AEROTECH, INC.

AEROTECH

SMART I

Programmable, Microprocessor-Based

Point to Point

Motor Controls

Instruction Manual

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1.0 GENERAL INFORMATION

1.1 INTRODUCTION

SMART I is a low cost CNC System. Although low cost, the capability of SMART I approaches that of CNC Systems costing two to three times as much. This high performance to cost benefit, is the result of its Micro-Processor Based Controls. This system utilizes any of Aerotech's Stepping Motor or Encoded DC Motor Drives. One* chassis contains all electronics, including Servo Controllers or Translators, for a complete 2-Axis System.

* DC Servo Controllers larger than 6020 require an additional chassis or plate for power amplifiers mounting.

1.2 FEATURES

1.2.1 STANDARD FEATURES

Manual Data Input-Keyboard Entry

Absolute/Incremental Programming-Mixed

Manual Control-run,Step

Five Digit Commands

Home (Reference Zero)

Home Offset (Full Floating Zero)

Programmable Dwell- .001 to 99.999 seconds

1000 Byte Program Storage - 250+ Commands

Editor

Search

Auto/Single Block Operation

Programmed Stop

Display-Input Commands in MDI or EDIT, block number in AUTO or SINGLE

Test RAM and PROM Memroy

Subroutines

Multiple Program Storage

Error Message Display

Program Length Display

Nested Subroutines

Jump Commands

Position Readouts

Six Latched M Functions

Programmable Stop at End of Each Block

Programmable Speed - Low, Medium, High

1.2.2 OPTIONS

8000 Byte Program Storage

16000 Byte Program Storage

Tape Reader Input

Magnetic Tape Read/Write

Serial I/O, TTY or RS 232C

Two Conditional Skip Options

99 M Functions

2.0 INSTALLATION INSTRUCTIONS

2.1 UNPACKING

Unpack the system from its shipping container and, referring to the sales order, verify that all of the items are present. Save the packing material for storing and reshipping the system. If the shipping container is damaged upon receipt, request that the carrier's agent be present while the system is being unpacked and inspected.

2.2 INSPECTION

The system should be inspected upon receipt for broken, damaged or loosened parts. Retighten any loosened connectors.

2.3 INSTALLATION

Install all motor connectors and cables before applying power to the system. If the system includes an Aerotech stage, refer to the stage manual and remove shipping clips; all adjustments have been made at the factory and no further adjustments are necessary. If the system does not include a stage, the drives will have to be adjusted for proper response to the load inertia and friction; refer to Section 5 and the drive manuals.

2.3.1 AC POWER REQUIREMENTS

The standard system requires 115 VAC $\pm$10%, 50-60 HZ. Chassis with internal Servo Controllers and Translators have the 115 VAC line fused at 5 amp. This is the maximum the SMART Chassis will require. Units with Servo Controllers larger than can be housed in the chassis will require additional power for the Servo Controller; the power requirement for the individual controllers is given in the Servo Controller manual.

2.4 CUSTOMER INTERFACE

The Customer Interface consists of the M Function and INPSN Outputs and a CONTINUE Input.

2.4.1 M FUNCTIONS

The Latched M Function and Isolator Card (LMI) provides the user with Six latched M Function Outputs, an unlatched MO or IN PSN Output, and a CONTINUE INPUT. These I/O are all isolated by relays or opto-isolators. The standard version (-1) has relay outputs and an optocoupler input. The -2 version has optically coupled outputs instead of relays.

Specifications

-1 Version

Outputs	Relay Contacts Form A (normally open)
Contact Ratings	0.5 amp MAX, 115 VAC
Input	5-28 VDC* (9 to 60 m.a.)

-2 Version

Outputs	Phototransistor (4N 33)
Maximum Voltage, DC	30 volts
Maximum Current	20 m.a.
Recommended Load	2 K ohm
Input	5-28 VDC*

* Other voltages can be accomodated by changing R12.

Installation Instructions

All customer connections to the I/O Card are through the Buchanon Screw-Terminal Block mounted on the rear or side panel. The terminal block accepts wire sizes #22 to 12 AWG. The connections are:

Outputs	Terminals
M11/21	1, 2
M12/22	3, 4
M13/23	5, 6
M14/24	9, 10
M15/25	13, 14
M16/26	15, 16
IN PSN or MO	17, 18
Input*	
CONTINUE	
+DC	7
-DC	8

* For input voltages other than 5 to 28 VDC, change R12 to R12 = $\frac{V}{.02}$, where V is the nominal DC input voltage

2.4.2 MO/CONTINUE

The panel connector containing the M Function Outputs also contains the INPSN or MO Output and the CONTINUE Input.

