ProtoTRAK® Plus
CAD/CAM Interface Manual

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SOUTHWESTERN INDUSTRIES, INC. ⌖ SWI

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CAD/CAM Interface Manual

SOUTHWESTERN INDUSTRIES, INC. *SWI*

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Southwestern Industries, Inc.

PROTOTRAK PLUS
CAD/CAM INTERFACE
MANUAL

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PROTOTRAK PLUS CAD/CAM INTERFACE MANUAL

The purpose of this manual is twofold. First, to provide the necessary data to establish a post-processor to link your CAD/CAM system to the ProtoTRAK. And second, to provide installation and checkout procedures to assure the proper physical connection.
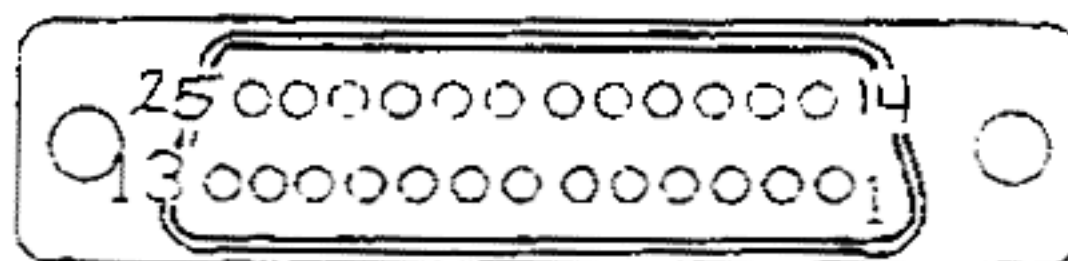
1.0   RS232 Specification

The RS232 port allows the user to receive ASCII formatted data.

BAUD RATE = 4800   PARITY = EVEN
STOP BIT = 1   DUPLEX = FULL
DATA BIT = 7

RS232 PIN OUT
PIN 2 = TRANSMIT (data to the computer)
PIN 3 = RECEIVE (data from the computer)
PIN 7 = GROUND

Cable Specification:

The ProtoTRAK Plus communicates with the computer over an RS232 cable with female connectors at each end, coupled to an "XT Null Modem" adapter with a male (pins) connector at one end, and a female (pin sockets) connector at the other end.

The XT Null Modem can be purchased at any computer store for a few dollars. If you have difficulty finding one, please contact the Southwestern Industries Customer Service Group at 213/608-4422. We will be happy to send one to you without delay.

2.0   Post-Processor

The ProtoTRAK Plus requires a customized post-processor to link it to your computer CAD/CAM system. Depending on your CAD/CAM system, the post-processor can be developed in one of two ways. One, by modifying a Fanuc 6 post-processor and, two, by creating a whole new post-processor just for the ProtoTRAK.

In either case these tasks are probably best handled by your CAD/CAM manufacturer or distributor. Some may already have post-processors developed for the ProtoTRAK. If not, the information in the following sections will be helpful in this process.

2.1   Post-Processor Using Modified Fanuc 6

The ProtoTRAK Plus · is a 2-axis control that has the ability to convert G codes that were intended for a 3-axis machining center (with tool changer) into its normal custom position, mill, arc events. Many CAD/CAM for which a post-processor already exists for a Fanuc 6 control may be modified with the three rules below, and used as a ProtoTRAK Plus post-processor.

1. G codes must be on every line.

2. G codes must have spaces between them.

3. End of block character must be ; (semicolon).

NOTE: While this section is very simple, it may not work with every CAD/CAM system. Some additional (and, hopefully, minor) changes will probably be required. In addition, it will generate a program which is very inefficient in utilizing the ProtoTRAK's memory space since it does not use the more powerful canned events.

See Section 2.2.6.2 for a sample program output from an unmodified Fanuc 6 post-processor, and Section 2.2.6.3 for the same program output from a modified Fanuc 6 post-processor.

