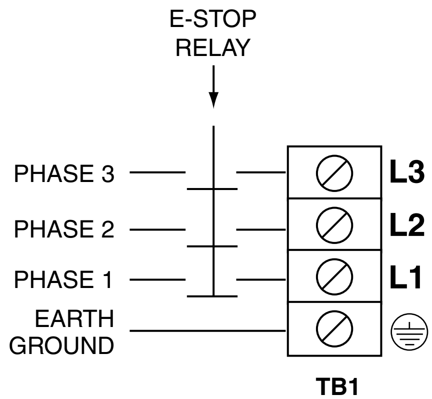


Figure 6.5 - Special E-Stop Connections

A few applications require that the drive or a controller maintain encoder feedback information after an E-stop.

In the first case, the emergency stop needs to disable the drive, then break the connection from the drive to the motor. The drive remains powered so that it maintains its phasing information. The buffered encoder output can be used to connect to a motion controller.

When recovering from the emergency stop condition, it is important to reconnect the motor to the drive before enabling the drive. Failure to do this will result in the drive entering a fault condition.

WARNING! While in the emergency stop condition, the motor may move out of position and cause a large following error to accumulate in the controller. It is the users responsibility to ensure that this is accounted for so that a large jerk that could cause damage or injury does not occur when the drive is enabled.

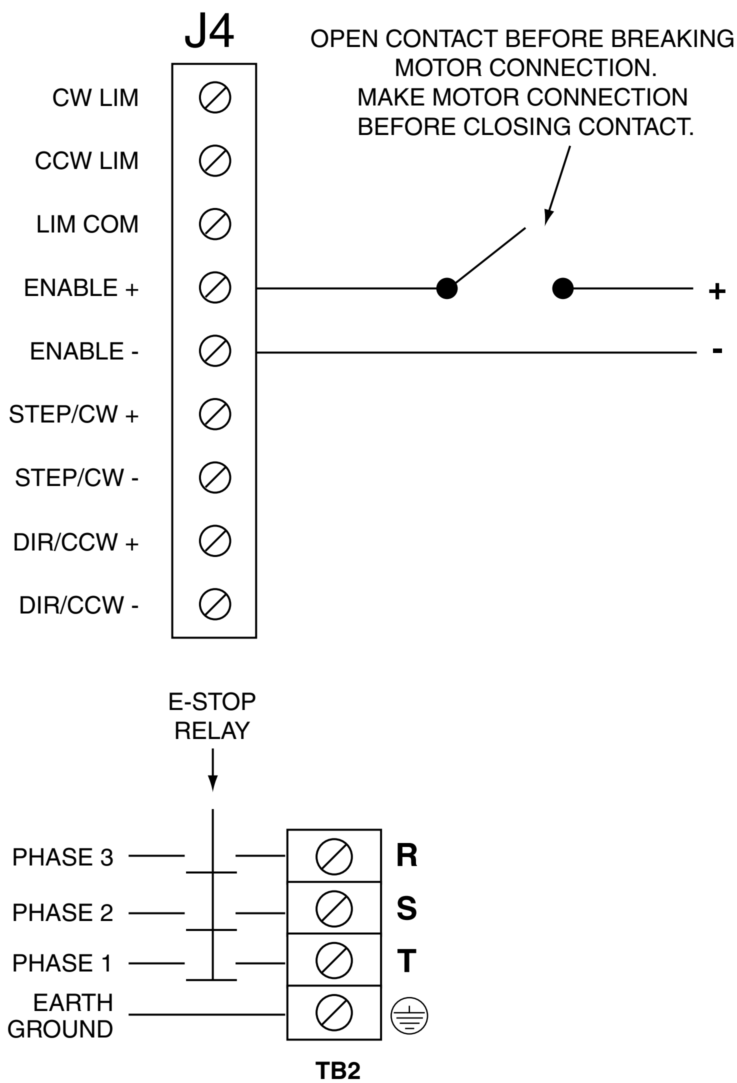


Figure 6.6 - Drive remains powered

In the second case, the encoder is powered from the motion controller. The encoder signal and common connections ONLY are made to the drive. Power is removed from the drive during an emergency stop. Upon reapplication of power, the drive will need to rephase the motor when it is enabled for the first time.

WARNING! While in the emergency stop condition, the motor may move out of position and cause a large following error to accumulate in the controller. It is the users responsibility to ensure that this is accounted for so that a large jerk that could cause damage or injury does not occur when the drive is enabled.

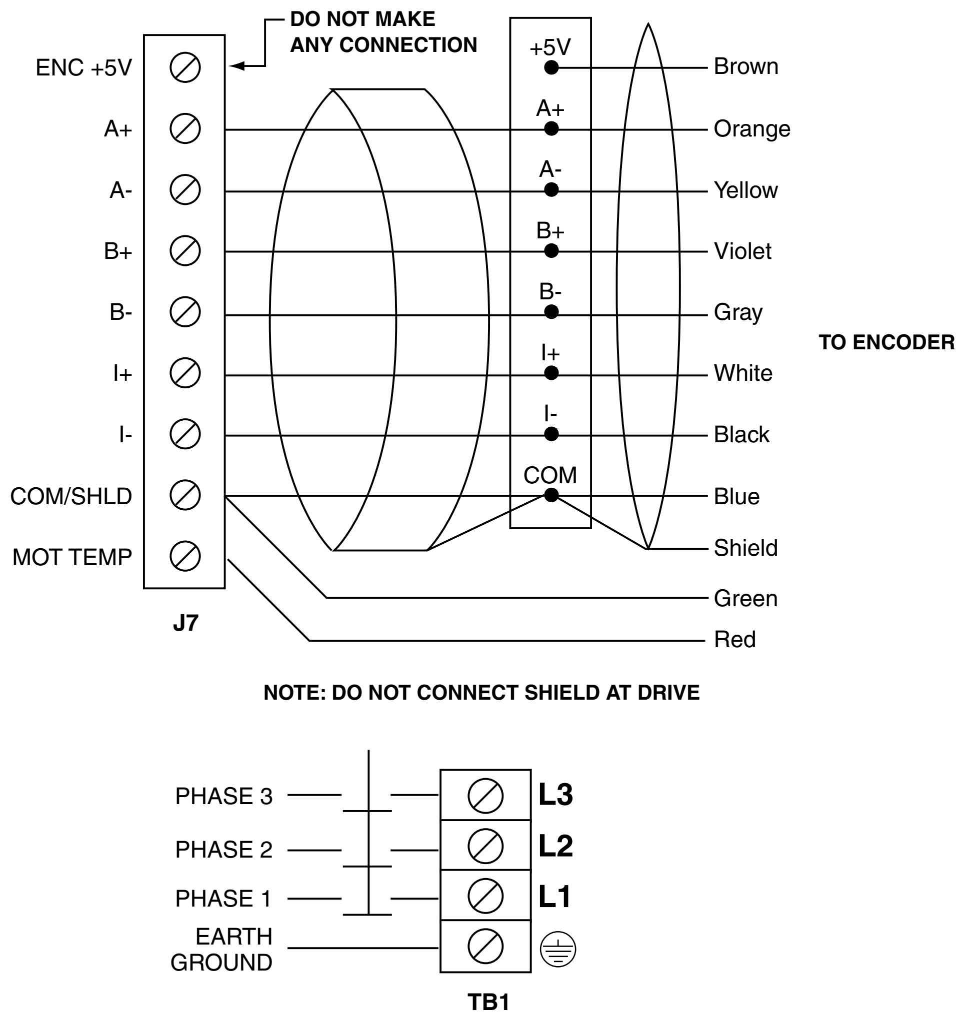


Figure 6.7 - Encoder powered from the motion controller

Software Installation 7

This chapter provides information about installation of Axiom software on a personal computer.

Hardware and Software Requirements

- A personal computer running Microsoft Windows 95, 98 or NT
- A hard disk with 10 MB of free disk space
- A drive capable of reading a CD-ROM disc or internet connection

Installation

1. Make a backup copy of the Axiom disc
2. Close all Windows® programs.
3. Insert the disk in the drive.
4. Choose Run from the File menu.
5. Type **A:setup** at the prompt.
6. Follow the screen prompts until installation is complete.

Initial Check Out 8

It is strongly recommended that an initial check out be performed on the motor-drive combination at this time. This should be done with the motor disconnected from the load. This procedure will guarantee that the correct motor is chosen and that it is connected and phased properly before proceeding further.

Check Out Procedure

1. Recheck power, motor and encoder connections to make sure all are correct.

2. Apply power to the motor drive. If the drive has NOT yet been configured, it should flash an “F-99” fault code. If it HAS been configured, it should display the letter “d” on the status indicator.

3. Open the Axiom setup software. The setup software main screen will appear (see Figure 8.1).

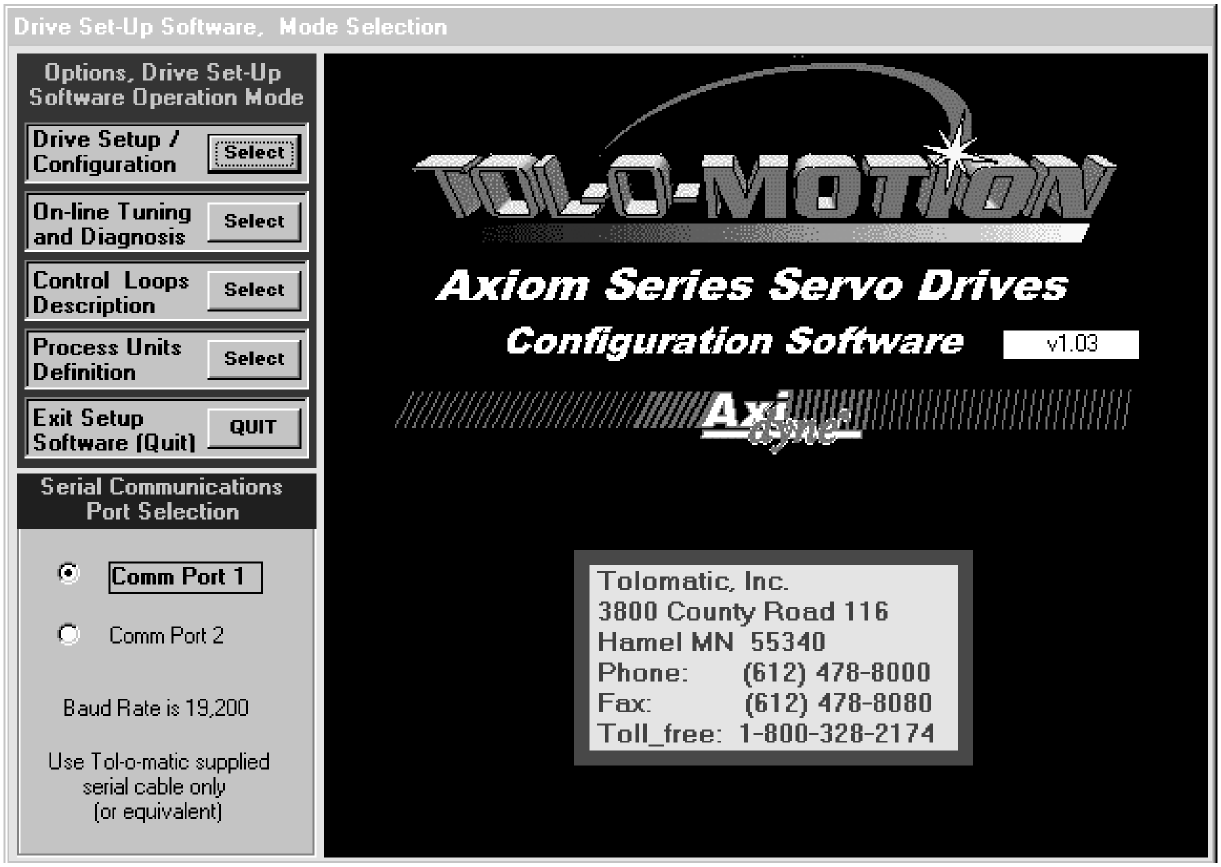


Figure 8.1 - Axiom Setup Software Opening Screen

4. Connect the serial communications cable from a spare serial port on your computer to the COMM connection (9-pin D-sub connector) on the drive.

5. From the opening screen, select COMM PORT. Then choose “Drive Setup Configuration” (see Figure 8.2).

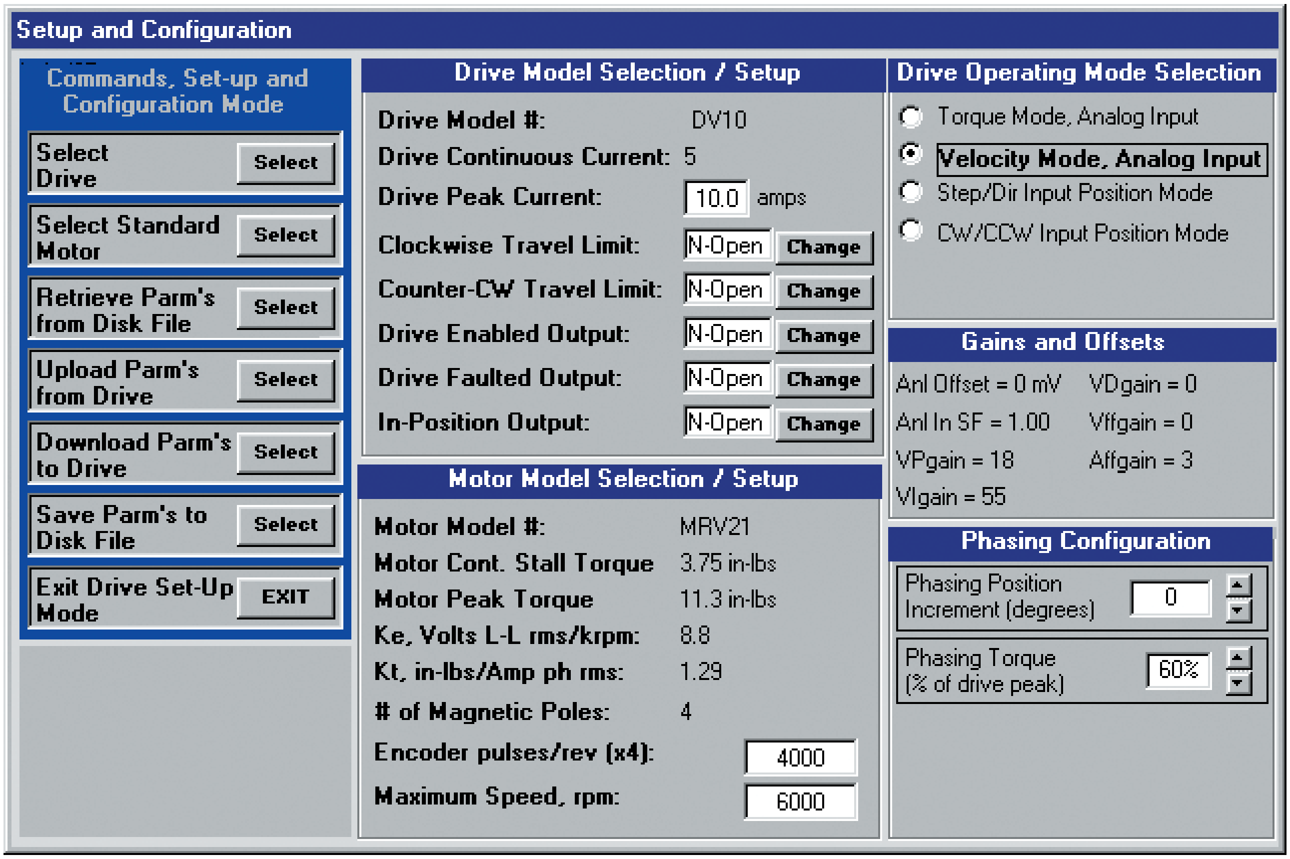


Figure 8.2 - Drive Setup Screen

6. Select “Upload Parm’s from Drive.” After a few seconds, the message “Upload Complete” should appear on the screen. The first time this is done, placeholder parameters will be displayed.

7. Choose the correct Tolomatic motor from the list displayed.

8. Choose the desired mode of operation (Torque Mode, Velocity Mode, etc.).

9. Choose whether the travel limit switches are normally open (N.O.) or normally closed (N.C.).

10. Choose whether the drive enabled, drive faulted and in-position output

will be normally open or closed.

11. Choose the desired input pulse multiplier when using step/dir or CW/CCW mode. The Input pulse multiplier is used when the stepper controller does not have a high enough pulse rate to reach desired speed.

12. If the actuator has high friction or has large overhung (vertical) load, the PHASING TORQUE can be increased. This will cause more motor movement when the drive "phases" when first enabled after power up. If the load is not vertical and the actuator is low friction, the phasing torque may be left at the default setting.

13. If the load always comes to rest at one end of travel (as in a back driving vertical load with no brake) the PHASING POSITION control should be used to bring the load off the end of travel limit when the motor phases. The units are in degrees of motor rotation. Positive (+) rotation corresponds to CW motor shaft rotation.,

14. Select "Download to Drive." After a few seconds, the message "Download Complete" should appear on the screen.

    NOTE: If the motor is a brush motor, skip Step 11.

15. The drive is now configured and ready to run. Remove power and connect the motor to the load.

I/O Connections 9

This chapter describes the dedicated I/O connections for the Axiom series of drives. Following is a list of these I/O and a description of their functions.

I/O Terms & Descriptions

OUTPUTS

ENABLED (+ and -) This is an optically isolated NPN transistor output capable of switching 50 mA at up to 25Vdc. It goes active anytime the drive's enable input is active, there are no faults and the drive is initialized and accepting input commands.

FAULT OUT (+ and -) This is an optically isolated NPN transistor output capable of switching 50 mA at up to 25Vdc. It goes active whenever the drive is in any fault condition.

IN POSITION (+ and -) This is an optically isolated NPN transistor output capable of switching 50 mA at up to 25Vdc. It goes active anytime the drive is "In Position" as defined in the setup software. This is useful in applications where the controller is not getting encoder feedback, yet needs to know when the drive has finished a move.

INPUTS

CW LIMIT This is an optically isolated input that goes active when the End of Stroke CW LIMIT switch is made. This inhibits any further CW direction command as long as this input is active. The drive will display an "L-0-1" code when this input is active.

CCW LIMIT This is an optically isolated input that goes active when the End of Stroke CCW LIMIT switch is made. This inhibits any further CW direction command as long as this input is active. The drive will display an "L-0-2" code when this input is active.

Limit Common Common connection for the LIMIT inputs. If connected to a positive 5 - 25Vdc, the LIMIT inputs will be sourcing. If connected to the negative side of a 5 - 25Vdc supply, The LIMIT inputs will be sinking inputs.

continued

ENABLE (+ and -)	When active, it enables the drive. When inactive, it disables the drive. The drive displays a “d” when disabled and an “E” when enabled if no faults or status conditions are present.
STEP (+ and -)	This input works with the DIRECTION input. It is designed to accept a 5Vdc step signal from a stepper motor type indexer. This can also be used as the STEP CW input.
DIRECTION (+ and -)	This input works with the STEP input. It is designed to accept a 5Vdc direction signal from a stepper motor type indexer. It can also be used as the STEP CCW input.
MOTOR TEMP	This is a normally closed contact input. When this connection is broken, the drive will fault and generate a motor temp fault indication. If this feature is not used, a jumper must be connected between the MOT TEMP and COM/SHLD terminals of J7.

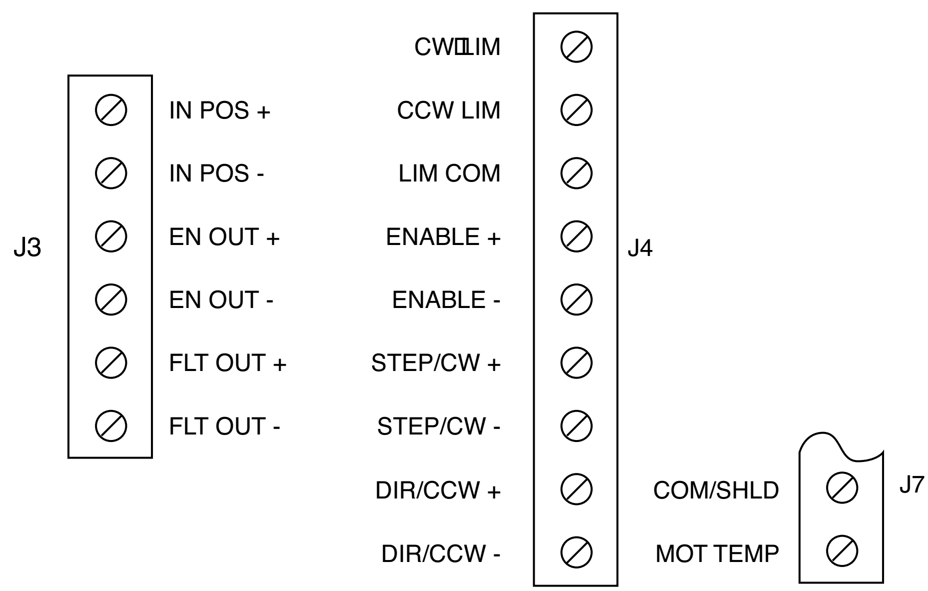


Figure 9.1 - I/O Connections

Enabled, Fault Out and In Position Output Connections

The Axiom series drives provide three dedicated outputs to allow the controlling PLC or Motion Controller to monitor the drive's status. They are the ENABLED, FAULT OUT and IN POSITION connections.

All of these outputs are opto-isolated NPN transistors. They can work with power supplies up to 25Vdc and can switch up to 50 mA of current. It is not necessary to use any of these outputs for the drive to function with a controller. However, they are often useful in setting up a system that functions safely, predictably and reliably.

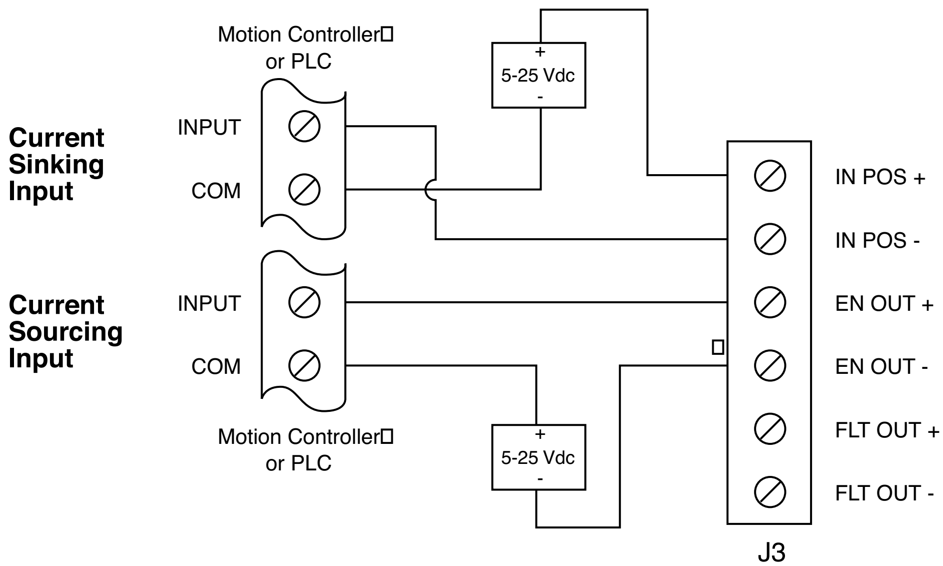


Figure 9.2 - Dedicated Output Connections

Limit Switch Connections

Refer to Figure 9.3 (next page)

The Axiom series servo motor drives are designed to be used with CW and CCW travel limit switches to help protect the motor and actuator from damage in the event of a "crash" at either end of travel. Normally Open (N.O.) or Normally Closed (N.C.) switches can be accommodated. The type of switch is chosen in the setup software.

The Axiom drive's Travel Limit Inputs are optically isolated and can be configured to source or sink current. This is accomplished by connecting the LIMIT COMMON connection to the positive power supply voltage for sourcing, or by connecting to the negative power supply voltage to sinking. The power supply voltage is commonly derived from the PLC or Motion Controller that is controlling the Axiom drive.

The Axiom drive's Travel Limit inputs are designed to work with supply voltages from 5 - 25 Vdc. Current consumption will range from 3 mA to 15 mA depending on supply voltage.

Tolomatic supply both Hall Effect and Reed current switches designed to work with Tolomatic linear actuators. Following are sample connection diagrams for all types of Tolomatic switches.

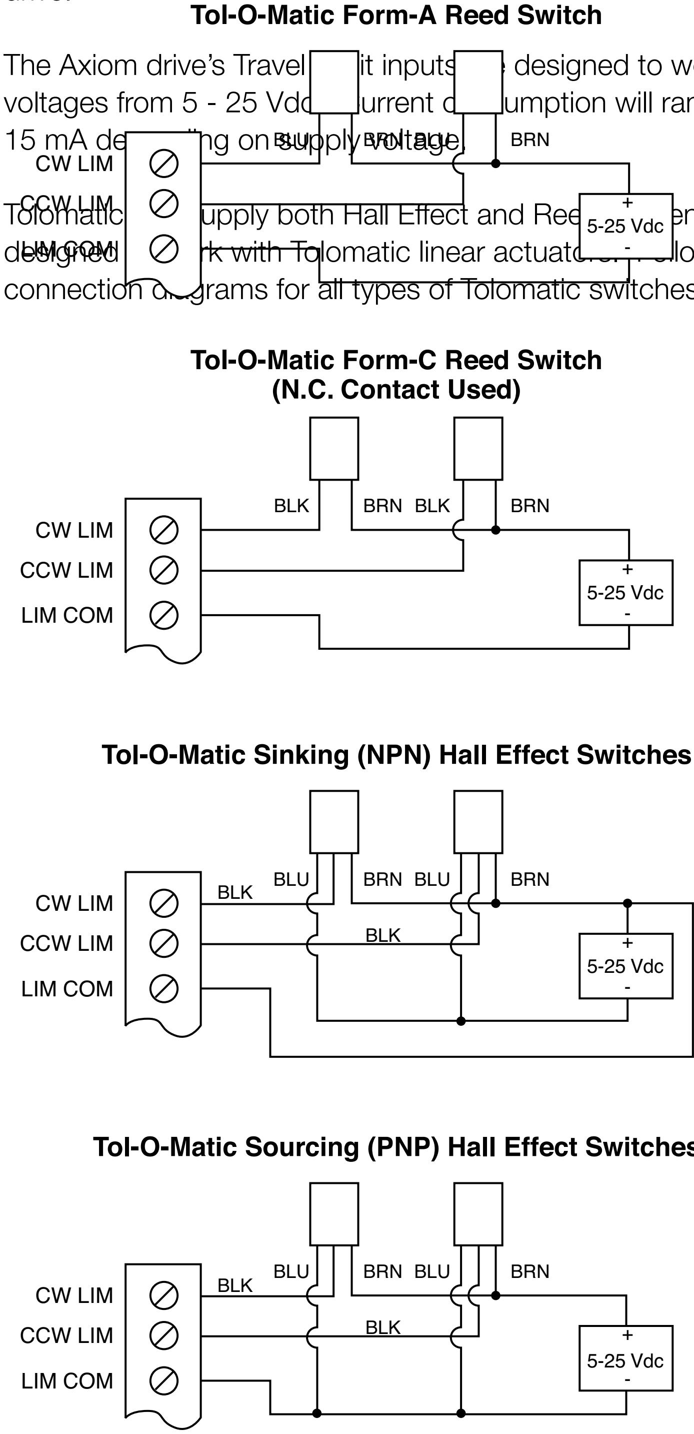


Figure 9.3 - Limit Switch Connections

Enable Input

The Axiom series drives all have an opto-isolated Enable Drive Input that enables the drive for operation when active. When inactive, the drive's output bridge circuit is put into a high impedance state. This causes the motor to enter a "free-wheeling" zero torque output state.

WARNING! The enable input should never be counted on for an emergency stop or to put the system into a "safe" condition. Always remove power from the drive and wait for the time period printed on the front of the drive before servicing the equipment.

Since both the plus and minus connections of the Enable Input are brought out, it can be configured to source or sink current. This input can be used with power supply voltages ranging from 5 to 25Vdc. Input current will range from 3ma to 15ma.

NOTE: It is always good practice for the controller to monitor the enabled output. After asserting the Enable input, the controller should wait for the Enabled Output to go active before applying a command signal to the drive. This will prevent a sudden motor jerk that will result if a command signal is sent to the drive before it is ready to respond.

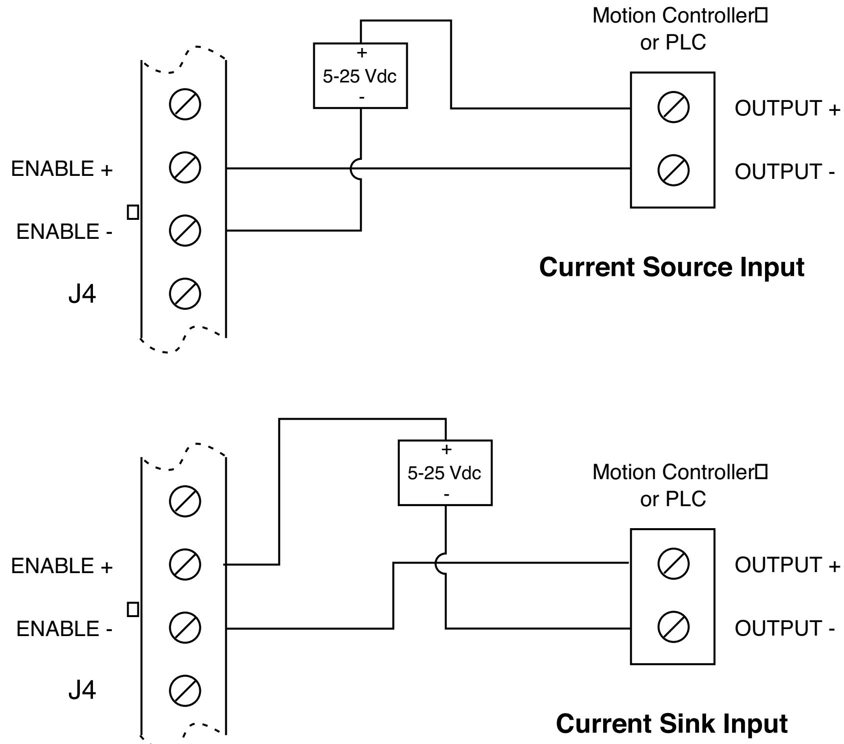


Figure 9.4 - Enable Input Connections

Input Command Connections 10

This chapter contains information on Input Command connections. The drive can operate in several modes: Torque Mode, Velocity Mode, Step/ Direction Mode, and Step CW/Step CCW Mode.

