SECTION I - INTRODUCTION

1.1 **Purpose**

This manual describes the function and operation of the Electro-Craft PRO-450 and the PRO-450B Programmable Motion Controller. The PRO-450B is functionally equivalent to the PRO-450 except that the sense of the inputs and outputs are reversed. It is intended for engineers or technicians directly involved in the installation, operation, and maintenance of the PRO-450 series products. Throughout this manual, as a convention, the term "PRO-450" wil refer to both the PRO-450 and the PRO-450B except where noted.

1.2 **Introduction**

The PRO-450 is a programmable motion controller designed for factory automation tasks. Motion programs may be created and stored in non-volatile battery-backed RAM.

Many serial RS-232C or RS-422 devices may be used to program the PRO-450, including virtually any ASCII terminal, personal computer, or host computer system with a serial RS-232C or RS-422 interface. The Electro-Craft Operator Station may be used as an operator interface for displaying messages, entering variables or running programs.

PRO-450 motion program statements include absolute position moves, incremental distance moves, relative distance moves referenced to master position, variable operations, simple math on variables, scanning inputs in order to record the position, programmable master gear ratio, programmable discrete outputs, programmable time dwells, repeat loops, and conditional program branching based on the state of discrete inputs or variables. Using the auxiliary encoder interface and the programmable electronic gearing feature of the PRO-450, Master-Slave operation and distance moves relative to a master axis are feasible.

Motion profiles may be specified with minimal programming. After entering traverse velocity and acceleration values, you specify the distance or end point desired, and the controller will automatically form trapezoidal or triangular motion profiles as needed. Variable moves are also provided. The distance variable can be entered from the Operator Station, or can be calculated within the program. Complex motion profiles (non-symmetric profiles) may be executed also--you specify the distance and velocity for a move segment and the PRO-450 will calculate the correct acceleration/deceleration necessary to attain the velocity in the specified distance.

Up to 15 separate motion programs may be stored in the PRO-450. A program may be selected and executed through either external inputs or through commands from the serial link. A special program called "AUTO" is also provided to display messages upon power up. Motion and output commands are not allowed in the AUTO program because unwanted motion could result in case of sudden power failure.

One useful feature of the PRO-450 is that distance may be defined in convenient units. It is not necessary to convert from commonly used units (such as inches, centimeters, etc.) to encoder counts before entering data. Instead, you define 1 user unit as a certain number of encoder counts (see SCale, Section 5.3.3), and enter all subsequent data in the defined units. Then, distance, speed, and acceleration values can be entered in familiar units, such as inches for distance, inches per minute for speed, and inches per second per second for acceleration.

1.3 **Recommended Reference Material**

The handbook listed below is a useful reference source and may be ordered from Reliance Motion Control.

DC Motors, Speed Controls, Servo Systems, an engineering handbook, Electro-Craft Corporation, 5th edition, 1980.

1.4 **Functional Description**

The PRO-450 is designed to operate with servo amplifiers which require a velocity reference or a torque reference input. Velocity mode servo amplifiers regulate the motor speed to match the velocity command signal (VCS) sent from the PRO-450, while torque mode servo amplifiers regulate the motor torque to match the VCS (refer to Figure 1-1). Velocity mode amplifiers provide the advantage of good stability for high bandwidth operation and higher performance capability. Some applications do not require the high performance of the velocity controlled servo amplifiers and there may be a cost advantage to using the torque mode amplifiers. The damping term KD is included in the PRO-450 to provide the damping which is necessary when interfacing to the torque mode servo amplifier, since there is no tachometer. Note that the Electro-Craft brushless servo amplifiers, such as the BRU-200 and BRU500, derive the velocity feedback from the encoder and can operate in torque or velocity modes without a tachometer. As a result, there is no advantage in using the BRU-200 or the BRU-500 amplifiers in torque mode with the PRO-450.

The PRO-450 develops a position command two ways:

1 From motion profile statements (the motion profile is determined by the parameters in the parameter table or from the program itself);

2 From external quadrature A and B signals from the auxiliary incremental encoder which can be enabled or disabled in the program.

The position regulator used enables the PRO-450 to determine the VCS necessary to cause the servo system to follow the commanded motion profile. The PRO-450 uses a PID control algorithm with velocity feedforward compensation. This regulator produces the velocity command (or torque command for servo amplifiers which operate with a torque command input) by summing the proportional, integral, damping, and feedforward components as shown in Figure 1-2. The proportional term KP and the integral gain KI are multiplied by the position error (difference between position command and position feedback) and the integral of position error respectively. The damping term KD is multiplied by velocity feedback, and the feedforward term KFF is multiplied by the velocity command. The intended use for KD is to provide damping for use with torque mode servo amplifiers, but it may also provide some damping benefit with velocity mode servo amplifiers.

Velocity Controlled Servo System

Torque Controlled Servo System

Figure 1-1 Two Types of Servo Amplifier Systems

Introduction

The VCS command is formed according to the following equation:

VCS = ((KP + KI/S) x (PCMD - POS1)) - (KD x (FB Vel))
+ (S x KFF x PCMD) + Offset

where:

KP -	Proportional Gain
KD -	Damping Gain
KFF -	Velocity Feedforward Gain
KI -	Integral Gain
PCMD -	Commanded position
FF Cmd -	Velocity feedforward command computed from change in PCMD
POS1 -	Position feedback developed from encoder
FB Vel -	Velocity feedback computed from change in POS1
Offset -	Offset compensation computed when Auto Offset is enabled
S -	Laplace operator

Figure 1-2 Functional Diagram of the PRO-450

Static position errors are caused by offset voltage in the PRO-450 digital-to-analog converter which converts the digital output from the position regulator into the velocity (or torque) reference signal which is sent to the servo amplifier. Errors are also caused by offset voltage in the servo amplifier. The effect of offset voltage is a static position error which can cause unnecessary delays in the profile or stop motion due to the position error being larger than the programmed 'in-position' window. An automatic offset removal algorithm has been incorporated to eliminate the effect of these offsets.

Other features provided include programmable 'in-position' window, following error limit, following error time, and jog speed.

SECTION II - SPECIFICATIONS

2.1 Performance Specifications

Encoder input frequency (Encoder A to B phasing 90 ± 22.5 degrees)	250 kHz maximum
Velocity command update 2.2	2.0 millisecond

Electrical Specifications

VCS output (into minimum 2K ohm load)	± 10 volt DC
Encoder power	250 mA Maximum 5 VDC
Encoder input levels	TTL levels (differential)
Amplifier inhibit	<15 mA
Amplifier SSO current 2.3	10-15 mA

Input Power Requirements

Chassis supply (single phase AC volts RMS) (Stand Alone units only)	115/230 VAC (± 15%) 0.3A/0.15A 50/60 Hz

2.4 Physical Specifications Stand Alone Configuration

Depth		7.5 in.(191 mm)
Width		3.0 in.(77 mm)
Height		15 in. (381 mm)
Weight (shipping)		9 lbs. 11 oz. (4.4 kg)
Kit Configuration		
Weight (shipping)		2 lbs. (0.9 kg)
Ambient Temperature	- Operating	32° to 122°F (0° to 50°C)
	- Storage/Shipping	-40° to 158°F (-40° to 70°C)
Relative Humidity		5% to 95% non-condensing

2.5 PRO-450 Outline and Mounting Dimensions

Drawing 9097-1016 in Section IX shows the outline and mounting dimensions of the PRO-450 (Stand Alone Configuration).

SECTION III - INSTALLATION

3.1 General Information

All wiring and mounting instructions described in this section should be made with reference to the PRO450 hardware drawings 9097-1016 and 9097-1017 in Section IX.

3.2 Mounting

If the PRO-450 stand alone configuration is being used, it should be mounted vertically, away from other heat-producing devices. For instance, if it is to be mounted in the same enclosure as the servo amplifiers, the PRO-450 should be mounted below the servo amplifiers to avoid the heat generated by them. If using the PRO-450 Kit, see drawing 9101-0143, 9101-1062 or 9106-0011 in Section IX for mounting instructions for use with the BRU- and BSA-Series amplifiers.

The PRO-450 is designed to operate in an environment that is clean and free of oil mist, coolant mist, conductive particles, and corrosive chemicals. For industrial applications, a Nema 12 or equivalent enclosure is recommended. The enclosure must be properly sized, and ventilated if necessary, to insure that the PRO-450's maximum ambient temperature specification is not exceeded.

3.3 AC Input to Chassis

A three position screw-terminal block is provided for connection to AC power. A jumper is provided on the power supply module (see drawing 9097-1017) to configure the power supply for 115 VAC or 230 VAC power input. In addition, the fusing of the AC input can be changed to provide maximum safety for different power configurations around the world.

3.3.1 115 VAC Power Connection

When shipped, the PRO-450 is configured for 115 VAC power. The screw-terminal block is marked L, N, and G. This stands for LINE, NEUTRAL, and GROUND. For safety reasons, the LINE terminal must be hooked up to the 'hot' side of the line, the NEUTRAL terminal must be hooked to the neutral power connection, and a separate safety ground must be connected to the GROUND terminal. The GROUND terminal is internally connected to the chassis of the PRO-450.

In the 115 VAC configuration, jumper W1 is installed, fuse F2 is installed, and Fuse F3 is not installed. The AC input voltage selector must be in the position marked 115 VAC.

3.3.2 230 VAC Power Connection (U.S.A.)

In the U.S.A., 230 VAC is usually provided by two 'hot' lines, with a Neutral. Thus, 115 VAC may be taken from either of the 'hot' lines to neutral, or 230 VAC may be taken across both the 'hot' lines, with the neutral providing a safety ground to be connected to the chassis. In this case, the following three steps must be followed:

1. L1 must be connected to the screw terminal marked L, L2 must be connected to the screw terminal marked N, and neutral must be connected to the screw terminal marked G.

2. **IN THIS CONFIGURATION, THE FUSING MUST ALSO BE CHANGED FOR SAFETY.** The change involves removing the jumper marked W1 on the power supply board (see drawing 90971017) and installing fuses F2 and F3.

3. The AC input voltage selector on the power supply must be changed to the position marked 220 VAC.

3.3.3 220 VAC Power Connection (European)

The 220 VAC power in Europe is different from that in the U.S.A. Instead of providing two separate 'hot' lines and a neutral, there is a 'hot', a neutral, and a safety ground. In this case, the following three steps must be performed:

1. The 'hot' line must be connected to the screw terminal marked L. The neutral connection must be wired to the screw terminal marked N. The safety ground must be wired to the screw terminal marked G.

2. The AC input voltage selector on the power supply must be changed to the position marked 220 VAC.

3. Fuse F2 must be changed to the value shown in drawing 9097-1017. Jumper W1 must remain installed and no fuse is installed in F3.

CAUTION:

Normally, the PRO-450 is shipped wired and fused for 115 VAC operation. It is the user's responsibility to determine the type and voltage of AC wiring and configure the jumpers and fusing as described above to fit other applications for maximum safety.

SECTION IV - INTERFACE CIRCUITRY

4.1 **Servo Interface**

All servo interface signals are connected through connector P6 and P8. Refer to drawing 9097-1067 for connection details.

4.1.1 VCS

The VCS (Velocity Command Signal) ranges from +10 to -10 volts DC. The load should exceed 2K ohms DC impedance. A separate VCS return is provided to reduce noise in those systems which accept the VCS signal differentially. 4.1.2 Amplifier INHIBIT

There are 2 lines associated with the inhibit signal, INHIBIT+, and INHIBIT-.

These outputs are the uncommitted collector and emitter of an opto-isolator transistor (refer to Figure 41). Both are provided to allow connection to amplifiers with either high or low true inhibit signals. The transistor is turned ON to enable the servo amplifier and OFF to disable the amplifier.

To provide the correct sense to an amplifier with a high true inhibit (the INHIBIT+ line must go LOW to enable the amplifier), the INHIBIT- line from the PRO-450 is connected to the amplifier's common connection, and the INHIBIT+ line is connected to the INHIBIT line on the amplifier. When the PRO-450 turns the transistor ON, the INHIBIT line to the amplifier is pulled low, and the amplifier is enabled.

Figure 4-1 Amplifier INHIBIT Connection

To provide the correct sense to an amplifier with a low true inhibit (the INHIBIT+ line must go HIGH to enable the amplifier), the INHIBIT+ line from the PRO-450 is connected to a positive supply connection from the amplifier (usually +15 VDC), and the INHIBIT- line from the PRO-450 is connected to the INHIBIT line of the amplifier. When the PRO-450 turns the transistor ON, the INHIBIT line to the amplifier is pulled to the positive supply, and the amplifier is enabled.

This output will withstand up to 48 volts DC when OFF, and will sink up to 15 mA with no more than 1 volt drop across the transistor when ON.

NOTE: When used with an Electro-Craft BRU- or BSA-Series amplifier, the INHIBIT lines do NOT have to be connected on the PRO-450 P6 connector as the lines are already connected through the P8 connector.

4.1.3 Amplifier SSO

An SSO (System Status Output) signal from the servo amplifier is monitored by the PRO-450. Two connections are associated with this signal, SSO+ and SSO-. These connections are the uncommitted emitter diode of an opto-isolator with enough series resistance to work with 15 volts DC (refer to Figure 4-2). Higher voltages may be accommodated by adding additional series resistance external to the controller. Both SSO lines are provided to accommodate servo amplifiers with high or low true SSO outputs.

For amplifiers with high true SSO outputs (SSO on the amplifier goes HIGH to indicate that the amplifier is functioning), the SSO- line from the PRO-450 should be connected to the amplifier common connection, and the SSO+ line from the PRO-450 should be connected to the amplifier's SSO connection. The amplifier's SSO line must be capable of sourcing 10 mA at no less than 10 volts when true.

For amplifiers with low true SSO outputs (SSO on the amplifier goes LOW to indicate that the amplifier is functioning), the SSO+ line from the PRO-450 should be connected to a positive supply on the amplifier (typically +15 VDC), and the SSO- line from the PRO-450 should be connected to the amplifier's SSO output. The amplifier's SSO line must be capable of sinking 10 mA at no more than 5 VDC drop when true.

NOTE: When used with an Electro-Craft BRU- or BSA-Series amplifier the SSO lines do NOT have to be connected on the PRO-450 P6 connector as the lines are already connected through the P8 connector.

The SSO signal should be driven by the servo amplifier at approximately 10 mA to indicate that the amplifier is ready and functional. This signal should become open-circuited to indicate a power-off or fault condition in the amplifier.

NOTE: The SSO signal is sampled by the PRO-450 and must be true (current flowing through the opto-isolator diode) before the PRO-450 will enable the amplifier. If the amplifier used with this controller must be enabled to return SSO true, the amplifier will *never* be enabled.

Figure 4-2 Amplifier SSO Connection

4.1.4 Servo Signal Shielding

A separate pin (pin 1) is provided on connector P6 for a shield connection. The signal wires to the amplifier should be shielded with the shield connected at the PRO-450 end. In some cases you may find it necessary to connect the shield at the amplifier end also. **THE SHIELD SHOULD NOT BE CONNECTED TO VCS RETURN.**

4.2 **Encoder Interface**

All encoder interface signals are connected through connector P4 and P8 (for the feedback encoder), and P5 (for the auxiliary encoder). Refer to drawing 9097-1067 for connection details.

4.2.1 Encoder Power

The PRO-450 can provide power for the encoder: 5 volts DC at no more than 250 mA current. (If the PRO-450 is being used with a BRU-200, BRU-500, or BSA-Series amplifier, the amplifier provides power to the encoder.)

4.2.2 Encoder Signals

The PRO-450 accepts standard quadrature signals from two incremental encoders driven differentially. The encoder must provide two lines for each signal (that is, A+ and A-) with one being the complement of the other.

The PRO-450 accepts A, B, and I (Index) signals from the feedback encoder, and A and B signals from the auxiliary encoder with A leading B for clockwise rotation (facing the motor drive shaft) with a positive VCS output (refer to Figure 4-3). Connections are provided for A+, A-, B+, B-, I+, and I-.

The PRO-450 will accept encoder inputs up to a maximum frequency of 250 kHz on a single channel (A or B) for encoders with phase error of less than or equal to 22.5 degrees (refer to Figure 4-3). Encoder counts are always at X4 encoder frequency internal to the PRO-450 (that is, one encoder line equals 4 encoder counts). Thus, a 2,000 line count encoder will provide 8,000 counts per revolution of the encoder.

Figure 4-3 A and B Encoder Signals

4.2.3 Encoder Index Signal

The encoder index signal (I) is conditioned by circuitry on the PRO-450 to guarantee a unique and repeatable position for home. The index level must be high (I+ high and I- low) when the A signal is high (A+ high and A- low) for the index to be recognized (refer to Figure 4-4).

If the encoder has an index signal inverted from the above definition, it may still be used with the PRO450 by swapping the I+ and I- signal lines.

If the encoder to be used with the PRO-450 has an index level with the correct sense but is active only when the A channel signal is low (a non-standard encoder, but one that is made by some manufacturers), this encoder may be used by swapping **both** the A+ and A- with each other **and** the B+ and B- signals with each other. This will allow correct sensing of the index signal **without** changing the sense of direction from the encoder lines. You should determine the sense of the index signal from the encoder and connect the encoder signals accordingly.

Figure 4-4 Index Signal Relationship to the A Channel

4.2.4 Encoder Signal Shielding

The encoder signal wires to the PRO-450 should be shielded with the shield connected only at the encoder end. However, in some applications it may be necessary to connect the shield at the PRO-450 end of the cable. A separate pin on connector P4 (pin 3) is included for this purpose (refer to Drawing 9097-1067).

4.2.5 Encoder Input/Output

The PRO-450 may be configured to act as a master encoder source or as a slave following a master encoder signal. When the PRO-450 is configured as a master, the feedback encoder signals are directed OUT the auxiliary encoder connector P3. To configure the PRO-450 as a master, install jumpers W8-W11 in the non-banded position (see drawing 9097-1066). When the PRO-450 is configured as a slave, the encoder signals come IN on auxiliary encoder connector P3. The PRO-450 will then follow the encoder signals coming in on P3 if the GEAR statement is used in a program. To configure the PRO-450 as a slave, install jumpers W8-W11 in the banded position (see drawing 90971066).

4.3 **User Interface**

There are sixteen digital inputs available on the PRO-450. The inputs are provided to control positioning manually or allow synchronization and monitoring of the application hardware external to the PRO-450.

Twelve of the digital inputs can be used as dedicated functions or used as general purpose inputs (see Optional Parameters, Section 5.4.3.1). The remaining four inputs, Estop, Start, Home Switch, and Home Command are dedicated and cannot be used for other purposes. (Note: The Home Switch may be used as a high speed input to capture master or feedback position - see Home Switch, Section 4.3.9 and Latched Distance Variables, Section 5.4.5)

The inputs on the PRO-450 require a closure to ground whereas the inputs on the PRO-450B require a closure to 24 volts.

The outputs are current sinking on the PRO-450 and current sourcing on the PRO-450B.

All of the digital signals are optically isolated in the PRO-450 and require a separate supply voltage (NOT common to the logic supplies for the PRO-450). The PRO-450 has a 24 VDC power supply for this purpose, with screw terminals for easy connections. For PRO-450 applications using the stand-alone configuration, a 24 VDC, 500 mA supply is provided. If more 24V supply current is required, an external 24 VDC power supply can be connected (refer to drawing 9097-1066), when wire jumpers W3 and W4 are removed. All user control and machine status inputs are connected to P1, P2, or P3 on the PRO450. See drawing 9097-1087 for the PRO-450 and drawing 9097-1129 for the PRO-450B connection details.

4.3.1 Jog Forward

When activated (switch closed), the Jog Forward (I08) input causes the PRO-450 to slowly ramp up to Jog velocity in a forward direction. Motion will continue at Jog velocity until deactivated (switch opened), at which point the PRO-450 will rapidly ramp down to a stop. **NOTE**: If Advance is enabled, the Jog inputs are used for the Advance/Return function while a program is running. However, if no program is running, the Jog inputs will still work (if Jog enabled) even if the Advance parameter is enabled. If either the Advance/Return or the Jog functions are not used, both jog inputs may be disabled and used as general purpose inputs (see Jog and Advance, Section 5.4.3.1).

4.3.2 Jog Reverse

When activated (switch closed), the Jog Reverse input (I07) causes the PRO-450 to slowly ramp up to Jog velocity in a reverse direction. Motion will continue at Jog velocity until deactivated (switch opened), at which point the PRO-450 will rapidly ramp down to a stop. **NOTE**: If Advance is enabled, the Jog inputs are used for the Advance/Return function while a program is running. However, if no program is running, the Jog inputs will still work (if Jog enabled) even if the Advance parameter is enabled. If either the Advance/Return or the Jog functions are not used, both jog inputs may be disabled and used as general purpose inputs (see Jog and Advance, Section 5.4.3.1).

4.3.3 Advance

The Advance parameter may be set to either I07 (same as Jog Reverse) or I08 (same as Jog Forward). If Advance is set to I07, the Return input is set to I08 and vice-versa. The Advance input is used along with the Return input (see below) to manually control a motion profile. Advance must be true (and Return false) for a program to advance through a motion profile. The Advance input may also be used as a general purpose input by disabling the Advance and the Jog parameters. See Advance, Section 5.4.3.1.

4.3.4 Return

The Return input will be set to I07 or I08 depending on the Advance parameter setting. If Advance is set to I08, then the Return input is set to I07 and vice-versa. The Return input is used along with the Advance input (see above) to manually control a motion profile. Return must be true (and Advance false)

for a program to return back through a motion profile. The Return input may also be used as a general purpose input by disabling the Advance and the Jog parameters. See Advance, Section 5.4.3.1.

4.3.5 Estop (Emergency Stop)

The Estop input (I03) is connected to a normally closed switch. When activated (switch opened), the PRO-450 applies a zero volt VCS to the amplifier for about 100 milliseconds which generates an immediate deceleration to stop, and then disables the amplifier. The error output (O8) is activated (if the Error and Estop error parameters are enabled). This is an emergency stop condition, and the PRO-450 will not control position while this switch is activated (switch opened), however, the position is maintained internally. In addition, this switch may be used to clear any error conditions detected by the PRO-450 during operation (see Section 4.4.3). **NOTE**: Activating Estop will not change any of the outputs (except IN-position). If any other outputs are left on when Estop is used to halt program execution, the outputs can only be turned off by cycling power, running a program that specifically turns off outputs, or by clearing outputs in Diagnostic mode.

4.3.6 Start

The Start input (I04) switch must be momentarily activated (switch closed) to start the execution of a program. The input is edge-triggered (the switch does not have to be a momentary type, however, the input must change state to be recognized). A program may also be started using the Run command from the serial terminal (see Run, Section 5.4.1).

The program number to be executed is based on the Default Run Program parameter value (0-15). If the Default Run Program parameter is 0 (zero), the external switch inputs I13 through I16 are used to select the program to be executed. (Section 4.3.15 describes inputs I13 through I16 in more detail.) If the parameter value is non-zero (1-15), then the program number to be executed will be the Default Run Program number.

4.3.7 Forward Limit

The Forward Limit input (I01) is connected to a normally closed limit switch at the end of forward travel. When the switch is activated (switch opened), the controller immediately sets the VCS output to 0 volts, delays about 100 milliseconds to allow the amplifier to stop the motor, then disables the amplifier. To move off the limit, the PRO-450 will accept ONLY a JOG reverse command, MOVV in the reverse direction command, or Home command. **NOTE:** Both limit switch inputs may be used as general purpose inputs if disabled (see Limit, Section 5.4.3.1).

4.3.8 Reverse Limit

The Reverse Limit input (I02) is connected to a normally closed limit switch at the end of reverse travel. When the switch is activated (switch opened), the controller immediately sets the VCS output to 0 volts, delays about 100 milliseconds to allow the amplifier to stop the motor, then disables the amplifier. To move off the limit, the PRO-450 will accept ONLY a JOG forward command, MOVV in the forward direction command, or Home command. **NOTE:** Both limit switch inputs may be used as general purpose inputs if disabled (see Limit, Section 5.4.3.1).

4.3.9 Home Switch (High Speed Input)

The Home Switch (I05) is used to identify the home position as defined in Section 4.3.10. The Home Switch input may be defined as either active closed or active open (see HomeSwitch, Section 5.4.3.1). It should be activated when the axis position is within one revolution from home position.

The Home Switch can also be used as a High Speed Input. Within 20 to 72 microseconds after a low to high transition on input I05 (closing the Home Switch), the motor position (POS1) and the master position (POS2) are latched and stored in the variables IP1 and IP2 respectively. (see also Latched Distance Variables, Section 5.4.5.1.)

4.3.10 Home Command

The Home Command input (I06) causes the PRO-450 to start the Home sequence. (The Home command in Execution mode will also start the Home sequence). When the Home command input goes active, the action taken depends on the present position relative to the position of the home switch (see Section 4.3.9) and the sign of the Home Velocity parameter (see Home Velocity, Section 5.4.3). Several possibilities exist; each is described in the following paragraphs:

NOTE: For clarity reasons, only the index pulse is used to describe the define home sequence below. If the Index parameter is off, then the Define Home input would be used instead of the index pulse to define home. In other words, home need not be tied to the encoder index (fixed with regard to the motor), but may be defined using an external switch or defined based on position. Only a positive Home Velocity direction is shown in each condition. (Rotation parameter is set to CW.)

If the home switch is inactive (present position not on the home switch), the system will move in the direction and at the velocity specified by the Home Velocity parameter (see Section 5.4.3). If a limit switch is found before the home switch, the system will reverse direction (see Figure 4-5). If a second limit switch is then found before the home switch, a 'Bad Home Switch' error message will be displayed (the home switch should lie between the two limit switches). When the home switch is found, the system continues moving through the switch until the home switch is no longer active. The system then reverses direction and moves at a slow speed until the home switch is found again. The first occurrence of the index pulse after the home switch is called HOME.

Figure 4-5 Start Position on Forward Limit side of Home Switch

If the home switch is found before a limit switch, the system will reverse direction until the home switch is no longer active (see Figure 4-6). The system then reverses direction and moves at a slow speed until the home switch is found again. The first occurrence of the index pulse after the home switch is then called HOME.

Figure 4-6 Start Position on Reverse Limit side of Home Switch

If the home switch is active when the command is received, the system will move in the direction opposite that specified in the home velocity parameter until the home switch is no longer active (see Figure 4-7). The system then reverses direction and moves at a slow speed until the home switch is again found. The first occurrence of the index pulse after the home switch is then called HOME.

Figure 4-7 Home Switch Active at Start Position

NOTE: This HOME strategy assumes that the limit switches are used. If there are no limit switches in the system, it must be ensured that the HOME switch is encountered before any fixed stops.

