Compumotor

L Drive User Guide

Compumotor Division
Parker Hannifin Corporation
p/n 88-007753-02 A

Parker

User Guide Change Summary

The following is a summary of the primary changes to this user guide since the last version was released. This user guide, version 88-007753-02A, supersedes version 88-007753-02Y.

When a user guide is updated, the new or changed text is differentiated with a change bar in the right margin (this paragraph is an example). If an entire chapter is changed, the change bar is located to the right of the chapter title.

NOTE: Key Terms have been moved from the beginning of each chapter to the Glossary found in the Appendices section.

Chapter 1.
Introduction

Chapter 1 was changed to include the added features provided by the new Accelerometer (-AC) option for the L20 forcer.

Chapter 2.
Getting Started

Changes to Chapter 2 are summarized as follows:

- Accelerometer (-AC) option set up and connections
- Ship kit changes

Chapter 3.
Installation

Changes to Chapter 3 are summarized as follows:

- All optional DIP switch settings moved to Chapter 5
- New drive and platen mounting information
- New forcer cable mounting information
- New assembly instructions for -RFKC coalescing filter kit

Chapter 4.
Application Design

Changes to Chapter 4 are summarized as follows:

- Effects of Accelerometer option on resonance and settling
- Updated tuning procedures

Chapter 5.
Hardware Reference

Changes to Chapter 5 are summarized as follows:

- Added Accelerometer specifications/settings
- Added default and optional DIP switch setting
- Changed motor current DIP switch settings
- Updated force/speed curves for each forcer
- Updated system specifications and dimensional drawings

Chapter 6.
Maintenance &
Troubleshooting

Changes to Chapter 6 are summarized as follows:

- Updated list of suggested spare parts
- Updated platen maintenance information
- Updated troubleshooting methods
- Added information on returning the system to affect repairs or upgrades

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How To Use This Manual

The manual is designed to help you install, develop, and maintain your system. Each chapter begins with a list of specific objectives that should be met after you have read the chapter. This section is intended to help you find and use the information in this manual.

Contents of This Manual

This user guide contains the following information:

Chapter 1: Introduction

This chapter provides a description of the product and a brief account of its specific features.

Chapter 2: Getting Started

This chapter contains a detailed list of the items you should have received with your L Drive shipment. It will help you to become familiar with the system and ensure that each component functions properly. You will learn how to configure the system properly in this chapter.

Chapter 3: Installation

This chapter provides instructions for you to properly mount the system and make all electrical and non-electrical connections. Upon completion of this chapter, your system should be completely installed and ready to perform basic operations.

Chapter 4: Application Design

This chapter will help you customize the system to meet your application needs. Important application considerations are discussed. Sample applications are provided.

Chapter 5: Hardware Reference

This chapter contains information on system specifications (dimensions and performance). This chapter may be used as a quick-reference tool for proper switch settings and I/O connections.

Chapter 6: Maintenance & Troubleshooting

This chapter describes Compumotor's recommended system maintenance procedures. It also provides methods for isolating and resolving hardware and software problems. A list of diagnostic codes is included in this chapter.

Installation Process Overview

To ensure trouble-free operation, you should pay special attention to the environment in which the L Series equipment will operate, the layout and mounting, and the wiring and grounding practices used. These recommendations are intended to help you easily and safely integrate L Series equipment into your manufacturing facility. Industrial environments often contain conditions that may adversely affect solid state equipment. Electrical noise, atmospheric contamination, or installation may also affect the operation of the L Series System.

Before you attempt to install this product, you should complete the following steps:

STEP 1 Review this entire manual. Become familiar with the manual's contents so that you can quickly find the information you need.

STEP 2 Develop a basic understanding of all system components, their functions, and interrelationships.

STEP 3 Complete the basic system configuration and wiring instructions provided in Chapter 2, Getting Started. *NOTE: This is a preliminary configuration, not a permanent installation, usually performed in a bench-top environment.*

STEP 4 Perform as many basic moves and functions as you can with the preliminary configuration. You can perform this task only if you have reviewed the entire manual. You should try to simulate the task(s) that you expect to perform when you permanently install your application. *However, do not attach a load at this time.* This will give you a realistic preview of what to expect from the complete configuration.

STEP 5 After you have tested all of the system's functions and used or become familiar with all of the system's features, carefully read Chapter 3, Installation.

STEP 6 After you have read Chapter 3 and clearly understand what must be done to properly install the system, you should begin the installation process. **Proceed in a linear manner**; do not deviate from the sequence or installation methods provided.

STEP 7 Before you begin to tune and customize your system, check all of the system functions and features to ensure that you have completed the installation process correctly.

The successful completion of these steps,will prevent subsequent performance problems and allow you to isolate and resolve any potential system difficulties before they affect your operation.

Developing Your Application

Before you attempt to develop and implement your application, you should consider the following issues:

- Recognize and clarify the requirements of your application. Clearly define what you expect the system to do.
- Assess your resources and limitations. This will help you find the most efficient and effective means of developing and implementing your application.
- Follow the guidelines and instructions outlined in this user guide. **Do not skip any steps or procedures**. Proper installation and implementation can only be ensured if all procedures are completed in the proper sequence

Conventions

To help you understand and use this user guide effectively, this user guide's conventions are explained in this section.

Highlighted Text

Several methods are used to highlight text. Explanations of special text and the way it is highlighted is presented below.

Warnings & Cautions

Warning and caution notes alert you to possible dangers that may occur if you do not follow instructions correctly. Situations that may cause bodily injury are presented as warnings. Situations that may cause system damage are presented as cautions. These notes will appear in bold face, within a box. The word warning or caution will be centered and in all caps. Refer to the examples shown below.

WARNING

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

CAUTION

System damage will occur is you power up the system improperly.

Italics

Italics are used to emphasize other important material. Refer to the example below.

Example: Outputs 1 and 2 are user programmable. *Do not use outputs 3 and 4.*

Change Bars

When a new user guide version is produced, the new or changed text is differentiated with a change bar in the right margin (this paragraph is an example). If the entire chapter is changed, the change bar is located to the right of the chapter title.

Related Publications

The following publications may be helpful resources:

- *Parker Compumotor Programmable Motion Control Catalog*
- Schram, Peter (editor). *The National Electric Code Handbook (Third Edition).* Quincy, MA: National Fire Protection Association

Chapter 1. INTRODUCTION

Chapter Objective

The objective of this chapter is to provide you with information to understand the product's basic functions and features.

Product Description

The L Drive is a bi-polar, microstepping drive designed to drive two-phase, permanent magnet, hybrid linear motors. The L Drive has been specifically designed to take full advantage of the performance of Compumotor's linear step motors.

The drive uses advanced MOSFET technology to provide high performance in a small package with short circuit, brownout, and over temperature protection.

The L Drive, compatible with all Compumotor indexers, uses a standard step and direction interface for controlled acceleration, velocity, and distance.

Each drive has an integral power supply, meaning it operates directly from 120VAC. It will produce up to 3A of current per motor phase.

L Drive systems are fully-packaged, single-axis, linear motion systems. No additional mechanical hardware is necessary for most L Drive system applications. The standard system consists of a forcer, platen, drive, and interconnecting cables. Four forcer sizes are available with static forces of 3, 6, 9, and 20 pounds.

The L Drive is designed for panel mounting and may be installed in a minimum depth or minimum width configuration by moving its mounting brackets to the side or back of the unit.

Accelerometer (-AC) Option

The -AC option includes an *accelerometer* which is mounted in the L20 forcer to electronically dampen the resonance, or *ringing*, which is present in all stepper systems. The -AC option is available for new and existing L Drive systems that use an L20 forcer.

Product Features

The L Drive provides the following features:

- A fully packaged system with a forcer, platen, drive, electronics, integral power supply, heat sink, and cables.
- Four forcer sizes are available (3 lb, 6 lb, 9 lb, and 20 lb).
- High-voltage operation (170V) for optimum high-speed performance.
- The drive provides 0-3 Amps/phase bipolar.
- 95VAC-135VAC, 50/60 Hz input power.
- Protected against short circuit, brownout, and over temperature. *NOTE: The L Drive has no phase-to-ground short circuit protection.*
- Microprocessor controlled microstepping ensures smooth operation.
- Optically isolated step and direction inputs compatible with all Compumotor indexers.
- Automatic Standby feature reduces forcer heating when the forcer is not moving.
- Microstepping resolutions are DIP switch selectable.
- A specially designed 12-foot forcer cable is provided with the L20 system to connect the forcer to the L Drive. The L3C, L5A, and L9A forcers include 10 feet of coiled drive cable.

-AC Option Features

The Accelerometer option offers the following enhancements to the L Drive using the L20 forcer:

- Higher Throughput
- Faster Settling
- Smoother Operation

Higher Throughput

The -AC option allows more of the forcer's force to be used for acceleration; therefore, less force is needed for a safety margin. Only 25-35% of the forcer force can be used for acceleration if an accelerometer is not used. This number is 60-70% for forcers with the accelerometer option. For most applications, you can double the acceleration.

Faster Settling

The duration of settling at the end of a move is reduced by more than 90%. If the settling time for an unloaded L20 forcer without an accelerometer is 190ms, it will be 13ms for an L20 forcer with accelerometer feedback. A similar reduction in settling time exists for L20 forcers with payloads.

Smoother Operation

The -AC option provides smoother operation at velocities around the forcer's resonant frequency. When the pole frequency of its 2nd or 4th harmonic (1 ips = 25Hz) falls on or near resonance, the forcer will run very roughly. The accelerometer feedback reduces this roughness by two-thirds.

Linear Motor Theory of Operation

The linear hybrid stepping motor operates on the same electromagnetic principles as the rotary hybrid motor. The stator or ***platen*** is a steel bar (with teeth) that extends over the distance to be traversed. The platen is entirely passive. All magnets and electromagnets are incorporated into the armature or ***forcer***. The forcer moves (bi-directionally) along the platen, assuming discrete locations in response to the state of the currents in its field windings. Figure 1-1 shows the a basic structure of the forcer and platen.

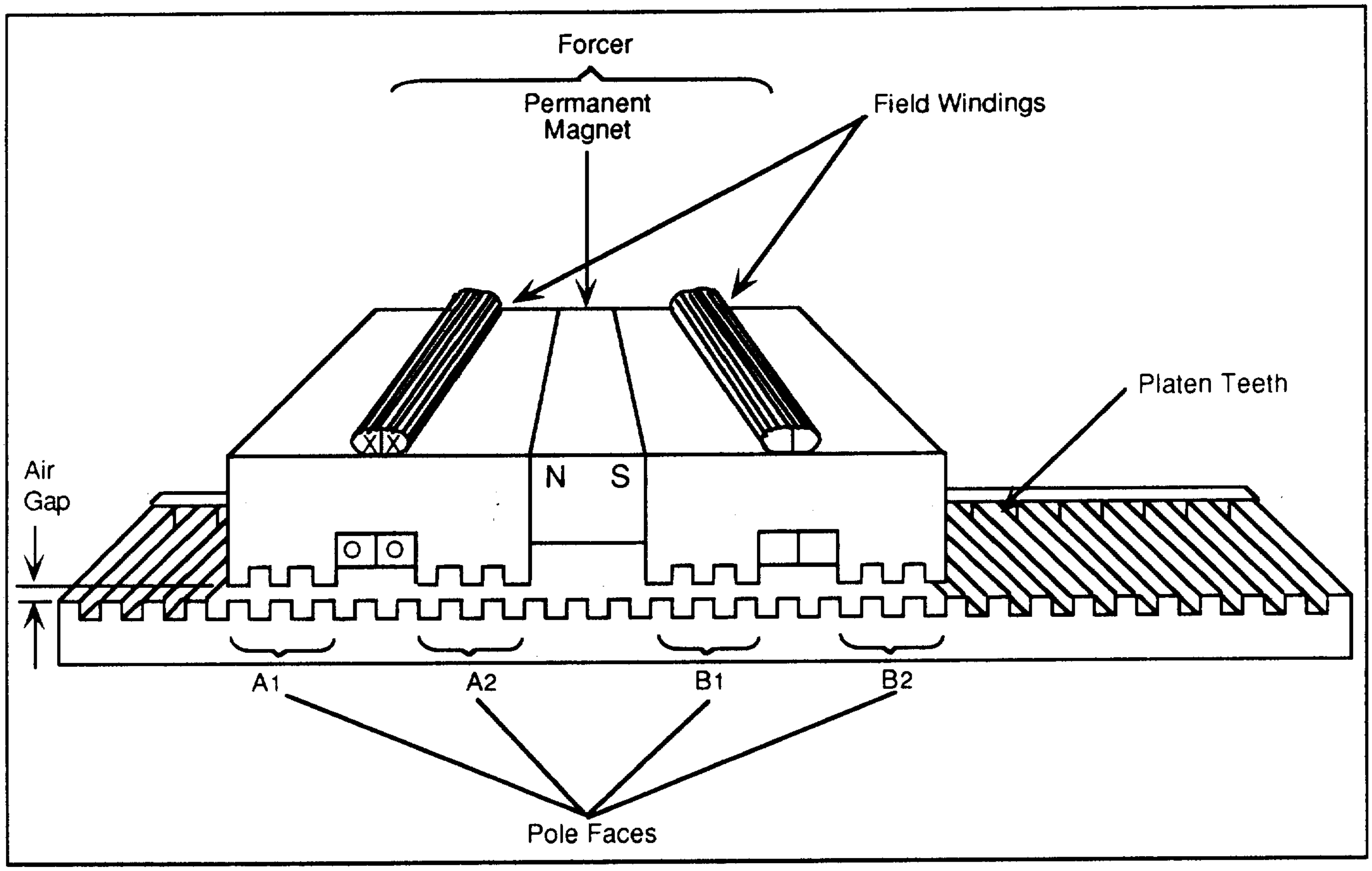


Figure 1-1. Construction of a Linear Motor

Figure 1-2 is a simplified schematic representation of the motor geometry and shows the forcer in four distinct stages of excitation. The forcer consists of two electromagnets (A and B) and a strong, rare-earth, permanent magnet (hence the name *hybrid*). The two pole faces of each electromagnet have teeth (to concentrate the magnetic flux).

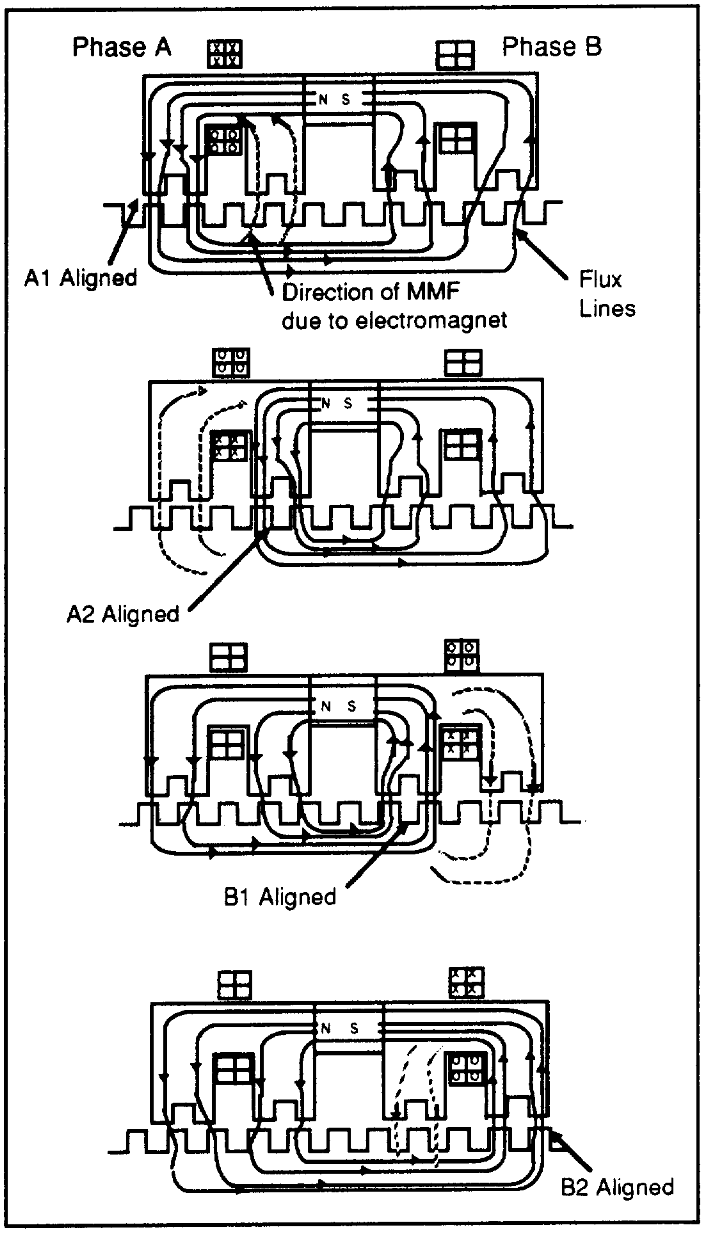


Figure 1-2. Four Steps of a Linear Step Motor

The four sets of teeth are spaced in mechanical quadrature, so that only one set at a time can be aligned with the platen teeth. When current is established in a field winding, the resulting magnetic field reinforces permanent magnet flux at one pole face and cancels it at the other. By reversing the current, the reinforcement and cancellation are exchanged. When current is removed, the PM flux divides equally between the pole faces. By selectively applying current to phase A and B, it is possible to concentrate flux at any of the forcer's four pole faces. The face receiving the highest flux concentration will attempt to align its teeth with the platen. Figure 1-2 depicts the four cardinal states or full steps of the forcer. The four steps result in motion of one tooth interval to the right. If you reverse the sequence, the forcer will move to the left.

Linear motors are microstepped by proportioning current to the two phases of the forcer (similar to rotary stepping motors). The L Drive steps the linear motor at 125, 100, 90, or 50 microsteps per full step.

If the sequence in Figure 1-2 is repeated, the forcer continues to move. When the sequence is stopped, the forcer stops with the appropriate tooth set aligned. At rest, the forcer develops a restoring or holding force that opposes any attempt to displace it from equilibrium. As the resting forcer is displaced further from equilibrium, the restoring force increases until the displacement reaches one-fourth of a tooth interval (see Figure 1-3). Beyond this point, the restoring force drops. If the forcer is pushed over the crest of its holding force, it slips or jumps rather sharply and comes to rest at an integer number of tooth intervals away from its original location. If this occurs while the forcer is traveling along the platen, it results in a stall condition.

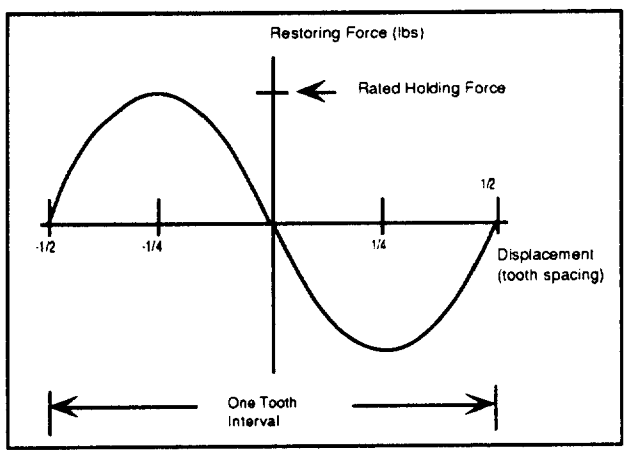


Figure 1-3. Force vs. Displacement Curve

The magnetic flux that passes between the forcer and the platen creates a very strong normal force of attraction between the two pieces. This force is as much as ten times the peak holding force of the forcer. The attractive force must be offset with some bearing arrangement to maintain precise clearance between the pole faces and the platen teeth. Compumotor forcers use either mechanical roller bearings or air bearings to maintain clearance.

Chapter 2. GETTING STARTED

Chapter Objectives

The information in this chapter will enable you to do the following:

- Verify that each component of your system has been delivered safely.
- Ensure that the unit functions properly by bench testing
- Configure the system properly

What You Should Have

Upon receipt, you should inspect your L Drive system for obvious damage to its shipping container. Report any damage to the shipping company as soon as possible. Parker Compumotor cannot be held responsible for damage incurred in shipment. Carefully unpack and inspect your L Series shipment. The ship kit items listed in Table 2-1 should be present and in good condition. Note that the Fan Kit and the Air Regulator/Filter Kit are optional.

Description	Part Number
Possible Drives:	
L Drive	L-DRIVE
L Drive with -AC Option	L-DRIVE-AC
Possible Forcers:	
L3C	L3C
L5A	L5A
L9A	L9A
L20	L20
L20 with -AC Option	L20-AC
Possible Platens:	
L3C	PO-L3C-P15
L5A	PO-L5A-Pxx
L9A	PO-L9A-Pxx
L20	PO-L20-Pxxx
Forcer-to-Drive Cable*	71-007553-12
AC Power Cable Assembly	71-006593-01
Male 25-Pin D-Connector	43-001989-01
D-Connector Shell	43-001990-01
5-Pin Phoenix Connector**	43-005561-01
L Drive User Guide	88-007753-02
Optional Parts:	
Air Regulator/Filter Kit	-RFKC
Fan Kit	-LFK

* L20 forcer-to-drive cable is integral to the forcer
** Included only in *Drive Only* shipments

Table 2-1. Ship Kit List

NOTE: When a drive/forcer system is ordered, the forcer is packaged with the L Drive. The platen is shipped separately.

