CHAPTER ⑥

Calculating How Many Drives & Motors The OEM300 Can Operate

You can use the OEM300 Power Module to power Compumotor's OEM Series servo motor drives (OEM670T, OEM670X, OEM670SD, etc.) and OEM Series step motor drives (OEM650, OEM650X, OEM350, OEM350X, etc.). This chapter will explain how to determine the number of *step motor* drives you can connect to the OEM300.

For a similar discussion about *servo motor* drives, see *Chapter ⑥ Power Supply Selection* in the *OEM670T User Guide* (part number 88-013599-01). The section of that chapter called *Peak Power Curves for OEM Series Motors* may be particularly useful for using the OEM300 Power Module with OEM670 drives.

GENERAL GUIDELINES – STEP MOTOR SYSTEMS

The OEM300 Power Module can deliver power to many different combinations of drives, indexers, and the motors they run. How many drives can one Power Module operate? The answer depends on several factors

- ❑ The size of each motor in the system.
- ❑ The work each motor must do—what its move profile looks like.
- ❑ The time when each move profile occurs.

There are three methods you can use to determine how many drives to connect to one OEM300.

- ❑ WORST-CASE METHOD: If you want all your motors to be able to simultaneously produce full power, connect the number of motors specified in the Worst-Case Table below.
- ❑ CALCULATION METHOD: Based on figures for peak and average power requirements, calculate the number of drives to connect.
- ❑ MEASUREMENT METHOD: Make a prototype of your system, and directly measure the power requirements.

For the simplest and most conservative way to proceed, use the worst-case numbers. However, in almost every application, you can operate more drives than these numbers suggest. Use the information in the other sections below to see if you can save money by operating additional drives with each Power Module.

The following sections use Compumotor OEM Series motors as examples. If you are using other motors, obtain information about the relevant motor specifications (copper losses, core losses, peak shaft power, etc.), and follow the same type of procedure as explained below.

NOTE: The techniques presented in this chapter apply to step motor systems. For information on how to determine the number of servo drives you can connect to an OEM300, consult your servo drive user's manual.

WORST-CASE METHOD

A system of drives and motors places the greatest demand on a power supply when each motor produces the maximum shaft power it can deliver, and all motors turn at the same time. For the power supply, this is the "worst-case" situation. There are no other times when the power supply must provide this much power.

The table below lists the maximum number of drives that can be connected to the OEM300 Power Module in the worst-case situation—each drive operating a motor at maximum shaft power; all motors turning simultaneously.

WORST-CASE NUMBER OF DRIVES			
MOTOR SIZE			NUMBER OF DRIVES
SIZE 23	OEM57-40-MO	1/2 Stack	5
	OEM57-51-MO	1 Stack	4
	OEM57-83-MO	2 Stack	3
SIZE 34	OEM83-62-MO	1 Stack	3
	OEM83-93-MO	2 Stack	2
	OEM83-135-MO	3 Stack	2

CALCULATION METHOD

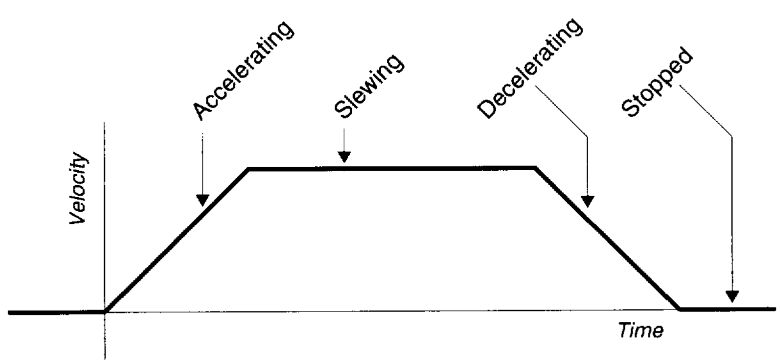
In most applications, the worst-case situation described above never occurs. Conditions where all motors in a system produce maximum shaft power, all at the same time, are extremely rare. Instead, it is more common for the motors to use power at different levels: one may be accelerating, another stopped, and others moving at constant velocity or decelerating.

