AXIS MOTION

Profiler

Profiler

General Reference Manual

Table of Contents

Introduction *11*

Overview *11*

Creating Drawings *13*

Loading Drawings from DXF and CNC Files *13*

Drawing Display *13*

Viewing 3D Shapes **14**

Mouse Usage *15*

Drawing and Editing Shapes *15*

Drawing Shapes **15**
Insert Circle 16
Insert Rectangle 16
Insert Point 16
Insert Line or Polyline 16
Insert Arc or Polyarc 16
Array Selected Objects 16

Editing Shapes **17**
Move 17
Copy 17
Rotate 17
Scale 17
Mirror 17
Fillet 17
Adjust Bulge or Radius 17
Adjust Vertex Position 17
Stretch Vertex Positions 18
Delete Vertices 18
Erase 18
Join 18
Break 18
Trim 18
Offset 18

Operations Supporting Drawing and Editing *19*

Mouse Snapping During Editing Operations **19**
Vertex 19
Centre 19
Midpoint 20
Intersection 20
Nearest 20
Orthogonal 20

None 20

Fast Zooming During Editing Operations 20
Zoom In 20
Zoom Out 20
Pan 20
View All 20

Rotation During Move, Copy and Paste Operations 21
Rotate Anticlockwise 21
Rotate Clockwise 21
Increase Rotation Step Size 21
Decrease Rotation Step Size 21

Changing the Layout 21
Left Justify 21
3D Surface Justify 21
3D Bottom Justify 22
Rotate90 22
Mirror 22
Change origin 22

Clipboard Operations 22
Copy to Clipboard 22
Load Fileto Clipboard 22
Clear Clipboard 22
Paste from Clipboard 22
Paste Absolute from Clipboard 22

Machine Path Editing 23
Change the start position 23
Reverse Direction 23
Set Directions Automatically 23
Pause 23

Sequencing 23
Full Sequencing 24
Group Sequencing 24
Reverse Sequencing 24
Automatic Sequencing 24
Level Sequencing 24

Engraving 25

Creating Tool Paths 26

Shape Group Classification 26

Group Cut Settings 26
Status 26
Traversal Shape 26
Tool Control 27
Group Cut Speed 27
Cut Height Type 27
Multipass 27
Distance per Pass 27
Rough Pass Offset (mm) 27

Group Machine Tool Path Creation Options 28
Offset 29

Double Line ... 29
Tag ... 29
Lead-In Radius and Angle ... 29
Lead-Out Radius and Angle ... 29

Special Offsets ... 30
Offsets of Shapes with Self Loops ... 30
Offsets of 3D Shapes ... 30

Arraying the Basic Block of Data ... 30

File Types and Saving the Data ... 33

File Type Extensions ... 33
DXF ... 33
RSG ... 33
RSM ... 33

File Comments ... 33

Machine Configuration and Operation ... 34

Axis Parameters ... 34
Motor Steps per Unit ... 34
Axis Lengths ... 34
Maximum Speeds ... 34
Maximum Accelerations ... 34
Limit Movement ... 35

Microstepping Drive Parameters ... 35
Direction Delay ... 36
Step Delay ... 36

Motor Parameters ... 37
Motor Directions ... 37
Motor to Axis Assignments ... 37

Special Z Axis Positions ... 38
Z Origin ... 38
Z Home ... 38
Z Top ... 38
Z Surface ... 38
Z Bottom ... 38

Maximum Machine Cutting Speeds ... 39
Machine Cutting Speed ... 39
Machine Plunging Speed ... 39

Special Delay Times During Cutting ... 39
Router/Shutter Start Delay ... 40
Air Tool Delay ... 40
Bottom Delay Type ... 40
Bottom Delay Time ... 40
End Delay Time ... 40
End Delay Intensity ... 40

Pausing the Machine ... 41
Raise On Pause? ... 41

Hardware Input and Output ... 41
Parallel Port Output ... 41
XYZW-Step Byte A ... 42

(Output Port A) 42
Control Byte B (Output Port B) 42
Control and QR-Step Byte C 42
(Output Port C) 42
Status Byte A (Input Port A) 43
Status Byte B (Input Port B) 43

Intensity Output 44
Intensity Output Example 44

Automatic Height Control 45
Maximum Speed 46
Maximum Acceleration 46
Activation Speed 46
Do Height Control between Shapes 46
Simple Height Control 46
Proportional Height Control 47
X Axis Set Point 47
Y Axis Set Point 47
Proportionality Constant 47
HC Input (POT) scale 48
HC Display Accuracy 48
HC Serial Port 48
HC Serial Port Speed 48

Plasma Startup Sequence 48
Initial Height 49
Initial Wait Time 49
Debounce Time 49

Laser Operation 50
Use Pierce Sequence? 50
Laser Piercing Frequency (Hz) 50
Pierce height above surface (mm) 50
Pierce Gas Tool Bit: 0(=none), 1, 2 or 3 50
Pierce Gas Wait Time (milliseconds) 50
Pierce Intensity 50
Pierce Time (milliseconds) 50
Pierce Gas Purge Time (milliseconds) 50
Laser Cutting Frequency 50
Cut Gas Tool Bit: 0(=none), 1, 2 or 3 50
Cut Gas Wait Time (milliseconds) 50
Cut Gas Control Bits Override Group Settings? 50
Engraving Cut Bit: 0(=none), 1,2 or 3 51
Set Low bit of intensity high during bottom delay? 51

Finding the Home Position on an Axis 51
Fast Homing Speeds 51
Slow Homing Speeds 51
Distance Off Homing Switches 51
Second Z Axis Adjustment 51
Home Two X or Y Motors Separately 51
X Home Position 52
Y Home Position 52

Emergency Stopping 53

Miscellaneous Configuration Options 53
Output the Intensity? 53

Do Height Control? 53
Use Plasma Startup Sequence? 53
Use Laser? 53
Do Double Job Start? 53
Use Tangential Axis? 54
Runtime Drawing Amount (0-10) 54
Automatic Homing Control 54

Tool Path Smoothing 54
Smoothing Factor 55
Stop Angle 55

When are the Smoothing Factors used? 55

Machining the Job 56

Job Origin and Finish Positions 56

Two Jig Machines 57

Changing the Tool Position 58
Move to Home 58
Move to Job Origin 58
Move to Job Finish 58
Arrow Keys 58
CutMoveTo… 58
MoveTo… 58

Controlling the Job Cutting 58

Using an External Job Start Input 59

Hand Console 60

Digitizing 65

Digitizing 2D Shapes 65

Digitizing 3D Shapes 65

Digitizing with the Hand Console 66

Sending Files 68

Customizing Profiler 68

Communication 68

General Options 69
Password protect configurations? 69
Do double job start? 69
Do automatic homing at program start? 69
Do automatic homing at job start? 69
Path vertex filtering distance 69
Default joining distance for shapes 69
Mouse selection radius (pixels) 69
Parallel port (1 or 2) 69

Viewing Options 70
Show each shape with its group colour? 70
Show Smoothed Paths? 70
Show shapes in groups which are turned off as dashed? 70
Show path starts (as yellow direction indicators)? 70

Show path vertices (as black crosses)? 70
Show filtered path vertices (as blue crosses)? 70
Show Rough Offsets 70
Window expansion factor (%) 70

Timing Diagrams*..... *72

..... *72*

..... *73*

..... *74*

PCI Card*..... *77

Outputs..... 77

Inputs..... 78

I/O Card*..... *79

Outputs..... 80
Manufacturing Applications 80

Inputs..... 81

Output and Input Pin Configuration*..... *82

Glossary*..... *84

Tables

Table 1 Drawing 2D Shapes 16
Table 2 Editing Operations 17
Table 3 Fast Zooming 20
Table 4 Live Rotation 21
Table 5 Layout Operations 21
Table 6 Clipboard Operations 22
Table 7 Machine Path Editing Operations 23
Table 8 Sequencing Operations 24
Table 9 Group Cut Settings 26
Table 10 Group Machine Tool Path Creation Settings 29
Table 11 File Types 33
Table 12 Axis Parameters 34
Table 13 Microstepping Drive Parameters 36
Table 14 Motor Parameters 37
Table 15 Special Z Axis Positions 38
Table 16 Maximum Machine Cutting Speeds 39
Table 17 Delay Parameters 40
Table 18 Pausing 41
Table 19 ***Profiler*** *Input and Output* 41
Table 20 Height Control Setup 46
Table 21 Proportional Height Control Setup 47
Table 22 Plasma Startup Sequence Parameters 49
Table 23 Homing Procedure Parameters 51
Table 24 Miscellaneous Machine Options 53
Table 25 Path Smoothing Control 55
Table 26 Moving the Tool 58
Table 27 Digitizing Functions 67
Table 28 Configuring File Sending 68
Table 29 Configuring Hand Console Communications 69
Table 30 General Options 69
Table 31 Viewing Options 70
Table 32 PCI Card Outputs 77
Table 33 PCI Card Inputs 78
Table 34 I/O Card Outputs 80

Figures

Figure 1 Bounding Box of Drawing *14*
Figure 2 An example of engraving *25*
Figure 3 Machine Path Creation: Offset, Tags and Lead-Ins. *28*
Figure 4 Definition of a Lead-In *28*
Figure 5 Two Level Arraying *31*
Figure 6 Examples of Array Ordering *32*
Figure 8 Example of PWM laser Intensity Output *45*
Figure 9 Cross Section Showing How ZSurface and ZTop Change During Height Control *46*
Figure 10 The Homing Procedure *52*
Figure 11 Path Smoothing and Turning Angles *55*
Figure 12 Position of data Relative to Machine Bounds and Job Origin *56*
Figure 13 Hand Console (or Keypad) *60*
Figure 18 I/O Card Layout Diagram *79*
Figure 19 I/O Card Inputs *81*
Figure 20 System Box Connections *82*

Introduction

This reference manual provides a description and a technical specification of **Profiler**, the machine control software from Axis Motion. **Profiler** is a unified program which makes it easy to import or create graphical drawing data, modify the data for cutting and directly control a machine during the cutting of the shapes defined by the data. The progress of the cutting is displayed graphically in real-time. The machining version of **Profiler** runs on any Pentium based computer that has the PCI bus interface card provided by Axis Motion.

This manual describes **Profiler** for technically oriented readers and is not an advertising brochure. It also gives the pin layout details of the supporting hardware provided by Axis Motion.

The glossary at the end of this manual provides a description of various terms and abbreviations that have been used within the document.

Overview

Profiler runs on any Pentium 600+ based computer and controls all aspects of the cutting process in a single, unified environment with a graphical user interface. The cutting process supported by **Profiler** can be summarised as follows:

- load drawings from a CAD program or draw the shapes to be cut;
- define various parameters to control the way in which the shapes will be cut;
- define any arraying of the drawing;
- automatically generate the cutting path drawing from the required specifications (including job arraying and offsetting);
- set up the machine parameters such as cutting speed and plunging speed and
- start cutting the shapes on the machine under direct operator control.

A drawing containing the shapes to be cut out can be defined in a number of ways. Drawings which have been developed in a CAD package capable of exporting descriptions of the drawing in DXF format can be loaded into **Profiler**. In addition, **Profiler** provides drawing facilities which allow circles, rectangles, polylines and polylines with arcs (polyarcs) to be drawn. **Profiler** also provides a digitizing facility in both two and three dimensions. Digitizing enables shapes to be specified as lines or arcs in 2 or 3 dimensions by recording successive positions of the machine tool.

The drawings can be modified in various ways within **Profiler**. For example, the starting points of shapes can be changed and the shape cutting sequence can be altered.

A machine cutting tool must follow a path which is different from the specified drawing in order to produce the desired shapes. For example, a routing tool has a certain diameter and so its path must be offset from the drawn shape if the cut shape is to have the correct size. Within **Profiler** shapes can be assigned to one of eight different groups. Each group has adjustable shape cutting parameters and cutting path creation parameters including the offsets, tags and lead-ins and lead-outs. **Profiler** automatically generates the correct cutting path for each shape using the appropriate group settings.

Profiler provides comprehensive support for a variety of machining tools including routers, lasers, plasmas and knives. For example, it is possible to specify shapes that require multiple cutting passes, a feature often used on routing machines with a limited cutting depth per pass. For laser and plasma tools a constant height above the job surface can be automatically maintained during cutting. This height control feature is crucial for the effective use of these tools when cutting warped sheets of material, for example. **Profiler** has also been used to control a variety of other machines such as lathes and punch machines.

Profiler *directly* controls all aspects of the machine operation: it generates the motor positioning pulses and tool control information (such as turning a laser on, setting the laser intensity or starting a router tool) and senses the machine state using input information (such as the state of homing switches or the state inputs which control the height of the tool). The operator can move the machine tool head by either using the computer keyboard or a hand console attached to the computer via a serial link. The machine motion and the progress of the cutting are displayed graphically in real-time so that the position of the machine in relation to the job is always visible.

Chapter 1

Creating Drawings

The drawings in **Profiler** can consist of two-dimensional or three-dimensional polyline or polyarc shapes. Polyline shapes consists of joined lines. Polyarc shapes consist of joined lines and arcs. Drawings in **Profiler** can be created by:

- Loading the drawing from a file produced by another CAD package.

- Drawing the shapes using the drawing and editing facilities provided by **Profiler**. These facilities include the insertion of two dimensional circles, rectangles, polylines and polylines with arcs. These facilities are described below in the sections on Drawing Shapes and Editing Shapes;

- Digitizing the shapes. If shapes are defined by using the machine to successive points then they become part of the current drawing. Either two or three-dimensional shapes can be digitized. The digitizing facilities of **Profiler** are described below in the section on Digitizing.

Loading Drawings from DXF and CNC Files

Profiler can read the following file types produced by other packages:

- DXF Release 12 format. Drawings created in another CAD package can be loaded if they have been exported from that package in DXF Release 12 format. It is possible to load such files directly or to load them into a clipboard and then to paste from the clipboard into the current drawing. **Profiler** recognises the following DXF entities: POLYLINE, LWPOLYLINE, LINE, POINT, CIRCLE, ELLIPSE and ARC;

- CNC files (having file extension ".nc"), which contain G codes defining the shapes. **Profiler** converts the path information in NC files, as defined by the G codes G1 (linear interpolation) and G2 and G3 (circular interpolation), into its own internal path representation. Other codes which are important for interpreting the path information are also used in constructing the path information. These codes include G0 (fast movement), G17, G18, G19 (setting the plane) G70, G71 (defining inch or mm mode). Generally, aspects other than the G code path description, such as dwell time, drill cycles, mist coolant control, tool changes and spindle speeds are ignored. These aspects of the cutting are controlled in alternative ways within **Profiler** and need to be set by the user. Note also that **Profiler** can read *general 3D arcs* specified by the current point (X0,Y0,Z0) and a G2 or G3 code block containing the next point (X1,Y1,Z1) and centre specified by (I,J,K) values.

Drawing Display

The display of the drawing data in **Profiler** is designed to offer as much information as possible to the user and to help in the cutting of shapes. All shapes are drawn in top view with the usual orientation of the *x* and *y* axes.. An important attribute of the drawing is its *bounds*. The bounds of the drawing are

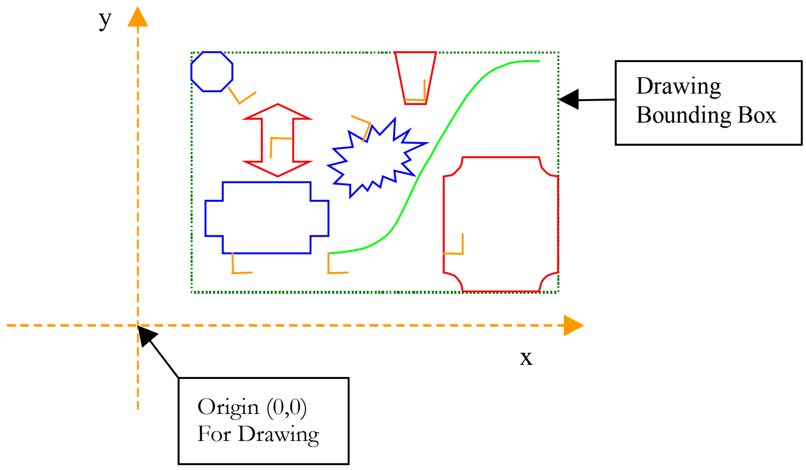

Figure 1 Bounding Box of Drawing

defined by the smallest enclosing rectangle or, in the case of 3D shapes, by the smallest enclosing box, as shown in Figure 1. Whenever the data is drawn the *x*-axis and *y*-axis bounds are shown as a dashed rectangle. The drawing bounding box is drawn as a green dashed rectangle and contains what is later referred to as the *basic block of data*. A small yellow direction indicator indicates the starting position of each shape. Closed shapes which are to be cut in a clockwise direction are drawn in red. Closed shapes which are to be cut in a counter-clockwise direction are drawn in blue. Open shapes are drawn in green. An alternative way of displaying shapes is by using their group colour – this will be explained in the section below on the classification of shapes into groups. See the section on Viewing Options for more details on how the drawing display can be adjusted. Note that 3D shapes can be viewed in an orthogonal projection by activating the "View in 3D" option in the view menu.

Viewing 3D Shapes

Profiler supports viewing of 3D shapes using orthogonal projection, side and end views. It is possible to zoom in and out and to pan during 3D display. As the viewing direction is changed the current *xy* coordinates of the mouse location are displayed as projected onto the currently defined *z*-plane. The current *z*-plane can be set by panning or zooming when the side or end views are being displayed.

During 3D viewing the 3D shapes are drawn as expected and all 2D shapes are drawn at their correct depths. In particular, shapes defined to be THRU shapes are displayed in the horizontal plane which has z coordinate equal to the currently defined ZBottom position; shapes defined as MM shapes are drawn in the plane with z coordinate the correct depth below the ZSurface machine positon; and shapes which are defined to be multi-pass (i.e. which require multiple cutting at different depths) are drawn multiple times at the required depths. In addition, when appropriate the current location of the machine is also displayed along with the important preset machine positions of ZTop, ZBottom and ZSurface.

Mouse Usage

The mouse can be used to control menu selections and the entering of data in dialogues. It is also used for special drawing purposes. When being used for drawing interaction the mouse cursor is displayed as a red cross-hair. To specify a point the Left Mouse Button (LMB) is clicked. To specify a region (for example, when zooming) the LMB is pressed and held down and the mouse moved (as the mouse moves a region is drawn). The region is selected when the LMB is lifted.

If the left side of the region was clicked first when selecting a set of shapes then only shapes contained completely within the mouse defined region are selected. If the right side of the region was clicked first then all shapes contained within or touching the mouse defined region are selected.

If the mouse is being used for shape selection then it is possible that the location at which the mouse is clicked has more than a single shape within the distance defined by the mouse selection radius. This may occur, for example, when there are identical shapes on top of each other such as after a *Copy To Group* operation. When this situation occurs a dialogue is displayed indicating the shapes within the selection radius by small buttons with the corresponding shape's group colour. The order of these buttons corresponds to the current sequence ordering of the shapes. Shapes which have already been selected are indicated by highlighted buttons. The selection is complete after one of the buttons in the dialogue is selected from the dialogue (or no selection is made by cancelling the dialogue).

The Right Mouse Button (RMB) is used in a variety of ways depending on the stage of an operation. The interaction has been designed to be intuitive and easy to use. Sometimes clicking the RMB finishes a current action, such as selecting a set of shapes with the LMB. Other times it will cancel an operation when the operation will be ended with the LMB, such as selecting the endpoint of a move operation.

To cancel an operation the Escape key can also be pressed.

If no operation is being performed then the RMB will initiate the previous type of operation if there is one. For example, when you have finished moving a set of shapes then clicking the RMB will start another Move operation.

Drawing and Editing Shapes

Once the drawing has been loaded, drawn or digitized in **Profiler** it can be modified in a number of ways. In what follows the modification operations are explained. The details of how these operations are performed within the user interface of **Profiler** are described in the implementation description and depend on the operating system being used.