Basic System Configuration

This section provides procedures and information to perform the basic configuration of your L Drive System. Please note that this is a temporary *bench-top* configuration. Instructions for complete permanent configuration are discussed in Chapter 3, Installation.

Verify Factory Settings

The L Drive has DIP switches for configuring drive functions. The standard L Drive uses the Drive DIP switch, while the -AC option L Drive uses the Drive DIP switch and the -AC DIP switch. These DIP switches are set at the factory to default settings. The motor current is set to accommodate the motor that you ordered with your L Drive system.

Before you perform system connections you should **inspect the L Drive DIP switches to ensure that they are set to the factory default configuration**. Figure 2-1 illustrates the location of the DIP switches on the L Drive.

Once you have permanently installed your L Drive system, refer to Chapter 5, Hardware Reference, for alternative DIP switch settings and adjustment procedures.

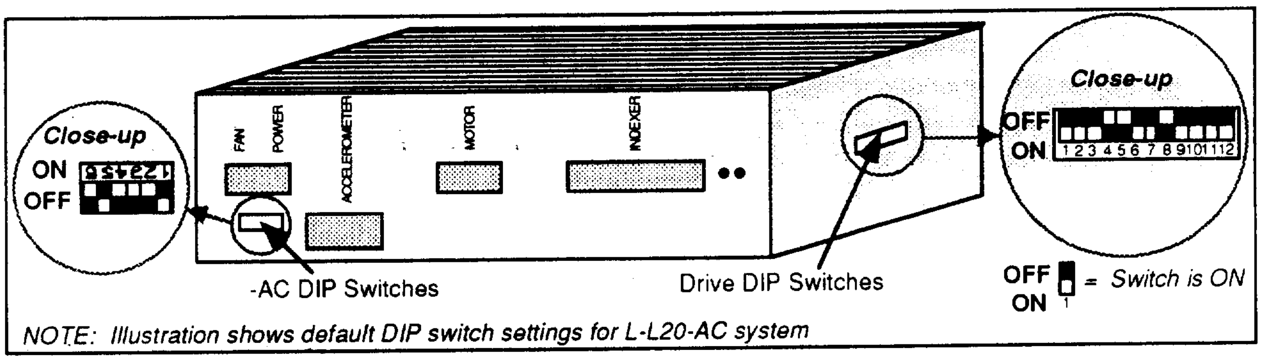


Figure 2-1. Location of L Drive DIP Switches

Motor Current

Refer to Table 2-2 for the factory default motor current settings. Motor current is set with the Drive DIP switch. *NOTE: These current values are approximate settings in the L Drive. The actual current will not match these settings exactly.*

CAUTION

Do not attempt to measure these currents without an isolated scope.

Forcer Size	Phase Current Amps	Maximum Force (Lbs)	Drive DIP Switch Settings 1	2	3	4	5
L-L3C	0.961	3.0	OFF	ON	OFF	ON	OFF
L-L5A	1.450	6.0	OFF	ON	ON	ON	ON
L-L9A	1.450	9.0	OFF	ON	ON	ON	ON
L-L20	2.721	20.0	ON	ON	ON	OFF	OFF
Drive-Only*	0.000	0.0	OFF	OFF	OFF	OFF	OFF

* Default setting if no motor is shipped with the L Drive order

Table 2-2. Factory Default Motor Current Settings

Motor Resolution

For proper operation of the -AC system, the resolution settings on the -AC DIP switch must be the same as those on the Drive DIP switch. Table 2-3 provides the default motor resolution settings.

Drive DIP Switch Settings			
8	9	10	Resolution
OFF	ON	ON	10,000 steps/in pure*

*6,000 steps/in for L3A forcers

-AC DIP Switch Settings (*-AC System Only*)				
4	5	6	Resolution	Pulse Width
ON	OFF	ON	10,000 steps/in	0.65 µs*

* An optional setting to accommodate a pulse width of 1.00 µs is to set switches 4, 5, and 6 to OFF, OFF, and ON respectively.

Table 2-3. Factory Default Motor Resolution Settings

Automatic Run

The Automatic Run feature allows you to perform a quick functional check of the system. Automatic Run is enabled or disabled using **Drive DIP switch #6**. The default setting is ON (disables the Automatic Run function).

Automatic Standby

The Automatic Standby feature allows the forcer to cool when it is not moving. When enabled, this feature drops the current to the forcer by 50% when the forcer receives no step pulses for one second. Full power is restored when a step pulse is received. Automatic Standby is enabled or disabled using **Drive DIP switch #7**. The default setting is ON (disables the Automatic Standby function).

Motor Waveforms

Drive DIP switches #11 and #12 select the current waveform to achieve the smoothest system operation. Leave switches 11 and 12 set to ON (factory setting) for optimum forcer performance (see Table 2-4).

Waveform Shape	11	12
Pure Sine	ON	ON

Table 2-4. Default Motor Waveform

Servo Gain (-AC Systems Only)

The servo gain is set using -AC DIP switches 1 - 3. The default setting is for a payload of 0 - 1 lb (see Table 2-5).

-AC DIP Switch Settings			
1	2	3	Description
OFF	ON	ON	payload: 0 to 1.0 lb

Table 2-5. Default Gain Settings

System Connections

Figure 2-2 shows the location of the connectors on the L Drive. Refer to Chapter 5, Hardware Reference, for detailed pinouts of each L Drive connector.

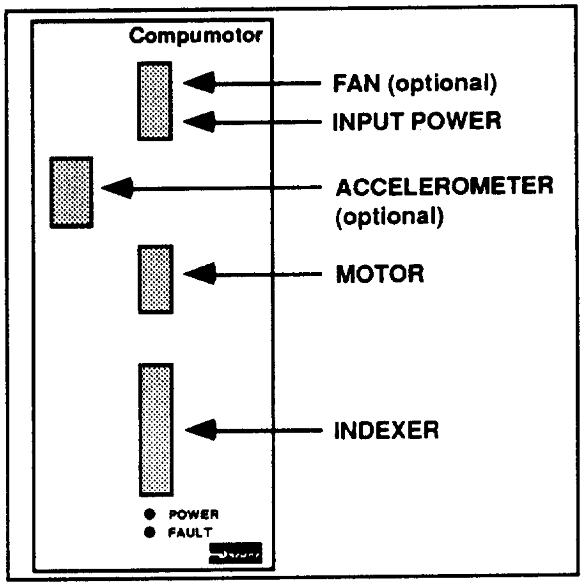


Figure 2-2. Location of L Drive Connectors

The L Drive is protected against over temperature and short circuits between forcer phases (but not phase-to-ground). Compumotor does not recommend that you test these features or operate your system in such a way as to induce short-circuit or over-temperature situations.

> **WARNING**
>
> **Ensure that AC power is disconnected before attempting to perform any wiring. NEVER disconnect the forcer with power applied to the drive.**

Air Connections

The air gap between the L3C and L5A forcers and platens is maintained with roller bearings. The L20 and L9A forcers use an air bearing to maintain a precise air gap between the forcer and the platen. The L20 requires 40 to 45 pounds per square inch (PSI) pressure at a flow rate of about 20 cubic feet of air per hour (SCFH). For an unloaded L20 forcer, the recommended air pressure is 40 PSI. The L9A requires between 50 and 70 PSI and a flow rate of about 30 SCFH.

Available *shop* air should be 70 PSI or higher in order to be regulated and filtered to the required pressure. For long life operation, the air must be non-lubricated, clean, and dry. An optional Coalescing Air Regulator/Filter Kit (-RFKC) can be purchased from Compumotor. In applications where air cannot be used, nitrogen is an excellent substitute.

NOTE: Too much air pressure makes the air bearing unstable. An unstable air bearing produces a loud tone in the forcer.

Figure 2-3 illustrates the air hose connections. Use the following procedures for mounting the forcer on the platen and connecting the air.

STEP 1 Connect the L20 or L9A forcer to the air regulator and apply air pressure (40 PSI for L20; 60 PSI for L9A).

STEP 2 Make sure the air bearing surfaces are clean.

STEP 3 Carefully place the forcer on the platen.

STEP 4 Manually move the forcer back and forth over the platen to verify that the forcer moves freely over the platen surface. Refer to Chapter 3, Installation, for a more detailed description.

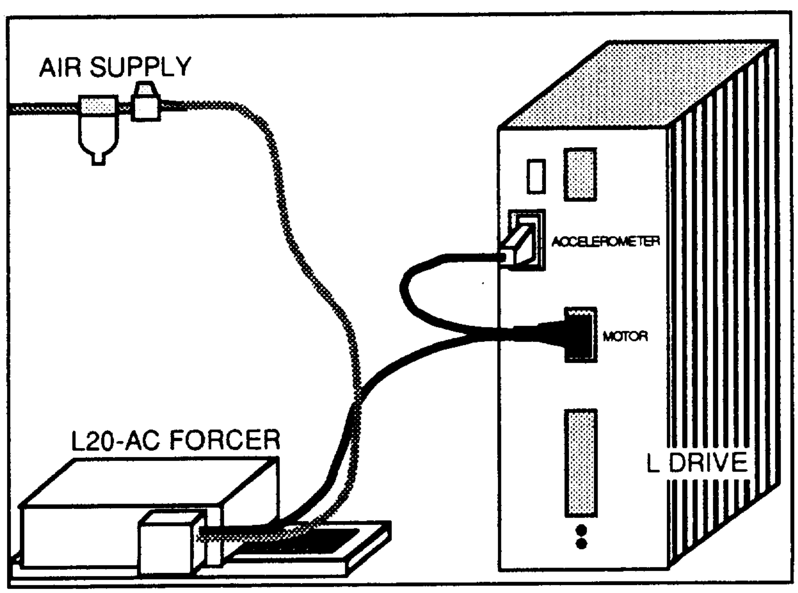


Figure 2-3. Forcer, Air, and Optional Accelerometer Connections

Forcer Connections

> **CAUTION**
>
> **Do not energize the forcer when it is not on the platen. If you apply power to the forcer when it is not on the platen, it will overheat. Never disconnect the forcer when power is being applied to the drive; this will damage the contacts of the motor connector.**

Do not operate the L Drive with a forcer that is not supplied by Compumotor.

If you have an L3C, L5A, or L9A forcer, connect the supplied coil cable between the forcer and the 5-Pin phoenix motor connector on the drive and verify the following color codes:

- Phase A+ = Red
- Phase A- = Black
- GND = Shield
- Phase B+ = White
- Phase B- = Green

Tighten the 9-Pin D-Connector screws to the forcer so that the cable will not come loose during operation.

The L20 forcer cable is prewired directly to the forcer. Simply plug the end with the 5-pin connector into the motor connector on the L Drive. If you have an L20 forcer with the -AC option, you must plug the additional 9-Pin D-Connector to the Accelerometer connector (see Figure 2-3) and tighten the screws.

Detailed cable mounting instructions are provided in Chapter 3, Installation.

Indexer Connections

Connect the indexer to the L Drive via the indexer connector on the drive front panel (see Figure 2-2). Refer to Table 5-1 in Chapter 5, Hardware Reference, for indexer interface specifications. Refer also to the indexer user guide for detailed pinouts and connection procedures.

If an indexer is not available, use a square wave generator. Procedures are discussed later in this chapter.

Transformer Connections (Optional)

This section addresses connecting an optional transformer to the L Drive. An isolation transformer can enhance phase-to-earth ground short circuit protection, personal safety, and electrical noise immunity. If you are not using a transformer with this system, simply proceed to the Power Connections section. *When using a transformer, the L Drive requires an input current equal to 0.6 x the DIP switch current setting.*

> **CAUTION**
>
> **AC power is limited to 132VAC. Higher voltages damage the L Drive. The low-voltage limit is 95VAC.**

Refer to the transformer user guide to determine which output leads correspond to LINE, NEUTRAL, and GROUND. As illustrated in Figure 2-4, connect the transformer leads to the AC power connector on the drive.

> **WARNING**
>
> **Do not apply power to the L Drive at this time. Do not connect the transformer to the L Drive while power is applied to the transformer. Do not touch the wiring studs on the transformer after it is plugged into an AC outlet. <u>This can cause serious personal injury</u>.**

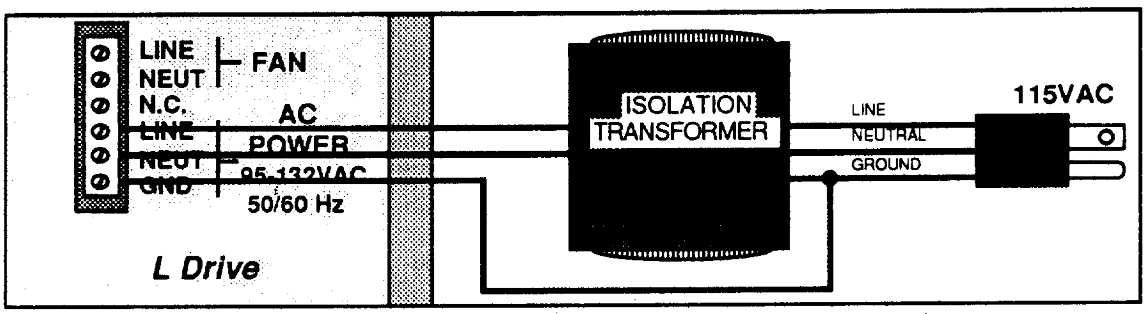


Figure 2-4. Transformer Connections (Optional)

Power Connections

The L Drive system is shipped with the power cable pre-wired to a 6-pin phoenix connector. Connect the power cable assembly to the L Drive power connector (see Figure 2-2) and verify that the color codes are correct.

- LINE = Black
- NEUT = White
- GND (Earth) = Green

European color codes differ in that LINE = Brown, NEUT = Blue, and GND = Green or Yellow.

REMEMBER: AC power is limited to 132VAC. <u>Higher voltages damage the L Drive</u>. The low-voltage limit is 95VAC.

Fan Connections (Optional)

If your L Drive systems will be operating in temperatures exceeding 45°C, you should use the optional fan kit for additional cooling. Connect the fan cable to the L Drive fan/power connector (see Figure 2-2). Make sure that line and neutral are connected to the appropriate screw terminals.

Applying Power

Before you power-up the system, you should verify that all cables and wires are properly connected and that the forcer is free from obstructions. If everything is OK, the drive will be enabled when you apply power. The green **POWER** LED will be on and the red **FAULT** LED will be off.

If there is a short circuit, over temperature or undervoltage condition, the red **FAULT** LED will be illuminated. If this happens, remove power to the system and refer to Chapter 6, Maintenance & Troubleshooting.

NOTE: The L20 system with the -AC option is a little louder than the standard L20 systems. During warm-up, the L-Servo PCB may generate audible noise in the forcer. This is normal.

System Test

Use the following procedures to test the functionality of the L Drive system and to verify proper system connections. *NOTE: Before you test the system, make sure you have verified the default settings.*

STEP 1 Make sure power is removed from the system.

STEP 2 Position Drive DIP Switch #6 to the OFF position. This enables the Automatic Run function during power-up. With the Automatic Run function enabled, powering up the system causes the forcer to move at 50 poles/sec (200 full steps/sec) until power is removed from the drive. This corresponds to the following speeds:

- L3C: 3.33 ips
- L5A, L9A, & L20: 2 ips

The forcer will continue to move until it reaches the end of the platen, or until the drive is powered down.

> **CAUTION**
>
> **Do not allow the forcer to travel over the end of the platen. This may damage the platen and the forcer.**

STEP 3 Place the forcer in the middle of the platen travel surface. Be sure that the forcer is free to move.

STEP 4 After verifying proper drive/forcer connections, apply 110VAC. ***Be ready to remove power when the forcer nears the end of the platen.*** The forcer should move at the speed specified above.

If the forcer does not move, refer to Chapter 6, Maintenance & Troubleshooting.

STEP 5 Turn the power off.

STEP 6 Position Drive DIP Switch #6 to the ON position. This disables the Automatic Run function.

STEP 7 Set up the indexer to run in accordance with the installation procedures outlined in the indexer manual.

STEP 8 To verify that the L Drive system is operating properly, apply power to the L Drive and set the indexer to perform a move with the following parameters:

- Velocity = 1 revolution per second (rps) (25,000 steps/rev)
- Acceleration = 100 rps^2
- Distance = 10,000 steps

Executing this move causes a 10,000-step L5A, L9A, or L20 forcer to move at a rate of 2.5 ips. The L3C forcer will move at a rate of 4.2 ips.

If the forcer does not move, refer to Chapter 6, Maintenance & Troubleshooting.

STEP 9 Stop the forcer with the **STOP** command or **STOP** push-button. The direction of the forcer can be changed by reversing the DIRECTION SETTING (+/-) on the indexer, and issuing a new START or GO command.

Accelerometer Test

Use the following procedures to verify the functionality of the Accelerometer (L20-AC). Rotary-to-linear indexer parameter conversions are found in Chapter 4, Application Design.

STEP 1 Make sure there is no payload attached to the forcer.

STEP 2 Set -AC DIP switches #1 through #3 ON. This disables the accelerometer.

STEP 3 Command the indexer to perform a move with the following parameters. *Note that the acceleration value can be higher for single moves than for repeated moves.*

- Velocity = 16 rps (40 ips)
- Acceleration = 300 rps^2 (≈2 g's)
- Distance = 100,000 steps (≈10 inches)

STEP 4 Determine the maximum acceleration by repeating step 3. Each time you repeat step 3, increase the Acceleration value in small increments until the forcer stalls or slips. The maximum acceleration should be around 464 rps^2 (≈3 g's).

STEP 5 Change -AC DIP switch #1 to OFF(enables the accelerometer).

STEP 6 Repeat step 4 to determine the maximum acceleration. The maximum acceleration should be around 6 or 7 g's. If the forcer stalls or slips at an acceleration value below 927 rps^2 (≈6 g's), the accelerometer is probably not operating properly.

Make sure Drive DIP switches #8 through #10 and -AC DIP switches #4 through #5 are set to the same resolution (see Table 2-3). Also, check the indexer step pulse widths. The -AC system can only accept 1.0 or 0.65 μs steps pulses. If the resolution and pulse width settings are correct, the accelerometer is faulty and must be returned for repair.

Checking the L Drive with a Square Wave Generator

To perform a functional check of the L Drive system using a square wave generator or some other pulse source, attach the positive lead of the square wave generator to the STEP+ Input on the L Drive. Refer to Figure 2-5 for connections. Attach the ground from the frequency generator to the STEP- Input on the L Drive. The output of the square wave generator should be set to 3V peak. There is a 100 ohm resistor and an opto coupler LED in series between the STEP+ and STEP- inputs. For reliable operation, the current through these components should be at least 20mA, but should not exceed 30mA.

Turn your square wave generator to a frequency output of 1,000 Hz. This causes the L5A, L9A, or L20 forcer to move at a rate of 0.1 ips. The L3C forcer will move at 0.16 ips.

If the forcer does not move, refer to Chapter 6, Maintenance & Troubleshooting.

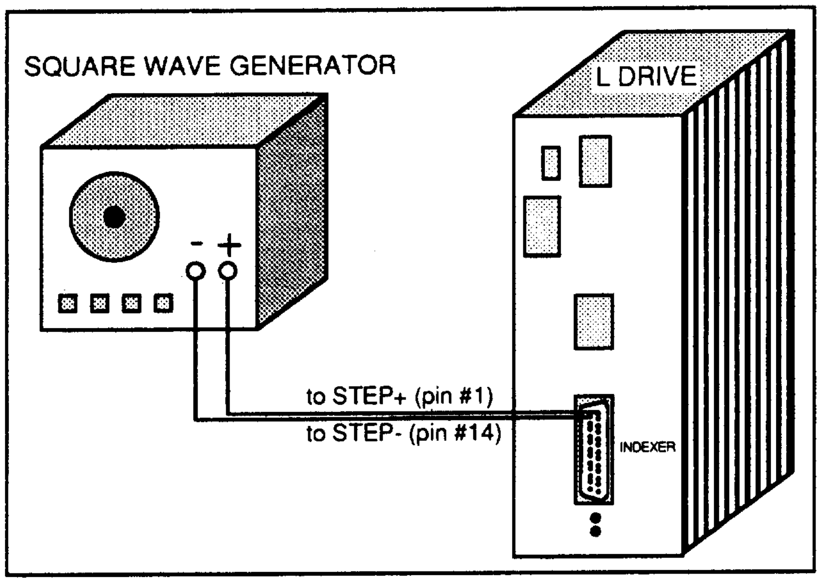


Figure 2-5. Connecting a Square Wave Generator

Chapter 3. INSTALLATION

Chapter Objectives

The information in this chapter will enable you to do the following:

- Properly mount all system components
- Connect all electrical and non-electrical system inputs and outputs properly
- Ensure that the complete system is installed correctly
- Perform basic system operations

NOTE: You must complete all the basic system configuration procedures in Chapter 2, Getting Started, before proceeding with the procedures in this chapter.

