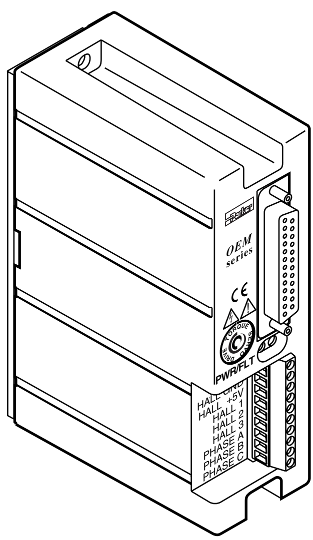
Compumotor

OEM770T OEM770SD

Servo Drive User Guide



Compumotor Division
Parker Hannifin Corporation
p/n 88-018467-01 A

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IMPORTANT

User Information

⚠ WARNING ⚠

OEM Series products are used to control electrical and mechanical components of motion control systems. You should test your motion system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

Since Parker Hannifin constantly strives to improve all of its products, we reserve the right to change this user guide and software and hardware mentioned therein at any time without notice.

Technical Assistance ⇨ *Contact your local automation technology center (ATC) or distributor,* ***or ...***

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Product Type:
OEM770T Torque Servo Drive
OEM770SD Step & Direction Servo Drive

The above products are in compliance with the requirements of directives

- **72/23/EEC Low Voltage Directive**
- **93/68/EEC CE Marking Directive**

The OEM770, when installed according to the procedures in the main body of this user guide, may not necessarily comply with the Low Voltage Directive (LVD) of the European Community. To install the OEM770 so that it complies with LVD, you must follow the additional procedures described in *Appendix A, LVD Installation Instructions*. If you do not follow these instructions, the LVD protection of the product may be impaired.

The OEM770 Series of drives are sold as complex components to professional assemblers. As components, they are not required to be compliant with Electromagnetic Compatibility Directive 89/336/EEC. However, information is offered in Compumotor's *EMC Installation Guide* on how to install the OEM770 in a manner most likely to minimize the effects of drive emissions and to maximize the immunity of drives from externally generated interference.

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CONTENTS

P R E F A C E

ABOUT THIS USER GUIDE

You may not need to read this user guide from cover to cover! You can find essential information in the first three chapters—a product description in Chapter 1, installation instructions in Chapter 2, and specifications for the drive and motors in Chapter 3. This may be all you need to use the OEM770.

Later chapters contain additional information about selected topics. Read them if you need a deeper understanding about these topics.

Special internal circuits, including an extended discussion of the current foldback circuit and the response circuit, are covered in Chapter 4. This chapter may interest you if you want to achieve optimum performance from the drive by adjusting the selectable resistors.

Hall effect sensors, and the way they affect commutation in brushless servo motors, are described in Chapter 5. If you use motors from manufacturers other than Compumotor, you may need this information to determine how to connect your motor to the drive.

Power supply selection is covered in Chapter 6. Read this chapter for information about calculating the power your system requires, how regeneration affects power supplies, and how you can specify a power supply for your system.

Troubleshooting procedures are covered in Chapter 7.

NAMES IN THIS USER GUIDE

This user guide describes two products:

- OEM770T Torque Servo Drive
- OEM770SD Step & Direction Servo Drive

In this user guide, when we use the name OEM770, it will apply to both products. Because most features are identical for the two products, this will usually be the case.

If we need to point out differences between the products, for features that are not identical, we will specifically call the product by its full name—OEM770T or OEM770SD.

WARNINGS AND CAUTIONS

Warning and caution notes alert you to problems that may occur if you do not follow the instructions correctly. Situations that may cause bodily injury are presented as warnings. Situations that may cause system damage are presented as cautions.

A typical warning note is shown below.

WARNING

Do not touch the motor immediately after it has been in use for an extended period of time. The motor may be hot.

A typical caution note is shown below.

CAUTION

Do not turn on power unless the motor's Hall effect sensors, Hall +5, and Hall GND are connected to the drive. The motor may be destroyed by overheating if these connections are not made.

CHAPTER 1

Introduction

OEM770T DESCRIPTION

The OEM770T is a torque servo drive designed to operate standard 3 phase brushless DC servo motors equipped with Hall effect sensors, or equivalent feedback signals. It can also operate brushed DC servo motors. It is a high-performance module around which the Original Equipment Manufacturer (OEM) can design a motion control system. The drive offers a basic set of features designed to meet the needs of most customers. It is compatible with standard industry servo controllers, and is intended to be used in positioning applications. It uses three-state current control for efficient drive performance and cooler motor operation.

The OEM770T is small and convenient to use. It installs with only two screws (the screws also provide grounding and captivate the cover). Its right angle screw terminal allows side-by-side mounting, and its small footprint maximizes cabinet space. The snap-on molded cover is removable for drive configuration, and helps provide a barrier against environmental contamination. The drive is the same size as a 3U Eurorack card. Its standard 25 pin D-connector is compatible with universally available connectors.

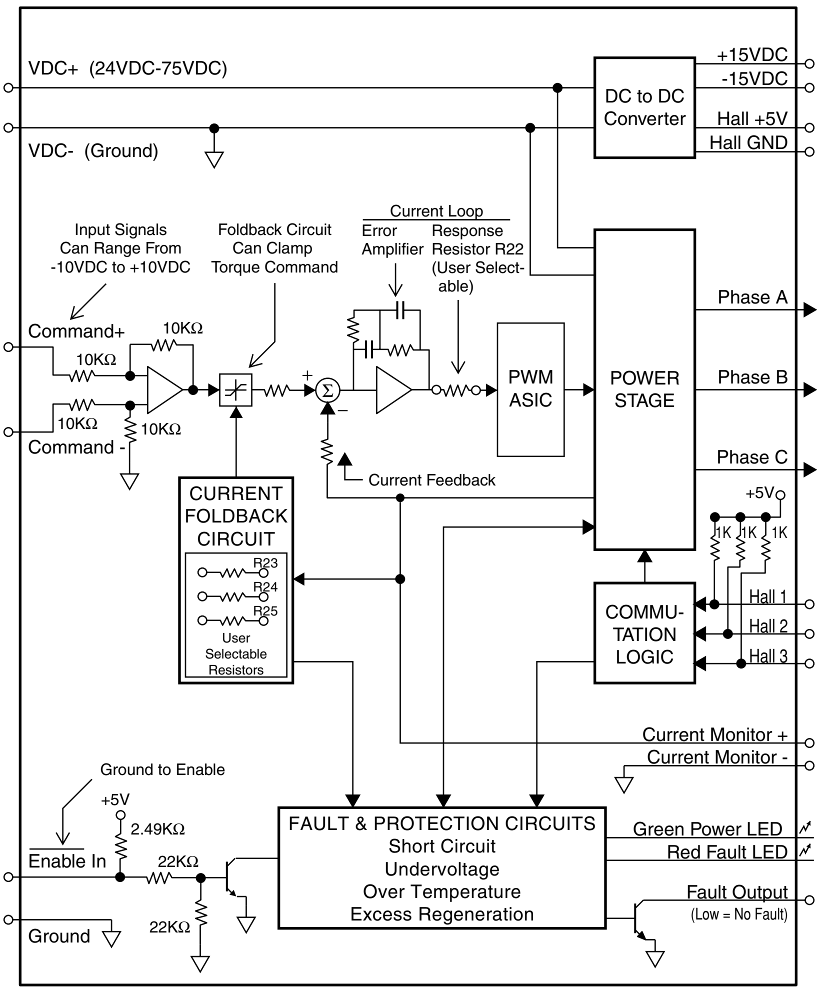
The drive is designed for manufacturability and reliability. It uses surface mount components and a custom designed ASIC to conserve space, reduce cost, and improve reliability. More than 90% of the components are auto inserted, which reduces assembly time and cost, and further improves reliability.

OEM770T OPERATION & BLOCK DIAGRAM

The OEM770T Torque Drive requires a single external power supply. The drive accepts 24VDC to 75VDC for its power input. Its internal DC-to-DC converter produces +5V to power Hall effect sensors, ±15V to power isolated outputs, and all internal voltages used for the drive's circuits.

The drive operates in *torque mode*, which means it provides a commanded amount of current to a motor. This current causes torque in the motor.

The drive's block diagram is shown in the next drawing.



Block Diagram — OEM770T Torque Servo Drive

Input to the drive is a voltage signal called *command input*. It can range from -10VDC to +10VDC. Output current is scaled so that each volt of command input corresponds to 1.2A of output current. For example, a command input of 5V results in a 6A output current. The maximum command input of 10V results in the full 12A output current.

The command input terminals can accommodate single ended, differential, or isolated controller wiring systems. When the command input signal enters the drive, it is amplified, sent through a foldback circuit (which may or may not be active) and an inverter, and summed with a current feedback signal that is proportional to the actual output current.

An error signal—the difference between commanded and actual output current—goes through an error amplifier. The amplifier's output controls a pulse width modulation (PWM) circuit. If actual current is too low, the PWM circuit will send longer pulses to the power stage. These pulses keep the stage turned on longer, which results in more output current. If actual current is too high, the PWM circuit sends shorter pulses, resulting in less current.

A *response resistor* affects the signal level that goes into the PWM circuit. The user can choose a value for this resistor that produces the best current loop gain and system dynamics for a particular motor.

The power stage has three outputs—each connects to a particular motor coil. The drive gets inputs from the motor's Hall effect sensors, and determines which of six possible positions the rotor is in. It then uses a six-state commutation technique to send current into one coil and out of another (the third coil receives no current). The current creates a torque on the rotor, and the rotor turns to the next position. The drive reads the new position from the Hall sensors, and switches current to a different combination of coils. The rotor turns further, and the process repeats. (The drive can also be configured to commutate brushed servo motors.)

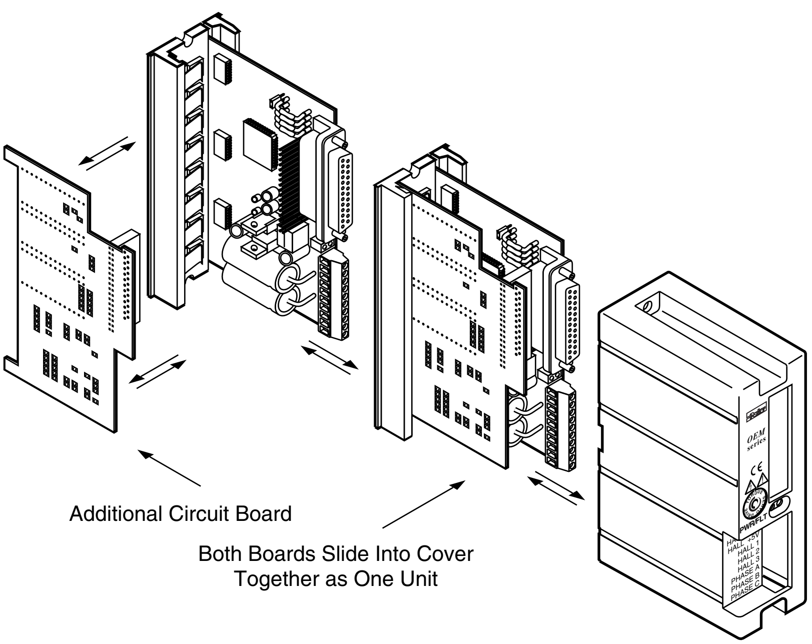
The drive has several fault and protection circuits. These monitor temperature, regeneration, undervoltage, and short circuits. They can shut down the drive if limits are exceeded. LEDs indicate power and fault status.

A foldback circuit monitors motor current, and protects the motor from overheating due to prolonged high currents. The user can install resistors to set levels for peak current, foldback current, and time constant. When the circuit invokes foldback, it clamps the command input signal at a voltage that reduces motor current to the preset level. After a period of time, the circuit may release its clamp on the command input signal, and normal operations can continue.

The drive has several other inputs and outputs. An enable input must be grounded to enable the drive. A fault output is held low if there are no faults. A current monitor output provides a voltage scaled to represent the actual output current. It can range from -10V to +10V, with one volt corresponding to 1.2 amps of output current.

RELATED PRODUCTS

The OEM770T is the “building block” in a family of servo drives. It has an internal slot where an additional circuit board can be inserted to make a different product.

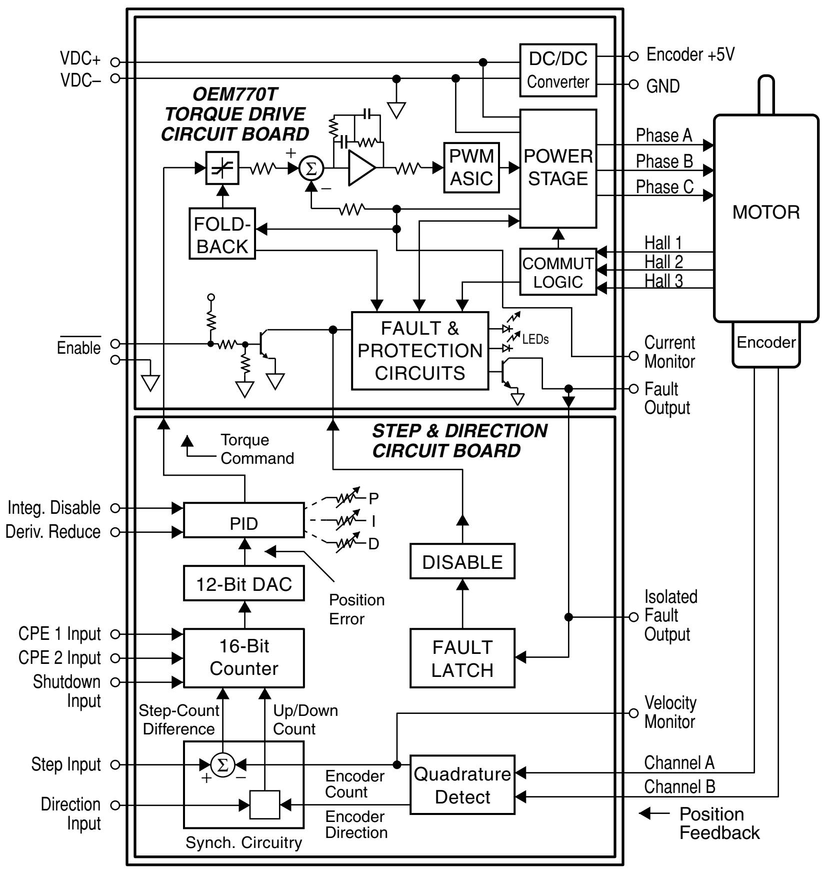


Additional Circuit Board Can Mount Internally

The additional circuit board is inserted at the factory, at the time of manufacture. Externally, the new product looks just like the OEM770T, except that the label is a different color.

OEM770SD Step & Direction Servo Drive

The OEM770SD Step & Direction Servo Drive consists of the OEM770T with a position controller circuit board added.



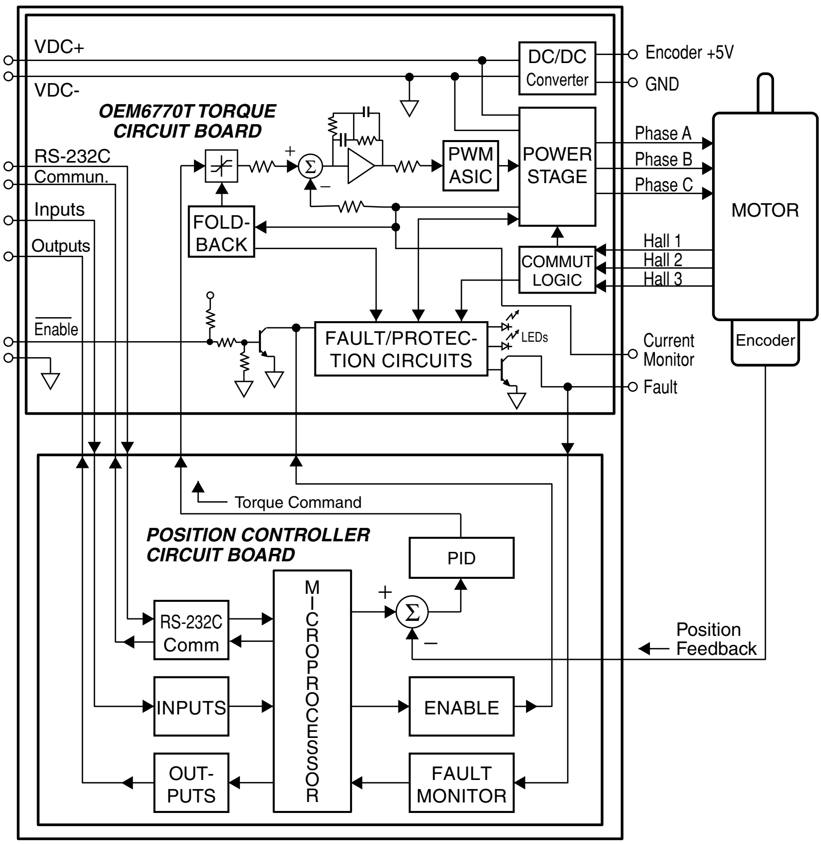
Block Diagram – OEM770SD Step & Direction Servo Drive

The controller accepts step and direction position commands from an indexer. It uses encoder signals for feedback. Its internal PID position control loop generates an analog command output voltage that is sent to the torque board.

Indexers intended for use with step motor systems can operate the OEM770SD. It emulates a stepper drive, but can achieve servo system levels of high speed performance and thermal efficiency.

OEM770X Position Controller/Drive

The OEM770X Controller/Drive consists of the OEM770T with a position controller circuit board.



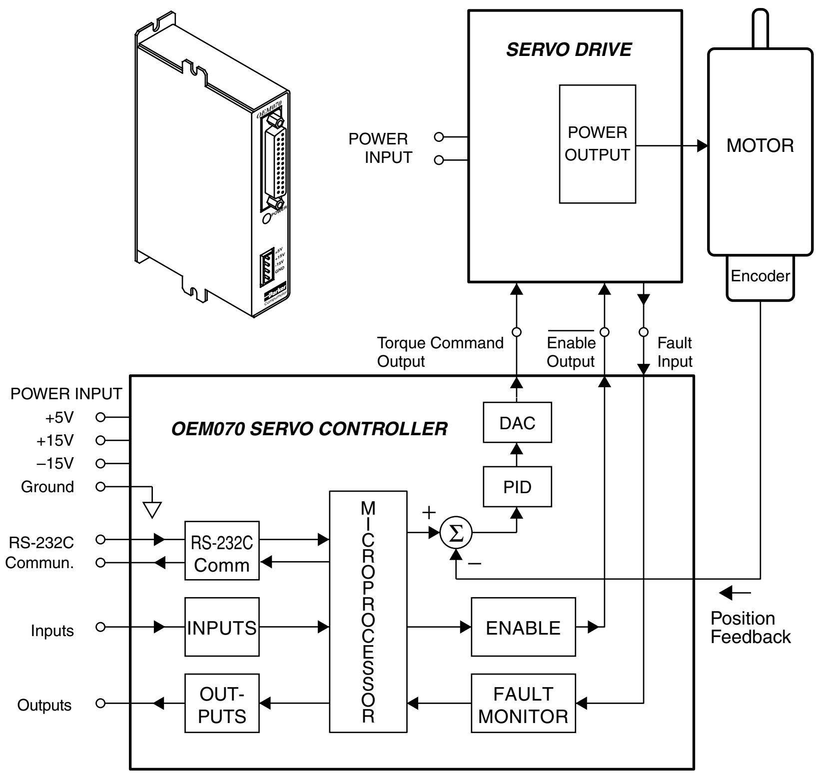
OEM770X Position Controller/Drive — Block Diagram

Inputs, outputs, and RS-232C communications are internally routed to the position controller board, where they interface with a microprocessor. The microprocessor generates a position command. It can also enable or disable the torque board.

The position controller board receives feedback about actual position from an encoder, and compares commanded position with actual position. It generates a torque command to correct any position errors. The torque command (which is an analog voltage) then goes to the torque board, passes through the foldback circuit, and proceeds through the remainder of the torque board's circuits.

OEM070 SERVO CONTROLLER

The OEM070 Servo Controller is a compact, stand-alone controller designed to operate with analog servo drives.



OEM070 Servo Controller – Block Diagram

The OEM070 contains the same position controller board used in the OEM770X . The board is packaged by itself in a minimum depth, small footprint housing. It controls motor torque or velocity with a ±10V command output signal. Through its I/O and RS-232C ports, the OEM070 can interface with external devices such as incremental encoders, switches, computers, and programmable control units.

SM AND NEOMETRIC SERIES SERVO MOTORS

Compumotor offers SM Series and NeoMetric Series servo motors designed to operate with OEM Series servo drives. Each motor is equipped with Hall effect outputs and an encoder.

CHAPTER 2

Installation

Complete the following installation steps before you use the OEM770 drive.

INSTALLATION STEPS

1. Verify shipment is correct.
2. Install selectable resistors.
3. Mount the drive.
4. Mount the motor.
5. Connect the motor to the drive.
6. Connect inputs, outputs, and controller.
7. Connect a power supply to the drive.
8. Tune the drive (OEM770SD only).

The sections in this chapter give basic instructions about how to complete each of these steps.

OEM770 SHIP KIT

Inspect the OEM770 upon receipt for obvious damage to its shipping container. Report any damage to the shipping company. Parker Compumotor cannot be held responsible for damage incurred in shipment. You should receive one or more drives, depending upon what you ordered. Compare your order with the units shipped.

Component	Part Number
OEM770 Drive	OEM770T or OEM770SD
Resistor Kit	73-018496-01
Accessories	
OEM770 User Guide	88-018467-01
Heatsink	OEM-HS1

User guides are not sent with each product. They are available upon request. Please order user guides as needed.

The following SM and NeoMetric Series servo motors are designed to be used with the OEM770. Compare your order with the motors shipped.

Motor Size	Part Number
Size 16	SM160A, SM160B, SM161A, SM161B SM162A, SM162B
Size 23	SM230A, SM230B, SM231A, SM231B, SM232A, SM232B, SM233A, SM233B
Size 34	NO341D, NO341F, NO342E, NO342F JO341D, JO341F, JO342E, JO342F
Size 70mm	NO701D, NO701F, NO702E, NO702F JO701D, JO701F, JO702E, JO702F

INSTALLING SELECTABLE RESISTORS and JUMPER

You must install four resistors into sockets on the OEM770's circuit board. Three of these are *foldback resistors*; they determine the parameters for the current foldback circuit, which can protect your motor from overheating due to prolonged high currents. The fourth resistor is a *response resistor*—it affects the gain and frequency response of the current loop. You can also install jumper JU1, located near the resistors, to adjust drive performance for your particular motor.

The OEM770 ships with resistors and jumper installed. These resistors are not appropriate for most applications. You *must* select other resistors and install them in the drive.

A resistor kit for use with Compumotor SM and NeoMetric Series motors is included with the drive. If the resistors are color coded, a key to the code is included in the kit. If the resistors have a numerical code, the first three digits are resistance values; the fourth digit is a multiplier.

Example: $3013 = 301 \times 10^3 = 301K\Omega$

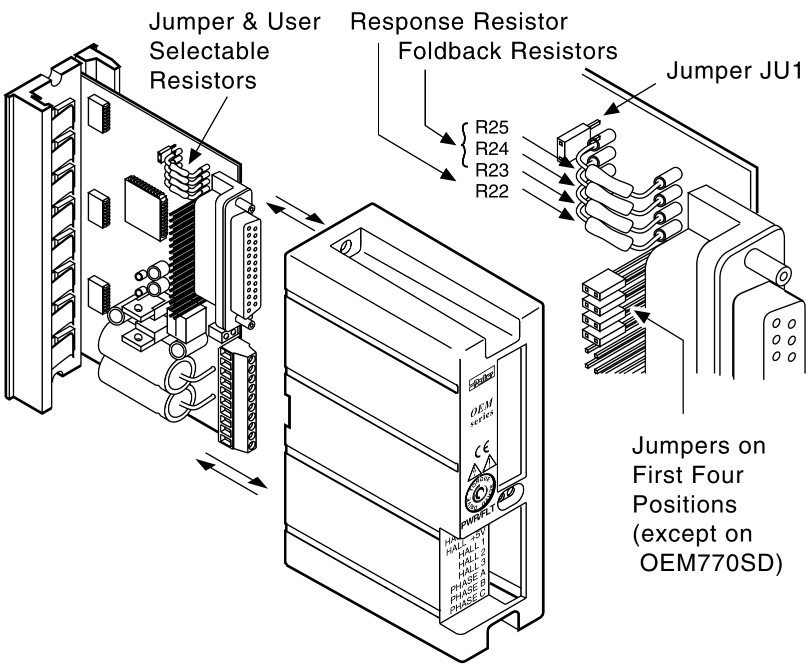
$6492 = 649 \times 10^2 = 64.9\ K\Omega$

Note: zero ohm resistors may be color coded (black band)

To install resistors or the jumper, remove the drive's molded plastic cover. Apply pressure to the D-connector while you hold the cover's sides. The circuit board will slide out. The resistors and jumper are located at the corner of the board, near the 25 pin D-connector, as shown in the next drawing.

WARNING

Remove power from the OEM770 before installing resistors or jumper.



Selectable Resistor and Jumper Locations

Remove any resistors that are in the sockets, and install those that you have selected. The next table shows recommended resistors for Compumotor SM and NeoMetric Series motors. For full details on further customizing the response and foldback circuits, or choosing resistors for non-Compumotor motors, see *Chapter 4 Special Internal Circuits*.

The next table also shows jumper position—installed or removed—for Compumotor motors.

NOTE: A 34 pin header is located below the selectable resistors. Four jumpers should be installed in the first four positions, as shown in the drawing above. These jumpers must be installed for the OEM770T to work properly as a torque servo drive. Ordinarily, these jumpers are installed at the factory, and are shipped with the drive. (The jumpers are removed at the factory when an OEM770T is converted to an OEM770SD.)

RESISTOR & JUMPER SELECTION FOR COMPUMOTOR MOTORS

Use the table below to select resistors and jumper position for Compumotor motors. (The next section shows default values.)

OEM770 – Resistor and Jumper Settings for Motors at 75VDC*

Motor	R22 ($R_{response}$)	R23 ($T_{c\text{-}therm}$)	R24 ($I_{pk\text{-}tune}$)	R24 ($I_{pk\text{-}final}$)	R25 (I_{fold})	Jumper Installed
SM160A	249 KΩ	5.1 MΩ	348 KΩ (5 A)	150 KΩ (7.5 A)	1.2 MΩ (2.2 A)	no
SM160B	750 KΩ	10 MΩ	64.9 KΩ (10 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM161A	301 KΩ	5.1 MΩ	450 KΩ (4 A)	249 KΩ (6 A)	1.2 MΩ (2.2 A)	no
SM161B	750 KΩ	10 MΩ	124 KΩ (8 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM162A	205 KΩ	5.1 MΩ	450 KΩ (4 A)	249 KΩ (6 A)	1.2 MΩ (2.2 A)	no
SM162B	402 KΩ	10 MΩ	124 KΩ (8 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM230A	402 KΩ	5.1 MΩ	348 KΩ (5 A)	150 KΩ (7.5 A)	1.2 MΩ (2.2 A)	no
SM230B	1 MΩ	10 MΩ	64.9 KΩ (10 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM231A	402 KΩ	5.1 MΩ	450 KΩ (4 A)	249 KΩ (6 A)	1.2 MΩ (2.2 A)	no
SM231B	604 KΩ	10 MΩ	124 KΩ (8 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM232A	205 KΩ	5.1 MΩ	450 KΩ (4 A)	249 KΩ (6 A)	1.2 MΩ (2.2 A)	no
SM232B	500 KΩ	10 MΩ	124 KΩ (8 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
SM233A	30.1 KΩ	5.1 MΩ	450 KΩ (4 A)	249 KΩ (6 A)	1.2 MΩ (2.2 A)	yes
SM233B	700 KΩ	10 MΩ	124 KΩ (8 A)	0 Ω (12 A)	124 KΩ (3.0 A)	no
NO701D/NO341D	205 KΩ	10 MΩ	249 KΩ (6 A)	90.9 KΩ (9 A)	1.2 MΩ (2.2 A)	yes
NO701F/NO341F	750 KΩ	10 MΩ	90.9 KΩ (9 A)	0 Ω (12 A)	124 KΩ (3.0 A)	yes
NO702E/NO342E	750 KΩ	10 MΩ	182 KΩ (7 A)	64.9 KΩ (10 A)	1.2 MΩ (2.2 A)	yes
NO702F/NO342F	604 KΩ	10 MΩ	90.9 KΩ (9 A)	0 Ω (12 A)	124 KΩ (3.0 A)	yes

* For supply voltages less than 75VDC, calculate R22 using the following equation: $R22_{new} = (R22_{old} \bullet V_{bus})/75$, where $R22_{old}$ is the value from the table above (at 75VDC). R23, R24, R25 remain the same as for 75VDC.

R24 – "pk-tune" and "pk-final"

NOTE: Two values are recommended for R24. Use the first value (*pk-tune*) when you begin your tuning procedure. This keeps peak currents low, avoiding the damaging currents instability may cause during tuning. As you refine your tuning settings, replace R24 with the second value (*pk-final*), if you require more torque.

RESISTOR & JUMPER SELECTION FOR NON-COMPUMOTOR MOTORS

The following sections describe how to choose resistor values and jumper position for other motors.

Selecting Foldback Resistors

The OEM770 ships with resistors already installed.

Default Foldback Resistors (as shipped)

Res. #:	Function	Value
R25	Foldback Current	23.7 KΩ (6A)
R24	Peak Current	Ø Ω (12A)
R23	Time Constant	5.1 MΩ

The default values may not be suitable for your application. If your system cannot withstand the peak torque, or if your controller cannot detect a mechanical jam, then choose and install resistor values appropriate for your application.

For details on choosing foldback resistors, and a description of the foldback circuit, see *Chapter 4 Special Internal Circuits*.

Selecting a Response Resistor

The OEM770 ships with a response resistor already installed.

Default Response Resistor (as shipped)

Res. #:	Function	Value
R22	Optimize gain and frequency response	100 KΩ

If your motor is not well matched to the default resistor, your system might not perform as well as you expect. In this case, improve your system's performance by selecting an appropriate response resistor, and installing it in the drive.

For full details about how to choose a value for the response resistor, and about how the circuit works, see *Chapter 4 Special Internal Circuits*.

Selecting Jumper Position for Non-Compumotor Motors

You can adjust the performance of the OEM770X's internal error amplifier by installing or removing jumper JU1. The drive ships with the jumper installed.

For motors with long electrical time constants (L/R), such as Compumotor's NeoMetric motors, install the jumper. Remove the jumper for motors with short time constants, such as Compumotor's SM motors (except SM233A).

Jumper Position Selection Procedure

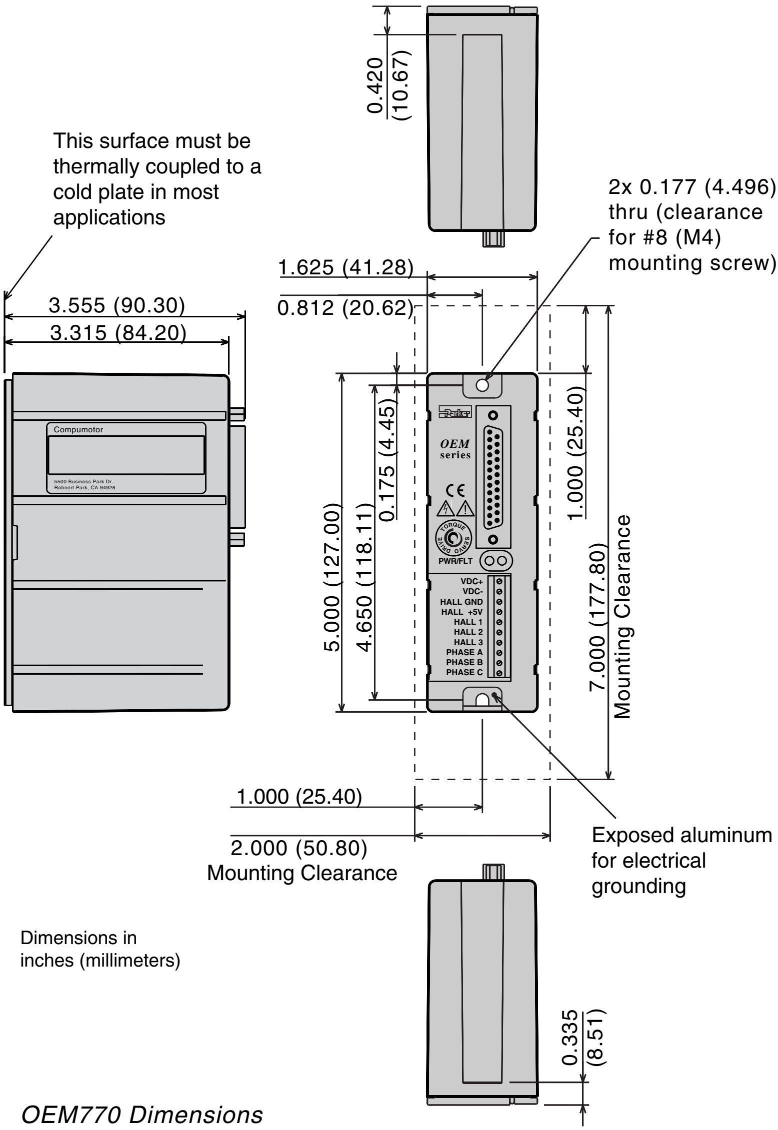
1. **Adjust R22 with Jumper JU1 Installed**
Starting with a high value, adjust R22 for optimum system response. For adjustment instructions, see *Response Circuit* in *Chapter 4 Special Internal Circuits*.

2. **If Unable to Obtain an Optimum Response:**
Chapter 4 Special Internal Circuits describes optimum responses. If you could not obtain an optimum response in *Step 1*–your adjustments produced overdamped or underdamped responses, with no range of optimum responses in between–then:
   - Replace R22 with a high value, to limit oscillations during *Step 3* below.
   - Remove Jumper JU1.

3. **Adjust R22 with Jumper JU1 Removed**
With Jumper JU1 removed, adjust R22 to achieve an optimum system response.

For further help, provide your motor's inductance (*L*) and resistance (*R*) values to Compumotor's Applications Department. We can calculate a recommended jumper position and R22 value, based on your motor's values.

DRIVE MOUNTING



OEM770 Dimensions

DRIVE DIMENSIONS

The OEM770 is designed to minimize panel area, or footprint, in an equipment cabinet. Dimensions are shown in the drawing. You can mount the drive in a "minimum depth" configuration if you use an optional heatsink. (See below.)

Panel Layout

Move profiles and loads affect the amount of heat dissipated by the OEM770. Applications with low average power (less than 3 Amps continuous motor current) and mild ambient temperatures may not require a heatsink.

The OEM770 is designed to operate within the following temperature guidelines:

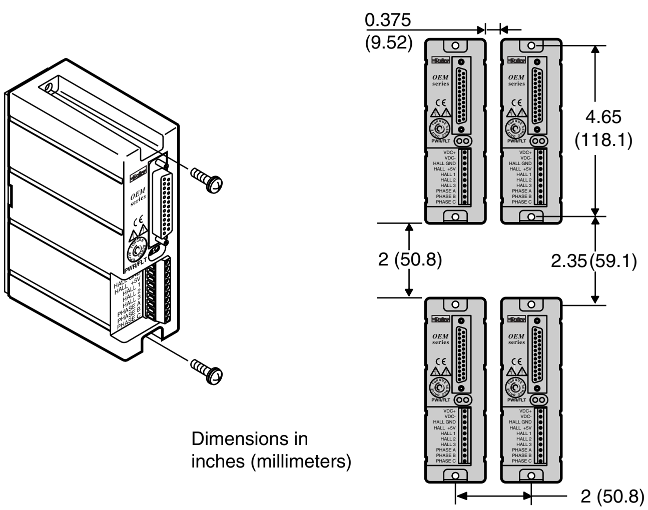
- Maximum Ambient Temperature: 45°C (113°F)
- Maximum Heatsink Temperature 45°C (113°F)

For applications with higher power or elevated ambient temperatures, you may need to mount the drive in a way that removes heat from it. The drive uses a heatplate design as a pathway to dissipate its excess heat; it should be mounted to a heatsink or a suitable heat sinking surface.

The OEM770 is overtemperature protected. (See *Chapter 4 Special Internal Circuits* for more information.)

Mounting Without a Heatsink

The next drawing shows the recommended panel layout for mounting the OEM770 without a heatsink.