4.3.11 Pause

The Pause input (I09) is used to interrupt motion programs while they are being executed. Execution of a motion program continues only as long as the Pause input is inactive. If the Pause input is activated, the controller decelerates the system to stop, and maintains position. If the Pause input is then deactivated, the motion program resumes executing. If motion is resumed, the end point target will be the same as before the interruption. The Pause input must be enabled (active CLOSED or OPEN) in order to interrupt programs (see Pause, Section 5.4.3.1).

4.3.12 Ereturn (Emergency Return)

The Ereturn input (I10) is used to return the system to a 'safe' position when activated (switch closed) under emergency conditions. The Ereturn input overrides all other inputs except for Estop. The Ereturn position is user-definable and is selected with Emergency Return Position in the Parameter mode. It is active ONLY in Absolute mode. If not used, the Emergency Return input may be disabled (see EREturn, Section 5.4.3) and used as a general purpose input. **NOTE**: Activating Ereturn will not change any of the outputs--it only returns the system to the Ereturn position. If any other outputs are left on when Ereturn is used, the outputs can only be turned off by cycling power, running a program that specifically turns off outputs, or by clearing outputs in Diagnostic mode.

4.3.13 Define Home

The Define Home input (I11) can be used to define the current position as HOME. The input is 'edgetriggered' (transition from inactive to active to be recognized). No program can be running (exception is Index disabled, see below), the drive must be enabled (Estop must **not** be active, switch closed), and the Define Home parameter must be enabled for the Define Home input to be recognized. The operation of the Define Home input is also related to the status of the Index parameter. If the Index parameter is enabled, the Define Home input may be used any time the drive is enabled and no program is running to define home. If the Index parameter is disabled, however, the Define Home input will only be recognized to define home when the Home program is running and the Home switch input is active. When using the Define Home input with the Index parameter disabled, to home to a switch rather than the index the Home Switch and the Define Home input should be connected together.

4.3.14 Operator Interface switch

The Operator Interface switch input (I12) is used when the Electro-Craft standard Operator Station is connected, or as a security feature to limit access to programs or parameters if the full ASCII terminal is used. The Operator interface parameter must be enabled for I12 to be recognized as the Operator interface input. If the Operator Interface parameter is enabled, and the Operator Interface input is off, and if the full ASCII terminal is used, then the only commands available through the serial terminal are Offset, Status, or X (Killmotion). If the Electro-Craft standard Operator Station is used, the only commands available are Run, Offset, Status, and Input. Any other command will only result in the 'PRO>' prompt being displayed.

4.3.15 Program Selection Inputs

The PRO-450 provides two methods for selecting which program to run. The first method allows you to select the desired program through the serial terminal (see Run, Section 5.4.1) by entering '**RUN XX**', where XX is the program number. The second method uses the Start input. If the Default Run Program parameter is set to 0, the program number to be executed is based on the settings of inputs I13 to I16 when the Start input is activated.

Input I13 is the least significant bit and I16 the most significant bit of a 4 bit binary number that selects the proper number (1 to 15) motion program to execute. A value of 0 (all inputs off) is an illegal program number, and will result in no motion program being executed.

If the Default Run Program parameter is not set to 0, the program number to be executed when the Start input is activated will be the Default Run Program number. (Inputs I13 to I16 are ignored by the program selection routine, and may be used for inputs in a motion program just like any other uncommitted input on the PRO-450.)

If the Electro-Craft standard Operator Station is used, a program may be run using the 'F1' key. Press 'F1' and then the program number.

Note that the 8 position dip switch (SW1 on drawing 9097-1066) is connected in parallel with inputs I09I16. (I09 is connected to dip switch position 1 and so on.) All the dip switch positions should be set to off for normal operation. However, if the program number to be run will never change, dip switch positions 5-8 may be used to select programs, just as if inputs I13-I16 were being used. In this case, dip switch position 5 corresponds to input I13, position 6 to input I14 and so on. If the dip switch is being used to select programs, make sure that *only* positions 5-8 are used. If any of the other positions are accidently turned on and inputs I09-I12 are used as normal inputs, any programs reading these inputs may act incorrectly.

4.3.16 Operation Without Limit Switches

In the descriptions of the Forward and Reverse Limit inputs (see Sections 4.3.5 and 4.3.6) the limit switch inputs are described to be active open rather than closed. The inputs are defined this way in order to make limit switch operation as fail-safe as possible. If the switches fail open, or a connection breaks, the signals become active.

Provisions are also made for software overtravel limits when the Absolute Mode parameter is enabled (parameter ABS=ON). If only the software overtravel limits are used for protection, then the limit switch inputs may be disabled and used as general purpose inputs (see Limit, Section 5.4.3.1). The limit switch inputs can also be permanently enabled (if not used) by connecting the inputs directly to 24 volt common (P2-1) for the PRO-450 or to +24 VDC (P2-1) for the PRO-450B. (See drawing 9097-1087 for the PRO450 and drawing 9097-1129 for the PRO-450B for connection details.)

4.4 Status Outputs

Eight optically isolated digital outputs are available from the PRO-450 to monitor operation of the positioning system and synchronize external operations. These outputs are all capable of sinking 75 mA continuously (sourcing on the PRO-450B), driven to less than 1 volt. The outputs are available at connector P1 on the controller card. See drawing 9097-1087 for the PRO-450 and drawing 9097-1129 for the PRO-450B for connection details.

The outputs are opto-isolated, and require a separate supply. (The supply should NOT be common to the PRO-450 logic supplies.) A separate 24 VDC power supply is included in the PRO-450 for this purpose. The +24 VDC connection is provided on P1-12 (P2-1 for the PRO-450B) for connection to user interfaces. The supply is fused separately by fuse F4 on the power supply card (stand alone configuration only). If the PRO-450 is being used with a BRU-200, BRU-500, or BSA-Series amplifier, the 24 VDC supply is provided by the amplifier. The 24 VDC supply from the amplifier can supply about 500 mA; the supply for the stand alone configuration is good for about 400 mA. If more current is needed, an external supply may be used (see drawing 9097-1066 for details).

Three of the outputs (O6-O8) are configured as dedicated outputs: In-Position, Home Sequence Complete and Error. Two other outputs (O4 & O5) may be dedicated as well: ATHome (O5) and PGMrun (O4). However, any of the three dedicated outputs may be disabled in the Optional Parameter table and used as general purpose outputs. The other three outputs, O1-O3, are always available as general purpose outputs.

4.4.1 In-Position

The In-Position output signal (O7) becomes active when the motor position is within plus or minus the Window distance of the commanded position. The Window distance is specified in the Window parameter. The motor must be within the distance for the time specified in the WindowTime parameter (see Section 5.4.3 and 5.4.3.1). The In-Position output can be used to synchronize external processes that must activate only after the controller has reached the commanded distance. The In-Position output may be disabled and used as a general purpose output (see INPosn, Section 5.4.3.1).

4.4.2 Home Sequence Complete

The Home Sequence Complete output signal (O6) becomes active after the home sequence has been completed (see Sections 4.3.9 and 4.3.10), and the PRO-450 is 'In-Position'. It remains active as long as the position feedback is valid. The only error which will cause this signal to go false is an encoder error, which implies that the encoder position feedback is invalid. As long as the PRO-450 can verify correct feedback, absolute position is maintained. The Home Sequence Complete output may be disabled and used as a general purpose output (see homeSEQuencecomplete, Section 5.4.3.1).

4.4.3 Error

The Error output signal (O8) becomes active whenever the PRO-450 detects an error (if Error output parameter enabled -- see Error, Section 5.3.3.1) or when the Estop input is active (switch open) (if Estop error parameter enabled -- see Estop error, Section 5.3.3.1). The PRO-450 will not execute motion programs while this signal is activated. If an error occurs, the Estop input must be activated (switch opened), the source of the error condition removed, and the Estop input deactivated (switch closed) before the PRO-450 will execute motion programs. The RESet command may also be used to clear the error condition. The errors that activate this signal include:

1. Encoder Error - transitions on the A and B channels of the encoder were detected simultaneously, indicating a possible problem with the encoder feedback or one of the encoder signals is missing (possible broken wire).

2. SSO from drive false - the SSO line from the amplifier went false while the drive was enabled, indicating a problem with the amplifier.

3. Maximum Following Error - the following error has exceeded the Following Error Limit (programmed into the parameter table) for a period greater than the Following Error Time (also in the parameter table). This may be caused by a loss of encoder feedback, improper polarity in the connection from the PRO-450 to the servo drive, a commanded velocity or acceleration that exceeds system capabilities. It could also be caused by Following Error Limit or Following Error Time parameter values that are beyond system capabilities.

4. Watchdog Timeout - the watchdog timer is pulsed by the microprocessor every 2.0 milliseconds to ensure that the microprocessor is running properly. If the microprocessor fails to pulse the watchdog, a system reset will occur (as if the system had just been powered up except that the drive will be disabled).

5. Parameter Checksum Error - when parameters are entered or changed, a checksum is computed and stored. When powering up, the PRO-450 recalculates the checksum and compares it with the stored value. If they differ, the contents of the battery-backed RAM are assumed invalid. The most likely cause of this will be a power failure while entering new data. When a parameter checksum error occurs, the parameter table should be checked for invalid values.

6. Program Checksum Error - when programs are entered, or any changes are made to programs, a checksum is computed and stored. Upon power-up, and when returning to the Execution mode from other modes, the checksum is recalculated and compared to the stored checksum. If they differ, the PRO-450 will try to recover the bad program. If an illegal or invalid instruction is found, the PRO-450 will change the bad instruction to an 'END' statement and issue a warning message: 'ERROR found in program # XX'. No programs will be allowed to run until the offending program is edited or erased.

7. Program Execution Error = XX - an error was found while trying to execute a program. The error number 'XX' is described in Appendix F. The most likely cause of this error is a faulty batterybacked RAM or microprocessor. If the error occurs when trying to RUN a program, re-editing the program should eliminate the problem. If the error occurs without trying to RUN a program, the system should be shut down, then powered up again to clear the problem. If the error still occurs, the controller card should be replaced.

The Error output may be disabled and used as a general purpose output (see Error, Section 5.4.3.1). Note that some errors occur as a result of bad programming practices or improper use of program statements. (For example, using the OFfset instruction in a program with DV moves, but not including a constant velocity DV move following the OFfset instruction.)

4.4.4 Athome

The Athome output signal (O5) becomes active whenever the PRO-450 is at home (within the number of encoder counts set by the Window parameter of position 0). The Athome output parameter must be enabled, home sequence must be complete, and the PRO-450 must be in Absolute mode for the Athome output to operate. The default setting for the Athome output parameter is disabled (off) (see Athome, Section 5.3.3.1).

4.4.5 Pgmrun

The Pgmrun output signal (O4) becomes active whenever a program is running. The Pgmrun output can be used as a 'controller ready' to indicate when the PRO-450 is ready to accept a command that can be executed only when a program is not running. The Pgmrun output parameter must be enabled for the Pgmrun output to operate. The default setting for the Pgmrun output parameter is disabled (off) (see Pgmrun, Section 5.3.3.1).

4.5 **LED Status Indicator**

The green LED (light emitting diode) on the front of the PRO-450 (see drawing 9097-1066) indicates functional status of the PRO-450. (The LED is labeled 'Controller Ok' on the cover of the stand alone PRO-450.) When the PRO-450 is powered up, a comprehensive set of diagnostics is run to determine whether the electronics are fully functional. If any problems are found, the PRO-450 will NOT function, and the green LED on the front of the controller will not be lit. If the green LED is not on after a powerup, either the controller card or the power supply is not functioning properly and must be replaced.

SECTION V - OPERATION

5.1 Programming Terminal Requirements

Programming the PRO-450 requires an ASCII serial terminal. The PRO-450 is designed to be used with many kinds of programming terminals. The terminal used should have 8 lines (40 characters per line) for display. Among the devices tested and found to work with the PRO-450 are the Tandy 102, NEC PC8300 (using the built-in TELCOM software), DEC VT-52, and IBM PC (or compatible) running a variety of different communication software packages. (EC COMM, a communication software package is available from Electro-Craft.)

The serial characteristics should be set for no parity, 1 stop bit, and 8 bit characters (see Drawing 91010136). The terminal or communication software should be set up NOT to provide a line feed automatically with a carriage return. The PRO-450 can be used at several baud rates (default is 9600): 1200, 2400, 4800, 9600, or 19200 baud. Refer to Appendix A or C for getting started with the recommended serial terminal.

5.2 Operator Station

Any ASCII terminal may be used as an Operator Station by setting the Operator parameter to ON (the Operator parameter limits the operator access to the controller-see Operator Parameter, Section 5.4.3.1). The Electro-Craft Operator Station, however, is designed specifically for this purpose. To use the Electro-Craft Operator Station, the Operator parameter should be set to ON, and input I12 should be off (if I12 is on, the display still works, but the key pad is disabled). When any key is pressed, the controller identifies the Electro-Craft Operator Station and selects the compatible mode of operation. The Electro-Craft Operator Station features a bright 2 X 40 vacuum fluorescent display, and a 22 key input key pad. In addition to numeric keys, there are specific function keys (F1--F6, STATUS) for operating the controller. The function keys are defined as follows:

F1:"RUN" command function. To run a program from the Electro-Craft Operator Station, press [F1], [the program number], and the [ENTER] keys. While running a program, the F1 key (run command) is ignored.

F2:"Offset" command function. This function key is used to change the tool offset (see **O**ffset). To enter the tool offset simply press [F2]. Once the present offset value is displayed, type in a new offset value to change the old one.

F3:"Input" display function. Continuously displays the current condition of the inputs I01 to I16; 0 is displayed for OFF, 1 for ON (except Estop and the limit switch inputs which are wired opposite that of the other inputs--normally closed). To stop the display of the inputs, press either [ENTER] or [ESCAPE].

F4:"Peak Following Error" command function. Displays the Peak Following Error (the maximum error between commanded position and feedback position). The display is reset each time F4 is pressed. To exit the following error display, press [ENTER] or [ESCAPE].

F5 and **F6**: Reserved for future development.

STATUS:"Status display" command. If the [STATUS] key is pressed, the status is displayed two lines at a time. Following the display of the current status and current program instruction, the current position is displayed, and updated approximately every half second. To stop the display of the position, press [ENTER].

ESCAPE: Press ESCAPE to exit from current display mode (Peak Following Error, Status, etc.), or to erase an accidental entry. The ESCAPE command does not affect the execution of programs which are running.

5.3 **The Status Display Line**

If the character 'S' on a ASCII terminal or 'STATUS' key on the Electro-Craft standard Operator Station is pressed, a Status Display Line appears and is updated about every 0.5 second. The Status Display Line will show fault conditions or Emergency stop (Estop) status, or, if the drive is enabled and controlling position, it will display either controller position or Peak Following Error. (If using the Electro-Craft Operator Station, Peak Following Error may be monitored by pressing "F4".)

5.3.1 Display Messages

The messages that appear on the status display line and the situations that cause them to appear are:

Par Chksum Error

When power was applied to the controller, the checksum calculated from the parameter table (stored in battery-backed RAM on the controller) did not agree with the checksum stored in RAM. The parameter table is assumed to be corrupt. All parameters should be checked to determine if the values have changed. The most likely cause of this fault is installation of a new battery-backed RAM or removal of power from the controller after making changes to the parameter table, but before exiting the Parameter mode. To correct this error, the Parameter mode must be entered. Upon entry to the Parameter mode, the PRO-450 will select the Auto mode of parameter entry (see Section 5.4.3). To provide a relatively fast mode of restoring parameters to known good values, you may quit Auto mode at any time by pressing 'Q', then load parameters from a file saved earlier. After pressing 'Q', if any parameters are out of range, a message will be displayed to that effect. Ignore the message(s) and type 'LOAD', then follow the screen prompts to load the parameter file. After the file is loaded, press 'Q' to exit the parameter mode. If there are no parameters out of range, the PRO-450 will return to Execution mode ('PRO>' prompt) after 'Q' is pressed.

When power was applied to the controller, the checksum calculated for the motion programs, stored in battery-backed RAM, did not agree with the checksum stored in RAM. The PRO-450 will try to recover the program that is at fault. If an invalid instruction is found in a program, it is converted to an 'END' statement--the balance of the program is lost. No programs will be allowed to run until the offending program is edited. The parameter table will still be intact. The most likely cause of this failure is removing power to the PRO-450 after making changes to the motion programs, but before exiting the Program Edit mode. Edit any program to re-calculate the program checksum and cancel this error message.

Program Is Blank

This message is displayed when trying to RUN a blank (non-existent) program.

Home sequence NOT complete

This message is displayed when trying to RUN a program in Absolute mode when the home sequence is not complete.

NOT in position

This message is displayed when trying to RUN, JOG, or HOME when not in position.

No program selected

This message is displayed when trying to RUN from the external switches when the switches are set to zero.

Encoder Err

Simultaneous transitions on both the A and B lines of the encoder providing position feedback were detected or one of the encoder signals is missing (possible broken wire). Encoder feedback is assumed to be invalid, and, if the controller is in Absolute mode, the machine must be re-homed before any motion programs may be run. Probable causes of this error are improperly shielded cables or an excessive encoder input frequency resulting from excessive motor speeds or an encoder with excessive line count.

Max Following Err

While the system was in motion, the following error exceeded the Following Error Limit (programmed into the parameter table) for a period greater than the Following Error Time (also in the parameter table). This may be caused by a loss of encoder feedback, improper polarity in the connection from the PRO450 to the servo drive, a commanded velocity or acceleration that exceeds system capabilities. It could also be caused by Following Error Limit or Following Error Time parameter values that are beyond system capabilities.

SSO from drive false

The SSO line from the amplifier went false while the drive was enabled. Potential sources for this error include a malfunction in the servo amplifier, or an acceleration rate in the parameter table that is so large it exceeds the servo amplifier's maximum RMS current limit or peak current limit. There could also be a mechanical problem in the system which causes the servo amplifier to exceed maximum current.

Watchdog Timeout

The microprocessor failed to pulse the watchdog timer which will cause a 'warm' reset--as if the system had just been powered up (except that the drive will be disabled). The watchdog timer is pulsed by the microprocessor every 2.0 milliseconds to ensure that the microprocessor is functioning properly. Probable causes are noise in the power supply or a momentary power failure.

**** E-STOP ****

The Emergency stop (Estop) input on the PRO-450 was activated (switch open). The amplifier is disabled and, as a result, the system will not try to maintain position. However, the encoder feedback will be used to maintain the absolute position internal to the controller. The Error output (O8) will be active (if Error output and Estop error output are enabled).

FLimit

Either the hardware forward limit input on the PRO-450 became activated, or, if in Absolute mode, the software overtravel limit in the forward direction was exceeded.

RLimit

Either the hardware reverse limit input on the PRO-450 became activated, or if in Absolute mode, the software overtravel limit in the reverse direction was exceeded.

Bad Command

This message is displayed when the entry does not match the command list.

Position = XXX

The current position is displayed whenever the controller is operating normally (Estop is not active, switch closed, and no errors exist). The position displayed is in terms of user units, and updated approximately once every 0.5 second. Note that position will continue to be displayed even if the drive has been disabled by the DISable command.

Peak FE = XXX

As the controller is displaying position, the display may be switched to capture peak following error by pressing '**F**' (no carriage return) on the keyboard. The message 'Capturing peak FE' will be displayed briefly. While this message is displayed, the controller is monitoring following error and keeping track of the largest value found. If this value is larger than any succeeding values for about 0.1 second, then it is displayed as the peak following error. If the following error is constantly increasing, however, no value is displayed, and the controller continues monitoring following error looking for a peak value. This algorithm insures that a peak value is captured, and not simply any value during a move. After a peak value is captured, it is displayed. The peak value may be reset by pressing '**F**' on the keyboard again. The position display may be reactivated by entering '**S**' (for Status) on the keyboard.

NOT Absolute Mode

This message is displayed when trying to run a program that contains absolute moves when the Absolute mode parameter is set to 'OFF' (controller is in Incremental mode).

CANNOT Do Makeup Move

This message is displayed if the Makeup parameter is set to 'ON' and a program is stopped, then started, before the program has executed twice.

PGM STOPPED

This message is displayed when a program has been stopped by entering '**X**' (kill motion).

CANNOT execute--pgm running

This message is displayed when trying to RUN a program or enter another mode if a program is still running (even though there may not be any motion). Typical causes for this message include Window parameter too small or the program is executing a 'WAIT IXX' statement.

NO depth instr in pgm

This message is displayed when attempting to run a program that contains no NFD or PFD statement when the Advance parameter is enabled.

QUEUE FULL

This message is displayed when there are two MOVP moves or two MOVD moves compiled and ready to run in memory and another MOVP or MOVD command is entered. The maximum number of MOVP or MOVD moves that can be compiled and ready to run is limited to two each.

Pgm Location Err, ALL pgms lost!

This message is displayed if the calculated program location table checksum differs from the stored checksum. If this happens, all programs are lost since the program location table is essentially the 'directory' for the PRO-450. The most likely cause of this fault is the installation of a new battery-backed RAM.

Pgm Execution Err = XX

This message is displayed when trying to run a program that has either invalid parameters or statements. The most likely cause of this error is either a faulty battery-backed RAM or microprocessor. However, some errors occur as a result of bad programming practices or improper use of program statements. If the message still occurs after carefully editing the program and the parameter table, the controller board should be replaced. See Appendix F for Execution Error descriptions.

5.3.2 Exiting the Status Display Line

The status display line is exited by pressing [**ENTER**], or by entering one of the PRO-450 Execution mode commands. When the first key is pressed, the PRO-450 stops displaying the status display line and enters the Execution mode. To re-display the Status line, press 'S' for Status. (If using the ElectroCraft Operator Station, simply press 'STATUS'.)

5.4 **Programming the PRO-450**

The PRO-450 operates in several modes, each with its own set of commands and functions. The top level mode is the Execution mode, which may be entered when the status display line is active by pressing [**ENTER**]. All other modes are entered by entering the appropriate command while in the Execution mode. **NOTE**: Number values that are entered (for various parameters, program statements, or commands) may appear to change when re-displayed. (Example: An entry of 'ACCEL=400' may be re-displayed as 'ACCEL=399.999'.) This is due to a rounding-off process used internally in the PRO-450 to display a number. The number is indeed stored correctly--no accuracy or resolution is lost.

Figure 5-1 PRO-450 Operating Modes

5.4.1 Execution mode (PRO> prompt)

The PRO-450, when first powered up, will be in the Execution mode. All other modes are selected from the Execution mode. The PRO-450 must be in the Execution mode to run any programs. To enter the Diagnostic mode the Estop input must be active (drive is disabled). (While in Diagnostic mode the controller will ignore the state of the Estop input, and will not control position.)

In the Execution mode, commands are available to run a motion program, delete (erase) a motion program, display the size of motion programs and the amount of program memory left, tune the system, check status, edit programs, execute moves, or enter other modes. **NOTE:** To enter a command, only the boldface, capital letters need to be entered. The controller will also accept the full name of a command (except **B**aud**R**ate and **D**efine**H**ome).

The commands available in Execution mode are:

The current baud rate is displayed (5 rates are possible: 1200, 2400, 4800, 9600, or 19200 baud). Note that the rate displayed is the actual baud rate--not the setting of the Baud parameter.

COpy XX YY

Allows one program to be copied to another. The format is **'COPY** XX YY' where XX is the source program and YY is the destination program. If the destination program is not blank, the message 'Overwrite program? Y/N' will be displayed. Entering any character other than '**Y**' will abort the copy command.

Defines the current position as Home. The system must be at rest (that is, no program running) with the drive enabled (Estop NOT active, switch closed) for this command to be executed. This command may be used any time the above conditions are met--any position may be defined as Home.

DELete XX

Deletes (erases) program XX. A warning message will appear asking for confirmation that you wish to delete program XX. Any answer except '**Y**' (for yes) will leave program XX intact and return to the 'PRO>' prompt.

Causes the controller to enter the PRO-450 Diagnostic mode (distinguished by the 'DIAG>' prompt). The Estop input must be active (switch open) before this mode will be entered. If it is not, the controller will issue a warning message and return to the 'PRO>' prompt. Refer to Section 5.4.2 for a description of diagnostic commands.

Displays all program numbers that are available in the PRO-450, and the size of each program in bytes. Also displays the number of bytes left in battery-backed RAM for additional programs.

Disable the amplifier through the serial terminal. This command will have no effect if Estop is active, switch open (amplifier is already disabled). The amplifier may be re-enabled using the ENAble command (if Estop not active, switch closed) or by toggling Estop. If there is motion occurring when the command is issued, the motor will decelerate to stop immediately (performs like Estop).

EDit XX

Causes the controller to enter the Program Edit mode (distinguished by the 'EDIT>' prompt). Program XX can then be edited. If the program is a new program, it will consist of only an END statement. Additional program statements may be entered at this point. Refer to Section 5.4.5 for a description of program edit commands. **NOTE**: If the Estop input is not active, (switch closed) the display screen will run slower than with Estop active because the controller must maintain position (drive is enabled). Activate Estop or use the DISable command before entering the Program Edit mode for faster editor performance.

Enable the amplifier through the serial terminal. This command will have no effect if Estop is active, switch open (the ENAble command will not override Estop). The command would normally be used to re-enable the amplifier if it had been previously disabled using the DISable command.

ERase XX

Same as DELete above.

GEAR=(-)XXXXX/**256**

Sets a gear ratio that allows the PRO-450 to follow the auxiliary encoder input (POS2) at the specified ratio. The denominator is fixed at 256. The gear value will remain in effect until a new GEAR command is issued. If the drive is disabled or a program is started, the gear value is set to zero.

Executes moves (MOVP or MOVD) that have been entered and compiled. Only one move will be executed for each Go command. If the Go parameter is disabled, the command has no effect. See the MOVP command in this section.

Displays a list of available Execution mode commands.

Fault history command. The HIst command displays the last fault (error condition) that occurred. The error conditions recorded are: Encoder Error, Maximum Following Error, SSO from drive false, Watchdog Timeout, Forward Limit Hit, Reverse Limit Hit, or Pgm Execution Error #XX. Only the last error that occurred will be saved. The fault history is saved in battery-backed RAM so it is retained even if the system is powered-down.

Performs the same function as the Home command switch (see Section 4.3.10).

Displays the current condition of the inputs I01 to I16; 0 is displayed for OFF, 1 for ON (except Estop and the limit switch inputs which are wired opposite that of the other inputs--normally closed). Note that the status of the Home switch (I05) will be displayed as 0 for OFF and 1 for ON even if the HomeSwitch parameter is set to Open. If a constantly updated display of the inputs is desired, see Diagnostic mode, Section 5.4.2.

