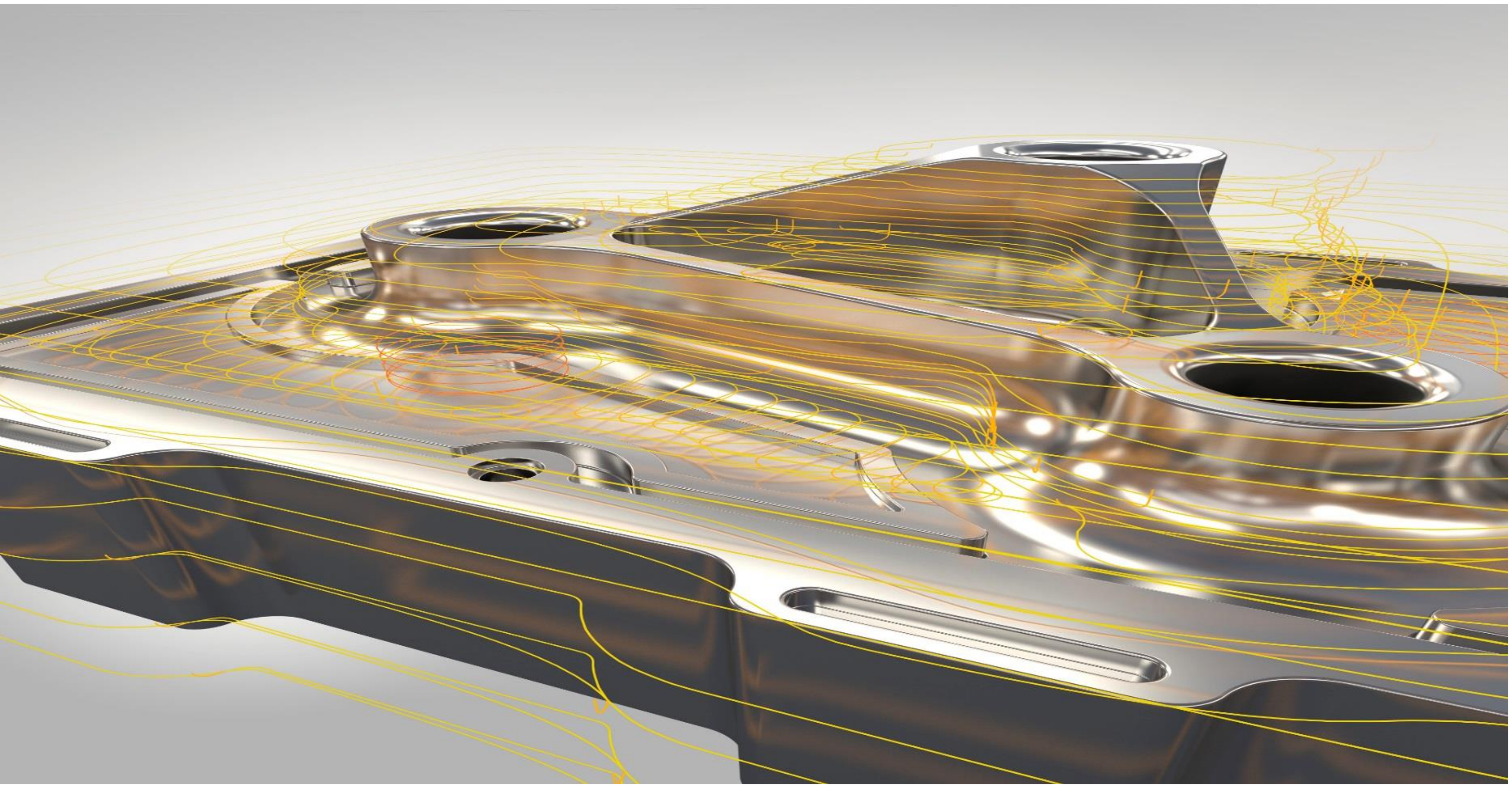

Post Processor Training Guide

For use with Fusion CAM, Inventor CAM, HSMWorks

CAM Post Processor Guide 4/2/25

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1 Introduction to Post Processors

1.1 Scope

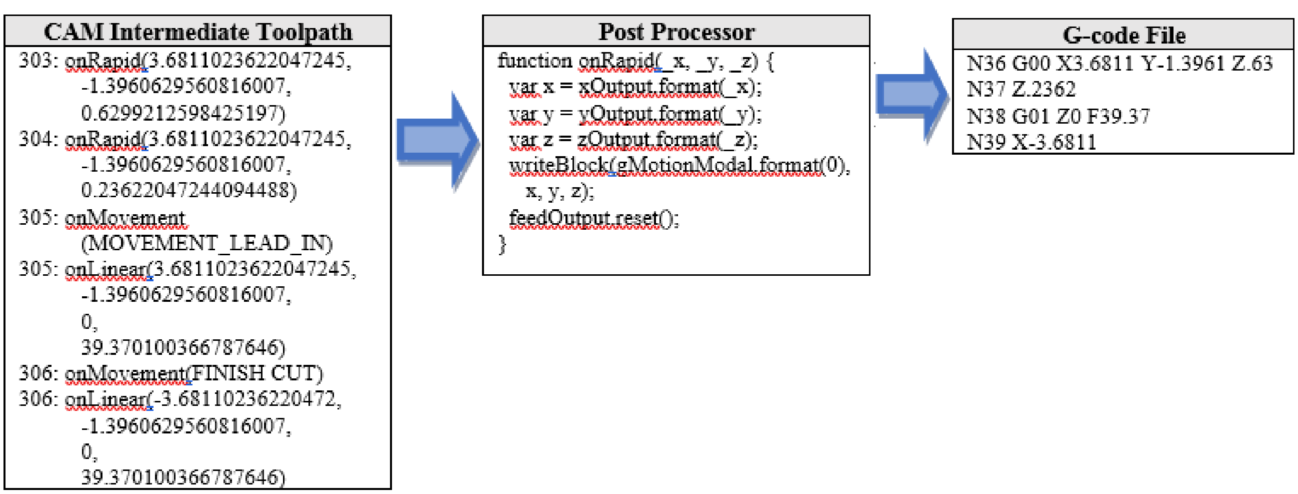
This manual is intended for those who wish to make their own edits to existing post processors. The scope of the manual covers everything you will need to get started; an introduction to the recommended editor (Autodesk Fusion Post Processor Editor), a JavaScript overview (the language of Autodesk post processors), in-depth coverage of the callback functions (onOpen, onSection, onLinear, etc.), and a lot more information useful for working with the Autodesk post processor system.

Most code samples provided in this manual can be found in a post processor located in the online Post Library depending on the capabilities of the post processor (milling, turning, additive, etc.). Most milling post processors will contain similar code, with the RS-247D Sample Multi-axis Post Processor supporting the latest post engine enhancements. Specialized functionality, such as subprograms and probing, can be found in controller specific post processors, such as Fanuc, Heidenhain, Siemens SINUMERIK 840D, etc.

It is expected that you have some programming experience and are knowledgeable in the requirements of the machine tool that you will be creating a post processor for.

1.2 What is a Post Processor?

A post processor, sometimes simply referred to as a "post", is the link between the CAM system and your CNC machine. A CAM system will typically output a neutral intermediate file that contains information about each toolpath operation like tool data, type of operation (drilling, milling, turning, etc.), and tool center line data. This intermediate file is fed into the post processor where it's translated into the language that a CNC machine understands. In most cases this language is a form of ISO/EIA standard G-code, even though some controls have their own proprietary language or use a more conversational language. All examples in this manual uses the ISO/EIA G-code format.

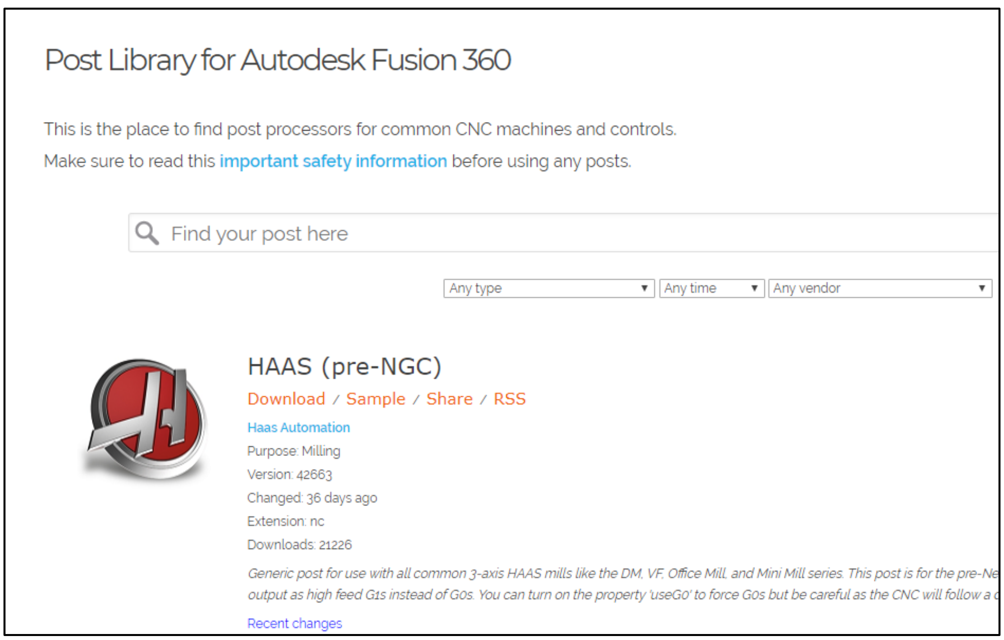


If you would like a bit more information on the G-code format the [Fundamentals of CNC Machining](#) guide contains a lot of useful information including a further explanation of the G-code format in Chapter 5 CNC Programming Language.

Though most controls recognize the G-code format the machine configuration can be different and some codes could be supported on one machine and not another, or the codes could be interpreted differently, for example one machine may support circular interpolation while another requires linear moves to cut the circle, which is why you will probably need a separate post processor for each of your machine tools.

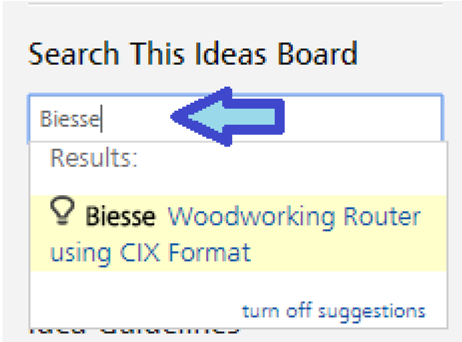
1.3 Finding a Post Processor

The first step in creating a post processor is to find an existing post that comes close to matching your requirements and start with that post processor as a seed. You will never create a post processor from scratch. You will find all the generic posts created by Autodesk on our online [Post Library](#). From here you can search for the machine you are looking for by the machine type, the manufacturer of the machine or control, or by post processor name.

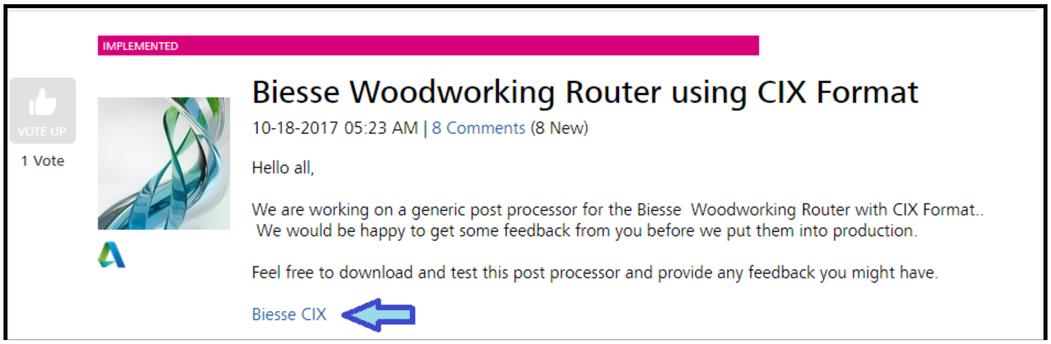


Other places to check for a post processor include the [HSM Post Processor Forum](#) or [HSM Post Processor Ideas](#).

It is possible that Autodesk has already created a post processor for your machine, but has not officially released it yet. These posts are considered to be in Beta mode and are awaiting testing from the community before placing into production. You can visit the [HSM Post Processor Ideas](#) site and search for your post here. This site contains post processor requests from users and links to the posts that are in Beta mode. You can search for your machine and/or controller to see if there is a post processor available.



Searching For a Post Processor on Ideas or the Forum



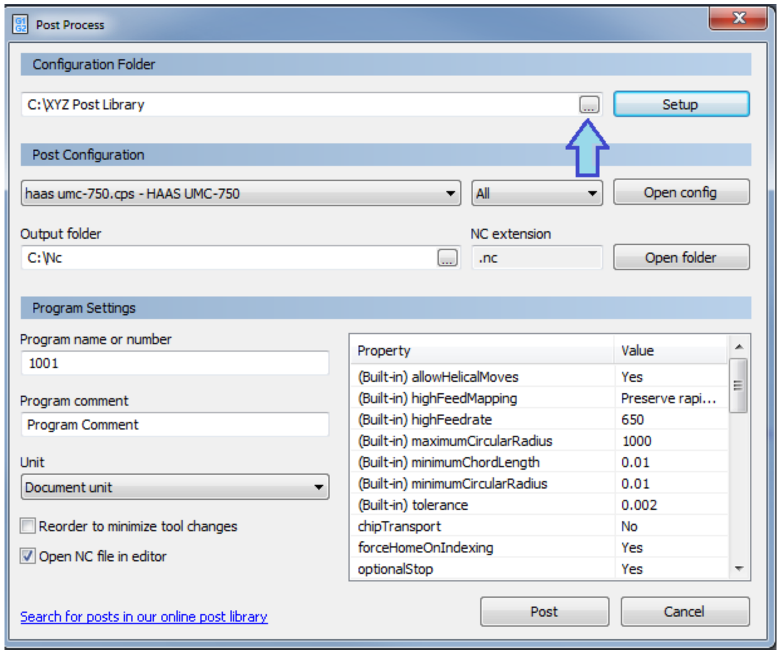
Beta Post Processor Found on HSM Post Processor Ideas

If your post processor is not found, then you should search the HSM Post Processor Forum using the same method you used on the HSM Post Processor Ideas site. The Post Processor Forum is used by the HSM community to ask questions and help each other out. It is possible that another user has created a post to run your machine.

You should always take care when running output from a post processor for the first time on your machine, no matter where the post processor comes from. Even though the post processor refers to your exact name, it may be setup for options that your machine does not have or the output may not be in the exact format that you are used to running on the machine.

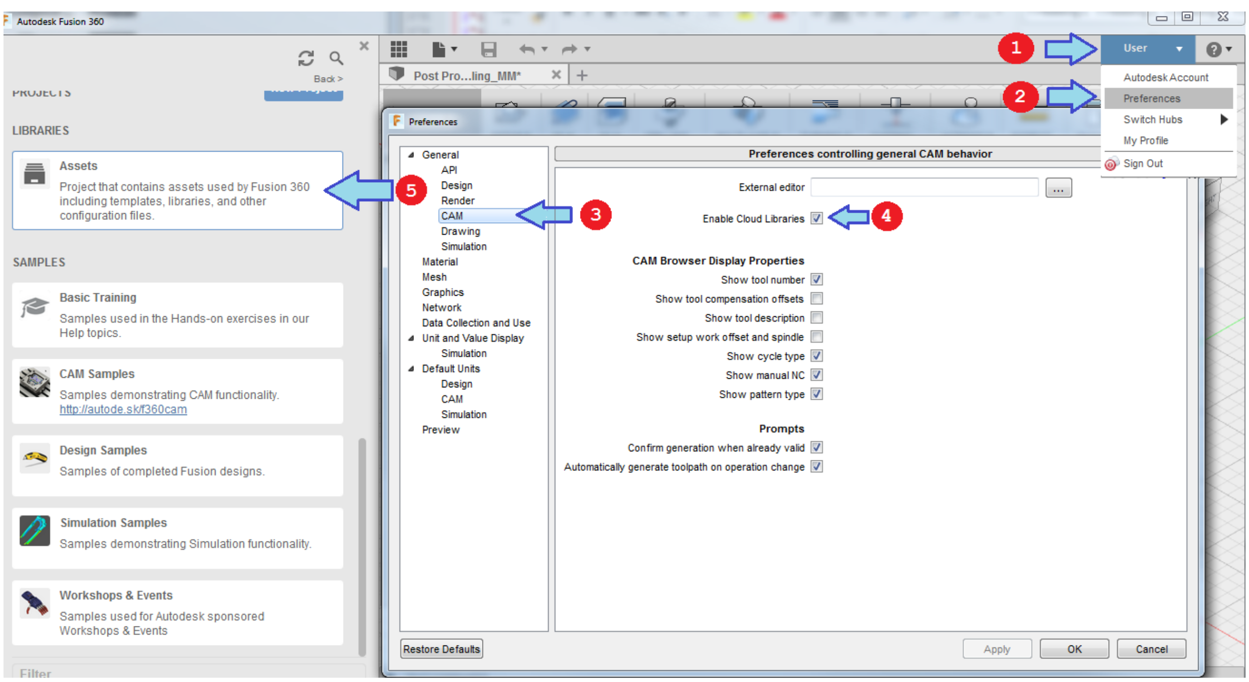
1.4 Downloading and Installing a Post Processor

Once you find the post processor that closely matches your machine you will need to download it and install it in a common folder on your computer. If you are working on a network with others then this should be in a networked folder so everyone in your company has access to the same library of post processors.

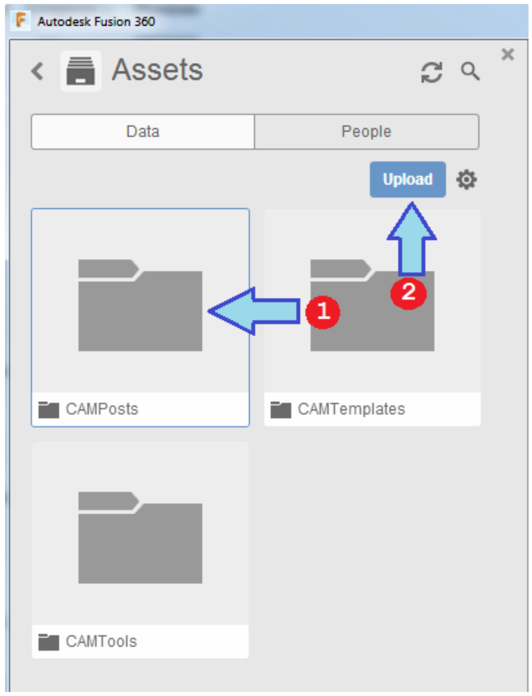


Selecting the Local Post Processor Folder

When using Fusion it is recommended that you enable cloud posts and place it in your Asset Library. This way post processors, tool libraries, and templates will be synched across devices and users at a company.

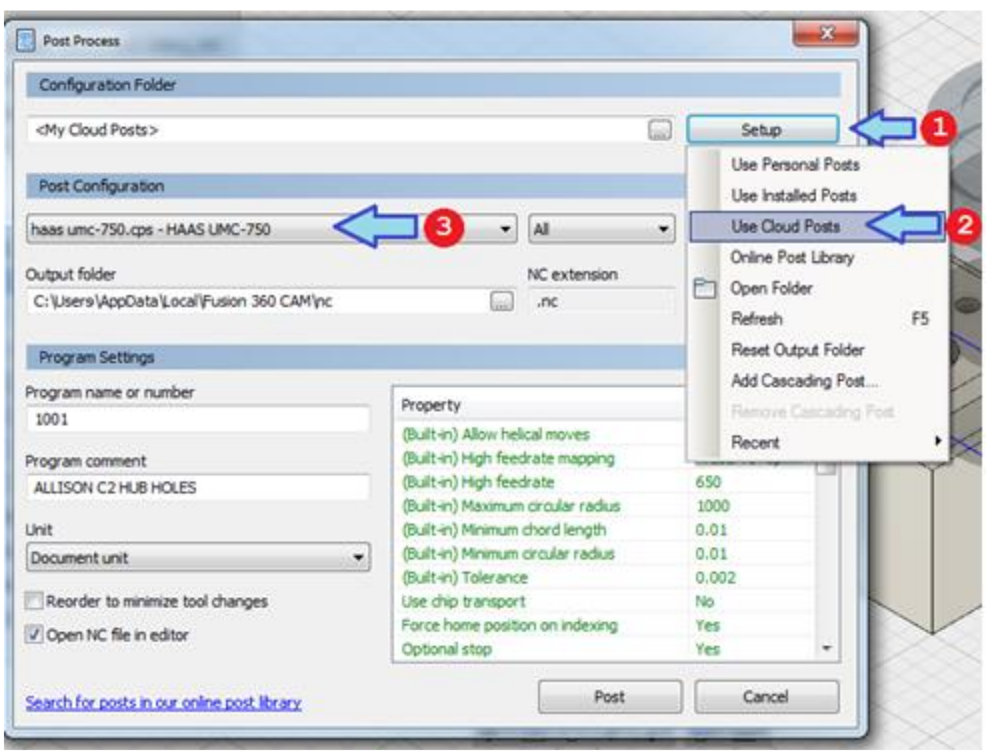


Enabling Cloud Post Processors in Fusion



Double Click the CAMPosts Folder and then Press the Upload Button

Once you have uploaded your post(s) to the Cloud Library you can access these from Fusion. You do this by pressing the Setup button in the Post Process dialog and selecting your post from the dropdown menu.

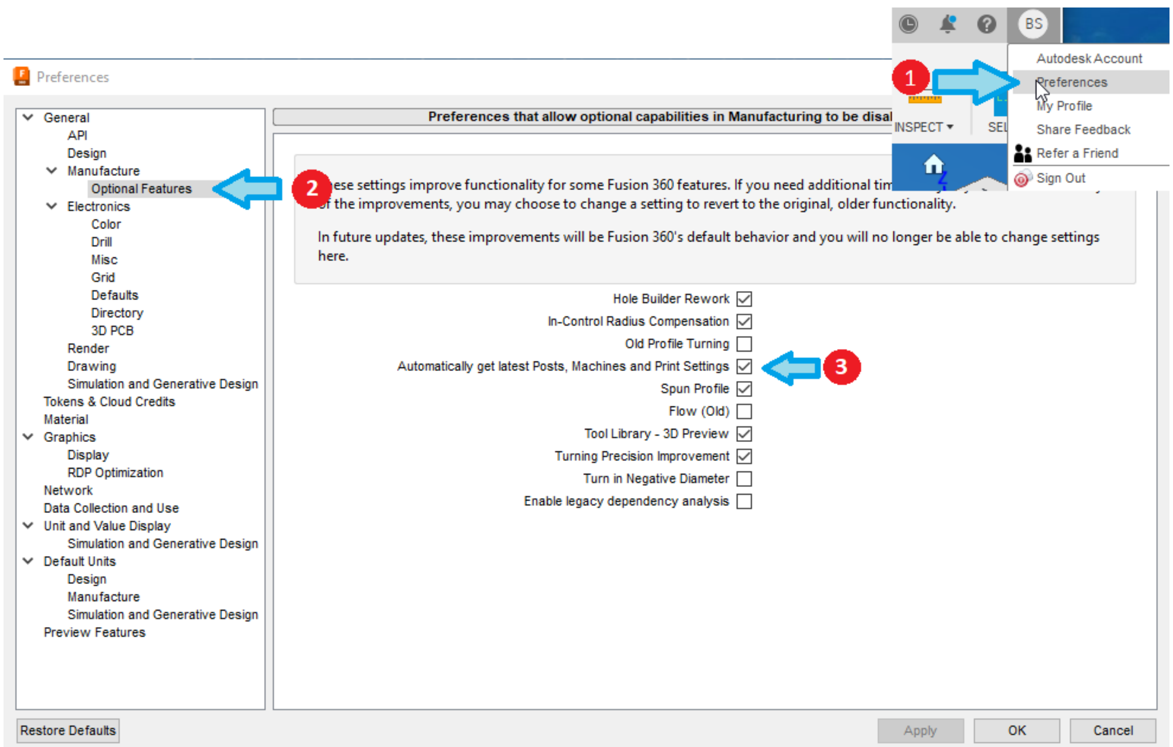


Selecting Your Post from the Cloud Library

In all cases you will want to avoid placing posts in the production install folder as these can be overwritten when HSM is updated. Downloading your posts to a separate folder means that you can reduce your list of post processors that show up in the Post Process dialog to those that you use in your shop.

1.4.1 Automatically Updating Your Post Processors

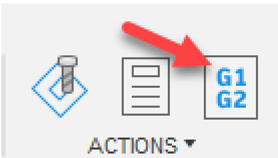
It is possible to have Fusion automatically search for the latest versions and additions of post processors and machines when they become available. This is accomplished by enabling *Automatically get latest Posts, Machines and Print Settings* in the Manufacture/Optional Features section of the User Preferences.



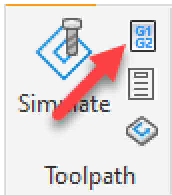
Automatic Update of Post Processors

1.5 Running the Post Processor

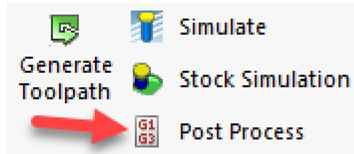
The post processor can be run from the Post Process dialog or from an NC Program in Fusion. You can either select the Post Process button or right click on an Operation/NC program and select Post Process from the menu. Multiple operations can be selected and post processed in a single operation.



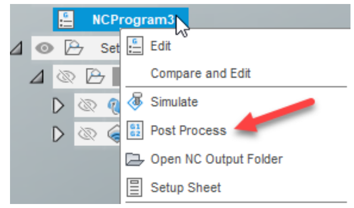
Fusion



Inventor



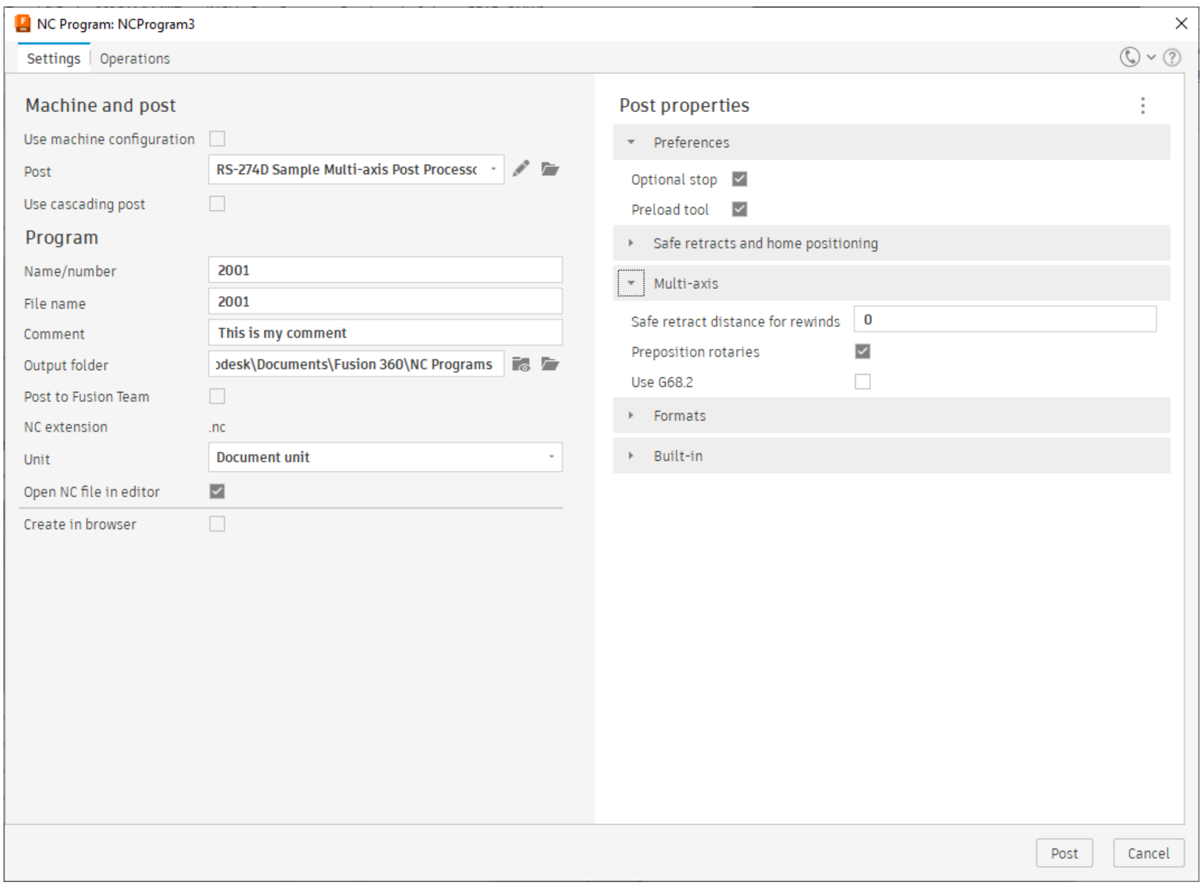
HSMWorks



Right Click

1.5.1 Post Process Dialog

Fusion uses the NC Programs dialog as its interface to the post processor, while Inventor CAM and HSMWorks use the legacy Post Process dialog. The display of the Post properties in the NC Programs dialog is more advanced, as it respects the group names from the property table and displays them in collapsible tabs.



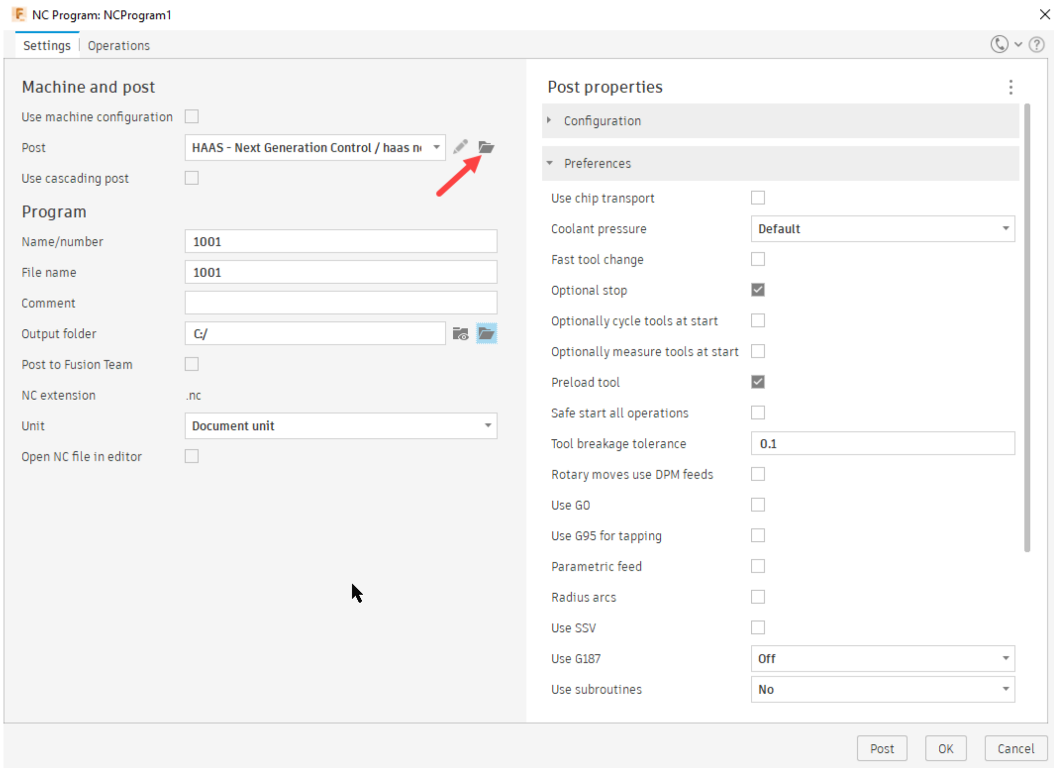
Fusion Post Process Dialog

Field	Description
Use machine configuration	Check this box to assign a Machine Definition to the post processor. Typically, you would assign a Machine Definition to the Manufacturing Setup in Fusion. If a machine is assigned to the Manufacturing Setup, then this box will be checked and the Machine Definition will be displayed below this field.

Field	Description
Post	Specifies the post processor you want to run. The dropdown arrow in this field will display a list of recently used post processors. Pressing the button will open a popup dialog that includes a list of linked folders and available posts that you can select from. The button allows you to edit the post processor.
Use cascading post	Used to select a cascading post. A cascading post is usually a 3rd party post processor or verification program that is run after the Fusion post processor.
Name or number	The name/number of the program. This name/number will usually be output as the first line of the NC file, usually as an Oxxxx code when a number is required or as a comment (xxxx) if a name is allowed. The post processor controls whether an alphanumeric name is allowed in this field or if a number must be entered. This is defined by the *programNameIsInteger = true;* statement in the post processor and can be set to either *true* (number required) or *false* (alphanumeric name allowed).
File name	The output NC file name. This will default to the program name/number.
Comment	The program comment, which is usually output as a comment at the top of the NC file.
Output folder	Specifies the folder for the output NC file. Pressing the button will open this folder in a File Explorer window. Pressing the button opens a folder browser window to select the folder for the NC file.
Post to Fusion Team	Saves the output file to the cloud. The *Fusion Team output folder* field will be displayed if this box is checked, allowing you to select the cloud folder to post to.
NC extension	Contains the default file extension for the output NC file as defined in the post processor. You cannot override the file extension.
Unit	Controls the output units of the NC file. This is usually set to use the same units as the model, but can be overridden to output in either Inch or Millimeters.
Open NC file in editor	Check this box if you want to open the output NC file in an editor after post processing is finished. The editor used is defined in your Fusion *Preferences* dialog in the *General->Manufacture-> External editor* field.
Create in browser	Check this box if you want an NC Program automatically created with the operations you are posting against. Be forewarned, if this box remains checked each time you post process outside of an NC Program, then you will continue to get new NC Programs added to the list.
Property Table	Displays the properties defined in the post processor and allows you to modify these properties. Please see the *Property Table*

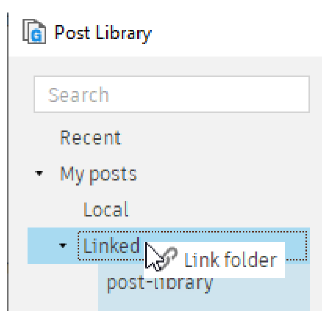
Field	Description
	section in this manual for a full description of post processor properties.

Fusion Post Process Dialog Fields

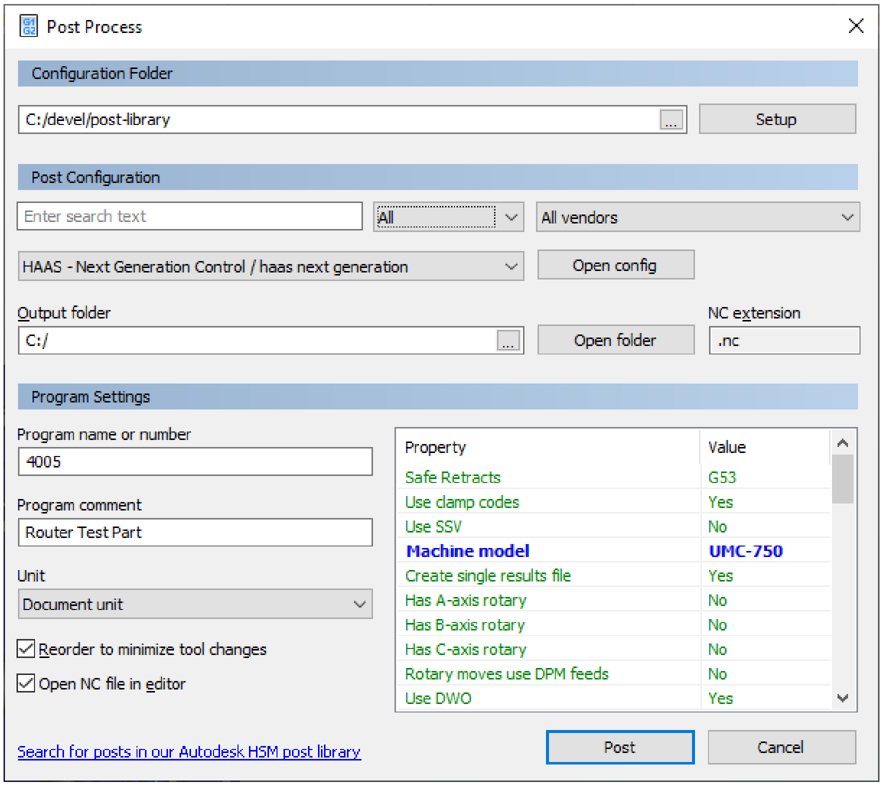


Selecting a Post Processor in Fusion

You select the folder for the post processor and the post processor itself by pressing the  button next to the *Post* field. You can right click on the *Linked* menu in the Post Library dialog to add a new folder to select post processors from. The new folder will be displayed in the Linked menu.



Selecting a New Folder for Post Processors



Inventor CAM and HSMWorks Legacy Post Process Dialog

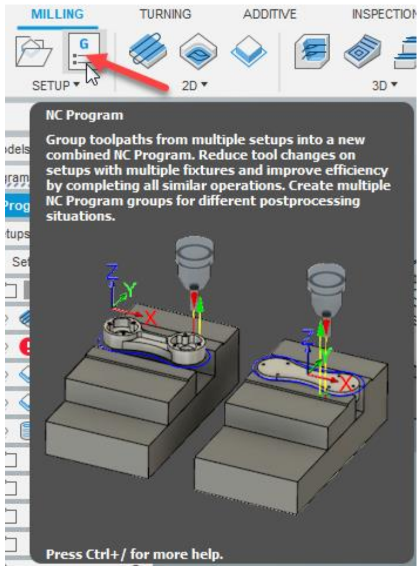
Field	Description
Configuration Folder	Specifies the folder location of the post processor you want to run. You can press the ... button to open a folder browser window to select the post processor. This field is only displayed in the legacy dialog, but you can select the folder in the NC Programs dialog by pressing the button next to the *Post* field.
Setup	Used to select preinstalled post processor libraries or to select a cascading post. A cascading post is usually a 3rd party post processor or verification program that is run after the HSM post processor. This field is only displayed in the legacy dialog.
Post Configuration	Defines the post processor you want to run. The available posts are listed in a dropdown menu. There are filters that will limit the post processors listed, including a Search Text field, Capabilities (milling, turning, etc.), and Vendors.
Output folder	Specifies the folder for the output NC file. Pressing the ... button opens a folder browser window to select the folder for the NC file. The *Open folder* button opens a file browser in this folder.
NC extension	Contains the default file extension for the output NC file as defined in the post processor. You can override the file extension in this field.

Field	Description
Program name or number	The name/number of the output NC file. This name/number will usually be output as the first line of the NC file, usually as an Oxxxx code when a number is required or as a comment (xxxx) if a name is allowed. The post processor controls whether an alphanumeric name is allowed in this field or if a number must be entered. This is defined by the *programNameIsInteger = true;* statement in the post processor and can be set to either *true* (number required) or *false* (alphanumeric name allowed).
Program comment	This field is output as a comment at the top of the NC file.
Unit	Controls the output units of the NC file. This is usually set to use the same units as the model, but can be overridden to output in either Inch or Millimeters.
Reorder to minimize tool changes	Check this box if you are running with multiple setups and you want the operations with the same tool numbers to be placed together to minimize tool changes. Operations within the same setup will not be reordered.
Open NC file in editor	Check this box if you want to open the output NC file in an editor after post processing is finished. The editor used is defined in the *Preferences* dialog in the *General->Manufacture-> External editor* field.
Property Table	Displays the properties defined in the post processor and allows you to modify these properties. Please see the *Property Table* section in this manual for a full description of post processor properties.

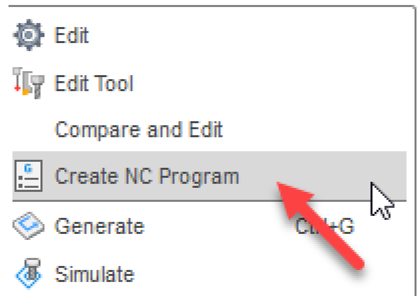
Inventor/HSMWorks Post Process Dialog Fields

1.5.2 NC Programs

NC Programs are supported in Fusion and allow you to group operations together and assign a post processor that is used for these operations. You create an NC Program by pressing the NC Program menu or right clicking on a (group of) operation(s) and selecting Create NC Program from the list. Pressing the Post Process button will bring up the NC Program dialog where you can create an NC Program from the selected operations when the Post or OK button are pressed. It is important to note that pressing the OK button will NOT post process the NC Program but will only save it.



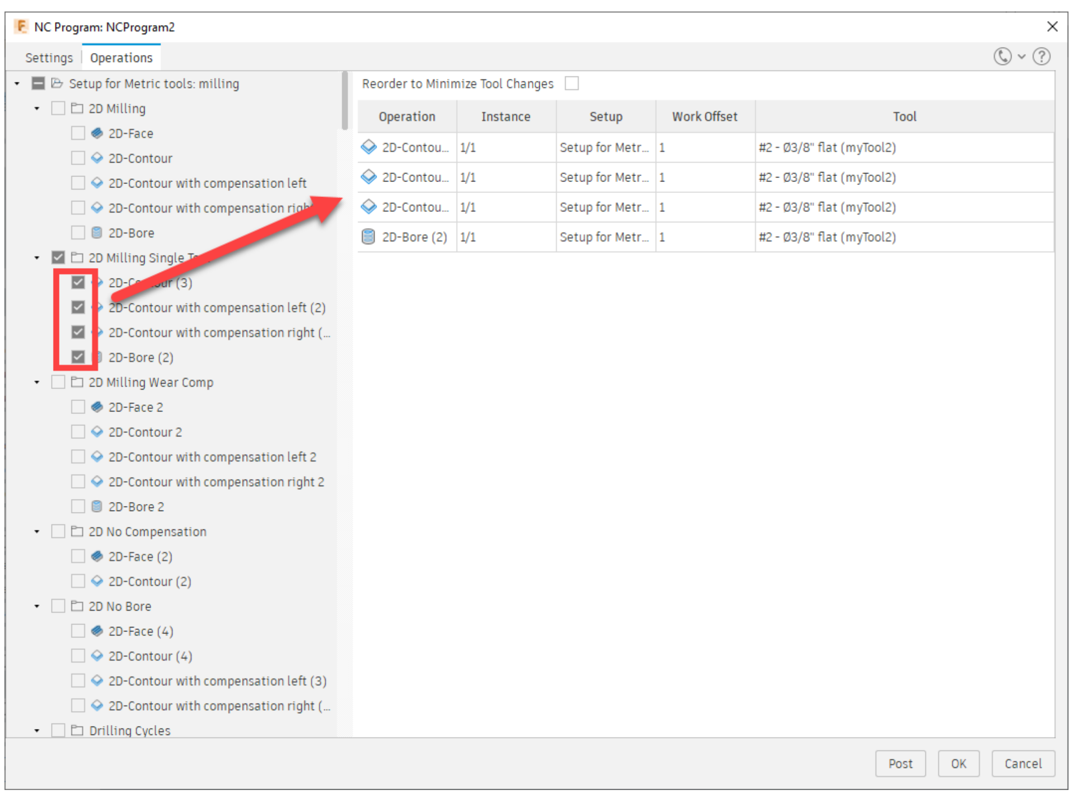
NC Program Button



Right Click to Create NC Program

The NC Program dialog contains two tabs, *Settings* and *Operations*. This is the same dialog that is displayed when Post Processing from the menus.

You will also notice that when you post process against an NC Program that the NC Program dialog is displayed. If you want to change any settings for post processing when using an NC Program, you must edit the NC Program to make changes.



Selecting Operations for an NC Program

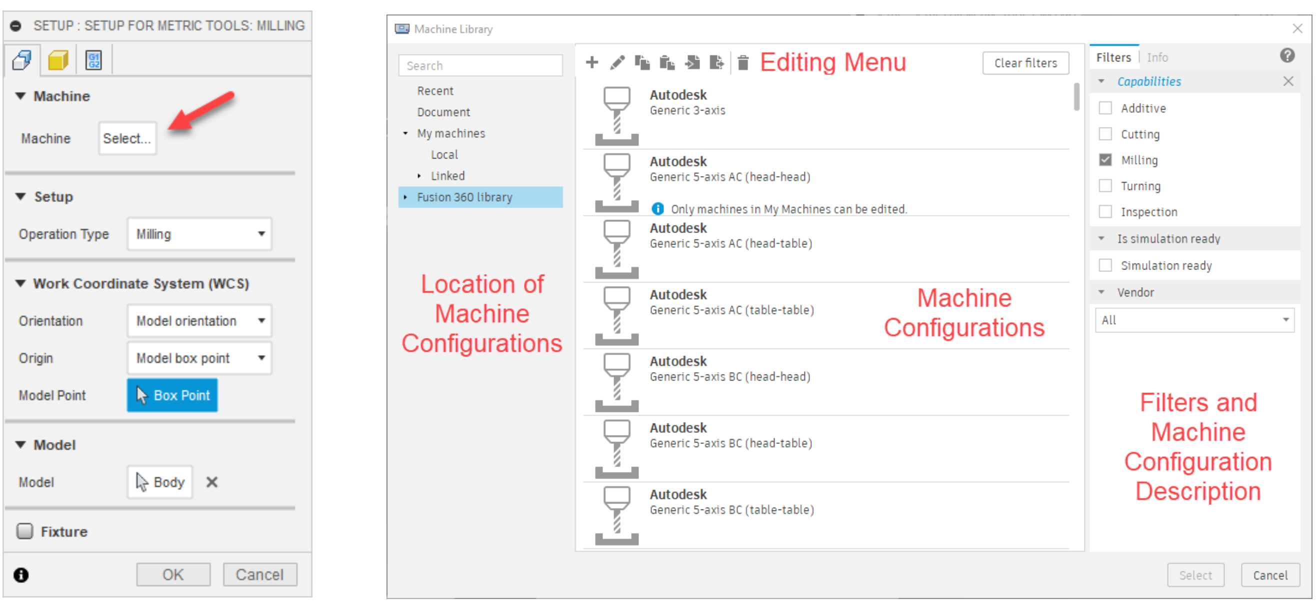
1.5.3 Machine Definitions

Machine Definitions can be used to define the kinematics and multi-axis capabilities of the machine for both the post processor and machine simulation. A Machine Definition is assigned to a Setup in the CAM system. The usage of a Machine Definition has distinct advantages.

1. Allows a single generic post processor to be used for multiple machines with different kinematics.
2. The post processor is assigned directly to the Machine Definition.
3. The NC output folder is defined in the Machine Definition.
4. Defines the unique multi-axis features for the machine.
5. Required for Machine Simulation.
6. Required for Operation Properties.

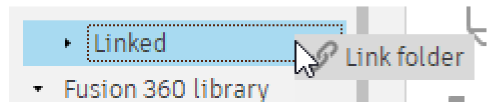
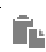
You can determine if a post processor supports a Machine Definition by checking for the *activateMachine* function inside of the post processor. If this function is not present, then the post processor will most likely not accept or fully support a Machine Definition. There are a number of post processors that support Machine Definitions, such as the Fanuc, Haas Next Generation, Heidenhain, Hurco, Siemens, and Tormach posts.

You assign a Machine Definition to a CAM Setup when creating or editing the Setup and pressing the *Select…* button. This will bring up the Machine Library dialog that allows you to select a machine from the available configurations.



Selecting a Machine Definition

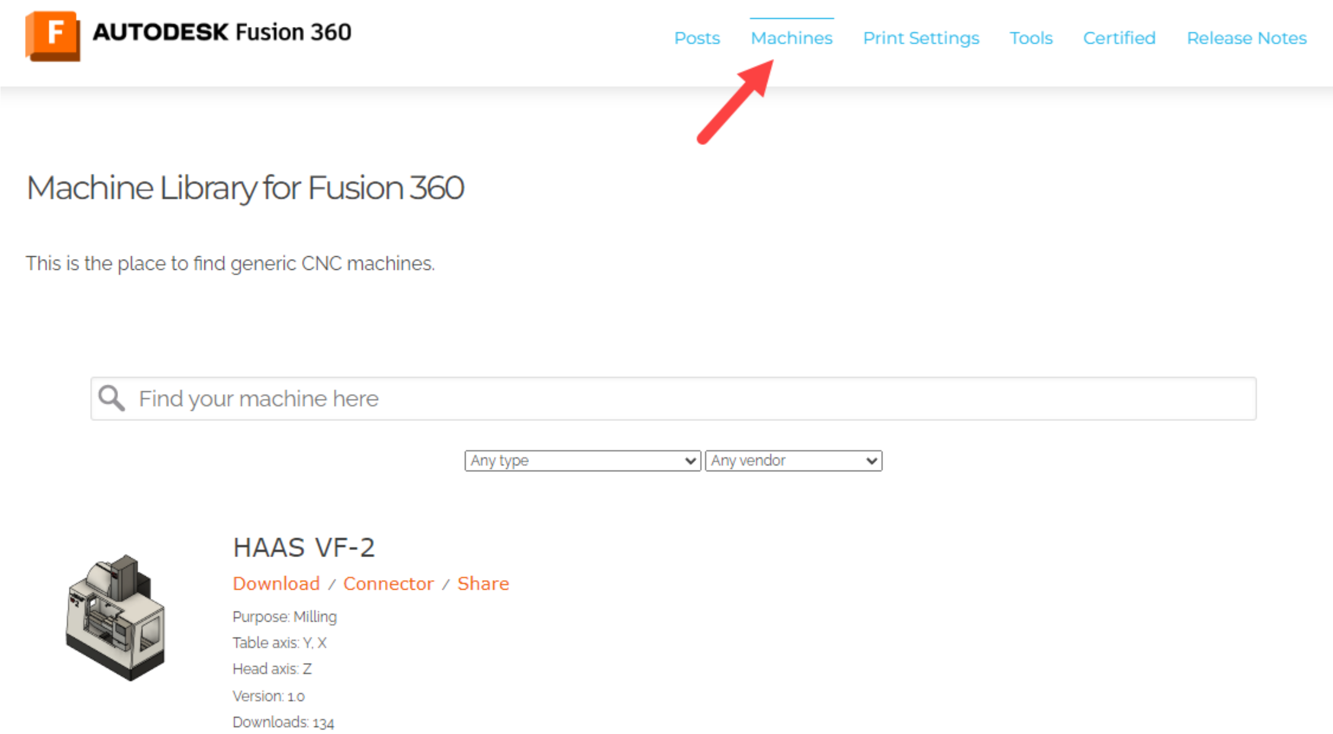
The Machine Library dialog consists of the following areas.

Area	Item	Description
Location of Machine Definitions		Specifies the area you want to select a Machine Definition from.
	Recent	Displays recently selected Machine Definitions.
	Document	Displays Machine Definitions used in the active model.
	My machines	Displays Machine Definitions stored locally on your computer or in selected (linked) folders. You can add folders to the linked area by right clicking on the Linked menu and selecting *Link folder*. 
	Fusion Library	Displays all Machine Definitions included with Fusion.
Machine Definitions		Lists the Machine Definitions stored in the selected location.
Filters and Machine Definition Description		The *Filter* tab allows you to filter the Machine Definitions based on Capabilities, Machine Simulation Ready, and Vendor. The *Info* tab displays information about the selected Machine Definition.
Editing Menu		Contains buttons for creating, editing, copying, and deleting Machine Definitions. Right clicking on a Machine Definition will also display this menu.
		Creates a new Machine Definition.
		Edits an existing Machine Definition. The Machine Definition must reside in one of the *My machines* folders.
		Copies the selected Machine Definition.
		Pastes the selected Machine Definition into the selected folder.
		Imports an external Machine Definition file.
		Exports the selected Machine Definition to an external file.
		Deletes the selected Machine Definition.

Machine Library Dialog

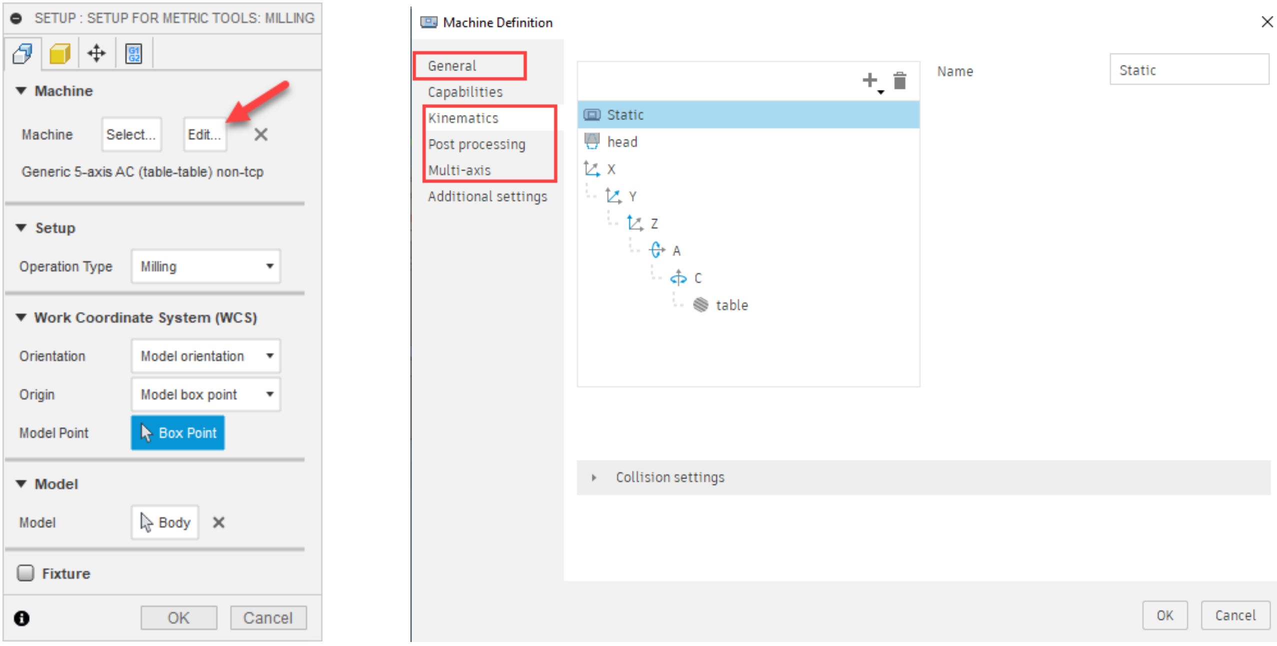
Once you find the Machine Definition you want to use you can copy it into your Local folder or a Linked Folder. You can do this by dragging the definition onto the desired *My machines* folder or by copying and pasting it into the desired folder. You can only edit Machine Definitions stored in one of the *My machines* folders.

The latest versions of Machine Definitions are available on our online Post Library. From here you can search for the machine by the machine type, the manufacturer of the machine, or by machine name.



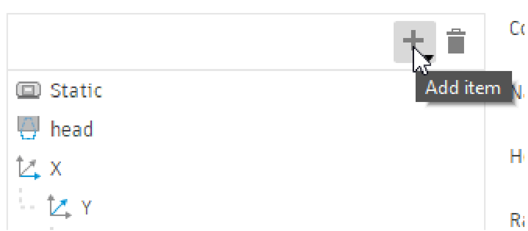
Online Machine Library

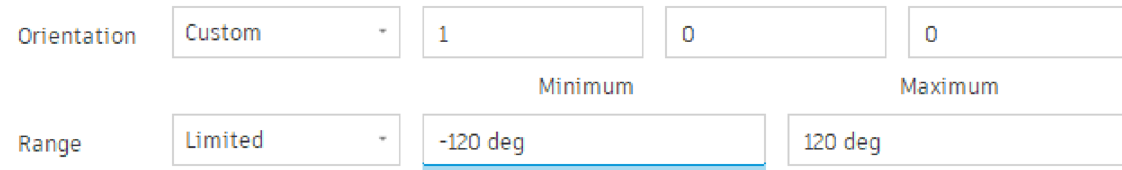
Once a Machine Definition is selected, you can edit it by pressing the *Edit...* button in the Setup dialog.

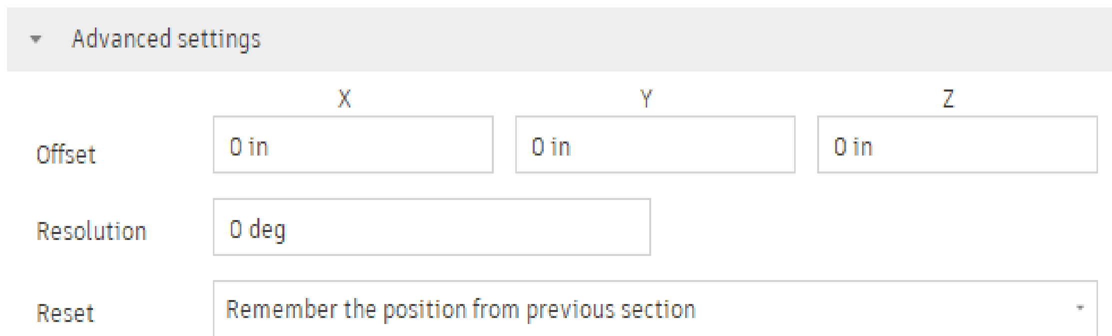


Editing/Creating a Machine Definition

The areas of the Machine Definition that are important for post processing are the General, Kinematics, Post Processing, and Multi-Axis settings. The information in the other areas can be accessed by the post processor, but not all are used by the library post processors as of this writing.

Area	Description
General	Describes the manufacture, machine model, and description of the configuration.
Kinematics	Defines the machine kinematics of the moving axes. You can define up to 3 linear axes, 2 rotary axes, a single spindle, and a table. You can add and axis by pressing the icon. When you add an axis, it will be added after the highlighted component. An axis can be deleted by highlighting it and pressing the icon.  The definition of the selected axis is displayed in the right pane of the dialog, including the name, home position, feedrates, preference, and TCP setting. The rotation vector (orientation) and range of the axis is defined below the kinematics diagram.

<table>
<tr><th>Area</th><th>Description</th></tr>
<tr><td></td><td>

The rotary axis pivot location (Offset) and initial location at the start of an operation (Reset) are located under the Advanced settings tab.


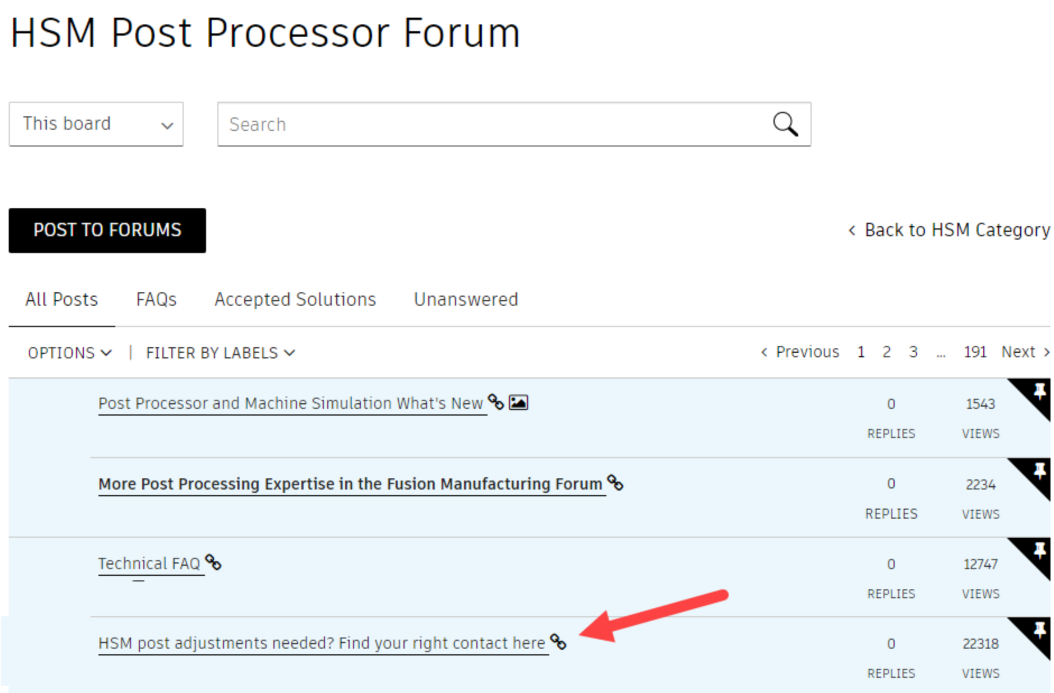
These fields apply directly to the parameters of the createAxis function as described in the Multi-Axis Post Processors chapter.</td></tr>
<tr><td>Post Processing</td><td>This is where you will select the location of the post processor, the post processor itself, and the output folder for the NC file. These will become the defaults when post processing and for NC Programs.</td></tr>
<tr><td>Multi-Axis</td><td>Defines the multi-axis capabilities of the control, along with how retract/reconfigure operations are handled, and singularity settings. These capabilities are described in the Multi-Axis Post Processors chapter.</td></tr>
</table>

Machine Definition Post Processor Settings

1.6 Creating/Modifying a Post Processor

Once you find a post processor that is close, but not exact to the requirements of your machine you will need to make modifications to it. The good news is, all of posts are open source and can be modified without limitation to create the post you need. You have a few options for making the modifications.

1. Make the modifications yourself using this manual as a guide and by asking for assistance from the HSM community on the HSM Post Processor Forum.
2. Visit HSM Post Processor Ideas and create a request for a post processor for your machine. Other users can vote for your request for Autodesk to create and add your post to our library.
3. Contact one of our CAM partners who offer post customization services. These partners can be found on the HSM Post Processor Forum at the top of the page.



Finding HSM CAM Partners

No matter which method you decide to use to create your post processor, you should have enough information available to define the requirements, which includes as much of the following as you can gather.

1. A post processor (.cps) that will be used as the seed post.
2. Sample NC code that has run on your machine.
3. The machine/control make and model.
4. The type of machine (mill, lathe, mill/turn, waterjet, etc.).
5. The machine configuration, including linear axes, rotary axes setup, etc.
6. A programming manual for your machine/control.

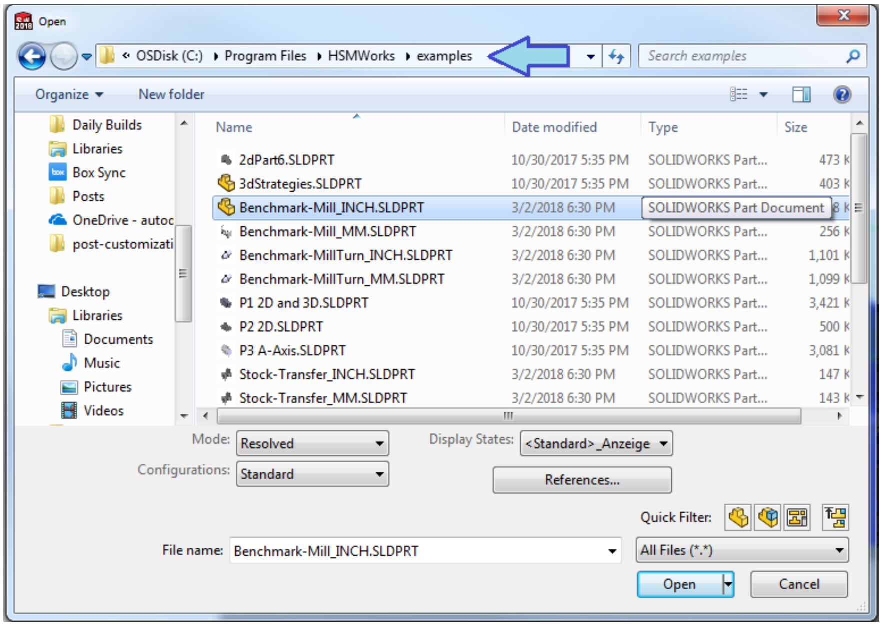
1.7 Testing your Post Processor – Benchmark Parts

When testing your post processor, you will need a part with cutting operations to post against. We have created standard benchmark parts for this specific purpose. These parts cover the most common scenarios you will come across when testing a post processor and are available for HSMWorks, Inventor CAM, and Fusion CAM. They are available in both metric and inch format for all three CAM systems. There are five different benchmark parts.

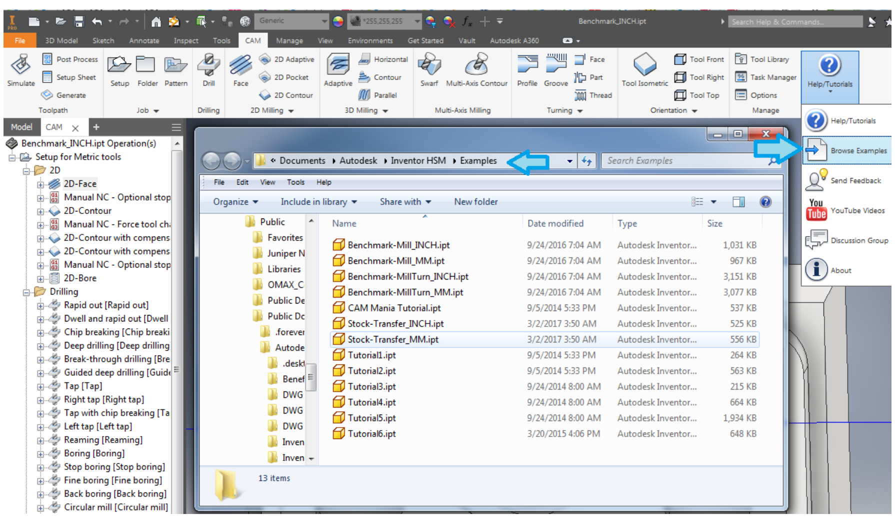
- Milling
- Turning and Mill/Turn
- Stock Transfers
- Waterjet-Laser-Plasma
- Probing

1.7.1 Locating the Benchmark Parts

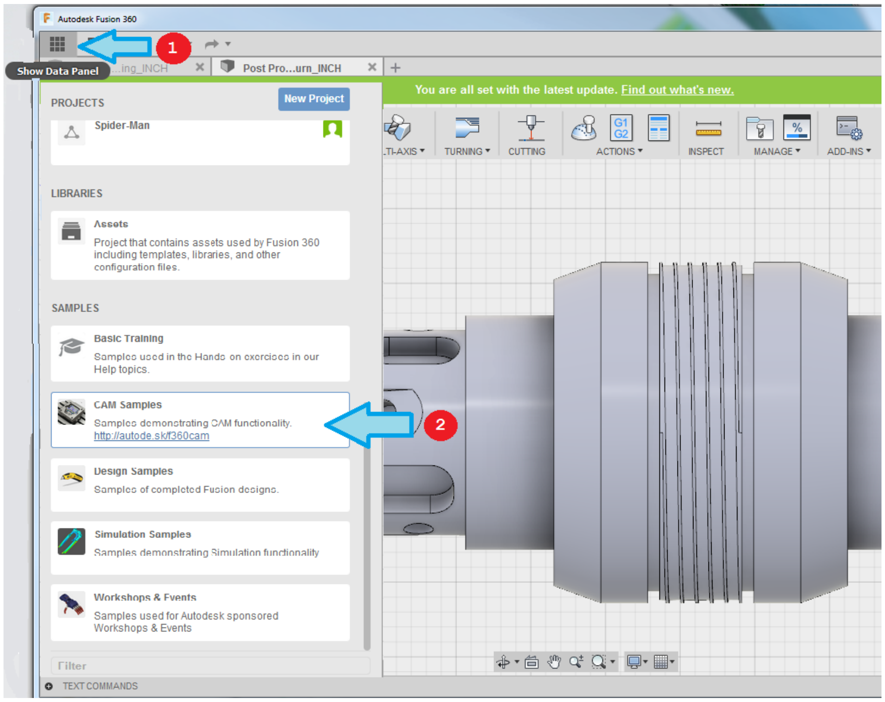
The benchmark parts are available to all users of Autodesk CAM and can be accessed in the Samples folder for each product.



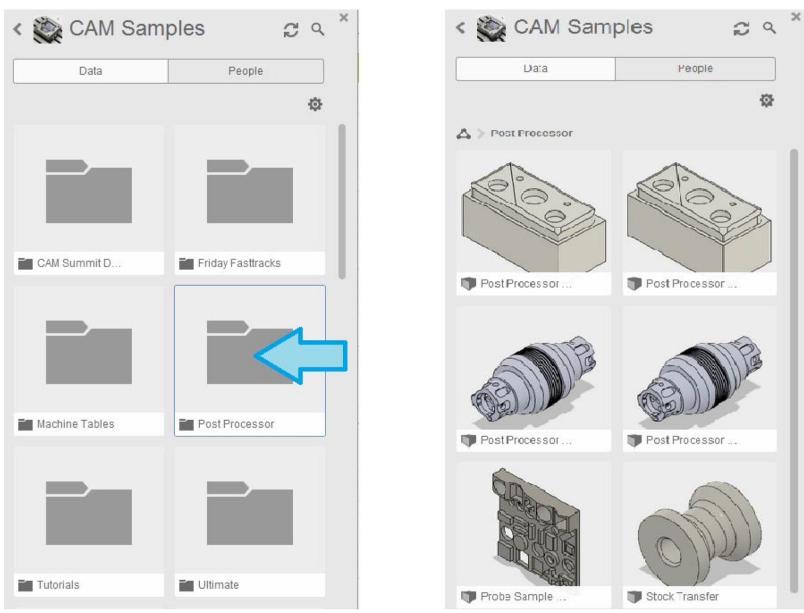
HSMWorks Sample Parts
C:\Program Files\HSMWorks\examples



Inventor CAM Sample Parts
C:\Users\Public\Public Documents\Autodesk\Inventor CAM\Examples



Fusion CAM
Select the Data Panel and Double Click on CAM Samples



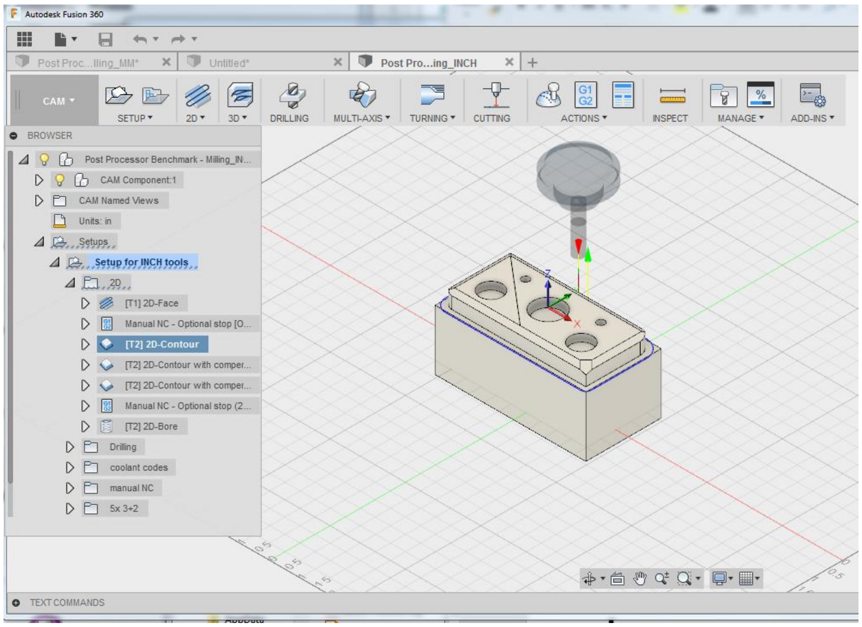
Fusion CAM (continued)
Double Click on Post Processor to Display the Sample Parts

1.7.2 Milling Benchmark Part

The milling benchmark parts include the following strategies.

- 2D

- Drilling
- Coolant codes
- Manual NC commands
- 3+2 5-axis
- 5-axis simultaneous

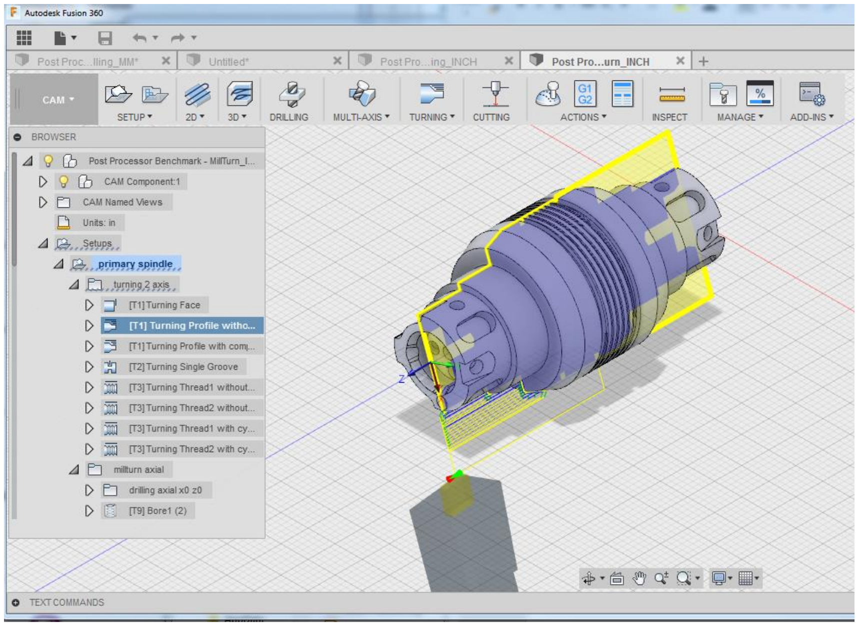


Mill Benchmark Part

1.7.3 Mill/Turn Benchmark Part

The mill/turn benchmark parts contain the following strategies.

- Primary and Secondary spindle operations
- Turning
- Axial milling
- Radial milling
- 5-axis milling

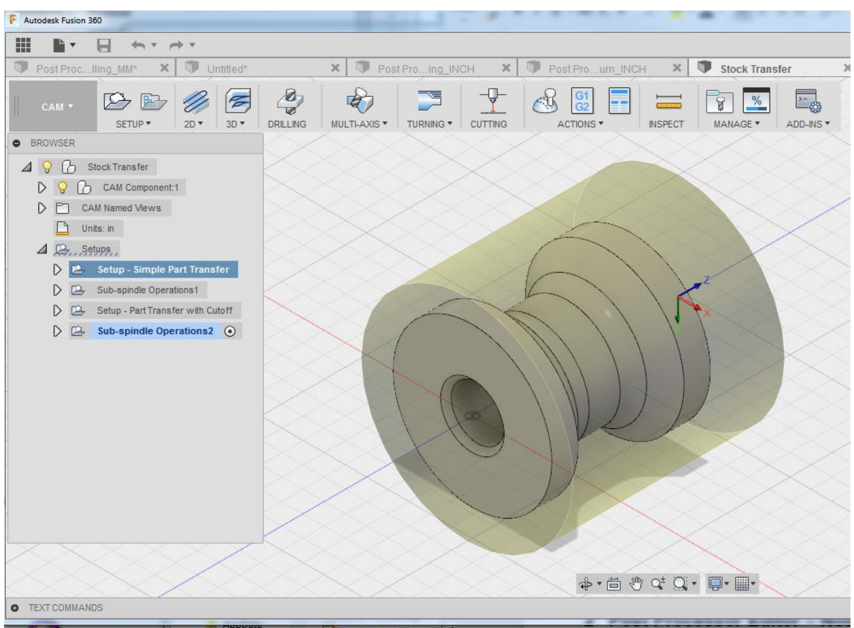


Turning and Mill/Turn Benchmark Part

1.7.4 Stock Transfer Benchmark Part

The stock transfer benchmark part contains the following strategies.

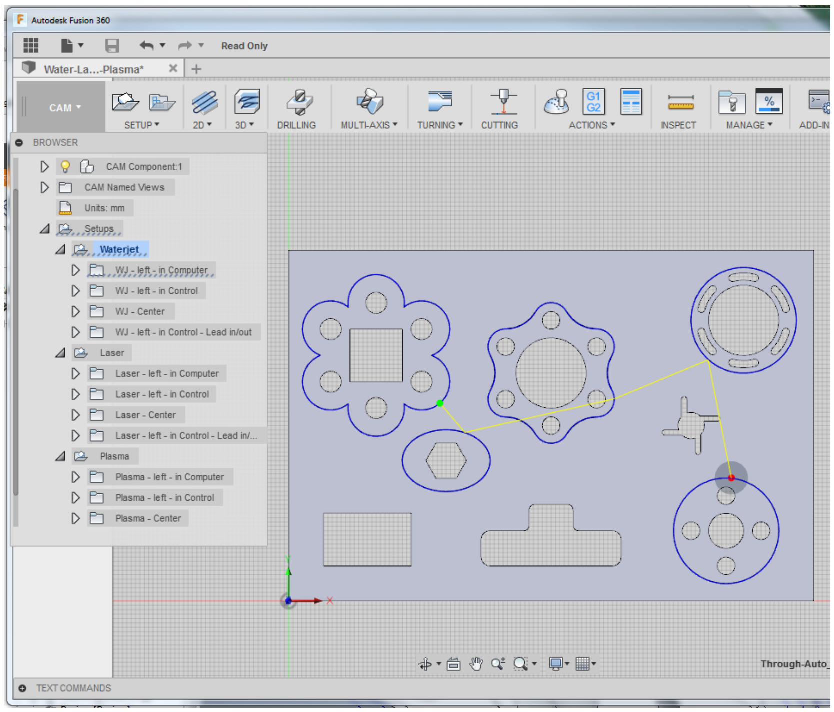
- Primary and Secondary spindle operations
- Simple part transfer
- Part transfer with cutoff



Stock Transfer Benchmark Part

The Waterjet-Laser-Plasma benchmark part contains the following strategies.

- Waterjet
- Laser
- Plasma
- Lead in/out
- Radius compensation

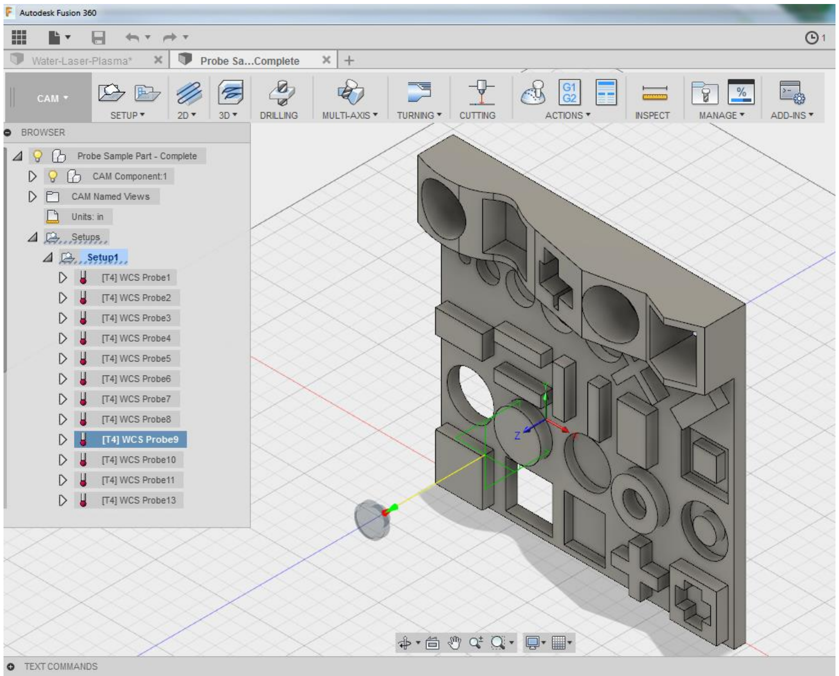


Waterjet-Laser-Plasma Benchmark Part

1.7.5 Probing Benchmark Part

The Probing benchmark part contains the following strategies.

- Various probing cycles


Probing Benchmark Part

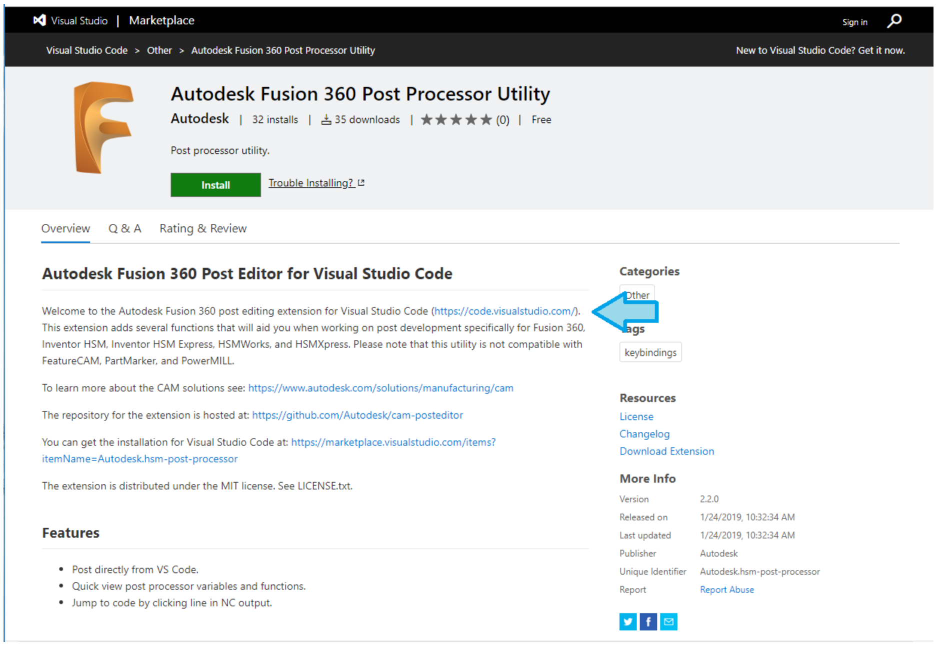
2 Autodesk Post Processor Editor

Since Fusion, Inventor CAM, and HSMWorks post processors are text-based JavaScript code, they can be edited with any text editor that you are familiar with. There are various editors in the marketplace that have been optimized for working with programming code such as JavaScript. We recommend Visual Studio Code with the *Autodesk Fusion Post Processor Utility* extension. Using this editor provides the following benefits when working with Autodesk post processors.

