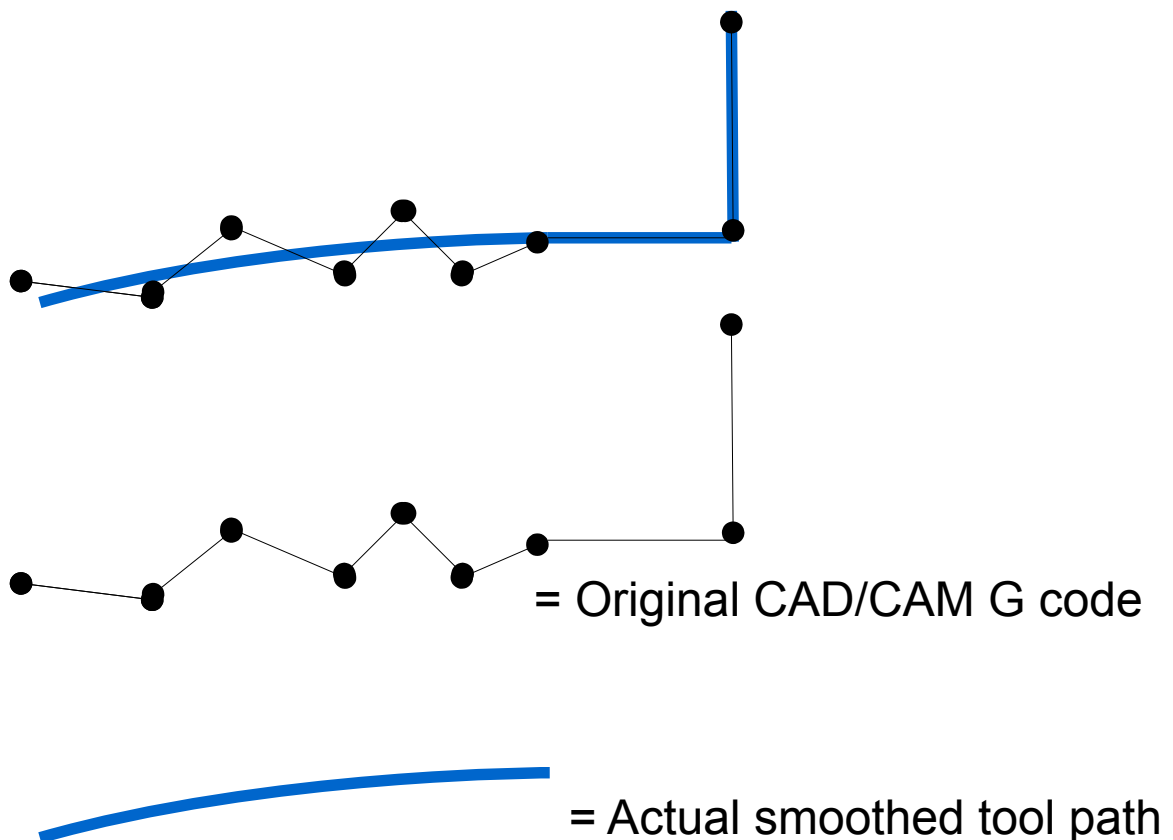


## Centroid Acorn CNC12 G-code Smoothing (AD2) User's Manual 9-30-19 rev5

**What is G-code smoothing?** G-code Smoothing (aka AD2) is an Accel decell algorithm that pre-processes G code and smooths out the G-code geometry ahead of time before handing off the moves to the Acorn. This allows fast, smooth tool motion at all speeds when running short vector G-code programs generated by CAD/CAM systems. The default accel decell algorithm known as AD1 executes the G-code as commanded with no smoothing or geometry manipulation. AD2 Smoothing was created to allow a CNC machine to run smoothly when running a G-code program that has lots of short vectors that may or may not be the best approximation of a curve. Believe it or not CAD/CAM system aren't perfect! And many of them and depending on the settings used put out ratty G-code especially when it comes to 3D work. If you zoom way in you will see the G-code position commands jumping around in lots of short vectors and not going in a nice smooth line or arc! Smoothing is best suited for high speed 2D contouring and all types of 3D surfacing programs generated by CAD/CAM systems, most machines will see big gains in performance in both speed and surface finish. Specifically, Milling machines cutting molds and CNC routers running high speed 2D contouring and 3D surfacing will see dramatic improvements in both feedrates and surface finish and overall time that it takes to machine the part. A machine tool will perform completely different running AD2 compared to AD1. AD2 works with all types of stepper motor and servo motors and drives.

**How does Smoothing work?** Simply said, Smoothing processes a G-code program and "looks" at the sharp jerky lines of G-code and lofts an arc through that data which then allows smooth continuous tool motion through that data by the machine tool. With the Smoothing Presets and the accompanying parameters outlined below, The user can control how big of a feature and how much rounding will be applied to the G-code tool path. These parameters allow fine control of AD2 Smoothing so that it is possible to squeeze every last bit of performance out of the machine tool and achieve the desired results. Below is one example of how Smoothing "corrects" bad CAD/CAM G-code. Notice that the large 90 degree feature is not effected, only the small ratty G code features are rounded.



AD2 will round only the small sharp features therefore "correcting" any poor quality CAD/CAM generated G-code while not effecting (no rounding of) the large features of the G code program. How large and how much rounding are all controllable with the AD2 parameter values.

## Types of G-code programs that work well with Smoothing.

3D surfacing and V Carve programs like this one below (by Scott aka “Sword”) benefit greatly with Smoothing check out his thread on the forum where he shares his Smoothing settings and strategy.

