Part Duplication
Guidelines And Procedure

Getting Started

About This Manual

CNC is a unique application involving hardware and software. We recommend that you read all of these instructions before using the product.

> **Since automated machining is potentially dangerous, please take the time to completely read through this manual and the software User's Guide to understand the operation of the electronics, software and machine before cutting a part.**

Turning Off the Controller

> **Always turn off the CNC Controller when it is not in use.**

Safety and Usage Guidelines

When running an automated machine tool, safety is of the utmost importance. For proper and safe use of the CNC program and your CNC machine, the following safety guidelines must be followed:

1. Never let the machine tool run unattended.
2. Require any person in the same room as a running machine tool to wear safety goggles and to stay a safe distance from the machine.
3. Allow only trained operators to run the machine tool. Any operator must have:
    - Knowledge of machine tool operation.
    - Knowledge of personal computer operation.
    - Knowledge of Microsoft Windows.
    - Good common sense.
4. Place safety guards around the machine to prevent injury from flying objects. It is highly recommended that you build a safety shield around the entire tool envelope.
5. Never place any part of your body within the tool envelope while the machine is online, since unexpected machine movement can occur at any time.
6. Always keep the tool envelope tidy and free of any loose objects.
7. Be on alert for computer crashes at all times.

WPI, Inc. is not responsible for the safe installation and use of this product. You and only you are responsible for the safety of yourself and others during the operation of your CNC machine tool. We supply this product but have no control over how it is installed or used. Always be careful!

WPI, Inc. or its affiliates are not responsible for damage to any equipment or workpiece resulting from use of this product.

If you do not understand and agree with all of the above safety guidelines, do not use this product.

Obtaining A Source Photograph

To produce an ideal image for this process, care must be taken to take the cleanest photograph possible. The accuracy of the duplicated part is more dependent on this photograph than any other part of the process. The following guidelines will improve the quality of the part's photograph, thereby decreasing errors in the duplicate part.

Photograph Environment

The part should be cleaned of debris and laid on a clean, uniform, black matte surface. A piece of black microfiber cloth or black construction paper are good examples. This, in turn, must have a flat sheet with fiducials at rectangular/square corners behind it (see appendix for printable example). The photograph should be taken in a dim room with no point-sources of light. A diffuse light source located close the camera without casting a shadow on the part should be used.

Photograph Technique

The camera should be held as far from the part as possible and aimed perpendicular to the part at its center. The focus should be set to maximize the sharpness of of contrast between the part and the matte surface. If available, optical zoom should be used to fill the frame with the part and fiducials as long as sharpness is not lost. It is beneficial to take multiple photographs of the part in this manner in order to capture the cleanest, highest-quality contrast along the part's edge.

Example Photograph

The following was selected as the highest-quality source image after following these guidelines. In this example, the subject was laid on the floor and the photographer stood on a step-stool above. This resulted in a camera-to-part distance of approximately 8'. A diffuse LED light bar was held next to the camera lens. The maximum optical zoom was used without sacrificing the contrast between the part and the matte surface.

Manipulating The Photograph

Even when following the aforementioned guidelines while photographing the original part, certain errors will inevitably be introduced. These can be corrected using an image manipulation software such as Adobe Photoshop—a free, open-source alternative was used for the example in this guide.

Compensating For Perspective

Using the fiducials, slight skew in the source image can be corrected. This will compensate for minor distortion introduced when taking the photograph. It is still important that the photograph be taken from as perpendicular as possible to minimize how much of the edge is captured.

Rotating The Photograph

First, rotate the image in the image manipulation software so that the top two fiducials are aligned horizontally. Identify where the two top fiducials are located. In this example, this was done using the pixel coordinates of the center of each fiducial. Use the following formula to determine the rotation that should be applied:

$$\arctan\left(\frac{Y_2 - Y_1}{X_2 - X_1}\right) = \text{rotation}$$

Where X_1 and X_2 are the X coordinates of the two fiducials and Y_1 and Y_2 are their Y coordinates.

Correcting Distortion

Once this rotation is completed, use a cage-selection distortion tool to select all four fiducials. Note the new location of the top and bottom left fiducials. Use the following formula to determine the distance between the two:

$$\text{sqrt}\left((Y_{top} - Y_{bot})^2 + (X_{top} - X_{bot})^2\right) = \text{distance}$$

Then, drag the bottom left corner of the cage selection so that its X coordinate is equal to the top left and that the Y is equal to the distance calculated above.

Next, drag the bottom right corner so that its X coordinate is equal to that of the top right and its Y coordinate is equal to the new location of the bottom left.