Torque Mode

This mode of operation accepts a +/- 10V torque command signal. This signal would normally come from a single or multi-axis controller with an analog torque command output. Both single ended and differential signals can be accommodated.

When used with a *Tolomatic MRV* motor, the proper range for this signal is automatically programmed by the software. This input can be scaled so that 10V represents from 50% to 200% of the programmed range. This allows flexibility in motor drive setup that may be necessary in some applications.

NOTE: It is important to use shielded wiring for this connection. Electrical noise in this part of the circuit can cause stability problems in the servo system response.

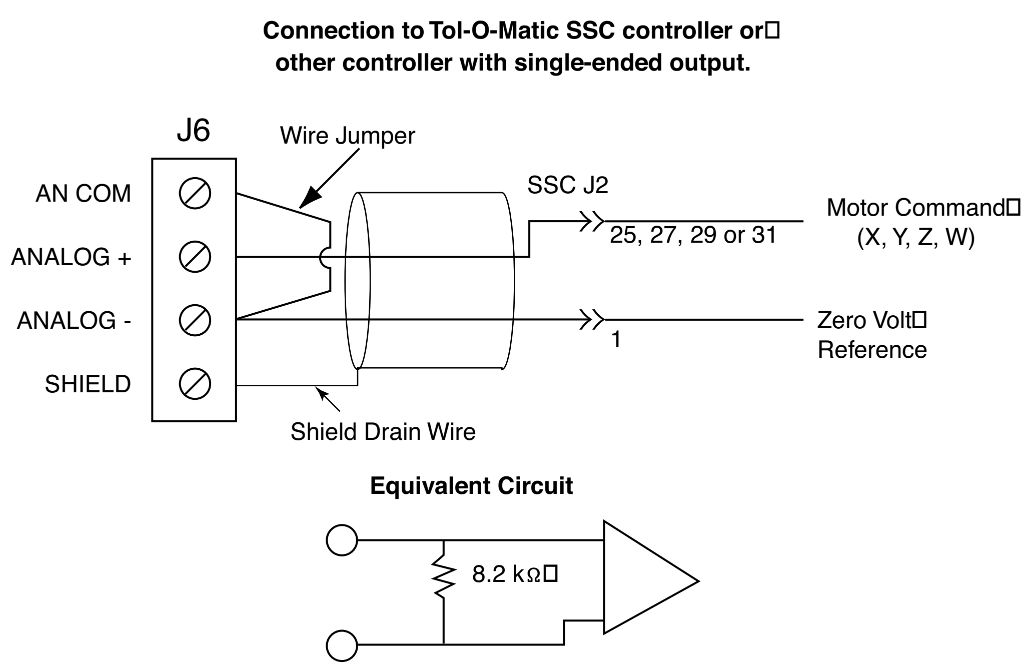


Figure 10.1a - Torque/Velocity Mode Connections

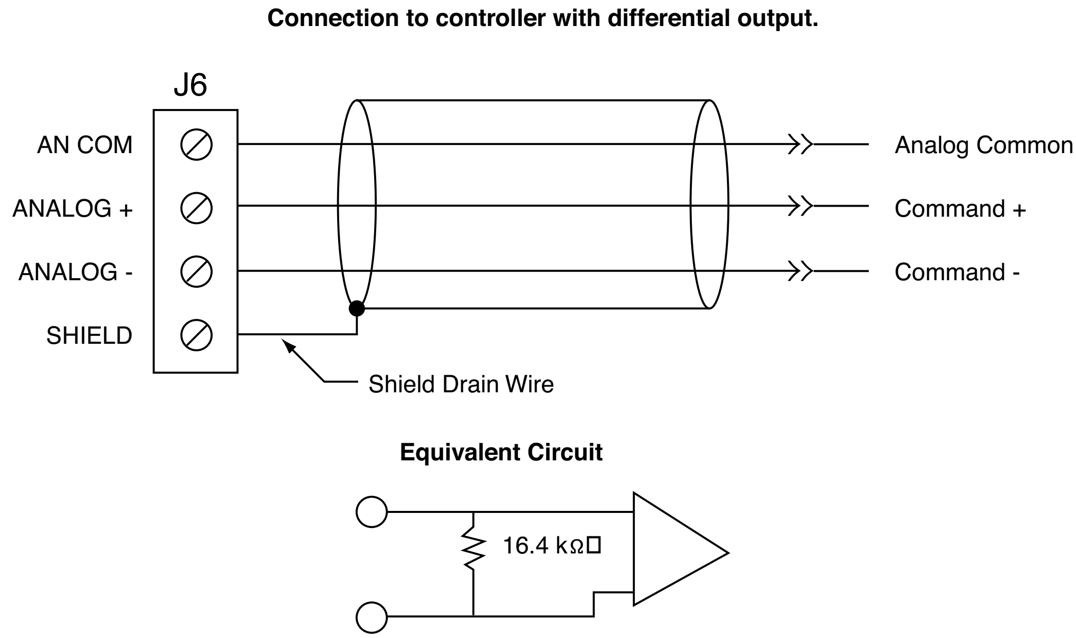


Figure 10.1b - Torque/Velocity Mode Connections (continued)

Velocity Mode

This mode of operation accepts a +/- 10V velocity command signal. This signal would normally come from a single or multi-axis controller with an analog velocity command output. Both single ended and differential signals can be accommodated.

When used with a *Tolomatic MRV* motor, the proper full scale range for this signal is automatically programmed by the software. This input can be scaled so that 10V represents from 50% to 200% of the programmed range. In addition, the full scale range can be reduced via the software in systems where slow operating speed is desired. This allows flexibility in motor drive setup that may be necessary in some applications.

NOTE: It is important to use shielded wiring for this connection. Electrical noise in this part of the circuit can cause stability problems in the servo system response.

Step/Direction Mode

(Refer to Figure 10.2)

This mode of operation accepts 5V step and direction signals commonly available from most stepper motor type controllers. These are optically isolated inputs.

Like all of the operating modes, it is selected through the setup software. In this mode, one “step” corresponds to one quad encoder count. With an MRV motor with the standard 1000 line encoder, this results in 4000 steps for each motor revolution.

Step CW/Step CCW Mode

(Refer to Figure 10.2)

This mode of operation accepts 5V STEP CW/STEP CCW signals available from some stepper motor type controllers. These are optically isolated inputs. The STEP input becomes the STEP CW input, the DIRECTION input becomes the STEP CCW input in this mode.

NOTE: This mode of operation is sometimes referred as STEP UP/ STEP DOWN.

Like all of the operating modes, it is selected through the setup software. In this mode, one “step” corresponds to one quad encoder count. With an MRV motor with the standard 1000 line encoder, this results in 4000 steps for each motor revolution.

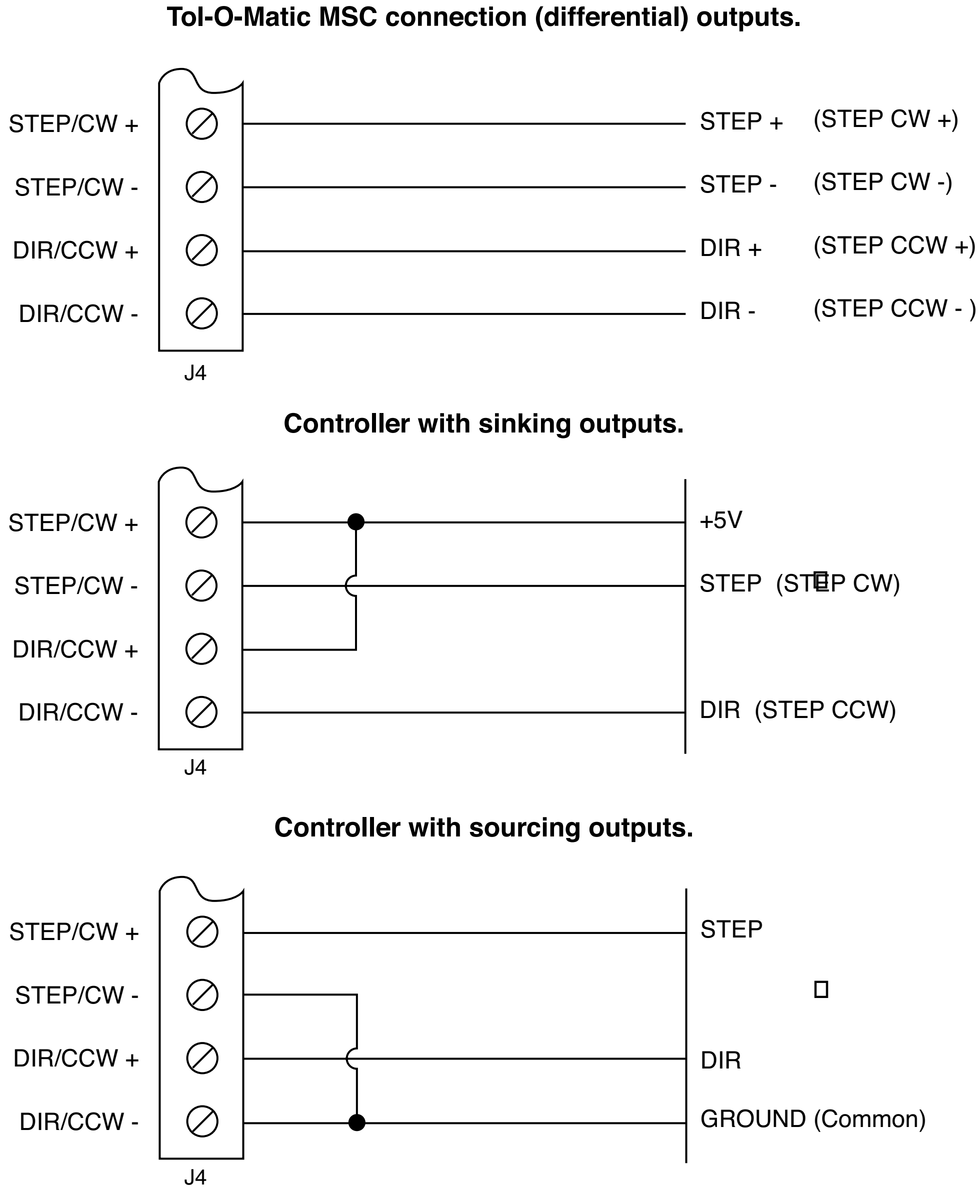


Figure 10.2 - STEP/DIRECTION mode connections.

Brake Connection & Regeneration Resistor Use & Sizing 11

Whenever the load applied to a motor attempts to overtake the motor, the motor starts receiving power from the load instead of providing power to it. It does this by acting as a generator. When it does this it puts power back into the drive's power supply capacitors. This power is pumped back into the motor as soon as it is needed.

Under many applications, some power is pumped back into the drive with each deceleration of the load. As long as this energy does not cause the bus voltage to exceed a safe level, no other form of regeneration is required.

In many horizontal applications where aggressive deceleration is demanded, and in most vertical load applications, the bus voltage would exceed safe levels. In these applications, switching circuitry and a high wattage resistive load are employed to dissipate this excess energy as heat.

All Tolomatic Axiom servo motor drives provide an internal regeneration resistor. In addition, all Axiom DV series brushless servo motor drives provide for connection of a high wattage external resistor pack to accommodate the most severe applications.

The Axiom DB20 has a permanently connected internal resistor. Since it is capable of dissipating the drives full peak load (1800W) and can dissipate 50W continuously, it is capable of handling the regeneration requirements of virtually any application employing Tolomatic MRB motors and Tolomatic actuators.

Since the internal resistors of the Axiom DV series drives can dissipate their drives full peak load, no external resistor pack is required in most applications. A simple rule of thumb is to use the internal resistor for horizontal screw drive actuator applications. Many belt drive and vertical screw drive actuator applications can also use the internal resistor if the duty cycle is low. For high duty cycle or heavy vertical load applications, use an external regeneration resistor.

CAUTION! If bus voltage regeneration causes a drive temperature fault, an external regeneration resistor is needed.

CAUTION! Either the internal or the external resistor pack should always be connected on any Axiom DV series drive application. Never connect both, as this may destroy the internal switching circuitry.

All Tolomatic *Axiom* drives incorporate a brake relay. This is designed for use with an “energize-to-release” type of load brake. The brake relay contacts are rated for 3A. The relay contact is closed (brake released) only when the drive is enabled and not faulted. At any other time, the relay contacts open to apply the brake.

NOTE: Always wire a snubber circuit in parallel with the brake coil unless it has one internally wired. This can be a silicon switching diode for a DC coil brake. An MOV or R-C circuit may be used on an ac coil.

WARNING! Do not connect a jumper wire from REGEN COM to EXT REGEN. Permanent drive damage will result.

WARNING! If external regeneration resistance is necessary - use a resistor of the desired Watt rating and with a resistance value within the range specified in Figure 11.1.

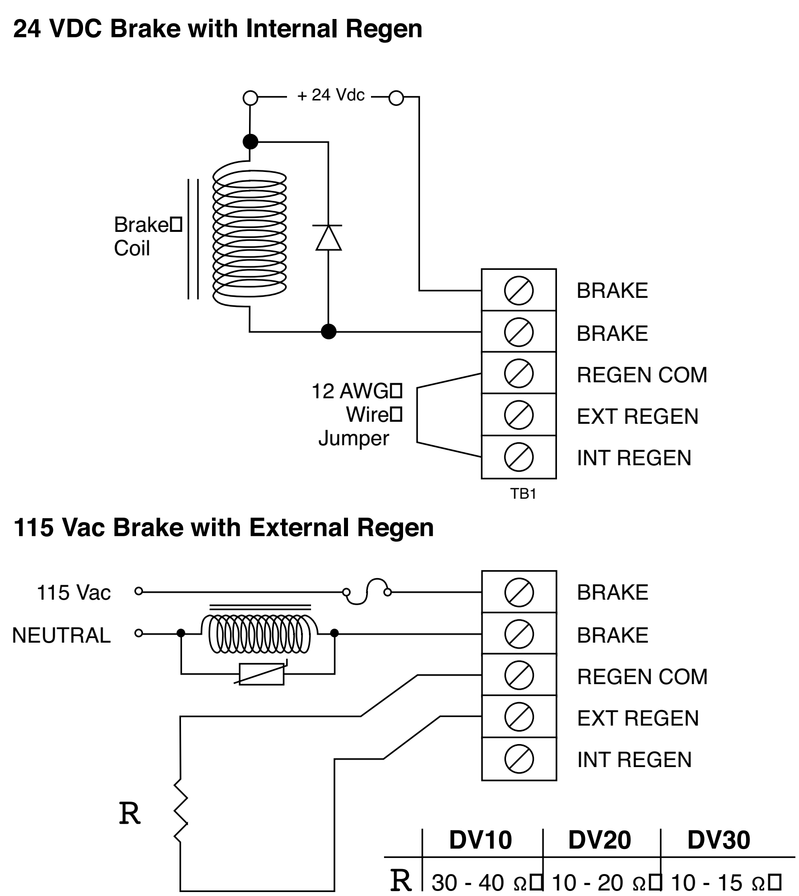


Figure 11.1 - Brake Connection & Regeneration Resistor Connections

Final Checkout & Tuning 12

Drive operating modes

The intent of this section is to give the user a basic familiarity with the operating modes of the Axiom series of servo-motor drives and how they affect tuning. The Axiom drive product line, manufactured by Tolomatic, Inc., consists of three brushless servo-motor drives and one drive for brushed motors.

For specific instructions on tuning the SSC see the tuning section in the SSC manual.

All of these drives support three primary modes of operation:

TORQUE MODE

The drive produces motor torque proportional to an analog voltage command signal. For operation in torque mode, the fundamental current control functions are accomplished automatically by the drive. When the drive is operating in torque mode, the command source is the analog input from the SSC (or customer supplied analog signal), that can be adjusted for offset and scaled by the drive. The user need only configure the drive to select the correct motor and make sure the analog input command signal is appropriately supplied. No tuning of the PID (proportional, integral, and derivative) is required in the drive. The tuning is done in the SSC (or customer supplied controller) by adjusting its PID values to achieve the desired response. The SSC creates a motion profile based on the distance, speed, acceleration and deceleration of the programmed motion, that determines the desired motor position at every sampling period. The closing of the position loop forces the motor to follow the desired position.

VELOCITY MODE

The drive controls motor speed in proportion to an analog voltage command signal from the controller. The fundamental control function of a servo drive operating in velocity mode is to control the rotational velocity of the connected motor with precision. This means that the control response must have a high bandwidth and enough stiffness to prevent external disturbances (load changes) from significantly affecting velocity regulation. Tight control of velocity allows positioning moves to be accomplished with smooth, accurate trajectories. When operated in velocity mode, Axiom series drives receive their command signal via an external, analog signal from the SSC (or customer supplied analog signal). The SSC needs only to handle the position loop calculations to derive a velocity command by tuning the proportional gain. The drives require tuning of the velocity PID control algorithm, whereby velocity control bandwidth and stiffness can be tailored for maximum performance with a given application. The Axiom software provides a very powerful tuning and diagnostic interface to aid the user in achieving optimum velocity control. Tuning of the PID values in the SSC is also required.

POSITION MODE

When the drive is operated in a positioning mode, the error in position is continuously calculated and used to derive a command velocity. The position error is simply the difference between the actual motor shaft position, determined via encoder feedback, and the commanded position. The commanded position comes to the drive by means of a pulse train input. If the drive operating mode is selected as step/dir., then this pulse train signal consists of one signal line that clocks in position counts, and one line that changes polarity based on the desired direction. One commanded position count clocked in will be evaluated by the drive as equivalent to a command for one quadrature encoder count of position change. Thus for a motor with a 1,000 line encoder (4,000 quadrature counts per motor revolution), 2000 step pulses should cause one half of a revolution of motor movement. This is true for "cw/ccw" mode as well. The difference is, when in "cw/ccw" mode, one signal line supplies clockwise step command pulses and the other, counter-clockwise command pulses. The MSC (or customer supplied controller), is the source of the command pulses, determines the speed and acceleration of movement, as well as the distance to be traversed. At steady state, the drive attempts to hold the motor at exactly the position commanded, (zero position following error). With proper tuning, response and stiffness can be matched to the application's load.

Tolomatic Controller / Drive Quick Tuning Reference:

SSC MULTI AXIS CONTROLLER:

1. Axiom setup in torque mode.
   Tuning is performed in the SSC only. The drive offset and scaling need to be set in the Axiom drive
2. Axiom setup in velocity mode.

Tuning is first performed in the Axiom drive and then the proportion gain is set in the SSC (see SSC manual for specific instructions).

MSC SINGLE AXIS CONTROLLER:

1. Tuning accomplished via the Axiom drive set in Step/Direction mode.

Scaling Factor and Offset Adjustments
(Torque or Velocity modes only)

Final checkout involve nothing more than setting the input signal scaling factor and input offsets (if necessary). Then, verifying that the I/O is working correctly.

ADJUST OFFSET

Offset should only be adjusted when the controller is putting out a zero command. A small amount of offset is normal in any system. If this offset exceeds a few tens of millivolts, there is probably a problem with the system. This may be a “ground loop” problem, or some other wiring problem between the controller and drive.

Most controllers have some means to zero their output command and adjust for any offset between the controller and drive. Follow the controllers instructions if possible. If the offset is nulled at the controller, then leave the drive’s offset at “zero.”

To “null” an analog offset in the drive:

1. Select *On Line Tuning* and *Diagnosis* from the main menu.
2. Disable the drive.
3. Make sure the controller is putting out a “zero” command.
4. Note the reading below the bar graph in the “Torque Command” window.
5. Click on *Drive Tune* button.
6. Click on the button in the *Gains* window to get to the *Feed-Forward* window.
7. Adjust the slide control labeled “Offset.”
8. Revert back to the *Diagnosis* window and check the new “Torque (or

Velocity) Command" reading.

9. Continue this process until the reading is "zero" or as close as it can be made to "zero."

ADJUST SCALING FACTOR

The scale factor is a multiplier used to scale the analog input range. If set to 1.000, a +/- 10V input signal will correspond to the drive's full current output range. A +/- 5V signal can correspond the drive's full range by setting the scale factor to 2.000. If it is desired to have a +/-9.5V signal correspond to the full range, set the scale factor to 1.053. (**NOTE:** For most applications, this can be left at the default setting of 1.000.)

From the *Feed-Forward* window set the scaling factor to the desired number.

Allowable Following Error and In-Position Window Adjust
(Position Mode only)

To adjust Allowable Following Error and In-Position Window:

1. Select *On Line Tuning* and *Diagnosis* from the main menu.
2. Select *Drive Tune.*
3. Click on button in *Gains* section for next parm's page.
4. Adjust the *Following Error* number to the value desired. Any time this value is exceeded during operation, the drive will fault.
5. Adjust the *In-Position Window* number to the desired value. Any time the drive's following error is less than or equal to this number, the drive's *In Position* output will be on. If the following error is greater than this value, the *In Position* output will be off. This is useful for telling a PLC or stepper type controller when a move has finished.

AUTO-PHASING SETUP

The Axiom series of brushless drives perform an automatic phase determination routine upon power-up and after a fault. This eliminates the need for magnetic Hall-effect sensors. This routine establishes an oscillating current vector in the motor and uses the resulting motor excitation to determine correct phasing. The Setup and Configuration screen of the Axiom software provides for adjustment of two parameters that affect auto-phasing. The first of these is a phasing position increment, which has a default value of zero. This value is entered in units of degrees of motor shaft rotation. Entering a positive or negative value for phasing increment will cause the motor to attempt to rotate the entered amount as it attempts to phase. This may be useful in applications where power up typically occurs with the machinery in a condition, which restricts motor rotation in one direction. In this case, it would be desirable to enter a phasing position increment, which would insure that, at the completion of phasing, the motor is in a position where its rotation is not affected by an end of travel condition. The other phasing parameter is phasing torque, which is entered as a percent of the drives peak rating. This parameter controls the strength of the current vector used for auto-phasing. A phasing torque value of 50 to 60% will work with most systems. Systems with a great deal of friction or steady-state loading may require higher values. A system in which the motor must support a large load against gravity will phase more quickly and accurately if a relatively high value of phasing torque is configured. A small amount of "jitter" is normal. Upon completion of phasing, the drive’s enable output will become active

PULSE MULTIPLIER SETUP

The purpose of the pulse multiplier function is to allow higher motor velocities when an Axiom drive is used in conjunction with a low-frequency step-pulse command source. The pulse multiplier value is used by the drive to scale the input position command pulses only when the drive operates in step/dir or cw/ccw step modes. The default value of 1 signifies a 1-to-1 correspondence between position command pulses and encoder quadrature feedback counts. Pulse multiplier values greater than 1 should only be used when absolutely necessary to compensate for slow position command pulse generators. Increasing the pulse multiplier value will decrease position command resolution and detrimentally affect the smoothness of motion. The range of possible values for pulse multiplication is from 1 to 50, integer.

Oscilloscope Setup

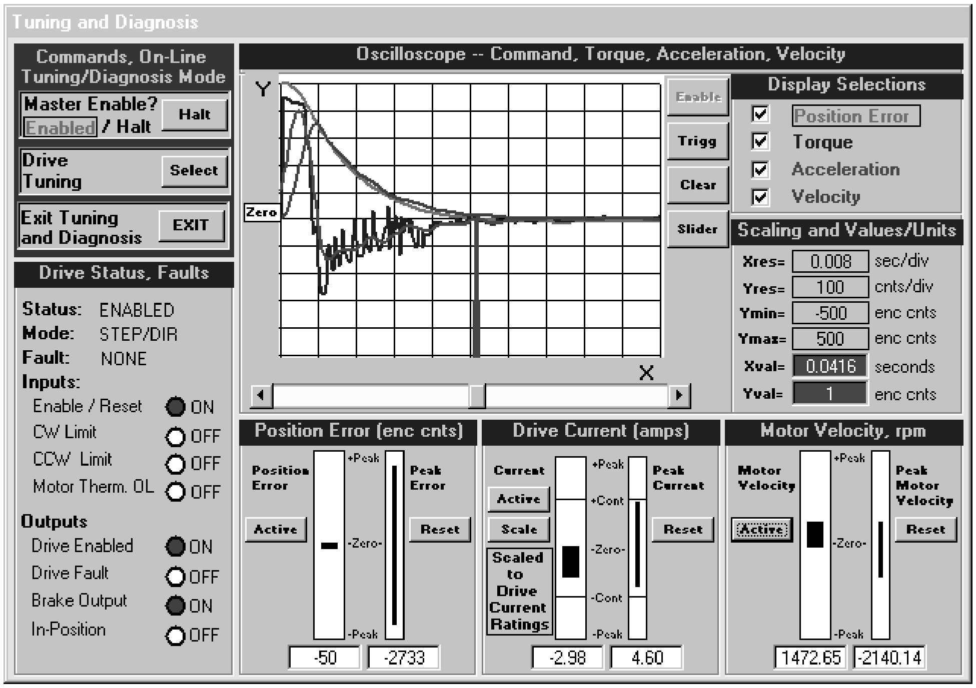


Figure 12.1 - Diagnosis Screen

Before attempting manual tuning it is important to become familiar with the controls for the oscilloscope function that is a built-in feature of the *Axiom* setup and tuning software. This virtual oscilloscope is designed specifically for *Axiom* drive tuning. As such it has the features necessary for this task, without features not useful for this purpose.

The oscilloscope is controlled by four buttons:

Enable - Sets the scope to trigger on the next event.
Trigger - Brings up the trigger menu.
Clear - Clears the screen of the last event snapshot.
Slider - Enables/disables the slider feature. This allows accurate readings of the traces.

The *Display Selections* section has four selections. They will change depending on what mode the drive is operating in. Any checked box will be displayed. The *Slider* will be referenced to the highlighted function. The graph will be normalized to the highlighted function.

You may click on the function you would like to normalize to and read with the slider.

All units are automatically scaled and displayed in the *Scaling and Values/ Units* boxes. The bottom two boxes display the X and Y coordinates that the Slider bar is reading.

To take a reading, you must first set up the *Oscilloscope Settings*. This is accomplished by clicking on the *Trigger* button.

- The scope Sweep Time can be set from .02 seconds to 20 seconds. This is the time period for one complete display sweep.
- Trigger Level can be set from 0 to 100%. The signal that causes the scope to trigger is displayed above it.
- The scope can trigger on a rising or falling slope. A rising slope would correspond to a CW step command.

Velocity or Position Mode Tuning

See Appendix F for detailed description of tuning.

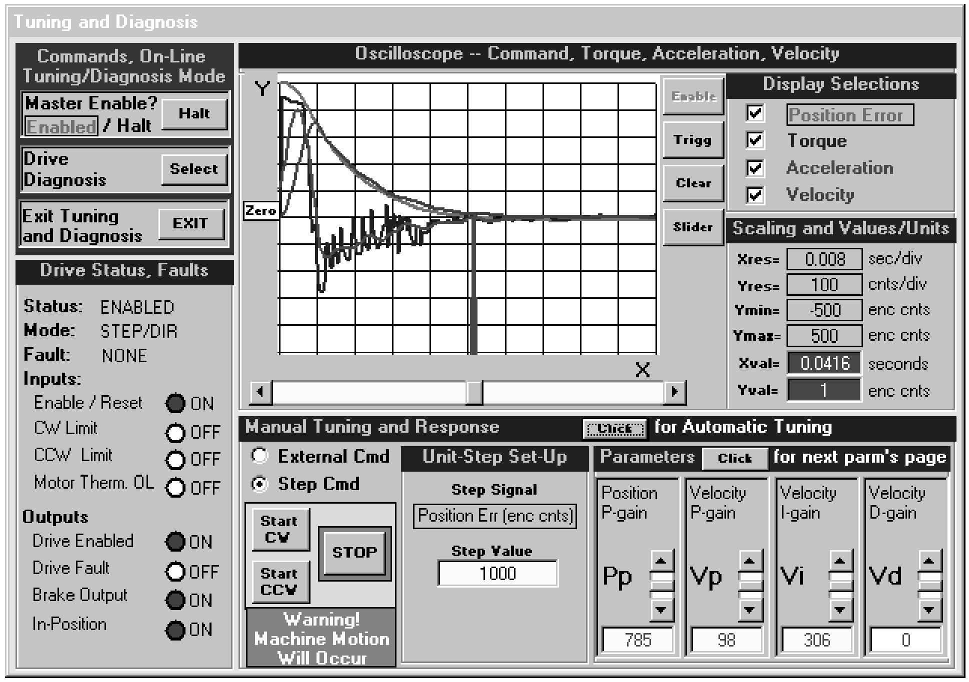


Figure 12.2 - Tuning Screen.

AUTO TUNING

To perform Auto Tune function:

1. Select *On Line Tuning* and *Diagnosis* from the main menu.
2. Select *Tuning* from the *Diagnosis* screen.
3. Click command button “for Automatic Tuning”.
4. Make sure the drive is enabled. The drive may be software disabled from the screen, but cannot be enabled unless the *Enable* input is active.
5. Use the “Start CW” and/or “Start CCW” command buttons to initiate tuning steps.
6. When the auto tune function is complete, the motor will stop and the PID tuning values will be displayed. These values can be accepted or rejected. Before accepting or rejecting calculated gain parameters, version 1.03 software allows the user to adjust the bandwidth of the system via a scroll bar. Lower bandwidths are appropriate for systems with high-inertia loads and/or poor coupling (compliance or bandwidth). Higher values of bandwidth give the best performance with stiffly coupled systems.