KD

Tune KD. The damping gain, KD, may be adjusted at any time (even 'on-the-fly' while a program is running) to better tune the system dynamically. After typing 'KD [ENTER]', the present value of KD is displayed. The value may now be changed by entering a new value and [ENTER] or left as it is by pressing [ENTER] alone. If a new value is entered, the new value is displayed without scrolling the display up. The value may now be changed again by entering a new value (without having to re-enter the command) or, if you are satisfied with the current entry, press [ENTER] to return to the normal position display.

KFf

Tune KFF. The velocity feedforward gain, KFF, may be adjusted at any time (even 'on-the-fly' while a program is running) to better tune the system dynamically. The entry of KFF is similar to that of KD above.

KI

Tune KI. The integral gain, KI, may be adjusted at any time (even 'on-the-fly' while a program is running) to better tune the system dynamically. The entry of KI is similar to that of KD above.

KP

Tune KP. The proportional gain, KP, may be adjusted at any time (even 'on-the-fly' while a program is running) to better tune the system dynamically. The entry of KP is similar to that of KD above.

MOVD=XXX[,**V**=YYY]

Move an incremental distance XXX (distance is in user units). Executes a trapezoidal or triangular move. The move will be made at the default velocity (stored in the parameter table) unless an optional velocity,

[**,V**=YYY], is specified (brackets indicate velocity is optional--they are not part of the command). Moves may be 'stacked' or queued in memory--see MOVP below.

MOVP=XXX[**,V**=YYY]
Move to an absolute position XXX. The controller will form a trapezoidal or triangular move. The move will be made at the default velocity (stored in the parameter table) unless an optional velocity, [**,V**=YYY], is specified (brackets indicate velocity is optional--they are not part of the command). The MOVP command can only be used in Absolute mode, after home has been defined.

If the Go parameter is enabled, up to two MOVP or MOVD moves may be entered and compiled in memory. If the Go parameter is not enabled, a MOVP or MOVD will be executed immediately after it is entered and compiled, unless a program is running or motion is occurring. If a program is running, the move will be made immediately after the program finishes. If both a MOVP and MOVD have been entered, the MOVP move will be executed first.

MOVV=±XXX

Serial jog command--MOVe at a Velocity. The velocity is specified by XXX with the sign of the velocity representing the direction of the jog (the forward direction is implied without a sign). This command acts just like the Jog inputs, but is entered through the serial terminal. The MOVV command may be used to move off a limit switch. Once the jog is started, motion may be stopped by using the Estop input to disable the drive or entering the 'X' command or a 'MOVV=0' command through the serial terminal. If a MOVV jog is currently running, the velocity of the MOVV may be changed by entering a new MOVV command.

The (Tool) Offset command allows slight distance changes in a motion profile while a program is running. It is useful in machining applications such as a drilling operation where the hole being drilled will not be the correct depth due to tool wear. The operator can adjust the distance moved (depth being drilled) by entering a tool offset distance. The offset will change the distance of the move without changing the original program. If the tool is changed later, the offset can be zeroed to return to the original depth being drilled. The Offset command requires that the program running have an OFFSet statement immediately preceding the move (MOVD or DV) that will be affected.

Enter 'O [Enter]' (F2 if Electro-Craft standard Operator Station is used) to display the present offset (stored in battery-backed RAM) or to enter a new value. Once the present offset value is displayed, type in a new offset value to change the old one. The offset value is cumulative--that is, the new value is added to or subtracted from the old value depending on the sign of both (a positive or a negative number may be entered). The resulting value, if not greater than the Max offset parameter, is then stored as the offset value. The new offset value (total cumulative value) will then be displayed on the screen.

The offset value should be entered only at the home position (Position=.0000) and will only be effective when an OFfset statement is encountered while running a program. If the offset value is larger in the opposite direction than the move to be made, the drive is disabled, and Execution Error **#24** is displayed. (Example: the move is for 2 units, but the offset value is equal to -2.1). If this occurs, the offset value will then have to be changed to run the program without generating an error. The offset value may be zeroed in two ways: entering a value of 0 at the 'Offset=' prompt or whenever the Max offset parameter is changed. See OFfset statement, Section 5.4.5.3 and Max offset parameter, Section 5.4.3.1.

The Parameter command causes the controller to enter the Parameter mode (distinguished by the 'PAR>' prompt). Refer to Section 5.4.3 for a description of Parameter mode commands.

The Query command is an error status request. The command works only in Host mode. It is designed to allow a Host (typically a computer) to find the cause of an error that has interrupted program execution.

The PRO-450 responds to the command by sending back a status byte. The status byte may or may not be a printable ASCII character depending on its value.
The status byte values correspond to the following errors:

Decimal	Hexadecimal	Error
3	3	Invalid opcode
6	6	Program acceleration=0
9	9	Program velocity=0
12	C	Negative acceleration
15	F	Move acceleration=0
18	12	Negative move velocity
21	15	Move velocity=0
24	18	Distance wrong direction
27	1B	Move distance=0
30	1E	Acceleration time too great
33	21	Acceleration time too small
36	24	Move velocity too large
39	27	Move distance too large
51	33	Velocity operand=0
54	36	Distance operand=0
57	39	Deceleration operand=0
60	3C	Loop counter > 16
63	3F	Jog velocity=0
66	42	Default acceleration=0
69	45	Home velocity=0
72	48	Invalid macroopcode
75	4B	Invalid opcode for Advance/Return
78	4E	No constant vel DV move for Offset
81	51	Accel too low for ADV/RET or PAUSE
84	54	Divide by zero
87	57	Cannot find correct motion statement
90	5A	Missing LBL AV or TC in program
93	5D	Outside profile--cannot return to profile
96	60	Cannot find move to makeup
99	63	Absolute mode counter rolled over
102	66	Negative loop count
105	69	Velocity variable = 0
201	C9	Parameter chksum error
204	CC	Program chksum error
207	CF	Encoder error
210	D2	Maximum following error
213	D5	SSO from drive false
216	D8	Watchdog timeout
219	DB	Flimit hit
222	DE	Rlimit hit
225	E1	Program location error, all programs lost

RESet

Resets error conditions such as Maximum Following Error or Program Execution Error from the serial terminal without having to toggle Estop. **NOTE**: If the drive had been disabled due to the error, the Reset command will enable the drive (if Estop is not active).

RUn XX

Runs program XX where XX can be any program number 1-15 or "AUTO" (this makes it possible to test the "AUTO" program without powering the system down). "AUTO" is a special program used to display messages upon power up. The status display line will appear so position (or any of the status messages) may be monitored while the program is running. The F1 key of the Electro-Craft standard Operator Station followed by the program number can also be used to run a program.

Displays several pertinent pieces of information as to machine status of the PRO-450.

The information displayed consists of certain inputs and outputs that are currently active: In Position (InPosn), Estop, Flimit, Rlimit, Home sequence complete (HoSeqCmpl), Pause, Jog forward (JOGF), Jog reverse (JOGR). If a program is running, the program number (Pgm # X) is displayed along with the current instruction that is being executed. A sample status screen is shown below. Note that if Host mode is enabled, the ADDRess parameter will be displayed also.

```
InPosn                          HoSeqCmpl
Pgm # 1
Pgm Instr:
Wait I12=ON
```

When using the Electro-Craft standard Operator Station, if the [STATUS] key is pressed, the status is displayed two lines at a time. Following the display of the current status and current program instruction, the current position is displayed, and updated approximately every half second. To stop the display of the position, press [ENTER].

The PRO-450 controller will enter the Tune mode when this command is issued. The Tune mode is an aid for setting up a system. The tuning parameters KD, KP, KI, and Zone may be changed while the drive is enabled. A step position command is defined with an adjustable amplitude and period. See Tune Mode, Section 5.4.4.

X (Killmotion)The [**X**] command with no [ENTER] stops motion (except JOG) using controlled deceleration during the execution of a program. This allows for the editing of a program or the ability to RUN another program without using the Estop procedure. Once the program is stopped, 'PROGRAM STOPPED' is displayed to show the reason that program execution was halted. The **X** command will **not** cause an ERROR output and the HOME SEQUENCE COMPLETE remains true. **NOTE**: If a key is pressed, then deleted, a CR must be used with '**X**' to scroll the display--motion will be stopped, however, with or without the CR. **(Note**: X will not stop motion during jogs or home routine.)

The Zone command allows the Integral Zone parameter to be examined or changed while in the Execution mode. Zone entry works similar to the KD command listed above. See Zone parameter, Section 5.4.3.1.

5.4.2 Diagnostic mode (DIAG> prompt)

The Diagnostic mode is useful for testing and verifying the PRO-450 hardware. Upon entry, a list of commands is displayed. In this mode, you may test discrete inputs and outputs, RAM storage, encoder feedback, and the D/A converter. Estop must be active (switch open) to enter the Diagnostic mode.

The commands available in Diagnostic mode are:

D Test the Digital to Analog converters (D/A). Three types of tests are available:

1. A constant voltage output (Press '**O**').

2. A square wave output (Press '**S**').

3. A triangular wave output (Press '**T**').

All of the D/A tests output a voltage at the VCS output (P6-3) and the DAC output (P6-8). The drive is disabled so no motion will result. The tests are useful for monitoring the state of VCS with an oscilloscope if the D/A operation is in question.

The constant voltage output is user-defined. The range is -10V to +10V with a resolution of 1V.

The square wave output is user-defined. The range is -10V to +10V with a resolution of 0.1V and a fixed period of 0.5 second.

The triangular wave output is pre-defined; the output is a triangular wave with an amplitude of ±10V and a period of about 0.5 second (2 Hz).

The PRO-450 will prompt you to select the constant voltage test, the square wave test, or the triangular test after entering '**D**'. Once a test has been selected, any of the other tests may be entered by pressing the appropriate key (**O**, **S**, **T**) or **Q** may be pressed to quit.

To select the constant voltage test, press the letter '**O**'. The PRO-450 will then ask for a voltage to output (-10V to +10V). (The voltage cannot be a value outside the ±10V range or a fractional value.) Enter the desired voltage and press [**ENTER**]. (Pressing [**ENTER**] without entering a voltage will force the default value, 5 volts, to be output on VCS.) The voltage level on the VCS output will then correspond to the value entered. If it does not, the PRO-450 control board should be replaced. Once a voltage has been entered, a new value may be entered at any time. Simply enter the new value, press [**ENTER**] and the new voltage will be output on VCS.

To select the square wave test, press '**S**'. The PRO-450 will then ask for a voltage to output (-10V to +10V). (The voltage cannot be outside the ±10V range.) Enter the desired voltage and press [**ENTER**]. (Pressing [**ENTER**] without entering a voltage will force the default value, a square wave with an amplitude of ±5 volts, to be output on VCS.) A square wave will be output on the VCS output. If there is no square wave present, the PRO-450 control board should be replaced. Once a voltage has been entered, a new value may be entered at any time. Simply enter the new value, press [**ENTER**] and the new square wave will be output on VCS.

After pressing '**T**', a triangular wave will be present on the VCS output. If there is no waveform, the PRO-450 control board should be replaced.

When 'Q' is pressed, the PRO-450 will return to the D/A test screen and the VCS output will go to zero (0) volts.

E Test the encoder. The position (in encoder counts) is displayed, and constantly updated. This command may be used to verify that the A and B outputs are phased correctly, and that the index output is functioning. It may also be used to determine a scaling factor for the system. This is done by locating the axis at a convenient starting point, clearing the position display by pressing '**C**', and then slowly moving the axis one 'user unit'. A user unit may be a revolution, or an inch, or any distance. The position display shows the number of encoder counts per user unit. When the

encoder index is active, the message 'Index' is displayed before the encoder count. When the Home switch input (I05) is active, the message 'Home Sw' is displayed after the encoder count. This feature helps to determine the relationship of the encoder index to the home switch active position. In addition, the encoder resolution may be determined. Pressing '**I**' on the keyboard will start the encoder sizing test. If the encoder is rotated in one direction, and two index pulses are detected, the resolution of the encoder in quadrature counts will be displayed. This would be the value of the Scale parameter to be entered in the parameter table (see Scale, Section 5.4.3) if one user unit is equal to one encoder revolution.

I Test the discrete inputs. All 16 inputs are read and the levels displayed on the screen (0=OFF, 1=ON) continuously. You may selectively activate/deactivate each input and watch for a change in the display to test the PRO-450's inputs and external wiring.

O Test the discrete outputs. You may selectively set or clear each output to test the outputs and external wiring. All outputs can be changed simultaneously using the 'ALL ON/OFF' command. The outputs will remain in their present state upon exiting Diagnostic mode, except the dedicated outputs, Error, In-position, and Home Sequence Complete (if the outputs are enabled--see Parameter mode, Section 5.4.3).

R Test non-volatile RAM. The non-volatile RAM is sized (2K, 8K, or 32K), and then tested thoroughly to insure that it is functional. Stored programs and parameters are not affected by this test.

Q Quit Diagnostic mode and return to Execution mode.

The Parameter mode is used to enter or change the PRO-450 parameter values. This mode is entered from the Execution mode ('PRO>' prompt) by entering '**P**AR [**ENTER**]'. Upon entry, the size of the nonvolatile RAM is determined and displayed.

A parameter value may be examined or changed by entering the command. For example, entering '**ACC** [**Enter**]' will display the current acceleration value. To change the value, simply enter the new value followed by [**ENTER**]. To leave the present value unchanged, press [**ENTER**]. It is also possible to change the value without examining it--enter the parameter name followed by '=' or a space and the new value. Press [**ENTER**] and the parameter will be changed. Entering '**ACC=100** [**ENTER**]' will set the acceleration value to 100 user units per second per second. Entering '**ACC?** [**ENTER**]', or any other illegal value, will cause a help message to appear, followed by a prompt for re-entry.

NOTE: To enter a command, only the boldface, capital letters need to be entered.

The commands available in Parameter mode are:

Enables/disables the Absolute Positioning mode. In Absolute mode, all moves are referenced to the home position. If set to ON, the controller will enable software overtravel limits, enable the emergency return function, and not allow motion programs to run until home position is established. If set to OFF, the controller disables software overtravel limits, disables the emergency return function, and allows motion programs to run without home position being established. Any programs with absolute moves (that is, MOVP moves) will not be executed if Absolute mode is off. Absolute mode OFF implies Incremental mode.

Defines default acceleration for all motion generated by the PRO-450. Acceleration and deceleration rates for the home function and motion profiles are specified by this parameter. The jog deceleration will be equal to the Acceleration parameter, but the jog acceleration will be 1/8 that of the Acceleration parameter. The Acceleration parameter is entered in user units per second per second. The maximum acceleration value is:

Max Acceleration = [(128(500)¨)/SCALE] - 1

where SCALE is the value of the SCALE parameter.

Allows for automatic parameter entry. When the parameter is displayed, the cursor is positioned at the end of the display line. To change the parameter value, enter the new value, then press [**ENTER**]. If the new value is good, the current parameter is changed to reflect the value entered and the next parameter is displayed. If an incorrect value is entered, a help message for the current parameter is displayed. If an error is made while entering the new value, pressing [**ESC**] will re-display the present value. Alternatively, the bad character(s) may be deleted (use the [**DEL**] or [**BKSP**] key) and [**ENTER**] or [**ESC**] to go on to the next parameter. Note that if there is a parameter checksum error, Auto mode will be selected automatically upon entering Parameter mode.

To exit AUTO mode, and return to the 'PAR>' prompt, press '**Q** [**ENTER**]' when a parameter is displayed.
EREturn **(E**mergency **RE**turn position)

Specifies the absolute position the machine moves to when the Emergency Return input is activated (see Section 4.3.12). The EREturn position is entered in user units. The EREturn function is active only in absolute mode.

To disable the Emergency Return input (I10), enter 'OFF' rather than a position at the 'Emergency Return Posn =' prompt. The formerly dedicated input I10 can now be used as a general purpose input. To reenable the Emergency Return input, enter a position at the prompt.

Following Error Limit. Sets the maximum allowable following error for fault recognition (following error is defined as the difference between commanded position and actual position). If this value is exceeded for an amount of time defined in FETime, then a fault occurs and system operation is halted. The Following Error Limit is entered in user units.

Following Error Time limit. Sets the amount of time that the system following error may exceed the limit defined by FELimit before system shutdown occurs. Allows peak following error values greater than the limit to exist without generating a fault condition. The Following Error Time limit is entered in seconds.

Forward software overtravel Limit. The limit is enabled when the Absolute mode parameter is ON. If travel exceeds this value in the forward direction, then a fault occurs and system operation is halted. The Forward Limit is entered in user units. The maximum value allowed for the software limits is:

Max Software Limit = 16,777,215/(2 x SCALE)

where SCALE is the value of the Scale parameter.

Displays the available commands (Help screen) to be used in the Parameter mode. If an invalid command is entered, the Help screen is displayed automatically.

Home OFfset. Specifies distance from encoder index to home position. The sign of this parameter specifies the direction of the offset. See Section 4.3.10 for a description of the home command operation. The Home OFfset is entered in user units.

Home Velocity. Defines the velocity for the home function. The sign of this parameter specifies the direction in which the controller will initially seek home. See Section 4.3.10 for a description of the home command operation. The Home Velocity is entered in user units per velocity time unit.

JVelocity

Jog Velocity. Defines velocity for forward and reverse jogs. The Jog Velocity is entered in user units per velocity time unit.
Damping gain. Adjusts the damping of the position loop and operates on feedback only (see Section 1.4). It is used to stabilize 'tachless' systems (torque amplifiers), or to provide damping for systems with large compliances. KD is entered in updates. Refer to Section 6.2.4 for KD calculations.

Velocity feedforward gain. Adjusts the following error of the position loop (see Section 1.4). KFF is entered in updates/count. Refer to Section 6.2.6 for KFF calculations.

If the PRO-450 is used in order to track another axis (master-slave mode), then the KFF parameter may be used to bring the machine within the in-position window. (Note that after any motion if the motor is not within the in-position window, the next instruction cannot be executed.)

Integral gain. Adjusts the integral gain of the position loop and operates on position error history only (see Section 1.4). The position error is continually added to itself and this sum is multiplied by KI. The result is used to reduce the steady state error of the motor position to commanded position. KI is entered in updates. The integral gain is only active in the target zone defined by the Zone parameter (described below in this section). Excessive KI can result in overshoot.

If the PRO-450 is used to track another axis (master-slave mode), then the KI parameter may be required to bring the machine within the in-position window. (Note that after any motion command if the motor is not within the in-position window, the next instruction cannot be executed.)

Proportional gain. Adjusts the bandwidth of the position loop (see Section 1.4). KP is entered in counts per count. Refer to Section 6.2.5 for KP calculations. Excessive KP can result in overshoot.

Load a parameter table saved earlier from the serial terminal. When this command is given, the PRO450 displays the message 'Ready to load parameters Start upload'. The PRO-450 waits for the parameter table to be transferred from the serial terminal. The PRO-450 terminates the load operation when it sees the end of file in the parameter table and then issues the 'Load Completed' message. Refer to Appendix B or C for loading parameter tables from a serial terminal. (**NOTE:** The PRO-450 must be disabled to load parameters.)

Offset removal enable. May be set to ON or OFF. Enables or disables the automatic offset removal feature (see Section 1.4).

OPT

Display Optional Parameter Help screen (see Optional Parameters, Section 5.3.3.1).

PAG2

The PAG2 command is similar to the AUTO command described above but allows for automatic entry of the optional parameters.

PRogram

Default Run Program. Identifies the number of the program that runs when the Start input is activated. Allowable values are 0 to 15 inclusive. A value of 0 will enable the external program select inputs (I13 through I16, see Section 4.3.15).

Quit Parameter mode and return to the Execution mode ('PRO>' prompt).

Reverse software overtravel Limit. The limit is enabled when the Absolute mode parameter is ON. If travel exceeds this value in the reverse direction, then a fault occurs and system operation is halted. The Reverse Limit is entered in user units. See FLimit above for the maximum value allowed.

Defines the direction of the motor. The parameter may be set to clockwise (CW) or counterclockwise (CCW). If set to CW, a clockwise rotation of the motor as viewed from the shaft end is defined as the forward direction and a counterclockwise rotation is defined as the reverse direction. Conversely, if the Rotation is set to CCW, a counterclockwise rotation is defined as the forward direction, a clockwise rotation as the reverse direction.

Save the parameter table in the serial terminal. When this command is given, the PRO-450 displays the 'Saving parameters ' message and then waits for the terminal to be put in the 'capture' mode. Once in the 'capture' mode, press the [**ENTER**] key. Pressing a key other than the [**ENTER**] key at this point aborts the download. If the [**ENTER**] key is pressed, the PRO-450 will send the entire parameter table to the serial terminal. (The information displayed as the parameter table is saved will be a combination of symbols and numbers--this is normal as the parameter table is not stored as a readable ASCII file.) Refer to Appendix B or C for specific instructions for saving parameter tables using a serial terminal.

Specifies user unit to controller unit (encoder counts) Scale factor. The number of encoder counts per revolution is four times (4X) the number of encoder lines. For example, if a particular machine has an encoder with 2,000 lines and a leadscrew with 5 turns per inch, the proper Scale factor for user units of inches is 4 x 2,000 x 5 = 40,000 counts per user unit. For user units of encoder counts, set the Scale factor to 1. **NOTE**: If the SCale parameter is changed after any programs have been written, the programs will be changed upon exiting the Parameter mode to reflect the new Scale parameter (unless a program contains a SCale statement). (Example: Doubling the Scale parameter will halve the distances in a program--the actual distance moved will remain the same, however.)

Selects velocity time unit. If set to SEC, velocity units are user units per second. If set to MIN, velocity units are user units per minute.
Defines default maximum traverse Velocity for motion profiles. When programming motion profiles, all moves are made at this velocity unless a different velocity is specified in the statement (or if the maximum velocity cannot be attained in the distance specified). The maximum Velocity is entered in user units per velocity time unit.

In-position Window. When the PRO-450 is stationary or tracking another system, Window defines the range of position error (difference between commanded position and actual position) that causes the Inposition output to activate. The Window parameter is important because the PRO-450 must be in position after any motion function ends and before the next motion function begins. The In-position Window is entered in user units. The time that the PRO-450 must be in the Window before activating the In-position output is controlled by the optional parameter, WindowTime (see Section 5.4.3.1).

NOTE: Disabling the Inposn output in the Optional Parameters has no effect on the Window parameter.

Target integral gain zone. The Zone parameter (entered in user units) is the zone in which the integrator will come into play to reduce position error when close to the target. It is used with the KI parameter (described elsewhere in this section). The Zone parameter should be greater than the current Window parameter to be effective. If the KI parameter is set to 0, no integral action will result regardless of the value of the Zone parameter.

Included in the back of this manual are two pages that help in programming the PRO-450. The first sheet provides space to list the parameter settings for the PRO-450 when used with a BRU-200 or BRU500 amplifier. The second sheet provides space to write a program and is a quick reference for the PRO-450 editing commands and all the PRO-450 program statements. Each sheet may be copied as needed.

After entering the Parameter mode, the parameter checksum is not updated until the Parameter mode is exited. Therefore, after entering Parameter mode, you MUST exit the Parameter mode AND return to the 'PRO>' prompt before removing power to the PRO-450. Failure to do so will cause a parameter checksum error.

5.4.3.1 Optional Parameters (PAR> prompt)

The optional parameters are entered the same way as the standard parameters. The optional parameters allow you to customize a system to better meet specific applications.

- Several of the dedicated inputs and outputs can be disabled and used as general purpose I/O.
- The default baud rate may be changed or an automatic baudrate recognition scheme selected.
- The Host mode may be selected.
- A 'makeup' move feature may be enabled.

The HELP screen for optional parameters may be displayed by entering '**OPT**' when in the Parameter mode.

NOTE: To enter a command only the boldface capital letters need to be entered.

The optional commands available in Parameter mode are:

ADDress XX

Allows setting the PRO-450 to a specific slave address of 1 to 255. This must be set before entering Host mode in order to access individual PRO units. To set the Address, enter a number from 1 to 255 at the 'Slave Address =' prompt. An address of 0 is not allowed as this is the address number for a global command (no response allowed) when in Host mode (see Host mode below).

Enable/disable Advance/Return. The Advance/Return function allows motion profile control under 2 external inputs: Advance, to advance through the motion profile, and Return, to return (in the negative direction) through the motion profile. To enable the Advance function, enter either I07 or I08 at the 'ADVance' prompt; to disable Advance (default), enter 'OFF' at the prompt. If Advance is enabled, the Return input will be set to the remaining inputs - if Advance is set to I07, Return will be set to I08 and vice-versa. As long as Advance is true, the profile will run normally until the velocity goes to 0 (completion of forward motion); at that point, Advance must go false **and** Return must go true for the profile to continue in the negative direction.

If, during forward motion, Advance goes false, the profile will decelerate to 0 and wait for Advance to go true to continue in the forward direction **or** for Return to go true to continue in the reverse direction. If, during reverse motion, Return goes false, the profile will decelerate to 0 and wait either for Advance or Return to go true and then move accordingly. The profile will never go outside the original profile envelope. The program must contain a dedicated label "LBL AV" and a depth statement "PFD" (see Section 5.4.5.3) to carry out the Advance/Return function.

NOTE: Enabling the Advance parameter disables the Pause function.

The Athome output (O5) may be disabled and used as a general purpose output. To disable the Athome output (default), enter 'OFF' at the 'ATHome output' prompt; to enable the Athome output, enter 'ON' at the prompt (see Athome, Section 4.4.4).

Enable/disable AutoBaud. To enable AutoBaud (default), enter 'ON at the 'Autobaud' prompt, to disable AutoBaud, enter 'OFF' at the prompt. If AutoBaud is enabled, the PRO-450 will wait for a carriage return (CR) for 5 seconds after power-up. When a CR is detected the PRO-450 will set the baud rate to that of the serial terminal. If no CR is issued within 5 seconds, the PRO-450 will set the baud rate to the rate set by the Baud parameter. If the Baud parameter is set to AutoBaud Forever, the PRO-450 will wait forever for a CR; no other action will result until a CR is received.

If the Electro-Craft standard Operator Station is used, the AutoBaud parameter should be turned off, and baud rate should be set to 9600. Failure to do so could result in no communication between PRO-450 and the Operator Station.

