Centroid CNC12 G-code Smoothing (AD2) User's Manual 12-12-24 rev9

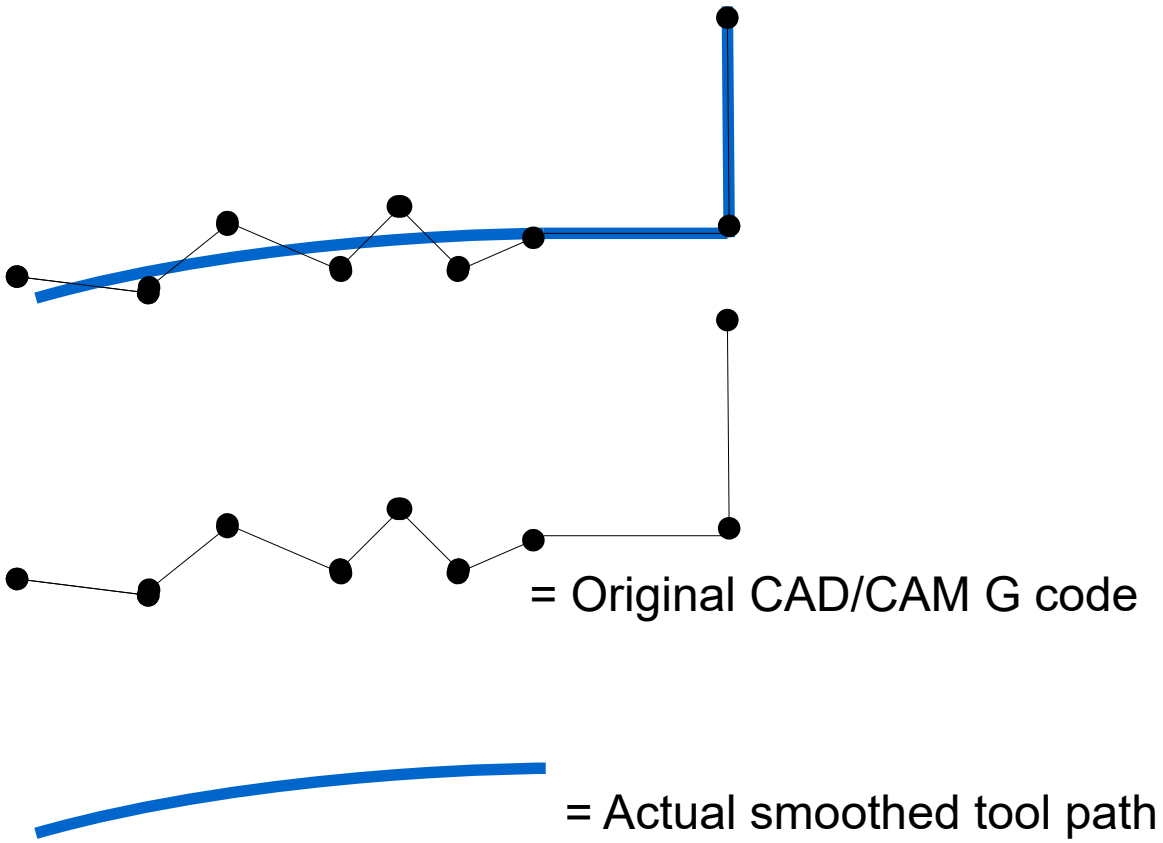
What is G-code smoothing? G-code Smoothing is a Centroid CNC control feature that pre-processes G-code and smooths out the G-code geometry before handing off the machine tool position moves to the Acorn/AcornSix/Hickory/Oak/Allin1DC/MPU11 cnc controllers. Smoothing as the name implies results in fast, smooth tool motion even when running short vector G-code programs generated by CAD/CAM systems.

To understand why smoothing is a useful tool lets first understand the default cnc control accel decel algorithm known as AD1. AD1 cnc motion executes the G-code exactly as commanded with no smoothing or geometry manipulation. Said another way the controller will move exactly the way the G code tells it to for better or worse. Garbage in garbage out. If you have “good” G code AD1 works well. If you have short vector g code that jumps all over the place while trying to approximate a curve, AD1 will move exactly as the g-code is commanding it to.

