OPERATION

1. General

The procedures outlined in this section are intended to help the user to quickly and safely begin operating the I-Drive. Once you have completed the installation of the system, there should be little or no adjustment required for most applications.

2. Initial Start-up

A. Powering Up the System

To familiarize yourself with the operation of the system, you may wish to go through the start-up procedures before final installation of the motor to your load. If so, you should first attach the motor, resolver and indexer cables before applying AC power. Be careful to keep the motor shaft away from any cables or other loose objects which could get tangled when the shaft rotates. The motor should be firmly supported to prevent it from moving while it is running.

WARNING

> Do not grab hold of the motor shaft while it is turning, since there are sharp surfaces on the shaft. Also be sure that the shaft key is removed from the shaft because it could fly off when the motor is rotating.

Verify that all cables and wiring are properly connected, that the motor shaft is free from obstructions and then apply power to the system.

B. Visual Indicators

Once you have successfully completed all connections and turned on the AC input power, you should check the LED indicators for their proper status before proceeding. The I-Drive has three externally visble LED's which should appear as follows:

STATUS -- Green

FAULT -- Off

ERROR -- Off

If any of the LED indicators are not as described above, REMOVE POWER, inspect all electrical connections, and verify proper input voltages. If no problem is found and LED indicators are not correct when power is reapplied, refer to the Troubleshooting and Maintenance section of this manual.

C. Indexer Functions

Compumotor offers a variety of Indexers which are compatible with the I-Drive. The 430, 1811, 1830 and 3000 indexers allow the user to specify velocity in steps per second. The 2100, 172 and 150 indexer require velocity to be specified in revolutions per second. For the standard indexer software options, 1 rps is equal to 25,000 steps per second. To achieve 4096 steps per second, set the velocity to 0.16384. The 2100, 172 and 150 indexers also come with R5 and R8 options, in which 1 rps is equal to 4096 and 16,384 steps per second respectively.

Performing a functional check using one of these indexers consists of the following steps:

1. Attach the motor/drive cable from the indexer to the I-Drive.
2. Set up the Indexer in accordance with the Installation and Hookup section.
3. To verify that the I-Drive is operating properly, apply power to the I-Drive (115 VAC) and set the indexer to perform a 4096 step/second constant velocity move. This will cause a 4096 steps per revolution motor to rotate at the rate of one revolution per second.

By increasing the velocity setting of the indexer and issuing a new START command you will increase the rotational velocity of the motor. The motor should be able to accept frequencies up to 4096 (PPR) X the maximimum rated speed (RPS) of the motor you are using without stalling, provided there is adequate inertia on the motor shaft and the motor has not been accelerated too quickly.

The direction of the motor can be changed by stopping the motor, changing the DIRECTION switch on the indexer, and issuing a new START command.

If you wish to make this functional check with a square wave generator or some other pulse source, the positive or "hot" lead of the square-wave generator should be attached to the STEP+ input on I-Drive. Refer to Appendix A for pin connections. Ground from the frequency generator should be attached to STEP-. The output of the square-wave generator should be set to 3 volts peak. There is an 220 ohm resistor and LED in series between the STEP+ and STEP- inputs. The current through these components should not exceed 20 mA for reliable operation.

D. Pushbutton Tuning

The I-Series drive has four pushbuttons on the front panel which provide a simple pushbutton method of fine tuning the systems performance to a specific attatched load. The I-Series system is factory preset for typical user loads and for the individual motor supplied with the system. For most applications no adjustment is required by the user.

Once you have the system installed and the motor connected to its intended load, you can determine wether any fine tuning is required by observing the response of the system to commands from your indexer and by observing how "stiff" the system is when at rest.

With the motor at rest, try to deflect the shaft. You should not be able to easily turn the shaft away from its rest position. If it feels very soft, the system gains probably need to be increased. This can be accomplished very easily using the tuning key.

There are four buttons on the front panel called UP, DOWN, ENTER and SAVE, also three test points, V (velocity), C (current) and G (ground). To begin tuning the system depress the UP button and while it is depressed also push the DOWN button. Let up on both buttons. The processor waits until all switches are released before performing any functions. This causes the I-Drive to enter the tuning mode using the gain that were in effect prior to entering tuning. If the I-Drive is being started for the first time these parameters will be the factory settings for typical load and performance requirements. The ERROR LED indicator on the front panel of the I-Drive should begin flashing at this time indicating that the processor is ready to accept tuning commands.

