

# **FLASHCUT CNC**

CONTROL MADE SIMPLE

## **Servo Drive Tuning Quickstart Guide**



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## Getting Started

### *About This Manual*

FlashCut 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 FlashCut 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.

FlashCut CNC, 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. FlashCut CNC supplies this product but has no control over how it is installed or used. Always be careful!

FlashCut CNC, 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.

## Tuning and Commutation

Once connected to a drive through ServoWare, manual drive tuning can be performed. Drive tuning is a multi-step process that involves proper tuning of three different servo loops. This section shows how to tune a Brushless DC servo motor equipped with hall sensors and an incremental encoder. Three servo loops will be tuned, as follows: Current, Velocity and Position.



**Before tuning, the drive MUST have the appropriate motor parameters and limits configured.**

**1. Current Loop Tuning:** Once the drive parameters are configured properly, the current loop must be tuned. You can select to have the current loop gains calculated based on motor data. This will typically provide a good starting point although some applications may require further refinement of the tuning parameters. If you calculate the current loop gains, it is recommended that you verify the operation at currents throughout the motor's operating range.

**2. AutoCommutation™:** This routine collects data on the motor and feedback parameters and prompts the user to verify that they match what is entered into the Motor Data page.

The motor MUST be free of mechanical load during auto-commutation.

**3. Velocity Loop Tuning:** A very tight current loop inside of a relatively tight velocity loop may cause audible noise. If maximum bandwidth is not necessary, de-tuning the current loop usually removes most of the audible noise. The velocity loop will have to be adjusted any time the current loop tuning is changed.

**4. Position Loop Tuning:** For the best positional accuracy, the position loop will be tuned around the velocity loop.

## Current Loop Tuning



**Make sure that the motor is free to move and decoupled from the load, as sudden motion may occur.**

### Inputs/Outputs Configuration Setup

Configure the User Disable function for proper operation in the system. (Set User Input 1 to General Purpose, Active Low with User Disable, Reset Events and Set Position functions).

### Waveform Generator Setup

1. Open the Scope/Tuning tab by clicking on the 'Scope/Tuning' icon  from the toolbar.
2. In the Waveform Generator pane, select the waveform Target as Current Loop.
3. Select the Square waveform Type.
4. Set Frequency (Freq) to 100 Hz. If your motor has low inertia and is very responsive, use 150 Hz or 200 Hz.
5. Ensure Offset is zero.
6. Ensure Symmetry (Sym) is 50%.
7. Set the waveform Amplitude (Ampl) to an appropriate value. Begin with 10% of the drive continuous current rating or 50% of the motor continuous current rating, whichever is lower.
8. Click the 'ON' button to turn on the Waveform Generator.

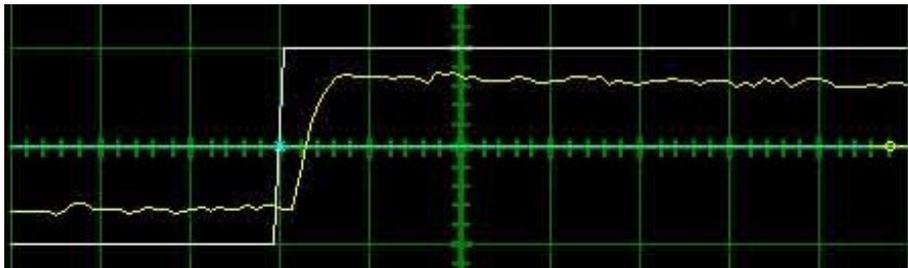
### Oscilloscope Setup

Select the Current oscilloscope preset from the Presets drop-down menu in the Scope/ Tuning tab or manually configure the settings by following the steps below:

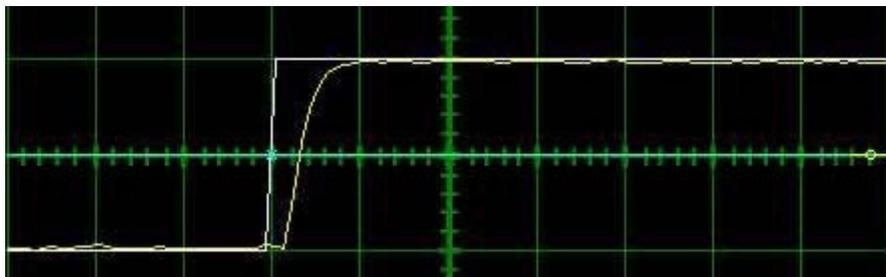
1. Change the channel 1 signal to Current Target.
2. Change the channel 2 signal to Current Measured.
3. Change the Trigger Source to Current Target with the Level set to zero.
4. Ensure Trigger Mode is Normal.
5. Change Time/Div to either 1 msec or 500 usec.