If you consider the move profiles of all motors in your system, and evaluate the amount of peak and average power the motors require, you will probably find that you can operate more drives and motors from one OEM300 than the worst-case numbers suggest. Details on how to perform these calculations are given below.

WHERE POWER IS USED IN A MOTION CONTROL SYSTEM

A motor can be in one of four states: stopped, accelerating, slewing, or decelerating. The power supply must satisfy the motor's power requirements, which are very different during each of these states.

A sketch of a typical move profile is shown below.



Typical Move Profile

In the following sections, we will see how the drive and motor use the power they get from the power supply. Then, we will examine the amount of power required by the drive and motor during each part of a move.

Copper Losses and Drive Losses

Two types of power losses always exist, whether a motor is in motion or stopped—copper losses and drive losses. Their values remain approximately constant, regardless of the speed at which the motor turns. If the motor is not moving, these are the only losses present.

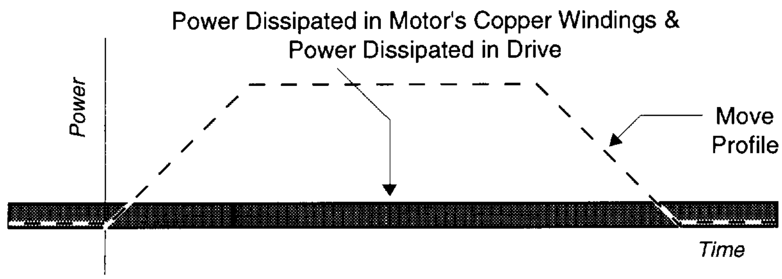
Copper losses are caused by resistance to current flow in the copper windings of the motor. A step motor that is stopped has a current flowing in it to maintain holding torque; approximately the same amount of current flows when the motor is in motion.

The copper losses are calculated as I^2R—the square of the current in the windings, multiplied by the resistance of the windings. Since the current stays the same, whether the motor is moving or stopped, the copper losses are constant. They are usually small, approximately 10 to 15 Watts, because the resistance of the windings is low.

Drive losses occur during normal operation of the drive. The drive receives power from the power supply, and sends most of that power to the motor. Some of the power, however, is lost as heat in the drive when resistors and other components heat up.

Power dissipated as heat in the drive constitutes the drive losses. These are usually small, approximately equal to the copper losses. They are proportional to the current the drive delivers. Since this current is fairly constant, drive losses are also constant—they do not change when motor speed changes.

Copper losses and drive losses are shown in the drawing below. Notice that these losses are constant, whether the motor is moving or stopped.



Copper Losses and Drives Losses

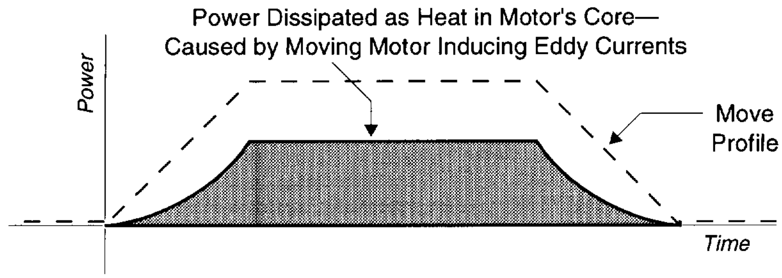
The following table lists the values for drive losses and copper losses.

COPPER LOSSES and DRIVE LOSSES				
OEM SERIES MOTORS		Copper Loss(W)	Drive Loss(W)	TOTAL (COPPER + DRIVE)
SIZE 23	OEM57-40-MO	9	9	18
	OEM57-51-MO	11	11	22
	OEM57-83-MO	9	13	22
SIZE 34	OEM83-62-MO	13	15	28
	OEM83-93-MO	14	20	34
	OEM83-135-MO	15	27	42

Core Losses Caused by Motion

When the motor is in motion, some power is lost because of the movement of the motor. The moving magnetic fields in the motor will induce eddy currents in the motor's iron core; these eddy currents cause heating in the core. The power supply delivers the power that ends up as heat in the motor's core.