<https://centroidcncforum.com/viewtopic.php?f=57&t=3021>



### Smoothing Requirements:

- 1.) Steps per revolution must be set to 1600 or higher and **MATCH** the step setting on the drive. [Refer to this post.](#)
- 2.) Overall Turns Ratio must be set properly. [refer to TB#36](#)
- 3.) Backlash must be kept to a minimum, if lash is over .001” then do not use Backlash compensation (set it to zero) [refer to TB#37.](#)
- 4.) A CNC PC that at least [meet the minimum single core benchmark requirements.](#) Smoothing will not work on slow computers!

### How do I use smoothing?

The CNC12 Smoothing Setup menu. F1 Setup > F8 Smoothing Setup. Select a Smoothing Preset or Create your own. See pages 332 – 334 of the [Mill Operator manual](#) on how to use the Smoothing menu. When you turn on smoothing with a preset in the smoothing setup menu, Smoothing is ON all the time which may or may not be desired. To further control smoothing use G64 to turn on and off the Smoothing at any point in the G-code program. See the Mill operator manual page 221 for several examples of how to use G64.

WCS #1 (G54) Current Position (Inches) Job Name: NO\_JOB\_LOADED.cnc  
X +0.2029 Tool: T---H---  
Y -0.2696 Feedrate: 100% 0.0 ipm  
Z +0.6400 Spindle: 0 A

335 Emergency stop released  
406 Emergency stop detected  
335 Emergency stop released  
307 Operator abort: job cancelled

Press CYCLE START to start job

### Smoothing Setup Menu

Smoothing on/off: **ON** Smoothing is ON (P220) \*  
Slower Curves  Faster Curves Curve Feedrate Multiplier at 100% (P230)  
Round All  Sharpen All Angles up to 95 degrees will be sharpened (P227)  
Gentler Stops  Faster Stops Acceleration Multiplier at 100% (P231)

Quick Setups  
\* F4 Precision Router is selected

Exact Stop F1	Precision Mill F2	Contouring Mill F3	Precision Router F4	Contouring Router F5	Customize Presets F9	Save F10
---------------	-------------------	--------------------	---------------------	----------------------	----------------------	----------

## When not to use smoothing.

Typically Smoothing is not necessary for most all kinds of job shop type 2.5 D G-code work that uses large G1 lines and G2/3 arcs such as but no limited to, Circular pockets, Rectangular Pockets, All types of Drilling and Tapping, and Line and Arc milling (on a milling machine at speeds under 100 ipm) and Thread milling. Avoid having smoothing on during Drilling, Tapping, Threadmilling and Circular pocket finish passes as, by definition, Smoothing alters the geometry and can have unexpected results when using it when it is not necessary as these types of operations do not consist of lots of short vector moves therefore they don't need to be smoothed out.