7. The auto tune function will normally provide stable tuning values. *However, these will not necessarily be optimum values. It is recommended that the user proceed to the manual tuning section and use the oscilloscope functions to observe the response.* The drive tuning may then be fine tuned for better response. Auto-tune step parameters (torque level and time duration) can be adjusted if necessary to improve auto-tuning. Default values are usually most appropriate.

MANUAL TUNING

To perform manual tuning

Velocity Mode

1. To help establish a good starting point for manual tuning, it may be helpful to use the auto tune function first.
2. Select drive tuning from the tuning/diagnosis mode.
3. Adjust the step value (RPM) and the distance (encoder counts) to provide the required motor movement.
4. Select "Step Cmd" to change control from the external signal to the internal control.
5. Setup the oscilloscope as described in the previous section.
6. Click on the "Start CW" or "Start CCW" to initiate movement in the desired direction.
7. Adjust the gains in an effort to obtain a "critically damped" response (See appendix F for more detailed description of gains).

a. P gain (Vp) increases stiffness (magnitude of response to position error)

b. I gain (Vi) will improve steady state following error. Excessive I gain will cause oscillations.

c. D (Vd) gain improves damping and stiffness. Excessive D gain promotes noise sensitivity and high frequency oscillations.

8. If necessary, Feed-forward gains may be set at this time. These should be left a zero for most applications. They may be useful in certain contouring applications.
9. Set Feed-Forward by clicking on the box above the tuning controls.

a. Acceleration feed forward (Aff) produces a direct component of torque that is proportional to the velocity command.

Figure 12.3 - Underdamped Signal

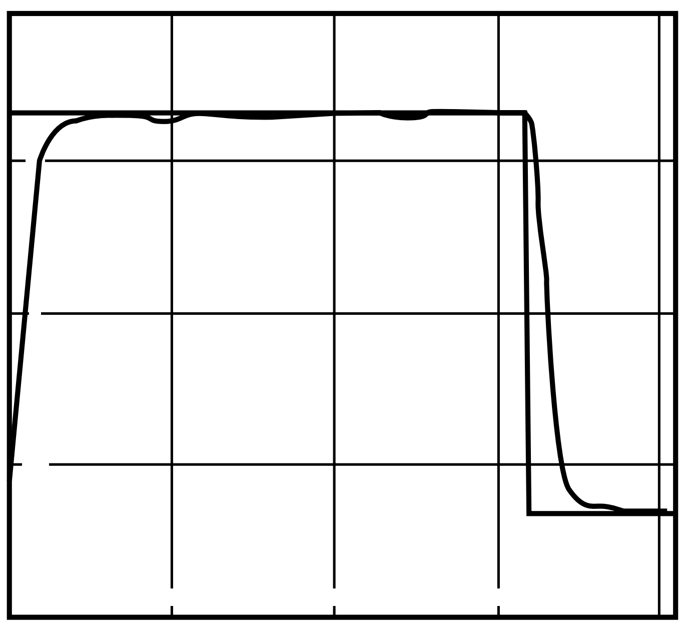


Figure 12.4 - Overdamped Signal

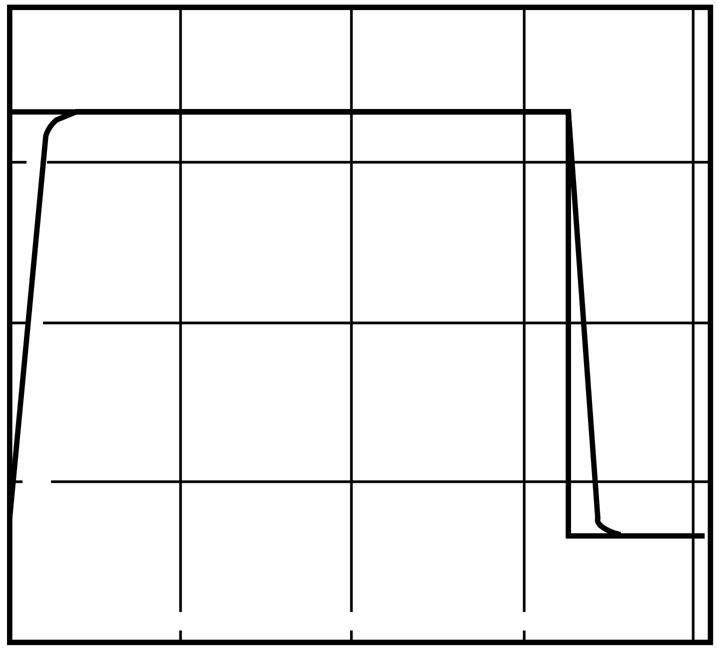


Figure 12.5 Critically Damped Signal (Ideal Tuning)

Position Mode

1. To help establish a good starting point for manual position mode tuning, it is helpful to first tune the drive in velocity mode. Once tuning is complete in velocity mode drive can be switched back to position mode.
2. Select drive setup/configuration and change the drive operating mode to "Velocity mode".
3. Cycle power on the drive to make the new configuration active.
4. Proceed with velocity mode tuning shown in previous section. Once the velocity mode tuning is complete return drive back to position mode (don't forget to cycle power to make the new setting active).
5. Adjust the step value (position error in encoder counts) to provide the required motor movement.
6. Select "Step Cmd" to change control from the external signal to the internal control.
7. Setup the oscilloscope as described in the previous section.
8. Click on the "Start CW" or "Start CCW" to initiate movement in the desired direction.

9. Adjust the gains in an effort to obtain a "critically damped" response (See appendix F for more detailed description of gains).

    a. Position P gain (Pp) increases stiffness (magnitude of response to position error). Excessive Pp gain will cause oscillations and excessive overshoot.

10. If necessary, Feed-forward gains may be set at this time. These should be left a zero for most applications. They may be useful in certain contouring applications.

11. Set Feed-Forward by clicking on the box above the tuning controls.

    b. Velocity feed forward (Vff) produces a direct component of velocity command feed forward that is proportional to position following error.

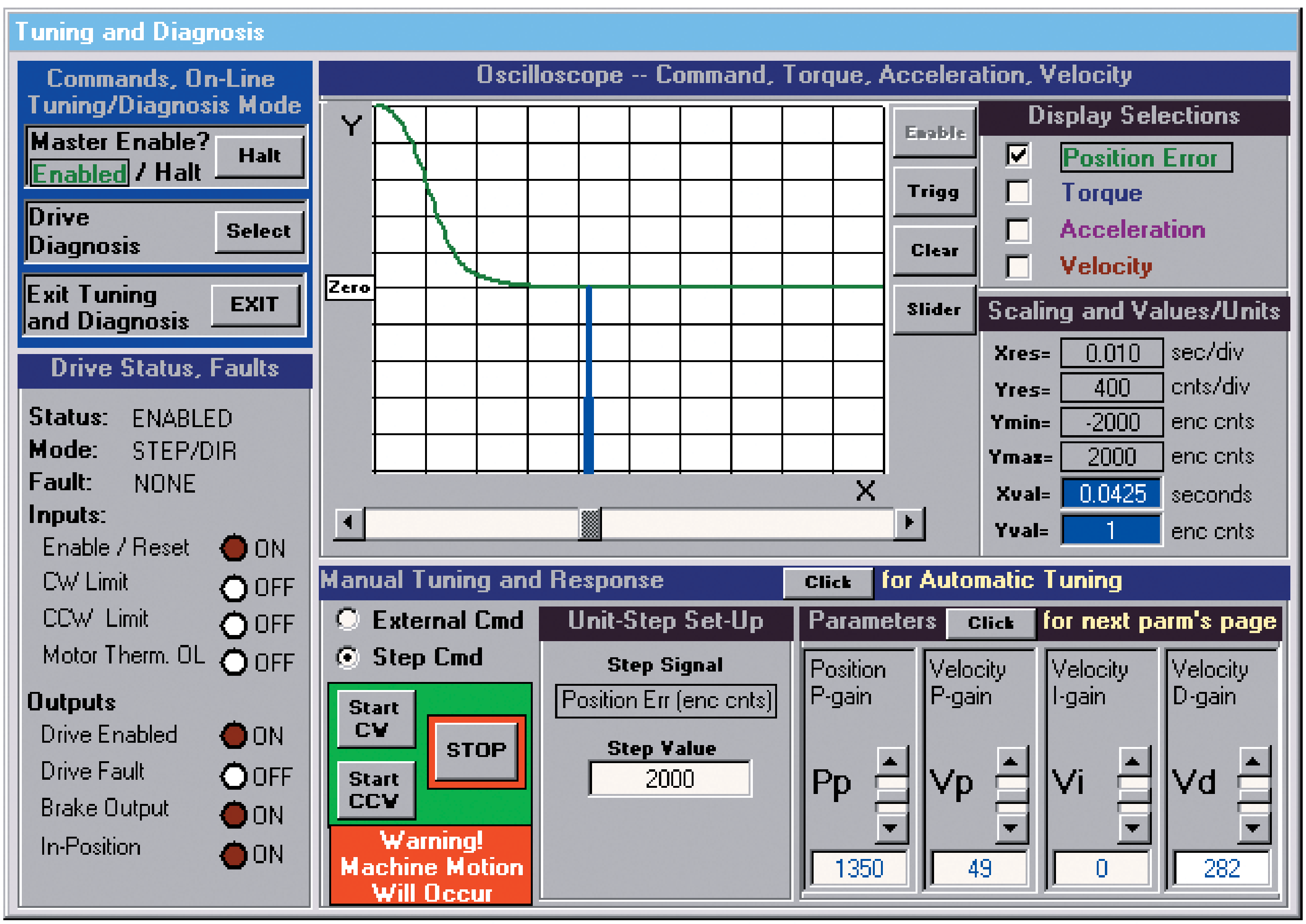


Figure 12.6 Critically Damped Set Command in Position Mode.

Status and Fault Display 13

The *Axiom* drives all support a set of status and fault conditions that can be displayed on the drive's seven-segment display. In addition, any fault will display on the diagnostic screen of the *Axiom* setup software whenever a computer is connected to the drive.

Normal Operation

Whenever the drive is powered, and no fault or status conditions are present, it will display the letter "d" when disabled or "E" when enabled. This lets the user know the drive's status at a glance.

Status Codes

Anytime the drive detects a condition that is not a "fault", yet not a normal condition, it will display a flashing three-character code. For example, "L"— "0" — "1" indicates the drive is enabled and has reached the CW end of travel limit switch.

Faults

Faults are caused by conditions that make it necessary for the drive to shut down. When one occurs, the drive disables its power amplifier output stage and displays the appropriate fault code. A fault is displayed by flashing "F" followed by a two-digit code. For example, "F" — "5" — "5" indicates that the maximum allowable following error has been exceeded.

There are two classes of faults in Tolomatic Axiom series servo motor drives. The first class are called *Fatal Faults.* These indicate that something is seriously wrong with the system and can only be cleared by removing power from the drive.

The second class of faults are *Non-Fatal Faults.* These faults are of a less serious nature. They can be cleared by disabling the drive, correcting the condition that caused the fault, then enabling the drive again.

FAULT AND STATUS CODES (Listed in order of decreasing priority).

NOTE: * - Indicates faults that do not apply to brush motor applications.

FATAL FAULTS (Requires line power-down, power-up and assertion of enable signal to reset.)

F00- Processor Fault
- An internal error has occurred in the DSP.

F01 - Power Selection Switch Fault
- Line-power selection switch set incorrectly.

F02 - Bridge Hardware Fault
- Short circuit or bus over-voltage.

F03 - Current Feedback Fault
- Line-to-line current discrepancy (possible open winding).
- Current feedback circuitry not functioning correctly.

F04 - Current Regulation Fault
- Drive current regulation out of tolerance.
  - Current feedback in "saturation" for 1 second.

F05 - Drive Over-Temperature Fault
- Drive heat sink over 90° C.

F06 - Motor Over-Temperature Fault
- Motor thermostat protection fault.

NON-FATAL FAULTS (Requires removal, then re-assertion of the enable signal to reset.)

F51*- Phasing Fault
- Initial phase estimation routine not executed successfully.

F52 - Drive Over-Current Fault
- Inverse time trip calculated based on the drive's peak and continuous rating.

F53 - Motor Over-Current Fault
- I^2*time protection based on the motor's peak and continuous rating.

F54 - Bus Under-Voltage Fault
- Bus voltage falls below low-limit.

F55 - Maximum Following-Error Fault
- (Position modes only), maximum following error reached. This limit is set in the setup software.

F56 - velocity regulation fault
- Velocity regulation out of tolerance.

F57 - serial communication fault

F99 - Drive has not yet been configured. The drive cannot be enabled until it has been configured.

STATUS CONDITIONS

d - Drive Disabled
- Drive not enabled due to state of enable input or command from PC. No faults are present.

E - Drive Enabled
- Drive is enabled and ready to respond to command.

P - Phasing in process

L01 - Drive Clockwise Travel Limit Reached
- Displayed when clockwise travel limit input is "made" and drive is enabled, with no faults.

L02 - Drive Counter-Clockwise Travel Limit Reached
- Displayed when counter-clockwise travel limit input is "made" and drive is enabled, with no faults.

Maintenance & Troubleshooting 14

This section provides a description of suggested maintenance activities and an in-depth troubleshooting chart.

Maintenance

The Axiom drive is designed to function with minimum maintenance.

DANGER! DC bus capacitors may retain hazardous voltages after input power has been removed. Before working on the drive, wait the full time interval listed on the warning on the front of the drive. Failure to observe this precaution could result in severe bodily injury or loss of life.

PERIODIC MAINTENANCE

Normally the only maintenance required is removal of superficial dust and dirt from the drive and a quick check of cabling insulation and connections.

Cleaning

To clean the drive, use a compressed air nozzle set for low pressure (<30 psi) to blow the exterior surface and the vents clean.

Cable Inspection

Inspect the cables, particularly the power connections, to verify the connection.

- All power connections should be securely tightened.
- D-shell connectors can be inspected for proper seating and signal continuity.
- Visually inspect all cables for abrasion.

Troubleshooting Guide

Tolomatic Axiom series drives are designed for ease of installation and years of trouble-free operation. If difficulties are encountered in the setup or in operation, this guide should prove useful in diagnosing and correcting the problem. If problems persist, please contact your Tolomatic distributor for further assistance.

Symptom/Fault Code: Status display not lit.
Possible Causes: No ac power; internal malfunction.
Possible Solutions: Verify ac power and connections; call your Tolomatic distributor.

Symptom/Fault Code: Digital I/O not working correctly.
Possible Causes: No 5-25Vdc power.
Possible Solutions: Verify correct connection.

Symptom/Fault Code: F01 - Power selection switch fault.
Possible Causes: Line-power selection switch set incorrectly.
Possible Solutions: Set to “115 V” for 115 Vac operation or “230 V” for 208 Vac or 230 Vac operation.

Symptom/Fault Code: F02 - Bridge hardware fault.
Possible Causes: Motor lead short circuit; bus over-voltage; drive’s output bridge damaged.
Possible Solutions: Check motor cables and motor for shorts; connect internal or external regen resistor; call your Tolomatic distributor.

Symptom/Fault Code: F03 - Current feedback fault.
Possible Causes: Possible open winding; current feedback circuitry not functioning correctly.
Possible Solutions: Check motor cable wiring and motor windings; call your Tolomatic distributor.

Symptom/Fault Code: F04 - Current regulation fault.
Possible Causes: Drive current regulation out of tolerance; current feedback in “saturation” for 1 second.
Possible Solutions: Check motor cables and motor windings; verify that torque/speed requirement not greater than motor/drive capability.

Symptom/Fault Code: F05 - Drive over-temperature fault.
Possible Causes: Drive heat sink over 90° C.
Possible Solutions: Ambient temp above 50° C.; need external regen pack.

Symptom/Fault Code: F06 - Motor over-temperature fault.
Possible Causes: Motor thermostat tripped.
Possible Solutions: Inadequate motor cooling; motor rating exceeded.

Symptom/Fault Code: F51 - Phasing fault.
Possible Causes: Initial phase estimation routine not executed successfully.
Possible Solutions: Check encoder and motor wiring; increase phasing torque.

Symptom/Fault Code: F52 - Drive over-current fault.
Possible Causes: Inverse time trip calculated based on the drive's peak and continuous rating exceeded.
Possible Solutions: Verify sizing requirements; check tuning; check for mechanical problems in system.

Symptom/Fault Code: F53 - Motor over-current fault.
Possible Causes: I^2*time protection based on the motor's peak and continuous rating exceeded.
Possible Solutions: Verify sizing requirements; check for mechanical problems in system.

Symptom/Fault Code: F54 - Bus under-voltage fault.
Possible Causes: Bus voltage falls below low-limit.
Possible Solutions: Check line voltage under load (must be at least 90 Vac).

Symptom/Fault Code: F55 - Maximum following-error fault.
Possible Causes: Maximum position following error reached.
Possible Solutions: Verify correct maximum following error setting; check tuning; check for mechanical problems in system.

Symptom/Fault Code: F56 - Velocity regulation fault.
Possible Causes: Velocity regulation out of tolerance.
Possible Solutions: Check tuning; check for mechanical problems in system.

Symptom/Fault Code: F57 - Serial communication fault.
Possible Causes: Communication cable not connected.
Possible Solutions: Check communication cable connections.

Cables

COMMUNICATION CABLES

Tolomatic offers a pre-wired RS-232 communication cable for connection between a computer and the drive. This cable is supplied with 9-pin D-sub connectors on both ends. Following is a connection diagram for this cable.

PIN #	COLOR	DRIVE FUNCTION	PC FUNCTION
PIN 2	WHITE	TX	RX
PIN 3	GREEN	RX	TX
PIN 5	BLACK	COMMON	COMMON
PIN 7	BLUE	NOT USED	NOT USED
PIN 8	ORANGE	NOT USED	NOT USED

Figure A.1 - RS-232 Communications Cable (P/N 3600-1172)

Tolomatic offers a pre-wired cable for encoder signal connection from the drive to a motion controller. This cable connects the drive's buffered encoder output signal to a controller's encoder feedback signal connection. This cable is supplied in a 3M length and has a 15-pin D-sub connector on the Axiom drive end. Following is a connection diagram for this cable.

PIN #	COLOR	FUNCTION
1	WHT/BLU STRIPE	RESERVED
2	WHT/ORG STRIPE	RESERVED
3	ORG/WHT STRIPE	RESERVED
4	WHT/GRN STRIPE	RESERVED
5	GRN/WHT STRIPE	RESERVED
6	WHT/BRN STRIPE	RESERVED
7	BRN/WHT STRIPE	RESERVED
8	BLU/WHT STRIPE	COMMON
9	WHT/GRA STRIPE	ENCODER OUT A +
10	GRA/WHT STRIPE	ENCODER OUT A -
11	RED/BLU STRIPE	ENCODER OUT B +
12	BLU/RED STRIPE	ENCODER OUT B -
13	RED/ORG STRIPE	ENCODER OUT I +
14	ORG/RED STRIPE	ENCODER OUT I -
15		RESERVED

Figure A.2 - Encoder Output Cable (P/N 3604-1213)

MOTOR CABLES

Tolomatic offers cables for connection of Axiom DV series brushless servo motors/drives.

MRV 1x motors are supplied with flying leads and do not require any special cable connectors.

Tolomatic motor/encoder cables have a connector pre-wired to the motor end. The other end may be cut to length by the customer and terminated directly to the screw terminal connections on the drive. No special connectors are needed on the drive end.

All MRV 2x, 3x and 5x series brushless servo motors use the same encoder cable connectors. Tolomatic encoder cables use 24AWG shielded, twisted pair cable.

Encoder cables for all MRV 2x,3x and 5x motors and all DV series drives:

6 m length 3604-1196
15 m length 3604-1197

Motor cables are offered for Tolomatic MRV 2x, 3x and 5x brushless servo motors. Cables for MRV 2x and 3x motors should be ordered according to the drive with which they will be used. All cables use shielded, four conductor cable. Wire size ranges from 16AWG to 12AWG.

MRV 5x motors have a different motor power connector and use a different cable.

Motor cables for MRV 2x and 3x motors used with DV10 drives (16AWG).

6 m length 3604-1190
15 m length 3604-1191

Motor cables for MRV 2x and 3x motors used with DV20 drives (14AWG).

6 m length 3604-1192
15 m length 3604-1193

Motor cables for MRV 2x and 3x motors used with DV30 drives (12AWG).

6 m length 3604-1194
15 m length 3604-1195

Motor cables for use with MRV 5x motors use with DV30 drives (12AWG).

7.5 m length 3604-1202
15 m length 3604-1203

MRV 1X Motor

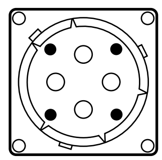
MOTOR CONNECTOR PINOUT	
RED	PHASE R
WHT	PHASE S
BLU	PHASE T

MRV 1X ENCODER

MOTOR CONNECTOR PINOUT	
RED	+ 5V
WHT	A +
YLW	A -
GRN	B +
BLU	B -
ORG	I +
BRN	I -
BLK	COM

MRV 2X/3X Motor

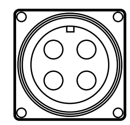
MOTOR CONNECTOR PINOUT	
PIN	FUNCTION
1	PHASE R
2	PHASE S
3	PHASE T
4	CASE GROUND



MS3112E - 14 - 8P
MOTOR CONNECTOR
MATING CONNECTOR
MS3116E - 14 - 8S
(NOT SHOWN)

MRV 5X Motor

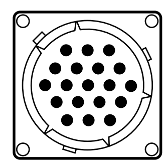
MOTOR CONNECTOR PINOUT	
PIN	FUNCTION
A	PHASE R
B	PHASE S
C	PHASE T
D	CASE GROUND



MS3102E - 20 - 4P
MOTOR CONNECTOR
MATING CONNECTOR
MS3106E - 20 - 45
(NOT SHOWN)

MRV 2X/3X/5X Encoder

		SENSOR/FEEDBACK CONNECTOR PINOUT			
	PIN	FUNCTION	PIN	FUNCTION	
Red	A	THERMOSTAT	L	N.C.	
Green	B	THERMOSTAT	M	N.C.	
	C	N.C.	N	CHANNEL B	Purple
Black	D	INDEX	P	CHANNEL $\overline{B}$	Grey
White	E	$\overline{INDEX}$	R	N.C.	
Orange	F	CHANNEL A	S	N.C.	
Yellow	G	CHANNEL $\overline{A}$	T	N.C.	
Blue	H	ENCODER GROUND	U	N.C.	
	J	N.C.	V	N.C.	
Brown	K	+5 VDC ENCODER			



MS3112E - 14 - 19P
MOTOR CONNECTOR
MATING CONNECTOR
MS3116E - 14 - 19S
(NOT SHOWN)

Figure A.3 - Tolomatic MRV Motor Connector Pinouts

AGENCY APPROVALS

Regulatory Compliance

The Axiom series drives have been shown to meet the requirements necessary to carry the UL and CE marks. These servo motor drives have been tested and found to be compliant with the following standards under the following conditions when installed in accordance with the procedures outlined in this manual and with the procedures and methods appropriate for the class of machine into which they are installed.

It should be noted that this device is intended to be used as a component of a machine. As such it is the responsibility of the machine manufacturer to demonstrate that the complete machine complies with all appropriate regulatory standards and electrical codes.

Certificates of compliance and test results are on file at Tolomatic, Inc. Please contact Tolomatic, Inc.

UL, cUL

The Axiom series brushless servo motor drive models DV10, DV20 and DV30 have been tested and found suitable to carry the UL and cUL mark in accordance with the requirements of UL standard 508C.

As such, this unit is suitable for use on a circuit capable of delivering not more than 5000 RMS symmetrical amperes, 250 Volts maximum.

CE

Tolomatic, Inc. Axiom series drives have been tested to the following standards.

Low Voltage Directive
EN50178

EMC Directive
EN55011 Class A
EN50082-2

EN61000-4-2	EN61000-4-3	EN61000-4-4
EN61000-4-6	EN61000-4-8	

This device is intended to be used as a component in a machine. In order to achieve CE compliance of the complete machine, it is incumbent upon the machine builder to use good practice in his design and construction. Following is a set of guidelines that will help ensure that the complete machine will meet CE requirements.

Line Filters

As with most servo drives, it is imperative that a line filter be used in order to meet EMC requirements. This line filter works to limit the amount of EMI conducted from the drive back through the power mains. Following are recommended line filters for use with Axiom DV series drives.

DV10
Schaffner model no. FN351-8-29 (three phase)
Schaffner model no. FN2060-30-08 (single phase)

DV20
Schaffner model no. FN258-30-07 (three phase)
Schaffner model no. FN2060-30-08 (single phase)

DV30
Schaffner model no. FN351-25-33 (three phase)
Schaffner model no. FN2060-30-08 (single phase)

Grounding

Though it is not necessary for Electromagnetic Compatibility, it is recommended that the drive be mounted in a NEMA rated electrical cabinet. In addition, an electrical cabinet will help provide for protection against electrical shock and provide appropriate environmental protection for the Axiom drive and other electronic equipment.

It is necessary for the drive and line filter to be mounted on a properly grounded metal plate. Paint should be removed from the drive, line filter and plate at the attachment points and where the plate or enclosure are grounded. In order to obtain a good RF (Radio Frequency) ground, the ground connection should be as short as possible. In addition, a flat braid with a 5:1 length versus width (or less) aspect ratio is preferable to a wire for this connection.

Shielding

It is absolutely necessary to use a properly terminated shielded motor cable. It is highly recommended that the user purchase motor power and encoder cables from Tolomatic, Inc. and install them according the this manual. In addition, the use of properly terminated shielded cable for all I/O wiring that enters or leaves the earth grounded electrical cabinet will help insure an EMI compliant installation. Shield termination should be made at the point of cabinet entry for I/O wiring.

Declarations of Conformity

Declaration Of Conformity

Application of Council Directives
89/336/EEC

Standards to which Conformity is Declared
EN50082-2 and EN55011 Class A

Manufacturer
Tol-O-Matic, Inc.

Manufacturer's Address
Tol-O-Matic, Inc.
3800 County Road 116
Hamel, MN 55340-9360
USA

Type of Equipment
Motor Controller/Drive

Model No.
Axiom DV10

Year of Manufacture
2000

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives.

Place:

Tol-O-Matic, Inc.
3800 County Road 116
Hamel, MN 55340-9360

Keith Hochhalter
(Signature)

Keith Hochhalter
(Full Name)

Director of Product Development
(Position)

January 15, 2001
(Date)

Declarations of Conformity

Declaration Of Conformity

Application of Council Directives
89/336/EEC

Standards to which Conformity is Declared
EN50082-2 and EN55011 Class A

Manufacturer
Tol-O-Matic, Inc.

Manufacturer's Address
Tol-O-Matic, Inc.
3800 County Road 116
Hamel, MN 55340-9360
USA

Type of Equipment
Three Phase Brushless Servo Drive

Model No.
Axiom DV20 / 30

Year of Manufacture
2000

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives.

Place: Keith Hochhalter (Signature)

Tol-O-Matic, Inc. Keith Hochhalter (Full Name)
3800 County Road 116
Hamel, MN 55340-9360 Director of product Dev. (Position)

August 6, 2001 (Date)

Declaration of Conformity

Application of Council Directives: 89/336/EEC, 73/23/EEC

Standard to which Conformity is Declared: EN 50178 (1997) and Annex A

Manufactures Name: TOL-O-MATIC, INC.

Manufactures Address: 3800 County Road 116
Hamel, MN 55340

Type of Equipment: Servo Motor Drives

Model No: DV10, DV20, and DV30

Serial No: **Year of Manufacture:** 2001

I the undersigned, hereby declare that the equipment specified above conforms to the above Directives.

Place: TOL-O-MATIC, INC
3800 County Road 116
Hamel, MN 55340

Keith Hochhalter (Signature)

Keith Hochhalter (Full Name)

Director of Product Development (Title)

Date: 5/24/01

POWER

DV10

Continuous Current Rating. . . . . .5A(Peak/Phase)
Peak Current Rating . . . . .10A(Peak/Phase)
Maximum Input Current (Single Phase). . . . . .12.5A(rms)
Maximum Input Current (Three Phase) . . . . .7.5A(rms)
Input Voltage (Single or Three Phase) . . . . .95Vac-130Vac/190Vac-250Vac; (voltage range is switch selected)
Input Frequency 47Hz-63Hz
Peak Inrush Current 65A

DV20

Continuous Current Rating. . . . . .10A(Peak/Phase)
Peak Current Rating . . . . .20A(Peak/Phase)
Maximum Input Current (Single Phase). . . . . .25A(rms)
Maximum Input Current (Three Phase) . . . . .15A(rms)
Input Voltage (Single or Three Phase) . . . . 95Vac-130Vac/ 190Vac-250Vac; (voltage range is switch selected)
Input Frequency:. 47Hz-63Hz
Peak Inrush Current 160A

DV30

Continuous Current Rating. . . . . .15A(Peak/Phase)
Peak Current Rating . . . . .30A(Peak/Phase)
Maximum Input Current (Single Phase). . . . . .37.5A(rms)
Maximum Input Current (Three Phase) . . . . .22.5A(rms)
Input Voltage (Single or Three Phase) . . . . .95Vac-130Vac/190Vac-250Vac; (voltage range is switch selected)
Input Frequency 47Hz-63Hz
Peak Inrush Current 160A

DB20

Continuous Current Rating. . . . . .15A(Peak/Phase)
Peak Current Rating . . . . .20A(Peak/Phase)
Maximum Input Current (Single Phase). . . . . .10A(rms)
Input Voltage (Single Phase). 95Vac-130Vac
Input Frequency 47Hz-63Hz

COMMAND SOURCES

Analog Torque/Velocity Input	+/-10V, 16 kΩ impedance.
Step/Direction (StepCW/StepCCW)	1 mHz max., 5V differential or single ended drivers

Serial Communication Port

Type	RS-232
Baud	19,200 Baud

Control Loops

Type	All digital
Modes	Torque, Velocity and Position control
Torque Loop Update Rate	10 kHz
Velocity Loop Update Rate	5 kHz
Position Loop Update Rate	2.5 kHz

Inputs and Outputs

Dedicated Optically Isolated Inputs	5Vdc - 25Vdc, 2.7mA - 15mA. ENABLE, CW LIMIT and CCW LIMIT; Can be configured to source or sink current.
Dedicated Optically Isolated Outputs	3 optically isolated, 25Vdc max., 20mA max. IN POSITION, ENABLED and FAULT. Can be configured to source or sink current.
Dedicated Relay Output	N.O. contact, 24Vdc, 115/230Vac, 3A max.
Motor Feedback	Incremental encoder, 5Vdc, differential, 4 mHz max., A/B/I channels. 500 line min. with a 4 pole motor, 250 line min. with a 2 pole motor.
Encoder Output	Differential, 5Vdc, A/B/I channels.