- Color coding
- Automatic closing and matching of parenthesis and brackets
- Automatic indentation
- Intelligent code completion
- Automatic syntax checking
- Function List
- Run the post processor directly from editor
- Match the output NC file line to the post processor command that created it

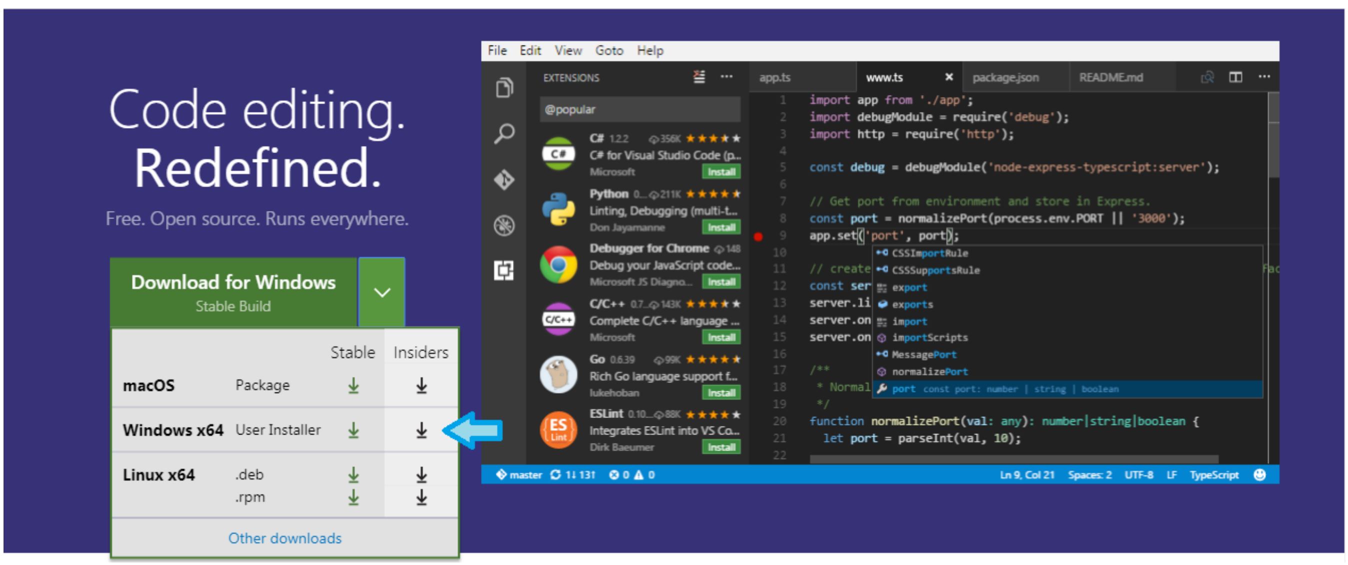
2.1 Installing the Autodesk Post Processor Editor

Before you can use the VSC editor you will need to install it. The easiest way is to visit the Autodesk Fusion Post Processor Utility page in the Visual Studio Marketplace, where you can download VSC and then the Autodesk Fusion Post Processor Utility extension. Please note that the Visual Studio Code site changes quite frequently, so the directions/pictures in this section might not be exactly what you see on the screen, but the installation steps should still be similar.



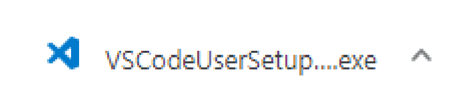
Installing Visual Studio Code

This link will take you to the Visual Studio Code installation page. Select the correct version for your operating system.



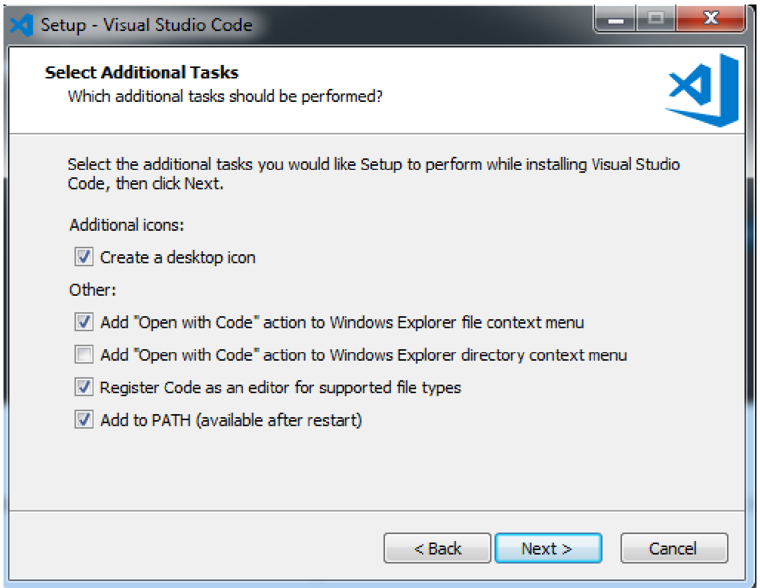
Installing the Windows Version of Visual Studio Code

This will download an installation program that you can run to do the actual install. Left click on the installation program to execute it.



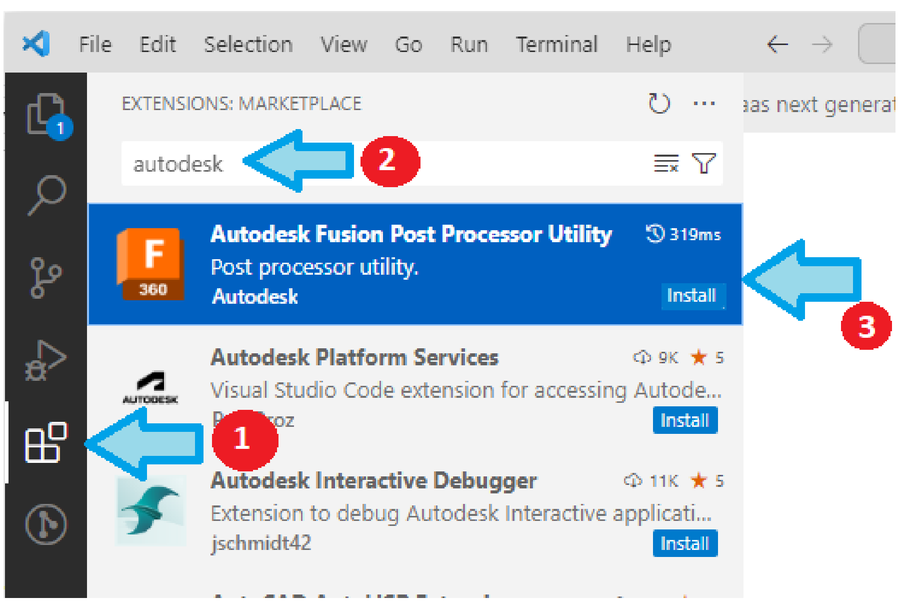
Click the Executable to Install VSC

Follow the instructions displayed on the screen to finish the installation. You should select the defaults for all questions, though you may want to make this the default code editor and add it to the Windows Explorer file context menu.

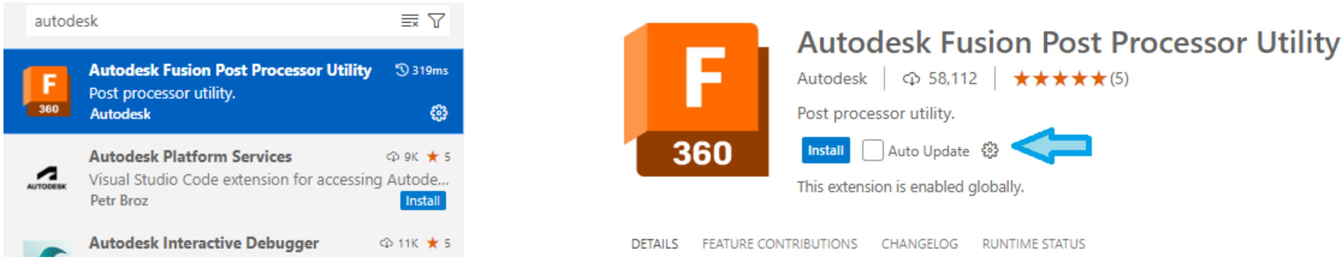


Selecting Installation Options

You can choose to start up the Visual Studio Code editor automatically after it is installed. Once the editor is opened you can install the Autodesk Fusion Post Processor Utility by opening the *Extensions* view in the left pane and searching for *Autodesk*. Select the Autodesk Fusion Post Processor Utility to install it.



Downloading the Autodesk Fusion Post Processor Extension

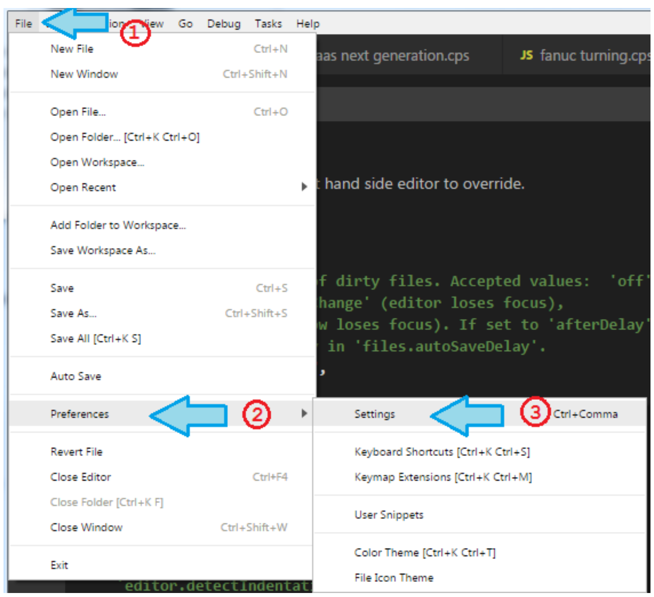


Installing the Autodesk Fusion Post Processor Extension

After installing the Autodesk Fusion Post Processor Utility extension you will want to exit the VSC editor and then restart it so that the extension is initialized. You are now ready to start editing Autodesk post processors.

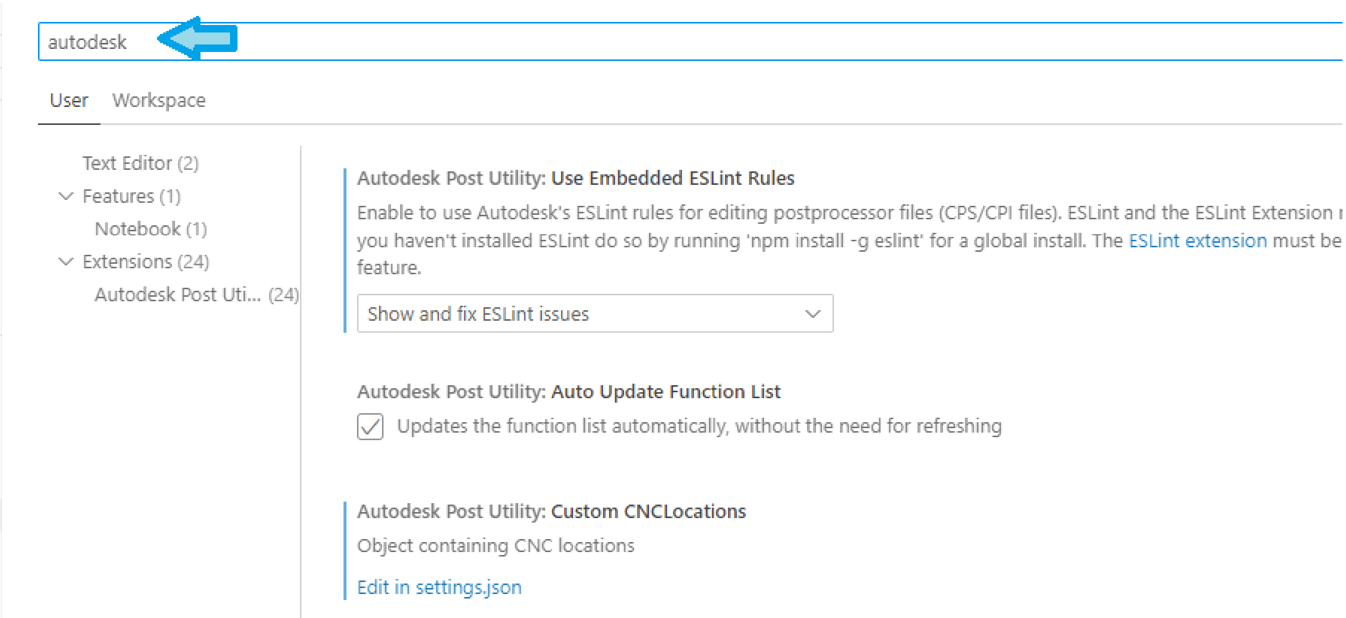
2.2 Autodesk Post Processor Settings

After installing the Autodesk Post Processor Utility, you will want to setup the editor to match your preferences. Open the settings file by selecting *File->Preferences->Settings*. This section will describe some of the most popular settings, but feel free to explore other settings at your leisure to find any that you may want to change. The User Settings can also be displayed by using the *Ctrl+Comma* shortcut.



Displaying the Editor Settings

The settings will be displayed in a separate tab. You can now search for individual settings using the Search bar. To display the Autodesk Fusion Post Processor Utility settings type in *autodesk* in the search bar.



Modifying the Editor Settings

There is a description that explains the setting making it easy for you to make the changes.

The following table provides a list of some of the more common settings and their descriptions.

Setting	Description
Autodesk Post Utility: Use Embedded ESLint Rules	Enable to use Autodesk's ESLint rules for editing post processors. You must install ESLint and the Visual Studio ESLint extension to support ESLint style syntax checking for the post processor. Use the command 'npm install -g eslint' in a Command Prompt window to install ESLint. The Visual Studio ESLint extension can be installed as any standard Visual Studio extension (refer to the *Extensions Flyout* section).
Autodesk Post Utility: Post Executable Path	Allows you to change the folder that contains the *post.exe* that will be used when post processing.
Autodesk Post Utility: Auto Update Function List	Updates the function list automatically, without the need for refreshing.
Autodesk Post Utility: Sort Function List Alphabetically	When checked the function list will be sorted. Unchecked will display the function names in the order that they are defined.
Autodesk Post Utility: Color Output	When checked, rapid, feedrate, and circular blocks will be displayed in color.

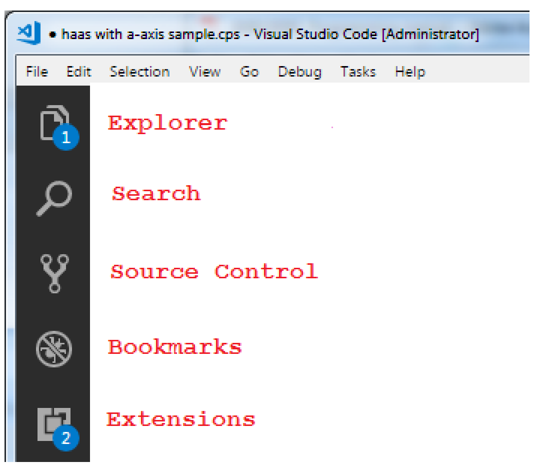
Setting	Description
Autodesk Post Utility: Rapid Color	Color for rapid move blocks.
Autodesk Post Utility: Linear Color	Color for feedrate move blocks.
Autodesk Post Utility: Circular Color	Color for circular move blocks.
Autodesk Post Utility: Enable Auto Line Selection	Enables the automatic selection of the line in the post processor that generated the selected line in the output NC file.
Autodesk Post Utility: Output Units	Sets the desired output units when post processing
Autodesk Post Utility: Shorten Output Code	Limits the number of blocks output when posting, making it easier to navigate.
Autodesk Post Utility: Shorten Output Line Limit	Specifies the maximum number of lines to display when the output size is limited.
Autodesk Post Utility: Post On CNC Selection	When checked, post processing will occur as soon as a CNC file is selected.
Autodesk Post Utility: Post on Machine Selection	When checked, post processing will occur as soon as a Machine is selected.
Autodesk Post Utility: Post On Property Change	When checked, post processing will occur as soon as a Post Property is changed.
Autodesk Post Utility: Post On Save	Automatically run the post processor when it is saved, only if the NC output file window is open.
Autodesk Post Utility: Show Warning Messages	Enable this setting to display a popup message when post processing generates warnings. You will be prompted to view the warnings in the log file.
Editor > Minimap	Controls if the minimap is shown. The minimap is a small representation of the entire file displayed on the right side of the window and allows you to easily scroll through the file.
Editor: Font Size	Size of the editor font.
Editor: Font Weight	Weight (thickness) of the editor font.
Editor: Detect Indentation	Automatically detects the *editor.tabSize* and *editor.insertSpaces* settings when opening a file.
Editor: Insert Spaces	When checked, spaces will be inserted into the file when the *tab* key is pressed. This is the Autodesk standard.
Editor: Tab Size	Sets the number of spaces a tab is equal to. The standard setting for Autodesk post processors is 2.
Editor > Parameter Hints	Enables a pop-up that shows parameter documentation and style information as you type.

Setting	Description
Editor: Auto Closing Brackets	Controls if the editor should automatically close brackets after opening them.
Extensions: Auto Check Update	Automatically checks for updated extensions and marks the extensions that have an update in the Extensions
Extensions: Auto Update	Controls the automatic update behavior of Visual Studio Code extensions.
Files: Associations	Associates file types with a programming language. This must have *"*.cps": "javascript"* set in it to enable the automatic features of the editor in Autodesk post processors.
Workbench: Color Theme	Defines the color theme for the editor. This setting can be changed using the *File->Preferences->Color* theme menu.

Commonly Changed User Settings

2.3 Left Side Flyout

On the left side of the editor window is a tab that will open different flyout dialogs. The features contained in the flyout dialogs are quite beneficial while editing a post processor and are explained in this section. The *Source Control* flyout is not used when editing post processors and will not be discussed.



Left Side Flyout Dialog

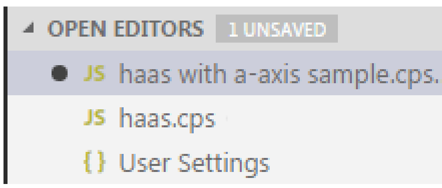
2.3.1 Explorer Flyout

The Explorer flyout contains expandable lists that are used to display the open editors, folders, variables, functions, and CNC selector. The arrow ► at the left of each entry is used to expand or collapse the list.

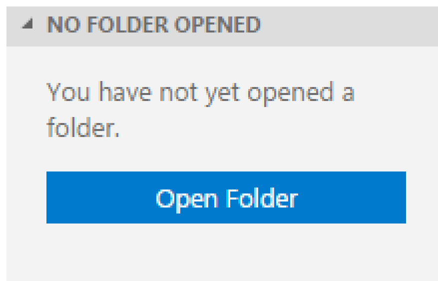
List	Description
OPEN EDITORS	Lists the files that are open in this instance of the VSC editor. Any files that have been changed, but not been saved will be marked with a bullet (•). The number of changed files that have not been saved is displayed in the Explorer icon.
NO FOLDERS OPEN	You can open a folder for quick access to all of the post processors in the folder. Expanding the folders will display the *Open Folder* button that can be used to open a folder. Clicking on a file in the open folder will automatically open it in the editor. Take note that if a folder is opened, then all opened files in the editor will first be closed and you will be prompted to save any that have been changed.
OUTLINE	Lists the functions defined in the post processor and the variables defined in each function. Expanding the function by pressing the arrow ► to the left of the function name will display the variables defined in the function. You can select any of the variables to go to the line where it is defined.
CNC SELECTOR	Contains the Autodesk intermediate files (*.cnc) that are available to the post processor from the VSC editor. This list is further explained in the *Running/Debugging the Post* section of this chapter.
FUNCTION LIST	Expanding the function list will display the functions defined in the active post processor. The functions will either be listed in alphabetical order or by the order they appear in the post processor depending on *the HSMPost Utility: Sort Function List Alphabetically* setting. You can select on a function in this list and the cursor will be placed at the beginning of this function in the editor window and while traversing through the post processor the function that the cursor is in will be marked with an arrow ►, making it easy for you to determine what function the active line is in.
POST PROPERTIES	Contains the Property Table for the post processor, similar to the Property Table displayed when running the post from CAM. This list is

List	Description
	further explained in the *Running/Debugging the Post* section of this chapter.
VARIABLE LIST	Lists the variable types supported by the post processor, such as Array, Format, Vector, etc. It does not contain a list of variables defined in the post processor. Expanding the variable type by pressing the arrow ▶ to the left of it will display the functions associated with the variable type.

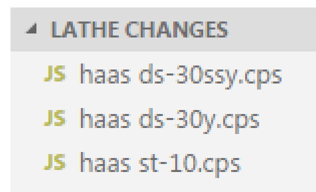
Explore Flyout Selections



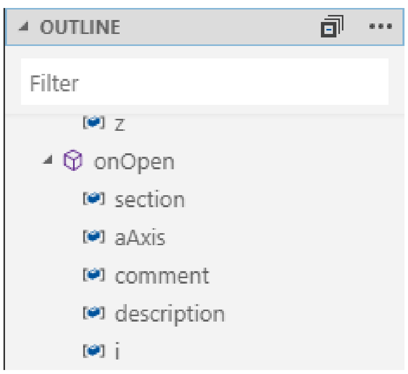
Open Editors



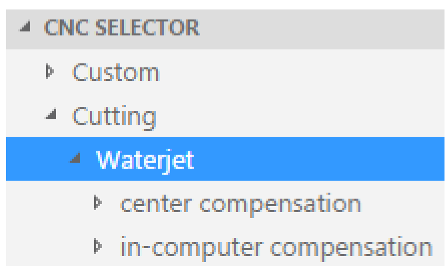
Opening a Folder



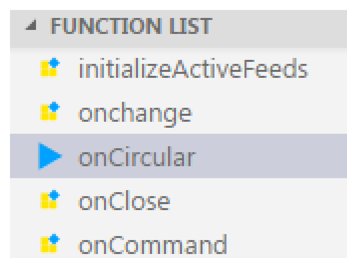
Open Folder File List



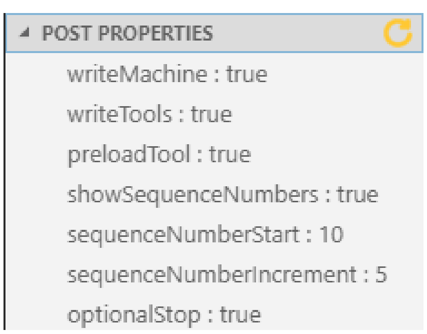
Outline



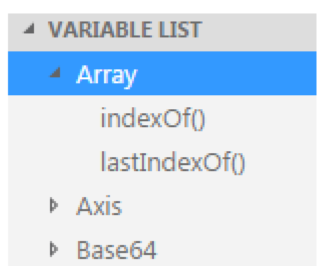
CNC Selector



Function List



Post Properties

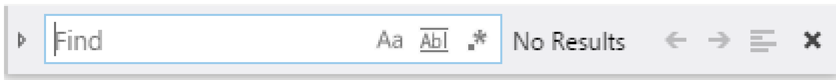


Variable List

2.3.2 Search Flyout

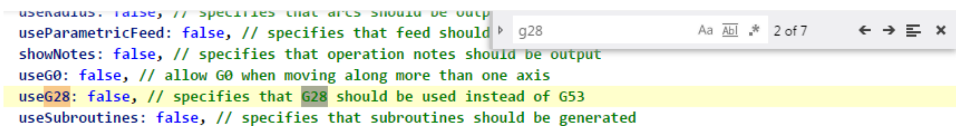
Search

You can search for a text string in the current file or in all of the opened files. To search for the text string in the current file you should use the Find popup window accessed by pressing the *Ctrl+F* keys.



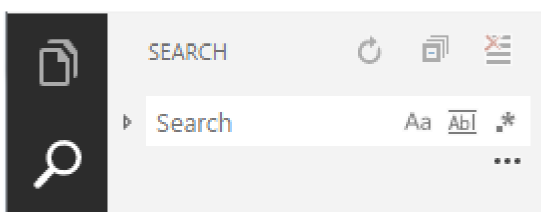
Ctrl+F Find Popup – Search for a Text String in the Current File

As you type in a text string the editor will automatically display and highlight the next occurrence of the text in the file. The number of occurrences of the text string in the file will be displayed to the right of the text field. You can use the *Enter* key to search for the next occurrence of the string or press the arrow keys to search forwards → and backwards ← through the file. If you use the *Enter* key, then the keyboard focus must be in the *Find* field.



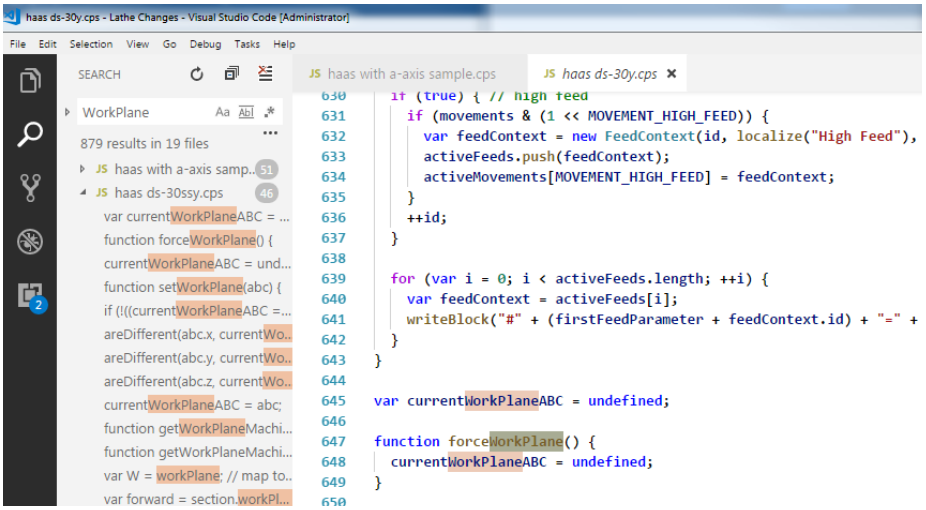
Using the Find Popup to Search for Text Strings

The *Search* flyout searches for a file in the opened files and in the files located in an open folder (refer to the *Explorer* flyout to see how to open a folder). The *Search* dialog will be displayed when you press the *Search* button.



Search Flyout – Search for a Text String in Multiple Files

Entering a text string to search for and then pressing the *Enter* key will display the files that contain the text string and the number of instances of the text string in each file. You can expand the file in the list by pressing the arrow key ▶ and each instance of the text string found in the selected file will be displayed. Clicking on one of the instances causes the editor to go to that line in the file and automatically open the file if it is not already opened. If you don't make any changes to the file and then select the text string in another file, then the first file will be closed before opening the next file. An unchanged file opened from the *Search* flyout will have its name italicized in the editor window.



Searching for a Text String in the Opened Files

There are options that are available when searching for text strings. These options are controlled using the icons in the *Search* dialog and *Find* popup.

Icon	Description
	When enabled, the case of the search string must be the same as the matching text string in the file.
	When enabled, the entire word of the matching text string in the file must be the same as search string. When disabled, it will search for the occurrence of the search string within words.
	When enabled, the '.' character can be used as a single character wildcard and the '*' character can be used as a multi-character wildcard in the search string.
	Search forward in the file. In the *Find* popup only.
	Search backward in the file. In the *Find* popup only.
	Searches for the text string only in the selected text in the file. In the *Find* popup window only.
	Closes the *Find* popup window.
	Refresh the results window. In the *Search* flyout only.
	Collapse all expanded files in the results window. In the *Search* flyout only.
	Displays fields that allow you to include or exclude certain files from searches. In the *Search* flyout only.
	Displays the *Replace* field, allowing you to replace the *Search* text with the *Replace* field text.
	Replaces the current (highlighted) occurrence of the *Search* text with the *Replace* field text. Hitting the *Enter* key while in the *Replace* field performs the same replacement. In the *Find* popup window only.
	Replaces all occurrences of the *Search* text with the *Replace* field text. When initiated from the *Search* flyout, all occurrences of the text in all files listed in the *Results* window will be replaced.

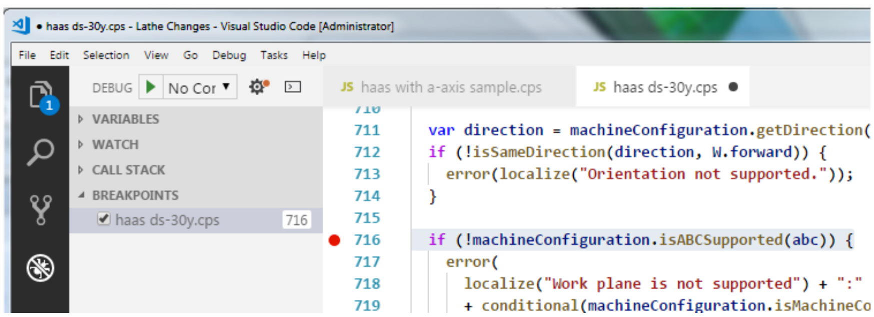
Search and Replace Options

2.3.3 Bookmarks Flyout

 Bookmarks

Okay, so the *Bookmarks* flyout is actually a Breakpoints flyout, but since JavaScript does not have an interactive debugger we are going to use it for adding bookmarks to the opened files. Placing the cursor to the left of the line number where you want to set a bookmark will display a red circle and then clicking at this position will add the bookmark.

To see the active bookmarks you can open the Bookmarks flyout and expand the *BreakPoints* window. You can then go directly to a line that is bookmarked by selecting that line in the Bookmarks flyout. Bookmarks set in all opened files will be displayed in the flyout and the file that the bookmark is set in will automatically be made the active window when the bookmark is selected.

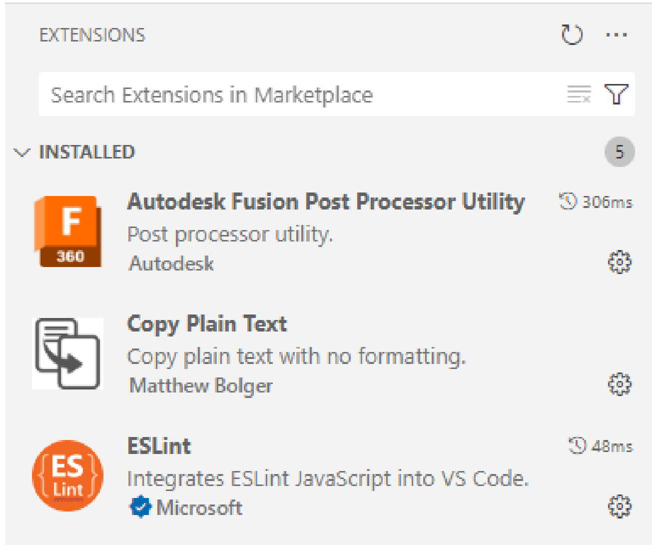


Using the Bookmarks Flyout

2.3.4 Extensions Flyout

 Extensions

Visual Studio Code is an open-source editor and there are many extensions that have been added to it by the community. For example, the *Autodesk Fusion Post Processor* Utility is an extension to this editor. By opening the Extensions flyout you can see what extensions you have installed and what extensions have updates waiting for them.

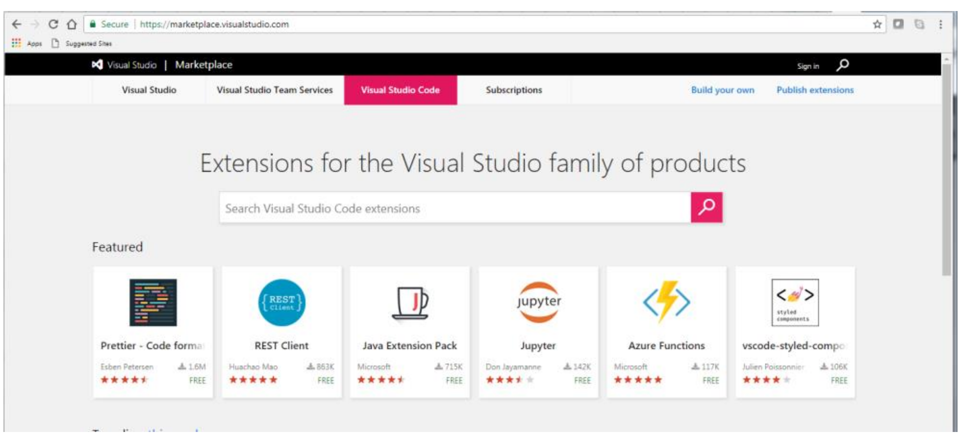


Viewing Installed Extensions

If there is an *Update* button displayed with the extension you can press this button to install the latest version of the associated extension.

You can search the Visual Studio Marketplace for extensions that are beneficial for your editing style by typing in a name in the *Search Extensions in Marketplace* field. For example, if you want a more dedicated way to set bookmarks you can type in bookmark in this field and all extensions dealing with adding bookmarks will be displayed. You can press the green *Install* button to install the extension.

You can also search for extensions online at the [Visual Studio Marketplace](https://marketplace.visualstudio.com).



Viewing Extensions in the Online Marketplace

2.4 Autodesk Post Processor Editor Features

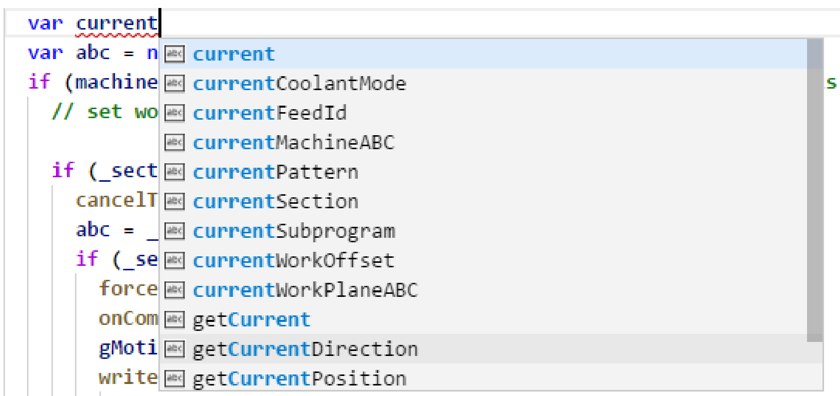
The Autodesk Post Processor editor has features to enhance the ease of editing of post processor JavaScript files. One example is the color coding of the text, variables are in one color, functions in another, JavaScript reserved words in yet another, and so on. The colors of each entity is based on the *Workbench Color Theme* setting.

This section will go over some of the more commonly used features. You are sure to discover other features as you use the editor.

2.4.1 Auto Completion

As you type the name of a variable or function you will notice a popup window that will show you previously used names that match the text as it is typed in. Selecting one of the suggestions by using the arrow keys to highlight the name and then the tab key to select it will insert that name into the spot where you are typing.

If the *Editor: Parameter Hints* setting is set to true, then when you type in the name of a function, including the opening parenthesis, you will be supplied the names of the function's arguments for reference.

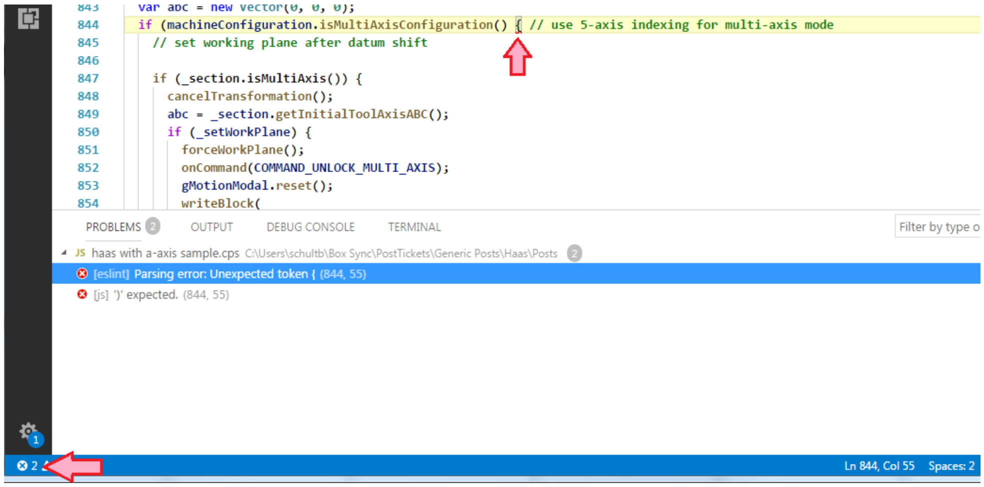


Using Auto Completion

2.4.2 Syntax Checking

If you have a syntax error while editing a file, the editor is smart enough to flag the error by incrementing the error count at the bottom left of the window footer and marking the problem in the file with a red squiggly line. You can open the Problems window by selecting the X in the window footer to see all lines that have a syntax error. Clicking on the line displaying the error will then take you directly to that line, so that you can resolve the error.

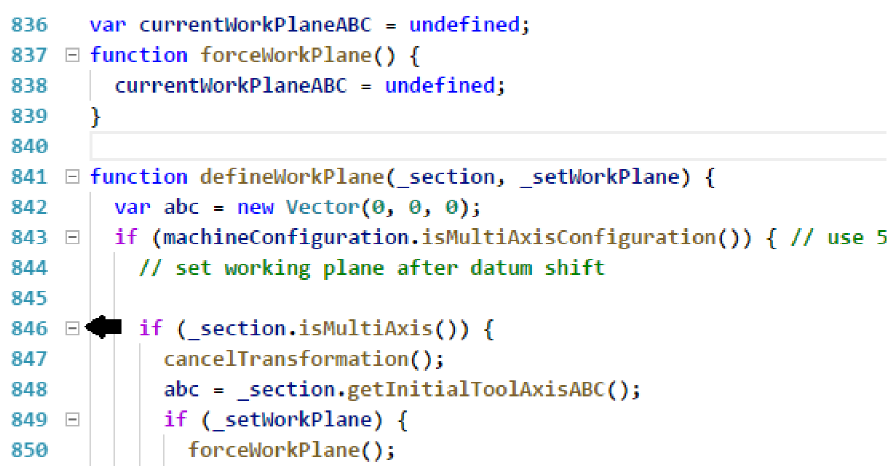
You can close the window by pressing on the X in the window footer or the X at the top right of the Problems window.



Displaying Syntax Errors

2.4.3 Hiding Sections of Code

You can hide code that is enclosed in braces {} by positioning the cursor to the right of the line number on the line with the opening brace and then pressing the [-] icon. The code can be expanded again by pressing the [+] icon. Note that the icons will not be displayed unless the cursor is placed in the area between the line number and the editing window.



Hiding Sections of Code

2.4.4 Matching Brackets

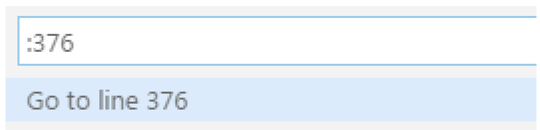
If you place the edit cursor at a parenthesis (()), bracket ([]), or brace ({}) the editor will highlight the selected enclosure as well as the opening/closing matching enclosure character. If there are multiple enclosure characters right next to each other, then the enclosure following the edit cursor will be selected. If the enclosure character does not highlight, then this means that there is not a matching opening/closing enclosure.

```
writeBlock(
  gMotionModal.format(0),
  conditional(machineConfiguration.isMachineCoordinate(0), "A" + abcFormat.format(abc.x)),
  conditional(machineConfiguration.isMachineCoordinate(1), "B" + abcFormat.format(abc.y)),
  conditional(machineConfiguration.isMachineCoordinate(2), "C" + abcFormat.format(abc.z))
);
```

Matching Parenthesis

2.4.5 Go to Line Number

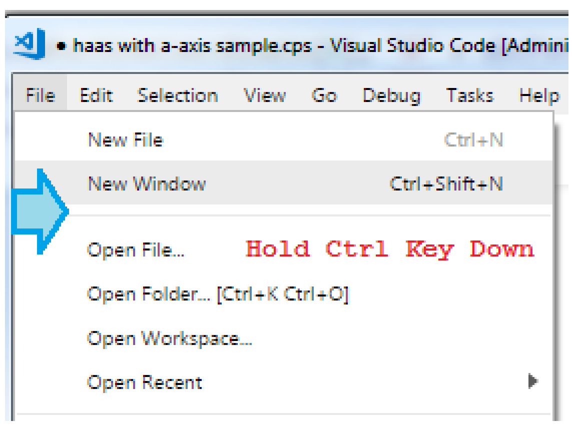
You can go to a specific line number in the file by pressing the *Ctrl+G* keys and then typing in the line number.



Go to Line Number

2.4.6 Opening a File in a Separate Window

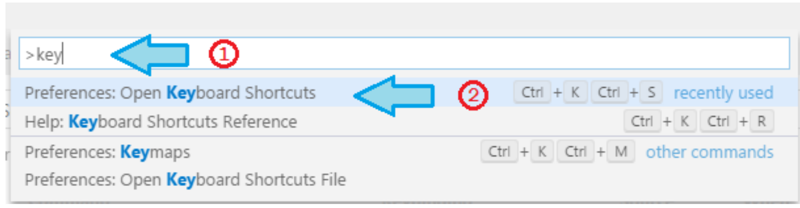
You can open a file in the current window by selecting the *File->Open File…* menu from the task bar or by pressing the *Ctrl+O* keys. You can open the active file in a separate VSC window by pressing the *Ctrl+K* keys and then pressing the *O* key. The file will be opened in the a new window and remain open in the active window. You can also open a new VSC window by selecting the *File->New Window* menu or by pressing the *Ctrl+Shift+N* keys.



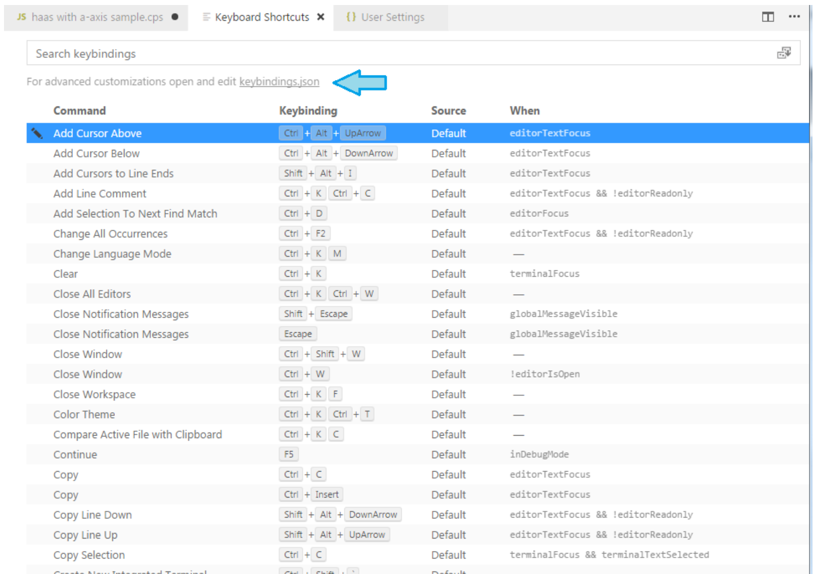
Open Separate VSC Window

2.4.7 Shortcut Keys

You can display the assigned Shortcut Keys by pressing the *F1* key and then typing in *key* to display all commands referencing the key string. Select the *Preferences: Open Keyboard Shortcuts* menu. You can also press the *Ctrl+K Ctrl+S* keys in sequence to display the Shortcut Keys window.



Display the Shortcut Keys



Shortcut Key Assignments

Modifications and/or additions to the Shortcut Key assignments can be made by selecting the *keybindings.json* link at the top of the page. This will open a split window display that displays the default Shortcut Keys in the left window and the user defined Shortcut Keys in the right window. Use the same procedure as modifying a setting to modify a Shortcut Key, by copying the binding definition from the left window into the right window and making the desired changes. Be sure to save the *keybindings.json* file after making your changes.

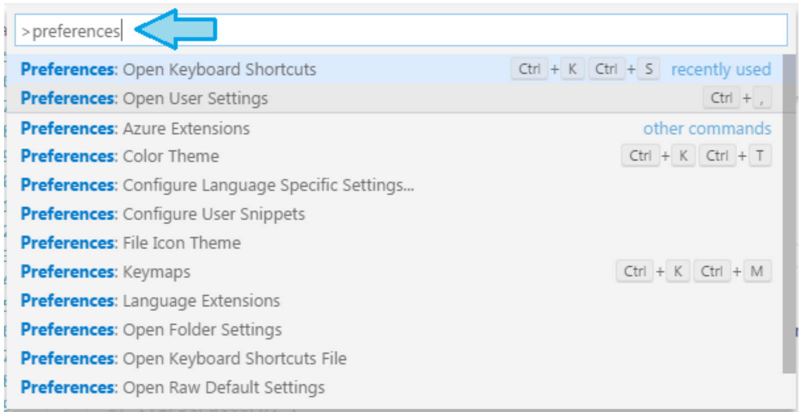
The format of the keystrokes that represent a single Shortcut is defined in the following table.

Shortcut	Sample	Description
key	F1	Press the single key.
key+key	Ctrl+Shift+Enter	*key* is the name of the key to press. The + character means that the keys must be pressed at the same time. The + key is not pressed.
key key	Ctrl+K Ctrl+S	The keys should be pressed in sequence, one after the other. Each key can be a combination of multiple keys that are pressed at the same time as explained above. Unless *Shift* is part of the key sequence, then lower case letters are being specified.

Shorcut Key Syntax

2.4.8 Running Commands

The commands accessible by shortcut keys or the menus can be found and run from the command popup dialog and are accessed in the editor by pressing the *F1* key. Once the command popup is displayed you can search for commands by typing in text in the search line. The commands that match the search will be displayed along with the Shortcut Keys that are assigned to the commands. Select on the command to run it.



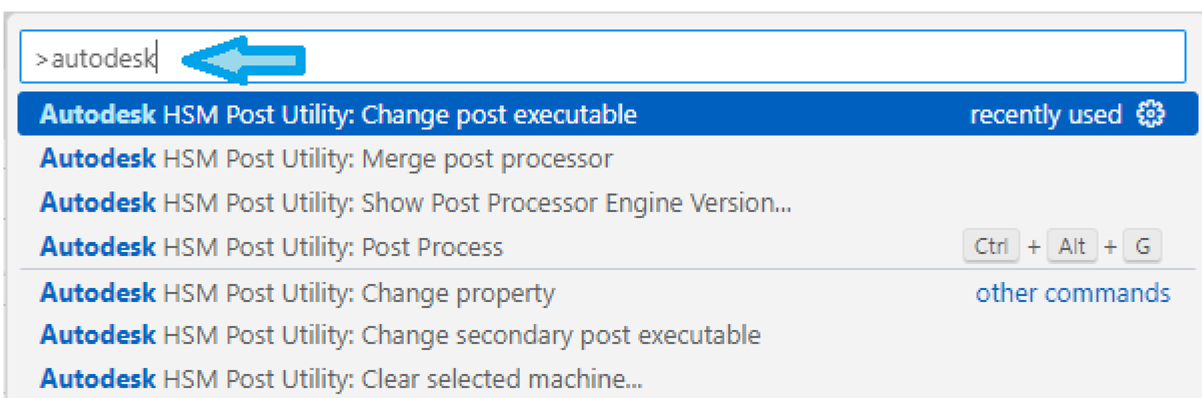
Running a Command

2.5 Running/Debugging the Post

The *Autodesk Fusion Post Processor Utility* extension allows you to run the post processor that you are editing directly from the editor and to debug the post by matching the output lines in the NC file with the code line that generated the output. You can run the post against the provided intermediate files generated from the Benchmark Parts or you can create your own intermediate file to run the post against.

2.5.1 Autodesk Post Processor Commands

There are built-in commands that pertain to running the post processor. These commands are accessed by pressing the F1 key and typing HSM in the search field.



Displaying the Autodesk Post Processor Commands

The following table describes some of the available commands.

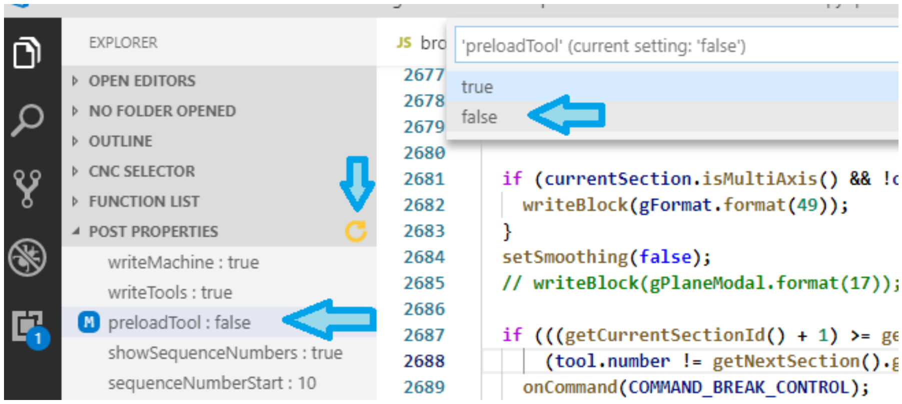
Command	Description
Post Process	Runs the post processor against the selected CNC file. You can also use the shortcut *Ctrl+Alt+G* to run the post processor.
Change post executable	Sets the location of the post processor engine executable.
Show debugged code	Displays the entry functions that are called and the line numbers that generated the block in the output NC file. This is the same output that is displayed when you call the *setWriteStack(true)* and *setWriteInvocations(true)* functions.
Delete CNC file	This command cannot be run from the Commands menu. Right clicking on a CNC file in the *CNC Selection* list and selecting *Delete CNC File* will delete the file and remove it from the list. The same applies to Machine files.
Disable auto line selection	Disables the feature of automatically displaying the line in the post processor that generated the selected line in the NC output file.
Download CNC exporting post processor	Downloads the *Exporting Post Processor* used for generating your own CNC files for testing.

The Autodesk Post Processor Commands

2.5.2 The Post Processor Properties

You can display the properties associated with the open post processor by opening the Explorer flyout and expanding the Post Properties list. Clicking on a property will prompt you to change the property. The  symbol will be displayed next to the property if it has been changed from the default value.

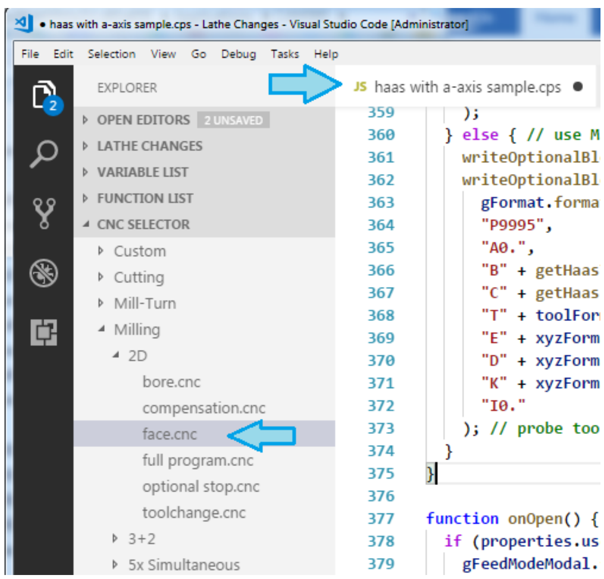
If you add a new property to the post or for some reason the properties don’t display, you can press the yellow refresh symbol in the Post Properties header to refresh the displayed properties.



Modifying the Post Properties

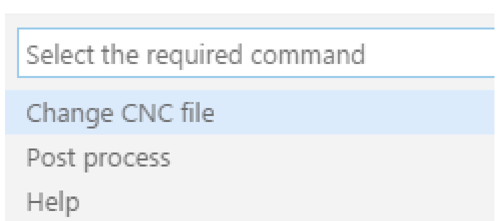
2.5.3 Running the Post Processor

To run the post processor that is open in the editor you can use the *Ctrl+Alt+G* shortcut or run the *Post Utility* from the Command window as described in the previous section. First you will need to select the intermediate CNC file to run the post against. You select the CNC file by opening the *Explorer* flyout and expanding the *CNC Selector* list until you find the desired CNC file.



Post the Selected CNC File Against the Active Post

You can also select the CNC file from the Post Utility menu.



Select the CNC File or Post Processor Using the Post Utility Command

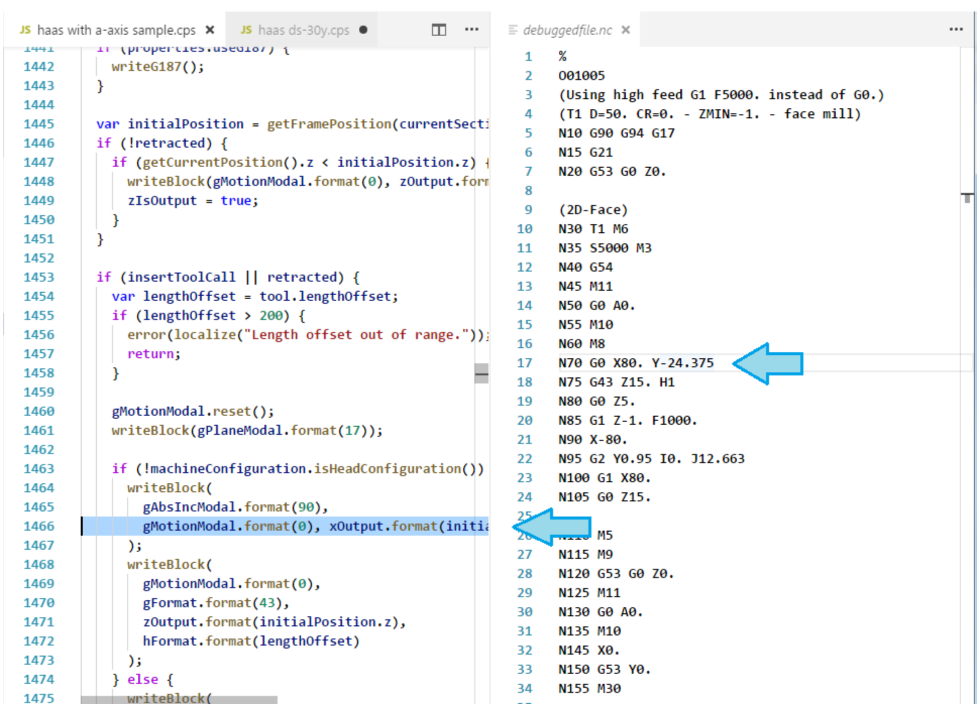
If running a post processor for the first time in the editor it is possible that the location of the post engine executable (post.exe) is not known. In this case you will see the following message displayed.

You can press the *Browse…* button to search for *post.exe*. The executable will be in one of the following locations depending on the version of HSM being run.

HSM Version	Post Executable Location
Fusion	C:\User*username*\AppData\Local\Autodesk\webdeploy\production*(id)*\Applications\CAM360 *username* is your username that you logged in as. *(id)* is a unique and long name that changes depending on the version of Fusion that you have installed. You will usually select the folder with the latest date.
Inventor	C:\Program Files\Autodesk\Inventor CAM *yyyy* *yyyy is* the version number (year) of Inventor.
HSMWorks	C:\Program Files\HSMWorks

Post Executable Locations

Once you have posted against the CNC file, the output NC file or Log file will be displayed in the right panel of the split screen. When the *HSMPostUtility: Enable Auto Line Selection* setting is true, then clicking twice on a line in the output NC file will highlight the line in the post processor that generated the output. The second click must be on a different character on the same output line to highlight the line. Then, by clicking on a different character in the same line you will be walked through the stack of functions that were called in the generation of the output.

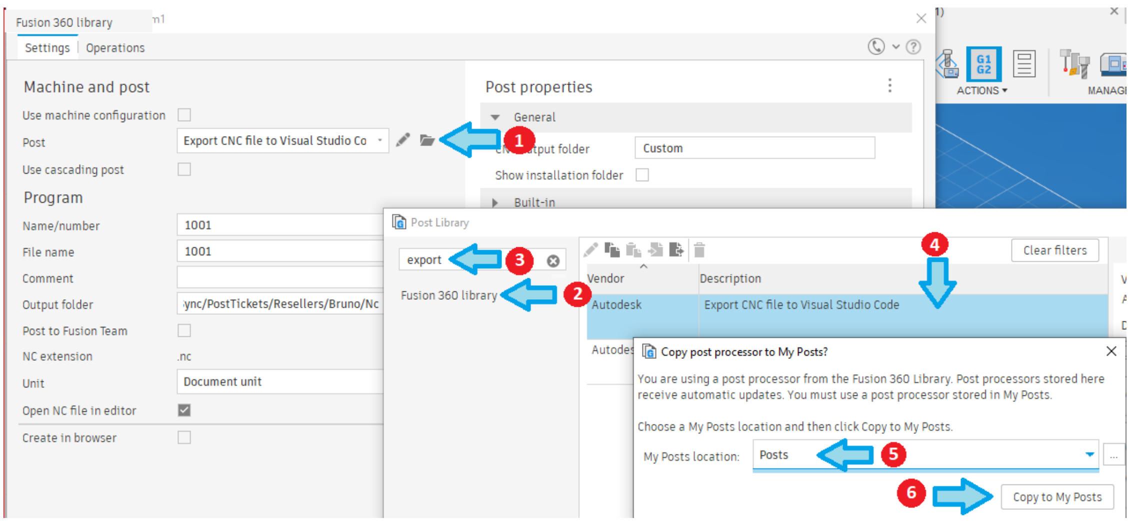


Output NC File, Click Twice on Output Line to See Code that Generated Output

2.5.4 Creating Your Own CNC Intermediate Files

The Autodesk Post Processor extension comes with built-in CNC intermediate files that are generated using the HSM Benchmark Parts. These can be used for testing most aspects of the post processor, but there are times when you will need to test specific scenarios. For these cases you can create your own CNC file to use as input.

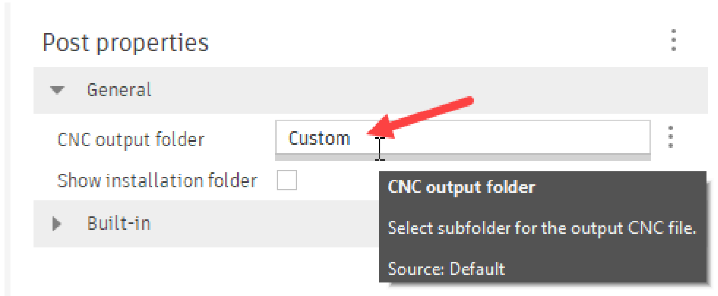
The *Export CNC file to Visual Studio Code* post processor from the Fusion Post Processor Library is used to create external CNC intermediate files that can be used from within the Visual Studio Code editor. You can download this post in the same manner as you download any post processor from within Fusion.



Download the CNC Exporting Post Processor

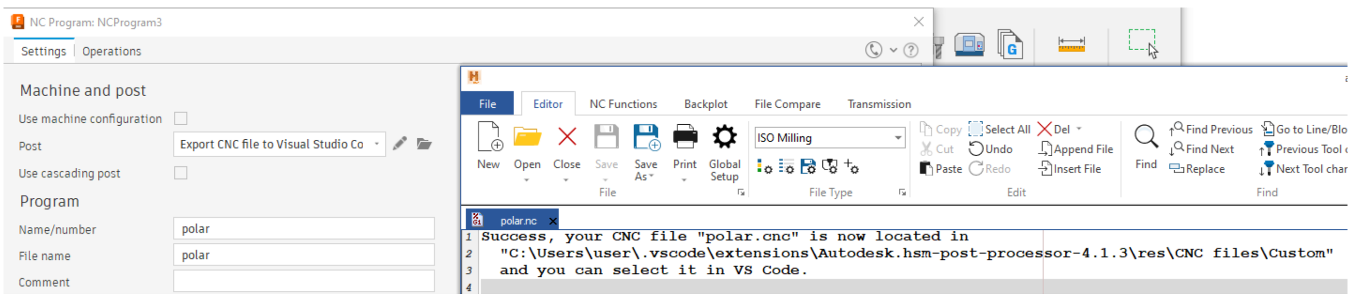
Follow the directions in the *Downloading and Installing a Post Processor* section for installing a post processor on your system.

Once the post processor is installed you will want to post process the operations you want to use for testing. The CNC exporting post processor is run just like any other Autodesk post processor, except it will not generate NC code, but will rather create a copy of the CNC file from the Autodesk CAM system in a folder within the *CNC Selector*. The CNC file will be stored in the Custom folder by default, but you can create your own private folder(s) by typing the custom folder name into *the CNC output folder field* when post processing.



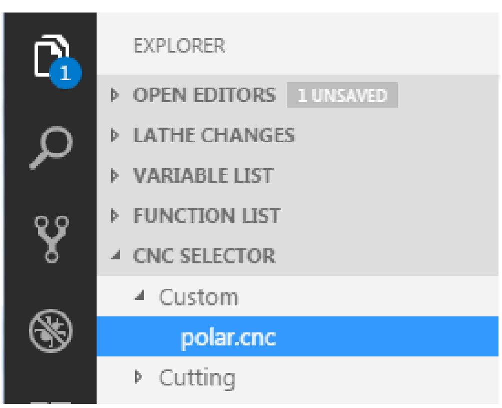
Selecting a Custom Folder for the Exported CNC File

Most posts use a number for the output file name, it is recommended that you give the CNC file a unique name that describes the operations that were used to generate it.

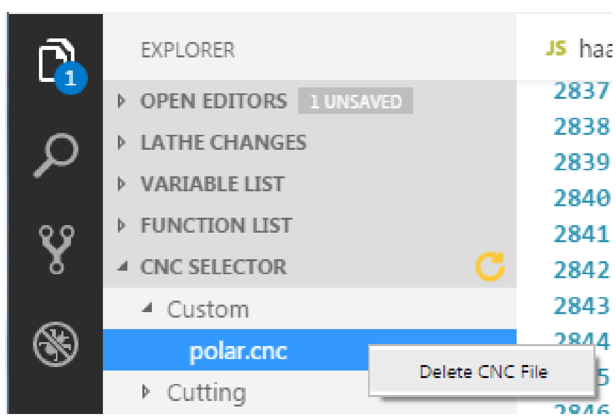


Create a Custom CNC Intermediate File

Once you click the yellow refresh button you should see the CNC file in the selected folder of the *CNC Selector* list and can use it when post processing from the VSC editor. If you decide that you no longer need a custom CNC intermediate file you can delete it by right clicking on the CNC file and select *Delete CNC File*.



Using a Custom CNC Intermediate File



Deleting a Custom CNC Intermediate File

3 JavaScript Overview

3.1 Overview

Autodesk post processors are written using the JavaScript language. It resembles the C, C++, and Java programming languages, is interpreted rather than being a compiled language, and is object-orientated. JavaScript as it is used for developing post processors is fairly simple to learn and understand, but still retains its complex nature for more advanced programmers.

This chapter covers the basics of the JavaScript language and conventions used by Autodesk post processors. There are many web sites that document the JavaScript language. The ELOQUENT JAVASCRIPT site has a nicely laid out format. If you prefer a hard copy JavaScript guide, then the *JavaScript the Definitive Guide, Author: David Flanagan, Publisher: O'Reilly* is recommended. Whichever manual you use, you will want to focus on the core syntax of JavaScript and ignore the browser and client-side aspects of the language.

The Autodesk post processor documentation is provided as the *post.chm* file with HSMWorks and Inventor CAM or you can visit the Autodesk CAM Post Processor Documentation web site. You will find that the *post.chm* version of the documentation is easier to view, since it has a working Index.

3.2 JavaScript Syntax

JavaScript is a case sensitive language, meaning that all functions, variables, and any other identifiers must always be typed exactly the same with regards to lower and uppercase letters.

```
currentCoolant = 7;
currentCoolant = 8;
currentcoolant = 9;
```

Case Sensitive Definition of 3 Different Variables

JavaScript ignores spaces and new lines between variables, operators, names, and delimiting characters. Variable and function names cannot have spaces in them, as this would create separate entities. Commands can be continued onto multiple lines and are terminated with a semicolon (;) to mark the end of the logical command. If you are defining a string literal within quotes, then the literal should be defined on a single line and not on multiple lines. If a text string is too long for a single line, then it should be concatenated using an operation.

```
message = "The 3 inch bore needs to be probed prior to starting " +
  "the next operation.";
```

Breaking Up a Text String onto Multiple Lines

There are two methods of defining comments in JavaScript. You can either enclose comments between the /* and */ characters, which will treat all text between these delimiters as a comment, or place the // characters prior to the comment text.

The */* comment */* format is typically used as the descriptive header of a function or to block out multiple lines of code. Any characters on the line that follow the // characters are treated as a comment, so you can have a single comment line or add a comment to the end of a JavaScript statement.

```
/**
  Output a comment.
*/
function writeComment(text) {
  writeln(formatComment(text)); // write out comment line
}
..
/*
  switch (unit) {
  case IN:
    writeBlock(gUnitModal.format(20));
    break;
  case MM:
    writeBlock(gUnitModal.format(21));
    break;
  }
*/
```

Comment Lines

Using indentation for function contents, if blocks, loops and continuation lines is recommended as this makes it easier to visualize the code. Tab characters, though supported by JavaScript, are discouraged from being used. It is preferred to use virtual tab stops of two spaces for indenting code in post processor code. Most editors, including the Autodesk Post Processor Editor can be setup to automatically convert tab characters to spaces that will align each indent at two spaces. Please refer to the Post Processor Editor chapter for an explanation on how to setup the Autodesk recommended editor.

```
function test (input) {
  // indent 2 spaces inside of function
  if (input == 1) {
    writeBlock(  // indent 2 more spaces in if block or loop
      gAbsIncModal.format(90),  // indent 2 more spaces for continuation lines
      gMotionModal.format(0)
    );
  }
}
```

Indent Code 2 Spaces Inside Function, If Block, Loop, and Continuation Line

3.3 Variables

Variables are simply names associated with a value. The value can be a number, string, boolean, array, or object. Variables in JavaScript are untyped, meaning that they are defined by the value that they have assigned to them and the value type can change throughout the program. For example, you can assign a number to a variable and later in the program you can assign the same variable a string value. The *var* keyword is used to define a variable.

If a variable is not assigned a value, then it will be assigned the special value of *undefined*.

```
var a;              // define variable 'a', it will have the value of undefined
var b = 1;          // assign a value of 1 to the variable 'b'
var c = "text";     // assign a text string to the variable 'c'
c = 2.5;            // 'c' now contains a number instead of string
```

Variable Definitions

While you can include multiple variable declarations on the same *var* line, this is against the standard used for post processors and is not recommended. You can also implicitly create a variable simply by assigning a value to the variable name without using the *var* keyword, but is also not recommended. When declaring a new variable, be sure to not use the same name as a JavaScript or Post Kernel keyword, for example do not name it *var, for, cycle, currentSection,* etc. Refer to the appropriate documentation for a list of keywords/variables allocated in JavaScript or the Post Kernel.

JavaScript supports both global variables and local variables. A global variable is defined outside the scope of a function, for example at the top of the file prior to defining any functions. Global variables are accessible to all functions within the program and will have the same value from function to function. Local variables are only accessible from within the function that they are defined. You can use the same name for local variables in multiple functions and they will each have their own unique value in the separate functions. Unlike the C and C++ languages, local variables defined within an if block or loop are accessible to the entire function and are not local to the block that they are defined in.

3.3.1 Numbers

Besides containing a standard numeric value, a variable assigned to a number creates a *Number* object. For this discussion, we will consider an object a variable with associated functions. These functions are specific to numbers and are listed in the following table.

Function	Description	Returns
toExponential(digits)	Format a number using exponential notation	String representation of number
toFixed(digits)	Format a number with a fixed number of digits	String representation of number
toLocaleString()	Format a number according to locale conventions	String representation of number
toPrecision(digits)	Format a number using either a fixed number of digits or using exponential notation depending on value of number	String representation of number
toString()	Format a number	String representation of number

Number Object Functions

```
var a = 12.12345;
```

```
b = a.toExponential(2);    // b = "1.21e+1"
b = a.toFixed(3);          // b = "12.123"
b = a.toString();          // b = "12.12345"
```
Sample Number Output

The JavaScript built-in Math object contains functions and constants that apply to numbers. The following table lists the Math functions and constants that are most likely to be used in a post processor. All Math functions return a value.

Function	Return value
Math.abs(x)	Absolute value of *x*
Math.acos(x)	Arc cosine of *x* in radians
Math.asin(x)	Arc sine of *x* in radians
Math.atan(x)	Arc tangent of *x* in radians
Math.atan2(y, x)	Counterclockwise angle between the positive X-axis and the point *x,y* in radians
Math.ceil(x)	Rounds up *x* to the next integer
Math.cos(x)	Cosine of *x*
Math.floor(x)	Rounds down *x* to the next integer
Math.max(args)	The maximum value of the input arguments
Math.min(args)	The minimum value of the input arguments
Math.PI	The value of PI, approximately 3.14159
Math.pow(x, y)	*x* raised to the power of *y*
Math.round(x)	Rounds *x* to the nearest integer
Math.sin(x)	Sine of *x*
Math.sqrt(x)	Square root of *x*
Math.tan(x)	Tangent of *x*
Math.NaN	The value corresponding to the not-a-number property

Math Object

```
a = Math.sqrt(4);               // a = 2
a = Math.round(4.59);           // a = 5
a = Math.floor(4.59);           // a = 4
a = Math.PI;                    // a = 3.14159
a = Math.cos(toRad(45));        // a = .7071
a = toDeg(Math.acos(.866));     // a = 60
```
Sample Math Object Output

The Math trigonometric functions all work in radians. As a matter of fact, most functions that pass angles in the post processor work in radians. There are kernel supplied functions that are available for converting between radians and degrees. *toDeg(x)* returns the degree equivalent of the radian value *x* and conversely the *toRad(x)* function returns the radian equivalent of the degree value *x*.

There are also standalone numeric functions that are not part of the Number of Math objects. These are listed in the following table.

Function	Return value
parseFloat(value)	Parses *value* as a string argument and returns a real number. Returns NaN if the string does not represent a valid number.
parseInt(value, radix)	Parses *value* as a string argument and returns an integer of the specified radix. *radix* is typically defined as 10, but can be 2, 8, 16, etc. Returns NaN if the string does not represent a valid integer.
spatial(value, unit)	Returns *value* converted to MM. *unit* specifies the units that *value* is defined in and can be either MM or IN. The unit conversion scale used is 25mm to 1in and not 25.4. This conversion creates a more acceptable scaled value for display, for example 4in scales to 100mm instead of 101.6mm. The spatial function is typically used to define the Built-in properties at the top of the post processor, since they are referenced as MM in the post engine.
toPreciseUnit(value, unit)	Returns *value* converted to the output units. *unit* specifies the units that *value* is defined in and can be either MM or IN A scale factor of 25.4mm to 1in is used.
toUnit(value, unit)	Returns *value* converted to the output units. *unit* specifies the units that *value* is defined in and can be either MM or IN. The unit conversion scale used is 25mm to 1in and not 25.4.

Other Numeric Functions

3.3.2 Strings

Variables assigned a text string will create a *String* object, which contain a full complement of functions that can be used to manipulate the string. These functions are specific to strings and are listed in the following table. The table details the basic usage of these functions as you would use them in a post processor. Some of the functions accept a *RegExp* object which is not covered in this manual, please refer to dedicated JavaScript manual for a description of this object.

Function	Description	Returns
charAt(n)	Returns a single character at position *n*	The *nth* character
indexOf(substring, start)	Finds the *substring* within the string. *start* is optional and specifies the starting location within the string to start the search at.	The location of the first occurrence of *substring* within the string.
lastIndexOf(substring, start)	Finds the last occurrence of *substring* within the string. *start* is optional and specifies the starting location within the string to start the search at.	The location of the last occurrence of *substring* within the string.
length	Returns the length of the string. *length* is not a function, but rather a property of a string and does not use () in its syntax.	The length of the string
localeCompare(target)	Compares the string with *target* string.	A negative number if *string* is less than *target*, 0 if the strings are identical, and a positive number if *string* is greater than *target*

Function	Description	Returns
replace(pattern, replacement)	Replaces the *pattern* text within the string with the *replacement* text.	The updated string.
slice(start, end)	Creates a substring from the string consisting of the *start* character up to, but not including the *end* character of the string.	A substring containing the text from *string* starting at *start* and ending at *end*-1. A negative value for *start* or *end* specifies a position from the end of the *string*; -1 is the last character, -2 is the second to last character, etc.
split(delimiter, limit)	Splits a string at each occurrence of the *delimiter* string.	An array of strings created by splitting *string* into substrings at the delimiter. A maximum of *limit* substrings will be created.
toLocaleLowerCase()	Converts the string to all lowercase letters in a locale-specific method.	Lowercase string.
toLocaleUpperCase()	Converts the string to all uppercase letters in a locale-specific method.	Uppercase string.
toLowerCase()	Converts the string to all lowercase letters.	Lowercase string.
toUpperCase()	Converts the string to all uppercase letters.	Uppercase string.

String Object Functions

```
var a = "First, Second, Third";
b = a.charAt(3);                  // b = "s"
b = a.indexOf("Second");          // b = 7
b = a.length;                     // b = 20
b = a.localeCompare("ABC");       // b = 5;
b = a.replace(/,/g, "-");         // b = "First- Second- Third"
b = a.slice(0, -7);               // b = "First, Second"

b = a.split(",");                 // b[0] = "First", b[1] = "Second", b[2] = "Third";
b = a.toLowerCase() ;             // b = "first, second, third"
b = a.toUpperCase();              // b = "FIRST, SECOND, THIRD"
```

Sample String Output

3.3.3 Booleans

Booleans are the simplest of the variable types. They contain a value of either *true* of *false*, which are JavaScript keywords.

```
var a = true; // 'a' is defined as a boolean
if (a) {
  // processes the code in this if block since 'a' is 'true'
}
```

Sample Boolean Assignment

3.3.4 Arrays

An array is a composite data type that stores values in consecutive order. Each value stored in the array is considered an element of the array and the position within an array is called an index. Each element of an array can be any variable type and each element can have a different variable type than the other elements in the array.

An array, like numbers and strings, are considered an object with functions associated with it. You can define an array using two different methods, as an empty array using a new *Array* object, or by creating an array literal with defined values for the array. You can specify the initial size of the array when defining an *Array* object. The initial size of an array defined with values is the number of values contained in the initialization.

```
var a = new Array();                           // creates a blank array, all values are assigned undefined
var a = new Array(10);                         // creates a blank array with 10 elements
var a = [true, "a", 3.17];                     // creates an array with the first 3 elements assigned
var a = [{x:1, y:2}, {x:3, y:4}, {x:5, y:6}];  // creates an array of 3 xy objects
```

Array Definitions

You can access an array element by using the [ ] brackets. The name of the array will appear to the left of the brackets and the index to the element within the array inside of the brackets. The index can be a simple number or an equation.

```
var a = [1, 2, "text", false];
b = a[0];          // b = 1
a[5] = "next";   // a = [1, 2, "text", false, "next"]
b = a[2+a[0]];  // b = false;
```

Accessing Elements Within an Array

The *Array* object has the following functions associated with it.

Function	Description	Returns
concat(values)	Appends the values to an array.	Original array with concatenated elements
join(separator)	Combines all elements of an array into a string. *separator* is optional and specifies the string used to separate the elements of the array. The default is a comma.	String containing array elements.
length	Returns the allocated size of the array. *length* is not a function, but rather a property of an array and does not use () in its syntax.	The size of the array.
pop()	Pops the last element from the array and decreases the size of the array by 1.	The value of the last element of the array.
push(values)	Pushes the *values* onto the array and increases the size of the array by the number of *values*.	Updated size of array.

Function	Description	Returns
reverse()	Reverses the order of the elements of the array.	Returns nothing, but rather modifies the original array.
shift(values)	Removes the first element from the array and decreases the size of the array by 1.	The value of the first element of the array.
slice(start, end)	Creates a new array consisting of the *start* element up to, but not including the *end* element of the array.	An array containing the elements from *array* starting at *start* and ending at *end*-1. A negative value for *start* or *end* specifies a position from the end of the *array*; -1 is the last element, -2 is the second to last element, etc.
sort(function)	Sorts the elements of the array. The original array will be modified. The sort method uses an alphabetical order of elements converted to strings by default. You can specify a function that overrides the default sorting algorithm.	The sorted array.
toLocaleString()	Format an array according to locale conventions	String representation of array
toString	Format an array	String representation of array
unshift()	Adds the *values* to the beginning of an array and increases the size of the array by the number of *values*.	Updated size of array.

Array Object Functions

```
var a = [1, 2, 3, 4, 5, 6, 7, 8];
b = a.concat(9, 10, 11);    // b = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
b = a.join(", ");           // b = "1, 2, 3, 4, 5, 6, 7, 8"
b = a.length;               // b = 8
a.push(9, 10, 11)           // a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
b = a.pop();                // a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10], b = 10
a.reverse();                // a = [10, 9, 8, 7, 6, 5, 4, 3, 2, 1]
b = a.unshift(12, 11);      // a = [12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1], b = 12
b = a.shift();              // a = [11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1], b = 12
b = a.slice(4, 7);          // b = [7, 6, 5]
a.sort(function(a, b) {     // a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
    return a-b;
  });
b = a.toString()            // b = "1,2,3,4,5,6,7,8,9,10,11"
```

Sample Array Output

3.3.5 Objects

An *Object* is similar to an array in that it stores multiple values within a single variable. The difference is that objects use a name for each sub-entity rather than relying on an index pointer into an array. The *properties* table in a post processor is an object. You can define an object using two different methods, explicitly using the *Object* keyword, or implicitly by creating an object literal with defined names and values for the object. Each named entity within an object can be any type of variable, number, string, array, boolean, and another object. Objects can also be stored in an array.

Objects can be expanded to include additional named elements at any time and are not limited to the named elements when they are created. You can reference the elements within an object using either the name of the element (object.element) or by using a text string or variable (object["element"]) as the name of the element. The following examples all reference the *moveTime* element of the *status* object.

```
var status = {moveDistance:0, moveTime:0, feedrate:0};
…
writeln("Move time = " + status.moveTime);
writeln("Move time = " + status["moveTime"];
var element = "moveTime";
writeln("Move time = " + status[element];
```

Referencing Elements Within an Object

```
var a = new Object();                        // creates a blank object, without named elements
var a = {x:1, y:2, z:3};                     // creates an object for storing coordinates
a.feed = 10.0;                               // adds the 'feed' element to the 'a' Object
a["feed"] = 10.0;                            // an alternate method for referencing the 'feed' element.
var a = [{x:1, y:2}, {x:3, y:4}, {x:5, y:6}]; // creates an array of 3 xy objects
```

Object Definitions

There is a difference between assigning an existing object to a different variable and copying the contents of an object. A direct assignment will point the assigned variable to the object but will not make a copy of the object. To copy the contents of an object into another object, you can either copy the contents manually or use the JSON.parse function.

```
var a = {x:1, y:2, z:3};                     // creates an object for storing coordinates
var b = a;                                   // 'b' and 'a' point to the same object
 a.x = 3.5;                                  // both 'a.x' and 'b.x' will be set to 3.5

 b = {x:a.x, y:a.y, z:a.z};                  // 'a' and 'b' are separate objects (manual assignment)
 a.x = 4.2;                                  // only 'a.x' is set to 4.2.

 b = JSON.parse(JSON.stringify(a));          // the contents of 'a' are copied into 'b'
```

Copying Objects

3.3.6 The Vector Object

The *Vector* object is built-in to the post processor and is used to store and work with vectors. The vector components are stored in the *x, y, z* elements of the *Vector* object. Certain post processor variables are stored as vectors and some functions require vectors as input. A *Vector* object is created in the same manner as any other object. *Vector* objects are typically used to store and work on vectors, spatial points, and rotary angles.

```
var a = new Vector();                   // creates a blank Vector object
var a = new Vector(1, 0, 0);            // creates an X-axis vector {x:1, y:0, z:0}
a.x = -1;                               // assigns -1 to the x element of the vector
setWorkPlane(new Vector(0, 0, 0));      // defines a null vector inline
```

Sample Vector Definitions

The following tables describe the attributes and functions contained in the *Vector* object. Since an attribute is simply a value contained in the *Vector* object, it does not have an argument.

Attribute	Description
abs	Contains the absolute coordinates of the vector
length	Contains the length of the vector
length2	Contains the length of the vector squared
negated	Contains the negated vector
normalized	Contains the normalized/unit vector
x	Contains the X-component
y	Contains the Y component
z	Contains the Z component

Vector Attributes

You can directly modify an attribute of a vector, but if you do then the remaining attributes will not be updated. For example, if you directly store a value in the *x* attribute, *vec.x = .707*, the *length* attribute of the vector will not be updated. You should use the *vec.setX(.707)* method instead.

If the Returns column in the following table has *Implicit*, then there is no return value, rather the *Vector* object associated with the function is modified implicitly. For this reason, if you are going to nest a *Vector* function within an expression, do not use the Implicit function, but rather the equivalent function that returns a vector.

Functions that take a *tolerance* argument can specify the tolerance as a real value, for example 0.0001, or as an integer value, for example 4. If *tolerance* is an integer value, then the vector(s) will be truncated to the number of digits to the right of the decimal point specified by *tolerance* prior to the comparison. *tolerance* is always optional and does not have to be specified.