Drawing Shapes

The drawing features of **Profiler** allow shapes to be inserted into a drawing. In many cases the ability to add these types of shapes to a drawing will obviate the need for the use of a CAD drawing package. The implementation of these drawing operations allows the mouse to be used to specify the shapes or, alternatively, for information to be typed in using the keyboard. In addition, snapping facilities (described in a table below) allow existing vertices, line and arc midpoints, arc centres and intersection points to be selected during drawing and editing operations.

Table 1 Drawing 2D Shapes

Drawing Operation	Description
Insert Circle	Specify the centre and radius using the mouse. Alternatively, type in the coordinates of the centre and the radius.
Insert Rectangle	Specify opposite corners of the rectangle using the mouse. Alternatively, type in the coordinates of the first corner of the rectangle and then the coordinates of the opposite corner or the width (in the x axis direction) and height (in the y direction). The width and height may be positive or negative.
Insert Point	A single ***point*** (used, for example, to specify drill holes). Specify the point using the mouse. Alternatively, type in the x and y coordinates of the point.
Insert Line or Polyline	Specify the successive points in the polyline using the mouse. Alternatively, a point can be specified by typing its x and y coordinates. The polyline can be inserted as a closed polyline (i.e. as a polygon) by snapping to the start point vertex or as an open polyline by clicking the right mouse button or snapping to the last vertex.
Insert Arc or Polyarc	Specify the successive points in the polyarc using the mouse. The bulge on the line joining the specified points can be adjusted by moving the mouse as each point is inserted. Alternatively, the next point can be specified by typing its x and y coordinates together with a bulge factor. The polyarc can be inserted as a closed polyarc (i.e. as a generalized polygon with arcs) by snapping to the start point vertex or as an open polyline by clicking the right mouse button or snapping to the last vertex. See the operating system specific implementation notes for the details of how to perform these operations.
Array Selected Objects	Select a set of objects and array them in either a rectangular or circular manner: 1. Rectangular array: specify the number of rows and columns of copies and the spacing between the rows and columns; 2. Circular array: specify a centre and the number of copies around the circle.

Editing Shapes

Shapes in the drawing can be edited using a number of operations. Some operations act on individual shapes whilst others can affect several shapes at once (e.g. the joining operation). The shapes to be operated on are selected before the operation is performed. The following table describes these operations.

Table 2 Editing Operations

Editing Operations	Description
Move	Selected shapes can be moved from a specified base point by a relative or an absolute distance in the *x* and *y* directions. The move can be specified using mouse operations or by typing in the x and y values of the new base point.
Copy	Selected shapes can be copied from a specified base point by a relative or an absolute distance in the *x* and *y* directions. The move can be specified using mouse operations or by typing in the x and y values of the new base point.
Rotate	Selected shapes can be rotated from a specified base vector by a relative or an absolute angle. The rotation can be specified using mouse operations or by typing in the coordinates of the base vector and the angle of rotation.
Scale	Selected shapes can be scaled by a non-zero positive multiplicative factor around a specified base point by typing in the scale factor. The base point can be specified using mouse operations or by typing in the *x* and *y* coordinates. For example, a factor of 2.0 will double the size of all of the selected shapes in the drawing and a factor of 25.4 will convert all of the selected shapes in the drawing from inches to millimetres. To scale the entire drawing all shapes must be selected. Selected shapes can also be scaled relative to a defined base vector length by typing in the new length or using a mouse selection.
Mirror	Selected shapes can be mirrored across a line defined by using the mouse or by typing in the coordinates of the line's start and end points.
Fillet	Add fillets of a specified radius between two successive segments of a path. The successive segments must each be at least the length of the radius for this operation to succeed.
Adjust Bulge or Radius	Individual line and arc segments of a shape can be modified by adjusting their bulge factor or radius. This can be done using the mouse to select and drag the segment or by typing in a new bulge factor.
Adjust Vertex Position	Vertex positions can be modified. This can be done by using the mouse to select and drag the vertex or by typing in a new vertex position. If a segment adjoining the vertex which is being modified is an arc then the original start point and mid-point of this arc together with the new vertex position are used to define the new arc.

Stretch Vertex Positions	Modify a set of vertex positions. Vertices are selected with the mouse and then moved from a specified base point by a relative or an absolute distance in the *x* and *y* directions. The move can be specified using mouse operations or by typing in the x and y values of the new base point. If only one end point of a segment is being moved then the segment is stretched (hence the name of the operation). If the segment is an arc then the bulge of the arc is kept constant (for example, a semicircle will remain as a semicircle).
Delete Vertices	Delete a set of vertices in 2D paths. Vertices are selected with the mouse and then deleted by clicking the right mouse button. If the segment before a deleted vertex is an arc then the bulge of the arc is kept constant (for example, a semicircle will remain as a semicircle).
Erase	Shapes can be selected and removed from the drawing.
Join	Join selected open shapes which have their endpoints within a specified distance. There are two ways of processing the endpoints which are within the joining distance: 1. Both endpoints appear in the resulting joined shape with a line joining the points or 2. One of the endpoints is removed. If the last segment is an arc then it is replaced by an arc with the same endpoint and midpoint and passing through the start point of the joining polyarc. This operation applies to all of the selected shapes in the drawing and is repeated automatically on pairs of shapes with endpoints within the join distance (but in a non-deterministic way, usually related to the sequence of the shapes) until there are no selected open shapes with endpoints within the specified join distance. This operation must be used with care. Its main use is for joining shapes which are obviously meant to be single shapes but which have been split into many smaller shapes (e.g. by a scanning process in a CAD package).
Break	Break a shape at a selected point. This operation is particularly useful for introducing small tags around a shape which will hold the shape in position while it is being cut. It can also be used for trimming shapes or erasing small sections of shapes.
Trim	Trim parts of shapes. This operation requires the selection of a set of trim shapes which control the trimming. Once the trim shapes have been defined then selecting any part of a shape will trim back to its intersection with the trim shapes (if any). Self-loops in the trim shapes can also be trimmed.
Offset	Selected shapes can be offset by a positive or negative amount. This offsetting does not effect the offseting which is applied to groups when creating the machining data.

Operations Supporting Drawing and Editing

Several features are included to help support the drawing and editing functions of Profiler. These include snapping to well defined locations, zooming in and out with simple key strokes and rotating shapes while performing move operations. The latter feature can be very useful for manual layout of shapes in order to optimise material usage or align a shape.

Mouse Snapping During Editing Operations

Snapping is a method of specifying positions with respect to existing shapes in the drawing. It can be used during various editing operations. Snapping can best be explained by considering an operation such as moving shapes. Moving shapes requires the specification of a position referred to as the base point and a position referred to as the endpoint. These two points together describe the vector by which to move the shapes.

The normal way to move a shape is to perform the following steps:

1. Select the shape (or shapes) with the left mouse button (LMB) - the right mouse button (RMB) finishes the selection;

2. Select a base point for the move operation. This can be done by either clicking the LMB at the desired location or by hitting the T key (for Type) and typing in the coordinates of the base point.

3. Move the shapes to the required location and select the end point using the LMB. Alternatively, type in the coordinates of the end point (either relative to the base point or as an absolute position).

Snapping enables the specification of the base point and end point for the move vector to be done with the mouse according to positions on existing shapes. For example,.suppose you want to move a rectangle so that its bottom left corner is at the top right corner of another rectangle. This can be done by selecting *vertex snapping* (by hitting hot key V) before selecting the base point and then clicking near the bottom left corner of the rectangle to be moved (so that the corner is within the mouse selection radius shown by a small circle). Similarly, select *vertex snapping* before selecting the end point of the move and then click near the top right hand corner of the desired rectangle. This will move the selected rectangle so that its bottom left corner coincides exactly with the top right corner of the desired rectangle.

Several different types of snapping are possible. They are selected during editing operations by simply hitting the corresponding hot-key given in the following table. The snapping operations available at any time during an editing operation are displayed in the message box at the bottom left of the screen by showing the hot-keys (e.g. VCMINQ).

Snap Type	Key	Description
Vertex	V	Select the nearest vertex to the current mouse position which is within the mouse selection area. No selection is made if there is no vertex within the selection radius.
Centre	C	Select the centre of the nearest arc to the current mouse position which is within the mouse selection area. No selection is made if there is no arc within the selection radius.

Snap Type	Key	Description
Midpoint	M	Select the midpoint of the nearest line or arc segment to the current mouse position which has a point within its middle 3/5ths which is within the mouse selection area. No selection is made if there is no line or arc within the selection radius.
Intersection	I	Select the nearest intersection point to the current mouse position which is within the mouse selection area. No selection is made if there is no intersection within the selection radius.
Nearest	N	Select the nearest point to the current mouse position which is on a shape and which is within the mouse selection area. No selection is made if there is no shape within the selection radius.
Orthogonal	G	When orthogonal snapping is on only points which have the same x or y coordinate as the base point of the current operation can be selected. If the base point is (bx, by) and the mouse is at (mx,my) then the current snap position S is defined as follows: if |mx-bx| > |my-by| then S=(mx-bx, by) else S=(bx, my-by). When orthogonal snapping is active a blue cross hair at the base point is shown.
None	Q	To turn off snapping for the next selection use the hot-key Q.

Fast Zooming During Editing Operations

During editing operations it is possible to control the displayed area using hot-keys to zoom in and out, to view all the data and to pan. The following table describes the hot keys available:

<u>Table 3 Fast Zooming</u>

Display Type	Key	Description
Zoom In	Z	The current position of the mouse becomes the centre of the new display area and the size of the displayed area is half the size of the previous display area.
Zoom Out	X	The current position of the mouse becomes the centre of the new display area and the size of the displayed area is twice the size of the previous display area.
Pan	S	The current position of the mouse becomes the centre of the new display area and the size of the displayed area is the same as the size of the previous display area.
View All	A	All of the data with its bounding box is displayed (with some expansion defined by the current setting of the expansion factor).

Rotation During Move, Copy and Paste Operations

When moving, copying or pasting shapes it is possible to use hot-keys to rotate the shapes as the move is being done. The following table describes the hot keys available for this purpose:

Table 4 Live Rotation

Action	Key	Description
Rotate Anticlockwise	Left arrow	The selected shapes are rotated anticlockwise by the current rotation step size.
Rotate Clockwise	Right arrow	The selected shapes are rotated clockwise by the current rotation step size.
Increase Rotation Step Size	Up arrow	The current rotation step size is increased. When the program starts the rotation step size is set to one degree. The only possible rotation step sizes are: 1, 2, 4, 8, 15, 30, 45, 60, 75 and 90 degrees. When the steps size is set to a value of 15 degrees or above then the shapes will be rotated from their initial positions in multiples of the step size only. For example, if the step size is 60 degrees then the possible angles of rotation from the initial orientation are 0, 60, 120, 180, 240 and 300 degrees.
Decrease Rotation Step Size	Down arrow	The current rotation step size is decreased.

Changing the Layout

The overall layout and orientation or location of the drawing with respect to the origin can be changed using the following functions.

Table 5 Layout Operations

Layout Operation	**Description**
Left Justify	Move the drawing so that the bottom left corner of the *x* and *y* bounding box is at the origin of the *x*- and *y*-axes.
3D Surface Justify	This is a 3D operation. Left Justify the drawing and (for 3D drawings) move the 3D shapes in the *z*-axis direction so that the top of the bounding box *of the 3D shapes* is at the *current value* of the machine position ZSurface (see the section below on special machine positions).

Layout Operation	Description
3D Bottom Justify	This is a 3D operation. Left Justify the drawing and (for 3D drawings) move the 3D shapes in the *z*-axis direction so that the bottom of the bounding box *of the 3D shapes* is at the *current value* of the machine position ZBottom (see the section below on special machine positions).
Rotate90	Left justify the drawing and then rotate it 90 degrees counter clockwise. Four successive rotations are equivalent to a left justification alone.
Mirror	Left justify and mirror the entire drawing in the *y*-axis. Two successive mirrorings are equivalent to a left justification alone.
Change origin	It is possible to change the position of the drawing by a translation (in the *x* and *y* plane only). Defining a new position for the origin, relative to the current origin, specifies a translation. This can be done by typing in the *x* and *y* coordinates of the new origin or by selecting a position with the mouse. The origin of the drawing when it was initially read from the file (referred to as the CAD origin) can also be recovered.

Clipboard Operations

A clipboard is provided with the following operations:

Table 6 Clipboard Operations

Clipboard Operation	Description
Copy to Clipboard	Copy selected shapes from the current drawing to the clipboard.
Load Fileto Clipboard	Load a dxf, rsg or rsm file into the clipboard.
Clear Clipboard	Clear the clipboard of all shapes.
Paste from Clipboard	Paste from the clipboard into the current drawing at any location. The shapes are pasted so that the bottom left corner of the bounding box of the pasted shapes is at the selected paste point.
Paste Absolute from Clipboard	Paste from the clipboard into the current drawing at any location. The shapes are pasted so that the absolute origin of the pasted shapes is at the selected paste point.

Machine Path Editing

The following table describes operations which change the machine path.

Table 7 Machine Path Editing Operations

Editing Operations	Description
Change the start position	All shapes have a starting position shown by a small indicator which also shows the direction in which the shape will be cut. For closed shapes the start point can be set to any arbitrary point on the shape by using the mouse pointer. For open shapes the start point can only be at either end of the shape.
Reverse Direction	The cutting direction of a shape can be reversed.
Set Directions Automatically	This operation automatically sets the shape directions according to whether or not a shape is contained within another shape. This operation is useful when cutting a collection of closed shapes for which some shapes are contained within others. In this situation it is often necessary to cut internal shapes in a clockwise direction and outside shapes in a counter-clockwise direction. The operation works for multiple levels of containment. This operation may not work correctly if there are intersecting shapes in the drawing.
Pause	Select shapes to be *pause* shapes: the machine will automatically pause at these shapes. The machine will only continue cutting the shape when the operator chooses to. This is useful, for example, when an operator must always pause at the same shape in a job in order to remove some material before continuing to cut the next shape or for manual tool changes.

Sequencing

It is important to be able to define the sequence of cutting when machining a set of shapes. For example, a closed shape which contains another shape should not be cut before the inside shape since otherwise there will be no material support when cutting the inside shape. The sequence in which shapes are cut can be easily defined within **Profiler** using one of several methods. In addition, if the basic block of data is repeated in an array then the sequence in which the array is cut can also be specified (see the section below on arraying the data).

Table 8 Sequencing Operations

Sequencing Operations	Description
Full Sequencing	The sequence can be defined by selecting each shape in turn in the required order of cutting. The sequence can be displayed in order and shapes deselected or selected to change the order.
Group Sequencing	The sequence of groups can be defined by selecting any shape in a group for each group in turn. The order of shapes within each group is not changed. The sequence can be displayed in order and any shape in a chosen group deselected or selected to change the group order.
Reverse Sequencing	The sequence of cutting is reversed.
Automatic Sequencing	Automatically set the sequence of shapes so that shapes contained within other shapes are cut first. The containment relation between shapes defines a hierarchy in which the shapes not contained in any other shape are at the top level, shapes contained within these shapes are at the next level and so on. If a shape contains several shapes at the next level then the sequence of these shapes must be defined in some way. The automatic sequencing operation requires the specification of a point S=(sx, sy). The sequence of shapes at the same level within another shape is then defined by the *distance of the starting point* of each shape from the specified point S – closer shapes are cut first. Generally, S would be chosen to be a point on one of the axes and far away from the bounding box. As an example, the sequence will change depending on S in roughly the following way, assuming that the job has been left justified and has a bounding box of, say, 500mm on a side: S=(-1000, 0) - the shapes will be cut from left to right and top to bottom. S=(1000, 0) - the shapes will be cut from right to left and top to bottom. S=(0, -1000) - the shapes will be cut from top to bottom and left to right. S=(0, 1000) - the shapes will be cut from bottom to top and left to right.
Level Sequencing	This operation can be useful when the drawing has a clear containment of shapes within other shapes. The operation allows just the sequence within a selected level within a containing shape to be changed. This is especially useful when used with the automatic sequencing operation described above. It may be necessary to modify the order of cutting of some shapes after applying an automatic sequencing operation. Level sequencing allows the order of some shapes to be changed without necessitating a full resequence.

Engraving

Engraving is usually used with routing machines to gouge all of the area within a shape to a certain depth. If there are holes in the shape then these holes should not be gouged. In order to accomplish engraving a tool path must be created. The tool cutting width and a tool overlap for each successive gouging needs to be set. For example, a tool with diameter 5mm might be used with a 0.1mm overlap.

Engraving in Profiler can be accomplished in two ways: either all of the shapes in the job can be engraved or only a set of selected shapes. In order to perform any engraving the shape directions must be set correctly.

When engraving the whole job it is expected that the outer-most shapes should, as usual, be set to be cut in a counter-clockwise direction and the shapes within these be set to be cut in the opposite direction. Profiler then automatically reverses these directions when performing the engraving. The black (inner) paths in the following diagram show the result of engraving the blue shapes (the outer path and the most inner rectangular path). Note how the inner paths have been connected to reduce the number of times the head has to be lifted.

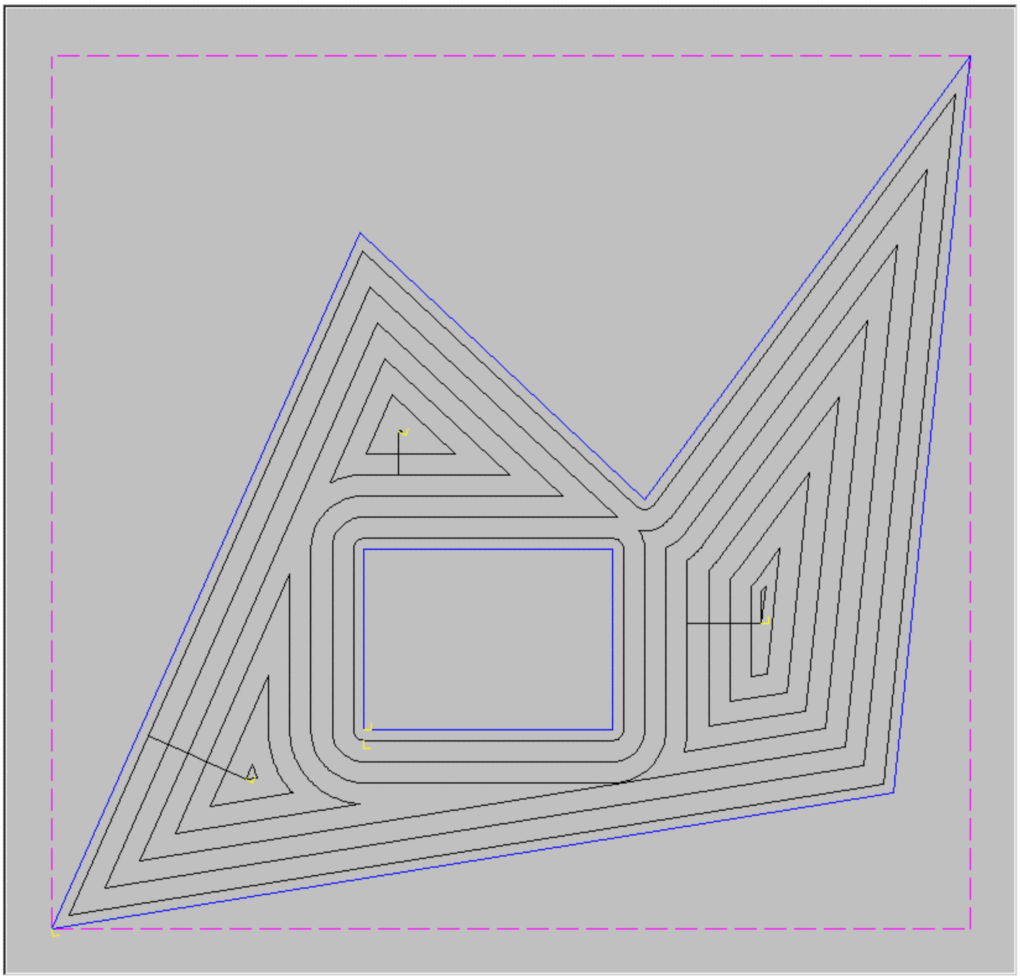

Figure 2 An example of engraving

Creating Tool Paths

Once the shapes have been sequenced and the appropriate shape directions and starting points set it is still necessary to specify the details of the machine cutting. For example, two-dimensional shapes must be cut at some given height, a tool type must be specified and the actual path of the cutting may need to be altered in order to take into account the width of the cutting tool. The possible options for controlling the cutting are split into two main categories: the *cut settings* and the *machine tool path generation settings*.