(0-5)

Selects the default baud rate according to the following listing:

ENTER	BAUD RATE (baud)
1	AutoBaud Forever
2	1200
3	2400
4	4800
5	9600
6	19200

To set a baud rate, enter the desired number from the above listing at the 'Baud Rate set to' prompt. If Autobaud Forever is selected, the PRO-450 will wait forever for a CR (ENTER) from the serial terminal at power up. When the CR is detected, the PRO-450 will set the baud rate to match that of the serial terminal. Autobaud Forever overrides Autobaud (described above). Default baud rate is 9600 baud. **NOTE**: Changing the Baud parameter will have no effect on the current baud rate until the *next* time the PRO-450 is powered up.

If the Electro-Craft standard Operator Station is used, the AutoBaud parameter should be turned off and baud rate should be set to 9600. Failing to do so could result in no communication between PRO-450 and the Operator Station.

Sets the DAC voltage to a default value after power up and at the end of each program. The entered value should be between -10 and +10 volts with no more than 3 digits after the decimal point.

Input debounce time. The Debounce parameter is the amount of time that an input should stay high or low to be recognized. The debounce time is entered in increments of 2 milliseconds (mS) with a range of 1-20 (default is 2 for 4 mS). If a relay or switch is used for the input, a relatively long Debounce time should be entered compared to the value used for a solid state switch.

Input I11 may be used to define home or as a general purpose input. To enable the Define Home input function, enter 'ON' at the 'Define Home input' prompt; to disable the Define Home input (default), enter 'OFF' at the prompt. The operation of the Define Home input is directly related to the Index parameter. If the Index parameter is enabled, the Define Home input may be used any time the drive is enabled to define home. If the Index parameter is disabled, however, the Define Home input will only be recognized to define home when the Home program is running and the Home input is active. This allows the Home position to be defined separately from the index position of the encoder on the motor, but still locates Home in a location relatively close to the Home switch. **NOTE**: Disabling the Define Home parameter will enable the Index parameter. Enabling the Define Home parameter will have no effect on Index.

The Error output (O8) may be disabled and used as a general purpose output. To disable the Error output, enter 'OFF' at the 'Error output' prompt; to enable the Error output (default), enter 'ON' at the prompt.

The Estop error parameter controls whether or not the Error output (O8) will be on when Estop is active (drive disabled). To disable the Estop error output, enter 'OFF' at the 'Estop error' prompt'; to enable the Estop error output (default), enter 'ON' at the prompt.

The Go parameter, if enabled, will cause the PRO-450 to wait for a 'Go' command to start motion once a MOVP or MOVD command has been entered and compiled in Execution mode. If the Go parameter is disabled, a MOVP or MOVD move entered in Execution mode will start running as soon as the move compilation is finished (unless a program or move is executing, in which case the compiled move will be executed as soon as the program or current move is complete). If the Go parameter is enabled, moves may be queued in memory for execution later--up to 2 MOVP moves and 2 MOVD moves (see MOVD and MOVP, Section 5.4.1). To disable the Go parameter (default), enter 'OFF' at the 'Enable GO' prompt; to enable the Go parameter, enter 'ON' at the prompt.

The Home Sequence Complete output (O6) may be disabled and used as a general purpose output. To disable the Home Sequence Complete output, enter 'OFF' at the 'Home SEQuence Complete output' prompt; to enable the Home Sequence Complete output (default), enter 'ON' at the prompt.

The active state of the Home Switch Input (I05) is selectable (open or closed). To set the active status to closed (default), enter CLOSED at the 'Home Switch active' prompt; to set the active status to open, enter OPEN at the prompt.

Selects the Host mode for a multiple PRO-450 system using RS-422 communications. Host mode OFF implies terminal mode (a single PRO-450 system). To use RS-422 communications, jumpers W13-15 must be changed to the RS-422 setting and 2 additional pins, P5-2 and P5-4 (XMT+ and RCV+), must be connected to the serial terminal to provide balanced mode communication. Jumpers W13-15 are shown in drawing 9097-1066. The serial connection is shown in drawings 9097-1088 and 9101-0136. When using Host mode, each PRO-450 in the system must be set to a different address (see ADDress above). Failure to do so will cause garbled communication, as more than one PRO-450 may respond when being addressed.

The communication scheme used is known as Master-Slave--only one master (the host) is allowed to initiate communication. The host is typically an IBM PC (or equivalent). The multiple slaves (the PRO450s) in the system cannot initiate communication (as opposed to peer-to-peer communication which allows any device to initiate communication). Once in Host mode, communication is initiated when the host issues a 'Start of Transmission' (STX) which is equal to a decimal 2 (same as a Ctrl-B). The STX should ***not*** be followed by a carriage return (CR). When an STX is received by the PRO-450s in the system, any PRO-450 that is transmitting will immediately stop transmission and wait for the next byte.

The next byte to be sent should be an address (the address must be a decimal number, ***not*** an ASCII number - for example, send a '2' for address 2, not a '50' which is an ASCII 2--same as 32 hexadecimal) and should not be followed by a CR. Each PRO-450 in the system will compare the address sent to its own internal address. If the addresses match, the PRO will then be selected and communication will be established until the next STX is issued. When the next STX is issued, the PRO that is selected will cease transmission and wait for the address to be sent. Valid addresses can be any number from 1 through 255. Addresses 1-30 may be sent using any terminal if it contains a Ctrl (Control) key. Ctrl-A corresponds to 1, Ctrl-B to 2 and so on. See Appendix I for a list of ASCII codes. If a Tandy is being used for the serial terminal, address 28 cannot be sent as it corresponds to a Ctrl-\ (the Tandy has no '\' key). In addition, some terminals (the Tandy included) may not be able to send an address of 0--the keystrokes required are 'Ctrl', 'Shift', and '@'. The terminal used should be checked for this condition.

Address 0 is reserved for a global address--no response is allowed. When a global address is issued, all PRO-450s in the system will execute any commands sent until the next STX is issued. Since no response is allowed from the slaves in the system, commands will not be echoed back to the host, so half-duplex communication should be used in order to view the commands on the screen.

If Host mode is enabled, but the address is not known, the PRO-450 in question may be selected by sending a CR within one (1) second of power-up regardless of the Autobaud parameter setting. The baud rate used will be the default baud rate parameter. The PRO-450 will respond as if its address had been sent. If this selection method is used, only one PRO-450 may be on the serial link--if more than one PRO-450 is connected serially, all the PRO-450s will respond to the CR and communication will become garbled. To enable Host mode, enter 'ON' at the 'Host mode' prompt; to disable Host mode (default), enter 'OFF' at the prompt. When Host mode is first enabled in Parameter mode, the slave is automatically selected, so Host mode selection should be done with only one PRO-450 connected on the serial link.

NOTE: Host mode is not designed to be used with the Electro-Craft standard Operator Station. Enabling Host mode automatically disables the Operator parameter.

The Index parameter is provided to allow the Define Home input to be used as an alternative to the encoder index to define home when running the Home program. When the Index parameter is enabled, the encoder index is used to define home when the home input is active and the Home program is running. When the Index parameter is disabled, the Define Home input is used to define home rather than the encoder index. To disable the Index parameter, enter 'OFF' at the 'Index' prompt; to enable the Index parameter (default), enter 'ON' at the prompt. **NOTE**: Disabling the Index parameter will enable the Define Home parameter. Enabling the Index parameter has no effect on Define Home.

The In-position output (O7) may be disabled and used as a general purpose output. To disable the Inposition output, enter 'OFF' at the 'In-position output' prompt; to enable the In-position output (default), enter 'ON' at the prompt.

The Jog Reverse and Jog Forward functions may be disabled and the corresponding inputs (I07 and I08) used as general purpose inputs. To enable the Jog functions (default), enter 'ON' at the 'Jog input' prompt; to disable the Jog functions, enter 'OFF' at the prompt.

The Forward and Reverse Limit functions may be disabled and the corresponding inputs (I01 and I02) used as general purpose inputs. To enable the limit functions (default), enter 'ON' at the 'Limit inputs' prompt; to disable the Limit functions, enter 'OFF' at the prompt.

The LOCKfn parameter locks out the function keys (F1-F4 and Status) of the Electro-Craft standard Operator Station if a program is running so that the program display will not be interrupted. If the parameter is enabled and no program is running, the function keys will operate normally. The default value of the LOCKfn parameter is OFF, which allows normal usage of the function keys. To disable the LOCKfn parameter (default), enter 'OFF' at the 'LOCK function keys' prompt; to enable the LOCKfn parameter, enter 'ON' at the prompt.

Allows the PRO-450 to retain its position if the amplifier is disabled or Estop is active. Upon amplifier power-up with Start active (or RUN command), a makeup move will be made (if actual position is not equal to commanded position) to get to the correct position. This eliminates the need to re-home and allows program execution to be resumed at the point of interruption. The Makeup feature will work *only* in the Incremental mode.

To complete the calculations necessary for Makeup, a program must be executed twice before the Makeup move can be done, and the program must start with a label and end with a JMP to that label statement. If the program has not been executed twice before a Makeup move is commanded (by the Start switch or a RUN command), the message 'CANNOT do Makeup Move' is displayed, and the PRO450 will *not* start executing the program until a second Start or RUN. The makeup move is designed to be used with simple repetitive motion profiles. To enable the Makeup move, enter 'ON' at the 'Makeup move' prompt; to disable Makeup (default) enter 'OFF' at the prompt.

The Max offset parameter defines the maximum tool offset allowed in either direction. Whenever the Offset command is used in a program and an offset value is entered in Execution mode, the new offset total (old offset plus or minus new value entered depending on the sign) is checked against the Max offset parameter. If the new offset total is greater than the Max offset, the new value is not accepted (old value remains unchanged) and an error message is displayed. If the Max offset parameter is changed, the current tool offset total is zeroed. Enter the maximum tool offset at the MAX tool offset prompt in user units (positive number only, as number is an absolute value). The default value for the Max parameter is 0. See Offset command, Section 5.4.1 and OFfset statement, Section 5.4.5.3.
The Operator parameter allows use of the Electro-Craft standard Operator Station or, if using a full ASCII terminal, provides a level of security as far as allowing access to programming functions within the PRO-450. The Operator parameter, along with input I12, affects serial terminal operations according to the following table:

Operator Parameter	I12Terminal	Used

Functions Allowed

	Off	-	Full ASCII	All
	On	On	Full ASCII	All
	On	Off	Full ASCII	X,O,S,F
Commands Only				
	On	On	Operator Station Display	
Only				
	On	Off	Operator Station Display	
& Function Keys				

When using the security feature with a full ASCII terminal, (Operator ON, I12 off), only 'X' (kill motion), 'O' (offset), 'S' (status), and 'F' (peak following error) commands will be recognized. Any other command will result in a 'PRO>' prompt only and will be ignored. If the Operator Station is used, (Operator parameter ON, I12 off), the 'F1' (run command), 'F2' (offset), 'F3' (inputs), 'F4' (peak following error), and 'Status' keys will be recognized. In either case, any programmed 'INPUT' statements may be entered. To enable the Operator parameter, enter 'ON' at the 'Operator' prompt; to disable the Operator parameter, enter 'OFF' at the prompt.

NOTE: Enabling the Operator Parameter automatically disables Host mode.

The active state of the Pause input (I09) is selectable (open or closed) or may be disabled (allows input I09 to be used as a general purpose input). To set the active state to closed (default), enter CLOSED at the prompt; to set the active state to open, enter OPEN at the prompt. To disable Pause, enter 'OFF' at the 'Pause input' prompt. **NOTE**: Enabling the Pause input disables the ADVance parameter.

The Pgmrun output (O4) may be disabled and used as a general purpose output. To disable the Pgmrun output (default), enter 'OFF' at the 'PGMrun output' prompt; to enable the Pgmrun output, enter 'ON' at the prompt.

In-position Window time. When the motor is stationary, WindowTime defines the length of time that the motor must be in the in-position window before the In-position output is activated. This parameter, along with the Window parameter, is used to determine when one motion function ends and the next one begins. The WindowTime is entered in increments of 2.0 milliseconds and has a range of 1-10 (default is 3).
The optional parameters are initialized to the default values as listed in the following table:

ADDress **1**
ADVance **OFF**
AThome output **OFF**
Auto**B**au**D** **ON**
Baud **4** (9600)
DAc=0
DEbounce 2
HOSt **OFF**
INDex **ON**
INPosn output **ON**
JOg input **ON**
LOCKfn **OFF**
LImit **ON**
MAKeup **OFF**

Define**H**ome input **OFF**

ERRor output **ON**

ESTop error output **ON**

Go **OFF**

home**SEQ**uencecomplete output **ON**

Home**S**witch active **CLOSED**

MAX offset 0

OPErator input **OFF**

PAuse input **CLOSED**

PGMrun output **OFF**

Window**T**ime 3

5.4.3.2 Exiting Parameter Mode

When the **Q**uit command is given in Parameter mode, the PRO-450 will re-calculate the parameters affected by changes in other parameters. For example, changing the Scale parameter affects all parameters entered in user units. If the re-calculations force any of the parameters out of the ranges that the PRO-450 allows, then you are notified of the out of range parameter and not allowed to exit the Parameter mode until the out of range condition is corrected. Upon exit from the Parameter mode, all programs are compiled with the new parameters (Velocity, Acceleration, Scale) unless the programs contain Velocity, Acceleration or Scale statements.

The parameter checksum is not updated until the Parameter mode is exited. Therefore, after making changes in the Parameter mode, you MUST exit the Parameter mode AND return to the 'PRO>' prompt before removing power to the PRO-450. Failure to do so will cause a parameter checksum error.

5.4.4 Tune Mode (TUNE> prompt)

The Tune mode allows the system to be tuned dynamically, that is, the tuning parameters (KD, KP, KI and Zone) may be changed while the drive is enabled and the motor is running a step position command. To enter the Tune mode, press '**T** [**ENTER**]'. The drive must be enabled (Estop not active) and no program running to enter the Tune mode. Upon entry, the 'TUNE>' prompt is displayed. At this point, you may enter the position and period values for the step position command. The position value is entered in user units followed by a space; the period value is entered in seconds. The minimum period that may be entered is 0.2 second.

A suggested value for the position entry is a value that would result in a move of 0.25 revolution of the motor.Once the position and period values have been entered, press [**ENTER**]. The PRO-450 will then output a waveform, similar to that shown below, on the VCS output with an amplitude that corresponds to the maximum commanded velocity and a period equal to the period value entered. The tuning parameters (KD, KP, KI, Zone) may now be changed or examined. To exit the Tune mode, press '**Q** [**ENTER**]' at any time.

Figure 5-2 Tune Waveform

To change the position or period values, press '**X**' to stop the existing motion, then enter the values.

5.4.5 Program Edit Mode (EDIT> prompt)

The Program Edit mode is used to edit motion programs. Program statements may be inserted, deleted, changed, or displayed. This mode is entered from the Execution mode ('PRO>' prompt) by entering '**Edit** XX [**ENTER**]', where XX is a valid program number from 1 to 15 inclusive, or "AUTO".

"AUTO" is a special program used to display messages upon power up. Motion and output commands are not allowed in the AUTO program because unwanted motion could result during power up.AUTO Program

When entering the Program Edit mode, if the program specified has no statements, the program editor will display 'New program', followed by the 'EDIT>' prompt. Since every program must conclude with an END statement, one is placed at the end of the program.

Programs may also be edited using any other editor or word processor on an IBM PC (or clone) as long as the file that is produced by the editor is unformatted ASCII text and an 'END' statement is the last statement in the program. After you have created or edited the file, the program may be sent to the PRO-450 using the LOAD command. See Appendix C for specific information on loading and saving programs using a PC.

NOTE: To enter a command, only the boldface, capital letters need to be entered. The controller will also accept the full name of a command.

The commands available in the Program Edit mode are:

[ENTER]

When [**ENTER**] alone is pressed (null line), the next step of the program is displayed. If used repeatedly, this command lists the program one statement at a time.

Change an existing statement to a new statement. The statement changed is the last one listed when the change command is given. The change command must be given individually for each statement changed.

Delete an existing statement. The statement deleted is the last one listed when the Delete command is given. The Delete command must be given individually for each statement deleted. After a statement is deleted, a '^Deleted' message appears below it. **NOTE**: When deleting labels within a program, the special command '**DEL LBL XX**' must be used.

Goto XX

Go to the program statement label XX. Entering '**GOTO AA** [**ENTER**]' displays label AA and the associated program statement. This command may be used to point the editor at a particular section of

the program. You may wish to place many labels in the program to allow rapid cursor positioning within the program. See Section 5.4.5.3 for information on program labels.

Insert new statements. Each new statement is inserted before the statement listed when the insert command was given. The Insert mode remains active until [**ENTER**] alone is pressed (null line). The insert mode is signified by a special prompt, 'EDIT*>'.

LIst X

List (display) X statements. The optional number X specifies how many statements will be displayed. Entering '**LIST 5** [**ENTER**]' will display five statements, starting with the last one listed. Entering '**LIST** [**ENTER**]' displays the entire program, starting with the last statement listed. If the last statement displayed is 'END', entering '**LIST** [**ENTER**]' will list the entire program starting at the beginning of the program. Pressing any key after sending the List command aborts the listing.

Load a previously saved program from the serial terminal. When this command is given, the controller will send the message 'Ready to load program Start upload'. The PRO-450 is now waiting for the program to be loaded from the serial terminal. The PRO-450 will terminate the load operation when it sees the first 'END' statement in the program and issue the 'Load Completed' message. Refer to Appendix B or C for loading programs from a serial terminal. While loading a program, the controller must be disabled. **NOTE**: When loading a previously saved program, the program is compiled with the present parameter table as it is being loaded. In order for the loaded program to stay as it was at the time it was originally written, the parameter table associated with the program must be loaded *before* loading the program.

Quit Program Edit mode, and return to the Execution mode.

NOTE: When the Quit command is given in Program Edit mode, the PRO-450 will recompile the program using the current parameters. The recompile process may take several seconds (longer if the drive is enabled) depending on the size of the program. Do Not power the PRO-450 down until the 'PRO>' prompt is displayed on the screen, as this could cause loss of data (the program would only be partially recompiled).

Save the program in the serial terminal. When this command is given, the controller will send the 'Saving this Program' message. Then, the terminal must be put in 'capture' mode. Pressing a key other than [**ENTER**] at this point will abort the download. If [**ENTER**] is pressed, the controller will list the entire program, and the serial terminal stores it in a capture buffer. After the END statement is listed, the controller will wait for [**ENTER**] to be pressed, which closes the capture buffer on the serial terminal. See Appendix B or C for specific instructions for saving programs using a serial terminal. **NOTE**: When a program is 'saved', the current parameter table should be 'saved' as well (suggested filenames: PGM1, PAR1, PGM2, PAR2, etc.). When a 'saved' program is reloaded, the current parameter table is used to compile the loaded program, therefore, the associated parameter table must be 'loaded' *before* the program is 'loaded'.

Move to the top (first statement) of the program.

Display the previous statement. The **U**p command does not change any information on the line that it moved from or the line it moved to. The Up command also responds to the '-' or '/' keys. (The Up command (Up, -, /) does not need to be followed by [**ENTER**] unless a character had been previously typed and deleted.)

When inserting or changing statements, the input to the PRO-450 must be a valid instruction for motion programs as described in Section 5.4.5.3. Any invalid motion program statements will not be inserted into the program.

Included in the back of this manual are two pages that help in programming the PRO-450. The first sheet provides space to list the parameter settings for the PRO-450 when used with a BRU-200 or BRU500 amplifier. The second sheet provides space to write a program and is a quick reference for the PRO-450 editing commands and all the PRO-450 program statements. Each sheet may be copied as needed.

5.4.5.1 Variables

The PRO-450 language supports the use of variables in the program. Variables may be used in the program to calculate a motion distance, define traverse speed, set the gear ratio, define the loop counts, or in the decision statements while a program is running. There are three types of variables: Distance variables, Speed variables, and Integer variables.

Distance Variables

Distance variables are used to define a distance. There are 32 user defined distance variables (D1 through D32), 4 read only distance variables (POS1, POS2, PCMD, and CMD2) and 2 read only latched distance variables (IP1 and IP2). The units of the distance variables are in user units. Maximum size of the distance variables is ±8,388,607 encoder counts. The read only variables (see Figure 1-2) may be read, but cannot be changed inside a program. The read only variables are:

POS1 - The feedback position from the feedback encoder.

POS2 - The command position from the auxiliary encoder.

CMD2 - The command position from the auxiliary encoder after being multiplied by the GEAR parameter.

PCMD - The overall commanded position (the sum of the command position from the profile generator and the auxiliary encoder).

The Home Sequence resets all the read only variables to zero.

Latched Distance Variables Using High Speed Input

In addition to the above distance variables, there are two other dedicated distance variables IP1 and IP2, which are used to capture the feedback position (POS1) and the command position (POS2) following a closure of input I05. Within 20 to 72 microseconds after a low to high transition on input I05 (Home Switch/High Speed Input), POS1 and POS2 are captured into IP1 and IP2 respectively. These dedicated variables may be used like the other distance variables.

Speed Variables

Speed variables define the maximum traverse speed that a variable distance move (MOVD=Dxx,V=Sxx) may attain. There are 16 user defined speed variables (S1 through S16). The units of the speed variables are user units per time unit. Maximum size of the speed variables is 32,768,000 encoder counts per second. Negative speed entry is accepted, but it is stored as a positive value.

Integer Variables

Integer variables must be whole numbers (no fractional part allowed). They are used to define integers such as counters, gear ratios, etc. There are 16 user defined integer variables (C1 through C16). The maximum size of the integer variables is ±65,535. In addition to the user defined integer variables, there are 16 counter variables (CT1 through CT16) for printing purposes only. These variables are used to show the progress of the program when inside a loop statement. The counter variables cannot be changed or used in an arithmetic operation.

The user defined variables (not the read only variables) can be loaded with a constant, loaded from another variable, entered from the Operator Station, or can be loaded with the result of an arithmetic operation.

Examples:

```
C1=D1/D2
D12=2.23
C10=234
D1=IP1
D1=D1-POS2
C12=C16*C12
D1=D2/C2
S10=S10/C1
INPUT "ENTER THE BATCH COUNT",C11
MOVD=D1,V=S1
```

NOTE: Variables will retain their values even if power is removed. Upon entering a program, if a variable is used but not initialized in that program, the value of the variable will be what it was when the variable was last used (even if it was used in a different program).

5.4.5.2 Math functionsOne of the most powerful features of the PRO-450 is the ability to do simple arithmetic on variables while running a program. All of the operations except multiplication or division must be of the same variable type. It is possible to multiply any variable by an integer variable (the variable type of the result would remain the same-it would not be changed to an integer), or divide two variables of the same type and store the integer part of the result in an integer variable. In the case of overflow, no message or execution error is issued. These operations are:

ADDITION and **SUBTRACTION**-Two variables of the same type may be added together or subtracted from each other. The use of constants inside an operation is not allowed. To add to or subtract from a constant, the constant should be loaded into a variable, and the variable then used for the addition or subtraction. If there is an overflow, no error message is issued. Overflows are not an error in incremental applications. However, in other applications where the overflow of variables is not allowed, it is the programmer's responsibility to prevent it by proper programming.

Examples:

D12=D2+CMD2
C12=C3-C2
S1=S2+S3

MULTIPLICATION-There are two kinds of multiplication in the PRO-450, fast and regular.

FAST MULTIPLY- The fast multiplication which takes 2 milliseconds (mS) to perform has the format:

variable 1 = variable 2 * constant

The constant is a positive real number less than 256 with up to 4 digits after the decimal point. The fractional part of the constant has the accuracy of 1/256. If an integer variable is multiplied by a fractional constant, the result of the multiplication is truncated, and the result is stored as an integer variable.

Example of fast multiplication:

D1=POS1*123.125
C1=C1*2
S3=S10*0.1250

REGULAR MULTIPLY- Two integer variables, one distance variable and one integer variable, or one velocity variable and one integer variable may be multiplied using the regular multiply format: variable 1 = variable 2 * integer variable

The regular multiplication may take up to 14 mS to be performed.

Examples of regular multiplication:

D1=POS2*C10
C2=C2*C1
S1=S10*C2

DIVISION-The following division operations are allowed in a program:

1-Any variable type may be divided by an integer variable; the type remains unchanged.

Examples: D1=D2/C2
S2=S2/C1
C12=C11/C2

2-Any variable can be divided by another variable of the same type; the result is an integer variable (the fractional part of the operation is truncated).

Example: C10=POS2/D2
C1=C2/C1
C1=S1/S10

Division may take up to 24 mS to be performed. If the time for the division calculation is a concern, a fast multiply may be used to do a fast division. For example, to divide a variable by 4, the variable may be multiplied by 0.25 (the time for this operation would be reduced from 24 mS to 2 mS).

5.4.5.3 Program Statements

The program statements are the most significant feature of the PRO-450. The statements can be used to move a machine a certain distance, or to move to a position (absolute or relative to another axis), communicate with the operator through the serial interface, and coordinate the motion selectively and sequentially with external I/O.

Following is a list of the available program statements, and descriptions of their functions in a motion program.

The Acceleration statement may be used within a program to change the Acceleration parameter (set in Parameter mode). The new value will be valid only for the program being edited--it will not affect any of the other programs. The statement should be used before any motion statement as the Acceleration parameter value is used to calculate the proper motion profile. If the ACceleration statement is not used, the current Acceleration parameter value is used for motion profile calculations.

Example: ACCEL=500

ALL ON/OFF

All of the outputs (O1-O8) will be turned on or off simultaneously depending on the statement. **NOTE**: The outputs O4-O8 will be affected only if the Home Sequence Complete, In-position, ATHome PGMrun, or Error dedicated outputs have been disabled in Parameter mode.

Example: ALL OFF

CMDrate=ON/OFF

The statement "CMDRATE=ON" limits the maximum command acceleration from the second (master) encoder to the programmed acceleration. If there is a sudden change in the command velocity from the second encoder (CMD2), the controller uses the programmed acceleration to get to commanded velocity. During this acceleration (or deceleration) the controller does not track the position. In applications where more exact position tracking is required, the "CMDRATE" should be set to "OFF" (default). **NOTE**: The CMDRATE statement has no effect unless a GEAR statement is included in the program.

Example: CMDRATE=ON

D=XXX,**V**=YYY

Form a 'stick' move for one leg or move segment of a complex motion profile. The PRO-450 will calculate the acceleration or deceleration of the move based on the distance 'D' and velocity 'V' specified in the instruction and on the velocity of the previous move. For example, if the previous move ended with a velocity of 0 (no motion), and the next instruction is 'D=10,V=100', the PRO-450 will calculate an acceleration move with a final distance of 10 user units and a final velocity of 100 velocity units. If the next instruction is also a 'D=10, V=100', the resulting move will continue at a velocity of 100 for 10 user units--there will be no acceleration.

Once a stick move is started, all succeeding stick moves must be in the same direction until the velocity returns to 0.

