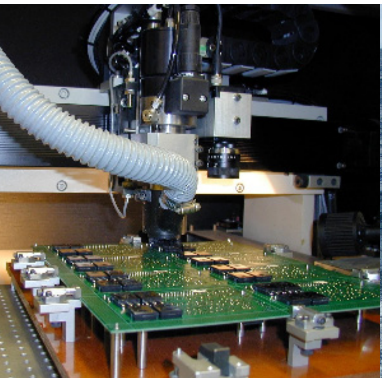
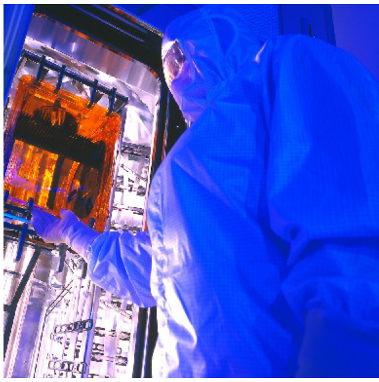
ADVANCED MOTION CONTROLS





Everything's possible.

M/V™ Analog Motor Controllers

for Electric Mobility and Vehicular Applications

Hardware

Installation Manual

www.a-m-c.com

MNALMVIN-02

Preface

ADVANCED Motion Controls constantly strives to improve all of its products. We review the information in this document regularly and we welcome any suggestions for improvement. We reserve the right to modify equipment and documentation without prior notice.

For the most recent software, the latest revisions of this manual, and copies of compliance and declarations of conformity, visit the company's website at *www.a-m-c.com*. Otherwise, contact the company directly at:

ADVANCED Motion Controls • 3805 Calle Tecate Camarillo, CA • 93012-5068 USA

Agency Compliances

The company holds original documents for the following:

- UL 508c, file number E140173
- Electromagnetic Compatibility, EMC Directive - 2014/30/EU
  EN61000-6-2:2005
  EN61000-6-4:2007/A1:2011
- Electrical Safety, Low Voltage Directive - 2014/35/EU
  EN 60204-1:2006/A1:2009
- Reduction of Hazardous Substances (RoHS III), 2015/863/EU

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Related Documentation

- Product datasheet specific for your drive, available for download at www.a-m-c.com.

Attention Symbols

The following symbols are used throughout this document to draw attention to important operating information, special instructions, and cautionary warnings. The section below outlines the overall directive of each symbol and what type of information the accompanying text is relaying.


Note

Note - Pertinent information that clarifies a process, operation, or ease-of-use preparations regarding the product.


Notice

Notice - Required instruction necessary to ensure successful completion of a task or procedure.


Caution

Caution - Instructs and directs you to avoid damaging equipment.


Warning

Warning - Instructs and directs you to avoid harming yourself.


DANGER

Danger - Presents information you must heed to avoid serious injury or death.

Revision History

Document ID	Revision #	Date	Changes
MNALMVIN-01	1	12/2011	Analog Electric Mobility Product Family Hardware Installation Manual First Release
MNALMVIN-02	2	8/2012	- Added 200A100 Power Module Information - Added 100C200 Power Module Information

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1 Safety

This section discusses characteristics of your analog servo drive to raise your awareness of potential risks and hazards. The severity of consequences ranges from frustration of performance, through damage to equipment, injury or death. These consequences, of course, can be avoided by good design and proper installation into your mechanism.

1.1 General Safety Overview

In order to install an analog drive into a servo system, you must have a thorough knowledge and understanding of basic electronics, computers and mechanics as well as safety precautions and practices required when dealing with the possibility of high voltages or heavy, strong equipment.

Observe your facility's lock-out/tag-out procedures so that work can proceed without residual power stored in the system or unexpected movements by the machine.

Notice

You must install and operate motion control equipment so that you meet all applicable safety requirements. Ensure that you identify the relevant standards and comply with them. Failure to do so may result in damage to equipment and personal injury.

Read this entire manual prior to attempting to install or operate the drive. Become familiar with practices and procedures that allow you to operate these drives safely and effectively. You are responsible for determining the suitability of this product for the intended application. The manufacturer is neither responsible nor liable for indirect or consequential damages resulting from the inappropriate use of this product.

Caution

Over current protective devices recognized by an international safety agency must be installed in line before the servo drive. These devices shall be installed and rated in accordance with the device installation instructions and the specifications of the servo drive (taking into consideration inrush currents, etc.). Servo drives that incorporate their own primary fuses do not need to incorporate over current protection in the end user's equipment.

Notice

High-performance motion control equipment can move rapidly with very high forces. Unexpected motion may occur especially during product commissioning. Keep clear of any operational machinery and never touch them while they are working.

Warning

Keep clear of all exposed power terminals (motor, DC Bus, shunt, DC power, transformer) when power is applied to the equipment. Follow these safety guidelines:

- Always turn off the main power and allow sufficient time for complete discharge before making any connections to the drive.
- Do not rotate the motor shaft without power. The motor acts as a generator and will charge up the power supply capacitors through the drive. Excessive speeds may cause over-voltage breakdown in the power output stage. Note that a drive having an internal power converter that operates from the high voltage supply will become operative.
- Do not short the motor leads at high motor speeds. When the motor is shorted, its own generated voltage may produce a current flow as high as 10 times the drive current. The short itself may not damage the drive but may damage the motor. If the connection arcs or opens while the motor is spinning rapidly, this high voltage pulse flows back into the drive (due to stored energy in the motor inductance) and may damage the drive.
- Do not make any connections to any internal circuitry. Only connections to designated connectors are allowed.
- Do not make any connections to the drive while power is applied.

Caution

- Do not reverse the power supply leads! Severe damage will result!
- If using relays or other means to disconnect the motor leads, be sure the drive is disabled before reconnecting the motor leads to the drive. Connecting the motor leads to the drive while it is enabled can generate extremely high voltage spikes which will damage the drive.

Caution

Use sufficient capacitance!

Pulse Width Modulation (PWM) drives require a capacitor on the high voltage supply to store energy during the PWM switching process. Insufficient power supply capacitance causes problems particularly with high inductance motors. During braking much of the stored mechanical energy is fed back into the power supply and charges its output capacitor to a higher voltage. If the charge reaches the drive's over-voltage shutdown point, output current and braking will cease. At that time energy stored in the motor inductance continues to flow through diodes in the drive to further charge the power supply capacitance. The voltage rise depends upon the power supply capacitance, motor speed, and inductance.

Caution

Make sure minimum inductance requirements are met!

Pulse Width modulation (PWM) servo drives deliver a pulsed output that requires a minimum amount of load inductance to ensure that the DC motor current is properly filtered. The minimum inductance values for different drive types are shown in the individual data sheet specifications. If the drive is operated below its maximum rated voltage, the minimum load inductance requirement may be reduced. Most servo-motors have enough winding inductance. Some types of motors (e.g. "basket-wound", "pancake", etc.) do not have a conventional iron core rotor, so the winding inductance is usually less than 50 µH.

If the motor inductance value is less than the minimum required for the selected drive, use an external filter card.

2 Products and System Requirements

This chapter is intended as a guide and general overview in selecting, installing, and operating an M/V™ series motor controller. Contained within are instructions on system integration, wiring, setup, and standard operating methods.

2.1 M/V™ Motor Controllers Family Overview

M/V motor controllers are fully functional, four-quadrant servo drives designed for either permanent magnet brushed or brushless motors for use in electric mobility and vehicular applications. M/V motor controllers provide high power from battery supplies, provide a variety of control and feedback options, and accept an analog command source. A digital motion controller can be used to command and interact with M/V drives, and a number of input/output pins are available for parameter observation and drive configuration.

TABLE 2.1 Standard M/V Series Part Numbers

		Max Voltage / Peak Current	60V 250A	80V 200A	175V 125A	175V 100A
Command Type	0-5V Analog, 0-5kΩ		AVB250A060	AVB200A100	AVB125A200	AVB100C200
	±10V Analog		AB250A060	AB200A100	AB125A200	AB100C200

Drive Datasheet Each M/V motor controller has a separate datasheet that contains important product-specific information on the modes and features available, including the functional block diagram of the specific drive's operation. The datasheet is to be used in conjunction with this manual for system design and installation.

2.1.1 Products Covered

The products covered in this manual adhere to the following part numbering structure. However, additional features and/or options are readily available for OEM's with sufficient ordering volume. Feel free to contact *ADVANCED* Motion Controls for further information.

FIGURE 2.1 M/V Product Family Part Numbering Structure

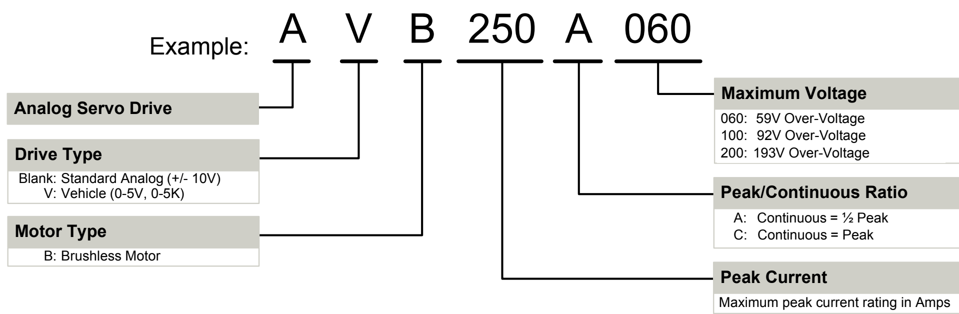


TABLE 2.2 Power Specifications

Description	Units	A_250A060	A_200A100	A_125A200	A_100C200
DC Supply Voltage Range	VDC	20-54	20-80	40-175	40-175
DC Bus Over Voltage Limit	VDC	59	92	190	190
DC Bus Under Voltage Limit	VDC	18	16	36	36
Logic Supply Voltage (Keyswitch) - AVB models only	VDC	20-54	20-80	40-175	40-175
Maximum Peak Output Current[1]	A	250	200	125	100
Maximum Continuous Output Current	A	150	125	80	100
Maximum Continuous Output Power	W	7695	9500	13300	16625
Maximum Power Dissipation at Continuous Current	W	405	500	700	875
Internal Bus Capacitance	µF	12600	6000	3840	3840
Minimum Load Inductance[2]	µH	200	250	300	300
Switching Frequency	kHz	14.5	14.6	14.5	14.6
Maximum Output PWM Duty Cycle	%	100	100	100	100

1. Maximum duration of zero-to-peak current commands is ~10 seconds for AVB drives and ~5 seconds for AB drives. Maximum duration of peak-to-peak current commands is ~10 seconds for AB drives. Peak-to-peak current commands should not be performed with AVB drives.
2. Lower inductance is acceptable for bus voltages well below maximum. Use external inductance to meet requirements.

TABLE 2.3 Control Specifications

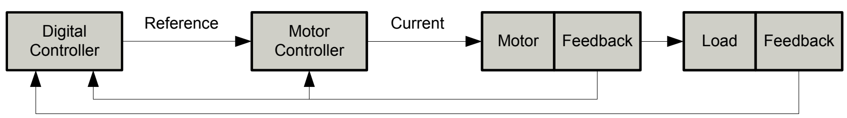
Description	Control Specifications AVB	AB
Command Sources	0-5V Analog, 0-5kΩ	±10V Analog
Commutation Methods	Trapezoidal	
Control Modes	Current, Voltage, IR Compensation, Duty Cycle (Open Loop), Hall Velocity, Encoder Velocity, Tachometer Velocity	
Motors Supported	Three Phase Single Phase	

2.2 Servo Drive Basics and Theory

Motor controllers are used extensively in motion control systems where precise control of position and/or velocity is required. The motor controller transmits the low-energy reference signals from the digital motion controller into high-energy signals (motor voltage and current). The reference signals can be either analog or digital, with a ±10 VDC signal being the most common. The signal can represent either a motor torque or velocity demand.

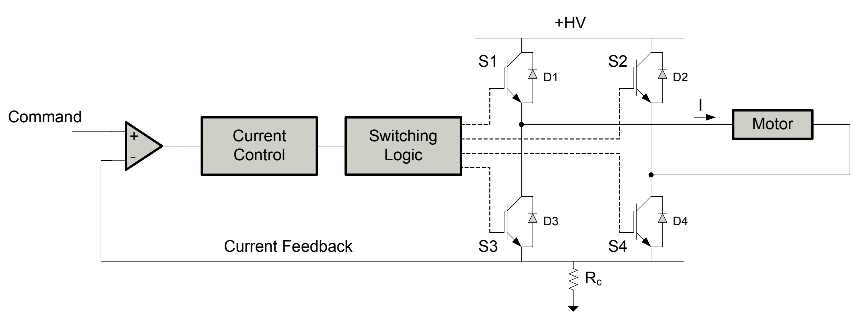
Figure 2.2 shows the components typically used in a servo system (i.e. a feedback system used to control position, velocity, and/or acceleration). The digital motion controller contains the algorithms to close the desired servo loops and also handles machine interfacing (inputs/outputs, terminals, etc.). The motor controller represents the electronic power converter that drives the motor according to the digital motion controller reference signals. The motor (which can be of the brushed or brushless type, rotary, or linear) is the actual electromagnetic actuator, which generates the forces required to move the load. Feedback elements are mounted on the motor and/or load in order to close the servo loop.

FIGURE 2.2 **Typical Motion Control System**



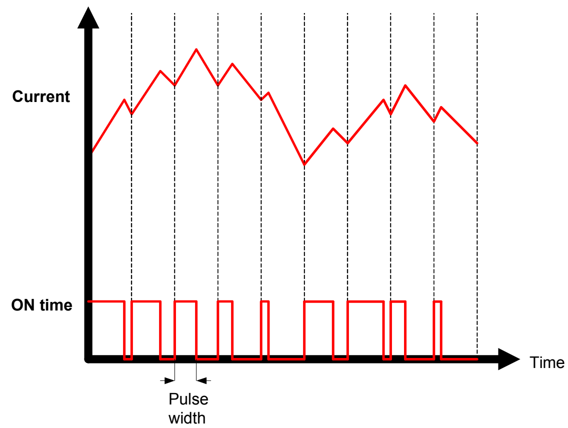
Although there exist many ways to "amplify" electrical signals, pulse width modulation (PWM) is by far the most efficient and cost-effective approach. At the basis of a PWM motor controller is a current control circuit that controls the output current by varying the duty cycle of the output power stage (fixed frequency, variable duty cycle). Figure 2.3 shows a typical setup for a single phase load.

FIGURE 2.3 **PWM Current Control Circuit**



S1, S2, S3, and S4 are power devices (MOSFET or IGBT) that can be switched on or off. D1, D2, D3, and D4 are diodes that guarantee current continuity. The bus voltage is depicted by +HV. The resistor R_c is used to measure the actual output current. For electric motors, the load is typically inductive due to the windings used to generate electromagnetic fields. The current can be regulated in both directions by activating the appropriate switches. When switch S1 and S4 (or S2 and S3) are activated, current will flow in the positive (or negative) direction and increase. When switch S1 is off and switch S4 is on (or S2 off and S3 on) current will flow in the positive (or negative) direction and decrease (via one of the diodes). The switch "ON" time is determined by the difference between the current demand and the actual current. The current control circuit will compare both signals every time interval (typically 50 µsec or less) and activate the switches accordingly (this is done by the switching logic circuit, which also performs basic protection functions). Figure 2.4 shows the relationship between the pulse width (ON time) and the current pattern. The current rise time will depend on the bus voltage (+HV) and the load inductance. Therefore, certain minimum load inductance requirements are necessary depending on the bus voltage.

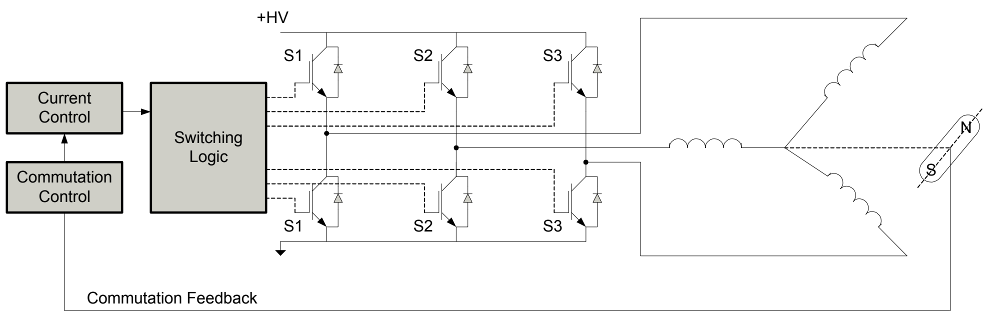
FIGURE 2.4 Output Current and Duty Cycle Relationship



2.2.1 Three Phase (Brushless) Motor Controllers

Three Phase (Brushless) motor controllers are used with brushless servo motors. These motors typically have a three-phase winding on the stator and permanent magnets on the rotor. Brushless motors require commutation feedback for proper operation (the commutators and brushes perform this function on brush type motors). This feedback consists of rotor magnetic field orientation information, supplied either by magnetic field sensors (Hall Effect sensors) or position sensors (encoder or resolver). Brushless motors have better power density ratings than brushed motors because heat is generated in the stator, resulting in a shorter thermal path to the outside environment. Figure 2.5 shows a typical system configuration.