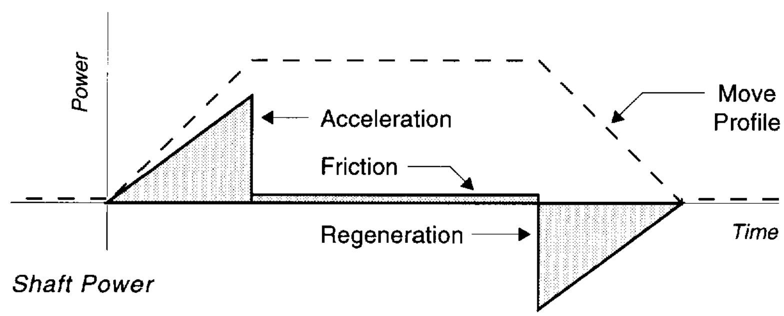
The power losses caused by eddy current induction are called *core losses* (they are also known as *iron losses*). Core losses are shown in the drawing below.



Core Losses

Core losses are proportional to v^2, the square of the motor's velocity. Notice that they can change rapidly during acceleration or deceleration, and are constant when the motor is slewing

Shaft Power During Acceleration, Slew, and Deceleration
To accelerate a load, the motor's shaft produces torque. The power required to accelerate the load is called shaft power (since torque multiplied by velocity equals power). During slew, a system with little friction will not require shaft power. If there is friction in the system, the motor must produce shaft power to overcome the friction. Shaft power is shown in the drawing below.



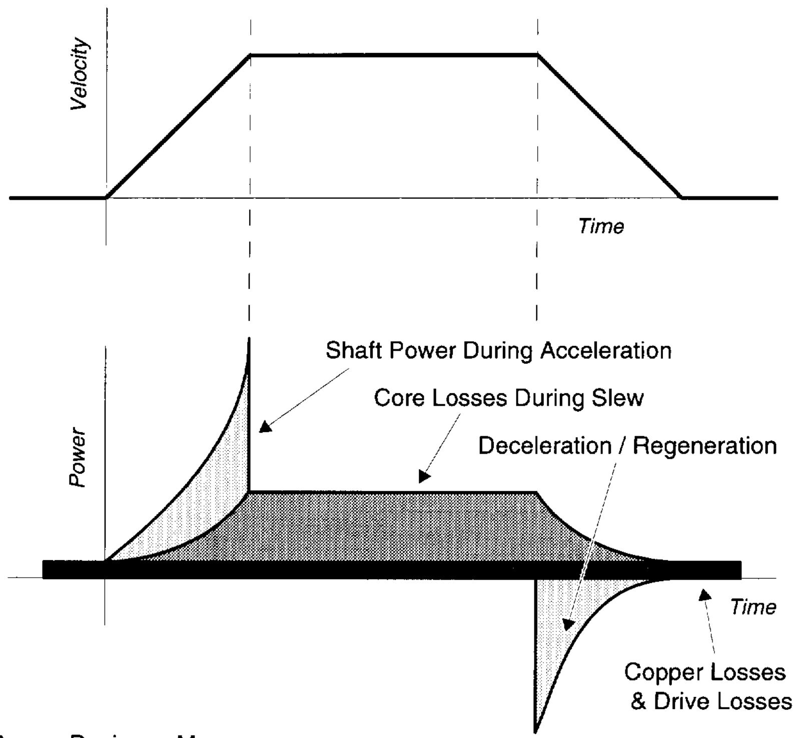
Shaft Power

Notice that shaft power rises at a constant rate during acceleration, and, if friction is negligible, will be close to zero during slew.

During deceleration, shaft power is negative. This means that the drive is not delivering power to the motor. In fact, the opposite happens: the motor delivers power to the drive and power supply. This is called regeneration.