At this time depressing the UP button will increase the system gain a small amount each time it is pushed. Depressing the DOWN button will decrease the gain. If you push the UP button and feel the motor shaft, you should notice the stiffness increasing. If the shaft begins vibrating it means that you've increased the gain too far and the system is slightly unstable. If you get to this point depress the DOWN button several times to reduce the gain. When the motor feels reasonably stiff you can begin operating the system as required by your application. At any time during the tuning process the I-Drive can be returned to the factory settings by depressing both the SAVE and DOWN buttons simultaneously.

The drive can be fine tuned while monitoring its performance as it is indexing. This can be done by watching to see if there is any overshoot or oscillation when it reaches position. You will also be able to hear a little grinding noise when there is a lot of overshoot.Increase or decrease the gain until the motor smoothly accelerates and decelerates to position with little or no overshoot. If you have an ocsilliscope available you can monitor the velocity for overshoot on test point V on the pushbutton panel. Connect your scope probe to test point V and probe ground to test point G. This test point should only be used to monitor relative performance and to minimize overshoot, it is not a true indication of absolute velocity. The voltage will be between 0 and 12 VDC with 0 VDC representing maximum velocity CCW and 12 VDC equal to maximum velocity CW. When stopped the voltage should be approximately 6 VDC.

When the I-Drive performance is satisfactory, depress the SAVE button to save the new servo parameters in the EEPROM memory. If you wish to exit the tuning mode and return to the gains that were in effect when you started tuning, depress the ENTER button.

For a more detailed description of the pushbutton commands and other tuning methods, refer to the Set-up and Tuning section.

3. Visual Indicators

There are three LED (light emitting diode) indicators on the front panel of the I-Drive, STATUS, FAULT, and ERROR.

STATUS -- will be green if power is applied and the system is functioning properly. If power is missing the LED will be off and if there is a controller failure the LED will be red.

FAULT -- occurs any time the I-Drive shuts itself down because of an internally sensed error condition in the amplifier section of the system or if a remote power shutdown is issued by the indexer or drive. This is most likely to occur as a result of over heating (the I-Drive has a built in temperature sensor), or as a result of a short circuit in the output wiring. A FAULT can be cleared by resetting the drive once the fault condition is removed.

ERROR -- occurs any time a "soft fault" is detected, such as excessive position error or exceeding the average current limit setting. This condition will also shut down the drive, causing the FAULT LED to go on. "ERROR" can be cleared by resetting the drive if the error condition is no longer present.

4. Indexer Inputs and Outputs

The indexer inputs provide the normal control signals for the I-Drive. Following is a functional description of how each is used.

A. Step Input

The STEP input causes the motor position to be incremented one unit of feedback resolution. The resolver feedback used on I-Drives is digitized to 4096 parts per revolution. An optional resolution of 16,384 parts per revolution is available. By applying STEPs at various rates the motor is made to rotate at proportional velocities. STEP pulses applied first slowly, and then more quickly have the effect of accelerating the motor. Attempting to accelerate the motor too quickly can cause the motor to lag behind the commanded position. There is an adjustable user defined value for maximum following error which will shut down the drive if exceeded.

B. Direction Input

The DIRECTION input controls the direction of rotation of the motor. When this signal is not activated the motor shaft rotates counter-clockwise as viewed from the flange end of the motor. The motor shaft rotates clockwise if the DIRECTION input is activated.

C. Remote Power Shutdown (RPS) Input

Activation of the REMOTE POWER SHUTDOWN (RPS) input causes the I-Drive to stop putting current through the motor. This will allow the motor to freewheel and as such is intended to allow manual positioning of the load or to keep the I-Drive from interfering with sensitive electronics in the immediate vicinity.

It is not intended to act as an emergency stop for the motor. If RPS is used in this fashion the motor will very likely move beyond its desired stopping position at the risk of **endangering property and life.**

D. Fault Reset Input

The FAULT RESET input will reset the microprocessor and clear an ERROR or DRIVE FAULT condition if the condition causing the fault has been removed.