Cage Selection Example

The location of each fiducial has been annotated on the following after rotation has been applied.

By following the procedure, it can be determined that the top left to bottom left distance is 1625 pixels. This means that the bottom left corner will be shifted to [1528, 2564]. Then, the bottom right should be shifted to [3558, 2564].
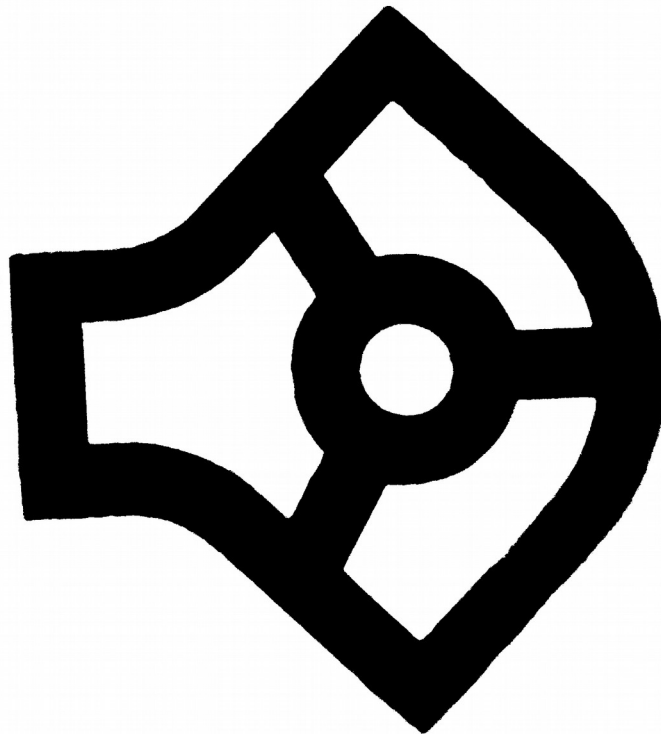
Creating A Silhouette

Next, use a Threshold filter to turn the photograph into white and black. Adjust the Threshold's value until the edge of the part is cleanly defined. There may be sections along the edge or in the interior that are not shaded correctly. This is expected and should be ignored in favor of accurately defining the majority of the edge. Now, use the Invert color tool to make the part black and the immediate surrounding white.

Cleaning And Cropping

To prepare the image for import to FlashCut CAD, use a Pencil or Line tool with a clean pixel edge to bridge any major inconsistencies along the edges of the silhouette. Then, use the Fill tool to remove any interior white spots that are not cutouts. Finally, crop the image so that only the part and a white background remain. Export the part as a high-quality bitmap-type file.

Example Silhouette

The following shows the image after these processes were applied. Additional cleaning was required on the lower right curve, as the part was naturally darker there. While this may have been filtered out when applying the Threshold, a lower Threshold value was used in the interest of maintaining the accuracy of the part's edges.

Import And Scale

Once a silhouette has been created, open FlashCut CNC and start a new 2D drawing.

Import Silhouette

Click the Image Import tool and select "Import Silhouette". Click the 'Browse' button on the parameter panel to the right, navigate to the location of the image, and open it. FlashCut will then import the file. A low Detail Level should usually be used in order to apply smoothing to the import. Arc Fitting may be used to further smooth and refine the import.