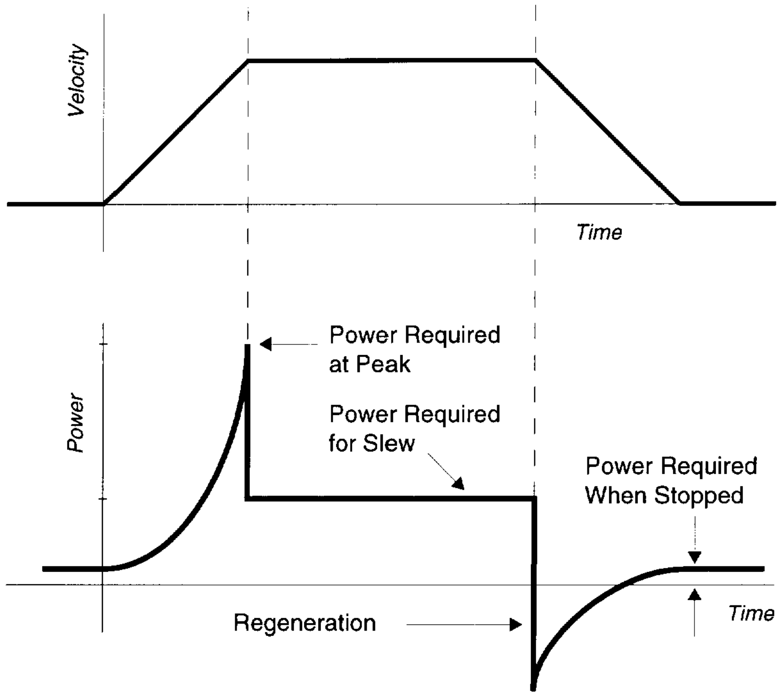
Power Requirements During a Typical Move

If we make a graph of all the places power is used, as we have done in the next drawing, we can see where power goes during a move.



Power During a Move

And, if we add up the values for the various losses, shaft power, regeneration, etc., we get a graph of the power that the power supply must deliver. This is shown in the next drawing.



Power Required During a Move

Using the drawings above, we can discuss the power required during each part of a move profile.

Stopped

When the motor is not moving, power is dissipated in copper losses and drive losses. The power supply must deliver power to replace these losses.

Accelerating

During acceleration, the motor develops shaft power. Because the motor is moving, core losses start to dissipate power, and play a larger role as speed increases. Copper losses and drive losses are still present. The power supply must deliver enough power for all these purposes.

In most applications, the period of time peak power is actually required is very brief—often just a few thousandths of a second. There is usually enough stored energy in the power supply's capacitors to meet this brief power demand.

Slewing

When the motor is slewing, the load moves at a constant speed. Demand placed on the power supply drops sharply, because shaft power is no longer required to accelerate the load. During slew, the power supply must replace losses caused by core losses; it must supply shaft power to overcome friction in the load; and, it must replace power dissipated in copper losses and in the drive itself.

Decelerating

During deceleration, the motor becomes a generator, and produces regenerated energy. The motor sends regenerated energy onto the power bus; this energy will be used to replace core losses, copper losses, and drive losses. If there is still excess energy, the power supply must be able to absorb this energy.

CALCULATING THE POWER REQUIRED

To calculate the power your system will require from the power supply, you need to know three numbers: power required at peak, power required for slew, and power required when the motor is stopped. The table below lists the power required by each OEM Series step motor.

POWER REQUIREMENTS — OEM SERIES MOTORS				
MOTOR SIZE		STOP (W)	SLEW (W)	PEAK (W)
SIZE 23	OEM57-40-MO	18	46	74
	OEM57-51-MO	22	54	101
	OEM57-83-MO	22	48	110
SIZE 34	OEM83-62-MO	28	67	115
	OEM83-93-MO	34	75	160
	OEM83-135-MO	42	89	189

These figures are for motors that are operating at maximum power. If your motors operate at less than maximum power, the figures for peak and slew power will be lower.

To determine the power that the OEM300 must deliver to your system at any given time, first determine where each motor is in its move profile—stopped, accelerating, slewing, or decelerating. Use the numbers from the table above to approximate the number of Watts each motor requires at that time. Add up the Watts required by each motor to obtain the total power demand.

The OEM300 can provide 200W on a continuous basis, and 300W peak for up to 30 seconds (with a 10% duty cycle). Identify the periods when your system requires the most power, and compare the power required with the amount of power the OEM300 can deliver.

Remember, there is a reservoir of additional power stored in the capacitors of the OEM300. If the peak power demand during acceleration of some motors briefly exceeds 300W, the OEM300 may still be able to deliver enough power, provided that the period of peak demand is short enough.