## Using the stock Presets and Adjusting Smoothing values to make a custom Preset.

A standard set of default Smoothing AD2 Presets and corresponding values have been developed. Precision Mill, Contouring Mill, Precision Router and Contouring Router. These are a good starting place and work out of the box for most, most of the time. If you chose, you can adjust the Smoothing AD2 values for the type of performance you are looking for with a particular machine and type of G-code. For instance, you would not use the same set of AD2 values for a high speed 3D CNC router that is cutting foam compared to a VMC machining an injection die mold out of tool steel. These two jobs have different requirements and we can adjust Smoothing to meet them both.

## If you'd like to experiment with the Smoothing AD2 parameter values:

You can manually adjust the values in the CNC12 parameter configuration menu or use the slider bars in the Smoothing menu.

Smoothing on/off: OFF

Slower Curves Faster Curves

Round All Sharpen All

Gentler Stops Faster Stops

Smoothing is OFF, Exact Stop Curve Feedrate Multiplier Angles up to 95 degrees v Acceleration Multiplier at 1

Quick Setups

F1 Exact Stop is selected (No Smoothing)

Esc	Exact Stop F1	Precision Mill F2	Contouring Mill F3	Precision Router F4	Contouring Router F5	Customize Presets F9	Save F10
-----	------------------	----------------------	-----------------------	------------------------	-------------------------	-------------------------	-------------

And then save the settings as a custom preset which you can call out with the G64 within a G-code program or turn on globally using the Smoothing Setup menu above. Here is a G-code program outline below on how to use G64 within a G-code programmed

all gcode here that you don't want smoothing to be on

G64 ON (turns on Smoothing, uses the Values contained in Smoothing parameters)

or

G64 "my preset" will activate any saved Smoothing preset simply by using its name in quotes or by number.

Your gcode here that you want smoothing to be ON

G64 OFF turn off Smoothing

See Mill operators manual on page 334 for more information on G64.

**Typical AD2 Smoothing values for Precision Milling machine.** Where maximum accuracy *and* a little Gcode smoothing is desired.

Smoothing on/off	P220 set to 1 (turns on Smoothing globally, see G64 for how to turn on smoothing selectively)
Nbpts	P221 set to 1
Step	P222 set to .001" to .0005" inch, ~.0254mm- .0127mm (set to .001" for mold work)
Umax	P223 typical values are 800-1000 depending on CNC PC cpu performance.
Centripetal	P224 set to 0
W	P226 set to 10
Min Angle	P227 set to 95 (91 to 100, 95 is typical)
S curve	P228 set to 0 (turns off S-Curve acceleration)
Accell Multiplier	P231 = 1
Lash comp type	P216 set to 1 (turns on backlash compensation, make sure mechanical backlash is under .001")
Set Accel in PID screen	.25 to .35 for all axes.

**Typical AD2 Smoothing values for a Contouring Router perform Artwork** where maximum speed and smoothness are paramount and a little rounding of all sharp corners is not a concern.

Smoothing on/off selectively)	P220 = 1 (turns on Smoothing globally, see G64 for how to turn on smoothing selectively)
Nbpts	P221 = 20 (experiment with 1-20 results will depend on data)
Step	P222 = .01" (~.254 mm)
Umax	P223 typical values are 800-1000 depending on CNC PC cpu performance
Centripetal	P224 =0
W	P226 = 20
Min A	P227 = 1 (round all corners)
S curve	P228 = 0 (turns <i>off</i> S-Curve acceleration for routers)
Accell Multiplier	P231 = 1
Lash comp type	P216 set to 0 (turns off backlash compensation to increase smoothness)
Set Accel in PID screen	.5 for all axes.