2.2 Post-Processor Input Data Format Specification

If a post-processor as described in Section 2.1 is not appropriate, use the following specifications to develop a custom ProtoTRAK Plus post-processor.

2.2.1 G Codes

G Codes	Function
G00	Position
G01	Linear Interpolation
G02	Circular Interpolation CW
G03	Circular Interpolation CCW
G20	Inch Programming
G21	Metric Programming
G40	Cutter Compensation Cancel
G41	Cutter Compensation Left
G42	Cutter Compensation Right
G90	Absolute Programming
G91	Incremental Programming
G100	Position Event (ProtoTRAK Plus)
G101	Mill Event (ProtoTRAK Plus)
G102	ARC Event CW (ProtoTRAK Plus)
G103	ARC Event CCW (ProtoTRAK Plus)
G104	Bolthole Event (ProtoTRAK Plus)
G105	Repeat Event (ProtoTRAK Plus)
G106	Rectangular Pocket Event (ProtoTRAK Plus)
G107	Rectangular Frame Event (ProtoTRAK Plus)
G108	Circular Pocket Event (ProtoTRAK Plus)
G109	Circular Frame Event (ProtoTRAK Plus)

2.2.2 Axis Codes

Axis Codes	Function
X	X Axis ending point
Y	Y Axis ending point
XB	X Axis beginning point
YB	Y Axis beginning point
XE	X Axis ending point
YE	Y Axis ending point
XC	X Center (absolute or incremental from X ending point)
YC	Y Center (absolute or incremental from Y ending point)
I	X Center (INC from X beginning point)
J	Y Center (INC from Y beginning point)
XD	X Diagonal Position (used by G106 & G107).
YD	Y Diagonal Position (used by G106 & G107).

2.2.3 Miscellaneous Codes

Codes	Function
A	Angle Input
HL	Number of Holes
PN	Part Number
R	Radius Input
CR	Conrad Input
F	Feed Rate Input
T	Tool Number Input
TC	Tool Compensation Input
D	Diameter Input
FE	From Event Input
FC	Finish Cut Input
DR	Direction Input
LE	To Last Event Input
RE	Repeat Event Input
N	Line Number
%	Beginning and End of File Character
;	End of Block Character
(	Start of Comment Character
)	End of Comment Character

2.2.4 Data Formats

o   Dimensions

Inch Mode		Metric Mode	
12.3456 =	+12.3456 Inches	1234.56 =	+1234.56mm
-123456 =	-12.3456 Inches	-123456 =	-1234.56mm
+1234 =	+ .1234 Inches	+1234 =	+12.34mm
-1. =	- 1.0000 Inches	-1. =	- 1.00mm
.1 =	+ 0.1000 Inches	.1 =	+ 0.10mm
00.1000 =	+ 0.1000 Inches	0000.10 =	+ 0.10mm

o   Incremental and Absolute Data Handling

Optional tags may be appended to the axis codes that will override (but not change) the incremental or absolute mode set by G90 or G91.

I = Incremental Tag   A = Absolute Tag

EXAMPLES

X-12.3456A   -12.3456 will be entered as absolute number
X13.5791   +13.5790 will be entered as incremental number
YE-33.4   -33.4000 will be entered as incremental or absolute
                  number, depending on the last G90 or G91

NOTE : If no G90 or G91 has been entered, system defaults to absolute
       mode.

o   Angle Data Formats

A-300.000 = -300.000 degrees
A-300000   = -300.000 degrees
A.12   = + .120 degrees
A0   =   0.000 degrees

o   Tool Number Format

RANGE = 1 TO 99 (No sign or decimal point)
DEFAULT = 1

EXAMPLES

T1   = TOOL #1
T001 = TOOL #1
T99   = TOOL #99

o   From Event/To Event Format

RANGE = 1 TO 255
DEFAULT = PREVIOUS EVENT #

EXAMPLES

FE1   = From Event #1
LE100   = To Event #100
FE009   = From Event #9

o   Part Number Format

One to eight numeric digits, no sign or decimal point.
DEFAULT = 0

EXAMPLES

PN12345678 = PART NUMBER "12345678"
PN1   = PART NUMBER "1"

o   Radius and Diameter Formats

Inch Range   = 0.0005 TO +99.9999
Metric Range = 0.01   TO +9999.99
Leading zeroes are optional.
Trailing zeroes are optional.
Decimal point is optional.
Plus sign is optional.
No negative signs.
DEFAULT = 0