Adjusting DIP Switches

If the factory default DIP switch settings (discussed in Chapter 2) are not appropriate for your application, refer to Chapter 5, Hardware Reference, for adjustment procedures and optional settings.

System Mounting

You should give special attention to the environment and location in which you will operate the L Drive system. Atmospheric contamination and excess heat should be considered before installing and operating the L Drive System.

Enclosure Considerations

You should install the L Drive in an enclosure to protect it against atmospheric contaminants such as oil, moisture, and dirt. The National Electrical Manufacturers Association (NEMA) has established standards that define the degree of protection that electrical enclosures provide. The enclosure should conform to NEMA Type 12 standards if the intended environment is industrial and contains airborne contaminants. Proper layout of components is required to ensure sufficient cooling of equipment within the enclosure.

Drive Mounting

Proper mounting and panel layout are essential for trouble-free operation of the L Drive. You should allow sufficient space for unrestricted air flow over the heatsink. The drive must always be mounted so that the heatsink fins are positioned vertically to allow efficient convection cooling of the drive (refer to Figure 3-1).

If you mount the L Drive in an enclosure, observe the following guidelines:

- The vertical clearance between the L Drive and other equipment, or the top or bottom of the enclosure, should be no less than 6 inches.
- The horizontal clearance should be no less than 4 inches.
- Large, heat-producing equipment should not be mounted directly beneath the L Drive.
- The L Drive should not be mounted directly below an indexer (the L Drive produces more heat than an indexer).
- The maximum allowable ambient temperature directly below the L Drive is 113°F (45°C). Fan cooling may be necessary if adequate air flow is not provided.

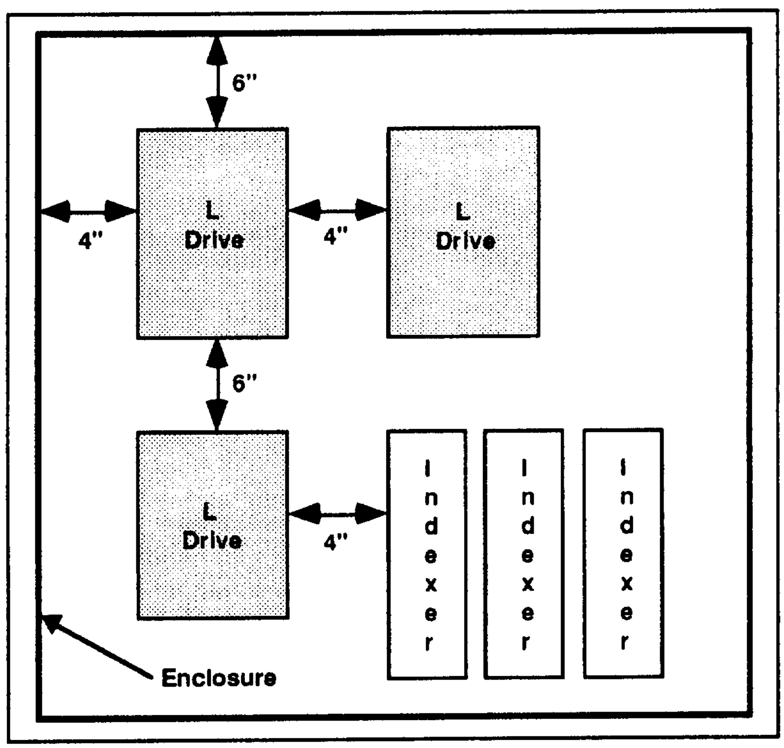


Figure 3-1. Panel Layout Guidelines

As discussed below, the L Drive can be mounted for minimum width or minimum depth, depending on how the mounting clips are attached to the L Drive.

Minimum-Width Mounting

Two clips are attached to the top and bottom rear of the drive, away from the power connectors (see Figure 3-2). This gives you the maximum amount of panel space possible. Units are shipped with clips in this configuration.

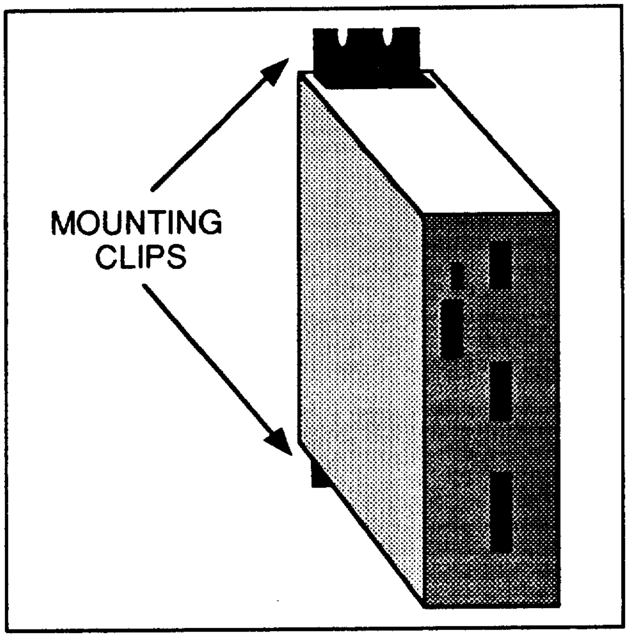


Figure 3-2. Minimum Width Panel Mount

Minimum-Depth Mounting

The two clips are moved and attached to the drive on the side away from the heatsink to provide minimum depth (see Figure 3-3). This allows you to mount the drive in the shallowest possible enclosure.

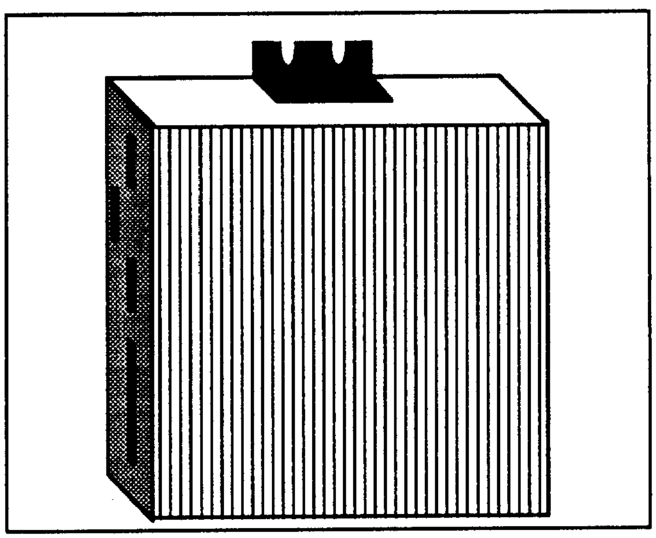


Figure 3-3. Minimum Depth Panel Mount

Platen Mounting

Platen Flatness

The platen is ground flat and parallel to the proper specifications while being held down on a magnetic chuck. When released from the magnetic chuck, mechanical stresses in the platen can cause it to bow or twist slightly. However, by mounting the slightly bowed or twisted platen on a ground flat surface, it will become flat again.

When the platen is not mounted, the L20 and L9A forcers may rub or even bind on uneven areas. The air gap between the L20 or L9A forcer and the platen is approximately 0.0005 inches. The forcer length is 4.6 inches. Therefore, when the platen has a *bump* with a slope greater than 0.0001:1 inches (vertical to horizontal), the forcer will not float properly and will rub the platen surface, and/or the air bearing will become unstable.

The air gap between the L3C or L5A forcer and the platen is approximately 0.0015 inches. This larger air gap makes these forcer systems less sensitive to bowed or twisted platens.

The recommended platen flatness for Compumotor forcers is provided in Table 3-1.

Platen	To Operate
PO-L3C-PXX	0.001 in/4 in (0.00025 in/in)
PO-L5A-PXX	0.001 in/4 in (0.00025 in/in)
PO-L9A-PXX	0.00025 in/5 in (0.00005 in/in)
PO-L20-PXX	0.00025 in/5 in (0.00005 in/in)

Table 3-1. Flatness Required for Platen Mounting

To prevent platen flatness problems, especially in the prototype phase of a project using forcers, Compumotor recommends using platens mounted on platen stiffeners. You can order platen stiffeners through the Compumotor Custom Product Group.

Platen Straightness

Long platens can also bend laterally (side-to-side). Therefore, when mounting a long platen, make sure that the platen is mounted as straight as possible. Refer to Chapter 5, Hardware Reference, for specifications.

Platen Mounting

Platens are not self-supporting. A platen suspended only by the ends will bow from 0.001 inches to more than 0.020 inches, depending on the length of the platen and the weight of the forcer with its payload. Also, mounting the platen by attaching only the ends, even on a flat surface, does not guarantee a flat platen surface. Consequently, ***you must bolt the platen on a flat surface using every available platen mounting hole.***

Mounting holes are drilled and tapped from the bottom of the platen. Refer to Table 3-2 for platen mounting hole specifications. **Do not over-tighten mounting bolts; this can warp the platen and the mounting surface.**

> **CAUTION**
>
> **You must exercise caution if you are drilling holes into the platen. Be sure that the holes are not in the travel path of the forcer. Also, avoid warping or contaminating the platen. Refer to Chapter 5 for mechanical specifications.**

Platen Type	Hole Specifications
L3C	8-32 UNC X 0.31 Deep
L5A	10-32 UNF 28 X 0.31 Deep
L9A	10-32 UNF 28 X 0.31 Deep
L20	10-32 UNF 28 X 0.31 Deep

Table 3-2. Platen Mounting Holes

For high-precision applications, mount the platen with dowel pins and then fasten with bolts. If you cannot bolt the platen from the bottom, you may glue the platen onto the mounting surface.

For suspended operation, such as an X-Y gantry system, you may mount the platen on a stiffener. Compumotor can provide a custom light-weight platen, if required.

To avoid warping the platen, you should make sure the base on which the platen is attached is constructed of a material with a similar coefficient of thermal expansion. The coefficient is 0.00000633 $in^2/°F$. For example, a platen mounted on an aluminum surface may warp when the forcer is run at high speeds and high duty cycles (see Figure 3-4).

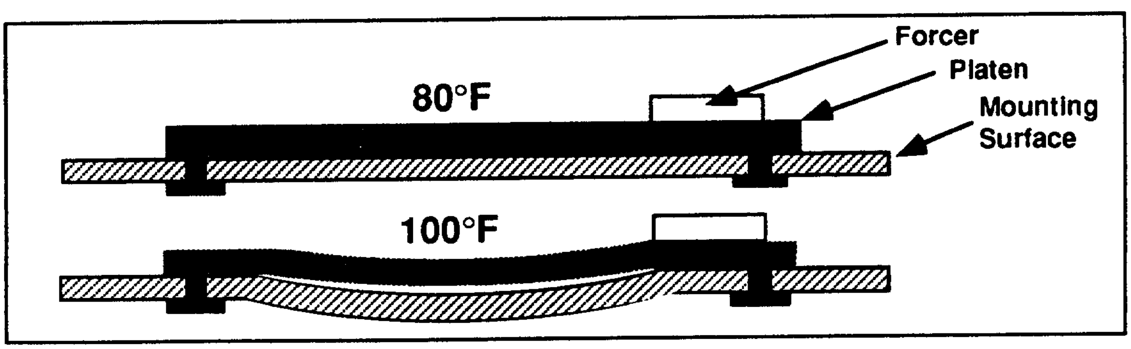


Figure 3-4. Mounting Platen for Heat Variances

Platen Contamination

Since the air gap of the forcer is crucial to its operation, you should take precautions to prevent contamination. You may therefore choose to mount the platen on its side, or upside down, to allow any non-adhesive material to fall off the platen. In other cases, a simple metal bracket can be put around two or three sides of the forcer to prevent contamination from reaching the platen. If a light amount of dust is present (such as flour or dry sawdust) the air bearing of the L20 will clean the unit as air moves in front of the forcer.

Periodic cleaning of the platen surfaces with alcohol or acetone is required, even in relatively clean environments such as normal engineering labs and offices. In dirtier environments, a protective boot may be needed. The boot covers both the platen and the forcer. As the forcer moves, the boot folds (like an accordion). Compumotor recommends the following source for protective boots:

A & A Manufacturing Co.
2300 S. Calhoun Rd.
New Berlin, WI 53151
Phone: (414) 786-1500
Specify: die #85-2524 Hypalon polyester material

Shiny spots or scratches on the platen surface indicate that the forcer is not floating properly. This is due to improper platen mounting and/or clogged orifices in the forcer. Using the forcer for extended periods with clogged orifices will damage the air bearing surface. Refer to Chapter 6, Maintenance and Troubleshooting, for procedures on checking and cleaning clogged orifices.

Use Lapping paper or a lapping stone to remove any burrs or scratches on the forcer and platen surfaces. After deburring, throughly clean the platen and forcer surface with alcohol to remove any loose particles and to prevent any more scratching.

Platen Corrosion

The L5A platen is chrome-plated on all sides. The L9A platen is also chrome-plated except for the top (*teeth*) surface. The L20 platen is electro-nickel plated on the sides and the bottom. The top and ends of the platen are treated with a chemical to prevent corrosion. However, over time (esp. in humid climates) the surface can corrode. You can use a polishing compound or lapping paper to remove oxidation spots (see below for recommended vendor). After polishing and/or lapping, the platen is more susceptible to corrosion, since the protective coating has been removed. Applying a paste wax to the top platen surface provides added protection in this circumstance.

If corrosion can not be tolerated in your application, Compumotor can provide a magnetic stainless steel platen. The forcer's performance with this type of platen is reduced by 10% to 20%. Note that the lead time for special platens can be 12 to 16 weeks.

RECOMMENDED LAPPING PAPER

Compumotor recommends using *3M* 261X Imperial Lapping Film (8.5 x 11 in. sheets) A/O (Aluminum Oxide) 3.0 Mil. This Lapping film can also be used to remove oxidation spots on the platen.

Checking and Correcting Flatness

After the platen is mounted, the flatness of the platen surface should be checked. The simplest method is to manually push a non-energized L20 forcer (with air applied) back and forth over the platen while checking where it rubs or binds on the platen. Rubbing spots are usually high spots. Another way of checking the platen flatness is to use a dial indicator referenced from a flat surface such as a granite surface plate. The most accurate way is to use a laser measurement system with flatness optics.

To lower the high spots, tighten the nearby bolts. To raise the low spots, loosen the nearby bolts. In worse-case situations, the platen may have to be shimmed or lightly lapped to obtain the required flatness.

Forcer Mounting

To place the forcer on the platen, refer to the Air Connection section in Chapter 2, Getting Started.

CAUTION

Do not energize the forcer when the forcer is not on the platen. Never disconnect the forcer when power is applied to the drive; this will damage the contacts to the motor connector.

Compumotor recommends installing rubber end-stops at each end of the platen to prevent the forcer from traveling beyond the platen's length. L20-AC forcers are shipped with rubber bumpers for added shock protection.

CAUTION

If the L20-AC forcer runs into a fixed metal object or into another forcer at high-speed deceleration values, the impact can break the accelerometer.

Removing the L9A or L20 Forcer

Because of their large normal force (100 to 200 lbs), the L9A and L20 linear forcers are difficult to remove from the platen. The easiest way is to remove power to the forcer and push it off the end of the platen **with air on**. The end of the platen should be deburred to prevent scratching of the forcer air bearing surface. Another way to remove the forcer is to use a lever to pry the forcer off the platen. This should be done carefully so that the forcer will not be permanently warped, or the side roller bearings and/or side magnets damaged. Protect the platen surface when using the platen as a prying surface.

WARNING

Always remove the forcer with the air turned on. Do not remove the forcer with your hands. The sudden release of the forcer can cause injury.

Forcer Cable Mounting

The 12-foot cable supplied with the L20 forcer is highly flexible and abrasion resistant. A cable trough is an effective way to guide the forcer's cable. The cable is laid in a trough that runs parallel to the platen. As the forcer travels, the cable extends and lays out in the trough. As the forcer returns, the cable retracts and forms a vertical loop (see Figure 3-5).

The L20-AC cable is custom-designed for high-flex and long-life. However, be especially careful when mounting the cable in the machine. An L20 forcer running back and forth at full speed can make the cable whip back and forth in a manner that could stall the forcer.

If the cable bends while moving, make sure that the radius of the bend is ≥2 inches; avoid *kinking* the cable.

With the L20 forcer, air is routed through 1/8" inner diameter by 1/4" outer diameter urethane tubing. Jacketing the cable and tubing helps to avoid restricting forcer movement. Compumotor recommends braided expandable sleeving for such applications. This product is available from the following source (Specify: 1/2" GP, clear or black length):

Natvar Company,
Clayton, North Carolina
Phone: (919) 553-4151

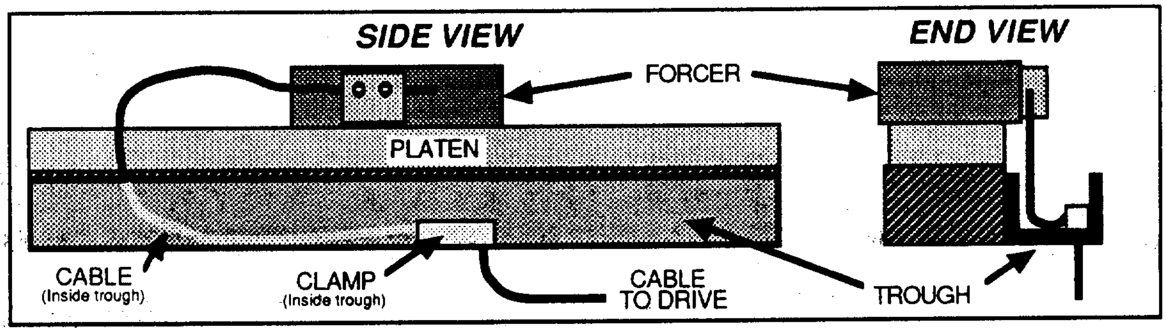


Figure 3-5. Cable Trough

-RFKC Option Assembly Instructions

The contents of the -RFKC Option kit are listed in Table 3-3. The kit provides a reliable air source for the L20 forcer. Figure 3-6 shows how the -RFKC components fit together.

Qty	Name	Function
1	Filter	Filters moisture and dust from air
1	Regulator	Regulates air pressure to the L20
1	Pressure Gauge	Visual pressure reading
1	Mounting Bracket	Mounts filter/regulator and gauge
1	Brass Quick Coupler	Connection to air supply source
2	Reducer	Reducer for hose fitting
1	Nipple	Connection between filter and regulator
1	Plug	Plugs into spare output in regulator
3	1/8" Male Hose Connector	Tubing connection
30 Ft.	Urethane Tubing	Routes air to L20
1	Roll of Teflon Tape	Seals threads
1	Assembly drawing and instructions	

Table 3-3. -RFKC Components

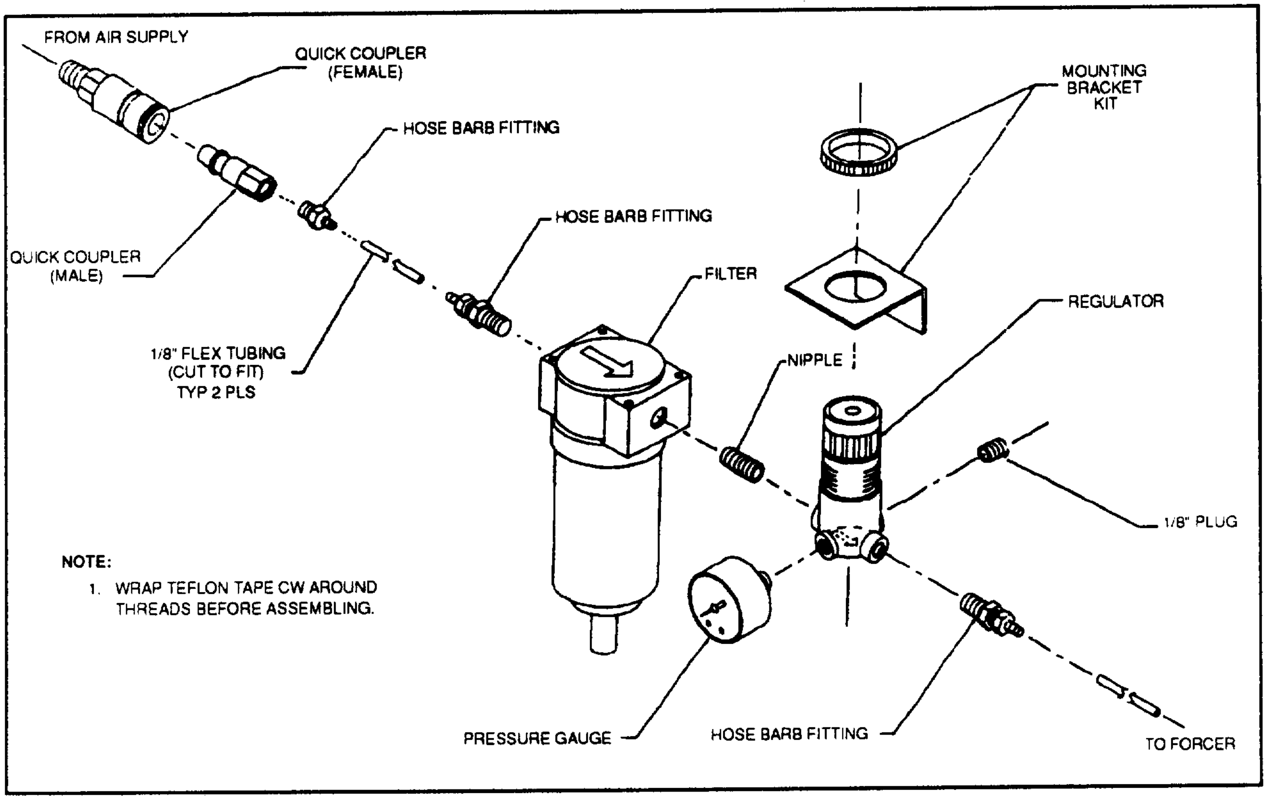


Figure 3-6. -RFKC Option Assembly

System Connections

Refer to Chapter 2, Getting Started, for instructions to connect the following:

- AC Power
- Fan (optional)
- Accelerometer (optional)
- Forcer
- Indexer
- Air

Detailed system pinouts and specifications are provided in Chapter 6, Hardware Reference.