E. Slip Fault Output

The SLIP FAULT output is activated whenever the actual position of the motor is outside the user defined deadband. This output will be turned off when the absolute value of the following error is less than the deadband.

F. Drive Fault Ouput

The DRIVE FAULT output is activated when the amplifiers in the I-Drive are shut down for any reason. Faults originating in the amplifier are: over-temperature condition, over-current condition, and abnormal internal circuit operation condition. Faults originating in the controller are: shutdown, excess following error, and average current limit exceeded. Once the condition causing the fault has been cleared and the drive reset, normal operation may resume.

5. Auxilliary Inputs and Outputs

A. Drive Enable Input

The DRIVE ENABLE input can be used to enable or disable operation of the I-Drive. This input requires a normally closed connection from the input to the PULLUPS terminal.

B. Drive Fault Output

This output is identical to the DRIVE FAULT OUTPUT on the indexer connector, except that "shutdown" does not activate it.

6. Set-up and Tuning

A. Introduction

The I-Drive controller board is the "main brain" behind the I-drive's ability to position a servomotor. It performs ALL of the compensation necessary to stabilize a AC servomotor. No compensation is provided by the three amplifier boards. In fact, the amplifier boards are slaves to the controller board; the amplifier boards controls the current in the motor, the level of that current is commanded by the controller board.

A block diagram of the I-Drive servo system appears below. The controller commands a "desired current" to the amplifier boards, the amplifier boards then attempt to generate that "desired current" in the motor's windings. The position of the motor's shaft is sensed by the controller via a position sensor attached to the motor. This positional information is used by the controller to generate the "desired current" command to the amplifiers.

```
       +--------------------------------------------+
       |                                            |
      \|/                                           |
+-------------+      +------------+      +--------+----------+
| controller  |  ___\ | amplifier |  ___\ | servo  | position |
|   board     |     / |   board   |     / | motor  |  sensor  |
+-------------+      +------------+      +--------+----------+
```

The generation of the current command to the amplifier by the controller is based on several quantities, not just the position of the servomotor's shaft; it is based on a desired position, which is generated by an indexer, and on previous current commands to the amplifiers. An indexer generates a stream of pulses which the controller collects with an up/down (ie.clockwise/counterclockwise) counter. The resultant pulse count, at any given instant of time, is the desired position. The controller subtracts the motor's actual position from this desired position to determine the positional error. The positional error is the difference between where we want the motor to be and where it actually is. This positional error is put into an equation, along with previous positional errors and previous commands to the amplifier, to generate the current command for the amplifier.

The equation used by the controller to calculate the current command for the amplifier is known as a recursive equation. It is a mathematical equation, or function, that is evaluated at periodic time intervals. In the case of the I-Drive controller the recursive equation is an approximation of an analog, continuous-time lead compensation network. The analog, continous-time lead compensation network is used quite often for the purpose of stabilizing conventional servo systems and consists of several potentiometers, resistors and capacitors. The I-Drive's recursive equation is the discrete-time equivalent to a continuous-time lead compensation network. It is called a discrete-time lead compensation network because it operates on sampled data not on continuous data. The sampling-rate of the I-Drive controller is the rate at which the recursive equation is evaluated and the rate at which the current command to the amplifier is changed. The sample-rate of the I-Drive controller is faster than one millisecond. In general we would like the sampling rate to be as high as possible to get the best dynamic response.

B. Tuning the I-Drive Servo System

The most important aspect of a servo system is setting the controller's "gains". The controller in a conventional continuous-time (i.e., analog) servo system is an active or passive filter network, usually an op-amp with resistive and capacitive feedback. The values and configuration of the resistors and capacitors in the filter network are determined by the compensation necessary to stabilize the servo system.

The values of the resistors and capacitors can be thought of as being the "gains" of the controller. To stabilize the servo system it is necessary to adjust the gains (potentiometers) to match the system being controlled (the "system" being the motor, its load, and the amplifier). In the case of the I-Drive the "gains" of the controller are the constant coefficients of the recursive equation (software). The form of the recursive equation determines how many of these "gains" must be adjusted in order to stabilize the system.

Fortunately, the equation is very simple and, better yet, it is not necessary to know its form to tune an I-Drive servo system. Tuning an I-Drive servo system usually requires adjusting only one controller gain. The other gains are predefined and, in most cases, require no further adjustment by the user.