EXAMPLES

      Inch Mode   Metric Mode

R01.2345   = +01.2345 Inches   RO123456 = +1234.56mm
D+.25   = +00.2500 Inches   D+1.35   = +0001.35mm
R2500   = +00.2500 Inches   R135   = +0001.35mm

o   Feedrate Formats

Inch range = 0.1 TO 99.9 Inches per minute
Metric Range = 0005 TO 2535 Millimeters per minute
Leading zeroes are optional.
Trailing zeroes are optional.
No decimal point.
Default Inches = 1.0 Inch per minute
Default Metric = 25.0 Millimeters per minute

EXAMPLES

      Inch Mode   Metric Mode

F99.9 = 99.9 IPM   F2535 = 2535mm per min
F1   = 00.1 IPM   F5   = 0005mm per min
F1.   = 01.0 IPM

o   Tool Compensation Formats

RANGE = 0, 1, OR 2
DEFAULT = 0 OR last value entered
0 = TOOL CENTER
1 = TOOL RIGHT
2 = TOOL LEFT

EXAMPLES

TC1 = set TOOL COMP right

o   Line Number Formats

RANGE = 0 TO 999

EXAMPLE
N1234
N01
N001

NOTE: The ProtoTRAK Plus converts G Code data into events. So line
number will not necessarily convert into the corresponding event
number.

o   CONRAD Formats

Inch Mode
RANGE = -99.9999 TO +99.9999 inch or -9999.99 TO +9999.99mm
Decimal point optional
Leading zeroes optional.
Trailing zeroes optional.
Plus sign optional.
DEFAULT = 0

NOTE: Negative values of conrad are used to incidate that the present
event is not connected to the next event.   Positive values
or 0 indicate that the present event is connective to the
next event.

EXAMPLES

       Inch Mode   Metric Mode
CR-1 = not connected   CR-1 = not coneccted
CR- = not connected   CR- = not connected
CR1.35 = conrad   1.3500 in.   CR1.35 = conrad 1.35mm
CR+12.2345 = conrad 12.2345 in. CR+1234.45 conrad = 1234.45mm

NOTE: The ProtoTRAK Plus is a 2-axis control.   Therefore, it uses the
Z information to decide if the movements are connective.
If the Z dimension changes, the conrad is set to the appro-
priate value.

2.2.5   Program Output Listing

This is a sample output of each event type.

```
PN2  G20;
N001  G100  X1.2A  Y2.2I  T01  ;
N002  G101  XB1.05A  YB2.025I  XE1.0I  YE3.0A  TC1  F20.0  D0.555  CR-  T02  ;
N003  G102  XB2.0A  YB0A  XE0A  YE0A  XC1.0A  YC0I  F10.0  TC2  D0.5  CR-  T03  ;
N004  G103  XB-1.0A  YB-1.0A  XE1.0A  YE1.0A  XC0A  YC0A  F15.5  TC0  D0.75  CR-  T04  ;
N005  G104  XC1.75A  YC0.75A  HL05  R1.5  A15.0  T01  ;
N006  G105  FE001  LE005  XO1.2  YO2.3  RE02  D0.555  T02  ;
N007  G106  XB1.0A  YB1.0A  XD2.0A  YD2.0A  DR1  TC2  FC0.05  F11.0  D0.23  CR0.25  T01  ;
N008  G107  XB-0.25A  YB-0.5A  XD0.25A  YD1.0I  DR1  TC1  FC0.02  F14.0  D0.555  CR0.3  T02  ;
N009  G108  XC1.4I  YC2.8I  R0.75  DR1  TC1  FC0.04  F10.4  D0.125  T07  ;
N010  G109  XC-2.0A  YC-1.0I  R1.0  DR2  TC1  FC0  F15.0  D0.75  T04  ;
%
```

2.2.6 Sample Program

The three subsections below detail the CAD/CAM output for the sample part described in Section 5.14 of the "ProtoTRAK Plus Programming, Operating and Care Manual."