Shape Group Classification

Different shapes may require different methods of machining. In order to facilitate the specification of these differences the shapes in the drawing can be classified into groups. Each group has its own settable options which control the way in which the shapes in the group will be cut on the machine. There are eight possible groups, each referred to by its colour: *Black, Blue, Green, Cyan, Red, Magenta, Brown* and *White*. The information defining each group is saved with the drawing (see the section on File Types below). The default group for shapes is the *Black* group.

The user interface enables shapes to be moved from group to group and also to be copied from one group to another group.

Group Cut Settings

The following table describes the possible group cut settings in more detail.

Table 9 Group Cut Settings

Cut Setting	Description
Status	The status of a group defines whether or not shapes in the group will be cut. If the status is *on* then shapes will be cut (shapes in the group are drawn on the screen as usual) and if it is *off* then the shapes will not be cut (shapes in the group are either drawn dashed or not at all, depending on a user selection).
Traversal Shape	A traversal shape is not cut but is instead followed at maximum speed. For THRU and MM type shapes the height at which the shape is traversed is at the machine position defined by Ztop. For 3D shapes, the shape itself is followed without cutting (no height control and no cut bit on). Traversal shapes are useful, for example, for moving the machine tool between other shapes to avoid obstacles. The default action after cutting a shape is to move in a straight line from the end position of the shape to the start position of the next shape in the sequence. Traversal shapes can be used to modify this behaviour.

Cut Setting	Description
Tool Control	Each group has associated with it two hardware outputs: the *tool control output* and the *tool cut output*. There are three different output bits to choose from for each of these outputs. The timing of the outputs is predefined (see the timing diagrams in the appendix) and has been designed to simplify the control of cutting. For example, the tool control bit selected for a group will be turned on when the plunge to the start of a shape in that group begins and the tool cut bit will be on during the actual cutting of the shape. The details of how these outputs are used to control cutting will be described in more detail when describing the machine control.
Group Cut Speed	The maximum machine tool cutting speed (in mm/minute) can be set to be a different value for each group. There are two other speeds which may affect the actual cutting speed: the global maximum cutting speed and the maximum speed of the machine. The actual cutting speed will be the minimum of these three speeds.
Cut Height Type	There are three possible types of cutting height for groups: 1. *THRU* - the shape is cut at the machine position defined by Zbottom; 2. *3D* - the shape is three-dimensional and each point of the shape includes a z-axis value. The z-axis value defines the height above the machine position defined by Zsurface. 3. MM - this type requires a distance value *d* to be specified: the shape is cut at the height Zsurface + *d* , with positive values of *d* being above Zsurface and negative values being below Zsurface.
Multipass	For multi-pass to be used the group's Cut Height type must be MM. If multi-pass is *on* then shapes in the group are machined more than once. Usually this means that several passes are made to cut the one shape, with each pass at a different depth (or negative height) below the surface.
Distance per Pass	If multi-pass is *on* then the cutting distance per pass must also be specified. *Example*: if the group has cutting height type MM with a height of -13mm and a distance per pass of 4mm then *four passes* will be made to completely cut the shape. These passes will be made at heights Zsurface-4mm, Zsurface-8mm, Zsurface-12mm and, finally, at height Zsurface-13mm.
Rough Pass Offset (mm)	Specifying a non-zero value will produce a rough cutting pass (or a number of passes if the shape uses multi-passes) before the final cut at the correct offset for the shapes in the group. The rough pass is automatically generated in the correct direction from the shape's offset. The sign of the rough pass offset is ignored except for when the offset of the group is 0. If the offset of the group is not zero then the roughing offset is calculated as: *rough offset = offset + sign(offset)*abs(roughing offset).*

Group Machine Tool Path Creation Options

In order to machine shapes it is often necessary for the machine tool path to be different from the path defined by the shape. The necessary changes are made when generating the tool path from the basic block of data. The following example shows how offsets then tags and then lead-ins are applied.

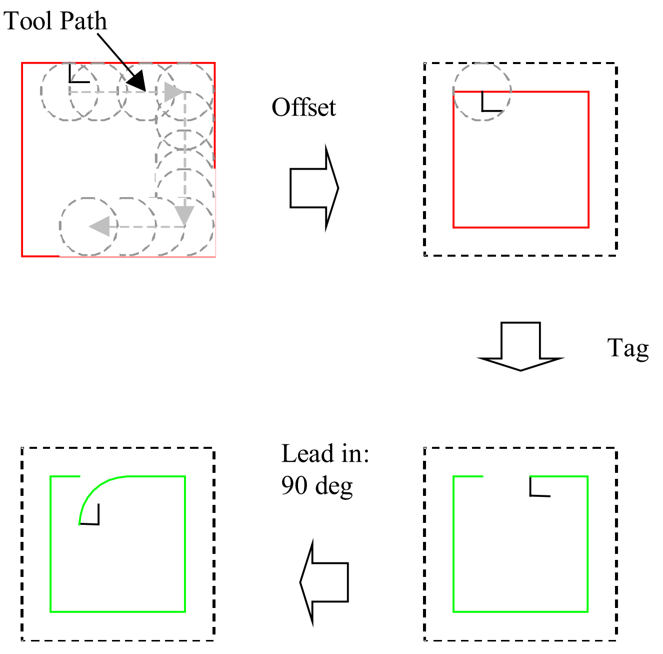

Figure 3 Machine Path Creation: Offset, Tags and Lead-Ins.

Lead-ins and lead-outs are used to improve the cutting of the shape at its start and finish. The definition of the lead-in requires two parameters: the lead-in radius and the lead-in angle. Similarly, the lead-out is also defined by two parameters. The following diagram shows how the lead-in is constructed from these parameters.

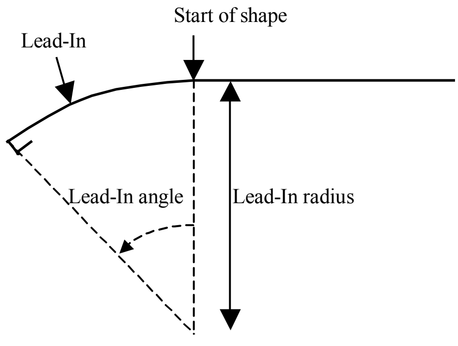

Figure 4 Definition of a Lead-In

The Machine tool path creation options are summarized in the table below.

Table 10 Group Machine Tool Path Creation Settings

Tool Path Generation Setting	Description
Offset	Offset shapes by a specified distance (in *mm*). The offset can be positive or negative. The required offset is, for example, the radius of a routing tool.
Double Line	If double line is on for a group and the group offset is not zero then both the positive and negative offsets are created. This is useful when cutting small slots in material such as for laser cutting Die Boards.
Tag	A tag is a small section of uncut material at the beginning of a shape. If a tag distance greater than zero is set then machining of the shape does not begin at the start position but rather at a distance from the start of the shape specified by the tag distance. The tag is applied to the offset shape *not* to the original shape (unless the offset is zero). This can be useful for holding a shape during the cutting process or for preventing it from falling out as it is being machined. Tags can be used effectively in conjunction with the Break operation to hold a shape in several positions when it is being cut.
Lead-In Radius and Angle	Specifies the radius of an arc and the angle of the arc to be added at the start of the shape. The arc is made to be tangential to the start of the shape. Lead-Ins are applied *after* the offset and tag have been constructed. This is often useful when it is desirable to have the tool plunge and start cutting away from the part. For example, a laser or plasma cut may have a slightly larger cut diameter when initially piercing the material.
Lead-Out Radius and Angle	The same as for lead-ins but applied at the end of the shape. The best way to understand lead-ins and lead-outs is to experiment within Profiler. The diagram above shows how lead-ins are defined.

After the shapes in the basic block of data have been assigned to groups and the group settings have been specified then the set of corresponding shapes for machining can be generated by the program with correct offsets, tags and lead-ins and lead-outs. This new set of shapes defines the machine tool path. As will be described in the file types section below, these two sets of shapes (the basic block of data and the corresponding generated tool path) are saved as separate files.

Special Offsets

Profiler incorporates some special offsets for shapes with self-loops and for some types of 3D shapes.

Offsets of Shapes with Self Loops

The above discussion of offsets applies to two dimensional shapes without self-crossings. For shapes with self crossings, such as paths which have loops, Profiler attempts to create a meaningful offset where possible. It is not always guaranteed to succeed and the feature should be used with caution. The main use of these types of offsets is in constructing a continuous cutting path incorporating many shapes. With careful design, the offset of such a path will also be continuous and will thus allow the shapes to be cut out without lifting the *z* axis head.

Offsets of 3D Shapes

The definition of offsets in Profiler has also been extended to cover a special type of offset of certain types of 3D shapes. In some circumstances, 3D shapes need to be trimmed. For example, a 3D shape may be produced from a mould and require trimming of excess material. The special offsetting incorporated into Profiler will only work correctly on shapes which project onto the *xy* plane as two dimensional shapes without self crossings. The trimming offset is calculated by back projecting the 2D offset of the projected 2D shape.

Arraying the Basic Block of Data

Having constructed the machine tool path for cutting out the basic block of data it is possible to array the drawing in order to generate multiple copies of the basic block.

There are two levels of arraying which can be applied to the basic block of data, each level having its own number of rows, number of columns and amount of space between the rows and the columns. The first level of arraying allows the basic block to be duplicated in an array, forming the *job* to be machined. The second level is referred to as the *job array*. This might be used when several repeats of the job are to be machined and it is desirable, for example, to be able to remove each job as it is completed. The order of machining of the arrays can be controlled by specifying the start point (at the Bottom Left, Bottom Right, Top Right or Top Left of the array) and the cutting order (as either row major, column major, row snake or column snake).

The following diagram shows how the two levels of arraying can be used. It shows an example in which the basic block of data has been arrayed to form a job with 3 columns and 2 rows (note that the row and column spacing is different). A second level of arraying has been applied with 1 column and 2 rows of jobs and where the job row spacing is different from the basic block row spacing.

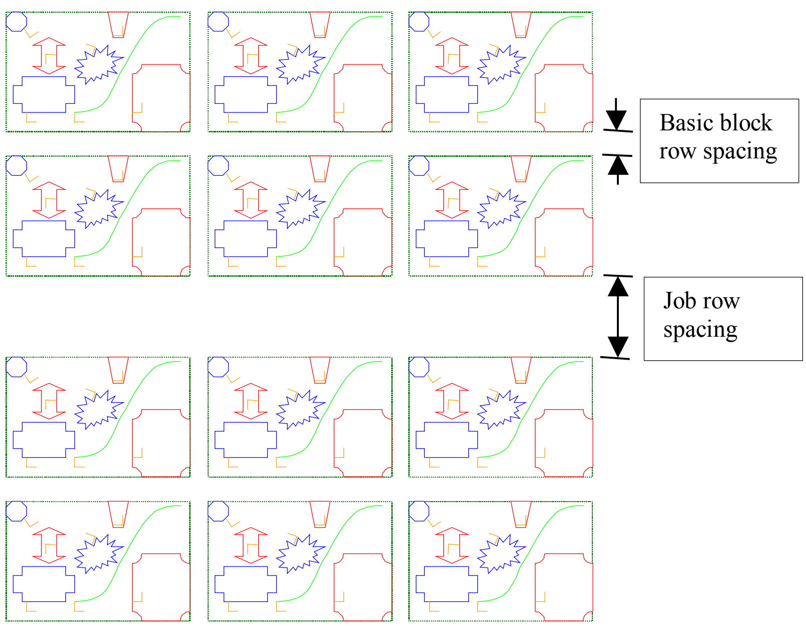

Figure 5 Two Level Arraying

Having arrayed the drawing it is also possible to control the cutting order of the basic block arraying and the job arraying by setting the array start point and the array ordering type.

The **start point of an array** can be at any of the corner blocks i.e. the Bottom Left, Bottom Right, Top Right or Top Left.

The **ordering type of an array** can be Row Major, Column Major, Row Snake or Column Snake.

The following diagram gives an example of these orderings.

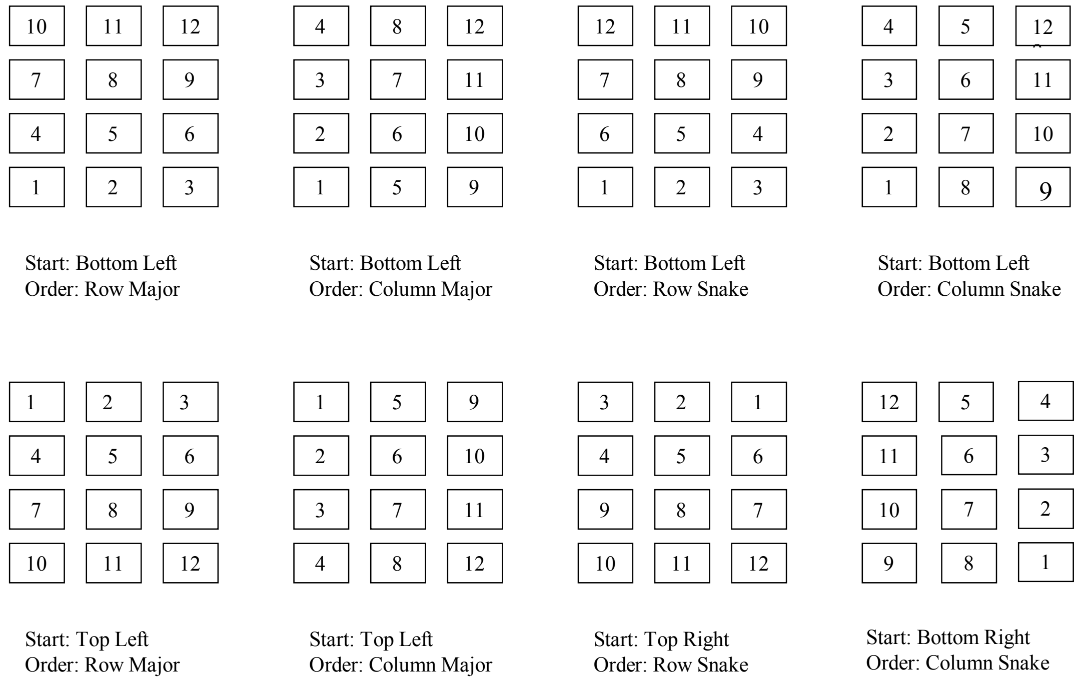

Figure 6 Examples of Array Ordering

File Types and Saving the Data

For any machining job there are two sets of closely related data which need to be saved:

1. the *basic block of data* describing the shapes with their groups and group options specified and

2. the set of corresponding tool paths with the offsets, tags and lead-ins and lead-outs applied to the shapes in the *basic block of data,* together with any arraying information.

File Type Extensions

Profiler clearly distinguishes between these sets of related data both within the user interface (this is described in a later section) and in the way in which the data is saved in files:

Table 11 File Types

File Extension	Description
DXF	Drawing files in DXF Release 12 format can be loaded into **Profiler** but these DXF files are generally modified to have the required information for controlling the machining and are then stored as RSG files. Note that if the modified drawing is saved as a DXF file then the group and arraying information will **not** be saved.
RSG	These are augmented DXF files which contain the drawing information together with the group settings (cutting and tool path creation settings) and arraying information. These files can be loaded by drawing packages capable of importing DXF files. These files are called drawing or Graphics files.
RSM	These are augmented DXF files which generally contain the tool path information generated by applying offsets, tags, lead-ins and lead-outs and arrays specified in the corresponding RSG file. These files can be loaded by drawing packages capable of importing DXF files. These files are referred to as Machining files.

Since it is generally the case that RSM files are generated automatically by **Profiler** from corresponding RSG files *it is not recommended that RSM files be changed directly* except for inserting digitized shapes. **Profiler** does, however, provide many of the same editing operations for RSM files as it does for RSG files.

File Comments

Comments describing each RSG or RSM file can be saved with the file. File comments are useful for providing any additional job specific information. For example, you might include operator messages, job material type, the customer for the job, the person who created the job, descriptions of the file and so on. Up to 10 lines of 50 characters can be saved.

Chapter 2

Machine Configuration and Operation

Profiler directly controls all aspects of the machine configuration and operation. The machine configuration defines a large range of adjustable parameters for controlling a machine's operation.

Profiler is capable of controlling machines with three axes (horizontal *x* and *y* axes and a vertical *z* axis) together with an optional fourth rotational axis (the tangential or rotational *w* axis). The *x*, *y* and *z*-axes are taken to have the usual three-dimensional orientation with the positive direction on the *z*-axis being upwards. In addition it is possible to use two *x*, two *y* or two *z* motors simultaneously. This makes it possible, for example, to drive a gantry with two motors or to use two *z* axis heads for simultaneous cutting.

Each axis can be fitted with a homing switch which enables absolute positions of the machine tool to be obtained. **Profiler** provides the ability to search for these homing switches. To initialise the absolute position correctly, a successful search for the homing switch on each axis must be completed. Appropriate homing is done when two *x*, *y* or *z* motors are used. The default home position on each axis is defined to be the position of the machine on that axis *when the program was started.* See the section on the Axis Motion I/O card for a specification of the inputs used for wiring the homing switches.

Axis Parameters

The following parameters can be adjusted for the axes:

Table 12 Axis Parameters

Axis Parameters	Description
Motor Steps per Unit	This gives the number of machine steps necessary to move a unit of distance on each axis. For the *x*, *y* and *z* axes this gives the number of steps (or microsteps) which are equivalent to a millimetre of movement. For the *w* axis this gives the number of steps (or microsteps) equivalent to a degree of rotation.
Axis Lengths	The machine dimensions for each of the *x*, *y* and *z*-axes. This enables soft bounds to be calculated if the homing position on each axis is known.
Maximum Speeds	The maximum machine speed on each axis in the appropriate units: mm/s for the *x*, *y* and *z*-axes and degrees/s for the *w* axis.
Maximum Accelerations	The maximum machine speed on each axis in the appropriate units: mm/s/s for the *x*, *y* and *z*-axes and degrees/s/s for the *w* axis.

Axis Parameters	Description
Limit Movement	Determines whether or not machine movement on the *x*, *y* and *z* axes will be limited by the soft bounds of the machine determined by the home position on the axis and the axis length. If movement is limited then the machine will abort a job if it is about to go outside the bounds. An "Out of bounds" message will be displayed.

Microstepping Drive Parameters

Profiler outputs a step and a direction bit to control each motor. These control bits are usually used as inputs to a microstepping drive for each motor. Axis Motion supplies microstepping drives for use with Profiler but any drives can be used for which these control bits are appropriate (including servo motor drives). The following figure shows the timing diagram for the motor control bits. Microstepping drives usually have a minimum step pulse on time. The *PC output delay* indicated in this figure is approximately the minimum time for outputting a bit on the PCI bus to the Axis Motion PCI card. It is safe to assume that this is of the order of one microsecond. Profiler provides two parameters *Microstepper Step Delay* and *Microstepper Direction Delay* for increasing the indicated times. *Note: For Axis Motion microstepping drives these parameters can be set to zero.* If the direction delay is set to zero then the Step and Direction bits are output simultaneously.