There are two methods available to adjust an I-Drive's servo compensation network. The four switches on the I-Drives front panel, and the RS-232 communications port. Tuning via the front panel switches will be described first followed by tuning through the RS-232 communications port. Following the tuning procedures, other commands not associated with tuning the I-Drive are described.

B.1 Pushbutton Tuning

There are four switches on the I-Drive front panel labelled ENTER, SAVE, UP, and DOWN. Next to the buttons are three LEDs:

The STATUS LED is bicolor and indicates the operating state of the I-Series controller board. If it is green the controller is operating properly, if it is red the controller is not operating properly and the switches will not be functional.

The FAULT LED indicates "hard faults". If a hardware fault occurs in any of the amplifiers or the high voltage power supply this red LED will light. Additionally, the "hard fault" LED will light if the amplifiers are disabled.

The ERROR LED indicates "soft faults". "Soft faults" are various programmable fault conditions, such as excessive following error or exceeding the average current limit. The "soft fault" LED flashes to indicate that we are in the tuning mode whenever the I-Drive is tuned via the front panel switches .

Before beginning the tuning process check the three LEDs. The bicolor LED must be green and the two fault LEDs must be off. If any of the LEDs glows a continuous red the tuning process cannot be started. If the "soft fault" LED is a flashing red it means the I-Drive currently thinks it is in the tuning mode.

To begin the tuning process depress the ENTER and SAVE buttons simultaneously. (It is not necessary to depress both buttons at precisely the same moment, you can hold down the ENTER button and then, while you are holding the ENTER button, depress the SAVE button.) When you release both buttons the tuning process will begin. (No action occurs until all switches that have been depressed are released.)

Entering the tuning mode takes about one second. When the gains have been initialized by the microprocessor the "soft fault" LED will begin to flash. If you feel the motor's shaft it should be relatively weak. To make the motor stiffer depress the UP button several times. Each time you depress either the UP or the DOWN button you should feel a change in the motor's stiffness. At this time or any time the I-Drive is in the tuning mode you can return to the factory gain settings by depressing the SAVE and DOWN buttons simultaneously. If you depress the UP button enough times you should be able to make the motor go unstable. This will be readily apparent since the shaft will begin to shake and you will hear a loud buzzing or grinding noise! If the motor does become unstable depress the DOWN button several times until the shaft no longer shakes. It is advisable to not leave the gain just at the edge of instability since this results in a system with a limited margin of stability, which means there is a small chance that the system could be upset into an unstable mode upon operation. Instability causes large commands to the amplifier and can cause the drive to overheat. Thus, bringing the gain back from the shaking point by depressing the DOWN button several times is best.

The ERROR LED will stop flashing and stay on if maximum or minimum gain is reached while in the tuning mode. For instance, during normal tuning the error LED flashes. If the gain is increased to its maximum value the error LED will stay on continuously. Decreasing the gain, by pushing the DOWN button, will cause the error LED to flash again, since we have moved away from the maximum gain value. The same holds true if the gain is decreased to its minimum value. When the minimum gain is reached the error LED will stop flashing and stay on continuously. Increasing the gain will cause the LED to flash again.

Once you have found a gain that is adequate you are ready to terminate the tuning process. To do this depress the SAVE switch. Depressing and releasing the SAVE switch will permanently save the new gains in the non-volatile EEPROM memory. Now, everytime the I-Drive is turned on or reset the new gains will be used.

During the process of tuning it is not necessary to make the motor shake, or go unstable. If the desired stiffness is found before the motor begins to shake the tuning process may be stopped there by depressing and releasing the SAVE switch.

The tuning process can be performed while the motor is moving by attaching an indexer to the I-Drive and commanding a move. If an oscilloscope is handy you can monitor the velocity of the motor via the test point labelled V. If you do monitor the velocity using this test point please keep in mind that the velocity output signal you are monitoring is synthesized and is not as accurate as a tachometer's output. The synthesized velocity output does not respond well to fast changes in the velocity and therefore it will never be possible to tune the motor such that the corners of the velocity profile are perfect. Some small overshoot is due to the synthesized velocity output. Large overshoots are real.