When MO is read in the program, the system will stop until a CONTINUE Command is received on the Rear Panel Interface. The application of a 5 to 28 VDC voltage (+ on 7) to terminals 7 and 8 will generate the CONTINUE Command.

The CONTINUE Command should remain low for at least 3 m.s. The CONTINUE Command should not be given until after the MO Command has been output, otherwise SMART will ignore it.

2.4.3 IN PSN/MO

The LMI Card can be configured to output IN PSN or MO (Standard) by changing jumpers on the card. Refer to 690C 1103 drawing.

2.4.4 PROGRAMMING

Programming the LMI Card is similar to programming the standard M Function. The specified command is initiated when read.

Example:

```
N104     M11     EOB
```

When SMART reads block 104, M11 will cause contacts TB1-1 and 2 to close.

Example:

```
N110     X1000     EOB
N111     MO        EOB
```

When Block N110 is read and the X Axis is commanded to move 1000 steps, N110 is displayed. When MO is read contacts TB1-17 and 18 close to signal the user the system has read a program stop. Nothing further will happen until the user applies the CONTINUE Command to TB1-7 and 8. When SMART recognizes that a transition from no voltage to voltage occurs at TB-7 and 8, it will continue the program.

2.5 LIMITS

If the system includes an Aerotech stage, the limits have already been wired. If not, they must be connected to limit motor travel when required. They must be connected if HOME is to be used. The CW limit must provide a signal COM to the CW limit input when the motor is at the maximum CW position (CW is defined looking into the mounting flange of the motor). The CCW limit must also provide a common to the CCW limit input when the motor is in the extreme CCW position; this CCW limit is also required for the HOME circuit to function.

For systems without an Aerotech stage, the limit appears on the 6 pin connector, with one foot wire length, coming out of the motor housing. Refer to stage wiring Drawing C630-1045 for connections. Care must be taken that noise on the LMT lines do not give false limit indications. Also the home limit should not "bounce" or a limit indication (N-90001) will occur during a home cycle.

3.0 OPERATION

The operation of the eight system modes are discussed in this section.

3.1 EDIT

The Edit Mode is used to examine memory, erase commands, and search for sequence (N) numbers. Searching is also used to count the number of bytes used in programming.

3.1.1 START

Pressing the START key places the memory pointer to the start of memory.

3.1.2 STEP

This key steps to the next command for display. Pressing - causes the previous command to be displayed.

3.1.3 ERASE

Causes the command, which is shown on the display, to be erased from memory.

3.1.4 SRCH

The SRCH key is upper case and requires that the SHIFT key be pressed (and released) prior to pressing SRCH. The displayed command will be searched for and, when found, the number of bytes from the beginning of memory to that command will be displayed. The searched for command must be entered into the display in the MDI Mode.

3.2 MDI

The Manual Data Input Mode is used to enter data into the display, and/or memory. When searching for a command or block number, data is entered only into the display.

3.2.1 START

Pressing START places the memory pointer at the start of memory

so that the following data will be entered at the beginning of the memory storage. Data which is already in memory will not be erased; it will simply be pushed toward the end of memory.

3.2.2 ENTER

Pressing ENTER enters the displayed data into memory and clears the display.

3.2.3 COMMANDS

All commands must be preceded by an address such as X, Y, D, N, etc. These letters (addresses) are all upper case. Upper case characters are obtained by pressing the SHIFT (↑) key first (and releasing it) and then pressing the desired character. The letter will then appear on the LED lamp. If a negative command is desired, it should be entered next (the negative light will come ON). The numerical data should then be entered next and will appear on the display. If zero numerical data is desired, it need not be pressed (such as MOO).

3.2.4 ERASE

After entering data into the display, but prior to entering it into memory, it can be erased from the display with the ERASE key. In the MDI Mode, data cannot be erased from memory.

3.2.5 EOB

Terminates all the commands to be executed in that block of information.

3.3 MANUAL MODE

The Manual Mode allows motor positioning via the keyboard ↑ ↓ → and ← commands which drive the Y motor CW, CCW, X CW and X CCW, respectively. Pressing 5 causes Z CW rotation, 0 causes Z CCW, 1 causes D CCW, and 3 causes D CW rotation. The absolute position of the motors is not kept track of, as it is in the AUTO or SINGLE Mode. Pressing

→ in the Manual Run Mode will cause the X Motor to turn CW until the key is released (if any other key is pressed before → is released, the motor will continue CW). Pressing → in the Manual Step Mode will cause the X motor to take a single step in the CW Direction.

3.4 AUTO

The AUTO Mode places SMART in the Automatic Mode whereby, once initiated, it continues executing the program until M0, M1 or M2 is encountered.

3.4.1 START

Pressing START places the memory pointer at the beginning of memory and starts executing the program.