Function	Description	Returns
divide(value)	Divides each component of the object vector by the value	Implicit
getCoordinate(coordinate)	Returns the value of the vector component (0=x, 1=y, 2=z)	Component of vector
getMaximum()	Determines the largest component value in the vector	Maximum component value
getMinimum()	Determines the minimum component value in the vector	Minimum component value

Function	Description	Returns
getNegated()	Calculates the negated vector	Vector at 180 degrees to the object vector (vector * -1)
getNormalized()	Calculates the normalized/unit vector	Normalized or unit vector
getX()	Returns the X-coordinate of the vector	X-coordinate
getXYAngle()	Calculates the angle of the vector in the XY-plane	Angle of vector in XY-plane
getY()	Returns the Y-coordinate of the vector	Y-coordinate
getZ()	Returns the Z-coordinate of the vector	Z-coordinate
getZAngle()	Calculates the Z-angle of the vector relative to the XY-plane	Z-angle of vector relative to the XY-plane
isNonZero(tolerance)	Determines if the vector has a nominal length.	*true* if the vector has a nominal length.
isZero(tolerance)	Determines if the vector is a null vector (0,0,0).	*true* if it is a null vector
multiply(value)	Multiplies each component of the vector by the value	Implicit
negate()	Multiplies each component of the vector by -1. Creates a vector at 180 degrees to the object vector	Implicit
setCoordinate(coordinate, value)	Sets the value of the vector component (0=x, 1=y, 2=z)	Implicit
setX()	Sets the X-coordinate of the vector	Implicit
setY()	Sets the Y-coordinate of the vector	Implicit
setZ()	Sets the Z-coordinate of the vector	Implicit
toDeg()	Converts radians to degrees	Angles in degrees
toRad()	Converts degrees to radians	Angles in radians
toString()	Formats the vector as a string, e.g. "(1, 2, 3)"	String representation of vector

Vector Object Functions

Static functions do not require an associated Vector object.

Function	Description	Returns
Vector.areDifferent(v1, v2, tolerance)	Determines if 2 vectors are different.	*true* if the vectors are different.
Vector.areParallel(v1, v2, tolerance)	Determines if 2 vectors are parallel.	*true* if the vectors are parallel.
Vector.arePerpendicular(v1, v2, tolerance)	Determines if 2 vectors are perpendicular.	*true* if the vectors are perpendicular.
Vector.areSameDirection(v1, v2, tolerance)	Determines if 2 vectors are in the same direction.	*true* if the vectors have the same direction.
Vector.cross(left, right)	Calculates the cross product of two vectors	Vector perpendicular to the two vectors
Vector.diff(left, right)	Calculates the difference between two vectors	Left vector minus right vector
Vector.dot(left, right)	Calculates the dot product of the two vectors	Cosine of angle between the two vectors

Function	Description	Returns
Vector.getAbsolute()	Converts the vector components to absolute values	Vector with absolute coordinates
Vector.getAngle()	Calculates the angle between two vectors	Angle between the two vectors in radians
Vector.getDistance(left, right)	Calculates the distance between two vectors. Typically used when the vectors store XYZ spatial coordinates rather than vectors.	Distance between two points.
Vector.getDistance2(left,right)	Calculates the square of the distance between two vectors.	Squared distance between two points.
Vector.lerp(left, right, u)	Calculates a point at a percentage of the distance between the two coordinates. 'u' specifies the percentage of the distance to create the point at.	Point at a percentage of the line between two points.
Vector.pointLineDistance(point, start, end)	Calculates the distance between a point and an infinite as defined as going through the *start* and *end* points.	The distance from the point to the infinite line.
Vector.pointPlaneDistance(point, planePoint, planeNormal)	Calculates the distance between a point and a plane as defined by a point on the plane and its normal vector.	The distance from the point to the plane.
Vector.pointSegmentDistance(point, start, end)	Calculates the distance between a point and a line segment as defined by its *start* and *end* points.	The distance from the point to the line segment.
Vector.product(vector, value)	Multiplies each component of the vector by the value	A vector as the product of *vector* times *value*.
Vector.projectPointToLine(point, start, end)	Projects a point to an infinite line as defined going through the *start* and *end* points.	The projected point on the infinite line.
Vector.projectPointToPlane(point, planePoint, planeNormal)	Projects a point to a plane as defined by a point on the plane and its normal vector.	The projected point on the plane.
Vector.sum(left, right)	Adds the two vectors	Left vector plus right vector
Vector.translatePoint(point, vector, distance)	Translates a point along a vector by a specified distance.	A point that is translated from the first point along a vector at a distance.

Static Vector Functions

```
b = a.length();                                   // b = length of Vector a
c = Vector.getAngle(a, b)                         // c = angle in radians between vectors a and b
var a = new Vector(1, 2, 1.5);
d = a.getMaximum();                               // d = 2
b = Vector.getDistance(point1, point2).normalized; // b = directional vector from point1 to point2
b = Vector.dot(vector1, vector2);                 // b = cosine of angle between vector1 & vector2
b = a.negated;                                    // b = vector at 180 degrees to  Vector a
```

Sample Vector Expressions

3.3.7 The Matrix Object

The *Matrix* object is built-in to the post processor and is used to store and work with matrices. Matrices are normally used when working with multi-axis machines, for 3+2 operations and for adjusting the coordinates for table rotations. Matrices in the post processor contain only the rotations for each axis and do not contain translation values.

Certain post processor variables are stored as matrices, such as the *workPlane* variable, and some functions require matrices as input. A *Matrix* object has functions that can be used when creating the matrix and are not dependent on working with an existing matrix.

Assignment Function	Definition
Matrix()	Identity matrix (1,0,0, 0,1,0, 0,0,1)
Matrix(i1, j1, k1, i2, j2, k2, i3, j3, k3)	Canonical matrix
Matrix(scale)	Scale matrix
Matrix(right, up, forward)	Matrix using 3 vectors
Matrix(vector, angle)	Rotation matrix around the vector

Matrix Assignment Functions

```
var a = new Matrix();                              // creates an identity matrix
var a = new Vector(-1, 0, 0, 0,-1,0, 0,0, 1);      // creates a matrix rotated 180 degrees in the XY-plane
var a = new Matrix(.5);                            // creates a half scale matrix
var a = new Matrix(new Vector(1, 0, 0), 30);  // creates an X-rotation matrix of 30 degrees
```

Sample Matrix Definitions

The following tables describe the attributes and functions contained in the *Matrix* object. Since an attribute is simply a value contained in the Matrix object, it does not have an argument.

Attribute	Description
forward	Contains the forward vector
n1	Contains the length of the row vectors of this matrix
n2	Contains the square root of this matrix vector lengths
negated	Contains the negated matrix
right	Contains the right vector
transposed	Contains the inverse matrix
up	Contains the up vector

Matrix Attributes

You can directly modify an attribute of a matrix, but if you do then the remaining attributes will not be updated. For example, if you directly store a vector in the *forward* attribute, the other attributes will not be updated to reflect this modification. You should use the *matrix.setForward(vector)* method instead.

If the Returns column in the following table has *Implicit*, then there is no return value, rather the *Matrix* object associated with the function is modified implicitly. For this reason, if you are going to nest a *Matrix* function within an expression, do not use the Implicit function, but rather the equivalent function that returns a matrix.

Function	Description	Returns
add(matrix)	Adds the specified matrix to this matrix	Implicit
getColumn(column)	Retrieves the matrix column as a vector	Vector containing the specified column of this matrix
getElement(row, column)	Retrieves the matrix element as a value	Value of this matrix element
getEuler2(convention)	Calculates the angles for the specified Euler convention	Vector containing Euler angles of this matrix. Refer to the *Work Plane* section of the manual for a description of Euler conventions.
getForward()	Returns the forward vector. This will be 0,0,1 in an identity matrix	Forward vector of this matrix
getN1()	Returns the length of the row vectors of this matrix	Returns right_vector + up_vector + forward_vector of matrix
getN2()	Returns the square root of this matrix vector lengths	Math.sqrt(n1)
getNegated()	Calculates the negated matrix	Matrix * -1.
getRight()	Returns the right vector. This will be 1,0,0 in an identity matrix	Right vector of matrix
getRow(row)	Retrieves the matrix row as a vector	Vector containing the specified row of this matrix
getTiltAndTilt(first, second)	Calculates the X & Y rotations around the fixed frame to match the forward direction. 'first' and 'second' can be 0 or 1 and must be different.	Calculated forward direction of this matrix
getTransposed()	Returns the transposed (inverse) of the matrix	Inversed matrix
getTurnAndTilt(first, second)	Calculates the X, Y, Z rotations around the fixed frame to match the forward direction. 'first' and 'second' can be 0, 1, or 2 and must be different.	Calculated forward direction
getUp()	Returns the up vector. This will be 0,1,0 in an identity matrix	Right vector of matrix
isIdentity()	Determines if the matrix is an identity matrix (1,0,0, 0,1,0, 0,0,1).	True if it is an identity matrix
isZero()	Determines if the matrix is a null matrix (0,0,0, 0,0,0, 0,0,0)	True if it is a null matrix
multiply(value)	Multiplies each component of the matrix by the value	Result of matrix times specified value
multiply(matrix)	Multiplies the matrix by the specified matrix	Results of matrix times specified matrix
multiply(vector)	Multiplies the specified vector by the matrix	Vector multiplied by the matrix
negate()	Calculates the negated matrix	Implicit
normalize()	Calculates the negated matrix	Implicit

Function	Description	Returns
setColumn(column, vector)	Sets the matrix column as a vector	Implicit
setElement(row, column, vector)	Sets the matrix element	Implicit
setForward(vector)	Sets the forward vector	Implicit
setRight(vector)	Sets the right vector	Implicit
setRow(row, vector)	Sets the matrix row as a vector	Implicit
setUp(vector)	Sets the up vector	Implicit
subtract(matrix)	Subtracts the specified matrix from this matrix	Implicit
toString()	Formats the matrix as a string, e.g. "[[1, 0, 0], [0, 1, 0], [0, 0, 1]]"	String representation of matrix
transpose()	Creates the transposed/inverse of this matrix	Implicit

Matrix Functions

Static functions do not require an associated *Matrix* object.

Function	Description	Returns
Matrix.diff(left, right)	Calculates the difference between two matrices	Left matrix minus right matrix
Matrix.getAxisRotation(vector, angle)	Calculates a rotation matrix	Rotation matrix of 'angle' radians around the axis 'vector'
Matrix.getOrientationFromDirection(forward)	Calculates a matrix based on a forward vector.	The up and right vectors of the calculated matrix will be perpendicular to the forward vector and each other, but the direction of each is undefined since only a single vector is provided to the function.
Matrix.getXRotation(angle)	Calculates a rotation matrix around the X-axis	Rotation matrix of 'angle' radians around the X-axis
Matrix.getXYZRotation(abc)	Calculates the rotation matrix for the given angles	Rotation matrix that satisfies the specified XYZ rotations
Matrix.getYRotation(angle)	Calculates a rotation matrix around the Y-axis	Rotation matrix of 'angle' radians around the Y-axis
Matrix.getZRotation(angle)	Calculates a rotation matrix around the Z-axis	Rotation matrix of 'angle' radians around the Z-axis
Matrix.sum(left,right)	Adds the two matrices	Left matrix plus right matrix

Static Matrix Functions

```
var abc = m.getEuler2(EULER_ZXZ_R);              // abc = ZXZ Euler angles for m
var t = m.getTransposed();                       // t = inverse/transposed matrix of m
var fwd = m.getForward();                        // fwd = forward (Z) vector of matrix m
var v = new Vector(0, 0, 1);
var q = m.multiply(v);                           // q = transformation of v though matrix m
var r = Matrix.getZRotation(toDeg(30));          // r = matrix rotated 30 degrees about Z
```

Sample Matrix Expressions

3.3.8 Deferred Variables

Deferred variables are used to output values to the NC file prior to them being defined. For example, you could calculate the cutting time or travel distance for each tool while processing the intermediate file and then reference these values in the tool list that is output at the header of the NC file. This is accomplished by defining the deferred variables during the normal processing of the intermediate file and using the deferred variables in an output string at a place that is processed prior to the processing of the section of the intermediate file that defines the deferred variables.

The way that deferred variables work is by using text substitution in the output NC file. The initial text string output to the NC file will include the name of the deferred variable enclosed by the defined separator for defined variables, for example ##id##. After all processing is finished, the post engine will scan the output NC file for the deferred variable text and replace it with the value stored in the deferred variable. It is important to know this procedure, since deferred variables cannot be accessed before they are defined in the post processor, the same as any other variable, except for when they are output to the NC file.

Deferred variables are stored in the DeferredVariables object, which has the following properties. The deferred variable properties are referenced as DeferredVariables.*property*.

DeferredVariables Propery/Function	Description
separator	Defines the prefix and suffix that will be added to the deferred variable name when the deferred variable is initially output to the NC file. This should be a unique string that is not normally seen in the NC file. The default is "##".
get(id, format)	Retrieves the deferred variable named *id* and formats it for output using the provided *format* as created by *createFormat*.
set(id, value)	Assigns *value* to the deferred variable named *id*. *value* must be numeric, it cannot be a text string, boolean, or an object.
isDefined(id)	Returns *true* if the deferred variable named *id* has been defined or *false* if it has not. Remember that the deferred variable is defined during the normal processing of the intermediate file, so if you call *isDefined* where the deferred variable is being output prior to processing the deferred variable definition, it will return *false*.

Deferred Variables

The following sample code will calculate the cutting time for each tool for linear, circular, and canned cycle moves. It will output these times in the tool list located in the header of the NC file.

```
// collected state
var toolTime = new Array();  // define an array to store the tool cutting times.
```

Define the Tool Times Array

```
function onOpen() {
  DeferredVariables.separator = "^&^"; // define a unique marker for deferred variables
…
    var tools = getToolTable();
    if (tools.getNumberOfTools() > 0) {
      for (var i = 0; i < tools.getNumberOfTools(); ++i) {
        var tool = tools.getTool(i);
        var comment = "T" + toolFormat.format(tool.number) + " " +
          "D=" + xyzFormat.format(tool.diameter) + " " +
          localize("CR") + "=" + xyzFormat.format(tool.cornerRadius);
        if ((tool.taperAngle > 0) && (tool.taperAngle < Math.PI)) {
          comment += " " + localize("TAPER") + "=" + taperFormat.format(tool.taperAngle) +
              localize("deg");
        }
        if (zRanges[tool.number]) {
          comment += " - " + localize("ZMIN") + "=" +
              xyzFormat.format(zRanges[tool.number].getMinimum());
        }
        comment += " - " + localize("TIME") + "=" +
            DeferredVariables.get("tool" + tool.number, xyzFormat); // Output cutting time for tool
        comment += " - " + getToolTypeName(tool.type);
        writeComment(comment);
      }
    }
```

Output Tool Cutting Times in onOpen

```
function onSection() {
…
    writeToolBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
    if (tool.comment) {
      writeComment(tool.comment);
    }
    // initialize the cutting time if not previously defined
    toolTime[tool.number] = toolTime[tool.number] ? toolTime[tool.number] : 0;
```

Initialize the Tool Cutting Time in onSection

```
function moveIsCutting() {
  return movement == MOVEMENT_CUTTING ||
      movement == MOVEMENT_FINISH_CUTTING ||
      movement == MOVEMENT_REDUCED;
}
```

Determine if this Move is a Cutting Move

```
function onCyclePoint(x, y, z) {
```

```
…
  // calculate the canned cycle cutting time
  if (!cycleExpanded) {
    toolTime[tool.number] += Math.abs(cycle.bottom - cycle.stock) / cycle.feedrate;
  }
}
```

Calculate the Canned Cycle Cutting Time in onCyclePoint

```
function onLinear(_x, _y, _z, feed) {
  // calculate linear cutting time
  if (moveIsCutting()) {
    toolTime[tool.number] += Vector.diff(new Vector(_x, _y, _z), getCurrentPosition()).length /
        feed;
  }
```

Calculate Linear Moves Cutting Time in onLinear

```
function onCircular (clockwise, cx, cy, cz, x, y, z, feed) {
..
  // calculate circular cutting time
  // be sure to return directly after any calls to linearize or time will be calculated twice
  if (moveIsCutting()) {
    toolTime[tool.number] += getCircularArcLength() / feed;
  }
}
```

Calculate Circular Moves Cutting Time in onCircular

```
function onSectionEnd() {
  DeferredVariables.set("tool" + tool.number, toolTime[tool.number]);
```

Assign the Tool Cutting Time to the Deferred Variable

3.4 Expressions

Variables can be assigned a simple value or text string or can be more complex in nature containing a list of variables or literals and operators that perform operations on the values contained in the expression. The following table lists the common operators supported by JavaScript. and provides samples using the operators. The operator precedence is also listed (column P), where the operators with a higher precedence number are performed prior to the operators of a lower precedence number. Operators with the same precedence number will calculate in the order that they appear in the expression.

Unary operators only require a single operand instead of two. For example, *y = x++* will increment the variable *x* after it is assigned to the variable *y*.

P	Operator	Operands	Description
13	()	Expression	Overrides the assigned precedence of operators
12	++	Integer	Unary increment

<table>
<tr><th>P</th><th>Operator</th><th>Operands</th><th>Description</th></tr>
<tr><td></td><td>--</td><td>Integer</td><td>Unary decrement</td></tr>
<tr><td></td><td>~</td><td>Integer</td><td>Unary bitwise complement</td></tr>
<tr><td></td><td>!</td><td>Boolean</td><td>Unary logical complement (not)</td></tr>
<tr><td>11</td><td>*</td><td>Number</td><td>Multiplication</td></tr>
<tr><td></td><td>/</td><td>Number</td><td>Division</td></tr>
<tr><td></td><td>%</td><td>Number</td><td>Remainder</td></tr>
<tr><td>10</td><td>+</td><td>Number, String</td><td>Addition</td></tr>
<tr><td></td><td>-</td><td>Number</td><td>Subtraction</td></tr>
<tr><td>9</td><td><<</td><td>Integer</td><td>Bitwise shift left</td></tr>
<tr><td></td><td>>></td><td>Integer</td><td>Bitwise shift right</td></tr>
<tr><td>8</td><td><</td><td>Number, String</td><td>Less than</td></tr>
<tr><td></td><td><=</td><td>Number, String</td><td>Less than or equal to</td></tr>
<tr><td></td><td>></td><td>Number, String</td><td>Greater than</td></tr>
<tr><td></td><td>>=</td><td>Number, String</td><td>Greater than or equal to</td></tr>
<tr><td>7</td><td>==</td><td>Any</td><td>Equal to</td></tr>
<tr><td></td><td>!=</td><td>Any</td><td>Not equal to</td></tr>
<tr><td></td><td>===</td><td>Any</td><td>Equal to and same variable type</td></tr>
<tr><td></td><td>!==</td><td>Any</td><td>Not equal to and same variable type</td></tr>
<tr><td>6</td><td>&</td><td>Integer</td><td>Bitwise AND</td></tr>
<tr><td>5</td><td>^</td><td>Integer</td><td>Bitwise XOR</td></tr>
<tr><td>4</td><td>|</td><td>Integer</td><td>Bitwise OR</td></tr>
<tr><td>3</td><td>&&</td><td>Boolean</td><td>Logical AND</td></tr>
<tr><td>2</td><td>||</td><td>Boolean</td><td>Logical OR</td></tr>
<tr><td>1</td><td>=</td><td>Any</td><td>Assignment</td></tr>
<tr><td></td><td>+=</td><td>Number, String</td><td>Assignment with addition</td></tr>
<tr><td></td><td>-=</td><td>Number</td><td>Assignment with subtraction</td></tr>
<tr><td></td><td>*=</td><td>Number</td><td>Assignment with multiplication</td></tr>
<tr><td></td><td>/=</td><td>Number</td><td>Assignment with division</td></tr>
</table>

Expression Operators

<table>
<tr><th>x</th><th>y</th><th>Expression</th><th>Result</th><th>Expression</th><th>Result</th></tr>
<tr><td>3</td><td>5</td><td>z = x + y * 3</td><td>18</td><td>z = (x + y) * 3</td><td>24</td></tr>
<tr><td></td><td></td><td>z = ++x</td><td>z = 4, x = 4</td><td>z = x++</td><td>z = 3, x = 4</td></tr>
<tr><td></td><td></td><td>x += y</td><td>8</td><td>x *= y</td><td>15</td></tr>
<tr><td></td><td></td><td>z = y / x</td><td>1.667</td><td>z = y % x</td><td>2.0</td></tr>
<tr><td>"Start"</td><td>"-End"</td><td>z = x + y</td><td>"Start-End"</td><td>x += y</td><td>"Start-End"</td></tr>
<tr><td>2</td><td>3</td><td>z = x & y</td><td>2</td><td>z = x | y</td><td>3</td></tr>
<tr><td>1</td><td>"1"</td><td>z = x == y</td><td>true</td><td>x === y</td><td>false</td></tr>
<tr><td>true</td><td>false</td><td>z = x</td><td>true</td><td>z = !y</td><td>true</td></tr>
<tr><td></td><td></td><td>z = x || y</td><td>true</td><td>z = x && y</td><td>false</td></tr>
</table>

Sample Expressions

3.5 Conditional Statements

Conditional statements are commands or functions that will test the results of an expression and then process statements based on the outcome of the conditional. Conditionals typically check Boolean type expressions, but can also be used to test if a value is *undefined* or a string is blank.

This section describes the conditional statements and functions used when developing a post processor. Some of the conditionals are supported by JavaScript and others are inherent in the post processor kernel.

3.5.1 The if Statement

The *if* statement is the most common method for testing a conditional and executing statements based on the outcome of the test. It can contain a single body of statements to execute when the expression is true, a second body of statements to execute when the expression is false, or it can contain multiple conditionals that are checked in order using the *else if* construct.

As with all commands that affect a body of code, *if* statements can be nested inside of other *if* bodies and loops.

The syntax of *if* statements should follow the Autodesk standard of always including the {} brackets around each body of code, specifying the opening bracket ({) on the conditional line, and the closing bracket (}) at the start of the line following the body of code for each section as shown in the following examples.

```
if (conditional1) {
  // execute code if conditional1 is true
}

if (conditional1) {
  // execute code if conditional1 is true
} else {
  // execute code if conditional1 is false
}

if (conditional1) {
  // execute code if conditional1 is true
} else if (conditional2) {
  // execute code if conditional1 is false and conditional2 is true
} else {
  // execute code if all conditionals are false
}
```

If Statement Syntax

```
if (hasParameter("operation-comment")) {
```

```
  comment = getParameter("operation-comment");
}

if (isProbeOperation()) {
  var workOffset = probeOutputWorkOffset ? probeOutputWorkOffset : currentWorkOffset;
  if (workOffset > 99) {
    error(localize("Work offset is out of range."));
    return;
  } else if (workOffset > 6) {
    probeWorkOffsetCode = probe100Format.format(workOffset - 6 + 100);
  } else {
    probeWorkOffsetCode = workOffset + "."; // G54->G59
  }
}
```

Sample If Statements

3.5.2 The switch Statement

The *switch* statement is similar to an *if* statement in that it causes a branch in the flow of a program's execution based on the outcome of a conditional. *switch* statements are typically used when checking the value of a single variable, whereas *if* conditionals can test complex expressions.

The syntax of *switch* bodies will contain a single switch statement with a variable whose value determines the code to be executed. *case* statements will be included in the *switch* body, with each one containing the value that causes its body of code to be executed. The end of each *case* body of code must have a *break* statement so that the next *case* body of code is not executed. A *default* statement can be defined that contains code that will be executed if the *switch* variable does not match any of the *case* values.

case statements should follow the Autodesk standard of always including specifying the opening bracket ({) on the *switch* line, and the closing bracket (}) at the start of the line at the end of the body of code for each section. The *case* statements will be aligned with the *switch* statement and all code within each *case* body will be indented.

```
switch (variable) {
case value1:
  // execute if variable = value1
  break;
case value2:
  // execute if variable = value2
case value3:
  // execute if variable = value3
default:
  // execute if variable does not equal value1, value2, or value3
  break;
}
```

Switch Block Syntax

```
switch (coolant) {
  case COOLANT_FLOOD:
    m = 8;
    break;
  case COOLANT_THROUGH_TOOL:
    m = 88;
    break;
  case COOLANT_AIR:
    m = 51;
    break;
  default:
    onUnsupportedCoolant(coolant);
  }
}
```

Sample Switch Blocks

3.5.3 The Conditional Operator (?)

The ? conditional operator tests an expression and returns different values based on whether the expression is true or false. It is a compact version of a simple *if* block and is used in an assignment type statement or as part of an expression.

```
var a = conditional ? true_value : false_value;
```

? Conditional Operator

In the above syntax, *a* will be assigned *true_value* if the conditional is true, or *false_value* if it is false.

```
homeGcode = getProperty("useG30") ? 30 : 28;

// could be expanded into this if block
if (getProperty("useG30")) {
  homeGcode = 30;
} else {
  homeGcode = 28;
}
```

Sample ? Conditional Operator

3.5.4 The typeof Operator

The *typeof* operator is not a conditional operator per the general terminology, but it is always used as a part of a conditional to determine if a function or variable exists. When used in an expression it will return a string that describes the variable type of the operand. This is the only way to test if a function exists prior to calling the function or if a variable exists before referencing it. If you try to reference a non-existent variable or function without testing to see if it exists first, the post processor will terminate with an error.

The *typeof* operator is followed by a single operand name, i.e. "typeof variable". It can return the following string values.

Operand Type	Return Values
number	"number"
string	"string"
boolean	"boolean"
object, array, null	"object"
function	"function"
undefined	"undefined"

typeof Return Values

```
if ((typeof getHeaderVersion == "function") && getHeaderVersion()) {
  writeComment(localize("post version") + ": " + getHeaderVersion());
}
```

Sample typeof Usage

3.5.5 The conditional Function

The *conditional* function will test an expression and if it is true will return the specified value. If the expression is false, then a blank string is returned. The *conditional* function is mainly used for determining if a specific code should be output in a block.

```
conditional(expression, true_value)
```

conditional Syntax

```
writeBlock(
  gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(82),
  getCommonCycle(x, y, z, cycle.retract),
  conditional(P > 0, "P" + milliFormat.format(P)), //optional
  feedOutput.format(F)
);
```

conditional Usage

Since *conditional* is a function, any function calls contained in the arguments will be processed even if the expression equates to false. This means that if a modal is used to format a value, the value will be formatted prior to evaluating the expression and the modal's current value will be set using this value, even if the value is not output.

```
writeBlock(conditional(isRapid, gMotionModal.format(0)), x, y, z);
```

Sets the gMotionModal Modal Value to 0 Even when isRapid is false and G00 is not Output

3.5.6 try / catch

The *try/catch* block is an exception handling mechanism. This allows the post processor to control the outcome of an exception. Depending on the exception that is encountered, the JavaScript code could continue processing or terminate with an error. The *try/catch* block is used to override the normal processing of exceptions in JavaScript.

```
try {
  // code that may generate an exception
} catch (e) { // e is a local variable that contains the exception object or value that was thrown
  // code to perform if an exception is encountered
}
```

try/catch Syntax

```
try {
  programId = getAsInt(programName);
} catch(e) {
  error(localize("Program name must be a number."));
  return;
}
```

try/catch Usage

3.5.7 The validate Function

The *validate* function tests an expression and raises an exception if the expression is false. The post processor will typically output an error if an exception is raised, so in essence, the *validate* function determines if an expression is true or false and outputs an error using the provided message if it is false.

```
validate(expression, error_message)
```

validate Syntax

```
validate(retracted, "Cannot cancel length compensation if the machine is not fully retracted.");
```

Sample validate Code

In the above sample, an error will be generated if *retracted* is set to false.

3.5.8 Comparing Real Values

Real values are stored as binary numbers and are not truncated as you see them in an output file, so there are times when the numbers are not equal even if they show as the same value in the output file. For this reason, it is recommended that you either use a tolerance or truncate them when comparing their values. The *format.getResultingValue* function can be used to truncate a number to a fixed number of decimal places.

```
var a = 3.141592654;
var b = 3.141593174;

// simple comparison
if (a == b) {  // false

// comparison using a tolerance
var toler = .0001;
if (Math.abs(a – b) <= toler) { // true

// comparison using truncated values
var spatialFormat = createFormat({decimals:4});
if (!spatialFormat.areDifferent(a, b)) { // true
```

Comparing Real Values

3.6 Looping Statements

Loops perform repetitive actions. There are various styles of looping statements; *for*, *for/in*, *while*, and *do/while*. You should choose the looping statement that lends itself to the style of loop you are coding.

The syntax of looping statements should follow the Autodesk standard of always including the {} brackets around each body of code, specifying the opening bracket ({) on the looping statement, and the closing bracket (}) at the start of the line following the body of code for the loop. Loops can be nested within other bodies of code, like conditionals or other loops.

3.6.1 The for Loop

The *for* loop is the most common of the looping statements. It includes a counter and an expression on when to end the loop, so it will loop through the body of the loop a fixed number of times, unless interrupted by the *break* command. The *counter variable* is initialized before the loop starts and is tested when the *expression* is evaluated before each iteration of the loop. The *counter variable* is incremented at the end of the loop, just before the *expression* is evaluated again.
Multiple counters can be initialized and incremented in a for loop by separating the counters with a comma (,).

```
for(initialize_counter; test expression ; increment_counter) {
  // body of loop
}
```

for Loop Syntax

```
for (var i = 0; i < getNumberOfSections(); ++i) { // loop for the number of sections in intermediate file
  if (getSection(i).workOffset > 0) {
```

```
    error(localize("Using multiple work offsets is not possible if the initial work offset is 0."));
    return;
  }
}

for (i = 0, j = ary.length - 1 ; i < ary.length / 2; ++i, --j) { // reverse the order of an array
  var tl = ary[i];
  ary[i] = ary[j];
  ary[j] = tl;
}
```

Sample for Loops

3.6.2 The for/in Loop

The *for/in* loop allows you to traverse the properties of an *object*. It is not commonly used in post processors (except for the dump.cps post processor), but can be useful for debugging the property names and values in an *object*.

```
for(variable in object) {
  // body of loop
}
```

for/in Loop Syntax

```
for(var element in properties) { // write out the property table
  writeln("properties." + element + " = " + properties[element]);
}
```

Sample for/in Loop

3.6.3 The while Loop

The *while* loop evaluates an expression and will execute the body of the loop when the expression is true and will end the loop when the expression is false. Since the expression is tested at the top of the loop, the body of code in the loop will not be executed when the expression is initially set to false.

```
while (expression) {
  // body of loop
}
```

while Loop Syntax

```
while (c > 2*Math.PI) {
  c -= 2 * Math.PI;
}
```

Sample while Loop

3.6.4 The do/while Loop

The *do/while* loop is pretty much the same as the while loop, but the expression is tested at the end of the loop rather than at the start of the loop. This means that the loop will be executed at least once, even if the expression is initially set to false.

```
do {
  // body of loop
} while (expression)
```

do/while Loop Syntax

```
var i = 0;
var found = false;
do {
  if (mtype[i++] == "Start") {
    found = true;
  }
} while (!found && i < mtype.length);
```

Sample do/while Loop

3.6.5 The break Statement

The *break* statement is used to interrupt a loop or switch statement prematurely. When the *break* statement is encountered during a loop or switch body, then the innermost loop/switch will be ended and control will move to the first statement outside of the loop/switch.

break is pretty much mandatory with switch statements. For loops, *break* can be used to get out of the loop when an error is encountered, or when a defined pattern is found within an array.

```
for (i = 0; i < mtype.length; ++i) {
  if (mtype[i] == "Start") {
    break; // exits the loop
  }
}
```

Sample Usage of break Command

3.6.6 The continue Statement

The *continue* statement is used to bypass the remainder of the loop body and restarts the loop at the next iteration.

```
for (i = 0; i < mtype.length; ++i) {
  if (mtype[i] < 0) {
    continue; // skips this iteration of the loop and continues with the next iteration
  }
  …
```

```
}
```

Sample Usage of break Command

3.7 Functions

Functions in JavaScript behave in the same manner as functions in other high-level programming languages. In a post processor all code, except for the global settings at the top of the file, is contained in functions, either entry functions (*onOpen*, *onSection*, etc.) or helper functions (*writeBlock*, *setWorkPlane*, etc.). The code in a function will not be processed until that function is called from within another routine (for the sake of clarity the calling function will be referred to as a 'routine' in this section). Here are the main reasons for placing code in a separate function rather than programming it in the upper level routine that calls the function.

1. The same code is executed in different areas of the code, either from the same function or in multiple functions. Placing the common code in its own function eliminates duplicate code from the file, making it easier to understand and maintain.
2. To logically separate logic and make it easier to understand. Separating code into its own function can keep the calling routine from becoming too large and harder to follow, even if the function is only called one time.

3.7.1 The function Statement

A function consists of the function statement, a list of arguments, the body of the function (JavaScript code), and optional return statement(s).

```
function name([arg1 [,arg2 […, argn]]]) {
  …
  code
  …
}
```

function Statement Syntax

The argument list is optional and contains identifiers that are passed into the function by the calling routine. The arguments passed to the function are considered read-only as far as the calling routine is concerned, meaning that any changes to these variables will be kept local to the called function and not propagated to the calling routine. You use the *return* statement to return value(s) to the calling routine.

```
function writeComment(text) {
  writeln(formatComment(text));  // text is accepted as an argument and passed to formatComment
}
```

Sample function Definition

Arguments accepted by a function can either be named identifiers as shown in the previous example, or you can use the *arguments* array to reference the function arguments. The *arguments* array is built-in to

JavaScript and is treated as any other *Array* object, meaning that it has the length property and access to the *Array* attributes and functions.

```
  transferType = parseChoice(getProperty("transferType"),"PHASE","SPEED","STOP");
…
function parseChoice() {
  for (var i = 1; i < arguments.length; ++i) {
    if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
      return i - 1;
    }
  }
  return -1;
}
```

Sample Usage of arguments Array

3.7.2 Calling a function

A function call is treated the same as any other expression. It can be standalone, assign a value, and be placed anywhere within an expression. The value returned by the called function is treated as any other variable. You simply type the name of the function with its arguments.

```
setWorkPlane(abc); // function does not return a value
seqno = formatSequenceNumber(); // function returns a value
circumference = getRadius(circle) * 2.0 * Math.PI; // function used in a regular expression
```

Sample function Calls

3.7.3 The return Statement

As you can see in the previous sections, a function can be treated the same as any other expression and all expressions have values. The *return* statement is used to provide a value back to the calling routine. You will recall that a function does not have to return a value, in this case you do not have to place a return statement in the function, the function will automatically return when the end of the function body is reached. You can place a *return* statement anywhere within the function, the function will be ended whenever a *return* statement is reached.

```
return [expression]
```

return Statement Syntax

The return value can be any valid variable type; a number, string, object, or array. If you want to return multiple values from a function, then you must return either an object or an array. You can also propagate the JavaScript *this* object which will be automatically returned to the calling routine when the end of the function is reached or when processing a return statement without an expression. If the *this* object is used, then the function will be used to create a new object and you will need to define the function call as if you were creating any other type of object as shown in the following example.

```
function writeComment(text) {
  writeln(formatComment(text));
} // implicit return

function parseChoice() {
  for (var i = 1; i < arguments.length; ++i) {
    if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
      return i - 1; // return the matching choice
    }
  }
  return -1; // return choice not found
}

function FeedContext(id, description, feed) {
  this.id = id;
  this.description = description;
  this.feed = feed;
} // return this object {id, description, feed}

var feedContext = new FeedContext(id, "Cutting", feedCutting); // create new FeedContext object
```

Sample return Usage

4 Post Processor Settings

Many of Autodesk's post processors contain common content that is shared between post processors. When a post processor uses common content, you will see the *settings* variable defined in the global section, just after the output variable definitions. These settings control the behavior of the post processor and can be modified to match the requirements of your machine.

```
var settings = {
  coolant: { …
  smoothing: { …
  retract: { …
  parametricFeeds: { …
  unwind: { …
  machineAngles: { …
  workPlaneMethod: { …
  subprograms: { …
  comments: { …
  probing: { …
}
```

Settings Object in Posts Utilizing Common Content

The settings are defined in the post processor and usually do not require changing from the interface like Post Properties do, though logic can be added that will modify a setting based on a Post Property as shown in the following sample code.

```
// setup usage of useTiltedWorkplane
settings.workPlaneMethod.useTiltedWorkplane =
  getProperty("useTiltedWorkplane") != undefined ? getProperty("useTiltedWorkplane") :
    getSetting("workPlaneMethod.useTiltedWorkplane", false);
```

useTiltedWorkplane Property Can Override workPlaneMethod.useTiltedWorkPlane Setting

4.1 Coolant Settings

```
coolant: {
  // samples:
  // {id: COOLANT_THROUGH_TOOL, on: 88, off: 89}
  // {id: COOLANT_THROUGH_TOOL, on: [8, 88], off: [9, 89]}
  // {id: COOLANT_THROUGH_TOOL, on: "M88 P3 (myComment)", off: "M89"}
  coolants: [
    {id:COOLANT_FLOOD, on:8},
    {id:COOLANT_MIST},
    {id:COOLANT_THROUGH_TOOL, on:88, off:89},
    {id:COOLANT_AIR},
    {id:COOLANT_AIR_THROUGH_TOOL},
    {id:COOLANT_SUCTION},
    {id:COOLANT_FLOOD_MIST},
    {id:COOLANT_FLOOD_THROUGH_TOOL, on:[8, 88], off:[9, 89]},
    {id:COOLANT_OFF, off:9}
  ],
  singleLineCoolant: false
}
```

coolant Setting	Description
coolants	Each entry in the coolants array contains an *id* and optional *on* and *off* code(s). If an on code is not defined for a coolant id, then this coolant is not supported by the post processor and an error will be output if it is used in an operation.
id	Each coolant type is defined in the *id* field. All coolant types should be defined here and not removed from this array.
on	Defines the code(s) that turn on the associated coolant type. A single code (8) or multiple codes ([8, 88]) can be defined. If a number is specified, then this will be output as an M-code (M08). You can also specify a text string that will be output as defined ("M08 (Coolant flood])").

coolant Setting	Description
off	Defines the code(s) that turn off the associated coolant type. The same rules for defining the *on* coolant code(s) apply to the *off* coolant code(s). If an *on* code is defined and an *off* code is not defined, then the code defined for COOLANT_OFF is used.
singleLineCoolant	When enabled, multiple coolant codes will be output in a single block (M08 M88). Disabling this setting will output each coolant code in a separate block.

The coolant settings define the supported coolant modes and associate on/off codes as well as the output style (single/multiple line) for the coolant codes.

4.2 Smoothing Settings

```
  smoothing: {
    roughing              : 1,
    semi                  : 4,
    semifinishing         : 7,
    finishing             : 10,
    thresholdRoughing     : toPreciseUnit(0.5, MM),
    thresholdFinishing    : toPreciseUnit(0.05, MM),
    thresholdSemiFinishing: toPreciseUnit(0.1, MM),
    differenceCriteria: "level",
    autoLevelCriteria : "stock",
    cancelCompensation: true
  }
```

smoothing Setting	Description
roughing	The smoothing level for roughing operations when smoothing is in automatic mode.
semi	The smoothing level for semi-roughing operations when smoothing is in automatic mode.
semifinishing	The smoothing level for semi-finishing operations when smoothing is in automatic mode.
finishing	The smoothing level for finishing operations when smoothing is in automatic mode.
thresholdRoughing	The threshold value used to determine if an operation is a roughing operation when in automatic mode. Operations with stock-to-leave or machining tolerance above this threshold will be considered a roughing operation.
thresholdFinishing	The threshold value used to determine if an operation is a finishing operation when in automatic mode. Operations with stock-to-leave

smoothing Setting	Description
	or a machining tolerance below this threshold will be considered a finishing operation.
thresholdSemiFinishing	The threshold value used to determine if an operation is a semi-finishing operation when in automatic mode. Operations with stock-to-leave or a machining tolerance above the finishing threshold and below this threshold will be considered a semi-finishing operation.
differenceCriteria	Criteria used to determine when the smoothing mode changes. Specify *"level"* when the level is output in the smoothing block (G187 P2), *"tolerance"* when the tolerance is output in the smoothing block (G187 E0.2), or *"both"* when both the level and tolerance are output (G187 P2 E0.2).
autoLevelCriteria	The method used to determine the smoothing level when automatic mode is active. *"level"* uses the stock-to-leave setting for the operation and *"tolerance"* uses the machining tolerance.
cancelCompensation	Set to *true* if the tool length compensation needs to be canceled prior to changing the smoothing level.

Defines the smoothing levels, tolerances, and criteria for enabling smoothing on the control. The smoothing settings are only required when the post supports smoothing control.

4.2.1 Smoothing Properties

The *useSmoothing* Post Property must also be defined. It allows you to choose between disabling smoothing, enabling smoothing in automatic mode, or enabling smoothing at a specific level for each operation.

```
  // define the useSmoothing property
  useSmoothing: {
    title      : "Use G187",
    description: "G187 smoothing mode.",
    group      : "preferences",
    type       : "enum",
    values     : [
      {title:"Off", id:"-1"},
      {title:"Automatic", id:"9999"},
      {title:"Rough", id:"1"},
      {title:"Medium", id:"2"},
      {title:"Finish", id:"3"}
    ],
    value: "-1",
```

```
    scope: "post"
  }
```
Define the useSmoothing Post Property

4.2.2 Implementing Smoothing Control in Your Post Processor

If smoothing is supported, then the *setSmoothing* function must be defined in the post processor, which outputs the smoothing codes to the NC file.

```
function setSmoothing(mode) {
  if (mode == smoothing.isActive && (!mode || !smoothing.isDifferent) && !smoothing.force) {
    return; // return if smoothing is already active or is not different
  }
  if (typeof lengthCompensationActive != "undefined" && smoothingSettings.cancelCompensation) {
    validate(!lengthCompensationActive, "Length compensation is active while trying to update
smoothing.");
  }
  if (mode) { // enable smoothing
    writeBlock(
      gFormat.format(187),
      "P" + smoothing.level,
      conditional((smoothingSettings.differenceCriteria != "level"), "E" +
        xyzFormat.format(smoothing.tolerance))
    );
  } else { // disable smoothing
    writeBlock(gFormat.format(187));
  }
  smoothing.isActive = mode;
  smoothing.force = false;
  smoothing.isDifferent = false;
}
```
setSmoothing Function

A call to *initalizeSmoothing* must be made in *onSection* to define the smoothing control and level for the current operation. A call to *setSmoothing* must also be added in the proper location in the *onSection* function.

```
function onSection() {
…
  initializeSmoothing(); // initialize smoothing mode
…
  setSmoothing(smoothing.isAllowed); // writes the required smoothing codes
```
Initialize Smoothing at each Operation

4.3 Retract Settings

```
  retract: {
    cancelRotationOnRetracting: false,
    methodXY                  : undefined,
    methodZ                   : undefined,
    useZeroValues             : ["G28", "G30"],
    homeXY                    : {
      onIndexing:false,
      onToolChange:false,
      onProgramEnd:{axes:[X, Y],
      singleLine: false
    }
  }
```

retract Setting	Description
cancelRotationOnRetraction	Set to *true* if a control supported rotation (G68) must be canceled prior to moving to the home position. Rotations are typically enabled when performing an angled probing cycle.
methodXY	Allows you to override the move to the home position method for X & Y moves. It can be set to *undefined* to use the default method or to any supported method, such as *"G28"*, *"G53"*, etc. The supported methods are defined using the *safePositionMethod* Post Property.
methodZ	Allows you to override the move to the home position method for Z moves. It accepts the same values as the *methodXY* setting.
useZeroValues	An array containing the safe positioning methods that require a value of 0 for the axis instead of using the home position for that axis, such as *"G28"*, *"G30"*, etc. These safe positioning moves are typically made in incremental mode (G91).
homeXY	Specifies when the tool should move to its home position in X and/or Y as described in the following table.

homeXY Setting	Description
onIndexing	Defines the axes that should move to their home position when the rotary axes change position at the start of an operation. A single axis or multiple axes in an array assigned to the *axes* parameter can be specified. You can also specify that the axes should move on the same block or on separate blocks by specifying

homeXY Setting	Description

	the *singleLine* parameter as part of the *onIndexing* setting. Set to *false* to output each axis on separate blocks and to *true* (or omit this setting) to output the axes on a single block.
	
	Set to *false* if the tool should remain at its current position when the rotary axes change position.
	
	// move to home in X
	onIndexing:{axes:X}
	
	// move to home in X & Y on a single block
	onIndexing:{axes:[X,Y]}
	
	// move to home in Y and then X in separate blocks
	onIndexing:{axes:[Y,X], singleLine:false}
	
	// do not move to the X & Y home positions
	onIndexing:false

onToolChange	Determines if the tool should be moved to home in X and/or Y at a tool change. The syntax is the same as the *onIndexing* parameter.
onProgramEnd	Determines if the tool should be moved to home in X and/or Y at the end of the program. The syntax is the same as the *onIndexing* parameter. This move is generated in the *onClose* function, which is unique to every post, so logic needs to be added to the *onClose* function for this setting to take effect. See the *onClose* function for sample code.

retract.homeXY Settings

4.3.1 Safe Positioning Properties

The *retract* settings work in conjunction with the *safePositionMethod* property that defines the default method to use when positioning to the home position of each axis. If the *safePositionMethod* property is not defined, then you must enter a value for the *methodXY* and *methodZ* settings.

```
// define the method to use when positioning to the safe/home position
safePositionMethod: {
   title      : "Safe Retracts",
   description: "Select your desired retract option",
   group      : "homePositions",
```

```
    type       : "enum",
    values     : [
      {title:"G28", id:"G28"},
      {title:"G53", id:"G53"},
      {title:"Clearance Height", id:"clearanceHeight"}
    ],
    value: "G53",
    scope: "post"
  }
```
The safePositionMethod Post Property

4.4 Parametric Feeds Settings

```
  parametricFeeds: {
    firstFeedParameter    : 500,
    feedAssignmentVariable: "#",
    feedOutputVariable    : "F#"
  }
```

parametricFeeds Setting	Description
firstFeedParameter	The first parameter to assign a movement type feedrate to when parametric feeds have been enabled.
feedAssignmentVariable	The prefix used to define a variable in the control, for example *"#"*.
feedOutputVariable	The prefixed used when outputting a parametric feedrate, for example *"F#"*.

Parametric feeds will define parameters for the feedrates representing each movement type at the beginning of an operation. The feedrates for the cutting moves will then reference these parameters on the motion blocks.

```
N60 G00 X3.1496 Y-0.9596
N65 G43 Z0.5906 H01
N70 #500=39.4 (CUTTING)
N75 #502=39.4 (FINISH)
N80 #503=39.4 (ENTRY)
N85 G00 Z0.1969
N90 G01 Z-0.0394 F#503
N95 X-3.1496 F#502
N100 G02 Y0.0374 J0.4985 F#500
N105 G01 X3.1496 F#502
```
Parametric Feed Output

4.4.1 Parametric Feed Properties

The parametric feed settings work in conjunction with the *useParametricFeed* property that is used to enable and disable parametric feeds.

```
// Enable/disable parametric feeds
 useParametricFeed: {
    title      : "Parametric feed",
    description: "Output parametric feed values based on movement type.",
    group      : "preferences",
    type       : "boolean",
    value      : false,
    scope      : "post"
  }
```

The useParametricFeed Post Property

4.5 Unwind Settings

```
  unwind: {
    method        : 2,
    codes         : [gFormat.format(92)],
    workOffsetCode: "",
    useAngle      : "true",
    anglePrefix   : [],
    resetG90      : false
  }
```

unwind setting	Description
method	A value of 1 states that the rotary axis reset block will cause machine movement to the closest iteration of 0 degrees (G28). The rotary movement is handled by the control and not by the post processor. A value of 2 states that the rotary axis reset block will define the rotary axis position between 0 and 360 degrees without moving the table (G92).
codes	Enter the formatted code(s) or text strings that define this as a rotary axis reset command, such as *[gFormat.format(92)] or [gAbsIncModal(91), gFormat.format(28)]*.
workOffsetCode	Enter a prefix for the active work offset if it needs to be output on the rotary axis reset command. If a prefix is not defined ("") then the work offset will not be output.
useAngle	Specifying *"true"* will output the calculated angle within 0 and 360 degrees using the standard output variable for this rotary axis. *"false"* does not output the rotary axis angle.

unwind setting	Description
	Specifying *"prefix"* will output the calculated angle using the prefix specified by the *anglePrefix* setting instead of the normal prefix associated with the rotary axis.
anglePrefix	Defines an array of three text strings that contain the prefix(es) for each of the internal rotary axes (A, B, C). It is only used if *"prefix"* is specified for the *useAngle* setting. A blank string should be used for rotary axes that do not require a rewind. For example, *["", "", "C1="]*.

The *unwind* settings determine if and how a rotary axis that is output on a linear scale can be reset to be within 0-360 degrees between operations if it is wound up outside of this range during an operation. The *unwindABC* function must be included in the post processor for the *unwind* settings to have any affect.

The rotary axis will be repositioned within the 0-360 degree range with minimum or no movement depending on the method defined, instead of unwinding the axis the total number of degrees of its current value.

G00 C13200
G92 C240 **(Reposition C-axis to within 0-360 degrees with no movement)**
G91 G28 C0 **(Reposition C-axis to 0 degrees. It will move 120 degrees to get to C0)**

Repositioning the C-axis to within 0-360 degrees

4.6 Machine Angles Settings

```
  machineAngles: {
    controllingAxis: ABC,
    type           : PREFER_PREFERENCE,
    options        : ENABLE_ALL
  }
```

machineAngles Setting	Description
controllingAxis	The axis used to determine the preferred solution in conjunction with the *type* argument. It can be *A*, *B*, or *C* for a single axis, or *ABC* to consider all defined rotary axes.
type	The preference type as defined in the *getABCByPreference* command. It can be *PREFER_PREFERENCE*, *PREFER_CLOSEST*, *PREFER_POSITIVE*, *PREFER_NEGATIVE*, *PREFER_CW*, or *PREFER_CCW*.

machineAngles Setting	Description
options	Options used to control the solution as defined in the *getABCByPreference* command. It can be *ENABLE_NONE*, *ENABLE_RESET*, *ENABLE_WCS*, or *ENABLE_ALL*.

The *machineAngles* settings directly correlate to the parameters supported by the *getABCByPreference* function.

4.7 workPlaneMethod Settings

```
  workPlaneMethod: {
    useTiltedWorkplane    : true,
    eulerConvention       : EULER_ZXZ_R,
    eulerCalculationMethod: "standard",
    cancelTiltFirst       : true,
    useABCPrepositioning  : false,
    forceMultiAxisIndexing: false,
    prepositionWithTWP    : false,
    optimizeType          : undefined,
    compensateToolLength  : false
  }
```

workPlaneMethod Setting	Description
useTiltedWorkplane	Set to *true* if the control supports a tilted work plane block for 3+2 operations. Examples of tilted work planes are G68.2, G254, PLANE SPATIAL, CYCLE800, etc. Set to *false* if the rotary axes position should be used for 3+2 operations. When disabled, the remaining *workPlaneMethod* settings, except for *optimizeType*, are not used.
eulerConvention	Specifies the Euler angle calculation method for tilted work planes as defined in the *getEuler2* command. For example, *EULER_ZXZ_R*, *EULER_XYZ_S*, etc. Set to *undefined* if the control uses the rotary axes position to define the tilted plane instead of Euler angles, such as Haas controls.
eulerCalculationMethod	Set to *"standard"* if a straight Euler angle calculation should be made. Set to *"machine"* if the Euler calculation should take into consideration the calculated machine

workPlaneMethod Setting	Description
	rotary angles for the 3+2 operation. *"machine"* will closely match the Euler angles to the rotary axis angles when the Euler convention used matches the rotary axis kinematics, for example *EULER_ZXZ_R* on a machine with AC-style rotaries, where the A-axis revolves around X and the C-axis around Z.
cancelTiltFirst	Set to *true* if the tilted work plane should be canceled prior to a WCS (G54, G59.1, etc.) change.
useABCPrepositioning	Set to *true* if the rotary axis angles should be output prior to the tilted work plane block. Set to *false* to use only the tilted work plane block for 3+2 operations.
forceMultiAxisIndexing	Set to *true* to output tilted work plane blocks on programs that are 3-axis in nature, without any 3+2 or multi-axis operations. This setting may be ignored by some post processors if a tilted work plane block for a 3-axis operation is not supported, for example the Fanuc control.
prepositionWithTWP	Set to *true* to use a tilted work plane to position the tool at the beginning of a multi-axis operation when TCP is supported. The first XY move of a multi-axis operation is typically output prior to enabling TCP, but HSM provides the TCP position to the post processor, so this position will be in the wrong coordinate system. Enabling this setting will cause the post to calculate the proper tilted work plane and position for this first move so that the machine positions above the entry point in XY as expected. If this setting is set to *false* and TCP is supported for this machine, then it is expected that the first move will be made with TCP enabled, otherwise the output position will not be correct.
optimizeType	Enter the method used to adjust the output coordinates for a 3+2 operation when a tilted work plane block is not supported by the machine (*useTiltedWorkplane = false*). This value matches the *optimizeType* parameter in the *optimize3DPositionsByMachine* and can be *OPTIMIZE_NONE*, *OPTIMIZE_BOTH*, *OPTIMIZE_TABLES*, *OPTIMIZE_HEADS*, or

workPlaneMethod Setting	Description
	OPTIMIZE_AXIS (preferred method). Set to *undefined* to use a rotation matrix to adjust the output coordinates. This setting should only be used with a rotary table configuration that has the origin defined to be at the center of the rotary axes.
compensateToolLength	Set to *true* when the tool length should be added to the pivot length for machines with a rotary head that do not support TCP or a tilted work plane. The tool length is defined in the *getBodyLength* function as the *Assembly Gauge Length*, which is the Tool *Length below the holder* plus the Holder *Gauge Length*. *compensateToolLength* is used in 3+2 operations when a tilted work plane is not supported and in multi-axis operations when TCP is not supported. Note that the *optimizeType* setting cannot be set to *undefined* when tool length compensation is required.

The *workPlaneMethod* settings control how 3+2 operations are output, including support for a tilted work plane block and how the coordinates are adjusted. The *getWorkPlaneMachineABC* and *setWorkPlane* functions use these settings, along with multi-axis prepositioning.

4.7.1 Work Plane Properties

The *useTitledWorkplane* and setting can be overridden by the *useTiltedWorkplane* post property if defined in the post processor.

```
  // enable/disable tilted work plane blocks
  useTiltedWorkPlane: {
    title      : "Use G68.2",
    description: "Enable to output G68.2 blocks for 3+2 operations.
    group      : "multiAxis",
    scope      : ["machine", "post"],
    type       : "boolean",
    value      : false
  }
```

Override Tilted Work Plane Settings using a Post Property

4.8 Subprogram Settings

```
subprograms: {
  initialSubprogramNumber: undefined,
  minimumCyclePoints     : 5,
  format                 : oFormat,
  startBlock             : {files:["%" + EOL + "O"], embedded:["O"]}
  endBlock               : {files:["mFormat(99) + %"],
    embedded:[mFormat.format(99)]},
  callBlock              : {files:[mFormat.format(98) + " P"],
    embedded:[mFormat.format(98) + " P"]}
}
```

subprograms Setting	Description
initialSubProgramNumber	Specifies the base number used for subprograms. The first subprogram output will be labeled this number plus one. If *undefined* is specified, then the main program number is used.
minimumCyclePoints	Specifies the minimum number of points in a cycle operation that will be considered for creating a subprogram. Cycle subprograms are used when multiple operations (center-drill, drill, tap) are performed on a large number of holes.
format	The *formatNumber* used to format the subprogram number. This *formatNumber* should be created without a prefix as this will be added by the *startBlock* setting.
files:{extension, prefix}	The *extension* parameter defines the file extension when subprograms are saved into external files. Setting it to *undefined* will use the same file extension as the main program file. *prefix* is added to the beginning number of the subprogram number to create the filename for external subprogram files. Set *prefix* to *undefined* to not have a subprogram filename prefix.
startBlock:{files, embedded}	The *files* parameter defines the code(s) that will be output at the start of a subprogram when subprograms are written to external files. The *embedded* parameter defines the prefix for the subprogram number when subprograms are contained in the same file as the main program. The subprogram number will be output whether external files are used or not.
endBlock:{files, embedded}	The *files* parameter defines the code(s) that will be output at the end of a subprogram when subprograms are written to external files. The *embedded* parameter defines the code(s) output at

subprograms Setting	Description
	the end of a subprogram when subprograms are contained in the same file as the main program.
callBlock:{files, embedded}	The *files* parameter defines the code(s) that will be output to call a subprogram when subprograms are written to external files. The *embedded* parameter defines the code(s) to call a subprogram when subprograms are contained in the same file as the main program. The subprogram number will be added to the call block.

4.8.1 Subprogram Name Place Holder

The following subprogram settings will output the subprogram number in the output string generated from the setting.

- files.prefix
- startBlock.files
- startBlock.embedded
- endBlock.files
- endBlock.embedded
- callBlock.files
- callBlock,embedded

The subprogram number will either be appended to the end of the generated string or it can be placed anywhere in the string by using the *%currentSubprogram* placeholder within the string.

```
startBlock: {files:"; %_N_" + %currentSubprogram + "_SPF", embedded:"LABEL" + "%currentSubprogram" + ":"}

// generates the following output for embedded subprograms
LABEL1001:
```

Using the %currentSubprogram Placeholder

4.8.2 Subprogram Properties

Subprograms can be output for every operation, patterned operations, and/or cycle operations. The output of subprograms is controlled by the *useSubroutines* post property, which must be defined to support subprograms. This property is usually defined with the common subprogram support functions defined later in this chapter.

```
properties.useSubroutines = {
  title      : "Use subroutines",
  description: "Select your desired subroutine option.
  group      : "preferences",
  type       : "enum",
```

```
  values      : [
    {title:"No", id:"none"},
    {title:"All Operations", id:"allOperations"},
    {title:"All Operations & Patterns", id:"allPatterns"},
    {title:"Cycles", id:"cycles"},
    {title:"Operations, Patterns, Cycles", id:"all"},
    {title:"Patterns", id:"patterns"}
  ],
  value: "none",
  scope: "post"
};
```

useSubroutines Post Property

The *useFilesForSubprograms* post property can be defined if external subprogram files are supported.

```
properties.useFilesForSubprograms = {
  title       : "Use files for subroutines",
  description: "Subroutines will be saved as individual files.",
  group       : "preferences",
  type        : "boolean",
  value       : false,
  scope       : "post"
};
```

useFilesForSubprograms Post Property

4.8.3 Implementing Subprograms in your Post Processor

To implement subprograms in your Post Processor you will need to define the subprogram settings, include the subprogram support functions, and add some specific calls to the post. The subprogram settings are already described in this chapter.

The subprogram support functions and properties can be included into your post by copying the following code from another post that already supports subprograms, such as the *fanuc.cps* post processor.

```
// >>>>> INCLUDED FROM include_files/subprograms.cpi
…
// <<<<< INCLUDED FROM include_files/subprograms.cpi
```

Implementing Subprogram Functions and Properties by Copying Code

The following modifications to your post will now need to be made to fully support subprograms. In *onSection* add the following codes at the end of the function.

```
function onSection() {
…
 if (subprogramsAreSupported()) {
   subprogramDefine(initialPosition, abc); // define subprogram
 }
```

```
}
```

Add this Code to the End of onSection

In *onCycleEnd* add the following code where the canned cycle is cancelled.

```
function onCycleEnd() {
…
  if (subprogramsAreSupported() && subprogramState.cycleSubprogramIsActive) {
    subprogramEnd();
  }
  if (!cycleExpanded) {
    writeBlock(gCycleModal.format(80));
    zOutput.reset();
  }
}
```

Add this Code to the onCycleEnd

Add the following code to the end of *onSectionEnd*.

```
function onSectionEnd() {
…
  if (subprogramsAreSupported()) {
    subprogramEnd();
  }
}
```

Add this Code to the End of onSectionEnd

And finally add the following code to the end of the *onClose* function.

```
function onClose() {
…
  if (subprogramsAreSupported()) {
    writeSubprograms();
  }
  writeln("%");
}
```

Add this Code to the End of onClose

4.9 Comment Settings

```
  comments: {
    permittedCommentChars: " abcdefghijklmnopqrstuvwxyz0123456789.,=_-",
    prefix               : "(",
    suffix               : ")",
    outputFormat         : "upperCase",
    maximumLineLength    : 80,
    showSequenceNumbers  : false
```

```
  }
```

comments Setting	Description
permittedCommentChars	Specifies the characters that are allowed in an output comment. Any character that is not part of this text string will be stripped from the output comment. Characters are not case sensitive in this text, use the *outputFormat* parameter to specify the case of the alphabetical characters. Set this parameter to *undefined* to allow any character in a comment. Take note that this will include the *prefix* and *suffix* characters.
prefix	Specifies the prefix character(s) that define the start of a comment in the NC code.
suffix	Specifies the suffix character(s) that define the end of a comment in the NC code.
outputFormat	Defines the case of the output comment characters and can be *"uppercase"*, *"lowercase"*, or *"ignoreCase"* (does not convert the input alphabetic characters).
maximumLineLength	Defines the maximum number of characters in an output comment, not including the prefix and suffix characters. Set this value to 0 if output comments do not need to be truncated.
showSequenceNumbers	Set to *true* to allow sequence numbers to be output on comment blocks, set to *false* if sequence numbers are not allowed on comment blocks. *false* is the default setting.

4.10 Probing Settings

```
  probing: {
    macroCall              : gFormat.format(65),
    probeAngleMethod       : undefined,
    probeAngleVariables    : {x:"#135", y:"#136", z:0, i:0, j:0, k:1,
      r:"#144", baseParamG54x4:26000, baseParamAxisRot:5200, method:0},
    allowIndexingWCSProbing: false
  }
```

probing Setting	Description
macroCall	Specifies the formatted code that is used to call a probing macro. It can either be a text string

probing Setting	Description
	("G65") or an *OutputVariable* can be used to format the code (gFormat.format(65)).
probeAngleMethod	Specifies the method used for the rotation adjustment defined by an angular probing cycle, such as *Angle along X-axis*. The *probeAngleMethod* setting is defined in the *Angular Probing Settings* section.
probeAngleVariables	Specifies the control parameters used for angular probing cycles. The *probeAngleVariables* setting is described in the *Angular Probing Settings* section.
allowIndexingWCSProbing	Set to *true* to enable probing when the rotary axes are not at zero degrees. Set to *false* if the control does not support probing with a tilted orientation.

4.10.1 Angular Probing Settings

The angular probing cycles are used to compensate for the rotation of a part on the machine and consist of the following cycles.

- Angle along X-axis (probing-x-plane-angle)
- Angle along Y-axis (probing-y-plane-angle)

The probing settings *probeAngleMethod* and *probeAngleVariables* control the output of the angular probing cycles.

probeAngleMethod Setting	Description
"OFF"	Disables angular probing. An error will be output if an angular probing cycle is programmed.
"AXIS_ROT"	Updates the rotational offset for the rotary table to control the angular compensation. If a rotary table that rotates around the Z-axis is not supported by the machine configuration an error will be output.
"G68"	Outputs a G68 rotational block to compensate for the angular rotation of the part placement on the machine.
"G54.4"	Outputs a G54.4 Workpiece Setup Error block to compensate for the angular rotation of the part placement on the machine.
undefined	Automatically determines the probe angular method using the following criteria.

probeAngleMethod Setting	Description
	1. "AXIS_ROT" – machine has a Z-axis rotary table. 2. "G54.4" – the post property *Use G54.4* is enabled. 3. "G68" – used by default when neither of the above conditions are met.

probeAngleVariables Setting	Description
x	X-axis shift parameter for use with the G54.4 angular probing method. It can be a string or a number. For example, "#135". This parameter is not used by the other angular probing methods.
y	Y-axis shift parameter for use with the G54.4 angular probing method. It can be a string or a number. For example, "#136". This parameter is not used by the other angular probing methods.
z	Z-axis shift parameter for use with the G68 angular probing method. It can be a string or a number. For example, 0. This parameter is not used by the other angular probing methods.
i, j, k	These parameters specify the rotational axis for the G68 angular probing method. They are typically set to i:0, j:0, k:1 which represents an XY-rotation around the Z-axis. These parameters are not used by the other angular probing methods.
r	The rotational angle parameter used for all angular probing methods. It should be a string representing the parameter number that the control sets the rotational angle in for the angular probe operation. For example, "#144".
baseParamG54x4	The base value for the parameters that will receive the results of the angular probing cycle when the G54.4 method is used. The X, Y, and Rotation parameters will be stored in the registers calculated from this base parameter. The post will calculate the actual control parameters based on this parameter.
baseParamAxisRot	The base value for the parameter that will receive the angular rotation of the angular probing cycle when the AXIS_ROT method is used. The Rotation parameter will be stored in the control parameter based on this parameter.

probeAngleVariables Setting	Description
method	Set to 0 to output an error if any other axis other than the C-axis is used for the AXIS_ROT method of angular probing. A value of 1 allows any of the rotary axes to be used.

4.10.2 Angular Probing Properties

The *useG54x4* Post Property must also be defined if the G54.4 method for angular probing is supported. If it is not defined or is disabled, the post will output G68 rotation blocks for angular probing when the *probeAngleMethod* setting is set to undefined and there is not a Z-axis rotary table on the machine.

```
  // define the useG54x4 property
  useG54x4: {
    title      : "Use G54.4",
    description: "Supports G54.4 for workpiece error compensation.",
    group      : "probing",
    type       : "boolean",
    value      : false,
    scope      : "post"
  },
```

Define the useG54x43 Post Property

4.11 Tool List Settings

```
  toolList: {
    criteria         : ["number"],
    flag             : SORT | NODUPLICATES,
    writeDescription: false,
    writeZMin        : true,
    writeOperations  : false
  },
```

toolList Setting	Description
criteria	Specifies one or more of the Tool object variables to use as criteria to determine if a tool is unique. This list of criteria can be "number", "description", "lengthOffset", or any other member of the Tool object.
flag	The bitwise of SORT or NOSORT and DUPLICATES or NODUPLICATES. SORT | NODUPLICATE will display the tool list sorted by tool number without any duplicate tools in the list.

toolList Setting	Description
	NOSORT | DUPLICATE will display the tool list with the tools in the order that they are used with duplicate tools contained in the list.
writeDescription	Includes the tool description with each tool that has a description defined.
writeZMin	Includes the minimum Z-level of the tool in the information for each tool.
writeOperations	Includes the operation names in the tool information. If duplicate tools are included in the list, the operation name will be on the same line as the tool definition. If duplicate tools are not included in the list, the operation names that use the tool are written out after the tool definition line.

The *toolList* settings control how the tool list is output in the program header.

```
(T1 D=2 CR=0 - ZMIN=0 - face mill)
(   Operation: 2D-Face)
(T2 D=0.375 CR=0 - ZMIN=-0.3937 - flat end mill)
(   Operation: 2D-Contour)
(   Operation: 2D-Contour with compensation left)
(   Operation: 2D-Contour with compensation right)
(   Operation: 2D-Bore)
```

Tool List with SORT | NODUPLICATES and writeOperations set to *true*

```
(2D-Face: T1 D=2 CR=0 - face mill)
(2D-Contour: T2 D=0.375 CR=0 - flat end mill)
(2D-Contour with compensation left: T2 D=0.375 CR=0 - flat end mill)
(2D-Contour with compensation right: T2 D=0.375 CR=0 - flat end mill)
(2D-Bore: T2 D=0.375 CR=0 - flat end mill)
```

Tool List with NOSORT | DUPLICATES and writeOperations set to *true*

4.11.1 Tool List Properties

The *writeTools* Post Property determines if the tool list is output in the program header.

```
  // define the writeTools property
properties.writeTools = {
  title      : "Write tool list",
  description: "Output a tool list in the header of the program.",
  group      : "formats",
  type       : "boolean",
  value      : true,
  scope      : "post"
```

```
};
```

4.12 Optional Settings

```
allowCancelTcpBeforeRetracting: true
maximumSequenceNumber         : undefined
maximumSpindleRPM             : 99999
maximumToolDiameterOffset     : 99999
maximumToolLengthOffset       : 99999
maximumToolNumber             : 99999
outputToolDiameterOffset      : true
outputToolLengthCompensation  : true
outputToolLengthOffset        : true
programNumber                 : {min:1, max:99, reserved:[8000, 9000]}
sequenceNumbrePrefix          : "N"
supportsInverseTimeFeed       : true
supportsOptionalBlocks        : true
supportsRadiusCompensation    : true
supportsTCP                   : true
supportsToolVectorOutput      : false
writeBlockSuffix              : ""
```

Optional Settings	Default	Description
allowCancelTCPBeforeRetracting	false	When enabled, TCP will be canceled prior to moving the tool to its home position in X, Y, or Z, e.g. prior to a G28/G53 block.
maximumSequenceNumber	undefined	Defines the maximum sequence number allowed. When the maximum sequence number is reached, the post will start again with the beginning sequence number. If this setting is set to *undefined*, then sequence numbers are unlimited.
maximumSpindleRPM	99999	Defines the maximum spindle speed when an external Machine Definition is not associated with the CAM Setup or the machine configuration maximum spindle speed is set to 0. A warning will be output if a programmed spindle speed exceeds this value.
maximumToolDiameterOffset	99999	Defines the maximum tool diameter offset value. A warning will be output if a programmed tool diameter offset exceeds this value.
maximumToolLengthOffset	99999	Defines the maximum tool length offset value. A warning will be output if a programmed tool length offset exceeds this value.
maximumToolNumber	99999	Defines the maximum tool number when an external Machine Definition is not associated with the CAM Setup or the machine

Optional Settings	Default	Description
		configuration maximum number of tools is set to 0. A warning will be output if a programmed tool number exceeds this value.
outputToolDiameterOffset	true	When enabled, the tool diameter offset code (Dxx) will be output to the NC file when tool radius compensation is enabled for an operation. The tool diameter offset code is output using the *diameterOffsetFormat* format, which must be defined if this setting is enabled. Set to *false* to not output the tool diameter offset code.
outputToolLengthCompensation	true	When enabled, the tool length compensation code (G43) will be output to the NC file. The tool length compensation code is defined in the *getOffsetCode* function. Set to *false* to not output the tool length compensation code.
outputToolLengthOffset	true	When enabled, the tool length offset code (Hxx) will be output to the NC file. The tool length offset code is output using the *hFormat* format, which must be defined if this setting is enabled. Set to *false* to not output the tool length offset code.
programNumber: {min, max, reserved}	min:1 max:9999 reserved: [8000, 9000]	Defines the minimum and maximum program number allowed. *reserved* specifies a range of program numbers that are reserved by the control and cannot be used as the program number. If your control does not have a reserved range of program numbers then specify a range of [0, 0], otherwise it defaults to [8000, 9000]. An error will be output if the program number is outside of the range specified by *min:max*. A warning will be output if the program number is within the range specified by *reserved*.
sequeneNumberPrefix	"N"	Specifies the sequence number prefix.
supportsInverseTimeFeed	true	Set to *false* if the controller does not support inverse time feedrates. In this case, the post will output an error if the machine configuration sets inverse time feedrate output for multi-axis moves.
supportsOptionalBlocks	true	Determines if optional blocks (/) are supported by the controller. An error will be output if an optional block/section is programmed and not supported.

Optional Settings	Default	Description
supportsRadiusCompemsation	true	Disable this setting if the controller does not support tool radius compensation (G41/G42). The post will output an error if tool radius compensation is enabled.
supportsTCP	true	When disabled, the post will output an error if the machine configuration enables TCP on any rotary axis.
supportsToolVectorOutput	false	Set to *true* to output tool axis vectors with multi-axis moves when the machine configuration does not contain any rotary axes. By default, an error will be output if a multi-axis operation is used with a machine configuration without a rotary axis.
writeBlockSuffix	""	Specifies the terminating string for output blocks. This string does not apply to comment blocks unless comment blocks can be output with a sequence number when *settings.comments.showSequenceNumbers* is enabled.

Optional settings do not need to be defined in the post processor and will take on their corresponding default value if they are not defined. The *getSetting* function is used to return the value for an optional setting, either returning its defined value or its default value if it is not defined.

```
var hOffset = getSetting("outputToolLengthOffset", true) ? hFormat.format(tool.lengthOffset) : "";
```

Calling getSetting to Get the Value of an Optional Setting

5 Entry Functions

The post processor Entry functions are the interface between the kernel and the post processor. An Entry function will be called for each record in the intermediate file. Which Entry function is called is determined by the intermediate file record type. All Entry functions have the 'on' prefix, so it is recommended that you do not use this prefix with any functions that you add to the post processor.

Here is a list of the supported Entry functions and when they are called. The following sections in this Chapter provide more detailed documentation for the most common of the Entry functions.

Entry Function	Invoked When …
onCircular(clockwise, cx, cy, cz, x, y, z, feed)	Circular move
onClose()	End of post processing
onCommand(value)	Manual NC command not handled in its own function
onComment(string)	*Comment* Manual NC command

Entry Function	Invoked When …
onCycle()	Start of a cycle
onCycleEnd()	End of a cycle
onCyclePoint(x, y, z)	Each cycle point
onDwell(value)	*Dwell* Manual NC command
onFeedMode(mode)	Feedrate mode changes.
onLinear(x, y, z, feed)	3-axis cutting move
onLinear5D(x, y, z, a, b, c, feed)	5-axis cutting move
onMachine()	Machine configuration changes
onManualNC()	Manual NC commands
onMovement(value)	Movement type changes
onMoveToSafeRetractPosition()	Move to a safe position at a retract/reconfiguration
onOpen()	Post processor initialization
onOrientateSpindle(value)	Spindle orientation is requested
onParameter(string, value)	Each parameter setting
onPassThrough(string)	*Pass through* Manual NC command
onPower(boolean)	Power mode for water/plasma/laser changes
onRadiusCompensation()	Radius compensation mode changes
onRapid(x, y, z)	3-axis Rapid move
onRapid5D(x, y, z, a, b, c)	5-axis Rapid move
onReturnFromSafeRetractPosition	Reposition after a retract/reconfiguration
onRewindMachineEntry()	Rotary axes limits are exceeded
onRotateAxes(x, y, z, a, b, c)	Reposition the rotary axes at a retract/reconfiguration
onSection()	Start of an operation
onSectionEnd()	End of an operation
onSectionEndSpecialCycle()	End of a special cycle operation
onSectionSpecialCycle()	Start of a special cycle operation (Stock Transfer)
onSpindleSpeed(value)	Spindle speed changes
onTerminate()	Post processing has completed, output files are closed
onToolCompensation(value)	Tool compensation mode changes

Entry Functions

5.1 Global Section

The global section is not an Entry function, but rather is called when the post processor is first initialized. It defines settings used by the post processor kernel, the property table displayed with the post processor dialog inside of HSM, definitions for formatting output codes, and global variables used by the post processor.

While the global section is typically located at the top of the post processor, any variables defined outside of a function are in the global section and accessible by all functions, even the functions defined before the variable. You may notice global variables being defined in the middle of the post processor code just before a function. This allows for a group of functions to be easily cut-and-pasted from one post to another post, including the required global variables.

5.1.1 Kernel Settings

Some of the variables defined in the global section are actually defined in and used by the post engine. These variables are usually at the very top of the file and are easily discerned, since they are not preceded by *var*. The following table provides a description of the kernel settings that you will find in most post processors.

Setting	Description
allowedCircularPlanes	Defines the allowed circular planes. This setting is described in the *onCircular* section.
allowFeedPerRevolutionDrilling	Set to FPRAll if the post processor supports feed-per-revolution (FPR) feed rates in drilling and tapping cycles, FPRDrilling or *true* if FPR feed rates are only allowed for drilling operations, or NoFPR if FPR feed rates are not supported. This setting is described in the *onCyclePoint* section.
allowHelicalMoves	Specifies whether helical moves are allowed. This setting is described in the *onCircular* section.
allowSpiralMoves	Specifies whether spiral moves are allowed. This setting is described in the *onCircular* section.
bufferRotaryMoves	Set to *true* to buffer moves where only a single rotary axis moves. This will keep multiple rotary axis moves from being output when it is the only axis moving. This is the default setting. Set to *false* to output all calculated rotary moves.
capabilities	Defines the capabilities of the post processor. The capabilities can be CAPABILITY_MILLING, CAPABILITY_TURNING, CAPABILITY_JET, CAPABILITY_SETUP_SHEET, CAPABILITY_INTERMEDIATE, and CAPABILITY_MACHINE_SIMULATION. Multiple capabilities can be enabled by using the logical OR operator. capabilities = CAPABILITY_MILLING | CAPABILITY_TURNING;
certificationLevel	Certification level of the post configuration used to determine if the post processor is certified to run against the post engine. This value rarely changes.
circularInputTolerance	The tolerance to use when determining if a spiral or helical move should be converted to a circular record. This setting is described in the *onCircular* section.

Setting	Description
circularMergeTolerance	The tolerance used to determine if consecutive circular records can be merged into a single circular record. This setting is described in the *onCircular* section.
circularOutputAccuracy	Defines the number of digits to the right of the decimal point to use when adjusting the final point to lie exactly on the circle. This setting is described in the *onCircular* section.
description	Short description of post processor. This will be displayed along with the post processor name in the *Post Process* dialog in Fusion when selecting a post processor to run.
extension	The output NC file extension.
highFeedMapping	Specifies the high feed mapping mode for rapid moves. Valid modes are HIGH_FEED_NO_MAPPING (do not map rapid moves to high feed), HIGH_FEED_MAP_MULTI (map rapid moves along more than one axis at high feed), HIGH_FEED_MAP_XY_Z (map rapid moves not in the XY-plane or along the Z-axis to high feed), and HIGH_FEED_MAP_ANY (map all rapid moves to high feed). This setting can be changed dynamically in the Property table when running the post processor.
highFeedrate	Specifies the feedrate to use when mapping rapid moves to linear moves.
legal	Legal notice of company that authored the post processor

linearOutputAccuracy	Defines the output accuracy of the linear axes. The output accuracy is used internally by the post engine to determine if the output linear position has changed from its previous position. It should be the same value as the defined in the *digits* parameter of the output format for the linear axes.
	
	linearOutputAccuracy = (unit == MM) ? 3 : 4;
	…
	var xyzFormat = createFormat({decimals:(unit == MM ? 3 : 4)});

mapToWCS	Specifies whether the work plane is mapped to the model origin and work plane. When disabled the post is responsible for handling mapping from the model origin to the setup origin. This variable must be defined using the following syntax and can only be defined in the global section. Any deviation from this format, including adding extra spaces, will cause this command to be ignored.
	
	mapToWCS = true;
	mapToWCS = false;

mapWorkOrigin	Specifies whether the coordinates are mapped to the work plane origin. When disabled the post is responsible for handling the work plane origin. This variable must be defined using the following syntax and can only be defined in the global section. Any

Setting	Description

	deviation from this format, including adding extra spaces, will cause this command to be ignored.
	
	mapWorkOrigin = true;
	mapWorkOrigin = false;

maximumCircularRadius	Specifies the maximum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the *onCircular* section.
maximumCircularSweep	Specifies the maximum circular sweep of circular moves that can be output as circular interpolation. This setting is described in the *onCircular* section.
minimumChordLength	Specifies the minimum delta movement allowed for circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the *onCircular* section.
minimumCircularRadius	Specifies the minimum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the *onCircular* section.
minimumCircularSweep	Specifies the minimum circular sweep of circular moves that can be output as circular interpolation. This setting is described in the *onCircular* section.
minimumRevision	The minimum revision of the post kernel that is supported by the post processor. This value will remain the same unless the post processor takes advantage of functionality added to a later version of the post engine that is not available in earlier versions.
programNameIsInteger	Specifies whether the program name must be an integer (*true*) or can be a text string (*false*).

rotaryOutputAccuracy	Defines the output accuracy of the rotary axes. The output accuracy is used internally by the post engine to determine if the output rotary position has changed from its previous position. It should be the same value as the defined in the *digits* parameter of the output format for the rotary axes.
	
	rotaryOutputAccuracy = 3;
	…
	var abcFormat = createFormat({decimals:3, scale:DEG});

tolerance	Specifies the tolerance used to linearize circular moves that are expanded into a series of linear moves. This setting is described in the *onCircular* section.
unit	Contains the output units of the post processor. This is usually the same as the input units, either MM or IN, but can be changed in the

Setting	Description
	onOpen function of the post processor by setting it to the desired units.
vendor	Name of the machine tool manufacturer.
vendorUrl	URL of the machine tool manufacturer's web site.