CAUTION

Do not energize the forcer when the forcer is not on the platen. Be certain that AC power is disconnected before wiring. Never disconnect the forcer when power is applied to the drive.

Grounding Information

Proper grounding of electrical equipment is essential to ensure the safety of personnel. The effects of electrical noise due to electromagnetic interference (EMI) can also be reduced by grounding. All Compumotor equipment should be properly grounded. A good source of information on grounding requirements is the National Electrical Code published by the National Fire Protection Association of Boston, Massachusetts.

In general, all components and enclosures must be connected to earth ground through a grounding electrode conductor to provide a low-impedance path for ground-fault or noise-induced currents. All earth ground connections must be continuous and permanent. Compumotor recommends a single-point grounding setup. You should prepare components and mounting surfaces prior to installation so that good electrical contact is made between mounting surfaces of equipment and enclosure. Remove the paint from equipment surfaces where the ground contact will be bolted to a panel and use star washers to assure solid, bare metal contact. The case of the forcer should be connected to the MOTOR GND terminal on the L Drive.

For temporary installation, or when the grounding method described above cannot be used, the GROUND terminal on the AC power connector must be connected to earth ground.

Wiring to Prevent EMI Problems

The L Drive delivers pulse-width-modulated (PWM) current to the forcer by switching 170VDC (120VAC input) at 20 kHz. The drive may radiate or conduct electrical noise along the forcer cable, through the forcer, and into the frame to which the forcer is attached. It can also be conducted out of the L Drive, into the AC power line. If electrical noise generated by the L Drive is a problem for other electronic equipment, take the following wiring precautions:

- Ground the forcer. This is already done for you with forcers that Compumotor supplies.
- Avoid extended forcer cable runs.
- Mount the electronic equipment affected by the noise as far as possible from the L Drive and forcer.
- Filter the power to the L Drive using a PI type of filter and an isolation transformer.
- Provide a separate power line for the L Drive. Do not use the same power circuit for the noise-sensitive electronic equipment and the L Drive.

Extending Forcer Cables

The L20-AC cable assembly is part of the L20 forcer and should **not** be removed by the user. While the standard L20 cable assembly can be replaced in the field, the L20-AC cable assembly must be replaced at the factory. If you need shorter or longer cable assemblies, order them from Compumotor's Custom Product Group at (800) 358-9068. ***Do not attempt to shorten or lengthen the -AC cable assembly yourself.***

To extend the forcer cable for systems not using the -AC option, use the specifications shown in Table 3-4. When extending the forcer cable, be sure to shield your cable. Compumotor recommends that you use a mating connector when you extend the cable. A non-shielded cable will create electrical noise. Refer to Chapter 5 for cable color codes.

Forcer	Maximum Current Per Phase (Amps)	Less Than 100 Ft (30.5M)	100 to 200 Ft (30.5M to 71M)
L3C	1.0	22 AWG	20 AWG
L5A	1.5	20 AWG	20 AWG
L9A	1.5	20 AWG	20 AWG
L20	2.7	20 AWG	18 AWG

Table 3-4. Current and Wire Size Specifications

Adjusting Air Pressure

Because of its higher force, the L20 air bearing is more sensitive to pressure changes than the L9A air bearing. There are several factors that determine what air pressure is required to make the forcer float properly. Some examples are as follows:

- Air hose length: Longer hoses require more pressure; shorter hoses require less pressure.
- Payload weight: A heavier payload requires more air pressure.
- Energized and non-energized forcers: A non-energized forcer requires less pressure than an energized one.
- Multiple forcers per regulator: More air pressure is required to float additional forcers using the same pressure regulator. Separate pressure regulators may be required, especially if the air hoses are of different lengths.
- Platen flatness: More air pressure is required to float a forcer on an uneven platen.

The best way to adjust the air pressure for the L20 forcer is to increase the air pressure until the forcer air bearing (with payload) becomes unstable (approximately 45 - 50 PSI). An unstable air bearing produces a loud humming sound. Decrease the air pressure by approximately 5 PSI or until the humming sound stops. In the non-energized state, the forcer should float freely over the entire platen.

If the air bearing is unstable only in certain areas of the platen, the problem may be caused by compromised platen flatness (refer to the Checking and Correcting Flatness section above).

Adjusting L5A Forcer Air Gap

Adjusting the air gap allows you to optimize the forcer's performance (speed and force). The L5A forcer allows you to mechanically adjust the air gap between the forcer and the platen by using the following procedure:

STEP 1 Remove the spring from the forcer's spring-loaded side bearing.

STEP 2 Use a piece of 0.0015 (1.5 mil) shim stock for forcer operation below 20 ips, or use 0.002" (2 mil) shim stock for continuous forcer operation more than 20 ips. Place the shim stock on the platen covering the platen teeth, but leave the bearing track open. Approximate dimensions of shim are 5" x 1 1/4".

STEP 3 Place the forcer on the platen over the shim stock. Make sure that the bearings are resting on the platen and not on the shim.

STEP 4 Loosen the four socket head screws on the two side sections of the forcer.

STEP 5 Press down firmly on the side section with the spring loaded bearings and tighten the socket head screws.

STEP 6 Tighten the screws on the other side section. This section has only one bearing in contact with the platen.

Compumotor properly adjusts the air gap before it ships the forcer. *You should have to adjust the air gap only if the forcer's performance deteriorates*.

Adjusting L20 Side Load Magnet Air Gap

The L20 side load magnet assembly is factory-set to provide a 7 to 10-lb side load for both roller bearings. *If the L20 forcer is run into a fixed object at a high speed, the side magnet assembly adjustment may be compromised. This can cause too little preload, or make the assembly touch (and scratch) the platen.* If this happens, the air gap must be reset according to the procedure below:

STEP 1 With the air on, place the forcer on the platen.

STEP 2 Turn the platen, with the forcer in place, upside down.

STEP 3 Loosen the three screws on the side magnet assembly. Make sure the side magnet assembly moves freely. *NOTE: In earlier forcer models, the side magnet assembly was tacked down with* ***TakPak***.

STEP 4 Push the forcer sideways so that the roller bearings make good contact with the side of the platen.

STEP 5 Turn off the air to the forcer.

STEP 6 Place a piece of 2 - 3 mil (0.002 - 0.003") shim-rock between the platen and the side magnet assembly.

STEP 7 Push the side magnet assembly against the platen and tighten the screws *while maintaining side pressure*.

STEP 8 Turn the air on and remove the shim-rock.

STEP 9 With a force gauge, check to see if the side load force is between 7 and 10 lbs. If the force is less than 7 lbs, repeat steps 3 through 8.

Verifying Proper Installation

This section provides procedures for verifying proper installation of the L Drive system.

System Functional Test

Return to Chapter 2, Getting Started and perform the System Test. The system test verifies power, forcer, air, and indexer connections.

Refer to the indexer user guide for procedures for testing the following indexer-related connections:

- Communication link
- CW and CCW end-of-travel limit inputs
- Home position limit input
- Trigger and Sequence inputs
- Programmable Outputs

Attaching the Load to the Forcer

The L3C, L5A, L9A, and L20 forcers all have threaded mounting holes located on the top surface (see Table 3-5). The payload should be rigidly attached to the forcer using the proper size hardware.

Forcer Type	Hole Specifications	# of Holes
L3C	8-32 UNC-2B Thru	4
L5A	6-32 UNC-2B X 0.25 Deep	4
L9A	6-32 UNC-2B X 0.21 Deep	4
L20	8-32 UNC-2B X 0.5 Deep	6

Table 3-5. Forcer Hole Specifications

There is an attractive force between the forcer and the platen that is almost ten times the forcer's rated force in the direction of travel. Without air pressure, you can achieve a magnetic force that is 20 times greater than the L20 or L9A forcer's maximum rated force. These forces are attained when the power is turned off. This magnetic attraction allows the forcer to operate in any spatial orientation and allows moment-producing forces to be placed on the forcer.

In some applications, such as when the load is not centered above the forcer's center of gravity, you must consider the forcer's *yaw, pitch, and roll* characteristics. If these torques applied to the forcer while accelerating and decelerating are strong enough, they will cause the forcer to lose index (stall) or even disengage from the platen.

The current revision of the Linear Motor Application software does not take into account any applied torques. Also, the payload is assumed to be centered on top of the forcer. Calculated accelerations will be less for off-centered payloads.

In X-Y gantry systems, the center of gravity of the Y-beam axis should be as close as possible to the platen surface of the two X-axis forcers (see Figure 3-7). The maximum yaw, pitch, and roll stiffness are specified in ounce-inches of external torque applied to the forcer. These values will help you determine the maximum applied torque at which the forcer still operates. These specifications are given in Chapter 5, Hardware Reference. Figure 3-8 illustrates the orientation of yaw, pitch, and roll.

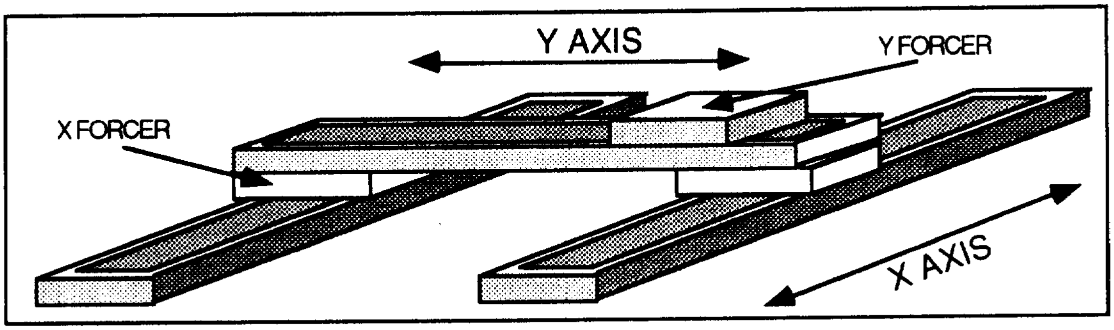


Figure 3-7. X-Y Gantry System

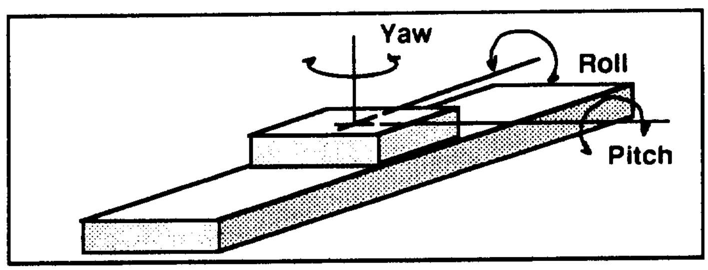


Figure 3-8. Orientation of Yaw, Pitch, and Roll

The following is a list of possible solutions to the problem of having the forcer (plus payload) exceed any of the torque specifications:

- Reduce the acceleration.
- Reduce the payload weight.
- Redesign the payload to bring the payload center of gravity closer to the platen surface (see Figure 3-9).
- Mount the payload on some sort of linear slide (e.g., Thompson rail) and use the forcer merely to push the payload back and forth on the linear slide. *When coupling the load to the forcer in this situation, you must allow some flexibility to compensate for the fact that the platen and the linear slide are not exactly parallel.* For more information, contact a Compumotor Applications Engineer at (800) 358-9070.

You must take special care when mounting a payload to a forcer, particularly the L9A and L20 forcer. **The area of the payload in contact with the forcer should be flat** (see Figure 3-9). A *non-flat* payload, when torqued down, can warp the forcer and cause the forcer to stall. If the payload covers the forcer opening, you can remove the forcer cover before attaching the payload.

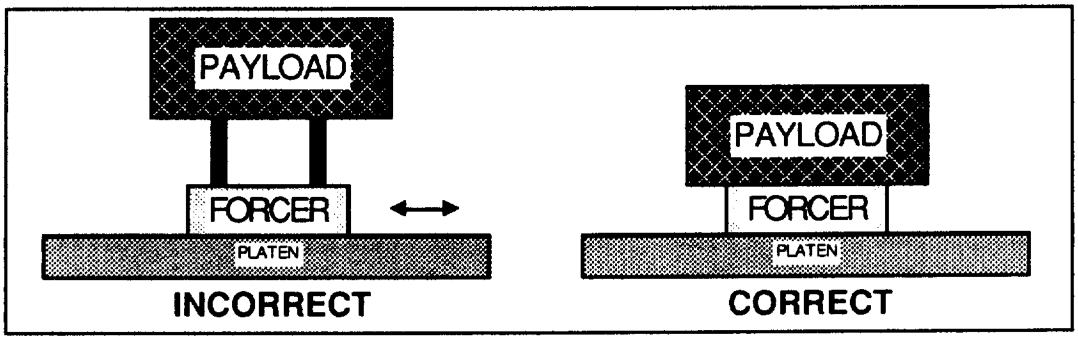


Figure 3-9. Proper Payload Mounting

In some applications, the existing roller bearing and side magnet assembly may not be strong enough. You can replace the existing arrangement with a custom assembly. Compumotor's Custom Products Group can provide several alternative side-roller bearing arrangements.

The maximum recommended load on the side roller bearing assembly is 15 pounds. Exceeding the side load will cause premature platen wear. Because the platen is made of a low carbon unhardened steel (C1018), a harder roller bearing surface is needed for heavier side loads (e.g., a flat piece of hardened steel glued or bolted on side of platen).

Chapter 4. APPLICATION DESIGN

Chapter Objectives

The information in this chapter will enable you to do the following:

- Recognize and understand important considerations that must be addressed before you implement your application
- Understand the capabilities of the system
- Customize the system to meet your requirements

Application Considerations

Linear step motors are most often used to move relatively light loads quickly. Successful application of a linear motor system requires consideration of the following important points:

- Motion Profiles
- Resonance
- Ringing and Overshoot
- Positional Accuracy and Repeatability
- Indexer Operating Modes (Normal and Continuous)
- Encoder Compatibility
- Supplying Air
- Rotary vs. Linear Indexers

Motion Profiles

A motion profile represents the velocity of the forcer during a period of time in which the forcer changes position. The type of motion profile needed will depend upon the motion control requirement. The basic types of motion profiles are described below.

Triangular and Trapezoidal Profiles

For constant acceleration indexing systems, velocity, acceleration, and distance parameters are defined before a preset move can be executed. The value of these parameters determines the type of motion profile as either triangular or trapezoidal. A triangular profile results when the velocity and acceleration are set such that the defined velocity is not attained before half of the specified distance has been traveled. This results from either a relatively low acceleration or a relatively high velocity or both. For example, if the acceleration is set to 1 g, velocity is set to 2 ips and distance is set to 10,000 steps (1 inch @ 10,000 steps/inch), a triangular motion profile will result (by the time the forcer reaches the defined velocity of 2 ips, it will also have traveled half of the defined distance due to the acceleration setting of 1 g). The motion profile for this move is illustrated in Figure 4-1.

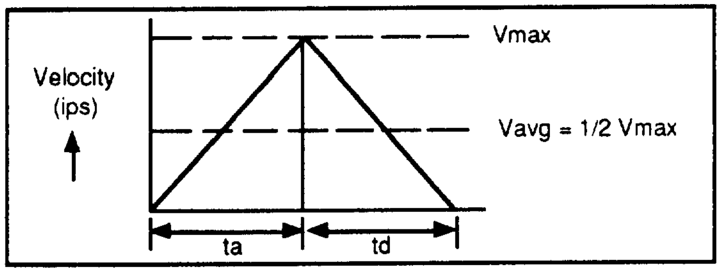


Figure 4-1. Triangular Profile

A trapezoidal move profile results when the defined velocity is attained before the forcer has moved half of the specified distance. This is due to a velocity that is relatively low, an acceleration that is relatively high, a move distance that is long, or a combination of all three. The resulting motion profile will resemble the profile shown in Figure 4-2.

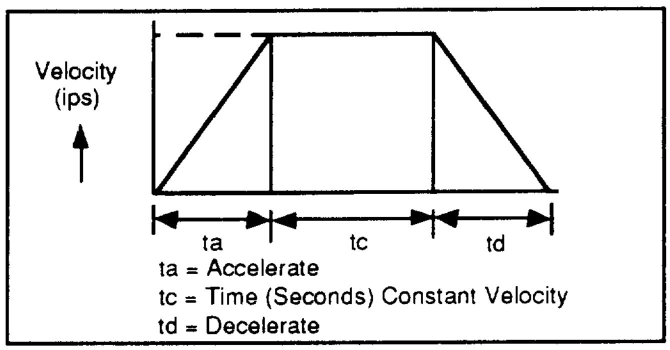


Figure 4-2. Trapezoidal Profile

Custom Move Profiles with Compumotor Indexers

It is possible to create move profiles other than triangular or trapezoidal. One way to do this is to use the Rate Multiplier in Velocity Streaming Mode (**RM**) command in Compumotor indexers. When this command is issued, the indexer instantly changes to the specified velocity. Sending these commands in rapid succession provides smooth profiling, which will allow you to trace circles and arcs using a two-axis system. The **RM** command also provides smooth (low-jerk) motion by virtue of S-curve acceleration rather than straight ramping associated with triangular and trapezoidal moves (see Figure 4-3).

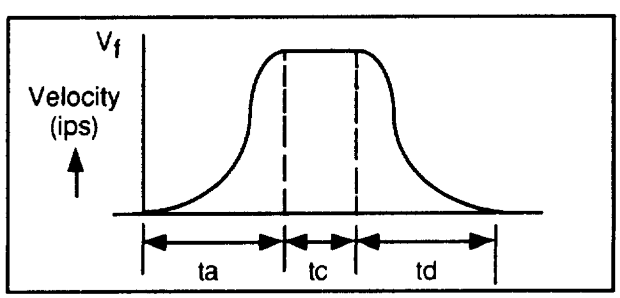


Figure 4-3. S-Curve Profile

For tightly controlled multi-axis contouring, Compumotor recommends using the L Drive with the PC23, 3000, or 4000 indexer, which have facilities for multi-axis synchronization. Both the PC23 and 3000 have a time distance mode that can be used for single-axis velocity profiling or multi-axis contouring.

Mechanical Resonance

Resonance is present in all stepper motors. If operated in a full-step or half-step mode, the forcer's performance would be greatly reduced at speeds below about two ips. The forcer may even stall. The L Drive's microstepping capability allows smoother operation at low speeds.

Forcers may stall due to resonance. Resonance in the L20 forcer may be remedied by adding the Accelerometer (-AC) Option.

-AC Option Reduces Resonance

The function of the Accelerometer option is to add *electronic friction* to the forcer, providing a more convenient way to dampen motor resonance. By feeding back to the commanded position a displacement proportional to velocity, the -AC Option introduces the equivalent of *viscous friction* into the forcer's dynamics. While some systems obtain velocity information with a velocity transducer (tachometer), the -AC Option system obtains the velocity information by integrating the difference between the commanded acceleration and the measured acceleration from an accelerometer mounted in the L20 forcer. The velocity error is introduced into the commanded position via the servo circuitry. The magnitude of the velocity error feedback required for the fastest settling time (damping ratio of ≈ 0.707) is payload-dependent. The gain switches (-AC DIP switches 1 - 3) can be used to select the proper magnitude (see Chapter 5, Hardware Reference). Figure 4-4 illustrates how the -AC option provides smoother operation at velocities around the forcer's resonant frequency.