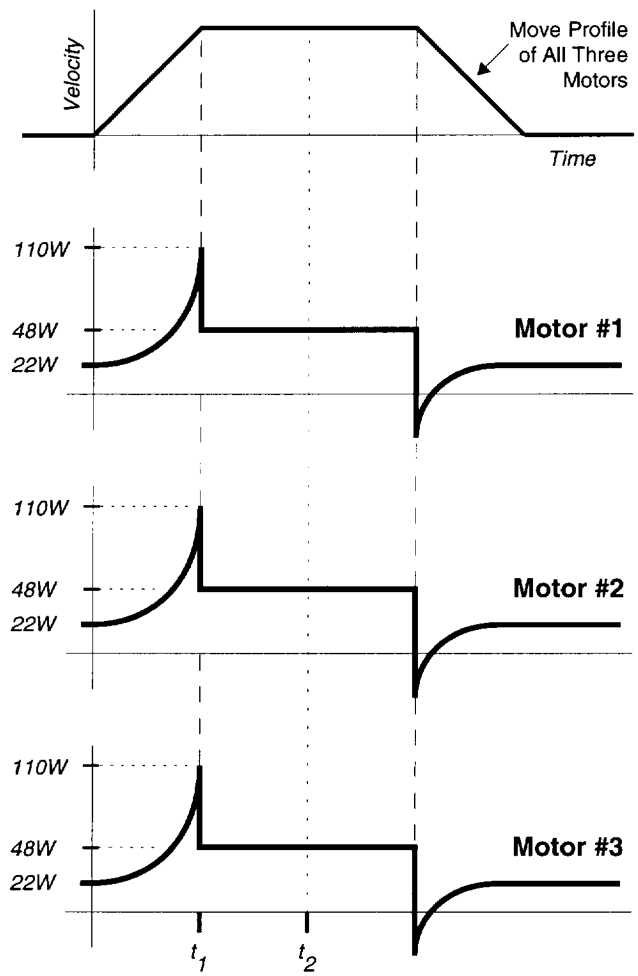
A Design Example

To illustrate the calculation method, we will determine how many OEM650 drives can be connected to one OEM300 Power Module, when each drive runs an OEM57-83 motor (a 23 frame size 2-stack step motor).

Because the number of drives that can be connected depends on the motors' move profiles, we will look at two situations. The first example has move profiles that occur simultaneously. The second example has move profiles that occur at different times.

Simultaneous Moves

The drawing below shows the move profile and power requirements in a system where three motors simultaneously accelerate until they reach maximum power, then move at constant velocity. We assume there is no friction in the system.



Total Power = 330W at Time t_1; 144W at Time t_2

Simultaneous Move Profiles

At time t_1, each motor requires peak power. From the table listing power requirements for OEM Series motors, we find a value of 110W at peak for the OEM57-83 motor. Next, we add together the power required by each motor:

Motor #1	110W
Motor #2	110W
Motor #3	110W
TOTAL	330W

We find the total power required at time t_1 is 330W.