Sometimes you may wish to tune the motor, not from the default starting gain values, but from the gains that are currently in effect. This can be done by simultaneously depressing both the UP and DOWN buttons. Depressing both the UP and DOWN buttons simultaneously starts the tuning process (the soft error LED will flash) but does not change the gains in use. Depressing the ENTER and SAVE buttons to begin the tuning process modifies the gains in effect at that time and returns to the default values (very low gain). By depressing the UP and DOWN buttons individually, as described previously, you may adjust the gain of the system.

Depressing and releasing the SAVE button still has the effect of saving the new gains in the EEPROM and terminating the tuning process. If, during the tuning process, you wish to return to the gains you had before you started the tuning process, depress and release the ENTER switch. This will cause you to exit the tuning mode and return to the gains that were in effect before the tuning process began. Depressing the SAVE and DOWN switches simultaneously, while you are in the tuning mode, will cause the I-Drive to compute its "factory default settings". The gains the system selects after depressing these two switches are the gains that were installed in the system when it was shipped. For most applications the factory default settings are adequate and no further tuning is required.

B.1.1 Switch Function Summary

Here is a summary of the functions available from the front panel switches. Not all of these functions have been described above.

NOTE:

Whenever a switch has been depressed the controller waits until ALL switches are released before performing any functions. In addition, it will remember all switches that were depressed while any other switch is depressed. For example, if one wants to depress the UP and DOWN buttons simultaneously do the following:

-- depress and hold down the UP button
-- depress and hold down the DOWN button
-- release the DOWN button
-- release the UP button

As far as the controller is concerned you have depressed the UP and DOWN buttons simultaneously. Two button commands are identified below with a plus sign.

If the I-Drive is not in the tuning mode (the "soft fault" LED is not flashing):

ENTER + SAVE

Starts the tuning process from the default gain values. The "soft fault" LED will begin to flash. Entering the tuning process via the ENTER + SAVE buttons takes approximately one second.

UP + DOWN

Starts the tuning process from the gains currently in effect. The "soft fault" LED will begin to flash.

ENTER + DOWN

Disables the amplifiers. This is equivalent to shutting down the motor/driver (like remote power shutdown on the step motor drives).

ENTER + UP

Enables the amplifiers. This is the opposite of ENTER + DOWN. If an error condition exists or the remote power shutdown input on the indexer/driver interface is active this function will not work.

ENTER + SAVE + UP + DOWN

This is a software reset.

If the controller is in the tuning mode (the "soft fault" LED should be flashing):

ENTER

Terminates the tuning process and reinstates the gains that were in effect before the tuning process began.

SAVE

Terminates the tuning process and saves the new gains in the EEPROM. The gains that were in effect before the tuning process began are lost.

UP

Increases the gain of the system. Makes the system respond faster to a commanded position change.

DOWN

Decreases the gain of the system. Makes the system respond slower to a commanded position change.

SAVE + DOWN

Return to the factory default settings. This function will reinstate the gains that were in effect when the unit was shipped from the factory.

ENTER + DOWN

Disables the amplifiers. This is equivalent to shutting down the motor/driver (like remote power shutdown on the step motor drives).

ENTER + UP

Enables the amplifiers. This is the opposite of ENTER +

UP. If an error condition exists or the remote power shutdown input on the indexer/driver interface is active this function will not work.

ENTER + SAVE + UP + DOWN
This is a software reset.

B.2 RS-232 Interface Commands

The tuning process described above for the front panel switches can be duplicated via the RS-232 communication port. In the interest of brevity the procedure is not repeated here but simply the description of the commands that may be issued via the RS-232 port to tune the motor/drive.

In order to tune the motor via the RS-232 port it is necessary to first enter the SETUP mode of operation. Initially the I-Drive should be in the normal operating mode of operation, or the BASE mode. If the prompt that appears on your terminal is an asterisk (*) the I-Drive is in the BASE mode. If an asterisk does not appear on the terminal try issuing a few carriage returns. If this does not work, something must be wrong!! It is possible that some RS-232 communication parameters on the terminal are set incorrectly. The I-Drive has only one setting for its RS-232 parameters -- 1200 baud, no parity and two stop bits.

