X-CARVE CNC CALIBRATION TEST PATTERN

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CALIBRATION TEST PATTERN DESCRIPTION

The X-Carve is an affordable hobby-sized CNC, with an accuracy of up to .003 inches (.075 millimeters) in all three dimensions under certain ideal conditions, including (but not limited to) the following:

- Adequate stiffening of X and Y axes
- Minimal runout of spindle or router
- Accurate measurement of milling bit diameter
- Appropriate settings for V-wheels, stepper motor potentiometers, and belt tension
- Proper settings of stepper motor steps per unit travel
- Spindle or router perpendicular to wasteboard

While an accuracy of .003 inches is not necessary for most hobby applications, each machine is unique and requires special calibration by the owner to obtain the desired level of accuracy. Additionally, harder materials such as metals require increased accuracy to keep from breaking bits.

This test pattern was developed to help users identify or troubleshoot specific problems common to hobby CNC machines, especially the X-Carve. These problems are loss of stepper motor steps, incorrect stepper motor calibration, and lack of perpendicularity between the spindle/router and wasteboard.

This test was designed for use with 1/2 inch thick medium density fiberboard (MDF). In order to ensure accurate measurements, the test material must have an equal material density in all directions. Materials with variations in density, such as wood with a grain structure or layered plywood, should not be used unless no other materials are necessary.

This test was also designed for use with a flat-bottom endmill with an approximate diameter of 1/8 inch. This size endmill will allow the user to take measurements on every outline cut and pocket using the depth rod on a typical dial or digital caliper.

The calibration pattern is available through Inventables' website Easel, in a project located at https://www.inventables.com/projects/calibration-test-pattern.

CALIBRATION TEST PATTERN MEASUREMENTS

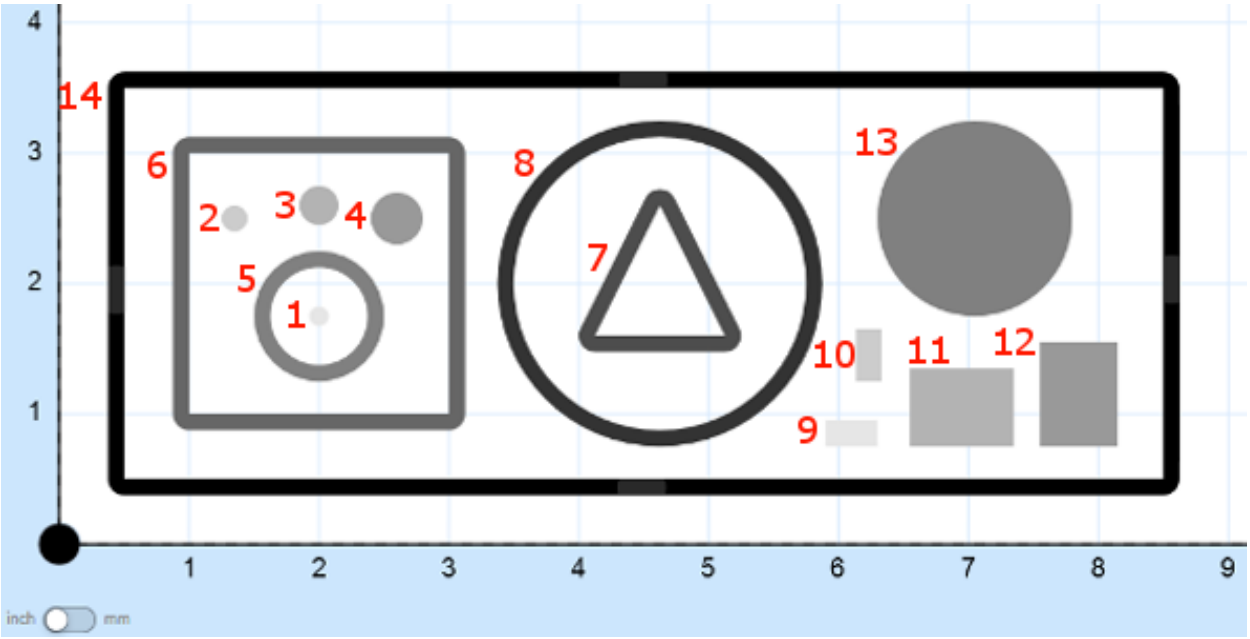

Figure 1 Calibration Test Pattern Map

Dimensions for each shape in the calibration test pattern map are provided below, and generic descriptions for each type of test are on the next page. When possible, depth and size measurements should be checked in multiple locations.