3.4.2 ENTER

Pressing ENTER leaves the memory pointer at its present location and starts executing the program from there.

3.4.3 RESET

The RESET pushbutton interrupts the operation of any mode, resets the drives and readouts, and awaits further commands from the keyboard.

3.5 SINGLE

In the SINGLE Mode, one block of data is executed each time a key is depressed. A block of data consists of all the commands between End Of Blocks (EOB).

If the mode switch is moved from AUTO to SINGLE while a program is executing, the system will not stop until the block of data after the current block has been executed.

3.5.1 START

The START key places the memory pointer at the beginning of memory and executes the first block of data (all the data from the beginning of memory to the first EOB).

3.5.2 ENTER

The ENTER key enters memory at the location indicated by the memory pointer and executes all data until an EOB is encountered. To step through the entire program one block at a time, press START, wait for the move to be completed, then press ENTER, wait for the move to be completed, then press ENTER, etc. The ENTER key can be considered a continue command.

3.6 EXTERNAL

The EXT Mode is used for optional input and output of programs. Refer to the appropriate option addendums.

3.7 TEST

The TEST Mode is used to test SMART.

3.7.1 CHECK RAM MEMORY

Pressing 0 causes all RAM Memory storage to be tested. The memory is then left cleared (all zeros). If a bad memory location is discovered, its location is output on the display. If no bad memory locations are discovered, the end of memory is displayed. For example, with the standard 1K Memory, if 1023 is displayed, all memory is good. If 735 is displayed, that memory location is defective.

3.7.2 CHECK ROM

Pressing 1 initiates a checksum of ROM Memory to verify that the executive program has not changed. N-90000 will be displayed if the check is good. N-90009 will be displayed if the check shows an error.

3.7.3 CHECK AND CLEAR RAM SCRATCHPAD

Pressing 2 checks and clears scratchpad RAM. These memory locations are used for internal SMART calculations and storage such as the absolute position registers. 124 is displayed when the check is good. Any number lower than 124 indicates that memory location is bad.

3.7.4 CHECK RAM

Pressing 3 is similar to the 0 test except memory is not cleared to zero: it is left intact. Therefore this test can be done without destroying programs in memory.

4.0 PROGRAMMING

4.1 ENTERING PROGRAMS AT THE BEGINNING OF MEMORY

Programs are entered at the beginning of memory by switching to the MDI Mode and pressing the START key. The first command entered will then be placed in the first memory location, the second command entered will be placed in the second memory location, etc. Any commands previously stored will be shifted toward the end of memory.

The code M30 is usually used to notify SMART that this is the last command in memory and is required for external I/O of programs. It is good practice to start all programs with START M30 START.

4.2 ENTERING MULTIPLE PROGRAMS

Additional programs may be entered in front of, or after, previously stored programs. To enter an additional program at the beginning of memory, refer to 4.1. To enter a program (PGM 2) after a previously entered program (PGM 1); search or step to the end of PGM 1, DO NOT PRESS START, switch to the MDI Mode and enter PGM 2.

Enter: N1 ... EOB

.
.
.

PGM 1

N99 M2 EOB

Search for N99, STEP until EOB is displayed on the LED, then switch to MDI and enter PGM 2.

4.3 ADDING, CHANGING OR DELETING COMMANDS

The programs can be easily changed by using the EDIT and MDI Mode. Commands are examined, deleted and searched for in the EDIT Mode; and entered in the MDI Mode.

4.3.1 ADDING A COMMAND

Before adding commands, read Section 4.12, "COMMAND ORDER".

Commands must be entered in the specified order because while the system is executing the current line of data, it is reading the next line in the program.

To add a command, display the previous command in the EDIT Mode. Switch to MDI and enter the desired command.

Example: It is desired to enter an M21 between the Y-200 move and the EOB in block N50.

Present Program

N50 X1000 Y-200 EOB

First search for the block.

MDI: SHIFT N 5 0

Note: The above means in the MDI Mode you pressed the key shown: SHIFT, N, 5, 0. If the display had not been cleared, precede the above with ERASE.

EDIT: SHIFT SRCH

SMART will search for N50 and display the number of bytes it took to find it.

Press STEP.

N50 will be displayed.

Press STEP twice more and Y-200 will be displayed.

Any data entered now will follow Y-200 and precede EOB.

Enter the M21.

MDI: ERASE SHIFT M21 ENTER

The Program is now:

N50 X1000 Y-200 M21 EOB

4.3.2 DELETING A COMMAND

To delete a command, display the command in the EDIT Mode and press ERASE.

Example: It is desired to delete the command Y-200 in Block N50.

Present Program:

N50 Y-200 X1000 EOB

Search for the command.

MDI: ERASE SHIFT N 5 0

EDIT: SHIFT SRCH

After the command is found, press STEP twice and Y-200 will be displayed. Press ERASE.