Post Kernel Settings

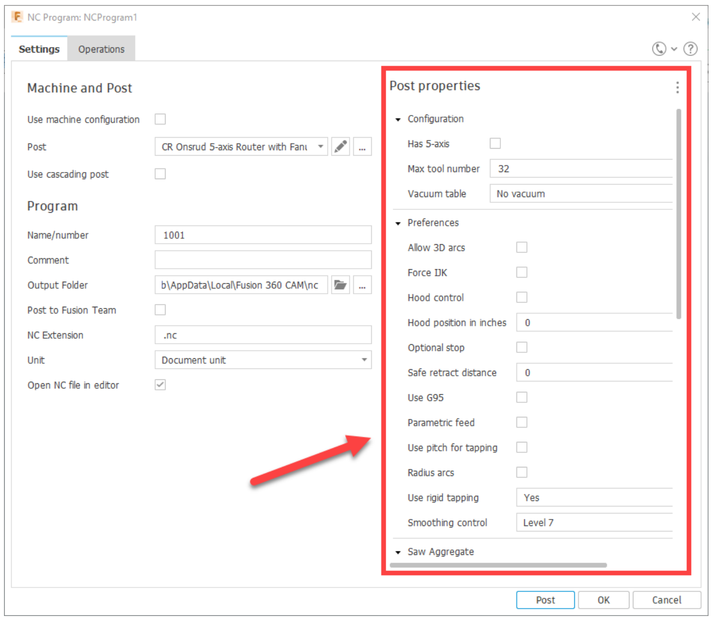
```
description = "RS-274D Sample Multi-axis Post Processor";
vendor = "Autodesk";
vendorUrl = "http://www.autodesk.com";
legal = "Copyright (C) 2012-2024 by Autodesk, Inc.";
certificationLevel = 2;
minimumRevision = 50171;

longDescription = "Generic Multi-axis post for the RS-274D format. Most CNCs will use a format
very similar to RS-274D. When making a post for a new CNC control this post will often serve as the
basis.";

extension = "nc";
setCodePage("ascii");

capabilities = CAPABILITY_MILLING | CAPABILITY_MACHINE_SIMULATION;
tolerance = spatial(0.002, MM);

minimumChordLength = spatial(0.25, MM);
minimumCircularRadius = spatial(0.01, MM);
maximumCircularRadius = spatial(1000, MM);
minimumCircularSweep = toRad(0.01);
maximumCircularSweep = toRad(180);
allowHelicalMoves = true;
allowedCircularPlanes = undefined; // allow any circular motion
bufferRotaryMoves = true;
allowFeedPerRevolutionDrilling = FPRAll;
highFeedrate = (unit == IN) ? 500 : 5000;
highFeedMapping = HIGH_FEED_NO_MAPPING;
```

Sample Post Kernel Settings Code

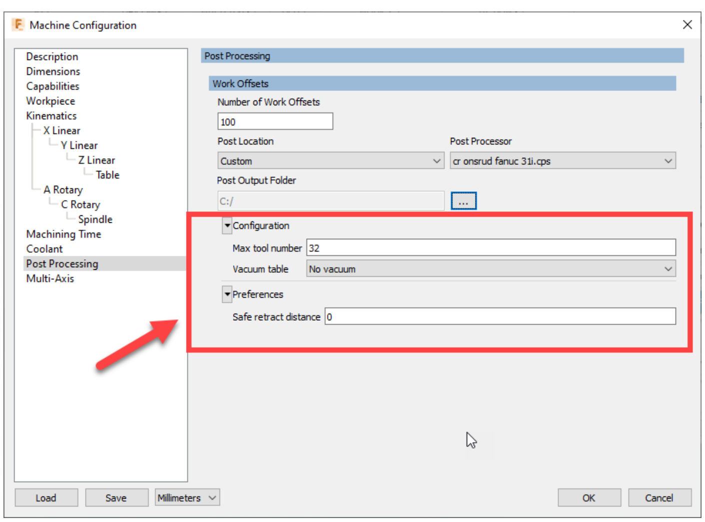
5.1.2 Property Table

Library post processors are designed to run the machine without any modifications but may not create the output exactly as you would like to see it. The Property Table contains settings that can be changed at runtime so that the library post can remain generic in nature, but still be easily customized by various users. The settings in the Property Table will typically be used to control small variations in the output created by the post processor, with major changes handled by settings in the Fixed Settings section.

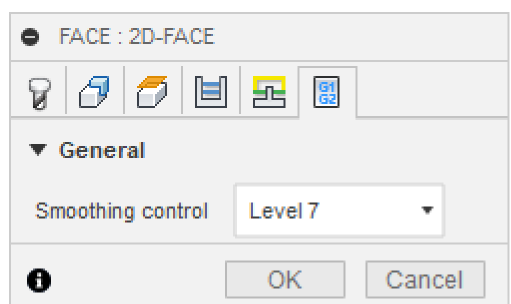
The properties can be displayed in multiple areas of HSM; when you use the Post Process dialog to run the post processor, in an NC Program, under the Post Processing tab in the Machine Definition, and in the Post Process tab of an operation. When you Post Process from HSM or edit an NC Program you may be presented with a dialog that allows you to select the post processor to execute, the output file path, and other settings. The Property Table will also be displayed in the dialog allowing you to override settings within the post processor each time it is run.



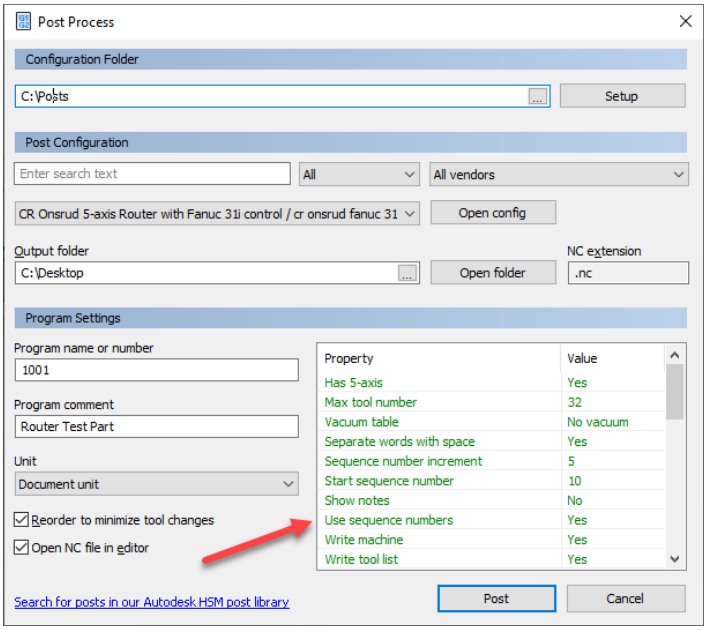
Property Table in NC Program



Property Table in Machine Definition



Property Table in Operation



Property Table in Inventor/HSMWorks Post Process Dialog

The Property Table is defined in the post processor so you have full control over the information displayed in it, with the exception of the *Built-in* properties, which are displayed with every post processor and define the post kernel variables described previously. The *properties* object defined in the post processor defines the property names as they are used in the post processor, the titles displayed in the Property Table, the accepted input types, the default values assigned to each property, and settings controlling the display attributes of the property in the property table.

```
// user-defined properties
properties = {
 writeMachine: {
  title: "Write machine",
  description: "Output the machine settings in the header of the code.",
  group: "general",
  type: "boolean",
  value: true,
  scope: "post"
 },
  useSmoothing: {
  title: "SGI / High Precision Mode",
  description: "High-Speed High-Precision Parameter.",
  type: "enum",
  group: "preferences",
  values:[
   {title:"Off", id:"-1"},
   {title:"Automatic", id:"9999"},
   {title:"Standard", id:"0"},
   {title:"High Speed", id:"1"},
```

```
    {title:"High Accuracy", id:"2"},
    {title:"Special", id:"3"}
  ],
  value: "-1",
  scope: ["post", "operation"]
 }, …
}
```

Property Table Definition

The following table describes the supported members in the *properties* object. It is important that the format of the *properties* object follows the above example, where the name of the variable is first, followed by a colon (:), and the members enclosed in braces ({}). The *values* property is an array and its members must be enclosed in brackets ([]).

Property	Description
title	Description of the property displayed in the User Interface within the *Property* column.
description	A description of the property displayed as a tool tip when the mouse is positioned over this property.
group	The group name that this property belongs to. All properties with the same group name will be displayed together in the User Interface. The groups are defined by the *groupDefinitions* object discussed further in this chapter.
type	Defines the input type. The input types are described in the following table.
value	The default value for this property.
range	The minimum and maximum allowable values for a numeric property specified as an array (*[-1000, 1000]*).
values	Contains a list (array) of choices for the *enum*, *integer*, or *boolean* input types. It is not valid with any other input type. For *boolean* values, it should be an array of 2 strings, with the first entry representing *true* and the second representing *false*.
presentation	Defines how a boolean will be displayed in the property table. Valid settings are defined as a text string and can be "*yesno*" (Yes/No), "*truefalse*" (True/False), "*onoff*" (On/Off), and "*10*" (1/0).
scope	Tells the post which dialogs will display this property. Supported settings are *post*, *machine*, and *operation*. The setting must be specified as a text string. *scope* can be a single value or an array of the supported dialogs. Examples: *scope: "post"*, *scope: ["post", "machine"]*. **There are caveats when enabling a property in more than one dialog type as described in the *Property Scopes* section of this chapter**.
enabled	Specifies the operation type where this property will be displayed in the HSM operation dialog. This property only applies to *operation* properties and has no effect on *post* and *machine* properties. The setting must be specified as a text string or an array of text strings. Valid settings are "*milling*", "*turning*", "*drilling*", "*probing*", "*inspection*", and "*additive*".

Property	Description
visible	Defines whether a property is visible in the NC Program and Operation dialogs. This setting has no effect on the Machine Definition or legacy Post Process dialogs. It can be set to *true* or *false*.
kind	Defines the unit-based style of the property. It can be set to "feed" for both linear (mm/min or in/min) and angular feeds (deg/min) or "speed" (RPM). **This is further explained in the *Unit-Based Properties* section of this chapter.**

Properties Settings

Input Type	Description
"integer"	Integer value
"number"	Real value
"spatial"	Real value
"angle"	Angular value in degrees
"boolean"	*true* or *false*
"string"	Text string
"enum"	The *enum* input type defines this variable as having fixed choices associated with it. These choices are defined individually in the *values* property array. An *enum* input type should be defined using string values.

Property Table Input Types

Values Property	Description
title	The text of the choice item displayed in the User Interface for this variable.
id	The value that will be returned in the variable when the post processor is called. All references to this property, e.g. *getProperty("rotaryTableAxis"),* in the post processor should expect only one of these *id* values as its value. The *id* must be a text string when associated with an *enum* input type or an integer value when associated with an *integer*.

Enum Choices Properties

5.1.3 Property Scopes

When multiple dialog types are specified for the *scope* property there is a hierarchy that defines which dialog has final say in the property value passed to the post processor. This hierarchy is as follows.

1. Operation property
2. Post property
3. Machine property

Therefore, if a property is defined as a *post* and an *operation* property, then the setting made in the Post Process, and NC Program dialogs will be ignored by the post processor, only the setting made in each separate operation will be used by the post processor. The only place you would be able to query the Post Process property setting is in *onOpen* when using the *getProperty* function. For these reasons it is highly recommended that operation properties are not defined in the post or machine scopes.

When specifying a property as a *machine* and *post* property, the setting made to the property in the Machine Definition dialog will become the default setting for the *post* property displayed in the corresponding dialogs. If the property setting is changed in the *post* dialog, then this value will override the *machine* property setting.

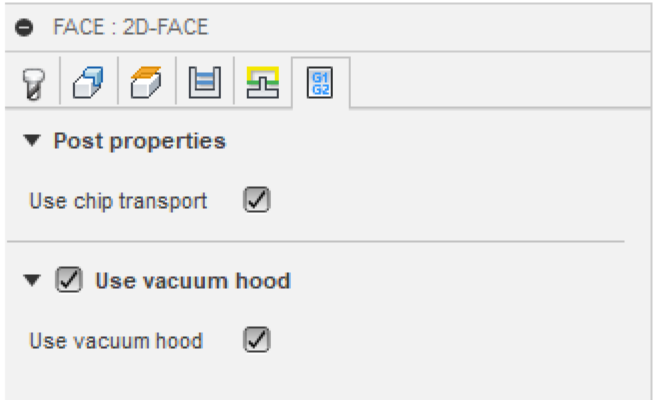
5.1.4 Operation Properties

Operation properties are shown in the *Post Process* tab of the *Operation* dialog and are defined by including *operation* in the *scope* of the property.

```
gotChipConveyor: {
  title      : "Use chip transport",
  description: "Enable to turn on the chip transport for this operation.”,
  group      : "configuration",
  type       : "boolean",
  value      : false,
  scope      : "operation", // Only displayed in the Operation dialog
  enabled    : "milling" // Only displayed for milling operations
},
useHood: {
  title      : "Use vacuum hood",
  description: "Enable to turn on the vacuum hood.",
  group      : "preferences",
  type       : "boolean",
  value      : true,
  scope      : ["post", "operation"], // Displayed in Post and Operation dialogs
  disabled   : "drilling" // Not displayed for drilling operations
  }
```

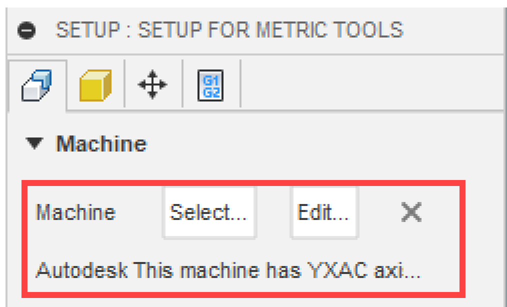
Defining an Operation Property

When the scope is set to *"operation"* only, then the single property will be displayed in the Operation dialog as shown with the *Use chip transport* property. When the scope includes another dialog to display the property in, a checkbox with the property name will be displayed in the Operation dialog. If this checkbox remains unchecked, then the post property value defined in either the Post Process or Machine Definition dialog will be used for this operation. You can change the value of post/machine/operation properties on an operation-by-operation basis by checking the box next to the property and then changing the value of the property itself as shown with the *useHood* property.

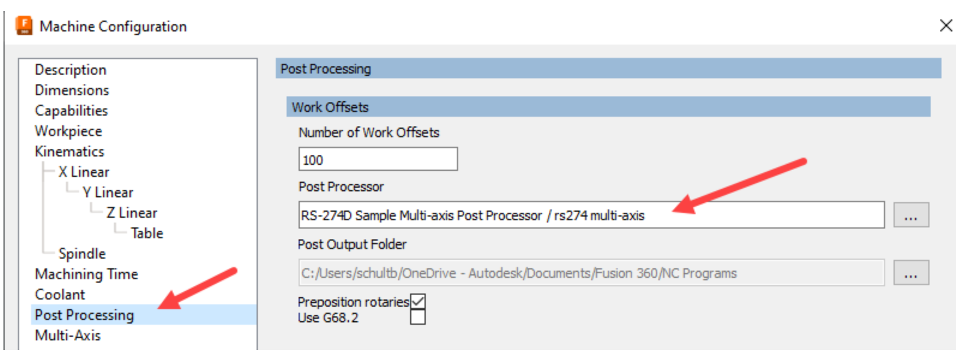


Properties Displayed in an Operation Dialog

To display operation properties in Fusion or Inventor CAM it is required that a Machine Definition be assigned to the Manufacturing Setup. The reason is that the Machine Definition has a post processor assigned to it and the operation properties are obtained from this known post processor.



Operation Properties Require a Machine Definition



Assigning a Post Processor to a Machine Definition

The *enabled* parameter in the property definition specifies the operation type where this property will be displayed in the HSM Operation dialog. The disabled parameter will not display the property for the specified operation type(s). These parameters only applies to *operation* properties and have no effect on *post* and *machine* properties. The setting must be specified as a text string or an array of text strings.

***enabled* Setting**	**Operation type property is displayed with**
"milling"	All milling and drilling operations.

enabled Setting	Operation type property is displayed with
"turning"	All turning operations.
"drilling"	All drilling operations.
"probing"	All probing operations.
"inspection"	All inspection operations.
"additive"	All additive operations.
"*operation-strategy*"	Only operations of the specified operation strategy, for example "face", "contour2D", "adaptive2D", "turningRoughing", etc. You can find the strategy for a certain operation type by running the Dumper post processor (dump.cps) and searching for operation-strategy. The operation strategies can be placed in an array to allow multiple strategies to be specified, for example: *enabled : ["contour2d", "chamfer2d"]*.

Property Table Input Types

5.1.5 Property Groups

The display order of the properties is controlled by the group setting in the property definition and in the *groupDefinitions* object, which defines which group the property belongs to and the order that the groups are displayed in the Property table in each dialog.

The post processor has a number of built-in property groups as defined in the following table. You can reference these groups in the property definition without creating the group in the *groupDefinition* object.

Group	Title	Description	Order	Collapsed
configuration	Configuration	Configuration options	10	true
preferences	Preferences	User preferences	20	false
homePositions	Safe retracts and home positioning	Settings related to safe retracts and home positioning	30	true
multiAxis	Multi-axis	Multi-axis settings	40	true
formats	Formats	NC code format settings	50	true
probing	Probing and Inspection	Probing and inspection settings	60	true

Built-in Group Definition

If a property does not fit into a predefined group, you can add to the built-in groups by defining these groups within the *groupDefinitions* object. In the following example, the *subSpindle* group will be displayed after the built-in *configuration* group and the *looping* group will be displayed after the built-in *preferences* group. This is determined by the value assigned to the *order* property.

```
// define the custom property groups
groupDefinitions = {
  subSpindle: {title: "Sub spindle", description: "Sub spindle options", collapsed:true, order:15},
  looping: {title:"Looping", description: "Looping control", collapsed:true, order:25}
```

```
};
```

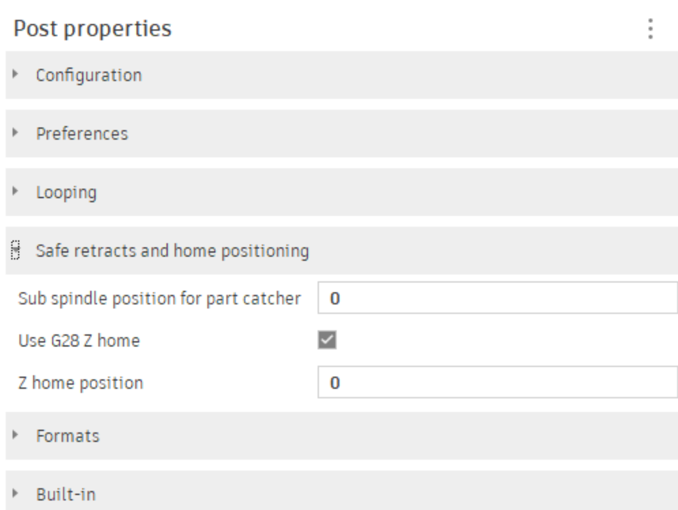
Property Group Definition

The following table describes the supported properties in the *groupDefinitions* object. It is important that the format of the *groupDefnitions* object follows the above example, where the name of the group is first, followed by a colon (:), and the properties enclosed in braces ({}).

Each group referenced in the *properties* definition and not one of the built-in property groups should be defined in *groupDefinitions*.

Property	Description
title	Title of the group displayed in the *Post properties* table. The title is not displayed in the legacy Post Process dialog.
description	A description of the group displayed as a tool tip when the mouse is positioned over this group name.
order	A number defining the displayed placement of the group in the *Post properties* table. For example, a value of less than 10 will be displayed first, 25 will display between the *preferences* and *homePositions* groups, and a value of 70 will be displayed after the *probing* group.
collapsed	Defines whether the group will be collapsed or expanded by default in the *Post properties* table. *true* collapses the group and *false* expands the group.

Group Definition Settings



Property Groups

5.1.6 Accessing Properties

```
getProperty(property [,default-value])
section.getProperty(property [,default-value])
```

Arguments	Description
property	The property you want to retrieve the value of. It can be specified as a text string (“useSmoothing”) or as a direct reference to the property (properties.useSmoothing). It is recommended to use the text string syntax. The *section.getProperty* function can be used to obtain the value of a property for a specific section. If the specified property is not an operation property, then the post property value will be returned. The *section.getProperty* function only needs to be used if you need to know the value of an operation property outside of when the operation is being processed, for example in *onOpen*.
default-value	The value to return from *getProperty* if the specified property does not exist. If a default value is not specified and the property does not exist, then *undefined* will be returned.

The *getProperty* function is used to obtain the value of a post processor property.

```
showSequenceNumbers = getProperty(“showSequenceNumbers”);
if (getProperty(properties.showSequenceNumbers) {
var smooth = section.getProperty(“useSmoothing”, false);
```

Sample getProperty Calls

```
function setProperty(property, value)
```

Arguments	Description
property	The property you want to set the value of. It can be specified as a text string (“useSmoothing”) or as a direct reference to the property (properties.useSmoothing). It is recommended to use the text string syntax.
value	The value to set the property to.

The *setProperty* function is used to set the value of a post processor property.

```
setProperty("showSequenceNumbers", true);
setProperty(properties.showSequenceNumbers, true);
```

Sample setProperty Calls

5.1.7 Unit-Based Properties

Properties with a type of (spatial, angle) can have their default values specified in the current units using the syntax *(unit == MM ? 25.4 : 1)*, where 25.4 is the default value in metric units and 1 is the default value in imperial units.

To mark a property as a unit-based number, the *type* parameter must be set to *spatial* or *angular*. The value must be specified as a number using the *toUnit()*, *toPreciseUnit()*, or a custom function that returns a number based on the current unit, or an inline condition *(unit == MM ? 25.4 : 1)*.
If a number is specified directly, it is treated as a unitless property.

```
  xHomePosition: {
    title      : "X-axis home position",
    description: "Define the X home position.",
    group      : "homePositions",
    type       : "spatial",
    value      : unit == MM ? 25.4 : 1, // mm and inches separately, alternatively
use toPreciseUnit(25.4, MM) to specify values based on active unit.
    scope      : "post"
  },
  maximumFeedRate: {
    title      : "Maximum Feed Rate",
    description: "Maximum feed rate",
    type       : "spatial",
    kind       : "feed",
    value      : unit == MM ? 10000 : 100, // mm/min and in/min separately
    scope      : "post"
  },
  maximumSpindleSpeed: {
    title      : "Maximum Spindle Speed",
    description: "Maximum spindle speed",
    type       : "angle",
    kind       : "speed",
    value      : 1000, // RPM
    scope      : "post"
  }.
  maximumCircularSweep: {
    title      : "Maximum Circular Sweep",
    description: "Maximum circular sweep for circular arcs",
    type       : "angle",
    value      : 90, // DEG
    range      : [0, 360],
    scope      : "post"
  }
```

Defining a Unit Based Property

5.1.8 Format Definitions

The format definitions area of the global section is used to define the formatting of codes output to the NC file. It consists of the format definitions (*createFormat*) as well as definitions that determine when the codes will be output or suppressed (*createOutputVariable).*

The *createFormat* command defines how codes are formatted before being output to the NC file. It can be used to create a complete format for an output code, including the letter prefix, or to create a primary format that is referenced with the output definitions. It has the following syntax.

createFormat({*specifier:value, specifier:value, …*});

createFormat Syntax

The specifiers must be enclosed in braces ({}) and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas.

Specifier	Value
base	The base increment of the output value. For example, a value of .002 will only output values on a .002 increment (.002, .004, .010, etc.). The default is 0.
decimals	Defines the number digits to the right of the decimal point to output. The default is 6.
forceSign	When set to *true* will force the output of a plus (+) sign on positive numbers. The default is *false*.
inherit	Inherits all properties from an existing *FormatNumber*.
minDigitsLeft	The minimum number of digits to the left of the decimal point to output. The default is 1.
minDigitsRight	The maximum number of digits to the right of the decimal point to output. The default is 0.
maximum	The unsigned maximum value that can be output. Formatted positive values will not be greater than this value and formatted negative values will not be less than the negative value. For example, defining a maximum value of 9999.99 will limit the output values to -9999.99 through 9999.99. The default is unlimited.
minimum	The unsigned minimum value that can be output. Formatted positive values will not be less than this value and formatted negative values will not be greater than the negative value. For example, defining a minimum value of 0.001 will limit the output values to less than -0.001 or greater than 0.001. The default is 0.
offset	Defines a number to add to the value prior to formatting it for output. The default is 0.
prefix	Defines the prefix of the output value as a text string. The prefix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is `""`.
scale	Defines a scale factor to multiply the value by prior to formatting it for output. *scale* can be a number or a number designator, such as *DEG*. The default is 1.
separator	Defines the character to use as the decimal point. The default is '.'.
suffix	Defines the suffix of the output value as a text string. The suffix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is `""`.
type	Defines the format of the number. Can be one of the following. • FORMAT_INTEGER – whole numbers do not contain a decimal point, fractional numbers contain a decimal point. • FORMAT_REAL – all numbers contain a decimal point. • FORMAT_LZS – Leading Zero Suppression. The decimal point is omitted and leading zeros are removed, including leading zeros in the fractional portion of the number if the value is less than 1. • FORMAT_TZS – Trailing Zero Suppression. The decimal point is omitted and trailing zeros are removed, including trailing zeros in the whole number if the fractional part is set to 0. The default is FORMAT_INTEGER.

createFormat Specifiers

The *createFormat* function creates a *FormatNumber* object. Once a *FormatNumber* is created, it can be used to create a formatted text string of a value that matches the properties in the defined *format*. The following table describes the functions defined in the *FormatNumber* object.

Function	Description
areDifferent(a, b)	Returns *true* if the input values are different after being formatted.
format(value)	Returns the formatted text string representation of the number.
getBase()	Returns the base increment of the format.
getDecimalSymbol()	Returns the character used as the decimal point symbol.
getError(value)	Returns the inverse of the remaining portion of the value that is not formatted for the number. For example, if the formatted value of 4.5005 is "4.500", then the value returned from *getError* will be -0.0005.
getForceSign()	Returns true if the + sign is output in the formatted number.
getMaximum()	Returns the maximum value that can be output.
getMinDigitsLeft()	Returns the minimum number of digits to output to the left of the decimal point.
getMinDigitsRight()	Returns the minimum number of digits to output to the right of the decimal point.
getMinimum()	Returns the minimum value that can be output.
getMinimumValue()	Returns the minimum value that can be formatted using this *format*, for example, 1 for *decimals:0*, .1 for *decimals:1*, etc.
getNumberOfDecimals()	Returns the maximum number of digits to output to the right of the decimal point.
getOffset()	Returns the number to add to the formatted number.
getPrefix()	Returns the prefix of the formatted number.
getResultingValue(value)	Returns the real value that the formatted output text string represents.
getScale()	Returns the scale to apply to the formatted number.
getSuffix()	Returns the suffix of the formatted number.
getType()	Returns the formatting type.
isSignificant(value)	Returns true if the value will be non-zero when formatted.
setBase(base)	Defines the base increment of the format.
setDecimalSymbol('symbol')	Defines the character used as the decimal point symbol.
setForceSign(forceSign)	Determines if the + sign is output in the formatted number.
setMaximum(max)	Defines the maximum value that can be output.
setMinDigitsLeft(min)	Defines the minimum number of digits to output to the left of the decimal point.
setMinDigitsRight(min)	Defines the minimum number of digits to output to the right of the decimal point.
setMinimum(min)	Defines the minimum value that can be output.
setNumberOfDecimals(number)	Defines the maximum number of digits to output to the right of the decimal point.
setOffset(offset)	Defines the number to add to the formatted number.
setPrefix(prefix)	Defines the prefix of the formatted number.

Function	Description
setScale(scale)	Defines the scale to apply to the formatted number.
setSuffix()	Defines the suffix of the formatted number.
setType()	Sets the formatting type, FORMAT_INTEGER, FORMAT_REAL, FORMAT_LZS, or FORMAT_TZS.

FormatNumber Functions

The following table shows how a value of 0 could be formatted depending on the format type and settings for the minimum digits to the left and right of the decimal point.

FORMAT_INTEGER minDigitsLeft:0 minDigitsRight:0	FORMAT_INTEGER minDigitsLeft:1 minDigitsRight:0	FORMAT_REAL minDigitsLeft:1 minDigitsRight:0	FORMAT_REAL minDigitsLeft:0 minDigitsRight:1
X	X0	X0.	X.0

Formatting the Number Zero

```
var xFormat = createFormat({type:FORMAT_REAL, decimals:3, minDigitsRight:3, forceSign:true});
xFormat.format(4.5); // returns "+4.500"
xFormat.areDifferent(9.123, 9.1234); // returns false, both numbers are 9.123
xFormat.getMinimumValue(); // returns 0.001
xFormat.isSignificant(.0006); // returns true (rounded to .001)
xFormat.isSignificant(.0004); // returns false

var yFormat = createFormat({prefix:"Y", decimals:3, forceSign:true});
yFormat.format(4.5); // returns "Y+4.5"
yFormat.format(6); // returns Y+6
yFormat.getResultingValue(3.1234); // returns 3.123

var toolFormat = createFormat({prefix:"T", decimals:0, minDigitsLeft:2});
toolFormat.format(7); // returns "T07"

var aFormat = createFormat({type:FORMAT_REAL, decimals:3, forceSign:true,  scale:DEG});
aFormat.format(Math.PI); // returns "+180."

var peckFormat = createFormat({type:FORMAT_LZS, decimals:4, minDigitsLeft:0});
peckFormat.format(1.23); // returns Q12300
peckFormat.format(0.001); // returns Q10
```

Example createFormat Commands

5.1.9 Output Variable Definitions

The format object is used to format values but has no connection to the output of the variable, except for formatting a text string that could be output. It does not know what the last output variable is, which is important when you do not want to output a code if the value has not changed from its previous output value.

The *createOutputVariable* function creates *OutputVariable* objects that are used to control the output of a code. The codes can be output only when they are changed, as an absolute value, as an incremental value, or as a directional value where the sign of the number determines a movement direction.

You can use the *FormatNumber* object, created from the *createFormat* function, for codes/registers that should be output whenever they are encountered in the post, just be sure to add the prefix to the definition.

```
createOutputVariable({specifier:value, specifier:value, ...}, format);
```

Output Variable Syntax

The specifiers must be enclosed in braces ({}) and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas. A *FormatNumber* object is provided as the second parameter. Supported specifiers are listed in the following table.

Specifier	Value
control	Determines when a formatted variable will be output. CONTROL_CHANGED will format the number when it has changed from the previously formatted value, CONTROL_FORCE will format the number each time, and CONTROL_NONZERO will format the number only when it is not equal to zero. If the number is not formatted, then a blank string will be returned.
current	Defines the initial value to store in the output variable.
cyclicLimit	Specifies the absolute range limit for the formatted value, for example it could be 360 for a rotary axis.
cyclicSign	Specifies the sign for a cyclic value and can be -1 (formatted numbers will always be negative), 0 (formatted numbers can be both positive and negative), or 1 (formatted numbers will always be positive).
onchange	Defines the method to be invoked when the formatting of the value results in output.
prefix	Text string that prepends to the prefix defined in the *format*.
suffix	Text string that appends to the suffix defined in the *format*.
tolerance	Defines a tolerance used to determine when the number should be formatted. A value must differ from the previous value by greater than this tolerance to be output.
type	Defines the output type of the variable. Can be one of the following. • TYPE_ABSOLUTE – The number will maintain its value when formatted. • TYPE_INCREMENTAL – The formatted number will be an incremental value from the previously formatted value. • TYPE_DIRECTIONAL – The formatted number will be negative if the value is less than the previously formatted value or will be positive if the value is greater than the previously formatted value. This type is usually used in conjunction with the *cyclicLimit* and *cyclicSign* specifiers for rotary axes that are output on a rotary scale. The default is TYPE_ABSOLUTE.

Output Variable Specifiers

The *onchange* property defines a function that is called whenever the formatting of the variable results in an output text string, such as when the value changes or is forced out. The following example will force out the *gMotionModal* code whenever the plane code is changed.

```
var gPlaneModal = createOutputVariable({onchange:function () {gMotionModal.reset();}}, gFormat);
```

onchange Usage

Once an output variable is created, it can be used to create a formatted text string for output. The following table describes the functions assigned to the output variable objects. The functions are properties of the defined *OutputVariable* object.

Function	Description
disable()	Disables this variable from being output. Will cause the return value from the *format* function to always be a blank string ("").
enable()	Enables this variable for output. This is the default condition when the variable is created.
format(value)	Returns the formatted text string representation of the number. A blank string will be returned when the value is the same as the stored value when *control* is set to CONTROL_CHANGED, or generates a value of 0 when *control* is set to CONTROL_NONZERO.
getControl()	Returns the *control* setting of the output variable.
getCurrent()	Returns the value currently stored in this variable.
getCyclicLimit()	Returns the absolute cyclic limit (rollover) of the output variable.
getCyclicSign()	Returns the cyclic sign setting of the output variable.
getFormat()	Returns the *FormatNumber* associated with this output variable.
getPrefix()	Returns the prefix of the output variable.
getResultingValue(value)	Returns the real value that the formatted output text string represents.
getSuffix()	Returns the suffix of the output variable.
getTolerance()	Returns the output tolerance of the output variable.
getType()	Returns the output type of the variable.
get---()	All *get* functions supported by the *FormatNumber* object can be called from an *OutputVariable* object. These calls return the values stored in the *FormatNumber*, for example *getDecimals*(), *getScale*(), etc. The only get functions not supported are those with the same names as *OutputVariable* functions, such as *getPrefix*().
isEnabled()	Returns *true* if this variable is enabled for output.
setControl(control)	Sets the control type, CONTROL_CHANGED, CONTROL_FORCE, or CONTROL_NONZERO.
setCurrent(value)	Sets the current value.
setCyclicLimit(value)	Defines the rollover value (cyclic limit).
setCyclicSign(value)	Defines the cyclic sign, -1 (formatted numbers will always be negative), 0 (formatted numbers can be both positive and negative), or 1 (formatted numbers will always be positive).

Function	Description
setFormat(format)	Changes the *FormatNumber* object associated with this output variable.
setPrefix(prefix-text)	Overrides the prefix of the variable.
setSuffix(suffix-text)	Overrides the suffix of the variable.
setTolerance(value)	Defines the output tolerance of the variable.
setType(type)	Sets the formatting type, TYPE_ABSOLUTE, TYPE_INCREMENTAL, or CONTROL_DIRECTIONAL.
set---()	All *set* functions supported by the *FormatNumber* object can be called from an *OutputVariable* object. These calls override the properties stored in the *FormatNumber* associated with this *OutputVariable*, for example *setDecimals*(3), *setScale*(2), etc. The only *set* functions not supported are those with the same names as *OutputVariable* functions, such as *setPrefix*(). When a *FormatNumber* is assigned to an *OutputVariable* then a copy of the *FormatNumber* is placed in the *OutputVariable*, so setting a *FormatNumber* property from an *OutputVariable* does not modify the original *FormatNumber* used when creating the *OutputVariable*.
reset()	Forces the output of the formatted text string on the next call to *format*, overriding the rules for not outputting a value.

***OutputVariable* Functions**

```
var xyzFormat = createFormat({decimals:3, type:FORMAT_REAL});
var xOutput = createOutputVariable({prefix:"X"}, xyzFormat);
xOutput.format(4.5); // returns "X4.5"
xOutput.format(4.5); // returns "" (4.5 is currently stored in the xOutput variable)
xOutput.reset();        // force xOuput on next formatting
xOutput.format(4.5); // returns "X4.5"
xOutput.disable();     // disable xOutput formatting
xOutput.format(1.2); // returns "" since it is disabled

var gFormat = createFormat({prefix:"G", decimals:0, minDigitsLeft:2});
var gMotionModal = createOutputVariable({control:CONTROL_FORCE}, gFormat);
gMotionModal.format(0); // returns G00
gMotionModal.format(0); // returns G00 (CONTROL_FORCE is set)
gMotionModal.setPrefix("[");
gMotionModal.setSuffix("]");
gMotionModal.format(1); // returns "[G01]"

var iOutput = createOutputVariable({prefix:"I", control:CONTROL_NONZERO}, xyzFormat);
iOutput.format(.001); // returns "I0.001"
iOutput.format(.0001); // returns ""

var zOutput = createOutputVariable({prefix:"Z", type:TYPE_INCREMENTAL, current:.5},
  xyzFormat);
zOutput.format(1.2); // returns "Z0.7"
```

```
zOutput.format(1.5); // returns "Z0.3"
zOutput.format(1.5); // returns ""
zOutput.format(0); // returns "Z-1.5"

var aFormat = createFormat({decimals:3, scale:DEG});
var aOutput = createOutputVariable({prefix:"A", type:TYPE_DIRECTIONAL, cyclicLimit:360,
  cyclicSign:1}, aFormat);
aOutput.format(Math.PI / 2); // returns "A90"
aOutput.format(Math.PI); // returns "A180"
aOutput.format(Math.PI / 2); // returns "A-90"
aOutput.format(0); // returns "A-360"
```

Example *OutputVariable* Commands

5.1.10 Modal Groups

Modal groups are similar to output variables (*createOutputVariable*), but are used to define codes that can be grouped together. For example, all G-codes that use the same formatting and output rules can be placed in a modal group. Modal groups can be considered part of the Output Variable definitions but behave in an expanded manner and limit control over the individual codes in a group element as can be done using a modal variable.

```
createModalGroup({specifier:value, specifier:value, …}, groups, format);
```

***createModalGroup* Syntax**

The specifiers must be enclosed in braces ({}) and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas. A *format* object is provided as the third parameter. The specifiers are listed in the following table.

Specifier	Value
force	When set to *true* forces the formatting of the value even if it does not change from the previous value. The default is *false*.
strict	When set to *true* requires that any code output using this modal must be present in one of the defined groups. An error will be output if any code is output that is not in one of the groups. Specifying *false* allows for codes not belonging to a group to be output. Codes that do not belong to a group will always be output, meaning they belong to a non-modal group.

Output Variable Properties

The code groups are defined as arrays of codes within an array. Each individual group is treated similar to as if it was defined as a separate Modal variable.

```
var mClampModal = createModalGroup(
  {strict:false},
  [
    [10, 11], // 4th axis clamp / unclamp
    [12, 13] // 5th axis clamp / unclamp
```

```
  ],
  mFormat
);

var gCodeGroup = createModalGroup(
  {strict:true, force:false},
  [
    [0, 1, 2, 3], // group 0 – motion codes
    [17, 18, 19], // group 1 – plane selection codes
    [80, 81, 82, 83, 84, 85, 86, 87, 88, 89], // group 2 – cycle codes
  ],
  gFormat
);
```

Sample *createModalGroup* Commands

Once a modal group is created, it can be used to create a formatted text string for output. The following table describes the functions assigned to the modal group object. Group numbers are based on 0, so the first group is referenced as 0, the second as 1, etc. The functions are properties of the defined *ModalGroup* object and are prefixed by the name of the group, for example *mClampModal.disable()*.

Function	Description
addCode(group, code)	Adds the specified code to the given group.
createGroup	Adds a group to the end of the groups.
disable ()	Disables all defined groups in this modal from being output. Will cause the return value from the *format* function to always be a blank string ("").
enable()	Enables all defined groups in this modal for output. This is the default condition when the modal is created.
format(code)	Returns the formatted text string representation of the number. Can return a blank string if the value is the same as the stored value in the ModalGroup object. If the code does not belong to a defined group, then it will always be output if the ModalGroup was defined with *strict:false*, or an error will be output if strict mode is enabled.
getActiveCode (group)	Returns the value currently stored in the specified group.
getGroup(code)	Returns the group id for the specified code. If the code does not belong to a group returns a very large number.
getNumberOfCodes()	Returns the combined number of codes in all groups.
getNumberOfCodesInGroup(group)	Returns the number of codes in the specified group.
getNumberOfGroups()	Returns the number of defined groups.
hasActiveCode(group)	Returns *true* if the specified group has a valid code. Returns *false* if a code has not been formatted in this group or if the group has been reset.
inSameGroup(code1, code2)	Returns *true* if the two codes are in the same group.
isActiveCode(code)	Returns *true* if the code is active within its group.

Function	Description
isCodeDefined(code)	Returns *true* if the code is defined in any of the groups.
isEnabled()	Returns *true* if this modal group is enabled for output.
isGroup(group)	Returns *true* if the specified group id is defined.
makeActiveCode(code)	Marks the specified code as the active code within its group.
removeCode(code)	Removes the specified code from its group.
reset ()	Resets all groups and forces the output of the formatted text string on the next call to format, overriding the rules for not outputting a value.
resetGroup(group)	Resets the specified group and forces the output of the formatted text string on the next call to format, overriding the rules for not outputting a value.
setAutoReset(flag)	Sets the auto-reset mode. When set to *true*, all groups are reset when a code that is not defined in any group is output. Strict mode must be disabled to output an undefined code.
setForce(force)	Forces the output of all group codes when enabled, even if the code value is the same as the active code value.
setFormatNumber(format)	Overrides the format variable assigned to the modal group.
setPrefix(prefix-text)	Defines the prefix of all groups. If a prefix is defined in the format assigned to the modal group, then the format prefix will be appended to this prefix.
setSuffix(suffix-text)	Defines the suffix of all groups. If a suffix is defined in the format assigned to the modal group, then the modal group suffix will be appended to the format suffix.

***ModalGroup* Functions**

The following sample code shows how a single Modal Group can be used to define the clamping codes for the rotary axes rather than creating two separate Modal variables to store the 4th and 5th axes clamping codes.

```
case COMMAND_LOCK_MULTI_AXIS:
  if (machineConfiguration.isMultiAxisConfiguration() &&
      (machineConfiguration.getNumberOfAxes() >= 4)) {
    writeBlock(mClampModal.format(10)); // unlock 4th-axis motion
    if (machineConfiguration.getNumberOfAxes() == 5) {
      writeBlock(mClampModal.format(12)); // unlock 5th-axis motion
    }
  }
  return;
case COMMAND_UNLOCK_MULTI_AXIS:
  if (machineConfiguration.isMultiAxisConfiguration() &&
      (machineConfiguration.getNumberOfAxes() >= 4)) {
    writeBlock(mClampModal.format(11)); // unlock 4th-axis motion
    if (machineConfiguration.getNumberOfAxes() == 5) {
      writeBlock(mClampModal.format(13)); // unlock 5th-axis motion
```

```
    }
  }
```
Sample Modal Group Code

5.1.11 Fixed Settings

The fixed settings area of the global section defines settings in the post processor that enable features that may change from machine to machine, but are not common enough to place in the Property Table. These settings are usually not modified by the post processor, but can be modified to enable features on your machine that are disabled in a stock post processor or vice versa.

```
// fixed settings
var forceResetWorkPlane = false; // enable to force reset of machine ABC on new orientation
var maxTappingRPM = 3000; // s/b 3000 for 10k spindle, 1500 for 7.5k spindle
```
Sample Fixed Settings Code

5.1.12 Collected State

The collected state area of the global section contains global variables that will be changed during the execution of the post processor and are either referenced in multiple functions or need to maintain their values between calls to the same function.

```
// collected state
var firstNote = true; // handles output of notes from multiple setups
```
Sample Collected State Code

5.2 onOpen

```
function onOpen() {
```

Settings used in onOpen	Description
maximumSpindleRPM	Maximum allowed spindle RPM.
maximumToolNumber	Maximum allowed tool number.
maximumToolLengthOffset	Maximum allowed tool length offset number.
maximumToolDiameterOffset	Maximum allowed tool diameter offset number.
programNumber	Minimum, maximum, and reserved range for program numbers.
supportsTCP	Control supports TCP.
supportsInverseTimeFeed	Control supports inverse time feed rates.
toolList	Tool list format.

The *onOpen* function is called at the start of post processing and can include the following logic.

1. Define settings based on properties
2. Define the multi-axis machine configuration

3. Output program name and header
4. Output initial startup codes
5. Perform checks for duplicate tool numbers and work offsets

5.2.1 Define Settings Based on Post Properties

The fixed settings section at the top of the post processor contain settings that are fixed and will not be changed during the processing of the intermediate file. Settings and variables that are dependent on the properties defined in the Property Table are defined in the *onOpen* function, since this is the function called when the post processor first starts.

Some of the variables that may be defined here are the maximum circular sweep, starting sequence number, formats, properties that can be changed using a Manual NC command, etc.

```
// avoid potential center calculation errors for CNC
if (getProperty("useRadius")) {
  maximumCircularSweep = toRad(90);
}

// separate codes with a space in output block
if (!getProperty("separateWordsWithSpace")) {
  setWordSeparator("");
}

// force IJK on circular blocks
if (getProperty("forceIJK")) {
  iOutput.setControl(CONTROL_FORCE);
  jOutput.setControl(CONTROL_FORCE);
  kOutput.setControl(CONTROL_FORCE);
}
```

Defining Dynamic Variables in the onOpen Function

The majority of machines on the market today accept input in both inches and millimeters. It is possible that your machine must be programmed in only one unit. If this is the case, then you can define the *unit* variable in the onOpen function to force the output of all relevant information in inches or millimeters.

```
unit = MM;  // set output units to millimeters, use IN for inches
```

Support for Only One Input Unit

5.2.2 Define the Multi-Axis Configuration

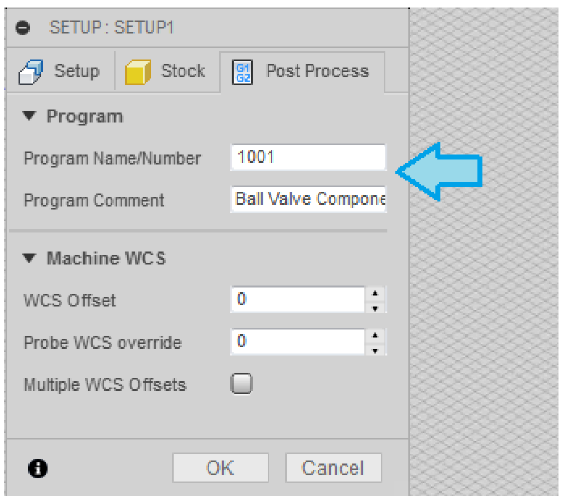
The *onOpen* function contains calls to the functions that will optionally create a hardcoded machine configuration and activate the machine configuration, whether it be hardcoded or defined in the CAM system. Following is an example of this code. For a complete description of defining a multi-axis configuration please see the *Multi-Axis Post Processors* chapter.

```
// define and enable machine configuration
receivedMachineConfiguration = machineConfiguration.isReceived();
if (typeof defineMachine == "function") {
  defineMachine(); // hardcoded machine configuration
}
activateMachine(); // enable the machine optimizations and settings
```

Defining the Machine Configuration

5.2.3 Output Program Name and Header

The program name and program comment are defined in the Post Process tab of the CAM setup in Fusion. The *programNameIsInteger* variable defined at the top of the program determines if the program name needs to be a number or can be a text string.



Defining the Program Name and Comment

```
writeln("%"); // output start of NC file
writeln("O" + oFormat.format(getProgramNumber());
writeComment(programComment);
```

Output the Program Name as an Integer and Program Comment

Some machines don't use a program number and accept the program name as a comment.

```
writeln("%"); // output start of NC file
writeComment(programName);
writeComment(programComment);
```

Output the Program Name as a Comment

The program header consists of the description of the machine and the list of tools used in the program by default. If you would like to add any other information to the program header, such as the output filename, version numbers, date and time of run, etc., you should add this to the *writeProgramHeader* function.

```
// write out program header
writeProgramHeader();
```

Output the Program Header

The *getToolList* function is used to obtain the list of tools used in the program based on the arguments passed to the function. It is controlled by the *toolList* setting and the arguments passed to *getToolList* mirror these settings. *getToolList* is called in the *writeProgramHeader* function.

```
getToolList(arguments, flag);
```

Arguments	Description
arguments	Any number of string arguments, which are the comparison criteria for determining if a tool is different from a previously found tool. These can be "number", "description", "lengthCompensation", or any other property in the tool object. The tool number is checked if there are no arguments.
flag	A bitwise of SORT or NOSORT and DUPLICATES or NODUPLICATES. For example, SORT | NODUPLICATES (which is the default setting). Sorting is based on the first property passed in *arguments*. If the first property matches during a sort, then the tools will be listed in the order that they are used.

Return Objects	Description
tool	The Tool object.
range	A Range object defining the minimum and maximum Z-levels reached for this tool.
operations	An array containing the Section Ids that the tool is used in. You can obtain the Section object from the Id by calling *getSection(id)*.

The getToolList Function

The following code is used to output the notes from the first setup. The property *showNotes* is defined in the properties, see the *Operation Comments and Notes* section to see how to define this property.

```
// output setup notes
if (getProperty("showNotes")) {
  writeSetupNotes();
}
```

Output Notes from First Setup

If your post needs to output the notes from multiple setups, then additional code outside of *onOpen* needs to be added.

First, define the *firstNote* property in the collected state section of the post.

```
// collected state
…
```

```
var firstNote; // handles output of notes from multiple setups
```

Define the firstNote Global Variable

In the *onParameter* function define the logic to process the *job-notes* parameter.

```
function onParameter(name, value) {
  switch (name) {
  …
  case "job-notes":
    if (!firstNote) {
      writeNotes(value, true);
    }
    firstNote = false;
    break;
  }
}
```

Handle the Setup Notes in onParameter

And finally, implement the *writeText* function. It can be placed in front of the *onParameter* function. This function can also be used to output the text from the *Pass through* Manual NC command.

```
// writes out multi-line text either as-is or as a comment
function writeNotes(text, asComment) {
  if (text) {
    var lines = String(text).split("\n");
    var r2 = new RegExp("[\\s]+$", "g");
    for (line in lines) {
      var comment = lines[line].replace(r2, "");
      if (comment) {
        if (asComment) {
          onComment(comment);
        } else {
          writeln(comment);
        }
      }
    }
  }
}
```

The writeNotesFunction is used to Output Multi-line Text

5.2.4 Output Initial Startup Codes

Codes that set the machine to its default condition are usually output at the beginning of the NC file. These codes could include the units setting, absolute mode, the feedrate mode, etc.

```
  // output default codes
```

```
writeBlock(gAbsIncModal.format(90), gFeedModeModal.format(94), gPlaneModal.format(17),
  gFormat.format(49), gFormat.format(40), gFormat.format(80));

writeBlock (gUnitModal.format(unit == MM ? 21 : 20));
```

Output Initial Startup Codes

5.2.5 Performing General Checks

Basic checks for using duplicate tool numbers, undefined work offsets, and other requirements are done in the *validateCommonParameters* function since all operations can be accessed at any time during post processing.

```
// validate operation and tool parameters
validateCommonParameters();
```

Check for Duplicate Tool Numbers using Different Cutter Geometry

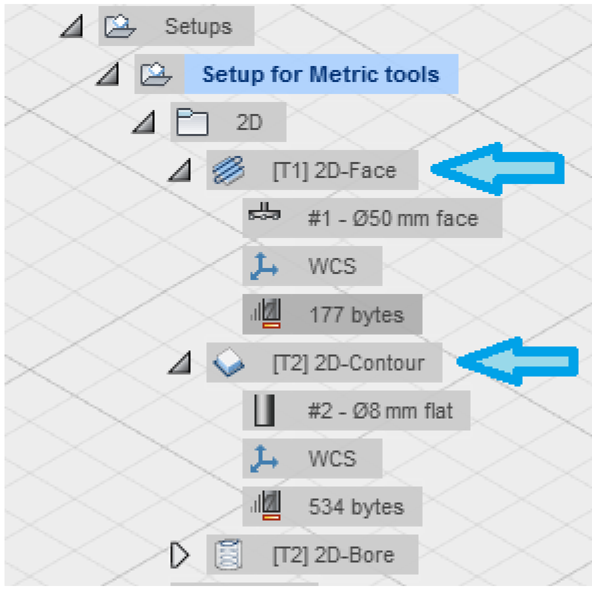
5.3 onSection

```
function onSection() {
```

Settings used in onSection	Description
allowCancelTCPBeforeRetracting	Cancel TCP prior to retracting the tool.
coolant	Supported coolant codes.
machineAngles	3+2 rotary axis calculations.
outputToolLengthCompensation	Tool length compensation output.
outputToolLengthOffset	Tool length offset output.
parametricFeeds	Parametric feed rate settings.
probing	WCS probing support.
retract	Safe positioning methods.
smoothing	Smoothing settings.
subprograms	Subprogram support.
supportsOptionalBlocks	Optional blocks are supported.
supportsToolVectorOutput	Tool vectors are supported for multi-axis toolpath.
workPlaneMethod	3+2 tilted work plane support.

The *onSection* function is called at start of each CAM operation and controls the output of the following blocks.

1. End of previous section
2. Operation comments and notes
3. Tool change
4. Work plane
5. Initial position



onSection is Called for Each Operation

The first part of *onSection* determines if there is a change in the tool being used and if the Work Coordinate System offset or Work Plane is different from the previous section. These settings determine the output required between operations.

```
var forceSectionRestart = optionalSection && !currentSection.isOptional();
optionalSection = currentSection.isOptional();
var insertToolCall = isToolChangeNeeded("number") || forceSectionRestart;
var newWorkOffset = isNewWorkOffset() || forceSectionRestart;
var newWorkPlane = isNewWorkPlane() || forceSectionRestart;
operationNeedsSafeStart = getProperty("safeStartAllOperations") && !isFirstSection();
```

Tool Change, Work Coordinate System Offset, Optional Section, Safe Start, and Work Plane Settings

5.3.1 Ending the Previous Operation

You would expect that the NC blocks output at the end of an operation to be output in the *onSectionEnd* function, but in most posts, this is handled in *onSection* and for the final operation, in the *onClose* function. This code will typically stop the spindle, turn off the coolant, and retract the tool.

```
if (insertToolCall || newWorkOffset || newWorkPlane || state.tcpIsActive) {

  // stop spindle and turn off coolant before retract during tool change
  if (insertToolCall && !isFirstSection()) {
    onCommand(COMMAND_STOP_SPINDLE);
    onCommand(COMMAND_COOLANT_OFF);
  }

  // retract to safe plane
  writeRetract(Z);
```

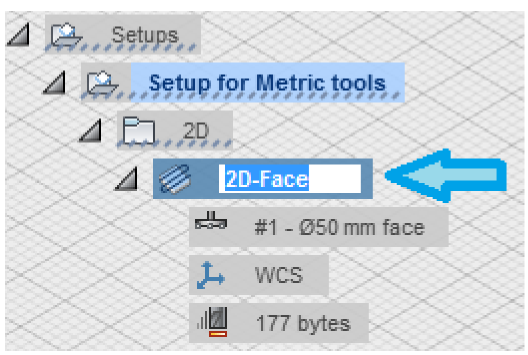
```
    // reset work plane
    if (isFirstSection() && machineConfiguration.isMultiAxisConfiguration()) {
      setWorkPlane(new Vector(0, 0, 0));
      forceABC();
    }
  }

    // cancel tool length compensation
    if (!isFirstSection() && (insertToolCall || state.tcpIsActive)) {
      disableLengthCompensation();
    }
}
```

Ending the Previous Operation

The code to retract the tool can vary from post to post, depending on the controller model and the machine configuration. It can output an absolute move to the machine home position, for example using G53, or move to a clearance plane relevant to the current work offset, for example G00 Z5.0.

5.3.2 Operation Comments and Notes

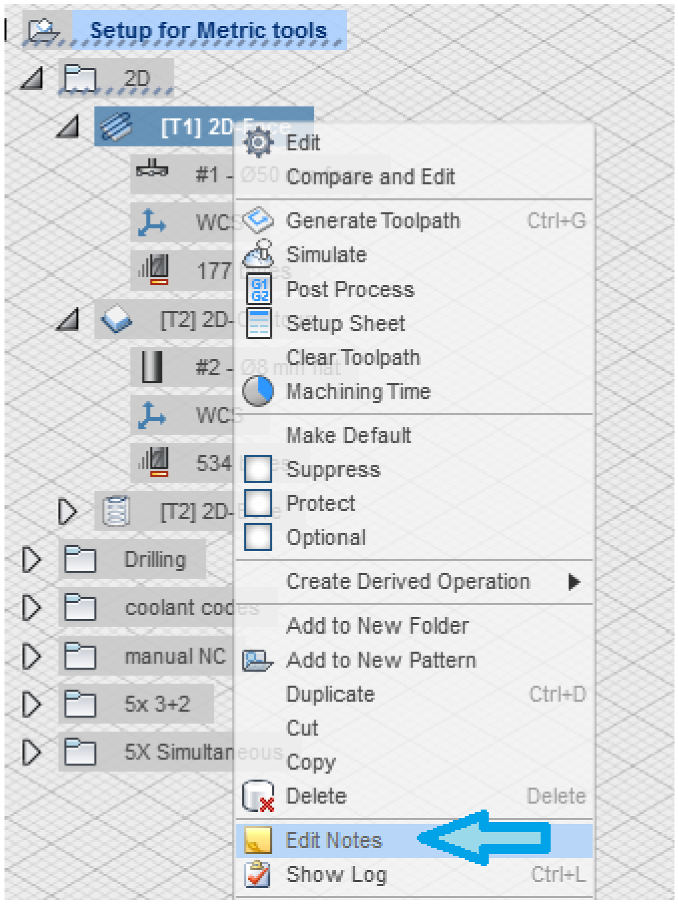
The operation comment is output in the *onSection* function and optionally the notes that the user attached to the operation.



Create Operation Comment

```
writeln("");
writeComment(getParameter("operation-comment", ""));
```

Output Operation Comment



Right Click to Show Menu to Create Operation Notes

The output of the operation notes is normally handled by the post processor property *showNotes*.

```
// user-defined properties
properties = {
…
  showNotes: {
    title      : "Show notes",
    description: "Writes setup and operation notes as comments in the output code.",
    type       : "boolean",
    value      : false,
    scope      : "post"
  },
…
}
```

Define the showNotes Property

```
  // output section notes
  if (getProperty("showNotes")) {
    writeSectionNotes();
  }
```

Output Operation Notes

5.3.3 Output Buffered Manual NC Commands

Manual NC commands are placed in the operation tree prior to the machining operation and are usually desired to be output after the previous section is ended and the current operation is started. Since the previous operation is typically canceled at the top of *onSection*, without special processing the Manual NC commands will be output prior to ending the previous section.

If the Manual NC commands are buffered, then a call to *executeManualNC* must be made in *onSection* to output the Manual NC commands. Refer to the *Manual NC Commands* chapter for a description on how to buffer Manual NC Commands.

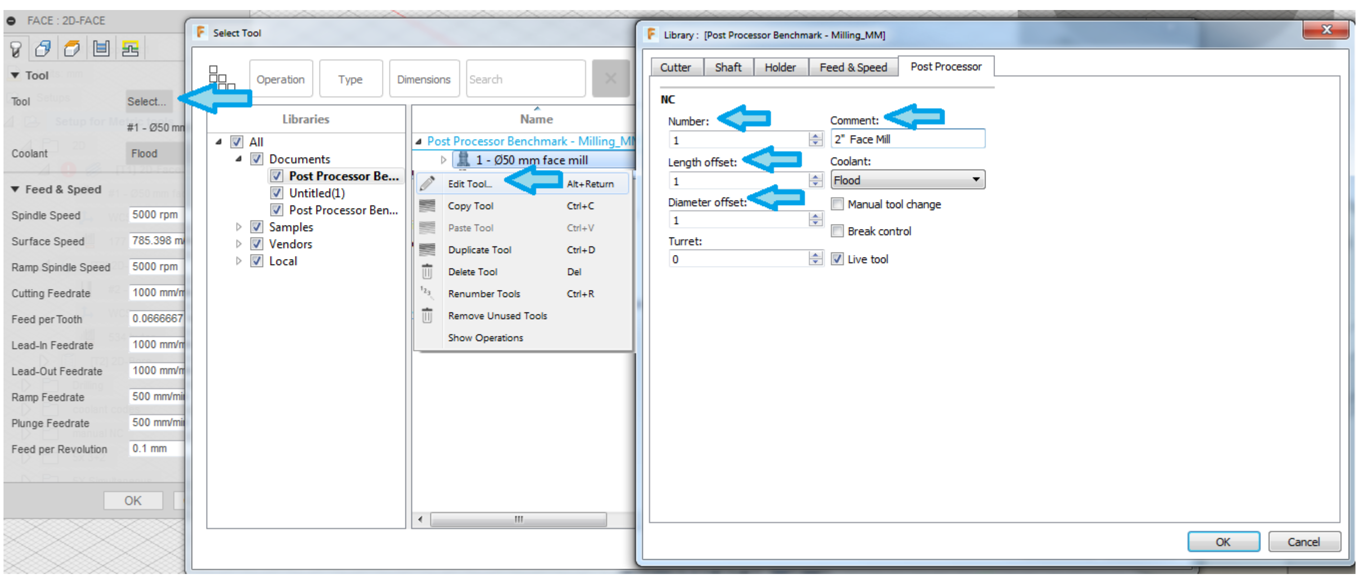
```
// process Manual NC commands
executeManualNC();
```

Output Manual NC Commands

5.3.4 Tool Change

Tool change blocks are output whenever a new tool is loaded in the spindle or the tool change is forced, either by a Manual NC *Force tool change* command or internally, for example when a safe start is forced at each operation. The tool change blocks usually contain the following information.

1. Tool number and tool change code
2. Tool comment
3. Selection of next tool



Tool Parameters Used in Tool Change

The Length Offset value is usually output with the Initial Position as described further in this chapter. The Diameter Offset value is output with a motion block in *onLinear*. All other tool parameters are output in the tool change code.

```
// output tool change
writeToolCall(tool, insertToolCall);
```

Output Tool Change

writeToolCall is the first in a list of helper functions that are used to output a tool change block. The following chart shows the tool change helper functions in the order that they are called and a description of what each helper function performs.

Tool Change Helper Function	Description
writeToolCall	Controlling function for tool change output. Positions the tool for a tool change, turns off the coolant if necessary, disables the tool length compensation, and outputs an optional stop if the *Optional stop* property is enabled.
writeStartBlocks	Handles the output of tool change blocks with support for safe starting an operation. See the *Safe Starting Operations* section for a description of this function.
(code)	Code passed to the *writeStartBlocks* function. See the *Safe Starting Operations* section for a description of this code.
onCommand	Outputs the tool change block and optionally preselects the next tool using the COMMAND_LOAD_TOOL command.

Tool Change Helper Functions

The *onCommand* function is typically the only tool change helper function that needs to be edited, as this is where the tool change block is defined and output.

```
  case COMMAND_LOAD_TOOL:
    writeToolBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
    writeComment(tool.comment);

    var preloadTool = getNextTool(tool.number != getFirstTool().number);
    if (getProperty("preloadTool") && preloadTool) {
      writeBlock("T" + toolFormat.format(preloadTool.number)); // preload next/first tool
    }
    return;
```

Output Tool Change Block and Preselect Next Tool

The selection of the next tool is optional and is controlled by the post processor property *preloadTool*.

```
// user-defined properties
properties = {
```

```
…
  preloadTool: {
    title      : "Preload tool",
    description: "Preloads the next tool at a tool change (if any).",
    type       : "boolean",
    value      : true,
    scope      : "post"
  }
}
```

Define the preloadTool Property

The first tool will be loaded in the last operation of the program.

5.3.5 Safe Starting Operations

It is possible to output the required blocks to start the NC program at operations that would not contain a tool change block due to the same tool being used as the previous operation. This is considered safe starting an operation.

A safe start operation will contain all blocks necessary to start the program at this operation. Blocks that would normally not be output will be output as optional skip blocks.

```
(2D-Contour with compensation left)
/ N285 G28 G91 Z0
/ N290 G90
/ N295 T2 M6
/ N300 T1
N305 G17 G90 G94
/ N310 S5000 M3
/ N315 G54
/ N320 G0 A0. C0.
/ N325 M8
/ N330 G49
/ N335 G0 X-0.4019 Y1.1944
/ N340 G0 G43 Z0.6299 H2
```

A Safe Start Operation

The *safeStartAllOperations* property must be defined to enable the use of safe start operations.

```
  safeStartAllOperations: {
    title      : "Safe start all operations",
    description: "Write optional blocks at the beginning of all operations to safe start that operation.",
    group      : "preferences",
    type       : "boolean",
    value      : false,
    scope      : "post"
```

```
},
```

Define the safeStartAllOperations Property

The controlling function for outputting blocks that should be considered for a safe start is the *writeStartBlocks* function.

```
writeStartBlocks(isRequired, function () {code});
```

Parameter	Description
isRequired	Determines if the *code* should be executed and any output generated by the code should be output. A value of *true* will process the code without exception. *false* will only process the code if the operation requires a safe start. In this case any output generated from the code will be output in optional skip blocks.
function ()	Required parameter.
{code}	Code to be executed by the *writeStartBlocks* function, following the rules of the *isRequired* parameter.

The writeStartBlocks Function

```
wcsIsRequired = newWorkOffset || insertToolCall || !operationNeedsSafeStart;
writeStartBlocks(wcsIsRequired, function () {
  writeBlock(currentSection.wcs);
});
```

Sample Call to the writeStartBlocks Function

5.3.6 Modal Codes

Codes that define the operation modes are output after the tool change and usually contain the planar code, absolute/incremental code, and feedrate mode. The *formatFeedMode* function determines if the operation uses Feed-per-Minute or Feed-per-Revolution feedrates and returns the appropriate code.

```
// Output modal commands here
var feedMode = formatFeedMode(currentSection.feedMode);
writeBlock(gPlaneModal.format(17), gAbsIncModal.format(90), feedMode);
```

Output Modals Codes

Refer to the *Feed per Revolution Output with Drilling Cycles* section for a description of the formatFeedMode function.

5.3.7 Spindle Codes

The spindle codes will be output with a tool change and if the spindle speed changes. The *startSpindle* function is used to output the spindle codes.

```
  // Start the spindle
startSpindle(tool, insertToolCall);
```
Start the Spindle

```
startSpindle(tool, insertToolCall);
```

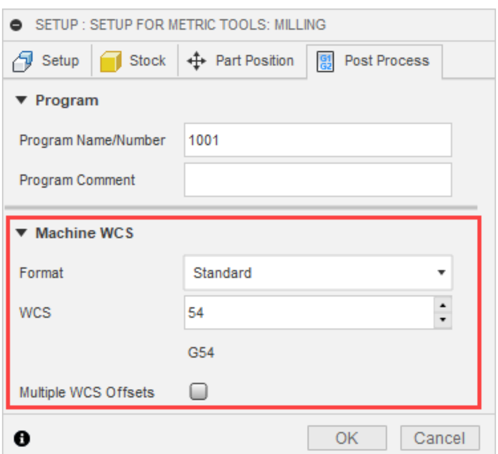
Parameter	Description
tool	The tool object contains the spindle parameters for the active tool.
insertToolCall	*true* indicates that this operation changes tools from the previous operation.

The startSpindle Function

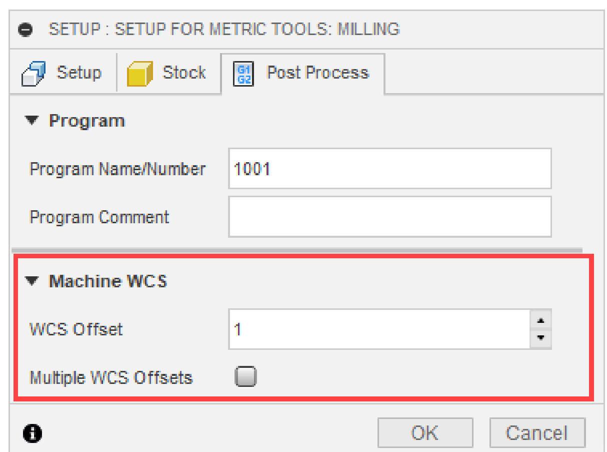
5.3.8 Work Coordinate System Offsets

The active Work Coordinate System (WCS) offset is defined in the CAM Setup dialog. You can override the WCS defined in the setup in either a folder or pattern. The *wcsDefinitions* variable defines the supported WCS codes that can be output, it is recommended that you include this variable definition in your post. All examples in this section assume that *wcsDefinitions* is defined.

If a Machine Definition is defined the WCS can be selected using the number as expected by the machine control. When a Machine Definition is not defined, then a simple value will be displayed.



WCS Offset with a Machine Definition



WCS Offset without a Machine Definition

WCS codes are output when a new tool is used for the operation or when the WCS offset number used is changed. WCS offsets are typically controlled using the G54 to G59 codes and possibly an extended syntax for handling work offsets past 6.

wcsDefinitions is defined just after the properties table at the top of the post processor.

```
var wcsDefinitions = {
  useZeroOffset: false, // set to 'true' to allow for workoffset 0, 'false' treats 0 as 1
  wcs          : [
    {name:"Standard", format:"G", range:[54, 59]}, // standard WCS, output as G54-G59
    {name:"Extended", format:"G59.#", range:[1, 64]} // extended WCS, output as G59.7, etc.
    // {name:"Extended", format:"G54 P#", range:[1, 64]} // extended WCS, output as G54 P7, etc.
  ]
};
```

Parameters	Description
useZeroOffset	Set to *true* to enable a work offset value of 0. Setting it to *false* will treat a work offset of 0 as 1.
wcs	Contains the definitions of the supported WCS formats.
name	The name of the WCS output format. This will usually be *Standard* or *Extended*. The name is displayed in the *Format* field of the Machine WCS frame.
format	The output format of the WCS. This is a text string that has an optional # character that defines where the offset value will be placed. If # is not specified, then the offset value will be placed at the end of the string. You can also use multiple consecutive # characters to define the number of digits to output with the WCS value, for example *P##* will output P01. Specifying $# will place a # character in the output.
range	Defines the valid range of work offsets for the defined format.

The wcsDefinitions Variable

The post processor kernel will format the output WCS code based on the format defined in *wcsDefinitions*. Both a string and number is available to the post processor in the *section* object.

Variable	Description
section.wcs	The output code of the work offset (G54, G51 P1, etc.).
section.workOffset	The work offset number.

```
  // set wcs
  var wcsIsRequired = true;
  if (insertToolCall || operationNeedsSafeStart) {
    currentWorkOffset = undefined; // force work offset when changing tool
    wcsIsRequired = newWorkOffset || insertToolCall || !operationNeedsSafeStart;
  }
  writeWCS(currentSection, wcsIsRequired);
```

Output the Work Coordinate System Offset Number

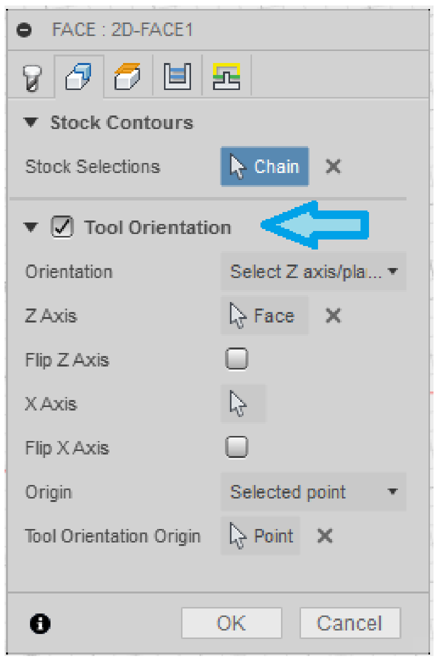
```
  writeWCS(section, wcsIsRequired);
```

Parameter	Description
section	The section containing the WCS to output.
wcsIsRequired	*true* indicates that WCS block needs to be output. Follows the same rules as the *isRequired* parameter of the *writeStartBlocks* function.

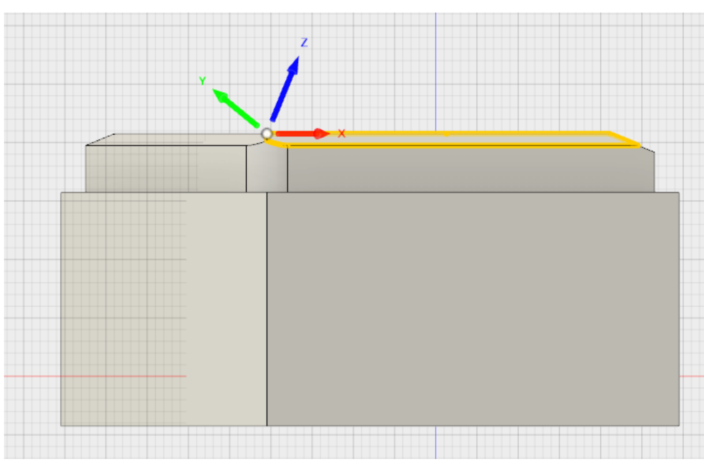
The writeWCS Function

5.3.9 Work Plane – 3+2 Operations

3+2 operations are supported by defining a tool orientation for the operation. This tool orientation is referenced as the Work Plane in the post processor. The tool orientation is defined in the Geometry tab of the operation.



Defining the Work Plane



Work Plane for 3+2 Operation

The output for a Work Plane will either be the rotary axes positions or the definition of the Work Plane itself, usually using Euler angles. The *workPlaneMethod* setting determines how tilted work planes are handled in the post processor.

The *eulerConvention* setting specifies the order of the primary axis rotations that the machine control requires and can be one of the values in the following table or *undefined* to use the rotary axis angles.

Parameter	Parameter	Parameter	Parameter
EULER_XYZ_R	EULER_XYX_R	EULER_XZX_R	EULER_XZY_R
EULER_YXY_R	EULER_YXZ_R	EULER_YZX_R	EULER_YZY_R
EULER_ZXY_R	EULER_ZXZ_R	EULER_ZYX_R	EULER_ZYZ_R
EULER_XYZ_S	EULER_XYX_S	EULER_XZX_S	EULER_XZY_S
EULER_YXY_S	EULER_YXZ_S	EULER_YZX_S	EULER_YZY_S
EULER_ZXY_S	EULER_ZXZ_S	EULER_ZYX_S	EULER_ZYZ_S

Euler Angle Order

Check the Programming Manual for your machine to determine if Euler angles are supported and the order of rotations. The _R (rotated) variants of the Euler angles will use the modified orientation after each rotation for each axis. The _S (static) variants will use the original coordinate system for all rotations and is sometimes referred to as pitch, roll, yaw.

The main function for handling 3+2 operations is the *defineWorkPlane* function.

```
// position rotary axes for multi-axis and 3+2 operations
var abc = defineWorkPlane(currentSection, true);
```

Calling the defineWorkPlane Function

The *defineWorkPlane* function is defined as follows and returns the initial rotary positions for multi-axis and 3+2 operations.

defineWorkPlane(_section, _setWorkPlane)

Arguments	Description
_section	The operation (section) used to calculate the rotary angles.
_setWorkPlane	*true* = output the rotary angle positions and adjust the output coordinates for the 3+2 rotation. *false* = don't output the rotary angle positions. The rotary angles will still be calculated, and the output coordinates will be adjusted for the 3+2 rotation.

The defineWorkPlane Function

The function *getWorkPlaneMachineABC* is used to calculate the rotary axes positions that satisfy the Work Plane. It will return the calculated angles of the rotary axis to fulfill the work plane orientation.

getWorkPlaneMachineABC(_section, rotate)

Arguments	Description
_section	The section to calculate the rotary-angles for.
rotate	Enable to adjust the output coordinates for the work plane orientation. Disable to just calculate the rotary angles and not adjust the XYZ coordinates for the axis rotations.

The getWorkPlaneMachineABC Function

The *getABCByPreference* function is used to calculate the rotary axis angles and is controlled by the *machineAngles* setting.

```
var abc = _section.getABCByPreference(
  machineConfiguration,
  _section.workPlane,
  getCurrentABC(),
  settings.machineAngles.controllingAxis,
  settings.machineAngles.type
  settings.machineAngles.options);
```

Calculate the Rotary Axis Angles Based on the Work Plane

abc = machineConfiguration.**getABCByPreference**(workPlane, current, controllingAxis, type, options)
abc = section.**getABCByPreference**(machineConfiguration, workPlane, current, controllingAxis, type, options)

Arguments	Description
machineConfiguration	The machine configuration. This parameter is only specified with the *section.getABCByPreference* version.
workPlane	The work plane matrix used to calculate the rotary-angles. This variable is typically *section.workPlane*.
current	The current rotary angles. This is usually the ABC position returned by *getCurrentABC*.
controllingAxis	The axis used to determine the preferred solution in conjunction with the *type* argument. It can be A, B, or C for a single axis, or ABC to consider all defined rotary axes.
type	The preference type as described in the *Preference Type* table.
options	Options used to control the solution as described in the *Controlling Options* table.

The getABCByPreference Function

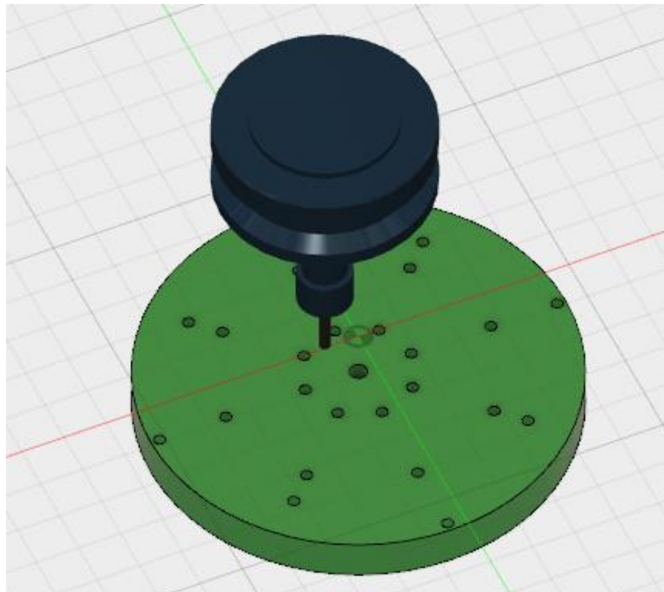
Preference Type	Description
PREFER_PREFERENCE	Uses the preference specified with the axis, either in the CAM Machine Definition or in the *createAxis* function for hardcoded kinematics.
PREFER_CLOSEST	Selects the solution closest to the current rotary axes position. All preference types will choose the closest solution that satisfies the

Preference Type	Description
	preference type chosen. PREFER_CLOSEST will select the closest solution without regards to any other preference.
PREFER_POSITIVE	The closest solution with a positive angle for the controlling axis. This preference cannot be used when ABC is the controlling axes.
PREFER_NEGATIVE	The closest solution with a negative angle for the controlling axis. This preference cannot be used when ABC is the controlling axes.
PREFER_CLW	The closest solution that moves in a clockwise direction from the current axis position. This preference cannot be used when ABC is the controlling axes.
PREFER_CCW	The closest solution that moves in a counterclockwise direction from the current axis position. This preference cannot be used when ABC is the controlling axes.

The Preferred Solution Types

Controlling Options	Description
ENABLE_NONE	Disables all controlling options.
ENABLE_RESET	Respects the *reset* parameter in the axis definitions. The *reset* parameter resets the axis to 0 degrees before calculating the closest solution.
ENABLE_WCS	Solves for a rotary axis perpendicular to the spindle vector as defined by the tool orientation of the operation. For example, if the tool orientation is facing up in Z and has an XY-rotation, then the C-axis will use the X-axis orientation of the rotation to determine the C-axis position.
ENABLE_LIMITS	Solves for a rotary axis perpendicular to the spindle vector to keep the linear axes within their defined limits. The limits (range) of the linear axes must be defined in the machine configuration. This option is only valid for the *section.getABCByPreference* version.
ENABLE_ALL	Enables all controlling options.

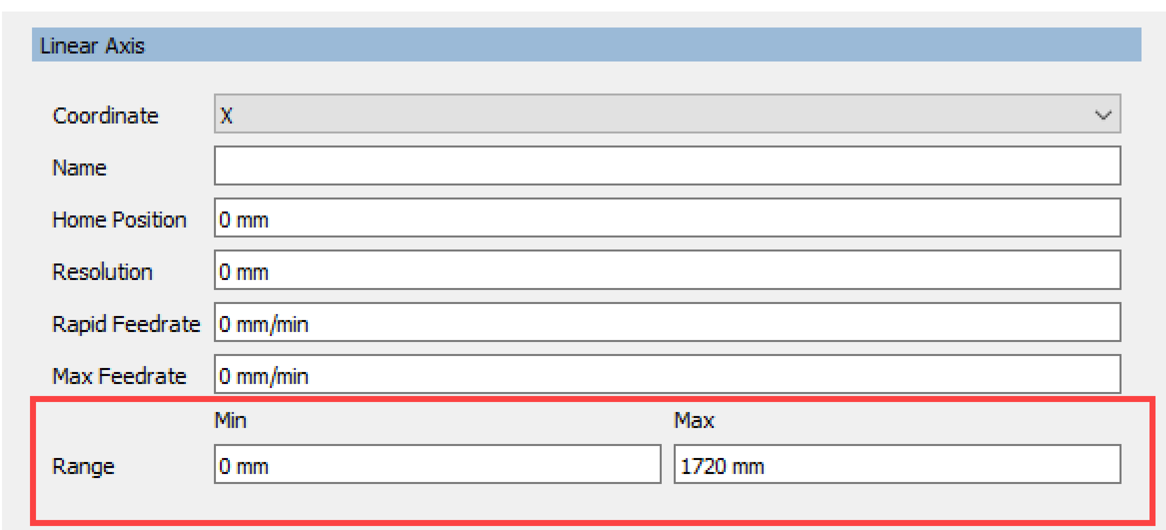
The Controlling Options for the Rotary Axes Solution



Use ENABLE_WCS for a Tool Perpendicular to the Rotary Table

There are two variations of the *getABCByPreference* function, one in the *machineConfiguration* object and the other in the *section* object. The only difference between the two is that the *section* function supports the ENABLE_LIMITS option, while the *machineConfiguration* function does not. The ENABLE_LIMITS works with rotary tables that are perpendicular to the spindle vector and will adjust the rotary table position to bring the linear XYZ coordinates within their defined limits if possible. If it is not possible to bring the machine within its limits, then the calculated rotary axis positions will be the same as if ENABLE_LIMITS was not specified.

You must define the limits of the linear axes in the machine configuration when using ENABLE_LIMITS. The limits can be defined as part of an external Machine Definition or hardcoded within the post processor if a Machine Definition is not used.



Defining the Limits of a Linear Axis in the Machine Definition

```
// define linear axes limits
var xAxis = createAxis({actuator:"linear", coordinate:0, table:true, axis:[1, 0, 0],
  range:[xAxisMinimum, xAxisMaximum]});
var yAxis = createAxis({actuator:"linear", coordinate:1, table:true, axis:[0, 1, 0],
  range:[yAxisMinimum, yAxisMaximum]});
var zAxis = createAxis({actuator:"linear", coordinate:2, table:true, axis:[0, 0, 1],
  range:[-100000, 100000]});
machineConfiguration.setAxisX(xAxis);
machineConfiguration.setAxisY(yAxis);
machineConfiguration.setAxisZ(zAxis);
```

Defining the Limits of the Linear Axes in the Post Processor

Since the *getABCByPreference* function will return a rotary axis position even if the machine is not within the defined linear limits, you must call the *doesToolPathFitWithinLimits* function to determine if the calculated rotary axis position will keep the machine within limits for this operation.

```
bestABC = section.getABCByPreference(machineConfiguration, section.workPlane,
  getCurrentDirection(), C, PREFER_CLOSEST, ENABLE_RESET | ENABLE_LIMITS);
bestABC = section.doesToolpathFitWithinLimits(machineConfiguration, bestABC) ?
  bestABC : undefined;
```

Determine if Linear Axes are Within Limits

```
withinLimits = section.doesToolpathFitWithinLimits(machineConfiguration, abc)
```

Arguments	Description
machineConfiguration	The machine configuration.
abc	The rotary angle positions used to determine if the linear XYZ axes are within their defined limits.