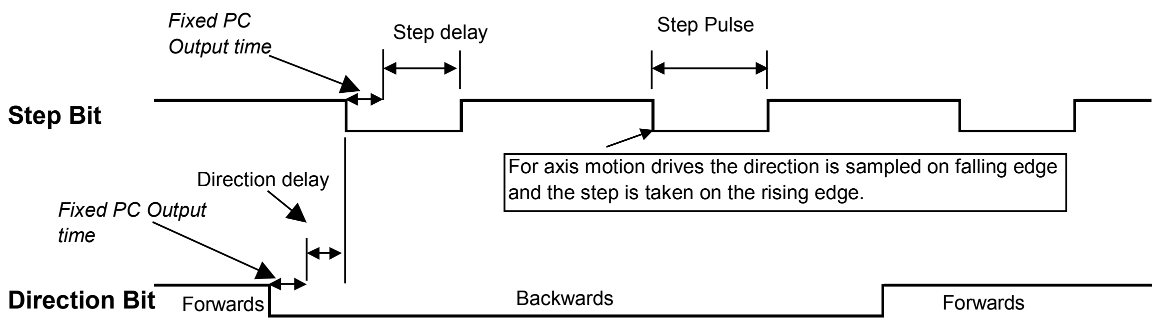

Figure 7 Microstepper Parameters

The following table describes the microstepper delays used by Profiler. These delays are advanced settings and once set for a given speed PC should not need to be changed.

Table 13 Microstepping Drive Parameters

Microstepping Parameter	Description
Direction Delay	A timing delay used when changing the direction bit. This delay is in addition to the PC output delay for the PCI bus mentioned above. If this value is zero then the direction bit is output simultaneously with the step bit (avoiding one of the PC output delays). For Axis Motion microstepping drives this parameter can be zero. IMPORTANT: Currently the time unit for the delay is one floating point addition on the given PC. This means that changing the clock speed of the PC *changes the absolute delay*.
Step Delay	A timing delay used when outputting the step pulse in order to increase the step pulse width. This delay is in addition to the PC output delay for the PCI bus mentioned above. For Axis Motion microstepping drives this parameter can be zero. IMPORTANT: Currently the time unit for the delay is one floating point addition on the given PC. This means that changing the clock speed of the PC *changes the absolute delay*.

Motor Parameters

Profiler supports up to six motors called X, Y, Z, W, Q and R. Each motor is controlled by two bits and so there are six pairs of motor output bits. These will be referred to as the X, Y, Z, W, Q and R motor output bits. These motors are used to drive the *x, y, z* and *w* axes supported by Profiler. The *x, y* and *z* axes can each have two motors. The extra "axes" will be referred to as the *x2, y2* and *z2* axes, where, for example, the *x2* axis will be run by a second motor. The *x2* and *y2* axes are never run independently of the *x* and *y* axes, except during homing of the axes (see the section on Axis Homing). However, the *z2* axis is an independent axis which is usually used to run a second *z* axis head. The motor output bits are located on the I/O card (see I/O card outputs for connection information).

Defining the motor set-up involves setting the positive direction of the motors and setting which motor drives which axis. See the following table.

Table 14 Motor Parameters

Motor Parameter	Description
Motor Directions	The positive direction of the motors for each axis. This can either be forwards or backwards.
Motor to Axis Assignments	Defines which motor drives which axis. The assignment for the *x, y* and *z* axes is fixed: The X motor always drives the *x* axis, The Y motor always drives the *y* axis and the Z motor always drives the *z* axis. The *w, x2, y2* and *z2* axes can be driven by any one of the remaining W, Q or R motors with the restriction, of course, that one motor can drive only one axis.

Special Z Axis Positions

There are several positions on the *z*-axis which have special meanings for cutting shapes. The positions Ztop, Zsurface and Zbottom can be set and saved by the operator by simply driving the machine to the required position and recording the position. These special positions are explained in the following table.

Table 15 Special Z Axis Positions

Z Axis Position	Description
Z Origin	This is where Z=0 (which is usually the home position situated at the top of the *z*-axis).
Z Home	This is the home position on the *z*-axis.
Z Top	The machine tool moves to this height when not machining and when moving between shapes.
Z Surface	This defines the surface of the job from which heights are calculated. Heights are specified in the group data as either a positive or negative height in *mm* or as *3D* (where heights are defined within the CAD drawing format for each shape). Note: If the machine is using height control (see below) then the Z surface position is *continuously changed* during the machine cutting. The Z top position is simultaneously adjusted so as to maintain a constant distance between Z surface and Z top.
Z Bottom	This is the bottom limit of the machine tool movement on the *z*-axis. The machine can only drive below this position when Z bottom is being redefined. The machine tool moves to this position when cutting shapes in groups which have the height attribute set to *THRU*.

Maximum Machine Cutting Speeds

The maximum horizontal and vertical machine cutting speeds can be changed at any time. In addition, the *x* and *y* axis maximum cutting speeds can be different. The cutting speeds are described in the table which follows.

Table 16 Maximum Machine Cutting Speeds

Speed Type	Description
Machine Cutting Speed	This is the maximum machine cutting speed. It cannot be set to be greater than the maximum speed of the machine on the *x* and *y* axes. Any shape with a group cutting speed set to be larger than the current maximum machine cutting speed will in fact be cut at the current maximum machine cutting speed.
Machine Plunging Speed	This is the maximum machine speed when the machine moves from Z Top to the correct cutting height for shapes for which the height attribute is set to THRU or to MM. It cannot be set to be greater than the maximum speed on the *z*-axis.
Y Axis Cutting Speed Factor	For non-homogeneous materials it is sometimes desirable to be able to use different *x* and *y* axis maximum cutting speeds. The *y* axis maximum cutting speed factor *Cf* is usually 1.0. The actual *y* axis maximum cutting speed is calculated from the *x* axis maximum cutting speed and Cf as: *y* axis maximum cutting speed = Cf * *x* axis maximum cutting speed. When cutting lines at an angle the cutting speed is adjusted proportionally. Thus a line at an angle of θ degrees (where $0 \le \theta \le 90$) will be cut at a maximum cutting speed of Maximum cutting speed = *x* axis maximum cutting speed * (1 + (Cf - 1) * $\theta/90$).

Special Delay Times During Cutting

During the machining of a job there are several adjustable delay times which can be used to support different tool functionality. See the Timing Diagrams section for more detail. The normal sequence for processing a job on a routing machine is as follows:

1. Move to the start of the first shape at height Z=0, move down to height Ztop, turn on the router/shutter bit and wait for the RouterStartDelay time;

2. Turn on the tool bit and wait for a specified AirToolDelay time;

3. Plunge to the correct depth (e.g. Zbottom for THRU shapes)

4. Turn on the cut bit and wait for the BottomDelay time;

5. Cut the shape;

6. Turn off the cut bit and wait for the specified EndDelay time;

7. Raise the head to Ztop, turn off the tool bit and wait for the specified AirToolDelay time;
8. Move to the next shape and repeat steps 2-8;
9. At the end of the last shape, turn off the router/shutter bit and move to the end position.

The following table shows the parameters used for controlling these delays.

Table 17 Delay Parameters

Delay Parameter	Description
Router/Shutter Start Delay	A time delay in seconds. This delay occurs at the first shape of the job after the router/shutter bit is turned on. If the machine is paused then the router/shutter bit is turned off. If the job is continued after a pause then the router/shutter bit is turned on and the machine waits once again for the router/shutter start delay time before continuing with the job.
Air Tool Delay	A time delay in seconds. This delay occurs at each shape immediately after the tool bit is turned on and immediately after the tool bit is turned off at the end of each shape. It is useful for controlling an air tool allowing time for the tool to plunge and lift before moving to the next shape.
Bottom Delay Type	The bottom delay can be either: 1. a timed delay specified in seconds or 2. a wait time which finishes when the EndBottomDelay input goes high (see I/O card inputs). There is a timeout of 10 seconds if no input is received. In addition, once the input goes high there is a following delay time as specified by the Bottom Delay Time (which may be zero).
Bottom Delay Time	This is the time in seconds to wait before cutting commences. This delay can be used, for example, to ensure that the tool is ready to start cutting or to allow for piercing time on plasma and laser cutters.
End Delay Time	This is the time in seconds to wait once the end of a shape is reached and the cut bit has been turned off and before raising the machine tool.
End Delay Intensity	During the end delay time, if the machine is using an intensity output (see below) then this parameter gives the value of the intensity in the range 0 to 127 during the end delay time. This value is modified and scaled as for all intensity outputs.

Pausing the Machine

The machine can be stopped or paused at any time by using either the stop keys (either from the keyboard or from the hand console) or the stop input on the I/O card. When this occurs the machine slows down and stops. If this happens during cutting of a job then the machine can be configured so that it either stays at the current height or moves up to the Ztop position. The parameter which controls this behaviour is called *RaiseOnPause* and can be set to *yes* or *no*.

Table 18 Pausing

Pausing Control	Description
Raise On Pause?	If RaiseOnPause is set to 'yes' then when the pause key is hit during the machining of a job or during a MoveTo operation then the machine comes to a stop and then moves upwards to the predefined position Z Top on the *z* axis.

When the machine has paused you can change the cutting speed or the plunging speed, adjust the Zbottom position by a specified amount (positive values are up and negative values are down) and either continue with the job or abort the job. You can also move the machine with the arrow keys which can, for example, help to allow removal or inspection of the material. If the machine has been moved during the pause then when the job is restarted it will automatically resume cutting at the correct position.

Hardware Input and Output

Profiler's interaction with the machine consists of output bits to control the cutting tool and the motors and input bits to monitor the status of the machine. Provision is also made within the program for performing hardware diagnostics. An interactive dialogue provides facilities to define and write individual output bits, to single step the motors and to read and display the input bits. The following table describes the inputs and outputs used by **Profiler**.

Table 19 **Profiler** Input and Output

I/O Type	Description
Parallel Port Output	One of the PC parallel ports (either LPT1 or LPT2) is used to output a desired intensity as a function of the machine speed. To accommodate the potential non-linearity of the desired intensity as a function of the machine speed **Profiler** enables the user to specify a mapping table for the intensity. Only the upper 7 bits of the parallel port byte are significant in controlling the machine speed, giving 128 different intensity levels. The lowest bit is reserved for special control during the bottom delay period. The parallel port is also used to set the laser frequency for a pulse width modulated laser.

I/O Type	Description
XYZW-Step Byte A (Output Port A)	A byte of information controlling the next motor step on motors X, Y, Z and W. An additional nibble will be output if motors Q and R are also being used. The rate at which steps are output depends on the scaling and speed of the machine. Typical values might be 250 steps/mm and 200mm/second giving a rate of 50,000 steps/second.
Control Byte B (Output Port B)	The bits of the control byte on Port B have the following meaning (details of the tool and cut bits are given in the Timing Diagram examples) 0. Tool 1. 1. Cut 1 2. Tool 2 3. Cut 2 4. Tool 3 5. Cut 3 6. Router/Shutter 7. Job Running
Control and QR-Step Byte C (Output Port C)	The bits of the control byte on Port C have the following meaning (details of the tool and cut bits are given in the Timing Diagram examples) 0. Jig 1: Turned on when cutting Jig 1 1. Jig 2: Turned on when cutting Jig 2 2. Unassigned (future use for Router 2) 3. Unassigned 4. R0: Q motor direction 5. R1: Q motor step 6. Q0: R motor direction 7. Q1: R motor step

I/O Type	Description
Status Byte A (Input Port A)	The bits of the input status byte from Port A have the following meaning to **Profiler**: 0. Zhome/Z2home: indicates when the homing switch for the z-axis is on. 1. Whome/Click-up input/Door close input: this bit currently has three uses: a) If the rotational *w* axis is being used then this bit indicates when the homing switch for the *w* axis is on; b) If the plasma start-up sequence is being used then this bit is used to indicate when the plasma head is too close to the material and c) as an external job start input. 2. Xhome/X2home: indicates when the homing switch for the x-axis is on. 3. Yhome/Y2home: indicates when the homing switch for the y axis is on. 4. Zhigh: used during simple height control to indicate that the machine is too high. When this becomes 1 the machine stops any upwards movement and begins to move down on the Z axis. 5. EndBottomDelay: This is a signal which goes from 0 to 1 to indicate when to end a bottom delay at the beginning of cutting a shape. It is used if the bottom delay is of type *Wait fir Input*. NOTE: The *EndBottomDelay* input is also referred to as the *BottomDelay* input and is marked BDEL on the I/O card. 6. Emergency Stop: If this bit is triggered then the machine decelerates to a stop, sets all output bits to zero, raises the *z* axis if RaiseOnPause is set and allows the operator to control the subsequent operation of the machine. The triggering state can be set to be either 0 or 1. 7. Zlow: used during simple height control to indicate that the machine is too low. When this becomes 1 the machine stops any downwards movement and then begins to move up on the Z axis.
Status Byte B (Input Port B)	The bits of the input status byte from Port B have the following meaning to **Profiler**: 0. Jig1: indicates that Jig 1 is ready for cutting. 1. Jig2: indicates that Jig 2 is ready for cutting. 2. Unassigned (future use for EndBottomDelay2) Bits 3-7 are currently unused.

Intensity Output

For those machine tool types which have an intensity control, such as is the case for some lasers, it is important to be able to vary the intensity as a function of the instantaneous cutting speed. During cutting **Profiler** outputs an intensity level on the parallel port with 128 levels of intensity resolution specified in the upper 7 bits of the parallel port byte. The value which is output onto the parallel port is obtained by firstly discretizing the current speed as a fraction of the current maximum cutting speed. This discetization is done using 128 levels (0 to 127). A user-defined table then maps this discretized speed to a discretized intensity value which is also between 0 and 127. In addition, a scaling factor is applied before the final intensity is output to the parallel port. This scaling can be used to match the table to a maximum power level of the tool. For example, a Pulse Width Modulated (PWM) laser with a maximum duty cycle of 60% would use a scaling factor of 60% to ensure that the laser is never on for more than 60% of a cycle. Finally, for pulse width modulated lasers the intensity output may be clipped to ensure that the duty cycle never falls below a minimum or maximum time.

The most common use for the intensity output is to control laser cutting. For PWM lasers the lowest bit can be used to set the laser to its maximum intensity during the bottom delay time (and so is sometimes referred to as the "burn bit").

Profiler provides a means of specifying an operating frequency and minimum and maximum pulse width times for a PWM laser. See the section on Laser Setup for more details on laser support in **Profiler**.

Intensity Output Example

The following diagram gives an example of how the intensity level in the table is used to change the pulse time of a PWM laser. Suppose the machine is currently cutting at speed s and the maximum cutting speed is C. Let the table with 128 entries which maps the current cutting speed to the required intensity be called T. Then the output intensity is given by I = T(i) where i=s*127/C. The output value to which clipping will be applied is then F(I) = scaleFactor * I.

The following example shows how the actual value output onto the parallel port is calculated::

1. Calculate the intensity table index for the current speed. If, for example, the machine is travelling at 80% of the current cutting speed then the table entry to be used is at i = 0.8*127 = 111.

2. Multiply the table entry at i by the PWM scale factor. In this example, if the duty cycle (PWM scale factor) is set to be 60% and the actual table entry at position 111 is 64 then the value output is scaleFactor * T(i) = 0.6*64=38. For the example in the figure below the period of the laser is set to be 10 microseconds (100kHz). The on time (pulse time) is thus T = 10*(38/127)=3 microseconds, as shown in the figure.

3. If PWM laser frequency control is on then the value calculated above will be modified using the minimum and maximum pulse width (in microseconds). In the current example since the minimum on time is 1 microsecond and the period is 10 microseconds any value of F(I) less than (1/10)*127=12 will be increased to 12 and any value larger than (5/10)*127=63 will be decreased to 63. In our example, the value of 38 is within the allowable range of 12 to 63. In some cases of frequency settings for the laser there may be no valid outputs (for example when the minimum pulse width time is larger than the period). In such cases the machine will not run the job.

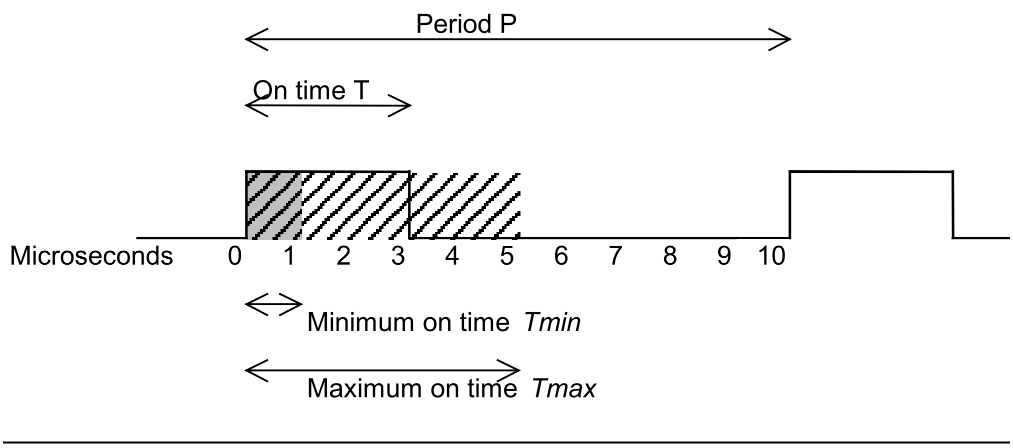

Figure 8 Example of PWM laser Intensity Output

Automatic Height Control

Profiler supports a height control mechanism which can solve the problem of keeping a tool at a constant height above the material being cut. The ability to maintain a constant height above a warped piece of material can be very important for tools such as lasers which require the focal point to be at a particular position in relation to the material. Profiler now supports two types of height control: a *simple* height control and a *proportional* height control.

It is important to note that during cutting with height control active the Zsurface position is constantly updated to be at the position at which the tool is cutting. Thus, if the material warps upwards then the Zsurface position will follow it upwards. Simultaneously, the distance from Zsurface to Ztop is maintained to be the original distance set by the operator. At the end of a job the Ztop and Zsurface positions are automatically reset to be exactly those at the start of the job.

Height control can be turned on or off. If it is turned *on* then for any shapes with height attribute set to THRU the height control will become active. When cutting shapes with height attribute MM or 3D the height control is *not* activated even if the machine has the height control facility turned *on*. This means that Zsurface is also not adjusted when cutting MM or 3D shapes. This feature can be used to advantage when, for example, shapes are to be engraved using a laser and not cut out. In this case the shapes height attribute should be set to MM with a positive value for the height. The amount of engraving for the shape will depend on the height setting for the shape (since this determines how out of focus the laser will be at the surface). If the engraving is done within a local area of where height control was last active then the Zsurface value will be locally correct for engraving.

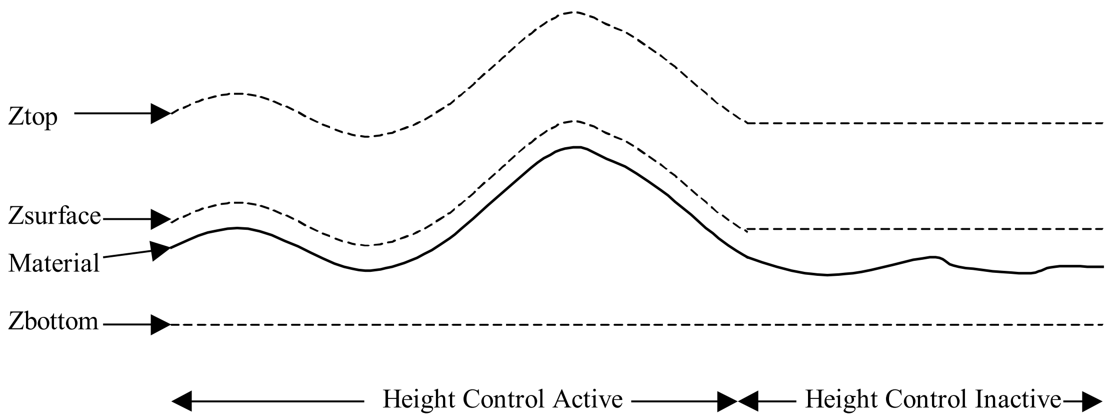

Figure 9 Cross Section Showing How ZSurface and ZTop Change During Height Control

The following table describes the parameters used by both simple and proportional height control..