## Tuning

1. With the Scope/Tuning window still open, select "Tuning....Current" Loop Gains from the System Browser.
2. To set starting values for the Current (Torque) Loop proportional ( $K_p$ ) and integral ( $K_i$ ) gains, click the Calculate button to calculate gains that utilize the values entered into the Motor Parameters, Feedback and Limits windows. The specified motor inductance, resistance and bus voltage determine the accuracy of the calculated values.
3. Enable the drive by clicking the Enable icon. The motor should emit an audible noise but remain still.
4. Proper current loop tuning starts with zero integral gain while increasing the proportional gain until a 'knee' is formed (with no overshoot) in the Current Measured trace.



5. At this point, the proportional gain is done and the Integral gain must be slowly increased to close the steady state error between the Current Target and Current Measured traces.



6. Tuning changes with signal amplitude. You should now re-adjust the current amplitude in the Waveform Generator tab according to your most common application current requirements and re-tune. Contouring applications generally use small signal transients while point-to-point applications use larger signal transients.
7. When current loop gain adjustments are complete, disable the drive.
8. Turn off the Waveform Generator to remove the command signal from the drive by clicking the 'OFF' button in the Waveform Generator pane.
9. Click 'Store' on the toolbar to store the parameters to the drive's nonvolatile memory.

## Commutation

Commutation of a servo motor is the process that maintains an optimal angle between the permanent magnet field and the electromagnetic field created by the motor current(s). This process ensures optimal torque or force generation at any motor position—regardless of speed—for brushless motors.

Most applications use the AutoCommutation routine for configuring a drive to a specific motor. This routine will detect the feedback devices attached to the motor and ask the user to verify them against the motor's datasheet.

### AutoCommutation™



#### ***Before you run AutoCommutation, be sure you:***

- **Enter in the correct motor information in the Motor window page.**
- **Specify the correct feedback information.**
- **Specify limits to protect the motor.**
- **Tune the current loop.**
- **Decouple the motor from any load and secure the motor. Sudden motion will occur!**

1. In Motor > Parameters, ensure that Sinusoidal Commutation is selected in the Commutation section of the window.
2. Open the AutoCommutation window ('Motor....AutoComm').
3. Enable the drive if it is not enabled.
4. Click 'Start AutoCommutation' to begin the process. Observe the motion traveled.
5. Rotary motors should turn 2.25 revolutions in each direction.
6. When AutoCommutation is complete, select whether the motor has moved the proper distance or has not moved the proper distance. If the motor did not rotate as expected, verify the motor parameters.
7. Once the motor has properly completed the AutoCommutation routine, verify the proper commutation and synchronization settings:
  - **Commutation:** It is recommended to select trapezoidal commutation. This will allow another motor of the same model to be connected to a drive and be used without performing the AutoCommutation procedure again.
    - **Trapezoidal:** The drive uses Hall Sensors to commutate trapezoidally.
  - **Synchronization:** It is recommended that None be selected.
    - **None:** No synchronization is performed.
8. Click 'Apply' from the toolbar to save the AutoCommutation parameters.

9. Click the 'Store' icon to store parameters to non-volatile memory.

### **AutoCommutation™ Warnings**

After running AutoCommutation, warnings may appear due to wiring errors or discrepancies between the information on the "Motor Data" page and the results of AutoCommutation.

Review the results and highlight any differences between what AutoCommutation detected and what was configured in the "Motor Parameters".

## Velocity Loop Tuning

Tuning of the velocity loop should only be performed after current loop tuning and motor commutation. Velocity loop tuning is dependent on the mechanical load, and therefore will change with any mechanical system changes. Velocity loop tuning should be performed with the motor installed in the system and connected to the load. Make sure that the load is free to move as sudden motion may occur. For velocity loop tuning, the 'Loop Configuration' setting in the active Configuration must be set to either Velocity or Position around Velocity.

It is recommended to disable the drive by clicking on the 'Disable' icon on the toolbar before beginning tuning. The procedure below will prompt you to enable the drive when necessary for tuning.