Centroid Smoothing is best suited for high speed 2D contouring (such as Adaptive Machining) 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. “Smoothing” aka “AD2” 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 are not perfect and don’t always produce nice smooth g code! Depending on the settings used most any CAD/CAM system can and will put out “ratty” G-code (especially when it comes to 3D work). How do you know if the CAD/CAM system is putting out ‘ratty’ short vectors? Zoom way in or open the G code file in an editor and observe the vector length and position end points 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!

Specifically, Milling machines cutting molds and CNC Routers running high speed 2D contouring and 3D surfacing Artwork and Plasma machines will see dramatic improvements in cutting performance, surface finish and overall time that it takes to machine the part. A machine tool will be perform completely different running AD2 compared to AD1. AD2 works with all types of axis stepper motors, servo motors and drives but the machine mechanical and electronic must be optimized as well to make use of Centroid’s G code smoothing. Smoothing will not compensate for a poorly designed or configured CNC machine tool.

How does Smoothing work? Simply said, Smoothing pre-processes a G-code program and “looks” at the sharp jerky lines of the G-code and lofts an arc(s) through that data. The Arcs then allows smooth continuous tool machine motion through that data. With the Smoothing Presets and the accompanying parameters outlined below, The user can control how big of a feature and how much arc 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 user controllable with the AD2 parameter values.

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

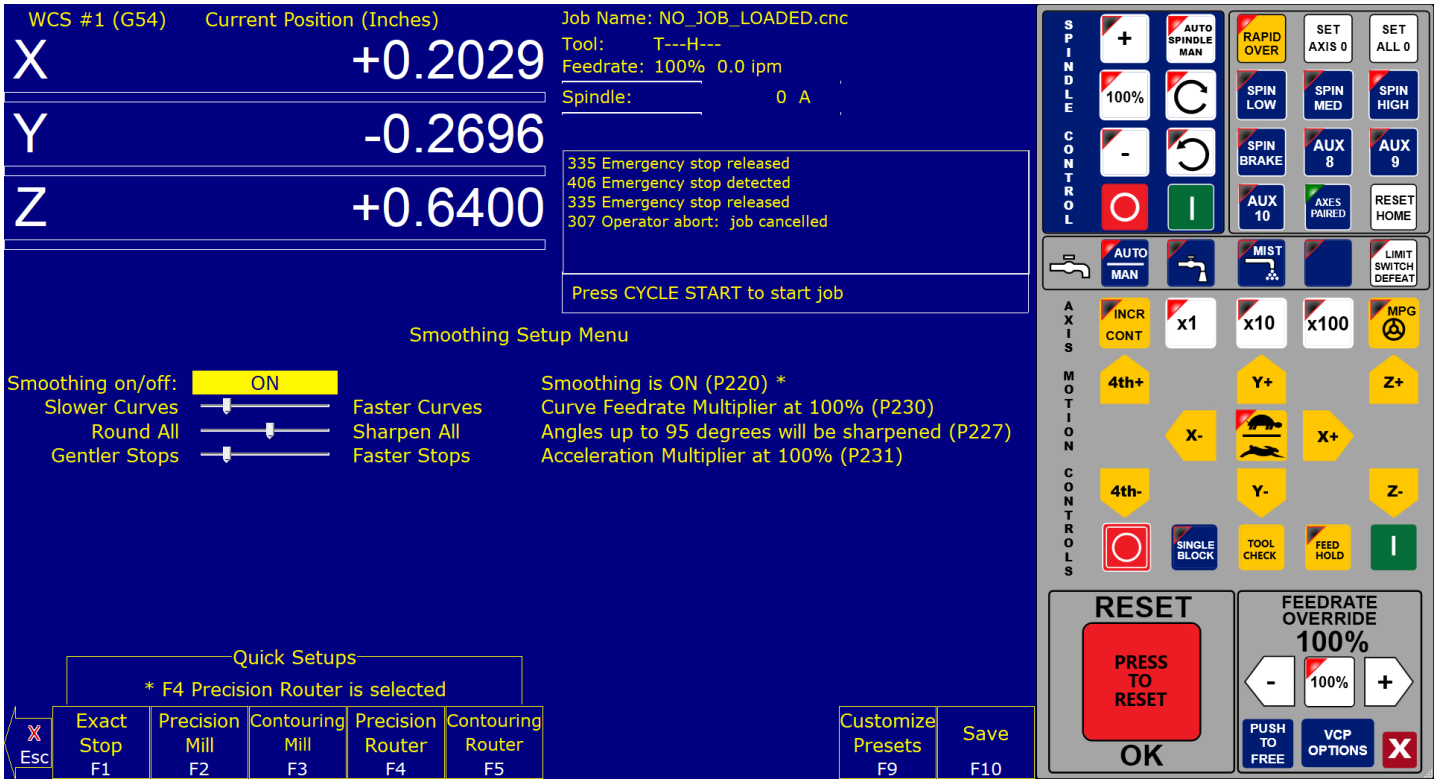
3D surfacing and V Carve programs like this one below (by Scott aka “Sword”) benefit greatly with Smoothing check out his thread on the forum where he shares his Smoothing settings and strategy.
https://centroidcncforum.com/viewtopic.php?f=57&t=3021