Table 20 Height Control Setup

Height Control Parameter	Description
Maximum Speed	This is the maximum speed attainable on the *z* axis during height control. It cannot be greater than the maximum speed on the *z* axis.
Maximum Acceleration	This is the maximum acceleration to be used on the *z* axis during height control. It cannot be greater than the maximum acceleration on the *z* axis.
Activation Speed	This specifies a percentage of the current cutting speed above which height control will become active for THRU shapes. If this value is 0 then the height control will be active whenever the machine is cutting a shape with height attribute set to THRU. This can be useful for controlling plasma cutting.
Do Height Control between Shapes	This parameter controls whether or not height control will be active when moving between THRU shapes. WARNING: height control is computationally intensive and if active may cause bad aberrations in the motion of the machine if the xy axis speed (such as when moving between shapes) is too high.

Simple Height Control

The only hardware requirements for this height control mechanism are two input bits: one to indicate when the tool is too low and the other to indicate when the tool is too high (see the description of the Input and Output Control for the input bits which are used for simple height control).

Proportional Height Control

Proportional height control relies on receiving continual positional information rather than just two bits of information. The positional information is expected to be an 8-bit unsigned input value. The desired position is specified as a set point between 0 and 255. The accuracy of the height control will depend on the frequency with which the positional information is received, along with other properties of the machine motion and the material surface.

Non-Homogeneous Materials

In order to cut materials with different properties in the x and y directions it is sometimes useful to be able to change the desired height of the cutting nozzle according to the direction of cutting. Profiler supports this by allowing different x and y axis set points to be defined. Lines at an angle are cut with the height proportional to the direction of cut. The set point for a line at an angle of θ degrees (where $0 \leq \theta \leq 90$) is defined to be: Set point (θ) = *x* axis set point * (1- θ/90) + y axis set point * θ/90. Thus, a line at 45 degrees will be cut with a height control set point midway between the x and y axis set points. In addition to different set points it is also possible to define different x and y axis maximum cutting speeds (see the section on Maximum Machine Cutting Speeds).

Proportional Height Control Parameters

The following table describes the settings for proportional height control.

Table 21 Proportional Height Control Setup

Proportional Height Control Parameter	Description
X Axis Set Point	This defines the height control set point when cutting in the x direction. It should be between 0 and 255.
Y Axis Set Point	This defines the height control set point when cutting in the y direction. For homogeneous materials this should be the same as the x axis set point. It should be between 0 and 255.
Proportionality Constant	The proportionality constant defines the relationship between the measured height control values (between 0 and 255) and the machine *z* axis distance. It can be used to tune the performance of the height control algorithm. See the description of the POT scale below.

Proportional Height Control Parameter	Description
HC Input (POT) scale	Most commonly, the input values for the height control are read from an approximately linear potentiometer (POT). The input scale gives the number of mm/POT unit. The proportionality constant for proportional height control should be set to be approximately the z axis scale (motor steps/mm) * POT scale (mm/POT unit). Thus the proportionality constant is the number of z axis motor steps per POT unit. For example, if the z axis is 250 steps/mm and the POT scale 0.04 mm/POT unit then the first approximation to the proportionality constant could be 10. Often halving this calculated value will improve the height control performance, but some experimenting might be required to obtain the optimal value of Kp.
HC Display Accuracy	This is a distance in mm. If drawing is active then any height control measurements which indicate an error of greater than the HC display accuracy will be indicated by a different colour. This can be used to confirm the accuracy of the proportional height control algorithm.
HC Serial Port	The height control inputs from the POT are input on this serial port which can be COM1, COM2, COM3 or COM4.
HC Serial Port Speed	This is the baud rate of the HC serial input. Usually a value of 9600 is sufficient for commonly used machine parameters (see discussion below).

Typical parameters for the current implementation of proportional height control are

Proportional Height Control Parameter	Value
HC Speed	30 mm/s
HC Acceleration	400 mm/s/s
X and Y Set Point	150
Proportionality Constant	20
POT scale	0.038 mm/POT unit
HC Display Accuracy	0.1mm

The accuracy of such a system with height control inputs on a serial connection at 9600 baud (corresponding to a reading every 1 to 4 milliseconds) can be within 0.1 mm at a cutting speed of 6 metres/minute.

Plasma Startup Sequence

Profiler has built-in support for plasma cutting. In particular, when using a plasma tool the sequence for starting the cutting is different from the startup sequence for other tools. Moreover, the *EndBottomDelay* input is used in a different manner from usual. To use a plasma tool the operator should choose to use the Plasma Startup Sequence. With this choice the behaviour of the cutting sequence changes and monitoring of both the state of the arcing and whether or not the tool is too close to the material is implied.

The details of the start-up sequence are introduced below and shown in more detail in the Timing Diagrams section below.

The state of the arcing of the plasma tool should be provided as the *EndBottomDelay* input to **Profiler** (see the Input/Output section for details of which bit is used). The *EndBottomDelay* input should be high (value of 1) when the plasma is arcing and low (i.e. value of 0) when it is not arcing. This input is used during the startup sequence for the plasma. In addition, if this input indicates that arcing has stopped (by going low after the expiry of a specified initial ignore time) then the machine is automatically paused. The control of the plasma tool also requires an additional input called the *Too-Close* input which should go high to indicate that the tool is too close to the material. This input is used to help find the initial height at which to cut the shape and, if it comes on during cutting, to pause the cutting. Note: in the hardware the *Too-Close* input doubles with the W-home input bit. The following table describes the plasma startup sequence parameters which can be configured by the user.

Table 22 Plasma Startup Sequence Parameters

Plasma Parameter	Description
Initial Height	When the plasma starts cutting a shape it moves down until it detects the *Too-Close* bit (Input Bit 1, see the Input/Output section). It then moves up from this point by the specified Initial Height distance.
Initial Wait Time	Once the Initial Height position is reached the program waits for the *EndBottomDelay* input. When the *EndBottomDelay* goes high the program waits without doing anything until the specified Initial Wait Time expires. This helps to ensure that the plasma arc starts correctly. During this time the *EndBottomDelay* input is ignored. When the time expires the program waits until the *EndBottomDelay* input goes high once again. When this happens it is assumed that the plasma tool is arcing correctly and that cutting can begin.
Debounce Time	Once cutting begins after the Initial Wait Time, the arc could still be turning on and off. In order to wait for it to stabilize the *EndBottomDelay* input is ignored for the specified Debounce Time. After the debounce time has expired, if the *EndBottomDelay* input goes high then the machine is automatically paused. If at any time during cutting the *Too-Close* input goes high it is assumed that an error condition has occurred and that the tool has moved too close to the material. In this case the cutting is automatically paused to allow for operator intervention. If at any time the cutting height reaches Z=0 then the cutting is also automatically paused.

Laser Operation

In addition to providing intensity control and height control for lasers **Profiler** enables several other aspects of laser operation to be controlled. In particular, piercing details and gas selection can be controlled The following table describes the Laser Setup options.

Laser Operation Parameter	Description
Use Pierce Sequence?	Usually piercing the material at the start of laser cutting requires different parameters from those used during cutting. This parameter sets whether or not the piercing sequence (controlled by the following parameters) will be used.
Laser Piercing Frequency (Hz)	This sets the piercing frequency of a PWM laser.
Pierce height above surface (mm)	This parameter sets the height above the surface for piercing. With height control active and piercing on, the head will move down until it finds the surface of the material. It will then move up by the given amount before piercing starts.
Pierce Gas Tool Bit: 0(=none), 1, 2 or 3	Once the head is at the correct height above the surface the pierce gas tool bit is turned on. This should be connected to the correct gas control for piercing. See Tool1-Tool3 outputs on the I/O card
Pierce Gas Wait Time (milliseconds)	This is the time to wait for the pierce gas to fill the gas line before the cut output is activated and piercing begins.
Pierce Intensity	This is a value between 0 and 127 which controls the laser intensity during piercing. It is mapped through the intensity table in the same way as all output intensities (see the section on Intensity Output).
Pierce Time (milliseconds)	This is the time the laser is turned on for piercing.
Pierce Gas Purge Time (milliseconds)	This is the time to wait for the pierce gas to be purged by the cut gas when piercing has completed and the cut gas is turned on.
Laser Cutting Frequency	This sets the cutting frequency of a PWM laser by sending a frequency byte to the PWM Card connected to the Parallel port.
Cut Gas Tool Bit: 0(=none), 1, 2 or 3	Once the head has moved to the surface the cut gas tool bit is turned on. This output which is on the I/O card should be connected to the cutting gas.
Cut Gas Wait Time (milliseconds)	This is the time to wait for the cut gas to fill the gas line before cutting begins.
Cut Gas Control Bits Override Group Settings?	The tool and cut bits to be used for cutting a shape are defined by the shape's group. If the cut gas control bits are set to override the group settings then the tool bit used for a shape is always the laser cut gas tool bit (as described above). Note that the cut bit used for the shape is still defined by the shape's group setting.

Laser Operation Parameter	Description
Engraving Cut Bit: 0(=none), 1,2 or 3	The engraving cut bit is used to indicate when the laser is engraving a shape rather than cutting a shape. If a group's cut bit is the same as the Engraving Cut Bit then no piercing will be done for any shape in the group. This means that the piercing sequence will not be done and also that during the bottom delay the output intensity will be zero.
Set Low bit of intensity high during bottom delay?	This setting allows the least significant bit of the intensity output to be set high during the bottom delay period. On legacy laser control boards, if the low bit of intensity is high during bottom delay then if the cut bit is 1 the laser output intensity is set to the maximum intensity (for piercing) but if the cut bit is 2 then the laser output is set to zero intensity (for engraving).

Finding the Home Position on an Axis

As already mentioned in the section on Axis Parameters, each axis can have a switch which indicates where the home position is on the axis. The procedure for finding the home position on an axis depends on the parameters described above. These parameters are repeated in the following table.

Table 23 Homing Procedure Parameters

Homing Parameters	Description
Fast Homing Speeds	This defines the speeds for the fast homing period on each axis.
Slow Homing Speeds	This defines the speeds for the slow homing period on each axis. A value of zero means that a fast but less accurate form of homing is performed.
Distance Off Homing Switches	This defines a distance off the precise homing switch position for each axis. This is used to ensure that the machine origin is off the switch position.
Second Z Axis Adjustment	When using two *z* axes on separate heads it is necessary to allow for a small difference between the *z* position of the heads. After homing the second *z* axis and moving off the switch by the required amount, the head is moved the extra distance specified by this adjustment.
Home Two X or Y Motors Separately	If two X or Y motors are being used then this determines whether or not the axis motors are homed separately. Suppose there are two X motors each with a homing switch connected in parallel. Firstly, homing is always done as usual with both motors being driven together. Then, if the motors are to be homed separately, each one is homed without the other motor being driven. Note that when there are two motors on an axis that the alignment of the machine will be effected by the precise positioning of the homing switches.

Homing Parameters	Description
X Home Position	The X home position can be at the Left or Right of the machine.
Y Home Position	The Y home position can be at the Front or Back of the machine.

The most accurate homing procedure uses both a fast search and a slow search. The following diagram illustrates the search procedure.

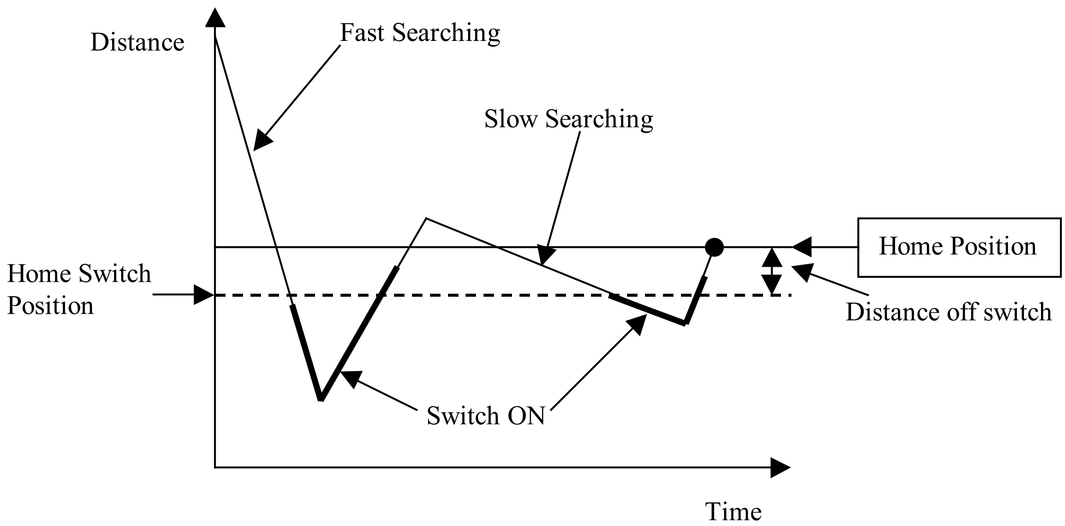

Figure 10 The Homing Procedure

The homing switch is assumed to be off in the normal area of machining and on otherwise. The direction in which to move from the region where the switch is off to the region where the switch is on depends on the axis: for the *x* and *y* axes the machine will move in the negative direction, for the *z* axis it will move in the positive (upwards) direction and for the *w* axis it will move in the positive (counter-clockwise) direction.

Assume that the machine is in a region where the home switch is off. The searching method which is most accurate and which is used when the Slow Searching Speed is non-zero is as follows:

1. Move towards the switch at the fast speed. When the switch turns on stop the machine.
2. Move back at the fast searching speed. When the switch turns off stop the machine. (If the Slow Search Speed is zero then the position at which the switch turned off is recorded and is used to calculate the final home position).
3. Move towards the switch at the slow speed. When the switch turns on, record the position and stop the machine.
4. Define the home position to be the recorded position displaced by the specified distance off the switch.

5. Move back to the new home position at the maximum speed for the axis.

Profiler can show the difference between the last homing position and the new homing position in machine steps.

Emergency Stopping

For safety reasons machines can be fitted with an emergency stop button. This is wired to the Emergency Stop input bit (see the section on Input and Output Control). As soon as the emergency stop bit goes high the machine decelerates to a stop, sets all output bits to zero, raises the *z* axis (if RaiseOnPause is on) and allows the operator to control the subsequent operation of the machine.

Miscellaneous Configuration Options

Profiler can be easily configured to support various machine options including those described above. The following table describes some miscellaneous machine options not already mentioned above.

Table 24 Miscellaneous Machine Options

Plasma Parameter	Description
Output the Intensity?	Selects whether the intensity as a function of the current speed and current cutting speed will be output to the parallel port.
Do Height Control?	Selects whether or not the machine height control will be used for THRU shapes.
Use Plasma Startup Sequence?	Selects whether the machine will use the plasma startup sequence when beginning to cut.
Use Laser?	Selects whether or not a laser tool is being used. If a laser is being used then it is also necessary to specify the type of laser.
	Is the laser a Pulse Width Modulated laser? Pulse width modulated lasers use a different laser control card. Currently these types of lasers use the low-order bit of the parallel port intensity output to control the intensity during the initial bottom delay. The low bit is set high during the bottom delay time.
Do Double Job Start?	The machining of jobs is most commonly controlled from the hand console (see the detailed description below). Usually when the Start button on the hand console is pressed the machine will perform preliminary actions, such as homing the *z* axis, and then wait for further instructions from the operator. The operator can choose to select a start shape (either by typing a number or moving the machine tool to successive or previous shapes) or simply start the job by pressing the Start button again. This is referred to as the normal *Double Start* action. If *DoDoubleStart* is set to 'No' then when the Start button on the Hand Console is pressed the machine will perform the preliminary actions for job cutting and then immediately start the job at the first shape.

Use Tangential Axis?	Selects whether or not a tangential axis is being used.
Runtime Drawing Amount (0-10)	When the machine is moving its position can be drawn on the screen. Since drawing can take a considerable time it may sometimes interfere with the motion of the machine. The Runtime Drawing Amount parameter controls when this drawing will occur as a function of the speed of the machine. The runtime drawing amount can have a value from 0 to 10. If the runtime drawing amount is set to 0 then no drawing will be done and if it set to 10 then the machine position will be drawn at all machine speeds.
Automatic Homing Control	The homing of the machine on each of the axes can be configured to be done automatically at the start of the **Profiler** program and at the start of each job. In most cases automatic homing would be set to be done on all axes at the start of the program. This ensures that the absolute position of the machine is set. Usually automatic homing on the *z* axis is also set to be done at the start of each job in order to ensure that the heights on the *z* axis are accurate. The setting for whether or not automatic homing on the *z* axis is done at job start also controls whether or not homing on the *z* axis is done before the standard *z* positions (Z Top, Surface and Bottom) are to be changed.

Tool Path Smoothing

For many applications it is desirable that a certain amount of tool path smoothing be done so that the machine will run smoothly without constantly starting and stopping. For example, curves are often approximated by small line segments when using scanning or some drawing packages. Machining these line segments exactly would require the machine to start and stop for each segment. As an example, the following diagram shows an original path consisting of small line segments. In many cases the desired machine tool path would be a spline curve approximation to this path (as shown by the smoothed path in the diagram). **Profiler** provides a parameter, the *smoothing factor*, for controlling this type of smoothing.

Another situation in which it is undesirable for the machine tool to stop is when two line segments join with a quite small turning angle (see the following diagram for an example of the turning angle). For small turning angles the machine may be capable of making the sudden change in direction without slowing down or stopping. **Profiler** provides another parameter, the *stop angle*, for controlling this type of motion smoothing. The stopping angle is applied to line segments which do not occur within a smoothed section of the path (as determined by the *smoothing factor*). The machine will not stop at the ends of line segments which have a turning angle smaller than the *stop angle*.

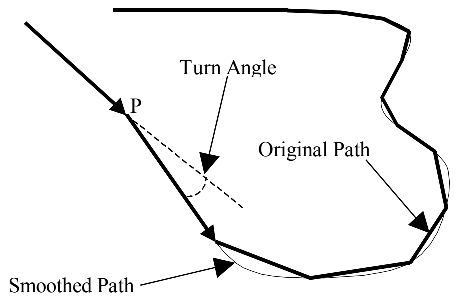

Figure 11 Path Smoothing and Turning Angles

The smoothing parameters are described in the following table:

Table 25 Path Smoothing Control

Path Smoothing Parameters	Description
Smoothing Factor	The smoothing factor is related to the allowed distance between the line segments and the resulting smoothed curve. The larger the value of the smoothing factor the more segments will be included in path smoothing. If the smoothing factor is set to zero then no path smoothing will be done. The **usual and default value** of the smoothing factor is 0.6.
Stop Angle	The turn angle between successive line segments in the path is shown in the accompanying diagram. If the turn angle of line segments outside a smoothed section of the path is less than the Stop Angle then the machine will not slow down at the turning point (labelled P in the accompanying diagram). The **default value** for the stop angle is 1.0 degrees.

When are the Smoothing Factors used?

The path smoothing parameters are saved as part of the machine configuration. **It is important to note** that these parameters are not only used when machining the data but also when the machine tool path for a job **is being created** when passing from edit mode to machine mode. The original drawing data would be smoothed according to these parameters, effectively defining spline approximation paths to the drawing. The offset required is in fact an offset of the smoothed, splined path which may be quite different from the offset of the original data. It follows that if these parameters are changed then **the machine tool path (RSM file) should be recreated from the original data (RSG file)**.

Machining the Job

This section describes the functionality provided by **Profiler** to control the machining of the job. In order to use this functionality you must be viewing machining data which has been generated from graphics data by applying any offsets, tags, lead-ins and lead-outs and arraying.

Job Origin and Finish Positions

The position at which a job is machined is determined by the **current job origin** which can be anywhere within the machine bounds. The following diagram shows the relation between the job origin, the machine bounds and the machine home position. (Note that in this example the data has *not* been left justified).