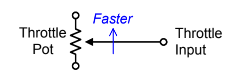
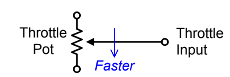
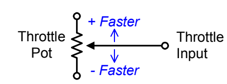
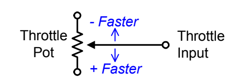
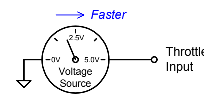
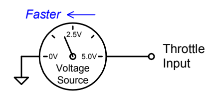
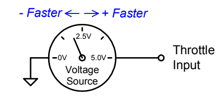
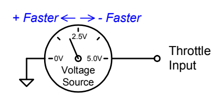
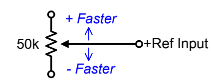
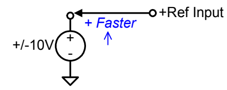
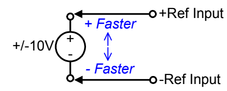
FIGURE 2.5 Brushless Servo System



2.3 Command Inputs

An analog reference signal can be used to command the motor controller by adjusting the motor current, voltage, or speed, depending on the mode of operation. Table 2.4 below outlines the command types available for the M/V series. An on-board low voltage output supply (3mA, 0-5V output for AVB models; 3mA, ±10V output for AB models) is provided for use with an external potentiometer. On AVB models, DIP switch bank SW2 selects between a 2-wire or 3-wire potentiometer configuration, Single-Ended or Wigwag, and Standard or Inverted command inputs (see “Switch Function Details” on page 40 for more information).

TABLE 2.4 Analog Command Types

		AVB	AB
Standard Single-Ended (0-5kΩ potentiometer; neutral point 0kΩ)		✔	
Inverted Single-Ended (5-0kΩ potentiometer; neutral point 5kΩ)		✔	
Wigwag (0-5kΩ potentiometer; neutral point 2.5kΩ)		✔	
Inverted Wigwag (0-5kΩ potentiometer; neutral point 2.5kΩ)		✔	
Standard Single-Ended (0-5V analog command range; neutral point 0V)		✔	
Inverted Single-Ended (5-0V analog command range; neutral point 5V)		✔	
Wigwag (0-5V analog command range; neutral point 2.5V)		✔	
Inverted Wigwag (5-0V analog command range; neutral point 2.5V)		✔	
Standard Differential (50kΩ potentiometer; ±10V analog command range)			✔
Standard Single-Ended (±10V analog command range)			✔
Standard Differential (±10V analog command range)			✔

For information on the recommended wiring for an analog input command, see “Command Wiring” on page 34.

2.4 Feedback Specifications

There are a number of different feedback options available for M/V motor controllers. The feedback component can be any device capable of generating a voltage signal proportional to current, velocity, position, or any parameter of interest. Such signals can be provided directly by a potentiometer or indirectly by other feedback devices such as Hall Sensors or Encoders. These latter devices must have their signals converted to a DC voltage, a task performed by the drive circuitry. Consult a specific datasheet to see which feedback devices are available for that model.

2.4.1 Feedback Polarity

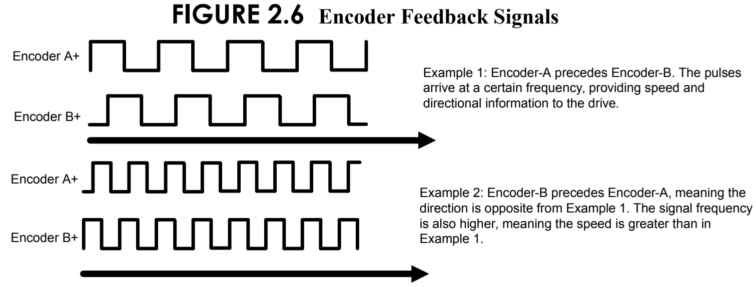
The feedback element must be connected for *negative* feedback. This will cause a difference between the command signal and the feedback signal, called the *error signal*. The drive compares the feedback signal to the command signal to produce the required output to the load by continually reducing the error signal to zero. This becomes important when using an incremental encoder or Hall sensors, as connecting these feedback elements for positive feedback will lead to a motor "run-away" condition. In a case where the feedback lines are connected to the drive with the wrong polarity in either Hall Velocity or Encoder Velocity Mode, the motor controller will attempt to correct the "error signal" by applying more command to the motor. With the wrong feedback polarity, this will result in a positive feedback run-away condition. To correct this, either change the order that the feedback lines are connected to the drive, or consult the M/V motor controller datasheet for the appropriate switch on the DIP switch bank that reverses the internal feedback velocity polarity. See “Switch Function Details” on page 40 for more information on DIP switch settings.

2.4.2 Incremental Encoder

Analog motor controllers that use encoder feedback utilize two single-ended incremental encoder inputs for velocity control. The encoder provides incremental position feedback that can be extrapolated into very precise velocity information. The encoder signals are read as "pulses" that the motor controller uses to essentially keep track of the motor’s position and direction of rotation. Based on the speed and order in which these pulses are received from the two encoder signals, the motor controller can interpret the motor velocity.

Figure 2.6 represents encoder "pulse" signals, showing how depending on which signal is read first and at what frequency the "pulses" arrive, the speed and direction of the motor shaft can be extrapolated. By keeping track of the number of encoder "pulses" with respect to a known motor "home" position, motor controllers are able to ascertain the actual motor location.

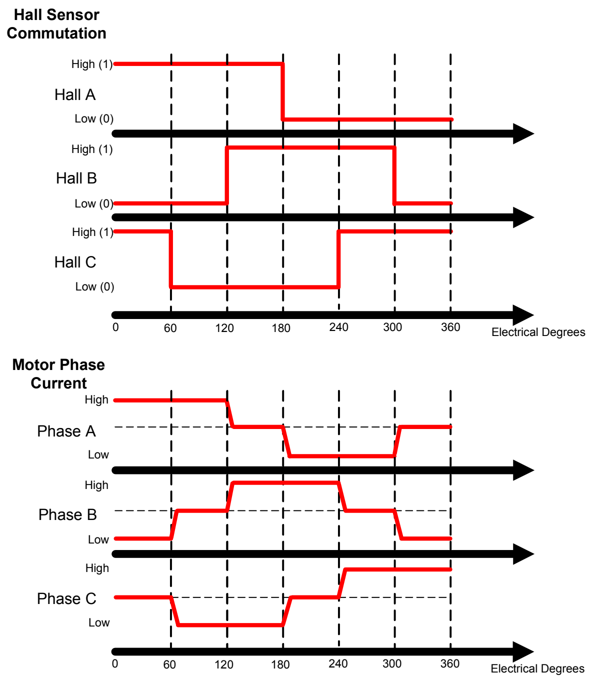
FIGURE 2.6 **Encoder Feedback Signals**



2.4.3 Hall Sensors

M/V motor controllers use Hall Sensors for commutation feedback and for velocity control. The Hall Sensors are built into the motor to detect the position of the rotor magnetic field. These sensors are mounted such that they each generate a square wave with either a 120-degree or 60-degree phase difference over one electrical cycle of the motor.

FIGURE 2.7 Hall Sensor Commutation and Motor Phase Current for 120-Degree Phasing



Note: Not all *ADVANCED* Motion Controls' servo drive series use the same commutation logic. The commutation diagrams provided here should be used only with drives covered within this manual.

Depending on the motor pole count, there may be more than one electrical cycle for every motor revolution. For every actual mechanical motor revolution, the number of electrical cycles will be the number of motor poles divided by two. For example:

- a 6-pole motor contains 3 electrical cycles per motor revolution
- a 4-pole motor contains 2 electrical cycles per motor revolution
- a 2-pole motor contains 1 electrical cycle per motor revolution

The motor controller powers two of the three motor phases with DC current during each specific Hall Sensor state: The table below shows the valid commutation states for both 120-degree and 60-degree phasing.

TABLE 2.5 Commutation Sequence Table

	60 Degree			120 Degree			Motor		
	Hall 1	Hall 2	Hall 3	Hall 1	Hall 2	Hall 3	Phase A	Phase B	Phase C
Valid	1	0	0	1	0	0	HIGH	-	LOW
	1	1	0	1	1	0	-	HIGH	LOW
	1	1	1	0	1	0	LOW	HIGH	-
	0	1	1	0	1	1	LOW	-	HIGH
	0	0	1	0	0	1	-	LOW	HIGH
	0	0	0	1	0	1	HIGH	LOW	-
Invalid	1	0	1	1	1	1	-	-	-
	0	1	0	0	0	0	-	-	-

2.4.4 Tachometer

A DC Tachometer can be used on M/V motor controllers for velocity control. The tachometer provides an analog DC voltage feedback signal that is related to the actual motor speed and direction. The motor controller subsequently adjusts the output current based on the error between the tachometer feedback and the input command voltage. The maximum range of the tachometer feedback signal is ±60 VDC.

Some applications may require an increase in the gain of the tachometer input signal. This occurrence will be most common in designs where the tachometer input has a low voltage to RPM scaling ratio. M/V motor controllers offer a through-hole location where a resistor can be added to increase the tachometer gain. Use the block diagram on the datasheet to determine an appropriate resistor value.

See “Tachometer Input Gain Scaling” on page 41 for more information.

2.5 Modes of Operation

M/V motor controllers offers a variety of different control methods. It is possible to select the control method by DIP switch settings (see “Potentiometer Function Details” on page 39 for more information). Consult the datasheet for the model in use to see which modes are available.

The name of the mode refers to which servo loop is being closed in the motor controller, not the end-result of the application. For instance, an M/V drive operating in Current (Torque) Mode may be used for a positioning application if the external digital motion controller is closing the position loop. Oftentimes, mode selection will be dependent on the requirements and capabilities of the digital motion controller in use as well as the end-result application.

2.5.1 Current (Torque) Mode

In Current (Torque) Mode, the input command voltage controls the output current. The motor controller will adjust the output duty cycle to maintain the commanded output current. This mode is used to control torque for rotary motors (force for linear motors), but the motor speed is not controlled. The output current can be monitored through an analog current monitor output pin. The voltage value read at the “Current Monitor Output (AB models)” can be multiplied by a scaling factor found on the M/V drive datasheet to determine the actual output current.

Note

While in Current (Torque) Mode, the motor controller will maintain a commanded torque output to the motor based on the input reference command. Sudden changes in the motor load may cause the motor controller to be outputting a high torque command with little load resistance, causing the motor to spin rapidly. Therefore, Current (Torque) Mode is recommended for applications using a digital position controller to maintain system stability.

2.5.2 Duty Cycle (Open Loop) Mode

In Duty Cycle Mode, the input command voltage controls the output PWM duty cycle of the drive, indirectly controlling the output voltage. Note that any fluctuations of the DC supply voltage will affect the voltage output to the motor.

Note

This mode is recommended as a method of controlling the motor velocity when precise velocity control is not critical to the application, and when actual velocity feedback is unavailable.

2.5.3 Hall Velocity Mode

In Hall Velocity Mode, the input command voltage controls the motor velocity, with the Hall Sensor frequency closing the velocity loop. An analog velocity monitor output allows observation of the actual motor speed through a Hz/V scaling factor found on the M/V motor controller datasheet. The voltage value read at the velocity monitor output can be used to determine the motor RPM through the scaling factor. See "Velocity Monitor Output" on page 39 for the motor RPM equation.

Note

Due to the inherent low resolution of motor mounted Hall Sensors, Hall Velocity Mode is not recommended for low-speed applications below 300 rpm for a 6-pole motor, 600 rpm for a 4-pole motor, or 900 rpm for a 2-pole motor. Hall Velocity Mode is better suited for velocity control applications where the motor will be spinning at higher speeds.

2.5.4 Encoder Velocity Mode

In Encoder Velocity Mode, the input command controls the motor velocity, with the frequency of the encoder pulses closing the velocity loop. An analog velocity monitor output allows observation of the actual motor speed through a kHz/V scaling factor found on the M/V motor controller datasheet. The voltage value read at the velocity monitor output can be used to determine the motor RPM through the scaling factor. See "Velocity Monitor Output" on page 39 for the motor RPM equation.

Note

The high resolution of motor mounted encoders allows for excellent velocity control and smooth motion at all speeds. Encoder Velocity Mode should be used for applications requiring precise and accurate velocity control, and is especially useful in applications where low-speed smoothness is the objective.

2.5.5 Tachometer Velocity Mode

In Tachometer Velocity Mode, the input command voltage controls the motor velocity. This mode uses an external DC tachometer to close the velocity loop. The M/V motor controller translates the DC voltage from the tachometer into motor speed and direction information. Some applications may require an increase in the gain of the tachometer input signal. This occurence will be most common in designs where the tachometer input has a low voltage to RPM scaling ratio. M/V drives offers a through-hole location where a resistor can be added to increase the tachometer gain. Use the drive's block diagram to determine an appropriate resistor value.

Note

DC Tachometers have infinite resolution, allowing for extremely accurate velocity control. However, they also may be susceptible to electrical noise, most notably at low speeds.

2.5.6 Voltage Mode

In Voltage Mode the input reference signal commands a proportional motor voltage regardless of power supply voltage variations. This mode is recommended for velocity control when velocity feedback is unavailable and load variances are small.

2.5.7 IR Compensation Mode

If there is a load torque variation while in Voltage Mode, the motor current will also vary as torque is proportional to motor current. Hence, the motor terminal voltage will be reduced by the voltage drop over the motor winding resistance (IR), resulting in a speed reduction. Thus, motor speed, which is proportional to motor voltage (terminal voltage minus IR drop) varies with the load torque.

In order to compensate for the internal motor voltage drop, a voltage proportional to motor current can be added to the output voltage. An internal resistor adjusts the amount of compensation, and an additional through-hole resistor can be added to the location listed on the M/V motor controller datasheet. Use caution when adjusting the IR compensation level. If the feedback voltage is high enough to cause a rise in motor voltage with increased motor current, instability occurs. Such a result is due to the fact that increased voltage increases motor speed and thus load current which, in turn, increases motor voltage. If a great deal of motor torque change is anticipated, it may be wise to consider the addition of a speed sensor to the motor (e.g. tachometer, encoder, etc.).

2.6 System Requirements

To successfully incorporate an M/V motor controller into your system, you must be sure it will operate properly based on electrical, mechanical, and environmental specifications, follow some simple wiring guidelines, and perhaps make use of some accessories in anticipating impacts on performance. Before selecting an M/V motor controller, a user should consider the requirements of their system. This involves calculating the required voltage, current, torque, and power requirements of the system, as well as considering the operating environment and any other equipment the motor controller will be interfacing with.

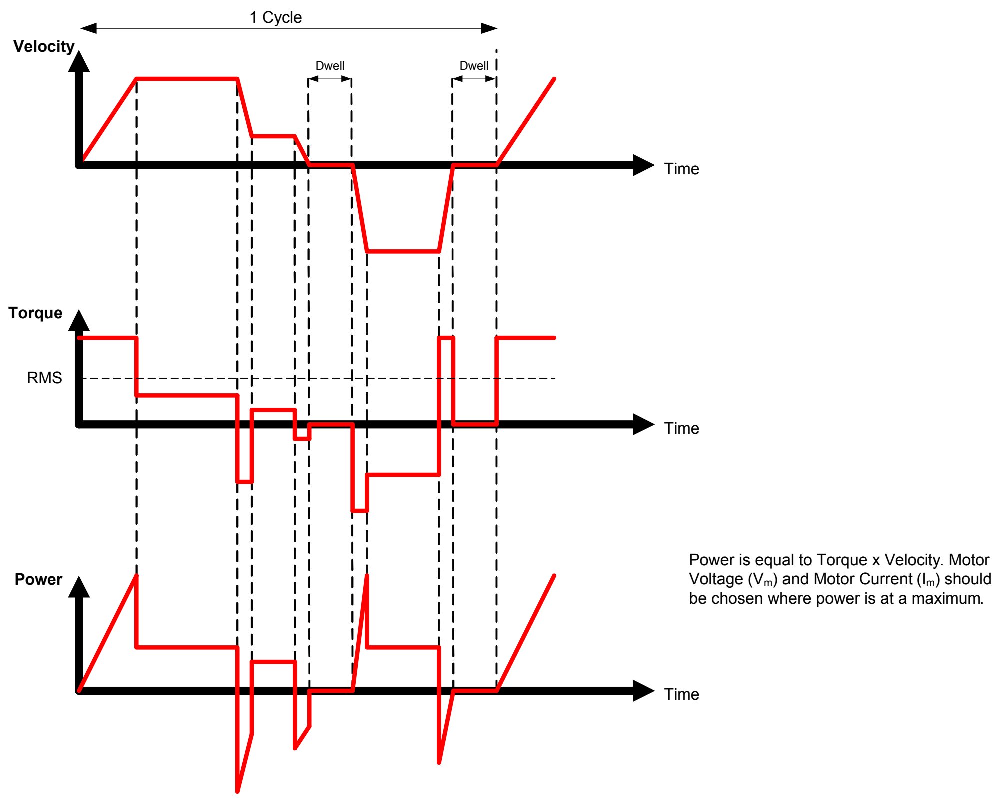
2.6.1 Motor Controller Selection and Sizing

M/V motor controllers have a given current and voltage rating unique to each drive. Based on the necessary application requirements and the information from the datasheet of the motor being used, a drive may be selected that will best suit the motor capabilities.

A motor controller should be selected that will meet the peak and continuous current requirements of the application, and operate within the voltage requirements of the system.

Motor Current and Voltage Motor voltage and current requirements are determined based on the maximum required torque and velocity. These requirements can be derived from the application move profiles (Figure 2.8).

FIGURE 2.8 **Example Velocity, Torque, and Power Curves**



The **motor current I_M** is the required motor current in amps DC, and is related to the torque needed to move the load by the following equation:

$$I_M = \frac{Torque}{K_T}$$

Where:

K_T -motor torque constant

The motor current will need to be calculated for both continuous and peak operation. The peak torque will be during the acceleration portion of the move profile.