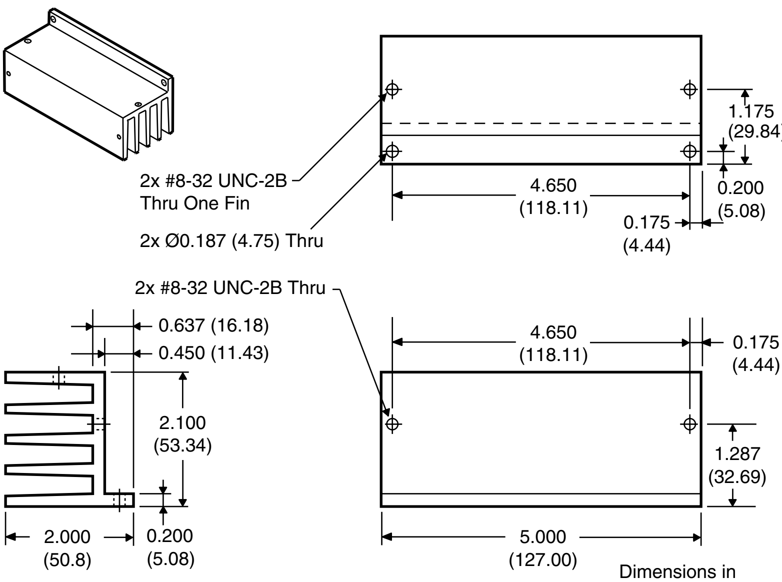
Panel Layout (Without a Heatsink)

Mounting With Compumotor Heatsink OEM-HS1

A heatsink designed to work with the OEM770 can be purchased from Compumotor (Part Number OEM-HS1). This heatsink is sufficient for most applications operating in 45°C (113°F) or lower ambient temperatures.

The drive may be mounted in two different configurations. One configuration uses a minimum amount of mounting area (*minimum area*). The other configuration uses a minimum amount of mounting depth (*minimum depth*).

Heatsink dimensions are shown in the next drawing.



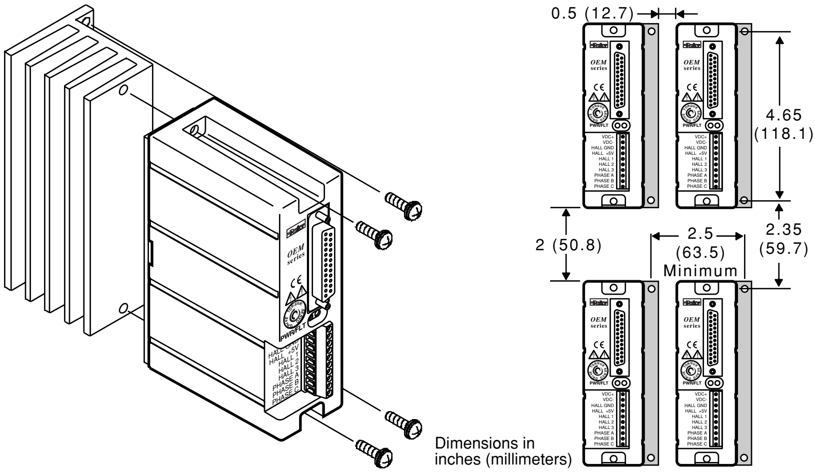
OEM-HS1 Heatsink Dimensions

Two #8-32 screws are needed to mount the OEM770 to the OEM-HS1 heatsink. Use a *star washer* on the bottom screw to ensure proper electrical grounding. Use two #8 screws to mount the OEM-HS1 to the cabinet.

Do not use a star washer between the back of the OEM770 heatplate and the mounting surface. The mounting surface must be flat. Use silicone thermal joint compound or thermal pads to facilitate heat transfer from the drive's heatplate to your mounting surface.

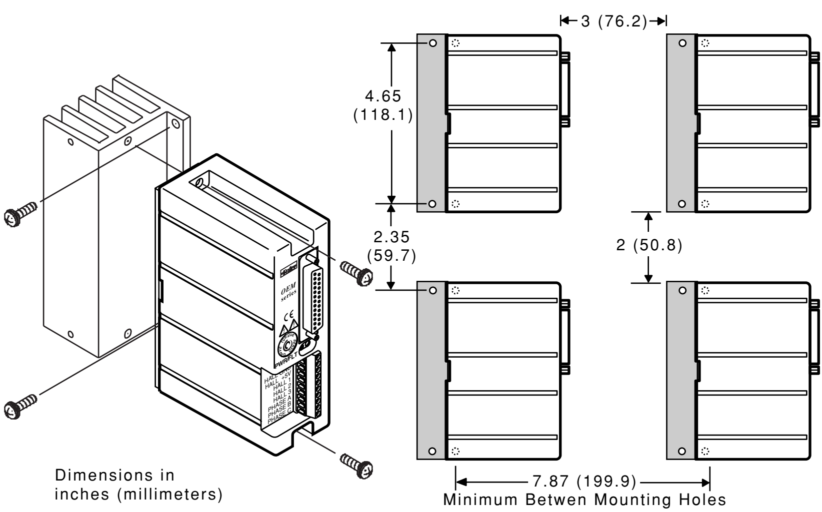
A heatsink with holes tapped for metric screws is available. Its part number is OEM-HS1-M4. Consult your Compumotor sales guide for more information.

The next drawing shows the panel layout for minimum area.



OEM-HS1 Minimum Area Panel Layout

The following drawing shows dimensions for a minimum depth panel layout.



OEM-HS1 Minimum Depth Panel Layout

MOTOR MOUNTING

The following guidelines present important points about motor mounting and its effect on performance.

For mechanical drawings of SM and NeoMetric Series servo motors, see *Chapter 3 Specifications*

WARNING
Improper motor mounting can reduce system performance and jeopardize personal safety.

Servo motors used with the OEM770 can produce large torques and high accelerations. This combination can shear shafts and mounting hardware if the mounting is not adequate. High accelerations can produce shocks and vibrations that require much heavier hardware than would be expected for static loads of the same magnitude.

The motor, under certain move profiles, can produce low-frequency vibrations in the mounting structure. These vibrations can cause metal fatigue in structural members if harmonic resonances are induced by the move profiles you are using. A mechanical engineer should check the machine design to ensure that the mounting structure is adequate.

CAUTION
Consult a Compumotor Applications Engineer (800-358-9070) before you machine the motor shaft. Improper shaft machining can destroy the motor's bearings. Never disassemble the motor.

Servo motors should be mounted by bolting the motor's face flange to a suitable support. Foot mount or cradle configurations are not recommended because the motor's torque is not evenly distributed around the motor case. Any radial load on the motor shaft is multiplied by a much longer lever arm when a foot mount is used rather than a face flange.

MOTOR HEATSINKING

Performance of a servo motor is limited by the amount of current that can flow in the motor's coils without causing the motor to overheat. Most of the heat in a brushless servo motor is dissipated in the stator—the outer shell of the motor. Performance specifications usually state the maximum allowable case temperature. Exceeding this temperature can permanently damage the motor.

If yours is a demanding application, your motor may become quite hot. The primary pathway through which you can remove the heat is through the motor's mounting flange. Therefore, mount the motor with its flange in contact with a suitable heatsink.

Specifications for Compumotor SM and NeoMetric Series servo motors apply when the motor is mounted to a ten inch by ten inch aluminum mounting plate, 1/4 inch thick. To get rated performance in your application, you must mount the motor to a heatsink of at least the same thermal capability. Mounting the motor to a smaller heatsink may result in decreased performance and a shorter service life. Conversely, mounting the motor to a larger heatsink can result in enhanced performance.

ATTACHING THE LOAD

Your mechanical system should be as stiff as possible. Because of the high torques and accelerations of servo systems, the ideal coupling between a motor and load would be completely rigid. Rigid couplings require perfect alignment, however, which can be difficult or impossible to achieve. In real systems, some misalignment is inevitable. Therefore, a certain amount of flexibility may be required in the system. Too much flexibility can cause resonance problems, however.

These conflicting requirements are summarized below.

- Maximum Stiffness (in the mechanical system)
- Flexibility (to accommodate misalignments)
- Minimum Resonance (to avoid oscillations)

The best design solution may be a compromise between these requirements.

MISALIGNMENT & COUPLERS

The type of misalignment in your system will affect your choice of coupler.

Parallel Misalignment
The offset of two mating shaft center lines, although the center lines remain parallel to each other.

Angular Misalignment
When two shaft center lines intersect at an angle other than zero degrees.

End Float
A change in the relative distance between the ends of two shafts.

There are three types of shaft couplings: single-flex, double-flex, and rigid. Like a hinge, a single-flex coupling accepts angular misalignment only. A double-flex coupling accepts both angular and parallel misalignments. Both single-flex and double-flex, depending on their design, may or may not accept endplay. A rigid coupling cannot compensate for any misalignment.

Single-Flex Coupling
When a single-flex coupling is used, one and only one of the shafts must be free to move in the radial direction without constraint. ***Do not use a double-flex coupling in this situation:*** it will allow too much freedom and the shaft will rotate eccentrically, which will cause large vibrations and catastrophic failure. ***Do not use a single-flex coupling with a parallel misalignment:*** this will bend the shafts, causing excessive bearing loads and premature failure.

Double-Flex Coupling
Use a double-flex coupling whenever two shafts are joined that are fixed in the radial and angular direction. (This is the most common situation. It results from a combination of angular and parallel misalignment).

Rigid Coupling
As mentioned above, rigid couplings would be ideal in servo systems, but are not generally recommended because of

system misalignment. They should be used only if the motor or load is on some form of floating mounts that allow for alignment compensation. Rigid couplings can also be used when the load is supported entirely by the motor's bearings. A small mirror connected to a motor shaft is an example of such an application.

RESONANCE ISSUES

A coupler that is too flexible may cause a motor to overshoot its commanded position. When the encoder sends a position feedback signal, the controller will command a correction move in the opposite direction. If the resonant frequency of the system is too low (too flexible), the motor may overshoot again and again. In extreme cases, the system could become an oscillator.

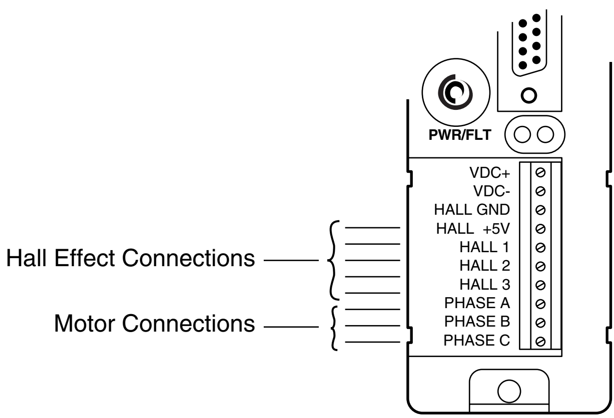
To solve resonance problems, increase the mechanical stiffness of the system to raise the resonant frequency so that it no longer causes a problem.

If you use a servo as a direct replacement for a step motor, you may need to modify your mechanical coupling system to reduce resonance. For example, we recommend using a bellows-style coupler with servo motors, rather than the helical-style coupler that is often used with step motors. Helical couplers are often too flexible, with resonant frequencies that can cause problems. Bellows couplers are stiffer, and perform better in servo systems.

CONNECTING A MOTOR TO THE DRIVE

The OEM770 drive is designed to work with three-phase brushless motors equipped with Hall effect sensors or equivalent feedback signals. The typical motor has a permanent-magnet rotor with four poles (two pole pairs).

Connect your motor's phase wires and Hall effect sensor wires to the 10-pin screw terminal on the OEM770. Each terminal is labeled with the name of the wire you should connect to it.



10-Pin Screw Terminal

14 AWG (2.5 mm^2) is the maximum wire size that can fit in the connector.

CAUTION

Do not turn on power unless the motor's Hall effect sensors, Hall +5, and Hall GND are connected to the drive. The motor may be destroyed by overheating if these connections are not made.

If the Hall effects are not connected, the drive determines that it is configured to run a *brushed* servo motor. With power and a command input applied, the drive will send the commanded DC current through the motor. If the motor is a *brushless* motor, it will not turn. Full current may flow in the motor and cause overheating, or destroy the motor within a short period of time.

Connecting Compumotor SM and NeoMetric Series Motors

To connect a Compumotor SM or NeoMetric Series motor to the OEM770, follow the color code shown below for flying lead or cable versions. (These motors have additional wires not used by the OEM770. See *Chapter 3 Specifications* for colors and functions of the additional wires.)

Function	**Wire Color**
Hall Ground	White/Green
Hall +5V	White/Blue
Hall 1	White/Brown
Hall 2	White/Orange
Hall 3	White/Violet
Phase A	Red/Yellow
Phase B	White/Yellow
Phase C	Black/Yellow

Connect each motor wire to its appropriate screw terminal on the OEM770. Wire sizes used for Compumotor motors are:

Phase:	18 AWG (0.75 mm^2)
Hall/Encoder:	24 AWG (0.25 mm^2)

Connecting Motors from Other Vendors

Before connecting a motor from another vendor, you must determine which motor phase wires correspond to Phase A, Phase B, and Phase C on the OEM770. Similarly, you must determine which Hall effect wires correspond to Hall 1, Hall 2, and Hall 3.

Connect each wire to its appropriate terminal on the OEM770. Ensure that the Hall effect sensors accurately transmit information about rotor position, and that motor current is commutated to the correct motor phases. See *Chapter 5 Hall Effect Sensors* for more information.

If your drive arrived with a response resistor installed, you should consider using a different response resistor. See *Chapter 4 Special Internal Circuits* for details about selecting a response resistor to improve your system's performance.

Connecting a Brushed DC Servo Motor

You can use the OEM770 as a drive for brushed DC servo motors. Follow these steps:

1. Connect HALL 1 and HALL 2 to HALL GND.
2. Make no connections to HALL 3.
3. Connect the drive's Phase A to your motor's positive input.
4. Connect the drive's Phase C to your motor's negative input.

Under these conditions, the drive's internal logic determines that a brushed motor is connected. DC current will flow out of Phase A, through the motor, and back into the drive through Phase C. The amount and polarity of the current will be determined by the command input signal.

Shielded Motor Cables

Prevent electrical noise from interfering with the signals that the Hall effect sensors send to the drive. Position the motor as close to the drive as possible. If you need to connect a long cable between the drive and motor, we recommend you use a shielded cable for the Hall wires (Hall 1, Hall 2, Hall 3, +5V, GND). Run the power wires (phase A, B, and C) separately from the Hall wires.

Motor Grounding

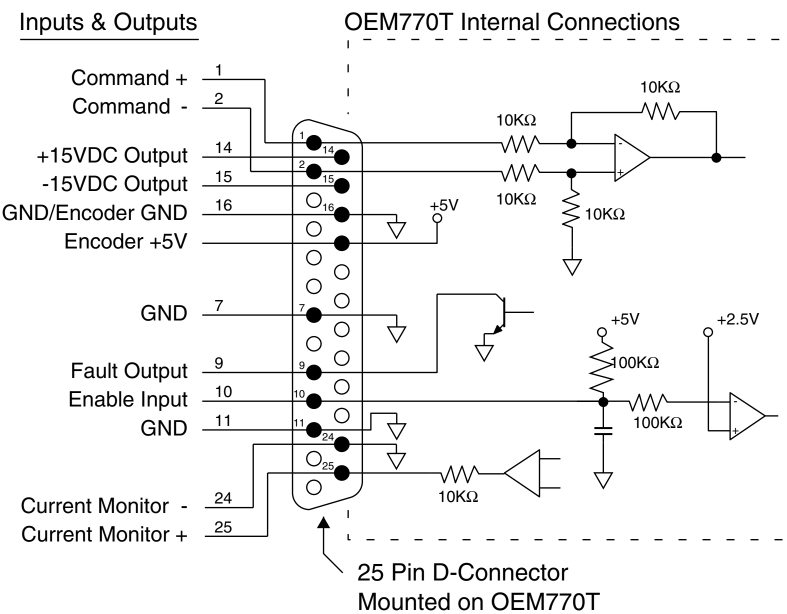
For safety reasons, the motor should be grounded. Often, the motor can be grounded through the equipment to which it is mounted. This requires a good electrical connection between the motor's mounting flange and the equipment, and that the equipment be connected to ground. Check with the National Electrical Code (NEC) and your local electrical code to ensure you use proper grounding methods.

Proper grounding can also reduce electrical noise.

OEM770T INPUTS AND OUTPUTS

Note: This section describes inputs and outputs for the OEM770**T**. See the following section for OEM770**SD** input/ output descriptions.

Connect command and enable signals from your controller to the 25 pin D-connector mounted on the OEM770T. The D-connector also contains a fault output, a current monitor output, and a voltage source for isolated controllers.



OEM770T Inputs & Outputs, and Internal Connections

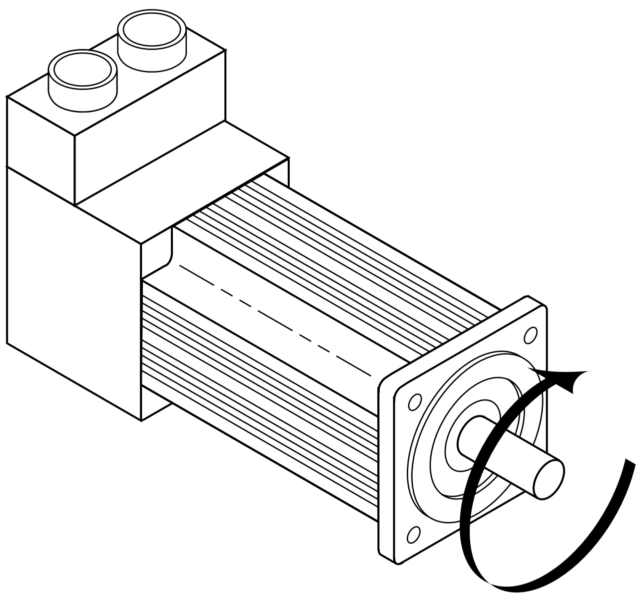
The following sections give details about each input and output. The final section discusses which ground pins to use for each I/O signal.

COMMAND INPUT

The OEM770T monitors an analog voltage signal, called *command input*, at its input terminals (Command + and Command –). It sends an output current to the motor that is proportional to the command input signal. Your controller's command voltage can range from -10VDC to +10VDC.

The OEM770T will produce 1.2 amps for each volt present at its input terminals. A 10 volt command input will result in peak current (12A) flowing to the motor. Smaller voltages result in proportionally less current, with a Ø volt command input resulting in no current to the motor.

Positive voltages cause the OEM770T to produce currents that turn the motor's shaft clockwise. Negative voltages cause currents that turn the shaft counterclockwise. As the next drawing shows, shaft rotation is defined as the direction the shaft rotates, as viewed from the mounting flange end of the motor.



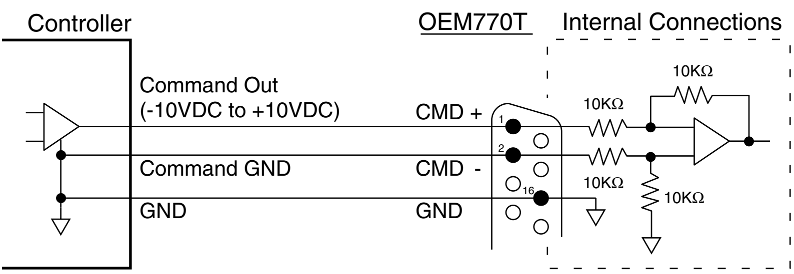
Clockwise Shaft Rotation

Connect your controller's command output signal to the OEM770T's command input terminals, Pin 1 and Pin 2, as described in the following sections.

Controller with Single-Ended Output

If your controller uses a single-ended output—a single terminal that produces a voltage ranging from -10VDC to +10VDC—connect that output to Command Plus (Pin 1) on the OEM770T.

Connect wires from the OEM770T's Command Minus and Ground terminals to the controller's ground terminal. If you connect the wires as shown in the next drawing, you will minimize electrical noise in the circuit.



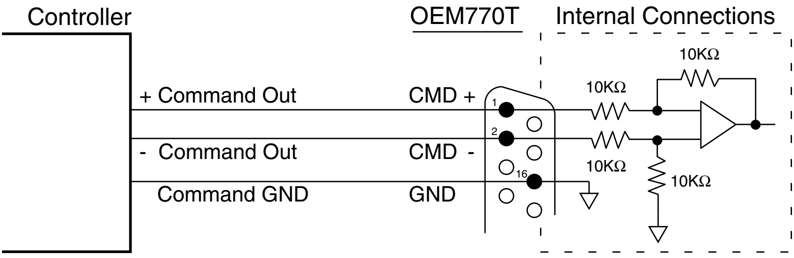
Controller—Single-Ended Output Connections

Bring both wires from the OEM770T to the controller, and connect them both to the controller. This will ensure that the OEM770T's Command Minus input and Ground input are both referenced to the controller's ground terminal, which minimizes electrical noise.

Controller with Differential Output

If your controller has a differential output, then it has two command signals. One is a signal that ranges from -5VDC to +5VDC. The other signal ranges from +5VDC to -5VDC. The two signals mirror each other—their magnitudes are equal, but they have opposite signs.

Your controller should also have a ground terminal to use as a reference for the positive and negative command outputs.



Controller—Differential Output Connections

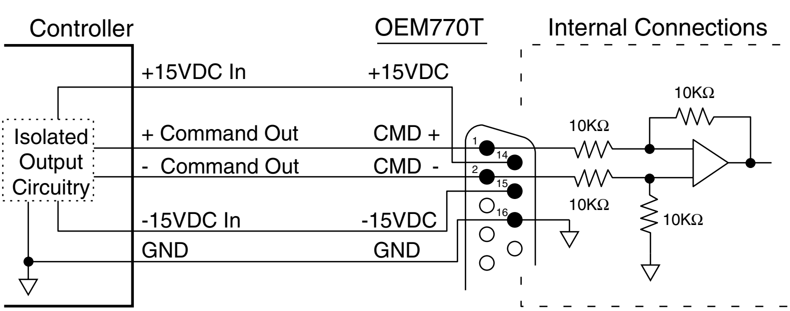
The figure above shows how to connect these three outputs to the OEM770T.

Controller with Isolated Output

Some controllers have isolated command outputs, and may require a voltage source to power their outputs. The OEM770T has three pins available to power isolated outputs on a controller. These pins provide:

- +15VDC on Pin 14
- -15VDC on Pin 15
- GROUND on Pin 16

The next figure shows a typical controller with isolated differential outputs, and illustrates how you can connect it to the OEM770T.



Controller—Isolated Output Connections

If your controller has an isolated single-ended output, connect the ±15VDC outputs as shown in this figure. Connect the command and ground signals as shown earlier in the section on single-ended outputs.

ENABLE INPUT

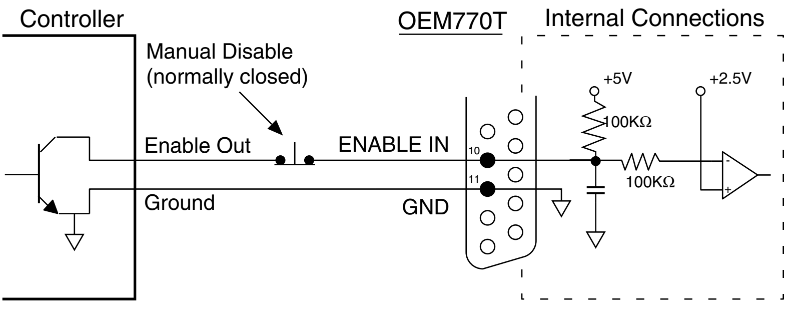
When the enable input of the OEM770T is connected to ground, the OEM770T is enabled, and will function normally. To disable the OEM770T, break the connection to ground, or connect the enable input to +5VDC.

WARNING

Dangerous conditions can result if the enable input is not connected to a suitable controller output. Many controllers produce uncontrolled command output voltages during power up, power down, fault, or reset conditions. Unpredictable and potentially dangerous machine movement may occur if the OEM770T's enable input is not properly connected.

The next figure shows how to connect a controller with an open collector enable output to the OEM770T.

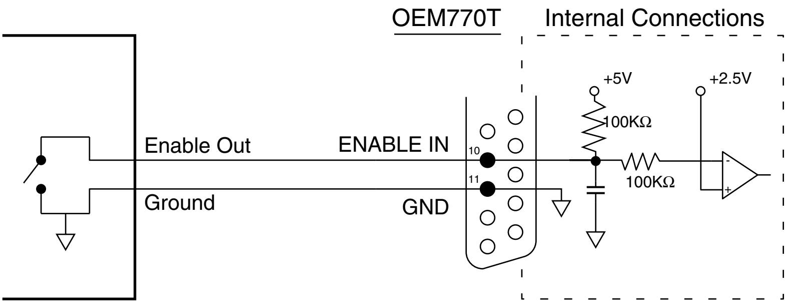
When the transistor in the controller is on, the controller's enable output is effectively tied to ground. This grounds the OEM770T's enable input, and the OEM770T is enabled.



Enable Input Connected to a Controller

This figure also shows an optional switch that can be used as a manual disable switch. The switch is normally closed. When it is opened, the drive will be disabled.

As the next figure shows, the OEM770T could also be enabled simply by closing a switch that connects its enable input to ground.

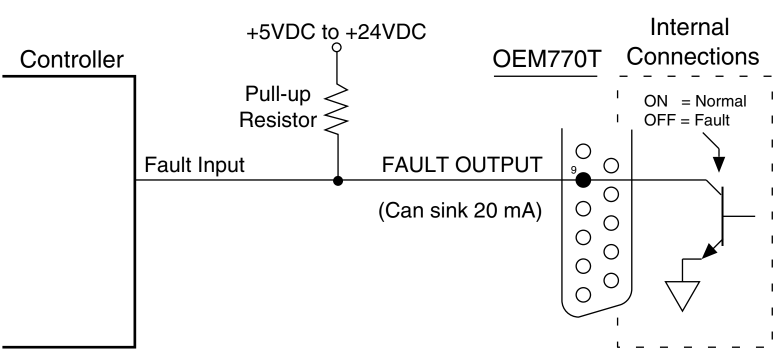


Enable Input Connected to a Switch

Connecting a jumper between the OEM770T's enable input and ground is a quick way to temporarily enable the OEM770T. You may wish to do this, for example, if you need to test the OEM770T when it is not connected to a controller. Enabling the drive in this manner may be dangerous, however—see the warning above.

FAULT OUTPUT

When the OEM770T is operating normally, its fault output is low. Under these conditions, an internal transistor acts as a switch, and grounds the fault output. To signal a fault, the OEM770T will turn off the transistor, and the fault output will float. The next drawing shows this circuit.



Fault Output

Use a pull-up resistor connected to a DC voltage source to ensure the appropriate signal level at your controller's fault input. The OEM770T can sink 20 mA maximum. Use the following formula to calculate your pull-up resistor value.

$R_{pull\text{-}up} = V_S \ / \ 5 \text{ mA}$

where

V_S is the value of your DC voltage source.

You can use the OEM770T's fault output as a signal to your controller that a fault has occurred. The following conditions will cause the fault output to go high.

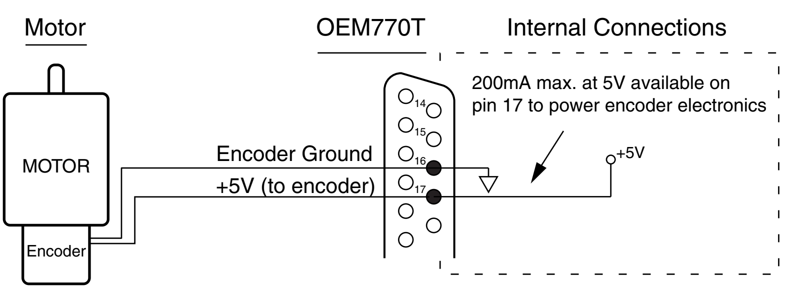
Condition		LED Status: Red	LED Status: Green
Drive Not Enabled		On	On
Over Temperature	(Latched)	On	On
Overvoltage	(Latched)	On	On
Undervoltage		On	On
Short Circuit	(Latched)	On	OFF
Power Supply Fault	(Latched)	On	OFF

The foldback circuit illuminates the red LED, but it does not make the fault output go high.

Latched means you must cycle power before the drive will operate again.

ENCODER +5V OUTPUT

Up to 200 mA at 5 volts is available on pin 17 to power encoder electronics.

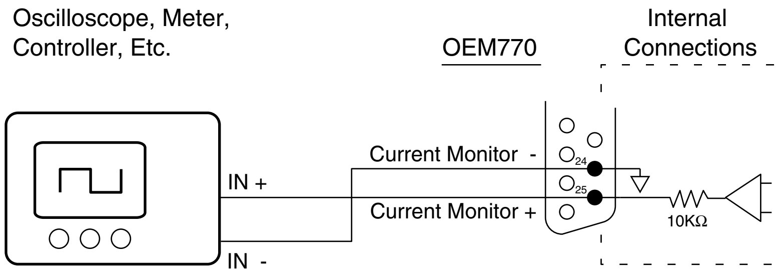


Encoder +5V Output

CURRENT MONITOR

You can use the OEM770T's current monitor output to measure motor current. Connect pin 25 to the positive input of your oscilloscope, meter, etc. Use pin 24 as a signal ground for your oscilloscope or meter.

The OEM770T monitors actual motor current. It puts out a voltage on pin 25 that is proportional to current, with 1 volt out = 1.2 amps of motor current. Positive voltages correspond to clockwise rotation (as viewed from the mounting flange end of the motor). Negative voltages correspond to counterclockwise rotation.



Current Monitor Output Connections

GROUND PINS – ANALOG AND DIGITAL

The OEM770T has four ground pins, located at pins 7, 11, 16, and 24. For noise-sensitive circuits, such as command input and current monitor output, use the "analog" ground pins, 16 and 24. For digital circuits, such as the enable input or the fault output, use the "digital" ground pins, 7 and 11.

Why the distinction? The analog grounds are for use with signals where electrical noise should be kept to a minimum. Digital circuits can be quite noisy. If a clean analog ground is connected to a noisy digital ground, some of the noise from the digital circuit may be coupled into the analog circuit.

The four grounds are eventually connected together inside the OEM770T, but features in the internal circuitry keep noise in the digital circuits from entering sensitive analog circuits. So, for noise sensitive signals, use the analog grounds.

Type of Ground	Pin #	Intended Use
Analog Ground	16	Command Input
	24	Current Monitor
Digital Ground	11	Enable Input
	7	Fault Output, or Misc. Digital Circuitry

OEM770SD INPUTS AND OUTPUTS

Note: This section describes inputs and outputs for the OEM770**SD**. See the previous section for OEM770**T** input/ output descriptions.

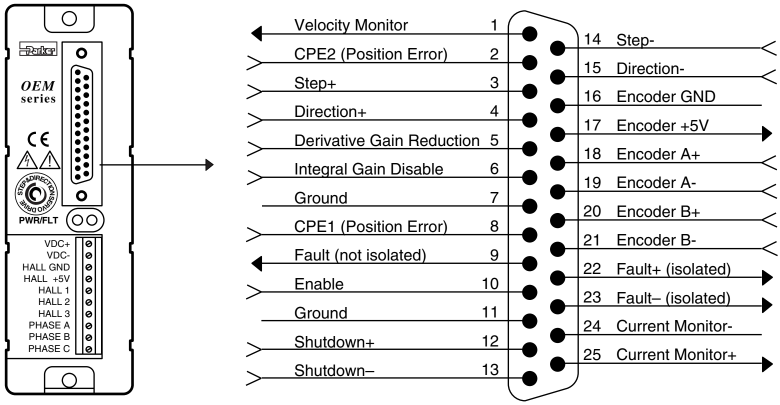
You *must* connect step and direction, enable, and encoder signals to the OEM770SD for it to work. Connections are described below under *Required Inputs*. Use the drive's other inputs and outputs, described under *Optional Inputs and Outputs*, for your application's specific requirements.

CLOCKWISE AND COUNTERCLOCKWISE – DEFINITIONS

Shaft rotation is defined as the direction the shaft rotates, when viewed from the mounting flange end of the motor. (See the drawing several pages earlier, which illustrates the clockwise direction.)

Unlike a step motor system, which operates *open loop*, the OEM770SD is a *closed loop* servo system. It requires feedback from the encoder for stability. For each step pulse received while Direction+ is positive, the drive will make the motor turn in the positive direction a distance of one positive encoder count. For stability, it is important that you connect your system so that a positive step command causes the encoder position to increment, not decrement.

If the system is connected incorrectly, each step pulse will cause the encoder to move in the wrong direction, causing increasing position errors. This could lead to instability and a *motor runaway*, in which the motor spins faster and faster, eventually going out of control.

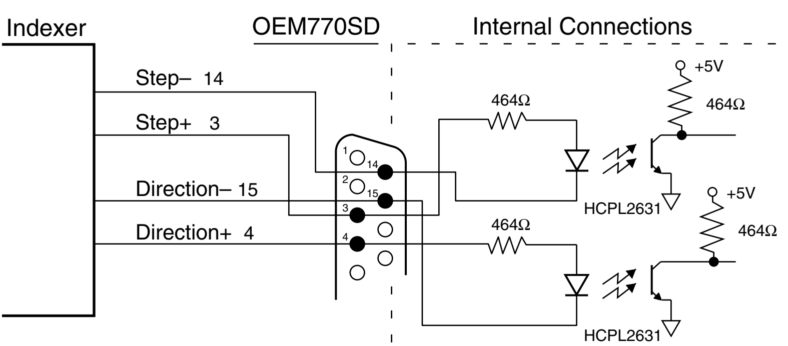


OEM770SD Inputs & Outputs, and Internal Connections

REQUIRED INPUTS

Step & Direction Inputs

Connect your indexer to the step and direction inputs, as shown in the next drawing. These inputs are optically isolated. For best performance, your indexer should drive the inputs differentially. Single-ended operation is also possible, especially at lower step frequencies (where the diode switching speed is not as critical).



Step & Direction Inputs

Specifications for the step and direction inputs are as follows:

Specifications	**Step+/Step–** (pin 3/pin 14) **Dir+/Dir–** (pin 4/pin 15)
Applied Voltage	5 V maximum
Input Current	12 mA maximum 6.3 mA minimum
Step Pulse	500 nsec minimum pulse width
Setup Time	Direction input may change polarity coincident with the last step pulse. The direction input must be stable for 500 nsec before the drive receives the first step pulse.

You can use an input voltage higher than 5V if you install a resistor, in series with the input, to limit current to the range specified above.

Enable Input

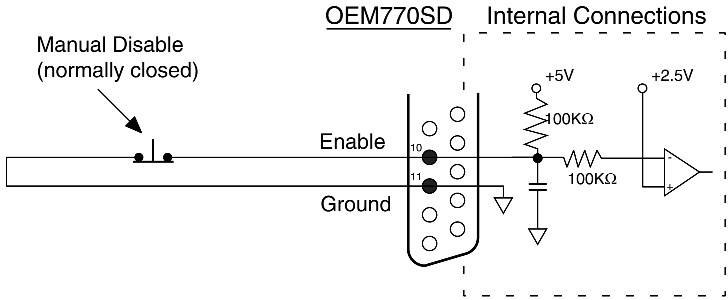
You must connect the enable input to ground *before* you power up the drive, in order for the drive to be enabled. This input is internally pulled up to +5V. If you break the connection to ground while the drive is on, the OEM770SD's fault circuitry will activate with these results:

- The drive will shut down power output to the motor.
- The motor will freewheel (it may not stop immediately).
- The red Fault LED will be illuminated.
- The fault output will become active (no current will flow through it).

To reset the drive, reestablish the connection between enable and ground, and cycle power.

In most applications, you can permanently wire the enable input to ground. If you need to disable the drive during normal operations, you should use the shutdown input—it allows you to re-enable the drive from the indexer without cycling power. The shutdown input is described later in this section.

If you need to disable the drive in an emergency, use the enable input—*not* the shutdown input. Connect a *manual disable* switch to the enable input, as the next drawing shows. The switch is normally closed. When it is opened, the drive will be disabled. The load can freewheel—therefore, you should use a brake to stop the motor immediately in applications where a freewheeling motor can cause injury or damage.