Example Import

The following shows the previously created silhouette mid-import as well as the final parameters that were used.
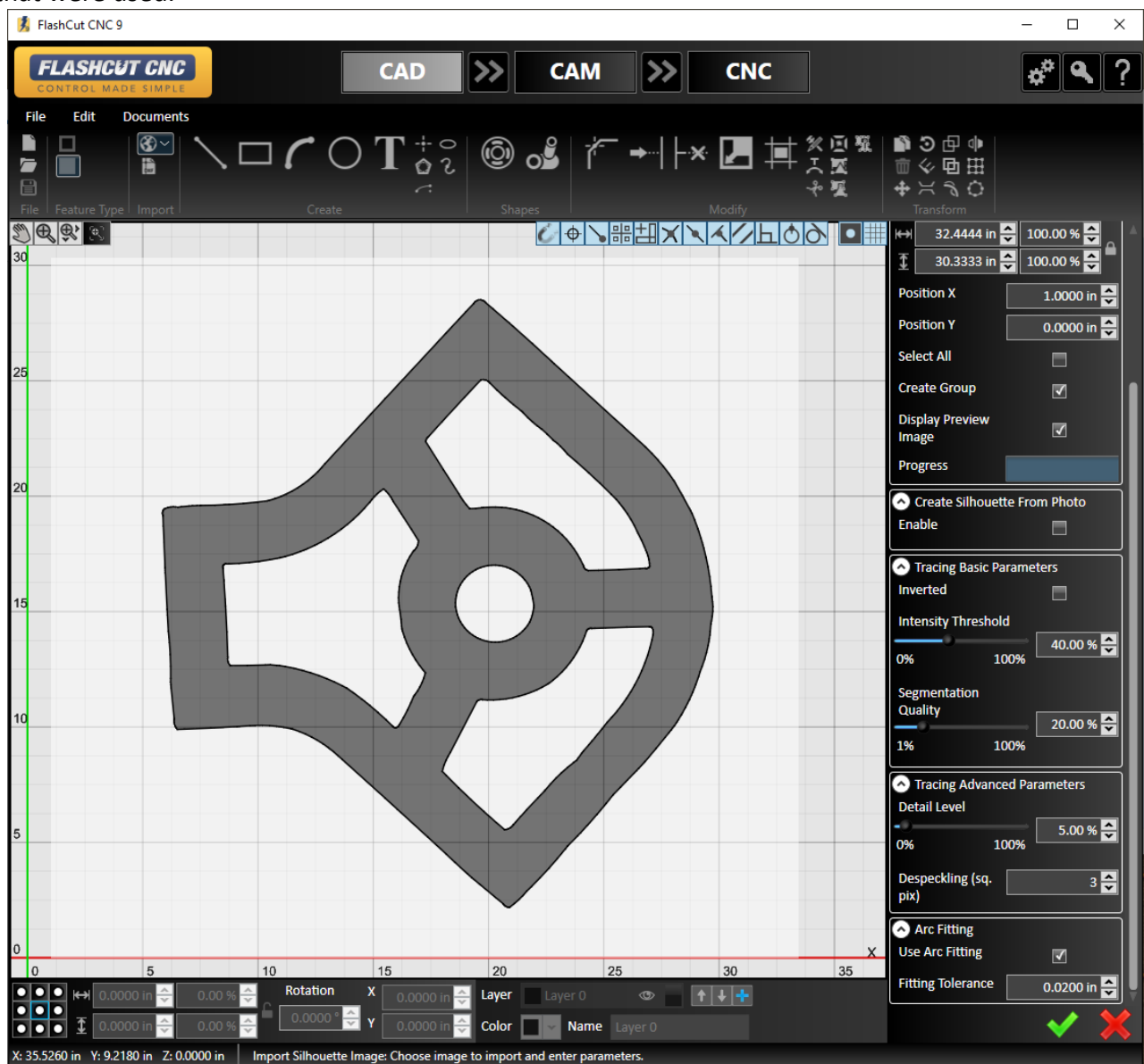
Scaling The Part

The final step to generating an accurate drawing from the original part is to ensure that the part is scaled correctly. This can be achieved by using a known measurement on the original part and comparing it with the results of using FlashCut's Measure tool. Then use the following formula to scale the entire part using either the quick manipulation panel at the bottom of the drawing or the dedicated Scale tool:

$$\frac{\text{Real measurement}}{\text{Software measurement}} \times 100\% = \text{Scale factor}$$
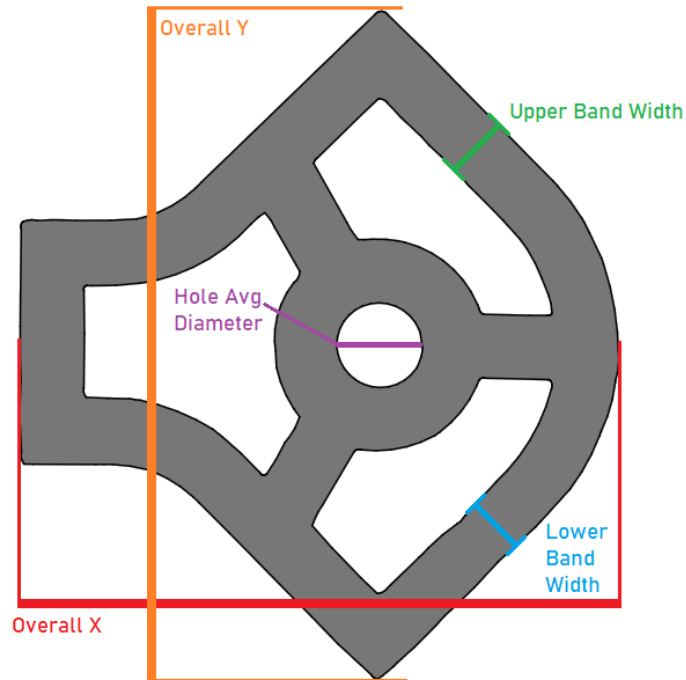
Example Scaling