The doesToolpathFitWithinLimits Function

The 3+2 operation coordinates may need to be adjusted for the rotary axes when a tilted work plane is not supported. This is done by calling *section.optimize3DPositionsByMachine* with the rotary axes and optimization type. Most posts will use the Tool Control Point (TCP) setting for each axis by using the OPTIMIZE_AXIS setting.

```
if (!currentSection.isOptimizedForMachine()) {
  machineConfiguration.setToolLength(addToolLength ? getBodyLength(tool)); // define the tool length for
head adjustments
  section.optimize3DPositionsByMachine(machineConfiguration, abc, OPTIMIZE_AXIS);
}
```

Adjust the Coordinates for the Rotary Axes

It is important to know that the XYZ coordinates provided to the post processor for 3+2 are in the work plane coordinate system, meaning they are in the XY-plane defined by the work plane. This is fine for machines that support multi-axis features such as G68.2, CYCLE800, etc., but could be incorrect for machines that do not support these features.

The *section.optimize3DPositionsByMachine* function is used to calculate the proper coordinates aligned with the defined machine configuration for the specified operation.

```
section.optimize3DPositionsByMachine(machineConfiguration, abc, optimizeType);
```

Arguments	Description
machineConfiguration	The active machine configuration.
abc	The current rotary axis positions passed as a Vector.
optimizeType	Optimization type as described in the following table.

The optimize3DPositionsByMachine Function

optimizeType	Description
OPTIMIZE_NONE	The coordinates will be the tool tip position (TCP).
OPTIMIZE_BOTH	The coordinates will be adjusted for the table and head rotations. The TCP settings for the axes will be ignored.
OPTIMIZE_TABLES	The coordinates will be adjusted for the rotary tables. The TCP settings for the axes will be ignored
OPTIMIZE_HEADS	The coordinates will be adjusted for the rotary heads. The TCP settings for the axes will be ignored
OPTIMIZE_AXIS	The coordinates will be adjusted based on the TCP setting for each axis as defined in the Machine Definition or *createAxis* command.

Optimization Types for 3+2 Operations

If TCP positions are output in a 3+2 operation you will have to ensure that the TCP has been enabled for this operation (G43.4, TRAORI, etc.).

You should be aware that the X-axis direction of the Work Plane does affect the Euler angle calculation. The typical method of defining the Work Plane is to keep the X-axis orientation pointing in the positive direction as you look down the Z-axis, but on some table/table style machines this will cause the machining to be on the back side of the table, so in this case you will want the X-axis pointing in the negative direction.

The *setWorkPlane* function does the actual output of the Work Plane and can vary from post processor to post processor, depending on the requirements of the machine control. It will output the calculated Euler angles or rotary axes positions, and in some cases, both.

```
setWorkPlane(abc)
```

Arguments	Description
abc	The rotary axis positions or Euler angles used to set the tilted work plane position.

The setWorkPlane Function

5.3.10 Coolant Codes

The coolant code is output using the following code. It uses the coolant codes defined in the coolant settings.

```
// writes the required coolant codes
setCoolant(tool.coolant);
```

Output of Coolant Codes

The *setCoolant* function will output each the coolant code(s) in standalone block(s).

It may be that you want to output the coolant codes(s) in a block with other codes, such as the initial position or the spindle speed. In this case you can call *getCoolantCodes* directly in the *onSection* function and add the output of the coolant codes to the appropriate block. The following example will output the coolant codes with the initial position of the operation.

```
  var coolantCodes = getCoolantCodes(tool.coolant);
  var initialPosition = getFramePosition(currentSection.getInitialPosition());
…
  writeInitialPositioning(initialPosition, isRequired, coolantCodes);
```

Output Coolant Codes with Initial Position

5.3.11 Initial Position

The initial position of an operation is output using the *writeInitialPositioning* function. This function controls the following aspects of positioning the tool at the start of an operation.

- Determines the positioning mode (G00/G01) based on the *highFeedMapping* variable.
- Multi-axis prepositioning using a tilted work plane if supported.
- Enables tool length compensation if supported.
- Handles positioning at a tool change and between operations without a tool change.

```
// prepositioning
var initialPosition = getFramePosition(currentSection.getInitialPosition());
var isRequired = insertToolCall || state.retractedZ || !state.lengthCompensationActive  ||
  (!isFirstSection() && getPreviousSection().isMultiAxis());
writeInitialPositioning(initialPosition, isRequired);
```

Output Current Position and Tool Length Compensation

```
writeInitialPositioning(position, isRequired, codes1, codes2)
```

Arguments	Description
position	The XYZ coordinates to position at.

Arguments	Description
isRequired	*true* indicates that a full positioning sequence needs to be output, for example at a tool change. Follows the same rules as the *isRequired* parameter of the *writeStartBlocks* function.

The writeInitialPositioning Function

5.4 The section Object

The start of a machining operation defined in CAM is stored in the intermediate file as a separate section. The *section* object contains the information used to generate the operation. All defined sections are accessible to the post processor at any time in the post processor by accessing the section by its ID. This section provides a description of some of the functions/variables used to access the information stored in a section. You will find a description of various *section* functions/variables in other sections of this manual where they are used.

5.4.1 currentSection

The *currentSection* variable refers to the active section/operation. It is unspecified if used outside of the scope of a section, for example in *onOpen* or *onClose*. In these functions you will need to access the section directly using the *getSection* function.

```
var firstSection = getSection(0); // access the first section of the program
var lastSection = getSection(getNumberOfSections() – 1) // access the last section of the program
```

Accessing the First and Last Sections

5.4.2 getSection

```
value = getSection(sectionId)
```

Arguments	Description
sectionId	The ID of the section to return. sectionId can be in the range of 0 through the number of defined sections (*getNumberOfSections*).

Returns the section object associated with the specified section ID.

5.4.3 getNumberOfSections

```
value = getNumberOfSections()
```

Returns the number of sections (operations) defined in the program.

```
for (var i = 0; i < getNumberOfSections(); ++i) { // loop through all sections
  var section = getSection(i);
  …
```

Looping Through All Defined Sections

5.4.4 getId

```
value = section.getId()
```

The *getId* function returns the ID of the provided section. It will be in the range of 0 through the number of defined sections minus 1 (*getNumberOfSections*).

```
// loop through sections defined after the current section
for (var i = currentSection.getId() + 1; i < numberOfSections; ++i) {
        var section = getSection(i);
```

Looping Through Following Sections

5.4.5 isToolChangeNeeded

```
value = isToolChangeNeeded([section], arguments)
```

Arguments	Description
section	Specifies the section to test for a tool change. If section is not specified, then *currentSection* is assumed.
arguments	Specifies one or more of the Tool object variables to use as criteria to determine if a tool change is needed. This list of criteria can be *number*, *description*, *lengthOffset*, or any other member of the Tool object.

Returns *true* if a tool change is required for the specified section. The comparison criteria are passed as a list of arguments to the function and can be any valid Tool object variable.

```
var insertToolCall = isToolChangeNeeded("number", “lengthOffset);
```

Determining if a Tool Change is Required for the Current Section Based on the Tool Number and Length Offset

5.4.6 isNewWorkPlane

```
value = isNewWorkPlane([section])
```

Arguments	Description
section	Specifies the section to test for a Work Plane change. If section is not specified, then *currentSection* is assumed.

Returns *true* if the work plane changes for the specified section as compared to the previous section.

```
var newWorkPlane = isNewWorkPlane();
```

Determining if the Work Plane Changes Between Sections

5.4.7 isNewWorkOffset

```
value = isNewWorkOffset([section])
```

Arguments	Description
section	Specifies the section to test for a Work Offset change. If section is not specified, then *currentSection* is assumed.

Returns *true* if the work offset changes for the specified section as compared to the previous section.

```
var newWorkOffset = isNewWorkOffset();
```

Determining if the Work Offset Changes Between Sections

5.4.8 isSpindleSpeedDifferent

```
value = isSpindleSpeedDifferent([section])
```

Arguments	Description
section	Specifies the section to test for a change in the spindle speed or spindle mode. If section is not specified, then *currentSection* is assumed.

Returns *true* if the spindle speed or spindle mode (RPM, SFM) differs from the previous section, *false* if they are the same.

```
  if (isSpindleSpeedDifferent ()) {
```

Determining if the Spindle Speed or Mode Changes Between Sections

5.4.9 isDrillingCycle

```
isDrillingCycle([section,] [checkBoringCycles])
```

Arguments	Description
section	Specifies the section to check for a drilling cycle. If section is not specified, then *currentSection* is assumed.
checkBoringCycles	When set to *false*, boring cycles with a shift value will not be considered a drilling cycle, otherwise if set to *true* or not specified shift boring cycles are considered drilling cycles.

Returns *true* if the section is a drilling operation, otherwise returns *false*. Milling cycles are not considered a drilling cycle.

```
  if (isDrillingCycle()) { // test if the current section is a drilling operation
  if (isDrillingCycle(false)) { // do not include shift boring cycles as a drilling operation
```

Determining if the Section is a Drilling Operation

5.4.10 isTappingCycle

isTappingCycle([section])

Arguments	Description
section	Specifies the section to check for a tapping cycle. If section is not specified, then *currentSection* is assumed.

Returns *true* if the section is a tapping cycle, otherwise returns *false*.

```
if (isTappingCycle()) { // test if the current section is a tapping operation
```

Determining if the Section is a Tapping Operation

5.4.11 isAxialCenterDrilling

isAxialCenterDrilling([section,] [checkLiveTool])

Arguments	Description
section	Specifies the section to check for an axial drilling cycle. If section is not specified, then *currentSection* is assumed.
checkLiveTool	When set to *false*, the live tool setting is ignored and will not be used in testing for an axial center drilling operation, otherwise if set to *true* or not specified operations using a live tool will not be considered as an axial center drilling operation.

Returns *true* if the section is an axial drilling cycle, otherwise returns *false*. Axial drilling cycles are considered drilling operations that are at X0 Y0 and are usually tested for on lathes.

```
if (isAxialCenterDrilling()) { // test if the current section is an axial center drilling cycle
if (isAxialCenterDrilling(false)) { // ignore the Live Tool setting
```

Determining if the Section is an Axial Center Drilling Operation

5.4.12 isMillingCycle

isMillingCycle([section,] [checkBoringCycles])

Arguments	Description
section	Specifies the section to check for a milling cycle. If section is not specified, then *currentSection* is assumed.
checkBoringCycles	When set to *true*, boring cycles with a shift value will be considered a milling cycle, otherwise if set to *false* or not specified shift boring cycles are not considered milling cycles.

Returns *true* if the section is a milling cycle, otherwise returns *false*.

```
if (isMillingCycle()) { // test if the current section is a milling cycle
if (isMillingCycle(true)) { // include shift boring cycles as a drilling operation
```

Determining if the Section is a Drilling Operation

5.4.13 isProbeOperation

```
value = isProbeOperation([section])
```

Arguments	Description
section	Specifies the section to check for a probing operation. If section is not specified, then *currentSection* is assumed.

Returns *true* if the section is a probing operation, otherwise return *false*. You can also check if the tool type is set to TOOL_PROBE to determine if probing is active for an operation.

```
if (isProbeOperation()) { // test if the current section is a probe operation
if (section(i).getTool().type == TOOL_PROBE) { // probing or inspection operation
```

Determining if the Section is a Probing Operation

5.4.14 isInspectionOperation

```
value = isInspectionOperation([section])
```

Arguments	Description
section	Specifies the section to check for an inspection operation. If section is not specified, then *currentSection* is assumed.

Returns *true* if the section is an inspection operation, otherwise return *false*.

```
if (isInspectionOperation()) { // test if the current section is an inspection operation
if (section(i).getTool().type == TOOL_PROBE) { // the specified section is a probing operation
```

Determining if the Section is an Inspection Operation

5.4.15 isDepositionOperation

```
value = isDepositionOperation([section])
```

Arguments	Description
section	Specifies the section to check for a deposition operation. If section is not specified, then *currentSection* is assumed.

Returns *true* if the section is a deposition operation, otherwise return *false*.

```
if (isDepositionOperation()) { // test if the current section is a deposition operation
```

Determining if the Section is a Deposition Operation

5.4.16 probeWorkOffset

```
value = section.probeWorkOffset;
```

The *probeWorkOffset* variable contains the WCS number that is active during the probing operation. It is the same as the *probe-output-work-offset* parameter.

```
validate(currentSection.probeWorkOffset <= 6, "Angular Probing supports work offsets 1-6.");
```

Validating the Range of the Probe Work Offset

5.4.17 getNextTool

```
tool = getNextTool([section,] [firstTool,] [arguments])
```

Arguments	Description
section	Specifies the section to use as the base tool. The next tool following the tool used in this section will be returned. If section is not specified, then *currentSection* is assumed.
firstTool	Returns the first tool if the end of the program is reached when set to *true*. Returns *undefined* if it is not specified or set to *false* and the end of the program is reached.
arguments	Specifies one or more of the Tool object variables to use as criteria to determine the next tool. This list of criteria can be *number*, *description*, *lengthOffset*, or any other member of the Tool object.

The *getNextTool* function returns the next tool used in the program based on the active tool in the current section. You can pass *number*, *description*, *diameter*, or any other member of the tool object as the criteria for determining if the tool is different than the current tool. This function will take any number of text string arguments. If an argument is not passed to this function, then it will choose the next tool based on the tool number.

```
var nextTool = getNextTool(true); // get next tool based on tool number, can return the first tool
var nextTool = getNextTool("description"); // get next tool based on tool description
```

Accessing the Next Tool

5.4.18 getFirstTool

```
tool = getFirstTool()
```

The *getFirstTool* function returns the first tool used in the program.

```
var firstTool = getFirstTool();
```

Accessing the First Tool

5.4.19 toolZRange

```
zRange = toolZRange()
```

The *toolZRange* function returns the Z-axis range for the active tool for the current and subsequent sections that use this tool. It will return undefined if the tool orientation of the active section is not along the Z-axis.

```
var zRange = toolZRange();
```

Calculate the Z-axis Minimum and Maximum for the Active Section(s)

5.4.20 strategy

```
value = section.strategy;
```

The *strategy* variable is part of the *section* object and contains a string that represents the machining strategy used for the section. It contains the same value as the *operation-strategy* parameter.

```
  } else { // do not output smoothing for the following operations
    smoothing.isAllowed = !(currentSection.strategy == "drill"));
  }
```

Checking for a Drill Operation

5.4.21 checkGroup

```
value = section.checkGroup(strategy-list)
```

Arguments	Description
strategy-list	A list of machining strategy groups to check, separated by commas.

The checkGroup function returns true if the section machining strategy belongs to all of the strategy groups specified in the *strategy-list.* The valid strategy groups are listed in the following table. Each of these variables should be prefixed with STRATEGY_, for example STRATEGY_2D.

2D	3D	ADDITIVE	CHECKSURFACE
FINISHING	HOLEMAKING	INSPECTION	JET
DRILLING	MILLING	MULTIAXIS	PROBING
ROTARY	ROUGHING	SAMPLING	SECONDARYSPINDLE
SURFACE	THREAD	TURNING	

Strategy Groups (Prefixed with STRATEGY_)

```
  } else { // do not output smoothing for the following operations
    smoothing.isAllowed = !(currentSection.checkGroup(STRATEGY_DRILLING));
  }
```

Checking for a Drill Operation

5.5 onSectionEnd

```
function onSectionEnd() {
```

The *onSectionEnd* function is pretty basic in most posts and will reset codes that may have been changed in the operation and possibly some variables that are operation specific.

```
function onSectionEnd() {
  writeBlock(gPlaneModal.format(17));
  forceAny();
}
```

Basic onSectionEnd Function

5.6 onClose

```
function onClose() {
```

Settings used in onClose	Description
retract	Retract settings.

The *onClose* function is called at the end of the last operation, after *onSectionEnd*. It is used to define the end of an operation, if not handled in *onSectionEnd*, and to output the end-of-program codes.

```
function onClose() {
  optionalSection = false;
  writeln("");

  // end previous section
  onCommand(COMMAND_STOP_SPINDLE);
  onCommand(COMMAND_COOLANT_OFF);
  writeRetract(Z); // retract
  disableLengthCompensation(true);
  forceWorkPlane();
  setWorkPlane(new Vector(0, 0, 0)); // reset working plane

  if (getSetting("retract.homeXY.onProgramEnd", false)) {
    writeRetract(settings.retract.homeXY.onProgramEnd);
  }

  // end of program
  writeBlock(mFormat.format(30)); // stop program, spindle stop, coolant off
  writeln("%");
}
```

Basic onClose Function

5.7 onTerminate

```
function onTerminate() {
```

The *onTerminate* function is called at the end of post processing, after *onClose*. It is called after all output to the NC file is finished and the NC file is closed. It may be used to rename the output file(s) after processing has finished, to automatically create a setup sheet, or to run another program against the output NC file.

```
function onTerminate() {
  var outputPath = getOutputPath();
  var programFilename = FileSystem.getFilename(outputPath);
  var programSize = FileSystem.getFileSize(outputPath);
  var postPath = findFile("setup-sheet-excel-2007.cps");
  var intermediatePath = getIntermediatePath();
  var a = "--property unit " + ((unit == IN) ? "0" : "1"); // use 0 for inch and 1 for mm
  if (programName) {
    a += " --property programName \"" + programName + "\"";
  }
  if (programComment) {
    a += " --property programComment \"" + programComment + "\"";
  }
  a += " --property programFilename \"" + programFilename + "\"";
  a += " --property programSize \"" + programSize + "\"";
  a += " --noeditor --log temp.log \"" + postPath + "\" \"" + intermediatePath + "\" \"" +
    FileSystem.replaceExtension(outputPath, "xlsx") + "\"";
  execute(getPostProcessorPath(), a, false, "");
  executeNoWait("excel", "\"" + FileSystem.replaceExtension(outputPath, "xlsx") + "\"", false, "");
}
```

Create and Display Setup Sheet from onTerminate

5.8 onCommand

```
function onCommand(command) {
```

Arguments	Description
command	Command to process.

The *onCommand* function can be called by a Manual NC command, directly from Fusion, or from the post processor.

Command	Description
COMMAND_ACTIVATE_SPEED_FEED_SYNCHRONIZATION	Activate threading mode
COMMAND_ALARM	Alarm

Command	Description
COMMAND_ALERT	Alert
COMMAND_BREAK_CONTROL	Tool break control
COMMAND_CALIBRATE	Run calibration cycle
COMMAND_CHANGE_PALLET	Change pallet
COMMAND_CLEAN	Run cleaning cycle
COMMAND_CLOSE_DOOR	Close primary door
COMMAND_COOLANT_OFF	Coolant off (M09)
COMMAND_COOLANT_ON	Coolant on (M08)
COMMAND_DEACTIVATE_SPEED_FEED_SYNCHRONIZATION	Deactivate threading mode
COMMAND_END	Program end (M02)
COMMAND_EXACT_STOP	Exact stop
COMMAND_LIVE_ALIGNMENT	Await part alignment
COMMAND_LOAD_TOOL	Tool change (M06)
COMMAND_LOCK_MULTI_AXIS	Locks the rotary axes
COMMAND_MAIN_CHUCK_CLOSE	Close main chuck
COMMAND_MAIN_CHUCK_OPEN	Open main chuck
COMMAND_OPEN_DOOR	Open primary door
COMMAND_OPTIONAL_STOP	Optional program stop (M01)
COMMAND_ORIENTATE_SPINDLE	Orientate spindle (M19)
COMMAND_POWER_OFF	Power off
COMMAND_POWER_ON	Power on
COMMAND_SECONDARY_CHUCK_CLOSE	Close secondary chuck
COMMAND_SECONDARY_CHUCK_OPEN	Open secondary chuck
COMMAND_SECONDARY_SPINDLE_SYNCHRONIZATION_ACTIVATE	Activate spindle synchronization
COMMAND_SECONDARY_SPINDLE_SYNCHRONIZATION_DEACTIVATE	Deactivate spindle synchronization
COMMAND_SPINDLE_CLOCKWISE	Clockwise spindle direction (M03)
COMMAND_SPINDLE_COUNTERCLOCKWISE	Counter-clockwise spindle direction (M04)
COMMAND_START_CHIP_TRANSPORT	Start chip conveyor
COMMAND_START_SPINDLE	Start spindle in previous direction
COMMAND_STOP	Program stop (M00)
COMMAND_STOP_CHIP_TRANSPORT	Stop chip conveyor
COMMAND_STOP_SPINDLE	Stop spindle (M05)
COMMAND_TOOL_MEASURE	Measure tool
COMMAND_UNLOCK_MULTI_AXIS	Unlocks the rotary axes
COMMAND_VERIFY	Verify path/tool/machine integrity

Valid Commands

The Manual NC commands that call *onCommand* are described in the *Manual NC Commands* chapter. Internal calls to *onCommand* are usually generated when expanding a cycle. The post processor itself will call *onCommand* directly to perform simple functions, such as outputting the tool change code, outputting a program stop, cancelling coolant, opening the main door, turning on the chip conveyor, etc.

```
// stop spindle and cancel coolant before retract during tool change
```

```
if (insertToolCall && !isFirstSection()) {
  onCommand(COMMAND_COOLANT_OFF);
  onCommand(COMMAND_STOP_SPINDLE);
}
```
Calling onCommand Directly from Post Processor

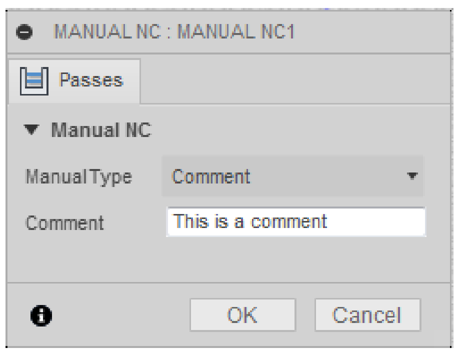
5.9 onComment

```
function onComment(text) {
```

Arguments	Description
text	Text of comment to output.

Settings used in onComment	Description
comments	Comment format parameters.

The *onComment* function is called when the Manual NC command *Comment* is issued. It will format and output the text of the comment to the NC file.



The Comment Manual NC Command

There are two other functions that are used to format and output comments, *formatComment* and *writeComment*. These comment functions are standard in nature and do not typically have to be modified. The comments setting controls the output of comments.

The *formatComment* function formats a comment using the parameters of the *comments* setting defined at the top of the post and returns the text of the formatted comment so it can be included on an output block. The *writeComment* function outputs the comment as a separate block.

```
// format a comment
var comment = formatComment(programComment);

//  output a comment
writeComment(text);
```

```
// process the Manual NC Comment command
onComment(text);
```

The Comment Functions

5.10 onDwell

```
function onDwell(seconds) {
```

Arguments	Description
seconds	Dwell time in seconds.

The *onDwell* function can be called by a Manual NC command, directly from Fusion, or from the post processor. The Manual NC command that calls *onDwell* is described in the *Manual NC Commands* chapter. Internal calls to *onDwell* are usually generated when expanding a cycle. The post processor itself will call *onDwell* directly to output a dwell block.

```
function onDwell(seconds) {
  var maxValue = 99999.999;
  if (seconds > maxValue) {
    warning(subst(localize("Dwelling time of '%1' exceeds the maximum value of '%2' in operation
'%3'"), seconds, maxValue, getParameter("operation-comment", "")));
  }
  seconds = clamp(0.001, seconds, 99999.999);
  var feedMode = gFeedModeModal.getCurrent();
  writeBlock(gFeedModeModal.format(94), gFormat.format(4), "P" + secFormat.format(seconds));
  writeBlock(gFeedModeModal.format(feedMode));
}
```

Output the Dwell Time in Milliseconds

```
  onCommand(COMMAND_COOLANT_ON);
  onDwell(1.0);  // dwell 1 second after turning coolant on
```

Calling onDwell Directly from Post Processor

5.11 onParameter

```
function onParameter(name, value) {
```

Arguments	Description
name	Parameter name.
value	Value stored in the parameter.

Almost all parameters used for creating a machining operation in Fusion are passed to the post processor. Common parameters are available using built in post processor variables (currentSection, tool, cycle, etc.) as well as being made available as parameters. Other parameters are passed to the *onParameter* function.

```
74: onParameter('operation:context', 'operation')
75: onParameter('operation:strategy', 'drill')
76: onParameter('operation:operation_description', 'Drill')
77: onParameter('operation:tool_type', 'tap right hand')
78: onParameter('operation:undercut', 0)
79: onParameter('operation:tool_isTurning', 0)
80: onParameter('operation:tool_isMill', 0)
81: onParameter('operation:tool_isDrill', 1)
82: onParameter('operation:tool_taperedType', 'tapered_bull_nose')
83: onParameter('operation:tool_unit', 'inches')
84: onParameter('operation:tool_number', 4)
85: onParameter('operation:tool_diameterOffset', 4)
86: onParameter('operation:tool_lengthOffset', 4)
```

Sample Parameters Passed to the onParameter Function from Dump Post Processor

The name of the parameter along with its value is passed to the *onParameter* function. Some Manual NC commands will call the *onParameter* function, these are described in the *Manual NC Commands* chapter. You can see how to run and analyze the output from the *dump.cps* post processor in the *Debugging* chapter.

```
function onParameter(name, value) {
  switch (name) {
  case "job-notes":
    if (!firstNote) {
      writeNotes(value, true);
    }
    firstNote = false;
    break;
  }
}
```

Sample onParameter Function

5.11.1 getParameter Function

```
value = getParameter(name [,default])
```

Arguments	Description
name	Parameter name.
default	The value to return if the requested parameter is not defined. If a *default* value is not specified and the parameter is not defined, then *undefined* is returned.

You can retrieve operation parameters at any place in the post processor by calling the *getParameter* function. Operation parameters are defined as parameters that are redefined for each machining operation. There is a chance that a parameter does not exist, so it is recommended that you check for the parameter either by specifying a default value in the *getParameter* call or by using the *hasParameter* function.

```
var comment = getParameter("operation-comment", ""); // get the parameter value
if (comment) {
  writeComment(comment);
}
```

Verify a Parameter Exists Using the getParameter Function

```
if (hasParameter("operation-comment")) { // verify the parameter exists
  var comment = getParameter("operation-comment"); // get the parameter value
  if (comment) {
    writeComment(comment);
  }
}
```

Verify a Parameter Exists Using the hasParameter Function

When scanning through the operations in the intermediate file it is possible to access the parameters for that operation by using the section variant of the *hasParameter* and *getParameter* functions.

```
// write out all operation comments
writeln("List of Operations:");
for (var i = 0; i < getNumberOfSections(); ++i) {
  var section = getSection(i);
  var comment = section.getParameter("operation-comment", "");
  if (comment) {
    writeln("  " + comment);
  }
}
writeln("");
```

Using Section Variant of getParameter

5.11.2 getGlobalParameter Function

```
value = getGlobalParameter(name [,default])
```

Arguments	Description
name	Parameter name.
default	The value to return if the requested parameter is not defined. If a *default* value is not specified and the parameter is not defined, then *undefined* is returned.

Some parameters are defined at the start of the intermediate file prior to the first operation. These parameters are considered global and are accessed using the *hasGlobalParameter* and *getGlobalParameter* functions. The same rules that apply to the operation parameters apply to global parameters.

```
-1: onOpen()
0: onParameter('product-id', 'fusion360')
1: onParameter('generated-by', 'Fusion CAM 2.0.3803')
2: onParameter('generated-at', 'Saturday, March 24, 2018 4:34:36 PM')
3: onParameter('hostname', 'host')
4: onParameter('username', 'user')
5: onParameter('document-path', 'Water-Laser-Plasma v2')
6: onParameter('leads-supported', 1)
7: onParameter('job-description', 'Laser')
9: onParameter('stock', '((0, 0, -5), (300, 200, 0))')
11: onParameter('stock-lower-x', 0)
13: onParameter('stock-lower-y', 0)
15: onParameter('stock-lower-z', -5)
17: onParameter('stock-upper-x', 300)
19: onParameter('stock-upper-y', 200)
21: onParameter('stock-upper-z', 0)
23: onParameter('part-lower-x', 0)
25: onParameter('part-lower-y', 0)
27: onParameter('part-lower-z', -5)
29: onParameter('part-upper-x', 300)
31: onParameter('part-upper-y', 200)
33: onParameter('part-upper-z', 0)
35: onParameter('notes', '')
```

Sample Global Variables

When processing multiple setups at the same time some of the global parameters will change from one setup to the next. The *getGlobalParameter* function though will always reference the parameters of the first setup, so if you want to access the parameters of the active setup then you will need to use the *onParameter* function rather than the *getGlobalParameter* function.

```
function onParameter(name, value) {
  if (name == "job-description") {
    setupName = value;
  }
}
```

Using onParameter to Store the Active Setup Name

5.12 onPassThrough

```
function onPassThrough (value)
```

Arguments	Description
value	Text to be output to the NC file.

The *onPassThrough* function is called by the *Pass through* Manual NC command and is used to pass a text string directly to the NC file without any processing by the post processor. This function is described in the Manual NC Commands chapter.

5.13 onSpindleSpeed

```
function onSpindleSpeed(speed) {
```

Arguments	Description
spindleSpeed	The new spindle speed in RPM.

The *onSpindleSpeed* function is used to output changes in the spindle speed during an operation, typically from the post processor engine when expanding a cycle.

```
function onSpindleSpeed(spindleSpeed) {
  writeBlock(sOutput.format(spindleSpeed));
}
```

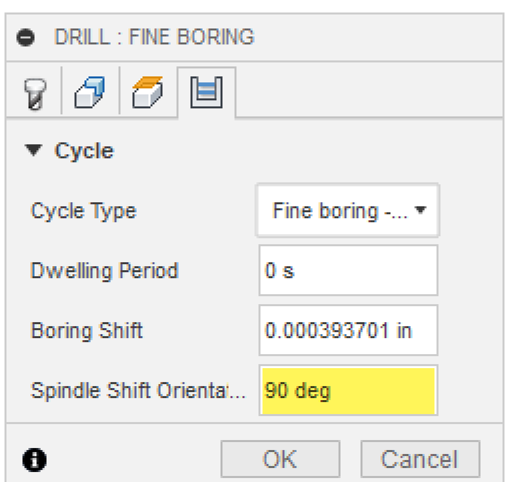
Sample onSpindleSpeed Function

5.14 onOrientateSpindle

```
function onOrientateSpindle(angle) {
```

Arguments	Description
angle	Spindle orientation angle in radians.

The *onOrientateSpindle* function is called when a cycle that orientates the spindle is expanded, and the spindle orientation angle is not zero degrees. When a cycle that orientates the spindle is expanded and the orientation angle is zero then the *onCommand(COMMAND_ORIENTATE_SPINDLE)* function is called.



onOrientateSpindle is Called

5.15 onRadiusCompensation

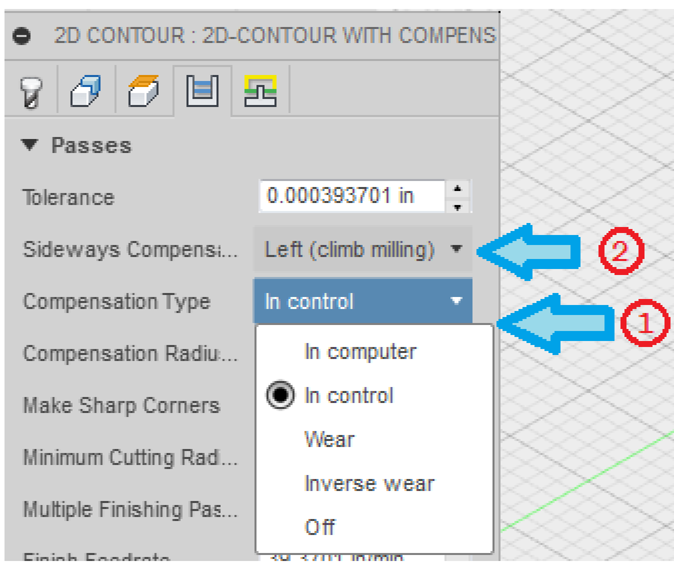
function onRadiusCompensation() {

Settings used in onRadiusCompensation	Description
supportsRadiusCompensation	Radius compensation is supported.

The *onRadiusCompensation* function is called when the radius (cutter) compensation mode changes. It will typically set the pending compensation mode, which will be handled in the motion functions (*onRapid*, *onLinear*, *onCircular*, etc.). Radius compensation, when enabled in an operation, will be enabled on the move approaching the part and disabled after moving off the part.

The *supportsRadiusCompensation* setting determines if radius compensation is supported by the machine control.

The state of radius compensation is stored in the global *radiusCompensation* variable and is not passed to the *onRadiusCompensation* function. Radius compensation is defined when creating the machining operation in Fusion (1). The Sideways Compensation (2) setting determines the side of the part that the tool will be on when cutting. It is based on the forward direction of the tool during the cutting operation.



Enabling/Disabling Radius Compensation

Compensation Type	Description
In computer	The tool is offset from the part based on the tool diameter. The center line of the offset tool is sent to the post processor and the radius compensation mode is OFF (G40).
In control	The tool is not offset from the part. The centerline of the tool as if it is on the part is sent to the post processor and the radius compensation

Compensation Type	Description
	mode is determined by the Sideways Compensation setting (G41/G42). The control will perform the entire offsetting of the tool.
Wear	The tool is offset from the part based on the tool diameter. The center line of the offset tool is sent to the post processor and the radius compensation mode is determined by the Sideways Compensation setting (G41/G42). The control will compensate for tool wear.
Inverse wear	Same as Wear, but the opposite compensation direction will be used (G42/G41).
Off	The tool is not offset from the part. The centerline of the tool as if it is on the part is sent to the post processor and the radius compensation mode will be disabled (G40).

Radius Compensation Modes

```
var pendingRadiusCompensation = -1;

function onRadiusCompensation() {
  pendingRadiusCompensation = radiusCompensation;
  if (pendingRadiusCompensation >= 0 && !getSetting("supportsRadiusCompensation", true)) {
    error(localize("Radius compensation mode is not supported."));
    return;
  }
}
```

Sample onRadiusCompensation Function

5.16 onMovement

```
function onMovement(movement) {
```

Arguments	Description
movement	Movement type for the following motion(s).

onMovement is called whenever the movement type changes. It is used to tell the post when there is a positioning, entry, exit, or cutting type move. There is also a *movement* global variable that contains the movement setting. This variable can be referenced directly in other functions, such as *onLinear*, to access the movement type without defining the *onMovement* function.

The supported movement types are listed in the following table.

Movement Type	Description
MOVEMENT_CUTTING	Standard cutting motion.
MOVEMENT_EXTENDED	Extended movement type. Not common.
MOVEMENT_FINISH_CUTTING	Finish cutting motion.

Movement Type	Description
MOVEMENT_HIGH_FEED	Movement at high feedrate. Not typically used. Rapid moves output using a linear move at the high feedrate will use the MOVEMENT_RAPID type.
MOVEMENT_LEAD_IN	Lead-in motion.
MOVEMENT_LEAD_OUT	Lead-out motion.
MOVEMENT_LINK_DIRECT	Direction (non-cutting) linking move.
MOVEMENT_LINK_TRANSITION	Transition (cutting) linking move.
MOVEMENT_PLUNGE	Plunging move.
MOVEMENT_PREDRILL	Predrilling motion.
MOVEMENT_RAMP	Ramping entry motion.
MOVEMENT_RAMP_HELIX	Helical ramping motion.
MOVEMENT_RAMP_PROFILE	Profile ramping motion.
MOVEMENT_RAMP_ZIG_ZAG	Zig-Zag ramping motion.
MOVEMENT_RAPID	Rapid movement.
MOVEMENT_REDUCED	Reduced cutting motion.

Movement Types

Movement types are used in defining parametric feedrates in some milling posts and for removing all non-cutting moves for waterjet/plasma/laser machines that require only the cutting profile.

5.17 onFeedMode

```
function onFeedMode(mode) {
```

Arguments	Description
mode	The active feedrate mode: FEED_PER_MINUTE, FEED_PER_REVOLUTION, FEED_DEGREE_MINUTE, or FEED_INVERSE_TIME.

The *onFeedMode* function will be called whenever the feedrate mode changes. The feedrate mode is most likely to change between operations or during a multi-axis operation (prior to onLinear5D) when a combination of 3-axis and multi-axis moves can be output in a single operation.

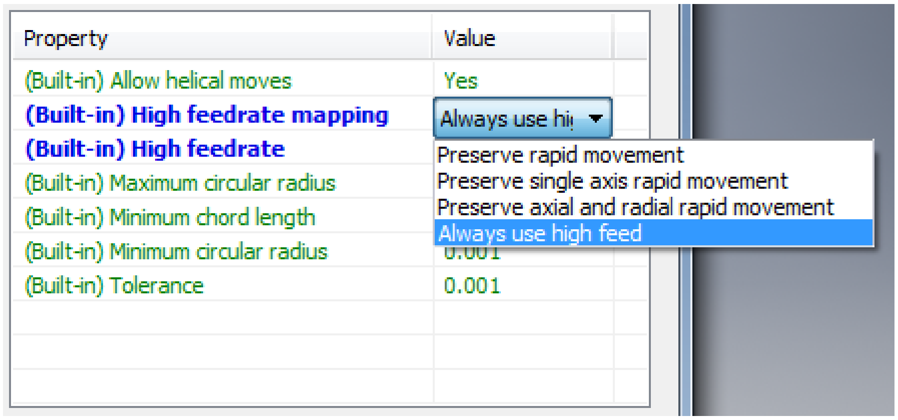
5.18 onRapid

```
function onRapid(_x, _y, _z) {
```

Arguments	Description
_x, _y, _z	The tool position.

The *onRapid* function handles rapid positioning moves (G00) while in 3-axis mode. The tool position is passed as the *_x, _y, _z* arguments. The format of the *onRapid* function is basically outputs the rapid move to the NC file.

If the *High feedrate mapping* property is set to anything other than *Preserve rapid movement*, then the *onLinear* function may be called with the high feedrate passed in as the feedrate and the *onRapid* function will not be called.



Using High Feedrates for Positioning Moves

```
function onRapid(_x, _y, _z) {
  // format tool position for output
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);

  // ignore if tool does not move
  if (x || y || z) {
    // handle radius compensation changes
    if (pendingRadiusCompensation >= 0) {
      error(localize("Radius compensation mode cannot be changed at rapid traversal."));
      return;
    }
    writeBlock(gMotionModal.format(0), x, y, z);
    forceFeed();
  }
}
```

Sample onRapid Function

5.19 invokeOnRapid

```
invokeOnRapid(x, y, z);
```

Arguments	Description
x, y, z	The tool position.

It is possible that the post processor will need to generate rapid positioning moves during the processing of the intermediate file. An example would be creating your own expanded drilling cycle. Instead of calling *onRapid* with the post generated moves, it is recommended that *invokeOnRapid* be called instead. This will ensure that the post engine is notified of the move and the current position is set. *invokeOnRapid* will then call *onRapid* with the provided arguments.

5.20 onLinear

```
function onLinear(_x, _y, _z, feed) {
```

Arguments	Description
_x, _y, _z	The tool position.
feed	The feedrate.

Settings used in onLinear	Description
outputToolDiameterOffset	Output tool diameter offset code.

The *onLinear* function handles linear moves (G01) at a feedrate while in 3-axis mode. The tool position is passed as the *_x, _y, _z* arguments. The format of the *onLinear* function will handle a change in radius compensation and outputs the linear move to the NC file.

```
function onLinear(_x, _y, _z, feed) {
  // force move when radius compensation changes
  if (pendingRadiusCompensation >= 0) {
    xOutput.reset();
    yOutput.reset();
  }

  // format tool position for output
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);

  // ignore if tool does not move
  if (x || y || z) {
    // handle radius compensation changes
    if (pendingRadiusCompensation >= 0) {
      pendingRadiusCompensation = -1;
      var d = getSetting("outputToolDiameterOffset", true) ?
        diameterOffsetFormat.format(tool.diameterOffset) : "";
      writeBlock(gPlaneModal.format(17));
      switch (radiusCompensation) {
      case RADIUS_COMPENSATION_LEFT:
        writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(41), x, y, z,
          d, getFeed(feed));
```

```
        break;
      case RADIUS_COMPENSATION_RIGHT:
        dOutput.reset();
        writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(42), x, y, z,
          d, getFeed(feed));
        break;
      default:
        writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(40), x, y, z,
          getFeed(feed));
      }
    // output non-compensation change move at feedrate
    } else {
      writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), x, y, z, getFeed(feed));
    }
  }
}
```

Sample onLinear Function

5.21 invokeOnLinear

```
invokeOnLinear(x, y, z, feed);
```

Arguments	Description
x, y, z	The tool position.
feed	The feedrate.

It is possible that the post processor will need to generate cutting moves during the processing of the intermediate file. An example would be creating your own expanded drilling cycle. Instead of calling *onLinear* with the post generated moves, it is recommended that *invokeOnLinear* be called instead. This will ensure that the post engine is notified of the move and the current position is set. *invokeOnLinear* will then call *onLinear* with the provided arguments.

5.22 onRapid5D

```
function onRapid5D(_x, _y, _z, _a, _b, _c) {
```

Arguments	Description
_x, _y, _z	The tool position.
_a, _b, _c	The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.

The *onRapid5D* function handles rapid positioning moves (G00) in multi-axis operations. The tool position is passed as the *_x, _y, _z* arguments and the rotary angles as the *_a, _b, _c* arguments. If a machine configuration has not been defined, then *_a, _b, _c* contains the tool axis vector. The *onRapid5D* function will be called for all rapid moves in a multi-axis operation, even if the move is only a 3-axis linear move without rotary movement.

The *High feedrate mapping* property is respected as it is for the *onRapid* function, except *onLinear5D* will be called instead of *onLinear*.

```
function onRapid5D(_x, _y, _z, _a, _b, _c) {
  if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation mode cannot be changed at rapid traversal."));
    return;
  }
  if (!currentSection.isOptimizedForMachine()) {
    forceXYZ();
  }
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var a = currentSection.isOptimizedForMachine() ? aOutput.format(_a) :
    toolVectorOutputI.format(_a);
  var b = currentSection.isOptimizedForMachine() ? bOutput.format(_b) :
    toolVectorOutputJ.format(_b);
  var c = currentSection.isOptimizedForMachine() ? cOutput.format(_c) :
    toolVectorOutputK.format(_c);

  if (x || y || z || a || b || c) {
    writeBlock(gMotionModal.format(0), x, y, z, a, b, c);
    forceFeed();
  }
}
```

Sample onRapid5D Function

Please refer to the *Multi-Axis Post Processors* chapter for a detailed explanation on supporting a multi-axis machine.

5.23 invokeOnRapid5D

```
invokeOnRapid5D(x, y, z, a, b, c);
```

Arguments	Description
x, y, z	The tool position.
a, b, c	The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.

It is possible that the post processor will need to generate multi-axis rapid positioning moves during the processing of the intermediate file. An example would be when handling the retract/reconfigure procedure. Instead of calling *onRapid5D* with the post generated moves, it is recommended that *invokeOnRapid5D* be called instead. This will ensure that the post engine is notified of the move and the current position is set. *invokeOnRapid5D* will then call *onRapid5D* with the provided arguments.

5.24 onLinear5D

```
function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
```

Arguments	Description
_x, _y, _z	The tool position.
_a, _b, _c	The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.
feed	The feedrate value calculated for the multi-axis feedrate mode.
feedMode	The active multi-axis feedrate mode It can be FEED_PER_MINUTE, FEED_INVERSE_TIME, or FEED_DEGREE_MINUTE.

The *onLinear5D* function handles cutting moves (G01) in multi-axis operations. The tool position is passed as the *_x, _y, _z* arguments and the rotary angles as the *_a, _b, _c* arguments. If a machine configuration has not been defined, then *_a, _b, _c* contains the tool axis vector. The *onLinear5D* function will be called for all cutting moves in a multi-axis operation, even if the move is only a 3-axis linear move without rotary movement.

It is important to know that the *feedMode* argument will not be present if multi-axis feedrates are not defined either in an external Machine Definition or within the post processor using the *setMultiAxisFeedrate* function. The feed value will always be passed as the programmed feedrate in this case.

```
function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
  // handle radius compensation changes
  if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation cannot be activated/deactivated for 5-axis move."));
    return;
  }

  // format tool position for output  if (currentSection.isOptimizedForMachine()) {
    if (!currentSection.isOptimizedForMachine()) {
    forceXYZ();
  }
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var a = currentSection.isOptimizedForMachine() ? aOutput.format(_a) :
    toolVectorOutputI.format(_a);
  var b = currentSection.isOptimizedForMachine() ? bOutput.format(_b) :
    toolVectorOutputJ.format(_b);
```

```
  var c = currentSection.isOptimizedForMachine() ? cOutput.format(_c) :
    toolVectorOutputK.format(_c);

    // get feedrate number
  if (feedMode == FEED_INVERSE_TIME) {
    forceFeed();
  }
  var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) : getFeed(feed);
  var fMode = feedMode == FEED_INVERSE_TIME ? 93 : getProperty("useG95") ? 95 : 94;

  // ignore if tool does not move
  if (x || y || z || a || b || c) {
    writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
  } else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
      forceFeed(); // force feed on next line
    } else {
      writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), f);
    }
  }
}
```
Sample onLinear5D Function

Please refer to the *Multi-Axis Post Processors* chapter for a detailed explanation on supporting a multi-axis machine.

5.25 invokeOnLinear5D

```
invokeOnLinear5D(x, y, z, a, b, c, feed);
```

Arguments	Description
x, y, z	The tool position.
a, b, c	The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.
feed	The feedrate.

It is possible that the post processor will need to generate multi-axis cutting moves during the processing of the intermediate file. An example would be when handling the retract/reconfigure procedure. Instead of calling *onLinear5D* with the post generated moves, it is recommended that *invokeOnLinear5D* be called instead. This will ensure that the post engine is notified of the move and the current position is set. *invokeOnLinear5D* will then call *onLinear5D* with the provided arguments.

The post engine will calculate the proper feedrate value and mode prior to calling *onLinear5D*.

5.26 onCircular

```
function onCircular(clockwise, cx, cy, cz, x, y, z, feed) {
```

Argument	Description
clockwise	Set to *true* if the circular direction is in the clockwise direction, *false* if counter-clockwise.
cx, cy, cz	Center coordinates of circle.
x, y, z	Final point on circle
feed	The feedrate.

The *onCircular* function is called whenever there is circular, helical, or spiral motion. The circular move can be in any of the 3 standard planes, XY-plane, YZ-plane, or ZX-plane, it is up to the *onCircular* function to determine which types of circular interpolation are valid for the machine and to correctly format the output.

The structure of the *onCircular* function in most posts uses the following layout.

1. Test for radius compensation. Most controls do not allow radius compensation to be started on a circular move.
2. Full circle output.
3. Center point (IJK) output.
4. Radius output.

Each of the different styles of output will individually handle the output of circular interpolation in each of the planes and possibly 3-D circular interpolation if it is supported.

```
  if (pendingRadiusCompensation >= 0) {  // Disallow radius compensation
    error(localize("Radius compensation cannot be activated/deactivated for a circular move."));
    return;
  }
…
  if (isFullCircle()) { // Full 360 degree circles
    if (getProperty("useRadius") || isHelical()) { // radius mode does not support full arcs
      linearize(tolerance);
      return;
    }
…
  } else if (!getProperty("useRadius")) {  // Incremental center point output
    switch (getCircularPlane()) {
    case PLANE_XY:
…
  } else { // Use radius mode
    var r = getCircularRadius();
    if (toDeg(getCircularSweep()) > (180 + 1e-9)) {
      r = -r; // allow up to <360 deg arcs
```

```
  }
…
```

Standard onCircular Structure

```
switch (getCircularPlane()) {
case PLANE_XY:
  writeBlock(gPlaneModal.format(17), gMotionModal.format(clockwise ? 2 : 3),
    xOutput.format(x), yOutput.format(y), zOutput.format(z),
    iOutput.format(cx - start.x), jOutput.format(cy - start.y), getFeed(feed));
  break;
case PLANE_ZX:
  writeBlock(gPlaneModal.format(18), gMotionModal.format(clockwise ? 2 : 3),
    xOutput.format(x), yOutput.format(y), zOutput.format(z),
    iOutput.format(cx - start.x), kOutput.format(cz - start.z), getFeed(feed));
  break;
case PLANE_YZ:
  writeBlock(gPlaneModal.format(19), gMotionModal.format(clockwise ? 2 : 3),
    xOutput.format(x), yOutput.format(y), zOutput.format(z),
    jOutput.format(cy - start.y), kOutput.format(cz - start.z), getFeed(feed));
  break;
default: // circular record is not in major plane
  linearize(tolerance);
}
```

Circular Output Based on Plane

5.26.1 Circular Interpolation Settings

There are settings that affect how circular interpolation is handled in the post engine, basically telling the post engine when to call *onCircular* or when to linearize the points by calling *onLinear* multiple times instead. The following table describes the circular interpolation settings.

Setting	Description
allowedCircularPlanes	Defines the standard planes that circular interpolation is allowed in, PLANE_XY, PLANE_YZ, PLANE_ZX. It can be set to *undefined* to allow circular interpolation in all three planes, 0 to disable circular interpolation, or a bit mask of PLANE_XY, PLANE_YZ, and/or PLANE_YZ to allow only certain planes.
allowHelicalMoves	Helical interpolation is allowed when this variable is set to *true*. Helical moves are linearized if set to *false*.
allowSpiralMoves	Spiral interpolation is defined as circular moves that have a different starting radius than ending radius and can be enabled by setting this variable to *true*. Spiral moves are linearized if set to *false*.
circularInputTolerance	The tolerance to use when determining if a spiral or helical move should be converted to a circular record. There are times when the CAM system

Setting	Description
	will output a circular record as a very small spiral or helical move, for example a helix with a linear distance of 0.0001 over 180 degrees could be programmed. Setting the *circularInputTolerance* variable to a nominal value will convert any helical/spiral moves to a pure circular move when the distance that marks the move as helical or spiral is less than this value. A value of 0 will disable this feature.
circularMergeTolerance	The tolerance used to determine if consecutive circular records can be merged into a single circular record. CAM systems will sometimes break up a single circle into multiple circular records. Setting the *circulareMergeTolerance* variable to a nominal value will combine consecutive circular records into a single circular record whose centers and radii are within this tolerance and the direction remains the same. A value of 0 will disable this feature. Circular moves will still be limited by the *maximumCircularSweep* value, so if you wish to have 360-degree circular records you must define *maximumCircularSweep* to be 360 degrees.
circularOutputAccuracy	Some controls are quite picky on the center/ending position of a circular record and will fail if either of these are off by a single digit. Defining the *circularOutputAccuracy* variable the same as the output number of digits to the right of the decimal point for the linear axes will cause the post to adjust the output center and/or ending positions so that they reflect the real circle without any discrepancies. Leave undefined or use a value of 0 to disable the adjustment of the center/final point. Example: *circularOutputAccuracy = unit == MM ? 3 : 4;* If the *circularOutputAccuracy* is defined, it is then recommended that the *circularInputTolerance* be set to the minimum value that corresponds to the *circularOutputAccuracy* value.
maximumCircularRadius	Specifies the maximum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose radius exceeds this value will be linearized. This variable must be set in millimeters (MM). `maximumCircularRadius = spatial(1000, MM); // 39.37 inch`
maximumCircularSweep	Specifies the maximum angular sweep of circular moves that can be output as circular interpolation and is specified in radians. Any circular records whose delta angle exceeds this value will be linearized.
minimumChordLength	Specifies the minimum delta movement allowed for circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose delta linear movement is less

Setting	Description
	than this value will be linearized. This variable must be set in millimeters (MM).
minimumCircularRadius	Specifies the minimum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose radius is less than this value will be linearized. This variable must be set in millimeters (MM).
minimumCircularSweep	Specifies the minimum angular sweep of circular moves that can be output as circular interpolation and is specified in radians. Any circular records whose delta angle is less than this value will be linearized.
tolerance	Specifies the tolerance used to linearize circular moves that are expanded into a series of linear moves. Circular interpolation records can be linearized due to the conditions of the circular interpolation settings not being met or by the *linearize* function being called. This variable must be set in millimeters (MM).

Circular Interpolation Settings

```
allowedCircularPlanes = undefined; // allow all circular planes
allowedCircularPlanes = 0; // disable all circular planes
allowedCircularPlanes = (1 << PLANE_XY) | (1 << PLANE_ZX); // XY, ZX planes

tolerance = spatial(0.002, MM); // linearization tolerance of .00008 IN
minimumChordLength = spatial(0.01, MM); // minimum linear movement of .0004 IN
minimumCircularRadius = spatial(0.01, MM); // minimum circular radius of .0004 IN
maximumCircularRadius = spatial(1000, MM); // maximum circular radius of 39.37 IN
minimumCircularSweep = toRad(0.01); // minimum angular movement of .01 degrees
maximumCircularSweep = toRad(180); // circular interpolation up to 180 degrees
allowHelicalMoves = true; // enable helical interpolation
allowSpiralMoves = false; // disallow spiral interpolation
```

Example Circular Interpolation Settings

5.26.2 Circular Interpolation Common Functions/Variables

There are built-in functions that are utilized by the *onCircular* function. These functions return values used in the *onCircular* function, determine if the circular record should be linearized, and control the flow of the *onCircular* function logic. Most circular functions have a corresponding variable that can be referenced instead of calling the function.

```
var center = getCircularCenter();  // returns the circle center
var center = circularCenter;  // references the circle center
```

Referencing the Circle Center Using Either a Function or Variable

Function	Variable	Description
getCircularArcLength()	circularArcLength	Returns the arc movement length of the circular interpolation record.
getCircularCenter()	circularCenter	Returns the center point of the circle as a Vector.
getCircularChordLength()		Returns the delta linear movement of the circular interpolation record.
	circularClockwise	Set to *true* if the circular move is in the clockwise direction, *false* if it is in the counter-clockwise direction.
getCircularNormal()	circularNormal	Returns the normal of the circular plane as a Vector. The normal is flipped if the circular movement is in the clockwise direction. This follows the righthand plane convention.
getCircularOffset()	circularOffset	Returns the distances from the start point to the circle plane in X, Y, and Z as a Vector.
getCircularPlane()	circularPlane	Returns the plane of the circular interpolation record, PLANE_XY, PLANE_ZX, or PLANE_YZ. If the return value is -1, then the circular plane is not a major plane, but is in 3-D space.
getCircularRadius()	circularRadius	Returns the end radius of the circular motion.
getCircularStartRadius()	circularStartRadius	Returns the start radius of the circular motion. This will be different than the end radius for spiral moves.
getCircularSweep()	circularSweep	Returns the angular sweep of the circular interpolation record in radians.
getCurrentPosition()		Returns the starting point of the circular move as a Vector.
getHelicalDistance()	circularHelicalDistance	Returns the distance the third axis will move during helical interpolation. Returns 0 for a 2-D circular interpolation record.
getHelicalOffset()	circularHelicalOffset	Returns the distance along the third axis as a Vector. This function is used when helical interpolation is supported outside one of the three standard circular planes.
getHelicalPitch()	circularHelicalPitch	Returns the distance that the third axis travels for a full 360-degree sweep, i.e. the pitch value of the thread.
getPositionU(u)		Returns the point on the circle at *u* percent along the arc as a Vector.
isFullCircle()	circularFullCircle	Returns *true* if the angular sweep of the circular motion is 360 degrees.
isHelical()	circularHelical	Returns *true* if the circular interpolation record contains helical movement. The variable

Function	Variable	Description
		allowHelicalMoves must be set to *true* for helical records to be passed to the *onCircular* function.
isSpiral()	circularSpiral	Returns true if the circular interpolation record contains spiral movement (the start and end radii are different). The variable *allowSpiralMoves* must be set to *true* for spiral records to be passed to the *onCircular* function.
linearize(tolerance)		Linearizes the circular motion by outputting a series of linear moves.

onCircular Common Functions

5.26.3 Helical Interpolation

Helical interpolation is defined as circular interpolation with movement along the third linear axis. The third linear axis is defined as the axis that is not part of the circular plane, for example, the Z-axis is the third linear axis for circular interpolation in the XY-plane. The variable *allowHelicalMoves* must be set to true for the post processor to support helical interpolation.

Helical interpolation is typically output using the same format as circular interpolation with the addition of the third axis and optionally a pitch value (incremental distance per 360 degrees) for the third axis. Most stock post processors are already setup to output the third axis with circular interpolation (it won't be output for a 2-D circular move).

```
case PLANE_XY:
  writeBlock(gPlaneModal.format(17), gMotionModal.format(clockwise ? 2 : 3),
    xOutput.format(x), yOutput.format(y), zOutput.format(z),
    iOutput.format(cx-start.x), jOutput.format(cy-start.y), kOutput.format(getHelicalPitch()),
    feedOutput.format(feed));
  break;
```

Helical Interpolation with Pitch Output

5.26.4 Spiral Interpolation

Spiral interpolation is defined as circular interpolation that has a different radius at start of the circular move than the radius at the end of the move. The variable *allowSpiralMoves* must be set to true for the post processor to support helical interpolation.

Spiral interpolation when supported on a control is typically specified with a G-code different than the standard G02/G03 circular interpolation G-codes. Most stock post processors do not support spiral interpolation.

```
if (isSpiral()) {
```

```
  var startRadius = getCircularStartRadius();
  var endRadius = getCircularRadius();
  var dr = Math.abs(endRadius - startRadius);
  if (dr > maximumCircularRadiiDifference) { // maximum limit
    if (isHelical()) { // not supported
      linearize(tolerance);
      return;
    }

    switch (getCircularPlane()) {
    case PLANE_XY:
      writeBlock(gPlaneModal.format(17), gMotionModal.format(clockwise ? 2.1 : 3.1),
        xOutput.format(x), yOutput.format(y), zOutput.format(z),
        iOutput.format(cx - start.x), jOutput.format(cy - start.y), getFeed(feed));
      break;
    case PLANE_ZX:
      writeBlock(gPlaneModal.format(18), gMotionModal.format(clockwise ? 2.1 : 3.1),
        xOutput.format(x), yOutput.format(y), zOutput.format(z),
        iOutput.format(cx - start.x), kOutput.format(cz - start.z), getFeed(feed));
      break;
    case PLANE_YZ:
      writeBlock(gPlaneModal.format(19), gMotionModal.format(clockwise ? 2.1 : 3.1),
        xOutput.format(x), yOutput.format(y), zOutput.format(z),
        jOutput.format(cy - start.y), kOutput.format(cz - start.z), getFeed(feed));
      break;
    default:
      linearize(tolerance);
    }
    return;
  }
}
```

Spiral Interpolation Output

5.26.5 3-D Circular Interpolation

3-D circular interpolation is defined as circular interpolation that is not on a standard circular plane (XY, ZX, YZ).

3-D circular interpolation when supported on a control is typically specified with a G-code different than the standard G02/G03 circular interpolation G-codes and must contain either the mid-point of the circular move and/or the normal vector of the circle. Most stock post processors do not support 3-D circular interpolation.

```
default:
  if (getProperty("allow3DArcs")) {  // a post property is used to enable support of 3-D circular
```

```
    // make sure maximumCircularSweep is well below 360deg
    var ip = getPositionU(0.5);  // calculate mid-point of circle
    writeBlock(gMotionModal.format(clockwise ? 2.4 : 3.4),  // 3-D circular direction G-codes
      xOutput.format(ip.x), yOutput.format(ip.y), zOutput.format(ip.z), // output mid-point of circle
      getFeed(feed));
    writeBlock(xOutput.format(x), yOutput.format(y), zOutput.format(z)); // output end-point
  } else {
    linearize(tolerance);
  }
}
```

3-D Circular Interpolation Output

5.27 invokeOnCircular

```
invokeOnCircular(clockwise, cx, cy, cz, x, y, z, i, j, k, feed);
```

Arguments	Description
clockwise	Set to *true* if the direction of the circular is in the clockwise direction, false if it is *counter-clockwise*.
cx, cy, cz	The center of the circle.
x, y, z	The tool position.
i, j, k	The normal vector of the circle.
feed	The feedrate.

It is possible that the post processor will need to generate circular arcs during the processing of the intermediate file. To do this *invokeOnCircular* can be called. Calling *invokeOnCircular* ensures that the post engine is notified of the arc move and the current position is set. *invokeOnCircular* will then call *onCircular* with the provided arguments and setting the proper circular variables.

5.28 onCycle

```
function onCycle() {
```

The *onCycle* function is called once at the beginning of an operation that contains a canned cycle and can contain code to prepare the machine for the cycle. Mill post processors will typically set the machining plane here.

```
function onCycle() {
  writeBlock(gPlaneModal.format(17));
}
```

Sample onCycle Function

Mill/Turn post processors will usually handle the stock transfer sequence in the *onCycle* function. Logic for the Mill/Turn post processors will be discussed in a dedicated chapter.

5.29 onCyclePoint

```
function onCyclePoint(x, y, z) {
```

Argument	Description
x, y, z	Hole bottom location.

The *onCyclePoint* function is the controlling function for drilling, probing, and inspection cycles. It calls the appropriate function based on the type of cycle programmed.

Function	Description
writeDrillCycle	Processes a drilling operation.
writeProbeCycle	Processes a probing operation.
inspectionCycleInspect	Processes an inspection operation.

Canned Cycle Functions

The *writeDrillCycle* function is described in this section, while the *writeProbeCycle* and *inspectionCycleInspect* functions are described in their own chapters.

```
function onCyclePoint(x, y, z) {
  // inspection cycle
  if (isInspectionOperation()) {
    if (typeof inspectionCycleInspect == "function") {
      inspectionCycleInspect(cycle, x, y, z);
      return;
    } else {
      cycleNotSupported();
    }

  // probing cycle
  } else if (isProbeOperation()) {
    if (typeof writeProbeCycle == "function") {
      writeProbeCycle(cycle, x, y, z);
    } else {
      cycleNotSupported();
    }

  // drilling cycle
  } else {
    writeDrillCycle(cycle, x, y, z);
  }
}
```

Sample onCycle Function

5.29.1 writeDrillCycle

```
function writeDrillCycle(cycle, x, y, z) {
```

Argument	Description
cycle	Cycle parameters.
x, y, z	Hole bottom location.

The *writeDrillCycle* function handles drilling and milling canned cycles, which includes positioning to the clearance plane, formatting of the cycle block, calculating the cycle parameters, discerning if the canned cycle is supported on the machine or should be expanded

The location of the hole bottom for the cycle is passed in as the *x, y, z* arguments. All other parameters are available in the *cycle* object or through cycle specific function calls. The flow for outputting canned cycles usually follows the following logic.

1. First hole location in cycle
   a. Position to clearance plane
   b. Canned cycle is supported on machine
      i. Calculate common cycle parameters
      ii. Format and output canned cycle
   c. Canned cycle is not supported on machine
      i. Expand cycle into linear moves
2. 2nd through nth holes
   a. Cycle is not expanded
      i. Output hole location
   b. Cycle is expanded
      i. Expand cycle at new location

The actual output of the cycle blocks is handled in a *switch* block, with a separate *case* for each of the supported cycles.

```
switch (cycleType) {
case "drilling":
case "counter-boring":
  writeBlock(
    gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(P > 0 ? 82 : 81),
    getCommonCycle(x, y, z, cycle.retract),
    conditional(P > 0, secFormat.format(P)),
    feedOutput.format(F)
  );
  break;
```

Sample Cycle Formatting Code

If a cycle is not supported and needs to be expanded by the post engine, then you can either remove the entire case block for this cycle and it will be handled in the default block, or you can specifically expand the cycle. The second method is handy when the canned cycle does not support all of the parameters available in Fusion, for example if a dwell is not supported for a deep drilling cycle on the machine, but you want to be able to use a dwell.

```
   case "deep-drilling":
     if (P > 0) {  // the machine does not support a dwell code, so expand the cycle
       expandCyclePoint(x, y, z);
     } else {
       writeBlock(
         gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(83),
         getCommonCycle(x, y, z, cycle.retract),
         "Q" + xyzFormat.format(cycle.incrementalDepth),
         feedOutput.format(F)
       );
     }
     break;
```

Expanding a Cycle When a Feature is not Support on the Machine

The 2nd through the nth locations in a cycle operation are typically output using simple XY moves without any of the cycle definition codes. Expanded cycles still need to be expanded at these locations.

```
 } else {  // end of isFirstCyclePoint() condition
   if (cycleExpanded) {
     expandCyclePoint(x, y, z);
   } else {
     if (!xyzFormat.areDifferent(x, xOutput.getCurrent()) &&
         !xyzFormat.areDifferent(y, yOutput.getCurrent()) &&
         !xyzFormat.areDifferent(z, zOutput.getCurrent())) {
       switch (gPlaneModal.getCurrent()) {
       case 17: // XY
         xOutput.reset(); // at least one axis is required
         break;
       case 18: // ZX
         zOutput.reset(); // at least one axis is required
         break;
       case 19: // YZ
         yOutput.reset(); // at least one axis is required
         break;
       }
     }
     writeBlock(xOutput.format(x), yOutput.format(y), zOutput.format(z));
   }
 }
```

Output the 2nd through nth Cycle Locations

5.29.2 Drilling Cycle Types

The following table contains the drilling (hole making cycles). The cycle type is stored in the *cycleType* variable as a text string. The standard G-code used for the cycle is included in the description, where expanded defines the cycle as usually not being supported on the machine and expanded instead.

cycleType	Description
drilling	Feed in to depth and rapid out (G81)
counter-boring	Feed in to depth, dwell, and rapid out (G82)
chip-breaking	Multiple pecks with periodic partial retract to clear chips (G73)
deep-drilling	Peck drilling with full retraction at end of each peck (G83)
break-through-drilling	Allows for reduced speed and feed before breaking through hole (expanded)
gun-drilling	Guided deep drilling allows for a change in spindle speed for positioning (expanded)
tapping	Feed in to depth, reverse spindle, optional dwell, and feed out. Automatically determines left or right tapping depending on the tool selected. (G74/G84)
left-tapping	Left-handed tapping (G74)
right-tapping	Right-handed tapping (G84)
tapping-with-chip-breaking	Tapping with multiple pecks. Automatically determines left or right tapping depending on the tool selected. (expanded)
reaming	Feed in to depth and feed out (G85)
boring	Feed in to depth, dwell, and feed out (G86)
stop-boring	Feed to depth, stop the spindle, and feed out (G87)
fine-boring	Feed to depth, orientate the spindle, shift from wall, and rapid out (G76)
back-boring	Orientate the spindle, rapid to depth, start spindle, shift the tool to wall, feed up to bore height, orientate spindle, shift from wall, and rapid out (G77)
bore-milling	Helical bore milling.
circular-pocket-milling	Mills out a hole (expanded)
thread-milling	Helical thread cutting (expanded)

Types of Drilling Cycles

Any of these cycles can be expanded if the machine control does not support the specific cycle. There are some caveats, where the post (and machine) must support certain capabilities for the expanded cycle to run correctly on the machine. The following table lists the commands that must be defined in the *onCommand* function to support the expansion of these cycles. It is expected that the machine will support these features if they are enabled in the post processor.

cycleType	Supported onCommand Command
tapping left-tapping right-tapping tapping-with-chip-breaking	COMMAND_SPINDLE_CLOCKWISE COMMAND_SPINDLE_COUNTERCLOCKWISE COMMAND_ACTIVATE_SPEED_FEED_SYNCHRONIZATION COMMAND_DEACTIVATE_SPEED_FEED_SYNCHRONIZATION

cycleType	Supported onCommand Command
stop-boring	COMMAND_STOP_SPINDLE COMMAND_START_SPINDLE
fine-boring back-boring	COMMAND_STOP_SPINDLE COMMAND_START_SPINDLE COMMAND_ORIENTATE_SPINDLE onOrientSpindle (calls this function instead of onCommand when spindle orientation is not at 0-degrees)

Required Command Support for Expanded Cycles

Certain cycles will use the following parameters when they are expanded.

machineParameters.	Description
drillingSafeDistance	Specifies the safety distance above the stock when repositioning into the hole for the *chip-breaking* and *deep-drilling* cycles.
spindleSpeedDwell	Dwell in seconds after the spindle speed changes during a cycle.

Parameters for Expanded Cycles

You define the expanded cycle parameters using the following syntaxes.

```
machineParameters.drillingSafeDistance = toPreciseUnit(2, MM);
machineParameters.spindleSpeedDwell = 1.5;
```

Defining Expanded Cycles Parameters

5.29.3 Cycle parameters

The parameters defined in the cycle operation are passed to the cycle functions using the *cycle* object. The following variables are available and are referenced as 'cycle.*parameter*'.

Parameter	Description
accumulatedDepth	The depth of the combined cuts before the tool will be fully retracted during a *chip-breaking* cycle.
backBoreDistance	The cutting distance of a *back-boring* cycle.
bottom	The bottom of the hole.
bottomPosition	XYZ coordinates of hole position at the bottom of the hole.
breakThroughDistance	The distance above the hole bottom to switch to the break-through feedrate and spindle speed during a *break-through-drilling* cycle.
breakThroughFeedRate	The feedrate used when breaking through the hole during a *break-through-drilling* cycle.
breakThroughSpindleSpeed	The spindle speed used when breaking through the hole during a *break-through-drilling* cycle.
chipBreakDistance	The distance to retract the tool to break the chip during a *chip-breaking* cycle.
clearance	Clearance plane where to tool will retract the tool to after drilling a hole and position to the next hole.

Parameter	Description
clearancePoint	Point on *clearance* plane.
clearancePosition	XYZ coordinates of hole position at the *clearance* plane.
compensation	Radius compensation in effect for *circular-pocket-milling, bore-milling,* and *thread-milling* cycles. This value can be *control*, *wear*, and *inverseWear*.
compensatedShiftOrientation	Same as *shiftOrientation*.
depth	The depth of the hole.
diameter	The diameter of the hole for *circular-pocket-milling* and *thread-milling* cycles.
direction	Either *climb* or *conventional* milling for *circular-pocket-milling, bore-milling,* and *thread-milling* cycles.
dwell	The dwell time in seconds.
dwellDepth	The distance above the cut depth at which to dwell, used for *gun-drilling* cycles.
feedrate	The primary cutting feedrate.
incrementalDepth	The incremental pecking depth of the first cut.
incrementalDepthReduction	The incremental pecking depth reduction per cut for pecking cycles.
minimumIncrementalDepth	The minimum pecking depth of cut for pecking cycles.
numberOfSteps	The number of horizontal passes for the *thread-milling* cycle.
pitch	Helical pitch for the *bore-milling* and *thread-milling* cycles.
plungeFeedrate	The cutting feedrate. The same as *feedrate*.
plungesPerRetract	The number of cuts before the tool will be fully retracted during a *chip-breaking* cycle.
postioningFeedrate	The feedrate used to position the tool during a *gun-drilling* cycle.
positioningSpindleSpeed	The spindle speed used when positioning the tool during a *gun-drilling* cycle.
repeatPass	Set to true if the final pass should be repeated for *circular-pocket-milling, bore-milling,* and *thread-milling* cycles.
retract	The plane where the tool will position to prior to starting the cycle (feeding into the hole).
retractFeedrate	The tool retraction feedrate, used when feeding out of the hole.
retractPoint	Point on *retract* plane.
retractPosition	XYZ coordinates of hole position at the *retract* plane.
shift	The distance to shift the tool away from the wall during a *fine-boring* and *back-boring* cycle.
shiftDirection	The direction in radians to shift the tool away from the wall during a *fine-boring* and *back-boring* cycle. The shift direction will be PI radians (180 degrees) from the wall plus this amount.
shiftOrientation	The spindle orientation of the tool in radians when shifting the tool away from the wall during a *fine-boring* or *back-boring* cycle.
stepover	The horizontal stepover distance for *circular-pocket-milling* and *thread-milling* cycles.
stock	The top of the hole.
stockPoint	Point on *stock* plane.

Parameter	Description
stockPosition	XYZ coordinates of hole position at the *stock* plane.
stopSpindle	When set to *1*, the spindle will be stopped during positioning/retracting in a *gun-drilling* cycle.
threading	Either *right* or *left*-handed threading for *thread-milling* cycles.

Cycle Parameters

5.29.4 The Cycle Planes/Heights

The drilling cycles use different heights during the execution of the cycle. These heights are specified in the Heights tab for the Drilling operation. One thing you should keep in mind is that the names given to these heights do not match the cycle parameter names in the post processor. The following table gives the relationship between the Fusion height names and the equivalent *cycle* parameter names.

Operation Heights Tab	Cycle Parameter	Description
Clearance Height	(none)	The plane to position to the first point of the cycle and to retract the tool to after the final point of the cycle.
Retract Height	cycle.clearance cycle.clearancePoint cycle.clearancePosition	The tool rapids to this plane from the clearance height and will position between the holes at this height.
Feed Height	cycle.retract cycle.retractPoint cycle.retractPosition	The tool will feed from this plane into the hole.
Top Height	cycle.stock cycle.stockPoint cycle.stockPosition	The top of the hole.
Bottom Height	cycle.bottom cycle.bottomPosition	The bottom of the hole. This height is the plane where the tool will drill to and will be different from the actual bottom of the hole if the *Drill tip through bottom* box is checked.

Correlation Between Cycle Operation Heights and Cycle Parameters

Fusion assumes that the tool will always be retracted to the Retract Height (*cycle.clearance*) between holes, you will notice this in the simulation of the cycle in Fusion. This is typically handled in the machine control with a G98 (Retract to clearance plane) code. Of course this code can be different from machine control to machine control and there are controls that will always retract to the Feed Height (*cycle.retract*) at the end of a drilling operation. In this case it is up to the post processor to retract the tool to the Retract Height.

You can cancel the cycle at the end of the *writeDrillCycle* function and output a tool retract block to take the tool back up to the Retract Height. When this method is used it is also mandatory that the full cycle be output for every hole in the operation and not just the first cycle point. Some machines support a retract plane to be specified with the cancel cycle code, i.e. G80 Rxxx.

```
function writeDrillCycle(cycle, x, y, z) {
…
 // if (isFirstCyclePoint()) {
 if (true) { // output a full cycle block for every hole in the operation
   repositionToCycleClearance(cycle, x, y, z);
...
...
   default:
     expandCyclePoint(x, y, z);
   }
   // retract tool (add at the end of the cycleType switch code)
   gMotionModal.format.reset();
   writeBlock(gCycleModal.format(80), gMotionModal.format(0), zOutput.format(cycle.clearance));
 } else {
   if (cycleExpanded) {
```

Retracting the Tool to the Retract Plane when Unsupported by Machine Control

5.29.5 Common Cycle Functions

There are functions that are commonly used in the *writeDrillCycle* function. The following table lists these functions.

Function	Description
isFirstCyclePoint()	Returns *true* if this is the first point in the cycle operation. It is usually called to determine whether to output a full cycle block or just the cycle location.
isLastCyclePoint()	Returns *true* if this is the last point in the cycle operation. This function is typically used for a lathe threading operation since HSM sends a single pass to the *onCyclePoint* function and the full depth of the thread is required to output a single threading block. *onCycleEnd* is used to terminate a drilling cycle, so this function is not typically used in drilling cycles.
repositionToCycleClearance()	Moves the tool to the Retract Height plane (*cycle.clearance*). This function is typically called prior to outputting a full cycle block.
getCommonCycle(x, y, z, r)	Formats the common cycle parameters (X, Y, Z, R) for output.

Common Cycle Functions

These functions are built into the post engine, except the *getCommonCycle* function, which is contained in the post processor. It takes the cycle location (x, y, z) and the retract plane/distance (r) as arguments. Some machines require that the retract value be programmed as a distance from the current location rather than as an absolute position. There are two ways to accomplish this. You can pass in the distance as the retract value.

```
function getCommonCycle(x, y, z, r) {
  forceXYZ();
  return [xOutput.format(x), yOutput.format(y),
    zOutput.format(z),
    "R" + xyzFormat.format(r)];
}
…
    case "drilling":
      writeBlock(
          gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(81),
          getCommonCycle(x, y, z, cycle.retract – cycle.clearance),
          feedOutput.format(F)
        );
        break;
```

Pass Retract Distance to Standard getCommonCycle Function

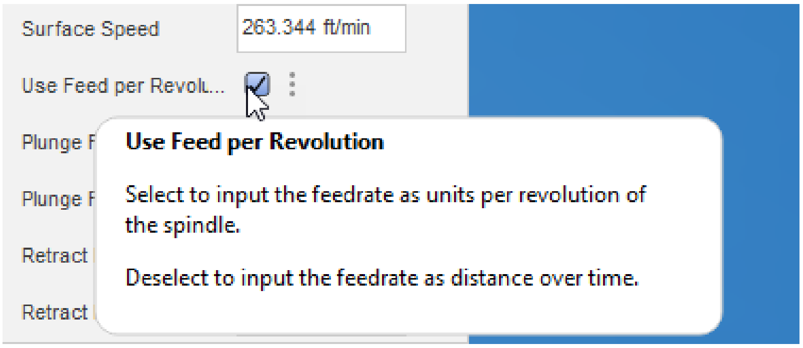
Or you can pass the clearance plane into the *getCommonCycle* function and have it calculate the distance. This method is typically used in post processors that support subprograms that require a retract plane while in absolute mode and a distance when in incremental mode.

```
function getCommonCycle(x, y, z, r, c) {
  forceXYZ(); // force xyz on first drill hole of any cycle
  if (subprogramsAreSupported() && subprogramState.incrementalMode) {
    zOutput.format(c);
    return [xOutput.format(x), yOutput.format(y),
      "Z" + xyzFormat.format(z - r),
      "R" + xyzFormat.format(r - c)];
  } else {
    return [xOutput.format(x), yOutput.format(y),
      zOutput.format(z),
      "R" + xyzFormat.format(r)];
  }
}…
    case "drilling":
      writeBlock(
        gRetractModal.format(98), gCycleModal.format(81),
        getCommonCycle(x, y, z, cycle.retract, cycle.clearance),
        feedOutput.format(F)
      );
      break;
```

Pass Retract and Clearance Heights to getCommonCycle Function

5.29.6 Feed per Revolution Output with Drilling Cycles

It is possible to support feed per revolution (FPR) feedrates with drilling cycles. FPR feedrates can be selected in the Drill operation by enabling the *Use Feed per Revolution* checkbox.



Specify that Feed per Revolution Feedrates are to be used with Drilling Cycles

The post must inform the CAM system that FPR feedrates are supported and have logic in the post to output the proper codes for FPR feedrates. The *allowFeedPerRevolutionDrilling* variable determines support for FPR feedrates in the post. If this variable is set to *NoFPR*, then drilling cycles that select FPR feedrates will be output in feed per minute (FPM) mode.

```
allowFeedPerRevolutionDrilling = FPRDrilling; // Enable FPR feedrates for drilling cycles
allowFeedPerRevolutionDrilling = true; // Same as FPRDrilling
allowFeedPerRevolutionDrilling = FPRAll; // Enable FPR feedrates for drilling and tapping cycles
allowFeedPerRevolutionDrilling = NoFPR; // Disable FPR feedrates for all drilling cycles
```

Enable FPR Feedrates for Drilling Cycles

A *formatNumber* must be defined to format FPR feedrate numbers. The format is defined at the top of the post processor with the rest of the format definitions. Refer to the *Format Defintions* section.

```
var fprFormat = createFormat({type:FORMAT_REAL, decimals:(unit == MM ? 3 : 4),
   minimum:(unit == MM ? 0.001 : 0.0001)});
```

Create Output Format for FPR Feedrates

The feedrate mode for the operation should be checked in the *onSection* function, the appropriate output format assigned, and the code to enable the feedrate mode output.

```
  // Output modal commands here
  var feedMode = formatFeedMode(currentSection.feedMode);
  writeBlock(gPlaneModal.format(17), gAbsIncModal.format(90), feedMode);
```

Define the Feedrate Output Format and Output the Feedrate Mode Code

The *formatFeedMode* function must be defined in the post to support FPR feedrates. It determines the feedrate format to use for FPR feedrates.

```
function formatFeedMode(mode) {
```

```
  var fMode = (mode == FEED_PER_REVOLUTION) ? 95 : 94;
  if (fMode) {
    if (mode == FEED_PER_REVOLUTION) {
      feedFormat = fprFormat;
    } else {
      feedFormat = fpmFormat;
    }
    feedOutput.setFormat(feedFormat);
  }
  return gFeedModeModal.format(fMode);
}
```

The formatFeedMode Function

Your post should now support FPR feedrates for drilling cycles.