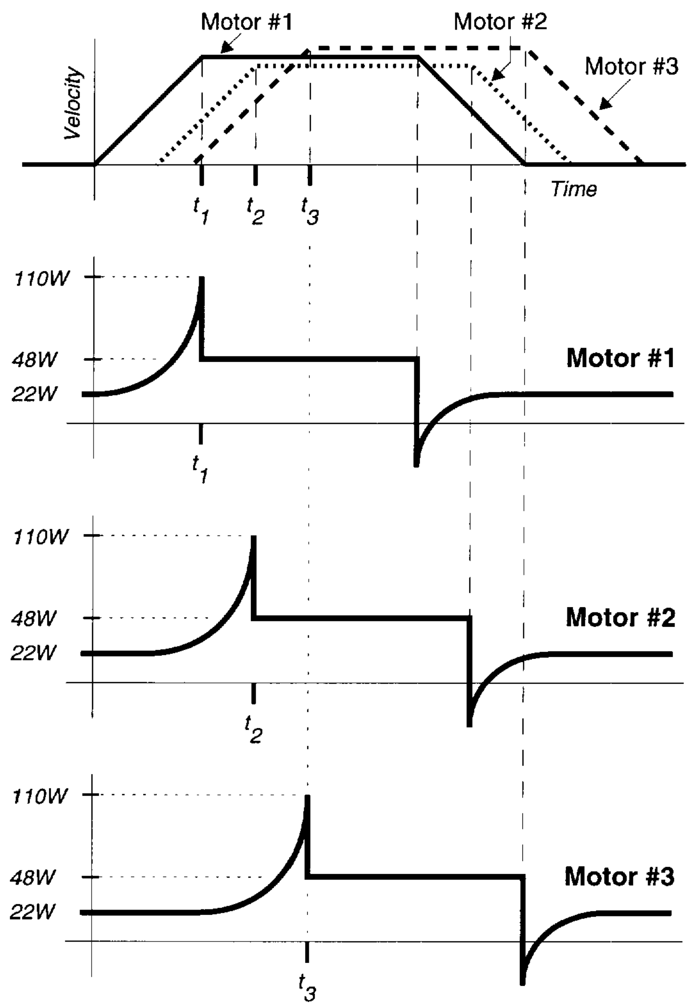
The OEM300 is specified as a 300W power supply. Can it provide 330W? Yes, because the duration of time that 330W is required is very brief; the OEM300 will use extra power stored in its capacitors to meet this demand.

Notice that every motor's peak power requirements occur at the same time. Because of this, we can only run three motors of this size. This is the same number that is listed in the worst-case table for OEM57-83 motors. The method discussed in this section was used to find the numbers in the worst-case table.

At time t_2, each motor is slewing and requires only 48W. The total power required to operate the system at this time is 144W. This means that most of the time this system operates, less than half of the capability of the Power Module is being used. The next section shows how to use the full capabilities of the Power Module, and operate additional drives.

Independent Moves

In this example, we consider the same three motors as in the previous example. This time, however, the move profiles are staggered, so that the peak power requirements of each motor occur at different times. Move profiles and power requirements for each motor are shown in the next drawing. (We assume there is no friction during slew.)



Total Power = 206W at Time t_3

Independent Move Profiles

In this system, when Motor #1 reaches its peak power at time t_1, Motor #2 is beginning to accelerate, and Motor #3 is stopped. At time t_3, Motor #3 accelerates to its peak power, and Motors #1 and #2 are slewing.

The peak power required by this system occurs at time t_3. Motors #1 and #2 each require 48W while slewing . Motor #3 requires 110W during its moment of peak power. (These numbers can be found in the Power Requirements table.)

We add each motor's power requirements:

Motor #1	48W
Motor #2	48W
Motor #3	110W
TOTAL	206W

The total power the three motors and drives require at time t_3 is 206W.

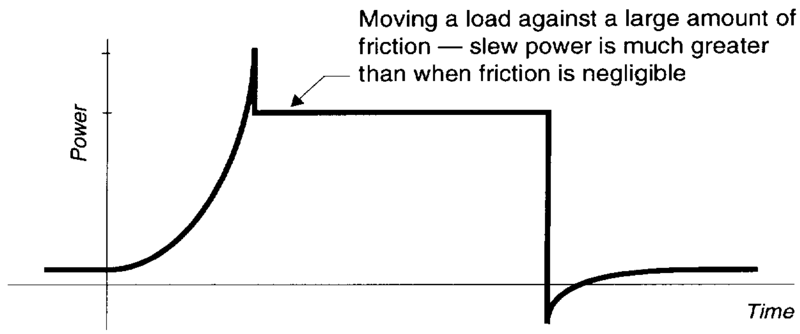
By staggering the move profiles, we have substantially reduced the peak power requirements of the total system. A fourth motor and drive could be added. The OEM300 would easily have the capability to provide the necessary power, no matter when the fourth motor's peak power demand occurred.

Even more drives and motors can be added. If the moves are organized so that some motors are stopped while others are running, the peak demand will be reduced. (Remember that a stopped motor still requires power—in this example, 22W). The peak demand will also be reduced if some motors operate at a level that requires less than full peak or full slew power.

Unusual Power Requirements

So far, the explanation of the calculation method has assumed that the power required during slew is substantially less than that required at peak acceleration. This is not always the case.

For example, the following drawing shows a graph of the power required by a motor while it moves a load against a large amount of friction.