The continuous torque is the average torque required by the system during the move profile, including dwell times. Both peak torque and continuous, or RMS (root mean square) torque need to be calculated. RMS torque can be calculated by plotting torque versus time for one move cycle.

$$T_{RMS} = \sqrt{\frac{\sum_i T_i^2 t_i}{\sum_i t_i}}$$

Here T_i is the torque and t_i is the time during segment i. In the case of a vertical application make sure to include the torque required to overcome gravity.

The system voltage requirement is based on the motor properties and how fast and hard the motor is driven. The system voltage requirement is equal to the **motor voltage**, V_M, required to achieve the move profile. In general, the motor voltage is proportional to the motor speed and the motor current is proportional to the motor shaft torque. Linear motors exhibit the same behavior except that in their case force is proportional to current. These relationships are described by the following equations:

$$V_m = I_m R_m + E$$

$$E = K_e S_m$$

for rotary motors $T = K_t I_m$

for linear motors $F = K_f I_m$

Where:

V_m	-motor voltage
I_m	-motor current (use the maximum current expected for the application)
R_m	-motor line-to-line resistance
E	-motor back-EMF voltage
T	-motor torque
F	-motor force
K_t	-motor torque constant
K_f	-motor force constant
K_e	-voltage constant
S_m	-motor speed (use the maximum speed expected for the application)

The motor manufacturer's data sheet contain K_t (or K_f) and K_e constants. Pay special attention to the units used (metric vs. English) and the amplitude specifications (peak-to-peak vs. RMS, phase-to-phase vs. phase-to-neutral).

The maximum motor terminal voltage and current can be calculated from the above equations. For example, a motor with a K_e = 10V/Krpm and required speed of 3000 RPM would require 30V to operate. In this calculation the IR term (voltage drop across motor winding resistance) is disregarded. Maximum current is maximum torque divided by K_t. For example, a motor with K_t = 0.5 Nm/A and maximum torque of 5 Nm would require 10 amps of current. Continuous current is RMS torque divided by K_t.

Motor Inductance

The motor inductance is vital to the operation of motor controllers, as it ensures that the DC motor current is properly filtered.

Caution

A motor that does not meet the rated minimum inductance value of the drive may damage the drive! If the motor inductance value is less than the minimum required for the selected drive, use of an external filter card is necessary. See "Inductive Filter Cards" on page 27 for more information.

A minimum motor inductance rating for each specific motor controller can be found in the M/V drive datasheet. If the motor controller is operated below the maximum rated voltage, the minimum load inductance requirement may be reduced.

In the above equations the motor inductance is neglected. In brushless systems the voltage drop caused by the motor inductance can be significant. This is the case in high-speed applications if motors with high inductance and high pole count are used. Please use the following equation to determine motor terminal voltage (must be interpreted as a vector).

$$V_m = (R_m + j\omega L)I_m + E$$

Where:

L	-phase-to-phase motor inductance
ω	-maximum motor current frequency

2.6.2 Power Supply Selection and Sizing

There are several factors to consider when selecting a power supply for an M/V motor controller.

- Power Requirements
- Isolation
- Regeneration
- Voltage Ripple

Power Requirements refers to how much voltage and current will be required by the motor controller in the system. Isolation refers to whether the power supply needs an isolation transformer. Regeneration is the energy the power supply needs to absorb during deceleration. Voltage Ripple is the voltage fluctuation inherent in unregulated supplies.

Power Supply Current and Voltage The power supply current rating is based on the maximum current that will be required by the system. If the power supply powers more than one motor controller, then the current requirements for each drive should be added together. Due to the nature of motor controllers, the current into the drive does not always equal the current out of the drive. However, the power in is equal to the power out. Use the following equation to calculate the power supply output current, I_{PS}, based on the motor voltage and current requirements.

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)}$$

Where:

V_{PS}	-nominal power supply voltage
I_M	-motor current
V_M	-motor voltage

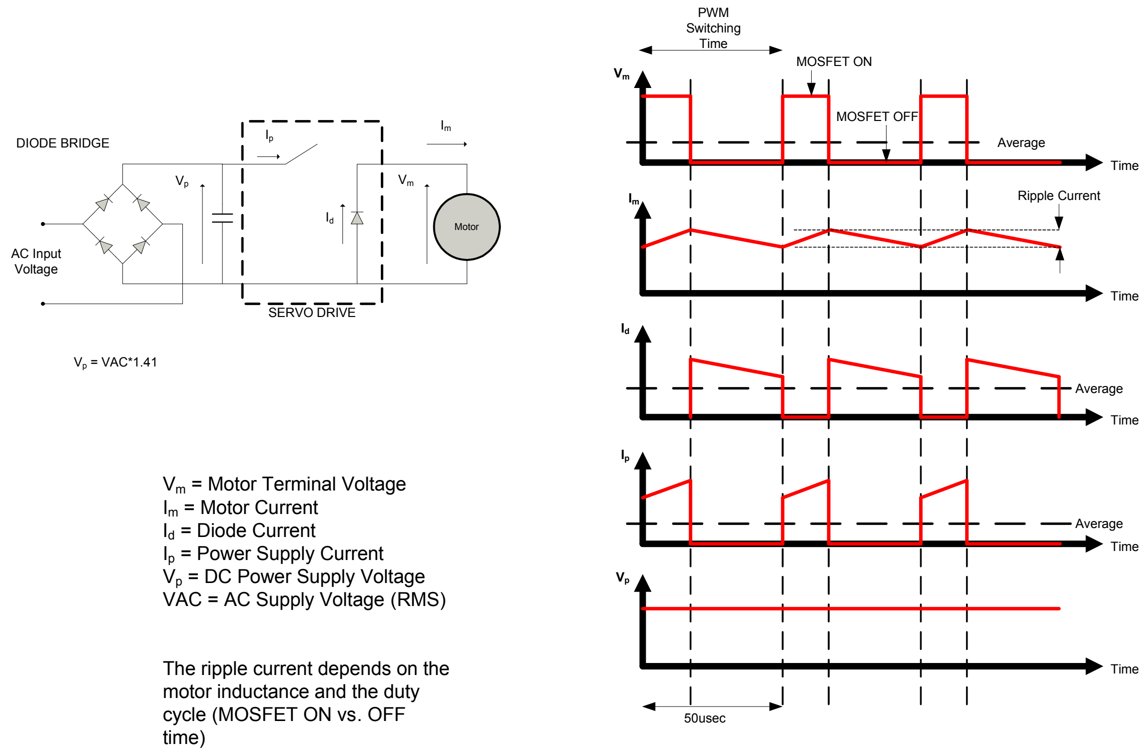
Use values of V_m and I_m at the point of maximum power in the move profile, Figure 2.8 (when $V_M I_M$ = max). This will usually be at the end of a hard acceleration when both the torque and speed of the motor is high.

The power supply current is a pulsed DC current (Figure 2.9): when the MOSFET switch is on, it equals the motor current; when the MOSFET is off it is zero. Therefore, the power supply current is a function of the PWM duty cycle and the motor current (e.g. 30% duty cycle and 12 amps motor current will result in 4 amps power supply current). 30% duty cycle also means that the average motor voltage is 30% of the DC bus voltage. Power supply power is approximately equal to drive output power plus 3 to 5%.

Caution

The only time the power supply current needs to be as high as the drive output current is if the move profile requires maximum current at maximum velocity. In many cases however, maximum current is only required at start up and lower currents are required at higher speeds.

FIGURE 2.9 **Unregulated DC Power Supply Current**



A system will need a certain amount of voltage and current to operate properly. If the power supply has too little voltage/current the system will not perform adequately. If the power supply has too much voltage the drive may shut down due to over voltage, or the motor controller may be damaged.

To avoid nuisance over- or under-voltage errors caused by fluctuations in the power supply, the ideal system power supply voltage should be at least 10% above the entire system voltage requirement, and at least 10% below the lowest value of the following:

- M/V motor controller over voltage
- External shunt regulator turn-on voltage (see "Regeneration and Shunt Regulators" on page 19)

These percentages also account for the variances in K_t and K_e, and losses in the system external to the motor controller. The selected margin depends on the system parameter variations.

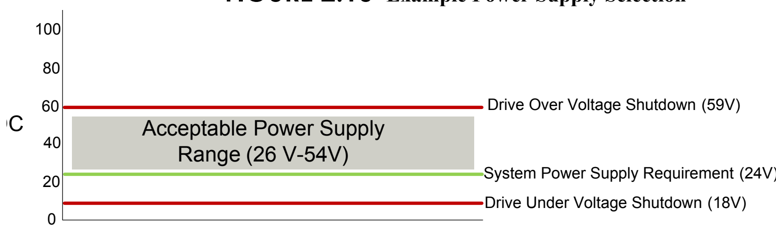
Caution

Do not select a supply voltage that could cause a mechanical over-speed in the event of a drive malfunction or a runaway condition.

Brushed Motors may have voltage limitations due to the mechanical commutators. Consult the manufacturer's data sheets.

Figure 2.10 provides one possible example of an appropriate system power supply voltage for an AB250A060 M/V motor controller. The over voltage and under voltage shutdown levels can be found on the drive datasheet. The system power supply requirement is based on the motor properties and how much voltage is needed to achieve the application move profile (see "Motor Current and Voltage" on page 14). Keep in mind that the calculated value for V_m is the minimum voltage required to complete moves at the desired speed and torque. There should be at least 10% headroom between the calculated value and the actual power supply voltage to allow for machine changes such as increased friction due to wear, change in load, increased operating speed, etc.

FIGURE 2.10 **Example Power Supply Selection**



Isolation

In systems where an AC line is involved, isolation is required between the AC line and the signal pins on the motor drive. This applies to all systems except those that use a battery as a power supply. There are two options for isolation:

1. The motor controller can have built in electrical isolation.
2. The power supply can provide isolation (e.g. a battery or an isolation transformer).

The system must have at least one of these options to operate safely.

200 volt M/V motor controllers come with standard electrical isolation between the high power and low power signals. The isolation is indicated by a dashed line through the functional block diagram separating power ground from signal ground.

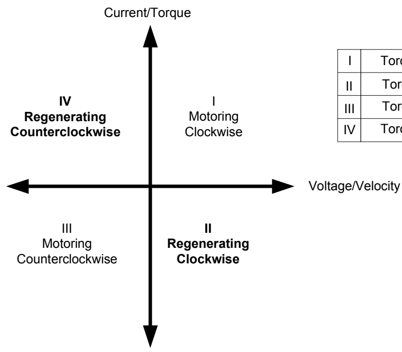
Power Supply with Isolation

An isolated power supply is either a battery or a power supply that uses an isolation transformer to isolate the AC line voltage from the power supply ground. This allows both the power ground on an isolated power supply and the signal ground on a non-isolated drive to be safely pulled to earth ground. Always use an isolated power supply if there is no isolation in the drive.

Regeneration and Shunt Regulators

Use of a shunt regulator is necessary in systems where motor deceleration or a downward motion of the motor load will cause the system's mechanical energy to be regenerated via the drive back onto the power supply.

FIGURE 2.11 **Four Quadrant Operation - Regeneration occurs when Torque and Velocity polarity are opposite**



I	Torque +	Velocity +	No Regen
II	Torque -	Velocity +	Regen
III	Torque -	Velocity -	No Regen
IV	Torque +	Velocity -	Regen

This regenerated energy can charge the power supply capacitors to levels above that of the motor controller over-voltage shutdown level. If the power supply capacitance is unable to handle this excess energy, or if it is impractical to supply enough capacitance, then an external shunt regulator must be used to dissipate the regenerated energy. Shunt regulators are essentially a resistor placed in parallel with the DC bus. The shunt regulator will "turn-on" at a certain voltage level (set below the drive over-voltage shutdown level) and discharge the regenerated electric energy in the form of heat.

The voltage rise on the power supply capacitors without a shunt regulator, can be calculated according to a simple energy balance equation. The amount of energy transferred to the power supply can be determined through:

$$E_i = E_f$$

Where:

E_i	-initial energy
E_f	-final energy

These energy terms can be broken down into the approximate mechanical and electrical terms - capacitive, kinetic, and potential energy. The energy equations for these individual components are as follows:

$$E_c = \frac{1}{2}CV_{nom}^2$$

Where:

E_c	-energy stored in a capacitor (joules)
C	-capacitance
V_{nom}	-nominal bus voltage of the system

$$E_r = \frac{1}{2}J\omega^2$$

Where:

E_r	-kinetic (mechanical) energy of the load (joules)
J	-inertia of the load (kg-m^2)
ω	-angular velocity of the load (rads/s)

$$E_p = mgh$$

Where:

E_p	-potential mechanical energy (joules)
m	-mass of the load (kg)
g	-gravitational acceleration (9.81 m/s^2)
h	-vertical height of the load (meters)

During regeneration the kinetic and potential energy will be stored in the power supply's capacitor. To determine the final power supply voltage following a regenerative event, the following equation may be used for most requirements:

$$(E_c \cdot E_r \cdot E_p)_i = (E_c \cdot E_r \cdot E_p)_f$$

$$\frac{1}{2}CV_{nom}^2 + \frac{1}{2}J\omega_i^2 + mgh_i = \frac{1}{2}CV_f^2 + \frac{1}{2}J\omega_f^2 + mgh_f$$

Which simplifies to:

$$V_f = \sqrt{V_{nom}^2 + \frac{J}{C}(\omega_i^2 - \omega_f^2) + \frac{2mg(h_i - h_f)}{C}}$$

The V_f calculated must be below the power supply capacitance voltage rating and the drive over voltage limit. If this is not the case, a shunt regulator is necessary. A shunt regulator is sized in the same way as a motor or controller, i.e. continuous and RMS power dissipation must be determined. The power dissipation requirements can be determined from the application move profile (see Figure 2.8).

ADVANCED Motion Controls offers a variety of shunt regulators for motor controllers. When choosing a shunt regulator, select one with a shunt voltage that is greater than the DC bus voltage of the application but less than the over voltage shutdown of the drive. Verify the need for a shunt regulator by operating the motor controller under the worst-case braking and deceleration conditions. If the drive shuts off due to over-voltage, a shunt regulator is necessary.

Continuous Regeneration

In the special case where an application requires continuous regeneration (more than a few seconds) then a shunt regulator may not be sufficient to dissipate the regenerative energy. Please contact *ADVANCED* Motion Controls for possible solutions to solve this kind of application. Some examples:

- Web tensioning device
- Electric vehicle rolling down a long hill
- Spinning mass with a very large inertia (grinding wheel, flywheel, centrifuge)
- Heavy lift gantry

Voltage Ripple

For the most part, *ADVANCED* Motion Controls motor controllers are unaffected by voltage ripple from the power supply. The current loop is fast enough to compensate for 60 Hz fluctuations in the bus voltage, and the components in the drive are robust enough to withstand all but the most extreme cases. Peak to peak voltage ripple as high as 25 V is acceptable.

There are some applications where the voltage ripple can cause unacceptable performance. This can become apparent where constant torque or force is critical or when the bus voltage is pulled low during high speed and high current applications. If necessary, the voltage ripple from the power supply can be reduced, either by switching from single phase AC to three phase AC, or by increasing the capacitance of the power supply.

The voltage ripple for a system can be estimated using the equation:

$$V_R = \frac{I_{PS}}{C_{PS}} F_f$$

Where:

V_R	-voltage ripple
C_{PS}	-power supply capacitance
I_{PS}	-power supply output current
F_f	-frequency factor (1/hertz)

The power supply capacitance can be estimated by rearranging the above equation to solve for the capacitance as:

$$C_{PS} = \frac{I_{PS}}{V_R} F_f$$

The frequency factor can determined from:

$$F_f = \frac{0.42}{f}$$

where f is the AC line frequency in hertz. Note that for half wave rectified power supplies, f = f/2.

The power supply output current, if unknown, can be estimated by using information from the output side of the motor controller as given below:

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)}$$

Where:

- I_M -current through the motor
- V_{PS} -nominal power supply voltage
- V_M -motor voltage (see "Motor Current and Voltage" on page 14)

2.6.3 Environmental Specifications

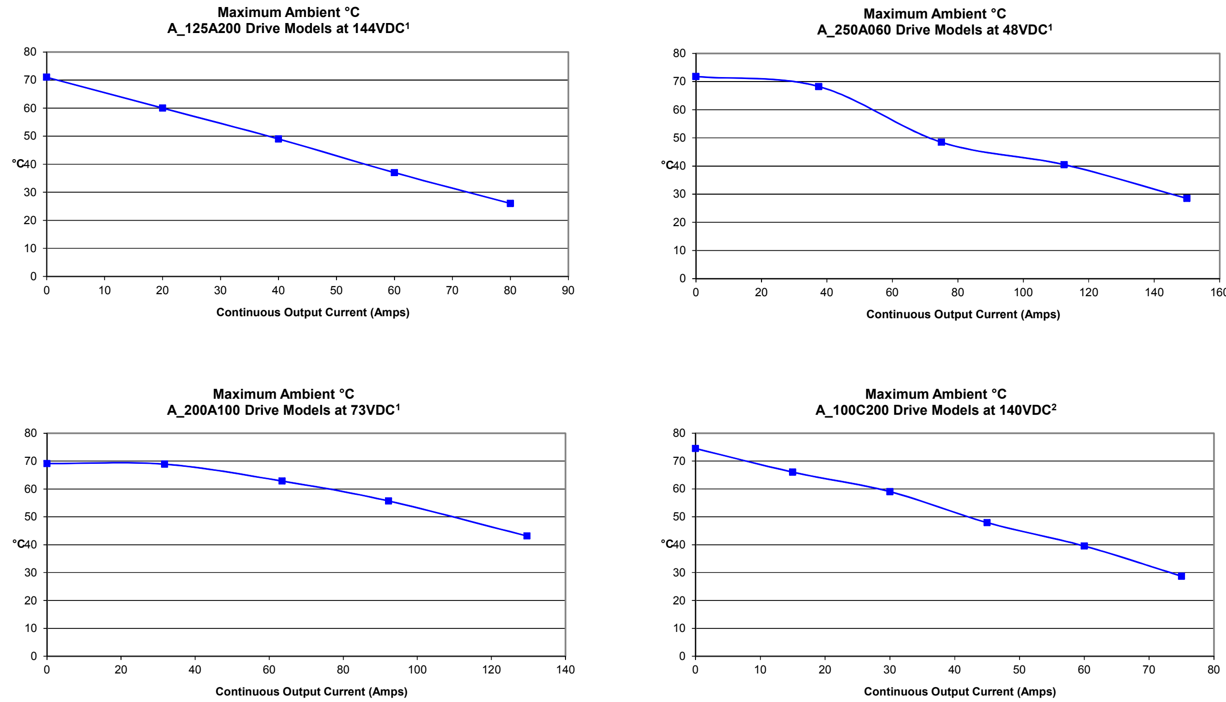
To ensure proper operation of an M/V motor controller, it is important to evaluate the operating environment prior to installing the drive.