5.29.7 Pitch Output with Tapping Cycles

Tapping cycles can sometimes be output with a standard FPM feedrate, sometimes with a thread pitch, and sometimes using the FPR feedrate mode. There are different variables and formats involved depending on the format used. When exclusively using pitch output you will need to create a format for this style of feedrate. The format is defined at the top of the post processor with the rest of the format definitions. Refer to the *Format Defintions* and *Output Variable Definitions* sections.

```
var feedFormat = createFormat({type:FORMAT_REAL, decimals:(unit == MM ? 0 : 1)});
var pitchFormat = createFormat({type:FORMAT_REAL, decimals:(unit == MM ? 3 : 4)});
…
var feedOutput = createOutputVariable({prefix:"F"}, feedFormat);
var pitchOutput = createOutputVariable({prefix:"F", control:CONTROL_FORCE},
    pitchFormat);
```

Create the Pitch Output Format

In the tapping sections of the *onCyclePoint* function you will need to assign the correct pitch value to the output. The tapping pitch is stored in the *tool.threadPitch* variable.

```
    case "tapping":
      writeBlock(
        gRetractModal.format(98), gCycleModal.format((84),
        getCommonCycle(x, y, z, cycle.retract),
        (conditional(P > 0, "P" + milliFormat.format(P)),
        pitchOutput.format(tool.threadPitch)
      );
      forceFeed(); // force the feedrate to be output after a tapping cycle with pitch output
      break;
```

Output the Thread Pitch on a Tapping Cycle

5.30 onCycleEnd

```
function onCycleEnd() {
```

The *onCycleEnd* function is called after all points in the cycle operation have been processed. The cycle is cancelled in this function.

```
function onCycleEnd() {
  if (!cycleExpanded) {
    writeBlock(gCycleModal.format(80));
    zOutput.reset();
  }
}
```

onCycleEnd Function

5.31 Common Functions

There are functions that are common in most of the generic posts. Some of these functions are used in conjuction with other post processor functions and are described in the appropriate section of this manual, for example the *formatComment* function is described with the *onComment* function. This section describes the common functions that are generic in nature and used throughout the post processor.

5.31.1 writeln

```
writeln(text);
```

Arguments	Description
text	Text to output to the NC file

The *writeln* function is built into the post engine and is not defined in the post processor. It is used to output text to the NC file without formatting it. Text can be a quoted text string or a text expression. *writeln* is typically used for outputting text strings that don't require formatting, or debug messages.

```
writeln("%"); // outputs '%'
writeln("Vector = " + new Vector(x, y, z));  // outputs the x, y, z variables in vector format
writeln("");  // outputs a blank line
writeln(formatComment("Load tool " + tool.number + " in spindle");
   // outputs 'Load tool n in spindle' as a comment
```

Sample writeln Calls

5.31.2 writeBlock

```
function writeBlock(arguments) {
```

Arguments	Description
arguments	Comma separated list of codes/text to output.

The *writeBlock* function writes a block of codes to the output NC file. It will add a sequence number to the block, if sequence numbers are enabled and add an optional skip character if this is an optional operation. A list of formatted codes and/or text strings are passed to the *writeBlock* function. The code list is separated by commas, so that each code is passed as an individual argument, which allows for the codes to be separated by the word separator defined by the *setWordSeparator* function.

```
/**
  Writes the specified block.
*/
function writeBlock() {
  var text = formatWords(arguments);
  if (!text) {
    return;
  }
  if (getProperty("showSequenceNumbers")) {  // add sequence numbers to output blocks
    if (optionalSection) {
      if (text) {
        writeWords("/", "N" + sequenceNumber, text);
      }
    } else {
      writeWords2("N" + sequenceNumber, text);
    }
    sequenceNumber += getProperty("sequenceNumberIncrement");
  } else { // no sequence numbers
    if (optionalSection) {
      writeWords2("/", text);
    } else {
      writeWords(text);
    }
  }
}
```

Sample writeBlock Function

```
writeBlock(gAbsIncModal.format(90), xFormat.format(x), yFormat.format(y));
writeBlock("G28", "X" + xFormat.format(0), "Y" + yFormat.format(0));  // outputs 'G28 X0 Y0'
writeBlock("G28" + "X" + xFormat.format(0) + "Y" + yFormat.format(0));  // outputs 'G28 X0Y0'
```

Sample writeBlock Calls

The *writeBlock* function does not usually have to be modified.

5.31.3 toPreciseUnit

```
toPreciseUnit(value, units);
```

Arguments	Description
value	The input value.
units	The units that the value is given in, either MM or IN.

The *toPreciseUnit* function allows you to specify a value in a given units and that value will be returned in the active units of the input intermediate CNC file. When developing a post processor, it is highly recommended that any unit based hard coded numbers use the *toPreciseUnit* function when defining the number.

```
yAxisMinimum = toPreciseUnit(gotYAxis ? -50.8 : 0, MM); // minimum range for the Y-axis
yAxisMaximum = toPreciseUnit(gotYAxis ? 50.8 : 0, MM); // maximum range for the Y-axis
xAxisMinimum = toPreciseUnit(0, MM); // maximum range for the X-axis (radius mode)
```

Defining Values using toPreciseUnit

5.31.4 force---

The *force* functions are used to force the output of the specified axes and/or feedrate the next time they are supposed to be output, even if it has the same value as the previous value.

Function	Description
forceXYZ	Forces the output of the linear axes (X, Y, Z) on the next motion block.
forceABC	Forces the output of the rotary axes (A, B, C) on the next motion block.
forceFeed	Forces the output of the feedrate on the next motion block.
forceAny	Forces all axes and the feedrate on the next motion block.

Force Functions

```
/** Force output of X, Y, and Z on next output. */
function forceXYZ() {
  xOutput.reset();
  yOutput.reset();
  zOutput.reset();
}

/** Force output of A, B, and C on next output. */
function forceABC() {
  aOutput.reset();
  bOutput.reset();
  cOutput.reset();
}

/** Force output of F on next output. */
function forceFeed() {
```

```
  currentFeedId = undefined;
  feedOutput.reset();
}

/** Force output of X, Y, Z, A, B, C, and F on next output. */
function forceAny() {
  forceXYZ();
  forceABC();
  forceFeed();
}
```

Sample Force Functions

5.31.5 writeRetract

```
function writeRetract(arguments) {
```

Arguments	Description
arguments	X, Y, and/or Z. Separated by commas when multiple axes are specified.

Settings used in writeRetract	Description
allowCancelTCPBeforeRetracting	Cancel TCP prior to retracting.
retract	Retract options.

The *writeRetract* function is used to retract the Z-axis to its clearance plane and move the X and Y axes to their home positions.

The *writeRetract* function can be called with one or more axes to move to their home position. The axes are specified using their standard names of *X, Y, Z*, and are separated by commas if multiple axes are specified in the call to *writeRetract*.

```
writeRetract(Z); // move the Z-axis to its home position
writeRetract(X, Y); // move the X and Y axes to their home positions
```

Sample writeRetract Calls

The *writeRetract* function handles positioning the linear axes to their home positions using standard methods, such as G28 or G53. If your machine supports a home positioning code that is not supported by the *writeRetract* function, you can either replace the *writeRetract* function in its entirety or add a *writeRetractCustom* function if the control supports the standard retract codes and in addition special codes that can be used to position the linear axes to their home positions.

```
function writeRetractCustom(retract) {
```

Arguments	Description
retract	Parameters based on the axes provided to the *writeRetract* function and the retract settings, as described in the following table.

Retract Parameter	Description
method	The method to use for positioning the linear axes, such as "G28", "G53", etc.
retractAxes	A three-element array that represents the axes that will be moved to their home position, where X = retractAxes[0], Y = retractAxes[1], Z = retractAxes[2]. A value of *true* states that this axis was passed to the *writeRetract* function and should be positioned.
words	A three-element array that contains the formatted representation of each axis to be output, for example "X0".
singleLine	*true* states that all axes can be output in a single block, *false* states that each axis must be output on a separate line.

If you do add an additional retract method, then you will need to update the *safePositionProperty* to support the additional retract method.

```
properties = {
…
  safePositionMethod: {
    title      : "Safe Retracts",
    description: "Select your desired retract option. 'Clearance Height' retracts to the operation clearance height.",
    group      : "homePositions",
    type       : "enum",
    values     : [
      {title:"G28", id:"G28"},
      {title:"G53", id:"G53"},
      {title: "WCS", id: "wcs"}  // added safe position method
    ],
    value: "G28",
    scope: "post"
  },
```

Adding a Custom Safe Positioning Method

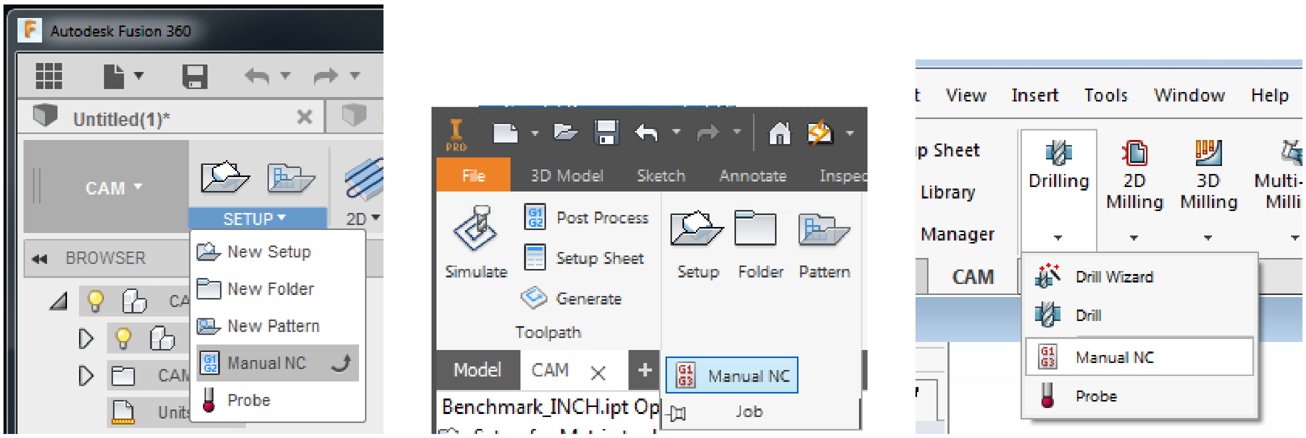
The *writeRetractCustom* function needs to be added to handle the custom safe positioning method.

```
function writeRetractCustom(retract) {
  switch (retract.method) {
  case "wcs":
    writeBlock(gMotionModal.format(0), retract.words);
    break;
  default:
    error(subst(localize("Unsupported safe position method '%1'"), retract.method));
    return;
  }
}
```

The writeRetractCustom Function

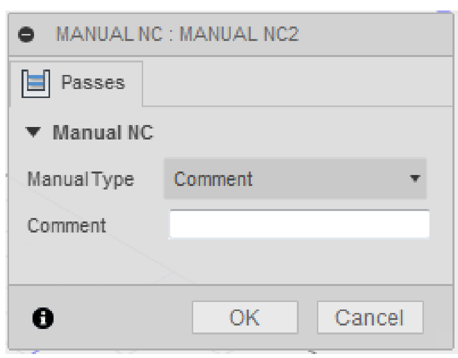
6 Manual NC Commands

Manual NC commands are used to control the behavior of individual operations when there is not a setting in the operation form for controlling a specific feature of a control. You can use Manual NC commands to display a message, insert codes into the output NC file, perform an optional stop, define a setting, etc. The Manual NC menu is accessed from different areas of the ribbon menu depending on the product you are running.



Selecting a Manual NC Command in the HSM Products (Fusion, Inventor, HSMWorks)

Once you select the Manual NC menu you will see a form displayed that is used to select the type of Manual NC command that you want to pass to the post processor and optionally the parameter that will be passed with the command.



Defining a Manual NC Command

If you use a Manual NC command in your part, then it is necessary that the post processor is equipped to handle this command. Some of the commands are supported by the stock post processors, such as *Stop*, *Optional stop*, and *Dwell*, while support would have to be added to the post processor to support other Manual NC commands. If you use a Manual NC command that is not supported by the post, then it will either generate an error or be ignored. The general rule is it will generate an error if the *onCommand* function is called and will be ignored when another function is called.

6.1 onManualNC and expandManualNC

function onManualNC(command, value) {
expandManualNC(command, value)

Arguments	Description
command	The Manual NC command that invoked the function.
value	The value entered with the command.

The *onManualNC* function is defined in the post processor and is used to process Manual NC commands. It accepts the command and the value that is assigned to the command. If the *onManualNC* function is not defined in the post processor, then a separate function will be called as listed in the table below.

The *expandManualNC* command can also be used to process the Manual NC command using the separate functions listed in the table. It is typically used as the default condition in the *onManualNC* function to process commands where you do not care if they are entered as a Manual NC command or from an internal call in the post processor.

The following table describes the Manual NC commands along with the function that will be called when the command is processed when the *onManualNC* function does not exist or *expandManualNC* is called.

Manual NC Command	Description	Command	Value	Function Called
Comment	Operator message	COMMAND_COMMENT	message	onComment
Stop	Machine stop	COMMAND_STOP		onCommand
Optional Stop	Optional stop	COMMAND_OPTIONAL_STOP		onCommand
Dwell	Dwell	COMMAND_DWELL	Dwell time in seconds	onDwell
Tool break control	Check for tool breakage	COMMAND_BREAK_CONTROL		onCommand
Measure tool	Automatically measure tool length	COMMAND_TOOL_MEASURE		onCommand
Start chip transport	Start chip conveyor	COMMAND_START_CHIP_TRANSPORT		onCommand
Stop chip transport	Stop chip conveyor	COMMAND_STOP_CHIP_TRANSPORT		onCommand
Open door	Open main door	COMMAND_OPEN_DOOR		onCommand
Close door	Close main door	COMMAND_CLOSE_DOOR		onCommand
Calibrate	Calibration of machine	COMMAND_CALIBRATE		onCommand

Manual NC Command	Description	Command	Value	Function Called
Verify	Verify integrity of machine	COMMAND_VERIFY		onCommand
Clean	Request a cleaning cycle	COMMAND_CLEAN		onCommand
Action	User defined action	COMMAND_ACTION	text	onParameter
Print message	Print a message from the machine	COMMAND_PRINT_MESSAGE	message	onParameter
Display message	Display operator message	COMMAND_DISPLAY_MESSAGE	message	onParameter
Alarm	Create an alarm on the machine	COMMAND_ALARM		onCommand
Alert	Request an alert event on the machine	COMMAND_ALERT		onCommand
Pass through	Output literal text to NC file	COMMAND_PASS_THROUGH	text	onPassThrough
Force tool change	Force a tool change	section.getForceToolChange()		(none)
Call program	Call a subprogram	COMMAND_CALL_PROGRAM	text	onParameter

Manual NC Commands

6.1.1 Sample onManualNC Function

The *onManualNC* function is a generic function to handle Manual NC commands. It does not have to be defined for the post processor to process Manual NC commands, and if it is defined, it does not need to process all Manual NC commands in this function. It could be used to process only the commands where you need to know if they were generated from a CAM Manual NC command instead of a direct call from within the post processor.

For example, the following *onManualNC* function definition could be used to process comments entered using the CAM Manual NC command differently than comments generated from the post processor. It simply appends the text ‘MSG,’ prior to the comment for a Manual NC *Display comment* command. All other Manual NC commands are processed normally.

```
function onManualNC(command, value) {
  switch (command) {
  case COMMAND_DISPLAY_MESSAGE:
    writeComment("MSG, " + value);
    break;
  default:
    expandManualNC(command, value);  // normal processing of Manual NC command
  }
```

```
}
```

Handling of Display Message Command in onManualNC

6.1.2 Delay Processing of Manual NC Commands

Manual NC commands are processed at the placement in the operation tree where they are entered, which means that they will be processed prior to the call to *onSection*. Since *onSection* typically terminates the previous operation prior to starting the new operation, this might not be the desirable location to process the Manual NC command.

The following code examples show how Manual NC commands can be buffered and output at any point during the operation. You can simply copy the *onManualNC* and *executeManualNC* functions into your post processor and add the appropriate call(s) to *executeManualNC* where you want to process the Manual NC commands.

```
/**
  Buffer Manual NC commands for processing later
*/
var manualNC = [];
function onManualNC(command, value) {
  if (getCurrentSectionId() != -1) { // output commands processed during a section immediately
    expandManualNC(command, value);
  } else { // buffer commands between sections to be output after ending the previous section
    manualNC.push({command:command, value:value});
  }
}
/**
  Processes the Manual NC commands
  Pass the desired command to process or leave argument list blank to process all commands
*/
function executeManualNC(command) {
  for (var i = 0; i < manualNC.length; ++i) {
    if (!command || (command == manualNC[i].command)) {
      expandManualNC(manualNC[i].command, manualNC[i].value);
    }
  }
  for (var i = manualNC.length - 1; i >= 0; --i) {
    if (!command || (command == manualNC[i].command)) {
      manualNC.splice(i, 1);
    }
  }
}
```

Manual NC Commands Support Functions

The calls to process the Manual NC commands can be placed anywhere in the post processor. In the following code example, the COMMAND_DISPLAY_MESSAGE command is processed just before the tool change block is output and the rest of the Manual NC commands after the tool change block.

```
  executeManualNC(COMMAND_DISPLAY_MESSAGE);  // display Manual NC message
  writeBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
  if (tool.comment) {
    writeComment(tool.comment);
  }
  executeManualNC(); // process remaining Manual NC commands
```

Processing of Manual NC Commands in the Desired Location

The following sections give a description of the functions that are called by the Manual NC commands outside of the *onManualNC* function and samples on how they are handled in the functions. The *onComment* and *onDwell* functions are described in the *Entry Functions* chapter, since they are simple functions and behave in the same manner no matter how they are called.

6.2 onCommand

```
function onCommand(command) {
```

Arguments	Description
command	Command to process.

All Manual NC commands that do not require an associated parameter are passed to the *onCommand* function and as you see from the *Manual NC Commands* table, this entails the majority of the commands. The *onCommand* function also handles other commands that are not generated by a Manual NC command and these are described in the *onCommand* section in the *Entry Functions* chapter.

```
// define commands that output a single M-code
var mapCommand = {
  COMMAND_STOP:0,
  COMMAND_OPTIONAL_STOP:1,
  COMMAND_START_CHIP_TRANSPORT:31,
  COMMAND_STOP_CHIP_TRANSPORT:33
  …
};

function onCommand(command) {
  switch (command) {
  …
  case COMMAND_BREAK_CONTROL: // handle the 'Tool break' command
    if (!toolChecked) { // avoid duplicate COMMAND_BREAK_CONTROL
      onCommand(COMMAND_STOP_SPINDLE);
      onCommand(COMMAND_COOLANT_OFF);
      writeBlock(
```

```
      gFormat.format(65),
      "P" + 9853,
      "T" + toolFormat.format(tool.number),
      "B" + xyzFormat.format(0),
      "H" + xyzFormat.format(getProperty("toolBreakageTolerance"))
    );
    toolChecked = true;
  }
  return;
case COMMAND_TOOL_MEASURE: // ignore tool measurements
  return;
}

// handle commands that output a single M-code
var stringId = getCommandStringId(command);
var mcode = mapCommand[stringId];
if (mcode != undefined) {
  writeBlock(mFormat.format(mcode));
} else {
  onUnsupportedCommand(command);
}
}
```
Handling Manual NC Commands in the onCommand Function

6.3 onParameter

```
function onParameter(name, value) {
```

Arguments	Description
name	Parameter name.
value	Value stored in the parameter.

The *onParameter* function is not only called for all parameters defined in the intermediate file (see the many calls to *onParameter* in the dump.cps post processor output) it also handles the *Action*, *Call program*, *Display message*, and *Print message* Manual NC commands. It is passed both the name of the parameter being defined and the text string associated with that parameter.

Manual NC Command	Name	Value
Action	action	text
Call program	call-subprogram	text
Display message	display	text
Print message	Print	text

Manual NC Commands Handled in onParameter

This section will describe how the *Action* command can be used, since this is the most commonly used of these commands.

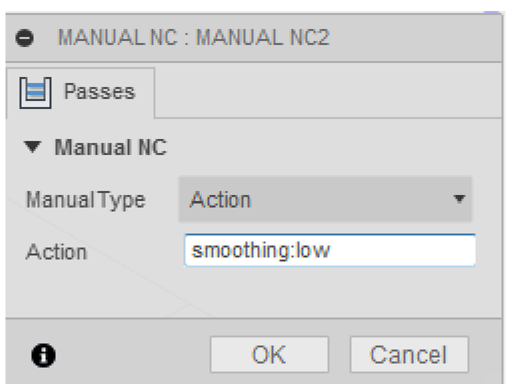
The *Action* command is typically used to define post processor settings, similar to the post properties defined at the top of the post processor, except that the settings defined using this command typically only apply to a single operation. Since the HSM operations are executed in the order that they are defined in the CAM tree, the Manual NC command will always be processed prior to the operation that they precede. You can also use the *Action* command to define a setting so that the command can be executed within another section of the post, by referencing this setting. You can even define settings that are typically set in the post properties into your program, so you are not reliant on making sure that the property is set for a specific program. In this case the *Action* command would set the value of the post property based on the input value associated with the command.

It is the *onParameter* function's responsibility to parse the text string passed as part of the *Action* command. The text string could be a value, list of values, command and value, etc. The following table lists the *Action* commands that are supported by the sample post processor code used in this section. These *Action* commands set variables that will be used elsewhere in the program.

Action Command	**Values**	**Description**
Smoothing	Off, Low, Medium, High	Sets the smoothing type
Tolerance	.001-.999	Smoothing tolerance
fastToolChange	Yes, No	Overrides the *fastToolChange* post property

Sample Action Type Manual NC Commands

In this example, the format for entering the *Action* Manual NC command is to specify the command followed by the ':' separator which in turn is followed by the value, in the *Action* text field.



***Action* Command Format**

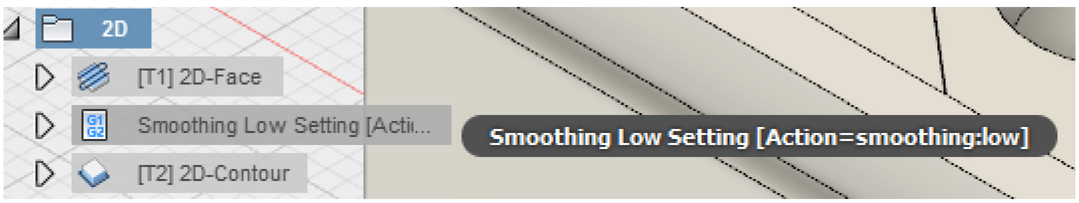
```
var smoothingType = 0;
var smoothingTolerance = .001;
function onParameter(name, value) {
  var invalid = false;
  switch (name) {
```

```
  case "action":
    var sText1 = String(value).toUpperCase();
    var sText2 = new Array();
    sText2 = sText1.split(":");
    if (sText2.length != 2) {
      error(localize("Invalid action command: ") + value);
      return;
    }
    switch (sText2[0]) {
    case "SMOOTHING":
      smoothingType = parseChoice(sText2[1], "OFF", "LOW", "MEDIUM", "HIGH");
      if (smoothingType == undefined) {
        error(localize("Smoothing type must be Off, Low, Medium, or High"));
        return;
      }
      break;
    case "TOLERANCE":
      smoothingTolerance = parseFloat(sText2[1]);
      if (isNaN(smoothingTolerance) || ((smoothingTolerance < .001) || (smoothingTolerance > .999))) {
        error(localize("Smoothing tolerance must be a value between .001 and .999"));
        return;
      }
      break;
    case "FASTTOOLCHANGE":
      var fast = parseChoice(sText2[1], "YES", "NO");
      if (fast == undefined) {
        error(localize("fastToolChange must be Yes or No"));
        return;
      }
      setProperty("fastToolChange", fast);
      break;
    default:
      error(localize("Invalid action parameter: ") + sText2[0] + ":" + sText2[1]);
      return;
    }
  }
}

/* returns the choice specified in a text string compared to a list of choices */
function parseChoice() {
  var stat = undefined;
  for (i = 1; i < arguments.length; i++) {
    if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
      if (String(arguments[i]).toUpperCase() == "YES") {
        stat = true;
      } else if (String(arguments[i]).toUpperCase() == "NO") {
```

```
      stat = false;
    } else {
      stat = i - 1;
      break;
    }
  }
}
return stat;
}
```

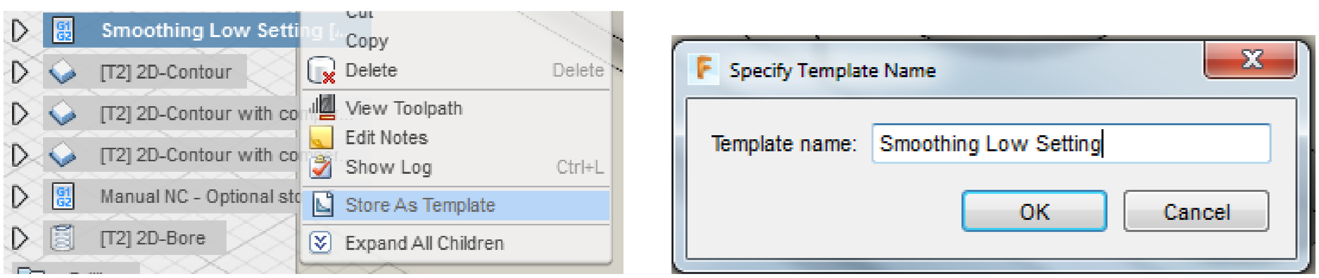
Handling the *Action* Manual NC Command

To make it easier to use custom *Action* Manual NC commands you can use the Template capabilities of HSM. First you will create the Manual NC command that you will turn into a template using the example in the *Action Command Format* picture shown above. Once the Manual NC command is created you will want to give it a meaningful name by renaming it in the Operation Tree.



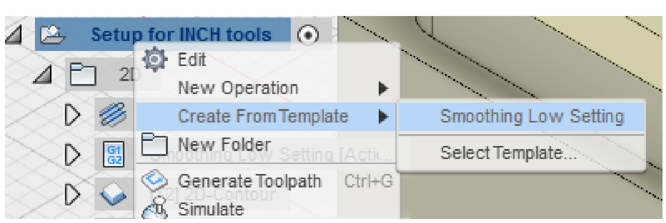
Rename the *Action* Manual NC Command Before Creating Template

Now you will create a template from this Manual NC command by right clicking on the Manual NC command and selecting *Store As Template*. You will want to give the template the same name as you did in the rename operation.



Creating the Manual NC Command Template

The template is now ready to be used in other operations and parts. You do this by right clicking a Setup or a Folder in the Operations Tree, position the mouse over the *Create From Template* menu and select the template you created.



Using the Manual NC Command Template You Created

6.4 onPassThrough

Function onPassThrough (value)

Arguments	Description
value	Text to be output to the NC file.

The *Pass through* Manual NC command is used to pass a text string directly to the NC file without any processing by the post processor. It is similar to editing the NC file and adding a line of text by hand. The text string could be standard codes (G, M, etc.) or a simple message. Since the post has no control or knowledge of the codes being output, it is recommended that you use the *Pass through* command sparingly and only with codes that cannot be output using another method.

The *onPassThrough* function handles the *Pass through* Manual NC command and is passed the text entered with the command. The following sample code will accept a text string with comma delimiters that will separate the text into individual lines.

```
function onPassThrough(text) {
  var commands = String(text).split(",");
  for (text in commands) {
    writeBlock(commands[text]);
  }
}
```

Output Lines of Codes/Text Separated by Commands Using the *Pass through* Manual NC Command

Like the *Action* Manual NC command, you can setup a Template to use with the *Pass through* command if you find yourself needing to output the same codes in multiple instances.

7 Debugging

7.1 Overview

The first thing to note when debugging is that there is not an interactive debugger associated with the Autodesk CAM post processors. This means that all debugging information must be output using settings within the post and with explicit writes. This section describes different methods you can use when debugging your post.

You can also use the HSM Post Processor Editor to aid in debugging your program as described in the *Running/Debugging the Post* section of this manual

7.2 The dump.cps Post Processor

The dump.cps post processor will process an intermediate CNC file and output a file that contains all of the information passed from HSM to the post processor. The output file has a file extension of *.dmp*. The contents of the dump file will show the settings of all parameter values and will list the entry functions called along the arguments passed to the function and any settings that apply to that function. The dump.cps output can be of tremendous value when developing and debugging a post processor.

```
342: onParameter('dwell', 0)
344: onParameter('incrementalDepth', 0.03937007874015748)
346: onParameter('incrementalDepthReduction', 0.003937007932681737)
348: onParameter('minimumIncrementalDepth', 0.01968503937007874)
350: onParameter('accumulatedDepth', 5)
352: onParameter('chipBreakDistance', 0.004023600105694899)
354: onMovement(MOVEMENT_CUTTING /*cutting*/)
354: onCycle()
  cycleType='chip-breaking'
  cycle.clearance=123456
  cycle.retract=0.19685039370078738
  cycle.stock=0
  cycle.depth=0.810440544068344
  cycle.feedrate=15.748000257597194
  cycle.retractFeedrate=39.370100366787646
  cycle.plungeFeedrate=15.748000257597194
  cycle.dwell=0
  cycle.incrementalDepth=0.03937007874015748
  cycle.incrementalDepthReduction=0.003937007932681737
  cycle.minimumIncrementalDepth=0.01968503937007874
  cycle.accumulatedDepth=5
  cycle.chipBreakDistance=0.004023600105694899
354: onCyclePoint(-1.25, 0.4999999924907534, -0.810440544068344)
355: onCyclePoint(1.25, 0.4999999924907534, -0.810440544068344)
356: onCycleEnd()
```

Sample dump.cps Output

7.3 Debugging using Post Processor Settings

There are variables available to the developer that control the output of debugging information. This section contains a description of these variables.

7.3.1 debugMode

```
debugMode = true;
```

Setting the *debugMode* variable to true enables the output of debug information from the *debug* command and is typically defined at the start of the post processor.

7.3.2 setWriteInvocations

setWriteInvocations (value);

Arguments	Description
value	*true* outputs debug information for the entry functions.

Enabling the *setWriteInvocations* setting will create debug output in the NC file similar to what is output using the *dump* post processor. The debug information contains the entry functions (*onParameter*, *onSection*, etc.) called during post processing and the parameters that they are called with. This information will be output prior to actually calling the entry function and is labeled using the *!DEBUG:* text.

```
!DEBUG: onRapid(-0.433735, 1.44892, 0.23622)
N190 Z0.2362
!DEBUG: onLinear(-0.433735, 1.44892, 0.0787402, 39.3701)
N195 G1 Z0.0787 F39.37
!DEBUG: onLinear(-0.433735, 1.44892, -0.5, 19.685)
N200 Z-0.5 F19.68
```

setWriteInvocations Output

7.3.3 setWriteStack

setWriteStack (value);

Arguments	Description
value	*true* outputs the call stack that outputs the line to the NC file.

Enabling the *setWriteStack* setting displays the call stack whenever text is output to the NC file. The call stack will consist of the *!DEBUG:* label, the call level, the name of the post processor, and the line number of the function call (the function name is not included in the output).

```
!DEBUG: 1 rs274.cps:108
!DEBUG: 2 rs274.cps:919
!DEBUG: 3 rs274.cps:357
N125 M5
```

setWriteStack Output

```
…
108: writeWords2("N" + sequenceNumber, arguments);
…
357: onCommand(COMMAND_STOP_SPINDLE);
…
919: writeBlock(mFormat.format(mcode));
```

Post Processor Contents

7.4 Functions used with Debugging

Functions that can be used to output debug information to the log and NC files include *debug*, *writeln*, and *log*. Additionally, the *writeComment* function present in almost all post processors can be used.

The text provided to the debug functions can contain operations and follow the same rules as defining a string variable in JavaScript. You can also specify vectors or matrixes and these will be properly formatted for output. For example,

```
var x = 3;
debug("The value of x is " + x);
```

For floating point values you may want to create a format that limits the number of digits to right of the decimal point, as some numbers can be quite long when output.

```
var numberFormat = createFormat({decimals:4});
var x = 3;
debug("The value of x is " + numberFormat.format(x));
```

When writing output debug information to the log and/or NC files it is recommended that you precede the debug text with a fixed string, such as "DEBUG – ", so that it is easily discernable from other output.

7.4.1 debug

```
debug (text);
```

Arguments	Description
text	Outputs *text* to the log file when *debugMode* is set to *true*.

The *debug* function outputs the provided text message to the log file only when the *debugMode* variable is set to true. The text is output exactly as provided, without any designation that the output was generated by the *debug* function.

7.4.2 log

```
log(text);
```

Arguments	Description
text	Outputs *text* to the log file.

The *log* function outputs the text to the log file. It is similar to the *debug* function, but does not rely on the *debugMode* setting.

7.4.3 writeln

writeln(text);

Arguments	Description
text	Outputs *text* to the NC file.

The *writeln* function outputs the text to the NC file. It is used extensively in post processors to output valid data to the NC file and not just debug text.

7.4.4 writeComment

writeComment(text);

Arguments	Description
text	Outputs *text* to the NC file as a comment.

The *writeComment* function is defined in the post processor and is used to output comments to the output NC file. It is described in the onComment section of this manual.

7.4.5 writeDebug

function writeDebug(text)

Arguments	Description
text	Outputs *text* to the NC and log files.

The *writeDebug* function is defined in the post processors and is used to output debug lines to the output NC file and log file so that if the post processor either fails or runs successfully you would still see the debug output.

8 Multi-Axis Post Processors

8.1 Adding Basic Multi-Axis Capabilities

Adding multi-axis capabilities to a post processor can be rather straight forward or difficult depending on the situation. This chapter will cover the basics and the more complex aspects of multi-axis support, such as adjusting points for a head, inverse time feedrates, etc.

The generic *RS-274D Sample Multi-axis Post Processor* is available to use as a sample for implementing multi-axis support in any post processor. It supports CAM defined and hardcoded machine configurations. You can use this post processor for testing rotary axes configurations and for copying functionality into your custom post processor.

Please note that support for 3+2 operations is not handled here, except for the setup of the machine. Refer to the *Work Plane* section in the *onSection* chapter for a description on how to handle 3+2 operations.

8.1.1 Create the Rotary Axes Formats

The output formats for the rotary axes must first be defined. In existing multi-axis posts and posts that contain the skeleton structure of multi-axis support these codes should already be defined. You should add (or verify that they already exist) the following definitions at the top of the post processor in the same area that all other formats are defined.

```
var abcFormat = createFormat({type:FORMAT_REAL, decimals:3, scale:DEG});
…
var aOutput = createOutputVariable({prefix:"A"}, abcFormat);
var bOutput = createOutputVariable({prefix:"B"}, abcFormat);
var cOutput = createOutputVariable ({prefix:"C"}, abcFormat);
```

Define the Rotary Axes Formats

The *scale:DEG* parameter specifies that the rotary axes angles will be output in degrees. If you require the output to be in radians, then omit the *scale* setting.

8.1.2 The Machine Configuration Settings and Functions

The machine configuration and the associated settings are above the *onOpen* function and define and activate the machine configuration in the post processor. If your post processor does not have the *defineMachine* function, then it should be copied from the *RS-274D Sample Multi-axis* post processor into your post. You will also need the *activateMachine* function if it is not present in your post.

```
function defineMachine() {
...
}

…

function activateMachine() {
…
}
```

Copy this Code to your Custom Post Processor

You will also need to add the following code to the top of the *onOpen* function to call the machine configuration functions.

```
function onOpen() {
  // define and enable machine configuration
  receivedMachineConfiguration = machineConfiguration.isReceived();
  if (typeof defineMachine == "function") {
    defineMachine(); // hardcoded machine configuration
  }
```

```
  activateMachine(); // enable the machine optimizations and settings
```

Copy this Code to the Top of the onOpen Function

8.1.3 Creating a Hardcoded Multi-Axis Machine Configuration

You can use a Machine Definition in the CAM system to define the rotary axis kinematics of the machine or it can be hardcoded in the post processor. This section describes how you would hardcode the machine configuration inside of the post processor script.

The hardcoded machine configuration can be found in the *defineMachine* function. It includes all applicable settings that are found in the Machine Definition and contains the following sections of code.

```
function defineMachine() {
  // if (!receivedMachineConfiguration) { // CAM machine definition takes precedence
  if (true) { // hardcoded machine configuration takes precedence
    // define machine kinematics
    var useTCP = false; // TCP support
    var aAxis = createAxis({coordinate:X, table:true, axis:[1, 0, 0], offset:[0, 0, 0], range:[-120, 30],
cyclic:false, preference:-1, tcp:useTCP});
    var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], offset:[0, 0, 0], cyclic:true, reset:0,
tcp:useTCP});
    machineConfiguration = new MachineConfiguration(aAxis, cAxis);
```

Define Machine Kinematics

The rotary axes can be customized to match the machine configuration using the parameters in the *createAxis* command.

Parameter	Description
table	Set to *true* when the rotary axis is a table, or *false* if it is a head. The default if not specified is *true*.
axis	Specifies the rotational axis of the rotary axis in the format of a vector, i.e. [0, 0, 1]. This vector does not have to be orthogonal to a major plane, for example it could be [0, .7071, .7071]. The direction of the rotary axes are based on the righthand rule for tables and the lefthand rule for heads. You can change direction of the axis by supplying a vector pointing in the opposite direction, i.e. [0, 0, -1]. This parameter is required.
offset	Defines the rotational position of the axis in the format of a coordinate, i.e. [0, 0, 0]. For machines that support TCP the *offset* parameter can be omitted. The offset values for tables are based on the part origin defined in the Setup. The offset value for the rider or primary rotary head is based on the distance from the tool stop (or spindle face) position to the pivot point of the rotary head. The offset value for the carrier rotary head (when the machine has a head/head configuration) is based on the pivot point of the rider axis to the pivot point of the carrier axis. The default is [0, 0, 0].
coordinate	Defines the coordinate of the axis, either X, Y, or Z. You will notice a number used in most of the generic posts, in this case 0=X, 1=Y, and 2=Z. Either specification is acceptable input. This parameter is required.

Parameter	Description
cyclic	Defines whether the axis is cyclic (continuous) in nature, in that the output will always be within the range specified by the *range* parameter. Cyclic axes will never cause the *onRewindFunction* to be called, since they are continuous in nature and do not have limits. The range applies specifically to output values for this axis. The default is *false*.
tcp	Defines whether the control supports Tool Center Point programming for this axis. Each axis can have its own setting. The default is *true*.
range	Defines the upper and lower limits of the rotary axis using the format [lower, upper]. If the rotary axis is cyclic, then the range sets the limits of the output values for this axis, if it is not cyclic the range is the actual physical limits of the machine.
preference	Specifies the preferred angle direction at the beginning of an operation. -1 = choose the negative angle, 0 = no preference, and 1 = choose the positive angle. The default is 0.
reset	Defines the starting position of the axis for a new operation and when the rotary axes need to be rewound and reconfigured due to exceeding the limits. 0 = remember the position from previous section, 1 = reset to 0 at start of operation, 2 = reset to 0 at automatic rewind, 3 = reset to 0 at start of operation and at automatic rewind. This parameter is implemented since R42225 of the post engine.
resolution	Specifies the resolution in degrees of the rotational actuator. Typically, this will be set to the number of digits to the right of the decimal as specified in the *createFormat* call for the rotary axes. The default is 0.

createAxis Parameters

The order in which the axes are defined in the *new MachineConfiguration* call is important and must use the following order.

Order	Rotary Axis
1	Rotary head rider
2	Rotary head carrier
3	Rotary table carrier
4	Rotary table rider

machineConfiguration Rotary Axis Order

```
// 4 axis setup, A rotates around X, direction is positive
var aAxis = createAxis({coordinate:X, table:true, axis:[1, 0, 0], cyclic:true, tcp:false, preference:1});
machineConfiguration = new MachineConfiguration(aAxis);

// 4 axis setup, A rotates around X, direction is negative
var aAxis = createAxis({coordinate:X, table:true, axis:[-1, 0, 0], cyclic:true, tcp:false,, preference:1});
machineConfiguration = new MachineConfiguration(aAxis);
setMachineConfiguration(machineConfiguration);

// 5 axis setup, B rotates around Y, C rotates around Z, directions both positive
var bAxis = createAxis({coordinate:Y, table:true, axis:[0, 1, 0], range:[-120,120], tcp:true,
  preference:1});
var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], cyclic:true, tcp:true});
```

```
machineConfiguration = new MachineConfiguration(bAxis, cAxis);
setMachineConfiguration(machineConfiguration);

// Same table/table setup, without TCP, top and center of C-axis is defined as the origin
var bAxis = createAxis({coordinate:Y, table:true, axis:[0, 1, 0], offset:0, 0, -12.5], range:[-120,120],
  tcp:false, preference:1});
var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], cyclic:true, tcp:false});
machineConfiguration = new MachineConfiguration(bAxis, cAxis);
setMachineConfiguration(machineConfiguration);

// 5-axis head/head setup without TCP
var aAxis = createAxis({coordinate:X, table:false, axis:[-1, 0, 0], offset:[0, 0, 8.75], range:[-120,120],
  tcp:false, preference:-1});
var cAxis = createAxis({coordinate:Z, table:false, axis:[0, 0, 1], cyclic:false, range:[-180, 180],
  tcp:false});
machineConfiguration = new MachineConfiguration(aAxis, cAxis);
setMachineConfiguration(machineConfiguration);
```

Sample Rotary Configurations

The determination if the output coordinates should be at the pivot point of the rotary heads or the virtual tooltip position (as if the tool is vertical) is decided by the *setVirtualTooltip* function. This setting is only applied to rotary heads that do not support TCP. The virtual tooltip position is described in the *Adjusting the Points for Offset Rotary Axes* section.

```
  // multiaxis settings
  if (machineConfiguration.isHeadConfiguration()) {
    machineConfiguration.setVirtualTooltip(false); // translate the pivot point to the virtual tool tip
for nonTCP rotary heads
  }
```

Virtual Tooltip Setting

It is possible on some machine configurations that the limits of the rotary axes will be exceeded and the tool has to be retracted and the rotary axes repositioned to within the limits of the machine. The following code defines the required settings for the retract/reconfigure logic. It is described in the *Rewinding of the Rotary Axes when Limits are Reached* section.

```
  // retract / reconfigure
  var performRewinds = false; // set to true to enable the retract/reconfigure logic
  if (performRewinds) {
    machineConfiguration.enableMachineRewinds(); // enables the retract/reconfigure logic
    safeRetractDistance = (unit == IN) ? 1 : 25; // additional distance to retract out of stock, can be
overridden with a property
    safeRetractFeed = (unit == IN) ? 20 : 500; // retract feed rate
    safePlungeFeed = (unit == IN) ? 10 : 250; // plunge feed rate
    machineConfiguration.setSafeRetractDistance(safeRetractDistance);
    machineConfiguration.setSafeRetractFeedrate(safeRetractFeed);
```

```
    machineConfiguration.setSafePlungeFeedrate(safePlungeFeed);
    var stockExpansion = new Vector(toPreciseUnit(0.1, IN), toPreciseUnit(0.1, IN),
toPreciseUnit(0.1, IN)); // expand stock XYZ values
    machineConfiguration.setRewindStockExpansion(stockExpansion);
  }
```

Retract/Reconfigure Settings

Multi-axis machines that do not support TCP will usually require inverse time or degree per minute feedrates. The mulit-axis feedrate format is defined in the following section of code. Multi-axis feedrates are discussed in more detail in the *Multi-Axis Feedrates* section.

```
  // multi-axis feedrates
  if (machineConfiguration.isMultiAxisConfiguration()) {
    machineConfiguration.setMultiAxisFeedrate(
      useTCP ? FEED_PER_MINUTE : getProperty("useDPMFeeds") ? FEED_DEGREE_MINUTE:
FEED_INVERSE_TIME,
      9999.99, // maximum output value for inverse time feed rates
      getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES, //
INVERSE_MINUTES/INVERSE_SECONDS or DPM_COMBINATION/DPM_STANDARD
      0.5, // tolerance to determine when the DPM feed has changed
      1.0 // ratio of rotary accuracy to linear accuracy for DPM calculations
    );
  }
```

Multi-Axis Feedrates Definition

The machine description can be output in the program header and is contained in the Machine Definition associated with the CAM Setup. If the post uses a hardcoded Machine Configuration, then the machine description should be added to the *defineMachine* function.

```
  machineConfiguration.setVendor("Doosan");
  machineConfiguration.setModel("Lynx");
  machineConfiguration.setDescription(description);
```

Defining the Machine Information

The home position of the machine can be defined in the *defineMachine* function. The home positions are used in the *writeRetract* function when positioning the machine in machine coordinates (G53) or WCS coordinates (G00).

```
  /* home positions */
  // machineConfiguration.setHomePositionX(toPreciseUnit(0, IN));
  // machineConfiguration.setHomePositionY(toPreciseUnit(0, IN));
  // machineConfiguration.setRetractPlane(toPreciseUnit(0, IN));
```

Defining the Machine Home Coordinates

Finally, the post processor engine needs to be informed of the hardcoded machine configuration.

```
  // define the machine configuration
  setMachineConfiguration(machineConfiguration); // inform post kernel of hardcoded machine configuration
  if (receivedMachineConfiguration) {
    warning(localize("The provided CAM machine configuration is overwritten by the postprocessor."));
    receivedMachineConfiguration = false; // CAM provided machine configuration is overwritten
  }
```
Informing the Post Engine of the Hardcoded Machine Configuration

8.1.4 Calculating the Rotary Angles

Once a machine configuration is defined the rotary axes angles need to be calculated and the tool end point needs to be adjusted for the rotary axes if TCP is not supported. This holds true for CAM and hardcoded machine configurations. This is handled in the *activateMachine* function and should not have to be modified. It is described here for reference purposes only.

The *optimizeMachineAngles2* function calculates the rotary axes angles and adjusts the XYZ coordinates for the rotary axes if TCP is not supported. The following values are passed to the *optimizeMachineAngles2* function.

Value	Description
OPTIMIZE_NONE	Don't adjust the coordinates for the rotary axes. Used for TCP mode.
OPTIMIZE_BOTH	Adjust the coordinates for the rotary axes. For rotary heads that do not support TCP it is possible that the tool length has to be added to the tool end point coordinates. This scenario is discussed further in the *Adjusting the Points for Rotary Heads* section of this chapter.
OPTIMIZE_TABLES	Adjust the coordinates for rotary tables. No adjustment will be made for heads.
OPTIMIZE_HEADS	Adjust the coordinates for rotary heads. No adjustment will be made for tables.
OPTIMIZE_AXIS	Adjust the coordinates for the rotary axes based on the TCP setting associated with the defined axes. This is the required setting for CAM defined Machine Definitions and hardcoded machine configurations that define the *tcp* variable in the *createAxis* definitions.

Settings for Adjusting the Input Coordinates for the Rotary Axes

Rotary head adjustments that require that the tool length be added to the offset distance of the axis cannot be adjusted using the *optimizeMachineAngles2* function, since the tool length will vary from tool to tool. Instead, the Section function *optimizeMachineAnglesByMachine* is called for each section. This is also true for post processors that may change the machine configuration during the processing of the operations. Following is the generic code used in the *activateMachine* function that is used to calculate the rotary axes angles and adjust the tool end point coordinates.

```
  // calculate the ABC angles and adjust the points for multi-axis operations
  // rotary heads may require the tool length be added to the pivot length
  // so we need to optimize each section individually
  if (machineConfiguration.isHeadConfiguration() &&
      getSetting("workPlaneMethod.compensateToolLength", false)) {
    for (var i = 0; i < getNumberOfSections(); ++i) {
      var section = getSection(i);
      if (section.isMultiAxis()) {
        machineConfiguration.setToolLength(getBodyLength(section.getTool())); // define the tool
length for head adjustments
        section.optimizeMachineAnglesByMachine(machineConfiguration, OPTIMIZE_AXIS);
      }
    }
  } else { // tables and rotary heads with TCP support can be optimized with a single call
    optimizeMachineAngles2(OPTIMIZE_AXIS);
  }
```

Rotary Axes Calculations and Coordinate Transformation

If the call to calculate the rotary axes and adjust the input coordinates is not made then the tool end point and tool axis vector will be passed to the *onRapid5D* and *onLinear5D* multi-axis functions.

8.1.5 Output Initial Rotary Position

A function should be defined that outputs the rotary axis position in a block by themselves. In legacy posts this code is contained inline can be found in multiple places within the post.

```
/** Positions the rotary axes in rapid mode */
function positionABC(abc, force) {
  if (typeof unwindABC == "function") {
    unwindABC(abc, false);
  }
  if (force) {
    forceABC();
  }
  var a = aOutput.format(abc.x);
  var b = bOutput.format(abc.y);
  var c = cOutput.format(abc.z);
  if (a || b || c) {
    if (!retracted) {
      if (typeof moveToSafeRetractPosition == "function") {
        moveToSafeRetractPosition();
      } else {
        writeRetract(Z);
      }
    }
```

```
    onCommand(COMMAND_UNLOCK_MULTI_AXIS);
    gMotionModal.reset();
    writeBlock(gMotionModal.format(0), a, b, c);
    setCurrentABC(abc); // required for machine simulation
  }
}
```

Output Initial Rotary Axes Positions

The initial rotary axes positions must be calculated prior calling the *positionABC* function. The function *getInitialToolAxisABC*() is used to obtain the initial rotary axes positions for multi-axis operations.

```
if (currentSection.isMultiAxis()) {
  var abc = section.getInitialToolAxisABC();
  positionABC(abc, true);
}
```

Calculate Initial Rotary Angles for a Multi-axis Operation

8.1.6 Create the onRapid5D and onLinear5D Functions

Now that you have the machine defined you will need to verify that the *onRapid5D* and *onLinear5D* functions are present. These are the functions that will process the tool path generated by multi-axis operations. If your post already has these functions defined, then great you should be (almost) ready to go, if not then add the following functions to your post.

```
function onRapid5D (_x, _y, _z, _a, _b, _c) {
  if (!currentSection.isOptimizedForMachine()) {
    error(localize("This post configuration has not been customized for 5-axis simultaneous 
toolpath."));
    return;
  }
  if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation mode cannot be changed at rapid traversal."));
    return;
  }
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var a = aOutput.format(_a);
  var b = bOutput.format(_b);
  var c = cOutput.format(_c);
  if (x || y || z || a || b || c) {
    writeBlock(gMotionModal.format(0), x, y, z, a, b, c);
    feedOutput.reset();
  }
}
```

onRapid Function

```
function onLinear5D (_x, _y, _z, _a, _b, _c, feed, feedMode) {
  if (!currentSection.isOptimizedForMachine()) {
    error(localize("This post configuration has not been customized for 5-axis simultaneous
toolpath."));
    return;
  }
  if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation cannot be activated/deactivated for 5-axis move."));
    return;
  }
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var a = aOutput.format(_a);
  var b = bOutput.format(_b);
  var c = cOutput.format(_c);
  var f = feedOutput.format(_feed);

  // get feedrate number
  var fMode = feedMode == FEED_INVERSE_TIME ? 93 : 94;
  var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) :
    feedOutput.format(feed);

  if (x || y || z || a || b || c) {
    writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
  } else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
      feedOutput.reset(); // force feed on next line
    } else {
      writeBlock(gfFeedModeModal.format(fMode), MotionModal.format(1), f);
    }
  }
}
```
onLinear5D Function

Both of these functions as presented are basic in nature and the requirements for your machine may require some modification.

8.1.7 Multi-Axis Common Functions

There are functions that are useful when developing a post processor for a multi-axis machine. These functions are used to determine if the rotary axes are configured, the beginning and ending tool axis or rotary axes positions for an operation, and control the flow of the multi-axis logic.

Function	Description
machineConfiguration.isMultiAxisConfiguration()	Returns *true* if a machine configuration containing rotary axes has been defined. It is still possible to create output for some multi-axis machines if the rotary axes have not been defined, by outputting the tool axis vector instead of the rotary axes positions or by using Euler angles for 3+2 operations.
machineConfiguration.getABCByPreference (matrix, current, controllingAxis, type, options)	Returns the preferred rotary axes angles for the provided matrix. This matrix is usually the Work Plane matrix (*currentSection.workPlane*). *getABCByPreference* is described in further detail in the *Work Plane – 3+2 Operations* section.
machineConfiguration.getDirection(abc)	Returns the tool axis vector that corresponds to the specified ABC angles.
section.isOptimizedForMachine()	Returns *true* if the rotary axes angles have been calculated for the section.
section.isMultiAxis()	Returns *true* if the operation specified by *section* is a multi-axis operation.
section.getGlobalInitialToolAxis()	Returns the initial tool axis for the provided section as a Vector. Usually used at the start of an operation using the *currentSection* variable.
section.getInitialToolAxisABC()	Returns the initial rotary axes angles for the provided section as a Vector. Usually used at the start of an operation using the *currentSection* variable. An error will be generated if a machine configuration containing rotary axes has not been defined.
section.getGlobalFinalToolAxis()	Returns the final tool axis for the provided section as a Vector. Usually used at the start of an operation using *getPreviousSection()*.
section.getFinalToolAxisABC()	Returns the final rotary axes angles for the provided section as a Vector. Usually used at the start of an operation using *getPreviousSection()*. An error will be generated if a machine configuration containing rotary axes has not been defined.
section.getOptimizedTCPMode()	Returns the mode used to adjust the output coordinates for the rotary axes for this section. The different modes are listed in the *Calculating the Rotary Angles* section in this chapter.
getCurrentABC()	Returns the current rotary axes angles as a Vector.
getCurrentDirection()	When the machine configuration is configured with defined rotary axes, the current rotary axes angles as a Vector will be returned. If the machine configuration does not contain rotary axes, then the tool axis Vector will be returned. It will return the Work Plane forward vector when in a 3-axis or 3+2 operation.
getCurrentToolAxis()	Returns the current tool axis Vector. It will return the Work Plane forward vector when in a 3-axis or 3+2 operation.

Function	Description
is3D()	Returns *true* if the entire program is a 3-axis operation with no multi-axis operations. Returns *false* if even one operation is a 3+2 or multi-axis operation.
setCurrentABC(abc)	Sets the current ABC position in the post engine. This function should be called whenever the rotary angles are calculated and output within the post processor.

Multi-Axis Common Functions

8.2 Output of Continuous Rotary Axis on a Rotary Scale

There are two different styles that are commonly used for rotary axes output, using a linear scale or a rotary scale. A linear scale is the more standard case in today's machines and will move on a progressive scale similar to a linear axis output. For example, a value of 720 degrees will move the axis two revolutions from 0 degrees. A linear scale is almost always used with a non-continuous axes and can be used with a continuous rotary axis.

A rotary scale on the other hand typically outputs the rotary angle positions between 0 and 360 degrees, usually with the sign ± specifying the direction. If a sign is not required and the control will always take the shortest route, then it is pretty straight forward to output the rotary axis on a rotary scale, simply define it as a cyclic axis with a range of 0 to 360 degrees.

```
var aAxis = createAxis({coordinate:0, table:true, axis:[1, 0, 0], cyclic:true, range:[0, 360]});
```

Create Rotary Axis Using a Rotary Scale. Machine will Take the Shortest Route

For controls that require a sign to designate the direction the rotary axis will move, you will need to define the rotary axis on a linear scale. Yes, it sounds counterintuitive, but the output variable will handle converting the linear scale value to a signed rotary scale value.

```
var aAxis = createAxis({coordinate:0, table:true, axis:[1, 0, 0], cyclic:true});
```

Create Rotary Axis Using a Linear Scale when Output Using a Rotary Scale

The *createOutputVariable* function can be used to output a directional value for a rotary axis on a rotary scale.

```
var aOutput = createOutputVariable({prefix:"A", type:TYPE_DIRECTIONAL, cyclicLimit:360,
  cyclicSign:1}, aFormat);
```

Create the Output Variable using a Rotary Scale

There are no more modifications needed.

8.3 Adjusting the Points for Offset Rotary Axes

The post processor kernel has support for offset tables and heads when TCP is not supported on the machine. The offsets from the part origin to the rotary center(s) must be defined when the axis is created. This is done using the *offset* parameter in *createAxis*.

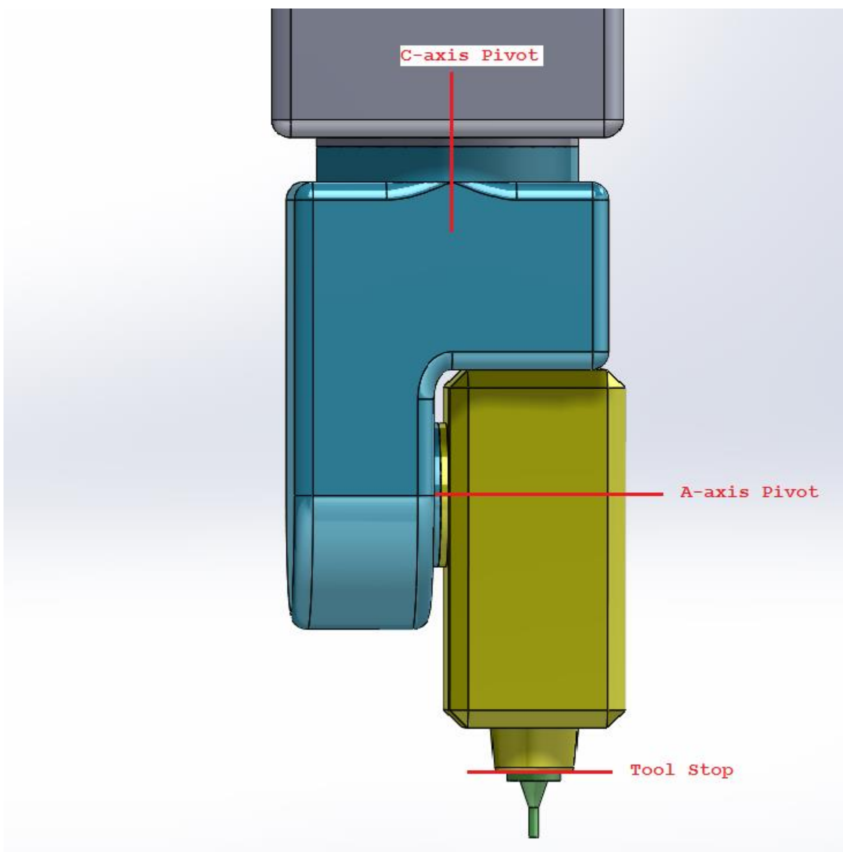
```
var aAxis = createAxis({coordinate:X, table:false, axis:[-1, 0, 0], offset:[0, 0, 8.75], range:[-120,120],
  tcp:false, preference:-1});
```

Create an Offset Rotary Head

It is important to know how the offsets are applied to each style of rotary axis. For rotary heads remember the head rider axis is defined first and then the head carrier axis. When the carrier and rider heads share a common pivot point, then only the offset for the rider axis needs to be defined. This offset is defined from the tool stop position to the pivot point. When the pivot points are different, the carrier axis offset is defined as the offset from the rider pivot point. Most machines will use a common pivot point for both rotary axes.

Rotary Axis	Rotary Axis
Rotary head rider	Distance from tool stop to pivot point
Rotary head carrier	Distance from Head Rider pivot point to Head Carrier pivot point
Rotary table carrier	Distance from part origin to center of table
Rotary table rider	Distance from part origin to center of table

Non-TCP Rotary Axis Offsets

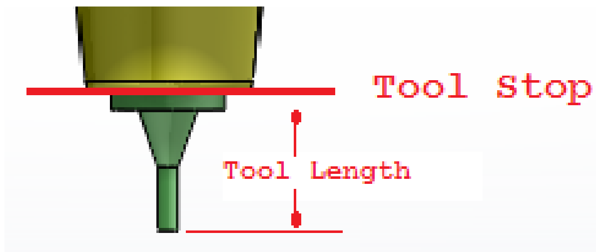


Rotary Head Pivot References

When defining an offset rotary table, defining the offset is all that is needed before the rotary angles and transformed coordinates are calculated.

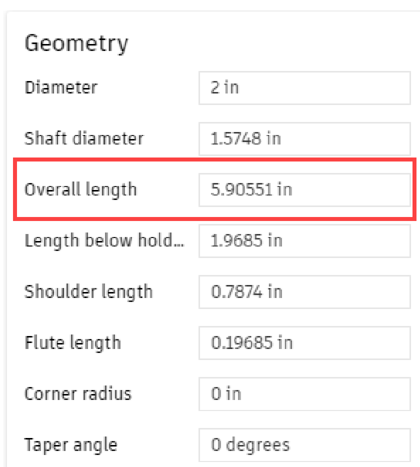
For offset heads on machines that do not support TCP there are a couple of more function calls that may be needed.

It is possible that the tool length needs to be added to the offset of the head rider axis defined in the *createAxis* function. On small hobbyist machines it could be that the tool will always be the same length and can then be defined as part of the offset. On machines that use different tool lengths you will need to inform the post engine of the tool length to be added to the pivot distance prior to calculating the offset coordinates for the section. This is done by calling the *machineConfiguration.setToolLength* function with the length of the tool from the tool end point to the tool stop position used to define the offset for the head.



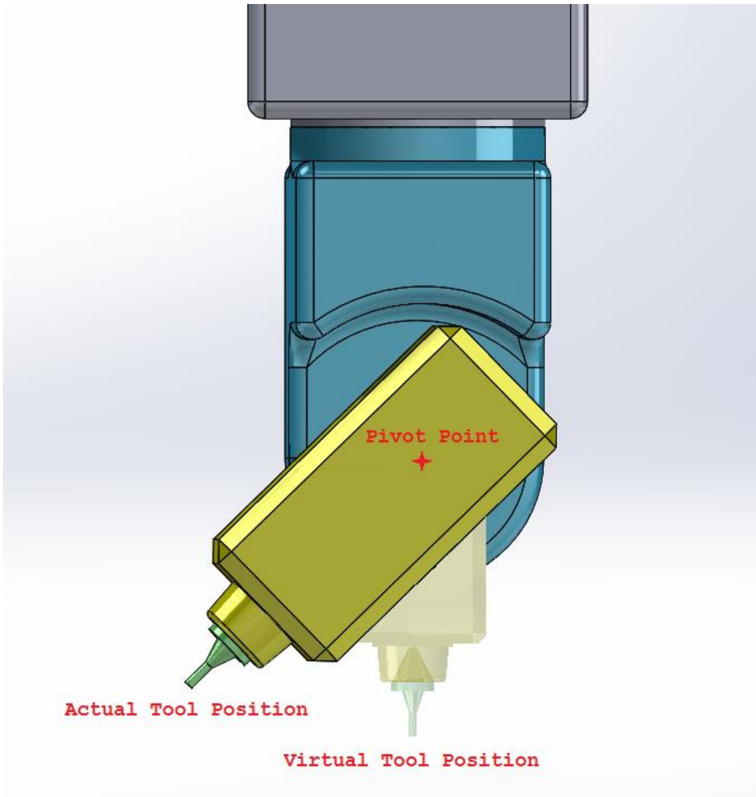
Tool Length Definition

The post processor will typically use the *Overall length* of the tool as defined in the CAM system as the tool length.



Overall Length Defines the Tool Length

The output of the offset head coordinates can either be at the pivot point of the axis or the tool end point when the rotary axes are at 0 degrees (the tool is vertical). You would normally setup the machine with the tool tip at Z0. In this case the output coordinates will be at the virtual tool tip, meaning that the coordinates will be where the tool tip position would be when the rotary axes are at 0 degrees, even when the axes are tilted.



Virtual Tool Tip

The *machineConfiguration.setVirtualTooltip* function is used to define whether the output coordinates are at the pivot point or at the virtual tool tip in a hardcoded machine configuration. In either case it is important that the proper offset distance and tool length are provided in order for the correct XYZ coordinates to be calculated. The *activateMachine* function handles the calculation of offset tables and heads based on the definition of each rotary axes and the following settings.

8.4 Calculation of the Multi-Axis Tool Position

It is possible to manually calculate the machine linear position based on the tool end point position or the tool end point position based on the machine linear position based on the rotary axis positions. The *machineConfiguration.getOptimizedPosition* function performs both conversions.

```
machineConfiguration.getOptimizedPosition(current, abc, tcpType, optimizeType, force)
```

Adjust a Coordinate for the Rotary Axis Positions

Parameter	Variable Type	Description
current	Vector	Either the tool tip or machine XYZ position based on *tcpType*.
abc	Vector	The rotary axis positions.
tcpType	Value	Type of conversion.

Parameter	Variable Type	Description
optimizeType	Value	Type of optimization.
force	Boolean	Set to true to adjust the values even if TCP is in effect. Valid for TCP_XYZ_OPTIMIZED and TCP_TOOL_OPTIMIZED.

getOptimizedPosition Parameters

Value	Description	Current Input Value
TCP_XYZ	Converts the tool tip to the machine XYZ position.	Tool tip
TCP_TOOL	Converts the machine XYZ position to the tool tip position.	Machine XYZ
TCP_XYZ_OPTIMIZED	Converts the tool tip to the machine XYZ position only when the input coordinates are adjusted for the rotary axes (non-TCP).	Position as supplied to onRapid5D and onLinear5D.
TCP_TOOL_OPTIMIZED	Converts the machine XYZ position to the tool tip position only when the input coordinates are adjusted for the rotary axes (non-TCP).	Position as supplied to onRapid5D and onLinear5D.

tcpType Values

Value	Description
OPTIMIZE_BOTH	Adjust the coordinates for both tables and heads.
OPTIMIZE_TABLES	Adjust the coordinates for rotary tables only.
OPTIMIZE_HEADS	Adjust the coordinates for rotary heads only.

optimizeType Values

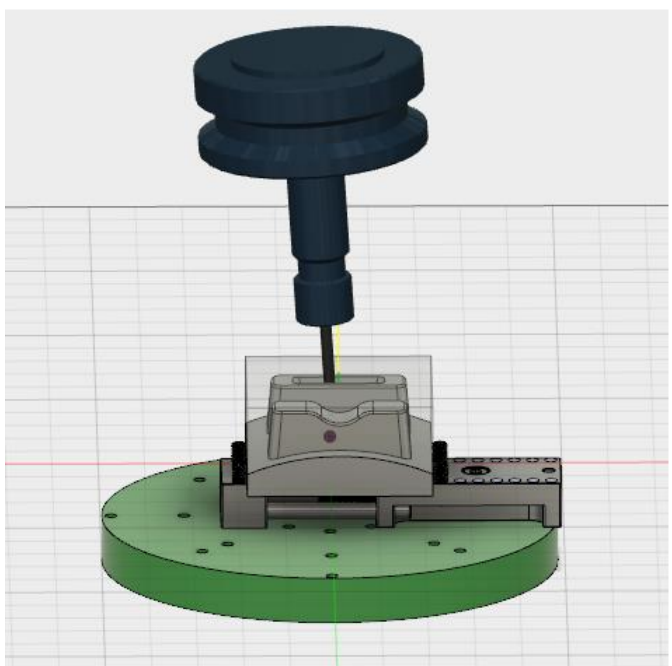
```
// calculate the machine XYZ position from the tool tip position
var xyz = machineConfiguration.getOptimizedPosition(toolTip, abc, TCP_XYZ, OPTIMIZE_BOTH,
false);

function onRapid5D(_x, _y, _z, _a, _b, _c) {
  // calculate the tool tip position
  // if the input coordinates are not adjusted for the rotary axes, the output coordinate will be
  // the same as the input coordinate
  var toolTip = machineConfiguration.getOptimizedPosition(
      new Vector(_x, _y, _z),
      new Vector(_a, _b, _c),
      TCP_TOOL_OPTIMIZED, OPTIMIZE_HEAD,
      false);
```

Sample Coordinate Conversions

8.5 Handling the Singularity Issue in the Post Processor

The post processor kernel handles the problem when the tool axis direction approaches the singularity of the machine. The singularity is defined as the tool axis orientation that is perpendicular to a rotary axis, either a table or head. When the tool direction approaches the singularity, you may notice that the rotary axis can start to swing violently even if there is only a small deviation in the tool axis. If you can imagine a machine with an A-axis trunnion carrying a C-axis table and the tool axis is 0, sin(.001), cos(.001). This causes the output rotary positions to be A.001 C0. Now if the rotary axis changes to 0, sin(.001), cos(.001), a change of less than .002 degrees you will notice that the rotary positions to be A.001 C90. You can see where a very small directional change in the tool axis (<.002) will cause a 90-degree change in the C-axis.

The singularity logic in the kernel will massage the tool axis direction to keep the tool within tolerance and minimize the rotary axis movement in these cases. A safeguard that linearizes the moves around the singularity has also been implemented. This linearization will add tool locations as necessary to keep the tool endpoint within tolerance of the part.



Tool Direction Approaching the Singularity

There are settings in the post processor that manage how the singularity issue is handled. These settings are defined using the following command.

```
machineConfiguration.setSingularity(adjust, method, cone, angle, tolerance, linearizationTolerance)
```

Variable	Description
adjust	Set to *true* to enable singularity optimization within the post processor. Singularity optimization includes the ability to adjust the tool axis to minimize singularity issues (large rotary axis movement when the tool axis approaches perpendicularity to a rotary axis) and the linearization of the moves around the singularity to keep the tool endpoint within tolerance. The default is *true*.
method	When set to SINGULARITY_LINEARIZE_OFF it disables the linearization of the moves to keep the tool endpoint within tolerance of the programmed tool path around the singularity. SINGULARITY_LINEARIZE_ROTARY will linearize the moves around the singularity. Additional points are added to keep the tool within the specified tolerance and is optimized for revolved movement as if the tool were moving around a cylinder or other revolved feature. SINGULARITY_LINEARIZE_LINEAR will also add additional points to keep the tool within tolerance, but will keep the tool endpoint moving in a straight line. The default is SINGULARITY_LINEARIZE_ROTARY.
cone	Specifies the angular distance that the tool axis vector must be within in reference to the singularity point before the singularity logic is activated. This is usually a small value (less than 5 degrees), since the further away the tool axis is from the singularity, the less noticeable the fluctuations in the rotary axes will be and the less benefit this feature will provide. This parameter is specified in radians and the default value is .052 (3 degrees).
angle	The minimum angular delta movement that the rotary axes must move prior to considering adjusting the tool axis vector for singularity optimization. This limit is used to keep from adjusting the tool axis vector when the rotary axes do not fluctuate greatly. This is typically set to a value of 10 degrees or more. This parameter is in radians and the default value is .175 (10 degrees).
tolerance	The tolerance value used to keep the tool within tolerance when the tool axis is adjusted to minimize rotary axis movement around the singularity. The default value is .04mm (.0015in).
linearizationTolerance	The tolerance value to use when additional points are added to keep the tool endpoint within tolerance of the programmed move when the tool axis is near the singularity. The default value is .04mm (.0015in).

The default settings are valid for most tool paths, but this command allows for some tweaking in special cases where you want to fine tune the output.

8.6 Rewinding of the Rotary Axes when Limits are Reached

The post processor kernel will select the starting angles of the rotary axes based on the best possible solution to avoid rewind situations when one of the rotary axes crosses its limits. This is accomplished by scanning the entire operation to see if a rewind of the rotary axes is required due to limit violations and if so adjusting the starting angles of the rotary axes to see if the rewind can be avoided. If a solution to avoid the rewind cannot be found, then the solution that produces the most rotary movement prior to requiring a rewind will be used.

The best possible solution for the rotary axes is always selected at the start of an operation and when a rewind is required due to a rotary axis crossing the limits, the tool will always stop on the exact limit of the machine, eliminating scenarios where a valid solution for the rewinding of the rotary axes could not always be found.

When a rewind is required there is a group of functions that can be added to the custom post processor to handle the actual rewinding of the affected rotary axis. This code can be easily copied into your custom post processor and modified to suit your needs with just a little bit of effort.

One setting that is very important when defining a rotary axis is the *cyclic* parameter in the call to *createAxis*. *cyclic* is considered synonymous with continuous, meaning that this axis has no limits and will not be considered when determining if the rotary axes have to be repositioned to stay within limits. The *range* specifier used in conjunction with a cyclic axis defines the output limits of a rotary axis, for example specifying a range of [0,360] will cause all output angles for this axis to be output between 0 and 360 degrees. The range for a non-cyclic axis defines the actual physical limits of that axis on the machine and are used to determine when a rewind is required. Please note that the physical limits of the machine may be a numeric limit of the control instead of a physical limit, such as 9999.9999.

Another important setting is the *reset* parameter, which allows you to define the starting angle at the start of an operation and after a rewind of the axes has occurred. By default, the post engine will use the ending angle of the previous multi-axis operation. Some controls allow for the rotary axis encoder to be reset so that the stored angle is reset to be within the 0-360 degrees without unwinding the axis. In this case you will want to issue the proper codes to reset the axis encoder, for example G28 C0, and specify *reset:3* when you create the axis.

Now on to how you can implement the automatic rewind capabilities in your post. The bulk of the feature is handled by the post processor kernel, but there are some variables and functions that are required in your post. The variables used for retract/reconfigure are either defined in the CAM Machine Definition settings or in the *defineMachine* function for hardcoded machine configurations.

```
  // retract / reconfigure
  var performRewinds = false; // set to true to enable the retract/reconfigure logic
  if (performRewinds) {
    machineConfiguration.enableMachineRewinds(); // enables the retract/reconfigure logic
    safeRetractDistance = (unit == IN) ? 1 : 25; // additional distance to retract out of stock
    safeRetractFeed = (unit == IN) ? 20 : 500; // retract feed rate
    safePlungeFeed = (unit == IN) ? 10 : 250; // plunge feed rate
    machineConfiguration.setSafeRetractDistance(safeRetractDistance);
    machineConfiguration.setSafeRetractFeedrate(safeRetractFeed);
    machineConfiguration.setSafePlungeFeedrate(safePlungeFeed);
    var stockExpansion = new Vector(toPreciseUnit(0.1, IN), toPreciseUnit(0.1, IN), toPreciseUnit(0.1, IN)); //
expand stock XYZ values
    machineConfiguration.setRewindStockExpansion(stockExpansion);
  }
```

Retract/Reconfigure Settings Defined in defineMachine

Variable	Description
performRewinds	When set to *false* an error will be generated when a rewind of a rotary axis is required. Setting it to *true* will enable the rewind logic..
safeRetractDistance	Defines the distance to be added to the retract position when the tool is positioned past the stock material to safely remove it from the stock. If it is set to 0, then the tool will retract to the outer stock plus the stock expansion.
safeRetractFeed	Specifies the feedrate to retract the tool prior to rewinding the rotary axis.
safePlungeFeed	Specifies the feedrate to plunge the tool back into the part after rewinding the rotary axis.
stockExpansion	The tool will retract past the defined stock by default. You can expand the defined stock on all sides by defining the *stockAllowance* vector, which contains the expansion value for X, Y, and Z.

Variables that Control Tool Retraction

You will need to copy the retract/reconfigure functions from a post that supports this logic into your post. These functions are defined in the following section of code and include the designated functions.

```
// Start of onRewindMachine logic
…
// End of onRewindMachine logic
```

Copy this Code into Your Post

Function	Arguments	Description
onRewindMachineEntry	(none)	This function is called at the start of the automatic rewind process and allows the user to override the default rewind logic. Returning *true* from this function will disable the rewind logic in the post engine, while *false* will continue with the rewind/reconfigure process.
onMoveToSafeRetractPosition	(none)	Moves the tool to a safe retract position after retracting the tool from the part.
onRotateAxes	x, y, z, a, b, c	Repositions the rotary axes to their new location as provided by *a,b,c* after the tool has been moved to its safe position.
onReturnFromSafeRetractPosition	x, y, z	Repositions the linear axes to the position of the tool when it was retracted from the part.

Automatic Rewind Entry Functions

The *onRewindMachineEntry* function is used to either override or supplement the standard rewind logic. It will simply return *false* when the standard rewind logic of retracting the tool, repositioning the rotary axes, and repositioning the tool is desired. Code can be added to this function for controls that just require the encoder to be reset or to output the new rotary axis position when the control will automatically track the tool with the rotary axis movement. The following example resets the C-axis encoder when it is currently at a multiple of 360 degrees and the B-axis does not change.

```
/** Allow user to override the onRewind logic. */
function onRewindMachineEntry(_a, _b, _c) {
  // reset the rotary encoder if supported to avoid large rewind
  if (false) { // disabled by default
    if ((abcFormat.getResultingValue(_c) == 0) && !abcFormat.areDifferent(getCurrentDirection().y,
_b)) {
      writeBlock(gAbsIncModal.format(91), gFormat.format(28), "C" + abcFormat.format(0));
      writeBlock(gAbsIncModal.format(90));
      return true;
    }
  }
  return false;
}
```

Sample Code to Reset Encoder Instead of Rewinding C-axis

Returning a value of *true* designates that the *onRewindMachineEntry* function performed all necessary actions to reposition the rotary axes and the retract/reposition/plunge sequence will not be performed. Returning *false* will process the retract/reposition/plunge sequence normally.

The *onMoveToSafeRetractPosition* function controls the move to a safe position after the tool is retracted from the part and before the rotary axes are repositioned. It will typically move to the home position in Z and optionally in X and Y using a G28 or G53 style block. You should find similar code to retract the tool when positioning the rotary axes for a 3+2 operation and in the *onClose* function, which positions the tool at the end of the program. You should use the same logic found in these areas for the *onMoveToSafeRetractPosition* function.

```
/** Retract to safe position before indexing rotaries. */
function onMoveToSafeRetractPosition() {
  writeRetract(Z); // retract to home position
  // cancel TCP so that tool doesn't follow rotaries
  if (currentSection.isMultiAxis() && operationSupportsTCP) {
    disableLengthCompensation(false);
  }

  if (false) { // enable to move to safe position in X & Y
    writeRetract(X, Y);
  }
}
```

Move to a Safe Position Prior to Repositioning Rotary Axes

The *onRotateAxes* function is used to position the rotary axes to their new position as calculated by the post engine. *_a, _b, _c* define the new rotary axis position. *_x, _y, _z* should be ignored and not used.

```
/** Rotate axes to new position above reentry position */
function onRotateAxes(_x, _y, _z, _a, _b, _c) {
  // position rotary axes
  xOutput.disable();
  yOutput.disable();
  zOutput.disable();
  invokeOnRapid5D(_x, _y, _z, _a, _b, _c);
  xOutput.enable();
  yOutput.enable();
  zOutput.enable();
}
```

Position the Rotary Axes

The *onReturnFromSafeRetractPosition* function controls the move back to the position of the tool at the original retract location past the stock. This function is called after the rotary axes are repositioned.

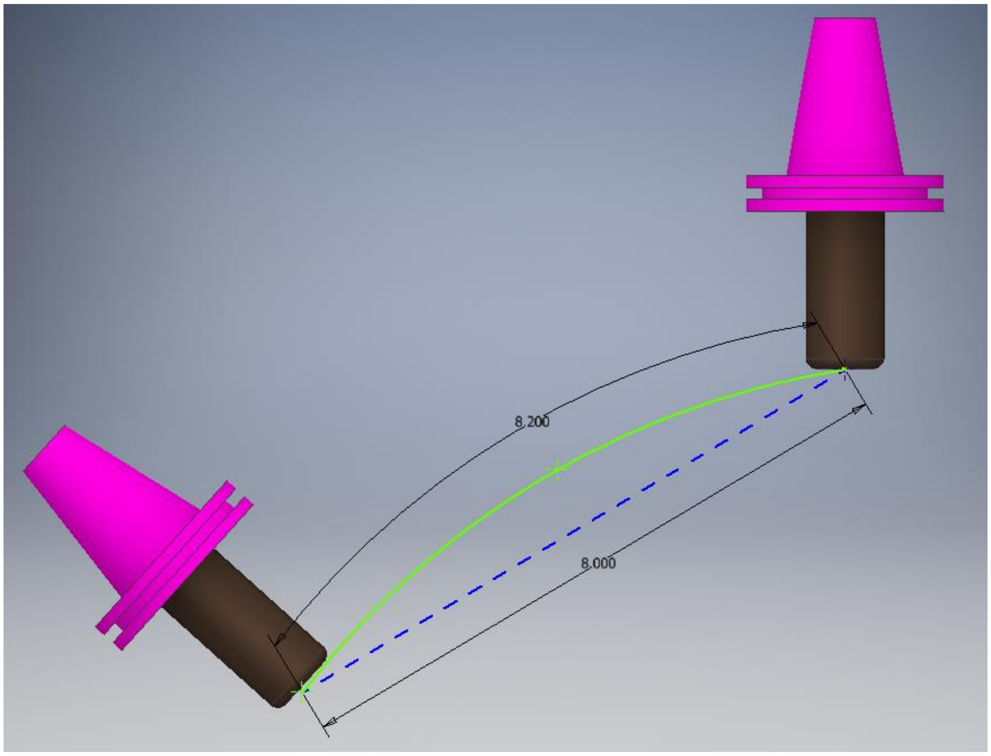
```
/** Return from safe position after indexing rotaries. */
function onReturnFromSafeRetractPosition(_x, _y, _z) {
  // reinstate TCP / tool length compensation
  if (!lengthCompensationActive) {
    writeBlock(gFormat.format(getOffsetCode()), hFormat.format(tool.lengthOffset));
    lengthCompensationActive = true;
  }

  // position in XY
  forceXYZ();
  xOutput.reset();
  yOutput.reset();
  zOutput.disable();
  invokeOnRapid(_x, _y, _z);

  // position in Z
  zOutput.enable();
  invokeOnRapid(_x, _y, _z);
}
```

Return from Safe Position after Repositioning Rotary Axes

8.7 Multi-Axis Feedrates

During multi-axis contouring moves, the machine control will typically expect the feedrate numbers to be either in Inverse Time or some form of Degrees Per Minute. Inverse Time feedrates are simply the inverse of the time that the move takes, i.e. *1 / movetime*. If your control supports both Inverse Time and Degrees Per Minute feedrates, it is recommended that you use Inverse Time as this is the most accurate. Please note that if your machine supports TCP (Tool Control Point) programming, then it probably supports direct Feed Per Minute (FPM) feedrates during multi-axis contouring moves and does not require either Inverse Time or DPM feedrates.

Multi-axis feedrate calculations are handled by the post engine and and will work with all machine configurations; table/table, head/head, and head/table. One capability of the multi-axis feedrate calculation is that it considers the actual tool tip movement in reference to the rotary axes movement and not just the straight-line movement along the programmed tool tip, creating more accurate multi-axis feedrates. In the following picture the move along the arc caused by the movement of the rotary axis (green arc) is used in the calculation instead of the straight-line move generated by HSM (blue line).