2.2.6.1   Sample Program Output From Standard Fanuc 6 Post-

Processor

```
%:SAMPLE  P/N
N1G00G90G92X0Y0Z0
N2T1M16
N3X0.7955Y0.7955S1000M03
N4G45H1Z0.05T1
N5G81R0.05Z-0.1F5.0
N6X-0.5107Y1.0024
N7X-1.1111Y-0.176
N8X-0.176Y-1.1111
N9X1.0024Y-0.5107
N10G80
N11M09
N12G28Z15.0
N13M06
N14G00X0.7955Y0.7955S1000M03
N15G45H2Z0.05T1
N16G81R0.05Z-0.6F5.0
N17X-0.5107Y1.0024
N18X-1.1111Y-0.176
N19X-0.176Y-1.1111
N20X1.0024Y-0.5107
N21G80
N22M09
N23G28Z15.0
N24M06
N25G00X0Y0S1000M03
N26G45H3Z0.05T1
N27G01Z-0.25F5.0
N28Y0.115F8.0
N29G03X0Y-0.115I0J-0.115
N30X0Y0.115I0J0.115
N31G01Y0.49
N32G03X0Y-0.49I0J-0.49
N33X0Y0.49I0J0.49
N34G00Z0.05
N35Y0.5
N36G01Z-0.25F5.0
N37G03X0Y-0.5I0J-0.5F8.0
N38X0Y0.5I0J0.5
N39G00Z0.05
N40Y-2.7
N41G01Z-0.5F5.0
N42G03X0Y2.7I0J2.7F8.0
N43X-0.134Y2.6611I0J-0.25
N44G01X-2.2953Y1.2887
```

```
N45G03X-2.4678Y-0.4177I0.5848J-0.921
N46G01X-0.1735Y-2.63
N47G03X0Y-2.7I0.1735J0.18
N48M09
N49G28Z15.0
N50G28X0Y0M05
N51M06
N52M30
%
```

2.2.6.2   Sample Program Output From FANUC 6 Post-Processor

Modified As Per Section 2.1 For The ProtoTRAK Plus

```
%:SAMPLE P/N;
N1  G00  G90  G92  X0  Y0  Z0;
N2  T1  M16;
N3  G00  X0.7955  Y0.7955  S1000  M03;
N4  G45  H1  Z0.05  T1;
N5  G81  R0.05  Z-0.1  F5.0;
N6  G00  X-0.5107  Y1.0024;
N7  G00  X-1.1111  Y-0.176;
N8  G00  X-0.176  Y-1.1111;
N9  G00  X1.0024  Y-0.5107;
N10  G80;
N11  M09;
N12  G28  Z15.0;
N13  M06;
N14  G00  X0.7955  Y0.7955  S1000  M03;
N15  G45  H2  Z0.05  T1;
N16  G81  R0.05  Z-0.6  F5.0;
N17  G00  X-0.5107  Y1.0024;
N18  GOO  X-1.1111  Y-0.176;
N19  G00  X-0.176  Y-1.1111;
N20  G00  X1.0024  Y-0.5107;
N21  G80;
N22  M09;
N23  G28  Z15.0;
N24  M06;
N25  G00  X0  Y0  S1000  M03;
N26  G45  H3  Z0.05  T1;

N28  G01  Y0.115  F8.0;
N29  G03  X0  Y-0.115  I0  J-0.115;
N30  G03  X0  Y0.115  I0  J0.115;
N31  G01  Y0.49;
N32  G03  X0  Y-0.49  I0  J-0.49;
N33  G03  X0  Y0.49  I0  J0.49;
N34  G00  Z0.05;
N35  G00  Y0.5;

N37  G03  X0  Y-0.5  I0  J-0.5  F8.0;
N38  G03  X0  Y0.5  I0  J0.5;
N39  G00  Z0.05;
```

```
N40  G00  Y-2.7;

N42  G03  X0  Y2.7  I0  J2.7  F8.0;
N43  G03  X-0.134  Y2.6611  I0  J-0.25;
N44  G01  X-2.2953  Y1.2887;
N45  G03  X-2.4678  Y-0.4177  I0.5848  J-0.921;
N46  G01  X-0.1735  Y-2.63;
N47  G03  X0  Y-2.7  I0.1735  J0.18;
N48  M09;
N49  G28  Z15.0;
N50  G28  X0  Y0  M05;
N51  M06;
N52  M30;
%;
```