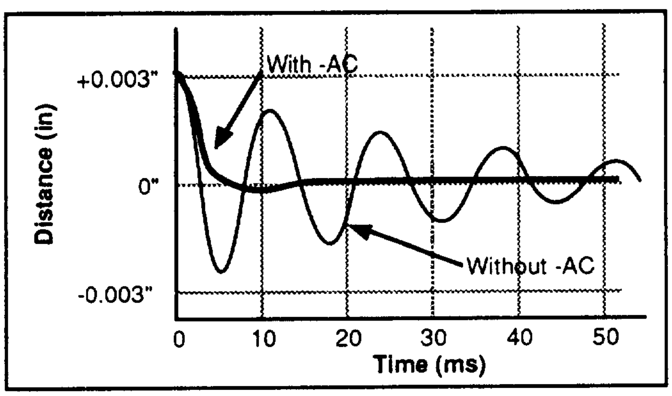


Figure 4-4. -AC Option Provides Smoother Operation

Constant Velocity Near the Resonant Frequency

The first step in determining if resonance will be a problem is to determine the forcer's resonant frequency. This value is predicted accurately with the following equation:

$$f = 2.26\sqrt{Fmax / W * T}$$

Where: f = Natural resonant frequency in Hz
F_{max} = Static force of the forcer (lbs)
W = Weight of the forcer plus its load (lbs)
T = Tooth pitch of the platen (ft)
T(L5A) = T(L20) T(L9A) = 0.00333 ft
T(L3C) = 0.00555 ft

The equation can be further simplified to:

f = 40 * sqrt (Fmax / W) for the L5A, L9A and L20
f = 30 * sqrt (Fmax / W) for the L3C

Velocity ripple will be most noticeable at the resonant frequencies of the system. Once the resonant frequency is determined, the velocities that have first, second, and fourth harmonics of force ripple at the resonant frequency can be predicted. These three velocities are influenced by the tooth pitch of the platen and can be calculated as follows:

For the L5A, L9A and L20, velocities are f/25, f/50, and f/100.
For the L3C, velocities are f/15, f/30, and f/60.

As a general rule, you should consider the accelerometer damping option for applications that require smooth velocity at speeds above 0.5 ips.

Ringing or Overshoot

The forcer's springiness and its mass form an underdamped resonant system that rings in response to acceleration transients (such as at the end of a move). Ringing at the end of a move prolongs settling time. The actual settling time of a system will depend on the forcer stiffness, the mass of the load, and any frictional forces that may be present.

-AC Option Reduces Settling Time

With the accelerometer option, the duration of settling at the end of a move is reduced by more than 90%. Figure 4-4 illustrates how the -AC option reduces settling time.

Positional Accuracy vs. Repeatability

In linear positioning systems, some applications require high absolute accuracy. Others require repeatability. You should clearly define and distinguish these two concepts when you address the issue of system performance.

If the positioning system is taken to a fixed place and the coordinates of that point are recorded, the only concern is how well the system repeats when you command it to go back to the same point. For many systems, what is meant by accuracy is really repeatability. Repeatability measures how accurately you can repeat moves to the same position.

Accuracy, on the other hand, is the error in finding a random position. For example, suppose the job is to measure the size of an object. The size of an object is determined by moving the positioning system to a point on the object and using the move distance required to get there as the measurement value. In this situation, basic system accuracy is important. The system accuracy must be better than the tolerance on the measurement that is desired.

Consult the technical data section of the *Compumotor Programmable Motion Control Catalog* for more information on accuracy and repeatability.

Open-Loop Accuracy

Open-loop absolute accuracy of a linear step motor is typically less than a precision grade lead screw system, but is better than most tangential drive systems. Of course, when you close the loop with a linear encoder, the accuracy of these systems is equivalent to any other transmission system.

The **worst-case accuracy** of the system is the sum of these errors. Accuracy = **A+ B+ C+ D + E**.

A **Cyclic Error**: The error that occurs due to motor magnetics. This error recurs once every pole pitch as measured on the body of the forcer.

B **Unidirectional Repeatability**: The error measured by repeated moves to the same point from different distances in the same direction.

C **Hysteresis**: The backlash of the forcer when it changes direction due to magnetic non-linearity and mechanical friction.

D **Thermal Expansion Error**: The error caused by a change in temperature, which expands or contracts the platen.

E **Random Platen Error**: The non-linear errors remaining in the platen after the thermal expansion error is disregarded.

Typical open loop accuracy for an L20 system is ±0.0035 in (90 microns) plus the effects of platen contraction and expansion due to ambient temperature changes and heating caused by forcer movement.

PLATEN THERMAL EXPANSION

The platen is manufactured at an ambient temperature between 65°F and 75°F (18°C - 24°C). The expansion rate is 0.000032 inches per 5°F (≈3°C) change. For example, a 36-inch platen, manufactured at 65°F (18°C), is 0.0012 inches longer at 70°F (21°C), an error of 0.003%.

High-speed moves (average velocity greater than 20 ips) at high duty cycles over distances of less than 2 feet can raise the platen temperature by 60°F (15.5°C). This kind of heating can make an 18-inch platen 0.007 inches longer (error of 0.039%).

Platen heating is caused by eddy current losses. To prevent over-heating, stepper motors normally have both the rotor and stator laminated. In linear motors, the forcer's magnetics is built around a laminated structure. For practical and cost reasons, the platen is made of a solid magnetic steel. As the forcer moves faster and the voltage across the forcer coils increases, more eddy currents are generated in the platen and warm the platen.

Use one or more of the following guidelines to minimize platen heating:

- Mount the platen on a good heat-conducting surface.
- Use a fan to increase the air flow over the forcer and the platen.
- Reduce the drive voltage. The L Drive bus voltage is 170VDC. With two forcers connected in series, the voltage over the forcer coils drops by 50% and the heating is reduced (as long as the forcers are not next to each other). Note that when two forcers are connected in series, the maximum possible velocity is reduced by 50%.
- Use the L Drive's Standby function to reduce the current while not moving.
- Reduce the average velocity. To calculate the average velocity, add all the move distances for a certain sequence of moves and divide the sum by the total time it takes to execute the sequence (including time delays). Use the following equation:

$$V_{average}\,[ips] = \frac{D_{total}\,[in]}{T_{total}\,[sec]}$$

Figure 4-5 illustrates a graph of platen temperature rise versus average velocity, worse-case (platen length = 15 in).

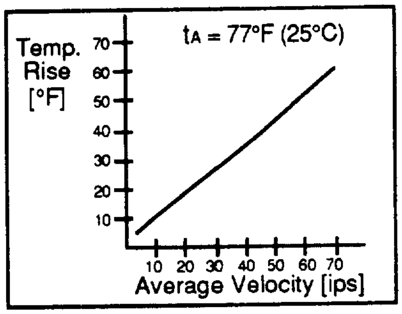


Figure 4-5. Platen Temperature Rise vs. Average Velocity

Indexer Operating Modes

Normal (Preset) Mode Moves

A preset move is a move of a specified distance (in motor steps). Preset moves allow you to position the forcer in relation to the forcer's previous stopped position (incremental moves) or in relation to a defined zero reference position (absolute moves).

Continuous Mode Moves

Continuous moves make the forcer accelerate to a defined velocity, and then continue to move at that velocity until you command it to decelerate to a stop or change velocity.

Encoder Compatibility

Encoder position feedback provides improved system accuracy, stall detection, and position tracking. Compumotor offers linear incremental encoders that are directly compatible with many of the Compumotor indexers. The requirement for compatibility with an indexer is that the motor's resolution be at least twice the encoder resolution for successful operation. The encoder model that is compatible with L Series linear motors is listed below:

Encoder Model	Resolution	Accuracy
IL-1-XX-1	0.0005 inches	±0.001 inches

The top speed of the indexer/L Drive/linear motor/encoder system is limited by the maximum input pulse rate of the indexer encoder input. Refer to the indexer's user guide for a description of the encoder input. In some cases, the maximum speed of the encoder may be the limiting factor in the system. Absolute linear encoders that can be interfaced with a host computer are available from Compumotor.

Rotary vs. Linear Indexers

Most Compumotor indexers are used for rotary motor systems; consequently, velocities and accelerations are selected in revs/sec (rps) and revs/sec/sec (rps^2) respectively. The default is often 25,000 steps/revolution. For linear motors, acceleration and velocities are usually defined in *g*'s and inches/sec (ips) respectively. Use the following equation to convert rps^2 to g's (1 g= 386 ips^2):

$$A[g] = \frac{A\,[rps^2] * \text{indexer resolution [steps/rev]}}{\text{L Drive resolution [steps/in]} * 386\,[ips^2]}$$

For example, if the indexer resolution is 25,000 steps/rev, the acceleration value is 100 rps^2, and the L Drive resolution is 10,000, the equation would look like this:

$$\frac{100\,[rps^2] * 25{,}000\,\text{[steps/rev]}}{10{,}000\,\text{[steps/in]} * 386\,[ips^2]} = 0.648\text{ g}$$

Use the following equation to convert rps to ips:

$$V[ips] = \frac{V\,[rps] * \text{indexer resolution [steps/rev]}}{\text{L Drive resolution [steps/in]}}$$

For example, if the indexer and L Drive resolutions are the same as defined above, and the velocity value is 1 rps, the equation would look like this:

$$\frac{1\,[rps] * 25{,}000\,\text{[steps/rev]}}{10{,}000\,\text{[steps/in]}} = 2.5\,[ips]$$

Example

STEP 1

Set-up the indexer with the following move parameters:

- Acceleration = 100 rps^2
- Velocity = 1 rps
- Distance = 10,000 steps

STEP 2

Execute a **START** or **GO** command.

If the indexer resolution is 25,000 steps/rev, the forcer should move 1 inch at a velocity of 2.5 ips.

If the forcer does not move, refer to Chapter 5, Maintenance & Troubleshooting and to your indexer user guide.

Tuning Linear Motors

The majority of applications will not require tuning of the L Drive. Tuning is done at the factory. If tuning is required, adjust the small potentiometers (pots) on the bottom of the drive. One situation which may require tuning is if a large load (more than 10 lbs) or very sensitive load, such as a camera, is mounted to the forcer.

To detect vibration, an accelerometer can be mounted to the forcer and the output monitored with an oscilloscope, or you can lightly place your hand on the forcer as it moves back and forth. The pot adjustments on the bottom of the L Drive are listed below. Pot #1 is closest to the DIP switches (see Figure 4-6).

Tuning the drive will reduce the fundamental and second harmonic component of the force ripple of the stepper motor. The fourth harmonic component of the force ripple is not affected by tuning, but can be reduced by selecting the waveform with -4% 3rd added. The fourth harmonic can also be reduced with the special L Drive firmware, p/n 92-010449-01SP (see Chapter 5, Hardware Reference).

Tuning Pots

#1 Current Trim: Adjusts the current setting approximately ±10%.

#2 Phase B Offset: Adjusts the DC offset of the Phase Current for Phase B.

#3 Phase A Offset: Adjusts the DC offset of the Phase Current for Phase A.

#4 Phase Balance: Adjusts the phase current of Phase B to approximately +10% of Phase A.

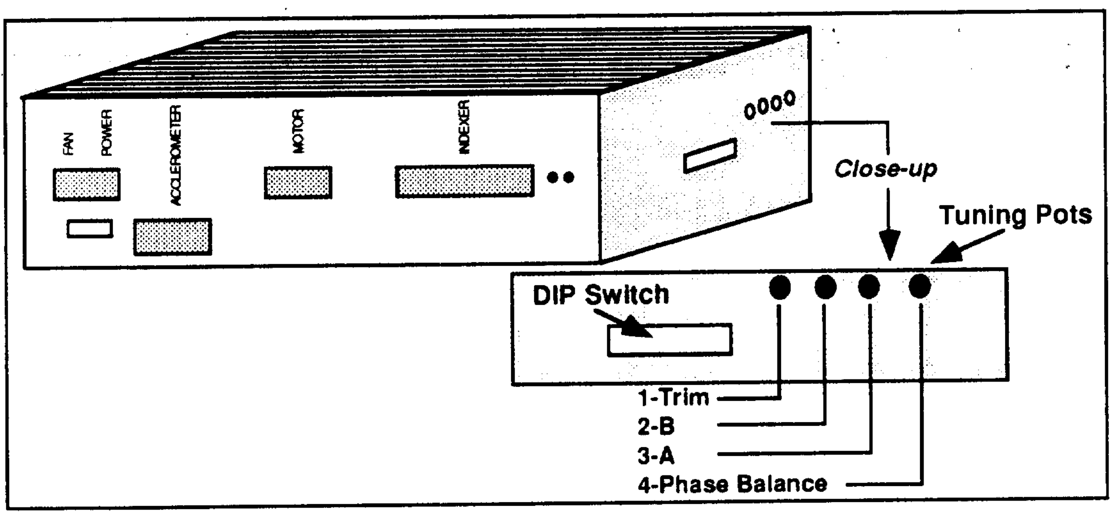


Figure 4-6. Location of Tuning Potentiometers (Pots)

Tuning Procedure

Use the following procedure to tune your system. For best results, the drive and forcer should be turned on, connected to the load, and warmed for 30 minutes prior to tuning. You must also disable the accelerometer if your system is equipped with one.

STEP 1

Connect an indexer and set the controls so that the forcer is running back and forth about 6 inches (or the full length of the platen, whichever is greater) at *maximum roughness*. Maximum roughness can be observed by lightly touching the forcer to feel for excessive vibration. Table 4-1 gives the speed at this fundamental resonant frequency for the appropriate forcer. Adjust Offset A and Offset B for best smoothness.

STEP 2

Cut the forcer's speed in half (the second harmonic of force ripple is now at the resonant frequency). Adjust the Balance for best smoothness.

STEP 3

Repeat the steps above until no further improvement is noted. The pot adjustments on the bottom of the L Drive (see Figure 4-6) are listed below.

STEP 4

Current Trim will increase and decrease the current that is set to the forcer. Decreasing the current will make the system run more smoothly. However, decreasing the current will also decrease the force. Use this adjustment tool if pots 2-4 do not provide measurable performance benefits.

Forcer	Resonant Frequency (Hz)	Fundamental/2nd/4th Resonant
L3C	f = 30*sqrt (3/W)	V = f/15,f/30,f/60
L5A	f = 40*sqrt (6/W	V = f/25,f/50,f/100
L9A	f = 40*sqrt (9/W)	V = f/25,f/50,f/100
L20	f = 40*sqrt (20/W)	V = f/25,f/50,f/100

Table 4-1. Fundamental Resonant Frequency

Chapter 5. HARDWARE REFERENCE

Chapter Objectives

This chapter is designed to function as a quick-reference tool for the following information:

- System specifications (dimensions & performance)
- Proper I/O connections
- DIP switch settings

System Specifications

L Drive Specifications

Parameter	Value
Amplifier	
Type	20 kHz fixed frequency, variable duty cycle, pulse-width modulated. Current controller, bipolar type. MOSFET construction.
Number of Phases	Two
Protection (auto-shutdown if encountered)	Shortcircuit: Phase-to-phase (**NOT** phase-to-ground) Brownout: If AC supply drops below 95 VAC Overtemperature: If internal air temperature exceeds 162°F (75°C)
Current Rating	0 - 3 amps/phase (DIP switch-selectable)
Input Power	
Voltage	95-132 VAC, single phase
Frequency	47 - 66 Hz
Current	3A maximum continuous (RMS)
Forcer Output Power	
Voltage	170 VDC (20 kHz PWM)
Current	3A maximum
Command Interface	These inputs are fully optically-isolated and require a TTL-type signal to operate. >3.5 VDC high, <0.8 VDC low. User-supplied indexer must be capable of providing 20mA.
Step Input	High-going pulse, 300 ns minimum pulse width. Max. pulse rate is 750 kHz. Use a differential driver (e.g., TI75174 line driver).
Direction Input	Logic high = forward; logic low = reverse. ≥50 µs of set-up time is required before step pulse is received.
Shutdown Input	Logic high (≥100 ms)= amplifier disable; logic low = normal operation. Must be removed for 100 ms before step pulse is received.
Accelerometer	
Input Signal	Analog accelerometer output voltage
Power	±12 VDC at 15mA provided to power the accelerometer
Accelerometer	Strain gauge output
Inductance	
Minimum Forcer Inductance	5 mH/phase measured end-to-end
Environmental	
Driver Operating Temperature	32° to 113°F (0° to +45°C). An optional fan kit is available for extra cooling.
Storage Temperature	-40° to 185°F (-40° to +85°C)
Humidity	0 to 95% Non-condensing

Table 5-1. L Drive Specifications

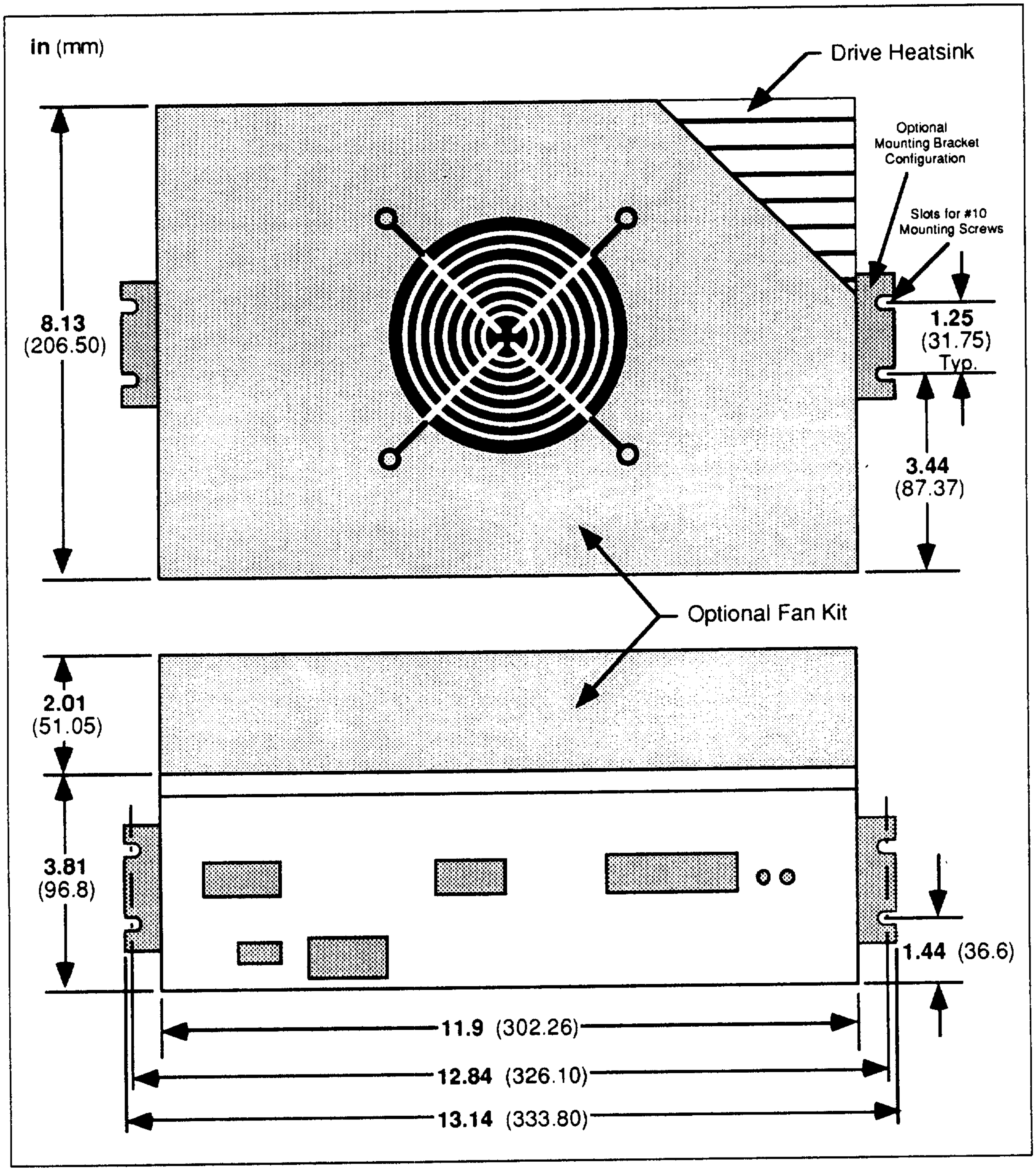


Figure 5-1. L Drive Dimensional Drawing

L-L3C System Specifications

L3C System	
Static Force	3.0 lbs (1.36 kgs)
Normal force between forcer and platen	28.0 lbs (12.7 kgs)
Accuracy (worst case)	±0.004 in (100 microns)*
Repeatability (unidirectional)	±0.0003 in (±7.5 microns)
Hysteresis	0.0008 in (20 microns)
Cyclic error (TIR/0.0167")	±0.002 in (50 microns)
Platen Errors:	
Cumulative	0.0003 in/in (0.3 µm/mm)
Non-cumulative random	±0.0006 in (15 microns)
Thermal expansion	0.00000633 in/in/°F (11.4 microns/meter/°C)
Straightness of travel	0.005 inches TIR** (127 microns)
Pitch Torque	Max: 180 oz-in (13.0 kg-cm)
Roll Torque	Max: 310 oz-in (22.0 kg-cm)
L3C Forcer	
Type	Two-phase, PM hybrid
Current per phase	1.0A
Maximum forcer case temp	190°F (88°C)
Bearing type	Ball bearing, ABEC 1 (Top and Side)
Air gap	0.003 in (75 microns)
Maximum forcer load	Top 10.0 lb (4.54 kg); Side 3 lbs (1 kg)
Forcer weight	1 lb (0.45 kg)
L3C Platen	
Flatness (assumes flat mounting)	0.003 in TIR (75 microns)
Standard length	15 in (381 mm)
Weight	2.42 oz/in (27.0 gm/cm)
Base material	Low carbon steel
Surface flatness required for forcer operation	0.0001 in/4 in (25 microns/100 mm)
Tooth Pitch	0.0667 in (1.693 mm)