The command will be erased from the display and memory.

The program is now:

N50 X1000 EOB

As can be verified in the Edit Mode.

4.3.3 CHANGING A COMMAND

To change a command, display the command and ERASE it, then enter the new command.

Example: It is desired to change the command X1000 to X1500 in Block N50.

Present Program:

N50 X1000 Y-200 EOB

Search for the command.

MDI: ERASE SHIFT N50

EDIT: SHIFT SRCH

After the command is found, press STEP twice. X1000 will now be displayed. Press ERASE. Then switch to MDI and enter the new command:

MDI: SHIFT X 1500 ENTER

The program is now:

N50 X1500 Y-200 EOB

as can be verified in the Edit Mode.

4.4 PREPARATORY CODES

4.4.1 DWELL, G4

The Dwell Command is used to insert timed delays from .001 to 99.999 seconds in the program. The command following G4 contains the magnitude of the dwell (D1000 means 1000 milliseconds or 1 second delay). When a dwell is encountered, the delay occurs before the rest of the block is executed. Example:

G7 G4 D1000 X100 EOB

will cause the drive to go to the Home Position, then dwell for 1 second, then index X 100. If the program order is reversed:

G4 D1000 G7 X100 EOB

will cause a 1 second dwell, then the drive will home, then index X100.

4.4.2 RESET ABSOLUTE POSITION REGISTERS, G5

G5 is used to reset the Absolute Position Registers for indexing in the Absolute Mode. All Absolute Commands following G5 will use the location where G5 occurred as the zero reference. The Absolute Mode (G90) should not be used until the Absolute Position Registers are reset.

4.4.3 HOME (REFERENCE ZERO), G7

The Home Command, G7, sends the drive to the Home or Reference Position. The drive finds the Home Position by driving in the CCW Direction until the CCW Limit Switch is closed. Then the motor reverses direction and begins rotating CW. It continues CW until the Marker Pulse is encountered. The first Marker Pulse after the limit resets the system and this establishes the Home Position.

Home Offset

Establishing a Home Offset or floating reference is accomplished by a procedure, rather than a special command. The procedure is: go to the Home Position, index the desired offset and reset the Absolute Position Registers (G5). It is optional whether the Position Readouts are reset or not, if it is desired that the Position Readouts agree with the Absolute Position Registers in SMART Memory, the G10 Command should follow G5. Home Offsets must be placed immediately following the Home Command, in the same block. Typically Home and Home Offset are placed in the first command block so that the Home Offset can easily be changed.

Example: Assume that SMART is positioning a 4 inch stage with .001 inch travel per step and it is desired to place the Home Offset in the center of travel (approx. 2 inch from CCW end).

The commands would be:

N1 G91 G7 X2000 F40 EOB

In the first block G7 would send the stage to the Home Position. After the stage reached the Home Position, the X axis would move 2 inches (2000) in the Incremental Mode (G91) at medium speed to establish the Home Offset Position.

To change the Home Offset Position simply change X2000 in Block N1 to the desired location.

4.4.4 RESET POSITION READOUTS AND DRIVES, G10

G10 sends a reset pulse to the drives, which in turn sends a reset pulse to the readouts. The readouts will read all zeros when reset.

4.4.5 PROGRAMMABLE STOP/NORMAL EXECUTION, G25/G26

If G25 is specified, the system will pause after each EOB and wait for the external CONTINUE. When G25 is in effect, the system behaves as though each block contains an MØ.

Once the G25 Command is specified, this programmable stop will remain in effect until cancelled by a G26 Command.

4.4.6 CONDITIONAL SKIP OPTION, G27/G28

When G27 is specified in a block, everything between G27 and the EOB are skipped during execution if an external input is active. If the external input is not active, the block will be executed normally.

A seperate external input is also available for G28 thus providing two user Controllable Skip Options.

G27 and G28 unlike other G Commands, are in effect for only the blocks in which they are programmed.

Example:

```
N1    X1000    F200     EOB
N2    G27      X-1000   EOB
N3    X-1000            EOB
M2
```

If the G27 external input is active - the system will skip Block N2. But if the G27 external input is not active, N2 will be executed.

4.4.7 ABSOLUTE/INCREMENTAL PROGRAMMING, G90/G91

ABSOLUTE PROGRAMMING, G90

G90 places SMART in the Absolute Programming Mode so that all axis commands are with respect to the position stored in Absolute Position Registers. The Absolute Position Registers will keep track of the motor position in all but the MANUAL Mode. Absolute Positioning Commands must never exceed an incremental index of 99,999 steps.

For example, if the Absolute Position is +60,000 a command to go to the position -60,000 is not allowed because it would require an incremental index of -120,000 steps which exceeds the 99,999 limitation.