TABLE 2.6 Environmental Specifications

Environmental Specifications	
Parameter	**Description**
Baseplate Temperature Range	0 - 75 °C (32 - 167 °F)
Humidity	90%, non-condensing
Mechanical Shock	10g, 11ms, Half-sine
Vibration	2 - 2000 Hz @ 2.5g
Altitude	0-3000m
IP Rating	IP65

Ambient Temperature Range M/V motor controllers contain a built-in over-temperature disabling feature if the baseplate temperature rises above 75°C. For a specific continuous output current and DC supply voltage, Figure 2.12 specifies an upper limit to the ambient temperature range M/V motor controllers can operate within while keeping the baseplate temperature below 75°C. Additional cooling and/or heatsinking are required to achieve rated performance. It is also recommended to apply thermal grease between the drive baseplate and external heatsink.

FIGURE 2.12 **M/V Ambient Temperature Range**



1. Heatsink used is 8 7/8" x 10 3/4" x 2 3/8" finned heatsink with 36 cfm air flow on heatsink
2. Heatsink used is 15" x 27 7/8" x 5/8" aluminum plate heatsink with 260 cfm air flow on heatsink. For output currents above 75 A, additional cooling and/or heatsinking is required.

Shock/Vibrations

While M/V motor controllers are designed to withstand a high degree of mechanical shock and vibration, too much physical abuse can cause erratic behavior, or cause operation to cease entirely. Be sure the motor controller is securely mounted in the system to reduce the shock and vibration exposure. The best way to secure the motor controller against mechanical vibration is to use screws to mount the drive by its baseplate. For information on mounting options and procedures, see “Mounting” on page 36 and the dimensional drawings and information on the motor drive datasheet.

Caution

Care should be taken to ensure the motor controller is securely mounted in a location where no moving parts will come in contact with the motor controller.

3 Integration in the Servo System

This chapter will give various details on incorporating an M/V motor controller into a system, such as how to properly ground the drive along with the entire system, and how to properly connect motor wires, power supply wires, feedback wires, and inputs into the M/V servo drive.

3.1 LVD Requirements

The servo drives covered in the LVD Reference report were investigated as components intended to be installed in complete systems that meet the requirements of the Machinery Directive. In order for these units to be acceptable in the end users' equipment, the following conditions of acceptability must be met.

1. European approved overload and current protection must be provided for the motors as specified in section 7.2 and 7.3 of EN60204.1.
2. A disconnect switch shall be installed in the final system as specified in section 5.3 of EN60204.1.
3. All drives that do not have a grounding terminal must be installed in, and conductively connected to a grounded end use enclosure in order to comply with the accessibility requirements of section 6, and to establish grounding continuity for the system in accordance with section 8 of EN60204.1.
4. A disconnecting device that will prevent the unexpected start-up of a machine shall be provided if the machine could cause injury to persons. This device shall prevent the automatic restarting of the machine after any failure condition shuts the machine down.
5. European approved over current protective devices must be installed in line before the servo drive, these devices shall be installed and rated in accordance with the installation instructions (the installation instructions shall specify an over current rating value as low as possible, but taking into consideration inrush currents, etc.). Servo drives that incorporate their own primary fuses do not need to incorporate over protection in the end users' equipment.

These items should be included in your declaration of incorporation as well as the name and address of your company, description of the equipment, a statement that the servo drives must not be put into service until the machinery into which they are incorporated has been declared in conformity with the provisions of the Machinery Directive, and identification of the person signing.

3.2 CE-EMC Wiring Requirements

The following sections contain installation instructions necessary for meeting EMC requirements.

Contact the factory for assistance in determining the type of drive in use.

General

1. Shielded cables must be used for all interconnect cables to the drive and the shield of the cable must be grounded at the closest ground point with the least amount of resistance.
2. The drive's metal enclosure must be grounded to the closest ground point with the least amount of resistance.
3. The drive must be mounted in such a manner that the connectors and exposed printed circuit board are not accessible to be touched by personnel when the product is in operation. If this is unavoidable there must be clear instructions that the drive is not to be touched during operation. This is to avoid possible malfunction due to electrostatic discharge from personnel.

Analog Input Drives

4. A Fair Rite model 0443167251 round suppression core must be fitted to the low level signal interconnect cables to prevent pickup from external RF fields.

PWM Input Drives

5. A Fair Rite model 0443167251 round suppression core must be fitted to the PWM input cable to reduce electromagnetic emissions.

MOSFET Switching Drives

6. A Fair Rite model 0443167251 round suppression core must be fitted at the load cable connector to reduce electromagnetic emissions.
7. An appropriately rated Cosel TAC series AC power filter in combination with a Fair Rite model 5977002701 torroid (placed on the supply end of the filter) must be fitted to the AC supply to any MOSFET drive system in order to reduce conducted emissions fed back into the supply network.

IGBT Switching Drives

8. An appropriately rated Cosel TAC series AC power filter in combination with a Fair Rite model 0443167251 round suppression core (placed on the supply end of the filter) must be fitted to the AC supply to any IGBT drive system in order to reduce conducted emissions fed back into the supply network.
9. A Fair Rite model 0443164151 round suppression core and model 5977003801 torroid must be fitted at the load cable connector to reduce electromagnetic emissions.

Fitting of AC Power Filters

It is possible for noise generated by the machine to "leak" onto the main AC power, and then get distributed to nearby equipment. If this equipment is sensitive, it may be adversely affected by the noise. AC power filters can filter this noise and keep it from getting on the AC power signal.The above mentioned AC power filters should be mounted flat against the enclosure of the product using the two mounting lugs provided on the filter. Paint should be removed from the enclosure where the filter is fitted to ensure good metal to metal contact. The filter should be mounted as close to the point where the AC power filter enters the enclosure as possible. Also, the AC power cable on the load end of the filter should be routed as far from the AC power cable on the supply end of the filter and all other cables and circuitry to minimize RF coupling.

3.2.1 Ferrite Suppression Core Set-up

If PWM switching noise couples onto the feedback signals or onto the signal ground, then a ferrite suppression core can be used to attenuate the noise. Take the motor leads and wrap them around the suppression core as many times as reasonable possible, usually 2-5 times. Make sure to strip back the cable shield and only wrap the motor wires. There will be two wires for single phased (brushed) motors and 3 wires for three phase (brushless) motors. Wrap the motor wires together as a group around the suppression core and leave the motor case ground wire out of the loop. The suppression core should be located as near to the drive as possible. TDK ZCAT series snap-on filters are recommended for reducing radiated emissions on all I/O cables.

3.2.2 Inductive Filter Cards

Inductive filter cards are added in series with the motor and are used to increase the load inductance in order to meet the minimum load inductance requirement of the drive. They also serve to counteract the effects of line capacitance found in long cable runs and in high voltage systems. These filter cards also have the added benefit of reducing the amount of PWM noise that couples onto the signal lines.

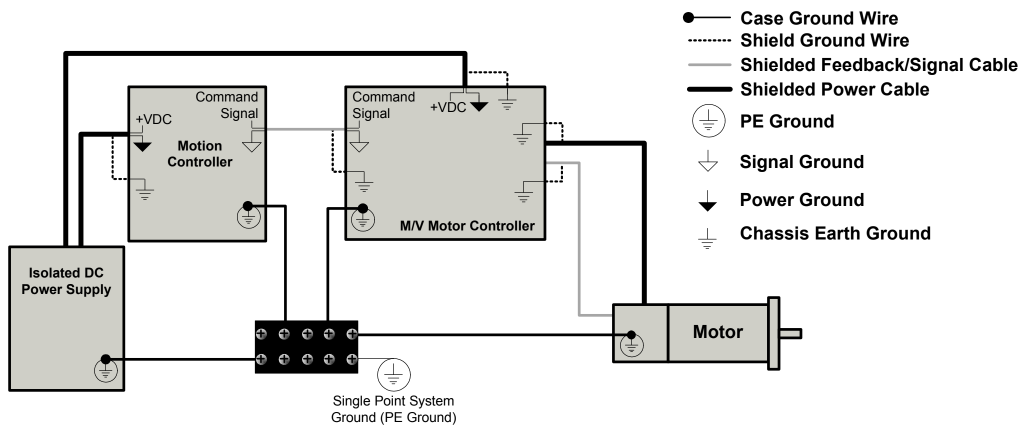
Visit www.a-m-c.com/products/filter_cards.html for information on purchasing *ADVANCED* Motion Controls inductive filter cards.

3.3 Grounding

In most servo systems all the case grounds should be connected to a single Protective Earth (PE) ground point in a "star" configuration. Grounding the case grounds at a central PE ground point reduces the chance for ground loops and helps to minimize high frequency voltage differentials between components. All ground wires must be of a heavy gauge and be as short as possible. The following should be securely grounded at the central PE grounding point:

- Motor chassis
- Controller chassis
- Power supply chassis
- Analog Servo Drive chassis

FIGURE 3.1 **System Grounding**



Ground cable shield wires at the drive side to a chassis earth ground point.

The DC power ground and the input reference command signal ground are oftentimes at a different potential than chassis/PE ground. The signal ground of the motion controller must be connected to the signal ground of the M/V motor controller to avoid picking up noise due to the "floating" differential servo drive input. In systems using an isolated DC power supply, signal ground and/or power ground can be referenced to chassis ground. First decide if this is both appropriate and safe. If this is the case, they can be grounded at the central grounding point. For systems using AC power referenced to chassis ground, the drive must have internal optical isolation to avoid a short through the the drive's diode bridge.

Warning

Grounding is important for safety. The grounding recommendations in this manual may not be appropriate for all applications and system machinery. It is the responsibility of the system designer to follow applicable regulations and guidelines as they apply to the specific servo system.

3.4 Wiring

Servo system wiring typically involves wiring a controller (digital or analog), a motor controller (servo drive), a power supply, and a motor. Wiring these servo system components is fairly easy when a few simple rules are observed.

As with any high efficiency PWM servo drive, the possibility of noise and interference coupling through the cabling and wires can be harmful to overall system performance. Noise in the form of interfering signals can be coupled:

- Capacitively (electrostatic coupling) onto signal wires in the circuit (the effect is more serious for high impedance points).
- Magnetically to closed loops in the signal circuit (independent of impedance levels).
- Electromagnetically to signal wires acting as small antennas for electromagnetic radiation.
- From one part of the circuit to other parts through voltage drops on ground lines.

Experience shows that the main source of noise is the high DV/DT (typically about 1V/nanosecond) of the drive's output power stage. This PWM output can couple back to the signal lines through the output and input wires. The best methods to reduce this effect are to move signal and motor leads apart, use an inductive filter card, add shielding, and use differential inputs at the drive.

Unfortunately, low-frequency magnetic fields are not significantly reduced by metal enclosures. Typical sources are 50 or 60 Hz power transformers and low frequency current changes in the motor leads. Avoid large loop areas in signal, power-supply, and motor wires. Twisted pairs of wires are quite effective in reducing magnetic pick-up because the enclosed area is small, and the signals induced in successive twist cancel.

3.4.1 Wire Gauge

As the wire diameter decreases, the impedance increases. Higher impedance wire will broadcast more noise than lower impedance wire. Therefore, when selecting the wire gauge for the motor power wires, power supply wires, and ground wires, it is better to err on the side of being too thick rather than too thin. This becomes more critical as the cable length increases. The following table provides recommendations for selecting the appropriate wire size for a specific current. These values should be used as reference only. Consult any applicable national or local electrical codes for specific guidelines.

TABLE 3.1 Current and Wire Gauges

Current (A)	Minimum Wire Size (AWG)	mm^2
10	#20	0.518
15	#18	0.823
20	#16	1.31
35	#14	2.08
45	#12	3.31
60	#10	5.26
80	#8	8.37
120	#6	13.3
150	#0	53.5
200	#00	67.4

3.4.2 Motor Wiring

The motor power wires supply power from the motor controller to the motor. Use of a twisted, shielded pair for the motor power cables is recommended to reduce the amount of noise coupling to sensitive components.

- For a brushless motor, twist all three motor wires together as a group.
- For a brushed motor or voice coil, twist the two motor wires together as a group.

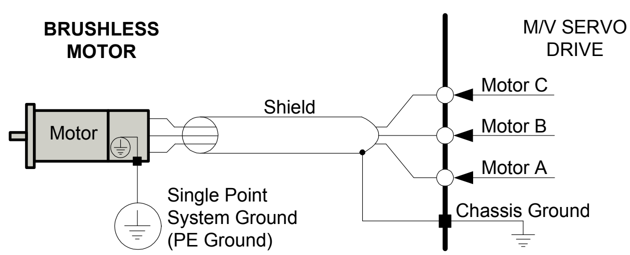
Ground the motor power cable shield at one end only to the motor controller chassis ground. The motor power leads should be bundled and shielded in their own cable and kept separate from feedback signal wires.

Caution

DO NOT use wire shield to carry motor current or power!

The diagram below shows how an M/V motor controller connects to a Brushless (three-phase) motor. Notice that the motor wires are shielded, and that the motor housing is grounded to the single point system ground (PE Ground). The cable shield should be grounded at the motor controller side to chassis ground.

FIGURE 3.2 **Motor Power Output Wiring**



Notice

If using a Brushed (single-phase) motor, connect the two motor wires to Motor A and Motor B pins only. See "Brushed Motor Setup" on page 44 for further connection instructions.

Caution

If using relays or other means to disconnect the motor leads, be sure the drive is disabled before reconnecting the motor leads to the drive. Connecting the motor leads to the drive while it is enabled can generate extremely high voltage spikes which will damage the drive.

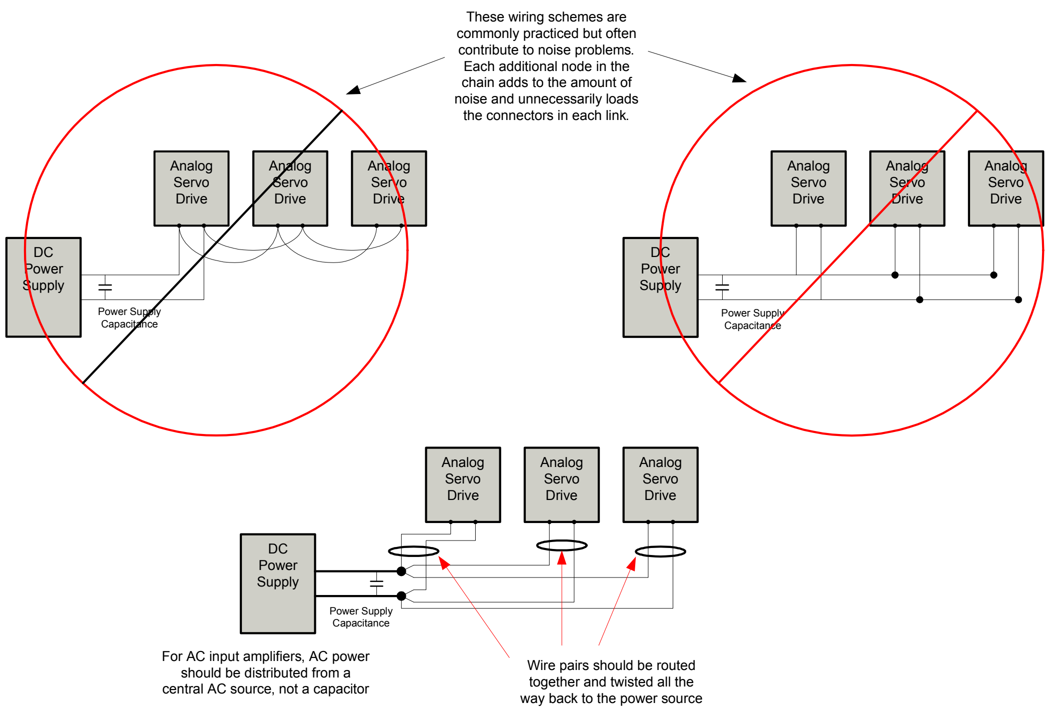
3.4.3 Power Supply Wiring

The PWM current spikes generated by the power output-stage are supplied by the internal power supply capacitors. In order to keep the current ripple on these capacitors to an acceptable level it is necessary to use heavy power supply leads and keep them as short as possible. Reduce the inductance of the power leads by twisting them. Ground the power supply cable shield at one end only to the servo drive chassis ground.