2.2.6.3   Sample Program Output From ProtoTRAK Plus Programming

```
SAMPLE P/N  G20 ;
N001  G104  XC0A  YC0A  HL05  R1.125  A45.0  T01 ;
N002  G104  XC0A  YC0A  HL05  R1.125  A45.0  T02 ;
N003  G108  XC0A  YC0A  R0.75  DR2  TC2  FC0.01  F8.0  D0.5  T03 ;
N004  G103  XB0A  YB-2.45A  XE0A  YE2.45A  XC0A  YC0A  F8.0  TC1  D0.5  CR0  T03 ;
N005  G101  XB0I  YB0I  XE-3.064A  YE0.5045A  TC1  F8.0  D0.5  CR0.841  T03 ;
N006  G101  XB0I  YB0I  XE0A  YE-2.45A  TC1  F8.0  D0.5  CR-  T03 ;
%
```

3.0   Installation and Communications Testing

3.1   Required Equipment

Check to see if you have the following items:

a)   A ProtoTRAK Plus system
b)   A computer
c)   An RS232 cable which will reach from your ProtoTRAK Plus to the computer (see Section 1.0 of this manual for the specifications).

3.1.1 RS232 Mini-Tester

The RS232 mini-tester is highly recommended in assuring the proper installation of the ProtoTRAK CAD/CAM interface.   There are several manufacturers of the testers and they are readily available at local computer retailers.   Most versions have seven bi-colored LED lamps that allow you to check the status of the RS232 communications.   A representative version is configured as shown below.
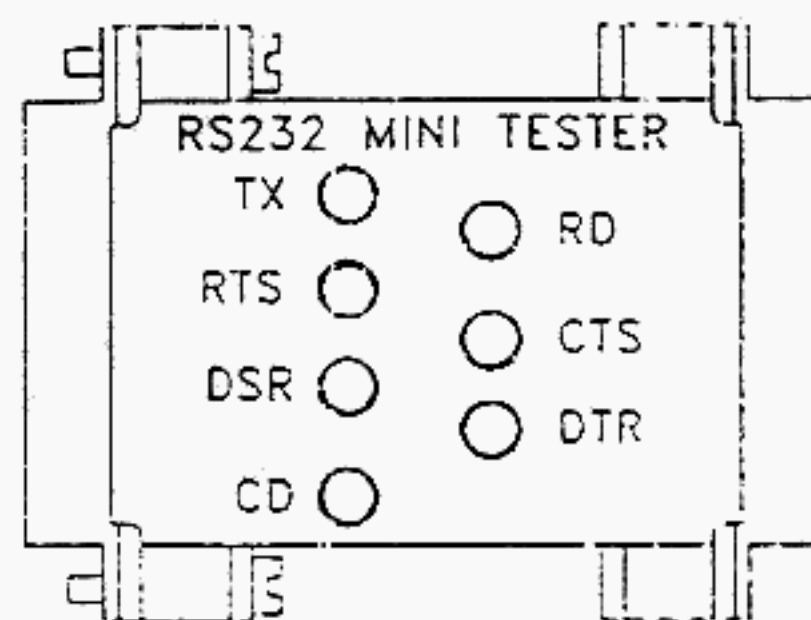
where:

TD or TX = Transmit
RD or RX = Receive
RTS = Ready To Send (jumpered to CTS at ProtoTRAK Plus)
CTS = Clear To Send (jumpered to RTS at ProtoTRAK Plus)
DTS = Data Set Ready (jumpered to CD & DTR at ProtoTRAK Plus)
CD = Carrier Detect (jumpered to DTS & DTR at ProtoTRAK Plus)
DTR = Data Terminal Ready (jumpered to DTS & CD at ProtoTRAK Plus)

3.2   Procedure

o STEP 1 - Check the ProtoTRAK Plus

Plug the RS232 mini tester into the ProtoTRAK RS232 connector.   Turn the power on and check for the following status on the mini tester:

TX or TD = GREEN   RD or RX = OFF
RTS = OFF   CTS = OFF
DSR = OFF   DTR = OFF
CD   = OFF

o STEP 2 - Check the Computer

Unplug the RS232 mini tester from the ProtoTRAK and plug it into the computer's RS232 connector.

> NOTE: On IBM PC's this communication connector is a 25-pin male (pins) connector (it's easily confused with the parallel port connector which is a 25-pin female).   On the IBM AT and PS/2 you will need a DB9 to DB25 adapter that is available from any computer retailer.

Turn the power on and check for the following status on the mini tester:

```
TX or TD   = GREEN        RD or RX  =  OFF
RTS  =  RED  or  GREEN    CTS  =  OFF
DSR  =  OFF               DTR  =  RED  or  GREEN
CD   =  OFF
```

You should have the TX = green.   This should ensure that the Transmit is not on the same wire as the ProtoTRAK's Transmit signal.   If you do not have the above condition, there may be a problem with your computer's RS232 port.

o STEP 3 - Check the cable.

With the power to the computer still on, unplug the mini tester from the computer and plug the cable with the proper configuration (including the XT Null Modem) into the computer's communication port.   Now plug the RS232 mini tester into the other end of the cable and check for the following status on the mini tester:

```
TX or TD = OFF           RD or RX =  GREEN
RTS  =  RED  or  GREEN    CTS  =  RED  or  GREEN
   (same  as  CTS)           (same  as  RTS)

DSR  =  OFF               DTR  =  RED  or  GREEN
CD   =  OFF
```

If you do not have the above condition, recheck Step 3 and if it is okay, then your cable is no good or not correct.   Replace it.

o STEP 4 - Test the transmit function from the computer.

To test the computer's transmit function, we need to send any available ASCII file out the communication port to watch the status of the RS232 mini tester.

IBM PC - If you have an IBM PC, use the DOS COPY command to send the test file out the comm port.   If your file name is TEST.DAT and the communication port is COM 1, type in COPY TEST.DAT COM1.   If you see the RS232 mini tester LED RD change from green to red, this means that the data has been successfully sent out of the communication port.

APPLE Macintosh - The Macintosh needs a communication program and a "MAC to HAYES modem" cable adapter (purchased from a local computer retailer). You will also need the Null Modem. Then you can send or receive data through the Macintosh MODEM port. Use an RS232 mini tester to check for a change of color on the RD LED.

Other Computers - The ProtoTRAK can communicate with most any RS232 device. By understanding the file format and the communication protocols you can send or receive data to the ProtoTRAK Plus.

o STEP 5 - Test communications.