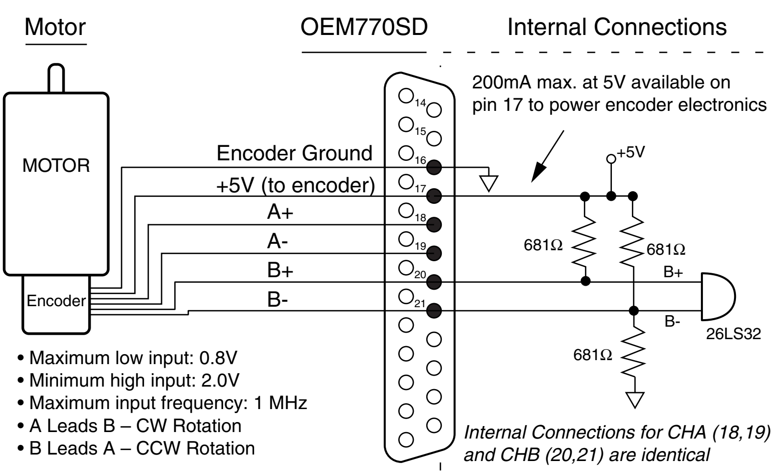
Enable Input Connected to a Switch

WARNING

Do not use the ENABLE INPUT by itself as an emergency stop. The motor can freewheel when the drive is disabled and may not stop immediately. Use a mechanical brake or some other method to stop the motor quickly.

Encoder Input Connections

You must connect an encoder to the OEM770SD's encoder inputs. These are differential inputs; therefore, your encoder should have differential outputs. Single-ended operation is possible, but is more susceptible to electrical noise and is not recommended. If you use an OEM Series motor, see *Specifications: Encoder* in *Chapter 3 Specifications* for the pinout of the encoder connector. Up to 200 mA at 5 volts is available on pin 17 to power encoder electronics.



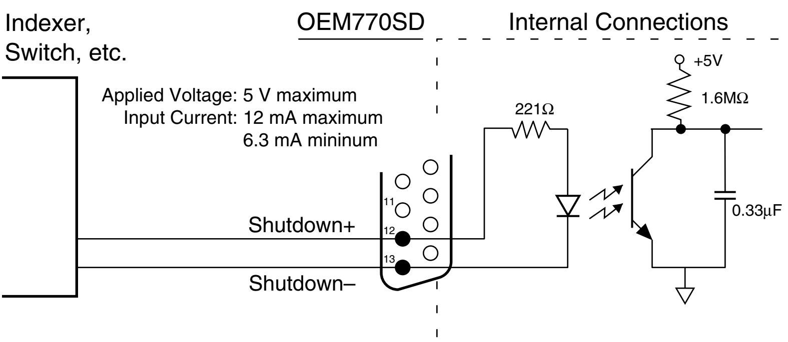
Encoder Input

Optional Inputs and Outputs

Connect any of the optional inputs and outputs that your application requires. Each is described below.

Shutdown Input

Use the isolated shutdown input on pins 12 and 13 if you need to temporarily disable the drive during normal operations. You may wish to do this, for example, to manually move the load to a desired position. Make connections according to the following diagram. The inputs are designed for 5V operation. You can use higher voltages if you connect an external resistor in series with Shutdown+ to limit the input current.



Shutdown Input

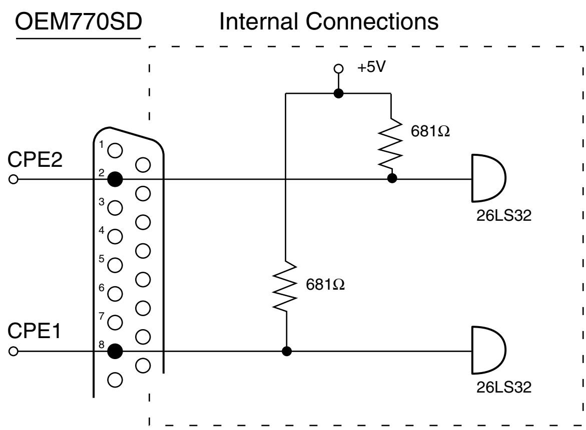
When +5V is applied to the Shutdown+ input, the OEM770SD's power output stage remains active, but its internal controller commands zero torque. This allows the motor shaft to be manually positioned. The controller will ignore encoder counts and position error as the shaft turns. Approximately one second after the shutdown input is released, the internal controller accepts the new position as the commanded position, and reestablishes servo action.

While the OEM770SD is in shutdown, it's small internal offset torque will be applied to the load. This torque is usually too low to overcome friction and cause motion. In some applications, however, the shaft may need to be held in the desired position during shutdown.

Note that shutdown in the OEM770SD functions differently than shutdown in a step motor drive. When a step motor drive is shut down, it actually shuts down its power output stage. When it comes out of shutdown, the step motor drive will command phase currents that immediately apply torque to the shaft, which holds it in some position between the poles.

CPE1 and CPE2 – Position Error Inputs

You can *configure position error* (CPE) with two position error inputs, CPE1 and CPE2, on pins 8 and 2 respectively. Position error faults provide warnings of impending problems such as increased friction, or of immediate problems such as a mechanical jam. Position error is measured in post-quadrature encoder counts. Four settings are available, as the next table shows.



CPE1 and CPE2 – Position Error Inputs

	Position Error Settings			**Number of Revolutions**	
				500 Line	1000 Line
	CPE1	CPE2	Error*	Encoder	Encoder
	low	low	2047	1.024	0.512
	high	low	4095	2.048	1.024
	low	high	8191	4.096	2.048
(default)	high	high	16383	8.196	4.096

high = not connected
low = connected to ground
**error* is measured in post-quadrature encoder counts

When the OEM770SD ships from the factory, neither CPE1 nor CPE2 is connected to ground. This is the default setting; it selects the widest position error range. You might begin with this setting when you start configuring your system. This will give you the widest range of motion. Once your system is tuned and performing properly, you can select one of the other three settings by connecting either or both of the inputs to ground.

The position error feature works as follows. Internally, the drive generates a control voltage proportional to the difference between the number of step pulses received and the number of post-quadrature encoder counts received. The first 2047 counts in each direction produce an increasing error voltage. This creates an increasing torque to move the load towards the commanded position. After the first 2047 counts, maximum torque is being commanded. Additional error counts have no immediate effect on torque, but they are accumulated until the error is reduced by shaft motion, or the CPE limit is reached. Reaching the limit causes a fault that disables the drive and illuminates the red LED. You can clear the fault by cycling power. Or, you can use the shutdown input to reset the drive—this will clear the position error fault.

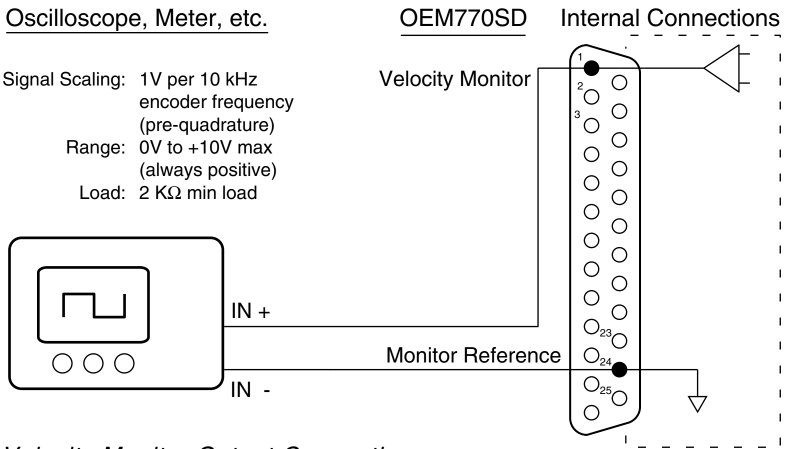
Velocity Monitor Output

A velocity monitor is available on pin 1. Its output is a voltage signal proportional to encoder speed. You can connect a voltmeter to the output to measure velocity, or you can connect an oscilloscope to help you tune your system. See the *Tuning* section at the end of this chapter for more information.

The signal is always positive, regardless of the direction of encoder rotation. It is scaled so that a pre-quadrature encoder count frequency of 10 kHz produces an output of one volt. The maximum output is +10V. (For example, a 1000 line encoder rotating at 100 rps (100 kHz) will produce the maximum signal of +10V. The same encoder at 10 rps will produce a signal of +1V.)

Encoder counts come slowly at low velocities, which can cause the velocity monitor to show ripple at four times the line frequency, resulting in a “fat” trace on the oscilloscope.

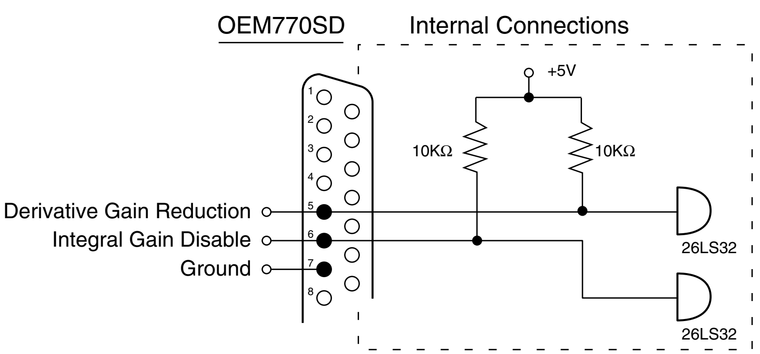
The next drawing shows typical connections to the velocity monitor. Use pin 24 as a ground reference for your signal.



Velocity Monitor Output Connections

Derivative Gain Reduction – Input

This input (pin 5) can affect the derivative gain in the OEM770SD's internal feedback loop. If no connections are made to the input, it leaves the gain unchanged. If the input is connected to ground, the drive gradually reduces derivative gain to a low value whenever motion stops. When commanded motion starts again, or if the motor shaft moves, the drive instantly increases derivative gain to the value set by the derivative tuning pot. See the *Tuning* section at the end of this chapter for more information. The internal schematic for the input is shown in the next drawing.



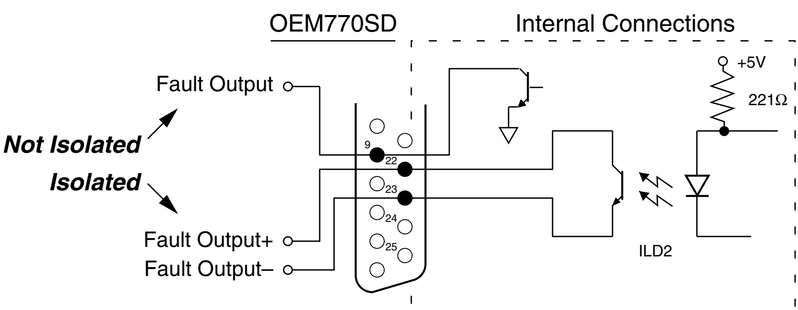
Derivative Gain Reduction & Integral Gain Disable Inputs

Integral Gain Disable – Input

This input (pin 6) can disable the integral gain in the OEM770SD's internal feedback loop. If this input is grounded, integral gain is disabled. If it is not grounded, integral gain is determined by the tuning pot setting. We recommend disabling integral gain by grounding pin 6, as an initial setting to simplify tuning. You can add integral gain later, if necessary. The internal schematic for the input is shown above. See the *Tuning* section at the end of this chapter for more information.

Fault Output – Isolated and Non-Isolated

The OEM770SD has two fault output signals. One is isolated (pins 22 and 23); the other is not isolated (pin 9). We recommend that you use the isolated fault output if you need a fault signal for your system. The schematic and specifications are:



Fault Output – Isolated and Non-Isolated

Specifications	Isolated Fault Output (pin 22 & 23)	Non-Isolated Fault Output (pin 9)
Maximum Applied Voltage	50 V	24 V
Maximum Current	10 mA	20 mA
Active Level	No Fault: Transistor *on*, current flows Fault: Transistor *off*, no current flows	

When the OEM770SD is operating normally, each fault output's internal transistor is in the "on" state, and conducts current. If the OEM770SD detects a fault, it turns off the transistors, and current stops flowing.

You can use the OEM770SD's fault output as a signal to an indexer or PLC that a fault has occurred. The following conditions will activate the fault output.

Fault Condition		LED Status Red	LED Status Green
Drive Not Enabled		On	On
Over Temperature	*(latched)*	On	On
Overvoltage	*(latched)*	On	On
Undervoltage	*(latched)*	On	On
Excess Position Error	*(latched)*	On	On
Short Circuit	*(latched)*	On	Off
Power Supply Fault	*(latched)*	On	Off
Foldback	Foldback is not a fault; the red LED is *ON* during foldback, but the fault output is not activated.		

Latched means you must cycle power before the drive will operate again. You can also use the shutdown input to clear position error faults, and to clear some undervoltage faults.

Current Monitor

The OEM770SD's current monitor output is identical to the OEM770T's current monitor output. See the current monitor description in the previous section, *OEM770T Inputs and Outputs*, for more information.

CONNECTING A POWER SUPPLY

The OEM770 requires a single external power supply with these features:

- 24VDC to 75VDC
- Fast Transient Response (can quickly supply enough current to meet your application's requirements)
- Power Dump (not required for all applications)

The power dump may be required if your system produces excess regenerated energy. To avoid damage, dissipate the regenerated energy in a power resistor, store it in extra capacitance (a blocking diode may be needed), or provide some other means to absorb regenerated energy.

For information about power supply selection, regeneration, and power dump methods, see *Chapter 6 Power Supply Selection*. The following table briefly lists the type of power supply you can use for different applications.

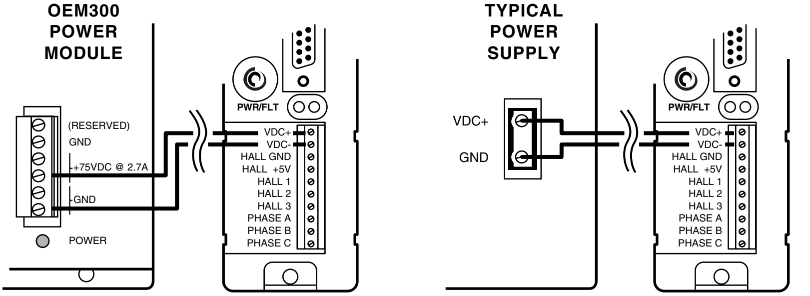
APPLICATION	RECOMMENDED POWER SUPPLY
Very Low Power (low regen)	24-48VDC Switching Power Supply 24-48VDC Linear Unregulated Supply OEM300 Power Module
Low Power (with regen)	Switching Power Supply with blocking diode and extra capacitance. Linear Unregulated Supply OEM300 Power Module
High Power (low regen)	Linear Unregulated Supply with Transformer OEM1000 Power Supply
High Power (with regen)	Linear Unregulated Supply with added Capacitance or added Power Dump OEM1000 Power Supply

The Compumotor OEM300 Power Module is a single unit that contains a 75VDC/300W power supply, integral power dump, and several protective circuits.

The Compumotor OEM1000 Power Supply is a linear power supply that can provide 1000W/15A at 70VDC.

CONNECTING THE POWER SUPPLY

Connect your power supply to the 10 pin screw terminal on the OEM770. The next drawing shows connections for a typical power supply, and for an OEM300 Power Module.



Power Supply Connections

- Connect the positive DC terminal of your power supply to the VDC+ input on the OEM770's 10-pin screw terminal.
- Connect the ground terminal of your power supply to VDC- on the OEM770.

To reduce electrical noise, minimize the length of the power supply wires and twist them tightly together.

Grounding

Internally, the Hall Ground and the grounds on the 25 pin D-connector (pins 7, 11, 16, 24) are connected to VDC-. Do not connect your power supply's ground to these pins, however. Connect it only to VDC-.

The shell of the 25 pin D-connector and the heatplate are connected internally. They are not connected to VDC-, Hall Ground, or the D-connector grounds (pins 7, 11, 16, 24).

Wire size

Use 18 AWG (0.75 mm^2) or greater diameter wire for power connections. For applications that use high peak power, use larger diameter wires. 14 AWG (2.5 mm^2) wire is the biggest wire that will fit in the 10-pin screw terminal.

TUNING – OEM770T Torque Drive

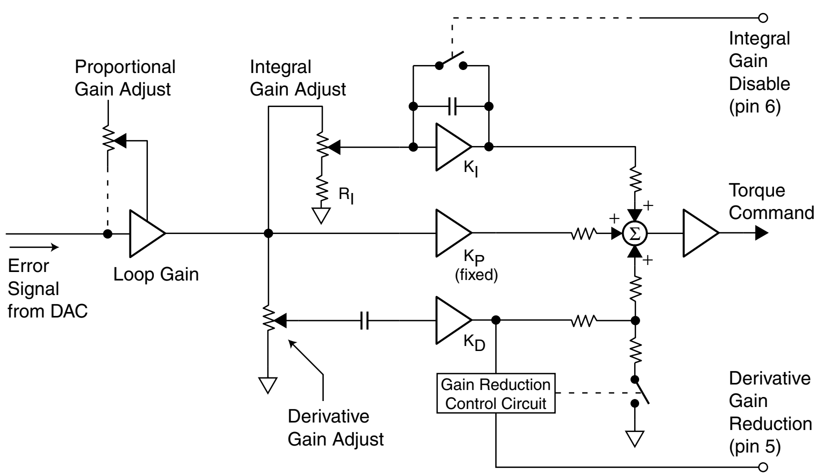
The OEM770T Torque Drive requires no tuning adjustments. See your controller's user guide for instructions on controller tuning adjustments.

TUNING – OEM770SD Step & Direction Drive

You must tune the OEM770SD's internal *Proportional Integral Derivative* (PID) servo control loop for optimum system performance. A properly tuned system will exhibit smooth motor rotation, accurate tracking, and fast settling time.

TUNING THEORY

The OEM770SD generates a move profile based on step and direction signals from the indexer. Incoming steps represent *commanded position*, and go to a summing node. Incoming encoder counts represent *actual position*, and also go to the summing node. During a move, actual position will differ from commanded position by at least several encoder counts. Actual position is subtracted from commanded position at the summing node—the resulting difference is the *position error*, which is converted into an analog voltage. This analog error signal is the input to the PID control loop, whose block diagram is shown below.



PID Control Loop – Block Diagram

You can adjust three potentiometers (pots) to tune the PID loop. These pots control the settings for proportional gain, integral gain, and derivative gain. You have two other options: you can connect pin 5 to ground to reduce derivative gain; and you can connect pin 6 to ground to disable integral gain.

Each tuning parameter is described in the following sections.

Proportional Gain

Proportional gain provides a torque that is directly proportional to the *magnitude* of the error signal. Proportional gain is similar to a spring—the larger the error, the larger the restoring force. It determines the stiffness of the system and affects following error. High proportional gain gives a stiff, responsive system, but can result in overshoot and oscillation. Damping—provided by derivative gain—can reduce this overshoot and oscillation.

Notice from the block diagram that adjusting proportional gain affects the loop gain. This means that integral gain and derivative gain are both affected by changes in the proportional gain tuning pot. This arrangement simplifies tuning; once you set the integral and derivative gains in the correct ratio to proportional gain, you only need to adjust proportional gain—integral and derivative gain will follow.

Derivative Gain

Derivative gain provides a torque that is directly proportional to the *rate of change* of the error signal. When the error's instantaneous rate of change, or *derivative*, increases, derivative gain also increases. Derivative gain opposes rapid changes in velocity. It will dampen the resonance effects of proportional gain. With higher derivative gain, you can use higher proportional gain.

Derivative Gain Reduction (Grounding Pin 5)

Many applications require high derivative gain for proper performance. High derivative gain, however, can cause jitter and audible shaft noise when the motor is at rest. Many applications have enough stiction that high derivative gain is not necessary for stability when the system is at rest. If your application must hold position with minimum jitter or noise, connect pin 5 to ground (see the *Inputs and Outputs* section earlier in this chapter). With this pin grounded, the drive will gradually reduce derivative gain to a low value whenever motion stops. When motion starts again, or if the motor shaft moves, the drive will instantly increase derivative gain to the value set by the tuning pot.

Integral Gain

Integral gain provides a torque that is directly proportional to the sum, over time, of the error signal—the *integral* of the error. If the error persists, integral gain provides a restoring force that grows larger with time. Integral gain can remove steady state errors that are due to gravity or a constant static torque. It can also correct velocity lag and following error in a constant velocity system.

Too much integral gain can cause overshoot during acceleration and deceleration, which will increase settling time. You should use only as much as your application requires; if your application does not need any integral gain, you should disable it by grounding pin 6 (see below).

Integral Gain Disable (Grounding Pin 6)

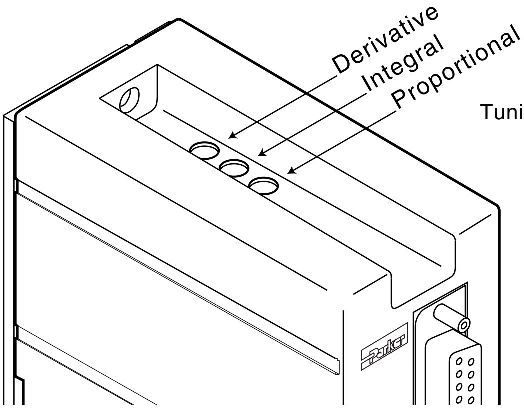
You can *permanently* disable integral gain by wiring pin 6 to ground. Notice on the block diagram that even if you zero the integral gain pot, integral gain is not reduced to zero, just to a lower value. There will still be integral gain in the system (because of voltage on resistor R_I). The only way you can eliminate integral gain is to connect pin 6 to ground.

Or, you can use a control signal to *temporarily* disable integral gain, by connecting pin 6 to ground only during acceleration and deceleration. This will disable integral gain during those parts of the move, which should decrease overshoot and settling time. When the system reaches constant velocity or comes to rest, use your control signal to break the ground connection, which will re-enable integral gain.

TUNING PROCEDURE

In the procedure described below, you will systematically vary the tuning pots until you achieve a move that meets your requirements for accuracy and response time. For the best results, make a consistent, repetitive move that is representative of your application.

Access to the pots is through three holes in the top of the drive's plastic cover. The proportional gain pot is closest to the front of the drive; the integral gain pot is in the middle; and the derivative gain pot is closest to the heatsink. Turn the pots clockwise to increase the gains.



Tuning Pot Locations

1. Disable Integral Gain (optional)

If you do not need integral gain in your application, wire pin 6 to ground to permanently disable integral gain (see above). If you *do* use integral gain, tuning will be simplified if you disable it now, and re-enable it in *Step 7* below.

2. Set up the Velocity Monitor (optional)

Connect an oscilloscope to the velocity monitor output on pin 1 of the 25 pin D-connector, as described earlier in the *Inputs and Outputs* section. You can tune without the velocity monitor, but using it will clearly show how your system responds when you adjust the tuning pots.

3. Set Pots to their Default Values

The tuning pots were set at default values when the OEM770SD shipped from the factory. If yours is a new unit, skip this step and proceed to *Step 4*. Otherwise, follow this procedure to return the settings to their default values:

1. Turn each pot 12 turns counterclockwise (zero each pot).
2. Turn the proportional gain pot 3 turns clockwise.
3. Leave the integral gain pot at zero.
4. Turn the derivative gain pot 4½ turns clockwise.

These settings will provide a stable but “mushy” response with most motors and light loads.

4. Increase Proportional Gain
Increase proportional gain until the system oscillates or becomes unstable, then decrease the gain until the system returns to stability (at least ½ turn counterclockwise).

5. Increase Derivative Gain
Increase derivative gain until the system oscillates or becomes unstable, then decrease the gain until the system returns to stability (at least ½ turn counterclockwise).

6. Repeat Step 4 and Step 5
With the increased damping from *Step 5*, you should now be able to increase proportional gain further. With higher proportional gain, you may need higher derivative gain. So, iteratively repeat *Step 4* and *Step 5* until your system is critically damped. In general, you will want values for proportional and derivative gain that are as high as possible, without producing unacceptable motor vibrations, overshoot, or ringing.

7. Adjust Integral Gain
If you need integral gain in your application, adjust it now. You should set integral gain to the lowest value that will correct following errors and static position errors, but not increase overshoot or settling time. Adjusting integral gain may require you to readjust the derivative and integral gain pots. In a system without static torque loading, you may wish to disable integral gain entirely (see *Step 1* above).

This completes the tuning procedure.

CHAPTER 3

Specifications

Complete specifications for the OEM770 Drive and Parker Compumotor SM, NeoMetric, and J Series motors are listed in this chapter.

The motors are described by the following numbering system:

SM — Frame, Magnet Length — Winding — Feedback — Shafting — Connections — Options

- **SM:** SM Series
- **Frame, Magnet Length:** 161, 162, 231, 232, 233
- **Winding:** A, B
- **Feedback:** D – 500 ppr encoder[1]; E – 1,000 ppr encoder[1]; H – Hall-effect only; R – resolver
- **Shafting:** N – normal; F – flat; K – keyway[2]; L – extended
- **Connections:** MS – military style; 10 – 10' cable[3]; 25 – 25' cable[3]; FL – 18" leads; TQ – TQ amp series
- **Options:** N – none; V – shaft seal[4]; Gxx – Gearhead

[1] includes Hall-effect
[2] not available on size 16
[3] cable is hard-wired
[4] size 23 w/MS or TQ connectors—IP65

N — Frame, Magnet Length — Winding — Feedback — Shafting — Connections — Options

- **N:** NeoMetric Series
- **Frame, Magnet Length:** xxxy; xxx = flange dia. 070 for 70 mm, 034 for 34 frame, 092 for 92 mm; y = magnet length reference 1 to 4
- **Winding:** Identifying character; D, E, F, etc.
- **Feedback:** D – 500 ppr encoder[2]; E – 1,000 ppr encoder; H – Hall-effect only; R – resolver
- **Shafting:** N – normal; F – flat; K – keyway
- **Connections:** FL[2]; MS; TQ[4]; PT[1]; 10[2]
- **Options:** B – brake; N – none; V – IP65[5]; W – IP67; Gxx – Gearhead[3]

[1] 92 mm motors only
[2] 70 mm and 34 frame motors only
[3] 34 frame motors only
[4] Not available on 92 mm motors
[5] IP65 when specified with MS or TQ connections

J — Frame, Magnet Length — Winding — Feedback — Shafting — Connections — Options

- **J:** J Series
- **Frame, Magnet Length:** xxxy; xxx = flange dia. 070 for 70 mm, 034 for 34 frame, 092 for 92 mm; y = magnet length reference 1 to 3
- **Winding:** Identifying character; D, E, F, etc.
- **Feedback:** D – 500 ppr encoder; E – 1,000 ppr encoder; H – Hall-effect only; R – resolver
- **Shafting:** N – normal; F – flat; K – keyway
- **Connections:** FL[2]; MS; TQ[4]; PT[1]; 10[2]
- **Options:** B – brake; N – none; V – IP65[5]; Gxx – Gearhead[3]

[1] 92 mm motors only
[2] 70 mm motors only
[3] 34 frame motors only
[4] Not available on 92 mm motors
[5] IP65 when specified with MS or TQ connections

Specifications: OEM770T Torque Drive

OEM770T Torque Drive – Specifications		
POWER INPUT		
	Voltage	24-75VDC
	Current	Ø-12 amps
POWER OUTPUT—MOTOR		
	Peak Current	12A (approx 2 sec maximum duration
		at 45°C ambient temperature.
		See *Current Foldback* for details)
	Continuous Current	6A
	Voltage	90VDC maximum
	Peak Power	840W (1.1 hp) (@75V supply voltage)
	Continuous Power	420W (0.56 hp)
	Switching Frequency	20 kHz
	Bandwidth	2 kHz typical (dependant on motor)
	Transconductance	1 volt = 1.2 amp
	Commutation	120° Hall Effect Sensors for
		Six-State Commutation Method,
		or Brushed DC Motor
	Short Circuit Protected	Yes
POWER OUTPUT—HALL EFFECT SENSORS		
	Voltage	+5VDC ± 0.5VDC
	Current	50 mA (maximum)
	Overload Protected	YES
POWER OUTPUT—TO CONTROLLER OUTPUT STAGE		
	Voltage	+15VDC ± 1.5VDC
		-15VDC ± 1.5VDC
	Current	10 mA maximum, each output
	Short Circuit Protected	NO
POWER OUTPUT—TO ENCODER		
	Voltage	+5VDC
	Current	200 mA maximum, each output
	Overload Protected	YES
CONTROL INPUTS		
	Command Input	-10V to +10V analog voltage
		1 volt input = 1.2 amp output
	Enable Input	Active LOW: Ø-0.8V @ 2mA
		When disabled: Internal 2.49 KΩ
		pullup resistor to +5VDC
HALL INPUTS		
	Low State	Ø-0.8V
	High State	Internal 1 KΩ pullup resistor to +5V
	Input Frequency	Ø-2 kHz maximum

OEM770T Torque Drive – Specifications (contin.)

SIGNAL OUTPUTS		
	Fault Output	Active HIGH: open collector output,
		maximum volts = 24VDC
		Inactive LOW: Ø-0.4VDC at Ø-20 mA
	Current Monitor	-10V to +10V analog voltage
		Scale: 1V corresponds to 1.2A output
		Output Impedance: 10 KΩ
	LEDs	GREEN: power
		RED: various fault conditions
		see *Troubleshooting* for details
PROTECTIVE CIRCUITS		
	Short Circuit	Turns Off Outputs to Motor; Latched
	Over Temperature	55°C ± 5°C trip temperature; Latched
	Overvoltage	95V ± 5V trip voltage; Latched
	Undervoltage	21.5V maximum; not Latched
	Current Foldback	Configurable with 3 resistors
		see *Special Internal Circuits* for details
MOTOR CHARACTERISTICS		
	Minimum Inductance	50 µH (micro Henrys)
	Minimum Resistance	0.25 Ω
	Loop Gain Adjustment	Configurable with one resistor
		see *Special Internal Circuits* for details
TEMPERATURE		
	Minimum Temperature	Ø°C (32°F)
	Maximum Temperature	45°C (113°F) (max. heatplate temp.)
	Storage Temperature	-30°C to 85°C (-22°F to 185°F)
	Package Dissipation	Heatplate: 0 to 30W, depending on
		motor current; P = (I_{AVG}/12 A)30 W
		Cover: 3 watts maximum
	Humidity	0 to 95% non condensing
	Contaminants	OEM770T is not waterproof,
		oilproof, or dustproof.
MECHANICAL		
	Power Connector	10 pin screw terminal
		14 AWG (2.5 mm^2) maximum wire size
	Input/Output Connector	25 Pin D-connector
	Size	5x1.6x3.5 in (127x41x89 mm) approx.
	Dimensions	see *Chapter 2 Installation*
	Weight	12 ounces (0.35 kg)

Specifications: OEM770SD Step & Direction Drive

OEM770SD Step & Direction Drive		
POWER INPUT		
	Voltage	24-75VDC
	Current	Ø-12 amps
POWER OUTPUT—MOTOR		
	Peak Current	12A (approx 2 sec maximum duration
		at 45°C ambient temperature.
		See *Current Foldback* for details)
	Continuous Current	6A
	Voltage	90VDC maximum
	Peak Power	840W (1.1 hp) (@75V supply voltage)
	Continuous Power	420W (0.56 hp)
	Switching Frequency	20 kHz
	Bandwidth	2 kHz typical (dependant on motor)
	Transconductance	1 volt = 1.2 amp
	Commutation	120° Hall Effect Sensors for
		Six-State Commutation Method,
		or Brushed DC Motor
	Short Circuit Protected	Yes
POWER OUTPUT—HALL EFFECT SENSORS		
	Voltage	+5VDC ± 0.5VDC
	Current	50 mA (maximum)
	Overload Protected	YES
POWER OUTPUT—TO ENCODER		
	Voltage	+5VDC
	Current	200 mA maximum, each output
	Overload Protected	YES
CONTROL INPUTS		
	Step+/Step–	5V maximum input
		Input current: 12 mA max., 6.3 mA min.
	Direction+/Direction–	5V maximum input
		Input current: 12 mA max., 6.3 mA min.
		Pos. input = clockwise motor rotation
HALL INPUTS		
	Low State	Ø-0.8V
	High State	Internal 1 KΩ pullup resistor to +5V
	Input Frequency	Ø-2 kHz maximum

OEM770SD Step & Direction Drive (contin.)

SIGNAL OUTPUTS		
	Fault Output-Isolated	50V max voltage, 10 mA max current
	Fault Output-Not Isolat.	24V max voltage, 20 mA max current
	Velocity Monitor	1V per 10 kHz pre-quad. encoder freq.
	Current Monitor	1V output per 1.2A motor current
		Output Impedance: 10 KΩ
	LEDs	GREEN: power
		RED: various fault conditions
		see *Troubleshooting* for details
PROTECTIVE CIRCUITS		
	Short Circuit	Turns Off Outputs to Motor; Latched
	Over Temperature	55°C ± 5°C trip temperature; Latched
	Overvoltage	95V ± 5V trip voltage; Latched
	Undervoltage	21.5V maximum; not Latched
	Current Foldback	Configurable with 3 resistors
		see *Special Internal Circuits* for details
	Position Error	2047–16383 post-quad encoder counts
MOTOR CHARACTERISTICS		
	Minimum Inductance	50 μH (micro Henrys)
	Minimum Resistance	0.25 Ω
	Loop Gain Adjustment	Configurable with one resistor
		see *Special Internal Circuits* for details
TEMPERATURE		
	Minimum Temperature	Ø°C (32°F)
	Maximum Temperature	45°C (113°F) (max. heatplate temp.)
	Storage Temperature	-30°C to 85°C (-22°F to 185°F)
	Package Dissipation	Heatplate: 0 to 30W, depending on
		motor current; $P = (I_{AVG}/12\ A)30\ W$
		Cover: 3 watts maximum
	Humidity	0 to 95% non condensing
	Contaminants	OEM770SD is not waterproof,
		oilproof, or dustproof.
MECHANICAL		
	Power Connector	10 pin screw terminal
		14 AWG (2.5 mm^2) maximum wire size
	Input/Output Connector	25 Pin D-connector
	Size	5x1.6x3.5 in (127x41x89 mm) approx.
	Dimensions	see *Chapter 2 Installation*
	Weight	14 ounces (0.4 kg)

Motor Specifications: SM160

Parameter	Symbol	Units	SM160A	SM160B
Stall Torque Continuous[1]	T_{cs}	lb-in/oz-in	0.8/13	0.8/13
		N-m	0.09	0.09
Stall Current Continuous[1]	I_{cs} (trap)	Amps DC	2.5	4.8
Rated Speed[2]	ω_r	rpm	7500	7500
Peak Torque[6]	T_{pk}	lb-in/oz-in	2.5/40	2.5/40
		N-m	0.28	0.28
Peak Current[6]	I_{pk} (trap)	Amps DC	7.4	14.4
Torque @ Rated Speed	T_r	lb-in/oz-in	0.6/10	0.6/10
		N-m	0.07	0.07
Rated Power–Output Shaft	P_o	watts	57	55
Voltage Constant[3,4]	K_b	volts/radian/sec	0.038	0.020
Voltage Constant[3,4]	K_e	volts/KRPM	4.02	2.08
Torque Constant[3,4]	K_t (trap)	oz-in/Amp DC	5.43	2.81
		N-m/Amp DC	0.038	0.020
Resistance[3]	R	ohms	3.43	0.90
Inductance[5]	L	millihenries	0.53	0.13
Thermal Resistance	R_{th} w-a	°C/watt	3.2	3.2
Motor Constant	Km	oz-in/√watt	2.93	2.96
		N-m/√watt	0.021	0.021
Viscous Damping	B	oz-in/Krpm	0.162	0.162
		N-m/Krpm	1.13E-3	1.13E-3
Static Friction	T_f	oz-in	0.10	0.10
		N-m	7.0E-4	7.0E-4
Thermal Time Constant	τ_{th}	minutes	10	10
Electrical Time Constant	τ_e	milliseconds	0.16	0.15
Mechanical Time Constant	τ_m	milliseconds	11.7	11.5
Rotor Inertia	J	lb-in-sec^2	4.4E-5	4.4E-5
		kg-m^2	5.0E-6	5.0E-6
Weight	#	pounds	0.7	0.7
	kg	kilograms	0.3	0.3
Winding Class			H	H

1. @ 25°C ambient, 125°C winding temperature, motor connected to a 10"x10"x1/4" aluminum mounting plate, @ 40°C ambient, derate phase currents and torques by 12%.
2. Maximum speed is 7500RPM with 500 line encoder. For 1000 line encoders, derate to 6000RPM. For higher speed operation, please call the factory.
3. Measured line-to-line, ±10% line-to-line.
4. Value is measured peak of sine wave.
5. ±30% line-to-line, inductance bridge measurement @ 1 kHz.
6. Initial winding temperature must be 60°C or less before peak current is applied.

Note: These specifications are based on theoretical motor performance and are not specific to any amplifier.