There are several advantages to using DV statements rather than MOVD or MOVP statements alone. Velocity may be changed on the fly, I/O may be changed in real time, and different acceleration/deceleration ramps can be done in the same profile.

Outputs may be turned on or off at the end of any stick move (for the best performance the number of outputs turned on or off at the end of a stick move should be limited to 2). Conditional branching is allowed in a motion profile made up of stick moves. If conditional branching is used, the velocity of the stick move just executed should match the beginning velocity of the target stick move (move that is executed if the branch is taken). Failure to match velocities will not guarantee the correct velocity of the target stick move. If the current velocity is 0 (no motion is occurring), a 'JMP' to a label in a stick move motion profile where velocity is *not* 0 should not be done as the results would be unpredictable.

When using the stick move instruction, there is no limit to the number of stick moves in a motion profile, however, the last stick move in a profile should have a velocity of 0 or be a 'DE' or 'EV' statement. See Appendix E EFFECT OF MOVE SEGMENT CHANGES IN A COMPLEX PROFILE for information on changing stick moves in a program.

If the acceleration/deceleration value calculated for a stick move is greater then the Acceleration parameter, a warning message is issued, but the move is allowed. If the acceleration/deceleration value is greater than the system limit (fixed limit, internal to the PRO-450), an error message is displayed and the move is not allowed.

Examples: D=12,V=2.02
D=-2,V=3 <--Note that the sign of the D term determines direction of the profile.

NOTE: The minimum constant velocity DV move that can be made is:

D=Velocity (units/second) * 0.002 seconds.

DAc Statements:

DAC=XXX
DAC=Cx/204.8

The 'DAC' (Digital to Analog Converter) statement is used in a program to change the DAC output voltage. The DAC value remains unchanged until the program encounters a new DAC command. The DAC voltage may be programmed directly by entering a voltage between ±10 volts with up to 3 digits after the decimal point, or by using an integer variable. The denominator of the DAC command with an integer variable is fixed at 204.8. If an integer variable is used as the argument of the 'DAC' command, an increment of the argument integer variable by 1 will increment the DAC voltage by 4.88 mV (1/204.8 volts). If the integer variable is greater than 2,048 or less than -2,048, the DAC voltage is clamped to +10 and -10 volts respectively. At the end of program execution, the DAC voltage returns to the DAC parameter value.

Examples: DAC=-4.342
DAC C1/204.8

DE Statements:

DE=XXX,**I**YY=**ON**/**OFF**

The 'DE' statement (Distance Event) is a conditional statement that will cause motion to decelerate to stop if the event occurs. If the event does not occur, the move will continue until the specified distance 'DE=XXX' is reached. This statement is used with the 'DV' stick move. The velocity of the move will be

that of the prior stick move. This statement should be used only as the last statement in a complex motion profile.

If the input condition (IYY=ON/OFF IYY: inputs I01-I16) is satisfied, the motion profile will end with an immediate deceleration to stop. The deceleration used will be the program acceleration parameter. If the condition is not satisfied, the profile will continue for the distance specified in the 'DE=XXX' portion of the statement and then do an immediate deceleration to stop again using the program acceleration parameter.

Example: DE=200,I12 ON

DH

The DH (Define Home) statement allows Home position to be re-defined from within a program. It can be used to compensate for mechanical wear in a system or, if running in Absolute mode, to zero the position counter so that software limits will not be hit. The DH statement cannot be inserted in the middle of a DV move.

Example:
```
IF I11 ON JMP NH
.
.
.
LBL NH
DH
```

DIF Statements:

DIF=XXX,**I**YY=**ON/OFF JMP** ZZ

The 'DIF' statement (Distance IF) is a conditional statement that will move the specified distance XXX at a constant velocity, then fall through to the next instruction unless the condition becomes true. This statement is used in conjunction with the 'DV' stick move. The velocity of the move will be that of the prior stick move. If the condition becomes true before the distance specified has been moved, program execution will branch (jump to label ZZ). The velocity at the target label should equal that of the DIF move.

If the input condition (IYY=ON/OFF IYY: inputs I01-I16) does not match the condition specified, the profile will continue for the distance specified in the 'DIF=XXX' portion of the statement and then program execution will fall through to the next instruction.

Example: DIF 150,I11=ON JMP AA

DISable

Disable drive statement. This statement disables the drive from a program. The drive must be enabled before any motion will be executed. The ENAble statement (see below) may be used to enable the drive from a program after it has been disabled. This statement should be used with caution as no motion will result after the drive has been disabled, even though a program is running. If a motion statement is executed after the drive has been disabled, the PRO-450 will be 'hung' trying to execute the motion profile. If this happens, toggling Estop will re-enable the drive; the ENAble or RESet commands can also be used to clear the 'hung' condition.

NOTE: If the X (Killmotion) command is issued while the drive is disabled in a program, the program will be stopped, but the drive will remain disabled. The drive must then be enabled by toggling Estop or using the ENAble or RESet commands before another program can be run (drive is not in position).

Example: DISABLE

DWL XX

Dwell statement. This statement causes the controller to delay for the specified number of seconds. A space (' ') or '=' may be used between 'DWL' and the number of seconds.

Examples: DWL 1
DWL .015
DWL=30.5

ENAble

Enable drive statement. This statement enables the drive from a program. The ENAble statement would normally be used sometime after the DISable statement had been used in a program (a program cannot be run if the drive is disabled at the time the Run command is issued).

Example: ENABLE

EV,IYY=**ON/OFF**

The 'EV' (EVent) statement is used at the end of a 'DV' motion profile. The 'EV' statement is similar to the 'DE' statement except no distance is specified (profile continues forever if condition not met). The 'EV,IXX=ON/OFF' statement, uses a digital input (I01-I16) to specify the condition. The resulting motion profile will end with an immediate deceleration to stop if the condition is met. The program acceleration parameter will be used for the deceleration. If the condition is not met during the move segment, the motion profile will continue at the velocity set by the previous move segment ('DV' statement) forever or, if in Absolute mode, until it reaches the software overtravel limit. In Incremental mode, the position display will roll over when it reaches the maximum position possible (maximum position = 16,777,215/SCALE where SCALE is the Scale parameter).

Example: EV,I11=OFF

FEL=XX

The FELimit statement may be used in a program at any time to change the default FELimit parameter value. The new value will affect only the current program being edited and will remain valid until changed by another FELimit statement. If the FELimit statement is not used in a program, the current parameter value is used for FELimit when the program is executed.

Example: FEL=.7

FET=XX

The FETime statement may be used in a program at any time to change the value of the default FETime parameter. The new value will affect only the current program being edited and will remain in effect until another FETime statement is encountered. If the FETime statement is not used in a program, the current parameter value will be used for FETime when the program is executed.

Example: FET=1.2

GEAR=[-]XXXXX/256

GEAR=[-]C*x*/256
For master-slave or relative positioning, the GEAR statement should be used in a program. A nonzero value for the GEAR ratio enables tracking by the PRO-450. The value of the auxiliary encoder (POS2) is

multiplied by the "GEAR" parameter, and the result (CMD2) is then added to the position command from the profile generator as shown in Figure 1-2. The gear ratio may be changed at any time. The denominator of the GEAR command is fixed at 256. The maximum value for the gear ratio is 65,535/256. It is also possible to use an integer variable as the argument of the GEAR statement. This allows the gear ratio to be calculated in a program, or the use of different gear ratios for different applications within the same program. To change the direction of tracking, a negative gear ratio may be entered. The rate of velocity change from the auxiliary encoder times the GEAR parameter (CMD2) may exceed the program acceleration, unless the command "CMDRATE=ON" (default=OFF) is used in the program.

Examples: GEAR=256/256
GEAR=-C1/256

IF IXX=**ON/OFF JMP** YY

Conditional branch (jump to label YY) on input. If the specified input IXX is in the proper state (ON or OFF), then the next statement executed will be the one associated with label YY. Valid input numbers are I01 through I16 inclusive. The target label does not have to be defined when this instruction is entered, but must exist before exiting the Program Edit mode. Failure to do so will cause an error message to appear, and you will not be allowed to exit the Program Edit mode. A space (' ') may be used in place of the '='. **NOTE**: Enter the number '0' for the input number, NOT the letter 'O'.

Examples: IF I08=ON JMP AA
IF I16=OFF JMP DE

IF variable 1<variable 2 **JMP** YY **IF**
variable 1>variable 2 **JMP** YY **IF**
variable 1=variable 2 **JMP** YY

Conditional branch (jump to label YY) based on the state of variables. Variables used in conditional statements should be of the same type (distance variables, speed variables, or integer variables). The use of read only distance variables is allowed in the conditional statements. If the ABSolute parameter in the parameter table is set to OFF (incremental mode), the comparison of the variables is based on the shortest distance. This allows variables to be compared, even after an overflow has occurred (the distance variables will overflow every 16,777,216 counts.) If the specified condition of the variables are met, then the next statement executed will be the one associated with label YY. The target label does not have to be defined when this instruction is entered, but must exist before exiting the Program Edit mode. Failure to do so will cause an error message to appear, and you will not be allowed to exit the Program Edit mode.

Examples: IF D2<POS1 JMP CC
IF C2=C5 JMP BB
IF S4<S6 JMP DD

IF(IXX=**ON/OFF AND I**YY=**ON/OFF)JMP** ZZ
IF(IXX=**ON/OFF OR I**YY=**ON/OFF)JMP** ZZ
IF(IXX=**ON/OFF XOR I**YY=**ON/OFF)JMP** ZZ

Boolean conditional jump. The three statements, 'IF AND', 'IF OR', and 'IF XOR', allow a combination of two inputs evaluated in a boolean fashion to specify a condition. The inputs specified must be I01-I16 inclusive and the label ZZ must be defined before exiting the Program Edit mode.
The IF(1XX=ON/OFF AND YY=ON/OFF)JMP ZZ will cause program execution to jump to label ZZ if input IXX satisfies the ON/OFF condition AND if input IYY satisfies the ON/OFF condition. If the condition is not met, the jump is not taken and program execution falls through to the next statement.

The 'IF(IXX=ON/OFF OR IYY=ON/OFF)JMP ZZ' statement will cause program execution to jump to label ZZ if either one of the input conditions is met. If neither condition is met, program execution will fall through to the next instruction.

The 'IF(IXX=ON/OFF XOR IYY=ON/OFF)JMP ZZ' statement will cause program execution to jump to label ZZ if only one of the input conditions is NOT met. If both conditions are met or if neither condition is met, program execution will fall through to the next instruction. A space (' ') may be used in place of the '='.

Examples: IF(I11=ON AND I12=OFF)JMP AA
IF(I10 OFF XOR I16 ON)JMP LL

The INPUT and FINPUT (formatted INPUT) commands are used to input distance (D1--D32), speed (S1-S16), or integer (C1--C16) variables from the Operator Station. These variables may define distances, gear ratio, batch count, speed, etc., inside a program. To make programming more flexible, you may display text before input is read, using the same instruction. Any message may be displayed if it is between quotation marks ("), and is no more than 29 characters long. (Note that the over all command should not exceed 39 characters.) Upon execution of a (F)INPUT statement, the serial terminal displays the text (if any). After a variable is entered, if the "INPUT" command is used, the controller displays "CORRECT?" to confirm the input. If "FINPUT" is used, nothing is displayed to confirm the data entry. If the input does not match the type of the variable, or exceeds the range, the controller displays a message and asks the operator to re-enter the variable. No program instruction is executed until a valid input is read.

The Formatted Input command "FINPUT" may be used to customize the screen of the display terminal. After each INPUT statement, the screen is scrolled up one line automatically, and the 'PRO>' prompt is displayed. The controller does not position the cursor until it is told to do so.

There are four dedicated control Characters which can be used with both INPUT and FINPUT statements:

Control Code (Hex)	Description
^&	carriage return and line feed command
^!	line feed
^@	carriage return

^1B ^x position the cursor at x where x is a two digit hexadecimal number (a leading 0 must be used with a single digit) - ^1B is the hexadecimal representation of ESC

The caret character, "^", followed by a two digit hexadecimal number is used to control the display screen. When using the Electro-Craft Operator Station, the character set {[ESC],r} positions the cursor to location r on the screen. The program statement to position the cursor at position 26 of the 1st line and ask for a distance variable would be: FINPUT "^1B^1A Distance", D1 (1B corresponds to ESC and 1A corresponds to the decimal number 26).

Examples:
```
INPUT "ENTER BATCH COUNT",C10
FINPUT "^& ENTER CUT LENGTH",D2
FINPUT "^1B^0B ENTER SPEED",S1
```

In the last statement, the character set "^1B^0B" (hexadecimal representation of [ESC],11) positions the cursor on the 11th column of the first row on the Electro-Craft Operator Station display before printing the statement.

An (F)INPUT statement used without a variable, may be used to pause a program until a key from the terminal is pressed.

Example: INPUT "ENTER ANY KEY TO CONTINUE"

K Gain Statements

All of the gains, KD, KFF, KI, and KP may be adjusted through program statements while a program is running. A typical use for changing the gains in a program would be an application where the load is changing drastically. For example, if the PRO-450 is controlling a reciprocating transfer shuttle that moves a work piece to an area, then returns empty for another work piece, the load may be very different when the shuttle is empty than when it is full. In this example, the KP statement could be used to raise the value of KP just prior to the move when the shuttle is loaded. Then, just prior to the return move (when the shuttle is empty), another KP statement could be used to drop the value of KP. Once a gain statement has been used in a program, that particular gain will remain in effect until another gain statement is executed or until a new program is started. When the new program is started, all the gains are set to the values in the Parameter table.

KD=XX

The damping gain, KD, may be adjusted while a program is running. The KD statement adjusts the damping of the position loop and operates on feedback only (see Section 1.4). It is used to stabilize 'tachless' systems (torque amplifiers), or to provide damping for systems with large compliances. KD is entered in updates. Refer to Section 6.2.4 for KD calculations.

KFf=XX

KFF, the velocity feedforward gain, can be adjusted while the program is running. KFF adjusts the following error of the position loop and is entered in updates/count. Refer to Section 6.2.6 for KFF calculations.

KI=XX

The integral gain, KI, can be adjusted while the program is running. The integral gain of the position loop operates on position error history only (see Section 1.4). The position error is continually added to itself and this sum is multiplied by KI. The result is used to reduce the steady state error of the actual position to commanded position. KI is entered in updates. The integral gain is only active in the target zone defined by the Zone parameter, so the Zone parameter must be set to a value other than zero for the KI statement to have any effect. Excessive KI can result in overshoot.

If the PRO-450 is used to track another axis (master slave mode), the KI parameter may be required to bring the machine within the in-position window. (Note that after any motion, if the motor is not within the in-position window, the next instruction can not be executed.)

KP=XX

The proportional gain, KP, can be adjusted while the program is running. The KP statement adjusts the bandwidth of the position loop. KP is entered in counts per count. Refer to Section 6.2.5 for KP calculations. Excessive KP can result in overshoot.

JMP XX

Unconditional branch (jump to label XX). The next statement executed will be the one associated with label XX. The target label does not have to be defined when this instruction is entered, but must exist before exiting the Program Edit mode. Failure to do so will cause an error message to appear, and you will not be allowed to exit the Program Edit mode.

Examples: JMP AA
JMP DE

LBL XX

Statement label. Identifies a statement for reference by an IF or a JMP statement. Valid labels are two alphabetic characters (A-Z). Numbers are not allowed. Up to 255 labels are possible.

After a label has been defined somewhere in a motion program, the label may be moved to a different place by inserting an identical label statement at that place. The PRO-450 will respond by informing you that the label is already defined, and ask if you wish to move the label. If the response is '**Y**' (yes), the label will be moved to the new location in the motion program. Answering '**N**' (no) will leave the label where it is.

Examples: LBL AA
LBL DE

LOOP XX,YYY
LOOP XX,Cx

Loop with repeat count. This instruction, along with the RPT or RPE instruction, defines a block of instructions to be repeated a specified number of times.

Loops are identified by the number XX. Sixteen loops are available, numbered 1 to 16 inclusive. A loop number may be used twice in a program, once in a LOOP instruction, and once in a RPT (RPE) instruction. Every LOOP instruction must be paired with a RPT (RPE) instruction with the same loop number. If you try to exit the Program Edit mode without pairing all LOOPs and RPTs (RPEs), an error message will be displayed, and you will not be allowed to exit the Program Edit mode.

The repeat count for a loop is defined by YYY or an integer variable C1 through C16. The repeat count may be any number 0 to 65,535 inclusive. A repeat count of 0 specifies an infinite loop. For repeat counts greater than 65,535, the LOOP, RPT (RPE) pairs may be nested (see examples below).

There is a descending loop counter variable (CT1 through CT16) assigned to each loop (used for print purposes only). This variable can display the progress of loop statements for a program.

Examples:

```
C1=10                                  The move MOVD=10 will be repeated
LOOP 1,C1                              10 times.
MOVD=10
PRINT "THE LOOP COUNTER IS",CT1
RPT 1
```

The display will show the value of CT1 as 9, 8, 7, 6, 5, 4, 3, 2, 1, 0 as the loop is repeating.

```
LOOP 1,10                              The move MOVD=25 will be repeated
LOOP 2,255                             2550 times (10 X 255 times). This
MOVD=25                                is an example of a nested LOOP, RPT
```

RPT 2 pair.
RPT 1

NOTE: When using nested LOOP RPT pairs, any inner loop must be correctly specified before entering any other loop. The PRO-450 does not check for location errors of LOOP, RPT statements, only that the LOOP, RPT pair is matched. An improperly specified nested LOOP, RPT may produce unexpected results as shown in the following example:

Incorrect use of nested LOOP, RPT statements:

```
LOOP 1,4
O3 ON
LOOP 2,10
O1 ON
DWL .5
O1 OFF
DWL .2
RPT 1
O3 OFF
DWL 1
RPT 2
```

In the above example, the 'RPT 1','RPT 2' statements have been interchanged. The 'RPT 2' statement should be placed *before* the 'RPT 1' statement. If this program were executed, the PRO-450 would continue in a loop forever--it would never finish the inner loop.

MOVD=[-]Dx[**,V**=Sx]
MOVD=XXX[**,V**=YYY]

Move an incremental distance. The entered distance can be either a numerical distance or a distance variable (D1--D32). If using a distance variable, the velocity may be specified in the move ONLY by using a speed variable (S1-S16). Specifying a velocity [,V=YYY] when using a distance variable is not allowed. The distance specified is relative to the machine's position just before the statement is executed. Positive or negative distances are allowed. The controller will form a trapezoidal profile using the acceleration and velocity values stored in the parameter table (ACC and V parameters may be overridden from within the program) unless the velocity of the move is specified in the instruction (the brackets shown above indicate velocity is optional--they are not part of the statement). If the velocity is specified in the instruction, the PRO-450 will calculate the move based on the new velocity and the current acceleration parameter. Specifying a velocity for a move affects only that move--it does not affect any other moves. Using a variable as the argument for the MOVD command, velocity can be overridden only by the speed variable. If the distance is too short for the traverse velocity to be reached, the controller will form a triangular profile. If a distance is specified with a variable, it should be less than 4,194,303 encoder counts. A distance move with a distance variable greater than 4,194,303 encoder counts will cause program execution error 39; (this is to prevent a distance move resulting from an overflowed variable due to calculations). A space (' ') may be used in place of the '='.

Examples:
```
MOVD 10.002
MOVD=-2
MOVD=1000,V 500
MOVD=D22
MOVD -D1, V=S1
```

MOVP=XXX[**,V**=YYY]
Move to an absolute position. The controller will form a trapezoidal (triangular) profile. An optional velocity value [,V=YYY] may be specified (brackets indicate velocity is optional--the brackets are not part of the statement); if it is not, the move is made using the velocity value taken from the parameter table unless overridden by a Velocity statement in the program. Likewise, the acceleration value used for the move is taken from the parameter table unless an ACceleration statement exists in the program. Absolute position is defined in the Absolute mode as a position relative to the home position. The PRO450 must be in Absolute mode and the home sequence must be completed for this move to be executed.

Examples: MOVP 0
MOVP=150,V=75

NFD, **PFD**

NFD (Negative Full Depth) and PFD (Positive Full Depth) are used to indicate the most negative position or the most positive position in a motion profile for applications using the Advance/Return function. Applications where Advance/Return can be used include program debugging, allowing operator (or automatic) control of the motion profile without complex conditional statments, or allowing a 'backup move' to clear a machine jam and then continue running the program. The Advance/Return function allows motion profile control under 2 external inputs: Advance, to advance (in the positive direction) through a motion profile, and Return, to return (in the negative direction) through a motion profile. This function is very similar to a Pause function, however with the additional Return input, it is possible to return through a motion profile even if the profile has not completed its forward motion. The profile can consist of several distinct moves regardless of the type of move (MOVP, MOVD, MOVD with a variable, or DV moves) as long as the profile is contiguous. The Advance input can be set to either input I07 or I08 or to OFF (disabled) in the Optional Parameter table. The Return input will be set to the remaining input once Advance is set--if Advance is set to I07, Return will be set to I08 and vice-versa.

To use the Advance/Return function in a program, the program must contain dedicated labels (LBL AV, LBL TC) signifying the start of the profile as it relates to position 0 (Home). Dedicated full depth program statements (NFD, PFD) must also be used to mark the most positive (or negative) position in the profile. 'LBL AV' (AV for AdVance) must be placed at the start of a profile in the forward direction to signify the beginning of forward motion. The program statement PFD must be placed at the end of the most positive point of the profile to signify maximum full depth. If a profile moves to the negative side of 0, 'LBL TC' (TC for Tool Change) must be placed at the start of the profile to signify the start of negative motion. To mark the most negative point of the negative profile, the program statement NFD is used. Failure to include either the dedicated labels or the depth statements and then trying to control motion using the Advance/Return inputs will generate an error condition (and the drive will be disabled).

Once motion is started, if the corresponding input goes false, the profile will decelerate to 0 and wait for either Advance to go true to continue in the forward direction or for Return to go true to follow the profile in the reverse direction. If the profile is advancing and the Return input comes on, the profile will continue as Advance is still true. Then, if Advance goes away while Return is still true, the profile will stop and reverse direction. The above holds true if you are Returning and Advance comes on and then Return goes away (except that the direction is reversed). The profile will automatically stop at the full depth statements and wait for the previously active input to go false and the other one to go true to reverse direction. The profile will NOT automatically stop at 0--it is up to the programmer to include a 'WAIT I07 (or I08) OFF' statement for the profile to stop at any points other than at the depth statements.
A sample Advance/Return program would look like this:

```
REM ADVANCE SET TO I07
LBL AA
```

```
        IF I07 ON JMP     ;Do nothing until Advance or Return go true
AV      IF I08 ON JMP
TC      JMP AA
        LBL AV            ;Beginning of forward motion
        MOVD 10
   PFD                    ;Opcode will automatically wait for I07 off
   MOVP 0                 ; and I08 on to continue program execution
        WAIT I08 OFF      ;Wait for Return to go false
        JMP AA
   LBL TC                 ;Beginning of negative motion
   MOVP -2
   MOVD -5
   D -1,V 100
   D -1,V 0
   NFD                    ;Opcode will automatically wait for I08 off
   MOVP 0                 ; and I07 on to continue program execution
        WAIT I07 OFF      ;Wait for Advance to go false
        JMP AA
```

NOTE: If the ADVance parameter is disabled, the NFD and PFD statements have no effect on program execution.

The OFfset statement is used ***immediately*** before a move in a program (MOVD or DV--see examples below) to change the actual distance moved (without altering the program). It is used to provide distance changes for circumstances such as tool wear or for fine adjustments during initial setup of a program. The offset will only affect the move immediately following the OFfset statement. The offset value (stored in battery-backed RAM) must be entered through the serial terminal while in Execution mode. If the offset value is the same sign as the move in the program, the actual move will be longer (offset is added on to distance) than that of the programmed move. If the offset is the opposite sign as that of the move, the actual move will be shorter (offset is subtracted from distance).

If the OFfset statement is being used with a DV move, the offset is added to the first DV move that has no acceleration (a constant velocity DV move). If there is no constant velocity DV move following the OFfset statement (for example, only 2 DV moves), the drive will be disabled, and Execution Error #78 will be displayed. See Offset command, Section 5.4.1 and Max offset parameter, Section 5.4.3.1.

Example Programs Using OFfset:

```
LBL AA                  LBL AA
OFFSET                  OFFSET
MOVD 2                  D 1,V 500
WAIT I11 ON             D 3,V 500 <--Constant Velocity DV move
MOVP 0                  D 1,V 0
IF I12 ON JMP AA        MOVP 0
                        JMP AA
```

OX **ON/OFF** (**OUT O**X**=ON/OFF**)

Turn an output 'X' ON or OFF. Valid output numbers are O1 through O8. **NOTE**: Enter the letter 'O' before the output names, not the number '0'. Either a space or '=' may be used in the statement. The word 'OUT' is optional.

Examples: O5 ON

O7=OFF

PRINT and FPRINT (formatted PRINT) commands are used to display a message, and (or) display the value of a variable. Strings must be between quotation marks ("), and no more than 29 characters long. (Note that the over all command should not exceed 39 characters.) Any distance variable (D1--D32, POS1, POS2, PCMD, and CMD2), speed variable (S1--S16), integer variable (C1--C16), or loop counter variable (CT1--CT16) may be displayed (one at a time). Upon execution of the PRINT/FPRINT statement, the text and (or) the variable is passed to the serial port to be transmitted. If the controller encounters a PRINT statement while the serial port is still transmitting the previous one, the controller delays the execution of the next instruction until the serial port has finished transmitting. To speed up the execution of a program, avoid using multiple print statements in succession.

The formatted print command "FPRINT" may be used to customize the screen of the display terminal. After each PRINT statement, the screen is scrolled up one line automatically, and the 'PRO>' prompt is displayed. When FPRINT statements are used, the controller does not position the cursor until it is told to do so.

There are several dedicated control Characters which can be used with both the PRINT and FPRINT statements:Control Characters

CONTROL CODE HEX	DESCRIPTION
^07	Enable bell output (150 ms)
^0B	Begin character blink field
^0C	End character blink field
^0E	Make cursor invisible
^0F	Make cursor visible
^16	Pause (creates a 3 second delay before processing next characters)
^19 ^0C	Clear display and home cursor (1st row, 1st column)
^19 ^0E	Home cursor (1st row,1st column)
^19 ^4C	Display blank
^19 ^4D	Display dim
^19 ^4E	Display bright
^19 ^4F	Display brightest (default)
^1B^(x)	Position the cursor at location (x) - Example: ^1B,^[location number 00-4F]; 4F hex is equal to location 79 (2nd row, last column); the second row starts at location 40 (28 hex); a leading 0 must be used if the location is a single digit
^&	carriage return and line feed command
^!	line feed
^@	carriage return
^x	where x is a two digit hexadecimal number (a leading 0 must be used with a single digit)

The caret character, "^", followed by a two digit hexadecimal number is used to control the display screen. When using the Electro-Craft Operator Station, the character set {[ESC] r} positions the cursor to location r on the screen. The program statement to do this would be: FPRINT "^1B^0C" to position the cursor at position 12 (1B corresponds to ESC and 0C corresponds to the decimal number 12). (For more information, consult your terminal instruction manual.)