When multiple drives are installed in a single application, precaution regarding ground loops must be taken. Whenever there are two or more possible current paths to a ground connection, damage can occur or noise can be introduced in the system. The following rules apply to all multiple axis installations, regardless of the number of power supplies used (see Figure 3.3):

1. Run separate power supply leads to each drive directly from the power supply filter capacitor.
2. Never "daisy-chain" any power or DC common connections. Use a "star"-connection instead.

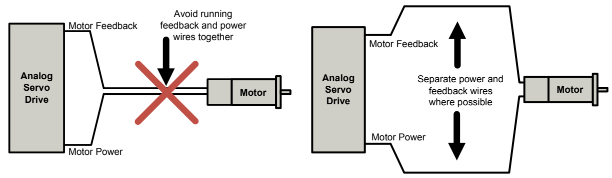
FIGURE 3.3 **Multiple Power Supply Wiring**



3.4.4 Feedback Wiring

Use of a twisted, shielded pair for the feedback wires is recommended. Ground the shield at one end only to the motor controller chassis ground. Route cables and/or wires to minimize their length and exposure to noise sources. The motor power wires are a major source of noise, and the motor feedback wires are susceptible to receiving noise. This is why it is never a good idea to route the motor power wires with the motor feedback wires, even if they are shielded. Although both of these cables originate at the motor controller and terminate at the motor, try to find separate paths that maintain distance between the two. A rule of thumb for the minimum distance between these wires is 10cm for every 10m of cable length.

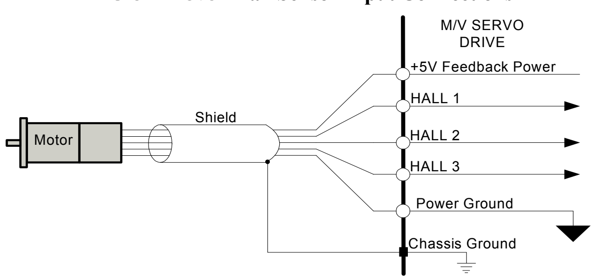
FIGURE 3.4 Feedback Wiring



Hall Sensors

M/V motor controllers accept single-ended Hall Sensor feedback for commutation and velocity control, and also include a +5V, 150mA low voltage supply output that can be used to power the Hall Sensors. Verify on the motor datasheet that the voltage and current rating of the supply output will work with the Hall Sensors before connecting.

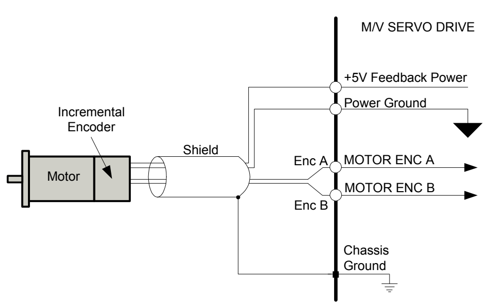
FIGURE 3.5 Hall Sensor Input Connections



Incremental Encoder

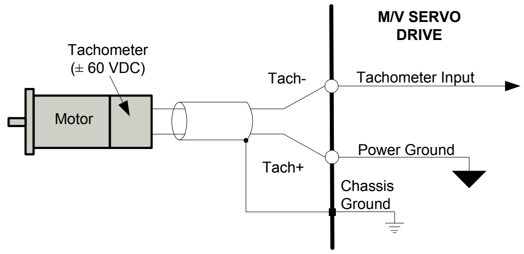
M/V motor controllers support single-ended incremental encoder feedback. Both the "A" and "B" channels of the encoder are required for operation. If using the +5V, 150mA low voltage power supply output from the motor controller, verify that the supply output voltage and current rating is sufficient for the encoder specifications.

FIGURE 3.6 Incremental Encoder Connections



Tachometer Connect the negative tachometer input to the tachometer input pin, and connect the positive tachometer input to power ground. The motor controller must be in Tachometer Velocity mode in order to properly use the tachometer input. See the M/V drive datasheet for specific DIP switch settings. The tachometer input has a range of ±60 VDC.

FIGURE 3.7 Tachometer Input Connections



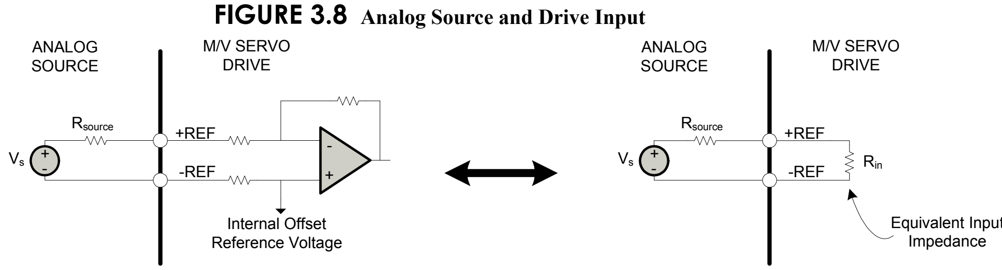
3.4.5 Input Reference Wiring

Use of a twisted, shielded pair for the input reference wires is recommended. Connect the reference source "+" to "+REF IN", and the reference source "-" (or common) to "-REF IN". Connect the shield to the servo drive chassis ground. The servo drive's reference input circuit will attenuate the common mode voltage between signal source and drive power grounds.

Long signal wires (10-15 feet and up) can also be a source of noise when driven from a typical op-amp output. Due to the inductance and capacitance of the wire the op-amp can oscillate. It is always recommended to set a fixed voltage at the motion controller and then check the signal at the M/V drive with an oscilloscope to make sure that the signal is noise free.

Analog Input When using an analog signal for an input command, it is important to consider the output impedance of the analog source when interfacing to input circuitry. A poorly designed analog input interface can lead to undesired command signal attenuation. Figure 3.8 shows an external analog source connected to an analog input. The ideal voltage delivered to the input is $\mathbf{V_S}$. However, the voltage drop across $\mathbf{R_{source}}$ will reduce the signal being delivered to the drive input. This voltage drop is dependent on the value of $\mathbf{R_{source}}$ and the drive's input impedance.

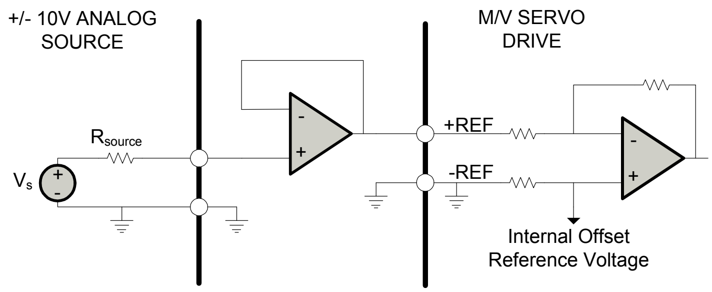
FIGURE 3.8 Analog Source and Drive Input



The drive's analog input can be simplified to a single impedance, $\mathbf{R_{in}}$, as shown in Figure 3.8. If the impedance of $\mathbf{R_{source}}$ is of the same magnitude or larger than $\mathbf{R_{in}}$, there will be a significant voltage drop across $\mathbf{R_{source}}$. Reduced values of $\mathbf{R_{source}}$ cause a lower voltage drop that increases signal integrity. In order to avoid a voltage drop of more than 5% between the source and the drive, it is recommended to use an $\mathbf{R_{source}}$ value of less than or equal to 2kohm.

If there is a large output impedance from the analog source, it is recommended to use a buffer circuit between the analog source output and the drive input. A unity gain op-amp circuit as shown in Figure 3.9 will ensure low output impedance with minimal voltage drop.

FIGURE 3.9 Optimized Low Impedance Interface



3.4.6 Command Wiring

The diagrams below show the recommended connections for the different command configurations. See Table 4.3 on page 41 for information on how to select the input command type for AVB drive models (Standard/Inverse, Single-Ended/Wigwag, 3-wire/2-wire).

FIGURE 3.10 AVB Models Command Source Wiring

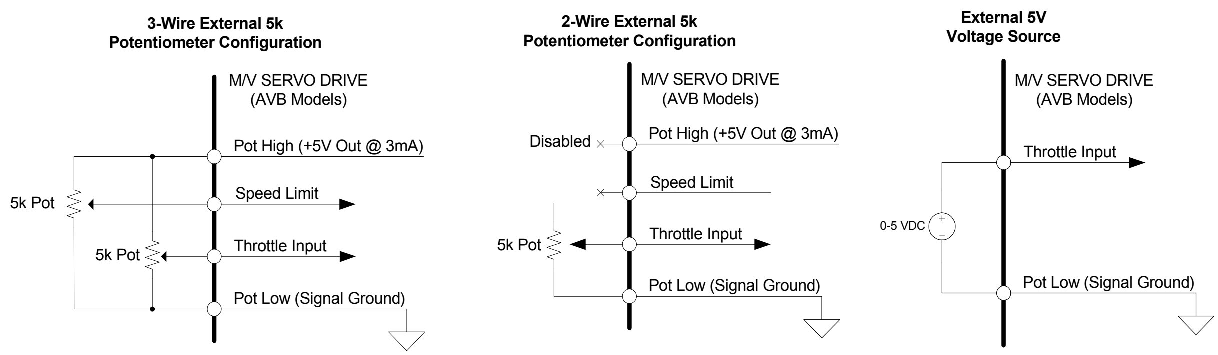
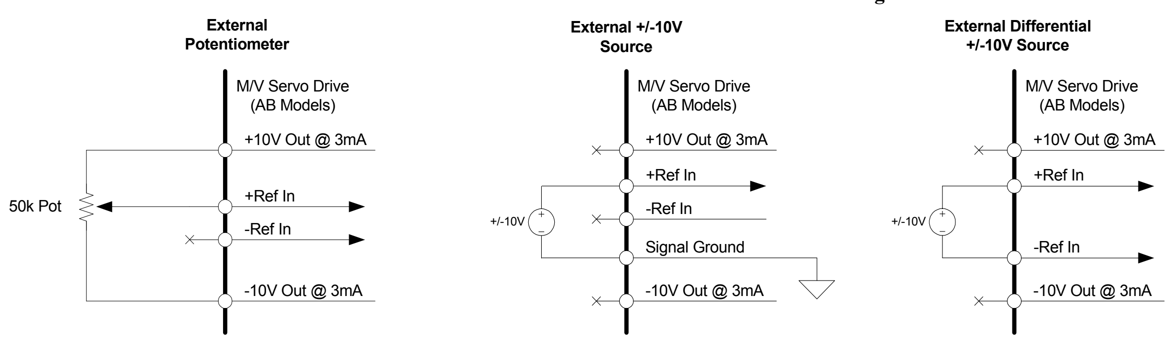


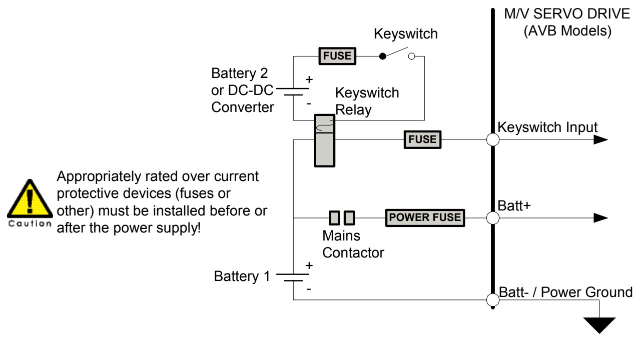
FIGURE 3.11 AB Models Command Source Wiring



3.4.7 Keyswitch Input

The Keyswitch input on AVB models provides logic power to the motor controller, and functions as the master switch. The Keyswitch must be on in order for the motor controller to function.

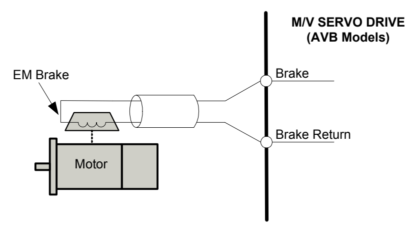
FIGURE 3.12 Keyswitch Input



3.4.8 Brake Output

AVB models feature an electromagnetic holding brake output (24V/200Hz PWM, 3A max) that will energize when the Keyswitch Input is on and the motor controller is enabled.

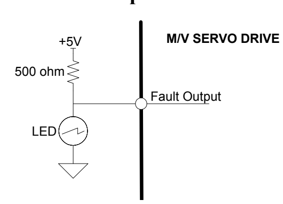
FIGURE 3.13 Brake Output



3.4.9 Fault Output

The diagram below shows the recommended circuitry for utilizing an external voltage supply and LED with the Fault Output.

FIGURE 3.14 Fault Output

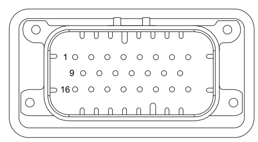


3.5 Mounting

M/V motor controllers provide mounting hole locations on the baseplate allowing either vertical or horizontal mounting configurations. Motor controllers can be mounted to a heatsink or other plane surface. Consult the datasheet for specific mounting dimensions and mounting hole locations.

3.6 Connectors

I/O Signal Connector		
Connector Information		23-pin, AMPSEAL connector
Mating Connector	Details	TE Connectivity: Housing P/N 770680-1; Socket Contacts P/N 770854-3 (loose); Seal Plug P/N 770678-1; Crimp Tool P/N 58529-1
	Included with Drive	No



Mating connector housing, socket contacts, and seal plugs can be ordered as a kit using *ADVANCED* Motion Controls' part number KC-23AMPSEAL01. Crimp tool not included with mating connector kit. Circuit cavities remain sealed until pierced. Seal plugs are included to reseal pierced circuit cavities that will not be used. Seal plugs should be inserted into the circuit cavity as far as possible, large end first.

MOTOR POWER Connectors		
Connector Information		Three individual M6 threaded terminals
Mating Connector	Details	M6 screw or bolt with washer
	Included with Drive	Yes

POWER Connectors		
Connector Information		Two individual M6 threaded terminals
Mating Connector	Details	M6 screw or bolt with washer
	Included with Drive	Yes

4 Operation

This chapter will describe the operation and setup of an *ADVANCED* Motion Controls M/V™ motor controller.

4.1 Initial Setup and Features

To begin operation with your M/V motor controller, be sure to read and understand the previous chapters in this manual as well as the product datasheet. Be sure that all system specifications and requirements have been met, and become familiar with the capabilities and functions of the motor controller. Also, be aware of the "Troubleshooting" section at the end of this manual for solutions to basic operation issues.

Do not install the motor controller into the system without first determining that all chassis power has been removed for at least 10 seconds. Never remove a motor controller from an installation with power applied. Carefully follow the grounding and wiring instructions in the previous chapters to make sure your system is safely and properly set up.

4.1.1 Pin Function Details

The family of M/V motor controllers provides a number of various input and output pins for parameter observation and configuration options. Not all M/V models will have each of the following pin functions. Consult the specific datasheet to see which input/output pin functions are available.

Current Monitor Output (AB models) Measured relative to power ground. The current monitor provides an analog voltage output signal that is proportional to the actual current output. The scaling factor can be found on the motor controller datasheet. The motor controller must be connected to a load in order to output actual current.

Example Measurement

The current monitor pin on a drive with a current monitor scaling factor of 14.4 A/V is measured to be 1.3V. This would mean the drive is outputting: (14.4 A/V)(1.3V) = **18.72A**.

DC Bus Current Monitor Output (AVB models) Measured relative to power ground. The DC Bus current monitor provides an analog voltage output signal that is proportional to the actual power supply DC Bus current. The scaling factor can be found on the motor controller datasheet. The motor controller must be connected to a load in order to output actual current.

Example Measurement

The DC bus current monitor pin on a motor controller with a current monitor scaling factor of 16.7 A/V is measured to be 0.3V. This would mean the drive is drawing: (16.7 A/V)(0.3V) = **5.01A**.

Forward / Reverse Inputs With only one input active at a time, the Forward and Reverse inputs (AVB models only) select the direction of motion. Pull low to Signal Ground to activate. When the drive is disabled or faulted, activating both pins at the same time will energize Brake Output (Pin 7) to release the electromagnetic holding brake in order to push the vehicle. Activating only one input when the drive is disabled/faulted will not excite the Brake Output.

In Wigwag mode, the Forward and Reverse inputs have no effect, as the direction of motion is controlled by the throttle input. However, activating both Forward and Reverse inputs when the drive is disabled will still energize Brake Output (Pin 7) in Wigwag mode.

Inhibit Input This pin provides a +5V TTL input that allows a user to enable/disable the motor controller by either connecting this pin to ground or by applying a +5VDC voltage level to this pin, referenced to signal ground. By default, the motor controller will be enabled if this pin is high, and disabled if this pin is low. This logic can be reversed through DIP switch setting. This will require the inhibit line to be brought to ground to enable.

Speed/Command Limit Input The Speed/Command Limit input pin (AVB models only) is used to limit the maximum command with an external potentiometer (command type dependent on the mode of operation). The potentiometer should be connected between the POT HIGH and POT LOW pins, with the pot wiper connected to the Speed Limit input. The voltage value at the Speed Limit input will act as the upper limit available for the throttle input command. See “Command Wiring” on page 34 for recommended connection diagrams.