Motor Specifications: SM161 and SM162

Parameter	Symbol	Units	SM161A	SM161B	SM162A	SM162B
Stall Torque Continuous[1]	T_{cs}	lb-in/oz-in	1.6/26	1.6/26	2.9/47	3.1/49
		N-m	0.18	0.18	0.33	0.34
Stall Current Continuous[1]	I_{cs} (trap)	Amps DC	2.3	4.5	2.3	4.4
Rated Speed[2]	ω_r	rpm	7,500	7,500	7,500	7,500
Peak Torque[6]	T_{pk}	lb-in/oz-in	4.9/78	4.9/78	8.8/141	9.1/145
		N-m	0.55	0.54	0.99	1.02
Peak Current[6]	I_{pk} (trap)	Amps DC	7.0	13.4	6.8	13.2
Torque @ Rated Speed	T_r	lb-in/oz-in	1.1/18	1.1/18	2.3/37	2.3/37
		N-m	0.13	0.13	0.26	0.26
Rated Power–Output Shaft	P_o	watts	97	100	205	204
Voltage Constant[3,4]	K_b	volts/radian/sec	0.079	0.041	0.147	0.078
Voltage Constant[3,4]	K_e	volts/KRPM	8.27	4.29	15.39	8.17
Torque Constant[3,4]	K_t (trap)	oz-in/Amp DC	11.19	5.81	20.82	11.04
		N-m/Amp DC	0.078	0.041	0.146	0.077
Resistance[3]	R	ohms	4.53	1.24	6.50	1.73
Inductance[5]	L	millihenries	0.81	0.21	1.39	0.33
Thermal Resistance	R_{th} w-a	°C/watt	2.70	2.70	2.00	2.00
Motor Constant	Km	oz-in/√watt	5.26	5.21	8.16	8.40
		N-m/√watt	0.037	0.036	0.057	0.059
Viscous Damping	B	oz-in/Krpm	0.284	0.284	0.300	0.300
		N-m/Krpm	1.99E-3	1.99E-3	2.1E-3	2.1E-3
Static Friction	T_f	oz-in	0.15	0.15	0.20	0.20
		N-m	1.05E-3	1.05E-3	1.40E-3	1.40E-3
Thermal Time Constant	τ_{th}	minutes	11.6	11.6	14.2	14.2
Electrical Time Constant	τ_e	milliseconds	0.18	0.17	0.21	0.19
Mechanical Time Constant	τ_m	milliseconds	7.7	7.8	5.5	5.2
Rotor Inertia	J	lb-in-sec^2	9.4E-5	9.4E-5	1.6E-4	1.6E-4
		kg-m^2	1.1E-5	1.1E-5	1.8E-5	1.8E-5
Weight	#	pounds	1.1	1.1	1.6	1.6
	kg	kilograms	0.5	0.5	0.7	0.7
Winding Class			H	H	H	H

1 @ 25°C ambient, 125°C winding temperature, motor connected to a 10"x10"x1/4" aluminum mounting plate, @ 40°C ambient, derate phase currents and torques by 12%.

2 Maximum speed is 7500RPM with 500 line encoder. For 1000 line encoders, derate to 6000RPM. For higher speed operation, please call the factory.

3 Measured line-to-line, ±10% line-to-line.

4 Value is measured peak of sine wave.

5 ±30% line-to-line, inductance bridge measurement @ 1 kHz.

6 Initial winding temperature must be 60°C or less before peak current is applied.

Note: These specifications are based on theoretical motor performance and are not specific to any amplifier.

Motor Specifications: SM230 and SM231

Parameter	Symbol	Units	SM230A	SM230B	SM231A	SM231B
Stall Torque Continuous[1]	T_{cs}	lb-in/oz-in	1.7/27	1.6/26	3.8/61	3.4/54
		N-m	0.19	0.18	0.43	0.38
Stall Current Continuous[1]	I_{cs} (trap)	Amps DC	2.4	4.7	2.5	4.8
Rated Speed[2]	ω_r	rpm	7500	7500	7,500	7,500
Peak Torque[6]	T_{pk}	lb-in/oz-in	5.1/82	4.9/78	11.3/181	10.0/160
		N-m	0.57	0.55	1.27	1.12
Peak Current[6]	I_{pk} (trap)	Amps DC	7.1	14.2	7.6	14.3
Torque @ Rated Speed	T_r	lb-in/oz-in	1.4/22	1.3/21	2.9/47	2.8/44
		N-m	0.15	0.15	0.33	0.31
Rated Power–Output Shaft	P_o	watts	122	116	261	244
Voltage Constant[3,4]	K_b	volts/radian/sec	0.081	0.039	0.169	0.079
Voltage Constant[3,4]	K_e	volts/KRPM	8.48	4.09	17.70	8.27
Torque Constant[3,4]	K_t (trap)	oz-in/Amps DC	11.47	5.54	23.93	11.19
		N-m/Amps DC	0.080	0.039	0.168	0.078
Resistance[3]	R	ohms	4.43	1.12	5.22	1.46
Inductance[5]	L	millihenries	1.19	0.28	1.64	0.44
Thermal Resistance	R_{th} w-a	°C/watt	2.67	2.67	2.00	2.00
Motor Constant	Km	oz-in/√watt	5.45	5.23	10.47	9.26
		N-m/√watt	0.038	0.037	0.073	0.065
Viscous Damping	B	oz-in/Krpm	0.160	0.160	0.250	0.250
		N-m/Krpm	1.12E-3	1.12E-3	1.75E-3	1.75E-3
Static Friction	T_f	oz-in	0.20	0.20	0.30	0.30
		N-m	1.4E-3	1.4E-3	2.10E-3	2.10E-3
Thermal Time Constant	τ_{th}	minutes	18.3	18.3	20	20
Electrical Time Constant	τ_e	milliseconds	0.27	0.25	0.31	0.30
Mechanical Time Constant	τ_m	milliseconds	18.3	19.9	9.5	12.2
Rotor Inertia	J	lb-in-sec²	2.4E-4	2.4E-4	4.6E-4	4.6E-4
		kg-m²	2.7E-5	2.7E-5	5.2E-5	5.2E-5
Weight	#	pounds	1.2	1.2	2.1	2.1
	kg	kilograms	0.5	0.5	1.0	1.0
Winding Class			H	H	H	H

1 @ 25°C ambient, 125°C winding temperature, motor connected to a 10"x10"x1/4" aluminum mounting plate, @ 40°C ambient derate phase currents and torques by 12%.

2 Maximum speed is 7500RPM with 500 line encoder. For 1000 line encoders, derate to 6000RPM. For higher speed operation, please call the factory.

3 Measure line-to-line, ±10% line-to-line.

4 Value is measured peak of sine wave.

5 ±30%, line-to-line, inductance bridge measurement @ 1 kHz.

6 Initial winding temperature must be 60°C or less before peak current is applied.

Note: These specifications are based on theoretical motor performance and are not specific to any amplifier.

Motor Specifications: SM232 and SM233

Parameter	Symbol	Units	SM232A	SM232B	SM233A	SM233B
Stall Torque Continuous[1]	T_{cs}	lb-in/oz-in	6.6/106	7.0/111	10.1/161	9.7/156
		N-m	0.74	0.78	1.13	1.09
Stall Current Continuous[1]	I_{cs} (trap)	Amps DC	2.4	4.7	2.4	4.5
Rated Speed[2]	ω_r	rpm	7,500	7,500	5,800	5,800
Peak Torque[6]	T_{pk}	lb-in/oz-in	19.8/316	20.9/334	30.2/483	29.2/467
		N-m	2.21	2.34	3.38	3.27
Peak Current[6]	I_{pk} (trap)	Amps DC	7.2	14.0	7.1	13.6
Torque @ Rated Speed	T_r	lb-in/oz-in	5.1/81	5.4/86	8.1/129	7.6/121
		N-m	0.57	0.60	0.90	0.85
Rated Power–Output Shaft	P_o	watts	449	477	553	519
Voltage Constant[3,4]	K_b	volts/radian/sec	0.310	0.169	0.484	0.242
Voltage Constant[3,4]	K_e	volts/KRPM	32.46	17.70	50.68	25.34
Torque Constant[3,4]	K_t (trap)	oz-in/Amp DC	43.90	23.93	68.53	34.27
		N-m/Amp DCs	0.307	0.168	0.480	0.240
Resistance[3]	R	ohms	7.50	2.00	9.65	2.58
Inductance[5]	L	millihenries	2.90	0.78	4.08	1.06
Thermal Resistance	R_{th} w-a	°C/watt	1.54	1.54	1.25	1.25
Motor Constant	Km	oz-in/√watt	16.03	16.92	22.06	21.33
		N-m/√watt	0.112	0.118	0.154	0.149
Viscous Damping	B	oz-in/Krpm	0.360	0.360	0.540	0.540
		N-m/Krpm	2.52E-3	2.52E-3	3.78E-3	3.78E-3
Static Friction	T_f	oz-in	0.70	0.70	1.00	1.00
		N-m	4.90E-3	4.90E-3	7.00E-3	7.00E-3
Thermal Time Constant	τ_{th}	minutes	21.6	21.6	23.3	23.3
Electrical Time Constant	τ_e	milliseconds	0.39	0.39	0.42	0.41
Mechanical Time Constant	τ_m	milliseconds	7.2	6.5	5.4	5.8
Rotor Inertia	J	lb-in-sec²	8.2E-4	8.2E-4	1.2E-3	1.2E-3
		kg-m²	9.3E-5	9.3E-5	1.3E-4	1.3E-4
Weight	#	pounds	3.0	3.0	3.9	3.9
	kg	kilograms	1.4	1.4	1.8	1.8
Winding Class			H	H	H	H

1 @ 25°C ambient, 125°C winding temperature, motor connected to a 10"x10"x1/4" aluminum mounting plate, @ 40°C ambient, derate phase currents and torques by 12%.
2 Maximum speed is 7500RPM with 500 line encoder. For 1000 line encoders, derate to 6000RPM. For higher speed operation, please contact factory.
3 Measured line-to-line, ±10% line-to-line.
4 Value is measured peak of sine wave.
5 ±30%, line-to-line, inductance bridge measurement @ 1 kHz.
6 Initial winding temperature must be 60°C or less before peak current is applied.

Note: These specifications are based on theoretical motor performance and are not specific to any amplifier.

Motor Specifications: NeoMetric & J Series

Parameter	Symbol	Units	N0701 or N0341		N0702 or N0342	
Winding Selection			D	F	E	F
Stall Torque Continuous[1]	T_{cs}	lb-in	5.7	5.6	10.4	10.4
		N-m	0.63	0.63	1.17	1.16
Stall Current Continuous[1]	I_{cs} (trap)	Amps DC	2.9	4.5	3.3	4.6
Rated Speed[2]	ω_r	rpm	7500	7500	7500	7500
Peak Torque[6]	T_{pk}	lb-in	17.0	16.8	31.2	31.1
		N-m	1.90	1.88	3.50	3.49
Peak Current[6]	I_{pk} (trap)	Amps DC	8.7	13.5	10.0	13.9
Torque @ Rated Speed	T_r	lb-in	4.7	4.6	7.1	7.9
		N-m	0.53	0.52	0.80	0.88
Rated Power–Output Shaft	P_o	watts	416	411	632	699
Voltage Constant[3, 4]	K_b	volts/radian/sec	0.221	0.140	0.353	0.253
Voltage Constant[3, 4]	K_e	volts/KRPM	23.14	14.66	36.97	26.49
Torque Constant[3, 4]	K_t (trap)	oz-in/Amp DC	31.29	19.82	49.98	35.82
		N-m/Amp DC	0.219	0.139	0.350	0.251
Resistance[3]	R	ohms	5.52	2.27	5.22	2.70
Inductance[5]	L	millihenries	12.98	5.23	15.80	8.16
Thermal Resistance	R_{th} w-a	°C/watt	1.44	1.44	1.15	1.15
Motor Constant	Km	oz-in/√watt	13.32	13.16	21.88	21.80
		N-m/√watt	0.093	0.092	0.153	0.153
Viscous Damping	B	oz-in/Krpm	0.2	0.2	0.4	0.4
		N-m/Krpm	1.4E-3	1.4E-3	2.8E-3	2.8E-3
Static Friction	T_f	oz-in	0.8	0.8	1.6	1.6
		N-m	5.6E-3	5.6E-3	1.2E-2	1.2E-2
Thermal Time Constant	τ_{th}	minutes	16.6	16.6	21.7	21.7
Electrical Time Constant	τ_e	milliseconds	2.35	2.30	3.03	3.02
NeoMetric Mech. Time Const.	τ_{mch}	milliseconds	1.6	1.7	0.6	0.6
J Series Mech. Time Const.	τ_{mch}	milliseconds	14.7	14.7	5.7	5.7
NeoMetric Rotor Inertia	J	lb-in-sec^2	1.1E-4	1.1E-4	1.7E-4	1.7E-4
		kg-m^2	1.2E-5	1.2E-5	2.0E-5	2.0E-5
J Series Rotor Inertia	J	lb-in-sec^2	1.1E-3	1.1E-3	1.2E-3	1.2E-3
		kg-m^2	1.3E-4	1.3E-4	1.4E-4	1.4E-4
NeoMetric Weight	#	pounds	3.5	3.5	4.5	4.5
	kg	kilograms	1.6	1.6	2.1	2.1
J Series Weight	#	pounds	4.4	4.4	5.4	5.4
	kg	kilograms	2.0	2.0	2.5	2.5
Winding Class				H		H

@ 25°C ambient, 125°C winding temperature, motor connected to a 10"x10"x1/4" aluminum mounting plate, @ 40°C ambient, derate phase currents and torques by 12%.

2 Maximum speed is 7500RPM with 500 line encoder. For 1000 line encoders, derate to 6000RPM. For higher speed operation, please contact factory.

3 Measured line-to-line, ±10% line-to-line.

4 Value is measured peak of sine wave.

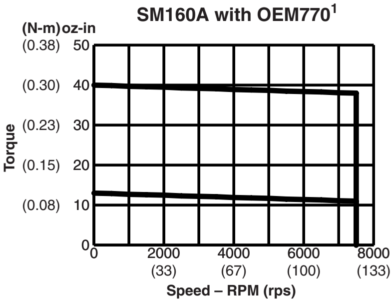
5 ±30%, line-to-line, inductance bridge measurement @ 1 kHz.

6 Initial winding temperature must be 60°C or less before peak current is applied.

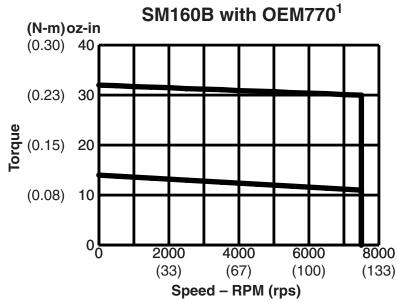
Note: These specifications are based on theoretical motor performance and are not specific to any amplifier.

Speed/Torque Curves[2]: SM 160, SM161 and SM162

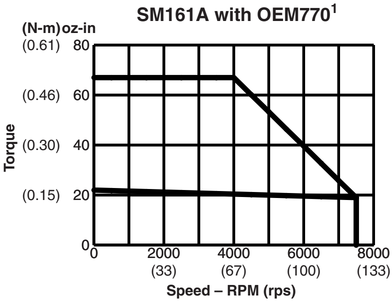
SM160A with OEM770[1]



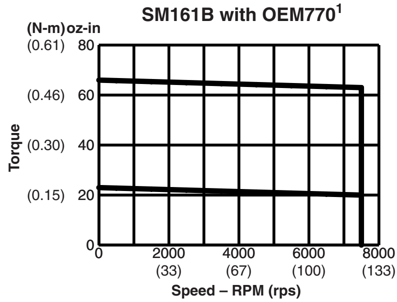
SM160B with OEM770[1]



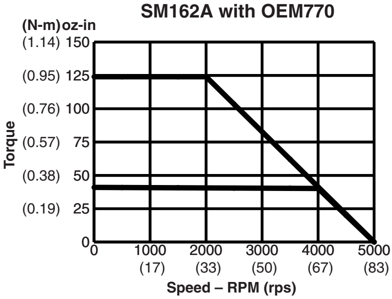
SM161A with OEM770[1]



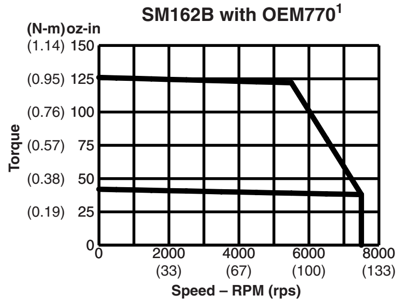
SM161B with OEM770[1]



SM162A with OEM770

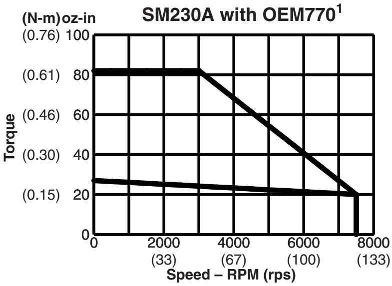


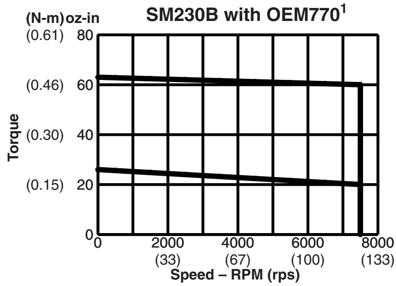
SM162B with OEM770[1]

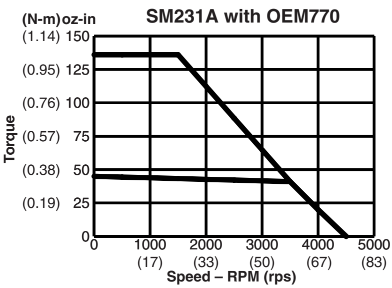


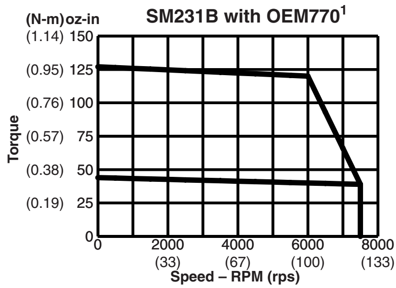
1 For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).
2 With 75VDC bus voltage; 25°C (77°F) ambient temperature.

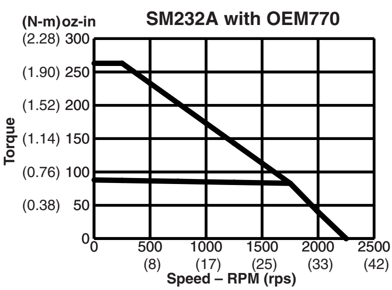
Speed/Torque Curves[2]: SM230, SM231, SM232, SM233

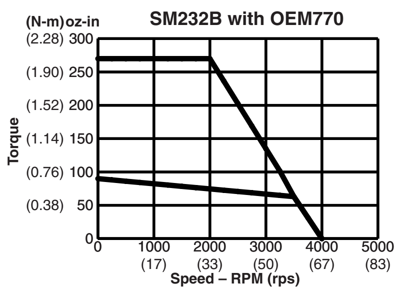


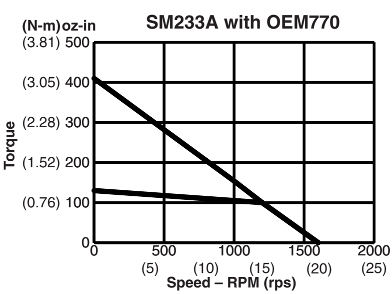


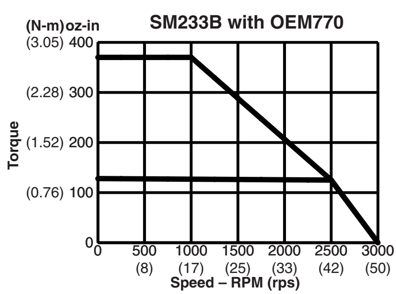








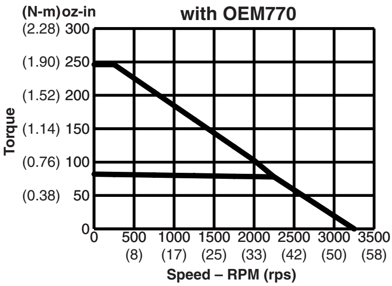




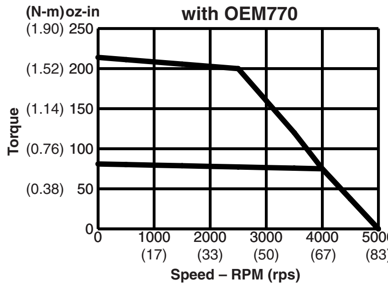
[1] For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).
[2] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Speed/Torque Curves[1]: NeoMetric Motors

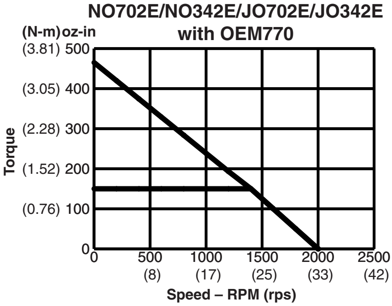
NO701D/NO341D/JO701D/JO341D with OEM770



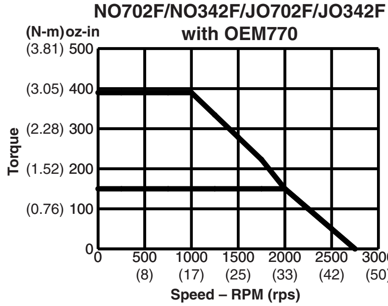
NO701F/NO341F/JO701F/JO341F with OEM770



NO702E/NO342E/JO702E/JO342E with OEM770



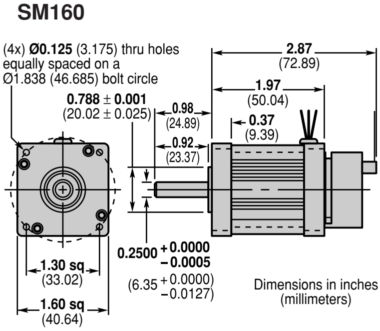
NO702F/NO342F/JO702F/JO342F with OEM770



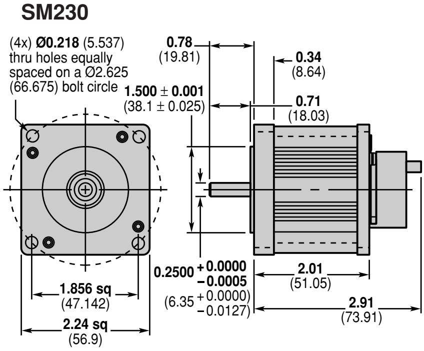
[1] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Motor Dimensions: Compumotor SM160 and SM230

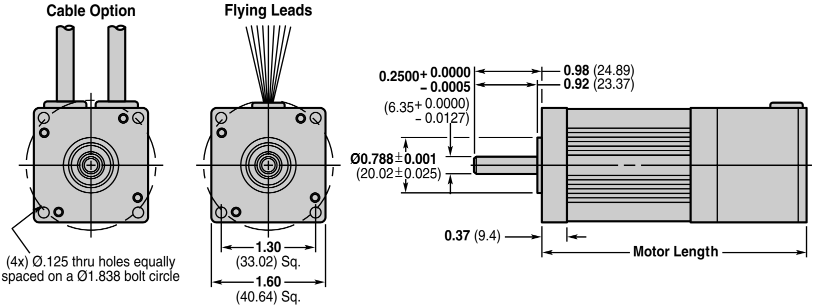
SM160



SM230



Motor Dimensions: Compumotor SM Series, Size 16

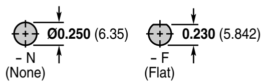


Dimensions in inches (millimeters)

Cable Options	
Part #	Description
– FL	18" Flying Leads
– 10	10 ft. Cable

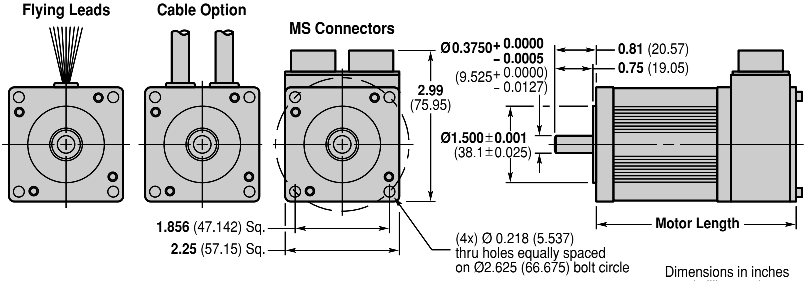
Longer lengths available
Consult Compumotor for information

Shaft Options



Motor Sizes	
Motor Length	Model
4.79 (121.66)	162 Motor
3.79 (96.27)	161 Motor

Motor Dimensions: Compumotor SM Series, Size 23

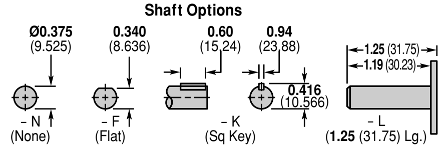


Dimensions in inches (millimeters)

Cable Options	
Part #	Description
– FL	18" Flying Leads
– 10	10 ft. Cable

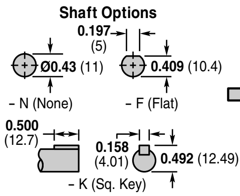
Longer lengths available
Consult Compumotor
for information

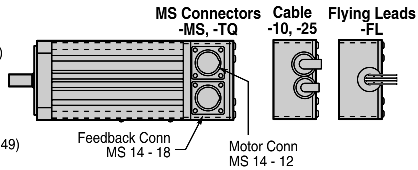
Shaft Options



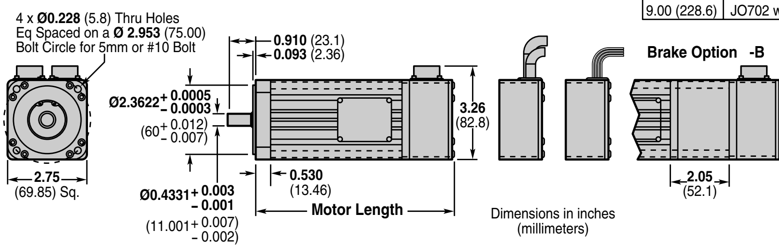
Motor Sizes	
Motor Length	Model
5.98 (151.89)	233 Motor
4.98 (126.49)	232 Motor
3.98 (101.09)	231 Motor

Motor Dimensions: NeoMetric & J Series, Size 70

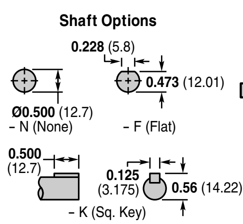


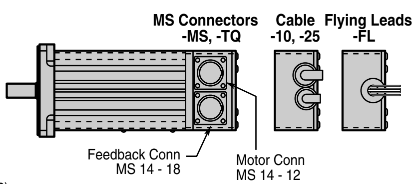


Motor Sizes	
Length	Model
4.94 (125.5)	NO701
5.94 (150.9)	NO702
5.94 (150.9)	JO701
6.94 (176.3)	JO702
7.00 (177.8)	NO701 w/Brake
8.00 (203.2)	NO702 w/Brake
8.00 (203.2)	JO701 w/Brake
9.00 (228.6)	JO702 w/Brake

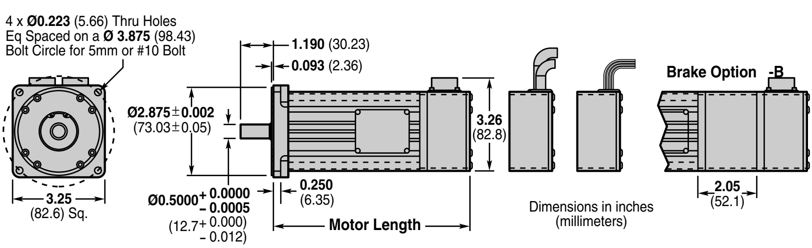


Motor Dimensions: NeoMetric & J Series, Size 34





Motor Sizes	
Length	Model
4.94 (125.5)	NO341
5.94 (150.9)	NO342
5.94 (150.9)	JO341
6.94 (176.3)	JO342
7.00 (177.8)	NO341 w/Brake
8.00 (203.2)	NO342 w/Brake
8.00 (203.2)	JO341 w/Brake
9.00 (228.6)	JO3422 w/Brake



Encoder Specifications

The same type of encoder is used on all SM and NeoMetric Series motors. Encoders have either 500 lines ("-D") or 1000 lines ("-E).

Mechanical	
Accuracy	±2 min of arc
Electrical	
Input power	5 VDC ±5%, 135 mA
Operating frequency	100 kHz max
Output device	26LS31
Sink/Source, nominal	20 mA
Suggested user interface	26LS32

Hall Effect Specifications

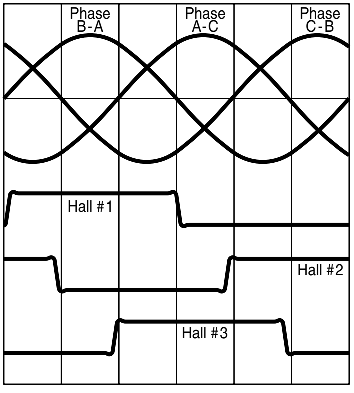
Specifications for Hall effect outputs on SM and NeoMetric Series motors are listed below.

Electrical	
Input power	5 VDC ±5%, 80 mA
Output device, open collector	LM339
Maximum pull up	12 VDC
Sink	16 mA

COMMUTATION CHART

This chart shows the relationship between motor back EMF and Hall state.

Clockwise rotation as viewed from front shaft.



Motor Wiring Information

SM Motors – Size 16 and Size 23

Motor Phase

Designation	-MS Option Pin No. MS14-12	-TQ Option Pin No. MS14-12	-H Option Pin No. MS14-12	-FL Option -10 Option -25 Option Wire Color
Phase A	J	J	J	Red/Yellow
Phase B	K	K	K	White/Yellow
Phase C	L	L	L	Black/Yellow
Ground	M	M	M	Green/Yellow
Shield	NC	NC	NC	—
Temp	G	G	G	Orange/Yellow or Yellow
Temp	H	H	H	Orange/Yellow or Yellow

Encoder

Designation	Pin No. MS14-18	Pin No. MS14-18	Not Applicable	Wire Color
Vcc	H	H	—	Red
Ground	G	G	—	Black
CH A+	A	A	—	White
CH A-	B	B	—	Yellow
CH B+	C	C	—	Green
CH B-	D	D	—	Blue
Index +	E	E	—	Orange
Index -	F	F	—	Brown
Shield	NC	NC	—	—

Hall-effect

Designation	Pin No. MS14-18	Pin No. MS14-12	Pin No. MS14-12	Wire Color
Hall GND	K	F	F	White/Green
Hall +5	M	B	B	White/Blue
Hall 1	T	C	C	White/Brown
Hall 2	U	D	D	White/Orange
Hall 3	P	E	E	White/Violet

Wiring color is provided for flying lead or cable versions.

NeoMetric & J Series Motors – Size 070 (Size 034)

Motor Phase

Designation	Pin No. MS14-12	Wire Color
Phase A	J	Red/Yellow
Phase B	K	White/Yellow
Phase C	L	Black/Yellow
Ground	M	Green/Yellow
Shield	NC	—
Continue for "H" or "TQ" Options		
Temp	G	Orange/Yellow or Yellow
Temp	H	Orange/Yellow or Yellow
Hall GND	F	White/Green
Hall +5	B	White/Blue
Hall 1	C	White/Brown
Hall 2	D	White/Orange
Hall 3	E	White/Violet

Encoder/Commutation Connections

Designation	Pin No. MS14-18	Wire Color
Encoder		
+5 VDC	H	Red
Ground	G	Black
CH A+	A	White
CH A-	B	Yellow
CH B+	C	Green
CH B-	D	Blue
Index +	E	Orange
Index -	F	Brown
Commutation		
Hall GND	K	White/Green
Hall +5	M	White/Blue
Hall 1	T	White/Brown
Hall 2	U	White/Orange
Hall 3	P	White/Violet
Temp	L	Orange/Yellow or Yellow
Temp	N	Orange/Yellow or Yellow
Brake Option		
Brake[1]	R	Red/Blue
Brake[1]	S	Red/Blue

[1] Brake will operate regardless of polarity of connection.

CHAPTER 4

Special Internal Circuits

The OEM770 has several internal circuits that can protect the drive, protect equipment connected to the drive, or change the drive's performance characteristics.

Four of the built-in circuits work automatically. Their performance cannot be changed or altered.

- Short Circuit Protection
- Undervoltage
- Overvoltage
- Overtemperature

Two of the circuits use removable resistors in sockets. You can change these resistors to alter the circuit parameters.

- Response Circuit
- Current Foldback Circuit

This chapter explains the performance of these circuits.

SHORT CIRCUIT PROTECTION

The OEM770 continuously monitors the current it sends to the motor. If it detects excessive current, it interprets the excessive current as a short circuit fault in the motor or cabling. The OEM770 disables then its power output to the motor terminals—Phase A, Phase B, and Phase C.

To show that a short circuit fault has occurred, the drive illuminates the red LED, turns off the green LED, and causes the fault output (pin 9) to go high. Other power outputs—Hall +5, +15VDC, -15VDC—remain on.

The short circuit fault is a *latched* condition. Latched means that the output will remain off until power is cycled. To *cycle power*, turn off the power to the drive, wait approximately 30 seconds, then turn on the power.

The other power outputs (Hall +5, +15VDC, -15VDC) are also short circuit protected.

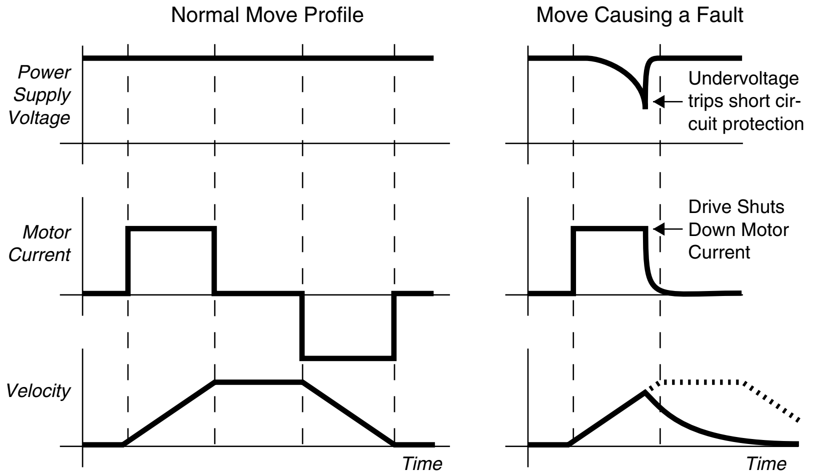
Short circuit protection features are summarized below.

- Power to motor is turned OFF
- Red LED is turned ON (Illuminated)
- Green LED is turned OFF (Not Illuminated)
- Fault output goes HIGH
- Latched
- Hall +5, +15VDC, -15VDC remain powered
- Hall +5, +15VDC, -15VDC are also short circuit protected

(*Troubleshooting Note:* Other faults will also turn on the red LED, but they leave the green LED illuminated. Short circuit protection is the only fault that will turn off the green LED when it turns on the red LED.)

A short circuit fault is not the only event that can trigger this circuit. A power supply fault can also trigger short circuit protection. The fault can occur if the supply is undersized, and cannot provide enough power during demanding move profiles.

The next drawing shows graphs for motor current and power supply voltage during a normal move profile.



Power Supply Fault

The drawing also shows what happens to voltage if the power supply is inadequate. During the first part of the move, energy stored in the power supply (in the capacitors, for example) can provide power for the move. As this energy is used up, the power supply cannot replenish it fast enough, and the voltage drops. If the voltage gets too low, short circuit protection is turned on, and shuts down motor current. At this point the power supply no longer needs to provide power to the drive. It can now direct power into its own capacitors. They recharge, and the supply voltage quickly returns to normal levels.

This is a transient event. Without short circuit protection, it may go undetected. Your system's performance could be less than you expected, and you might not know why. Short circuit protection latches the drive *off* during the transient event, however. This allows you to realize there is a problem, and find the cause. Once you determine there is no short circuit in your motor or cabling, you can inspect your power supply.

If your system runs while the motor is stopped or turning slowly, but faults during demanding move cycles, then your power supply may be causing the fault because it is inadequate for the task. Consider using a larger power supply, or altering your move profile so that the move requires less power.

The same condition—a momentary power supply fault—can sometimes turn on the undervoltage circuit, rather than short circuit protection. The undervoltage circuit is explained in the next section.

There are two potential warning signals, then, to alert you about power supply problems. Short circuit protection will latch, and shut down the drive. Undervoltage protection will momentarily turn on the red LED (but not turn off the green LED), and will not latch.