Examples:
```
PRINT "THE CURRENT POSITION IS:",POS1
FPRINT "^&LOOP COUNTER:",CT1
FPRINT "^1B^0B BATCH COMPLETED"
```

In the last statement, the character set "^1B^0B" (hexadecimal representation of [ESC],11) positions the cursor on the 11th column of the first row on the Electro-Craft Operator Station display before printing the statement.

The REM statement allows comments to be inserted into a program. Comments may only be used as the very first line(s) in a program and are limited to a maximum of 29 characters per comment. If more than one line is needed for comments, use multiple lines, but each comment line must start with the REM statement.

RPT XX

Repeat a loop. This instruction, along with the LOOP instruction, defines a block of instructions to be repeated a specified number of times. **RPE** XX may also be used as a repeat loop instruction.

Loops are identified by the number XX. Sixteen loops are available, numbered 1 to 16 inclusive. A loop number may be used twice in a program, once in a LOOP instruction, and once in a RPT instruction. Every LOOP instruction must be paired with a RPT instruction with the same loop number. If you try to exit the Program Edit mode without pairing all LOOPs and RPTs, an error message will be displayed, and you will not be allowed to exit the Program Edit mode. For examples, refer to the LOOP instruction description.

SCALe=XX

The SCALE statement may be used once in a program to change the default SCALE parameter. The statement must be used before any motion statements, since all motion profile calculations are based on the SCALE parameter. The new scale value will remain valid for the program being edited unless the SCALE statement is changed or deleted. The new SCALE parameter will not affect other programs. If the SCALE statement is not used, the current SCALE parameter value is used for all motion profile calculations.

Example: SCALE=4000

SCAN IYY=**ON/OFF Dx=POS2 SCAN**
IYY=**ON/OFF Dx=POS1**
SCAN IYY=**ON/OFF Dx=PCMD**
SCAN IYY=**ON/OFF Dx=CMD2**

The SCAN command saves the value of a read only variable in a defined distance variable if the input condition is true.

There are four SCAN commands, one for each of the read only distance variables (POS1, POS2, PCMD, and CMD2). The SCAN command causes the controller to look for a specific condition on the inputs (I01-I16) every 2 mS. The input state must be edge-triggered (the input must change state) for the condition to be satisfied except the first time the SCAN statement is executed. (The first time through the statement if the condition is true, the variable is saved.) If the condition is satisfied, the current value of the specified read only variable is saved in the defined distance variable (D1--D32). This statement can be used for applications that require constant monitoring of the inputs to capture the position of an event. Once executed in a program, the SCAN command is enabled and may not be disabled unless the program is stopped. It is possible to reassign the input and the condition (on or off) to be satisfied by using another SCAN command on the same read only variable. If the SCAN command is reassigned for a particular read only variable, any previous SCAN commands for that read only variable are no longer valid.

Examples: SCAN I13=OFF D32=PCMD
SCAN I16=ON D22=POS1

Velocity=XXX

The Velocity statement may be used once in a program to change the default Velocity parameter. The statement must be used before any motion statements since the Velocity parameter is used for motion profile calculations (unless overridden by a motion statement specifying velocity such as MOVD=100,V=1000). The new Velocity parameter will remain valid for the current program being edited unless the Velocity statement is changed or deleted. The new Velocity parameter will not affect other programs. If the Velocity statement is not used, the current Velocity parameter value is used for motion profile calculations.

Example: VEL=100

WAIT IXX**=ON/OFF**

Wait for input. Program execution is delayed until the specified input IXX is in the proper state (ON or OFF), then the next statement in the program is executed. Valid inputs are I01 through I16 inclusive. A space (' ') may be used in place of the '='. **NOTE**: Enter the number '0' when specifying the input number, not the letter 'O'.

Examples: WAIT I01=ON
WAIT I13 OFF

WIndow=XX

The WIndow statement can be used at any time in a program to alter the size of the in position window. The new size of the window will remain valid until another window statement is encountered. If the Window statement is not used in a program, the current Window parameter value is used to determine if the machine is in position after a motion profile.

Example: WINDOW=.05

SECTION VI - SETUP

6.1 **User Adjustments**

There are NO potentiometer adjustments. All user parameters and tuning adjustments are input and displayed via an RS-232 input terminal, or host computer system.Setup

6.2 **Steps for Setup**

1. Verify that the AC power input is wired correctly for the voltage available according to Section 3.3 of this manual.

2. Assemble the equipment needed as specified in Section 6.2.1.

3. Follow the setup procedure outlined in Section 6.2.2 or Section 6.2.3.

6.2.1 Setup Equipment Required

1. LED and 2.2k ohm resistor to observe the in-position output. (This LED/resistor combination may be wired to the in-position output for observation during the tuning process, see drawing 9097-1087 for connection details.)

2. Oscilloscope for observing the VCS and/or the tachometer signals.

6.2.2 Tuning Procedure for Torque Mode Servo Systems

Torque mode servo systems are distinguished from velocity mode servo systems by the command input to the servo drive. The input to a torque mode servo is a torque command. The position and velocity regulators are external to the servo drive. Note that using the PRO-450 to control the torque mode servo requires the KD parameter to be non-zero. **Failure to input KD can result in instability**. The following instructions are guidelines for tuning the PRO-450 to work with torque mode servos. Note that due to large differences between systems, the formulas used will provide approximate (not necessarily optimal) numbers to be used for tuning.

1. Using the formula for calculating KP in Section 6.2.5, calculate the appropriate value for KP and enter it.

2. Using the formula for calculating KD in Section 6.2.4, calculate the appropriate value for KD and enter it. The actual value of KD is not critical, so the calculated value of KD should not have to be fine-tuned, provided the values used to calculate KD are accurate.

3. Set the Offset removal parameter to OFF, KFF parameter to 0, and KI parameter to 0.

4. Set FELimit and FETime parameters to the maximum allowed to avoid excess following error faults while tuning.

5. Open the in-position WIndow to allow the motion program to execute without the delays caused by any position loop offset. (A reasonable window size is 50 encoder counts.) For example, if the Scale parameter is set so 1 user unit = 8,000 encoder counts, then a reasonable in-position WIndow value would be 50/8,000 = 0.006.

6. Enter a small motion program which will move the axis a specified distance and then return. Verify that it is a trapezoidal move (that is, it accelerates to a velocity, travels a certain distance at that velocity, then decelerates to a stop). If it is triangular, then increase the distance of the

move until it is trapezoidal. Executing this test program will allow the effects of changes in KP to be verified with the oscilloscope.

7. While observing VCS (velocity command output of the PRO-450, P6-3) with the oscilloscope, adjust KP for the quickest response with minimum overshoot. See drawings 9097-1088 or 90971066 for VCS and VCS return pin locations.

8. Adjust following error limits. Set the FELimit parameter to its maximum value, and adjust the FETime parameter to be slightly longer than the time necessary to reach maximum traverse velocity.

6.2.3 Tuning Procedure for Velocity Mode Servo Systems

Velocity mode servo systems are distinguished from torque mode servo systems by the command input to the servo drive. The input to a velocity mode servo is a velocity command. The position regulator is external to the servo drive and the velocity regulator is internal to the servo drive. The following instructions are guidelines for tuning the PRO-450 to work with velocity mode servos. Note that due to large differences between systems, the formulas used will provide approximate (not necessarily optimal) numbers to be used for tuning.

1. Using the formula for calculating KP in Section 6.2.5, calculate the appropriate value for KP and enter it.

2. Set the Offset removal parameter to OFF, KFF parameter to 0, KI parameter to 0, and KD parameter to 0.

3. Set FELimit and FETime parameters to the maximum allowed to avoid excess following error faults while tuning.

4. Open the in-position WIndow to allow a motion program to execute without the delays caused by any position loop offset. (A reasonable window size is 50 encoder counts.) For example, if the Scale parameter is set so 1 user unit = 8,000 encoder counts, then a reasonable in-position WIndow value would be 50/8,000 = 0.006.

5. Adjust KP. Enter Tune mode (the drive must be enabled). Enter the position and period values to be used (0.25, 0.5 are reasonable values). The motor will then move back and forth. Enter '**KP**' [**ENTER**] to view the current setting of the KP parameter. If the motor response seems sluggish, slightly increase the value of KP. If the motor response is too stiff, enter a slightly lower KP value.

6. While observing tachometer feedback, or VCS (velocity command output of the PRO-450, P63), with the oscilloscope, adjust KP for the quickest response with minimum overshoot. (The waveform should match that of Figure 5-2.) When the desired results are achieved, press '**Q**' [**ENTER**] to exit the Tune mode. See drawings 9097-1088 or 9097-1066 for VCS and VCS return pin locations.

7. Adjust KFF. Using the formula for calculating KFF in Section 6.2.6, calculate the value of KFF for 75% velocity feedforward. Enter a small motion program which will move the axis a specified distance and then return. Verify that it is a trapezoidal move (that is, it accelerates to a velocity, travels a certain distance at that velocity, then decelerates to a stop). If it is triangular, then increase the distance of the move until it is trapezoidal. Executing this test program will allow the effects of changes in KFF to be verified with the oscilloscope. If more or less feedforward is desired, use this value for a starting point and slightly change the value of KFF, observing the

effects on VCS with the oscilloscope while executing the test program. A KFF value that is too large will cause overshoot.

8. Adjust following error limits. Monitor the peak following error on the status display line while executing the test program to capture the maximum following error generated during a move. A value 10 to 20% larger than this value should be entered for the FELimit parameter. Set the FETime parameter to no longer than the time to reach maximum traverse velocity, and decrease the value by repeated trials to find the minimum time that does not give false excess following error faults during the execution of the test program. If these limits are small, then excess following error faults, such as loss of encoder or loss of tachometer, can be detected early and possible damage avoided.

6.2.4 KD Calculation

KD represents a damping adjustment. When the PRO-450 is connected to a velocity mode servo, KD may be used to increase damping for a given value of KP. For a torque mode servo, it is used to replace a tachometer. The following equation computes KD for the tachless, torque mode servo:

$$KD = \frac{15{,}360{,}000}{Vmax \times Kenc} \text{ (updates)}$$

where Vmax = maximum motor velocity in RPM
Kenc = (# of encoder lines) x 4

For example:

With Vmax = 3,000 RPM, Kenc = 2,000 x 4 = 8,000,

$$KD = \frac{15{,}360{,}000}{3{,}000 \times 8{,}000} = 0.64 \text{ updates}$$

6.2.5 KP Calculation

KP represents a position loop bandwidth adjustment. The following equation may be used to determine the value of KP given the desired position loop bandwidth in ipm/mil (inches per minute per mil). If the desired bandwidth is given in Hertz, divide it by 2.65 to convert to ipm/mil.

For velocity servos:

$$KP = \frac{204{,}800 \times BWposn}{Vscl \times Kenc} \text{ (counts per count)}$$

NOTE: If the position loop bandwidth is unknown, and the velocity loop bandwidth is known, multiply the velocity loop bandwidth (in Hertz) by 0.3 to get a reasonable position loop bandwidth value (in Hertz). If neither position loop or velocity loop bandwidth is known, use BWposn = 1 ipm/mil.

For torque servos:

$$KP = \frac{2{,}048{,}000 \times BWposn}{Vmax \times Kenc} \text{ (counts per count)}$$

where BWposn = position loop bandwidth in ipm/mil
Vscl = velocity servo scaling in RPM per volt
Kenc = (# of encoder lines) x 4
Vmax = maximum motor velocity in RPM

For example, for a velocity servo:

With BWposn = 1 ipm/mil, Vscl = 300 RPM/volt, &

Kenc = 2,000 x 4 = 8,000,

$$KP = \frac{204{,}800 \times 1}{300 \times 8{,}000} = 0.09 \text{ counts per count}$$

6.2.6 KFF Calculation

KFF represents a following error adjustment. KFF may be used to reduce the difference between commanded position and actual position when the system is moving. The following equation computes KFF for a given percentage of velocity feedforward:

For velocity servos:

$$KFF = \frac{30{,}720 \times FF\%}{Vscl \times Kenc} \text{ (updates/count)}$$

For torque servos:

$$KFF = \frac{307{,}200 \times FF\%}{Vmax \times Kenc} \text{ (updates/count)}$$

where
FF% = velocity feedforward percentage (range: 0 - 100%)
Vscl = velocity servo scaling in RPM per volt
Kenc = (# of encoder lines) x 4
Vmax = maximum motor velocity in RPM

NOTE: A reasonable value for FF% is 75%. Values greater than 75% tend to produce overshoot in the position loop response.

For example, for a velocity servo:

With FF% = 75%, Vscl = 300 RPM/volt, &

Kenc = 2,000 x 4 = 8,000,

$$KFF = \frac{30{,}720 \times 75}{300 \times 8{,}000} = 0.96 \text{ updates/count}$$

SECTION VII - MAINTENANCE

7.1 Scheduled Maintenance

The PRO-450 has been designed to require minimum maintenance. The following are suggestions for preventive maintenance:

1. Keep the PRO-450 as clean as possible. This will result in cooler operation and more reliable performance.

2. Ensure that the printed circuit boards do not collect metal particles that may cause short-circuits.

3. Periodically check that all connections and fasteners are tight.

4. Check the incoming AC line periodically for high or low line conditions. If the line is consistently high or low, correct the AC distribution system (plant transformer taps, etc.).

7.2 Troubleshooting, Replacements, and Repairs

7.2.1 Troubleshooting

The PRO-450 controllers are very reliable units, designed for years of trouble-free operation. Sections 7.2.4 through 7.2.6 list the most common symptoms of problems and probable causes to help in troubleshooting.

7.2.2 Replacements

Section VIII of this manual lists replacement assemblies that may be ordered from Reliance Motion Control. Consult Reliance Motion Control Field Service about recommended replacement procedures.

7.2.3 Repairs

Reliance Motion Control does not recommend on-site user repairs of the PRO-450 controller circuits and subassemblies. The only repairs that should be done are minor repairs such as broken wires, loose terminals, open fuses, etc. **Unauthorized alterations or disassembly of the PRO-450 will void the warranty.**

7.2.4 PRO-450 System Problems and Possible Causes

LED Status indicator OFF

1. No AC power to controller/amplifier

2. Fuse(s) F2, F3 open (stand alone only)

3. Defective power supply (check TP4 thru TP7 on controller card) See drawing 9097-1066

4. Defective controller card

No 24 volts between P2, pin 1 and P1, pin 12

1. Fuse F4 open (stand alone only)
2. P7 disconnected on controller card (stand alone only)
3. Defective power supply card (stand alone only)
4. Defective power supply on amplifier

Motor responds to commands only in one direction

1. FAC or RAC clamp active on drive
2. Software forward or reverse limits active on controller card
3. Defective or missing limit switch
4. Defective controller card

No VCS output to servo

1. ±15 volt regulators on power supply card defective
2. Defective controller card

Inaccurate positioning

1. Noisy encoder lines (check shielding per Section 4.2.4)
2. Defective encoder
3. Defective controller card

No HOME SEQUENCE COMPLETE or IN-POSITION Output

1. Not within In-position Window -adjust servo amplifier offset, enable Auto Offset, or increase In-position Window
2. HOME SEQUENCE COMPLETE or IN-POSITION Outputs disabled in Parameter mode

Inputs I09-I16 don't change state

1. Some of the positions on dip switch SW1 set to on (see drawing 9097-1066)

7.2.5 Communication Problems and Possible Cures

Terminal displays 'PRO>' prompt only--cannot access program editor

1. Operator parameter may be enabled; if so, operator switch (I12) must be on to access program and parameter editors

Terminal displays 'WHAT? Err detected' in response to any key stroke

1. A program Load was aborted or a program without an END statement was loaded - the PRO-450 is waiting for an END statement to indicate the end of the file - type 'END [**ENTER**]' to get out of the program load mode.

No Communications between PRO-450 and Serial Terminal

1. Check baud rate, parity, data, and number of stop bits settings on serial terminal (see Section 5.1)

2. Press Ctrl-Q (send XON)

3. If using a Tandy, press Shift-Break (Tandy may be locked up--this will clear it)

4. If the terminal beeps when a key is pressed, press DEL or BKSP a few times (this will clear some space in the serial buffer in the PRO-450), then press ENTER

5. If Host mode is being used, a Ctrl-B must be the first character sent followed by the slave's address; the address must be sent in decimal NOT ASCII (for example, send a '2' for address 2, not a '50' which is an ASCII 2--same as 32 Hex)

6. If Host mode is being used, and you don't know the correct address of the slave, disconnect all other PRO-450's on the serial cable. Power down the PRO-450 that you want to address, then power up the PRO-450 and send a carriage return (CR) within the first second of applying power.

7. Check jumpers W13-15 for the correct communications mode: RS-232 or RS422; (factory default setting is RS-232) refer to drawing 9097-1066 for correct settings

8. If using a Tandy, and there is no cursor, press ESC-P to restore the cursor (ESC-Q hides the cursor)

9. Make sure that the terminal ground and the PRO-450 ground are referenced to the same point

10. If using a PC for communication, make sure that the correct COM port is selected

7.2.6 Communications Problems Between PRO-450 and Operator Station

Display works, but incorrect characters are displayed

1. Check baud rate, parity, data and number of stop bits settings on Operator Station (see jumper settings below)

Display works, but keys do not

1. Make sure Operator parameter is ON and I12 is off

2. Check serial cable for open conductors (see drawing 9101-0136)

If 1. and 2. above are OK, run the self-test on the Operator Station. To run the self-test, remove power and disconnect the serial cable from the Operator Station. Move the jumper on the back of the unit from E10 and E11 to E11 and E12. Apply power to the Operator Station. The message "DISPLAY TEST" should appear on the display, followed by the software #, the baud rate, number of data bits, parity, and number of stop bits settings. Several other messages about the internal ROM and messages will then be displayed followed by a brightness test, then a character test. When the character test is complete, the display will read "READY" indicating that the unit is ready for the switch test. Pressing any key at this point will result in a "SWITCH DATA" message showing the corresponding hexadecimal codes for the key pressed.

To check the serial line drivers and receivers as well as the display and keypad, set up the unit for selftest as described above. In addition, move jumper E30 and E31 to E29 and E32 and connect TXD (J2 pin 2) to RXD (J2 pin 3). The test will run exactly like the display test except the "SWITCH DATA" message will be replaced by a "LAST BYTE IN" message and the corresponding hexadecimal codes will be shown when a key is pressed. When the test is complete, return the jumpers to their original positions (E10 and E11, E30 and E31).

If the Operator Station fails any part of the self-test, it is defective and should be replaced.

The factory jumper settings are shown below:

Reserved	E19..... ___		E26	Reserved
1 Stop Bit	E18..... ___		E25	2 Stop Bits
7 Data Bits	E17..... ___		E24	8 Data Bits
Reserved	E16..... ___		E23	Reserved
Odd Parity	E15..... ___		E22	Even Parity
Enable Parity	E14	___.....	E21	Disable Parity
9600 Baud	E13..... ___		E20	19200 Baud
Self Test	E12	E11.....	E10	Normal Operation
Reserved	E9.....	E8	E7	Reserved
Op Ready	E38	E37	E36	Host Ready
Host Ready	E35	E34	E33	Op Ready
Op Ready	E32	E31.....	E30	Host Ready
Host Ready	E29	E28	E27	Op Ready
TXD	E6	E5.....	E4	RXD
RXD	E3	E2.....	E1	TXD

SECTION VIII - REPLACEMENT PARTS

8.1 List of Replacement Parts

The following is a listing of replacement parts and assemblies for the PRO-450 position controller. Use the Electro-Craft part numbers when ordering or consulting the factory.

LIST OF REPLACEMENT PARTS

ELECTRO-CRAFT P/N	DESCRIPTION
8175-4026	32K Nonvolatile RAM
9097-0337	Operator Station Power Supply
9097-1009	PRO Chassis With Power Supply
9097-1025	Fuse kit (220 VAC)
9097-1040-010	Cable, PRO P5 to Tandy 102 Terminal, or Electro-Craft Operator Station (25 Pin D)
9097-1079	PRO series stand alone Connector Kit (crimp pins and housings for PRO connectors P3-P6 and plug-in screw terminal blocks for P1,P2)
9097-1091	PRO-450 stand alone Cover
9097-1093	Electro-Craft Operator Station Power Connection Kit
9097-1094	Electro-Craft Operator Station
9097-1108-010	Cable, PRO P5 to IBM PC (9 Pin D)
9097-1116	PRO-450 Controller Card Kit for BRU- and BSA-Series only
9097-1117	PRO-450B Controller Card Kit for BRU- and BSA-Series only
9097-1120	Interconnect Kit, PRO series Controller Card to BRU- or BSA-Series (PRO Connectors P1-P6, and P8)
9097-1126	Complete stand alone PRO-450
9097-1135	Complete stand alone PRO-450B
9101-0163	Serial Terminal (Tandy 102 Cat. No. 26-3803)
9101-0164	Serial Terminal AC Adaptor (Tandy AC Adaptor, Cat. No. 26-3804)

Reference Drawings

SECTION IX - REFERENCE DRAWINGS

9.1 **List of Drawings**

Drawing Number	Description
9097-1016	Outline and Mounting Diagram
9097-1017	Power Supply Component Location
9097-1022	PRO Connections to Electro-Craft Servo Amplifiers (Except BRU- & BSA-Series)
9097-1066	Controller Card Component Location
9097-1067	PRO-450 Signal Interface
9097-1087	PRO-450 Input/Output Connections
9097-1088	PRO-450 Connections
9097-1089	PRO-450 Operator Station Outline Drawing
9097-1127	PRO-Series Kit for BRU-500 Drive Module
9097-1128	PRO-Series Kit for BRU-200 Drive Module
9097-1129	PRO-450B Input/Output Connections
9097-1130	PRO-450B Connections
9101-0136	Serial Terminal Connections
9106-0011	Installation Diagram, PRO Kit to BSA-Series

APPENDIX A Getting Started with Serial Terminals

Getting Started with the Tandy 102 Computer

The following procedure outlines the steps required to establish communications with the PRO-450 using the Tandy 102. Refer to the Tandy 102 owner's manual for switch locations and initial power up instructions.

1. After powering up the Tandy 102, press function key F8 to bring the Tandy main menu to the screen.

2. Move the program selector using the arrow keys or the space bar to the 'TELCOM' program and press [**ENTER**]. The telecommunications program will be executed which allows the Tandy 102 to talk to the PRO-450.

3. The top line of the screen is the status code which shows the TELCOM communication parameters (for example, 'M7I1D,10 pps'). This code must be changed before the Tandy 102 will talk to the PRO-450. To change the code, press function key F3. The 'STAT' prompt will be displayed beside 'TELCOM:'.

4. Enter **88N1E** [**ENTER**]. This sets the TELCOM communication parameters to 9600 baud, 8 bit character length, no parity, 1 stop bit, and XON/XOFF enabled. If another baud rate is desired, the PRO-450 must have the Baud parameter set to Autobaud or to the new baud rate before trying to communicate. Refer to the Tandy 102 owner's manual for further explanation of the TELCOM communication parameters.

5. Select terminal mode by pressing function key F4.

6. Terminal mode functions are displayed on the bottom line of the screen. The word 'FULL' (full duplex) should be displayed above [4]. If 'HALF' (half duplex) is displayed, press function key F4 to change to 'FULL'. Press [**ENTER**] to establish communication with the PRO-450 ('PRO>' prompt will be displayed). **NOTE**: If there is no blinking cursor on the screen, press **ESC P** to display the cursor (**ESC Q** hides the cursor).

Getting Started with the NEC PC-8300

The following procedure outlines the steps required to establish communications with the PRO-450 using the NEC PC-8300. Refer to the NEC PC-8300 user's guide for switch locations and initial power up instructions.

1. After powering up the NEC PC-8300, press function key F.10 (SHIFT + F.5) to bring the NEC main menu to the screen.

2. Move the program selector using the arrow keys or the space bar to the 'TELCOM' program and press [**ENTER**]. The telecommunications program will be executed which allows the NEC PC8300 to talk to the PRO-450.

3. The top line of the screen is the status code which shows the TELCOM communication parameters (for example, 'MN71XSP10'). This code must be changed before the NEC PC-8300 will talk to the PRO-450. To change the code, press function key F.3. The 'STAT' prompt will be displayed beside 'TELCOM:'.

4. Enter **8N81XNP10** [**ENTER**]. This sets the TELCOM communication parameters to 9600 baud, no parity, 8 bit character length, 1 stop bit, and XON/XOFF enabled. If another baud rate is desired, the PRO-450 must have the Baud parameter set to Autobaud or to the new baud rate before attempting communication. Refer to the NEC PC-8300 user's guide for further explanation of the TELCOM communication parameters.

5. Select terminal mode by pressing function key F.4.

6. Terminal mode functions are displayed on the bottom line of the screen. The word 'FULL' (full duplex) should be displayed above the F.2 key. If 'HALF' (half duplex) is displayed, press function key F.2 to change to 'FULL'. Press [**ENTER**] to establish communication with the PRO450 ('PRO>' prompt will be displayed). **NOTE**: If there is no blinking cursor on the screen, press **ESC P** to display the cursor (**ESC Q** hides the cursor).

APPENDIX B Program/Parameter Save/Load
Program/Parameter Save/Load with a Tandy 102 Computer

RAM memory in the Tandy 102 may be used for storing a copy of a PRO-450 motion program or the parameter table. This appendix describes the procedure to be used for *saving* programs or parameters *from* the PRO-450 *to* the Tandy 102 and for *loading* saved programs or parameters *from* the Tandy 102 *to* the PRO-450.

NOTE: The terms '**SAVE**' and '**LOAD**' as used by the PRO-450 correspond to the terms '**DOWNLOAD**' AND '**UPLOAD**' as used by the TELCOM communications program.

To Save Programs/Parameters to the Tandy 102

1. Make sure the PRO-450 is in the Execution mode ('PRO>' prompt).

2. To save a program, go to the Program Edit mode (enter **EDIT X** [**ENTER**] where X is the number of the program to be saved). To save the parameter table, go to the Parameter mode (enter **P** [**ENTER**]).