Once in the BASE mode the I-Drive may be put in the SETUP mode so the tuning process may begin. This is done by issuing the two letter command ES (for Enter Setup mode) followed by a carriage return. A greater-than character should appear on the screen as your prompt (>) and the ERROR LED should begin to flash. The act of entering the SETUP mode is equivalent to depressing both front panel buttons simultaneously.

(Incidentally, when using either of the tuning processes, front panel or RS-232, you cannot use the other.) The commands available in the SETUP mode are single character commands and do not require a carriage return, they are acted upon immediately. The SETUP mode commands are summarized below.

U - Increases the gain of the system. Depressing the "U" key is equivalent to depressing the UP button on the front panel.

D - Decreases the gain of the system. Depressing the "D" key is equivalent to depressing the DOWN button on the front panel.

E - Enter the manual tuning process, initializes the controller's gains to some default starting values. This is equivalent to starting the tuning process via the ENTER + SAVE front panel switches.

S - Save the new gains. This is equivalent to depressing the SAVE switch on the front panel. The "S" key will cause the controller to save the gains as they are now adjusted and exit the tuning process, meaning the SETUP mode will be exited.

X - Exit the SETUP mode and return to the gains that were in effect before the entering the SETUP mode. This is equivalent to depressing the ENTER switch when we are in the process of tuning. Any changes that have been made to the controller's gains are forgotten and the gains in effect before the tuning process began are reinstated.

B.2.1 The Other RS-232 Commands

All other RS-232 commands are available in the BASE mode. The BASE mode is indicated by an asterisk prompt. If you are currently in the SETUP mode you can enter the BASE mode by issuing an "X" or "S" command (see the above command description).

All the commands which can be issued in the BASE mode are two letter commands. The controller will accept lower or upper case ASCII characters, it automatically converts all lower case characters to upper case when they are received. Spaces may be used in a command, since all spaces are ignored. All commands in BASE mode are terminated with a carriage return. To determine if you are in the BASE mode type several carriage returns and look at the prompts on the screen, they should be asterisks (*).

Many of the commands expect parameters. There are two types of parameters, numeric and boolean. A numeric parameter is an integer in the range of approximately minus two billion to plus two billion. Floating point numbers are not accepted (numbers with a decimal point). Boolean parameters are either an "ON" or an "OFF".

If you supply an invalid parameter to a command the command will not be performed and an error message will appear. Error messages are always preceded by two question marks (??).

Following are the commands available in the BASE mode or normal RS-232 mode of operation. They are listed in alphabetical order. Any changes made to parameters using these commands are NOT permanent. To make a change permanent the SAVE command (SV) must be issued. The SAVE command will save all changes that have been made into the EEPROM. Thus, if changes are made with these commands and then the machine is reset the changes are lost unless the SAVE command was issued before resetting the machine. (Issuing the "S" command in the SETUP mode is equivalent to issuing a SAVE command in the BASE mode.)

AC - Average Current definition/report.
Numeric parameter expected.
Range: 0 to 9500 mA
If no parameter is supplied "AC" will report the currently defined maximum allowed average current, in milliamps. If a parameter is supplied that number will be used as the new maximum average current. The controller continuously computes an average current command issued to the amplifiers. If the average current command exceeds the value defined by the "AC" command the controller will disable the amplifiers and indicate an error. The factory default setting is 9000 mA.

CF - Define/report the desired Crossover Frequency.
Numeric parameter expected.
Range: 1 to 200 Hz
This command allows one to change the crossover frequency which is used for defining the default controller gains when performing system tuning. If no parameters are supplied the desired crossover frequency (in Hertz) currently in use will be displayed. The crossover frequency is very close to the bandwidth of the system. When the system is shipped a default crossover frequency of 35 Hz has already been entered and saved into the system. This command should be followed by an LD command.

CL - Current Limit definition/report.
Numeric parameter expected.
Range: 0 to 18,000 mA.
If no parameter is supplied the "CL" command will report the current definition of the maximum current, in milliamps. If a number is supplied, that number becomes the new maximum current. The maximum current is the absolute maximum current command that will be issued to the amplifiers, it is not the maximum average current command but the maximum transient current. It is the upper limit of how large the current command can ever be. A default value of 18,000 mA is set at the factory.