Fault Output This pin provides a +5V TTL output measured relative to signal ground that will indicate when the motor controller is subject to one of the following fault conditions: inhibit, invalid Hall State, output short circuit, over voltage, over temperature, or power-up reset. This pin will read +5V (High) when the drive is in a fault state. The Fault Output can be used with an external voltage supply and LED. See “Fault Output” on page 35 for the recommended circuitry.

M/V motor controllers automatically self-reset once all active fault conditions have been removed. For instance if the DC power supply rises above the over-voltage shutdown level, the Fault Output will indicate a fault, and the motor controller will be disabled. Once the DC power supply level is returned to a value below the over-voltage shutdown level, the Fault Output will return to the normal state, and the motor controller will automatically become enabled.

Low Voltage Power Supply Outputs M/V motor controllers include low voltage power supply outputs meant for customer use.

- **±10V (AB models) or 0-5V (AVB models), 3mA Output -** Typically used as an on-board analog input signal, can also be used with an external pot to vary the input signal.

- **+5V, 150 mA Output -** Can be used as power for an encoder or Hall Sensors. Consult the motor or encoder datasheet to determine the appropriate supply voltage and current requirements, as well as which wire from the motor is the feedback power supply wire before connecting this supply.

Velocity Monitor Output This pin provides an analog voltage output that is proportional to the actual motor speed. The scaling factor for each drive can be found on the drive datasheet.

- For a drive in Encoder Velocity Mode, substitute the voltage value read at the velocity monitor pin, $V_{monitor}$, into the below equation to determine the motor RPM:

$$\text{Motor Velocity [RPM]} = \frac{V_{monitor} \cdot \text{Scaling Factor} \cdot 60}{\text{Number of encoder lines}}$$

- For a drive in Hall Velocity Mode, substitute the voltage value read at the velocity monitor pin, $V_{monitor}$, into the below equation to determine the motor RPM:

$$\text{Motor Velocity [RPM]} = \frac{V_{monitor} \cdot \text{Scaling Factor} \cdot 120}{\text{Number of motor poles}}$$

4.1.2 Potentiometer Function Details

All on-board potentiometers vary in resistance from 0 to 50 kohm, over 12 turns. An additional full turn that does not effect resistance is provided on either end, for a total of 14 turns. When the end of potentiometer travel is reached, it will click once for each additional turn.

TABLE 4.1 Potentiometer Function Details

Potentiometer	Description
1 - Loop Gain Adjustment	This potentiometer must be set completely counter-clockwise in Current Mode. In Velocity, Voltage, or Duty Cycle Mode, this potentiometer adjusts the gain in the velocity forward position of the closed loop. Turning this potentiometer clockwise increases the gain. Start from the full counter-clockwise position, turn the potentiometer clockwise until the motor shaft oscillates, then back off one turn.
2 - Current Limit	This potentiometer adjusts the current limit of the drive. To adjust the current limit, use the following equation to determine the number of clockwise turns from the full counter-clockwise position necessary to set the desired current limit: $\text{\# of turns (from full CCW)} = \left(\frac{I_{system}}{I_{max}}\right)12 + 1$ I_{system} = the desired current limit of the system (typically determined by motor current rating) I_{max} = maximum current capability of the drive; this value is determined after any external current limiting resistors have been used. If no external resistors have been used, then I_{max} is the default maximum continuous current limit set by the drive hardware. See “Current Limiting Procedure” on page 42 for an example of how to use this potentiometer.
3 - Reference Gain	This potentiometer adjusts the ratio between the input signal and the output variable (voltage, current, velocity, or duty cycle). For a specific gain setting, turn this potentiometer fully counter-clockwise, and adjust the command input to 1V. Then turn clockwise while monitoring motor velocity or drive output voltage (depending on mode of operation) until the required output is obtained for the given 1V command. Turning this potentiometer counter-clockwise decreases the reference in gain, while setting this potentiometer in the fully clockwise position makes the whole range of drive output available. This potentiometer may be left in the fully clockwise position if a controller is used to close the velocity or position loops.
4 - Test/Offset	This potentiometer acts as an internal command source for testing when the Test/Offset switch is in the ON position. If the Test/Offset switch is in the OFF position, then this potentiometer can be used to adjust a small amount of command offset in order to compensate for offsets that may be present in the servo system. Turning this potentiometer clockwise adjusts the offset in a negative direction relative to the +Ref input command. Before offset adjustments are made, the reference inputs must be grounded or commanded to 0 volts.

Potentiometer	Description
5 - Ramp Time	This potentiometer adjusts the ramp time (both acceleration and deceleration) in both directions. The ramp time is the time required for the drive output to linearly ramp to the maximum possible commanded output. Adjustable range is from 0 to 20 seconds. No ramping will occur when set to zero. Turning clockwise will decrease the ramp time (faster response time).
6 - Deadband	This potentiometer adjusts the range of the command voltage which the drive will interpret as no output. Turning clockwise will decrease the deadband. The maximum deadband range is 30% in each direction. Therefore: - Command Range of 0 to 5V: Deadband range is 0 to 1.5V (both directions) - Command Range of 0 to ±10V: Deadband range is 0 to ±3V - Wigwag Command Range of 0 to 5V: Deadband range is 1.75V to 3.25V (2.5V ±0.75V) The Neutral point is 0V for single-ended commands and 2.5V for Wigwag commands. The Deadband will have an effect on the rest of the command range. Therefore, to reach the maximum command would require increasing the Reference Gain (potentiometer 3).

Potentiometer Tool *ADVANCED* Motion Controls offers a tool for adjusting the potentiometers, part number PT01. This tool features an exposed stainless steel blade on one end and a recessed stainless steel blade on the other end. Contact customer service for ordering information.

4.1.3 Switch Function Details

Together with the described functions below certain switches may also be used in selecting the mode of operation or command input type. Switch implementation and functionality within the motor controller circuitry is included on the block diagram of the datasheet.

Switch bank SW1 contains switches used for drive configuration and mode selection.

TABLE 4.2 Switch Bank SW1 - Function Details

Switch		Description
1-1	Test/Offset	Switches the drive between Test mode and Offset mode. In Test mode, the command signal is adjustable via the Test/Offset potentiometer. In Offset mode, the drive will accept commands via the reference inputs, but a small amount of offset can be adjusted in order to compensate for offsets that may be present in the servo system.
1-2	120/60 Phasing	Selects Hall commutation phasing type. On = 120; Off = 60
1-3	Mode Selection	**See drive datasheet for specific mode selection information.**
1-4	Mode Selection	
1-5	Mode Selection	
1-6	Mode Selection	
1-7	Velocity Integrator Capacitor	Adds more capacitance to the velocity integrator function. Turn on for Hall Velocity Mode. On = more capacitance; Off = less capacitance
1-8	Velocity Feedback Polarity	Changes the polarity of the internal feedback signal and the velocity monitor output signal (Encoder or Hall Velocity modes only). Inversion of the feedback polarity may be required to prevent a motor run-away condition. See "Motor Problems" on page 58 for more information.
1-9	Inhibit Logic Selection	Sets the logic of the inhibit pins: On = Low to Inhibit; Off = Low to Enable
1-10	Ramp Command	Enables or disabled the Ramp feature. On = Enable Ramping; Off = Disable Ramping

Switch bank SW2 is included on AVB models only, and is used to select the command input type.

TABLE 4.3 Switch Bank SW2 (AVB models only) - Function Details

Switch		Description
2-1	Wigwag Select	Selects the command type between Wigwag or Single Ended. On = Wigwag; Off = Single-Ended
2-2	3 or 2-wire Pots	Selects the type of external potentiometers used for the application. On = 3-wire; Off = 2-wire. Note that when 2-wire is selected, the Pot High input (pin 3) becomes disabled. As an additional protection in 2-wire setting, whenever the command input exceeds the acceptable range (0-5V or 0-5kΩ) the output command will be disabled until the command input is reset to a zero output command.
2-3	Inverted Inputs	Selects whether the command input will interpret the command proportional or inversely proportional to the output. On = Standard; Off = Inverted Inputs
2-4	Half Speed Reverse	Rescale the reverse speeds to half of forward speeds. On = Half Speed Reverse; Off = Normal Speed Reverse

Switch bank SW3 is used to add additional resistance and capacitance to the current loop tuning circuitry. SW3 switches 1 through 5 add additional parallel capacitance to the current loop integrator capacitor, and SW3 switches 6 through 10 add additional series resistance to the current loop gain resistor (locations shown on datasheet block diagram). Capacitance and resistance values are given in Table 4.4 below along with the appropriate DIP switch settings.

TABLE 4.4 Switch Bank SW3 - Function Details

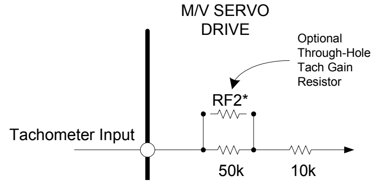
SW3 1-5 Additional Current Loop Integrator Capacitance (μF)																	
	SHORT	.082	.077	.072	.067	.062	.057	.052	.047	.035	.030	.025	.020	.015	.010	.005	OPEN
3-1	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
3-2	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
3-3	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
3-4	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
3-5	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

SW3 6-10 Additional Current Loop Gain Resistance (kohm)																
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
3-6	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
3-7	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
3-8	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
3-9	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
3-10	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
SW3 6-10 (cont.) Additional Current Loop Gain Resistance (kohm)																
Switch	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310
3-6	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
3-7	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
3-8	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
3-9	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
3-10	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

4.1.4 Tachometer Input Gain Scaling

Standard drive tachometer inputs are typically pre-configured such that the standard 60k input resistance scales the maximum tach input voltage to 60V. The 60k tachometer input resistance is actually populated with a 50k resistor in series with a 10k resistor. M/V drives also have a through-hole resistor location in parallel with the 50k resistor, as shown in Figure 4.1.

FIGURE 4.1 **Tachometer Input Resistance**



This allows users to optionally reduce the effective input resistance to a value that more closely matches their maximum application feedback voltage in order to increase the tachometer input gain. An appropriate tachometer input resistance value should be at least 1000 times the maximum tachometer voltage feedback value. From zero to infinite resistance (open connection), this through-hole location can scale the tachometer's maximum input voltage range from 10V to 60V.

To determine the maximum feedback voltage for the application:

1. Determine the absolute maximum speed required of the motor for the application (S_m, in kRPM).
2. Look up the tachometer's voltage to speed constant (K_v, in V/kRPM).
3. Calculate for the tachometer's maximum voltage output in the application:

$$V_{max} = K_v \cdot S_m$$

Example

An application's maximum motor speed is 4.7 kRPM, and the tachometer is rated for 7 V/kRPM. Using the above equation, the maximum voltage from the tachometer input, V_{max}, will be 33V. Therefore, the equivalent tachometer input resistance must be at least 33k. Choosing an equivalent resistance value of 35k, solve for the required resistance of the through-hole resistor.

$$\textbf{Tach Gain Through-Hole Resistor (in kohm)} = \frac{(50 \cdot V_{max}) - 500}{60 - V_{max}} = \frac{(50 \cdot 35) - 500}{60 - 35} = 50k$$

As solved for above, the equivalent 35k resistance can be achieved by adding a 50k through-hole resistor in parallel with the existing 50k resistor on the drive tachometer input.

Notice

Scaling the tachometer input gain is not a required procedure for all applications. Most applications will work well even with low gains. The effect of low gains is only a slower velocity loop response.

4.1.5 Current Limiting Procedure

Before operating an M/V motor controller, the current output of the drive must be limited based on motor and system current limitations. The current limiting potentiometer (see "Potentiometer Function Details" on page 39) is used to manually adjust both the drive peak and continuous current limits to an appropriate value.

Example

An AB125A200 drive is going to be used with an application having a continuous current requirement of 45 amps, a peak current requirement of 75 amps, and a peak current limit of 85 amps. The current limiting potentiometer will be used to adjust the default AB125A200 current ratings to values within the system specifications.

1. Typically it is recommended to set the current limits of the drive below any continuous or peak current limits of the motor or application, allowing some headroom for safety, but above the application requirements if possible. In this case, the continous current will be chosen at approximately 50 amps.
2. To reduce the current limits to the desired values, the current limit potentiometer can be used. Begin with the continuous current requirement, using the equation below to determine the number of clockwise turns for the Current Limit potentiometer:

$$\text{\# of turns} = \frac{50amps}{80amps}12 + 1$$

   Solving for the number of turns yields approximately 8.5 turns in the clockwise direction from the fully counter-clockwise position.
3. The number of turns calculated above will therefore yield a peak current limit of approximately 78 amps, thereby satisfying both the continuous and peak current requirements of the application.

4.1.6 Drive Set-up Instructions

1. It is recommended to reduce the drive output current to avoid motor over heating during the setup procedure. Make sure the current has been set appropriately based on the procedure outlined in "Current Limiting Procedure" on page 42.
2. According to the the mode selection table on the drive datasheet, set the drive for Duty Cycle (Open Loop) Mode, and set the Test/Offset switch to Test (SW1-1 = ON).
3. Check the power and connect it to the drive. Do not connect the motor lead wires.
4. Make sure the drive is in an enabled state via all enable inputs. See drive datasheet for details.
5. Set the Hall Sensor Commutation Switch (SW1-2) for the appropriate phasing (typically 120 degree). Connect the Hall sensor inputs. The drive status LED should be GREEN. Manually turn the motor shaft one revolution. The LED should remain green. If the LED turns red or changes between green and red:
   - check the Hall Sensor Commutation Switch
   - check power for the Hall Sensors
   - check the voltage level of the Hall inputs (see Table 4.5)
   - for 60 degree phasing interchange Hall 1 and Hall 2

   (for more information see "Invalid Hall Sensor State" on page 56)

TABLE 4.5 Commutation Sequence Table

	60 Degree			120 Degree			Motor		
	Hall 1	Hall 2	Hall 3	Hall 1	Hall 2	Hall 3	Phase A	Phase B	Phase C
Valid	1	0	0	1	0	0	HIGH	-	LOW
	1	1	0	1	1	0	-	HIGH	LOW
	1	1	1	0	1	0	LOW	HIGH	-
	0	1	1	0	1	1	LOW	-	HIGH
	0	0	1	0	0	1	-	LOW	HIGH
	0	0	0	1	0	1	HIGH	LOW	-
Invalid	1	0	1	1	1	1	-	-	-
	0	1	0	0	0	0	-	-	-

6. Remove power. For three phase (brushless) motors, there are six different ways to connect the three motor wires to the Motor A, Motor B, and Motor C pins. All six combinations must be tested to find the proper combination. The correct combination should yield approximately identical motor speed in both directions. If the motor runs slower in one direction, or if the motor shaft has to be moved manually by hand to start the motor, the combination is incorrect. Motor speed can be verified by using the velocity monitor or by measuring the frequency of the Hall Sensors.
7. To begin, connect the three motor wires in any order.
8. Apply power to the drive, and slowly turn the Test/Offset potentiometer (Pot 4) in both directions. Observe the motor speed for both directions. Remove power from the drive, and rewire the three motor wires for a different combination. Test all six different combinations before proceeding.
9. Once the proper combination has been found, set the Test/Offset switch to Offset (SW1-1 = OFF), ground both reference inputs, and then adjust the Test/Offset potentiometer for zero speed.
10. Set the control mode suitable for the application.

Brushed Motor Setup M/V drives are also compatible with single phase (brushed) motors. However, because there are no Hall Sensors on a brushed motor, one of the following courses of action must be taken to properly commutate the drive:

- Set the Hall Sensor Commutation Phasing DIP switch for 60-degree phasing (SW1-2 = OFF). Leave all the Hall Sensor inputs on the drive open. These inputs are internally pulled high to +5V, creating a "1-1-1" commutation state (see Table 4.5 above) which is a valid state in 60-degree phasing. Only use Motor A and Motor B output in this configuration.

or:

- Tie one of the Hall Sensor inputs on the drive to signal ground. Since the Hall Sensor inputs are by default internally brought high to +5V, this will put the drive in a commutation state where two Hall inputs are high, and one is low (as shown in Table 4.5, having all three Hall inputs pulled high is an invalid commutation state in 120-degree phasing). Depending on which Hall Sensor input is tied to ground, consult Table 4.5 to determine which two motor output wires will be conducting current for that specific commutation state.

4.1.7 Tuning Procedure

The standard tuning values used in *ADVANCED* Motion Controls M/V motor drives are conservative and work well in over 90% of applications. However some applications and some motors require more complete current loop tuning to achieve the desired performance. The following are indications that additional current loop tuning is necessary:

- Motor rapidly overheats even at low current
- Drive rapidly overheats even at low current
- Vibration sound comes from the drive or motor
- The motor has a high inductance (>5mH)
- The motor has a low inductance (near minimum rating of the drive)
- Slow system response times
- Excessive torque ripple
- Difficulty tuning position or velocity loops
- Electrical noise problems
- High power supply voltage (power supply is significantly higher than the motor voltage rating or near the drive's upper voltage limit)
- Low power supply voltage (power supply voltage is near the drive's lower voltage limit)

The above indicators are subjective and suggest that the current loop may need to be tuned. These can also be signs of other problems not related to current loop tuning.

The resistors and capacitors shown under the current control block on the datasheet block diagram determine the frequency response of the current loop. It is important to tune the current loop appropriately for the motor inductance and resistance, as well as the bus voltage to obtain optimum performance. M/V motor drives have a single current loop, and the loop gain and integrator capacitance of the current loop must both be adjusted for the tuning to be complete.

Caution

Improper current loop tuning may result in permanent drive and/or motor damage regardless of drive current limits.