3. Issue the save command by entering **SAVE** [**ENTER**]. The text on the screen will instruct you to prepare to capture the program/parameters. The PRO-450 will now wait to start the capture mode.

4. To start the capture mode on the Tandy 102, press function key F2. The Tandy will ask for the filename (6 or fewer characters) of the file to be saved (downloaded). Enter the filename and press [**ENTER**]. The word 'DOWN' above key F2 will be highlighted to show that the function is on. (**NOTE**: if the labels above the function keys on the Tandy 102 have been turned off, press the 'LABEL' key to re-display the labels). The Tandy is now ready to capture the program/parameters.

5. Press [**ENTER**] again to start the save operation. If saving a program, the program will be displayed as it is being saved. If saving parameters, a combination of numbers and symbols will be displayed.

6. When the save operation has been completed ('END' statement displayed if saving a program, 'PAR>' prompt displayed if saving parameters), press the F2 key to exit the capture mode ('DOWN' is no longer highlighted). **NOTE**: Failure to press the F2 key to exit the capture mode will result in all subsequent information displayed on the screen to be stored under the filename selected in the Tandy 102.

7. If in Program Edit mode, press [**ENTER**] to return to the 'EDIT>' prompt. If in Parameter mode, the 'PAR>' prompt is already displayed.

To Load Programs/Parameters from the Tandy 102

1. Make sure the PRO-450 is in the Execution mode ('PRO>' prompt) and is disabled.

2. To load a previously saved program, go to the Program Edit mode (enter **EDIT X** [**ENTER**] where X is the program number to receive the saved program from the Tandy 102). The PRO450 will display 'New program', and then the 'EDIT>' prompt. (If the program number already exists in the PRO-450, it can be deleted by entering **ERASE X** [**ENTER**] where X is the program number.) To load a previously stored parameter table, go to the Parameter mode (enter **P** [**ENTER**]).

3. Enter **LOAD** [**ENTER**] to start the load function of the PRO-450.

4. Press function key F3 to load (upload). The Tandy will reply with 'File to Upload?'. Enter the filename (6 or fewer characters) to be loaded and press [**ENTER**]. The Tandy replies with 'Width:'. Press [**ENTER**] again. The Tandy starts sending the file to the PRO-450 ('UP' will be highlighted). The display will show a series of dots (.....) rather than the actual program or parameter table.

5. When the program (or the parameter table) has been completely loaded, the message 'Load Completed' is displayed. Press **Q** to return to the Execution mode.

Program/Parameter Save/Load with a NEC PC-8300 Computer

RAM memory in the NEC PC-8300 may be used for storing a copy of a PRO-450 motion program or the parameter table. This appendix describes the procedure to be used for *saving* programs or parameters *from* the PRO-450 *to* the NEC PC-8300 and for *loading* saved programs or parameters *from* the NEC PC-8300 *to* the PRO-450.

NOTE: The terms '**SAVE**' and '**LOAD**' as used by the PRO-450 correspond to the terms '**DOWNLOAD**' AND '**UPLOAD**' as used by the TELCOM communications program.

To Save Programs/Parameters to the NEC PC-8300

1. Make sure the PRO-450 is in the Execution mode ('PRO>' prompt).

2. To save a program, go to the Program Edit mode (enter **EDIT X** [**ENTER**] where X is the number of the program to be saved). To save the parameter table, go to the Parameter mode (enter **P** [**ENTER**]).

3. Issue the save command by entering **SAVE** [**ENTER**]. The text on the screen will instruct you to prepare to capture the program/parameters. The PRO-450 will now wait to start the capture mode.

4. To start the capture mode on the NEC PC-8300, press function key F.5. The NEC will ask for the filename (6 or fewer characters) of the file to be saved (downloaded). Enter the filename and press [**ENTER**]. 'XMODEM?' will then be displayed. Press [**ENTER**] and the word 'DOWN' above key F.5 will be highlighted to show that the function is on. (**NOTE**: If the labels above the function keys on the NEC PC-8300 have been turned off, press **ESC T** followed by the **SHIFT** key [**ENTER**] to re-display the labels--**ESC U** [**ENTER**] hides the labels). The NEC is now ready to capture the program/parameters.

5. Press [**ENTER**] again to start the save operation. If saving a program, the program will be displayed as it is being saved. If saving parameters, a combination of numbers and symbols will be displayed.

6. When the save operation has been completed ('END' statement displayed if saving a program, 'PAR>' prompt displayed if saving parameters), press the F.5 key to exit the capture mode ('DOWN' is no longer highlighted). **NOTE**: Failure to press the F.5 key to exit the capture mode will result in all subsequent information displayed on the screen to be stored under the filename selected in the NEC PC-8300.

7. If in Program Edit mode, press [**ENTER**] to return to the 'EDIT>' prompt. If in Parameter mode, the 'PAR>' prompt is already displayed.

To Load Programs/Parameters from the NEC PC-8300

1. Make sure the PRO-450 is in the Execution mode ('PRO>' prompt) and is disabled.

2. To load a previously saved program, go to the Program Edit mode (enter **EDIT X** [**ENTER**] where X is the program number to receive the saved program from the NEC PC-8300). The PRO-450 will display 'New program', and then the 'EDIT>' prompt. (If the program number already exists in the PRO-450, it can be deleted by entering **ERASE X** [**ENTER**] where X is the program number.) To load a previously stored parameter table, go to the Parameter mode (enter **P** [**ENTER**]).

3. Enter **LOAD** [**ENTER**] to start the load function of the PRO-450.

4. Press function key F.4 to load (upload). The NEC will reply with 'File to Upload?'. Enter the filename (6 or fewer characters) to be loaded and press [**ENTER**]. The NEC replies with 'XMODEM?'. Press [**ENTER**] again. The NEC replies with Width?'. Press [**ENTER**] again. The NEC starts sending the file to the PRO-450 ('UP' will be highlighted). The display will show a series of dots (.....) rather than the actual program or parameter table.

5. When the program (or parameter table) has been completely loaded, the message 'Load Completed' is displayed. Press **Q** to return to the Execution mode.

APPENDIX C PRO-450 to PC Communication

Communication Using EC COMM

1. Connect cable from the PRO-450 serial port (P5) to the PC according to the following pinout:

PRO-450 P5		PC (9 Pin)	PC (25 Pin)
1 XMT-	2 RXD	3 RXD	
3 Signal GND	5 GND	7 GND	
5 RCV-	3 TXD	2 TXD	

If using RS-422, two additional connections must be made:

2 XMT+.....* RXD+ or B ..... * RXD+ or B 4
RCV+.....* TXD+ or B ..... * TXD+ or B

*--Correct pin numbers depend on RS-422 board being used

2. Invoke EC COMM--type '**ECC**' (for a monochrome monitor, type '**ECC /b**')

3. EC COMM will look for a file called ECC.CFG in the current directory to load parameters from; if there is no ECC.CFG file, one will be created and default parameters will be used:

Baud rate:	9600	BRU emulation
Parity:	none	Color monitor
Data bits:	8	Full Duplex
Stop bits	1	No LF after CR
Com1		

Parameters may be changed and then stored using the 'Alt S' command; for example, to save the monochrome monitor setting, use the '/b' command tail shown in 2 above, then press 'Alt S' once in EC COMM--when ECC is invoked again, the screen will be in monochrome rather than color; to return EC COMM to the default parameters, delete the ECC.CFG file

4. Press '**Alt P**' to set the communication parameters:
BAUD 9600 (or match baud rate of PRO-450)
PARITY NONE
DATA BITS 8
STOP BIT 1
Select correct COM port

If communicating with a BRU-200 or BRU-500 amplifier, select BRU; if communicating with a PRO-450, the terminal emulation may be set to either BRU or ANSI

5. Press [**ENTER**] to establish communication

6. If using RS-422 (multiple PRO-450s on the serial link), an individual PRO-450 may be selected very easily by pressing 'F1'. You will be prompted for the address of the slave PRO-450 to be selected. Enter the address and the PC will automatically send the STX (start of transmission) and the correct address. Press [**ESC**] instead of entering an address to clear any address

PRO-450 to PC Communication

currently selected. To select the global address (0), press [**ENTER**] alone (don't enter an address).

7. To SAVE a program/parameter table from the PRO-450 to the PC:

a.a. Enter PRO-450 Edit/Parameter Mode
a.b. Type **SAVE** [**ENTER**]
a.c. Press '**PgDn**'
a.d. Enter filename [**ENTER**] (including Directory) at prompt for file to be written to
a.e. Press [**ENTER**] to start file transfer
a.f. Press '**ESC**' to Halt Receive mode when transfer done

8. To LOAD a program/parameter table from the PC to the PRO-450:

a. FOLLOW steps 1-5 above to establish communication
b. Make sure the PRO-450 is disabled
c. Enter PRO-450 Edit/Parameter Mode
d. Type '**LOAD** [**ENTER**]'
e. Press '**PgUp**'
f. Enter filename [**ENTER**] (including Directory) at prompt for file to be loaded to the PRO--450
g. When transfer is complete, resume editing or exit the Edit/Parameter Mode

9. Press 'ALT H' for the Help screen

10. Press 'Alt F4' to return to DOS temporarily (DOS shell); once in the DOS shell type 'EXIT' to return to EC COMM

11. To exit EC COMM, press 'Alt X'

Communication Using PROCOMM

1. Connect cable from the PRO-450 serial port (P5) to the PC according to the following pinout:

PRO-450 P5	PC (9 Pin)	PC (25 Pin)
1 XMT-	2 RXD	3 RXD
3 Signal GND	5 GND	7 GND
5 RCV-	3 TXD	2 TXD

If using RS-422, two additional connections must be made:

2 XMT+	* RXD+ or B	* RXD+ or B	4
RCV+	* TXD+ or B	* TXD+ or B	

*--Correct pin numbers depend on RS-422 board being used

2. Invoke PROCOMM

3. Press '**Alt P**' to set the communication parameters:

BAUD 9600 (or match baud rate of PRO-450)
PARITY NONE
DATA BITS 8
STOP BIT 1
Select correct COM port

4. Press '**Alt S**' for SETUP MENU

5. Select TERMINAL OPTIONS

a. Set DUPLEX to FULL
b. Set XON/XOFF to ON
c. Press '**ESC**' to exit
d. Press '**ESC**' to exit the SETUP MENU

6. Press [**ENTER**] to establish communication

7. To SAVE a program/parameter table from the PRO-450 to the PC:

a. Enter PRO-450 Edit/Parameter Mode
b. Type **SAVE** [**ENTER**]
c. Press '**PgDn**'
d. Select 'ASCII' mode
e. Enter filename [**ENTER**] (including Directory) at prompt for file to be written to
f. Press [**ENTER**] to start file transfer
g. Press '**ESC**' to Halt Receive mode when transfer done

8. To LOAD a program/parameter table from the PC to the PRO-450:

a. FOLLOW steps 1-6 above to establish communication
b. Make sure the PRO-450 is disabled

PRO-450 to PC Communication

c. Enter PRO-450 Edit/Parameter Mode
d. Type '**LOAD** [**ENTER**]'
e. Press '**PgUp**'
f. Select 'ASCII' mode
g. Enter filename [**ENTER**] (including Directory) at prompt for file to be loaded to the PRO-450
h. When transfer is complete, resume editing or exit the Edit/Parameter Mode

9. To exit PROCOMM, press 'Alt X'

Communication Using BitCom

1. Connect cable from the PRO-450 serial port (P5) to the PC according to the following pinout:

PRO-450 P5	PC (9 Pin)	PC (25 Pin)
1 XMT-	2 RXD	3 RXD

3 Signal GND.....5 GND..... 7 GND
5 RCV- .....3 TXD ..... 2 TXD

If using RS-422, two additional connections must be made:

2 XMT+.....* RXD+ or B ..... * RXD+ or B 4
RCV+.....* TXD+ or B ..... * TXD+ or B

*--Correct pin numbers depend on RS-422 board being used

2. Invoke BitCom

3. Select '1' (Select/Edit Phone Numbers) from Main Menu

4. Select Record ID with arrow keys (if already defined), then go to step 7 5. If Record not defined, press F10 to define a Record ID

a. Enter name for Record ID
b. Set communications options using arrow keys:

Baud 9600 (or match PRO-450)	Echo No
Parity None	Mode Drct
Data 8	Ignore Both
Stop 1	Auto LF No

6. Press function key F2 to go back to Main Menu

7. Press **C** [**ENTER**] to establish connection

8. To SAVE a program/parameter table from the PRO-450 to the PC:

a. Enter PRO-450 Edit/Parameter Mode
b. Type **SAVE** [**ENTER**]
c. Press function key F2 to select Option Menu
d. Enter '1' to Receive File
e. Enter filename [**ENTER**] (including Directory) at prompt for file to be written to
f. Press [**ENTER**] to start file transfer
g. Press function key F2 to Halt Receive mode when transfer done
h. Press [**ENTER**] to exit PRO-450 SAVE mode

9. To LOAD a program/parameter table from the PC to the PRO-450:

a. FOLLOW steps 1-7 above to establish communication
b. Make sure the PRO-450 is disabled
c. Enter PRO-450 Edit/Parameter Mode
d. Type **LOAD** [**ENTER**]
e. Press function key F2 (Option Menu)
f. Enter '2' to Send file
g. Enter filename [**ENTER**] (including Directory) at prompt for file to be loaded to the PRO-450
h. Press [**ENTER**] to start file transfer
i. When transfer is complete, resume editing or exit the Edit/Parameter Mode

APPENDIX D Electro-Craft Operator Station (optional)

1. Introduction

The Electro-Craft standard Operator Station is ideally suited for applications that require user interaction. It features a bright 2 x 40 vacuum fluorescent display with a 22 position keypad. It is designed to be drip-proof and meets the requirements of NEMA 12. The Operator Station supports RS-232 serial communication.

2. Interface

Connect a cable from the PRO-450 serial port (P5) to the Operator Station according to the following pinout:

PRO-450 P5	Operator Station (25 Pin)
1 XMT-	3 RXD
3 Signal GND	7 GND
5 RCV-	2 TXD

3. Power Requirements

The Operator Station requires 5 VDC at 5.0 watts. The rise time of the power supply should be less than 100 mS. (Note that the 5 volts DC provided on the PRO-450 controller cannot be used to power the Operator Station.)

Connector Pin Assignments J1 (Power)

+ 5 VDC .....J1-1 Bell Output

(*).....J1-2

No Connection.....J1-3

Common.....J1-4

No Connection.....J1-5

Reset.....J1-6

(*) Open collector output 100 mA max. sink (+24 VDC max.)

4. Operation

To operate the Electro-Craft Operator Station, the Operator parameter should be "ON", and input I12 should be open (if closed, the display is still operational, however the keypad inputs are ignored). When any key is pressed, the controller identifies the terminal and changes the operation mode to that of the Electro-Craft Operator Station.

5. Control Codes

NOTE: DO NOT SEND UNDEFINED CONTROL COMMAND CODES TO THE OPERATOR STATION AS THIS MAY AFFECT THE DISPLAY OF THE TEXT TO BE PRINTED.

To customize the screen to the user needs, the following control codes may be programmed inside the "text" to be printed by the controller.

CONTROL CODE (HEX)	DESCRIPTION
^07	Enable bell output (150 ms)
^0B	Begin character blink field
^0C	End character blink field
^0E	Make cursor invisible
^0F	Make cursor visible
^16	Pause (creates a 3 second delay before processing next characters)
^19 ^0C	Clear display and home cursor (1st row, 1st column)
^19 ^0E	Home cursor (1st row,1st column)
^19 ^4C	Display blank
^19 ^4D	Display dim
^19 ^4E	Display bright
^19 ^4F	Display brightest (default)

^1B^x Position the cursor at location (x) - Example: ^1B,^[location number 00-4F]; 4F hex is equal to location 79 (2nd row, last column); the second row starts at location 40 (28 hex); a leading 0 must be used if the location is a single digit

Example:

To position the cursor at the first row and the 20th position, "^1B^14" should be entered. (Note that 1B,14 is the hexadecimal representation of

[ESC],20.) PRINT "^1B^14<-THIS IS POSITION 20" 6. Absolute Maximum

Ratings

Primary voltage:	+5.5 VDC
Bell output:	+30 VDC maximum (Open collector output) Load 100 ma maximum

7. Environmental Characteristics

Operating temperature:	32° to 131°F (0° to 55°C)
Relative humidity:	0 to 95% (non-condensing)

Vibration:	10 to 50 Hz 2mm peak-to-peak (3 axis)
Shock:	20 G (3 axis)

APPENDIX E Programming Examples

CUT TO LENGTH APPLICATION

In this example, the operator enters the cut length and the number of cuts from the Operator Station. After receiving the clear signal from the cutter, the motor moves the cut length distance and sends a cut signal.

```
INPUT "ENTER THE CUT LENGTH",D1.....Get the cut length
INPUT "ENTER BATCH COUNT",C1 .....Get the batch count
LOOP 1, C1.....Start the batch
WAIT I13=ON.....Wait until it is clear to move
OUT O1=ON .....Signal beginning of the move
MOVD D1.....Move the entered distance
OUT O1=OFF.....Signal end of the move (or cut signal)
RPT 1.....Continue until done
PRINT "BATCH DONE".....Send a finished message
END
```

SIMPLE TRACKING PROGRAM

The following is a simple tracking program. The PRO-450 tracks the command from a master encoder. In this program, if the commanded acceleration exceeds that of the programmed acceleration, the rate of the velocity change is clamped to the program acceleration. The gear ratio is one to one.

```
WAIT I13=ON.....Wait until I13 is ON
KI=.5 .....Turn on the integrator to
                                        reduce the following error to zero
GEAR 256/256 .....Set the gear ratio to one to one;
                                        start tracking
WAIT I13=OFF.....Wait until I13 is OFF
END
```

The above program is a velocity tracking program-the rate of velocity change is clamped by the program acceleration (a default setting in order to protect the system from exceeding its limit). If more exact position tracking is desired, the above program may be modified using the "CMDRate=OFF" command to disable the check on the commanded acceleration as shown below.

```
WAIT I13=ON.....Wait until I13 is ON
        CMDRate=OFF                     Do not check the command acceleration
KI=.5 .....Turn on the integrator to reduce the
                                        following error to zero
GEAR 256/256 .....Set the gear ratio to one to one;
                                        start tracking
WAIT I13=OFF.....Wait until I13 is OFF
END
```

In the programs above, the KI parameter and a nonzero ZONE parameter are required in order to bring the following error (the difference between the commanded position and actual feedback position) to zero. The KI parameter may also be set in the parameter table or could be set from Execution mode.
To make the program more flexible, variables may be used to change the gear ratio. In the following program the operator enters a number which corresponds to a different gear ratio.

```
FPRINT "^&ENTER GEAR RATIO X: Y".....Display instruction for the operator
FINPUT "^&FIRST ENTER X:",C1.....Get the first variable "X"
FPRINT "^&NOW ENTER Y:",C2 .....Get the second variable "Y"
C3=256.....Set C3 to constant 256
C4=C3*C1.....Multiply "X" by 256, because the denominator
                                                    of the GEAR instruction is 256
C4=C4/C2 .....Now divide the result by "Y"
WAIT I13=ON.....Wait until I13 is ON
CMDRate=OFF .....Do not check the command acceleration
KI=.5 .....Turn on the integrator to
                                                    reduce the following error to zero
GEAR C4/256.....Set the gear ratio to X:Y; start tracking WAIT
I13=OFF.....Wait until I13 is OFF
END
```

FLYING SHEAR PROGRAM

In this program, the PRO-450 is connected to a rotary cutter and monitors the distance moved by the master encoder. If the distance is equal to the cut length, the PRO-450 starts tracking the master encoder, and the blade cuts the material while moving. When the cutter is off the material, it moves to the starting position in the same direction, and waits for the next cut. For this program, the cut length should be longer than one user motor revolution.

```
CMDRate=OFF .....Do not check the command acceleration
INPUT "ENTER CUT LENGTH ",D1.....Ask for cut length; initialize variables
D2=POS2.....Record the current position of the master
                                                    encoder
D10=PCMD.....Record the position of the rotary cutter
D4=.5 .....Distance cutter will track the master
D12=1 .....Constant equal to one user unit
LBL AA.....Start monitoring master position
D3=POS2-D2 .....Measure the distance moved
IF D3<D1 JMP AA.....If distance moved is equal to cut length, then
KI=.5 .....Set integrator to minimize the following error
GEAR=256/256 .....Set gear ratio to 1:1 (start tracking)
LBL BB.....Monitor the cutter
D5=PCMD-D10.....Measure the distance moved by cutter
IF D5<D4 JMP BB.....If cutter is cleared from material, then
GEAR=0/256.....Stop tracking
KI=0 .....Turn off the Integrator
D10=D10+D12.....Calculate next cutter position
D11=D10-PCMD.....Calculate the distance to move
D2=D2+D1 .....Find position of next cut
MOVD=D11.....Go to next start position JMP
AA.....Repeat
END
```

RANDOM TIMING INFEED PROGRAM

In packaging applications, products are often fed to a machine on a conveyor belt in a random fashion. Many packaging machines require the random product position to be adjusted to a moving fixed reference point (flights, overhead sweeps, etc.). A "smart servo belt" consisting of two PRO-450s or one PRO-450 and one PRO-150 will provide uniform position spacing to match the moving reference point. The velocity of axis 1 (the master) may be controlled by any velocity controller; axis 2 and 3 are slaves (they follow axis 1 so any motion is relative to the master axis). Axis 3 is an accelerator belt; it may be programmed to have the same velocity or some multiple velocity of axis 1. Axis 3 separates the products so that axis 2 can position the products into the flights one at a time. The PRO-450 on axis 2 monitors the position of the flights. If a product is detected on the second belt, a make up distance is calculated and the motion is made (the makeup move is relative and is added to the position command from the master encoder) to ensure that the product will be positioned correctly within the flight.

```
ACCEL=20 .....Set acceleration (optional)
VELOCITY=15.....Set velocity (optional)
KI=.5 .....Turn on the integrator to reduce the following
        error to zero (no motion results if the motor        does not come within the in-position window)
SCAN I13=ON D1=POS2.....Start scanning input I13 and save the
                                                    position of the master encoder when the
                                                    flights are detected
GEAR=256/256 .....Start tracking the master by setting the GEAR
                                                    command
WAIT I13=ON.....Wait for the first flight
```

```
LBL AA
WAIT I14=ON.....Wait for a product
D2=POS2-D1 .....Calculate the make up distance
MOVD=D2.....Make the adjustment move
WAIT I14=OFF.....Wait until the product has cleared the sensor JMP
AA.....Continue the process
END
```

In this program the controller monitors the position of the flights by input I13. If any product is detected by input I14, the make up distance is calculated and made.

COIL WINDING APPLICATION

This is an example where the "GEAR" ratio may be changed while the program is running. The PRO450 is connected to a ball screw to guide the wires wound by the coil axis. The system must be homed before starting the program. The PRO-450 moves the guide in the forward and reverse direction at a ratio of the master velocity set by the GEAR command. When the guide reaches the width of the coil, it changes direction toward the starting point. It changes direction again when it reaches the beginning of the coil.

```
INPUT "ENTER COIL WIDTH",D1.....Get the coil width from operator
INPUT "ENTER GEAR SCALING",C1 .....Get the gear scaling
D2=0 .....D2 is home position
KI=.5 .....Turn on the integrator to reduce the following
                                                    error to zero (no motion results if the motor
                                                    does not come within the in-position window)
LBL AA
GEAR=C1/256.....Start going forward
LBL AB
IF PCMD<D1 JMP AB.....If end of the coil, then GEAR=-
C1/256 .....change direction
LBL BB
IF PCMD>D2 JMP BB.....If beginning of the coil,
JMP AA.....continue
```

RECIPROCATING GRINDER

A reciprocating grinder requires an operator to set the number of strokes, the distance, and the speed to machine a part. The grinder table is driven by a lead screw, and the work piece is mounted on the grinder table. The grinding wheel is mounted above the grinding table, and is indexed down following each stroke. An Operator Station is required to allow the grinder operator to change the operating parameters. The grinder table must be retracted to load and unload work pieces, and must have a simple operator interface.

A Electro-Craft PRO-450 controller and BRU-Series brushless servo drive are used to control the screw which drives the grinder table. The PRO-450 Operator Interface option connects to the RS-232 port of the PRO-450, and can be accessed in the motion program to prompt the machine operator to load and modify variables to change the distance, speed, or number of strokes for a part. The predefined distance, speed, and integer variables available in the PRO-450 simplify programming, and the flexible I/O capability provides uncomplicated machine control inputs.

```
WAIT I16 ON.....Wait until I16 is on to begin motion
LBL AA
MOVP -5, V=500.....Retract the grinding table to allow a part to be
                                                    loaded
FPRINT "^& RETRACT COMPLETE"
FPRINT "^& PRESS I14 FOR GRIND" .....Print message on operator terminal (^& is
                                                    carriage return and line feed)
WAIT I14 ON.....Wait until I14 is on to begin the grinding routine
LBL ZZ
FPRINT "^&"
FINPUT "^& ENTER STROKE(INCHES):",D1
FINPUT "^& ENTER SPEED(INCHES PER MIN):",S1
FINPUT "^& ENTER # OF STROKES:",C1.....The FINPUT command causes the PRO-450 to
        wait for an input from the operator interface        terminal; any text in quotation marks is printed     on the
screen as a prompt;  no other
                                                    instructions are executed until a valid input is
                                                    received
FPRINT "^& PRESS I16 TO START CYCLE"

WAIT I16 ON.....Wait for I16 on to begin motion
MOVP 0.....Move to position 0
LOOP 1,C1.....Beginning of loop 1
MOVD D1,V=S1.....Move the stroke distance forward at speed S1
MOVD  -D1,V=S1.....Return  stroke  at  speed  S1  OUT  01
ON .....Turn output 1 on

FPRINT "^& INDEX GRINDING WHEEL".....Print status message to operator terminal FPRINT "^&"
DWL 1.5.....Dwell 1.5 seconds
OUT 01 OFF .....Turn output 1 off
FPRINT "^& INDEXES TO COMPLETE = ",CT1
FPRINT "^&".....Print status message to operator terminal (CT1
                                                    is loop counter for loop 1)
RPT 1.....End of loop 1
FPRINT "^&^&^".....Clear display (do 2 carriage returns)
FPRINT "1B^0D" .....Position cursor at first row and 13th column
                                                    (0D=13 in decimal)
FPRINT "^0B CYCLE COMPLETE ^0C".....Display end of cycle (blinking format)
FPRINT "^&"
FPRINT "I15 = RETRACT"
FPRINT "I14 = GRIND"
```

```
LOOP 2,0.....Beginning of loop 2 (a repeat count of zero is
                                    an infinite loop)
IF I15=ON JMP AA
IF I14=ON JMP ZZ
RPT 2.....Loop until either I14 or I15 is selected
END
```

POSITION TRACKING FOR A BOTTLE-FILLING MACHINE

A conveyor feeds bottles through a fill station, which consists of fill nozzles mounted on a carriage which is driven by a lead screw. The filler carriage must track the speed of the conveyor during the fill operation, and then return and be in position to track and fill the next batch of bottles. The maximum throughput is 150 bottles per minute, and the fill operation requires 1.5 seconds. The bottle spacing is 2 inches on center, and the filler fills 10 bottles in one operation.