* Platen heating error not included
** TIR = Total Indicated Reading (difference between maximum and minimum reading)

Table 5-2. L-L3C System Specifications

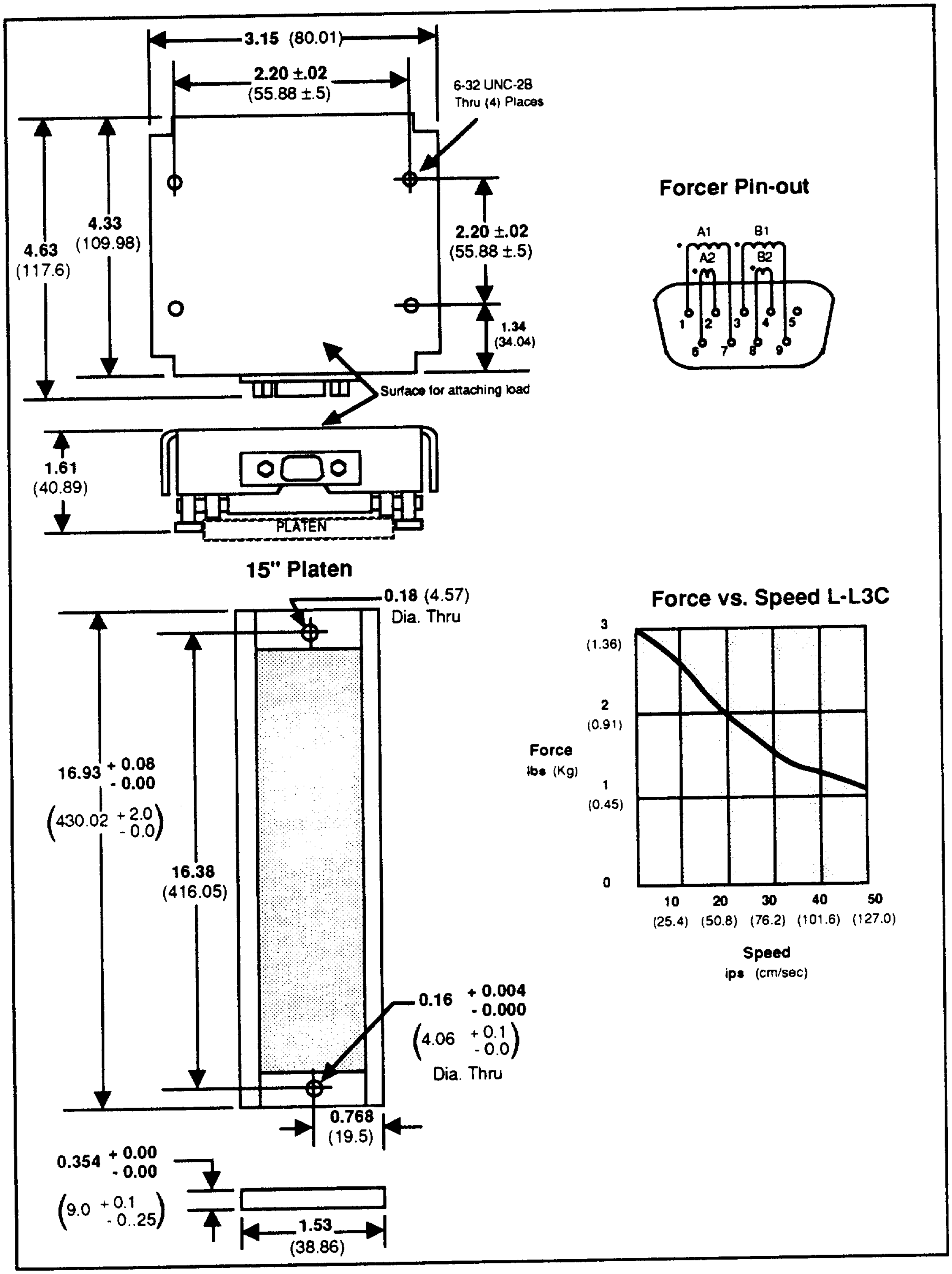


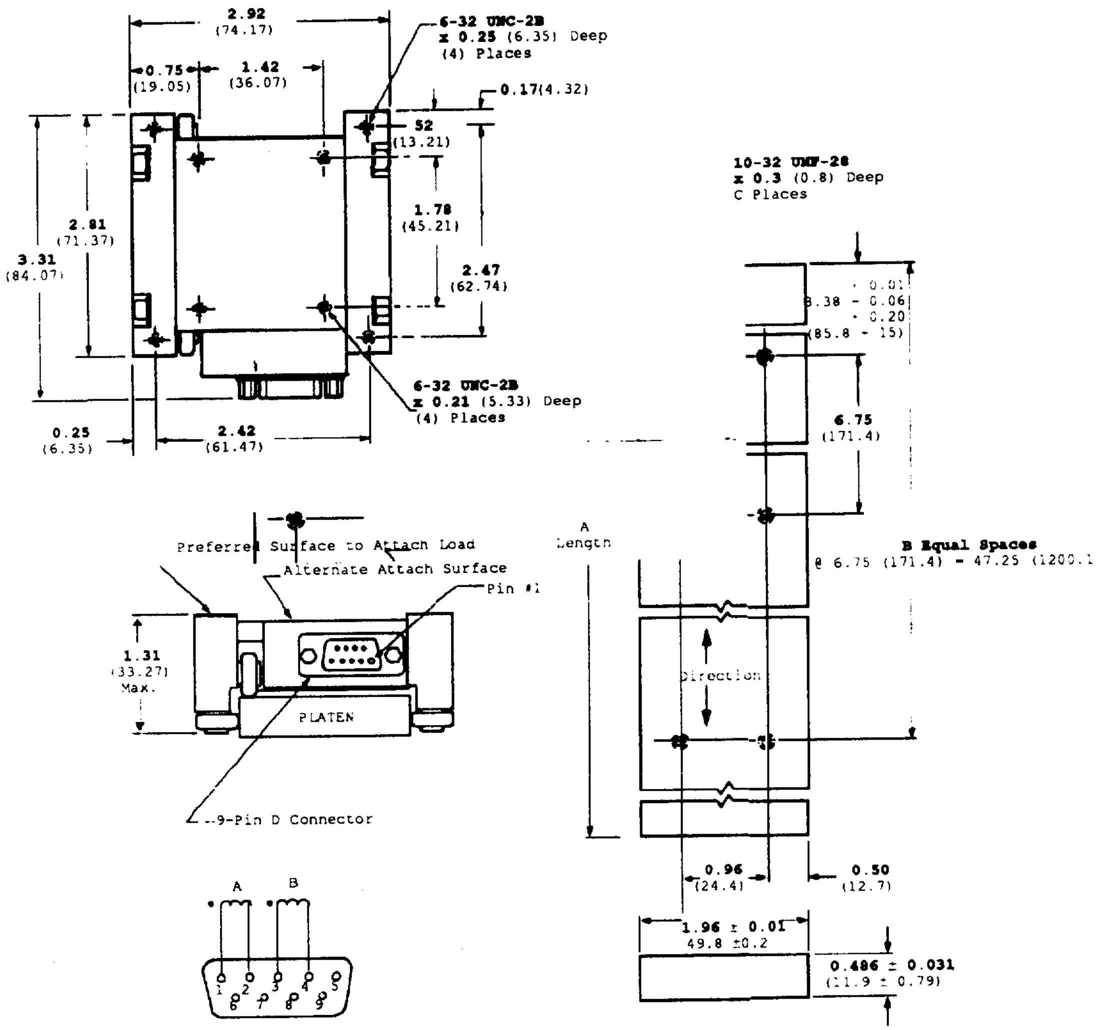
Figure 5-2. L-L3C Dimensional Drawing and Performance Curve

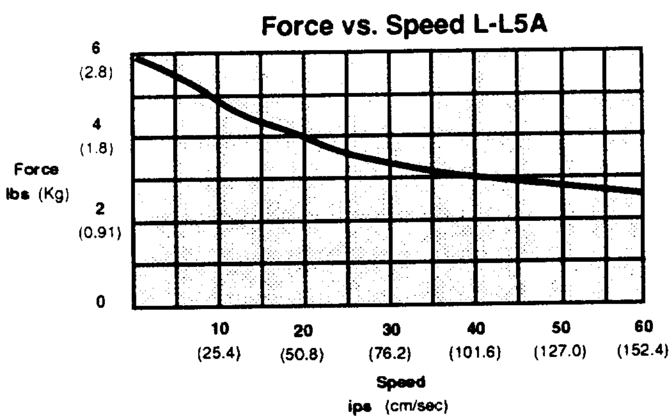
L-L5A System Specifications

L5A System	
Static Force	6.0 lbs (2.27 kgs)
Normal force between forcer and platen	46.0 lbs (20.9 kgs)
Accuracy (worst case)	±0.0035 in (90 microns) *
Repeatability (uni-directional)	±0.0003 in (±7.5 microns)
Hysteresis	0.0008 in (20 microns)
Cyclic error	±0.002 in (±50.0 microns)
Platen Errors: Cumulative Non-cumulative random Thermal expansion	 0.0001 in/in (0.1 micron/mm) ±0.0006 in (15 microns) 0.00000633 in/in/°F (11.4 microns/meter/°C)
Straightness of travel	0.002 in TIR (50 microns)
Pitch Torque	Max: 90 oz-in (7.0 kg-cm)
Roll Torque	Max: 190 oz-in (14.0 kg-cm)
L5A Forcer	
Type	Two-phase, PM hybrid
Current per phase	1.5A
Maximum forcer case temp	190°F (88°C)
Bearing type	Ball bearing, ABEC 3 (Top and Side)
Air gap (typical)	0.0015 in (37.5 microns)
Maximum forcer load	Top 10.0 lbs (4.54 kgs); Side 10.0 lbs (4.45 kgs)
Forcer weight	0.8 lbs (0.36 kgs)
L5A Platen	
Flatness (assumes flat mounting)	0.002 in TIR (50 microns)
Standard lengths	13, 27, or 54 inches (330, 686, 1372 mm)
Weight	4.15 oz/in (45.0 gm/cm)
Platen material	1018 steel
Platen plating	Chromium, class 2B
Surface flatness required for forcer operation	0.001 in/4 in (25 microns/100 mm)
Tooth pitch	0.040 in (1.016 mm)

* Platen heating error not included

Table 5-3. L-L5A System Specifications





Model	A Length	B # Spaces	C # Holes
PO-L5A-P13	13.5 (342.9)	1	4
PO-L5A-P26	27.0 (685.8)	3	8
PO-L5A-P54	54.0 (1371.6)	7	16

Figure 5-3. L-L5A Dimensional Drawing and Performance Curve

L-L9A System Specifications

L9A System	
Static Force	10.0 lbs (4.54 kgs)
Static normal force between forcer and platen	80.0 lbs (36.4 kgs)
Accuracy (worst case)	±0.0025 in*
Repeatability (uni-directional)	±0.0001 in (±2.5 microns)
Hysteresis	0.0005 in (12.5 microns)
Cyclic error (TIR/0.01")	±0.0015 in (35.5 microns)
Platen Errors:	
Cumulative	±0.0001 in/in (0.1 µm/mm)
Non-cumulative random	±0.0004 in (10 microns)
Thermal expansion	0.00000633 in/in/°F (11.4 microns/meter/°C)
Straightness of travel	0.002 in TIR (50 microns)
Pitch Torque	Max: 120 oz-in (9.0 kg-cm)
Roll Torque	Max: 120 oz-in (9.0 kg-cm)
L9A Forcer	
Type	Two-phase, PM hybrid
Current per phase	1.5A
Maximum forcer case temp	167°F (75°C)
Bearing type	Ball bearing, ABEC 3 (top and side)
Air gap (typical)	0.0005 in (12.5 microns)
Maximum forcer load	Top: 50 lbs (22.7 kgs); Side: 10 lbs (4.54 kgs)
Forcer weight	1.4 lbs (0.64 kgs)
L9A Platen	
Flatness (assumes flat mounting)	0.002 in TIR (50 microns)
Standard lengths	13, 27, or 54 inches (330, 686, 1372 mm)
Weight	4.15 oz/in (45.0 gm/cm)
Platen material	1018 steel
Bottom and sides surface plating (top is untreated)	Chromium, class 2B
Surface flatness required for forcer operation	0.00025 in/5 in (0.635 microns/125 mm)
Tooth pitch	0.040 in (1.016 mm)

* Platen heating error not included

Table 5-4. L-L9A System Specifications

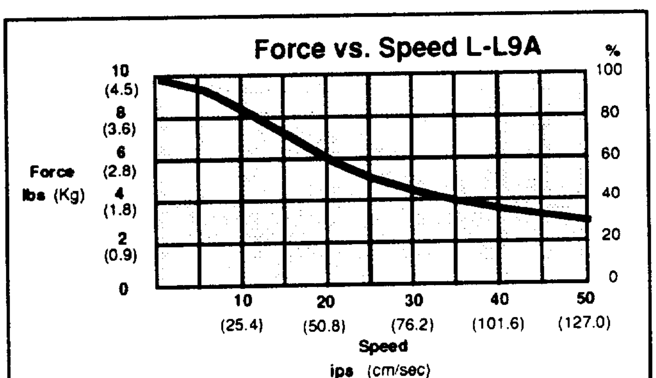
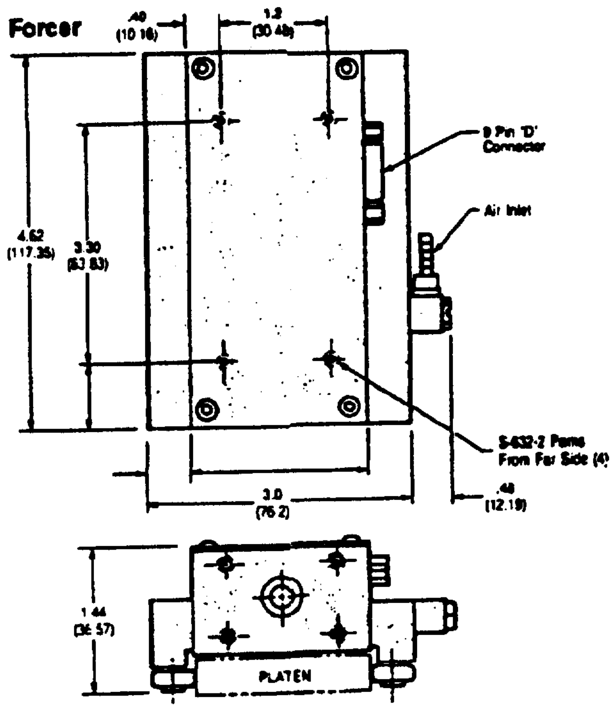
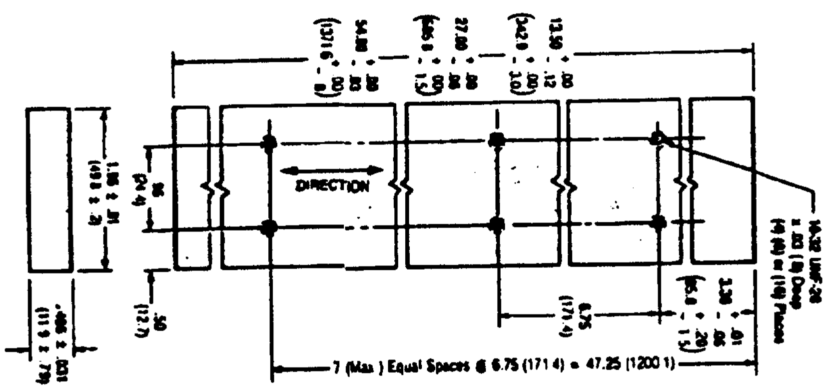


Figure 5-4. L-L9A Performance Curve

Forcer



Platen



Forcer Pin-out

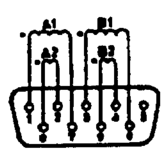


Figure 5-5. L-L9A Dimensional Drawing

L-L20 System Specifications

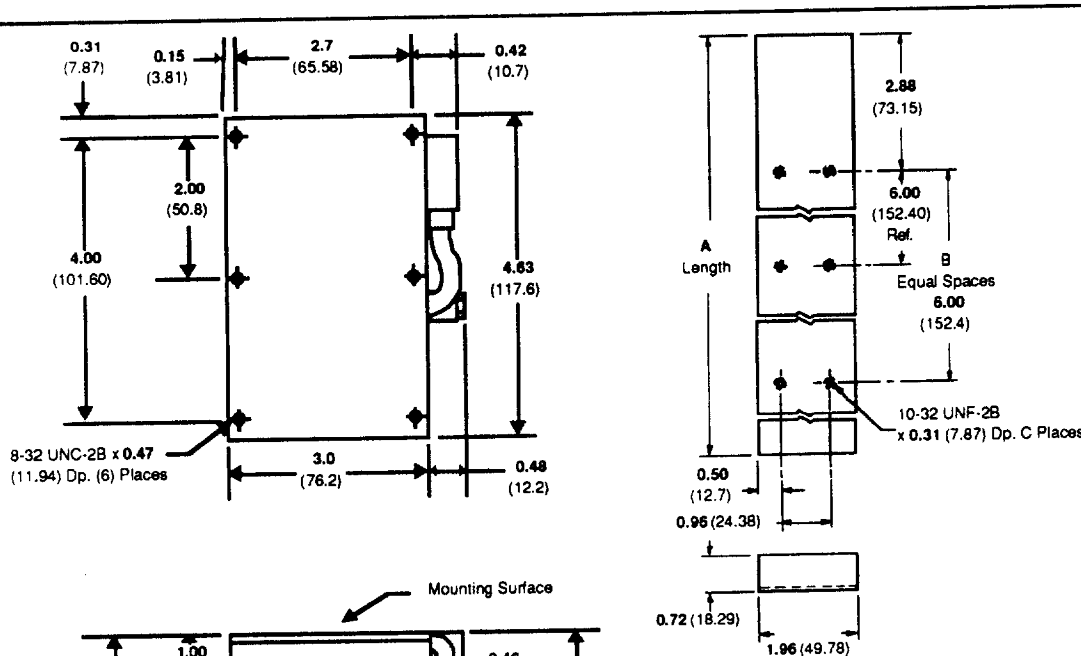
L20 System	
Static Force	20.0 lbs (9.087 kgs)
Static normal force between forcer and platen	180.0 lbs (81.8 kgs)
Accuracy (worst case)*	±0.0035 in (90 microns)
Repeatability (uni-directional)	±0.0001 in (±2.5 microns)
Hysteresis	0.0005 in (12.5 microns)
Cyclic error (TIR/0.01")	±0.0015 in (±37.5 microns)
Platen Errors:	
Cumulative	±0.0001 in/in (0.1 μm/mm)
Non-cumulative random	±0.0015 in (±37.5 microns)
Thermal expansion	± 0.00000633 in/in/°F (11.4 microns/meter/°C)
Straightness of travel	0.0025 inches TIR (62.5 microns)
Yaw Torque**	Max: 90 oz-in (7.0 kg-cm)
Pitch Torque**	Max: 120 oz-in (9.0 kg-cm)
Roll Torque**	Max: 120 oz-in (9.0 kg-cm)
L20 Forcer	
Type	Two-phase, PM hybrid
Current per phase	2.7A
Operating temperature, forcer (Ta)	32° - 104°F (0° - 40°C)
Maximum forcer case temp	167°F (75°C)
Bearing type	Top: Air bearing, forced air @ 40 PSI, 20 SCFH; Side: Ball bearing (2), ABEC 3, 8 lb magnetic preload
Air gap (typical)	0.0005 in (12.5 microns)
Maximum forcer load***	Top: 50 lbs (22.7 kgs); Side: 5 lbs (2.27 kgs)
Forcer weight	2 lbs (0.8 kgs)
L20 Platen	
Flatness (assumes flat mounting)	0.002 in TIR (50 microns)
Standard lengths	18, 36, 54, 72, 96, or 144 inches (457, 914, 1372, 1828, 2438, 3658 mm)
Weight	6.23 oz/in (67.5 gm/cm)
Platen material	1018 steel
Bottom and side surface plating	Nickel plated (top is treated to prevent corrosion)
Surface flatness required for forcer operation	0.00025 in/5 in (0.635 microns/125 mm)
Tooth pitch	0.040 in (1.016 mm)

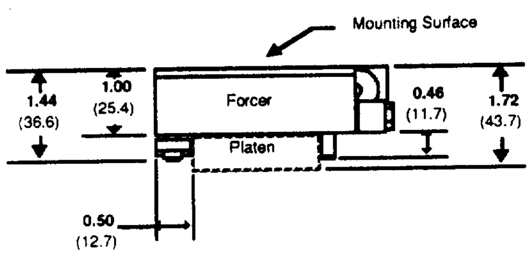
* Platen heating error is not included.