Since most *ADVANCED* Motion Controls servo drives close the current loop internally, poor current loop tuning cannot be corrected with tuning from an external controller. Only after the current loop tuning is complete can optimal performance be achieved with the velocity and position loops.

The general current loop tuning procedure follows these steps:

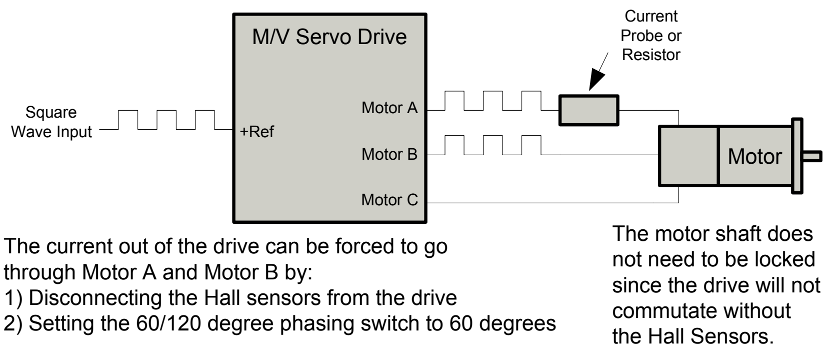
1. Determine if additional current loop tuning is necessary.
2. If current loop tuning is necessary, then the current loop components must be changed.
   - Tune the current loop proportional gain.
   - Tune the current loop integral gain.
3. Once the current loop is tuned, then the velocity and/or position loops may be tuned as well if necessary.

Current Loop Proportional Gain Adjustment

The Current Loop Gain should be adjusted with the motor uncoupled from the load, and the motor secured as sudden motor shaft movement may occur. Keep in mind before beginning the tuning procedure that M/V drives should be configured for 60 degree phasing in order to get output current. The current can be measured through either motor phase A or B.

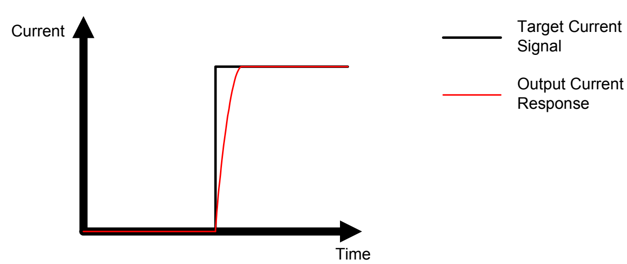
1. Use the DIP switches and Current Limit Potentiometer to select Current Mode and to set the appropriate current limit for the motor.
2. Connect only the motor power leads to the drive. No other connections should be made at this point.
3. Using a function generator, apply a ±0.5 V, 50-100 Hz square wave reference signal to the input reference pins.
4. Short out the current loop integrator capacitor by setting SW3 switches 1 through 5 to ON.
5. Apply power to the drive. Use a bus voltage that is approximate to the desired application voltage or the current loop compensation will not be correct.
6. The drive should be enabled (GREEN LED). Observe the motor current using a current probe or resistor in series with the motor (<10% of motor resistance). Table 4.4 lists the different current loop gain resistor values available by adjusting SW3 switches 6 through 10. Observe the motor current at different resistor values until the best response is found. Set up the drive as shown below to view the current loop response properly.

FIGURE 4.2 Current Loop Response Setup



7. The drive output should follow the input command. The best response will be a critically damped output waveform, similar to what is shown in Figure 4.3.

FIGURE 4.3 Current Loop Response



8. If neither current loop gain DIP switch position gives a proper square wave response, then the current loop gain resistors may need to be changed to optimize the response. See "Through-hole Components" on page 49 for more information.
9. When the proper response has been achieved, remove the input signal from the drive, and disconnect power.

Current Loop Integrator Adjustment

1. Enable the Current Loop Integrator Capacitor by setting SW3 switches 1 through 5 to OFF.
2. Using a function generator, apply a ±0.5V, 50-100 Hz square wave reference signal.
3. Apply power to the drive. Use a bus voltage that is approximate to the desired application voltage or the current loop compensation will not be correct.
4. The drive should be enabled (GREEN LED). Observe the motor current using a current probe or resistor in series with the motor (<10% of motor resistance). Table 4.4 lists the different current loop integrator capacitor values available by adjusting SW3 switches 1 through 5. Observe the motor current at different capacitor values until the best response is found. The output should settle to a flat top with minimal current following error (difference between commanded current and actual current). There can be some overshoot, but it should be less than 10%.

Notice

Because the oscilloscope measurements are voltage representations of current, the commanded and actual currents will most likely have different current to voltage scalings and tolerances. Therefore, even with perfect current loop tuning, the two amplitudes (scope traces) may not line up as shown in Figure 4.3.

5. If the square wave output overshoots too much or is over-damped (sluggish), the current loop integrator capacitor will need to be changed to optimize the response. See "Through-hole Components" on page 49 for more information.

Voltage or Velocity Loop Tuning

These adjustments should initially be performed with the motor uncoupled from the mechanical load.

Configure the drive for the desired operation mode using the DIP switch settings (see the block diagram on the specific drive datasheet).

- **Voltage Loop or Duty Cycle Loop**- Compensating the voltage loop requires the least amount of effort. Turn the Loop Gain potentiometer clockwise until oscillation occurs, then back off one turn.
- **IR Feedback Loop -** IR Compensation mode requires adding an additional through-hole resistor to the M/V motor controller PCB. **Note that any damage done to the drive while adding through-hole components or removing the cover seal rings will void the product warranty.** See "Through-hole Components" on page 49 for information on adding additional through-hole components to the PCB.

  Start with a very high (or open) IR feedback resistor with an unloaded motor shaft. Command a low motor speed (about 20-200 RPM). Without the IR feedback the motor shaft can be stalled easily. Decreasing the IR feedback resistor will make the motor shaft more difficult to stop. Too much IR feedback, i.e. too low a resistor value, will cause motor run-away when torque is applied to the motor shaft.
- **Velocity Loop (Encoder, Halls, or Tachometer) -** The velocity loop response is determined by the Loop Gain potentiometer. A larger resistance value (clockwise) results in a faster response. The velocity integrator capacitor can be used to compensate for a large load inertia. A large load inertia will require a larger capacitor value. Either using the DIP switches to add in extra capacitance or installing a through-hole capacitor may accomplish this (see "Through-hole Components" on page 49 for more information). The need for an extra capacitor can be verified by shorting out the velocity integrator

capacitor by DIP switch setting. If the velocity loop is stable with the capacitor shorted out, and unstable with the capacitor in the circuit, then a larger capacitor value is needed.

Analog Position Loop

- Use of an encoder or tachometer is recommended to obtain a responsive position loop, since the position loop is closed around the velocity loop. First the velocity loop must be stabilized (or voltage loop for undemanding applications). The position loop gain is determined by the fixed gain of the input differential amplifier of the drive. For best results the servo drive can be ordered with a higher differential gain.

A Through-hole Components

In general, *ADVANCED* Motion Controls M/V motor controllers will not need to be further tuned with through-hole components. However, for applications requiring more precise tuning than what is offered by the DIP switches and potentiometers, or for applications operating in IR Compensation Mode, the drive can be manually modified with through-hole resistors and capacitors as denoted in Table A.1 below. The through-hole locations are not populated when the drive is shipped.

It is recommended to contact *ADVANCED* Motion Controls to discuss application requirements and proper drive tuning prior to making any adjustments.

Notice

Through-hole component locations are underneath the sealed cover. Any damage done to the drive or cover seal rings while performing these modifications will void the product warranty.

Before attempting to add through-hole components to the board for tuning purposes, see "Tuning Procedure" on page 44. Some general rules to follow when adding through-hole components are:

- A larger resistor value will increase the proportional gain, and therefore create a faster response time.
- Use non-polarized capacitors.
- A larger capacitor value will increase the integration time, and therefore create a slower response time.

For applications using IR Compensation mode, an additional through-hole resistor is required for proper operation. "Through-Hole Component Procedures" below offers helpful guidelines in how to efficiently select and install a through-hole resistor. The final resistor value will be dependent on the application and system performance requirements. "Voltage or Velocity Loop Tuning" on page 47 gives information on how to find the appropriate IR Compensation resistor value.

A.1 Through-Hole Component Procedures

Proper tuning using through-hole components will require careful observation of the loop response on a digital oscilloscope to find the optimal through-hole component values for the specific application.

The following are some helpful hints to make the loop tuning process easier:

- **Use pin receptacles to reduce the need for soldering -** Some drives have pin receptacles that make it easy to change the tuning resistors and capacitors without the need for soldering. Other drives do not have these receptacles, so soldering is required. To avoid the need to solder every time a tuning value needs to be changed a pin receptacle can be soldered into the the through-hole location of the tuning component.
- **Use a potentiometer to find the correct current loop gain value -** A potentiometer can be used to continuously adjust the gain resistance value during the tuning process. Install a potentiometer in place of the gain resistor. Adjust the potentiometer while viewing the current loop response on an oscilloscope. When the optimal response is achieved turn off the drive, remove the potentiometer, and measure the potentiometer resistance. Use the closest resistor value available. (Note: This method will not work if the optimal tuning value is beyond the range of the potentiometer).
- **Progressively double the resistance value when tuning the current loop gain for faster results -** If the gain resistor needs to be increased during the tuning process the fastest results are achieved by doubling the resistance from the last value tried. Use this method until overshoot is observed and then fine tune from there.
- **Be aware of any components that are in parallel with the values you are trying to tune -** There may be one or more gain resistors in parallel with the through-hole resistor location. The equivalent resistance value of the SMT resistor(s) on the board and the additional through-hole resistor will be limited by the smallest resistance value of the group of resistors in parallel. Consult the block diagram on the drive datasheet to determine the specific resistor values. The same situation can occur when trying to decrease the integrator capacitor value, since capacitors in parallel will be added together.
- **Safety**

Caution

Always remove power when changing components on the drive.

Caution

Float the oscilloscope and function generator grounds to avoid large ground currents.

DANGER

Decouple the motor from the load to avoid being injured by sudden motor movements.

Table A.1 lists the different through-hole components that can be used for loop tuning. Consult the drive datasheet to see which options are available for a specific drive. Please contact *ADVANCED* Motion Controls Applications Engineering for assistance in determining the PCB location of the through-hole component options for the drive model in use.

TABLE A.1 Through-Hole Tuning Component

Component	Description
Current Loop Integrator Capacitor	Through-hole capacitor that can be added for more precise current loop tuning.
Velocity Loop Integrator Capacitor	Through-hole capacitor that can be added for more precise velocity loop tuning.

A.1.1 Procedure

Before changing any components on the PCB, follow the steps in "Tuning Procedure" on page 44 to determine if any additional tuning is necessary. Observe the drive output current response on an oscilloscope for all the different DIP switch proportional and integral gain settings. If further tuning is necessary or desired, please contact *ADVANCED* Motion Controls before proceeding through the through following steps.

Tune the Current Loop Integral Gain

1. After the proportional gain resistance has been adjusted to an acceptable value using SW3 switches 6 through 10, re-enable the current loop integrator capacitor (SW1-7=ON).
2. Observe the drive current response on an oscilloscope. Small step tuning is different than large step tuning, so adjust the function generator square wave amplitude so the drive outputs a current step similar to what will be expected in typical operation.
3. The current loop integrator capacitor can be changed or shorted out of the circuit by DIP switch setting. Test both settings while observing the current loop response.
   - If the current response square wave oscillates or overshoots, a larger equivalent capacitance value is necessary.
   - If the current response square wave corners are too rounded, a smaller equivalent capacitance value is necessary to sharpen the corners.
4. Finding an acceptable equivalent capacitance may take a few iterations. Using pin receptacles at the through-hole locations will greatly assist in finding an acceptable capacitance value. Also keep in mind that the through-hole capacitor location may be in parallel with SMT capacitors on the PCB. Use the block diagram on the drive datasheet to determine the equivalent integrator capacitance value (capacitors in parallel add together).
5. Although the ideal current loop response after integral gain tuning will be a critically damped square wave, the application requirements will determine what the desired response will be (i.e. how much overshoot, steady-state error, oscillation, is acceptable).

Velocity Loop Integral Gain Tuning The velocity loop proportional gain is adjusted by the on-board Loop Gain potentiometer. The velocity loop integral gain can be adjusted by DIP switch settings similar to the current loop integral gain (capacitance value can be changed, capacitor can be shorted out, extra capacitor can be added in parallel). M/V drive models also include an additional through-hole location where a through-hole capacitor can be added to further adjust the velocity loop integral gain. As in tuning the current loop integral gain, use larger value equivalent capacitance to correct for overshoot or oscillation, and smaller value equivalent capacitance for a quicker response time.

B Specifications

B.1 Specifications Tables

TABLE B.1 Power Specifications

Description	Units	A_250A060	A_200A100	A_125A200	A_100C200
DC Supply Voltage Range	VDC	20-54	20-80	40-175	40-175
DC Bus Over Voltage Limit	VDC	59	92	190	190
DC Bus Under Voltage Limit	VDC	18	16	36	36
Logic Supply Voltage (Keyswitch) - AVB models only	VDC	20-54	20-80	40-175	40-175
Maximum Peak Output Current[1]	A	250	200	125	100
Maximum Continuous Output Current	A	150	125	80	100
Maximum Continuous Output Power	W	7695	9500	13300	16625
Maximum Power Dissipation at Continuous Current	W	405	500	700	875
Internal Bus Capacitance	μF	12600	6000	3840	3840
Minimum Load Inductance[2]	μH	200	250	300	300
Switching Frequency	kHz	14.5	14.6	14.5	14.6
Maximum Output PWM Duty Cycle	%	100	100	100	100

1. Maximum duration of zero-to-peak current commands is ~10 seconds for AVB drives and ~5 seconds for AB drives. Maximum duration of peak-to-peak current commands is ~10 seconds for AB drives. Peak-to-peak current commands should not be performed with AVB drives.
2. Lower inductance is acceptable for bus voltages well below maximum. Use external inductance to meet requirements.

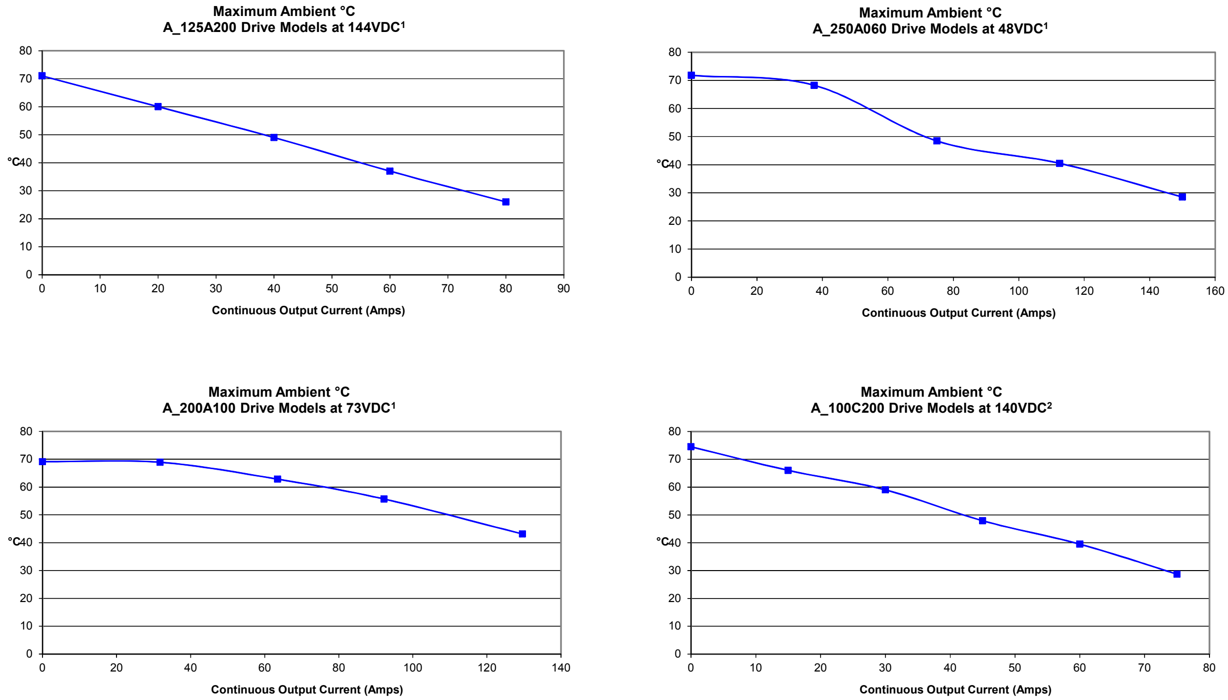
TABLE B.2 Control Specifications

Control Specifications		
Description	AVB	AB
Command Sources	0-5V Analog, 0-5kΩ	±10V Analog
Commutation Methods	Trapezoidal	
Control Modes	Current, Voltage, IR Compensation, Duty Cycle (Open Loop), Hall Velocity, Encoder Velocity, Tachometer Velocity	
Motors Supported	Three Phase Single Phase	

TABLE B.3 Standard Environmental Specifications

Environmental Specifications	
Parameter	Description
Baseplate Temperature Range	0 - 75 ºC (32 - 167 ºF)
Humidity	90%, non-condensing
Mechanical Shock	10g, 11ms, Half-sine
Vibration	2 - 2000 Hz @ 2.5g
Altitude	0-3000m
IP Rating	IP65