Plug the female side (pin socket) of the RS232 mini tester into the ProtoTRAK RS232 connector with the cable still connected to the computer. Turn the ProtoTRAK on and check for the following status on the mini tester:

TX or TD = GREEN   RD or RX = GREEN
RTS = RED or GREEN   CTS = RED or GREEN
   (same as CTS)   (same as RTS)
DSR = } All should be the same color
DTR = } due to jumpers on ProtoTRAK
CD = } Plus back panel

Use the following example to try to receive a file from the computer:

IBM PC - With an IBM PC we can use the DOS COPY command to send or receive a file from the PC's floppy or hard disk.

a. Configure communications port by the MODE command:
   MODE COM1:4800,e,7,1,
b. Write and save a simple program on the computer with any label; for example, 1.CNC. Delete the program from the ProtoTRAK. Press the Tape/RS232 button and you should see TAPE=1, COMM=2 alternately flash in the conversation display. Press 2 for the COMM option and the conversation display will alternately flash RECEIVE=1 SEND=2. Enter 1 and press the +/- key. The display will say OK TO RCV. At this point go over to the IBM PC and type the following: COPY 1.CNC COM1. The program should be copied from the floppy disk to the COM1 communication port. The Proto-TRAK Plus should respond with a RECEIVE OK. Press RESTORE and go into EDIT to see if all of the data is correct.

Apple Macintosh - The Apple Macintosh will need a communication program that is used to communicate with phone modems. This program can be purchased from any computer retailer. The ProtoTRAK Plus will operate as "REMOTE DEVICE" when connected as if it was a modem. If you have the EZ-CAM family of products from Bridgeport Machines, use the EZ-LINK protocol option.

Other Computers - Most other computers have the ability to communicate with a modem. You can send the ProtoTRAK ASCII file via your computer's RS232 port. Review the file specifications to determine if it will work with your particular computer and programs.

G Code	Meaning
G0	rapid positioning
G1	linear interpolation
G2	circular/helical interpolation (clockwise)
G3	circular/helical interpolation (counterclockwise)
G4	dwell
G10	coordinate system origin setting
G17	XY-plane selection
G18	XZ-plane selection
G19	YZ-plane selection
G20	inch system selection
G21	millimeter system selection
G28	return to home
G30	return to secondary home
G38.2	straight probe
G40	cancel cutter radius compensation
G41	start cutter radius compensation left
G42	start cutter radius compensation right
G43	tool length offset (plus)
G49	cancel tool length offset
G53	motion in machine coordinate system
G54	use preset work coordinate system 1
G55	use preset work coordinate system 2
G56	use preset work coordinate system 3
G57	use preset work coordinate system 4
G58	use preset work coordinate system 5
G59	use preset work coordinate system 6
G59.1	use preset work coordinate system 7
G59.2	use preset work coordinate system 8
G59.3	use preset work coordinate system 9
G61	set path control mode: exact path
G61.1	set path control mode: exact stop
G64	set path control mode: continuous
G80	cancel motion mode (including any canned cycle)
G81	canned cycle: drilling
G82	canned cycle: drilling with dwell
G83	canned cycle: peck drilling
G84	canned cycle: right hand tapping
G85	canned cycle: boring, no dwell, feed out
G86	canned cycle: boring, spindle stop, rapid out
G87	canned cycle: back boring
G88	canned cycle: boring, spindle stop, manual out
G89	canned cycle: boring, dwell, feed out
G90	absolute distance mode
G91	incremental distance mode
G92	offset coordinate systems and set parameters
G92.1	cancel offset coordinate systems and set parameters to zero
G92.2	cancel offset coordinate systems but do not reset parameters
G92.3	apply parameters to offset coordinate systems
G93	inverse time feed rate mode
G94	units per minute feed rate mode
G98	initial level return in canned cycles
G99	R-point level return in canned cycles

Table 5. G Codes

3.6 Input M Codes

M codes of the RS274/NGC language are shown in Table 7.

M Code	Meaning
M0	program stop
M1	optional program stop
M2	program end
M3	turn spindle clockwise
M4	turn spindle counterclockwise
M5	stop spindle turning
M6	tool change
M7	mist coolant on
M8	flood coolant on
M9	mist and flood coolant off
M30	program end, pallet shuttle, and reset
M48	enable speed and feed overrides
M49	disable speed and feed overrides
M60	pallet shuttle and program stop

Table 7. M Codes

3.6.1 Program Stopping and Ending — M0, M1, M2, M30, M60

To stop a running program temporarily (regardless of the setting of the optional stop switch), program M0.