### Waveform Generator Setup

1. Open the Scope/Tuning tab by clicking on the 'Scope/Tuning' icon  from the toolbar.
2. Select the waveform Target as Velocity Loop.
3. Select the Square waveform Type.
4. Set Frequency to around 1-3 Hz. The frequency should be slow enough to achieve commanded velocity, but fast enough to prevent the system from reaching a mechanical limit.
5. Ensure Offset is zero.
6. Ensure Symmetry is 50%.
7. Set the waveform Amplitude to approximately 10% of motor nominal speed.
8. Click the 'ON' button to turn on the Waveform Generator.

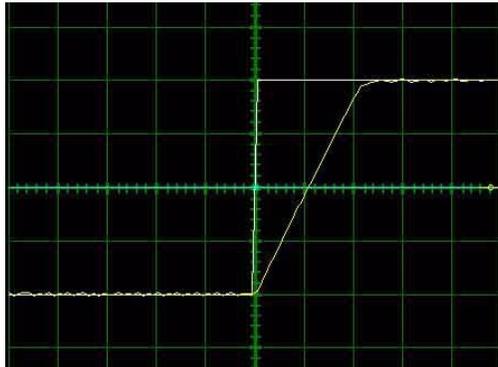
### Oscilloscope Setup

Select the Velocity Scope Preset or manually configure the settings by following the steps below:

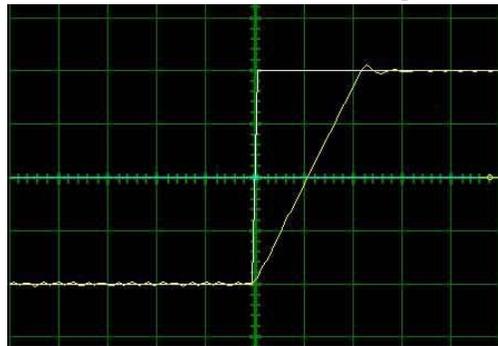
1. Change the channel 1 signal to Velocity Target.
2. Change the channel 2 signal to Velocity Measured.
3. Change the Trigger Source to Velocity Target with the Level set to zero.
4. Ensure Trigger Mode is Normal.
5. Change Time/Div to 10-20msec. The Scale on the display will need to be adjusted accordingly for each trace.

## Tuning

1. With the Scope/Tuning tab still open, select either "Tuning....Gain Set 0" or "...Gain Set 1" from the System Browser depending on which Gain Set is currently used for the active Configuration.
2. Begin by setting all the velocity loop gains to zero (Kp-Proportional, Ki-Integral, Kd-Derivative, Aff-Feedforward).
3. Enable the drive by clicking the 'Enable' icon.
4. Proper Velocity loop tuning starts with zero integral gain while increasing the proportional gain until a "knee" is formed (with no overshoot) in the Velocity Measured trace, as shown below. There may or may not be an error between the Target and Measured traces; the key is to have a smooth knee shape.



5. At this point, the proportional gain is left alone and the integral gain is increased slowly until the "knee" begins to deform as shown below. It's okay if the waveform does not start to distort until the integral gain is very high. When the distortion occurs, back off the Integral gain until the knee becomes smooth again.



6. Next, in order to improve the smoothness of the response, it may be beneficial to adjust the velocity feedback filter cutoff frequency in the "Tuning....Filters" window. The Filter Frequency is used to dampen oscillations and noise in the velocity measurements. For most systems, the ideal cutoff frequency will be somewhere between 50Hz and 1500Hz.
7. Most systems will be tuned properly at this point. If your system requires fine-tuning, you may adjust the derivative and feed-forward gains. If the motor starts to make audible noise, increase the Low Speed Smoothing in the Loop Filters window until the vibration and noise stops.

8. When tuning is complete, disable the drive by clicking the 'Disable' icon on the toolbar. Turn off the Waveform Generator by clicking the 'OFF' button in the waveform generator pane.
9. Click 'Store' on the toolbar to store the parameters to the drive's nonvolatile memory.

## Position Loop Tuning

Position loop tuning is dependent on the mechanical load and therefore will change with any mechanical system changes. Position loop tuning should be performed with the motor installed in the system.