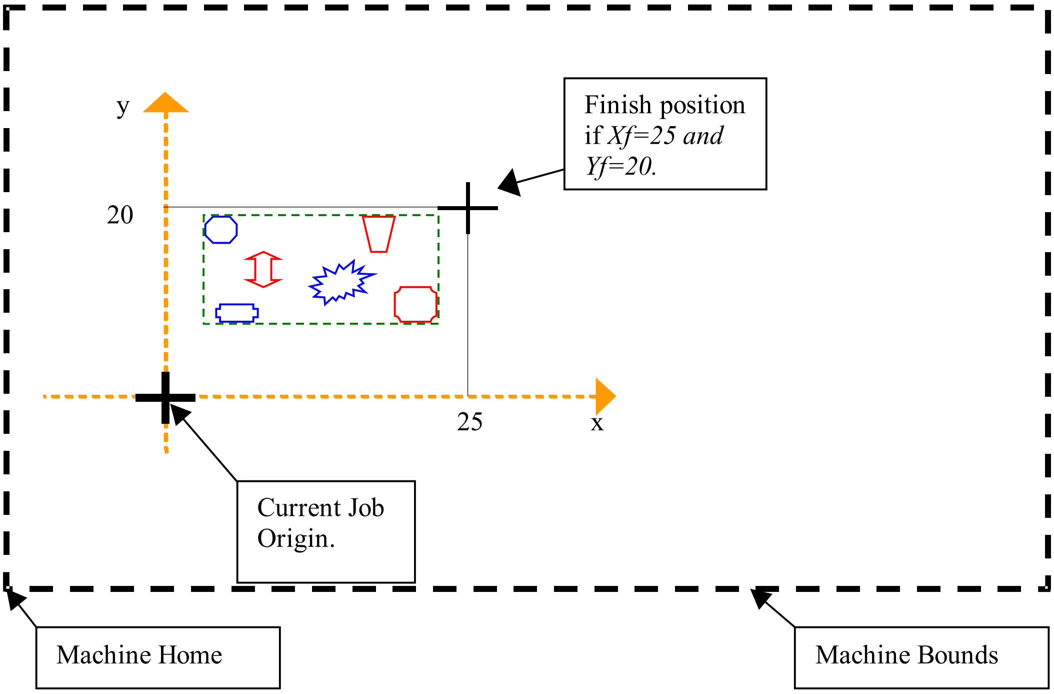

Figure 12 Position of data Relative to Machine Bounds and Job Origin

The job origin can be changed in several ways:

1. At any time the job origin can be set to be at the *Current Machine Position (CMP).*

2. The position of the job origin relative to the *xy*-home position defined by the homing switches of the machine is saved in the job machining file. Whenever a job is opened the job's saved job origin becomes the job origin. This means that if the machine has found its home positions correctly then the job origin will be at exactly the same location within the machine bounds whenever the job is opened.

3. If the parameter Change job origin at start is set to *yes* then every time the job is started the current job origin is automatically changed and set to be at the Current Machine Position. If the option Change job origin at start is set to *no* then the previously set value of the job origin will be used.

4. If the job origin is changed after the job has been opened then the only (easy) way to reset the job origin to its original location is to open the job file again.

Any movement of the machine is always with respect to the current job origin. For example, if the MoveTo function (see below) is used to move the machine to the absolute position x=0 and y=0 then the machine will move to the current job origin.

Each job also has a defined **finish** position. At the completion of the job the machine moves to the job finish position. The finish position *(Xf, Yf)* for a job is a position *relative to the current job origin* – if the job origin changes then the finish position changes with it. In the default case, *Xf=0* and *Yf=0* and when the job is finished the machine moves back to the job origin.

This can be very useful for automatically moving the machine at the end of a job so as to enable easy removal of the material. The finish position is also saved in the job machining file.

If, for example, *Xf=25* and *Yf=20* then when the job is finished the current machine tool position will be the point *x=25* and *y=20.* The job finish position is illustrated in the diagram above.

Two Jig Machines

For continuous production it is often useful to have two jigs set up on the machine. Whilst the material sheet in one jig is being cut the sheet in the second jig can be removed and replaced with a new sheet. To maximise the usefulness of this feature and to avoid continual operator monitoring each jig has a start switch. Initially, neither start switch is on. Once the first jig is loaded with a sheet of material the operator turns the jig1 start switch on. The machine starts cutting the shapes on this jig and automatically turns off the jig1 switch. The operator can then load the second jig with a sheet of material and turn the jig2 switch on. When the machine finishes cutting the shapes on jig1 it will determine that the jig2 switch is on and will start cutting jig2, automatically turning the jig2 start switch off. Now, as soon as the machine starts cutting jig2 the operator can load material into jig1 and turn the jig1 switch on. This process can continue, resulting in maximum use of cutting time.

In order to support two jigs the following features are required:

- Two input bits called Jig1 and Jig2 are used for the jig switches;
- Two output bits Jig1 and Jig2 are used to indicate when the switches should be turned off;
- A jig divider position on the X axis which is specified relative to the home position of the machine.

The jig divider position divides the machine into two jigs: the left jig (including all shapes left of the divider position) and the right jig (including all shapes on the right of the divider position). Note that the shapes which straddle the divider position will *not* be cut.

If the machine has two jigs then the jig containing the start shape is the jig which is cut first.

Changing the Tool Position

The position of the tool can be changed on the *x*, y and *z* axes. The following table shows the ways in which this can be done:

Table 26 Moving the Tool

Move Functions	Description
Move to Home	The machine will move to the home position on the selected axes.
Move to Job Origin	The tool will move to the current job origin position on the *x* and *y* axes.
Move to Job Finish	The tool will move to the current job finish position on the *x* and *y* axes.
Arrow Keys	The arrow keys on the keyboard keypad (or on the Hand Console described in a later section) enable direct movement of the tool. The directions of movement which are possible are horizontally and diagonally in the *x* and *y* plane and up and down on the *z* axis. The maximum speed and acceleration during arrow moves can be changed to be a percentage of the maximum values of the speed and acceleration on the axes. See the Hand Console section for more details. If the limits have been activated then it is not possible to move the machine tool outside the machine boundaries.
CutMoveTo…	Move the machine to a new position by specifying the *x* and *y* coordinates relative to the current job origin position. If this function is used with cutting selected then the move will be done as if it is part of a job. For example, the router or laser will turn on and if the machine has height control it will be activated as if cutting a THRU shape.
MoveTo…	Move the machine to a new position by specifying the *x*, *y* and z coordinates, whether it is a relative or an absolute move and whether it is a 2D move in the x and y directions followed by a z move or a true 3D move.

Controlling the Job Cutting

This section briefly describes the normal sequence for cutting a job. Details of the program user interface and the methods of accomplishing the tasks are given later.

1. Set the desired plunge speed and cut speed.

2. Ensure that the *z* axis height settings, Zbottom, Zsurface and Ztop, are at the required positions. This can be done by using the procedures provided for setting these values - drive the tool to the correct height for each position and record it. These positions are saved as part of the machine configuration and can be checked at any time.

3. Ensure that the job origin is correct. If the job is to be cut at a different location each time then drive the machine to the correct position and make sure that *Change job origin at start* is true. If this is a job that is

always cut at the same position (for example, if there is a jig to hold the material at a set place on the machine table) then make sure that *Change job origin at start* is false. If you need to check the location of the current job origin then use the *Move to Job Origin* function to move the machine there.

4. Start the job by using the start key (either on the hand console or on the PC keyboard). At this time the machine will usually be configured to find the home position on the *z* axis before waiting for further commands. It is possible to configure whether or not the search for the home position occurs at the start of each job (and to specify on which axes it occurs).

5. At this point it is possible to specify the starting shape using a number of methods. The start shape number can be typed in or it is possible to repeatedly move to the next or to the previous shape. Once the starting shape is specified the job cutting can be started by using the start key again. In a large array of shapes it may be difficult to tell what the required start shape number is or at least tedious to repeatedly move to each shape until the correct shape is reached. In this case a function is provided for retrieving shape numbers by simply selecting the shapes on the screen with the mouse. This should be done *before* starting the job.

Using an External Job Start Input

In some circumstances it is useful to be able to use an external input as a job start input together with associated door close checking. This option is controlled in the machine configuration by setting "Use external input to start job?" to Yes or No. Currently the WHOME input line is used for this external input. (Note: later versions may use a different input.). Whenever the external input is triggered a job start event (similar to the event generated by pressing the hand console Start key) is generated. If the hand console or keyboard is used to start a job when the "Use external input" option is set to Yes then, before doing any other actions the program waits until the WHOME input goes high. If there is a safety door on the machine and the WHOME input is wired so that it is only triggered when the door is closed then waiting for the WHOME input bit to go high prevents the hand console or keyboard from starting the job when the door is open. Note that:

- The external input bit IS NOT checked during the running of the job. This means that if an emergency stop is required when a job is running and the door is opened then door opening must trigger the emergency stop input.
- If an external input is being used then homing of the W axis will not be possible.
- If an external input is being used then the use of two jigs is not allowed.

Hand Console

The machine operator can use a **hand console** (also referred to as a **keypad** or as a **teach box**) to control the machine. The hand console has a character screen of size 2 rows x 20 characters together with the following 16 keys: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, +/-, *Enter, File, Start, Stop* and *Func.*

The hand console can be easily carried to where the job is being machined, communicating with the PC via a serial connection. It provides a convenient way of controlling the machining although it doesn't provide the full functionality of the screen based user interface.

The hand console operation is mimicked on the computer keyboard and screen. The hand console keys correspond to the *PC keyboard* keypad except for the *File, Start, Stop* and *Func* hand console keys which have the following correspondence: *File→F9, Start→F10, Stop→F11 and Func→F12.*

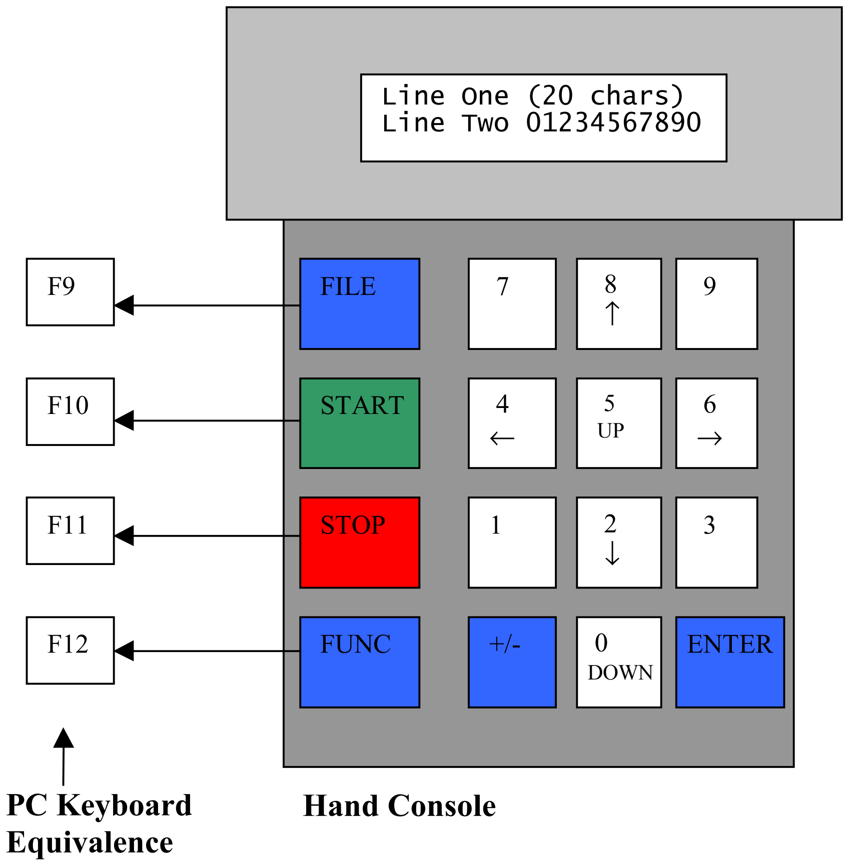

Figure 13 Hand Console (or Keypad)

The following tables describe the use of the hand console. Typical hand console screens are shown as they appear after the given key is hit. The typical hand console screen before any key is hit is shown below.

Typical Hand Console Screen BEFORE Any Key is Hit	`JOB: SAMPLE.RSM`

Hit The top line shows the current job name (or Untitled if no file has been opened) and the bottom line the size of the job and the number of shapes in the job.	720x360mm #16

<table>
<tr><td>KEY</td><td colspan="2">USAGE</td></tr>
<tr><td rowspan="3">File (F9)</td><td colspan="2">This is the hand console equivalent of the File|Open dialogue. Files in the current directory with extension RSM can be displayed in alphabetical order one at a time. The current directory can only be changed using the PC screen File|Open menu. The hand console down and up arrow keys (2 and 8) are used to cycle through the files. The PgDn and PgUp hand console keys (3 and 9) are used to cycle in steps of 5 files. When the desired file is displayed pressing Enter opens it.</td></tr>
<tr><td rowspan="2">Typical Hand Console Screen AFTER Key <u>File</u>. The top line names the action being performed. The bottom line, the currently selected file name.</td><td>Select File (2839):</td></tr>
<tr><td>SAMPLE.RSM</td></tr>
</table>

<table>
<tr><td rowspan="9">Start (F10)</td><td colspan="3">This is the hand console equivalent of the Machine|StartJob menu. After <u>Start</u> the hand console keys have the following meaning:</td></tr>
<tr><td>KEY</td><td colspan="2">USAGE</td></tr>
<tr><td>File</td><td colspan="2">No action.</td></tr>
<tr><td>Start</td><td colspan="2">Start machining the job from the current shape number.</td></tr>
<tr><td>Stop</td><td colspan="2">If a number is being typed Stop can be used for backspacing.</td></tr>
<tr><td>Func</td><td colspan="2">Abort the machining (with confirmation) and return to origin.</td></tr>
<tr><td>+/-</td><td colspan="2">Move the machine tool to the previous shape.</td></tr>
<tr><td>Enter</td><td colspan="2">If a shape number is being typed then Enter will move the machine tool to the shape number. If a number is not being typed then Enter will move to the next shape.</td></tr>
<tr><td>0-9</td><td colspan="2">A start shape number can be typed at any time and the machine will move to that shape.</td></tr>
<tr><td></td><td colspan="2">Typical Hand console Screen AFTER Key <u>Start</u>. Top Line: action being performed; Bottom Line: Start shape number of total number of shapes.</td><td><code>Start shape is</code>
<code>3 of 16</code></td></tr>
</table>

<table>
<tr><td>Stop (F11)</td><td colspan="2">Used to pause the machine when it is machining (also see above for use as a backspace during hand console entry).</td></tr>
<tr><td rowspan="2">Func (F12)</td><td colspan="2">Used to select machine control and configuration functions. Typing a number selects the function to be performed, <u>Func</u> exits the selection dialogue, <u>Enter</u> initiates the function and <u>Stop</u> backspaces.</td></tr>
<tr><td>Typical Hand console Screen AFTER Key <u>Func</u>. Top Line: action being performed (function selection); Bottom Line: Function number and brief explanation.</td><td><code>Enter function:</code>
<code>0 Cut speed</code></td></tr>
<tr><td>Enter</td><td colspan="2">Redraws the hand console display with the current job name, size and number of shapes.</td></tr>
</table>

The functions which can be initiated using the Func key are as follows:

Function	Description
0	Cut speed
1	Plunge speed
2	ZSetting: drive machine to each Z position in turn
3	ZBottom adjust (-ve down, +ve up)
4	Move to job origin
5	Move to job finish
6	Move machine by ...
7	Set job origin at Current Machine Position (CMP)
8	Set job finish using Current Machine Position
10	Save job (with current origin and start)
11	Save machine configuration
17	Set proportional height control scale
18	Set proportional height control *x* and *y* axis set point
18.1	Set proportional height control *x* axis set point only
18.2	Set proportional height control *y* axis set point only
19	Adjust proportional height control *x* and *y* axis set point (mm)
19.1	Adjust proportional height control *x* axis set point only (mm)
19.2	Adjust proportional height control *y* axis set point only (mm)
20	Move to machine homes
21	Move machine to...
23	Second Z axis adjustment (mm)
30	Set bottom delay time (seconds)
31	Set bottom delay by input: YES(=1) or NO(=0)
32	Set raise on pause: YES(=1) or NO(=0)
34	Change job orig@job start: YES(=1) or NO(=0)
38	Set arrow moves speed (% of maximum)
39	Set arrow moves acceleration (% of maximum)
40	Centripetal acceleration as percentage of normal x and y axis acceleration.
50	Find machine z(w) home(s)

Function	Description
51	Find machine xy homes
52	Find nearest shape number to CMP
60	Offset job (offset by 0mm restores the original job)
61	Number of times to repeat the job
70	Digitize
100.2	Set *y* axis cutting speed factor
300	ZBottom adjust (-ve down, +ve up) followed by 3D bottom justify

Digitizing

Profiler can be used to digitize both two and three-dimensional shapes by driving the machine tool to, and recording, successive points on the shape. The hand console interface is provided with additional functionality to support this feature. For digitizing the hand console is often referred to as the **teach box**. This section describes the methods used to digitize shapes.

Digitizing 2D Shapes

Firstly, the concepts used for digitizing two-dimensional shapes will be explained. The functionality of each of the hand console keys is summarized in the table below. The extension to 3D digitizing is straightforward although 3D arcs are not currently supported.

The digitizing interface is designed to be simple but powerful. Once you put the machine into digitizing mode you can drive the tool to any position in space using the arrow keys or the Move To functions. In particular, you can drive the tool to successive points on the shape and record the position as the next *line point* or next *arc point* on the tool path. A *line point* defines the start or end of a simple line segment. An *arc point*, together with its preceding and succeeding points, defines the unique arc, which starts at the preceding point, goes through the arc point and ends at the succeeding point. When you finish digitizing the shape the path can be saved as a closed or open polyarc.

While digitizing a shape you might wish to modify or delete points which you have already inserted or you might wish to insert new points in the path. To support this functionality **Profiler** uses the concept of the *current point*. Modifications, deletions and insertions are all applied relative to the current point. At any time while digitizing the shape you can move backwards or forwards through the points which you have already digitized. As you move to an already digitized point it becomes the current point. If you want to continue appending points to the end of the path then you must move the tool to the last point of the path.

The properties of the current point which can be modified are its position and whether or not it is a normal point or an arc point. These properties can be changed by simply driving the tool to a new position (using the arrow keys or a move function) and specifying the point type.

Another important feature of digitizing is the ability to load existing shapes (either shapes from a drawing package or shapes previously digitized) by simply driving close to the shape and selecting the load function. Once loaded the shape can be modified as usual using the digitizing functions.

Digitizing 3D Shapes

The same concepts used for digitizing 2D shapes are used for digitizing 3D. The normal smoothing of short line segments when they closely follow a curved path is done when machining 3D shapes as it is for 2D shapes.

Digitizing with the Hand Console

The following table describes how digitizing is implemented using the Hand Console.