DB - DeadBand definition/report.
Numeric parameter expected.
Range: 0 to 32767
If no parameter is supplied "DB" will report the current value of the deadband, in motor steps. If a number is supplied that number becomes the new deadband. The slip fault line to the indexer is used to indicate when the absolute value of the following error is within the deadband region. It has no effect on the controller (the "position maintainer"). The slip fault line to the indexer will be on to indicate that the following error exceeds the deadband and off to indicate that the absolute value of the following error is within the deadband. (The slip fault line is active high). The default factory setting is zero.

DE - Drive Enable Input activation/report
Boolean parameter expected.
Range: On or Off
If no parameter is given, the Drive Enable Input status is reported. If ON is specified, the Drive Enable Input becomes active, requiring 7 to 60 mA to enable the drive. If OFF is specified, the Drive Enable Input is ignored and may be left with no connection. The I-drive is shipped from the factor with the Drive Enable Input not active.

ES - Enter the SETUP mode.
No parameter expected.
This command allows the SETUP mode to be entered, which was described in preceding sections. The SETUP mode is used as an alternative to the front panel switches for tuning the servo system. To exit the setup mode type an "X" character. The setup mode is indicated by a ">" prompt.

FE - Define/report the maximum Following Error.
Numeric parameter expected
Range: 0 to 32767 Steps
If no parameter is supplied the maximum following error is displayed, in motor steps. Exceeding the maximum following error is an error condition that will cause the amplifier to be shutdown. If the maximum following error is defined as zero the "shutdown motor on following error exceeded" function is disabled and no amount of following error will generate an error condition or shutdown the motor. A 4096 step maximum following error is defined when the motor is shipped as an R5 (4096 steps per revolution). A 16,384 step maximum is defined when the motor is shipped as an R8 (16,384 steps per revolution).

LD - Load Specification/report
Numeric parameter expected
Range: 1 to 65,535
If no parameter is supplied, the estimated load is displayed in oz.-in.^{2}. If a parameter is supplied, this command causes the controller to calculate gains for a system with the specified load. These new gains are not saved unless the SAVE command is issued. The factory default setting for the I610 motor is 67 oz.-in.^{2}, and for the I620 it's 134 oz.-in.^{2}.

MS - Motor Shutdown toggle/report.
Boolean parameter expected.
Range: On or Off
If no parameter is supplied the shutdown state of the motor is reported. "ON" will shutdown the motor and "OFF" will turn the shutdown off (or "unshutdown" the motor).

PM - Define/report the desired Phase Margin.
Numeric parameter expected.
Range: 0 to 70 Degrees.
If no parameter is supplied the desired phase margin currently defined is displayed in degrees. When the phase margin is redefined the microprocessor calculates new gains based on this new desired phase margin. The new gains may be modified by entering the setup mode. These new gains are not saved unless the SV command is issued. The default factory setting is 55 Degrees. This command should be followed by an LD command.

RE - Report any Error conditions.
No parameters expected.
If an error condition exists, such as excessive following error or an EEPROM failure, it will be reported. Errors are "soft errors" that are indicated with the "soft error" LED. To clear an error one must reset the machine.

RF - Return to Factory settings.
No parameters expected.
This command causes the controller to calculate gains for a system that has a load of one-half the rotor inertia attached to the motor. These new gains are not saved unless the SAVE command is issued. Issuing this command is equivalent to issuing the "LD" command with an estimated load equal to one-half the rotor inertia.

RS - ReSet the driver system.
No parameters expected.
This command implements a software reset of the system. It is equivalent to depressing all four of the front panel switches simultaneously. A software reset is not identical to a hardware reset, it is as close as is

possible. There is a button on the edge of the front control board available to perform a true hardware reset of the controller board. Any changes that have not been saved before issuing this command will be lost. It is a good idea to issue this command after changes have been made and saved.

RV - Software ReVision level reported.
No parameters expected.
This command is for determining the software revision level of the controller software. It will report the part number that is written on the label of the controller's EPROMs. Using this command means it is not necessary to open the I-Drive amplifier's box in order to determine the revision level of the software!

SC - Stream report the average Current.