The filler carriage leadscrew is driven by a Electro-Craft brushless servo and a PRO-450 position controller. A master reference encoder on the conveyor provides feedback to the PRO-450 for tracking the bottle speed during filling. Two external sensors are also added, one to sense the position of a bottle and a second to sense the filler carriage home position. The outputs of these two sensors are used as inputs to the PRO-450. The PRO-450's programmable electronic gearing will precisely track the bottle speed during the fill operation. Once the filler carriage is tracking the bottle speed, the PRO-450 records the position of the carriage and bottle as indicated by the external sensors, and then calculates and executes a position correction move. After the correction is executed, an output from the PRO-450 indicates that the fill operation may begin. Once the fill operation is complete, indicated by an input to the PRO-450, the carriage returns to its original position and begins another cycle when the next batch of ten bottles is at the filler carriage. This program uses the PRO-450 SCAN input capability to detect the position of a bottle on the conveyor. After the filler is tracking the bottle speed, the PRO-450 math functions are used to calculate a position error and perform a correction move. Before the program is run, the home sequence must be completed, because absolute positioning commands are used. This program fragment assumes that the filler is at position 0 when started. Note that the Zone parameter is set to a value that is larger than the in-position Window parameter.

```
REM  BOTTLE FILLING PROGRAM
REM  RELIANCE MOTION CONTROL
REM  PRO-450 CONTROLLER
REM  LABEL AA DWELL ROUTINE
REM  LABEL BB TRACKING .....REM statements allow comments to be inserted at the
        start of a program. Multiple comment lines may be used,  each starting with a REM statement.
KI = 0.4.....Make sure integrator is on.
CMD=ON.....Limit the command acceleration from encoder 2.

SCAN I13=ON D1=POS2
SCAN I13=ON D2=CMD2.....Scan input I13 to detect a bottle. When a bottle is
        detected, store the master reference encoder position  POS2 in variable D1 and the position command
after the  gear, CMD2, in variable D2.

D11=9 .....Set variable D10 equal to the distance between each fill
operation minus one bottle. In this example, the scaling  is set so 1 unit equals 1 bottle.
LBL BB
WAIT I13 ON.....Wait at this instruction until input I13 is on.
GEAR=4096/256 .....Set gear ratio to track the conveyor speed.
D20=D1-D2 .....Calculate the difference between the encoder 2 input
        when the bottle was detected and the command after the  gear at the same time.

D10=D1.....Set D10 to the encoder 2 position when the bottle was
detected.

DWL 0.15.....Dwell for 150 milliseconds to allow the filler to accelerate  to  the
conveyor speed.
D21=POS2-CMD2.....Calculate the difference between the encoder 2 input
        and the command after the gear while the filler is tracking  the conveyor speed. For zero error, this
should be the  same as the difference calculated when the bottle was  detected. Using both POS2 and CMD2
in a single  program statement causes both variables to be read  within the same 2 millisecond instruction
time to  minimize calculation error.

D22=D21-D20.....Calculate the tracking error.
MOVD D22.....Make a relative move to correct the tracking error. Note
```

that this move is in addition to the command from the master reference encoder on the bottle conveyor.

OUT 01=ON.....Turn on output 1 to indicate that the filler is tracking and the fill nozzles can be lowered and the fill operation started.

WAIT I14 ON.....Continue tracking conveyor speed until input 14 turns on indicating the fill operation is complete and the fill nozzles are retracted.

OUT 01=OFF .....Turn output 1 off.
GEAR=0/256

DWL .15.....Set the gear ratio to zero and then wait 150 milliseconds for the filler to decelerate to zero speed.

MOVP 0.....Return the filler to the home position. If the filler has not decelerated to zero speed before this move is begun, the accumulated counts from the master reference encoder are added to the distance to move, and the final position will be off from the zero position.

LBL AA
D15=POS2-D10.....Calculate the encoder 2 position where the PRO-450 should begin looking for the tenth bottle to begin tracking for the next fill operation.

IF D15<D11 JMP AA.....Loop until nine empty bottles are under the filler carriage.
WAIT I13 OFF

JMP BB.....Wait until the ninth empty bottle is completely past the bottle sensor, then jump to the beginning of the tracking routine.
END

EFFECT OF MOVE SEGMENT CHANGES IN A COMPLEX PROFILE

This example shows the effects of changing move segments in a complex motion profile. Initially a program consists of the statements below.

PROGRAM PROFILE

```
LBL AA
D=5,V=400
O1 ON
D=5,V=600
O1 OFF
O2 ON
D=4,V=300 D=3,V=300
O2 OFF
D=2,V=0
DWL .5
IF I11=OFF JMP AA
END
```

Changing the first move segment from 'D=5,V=400' to 'D=5,V=800' will change the second move segment 'D=5,V=600' from an acceleration move segment to a deceleration move segment. The result will have no effect on the distance moved, however. The only change that occurs is how the PRO-450 arrives at the distance point in the motion profile. The new profile is shown below.

SPEED CHANGES ON THE FLY

This example shows how to change speeds on the fly using DV moves and combinations of 2 inputs to select between 4 different velocities. Each label section of the program represents a different velocity. Each different velocity is signified by a different output. In each section, there is an infinite loop which continues the move unless a condition is met. (The use of blank lines in the listing is used only for clarity.)

```
LBL AA
ALL OFF
O1 ON
LOOP 1,0
D .2,V 500 ..... Slow speed
IF (I11=OFF AND I12 ON)JMP AB..... Conditional velocity
        IF (I11=ON AND I12 OFF)JMP AC          selection section
IF (I11 ON AND I12 ON)JMP AD
RPT 1

LBL AB
ALL OFF
O2 ON
LOOP 2,0
D .2,V 1000 ..... Speed #2
IF (I11=OFF AND I12 OFF)JMP AA ..... Velocity selection
IF (I11=ON AND I12 OFF)JMP AC
IF (I11 ON AND I12 ON)JMP AD
RPT 2

LBL AC
ALL OFF
O3 ON
LOOP 3,0
D .2,V 1500 ..... Speed #3
IF (I11=OFF AND I12 OFF)JMP AA ..... Velocity selection
IF (I11=OFF AND I12 ON)JMP AB
IF (I11 ON AND I12 ON)JMP AD
RPT 3

LBL AD
ALL OFF
O4 ON
LOOP 4,0
D .2,V 2000 ..... Fastest speed
IF (I11=OFF AND I12 OFF)JMP AA ..... Velocity selection
IF (I11=OFF AND I12 ON)JMP AB
IF (I11 ON AND I12 OFF)JMP AC
RPT 4

END
```

PECK DRILL PROGRAM

This example shows the use of loops in a program to perform repetitive moves. The first line performs a rapid advance to the work piece. The next line drills the first inch of the hole. The third line names the program loop (1) and the number of times to repeat the loop (3). The fourth line of the program pulls the drill back one inch to relieve chip load. The fifth line rapidly returns the drill to the bottom of the hole. The next line drills one inch. The repeat line with the loop number marks the end of the loop (repeated three times in this example). The seventh line rapidly moves the drill back ten inches to the original starting point.

```
MOVD=6,V=100
MOVD=1
LOOP 1,3 MOVD=-1
MOVD=1,V=100
MOVD=1
RPT 1
MOVD=-10,V=100
END
```

MULTI-VELOCITY PROGRAM WITH A DWELL

```
LBL AA
```

```
MOVD=3,V=100
MOVD=5.5,V=200
MOVD=3,V=100
DWL 5
IF I12=ON JMP AA
END
```

This program shows how to mix velocities in a motion profile. After a start command, the axis moves a distance of 3 units at a velocity of 100, stops momentarily, moves 5.5 units at a velocity of 200, stops again, then moves 3 units at a velocity of 100. The program then waits (dwells) for 5 seconds. After 5 seconds, if input I12 is on, the program will jump to label AA and start over. If I12 is off after the dwell, the program ends.

A PROGRAM SELECTION TECHNIQUE

This example shows how to run different profiles within one program using inputs to select the desired profile. The label select section of the program enables different program branching depending on the external inputs. The start and stop positions can be determined with position moves if needed. The label select section loops until one of the four label select inputs goes true. The only priority associated with the conditional inputs is the order of program execution.

```
LBL AA
IF I16=ON JMP AB.....Conditional profile selection section
IF I15=ON JMP AC
IF I14=ON JMP AD
IF I13=ON JMP AE
JMP AA
LBL AB.....Rapid advance label
MOVP=0
MOVD=7
```

```
JMP AA
LBL AC.....Reciprocating move label
MOVD=5,V=100
MOVD=-5,V=100
JMP AA
LBL AD.....Rapid return label
MOVP=0
JMP AA
LBL AE.....Program end label
END
```

COORDINATION OF PROGRAM EXECUTION BETWEEN TWO PRO-450s

This example shows how to coordinate motion using two PRO-450s through I/O handshaking. The first PRO-450 controls an indexing rotary table that will control the output of bottles being fed to it by a leadscrew. The second PRO-450 controls the leadscrew. The I/O connections between the two PRO450s are shown in Figure E-2. Input I10 on the rotary table PRO-450 is used to control table motion. Input I02 is used as a 'stop' switch. A photo eye is used to detect the presence of bottles and is read by I09 on the leadscrew PRO-450. Input I10 on the leadscrew PRO-450 is used to control the motion of the leadscrew.

Figure E-1 Leadscrew-Rotary Table Example

Leadscrew

```
LBL AA
OUT O1 OFF
WAIT I1O ON
LOOP 1,0
D .5,V 500
D .5,V 0
IF I09 ON JMP DD
DWL .3
RPT 1
LBL DD
O1 ON
DWL .3
JMP AA
END
```

The start command turns off output O1 which disables the rotary table. The leadscrew program then waits for I10 to go true to start the move. When input I10 goes true, the leadscrew starts to move. The program enters an infinite loop while it waits for I09 (the photo-eye) to go true signifying the presence of a bottle. The infinite loop is used so the leadscrew will keep moving until a bottle is present.

When input I09 goes true (a bottle is present), the program exits the infinite loop and then turns on output O1 to signal the table to start its move.

After turning on output O1, the leadscrew program delays for a short while, then jumps back to the top of the program to repeat the process.

If the rotary program ends, the leadscrew program will wait for input I10 to go true which will not happen unless the rotary program is restarted.

Figure E-2 I/O Handshaking

SCALE CALCULATION EXAMPLE

The example below shows how to calculate the correct Scale parameter to equate move distances to inches when using a gear box and a ball screw. A motor with a 2,000 line encoder is driving a ball screw with a 0.5 pitch through a gear box with a ratio of 1.857:1. The calculation need be done only once and entered for the Scale parameter. All moves can then be programmed using inches rather than the more cumbersome encoder counts.

The gear ratio is 1.857:1 so:

1 rev ball screw = 1.857 motor revs

The pitch of the ball screw is 0.5 inch so:

1 inch travel = 2 revs ball screw

The PRO-450 multiplies the encoder line count times 4 so:

1 motor rev = 4 x 2,000 encoder lines = 8,000 encoder counts

Therefore:

1 inch travel = 2 revs ball screw x 1.857 motor revs =

3.714 motor revs

Scale = 3.714 motor revs x 8,000 encoder counts =

29,712 encoder counts

The Scale parameter is then set to 29,712 so that all moves can be entered in inches.

APPENDIX F Error Summary

PROGRAM EXECUTION ERRORS

Error Number	Description
3	Invalid opcode
6	Program acceleration = 0
9	Program velocity = 0
12	Negative acceleration
15	Move acceleration = 0
18	Negative move velocity
21	Move velocity = 0
24	Distance wrong direction
27	Move distance = 0
30	Acceleration time too great
33	Acceleration time too small
36	Move velocity too large
39	Move distance too large
51	Velocity operand = 0
54	Distance operand = 0
57	Deceleration operand = 0
60	Loop counter > 16
63	Jog velocity = 0
66	Default acceleration = 0
69	Home velocity = 0
72	Invalid macroopcode
75	Invalid opcode for Advance/Return
78	No constant vel DV move for Offset
81	Accel too low for ADV/RET or Pause
84	Divide by zero
87	Cannot find correct motion statement
90	Missing LBL AV or LBL TC in program
93	Outside motion profile cannot return to profile
96	Cannot find move to makeup
99	Absolute mode counter rolled over
102	Negative loop count
105	Velocity Variable = 0

APPENDIX G Summary of Commands/Mnemonics

**********EXECUTION MODE**********

Baud**R**ate
COpy XX YY
Define**H**ome
DELete XX
DIAgnostic
DIRectory
DISable
EDit XX
ENable
ERase XX
GEar=(-)XXXXX/256
Go
Help
HIst
HOme
Input
KD
KFF
KI
KP
MOVD=XXX[,**V**=YYY]
MOVP=XXX[,**V**=YYY]
MOVV=±XXX
Offset
Parameter
Query
RESet
RUn XX [Auto]
Status
Tune
X (Killmotion)
Zone

**********DIAGNOSTIC MODE**********

D/a converter test
Encoder test
Input test
Output test
Ram test
Quit

**********PROGRAM EDIT MODE**********

[**ENTER**]
Change
DELete
Goto XX
Insert
LIst
LOad
Quit
Save
Top
Up (/,-)

**********PARAMETER MODE**********

ABSolute **ON/OFF**
LOAd

ACceleration
AUto
EREturn **OFF/XXX**
FELimit
FETime
FLimit
Help
HOFfset
HVelocity
JVelocity
KD
KFf
KI
KP
OFfset removal **ON/OFF**
OPT
PAG2
PRogram
Quit
RLimit
ROTation
SAve
SCale
Timebase
Velocity
WIndow
Zone

**********OPTIONAL PARAMETER MODE**********

ADDress XX
ADVance **I07/I08/OFF**
AThome **ON/OFF**
Auto**B**au**D ON/OFF**
BAud (**0-5**)
DAc
DEbounce
Define**H**ome **ON/OFF**
ERRor **ON/OFF**
ESTop error **ON/OFF**
Go **ON/OFF**
home**SEQ**uencecomplete **ON/OFF**
Home**S**witch **OP**en/**CL**osed
HOSt **ON/OFF**
INDex **ON/OFF**
INPosn **ON/OFF**
JOg **ON/OFF**
LImit **ON/OFF**
LOCKfn **ON/OFF**
MAKeup **ON/OFF**
MAX offset
OPErator **ON/OFF**
PAuse **OPEN/CLOSED/OFF**
PGMrun
Window**T**ime

**********TUNE MODE**********

KD
KI
KP
Quit
Zone

**********PROGRAM STATEMENTS**********

ACceleration
KP

ALL ON/OFF
CMDrate=**ON/OFF**
D=XXX,**V**=YYY
DAc=X.XXX
DAc=Cxx/204.8
DE=XXX,**I**YY=**ON/OFF**
DH
DIF=XXX,**I**YY=**ON/OFF JMP** ZZ
DISable
DWL=XX
ENAble
EV,IXX=**ON/OFF**
FELimit
FETime
GEar=[-]XXXXX/256
GEar=[-]**C**xx/256
IF IXX=**ON/OFF JMP** YY
IF var1<var2 **JMP** XX
IF var1>var2 **JMP** XX
IF var1=var2 **JMP** XX
IF(IXX=**ON/OFF AND I**YY=**ON/OFF)JMP** ZZ
IF(IXX=**ON/OFF OR I**YY=**ON/OFF)JMP** ZZ
IF(IXX=**ON/OFF XOR I**YY=**ON/OFF)JMP** ZZ
INPUT/FINPUT "text",variable
JMP XX
KD
KFF
KI
LBL XX
LOOP XX, **C**xx
LOOP XX, YYYYY
MOVD=[-]**D**xx[**,V**=Sxx]
MOVD=XXX[,**V**=YYY]
MOVP=XXX[**,V**=YYY]
NFD
OFfset
OX=**ON/OFF**
PFD
PRINT/FPRINT "text",variable
REM
RPE XX
RPT XX
SCALe
SCAN IXX=**ON/OFF D**xy=read only vars
Var1=Constant
Var1=Var2+Var3
Var1=Var2-Var3
Var1=Var2*Constant [fast]
Var1=Var2***C**xx [regular]
Var1=Var2/**C**xx(**C**xx=Var1/Var2)
Velocity
WAIT IXX=**ON/OFF**
WIndow

Variables:

Distance Variables:	D1--D32, POS1, POS2, PCMD, CMD2
Speed Variables:	S1--S16
Integer Variables:	C1--C16

Profile Equations

APPENDIX H Profile Equations

The following equations show the relationships between distance, acceleration, velocity, and time required to make a move. (A triangular motion profile is assumed.) If two of the variables are known, the other variables may be calculated using the equations below. The time variable is the theoretical time required to make a move. The time will be longer if there are any mechanical losses in the system (couplings, belts, gearboxes, etc.).

The variables are:

Acceleration (a) in units/time$^{\cdot\cdot}$

Velocity (v) in units/time

Total Move Distance (D) in units

Total Move Time (T) in seconds or minutes

Accel/Decel distance (d) in units (=D/2)

Accel/Decel time (t) in seconds or minutes (=T/2)

Acceleration:

$a=v/t$

$a=v^{\cdot\cdot}/2d$

$a=2d/t^{\cdot\cdot}$

Distance:

$2d=at^{\cdot\cdot}$

$2d=v^{\cdot\cdot}/a$

$2d=vt$

Velocity:

$v=2d/t$

$v^{\cdot\cdot}=2da$

$v=at$

Time:

$t^{\cdot\cdot}=2d/a$

$t=v/a$

$t=2d/v$

APPENDIX I ASCII Codes

Ctrl	Decimal No.	Symbol	Decimal No.	Symbol	Decimal No.
00	+	43	V	86	
01	,	44	W	87	
02	-	45	X	88	
03	.	46	Y	89	
04	/	47	Z	90	
05	0	48	[	91	
06	1	49	\	92	
07	2	50	]	93	
08	3	51	^	94	
09	4	52	_	95	
10	5	53	`	96	
11	6	54	a	97	
12	7	55	b	98	
13	8	56	c	99	
14	9	57	d	100	
15	:	58	e	101	
16	;	59	f	102	
17	<	60	g	103	
18	=	61	h	104	
19	>	62	i	105	
20	?	63	j	106	
21	@	64	k	107	
22	A	65	l	108	
23	B	66	m	109	
24	C	67	n	110	
25	D	68	o	111	
26	E	69	p	112	
27	F	70	q	113	
28	G	71	r	114	
29	H	72	s	115	
30	I	73	t	116	
31	J	74	u	117	
		K	75	v	118
Decimal No.	L	76	w	119	
	M	77	x	120	
32	N	78	y	121	
	33	O	79	z	
	34	P	80	{	
35	Q	81	|	124	
36	R	82	}	125	
37	S	83	~	126	
38	T	84	DEL	127	
39	U	85			
	40				
	41				

ASCII Codes

APPENDIX J Decimal To Hexadecimal Conversion

Hex	48	30	97	61	146	92	195	C3
00	49	31	98	62	147	93	196	C4
01	50	32	99	63	148	94	197	C5
02	51	33	100	64	149	95	198	C6
03	52	34	101	65	150	96	199	C7
04	53	35	102	66	151	97	200	C8
05	54	36	103	67	152	98	201	C9
06	55	37	104	68	153	99	202	CA
07	56	38	105	69	154	9A	203	CB
08	57	39	106	6A	155	9B	204	CC
09	58	3A	107	6B	156	9C	205	CD
0A	59	3B	108	6E	157	9D	206	CE
0B	60	3C	109	6D	158	9E	207	CF
0C	61	3D	110	6E	159	9F	208	D0
0C	62	3E	111	6F	160	A0	209	D1
0E	63	3F	112	70	161	A1	210	D2
0F	64	40	113	71	162	A2	211	D3
10	65	41	114	72	163	A3	212	D4
11	66	42	115	73	164	A4	213	D5
12	67	43	116	74	165	A5	214	D6
13	68	44	117	75	166	A6	215	D7
14	69	45	118	76	167	A7	216	D8
15	70	46	119	77	168	A8	217	D9
16	71	47	120	78	169	A9	218	DA
17	72	48	121	79	170	AA	219	DB
18	73	49	122	7A	171	AB	220	DC
19	74	4A	123	7B	172	AC	221	DD
1A	75	4B	124	7C	173	AD	222	DE
1B	76	4C	135	7D	174	AE	223	DF
1C	77	4D	126	7E	175	AF	224	ED
1D	78	4E	127	7F	176	B0	225	E1
1E	79	4F	128	80	177	B1	226	E2
1F	80	50	129	81	178	B2	227	E3
20	81	51	130	82	179	B3	228	E4
21	82	52	131	83	180	B4	229	E5
22	83	53	132	84	181	B5	230	E6
23	84	54	133	85	182	B6	231	E7
24	85	55	134	86	183	B7	232	E8
25	86	56	135	87	184	B8	233	E9
26	87	57	136	88	185	B9	234	EA
27	88	58	137	89	186	BA	235	EB
28	89	59	138	8A	187	BB	236	EC
29	90	5A	139	8B	188	BC	237	ED
2A	91	5B	140	8C	189	BD	238	EE
2B	92	5C	141	8D	190	BE	239	EF

2C		93	5D		142	BE		191	BF		240	F0
2D		94	5E		143	BF		192	C0		241	F1
2E		95	5F		144	90		193	C1		242	F2
2F		96	60		145	91		194	C2		243	F3

244	F4	247	F7	250	FA	253	FD
245	F5	248	F8	251	FB	254	FE
246	F6	249	F9	252	FC	255	FF

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ELECTRO-CRAFT BRU/PRO SERIES PARAMETERS Date_____

Programmer_____ Machine Name_____

BRU-____ Parameters Information for _____Axis

SCALE _____ RPM/VOLT P GAIN _____ AMPLIFIER MODEL DM-____ OFFSET _____ VOLTS I GAIN _____ MOTOR MODEL _____ PEAK I _____ AMPS D GAIN _____ GEAR RATIO _____
OVERSPEED _____ RPM MODE _____ TYPE MOTION _____
FILTER BW _____ HZ MONITOR ____ (ROTARY, CONVEYOR, LINEAR)

PRO-450 POSITION CONTROLLER PARAMETERS

KP gain _____ ACcel _____ KD gain _____ Jog Vel _____ KFF gain _____
Home Vel _____ KI gain _____ Home OFFset _____ Zone _____ FEL _____ OFfset removal ON/OFF FET _____ ROtation CW/CCW WIndow _____
ABSolute mode ON/OFF run PRogram _____ SCale _____ Forward Limit _____ Timebase MIN/SEC Reverse Limit _____ Velocity _____
EREturn posn _____

OPTIONAL PARAMETERS (PAG2)

ADDress _____ HOSt mode ON/OFF ADVance OFF/I07/I08 Index ON/OFF ATHome ON/OFF INPosn output ON/OFF AutoBauD ON/OFF JOG inputs ON/OFF
Baudrate _____ LIMit inputs ON/OFF DAc _____ LOCKfn ON/OFF DEBounce _____ MAKeup ON/OFF
Def Home input ON/OFF MAX offset _____
ERRor output ON/OFF OPErator ON/OFF
ESTop error ON/OFF PAUse input OFF/OPEN/CLOSED

Go enable ON/OFF PGMrun output ON/OFF
Home Sw active OPEN/CLOSED Window Time _____
Home SEQ compl ON/OFF

ELECTRO-CRAFT PRO-450 PROGRAM WORKSHEET Date____

Programmer_____ Machine Name_____

Program #_____ for controlling the _____Axis Page __ of ___

Program Statement	Comment

Program Editor Commands:

C Change instr **DEL** Delete instr **ENTER** Cursor down **G** GOTO LBL XX

LI (XX) List pgm (# of lines) **I** Insert instr **LO** Load pgm
Q Quit editor **U,/,-** Cursor up **S** Save pgm **T** Go to top of pgm

Program Statements:

ACceleration **ALL ON/OFF CMD**rate=**ON/OFF D**=XXX,**V**=YYY **DAC**=XXX
DE=XXX,**I**YY=**ON/OFF DH DIF**=XXX,**I**YY=**ON/OFF JMP** ZZ **DIS**able
DWL=XX **ENA**ble **EV,I**YY=**ON/OFF FEL**imit **FET**ime **GEAR**=XXXXX/256
IF IXX=**ON/OFF JMP** XX **IF** var1**<**var2 **JMP** ZZ **IF**
var1 **>** var2 **JMP** ZZ **IF** var1**=**var2 **JMP** ZZ
IF(IXX=**ON/OFF AND I**YY=**ON/OFF)JMP** ZZ **IF(I**XX=**ON/OFF OR I**YY=**ON/OFF)JMP** ZZ
IF(IXX=**ON/OFF XOR I**YY=**ON/OFF)JMP** ZZ **INPUT/FINPUT JMP** XX **KD KFF KI KP**
LBL XX **LOOP** XX,YYYYY **MOVD**=XXX[,**V**=YYY] **MOVD =**DXX[,**V**=SXX]
MOVP=XXX[,**V**=YYY]
OFfset **OX**=**ON/OFF NFD PFD PRINT/FPRINT REM RPE** XX **RPT** XX **SCAL**e
SCAN IXX=**ON/OFF D**X=POS1/POS2/PCMD/CMD2 var1**=**var2**+**var3
var1**=**var2**-**var3 var1**=**var2*****const var1**=**var2***C**x var1**=**var2**/C**x
Velocity **WAIT I**XX=**ON/OFF WI**ndow

CERTAIN ACCESSIBLE TERMINALS OF THE
PRO-450 CARRY POTENTIALLY LETHAL VOLTAGES.

ENSURE THAT THE SYSTEM IS INSTALLED, OPERATED, AND SERVICED BY FULLY QUALIFIED AND KNOWLEDGEABLE PERSONNEL.

Progress is an ongoing commitment at Reliance Motion Control. We continually strive to offer the most advanced products in the industry; therefore, specifications within this manual are subject to change.

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