To stop a running program temporarily (but only if the optional stop switch is on), program M1.

It is OK to program M0 and M1 in MDI mode, but the effect will probably not be noticeable, because normal behavior in MDI mode is to stop after each line of input, anyway.

To exchange pallet shuttles and then stop a running program temporarily (regardless of the setting of the optional stop switch), program M60.

If a program is stopped by an M0, M1, or M60, pressing the cycle start button will restart the program at the following line.

To end a program, program M2. To exchange pallet shuttles and then end a program, program M30. Both of these commands have the following effects.

1. Axis offsets are set to zero (like G92.2) and origin offsets are set to the default (like G54).
2. Selected plane is set to CANON_PLANE_XY (like G17).
3. Distance mode is set to MODE_ABSOLUTE (like G90).
4. Feed rate mode is set to UNITS_PER_MINUTE (like G94).
5. Feed and speed overrides are set to ON (like M48).
6. Cutter compensation is turned off (like G40).
7. The spindle is stopped (like M5).
8. The current motion mode is set to G_1 (like G1).
9. Coolant is turned off (like M9).

G CODES FOR MACHINING CENTERS

G00 positioning (rapid traverse)	G54 work coordinate system 1 select
G01 linear interpolation (feed)	G55 work coordinate system 2 select
G02 circular interpolation CW	G56 work coordinate system 3 select
G03 circular interpolation CCW	G57 work coordinate system 4 select
G04 dwell	G58 work coordinate system 5 select
G07 imaginary axis designation	G59 work coordinate system 6 select
G09 exact stop check	G60 single direction positioning
G10 offset value setting	G61 exact stop check mode
G17 XY plane selection	G64 cutting mode
G18 ZX plane selection	G65 custom macro simple call
G19 YZ plane selection	G66 custom macro modal call
G20 input in inch	G67 custom macro modal call cancel
G21 input in mm	G68 coordinate system rotation ON
G22 stored stroke limit ON	G69 coordinate system rotation OFF
G23 stored stroke limit OFF	G73 peck drilling cycle
G27 reference point return check	G74 counter tapping cycle
G28 return to reference point	G76 fine boring
G29 return from reference point	G80 canned cycle cancel
G30 return to 2nd, 3rd & 4th ref. point	G81 drilling cycle, spot boring
G31 skip cutting	G82 drilling cycle, counter boring
G33 thread cutting	G83 peck drilling cycle
G40 cutter compensation cancel	G84 tapping cycle
G41 cutter compensation left	G85,G86 boring cycle
G42 cutter compensation right	G87 back boring cycle
G43 tool length compensation + direction	G88,G89 boring cycle
G44 tool length compensation - direction	G90 absolute programming
G49 tool length compensation cancel	G91 incremental programming
G45 tool offset increase	G92 programming of absolute zero point
G46 tool offset decrease	G94 per minute feed
G47 tool offset double increase	G95 per revolution feed
G48 tool offset double decrease	G96 constant surface speed control
G50 scaling OFF	G97 constant surface speed control cancel
G51 scaling ON	G98 return to initial point in canned cycle
G52 local coordinate system setting	G99 return to R point in canned cycle

STANDARD M-CODES

M00 program stop	M21 tool magazine right
M01 optional stop	M22 tool magazine left
M02 end of program (no rewind)	M23 tool magazine up
M03 spindle CW	M24 tool magazine down
M04 spindle CCW	M25 tool clamp
M05 spindle stop	M26 tool unclamp
M06 tool change	M27 clutch neutral ON
M07 mist coolant ON	M28 clutch neutral OFF
M08 flood coolant ON	M30 end program (rewind stop)
M09 spindle orientation ON	M98 call sub-program
M19 spindle orientation ON	M99 end sub-program