UNDERVOLTAGE

The undervoltage circuit monitors power supply voltage. If the voltage falls below a threshold level—21.5VDC or less—the undervoltage circuit will illuminate the red LED, and cause the fault output (pin 9) to go high. The green LED remains illuminated.

For the OEM770T, this condition *is not latched*. If the power supply voltage rises above the threshold, the red LED turns off, and the fault output goes low.

For the OEM770SD, this condition *is latched*.

Undervoltage circuit features are summarized below.

- 21.5VDC threshold (Maximum)
- Red LED is turned ON (Illuminated)
- Green LED stays ON (Illuminated)
- Fault output goes HIGH
- Not Latched – OEM770T
  Latched – OEM770SD

The undervoltage circuit ensures an orderly startup and shutdown process. During startup, when the power supply's voltage is rising, the undervoltage circuit will not allow the drive to turn on until the voltage rises above the threshold, and there is enough power to maintain the drive's circuits. During shutdown, when the power supply voltage falls below the threshold, the circuit will turn off the drive's circuits in an orderly and systematic manner. You may see the red LED come on briefly when the drive is turned on or off. This is normal, and does not indicate a problem.

One problem situation—a power supply undervoltage fault—can trigger the undervoltage circuit. (See the power supply fault explanation above, under *Short Circuit Protection*.) An undervoltage fault can trigger either the undervoltage circuit or short circuit protection. Sometimes the undervoltage circuit will react first, and turn on the red LED and send the fault output high. At other times, short circuit protection will react first, and latch the drive off. Which circuit reacts first depends on the dynamics of the fault, and is not easily predictable.

The undervoltage circuit can help you diagnose power supply problems.

OEM770T Example: You use a 24VDC power supply to power an OEM770T. During certain parts of the move, your system's performance is less than you expect, and you notice that the red LED flashes. The flashing LED indicates that either the drive is in current foldback, or that the power supply's voltage is too low. If you monitor the fault output and notice that Pin #9 goes high when the LED flashes, you can rule out foldback. Foldback does not make the fault output go high. The problem is a power supply undervoltage fault. Try a larger power supply, or a less demanding move profile.

OVERVOLTAGE

The overvoltage circuit protects the drive from regeneration. The OEM770 monitors voltage at its motor output terminals—Phase A, Phase B, and Phase C. If the motor regenerates energy, and the voltage rises above a threshold level—95VDC ± 5VDC—the circuit will disable power output to the motor. This is a latched condition. You must cycle power to restart the drive.

The circuit also turns on the red LED, and activates the fault output. Other power outputs—Hall +5, +15VDC, -15VDC—remain on. The green LED also stays on.

Overvoltage circuit features are listed below.

- 95VDC ± 5VDC threshold
- Power to motor is turned OFF
- Red LED is turned ON (Illuminated)
- Green LED stays ON (Illuminated)
- Fault output goes HIGH
- Latched
- Motor freewheels to a stop
- Does not protect against power supply overvoltage

After an overvoltage fault, the drive does nothing to stop the motor. When it stops receiving current, the motor will freewheel to a stop. If you have components that could be damaged by a freewheeling motor, consider using an external brake.

For example, in a system that raises and lowers a load, regeneration may occur while the load is being lowered. If the regeneration exceeds the 90VDC threshold and the overvoltage circuit shuts down motor current, the motor might freewheel, and the load could plunge to the floor. To avoid damage, a brake could be employed to stop the load in the event of a sudden loss of motor torque.

CAUTION

The overvoltage protection circuit can shut down current to the motor. This can cause a sudden and unexpected loss of motor torque. The motor will freewheel to a stop. Consider using a brake to arrest motion if your system regenerates energy.

Another possible concern is power supply overvoltage. The overvoltage circuit only monitors voltage at the output terminals to the motor. It does not monitor power supply voltage. This means that the drive is not protected from a defective power supply that produces excessive voltage. To protect the drive in this situation, use a power supply with built-in overvoltage protection on its outputs, such as Compumotor's OEM300 Power Module.

OVERTEMPERATURE

The overtemperature circuit protects the OEM770 from damage due to overtemperature conditions. This circuit monitors the temperature of the drive's heatplate. A temperature rise above 50°C (122°F) will cause an overtemperature fault. The protection circuit will disable power output to the motor, turn on the red LED, and activate the fault output. This is a latched condition. Other power outputs—Hall +5, +15VDC, -15VDC—remain on.

Overtemperature circuit features are listed below.

- 55°C ± 5°C (131°F ± 9°F) threshold
- Power to motor is turned OFF
- Red LED is turned ON (Illuminated)
- Green LED stays ON (Illuminated)
- Fault output goes HIGH
- Latched
- Cool below 40°C (104°F) and cycle power to restart

The overtemperature protection circuit has built-in thermal hysteresis. This means that the OEM770 cannot operate again until it has had time to cool below approximately 40°C (104°F). Once it has cooled, you must cycle power to restart the drive.

Design Tip

Use 50°C (122°F) as the maximum heatplate temperature allowed for continuous operation of the drive. Because of manufacturing tolerances on circuit components, different OEM770 units will shut down at different temperatures in the 50°C to 60°C range (122°F to 140°F). For predictability, use 50°C (122°F) as the shutdown temperature.

Troubleshooting Note

An overtemperature fault is a sign that something is wrong with your installation. Typical causes of overtemperature faults are:

- Inadequate Ventilation (broken fan, blocked vent, etc.)
- Inadequate Heatsink (too small, missing, not cooled properly, etc.)
- Assembly mistakes (mounting screw not tight, poor thermal contact, etc.)

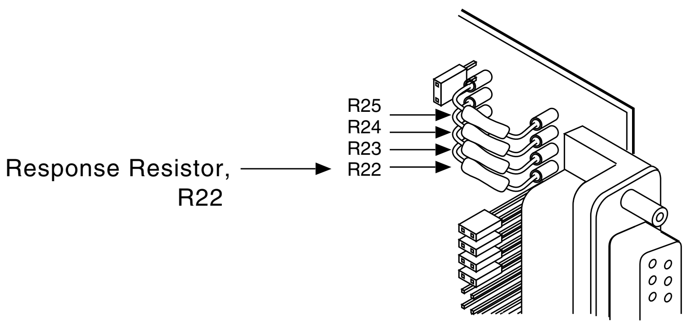
If your drive has an overtemperature fault, do not simply cool the drive, cycle power, and resume operations. Instead, find the problem that caused the fault, and fix the problem.

RESPONSE CIRCUIT

All servo motors are not the same! The inductance of different motors covers a wide range. When you select a motor for use with the OEM770, its inductance affects the gain and frequency response of the current feedback loop, and thus the performance of your system.

To accommodate the wide range of motors that customers are likely to use, the drive has a response circuit that is adjustable. You can tailor the response circuit to match your motor. This can help you achieve optimum performance.

You can adjust the response circuit by changing the response resistor, R22, on the drive's circuit board.



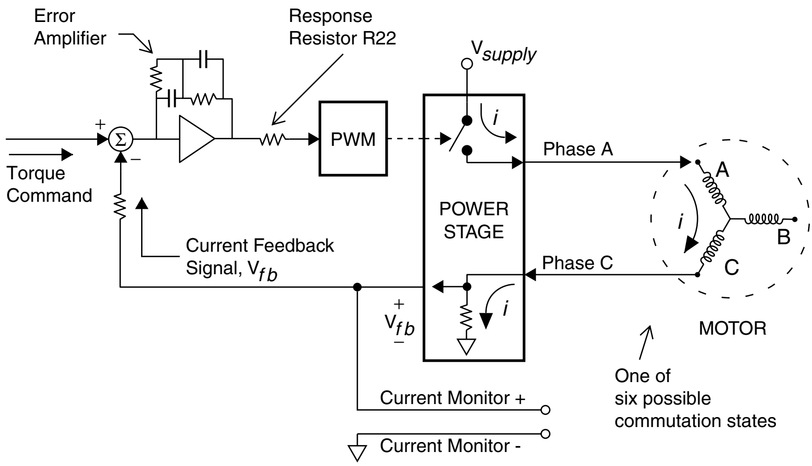
Response Resistor Location

See *Installing Selectable Resistors* in *Chapter 2 Installation* for instructions about installing a different response resistor, and for a list of resistors to use with Compumotor motors.

In the following sections, we will explain how the current feedback loop works, how motor inductance affects the loop, and how the response resistor can adjust drive performance to compensate for different motor inductances. Then, we will give detailed instructions for selecting a response resistor.

CURRENT FEEDBACK LOOP

The following section of the OEM770's block diagram shows the main components in the *current feedback loop*. This diagram shows the drive in one particular Hall state, with current flowing into phase A and out of phase C. Five other Hall states are possible. Their diagrams are similar.



Current Feedback Loop

The torque command is a signal that tells the drive how much current to produce. This desired current is called *commanded current*. It enters the loop through a summing node, where it is combined with a current feedback signal.

The feedback signal is a voltage that represents *actual current* flowing in the motor. The signal's polarity is adjusted so that it is inverted at the summing node. (Inverters and other components that accomplish this are not shown in the diagram.) This makes it a negative feedback signal. If actual current is identical to commanded current, the sum of the two signals will be zero.

If the two currents are not identical, the summing node will produce an *error signal*, which enters an *error amplifier*. This amplifier has very high gain at low frequencies, and will amplify even very small signals by a factor of thousands.

The amplified error signal next passes through the *response resistor*, which can change the level of the error signal, and thus modify the gain of the error amplifier. Higher resistor values will reduce the signal; lower values will increase it. (More information about selecting a response resistor will be given at the end of this section.)

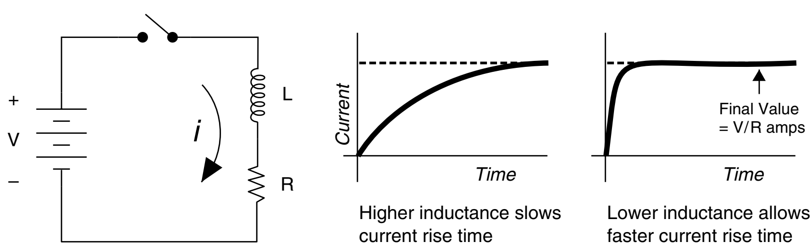
The error signal enters a *pulse width modulation* (PWM) circuit that controls the power stage. The drawing shows a simplified conceptual representation of how this control is accomplished. Voltage from a PWM pulse causes a switch to close. Current can then flow from an external power supply, through two coils of the motor, a sense resistor, and to ground. When the PWM pulse stops, the voltage controlled switch opens, which disconnects the power supply from the motor.

Together, the error amplifier, PWM circuit, and power stage form a voltage–to–current converter. A voltage that represents commanded current is converted to an actual current flowing in the motor. Longer PWM pulses will cause more current to flow; shorter pulses will cause less current to flow.

Notice that the motor current goes through a *sense resistor* before it reaches ground. The sense resistor is a current–to–voltage converter. Motor current flowing through it generates a voltage across the resistor. This voltage is proportional to actual current. It is used as the current feedback signal, v_{fb}, which is fed back to the summing node. This signal is also accessible to the user at the current monitor output.

MOTOR INDUCTANCE AFFECTS FEEDBACK

So far, we have seen that there is motor inductance in the feedback loop, but we have not discussed its significance. To understand how inductance can affect a circuit, let us first look at a very simple circuit.



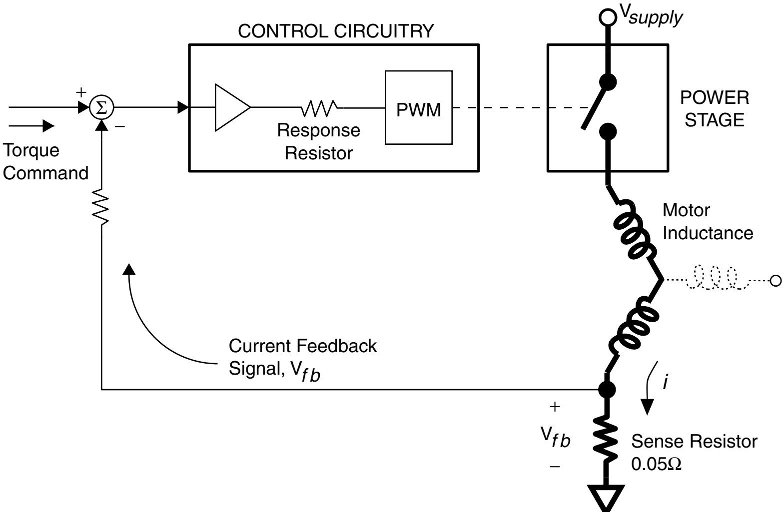
Inductance Controls Rise Time

This circuit consists of a battery, an inductor, a resistor, and a switch. When the switch is closed, current begins to flow in the circuit. The final value of the current depends on the voltage of the battery, V, and the size of the resistor, R. Its value is

$$I_{final} = V/R \text{ amps}$$

How long until the current reaches this final value? The rise time is determined by the size of the inductor. The inductor opposes the *change* in current flow. A large inductor will cause slow rise times. A small inductor will allow much faster rise times.

This circuit, although quite simple, is actually very similar to the OEM770's current feedback loop, which is redrawn below.



Inductance in Feedback Loop

Compare this circuit to the simple circuit with a battery, switch, inductor and resistor. In this circuit, the battery has been replaced with a power supply, the switch has been replaced by the power stage, the inductor has been replaced by the motor inductance, and the resistor has been replaced with a sense resistor (and motor and cabling resistance).

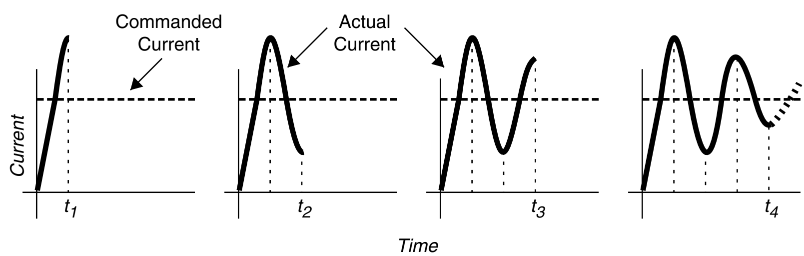
Most importantly, the switch is no longer controlled manually—it is now automatically controlled by a feedback loop. The most important control elements are shown together in the box labeled *Control Circuitry*.

In the feedback loop, commanded current is compared with actual current 20,000 times each second. After each comparison, the control circuit increases or decreases current flow by changing the width of PWM pulses. Feedback about results of the change is not instantaneous, however, because time delays are built into each step of the feedback loop. Each PWM setting is maintained for 50 microseconds, until the next comparison is made. At that time, the control circuit compares the feedback signal to the command signal, adjusts PWM pulses—and the whole process repeats.

How does motor inductance affect feedback and the current control process? We will consider several situations in which the only variable that changes is motor inductance. In each of the following examples, assume that the power supply voltage and error amplifier gain do not change.

Response with Low Inductance Motor

The first drawing shows what can happen when the motor's inductance is low.

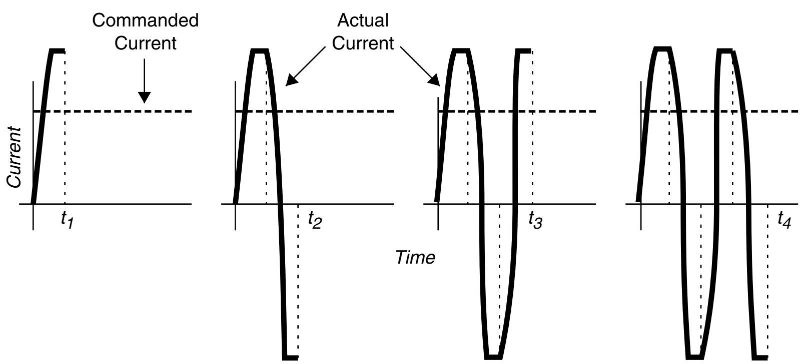


Underdamped Response

Recall that a low inductance permits a fast current rise. In this drawing, the system is given a commanded current. The drive compares actual current with commanded current, sees a large error, and directs the PWM circuit to produce maximum current. Motor inductance barely opposes current rise; because of the error amplifier's high gain, the current quickly rises to a level *higher* than commanded current.

At time t_1, the drive again compares actual with commanded current, and sees that actual current is too high. As a result, it *reduces* the power stage's current output. The change quickly results in an actual current that, at the next sample time t_2, is too low. Current is *increased*, and by the next sample point, time t_3, it is once again too high. Adjustments continue in this manner, and eventually the amount of actual current settles near the commanded current level.

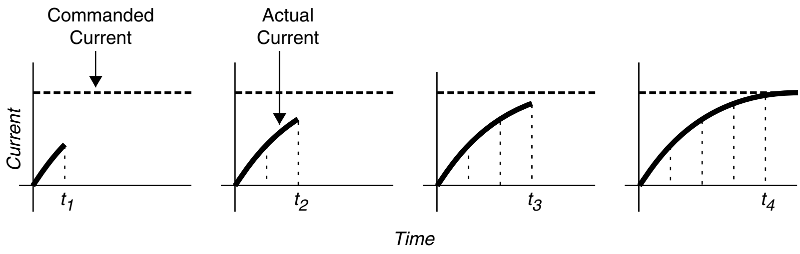
This type of response is called an *underdamped* response. For a given loop gain and power supply voltage, the main component influencing this response is the inductance of the motor. If the inductance is *very* low, the system can oscillate, with actual current never settling near commanded current. The next drawing shows this case.



Oscillating Response

Here we see that current rise is so fast that the current output saturates at its maximum level before each successive sample. With 12A set as the maximum current, for example, actual current will oscillate between +12A and -12A. The motor will probably not turn—it can not respond as fast as the quickly changing currents—but it may become excessively hot due to the oscillating currents.

Response with High Inductance Motor
Next, we consider the effects that a high inductance motor has on the feedback loop. The drawing below shows the *overdamped* response that is typical with high inductance.

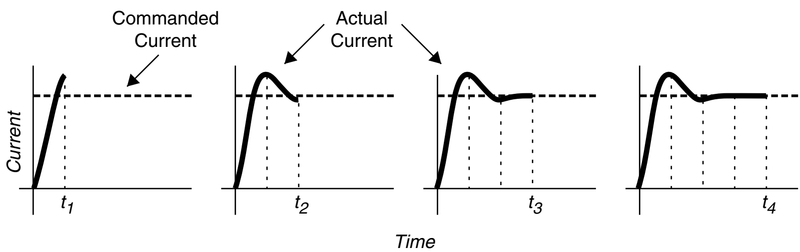


Overdamped Response

We see that actual current slowly rises to meet commanded current. The high inductance limits the current rise so much that by times t_1, t_2, and t_3, actual current is still too low. In overdamped situations, we can achieve very good control, with no overshoot—but the response time is very slow.

Optimum Response

What type of response, then, is best? We want a fast current rise, so the system can quickly get to the commanded current level. But, the rise should not be so fast that the system repeatedly overshoots, and is underdamped. The next drawing shows an *optimum* response.



Optimum Response

In this example, the motor's inductance is well matched with the gain and timing of the current feedback loop. The inductance allows a fast current rise—but just fast enough so that, when the actual current level is rising past the commanded current level, it is time for the next sample. The control circuit compares commanded with actual current, and makes an adjustment. There is little overshoot, with a minimum settling time before actual current reaches commanded current.

If you change one component in this well-matched system—motor inductance, for example—you may need to adjust some other component to maintain the system's optimum response.

SELECTING A RESPONSE RESISTOR

In the previous section, we discussed the effect different motors have on the drive's response. Once you have chosen a motor, the inductance in your system is fixed—it is no longer a variable. To adjust the response of your system for the motor you have chosen, you can install the correct response resistor.

If yours is a Compumotor motor, use the response resistor recommended for your motor in *Installing Selectable Resistors* in *Chapter 2 Installation*. If yours is a non-Compumotor motor, examine the motor specification tables for Compumotor motors in *Chapter 3 Specifications*; find a motor with inductance and resistance similar to yours, and use the resistor recommended for that motor. In either case, you may have to make further adjustments as described below.

Once you have chosen a resistor, there are three possibilities for what to do next, based upon the response of your system.

- OPTIMUM RESPONSE – Use the resistor you have chosen.
- UNDERDAMPED RESPONSE – Use a higher value than the resistor you have chosen.
- OVERDAMPED – Use a lower value than the resistor you have chosen.

We will discuss each of these options below, and show a method for viewing response waveforms on an oscilloscope.

Optimum Response

If your system has an optimum response with the resistor you have chosen, no further adjustments are necessary.

Underdamped Response

To optimize if your system is underdamped, use a resistor whose value is *larger*. The increased resistance will reduce the gain of the error amplifier, and diminish the signal that goes into the PWM circuit. Consequently, the power stage will be on for a shorter period of time, current rise will be slowed, and damping in your system will be increased.

Overdamped Response

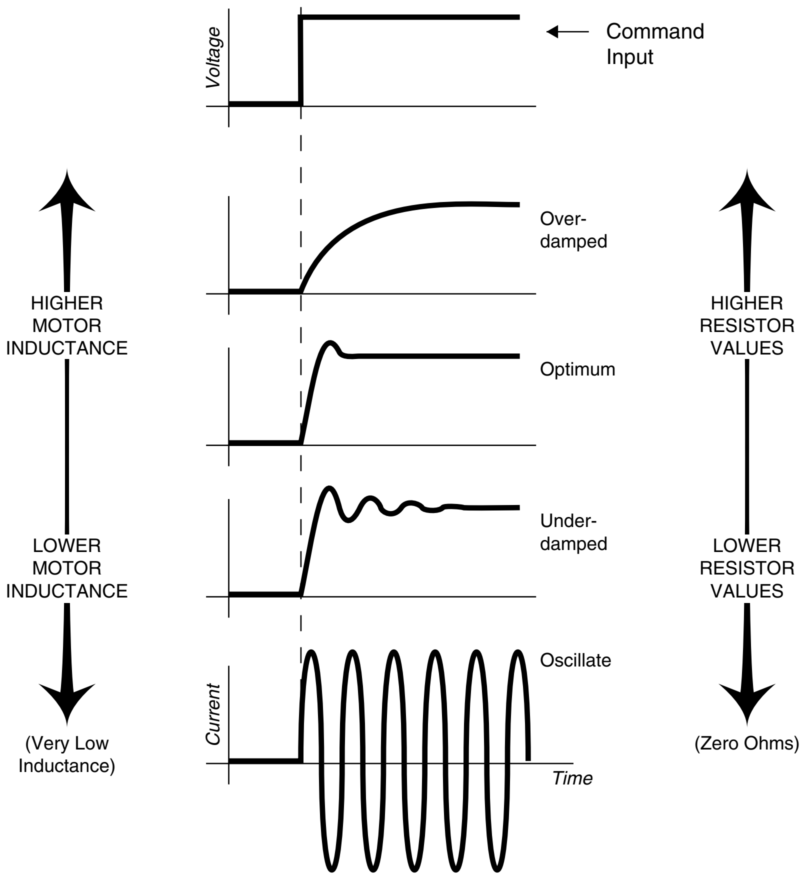
To optimize if your system is overdamped, use a resistor whose value is *smaller*. With less resistance, the error amplifier's gain will be higher, a larger signal will reach the PWM circuit, and the power stage will stay on longer. More current will flow, which will cause a faster current rise. The system will have less damping, and will respond more quickly.

A Graphical Representation

The next drawing provides a visual summary of effects you can expect from changing either the motor inductance or the response resistor.

Arrows on the left side of the drawing show the effects of changing the motor inductance while keeping other components unchanged. Increasing the inductance will cause overdamping; decreasing the inductance will cause underdamping.

Arrows on the right side of the drawing show the effects of changing the response resistor while keeping other components unchanged. Increasing the resistance will make your system overdamped; decreasing the resistance will make it underdamped.

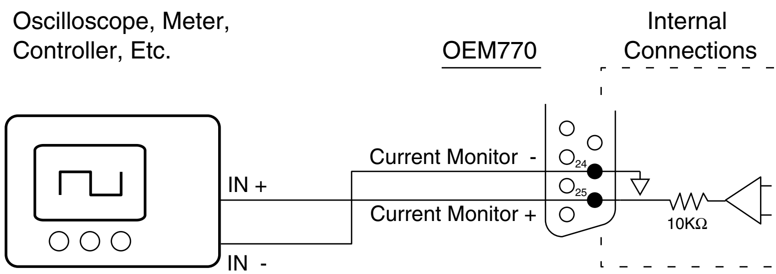


Response Waveforms

Viewing the Response Waveform

You can view your system's response waveforms on an oscilloscope, and compare them to the drawings we have presented throughout this section.

Connect an oscilloscope to the drive's current monitor output, as shown in the next drawing.



Current Monitor Output Connections

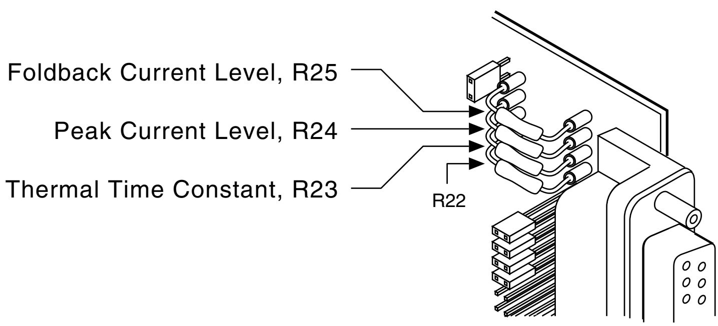
From the picture on your oscilloscope screen, you can see if your system is overdamped or underdamped. If necessary, change the value of the response resistor to improve performance. Monitor the waveforms until you get the response you want.

CURRENT FOLDBACK

A mechanical jam in a servo system can cause the motor to overheat. In contrast to a stepper motor, which does not run hotter when jammed, a servo will apply full current (for full torque) while it attempts to move as commanded. Usually, this current will be *much* higher than the motor can withstand continuously. If it persists indefinitely, it may damage the motor's windings.

To help protect the motor from overheating, the OEM770 has a *current foldback* circuit. If high motor current continues for too long, the circuit reduces the current to a lower level, which decreases the rate of motor heating.

You can adjust the foldback circuit by changing three resistors on the drive's circuit board—R23, R24, and R25.



Foldback Resistor Locations

See *Installing Selectable Resistors* in *Chapter 2 Installation* for an explanation on how to change foldback resistors.

You have two options for choosing resistors for current foldback:

- Select resistors to use with Compumotor SM and NeoMetric Series motors.
- Select resistors to use with motors from other vendors.

The following sections will explain when you should use foldback, how the current foldback circuit works, and how to choose resistor values.

When Do You Need Foldback?

If you have properly sized the motor for your application, and you use a controller that can detect a mechanical jam, *you do not need foldback*. The controller can protect the motor more quickly and completely than a foldback circuit can. It can also keep the machine from producing bad parts, which sometimes happens when one axis folds back and others continue to run normally.

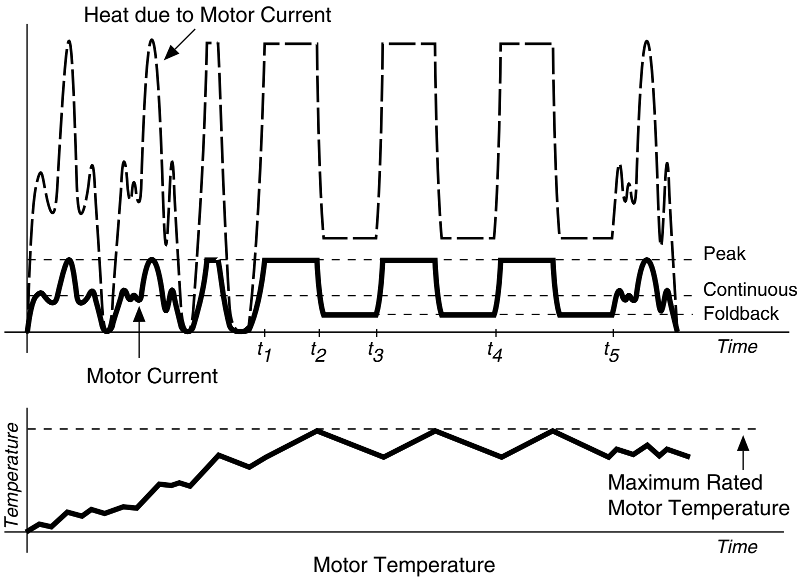
In the most common method of detecting a jam, the controller shuts down the system if the actual position is significantly different from the commanded position. All servo applications should include a position error shutdown, if possible.

If your controller cannot detect a jam, or if you need to limit peak torque in your system, you should use the foldback circuit.

Current Foldback—How Does It Work?

The OEM770 does not directly measure motor temperature. Instead, it uses an electrical circuit to model the motor's thermal performance. Actual current flows in the motor; a replica of the actual current flows in the foldback circuit. Current in the motor is converted to heat, and the motor temperature rises; current in the foldback circuit charges a capacitor, and the voltage on the capacitor rises. The drive uses the capacitor voltage to represent motor temperature.

The following drawing shows the relationship between current, heat, and temperature in the motor. (For clarity, only positive motor currents are shown.)



Current Foldback

The current waveforms for several moves are shown. The rotor becomes locked at time t_1, and peak current flows in the motor (for maximum torque). Current is converted to heat, and the motor temperature rises. When the temperature reaches the motor's maximum rating at time t_2, the foldback circuit takes control, and reduces motor current to a lower level. The motor can then cool down.

At times t_3 and t_4, the foldback circuit permits full current to flow again. Because the rotor is still locked, the foldback cycle repeats. By time t_5, however, the rotor has been released. Normal operations can now continue. (*Note*: Sometimes when the drive goes into foldback, it stays in foldback until the command input voltage is reduced. The system's parameters determine whether the drive goes in and out of foldback, as shown in the drawing above, or stays in foldback.)

While the rotor was locked, the foldback circuit reduced the rate of motor heating.

Notice the relationship between current, heat, and motor temperature. Current is converted to heat in the motor. The heat's magnitude is proportional to the *square* of the current. As this heat is dumped into the motor, the motor's temperature rises. The temperature is the accumulation, over time, of the net heat in the motor. It is also proportional to the square of the motor current.

You can match the foldback circuit to your particular motor and application by selecting three resistors. The following sections describe the function of each resistor.

Peak Current: I_{pk}, R24

Peak current is the maximum current the OEM770 will produce in the motor. You can set it as high as 12 amps. For Compumotor SM motors with "A" windings, and NeoMetric motors with "D" or "E" windings, recommended peak currents are in the 6 – 10 amp range.

In applications where you wish to limit peak current, or the peak torque applied to mechanical assemblies, use R24 to reduce the peak current the drive supplies to your motor.

Foldback Current: I_{fold}, R25

When the foldback circuit takes control, it reduces motor current to a lower level, which is called the *foldback current.* R25 sets the foldback current level.

To ensure that the rate of motor heating is reduced, the foldback circuit enforces a limited duty cycle between operations at high current and operations at foldback current. The *average* power in the motor during this period is approximately equal to the power that would be produced if the motor operated at its rated continuous current level for the same period of time.

The motor's continuous current rating specifies the maximum current at which the motor can run indefinitely without overheating. Try to match your motor's current rating to your application and operating conditions.

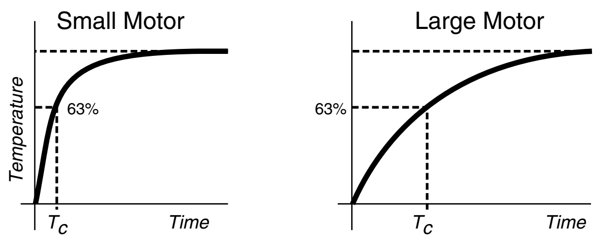
If you use R24 to limit peak current, be sure to also change R25, so that the foldback current is lower than the peak current.

Thermal Time Constant: $T_{c\text{-}therm}$, R23

Every motor has its own particular winding-to-stator time constant. This is the time it takes for the *motor winding* to reach 63% of its equilibrium temperature, after application of rated current. The time for the *motor case* to reach equilibrium temperature is different, and is usually much longer.

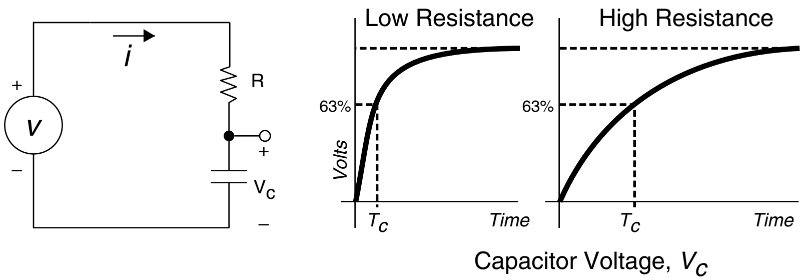
Small motors usually have much shorter time constants than large motors. Heat dumped into a small motor causes a fast rise to the equilibrium temperature. A large motor has a much greater thermal mass—consequently, the same quantity of heat will cause a much lower temperature rise. The large motor can absorb heat over a longer period of time before it reaches its maximum rated winding temperature.

The next drawing shows time constants for a small motor and a large motor.



Motor Time Constant

The drive uses an electrical circuit to model the motor's thermal characteristics. The next drawing shows the part of the circuit that models the motor's thermal time constant.



Foldback Time Constant

In this circuit, the voltage source υ is proportional to heat in the motor.

$$\upsilon \propto (I_{replica})^2 - (I_{foldback})^2$$

where

$I_{replica}$	is a scaled replica of the motor current
$(I_{replica})^2$	represents heat entering the motor
$(I_{foldback})^2$	represents heat leaving the motor

υ_c, the voltage on the capacitor, represents motor temperature. R23 controls how fast υ_c can change.

If you select an appropriate value for R23, the *RC* time constant of the circuit will match the thermal time constant of your motor. In the drawing above, the two graphs on the right show that a low resistance produces a time constant similar to a small motor's time constant; a high resistance gives a longer time constant, similar to that in a large motor.

R23, therefore, controls the time constant in the foldback circuit. It is scaled to one second per megohm. Very small motors should use a lower (faster) value for R23. For larger motors that need peak power for long acceleration times, you can increase R23 to as high as 10 megohms. Values higher than this are not recommended.

These points are summarized below.

- SCALING: 1 sec per MΩ
- MAXIMUM: 10 MΩ

Notice that the time constant *averages* the flow of heat in the motor. This means that previous circuit behavior will affect foldback. If the motor has been working hard, then suddenly demands peak current, the time to foldback will be short. On the other hand, if the motor has been idle much of the time, its average heat will be low. The circuit will recognize this—if the motor demands peak current, the time before foldback occurs will be longer.

As a general guideline, if you reduce R23 by half, then time to foldback will be cut almost in half.

RESISTOR SELECTION

The following sections describe three application situations.

- High Torque Permitted / Controller Can Detect a Jam
- High Torque Not Permitted
- Controller Cannot Detect a Jam

To select foldback resistors, determine which of the situations apply to your system, and follow the instructions in the relevant section below.

High Torque Permitted/Controller Detects Jam

If your mechanical system can withstand the peak torque of your motor with 12 amps in it, and your controller can detect a jam, you can probably use the resistors in the table below. These resistors allow 12 amps peak current for 0.5 – 2 seconds before foldback occurs (depending on the level of current *before* the peak), and will allow currents up to 6 amps continuously.

Foldback Resistors for 12A Peak, 6A Continuous

Res. #:	Function	Resistor Value	Current
R25	Foldback Current	23.7 KΩ	6A
R24	Peak Current	Ø Ω	12A
R23	Time Constant	5.1 MΩ	

To verify that these resistors are suitable for your application, test your system as described below.

If you experience undesired foldback (red LED lights, but goes out when the command input voltage is reduced), the foldback circuit can be disabled by replacing R25 with a 0 – 10 ohm resistor. Even with foldback disabled, you can still limit peak current (and thus peak torque), by installing an appropriate resistor value for R24, I_{pk}.

High Torque Not Permitted

If your mechanical system cannot withstand the peak torque that the OEM770 can produce, you can limit peak current, and thus peak torque, with R24. See the *Peak Current* table below for appropriate resistor values.

Controller Cannot Detect a Jam

If your controller *cannot* detect a jam, you should determine foldback resistor values appropriate for your application and install them in your drive. When a jam occurs with these resistors installed, the OEM770 will reduce the motor current to a lower level. *(OEM770SD only:* see *CPE – Position Error Limits* in *Chapter 2 Installation*. If the drive does not detect a jam soon enough with position error limits set, then install foldback resistors.)

This mode of operation greatly reduces the rate of motor heating, and allows more time for the machine operator to notice that there is a problem and shut the system down. As a warning to the operator, the red LED on the front panel will be illuminated while the drive is in foldback.