1. Circle pocket, .050" deep, .150" diameter. Examine for depth and circularity.
2. Circle pocket, .100" deep, .200" diameter. Examine for depth and circularity.
3. Circle pocket, .150" deep, .300" diameter. Examine for depth and circularity.
4. Circle pocket, .200" deep, .400" diameter. Examine for depth and circularity.
5. Circle outline, .250" deep, .750" diameter on inside of cut. Examine for depth and circularity.
6. Square outline, .300" deep, 2.000" square on inside of cut. Examine for depth and size.
7. Triangle outline, .350" deep, 1.000" wide on inside of cut, 1.000" high on inside of cut. Examine for depth and size.
8. Circle outline, .400" deep, 2.250" diameter on inside of cut. Examine for depth and circularity.
9. Rectangle pocket, .050" deep, .400" wide, .200" high. Examine for depth and size.
10. Rectangle pocket, .100" deep, .200" wide, .400" high. Examine for depth and size.
11. Rectangle pocket, .150" deep, .800" wide, .600" high. Examine for depth, size, and bottom quality.
12. Rectangle pocket, .200" deep, .600" wide, .800" high. Examine for depth, size, and bottom quality.
13. Circle pocket, .250" deep, 1.500" diameter. Examine for depth, circularity, and bottom quality.
14. Rectangle outline, .500" deep (full thickness), 8.000" wide, 3.000" high, with tabs in center of each side. Examine for size and edge quality.

CALIBRATION TEST PROCEDURE

*It is assumed that the user will be using calipers (dial or digital), and knows the proper method of use.

For maximum measurement accuracy, wipe dust off jaws and zero caliper before the first measurement and between every measurement using jaws.

This procedure should be performed in the order of numbered steps, and a new step should not be performed until the previous numbered step and its substeps have been completed. Substeps of a numbered step are primarily informational, and may be performed in any order desired.

1. Before performing calibration test, check the following:
    a. M3 bolts on belt pulleys are tight and seated in the center of the flat on the shaft.
    b. Belt tensions are set to desired tension setting.
    c. V-wheels are set to proper tightness.
2. Open calibration test pattern project Easel file located at https://www.inventables.com/projects/calibration-test-pattern.
3. Install and clamp down a piece of 1/2 inch MDF that is at least 9 inches wide and 4 inches tall.
    a. If material thickness is not .500 inches, change the cut depth of cut 14 to the full thickness of the material.
    b. If necessary, level the material by removing just enough material to ensure that it is perpendicular to the X and Y axes. Then change the cut depth of cut 14 to the full thickness of the material.
4. Measure 1/8 inch endmill diameter, change the bit size in the CNC program, and install in the spindle/router.
5. Home the center of the bit to the lower left corner of the material, or as appropriate to ensure the full pattern will be cut in the material without running the bit into the clamps.
6. Cut calibration test pattern using spindle/router speed, cut depth, and feed rate appropriate to the material.
7. Carefully remove calibration pattern test from the material to allow examination of the sides of cut 14. Take care not to scratch the sides of the piece when cutting through the tabs, and do not sand off or remove the tabs from the piece.
8. Remove dust and particles from all surfaces and cuts, preferably using a method that will not remove material (such as compressed air).
9. Perform measurements of individual shapes, and record data on data sheet.
    a. TO MEASURE DEPTH
        i. *Depth can only be accurately measured if a flat bottom endmill was used. If a ball bottom endmill was used, depths of outlines and pockets may not be accurate.*
        ii. Measure depth of pockets and outlines using depth rod on caliper. Perform and record multiple measurements to obtain an average cut depth that can be used to calibrate the steps per unit distance of the Z axis.