Actual Tool Path on Machine is Used in Feedrate Calculations

Multi-axis feedrate support is handled in the CAM Machine Definition or in the *defineMachine* function for a hardcoded machine configuration.

```
  // multi-axis feedrates
  if (machineConfiguration.isMultiAxisConfiguration()) {
    machineConfiguration.setMultiAxisFeedrate(
      useTCP ? FEED_PER_MINUTE : getProperty("useDPMFeeds") ? FEED_DEGREE_MINUTE :
FEED_INVERSE_TIME,
      9999.99, // maximum output value for inverse time feed rates
      getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES, //
INVERSE_MINUTES/INVERSE_SECONDS or DPM_COMBINATION/DPM_STANDARD
      0.5, // tolerance to determine when the DPM feed has changed
      1.0 // ratio of rotary accuracy to linear accuracy for DPM calculations
```

```
    );
  }
```

Enabling Multi-Axis Feedrates

Variable	Description
feedMode	FEED_INIVERSE_TIME (inverse time), FEED_DEGREE_MINUTE (degrees per minute), or FEED_PER_MINUTE (programmed feedrate).
maximumFeedrate	Defines the maximum value that can be output for both inverse time and degrees per minute feedrates.
feedType	Multi-axis feedrate options. For inverse time feedrates, the options are INVERSE_MINUTES or INVERSE_SECONDS, defining the units of time to use in inverse time feedrate calculations. For DPM feedrates, then the options are DPM_STANDARD for straight degrees per minute calculations or DPM_COMBINATION which uses a combination of degrees per minute and linear feed per minute (this is the most typical for machines that want a form of DPM feedrates).
outputTolerance	The tolerance for deciding whether to output a feedrate value or not. If the feedrate value is within this tolerance of the previous feedrate value, then it will be set to the previous value. This is used to minimize the output of multi-axis feedrate numbers.
bpwRatio	Defines the pulse weight ratio for the rotary axes when DPM feedrates are output as a combination of linear and rotary movements. The pulse weight is a scale factor based on the rotary axes accuracy compared to the linear axes accuracy. For example, it should be set to .1 when the linear axes are output on .0001 increments and the rotary axes on .001 increments.

setMultiAxisFeedrate Parameters

If Inverse Time feedrates are supported you will need to create the *inverseTimeOutput* variable at the top of the post processor code and if the accuracy of the Inverse Time feedrates is different than the standard FPM feedrate you will also need to create a new format to associate with it. The *gFeedModeModal* modal variable will also need to be defined for support of G93/G94 output if it does not already exist.

```
var gFeedModeModal = createOutputVariable({}, gFormat); // modal group 5 // G93-94
…
var inverseFormat = createFormat({type:FORMAT_REAL, decimals:4});
…
var inverseTimeOutput = createOutputVariable ({prefix:"F", control:CONTROL_FORCE},
   feedFormat);
…
```

Create *inverseTimeOutput* Variable

Now there are other areas of the post processor that need to be changed to support these feedrate modes. First, the *onLinear5D* function must have support added to receive and output the feedrate mode and to output the feedrate value using the correct format.

```
function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
  if (!currentSection.isOptimizedForMachine()) {
    error(localize("This post configuration has not been customized for 5-axis simultaneous
toolpath."));
    return;
  }
  // at least one axis is required
  if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation cannot be activated/deactivated for 5-axis move."));
    return;
  }
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var a = aOutput.format(_a);
  var b = bOutput.format(_b);
  var c = cOutput.format(_c);

  // get feedrate number
  var fMode = feedMode == FEED_INVERSE_TIME ? 93 : 94;
  var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) :
feedOutput.format(feed);

  if (x || y || z || a || b || c) {
    writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
  } else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
      feedOutput.reset(); // force feed on next line
    } else {
      writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), f);
    }
  }
}
```

***onLinear5D* Required Changes**

You will need to reset the feedrate mode to FPM either at the end of the multi-axis operation or on a standard 3-axis move. It is much easier to do this at the end of the section, otherwise you would have to modify all instances that output feedrates, such as in *onLinear*, *onCircular*, *onCycle*, etc.

```
function onSectionEnd() {
…
  if (currentSection.isMultiAxis()) {
    writeBlock(gFeedModeModal.format(94)); // inverse time feed off
  }
```

Reset FPM Mode in *onSectionEnd*

```
  writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(40), x, y, z,
f);
```
Optionally Reset FPM Mode in All Output Blocks with Feedrates

It is possible that your machine control does not support standard inverse time or DPM feedrates. If this is the case you will need to write your own function to handle multi-axis feedrates. The *getMultiAxisMoveLength* function will assist in the movement length calculations required for calculating multi-axis feedrates. It takes the current position for the linear and rotary axes and will calculate the tool tip, linear axes, and rotary axes lengths of the move from the previous location.

```
var length = machineConfiguration.getMultiAxisLength(x, y, z, a, b, c);
```
Calculate the Length of the Multi-Axis Move

getMultiAxisMoveLength will return *MoveLength* obect, which can then be accessed using the following functions to obtain the different move lengths.

Function	Description
getRadialToolTipMoveLength	Calculated tool endpoint movement along the actual tool path.
getLinearMoveLength	Combined linear delta movement.
getRadialMoveLength	Combined rotary delta movement.

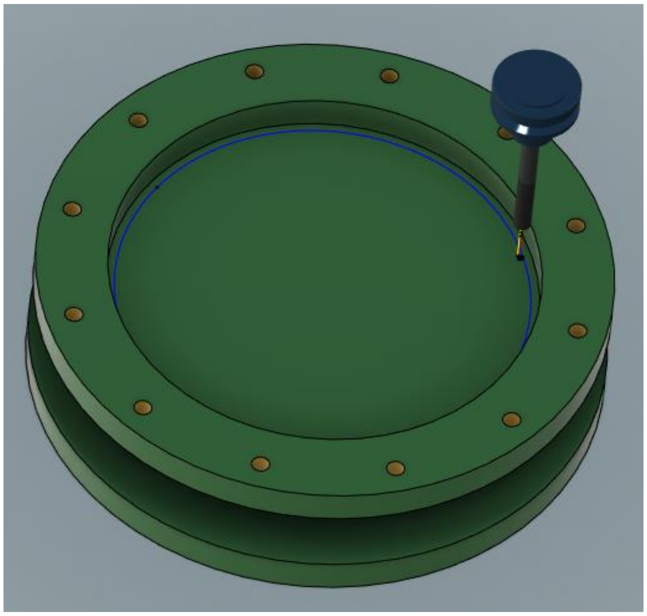
MoveLength Functions

```
  var moveLength = getMultiAxisMoveLength(x, y, z, a, b, c);
  var toolTipLength = moveLength.getRadialToolTipMoveLength();
  var xyzLength = moveLength.getLinearMoveLength();
  var abcLength = moveLength.getRadialMoveLength();
```
Retrieve the Calculated Move Lengths for the Tool Tip, Linear Axes, and Rotary Axes

8.8 Polar Interpolation

Polar interpolation replaces a linear axis in a 3-axis milling operation with a rotary axis. Polar interpolation can be used to keep machining operations within the limits of the machine or simplify the output of circular milling/drilling operations. It is sometimes referred to as XZC interpolation since it is quite common to replace the Y-axis with the C-axis.

It can be supported in the control, for example using G12.1 on Fanuc style controls or handled within the post processor. Machine control polar interpolation is typically supported on Mill/Turn machines.

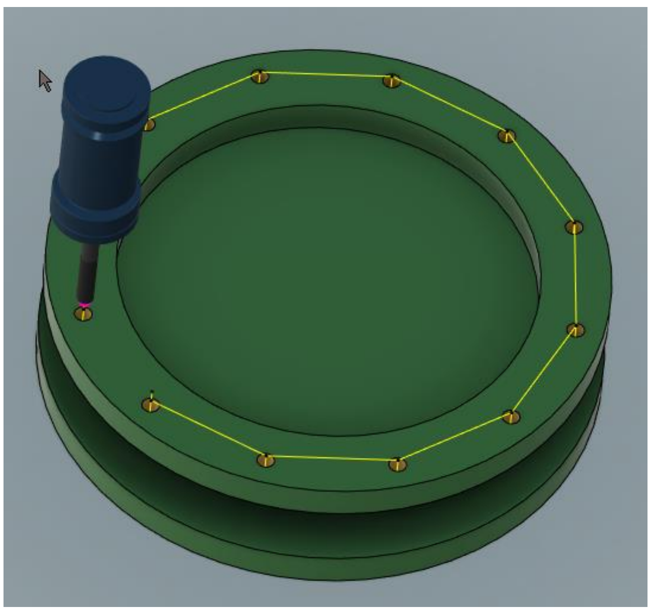


```
N55 G0 B0. C0.
N60 M10
N65 M12
N70 M8
N75 G1 X5.75 Y0. F650.
N80 G0 G43 Z4.6 H2
N85 G0 Z4.2
N90 G1 Z4.0394 F13.333
N95 Z3.
N100 G3 X-5.75 I-5.75 J0. F40.
N105 X5.75 I5.75 J0.
N110 G0 Z4.6
```

Without Polar Interpolation

```
N55 G0 B0. C0.
N60 M8
N65 G1 X5.75 Y0. F650.
N70 G0 G43 Z4.6 H2
N75 G0 Z4.2
N80 G1 Z4.0394 F13.333
N85 Z3.
N90 G93 C179. F2.227
N95 C358. F2.227
N100 C360. F199.29
N105 G0 Z4.6
N110 G94
```

With Polar Interpolation



```
N90 G98 G81 X-7.2 Y0. Z3. R4.2 F40.
N95 X-6.2354 Y3.6
N100 X-3.6 Y6.2354
N105 X0. Y7.2
N110 X3.6 Y6.2354
N115 X6.2354 Y3.6
N120 X7.2 Y0.
N125 X6.2354 Y-3.6
N130 X3.6 Y-6.2354
N135 X0. Y-7.2
N140 X-3.6 Y-6.2354
N145 X-6.2354 Y-3.6
N150 G80
```

Without Polar Interpolation

```
N80 G98 G81 X7.2 Y0. Z3. R4.2 F40.
N85 C150.
N90 C120.
N95 C90.
N100 C60.
N105 C30.
N110 C360.
N115 C330.
N120 C300.
N125 C270.
N130 C240.
N135 C210.
N140 G80
```

With Polar Interpolation

Sample Output Without and With Polar Interpolation

This section describes how to implement post processor generated polar interpolation support in your post and how to activate it using a Manual NC command. The *Haas Next Generation* post processor has polar interpolation implemented and can be used as a reference and to copy code from into your post.

8.8.1 Polar Interpolation Functions

The following functions are used with post generated polar interpolation. The *setPolarMode* and *setPolarFeedMode* functions are defined in the post processor, all other functions are embedded in the post processor kernel.

Function	Description
activatePolarMode(toler, angle, axis)	Activates polar interpolation. *tolerance* specifies the tolerance to use to keep the tool within the programmed tool path. It is typically set to be tighter than the post processor defined tolerance by a factor of 2 or 4 (tolerance / 2) to keep a smooth finish. *angle* defines the current angle of the rotary axis used in polar interpolation. *axis* defines the line that the tool can move along during polar interpolation. A vector of (1, 0, 0) keeps the tool along the X-axis.
deactivatePolarMode()	Disables polar interpolation.
getPolarPosition(x, y, z)	Returns the polar coordinates as a *VectorPair* for the input x,y,z coordinates. The first vector is the XYZ coordinates and the second vector is the ABC angles of the polar position.
isPolarModeActive()	Returns *true* if polar mode is in effect.
setCurrentPositionAndDirection(position)	Sets the current XYZ and ABC position. *position* is a *VectorPair* that contains the XYZ coordinates in the first vector and the ABC angles in the second vector.
setPolarFeedMode(mode)	Defines the feedrate mode for polar interpolation. This will usually be set to either Inverse Time or DPM feedrates depending on capabilities of the control. This multi-axis feedrate mode only needs to be changed for polar interpolation if the machine supports TCP and outputs FPM (programmed) feedrates with multi-axis moves. Polar interpolation is not output using TCP, so requires a different feedrate mode in this case. *mode* determines if polar interpolation is being activated (*true*) or deactivated (*false*). This function must be defined in the post processor.
setPolarMode(section, mode)	Enables/disables polar interpolation mode for the specified section. *section* should be set to *currentSection*. *mode* can be set to *true* to enable polar interpolation or *false* to disable it. This function must be defined in the post processor.

Polar Interpolation Functions

The required polar interpolation variables and functions can be copied from the *Haas Next Generation* post processor. These functions are bounded by the *Start of polar interpolation* and *End of polar interpolation* comments.

```
// Start of polar interpolation
…
// End of polar interpolation
```

Copy the Required Polar Interpolation Code

Most of this code will not require any modification. You may want to change the line/vector that polar interpolation will move along during generation of the polar coordinates. This is defined by the *polarDirection* variable at the top of the copied code. It is set to the X-axis (1, 0, 0) by default.

```
// Start of polar interpolation
var usePolarMode = false; // controlled by manual NC operation, enables polar interpolation for a single operation
var defaultPolarDirection = new Vector(1, 0, 0); // default direction for polar interpolation
var polarDirection = defaultPolarDirection; // vector to maintain tool at while in polar interpolation
```

Define the Axis Line for Polar Interpolation

You may have to modify the *setPolarFeedMode* to set the proper feedrate mode for polar interpolation. If your machine does not support TCP, then this function can be blank and the same feedrate mode for multi-axis and polar interpolation operations will be used.

```
function setPolarFeedMode(mode) {
  if (machineConfiguration.isMultiAxisConfiguration()) {
    machineConfiguration.setMultiAxisFeedrate(
      !mode ? multiAxisFeedrate.mode : getProperty("useDPMFeeds") ? FEED_DEGREE_MINUTE :
        FEED_INVERSE_TIME,
      multiAxisFeedrate.maximum,
      !mode ? multiAxisFeedrate.type : getProperty("useDPMFeeds") ? DPM_COMBINATION :
        INVERSE_MINUTES,
      multiAxisFeedrate.tolerance,
      multiAxisFeedrate.bpwRatio
    );
    if (!receivedMachineConfiguration) {
      setMachineConfiguration(machineConfiguration);
    }
  }
}
```

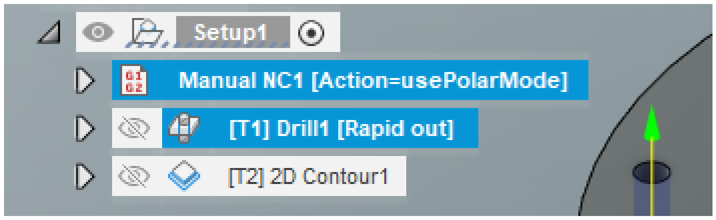
setPolarFeedMode to Use when TCP is Supported

```
function setPolarFeedMode(mode) {
}
```

setPolarFeedMode to Use when TCP is Not Supported

8.8.2 Manual NC Command to Enable Polar Interpolation

The Action Manual NC *usePolarMode* command is used to enable polar interpolation for a single operation and must be placed prior to this operation. Polar interpolation will be automatically cancelled after this operation, but since polar interpolation is handled in the post processor, you can make changes to make the command modal.



usePolarMode Manual NC Command

The *usePolarMode* Manual NC command is implemented in the *onManualNC* function.

```
function onManualNC(command, value) {
  switch (command) {
  case COMMAND_ACTION:
    if (String(value).toUpperCase() == "USEPOLARMODE") {
      usePolarMode = true;
    }
    break;
  default:
    expandManualNC(command, value);
  }
}
```

Implementing the usePolarMode Manual NC Command

8.8.3 Calculating the Polar Interpolation Initial Angle

The initial XYZ position and ABC angles for polar interpolation is calculated in the *defineWorkPlane* function.

```
function defineWorkPlane(_section, _setWorkPlane) {
  var abc = new Vector(0, 0, 0);
  if (machineConfiguration.isMultiAxisConfiguration()) { // use 5-axis indexing for multi-axis mode

    if (isPolarModeActive()) { // calculate the initial ABC position for polar interpolation
      abc = getCurrentDirection();
    } else {
      abc = _section.isMultiAxis() ? _section.getInitialToolAxisABC() :
          getWorkPlaneMachineABC(_section.workPlane, _setWorkPlane);
    }

    // polar interpolation is treated as a multi-axis operation
    if (_section.isMultiAxis() || isPolarModeActive()) {

      cancelTransformation();
      if (_setWorkPlane) {
        if (activeG254) {
          writeBlock(gFormat.format(255)); // cancel DWO
```

```
        activeG254 = false;
      }
      forceWorkPlane();
      positionABC(abc, true);
    }
  } else {
```

Calculating the Initial ABC Position for Polar Interpolation in defineWorkPlane

Polar interpolation converts a 3-axis operation to a multi-axis operation, so it must be treated as such. This means that the rotary axis must be unlocked prior to the initial positioning move, but not clamped afterwards. This is handled in the *setWorkPlane* function.

```
if (!currentSection.isMultiAxis() && !isPolarModeActive()) {
  onCommand(COMMAND_LOCK_MULTI_AXIS);
}
```

Don't Lock the Rotary Axis During Polar Interpolation in setWorkPlane

There could be code in the *onCommand* function for unlocking the rotary axis that may need to be changed also.

```
case COMMAND_UNLOCK_MULTI_AXIS:
  var outputClampCodes = getProperty("useClampCodes") || currentSection.isMultiAxis()
    || isPolarModeActive();
  if (outputClampCodes && machineConfiguration.isMultiAxisConfiguration() &&
     (machineConfiguration.getNumberOfAxes() >= 4)) {
```

Unlocking the Rotary Axis During Polar Interpolation in onCommand

8.8.4 Initializing Polar Interpolation

The following modifications to *onSection* must be made to support polar interpolation. First, you need to enable polar interpolation. This code is usually placed prior to the *defineWorkPlane* call.

```
  // Use new operation property for polar milling
if (currentSection.machiningType &&
    (currentSection.machiningType == MACHINING_TYPE_POLAR)) {
  usePolarMode = true;

  // Update polar coordinates direction according to operation property
  polarDirection = currentSection.polarDirection;
}
// enable polar interpolation
if (usePolarMode && (tool.type != TOOL_PROBE)) {
  if (polarDirection == undefined) {
    error(localize("Polar direction property must be a vector - x,y,z."));
    return;
```

```
  }
  setPolarMode(currentSection, true);
 }

 defineWorkPlane(currentSection, false);

 var initialPosition = isPolarModeActive() ? getCurrentPosition() :
  getFramePosition(currentSection.getInitialPosition());

 forceAny();
```

Enabling Polar Interpolation in onSection

8.8.5 Disabling Polar Interpolation

Polar interpolation is disabled after each operation in the *onSectionEnd* function when it is only active for a single operation.

```
function onSectionEnd() {
 …
 setPolarMode(currentSection, false);
}
```

Disabling Polar Interpolation in onSectionEnd

8.8.6 Enabling Polar Interpolation in Drilling Cycles

Polar interpolation is supported for both 3-axis milling operations and in drilling cycles. The milling operations will be converted to multi-axis operations once polar interpolation is activated, calling *onRapid5D* and *onLinear5D* linear motion. No modifications to these functions need to be made to support polar interpolation.

Drilling cycle locations will still call *onCyclePoint* during polar interpolation, so modifications must be made to output the rotary axis with the cycle positions. This is done by making the following modification to the *getCommonCycle* function for the first point of a cycle operation.

```
function getCommonCycle(x, y, z, r, c) {
 forceXYZ();

 if (isPolarModeActive()) { // format polar interpolation position
  var polarPosition = getPolarPosition(x, y, z);
  return [xOutput.format(polarPosition.first.x), yOutput.format(polarPosition.first.y),
   zOutput.format(polarPosition.first.z),
   aOutput.format(polarPosition.second.x),
   bOutput.format(polarPosition.second.y),
   cOutput.format(polarPosition.second.z),
   “R” + xyzFormat.format®];
```

```
  } else { // format linear interpolation position

    if (incrementalMode) {
      zOutput.format(c);
      return [xOutput.format(x), yOutput.format(y),
        "Z" + xyzFormat.format(z - r),
        "R" + xyzFormat.format(r - c)];
    } else {
      return [xOutput.format(x), yOutput.format(y),
        zOutput.format(z),
        "R" + xyzFormat.format(r)];
    }
  }
}
```

Formatting the Polar Interpolation Cycle Position in getCommonCycle

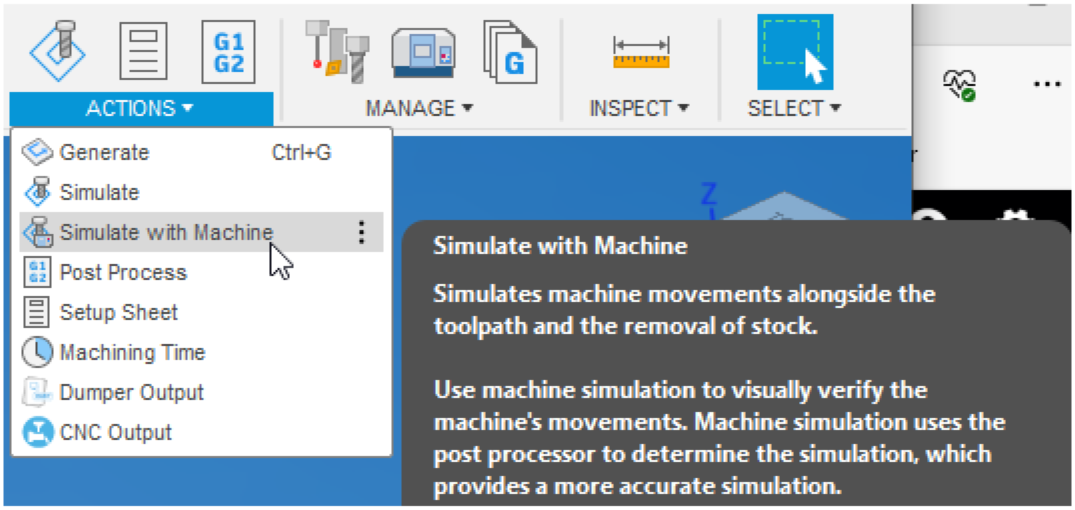
In the *onCyclePoint* function you need to format the cycle location for polar interpolation for the 2nd through final cycle point.

```
// 2nd through nth cycle point
  } else {
    if (cycleExpanded) {
      expandCyclePoint(x, y, z);
    } else {

      if (isPolarModeActive()) { // format polar interpolation position
        var polarPosition = getPolarPosition(x, y, z);
        writeBlock(xOutput.format(polarPosition.first.x), yOutput.format(polarPosition.first.y),
          zOutput.format(polarPosition.first.z),
          aOutput.format(polarPosition.second.x), bOutput.format(polarPosition.second.y),
          cOutput.format(polarPosition.second.z));
        return;
      }
```

Formatting the Polar Interpolation Cycle Position in onCyclePoint

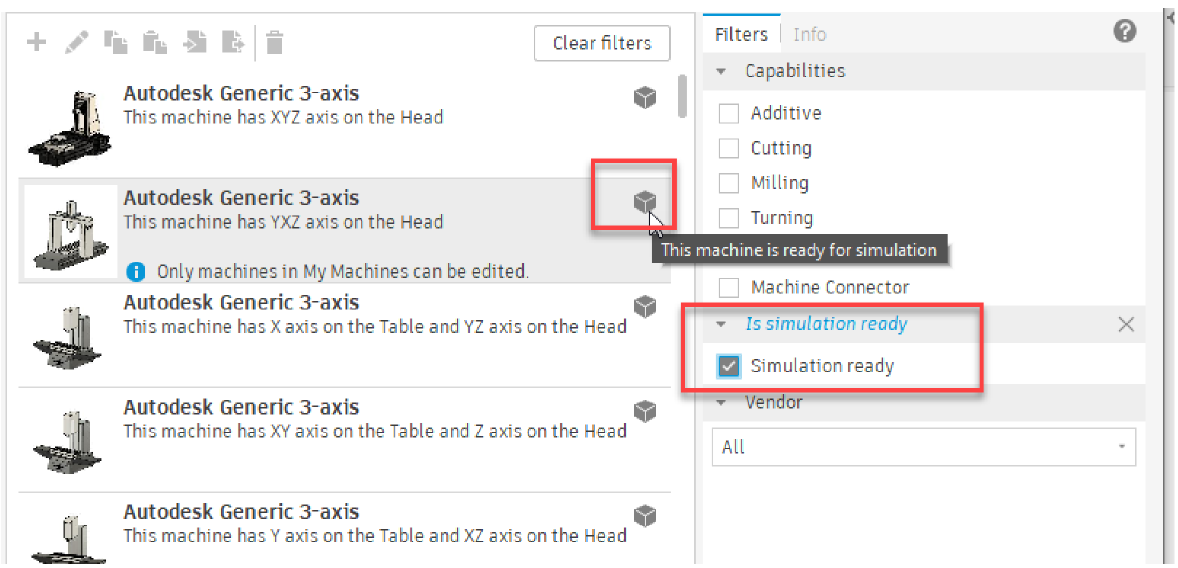
9 Support for Machine Simulation

Fusion can simulate the movements of a machine when replaying an operation using the Simulate with Machine process when a Machine Definition is attached to the CAM Setup and it contains a model of the machine.



Simulating Machine Movements During Playback

Most Machine Definitions available in the Machine Library have associated CAD models of the machine that can be used for machine simulation. Checking the *Simulation ready* box in the *Filters* tab will display all machines that have a machine model and can be used for simulation. These will be shown in the Machine Definition list with a 3D cube next to their name.



Machine Definition with a Machine Model Suitable for Simulation

9.1 Post Processor Support for Machine Simulation

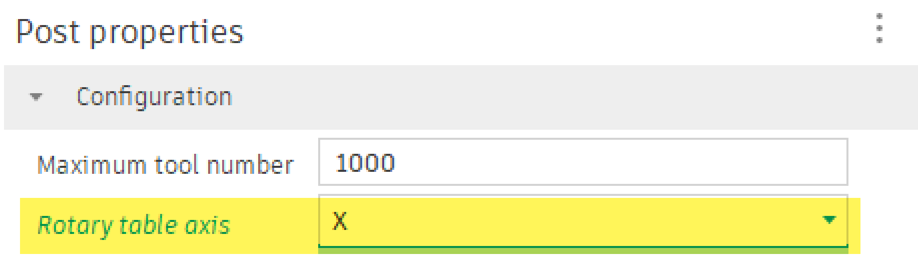
Post processors that support machine simulation will have CAPABILITY_MACHINE_SIMULATION defined as one of their capabilities.

```
capabilities = CAPABILITY_MILLING | CAPABILITY_MACHINE_SIMULATION;
```

Specifying Machine Simulation Capabilities in the Post

The post will also have the *activateMachine* function present. One thing to note is that the post processor cannot make changes to the machine configuration when machine simulation is supported. This means that no calls to the *machineConfiguration.set*--- functions can be made nor can *setMachineConfiguration* be called.

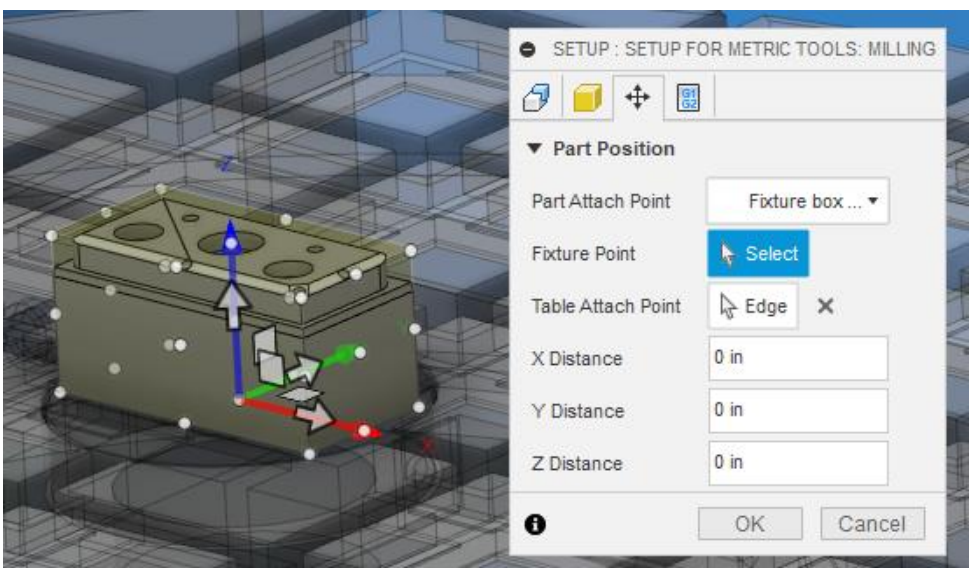
There are some posts that can enable rotary axes using a post property. You cannot use this property to define the rotary axes if you wish to use machine simulation, the rotary axes must be defined in the external Machine Definition.



Using a Property to Define the Rotary Axis is not Allowed for Machine Simulation

9.2 Placing the Part onto the Machine

Once you have a Machine Definition with a machine model assigned to the Setup you will need to place the part on the machine. This is handled in the tab of the Setup dialog box. You will need to select the Part Attach Point and the Table Attach Point. Optionally, you can shift the part by distances in the X, Y, and Z directions.



Placing the Part onto the Machine

9.3 Obtaining the Part/Machine Attach Points

```
var partAttachPoint = section.getPartAttachPoint();
```

```
var tableAttachPoint = machineConfiguration.getTableAttachPoint();
var headAttachPoint = machineConfiguration.getHeadAttachPoint();
```

Obtaining the Part/Machine Attach Points

The *getPartAttachPoint* function returns the location on the part where it is attached to the machine model. This location will be in reference to the Work Coordinate System (WCS) Origin as defined in the CAM Setup.

The *getTableAttachPoint*() function returns the location on the machine where the part is attached. This is the same location as the part attach point except that it is in the Machine Coordinate System (MCS) in relation to where the machine origin is defined in the machine model.

The *getHeadAttachPoint*() function returns the location on the machine where the tool is attached to the spindle in the Machine Coordinate System (MCS).

Using these functions, you can calculate the position in the Machine Coordinate System from a position in the Work Coordinate System and vice versa as long as the origin position (0, 0, 0) of the machine is defined correctly in the machine model. You will need to ensure that the WCS position is relative to the CAM Setup System and not a Tilted Work Plane system.

```
// convert coordinates from the tilted work plane system to the setup system
var tcpPosition = section.workPlane.multiply(twpPosition);
```

Calculate the TCP Position from a Tilted Work Plane Position

```
function toMCSPosition(wcsPosition) {
  var partAttachPoint = currentSection.getPartAttachPoint();
  var tableAttachPoint = machineConfiguration.getTableAttachPoint();
  var mcsPosition = Vector.sum(tableAttachPoint, Vector.diff(wcsPosition, partAttachPoint));
  return mcsPosition;
}
```

Convert from the Work Coordinate System to the Machine Coordinate System

```
function toWCSPosition(mcsPosition) {
  var partAttachPoint = currentSection.getPartAttachPoint();
  var tableAttachPoint = machineConfiguration.getTableAttachPoint();
  var wcsPosition = Vector.sum(partAttachPoint, Vector.diff(mcsPosition, tableAttachPoint));
  return wcsPosition;
}
```

Convert from the Machine Coordinate System to the Work Coordinate System

9.4 Simulating Post Processor Connection Moves

The machine movement seen in machine simulation is mostly handled by the post engine. These include all movements generated during an operation and shown in Fusion. This motion generates calls to the motion functions in the post processor.

- onLinear
- onRapid
- onLinear5D
- onRapid5D
- onCircular
- onCyclePoint

There can be machine movement generated by the post processor, such as retracting the tool, moving to the machine's home position, tool changes, etc. that is not simulated during machine simulation. Post processor generated moves can be viewed during machine simulation by using calls to the *machineSimulation* function.

You will need to include the machine simulation connection moves logic in your post if it is not already there. You can copy the machineSimulation function from the *RS-74 Sample Multi-axis Post Processor*.

9.4.1 The machineSimulation Function

```
function machineSimulation(parameters) {
```

The *machineSimulation* function is used to generate movement only during machine simulation for machine movements that are not generated by the post engine. These movements are usually generated at the start of an operation or during a retract/reconfiguration operation.

The *parameters* argument is passed to the *machineSimulation* function as a list of specifiers in the following format.

```
machineSimulation({specifier:value, specifier:value, …});
```

machineSimulation Syntax

The specifiers must be enclosed in braces ({}) and contain the specifier name following by a colon (:) and then by a value. Multiple specifiers are separated by commas.

Specifier	Value
x	X-axis position of move.
y	Y-axis position of move.
z	Z-axis position of move.
a	A-axis position in radians.
b	B-axis position in radians.
c	C-axis position in radians.

Specifier	Value
feed	The feedrate of the move. If *feed* is not specified, then the move is made at the high feedrate.
mode	Supported modes are: TCPON, TCPOFF, TWPON, TWPOFF, TOOLCHANGE, RETRACTTOOLAXIS **The TCP/TWP modes are optional and should not be used unless necessary, as the modes are automatically updated with the embedded TCP/TWP states.** TOOLCHANGE performs the tool change in simulation. RETRACTTOOLAXIS moves the machine simulation to its limits along the current tool axis.
coordinates	The type of coordinates that the linear axes are specified as. WORK specifies the axes are in the part system and MACHINE specifies the axes are in the machine system. If *coordinates* is not specified, WORK coordinates will be used by default.
eulerAngles	Euler angles that are used to override the current tool orientation. If this parameter is not specified, then the active WCS plane is used.

machineSimulation Specifiers

The linear axes values can be a number, MIN (moves to the minimum axis limit), or MAX (moves to the maximum axis limit). MIN and MAX are typically only used for coordinates in the machine system. The *machineSimulation* function will only move the axes that are passed to the function, for example, if only *x* and *y* are passed, the machine will not move in the Z-axis.

```
// Position the rotary axes during machine simulation
machineSimulation({a:_a, b:_b, c:_c, coordinates:MACHINE});

// Position in X & Y in the current WCS mode
machineSimulation({x:_x, y:_y});

// Execute a tool change
machineSimulation({mode:TOOLCHANGE});
```

Example machineSimulation Commands

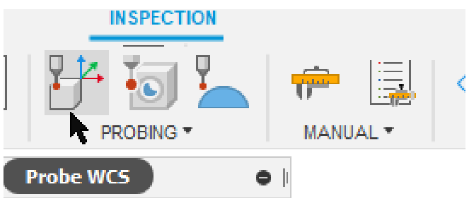
10 Adding Support for Probing

Settings used in Probing	Description
probing	Probing support.

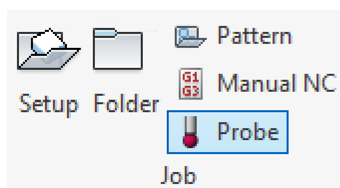
Fusion, Inventor CAM, and HSM have support for multiple styles of probing operations, including WCS Probing, Geometry Probing, and Surface Inspection. While the probing capabilities are supported by many of the library post processors, they are not supported by all of them, and custom post processors may not have these capabilities. This chapter discusses the required changes to a post processor to support the probing operations.

10.1 WCS Probing

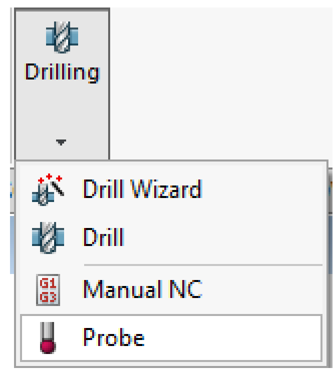
WCS Probing is defined as probing operations that are used to probe the part for the purpose of defining a Work Coordinate System. While all Autodesk CAM products support WCS Probing, you will find these operations in a different area of the interface for each of the products.



Fusion



Inventor CAM



HSMWorks

You can check the post processor you are working with to see if it supports WCS Probing. The easiest method is to try to run a probing operation against the post, the post will fail if probing is not supported. You may see an error message complaining about the spindle speed being out of range (probe operations do not turn on the spindle) or a message that states that the probing cycle must be handled in the post processor.

```
##########################################################################################
Error: Spindle speed out of range.
Error at line: 735
Error in operation: 'WCS Probe1'
Failed while processing onSection() for record 261.
##########################################################################################
```

Spindle Speed Error Message

```
##########################################################################################
Error: The probe cycle 'probing-xy-outer-corner' is machine specific and must always be handled in the post configuration.
```

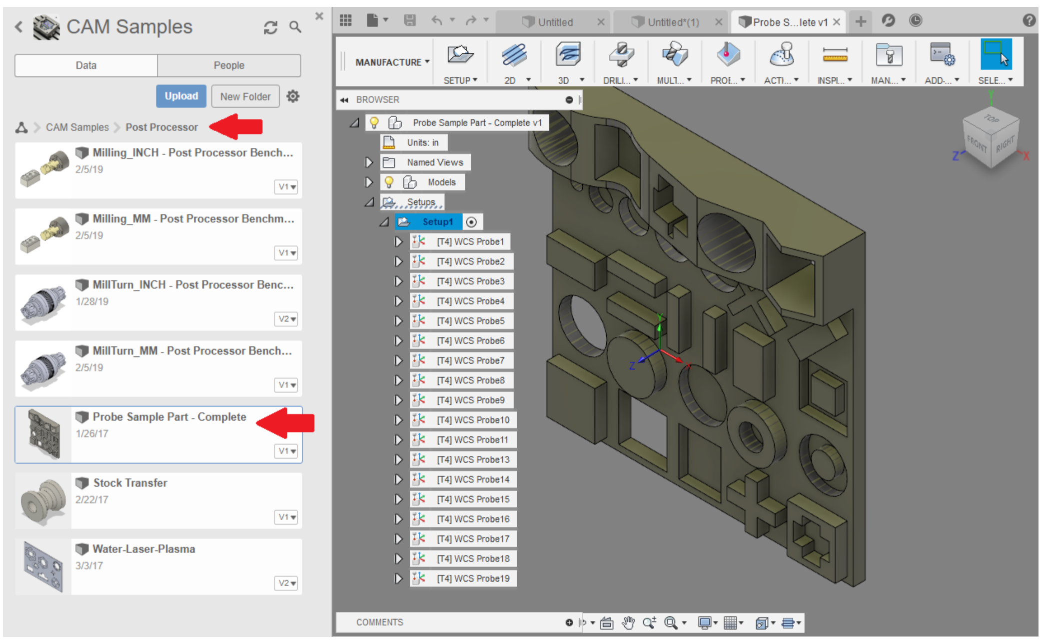
```
Error in operation: 'WCS Probe1'
Failed while processing onCycle() for record 280.
#########################################################################################
```

Machine Specific Error Message

If you receive either of these messages, then probing is not supported in your post processor, and you will need to add it.

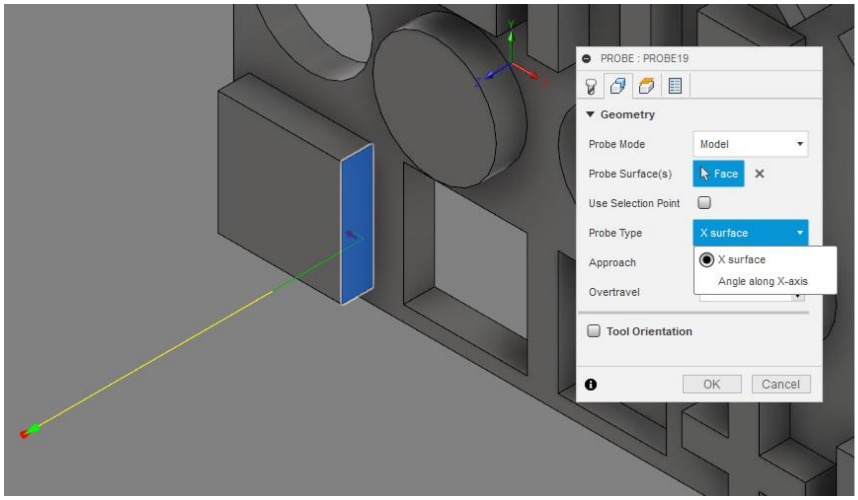
10.1.1 Probing Operations

There is a sample model available for testing the probing logic in a post processor. In Fusion it is contained int the CAM Samples/Post Processor folder. This model contains a part designed for testing probing cycles using the available WCS Probing operations.



Sample Probing Part

One thing you will notice when creating a probing operation is that interface is intelligent enough to only give you the probing operation types that apply to the type of geometry selected. For example, if you select a planar face perpendicular to the X-axis, then the only operations available to you are the *X surface* and *Angle along X-axis* operations.



Intelligent Probe Selection

The WCS Probing operations are considered a canned cycle in the post processor and are output in the *writeProbeCycle* function, with the probe type being stored in the *cycleType* variable. The following table lists the available probing operations. You should note that probing cycles cannot be expanded and must be handled in the post processor, either by performing the cycle, by giving an error, or by expanding the cycle in the post processor.

cycleType	Description
probing-x	Probes a wall perpendicular to the X-axis.
probing-y	Probes a wall perpendicular to the Y-axis.
probing-z	Probes a wall perpendicular to the Z-axis.
probing-x-wall	Probes a wall thickness in the X-axis
probing-y-wall	Probes a wall thickness in the Y-axis
probing-x-channel	Probes the open distance between two walls in the X-axis
probing-y-channel	Probes the open distance between two walls in the Y-axis
probing-x-channel-with-island	Probes the open distance between two walls with an island between the walls in the X-axis
probing-y-channel-with-island	Probes the open distance between two walls with an island between the walls in the Y-axis
probing-xy-circular-boss	Probes the outer wall of a circular boss
probing-xy-circular-partial-boss	Probes the outer wall of a circular boss that is not a complete 360 degrees
probing-xy-circular-hole	Probes the inner wall of a circular hole
probing-xy-circular-partial hole	Probes the inner wall of a circular hole that is not a complete 360 degrees
probing-xy-circular-hole-with-island	Probes the inner wall of a circular hole with an island in the hole
probing-xy-rectangular-boss	Probes the outer walls of a rectangular protrusion
probing-xy-rectangular-hole	Probes the inner walls of a rectangular hole

cycleType	Description
probing-xy-rectangular-hole-with-island	Probes the inner walls of a rectangular hole with an island in the hole
probing-xy-inner-corner	Probes an inner corner. Modifies the origin and rotation of the part.
probing-xy-outer-corner	Probes an outer corner. Modifies the origin and rotation of the part.
probing-x-plane-angle	Probes a wall at an angle to the X-axis. Modifies the rotation of the part.
probing-y-plane-angle	Probes a wall at an angle to the Y-axis. Modifies the rotation of the part.

Probing Cycles

The parameters defined in the WCS Probing operation are passed to the cycle functions using the *cycle* object. The following variables are available and are referenced as 'cycle.*parameter*'.

Parameter	Description
angleAskewAction	This parameter will only be defined with an angular probing cycle when the *Askew* box is checked. The only valid setting when it is defined is the string *stop-message*.
approach1	The direction the probe moves at it approaches the part. It is a string variable and can be either *positive* or *negative*.
approach2	The direction the probe moves as it approaches the part for the second face of a multi-face operation. It is a string variable and can be either *positive* or *negative*.
bottom	The final depth position along the probe axis to touch the part.
bottomPosition	XYZ coordinates of the final depth position along the probe axis.
clearance	The height the probe rapids to on its way to the start of the probing operation and the position it returns to after the probing operation is finished.
clearancePosition	XYZ coordinates of the probe clearance position.
depth	The unsigned incremental distance from the top of the part along the probe axis where the probe will touch the part.
feedrate	The feedrate the probe will approach the part at.
hasAngleTolerance	Set to 1 if an angular tolerance is specified. The angular tolerance is stored in the *toleranceAngle* parameter.
hasPositionalTolerance	Set to 1 if a positional tolerance is specified. The positional tolerance is stored in the *tolerancePosition* parameter.
hasSizeTolerance	Set to 1 if a size tolerance is specified. The size tolerance is stored in the *toleranceSize* parameter.
incrementComponent	Set to 1 if the *Increment Component* box is checked under *Print Results*.
outOfPositionAction	This parameter will only be defined when the *Out of Position* box is checked. The only valid setting when it is defined is the string *stop-message*.

Parameter	Description
printResults	Set to 1 when the *Print Results* box is checked in the probing operation.
probeClearance	The approach distance in the direction of the probing operation. The probe will be positioned at this clearance distance prior to approaching the part.
probeOvertravel	The maximum distance the probe can move beyond the expected contact point and still record a measurement.
probeSpacing	The probe spacing between points on the selected face for Angle style probing.
retract	The height to feed from to the probing level and to retract the probe to after probing is finished.
retractPosition	XYZ coordinates of the probe retract position.
stock	The top of the part.
stockPosition	XYZ coordinates of the probing position at the top of the part.
toleranceAngle	The acceptable angular deviation of the geometric feature.
tolerancePosition	The acceptable positional deviation of the geometric feature.
toleranceSize	The acceptable size deviation of the geometric feature.
width1	The width of the boss or hole being probed.
width2	The width of the secondary walls (Y-axis) of a rectangular boss or hole being probed.
wrongSizeAction	This parameter will only be defined when probing a feature that defines a fixed size and the *Wrong Size* box is checked. The only valid setting when it is defined is the string *stop-message*.

Probing Parameters

10.1.2 Adding the Core Probing Logic

Adding WCS Probing support requires the main logic to output the probing cycle, supporting functions, and some logic added to the main sections of the post processor. You should first open a post processor that contains support for probing before starting to add probing to your post processor, since the logic and most of the code will remain the same. Most of the generic post processors use Renishaw style probing Macros (Fanuc, Haas, etc.), but there are also controls that support probing without the use of these Macros, such as the Datron, Heidenhain, and Siemens controls. Be sure to start with closest match to the machine you are creating a post processor for. The examples used in this chapter use the code for the Renishaw style probing Macros.

To add the core probing logic, you will need to copy it from a post that uses the same or similar probing macros to your post. The core probing functions are found in files that have been included into the main post and are marked as follows.

```
// >>>>> INCLUDED FROM include_files/probeCycles_renishaw.cpi…
…
(included file)
```

```
….
// <<<<< INCLUDED FROM include_files/probeCycles_renishaw.cpi
```

Required Angular and Safe Positioning Probe Functions

You need to copy the entire contents of the following include files to your post so that it includes the core probing functions. Some of the name suffixes will differ based on the post you are using to copy the code from.

Include File	Contents
probeCycles_renishaw	The *writeProbeCycle* function.
commonInspectionFunctions_fanuc	Functions for writing the probing results.
getProbingArguments_renishaw	The *getProbingArguments* function.
protectedProbeMove_renishaw	The *protectedProbeMove* function.
setProbeAngle_fanuc	The *setProbeAngle* function.
setProbeAngleMethod	The *setProbeAngleMethod* function.

Include Files Containing the Probing Functions

The controlling function for probing is *writeProbeCycle*. It is similar to the *writeDrillCycle* function in that it contains cases for the supported probing cycles. If you need to remove or add support for a probing cycle, it will be done in the *writeProbeCycle* function. All probing operations are considered a separate operation and are not modal.

```
function writeProbeCycle(cycle, x, y, z)
…
  switch (cycleType) {
  case "probing-x":
    protectedProbeMove(cycle, x, y, z - cycle.depth);
    writeBlock(
      macroCall, "P" + 9811,
      "X" + xyzFormat.format(x + approach(cycle.approach1) * (cycle.probeClearance + tool.diameter / 2)),
      "Q" + xyzFormat.format(cycle.probeOvertravel),
      getProbingArguments(cycle, true)
    );
    break;
  case "probing-y":
    protectedProbeMove(cycle, x, y, z - cycle.depth);
    writeBlock(
      macroCall, "P" + 9811,
      "Y" + xyzFormat.format(y + approach(cycle.approach1) * (cycle.probeClearance + tool.diameter / 2)),
      "Q" + xyzFormat.format(cycle.probeOvertravel),
      getProbingArguments(cycle, true)
    );
    break;
```

writeProbeCycle is the Controlling Function for Probing Cycles

Below is a list of the common probing functions

Function	Description
approach	Determines the approach direction of the probe to the part.
inspectionCreateResultsHeader	Writes out the probing results header.
inspectionWriteCADTransform	Writes out the model transformation plane.
inspectionWriteWorkplaneTransform	Writes out the CAM setup transformation plane.
getProbingArguments	Returns the common codes output in the different probing cycles.
protectedProbeMove	Outputs a probe-safe positioning move.
setProbeAngle	Outputs the rotation block when for an angle probing operation. The rotation block will be output at the start of the operation following the probing operation.
setProbeAngleMethod	Determines the method to use for the angle probing rotation block.
writeProbingToolpathInformation	Prints out the depth of the probing cycle.

Common Probing Cycles

10.1.3 Adding the Supporting Probing Logic

There are various locations that contain support logic for probing operations in the post processor. Some of this code may already be in your post processor. The format used for the Probe WCS code needs to be added at the top of the post where other formats are defined, if it is not already present in the post processor.

The following properties may need to be added.

```
properties = {
…
  useG54x4: {
    title      : "Use G54.4",
    description: "Fanuc 30i supports G54.4 for workpiece error compensation.",
    group      : "probing",
    type       : "boolean",
    value      : false,
    scope      : "post"
  },
  singleResultsFile: {
    title      : "Create single results file",
    description: "Set to false if you want to store the measurement results for each probe / inspection toolpath in a separate file",
    group      : "probing",
    type       : "boolean",
    value      : true,
    scope      : "post"
  }
```

Probing Properties

```
var probeWCSFormat = createFormat({type:FORMAT_REAL, decimals:0});
var probeExtWCSFormat = createFormat({prefix:"S", type:FORMAT_REAL, decimals:0,
  offset:100});
```

Required for Formatting the Probe WCS Code

The following code needs to be added to the *onSection* function.

```
  setProbeAngle(); // output probe angle rotations if required

  setCoolant(tool.coolant); // writes the required coolant codes
```

Set Rotation Based on Angular Probing Results

```
  if (isProbeOperation()) {
    validate(probeVariables.probeAngleMethod != "G68",
      "You cannot probe while G68 Rotation is in effect.");
    validate(probeVariables.probeAngleMethod != "G54.4",
      "You cannot probe while workpiece setting error compensation G54.4 is enabled.");
    writeBlock(settings.probing.macroCall, "P" + 9832); // spin the probe on
    inspectionCreateResultsFileHeader();
  }

  if (subprogramsAreSupported()) {
    subprogramDefine(initialPosition, abc); // define subprogram
  }
}
```

Add at the end of the onSection Function

Make sure that the *onCyclePoint* function supports probing cycles.

```
function onCyclePoint(x, y, z) {
  if (isInspectionOperation()) {
    if (typeof inspectionCycleInspect == "function") {
      inspectionCycleInspect(cycle, x, y, z);
      return;
    } else {
      cycleNotSupported();
    }
  } else if (isProbeOperation()) {
    writeProbeCycle(cycle, x, y, z);
  } else {
    writeDrillCycle(cycle, x, y, z);
  }
}
```

Call the writeProbeCycle Funcion

Add the following code to *onCycleEnd* if it is not already present.

```
function onCycleEnd() {
  if (isProbeOperation()) {
    zOutput.reset();
    gMotionModal.reset();
    // protected retract move
    writeBlock(settings.probing.macroCall, "P" + 9810, zOutput.format(cycle.retract));
  } else {
```

Retract Probe

The probe should be turned off and angular probing codes output in the *onSectionEnd* function.

```
function onSectionEnd() {
…
  if (isProbeOperation()) {
    writeBlock(gFormat.format(65), "P" + 9833); // spin the probe off
    if (probeVariables.probeAngleMethod != "G68") {
      setProbeAngle(); // output probe angle rotations if required
    }
  }
}
```

Spin the Probe Down

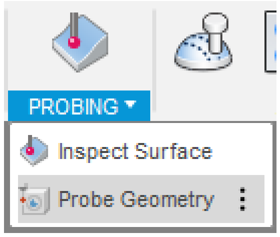
Finalize the probing results and cancel the angular probing rotation in *onClose*.

```
function onClose() {
  optionalSection = false;
  if (isDPRNTopen) {
    writeln("DPRNT[END]");
    writeBlock("PCLOS");
    isDPRNTopen = false;
  }
  if (probeVariables.probeAngleMethod == "G68") {
    cancelWCSRotation();
  }
```

Finalize Probing Results and Cancel the Angular Probing Rotation

10.2 Geometry Probing

Geometry Probing behaves similarly to WCS Probing. It is used to measure geometric features on the part during machining. The measured geometric features are checked against specified tolerances for size and position. Based on the result, you can update the tool wear, or instruct the machine to stop machining if the feature is out of tolerance. Geometry Probing is initiated using the *Probe Geometry* operation listed in the PROBING menu.

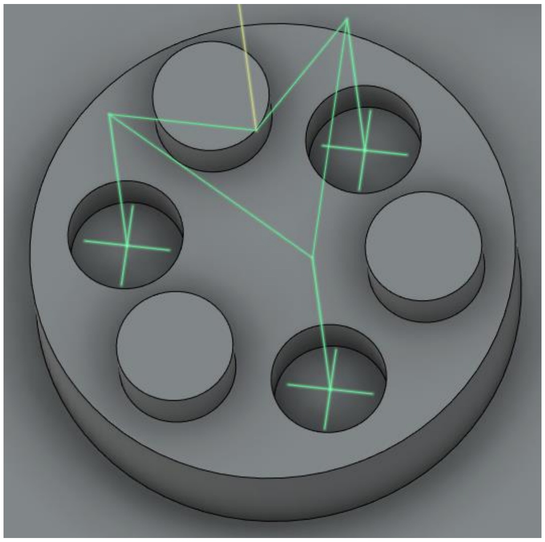


Geometry Probing Operation

The Pitch Circle Diameter (PCD) probing cycles are an addition to Geometry Probing that do not exist in WCS Probing. Like all other probing cycles, the PCD cycle types are stored in the *cycleType* variable.

cycleType	Description
probing-xy-pcd-hole	Probes holes around a PCD.
probing-xy-pcd-boss	Probes bosses around a PCD.

Pitch Circle Diameter (PCD) Probing Cycles



PCD Probing Geometry

Like in WCS Probing, the parameters defined in the Geometry Probing operation are passed to the cycle functions using the *cycle* object. These are in addition to the parameters defined for WCS Probing, which are also available in Geometry Probing. The following variables are available and are referenced as 'cycle.*parameter'*.

Parameter	Description
numberOfSubfeatures	Number of geometric entities in a PCD probing operation.
pcdStartingAngle	The starting angle of the first geometric entity to be probed in a PCD probing operation.
toolDiameterOffset	Defines the tool diameter offset register used to machine the feature.
toolLengthOffset	Defines the tool length offset register used to machine the feature.

Parameter	Description
toolWearErrorCorrection	The percentage of the deviation to update the tool wear by.
toolWearUpdateThreshold	The minimum deviation that will trigger a tool wear update.
updateToolWear	Enabled when tool wear compensation should be activated on the controller.
widthFeature	The diameter of the geometric feature for a PCD probing operation.
widthPCD	The pitch circle diameter (PCD) of the geometric features.

Geometry Probing Parameters

To add Geometry Probing to your post you will first need to implement WCS Probing. After this there are only minor changes required to support Geometry Probing.

The *probeMultipleFeatures* variable instructs the post engine that multiple geometric entities can be probed in a single operation. The probing logic in all posts now support this feature, so it should be set to *true*. It should be defined with the other post engine variables (*allowedCircularPlanes*, *highFeedrate*, etc.).

```
highFeedrate = (unit == IN) ? 500 : 5000;
probeMultipleFeatures = true;
```

Enable the Probing of Multiple Geometric Entities

If the control supports PCD probing cycles be sure to include cases for these cycles in *onCyclePoint*, where the other probing cycle code is located.

```
  case "probing-xy-pcd-hole":
    protectedProbeMove(cycle, x, y, z);
    writeBlock(
      gFormat.format(65), "P" + 9819,
      "A" + xyzFormat.format(cycle.pcdStartingAngle),
      "B" + xyzFormat.format(cycle.numberOfSubfeatures),
      "C" + xyzFormat.format(cycle.widthPCD),
      "D" + xyzFormat.format(cycle.widthFeature),
      "K" + xyzFormat.format(z - cycle.depth),
      "Q" + xyzFormat.format(cycle.probeOvertravel),
      getProbingArguments(cycle, false)
    );
    if (cycle.updateToolWear) {
      error(localize("Action -Update Tool Wear- is not supported with this cycle."));
      return;
    }
    break;
  case "probing-xy-pcd-boss":
    protectedProbeMove(cycle, x, y, z);
    writeBlock(
      gFormat.format(65), "P" + 9819,
      "A" + xyzFormat.format(cycle.pcdStartingAngle),
```

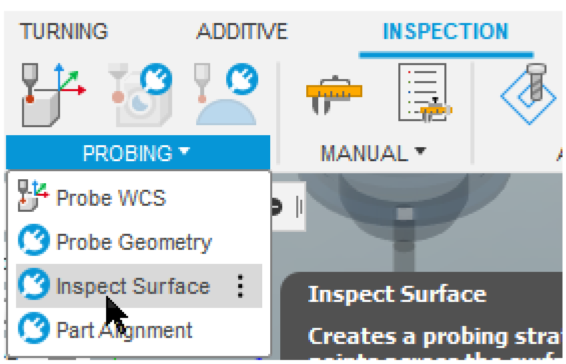
```
    "B" + xyzFormat.format(cycle.numberOfSubfeatures),
    "C" + xyzFormat.format(cycle.widthPCD),
    "D" + xyzFormat.format(cycle.widthFeature),
    "Z" + xyzFormat.format(z - cycle.depth),
    "Q" + xyzFormat.format(cycle.probeOvertravel),
    "R" + xyzFormat.format(cycle.probeClearance),
    getProbingArguments(cycle, false)
  );
  if (cycle.updateToolWear) {
    error(localize("Action -Update Tool Wear- is not supported with this cycle."));
    return;
  }
  break;
```
PCD Probing Support in onCyclePoint

10.3 Inspect Surface

The *Inspect Surface* operation creates a probing strategy that specifies contact points across the surfaces of the model to be measured by a probe while the part is still on the machine tool. The results can then be imported and compared against the model to identify if the manufactured part is in or out of tolerance.

Inspection streamlines the manufacturing process by letting you identify problem areas and decide on any rework needed early in the process. It also helps to reduce the need to move parts between the machine tool and a measuring device.

Surface Inspection is initiated using the *Inspect Surface* operation listed in the INSPECTION/PROBING menu.



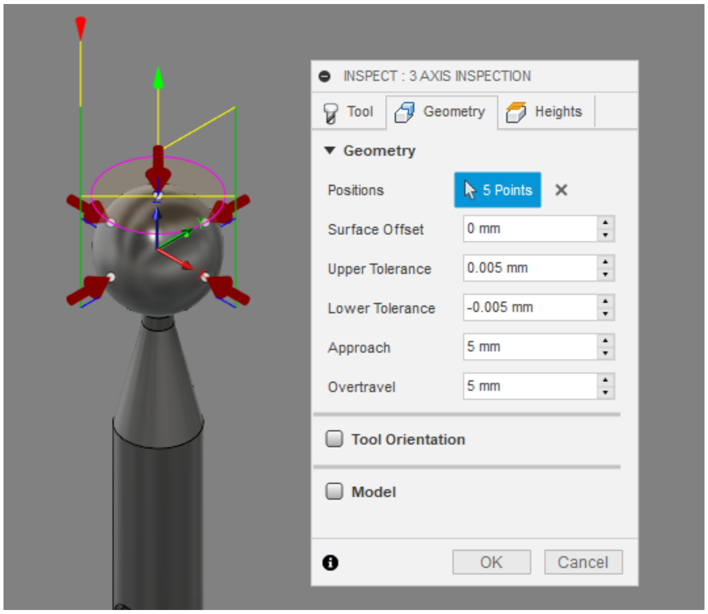
Inspect Surface Operation

If you wish to use the *Inspect Surface* operations, you will need a post processor that will allow you to output and run these inspection paths on your machine. You can either use one of the generic Inspection post processors available on the [Post Library for Autodesk Fusion](), or modify your current milling post which is already set up for your machine to add in the inspection functionality. You will need to add support for probing to your post processor before adding the inspection capabilities.

The Inspection post processors will have the *inspection* suffix appended to the name of the post processor. These are the only post processors that support Inspect Surface operations. You will need to use one of these generic posts as a source for adding the inspection code to your post processor.

10.3.1 Inspect Surface Operations

Inspect Surface operations differ from the other probing operations, in that you will select points on the face of the part to inspect instead of individual features of the part.



Surface Inspect Interface

The Surface Inspect operations are considered a cycle in the post processor and therefore call the *onCyclePoint* function, though they are expanded in the *inspectionCycleInspect* function. The standard *cycleType* variable to define the cycle type is not set for Surface Inspect operations, but rather the *isInspectionOperation* function is used to determine if it is a Surface Inspection cycle. This is further explained in the *Adding the Supporting Surface Inspect Logic* section. Unlike other cycles that pass a single point to the *onCyclePoint* function, the Surface Inspect cycle will contain the following 3 points per cycle location, with each location generating a separate and subsequent call to *onCyclePoint*.

Location	How to determine	Description
First	isFirstCyclePoint()	Safe move to approach inspection location
Second	(default)	Inspection move
Third	isLastCyclePoint()	Retract move

Three Points per Inspection Location

10.3.2 Inspection Parameters

The parameters defined in the Inspect Surface operation are passed to the inspection functions using either the *cycle* object or through section parameters (*getParameter*). These parameters are handled in the core Surface Inspect functions that are copied from an existing inspection post processor. Standard probing parameters can be referenced in the inspection functions.

The following variables are referenced as 'cycle.*parameter*'.

Cycle Parameter	Description
linkFeed	The feedrate used to position between inspection locations.
measureFeed	The feedrate used to approach the part.
nominalI	The I-component of the vector normal to the surface inspection point.
nominalJ	The J-component of the vector normal to the surface inspection point.
nominalK	The K-component of the vector normal to the surface inspection point.
nominalX	The X-axis position of the inspection point.
nominalY	The Y-axis position of the inspection point.
nominalZ	The Z-axis position of the inspection point.
outOfPositionAction	This parameter will only be defined when the *Out of Position* box is checked. The only valid setting when it is defined is the string *stop-message*.
pointID	The numeric ID of the inspection point.
probeClearance	The distance from the contact point where the probe starts to approach the part.
probeOvertravel	The maximum distance the probe can move beyond the expected contact point. If no contact is made within this distance, the probe returns an invalid measurement.
safeFeed	The feedrate at which to approach the part.

Inspection cycle Parameters

The following parameters are inspection specific and are prefixed with the *operation:* string. They are referenced using the getParameter("operation:*parameter* ") function.

Parameter	Description
inspectLowerTolerance	The lower limit distance at which an inspected point is considered within tolerance of the model.
inspectSurfaceOffset	The positive or negative distance from the model from where inspection points are measured.
inspectUpperTolerance	The upper limit distance at which an inspected point is considered within tolerance of the model.

Inspection Parameters

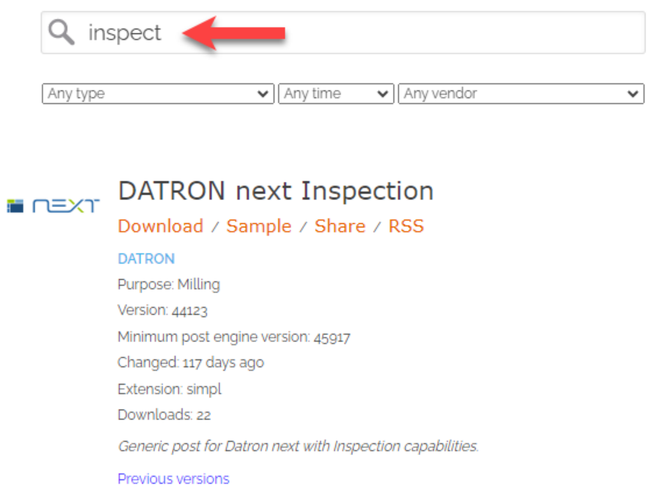
10.3.3 Adding the Core Inspect Surface Logic

Adding Surface Inspect support requires the main logic to be copied directly from a post processor that already supports inspection, and logic added to the main sections of the post processor. You should first open a post processor that contains support for inspection before starting to add Inspect Surface support to your post processor, since the logic and most of the code will remain the same. As of this writing, the following post processors have support for inspection, notice that all of them are named with the *inspection* suffix.

Post Library Name	Filename
DATRON next Inspection	datron next inspection.cps
Fanuc Inspection	fanuc inspection.cps
HAAS (pre-NGC) Inspection	haas inspection.cps
HAAS – Next Generation Control Inspection	haas next generation inspection.cps
Heidenhain Inspection	heidenhain inspection.cps
Hurco Inspection	hurco inspection.cps
Mazak Inspection	mazak inspection.cps
Results file generator for probing and inspection	result generator inspection.cps
Siemens SINUMERIK 840D Inspection	siemens 840D inspection.cps

Post Processors that Support Surface Inspect Operations

You can also search the online [Post Library for Autodesk Fusion]() to see if any other post processors have been added with inspection capabilities.



Search for Posts that Support Surface Inspect Operations

The main code for Inspect Surface logic is located at the end of the post processor. You will need to copy from the definition of *capabilities* located after the *onClose* or *onTerminate* function to the end of the file and add this code to the end of your post processor.

```
capabilities = |= CAPABILITY_INSPECTION;
description = "HAAS - Next Generation Control Inspection";
longDescription = "Generic post for the HAAS Next Generation control with Inspection capabilities.";
```

Copy From this Code to the End of the File for Core Surface Inspect Logic

10.3.4 Adding the Supporting Inspect Surface Logic

There are a number of locations that contain support logic for Inspect Surface operations in the post processor. You can refer to any of the generic post processors that support Inspect Surface operations for an example on where this code is implemented.

Add the following code at the end of the *onOpen* function.

```
  // inspection
  if (typeof inspectionWriteVariables == "function") {
    inspectionWriteVariables();
  }
```

Add to the End of the onOpen Function

For multi-axis machines it is important that an actual machine configuration is defined and is not reliant on 3+2 plane codes and/or IJK output. Please refer to the *Multi-Axis Post Processors* section for a description on implementing multi-axis support to your post processor.

At the end of the *onSection* function, but before any subprograms are defined, add the following code.

```
  // inspection
  if (typeof inspectionProcessSectionStart == "function") {
    inspectionProcessSectionStart();
  }
```

Initialize the Surface Inspect Operation

At the top of the *onCyclePoint* function add in the following code.

```
  if (isInspectionOperation()) {
    if (typeof inspectionCycleInspect == "function") {
      inspectionCycleInspect(cycle, x, y, z);
      return;
    } else {
      cycleNotSupported();
    }
  }
```

Call the Controlling Surface Inspect Function

At the start of the *onSectionEnd* function add the following code.

```
// add at the top of onSectionEnd
 if (isInspectionOperation() && !isLastSection()) {
   // the following command(s) will differ depending on the post processor
   writeBlock(gFormat.format(103), "P0", formatComment("LOOKAHEAD ON"));
 }
…
// add at the end of onSectionEnd
  if (typeof inspectionProcessSectionEnd == "function") {
```

```
  inspectionProcessSectionEnd();
}
```

Finalize the Surface Inspect Operation

In the *onClose* function, before any subprogram statements, add the following code after the results file is closed.

```
if (typeof inspectionProgramEnd == "function") {
  inspectionProgramEnd();
}
```

Finalize the Surface Inspect Program

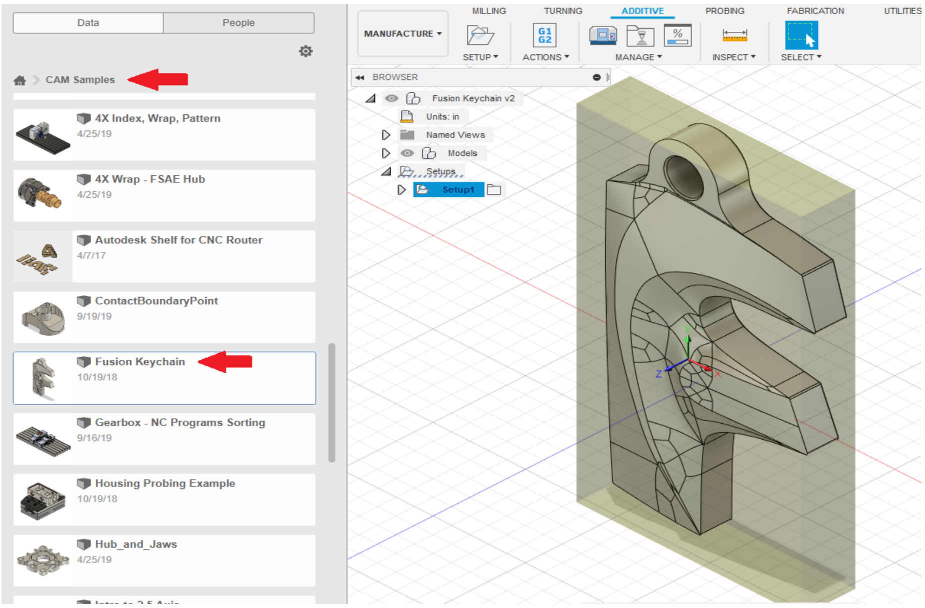
11 Additive Capabilities and Post Processors

So far in this guide we've discussed post processors as they pertain to subtractive machining, but Fusion also supports Additive FFF (fused filament fabrication) printers. This chapter discusses the basics of selecting a machine capable of additive manufacturing, generating an additive tool path, creating output, and the details of an additive post processor.

11.1 Getting Started

This section will give an overview of creating an Additive tool path but will not go into great detail on all of the features of the Additive capabilities of Fusion, just enough to get you started on post processing.

You will of course need a model that you want to print to start with. For the examples in this manual we will use the Fusion Keychain model provided as a CAM sample with your installation of Fusion. This model contains subtractive manufacturing operations which can be combined with Additive manufacturing operations as long as your machine supports both capabilities.



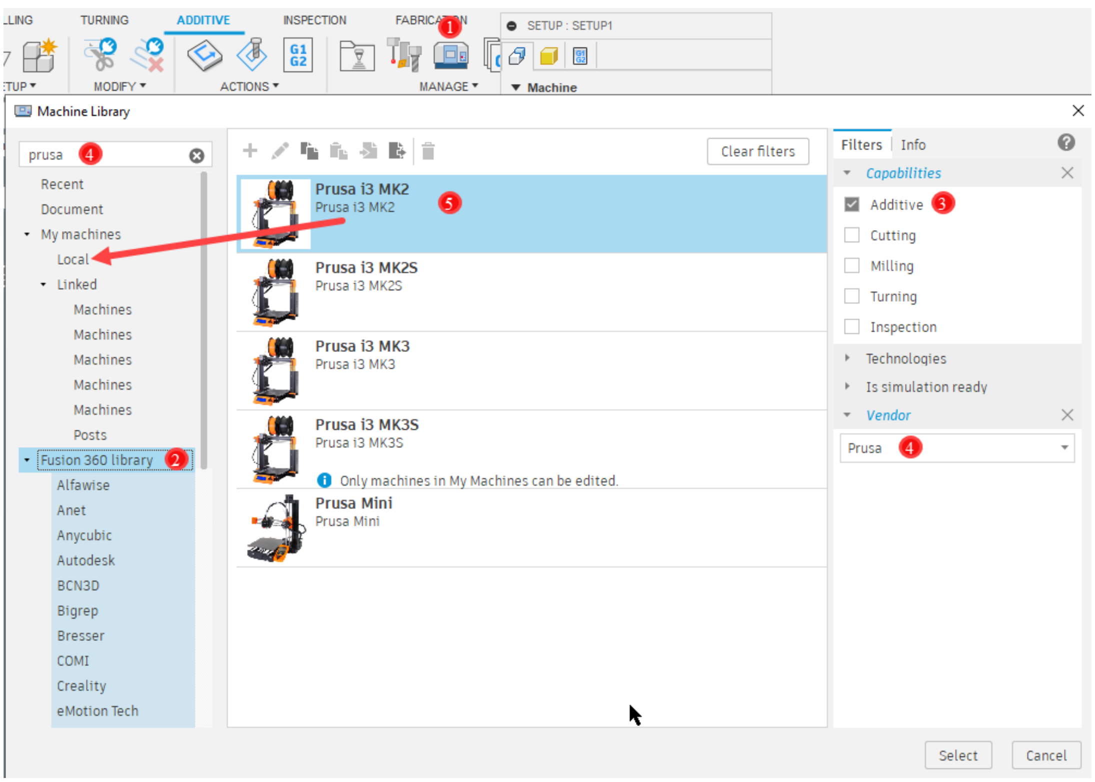
Sample Additive Part

You will see the ADDITIVE tab on the MANUFACTURE ribbon. Selecting this tab will display the Additive menus.

Additive Menus

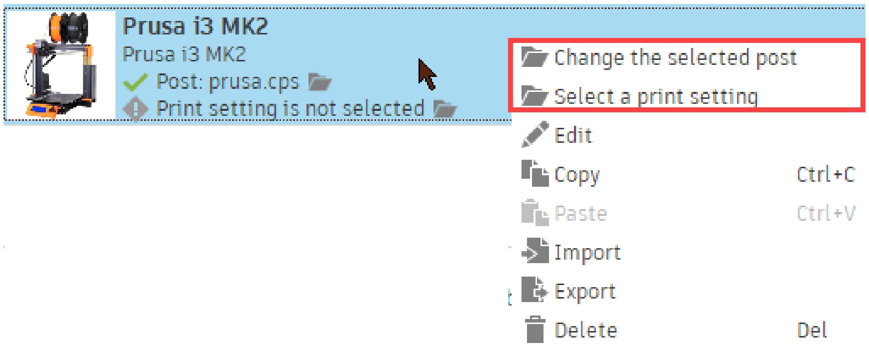
11.1.1 Finding a Machine

The first step in creating an Additive tool path is to define the machine that you will be using. Unlike Subtractive operations where the Machine Definition is optional, it is required for Additive operations. Pressing the *Machine Library* icon in the Additive menus will display the *Machine Library* dialog. Select the *Fusion Library* menu and check the *Additive* box to list the available Additive machines. You can use the Search field or Vendor pull down menu to filter the machines that are displayed. We will be using the *Prusa i3 MK2* machine. You should drag this machine into your Local library for both convenience and the ability to edit the machine.



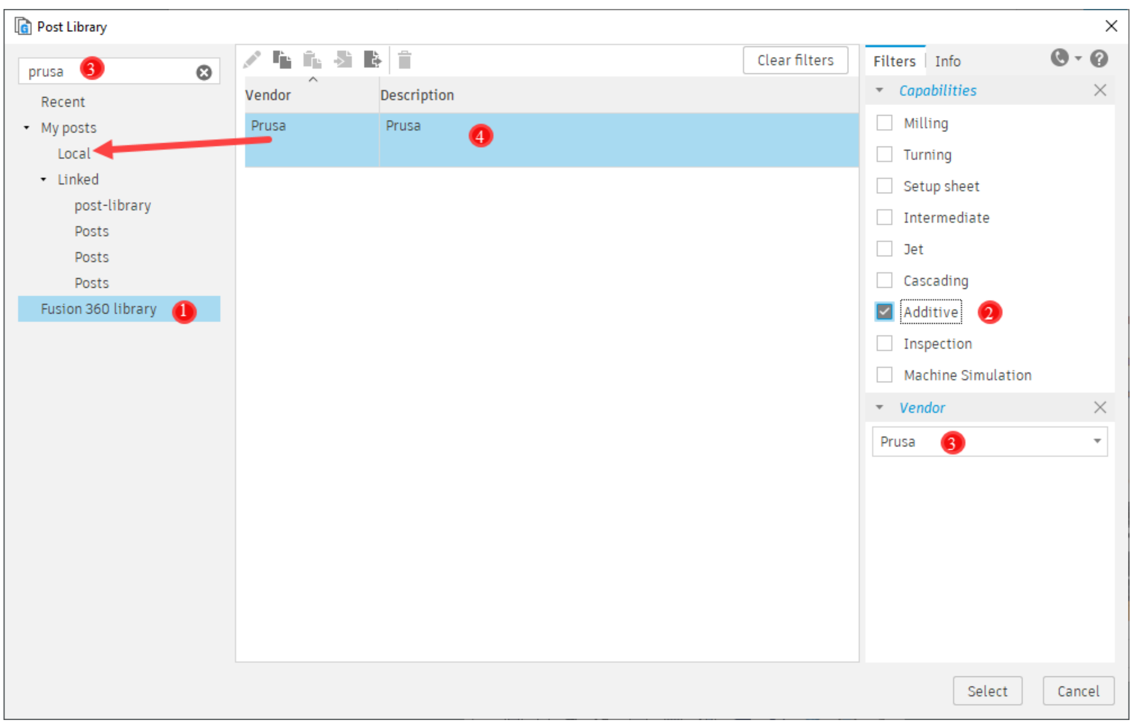
Finding an Additive Machine and Storing in Your Local Library

Once you find your machine you may need to select the post processor and Print Settings that correspond to this machine. The machines in the Fusion Library should all be assigned to the correct post processor for each machine, so it is rare that you would need to change the post processor. If necessary, you can select/change the post processor by right clicking on the *Prusa i3 MK3* machine and choosing *Change the selected post.*



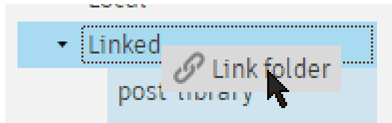
Selecting/Changing the Post Processor and Setting the Print Settings

The *Post Library* dialog will then be displayed. Select the *Fusion library* and check the Additive box to display only the post processors supporting the Additive capabilities. You will want to select the *Prusa I3 MK2* machine. You will need to drag this post processor into to your Local library if you plan on editing it.



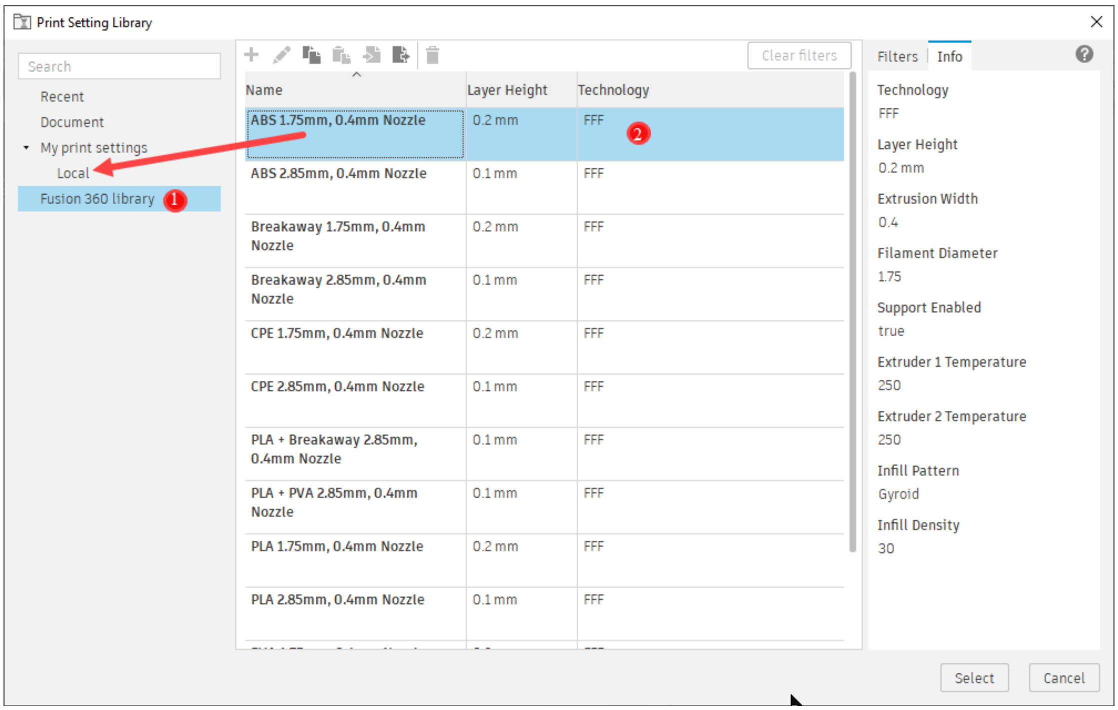
Selecting the Post Processor

You can also create linked folders on your computer to store both the machines and post processors. You do this by right clicking on the Linked menu and selecting the Link Folder menu. A browser will be displayed allowing you to select a folder to place your machines/posts.