Connectors

Serial	9 pin D-Sub.
Encoder Output	15 pin D-Sub.
Power, Motor, Brake Relay and Regen	Screw terminal block.
All Others	Pluggable screw terminal blocks.

Environmental

Storage Ambient Temperature	-40° to 70° C.
Operating Ambient Temperature	0° to 50° C.
Humidity	5% to 95%, non-condensing.
Weight	DV10 8lbs. (3.7kg).
	DV20 12lbs. (5.5kg)
	DV30 12lbs. (5.5kg)
	DB20 26lbs. (12kg)

MOTOR PROTECTION

The drive has internal shut down circuitry to protect against motor phase to phase short circuits and phase to ground short circuits. This circuitry will shut down drive's output amplifier stage in a small fraction of a second when it detects a short circuit condition.

In addition, the drive does an I^2T calculation based on the motor's thermal time constant. A fault indication is generated if this calculation indicates that the motor windings are about to exceed a safe temperature.

DANGER! Always make sure drive has a proper earth ground before operating system. A drive with an inadequate earth ground connection can present a dangerous shock hazard to operating personnel.

WARNING! Every effort should be made to prevent motor power connection short circuits form occurring. Even though the drive will shut down when such a condition is detected, very high currents will flow and there is still danger of damage to the drive and motor. In addition, a possibility of electrical shock may be present in some circumstances.

REGENERATION RATINGS

DV10	25W rms at 25°C ambient. Derate linearly to 10W rms at 50°C ambient.
DV20	50W rms at 25°C ambient. Derate linearly to 20W rms at 50°C ambient.
DV30	50W rms at 25°C ambient. Derate linearly to 10W rms at 50°C ambient.
DB20	50W rms at 25°C ambient. Derate linearly to 20W rms at 50°C ambient.

POWER DISSIPATION

The Axiom drive dissipates power that results in cabinet heating. The following table lists power dissipation values. Calculate the cabinet cooling requirements using the power dissipation information and formulae below.

NOTE: These values do not include shunt regulator power (regenerated power).

NOTE: These values correspond to a drive operating at its full continuous current rating at 100% duty cycle. As such they can be considered as maximum or "worst case."

DV10	23W
DV20	42W
DV30	60W
DB20	20W

Maximum power losses are shown to help size a NEMA 12 or equivalent enclosure and to ensure the required ventilation. Typical power losses are about one-half maximum power losses.

When sizing an enclosure with no active method of heat dissipation, the following equation approximates the size of the required enclosure:

T = 4.08 * (Q/A) + 1.1

where:

T = Temperature difference between inside air and outside ambient air (°F)

Q = Heat generated in enclosure (watts)

A = Enclosure surface area in ft^2 = (2dw + 2dh + 2wh) / 144

d = Depth in inches

h = Height in inches

w = Width in inches

Motor Performance Data

C

Tolomatic can provide a range of brush and brushless servo motors to cover a broad range of applications. Following are the torque/speed curves for these motors paired with *Axiom* drives.

Motor Drive Performance Curves

MRV SERIES MOTOR DRIVES

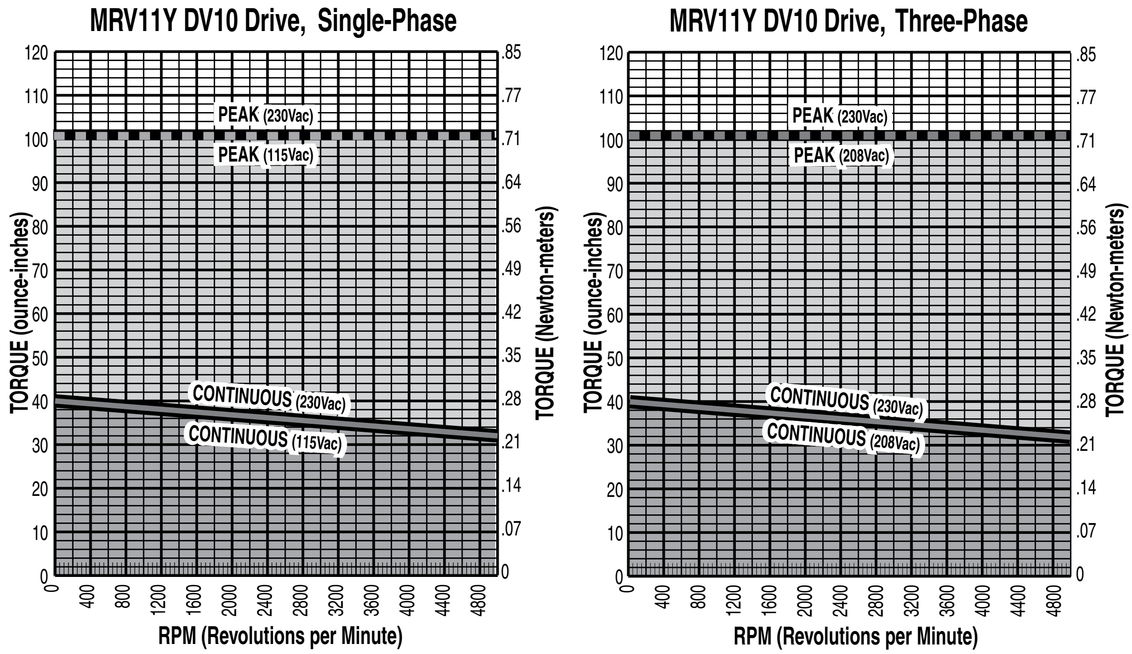


Figure C.1 - MRV 11Y DV10 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

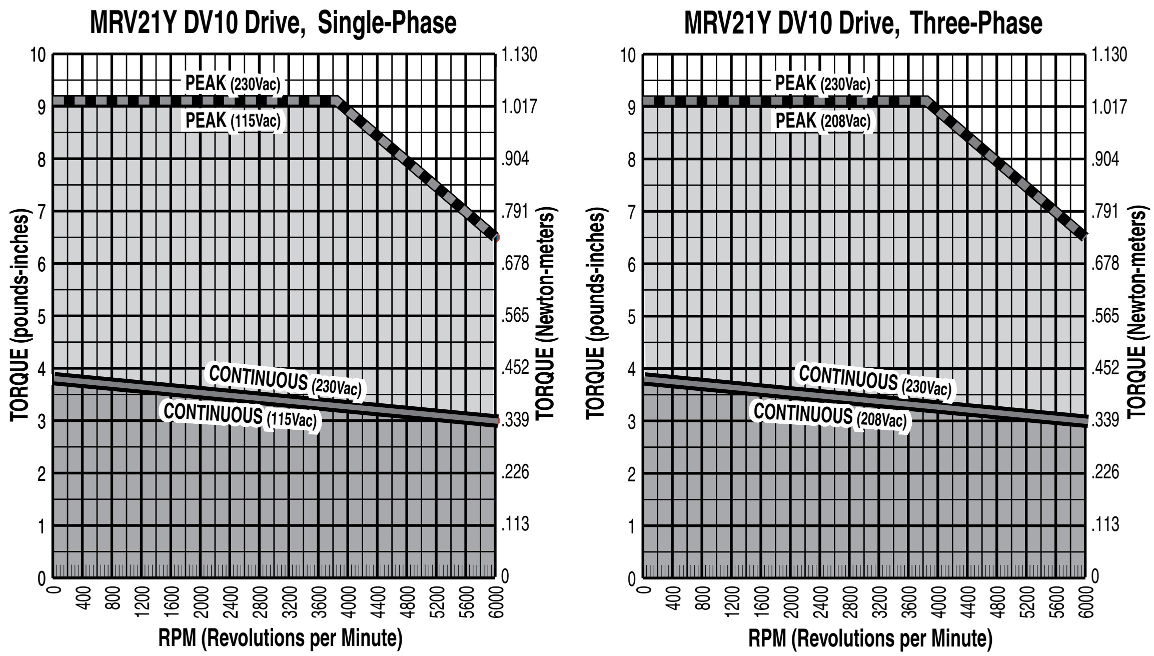


Figure C.2 - MRV 21Y DV10 Single-Phase, Three-Phase Drive

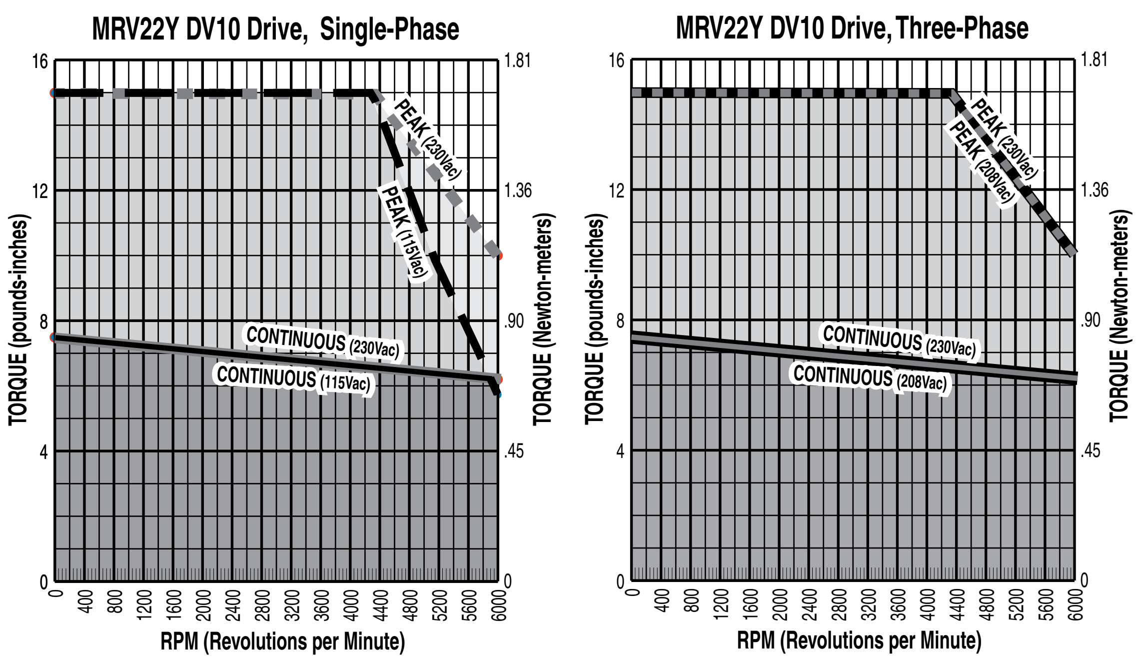


Figure C.3- MRV 22Y DV10 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

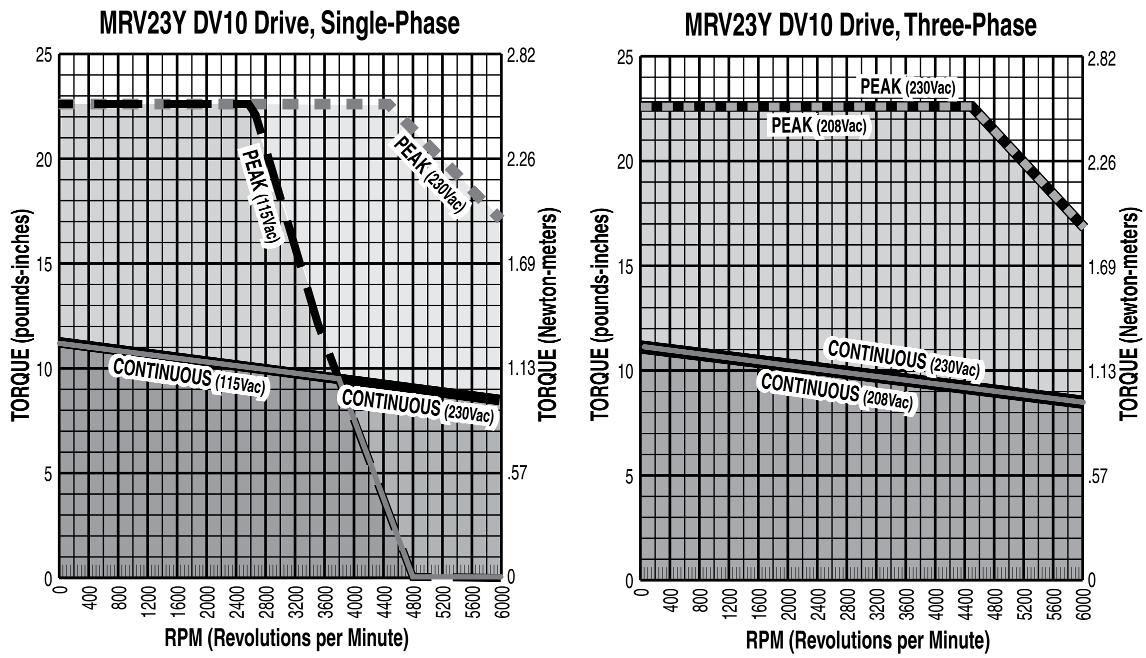


Figure C.4- MRV 23Y DV10 Single-Phase, Three-Phase Drive

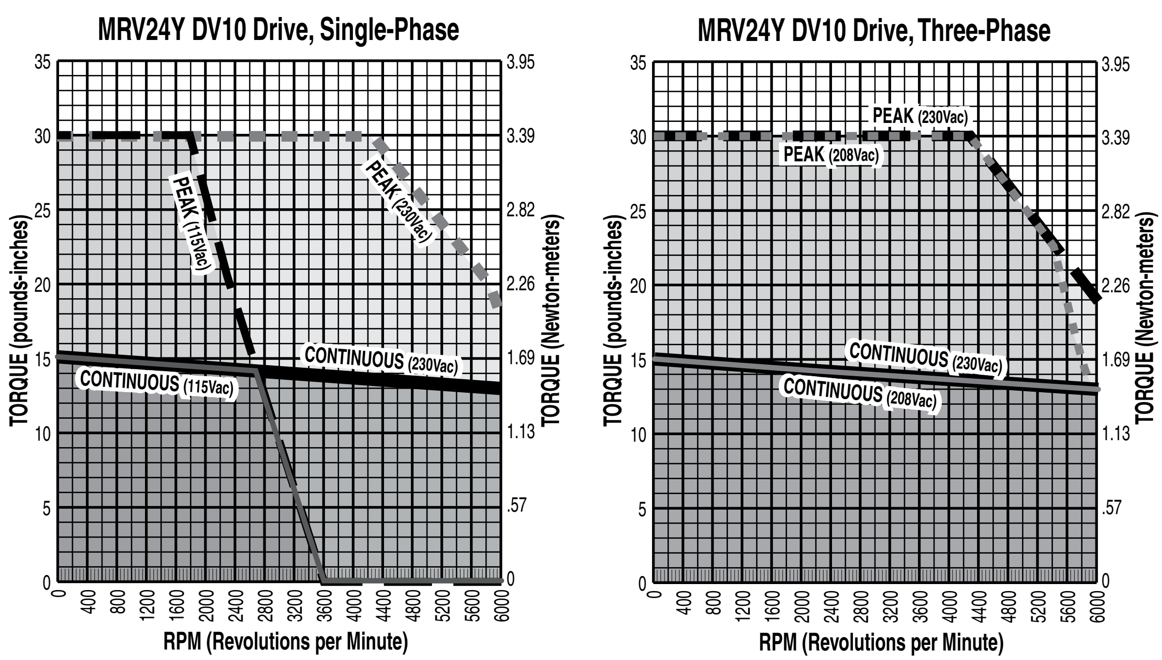


Figure C.5- MRV 24Y DV10 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

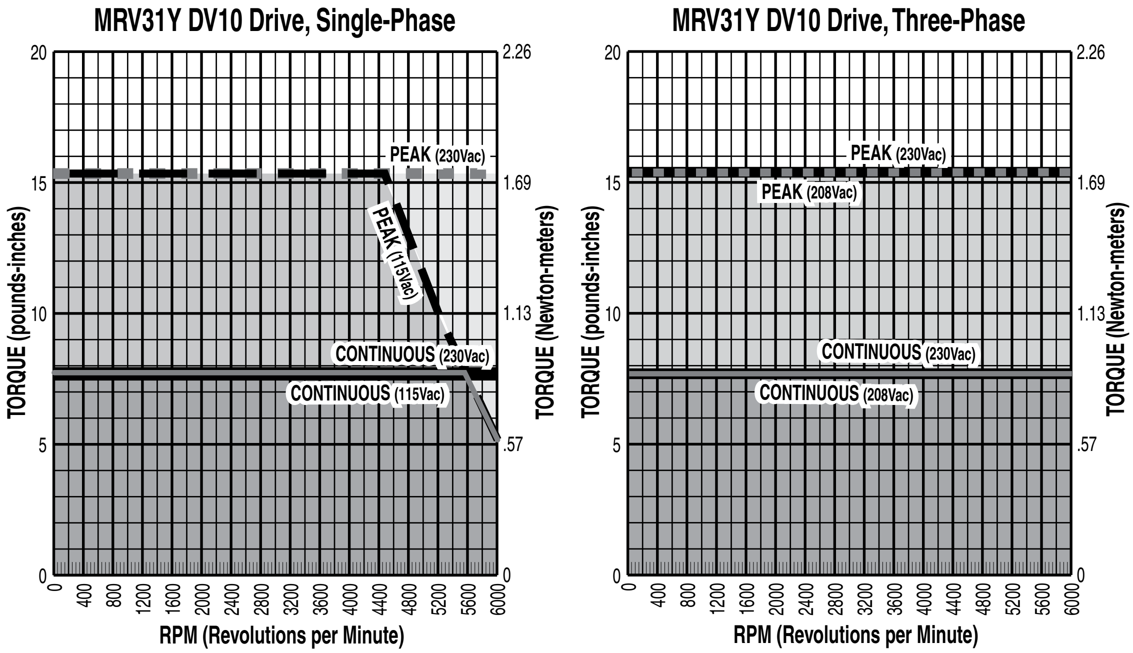


Figure C.6- MRV 31Y DV10 Single-Phase, Three-Phase Drive

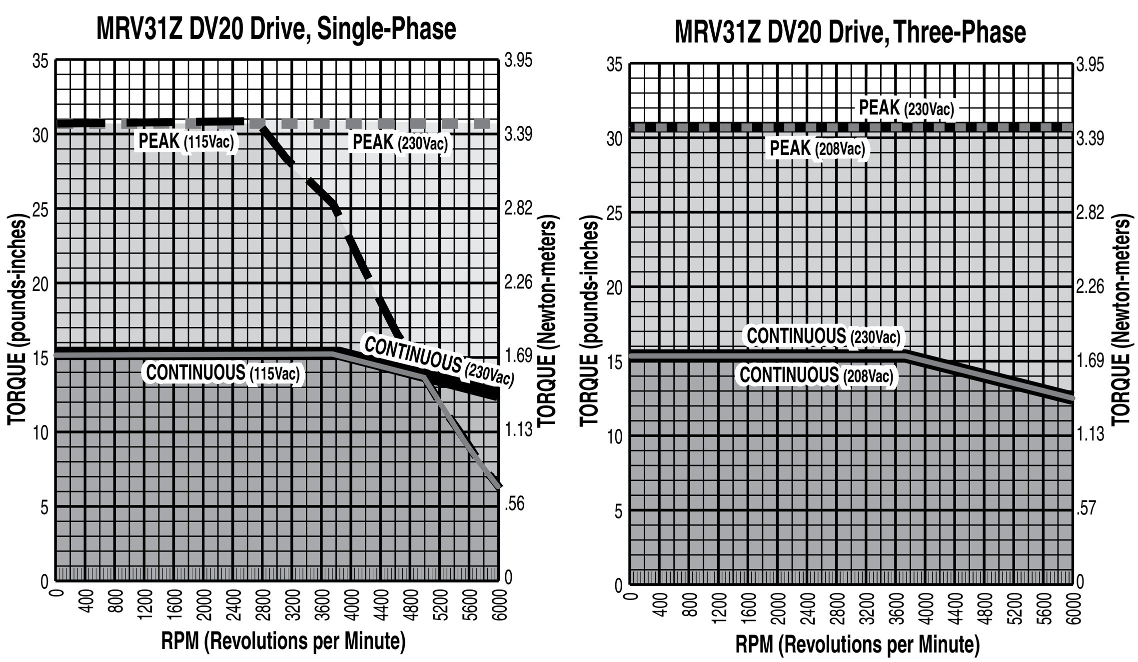


Figure C.7- MRV 31Z DV20 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

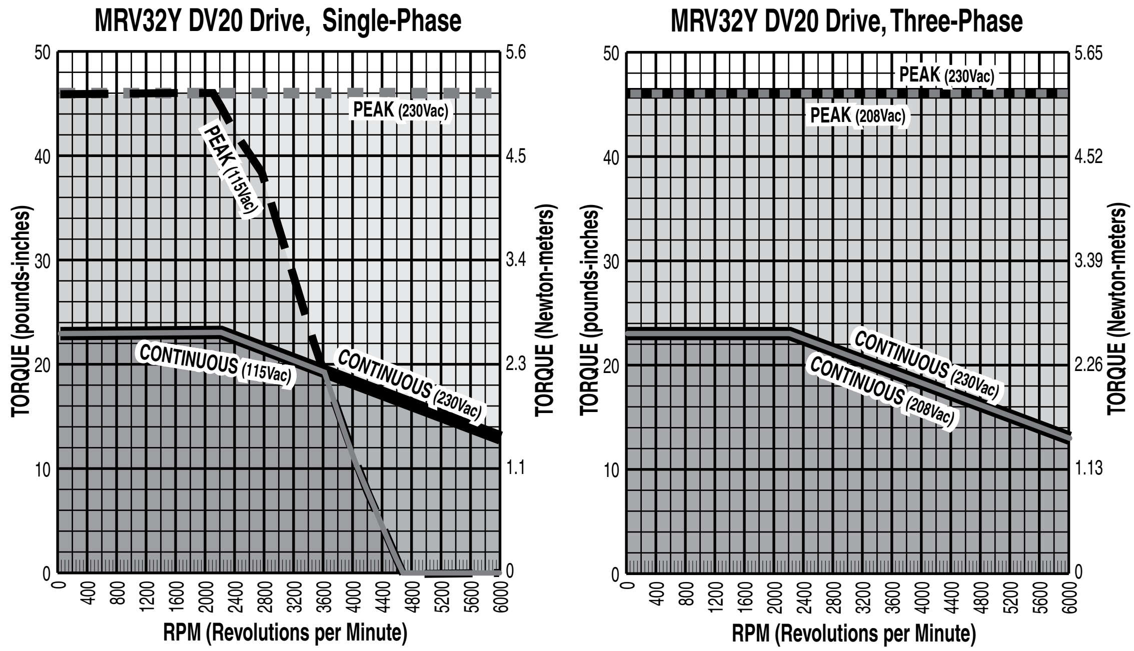


Figure C.8- MRV 32Y, DV20 Single-Phase, Three-Phase Drive

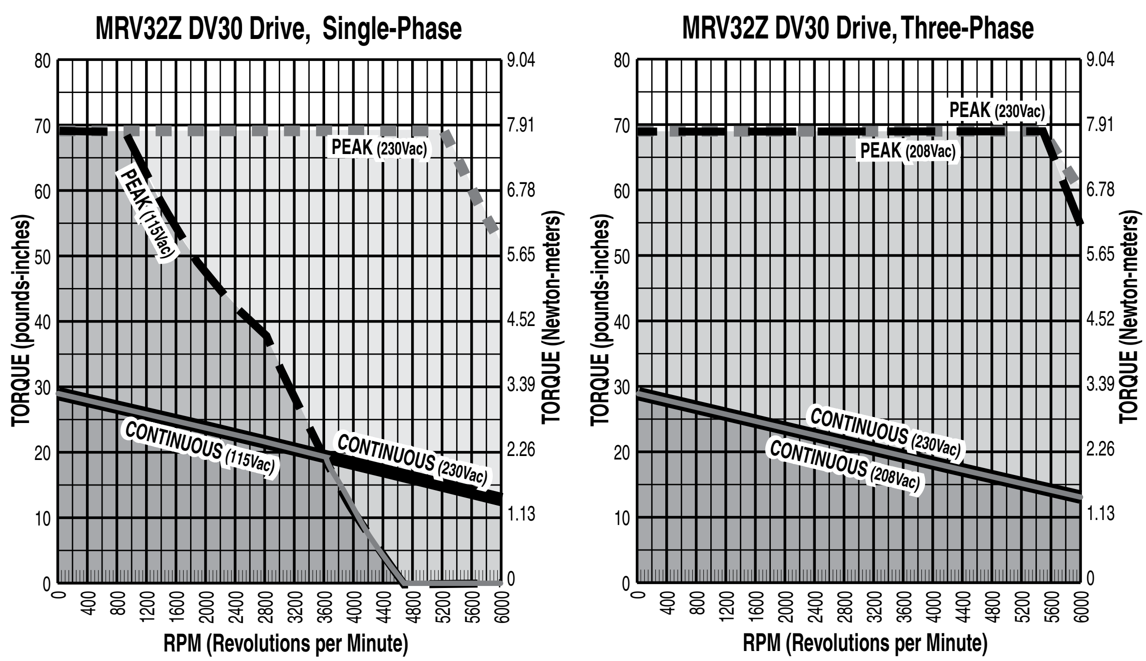


Figure C.9- MRV 32Z DV30 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

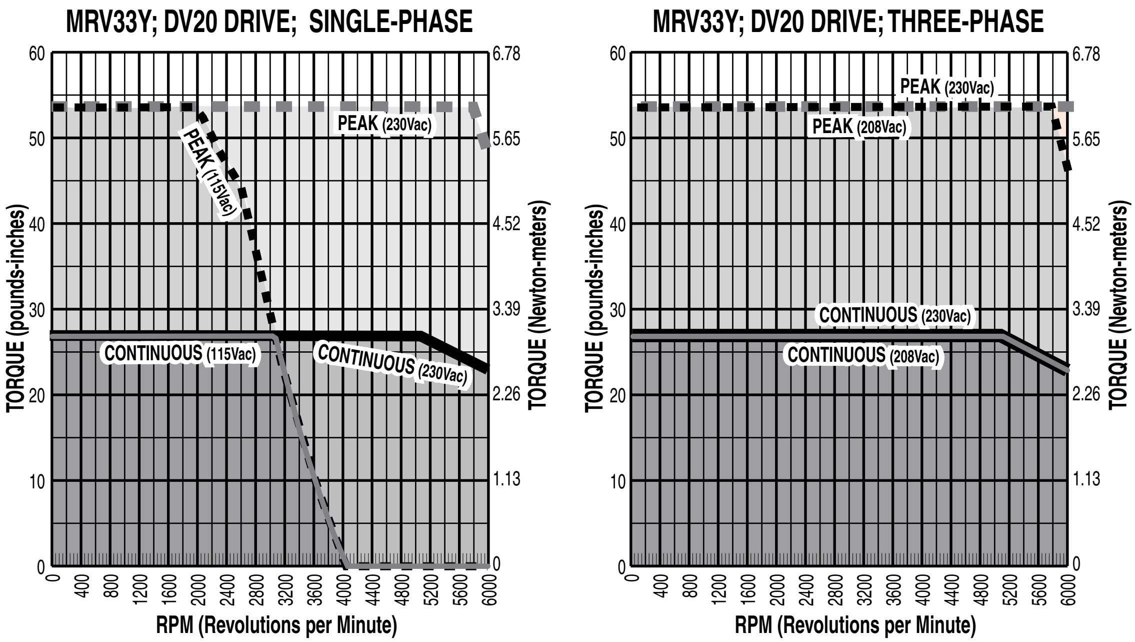


Figure C.10- MRV 33Y DV10/20 Single-Phase, Three-Phase Drive

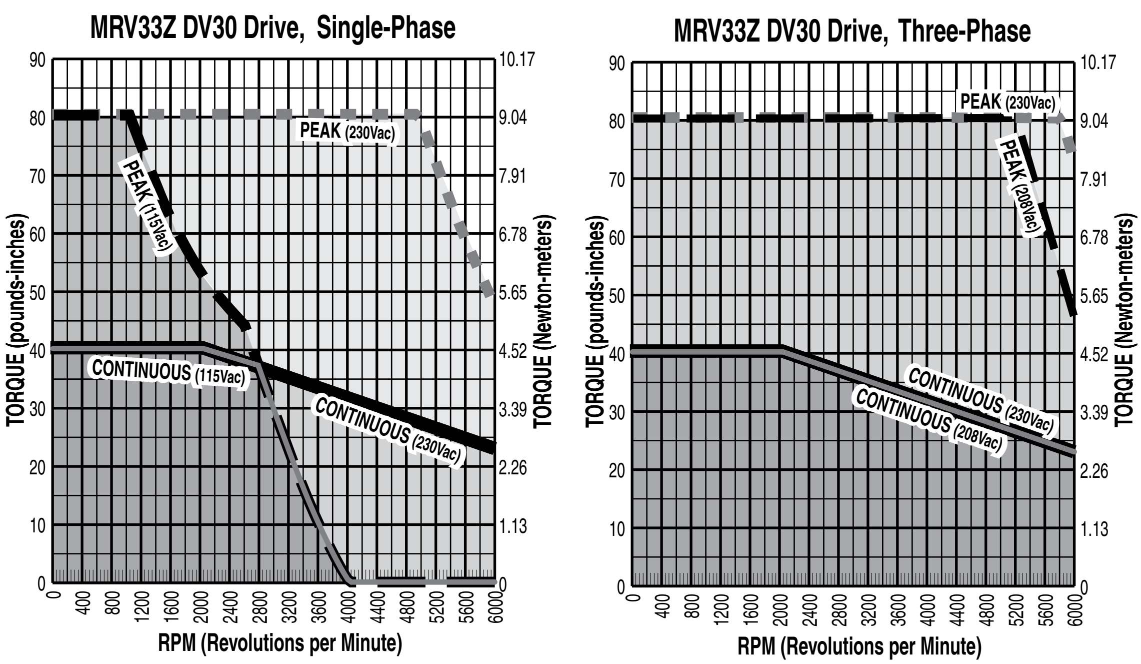


Figure C.11- MRV 33Z DV30 Single-Phase, Three-Phase Drive

MRV Series Motor Drives (continued)