** Refer to Chapter 3, Installation, for a description of *Yaw, Pitch, and Roll.*

*** *Top* load refers to the vertical force on top of the forcer in the normal horizontal (flat) mounting configuration. *Side* load refers to the side force (perpendicular to the platen length, pressing on the forcer side bearings) on a forcer when the forcer/platen is mounted vertically.

Table 5-5. L-L20 System Specifications





Model	A Length	B # Spaces	C # Holes
PO-L20-P18	17.75 (451)	2	6
PO-L20-P36	35.75 (908)	5	12
PO-L20-P54	53.75 (1365)	8	18
PO-L20-P72	71.75 (1822)	11	24
PO-L20-P96	95.75 (2432)	15	32
PO-L20-P144	143.75 (3651)	23	48

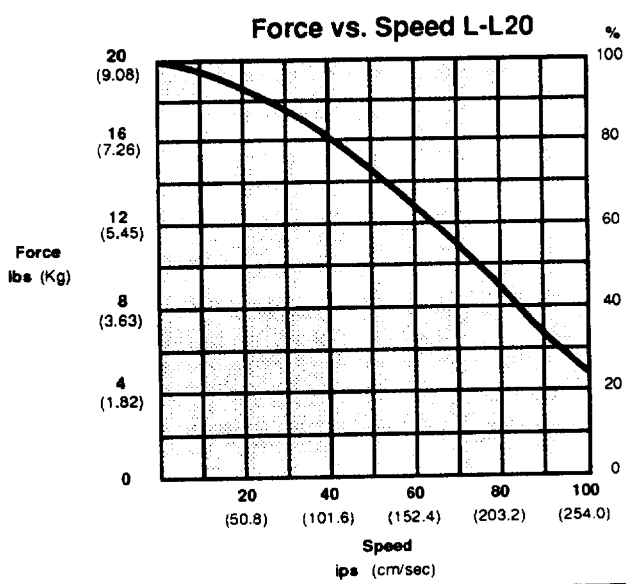


Figure 5-6. L20 Dimensional Drawings and Performance Curve

Connector Summary and Pinouts

Figure 5-7 is a pinout and connector summary diagram for the L Drive. Refer to Table 5-1 for system specifications.

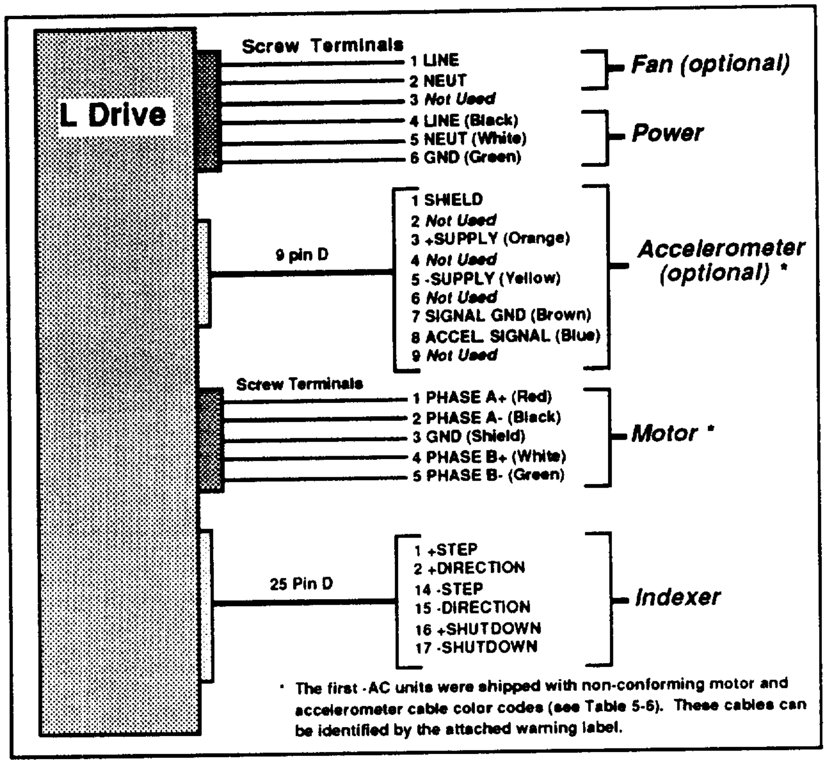


Figure 5-7. L Drive Connectors and Pinouts

Accelerometer		
Pin	**Description**	**Color**
1	Shield	Shield
2	*not used*	--------
3	+Supply	Red
4	*not used*	--------
5	-Supply	White
6	*not used*	--------
7	Signal GND	Black
8	Accel. Signal	Green
9	*not used*	--------

Motor		
Pin	**Description**	**Color**
1	Phase A+	Brown
2	Phase A-	Blue
3	GND	Shield
4	Phase B+	Orange
5	Phase B-	Yellow

Table 5-6. Non-Conforming Color Codes for L20-AC Forcer and Accelerometer Cables (Initial Shipments Only)

Wire Gauges

Accelerometer wire gauges are all 30AWG. Motor wire gauges are all 22AWG.

L Drive DIP Switch Settings

You can select options and functions for the motor being used and your application. If purchased with a linear motor, the L Drive is configured at the factory for the proper current and standard resolution of the system. To change any of the settings, use the DIP switches. Refer to Figure 2-1 in Chapter 2 for the location of the DIP switches. The ON/OFF switch convention is as follows:

- **ON** = DIP switch moved towards the PCA
- **OFF** = DIP switch moved away from the PCA

The following procedure should be followed when adjusting the L Drive's DIP switches:

STEP 1 Remove power.

STEP 2 Check all DIP switch settings. Use the tables below to ensure that the switches are set properly.

STEP 3 If you must make DIP Switch adjustments, use a narrow instrument, such as a thin, flat screw driver.

Motor Current Settings

	Drive DIP Switch Settings				
Motor Current (amps)	**1**	**2**	**3**	**4**	**5**
0.000*	OFF	OFF	OFF	OFF	OFF
0.093	OFF	OFF	OFF	OFF	ON
0.186	OFF	OFF	OFF	ON	OFF
0.279	OFF	OFF	OFF	ON	ON
0.396	OFF	OFF	ON	OFF	OFF
0.489	OFF	OFF	ON	OFF	ON
0.582	OFF	OFF	ON	ON	OFF
0.675	OFF	OFF	OFF	OFF	OFF
0.775	OFF	ON	OFF	OFF	OFF
0.868	OFF	ON	OFF	OFF	ON
0.961 (L3C)**	**OFF**	**ON**	**OFF**	**ON**	**OFF**
1.054	OFF	ON	OFF	ON	ON
1.171	OFF	ON	ON	OFF	OFF
1.264	OFF	ON	ON	OFF	ON
1.357	OFF	ON	ON	ON	OFF
1.450 (L5A & L9A)**	**OFF**	**ON**	**ON**	**ON**	**ON**
1.550	ON	OFF	OFF	OFF	OFF
1.643	ON	OFF	OFF	OFF	ON
1.736	ON	OFF	OFF	ON	OFF
1.824	ON	OFF	OFF	ON	ON
1.946	ON	OFF	ON	OFF	OFF
2.039	ON	OFF	ON	OFF	ON
2.132	ON	OFF	ON	ON	OFF
2.225	ON	OFF	ON	ON	ON
2.325	ON	ON	OFF	OFF	OFF
2.418	ON	ON	OFF	OFF	ON
2.511	ON	ON	OFF	ON	OFF
2.604	ON	ON	OFF	ON	ON
2.721 (L20)**	**ON**	**ON**	**ON**	**OFF**	**OFF**
2.814	ON	ON	ON	OFF	ON
2.907	ON	ON	ON	ON	OFF
3.000	ON	ON	ON	ON	ON

* Factory Default Setting if the L Drive is shipped without a forcer
** Factory Default Setting for the accompanying forcer

Table 5-7. Motor Current Settings

Automatic Run Settings

CAUTION

Be sure that the forcer is free to move. ***Be ready to remove power.***

Automatic Run is enabled and disabled with **Drive DIP switch #6**. Auto Standby, motor resolution, and waveform options are disabled while in the Automatic Run mode.

SW6 - ON Disables the function*
SW6 - OFF Enables the function

**** Factory Default***

Automatic Standby Settings

Automatic Standby is enabled/disabled with **Drive DIP switch #7**. When enabled, this feature drops the current to the forcer by 50% when the forcer receives no step pulses for one second. Full power is restored when a step pulse is received.

SW7 - ON Disables the function*
SW7 - OFF Enables the function

**** Factory Default***

Motor Resolution Settings

Table 5-8 provides motor resolution settings for the standard L Drive system using Drive DIP switches 8 - 10.

Microsteps Per Full Step	Steps/In L20, L9A & L5A	Steps/In L3C	Drive DIP Switch Settings 8	9	10
125	12,500	7.500	ON	ON	ON
*100**	*10,000**	*6,000**	*OFF*	*ON*	*ON*
90	9,000	5,400	ON	OFF	ON
50	5,000	3,000	OFF	OFF	ON

****Factory Setting***

Table 5-8. Motor Resolution Settings (Drive DIP Switches 8 - 10)

-AC Option Resolution Settings

For proper operation of the L Drive L20-AC system, the motor resolution settings on the -AC DIP switch must be the same as those on the Drive DIP switch. *Not all L Drive resolutions are available on the -AC DIP switch (see Tables 5-9 and 5-10). Selecting the wrong motor resolution reduces motor performance.*

Drive DIP Switch Settings			Standard L Drive Firmware
8	9	10	Standard resolution
OFF	OFF	OFF	*invalid*
ON	OFF	OFF	*invalid*
OFF	ON	OFF	*invalid*
ON	ON	OFF	*invalid*
OFF	OFF	ON	5,000 steps/in pure
ON	OFF	ON	9,000 steps/in pure
OFF	ON	ON	10,000 steps/in pure*
ON	ON	ON	12,500 steps/in pure

**** Factory Default Settings***
NOTE: Both 5,000 and 10,000 steps/rev compatible with -AC

Table 5-9. Drive DIP Switch Resolution Settings

-AC DIP Switch Settings				
4	5	6	Pulse Width	Resolution
OFF	OFF	OFF	1.00 µs	5,000 steps/in*
ON	OFF	OFF	0.65 µs	5,000 steps/in
OFF	ON	OFF	1.00 µs	*do not use*
ON	ON	OFF	0.65 µs	*do not use*
OFF	OFF	ON	1.00 µs	10,000 steps/in
ON	OFF	ON	0.65 µs	10,000 steps/in**
OFF	ON	ON	1.00 µs	20,000 steps/in
ON	ON	ON	0.65 µs	20,000 steps/in

**** Setting for use with a Compumotor PC21, PC23, STD22, or 371 indexer***
***** Factory Default Setting***

Table 5-10. -AC DIP Switch Resolution Settings

Motor Waveform Settings

Use Drive DIP switches #11 and #12 to select the current waveform that provides the smoothest operation (see Table 5-11).

Waveform Shape	11	12
Pure Sine	OFF	OFF
+4% 3rd Harmonic	ON	OFF
-4% 3rd Harmonic	OFF	ON
Pure Sine*	ON	ON

**** Factory Default Setting***

Table 5-11. Motor Waveform Settings

Gain Settings (-AC Option Only)

To achieve a damping ratio of approximately 0.707, you must set -AC DIP switches 1 - 3 according to Table 5-12. Too much gain makes the forcer behavior sluggish, taking longer for the forcer to reach the end-point of the move. Too little gain will make the forcer ring. This reduces the performance of the system by requiring a larger safety margin. With no gain (all DIP switches on), the forcer will ring the same as a system without accelerometer feedback.

-AC DIP Switch Settings			
1	2	3	Payload
OFF	OFF	OFF	77 to 105 lb**
ON	OFF	OFF	53 to 77 lb**
OFF	ON	OFF	33 to 53 lb**
ON	ON	OFF	17.6 to 33 lb
OFF	OFF	ON	6.6 to 17.6 lb
ON	OFF	ON	1.0 to 6.6 lb
OFF	ON	ON	0 to 1.0 lb*
ON	ON	ON	Disable accelerometer feedback (gain 0)

* ***Factory Default Setting***

Table 5-12. Gain Settings for Different Payloads

** *NOTE: The maximum recommended payload for the L20 forcer is 50 lbs. The L20 forcer can move higher payloads if it is supported by some kind of linear guide along the platen.*

Chapter 6. MAINTENANCE & TROUBLESHOOTING

Chapter Objectives

The information in this chapter will enable you to do the following:

- Maintain the system's components to ensure smooth, efficient operation
- Isolate and resolve system hardware problems
- Use this chapter as a quick-reference tool for a description of system error codes

Maintenance

The following system components require periodic maintenance:

- The Forcer
- The L Drive
- The Platen

Spare Parts Table

Table 6-1 provides a list of recommended spare parts to use with the L Drive system.

Description	Compumotor Part #
Forcer Cables:	
L3C, L5A, L9A	71-007553-12
L20	71-008024-12
L20-AC*	71-010635-12
AC Power Cable	71-006593-01
6-Position Power Connector	43-006606-01
5-Position Motor Connector	43-005561-01
Mounting Brackets	53-006007-01
Air Regulator/Filter Kit (optional)	-RFKC
Fan Kit (optional)	-LFK
Male 25-Pin D-Connector	43-001989-01
D-Connector Shell	43-001990-01

* ***This cable <u>must</u> be factory-installed.***

Table 6-1. Spare Parts List

Forcer Maintenance

You should inspect all mechanical parts of the forcer regularly to ensure that no bolts or couplings have become loose during normal operation. This will prevent some minor problems from developing into more serious problems.

The ball bearings used in the L3C, L5A, L9A, and L20 forcers are not sealed against severe environments, but are permanently lubricated and require no maintenance.

You should inspect the forcer cable periodically for signs of wear. This inspection interval is duty-cycle, environment, and travel-length dependent. You should not apply excessive tensile force to the cable. Also, you should not bend the cable beyond a two-inch radius of curvature during normal operation. Tighten all cable connectors.

L Drive Maintenance

Check that the drive heatsink is free of dust and has a free flow of air over its entire surface. The drive should be allowed to function without shutting itself down at an internal temperature of 165°F (74°C).

Enclosures must be connected to earth ground through a grounding electrode conductor to provide a low-impedance path for ground-fault or noise-induced currents. All earth ground connections must be continuous and permanent.

Platen Maintenance

If you shorten the length of your platen, treat the end of the platen with non-corrosive Rust-Oleum™. If your platen is corroded, use lapping paper to remove the corrosion, then clean it with rubbing alcohol. Compumotor recommends the following Lapping paper: *3M* 261X Imperial Lapping Film (8.5 x 11 in sheets) A/O (Aluminum Oxide) 3.0 Mil.

Periodically check the platen mounting bolts for tightness. Periodically clean the platen surfaces with alcohol or acetone, even in relatively clean environments such as normal engineering labs and offices. In dirtier environments, a protective boot may be needed. The boot covers both the platen and the forcer. As the forcer moves, the boot folds (like an accordion).

Shiny spots or scratches on the platen surface indicate that the forcer is not floating properly on the air bearing. This is due to improper platen mounting and/or clogged air orifices in the L20 or L9A forcer. Use the following procedure to check and clean clogged orifices:

STEP 1 Remove the non-energized forcer carefully from the platen.

STEP 2 With the air on, check with your finger tips for a fine stream of air from the orifices. The air flow for each orifice should be similar.

STEP 3 When a clogged orifice is found, turn off the air and remove the orifice with a small screw driver.

STEP 4 Dislodge the debris from the orifice with a small piece of wire (≈0.01 inches in diameter) or with a burst of air.

STEP 5 Turn the air on to remove other debris in the air channels of the forcer.

STEP 6 Reinstall the orifice and repeat the process to check for other clogged orifices.

Troubleshooting

This section discusses methods to identify, isolate, and resolve problems that may occur with your L Drive system.

Problem Isolation

When your system does not function properly (or as you expect it to operate), the first thing that you must do is identify and isolate the problem. When you accomplish this, you can effectively begin to eradicate and resolve the problem.

The first step is to isolate each system component and ensure that each component functions properly when it is run independently. You may have to dismantle your system and put it back together piece by piece to detect the problem. If you have additional units available, you may want to use them to replace existing components in your system to help identify the source of the problem.

Try to determine if the problem is mechanical, electrical, or software-related. *Can you repeat or recreate the problem?* Do not attempt to make quick rationalizations about problems. Random events may appear to be related, but they are not necessarily contributing factors to your problem. You must carefully investigate and decipher the events that occur before the subsequent system problem.

You may be experiencing more than one problem. You must solve one problem at a time. Log (document) all testing and problem isolation procedures. You may need to review and consult these notes later. This will also prevent you from duplicating your testing efforts.

Once you have isolated the problem, take the necessary steps to resolve it. Refer to the problem solutions contained in this chapter. If your system's problem persists, contact Parker Compumotor's Applications Department at (800) 358-9070.

> **WARNING**
>
> **Be sure to remove power before testing L Drive system components.**

Forcer Fails to Move

Test the forcer to see if it has holding force. If there is no holding force, here are some probable causes:

- There is no AC power.
- The forcer cable is disconnected.
- There are bad connections or bad cables (disconnect power connector, then use an ohm meter to monitor continuity).
- The L Drive's amplifier is being disabled by the Shutdown input from the indexer. This is pin 16 of the indexer connector. If pin 16 is high (TTL level) with respect to pin 17, the amplifier board is disabled.

If the unit has holding force but does not move, here are some probable causes:

- There is no air to the air bearing.
- The limit switches have been tripped or are faulty.
- The load is jammed. You should hear the drive attempting to move the forcer. Remove AC power from the driver and verify that the forcer and the payload can be moved manually away from the point of the jam.
- No step signal is coming to the L Drive. Check that a pulse train meets all requirements for voltage, current, and pulse width (refer to Table 5-1 in Chapter 5).
- Indexer parameters are incorrectly set up. If certain parameters are out of range or are missing, nothing will happen when you push the start button or issue the GO command.

Forcer Stalls

A forcer stall during acceleration may be caused by one or more of the following factors:

- The force requirements may be excessive.
- The acceleration ramp may be too steep.
- The payload torque specifications may be exceeded.
- The platen surface may be uneven or damaged.
- The forcer air orifices may be clogged.

If the forcer stalls during the constant velocity portion of a move, the platen may be damaged or is uneven. It is also possible that dirt on either the forcer or platen surface is obstructing the air gap. You should inspect the system for flatness and damage, then clean the system thoroughly.

A stall may also occur if the motor current DIP switch setting is incorrect. The forcer may not be receiving enough current to operate. Refer to Chapter 5 for the proper current selection.

Fault LED

There is a red FAULT LED located on the L Drive front panel. The LED may be activated (illuminated) if one of the following conditions exist:

- The drive is overheating. You may consider cooling the cabinet to the temperature specified in the Hardware Reference section. The fan kit will solve the problem.
- A short circuit exists in the forcer current output. Use the Ohm meter to make sure that there is not a short circuit between phases or to earth ground. **NOTE: Make sure power is removed before you test the forcer.**
- The shutdown input may be active.
- A brownout condition exists. Check the AC input voltage to verify that the drive is receiving ≥95VAC.

If the fault condition is caused by short circuit or brownout, the LED remains on until you cycle power to the L Drive. If the fault is caused by overheating, the LED will turn off when the drive cools to an acceptable operating temperature.

Forcer Fails to Run at High Speeds

The forcer may fail to run at high speeds due to the following factors:

- It is possible that the forcer may not produce enough force to move a given load at these velocities. Check the force/speed curve in Chapter 5 to make sure you are trying to operate the forcer in the proper range
- Many Compumotor indexers will not produce pulse trains faster than 500,000 pulses per second. Dividing 500,000 pulses/sec by the set L Drive resolution (steps/inch) will give the maximum speed expected.

Forcer is Jerky or Weak

Check that there are no mechanical problems at the load, causing highly variable loading conditions. Disconnect the forcer from the load and run it without a load connected. To determine if the forcer is developing its full holding force, use a fish scale to pull in the direction of travel until the stationary forcer slips. If these problems persist, service repair is necessary.