The left-hand width of the original part in the example was measured as 2.003". Using this and the measured value in the software, a scaling factor of 20.77% should be applied.
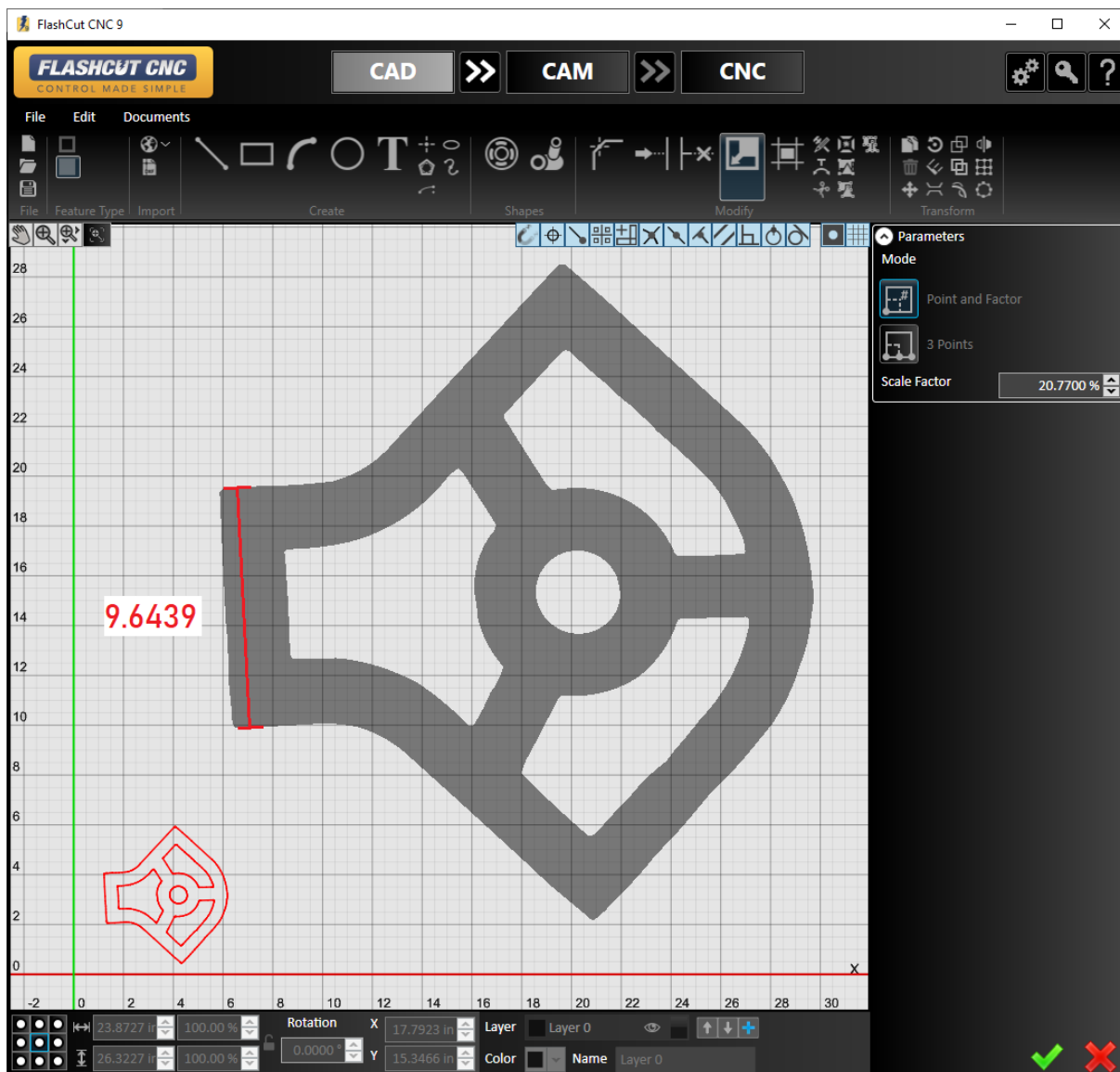
Appendix

Example Tolerances

	Original Part (in)	Duplicate Drawing (in)	Tolerance (in)	Tolerance (% original)
Overall X	4.9895	5.014	0.0245	100.491031
Overall Y	5.634	5.5836	-0.0504	99.1054313
Upper Band Width	0.514	0.5251	0.0111	102.159533
Lower Band Width	0.499	0.4993	0.0003	100.06012
Hole Avg Diam	0.7435	0.7287	-0.0148	98.0094149

Sample Fiducial Sheet