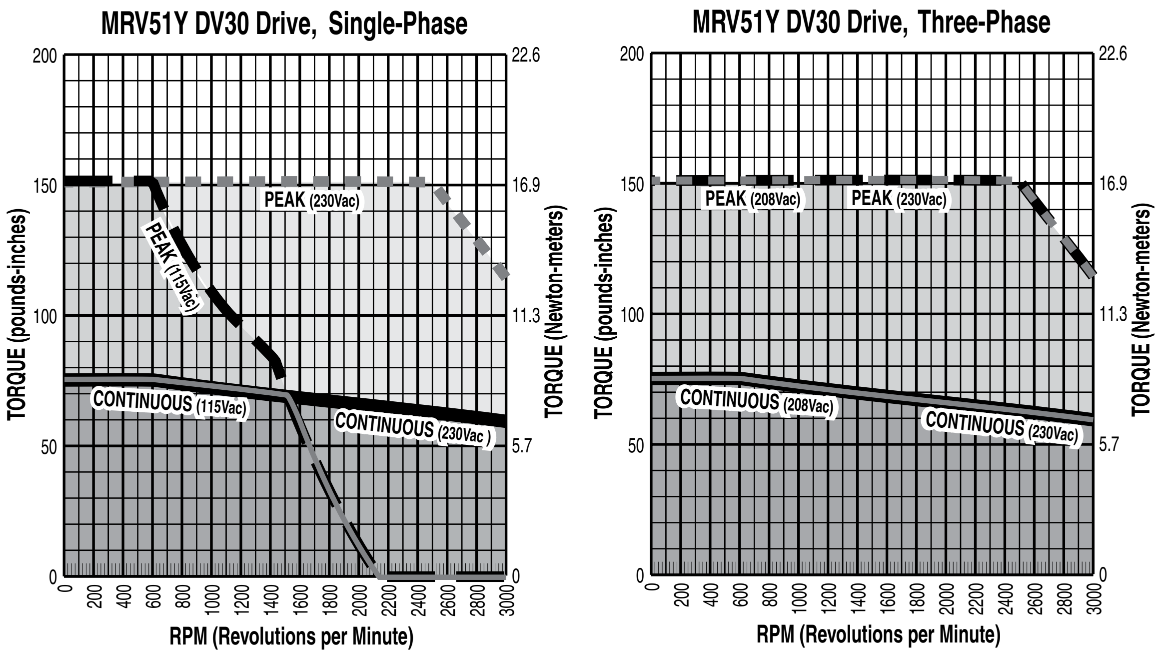


Figure C.12- MRV 51Z DV30 Single-Phase, Three-Phase Drive

MRB SERIES MOTOR DRIVES

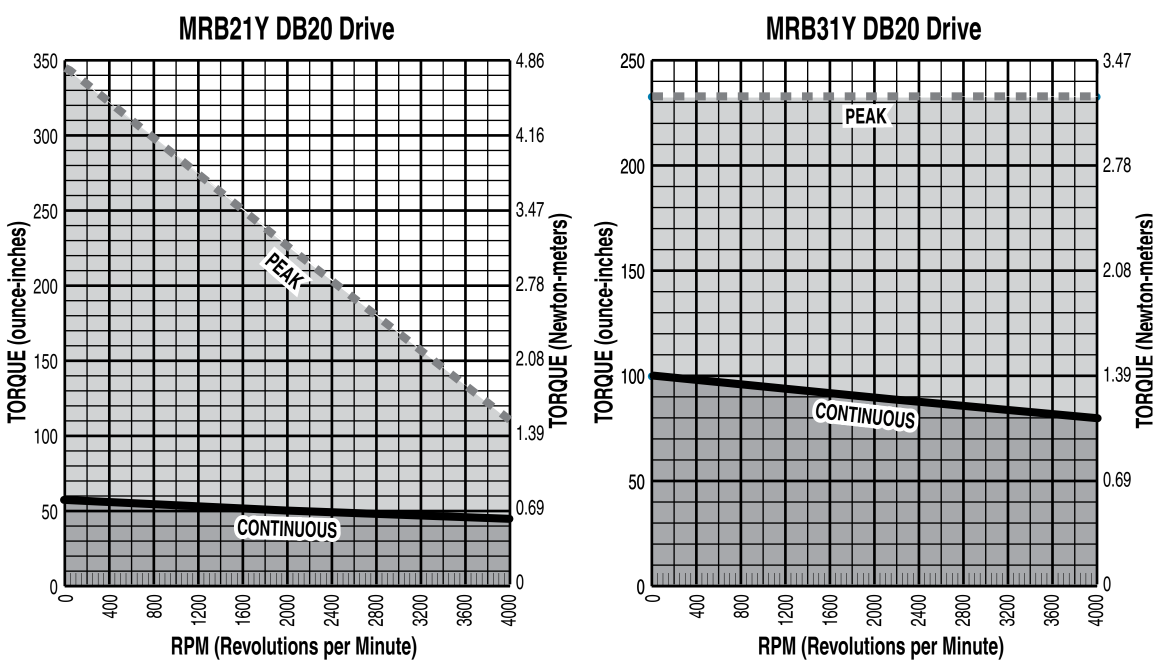


Figure C.13- MRB 21Y/31Y DB20 Drive

MRB Series Motor Drives (continued)

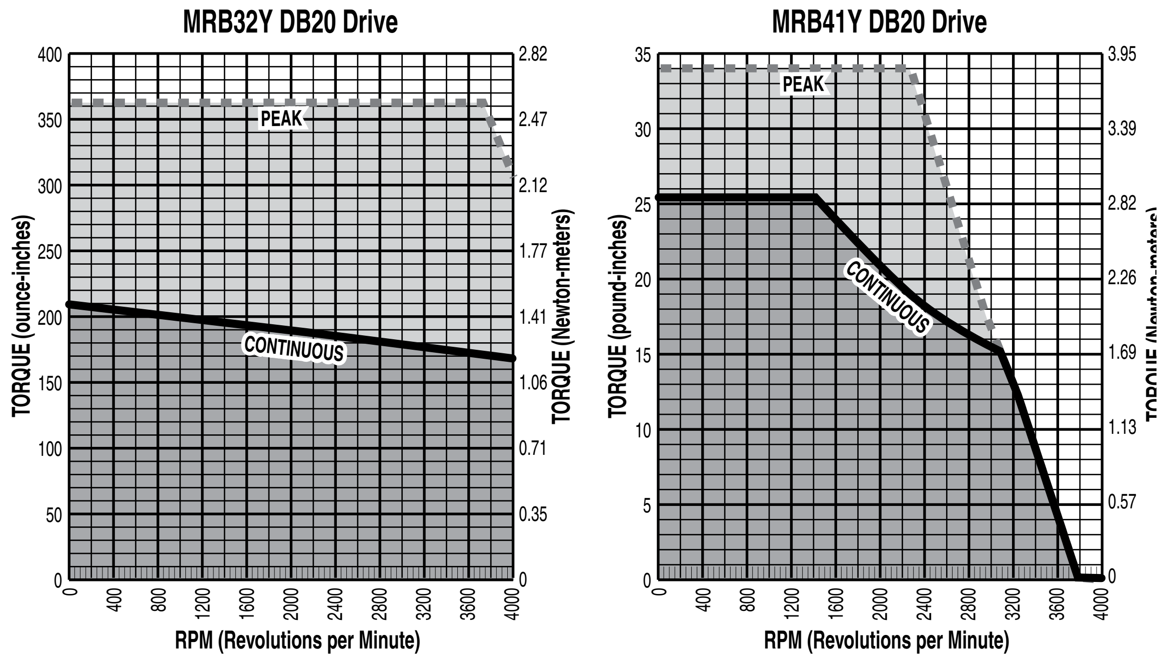


Figure C.14- MRB 32Y/41Y DB20 Drive

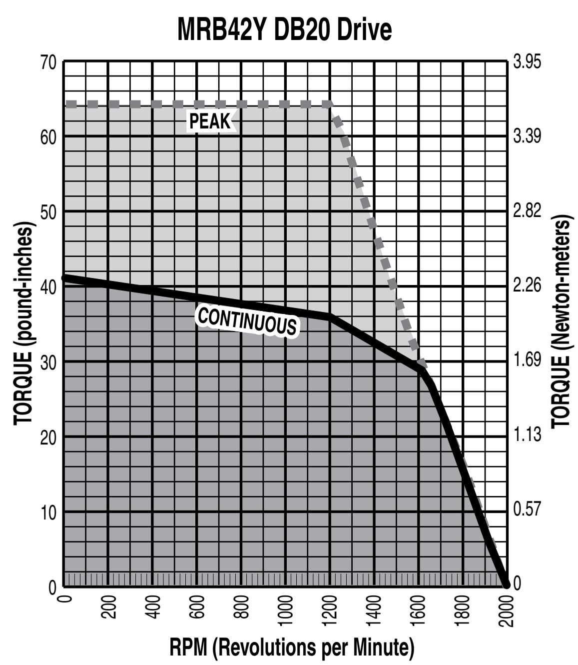


Figure C.15- MRB 42Y DB20 Drive

Brushless MRV Motors

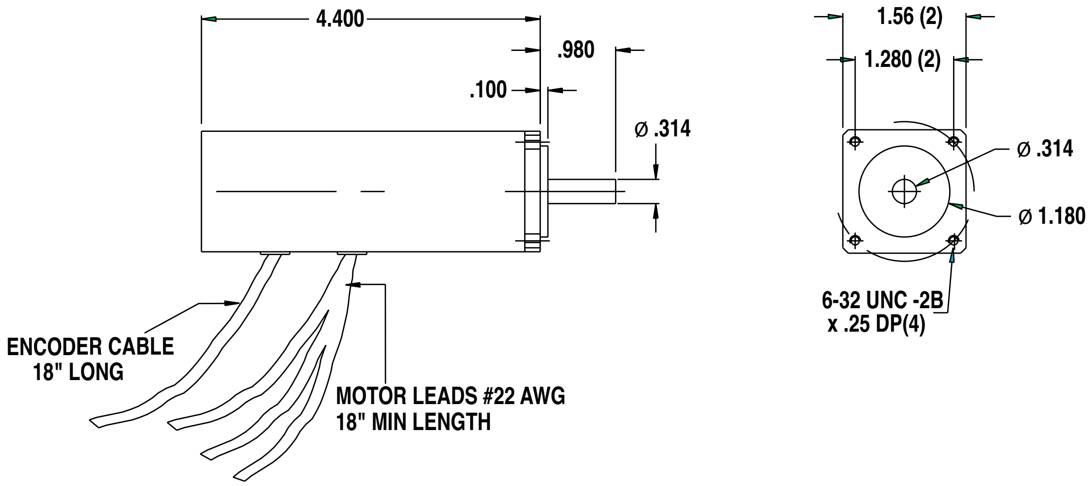


Figure D.1- MRV 11 Motor

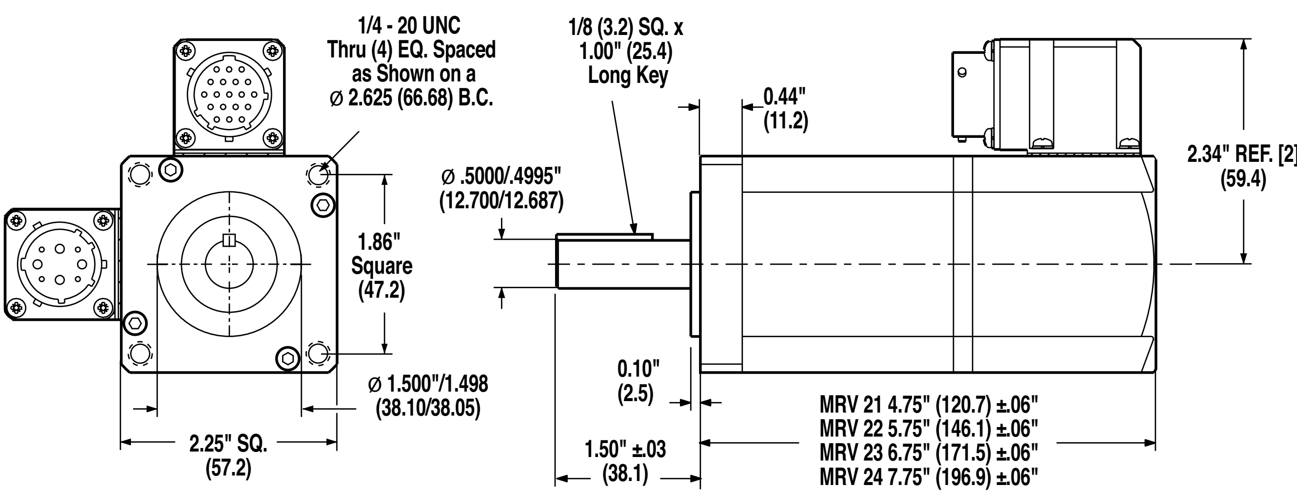


Figure D.2- MRV 21/22/23/24 Motors

Brushless MRV Motors

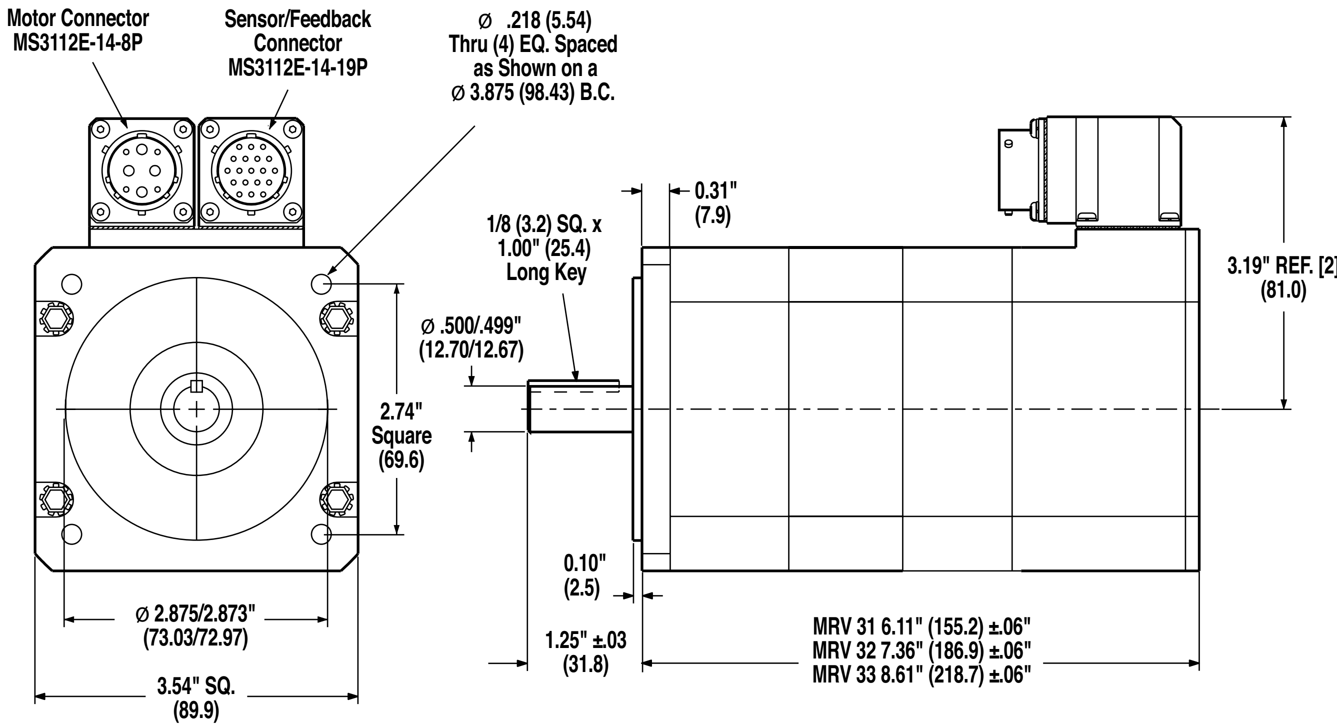


Figure D.3- MRV 31/32/33 Motors

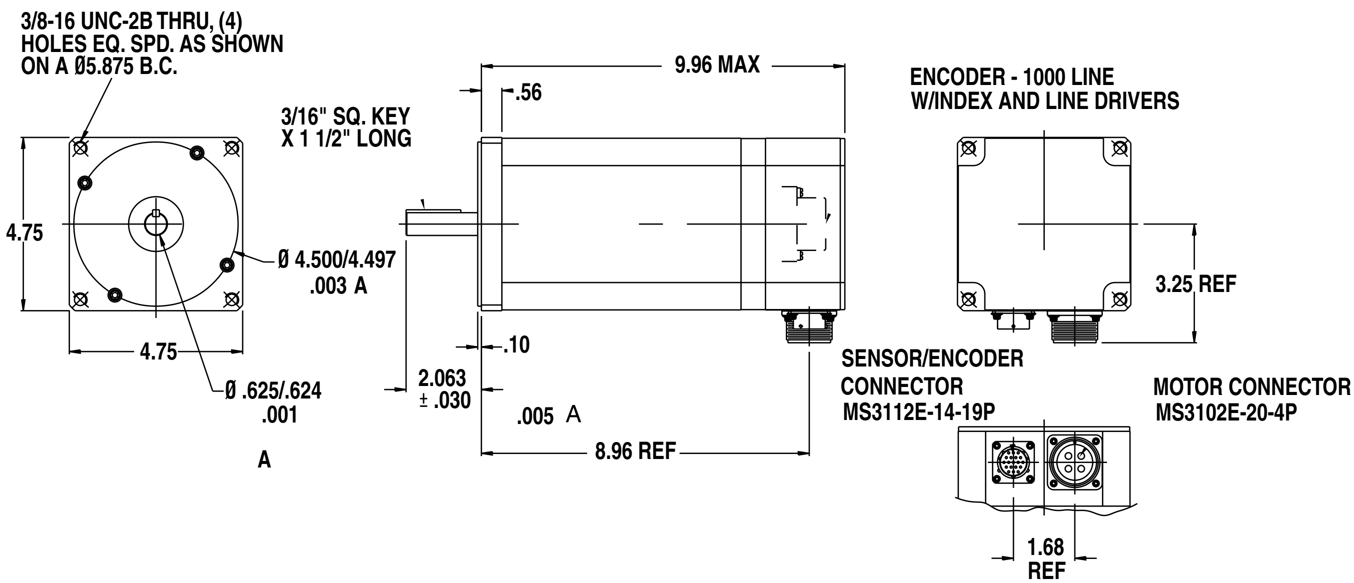


Figure D.4- MRV 51 Motor

Brushed MRB Motors

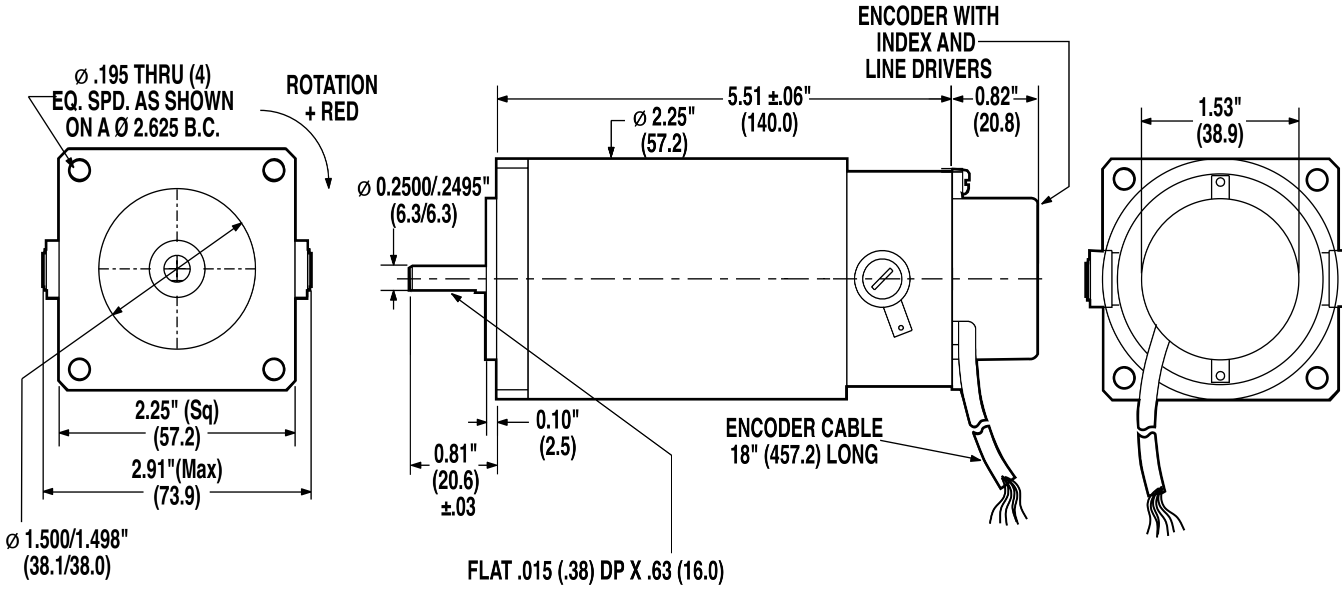


Figure D.5- MRB 21 Motor

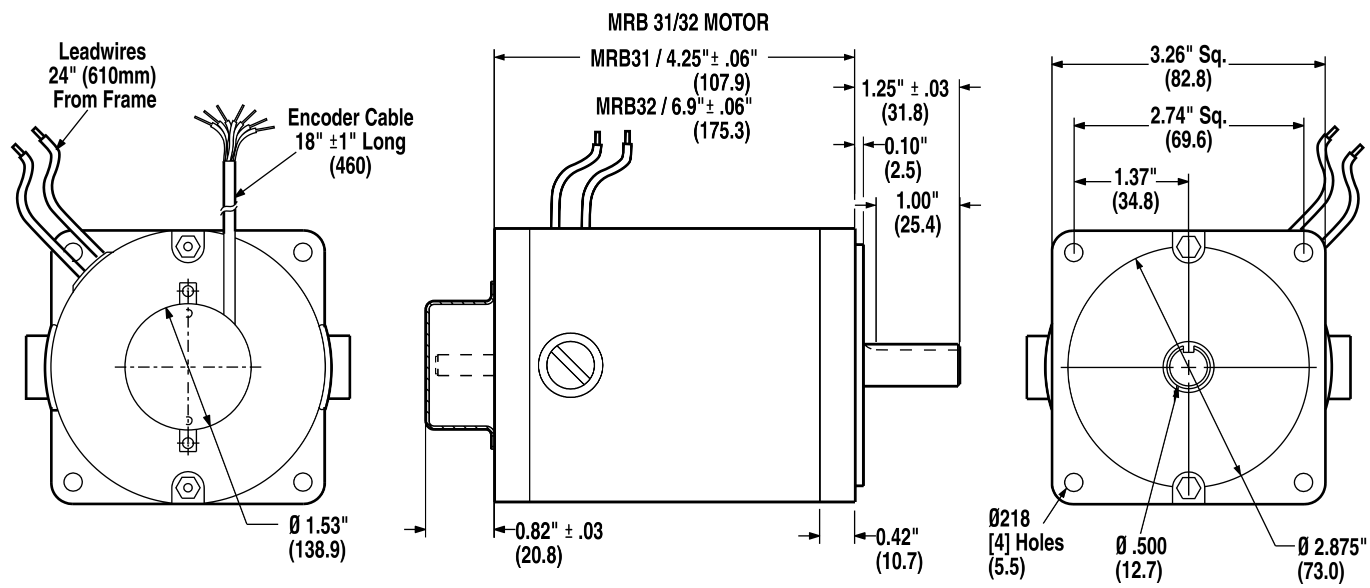


Figure D.6- MRB 31/32 Motors

Brushed MRB Motors

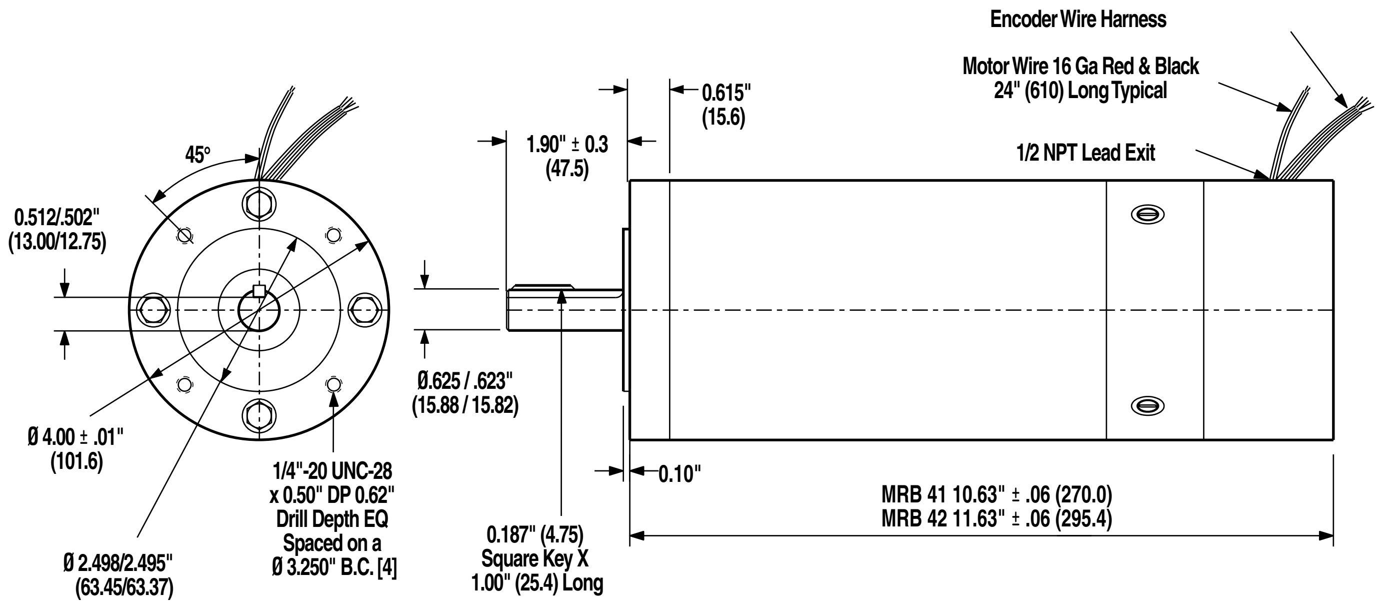


Figure D.7- MRB 41/42 Motors

Warranty Information E

The following product warranty and returned goods information summarizes the product warranty and return policy of Tolomatic. A copy of the formal Returned Goods and Field Service Policy is available upon request.

Defective Equipment

If the user is unable to correct a problem, and the product is defective, the unit may be returned to any distributor of Tolomatic products for repair or replacement.

There are no field serviceable parts in the drive. If the drive fails, the unit should be returned to Tolomatic for repair or replacement. To save unnecessary work and repair charges, please verify that the drive unit is defective before returning it for repair.

Axiom drives are warranted against defects in material and assembly. Limitations to warranty coverage are detailed in Returned Goods and Field Service Policy. Products that have been modified by the customer, physically mishandled, or otherwise abused through incorrect wiring, inappropriate settings, and so on, are exempt from the warranty plan.

Return Procedure

To ensure accurate processing and prompt return of any Tolomatic product, the following procedure must be followed:

1. Call the nearest distributor of Tolomatic products to obtain a Return Material Authorization (RMA) number. Do not return the drive or any other equipment without a valid RMA number. Returns lacking a valid RMA number will not be accepted and will be returned to the sender.

2. Pack the drive in the original shipping carton. Tolomatic is not responsible or liable for damage resulting from improper packaging or shipment.

   Repaired units are shipped via UPS Ground delivery. If another method of shipping is desired, please indicate this when requesting the RMA number and include this information with the returned unit.

Product Support

Tolomatic product support is available over the phone. When you call, you should be at your computer and have the hardware and software manuals at hand. Be prepared to give the following information:

- The version numbers of the hardware and software products.
- The type of hardware that you are using.
- The fault indicators and the exact wording of any messages that appears on your screen.
- How you have tried to solve the problem.

Distributor & Representative Network

Tolomatic has a wide network of distributors that are trained to support our products. If you encounter problems, call the distributor or representative where you purchased the product before contacting Tolomatic.