iii. If cut depths in a single cut are slightly different, the material may not have been level prior to testing.
iv. If the difference between the average and desired depth is scalable (i.e. a set value is either added or removed from every .100 inches), this is an indication that Z axis stepper motor calibration is required.
v. If the difference between the average and desired depth is NOT scalable, this may be an indication of lost steps in the Z axis stepper motor.

b. TO MEASURE SIZE
   i. Measure width and height of the inside of the square outline using lower jaws, and measure width and height of rectangular pockets using upper jaws. Perform and record multiple measurements to obtain average cut widths and heights that can be used to calibrate the steps per unit distance of the X and Y axes.
   ii. If the difference between the average and desired widths and/or heights are scalable (i.e. a set value is either added or removed from every .100 inches), this is an indication that X and/or Y axis stepper motor calibration is required.
   iii. If the difference between the average and desired widths and/or heights is NOT scalable, this may be an indication of lost steps in the stepper motors.
c. TO MEASURE CIRCULARITY
   i. Measure circular outlines using lower jaws and measure circular pockets using upper jaws. Measure all all around the circles to find the smallest (circular min) and largest measurements (circular max), and note where the min and max measurements are on the circle. It is useful to use a pencil to make these marks, and to note the location as if you were looking at a clock (e.g. circular min is located when measuring at 2 o'clock and 8 o'clock). Record measurements to obtain average diameter.
   ii. Large differences between the circular min and max indicate a circle is not truly round, and may be an indication of lost steps in the stepper motors.
d. TO CHECK BOTTOM QUALITY
   i. Examine the bottom of pockets with a bright handheld light and a magnifying glass and loupe. Visible and/or physical evidence of lines in the X or Y axes are an indication that the bottom of the endmill is not perpendicular to the material.
e. TO CHECK EDGE QUALITY
   i. Examine all four edge of calibration pattern cut 14 with a bright handheld light and a magnifying glass and loupe.
   ii. Visible and/or physical evidence of small horizontal lines along one side, but not the opposite, indicates the endmill is not perpendicular to the material.
   iii. Visible and/or physical evidence of vertical lines at the tabs may indicate a bent endmill, excessive runout of the spindle, and/or the endmill is not perpendicular to the material.

10. If lost steps are indicated, visit https://discuss.inventables.com/t/guide-offset-cutting-lost-steps-positioning-errors-etc/16084 for a useful guide to troubleshooting lost steps.
    a. Before performing stepper motor calibration, ensure there are no indications of lost steps. Reperform this calibration test if necessary.
11. If stepper motor calibration is indicated, calibrate the appropriate stepper motor(s). Useful video tutorials, including calibration of stepper motors, can be found at https://discuss.inventables.com/t/x-carve-maintenance-troubleshooting-videos-add-your-own/13405.
12. If there are indications that the endmill is not perpendicular, use a square to ensure the spindle/router mount is perpendicular to the wasteboard and add shims as necessary.
    a. An easy way to check perpendicularity is to use a large bit (3/4 inch or larger) to cut a 6 inch square pocket .050 inches deep. Lines in the X and Y directions will be more visible, allowing more accurate squaring of the spindle/router to the wasteboard.

CALIBRATION TEST DATA SHEET

Date Performed:_____

Endmill Used:_____

Material Used:_____

CIRCLES	DEPTH 1	DEPTH 2	DEPTH 3	CIRCULAR MIN	CIRCULAR MIN LOCATION	CIRCULAR MAX	CIRCULAR MIN LOCATION	BOTTOM QUALITY
1								
2								
3								
4								
5								
8								
13								

TRIANGLE	DEPTH 1	DEPTH 2	DEPTH 3	WIDTH	HEIGHT
7					

RECTANGLE/ SQUARE	DEPTH 1	DEPTH 2	DEPTH 3	DEPTH 4	WIDTH 1	WIDTH 2	HEIGHT 1	HEIGHT 2	BOTTOM QUALITY
6									
9									
10									
11									
12									
14									

NOTES:_____

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