**It is recommended to disable the drive by clicking on the 'Disable' icon on the toolbar before beginning tuning. The procedure below will prompt you to enable the drive when necessary for tuning.**

### Waveform Generator Setup

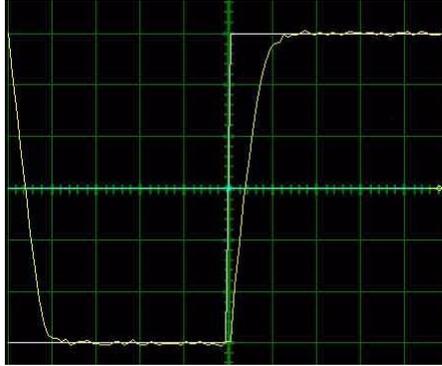
1. Open the Scope/Tuning tab by clicking on the Scope/Tuning icon  from the toolbar.
2. Select Position Loop as the waveform Target.
3. Select the Square waveform Type.
4. Set Frequency to around 1-3 Hz. The Frequency should be slow enough to allow the motor to settle in position.
5. Set Offset to zero.
6. Ensure Symmetry is 50%.
7. Leave the Amplitude at zero for the moment.
8. Click the ON button to turn on the Waveform Generator

### Oscilloscope Setup

Select the Position Scope Preset or manually configure the settings by following the steps below:

1. Change the channel 1 signal to Position Target.
2. Change the channel 2 signal to Position Measured.
3. Change the Trigger Source to Position Target with the Level set to zero.
4. Ensure Trigger Mode is Normal.
5. Change Time/Div to 20-50 msec. The Scale on the display will need to be adjusted accordingly for each trace.

## Tuning



1. With the Scope/Tuning window still open, select "Tuning....Gain Set 0".
2. In the Gain Set tab, set all gains to zero (Kp-Proportional, Ki-Integral, Kd-Derivative, Vff-Velocity Feedforward, and Aff-Acceleration Feedforward).
3. The Set Position function is used to set the measured and target position to the value defined in the Preset Position field. It is recommended to set the Preset Position to zero before beginning tuning to avoid any unexpected jumps when the drive is enabled. Enter "0" in the Preset Position field and then click the Set button.
4. Enable the drive by clicking the 'Enable' icon. Set the waveform Amplitude between 1/8 and 1/2 revolution (between 500 and 2000 encoder counts) for a rotary motor. Use the Proportional Gain, Integral Gain and Derivative Gain sliders or arrow buttons in the Position Loop window to adjust the Position Measured waveform on the oscilloscope and match the Position Target as closely as possible without excessive overshoot. Proportional Gain, Integral Gain and Derivative Gain should be adjusted in that order. It is not necessary to adjust the Velocity or Acceleration Feed-forward Gains.
5. Readjust the Gains as Necessary.
6. When position loop gain adjustments are complete, disable the drive by clicking the Disable icon on the toolbar. Turn off the Waveform Generator by clicking the OFF button in the waveform generator pane.
7. Click the Store icon on the toolbar to store parameters to the drive's nonvolatile memory.

## ***Velocity Feedback Filter***

The velocity loop feedback filter uses a single pole low-pass filter to attenuate changes in velocity feedback. This helps to avoid responding to high frequency “spikes” in velocity, resulting in a smoother response to velocity commands.

### **Effects of the Feedback Filter**

**Cutoff Frequency Set to Infinite:** With no feedback filter, the velocity measured and velocity feedback are equal. The velocity loop responds instantly to all measured changes in velocity. The resulting velocity profile is distorted. A loud audible noise is heard from the motor.

**Cutoff Frequency Set to 300Hz:** At this level, the audible noise is no longer present and the response is smooth. The two waveforms are nearly identical. This is the optimum setting because it results in no distortion and no phase lag.

**Cutoff Frequency Set to 50Hz:** At this level, the response is still smooth, but phase lag is apparent as the two waveforms begin to separate.

**Cutoff Frequency Set to 10Hz:** With the cutoff frequency set to 10Hz, there is an obvious difference between the two waveforms. The response is also noticeable in the motor shaft. The phase lag results in the motor motion becoming unstable.

### **Filtering Results**

The velocity loop cutoff frequency filter allows you to tune with higher velocity loop gains, which results in a faster response. Most applications will benefit from a velocity feedback filter cutoff frequency between 50Hz and 1500Hz. Too high of a cutoff frequency may result in audible noise from the motor. Too low of a cutoff frequency will cause significant phase lag and may lead to instability. The cutoff frequency should be adjusted during velocity loop tuning. For the worst-case move, the motor should follow the command smoothly and there should be little or no phase lag between the velocity feedback and velocity measured traces.