Note: Accel values in PID work with AD2 as well. Increase for softer transitions from one straight line feedrate to another.

## Technical Background description of AD2 :

AD2 performs several related functions:

### 1. Smoothing NBPTS (P221) and STEP (P222)

These parameters control smoothing of the user supplied G-code. Smoothing allows significantly higher feedrates to be achieved while reducing vibration, bumps and bangs at corners and angles. It is also great for smoothing over a CAD-CAM generated data with peculiar features. See Fig 1. Smoothing's strength is also a potential disadvantage, it modifies geometry and rounds corners!. See Fig 2. When would you want to use smoothing? The user may want to run smoothly through rectangular Z movements created by "breakout tabs" on a router job. Smoothing will allow the job to run at high speed right through the breakout tabs, if the min angle P227 is set to less than 90 degrees.

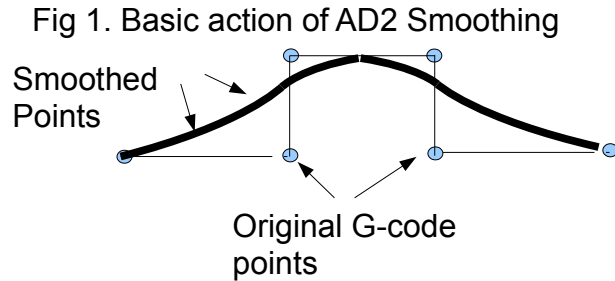


Fig. 2 Rule of thumb for estimating Smoothing tolerance  $\sim = (\text{NBPTS} * \text{STEP})/3$

Example: for NBPTS= 5 , and STEP= .001  
 $5 * .001 ; .005/3 \sim = .00167$  in Smoothing Tolerance

Gives an estimate of the smoothing tolerance  
When rounding a 90deg corner, assuming  
That the min angle P227 is less than 90deg

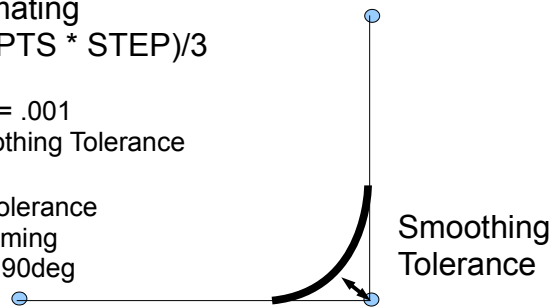
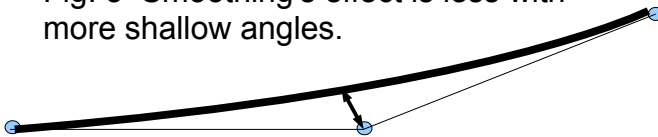


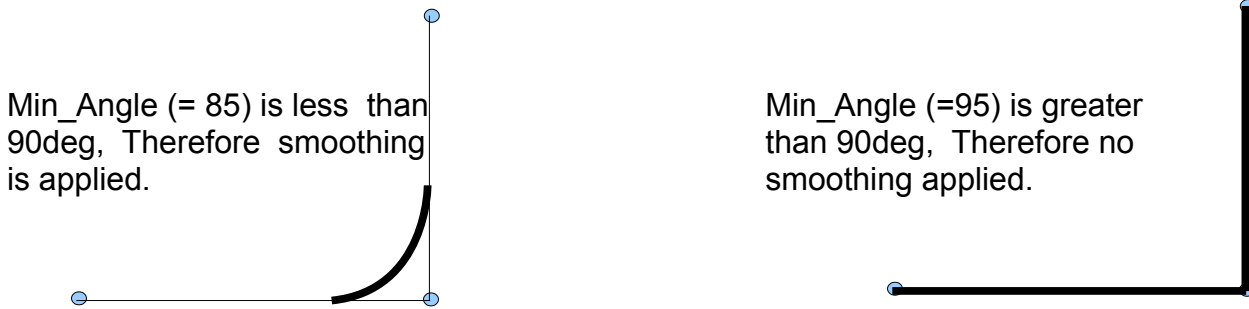
Fig. 3 Smoothing's effect is less with more shallow angles.