If you use Compumotor servo motors, the table *Resistors for SM and NeoMetric Motors* in *Chapter 2 Installation* lists suggested resistors for you to use.

These values will be appropriate for most applications. However, there are many variables that affect the actual motor operating temperature (see the list below in *Application Conditions Affect Foldback*). You may need to adjust these resistors further.

The next table gives resistor values for specific peak currents and foldback currents.

R24, PEAK CURRENT		**R25, FOLDBACK CURRENT**	
I_{pk} (*amps*)	R24	I_{fold} (*amps*)	R25
3	845 KΩ	2	1.2 MΩ
4	450 KΩ	3	124 KΩ
5	348 KΩ	4	53.6 KΩ
6	249 KΩ	5	36.5 KΩ
7	182 KΩ	6	26.1 KΩ
8	124 KΩ	7	18.7 KΩ
9	86.6 KΩ	8	13.3 KΩ
10	56.2 KΩ		
12	Ø Ω		

A starting point for I_{fold} is to choose R25 so that the foldback current is 70% of the motor's continuous current rating.

If you experience "nuisance" foldback where the current is reduced, but the motor is not too hot and no jam exists, try increasing the foldback current.

To disable current foldback, replace R25 with a 0 – 10 ohm resistor. You can still specify peak current with R24—but the drive will never reduce current with R25 below 10 ohms.

Application Conditions Affect Foldback

The foldback circuit is well defined, but it is a simplified, approximate model of what actually occurs in the motor. Circuit limitations and differences in application conditions can cause widely varying results.

Some conditions that affect motor temperature are:

- Ambient temperature
- Air flow on the motor
- Heatsinking of motor (size, composition, and temperature of the motor mounting surface)
- Move profile and duty cycle
- Motor core losses

Other conditions may be important in your system.

Because many variables affect motor temperature, we recommend that you treat the suggested resistor values as a starting point in developing your thermal management strategy. You may need to determine the best values empirically. For optimum motor protection, choose values as conservatively as possible. Finally, test your system as described below.

Application Examples

If you have a load that is primarily frictional (for example, a spindle drive), you can set the peak current limit resistor, R24, to a value that will keep the current below the continuous current rating of your motor. This will ensure that the current cannot exceed the motor's rating. Check the motor temperature under actual operating conditions.

If you have a load that is primarily inertial (for example, a point-to-point move with low friction), you can set the foldback current resistor, R25, to a low value that will protect against a jam but still allow full peak current for the acceleration portion of the move. If the move duty cycle is low, the overall average power will also be low, even though the peak power may be quite high. Therefore, you can use a low foldback current setting.

TEST YOUR SYSTEM

Once you have selected and installed foldback resistors, you should perform two tests to verify that the foldback circuit adequately protects your motor.

- Measure Motor Temperature
- Simulate a Jam

These tests are described below.

Measure Motor Temperature

Measure the motor case temperature under actual operating conditions. Make your measurements after the motor temperature has reached equilibrium (which can take several hours). Compare the results with the motor's ratings.

Compumotor servo motors have an internal thermoswitch, with normally closed contacts. If the motor windings exceed predetermined temperature levels, the contacts will open. Monitor the thermoswitch to verify that the contacts remain closed during operating conditions.

Simulate a Jam to Verify Resistor Values

Set controller position-error shutdown limits to appropriate values. To avoid motor overheating, follow these steps:

1. With foldback resistors installed, start your test with a cold motor. Command full current while you simulate a jam.

3. Monitor the red LED. It will illuminate when the drive goes into foldback. ***Do not overheat the motor!*** If the drive does not go into foldback when you expect it to, stop the test immediately.

4. Monitor the fault output. It should be low at the start of your test, and should remain low when the drive goes into foldback. (Foldback is the only condition where the red LED illuminates, but the fault output is low.)

5. Watch to see that the drive comes out of foldback, indicated by the red LED turning off. If the drive does not come out of foldback on its own, reduce the command input voltage; the red LED should then turn off.

The results of your test indicate how much time an operator has to shut down the system in the event of an actual jam.

HOW LONG WILL FOLDBACK PROTECT YOUR SYSTEM?

Ideally, foldback should prevent the motor from overheating under all conditions of improper application. In practice, because of the many variables affecting motor temperature, foldback can only *delay* motor overheating. This will allow more reaction time for an operator or control system to detect that the machine is jammed.

With foldback, the time before motor overheating occurs can be increased from a few minutes to 10 – 30 minutes for large motors, or from seconds to 1 – 2 minutes for small motors.

The degree of expected operator attention is also a factor. If the machine will be running unattended, we strongly recommend you use a controller that can detect a jam. (For the OEM770SD, we recommend you set tight position error limits.)

If your controller cannot detect a jam, use a conservative approach and select foldback resistors that limit worst-case motor temperature to a safe value for an indefinitely long period of time.

If the machine operator is nearby and will notice within a reasonable period of time that the machine is jammed, you can use a more aggressive approach to selecting resistors. Different resistors may allow higher motor performance, yet still limit the rate of rise of motor temperature so that the operator has time to react, and shut the machine down.

C H A P T E R 5

Hall Effect Sensors

The OEM770 works with three-phase brushless motors equipped with Hall effect sensors or equivalent feedback signals. In this chapter we will explain how Hall effect sensors are used in brushless motors, and how the OEM770 uses Hall effect outputs from Compumotor servo motors for commutation.

If you are using a motor from another vendor, obtain information about your motor's Hall signals and commutation sequence. Then use the information in this chapter to help you connect your motor to the OEM770.

HALL EFFECT SENSORS AND COMMUTATION

To move the rotor in the commanded direction, the drive will send current through two of the motor's stator coils. This current produces electromagnetic fields that develop a torque on the rotor, and the rotor turns. The rotor will stop if it can reach a position where its permanent magnets are next to the magnetic fields that attract them. Before the rotor can get to this position, though, the drive switches the current to a new combination of stator coils, and creates a new set of electromagnetic fields that cause the rotor to continue its movement.

The process of continually switching current to different motor coils to produce torque on the rotor is called *commutation.*

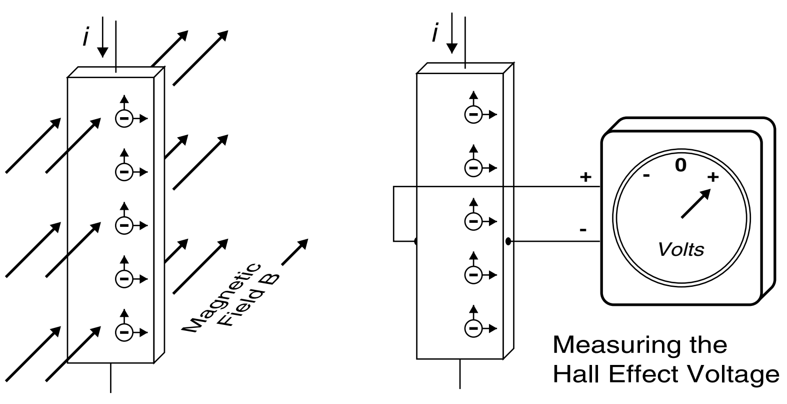
If the drive knows the position of the rotor's permanent magnets, it can set up magnetic fields in the stator that have the correct location and polarity to cause the rotor to turn. How can the drive know rotor position? Three Hall effect sensors located in the motor are affected by the rotor's permanent magnets. The three sensors transmit a unique pattern of signals for each rotor position. The drive uses these signals to determine the position of the rotor.

THE HALL EFFECT

Electrically charged particles moving through a magnetic field experience a deflecting force perpendicular to both the direction of their motion and the direction of the magnetic field.

The *Hall effect* is a phenomenon which shows that if a magnetic field is perpendicular to a thin strip of conductive material, and an electric current flows lengthwise through the strip, the mobile charges that carry the current will drift to one edge as they move along the strip.

In the example shown in the next drawing, assume that the conductive strip is metal. Electrons are the mobile charges. With a current *i* as shown in the drawing, the electrons will move upwards through the strip. In the presence of the magnetic field *B*, shown in the drawing, the electrons will drift toward the right edge of the strip.



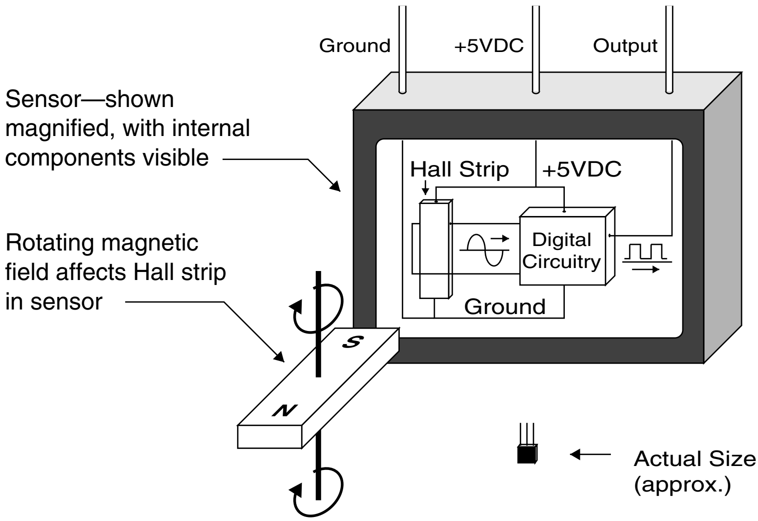
The Hall Effect

Because electrons are concentrated along one edge, there is a potential voltage difference across the strip. This voltage is known as the *Hall effect voltage*. The drawing shows a voltmeter connected across the strip to measure Hall effect voltage.

If the magnetic field is removed, the Hall effect voltage disappears. If the magnetic field is reversed, the Hall effect voltage will also be reversed.

HALL EFFECT SENSORS

Many types of sensors use the Hall effect to sense the presence of magnetic fields. The next figure is a conceptual drawing of a Hall effect sensor.



Hall Effect Sensor

A constant current runs through a conductive Hall strip inside the sensor. The drawing shows a rotating magnet near the sensor. The alternating field from this rotating magnet will cause an alternating Hall effect voltage to be generated across the strip.

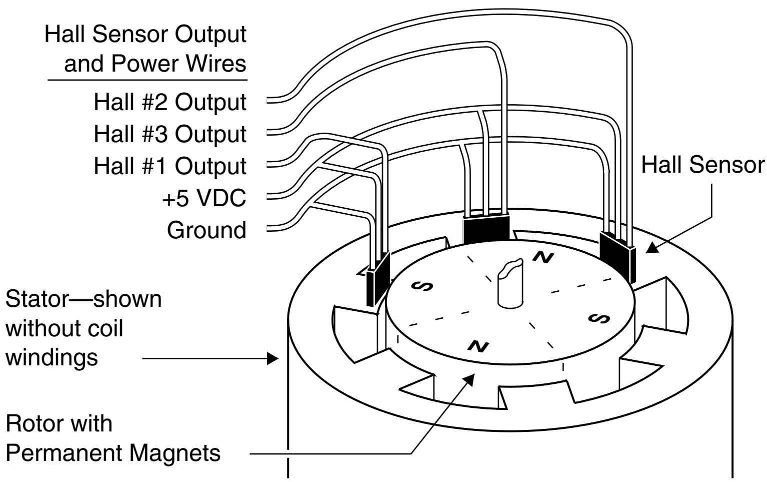
This alternating voltage waveform is fed into circuitry that shapes the waveform. The output of the circuitry is a digital signal that is either +5VDC or ØVDC.

Sensors are available with a variety of output voltages and polarities. In the following discussion, we assume that the sensor is turned ON by a south magnetic pole, and remains on after the south pole is removed. When a north magnetic pole approaches, the north pole will turn the sensor OFF.

Note from the drawing that the sensor requires power connections for its internal circuitry (+5VDC and Ground). Also note that although the actual Hall effect voltage generated inside the sensor is an analog signal, the *output* from the sensor is a digital signal that is either ON or OFF.

HALL EFFECT SENSORS USED INSIDE BRUSHLESS MOTORS

There are three Hall effect sensors inside of a motor. The next figure shows a conceptual drawing of the inside of the motor, and the three sensors.



Hall Sensor Location (Shown Mounted Above Stator Pole Faces)

For clarity, the stator is depicted in simplified form, without its coil windings. The Hall effect sensors are located at one end of the stator, near the pole faces of the rotor. They are positioned approximately as shown in the figure.

Five wires are shown for making connections to the Hall sensors. Three wires are for individual outputs. The fourth and fifth wires are for +5VDC and Ground, which are internally connected to all three sensors.

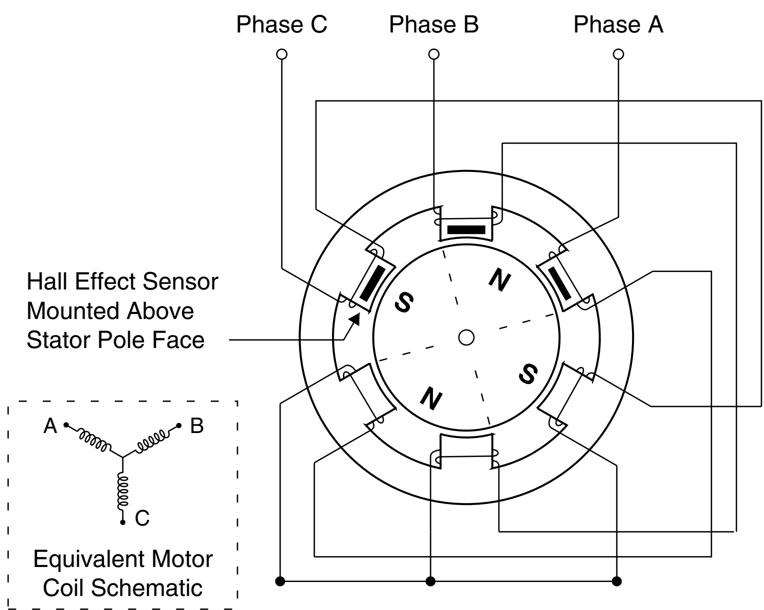
Note that Hall #3 is positioned between Hall #1 and Hall #2.

Do Compumotor Motors Have Hall Effect Sensors?

Most Compumotor servo motors do not use Hall effect sensors. Instead, the motor's encoder has an extra *commutation track*, with three outputs. These outputs mimic signals that would be obtained from Hall sensors; in fact, the outputs are called *Hall outputs*. For conceptual reasons, in the discussion that follows we assume the motor contains Hall sensors. Keep in mind that no matter how the original signals are generated—from sensors or from an encoder—the result is the same: three output wires that deliver commutation information to the drive.

WINDINGS IN A THREE PHASE BRUSHLESS MOTOR

The next drawing depicts an end view of the motor, with the separate phase windings shown in their relative positions around the stator. The three phases share a center connection, as the detail within the dotted line shows.



3-Phase Servo Motor with Hall Effect Sensors

The physical spacing of the Hall effect sensors is very important. Notice that one pole of the rotor can affect two sensors at the same time. In this drawing, the rotor's north pole is adjacent to both Hall 2 and Hall 3. Since south turns a sensor ON and north turns it OFF, the Hall outputs in this drawing would be 1ØØ. (In this example, 1 = ON and Ø = OFF. 1ØØ, therefore, means that Hall 1 is ON, Hall 2 is OFF, and Hall 3 is OFF.)

The OEM770 will send current into one phase and out of another—the third phase receives no current. When current flows through a phase, two magnetic poles of the same sign are formed on opposite sides of the motor. We will use the convention in these drawings that when current flows from the drive into a coil, it will produce a north pole. When it flows from a coil to the drive, it will form a south pole.

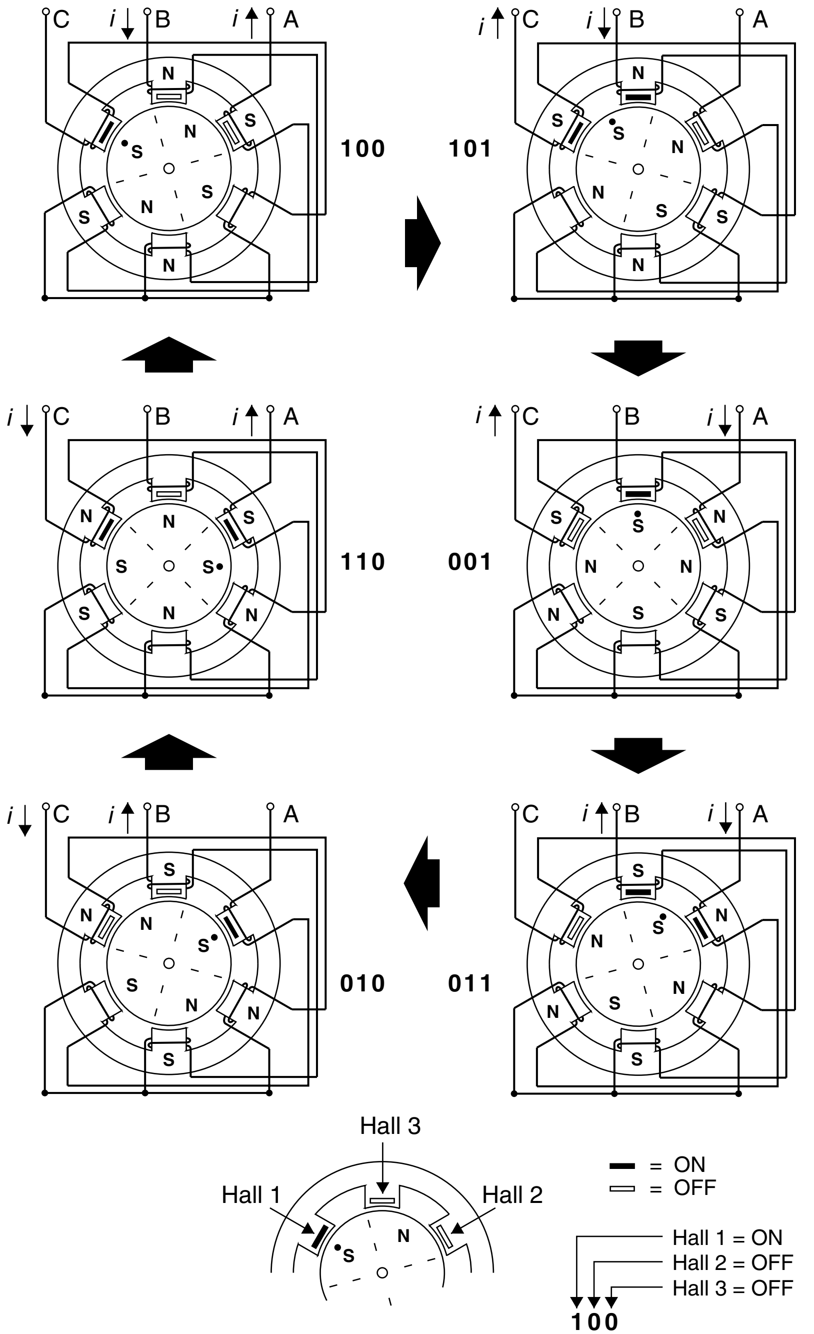
For example, suppose current goes into the motor through Phase A, and exits through Phase B. (Phase C has no current in it.) The current will flow through the windings in A and form north magnetic poles on opposite sides of the stator. The current flows through the center connection, and enters B's windings, where, because of the direction of the current, south magnetic poles are formed on opposite sides of the stator. (Refer to the previous drawing.)

From this example, notice that, although the stator has six locations for pole faces, there are only four poles at any one time. The other two pole faces have windings that carry no current—therefore no magnetic poles are formed by those windings.

THE SIX POSSIBLE HALL STATES

The next figure illustrates that, as the rotor turns, six different Hall states will be produced in a predictable and repeatable sequence.

This drawing shows the rotor, stator, phase coils, and Hall sensors. A small black dot has been drawn next to one of the south poles, to help show the motion of the rotor as it turns. (The two south poles in the rotor are actually indistinguishable from each other, as are the north poles.)



Hall Sensor States

For each of the six different rotor positions in the drawing, a current is shown that will cause the rotor to rotate in a clockwise direction. The stator is labeled with N or S, to show the magnetic fields the current produces. These fields exert the torque on the rotor that causes it to move.

Each rotor position is labeled with its corresponding Hall state (100, 101, 001, etc.). These numbers represent the three Hall sensors, and whether they are on or off. The first digit corresponds to Hall 1, the second to Hall 2, and the third to Hall 3.

What voltage levels correspond to on and off? We use the following convention:

- 1 = ON = +5VDC
- Ø = OFF = ØVDC
- Voltage is measured at the OEM770's Hall input, with the Hall wire connected to the input, and the drive turned on.
- If no drive is available, connect the Hall wire to a 1KΩ pullup resistor. Connect the resistor to +5VDC. Connect Hall +5 and Hall Gnd to your power supply. Measure the voltage at the point where the Hall wire is connected to the resistor.

To understand this drawing, examine the rotor position at Hall state 100. The south pole turns Hall 1 on. The north pole turns off Hall 2 and Hall 3. The Hall state, therefore, is 100. (Hall 1 = ON, Hall 2 = OFF, Hall 3 = OFF)

If current flows into phase B and out of phase A, north and south poles form in the stator. These poles exert a strong torque on the rotor's north pole, and it will turn clockwise.

If the rotor could turn far enough so that its north pole was aligned with the south pole in the stator, the rotor would stop. However, immediately before the rotor reaches this position, the Hall state changes. The south pole (with a dot on it, in this figure) moves into position next to Hall 3 and turns it on. The Hall state is now 101 (Hall 1 = ON, Hall 2 = OFF, Hall 3 = ON. Remember, Hall 3 is located between Hall 1 and Hall 2. See the detail at the bottom of the drawing.)

If current is now directed into phase B and out of phase C, a new set of magnetic fields forms in the stator that exert a strong torque on the rotor's south pole. The rotor moves further in a clockwise direction, and when it turns far enough, the Hall state changes to 001. At this point, directing current into phase A and out of phase C will keep the rotor turning to state 001.

The next Hall states the rotor will pass through are 010 and 110. When the south pole *without* the dot reaches state 100, a complete electrical cycle has occurred, and the rotor has rotated through 360 *electrical* degrees. (Physically, it has rotated through 180 *mechanical* degrees.) At this point, the same sequence of Hall states begins again.

Notice that the Hall states are not determined by the current flowing in the stator. They simply report information about the position of the rotor. Whether you turn the rotor by hand, or cause it to turn by directing current through the motor's coils, the Hall effect sensors are influenced only by the magnetic fields of the rotor.

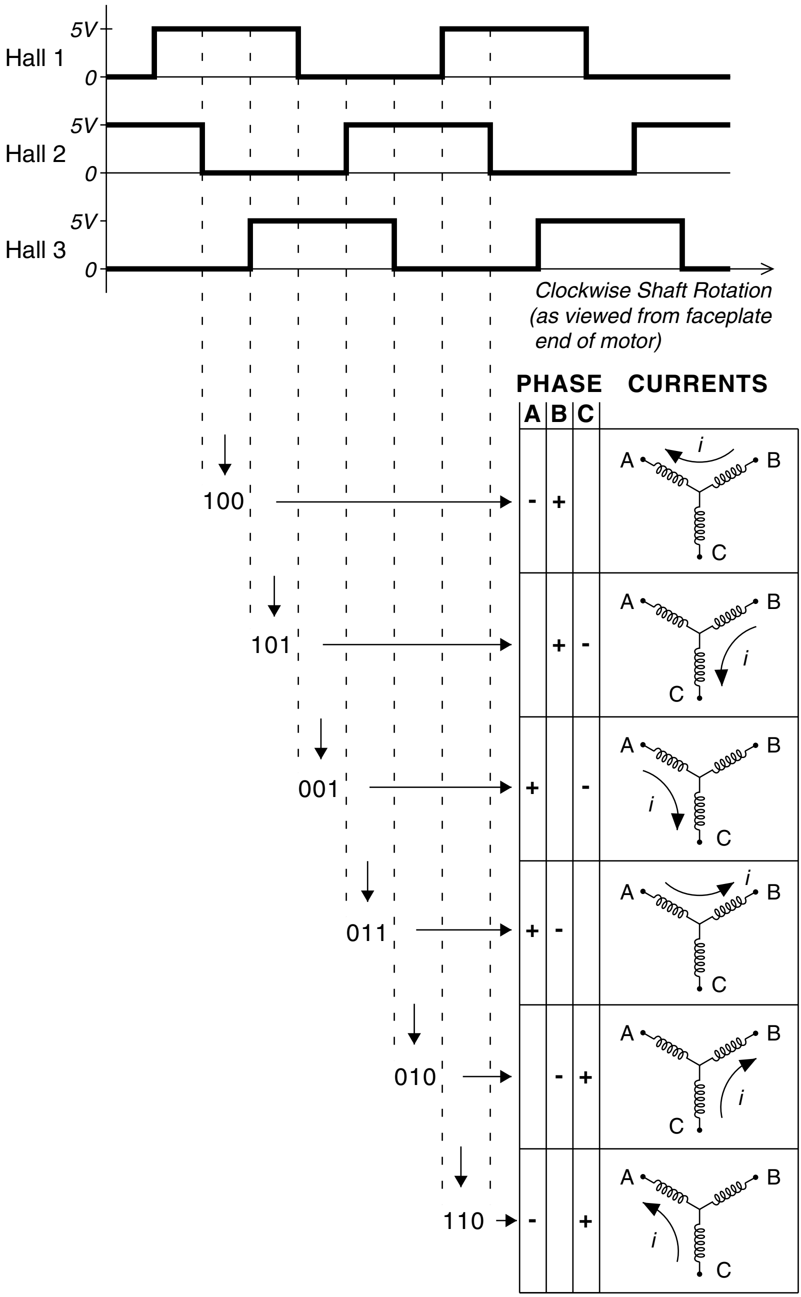
The Hall effect outputs in Compumotor servo motors divide the electrical cycle into three equal segments of 120° (*electrical* degrees, not *mechanical* degrees). Outputs used in this arrangement are called 120° Hall effect outputs. The Hall states 111 and 000 never occur in this configuration.

Another arrangement, rarely used in modern servo motors, uses a 60° Hall effect sensor configuration, in which the states 111 and 000 can occur. Do not attempt to use such a motor with the OEM770. It will not operate properly.

COMMUTATION BASED ON HALL STATES

The OEM770 monitors its three Hall inputs. It uses internal logic circuitry to assign a rotor position to each of the six Hall states, and then direct a motor current that results in rotor movement in the commanded direction.

The three Hall signals produced by clockwise shaft rotation are shown at the top of the next drawing. The Hall states are also listed, along with the table of phase currents the OEM770 uses for each Hall state.



Commutation for Clockwise Shaft Rotation—Based on Hall States

For counterclockwise rotation, two changes are made. First, as the rotor moves counterclockwise, it passes through the same Hall states, but in the opposite order. (In this drawing, read the Hall states from the bottom up for counterclockwise rotation.) The drive sends currents through the same coils shown in this picture, but the direction of the current is reversed from that shown. As a result, a torque is produced in each state that causes the rotor to turn counterclockwise.

CONNECTING MOTORS FROM OTHER VENDORS

The previous discussion described Compumotor servo motors, and how the OEM770 drive operates them. If you use a motor from another vendor, obtain information from the motor's manufacturer about its sequence of Hall states, commutation scheme, etc. Use the above information about Compumotor motors for guidance on how to connect your motor to the OEM770.

Improper Wiring Can Result in Poor Performance

Assume that you arbitrarily connect your motor's three Hall wires to the OEM770's Hall inputs. For any particular Hall wiring pattern, there are six different ways you can connect wires to Phase A, Phase B, and Phase C.

Of these six possible phase wiring combinations, only one will work properly. Three will not work at all. The other two deserve particular attention: if the motor is wired in one of these two configurations, the motor will turn, but its performance will be severely impaired.

How can you tell if your motor is wired improperly? If it is in one of the two poor-performance configurations, its torque will be much lower than the torque level of a properly wired motor. Also, torque ripple will be very pronounced as the motor turns.

The best way to determine whether or not your motor is wired correctly is to find the three wiring configurations that enable the motor to turn. Compare the motor's torque in each configuration. The configuration with the most torque will be the proper configuration.

TRIAL AND ERROR METHOD

You can use a trial and error method to connect your motor to the OEM770. Follow these steps:

1. Arbitrarily assign numbers to your motor's three Hall output wires, and connect them to Hall 1, Hall 2, and Hall 3 on the OEM770.

2. Connect Hall +5V and Hall GND.

3. Arbitrarily assign letters (A, B, C) to your motor's phase wires, and connect them to Phase A, Phase B, and Phase C on the OEM770.

4. If the motor turns, find the best phase wiring configuration:
   - Move each phase wire over one position (A B C ➔ C A B). Compare torque and torque ripple.
   - Move each phase wire one position further (C A B ➔ B C A). Compare torque and torque ripple.
   - Use the wiring configuration that gives highest torque and lowest torque ripple.

5. If the motor does not turn, exchange two of the phase wires. The motor should now turn. Go to *Step 4*, compare the three wiring configurations that make the motor turn, and use the proper one.

6. If your motor turns in the opposite direction than you want, you can reverse it using one of several methods.
   - Reverse the command input wires.
   - Reverse the appropriate encoder connections.
   - Exchange two Hall input wires, then follow *Steps 2 – 5* above.

CHAPTER 6

Power Supply Selection

To choose a power supply for the OEM770, you need to answer some important questions.

- How many watts does your system need?
- Will regeneration be a concern ?
- At what voltage should your system operate?
- Should you use a linear power supply or a switching power supply?

The sections in this chapter will help you answer these questions.

A Word About Units

We want a solution for power that is expressed in *watts*. To be consistent with watts, we will express all quantities in SI (metric) units, derived from kilograms, meters, and seconds. The quantities and units we will use are:

QUANTITY	SYMBOL	UNITS	
Torque	T	Nm	(newton meter)
Shaft Velocity	v	rps	(revs per second)
	ω	rad/s	($2\pi v = \omega$)
Shaft Acceleration	a	rps^{-2}	(revs per sec^2)
	α	rad/s^{-2}	($2\pi a = \alpha$)
Motor Resistance	Ω	ohms	
Torque Constant	k_T	Nm/A	
Current	I	A	(amps)
Inertia	J	$kg\text{-}m^2$	

If you want to use other units, apply conversion factors in the appropriate places.

HOW MUCH POWER DOES YOUR SYSTEM NEED?

The first step in choosing a power supply is to analyze your motion control system, and determine two quantities:

- Peak Power
- Average Power

Peak power is the maximum number of watts the power supply must provide during the most demanding part of the move.

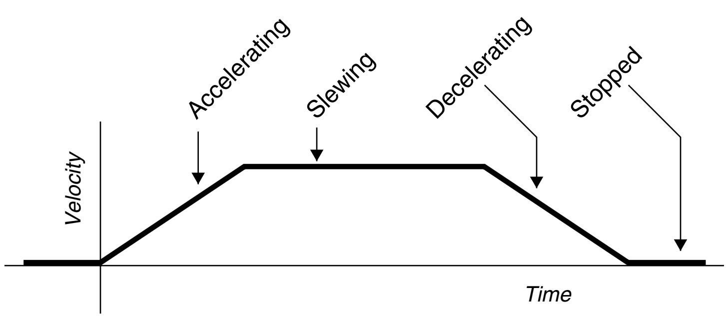
Average power is the number of watts required for a repetitive move, averaged over the entire move cycle, including time spent at rest.

In the sections below, we show several ways to determine how much power your system needs: a calculation method; a graphical method; and an empirical method.

It is not our goal to calculate power *precisely*. A full analysis of power in a servo system can be quite complicated and time consuming. Rather, our goal is to easily arrive at a reasonably accurate *estimate* of power needs, and then use this estimate for power supply decisions.

PEAK POWER—A CALCULATION METHOD

Servo applications vary widely, with many possible move profiles. We will show how to calculate power requirements for the most common move profile, a trapezoidal move.



Trapezoidal Move Profile

In the calculation method, we follow these steps:

1. Calculate power required for copper losses
2. Calculate shaft power
3. Add shaft power and copper losses, for total power
4. Add 10% to total power, for miscellaneous losses

Each of these steps will be explained below. To simplify the analysis, we make the following assumptions:

- Equal acceleration and deceleration rates
- Friction is negligible, and can be ignored

Power for Copper Losses

During the acceleration portion of a trapezoidal move, constant current in the motor produces constant torque. With a constant torque applied, the motor accelerates at a constant rate until it reaches slew velocity.

Torque is directly proportional to the current in the motor.

$$T = k_T I, \quad or \quad I = \frac{T}{k_T}$$

The proportionality constant, k_T, is called the torque constant, and is determined by the motor's physical parameters.

The current that produces torque flows through the resistance, *R*, of the motor's copper coils, and causes heat. The power to produce this heat comes from the power supply. (The coil resistance *R* may change with temperature. When you use the equations that follow, use the resistance of your motor at its actual operating temperature.)

Power converted to heat, rather than useful work, is called a *loss*. The losses resulting from current flowing in the motor's copper coils are called *copper losses*, or *I^2R losses,* so named from the formula used to calculate them:

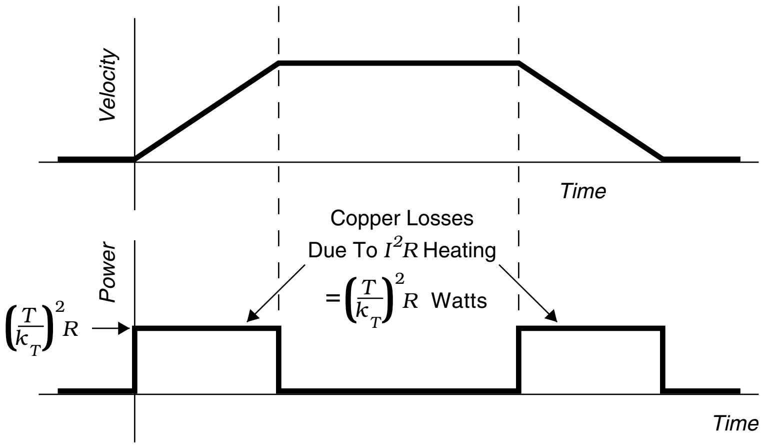
$$P_{copper} = I^2 R$$

P_{copper} represents power used for copper losses.

You can calculate copper losses, even if you do not know the motor current *I*. The following equation uses the relationship between current and torque to express copper losses in terms of torque, resistance, and the torque constant.

$$P_{copper} = I^2 R = \left(\frac{T}{k_T} \right)^2 R$$

Copper losses are shown in the next drawing.



Copper Losses

The supply must deliver power only during acceleration and deceleration. During slew with no friction, there is no torque on the motor shaft, and no motor current—consequently, there are no copper losses

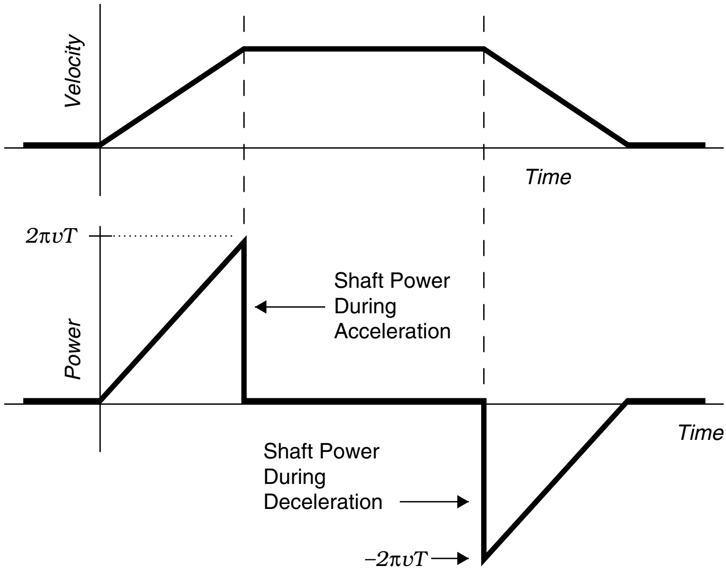
Shaft Power

A motor uses shaft power to accelerate or decelerate a load. The equation for shaft power, the product of torque and shaft velocity, is

$$P_{shaft} = \omega T = 2\pi v T$$

where P_{shaft} is shaft power, in watts.

The graph for shaft power is shown in the next drawing.