Application Engineers & Field Service

In the United States, you can reach the Tolomatic factory based support staff by phone Monday through Friday at 1-800-328-2174. The applications engineers can assist you with programming difficulties as well as ideas for how to approach your automation task. Should your problem require on-site assistance, field service is available.

From outside the United States, call 763-478-8000 using the appropriate international access code.

Section 1 — Introduction

The intent of this application note is to give the reader a basic familiarity with the operating features and functions of the Axiom series of servo-motor drives, with particular regard to initial configuration and tuning adjustments. The Axiom drive product line, manufactured by Tolomatic, Inc., consists of three brushless servo-motor drives and one drive for brushed motors.

The brushless motor drives (DV10, DV20, and DV30) are designed to give optimum performance with modern, permanent magnet brushless AC servo-motors. The DB20 is for use with traditional brush-commutated DC servo-motors. All of these drives support three primary modes of operation:

1.) torque mode
-drive produces motor torque proportional to an analog voltage command signal

2.) velocity mode
-drive controls motor speed in proportion to an analog voltage command signal

3.) position control mode
-drive controls motor rotational position using encoder feedback
-command source is pulse train, either step and direction or cw/ccw step

All Axiom drives are fully digital, with non-volatile storage of configuration and tuning parameters. An advanced DSP (digital signal processing) microprocessor provides for fast loop execution rates, with torque bandwidths as high as 1.5 kHz. In addition, Axiom brushless servo-motor drives perform true flux-vector current commutation. This approach provides significant horsepower and efficiency advantages over the traditional sinusoidal commutation method. All drives have current-time protection for drive and motor.

Figure 1.0, at right, shows the basic functional elements of a DV-series brushless servo-motor drive. Rectified DC voltage is switched (commutated) to the motor windings using a three-phase, pulse-width-modulated output bridge. Motor current feedback and rotational position feedback (via encoder) are provided to the DSP processor and used to calculate the bridge switching levels for precise current control. The current control algorithm is based on vector calculations, allowing the bus voltage to be switched to the motor leads in proper proportion for maximum efficiency and torque bandwidth. The DB20 brushed servo-motor drive functions in similar fashion, and is also fully digital. This drive controls torque (current) in the motor's armature circuit – commutation is accomplished by the motor brushes and commutator. Both drive series incorporate a differential analog input for a command signal, as well as optically isolated digital I/O. Accurate, high bandwidth torque control is the most important, fundamental function of any servo motor drive.

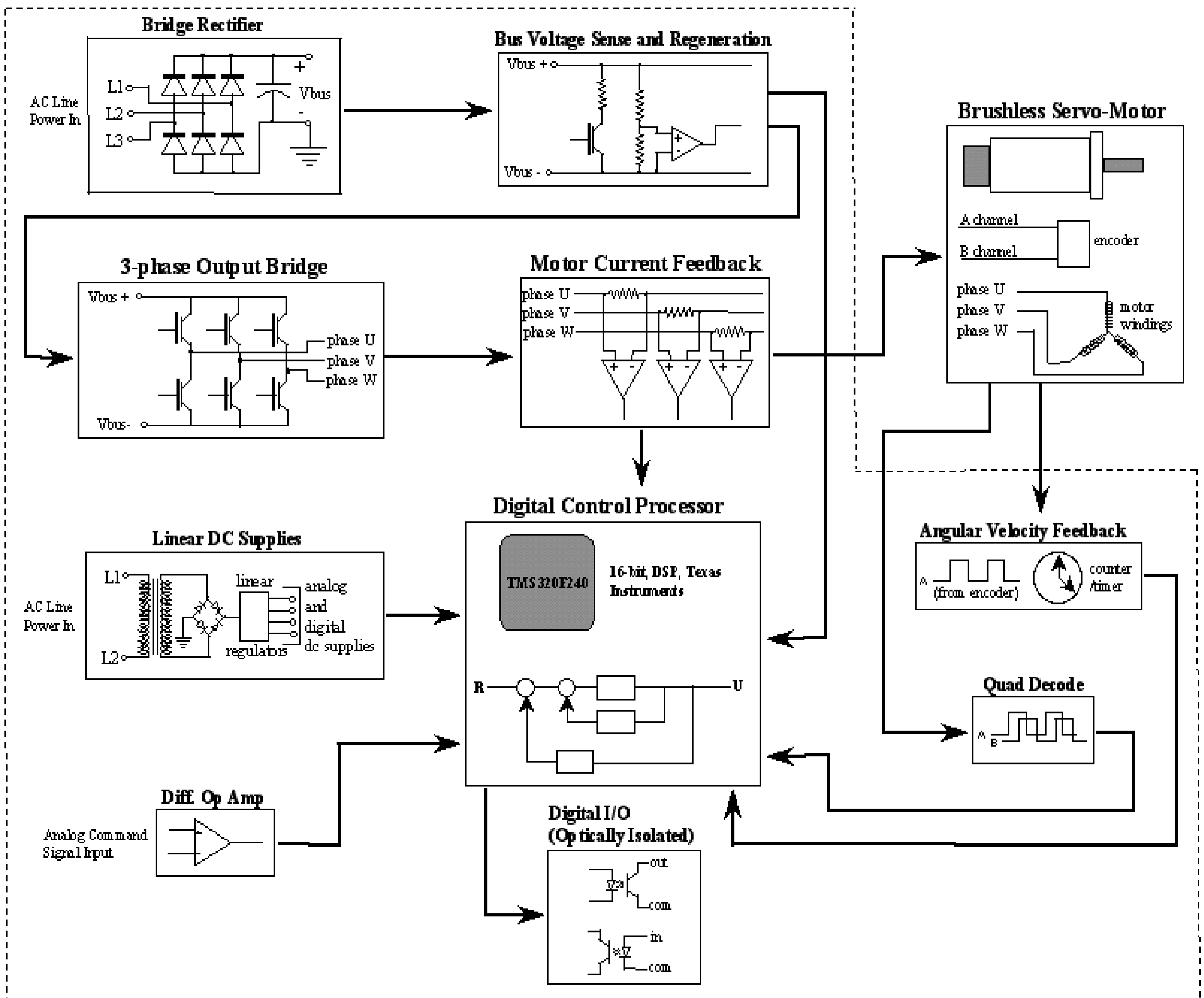


Figure 1.0: Diagram of Drive Hardware Functions

Section 2 – Configuration and Operation of Axiom Drives in Torque Mode

2.0 – DESCRIPTION OF TORQUE MODE OPERATION

For operation in torque mode, the fundamental current control functions are accomplished automatically by the drive. The user need only configure the drive to select the correct motor and make sure the analog input command signal is appropriately supplied.

Consider the combination of a DV10 drive and MRV23 brushless servo-motor. This combination can provide 22.5 in-lbs of peak torque, and speeds to 6000 rpm. Initial configuration of the drive can be accomplished without the motor being connected, if desired. A block diagram representation of the drive control functions when operating in torque mode is shown in Figure 2.0. The control loops are closed for both torque-producing and non-torque-producing current, for true flux-vector control. As shown, when the drive is operating in torque mode, the command source is the external analog input, which can be adjusted for offset and scaled by the drive. If the drive is not in torque mode, the input to the torque control loop comes from the velocity loop output.

2.1 – SELECTING THE MOTOR AND DRIVE OPERATING MODE

The first step in drive configuration is to initialize the drive for operation with the desired motor. This is accomplished using the Axiom setup software and a serial connection with the drive. The drive must be powered up and its comm port connected with the appropriate PC serial communications port via the Tolomatic supplied cable. The following steps give an example of the configuration process for the drive-motor combination given above. Assume that torque mode operation is desired, with a +/- 10 volt analog command corresponding to +/- peak attainable torque.

1.) From the main Axiom software screen, click on the "Drive Setup / Configuration" command button.

    -the Setup and Configuration screen will be displayed, with main function menu at upper left.

2.) Click on the command button for the "Select Drive" function.

-a pop-up menu of drive options will appear, choose "DV10, 10 amp peak brushless drive" and click "SELECT".

-if the drive selection does not match the connected drive, an error will be generated when downloading

the configuration.

3.) Leave the displayed value for drive peak current at 10 amps.

-some applications may require a reduction in this value.

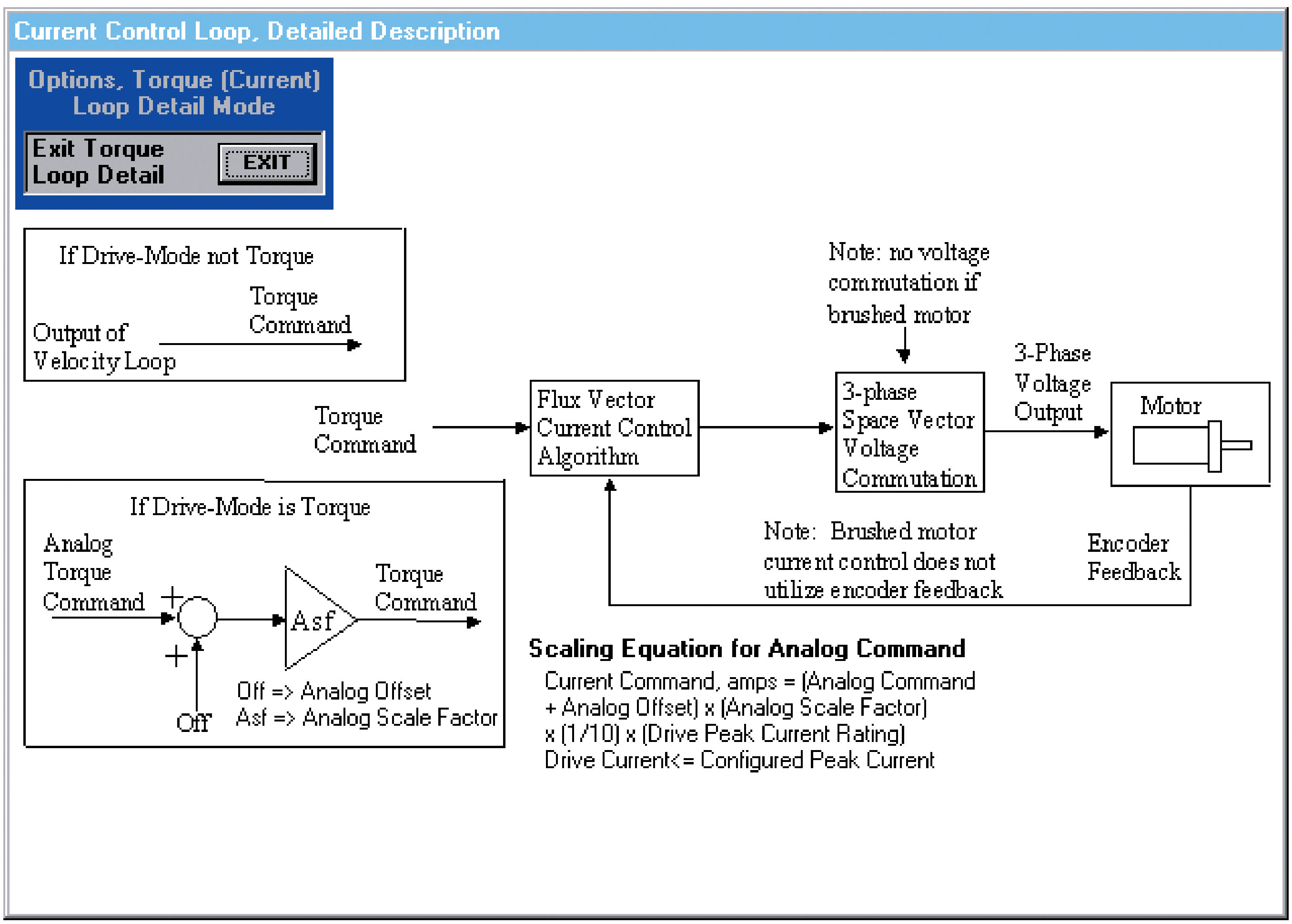


Figure 2.0: Block Diagram showing Torque-Mode Control Functions

4.) Change the limit switch polarities to "N-Open" (normally open) or "N-Clsd" (normally closed) as desired.

-for this example we will configure both travel limit switches for normally-open operation.

-a normally-open limit switch will zero the drive torque in the corresponding direction when the switch closes.

5.) Click on the main function command button for the function, "Select Standard Motor".

-choose the correct motor from the pop-up menu, and click "SELECT".

-for this example, choose "MRV23, 23 frame brushless motor".

6.) Select torque mode from choices in the Drive Operating Mode Selection box at the upper right of the screen.

-torque mode is the default

7.) Set the level of torque used for auto-phasing in the Phasing Configuration box at the lower right.

-for typical systems, a value of 30% should work well.

8.) Click on the main function command button for the function, "Download Parm's to Drive".

-the complete set of configuration parameters will be downloaded to the drive and saved in non-volatile

EEPROM memory.

-a prompt will confirm a successful download.

9.) Drive power must be cycled (the drive reset) before the downloaded configuration will be active.

Upon completion of the above steps, the drive should be properly configured for operation in torque mode with the MRV23 motor. Other main functions available allow configuration parameters to be saved and retrieved from disk files, a useful function when several drives need to be configured for identical applications. The parameters that define the auto-phasing cycle will be discussed in greater detail in a later section of this document. Figure 2.1 on the following page shows how the Setup and Configuration screen should appear after steps 1-7 above.

2.2 – ANALOG INPUT OFFSET AND SCALING

For the example chosen, +/- 10 volts of analog command should provide the full range of motor-drive peak torque. Thus, a controller should be chosen with a +/- 10 volt analog output. Proper signal connection is shown in the Axiom drives manual.

Many controllers will have an analog output which exhibits some offset, i.e. when commanding zero torque the analog output will have a non-zero value. The drive can be configured to cancel or "null" this offset, which will improve performance and accuracy.

The drive also allows multiplicative scaling of the input value to improve matching, if necessary.

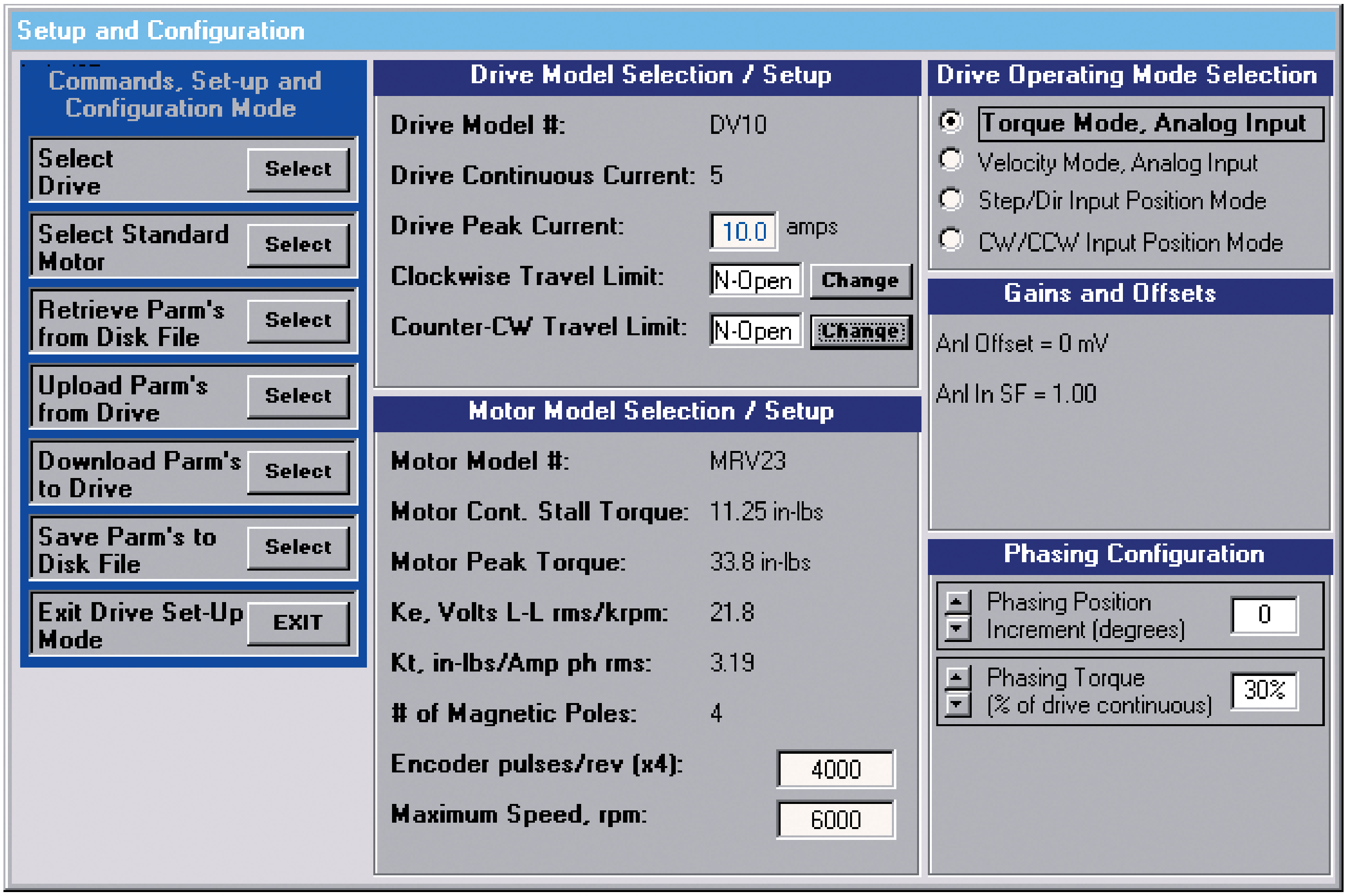


Figure 2.1: DV10 Drive Configuration for Torque Mode, MRV23 Motor

At this point in the drive setup process it is best if the motor is physically disconnected from its intended load, for safety purposes and also to prevent machine damage. The analog input parameters can be accessed in the "Tuning and Diagnosis" screen. The following list of steps illustrates a typical approach to adjusting these parameters.

1.) From the main Axiom screen, select "On-line Tuning and Diagnosis".

-the Tuning and Diagnosis screen will be displayed, which provides on-line continuous monitoring of drive I/O

and diagnostic data, as well as access to tuning parameters.

2.) From the main function menu at the upper left, select "Drive Tuning".

-controls for on-line parameter adjustment will become visible at the lower portion of the screen.

-scroll bars for the analog offset and analog scale factor parameters are to the right.

3.) From the main Axiom screen, select "On-line Tuning and Diagnosis".

-the Tuning and Diagnosis screen will be displayed, which provides on-line continuous monitoring of drive I/O and diagnostic data, as well as access to tuning parameters.

4.) From the main function menu at the upper left, select "Drive Tuning".

-controls for on-line parameter adjustment will become visible at the lower portion of the screen.

-scroll bars for the analog offset and analog scale factor parameters are to the right.

5.) With the drive disabled and controller analog input connected, force the controller to output a command for zero torque. Click on the "Drive Diagnosis" main function command button to display the diagnostic bar-graphs. Activate the torque command bar graph display by clicking on the command button labeled "Active". This bar-graph and associated display box give the command voltage as read by the drive. As an example, if the reading were +0.040, it would mean that the controller output has a positive offset of 40 millivolts. By switching back to the Drive Tuning functions and adjusting the scroll bar labeled "Analog Offset", this input offset can be compensated.

6.) Continue "tweaking" the offset parameter and then switching to the bar-graph display until the drive reads a command voltage as close to zero as possible.

7.) Now force the controller to output a full-scale voltage (positive or negative 10 volts).

8.) Use the Torque Command bar graph display to verify the value of command voltage seen by the drive. The scroll bar labeled "Analog Scale Factor" can be used to provide a multiplier to the analog input if necessary. Note that the Torque Command bar-graph displays the raw command voltage sensed plus the analog offset – it does not reflect the scaling factor. As an example, if the full scale output of the controller was +/- 9.7 volts as determined from the bar graph numerical display, then an appropriate value for the analog scale factor would be: 10.0 / 9.7 = 1.03.

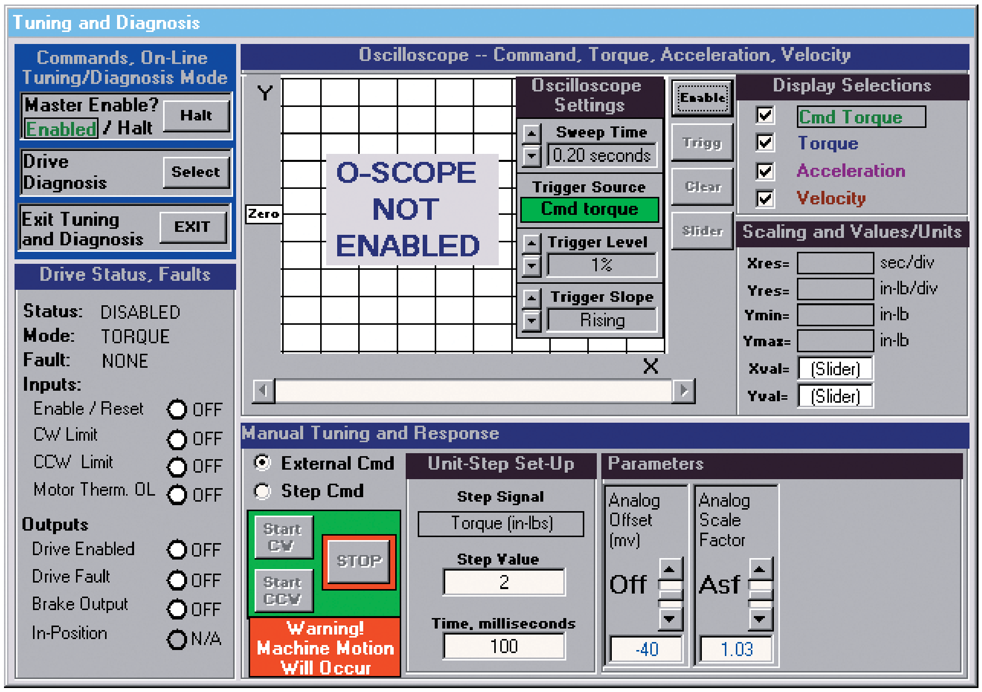


Figure 2.2: Example of Analog Command Offset and Scaling Factor Settings

Figure 2.2 on the previous page shows the appearance of the Tuning and Diagnosis screen after following the preceding steps. The drive is now fully configured and ready for operation in torque mode. However, its operation in conjunction with the control should be verified before the motor is physically connected to the load. The next section will discuss the use of some of the diagnostic functions available through the setup software with regard to system checkout and operation.

2.3 — FINAL OPERATIONAL CHECKS, TORQUE MODE

With the drive-motor combination fully configured for torque-mode operation and the analog command interface with the controller verified and scaled as necessary, a few remaining checks should be carried out before physically attaching the motor to its intended load. First, all wiring terminations should be verified with respect to the Axiom drives manual. The motor lead connections must be made to the drive exactly as noted in the manual for proper phasing and rotation. Initially, the analog command from the controller should be disconnected from the drive and the drive powered up and enabled. The drive LED display should register the character "P" briefly while the auto-phasing sequence executes, and then "E" for enabled. Once phasing is complete, the motor should remain at rest with zero applied torque. The following sequence of steps describes how to manually provide torque step commands to the drive using the setup software. Also discussed is the use of the oscilloscope functions to observe and verify torque response.

1.) From the Axiom software main menu, select "On-Line Tuning and Diagnosis".

    -at this point the drive should be powered up and enabled, with motor connected.

2.) View the "Drive Status, Faults" section (lower-left) to verify that the drive is in torque mode, is enabled, and that no fault conditions exist.

    -if a drive fault condition does exist, click on the "Describe" command button next to the fault listing for a description of the fault.

3.) Select the main function, "Drive Tuning" from the function menu at the upper left.

    -controls for manually initiated step commands and analog command parameters will be displayed at the lower portion of the screen.

4.) The desired magnitude of the torque step command can be entered, in inch-pounds, where indicated.

    -for this example a step value of 15 inch-pounds will be entered.

5.) The time duration, in milliseconds, can be entered. This is the length of time that the torque command will be applied.-for this example, 15 milliseconds will be entered.

6.) Click on the option button to select the command source as "Step Cmd". The motor can now be stepped with clockwise or counter-clockwise torque commands with strength and duration as entered above.

7.) If motor rotation is consistent (clockwise meaning clockwise movement of the motor shaft as viewed when facing the shaft end of the motor) then the oscilloscope function can be used to view the actual torque response of the motor. The scope trigger adjustments are located at the upper right corner of the scope display. To view a clockwise torque step of 15 milliseconds, set up the scope for a total sweep time of 40 milliseconds, and a rising edge trigger of 1%. Figure 2.3 on the following page shows how the corresponding scope data will look.

The drive and motor combination has now been checked out and the external controller can be connected. Note that the command source selection in the Axiom software needs to be selected as "External Cmd" before the drive will respond to an analog command voltage. This is the default command source selection whenever the drive is powered up. It is likely that the external controller incorporates position and/or velocity control. This makes it very important that the physical polarity of the analog command connection is correct. In other words, if the controller is trying to command some positive (clockwise) torque, the associated command voltage should be positive at the input terminals of the drive. If the connection is reversed, the motor will "run-away", i.e. accelerate to maximum velocity when the system is activated. Incorrect sense of the encoder connections at the controller can cause a similar situation. These connections are best verified by operating the system with the motor physically disconnected from the load and checking for proper controllability.

If the system controller (command source) is controlling position and/or velocity, then it will likely need adjustment of some control parameters so that the overall system is tuned for the desired response. For most positioning applications, it is better to operate the drive in velocity-mode. The reason for this is that the drive can close the velocity loop with higher precision and bandwidth than typical controllers. Torque mode is usually only desirable for applications where torque or tension is the primary variable to be controlled, (versus velocity or position). Torque bandwidth for Axiom brushless servo-motor and drive combinations is +1.5 kHz. Brush-commutated motors will have a torque bandwidth of about 1.2-1.3 kHz. Figure 2.4 on the previous page shows theoretical step response and frequency response to a torque command for the DV10 / MRV23 combination. These responses are representative of obtainable torque response for all Axiom brushless drive and motor combinations.

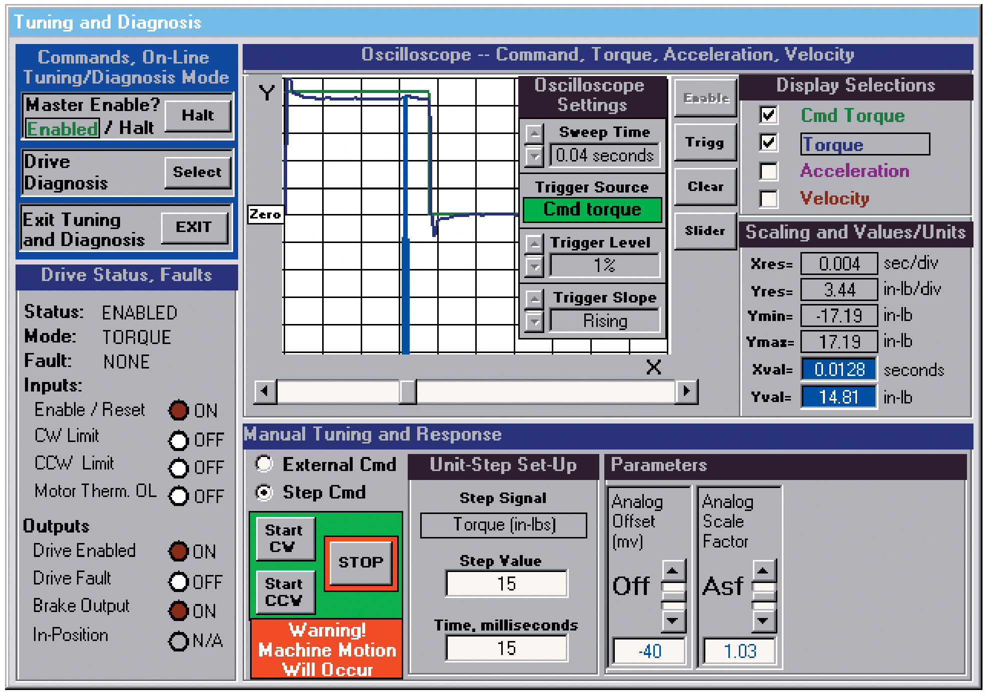


Figure 2.3: Example of Torque Step Response

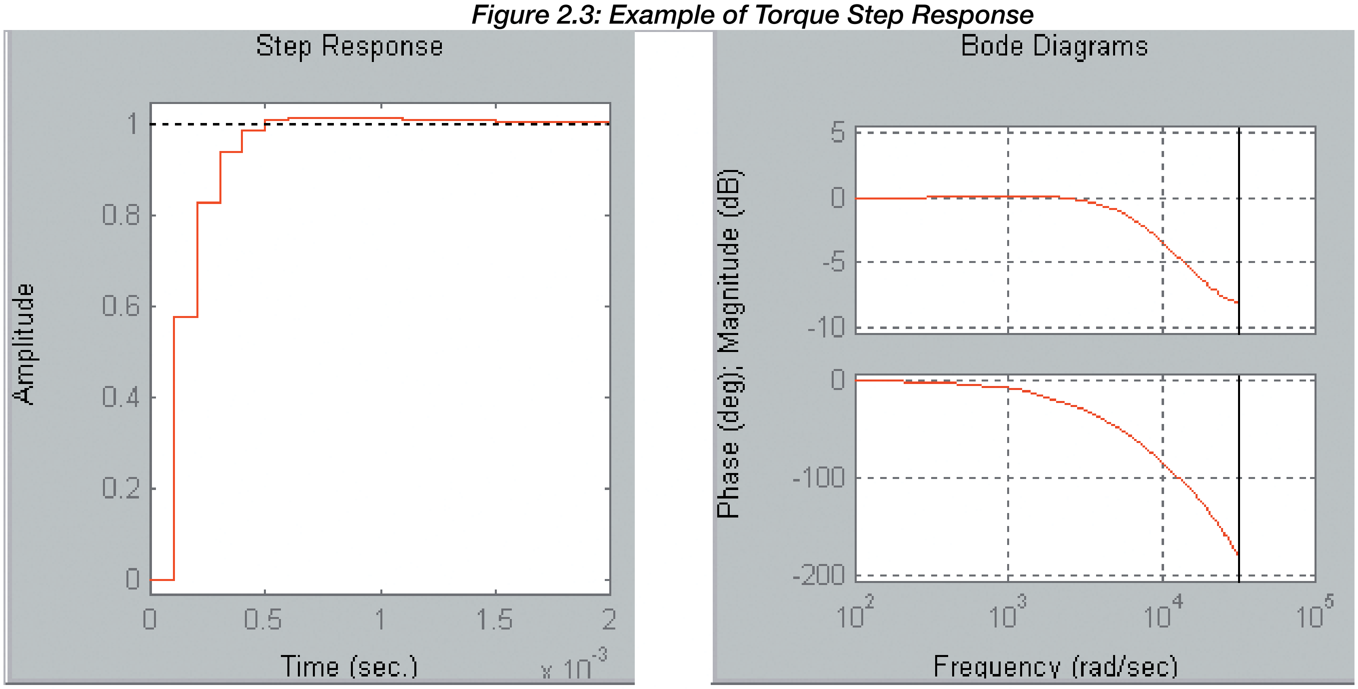


Figure 2.4: Step and Phase-Frequency Torque Response, DV10 and MRV23

2.4 — SUMMARY OF TORQUE MODE DRIVE SETUP AND CONFIGURATION

Applications that are most suitable for drive operation in torque mode typically involve tensioning or force (thrust) control. Positioning applications will usually benefit from operating the drive in velocity mode. This is due to the fact that the drive velocity loop bandwidth will typically be higher than that achievable by the controller. Also, the Axiom series drives provide a very versatile velocity loop algorithm, with advanced tuning options. Some controllers are fully capable of performing position and velocity loop-calculations and providing an analog torque command output. If performance goals are met, there is nothing wrong with operating the drive in torque mode for a positioning or contouring application.