**Min\_Angle (P227)** defines the minimum angle to apply Smoothing to. All angles below the minimum angle will be sharp. For example if Min Angle is set to 95deg then all angles less than 95 right angle (including 90deg) corners will be sharp (not smoothed).

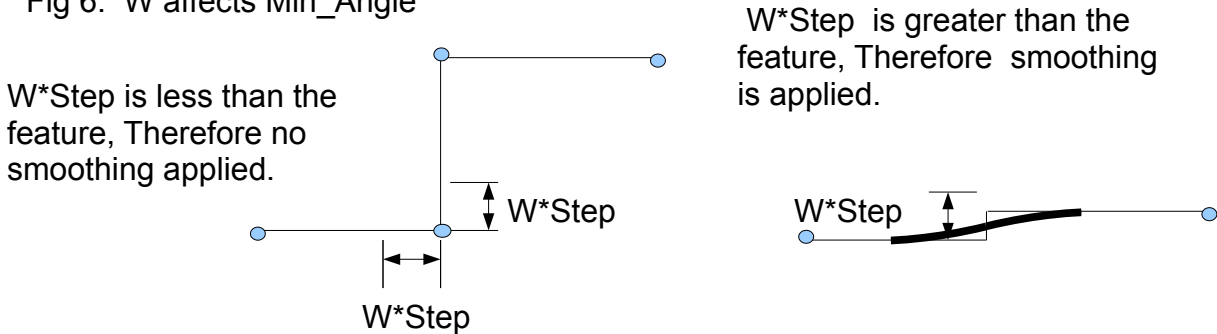
Fig. 5 Min\_Angle allows or inhibits smoothing



**Feature width W (P226)**

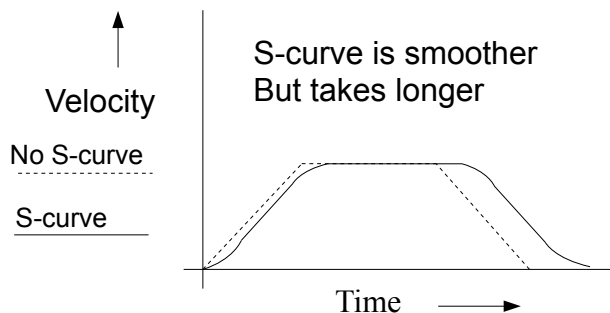
W and Min\_Angle work together to determine which angles will be "sharp" (not be smoothed). For example a G-code file may contain small spikes, double backs or zig zags of less 1mm that may be causing unwanted slowdowns in an otherwise high speed stretch of toolpath. Given a STEP (P222) = .25mm , setting W (P226)= 4 ( $4 \cdot .25=1\text{mm}$ ) should reduce or eliminate deceleration across the problem toolpath. W does not itself smooth the offending data, that's the job of Smoothing (controlled by NBpts and STEP), but W does allow you to minimize slowdowns caused by small features, which is very helpful for running smooth thru jagged CAD/CAM generated G code.