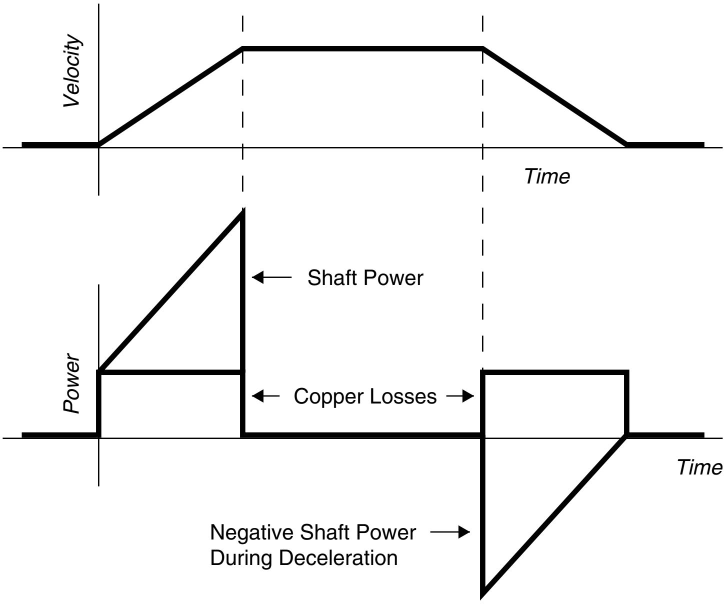
Shaft Power

Torque and velocity are both positive during acceleration. Shaft power, therefore, is also positive.

During deceleration, velocity is still positive, but torque is applied in the opposite direction, and thus is negative. Shaft power, then, is *negative* during deceleration. Negative power is *regeneration*—power flows from the motor, and back into the drive. Later in this chapter, we will discuss regeneration in detail.

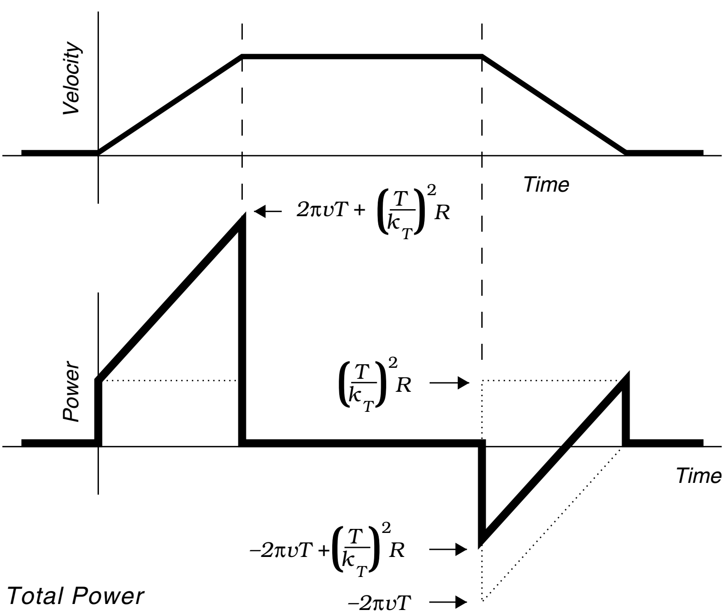
Total Power

In the next drawing, we have combined the graphs for copper losses and shaft power.



Copper Losses & Shaft Power

To obtain the total power, we can add together copper losses and shaft power. The heavy line in the next drawing shows the total power that the power supply must provide.



Total Power

The equation for power, then, at any velocity during acceleration or deceleration, is:

$$P_{total} = P_{shaft} + P_{copper} = 2\pi vT + \left(\frac{T}{k_T}\right)^2 R$$

The first term on the right represents shaft power. The second term represents copper losses.

Notice that power demand increases as velocity increases during acceleration, and reaches a peak just before the motor reaches its slew velocity. The equation for peak power is:

$$P_{peak} = 2\pi v_{slew} T + \left(\frac{T}{k_T}\right)^2 R$$

Estimation Factor

The power equations above show how much power the supply must deliver for shaft power and copper losses. There are other losses, which are usually smaller and less significant, such as:

- Drive Losses
- Core Losses
- Switching Losses

Core losses are dependent on velocity. To approximate their effect, use the power equation from above, and add 10% to it.

$$P = \left[2\pi vT + \left(\frac{T}{k_T}\right)^2 R\right](1.1)$$

For clarity and simplicity in the rest of this chapter, we will omit the 10% figure that represents miscellaneous losses. If you need more accuracy in your estimate, you should include this estimation factor.

Drive losses are not dependent on velocity. When the motor is at rest, or during slew, drive losses are approximately 5–10W.

Power Supply Current Does Not Equal Motor Current

The equation we have developed represents power that the *power supply* must deliver to the system. This is not the same as *motor power*, or *drive power*. Similarly, current from the power supply will not be the same as current flowing in the motor.

These distinctions can be confusing! To help clarify the situation, think of the equation as an accounting system. All terms on the right side of the equation represent places where power is used in the system: motor heating, shaft power, drive losses, hysteresis, etc. We add up these amounts of power, find the total, and then insist that this total power must have come from the power supply. Therefore, the equation shows how much power the supply must provide for every use on the right side of the equation.

What about Acceleration and Inertia?

To use the equation we have developed, you only need four pieces of information about your system:

T	Torque
v	Velocity
k_T	Motor Torque Constant
R	Motor Resistance

You may be wondering why acceleration, rotor inertia, or load inertia do not appear in the equation, and what effect these parameters have on power requirements.

The answer is that acceleration and inertia *are* in the equation—they are hidden within the values for torque and velocity. Recall that torque is equal to the product of acceleration and inertia.

$$T = \alpha J = 2\pi a J$$

When you analyze your system, you can derive torque and velocity terms based on acceleration requirements, load inertia, and rotor inertia. Acceleration and inertia, therefore, are implicit in the equation we have developed (and are also implied in speed/torque curves for motors).

PEAK POWER—A GRAPHICAL METHOD

Given a speed/torque curve for a particular motor, you can overlay a family of curves that show peak power levels for various moves. To do this, start with the equation for peak power that we developed above. Next, set *P* equal to a fixed value, and then solve for velocity.

$$v = \frac{P - \left(\frac{T}{k_T}\right)^2 R}{2\pi T}$$

For any given torque, you can determine a velocity such that the peak power required to reach that velocity is equal to *P* watts. The graphical method is illustrated in the next example.

Example

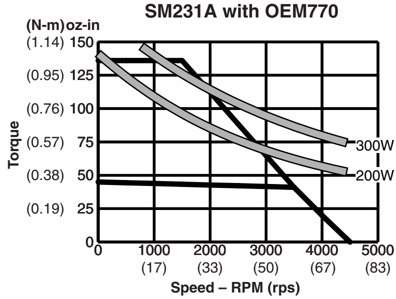
For the SM231A motor at 75VDC, we wish to determine a curve that shows all of the possible speed/torque combinations that require 300W peak power. So, set P = 300W. We then have;

$$v = \frac{300 - \left(\frac{T}{k_T}\right)^2 R}{2\pi T}$$

Torque *oz–in* (*Nm*)	*Velocity* (*rps*)
75 (0.53)	73
100 (0.71)	45
125 (0.88)	26

For each torque listed in the table, the peak power required to reach the corresponding velocity is 300W.

In the next drawing, we have plotted these values on the speed torque curve for the SM231A motor. We have also plotted a similar curve, corresponding to moves of 200W peak power.



Peak Power Curves: SM231A at 200W and 300W

Any move that falls on the 300W curve will require 300W peak power from the power supply. Moves that lie above the curve will use more torque, a faster velocity, or both, and consequently will need more peak power. Moves that lie below the curve will need less power.

Compumotor's OEM300 Power Module produces 300W peak and 200W continuous. You could use it to power any move on or below the 300W curve. You could use it continuously for any move below the 200W curve.

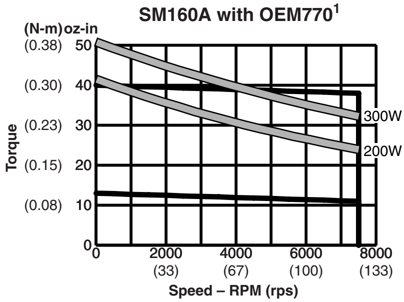
Compumotor's OEM1000 Power Supply produces 1000W. You could use it to power any move within the speed/torque curve.

Peak Power Curves for Compumotor Servo Motors

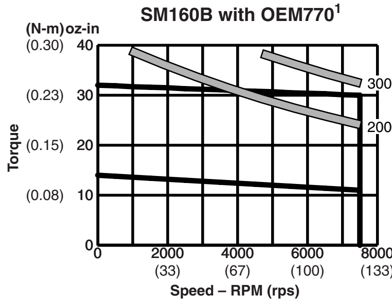
The following drawings show speed/torque curves for SM16, SM23, and NeoMetric servo motors, with peak power curves added.

Peak Power Curves: SM Motors, Frame Size 16 [2]

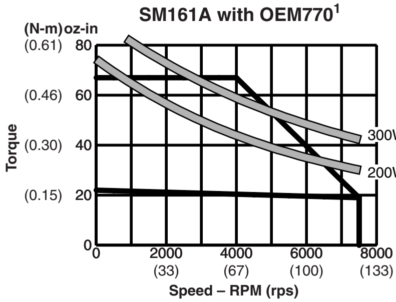
SM160A with OEM770[1]



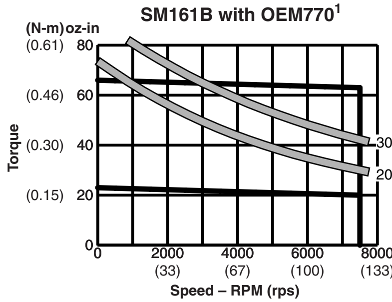
SM160B with OEM770[1]



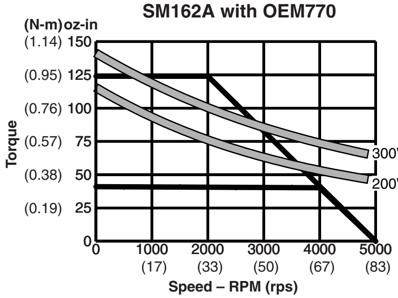
SM161A with OEM770[1]



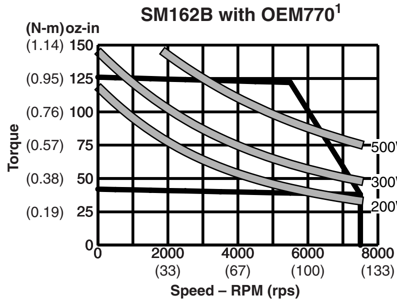
SM161B with OEM770[1]



SM162A with OEM770



SM162B with OEM770[1]

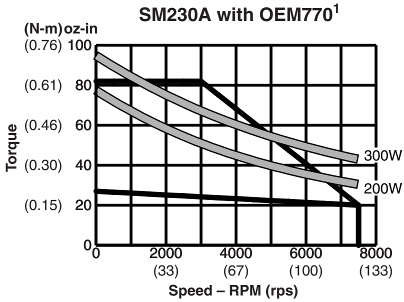


1 For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).

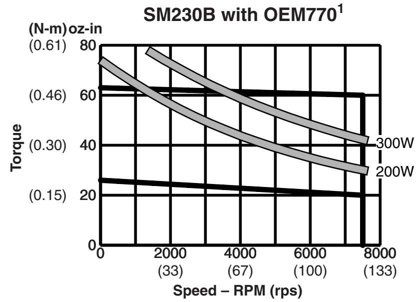
2 With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Peak Power Curves: SM Motors, Frame Size 23 [2]

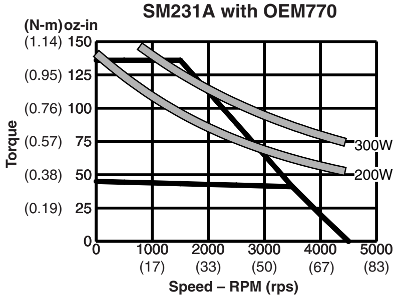
SM230A with OEM770[1]



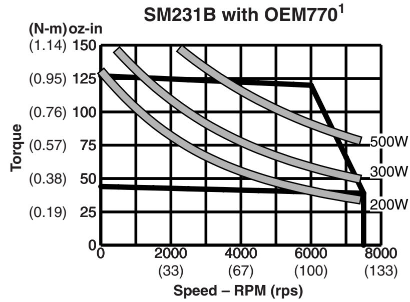
SM230B with OEM770[1]



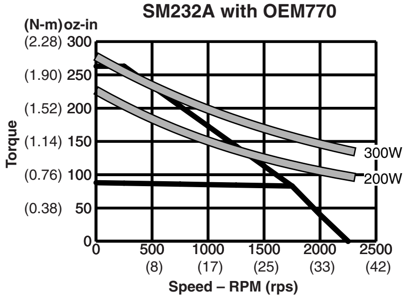
SM231A with OEM770



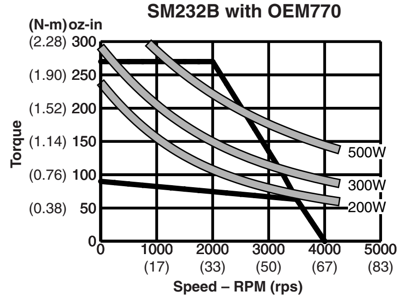
SM231B with OEM770[1]



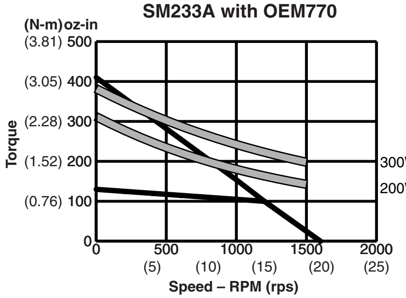
SM232A with OEM770



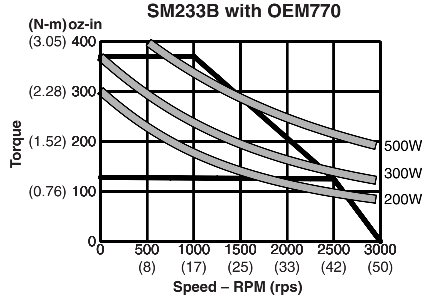
SM232B with OEM770



SM233A with OEM770



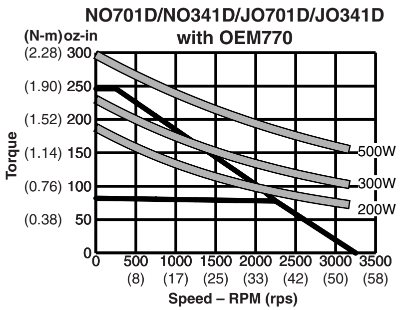
SM233B with OEM770

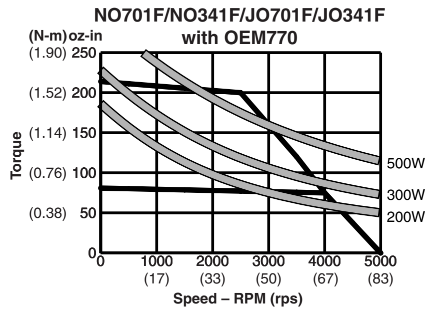


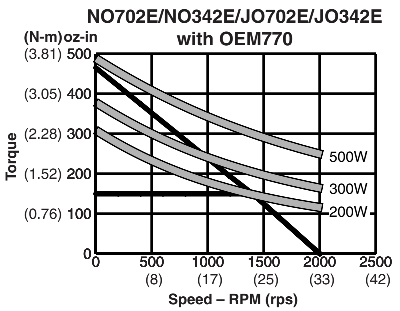
[1] For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).

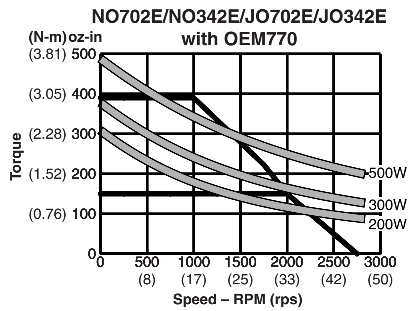
[2] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Peak Power Curves: NeoMetric Motors [1]









[1] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Example

Use the peak power curves to choose a power supply to use with a system consisting of an OEM770 with an SM233B motor. The motor must accelerate with a torque of 200 oz-in (1.52 Nm), until it reaches a velocity of 1,500 rpm (25 rps). It then slews at constant velocity until it decelerates.

From the peak power curves, observe that this move requires approximately 300W peak power. Choose a power supply that provides at least 330W peak to accomplish this move. (330W includes an extra 10% for miscellaneous losses.)

Example

A system must make a trapezoidal move, and reach 2,000 rpm (33.3 rps) at a torque of 125 oz-in (0.88 Nm). Which size 23 motor requires the smallest power supply to make this move?

From the peak power curves:

Motor	Peak Power	Peak + 10%
SM230A	n/a	n/a
SM230B	n/a	n/a
SM231A	340W	374W
SM231B	365W	401W
SM232A	n/a	n/a
SM232B	240W	264W
SM233A	n/a	n/a
SM233B	220W	242W

This move is beyond the speed/torque range of four motors. Of the remaining motors, the SM233B requires a 242W power supply to make the move. The other motors need larger power supplies.

FRICTION, GRAVITY, AND DIFFERENT MOVE PROFILES

The techniques we have discussed so far apply to trapezoidal moves with negligible friction. Below, we will briefly mention some salient points about other types of moves. If your system has moves similar to one of these, apply the techniques developed above to your application.

Friction

The presence of friction requires additional torque to overcome the friction. We will consider Coulomb friction in a trapezoidal move. (Coulomb friction does not change with velocity. Viscous friction, which *does* depend on velocity, is much more difficult to analyze.)

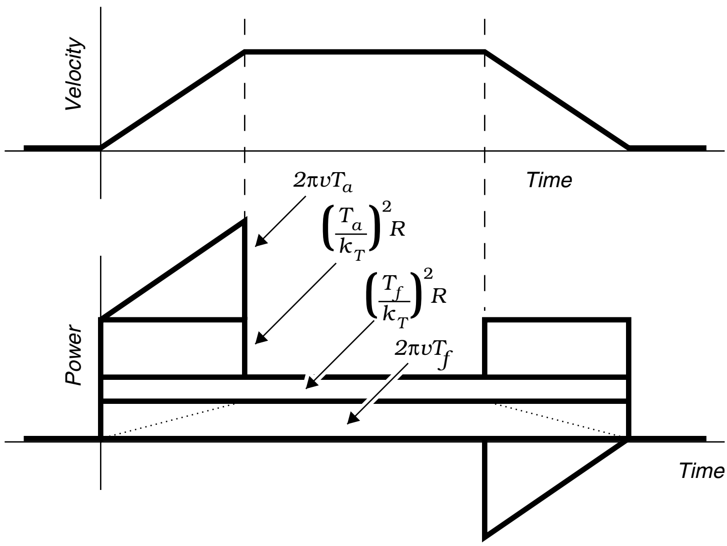
During acceleration, total torque is equal to the torque required for acceleration plus the torque required to overcome friction.

$$T_t = T_a + T_f$$

where

T_t = Total Torque
T_a = Acceleration Torque
T_f = Friction Torque

The next drawing illustrates how friction affects a system.



Friction

Observe that friction adds additional plateaus to the drawing. The actual shape of the plateau due to frictional shaft power is shown by the dotted lines. For simplicity, we approximate the shape with a rectangle.

The equation for peak power becomes

$$P_{peak} = 2\pi v\left(T_a + T_f\right) + \left(\frac{T_a + T_f}{k_T}\right)^2 R$$

The power supply must also provide power while the motor is slewing at constant velocity. The equation for power during slew is:

$$P_{slew} = 2\pi v_{slew} T_f + \left(\frac{T_f}{k_T} \right)^2 R$$

You can use the peak power curves (discussed in the previous section) to predict the peak power and slew power that the power supply must provide. Be sure that you include the friction torque in the appropriate places, however. The next example illustrates this.

Example

Determine peak power and slew power that an SM232B motor will require. Acceleration torque is 100 oz-in (0.71 Nm). Friction torque is 50 oz-in (0.35 Nm). The slew velocity is 2,000 rpm (33 rps).

Total torque during acceleration is 150 oz-in (1.06 Nm), the sum of acceleration and friction torque. On the curves, the intersection of 150 oz-in and 2,000 rpm lies on the 300W line.

During slew, the only torque present is friction torque. At 50 oz-in and 2,000 rpm, the curves show that 80W is required.

The power supply must be capable of providing at least 330W peak and 88W continuous power (these values include a 10% estimation factor).

Gravity

We can distinguish two distinct situations when gravity is involved in an application.

- Lifting a load against gravity
- Lowering a load with gravity

These situations must be analyzed separately.

When your system lifts a load, gravity imposes a force downward. The motor must exert an additional torque to counteract this force. This is similar to a system that has friction, where the motor must exert an additional torque to overcome the friction. One possible difference can occur if the motor must provide holding torque while the load is stationary, to prevent the load from moving downward. In this case, the supply must provide power for the copper losses due to the holding torque, even when the motor is not moving.

The analysis for lowering a load can be much more complicated. The basic power equation can still be used, but you must take care to use the proper algebraic sign for the various torques, forces, velocities, etc. A full analysis of the calculation method is beyond the scope of this text. The easiest way to determine your system's power needs may be the empirical method, discussed in the next section.

As an example of the complexity of the calculation involved, consider just one part of the move profile—acceleration from rest, with the load moving downward. Depending upon whether the acceleration is faster, slower, or equal to gravitational acceleration, net power can be positive, negative (regeneration), or even zero! Other parts of the move profile are equally complicated.

Other Move Profiles

Many other move profiles and application conditions are possible. For example, moves can be sinusoidal, s–curve, or random, with or without friction, with or without or gravity.

To calculate power needs for moves such as these, you may be able to follow the methods we have developed above, and modify the equations to suit your application. Or, you may need to use the empirical method, presented below.

POWER REQUIREMENTS—AN EMPIRICAL METHOD

You can use an empirical approach to measure the voltage and current going from a power supply to an OEM770, and directly determine your system's power requirements.

You will need the following equipment:

- DC Current Probe
- Oscilloscope
- Large Power Supply

This method also requires that you make a prototype of your system.

Prototype Your System

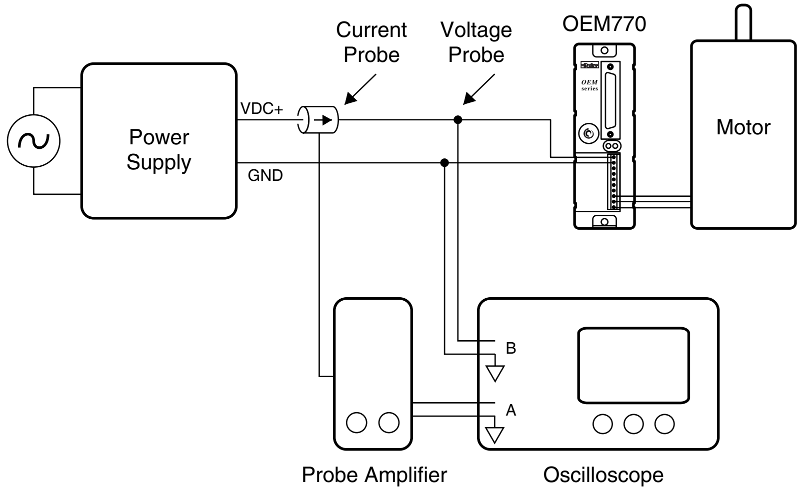
Make a working prototype of your system. For the power supply, temporarily use a large power supply that is capable of providing enough power for all the moves your system makes. The temporary power supply should operate at the same voltage at which you intend your final system to run. Once you determine the power requirements, you can replace the temporary power supply with a permanent one.

Measure Current

Connect a current probe to one channel of an oscilloscope. (Connect the probe in the correct direction. With the motor at rest, the probe should measure *positive* current.) Measure current going from the power supply to the OEM770 while your system performs its moves under actual operating conditions. Current going from the OEM770 to the motor is not relevant in this procedure; you do not need to measure it.

Your current probe must be of the type that connects to an oscilloscope, and is fast enough to show current variations (such as a Tektronix A6302 Current Probe and AM 503 Current Probe Amplifier). The current probe in a digital multimeter will not work in this situation, nor will an AC current probe.

Connect an oscilloscope probe to the second channel of the oscilloscope, and use it to monitor power supply bus voltage.



Setup for Current Measurement

The bus voltage should drop no more than 10% during peak power events. If it drops more than 10%, use a larger power supply.

Determine Power Needs

At any moment the power used by your system is

$$P = V_{supply} I_{supply}$$

When the current is positive, current flows from the supply to the drive, and the supply delivers power to your system. When current is negative, the system is regenerating—power flows from your system, and back into the supply.

To determine the peak power that the supply must deliver, measure the highest current (as seen on the oscilloscope screen). Substitute this current in the power equation, to get

$$P_{peak} = V_{supply} I_{peak}$$

Once you know the peak power that your system demands, you can select a supply that can deliver enough power.

AVERAGE POWER CALCULATIONS

Many power supplies have a peak power rating and an average power rating. The peak power may be much higher than the average power rating.

For example, the OEM300 Power Module can deliver 300W peak for 30 seconds, at a 10% duty cycle. It can deliver 200W continuously.

To determine the average power in your system, calculate the area under the graph of power, and multiply by the repetition frequency.

Example

Consider a trapezoidal move with acceleration *a*, velocity *v*, and repetition frequency f_{rep}. Ignore friction, and assume that regeneration provides power for deceleration. Therefore, the power supply only delivers power during acceleration.

The average power is

$$P_{avg} = f_{rep}\frac{v}{a}\left[\tfrac{1}{2}(2\pi vT) + \left(\frac{T}{k_T}\right)^2 R\right]$$

If your system needs power to decelerate, you should add a term to the equation that represents power needed to decelerate, and include this power in the average.

REGENERATION

At certain times during a move, particularly during deceleration or while lowering a load, energy can be transferred from the motor and load, and back to the power supply. This is called *regeneration*.

The following sections will describe methods to calculate the power and energy that regeneration can produce during deceleration in a trapezoidal move. You can use this information to help you select a power supply that can deal with regenerated energy.

Power Flow During Deceleration

In the trapezoidal moves we have analyzed, we used the convention that torque and velocity are positive during acceleration. During deceleration, however, torque is applied in the opposite direction. Therefore, torque is negative, and shaft power, the product of torque and shaft velocity, is also negative.

$$P_{shaft} = \omega(-T) = 2\pi v(-T)$$

Negative shaft power means that power flows from the motor back to the drive. Does this mean that deceleration always causes regeneration? Not necessarily. Current must flow in the motor to produce the negative torque. The heat that this current produces is proportional to the *square* of the torque. Copper losses, therefore, are always positive.

$$P_{copper} = \left(\frac{-T}{k_T}\right)^2 R$$

The total power during deceleration, then, is the sum of shaft power and copper losses.

$$P_{decel} = -2\pi vT + \left(\frac{-T}{k_T}\right)^2 R$$

If the magnitude of the first term is larger than the magnitude of the second term, then the net power is negative—power will flow from the system, and back into the power supply. When the second term is larger than the first, the power supply must provide power for deceleration.

Energy During Regeneration

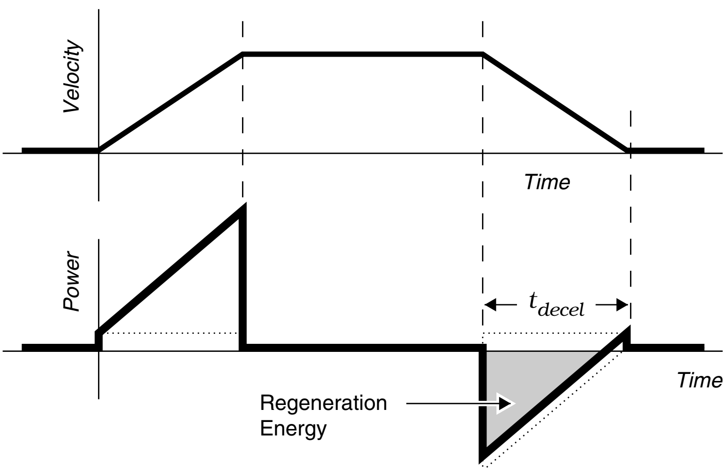
The power supply must be capable of absorbing or dissipating energy that flows into it during regeneration. The amount of energy is related to the power that we discussed above.

Recall from physics that the *joule* is the unit of energy in the

SI system, and that power is the rate of energy flow. One watt is equal to an energy flow of one joule per second.

1 watt = 1 joule/second

Energy is also the integral of power. Therefore, you can determine the total energy produced during deceleration by finding the area under the peak power curve. The next drawing shows this area, for a situation where copper losses are small, and shaft power is large.

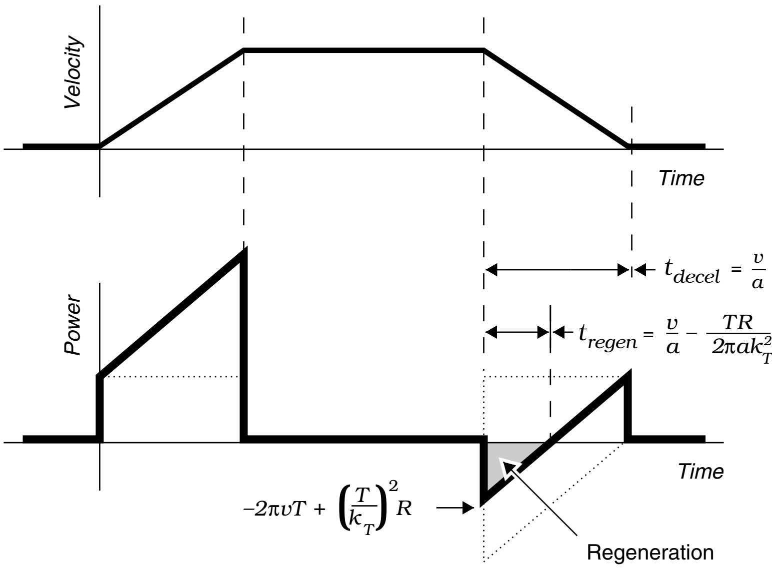


Regeneration with Low Torque

To approximate the total energy from regeneration, find the area of the triangle representing shaft power. You can ignore the copper losses, because they are small.

$$E_{regen} = \tfrac{1}{2} \cdot base \cdot height = \tfrac{1}{2}(-2\pi vT)(t_{decel})\ , in\ joules$$

The next drawing shows the deceleration portion of a move that uses a higher torque to decelerate the motor. Consequently, the copper losses are greater.



Regeneration with High Torque

If you ignore copper losses when you calculate energy from regeneration in this type of situation, the answer will be much larger than the actual energy produced. To accurately calculate the energy, use the next equation to find the area of the regeneration triangle.

$$E_{regen} = -\tfrac{1}{2}\left[2\pi vT - \left(\frac{T}{k_T}\right)^2 R\right]\left[\frac{v}{a} - \frac{TR}{2\pi a k_T^2}\right], \text{ in joules}$$

In this equation, v is the slew velocity, and a is the deceleration rate.

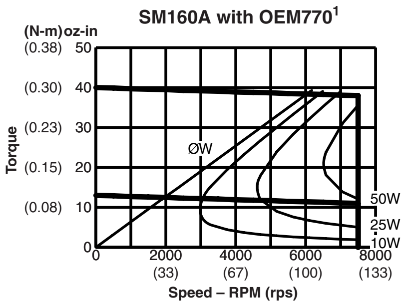
Regeneration Curves

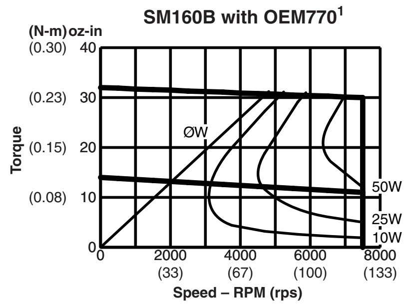
In the following version of the regeneration equation:

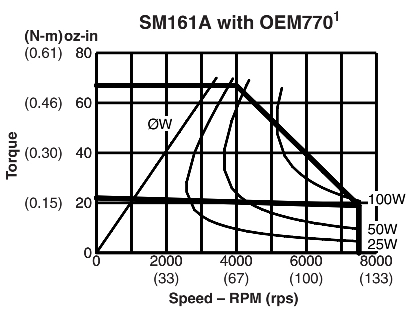
$$v = \frac{P + \left(\frac{T}{k_T}\right)^2 R}{2\pi T}$$

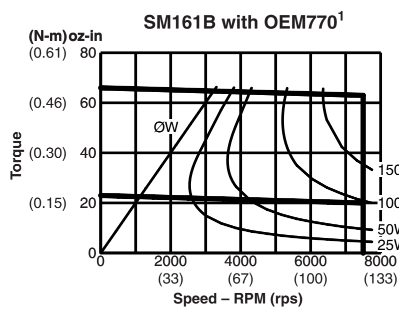
if we set power equal to a specific value, and solve for velocity at various torques, we can plot a family of curves that represent peak regeneration watts. We have done this below for Compumotor servo motors.

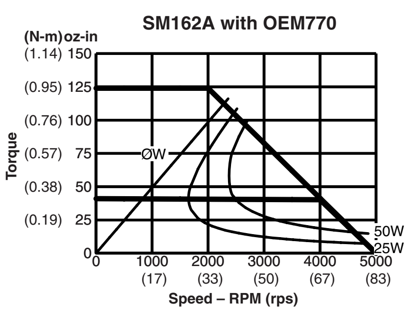
Peak Regeneration Curves: SM Motors, Frame Size 16 [2]

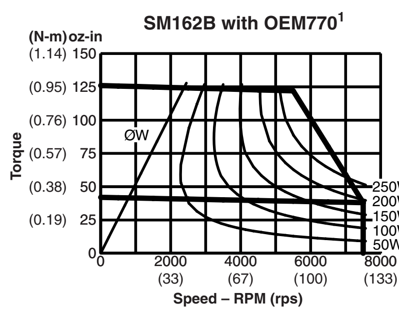










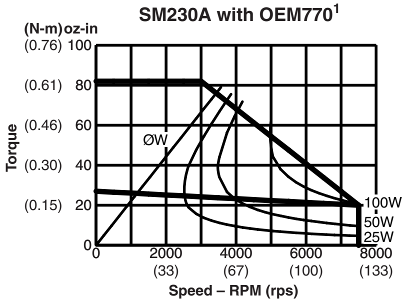


[1] For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).

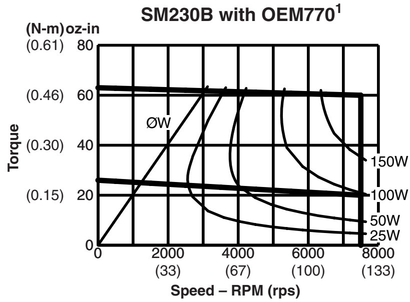
[2] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Peak Regeneration Curves: SM Motors, Frame Size 23 [2]

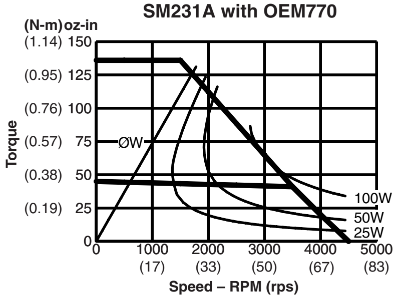
SM230A with OEM770[1]



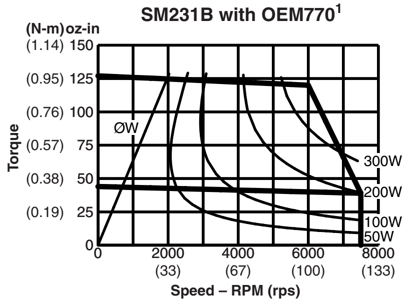
SM230B with OEM770[1]



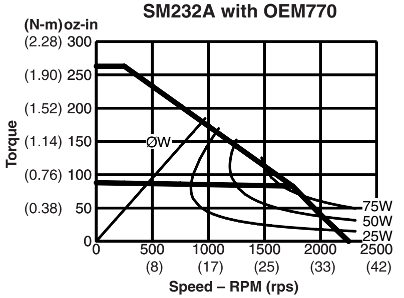
SM231A with OEM770



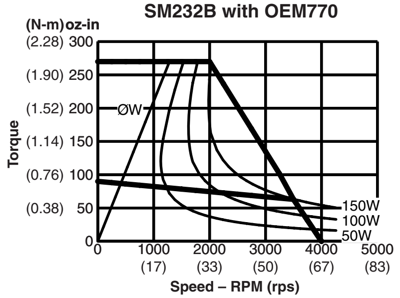
SM231B with OEM770[1]



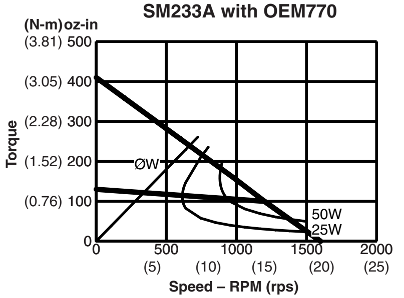
SM232A with OEM770



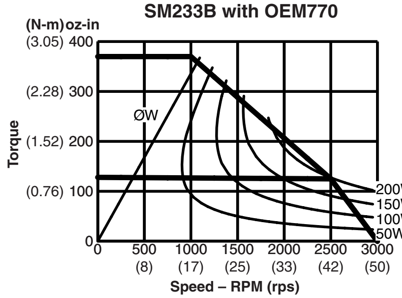
SM232B with OEM770



SM233A with OEM770



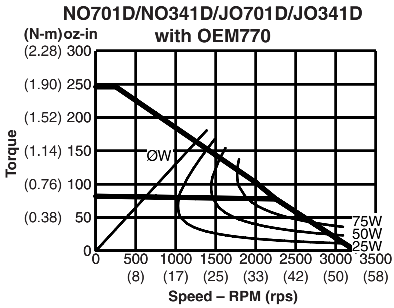
SM233B with OEM770

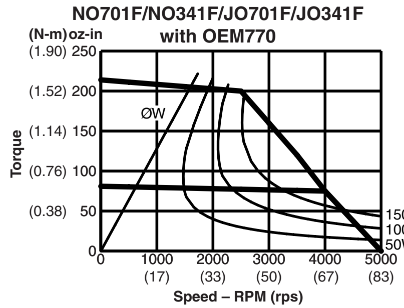


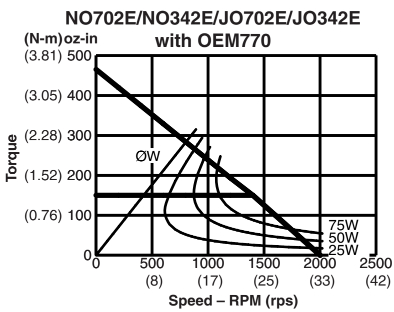
[1] For "E" encoder option (1000 ppr), maximum velocity is 6,000 rpm (100 rps).