SE - Stream report the Error in position.
No parameters expected.
Each of these commands results in the controller continuously reporting the appropriate parameter to the display. When any of these commands is issued no other command may be issued until the stream report is terminated. To terminate a stream report send a space character (hit the space bar) to the controller. The position is reported in motor steps and the current is reported in milliamps.

SV - SaVe all EEPROM or permanent variables.
No parameters expected.
Issuing this command results in permanent saving of all EEPROM variables. All previous EEPROM variables are lost. After a SAVE is performed the controller will use these new variables whenever it is turned on or reset. This allows you to customize the system to your specific application without the necessity of custom software.

B.3 Tuning the I-Drive with Base Mode Commands

The preceding sections described an empirical method of tuning the I-drive by changing the system gain. The base mode commands provide a quantitative method of tuning which may include parameters other than gain. The LD command causes the I-drive to calculate the optimum servo parameters (gain, pole, and zero) based on the user specified system pararmeters; phase margin (PM), crossover frequency (CF), and load (LD). The gain calculated by the LD command is the same servo parameter altered by the setup mode tuning, so using one tuning method will undo the results of the other.

Phase margin is essentially a measure of the desired stability of the system. Increasing the phase margin will tend to damp out end-of-move oscillations and snappy response, much the same as adding damping to the physical load would. If too much phase margin is added, the frequency response of the system is decreased and the system takes longer to settle.

Crossover frequency is literally the frequency at which the system gain is unity. Practically speaking, it is a measure of frequency response, because frequency response goes up and down with crossover frequency. The number specified in the CF command is the desired crossover frequency, which may or may not be attainable with the specified load and phase margin. The actual attainable crossover frequency will increase as the servo gain increases and decrease as the physical load increases.

Load is the inertia seen by the shaft of the motor, measured in $Oz.-In.^2$. This is not a measure of torque required, and is not a function of acceleration. The LD command takes the user specified load, phase margin, and desired crossover frequency and uses these parameters to calculate the optimum gain, pole and zero for the servo system assuming there is no friction and that the load is rigidly coupled to the shaft. If the resulting actual crossover frequency is less than the specified desired crossover frequency, system response may be slower than expected.

In systems which have significant friction or which have non-rigid coupling it may be necessary to use non-ideal tuning parameters. Some examples are given below:

B.3.1 Position Errors Due to Friction

Significant friction in the load may cause the end-of-move position to be unacceptably in error. Increasing the gain either with the setup commands or by specifing a larger value for the load may reduce the error. If increasing the gain causes the system to go unstable before the error is reduced, it may be possible to increase stability by increasing the phase margin. Remember the PM command must be followed by an LD command before the new phase margin takes effect. The LD command then establishes a value for gain.

B.3.2 Shaft and Coupling Vibration

If the load is coupled to the shaft through a non-rigid coupler, it is possible for the shaft and coupler to oscillate at a frequency greater than would be possible for the system as a whole. In this case it may be possible to set the desired crossover lower and/or the phase margin higher (followed by an LD command) to eliminate the oscillation.

B.3.3 Inadequate Response Time (Frequency Response)

Some systems may involve very little inertia, but need the torque for very high acceleration and/or to overcome friction. In this case, the factory default setting of 35 HZ for crossover frequency may unnecessarily limit the frequency response of the system. By giving a larger value for desired crossover frequency, it may be possible to increase the frequency response of the system. The CF command must be followed by an LD command for the I-drive to calculate the attainable crossover frequency.

NOTE: After the LD command is issued, giving the CF command with no parameter will report the actual attainable crossover frequency, automatically lowering the effective CF parameter if the specified value is too high. If the LD command is given again with a smaller load specification, the CF parameter will not be automatically increased. Thus it is best to re-specifiy the desired crossover frequency before giving a new LD command.

7. Motor Compatibility

The I-Drive is designed to be compatible with at least the following motor sizes:

Model number

I610
I620

For motors other than those listed above consult Compumotor for information regarding available options.

8. Line Power Considerations

The 120 VAC input to the I-Drive is not isolated by a transformer. To provide isolation or to step down from a 480 or 240 VAC supply, power to the I-Drive should be routed through an isolation transformer with a power rating of 2500 VA.

An isolation transformer with line filtering capabilities will also insulate sensitive equipment on the same power line from the noise induced in the power line by the switchmode amplifiers in the I-Drive.