FIGURE B.1 Ambient Temperature Ranges

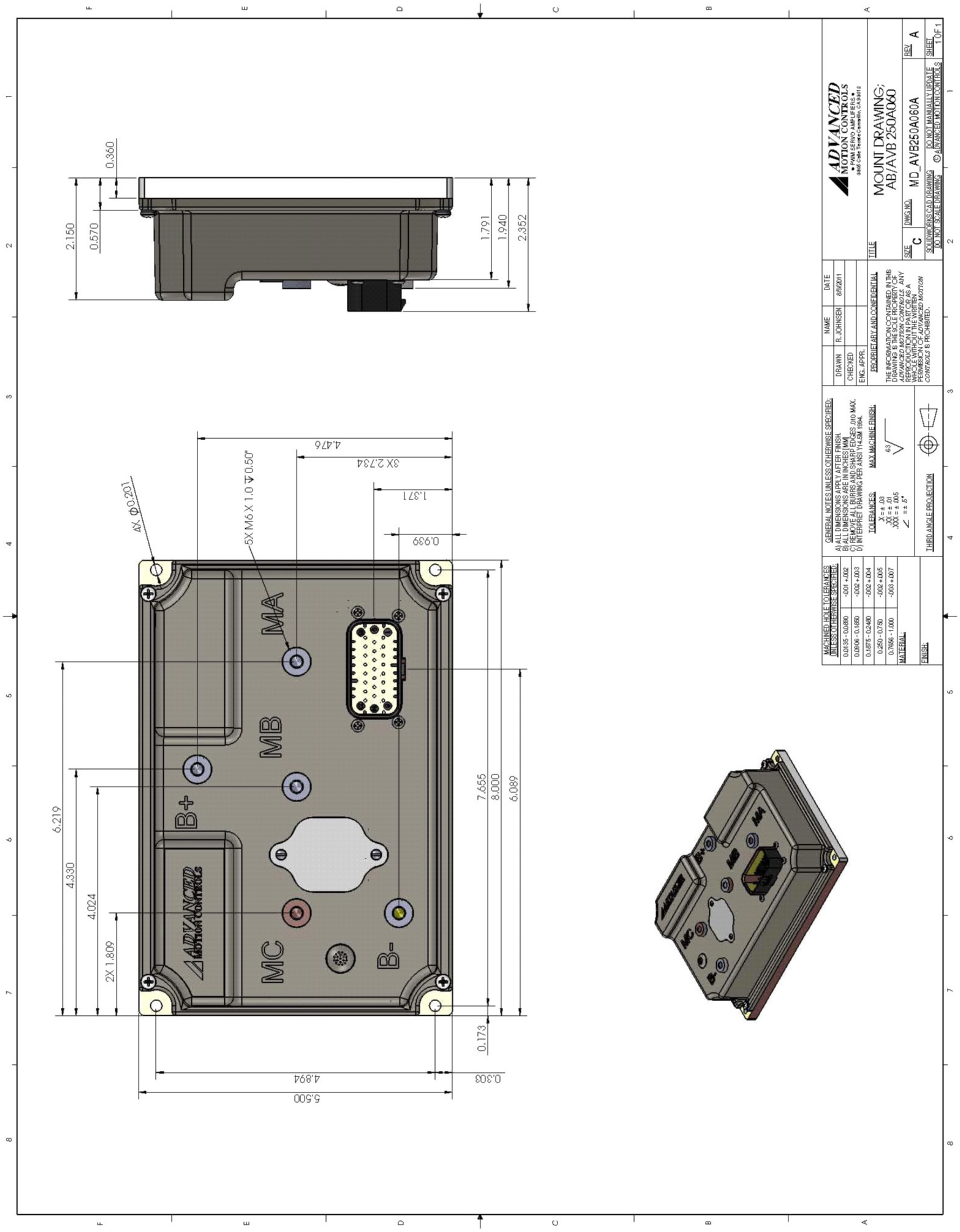


1. Heatsink used is 8 7/8" x 10 3/4" x 2 3/8" finned heatsink with 36 cfm air flow on heatsink.
2. Heatsink used is 15" x 27 7/8" x 5/8" aluminum plate heatsink with 260 cfm air flow on heatsink. For output currents above 75 A, additional cooling and/or heatsinking is required.

TABLE B.4 Physical Dimensions

Description	Units	
Height	mm (in)	203.2 (8.0)
Width	mm (in)	139.7 (5.5)
Depth	mm (in)	59.7 (2.4)
Depth (with 23-pin AMPSEAL connector installed	mm (in)	74.0 (2.9)
Weight	kg (oz)	1.64 (57.8)

FIGURE B.2 Mounting Dimensions (inches and [mm])



C Troubleshooting

This section discusses how to ensure optimum performance and, if necessary, get assistance from the factory.

C.1 Fault Conditions and Symptoms

An inoperative drive can indicate any of the following fault conditions:

- over-temperature
- over-voltage
- under-voltage
- short-circuits
- invalid commutation
- inhibit input
- power-on reset

All of the above fault conditions are self-reset by the drive. Once the fault condition is removed the drive will become operative again without cycling power. To determine whether the drive is in a fault state, measure the "Fault Output" pin with a digital multimeter or voltmeter. A high at this pin (or a low, depending on the drive model and configuration - see drive datasheet) will indicate that the drive is subject to one of the above fault conditions, and the drive will be disabled until the drive is no longer in a fault state. To remove the fault condition, follow the instructions in the sections below describing each possible fault state.

Over-Temperature

Verify that the baseplate temperature is less than the maximum allowable baseplate temperature as denoted on the drive datasheet, 75°C (167°F). The drive remains disabled until the temperature at the drive baseplate falls below this threshold.

Over-Voltage Shutdown

1. Check the DC power supply voltage for a value above the drive over-voltage shutdown limit. If the DC bus voltage is above this limit, check the AC power line connected to the DC power supply for proper value.
2. Check the regenerative energy absorbed during deceleration. This is done by monitoring the DC bus voltage with a voltmeter or oscilloscope. If the DC bus voltage increases above the drive over-voltage shutdown limit during deceleration or regeneration, a shunt regulator may be necessary. See "Regeneration and Shunt Regulators" on page 19 for more information.

Under-Voltage Shutdown Verify power supply voltages for minimum conditions per specifications. Also note that the drive will pull the power supply voltage down if the power supply cannot provide the required current for the drive. This could occur when high current is demanded and the power supply is pulled below the minimum operating voltage required by the drive.

Short Circuit Fault

1. Check each motor lead for shorts with respect to motor housing and power ground. If the motor is shorted it will not rotate freely when no power is applied while it is uncoupled from the load.
2. Disconnect the motor leads to see if the drive will enable without the motor connected. If the drive enables with the motor disconnected, there is a possible short circuit in the motor wiring.
3. Measure motor armature resistance between motor leads with the drive disconnected. Verify these measurements against the motor datasheet to determine if there is a short or open circuit in the motor windings.

Invalid Hall Sensor State See the "Commutation Sequence" table in "Hall Sensors" on page 10 for valid commutation states. If the drive is disabled check the following:

1. Make sure that the Hall Sensor Commutation Phasing switch is in the correct setting per motor data sheets. When driving a single phase (brushed type) motor with a three phase (brushless) drive use the 60-degree phase setting (see "Brushed Motor Setup" on page 44 for more information on this particular configuration).
2. Check the voltage levels for all the Hall Sensor inputs. Turn the motor by hand while measuring the Hall Sensor inputs to verify that all three Hall Sensors are changing. The voltage should read approximately +5V for a "high (1)" Hall state, and approximately 0V for a "low (0)" Hall state.
3. Make sure all Hall Sensor lines are connected properly.

Inhibit Input Check inhibit input for correct polarity (that is, pull-to-ground to inhibit or pull-to-ground to enable). Inhibit configuration depends either on the DIP switch settings or a 0 ohm SMT resistor marked on the board. Also, keep in mind that noise on the inhibit line could be a cause for a false inhibit signal being given to the drive.

Power-On Reset All drives have a power-on reset function to ensure that all circuitry on the board is functional prior to enabling the drive. The board will only be disabled momentarily, and will quickly enable upon power up.

C.1.1 Overload

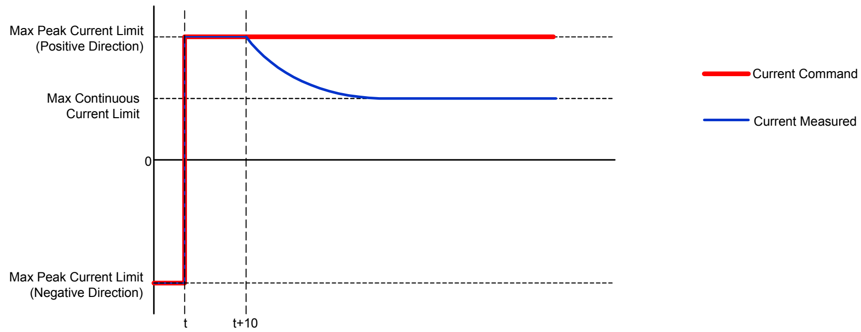
Verify that the minimum inductance requirement is met. If the inductance is too low it could appear like a short circuit to the drive and thus it might cause the short circuit fault to trip. Excessive heating of the drive and motor is also characteristic of the minimum inductance requirement not being met. See drive datasheet for minimum inductance requirements.

C.1.2 Current Limiting

M/V servo drives incorporate a "fold-back" circuit for protection against over-current. This "fold-back" circuit uses an approximate "I^2t" algorithm to protect the drive.

- Maximum peak current output level can be sustained for about 10 seconds.
- To actually achieve maximum peak current output for 10 seconds requires the current command to fully swing from peak in one direction to the other.

FIGURE C.1 **Maximum Peak Current Foldback**

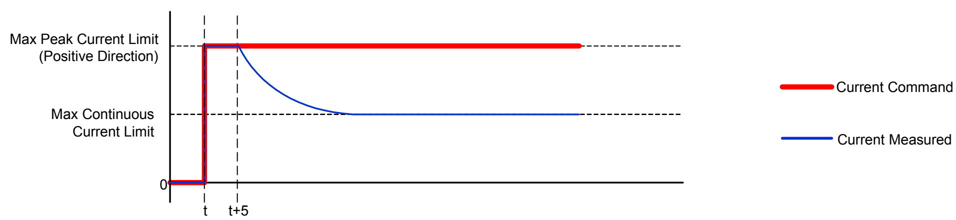


Caution

Sustained maximum current demand, when switching between positive and negative maximum current without allowing sufficient time for fold-back, will result in drive damage. Drive RMS current should be below the continuous current setting!

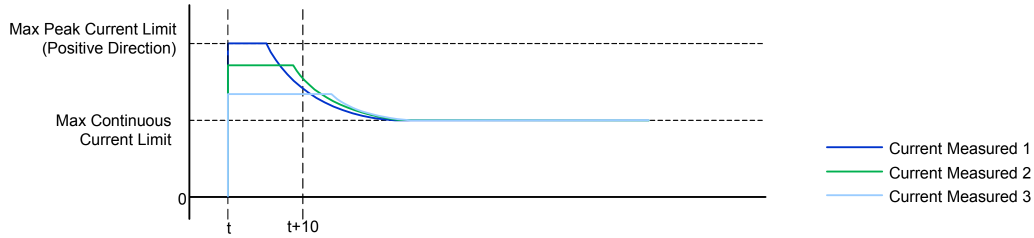
- For most applications, it's a rare occurrence to fully swing from peak in one direction to the other. It is more likely the drive will be commanded from zero to max peak current. Under this condition, the drive will sustain the maximum peak current for about five seconds for AB drives or 10 seconds for AVB drives.

FIGURE C.2 **Peak Current Foldback**



- Commanding maximum peak current output starting from above zero command will also yield reduced peak current output time.
- When commanding output current less than the max peak limit, but more than the max continuous limit, the current output can be sustained for a longer time period than a maximum peak command before folding back.

FIGURE C.3 Above Continuous Current Foldback



- The closer the commanded current is to the peak current limit, the shorter the peak output time will be.
- Any command at or below the maximum continuous current limit can be achieved for as long as there are no fault conditions present.
- When the drive is configured for any of the velocity modes, the user is no longer in direct control of the current output. The current commands will be determined by the velocity loop. Though internally the current loop still functions like it is described above, it will do only what is necessary to meet the velocity demand. The current output will be heavily dependent on:
  - How tight the velocity loop is tuned
  - The load characteristics
  - The speed the motor is already turning
  - Magnitude and slope of velocity step

C.1.3 Motor Problems

A motor run-away condition is when the motor spins rapidly with no control from the command input. The most likely cause of this error comes from having the feedback element connected for positive feedback. This can be solved by changing the order that the feedback element lines are connected to the drive, or changing the feedback polarity switch on the DIP switch bank to the opposite setting.

Another common motor issue for brushless motors with Hall Sensor commutation is when the motor spins faster in one direction than in the other for the same velocity command in the opposite direction. This is typically caused by improper commutation, usually because the motor power wires are connected in the wrong order with respect to the Hall Sensor wiring. Try all six combinations of connecting the motor power wires to the drive to find the correct commutation order. The proper combination of motor wires will yield smooth motion and identical speeds in both directions. Improper combinations will cause jerky motion, slow movement in one direction, and/or audible noise. As a final verification that the commutation is correct, use the Velocity Monitor Output pin to measure motor speed in both directions . This can also be caused by invalid Hall phasing. Check to see if the drive is set for 120- or 60-degree phasing, and verify that the drive DIP switch setting corresponds to the Hall phasing used on the motor. See “Hall Sensors” on page 10 for more information.

C.1.4 Causes of Erratic Operation

- Improper grounding (i.e. drive signal ground is not connected to source signal ground).
- Noisy command signal. Check for system ground loops.

- Mechanical backlash, dead-band, slippage, etc.
- Noisy inhibit input line.
- Excessive voltage spikes on bus.

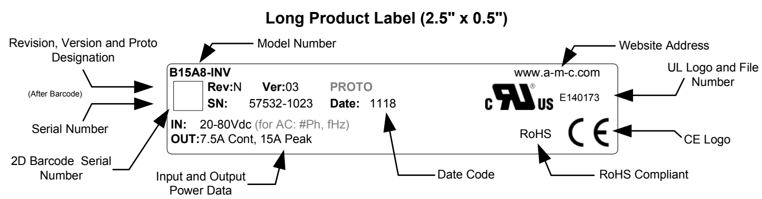
C.2 Technical Support

For help from the manufacturer regarding drive set-up or operating problems, please gather the following information.

C.2.1 Product Label Description

The following is a typical example of a product label as it is found on the drive:

FIGURE C.4 Product Label



1. Model Number: This is the main product identifier. The model number can have a suffix designating a change from the base model.
2. Revision Letter: Product revision level letter ('A' is the earliest release from any model).
3. Version: The version number is used to track minor product upgrades with the same model number and revision letter ('01' is the earliest release of any revision).
4. Proto Designation: When included, indicates that the model is a prototype unit and model number will also begin with an 'X' designator.
5. Serial Number: The serial number consists of a 5-digit lot number followed by a 4-digit sequence number. Each product is assigned a unique serial number to track product life cycle history.
6. Date Code: The date code is a 4-digit number signifying the year and week of manufacture. The first two digits designate the year and the second two digits designate the week (e.g. the drive label shown would have been built in the year 2011 during the 18th week).
7. Input and Output Power Data: Includes basic power parameters of the product.
8. General Information: Displays applicable agency approvals, UL file reference number, and compliance approvals. More complete product information is availabe by following the listed website.

C.2.2 Drive System and Application Information

- DC bus voltage and range
- Motor type (brushed, brushless, AC induction)
- Motor characteristics (inductance, torque constant, winding resistance, etc.)
- Position of all DIP switches

- Length and make-up of all wiring and cables
- If brushless, include Hall sensor information
- Type of controller
- Full description of feedback devices
- Description of problem: instability, run-away, noise, over/under shoot, etc.
- Complete part number and serial number of the product. Original purchase order is helpful, but not necessary

C.3 Warranty Returns and Factory Help

Seller warrants that all items will be delivered free from defects in material and workmanship and in conformance with contractual requirements. The Seller makes no other warranties, express or implied and specifically NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. The Seller's exclusive liability for breach of warranty shall be limited to repairing or replacing at the Seller's option items returned to Seller's plant at Buyer's expense within one year of the date of delivery. The Seller's liability on any claim of any kind, including negligence, for loss or damage arising out of, connected with or resulting from this order, or from the performance or breach thereof or from the manufacture, sale, delivery, resale, repair or use of any item or services covered by or furnished under this order shall in no case exceed the price allocable to the item or service or part thereof which gives rise to the claim and in the event Seller fails to manufacture or deliver items other than standard products that appear in Seller's catalog. Seller's exclusive liability and Buyer's exclusive remedy shall be release of the Buyer from the obligation to pay the purchase price. IN NO EVENT SHALL THE SELLER BE LIABLE FOR SPECIAL OR CONSEQUENTIAL DAMAGES. Buyer will take all appropriate measures to advise users and operators of the products delivered hereunder of all potential dangers to persons or property, which may be occasioned by such use. Buyer will indemnify and hold Seller harmless from all claims of any kind for injuries to persons and property arising from use of the products delivered hereunder. Buyer will, at its sole cost, carry liability insurance adequate to protect Buyer and Seller against such claims.

All returns (warranty or non-warranty) require that you first obtain a Return Material Authorization (RMA) number from the factory. Request an RMA number by:

web	www.a-m-c.com/download/form/form_rma.html
telephone	(805) 389-1935
fax	(805) 389-1165

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M/V Product Family

Hardware Installation Manual

MNALMVIN-02

ADVANCED MOTION CONTROLS

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