<table>
<tr><td>KEY</td><td colspan="2">USAGE</td></tr>
<tr><td rowspan="3">File (F9)</td><td colspan="2">Move the tool to the digitized point before the current point (if there is one), following a straight line or arc segment as appropriate.</td></tr>
<tr><td rowspan="2">Typical Hand Console Screen AFTER Key File. The top line shows the dimension. The bottom line shows the current point number and the total number of points.</td><td>Digitize: 2D Point</td></tr>
<tr><td>Cur=5 of 11</td></tr>
<tr><td rowspan="3">Start (F10)</td><td colspan="2">Move to the digitized point after the current point (if there is one), following a straight line or arc segment as appropriate.</td></tr>
<tr><td rowspan="2">Typical Hand Console Screen AFTER Key Start. The top shows the dimension. The bottom line shows the current point number and the total number of points.</td><td>Digitize: 2D Point</td></tr>
<tr><td>Cur=6 of 11</td></tr>
<tr><td>Stop (F11)</td><td colspan="2">No action but note that this key is used as a backspace during hand console number entry.</td></tr>
<tr><td rowspan="3">Func (F12)</td><td colspan="2">Used to select digitizing functions. Typing a number selects the function to be performed. Typing Func exits the selection dialogue. Typing Enter initiates the function. See below for a description of the digitizing functions.</td></tr>
<tr><td rowspan="2">Typical Hand console Screen AFTER Key Func

Top Line: action being performed (function selection); Bottom Line: Function number and brief explanation.</td><td>Enter function:</td></tr>
<tr><td>0 Insert before</td></tr>
<tr><td>+/-</td><td colspan="2">Toggle between a line point type and an arc point type for the next point insertion</td></tr>
<tr><td>Enter</td><td colspan="2">If the current point is at the end of the digitized path then a new digitized point is appended to the end of the path with its position value being the current location of the tool and its point type being the currently selected point type.</td></tr>
<tr><td>Digits 0 to 9</td><td colspan="2">Move the tool using the arrow keys</td></tr>
</table>

Table 27 Digitizing Functions

Digitizing Function	Description
0	Insert a new digitized point **after** the current point. The position of the new point is the current location of the tool and its point type is the currently selected point type.
1	Insert a new digitized point **before** the current point. The position of the new point is the current location of the tool and its point type is the currently selected point type.
2	Delete the current point
3	Modify the current point. The position of the modified point is the current location of the tool and its point type is the currently selected point type.
4	Move to end: follows the digitized path from the current point to the end point, passing through each digitized line point or arc point on the way
5	Move to start: follows the digitized path from the current point to the start point, passing through each digitized line point or arc point on the way
6	Move to current: moves the tool in a straight line to the current point.
7	Move to nearest: moves the tool in a straight line to the nearest digitized point.
8	Save shape as an open shape
9	Save shape as a closed shape
10	Load nearest shape
11	Set dimension to 2D: shapes will be saved as 2D
12	Set dimension to 3D: shapes will be saved as 3D
15	Clear all digitized points
20	Move To: moves the tool to an absolute position w.r.t. current job origin
21	Move By: moves the tool to a relative position w.r.t. to its current position
30	Draw currently digitized shape
31	Draw data limits: draws all of the data within the data limits
32	Draw machine limits: draws the machine bounds and the data
33	Zoom out
38	Set arrow move speed as % of maximum speeds on axes
39	Set arrow move acceleration as % of maximum accelerations on axes
40	Show current x, y and z tool position
99	EXIT digitizing

Chapter 3

Sending Files

The design of a job file ready for machining can be accomplished using the editing-only version of **Profiler**. The editing-only version does not have the machining capability of the full version and can be run on an office computer. The job files can be sent over a serial connection to the computer controlling the machine. The transfer will only proceed while the machine is not moving. The program provides facilities to monitor the transfer and to also stop the transfer if desired. The parameters for setting up file sending are described below in the Communication section.

Customizing Profiler

Several additional parameters for customizing **Profiler** are described in the following tables. These include parameters to set up the serial communications for both the transfer of files and for the hand console, default options concerning paths, general machine options and viewing options. In addition, the dialogues which are used for customizing **Profiler can** be password protected.

Communication

In general, it is assumed that the full machine version will use a PS/2 mouse and that the standard two serial ports will be used for the hand console and for the file sending respectively. The following tables show the configuration options for sending files and for the hand console communication. Only the full machining version uses the hand console communication. A COM port and a speed must be specified for sending files and for the hand console. The interrupt request for the port is taken from the Port to IRQ mapping (but this may be operating system dependent).

Table 28 Configuring File Sending

File Sending Communication Parameter	Description
Port	This is the communications port for sending files between an office computer running the editing-only version and the computer controlling the machine. It can have values of 1, 2, 3 or 4.
Speed	The required baud rate usually one of 2400, 4800, 9600, 19200 or 38400.
Port to IRQ Mapping	The Interrupt Request line (with a value of 1, 3, 5, 7, 9, 10, 11 or 15) for each COM port (1, 2, 3 and 4). This is also used for the Hand Console communication settings.

Table 29 Configuring Hand Console Communications

Hand Console Communication Parameter	Description
Port	This is the communications port for the hand console. It can have values of 1, 2, 3 or 4.
Speed	The required baud rate which currently must be 2400.

General Options

The following table describes other general options which are available for configuring **Profiler**.

Table 30 General Options

Option	Description
Password protect configurations?	If set to *yes* then the dialogues for changing the machine configuration and general options require a password to be used.
Do double job start?	If set to *yes* then, when a job is started, the user can set the shape at which to start cutting. Once the starting shape is set (the default is to start at shape 1) then the cutting can be started.
Do automatic homing at program start?	This controls the homing of each axis when the program is started. The *x*, *y* and *z* and *w* axes can be controlled separately.
Do automatic homing at job start?	This controls the homing of each axis when a job is started. The *x*, *y* and *z* and *w* axes can be controlled separately.
Path vertex filtering distance	Some polylines or polyarcs may have points which are very close together (for example, less than 0.02mm). Such points can be filtered out by setting the path vertex filtering distance to an appropriate value. If the filtering distance is 0 then no filtering is done.
Default joining distance for shapes	The join operation requires the specification of a joining distance. This option shows the default value which will be used. Whenever the distance used for joining is changed the new value used becomes the default.
Mouse selection radius (pixels)	When selecting a shape with the mouse the shape only becomes selected if the selection point is within the specified number of pixels of the shape. When a snap function is being used the selection circle is drawn at the centre of the cross hair cursor.
Parallel port (1 or 2)	For some machines such as a laser with intensity control the intensity is output on the selected parallel port.

Viewing Options

There are several options available for controlling the way in which data is displayed. They are explained in the following table:

Table 31 Viewing Options

View Option	Description
Show each shape with its group colour?	If set to *yes* then each shape is displayed using its group colour; otherwise each shape is shown as follows: • Red if clockwise • Blue if anti-clockwise • Green if an open shape or • Magenta if a closed shape which crosses itself.
Show Smoothed Paths?	Paths can be smoothed (as described in an earlier section). This option allows the smoothed path to be displayed yellow. This drawing can be time consuming and is suggested for advanced use only.
Show shapes in groups which are turned off as dashed?	If set to *yes* then each shape is displayed using the current display method but with shapes in groups which are turned off being displayed using dashed lines; If set to *no* then shapes which are in groups which are off are not displayed at all.
Show path starts (as yellow direction indicators)?	If set to *yes* then the start vertex of each shape is displayed with an attached indicator showing the direction of the shape and the cutting side.
Show path vertices (as black crosses)?	If set to *yes* then the vertices in each shape are displayed as small black crosses.
Show filtered path vertices (as blue crosses)?	If set to *yes* then the vertices which will be filtered in each shape are displayed as small blue crosses.
Show Rough Offsets	Draw the roughing offsets for shapes in addition to the final offset.
Window expansion factor (%)	This factor which is set in options general is used to expand the displayed window size. For example, when displaying all of the shapes the display area is made larger than the bounding box of the shapes by the window expansion factor. For example, a value of 5% will increase the display window size by 5% in world coordinates. If all of the data is displayed and its bounding box is, say, 100mm by 100mm then the area displayed in the window will be 105mm by 105mm.

Appendix A
Timing

Timing Diagrams

The example timing diagrams below give some examples of how the hardware input and output bits control the machine motion. Examples are given for normal router, laser, laser using a piercing sequence and plasma timing.

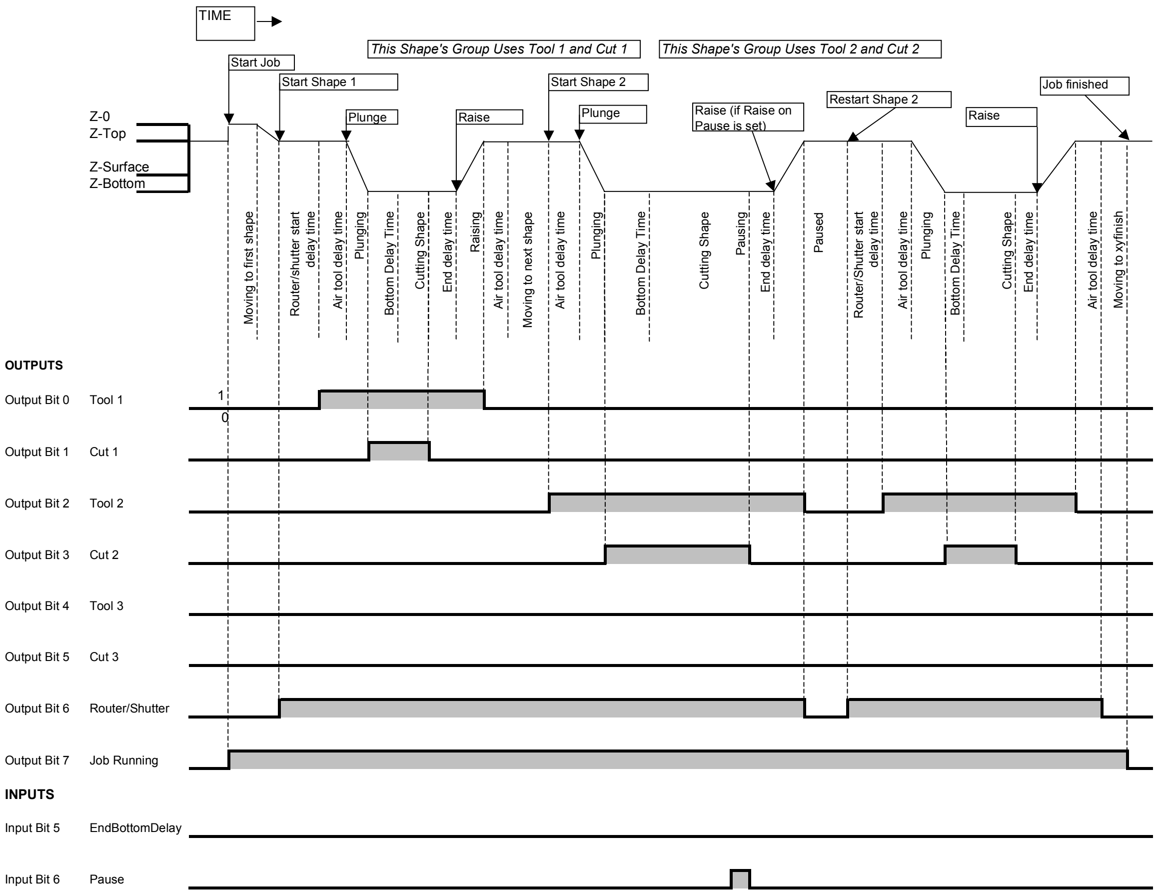

Figure 14 Timing and control inputs and outputs (e.g. router)

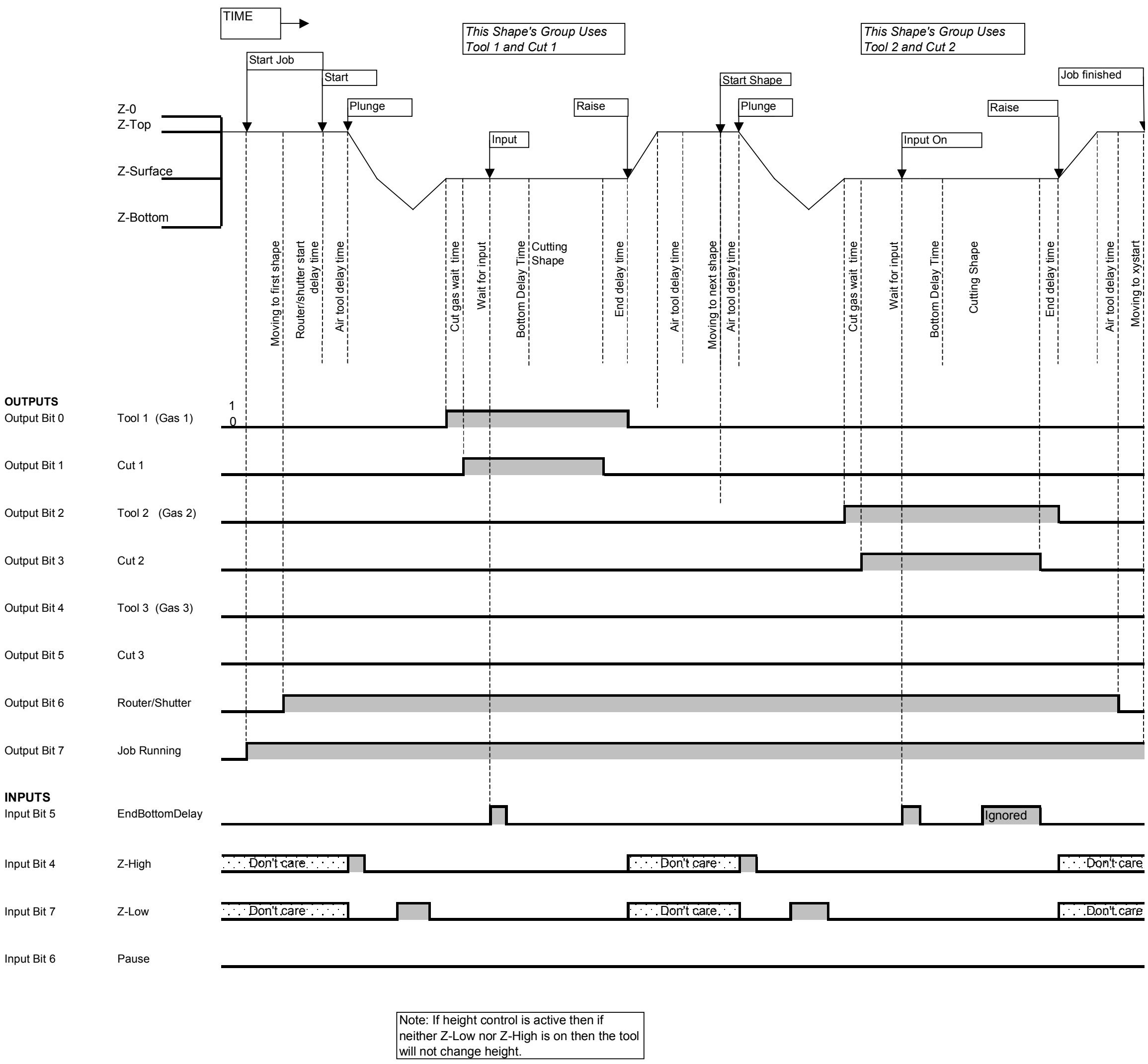

Figure 15 Timing and control inputs and outputs with bottom delay input (e.g. lasers)

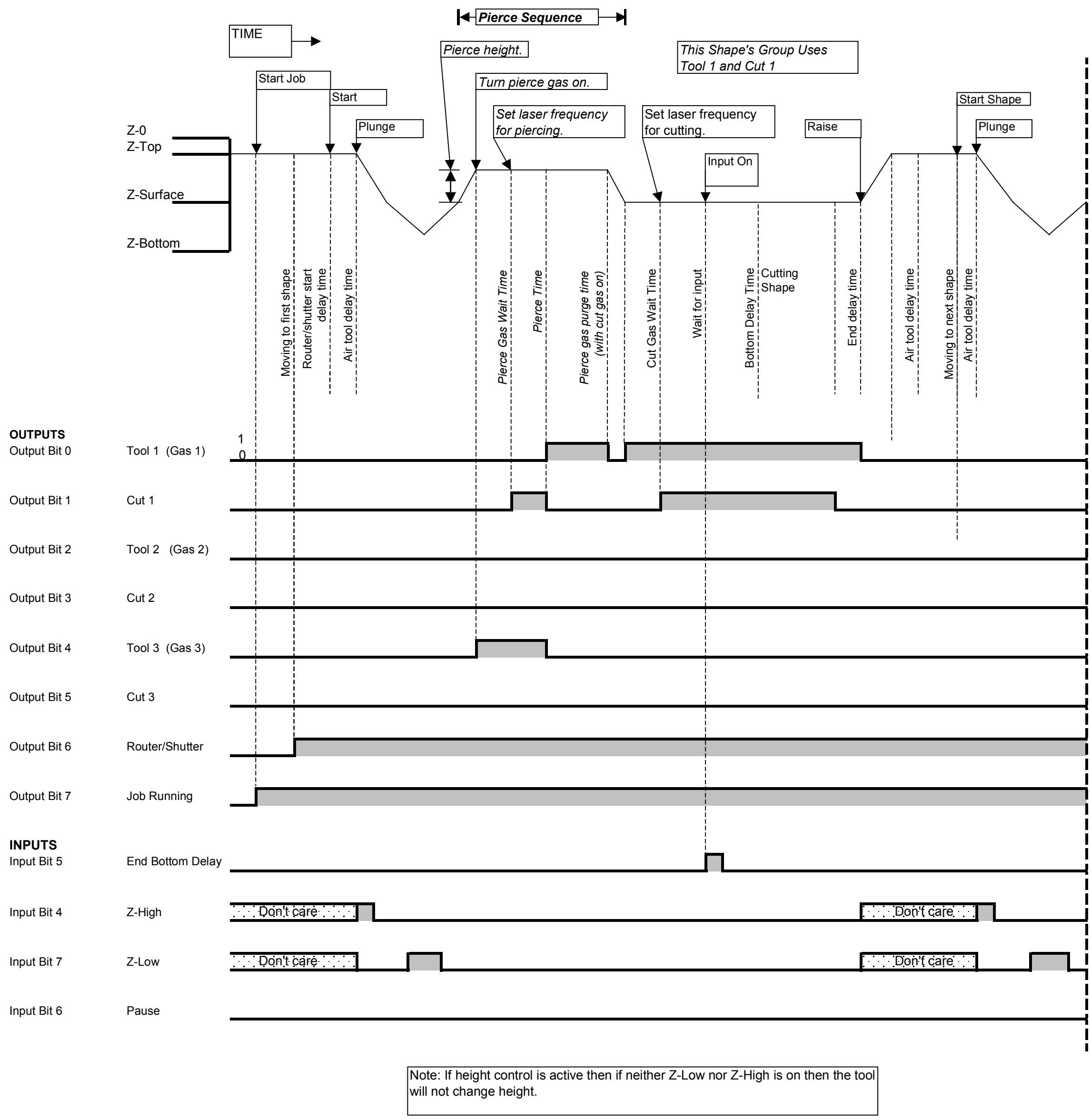

Figure 16 Timing of control inputs and outputs for laser with pierce sequence.

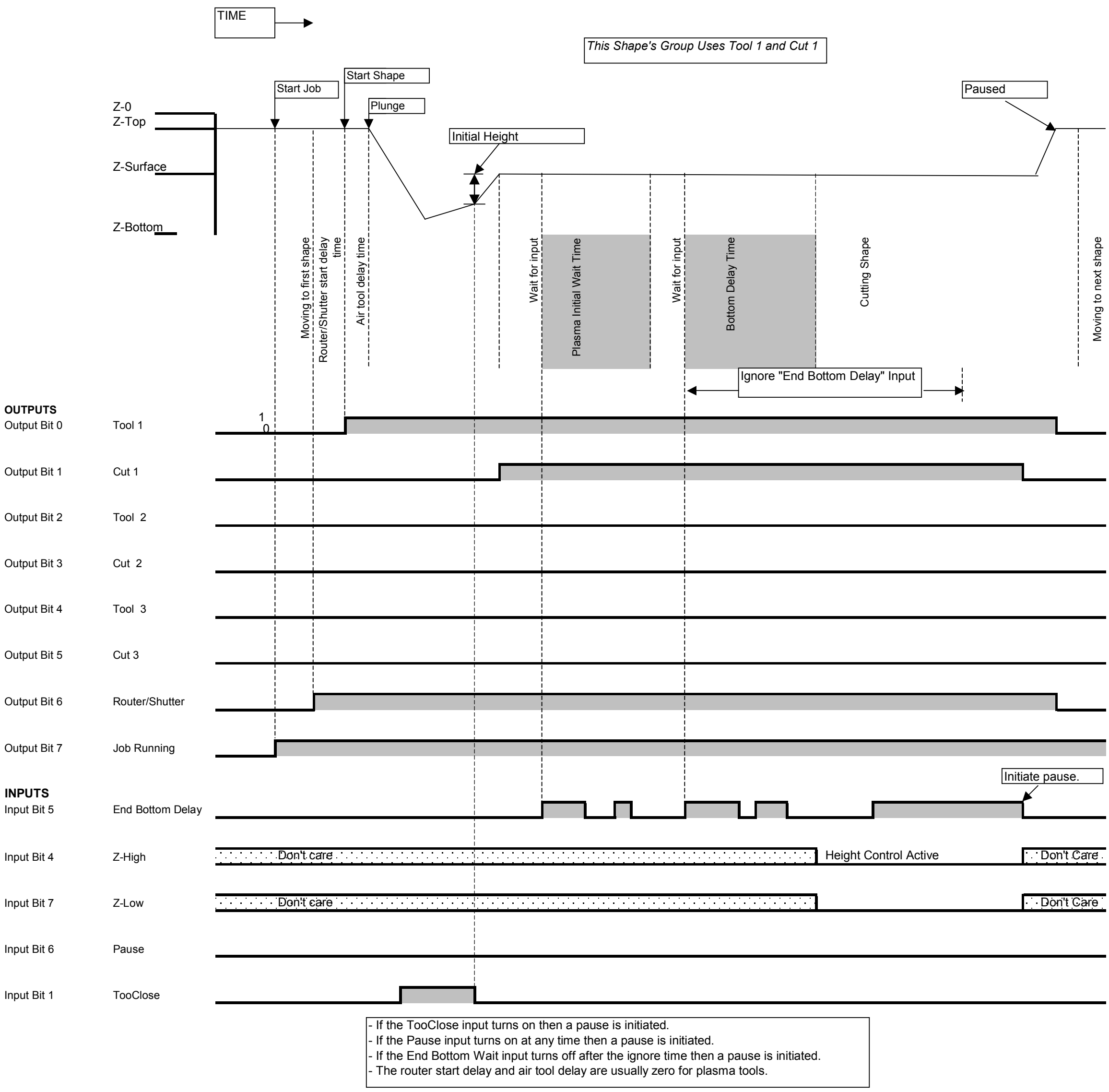

Figure 17 Timing and control inputs and outputs showing the plasma startup sequence.