Fig 6. W affects Min\_Angle



**S curve (P228)** The S-curve feature changes acceleration rate more slowly. Its effect is most noticeable at direction changes. On a router where max speed is desired, turn S curve off. On a milling machine where max accuracy is desired turn S curve on, to eliminate as much vibration as possible

Fig. 7 S-curve



Smoothing AD2 Parameter Description	Typical Values	Parameter #
Turn the AD2 feature ON or OFF . If set to 0 the control uses Accel algorithm that we have been running for years.(AD1)	ON=1 OFF=0	220
<b>NBpts</b> the number of points in the smoothing filter ,the higher this value, the more rounded sharp corners will be made.	5-20 is typical for a router 5-10 for a milling machine	221
<b>STEP</b> Size of the smallest vector to process, use rule of thumb: Max smoothing error = (Nbpts*STEP)/3. AD2 breaks up a G code program to this vector size.	Router = 0.01" ~ .25mm Milling machine = .001" ~.025mm	222
<b>Umax</b> Sustained safe throughput rate going to the Acorn. CNC PC must meet <a href="#">single core min. requirements.</a>	600-1000 depending on CNC PC CPU single core performance	223
<b>Centripetal</b> control options. Centripetal control options: This bitfield parameter controls the Centripetal stage of the Smoothing module. Value 0 (default) makes Centripetal operate on all axes and dis-ables excessive axis accel checking. Values 1 and 3 (bit 0 = 1) limits Centripetal to only linear axes. Values 2 and 3 (bit 1 = 1) enables excessive axis accel checking		224
<b>W:</b> Feature Width over which the Min Angle is determined. Ten has turned out to be good universal value for all machines.	Routers and Mills Typically 10 Sometimes data dependant Experiment with values 1-10	226
<b>Min_Angle:</b> Minimum angle to smooth in degrees,60 to 85 will give rounded right angles (60 rounds more 85 less) , 95 to 100 will give crisp right angles. (60-85) will round sharp corners for fast smooth movement thru a corner when a little rounding of the tool path is not a concern and speed is (such as a router) OR it will give a sharp corners when accuracy is most important. (milling machine)	Routers= 60- 85 (rounded corners) Milling machines= 95-100 (sharp corners)	227
<b>S curve</b> Accel / decell Off for routers, on for milling machines. S curve is a more controlled way to change directions. On a router where max speed is desired, turn S curve off. On a milling machine where max accuracy is desired turn S curve on but at this point on a miling machine you may not want to be using smoothing at all if you are trying to hold super true to the geometry.	0=Off, 1= ON recommended setting is =0 Off!	228
<b>Backplot/Smoothing Mode:</b> Smoothing may slow down the display of Backplot Graph-ics. This parameter allows a faster backplot by not showing Smoothing. Note: It is useful to use Backplot and zoom way in to see the effect of the smoothing settings on the geometry before running the job. Experiment with this program a 90 degree angle g code move , turn on smoothing set 229 = 1 and take a look at the backplot of the tool path you will notice the rounding of the corner, adjust smoothing parameters and plot again to see the differences.	0 = Faster Backplot, smoothing may be active but is not shown in the backplot. 1 = Slower Backplot, but smoothing effects are visable on the backplot.	229
<b>Curve Feedrate Multiplier:</b> Reducing this value below 1.0 will cause the machine to move slower around curves and corners, minimizing "bangs" and overshoots. Increasing this value above 1.0 may allow you to run your machine faster if the feedrates in arcs and corners are still satisfactory.	1 (default value) 0.1 to 5.0 (Depending on user's preference for speed vs "bangs" and overshoots)	230
<b>Acceleration Multiplier:</b> This parameter allows you to adjust the overall acceleration /deceleration rate as a means to reduce machine vibration, and noise during starting, stopping and feedrate changes. Reducing this value be-low 1.0 will cause more gentle accelerations and decelerations. Increasing this value above 1.0 will cause faster accelerations / decelerations.	1.0 (default value) 0.5 to 1.5 (Depending on user's preference for quickness of accelerations / decelerations)	231
<b>Lash Type</b> , users have a choice for backlash compensation to occur in the PC or in the MPU11 card itself. This is a new feature and is still under testing, use pc side comp for now. PC side comp is what we've been using for years.	PC Side =1 , MPU11 Side =0	216