Once the appropriate motor and drive combination has been selected for the load, the drive must be initially configured for the chosen motor and put into torque mode. These functions can be accomplished via the configuration functions of the Axiom PC software. The maximum drive current can be reduced by the user as applicable. The user can also select whether travel limit switches are to be sensed by the drive as normally-open or normally-closed. Torque mode should be selected in the software, and a value for phasing torque set. The final configuration data set must then be downloaded to the drive and drive power cycled. *Remember that a downloaded configuration is not active in the drive until the drive has been powered down and then back up.*

After the drive is configured for the correct motor and for torque mode operation, the analog offset and scaling factor parameters can be adjusted as necessary. The goal is to match the full-scale controller output command range with the drive's full-scale (peak) current range. These parameters are adjusted via the on-line functions of the Axiom PC software. The software can be used to manually step the motor as a quick check of function and rotational direction.

The final step is to interface the controller (command source) to the drive via the analog input. The polarity of analog command connections and encoder feedback signals must be consistent with the controller's conventions. It is advisable to verify controllability and direction of rotation before the motor is physically connected to the load. Once the system is functioning, the controllers' tuning parameters, if any, can be adjusted for the desired response. The on-line diagnostic functions of the Axiom software may be useful for performance verification.

Section 3 – Configuration and Operation of Axiom Drives in Velocity Mode

3.0 – DESCRIPTION OF VELOCITY MODE OPERATION

Obviously, the fundamental control function of a servo drive operating in velocity mode is to control the rotational velocity of the connected motor with precision. This means that the control response must have a high bandwidth and enough "stiffness" to prevent external disturbances (load changes) from significantly affecting velocity regulation. Tight control of velocity allows positioning moves to be accomplished with smooth, accurate trajectories. When operated in velocity mode, Axiom series drives receive their command signal via an external, analog signal. For typical closed loop positioning applications, the controller needs only to handle the position loop calculations to derive a velocity command value. This velocity command is fed to the Axiom drive. Axiom series drives afford a very versatile velocity control algorithm, whereby velocity control bandwidth and stiffness can be tailored for maximum performance with a given application. The Axiom software provides a very powerful tuning and diagnostic interface to aid the user in achieving optimum velocity control. Velocity mode is typically the best choice for positioning applications in which the controller monitors position and produces an analog command.

Figure 3.0 on the following page is a block diagram representation of the drive control functions when operating in velocity mode. The velocity control algorithm utilizes encoder feedback to calculate actual motor velocity, then closes the velocity loop around the drive's torque control functions. Note that the velocity loop command can come from either of two sources. If the drive is in velocity mode, then the command source is the external analog input, as discussed. If the drive is in a positioning mode, the command source is calculated by the drive's position loop. The velocity control algorithm consists of a digitally implemented PID (proportional, integral, derivative) control function, with both acceleration and velocity feedforward gains. The execution rate of the velocity control algorithm in the Axiom series drives is 5 kHz. Actual velocity loop bandwidth depends on the application, (load inertia, friction, backlash, etc.).

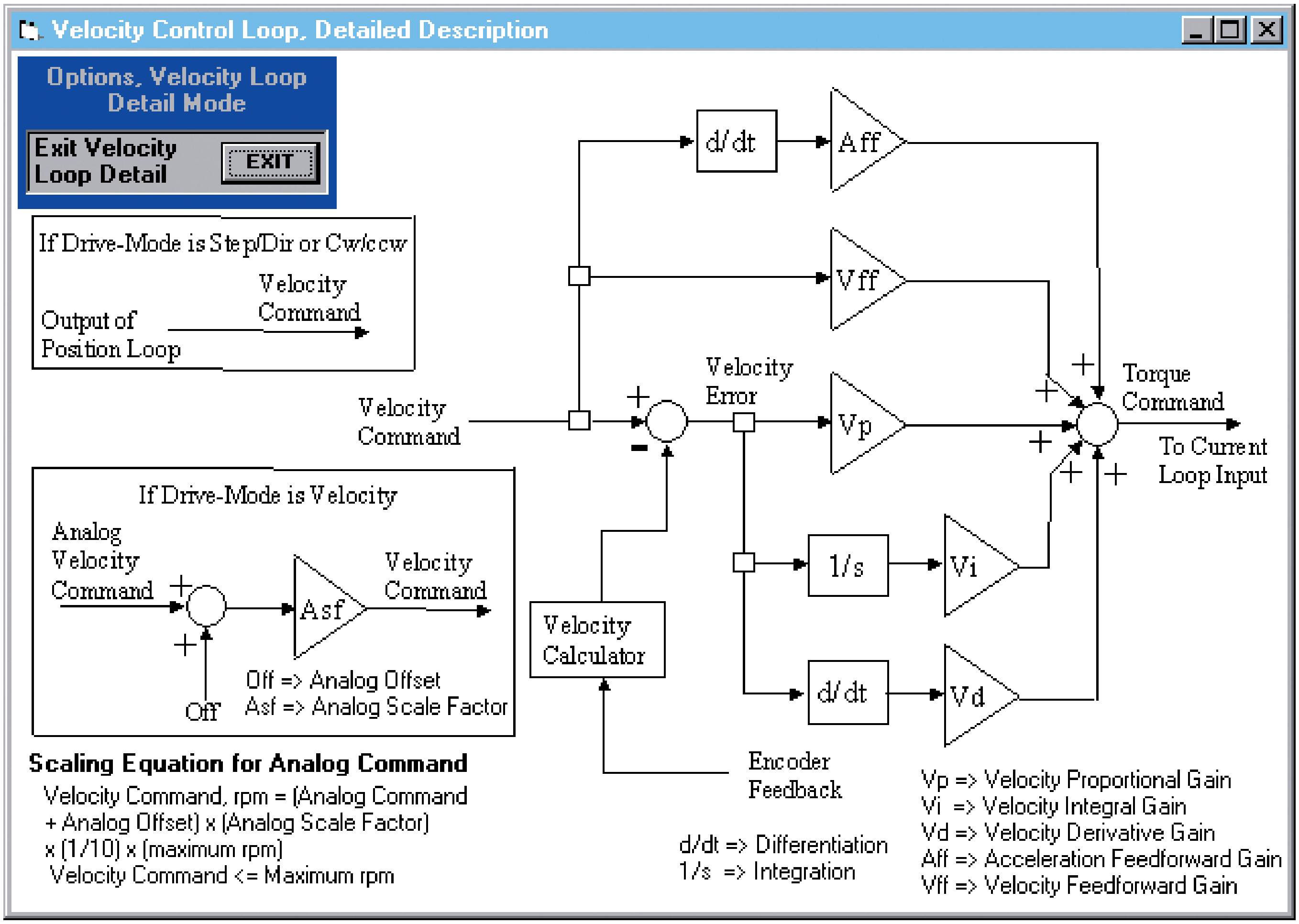


Figure 3.0: Block Diagram showing Velocity-Mode Control Functions

3.1 – INITIAL DRIVE CONFIGURATION, VELOCITY MODE

Configuring the drive for velocity mode involves the use of the Axiom setup software. Once the drive is powered up and connected to the comm port of a PC running the Axiom software, the following steps must be completed to properly configure the drive:

1.) From the main Axiom software screen, click on the "Drive Setup / Configuration" command button.

-the Setup and Configuration screen will be displayed, with main function menu at upper left.

2.) Select the corresponding drive model #, refer to Section 2.1 for details

-note that performing a parameter upload will automatically select the model # of the drive being communicated with.

3.) Reduce the value of drive peak current only if the application requires torque-limiting.

-reducing this value will reduce bandwidth and acceleration.

4.) Select the proper sense for the over-travel limit switches (normally-open or normally-closed).

5.) Select the motor model #, Section 2.1 gives a detailed description of how this software function works.

6.) Enter a value for maximum rpm

-choose this value based on the maximum speed needed for the application. The drive will assign this velocity to correspond to a full-scale (+/- 10 volt) analog command input.

7.) Select velocity mode from the choices in the mode selection box at the upper right.

8.) Adjust the value of phasing torque.

-this value corresponds to the torque level that will be applied when the drive auto-phases on power-up. A value of 30% will be a good choice for most systems. Auto-phasing will be discussed in more detail in a later section of this document.

9.) Download the complete configuration parameter set to the drive.

10.) Reset the drive by cycling drive power to make the new configuration active.

After the above actions are completed, the drive should be properly configured to operate in velocity mode with the assigned motor. Figure 3.1 on the next page gives an example of the appearance of the "Setup and Configuration" screen after completion of configuration for velocity mode. The configuration corresponds to a DV10 / MRV23 drive motor combination, with a maximum velocity of 4000 rpm entered.

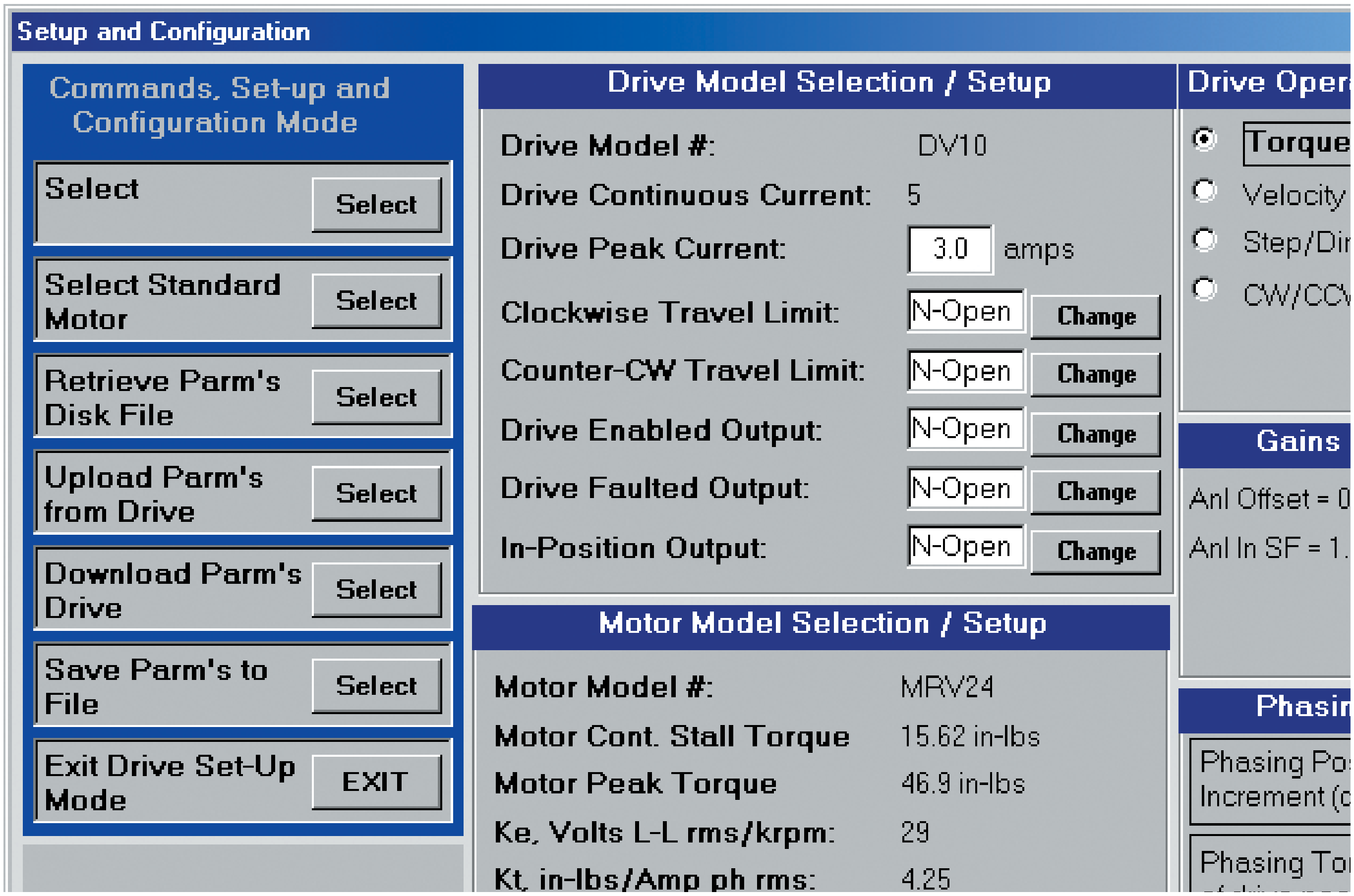


Figure 3.1: DV10 Drive Configuration for Velocity Mode, MRV23 Motor

3.2 – ANALOG INPUT OFFSET AND SCALING, VELOCITY MODE

The drive will always attempt to produce a velocity equal in magnitude to the maximum rpm value entered during initial configuration when the analog command input goes full-scale (+ or – 10 volts). For the example chosen, 4000 rpm was entered as the maximum value. Thus, the analog command will be evaluated by the drive according to the ratio 4000 / 10, or 400 rpm / volt. Just as in torque mode, values for an analog offset and/or scaling factor can be chosen to better match the controller's analog output to the drive command input. The means of adjusting these parameters when in velocity mode is similar to the process when in torque mode. Following is a step-by-step guide to analog input offset adjustment and scaling:

1.) Starting at the main (startup) Axiom setup software screen, select "On-Line Tuning and Diagnosis".

-the Tuning and Diagnosis screen will be displayed.

2.) Select option "Drive Tuning" from the main function menu at the upper left of the Tuning and Diagnosis screen.

-controls for on-line parameter adjustment will become visible at the lower portion of the screen.

-the default values for velocity loop gain parameters are all zero. Do not modify the values of these gain parameters at this time.

3.) Click on the command button labeled "Click for next parm's page".

-the scroll bars for adjusting the analog offset and the analog scaling factor are now visible.

4.) Do not enable the drive. Set up the controller so it is out-putting a zero voltage command. Click on the "Drive Diagnosis" main function menu command to display the diagnostic bar-graphs. Activate the velocity command bar-graph by clicking on the adjacent command button labeled "Active". This bar-graph and its associated value display give the command voltage as read by the drive, with the analog offset applied. By switching back to the "Drive Tuning" functions and adjusting the scroll bar labeled "Analog Offset", an input offset can be compensated.

5.) The controller should now be set up to output a steady-state full-scale voltage.

6.) Again, observe the command voltage value using the diagnostic bar-graph. The scroll bar labeled "Analog Scale Factor", on the second page of the Drive Tuning parameter adjustment controls, can be used to provide a multiplying factor by which the input voltage is scaled. Note that the Velocity Command bar-graph displays the raw voltage read at the analog input plus the analog offset, if any – it does not reflect the multiplicative scaling factor. As an example, if the maximum motor rpm is configured as 4000 rpm, and the full-scale voltage output of the controller is +/- 8.6 volts, then a scale factor of 10 / 8.6 = 1.16 would be necessary to match the 4000 rpm speed range with the full-scale controller output.

Figure 3.2 on the following page shows how the Tuning and Diagnosis screen would look after entering an analog scale factor of 1.16 for velocity mode. The analog offset was left at zero. Before the drive-motor combination will provide optimum velocity control, the gain parameters must be adjusted to match the load. After an initial configuration, these gain parameters all have a default value of zero. The "Auto-Tuning" function can be used to get some starting values. Performance can usually be improved subsequently by utilizing the Axiom setup software's powerful digital oscilloscope and tuning step functions to manually fine-tune the gain parameters. The next section will discuss the significance of the various velocity mode tuning parameters, and provide some examples of tuning typical systems. It is best if the motor is disconnected from its load until rotational direction is verified.

3.3 – DISCUSSION OF VELOCITY MODE TUNING PARAMETERS

There are five tuning parameters available to the user for adjusting the velocity control response:

Velocity Proportional Gain, Vp
Velocity Integral Gain, Vi
Velocity Derivative Gain, Vd
Acceleration Feedforward Gain, Aff
Velocity Feedforward Gain, Vff

Figure 3.0 in Section 3.0 gives a block diagram representation of the role of each of these gains in the overall control effort. A brief discussion of each parameter and its primary control effect is in order:

Velocity Proportional Gain, Vp

Proportional gain is the most common form of control loop compensation. Basically, a proportional gain factor defines the ratio by which a control error is multiplied to provide a value for the driving output. In this case (velocity mode), the proportional gain produces a torque command proportional to the difference between

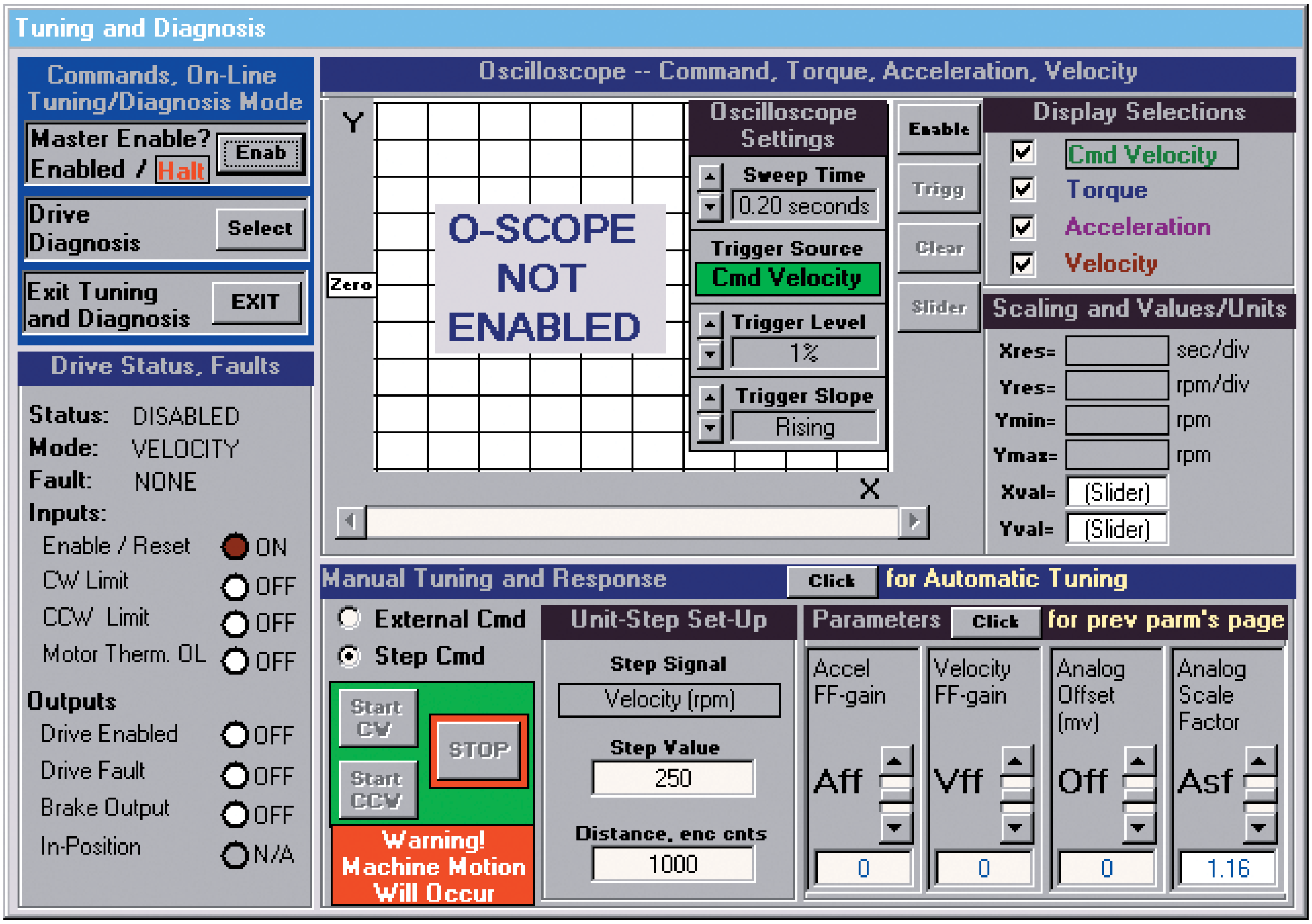


Figure 3.2: Example Analog Scale Factor Setting, Velocity Mode

the commanded motor speed and actual motor speed. The effect of this action is to force the actual velocity to track the command. Increasing proportional gain generally increases bandwidth, however, system stability margins will limit the allowable gain value. Inertial loading is present, to a greater or lessor degree, in all motor control systems. The inertia seen by the motor forces velocity to lag torque. Proportional gain can reduce this lag by generating relatively large driving torque levels for small velocity errors. Since a proportional gain term requires some finite amount of error to produce an output, proportional gain alone will not drive steady-state error completely to zero.

Velocity Integral Gain, Vi

Integral gain is applied to control loops to eliminate steady-state error and to offset changing load conditions. Integral gain in a velocity loop produces a component of torque command that is proportional to the integration over time of the velocity error. In other words, the magnitude of the torque component due to an integral term increases with both the magnitude of the velocity error and the length of time the error has existed. In this way, an integral term can theoretically eliminate steady-state error. Excessive integral gain will tend to produce oscillatory behavior in the control loop.

Velocity Derivative Gain, Vd

Derivative control effectively adds phase lead to a control system. The derivative term produces a torque component that is proportional to the rate of change of the velocity error. For example, if the actual velocity began to quickly decrease while the velocity command did not change, this would produce a positive rate of change in the velocity error. The derivative term would produce a proportional positive torque component. Derivative gain in the velocity loop can be increased to improve velocity smoothness and damping. Excessive derivative gain will make the control loop very "noisy", wasting current.

Acceleration Feedforward Gain, Aff

Acceleration feedforward simply produces a torque component proportional to the rate of change of the command velocity. This term is not part of the closed-loop velocity transfer function. As acceleration feedforward gain is increased, more torque is produced to counter command velocity changes. One use for acceleration feedforward gain is to help compensate for large load inertias. A value of acceleration feedforward gain that is too high for the corresponding system will likely cause current noise (oscillation).

Velocity Feedforward Gain, Vff

The velocity feedforward term will produce a torque component directly proportional to the command velocity. As for acceleration feedforward, velocity feedforward is not part of the closed-loop velocity control scheme. Increasing velocity feedforward gain will increase the magnitude of the torque component produced for a given velocity command. This gain can be adjusted to help compensate for viscous friction in a system. Viscous friction is friction that increases as motor speed increases. Judicious use of velocity feedforward gain can reduce velocity following error. Excessive values of velocity feedforward gain may increase "hunting" when the motor tries to remain at rest at a given position.

When operating in velocity mode, the proportional (Vp) and integral (Vi) gains are most useful with typical systems. Small amounts of derivative gain (Vd) may improve performance. Acceleration feedforward gain (Aff) should be applied only as necessary to help offset large load inertias. Velocity feedforward gain (Vff) can probably be left at zero for most systems. If friction is causing excessive velocity following errors at high speeds, some Vff gain may be helpful. The next section will document an example of velocity mode tuning, with a step-by-step description of the most straightforward way to utilize the Axiom software to produce good response.

3.4 – CASE STUDY, VELOCITY MODE TUNING, DV10 DRIVE, MRV23 MOTOR, 1 TO 1 INERTIA MATCH

This section will detail the entire tuning process for the DV10 drive and MRV23 motor with the drive operated in velocity mode. The motor will be loaded with a solid disk attached to its shaft, sized to provide an inertia equal to that of the motor (0.00037 in-lbs-sec^2). This is then obviously a system with very good coupling (little springiness, backlash, or compliance) between motor and load. It is desired to tune this system for maximum velocity response bandwidth, while still maintaining good smoothness. The general significance of the various velocity mode tuning parameters has already been discussed in the previous section. It should be noted that the values entered for these parameters can be related to common engineering units by a proportional scale factor. Figure 3.3 on the following page lists these relationships for all Axiom tuning parameters. This data can be accessed directly from the main Axiom software screen by clicking on the "Select" command button for the option "Process Units Definition". As an example of how to apply this information, consider the units for acceleration feedforward gain, (in-lb-sec^2)/rad x’s 10. This means that 1 unit of Aff gain corresponds to 1/10 (in-lb-sec^2)/rad of acceleration feedforward compensation. Our example has a total load inertia (including motor inertia) of 2 x’s 0.00037 = 0.00074 in-lb-sec^2. This inertia would require .00074 in-lbs of torque for an acceleration of 1 rad/sec^2. Thus, to use Aff gain to compensate for this load inertia, a desired acceleration of 1 rad/sec multiplied by the value of Aff x’s 1/10 should give a torque of .00074 in-lbs. Solving for Aff in this relationship gives a value of .0074. Since gain values can only be adjusted in integer increments, the value of Aff gain could just be left at zero. Even a value of 1 would be more compensation than necessary. Typically, in velocity mode, Aff gain is useful only when dealing with very large load inertias.

The first step in tuning the example system after the drive has been properly configured is to run the auto-tuning routine a few times to try to get some reasonable starting values. Following is a step-by-step description of this process.

1.) From the main Axiom screen, select "On-Line Tuning and Diagnosis".

   -the Tuning and Diagnosis screen will be displayed.

2.) From the main function menu at the upper left, select "Drive Tuning".

   -the tuning controls will become visible at the lower right of the screen.

3.) Click on the command button to select Automatic Tuning.

   -the software will switch to the automatic-tuning mode.

4.) Select the command source as "Step Cmd" versus "External".

   -torque steps can now be initiated for automatic tuning calculations.

5.) With smaller load inertias, as is the case with this example, the torque setting for an auto-tuning step is best left low. The value for step duration time, in milliseconds should be reduced for best results. In this case, leave the step magnitude at the default and enter a time of 10 milliseconds.

6.) Click on the "Start CW" to initiate the step move.

   -gains will be calculated and displayed for review.

7.) To make the calculated gains active, click on the command button labeled "Accept New Gains".

   -a message box prompt will ask for confirmation, click "OK".

   -the newly calculated values will be loaded into non-volatile EEPROM memory on the drive.

   -the drive will be disabled.

8.) Re-enable the drive using the main function command at the upper left of the screen.