INCREMENTAL PROGRAMMING, G91

G91 places SMART in the Incremental Mode so that all axis commands are with respect to the present position. The command X1000 in the Incremental Mode will cause the motor to take 1000 steps in CW Direction, regardless of where the present position is.

4.4.8 REPEAT FROM BEGINNING OF MEMORY, G99

G99 will cause the program to return to the beginning of memory and start executing from there.

Example:

N1	X1000	F500	EOB
N2	X-1000		EOB
N3	G99		

Will cause the drive to cycle endlessly through N1, N2, N3, N1, N2, etc.

4.5 MISCELLANEOUS CODES

M Functions are output when read by the control.

4.5.1 PROGRAMMED STOP, MO

MO is used in the AUTO Mode to stop the program. A 5-28 VDC level applied to the rear panel CONTINUE will cause the program to continue from the location it has stopped, and cause the MO output to open. As soon as MO is read in a block of data, the system will wait until the CONTINUE Input goes low before continuing.

4.5.2 PROGRAM STOP, M1

M1 is used in the Automatic Mode to stop program execution.

Pressing ENTER will cause SMART to enter the program at the point it had stopped and continue executing data.

4.5.3 END OF PROGRAM, M2

M2 is used in the Automatic Mode to stop program execution and set the Memory Pointer to the Beginning of Memory.

4.5.4 END OF TAPE, M30

The M30 signals SMART that this the end of the program when interfacing to a Paper Tape Reader, Mag Tape Read/Write, or Serial I/O. It is recommended the command always be placed at the end of all programs, even those entered in MDI Mode.

MDI: START
SHIFT M 3 0 ENTER
START

Now enter your program. M30 will be pushed along in memory but stay at the end of the program.

4.5.5 RETURN FROM SUBROUTINE, M99

This code tells SMART that this is the end of the subroutine and to return to the Main Program. M99 should appear in a block by itself.

4.5.6 END OF REPEAT, M98

M98 signals the end of a repeat operation. All the data between N8 AA BB and M98 will be repeated BB times. M98 should appear in a block by itself.

Examples:

```
N80010  X1000   EOB
M98     EOB
```

will cause X1000 to be executed 10 times.

```
N80105     Y1000     EOB
G4     D1000     X-100    EOB
M98    EOB
```

will cause the sequence Y1000, 1 sec. dwell, X-100 to be executed 5 times.

```
N80215   N-100   EOB
M98    EOB
```

will cause the subroutine N100 to be executed 15 times.

4.6 FEEDRATE

4.6.1 HIGH SPEED, F0

F followed by all zeros will make the drive position at the maximum speed for all blocks of commands following the F Commands.

4.6.2 MEDIUM SPEED, F40

F40 will make the drive position at medium speed which is about one-tenth that of maximum speed.

4.6.3 LOW, F70

F70 will make the drive position at low speed which is about one-tenth that of medium speed.

4.7 RESET

The RESET pushbutton on the Front Panel is used to interrupt the system from its present task and send it back to the mode switch and keyboard for further commands. When the system is RESET, N90016 will be displayed.

4.8 BLOCK NUMBERS, N

Block Numbers are not required but will save time in changing or checking programs. They are also displayed when that block of axis commands are being executed.

Example 1:

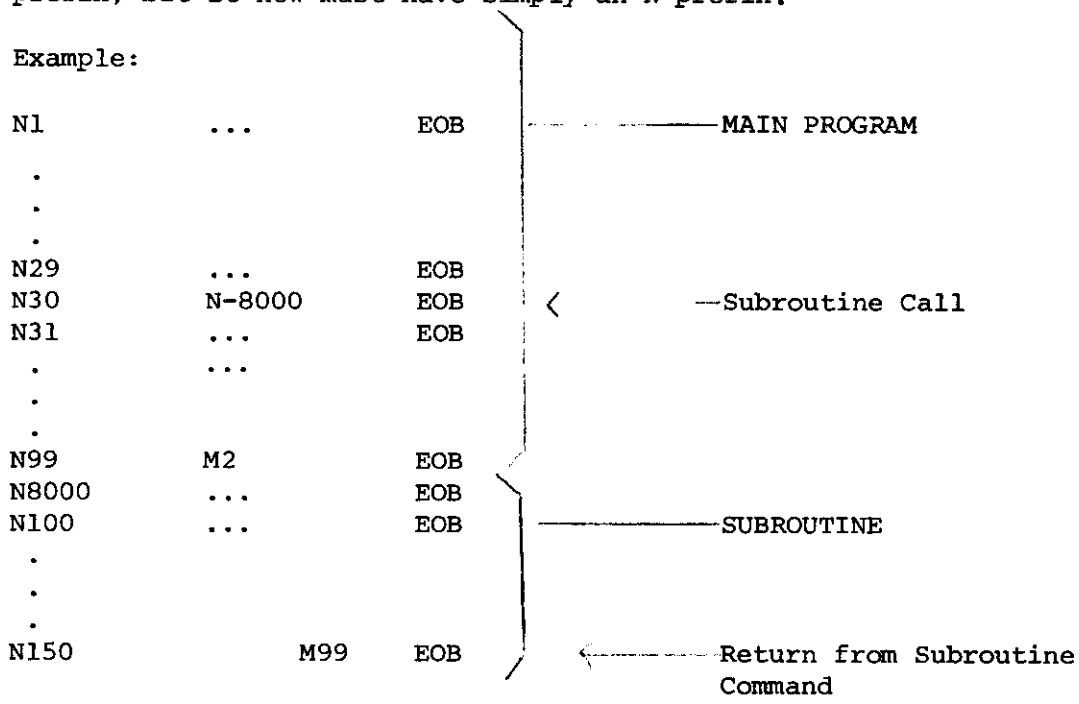
N100 X1000 Y200 EOB

While the motors are positioning X1000 steps and Y200 steps, the display will show N100.

4.9 SUBROUTINES, N-

Subroutines are used to reduce programming time and memory for repetitive operations. The subroutine is called by the N- prefix. The end of the subroutine is identified by M99. The subroutine must be written after M2 and use the same number that followed the N- prefix, but it now must have simply an N prefix.

Example:



The program will begin at N1 when START is pressed in the AUTO Mode and execute the N29 Block. Block N30 calls the subroutine N8000 and SMART will jump to the Block N8000 and execute the subroutine. Block N150 contains the Return Code which causes the program to jump back and begin executing Block N31. When Block N99 is read, M2 will cause the program to go back to the beginning of memory and

await further operator commands.

A Subroutine Call must be immediately followed by an EOB.

Example:

```
N2    N-100     EOB
```

Multiple subroutines can be used and called any number of times, but they must appear following M2 of the Main Program (otherwise they will be executed with the normal flow of the program). Subroutines may be nested up to three deep.

4.9.1 JUMP COMMANDS

N-7XXXX will cause a jump to block N7XXXX without a return. N- Commands normally save a return location because the control must return after the subroutine is executed. N-7 (any 4 digits) will not save a return location. This feature can be used to change the execution of a program in conjunction with the SKIP Option, or cut down programming of subroutines which share commands.

Example of use with SKIP:

```
N1     G27   N-70001   EOB
N2     ...
 .
 .
 .
M2
N70001
 .
 .
 .
M2
```

If the SKIP input is active, N-70001 will be skipped and N2 will be executed. If the SKIP input is not active, the control will jump to N70001 and starts executing that program. This allows an external input to control the program being executed, via the JUMP Commands.

Example of use with subroutines:

```
N1   N-100   EOB
N2   N-200   EOB
M2           EOB
N100   X100   EOB
N-70003      EOB
N200   X1000   EOB
N 70003   EOB
N 70003   Y200   EOB
M99   EOB
```

In the above overly simply example, N70003 contained a program used by both subroutines and N70003 contained the M99. The JUMP allows both N100 and N200 to share the commands in N70003.

4.10 REPEATS

The Repeat Command is a powerful programming tool to reduce programming time, memory and tape requirements. This six digit special code allows any command or subroutine to be repeated up to 99 times.

The Repeat Command is N8 AA BB where:

- N8 — Specifies the Repeat Operation.
- AA — Is simply an operator inserted number similar to an ordinary number.
- BB — Specifies the number of repeat cycles.

The command to be repeated must be followed by an M98 to signify the end of the Repeat Operation: i.e. all commands between N8 AA BB and M98 will be repeated.

For Example:

```
N80015   X100   EOB
M98   EOB
```

Instructs the control to move X100 steps 15 times.

```
N80015   G4   D1000   X100   EOB
M98   EOB
```

Instructs the control to again index X 15 times, but also dwell one second before each index.

```
N80005   N-100   EOB
M98   EOB
```

Instructs the control to execute the subroutine, N100, five times.

During execution of the repeats, the display will show N AA CC; where CC is the number of repeats left to perform.

4.11 TOOL OFFSETS

The number and type (single or pairs) of tool offsets can be selected by the user; up to the memory capability of the system. Offset magnitudes are up to the full indexing capability of the system. Offset directions can be either + (CW) or - (CCW Motor Rotation).

Once programmed, the Tool Offsets can be used by any or all programs in memory. The Tool Offsets can also be read and/or stored via any of the standard SMART interfaces: Magtape, Papertape, TTY, or RS232. The Tool Offsets can be entered, examined, deleted and searched for.