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.

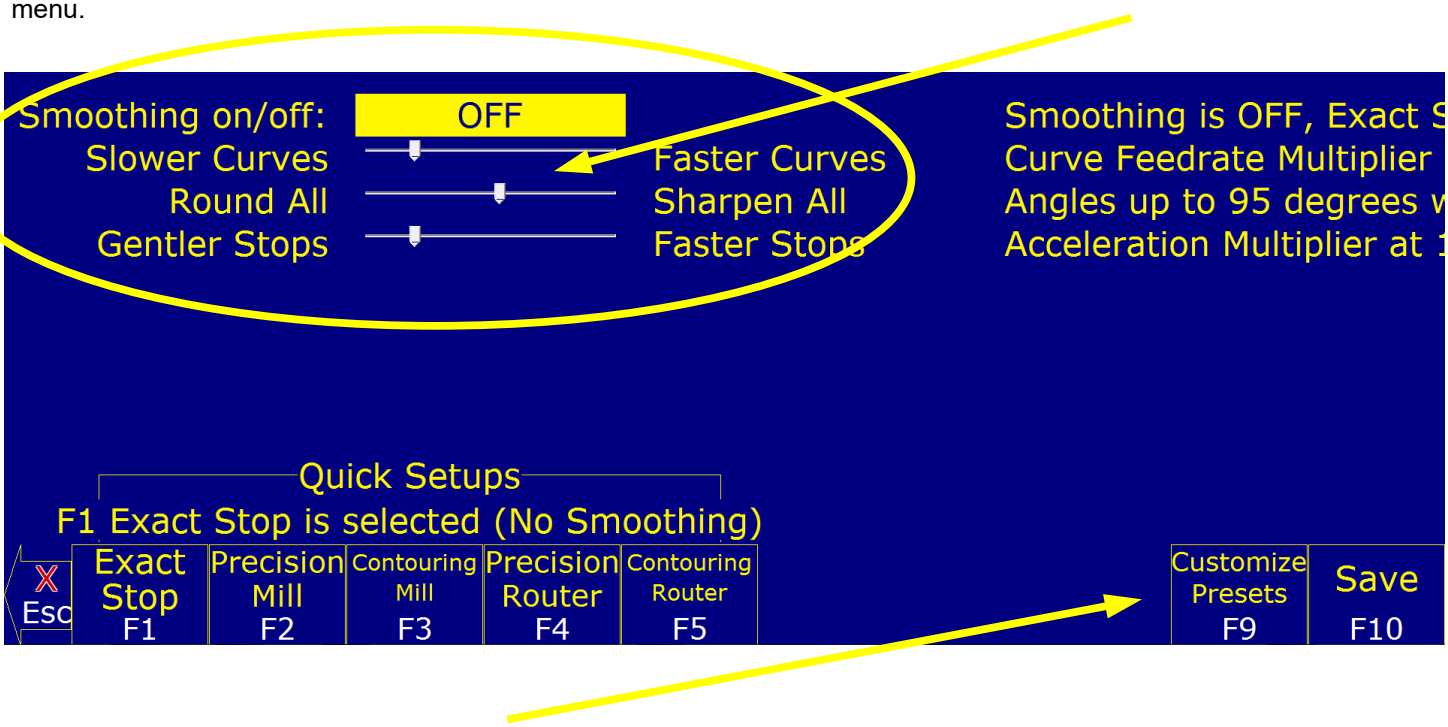


Using the stock Presets and Adjusting Smoothing values to make a custom Preset.

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.



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 belwo 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.

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.

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)
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	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)