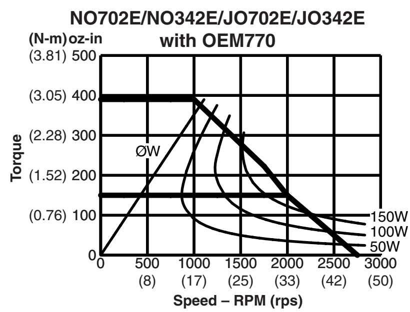
[2] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

Peak Regeneration Curves: NeoMetric Motors [1]









[1] With 75VDC bus voltage; 25°C (77°F) ambient temperature.

On each of these charts, there is a straight line corresponding to zero watts. This is where

$$2\pi v T = \left(\frac{T}{k_T}\right)^2 R$$

In areas to the left of this line, copper losses are always greater than shaft power, and the power supply must always provide power. In other words, for any move to the left of this line, the power supply will not receive regeneration energy from the system, because copper losses will be greater than negative shaft power.

Example

An SM232B motor performs a trapezoidal move. It slews at 50 rps, and decelerates at 100 rps^{-2} with a torque of 75 oz-in (0.53 Nm). Does the power supply receive regenerated energy? If so, how much? The motor has a torque constant

k_T = 0.169 Nm/A, and a resistance R = 2.01 ohms.

Using the regeneration equation,

$$
\begin{aligned}
E_{regen} &= \tfrac{1}{2}\left[2\pi vT - \left(\frac{T}{k_T}\right)^2 R\right]\left[\frac{v}{a} - \frac{TR}{2\pi a k_T^2}\right] \\
&= \tfrac{1}{2}\left[2\pi(50)(0.53) - \left(\frac{0.53}{0.169}\right)^2 2.01\right]\left[\frac{50}{100} - \frac{(0.53)2.01}{2\pi(100)(0.169)^2}\right] \\
&= \tfrac{1}{2}[166.5 - 19.8][0.5 - 0.06] \\
&= \tfrac{1}{2}[146.7 \ \text{watts}][0.44 \ \text{seconds}] \\
&= 32.3 \ \text{joules}
\end{aligned}
$$

At the moment deceleration began, the peak regenerated shaft power was 166.5W, and copper losses were 19.8W. The peak regeneration power was therefore 146.7W, which you can also read directly from the chart for the SM232B motor. To determine regeneration energy (joules), however, you need to perform the calculation.

The last term in the equation shows that total deceleration time (v/a) was 0.5 seconds. The power supply received regenerated energy for the first 0.44 seconds, and had to supply power for the final 0.6 seconds.

WHAT VOLTAGE DO YOU NEED?

The OEM770 uses the DC power supply voltage as the supply voltage for the motor. The motor's performance depends on the voltage at which it runs. Therefore, the power supply voltage you choose will affect motor performance. We will use Compumotor servo motors as examples to illustrate this, but the points presented below apply to any servo motor.

Because the OEM770 accepts such a wide range of input voltage (24 – 75VDC), you have several options for choosing a power supply voltage. These options are explained below.

MATCH THE POWER SUPPLY TO THE MOTOR

Manufacturers wind servo motors for optimum performance at a specific voltage. They publish speed/torque curves measured at that voltage. If you select a motor because you need the performance shown in the curves, choose a power supply that produces at least as much voltage as that for which the motor was designed.

For example, Compumotor servo motors specified in this user guide are wound for 75VDC operation. The speed/torque curves were measured with a 75VDC power supply. If you want the full performance shown in the curves, use a power supply that operates at 75 volts.

USE AVAILABLE POWER, AND CUSTOM WIND A MOTOR

In many machines, the motion control system is but one component among many in the entire machine. Power may be available from a large power supply that runs other parts of the machine. We designed the OEM770 so that you can take advantage of available power.

If power is available, but at a voltage lower than specified for the motor you have chosen, you can contact the manufacturer to see if the motor can be made with the voltage rating you need. Motor manufacturers can design a motor's windings so that it can have similar performance characteristics at different voltages.

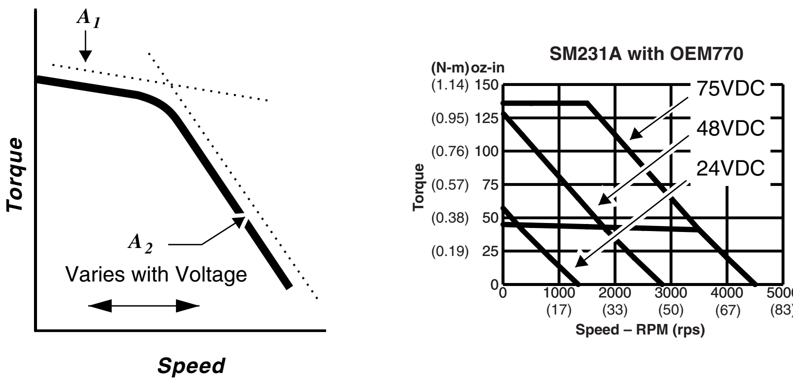
For example, suppose you decide to use the SM231A motor. You want to make moves that lie within the 75VDC speed/torque curve, but you only have 48VDC available. If you cannot get the performance you need from the standard motor at 48VDC, you should call Compumotor. We can make the motor with a special winding to obtain performance similar to that shown in the 75VDC speed/torque curve, but at 48VDC.

USE AVAILABLE POWER AND AN AVAILABLE MOTOR

You can use a power supply whose voltage is less than the voltage at which your motor's speed/torque curve was specified. The motor will not be able to perform the full range of moves shown on the speed/torque curve, however.

The next drawing shows how varying the power supply voltage affects a motor's speed/torque curve. The speed/torque curve can be approximated by two asymptotes, labeled A_1 and A_2 in the curve on the left. A_1 is not affected by voltage changes, but A_2 is. As the voltage is decreased, A_2 will shift to the left. The slope of A_2 will not change.

A_2 will move a distance proportional to the decrease in voltage. If the voltage is cut in half, A_2 will move halfway to the origin. If voltage is reduced by two thirds, A_2 will move two thirds of the way toward the origin.



Voltage Affects the Speed/Torque Curve

To illustrate how voltage affects performance for a specific motor, the drawing shows the speed/torque curve for the SM231A motor at 75VDC, 48VDC, and 24VDC.

POWER SUPPLY CHOICES

If you have worked through the previous sections, then by this point you have:

- Determined how much power your system needs.
- Determined whether regeneration is a concern.
- Selected a power supply voltage.

Armed with this information, you are now ready to choose a power supply! You have three main choices:

- Linear Unregulated Power Supply (OEM1000)
- Switching Power Supply
- OEM300 Power Module

In the following sections, we will explain the advantages and disadvantages of linear and switching supplies. We will also present information about Compumotor's OEM300 Power Module and OEM1000 Power Supply.

LINEAR POWER SUPPLY

The simplest linear power supply consists of a transformer, bridge rectifier, and capacitor. The transformer changes the level of the AC input voltage. Diodes in the rectifier change the AC to DC. The capacitor filters the DC, and stores energy. Such linear supplies are unregulated.

Some models have a fuse to provide overcurrent protection. To improve the transient response, the single output capacitor can be replaced by combinations of capacitors and inductors.

Compumotor's OEM1000 is a linear power supply.

Advantages of Linear Power Supplies

- **SIMPLICITY** – Linear supplies are simple, robust, and repairable. They have very few parts. Once the supply is working, it usually keeps working for a long time. If a part fails, diagnosing the failure is straightforward, and the part can be replaced.

- **LOW COST** – In many applications, a linear supply costs less than a switching supply. (This depends upon power level and number of units.)

- **LOW NOISE** – Linear supplies are virtually free of electrical noise, and give excellent results in noise-sensitive applications.

Disadvantages of Linear Power Supplies

- **POOR LINE REGULATION** – If the input line voltage rises or falls, the power supply’s output voltage will also rise or fall.

- **POOR LOAD REGULATION** – When the load uses more power, the power supply's output voltage may drop.
- **VOLTAGE RIPPLE** – Large ripple voltage in the output requires a relatively large output capacitor for smoothing.
- **LARGE SIZE** – Compared to a switching supply of the same power level, a linear supply is larger, heavier, and takes up more space.
- **LOW EFFICIENCY** – The linear supply suffers losses in the transformer and other components. This dissipation can result in heat and higher operating temperatures.
- **SLOW TRANSIENT RESPONSE** – The linear supply may not be capable of keeping up with the rapidly changing load requirements of some servo systems. Designing a linear supply for a high performance system can be quite complex.

Regeneration and Linear Power Supplies

Dealing with regeneration is simpler with linear supplies than with switching supplies. The linear supply's transformer and rectifier will continue to operate during regeneration.

During regeneration, the supply's capacitors will absorb energy from the load. As the energy is stored in the capacitors, the supply's output voltage will rise. If it goes higher than the threshold of 90VDC, the OEM770's overvoltage protection will disable the drive. To avoid overvoltage shutdowns, you can use larger capacitors to store more energy, or use a power supply that operates at a lower bus voltage.

SWITCHING POWER SUPPLY

A switching power supply takes an AC input voltage at power line frequency, and uses switching transistors to increase the frequency. Various techniques are used to modify the high frequency voltage and obtain the desired DC output voltage. The chief advantage of operating at higher frequency is that many components, particularly transformers and capacitors, can be much smaller, and operate more efficiently.

A switching power supply is regulated. It actively monitors the input line voltage, and keeps its output voltage constant, even when the input voltage varies. If the load demands more power, the supply will increase its output current, but its output voltage will stay at a constant level.

Advantages of Switching Power Supplies

- **REGULATION** – The supply will try to keep its output at a constant voltage, regardless of line or load variations. (There are limitations on how well it can do this.)
- **SMALL VOLTAGE RIPPLE** – The output voltage ripple is small, and at a high frequency. Therefore, a relatively smaller output capacitor can be used for smoothing.
- **SMALL SIZE** – A switching supply will be much smaller than a linear supply of the same power rating.
- **EFFICIENCY** – Switching supplies are efficient—they dissipate less power as heat than linear supplies.
- **FAST TRANSIENT RESPONSE** – Because a switching supply monitors its output, it can quickly adapt its performance to provide changing amounts of power for changing load conditions. (Power supply transient response depends upon the supply's design.)

Disadvantages of Switching Power Supplies

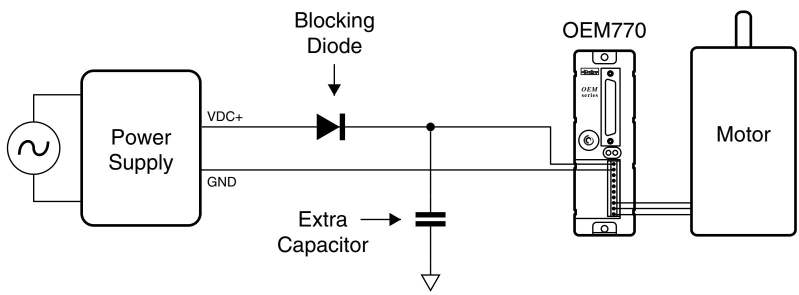
- **HIGH COST** – In most applications, a switching supply will cost more than a linear supply. (Depends upon power level and number of units.)
- **ELECTRICAL NOISE** – Switching supplies produce electrical noise, which may be transmitted to load equipment and power lines. They may not be suitable for noise-sensitive applications.
- **LESS RELIABLE** – Switching supplies are much more complex than linear supplies. More components means that more things can go wrong. Consequently, the time before failure may be shorter for switching supplies.
- **LESS REPAIRABLE** – If a switching supply fails, it usually can only be repaired by its manufacturer. The

user probably cannot repair it, and may need to replace the entire unit.

Regeneration and Switching Power Supplies

Regenerated energy flowing from the load to a switching supply may cause the supply to behave erratically and unpredictably. Accommodating regeneration is more difficult with a switching supply than with a linear supply.

You may need to install a *blocking diode* if regeneration causes problems with your switching supply. The next drawing shows where the diode should be positioned.

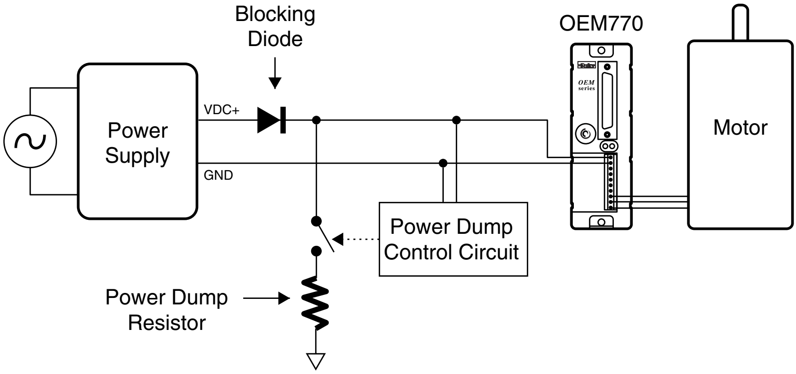


Blocking Diode with Extra Capacitor

The blocking diode will prevent regenerated energy from entering the power supply. This energy *must* go somewhere. If it is not absorbed by the supply, it will charge up the drive's internal capacitors, and cause an overvoltage fault. (In a vertical application, it may damage the drive.)

The drawing above shows one possibility for removing regenerated energy. You can install extra capacitors on the power bus, and allow the energy to charge up the capacitors.

The next drawing shows another possibility for removing regenerated energy. You can install a power dump resistor, and circuitry to monitor the voltage on the power bus.



Blocking Diode with Power Dump

Design the circuit so that when regeneration causes a voltage rise, the power dump will turn on and dissipate regenerated energy in the resistor.

OEM300 Power Module

The OEM300 Power Module is a Compumotor product that contains a switching power supply, and several additional circuits that make it an ideal power supply for many servo applications. Its features are summarized below. For additional information, contact Compumotor at 800-358-9070, and request a copy of the OEM300 User Guide.

Power Supply

The switching power supply in the OEM300 has characteristics that are highly compatible with OEM Series Servo Drives and microstepping drives. It can provide 300W peak/200W continuous power, at 4.0A/2.7A, respectively. The transient response of the OEM300 is matched to that of OEM Series drives.

Power Dump

The OEM300 contains a power dump circuit that turns on at 85VDC. The power dump can dissipate as much as 400 joules of energy, at a peak dissipation rate of 722.5 watts.

Short Circuit Protection

The OEM300 will shut down its output if its current exceeds 9 amps.

Overtemperature Protection

An internal temperature sensor will shut down the OEM300 if its temperature reaches 60°C (140°F).

Overvoltage Protection

The OEM300 will shut down its output if an overvoltage condition lasts longer than 0.5 seconds.

POWERING MULTIPLE AXES

So far in this chapter, we have presented several methods for choosing a power supply for a single axis system—one drive and one motor. You can also use a supply to provide power to multiple axes.

To choose a power supply for multiple axis operation, the first step is to determine the power each individual axis requires, using any of the methods we presented above.

Next, determine how the power requirement of each axis relates, in time, to the other axes. There are two possibilities: each axis moves independently; or, the various axes move in a coordinated way, with the motion of each axis depending upon the other axes.

For independent moves, the largest power demand will occur if all axes simultaneously reach their peak power points. Choose a power supply that can provide enough power for this peak demand.

For dependent moves, find the times when the maximum power is required. Add together the power requirements for each axis at these times, to find the peak power requirement. Choose a power supply that can satisfy the peak requirement.

CHAPTER 7

Troubleshooting

When a problem occurs in your system, use the following strategy to isolate and identify the problem:

- Check Light Emitting Diodes (LEDs) and the Fault Output for an indication of the cause of the problem.
- Check other possible causes.

When we refer to LEDs,

- **ON** means *illuminated.*
- **OFF** means *not illuminated.*

When we refer to the Fault Output,

- **HIGH** means +5VDC to +24VDC (depending upon what DC voltage you use for the pullup resistor, when you connect the fault output to your controller).
- **LOW** means ground, or ØVDC to Ø.8VDC.

The next table summarizes LED & Fault Output information. The table after that summarizes other possible sources of problems. Detailed troubleshooting procedures follow the tables.

CHECK LEDS FIRST!

If you encounter problems, you may be able to quickly identify the problem by looking at the LEDs and the fault output. The next table summarizes possible LED and fault output states.

LEDs and FAULT OUTPUT

GREEN LED	RED LED	FAULT OUT	CONDITION	
OFF	OFF	HI	No Power	
ON	OFF	LO	Normal operating condition	
ON	INT	LO	Foldback	
ON	ON	LO	Foldback (OEM770T only: Red LED turns off within 10 seconds if command input is reduced to ØV)	
ON	INT	INT	Normal condition while drive is powering up, or turning off; or, Weak power supply, VDC is too low for operation	
ON	ON	HI	OEM770T only: Power supply undervoltage; or, OEM770T only: No enable	
	↑		**NOT LATCHED**	Can recover from above conditions without cycling power.
	↓		**LATCHED**	Cycle power to reset drive, and recover from conditions below.
ON	ON	HI	Overvoltage from regeneration; or overtemperature; OEM770SD only: no enable, or power supply undervoltage	
OFF	ON	HI	Short circuit in load or cables; or bad Hall state (all high or low); or, Power supply fault (typically, a transient undervoltage)	

Legend	
	ON = LED is ON (Illuminated); or, **HI** = Fault Output is HIGH (+5VDC to +24VDC)
	OFF = LED is OFF (Not Illuminated); or, **LO** = Fault Output is LOW (ØVDC, or Ground)
	INT = LED turns ON, then turns OFF; or, **INT** = Fault Output goes LOW, then goes HIGH

For a detailed description of the various fault conditions, see the basic troubleshooting procedure below.

OTHER POSSIBLE PROBLEMS

If the drive is powered up, enabled, and operating properly:

- The green LED is ON
- The red LED is OFF
- The fault output is LOW

These conditions indicate that the OEM770 is probably not the source of the problem. The next table summarizes other possible sources of problems.

TROUBLESHOOTING TABLE

Possible Source of Problem	*SOLUTION*
CONTROLLER (INDEXER)	Verify that controller delivers proper command input voltage. (OEM770SD: cycle power to clear fault latch. Verify step pulses at 25 pin D-connector.)
MOTOR	Check for motor problems. Check motor coils for continuity, shorts, proper resistance. Check Hall and Phase wiring.
MECHANICAL SYS.	Check for jams, binds, increased friction, etc.
WIRING	Check motor wiring: Phases, Hall Effects. Check power supply wiring. Check controller wiring. (OEM770SD: check indexer wiring, enable input.)
OVERHEATING	Verify that drive's heatplate has good thermal contact with heatsink. Check mounting screws. Provide sufficient ventilation.
POWER SUPPLY	Verify power supply delivers enough power during entire move, without undervoltage, or overvoltage caused by regeneration.
MOVE PROBLEMS	Check speed/torque limitations. Check for excessive friction, regeneration, problems with gravity, transient undervoltage, etc.
ELECTRICAL NOISE	Check for problems caused by electrical noise. Consult Compumotor's *EMC Installation Guide* for possible solutions.

Details on these problems are discussed after the next section.

BASIC TROUBLESHOOTING METHOD

To identify the cause of a problem, find the condition below that matches your situation. Then follow the detailed procedure listed under that condition.

ARE BOTH LEDS OFF?

Possible Problem:

- No power from power supply

Procedure

1. Remove power. Disconnect all wiring except VDC+ and VDC–. Reapply power. Verify that power supply voltage is in the 24VDC – 75VDC range. Is the green LED now on?
2. If the green LED is still off, return the drive to Compumotor.

IS THE GREEN LED OFF, AND RED LED ON?

Possible problem:

- Short circuit in motor or cabling

Procedure

1. Remove power.
2. Disconnect all wiring except VDC+ and VDC–.
3. Reapply power.
4. Green LED should now be on, and red LED should be off. This indicates the problem is a short circuit in the cabling or motor.
5. Fix the short, and cycle power.

Possible problem:

- Bad Hall state (all three HIGH or all three LOW)

Procedure

1. Remove power.
2. Disconnect all wiring except VDC+ and VDC–.
3. Connect a jumper wire from any Hall input to HALL GND.
4. Apply power. The green LED should now be on.
5. Next, remove power again. Connect Hall wires to motor (Hall 1, Hall 2, Hall 3, Hall GND, Hall +5). *Do not connect motor phase wires.*
6. Apply power.
7. If green LED is off, and red LED is ON, then problem is a bad Hall state (all three HIGH or all three LOW). Possible causes are Hall miswiring, a damaged motor, or a short in Hall or encoder power wiring. Check Hall wiring, and voltage levels at Hall terminals. Check motor for faulty Hall sensors.
8. Measure HALL +5V with respect to HALL GND. If there is no HALL +5V, disconnect Encoder +5V and cycle power. If HALL +5V returns after you cycle power, then the encoder power wiring is bad (possibly a short on Encoder +5V wiring).

Possible problem:

- Power supply undervoltage during move

Procedure

1. Cycle power. Green LED should now be on, red LED off.
2. Make the move.
3. If the move causes a fault, the problem is probably a power supply undervoltage during the move. Try a larger power supply.

IS GREEN LED ON, RED LED OFF—BUT NO MOTION?

These conditions indicate that the OEM770 is powered up, enabled, and operating properly. It is probably not the source of the problem. Look for the cause of the problem elsewhere in your system.

Possible problems:

- No command voltage from controller to OEM770T (controller problem)
- Indexer issued shutdown to OEM770SD
- Wrong motor phase wiring
- Wrong motor Hall effect wiring
- Mechanical jam

Procedure

1. OEM770T: Measure the command input voltage. If it is near ØVDC, then the controller is not commanding a move, or has very low gains. Adjust your controller. Check for possible RS-232 problems (consult your controller manual).

   OEM770SD: Measure the step input. If there are no step pulses, then the indexer is not commanding a move. Adjust your indexer. Check for possible RS-232 problems (consult your indexer manual).
2. With a proper command input signal (a nonzero voltage for the OEM770T; step pulses for the OEM770SD), try to rotate the shaft manually. If you can, then the motor phases are probably miswired. Or, the motor may be damaged—check its phases for proper resistance, continuity, shorts, shorts to the case, etc.
3. If you cannot rotate the shaft, disable the drive. Try to rotate the shaft manually.
4. If you can rotate the shaft, then Hall wires are probably miswired. Check them, and check the motor temperature. (Without proper Hall inputs, the drive may command maximum current and overheat the motor—but no motion will result.)
5. If you cannot rotate the shaft, the machine is mechanically jammed.

ARE GREEN AND RED LEDS BOTH ON?

Possible problems:

- Not Enabled
- Foldback
- Power Supply problem
- Overvoltage
- Overtemperature

Procedure

1. Check the enable input to see if it is low (grounded). If not, then the drive is not enabled.

2. With the drive enabled, reduce command input to ØVDC (OEM770SD: stop sending step pulses from your indexer). If the red LED goes out within 10 seconds, then foldback was the problem. Check motor temperature. Check for a mechanical jam in your system.

   (***NOTE***: The fault output stays LOW during foldback. Foldback is the only condition that turns the red LED ON, but keeps the fault output LOW)

3. If red LED is still on (with a ØVDC command input; or no step pulses), measure power supply voltage at the drive terminals, VDC+ and VDC–. It should be in the 24VDC – 75VDC range. If not, there is a power supply or power cabling problem.

4. With proper power supply voltage at the drive, measure the temperature of the drive's heatplate. Is it hot? If so, the problem could be an overtemperature shutdown. Wait 30 minutes for the drive to cool. Check for proper drive mounting and heatsinking. Check for a mechanical jam. When the drive has cooled, cycle power to resume operations. If overheating persistently causes shutdowns, you can try several remedies: change move profile or duty cycle; improve drive mounting or heatsinking; reduce drive ambient temperature; add forced air cooling.

5. With proper power supply voltage at the drive, and if the drive is not hot, the problem could be an overvoltage

fault. Regeneration during deceleration could have caused the overvoltage fault. Cycle power to resume operations. If regeneration repeatedly causes overvoltage faults, you can try several remedies to solve the problem: reduce deceleration rate; reduce bus voltage; add bus capacitance; add power dump circuitry.

NOTE: Overvoltage and overtemperature faults both have identical indicators: red and green LEDs both ON; fault output HIGH; fault condition is *latched*. To distinguish between the two faults, monitor conditions while the drive runs. Monitor heatplate temperature to see if it gets too high, which could cause an overtemperature fault. Monitor power bus voltage, to see if it gets too high, particularly during deceleration. This could cause an overvoltage fault.

MISCELLANEOUS PROBLEMS

The basic troubleshooting procedure, presented above, will identify most problems, particularly those that affect the LEDs or the fault output. Some problems, however, occur transiently during a move, or do not affect the LEDs. Others may be due to wiring mistakes, or failure of other components in the system (controller, encoder, motor, etc.). The sections below will help you identify such problems.

PROBLEMS DURING MOVE

Speed/Torque Limitations

Make sure that you are not commanding a move that requires the motor to go faster than it can, or use more torque than it can produce. Check the motor's speed/torque curve for your operating voltage.

Weak Power Supply

A weak power supply may not produce sufficient power during all parts of the move. It can cause an undervoltage problem. Undervoltage can affect the drive in two ways:

- Temporary Fault – for the OEM770T, the red LED will turn ON and the fault output will go HIGH during the undervoltage condition. The fault is *not latched*, and will disappear when the voltage goes above approximately 24VDC.

For the OEM770SD, *any* undervoltage fault is latched by the controller.

- Latched Fault—The undervoltage trips the short circuit protection. The green LED is turned off, the Red LED is turned ON, and the fault output goes HIGH. This is a *latched* condition.

For a full description of faults caused by a weak power supply, see the section on *Undervoltage*, and the section on *Short Circuit Protection*, in *Chapter 4 Special Internal Circuits*.

Excessive Friction

Too much friction in your system might cause move problems. Excessive friction can cause trouble when mechanical components in a system age. As friction increases, problems may occur in a system that had previously been working well.

MECHANICAL PROBLEMS

Check for binds, jams, increased friction, or other problems in the mechanical system. If a system was working properly, but then suddenly develops new problems, check for changes in the mechanical system that could be causing the problems.

ENCODER PROBLEMS

Encoders that are miswired or malfunctioning can cause problems during a move. Check wiring from the encoder to the controller (or to the OEM770SD). To isolate a malfunctioning encoder, rotate the motor shaft a known distance, and check the encoder readout.

ELECTRICAL NOISE PROBLEMS

Electrical noise can cause problems, depending on the application and the sensitivity of equipment in the system. For more information on identifying problems caused by electrical noise, and solutions to those problems, consult the technical section in Compumotor's *EMC Installation Guide*.

PRODUCT RETURN PROCEDURE

If you must return the OEM770 for repairs, use the following steps:

1. Get the serial number and the model number of the defective unit, and a purchase order number to cover repair costs in the event the unit is determined to be out of warranty.

2. In the USA, call your Automation Technology Center (ATC) for a Return Material Authorization (RMA) number. Returned products cannot be accepted without an RMA number. If you cannot obtain an RMA number from your ATC, call Parker Compumotor's Customer Service Department at (800) 722-2282.

Ship the unit to:

Parker Hannifin Corporation
Compumotor Division
5500 Business Park Drive, Suite D
Rohnert Park, CA 94928
Attn: RMA # xxxxxxxxx

3. In the UK, call Parker Digiplan for a GRA (Goods Returned Authorization) number. Returned products cannot be accepted without a GRA number. The phone number for Parker Digiplan Repair Department is 0202-690911. The phone number for Parker Digiplan Service/Applications Department is 0202-699000.

Ship the unit to:

Parker Digiplan Ltd.
21, Balena Close,
Poole, Dorset,
England. BH17 7DX

4. Elsewhere: Contact the distributor who supplied the equipment.

APPENDIX A

LVD Installation Instructions

For more information about LVD, see 73/23/EEC and 93/68/EEC, published by the European Economic Community (EEC).

Environmental Conditions

Pollution Degree
The OEM770 is designed for pollution degree 2.

Installation Category
The OEM770 is designed for installation category II.

Electrical

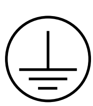
Connecting and Disconnecting Power
The OEM770's protective earth connection is provided through its heatsink. You must reliably earth the OEM770's protective earth connection.

Attach or remove the OEM770's power connections only while input power is OFF.

The OEM770's supply voltage is limited to 75 VDC.

Connecting the Protective Conductor Terminal to Earth
You must provide a connection from the OEM770's protective conductor terminal to a reliable earth point.

The protective conductor terminal is marked with a label on the product bearing the following symbol:



Protective Conductor Terminal Marking

To connect the protective conductor terminal to earth, complete these steps:

1. Use a ring terminal in combination with a star washer to make good contact with the exposed metal surface surrounding the lower mounting hole on the OEM770. (The dimension drawing in *Chapter 2, Installation* indicates that the lower mounting hole is surrounded by exposed metal.)

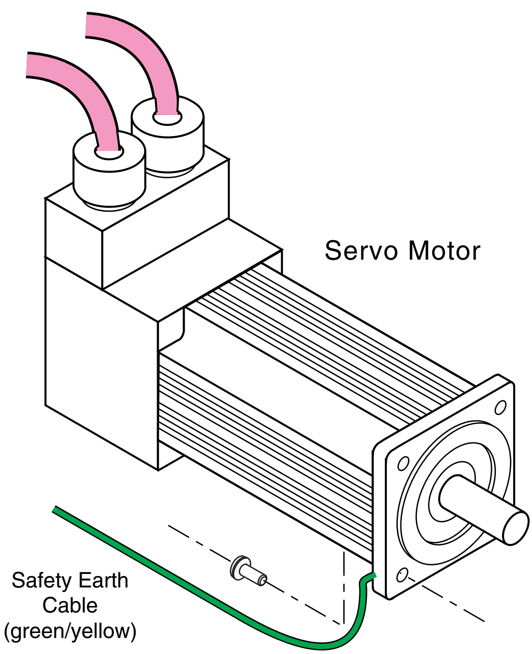
2. Use a VDE approved green/yellow protective conductor terminal wire to reliably earth the protective conductor terminal. Wire gauge must be no thinner than the current-carrying wire in the product's mains supply.

3. Resistance between the protective conductor terminal and earth must be no greater than 0.1 ohm. Use thicker gauge wire if the resistance is too high.

Providing a Protective Earth Connection for Motors

You must provide a connection from the motor to a reliable protective earth. This connection provides a protective earth for the motor contact point. The motor's protective earth connection is important for safety reasons, and *must not be omitted.*

Make connections according to the following instructions and diagram:



1. Use a ring terminal in combination with a star washer and mounting bolt to make good contact with the bare metal surface of the motor's mounting flange.

2. Use a VDE approved green/yellow protective conductor terminal wire to make the connection between the motor and earth. Wire gauge must be no thinner than the current carrying wire in the motor's power cable.

3. Resistance between the motor and earth must be no greater than 0.1 ohm. Use thicker gauge wire if the resistance is too high.

MECHANICAL

Installing in an Enclosure

The OEM770 must be installed within an enclosure. The enclosure's interior must not be accessible to the operator. The enclosure should be opened only by skilled or trained service personnel.

Do Not Operate the OEM770 Without Cover

The cover provides mechanical support to the circuit assemblies inside.

SERVICING THE OEM770

Changing Firmware

Only skilled or trained personnel should change firmware.

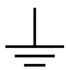
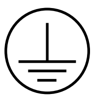
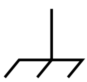
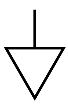
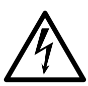
THERMAL SAFETY

The Motor May Be Hot

The motor may reach high temperatures during normal operations, and may remain hot after power is removed.

Table of Graphic Symbols and Warnings

The following symbols may appear in this user guide, and may be affixed to the products discussed in this user guide.

Symbol	Description
	Earth Terminal
	Protective Conductor Terminal
	Frame or ChassisTerminal
	Equipotentiality
	Caution, Risk of Electric Shock
	Caution, Refer to Accompanying Text
	Hot Surface

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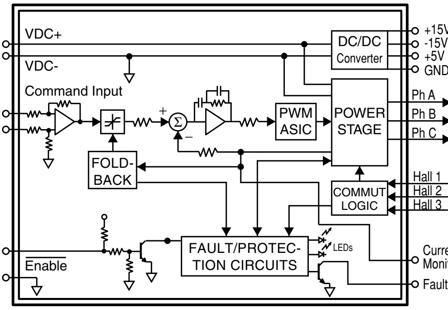
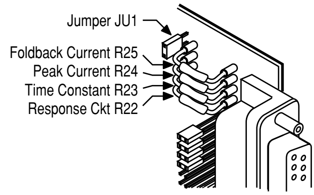
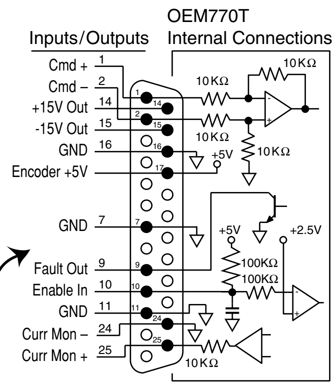


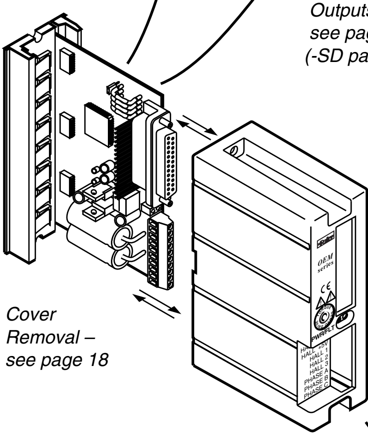
OEM770T Block Diagram – see page 10



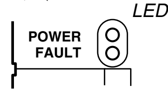
Selectable Resistors – page 18
Foldback Circuit – page 95
Response Circuit – page 84
Jumper JU1 – page 18



Inputs & Outputs – see page 33 (-SD page 41

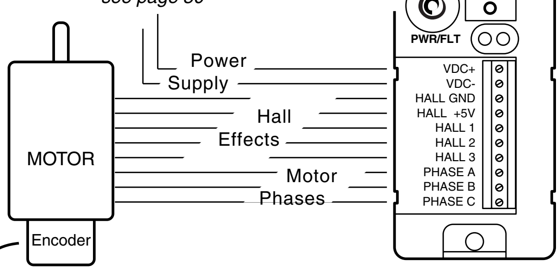


Cover Removal – see page 18



LEDs & Faults – page 156

Power Supply Connections – see page 50



Motor Connections – see page 30
Motor Color Code – see page 31, 75
Motor Specifications – see page 64
Encoders – see page 74