Appendix B Hardware Details

PCI Card

The PCI card provides the interface between the computer and the control system. It provides for all of the input and output requirements needed to control a machine. Following is a table describing the functionality and pin-outs for the PCI card and also the relevant circuit diagram.

Outputs

The outputs from the pci card are open collector outputs in series with a 1K resistor. They will sink up to 200mA of current to ground when activated. Output from the card is provided by the 37pin female D connector located on the board. The outputs are as follows:

Pin	Name/Func	Description
1	+12V X	Power supply generally used for X Step and Dir
2	+12V Y	Power supply generally used for Y Step and Dir
3	+12V Z	Power supply generally used for Z Step and Dir
4	+5V	5 Volt power supply for external circuit
5	X Direction	direction output for X axis
6	Y Direction	direction output for Y axis
7	Z Direction	direction output for Z axis
8	W Direction	direction output for W axis
9	Cut 1	Cut signal generally used for turning the cutter on and off. Active for shapes on tool 1
10	Cut 2	Cut signal generally used for turning the cutter on and off. Active for shapes on tool 2
11	Cut 3	Cut signal generally used for turning the cutter on and off. Active for shapes on tool 3
12	Run	Active while a job is running
13	Not Used	
14	Not Used	
15	Not Used	
16	Not Used	
17	Gnd	Connected to computer ground
18	Gnd	Connected to computer ground
19	Gnd	Connected to computer ground
20	+12V	+12 Volts
21	+12V	+12 Volts
22	+12V	+12 Volts
23	X Step	Outputs pulses for stepping in the X axis
24	Y Step	Outputs pulses for stepping in the X axis
25	Z Step	Outputs pulses for stepping in the X axis
26	W Step	Outputs pulses for stepping in the X axis
27	Tool 1	Output is active during a shape on tool 1 including Z movement
28	Tool 2	Output is active during a shape on tool 2 including Z movement
29	Tool 3	Output is active during a shape on tool 3 including Z movement
30	Router/Shutter	Output active during entire job, deactivates on pause
31	Not Used	
32	Not Used	
33	Not Used	
34	Not Used	
35	Gnd	Connected to computer ground
36	Gnd	Connected to computer ground
37	Gnd	Connected to computer ground

Table 32 PCI Card Outputs

Inputs

The inputs on the PCI card are connected via the 37pin male D connector attached to the main board via a ribbon cable and IDC connector. The inputs are connected to opto-isolators on the main board. The power line is common for the inputs and is pin 20. The inputs have 1K resistors in series which is ideal for 12V supply. The inputs must be connected to ground to make them active. This is usually achieved through an open collector output. The input pin configuration is as follows.

Pin	Name/Func	Description
1	+12V	12 Volt Supply from Computer
2	+12V	12 Volt Supply from Computer
3	+12V	12 Volt Supply from Computer
4	+5V	5 Volt Supply from Computer
5	W Home	Homing Sensor input for W axis
6	Y Home	Homing Sensor input for Y axis
7	BottomDelay	If configured the software waits for this input before starting a shape
8	Z Low HC	Used during height control to indicate that the head is to low
9	Not Used	
10	Not Used	
11	Not Used	
12	Not Used	
13	Not Used	
14	Not Used	
15	Not Used	
16	Not Used	
17	Gnd	Connected to computer Gnd
18	Gnd	Connected to computer Gnd
19	Gnd	Connected to computer Gnd
20	Input Power A	Power Supply input needed for input pins 5-8 and 23-26
21	Input Power B	Power Supply input needed for input pins 9-12 and 27-30
22	Input Power C	Power Supply input needed for input pins 13-16 and 31-24
23	Z Home	Homing Sensor input for Z axis
24	X Home	Homing Sensor input for X axis
25	Z High HC	Used during height control to indicate that the head is to high
26	Stop	If active machine pauses and turns all outputs off.
27	Not Used	
28	Not Used	
29	Not Used	
30	Not Used	
31	Not Used	
32	Not Used	
33	Not Used	
34	Not Used	
35	Gnd	Connected to computer Gnd
36	Gnd	Connected to computer Gnd
37	Gnd	Connected to computer Gnd

Table 33 PCI Card Inputs

I/O Card

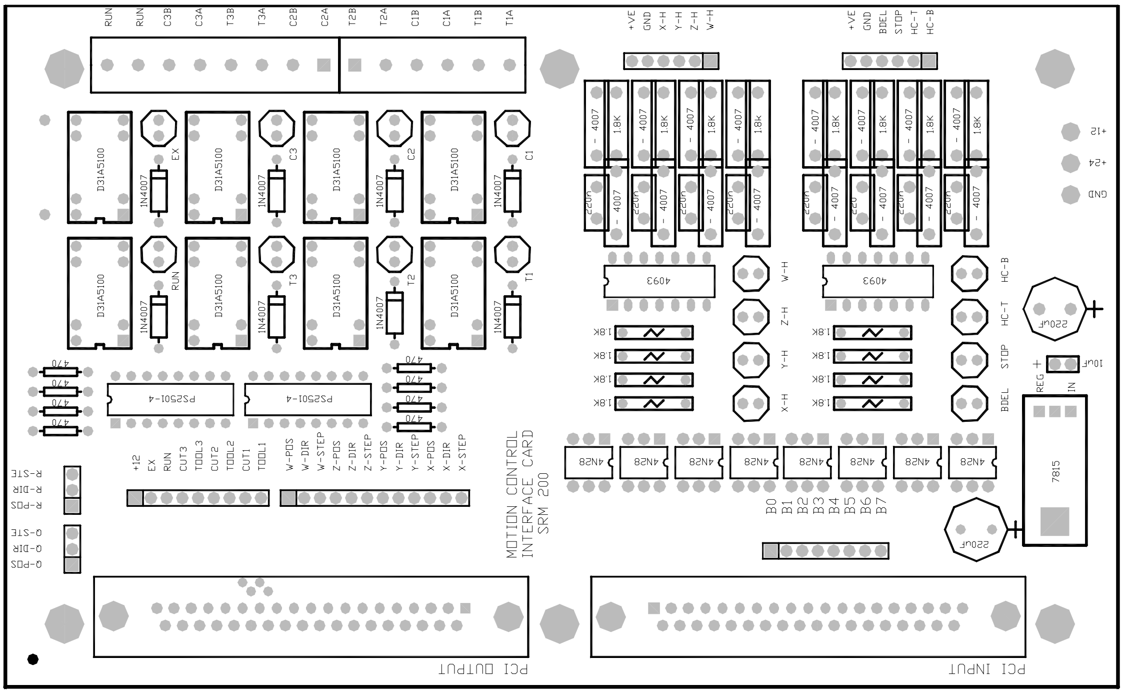

Figure 18 I/O Card Layout Diagram

The I/O card shown above connects directly to the PCI card using the cables provided. The cables are straight through pin1-1, 2-2, etc. The output D connector on the PCI card connects into the 90° D connector on the I/O card labelled PCI OUTPUT on the diagram above. Likewise the input on the PCI card connects directly into the PCI INPUT.

Outputs

The I/O card provides easy interfacing to the PCI card and also provides relay outputs for the external device control lines. The SIL friction headers are labelled on the diagram and have the following functions.

X-STEP	Outputs pulses for stepping in the X axis, connects directly to PCI card pin 23
X-DIR	Outputs direction for X axis, connects directly to PCI card pin 5
X-POS	Power supply for the X axis control lines, connects directly to PCI card pin 1
Y-STEP	Outputs pulses for stepping in the Y axis, connects directly to PCI card pin 24
Y-DIR	Outputs direction for Y axis, connects directly to PCI card pin 6
Y-POS	Power supply for the Y axis control lines, connects directly to PCI card pin 2
Z-STEP	Outputs pulses for stepping in the Z axis, connects directly to PCI card pin 25
Z-DIR	Outputs direction for Z axis, connects directly to PCI card pin 7
Z-POS	Power supply for the Z axis control lines, connects directly to PCI card pin 3
W-STEP	Outputs pulses for stepping in the W axis, connects directly to PCI card pin 26
W-DIR	Outputs direction for W axis, connects directly to PCI card pin 8
W-POS	Power supply for the W axis control lines, connects directly to PCI card pin 21
TOOL1	Output is active during shape on tool 1 including Z movement, PCI pin 27 Relay output terminals N/O labelled T1A and T1B
CUT1	Active for shapes on tool 1, PCI pin 9 Relay output terminals N/O labelled T1A and T1B
TOOL2	Output is active during shape on tool 2 including Z movement, PCI pin 28 Relay output terminals N/O labelled T2A and T2B
CUT2	Active for shapes on tool 2, PCI pin 10 Relay output terminals N/O labelled C2A and C2B
TOOL3	Output is active during shape on tool 3 including Z movement, PCI pin 29 Relay output terminals N/O labelled T3A and T3B
CUT3	Active for shapes on tool 3, PCI pin 11 Relay output terminals N/O labelled C3A and C3B
RUN or ROUTER	Older revision boards are labelled run but now function as Router/Shutter control, output is active while job not paused and includes a Router start delay Relay output terminals N/O labelled RUN and RUN or RTR and RTR
EX or RUN	This output now has the Run function and is active during the entire job even if the job is paused. There are two solder points at the top of the board for the relay output.
+12	Power supply for the control lines
R-STE	Not Used
R-DIR	Not Used
R-POS	Not Used
Q-STE	Not Used
Q-DIR	Not Used
Q-POS	Not Used

Table 34 I/O Card Outputs

Manufacturing Applications

The X,Y,Z and W outputs are configured in a standard way for connecting to a microstepping drive. Most microstepping drives on the market today have opto-isolated inputs and use the same configuration as the microsteppers included with the system. The Positive, Step and Direction signals connect directly into the associated inputs on the drives.

The control signals with N/O relay contacts are used to control various tools on the machine. For example, if you build a routing table the standard configuration would be to connect your spindle inverter On/Off control to the Router/Shutter output. Then if you wanted mist or fluid you would connect this to, say, tool1 output and then set all jobs using fluid to tool1 in the software group options. If on the other hand you were building a laser cutter, then you would connect to the shutter control to the Router/Shutter output. Then you would connect the laser On/Off control to cut1. The associated timing diagrams are shown above in Appendix A (Timing).

The LED's on the I/O Card board light up when the associated output is on to help with diagnostics.

Inputs

The inputs on the I/O card are connected to the 15pin D connectors on the LH side of the box. There are 8 inputs on the board. All inputs are positive switching and designed for pnp transistor connection. The proximity sensors provided are pnp and connect directly to the power and sensor input lines. If you have a switch input then you connect a N/O switch between the input and +VE. The ground (GND) and positive (+VE) lines provide a regulated +15V for use on sensors or switches. The inputs are smoothed and have suppression diodes. The LED's are labelled to correspond to the inputs and turn on when the input is active. The inputs are opto isolated and connect to the corresponding pin on the PCI card via the 37pin D connector. The inputs are as follows.

X-Home	Homing Sensor input for X-axis, used to home machine and set absolute origins.
Y-Home	Homing Sensor input for Y-axis, used to home machine and set absolute origins.
Z-Home	Homing Sensor input for Z-axis, used to home machine and set absolute origins.
W-Home	Homing Sensor input for W-axis, used to home machine and set absolute origins.
BDEL	Bottom Delay Inout: If the software is configured to wait for input, at the start of a shape the corresponding cut bit goes active then the software waits for this input to become active before driving off. It only needs to be pulsed active. See timing diagrams
STOP	Stop Input: If this input goes high the machine pauses.
HC-T	Height Control Top (Zhigh): Used during height control to indicate that machine is too high. When this input active the machine drives the Z-axis downward until this sensor is de-activated.
HC-B	Height Control Bottom (Zlow): Used during height control to indicate that machine is too low. When this input active the machine drives the Z-axis upward until this sensor is de-activated.

Figure 19 I/O Card Inputs

Output and Input Pin Configuration

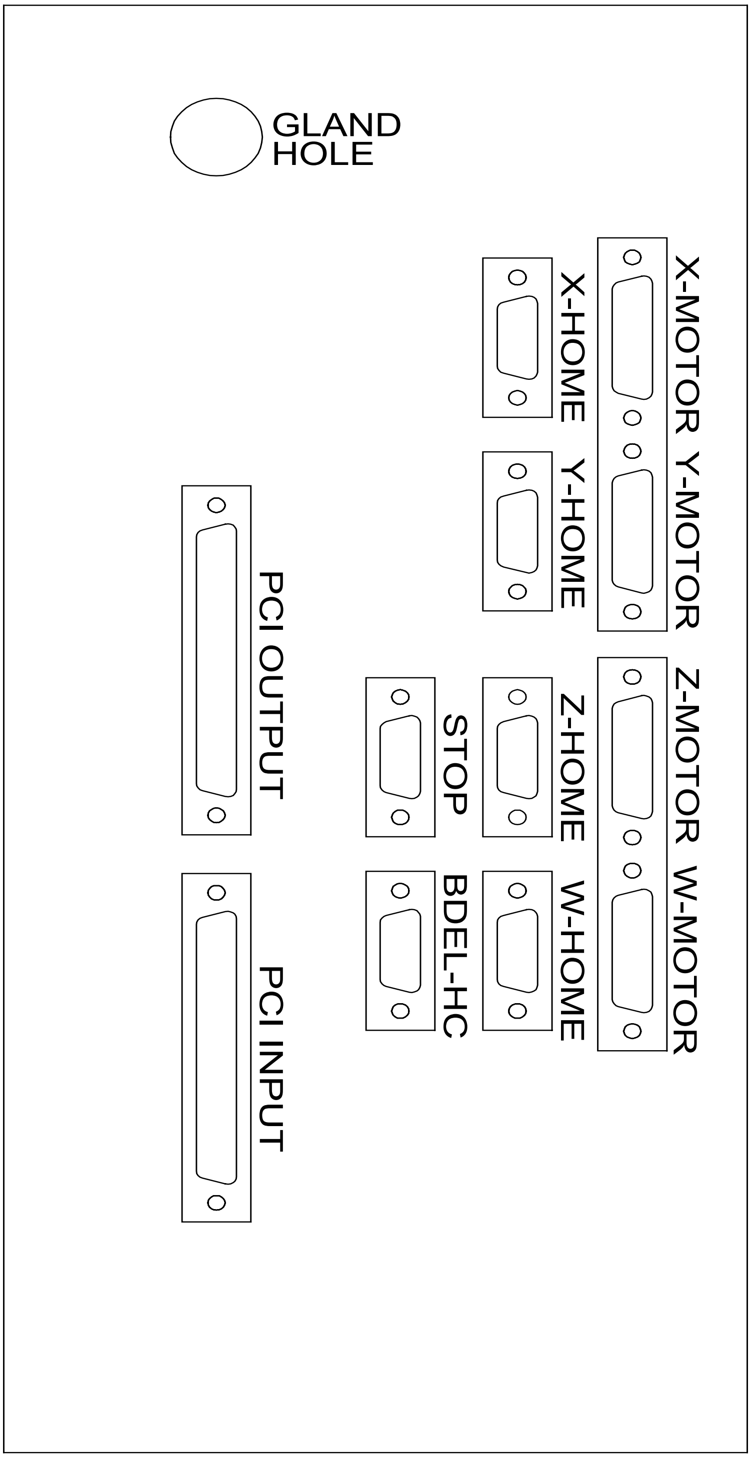

Figure 20 System Box Connections

X-MOTOR: 15 pin female D connector

Pins	Description
1,2,9	X Phase A
3,4,11	X Phase A Bar
5,6,13	X Phase B
7,8,15	X Phase B Bar

Y-MOTOR: 15 pin female D connector

Pins	Description
1,2,9	Y Phase A
3,4,11	Y Phase A Bar
5,6,13	Y Phase B
7,8,15	Y Phase B Bar

Z-MOTOR: 15 pin female D connector

Pins	Description
1,2,9	Z Phase A
3,4,11	Z Phase A Bar
5,6,13	Z Phase B
7,8,15	Z Phase B Bar

W-MOTOR: 15 pin female D connector

Pins	Description
1,2,9	W Phase A
3,4,11	W Phase A Bar
5,6,13	W Phase B
7,8,15	W Phase B Bar

X-HOME: 9 pin female D connector

Pins	Description
1	+15 Volts
2	X-Home
5	Gnd

Y-HOME: 9 pin female D connector

Pins	Description
1	+15 Volts
2	Y-Home
5	Gnd

Z-HOME: 9 pin female D connector

Pins	Description
1	+15 Volts
2	Z-Home
5	Gnd

W-HOME: 9 pin female D connector

Pins	Description
1	+15 Volts
2	X-Home
5	Gnd

STOP: 9 pin female D connector

Pins	Description
1	+15 Volts
2	Stop
5	Gnd

BDEL-HC: 9 pin female D connector

Pins	Description
1	+15 Volts
2	Height Control Top (Zhigh)
3	Height Control Bottom (Zlow)
4	Bottom Delay
5	Gnd

PCI OUTPUT: 37 pin female D connector
For Pin definitions see PCI Card in technical appendices.

PCI INPUT: 37 pin female D connector
For Pin definitions see PCI Card in technical appendices.

Glossary

Basic block of data	The basic block of data is the drawing data before any arraying is applied.
Bulge factor	A real number which defines an arc between two points. Four times the arctangent of the bulge factor is the included angle of the arc. If it is positive then it defines an anti-clockwise arc, if it is zero it defines a straight line joining the two points and if it is negative then it defines a clockwise arc. A bulge factor of 1.0 defines a semicircle.
CNC	Computer Numerical Control is the traditional and commonly used method of describing how to machine shapes. A standard describes the meaning of the common G codes. **Profiler** can read the usual G codes defining paths.
DXF	Drawing eXchange Format: drawings described in AutoCAD's file format. There are several versions of this format. **Profiler** currently reads Release 12 DXF files.
RSG	A **Profiler** graphics file containing all drawing information (for example, from a DXF file) together with information for controlling the cutting of shapes and for generating the machine tool path.
RSM	A **Profiler** machining file containing all drawing and tool path information. An RSM file is generally created automatically from an RSG file and would normally have the same filename as the RSG file. An exception to this is when digitizing shapes directly with the machine.
Polyline	A sequence of joined line segments. If the polyline is closed then the last point is the same as the start point.
Polyline with arcs (or polyarc)	A sequence of joined line segments or arcs. If the polyarc is closed then the last point is the same as the start point.
Simple polygon	A closed polyline which does not intersect itself.
Hand Console	A hand-held control device with a small LCD display and 12 buttons. It is connected to the PC by a serial connection and is used to control the cutting machine.
PCI Card	Peripheral Control Interface card for input/output buffering.

This document was last updated on 24 April 2003.