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 1. Basic action of AD2 Smoothing

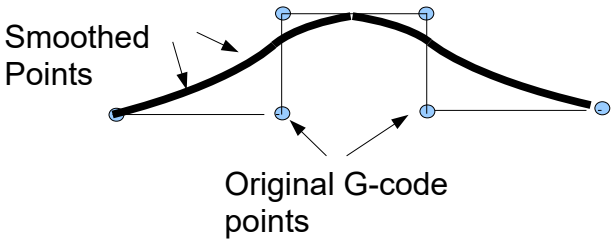


Fig. 2 Rule of thumb for estimating
Smoothing tolerance ~= (NBPTS * STEP)/3

Example: for NBPTS= 5 , and STEP= .001
5 X .001 ; .005/3 ~= .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

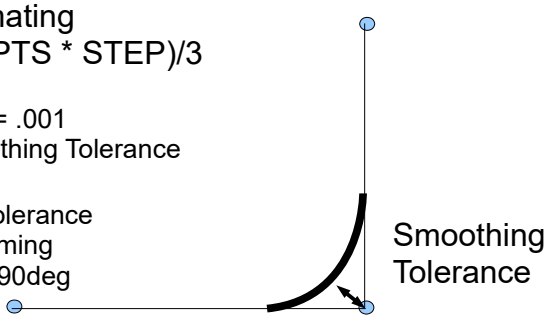
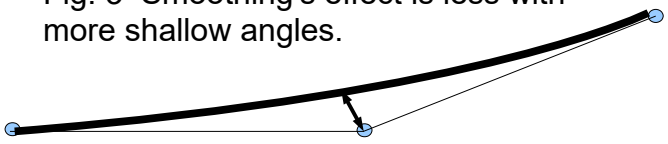
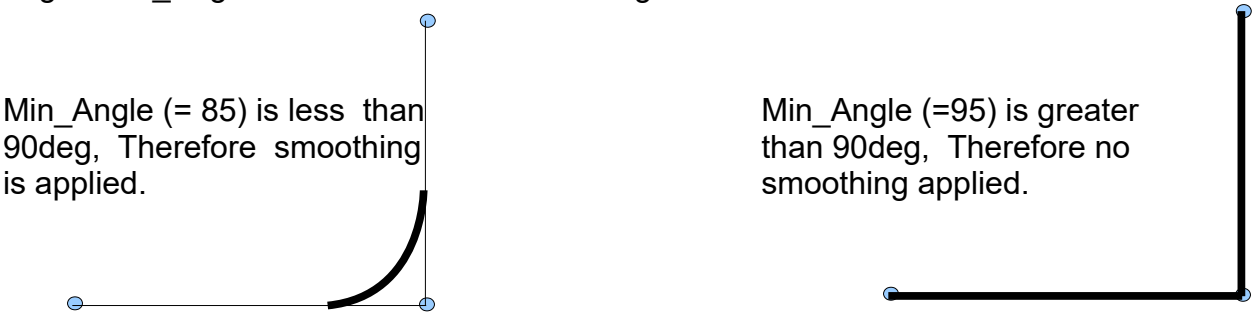


Fig. 3 Smoothing's effect is less with more shallow angles.



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).