Forcer Overheats

If the forcer exceeds its maximum forcer case temperature rating, failure will eventually result. Check your DIP Switch setting to ensure that the current setting is correct for the forcer you are using (refer to Chapter 5). If the current setting is correct, and you want to run the forcer at a lower temperature, turn DIP Switch 7 to the OFF position. This will reduce your motor current to 1/2 of the set value that is used when your forcer is moving. This should make the forcer run cooler. Use a fan to increase the airflow around the forcer and the platen.

Forcer Disengages from Platen

The forcer will disengage from the platen if the maximum yaw, pitch, or roll specifications are exceeded. One or more of the following may cause such a situation:

- Overhung or cantilevered loads
- A load that is not sufficiently fixed to the forcer
- A moment-producing force being applied to the forcer

Refer to Chapter 5 for the maximum pitch and roll specifications (maximum yaw specifications are applicable only to the L20 forcer).

Platen Develops Signs of Wear

Pitting is a normal occurrence for mechanical bearing surfaces and is not an indication of platen failure. The platen's functional life span is limited and its wear is governed by standard mechanical bearing considerations. Load, speed, duty cycle, temperature, cleaning, and abrasion all affect the platen's life span.

Reducing Electrical Noise

For information on identifying and suppressing electrical noise, refer to the Technical Data section of the *Compumotor Programmable Motion Control Catalog*.

Returning The System

If you must return your L Drive system to effect repairs or upgrades, use the following steps:

STEP 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 by Parker Compumotor to be out of warranty.

STEP 2 Before you ship the drive to Parker Compumotor, have someone from your organization with a technical understanding of the L Drive system and its application include answers to the following questions:

- What is the extent of the failure/reason for return?
- How long did it operate?
- How many units are still working?
- How many units failed?
- What was happening when the unit failed (i.e., installing the unit, cycling power, starting other equipment, etc)?
- How was the product configured (in detail)?
- What, if any, cables were modified and how?
- With what equipment is the unit interfaced?
- What was the application?
- What was the system sizing (speed, acceleration, duty cycle, inertia torque, friction, etc.)?
- What was the system environment (temperature, enclosure, spacing, unit orientation, contaminants, etc.)?
- What upgrades, if any, are required (hardware, software, user guide)?

STEP 3 Call Parker Compumotor for a Return Material Authorization (RMA) number. Returned products cannot be accepted without an RMA number. The phone number for Parker Compumotor Applications Department is (800) 358-9070.

STEP 4 Ship the unit to:

Parker Compumotor Corporation
5500 Business Park Drive
Rohnert Park, CA 94928
Attn: RMA # xxxxxxx

Warranty

The items described in this document are hereby offered for sale at prices to be established by Parker Hannifin Corporation, its subsidiaries, and its authorized distributors. This offer and its acceptance by any customer ('Buyer') shall be governed by all of the following Terms and Conditions. Buyer's order for any item described in its document, when communicated to Parker Hannifin Corporation, its subsidiary, or an authorized distributor ('Seller') verbally or in writing, shall constitute acceptance of this offer.

1. Terms and Conditions of Sale
All descriptions, quotations, proposals, offers, acknowledgements, acceptances, and sales of Seller's products are subject to and shall be governed exclusively by the terms and conditions stated herein. Buyer's acceptance of any offer to sell is limited to these terms and conditions. Any terms or conditions in addition to, or inconsistent with those stated herein, proposed by Buyer in any acceptance of any offer by Seller, are hereby objected to. No such additional, different or inconsistent terms and conditions shall become part of the contract between Buyer and Seller unless expressly accepted in writing by Seller. Seller's acceptance of any offer to purchase by Buyer is expressly conditional upon Buyer's assent to all the terms and conditions stated herein, including any terms in addition to, or inconsistent with those contained in Buyer's offer. Acceptance of Seller's products shall in all events constitute such assent.

2. Payment
Payment shall be made by Buyer net 30 days from the date of delivery of the items purchased hereunder. Amounts not timely paid shall bear interest at the rate of 1-1/2% for each month or a portion thereof that Buyer is late in making payment. Any claims by Buyer for omissions or shortages in a shipment shall be waived unless Seller receives notice thereof within 30 days after Buyer's receipt of the shipment.

3. Delivery
Unless otherwise provided on the face hereof, delivery shall be made F.O.B.Seller's plant. Regardless of the method of delivery, however, risk of loss shall pass to Buyer upon Seller's delivery to a carrier. Any delivery dates shown are approximate only and Seller shall have no liability for any delays in delivery.

4. Warranty
Seller warrants that the items sold hereunder shall be free from defects in material or workmanship for a period of 365 days from the date of shipment to Buyer. THIS WARRANTY COMPRISES THE SOLE AND ENTIRE WARRANTY PERTAINING TO ITEMS PROVIDED HEREUNDER. SELLER MAKES NO OTHER WARRANTY, GUARANTEE, OR REPRESENTATION OF ANY KIND WHATSOEVER. ALL OTHER WARRANTIES, INCLUDING BUT NOT LIMITED TO, MERCHANTABILITY AND FITNESS FOR PURPOSE, WHETHER EXPRESS, IMPLIED, OR ARISING BY OPERATION OF LAW, TRADE USAGE, OR COURSE OF DEALING ARE HEREBY DISCLAIMED. NOTWITHSTANDING THE FOREGOING, THERE ARE NO WARRANTIES WHATSOEVER ON ITEMS BUILT OR ACQUIRED WHOLLY OR PARTIALLY, TO BUYER'S DESIGNS OR SPECIFICATIONS.

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SELLER'S LIABILITY ARISING FROM OR IN ANY WAY CONNECTED WITH THE ITEMS SOLD OR THIS CONTRACT SHALL BE LIMITED EXCLUSIVELY TO REPAIR OR REPLACEMENT OF THE ITEMS SOLD OR REFUND OF THE PURCHASE PRICE PAID BY BUYER, AT SELLER'S SOLE OPTION. IN NO EVENT SHALL SELLER BE LIABLE FOR ANY INCIDENTAL, CONSEQUENTIAL, OR SPECIAL DAMAGES OF ANY KIND OR NATURE WHATSOEVER, INCLUDING BUT NOT LIMITED TO LOST PROFITS ARISING FROM OR IN ANY WAY CONNECTED WITH THIS AGREEMENT OR ITEMS SOLD HEREUNDER, WHETHER ALLEGED TO ARISE FROM BREACH OF CONTRACT, EXPRESS OR IMPLIED WARRANTY, OR IN TORT, INCLUDING WITHOUT LIMITATION, NEGLIGENCE, FAILURE TO WARN, OR STRICT LIABILITY.

6. Changes, Reschedules and Cancellations
Buyer may request to modify the designs or specifications from the items sold hereunder as well as the quantities and delivery dates thereof, or may request to cancel all or part of this order, however, no such requested modification or cancellation shall become part of the contract between Buyer and Seller unless accepted by Seller in a written amendment to this Agreement. Acceptance of any such requested modification or cancellation shall be at Seller's discretion, and shall be upon such items and conditions as Seller may require.

7. Special Tooling
A tooling charge may be imposed for any special tooling, including without limitation, dies, fixtures, molds and patterns, acquired to manufacture items sold pursuant to this contract. Such special tooling shall be and remain Seller's property notwithstanding payment of any charges therefore by Buyer. In no event will Buyer acquire any interest in apparatus belonging to Seller which is utilized in the manufacture of the items sold hereunder, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer therefor. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special

tooling or other property in its sole discretion at any time.

8. Buyers Property
Any designs, tools, patterns, materials, drawings, confidential information, or equipment furnished by Buyer or any other items which become Buyer's property, may be considered obsolete and may be destroyed by Seller after two (2) consecutive years have elapsed without Buyer placing an order for the items which are manufactured using such property. Seller shall not be responsible for any loss or damage to such property while it is in Seller's possession or control.

9. Taxes
Unless otherwise indicated on the face hereof, all prices and changes are exclusive of excise, sales, use, property, occupational or like taxes which may be imposed by any taxing authority upon the manufacture, sale, or delivery of the terms sold hereunder. If any such taxes must be paid by Seller or if Seller is liable for the collection of such tax, the amount thereof shall be in addition to the amount for the items sold. Buyer agrees to pay all such taxes or to reimburse Seller therefore upon receipt of its invoice. If Buyer claims exemption from any sales, use, or other tax imposed by any taxing authority, Buyer shall save Seller harmless from and against any such tax, together with any interest or penalties thereon which may be assessed if the items are held to be taxable.

10. Indemnity for Infringement of Intellectual Property Rights
Seller shall have no liability for infringement of any patents, trademarks, copyrights, trade dress, trade secrets, or similar rights except as provided in the Part 10. Seller will defend and indemnify Buyer against allegations of infringement of US patents, US trademarks, copyrights, trade dress, and trade secrets (hereinafter 'Intellectual Property Rights'). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in any action brought against Buyer based on an allegation that an item sold pursuant to this contract infringes the Intellectual Property Rights of a third party. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If an item sold hereunder is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at his sole expense and option, procure for Buyer the right to continue using said item, replace or modify said item so as to make it non-infringing, or offer to accept return of said item and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for claims of infringement based on information provided by Buyer, or directed to items delivered hereunder for which the designs are specified in whole or part by Buyer, or infringements resulting from the modification, combination, or use in a system of any item sold hereunder. The foregoing provisions of this Part 10 shall constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for infringement of Intellectual Property Rights.

If a claim is based on information provided by Buyer or if the design for an item delivered hereunder is specified in whole or in part by Buyer, Buyer shall defend and indemnify Seller for all costs, expenses, or judgments resulting from any claim that such item infringes any patent, trademark, copyright, trade dress, trade secret, or any similar right.

11. Force Majeure
Seller does not assume the risk of and shall not be liable for delay or failure to perform any of Seller's obligations by reason of circumstances beyond the reasonable control of Seller (hereinafter 'Events of Force Majeure'). Events of Force Majeure shall include without limitation, accidents, acts of God, strikes or labor disputes, acts, laws, rules or regulations of any government or government agency, fires, floods, delays or failures in delivery of carriers or suppliers, shortages of materials, and any other cause beyond Seller's control.

12. Entire Agreement /Governing Law
The terms and conditions set forth herein, together with any amendments, modifications, and any different terms or conditions expressly accepted by Seller in writing, shall constitute the entire Agreement concerning the items sold, and there are no oral or other representations or agreements which pertain thereto. This Agreement shall be governed in all respects by the law of the State of Ohio. No actions arising out of the sale of the items sold hereunder of this Agreement may be brought by either party more than two (2) years after the cause of action accrues.

Glossary

Absolute Positioning
Refers to a motion control system employing position feedback devices (absolute encoders) to maintain a given mechanical location.

Absolute Programming
A positioning coordinate reference wherein all positions are specified relative to some reference, or *home* position. This is different from incremental programming, where distances are specified relative to the current position.

Acceleration
The change in velocity as a function of time. Acceleration usually refers to increasing velocity and deceleration describes decreasing velocity.

Accelerometer
A small sensor that measures forcer acceleration and provides an electrical signal proportional to acceleration.

Accuracy
A measure of the difference between expected position and actual position of a forcer or mechanical system. Forcer accuracy is usually specified as a distance representing the maximum deviation from expected position.

Address
Multiple devices, each with a separate address or unit number, can be controlled on the same bus. The address allows the host to communicate individually to each device.

Ambient Temperature
The temperature of the cooling medium, usually air, surrounding the forcer or another device.

ASCII
American Standard Code for Information Interchange. This code assigns a number to each numeral and letter of the alphabet. In this manner, information can be transmitted between machines as a series of binary numbers.

Bandwidth
The frequency range in which the size of the system gain expressed in dB is greater than -3 dB.

Baud Rate
The number of bits transmitted per second. Typical rates include 300, 600,1200, 2400, 4800, 9600, 19,200. This means at 9600 baud, one character can be sent nearly every millisecond.

BCD
Binary Coded Decimal is an encoding technique used to describe the numbers Ø - 9 with four digital (on or off) signal lines. Popular in machine tool equipment, BCD interfaces are now giving way to interfaces requiring fewer wires—such as RS-232C.

Bipolar
The Drive current is bi-directional through each motor phase. There are two motor phases: *Phase A* (A+/A-) & *Phase B* (B+/B-).

Bit
Abbreviation of Binary Digit, the smallest unit of memory equals 1 or Ø.

Block Diagram
A simplified schematic representing components and signal flow through a system.

Bode Plot
A graph of system gain and phase versus input frequency which graphically illustrates the steady state characteristics of the system.

Break Frequency
Frequency(ies) at which the gain changes slope on a Bode plot. (Break frequencies correspond to the poles and zeroes of the system.)

Brownout
Low-line voltage at which the device no longer functions properly.

Byte
A group of 8 bits treated as a whole, with 256 possible combinations of ones and zeros, each combination representing a unique piece of information.

Closed Loop
A broadly applied term relating to any system where the output is measured and compared to the input. The output is then adjusted to reach the desired condition. In motion control, the term is used to describe a system wherein a velocity or position (or both) transducer is used to generate correction signals by comparison to desired parameters.

Critical Damping
A system is critically damped when the response to a step change in desired velocity or position is achieved in the minimum possible time with little or no overshoot.

Crossover Frequency
The frequency at which the gain intercepts the Ø dB point on a Bode Plot. (Used in reference to the open-loop gain plot.)

Cyclic Error
The difference between the commanded and actual position over a distance of one tooth pitch. These position errors are repeatable. This error occurs due to motor magnetics. This error recurs once every pole pitch as measured on the body of the forcer.

Daisy-Chain
A term used to describe the linking of several RS-232C devices in sequence such that a single data stream flows through one device and on to the next. Daisy-chained devices usually are distinguished by device addresses, which serve to indicate the desired destination for data in the stream.

Damping
An indication of the rate of decay of a signal to its steady state value. Related to settling time.

Damping Ratio
Ratio of actual damping to critical damping. Less than one is an underdamped system and greater than one is an overdamped system.

Data Bits
Since the ASCII character set consists of 128 characters, computers may transmit only seven bits of data. However, most computers support an eight bit extended ASCII character set.

DCE
Data Communications Equipment transmits on pin three and receives on pin two.

Dead Band
A range of input signals for which there is no system response.

Decibel
A logarithmic measurement of gain. If G is a system gain (ratio of output to input), then 20 log G equals gain in decibels (dB).

Delimiter
A character (space or carriage return) used to separate fields in a command.

Detent Force
The minimal force present in an unenergized forcer. The detent force of a Compumotor or step motor is typically about one percent of its static energized force.

Drive
This is the electronics portion of the system that controls power to the forcer. This portion controls the forcer to provide micro-stepping.

DTE
Data Communications Equipment transmits on pin two and receives on pin three.

Duty Cycle
For a repetitive cycle, the ratio of on time to total cycle time.
Duty Cycle = *On Time ÷*
On Time + Off Time

Efficiency
The ratio of power output to power input.

Encoder
A device which translates mechanical motion into electronic signals used for monitoring position or velocity.

Following
The ability to make one axis perform motion based on the motion of a second, or *master*, axis.

Friction
A resistance to motion caused by surfaces rubbing together. Friction can be constant with varying speed (Coulomb friction) or proportional to speed (viscous friction).

Full Duplex
The terminal will display only received or echoed characters.

Gain
The ratio of system output signal to system input signal.

Half Duplex
In half duplex mode, a terminal will display every character transmitted. It may also display the received character.

Hand Shaking Signals
RST: Request To Send
CTS: Clear To Send
DSR: Data Set Ready
DTR: Data Terminal Ready
IDB: Input Data Buffer
ODB: Output Data Buffer

Holding Force
Sometimes called static force, it specifies the maximum external torque that can be applied to a stopped, energized forcer without causing it to move.

Home
A reference position in a motion control system, usually derived from a mechanical datum. Often designated as the *zero* position.

Hysteresis
The difference in response of a system to an increasing or a decreasing input signal.

IEEE-488
A digital data communications standard popular in instrumentation electronics. This parallel interface is also known as GPIB, or General Purpose Interface Bus.

Incremental Motion
A motion control term that is used to describe a device that produces one step of motion for each step command (usually a pulse) received.

Incremental Programming
A coordinated system where position or distances are specified relative to the current position.

Indexer
This portion of the system provides communication with the external I/O. It allows you to program sequences and direct motion control.

Inertia
A measure of an object's resistance to a change in velocity. The larger an object's inertia, the larger the torque that is required to accelerate or decelerate it. Inertia is a function of an object's mass and its shape.

Limits
Properly designed motion control systems have sensors called limits that alert the control electronics that the physical end of travel is being approached and that motion should stop.

Logic Ground
An electrical potential to which all control signals in a particular system are referenced.

Microstepping
An electronic control technique that proportions the current in a step motor's windings to provide additional intermediate positions between poles. Produces smooth movement over a wide speed range and high positional resolution.

Null Modem
A simple device or set of connectors which switches the receive and transmit lines of a three wire RS-232C connector.

Open Collector
A signal output that is performed with a transistor. An open collector output acts like a switch closure with one end of the switch at ground potential and the other end of the switch accessible.

Open Loop
A motion control system where no external sensors are used to provide position or velocity correction signals.

Opto-Isolated
A method of sending a signal from one unit to another without the usual requirement of common ground potentials. The signal is transmitted optically with a light source (usually a Light Emitting Diode) and a light sensor (usually a photosensitive transistor). These optical components provide electrical isolation.

Parallel
A data communication format wherein many signal lines communicate several pieces of data simultaneously.

Parity
An RS-232C error detection scheme that detects an odd number of transmission errors.

PCA
Printed circuit (board) assembly.

PLC
Programmable logic controller. An industrial control device that turns on and off outputs based upon responses to inputs.

Pole
A frequency at which a system's transfer function goes to infinity.

Primary
With respect to following, this refers to the *master* axis motion being followed by another axis.

Pulse Rate
The frequency of the step pulses applied to a motor driver. The pulse rate multiplied by the resolution of the motor/drive combination (in steps per revolution) yields the speed in inches per second.

Quadrature
A type of incremental encoder output in which the two square wave outputs are offset by 90°.

Ramping
The acceleration and deceleration of a motor. May also refer to the change in frequency of the applied step pulse train.

Rated Force
The force-producing capacity of a forcer at a given speed. This is the maximum force the forcer can deliver to a load and is usually specified with a force/speed curve.

Registration
The ability to execute a preset move with reference to an external event while the forcer is executing another move.

Relative Accuracy
Also referred to as *Step-to-Step Accuracy*, this specification tells how microsteps can change in size. In a perfect system, microsteps would all be exactly the same size, but drive characteristics and the absolute accuracy of the motor cause the steps to expand and contract by an amount up to the relative accuracy figure. The error is not cumulative.

Repeatability
The degree to which the positioning accuracy for a given move performed repetitively can be duplicated.

Resolution
The smallest positioning increment that can be achieved.

Ringing
Oscillation of a system following a sudden change in state.

RS-232C
A data communications standard that encodes a string of information on a single line in a time sequential format. The standard specifies the proper voltage and timing requirements so that different manufacturers' devices are compatible.

Secondary
With respect to following, this refers to the *slave* axis motion being controlled by the primary axis.

Sequence
A series of motion control commands. These commands are created, stored, and executed from the indexer's non-volatile memory such as EEPROM or battery-backed RAM..

Short-Circuit
A defect in a winding which causes part of the normal electrical circuit to be bypassed. This frequently results in reducing the resistance or impedance to such an extent (near zero) as to cause overheating of the circuit, and subsequent burnout.

Slew
In motion control, the portion of a move made at a constant non-zero velocity.

Speed
Used to describe the linear velocity of a forcer or other object in motion.

Start Bits
RS-232C character transmissions begin with a bit which signals the receiver that data is now being transmitted.

Static Force
The maximum force available at zero speed.

Stiffness
The ability to resist movement induced by an applied force. Is often specified as a force displacement curve, indicating the amount a forcer will move upon application of a known external force when stopped.

Stop Bits
When using RS-232C, one or two bits are added to every character to signal the end of a character.

Text/Echo (Off/On)
This setup allows received characters to be re-transmitted to the original sending device. Echoing characters can verify or *close the loop* on a transmission.

Transfer Function
A mathematical means of expressing a system's output to input relationship.

TTL
Transistor-Transistor Logic. Describes a common digital logic device family that is used in most modern digital electronics. TTL signals have two distinct states that are described with voltages: a logical **Ø** or *low* is represented by a voltage of less than 0.8V and a logical **1** or *high* is represented by a voltage from 2.5 to 5V.

XON/XOFF
Two ASCII characters supported in some serial communication programs. If supported, the receiving device transmits an XOFF character to the host when its character buffer is full. The XOFF character directs the host to stop transmitting characters to the device. Once the buffer empties the device will transmit an XON character to signal the host to resume transmission.

Zero
A frequency at which the transfer function of a system goes to zero.

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