4.11.1 TOOL OFFSET PROGRAMMING

Tool Offsets are accomplished with subroutines. This allows any number of offsets or offset pairs to be programmed. Assume the following offsets are desired:

Tool Offset Sequence Number	Offset Axis/Direction/Distance
N511	X - 200
N512	X - 500
N513	X - 100 Y - 300

The Tool Offset Programming can be done in two steps whereby each Tool Offset has a corresponding offset cancel, or it can be done in an incremental fashion for minimum time. Both methods will be illustrated.

The program for Tool Offsets with cancels would be:

```
N511   X-200    EOB
 M99            EOB
N521   X200     EOB
 M99            EOB
N512   X-500    EOB
 M99            EOB
M522   X500     EOB
 M99            EOB
M513   X-100    Y-300   EOB
 M99            EOB
M523   X100    Y300    EOB
 M99            EOB
```

To call Tool Offset 1, the program need only be N-511, to cancel Tool Offset 1, program N-521. To call offset 2, program N-512; to cancel offset 2, program N-522. Etc. Feedrates should be included to program the speed of the offset.

A program using the Tool Offsets with cancel would be:

```
N1    G91   G7   EOB
N-511  Inserts Tool Offset 1.
Program using Tool Offset 1.
N-521  Removes Tool Offset 1.
N-512  Inserts Tool Offset 2.
Program using Tool Offset 2.
N-522  Removes Tool Offset 2.
N-513  Inserts Tool Offset 3.
Program using Tool Offset 3.
N-523  Remove Tool Offset 3.
 M2   EOB
N511  X-200   EOB
 M99   EOB
N521   X200   EOB
 M99   EOB
N512   X-500   EOB
 M99   EOB
N522   X500   EOB
 M99   EOB
N513   X-100   Y-300   EOB
 M99   EOB
N523   X100   Y300   EOB
 M99   EOB
 M30
```

The first block placed the system in Incremental Mode. The second block caused the N511 subroutine to be executed, which inserted Tool Offset 1. That part of the program using Tool Offset 1 was executed. Then N-521 caused subroutine N521 to be executed, removing tool offset 1.

Then N512 was executed, inserting Tool Offset 2; etc. Note that the last block removed Tool Offset 3; in this case it was not necessary since the first block removed Tool Offset 3; in this case it was not necessary since the first block sent the drives to the home position (G7), however, it is a necessary procedure to remove all tool offsets at the end of the program when the first block does not contain a G7 Command.

The second method for using Tool Offsets does not require going back to the reference position (removing the previous Tool Offset), but it does not require that the operator keep track of the tool position. The previous program could have been written as follows:

```
N1    G91    G7   EOB
N-511  Inserts Tool Offset 1.
   Program using Tool Offset 1.
N-515  Inserts Tool Offset 2.
   Program using Tool Offset 2.
N-516  Inserts Tool Offset 3.
  Program using Tool Offset 3.
N-523  Remove Tool Offset 3.
  M2   EOB
N511  X-200   EOB
  M99  EOB
N515  X-300   EOB
  M99  EOB
N516  X400   Y-300  EOB
  M99  EOB
N523  X100  Y300    EOB
  M99  EOB
  M30
```

This program is the same as the previous one, up to the end of the part of the program using Tool Offset 1. Then Tool Offset N515 combines

N521 and N512. This saves the time and memory required to go back to the reference position and then to the new offset position. Similarly N516 combines the previous N522 and N513 Tool Offsets.

4.11.2 INSERTING, EXAMINING AND CHANGING TOOL OFFSETS

The Tool Offsets must be added following M2 of the program, the same as any other subroutines. To examine or change the offsets, enter the Tool Offset number in MDI into the display, then switch to EDIT and press SHIFT SRCH. The number of bytes of program memory preceding that offset will be displayed. Then press STEP and the Tool Offset sequence number will be displayed, followed by the offset commands when the subroutine is stepped through.

To change a Tool Offset Command, search for and display the offset, then press ERASE, Then switch to MDI and enter the desired offset.

4.12 COMMAND ORDER

SMART processes the data block in the order it is read.
The command sequence which should be followed (per EIA RS-274) is:

First N	Line Number, if desired
Second G	Any and all G Commands
Third X, Y, Z	Any and all displacement commands
Fourth F	Feedrate
Fifth M	Any and all M Functions
Sixth EOB	End-Of-Blocks Command must terminate this command line.

No harm will result if this order is violated.

4.13 COMMAND EXECUTION PRIORITY

Commands will be executed according to the order in which they

appear in the block.

N1 M11 G4 D1000 M21 G7 X100 EOB

When the above block is read M11 will be output, then there will be a one second delay, then M21 will be output (cancels M11), then the drives will return to the home position, then X100 will be executed (while X100 is being executed, the display will show N1).