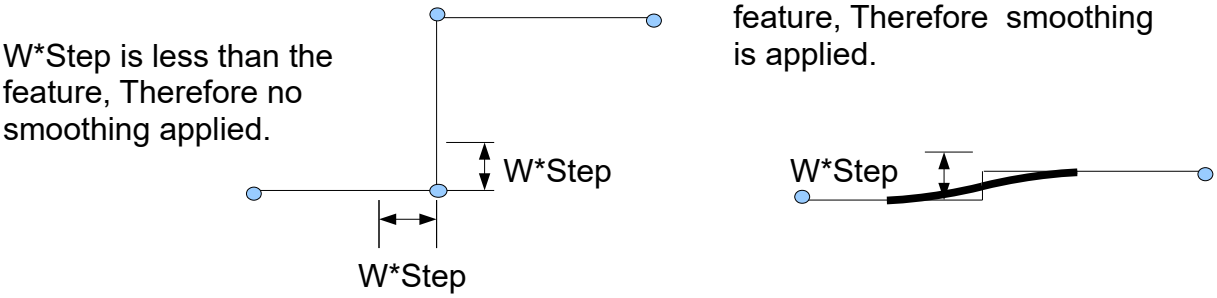
Fig. 5 Min_Angle allows or inhibits smoothing



Feature width W (P226)

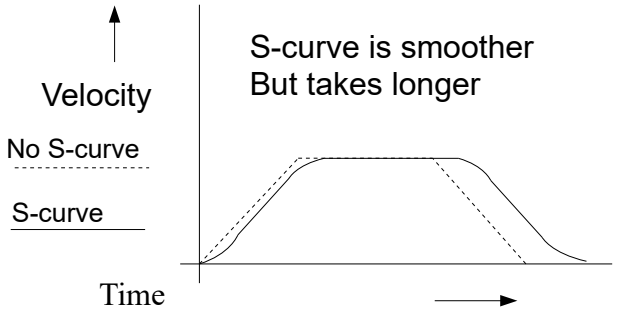
W and Min_Angle work together to determine which angles will be "sharp" (not be smoothed). For example a G-code file may contain small spikes, double backs or zig zags of less 1mm that may be causing unwanted slowdowns in an otherwise high speed stretch of toolpath. Given a STEP (P222) = .25mm , setting W (P226)= 4 (4*.25=1mm) 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) Experimental! Usually not needed since AD2 is rounding the geometry. This is an experimental parameter which will allow you to force S-curve accel/decel onto the new rounded AD2 geometry. The S-curve feature changes acceleration rate more slowly, softer. 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 maintain maximum accuracy while using AD2 Smoothing. Changes in motion will most likely only be apparent on abrupt (180) type direction changes. Note: This P228 S-curve is a sinusoidal S-curve and is not the same S curve used in AD1 (G64 OFF).

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
NBpts 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
STEP 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
Umax Sustained safe throughput rate going to the Acorn. CNC PC must meet single core min. requirements.	600-1000 depending on CNC PC CPU single core performance	223
Centripetal 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
W: 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 Somtimes data dependant Experiment with values 1-10	226
Min_Angle: 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
Sinusoidal S curve accel/decel: Force S curve on the AD2 calculated geometry. S curve is a softer way to change directions. For the case of a CNC router where max speed is desired, turn S curve OFF let AD2 determine whats best. On a milling machine where max accuracy is desired WHILE using AD2 turn S curve ON but, at this point on a milling machine you may not want to be using smoothing at all if you are trying to hold super true to the geometry! P228 is not to be confused with AD1 S curve acel/decel. P228 is used to force AD2 to apply a sinusoidal S curve at the junctions of the AD2 generated smooth geometry. Experimental, this parameter can also be applied in fractional amounts. So .1, .5, .75 are also valid values. Where .5 would be applying half S curve to the acel decel rate that AD2 calculates for the new smooth geometry tool path.	0=Off, 1= ON recommended setting is =0 OFF as this is an experimental parameter.	228

Backplot/Smoothing Mode: Smoothing may slow down the display of Backplot Graphics. 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 visible on the backplot.	229
Curve Feedrate Multiplier: 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
Acceleration Multiplier: 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
Lash Type , 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