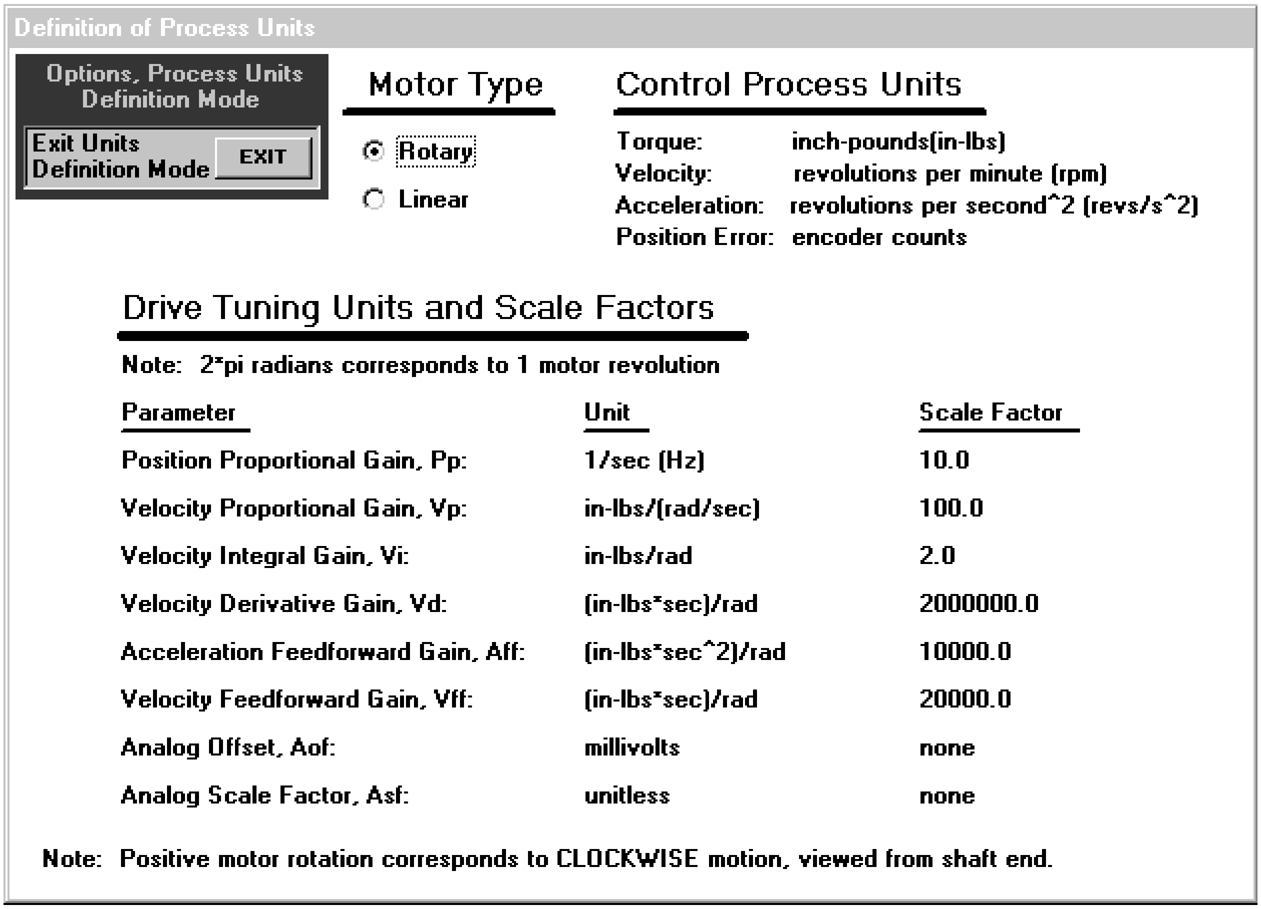


Figure 3.3: Definition of Units for Axiom Tuning Parameters

When auto-tuning, it may be advantageous to repeat the process several times to make sure that calculated values are consistent before accepting them. The next thing to do is view the response using manual velocity step commands initiated from the PC and the oscilloscope functions. Manual tuning adjustments can then be made to optimize the response. To accomplish this, select the manual tuning mode and enter an rpm value and distance in encoder counts for the velocity unit step. Good values for this example would be 3500 rpm and 10,000 encoder counts. The scope trigger settings should be at the default values, with the trigger source being command velocity, rising slope, at a level of 1%. The default sweep time is .20 seconds. By enabling the scope and clicking on the "Start CW" command button, the motor will be stepped and the scope will trigger and display data. The scope sweep time can then be adjusted to best show this step. Figure 3.4 shows what the response looks like. The velocity overshoot is significant due to integral gain. Since the goal was to produce maximum bandwidth and smoothness with minimal concern for reaction to load changes, it would be best to manually adjust the values to reduce this overshoot.

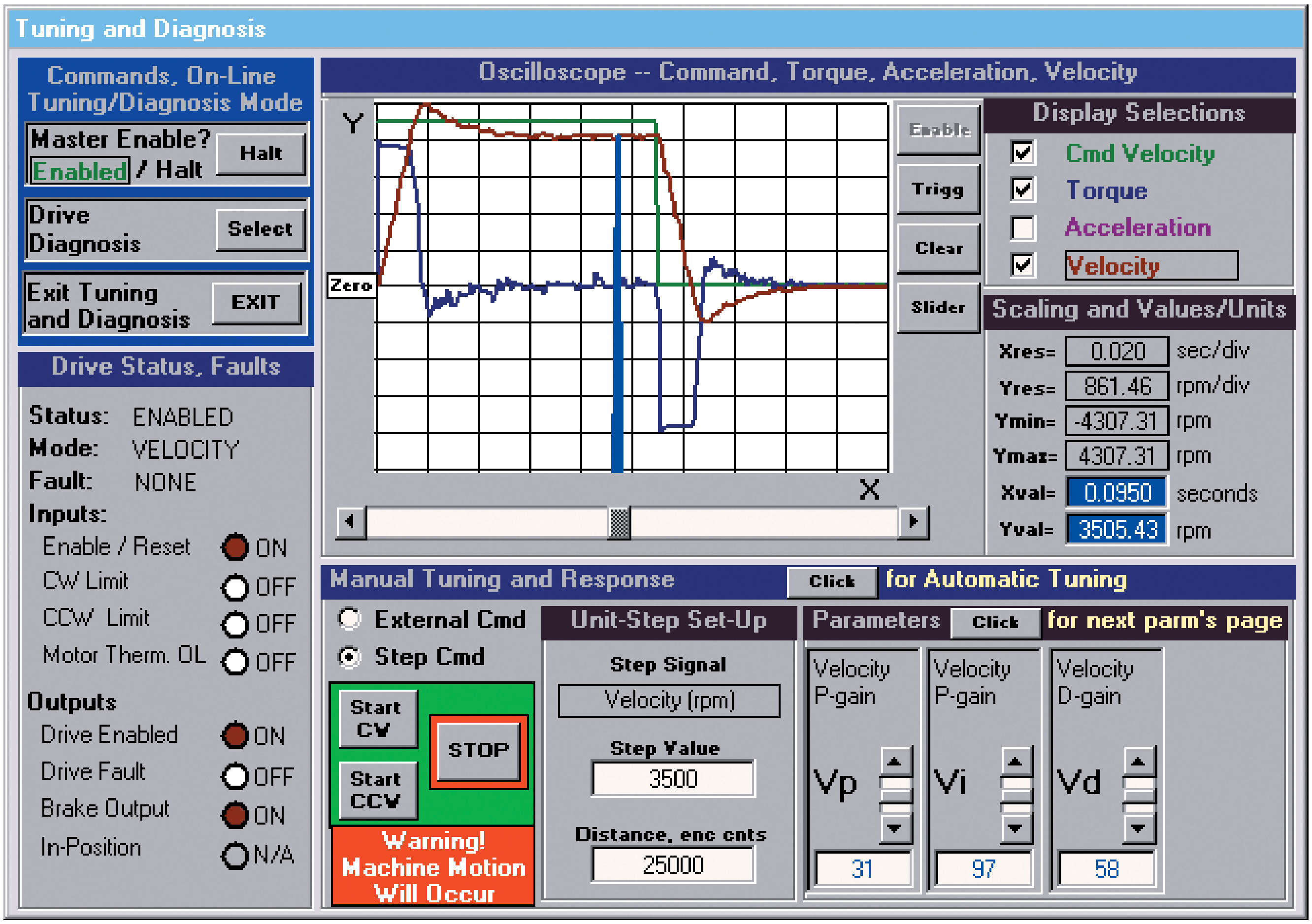


Figure 3.4: Velocity Step-Response after Auto-Tuning

The manual tuning mode provides scroll bars for on-line gain adjustment. There are two "pages" of parameters that can be adjusted. The first page allows values for Vp, Vi, and Vd to be changed. One approach to manually adjust velocity-mode tuning that will typically give good results is to follow these steps:

1.) Make sure the Aff and Vff gains are set to zero. They can be adjusted on the second parameter's page.

2.) Set the integral gain (Vi) to zero, (on the first parm's page.)

3.) Increase the proportional gain and view the step response using the oscilloscope until the torque trace on the oscilloscope begins to look erratic and/or the motor begins to "buzz". Then back off the value of Vp by 10 or 20%.

4.) Adjust the value of derivative gain and take scope shots. Try to improve the smoothness of the velocity response. Excessive Vd gain will make the system noisy.

5.) Some integral gain (Vi) can be applied. Integral gain usually tends to produce more oscillatory behavior and possibly overshoot. Systems with significant drag or viscous friction loading will generally tolerate higher values of Vi.

6.) Acceleration feedforward gain (Aff) can be adjusted via the scroll bar on the second parm's page. Unless inertial loads are very high, very little if any Aff is necessary in velocity mode. Larger values of Aff are occasionally useful when the drive is in a positioning mode, in which case it provides damping.

7.) Velocity feedforward gain (Vff) can be increased to the point where detrimental overshoot or "hunting" at zero speed is observed. Vff can help compensate for friction that increases with speed

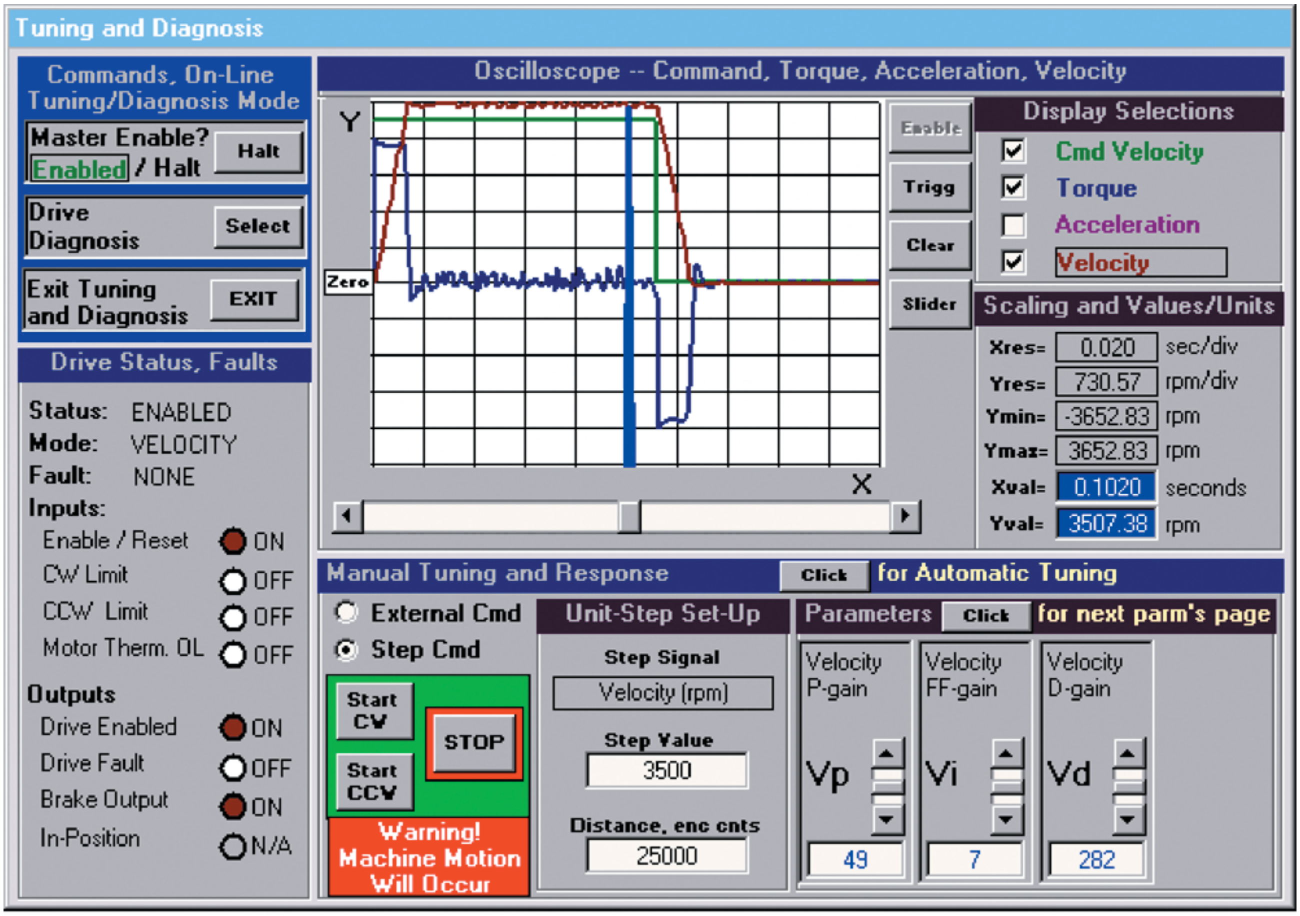


Figure 3.5: Velocity Step-Response after Manual Tuning Adjustments

Figure 3.5 shows the final values arrived at after manually adjusting the gains as described above. Also shown is the oscilloscope step response for a step magnitude of 3500 rpm. The overshoot has been reduced and the response bandwidth looks good. Note that the torque at steady speed has some ripple. Torque and velocity smoothness could be improved at the expense of bandwidth by reducing the gains.

3.5 — SUMMARY OF VELOCITY MODE DRIVE OPERATION

The drive tuning parameters must be adjusted to match the load for proper drive operation in velocity mode. This is best done by starting with the automatic tuning function of the Axiom software and then manually making finer adjustments as necessary. The maximum motor speed should be entered when initially configuring the drive as a value 10 or 15% above the calculated maximum speed necessary for the particular application. Following the steps outlined in Section 3.3 should produce a good velocity loop response. It is important to remember that back emf may limit the maximum speed obtainable – consult the motor and drive combination speed-torque curves in the Axiom manual for definition of the continuous and peak operating regions.

The tuning response achieved for this example should work well if the system incorporates a controller used for positioning applications which outputs an analog velocity command. Again, it should be mentioned that systems with larger loads and/or loads that vary will greatly benefit from more velocity integral gain (Vi). The Axiom software oscilloscope function allows detailed analysis of system step response. Using this feature allows precise fine-tuning of gain parameters to get the type of response desired. Figures 3.4 and 3.5 exhibit the use of the "slider" function to read values directly from a scope trace. To use this function, simply click on the command button labeled "slider" to the right of the scope display once a trigger event has been captured and displayed. Clicking on the name of the particular data to be viewed at the upper right will select which trace the slider follows. The horizontal scroll bar below the scope display can be used to move the slider, and the values at each point can be read from the fields at the lower right, which have a light blue background. Both the signal magnitude and units and the elapsed time since the trigger event will be displayed for any point selected on a trace by the slider function. This allows very precise analysis of overshoot, settling time, accuracy, etc.

Properly tuning a motor-drive combination for velocity mode will allow the controller to process only position loop calculations. The overall system bandwidth and stiffness can thus be maximized. Contouring applications where a single controller provides commands to multiple axis to generate linear or curved interpolated moves will usually be best accomplished by operating the drives in velocity mode. It should be noted that the oscilloscope displays velocity values as actually calculated by the DSP based on an encoder pulse timing algorithm. With typical encoder line counts this feedback value will have some variance or ripple due to feedback frequency being less than the loop execution rate of 5 kHz. This is particularly true at lower rpm's. Actual average motor shaft speed should not exhibit this ripple if the drive is properly tuned.

Section 4 – Configuration and Operation of Axiom Drives in Positioning Mode

4.0 — DESCRIPTION OF POSITIONING MODE OPERATION

When the drive is operated in a positioning mode, the error in position is continuously calculated and used to derive a command velocity. The position error is simply the difference between the actual motor shaft position, determined via encoder feedback, and the commanded position. The commanded position comes to the drive by means of a pulse train input. If the drive operating mode is selected as step/dir, then this pulse train signal consists of one signal line that clocks in position counts, and one line that changes polarity based on the desired direction. One commanded position count clocked in will be evaluated by the drive as equivalent to a command for one quadrature encoder count of position change. Thus for a motor with a 1,000 line encoder (4,000 quadrature counts per motor revolution), 2000 step pulses should cause one half of a revolution of motor movement. This is true for "cw/ccw" mode as well. The difference is, when in "cw/ccw" mode, one signal line supplies clockwise step command pulses and the other, counter-clockwise command pulses. The external controller, which is the source of the command pulses, determines the speed and acceleration of movement, as well as the distance to be traversed. At steady state, the drive attempts to hold the motor at exactly the position commanded, (zero position following error). With proper tuning, response and stiffness can be matched to the application's load. The loop update rate of the position loop in all Axiom series drives is 2.5 kHz. Figure 4.0 shows a block diagram representation of the drive control algorithm which operates when in a positioning mode.

4.1 — CONFIGURATION FOR POSITIONING MODE

Initial configuration is very similar to that for velocity mode. Before downloading, either "Step/Dir Input Position Mode" or "Cw/Ccw Input Position Mode" should be selected, depending on the type of command signal supplied by the external controller. Once the configuration has been downloaded and the drive reset by cycling power, parameter tuning can start. One key to good performance in positioning mode is proper velocity loop tuning. This subject was discussed in detail in Section 3. The velocity loop can be tuned by first placing the drive in velocity mode, adjusting the velocity mode tuning parameters for optimum response, and then configuring the drive for the desired positioning mode and tuning the position loop proportional gain. Alternatively, velocity loop tuning can be accomplished with the drive in a positioning mode, with a low value of position proportional gain entered. The next section will provide an example of tuning the same DV10 / MRV23 combination used to explain velocity mode tuning. Again, the load consists of an inertial disk, with rotational inertia equal to that of the motor. Since the velocity loop tuning parameters have already been determined for this application, all that needs to be adjusted is the position loop proportional gain (Pp). This proportional gain will largely determine overall positioning bandwidth and stiffness of the system.

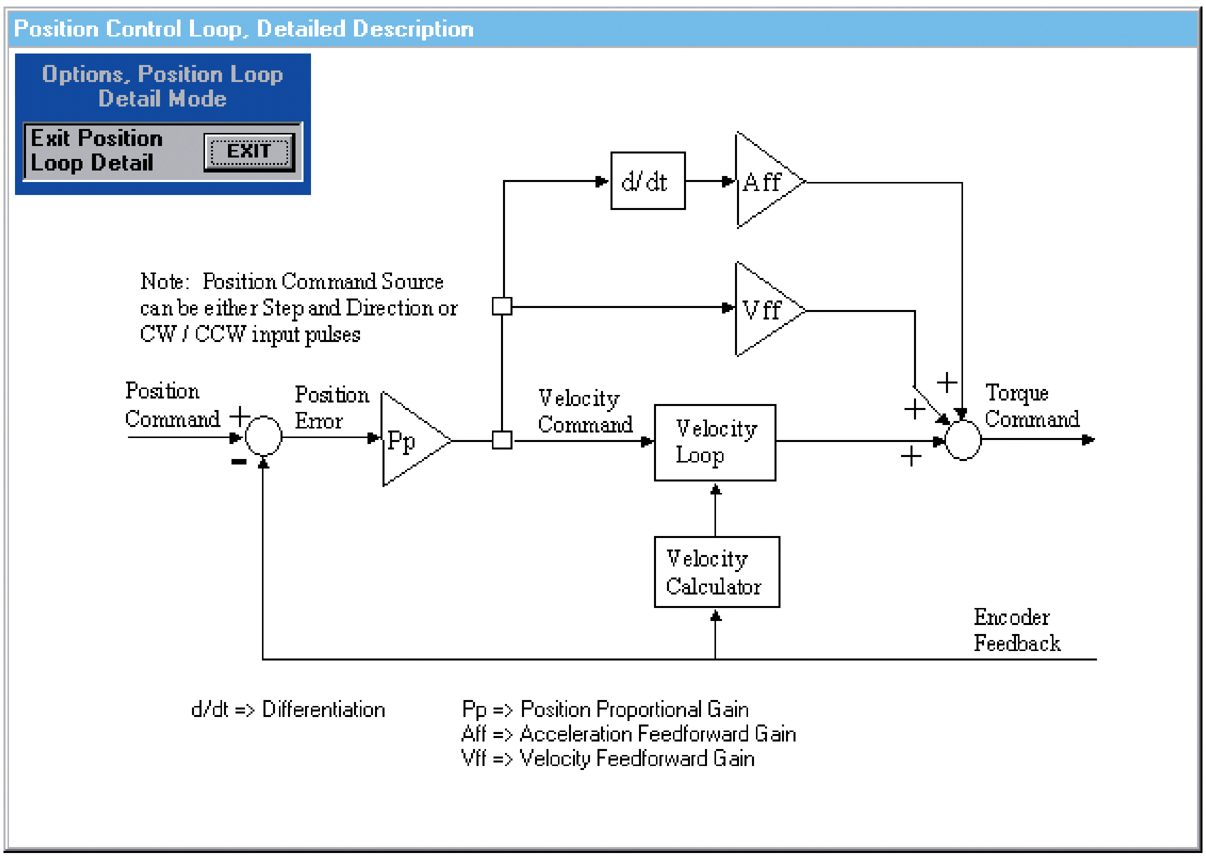


Figure 4.0: Block Diagram showing Positioning Mode Control Functions

4.2 – CASE STUDY, POSITIONING MODE TUNING, DV10 DRIVE, MRV23 MOTOR, 1 TO 1 INERTIA MATCH

Tuning the position loop is quite straightforward once the velocity loop tuning parameters have been optimized. For this example, the velocity tuning values previously used will suffice. As mentioned, position proportional gain corresponds almost directly to system positioning bandwidth. The best approach is to provide manual position error command steps to the drive and use the oscilloscope to observe the response while gradually increasing the proportional gain (Pp). As the Pp gain is increased, system response will get faster and stiffness will increase. Excessive Pp gain will cause overshoot to occur. Another trick that can be used when tuning the position loop is to increase acceleration feedforward gain (Aff). This provides a damping affect and may allow the use of higher Pp gain values without overshoot. Figure 4.1 on the following page shows the final Pp gain setting and a scope shot of the response to a one-half revolution step command. Note that the half revolution move has been completed with positioning to within 1 encoder count after 42.5 milliseconds. There is no significant position overshoot. Note that the velocity integral gain (Vi) was reduced to zero, since it made the system "hunt" slightly. By adjusting the values for Aff, Vp, and Pp, even faster response could be obtained with acceptable damping.

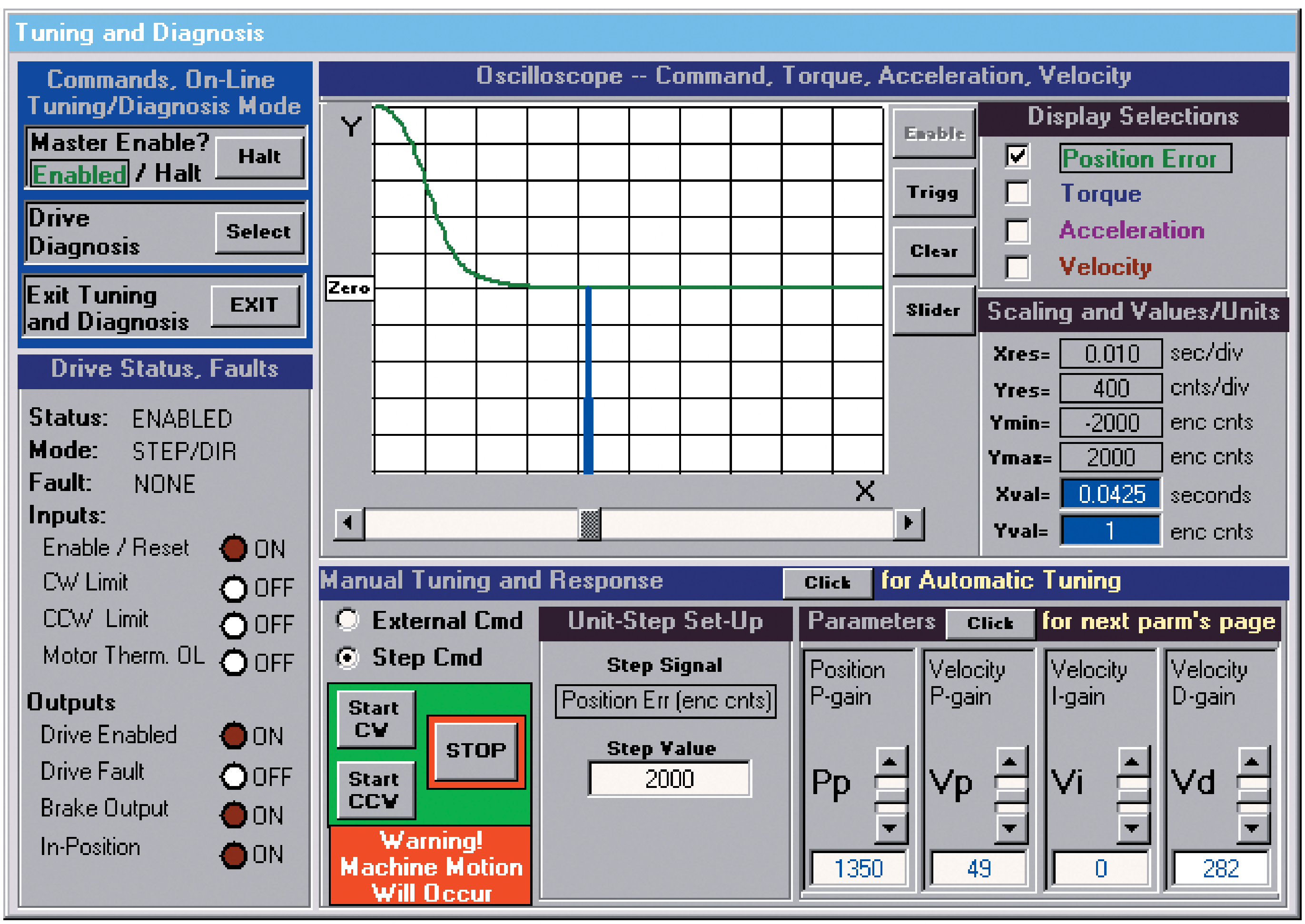


Figure 4.1: Response to Unit-Step Position Command of One-Half Revolution

4.3 — SUMMARY OF POSITIONING MODE DRIVE OPERATION

One of the drive positioning modes should be chosen if the drive is to be used in conjunction with an external controller which provides a pulse-type position command. As discussed, the drive can be configured to accept either step and direction signals or step signals for clockwise and counter-clockwise movement. Make sure that the drive configuration matches the type of command supplied by the controller. All three control loops are closed by the drive when operating in either "Step/Dir Input Position Mode" or "CW/CCW Input Position Mode". Figure 4.2 provides a block diagram representation of the relationship between the position, velocity, and torque (current) control loops.

Tuning the drive in position mode is relatively straightforward once the velocity loop is performing properly. The basic rule of thumb is to increase position proportional gain (Pp) until desired response is achieved. In most systems, minimizing position overshoot is important. The step command and oscilloscope functions of the Axiom software make it easy to adjust parameters for exactly the type of response desired. The scope slider function provides a means of exactly verifying final positioning accuracy.

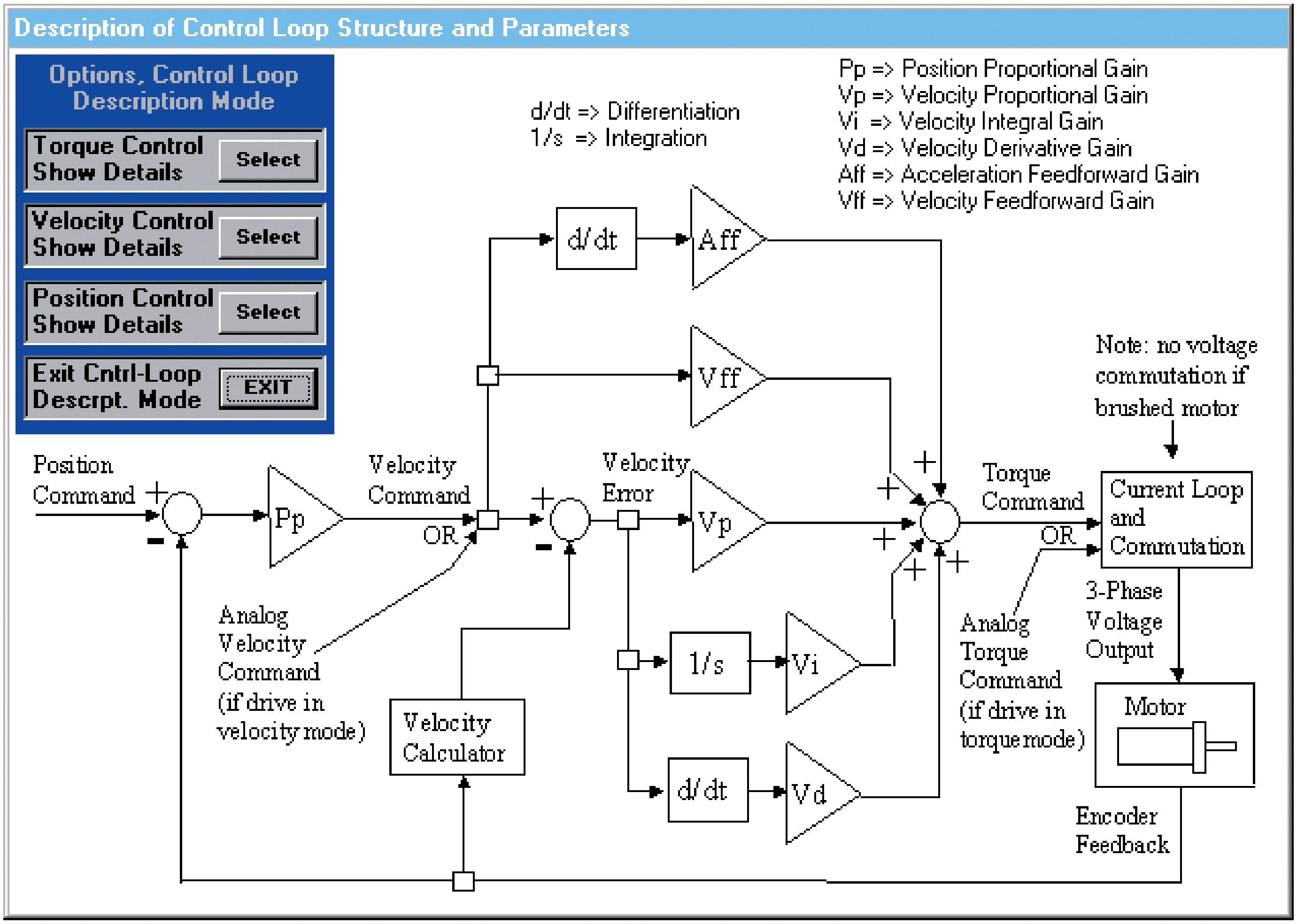


Figure 4.2: Block Diagram of All Drive Control Functions

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