5.0 MAINTENANCE AND ADJUSTMENTS

There is no maintenance required on the electronics or stepping motors. DC Motor/Tachs should be checked for brush wear at 5000-hour intervals; refer to the maintenance section of the Parallel Load Encoded DC Motor Drive Instruction Manual.

5.1 ENCODED DC MOTOR DRIVE ADJUSTMENTS

Refer to the Parallel Load Instruction Manual

6.0 TROUBLESHOOTING

Troubleshooting will be aimed at determining whether the Drive or Computer Control is malfunctioning. The control stores and processes the command signals to the Drive. The Drive accepts incremental commands from the control, positions the motor, then sends a signal to the control indicating all commands have been completed; the control then processes the remaining data. The control will not continue unless the drive returns the CZ signal (PSN LED on Front Panel). The control will not continue after a HOME Command unless the Drive has arrived at the Home Position, and sends back an AT HOME indication (HOME LED on Front Panel).

6.1 GENERAL

The Drive consists of a Parallel Load Card, the Servo Controller, and the Motor/Tach/Encoder Assembly.

Troubleshooting hints for the Drive can be found in the Parallel Load Instruction Manual. The control consists of the Microcomputer Card and the I/O Card. The Control requires a ±12V and +5V DC supply for operation. The Drive also uses a +5V DC supply and ±12VDC supplies. A check of all power supplies should precede other tests for a malfunctioning system.

The I/O Card communicates with all Parallel Interface Options (Magtape, Papertape Reader), and the Front Panel Card with the keyboard and switches. The Microcomputer Card interfaces to the Serial Interface Options (TTY, RS232) and all the remaining cards.

6.2 SYSTEM STOPS AFTER HOME COMMAND

If the system did not contain an Aerotech Stage, the problem may be caused by the encoder marker position being off with respect to the CCW $\overline{\text{Limit}}$. The system operates by driving into the CCW Limit, reversing

rotation (motor turns CW), and resetting the drive at the first marker pulse encountered. The marker should be located 1/4 to 3/4 revolution away from the limit.

The Drive can be checked by observing the led HOME indication, this LED must light when the Home Reference Position is reached, for the control to continue.

6.3 SYSTEM STOPS AFTER INDEX COMMAND

Check that the Drive is getting to position (PSN LED ON). If it is not, the Drive Balance or Analog Detent may be misadjusted. If it is ON, replace the I/O Card.

6.4 ERROR MESSAGES, N-9

The display will show error messages preceded by N-900 XX.

The messages are:

00 Check AOK

01 LIMIT. One of the drives has entered a CW or CCW limit.

02 through 04 Reserved

05 MEMORY OVERFLOW. The RAM Memory capacity has been exceeded.

07 INVALID DIRECTIVE. The command is not allowed.

09 PROM ERROR. The Prom Checksum has failed indicating a failure in the executive program.

10 PARITY ERROR, Paper Tape. A parity error has occurred on the paper tape reader input.

11 IC ERROR, Magtape. An incomplete character was read from the magnetic tape.

12 CHECKSUM ERROR, Magtape. The checksum generated when reading the tape does not agree with the tape checksum.

23 IC and CHECKSUM. Both errors 11 and 12 occurred.

14 SEARCH ERROR. Cannot find data being searched for.

16 SYSTEM HAS BEEN RESET

17 Attempt to store program in Nonexistent RAM Memory (MDI Mode only).

13 Repeat Error (nested Repeats)

Additional error messages are found in the option instruction manuals.

POINT TO POINT SMART COMMAND SUMMARY

X Y Z	Dimension words of X, Y, Z or D axis in steps. 1 mil/step resolution command in mills. D used for θ axis.	
N	Programmable line (sequence) numbers	
	N- Subroutine Call	
	N8 Repeats	
	N-7 JUMP	
F	Speed	
	F0 High	
	F40 Medium	
	F70 Low	
	G4 DWELL	
	G5 Reset absolute position registers	
	G7 Go Home	
	G10 Reset position readouts and drives	
	G25 Programmed MØ	one must be in effect
	G26 No Prog MØ (default)	
	G27 Skip if Ext 1 active	
	G28 Skip if Ext 2 active	
	G90 Absolute programming	one must be in effect
	G91 Incremental programming (default)	
	G99 Return to beginning of memory and start executing	
M	M0 Programmed stop--CONTINUE Input continues program.	
	M1 Program stop--ENTER Button continues program.	
	M2 Operating end of program.	
	M30 Physical end of a program.	
	M98 End of Repeat	
	M99 Return from subroutine.	
EOB	End of Block--terminates all commands in a block and displays sequence number.	

See manual for details of each command and proper command sequencing.