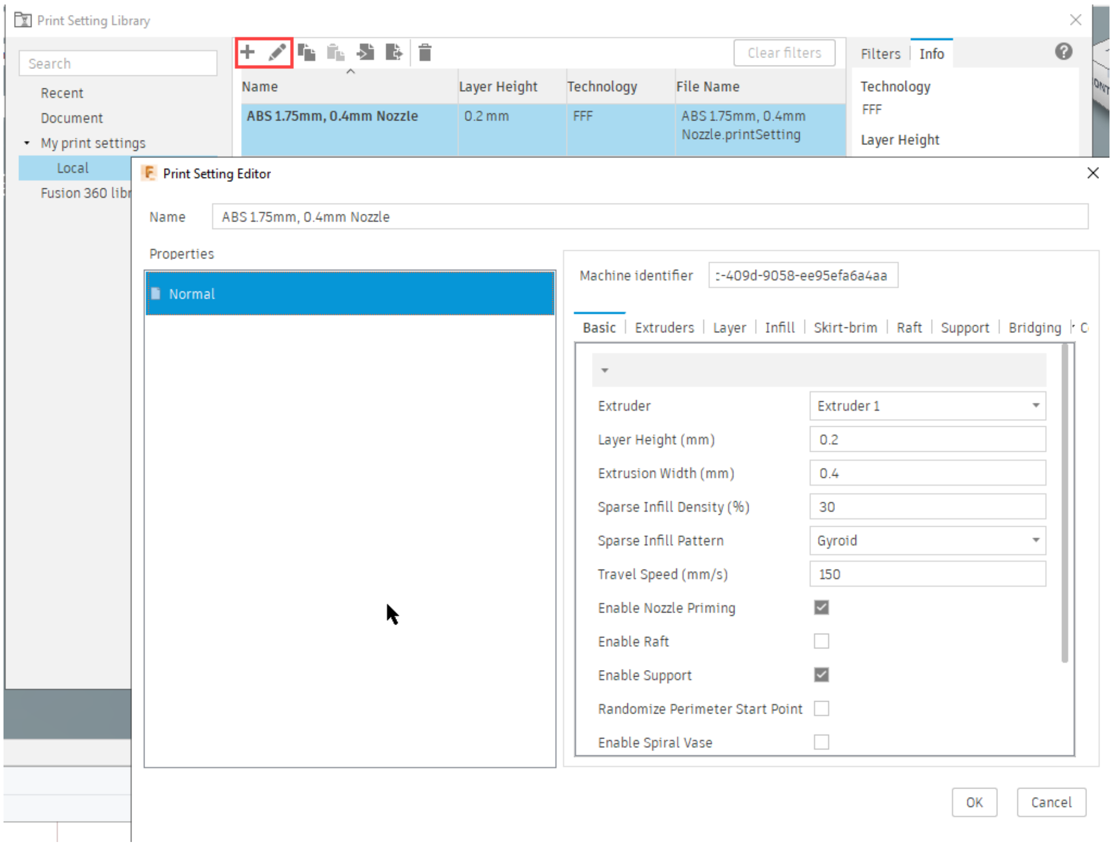
Selecting a Local Folder for The Machines and Post Processors

To select the Print Settings for the printer, right click on the *Prusa i3 MK3* machine and choose *Select a print setting.* This will bring up the Print Setting Library dialog allowing you to either select an existing print setting or creating a custom print setting. Print Settings must be stored in the Local library in order to create or edit them.



Selecting the Print Setting

Once the Print Setting is in your local library you can edit it by pressing the + button. Press the to create a new Print Setting, you will be prompted to select an existing Print Setting to use as the template for the new Print Setting.

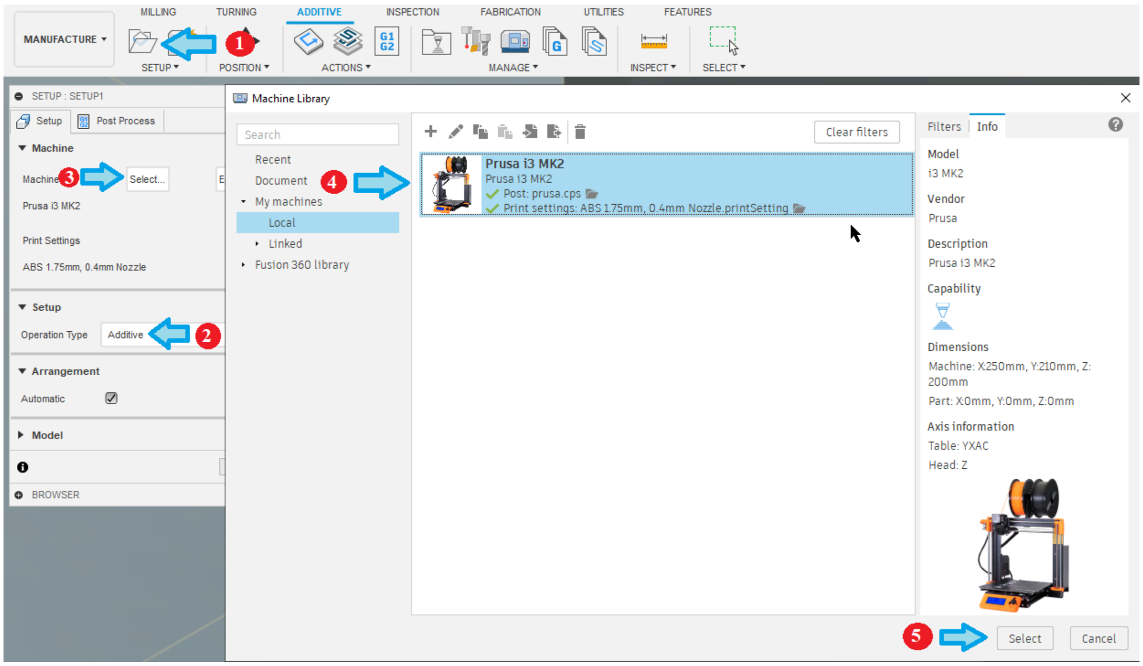


Editing a Print Setting

11.1.2 Creating an Additive Setup

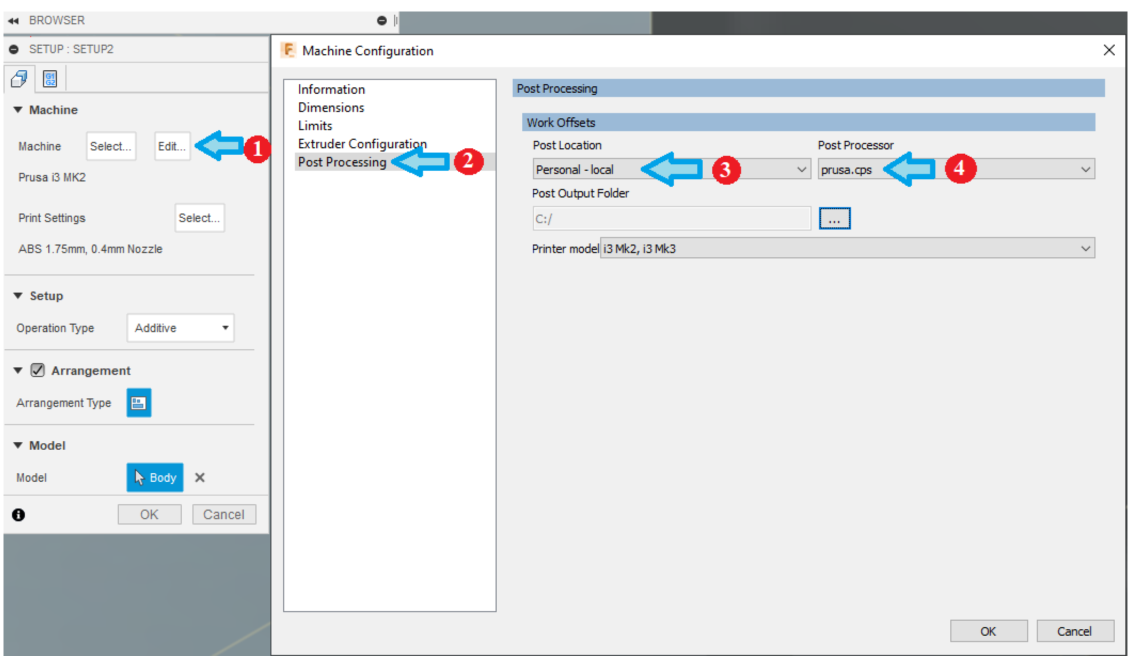
In the Fusion Keychain model you will notice that there is already a subtractive setup defined. For machines that support both additive and subtractive machining you can define both types of operations as long as they are in separate setups. The subtractive operations for these machines are exactly the same as they would be for a purely subtractive (milling) machine. For this sample we will be ignoring the subtractive setup and working with the additive only.

To create an Additive setup, press the *Setup* menu, change the *Operation Type* to *Additive*, and select the configuration for your machine by pressing the *Select…* button under *Machine*.



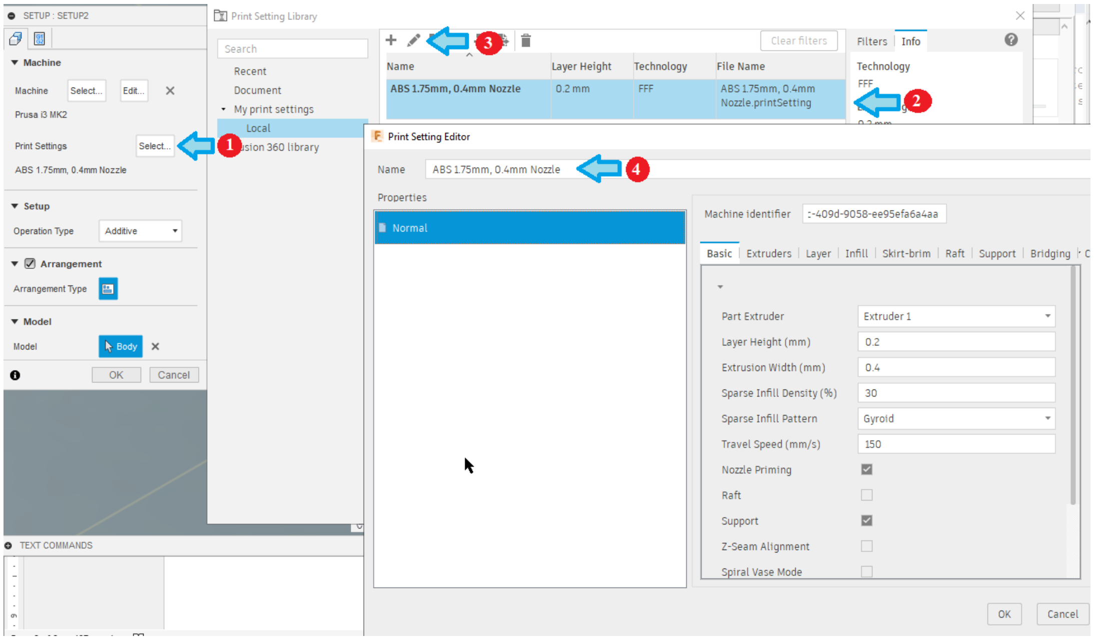
Defining an Additive Setup

If you have not already assigned a post processor to this machine you will need to do so now. Do this by pressing the *Edit…* button under the *Machine* prompt. The Machine Definition will display, change the *Post location* to *Personal – local*, and select the *prusa.cps* post processor from the *Post Processor* drop down menu.



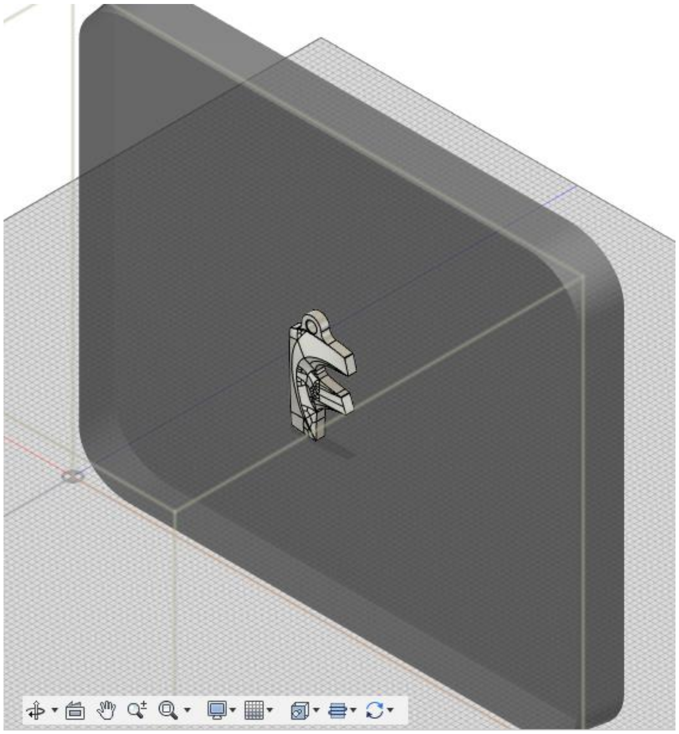
Associating a Post Processor to a Machine Definition

You can select and/or edit the Print Settings directly from the Setup dialog when creating the Additive Setup. The Print Settings are specific to the creation of the Additive toolpaths, with settings to modify the bed temperature, nozzle temperature, layer thickness, infill style, etc. You can also create your own default print settings by giving them a new name.



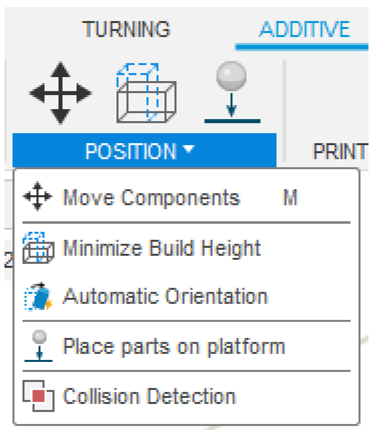
Defining the Print Settings

After creating the Setup you should see a representation of the machine base and envelope with the part located on it. Feel free to rename the new setup to Additive so you know that this is an additive operation. If you were going to do both additive and subtractive operations in the same model, then you will want to move the Additive setup above the Subtractive setup.



Part Displayed on Machine

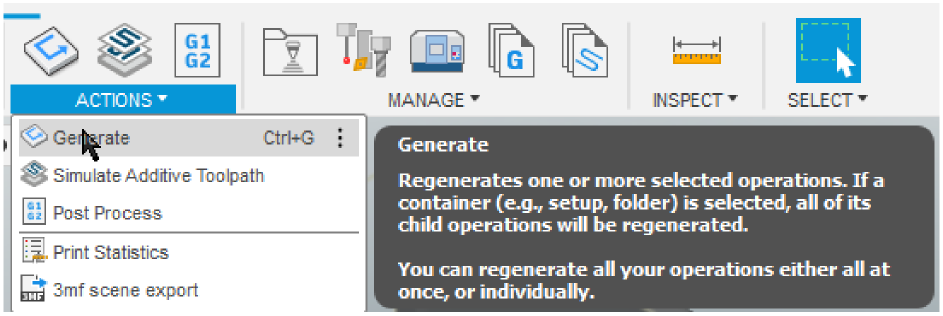
If the part is not in the location on the machine where you want it, you can easily reposition it using the POSITION menus.



Positioning Menus

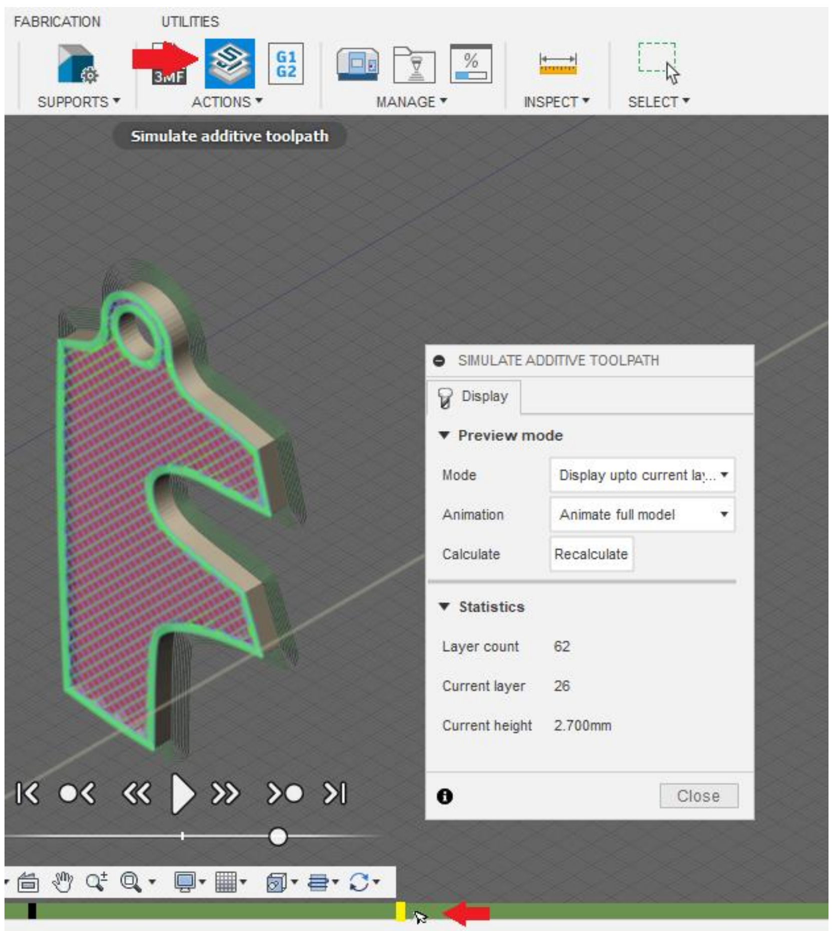
11.1.3 Creating and Simulating an Additive Operation

An Additive operation is automatically created when an Additive setup is created. You can see this operation by expanding the Additive setup in the Browser. There can only be one Additive operation per setup. You will need to generate the Additive Toolpath manually by selecting Generate from the ACTIONS menus or by pressing *Ctrl+G*. This may take a while depending on the complexity of the model.



Generating the Additive Toolpath

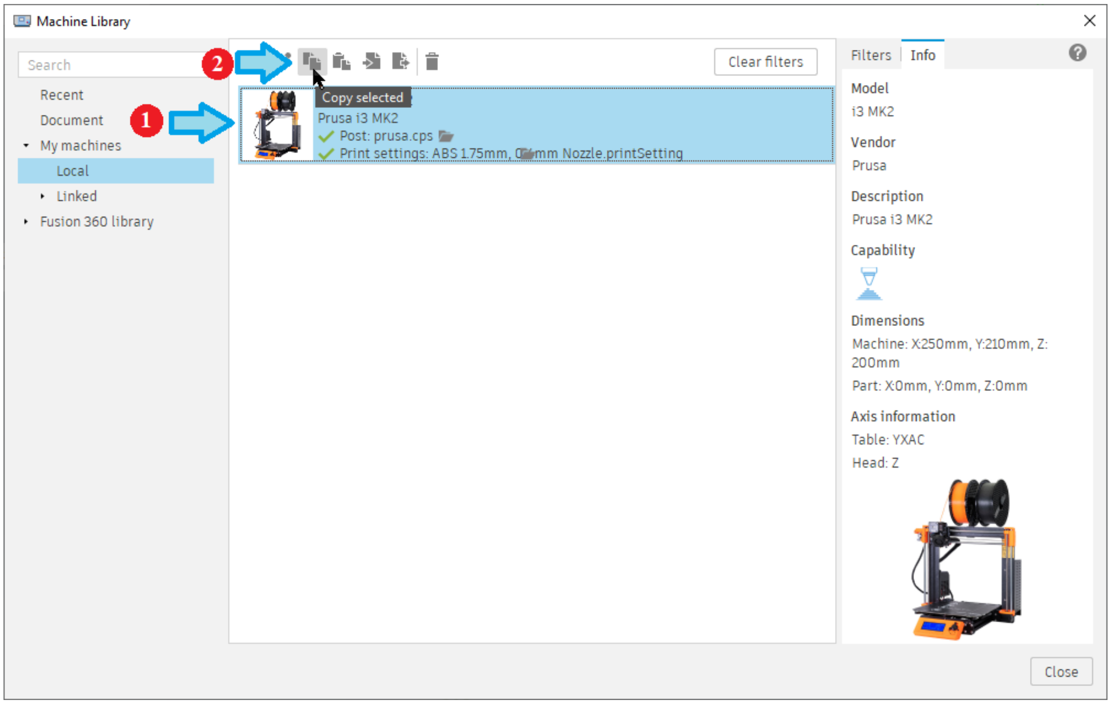
To simulate the Additive toolpath press the *Simulate* button in the ACTIONS menus. Additive toolpaths simulate in the same manner as Subtractive toolpaths, but it is recommended that you place the cursor over the green slide bar at the bottom of the window, hold down the left mouse button, and move the mouse to the left and right to visualize the Additive process.



Simulating the Additive Toolpath

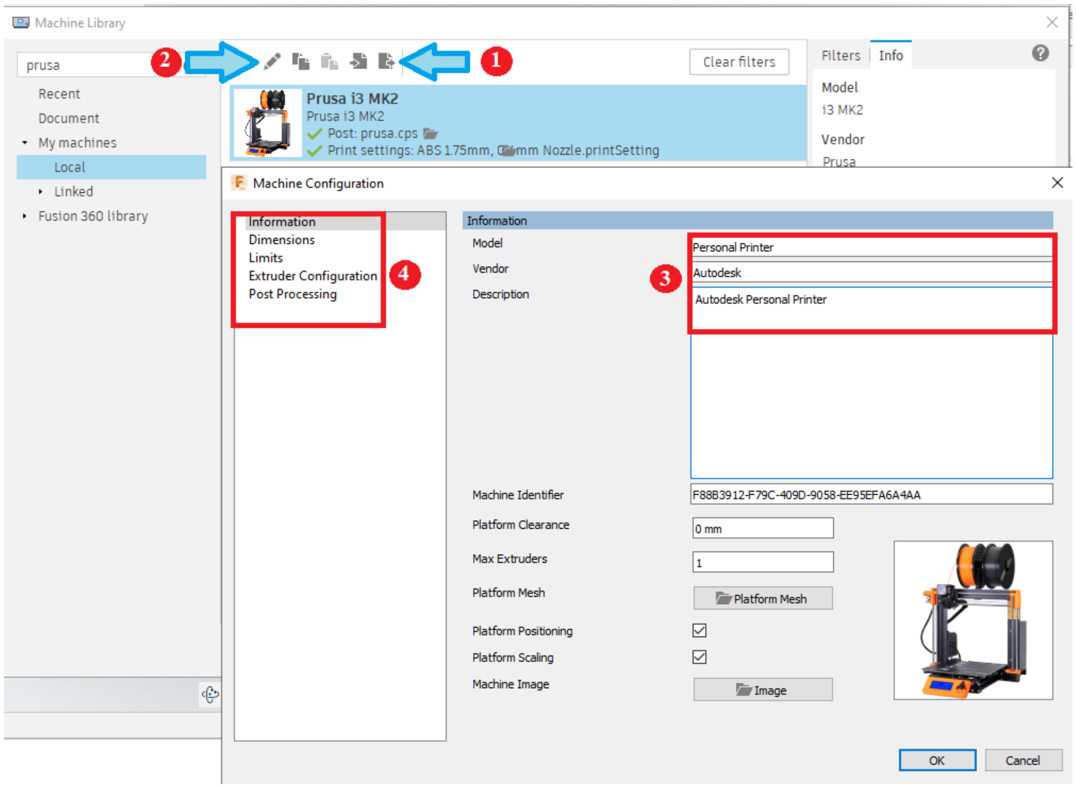
11.2 Creating a New Machine Definition

When adding a new Additive post processor you will need to create a corresponding Machine Definition. You do this by copying an existing Machine Definition into your Local library by opening the *Machine Library* dialog, selecting the Machine Definition you want to copy, and then pasting it into your Local folder.



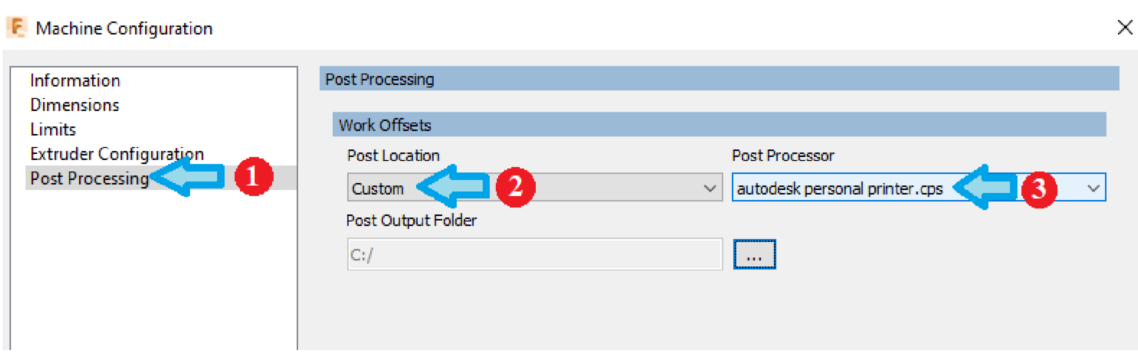
Copying a Machine Definition

Once you create a copy of the Machine Definition in your Local folder you will need to edit it and describe your machine. Be sure to give it a unique name and description and go through all sections to properly define the machine.



Duplicating and Editing the Machine Definition

After creating your Machine Definition you will need to copy a seed post into a local folder, for example *prusa.cps*, and give it a meaningful name. You can then assign this post processor to your machine. You can also select the default output folder for your G-code files when posting.



Assigning a Post Processor to Your Additive Machine

You are now ready to edit your post processor.

11.3 Additive Common Properties

The additive post processors have properties that are common to most of them. These properties are listed in the following table.

Title	Property	Description
Relative extrusion mode	relativeExtrusion	Selects between an absolute or relative extrusion mode.
Trigger	_trigger	Specifies the method used to trigger a change of extruder temperature. It can be disabled or controlled by the Z-height or layer number.
Trigger Value	_triggerValue	Specifies the Z-height difference or layer number increment to trigger an extruder temperature change.
Start Temperature	tempStart	The starting temperature in Celsius for the extruder, overrides the starting temperature in the Print Settings.
Temperature Interval	tempInterval	The degrees in Celsius to increase the temperature of the extruder for each trigger event.

Common Additive Properties

The Temperature Tower properties are typically used to test new filaments in order to identify the best printing temperatures. These properties are listed in the Temperature Tower group.

11.4 Additive Variables

There are variables that are specific to Additive machines. These variables are either globally defined or are accessed through function calls. The following table lists the variables available for Additive machines.

Variable	Description
bedTemp	Temperature of bed.
commands	Post processor defined variable that defines the codes that are output for additive commands.
Extruder	An unnamed object that contains the extruder definition. This object is obtained by calling the *getExtruder* function.
layerCount	Number of printed layers for entire printing operation.
machineConfiguration	The machine configuration definition.
numberOfExtruders	Number of extruders used.
partCount	Number of bodies created during printing.
printTime	The amount of time the print should take.
settings	Post processor defined variable that defines settings specific to additive machines.

Global Additive Variables

The post processor defined variables are defined in the *getPrinterGeometry* function from the *machineConfiguration* settings and are typically in all Additive post processors.

11.4.1 The machineConfiguration Object

The *machineConfiguration* object is standard between all machine types, milling, turning, additive, etc. machineConfiguration settings are always referenced using a function. The variables returned from the functions are described in the following table.

MachineConfiguration Function	Description
getCenterPositionX(id)	The center of the printer table in X.
getCenterPositionY(id)	The center of the printer table in Y.
getCenterPositionZ(id)	The center of the printer table in Z.
getExtruderOffsetX(id)	The offset in X from the reference extruder.
getExtruderOffsetY(id)	The offset in Y from the reference extruder.
getExtruderOffsetZ(id)	The offset in Z from the reference extruder.
getVendor()	Th manufacturer of the printer.
getModel()	The model type of the printer.
getNumberExtruders()	Number of defined extruders.
getWidth()	The width of the machine in X.
getDepth()	The depth of the machine in Y.
getHeight()	The height of the machine in z.

machineConfiguration Functions used for Additive

11.4.2 The Extruder Object

There is not really a named Extruder object, meaning you cannot use the *new Extruder* syntax to create an object as you would a Vector, but there is the *getExtruder* function that will return an unnamed object that has extruder specific variables. Each extruder can be referenced by passing the extruder number to the *getExtruder* function.

```
var totalLength = getExtruder(1).extrusionLength;
```

Get the Total Length of Material Used for Extruder 1

The following table defines the variables accessible using the *getExtruder* function

Extruder Variable	Description
extrusionLength	Total length of material used for this extruder during printing.
filamentDiameter	The diameter of the filament material.
materialName	The name of the material used for the extruder.
nozzleDiameter	The diameter of the extruder nozzle.
temperature	The temperature setting for the extruder.

Extruder Variables

11.4.3 The commands Object

The *commands* object is defined in the post processor and defines the output codes for common additive commands. Define the proper code to be output for each command in this definition. Some of the commands may have specifiers that define subcommands, such as *on* and *off* for fan. The following table lists the commands supported by the library additive post processors.

The code values can be a formatted number or a text string. If a command does not exist for your printer, then define the code as *undefined*.

```
// Specify the required commands for your printer below.
var commands = {
  extruderChangeCommand : undefined, // command to change the extruder
  setExtruderTemperature: mFormat.format(104), // command to set the extruder
temperature
  waitExtruder          : mFormat.format(109), // wait command for the extruder
temperature
  setBedTemperature     : mFormat.format(140), // set the bed temperature
  waitBed               : mFormat.format(190), // wait for the bed temperature
  reportTemperatures    : undefined, // report the temperatures to the printer
  fan                   : {on:mFormat.format(106), off:mFormat.format(107)},
  extrusionMode         : {relative:mFormat.format(83),
                           absolute:mFormat.format(82)} // extrusion mode
};
```

commands Definition

commands Variable	Description
extruderChangeCommand	Command to change the extruder.
setExtruderTemperature	Command to set the extruder temperature.
waitExtruder	The wait command when setting the extruder temperature.
setBedTemperature	Command to set the bed temperature.
waitBed	The wait command when setting the bed temperature.
reportTemperatures	Command to report the temperatures to the printer.
Fan	Commands to turn the fan on and off, defined using the syntax {on:---, off:---}.
extrusionMode	Commands to select either relative or absolute filament extrusion modes, defined using the syntax {relative:---, absolute:---}.

The commands Object

11.4.4 The settings Object

The *settings* object is post processor defined and defines fixed settings that are not controlled by post properties.

```
var settings = {
  useG0              : true, // use G0 or G1 commands for rapid movements
  maximumExtruderTemp: 260 // specifies the maximum extruder temperature
};
```

settings Definition

settings Variable	Description

useG0	Specifies whether to use G0 (*true*) or G1 (*false*) for rapid moves.
maximumExtruderTemp	Sets the maximum extruder temperature.

The settings Object

11.5 Additive Entry Functions

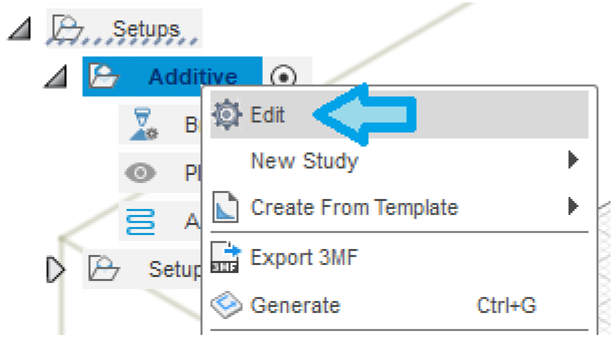
Additive post processors use most of the common Entry functions for Subtractive posts, with some specialized Entry functions for Additive post processors only. Remember that Entry functions are called from the post processor kernel based on the record type in the intermediate file, so this means that there is a difference between Subtractive and Additive intermediate files.

The following table defines the unique or modified Entry Functions for Additive post processors. You can reference the table in the subtractive *Entry Functions* section for a description of the common entry functions.

Entry Function	Invoked When …
onAcceleration(travel, printing, retract)	Acceleration is changed in an additive pass.
onBedTemp(temp, wait)	Bed temperature change.
onCircularExtrude(_clockwise, _cx, _cy, _cz, _x, _y, _z, _f, _e)	Additive circular pass.
onClose()	End of post processing.
onExtruderChange(id)	Change of extruders.
onExtruderTemp(temp, wait, id)	Extruder temperature change.
onExtrusionReset(length)	Resets the length of the extrusion material used.
onFanSpeed(speed, id)	Change of fan speed.
onJerk(x, y, z, e)	The axis jerk is changed in an additive pass.
onLayer(layer)	Change of layer level.
onMaxAcceleration(x, y, z, e)	Max axis acceleration is changed in an additive pass.
onOpen()	Post processor initialization.
onLinearExtrude(x, y, z, f, e)	Additive pass.
onParameter(string, value)	Each parameter setting.
onRapid(x, y, z)	Positioning Rapid move.
onSection()	Start of an operation.

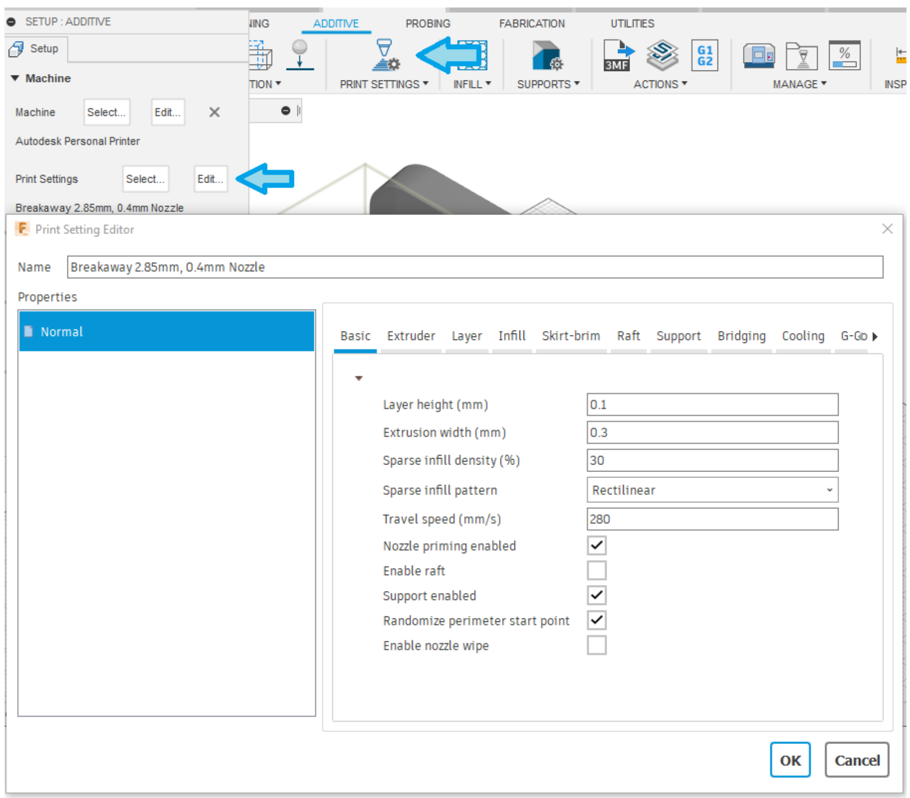
Additive Entry Functions

Many of the entry functions will get their arguments and settings from either the Machine Definition or Print Settings. These dialogs can be accessed by pressing the right mouse button when over the Additive setup and selecting *Edit*.



Editing the Setup

This will display the Setup dialog, where you can select to edit either the Machine Definition (described in the previous section) or Print Settings. You can also display the Print Settings dialog by pressing the *Print Settings* button in the *Additive* menus.



Editing the Print Settings

11.5.1 Global Section

The global section for an Additive post is consistent with the standard global section for Subtractive posts, it contains the description of the post processor and machine, its capabilities, kernel settings, property table, and global variables. The capabilities of the post must be set to CAPABILITY_ADDITIVE.

```
capabilities = CAPABILITY_ADDITIVE;
// capabilities = CAPABILITY_ADDITIVE | CAPABILITY _MILLING; // additive & subtractive
```

Setting the Post Processor Capabilities to Additive

The common global variables found in an Additive post are defined in the *Additive Variables* section.

11.5.2 onOpen

```
function onOpen()
```

The *onOpen* function is called at the start of post processing and is used to define settings and output startup blocks. It usually varies from machine to machine.

1. Define settings
2. Output machine and program description
3. Output initial startup codes

Following is an example onOpen function.

```
function onOpen() {
  setFormats(MM); // machine require input code in MM
  // output machine and program description
  if (typeof writeProgramHeader == "function") {
    writeProgramHeader();
  }

  // output start of program codes
  writeBlock(gFormat.format(unit == MM ? 21 : 20)); // set unit
  writeBlock("M115 U3.0.10 ; tell printer latest fw version");
  if (getProperty("printerModel") == "i3mk2mk3") {
    writeBlock(gFormat.format(28), "W ; home all without mesh bed level");
  }  else if (getProperty("printerModel") == "mini") {
    writeBlock(gFormat.format(28), "; home all without mesh bed level");
  }
}
```

Example onOpen Function

11.5.3 onSection

```
function onSection() {
```

The *onSection* function is called at the start of each Additive operation and outputs the starting codes for an Additive operation. It usually varies from machine to machine.

```
function onSection() {
```

```
  // probe bed after heating
  if (getProperty("printerModel") == "i3mk2mk3") {
    writeBlock(gFormat.format(80), "; mesh bed leveling");
  }  else if (getProperty("printerModel") == "mini") {
    writeBlock(gFormat.format(29), "; mesh bed leveling");
  }

  // output start of operation codes
  writeBlock(gFormat.format(92), eOutput.format(0));
  writeBlock(gAbsIncModal.format(90)); // absolute spatial co-ordinates
  writeBlock(getCode(getProperty("relativeExtrusion") ? commands.extrusionMode.relative :
commands.extrusionMode.absolute));
}
```

Sample onSection Function

11.5.4 onClose

```
function onClose() {
```

The *onClose* function is called at the end of the last operation. It is used to output the end-of-program codes. It usually varies from machine to machine.

```
function onClose() {
  // output end-of-program codes
  writeBlock("G4 ; wait");
  xOutput.reset();
  yOutput.reset();
  if (getProperty("printerModel") == "i3mk2mk3") {
    writeBlock(gMotionModal.format(1), xOutput.format(0),
        yOutput.format(toPreciseUnit(200, MM)), "; home X axis");
  } else if (getProperty("printerModel") == "mini") {
    writeBlock(gMotionModal.format(1), xOutput.format(0),
        yOutput.format(toPreciseUnit(150, MM)), "; home X axis");
  }
  writeBlock(mFormat.format(84), "; disable motors");
}
```

Sample onClose Function

11.5.5 onBedTemp

```
function onBedTemp(temp, wait) {
```

Arguments	Description
temp	The bed temperature in Celsius.
wait	Set to *true* when the machine should wait for the bed to warm up.

The *onBedTemp* function is called multiple times during a toolpath. At the start of the operation *onBedTemp* is called with *wait* set to *false* to start heating the bed. It is called a second time prior to the start of the toolpath with *wait* set to *true* so that the machine waits for it to reach the targeted temperature. It will also be called at the end of the program to turn off the heating of the bed.

The maximum bed temperature is defined in the *Limits* tab when defining the Machine Definition in Fusion. The *onBedTemp* function is common to most additive posts.

```
function onBedTemp(temp, wait) {
  if (wait) {
    writeBlock(getCode(commands.reportTemperatures));
    writeBlock(getCode(commands.waitBed), sOutput.format(temp));
  } else {
    writeBlock(getCode(commands.setBedTemperature), sOutput.format(temp));
  }
}
```

onBedTemp Function

11.5.6 onExtruderTemp

```
function onExtruderTemp(temp, wait, id) {
```

Arguments	**Description**
temp	The extruder temperature in Celsius.
wait	Set to *true* when the machine should wait for the extruder to warm up.
id	Extruder number to set the temperature for. The first extruder is 0.

The *onExtruderTemp* function is called multiple times during a toolpath. At the start of the operation *onExtruderTemp* is called with *wait* set to *false* to start heating the extruder. It is called a second time prior to the start of the toolpath with *wait* set to *true* so that the machine waits for it to reach the targeted temperature. It will also be called at the end of the program to turn off the heating of the extruder.

The desired extruder temperature is defined in the *Extruder* tab of the *Print Settings* dialog. The maximum extruder temperature is set in the *Extruder Configuration* tab when defining the Machine Definition in Fusion. The *onExtruderTemp* function is common to most additive posts.

```
function onExtruderTemp(temp, wait, id) {
  if (typeof executeTempTowerFeatures == "function" && getProperty("_trigger") != undefined) {
    if (getProperty("_trigger") != "disabled" && (getCurrentPosition().z == 0)) {
      temp = getProperty("tempStart"); // override temperature with the starting temperature
    }
  }
  if (wait) {
    writeBlock(getCode(commands.reportTemperatures));
```

```
    writeBlock(getCode(commands.waitExtruder), sOutput.format(temp), tFormat.format(id));
  } else {
    writeBlock(getCode(commands.setExtruderTemperature), sOutput.format(temp),
                    tFormat.format(id));
  }
}
```

onExtruderTemp Function

11.5.7 onExtruderChange

```
function onExtruderChange(id) {
```

Arguments	Description
id	Extruder number to activate. The first extruder is 0.

The *onExtruderChange* function handles a switch between extruders, similar to a tool change in a subtractive machine. The number of extruders is defined in the *Information* tab when defining the Machine Definition in Fusion. The *onExtruderChange* function is common to most additive posts.

```
function onExtruderChange(id) {
  if (id > machineConfiguration.getNumberExtruders()) {
    error(subst(localize("This printer does not support the extruder '%1'."), integerFormat.format(id)));
    return;
  }
  writeBlock(getCode(commands.extruderChangeCommand), tFormat.format(id));
  activeExtruder = id;
  forceXYZE();
}
```

Sample onExtruderChange Function

11.5.8 onExtrusionReset

```
function onExtrusionReset(length) {
```

Arguments	Description
length	Length of the additive material used for the active extruder.

The *onExtrusionReset* function will be called to reset the length of the used additive material when the active extruder changes. At the beginning of the program it will be called with a value of 0 and when switching between one extruder and another it will pass the length of additive material used for the newly activated extruder. The *onExtruderChange* function is common to most additive posts.

```
function onExtrusionReset(length) {
  if (getProperty("relativeExtrusion")) {
    eOutput.format(0);
```

```
    eOutput.format(0);
  }
  eOutput.reset();
  writeBlock(gFormat.format(92), eOutput.format(length));
}
```

onExtrusionReset Function

11.5.9 onFanSpeed

```
function onFanSpeed(speed, id) {
```

Arguments	Description
speed	The fan speed as a percentage of the default speed in the range of 0-255.
id	Extruder number to set the fan speed for, typically the active extruder.

The *onFanSpeed* function is used to turn on and off the fan used for cooling the extruded material. The fan is controlled starting at the layer after the number of disabled layers defined in the *Cooling* tab of the *Print Settings* dialog. The *onFanSpeed* function is common to most additive posts.

```
function onFanSpeed(speed, id) {
  if (!commands.fan) {
    return;
  }
  if (speed == 0) {
    writeBlock(getCode(commands.fan.off));
  } else {
    writeBlock(getCode(commands.fan.on), sOutput.format(speed));
  }
}
```

onFanSpeed Function

11.5.10 onAcceleration

```
function onAcceleration(travel, printing, retract) {
```

Arguments	Description
travel	The travel acceleration, used for positioning moves.
printing	Printing acceleration, used for extrusion moves.
retract	Retract acceleration, used for extruder retract moves.

The *onAcceleration* function is invoked when the acceleration changes in an Additive toolpath. The acceleration values are provided in (velocity_change/seconds)^2.

```
// set the current acceleration rate for the move types
```

```
function onAcceleration(travel, printing, retract) {
  writeBlock(mFormat.format(204), "P" + integerFormat.format(printing), "T" +
                    integerFormat.format(travel), "R" + integerFormat.format(retract));
}
```

onAcceleration Function

11.5.11 onMaxAcceleration

```
function onMaxAcceleration(x, y, z, e) {
```

Arguments	Description
x	The maximum acceleration along X.
y	The maximum acceleration along Y.
z	The maximum acceleration along Z.
e	The maximum acceleration of the extrusion.

The *onMaxAcceleration* function is invoked when the maximum axis acceleration changes in an Additive toolpath. The acceleration values are provided in (velocity_change/seconds)².

```
// set the maximum acceleration for each axes
function onMaxAcceleration(x, y, z, e) {
  writeBlock(mFormat.format(201), "X" + integerFormat.format(x), "Y" +
    integerFormat.format(y), "Z" + integerFormat.format(z), "E" + integerFormat.format(e));
}
```

onMaxAcceleration Function

11.5.12 onJerk

```
function onJerk(x, y, z, e) {
```

Arguments	Description
x	The X-axis jerk.
y	The Y-axis jerk.
z	The Z-axis jerk.
e	The extruder jerk.

The *onJerk* function is invoked when the axis jerk changes in an Additive toolpath. The jerk control values are provided in velocity_jerk/seconds.

```
// jerk control
function onJerk(x, y, z, e) {
  writeBlock(mFormat.format(205), "X" + integerFormat.format(x), "Y" + integerFormat.format(y),
    "Z" + integerFormat.format(z), "E" + integerFormat.format(e));
```

```
}
```

onJerk Function

11.5.13 onLayer

```
function onLayer(layer) {
```

Arguments	Description
Layer	Current layer being printed.

The *onLayer* function is called for every printed layer and passes in the active layer. It can be used to output a comment prior to the toolpath for each layer and/or to increment a counter on the machine control to show the printing progress. The *onLayer* function is common to most additive posts.

```
function onLayer(num) {
  if (typeof executeTempTowerFeatures == "function") {
    executeTempTowerFeatures(num);
  }
  writeComment("Layer : " + integerFormat.format(num) + " of " +
integerFormat.format(layerCount));
}
```

Sample onLayer Function

11.5.14 onParameter

```
function onParameter(name, value) {
```

Arguments	Description
name	Parameter name.
value	Value stored in the parameter.

The onParameter function behaves the same as it does in a Subtractive post processor, but there is one parameter that is specific to Additive machines. This is the *feedRate* parameter that defines the travel speed that the machine will move when positioning without extruding material and for extruder changes. The *onParameter* function is common to all additive posts.

```
function onParameter(name, value) {
  switch (name) {
  case "feedRate":
    rapidFeedrate = toPreciseUnit(value > highFeedrate ? highFeedrate : value, MM);
    break;
  }
}
```

onParameter Function

11.5.15 onRapid

```
function onRapid(_x, _y, _z) {
```

Arguments	Description
_x, _y, _z	The tool position.

The *onRapid* function handles positioning moves, which do not extrude the additive material. The output of the *onRapid* function usually outputs a single block for the positioning move. The *onRapid* function is common to all additive posts.

```
var rapidFeedrate = highFeedrate;
function onRapid(_x, _y, _z) {
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var f = feedOutput.format(rapidFeedrate);
  if (x || y || z || f) {
    writeBlock(gMotionModal.format(settings.useG0 ? 0 : 1), x, y, z, f);
    feedOutput.reset();
  }
}
```

onRapid Function

11.5.16 onLinearExtrude

```
function onLinearExtrude(_x, _y, _z, _f, _e) {
```

Arguments	Description
_x, _y, _z	The tool position.
_f	The feedrate.
_e	Length of additive material to extrude during the move.

The *onLinearExtrude* function handles linear moves that extrude the additive material. The tool position, feedrate and length of material to extrude are passed as the arguments. The *onLinearExtrude* function is common to all additive posts.

```
function onLinearExtrude(_x, _y, _z, _f, _e) {
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var f = feedOutput.format(_f);
  var e = eOutput.format(_e);
  if (x || y || z || f || e) {
    writeBlock(gMotionModal.format(1), x, y, z, f, e);
```

```
  }
}
```
onLinearExtrude Function

11.5.17 onCircularExtrude

```
function onCircularExtrude(_clockwise, _cx, _cy, _cz, _x, _y, _z, _f, _e) {
```

Argument	Description
_clockwise	Set to *true* if the circular direction is in the clockwise direction, *false* if counter-clockwise.
_cx, _cy, _cz	Center coordinates of circle.
_x, _y, _z	Final point on circle
_f	The feedrate.
_e	Length of additive material to extrude during the move.

The *onCircularExtrude* function handles circular moves that extrude the additive material. The tool circle parameters, position, feedrate and length of material to extrude are passed as the arguments. The *onCircularExtrude* function is common to all additive posts.

```
function onCircularExtrude(_clockwise, _cx, _cy, _cz, _x, _y, _z, _f, _e) {
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var f = feedOutput.format(_f);
  var e = eOutput.format(_e);
  var start = getCurrentPosition();
  var i = iOutput.format(_cx - start.x, 0);
  var j = jOutput.format(_cy - start.y, 0);

  switch (getCircularPlane()) {
  case PLANE_XY:
    writeBlock(gMotionModal.format(_clockwise ? 2 : 3), x, y, i, j, f, e);
    break;
  default:
    linearize(tolerance);
  }
}
```
onCircularExtrude Function

11.6 Common Additive Functions

There are non-entry functions that are common to Additive post processors. Some of these are defined in the post processor kernel and some in the post processor itself. The following sections describes these functions.

11.6.1 getExtruder

```
function getExtruder(id) {
```

Arguments	Description
id	Extruder number to get information about.

The *getExtruder* function returns the Extruder variable, which includes information about the specified extruder. Unlike the entry functions where the extruder base is 0, in the *getExtruder* function the first extruder is referenced as *id*=1, the second as *id*=2, etc.

```
  writeComment("Material used: " + dimensionFormat.format(getExtruder(1).extrusionLength));
  writeComment("Material name: " + getExtruder(1).materialName);
  writeComment("Filament diameter: " + dimensionFormat.format(getExtruder(1).filamentDiameter));
  writeComment("Nozzle diameter: " + dimensionFormat.format(getExtruder(1).nozzleDiameter));
```

Sample Calls to getExtruder

11.6.2 isAdditive

```
function isAdditive() {
```

Returns *true* if any of the operations in the part are Additive in nature.

11.6.3 executeTempTowerFeatures

```
function executeTempTowerFeatures(num) {
```

Arguments	Description
num	The event that triggered the need to change the temperature. It is set to 1 on the first call and then successive numbers on the remaining calls.

The *executeTempTowerFeatures* function is defined in the post processor and sets the temperature based on the event specified by *num*. The initial value is 1 and ascends by 1 in each successive call. The *executeTempTowerFeatures* function is common to all additive posts that support Temperature Tower features.

```
var nextTriggerValue;
var newTemperature;
var maximumExtruderTemp = 260;
function executeTempTowerFeatures(num) {
  if (settings.maximumExtruderTemp != undefined) {
    maximumExtruderTemp = settings.maximumExtruderTemp;
  }
  if (getProperty("_trigger") != "disabled") {
    var multiplier = getProperty("_trigger") == "height" ? 100 : 1;
    var currentValue = getProperty("_trigger") == "height" ?
```

```
      xyzFormat.format(getCurrentPosition().z * 100) : (num - 1);
    if (num == 1) { // initialize
      nextTriggerValue = getProperty("_triggerValue") * multiplier;
      newTemperature = getProperty("tempStart");
    } else {
      if (currentValue >= nextTriggerValue) {
        newTemperature += getProperty("tempInterval");
        nextTriggerValue += getProperty("_triggerValue") * multiplier;
        if (newTemperature <= maximumExtruderTemp) {
          onExtruderTemp(newTemperature, false, activeExtruder);
        } else {
          error(subst(
            localize("Requested extruder temperature of '%1' exceeds the maximum value of '%2'."),
             newTemperature, maximumExtruderTemp)
          );
        }
      }
    }
  }
}
```

executeTempTowerFeatures Function

```
  if (typeof executeTempTowerFeatures == "function") {
    executeTempTowerFeatures(num);
  }
```

Sample Calls to executeTempTowerFeatures

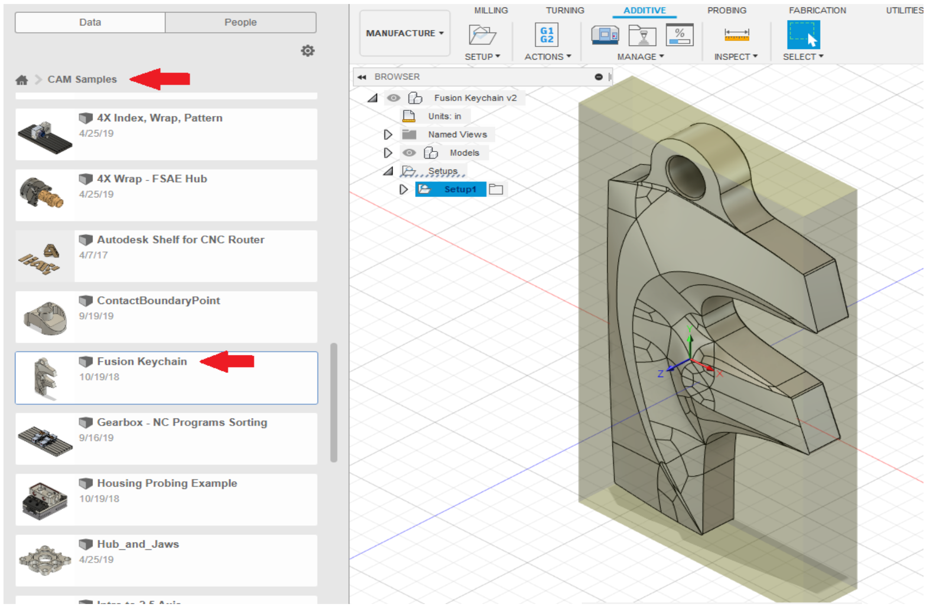
12 Deposition Capabilities and Post Processors

Another additive capability supported by Fusion and the post processor is multi-axis deposition, for example Directed Energy Deposition (DED). This technology is used to build up a part feature using a metal depositing method. This chapter discusses the basics of generating a deposition tool path, creating output, and the details of a deposition post processor.

12.1 Getting Started

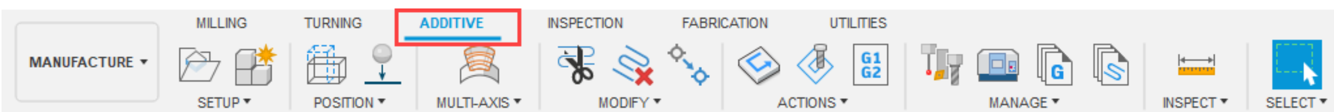
This section will give an overview of creating a Deposition tool path using the multi-axis Feature Construction operation inside of Fusion. It will not go into great detail on all of the features of the Deposition capabilities of Fusion, just enough to get you started on post processing.

You will of course need a model to start with. For the examples in this manual, we will use the *Fusion Keychain* model provided as a CAM sample with your installation of Fusion. This model contains subtractive manufacturing operations which can be combined with Additive manufacturing operations as long as your machine supports both capabilities.



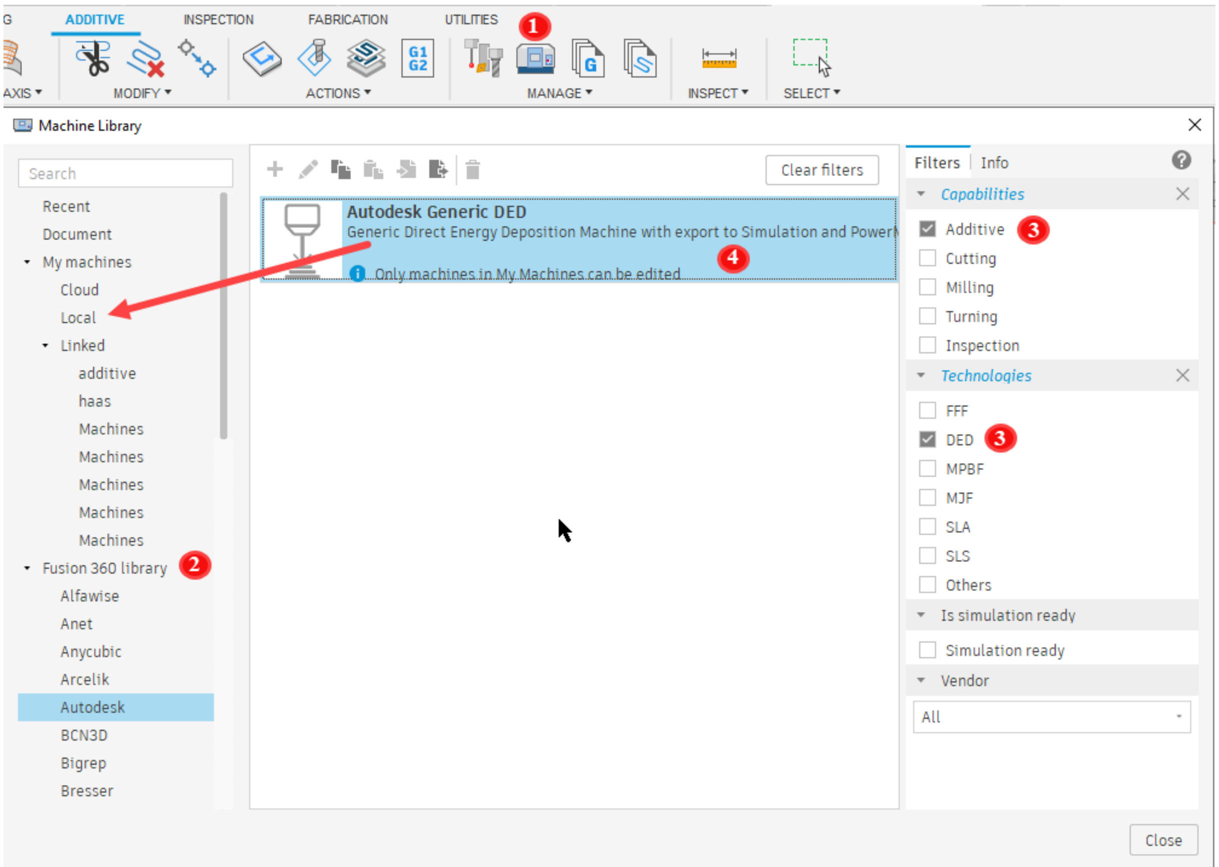
Sample Deposition Part

You will see the ADDITIVE tab on the MANUFACTURE ribbon. Selecting this tab will display the Additive menus.



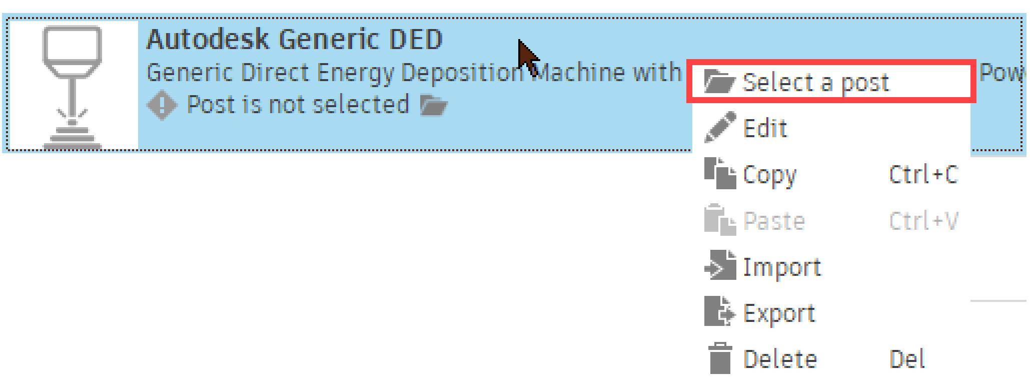
12.1.1 Finding a Machine

The first step in creating a Deposition tool path is to define the machine that you will be using. Unlike Subtractive operations where the Machine Definition is optional, it is required for Deposition operations since they are considered Additive operations. Pressing the *Machine Library* icon in the Additive menus will display the *Machine Library* dialog. Select the *Fusion Library* menu and check the *Additive* box under *Capabilities* and the DED box under *Technologies*. to list the available Deposition machines. Fusion comes with a single DED machine. You should drag this machine into your Local library for both convenience and the ability to edit the machine.



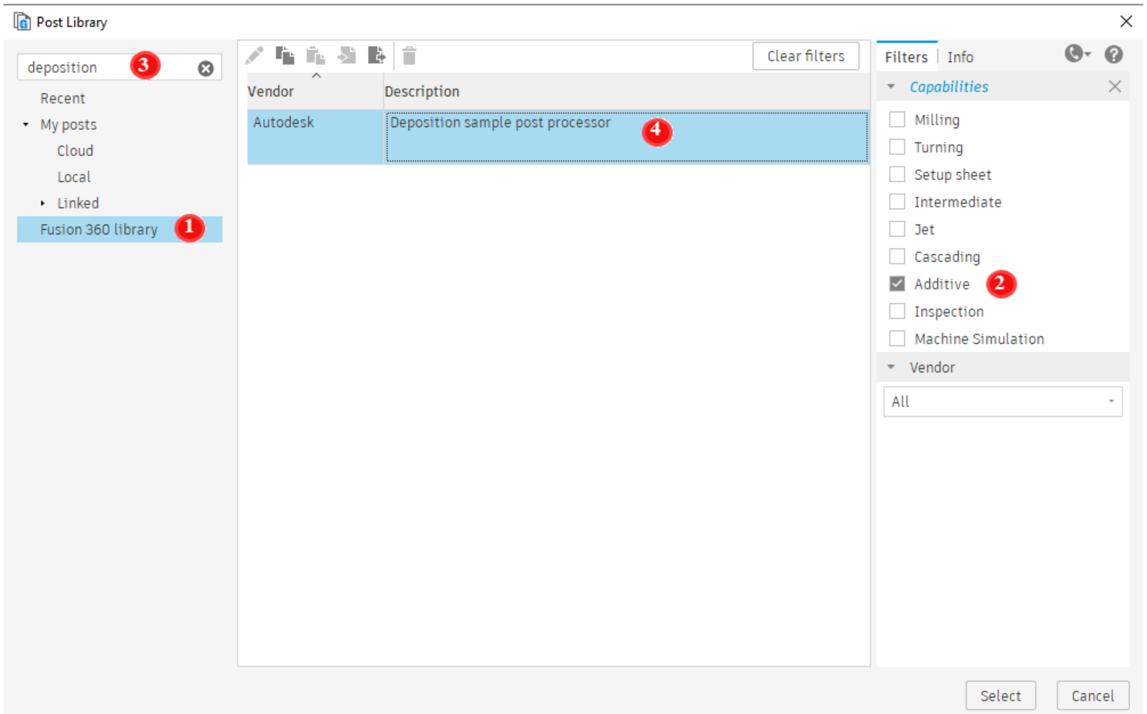
Finding a DED Machine and Storing in Your Local Library

Once you find your machine you will need to select the post processor that corresponds to this machine. You can select/change the post processor by right clicking on the *Autodesk Generic DED* machine and choosing *Select a post*.



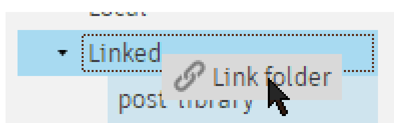
Selecting/Changing the Post Processor

The *Post Library* dialog will then be displayed. Select the *Fusion library* and check the Additive box to display only the post processors supporting the Additive capabilities. For training purposes, you will select the *Deposition sample post processor*. This post processor is not a full post processor, but rather a template used to modify an existing post processor to include Deposition support. The post modification will be discussed later in this chapter.



Selecting the Post Processor

You can also create linked folders on your computer to store both the machines and post processors. You do this by right clicking on the Linked menu and selecting the Link Folder menu. A browser will be displayed allowing you to select a folder to place your machines/posts.

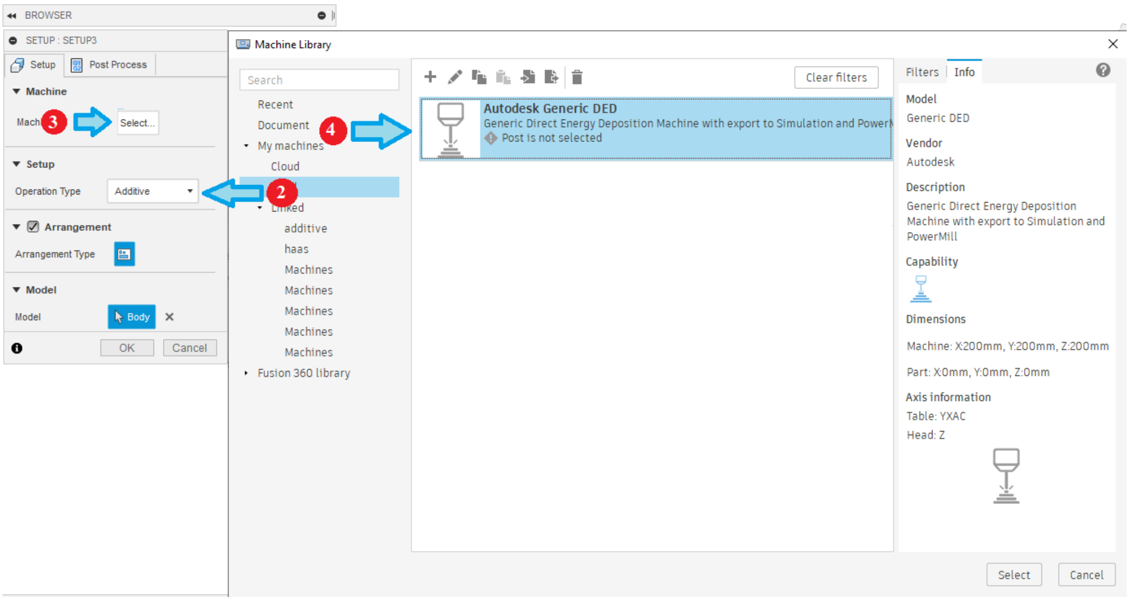


Selecting a Local Folder for The Machines and Post Processors

12.1.2 Creating an Additive Setup for Deposition

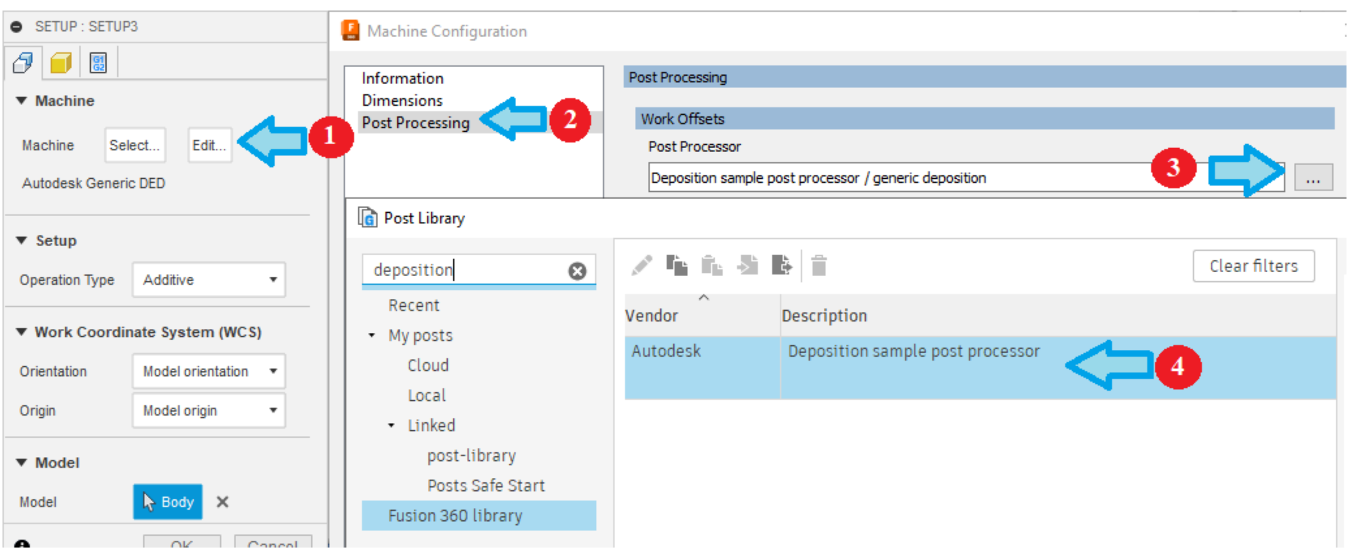
In the *Fusion Keychain* model you will notice that there is already a subtractive setup defined. For machines that support both additive and subtractive machining you can define both types of operations as long as they are in separate setups. The subtractive operations for these machines are exactly the same as they would be for a purely subtractive (milling) machine. For this sample we will be ignoring the subtractive setup and working with the additive only.

To create an Additive setup, press the *Setup* menu, change the *Operation Type* to *Additive*, and select the configuration for your machine by pressing the *Select…* button under *Machine*.



Defining an Additive Setup

If you have not already assigned a post processor to this machine you will need to do so now. Do this by pressing the *Edit…* button under the *Machine* prompt. The Machine Definition will display, select the *Post Processing* menu, press the … button and then select the *Deposition sample post processor*.

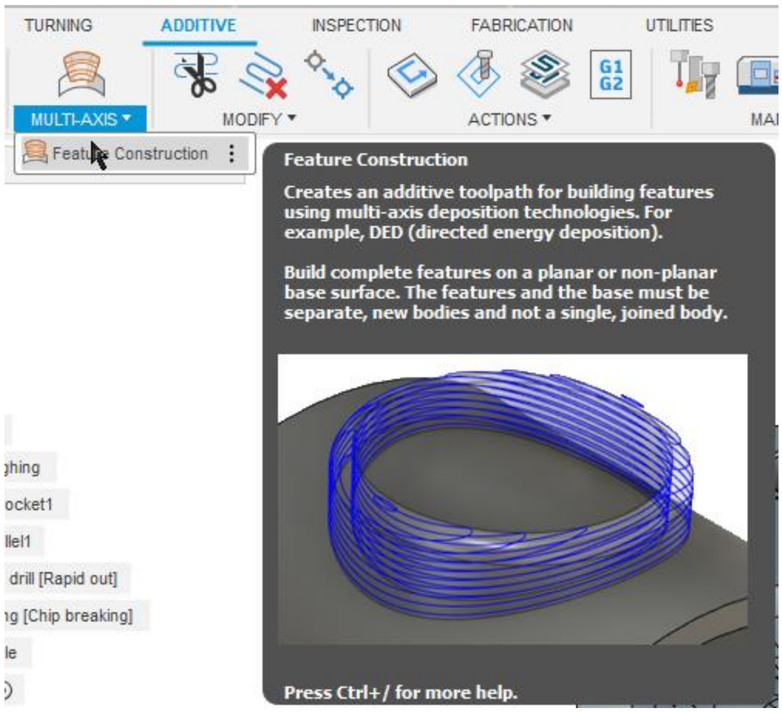


Associating a Post Processor to a Machine Definition

Feel free to rename the new setup to Deposition so you know that this is a deposition operation. If you are going to do both deposition and subtractive operations in the same model, then you will want to move the Deposition setup above the Subtractive setup.

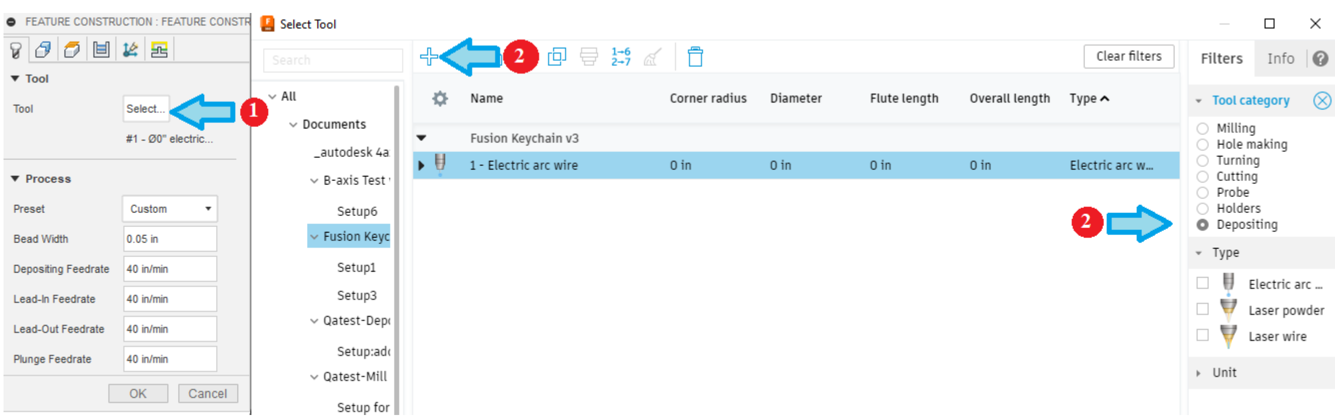
12.1.3 Creating and Simulating a Deposition Operation

The Deposition operation in Fusion is named Feature Construction and is located in the MULTI-AXIS pulldown.



Creating a Deposition Operation

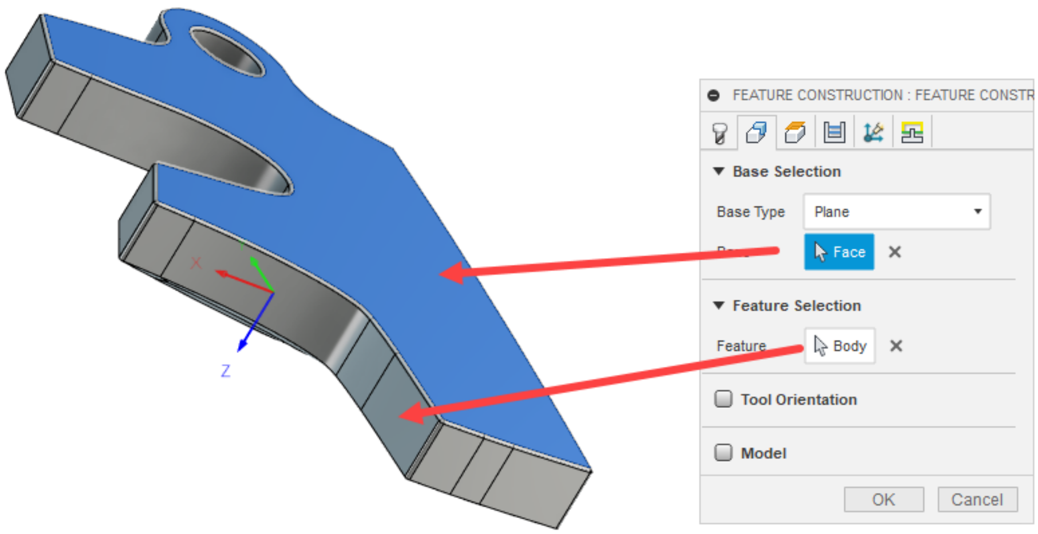
A proper tool should be selected for depositing the material. Fusion supports Electric Arc Wire, Laser Powder, and Laser Wire Deposition tools. If you don't already have deposition tools defined, you can create one using the normal method for creating a tool by pressing the + menu in the *Select Tool* form.



Selecting/Defining a Deposition Tool

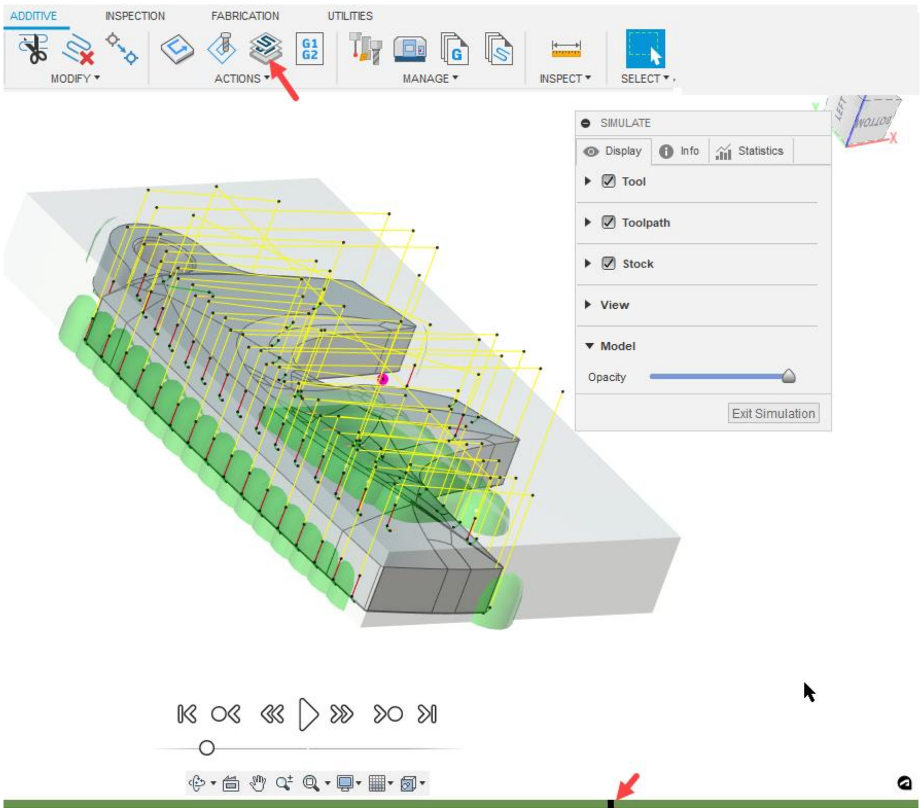
You will need to select the base the Feature being built lies on and the Feature itself. You can also generate multi-axis deposition moves by specifying a Forward Tilt and/or a Sideways Tilt.

For this exercise you can select the bottom surface of the keychain as the Base and the body of the keychain as the Feature. The remaining tabs/fields in the Feature Construction form are similar to other milling operations.



Selecting/Defining the Base Plane and Body for Deposition

To simulate the Deposition toolpath press the Simulate button in the ACTIONS menus. Deposition toolpaths simulate in the same manner as Subtractive toolpaths, but it is recommended that you place the cursor over the green slide bar at the bottom of the window, hold down the left mouse button, and move the mouse to the left and right to visualize the Deposition process.



Simulating the Deposition Toolpath

12.2 The Deposition Sample Post Processor

Unlike additive post processors, which are standalone and created for a specific machine, deposition capabilities are typically added to existing subtractive post processors for machines that support both subtractive and deposition operations. The Deposition Sample Post Processor contains the basic deposition functionality that can be added to a subtractive post. It is designed so that you can easily copy the required code from this post processor into a post processor that you want to add deposition capabilities to. In itself, it does not create a valid NC program for any machine.

The sample deposition post processor is broken up into separate sections, the first being code that will be placed into existing functions, new code to be added to your post processor, and code that is common to all other post processors used to create the sample output.

12.3 Deposition Specific Functions

You can start the modification of your post processor by copying the deposition specific functions into your post processor. This code is marked in the sample post processor as follows.

```
// Start of Deposition logic
…
// End of Deposition logic
```

Copy this Code to Your Post Processor

The following table describes the functions included in the deposition code that is being copied to your post.

Function	Description	Requires Editing
setDepositionCommands()	Enable to keep deposition on during transition moves, or disable it to turn deposition off.	Yes
getProcessParameters()	Processes the deposition parameters and properties related to deposition operations and stores them in the *processParameters* object for use in other functions.	No
writeDepositionHeader(tool)	Writes out a header containing the deposition settings per operation.	Maybe
writeProcessEquipmentCommands (activate)	Writes out the commands to turn deposition on or off as defined in the *setDepositionCommands* function.	No
onLayer(index)	Entry function called when a new layer is started. *index* specifies the layer. 0 is the first layer, 1 the second, etc.	Maybe
onLayerEnd(index)	Entry function called when the current layer is completed.	Maybe
onMovemeentDeposition(movement)	Called from the *onMovement* function. It turns on or off the depending on the movement type.	No

Deposition Specific Functions

12.3.1 Deposition Common Properties

The deposition functions have properties that are common between most depositing machines. These properties are listed in the following table.

Title	Property	Description
Deposit during transitions	depositOnTransitions	Enable to keep deposition on during transition moves, or disable it to turn deposition off.

Common Deposition Properties

12.3.2 Deposition Commands

The commands to control the deposition operations are defined in the *setDepositionCommands* function and will need to be edited to output the correct codes for your machine. It contains the commands to turn on and off the process equipment for Electric Arc Wire, Laser Powder, and Laser Wire tools.

```
  case TOOL_DEPOSITING_ELECTRIC_ARC_WIRE:
```

```
  // insert startup codes for electric arc wire here
  commands = {
    deposition      : {on:mFormat.format(101), off:mFormat.format(103)},
    processEquipment: {
      on: [  // commands to turn on process equipment
        formatWords(gFormat.format(90), formatComment("ABSOLUTE MODE")),
        formatWords(gFormat.format(300), "F" + processParameter.gasFlowRate,
          formatComment("SHIELD GAS FLOW RATE")),
        formatWords(gFormat.format(301), "V" + processParameter.arcCurrent,
          formatComment("ARC VOLTAGE")),
        formatWords(gFormat.format(302), "A" + processParameter.arcVoltage,
          formatComment("ARC CURRENT")),
        formatWords(gFormat.format(303), "S" + processParameter.wireSpeed,
          formatComment("WIRE SPEED")),
        formatWords(mFormat.format(304), formatComment("PROCESS ON"))],
      off: [  // commands to turn off process equipment
        formatWords(mFormat.format(305), formatComment("PROCESS OFF")),
        formatWords(gFormat.format(303), "S0", formatComment("WIRE STOP")),
        formatWords(gFormat.format(300), "F0000", formatComment("GAS OFF"))]
    }
  };
  break;
```

Commands to Turn On and Off Deposition

12.3.3 Modifying Existing Functions to Support Deposition

After copying the deposition specific code and making the needed modifications you will need to modify existing functions in your post processor to support deposition operations.

Function	Modification
onSection	Add code to define the deposition commands, write the deposition operation head, and enable the deposition operation.
onSectionEnd	Add code to disable the deposition operation.
onMovement	Add a call to *onMovementDeposition* for a deposition operation.

Modification of Existing Functions for Deposition Support

```
function onSection() {
  // #### Add the code below into the onSection function of your postprocessor ####
  if (isDepositionOperation()) {
    setDepositionCommands(); // setup for deposition process parameters
    writeDepositionHeader(tool);
    writeProcessEquipmentCommands(true);
  }

  // Important note, make sure that you disable the spindle speed output for deposition
  // operations in your postprocessor.
```

```
}
```

Enable a Deposition Operation in onSection

```
function onSectionEnd() {
  // #### Add the code below into the onSectionEnd function of your postprocessor ####
  if (isDepositionOperation()) {
    writeProcessEquipmentCommands(false);
  }
}
```

Disable a Deposition Operation in onSectionEnd

```
// #### If your postprocessor does not have the onMovement function, you have to add the
// entire function below. ####
function onMovement(movement) {
  // #### Add the code below into the onMovement function of your postprocessor. ####
  if (isDepositionOperation()) {
    onMovementDeposition(movement);
  }
}
```

Call onMovementDeposition from onMovement

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