Unusual Power Requirements

The demand for power rises as the load accelerates, and stays near the peak level while the load moves at constant velocity.

A motor lifting a load against gravity would have a similar graph for its power requirements.

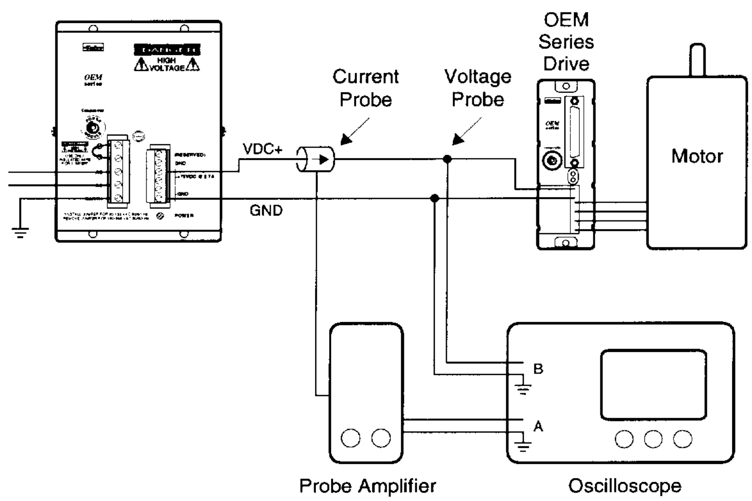
If your system has unusual power requirements, you must make appropriate adjustments to the figures given earlier for power required by OEM Series motors. Or, use the measurement method discussed in the next section, and determine the actual current requirements.

MEASUREMENT METHOD

The measurement method empirically measures actual current flowing from a power supply to each drive. To use the measurement method, you must first make a working prototype of your system, and measure the current required by each drive as the motors operate. You can then compare the total current required with that available from the OEM300.

For your prototype system, use a large temporary power supply, capable of providing enough current for all drives in your system at 75VDC. Once you determine the current requirements, you will replace the temporary power supply with one or more OEM300 Power Modules.

Use a DC current probe to measure the current going from the power supply to each drive. (Currents going from the drive to the motor are not relevant in this procedure; you do not need to measure them.)



Setup for Current Measurement

You need to find two values: the total peak current demand; and the duration, or duty cycle, of that total peak demand. The total current demand will probably be changing continuously.

One way to locate the peak demand periods and find their duty cycles is to connect the current probes to a storage oscilloscope. For any given time, you can then add up the demand from each drive to obtain the total demand. You can also measure the duration of the peak demand, find how frequently it occurs, and calculate its duty cycle.

The OEM300 is rated to deliver current at these levels:

	RATED CURRENT
2.7A	Continuous
4.0A	Peak (30 sec; 10% duty)

Current levels that activate the OEM300's short circuit protection are shown in the next table.

SHORT CIRCUIT PROTECTION	
Current Level:	Shutdown Within....
6A	3 seconds
9A	Immediate

With the results of your current probe measurements, and the current levels listed above, determine how many drives you can connect to each OEM300. Try to keep the current produced by the OEM300 within the rated levels.

What happens when your system operates on the borderline, and occasionally requires more than 4 Amps of current? The answer depends on the duration and level of the excess current demand. If asked to deliver excess current, the OEM300 will do so for brief periods. Voltage will stay very near the rated voltage of 75VDC.

However, there are two possible consequences if the OEM300 operates outside its specified range. The first is related to over-temperature protection. If the OEM300 continually provides current in excess of 4.0 Amps, it may become excessively hot. The OEM300 will not be damaged, but when its heatplate temperature exceeds 60°C, the over-temperature protection circuit will shut down the output of the OEM300.

The second potential problem is related to the short circuit protection feature. The OEM300 will produce currents above 4.0 Amps, to satisfy brief demands; but, if it produces 6.0 Amps, the short circuit protection feature will shut down the output within seconds. If the current reaches 9.0 Amps, however briefly, the OEM300 will shut down immediately.

Operating the OEM300 beyond its specified range can cause unpredictable results. Therefore, to achieve optimum performance from the Power Module, connect the appropriate number of drives.